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PROJECT REPORTS OF ME

DEPARTMENT OF MECHANICAL ENGINEERING
PROJECT LIST
ACADEMIC YEAR -2020-2021
NUMBER OF BATCHES: 42

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1	Automatic Drum Seeding	17K81A0307 17K81A0304 17K81A0309 17K81A0327	B.Akhil goud A. Dhakshitha B.Tharun kuma K.Dinesh	R. Suvarna babu
2	Design and Development of Autopilot Delivery Drone	17K81A0317 17K81A0356 17K81A0318 17K81A0333	Ch. Dinesh Karthik V. Rakesh CH. Sri ramya K. Naveen	Dr. D.V .Srikanth
3	Development of Autopilot Delivery Drone	17K81A0334 17K81A0311 17K81A0338 17K81A0346	M. Tejdeep Bhamidipati Paven Marcel Noel Isaac N. Preethi	Dr. D.V.Srikanth
4	development of grease trap	17K81A0323 17K81A0328 17K81A0331 17K81A0340	G. Vishal K. Stephen Calvin K. Hemanth Kumar Afroz	Dr. D.V.Srikanth
5	Development of Chainless bicycle	17K81A0360 17K81A0345 17K81A0320 17K81A0399	Y prajwal sharma N. Preetham E.balaraju N.goutham	Dr. D.V.Srikanth
6	Design, Analysis and Prototype of Air-less tyre by Additive Manufacturing Process	17K81A0357 17K81A0312 17K81A0355 17K81A0347	Ritesh Rohith Vishal Vishnu	Ch Ranga Rao
7	Tailoring The Thermo Mechanical Properties Of High-Performance Aerospace & Automotive Composite Materials	17K81A0322 17K81A0335 16K81A0361 15K81A03E8	Sai Sumanth M. Ashish Calvin Abhinav Sai Kiran	Dileep Panchal
8	Weight Optimization Of Chassis Frame By Using Topology Optimization To Reduce The Pollution In Environment	17K81A0352 17K81A0344 17K81A0303 17K81A0359	Sisir Akash Abdul Yatish	Ranjith A

9	Natural Convective Heat Transfer From Inclined Narrow Plates With Geometry Variation	17K81A0301 17K81A0310 17K81A0332 17K81A0342	Kumar Karthik Rajesh Vamshi Krishna Surender Reddy	Mukunda Dabair
10	Experimental Study On Discharging Performance Of Vertical Multitube Shell And Tube Latent Heat Thermal Energy Storage	17K81A0315 17K81A0326 17K81A0353	Ch Sai Krupa Jsd Varma S Uday Kiran	S Amith Kumar
11	Prediction And Comparison Of The Dilution And Heat Affected Zone In Submerged Arc Welding (Saw) Of Low Carbon Alloy Steel Joints	16K81A0313 16K81A0397 16K81A03C4 16K81A03D1	Dastagiri Khan Mohammed Rauoof Sai Dinesh Reddy Chandak Ankit	Y C Yadav
12	Experimental Investigation And Optimization Of Process Parameters Of Awjm By Cfd Flow Analysis	17K81A0336 17K85A0310 17K85A0301 17K85A0344	M.Samuel P.Madhu R.Dillp Kumar P.Saketh Kumar	T Paramesh
13	Modelling And Experimental Study Of Latent Heat Thermal Energy Storage With Encapsulated Pcms For Solar Thermal Applications	17K81A0302 17K81A0308 15K81A0332 17K81A0330	A. Rakesh Reddy B. Vinay M Goutam K Phani Ganesh	K Archana

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15	Design of grease interceptor	17K81A0373 17K81A03A0	Vineeth Siddharth	Dr.D.V Srikanth
16	Development Of Punctureless Tire By Additive Manufacturing Technology	17K81A0364 17K81A0376 17K81A03A3 17K81A03B2	A Sai Krishna Reddy G Vamshi Krishana P Reshma Chowdary T Akash Singh Rajput	Dr. D.V. Srikanth
17	Design and Development of Air Purification System	17K81A0366 17K81A0386 17K81A0396 17K81A03A5	B. Nithin Goud M. Kavya Sri M. Yashwanth Kumar P. Shiva Sai Krishna	Dr. D.V .Srikanth

18	Machining of CFRP using AWJM and analysis using CFD	17K81A0363 17K81A0384 17K81A0387 17K81A0398	Aniketh kumar singh M .Madhu Vyshnavi N.Akhil kumar	Dr. D. V Srikanth
19	Development of Metal Matrix composite using sand castig	17K81A 0378 17K81A0379 17K81A0380 17K81A03B6	Sahiti j.pavan.teja K.sanjay.reddy T.vinitha.reddy	Dr. D. V Srikanth
20	LPG refrigeration system with zero operating cost.	17K81A0370 17K81A0371 17K81A0375 17K81A03B8	D.Rama Krishna Vamshi E.Ramya G.Sai Krishna V.Satish Kumar	Ch Ranga Rao
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26	Design and Development of artificial wireless arm	17K81A0367 17K81A0382 17K81A03B0 17K81A03B9	B. Sandeep Vishal S.Tanveer V.Mani Teja	Dr lavanya M

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28	Fabrication of Uniform water cooler with copper tubes	18K85A0324 18K85A0333 18K85A0337 18K85A0339	Vamshi Krishna Vinod Kumar Nikhil T.Vineeth	Ch. Nagaraju
29	Pneumatic Powered Metal Pick And Place Arm	17K81A03D0 18K85A0313 18K85A0310 18K85A0325 17K81A03C9	D Susheel kubeer S. Shiva Reddy M. Ruchith K. Gouri Shankar Ch. Ritheesh Sagar	R Hanuma Naik
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A Major Project Report
On

AUTOMATIC DRUM SEEDER

SUBMITTED TO

JawaharlalNehruTechnologicalUniversityHyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

B. AKHIL GOUD	**-**	**(17K81A0307)**
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Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **AUTOMATIC DRUM SEEDER**, is being submitted by **B. Akhil Goud (17K81A0307), A. Dhakshitha (17K81A0304), B. Tharun kumar(17K81A0309), K. Dinesh(17K81A0327)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OFTECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide	**Signature of HOD**
Mr. SUVARNABABU	**Dr. D.V. SREEKANTH**
Assistant Professor,	**Professor& Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in **Department of Mechanical engineering** session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **AUTOMATIC DRUM SEEDER** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Direct seeding and transplanting are the two methods of planting rice. The traditional method followed by many years in lot of farming lands is transplanting of seeding raised in nursery. Transplanting method involves seedbed preparation, nursery growing, care of seeding in nursery, uprooting of seeding, hauling and transplanting operations. The preparation of seedbed and sowing are done 30 days before planting. The rice farmers practicing transplanting are facing problems like shortage of labour during peak time, hike in labour charges, small and fragmented land holdings etc. Direct seeding is becoming increasingly popular now days in India. The wet seeding of rice is generally followed in irrigated areas. For wet drum seeding the paddy seeds are soaked in water for 24 hours and incubated for 24-48 hours. These sprouted seeds are sown in puddle field 1-2 days after paddling using perforated drum seeder. Eight row paddy seeder is manually drawn low-cost equipment. Direct paddy drum seeder tested was manually drawn

Rice cultivation in INDIA is predominantly practiced in transplanting method which involves raising, uprooting and transplanting of seedlings. This is rather a resource and cost intensive method. Since, preparation of seedbed, raising of seedling and transplanting are labour and time intensive operations. Research reports show that labour involvement in these operations consume nearly one third of the total cost of production in INDIA. In addition, transplanting is not a healthy method as the farmers as it takes huge troll to their body. Direct sowing by drum seeder in 8 rows facilitated to take up organic fertilizer application, plant protection measures and weed control in an efficient manner. Further the crop duration is reduced around one weak in direct sown rice as compared to normal transplanted which facilitated to raise another crop. The farmers in OFTs had realized that direct sowing by drum seeder is only a viable option to reduce cost of cultivation of rice and increase net return due to less seed rate, less labour requirements at the time of sowing and no need of nursery raising etc.

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INTRODUCTION

1.0 OVERVIEW OF PROJECT:

The transplanting of rice seedlings being a high labour-intensive and expensive operation needs to be substituted by direct seeding which could reduce labour needs by more than 20 per cent in terms of working hours. Direct seeding is an age-old practice of paddy cultivation in India, particularly in rain fed areas, where farmers totally eliminate seedling preparation in nursery and the required transplanting operation. Rice is either dry seeded on well prepared dry and moist soil or wet seeded on a puddled soil. Drum seeder is becoming popular for wet seeding because of its less initial investment, easy operation, and low repair and maintenance cost. Different models of drum seeders which are manually operated and are highly suitable for fragmented Indian fields were developed by International Rice Research Institute, Philippines and modified by different organizations/institutions. In all these models, the dry and wet seeds are drilled continuously at a higher seed rate than the recommended seed rate and without any seed to seed spacing. It is observed that as the seed drum empties, the seed rate obtained increases steadily and steeply at the end i.e., the uniformity in seed rate is not maintained throughout the operation. Hence, a modified drum seeder which provides uniform seed distribution with respect to time will be more useful in maintaining uniform plant population. This creates a condition similar to that of the transplanted crop to have a noticeable improvement in crop growth environment. Also, the problem of thinning the crop sown by presently available models of drum seeder could be eliminated

Rice is one of the most important crops of India and occupies 23.3% of gross cropped area of the country. Rice contributes 43% of total grain production and 46% of total cereal production. India has largest area under rice crop and it is about 45 million hectares. Rice is grown in all the states of INDIA with low to high acreage. The monsoon starts at late fortnight of June and continues up to the end of November. Therefore, most of farming done Kharif season. Rice being a tropical and sub-tropical crop requires fairly high temperature ranging from 30°C to 40°C. The optimum temperature required is 30°C. Direct seeding and transplanting are the two methods of planting rice. Transplanting method involves seedbed preparation, nursery growing, care of seedlings in nursery, uprooting of seedlings, hauling and transplanting operations. The preparations of seedbed sowing are done 30 days before planting. The transplanting of paddy at right time is also important parameter. A delay in transplanting by one month reduces the yield of rice by 25 percent and delay by two months results in 70 percent reduction in yield. The rice farmers practicing transplanting are facing problem of storage of labour during peak time, hike in labour charges, small and fragmented land holdings, lack of technical knowledge, non-availability of ample water and other inputs. To tackle all these problems direct seeding of rice has been found most appropriate alternative to transplanting. It not only avoids seedbed preparation, nursery raising and transplanting but also gives better yield than existing manual transplanting. Therefore, direct seeding is becoming increasingly popular now days in India.

Drum seeding technique involves direct seeding of pre-germinated paddy seeds in drums made up of fibre material to dispense seeds evenly in lines spaced at 20 cm apart in puddled and levelled fields. About 35 to 40 kg paddy seed/ha is soaked overnight in water and allowed to sprout. Care should be taken not to delay sowing as seeds with long shoot growth are not suitable for drum seeding. The sprouted seed is air-dried in shade briefly prior to sowing for easy dispensing through the holes in the drum seeder. Excess water in puddled field is drained out ensuring the soil surface is moist. Drums are filled with sprouted seeds (3/4th full) and pulled across the field maintaining a steady speed for evenly sowing. Number of drums could vary between 4 and 8 with number of lines sown ranging from 8 to 16 in one pass. Irrigation water should not be applied for 2-3 days after sowing to allow rooting and anchoring to soil. As the seedlings grow, water level in the field can rise for better weed control. Intermittent irrigation is given till the panicle initiation stage. Where weed problem is severe, herbicide is applied within 1-2 days after seeding. Line sowing permits operation of modified weeder between the rows in the same direction adopted for drum seeding. Drum seeding in one ha area can be completed in 5 to 6 hours' time by three persons compared to transplanting operation which requires about 30-to-40-man days. This technique can help in saving seed, water, labour requirement apart from improving productivity because of line sowing (spacing of 20 cm between rows) and early maturity of crop (by 7-10 days). Drum seeding reduces the cost of cultivation as it does away with the requirement for raising paddy nursery and transplanting thereafter. The technique fits into contingency planning as it provides flexibility in timing of sowing in lands prepared using irrigation water or immediately after receipt of monsoon rains with a crop variety of suitable duration to fit into the left-over season. The direct seeding is further of two types, broadcasting and row seeding by using drum seeder. The direct seeding is grouped in to first, dry seeding i.e., dry seeds are directly seeded on the dry soil and second wet seeding. sprouted seeds are sown in the puddle field. The wet seeding of rice is generally followed in irrigated areas. For wet drum seeding sprouted seeds, soaked for 24 hours and incubated for 24-48 hours are sown in the puddled soils 1-2 days after paddling using perforated drum seeder. Drum seeder is essential for farming. Health of the farmers are taken into consideration. In addition, transplanting is not a healthy method as the farmers as it takes huge troll to their body. Direct sowing by drum seeder in 8 rows facilitated to take up organic fertilizer application, plant protection measures and weed control in an efficient manner. Further the crop duration is reduced around one weak in direct sown rice as compared to normal transplanted which facilitated to raise another crop. In INDIA, labor requirement is high for land preparation, sowing seeds, transplanting and weeding crop. In order to minimize this problem 'DRUM SEEDER' can be used in which paddy, wheat, mung bean, black gram, lentil, mustard, and radish could be sown by changing the seed opening plate depending on the seed size and row to row distance. The farmers in OFTs had realized that direct sowing by drum seeder is only a viable option to reduce cost of cultivation of rice and increase net return due to less seed rate, less labour requirements at the time of sowing and no need of nursery raising etc.

It works on simple mechanism; a battery-operated Electrical motor is used transmits the rotary motion to the shaft with the help of chain drive Another connection of sprocket and chain to the rotary motion. When the farmer puts the seeds into the drum. As the prototype moves forward, the seed drops from the holes provided in the drum. AUTOMATIC DRUM SEEDER that covers 8 rows of 20cm, row to row spacing. The operator can move the prototype in both forward and backward direction

1.1 OBJECTIVE OF THE STUDY:

The main objective of the project to design and development of agitators for drum seeder for minimizing the ununiformed of seeding rate to design a mechanical drum seeder for DS of pre germinated paddy seeds and evaluate its performance in relation to MB. The drum seeder should be able to: operate with minimum operator skill and effort, control seed rate according to size/variety of paddy seeds, establish a uniform plant population in a paddy field, and be suitable for use in small and medium size plots. It should also be light enough in weight for one man operation it can be used as manually and automatically, AUTOMATIC DRUM SEEDER has a powerful motor that can operate in wet land and in dry land. It is simple and low cost.

1.2 SCOPE OF STUDIES:

Paddy is an important food crop grown in almost all the part of INDIA. The farmers were following conventional methods of paddy and rice cultivation. The conventional method leads to high investment cost, non-availability and higher costs on labour at the critical crop stages like transplanting, weeding and harvesting. This leads to higher cost on cultivation and delaying in carry out the required operations resulted in yield reduction. Besides delay or no seasonal rainfall and unequal distribution of rain is affecting the regular operations in paddy cultivation. The area under paddy cultivation is decreasing annually mainly due to labour constraints. The rice farmers practicing transplanting are facing problem of storage of labour during peak time, hike in labour charges, small and fragmented land holdings, lack of technical knowledge, non-availability of ample water and other inputs. To tackle all these problems direct seeding of rice has been found most appropriate alternative to transplanting. The farmers of INDIA still practice their old broadcasting methods of seed sowing in which line to line distance and row to row distance are not maintained. Wheat, maize, paddy, jute, pulses and oil seeds are usually line sowing crops and it contributes to higher yield and involves less cost. ‘DRUM SEEDER’ can be used in which paddy, wheat, mung bean, black gram, lentil, mustard, and radish could be sown by changing the seed opening plate depending on the seed size and row to row distance.

1.3 MATERIAL REQUIRMENT

1.3.1 Plastic seed drum

1.3.2 Ground wheel

1.3.3 12 volts electric motor

1.3.4 Fly wheel

1.3.5 12 volts lithium-ion battery

1.3.6 nuts and bolts

1.3.7 Iron frame

1.3.8 Motor controller

Fig.1 Automatic drum seeder

1.3.1 PLASTIC SEED DRUM:

Fig.2 Seed drum

The seed drum is hyperboloid shaped with 200 mm diameter. There are 8 number of seeding metering holes of 9 mm hole diameter. The seed drum is hyperboloid shaped. There are 8 number of seeding metering holes of 9mm diameter hole. Baffles are provided inside the seed drum between the seed holes to ensure the uniform seed rate in operation as well as to ensure hill dropping of the seeds.

There are a number of holes around the drum in four rows. In both sides of the drum, there are 2 rows. These Effect the opening of number of holes on seeding rate, the number of holes in one of them row is twice then other row. Figure of seed drum shows the stretch out of the drum. The arrangements of the holes in different numbers and rows provide different seed rates. Experiments were conducted to find the seed rate at different agitators, number of seeds in drum and number of holes opening.

Specifications of drum		
Sr. No.	Particulars	Specifications
1	Material of construction	Polypropylene copolymer sheet of thickness 2.5mm
2	Number of drums	4
3	Shape of drum	Hyperboloid
4	Drum diameter(outer), cm	20.00
5	Drum diameter(middle), cm	16.25

Table-1 Drum specification

1.3.2 GROUND WHEEL:

Fig.3 Ground wheel

A ground wheel is a mechanical device specifically designed to use the conservation of angular momentum so as to efficiently store rotational energy; a form of kinetic energy proportional to the product of its moment of inertia and the square of its rotational speed. In particular, if we assume the flywheel's moment of inertia to be constant (i.e., a flywheel with fixed mass and second moment of area revolving about some fixed axis) then the stored (rotational) energy is directly associated with the square of its rotational speed.

Since a ground wheel serves to store mechanical energy for later use, it is natural to consider it as a kinetic energy analogue of an electrical inductor. Once suitably abstracted, this shared principle of energy storage is described in the generalized concept of an accumulator. As with other types of accumulators, a flywheel inherently smooth sufficiently small deviations in the power output of a system, thereby effectively playing the role of a low-pass filter with respect to the mechanical velocity (angular, or otherwise) of the system. More precisely, a flywheel's stored energy will donate a surge in power output upon a drop in power input and will conversely absorb any excess power input (system-generated power) in the form of rotational energy. A wheeled vehicle requires much less work to move than simply dragging the same weight. The low resistance to motion is explained by the fact that the frictional work done is no longer at the surface that the vehicle is traversing, but in the bearing. In the simplest and oldest case, the bearing is just a round hole through which the axle passes Even with a plain bearing, the frictional work is greatly reduced because the normal force at the sliding interface is same as with simple dragging. The sliding distance is reduced for a given distance of travel. The coefficient of friction at the interface is usually lower.

1.3.3 24volts ELECTRIC MOTOR

Fig.4 Electric motor

An electric motor is an electrical machine that converts electric energy into mechanical energy Most electric motors operate through the interaction between the motor's magnetic field and electric field in a wire winding to generate force in the form of torque applied on the motor's shaft. Electric motors can be powered by direct current (DC) sources, such as from batteries, or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. An electric generator is mechanically identical to an electric motor, but operates with a reversed flow of power, converting mechanical energy into electrical energy.

Electric motors may be classified by considerations such as power source type, internal construction, application and type of motion output. In addition to AC versus

DC types, motors may be brushed or brushless, may be of various phase, and may be either air-cooled or liquid-cooled. General-purpose motors with standard dimensions and characteristics provide convenient mechanical power for industrial use. DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. The universal motors can operate on direct current but is a light weight brushed motor used for portable power tools and appliances. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motor possible in many applications.

The largest electric motors are used for ship propulsion, pipeline compression and pumped storage applications with ratings reaching 100 megawatts. Electric motors are found in industrial fans, blowers and pumps, machine tools, household appliances, power tools and disk drives. Small motors may be found in electric watches. In certain applications, such as in regenerative braking with traction motors, electric motors can be used in reverse as generators to recover energy that might otherwise be lost as heat and friction.

Electric motors produce linear or rotary force intended to propel some external mechanism, such as a fan or an elevator. An electric motor is generally designed for continuous rotation, or for linear movement over a significant distance compared to its size. Magnetic solenoids are also transducers that convert electrical power to mechanical motion, but can produce motion over only a limited distance.

Electric motors are much more efficient than the other prime movers used in industry and transportation, the internal combustion engine (ICE); electric motors are typically over 95% efficient while ICEs are well below 50%. They are also lightweight, physically smaller, are mechanically simpler and cheaper to build, can provide instant and consistent torque at any speed, can run on electricity generated by renewable sources and do not exhaust carbon into the atmosphere. For these reasons electric motors are replacing internal combustion in transportation and industry, although their use in vehicles is currently limited by the high cost and weight of batteries that can give sufficient range between charges.

1.3.4 Fly wheel:

Fig.5 Fly wheel

A flywheel is a mechanical device specifically designed to use the conservation of angular momentum so as to efficiently store rotational energy; a form of kinetic energy proportional to the product of its moment of inertia and the square of its rotational speed. In particular, if we assume the flywheel's moment of inertia to be constant (i.e., a flywheel with fixed mass and second moment of area revolving about some fixed axis) then the stored (rotational) energy is directly associated with the square of its rotational speed.

Since a flywheel serves to store mechanical energy for later use, it is natural to consider it as a kinetic energy analogue of an electrical inductor. Once suitably abstracted, this shared principle of energy storage is described in the generalized concept of an accumulator. As with other types of accumulators, a flywheel inherently smooth sufficiently small deviations in the power output of a system, thereby effectively playing the role of a low-pass filter with respect to the mechanical velocity (angular, or otherwise) of the system. More precisely, a flywheel's stored energy will donate a surge in power output upon a drop in power input and will conversely absorb any excess power input (system-generated power) in the form of rotational energy.

Common uses of a flywheel include:

- Smoothing the power output of an energy source.
- Controlling the orientation of a mechanical system, gyroscope and reaction wheel

APPLICATIONS:

Flywheels are often used to provide continuous power output in systems where the energy source is not continuous. For example, a flywheel is used to smooth fast angular velocity fluctuations of the crankshaft in a reciprocating engine. In this case, a crankshaft flywheel stores energy when torque is exerted on it by a firing piston, and returns it to the piston to compress a fresh charge of air and fuel. Another example is the friction motor which powers devices such as toy car. In unstressed and inexpensive cases, to save on cost, the bulk of the mass of the flywheel is toward the rim of the wheel. Pushing the mass away from the axis of rotation heightens rotational inertia for a given total mass.

A flywheel may also be used to supply intermittent pulses of energy at power levels that exceed the abilities of its energy source. This is achieved by accumulating energy in the flywheel over a period of time, at a rate that is compatible with the energy source, and then releasing energy at a much higher rate over a relatively short time when it is needed. For example, flywheels are used in power hammer and other machines

1.3.5 24volts LITHIUM-ION BATTERY:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal

Fig.6 Battery

When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy.

Historically the term "battery" specifically referred to a device composed of multiple cells; however, the usage has evolved to include devices composed of a single cell. Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones, wristwatches to small, thin cells used in smart phone large lead acid batteries or lithium-ion batteries in vehicles. A lithium-ion battery or Li-ion battery is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications.

In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. The batteries have a high energy density, no memory effect. They can however be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires. Samsung was forced to recall handsets following lithium-ion fires, and there have been several incidents involving batteries on vehicles, Chemistry, performance, cost and safety characteristics vary across types of lithium-ion batteries. Handheld electronics mostly use lithium polymer oxide, a lithium cathode oxide cathode material, and a graphite anode, which together offer a high energy density. Lithium iron phosphate, lithium manganese oxide lithium rich layered materials, and lithium nickel manganese cobalt oxide may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC and its derivatives are widely used in electric vehicles.

1.3.6 NUTS AND BOLTS:

Fig.7 Nuts and bolts

A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunctions with a mating bolt of fasten multiple parts together. The two partners are kept together by a combination of their thread's friction (with slight elastic deformation), a slight stretching of the bolt, and compression of parts to be held together. In applications where vibrations or rotation may work a nut loose, various locking mechanisms may be employed: lock washers, jam nuts, specialist adhesive thread-locking fluid such as safety pins or lockwire in conjunctions with castellated nuts, nylon inserts (nylon nuts), or slightly oval-shaped threads. Squares nuts, as well as bolt heads, where the first shape made and used to be the most common largely because they were easier to manufacture, especially by hand. Square nuts, as well as bolt heads, were the first shape made and used to be the most common largely because they were much easier to manufacture, especially by hand. While rare today due to the reasons stated below for the preference of hexagonal nuts, they are occasionally used in some situations when a maximum amount of torque and grip is needed for a given size: the greater length of each side allows a spanner to be applied with a larger surface area and more leverage at the nut.

The most common shape today is hexagonal for similar reasons as the bolt head: six sides give a good granularity of angles for a tool to approach from, but more corners would be vulnerable to being rounded off. It takes only one sixth of a rotation to obtain the next side of the hexagon and grip is optimal. However, polygons with more than six sides do not give the requisite grip and polygons with fewer than six sides take more time to be given a complete rotation. Other specialized shapes exist for certain needs, such as wignuts for finger adjustment and captive nuts for inaccessible areas.

1.3.7 IRON FRAME:

Fig.8 Iron frame

Iron frame is a building technique with a skeleton frame of vertical iron column and horizontal beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. The development of this technique made the construction of the skyscraper possible. The iron rolled "profile" or cross section of iron columns takes the shape of the letter I. The two wide flanges of a column are thicker and wider than the flanges on a beam, to better withstand compressive stress in the structure. Square and round tubular sections of steel can also be used, often filled with concrete. Steel beams are connected to the columns with bolts and threaded fasteners, and historically connected by reverts. The central "web" of the steel beam is often wider than a column web to resist the higher bending moments that occur in beams.

Wide sheets of steel deck can be used to cover the top of the steel frame as a form or mould, below a thick layer of concrete and steel reinforcing bar. Another popular alternative is a floor of precast concrete flooring units with some form of concrete topping. Often in office buildings, the final floor surface is provided by some form of raised flooring system with the void between the walking surface and the structural floor being used for cables and air handling ducts.

The frame needs to be protected from fire because steel softens at high temperature and this can cause the building to partially collapse. In the case of the columns this is usually done by encasing it in some form of fire-resistant structure such as masonry, concrete or plasterboard. The beams may be cashed in concrete, plasterboard or sprayed with a coating to insulate it from the heat of the fire or it can be protected by a fire-resistant ceiling construction. asbestos was a popular material for fireproofing steel structures up until the early 1970s, before the health risks of asbestos fibres were fully understood.

The exterior "skin" of the building is anchored to the frame using a variety of construction techniques and following a huge variety of architectural styles

1.3.8 MOTOR CONTROLLER:

A motor controller is a device or group of devices that can coordinate in a predetermined manner the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and electrical faults.

There are many types of motor controller:

- Motor Starters.
- Reduced voltage starter.
- Adjustable speed driver.
- Intelligent controller.

Motor starter:

A small motor can be started by simply connecting it to power. A larger motor requires a specialized switching unit called a motor starter or motor contactor. When energized, a direct on line (DOL) starter immediately connects the motor terminals directly to the power supply. In smaller sizes a motor starter is a manually operated switch; larger motors, or those requiring remote or automatic control, use magnetic contactors. Very large motors running on medium voltage power supplies (thousands of volts) may use power circuit breakers as switching elements.

A direct on line (DOL) or across the line starter applies the full line voltage to the motor terminals. This is the simplest type of motor starter. A DOL motor starter also contains protection devices, and in some cases, condition monitoring. Smaller sizes of direct on-line starters are manually operated; larger sizes use an electromechanical contactor to switch the motor circuit. Solid-state direct on-line starters also exist.

A direct on-line starter can be used if the high inrush current of the motor does not because excessive voltage drops in the supply circuit. The maximum size of a motor allowed on a direct on-line starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.

DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts in the case of an asynchronous motor, such as the 3-phase squirrel-cage motor, the motor will draw a high starting current until it has run up to full speed. This starting current is typically 6-7 times greater than the full load current. To reduce the inrush current, larger motors will have reduced-voltage starters or adjustable -speed drives in order to minimise voltage dips to the power supply.

A reversing starter can connect the motor for rotation in either direction. Such a starter contains two DOL circuits — one for clockwise operation and the other for counter-clockwise operation, with mechanical and electrical interlocks to prevent simultaneous closure. For three phase motors, this is achieved by swapping the wires connecting any two phases. Single phase AC motors and direct-current motors require additional devices for reversing rotation.

Reduced voltage starters:

Reduced-voltage, star-delta or soft starters connect the motor to the power supply through a voltage reduction device and increases the applied voltage gradually or in steps. Two or more contactors may be used to provide reduced voltage starting of a motor. By using an autotransformer or a series inductance, a lower voltage is present at the motor terminals, reducing starting torque and inrush current. Once the motor has come up to some fraction of its full-load speed, the starter switches to full voltage at the motor terminals. Since the autotransformer or series reactor only carries the heavy motor starting current for a few seconds, the devices can be much smaller compared to continuously rated equipment. The transition between reduced and full voltage may be based on elapsed time, or triggered when a current sensor shows the motor current has begun to reduce. An autotransformer starter was patented in 1908.

ADJUSTABLE SPEED DRIVERS

An adjustable-speed drive or variable-speed drive (VSD) is an interconnected combination of equipment that provides a means of driving and adjusting the operating speed of a mechanical load. An electrical adjustable-speed drive consists of an electric motor and a speed controller or power converter plus auxiliary devices and equipment. In common usage, the term "drive" is often applied to just the controller. Most modern ASDs and VSDs can also implement soft motor starting**.**

Intelligent controllers:

An Intelligent Motor Controller (IMC) uses a microprocessor to control power electronic devices used for motor control. IMCs monitor the load on a motor and accordingly match motor torque to motor load. This is accomplished by reducing the voltage to the AC terminals and at the same time lowering current and kvar. This can provide a measure of energy efficiency improvement for motors that run under light load for a large part of the time, resulting in less heat, noise, and vibrations generated by the motor.

1.4 PROCUMENT OF EQUIPMENT

- Plastic seed drum and ground wheel are made by polypropylene co-polymer, they are manufactured by KSIM company
- 24 volts lithium-ion battery and 24 volts electric motor are obtained online through www.amazon.com

- We made iron wheel and iron frame through welding, iron is purchased in Balanagar
- Motor controller is purchased king koti

CHAPTER-2

LITERATURE SURVEY

2.0 LITERATURE REVIEW ON RESEARCH AREA:

An attempt has been made in this chapter to present brief review of research works in relation to the design and development of direct seeder for rice culture carried out in the different countries of the world including INDIA. Balasubramanian et. al (1998) defined seeder as a device to drop the seeds in rows or all along the width of machine on the surface of seed bed from the seed hopper when it was operated. The drum seeder means the machine, which sows dry seeds at specified rates on seedbed. The wet seeder means the machine that uses wet seeds (soaked and incubated seeds) and spread seeds on wet seedbed on wet puddle soil. Sivakumar et al. (2003) conducted a study on the performance of prototype direct-rice seeders with single and double ground wheels with and without furrow openers using dry and soaked seeds. It was found that the use of soaked seeds in the improved seeder with furrow opener resulted in a higher yield of grain and straw. Devnani (2002) reported that labour intensive rice transplanting operation would be replaced by direct seeding to tackle the problem of labor scarcity at the time of planting, to reduce the cultivation cost and achieve proper and timely crop establishment. The direct seeding of rice could help the farmers greatly in establishment of crop especially for high yielding rice varieties. The seeding techniques had been developed as dry seeding for uplands, rain fed lowlands and wet seeding. However, the rice farmers should understand the various methods and techniques for seeding rice in their areas before adopting the seeders and seeding techniques

2.1 REVIEW ON RELATED LITERATURE:

Flin (1986) developed a super wide spreader for rice direct sowing in wetland in order to reduce the production cost of rice and estimate troublesome handling work of nursery mats. The adoption of direct seeded rice culture was gradually increasing in some parts of rice growing areas in the world in order to minimize production cost. Soni et al. (1986) developed a hydraulic direct seeder for use particularly in forestry on steep and rough ground. It was used to spray a mixture of seed, fertilizer and wood cellulose or other soil binder in the form of slurry under hydraulic pressure. It had 13 liters slurry tank and operated successfully on a 70° slope with a mixture of 3 parts soil, 1.75 parts organic manure, 0.25 parts grass seed and 0.25 parts adhesive in 7.8 liters of water at an application pressure of 100 lb/square inch. Srivastava (1985) reported that the pre-germinated paddy seeders were developed for sowing seeds in wet soils during 1968 to 1978 at Orissa, I.I.T., Kharagpur and Pant Nagar, Rajendran agar. These seeders were 2, 4, 5 and 6 rows machines. Their performances were reported to good. Moody (1985), In central Luzon, (1983) developed a six-row IRRI–Pant Nagar bullock-drawn paddy seeder which required 1443 men-h/ha for all the agricultural operations whereas transplanting methods required 1682 men-h/ha. The maturity of the crop was advanced 10 days in the bullock-drawn treatment. Tiwari et. al (1983) developed a wetland seeder, capable of sowing 6 seeds per hill at a hill-to-hill spacing of 16.0 cm. The average seed rate was 43.2 kg/ha for paddy at field capacity of 0.08 ha/h. In agronomical consideration this two-row machine could be comfortably operated by one man. Khan (1975) developed a 6-rows paddy seeder at IRRI for seeding pregerminated seeds. The planting by this seeder was 20 times faster than manual transplanting. Navasero (1969) designed and tested a paddy seeder with two-step metering mechanism. The first step was to meter a large quantity of seeds from the hopper and the second step was to distribute the metered seeds to the individual rows. One hectare required 4.9 man-h with this 8 row seeder as compared to 199 man-h for manual transplanting.

2.2 CONCLUSION ON REVIEW

As for the above literature survey lot of survey has been done, in lot of areas and agricultural lands but even though after all these experiments we came to the conclusion that drum seeder of four drum 8 rows are needed for fast cultivation and seeding ,it has been introduced to he market even though it reduce the labour work and time for cultivation to minimise the pressure on the farmers for pulling the drum seeder and to reduce the time even further we are introducing AUTOMATIC DRUM SEEDER

CHAPTER-3

3.0 OVERVIEW OF THE DESIGN

CATIA- computer-aided three-dimensional interactive application is a multi-platform software suite for CAD, CAE, CAM, PLM and 3D Since it supports multiple stages of product development from conceptualization, design and engineering to manufacturing, it is considered a cax -software and is sometimes referred to as a 3D product lifecycle management software suite. Like most of its competition it facilitates collaborative engineering through an integrated cloud service and have support to be used across disciplines including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and system engineering

Besides being used in a wide range of industries from aerospace and defence to packaging design, CATIA has been used by architect frank Gehry to design some of his signature curvilinear buildings and his company was developing their digital project software based on CATIA.

3.0.1 DESIGN CONSIDERATION

- Component's size, design and form.
- Use of standard parts.
- Optimize part handling, Cost of making the prototype
- Material selection should have based on factors like strength, weight and durability
- Assemble in the open area. Manufacturing facilities available.

3.1 DESIGNED COMPONENTS

3.1.0 SEED DRUM:

The seed drum is hyperboloid shaped with 200 mm diameter. There are 8 number of seeding metering holes of 9 mm hole diameter. The seed drum is hyperboloid shaped. There are 8 number of seeding metering holes of 9mm diameter hole. In both sides of the drum, there are 2 rows.

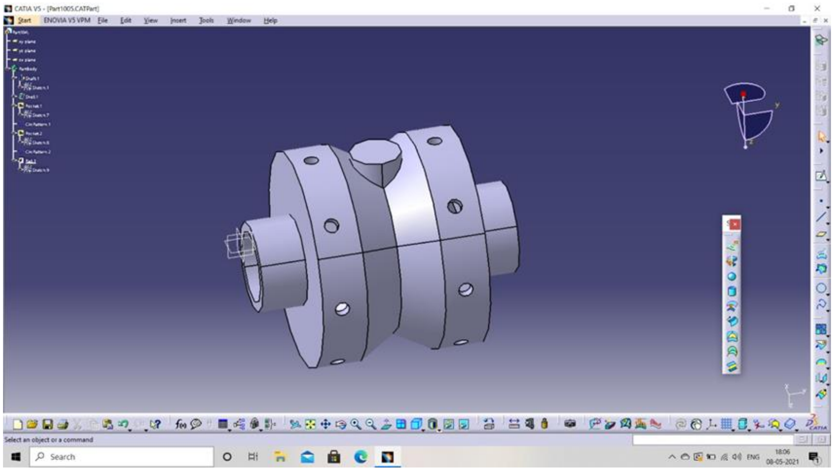


Fig.9 Drum design

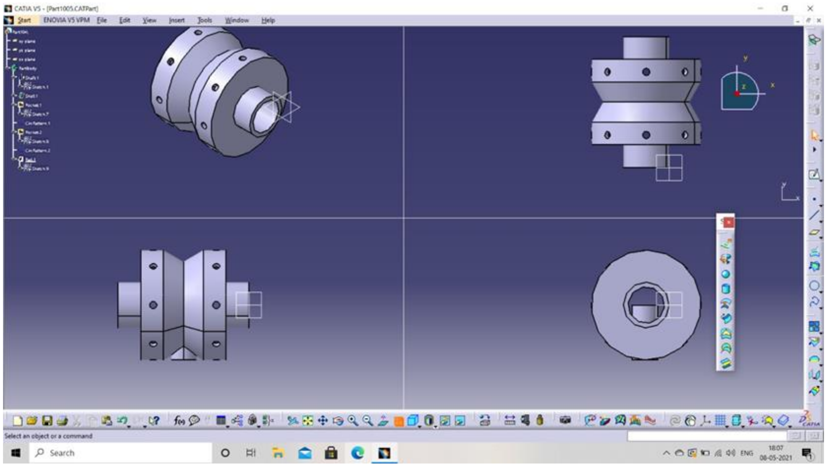


Fig.10 Drum design 2

3.1.1 WHEEL:

a wheel is a circular block of a hard and durable material at whose center has been bored a hole through which is placed an axel bearing about which the wheel rotates when torque is applied to the wheel about its axis. The wheel and axis assembly can be considered one of the sex simple machines

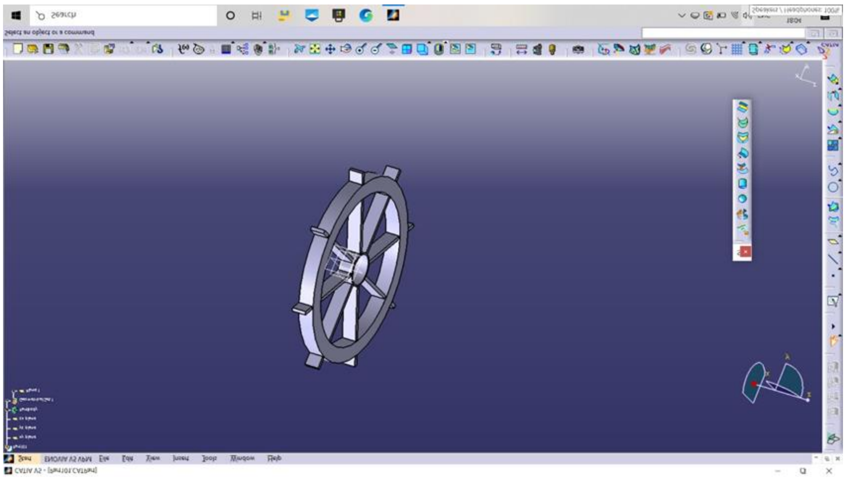


Fig.11Wheel design

3.1.2 IRON TUBE:

Cast iron pipe is pipe made predominantly from gray cast iron It was historically used as a pressure pipe for transmission of water, gas and sewage, and as a water drainage pipe during Cast iron pipe was frequently used uncoated, although later coatings and linings reduced corrosion and improved hydraulics. In cast iron pipe, the graphite forms flake during the casting process, when examined under a microscope

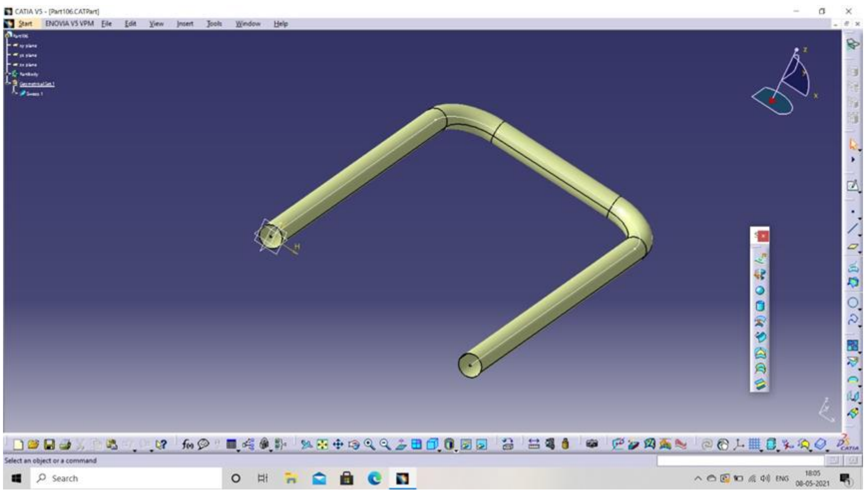


Fig.12 Iron tube

3.1.3 FRAME:

Iron frame is a building technique with a skeleton frame of vertical iron column and horizontal beams The central "web" of the steel beam is often wider than a column web to resist the higher bending moments that occur in beams. Another popular alternative is a floor of precast concrete flooring units with some form of concrete topping. Often in office buildings, the final floor surface is provided by some form of raised flooring system with the void between the walking surface and the structural floor

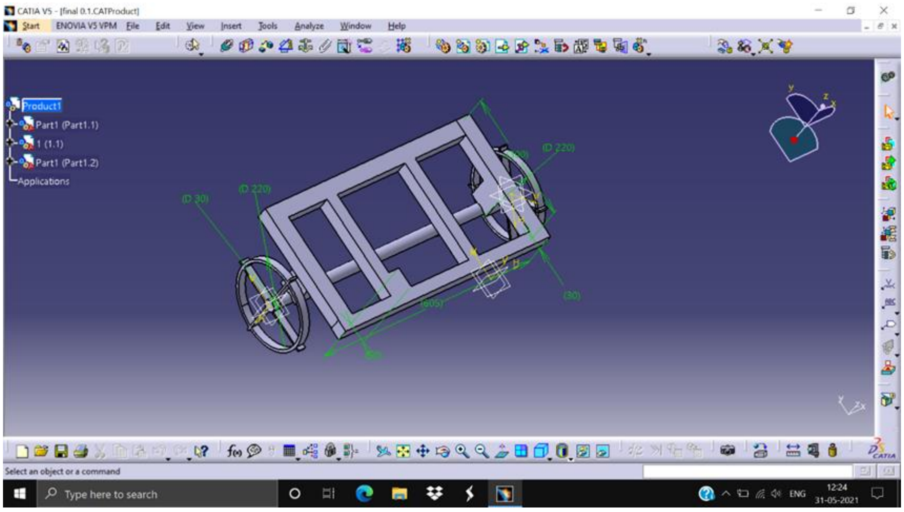


Fig.13 Iron frame design

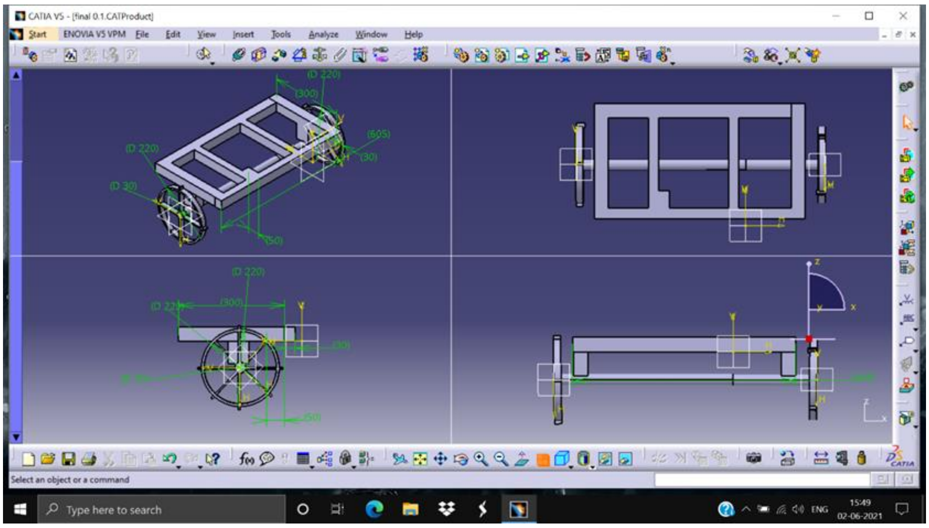


Fig.14 Iron frame design 2

3.1.4 FINAL DESIGN:

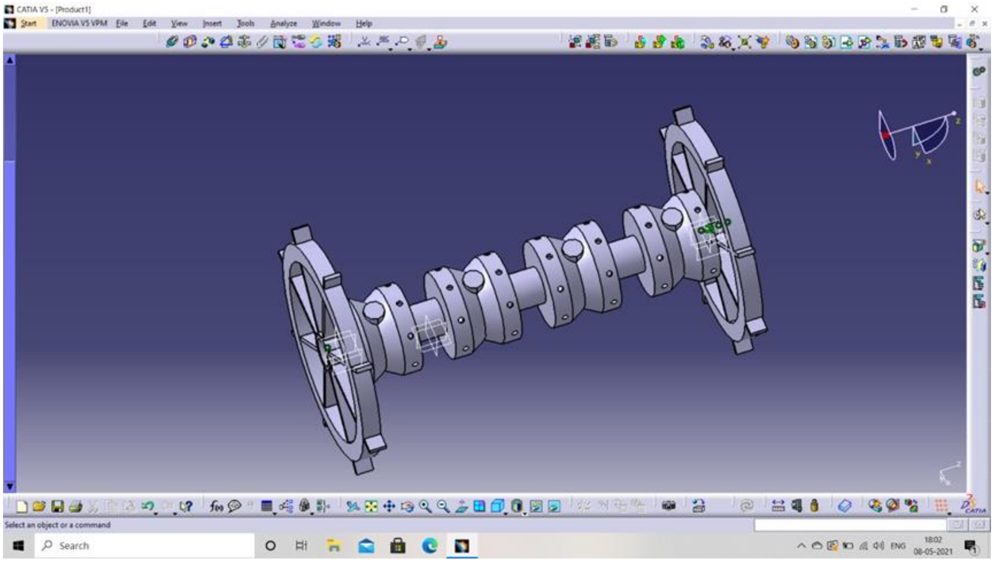


Fig.15 Drum assembly

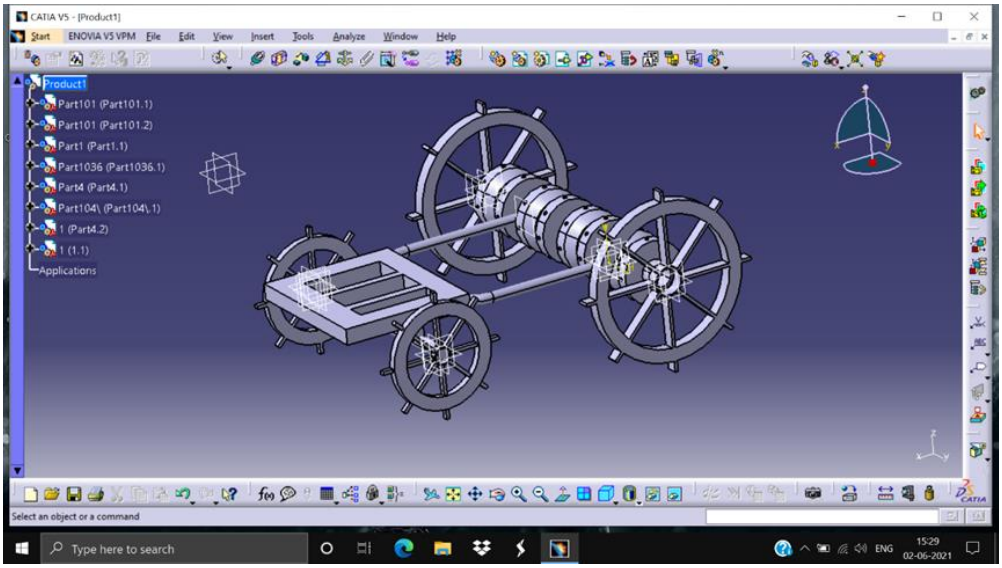


Fig.16 Final design

wheel dia (1) =60cm, wheel dia (2) =30cm, length of iron frame=65cm, length of drum seeder=170cm, length of each drum=32cm, distance between each hole=20cm

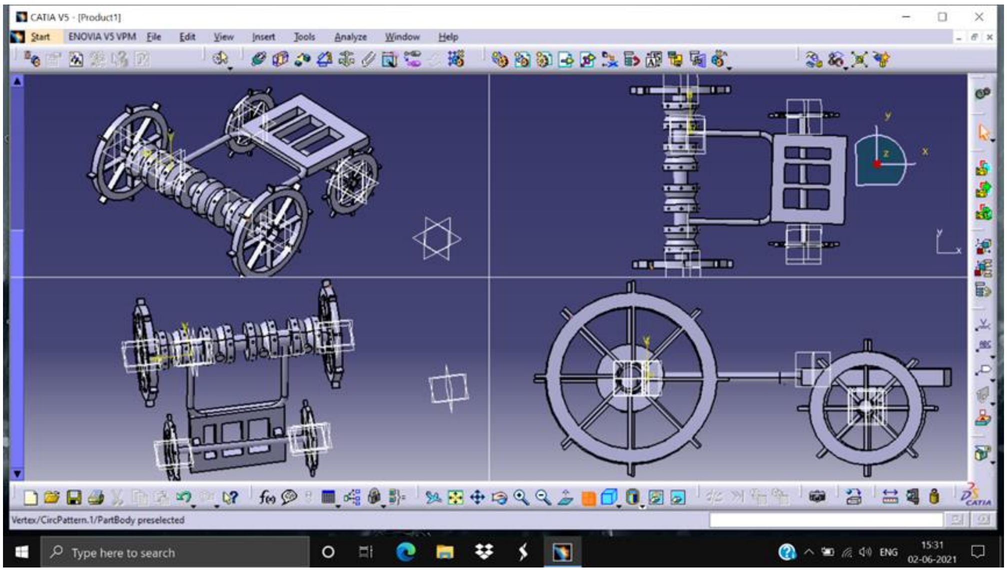


Fig.17 Final design 2

3.2 DEFINE THE MODULES

3.2.0 DESIGN ENGINEERING:

The design engineer usually works with a team of other engineers and other types of designers, to develop conceptual and detailed designs that ensure a product functions, performs, and is fit for its purpose. They may also work with marketers to develop the product concept and specifications to meet customer needs, and may direct the design effort. In many engineering areas, a distinction is made between the "design engineer" and other engineering roles planning engineer, project engineer, test engineer). analysis tends to play a larger role for the latter areas, while synthesis is more paramount for the former; nevertheless, all such roles are technically part of the *overall* engineering design process.

Design engineers may work in a team along with other designers to create the drawings necessary for prototyping and production, or in the case of buildings, for construction. However, with the advent of CAD and solid modelling software, the design engineers may create the drawings themselves, or perhaps with the help of many corporate service providers.

The next responsibility of many design engineers is prototyping. A model of the product is created and reviewed. Prototypes are either functional or non-functional. Functional "alpha" prototypes are used for testing; non-functional prototypes are used for form and fit checking. Virtual prototyping and hence for any such software solutions may also be used. This stage is where design flaws are found and corrected, and tooling, manufacturing fixtures, and packaging are developed. The design engineer may follow the product and make requested changes and corrections throughout the life of the product. This is referred to as "cradle to grave" engineering. The design engineer works closely with the manufacturing engineer throughout the product life cycle.

The design process is an information intensive one, and design engineers have been found to spend 56% of their time engaged in various information behaviours, including 14% actively searching for information. In addition to design engineers' core technical competence, research has demonstrated the critical nature of their personal attributes, project management skills, and cognitive abilities to succeed in the role.

3.2.1 DASSAULT SYSTEM:

it is a French software corporation. It is among *Fortune 50* list of the largest software company that develops software for 3D product design, simulation, manufacturing and more.

A Dassault Group subsidiary spun off from Dassault system in 1981, it is headquartered in, France, and has around 20,000 employees in 140 different countries. A pioneer in CAD with CATIA, 3DS has expanded into a diverse range of software categories and industries. Established companies and start-ups use the company's 3D EXPERIENCE platform to create, test and optimize consumer and business to business products and services. A design engineer is an engineer focused on the engineering design process in any of the various engineering disciplines and design disciplines like human computer interaction. Design engineers tend to work on products and systems that involve adapting and using complex scientific and mathematical techniques. The emphasis tends to be on utilizing engineering physics and other applied sciences to develop solutions for society

CHAPTER-4

PROJECT IMPLEMENTAION

4.0 METHODOLOGY:

In order to achieve uniform flow rate with the decrease in the percentage fill of the drum, the conventional cylindrical shape of the drum was changed to a conical shape. The geometry of the conical shape was derived using trial and error methods based on the experience gained from other currently available seeder. The conical shape geometry allows grains to flow to the bottom-most position of the drum via gravity, which is not the case in the cylindrical shaped drum. Also, in order to maintain uniform seed spacing and seed rate, tubes were introduced to each hole around the circumference of the drum. This allows the required delay to meet uniform seed spacing as the grains are passing through the tube. Inside the drum, agitators were fixed to control the flow against the possible centrifugal flow of seeds. A floater was designed and attached in order to float in boggy conditions. Sheet metal of gauge 18 was used to fabricate the drum and floater. The initial design had three drums forming six rows. Drums were fixed to an axle, which was connected to two wheels having lugs to facilitate rotating even in

boggy fields. A skid was attached to the frame for floating in boggy conditions. The skid was designed with open slots to be able to position seeds in the soil. Two rows of orifices were provided on the circumference of each conical-shaped drum in order to obtain the recommended spacing of 20 cm between the rows and 15 mm between the hills. Drums were rigidly fitted 20 cm apart on the axle. Wheels of 60cm diameter were connected to the axle such that when the wheels rotate, drums rotate along with the shaft and wheels, placing 12 hills in 6 rows per revolution. The handle is connected to the axle by steel bushings. The skid is supported by the frame and hinged to the axle so that the operator can adjust the angle according to his height and field conditions. After carefully looking at the situation with the conical drum seeder, it was found that there was no proper mechanism to control the seed rate according to the variety of the seed. For instance, if the size of the holes along the circumference of the conical drum was designed for a variety of rice having long grains, an excessive amount of short grain rice was delivered without control. On the other hand, if the hole size is kept for a variety of rice having shorter grain size, then a longer grain rice variety will not drop at all. Hence, a mechanism was designed to control the size of the hole according to the grain size of the rice variety. Apart from that, it was also revealed that the weight of the machine was excessive, it was difficult to turn the seeder at the end of the plot, and the drums and folate could corrode easily as it is generally supposed to be used in mud. Hence, in order to improve the performance of the seeder, some changes were made. The number of conical drums was reduced to two from three to reduce weight and facilitate turning at the end of the plot. Also, in the new design, an inner drum was introduced, concentric to the outer drum

After careful analysation we decided to add motor to the DRUM SEEDER making it automatic, which is very useful for the farmers, the motor is powered by battery with only one push of the button we can start the motor, it is easy to use and it comes with low maintenance.

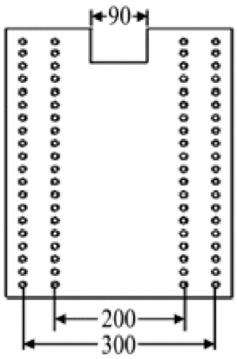
4.1 PRINCIPLE OF AUTOMATIC DRUM SEEDER;

The seed was deposited in four drums mounted on a shaft which was supported by two ground wheels on either side and pulled by a motor. When an operator pulled the machine, the forward movement of the machine rotated the driving wheels, which consequently rotated the drum hoppers attached to the shaft and dropped the seeds due to gravity force in rows on the field. The power to the motor is provided by the battery and the prototype moves forward based on that power

4.2 PHYSICAL PROPERTIES OF SEED;

Paddy, wheat, mung bean, black gram, lentil, mustard, and radish seeds were used in the experiment. As it is a multi-crop seed drill machine, different types of seeds were tried to sow only by changing the seed opening plate because the size of seeds are different. The weight of seed was determined by weighing 10 samples of 100 grains by an electronic balance. Since the shapes of seeds were irregular and sizes were too small, it was difficult to measure these attributes by slide callipers or other instruments. Preparation of Pre-germinated Paddy Seeds Seed preparation for wet seeding, the salt was mixed with water in the proportion. Seeds were then soaked in salted water in bucket. After one-hour lighter seeds and other impurities floating on the water were removed. Seeds were kept in the water for 24 hours. After 24 hours excess water in bucket was drained out. The soaked seeds were placed in gunny bags and kept for next 24 hours. Length of sprout expected to be 1mm to 2mm. The sprout lengths more than this limit will result in intervening of root and prevent free flow of seeds through the holes of the drums. For increasing the temperature during the incubation, gunny bags were kept surrounded by paddy straw. Therefore, the sizes of seeds were measured by Image J software. In that case, a number of seed were scanned in scanner and black and white image was stored in the computer. During scanning a known scale was always maintained to get actual data from Image-J. After that the size was determined using Image J software. The maximum and minimum dimensions of seeds were recorded and maximum dimension with shape of the seed was considered to design the opening for dropping seed.

4.3 Adjustment of opening hole and row-row distance for different seeds:



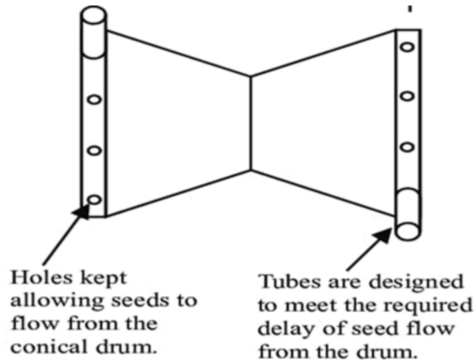


Fig.18 Drum hole   Fig.19 Drum hole

There is an opening in each drum covered by a plate with the help of screw. By displacing the plate, drums were filled by the seed and then attached the plate to close the opening. The diameter of holes on the drum was the highest diameter of the experimental seeds and the holes were arranged in seven rows at a given distance on two drums. There was a provision to fix another plate with desired size of hole on the drum for sowing a specific seed as shown in. However, an arrangement was kept for setting the drums and wheels at a desired distance to adjust the spacing between rows.

There is the opening for mustard seeds. This opening was made according to the seed dimensions and it is different for different crop seeds. A metal band without hole was made to close a series of hole which was not needed during sowing a specific seed. the adjustment of distance between row to row for different seeds such as paddy, wheat, mung bean, black gram, lentil, mustard, and radish is possible, with the power of the motor the drum seeder works effectively

Specifications of holes of drum		
Sr. No.	Particulars	Specifications
1	Number of holes on one side of drum	8
2	Average diameter of holes, mm	9
3	Peripheral spacing between two holes, mm	60
4	Shape of holes	Circular
5	Number of rows per drum	2
6	Spacing between two rows in a drum, mm	200

Table-2 Hole specification

POLYPROPYLENE CO-POLYMER

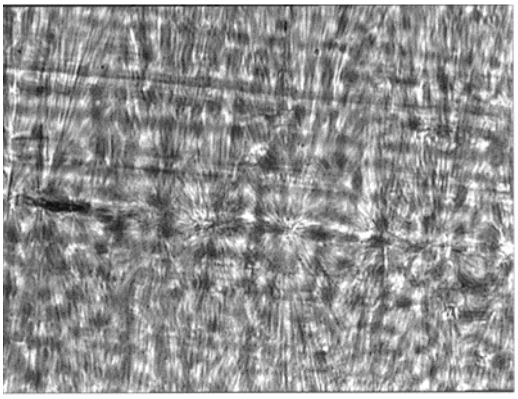


Fig.20 Micrographic view

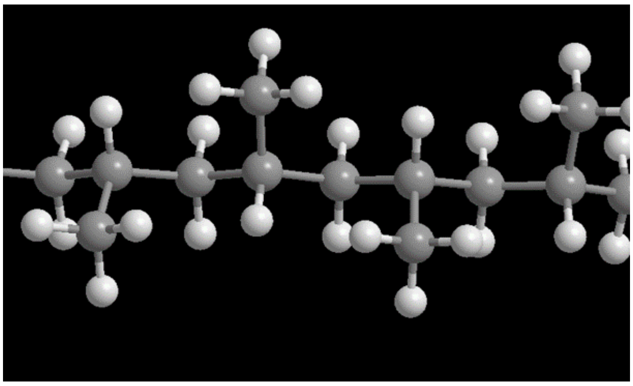


Fig.21 Structure

Polypropylene, also known as polypropene, is a thermoplastic polymer used in a wide variety of applications. It is produced via chain growth polymerization from the monomer propylene

Polypropylene belongs to the group of polyphines and is non polar. Its properties are similar to polyethylene, but it is slightly harder and more heat resistant. It is a white, mechanically rugged material and has a high chemical resistance.

4.4 DETERMINING SEED RATE;

The seeder has 6-drums mounted on a shaft with two ground wheels on either side. There are a number of holes in four rows on around the drum. It had a handle to pull the machine. When the seeder was pulled by an operator, the forward movement of the seeder rotated the driving wheels, which rotated the drum hoppers and dropped the seeds for gravity force in rows through the seeding holes of the hoppers.

However, the seed rate was determined in the laboratory of Farm Power & Machinery, INDIAN Agricultural University. Before starting the laboratory test, seeds were soaked in a drum for 2 days. Then, the soaked seed were kept in the basket by covering banana leaves for a day and seeds germinated. Then, the drum of the seeder was filled with germinated seed and the seeder was jacked to clear the wheel from ground. The drums were rotated 30 times by turning the wheels with hand. The amount of seed metered from each drum for the given turn was collected and weighed. The time of turning was also recorded with a stopwatch. The seed rate was determine using the following equation;

$$C = \frac{W \times 10000}{N.\ A}$$

Where,

C = seed rate in kg/ha

W = weight of seed collected in N times of wheel revolutions, kg

A = area of covered per turn of wheel revolution, m2

D = Diameter of wheel, m

Uniformity of seeding

Carry out the following test to ensure the uniformity seeding device of the direct paddy drum seeder. 1. Sticky Belt Method 2. Sand Bed Method Uniformity of seed spacing is the manner of placing of seeds. The uniformity of seed distribution is checked as; a bed of polythene measuring 15m x1.6cm was spread on the hard surface. The polythene was coated with white grease that helps in striking of seeds without rolling or bouncing on the bed surface. Direct paddy drum seeder was manually operated forward maintaining the speed of 1, 1.5 and 2 km/h. The seed metering system of the direct paddy drum seeder was set to place the pre germinated paddy seeds. Seed spacing of 100 -100 seeds of pre germinated paddy were measured on the sticky bed to estimate the performance indices and to check the dropping pattern. The test was replicated three times

4.5 WORKING PRINCIPLE OF DRUM SEEDER WITH UREA;

When an operator pulls the applicator manually or automatically controlled by the switch, the forward movement of the machine rotates the driving wheels which rotate the drum and the metering device in the hopper. One GU is hold in the cup of metering device and dropped on the furrow making by the furrow opener. After that, the furrow closer covers GU with soil. The developed applicator's aims to place Urea continuously at the subsurface of soil between two rows of plants. A line-to-line distance of 20 cm, depth of prilled urea placement of 5-7 cm, and field operating condition at 1-1.5 cm standing water (for softening the field) was the designed hypothesis. The size of the metering cup is designed in such a way so that each cup takes one urea at a time. There is no way to block their passage due to shape of the urea and cup, rubber gate and enough forces applied due to fixed attachment of metering cup with rotating driving shaft.

- Areas can be revegetated quickly and cheaply
- Seeds cost less than seedlings
- Seed is easier and cheaper to transport and store than seedlings
- Seeding requires less time and labour than seedlings
- A mixture of trees, shrubs and groundcovers can be sown at the sometime. The different rates of germination mimics natural regeneration
- The mixture of tall, medium and small species can make a more effective windbreak
- Direct seeded plants tend to have better root growth and are therefore more prepared for climatic extremes
- More plants may germinate in the years following sowing
- On farm machinery can be used to prepare seed beds. This removes the need to use specialised seeders.

4.6 RESULT

Particulars	Transplation method	Automatic seeding method
Days of transplant	8-10 days	0 days
Cost of raising nursery	1,500rs	0
Labour requirement	5-7 people	2 people
Time required for seeding(one acer land)	120minutes	70 minutes
Cost for uprooting	2000rs	0
Total cost for planation (one acer land)	10,000rs	12,000rs

Table-3 Result

CHAPTER-5

PROJECT TESTING

Automatically operated prototype model of the drum seeder with optimized levels of variables was fabricated for performance evaluation. The unit consists of a seed drum, main shaft, ground wheel, floats, Battey, electric motor and handle for manual operation. The seed drum is of hyperboloid in shape with 200 mm diameter having 12 mm flat spikes of 25 mm length kept parallel to the axis of rotation. The slopes of the cone facilitate the free flow of seeds towards the metering holes. Nine seed metering holes were provided along the circumference of the drum at both ends at a row-to-row spacing. The main shaft of the drum seeder consists of a 25 mm diameter mild steel pipe of thickness 1.5 mm to accommodate the seed drums.

For better traction, numbers of lugs made of galvanized iron sheet were welded to the inner periphery of the wheel. Two floats were provided on either side to restrict the sinkage and to facilitate easy pulling of the unit with proper use this seeder can be used manually and also with a motor that make it use effortlessly. To make the seeds fall on an opened hole and to avoid the scattering of seeds hole were provided with careful inspection. The position of the opener was set to have a marked furrow on the soil surface. The depth of furrow can be adjusted by adjusting the position of nut and bolt on the travel hole of the furrow opener.

The handle of the drum seeder was made of 18 mm diameter mild steel pipe and hinged to the main shaft by 25 mm mild steel pipe bushes. The height of the handle from the ground level can be adjusted using the holes provided depending on the height of the operator although the handle can be removed for automatic purpose, taking that as a consideration the distance between the shaft and iron frame to which the motor is attached is 25mm. The forward direction movement of the machine is done on the wheel shaft is connected to the motor, when the switch is on the prototype moves forward at considerable speed. It can forward and backward direction by the arrangement of wires or just by the click of a switch

5.1 OVERVIEW OF TESTING METHOD:

Fig.22 Final project

we completed testing of automatic drum seeder by using wheat seeds we couldn't test it on agricultural field so we did the test on concrete lands with100square feet area. The total length of automatic drum seeder is 5.5 feet in length and 4.8 feet in breadth the test was successful the prototype was moving with a speed of 9 km per hour we completed our test moderately the seed rate was uniform

CHAPTER-6

CONCLUSION AND FUTURE ENHANCEMENT

Agricultural development plays important role as a driver of rural poverty reduction. The effort required to develop an automatic drum seeder will meet the demand of farmers. The implement is used for sowing pre-germinated paddy seeds. The sprouted seeds are filled in the drums of seeder and single person pulls the seeds in the field. Automatic seeder completed the work faster than normal speed of the daily labour, cost of labour is reduced, the crop efficiency has also increased. field test was included in the testing of seeder, so this can be the best machine for the farmers with small land. This semi-automatic drum seeder is developed to reduce the time and effort required for production up to the great extent also this machine manufacturing cost is less as compared to other The efficiency of drum seeder should be satisfactory and it is easy to operate. It was faster than the traditional method of. Less labour needed and it is more economical than hand seeding. Here do not use any fuel and power. Hence maintenance cost is very less. Cost of seeding by this machine comes to only one-third of the corresponding cost by manual laborers. The development of Low -cost automatic drum seeder is done with locally available material. The overall performance of the was satisfactory.

FUTURE ENHANCEMENT

- The size of the wheel can be change according to the land
- Improvements can be done so, that the prototype can work using Bluetooth devices
- Solar panel can be attached to the drum seeder for continuous energy

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6.2 WEBSITE

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3. **https://en.wikipedia.org/wiki/Electric_moto**
4. **https://en.wikipedia.org/wiki/Electric_battery**
5. **https://en.wikipedia.org/wiki/Seed_treatment**

A Major Project Report

On

DEVELOPMENT OF AUTOPILOT DELIVERY DRONE

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

B. PAVEN MANO RAIVATH -	**(17K81A0311)**
M. TEJDEEP -	**(17K81A0334)**
MARCEL NOEL -	**(17K81A0338)**
N. PREETHI -	**(17K81A0346)**

Under the Guidance of

Dr. D.V. SREEKANTH

Professor & Head of the Department

DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Development of Autopilot Delivery Drone**, is being submitted by **B. Paven Mano (17K81A0311), Marcel Noel Issac(17K81A0338), N. Preethi (17K81A0346), M.Tejdeep (17K81A0334)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide	Signature of HOD
Dr. D.V. SREEKANTH	**Dr. D.V. SREEKANTH**
Professor & Head of the Department	**Professor & Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin’s Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Development of Autopilot Delivery Drone** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has beencarried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

B. PAVEN MANO (17K81A0311)
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ABSTRACT

The rapid increase in usage of online ordering has increased the requirement of manpower to deliver in multiple folds. Drone based technology is being used to meet this requirement. A quadcopter can achieve vertical flight in a stable manner and be used to monitor or collect data, delivery in a specific region.As the demand for commercial deliveries increases within cities, companies face a fundamental limitation in surface road capacity. Drone delivery aims to overcome that limitation by exploiting the vertical dimension above city streets.With advancing drone technologies and increasing commercial usage, we believe the last mile shipping industry is ripe for disruption by delivery drones. Drones can significantly accelerate delivery times and reduce the human cost associated with the delivery.

UAV has been designed which is an unmanned aerial vehicle that have reduced the cost and increase the performance of the low power microcontrollers that allowed the general public to develop quadcopter. The goal of this project is to design the brushless direct current (BLDC) motor and its driving circuits, for quadcopter kit to obtain stable flight, gather and store GPS data, and perform auto commands, such as auto-landing.

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CHAPTER-1

INTRODUCTION

1.1 Overview of the project

An unmanned aerial vehicle (UAV for short; also known as a drone) is any aircraft that does not have a human pilot onboard. UAVs have their origins as early as 1915 when Nikolai Tesla wrote a dissertation in which he described “an armed, pilotless-aircraft designed to defend the United States.”

UAVs come in a variety of sizes, designs and purposes. Initially, UAVs were merely remotely piloted; however, autonomous control is becoming more widely utilized.

Developing an unmanned aerial vehicle has been one of the main points of concern by many counties all over the world; about 70 different countries have some sort of UAV technology.
UAVs are used to gather information from the air in hostile areas. They can also be used in devastated areas where man support may not be available. These types of UAVs must be portable by ground and very reliable for recurrent use.

Operators use ground control stations to set the parameters of the mission and the UAV autopilot directs the drone or other unmanned craft to complete the task. The main goal of the project is to deliver any product autonomously by an automated path with minimal human effort.

1 .2 Objective of study

The main objective of the work is to design a UAV (unmanned aerial vehicle) which is drone (Dynamic Remotely Operated Navigation Equipment) with BLDC driver circuit and servo mechanism, which can deliver any product autonomously by an automated path with minimal human effort.

An autopilot is a flight control system that allows a pilot to fly an airplane without continuous hands-on control.

Autopilot system works by sending signals to the flight control system. The pilot inputs the type of waypoints in mission planner software by connecting USB to the drone.

The commands will be stored in the memory of drone. After initiating the autopilot mode, the drone follows the commands which are given.

While landing servomechanism comes to part which involves in delivery of the product.

The drone has significant amount of requirement in especially the commercial industry in order to overcome the difficulties by conventional methods. Now, along with the commercial industry, there is a wide range of scope for the usage of an autopilot UAV.

1.3 Scope of study

Whether you call them Unmanned Aerial Vehicles (UAVs), Miniature Pilotless Aircraft or Flying Mini Robots, drones are rapidly growing in popularity. They are still in the infancy stage in terms of mass adoption and usage, but drones have already broken through rigid traditional barriers in industries which otherwise seemed impenetrable by similar technological innovations.

Over the past few years, drones have become central to the functions of various businesses and governmental organizations and have managed to pierce through areas where certain industries were either stagnant or lagging behind. From quick deliveries at rush hour to scanning an unreachable military base, drones are proving to be extremely beneficial in places where man cannot reach or is unable to perform in a timely and efficient manner.

Increasing work efficiency and productivity, decreasing workload and production costs, improving accuracy, refining service and customer relations, and resolving security issues on a vast scale are a few of the top uses drones offer industries globally. Adoption of drone technology across industries leapt from the fad stage to the mega-trend stage fairly quickly as more and more businesses started to realize its potential, scope, and scale of global reach.

Whether drones are controlled by a remote or accessed via a smartphone app, they possess the capability of reaching the most remote areas with little to no manpower needed and require the least amount of effort, time, and energy. This is one of the biggest reasons why they are being adopted worldwide, especially by these four sectors:

- Military

Military usage of drones has become the primary use in today's world. Used as target decoys, for combat missions, research and development, and for supervision, drones have been part and parcel of the military forces worldwide.

- Commercial (construction, food delivery, health care delivery, etc.)

As it becomes cheaper to customize commercial drones, the door will be opened to allow new functionality in a wide array of niche spaces. Sophisticated drones could soon be doing everyday tasks like fertilizing crop fields on an automated basis, monitoring traffic incidents, surveying hard-to-reach places, or even delivering pizzas.

- Personal

Personal drones are used for filmmaking, recording, still photography and gaming by common tech-savvy enthusiasts. While primarily aimed at hobbyists, these types of devices are widely available, and the market is growing.

- Future Technology

Drone technology is constantly evolving, so future drone tech is currently undergoing groundbreaking progressive improvement. Research suggests that drone technology has seven potential generations, and the majority of current technology sits in the fifth and sixth generations, i.e., commercial suitability, safety and regulatory standards-based design, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.

The technological potential with drones is immense, and its uses will only grow with time.

1.4 Material requirement

Material involves seeking the best match between property-profiles of the materials and that required by design. To sustain quality assurance, we have chosen the following materials.

SR NO	**ELEMENT NAME**	**MATERIAL**
1	ARMS	POLYAMIDE NYLON
2	LANDING GEARS	POLYCARBONATE
3	TOP PLATE	ABS PLASTIC
4	BOTTOM PLATE	ABS PLASTIC

Table No:1

Polyamide Nylon: A polyamide is a polymer with repeating units linked by amide bonds. Polyamides occur both naturally and artificially. Polyamides (or Nylon) are made from polycondensation of diacid with a diamine or by ring-opening polymerization of lactams with 6, 11 or 12 carbon atoms.

Advantages

- High Abrasion Resistance – Higher levels of resistance to wear by mechanical action.
- Good Thermal Resistance – Special grades of nylon can have a melting point of almost 300°C.
- Good Fatigue Resistance – This makes it ideal for components in constant cyclic motion like gears.
- High Machineability – Cast billets can be machined into various components that would be too costly to cast into intricate shapes.

Polycarbonate: Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. organic functional groups linked together by carbonate groups (–O–(C=O)–O–) and offers a unique combination of properties.

Advantages

- Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent.
- They are easily worked, molded, and thermoformed.
- It is also very lightweight and capable of withstanding extreme temperatures, either hot or cold.
- It is affordable protect against discoloring and perfect for greenhouse.

ABS Plastic: ABS (acrylonitrile-butadiene-styrene) is a low-cost engineering thermoplastic that is easily machined, fabricated, and thermoformed. This thermoplastic material has good chemical stress and creep resistance.

Advantages

- Excellent impact, chemical and abrasion resistance.
- Superior stiffness and strength.

- Easily machined and thermoformed.
- Easy to paint and glue.
- Good dimensional stability.
- Excellent electrical properties.

1.5 PROCUREMENT OF MATERIALS:

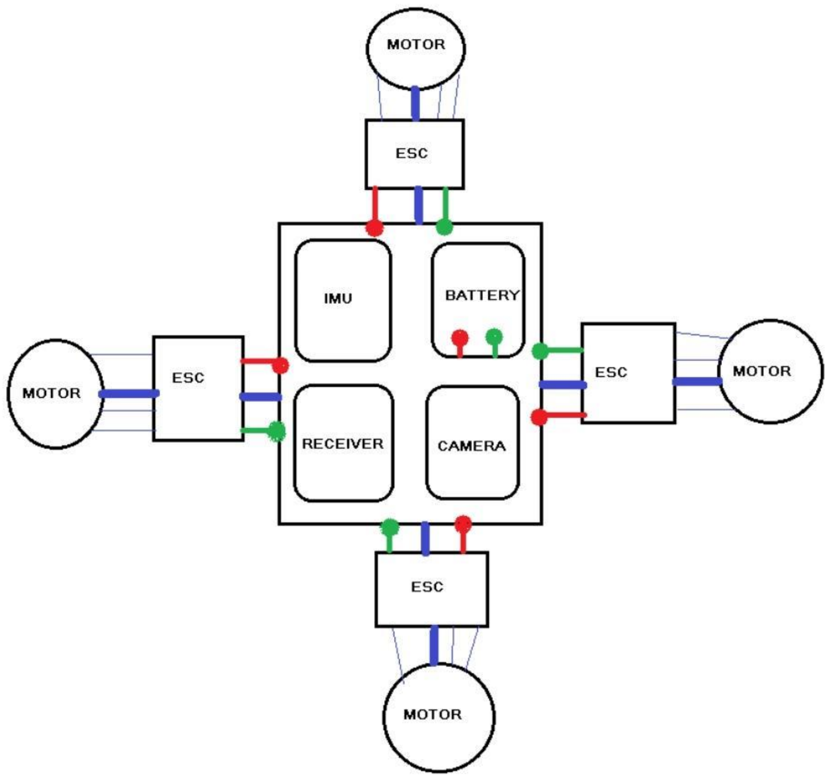


Fig.no.1 Block diagram

Selection of Components:

1. Structure (Frame).

2. Printed Circuit Board (PCB Boards).

3. Propulsion System (Motor - 4).

4. Landing Gears (4).

5. Telemetry and Remote (Transmitter and Receiver).

6. Electronic Speed Controller (ESC - 4).

7. Control System (Flight Controller).

8. Power Source (Lithium-Ion Battery Pack).

9. Servo Mechanism.

1.5.1 Frame :

The frames are cut from carbon fiber sheet. Carbon fiber is a composite material, being made up of many layers of interwoven carbon fibers that have been rigidly cemented within a binding matter. Developing an Aerial will definitely start from the weight strength of the material Structure are made from carbon fiber here we designed a multirotor aircraft which has 4 rotors to deliver thrust that can lift whole aircraft as we used 4 rotors it is known as a quadcopter, so the construction and design concentrates that the payload is near to the center of Gravity so that the equal amount of load sharing happens to be the basic element of a drone is a frame. The classification of the frame construction is shown in Figure. Due to the number of arms and the motors used the drones are classified as shown below.

1. Bi-copters – Two Motors
2. Tri-copters – Three Motors
3. Quad-copters – Four Motors
4. Hexa-copters – Six Motors
5. Octo-copters – Eight Motors

Fig No: 2 Frame parts

Main part of drone is the PCD Board which has a key role were landing gears and arms of the motor were connected it transfer the weight to all the arms equally so that drone can be fly stable.

1.5.2 Printed Circuit Board (PCB Boards):

A drone power distribution board (PDB) I is simply a printed circuit board (PCB) used to supply power from the source to the various parts of a drone. Before the invention of PDBs, designers used to connect drone parts with a wires help, resulting km heavy weights because if copped and solder joints in the cables. A PCB board i.e., Printed circuit board mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.

1.5.3 Propulsion System :

The next components of a drone are engine and propellers. They constitute the main propulsion system of a drone and are subjected to the highest loads; therefore, their durability is very system of a drone and are subjected to highest loads, therefore their durability is very important. The propellers change a torque (derived from the engine) for a work used for lifting the vehicle in the air. Due to the propeller system in relation to the flight direction it can be divided into the following types:

- + – One is the leading propeller (at least four propellers)
- X – The most common construction, in which two propellers are leading (with an even number of propellers)
- Y – Three arms stacked in the Y, where one or two arms can be leading.
- V – Very rare arrangement in which two propellers lead onto outstretched arms.
- H – A very rare arrangement where the construction is based on the H- shaped with two propellers leading.

In each of the about mentioned constructed can be mounted double propellers (At the top and in bottom), which significantly increases the strength of the drone, and does not require the addition of another arm. Double propellers mounted on a smaller number of arms increases the strength of a drone allowing more lift capacity and insuring the parallel motors in case of failure. The wings of drones are divided based on adopted for rotation:

- Clockwise (CW)
- Counterclockwise (CCW)

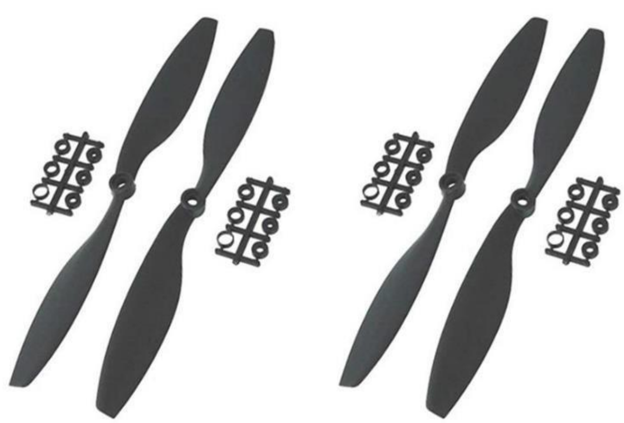


Fig No: 3 Propellers

The wings are made of carbon fiber, plastic and are attached to each other by lamination. B Bigger the propeller blades the stronger must also. The brushless motors are used very often for building drones. However, using brushless motors improves durability, efficiency and reduces the reduces the consumption of moving parts.

Propulsion System Lift

Lift of the drone is caused due to thrust generated by propeller which revolved by a brushless motor the calculation starts from AUW of the aircraft that is gross weight of the drone the propulsion system should be able to produce double thrust than AUW at 100% throttle so that it can hover at 50% throttle so the selection of propulsion system is by calculating the total weight times 2 and divided by no of rotors so that we can get thrust per rotor.

Propeller is the key element in any aerial vehicle where the thrust is generated main aspects in choosing of propeller is the length and pitch of the blade as length and pitch angle increases thrust increases, we length of the propeller is determined by rpm of the motor and pitch is directly proportional to torque of the motor.

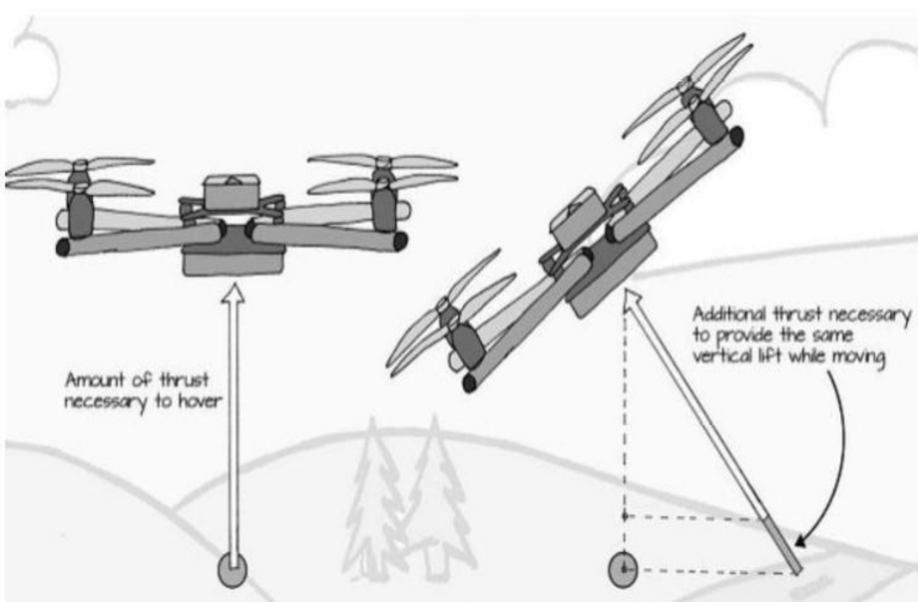


Fig No: 4 Propulsion Lift

1.5.4 Landing Gears:

Landing Gear for drones provides additional ground clearance. This can help protect the drone from Crashes. They can widen the drone's "stance", allowing for a more stable take-off and landing.

Fig.No. 5 Landing gears

1.5.5 Telemetry and Remote:

- Ensure the battery is disconnected (this is important because it is possible to accidentally arm the vehicle during the RC calibration process)
- Ensure the RC receiver is connected to the autopilot.
- Turn on your RC transmitter and if it has "trim tabs" ensure they are in the middle.
- Connect the autopilot to the PC using a USB cable.
- On the Mission Planner press the "Connect" button and open Mission Planner's INITIALSETUP | Mandatory Hardware | Radio Calibration screen
- Some green bars should appear showing the Ardupilot is receiving input from the Transmitter/Receiver. If no bars appear check the receiver's LED:

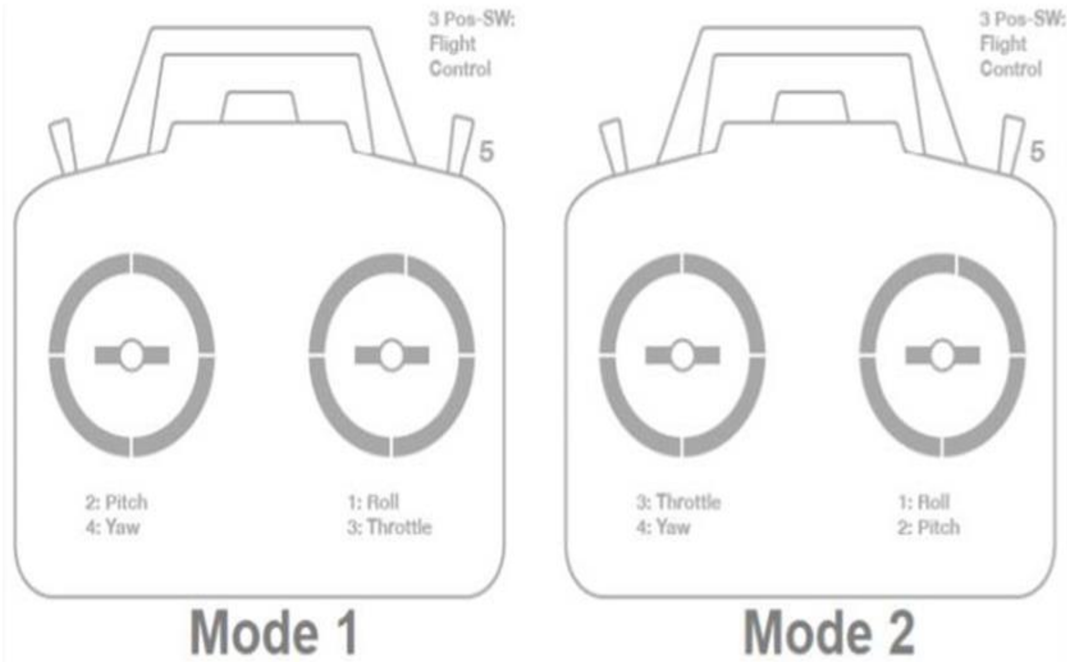
1. No lights may indicate that it is incorrectly wired to the autopilot. Look for connectors that may have been inserted upside down.
2. A Red or flashing LED may indicate that your RC transmitter/receiver need be bound.

See the manual that came with your RC equipment for instructions.

Model 1 and Model 2 Transmitter setup

There are two main transmitter configurations:

- Mode 1: left stick controls pitch and yaw, the right stick will control throttle and roll.
- Mode 2: left stick controls throttle and yaw; the right stick will control pitch and roll.



1.5.6 Electronic Speed Controller (ESC):

An electronic speed control or ESC is an electronic circuit that controls and regulates the speed of an electric motor. It may also provide reversing of the motor and dynamic braking. Miniature electronic speed controls are used in electrically powered radio-controlled models. Full-size electric vehicles also have systems to control the speed of their drive motors.

Electronic speed control basically a motor driver which acts as an inverter converts dc supply to 3 phase ac with frequency control with input PWM signal and the major parts of the esc are MOSFETS which switches the power in very less time and supply to three phases of the motor all this MOSFETS are controlled by a microcontroller which is inbuilt in the esc board.

Fig No: 5 Electronic Speed Controller

This is responsible for speed control of the motor by changing output frequency in phase windings which are connected to outputs of esc generally esc is rated in maximum amp draw that is 80A at 52V max in our case and allow input PWM throttle frequency from 50 to 500hz which determine the rpm of the motor which regulates the thrust of each axis.

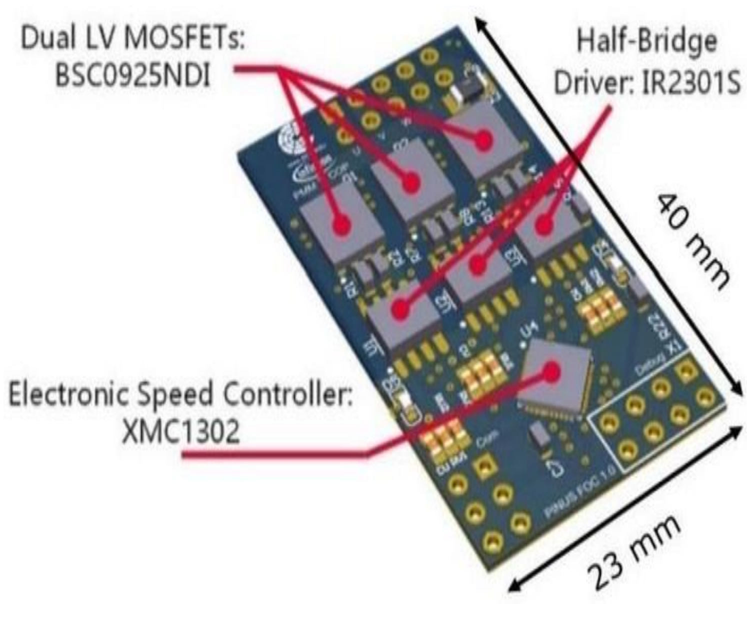


Fig No:6   PCB of ESC

1.5.7 Control System (Flight Controller):

A flight controller (FC) is a small circuit board of varying complexity. Its function is to direct the RPM of each motor in response to input. A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

Most flight controllers also employ sensors to supplement their calculations. These range from simple gyroscopes for orientation to barometers for automatically holding altitudes. GPS can also be used for auto- pilot or fail-safe purposes. More on that shortly. With a proper flight controller setup, a pilot’s control inputs should correspond exactly to the behavior of the craft. Flight controllers are configurable and programmable, allowing for adjustments based on varying multi-rotor configurations. Gains or PIDs are used to tune the controller, yielding snappy, locked-in response. Depending on your choice of flight controller, various software is available to write your own settings.

Many flight controllers allow for different flight modes, selectable using a transmitter switch. An example of a three-position setup might be a GPS lock mode, a self-levelling mode, and a manual mode. Different settings can be applied to each profile, achieving varying flight characteristics.

Fig No:7 Flight Controller

Main controller and flight controller regulate all the esc of motor with respect to integrated sensors and pilot or ground station commands. Its main controller responsibility to control the drone in stable position. Main sensors in flight controller are:

1. Accelerometer
2. Gyroscope
3. Compass
4. Magnetometer
5. Barometer
6. GPS

Circuit Overview

1. Telemetry System — Allows you to plan/run missions, and control and monitor the vehicle in real time. Typically includes telemetry radios, tablet/PC, and ground station software.
2. Buzzer — Provides audio signals that indicate what the UAV is doing.
3. Remote Control Receiver System — Connects to a hand-held transmitter that an operator can use to manually fly the vehicle (shown is a PWM receiver with PWM->PPM converter
4. (Dedicated) Safety switch — Press and hold to lock and unlock motors. Only required if you are not using the recommended GPS with inbuilt safety switch.
5. GPS, Compass, LED, Safety Switch — The recommended GPS module contains GPS, Compass, LED, and Safety Switch.
6. Power System — Powers Cube and the motor ESCs. Consists of LiPo battery, power module, and optional battery warning system (audio warning if battery power goes below a predefined level).

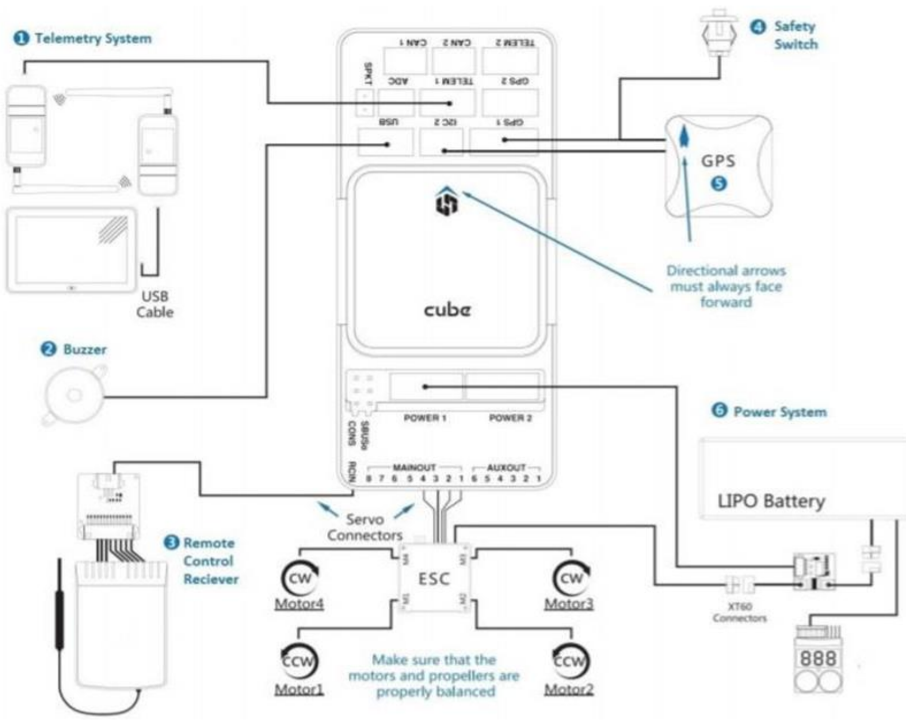


Fig No: 8 PCB of Flight Controller

Sensors:

All flight sensors in Pixhawk 2 Cube are connected via SPI. On-board we have an MPU9250 or ICM 20xxx Gyro and Accelerometer, and a MS5611 used in SPI mode. On the vibration isolated board, we have the L3GD20 gyro, the LSM303D Accelerometer and magnetometer, another MPU9250 or ICM 20xxx, and MS5611 also used in SPI mode. The board mounted sensors run on a separate bus to the Vibration isolated sensors.

Interfaces

- 2x CAN (one with internal 3.3V transceiver, one on expansion connector)
- Spectrum DSM / DSM2 / DSM-X® Satellite compatible input
- Futaba S.BUS® compatible input and output
- PPM sum signal input
- RSSI (PWM or voltage) input
- I2C o SPI
- 3.3 and 6.6V ADC inputs

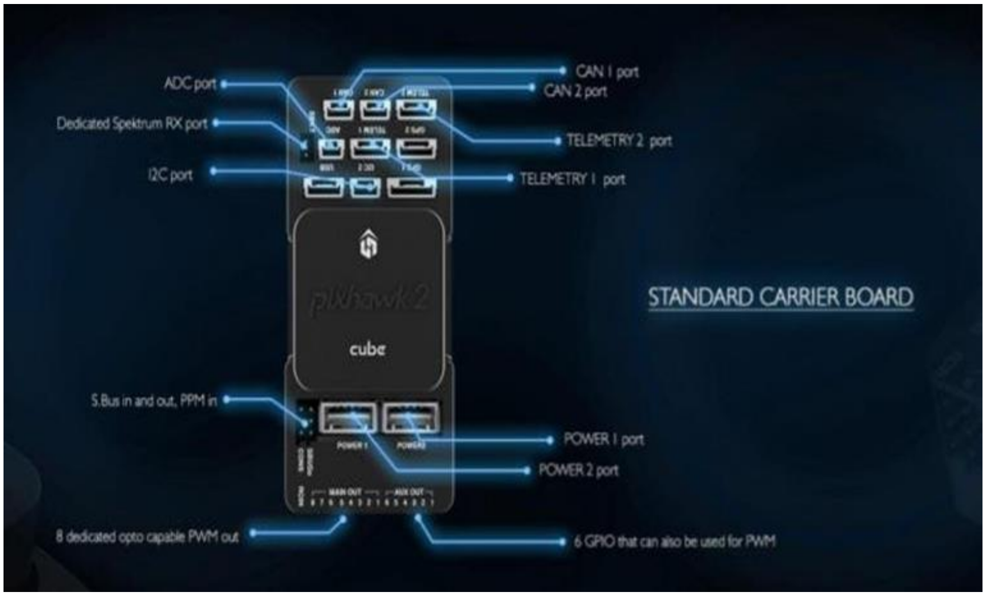


Fig N0: 9 Standard Carrier Board

- Internal micro-USB port and external micro-USB port extension

External Sensors

- Concurrent reception of up to 3 GNSS (GPS, Galileo, GLONASS, Bei Dou)
- Industry leading –167 dBm navigation sensitivity
- Security and integrity protection
- Supports all satellite augmentation systems.
- Advanced jamming and spoofing detection
- Breakaway mount
- Notification RGB LED
- HMC5983 MAG, and LIS3MDL Mag & 6CM Ground plane

Fig No: 10 Global Positioning System (GPS)

1.5.8 Battery:

The energy density of lithium-ion is typically twice that of the standard nickel-cadmium. There is potential for higher energy densities. The load characteristics are reasonably good and behave similarly to nickel-cadmium in terms of discharge. The high cell voltage of 3.6 volts allows battery pack designs with only one cell. Most of today's mobile phones run on a single cell. A nickel-based pack would require three 1.2-volt cells connected in series.

Lithium-ion is a low maintenance battery, an advantage that most other chemistries cannot claim. There is no memory, and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to nickel-cadmium, making lithium-

Ion well suited for modern fuel gauge applications. lithium-ion cells cause little harm when disposed.

Despite its overall advantages, lithium-ion has its drawbacks. It is fragile and requires a protection circuit to maintain safe operation. Built into each pack, the protection circuit limits the peak voltage of each cell during charge and prevents the cell voltage from dropping too low on discharge. In addition, the cell temperature is monitored to prevent temperature extremes. The maximum charge and discharge current on most packs is limited to between 1C and 2C. With these precautions in place, the possibility of metallic lithium plating occurring due to overcharge is virtually eliminated.

Advantages

- High energy density - potential for yet higher capacities.
- Does not need prolonged priming when new. One regular charge is all that is needed.
- Relatively low self-discharge - self-discharge is less than half that of nickel-based batteries.
- Low Maintenance - no periodic discharge is needed there is no memory.

1.5.9 Servo Mechanism:

Servomechanism , automatic device used to correct the performance of a mechanism by means of an erroe-sensing feedback . The term servomechanism properly applies only on to systems in which the feedback and error-correction signals control mechanical position or one of its derivatives such as velocity or acceleration . A servomotor is rotary actuator or Linear actuator that allows for precise control of angular or linear position, velocity, and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servo uses in UAV

- Copter, Plane and Rover can control servos for any purpose, including triggering a camera shutter, releasing a parachute, or dropping a tennis ball. These servo(s) can be controlled either directly by the pilot via a switch on the transmitter, through commands sent from the ground station or as part of a mission.
- Either analog or digital servos may be used.
- We are using analog servo as we are releasing a payload of 500 gm.

Connection:

- Connect the servo to AUX OUT 1, 2, 3 or 4.
- The Pixhawk autopilot cannot provide power to the servos so an external BEC or ESC that can provide 5V should be used.

Fig.No. 11 Servomechanism

CHAPTER-2

LITERATURE SURVERY

2.0 LITERATURE REVIEW ON RESEARCH AREA

UAVs have been in production since before the Wright Brothers first took their historic flight. The earliest account can be traced back to the American Civil War, when an inventor patented an unmanned balloon that carried explosives that could be dropped after a time-delay fuse mechanism triggered a basket to overturn its contents. While this is a relatively primitive idea of what the world has come to know today as “drones” it goes to show how early man began thinking about unmanned aerial systems. This technology began taking small leaps in the years following the American Civil War - the first military aerial reconnaissance photos were taken in 1898 during the Spanish-American War via a camera attached to a kite. As the trend shows, many of the advancements in this technology arose during times of war, whether it was used to help with an offensive strike or just to acquire intelligence on enemy locations and activities.

This is seen throughout the history and progress of unmanned aerial technologies. Advancements took place in Britain during the 1930s, where a radio-controlled UAV (dubbed the Queen Bee) served as aerial target practice for British pilots, and also during World War II, during which 10 time the Nazi’s developed an unmanned flying bomber known as the V-1. It wasn’t until the 1970s that Israel developed the Scout and the Pioneer, which started the development toward the more widely known glider-type UAVs. It was from this design that the Predator drone came to be the Predator is the most sophisticated UAV in existence to date, these drones have come a long way from the “balloons” of the past. It’s autonomous control networks show just how much this technology has evolved. The structural design of UAVs has changed over their developmental history in order to serve a variety of purposes. UAV design and advancement is a global activity.

As technology and needs change, UAVs can be improved to serve these needs. There are several design considerations that are constant. The first of these design criteria is the degree of autonomy. Early UAV designs were mostly set to fly a specified path until they ran out of fuel. They carried a camera onboard, which would be recovered after the UAV landed. Later, the advent of radio control systems allowed UAVs to be piloted from the ground. Modern UAVs often combine these two basics 11 functionalities. These two modes of operation do not strictly signify autonomy. True autonomy suggests the ability of the aircraft to operate without human interaction. In this regard, UAVs are still very immature. UAV autonomy technology is divided into the following categories:

- Sensor fusion: On board the vehicle a combination of sensors is used.
- Communications: Communication and coordination will be handled between multiple sources in the existence of curtailed and imperfect information
- Motion planning (also called Path planning): Determining the optimal path for the vehicle in accordance with specific objectives and constraints such as obstacles go.
- Trajectory Generation: Designed for optimal control and maneuverability to follow a particular route or to go from one place to another.
- Task Allocation and Scheduling: Set the optimal distribution of tasks between a group of agents, with time constraints and equipment limitations.
- Cooperative Tactics: The optimal sequence and spatial distribution of activities between agents in order to make the most of the chances of success in any case or situation.

2.1 REVIEW ON RELATED LITERATURE

The ultimate goal of UAVs is to replace human pilots altogether. Another major design criterion is UAV endurance (range). Since there is no human pilot onboard, there is no concern for pilot fatigue. UAVs can be designed to maximize flight times to take advantage of this fact. Different systems can afford a wide variety of maximum range. Internal combustion engines require relatively frequent refueling and inflight refueling is a major obstacle for this type of propulsion system. Photovoltaic UAVs offer the potential for unlimited range and there is much research in this field. One more type of fuel system is hydrogen, which is proposed for use with certain models of stratospheric persistent UAVs.

The AeroVironment's Global Observer is one such UAV. This aircraft runs on hydrogen and has a range of 7 days. The idea is for two of such UAVs to be used in tandem to provide continuous, uninterrupted operation 365 days a year. With the sophistication that these systems have arrived at, the market for them has grown astronomically. While the United States still has the largest stockpile of unmanned aircraft, the rest of the world is beginning to follow suit. More than 50 countries have purchased surveillance drones, and many have started in-country development programs for armed versions. More than two-dozen different models were shown at a recent aviation show in China.

Due to the changing landscape of the theater of war, many nations are leaning toward unmanned aircraft to handle delicate situations in which human lives need not be put at risk. Also, taking into account the fact that drones sell for a fraction of the cost of manned airplanes, the amount of UAVs a nation can purchase at once has enticed many nations into entering the drone zone. In general, UAVs fall into one of six functional categories:

- Target and Decoy: simulating enemy missiles or aircraft for ground and air gunnery.
- Reconnaissance: battlefield intelligence gathering
- Logistics: cargo and logistics application
- Research and Development: used for UAV technology development 14.
- Civil and Commercial: specifically designed for civil and commercial applications.

2.2 CONCLUSION ON REVIEWS

In hindsight, we have come to know that our previous project i.e., Manual controlled quadcopter, had few crashes as we are amateur pilots and faced inefficiencies in accomplishing the tyro missions. So, we got an idea of implementing Autopilot technology (Using Pixhawk flight controller) to our drone, with this we resolved the problem of crashes and that is our mini project (3^{rd} year). After the mini project we have identified one more problem i.e., we do not have automatic dropping of product, because of that it may cause travails to the receiver. Then we got an idea of the using “Servo Mechanism” to our drone, for automatic releasing of product at the desired location. we have to setup the waypoints of our mission in the memory of flight controller by using mission planner software. When we turn on the Autopilot mode, drone will follow the waypoints and drops the product and returns to the home position as per the path provided in mission planner software.

CHAPTER 3

PROJECT IMPLEMENTATION

3.0 IMPLEMENTATION STAGES:

Assembly of Parts: With the assembly of parts the drone is made to fly with the weight of 300gm using mission planner software as process in below:

3.1 Mission Planner Software:

Mission Planner is a full-featured ground station application for the ArduPilot open-source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for any autonomous vehicle. The assembly of parts the drone is made to fly with the weight of 300gm using mission planner software as process.

Fig.No. 12 Mission Planner Software Logo.

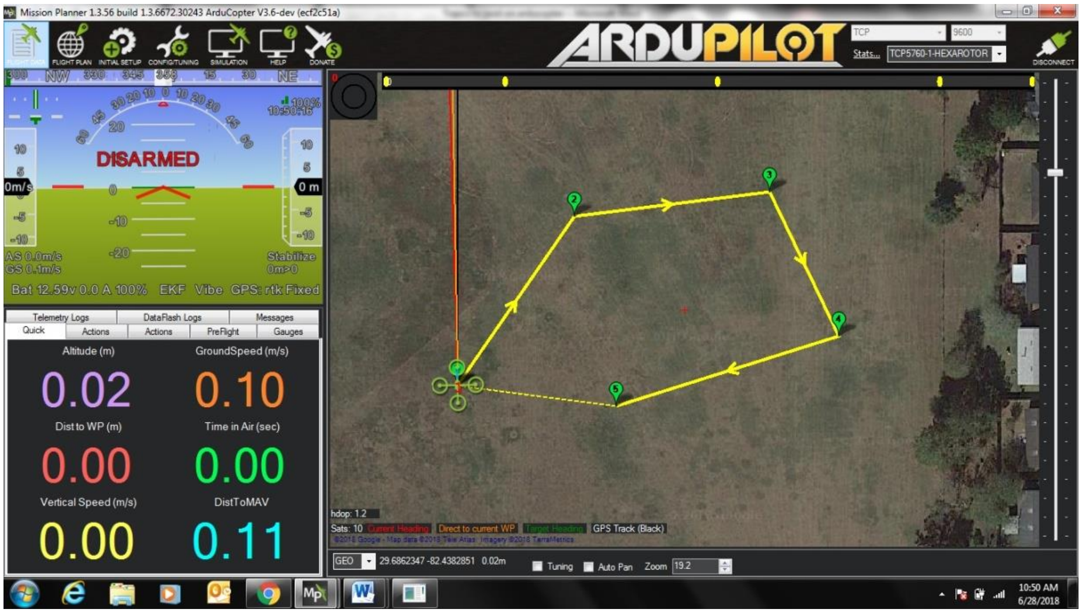


Fig.No. 13 Mission Planner Software.

Mission Planner is a full-featured ground station application for the ArduPilot open-source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for any autonomous vehicle. Here are just a few things you can do with Mission Planner:

- Load the firmware (the software) into the autopilot board (i.e., Pixhawk series) that controls your vehicle.
- Setup, configure, and tune your vehicle for optimum performance.
- Plan, save and load autonomous missions into you autopilot with simple point-and-click way-point entry on Google or other maps.
- Download and analyze mission logs created by your autopilot.
- Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.
- With appropriate telemetry hardware you can:
- Monitor your vehicle's status while in operation.
- Record telemetry logs which contain much more information the on-board autopilot logs.
- View and analyze the telemetry logs.
- Operate your vehicle in FPV (first person view)

Install Firmware:

0n the Mission Planner's Initial Setup is to install firmware screen then select the appropriate icon that matches your frame that is (i.e., Quad , Hexa , octa) . Then Answer Yes when it asks "Are you sure?" .

After the CGS detetcs which board you are using it will ask you to unplug the board, plug it back in. Then click OK within a few seconds i.e., during the breif period , the bootloader accepts requests to upload new firmware.

If all goes well then you will see some status appearing on the bottom right including the words like , "erase..." "program..." "verify..." and "upload done".

The firmware will be successfully uploaded to the board.

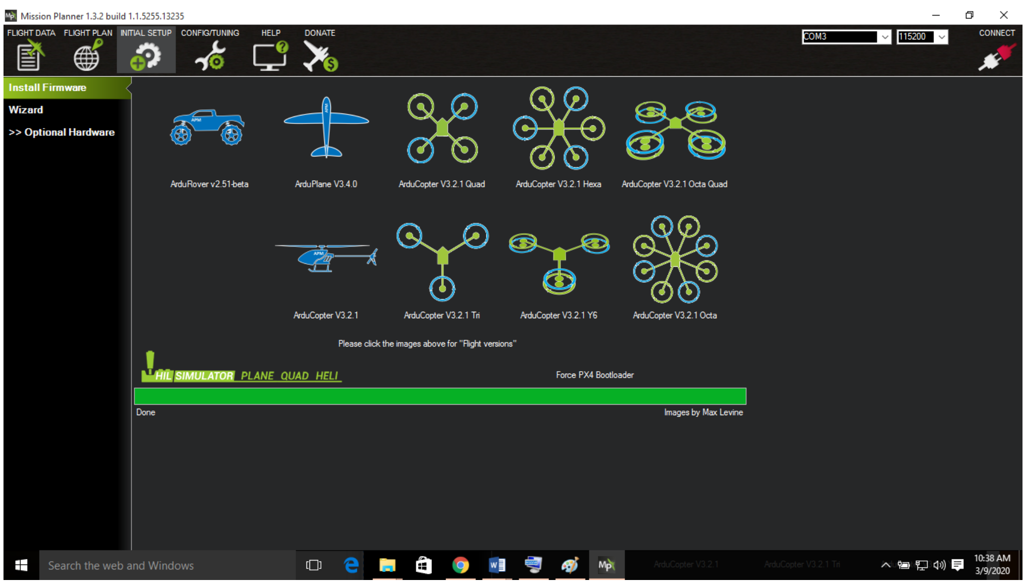


Fig No: 14 firmware installation

3DR Radio

You will see this menu item If the auto pilot is Not connected.

Antenna Tracker

You will see this menu item If the auto pilot is not connected.

Mandatory Hardware

You will see this menu item If the auto pilot is connected. Click this menu item to see the items you must complete before you attempt to operate your vehicle. Specifics are located in the area of the web that covers your specific vehicle (Copter, Plane, Rover)

Setting up the connection

To establish a connection, you must first choose the communication method/channel you want to use, and then set up the physical hardware and Windows device drivers. You can connect the PC and autopilot using USB cables, Telemetry Radios, Bluetooth, IP connections etc.

On Mission Planner, the connection and data rate are set up using the drop-down boxes in the upper right portion of the screen.

Fig No: 15 Connection

Once you've attached the USB or Telemetry Radio, Windows will automatically assign your autopilot a COM port number, and that will show in the drop-down menu (the actual number does not matter). The appropriate data rate for the connection is also set (typically the USB connection data rate is 115200 and the radio connection rate is 57600)

Select the desired port and data rate and then press the Connect button to connect to the autopilot. After connecting Mission Planner will download parameters from the autopilot and the button will change to Disconnect as shown:

Fig No: 16 Disconnection

Mission Planning

This section contains articles about creating missions that will run when the vehicle switched to AUTO mode. Setting your home location to the current location is easy, just click Home Location above where you enter your home location, and it will set your home location to the current coordinates. You can measure the distance between waypoints by right-clicking at one end and selecting the Measured Distance. And it will set your home location to the current coordinates.

Setting your home location to the current location , just clicking on Home Location above where you enter your home location, and it will set your home location to the current coordinates. We can measure the distance between waypoints by right-clicking at one end and selecting Measure Distance.

Fig No: 17 Setting-up Home Point

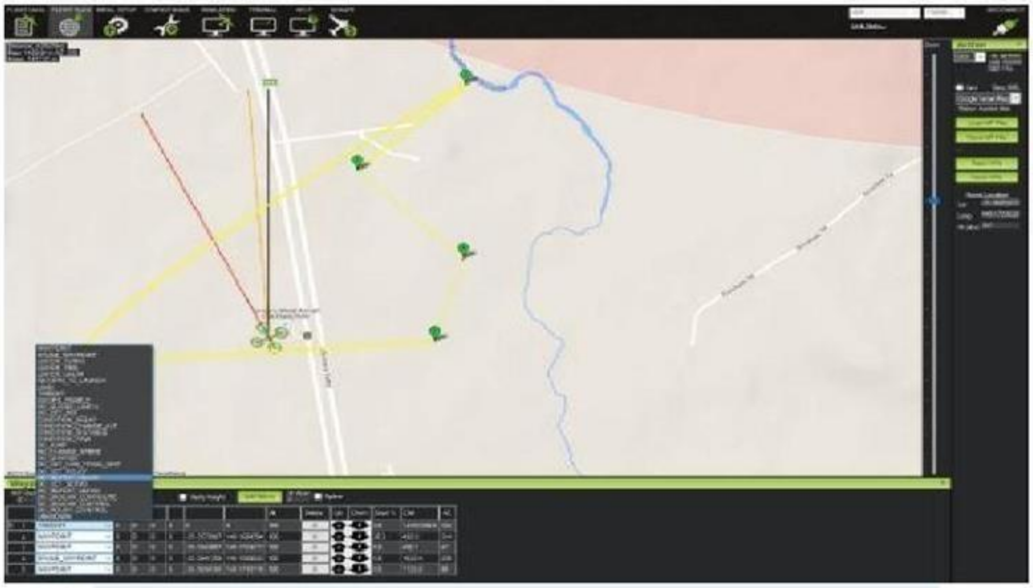


Fig No: 18 Setting to Autopilot

Setting the Waypoints

For Copter, Plane and Rover the home position is set as the location where the vehicle was armed. This means if you execute an RTL, it will return to the location where it was armed, so arm your vehicle in the location you want it to return to or use a rally point to setup an alternative return point. A waypoint is an intermediate point or place on a route or line of travel, a stopping point or point at which course is changed, the first use of the term tracing to 1880.

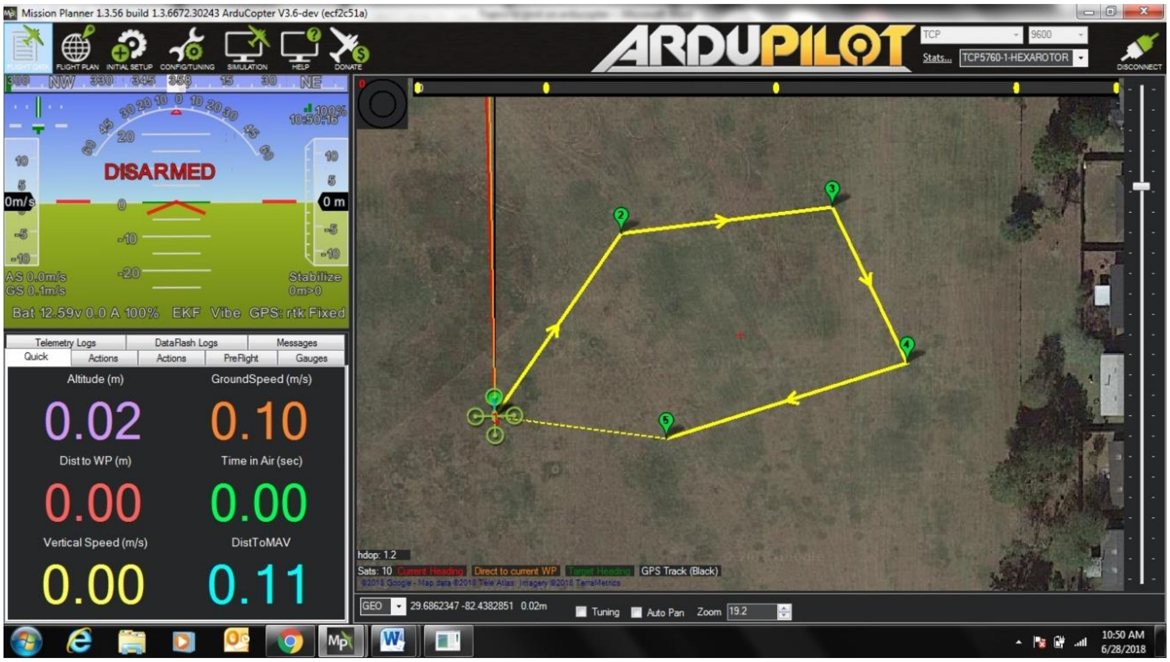


Fig No: 19 Setting up Way Points.

You can enter waypoints and other commands (see the Mission commands section below for more information). In the dropdown menus on each row, select the command you want. The column heading will change to show you what data that command requires. Lat and Lon can be entered by clicking on the map. Altitude is relative to your launch altitude/home position, so if you set 100m, for example, it will fly 100m above you.

Default Alt is the default altitude when entering new waypoints.

Verify height:

Itmeans that the Mission Planner will use Google Earth topology data to adjust your desired altitude at each waypoint to reflect the height of the ground beneath. So, if your waypoint is on a hill, if this option is selected the Mission Planner will increase your ALT setting by the height of the hill. This is a good way to make sure you don't crash into mountains!

Once you are done with your mission, select **Write** and it will be sent to APM and saved in EEPROM. You can confirm that it's as you wanted by selecting **Read.**

You can save multiple mission files to your local hard drive by selecting **Save WP File** or read in files with **Load WP File** inthe right-click menu:

Auto Grid

You can also have the Mission Planner create a mission for you, which is useful for function like mapping missions, where the aircraft should just go back and forth in a “lawnmower” pattern over an area to collect photographs.

To do this, in the right-click menu select Polygon and draw a box around the area you want to map. Then select Auto WP, Grid. Follow the dialog box process to select altitude and spacing. The Mission Planner will then generate a mission that looks something like this:

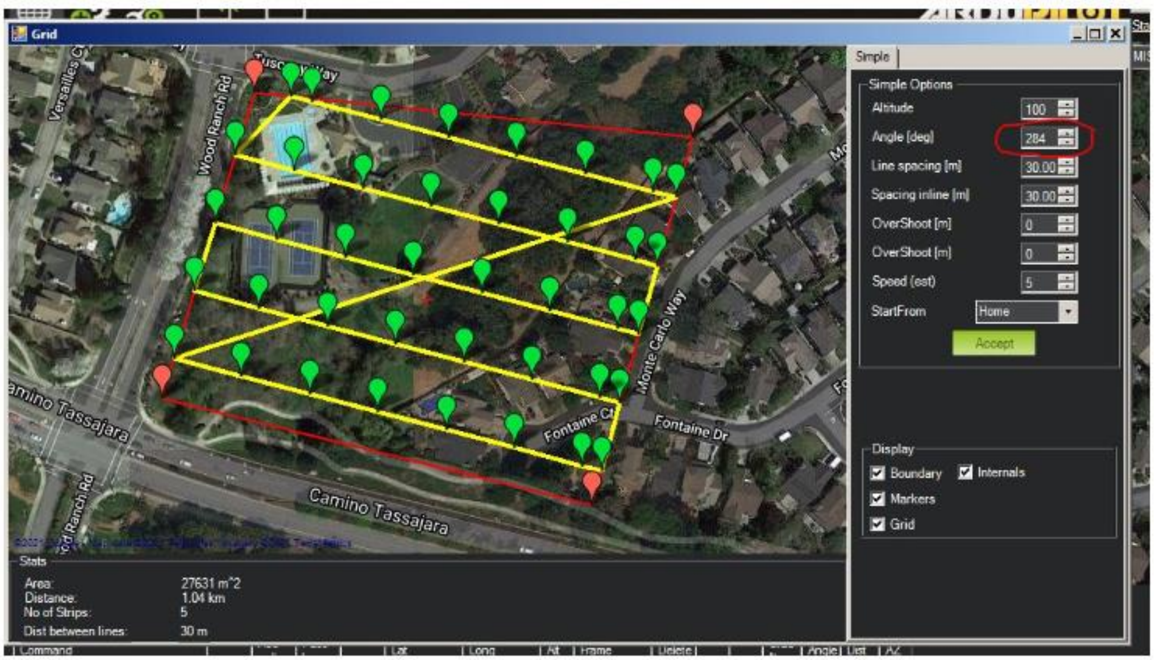


Fig No: 20 Grid View

Mission Planner Ground Control System:

Fig.No. 21 mission planner ground control system

The GCS Flight Data Screen:

Fig.No. 22 GCS Data Screen

We can start or stop recording the HUD as an .avi video stored in the logs folder .

Set MJPEG Source : Connect and display .

MJPEG video source from network.

Start camera : If a video source has been selected in the CONFIG / Planner page, I starts displaying it in the HUD window.

Set GStreamer source: connect and display Gstreamer video stream .

Here link video : Displaying the HereLink video, use same IP as when connecting MP via UDpcl to

HereLink for telemetry.

See the HereLink documentation.

Set Aspect Ratio: Clicking this alternates between 4:1 and 16:9 aspect ratio.

User Items: You can add any of the telemetry parameters to the display by right clicking on the HUD, clicking User Items, and checking the items you want displayed. Note that you can view all of the telemetry in the Control and Status area by clicking the Status button.

Russian HUD: Clicking this changes to/from a Russian style HUD (ground horizon fixed).

Swap with Map: Swap map to this window and vice versa.

Ground Color: Click to change ground color.

GStreamer Stop: Stop GStreamer video

The screenshot below shows the main “Heads-up Display (HUD)” view of the Mission Planner Ground Station. Once you have connected to a vehicle this screen will display the telemetry sent by Ardupilot.

Figure No: 23 Ground Control Station

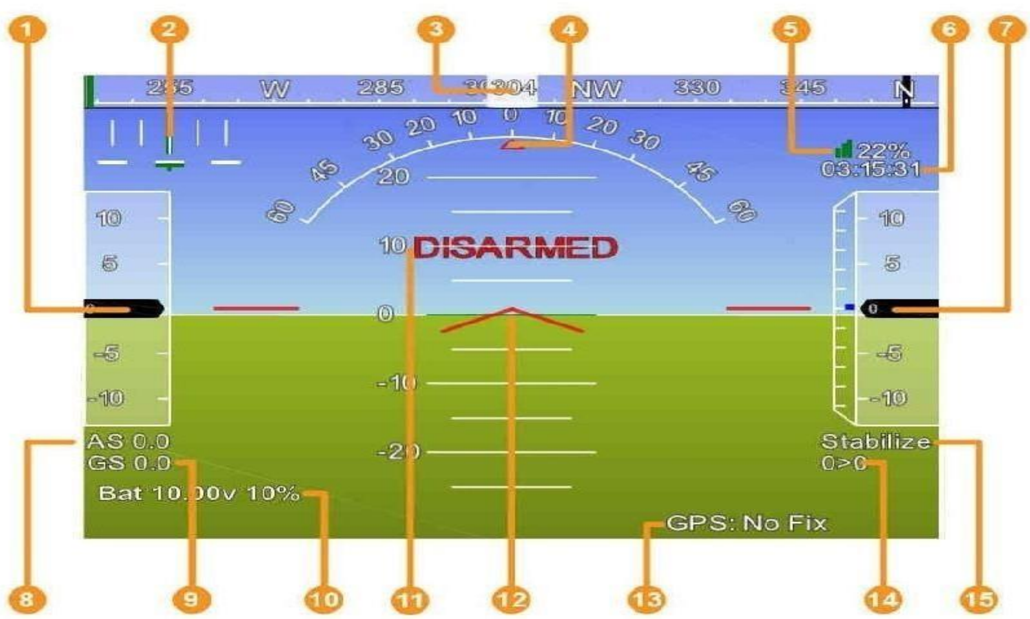


Figure No: 24GCS Disarmed

1. Air speed (Ground speed if no airspeed sensor is fitted)
2. Cross track error and turn rate (T)
3. Heading direction
4. Bank angle
5. Telemetry connection link quality (averaged percentage of good packets)
6. GPS Time
7. Altitude (blue bar is rate of climb)
8. Air Speed
9. Ground Speed
10. Battery status
11. Artificial horizon
12. Aircraft attitude
13. GPS Status
14. Current waypoint number> Distance to waypoint
15. Current Flight Mode

Mission Planning Configuration and Tuning:

This section of Mission Planner, invoked by the Menu item Config/Tuning at the top of Mission Planner, has several subsections. The subsection is where you configure the parameters that control how your auto pilot controls your vehicle. Tuning refers to adjusting parameters in the control loops, so your vehicle behaves the way you desire. Most of these parameters are set for you when you first install your firmware, but some must be set before your first flight or roaming adventure.

What you see when you enter this section depends on whether or not you are connected.

Planner

You will see this menu item if the auto pilot IS or Is Not connected. This is where you set up most of the options for how the Mission Planner works. Such things and enabling speech, where the logs are saved, the units of measure you want to use, ETC. Some of the specifics are covered here.

Full Params Limit

You will see this menu item if the auto pilot Is connected. Here is what you can do in this section TBD options on the right-hand side of this screen: You can save the parameters for your vehicle. It is a good idea to do that often. Also, you can reload all your parameters from a saved file. You can also compare the parameters in your vehicle to those in a saved file.

This is a very valuable feature in case you forget what you changed or if your vehicle behaves badly after a change, but you don't remember the previous value(s) of the parameters you changed - or even what you changed. An important aspect of the compare feature:

After you select the file with the save parameters you want to compare; you will get a window that lists every parameter that is different. At the time of the window, nothing has been changed, but if you check some items and then click Continue, those items will be changed in the local memory of Mission Planner. You will then need to click the Write Params parameters button in the right-hand panel to copy the changes to the memory in your auto pilot. Until we get more words here, just experiment.

Clean this up with the right menu words, Load, Save Refresh Parms etc. Copter Pids You will see this menu item if the auto pilot Is connected to an ArduCopter.

CHAPTER 5

PROJECT TESTING

5.0 TESTING

Fig No: 25 Prototype testing

The above picture is the testing of the drone for medical emergency using a weight of 300 grams as the payload for the mission in the span of 3 minutes. We safely dropped the payload using servomechanism and our mission was then accomplished, the drone was then returned to the home position.

- The drone passed the test.

5.1 EXPERIMENTAL RESULTS

The voltage (V)	Paddle size	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)	Working temperature (° C)
11	EMAX8045	1	110	11	10.0	3650	
		2	200	22	9.1	4740	
		3	270	33	8.2	5540	
		4	330	44	7.5	6200	
		5	390	55	7.1	6700	
		6	440	66	6.7	7150	
		7.1	490	78.1	6.3	7400	36
	EMAX1045	1	130	11	11.8	2940	
		2	220	22	10.0	3860	
		3	290	33	8.8	4400	
		4	370	44	8.4	4940	
		5	430	55	7.8	5340	
		6	480	66	7.3	5720	
		7	540	77	7.0	5980	
		8	590	88	6.7	6170	
		9	640	99	6.5	6410	
		9.6	670	106	6.3	6530	43

Data Sheet

Drone weight without payload= 1150gm

Payload= 200gm

Drone Weight with Payload= 1350 gm

Load on each motor= 1350/4=337.5gm

Propeller length= 10 in

Battery= 4500mAh

Motor (4)= 8910 rpm

ACTIVITY:

Total time= 3 min at 30 km/h

Take off:

Thrust load on each motor= 337.5*2=675gm

From motor data sheet Power(P)=40*4=160W

Energy consumption= (160*25)/3600=1.11Wh

Forward:

Thrust load on each motor= 337.5*1.2=405gm

From motor data sheet Power(P)=50*4=200W

Energy consumption= (200*100)/3600=5.56Wh

Landing:

Thrust load on each motor= 337.5*0,7=236.25gm

From motor data sheet Power(P)=25*4=100W

Energy consumption= (100*25)/3600=0.69Wh

Total energy consumed by the drone for given activity(E) = 10.89Wh=653.4Wmin

Source Energy (Es)= Power*time

=V*I*time

=11*4.5*1=45Wh

=2750Wmin

Flight time= Es/E= 2750/653.4= 12.6 min

Total flight time for the activity= 12.6 min

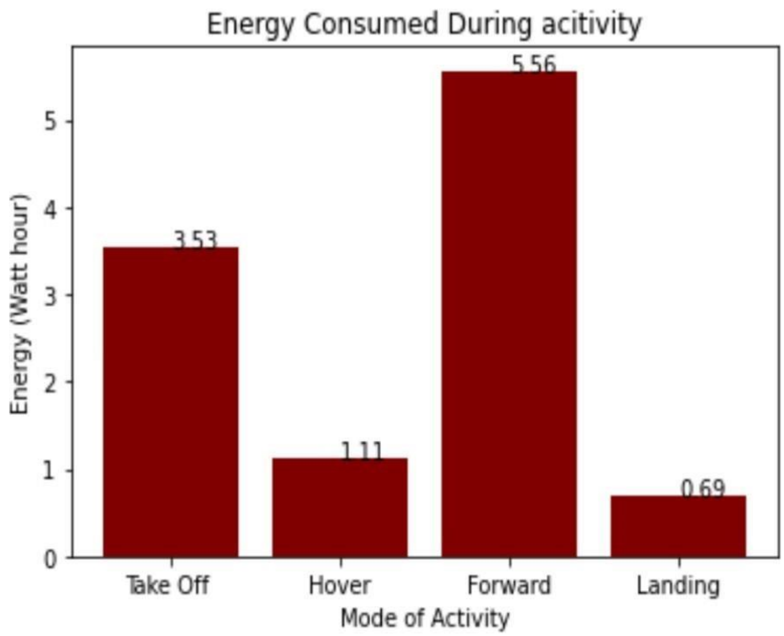
We can comfortably finish the task with the achieved flight time.

RESULT	THEORETICAL	PRACTICAL
WEIGHT	500GM	500GM
MAX SPEED	45KMPH	43KMPH
BATTERY	4500mAh li-polymer	4500Mah li-polymer
MAX FLIGHT TIME	18.8 minutes	16.9 minutes

Table No:2

Fig No: 26 Prototype

Fig No: 27 Prototype during flight



5.2 GRAPHICAL REPRESENTATION

The graphical representation of the Energy consumed at certain activity is shown.

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

- If there is a distinctive path that modern change has followed, it’s automation.
- Automation will be creating a greater impact on our daily lives as every machine and material is made through automation.
- For the ongoing crisis of the pandemic, the drones are used for most of the emergencies. To make it fast, accurate and simple, we have used autopilot drone.
- The autopilot drone will make sure the path and flight controller direct the drone to pass through the waypoints given to it.
- Overall, the autopilot system in the drone helped during emergencies.

FUTURE ENHANCEMENT

- As we are living in a developing country, automated vehicles would create an impact on lifestyle. Autopilot can be developed in such a way that it flies according to gestures using AI and ML.
- This autopilot drone can be upgraded to obstruction handler by using automated sensors and can be made to fly higher.

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A

PROJECT REPORT

On

DEVELOPMENT OF AUTOPILOT DELIVERY DRONE

Submitted by

B. PAVEN MANO RAIVATH - 17K81A0311
M. TEJDEEP - 17K81A0334
MARCEL NOEL ISAAC - 17K81A0338
N. PREETHI - 17K81A0346

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

Under the Guidance of

Dr. D.V. Sreekanth

Professor & Head of the Department

DEPARTMENT OF MECHANICAL ENGINEERING

St. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally,Secundrabad-500100

JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500010

BONAFIDE CERTIFICATE

This is to certify that the mini project report entitle "**DEVELOPMENT OF AUTOPILOT DELIVERY DRONE**" is submitted by "**BHAMIDIPATI PAVEN MANO RAIVATH (17K81A0311), M. TEJDEEP(17K81A0334), MARCEL NOEL ISAAC(17K81A0338), N. PREETHI(17K81A0346)**" in partial fulfilment of the requirements for the award of the Degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them . The result embodied in this report have been verified and found satisfactory

Signature	Head of the Department
Dr. D.V. SREEKANTH	Dr. D.V. SREEKANTH
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner External Examiner

Place:

Date :

DECLARATION

We, the student of **Bachelor of Technology** in Department of ‘MECHANICAL ENGINEERING’, session: 2017 – 2021, St. Martin’s Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled “DEVELOPMENT OF AUTOPILOT DELIVERY DRONE” is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

BHAMIDIPATI PAVEN MANO RAIVATH -17K81A0311

M. TEJDEEP -17K81A0334

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ABSTRACT

The rapid increase in usage of online ordering has increased the requirement of manpower to deliver in multiple folds. Drone based technology is being used to meet this requirement. A quadcopter can achieve vertical flight in a stable manner and be used to monitor or collect data, delivery in a specific region.As the demand for commercial deliveries increases within cities, companies face a fundamental limitation in surface road capacity. Drone delivery aims to overcome that limitation by exploiting the vertical dimension above city streets.With advancing drone technologies and increasing commercial usage, we believe the last mile shipping industry is ripe for disruption by delivery drones. Drones can significantly accelerate delivery times and reduce the human cost associated with the delivery.

UAV has been designed which is an unmanned aerial vehicle that have reduced the cost and increase the performance of the low power microcontrollers that allowed the general public to develop quadcopter. The goal of this project is to design the brushless direct current (BLDC) motor and its driving circuits, for quadcopter kit to obtain stable flight, gather and store GPS data, and perform auto commands, such as auto-landing.

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CHAPTER-1

INTRODUCTION

1.1 Overview of the project

An unmanned aerial vehicle (UAV for short; also known as a drone) is any aircraft that does not have a human pilot onboard. UAVs have their origins as early as 1915 when Nikolai Tesla wrote a dissertation in which he described “an armed, pilotless-aircraft designed to defend the United States.”

UAVs come in a variety of sizes, designs and purposes. Initially, UAVs were merely remotely piloted; however, autonomous control is becoming more widely utilized.

Developing an unmanned aerial vehicle has been one of the main points of concern by many counties all over the world; about 70 different countries have some sort of UAV technology.
UAVs are used to gather information from the air in hostile areas. They can also be used in devastated areas where man support may not be available. These types of UAVs must be portable by ground and very reliable for recurrent use.

Operators use ground control stations to set the parameters of the mission and the UAV autopilot directs the drone or other unmanned craft to complete the task. The main goal of the project is to deliver any product autonomously by an automated path with minimal human effort.

1 .2 Objective of study

The main objective of the work is to design a UAV (unmanned aerial vehicle) which is drone (Dynamic Remotely Operated Navigation Equipment) with BLDC driver circuit and servo mechanism, which can deliver any product autonomously by an automated path with minimal human effort.

An autopilot is a flight control system that allows a pilot to fly an airplane without continuous hands-on control.

Autopilot system works by sending signals to the flight control system. The pilot inputs the type of waypoints in mission planner software by connecting USB to the drone.

The commands will be stored in the memory of drone. After initiating the autopilot mode, the drone follows the commands which are given.

While landing servomechanism comes to part which involves in delivery of the product.

The drone has significant amount of requirement in especially the commercial industry in order to overcome the difficulties by conventional methods. Now, along with the commercial industry, there is a wide range of scope for the usage of an autopilot UAV.

1.3 Scope of study

Whether you call them Unmanned Aerial Vehicles (UAVs), Miniature Pilotless Aircraft or Flying Mini Robots, drones are rapidly growing in popularity. They are still in the infancy stage in terms of mass adoption and usage, but drones have already broken through rigid traditional barriers in industries which otherwise seemed impenetrable by similar technological innovations.

Over the past few years, drones have become central to the functions of various businesses and governmental organizations and have managed to pierce through areas where certain industries were either stagnant or lagging behind. From quick deliveries at rush hour to scanning an unreachable military base, drones are proving to be extremely beneficial in places where man cannot reach or is unable to perform in a timely and efficient manner.

Increasing work efficiency and productivity, decreasing workload and production costs, improving accuracy, refining service and customer relations, and resolving security issues on a vast scale are a few of the top uses drones offer industries globally. Adoption of drone technology across industries leapt from the fad stage to the mega-trend stage fairly quickly as more and more businesses started to realize its potential, scope, and scale of global reach.

Whether drones are controlled by a remote or accessed via a smartphone app, they possess the capability of reaching the most remote areas with little to no manpower needed and require the least amount of effort, time, and energy. This is one of the biggest reasons why they are being adopted worldwide, especially by these four sectors:

- Military

Military usage of drones has become the primary use in today's world. Used as target decoys, for combat missions, research and development, and for supervision, drones have been part and parcel of the military forces worldwide.

- Commercial (construction, food delivery, health care delivery, etc.)

As it becomes cheaper to customize commercial drones, the door will be opened to allow new functionality in a wide array of niche spaces. Sophisticated drones could soon be doing everyday tasks like fertilizing crop fields on an automated basis, monitoring traffic incidents, surveying hard-to-reach places, or even delivering pizzas.

- Personal

Personal drones are used for filmmaking, recording, still photography and gaming by common tech-savvy enthusiasts. While primarily aimed at hobbyists, these types of devices are widely available, and the market is growing.

- Future Technology

Drone technology is constantly evolving, so future drone tech is currently undergoing groundbreaking progressive improvement. Research suggests that drone technology has seven potential generations, and the majority of current technology sits in the fifth and sixth generations, i.e., commercial suitability, safety and regulatory standards-based design, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.

The technological potential with drones is immense, and its uses will only grow with time.

1.4 Material requirement

Material involves seeking the best match between property-profiles of the materials and that required by design. To sustain quality assurance, we have chosen the following materials.

SR NO	ELEMENT NAME	MATERIAL
1	ARMS	POLYAMIDE NYLON
2	LANDING GEARS	POLYCARBONATE
3	TOP PLATE	ABS PLASTIC
4	BOTTOM PLATE	ABS PLASTIC

Table No:1

Polyamide Nylon: A polyamide is a polymer with repeating units linked by amide bonds. Polyamides occur both naturally and artificially. Polyamides (or Nylon) are made from polycondensation of diacid with a diamine or by ring-opening polymerization of lactams with 6, 11 or 12 carbon atoms.

Advantages

- High Abrasion Resistance – Higher levels of resistance to wear by mechanical action.
- Good Thermal Resistance – Special grades of nylon can have a melting point of almost 300°C.
- Good Fatigue Resistance – This makes it ideal for components in constant cyclic motion like gears.
- High Machineability – Cast billets can be machined into various components that would be too costly to cast into intricate shapes.

Polycarbonate: Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. organic functional groups linked together by carbonate groups (–O–(C=O)–O–) and offers a unique combination of properties.

Advantages

- Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent.
- They are easily worked, molded, and thermoformed.
- It is also very lightweight and capable of withstanding extreme temperatures, either hot or cold.
- It is affordable protect against discoloring and perfect for greenhouse.

ABS Plastic: ABS (acrylonitrile-butadiene-styrene) is a low-cost engineering thermoplastic that is easily machined, fabricated, and thermoformed. This thermoplastic material has good chemical stress and creep resistance.

Advantages

- Excellent impact, chemical and abrasion resistance.
- Superior stiffness and strength.

- Easily machined and thermoformed.
- Easy to paint and glue.
- Good dimensional stability.
- Excellent electrical properties.

1.5 PROCUREMENT OF MATERIALS:

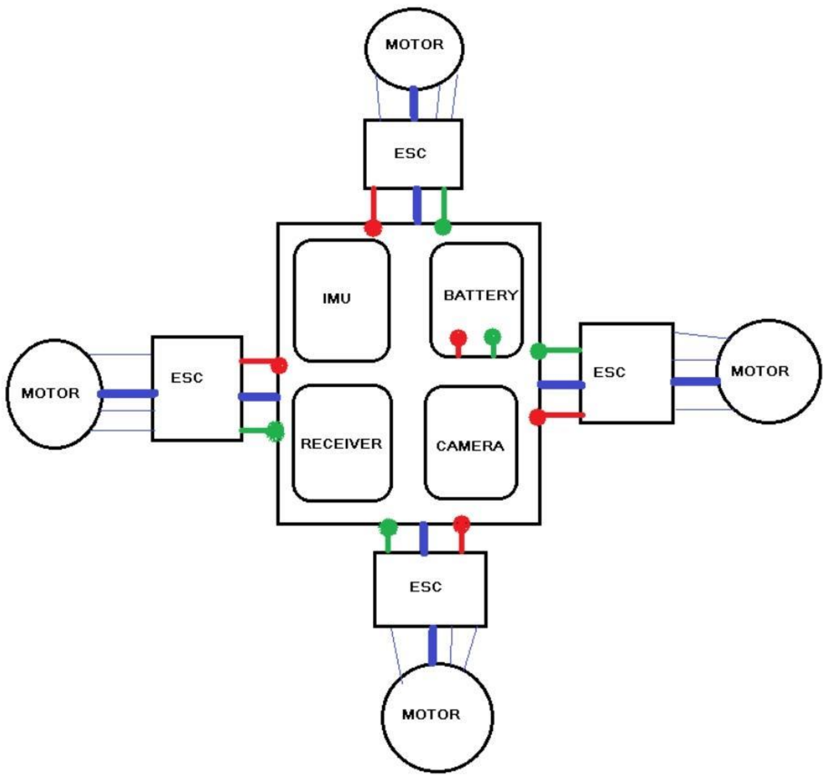


Fig.no.1 Block diagram

Selection of Components:

1. Structure (Frame).
2. Printed Circuit Board (PCB Boards).
3. Propulsion System (Motor - 4).
4. Landing Gears (4).

5. Telemetry and Remote (Transmitter and Receiver).
6. Electronic Speed Controller (ESC - 4).
7. Control System (Flight Controller).
8. Power Source (Lithium-Ion Battery Pack).
9. Servo Mechanism.

1.5.1 Frame :

The frames are cut from carbon fiber sheet. Carbon fiber is a composite material, being made up of many layers of interwoven carbon fibers that have been rigidly cemented within a binding matter. Developing an Aerial will definitely start from the weight strength of the material Structure are made from carbon fiber here we designed a multirotor aircraft which has 4 rotors to deliver thrust that can lift whole aircraft as we used 4 rotors it is known as a quadcopter, so the construction and design concentrates that the payload is near to the center of Gravity so that the equal amount of load sharing happens to be the basic element of a drone is a frame. The classification of the frame construction is shown in Figure. Due to the number of arms and the motors used the drones are classified as shown below.

1. Bi-copters – Two Motors
2. Tri-copters – Three Motors
3. Quad-copters – Four Motors
4. Hexa-copters – Six Motors
5. Octo-copters – Eight Motors

Fig No: 2 Frame parts

Main part of drone is the PCD Board which has a key role were landing gears and arms of the motor were connected it transfer the weight to all the arms equally so that drone can be fly stable.

1.5.2 Printed Circuit Board (PCB Boards):

A drone power distribution board (PDB) I is simply a printed circuit board (PCB) used to supply power from the source to the various parts of a drone. Before the invention of PDBs, designers used to connect drone parts with a wires help, resulting km heavy weights because if copped and solder joints in the cables. A PCB board i.e., Printed circuit board mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.

1.5.3 Propulsion System :

The next components of a drone are engine and propellers. They constitute the main propulsion system of a drone and are subjected to the highest loads; therefore, their durability is very system of a drone and are subjected to highest loads, therefore their durability is very important. The propellers change a torque (derived from the engine) for a work used for lifting the vehicle in the air. Due to the propeller system in relation to the flight direction it can be divided into the following types:

- + – One is the leading propeller (at least four propellers)
- X – The most common construction, in which two propellers are leading (with an even number of propellers)
- Y – Three arms stacked in the Y, where one or two arms can be leading.
- V – Very rare arrangement in which two propellers lead onto outstretched arms.
- H – A very rare arrangement where the construction is based on the H- shaped with two propellers leading.

In each of the about mentioned constructed can be mounted double propellers (At the top and in bottom), which significantly increases the strength of the drone, and does not require the addition of another arm. Double propellers mounted on a smaller number of arms increases the strength of a drone allowing more lift capacity and insuring the parallel motors in case of failure. The wings of drones are divided based on adopted for rotation:

- Clockwise (CW)
- Counterclockwise (CCW)

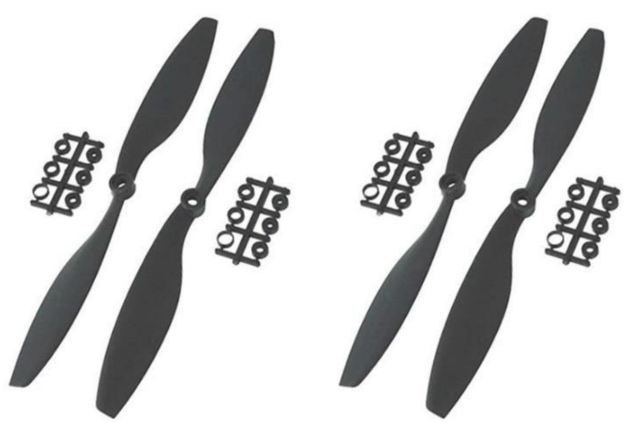


Fig No: 3 Propellers

The wings are made of carbon fiber, plastic and are attached to each other by lamination. B Bigger the propeller blades the stronger must also. The brushless motors are used very often for building drones. However, using brushless motors improves durability, efficiency and reduces the reduces the consumption of moving parts.

Propulsion System Lift

Lift of the drone is caused due to thrust generated by propeller which revolved by a brushless motor the calculation starts from AUW of the aircraft that is gross weight of the drone the propulsion system should be able to produce double thrust than AUW at 100% throttle so that it can hover at 50% throttle so the selection of propulsion system is by calculating the total weight times 2 and divided by no of rotors so that we can get thrust per rotor.

Propeller is the key element in any aerial vehicle where the thrust is generated main aspects in choosing of propeller is the length and pitch of the blade as length and pitch angle increases thrust increases, we length of the propeller is determined by rpm of the motor and pitch is directly proportional to torque of the motor.

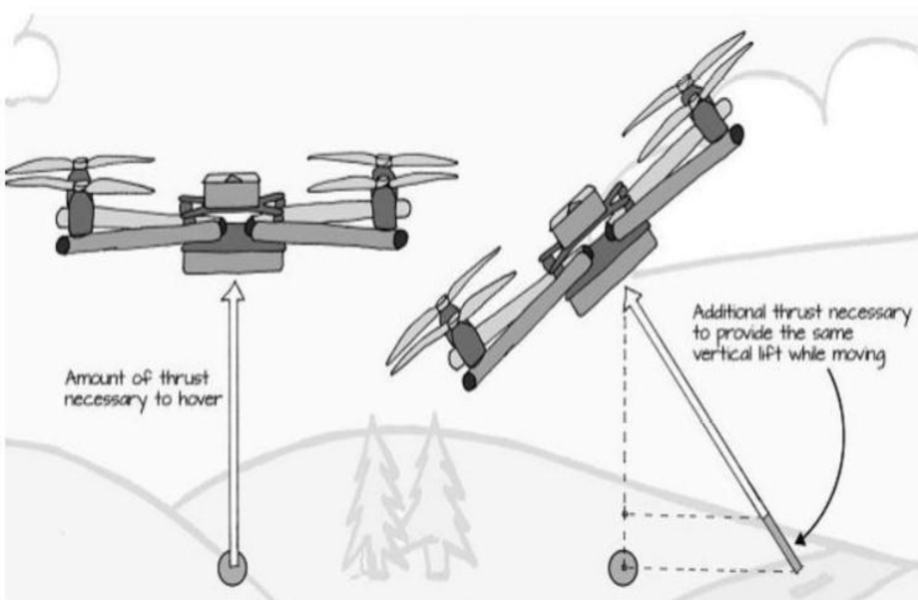


Fig No: 4 Propulsion Lift

1.5.4 Landing Gears:

Landing Gear for drones provides additional ground clearance. This can help protect the drone from Crashes. They can widen the drone's "stance", allowing for a more stable take-off and landing.

Fig.No. 5 Landing gears

1.5.5 Telemetry and Remote:

- Ensure the battery is disconnected (this is important because it is possible to accidentally arm the vehicle during the RC calibration process)
- Ensure the RC receiver is connected to the autopilot.
- Turn on your RC transmitter and if it has "trim tabs" ensure they are in the middle.
- Connect the autopilot to the PC using a USB cable.
- On the Mission Planner press the "Connect" button and open Mission Planner's INITIALSETUP | Mandatory Hardware | Radio Calibration screen
- Some green bars should appear showing the Ardupilot is receiving input from the Transmitter/Receiver. If no bars appear check the receiver's LED:

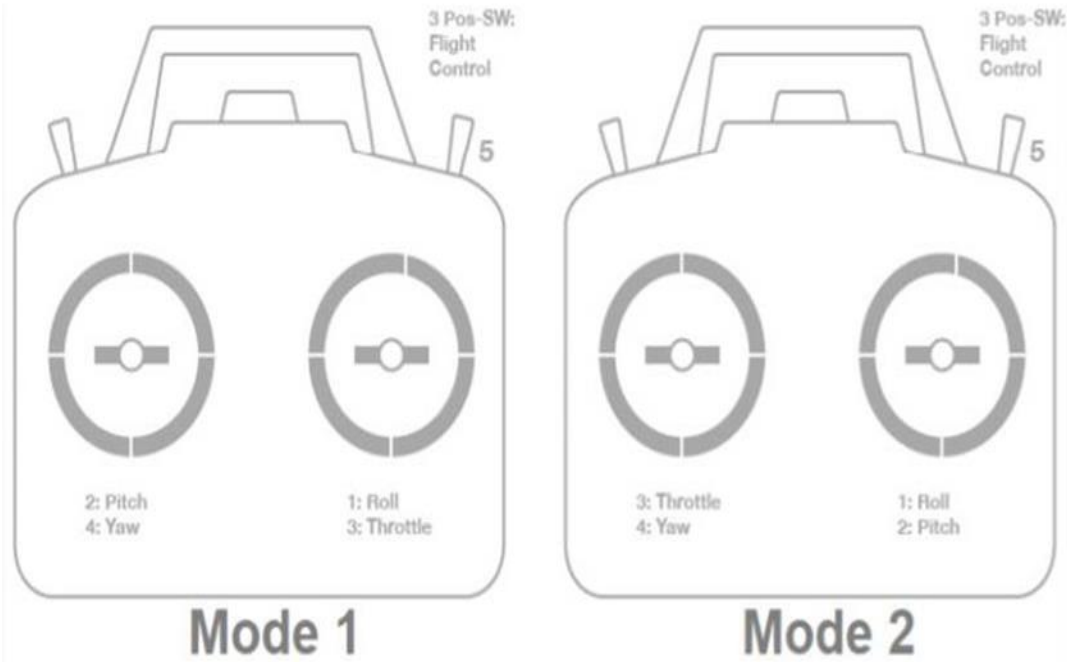
1. No lights may indicate that it is incorrectly wired to the autopilot. Look for connectors that may have been inserted upside down.
2. A Red or flashing LED may indicate that your RC transmitter/receiver need be bound.

See the manual that came with your RC equipment for instructions.

Model 1 and Model 2 Transmitter setup

There are two main transmitter configurations:

- Mode 1: left stick controls pitch and yaw, the right stick will control throttle and roll.
- Mode 2: left stick controls throttle and yaw; the right stick will control pitch and roll.



1.5.6 Electronic Speed Controller (ESC):

An electronic speed control or ESC is an electronic circuit that controls and regulates the speed of an electric motor. It may also provide reversing of the motor and dynamic braking. Miniature electronic speed controls are used in electrically powered radio-controlled models. Full-size electric vehicles also have systems to control the speed of their drive motors.

Electronic speed control basically a motor driver which acts as an inverter converts dc supply to 3 phase ac with frequency control with input PWM signal and the major parts of the esc are MOSFETS which switches the power in very less time and supply to three phases of the motor all this MOSFETS are controlled by a microcontroller which is inbuilt in the esc board.

Fig No: 5 Electronic Speed Controller

This is responsible for speed control of the motor by changing output frequency in phase windings which are connected to outputs of esc generally esc is rated in maximum amp draw that is 80A at 52V max in our case and allow input PWM throttle frequency from 50 to 500hz which determine the rpm of the motor which regulates the thrust of each axis.

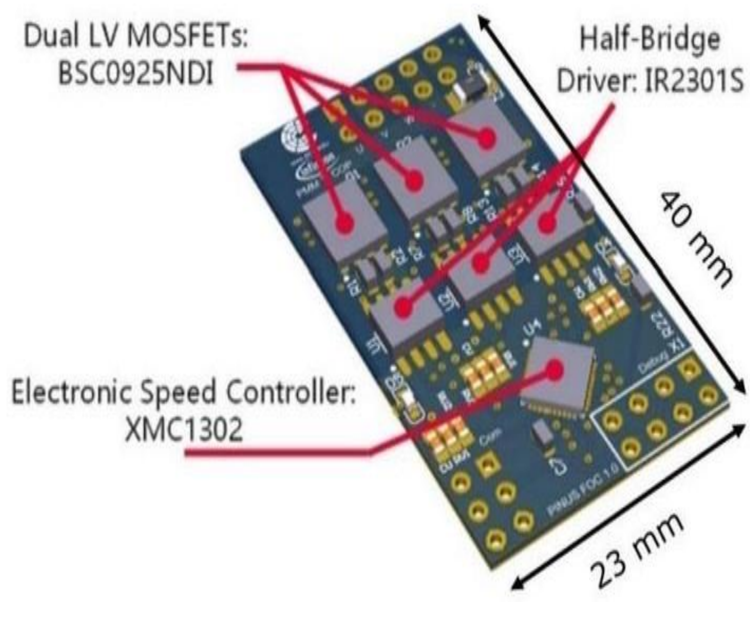


Fig No:6 PCB of ESC

1.5.7 Control System (Flight Controller):

A flight controller (FC) is a small circuit board of varying complexity. Its function is to direct the RPM of each motor in response to input. A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

Most flight controllers also employ sensors to supplement their calculations. These range from simple gyroscopes for orientation to barometers for automatically holding altitudes. GPS can also be used for auto- pilot or fail-safe purposes. More on that shortly. With a proper flight controller setup, a pilot’s control inputs should correspond exactly to the behavior of the craft. Flight controllers are configurable and programmable, allowing for adjustments based on varying multi-rotor configurations. Gains or PIDs are used to tune the controller, yielding snappy, locked-in response. Depending on your choice of flight controller, various software is available to write your own settings.

Many flight controllers allow for different flight modes, selectable using a transmitter switch. An example of a three-position setup might be a GPS lock mode, a self-levelling mode, and a manual mode. Different settings can be applied to each profile, achieving varying flight characteristics.

Fig No:7 Flight Controller

Main controller and flight controller regulate all the esc of motor with respect to integrated sensors and pilot or ground station commands. Its main controller responsibility to control the drone in stable position. Main sensors in flight controller are:

1. Accelerometer
2. Gyroscope
3. Compass
4. Magnetometer
5. Barometer
6. GPS

Circuit Overview

1. Telemetry System — Allows you to plan/run missions, and control and monitor the vehicle in real time. Typically includes telemetry radios, tablet/PC, and ground station software.
2. Buzzer — Provides audio signals that indicate what the UAV is doing.
3. Remote Control Receiver System — Connects to a hand-held transmitter that an operator can use to manually fly the vehicle (shown is a PWM receiver with PWM->PPM converter
4. (Dedicated) Safety switch — Press and hold to lock and unlock motors. Only required if you are not using the recommended GPS with inbuilt safety switch.
5. GPS, Compass, LED, Safety Switch — The recommended GPS module contains GPS, Compass, LED, and Safety Switch.
6. Power System — Powers Cube and the motor ESCs. Consists of LiPo battery, power module, and optional battery warning system (audio warning if battery power goes below a predefined level).

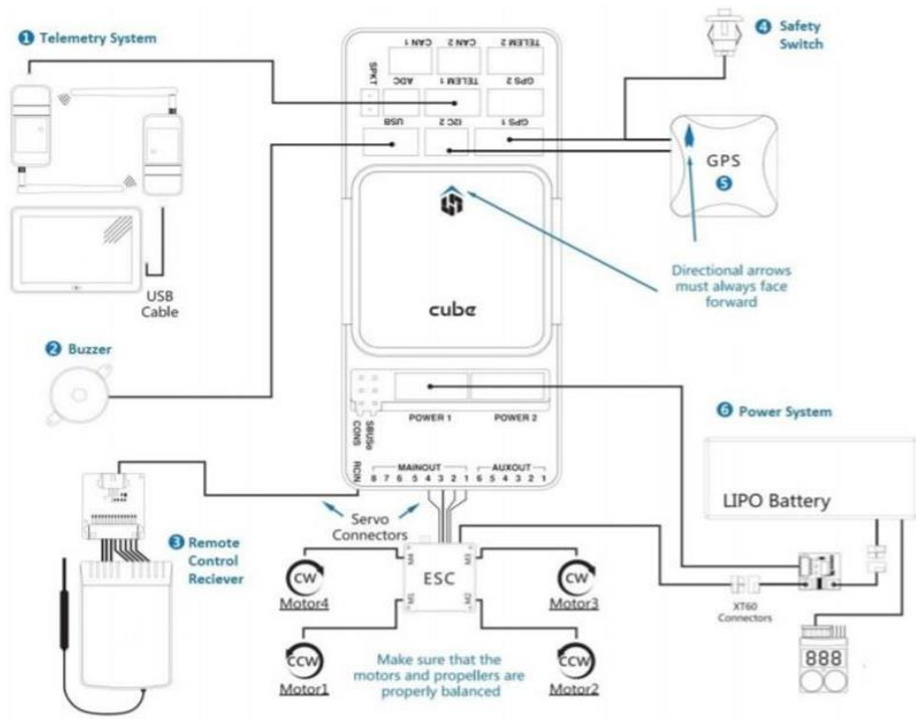


Fig No: 8 PCB of Flight Controller

Sensors:

All flight sensors in Pixhawk 2 Cube are connected via SPI. On-board we have an MPU9250 or ICM 20xxx Gyro and Accelerometer, and a MS5611 used in SPI mode. On the vibration isolated board, we have the L3GD20 gyro, the LSM303D Accelerometer and magnetometer, another MPU9250 or ICM 20xxx, and MS5611 also used in SPI mode. The board mounted sensors run on a separate bus to the Vibration isolated sensors.

Interfaces

- 2x CAN (one with internal 3.3V transceiver, one on expansion connector)
- Spectrum DSM / DSM2 / DSM-X® Satellite compatible input
- Futaba S.BUS® compatible input and output
- PPM sum signal input
- RSSI (PWM or voltage) input
- I2C o SPI
- 3.3 and 6.6V ADC inputs

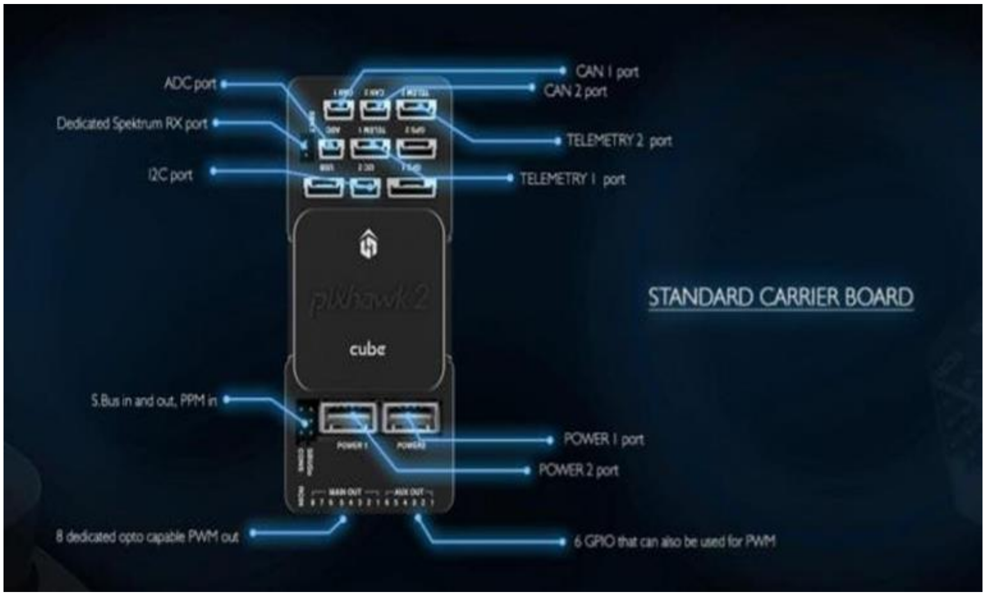


Fig N0: 9 Standard Carrier Board

- Internal micro-USB port and external micro-USB port extension

External Sensors

- Concurrent reception of up to 3 GNSS (GPS, Galileo, GLONASS, Bei Dou)
- Industry leading –167 dBm navigation sensitivity
- Security and integrity protection
- Supports all satellite augmentation systems.
- Advanced jamming and spoofing detection
- Breakaway mount
- Notification RGB LED
- HMC5983 MAG, and LIS3MDL Mag & 6CM Ground plane

Fig No: 10 Global Positioning System (GPS)

1.5.8 Battery:

The energy density of lithium-ion is typically twice that of the standard nickel-cadmium. There is potential for higher energy densities. The load characteristics are reasonably good and behave similarly to nickel-cadmium in terms of discharge. The high cell voltage of 3.6 volts allows battery pack designs with only one cell. Most of today's mobile phones run on a single cell. A nickel-based pack would require three 1.2-volt cells connected in series.

Lithium-ion is a low maintenance battery, an advantage that most other chemistries cannot claim. There is no memory, and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to nickel-cadmium, making lithium-

Ion well suited for modern fuel gauge applications. lithium-ion cells cause little harm when disposed.

Despite its overall advantages, lithium-ion has its drawbacks. It is fragile and requires a protection circuit to maintain safe operation. Built into each pack, the protection circuit limits the peak voltage of each cell during charge and prevents the cell voltage from dropping too low on discharge. In addition, the cell temperature is monitored to prevent temperature extremes. The maximum charge and discharge current on most packs is limited to between 1C and 2C. With these precautions in place, the possibility of metallic lithium plating occurring due to overcharge is virtually eliminated.

Advantages

- High energy density - potential for yet higher capacities.
- Does not need prolonged priming when new. One regular charge is all that is needed.
- Relatively low self-discharge - self-discharge is less than half that of nickel-based batteries.
- Low Maintenance - no periodic discharge is needed there is no memory.

1.5.9 Servo Mechanism:

Servomechanism , automatic device used to correct the performance of a mechanism by means of an erroe-sensing feedback . The term servomechanism properly applies only on to systems in which the feedback and error-correction signals control mechanical position or one of its derivatives such as velocity or acceleration . A servomotor is rotary actuator or Linear actuator that allows for precise control of angular or linear position, velocity, and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servo uses in UAV

- Copter, Plane and Rover can control servos for any purpose, including triggering a camera shutter, releasing a parachute, or dropping a tennis ball. These servo(s) can be controlled either directly by the pilot via a switch on the transmitter, through commands sent from the ground station or as part of a mission.
- Either analog or digital servos may be used.
- We are using analog servo as we are releasing a payload of 500 gm.

Connection:

- Connect the servo to AUX OUT 1, 2, 3 or 4.
- The Pixhawk autopilot cannot provide power to the servos so an external BEC or ESC that can provide 5V should be used.

Fig.No. 11 Servomechanism

CHAPTER-2

LITERATURE SURVERY

2.0 LITERATURE REVIEW ON RESEARCH AREA

UAVs have been in production since before the Wright Brothers first took their historic flight. The earliest account can be traced back to the American Civil War, when an inventor patented an unmanned balloon that carried explosives that could be dropped after a time-delay fuse mechanism triggered a basket to overturn its contents. While this is a relatively primitive idea of what the world has come to know today as “drones” it goes to show how early man began thinking about unmanned aerial systems. This technology began taking small leaps in the years following the American Civil War - the first military aerial reconnaissance photos were taken in 1898 during the Spanish-American War via a camera attached to a kite. As the trend shows, many of the advancements in this technology arose during times of war, whether it was used to help with an offensive strike or just to acquire intelligence on enemy locations and activities.

This is seen throughout the history and progress of unmanned aerial technologies. Advancements took place in Britain during the 1930s, where a radio-controlled UAV (dubbed the Queen Bee) served as aerial target practice for British pilots, and also during World War II, during which 10 time the Nazi’s developed an unmanned flying bomber known as the V-1. It wasn’t until the 1970s that Israel developed the Scout and the Pioneer, which started the development toward the more widely known glider-type UAVs. It was from this design that the Predator drone came to be the Predator is the most sophisticated UAV in existence to date, these drones have come a long way from the “balloons” of the past. It’s autonomous control networks show just how much this technology has evolved. The structural design of UAVs has changed over their developmental history in order to serve a variety of purposes. UAV design and advancement is a global activity.

As technology and needs change, UAVs can be improved to serve these needs. There are several design considerations that are constant. The first of these design criteria is the degree of autonomy. Early UAV designs were mostly set to fly a specified path until they ran out of fuel. They carried a camera onboard, which would be recovered after the UAV landed. Later, the advent of radio control systems allowed UAVs to be piloted from the ground. Modern UAVs often combine these two basics 11 functionalities. These two modes of operation do not strictly signify autonomy. True autonomy suggests the ability of the aircraft to operate without human interaction. In this regard, UAVs are still very immature. UAV autonomy technology is divided into the following categories:

- Sensor fusion: On board the vehicle a combination of sensors is used.
- Communications: Communication and coordination will be handled between multiple sources in the existence of curtailed and imperfect information
- Motion planning (also called Path planning): Determining the optimal path for the vehicle in accordance with specific objectives and constraints such as obstacles go.
- Trajectory Generation: Designed for optimal control and maneuverability to follow a particular route or to go from one place to another.
- Task Allocation and Scheduling: Set the optimal distribution of tasks between a group of agents, with time constraints and equipment limitations.
- Cooperative Tactics: The optimal sequence and spatial distribution of activities between agents in order to make the most of the chances of success in any case or situation.

2.1 REVIEW ON RELATED LITERATURE

The ultimate goal of UAVs is to replace human pilots altogether. Another major design criterion is UAV endurance (range). Since there is no human pilot onboard, there is no concern for pilot fatigue. UAVs can be designed to maximize flight times to take advantage of this fact. Different systems can afford a wide variety of maximum range. Internal combustion engines require relatively frequent refueling and inflight refueling is a major obstacle for this type of propulsion system. Photovoltaic UAVs offer the potential for unlimited range and there is much research in this field. One more type of fuel system is hydrogen, which is proposed for use with certain models of stratospheric persistent UAVs.

The AeroVironment's Global Observer is one such UAV. This aircraft runs on hydrogen and has a range of 7 days. The idea is for two of such UAVs to be used in tandem to provide continuous, uninterrupted operation 365 days a year. With the sophistication that these systems have arrived at, the market for them has grown astronomically. While the United States still has the largest stockpile of unmanned aircraft, the rest of the world is beginning to follow suit. More than 50 countries have purchased surveillance drones, and many have started in-country development programs for armed versions. More than two-dozen different models were shown at a recent aviation show in China.

Due to the changing landscape of the theater of war, many nations are leaning toward unmanned aircraft to handle delicate situations in which human lives need not be put at risk. Also, taking into account the fact that drones sell for a fraction of the cost of manned airplanes, the amount of UAVs a nation can purchase at once has enticed many nations into entering the drone zone. In general, UAVs fall into one of six functional categories:

- Target and Decoy: simulating enemy missiles or aircraft for ground and air gunnery.
- Reconnaissance: battlefield intelligence gathering
- Logistics: cargo and logistics application
- Research and Development: used for UAV technology development 14.
- Civil and Commercial: specifically designed for civil and commercial applications.

2.2 CONCLUSION ON REVIEWS

In hindsight, we have come to know that our previous project i.e., Manual controlled quadcopter, had few crashes as we are amateur pilots and faced inefficiencies in accomplishing the tyro missions. So, we got an idea of implementing Autopilot technology (Using Pixhawk flight controller) to our drone, with this we resolved the problem of crashes and that is our mini project (3^{rd} year). After the mini project we have identified one more problem i.e., we do not have automatic dropping of product, because of that it may cause travails to the receiver. Then we got an idea of the using “Servo Mechanism” to our drone, for automatic releasing of product at the desired location. we have to setup the waypoints of our mission in the memory of flight controller by using mission planner software. When we turn on the Autopilot mode, drone will follow the waypoints and drops the product and returns to the home position as per the path provided in mission planner software.

CHAPTER 3

PROJECT IMPLEMENTATION

3.0 IMPLEMENTATION STAGES:

Assembly of Parts: With the assembly of parts the drone is made to fly with the weight of 300gm using mission planner software as process in below:

3.1 Mission Planner Software:

Mission Planner is a full-featured ground station application for the ArduPilot open-source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for any autonomous vehicle. The assembly of parts the drone is made to fly with the weight of 300gm using mission planner software as process.

Fig.No. 12 Mission Planner Software Logo.

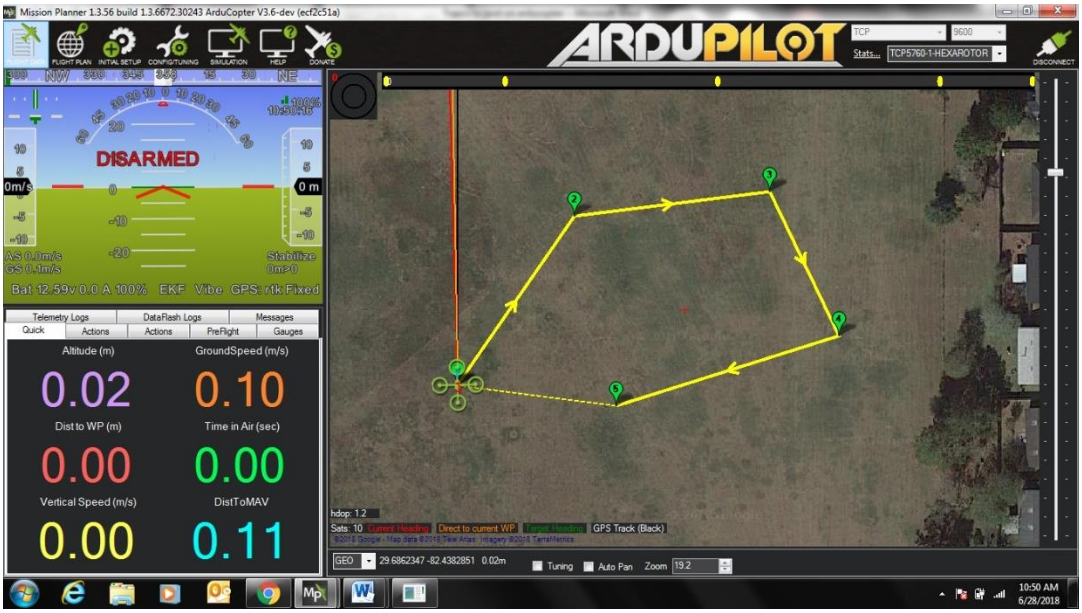


Fig.No. 13 Mission Planner Software.

Mission Planner is a full-featured ground station application for the ArduPilot open-source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for any autonomous vehicle. Here are just a few things you can do with Mission Planner:

• Load the firmware (the software) into the autopilot board (i.e., Pixhawk series) that controls your vehicle.
• Setup, configure, and tune your vehicle for optimum performance.
• Plan, save and load autonomous missions into you autopilot with simple point-and-click way-point entry on Google or other maps.
• Download and analyze mission logs created by your autopilot.
• Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.
• With appropriate telemetry hardware you can:
• Monitor your vehicle's status while in operation.
• Record telemetry logs which contain much more information the on-board autopilot logs.
• View and analyze the telemetry logs.
• Operate your vehicle in FPV (first person view)

Install Firmware:

0n the Mission Planner's Initial Setup is to install firmware screen then select the appropriate icon that matches your frame that is (i.e., Quad , Hexa , octa) . Then Answer Yes when it asks "Are you sure?" .

After the CGS detetcs which board you are using it will ask you to unplug the board, plug it back in. Then click OK within a few seconds i.e., during the breif period , the bootloader accepts requests to upload new firmware.

If all goes well then you will see some status appearing on the bottom right including the words like , "erase..." "program..." "verify..." and "upload done".

The firmware will be successfully uploaded to the board.

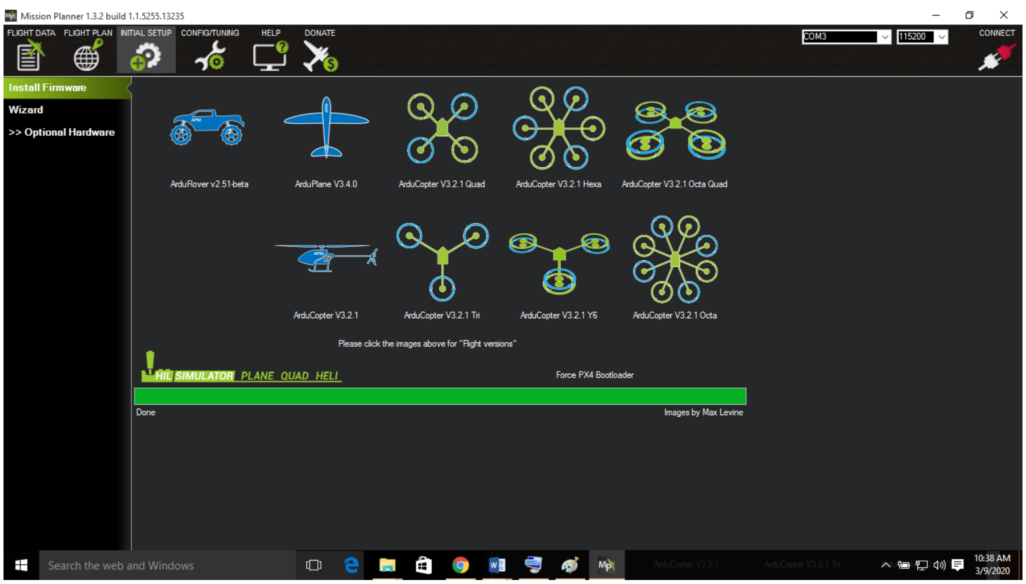


Fig No: 14 firmware installation

3DR Radio

You will see this menu item If the auto pilot is Not connected.

Antenna Tracker

You will see this menu item If the auto pilot is not connected.

Mandatory Hardware

You will see this menu item If the auto pilot is connected. Click this menu item to see the items you must complete before you attempt to operate your vehicle. Specifics are located in the area of the web that covers your specific vehicle (Copter, Plane, Rover)

Setting up the connection

To establish a connection, you must first choose the communication method/channel you want to use, and then set up the physical hardware and Windows device drivers. You can connect the PC and autopilot using USB cables, Telemetry Radios, Bluetooth, IP connections etc.

On Mission Planner, the connection and data rate are set up using the drop-down boxes in the upper right portion of the screen.

Fig No: 15 Connection

Once you've attached the USB or Telemetry Radio, Windows will automatically assign your autopilot a COM port number, and that will show in the drop-down menu (the actual number does not matter). The appropriate data rate for the connection is also set (typically the USB connection data rate is 115200 and the radio connection rate is 57600)

Select the desired port and data rate and then press the Connect button to connect to the autopilot. After connecting Mission Planner will download parameters from the autopilot and the button will change to Disconnect as shown:

Fig No: 16 Disconnection

Mission Planning

This section contains articles about creating missions that will run when the vehicle switched to AUTO mode. Setting your home location to the current location is easy, just click Home Location above where you enter your home location, and it will set your home location to the current coordinates. You can measure the distance between waypoints by right-clicking at one end and selecting the Measured Distance. And it will set your home location to the current coordinates.

Setting your home location to the current location , just clicking on Home Location above where you enter your home location, and it will set your home location to the current coordinates. We can measure the distance between waypoints by right-clicking at one end and selecting Measure Distance.

Fig No: 17 Setting-up Home Point

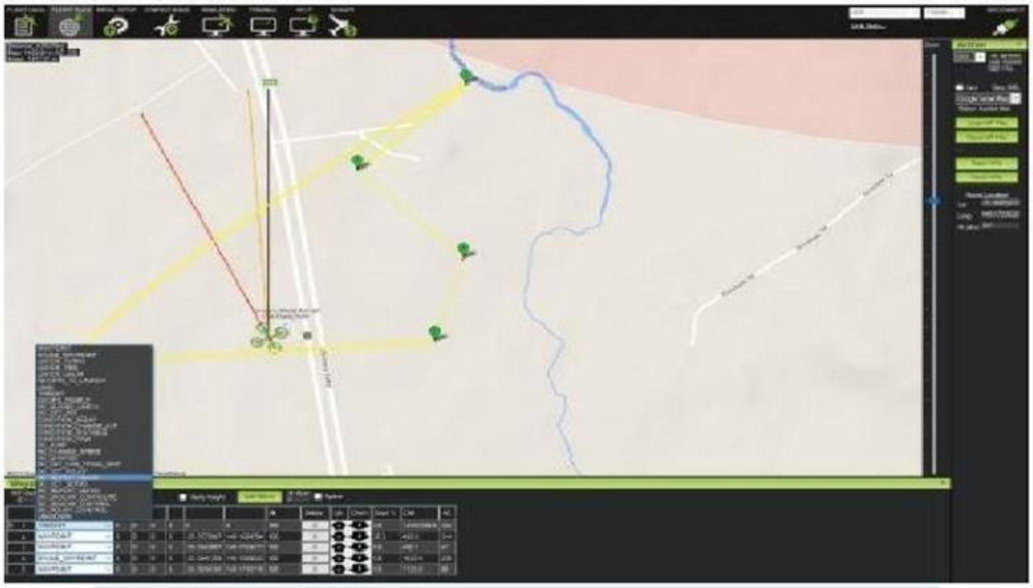


Fig No: 18 Setting to Autopilot

Setting the Waypoints

For Copter, Plane and Rover the home position is set as the location where the vehicle was armed. This means if you execute an RTL, it will return to the location where it was armed, so arm your vehicle in the location you want it to return to or use a rally point to setup an alternative return point. A waypoint is an intermediate point or place on a route or line of travel, a stopping point or point at which course is changed, the first use of the term tracing to 1880.

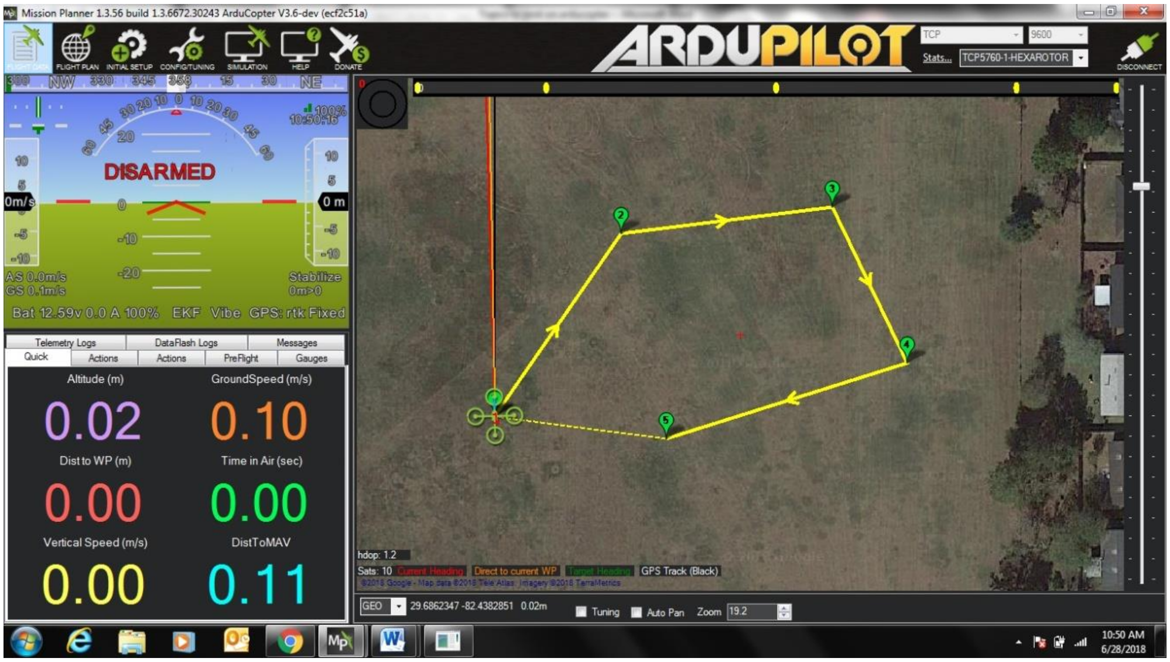


Fig No: 19 Setting up Way Points.

You can enter waypoints and other commands (see the Mission commands section below for more information). In the dropdown menus on each row, select the command you want. The column heading will change to show you what data that command requires. Lat and Lon can be entered by clicking on the map. Altitude is relative to your launch altitude/home position, so if you set 100m, for example, it will fly 100m above you.

Default Alt is the default altitude when entering new waypoints.

Verify height:

Itmeans that the Mission Planner will use Google Earth topology data to adjust your desired altitude at each waypoint to reflect the height of the ground beneath. So, if your waypoint is on a hill, if this option is selected the Mission Planner will increase your ALT setting by the height of the hill. This is a good way to make sure you don’t crash into mountains!

Once you are done with your mission, select **Write** and it will be sent to APM and saved in EEPROM. You can confirm that it’s as you wanted by selecting **Read.**

You can save multiple mission files to your local hard drive by selecting **Save WP File** or read in files with **Load WP File** inthe right-click menu:

Auto Grid

You can also have the Mission Planner create a mission for you, which is useful for function like mapping missions, where the aircraft should just go back and forth in a "lawnmower" pattern over an area to collect photographs.

To do this, in the right-click menu select Polygon and draw a box around the area you want to map. Then select Auto WP, Grid. Follow the dialog box process to select altitude and spacing. The Mission Planner will then generate a mission that looks something like this:

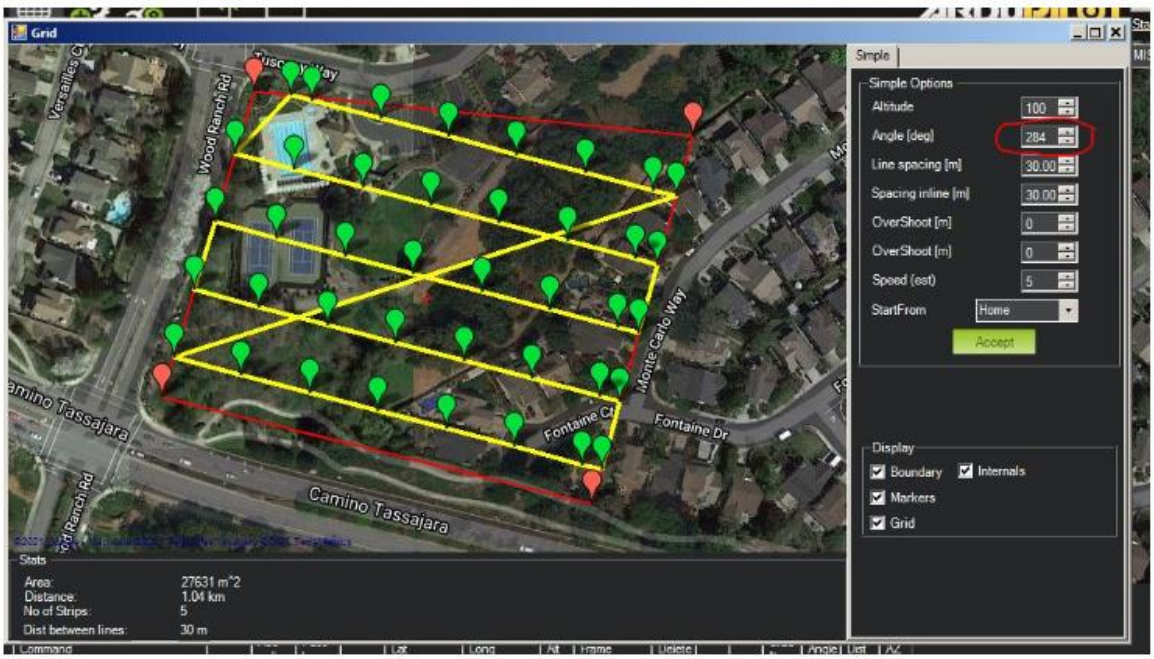


Fig No: 20 Grid View

Mission Planner Ground Control System:

Fig.No. 21 mission planner ground control system

The GCS Flight Data Screen:

Fig.No. 22 GCS Data Screen

We can start or stop recording the HUD as an .avi video stored in the logs folder .

Set MJPEG Source : Connect and display .

MJPEG video source from network.

Start camera : If a video source has been selected in the CONFIG / Planner page, I starts displaying it in the HUD window.

Set GStreamer source: connect and display Gstreamer video stream .

Here link video : Displaying the HereLink video, use same IP as when connecting MP via UDpcl to

HereLink for telemetry.

See the HereLink documentation.

Set Aspect Ratio: Clicking this alternates between 4:1 and 16:9 aspect ratio.

User Items: You can add any of the telemetry parameters to the display by right clicking on the HUD, clicking User Items, and checking the items you want displayed. Note that you can view all of the telemetry in the Control and Status area by clicking the Status button.

Russian HUD: Clicking this changes to/from a Russian style HUD (ground horizon fixed).

Swap with Map: Swap map to this window and vice versa.

Ground Color: Click to change ground color.

GStreamer Stop: Stop GStreamer video

The screenshot below shows the main "Heads-up Display (HUD)" view of the Mission Planner Ground Station. Once you have connected to a vehicle this screen will display the telemetry sent by Ardupilot.

Figure No: 23 Ground Control Station

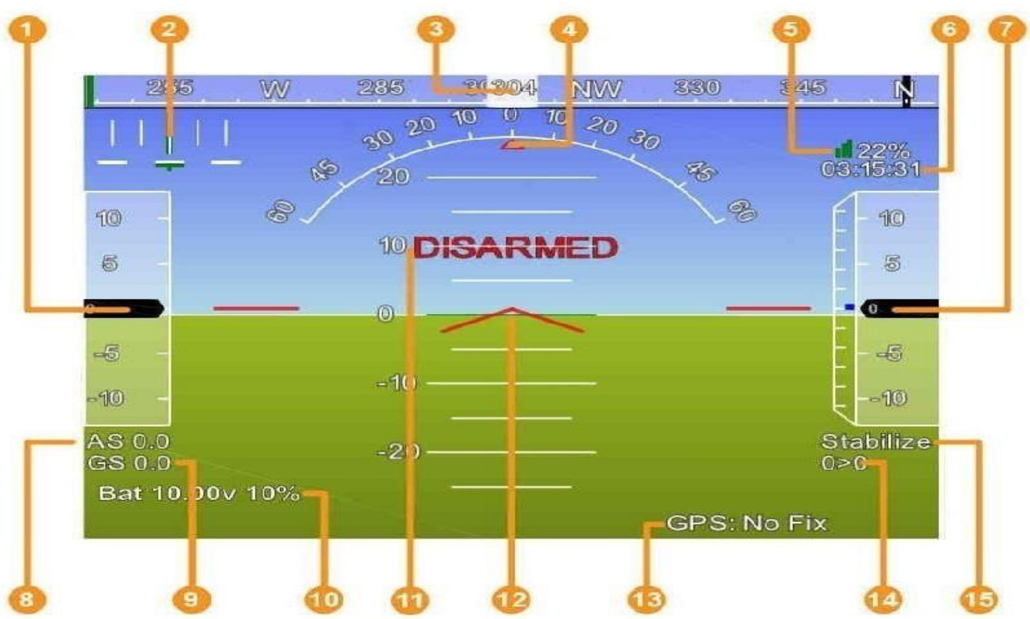


Figure No: 24GCS Disarmed

1. Air speed (Ground speed if no airspeed sensor is fitted)

2. Cross track error and turn rate (T)

3. Heading direction

4. Bank angle

5. Telemetry connection link quality (averaged percentage of good packets)

6. GPS Time

7. Altitude (blue bar is rate of climb)

8. Air Speed

9. Ground Speed

10. Battery status

11. Artificial horizon

12. Aircraft attitude

13. GPS Status

14. Current waypoint number> Distance to waypoint

15. Current Flight Mode

Mission Planning Configuration and Tuning:

This section of Mission Planner, invoked by the Menu item Config/Tuning at the top of Mission Planner, has several subsections. The subsection is where you configure the parameters that control how your auto pilot controls your vehicle. Tuning refers to adjusting parameters in the control loops, so your vehicle behaves the way you desire. Most of these parameters are set for you when you first install your firmware, but some must be set before your first flight or roaming adventure.

What you see when you enter this section depends on whether or not you are connected.

Planner

You will see this menu item if the auto pilot IS or Is Not connected. This is where you set up most of the options for how the Mission Planner works. Such things and enabling speech, where the logs are saved, the units of measure you want to use, ETC. Some of the specifics are covered here.

Full Params Limit

You will see this menu item if the auto pilot Is connected. Here is what you can do in this section TBD options on the right-hand side of this screen: You can save the parameters for your vehicle. It is a good idea to do that often. Also, you can reload all your parameters from a saved file. You can also compare the parameters in your vehicle to those in a saved file.

This is a very valuable feature in case you forget what you changed or if your vehicle behaves badly after a change, but you don't remember the previous value(s) of the parameters you changed - or even what you changed. An important aspect of the compare feature:

After you select the file with the save parameters you want to compare; you will get a window that lists every parameter that is different. At the time of the window, nothing has been changed, but if you check some items and then click Continue, those items will be changed in the local memory of Mission Planner. You will then need to click the Write Params parameters button in the right-hand panel to copy the changes to the memory in your auto pilot. Until we get more words here, just experiment.

Clean this up with the right menu words, Load, Save Refresh Parms etc. Copter Pids You will see this menu item if the auto pilot Is connected to an ArduCopter.

CHAPTER 5

PROJECT TESTING

5.0 TESTING

Fig No: 25 Prototype testing

The above picture is the testing of the drone for medical emergency using a weight of 300 grams as the payload for the mission in the span of 3 minutes. We safely dropped the payload using servomechanism and our mission was then accomplished, the drone was then returned to the home position.

- The drone passed the test.

5.1 EXPERIMENTAL RESULTS

The voltage (V)	Paddle size	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)	Working temperature (° C)
11	EMAX8045	1	110	11	10.0	3650	
		2	200	22	9.1	4740	
		3	270	33	8.2	5540	
		4	330	44	7.5	6200	
		5	390	55	7.1	6700	
		6	440	66	6.7	7150	
		7.1	490	78.1	6.3	7400	36
	EMAX1045	1	130	11	11.8	2940	
		2	220	22	10.0	3860	
		3	290	33	8.8	4400	
		4	370	44	8.4	4940	
		5	430	55	7.8	5340	
		6	480	66	7.3	5720	
		7	540	77	7.0	5980	
		8	590	88	6.7	6170	
		9	640	99	6.5	6410	
		9.6	670	106	6.3	6530	43

Data Sheet

Drone weight without payload= 1150gm

Payload= 200gm

Drone Weight with Payload= 1350 gm

Load on each motor= 1350/4=337.5gm

Propeller length= 10 in

Battery= 4500mAh

Motor (4)= 8910 rpm

ACTIVITY:

Total time= 3 min at 30 km/h

Take off:

Thrust load on each motor= 337.5*2=675gm

From motor data sheet Power(P)=40*4=160W

Energy consumption= (160*25)/3600=1.11Wh

Forward:

Thrust load on each motor= 337.5*1.2=405gm

From motor data sheet Power(P)=50*4=200W

Energy consumption= (200*100)/3600=5.56Wh

Landing:

Thrust load on each motor= 337.5*0,7=236.25gm

From motor data sheet Power(P)=25*4=100W

Energy consumption= (100*25)/3600=0.69Wh

Total energy consumed by the drone for given activity(E) = 10.89Wh=653.4Wmin

Source Energy (Es)= Power*time

=V*I*time

=11*4.5*1=45Wh

=2750Wmin

Flight time= Es/E= 2750/653.4= 12.6 min

Total flight time for the activity= 12.6 min

We can comfortably finish the task with the achieved flight time.

RESULT	THEORETICAL	PRACTICAL
WEIGHT	1350GM	1350GM
MAX SPEED	30KMPH	30KMPH
BATTERY	4500mAh li-polymer	4500Mah li-polymer
MAX FLIGHT TIME	12.6 minutes	12 minutes

Table No:2

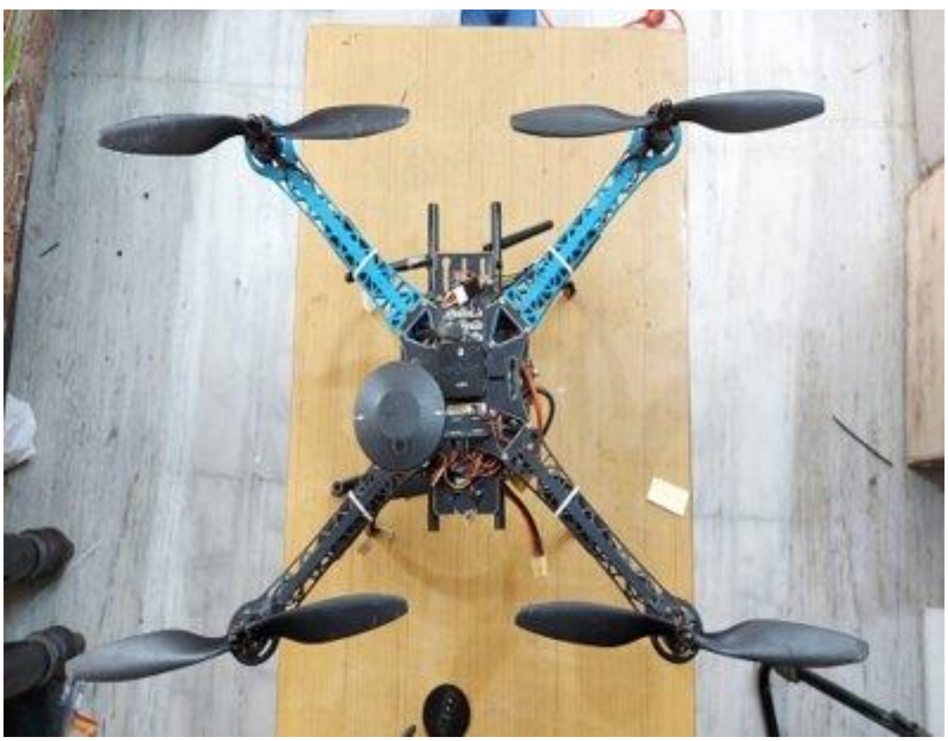
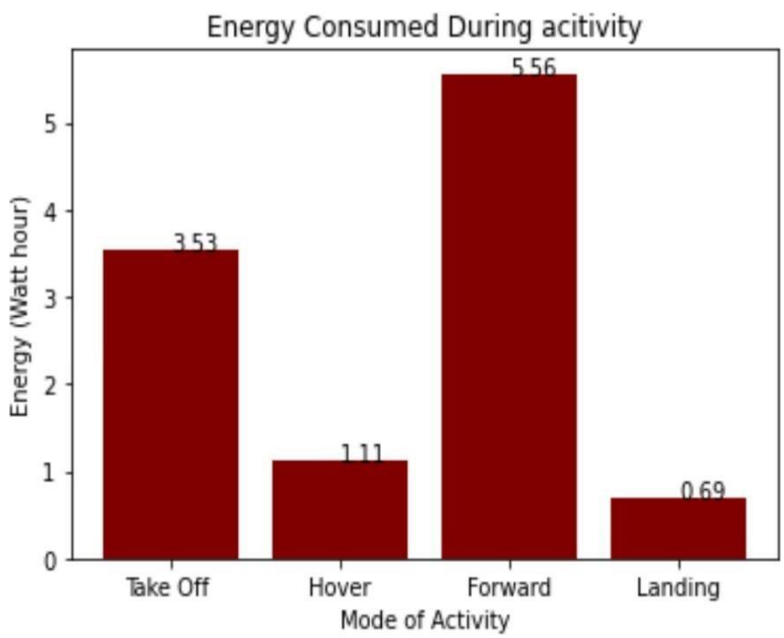


Fig No: 26 Prototype

Fig No: 27 Prototype during flight



5.2 GRAPHICAL REPRESENTATION

The graphical representation of the Energy consumed at certain activity is shown.

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

- If there is a distinctive path that modern change has followed, it’s automation.
- Automation will be creating a greater impact on our daily lives as every machine and material is made through automation.
- For the ongoing crisis of the pandemic, the drones are used for most of the emergencies. To make it fast, accurate and simple, we have used autopilot drone.
- The autopilot drone will make sure the path and flight controller direct the drone to pass through the waypoints given to it.
- Overall, the autopilot system in the drone helped during emergencies.

FUTURE ENHANCEMENT

- As we are living in a developing country, automated vehicles would create an impact on lifestyle. Autopilot can be developed in such a way that it flies according to gestures using AI and ML.
- This autopilot drone can be upgraded to obstruction handler by using automated sensors and can be made to fly higher.

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A Major Project Report
On

DEVELOPMENT OF GREASE TRAP

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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Under the Guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE
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Dhulapally, Secunderabad – 500 100

JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Development of Grease Trap**, is being submitted by **G. Vishal (17K81A0323), K. Stephen Calvin (17K81A0328), K. Hemanth Kumar (17K81A0331), Md. Afroz Pasha (17K81A0340)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

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Dr. D.V. SREEKANTH
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Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Development of Grease Trap** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

A Grease Trap manufactured to properly manage the Fats, Oils and Greases (FOG) in sewage that impacts our collection systems and treatment processes, the reason for this is these materials harden and plug sewer line. Small amounts of grease and oil accumulate in the sewers resulting in a large blockage in pipelines which can be prevented using grease trap. All the sanitary sewers flow through local wastewater treatment plants which are designed to remove fuel products, grease, or cooking oils, more commonly known as FOG. Our device is significantly needed in large scale usage of filtering water outlet and removing the excess materials like oil and grease. Given the current environmental conditions it is crucial to decrease pollution for creating a sustainable environment. The wastes in food solids, oil, and grease (FOG) if left unchecked, could end up accumulating in pipes creating problems such as foul odor, blocked drainpipes, restricted flow rate of wastewater. Our objective in his project is to create an efficient and economical grease trap to treat these mixture and separate water from FOG.

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CHAPTER-1
INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

Wastewater discharges containing high concentrations of fats, oils, and grease from Food service establishments are the primary cause of wastewater collection and transmission system blockages and sanitary sewer overflows in the City’s sanitary sewer service area. Overflows of wastewater into the storm water collection system and natural bodies of water can be significantly reduced by controlling the discharge of fats, oils, and grease into the wastewater collection and transmission system. This source of pollution is also readily preventable by implementing good management practices and proper maintenance at food service establishments and automotive related enterprises.

To address this issue, the City has developed the following design and performance criteria for grease traps, grease interceptors, and oil/water interceptors. The objectives of the following criteria are To regulate the use of the City’s wastewater collection and transmission system by effectively precluding the introduction of excessive amounts of fats, oils, and grease into the system; To prevent obstruction or blockage of the City’s sanitary sewer lines due to grease build-up; and To eliminate sanitary sewer overflows or releases of wastewater that reach waters of the United States, publicly and privately-owned properties, streets, and residential and commercial buildings, resulting in potential liability to the City; and To protect the health, safety, and welfare of the citizens of and visitors to the City of Milton and the integrity of the environment; and To reduce maintenance costs associated with the City’s wastewater collection and transmission system and to improve its operation

“Grease”. A material, either liquid or solid, containing substances which may solidify or become viscous at temperatures between 32 degrees and 150 degrees Fahrenheit, composed primarily of fats, oils or grease from animal or vegetable sources. The phrases "fats, oils and grease”, “FOG”, "oil and grease," or "oil and grease substances" shall be included in this definition.

1 .2 OBJECTIVE OF STUDY

To regulate the use of the kitchen’s wastewater collection and transmission system by effectively precluding the introduction of excessive amounts of fats, oils, and grease into the system.

To prevent obstruction or blockage of the City’s sanitary sewer lines due to grease build-up.

To eliminate sanitary sewer overflows or releases of wastewater that reach waters of the United States, publicly and privately-owned properties, streets, and residential and commercial buildings, resulting in potential liability to the City.

To protect the health, safety, and welfare of the citizens of and visitors to the City of Milton and the integrity of the environment.

To reduce maintenance costs associated with the City’s wastewater collection and transmission system and to improve its operation.

The treatment objective was to reduce the fat, oil and grease (FOG) buildup in the grease trap of the 30-table seating-capacity restaurant. The buildup caused blockages in the restaurant's sewer lines and caused odor complaints.

Oil and grease (O&G) in wastewater can be considered as two parts or proportion contained in emulsion which exceeded O&G standard. Most of oil becomes emulsified with water when they pass through grease trap and discharged in the effluents. Thus, it may indicate that either treatment of grease traps or standards for O&G content stipulated in technical memorandum of Water Pollution Control Ordinance (WPCO) do not reflect the actual situation.

The objective of this study was to assess the feasibility of co-digesting food waste (FW) and de-oiled grease trap waste (GTW) to improve the biogas production. A lab-scale mesophilic digester (MD), a temperature-phased anaerobic digester (TPAD) and a TPAD with recycling (TPAD-R) were synchronously operated under mono-digestion.

1.3 SCOPE OF STUDY

Determine the optimal design, sizing, and operations and maintenance criteria for grease interceptors. Researchers employed experimental and numerical techniques to understand and quantify the performance of grease interceptors. They developed alternative designs using numerical models followed by physical models of the most promising alternative designs, which were tested on a laboratory scale grease interceptor. Researchers examined different theoretical residence times to quantify the increase in FOG removal performance with reactor size. In addition, they investigated the impact of temperature and detergents to determine how food service establishments' operational conditions influence the FOG removal process within grease interceptors. The research team conducted field measurements of grease interceptors to understand the dynamics of FOG separation when food solids are also discharged into the grease interceptor. Develop a grease interceptor design methodology that can be submitted to the International Association of Plumbing & Mechanical Officials (IAPMO) for consideration for inclusion into the Uniform Plumbing Code (UPC).

This model will be used to evaluate design changes, and operation and maintenance (O&M) conditions on the removal of FOG from foodservice waste. The model will be validated using a laboratory-scale grease trap.

In this study, strengths and weaknesses of installed or under installation grease trap were identified. A new grease removal system was then designed and built to resolve these weaknesses. The system was an 800 L cylinder (1 m diameter and 1 m height) from galvanized metal coated with two layers of composite at both sides. A cubic basket (20 × 20 × 20 cm) was installed at the system inlet to prevent entering trashes into the system. Removability of the basket and two baffles installed on the system facilitates discharge and cleaning process. A grease remover bridge of 50 cm length equipped with a gearbox motor (12 V, 3 rpm), discharges accumulated grease automatically in adjustable time periods. The system was designed based on retention of 30 min.

1.4 MATERIAL REQUIREMENT

Grease traps usually consist of an underground, watertight, concrete tank with baffled inlet and outlet piping. The outlet pipe has a tee that allows the internal discharge to be located within 0.3 m of the tank bottom. The size of the grease trap depends on the anticipated flow rate, water temperature, and grease concentration. In general, grease traps range from a minimum capacity of 2.8 m3 to a maximum capacity of 4.7 m3. Where a capacity of more than 4.7 m3 is required, two or more grease traps may be placed in a series. Access to the tank is typically through one or two manhole rings and covers. Grease traps should be located outside food-service buildings in an accessible location for inspection and maintenance. The traps are installed in the waste line between the sink drains, floor drains and kitchen fixtures and the wastewater collection system.

We are fabricating final model using Stainless Steel AISI 304 with thickness of 2mm (or) 0.2cm. SS 304 is an economical material which has high resistance towards rusting and corrosion, making it a viable metal for application in water treatment-based products. Here is the outer shell of our grease trap with inlet of diameter 50 mm, approx. 2in. A lid holder is placed on the top with a latch on the side to allow opening of the grease trap for cleaning and maintenance. The 2 mm thick SS 304 can withstand heavy load without bending or damaging the structure.

Figure 1 - Stainless steel AISI 304

1.5 PROCUREMENT OF EQUIPMENT

1.5.1 Meshing

Mesh filters have been around for several years so they're a common fixture in older range hoods. Modern hoods don't have mesh because this component is considered unsafe, highly susceptible to fire. These filters have multiple layers of fine metal mesh stacked on top of one another, creating a very fine filter. When kitchen air is forced through it, grease particles become trapped in mesh while air passes safely. Mesh filters are not approved for commercial kitchen use and must be replaced with baffled filters. It's important to ensure the filters are of correct size and shape so your hood functions properly.

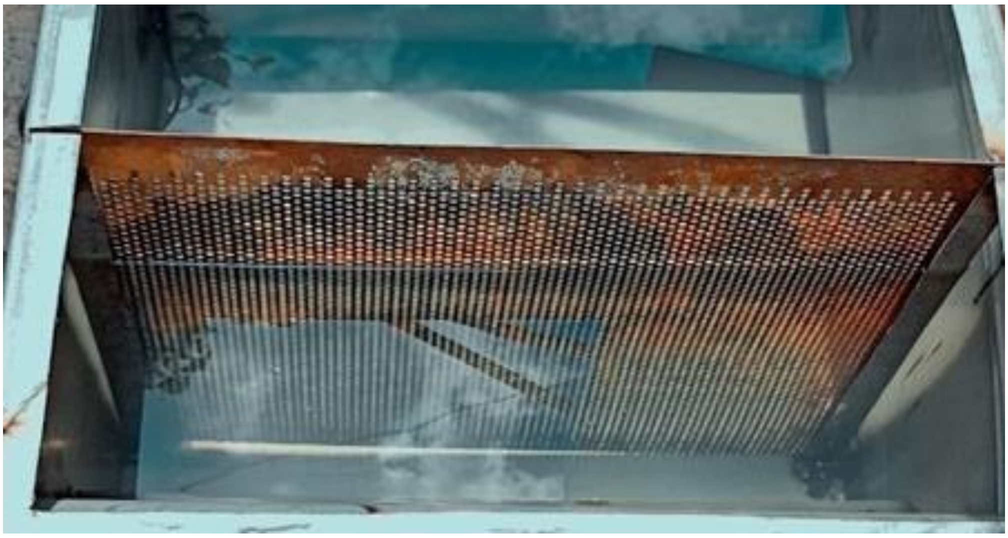


Figure 2 – Mesh used in the trap of ss 304 steel.

1.5.2 Baffles

These are more common in modern range hoods because it is considered safer than regular mesh filters. They are made from metals like aluminum, mild steel, or stainless steel. It forces air passing through the system to quickly change directions repeatedly. Grease particles can't keep up with these swift changes, so they cling to baffle grill in a condensed form, eventually dripping down towards a collection tray. This system eventually drains its collection tray. Experts consider baffle grease filter to be the safest filter with a very low combustion rate. Here are some benefits of this system: The baffle grill is easier to clean and maintain, which makes it a popular choice in commercial kitchens where hoods need to be cleaned more often. An all-metal construction ensures this product is very durable, withstanding years of use without problems. Baffle filters have a grease trap that helps stifle fire in case of an accident, keeping it from spreading to other areas of your hood or kitchen.

Figure 3 – Baffle made up of SS 304 material.

1.5.3 Inlet & outlets

Figure 4 – Diameter of the inlet.

Here is the outer shell of our grease trap with inlet of diameter 50 mm, approx. 2in. An inlet of 50 mm is given at one end of grease trap with a hollow pipe of 70mm length.

CHAPTER-2
LITERATURE SURVEY

2.1 LITERATURE REVIEW ON RESEARCH AREA

Current grease interceptor evaluations use animal fat as a test medium for finding minimum retention time. These tests do not consider that many restaurants use detergents, sanitizers, and vegetable oils. These factors can influence emulsification characteristics (e.g., droplet size) of FOG discharges, and thus influence separation efficiencies. Grease trap are sized according the volume of effluent expected, the retention time necessary for separation at the temperature of the waste, the frequency of cleaning, and the quantity of emulsified grease "Grease" is being referred to as a "catch-all" phrase by the utility industry for FOG and include some waxes and paraffin. Each of these categories of FOG exhibit different chemical and physical properties.

Presently, the universal plumbing standards are based solely on effluent measurements. These standards do not consider chemical composition of FOG, baffle arrangement, maintenance, and geometry criteria. However, jurisdictions such as Austin, Texas recommend two baffles, citing increased grease interceptor efficiency. Many authorities believe length of the interceptor is more significant for separation than depth. In the case of cleaning frequency, the U.S. EPA recommends cleaning of interceptors when the volume is at 75% of maximum. However, many cities recommend cleaning frequencies between 60 and 120 days (Fankel, 2004). Stoll and Gupta (1997) developed management strategies for FOG collection, treatment, and disposal.

♦ Avoid the use of emulsions and use cleaning agents sparingly.

♦ Drain surfactant-laden food wastes only at the end of the day to provide longer periods in the grease interceptor and improve separation.

♦ Encourage intermediate machine cleaning to working surfaces and floors with hot water at high pressure, without cleaning agents, and drain scalding and boiling containers slowly after cooling first.

♦ Train and keep an eye on kitchen staff.

2.2 REVIEW ON RELATED LITERATURE

The purpose of the grease trap is to reduce the amount of Animal and Vegetable Fats, Oils and Greases (AVFOG or FOG) in wastewater to acceptable levels as established by the Authority Having Jurisdiction (AHJ). Precast concrete gravity grease interceptors should be provided with easy access for maintenance, be sized to hold large quantities of grease (to reduce pumping/cleanout costs) and be outdoors to facilitate easy inspection and reduce the possibility of food contamination during cleanout. Solidified grease can cause sewer blockages and overflows that pose unnecessary health hazards as raw sewage backs up into residence or commercial establishments. A properly plumbed and maintained grease interceptor will protect sewer systems from these occurrences. Municipalities continue to require food establishments and other FOG generators to pretreat their grease-laden waste streams through the use of interceptors to protect the sewer system. Non-conforming establishments can face fines and the associated costs for blockages, overflows, and cleanup.

Engineer ran an extensive feature article on FOG (fats, oils, and grease) and the importance of using grease interceptors to keep kitchen grease out of the municipal sanitary system.

Because the article was very well received, PME then decided to survey its readers about their design practices with grease interceptors. This article provides and analyzes the results of that survey.

Both the Code require installation of a device (or devices) to contain grease at all foodservice establishments. Grease must be properly contained to prevent blockage of piping in the building's plumbing system and in the public sewer system. Such blockages cause sewage to backup and can result in unsanitary conditions; moreover, such blockages present costly and unnecessary maintenance problems.

The Building Code require that any plumbing fixture that may discharge grease to the plumbing system must have provisions in place to contain the grease. Included in such fixtures are pot sinks, hand sinks, mop sinks, food preparation sinks, floor drains, floor sinks, dishwashers, premise sinks, WOK stove drains, steam tables, and hood drains.

Grease-trap manholes are required because they remove grease in the most sanitary, efficient, and economical manner. Located outside the building and the kitchen, they can be readily cleaned at any time by a truck equipped with a vacuum hose. Since they have a larger size, they can be cleaned less frequently and more economically than small interior interceptors. An added advantage is that more kitchen fixtures can be added at any time without the need to modify the system for grease containment.

2.3 CONCLUSION OF REVIEW

In this study, researchers analyzed field grease trap during their maturation cycle, conducted controlled laboratory experiments to assess the FOG removal performance of grease. traps under different operating conditions and design configurations, and simulated grease trap to evaluate the use of numerical tools in the assessment and design of grease trap. As a result of the analysis of grease interceptor performance, the researchers concluded:

♦ Extending the residence time in a standard GI by a factor of 3 only yielded a 10% improvement in performance, suggesting that FOG loading is only one of the factors. affecting performance.

♦ FOG droplet size significantly affected FOG removal performance.

♦ Decrease in GI separation efficiency will result with the use of detergents and mixing while cleaning in-kitchen FOG wastes.

♦ Inlet/out configurations must be designed to distribute the flow.

♦ More effective FOG separation was achieved when fluid velocities near the inlet and outlet was kept below 0.015 m/s.

♦ Only include baffle walls with specific inlet/outlet configurations.

♦ Design baffle wall to distribute the flow and minimize the occurrence of high local fluid velocity

CHAPTER-3
PROJECT DESIGN

3.1 OVERVIEW OF THE DESIGN

The design factors to consider when sizing a grease trap are as follows:

- Flow rate of discharge to grease trap.
- Retention time in the grease trap.
- FOG concentration of the influent waste.
- Emptying frequency

A 3-D model of grease trap was designed using computer aided design software and a flow analysis has been performed on the design. Grease traps shall be readily accessible for inspection and cleaning. Grease traps shall be equipped with a cover that can be opened for inspection and cleaning and a mechanism for a secure closing.

Modification to or removal of any of the grease retention components, which cause a grease pass through, sufficient enough to pose a threat of blockage, is strictly prohibited Capacity. Grease traps shall have the grease retention capacity outlined in the most recent edition. Flow control device. Grease traps shall be equipped with a device to control the rate of flow through the unit. The rate of flow shall not exceed the manufacturer's rated capacity recommended in gallons per minute for the unit. Each FSE is responsible for maintaining appropriate flow control devices.

Inspection, pumping, and maintenance. In addition to required quarterly pumping, each FSE shall determine an additional frequency at which its grease interceptor(s) shall be pumped according to the following criteria: When the floatable grease layer exceeds six inches (6") in depth as measured by an approved method; When the settle able solids layer exceeds eight inches (8") in depth as measured by an approved method .When the total volume of captured grease and solid material displaces more than twenty-five percent (25%) of the capacity of the interceptor as calculated using an approved dipping method When the interceptor is not retaining/capturing oils and greases.

Venting the flow control device and the grease trap shall be vented in accordance with the most current edition of the most current edition. The vent shall terminate not less than six (6) inches above the food rim level or in accordance with the manufacturer's instructions. Each FSE is responsible for maintaining appropriate venting of the grease trap.

Inspection, cleaning, and maintenance. Cleaning and maintenance must be performed when the total volume of captured grease and solid material displaces more than twenty-five percent (25%) of the total volume of the grease trap. Each FSE shall determine the frequency at which their grease trap shall be cleaned, but all grease traps shall be opened, inspected, cleaned, and maintained at a minimum of once per week.

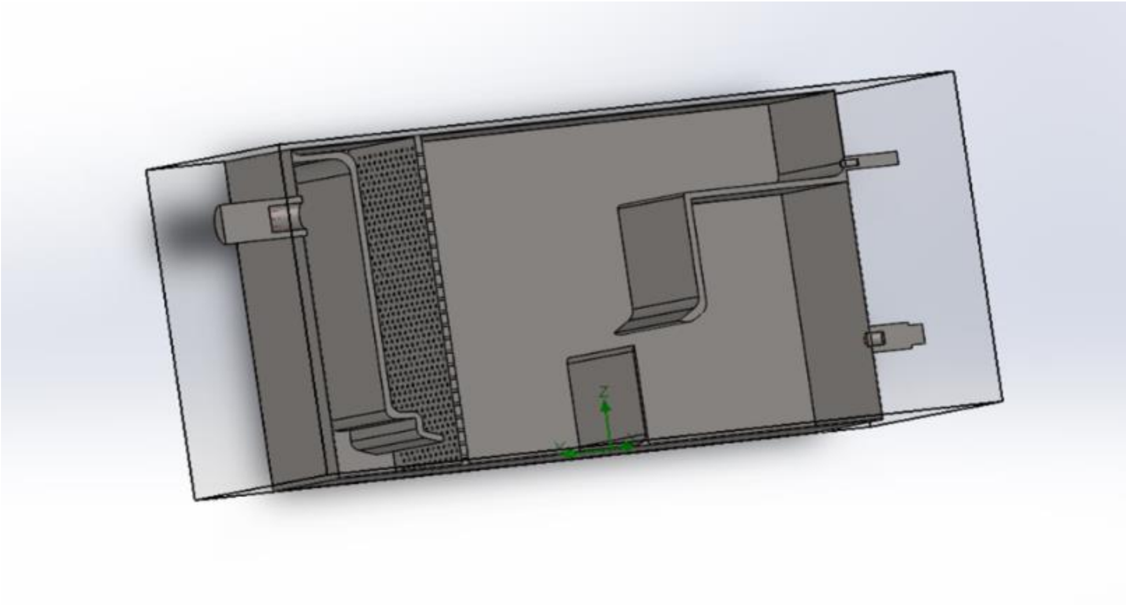


Figure 5 – Sectional view of grease trap.

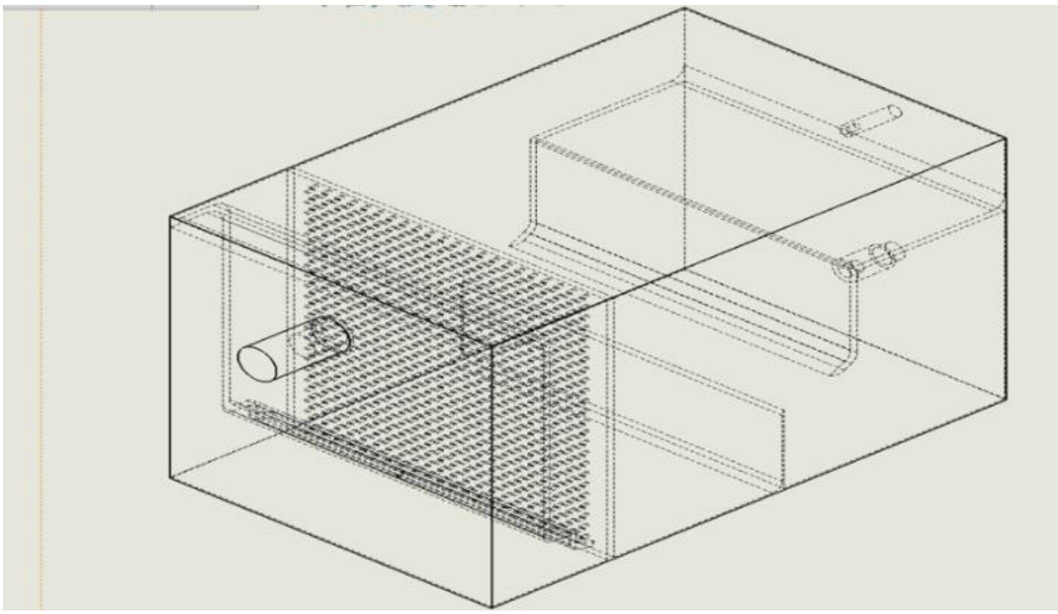


Figure 6 – Isometric view of grease trap.

3.2 EQUIPMENT ANALYSIS

3.2.1 Grease trap Influent Solids and Particle Analysis

The results of the particle size analysis using the mesh apparatus the results show a range of food items captured by the mesh apparatus including vegetable, meat, poultry, fish, and starch. For this grease interceptor, food items were retained by all mesh sizes, indicating that a wide range of particle sizes (2-11 mm) can be found in full-fare restaurant waste streams.

In addition, the settling rates for the different food items ranged from 0.05-0.2 ft/s. These results suggest that typical food waste solids have a high settling rate and would likely settle out efficiently in a grease interceptor assuming that quiescent fluid flow patterns have been developed. Any transport of these types of solids into a second compartment of a two-compartment grease trap suggests the following conditions:

1) Quiescent fluid flow patterns have not been maintained

2) Inappropriate grease trap cleans out frequency

3) Density outfall event

3.2.2 Grease trap Influent Fluid Flow Analysis

Our goal is to create a grease trap which would separate the mixture of grease and water using the density difference of the fluids and the overall turbulence that would help FOG to escape through the upper outlet. The research team measured flow at several grease trap to provide additional data on the variability of the grease interceptor influent flow field. Analysis of the influent flow field is displayed (mean, minimum, and maximum) and (frequency and cumulative distributions). Figure 4-3 displays several time histories traces of the flow data over a 24-hour period for different food service establishments. The total water usage to the grease interceptors ranged between 1,700 to 6,300 gallons. These values are consistent with those measured by Nashville Metro Water Services, where their GI water usage displayed values between 1,140 and 6,660 gallons. These total water usages were within the range found by Garza (2005) that also characterized the wastewater stream of several types of food service establishments. Grease trap sizes at these measurement sites ranged from 1,000 to 1,500 gallons.

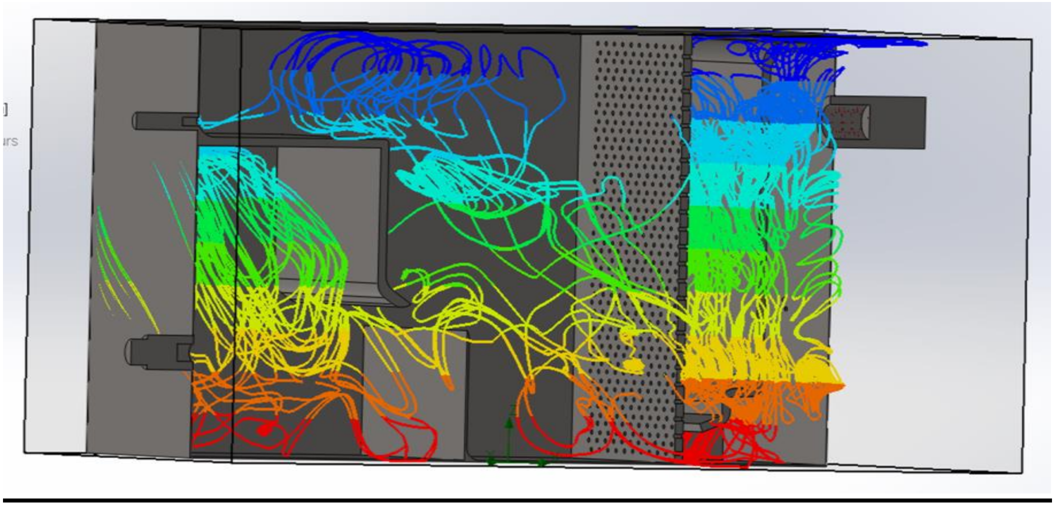


Figure 7 - CFD flow analysis of mixture of two fluids in solidworks.

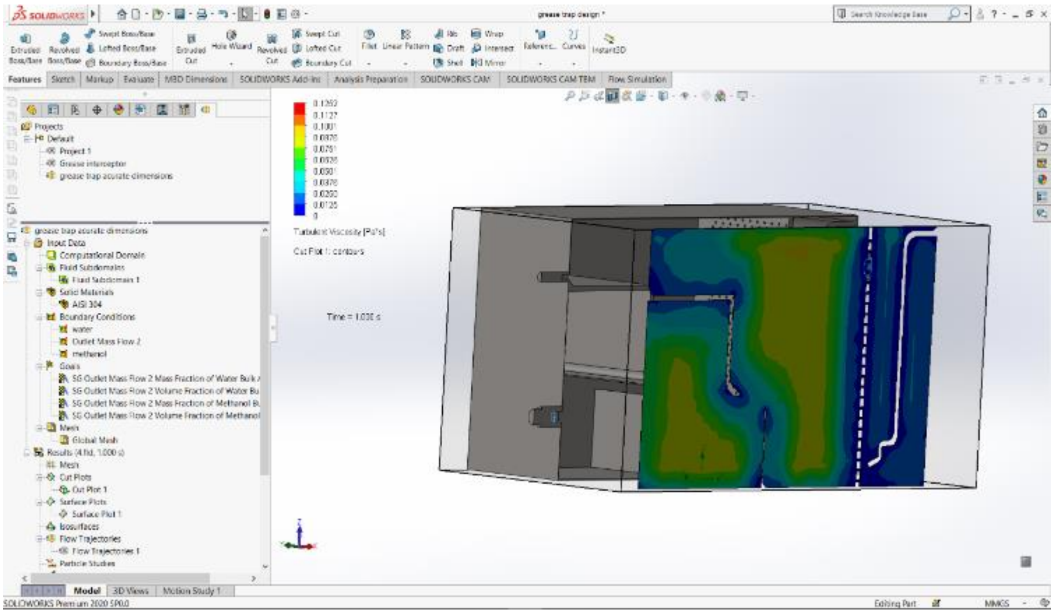


Figure 8 – Turbulence of methanol and water.

3.3 DEFINE THE MODULE.

3.3.1 Properties of the grease trap

Important physical and chemical properties of trap grease relevant to its pretreatment were found for grease samples collected at Gloucester County Utilities Authority wastewater treatment plant (GCUA). Raw grease was separated to find its moisture, solids, and grease phase contents. Raw grease, even after initial gravity separation at GCUA, contained ~47 mass % water on average. An average of 49 mass % was grease, and the remaining 4 mass % was solids (on a dry basis).

Specific gravity of the raw trap grease, including the water and solids, was ~0.91.

The grease-only phase was isolated to determine its chemical composition (fatty acid spectrum), acid number (free fatty acid content), meniscus point (incipient melting temperature), and specific gravity. Grease analyzed by gas chromatography at the USDA Eastern Regional Research Center (ERRC), an institutional partner for this project, showed a fatty acid spectrum expected for an edible-oil based grease. Presence of short-chained fatty acids may indicate some microbiological, chemical, or thermal degradation of the grease, but the overall composition indicated that trap grease-derived biofuel may form less oxides of nitrogen and have better fuel stability than traditional soy-derived biodiesel. Acid number for the grease was measured by titration and averaged 182 mg KOH/g, or 91% free fatty acid (FFA) expressed as oleic acid. This is significant since traditional alkaline biofuel transesterification reactions (e.g., for soybean oil feedstock) are sensitive to even a few percent FFA. The meniscus points at which solid grease began to melt averaged 30°C (88°F), although in one trial it was measured as high as 36°C (97°F). This meniscus point temperature serves as a lower limit to which process equipment, piping, etc., must be heated in order for grease to flow. Specific gravity of the grease-only phase averaged 0.87.

These chemical and physical properties of raw and dry, solids-free grease, along with kinetic data from project partner Philadelphia Fry-o-Diesel, were used to design a ~2 million gallons per year trap grease-to-biofuel process. Laboratory data taken in this Phase I project are unavailable in the literature, and thus were instrumental in developing mass and energy balances for the process, selecting and sizing equipment, and completing the preliminary feasibility study. For example, sizing of the pretreatment centrifuge was enabled by determining the composition and density of raw trap grease (moisture, solids, and grease) as well as the density of dry, solids-free grease.

3.4 MODULE FUNCTIONALITIES

The purpose of the gravity grease trap is to reduce the amount of Animal and Vegetable Fats, Oils and Greases (AVFOG or FOG) in wastewater to acceptable levels as established by the Authority Having Jurisdiction (AHJ). Precast concrete gravity grease interceptors should be provided with easy access for maintenance, be sized to hold large quantities of grease (to reduce pumping/cleanout costs) and be outdoors to facilitate easy inspection and reduce the possibility of food contamination during cleanout. Solidified grease can cause sewer blockages and overflows that pose unnecessary health hazards as raw sewage backs up into residence or commercial establishments. A properly plumbed and maintained grease interceptor will protect sewer systems from these occurrences. Municipalities continue to require food establishments and other FOG generators to pretreat their grease-laden waste streams through the use of interceptors to protect the sewer system. Non-conforming establishments can face fines and the associated costs for blockages, overflows, and cleanup.

The properties of grease-laden wastewater must be considered when determining the size of an effective grease interceptor. For instance, greases and oils have a lower specific gravity than water – when left undisturbed a grease-laden mixture will separate, with the grease and oil floating to the top. Another factor to consider is the congealing temperature of the FOG. Other factors affecting interceptor size include:

Retention Time: Retention time is the amount of time it takes one particle of influent to travel though the system and discharge out of the interceptor. It is a critical factor in removing an adequate amount of FOG. The wastewater entering an interceptor requires a certain amount of time for gravity separation of the FOG to occur. Therefore, designing an interceptor to maximize retention time is the most important factor in its effectiveness. The various studies and specifications referenced in this paper approach retention time differently and calculate differing retention times – however, all agree that the FOG must spend sufficient time in an interceptor to allow for gravity separation.

Flow rates: Wastewater flow rates and retention times are inversely proportional. The greater the flow rate, the lower the retention time. There is no singularly accepted method for calculating the anticipated flow rate but most studies and AHJs agree that it must be taken into account when sizing an interceptor.

Concentration: The strength of the influent waste is another important factor. An effective interceptor should be large enough to accumulate a significant amount of grease without affecting the retention effectiveness, but this should not be the predominant sizing factor, as cleaning frequencies should be factored in.

Pumping Frequency: The size shall be sufficient to optimize cleaning and pump outs (to reduce an owner’s operating costs).

Chemistry: Wastewater temperatures and emulsifying chemicals affect the rate at which greases, and oils will separate from the wastewater. Therefore, interceptors should be large enough to act as a heat sink, giving new influent the time to cool while giving emulsifiers time to release their chemical bonds on greases and oils.

3.5 RELATED DESIGNS AND GRAPHS

It is generally accepted that a grease trap would allow sufficient retention time for separation and settling and should have storage capacity. The liquid depth should be between 30 inches and 72 inches, and that the tank length should be greater than the tank width.

Additional internal design considerations include a definition for the number of compartments, multiple tanks and associated plumbing, inlet and outlet piping and access openings. Other important factors in the design of an interceptor are partitioning and baffling. Various regulations and studies discuss the need for one or two partitions and their effect on grease removal. What is clear is that there should be at least one partition wall in a grease trap to keep floating grease away from the outlet.

There should also be an inlet baffle designed to divert incoming flows from a straight-line path to the outlet. An outlet baffle keeps grease that gets past the partition from escaping out of the trap. Studies have shown that performance can be further enhanced with the use of effluent filters on the outlet. This is of particular significance where additional protection is desirable for the on-site disposal situations. All components should be made of durable materials. Following the guidance of nationally recognized standards, your local code requirements will insure adequate retention time and proper design.

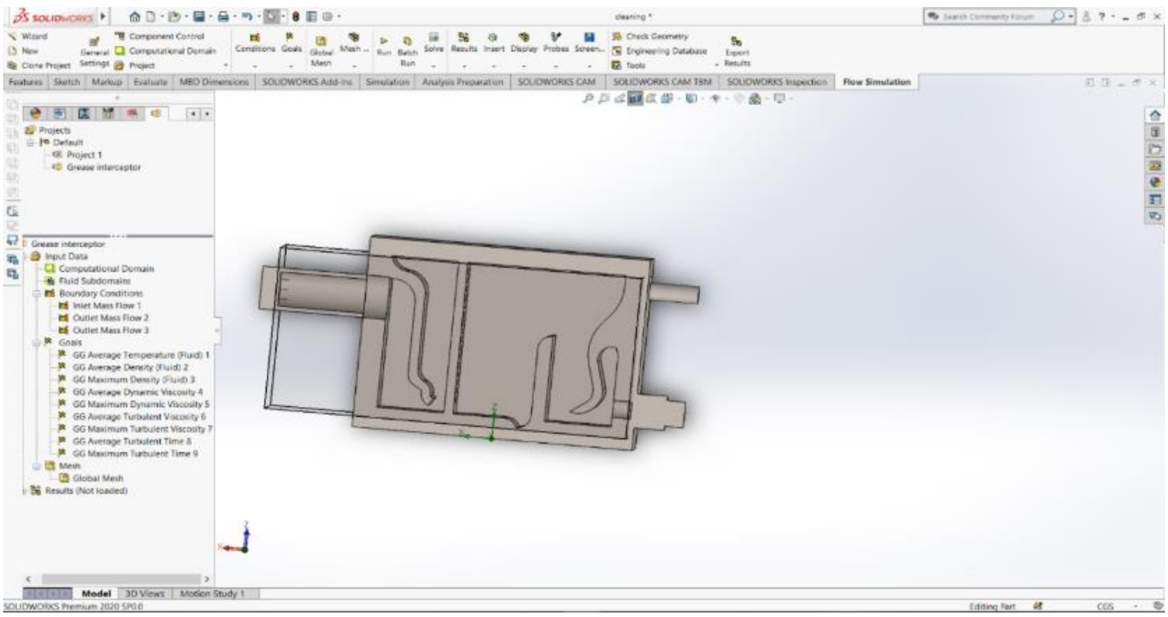


Figure 9 – Design of model using solids works.

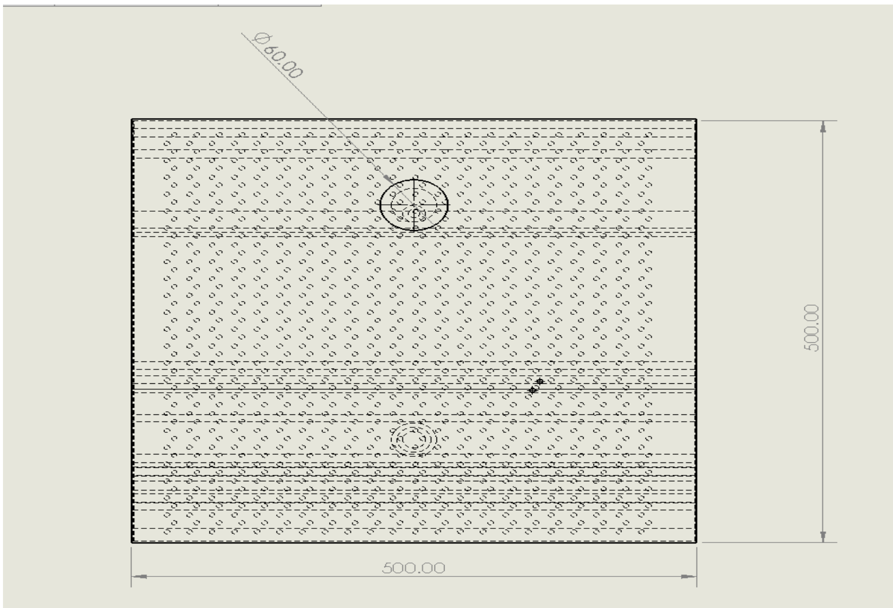


Figure 10 – The front view of the design.

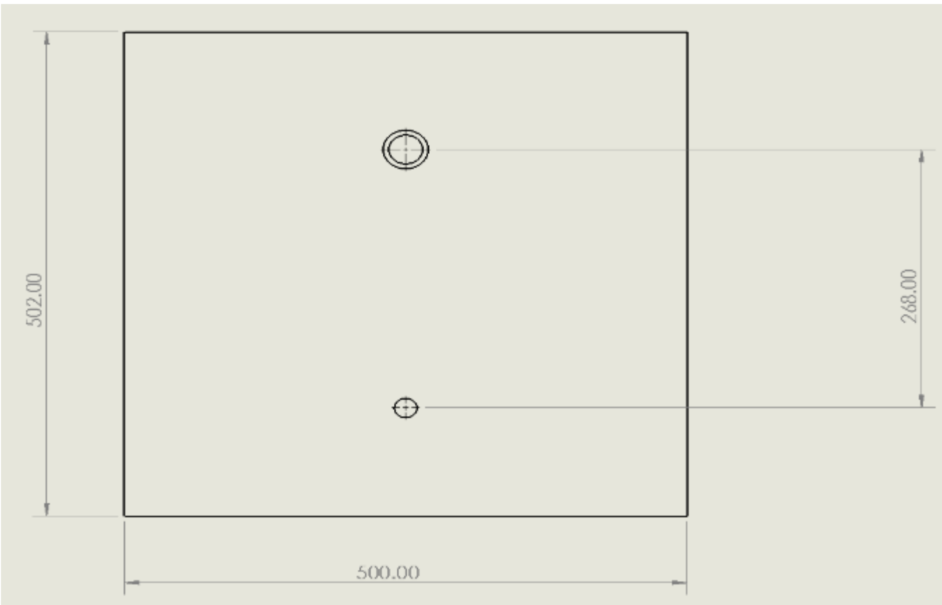


Figure 11 – The rare view of grease trap.

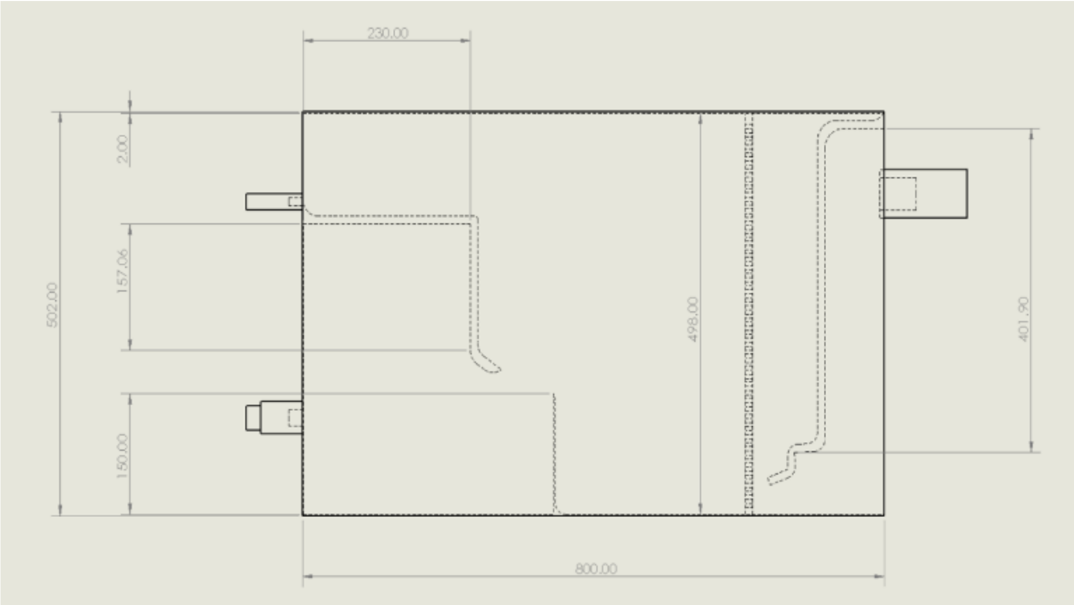


Figure 12 – Sectional view of grease trap all dimensions are in mm.

3D CFD Simulations of grease trap

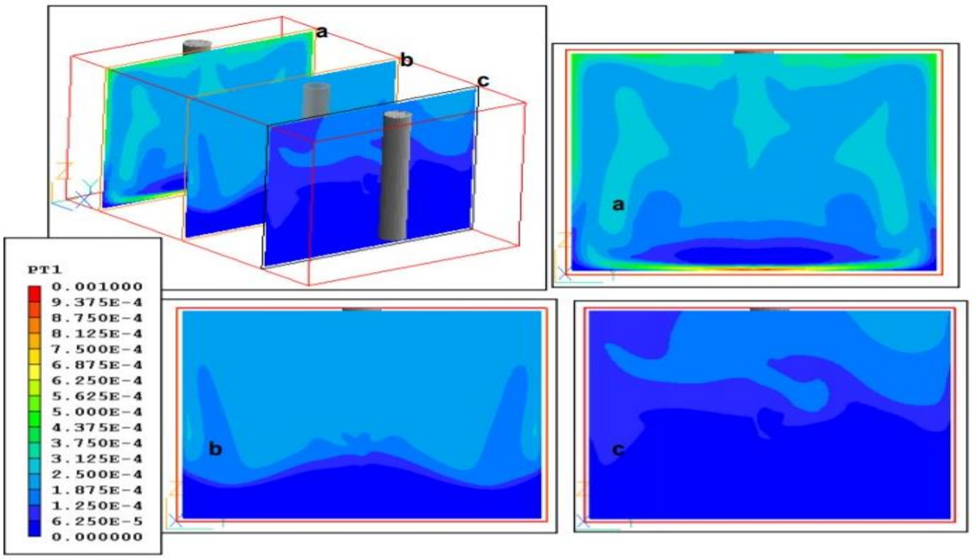


Figure 13 – volume fraction of oil at 5 gph.

This is particularly clear with the short inlet configuration, as there is a region of low concentration near the outlet region. The increase in residence time to 1 hour (Figure13) also performed favorably be reducing the velocity to the outlet and thereby allowing for greater separation in the system.

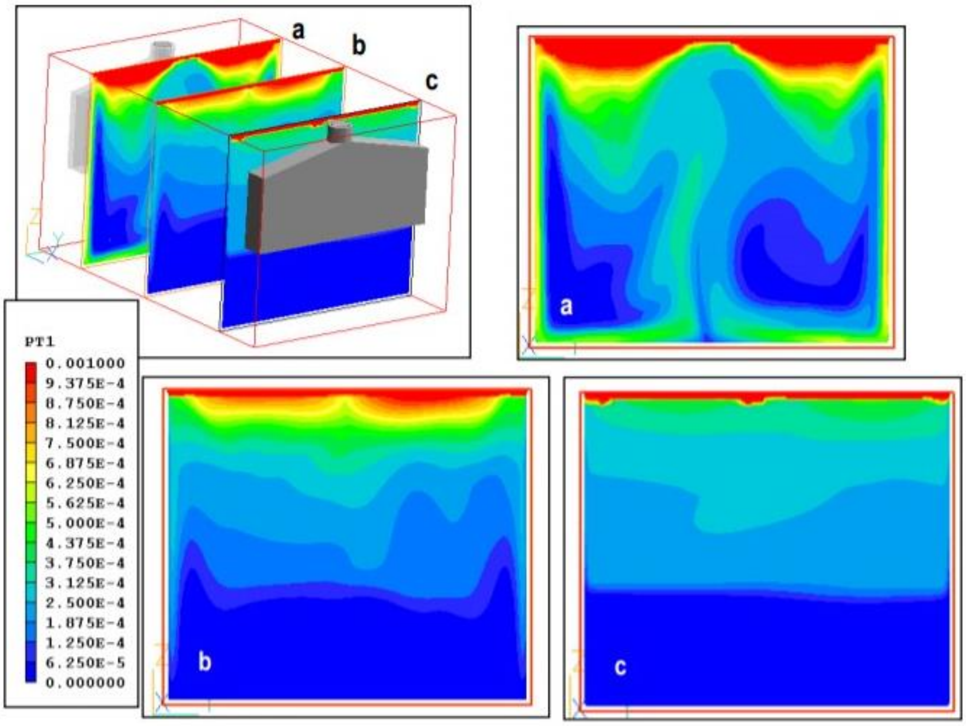


Figure 14 – volume fraction of oils at 15 gph.

The distributive plane jet configuration (Figure 14) designed to utilize a greater area of flow also performed favorably (though it was not as successful as the distributive/no baffle configuration). Like the distributive no-baffle configuration, the secondary flow patterns of the plane jet appeared to enhance the upward migration of the oil phase near the inlet.

Also similar is the quiescent nature of the flow by the time it reached the outlet. The slightly poorer performance of the DPJ design compared to the distributive no baffle configuration is possibly due to the location of the outlet height.

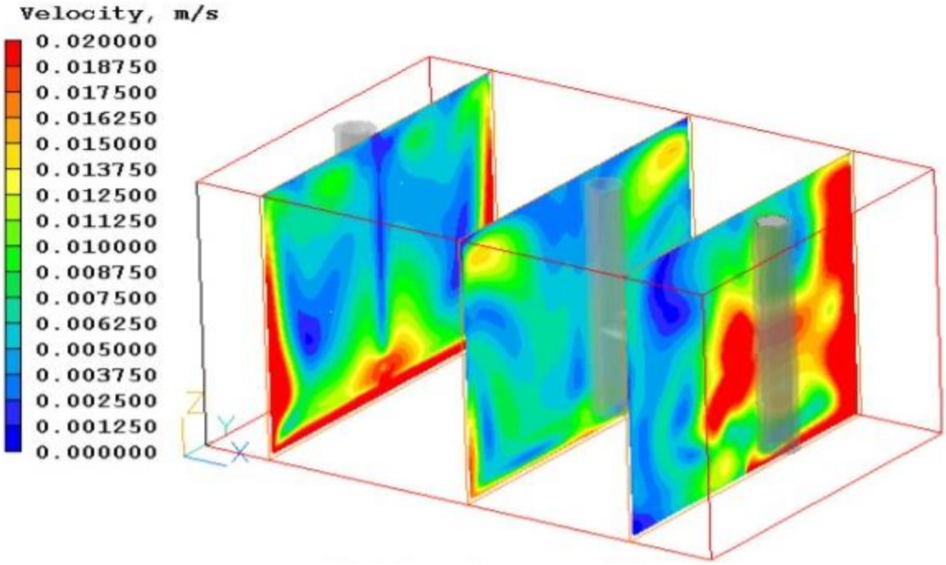


Figure 15 – Velocity of the flow per 15 gph.

The velocity contours in the direction of flow (Figure15) suggests several regions of high velocity along the bottom of the tank and along the side walls.

3.5.1 Graphs

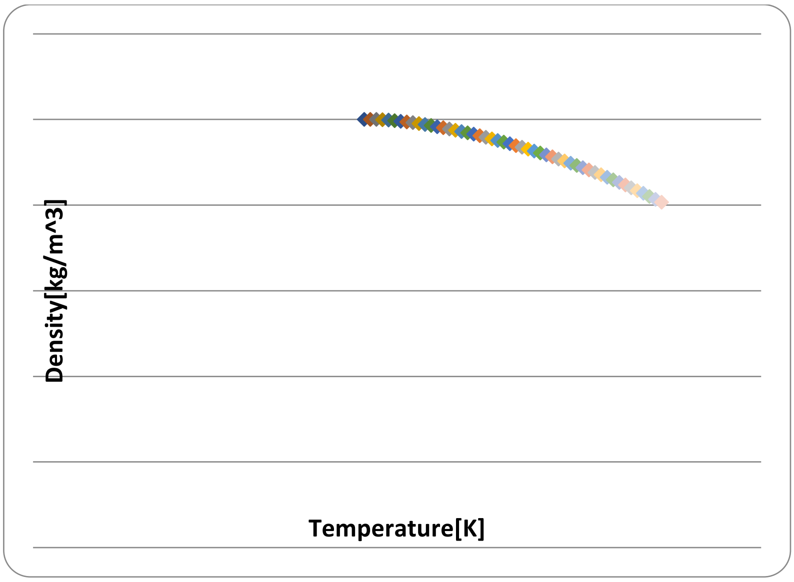
Engineering Database

Liquids

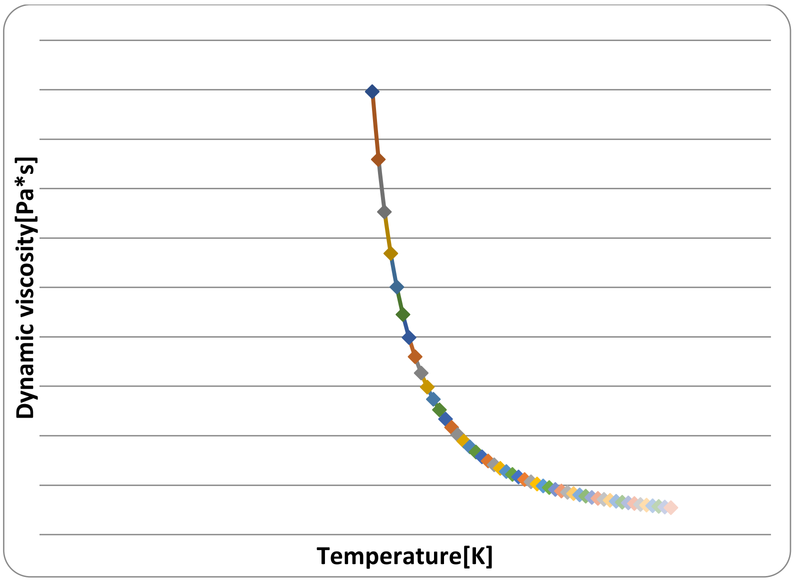
Water

Path: Liquids Pre-Defined

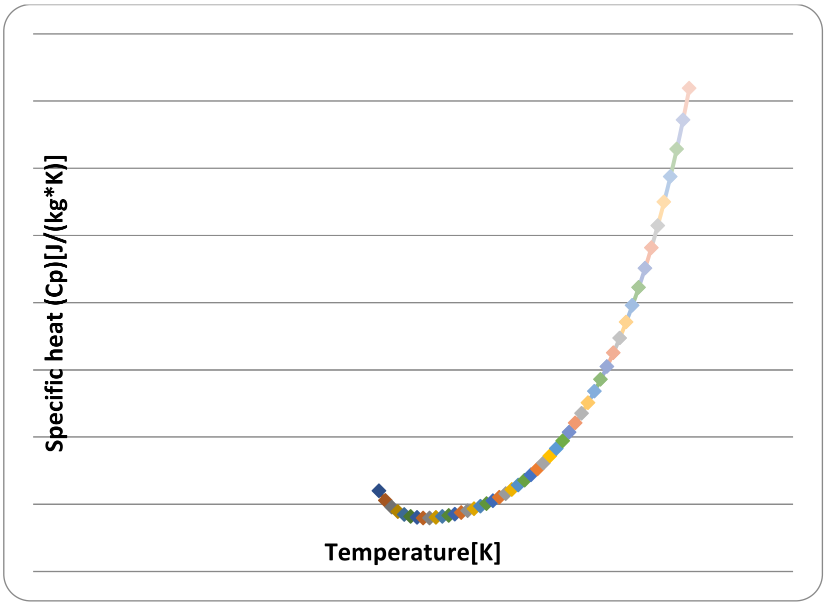
Density



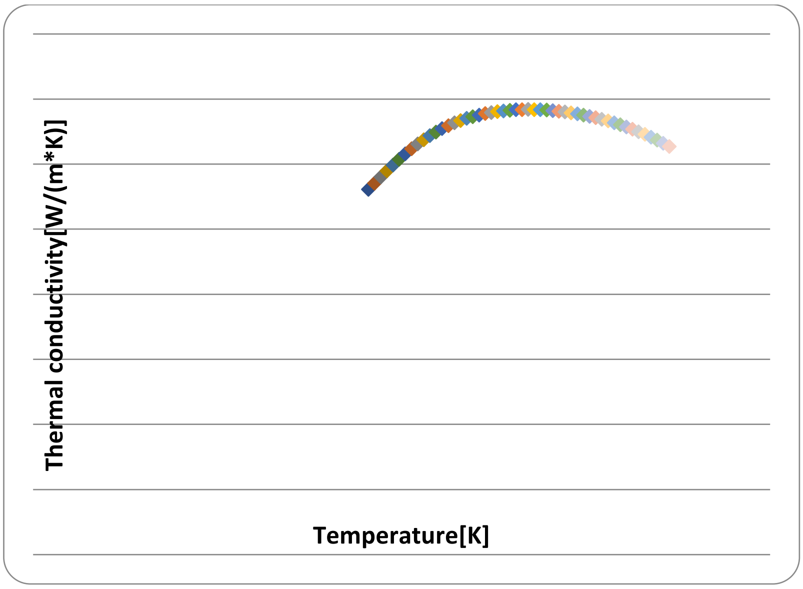
Dynamic viscosity



Specific heat (Cp)



Thermal conductivity



Cavitation effect: Yes

Temperature: 0 K

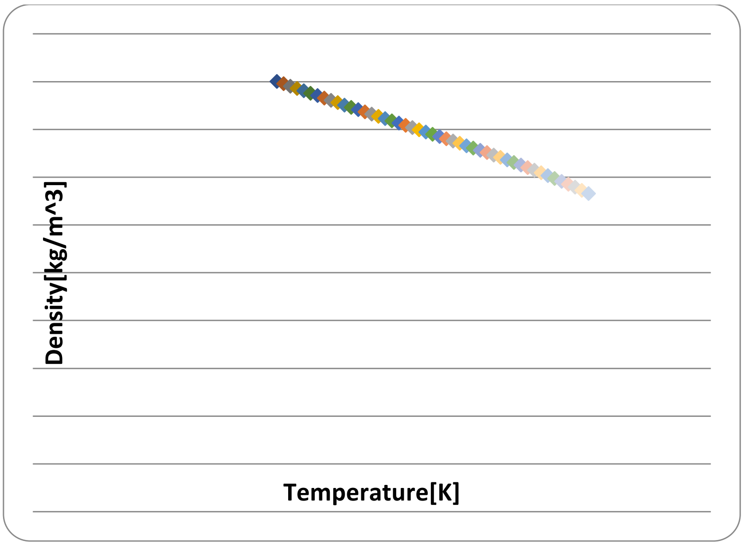
Saturation pressure: 0 Pa

Radiation properties: No

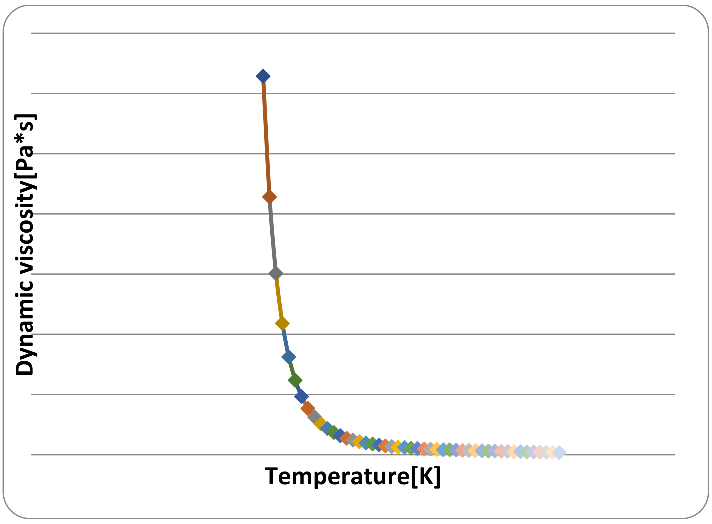
Methanol

Path: Liquids Pre-Defined

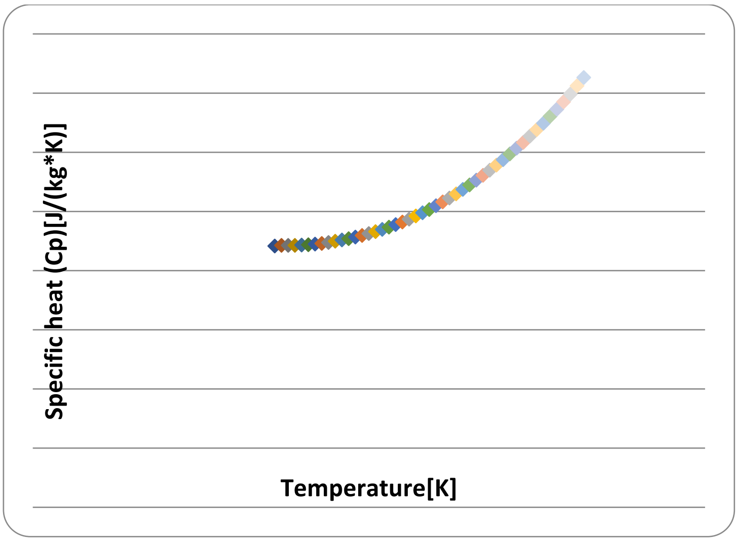
Density



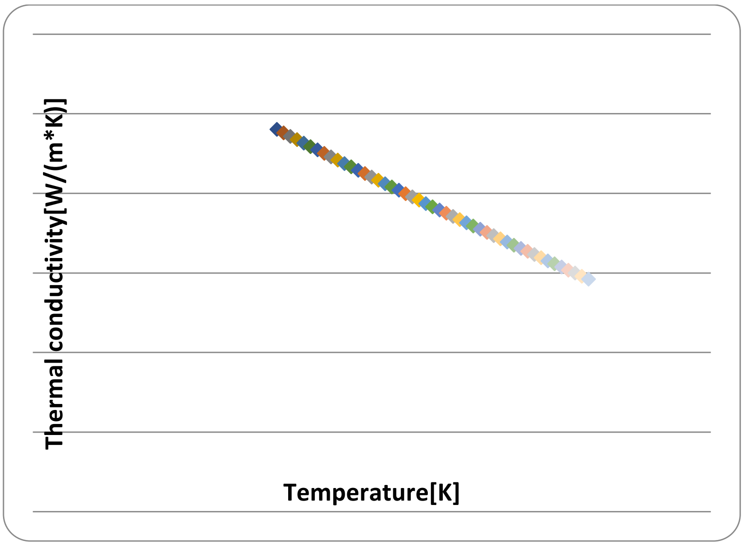
Dynamic viscosity



Specific heat (Cp)



Thermal conductivity



Cavitation effect: No

Radiation properties: No

Solids

AISI 304

Path: Solids User Defined\SOLIDWORKS Material\AISI 304

Density: 8000.00 kg/m^3

Specific heat: 500.0 J/(kg*K)

CHAPTER-4

PROJECT IMPLEMENTATON

4.1 IMPLEMENTATION STAGES

4.1.1 Sizing a grease trap.

A grease trap is designed to prevent greasy substances from entering plumbing systems, septic tanks, and wastewater treatment facilities where they are difficult to process and may create a number of environmental problems. Understanding how to size a grease trap is an important way to keep your establishment up to code and ensure that your plumbing is running smoothly.

Properly sizing a grease interceptor, also known as a fat, oils and grease (FOG) waste interceptor, requires an open mind and a willingness to accept that, for the most part, it has been done incorrectly. Several commonly used methods for sizing an interceptor include the Environmental Protection Agency (EPA) calculation method and the Uniform Plumbing Code (UPC) calculation method, as well as many manufacturers developing their own sizing methods, typically based on one of these two methods.

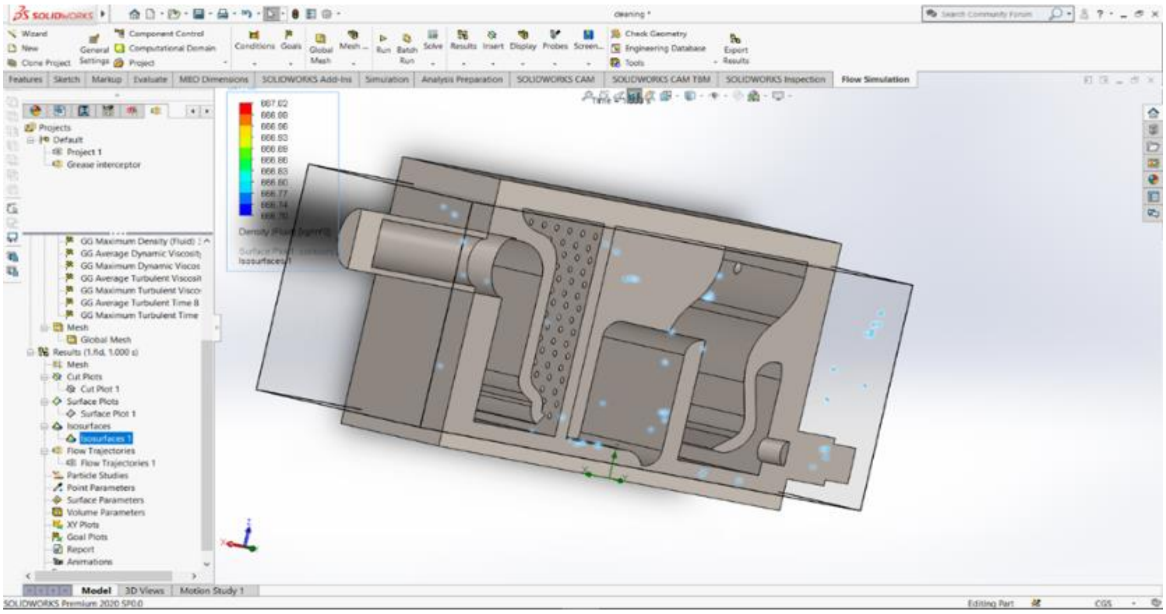


Figure 16 – Designing model in solid works.

4.1.2 Selection of materials

SAE 304 stainless steel is the most common stainless steel. The steel contains both chromium (between 18% and 20%) and nickel (between 8% and 10.5%) [1] metals as the main non-iron constituents. It is an austenitic stainless steel. It is less electrically and thermally conductive than carbon steel and is essentially magnetic but less magnetic than steel. It has a higher corrosion resistance than regular steel and is widely used because of the ease in which it is formed into various shapes.

Figure 17 – SS 304 steel sheet.

4.1.3 Bending and molding

Moulding is a manufacturing process that involves shaping a liquid or malleable raw material by using a fixed frame; known as either a mould or a matrix. The mould is generally a hollow cavity receptacle, commonly made of metal, where liquid plastic, metal, ceramic, or glass material is poured.

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal. Commonly used equipment include box and pan brakes, brake presses, and other specialized machine presses. Typical products that are made like this are boxes such as electrical enclosures and rectangular ductwork.

Figure 18 – Bending of SS304 steel.

4.1.4 Tig welding

In the TIG welding process the arc is formed between a pointed tungsten electrode and the workpiece in an inert atmosphere of argon or helium. The small intense arc provided by the pointed electrode is ideal for high quality and precision welding. Because the electrode is not consumed during welding, the TIG welder does not have to balance the heat input from the arc as the metal is deposited from the melting electrode. When filler metal is required, it must be added separately to the weld pool.

Figure 19 – Assembly after tig welding.

Figure 19 a – Tig welding baffles.

4.1.5 Drilling

The usual starting point for drilling with a center lathe is to use a countersink bit. This is used to drill slightly into the material and creates a starting point for other drills that are going to be used. Attempting to drill with a traditional drill bit without countersinking first will lead to the drill bit slipping straight away. It is not possible to drill a hole successfully or safely without using a center drill first.

Figure 20 – Drilling holes using lathe machine for inlet and outlet.

4.1.6 Pump installation

An AC 165-240V pump is attached to the upper outlet. A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action, typically converted from electrical energy into hydraulic energy.

Figure 21 – Installing pump for automatic removal of grease.

4.2 CALCULATIONS

Grease Traps are sized according to the amount of wastewater coming from the sink, referred to as the flow rate and measured by Gallons Per Minute or GPM. Most standard grease traps are capable of storing twice the flow rate of grease, for instance a 25 GPM trap could retain 50 pounds of grease. Newer technology used in Schier and Canplas grease traps allow for higher grease retention.

To calculate the flow rate.

- First, start by multiplying the length by the width and depth of your sink in inches. This gives you the capacity of the sink in cubic inches.

- Then convert these cubic inches to gallons per minute in order to get the flow rate. You will do this by dividing the cubic inches by 231.

- Adjust for displacement i.e., the actual capacity of the sink that you will be using, by multiplying it by 0.75.

Your math should look like this.

L x W x D to give you X as the capacity of the sink then X/231 to give you Y as the flow rate in gallons per minute (GPM). Then Y multiplied by 0.75 to give you the size of the grease trap you will need for your commercial kitchen.

In the event you are using multiple sinks in your establishment and one grease trap.

- Calculate the flow rate for each individual sink.

- Take 100% of the largest flow rate, 50% of the second largest and 25% of the rest and add them together.

- The flow rate you get is what is recommended for that particular grease trap.

The capacity of the grease which we are preparing can convert wastewater of 60 liters in quantity and a sink of capacity of 0.63 cubic meters. The design is also capable of carrying density up to 791kg per meters.

Figure 22 – grease trap with a capacity of 60 liters.

4.3 RESULTS

A grease trap lives and works hard in your drainage system. It is primarily designed to be used for catching excess fats and oils and preventing them from being flushed into the main drainage system that we all share. This normally happens as a byproduct from assorted cooking and cleaning actions that you participate in. In this way, the big advantage of having a grease trap installed is that it prevents blockages of the main sewage lines.

Economical

The project totally costed 20 thousand hence it has main economic advantage of using a grease trap is that sewers will need less maintenance and expensive repairs. Warm grease would cool inside the sewer system and create blockages and flooding to the surrounding areas. Therefore, you can save time and money by installing a grease trap as an extremely economical safety mechanism – as long as you service it properly. You can prevent temporary closure of your business that can be caused by odors or blockages. There is also legal consideration here for commercial food companies, the costs of repairing main systems need to be avoided. They are not as expensive as you may think to install either, so it gives you a cost-effective long-term solution to maintaining your drainage systems.

Environmentally friendly

You will be doing your bit to keep the environment clean. This is because you are preventing the release of FOG into local rivers and streams which can be harmful to all of us. Maintaining a grease trap system is usually hassle-free and it is worth it for everyone’s benefit. The environmental advantages of using grease traps to recycle grease are surprisingly numerous. Firstly, liquid waste does not need to end up in our oceans as they reduce the amount of runoff into our water catchment areas. Secondly, solid waste can be collected and used in specialized treatment plants which will convert it into agricultural mulch.

As a result, the following table shows the detailed report of the designed grease trap which shows the density of water, the intel and outlet velocities of the grease trap etc.

Min/Max Table

Name	Minimum	Maximum
Density (Fluid) [kg/m^3]	791.32	994.85
Density (Solid) [kg/m^3]	8000.00	8000.00
Immiscible Methanol [ ]	0.5000000	1.0000000
Immiscible Water [ ]	0.5000000	1.0000000
Mass Fraction of Methanol [ ]	0	1.0000
Mass Fraction of Water [ ]	0	1.0000
Pressure [Pa]	101323.03	105195.19
Temperature [K]	293.20	303.00
Temperature (Fluid) [K]	293.20	303.00
Temperature (Solid) [K]	293.20	294.03
Velocity [m/s]	0	0.188
Velocity (X) [m/s]	-0.182	0.125
Velocity (Y) [m/s]	-0.049	0.138
Velocity (Z) [m/s]	-0.114	0.135
Volume Fraction of Methanol [ ]	0	1.0000
Volume Fraction of Water [ ]	0	1.0000
Circumferential Velocity [m/s]	-0.136	0.108
Velocity RRF [m/s]	0	0.188
Velocity RRF (X) [m/s]	-0.182	0.125
Velocity RRF (Y) [m/s]	-0.049	0.138
Velocity RRF (Z) [m/s]	-0.114	0.135
Vorticity [1/s]	1.44e-03	53.42
Vorticity (X) [1/s]	-19.06	20.52
Vorticity (Y) [1/s]	-34.60	28.03
Relative Pressure [Pa]	-1.97	3870.19
Shear Stress [Pa]	0	0.56
Bottleneck Number [ ]	1.6801359e-29	1.0000000
Heat Transfer Coefficient [W/m^2/K]	0	7.913e+07
ShortCut Number [ ]	8.5811014e-29	1.0000000
Surface Heat Flux [W/m^2]	-10200.707	0.019
Surface Heat Flux (Conductive) [W/m^2]	0	0
Surface Heat Flux (Convective) [W/m^2]	-5.753e+07	2.825e+07
Turbulence Intensity [%]	4.18e-10	1000.00
Turbulence Length [m]	0	0.009
Turbulent Dissipation [W/kg]	1.00e-20	22466.92
Turbulent Energy [J/kg]	0	0.003

Table 1 - Analysis report

CHAPTER-5

PROJECT TESTING

5.1 OVERVIEW OF TESTING METHODS.

Waste from grease traps is called brown grease. Brown grease is rotted food solids in combination with fats, oils, and grease (FOG). Brown grease is pumped from the traps by grease pumping trucks. Unlike the collected yellow grease, the majority of brown grease goes to landfill sites.

Figure 23 – Extraction of oils from outlet.

The separation area allows for oil to float to the surface of the water. Discharge water is drawn from an outlet below the surface, preventing oil from being carried over into a sewer. The resulting wastewater is largely clean from solids and oils.

It was observed that, oil removal efficiency is decreased under low flow rate and low length conditions which adsorption process depends on time's contact and increase spacing between zeolite spacing. In medium flow rate, efficiency of removal slightly increased. However, an efficiency of 67% could be seen for slower flow rate and more column length and it was comparable with the efficiency achieved in zeolite dosage. But in high flow rate, the maximum efficiency reached to 80%, which was comparable with the efficiency achieved for 200 cm for column length.

Figure 24 – Automatic separation of water from fogs and food particles.

5.2 FINAL PRODUCT

Here is the outer shell of our grease trap with inlet of diameter 50 mm, approx. 2in. A lid holder is placed on the top with a latch on the side to allow opening of the grease trap for cleaning and maintenance. The 2 mm thick SS 304 can withstand heavy load without bending or damaging the structure.

An AC 165-240V pump is attached to the upper outlet.

A regulator is used to control the capacity of pump, while a thick viscous oil is used for testing the grease trap.

Figure 25 –The grease trap of filled with a mixture of FOG and water.

Figure 26 – Outlet of the grease trap with the pump connected to upper outlet.

Figure 27 – Final outer shell of the grease trap.

Figure 28 –The inner body of the grease trap.

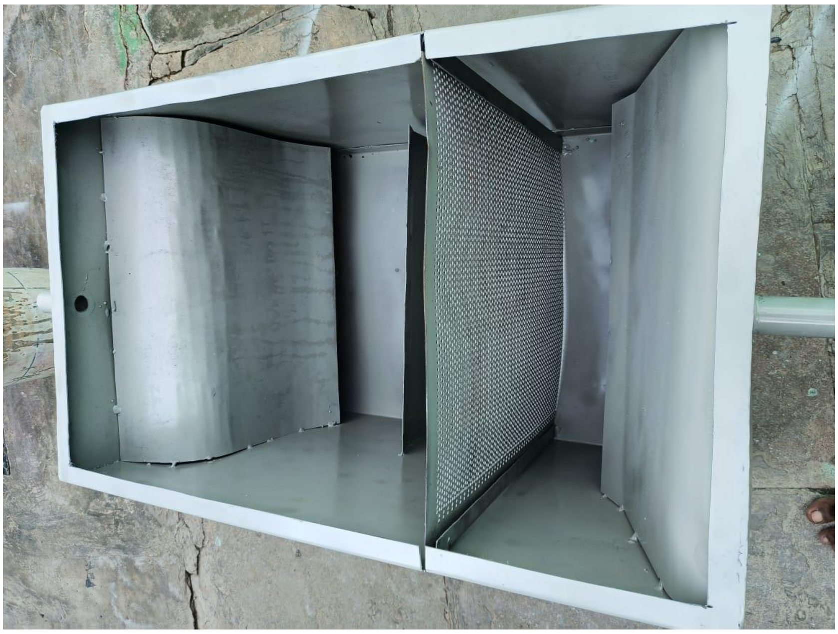


Figure 29 –Inner body of the grease trap after installing the mesh.

CHAPTER-6

CONCLUSION AND FUTURE ENHANCEMENT

The design and development of grease trap was designed using the software SOLIDWORKS and flow analysis has been performed on the design using FlowXpress, before proceeding for manufacturing. The assumptions made for the design and calculations are mentioned in the respective chapters.

Development of grease trap has been done under supervision of experts with help of few workers, procurement of material and tools required for manufacturing was done by selecting efficient and economical ways. Performing the required tests after designing and fabricating the grease trap, adequate amount of grease removal has been observed without use of external force, i.e., a pump of 165-250V.

A regulator has been attached to the pump to control its capacity for efficient removal of grease to decrease the performance time and increase the work rate of grease trap, the capacity of our grease trap is about 60 liters.

Future Enhancement:

As further scope of study different designs and materials could be explored for comparison and selection of best product according to the required size, thereby increasing the efficiency of the grease trap.

PUBLICATION

Conference

- (ICRIM-2021)
- “Online International Conference on “Robotics and Intelligent Manufacturing”

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A Major Project Report
on

DEVELOPMENT OF CHAINLESS BICYCLE

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

E. BALARAJU	**-**	**(17K81A0320)**
N. PREETHAM	**-**	**(17K81A0345)**
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Under the Guidance of

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Professor & Head of the Department

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JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Development of Chainless Bicycle**, is being submitted by **E. Balaraju (17K81A0320), N. Preetham (17K81A0345), Y. Gopi Prajwal (17K81A0360), N. Goutham (17K81A0399)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Development of Chainless Bicycle** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Chainless Bicycle System (CBS) is a setup which makes bicycles run on the road without chains. CBS uses a shaft-driven concept; it uses a drive-shaft for the transmission of power from the pedals to the wheels in place of chains. In the present era, development in internal gear technology produces various advantages. So, decided to construct a bicycle using the shaft-driven system rather than using chain-driven. In this system, spur gears, shaft rod, and another two spur gears and the hub assembly. The rider pushes the pedal which rotates the shaft rod using spur gears at the front end. This rotating shaft has a spur gear at the rear end also which meshes with another spur gear on the rear hub along with the rear wheel and drive the rear wheel of bicycle. the design of the cycle is done through *Solid Works* and structural analysis of the frame is performed to analyse the strength of the design using *Ansys* software.

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CHAPTER -1 INTRODUCTION

1.1 Overview of the Project:

A shaft-driven bicycle is a bicycle that uses a drive shaft instead of a chain to transmit power from the pedals to the rear wheel. Shaft drives were introduced over a century ago, but were mostly supplanted by chain-driven bicycles due to the gear ranges possible with sprockets and derailleur. If bevel-gear could be accurately and cheaply cut by machinery, it is possible that gears of this description might supplant, to a great extent. Shaft-driven bikes have a large bevel gear where a conventional bike would have its chain ring. This meshes with another bevel gear mounted on the drive shaft. The use of bevel gears allows the axis of the drive torque from the pedals to be turned through 90 degrees. The drive shaft then has another bevel gear near the rear wheel hub which meshes with a bevel gear on the hub where the rear sprocket would be on a conventional bike, and cancelling out the first drive torque change of axis

The design of bevel gear produces less vibration and less noise than conventional straight-cut or spur-cut gear with the straight teeth. The shaft drives only needs periodic lubrications using a grease gun to keep the gears running quiet, smooth and efficient transfer of energy from the pedals to the rear wheel. It is attractive in look compared with chain driven bicycle. An automotive drive shaft transmits power from the engine to the differential gear of a rear-wheel-drive vehicle. The drive shaft is usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely proportional to the square of beam length and proportional to the square root of specific modulus which increases the total weight of an automotive vehicle and decreases fuel efficiency. So, a single piece drive shaft is preferred here and the material of it is considered to be Titanium alloy because of its high strength and low density. Drive shafts are carriers of torque and are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

Functions of the Drive Shaft:

a) First, it must transmit torque from the transmission to the differential gear box.

b) During the operation, it is necessary to transmit maximum low-gear torque developed by the engine.

c) The drive shafts must also be capable of rotating at the very fast speeds required by the vehicle.

d) The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axles. As the rear wheels roll over bumps in the road, the differential and axles move up and down. This movement changes the angle between the transmission and the differential.

e) The length of the drive shaft must also be capable of changing while transmitting torque. Length changes are caused by axle movement due to torque reaction, road deflections, braking loads and so on. A slip joint is used to compensate for these 02 motions. The slip joint is usually made of an internal and external spline. It is located on the front end of the drive shaft and is connected to the transmission.

1.2 objective of the Project:

Reasons to Make Chainless Bicycle System In school life, children go to school by using a bicycle and face some issues like: -

- ➢ The grease, oil of chain makes their school dress, clothes dirty.
- ➢ To increase the durability of a bicycle
- ➢ To reduce the overall maintenance cost of a cycle.
- ➢ To make cycle better, comfortable and admirable.
- ➢ To increase the overall strength and power.
- ➢ To increase the efficiency of the bicycle system.
- ➢ To reduce the dirty clothes problem caused by grease

1.3 Scope of the Project:

- ➢ This Chainless Bicycle System generates efficient and reliable output as compared to the traditional system.
- ➢ In Future, this system can implement on bikes and also become a better transmission system.
- ➢ This can also be implemented on the vehicles run by engines such as truck or other high-powered vehicles

1.4 Materials Selection:

Based on the availability, cost and mechanical properties, I decided to make the Chainless Bicycle System as per the material I mention below.

Table 1. List if selected Materials

Sr. No.	Element Name	Use Material
1	Shaft	EN-8
2	Bearing	Cast Iron
3	spur gear set	Alloy Steel
4	Frame	Mild Steel
5	Universal Joint	Alloy Steel
6	Rod	Mild Steel

1.5 Procurement of materials:

The procurements of materials indicate the total materials used for the project and the quantity of the materials used for it. And the below bill of materials indicates the number of materials and type of materials used for the total project in detail

ITEM NO.	PART NUMBER	DESCRIPTION	QTY
1	frame	Mild Steel	1
2	Shaft	EN-8 Alloy	1
3	Bike Seat	Steel Alloy	1
4	rear tyre support	Fiber	1
5	tyre	Synthetic Fiber	2
6	rear fork	Aluminium Alloy	1
7	handle	Steel Alloy	1
8	Pin1	Mild Steel	1
9	Pin2	Mild Steel	1
10	Pin3	Mild Steel	1
11	Bearing	Cast Iron	2
12	gear	Alloy Steel	2
13	connecting rod	Mild Steel	2
14	connecting rod pin	Mild Steel	2
15	Pedal1	Plastics	1
16	Pedal2	Plastics	1

Table 2: Procurement of Materials

1.6 History of chainless bicycle:

The first shaft drives for cycles appear to have been invented independently in 1890 in the United States and England. A. Fearnhead, of 354 Caledonian Road, North London developed one in 1890 and received a patent in October 1891.His prototype shaft was enclosed within a tube running along the top of the chain stay; later models were enclosed within the actual chain stay. In the United States, Walter Still man filed for a patent on a shaft-driven bicycle on Dec. 10, 1890 which was granted on July 21, 1891.

- The shaft drive was not well accepted in England, so in 1894 Fearne head took it to the USA where Colonel Pope of the Columbia firm bought the exclusive American rights. Belatedly, the English makers took it up, with Humber in particular plunging heavily on the deal. Curiously enough, the greatest of all the Victorian cycle engineers, Professor Archibald Sharp, was against shaft drive; in his classic 1896 book "Bicycles 05 and Tricycles", he writes "The Fearne head Gear.... if bevel-wheels could be accurately and cheaply cut by machinery, it is possible that gears of this description might supplant, to a great extent, the chain-drive gear; but the fact that the teeth of the bevel wheels cannot be accurately milled is a serious obstacle to their practical success".

- In the USA, they had been made by the League Cycle Company as early as 1893. Soon after, the French company Metro pole marketed their Acatane.By 1897 Columbia began aggressively to market the chainless bicycle it had acquired from the League Cycle Company. Chainless bicycles were moderately popular in 1898 and 1899, although sales were still much smaller than regular bicycles, primarily due to the high cost. The bikes were also somewhat less efficient than regular bicycles: there was roughly an 8 percent loss in the gearing, in part due to limited manufacturing technology at the time. The rear wheel was also more difficult to remove to change flats. Many of these deficiencies have been overcome in the past century.
- In 1902, The Hill-Climber Bicycle Mfg. Company sold a three-speed shaft-driven bicycle in which the shifting was implemented with three sets of bevel gears. While a small number of chainless bicycles were available, for the most part, shaft-driven bicycles disappeared from view for most of the 20th century. There is, however, still a niche market for chainless bikes, especially for commuters, and there are a number of manufacturers who offer them either as part of a larger range or as a primary specialization. A notable example is Bio mega in Denmark. 2.3 Different Types of Shafts

Transmission shaft: These shafts transmit power between the source and the machines absorbing power. The counter shafts, line shafts, overhead shafts and all factory shafts are transmission shafts. Since these shafts carry machine parts such as pulleys, gears etc., therefore they are subjected to bending moments in addition to twisting

Machine Shaft: These shafts form an integral part of the machine itself. For example, the crankshaft is an integral part of I.C engines slider-crank mechanism.

Axle: A shaft is called “an axle”, if it is a stationary machine element and is used for the transmission of bending moment only. It simply acts as a support for rotating bodies. Application: To support hoisting drum, a car wheel or a rope sheave.

Spindle: A shaft is called “a spindle”, if it is a short shaft that imparts motion either to a cutting tool or to a work-piece.

1.7 Types of gears in chainless bicycle:

Types of Spur Gears:

* External Spur Gear
* Internal Spur Gear
* Rack and Pinion Gears

External Spur Gears:

External Spur Gears are the most popular and common type of spur gear. They has their teeth cut on the outside surface of mating cylindrical wheels. While the larger wheel is referred to as the gear and the smaller wheel is known as the pinion. Single reduction stage is the most basic type of arrangement of single pair of spur gears. Here the output rotation is in opposite direction to that of the input. In other arrangements of multiple stages higher net reduction can be achieved where the driven gear is connected rigidly to a third gear. This third gear in turn drives a mating fourth gear. This serves as the ideal output for the second stage. In this way, many output speeds on different shafts are produced starting from a just single input rotation.

Internal Spur Gear:

This is actually a type of Spur Gear. Internal Spur Gear is not much different from a regular spur gear. These gear by appearance shows pitch surface that is cylindrical. Here the tooth is parallel to the axis. In case of Internal Spur Gear, the gears are positioned to make internal contact. It is also referred to popularly as Ring gears. The output rotation produced by the Ring gears is direction wise same as that of input rotation. As is clear from the figure the gear tooth are cut from inside. A typical Internal Spur Gear or Ring Gear consists of typically three or four larger spur gears referred to as planets. That surrounds a smaller central pinion referred to as sun. Normally, the ring gear remains stationary. This is quite like our own Planetary system, where the planets orbit round the sun in the same rotational direction. It is quite obvious that this class of gear is known as a planetary system. It is through a planet carrier that transmits the orbiting motion of the planets to the output shaft. In a different planetary arrangement, the ring may be left to move freely. This is done by restricting the planets from orbiting round the sun. This action results in the ring gear rotating in an opposite direction to that of the sun. Thus, a differential gear drive is affected as a result of rotation of both the ring gear and the planet carrier. The output speed of the shafts is interdependent.

Rack and Pinion gear:

Rack and pinion gears are also one of the most useful gears used in all manufacturing machines. It can be used for various purposes. They are below: Rack and pinion Gear are another variety of Spur gears. Actually, a Rack is defined as a straight bar that has teeth which are cut straight and across. Basically, The Rack is considered as a spur gear that is unrolled and laid flat. Pinion is the normal gear. A rack and pinion is really a very special example of spur gearing. The rack-and-pinion has been found to be especially useful in conversion of rotary motion into linear and vice versa. Rotating a pinion produces a linear motion of the rack. Alternately moving a rack causes rotation in the pinion.

CHAPTER-2

2.1 Literature Review:

- The Dandy horse, also called Draisienne or Laufmaschine, was the first human means of transport to use only two wheels in tandem and was invented by the German Baron Karl von Drais. It is regarded as the modern bicycle's forerunner. Drais introduced it to the public in Mannheim in summer 1817 and in Paris in 1818. Its rider sat astride a wooden frame supported by two in-line wheels and pushed the vehicle along with his or her feet while steering the front wheel.
- Pierre Lallement took bicycle design in a new direction by adding a mechanical crank drive with pedals on an enlarged front wheel. Another French inventor named Douglas Grasso had a failed prototype of Pierre Lallement's bicycle several years earlier.
- Several inventions followed using rear-wheel drive, the best known being the rod driven velocipede by Scotsman Thomas McCall in 1869. In that same year, bicycle wheels with wire spokes were patented by Eugene Meyer of Paris. Further innovations increased comfort and ushered in a second bicycle craze.
- Scotsman John Boyd Dunlop introduced the first practical pneumatic tire, which soon became universal. Soon after, the rear freewheel was developed, enabling the rider to coast.
- Derailleur gears and hand-operated Bowden cable-pull brakes were also developed during these years, but were only slowly adopted by casual riders. By the turn of the century, cycling clubs flourished on both sides of the Atlantic, and touring and racing became widely popular. The bicycle has undergone continual adaptation and improvement since its inception. These innovations have continued with the advent of modern materials and computer-aided design, allowing for a proliferation of specialized bicycle types.

2.2 Literature Survey:

A 4-bar link bicycle is a bicycle that uses a drive shaft instead of a chain to transmit power from the pedals to the rear wheel. Shaft drives were introduced over a century ago, but were mostly supplanted by chain-driven bicycles due to the gear ranges possible with sprockets and derailleur. If bevel-gear could be accurately and cheaply cut by machinery, it is possible that gears of this description might supplant, to a great extent. 4 bar link bikes have a large bevel gear where a conventional bike would have its chain ring. This meshes with another bevel gear mounted on the drive shaft. The use of bevel gears allows the axis of the drive torque from the pedals to be turned through 90 degrees. The drive shaft then has another bevel gear near the rear wheel hub which meshes with a bevel gear on the hub where the rear sprocket would be on a conventional bike, and cancelling out the first drive torque change of axis.

2.3 Conclusion:

The design of link produces less vibration and less noise than conventional straight-cut or hub gear with the straight teeth. The shaft drives only needs periodic lubrications using a grease gun to keep the gears running quiet, smooth and efficient transfer of energy from the pedals to the rear wheel. It is attractive in look compared with chain driven bicycle. So, a single piece drive shaft is preferred here and the material of it is considered to be Titanium alloy because of its high strength and low density. Drive shafts are carriers of torque and are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

CHAPTER 3: PROJECT DESIGN

3.1 Overview of the Design:

The design of the chainless bicycle is done by solid works software. And there are certain assumptions and consideration has taken the chainless bicycle has major important and designed components are frame, fork, wheel, spur gears, handle bar, crank shaft, connecting rod.

SOLIDWORKS: It was developed by MIT graduate Jon Hirsch tick and was bought by Dassault Systems in 1997. The software now encompasses a number of programs that can be used for both 2D and 3D design.

SOLIDWORKS is used to develop mechatronics systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modelling, feasibility assessment, prototyping, and project management. The software is then used for design and building of mechanical, electrical, and software elements. Finally, the software can be used for management, including device management, analytics, data automation, and cloud services.

The SOLIDWORKS software solutions are used by mechanical, electrical, and electronics engineers to form a connected design. The suite of programs is aimed at keeping all engineers in communication and able to respond to design needs or changes. SOLIDWORKS continues to adapt their solutions to include new capabilities based on the feedback of users.

3.2 Machine Design Consideration:

Following points has to consider while designing a machine: -

- Applied forces that cause many types of stress and load on the system
- Material selection should have based on factors like strength, weight and durability.
- Consider the material with moderate weldability, machinability, and corrosion resistance properties.
- Cost of making the machine, etc.
- Consider the kinematics to deal with rotational motion, oscillation and reciprocating motion.
- Component’s size, design and form.
- Frictional resistance and ease of lubrication.
- Use of standard parts.
- Select the material with high weldability.
- Optimize part handling.
- Assemble in the open area.
- Manufacturing facilities available.

Design Assumptions:

- This Drive-shaft rotates at a constant speed about its longitudinal axis.
- This drive-shaft is made up uniformly with a circular cross-sectional area.
- The mass centre coincides with the geometric centre at every cross-section. Because of that drive shaft is flawlessly balanced.
- It has assumed that the shaft is acting in a vacuum.
- We consider that the nonlinear and damping effects of all types have excluded.

Factor of Safety:

It is the supreme aspects to design a Bicycle. It has used to express the safety of the system. It shows that for an intended load, the system needs to be that much stronger to perform well. It has calculated as the ratio of the structure's absolute strength that is, in other words, the capability of a structure to the actual applied load. For a particular design, we calculate the factor of safety to find out the reliability of the structure

Design Optimization:

Design optimization is a principal part of engineering design. By design optimization, we can improve our designs to a very considerable extends. It shows us where the improvement is needed & according to the result; we can improve our product at minimum cost. We can choose the best property materials for our design. Various methods have applied for the design optimization process includes the mathematical optimization to design and calculation problem formulations, physics law. Design optimization also performs engineering optimization

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3.3 DESIGN CALCULATIONS:

Assumptions:

Let us assume, the mass of rider=110 kg

Shaft's Inner Diameter(di) = 22mm = 0.022m

Shaft's Outer Diameter (do) = 24mm = 0.024m

Length of Shaft (L) = 410mm = 0.410m

Drive shaft calculations:

1. Transmitted Torque (T)= Cyclist's Mass *g* Length of Shaft

   = 80 * 9.81 * 0.410

   = 442.431 Nm

   = 442431Nmm

2. Polar moment of inertia (J) = π (do4 – di4)/32

   = π [(0.024) ^4 – (0.022) ^4]/32

   = π (9.752*10^-8)/32

   = (3.063681156*10^-7)/32

   = 9.574*10^-9 m^4

3. Power (P) = 2πNT /60

   = 2π*100*442.431/60

   = 4633.125 W

4. Shear Stress (τ) = Tρ/J = (442.431) (7800)/ 9.574*10^-9

   = 3.604*10^14 N/ m^2

5. Maximum Shear Stress (τmax) = TRo/J

   = (442.431) (0.012)/ 9.574*10^-9

   = 55.45*10^7 N/ m^2

Front Gear Set Calculation:

Module is the term or says unit used to show the size of gears. It is equal to the ratio of the reference diameter of the gear to the total number of teeth. It is shown by 'm' & the unit of size.

Module (m) = Gear reference diameter/ no. of teeth present on the gear

Or, m=d/z

Let, Module (m) = 4

Pressure Angle (α) = 20 degree

On Pinion, no. of Teeth (Zp) = 24

On Gear, no. of Teeth (Zg) = 44

Pitch Circle Diameter (D) = m*Z

Pinion pitch circle diameter (Dp) = 4*24 = 96mm

Gear Pitch Circle Diameter (Dg) = 4*44 = 176 mm

Addendum (ha) = module (m) = 4mm

Dedendum (hd) = 1.25m = 1.25*4 = 5 mm

Clearance (c) = 0.25m = 0.25*4= 1 mm

Working depth (hw) = 2m = 2*4 = 8 mm

Whole depth (h) = 2.25m = 2.25*4 = 9 mm

Thickness of Tooth (s) = 1.5708m = 1.5708*4 = 6.28mm

Tooth Space = 1.5708m = 1.5708*4 = 6.28mm Fillet Radius = 0.4m = 0.4*4 = 1.6mm

Rear Gear Set Calculation

Module (m) = 4

Pressure angle (α) = 20Degree

On Pinion, no. of Teeth (Zp) = 24

On Gear, no. of Teeth (Zg) = 24

Pitch Circle Diameter (D) = m*Z

Pinion pitch circle diameter (Dp) = 4*24 = 96 mm

Gear pitch circle diameter (Dg) = 4*24 = 96 mm

Addendum (ha) = m = 4 mm

Dedendum (hd) = 1.25m = 1.25*4 = 5 mm

Clearance (c) = 0.25m = 0.25*4 = 1 mm

Working depth (hw) = 2m = 2*4 = 8 mm

Whole depth (h) = 2.25m = 2.25*4 = 9 mm

Thickness of Tooth (s) = 1.5708m = 1.5708*4 = 6.28 mm

Tooth space = 1.5708m = 1.5708*4 = 6.28 mm

Fillet radius = 0.4m = 0.4*4 = 1.6 mm

3.4 DESIGNED COMPONENTS

3.4.1 FRAME OF BICYCLE:

A bicycle frame is the main component of a bicycle, onto which wheels and other components are fitted. The modern and most common frame design for an upright bicycle is based on the safety bicycle, and consists of two triangles: a main triangle and a paired rear triangle. This is known as the diamond frame. Frames are required to be strong, stiff and light, which they do by combining different materials and shapes.

A frameset consists of the frame and fork of a bicycle and sometimes includes the headset and seat post. Frame builders will often produce the frame and fork together as a paired set.

For ride comfort and better handling, shock absorbers are often used; there are a number of variants, including full suspension models, which provide shock absorption for the front and rear wheels; and front suspension only models (*hardtails*) which deal only with shocks arising from the front wheel. The development of sophisticated suspension systems in the 1990s quickly resulted in many modifications to the classic diamond frame.

Recent mountain bicycles with rear suspension systems have a pivoting rear triangle to actuate the rear shock absorber. There is much manufacturer variation in the frame design of full-suspension mountain bicycles, and different designs for different riding purposes.

Fig.1 Frame of Bicycle

3.4.2 WHEEL:

A bicycle wheel is a wheel, most commonly a wire wheel, designed for a bicycle. A pair is often called a wheelset, especially in the context of ready built "off the shelf" performance-oriented wheels. Bicycle wheels are typically designed to fit into the frame and fork via dropouts, and hold bicycle tires The wheels ultimately support your entire weight, but in a very interesting way. If the wheels were solid, they'd be squashed down (compressed) as you sat on the seat, and pushing back up to support you. However, the wheels of most bikes are actually formed of a strong hub, a thin rim, and about 24 highly tensioned spokes. Bicycles have spoked wheels, rather than solid metal wheels, to make them both strong and lightweight, and to reduce drag (some riders use flat "bladed" spokes or ones with an oval shape, instead of traditional rounded ones, in an attempt to cut drag even more).It's not just the number of spokes that's important but the way they're connected between the rim and its hub. Like the strands of a spider's web, or the dangling ropes of a suspension bridge, a bike wheel is in tension—the spokes are pulled tight. Since the spokes criss-cross from the rim to the opposite side of the hub, the wheel isn't as flat and flimsy as it appears, but actually an amazingly strong, three-dimensional structure. When you sit on a bike, your weight pushes down on the hubs, which stretch some of the spokes a bit more and others a bit less. If you weigh 60kg (130lb), there's about 30kg (130lb) pushing down on each wheel (not including the bicycle's own weight), and the spokes are what stops the wheels from buckling.

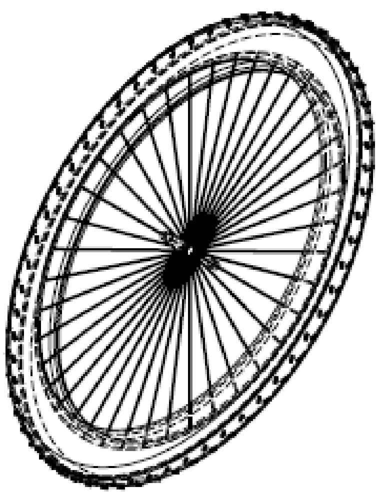


Fig:2 Wheel of Bicycle

3.4.3 FORK:

A **bicycle fork** is the part of a bicycle that holds the front wheel. A fork typically consists of two *blades* which are joined at the top by a fork *crown.* The crown is often at the front. Most suspension forks have an arch connecting the two side of the lowers (the part connected to the axle) It is often in front of the stanchions (shaft the lowers slide on) but not always. Above the crown, a *steerer tube* attaches the fork to the bicycle and the handlebars (via a stem) allowing the rider to steer the bicycle. The steerer tube of the fork interfaces with the frame via bearings called a headset mounted in the head tube. At the bottom of the fork, *fork ends* hold the wheel. Usually, either the axle is bolted to the fork, or a *quick release skewer* passes through a hollow axle, clamping the axle to the fork. The term *fork* is sometimes also used to describe the part of a bicycle that holds the rear wheel, which on 19th century *ordinary* or *penny-farthing* bicycles was also a bladed fork.

Fig:3 Fork of Bicycle

3.4.4 SPUR GEARS:

A gear system is a system in which a set or a series of gears are meshed to transmit torque and power between the input and the output shaft. There are number of examples for the usage of gear systems such as all two wheelers all lathe and lathe related machines. External Spur Gears are the most popular and common type of spur gear. They have their teeth cut on the outside surface of mating cylindrical wheels. While the larger wheel is referred to as the gear and the smaller wheel is known as the pinion.

Single reduction stage is the most basic type of arrangement of single pair of spur gears. Here the output rotation is in opposite direction to that of the input. In other arrangements of multiple stages higher net reduction can be achieved where the driven gear is connected rigidly to a third gear. This third gear in turn drives a mating fourth gear. This serves as the ideal output for the second stage. In this way, many output speeds on different shafts are produced starting from a just single input rotation.

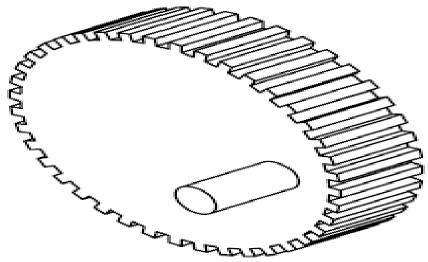


Fig.4 Spur Gears

3.4.5 CRANK SHAFT:

Fundamentally, the crankshaft performs a simple task: translate the linear motion of the pistons into rotation. It's doing the same job as the crank arm of a bicycle, which turns the more-or-less up and down motion of your legs into rotation. Although the principal is simple, there are complications aplenty when it comes to high performance motorcycle engines. But before we get into them, we need a few definitions. The crankshaft (or crank) is connected to the pistons by connecting rods (conrods), which have a bearing at each end. The end connected to the crank is bigger, because the bearing it holds has to fit around the crank, which has to be chunky to resist a multitude of forces. So that's called the big end. The bits of the crank which hold bearings are called journals - and there are two types. The main journals are where the crank is held in place, so these are along the crank's centreline. The rod journals are, you guessed it, the bits the conrods attach to (these are also known as crank pins). Then there are the webs. These are the lumpy bits which look relatively unmachined compared to the rest of the crankshaft. Their job is to try and balance out the forces created by the pistons flying up and down and the crank itself rotating.

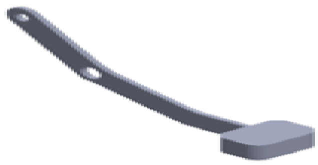


Fig.5 Crankshaft

3.4.6 CONNECTING ROD:

A **connecting rod** is the part of a piston engine which connects the piston to the crankshaft. Together with the crank, the connecting rod converts the reciprocating motion of the piston into the rotation of the crankshaft.[1] The connecting rod is required to transmit the compressive and tensile forces from the piston. In its most common form, in an internal combustion engine, it allows pivoting on the piston end and rotation on the shaft end.The predecessor to the connecting rod is a mechanic linkage used by water mills to convert rotating motion of the water wheel into reciprocating motion. The most common usage of connecting rods is in internal combustion engines or on steam engines**.** The materials used for connecting rods widely vary, including carbon steel, iron base sintered metal, micro-alloyed steel, spheroidized graphite cast iron. In mass-produced automotive engines, the connecting rods are most usually made of steel. In high performance applications, "billet" connecting rods can be used, which are machined out of a solid billet of metal, rather than being cast or forged.

Other materials include T6-2024 aluminium alloy or T651-7075 aluminium alloy, which are used for lightness and the ability to absorb high impact at the expense of durability. Titanium is a more expensive option which reduces the weight. Cast iron can be used for cheaper, lower performance applications such as motor scooters.

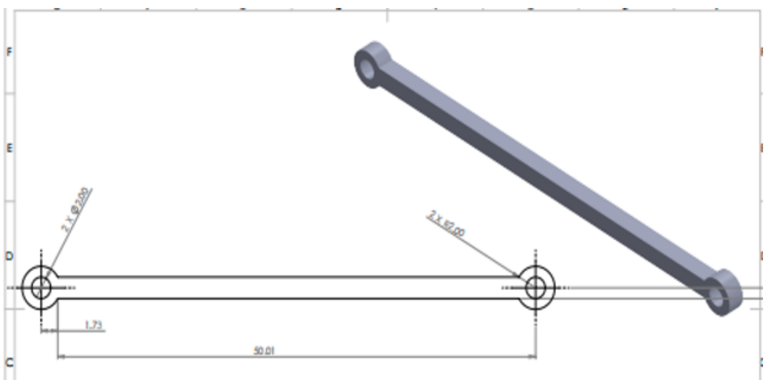


Fig.6 Connecting Rod

3.4.7 HANDLE BAR:

A **bicycle handlebar** is the steering control for bicycles. It is the equivalent of a tiller for vehicles and vessels, as it is most often directly mechanically linked to a pivoting front wheel via a stem which in turn attaches it to the fork. Besides steering, handlebars also often support a portion of the rider's weight, depending on their riding position, and provide a convenient mounting place for brake levers, shift levers, cycle, bells, etc. Handlebars. All bikes whether mountain bikes, road bikes or single-speed fixed-gear bikes use a trusty handlebar. There are so many types out there. Each has its own unique advantages and disadvantages that can make or break your biking experience. Handlebars greatly influence the overall handling, stability and reliability of your bike, so picking the right type for your biking style is essential. I have created an easy understandable handlebar guide to show you the essential differences between each kind of handlebar. After reading this no-nonsense guide, you can probably cite "handlebar guru" in your resume. I even took a considerable amount of time animating that gif above so that this guide really feels like the best most complete guide out there. So, let's get straight to it. I bring you the ultimate guide to bicycle handlebars.

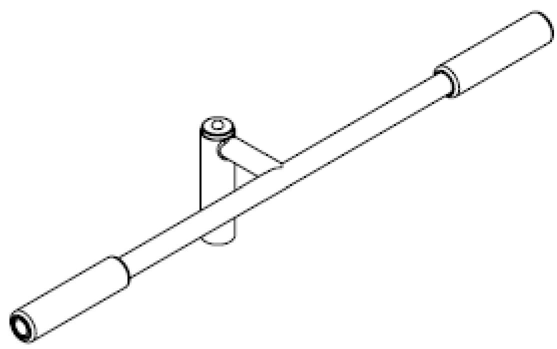
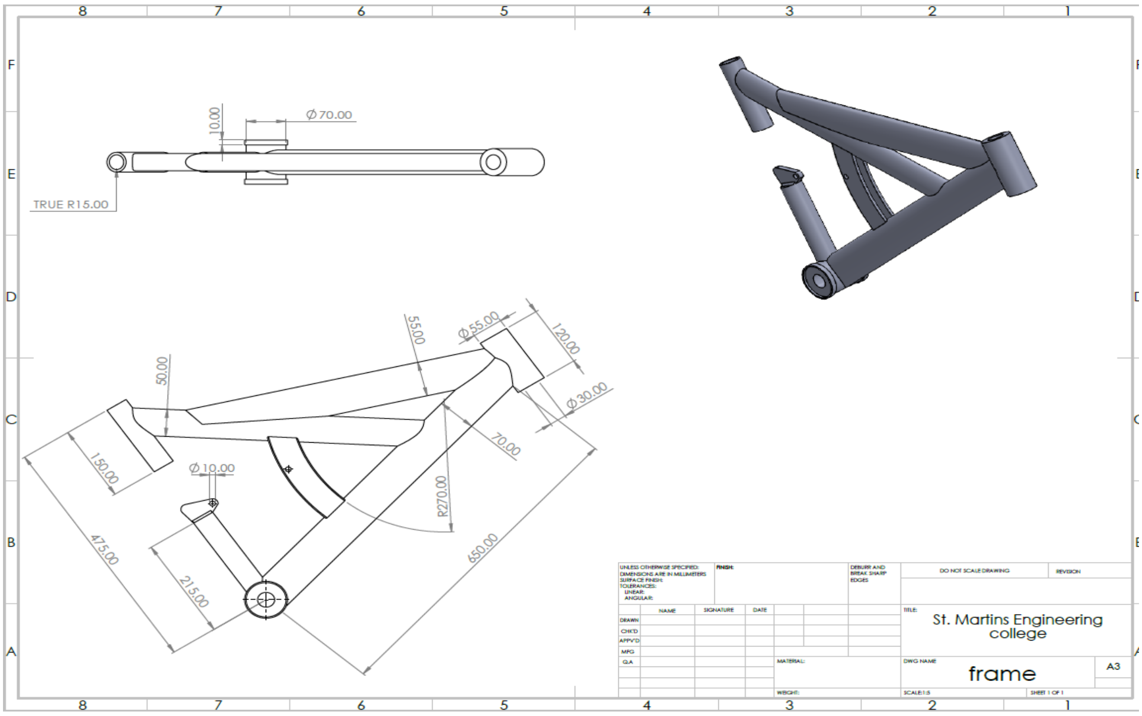


Fig.7 Handle Bar

3.5 DRAFTING OF BICYCLE



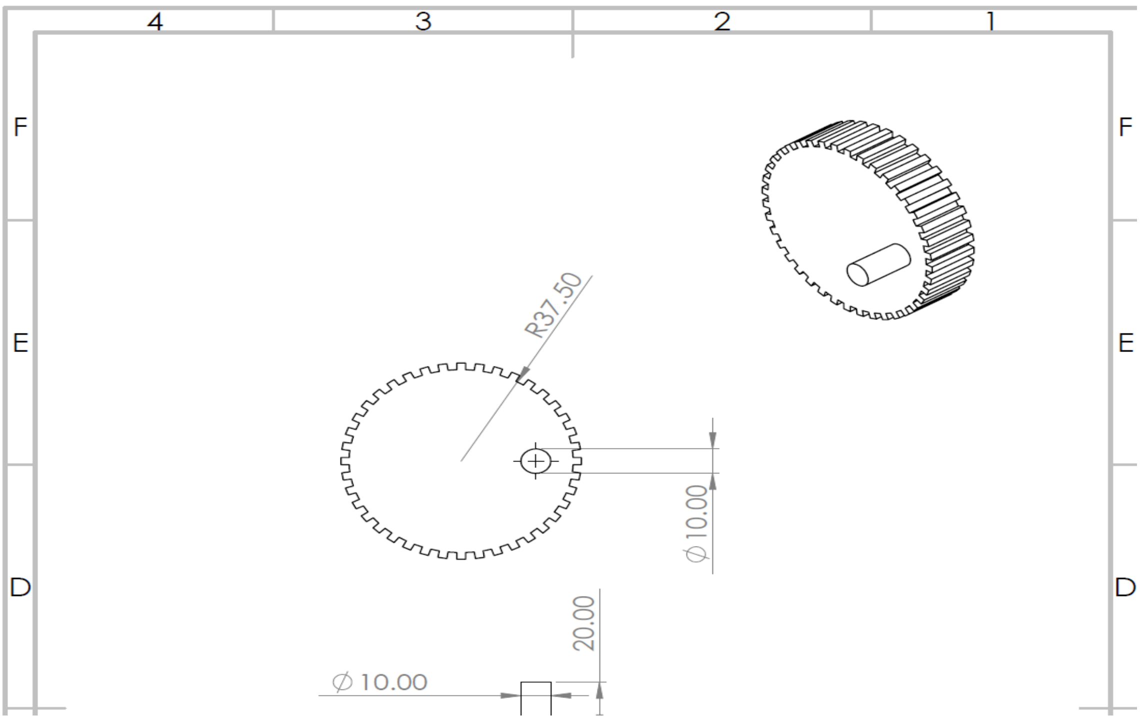
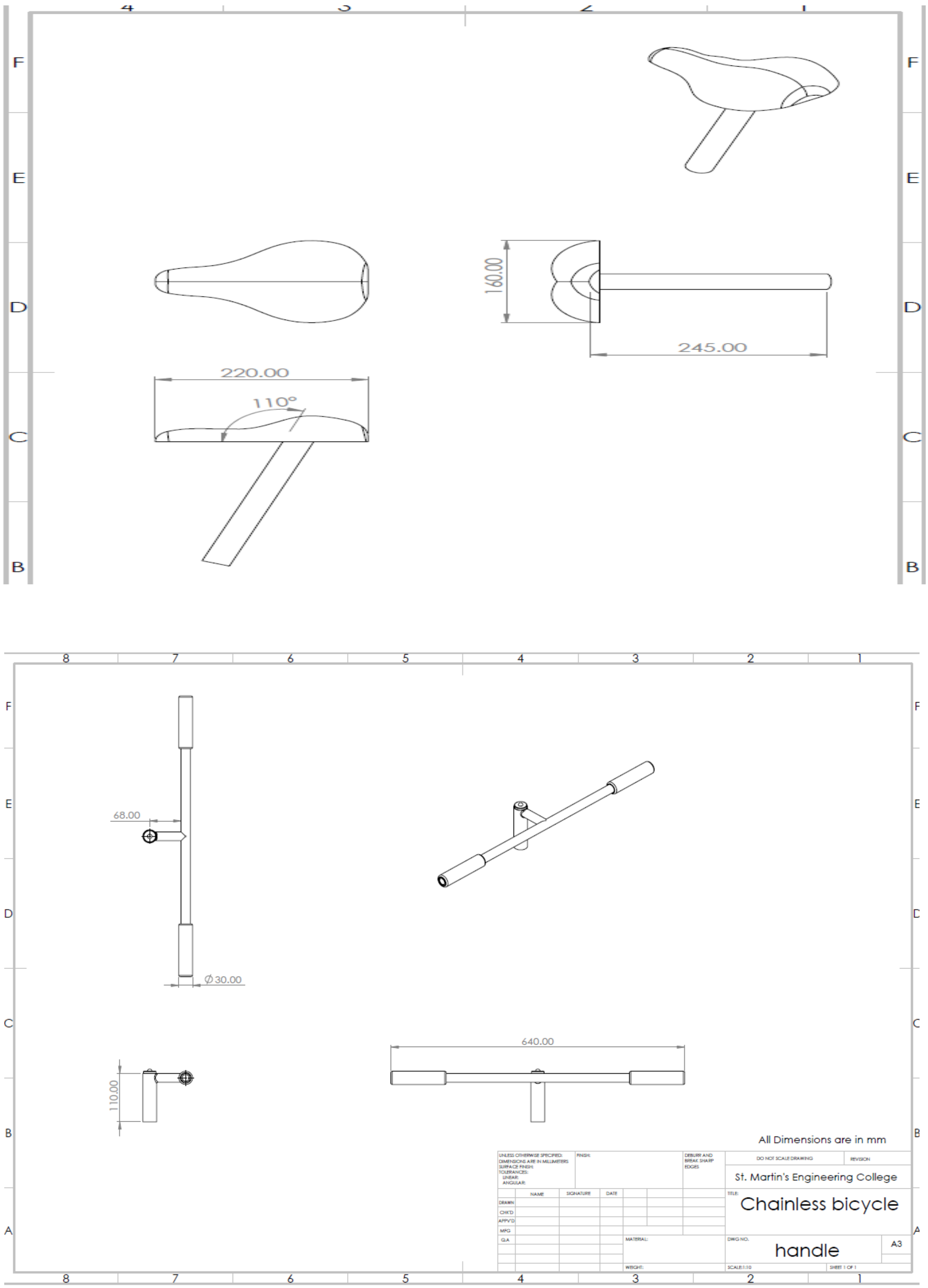


Fig.8 Drafting Sheets



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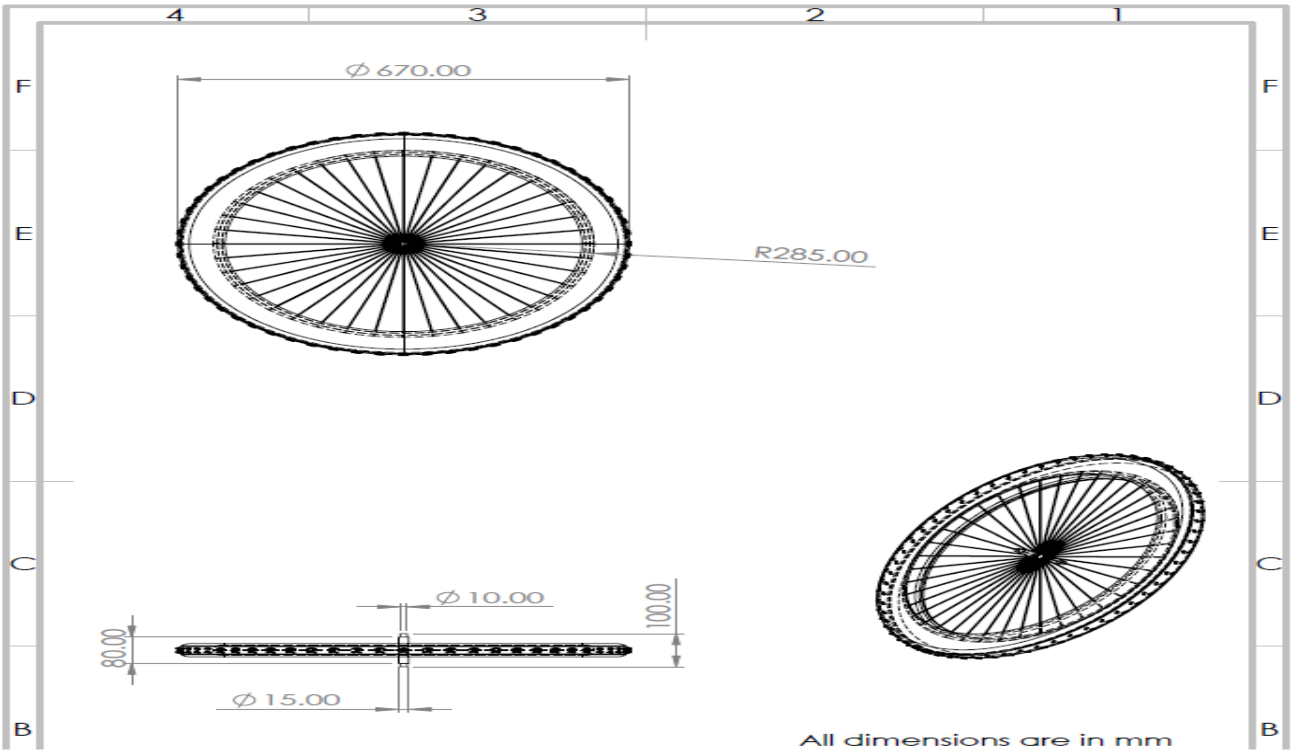

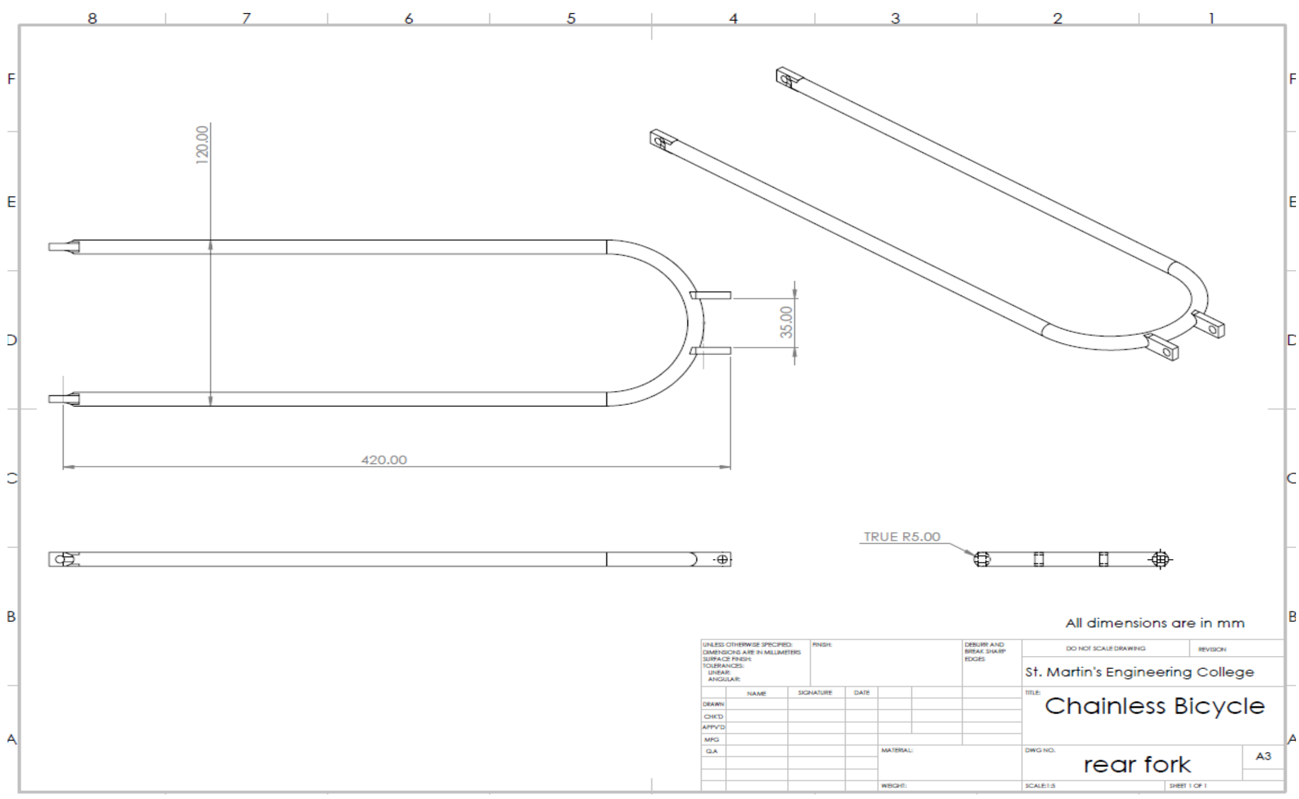

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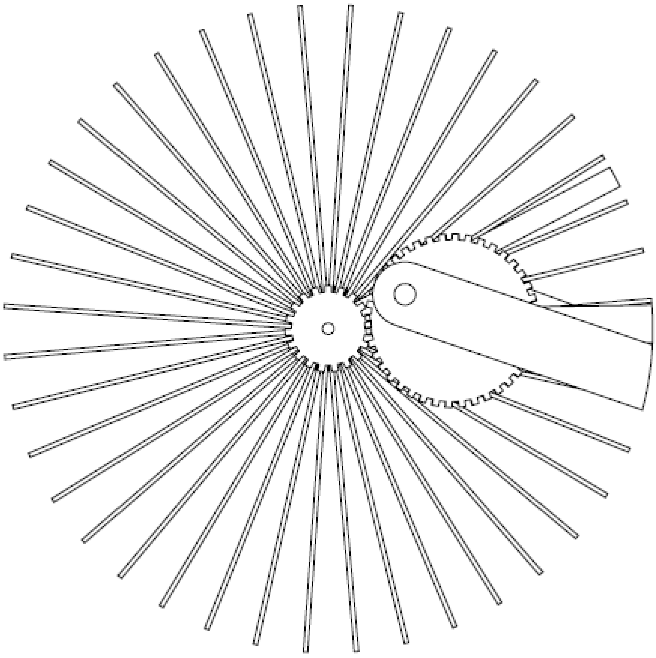

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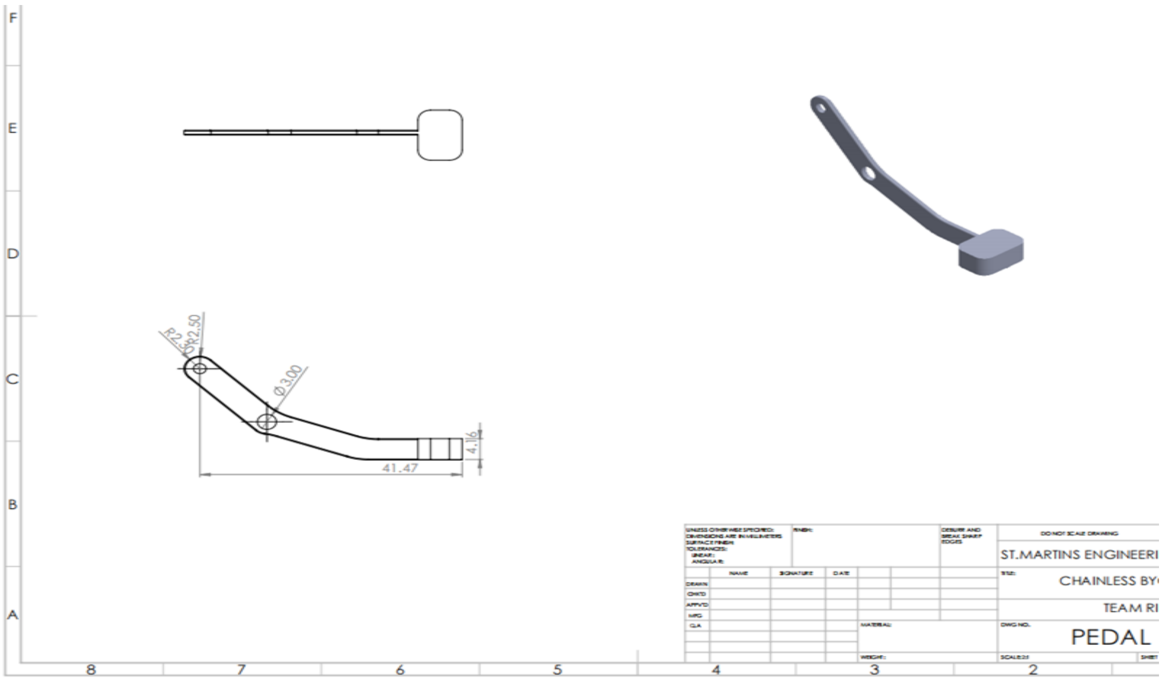


Fig.11 Drafting Sheets

3.6 MINOR COMPONENTS:

The minor components are directly taken from the market which is easily available, and these components are directly taken and not designed to the cycle. The following components are

- Bearings
- Seat
- Pedals
- Nuts & Bolts

3.6.1 Bearings:

Bearings often-overlooked components that actually bring life to your bicycle. You can’t steer, roll, pedal or have a functioning drivetrain without bearings. Bearings are found in your hubs, bottom bracket, headset, suspension pivots, pedals, shifters… the list goes on – basically, anything that moves on your bike will have some kind of bearing in it. In this guide we’ll go over the different types of bearings commonly used on a bike, how to measure the bearings on your bike, what makes one bearing better than another and how to maintain bearings. A bearing is used to reduce friction between two surfaces. You can find bearings in the front or rear hub in your wheels, inside the bottom bracket where the axle is connected to the cranks and in the frame where your headset sits. All these are applicable to either mountain bikes or road bikes.

Fig.12 Bearings

3.6.2 Seat:

A bicycle saddle, often called a bicycle seat, is one of five contact points on an upright bicycle, the others being the two pedals and the two handles on the handlebars. (A bicycle seat in the specific sense also supports the back.) The bicycle saddle has been known as such since the bicycle evolved from the draisine, a forerunner of the bicycle. It performs a similar role as a horse's saddle, not bearing all the weight of the rider as the other contact points also take some of the load.

A bicycle saddle is commonly attached to the seat post and the height of the saddle can usually be adjusted by the seat post telescoping in and out of the seat tube bicycle seat, unlike a bicycle saddle, is designed to support the rider's buttocks and back, usually in a semi-reclined position. Arthur Graford is credited with inventing the padded bicycle seat in 1892, and they are now usually found on recumbent bicycles. Bicycle seats come in three main styles; mesh, hard-shell and combination

Fig.13 Seat

3.6.3 Pedals:

The pedal is the part of a bicycle that the rider pushes with their foot to propel the vehicle. It provides the connection between the cyclist's foot or shoe and the crank allowing the leg to turn the bottom bracket spindle and propel the bicycle's wheels. A pedal usually consists of a spindle that threads into the end of the crank, and a body on which the foot rest is attached, that is free to rotate on bearings with respect to the spindle.

Pedals were initially attached to cranks connecting directly to the driven (usually front) wheel. The safety bicycle, as it is known today, came into being when the pedals were attached to a crank driving a sprocket that transmitted power to the driven wheel by means of a roller chain.

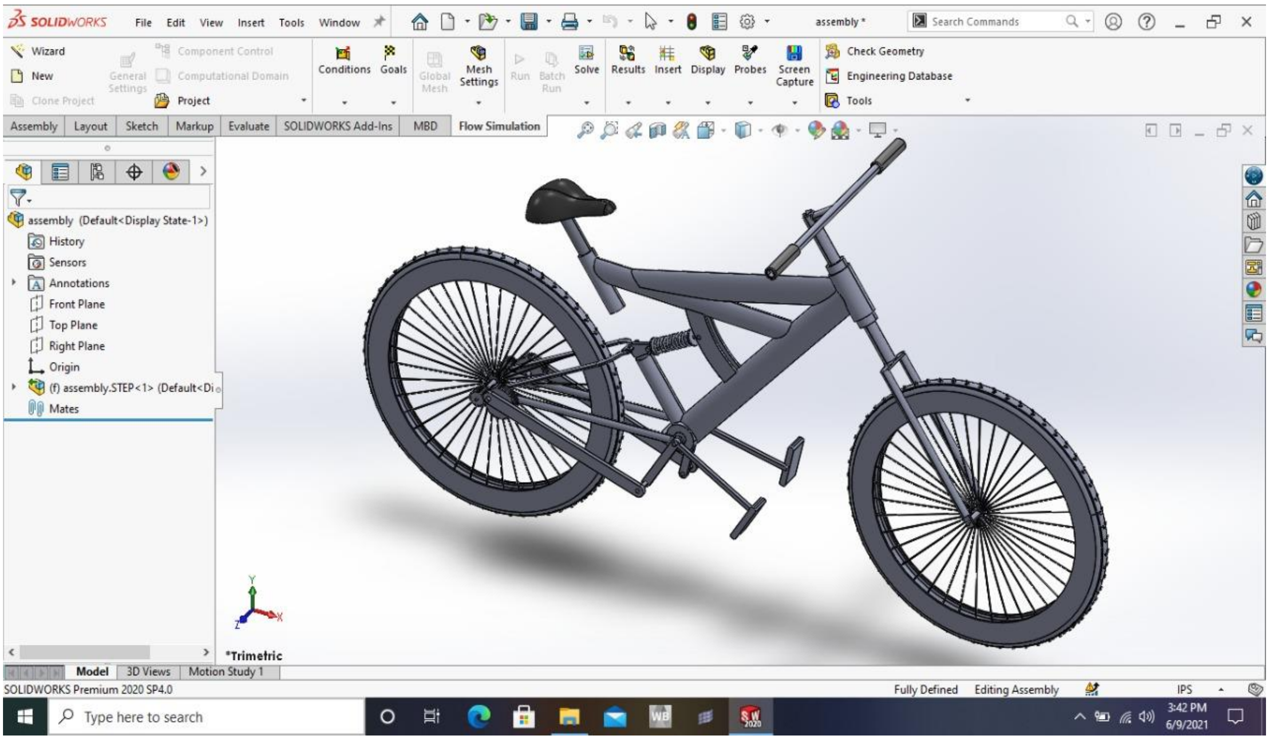
Fig.14 Pedals

3.6.4 Nuts & Bolts:

A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunction with a mating bolt to fasten multiple parts together. The two partners are kept together by a combination of their threads' friction (with slight elastic deformation), a slight stretching of the bolt, and compression of the parts to be held together. In applications where vibration or rotation may work a nut loose, various locking mechanisms may be employed: lock washers, jam nuts, specialist adhesive thread-locking fluid such as Loctite, safety pins (split pins) or lockwire in conjunction with castellated nuts, nylon inserts (nylon), or slightly oval-shaped threads. A wide variety of nuts exists, from household hardware versions to specialized industry-specific designs that are engineered to meet various technical standards. Fasteners used in automotive, engineering, and industrial applications usually need to be tightened to a specific torque setting, using a torque wrench. Nuts are graded with strength ratings compatible with their respective bolts; for example, an ISO property class 10 nut will be able to support the bolt proof strength load of an ISO property class 10.9 bolt without stripping. Likewise, an SAE class 5 nut can support the proof load of an SAE class 5 bolt, and so on.

Fig.15 Nuts & Bolts

3.7 FINAL ASSEMBLY OF THE BICYCLE



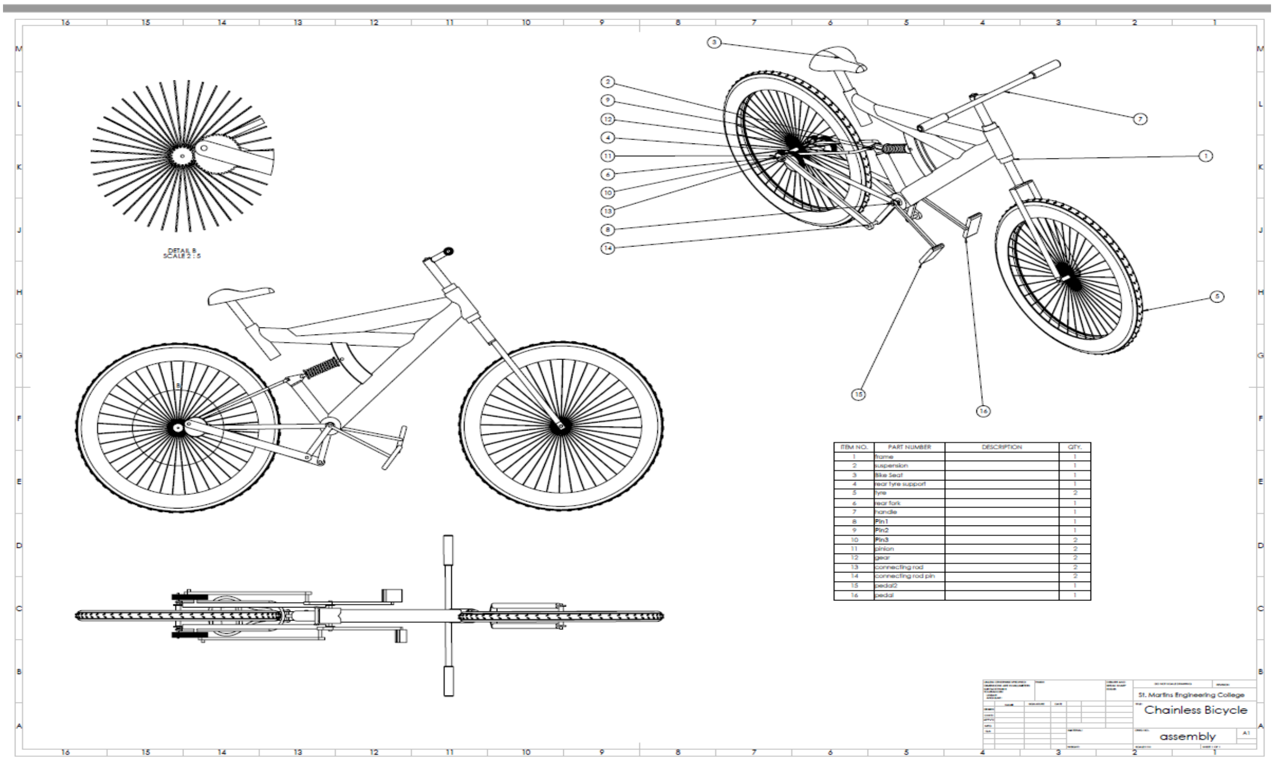


Fig.16 Design Final Assembly

3.8 ANALYSIS OF THE FRAME

3.8.1 Introduction

Ansys is a engineering Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. ohn A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold. The new owners took SASI ‘s leading software, called ANSYS®, as their flagship product and designated ANSYS, Inc. as the new company name.

Advantage of ANSYS:

The ANSYS advantage and benefits of using a modular simulation system in the design process are well documented. According to studies performed by the Aberdeen Group, best-in-class companies perform more simulations earlier. As a leader in virtual prototyping, ANSYS is unmatched in terms of functionality and power necessary to optimize components and systems. The ANSYS advantage is well-documented. ANSYS is a virtual prototyping and modular simulation system that is easy to use and extends to meet customer needs, making it a low-risk investment that can expand as value is demonstrated within a company. It is scalable to all levels of the organization, degrees of analysis complexity, and stages of product development.

Advantage post-processing:

ANSYS provides a comprehensive set of post-processing tools to display results on the models as contours or vector plots, provide summaries of the results (like min/max values and locations). Powerful and intuitive slicing techniques allow to get more detailed results over given parts of your geometries. All the results can also be exported as text data or to a spreadsheet for further calculations. Animations are provided for static cases as well as for nonlinear or transient histories.

ANSYS:

For all engineers and students coming to finite element analysis or to ANSYS software for the first time, this powerful hands-on guide develops a detailed and confident understanding of using ANSYS's powerful engineering analysis tools. The best way to learn complex systems is by means of hands-on experience. With an innovative and clear tutorial-based approach, this powerful book provides readers with a comprehensive introduction to all of the fundamental areas of engineering analysis they are likely to require either as part of their studies or in getting up to speed fast with the use of ANSYS software in working life. Opening with an introduction to the principles of the finite element method, the book then presents an overview of ANSYS technologies before moving on to cover key applications areas in detail. Key topics covered: Introduction to the finite element method Getting started with ANSYS software stress analysis dynamics of machines fluid dynamics problems thermo mechanics contact and surface mechanics exercises, tutorials, worked examples With its detailed step-by-step explanations, extensive worked examples and sample problems, this book will develop the reader's understanding of FEA and their ability to use ANSYS's software tools to solve their own particular analysis problems, not just the ones set in the book. At ANSYS, we bring clarity and insight to customers' most complex design challenges through fast, accurate and reliable simulation. Our technology enables organizations to predict with confidence that their products will thrive in the real world

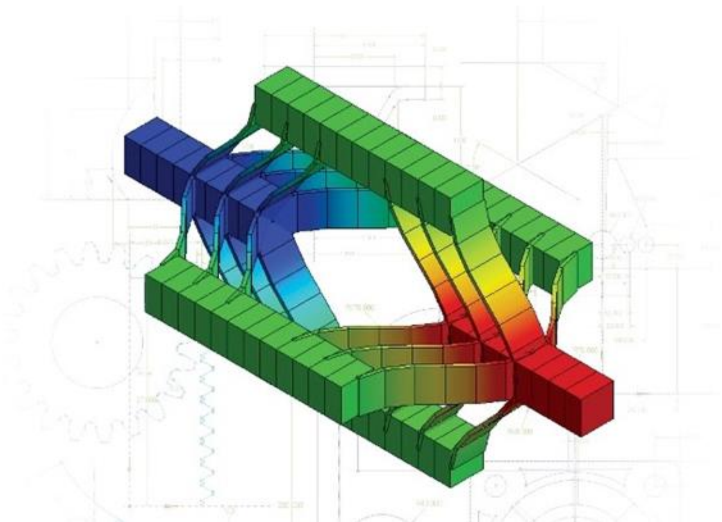


Fig.17 ANSYS

3.8.2 Meshing:

Meshing is an integral part of the engineering simulation process where complex geometries are divided into simple elements that can be used as discrete local approximations of the larger domain. The mesh influences the accuracy, convergence and speed of the simulation. Furthermore, since meshing typically consumes a significant portion of the time it takes to get simulation results, the better automated the meshing tools, the faster and more accurate the solution.

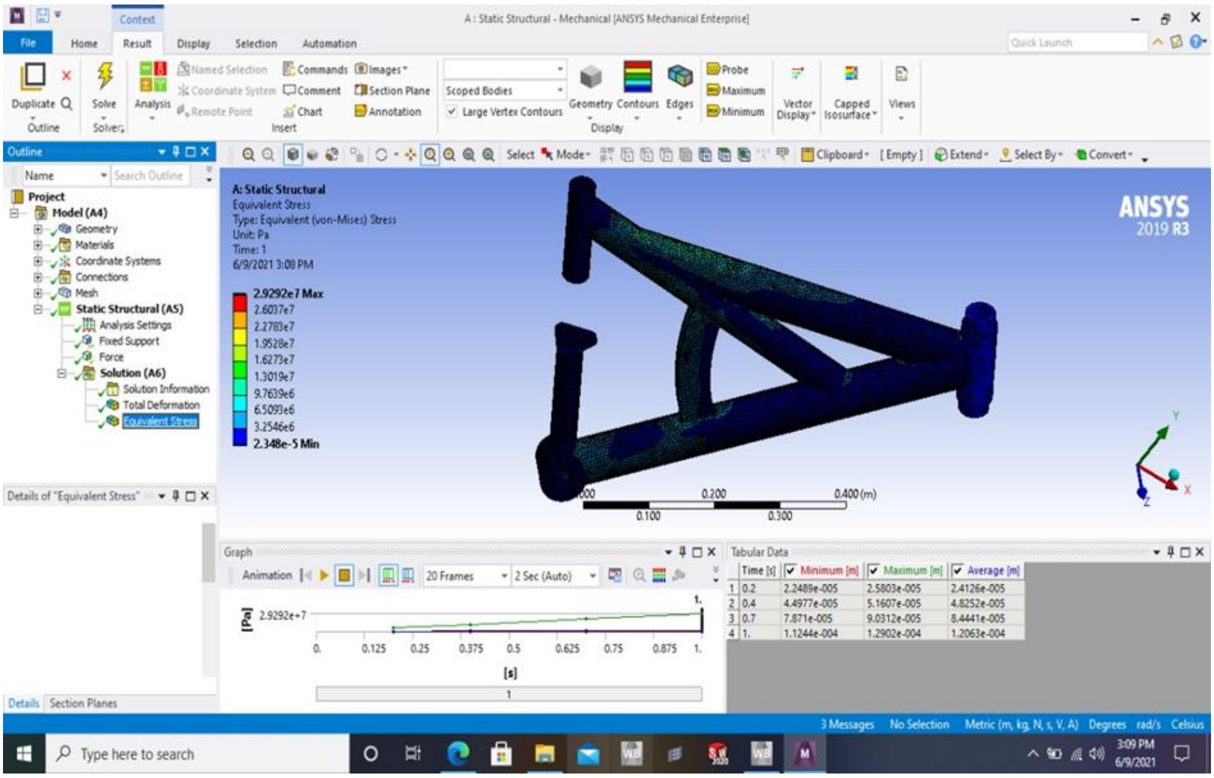


Fig.18 Meshing

3.8.3 Structural Analysis:

Structural analysis is the determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, aircraft and ships. Structural analysis employs the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often precluding physical tests. Structural analysis is thus a key part of the engineering design of structures.

- We have applied 100Kg pressure weight on the bicycle saddle and we have assumed and constructed a frictionless support on each piston in order to balance, we have taken standard centre of gravity we have calculated the total amount of deformation occurred due to the given loads
- When we apply the load to the centre on the frame that means on the seat then we will be calculating and analysing the strength and the durability of the frame of the chainless bicycle

In structural we will be performing these parameters to know the strength on the frame.

1. ***Total deformation***
2. ***Equivalent strain***
3. ***Equivalent stress***

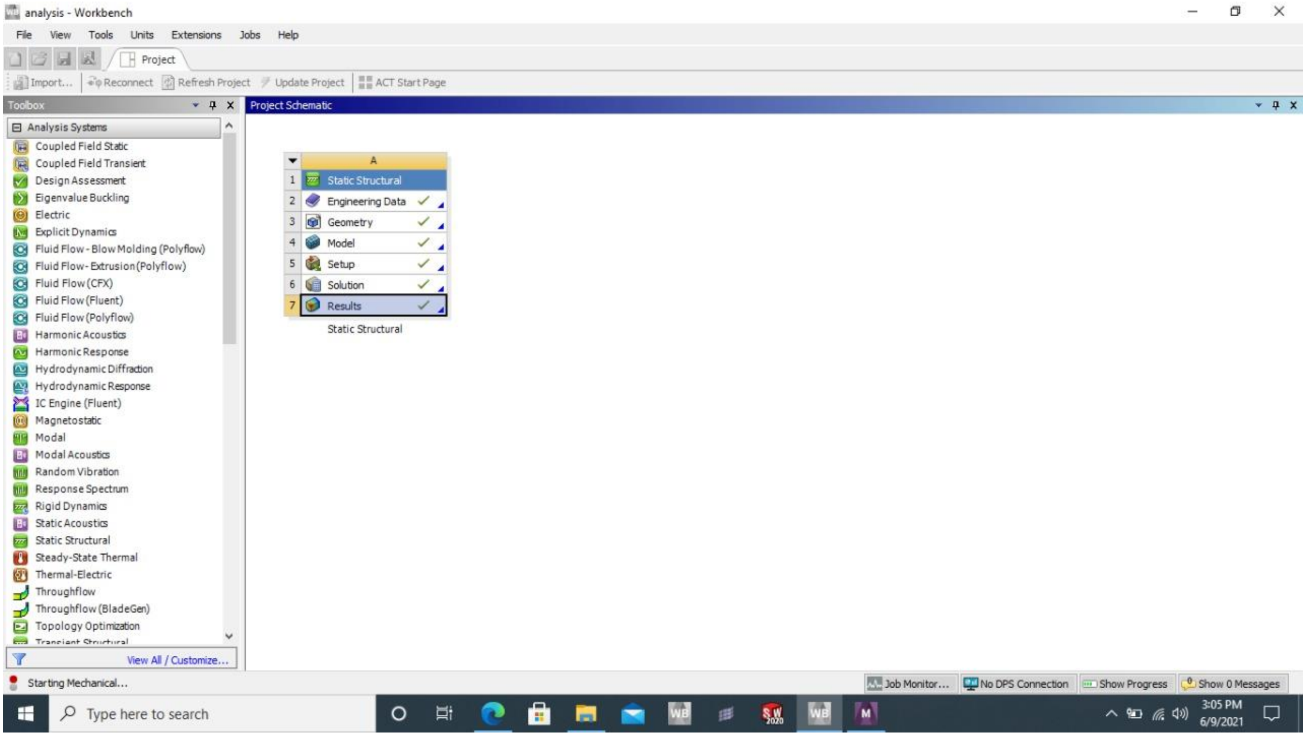


Fig.19 Experimental results

BOUNDARY CONDITIONS:

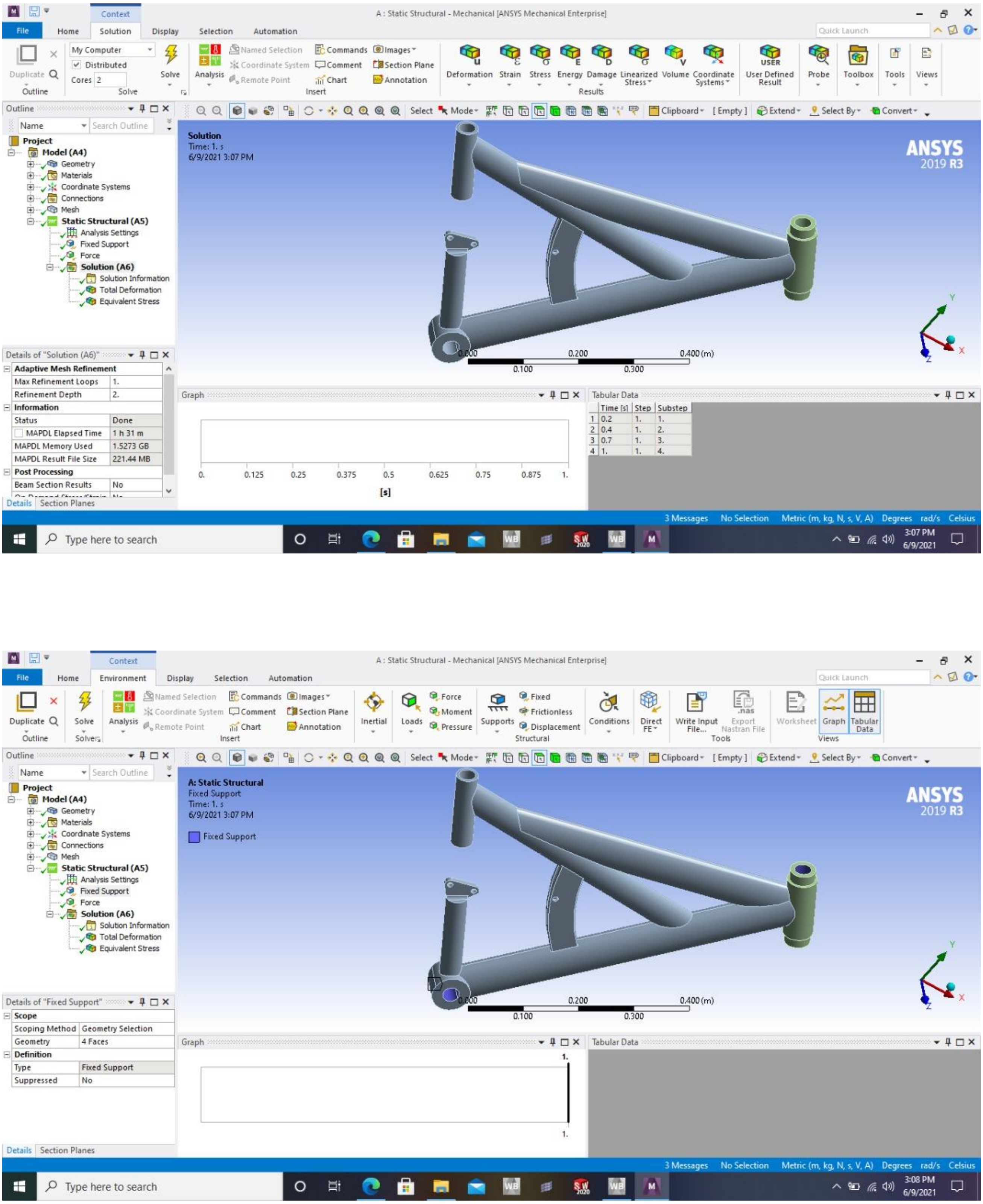


Fig.20 Boundary Conditions

1.LOAD APPLIED:

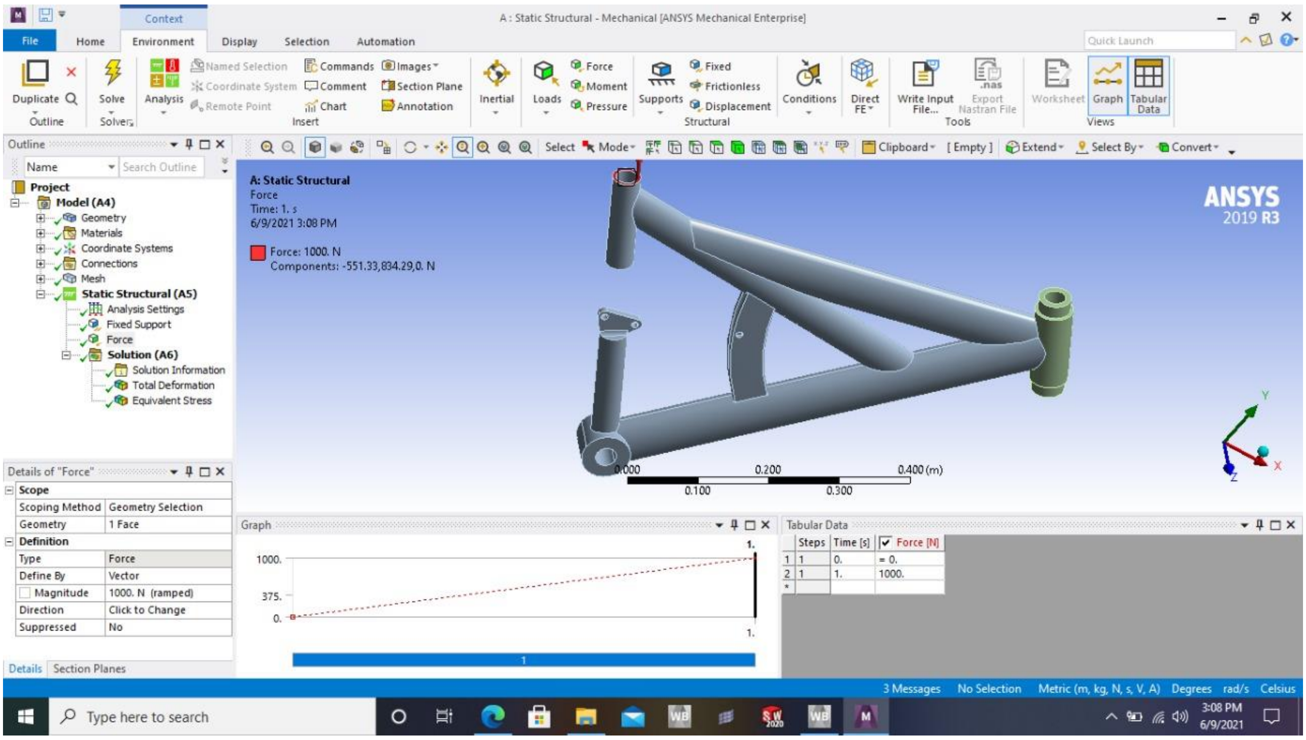


Fig.21 Load Applied

2.EQUIVALENT STRESS:

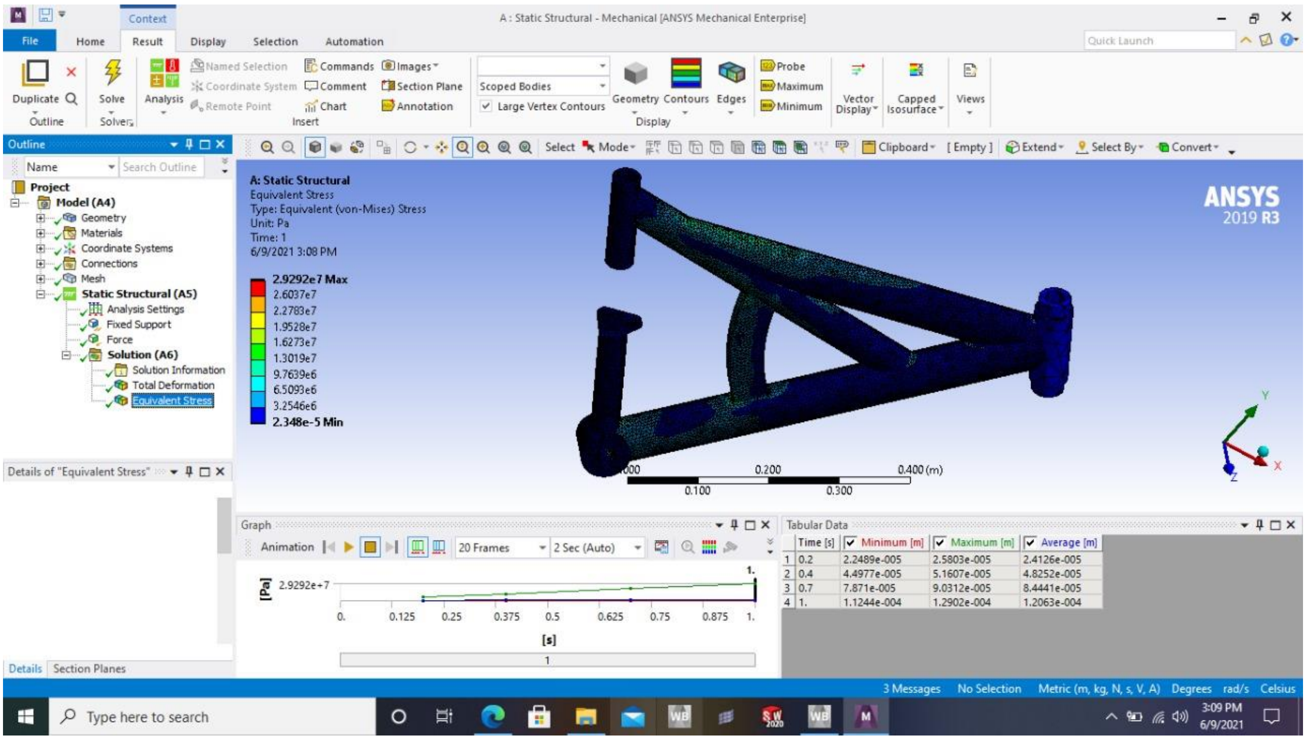


Fig.22 Equivalent Stress

3.EQUIVALENT STRAIN:

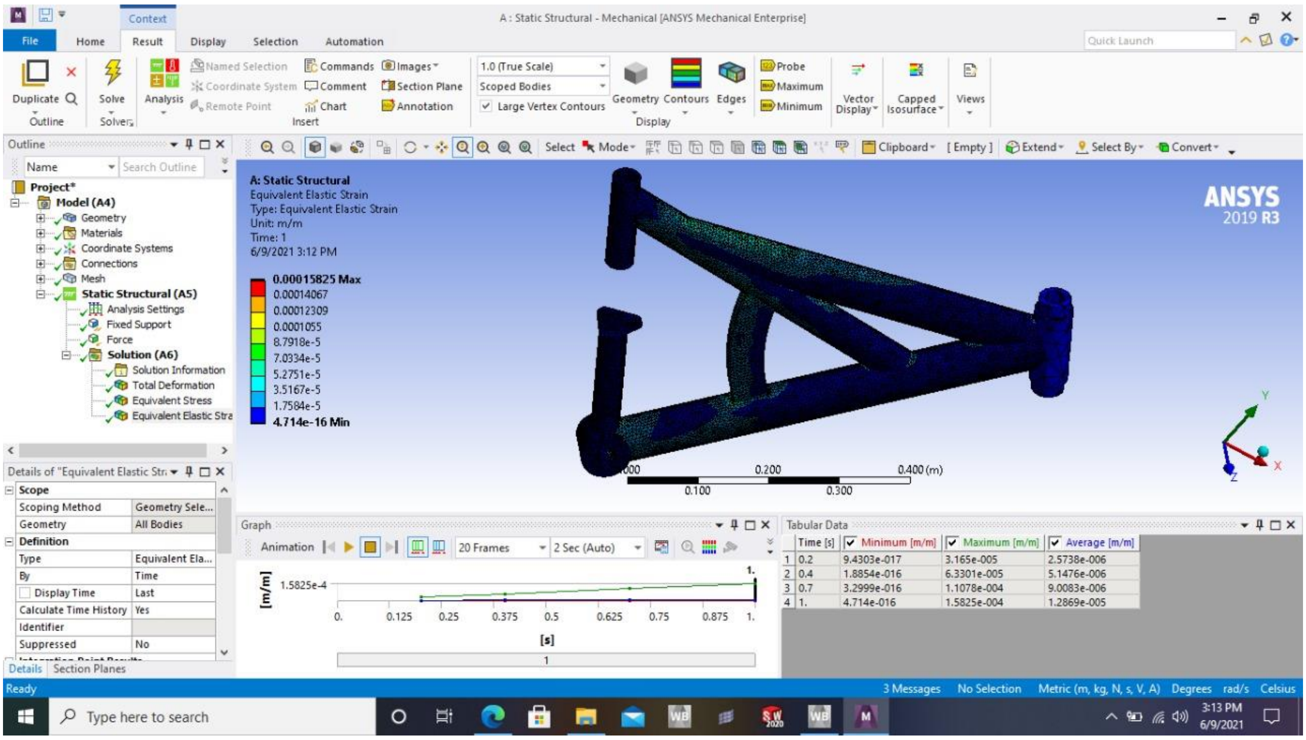


Fig.23 Equivalent Strain

4.TOTAL DEFORMATION:

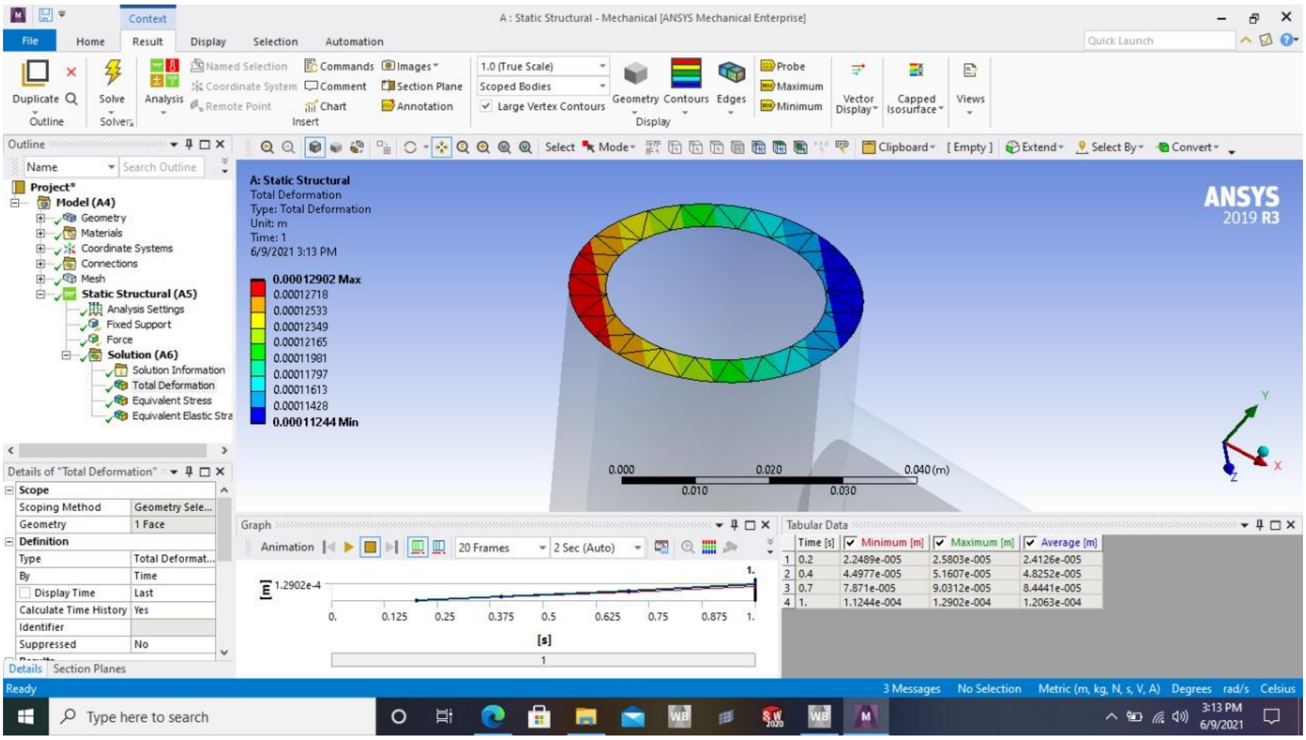


Fig.24 Total Deformation

CHAPTER 4

PROJECT IMPLEMENTATION

4.1 Proposed Model of Chainless Bicycle:

Chainless bicycle system has used drive shaft in place of chains to transfer power to the rear wheel by means of pedalling the bicycle through pedals. This system uses shaft rod and gears as the main parts to deliver power to the wheel. Chainless Bicycle is very smooth and efficient. The shaft-driven bicycles were introduced 100 years ago but have not got popularity because chain drive bicycles system comes with the possibility of various gear ranges with the sprockets assembly. In the present scenario, few modern shaft-driven bicycles have introduced due to the advantages of internal gear technology. I design a suitable drive shaft which can take the place of chain drive easily and transfer power to the rear wheel from the pedals through pedalling without creating any issue. For keeping running of gears smooth and quiet, this chainless-bicycle system needs periodic lubrication. This setup of bicycle provides the transfer of energy efficiently to the rear wheel from the pedals. It is the supreme aspects to design a Bicycle. It has used to express the safety of the system. It shows that for an intended load, the system needs to be that much stronger to perform well. It has calculated as the ratio of the structure's absolute strength that is, in other words, the capability of a structure to the actual applied load. For a particular design, we calculate the factor of safety to find out the reliability of the structure. This Chainless Bicycle System generates efficient and reliable output as compared to the traditional system. In Future, this system can implement on bikes and also become a better transmission system. This can also be implemented on the vehicles run by engines such as truck or other high-powered vehicles. During the meshing of gears, the backlash is the amount by which tooth space exceeds the thickness of gear. For smooth rotation of messed gears, a little backlash is necessary & for the high precision gear application, zero backlash or low backlash has required. In simple words, backlash refers to the size of the gap between the trailing face of the meshing tooth. If the amount of backlash is high then it can damage teeth and other components. Backlash should be less than 1/10 of the module.

The Grashof's condition for a four-bar linkage states: If the sum of the shortest and longest link of a planar quadrilateral linkage is less than or equal to the sum of the remaining two links, then the shortest link can rotate fully with respect to a neighboring link. In other words, the condition is satisfied if $S+L \leq P+Q$ where S is the shortest link, L is the longest, and P and Q are the other link The movement of a quadrilateral linkage can be classified into eight cases based on the dimensions of its four links. Let a, b, g and h denote the lengths of the input crank, the output crank, the ground link and floating link, respectively. Then, we can construct the three terms:

The movement of a quadrilateral linkage can be classified into different types based on the positive and negative values for these three terms, T1, T2, and T3.

T1=g+f-a-b,

T2=b+g-a-f,

T3= b+f-a-g,

A planar four-bar linkage consists of four rigid rods in the plane connected by pin joints. We call the rods/ links:

• Ground link 'g': Fixed to anchor pivots A and B.

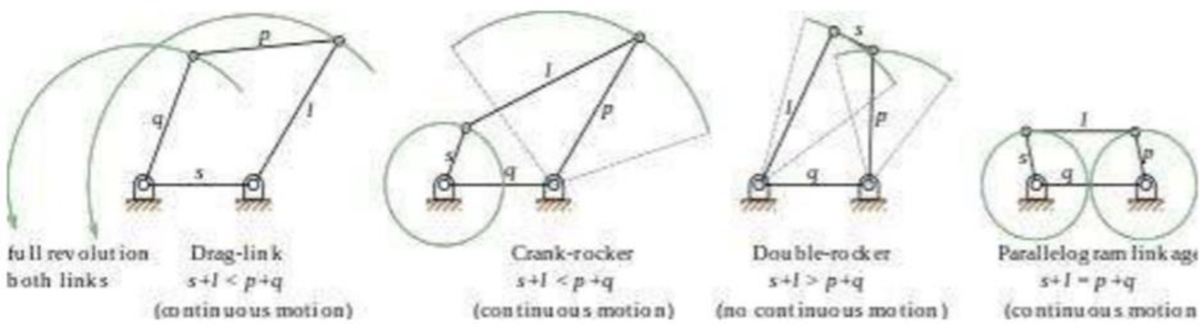
• Input link 'b': Driven by a lever with input angle

• Output link 'a': Gives output angle

• Floating link 'f': Connects the two moving pins C and D.

T1	T2	T3	Grashof's Condition	Input link	Output link
-	-	+	Grashof	Crank	Crank
+	+	+	Grashof	Crank	Rocker
+	-	-	Grashof	Rocker	Crank
-	+	-	Grashof	Rocker	Rocker

Table.3 4-Bar Mechanism



• The entire mechanism is designed using Grashof's law.

• Here the output crank is driven by its neighboring oscillating arm.

• This arm is connected with lever mechanism with pedal on the other end and hinged at a point to transmit required force.

• When the force is applied on the pedal, the rocker arm starts oscillating which further helps in rotating the wheel.

CUSTOMIZATION:

In 2016, we truly are on the verge of seeing mass customization arise and provide a viable alternative to the process of homogenized mass production that has been so prevalent. At the same time, technology itself has become more advanced, allowing business to build sophisticated, yet easy-to-use configurations. Here, he handle and seat used here are customizable depending on the height of the person to make it more personal and comfortable while riding the bicycle. The lower point of handle is hinged, so that it oscillates with respect to Y- axis. This helps in adjusting the handle to possible comfortable position of the rider. Also, the handle can move in X-axis i.e., in horizontal direction to make it more customizable and to provide lot more comfort in riding the bicycle when compared to conventional bicycles

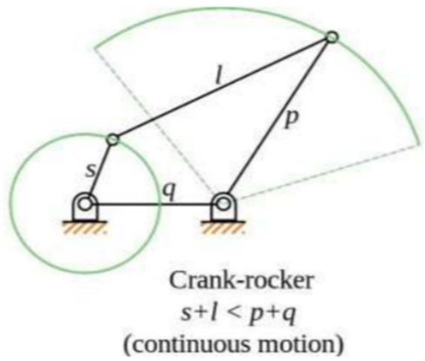


Fig.25 Crank-Rocker Mechanism

It is rather important to understand how the mechanism will function under loaded conditions in practice while the kinematic characteristics of the mechanism is being considered. By the performance of the mechanism, we mean the effective transmission of motion (and force) from the input link to the output link This also means that for a constant torque input, in a well performing mechanism we must obtain the maximum torque output that is possible and the bearing forces must be a minimum. Of course, torque and force are not the quantities that has been in the kinematics and whatever kinematic quantity we use to define the performance of the mechanism, this quantity will only approximate the static force characteristics of the mechanism. The dynamic characteristic, which is a function of mass and moment of inertia of the rigid bodies, may be several times more than the static forces and the behavior of the mechanism under the dynamic forces cannot be predicted by kinematics. Still, some rule-of thumb of the behavior of the mechanism under load is better than none.

Four-bar linkage:

A four-bar linkage, also called a four-bar, is the simplest movable closed-chain linkage. It consists of four bodies, called bars or links, connected in a loop by four joints. Generally, the joints are configured so the links move in parallel planes, and the assembly is called a *planar four-bar linkage*. Spherical and spatial four-bar linkages also exist and are used in practice.

Planar four-bar linkage:

Coupler curves of a crank-rocker four-bar linkage. Simulation done with MeKin2D.

Planar four-bar linkages are constructed from four links connected in a loop by four one-degree-of-freedom joints. A joint may be either a *revolute*, that is a hinged joint, denoted by R, or a prismatic, as sliding joint, denoted by P.

A link connected to ground by a hinged joint that can rotate 360° is usually called a crank. A link connected to fixed line (generally known as ground) by a prismatic joint is called a slider. Sliders are sometimes considered to be cranks that have a hinged pivot at an extremely long distance away perpendicular to the travel of the slider.

The link that connects two cranks is called a *floating link* or *coupler*. A coupler in a single slider Crank mechanism that connects a crank and a slider is often called a *connecting rod.*

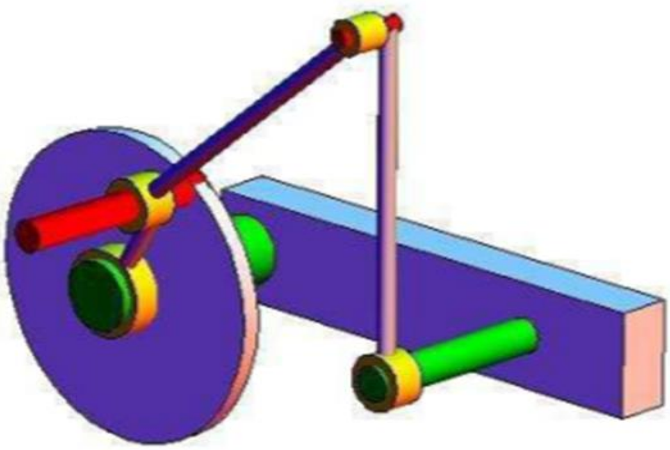


Fig.26 Four-bar Linkage

There are three basic types of planar four-bar linkage depending on the use of revolute or prismatic joints:

1. Four revolute joints: The planar quadrilateral linkage is formed by four links and four revolute joints, denoted RRRR. It consists of either two cranks or two rocker or one crack and one rocker connected by a coupler.

2.Three revolute joints and a prismatic joint denoted RRRP or PRRR or RPRR or RRPR: The slider-crank linkage is constructed from four links connected by three revolute and one prismatic joint, or RRRP. It can be constructed with crank and a slider connected by the connecting rod. Or it can be constructed as two cranks with the slider acting as the coupler, known as an *inverted slider-crank.*

3.The known example of 3R1P is single slider crank mechanism (used in IC engine) Whitworth Quick Return motion mechanism (earlier use in shaper machine) Crank and slotted lever quick return motion mechanism (used in shaper machine) Fixed piston mechanism (used in hand pumps) Two revolute joints and two prismatic joints: The double slider is a PRRP linkage. This linkage is constructed by connecting two sliders with a coupler link. If the directions of movement of the two sliders are perpendicular then the trajectories of the points in the coupler are ellipses and the linkage is known as an elliptical trammel, or the Trammel of Archimedes.

Other example of two revolute and two sliding joints are scotch York mechanism and Oldham's coupling.

Planar four-bar linkages are base of mechanisms found in machines. The kinematics and dynamics of planar four-bar linkages are important topics in mechanical engineering.

Planar four-bar linkages can be designed to guide a wide variety of movements.

Planar quadrilateral linkage

Planar quadrilateral linkage, RRRR or 4R linkages have four rotating joints. One link of the chain is usually fixed, and is called the *ground link*, *fixed link*, or the *frame*. The two links connected to the frame are called the *grounded links* and are generally the input and output links of the system, sometimes called the *input link* and *output link*. The last link is the *floating link*, which is also called a *coupler* or *connecting rod* because it connects an input to the output.

Assuming the frame is horizontal there are four possibilities for the input and output links:

- A crank: can rotate a full 360 degrees
- A rocker: can rotate through a limited range of angles which does not include 0° or 180°
- A 0-rocker: can rotate through a limited range of angles which includes 0° but not 180°
- A π-rocker: can rotate through a limited range of angles which includes 180° but not 0°

Grashof condition:

The Grashof condition for a four-bar linkage states: If the sum of the shortest and longest link of a planar quadrilateral linkage is less than or equal to the sum of the remaining two links, then the shortest link can rotate fully with respect to a neighboring link. In other words, the condition is satisfied if $S + L \leq P + Q$, where S is the shortest link, L is the longest, and P and Q are the other links.

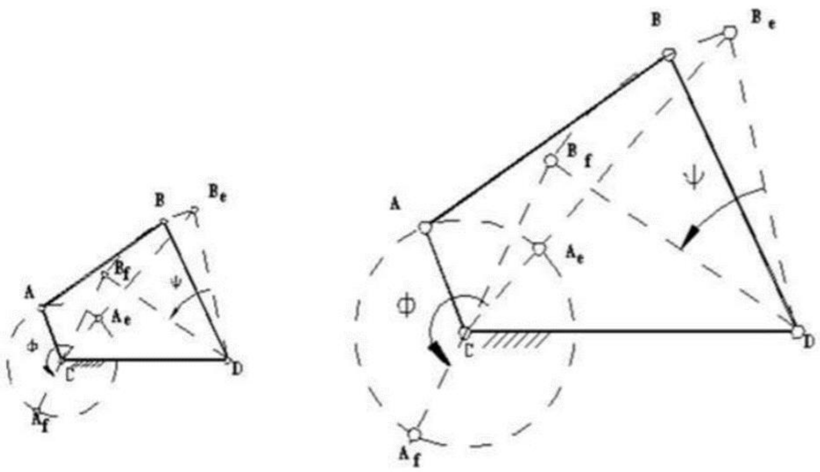


Fig.27 Grashoff’s Condition

TIME RATIO

With four bar mechanisms there are two strokes, the forward and return, which when added together create a cycle. Each stroke may be identical or have different average speeds. The time ratio numerically defines how fast the forward stroke is compared to the quicker return motion mechanism.

4.2 Gears Shifting:

It is the marvellous phenomena of the meshing of gears provide various advantages and have several outcomes. As per the requirement of the vehicle and task, we have to change the gear ratio.

Gear material

Generally, gears have made up of steel. As per the requirements, Gears may have made up of other materials like cast iron, aluminium, plastic and nonferrous alloys. It has also made up of iron-based material. Generally, gears are made up of steel material because steel is available easily in the market, cheap in price, come with a lightweight and have high strength. The strength of gear is different and depending upon the type of material, heat treatment & quenching applied. Plastics have various properties including low-speed meshing, dirt tolerance. Plastics do not need extra lubrication. That is why; a well manufactured plastic gear can take the place steel gears in a few ways.

BACKLASH: During the meshing of gears, the backlash is the amount by which tooth space exceeds the thickness of gear. For smooth rotation of messed gears, a little backlash is necessary & for the high precision gear application, zero backlash or low backlash has required. In simple words, backlash refers to the size of the gap between the trailing face of the meshing tooth. If the amount of backlash is high then it can damage teeth and other components. Backlash should be less than 1/10 of the module.

4.3 DRIVE MECHANISM:

- Gears have come in the vast range of tooth, shape and sizes. For driving the shaft, meshing gears have to transmit rotational motion. As compared to the large gear, small gears rotate much faster. But the torque of large gear is proportionally more than the small gears. To achieve, a particular arrangement of the drive mechanism, both meshing gears have the same linear speed at the pitch diameter.
- Gears can produce both translational and rotational motion as per the arrangements of the gear system. Gears have cut teeth; they are machine elements which rotate and mesh with other toothed or cut parts to perform a function of transmitting torque. When gear meshes with stationary toothed machine part, it produces translation motion. These gear devices have used to transmit power, change the torque and speed and also to change the direction of power. Gear can transmit high torques values. Employing different gear ratios, they provide various mechanical advantages.
- We can make a gear system according to the need where two, three or more gears mesh with each other to transmit power. When gear of different sizes with similar tooth size is meshes, they produce a mechanical advantage such as high torque. The meshing of teeth of gears prevents slippage. The efficiency of gear is very high.

4.4 Comparison of Shaft Drive vs Chain Drive:

- This Shaft-Driven System is packed and has not affected by weather and only needs periodic lubrication whereas, Chain-Drive System needs lubrication frequently, mainly in poor weather condition that may be dirty and troublesome.
- Shaft Drive System is the most robust, soft and requires less maintenance, costs and cleanliness. Whereas, Chain Drive System is generally open to the elements and generates a lot of dust and dirt also needs their chains adjusting time to time as chain length tends to increase over time. And they can be expensive to restore when they wore out.
- Shaft-Drive System consists of an axle connected to the output of the gearbox through a universal joint, which is a coupling that transmits the torque at a selected angle. At the other end, the axle has connected to the rear wheel hub through a spiral bevel gear. The bevel gear rotates the wheels by turning this axle 90 degrees. Whereas, Chain-Drive System consists of a simple connection chain that connects the sprockets.

- Shaft-Drive System is very smooth and generates no noise while Chain-Drive System is noisy, especially when the chain is loose.

4.5 Construction and Working Principle:

- The shaft may be of two types that are propeller shaft and drive-shaft. The propeller shaft has used to propel the vehicle and drive-shafts are one which we use to transferring motion from one point to another. In this chainless bicycle system, the drive shaft has used to transfer rotational motion from the front end of the bicycle to the rear wheel to propel the bicycle forward so in this project drive-shaft also referred as the propeller shaft.
- The drive-shaft is the chief connection of bicycle which has used to connect the front end that is pedal and crank to the rear hub along with the wheel. Drive-shaft performs the job of propelling the front end and transmitting motion. The pedal has connected to the crank set which is further connected to the drive-shaft by mean of spur gear.
- Drive-shaft consists of shaft rod, four spur gears and universal joint. spur gears are present at both ends of the drive-shaft.
- On the bicycle's rear end, drive-shaft spur gear is connected to the gear on the rear hub assembly along with the rear wheel.
- The strength of this system is high and takes small maintenance.
- Drive shaft's centre has fitted with a flexible universal joint. Thus, absorbs shock
- Use of drive shaft provides protection to clothes and safety of cyclist as there is no more chain bite, also no more grease on hand to maintain the chain.
- Rider of the chainless bicycle system has not to apply extra power to push the vehicle forward. This chainless bicycle system has a spur gear in place of the chain-ring. This large spur gear is attached to the crank set and mashes with the spur gear which attached to the drive shaft at the front end.
- The cyclist pushes the pedal which turns the spur gear of the crank set and spur gear of the shaft allow the axis of drive torque to turns by 90 degrees.
- At the rear end of the drive shaft, another spur gear is mounted and mesh with the spur gear on the rear hub assembly along with the rear wheel and cancel out the change of axis of first drive torque.
- The rider pushes the pedal which rotates the shaft rod by means of spur gear at the front end. This rotating shaft has a spur gear at the rear end which meshes with another spur gear on the hub along with the rear wheels.

Drive Shaft Specifications:

- Drive-shaft has subjected to various forces. It has the torque transmission capacity of more than or equal to 3500Nm. For optimal design, the specifications EN 8 drive shaft is almost similar to that of a steel shaft.
- The outer and inner diameter of the drive-shaft should not exceed 70mm and 60mm approximately due to the limitation of space.
- Following specific design, requirements are used for optimally design of drive shaft transmission system.

S. No.	Name	Notation	Unit	Value
1	Length of shaft	L	mm	410
2	Ultimate torque	Tmax	Nm	3500
3	Max. speed of shaft	Nmax	Rpm	6500

Table.4 Driveshaft Specifications

EN-8 has used for automotive drive shaft applications. EN 8 which is an unalloyed medium carbon grade steel with moderate wear resistance and reasonable tensile strength. It has also called as Engineering Steel. It is also a freely machinable material.

Applications of EN 8 are: -

- Used in making general engineering components.
- Used in making various automotive parts.
- Used to make a connecting rod.
- Used to make bolts and studs sometimes.
- Used to make spindle or axles also Mechanical properties of EN-8 Carbon Steel

S. No	Mech. Properties	Symbol	Units	EN-8 Carbon Steel
1	Density	ρ	Kg/m3	7800
2	Young's modulus	E	GPa	190
3	Poisson ratio	v	--	0.3

Table.5 Mechanical Properties of Driveshaft

4.6 Advantages of Chainless Bicycle System:

- This chainless Bicycle system does not jam.
- Cyclist of this chainless bicycle system does not get injured because of chain bite as in this system chain is not present.
- The rider's clothes not any more affected by the chain grease. Rider's footwear, pants do not get accidental damage.
- This chainless bicycle system is fully enclosed and requires less maintenance, and periodic lubrication through a grease gun.
- This system can deliver more efficiency as compared to the chain drive system.
- This bicycle has a greater clearance compared to the traditional bicycle. The rider cannot become dirtied from chain grease or injured by the chain from "Chain", which occurs when clothing or even a body part catches between the chain and a sprocket.
- Lower maintenance than a chain system when the drive shaft is enclosed in a tube More consistent performance. Efficiency may increase if we are using aluminium material.

Disadvantages of Chainless Bicycle System:

- The weight of the chainless bicycle system is a little bit more as compared to the chain drive system.
- Hub Assembly has used; is complex.
- This system can't use derailleur gears; these gears are light in weight and come in a variety of the gears ratio.
- This chainless bicycle system is complex to dismantle when repairing the rear tyre.

FABRICATION PROCESS

Fig.28 Fabrication Process

Fig.29 Fabrication Process

Fig.30 Fabrication Process

4.7 FINAL PRODUCT

Fig.31 Final Product

CHAPTER 5

PROJECT TESTING

The testing of the project is done after the fabrication of the cycle has done and also the testing is done with a weight of 80kg and the total amount of distance the cycle travelled is 3km without fail. The product is strong and after the testing the strength of the cycle is same before and after it has been tested.

Fig.32 Project Testing

CHAPTER 6: CONCLUSIONS & FUTURE ENHANCEMENT

The design and development of chainless bicycle are done through the recent software SOLIDWORKS and ANSYS which are popularly used for design and analysis. We have designed the chainless bicycle.

The assumptions that are made for the design and design calculations are mentioned in the respective chapters.

After design we performed structural analysis with the certain load of a rider according to the practical applications. we have performed analysis with structural steel for the frame of the Bicycle. So, we recommend the chainless bicycle fabrication can be done through same material in order to increase the life and fatigue strength of the cycle. The chainless bicycle works on important components like frame, spur gears, connecting rod, crankshaft. The cycle fabricated is more comfortable for rider and also productivity is less when compared to other chainless bicycles. This Chainless Bicycle System would be able to replace the existing traditional bicycle system of chain and sprocket arrangement.

- This Chainless Bicycle is run successfully with the use of drive-shaft in place of chain-ring.
- This chainless bicycle system has manufactured for quiet, smooth and easy power transmission.
- This chainless bicycle system has optimally designed and use drive shaft which consists shaft rod, spur gears, bearing in place of chain drive that consists of chains, sprocket.
- This Chainless Bicycle System would be very comfortable for off-road racing.
- This Chainless Bicycle System requires little maintenance with comparatively a longer life.
- This Chainless Bicycle System generates efficient and reliable output as compared to the traditional system.
- In Future, this system can implement on bikes and also become a better transmission system.
- This can also be implemented on the vehicles run by engines such as truck or other high-powered vehicles

Future Enhancement:

As a future scope of study, we can use different of types of gears and by using different sizes of gears can be used for increasing efficiency of the cycle. And also, we can use different kinds of road and mountain bicycle for incorporating this mechanism

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A Major Project Report
On

DESIGN, ANALYSIS AND PROTOTYPE OF AIR-LESS TYRE BY ADDITIVE MANUFACTURING PROCESS

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Design, Analysis and Prototype of Air-Less Tyre by Additive Manufacturing Process**, is being submitted by **Bhudhavarapu Sai Rohit (17K81A0312), Neeli Vishnudeep (17K81A0347), Taravath Vishal (17K81A0355), Vontari Sai Ritesh Reddy (17K81A0357)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Prof. C.H RANGARAO
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Signature of HOD

Dr. D.V. SREEKANTH
Professor& Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Design, Analysis and Prototype of Air-Less Tyre by Additive Manufacturing Process** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Non-Pneumatic Tyre (NPT) as the name suggests is a type of tyre that doesn't use air to support the load. The main principle involved in the airless tyre is, the flexible tread and shear bands deform temporarily as the spokes bend, then quickly going back to the initial shape. The NPT discussed here consists of mainly three parts. A rigid hub, Deformable spokes that support vertical load, Reinforced shear band and tread made out of rubber which comes into contact with the surface. Several types of research are being carried out all over the globe to make NPT an alternative to the conventional pneumatic tyre. This project consolidates an overview of the design and analysis of the Non-Pneumatic Tyre. The model of the tyre is designed in NX Cad software and Analysis is to be done in the Ansys workbench. The prototype of the model is done by 3D printing.

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CHAPTER-1 INTRODUCTION

Conventional pneumatic (air-inflated) tyres have dominated the tyre market for over a century. Since the earlier invention of the non-pneumatic wheel in the 1920s, the non-pneumatic tyre (NPT) is getting more attention due to its advantages over the pneumatic counterpart.

As far as automobiles are concerned, the engine, transmission and all other powertrain parts are only good as the tyres are. Since its invention in 1888 by Dunlop, the pneumatic tyre has been the primary choice for use in automobile subjected to different operating conditions due to the several advantages offered by it mainly:

1. Low energy loss while rolling
2. Low vertical stiffness which produces cushioning effect.
3. Low contact pressure and
4. Low mass.

Even though several advantages exist for a pneumatic tyre which resulted in its widespread acclaim, there exists a chance for it to go flat during operation which is its greatest drawback to date. In the case of vehicles that are subjected to extreme conditions like tractors, solid tyres are used to avoid this issue but this deteriorates ride quality. Researchers have been trying long back as 1920s to build a non-pneumatic tyre (NPT) that has sufficient resilience. With advancement in material science and manufacturing technologies, researchers were able to create NPTs having sufficient compliance. Modern NPT designs integrate wheel and tyre into a single component. The NPT consists of a rigid hub, flexible spokes, shear band and tread which is made up of rubber as shown in Figure. The flexible spokes and shear band are the components that support the load acting on an NPT like air in the case of a pneumatic tyre. Several researches are going on to optimize the design of spokes and shear band of an NPT and some of them are discussed below. Akshay Narasimhan et al studied the effect of material properties on static behavior of an NPT having radial spokes and shear band made of polyurethane and concluded that increase in shear modulus increased the stiffness of the NPT. Hysteresis loss due to the viscoelastic nature of rubber accounts for 90 % of energy loss. The spokes and shear band of NPT are usually made of polyurethane which also exhibits viscoelasticity.

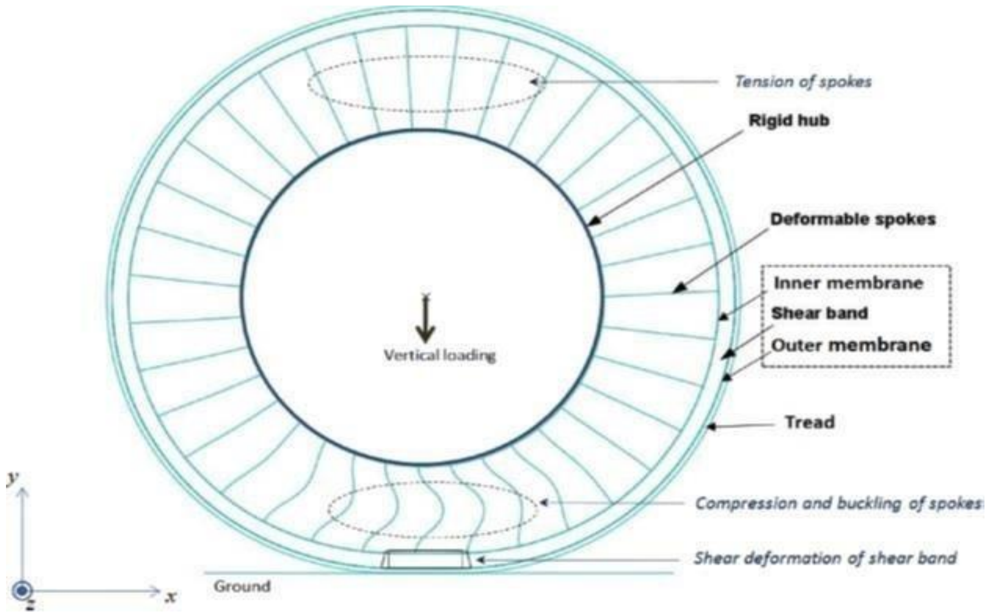


Fig 1: Schematic Representation of Airless Tyre

Non-Pneumatic Tyres

Airless tires, non-pneumatic tires (NPT), or flat-free tyres are tyres that are not supported by air pressure. In 2005, Michelin started developing an integrated tire and wheel combination, the "Tweel" (derived from "tyre" and "wheel," which, as the name "Tweel" suggests, are combined into one new, fused part), which operates entirely without air. Michelin claims its "Tweel" has load carrying, shock absorbing, and handling characteristics that compare favorably to conventional pneumatic tyres. In 2019 however Michelin and GM announced that, their goal of making a new airless tyre for passenger vehicles available in 2024.

Big Tyre Pvt Ltdin Australia is developing a "non-pneumatic, non-solid wheel", which is designed to handle high working loads, such as those found in underground mines. A non-pneumatic or airless tyre for passenger vehicles can be more efficient than the traditionally used pneumatic tyres. One or the other way there are many advantages over using pneumatic tyres. The main advantage of airless tyres is that they do not go flat. Other advantages are that airless tyres need to be replaced less, resulting in savings. Heavy equipment outfitted with airless tyres will be able to carry more weight and engage in more rugged activities.

Fig 2: Michelin Twill

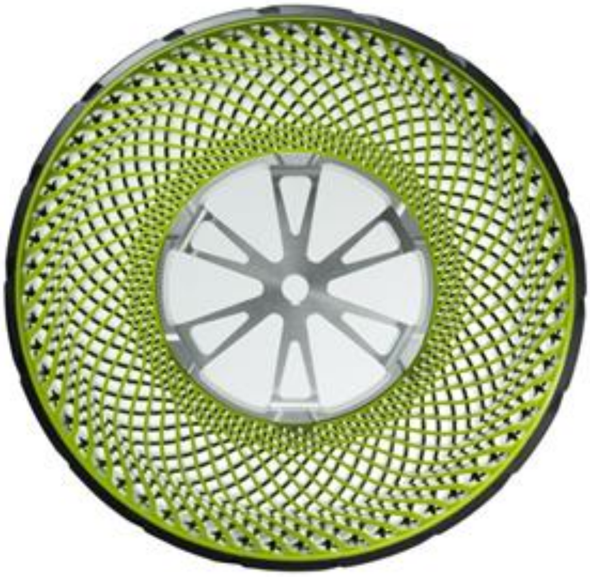


Fig 3: Bridgestone

Advantages of Air-Less Tyre:

For one thing, there are huge safety benefits. Having an airless tyre means there is no possibility of a blowout, which, in turn, means the number of highway accidents will but cut significantly. Even for situations such as Humvees in the military, utilizing non-pneumatic tyres has a great positive impact on safety

1.1 Overview of The Project

The basic outline of the project is to bring out the airless tyre design and to do the deformation analysis. Non-Pneumatic Tyre (NPT) as the name suggests is a type of tyre that doesn't use air to support the load. Even though tyres made out of solid rubber exists, they don't have enough compliance and will not provide a supple ride if used in normal vehicles. Heavy equipment outfitted with airless tyres will be able to carry more weight and engage in more rugged activities. In this project we designed and analyzed the design and suitable pattern is prototyped. The flexible tread and shear bands deform temporarily as the spokes bend, then quickly go back to the initial shape. There is additionally an environmental profit to victimization this sort of tyre. Since they never go flat and may be rethreaded, unventilated tyres won't ought to be thrown away and replaced nearly as usually as gas tyres. This can weigh down lowland mass considerably.

1.2 Objectives of The Study

According to NPT, the main component contributing to the energy loss of the NPT is the shear band due to the shear loading at the contact area. With Non pneumatic tyres or airless tyres, you never have to worry about your tires leaking because you knew this was coming--non-pneumatic tires have no air to leak. For most drivers, this feature will sound nothing short of revolutionary. When you run over a sharp object in the road, you won’t have to worry about a flat tire because tires without air can’t go flat. An end to the days of changing a tire on the highway shoulder would be welcome to drivers everywhere. Since you won’t be changing or repairing a flat, you don’t need to carry a spare. Just like cars using run-flat tires, this feature could free up trunk space. No spare also means less weight and less weight means better fuel economy. The airless concept tire is one of the initiatives aimed toward Bridgestone’s long-term vision of the use of sustainable materials. The materials used in the tire are recyclable, contributing to the efficient use of resources

Airless tires will be among the first for which this process is a reality. It is the design of shear beam and spokes which allows for the potential to achieve a relatively uniform surface contact distribution with the ground under load. The spokes and ring are manufactured in a mold with imbedded reinforcements. A rubber tread is bonded to the outer ring to provide traction. Use of PLA for the spokes and the shear band having low viscoelastic energy loss than rubber may result in design of NPT with low rolling resistance. The use of hyper elastic materials such as PLA is important because of their shearing properties that contribute to the flexibility, energy loss, damping, and the pressure distribution between the NPT and the road. When the NPT is loaded at the hub center, the composite ring flattens in the contact area, forming a contact patch. The deformable spokes buckle due to the applied load. The spokes out of the contact area do not undergo deformation and remain in tension. The airless concept can lead to reduced CO2 emissions because of their low rolling resistance. While the load-carrying structure is made of composite materials such as polyurethane, thermoplastics, fiberglass and epoxy laminates, but also eco-friendlier and bio-degradable materials have been proposed.

1.3 Scope of The Study

Our tires require less maintenance and worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheel chairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement.

This can be the revolutionary concept in the future.

1.4 Material Requirement

The materials required for the Analysis and Fabrication is Aluminum Alloy and PLA (Poly lactic acid).

RIM-Aluminum Alloy,

TYRE-PLA (Poly-Lactic Acid).

1.4.1 Aluminum Alloy:

In the automotive industry alloy wheels are wheels that made from an alloy of aluminum or. Alloys are mixtures of a metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of aluminum are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels.

S. No	Property	Value
1	Density	2770 kg/m^3
2	Young's Modulus	7.1e+ 10 Pa
3	Poisson's Ratio	0.33
4	Bulk Modulus	6.9608e+ 10 Pa
5	Shear Modulus	2.6692e+ 10 Pa
6	Compressive Ultimate Strength	0 Pa
7	Compressive Yield Strength	2.8e+ 08 Pa
8	Tensile Ultimate Strength	3.1e+ 08 Pa
9	Tensile Yield Strength	2.8e+ 08 Pa

Table 1: Properties of Aluminium Alloy

1.4.2 Poly Lactic Acid:

Polylactic Acid (PLA) is different than most thermoplastic polymers in that it is derived from renewable resources like corn starch or sugar cane. Most plastics, by contrast, are derived from the distillation and polymerization of non-renewable petroleum reserves. Plastics that are derived from biomass (e.g., PLA) are known as "bioplastics."

Polylactic Acid is biodegradable. It can be produced from already existing manufacturing equipment (those designed and originally used for petrochemical industry plastics). This makes it relatively cost efficient to produce.

S. No	Property	Value
1	Density	1255 kg/m^3
2	Young's Modulus	3.447e+ 09 Pa
3	Poisson's Ratio	0.3899
4	Bulk Modulus	5.218e+ 09 Pa
5	Shear Modulus	1.24e+ 09 Pa
6	Tensile Ultimate Strength	6.293e+ 07 Pa
7	Tensile Yield Strength	5.244e+ 07 Pa
8	Isotropic Thermal Conductivity	0.1442 W/m^{o}C
9	Specific Heat Constant Pressure	1195 J/kg^{0}C
10	Isotropic Resistivity	4.313e+ 09 ohm.m

Table 2: Properties of Pla

CHAPTER 2 LITERATURE SURVEY

2.1 Literature Review on Research Area

Mohammad Fazelpour et al, [1] stayed considered about the evolution of meso-structures in the development of the shear band of non-pneumatic tyre and he concluded as follows below. To increase fuel efficiency in NASA manned exploration system. They replaced elastomeric material with shear of shear band with materials which can tolerate harsh temperatures and shear loads or to replace the materials with linear elastic low-hysteretic loss materials. Topologies were created such as honeycombs; new shapes like s-type meso-structures and the structural analysis were carried out of shear band of non-pneumatic tyre with meso-structure was investigated through shear flexure, shear strain, and contact pressure. At the end of research, they set up guidelines on custom designing meso-structures for challenging applications such as non-pneumatic tyre and passive morphing air foils which will be addressed in future research. A.M. Abdul-Yazid et al, [2] examined three dissimilar structures of the Tweel, resistant technologies, and NPT by seeking yielding spoke structures. He conducted the quasi-static, 2D analysis on contact pressure, vertical tire stiffness and stress which are affected by spoke structures and shear band by creating two NPTs, a tire with a composite ring and another without composite ring. The results showed that shape and size of spokes has effect on tire behaviour and the shear layer reduces the impact of the deformed spokes shape in contact pressure distribution. Bert Bras et al, [3] discussed about the ecological effect of the Tweel tyre amid its lifecycle from assembling, through use and transfer. Since the Tweel tyre is as of now still in the examination stage and is most certainly not made and utilized on a vast scale, there are instabilities as for end-of-life situations and rolling resistance evaluates that will influence the LCA.

2.2 Review on Related Literature

Development of a two-dimensional model of a compliant non-pneumatic tire Amir Gasmi a, Paul F. Joseph a, Timothy B. Rhyne b, Steven M. Cron b an analytical model for a compliant non-pneumatic tire on frictionless, rigid ground is presented. The tire model consists of a thin flexible annular band and spokes that connect the band to a rigid hub. The annular band is modelled using curved beam theory that takes into account deformations due to bending, shearing and circumferential extension. The effect of the spokes, which are distributed continuously in the model and act as linear springs, is accounted for only in tension, which introduces a nonlinear response. The quasi-static, two-dimensional analysis focuses on how the contact patch, vertical tire stiffness and rolling resistance are affected by the stiffness properties of the band and the spokes. A Fourier series representation of the shear strain in the annular band and the complex modulus of the material were used to predict rolling resistance due to steady state rolling. From the analysis point of view, when the wheel is loaded at its hub, the following three distinct regions develop: (1) a support region where the hub hangs by the spokes from the upper part of the flexible band, (2) a free surface region where the spokes buckle and have no effect, and (3) a contact region where the flexible band is supported by the ground without the effect of the spokes. The angular bounds of these three regions are determined by the spoke angle and the contact angle, which are respectively the angle at which the spokes start to engage in tension and the angle that defines the edge of contact. Closed-form expressions of contact stress, stress-resultants and displacements at the centroids of the cross-sections of the flexible band are expressed in terms of these angles, which must be determined numerically. A thorough parametric analysis of quantities of interest for the tire is presented, which can be used to help support the optimal and rational design of compliant nonpneumatic tires. The model was validated by comparison with two computational models using the commercial finite element software ABAQUS and by experimental rolling resistance data.

2.3 Conclusion on Review

Air-less tyres or Non-Pneumatic Tyres require less maintenance and worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheel chairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement.

CHAPTER 3 PROJECT DESIGN

3.1 Over View Of the Design

The design of the tyre is done in NX Cad software. The basic requirement for the design is to know the different pattern to design and the dimensions to consider. By considering the original equipment manufacturers standards the dimensions are taken for the design. The dimensions are, the outer diameter of the tyre is 460mm, the inner diameter of the tyre is 420mm. At this point the spokes will be in the contact to the inner core of the tyre. The diameter of the outer part of the is 210mm. The spokes will be attached to the outer part of the rim and the inner core of the tyre.

3.2 Introduction to NX Cad

The design is carried out in NX Cad software. NX, formerly known as "Unigraphics", is an advanced high-end CAD/CAM/CAE, which has been owned since 2007 by Siemens PLM Software. In 2000, Unigraphics purchased SDRC I-DEAS and began an effort to integrate aspects of both software packages into a single product which became Unigraphics NX.

Fig 4: NX Cad Icon

It is used, among other tasks, for:

- Design (parametric and direct solid/surface modelling)
- Engineering analysis (static; dynamic; electro-magnetic; thermal, using the finite element method; and fluid, using the finite volume method.
- Manufacturing finished design by using included machining modules.

NX CAD is very useful platform for design engineer. It's providing many applications like sheet modelling and modelling; drafting is also there but most important thing is synchronous modelling through which you can work on solid dump body. It is used for mechanical simulation, electromechanical systems design, tooling and fixture design, package design and mechanical design. Siemens NX is a cutting-edge software which is highly useful for the manufacturing sectors. The most powerful, flexible, and innovative product development solution in the industry, NX for Design has the features, performance, and capabilities to help you get a product to market faster than ever before. NX generally provides the users with the most effective possibilities to fasten the production process resulting with excellent quality products.

NX can be more helpful for easy product tracking through various phases across the entire production lifecycle.

3.3 Uses of NX Cad

Surfacing & Shape Design

NXCAD provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From styling, subdivision, and Class A surfaces to mechanical functional surfaces.

Mechanical Engineering

Modules like 3D sketches, sheet metal work bench, forged or tooling parts for creation of 3D parts like assemblies and moulded are available in NXCAD. The tools in the NXCAD enable functional tolerances, Kinematics definition and product definition.

Equipment Design

The design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing can be done by NXCAD.

Systems Engineering

NX CAD solves intelligent products and Model complex through the systems engineering approach. It covers the requirements definition, the systems architecture, the behaviour modelling and the virtual product or embedded software generation. It can be customized via application programming interfaces (API). Visual Basic and C++ programming languages via CAA (Component Application Architecture); a component object model (COM)-like interface is adapted using NX CAD.

3.4 Modelling of The Tyre in NX Cad Software

3.4.1 Design Procedure:

Modelling of a TYRE is done through NX CAD by considering all the specifications of the design and Dimensions of TYRE. Draft sheet of the design can be seen in the following figure.

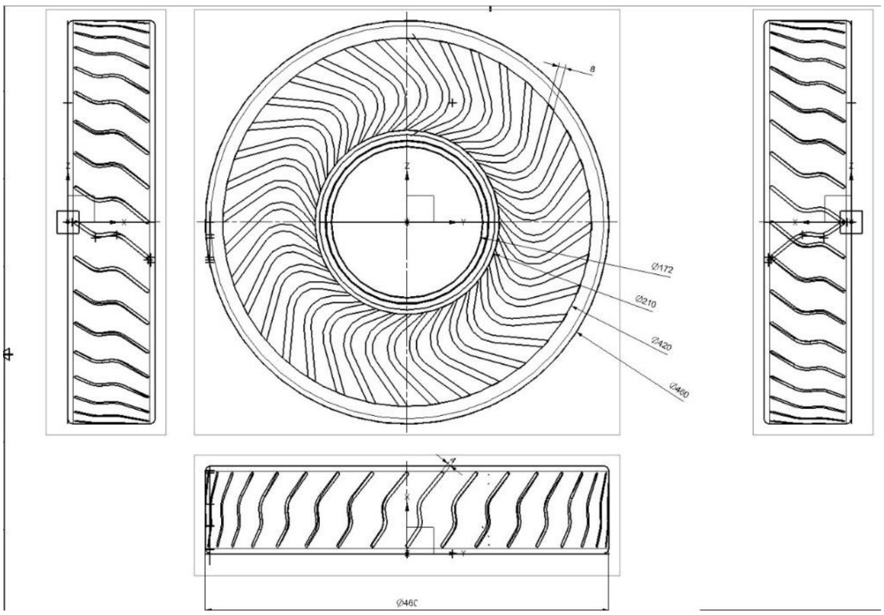


Fig 5: 2D Draft Sheet of The Tyre

Dimensions of the Tyre:

- Outer diameter of the tyre (460mm)
- Inner diameter of the tyre (420mm)
- Thickness of a spoke (8mm)
- Outer diameter of the rim (210mm)
- Inner diameter of the rim (172mm)
- Angle of a grooves (46^0)
- Thickness of the grooves (4mm)
- Thickness of the tyre (100mm)

3.4.2 Part Design:

Open the New window on the screen, select model and select assembly for the design. From the coordinate system select the X-Y plane and click on sketch. By taking the rim design and the references the outer part of the tyre and the inner part of the tyre is modelled.

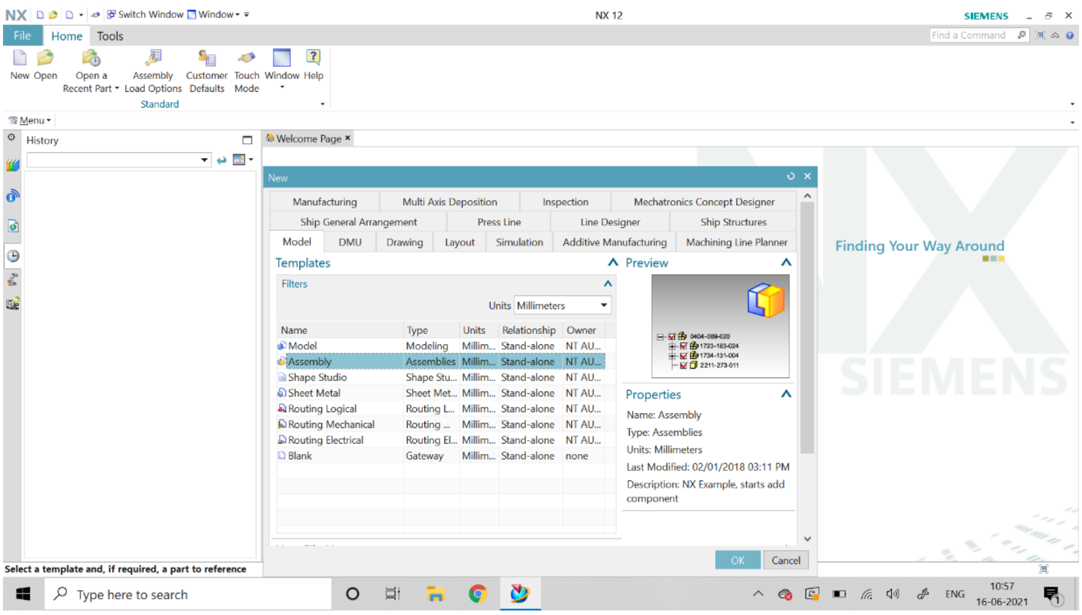


Fig 6: Part Design Model.

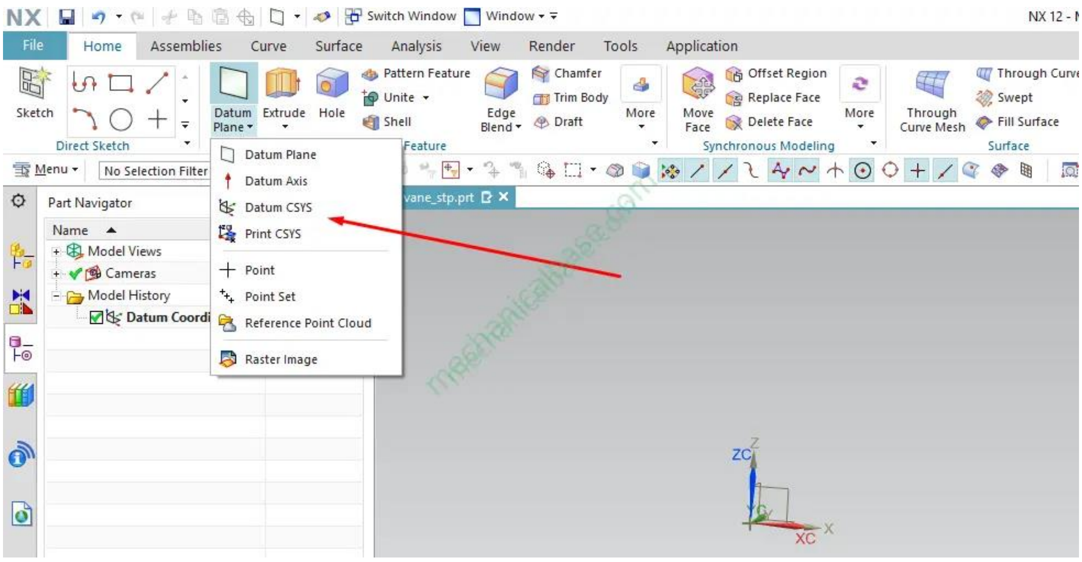


Fig 7: Selection of Coordinate System

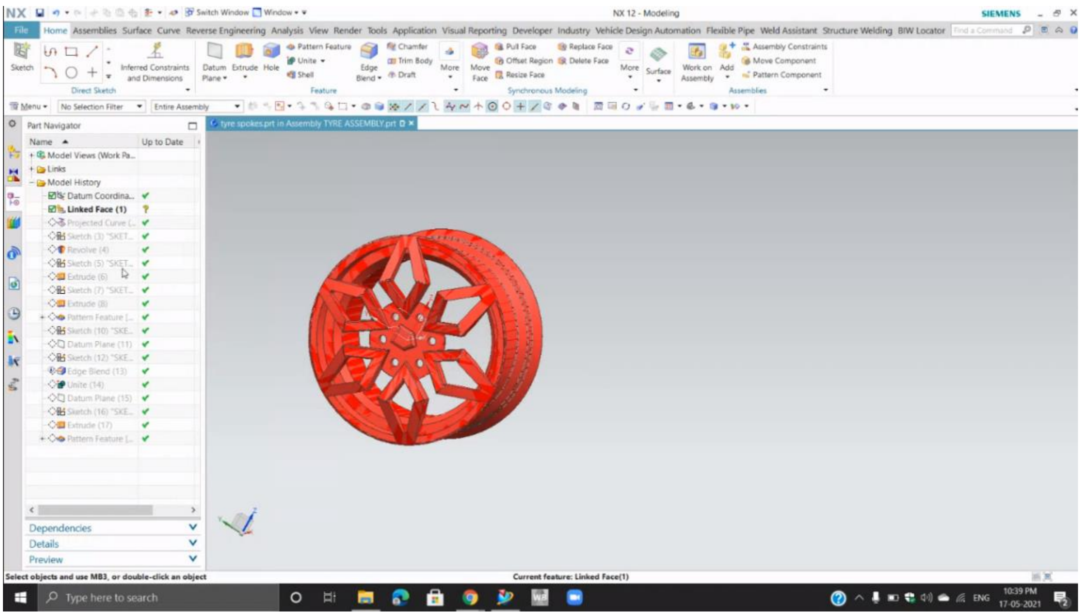


Fig 8: Design of The Rim

3.4.3 Sketching

After importing the designed rim, now use the wave geometry linker and the part is shown in side view. Then select extract geometry. After take the references through the edges of the RIM. Project curves tool helps us to join the references of the rim as shown in below figures. The references of the rim can be seen in the figure. By using revolve command, Sketch the inner part of the tyre and the outer part of the Tyre.

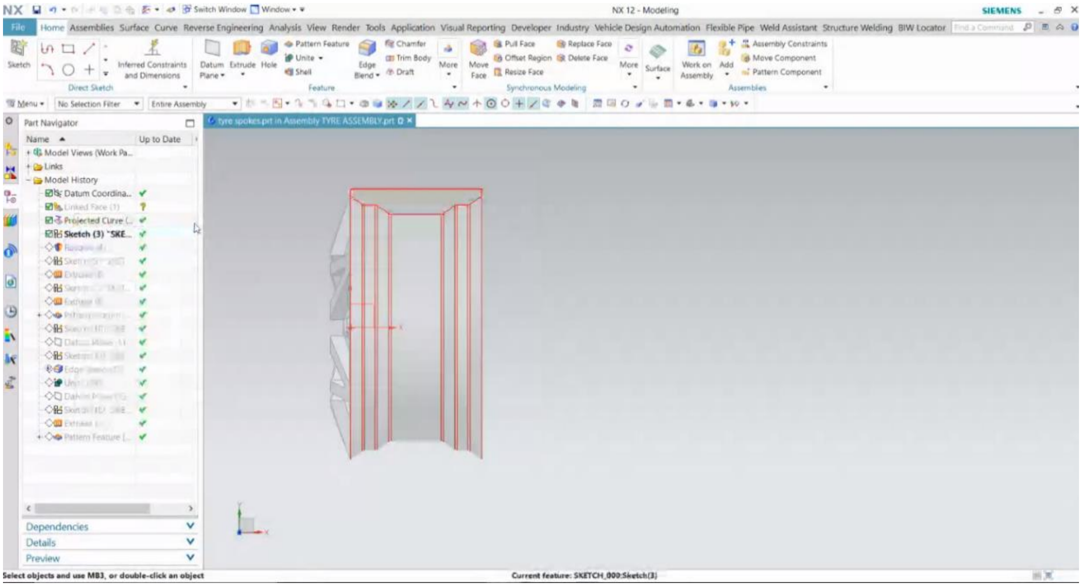


Fig 9: Sketching of The Rim

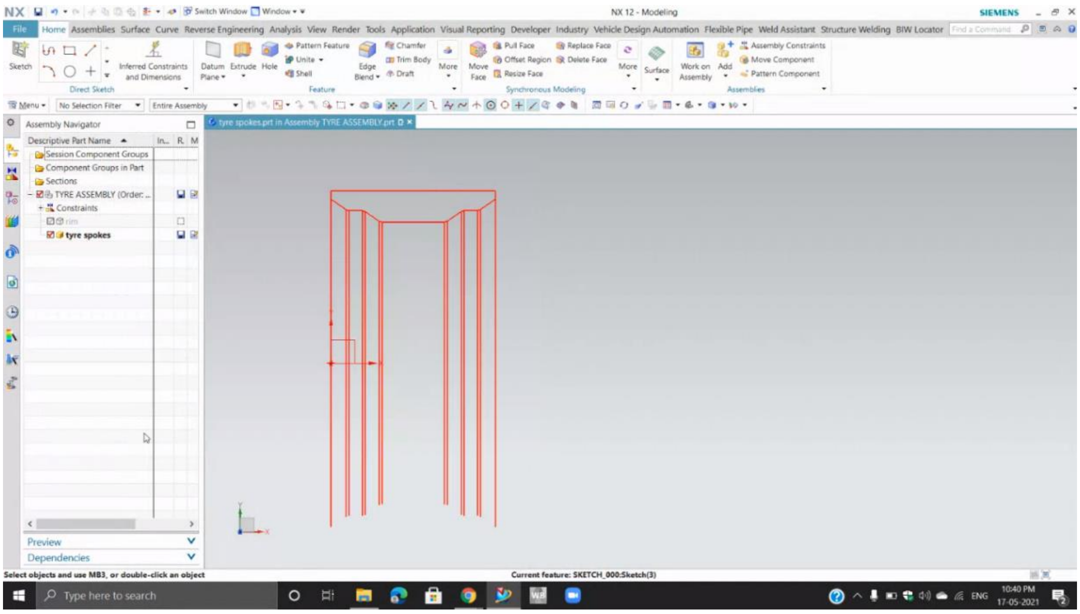


Fig 10: Joining the References

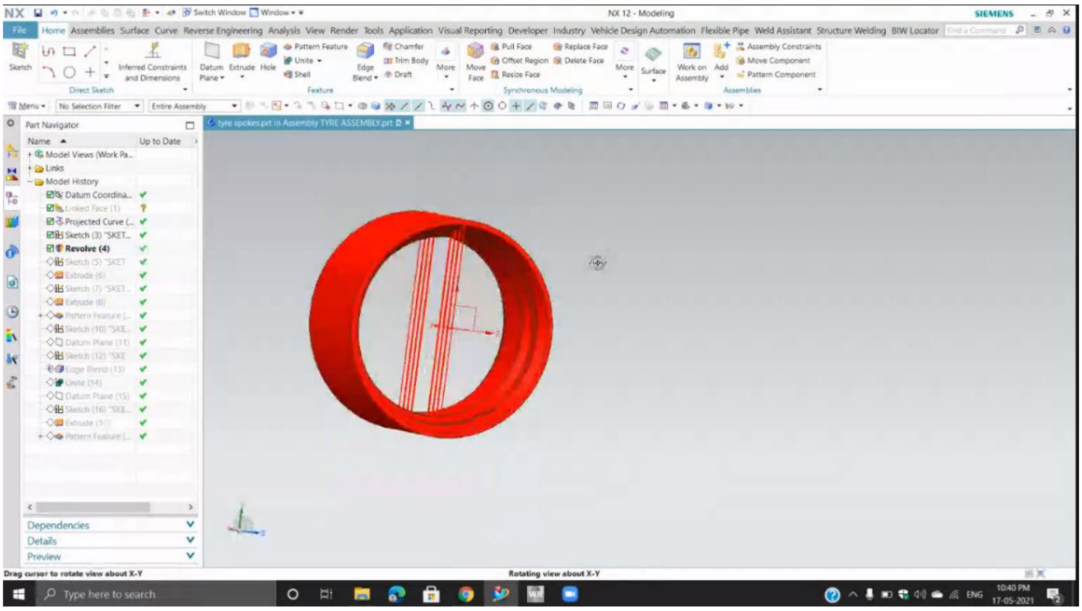


Fig 11: Outer Core of The Rim

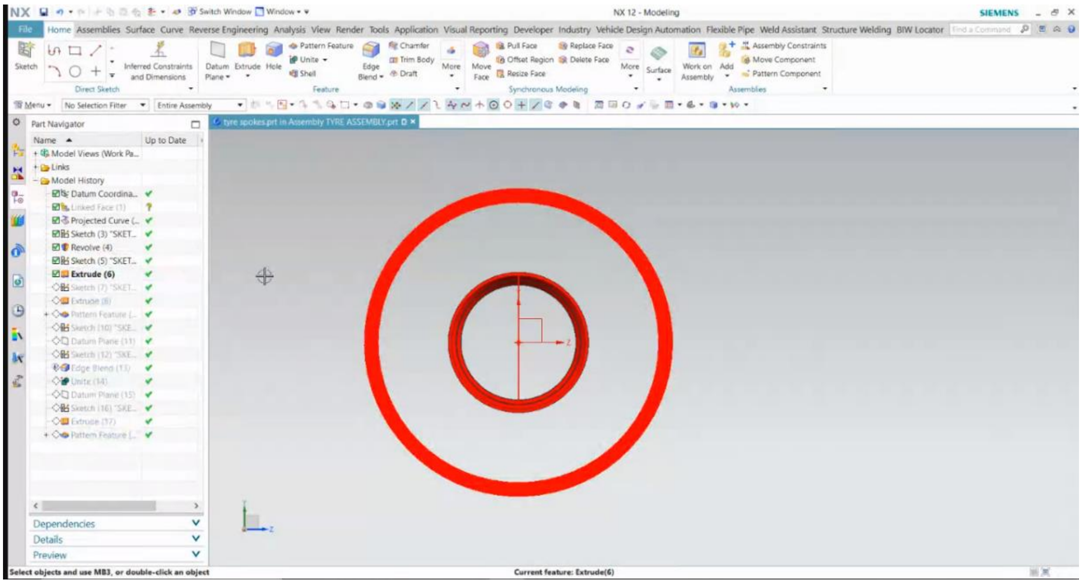


Fig 12: Sketching of Tyre

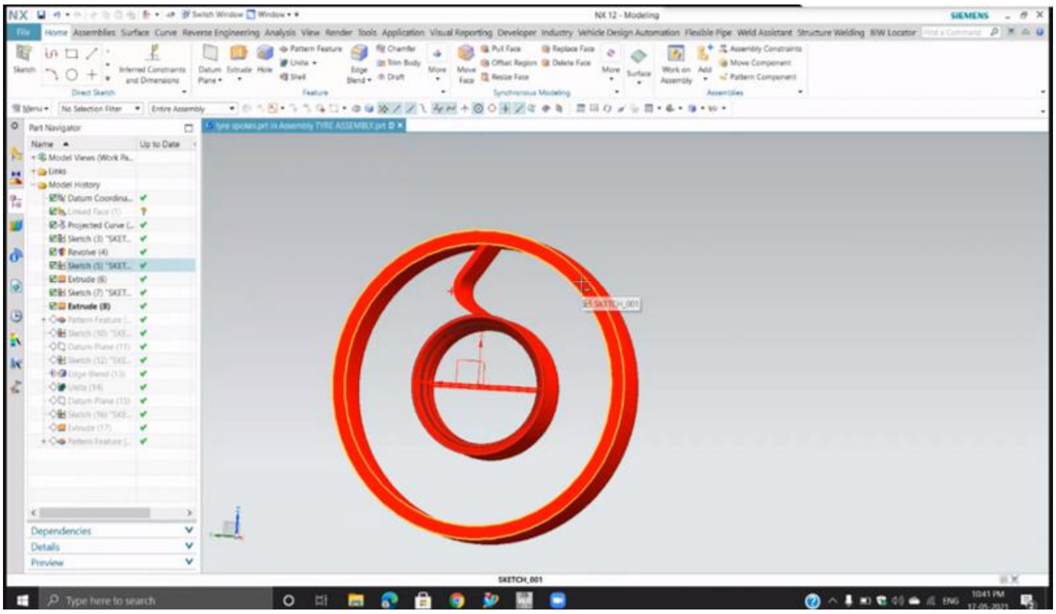


Fig 13: Sketching of a Spoke

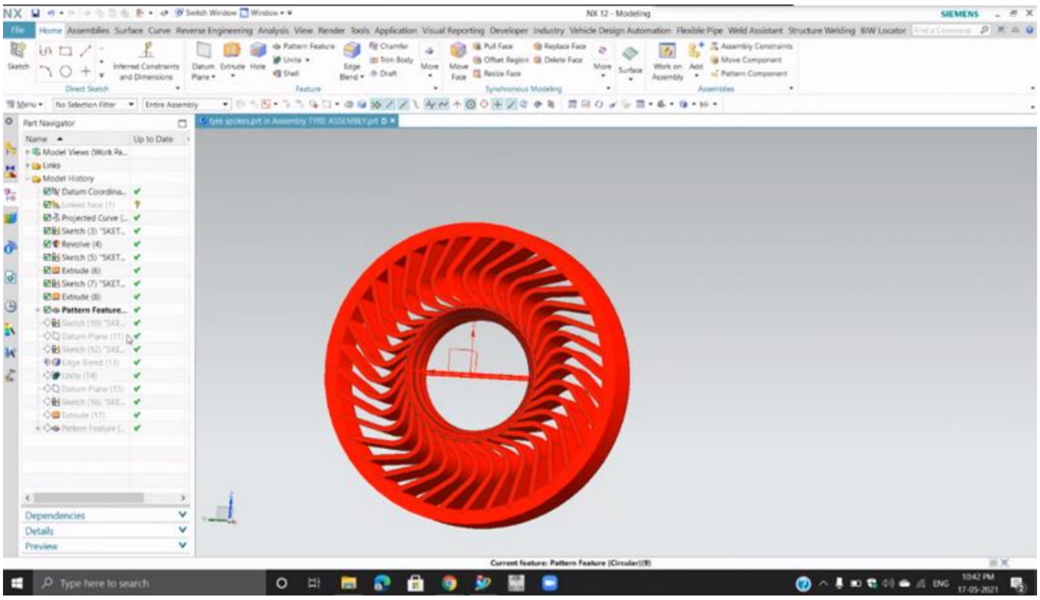


Fig 14: Modelling of The Spokes

Through pattern feature, design the spokes along the inner core of the tyre i.e., the spokes should attach between the inner core of the tyre and the exterior of the rim. Now design the grooves on the outer part of the tyre.

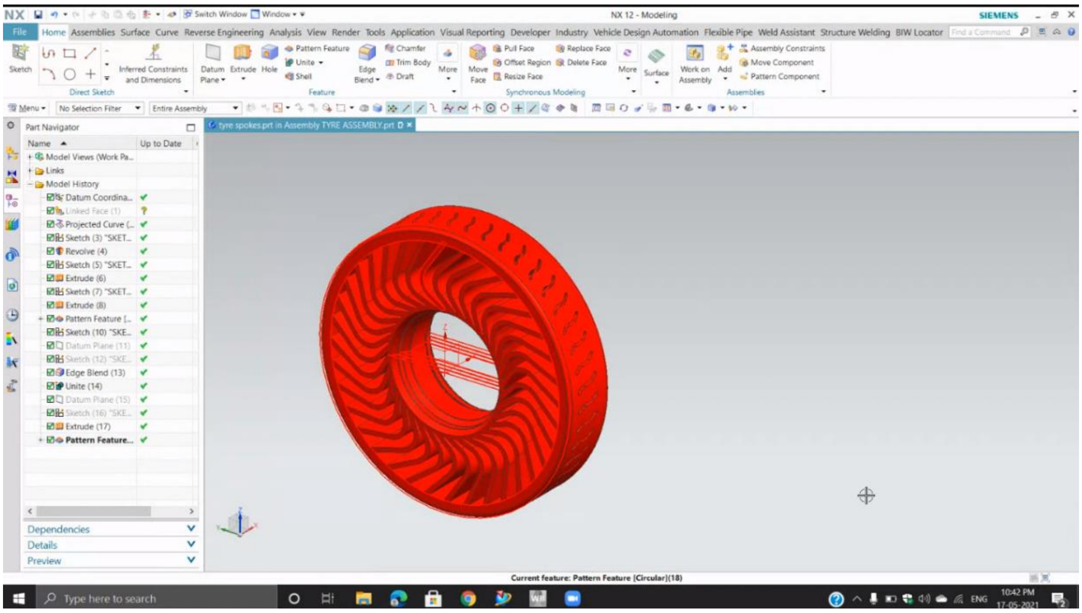


Fig 15: Modelling of The Grooves

3.4.4 Final Design:

By assembling the rim part and the sketched outer and inner part of the tyre with spokes attached, we can see the final design.

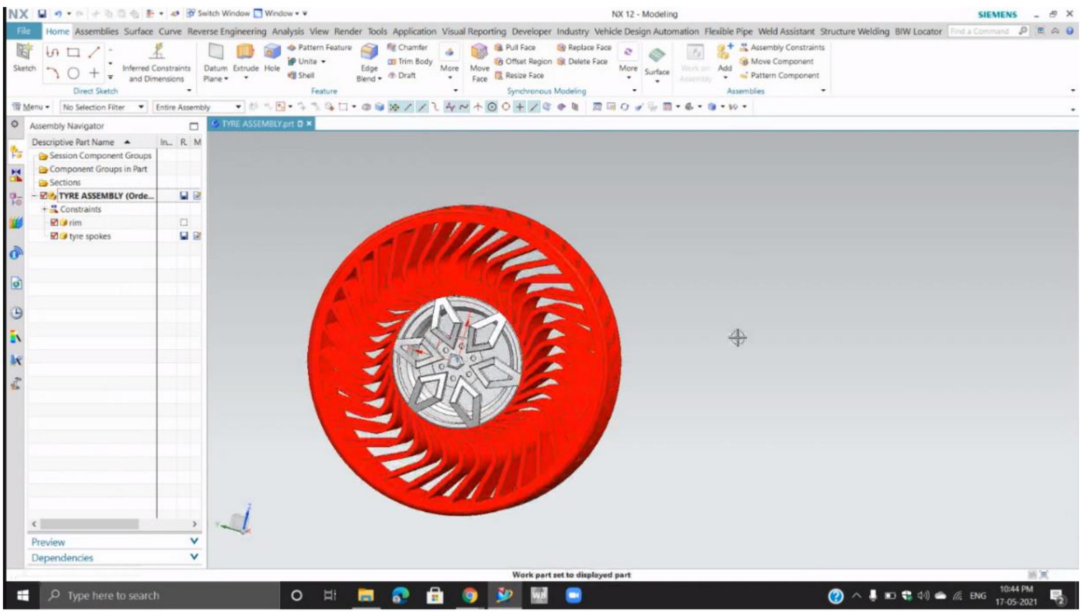


Fig 16: Final Design of Air-Less Tyre

CHAPTER 4 PROJECT IMPLEMENTATION

4.1 Introduction to Ansys:

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.

A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

4.2 Organization of Ansys Program

The ANSYS program is organized into two basic levels:

- Begin level (Start level)
- Processor (or routine) level

Begin level acts as a gateway into and out of the ANSYS program. Changing the name of job, database clearing, and binary files copying are program controls used. When we first enter the program, we at the begin level.

At the processor level, several processors are available; each processor is a set of functions that specific analysis task perform. For instance, the general preprocessor (PREP7) is the place we fabricate the model, the arrangement processor (SOLUTION) is the place we apply stacks and get the arrangement, and the general postprocessor (POST1) is the place we assess the outcomes and acquire the arrangement. An extra postprocessor (POST26), empowers we to assess arrangements results at particular focuses in the model as an element of time.

4.3 Performing A Typical Ansys Analysis:

The ANSYS system has numerous limited component investigation capacities, extending from a straightforward, direct, static examination to a nonlinear, transient element investigation. The investigation guide manuals in the ANSYS documentation set portray particular systems for performing examination for diverse building controls.

ANSYS analysis has three distinct steps:

- Construct the model
- Apply loads and boundaries
- Obtain the solution
- Review the results

The following table shows the brief description of steps followed in each phase.

Pre-processor	Solution processor	Post processor
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graphs
Assigning real constants	load definition	view animated results
Material definition	Solve	
Mesh generation		
Model display		

Table 3: Phases of ANSYS

4.3.1 Pre-Processor

Preprocessor prepares the input data for ANSYS analysis. The general preprocessor (PREP 7) contains solid modeling and mesh generation capabilities, and is also used to define all other analysis data with the benefit of data base definition and manipulation of analysis data. Parametric input, user files, macros and extensive online documentation are also available, providing more tolls and flexibility for the analyst to define the problem. Extensive graphics ability is available throughout the ANSYS program, including isometric, perceptive, section, edge and hidden-line displays of three-dimensional structures-y graphs of input quantities and results, and contour displays of solution results.

The preprocessor stage involves the following:

- Specify the title, which is the name of the issue. This is discretionary yet exceptionally valuable, particularly if various configuration cycles are to be finished on the same base mode.
- Analysis types thermal analysis, modal analysis, Harmonic analysis etc.
- Creating the model: The model may be made in preprocessor, or it can be imported from other design software by changing the file format.

- Defining element type: these chosen from element library.
- Assigning real constants and material properties like young`s modules, Poisson's ratio, density, thermal conductivity, damping effect, specific heat, etc.
- Apply mesh: Meshing is nothing but dividing the whole area into discrete number of particles.

4.3.2 Solution Processor:

Here we create the environment to the model, i.e., applying constraints & loads. This is the main phase of the analysis, where the problem can be solved by using different solution techniques. Here three major steps involved:

- Solution type required, i.e., static, modal, or transient etc. is selected.
- Defining loads: The loads may be surface loads, point loads; thermal loads like temperature, or fluid pressure, velocity is applied.
- Solve FE solver can be logically divided into three main steps, the pre-solver, the solution and post-solver. Model read by presolver which is created by the pre-processor and makes the arithmetical representation of the model and calls the mathematical-engine, which calculates the result. The result return to the solver and the strains, stresses, etc. for each node within the component or continuum are calculated by post solver.

4.3.3 Post Processor:

Post processing means the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affects the design, how the meshing is done.

Post processor analyzes results, which display stress and strain contours, distorted geometries, flow fields, safety factor contours, contours of potential field results; vector field displays shapes of mode and graphs related to time history. The post processor can also be used for algebraic operations, database manipulators, differentiation and integration of calculated results.

4.3.4 Review

Once the solution has been calculated, results can be reviewed in post processor. Two post processors are available: POST 1 and POST 26. We use POST 1, the general post processor to review the results at one sub step over the entire model or selected portion of the model. We can obtain contour displays, deform shapes and tabular listings to review and interpret the results of the analysis. POST 1 offers many other capabilities, including error estimation, load case combination, calculation among results data and path operations.

The simultaneous set of equations that the finite element method generates the solution taken by the computer, the results of the solution are:

- Nodal degree of freedom values, which form the primary solution.
- Derived values which frame the component arrangement.

Meshing:

Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components.

4.4 Static Structural Analysis:

The load effects can be calculated on a structure by ignoring the damping and inertia effects, such as those caused by time varying loads can be calculated by structural static analysis. Steady equivalent loads like steady inertia loads and time varying loads are included in Static analysis. Static analysis is utilized to decide the removals, burdens, strains and powers in structures or segments brought about by burdens that don't instigate noteworthy dormancy and damping impacts. Enduring stacking and reaction conditions are accepted, i.e. the stress and the structure's reactions are expected to differ gradually as for time. The kinds of load can be applied in static analysis include:

- Force and pressure application on body.
- Steady state inertial forces.
- Displacement.
- Thermal behavior.

Analysis Steps:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties.
- Specify restraints and loads.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.
- View results.

4.4.1 Process for Analysis of The Tyre

In this section, the modeling and analysis of the Air-less Tyre or Non-pneumatic tyre is discussed. Start the **ANSYS Product Launcher**. Select a working directory for storing your model data and launch **ANSYS Workbench**. You will see the software outfit as Fig. 1

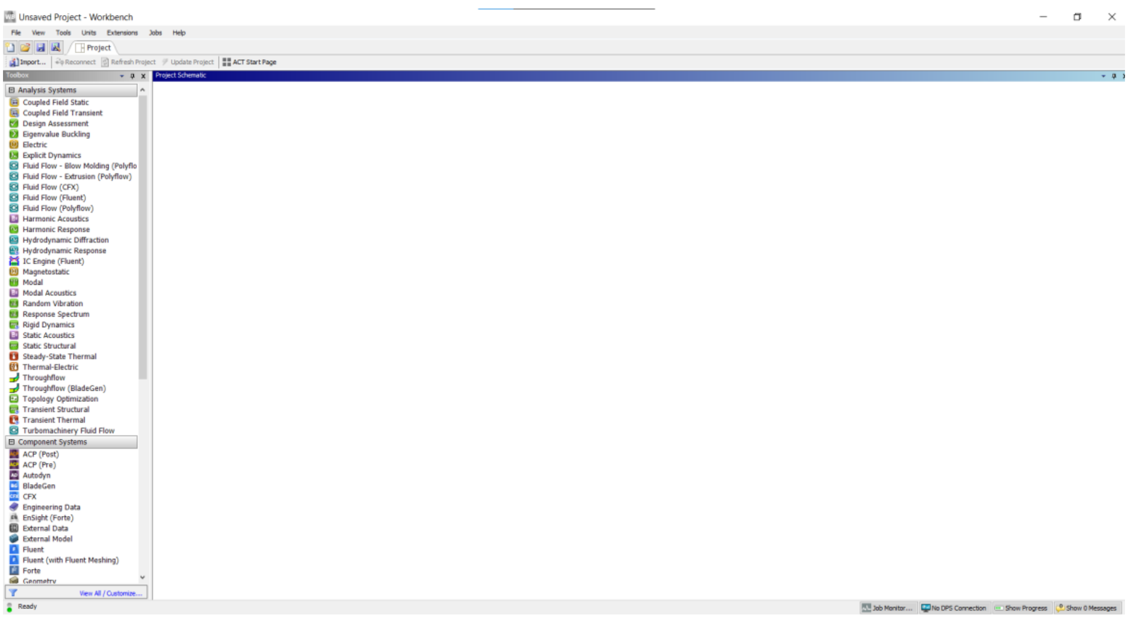


Fig 17: Ansys Workbench Software Outfit

Drag Static Structural (ANSYS) tab from Analysis Systems of Toolbox window to the Project Schematic window. Now, your static structural analysis model should be in the Project Schematic.

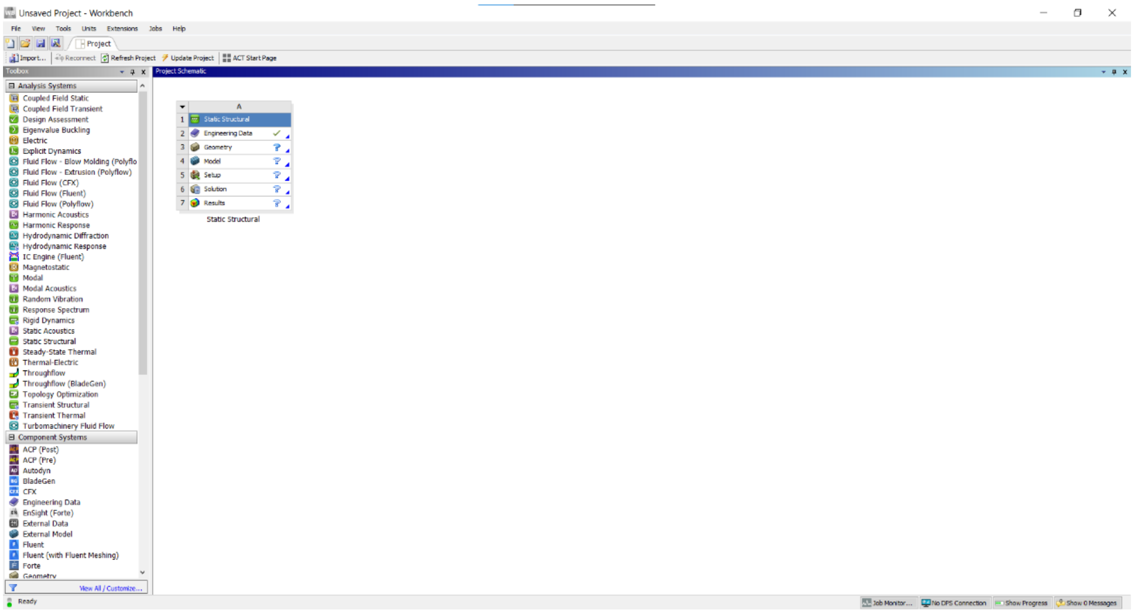


Fig 18: Tool Box View

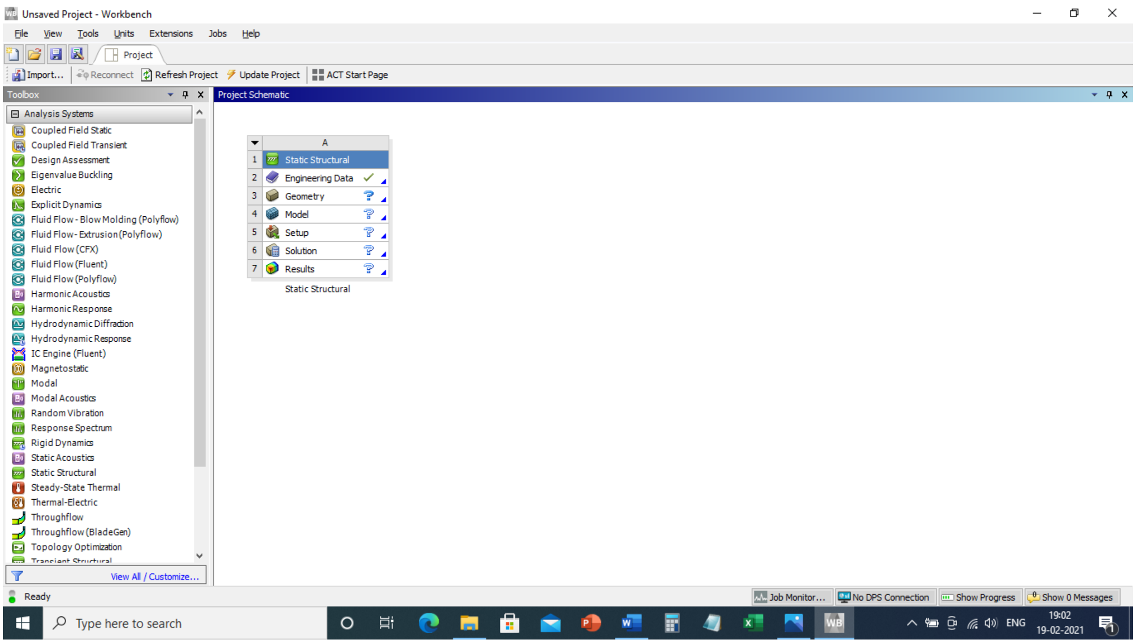


Fig 19: Static Structure

Now, the Engineering Data of the materials should be added to your project to assign during modelling the product. To select more materials under different sources, we should select engineering data sources tab which is adjacent to filter engineering sources.

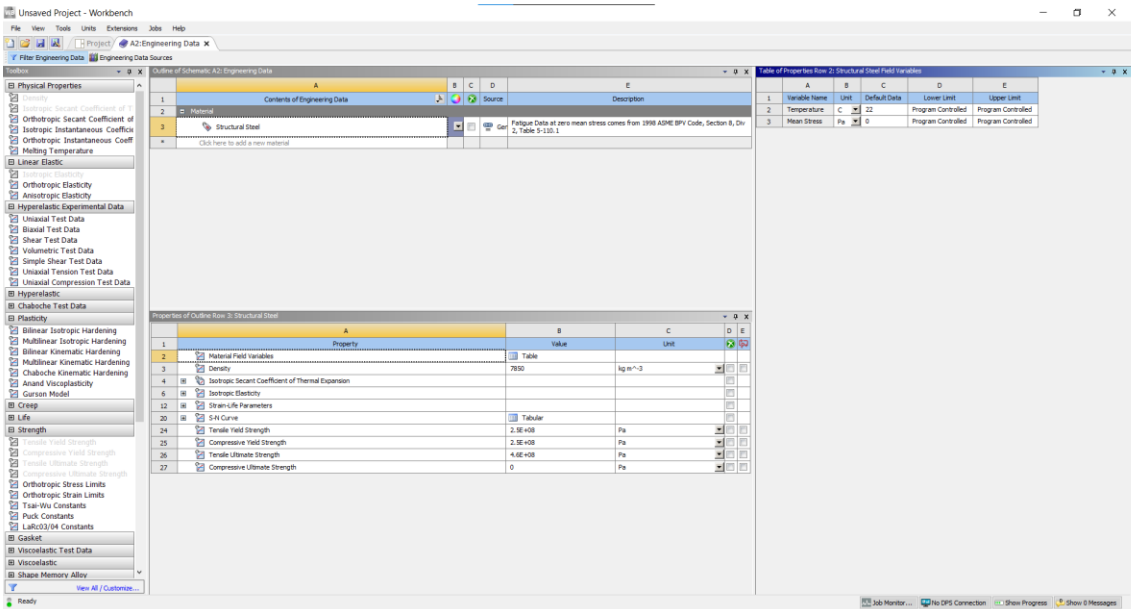


Fig 20: Engineering Data Materials

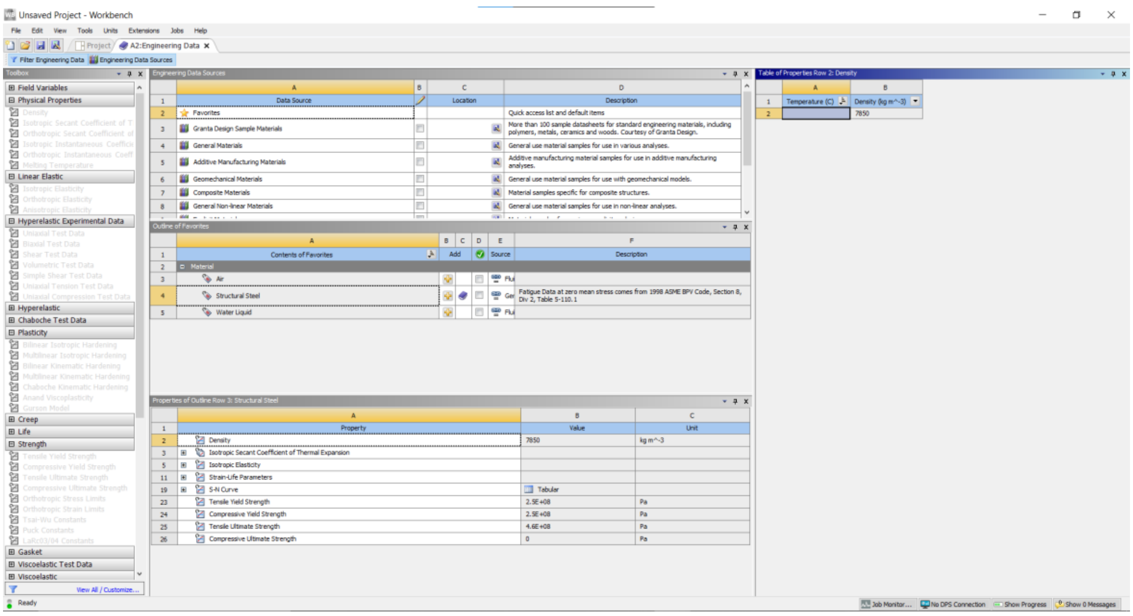


Fig 21: Engineering Data Sources

After completion of Engineering data tools, the designed product should be imported to the project Geometry.

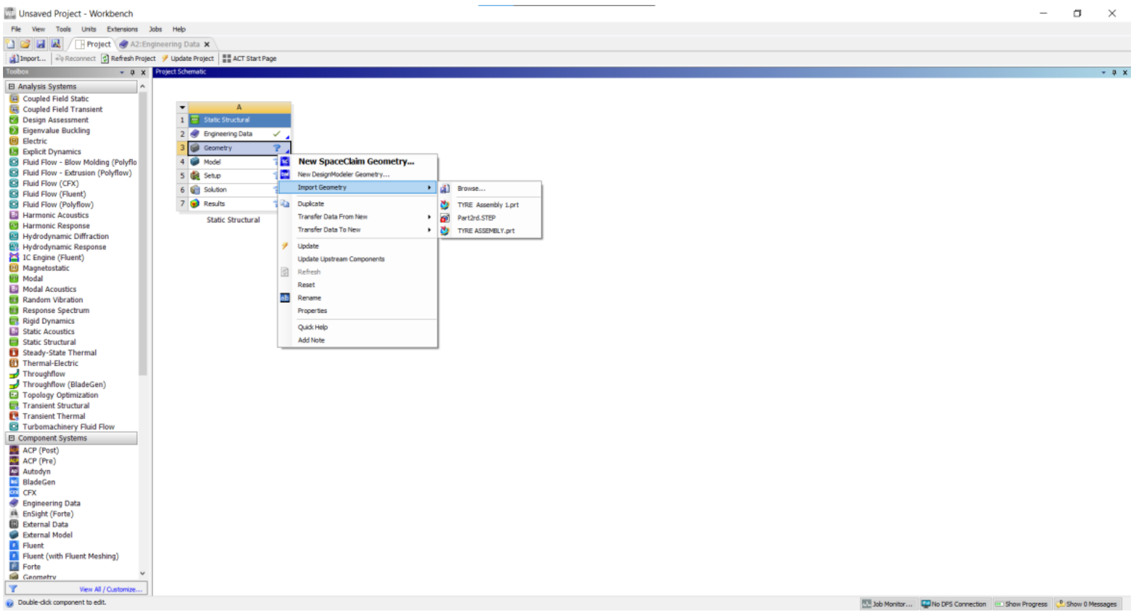


Fig 22: Importing the Geometry

In design modeler, road surface to the tyre is been sketched. By selecting the coordinate axis and the required direction for the sketch and extruding the sketch for required dimension is done.

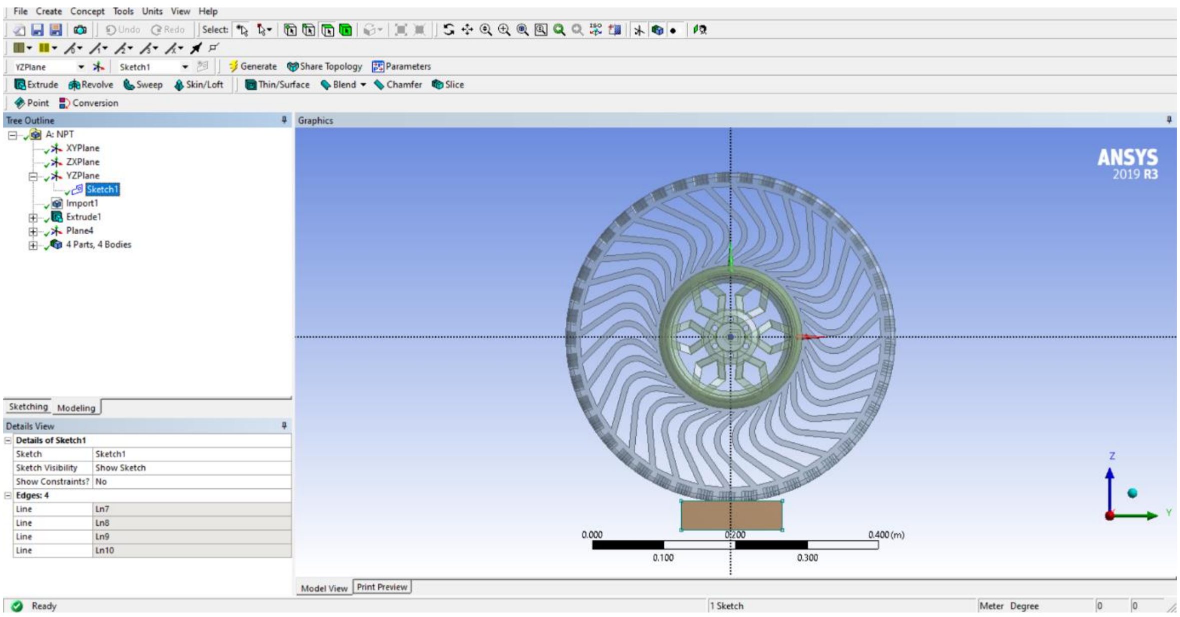


Fig 23: Selecting the sketch

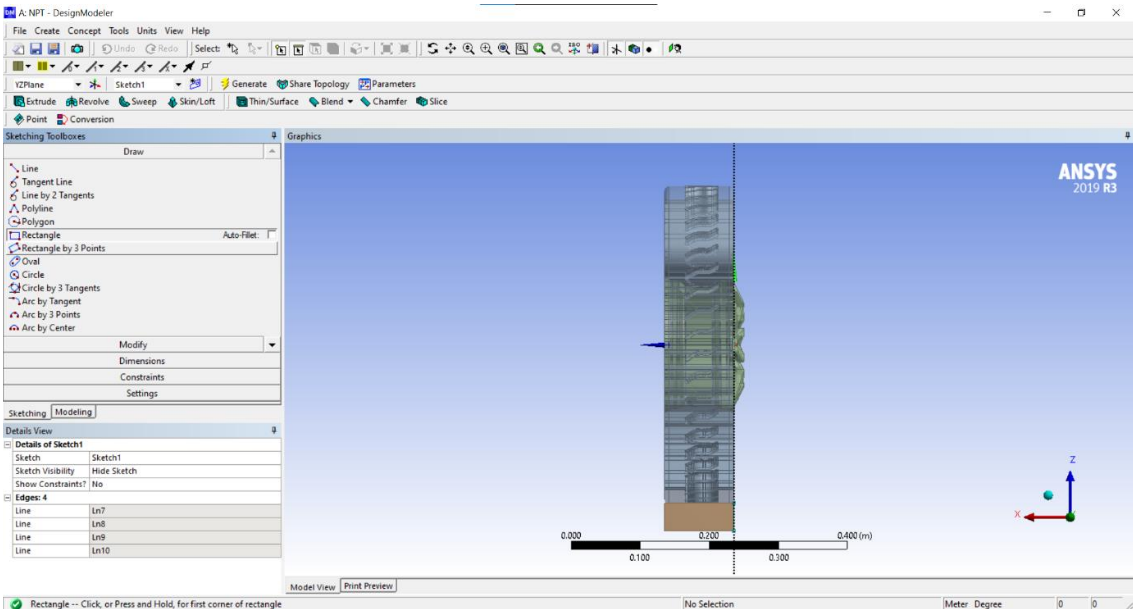


Fig 24: Sketching and Extruding the Road Surface

4.5 Static Structural of The Model

In the model tool, the material assignment for different parts of the product, assigning of force, fixed support to the tyre, meshing and solving the model for Deformation Analysis is carried out.

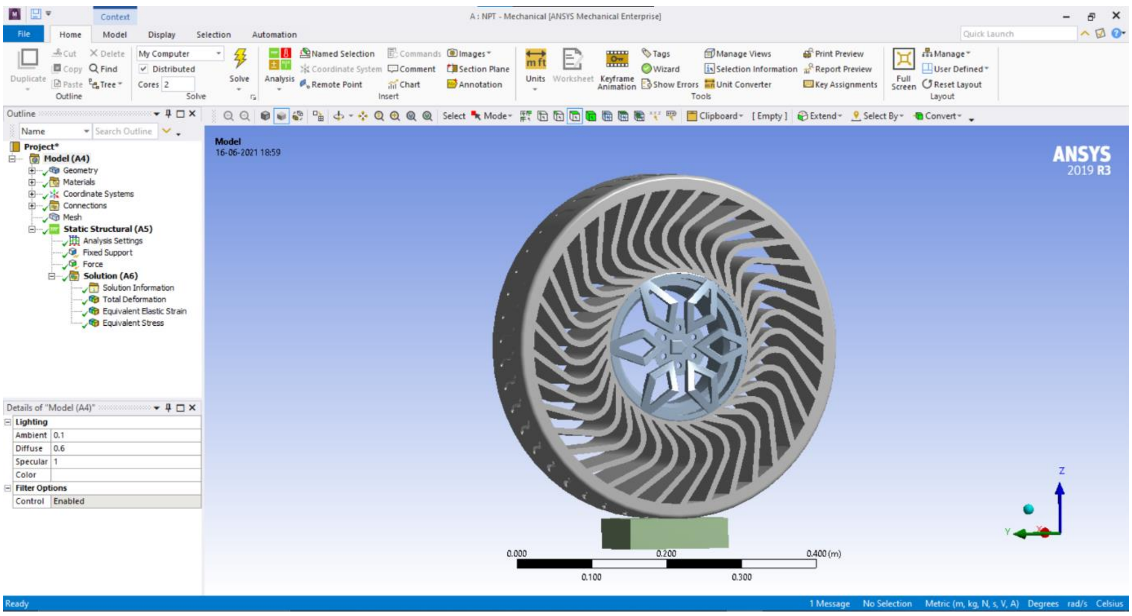


Fig 25: Model of the Type

Under the project tool the model is displayed. The model consists of geometry, materials, coordinate system, connections, mesh, static structural and solution.

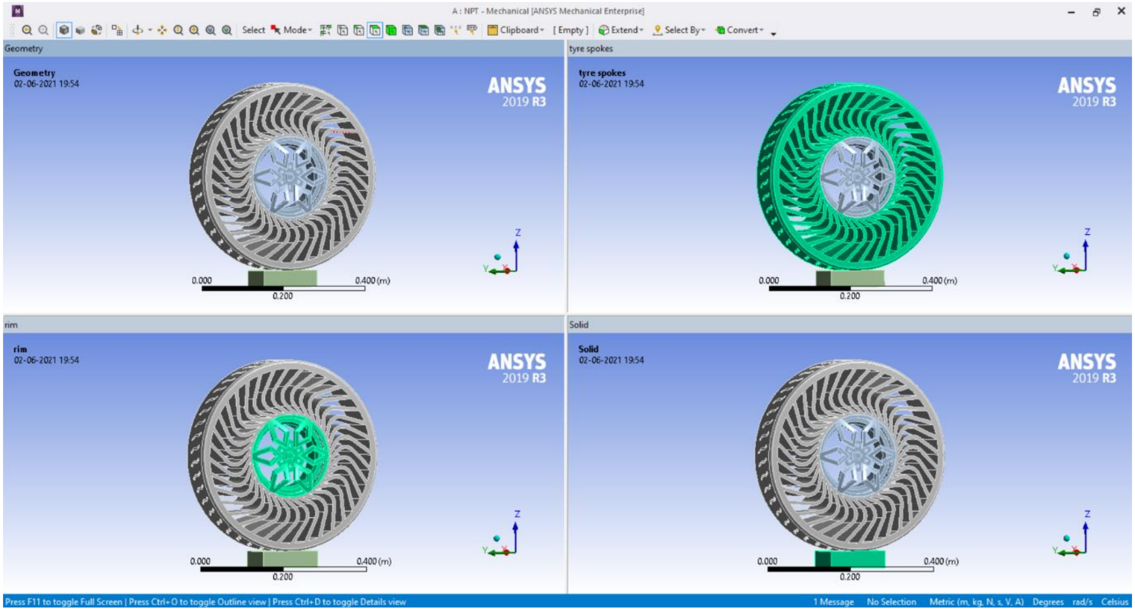


Fig 26: Geometry of The Mode

In the below figures we can see the geometry of each part of the tyre and the coordinate system.

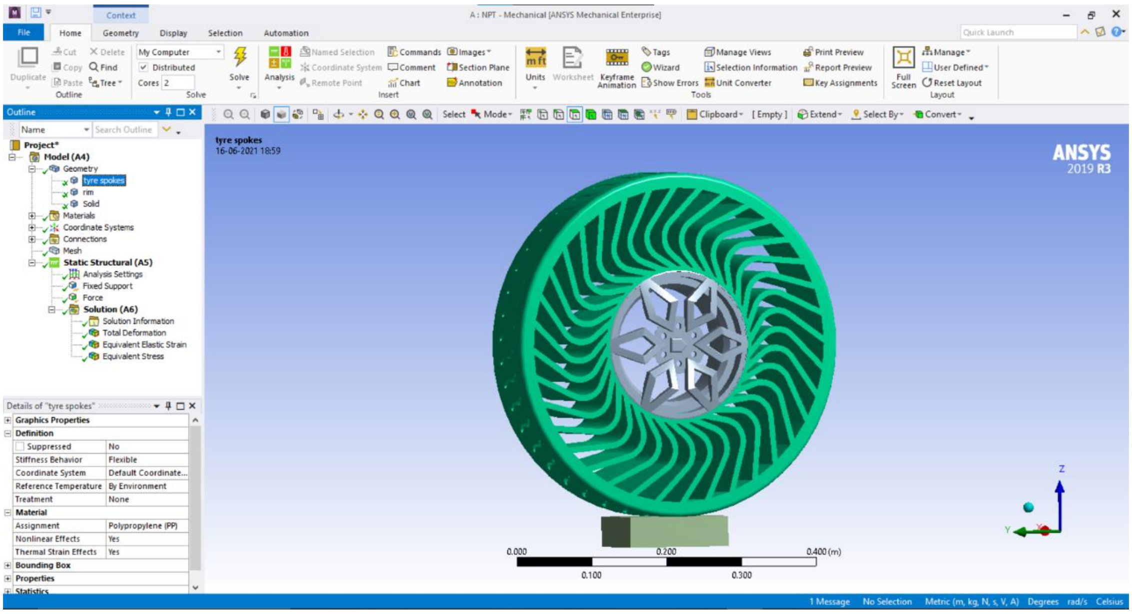


Fig 27: Geometry of Tyre Spokes

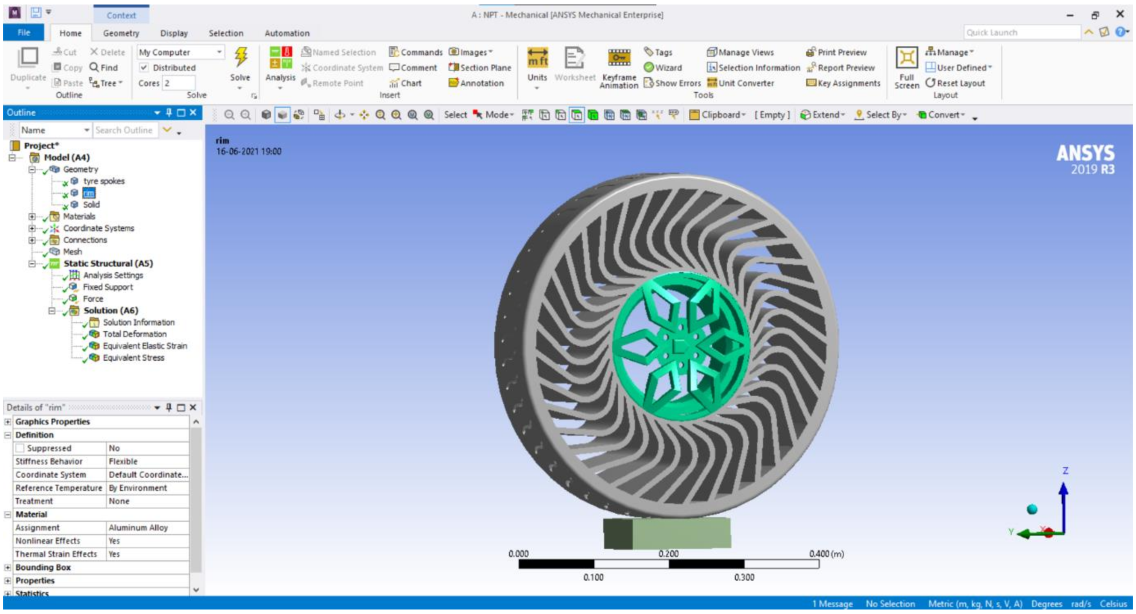


Fig 28: Geometry of The Rim

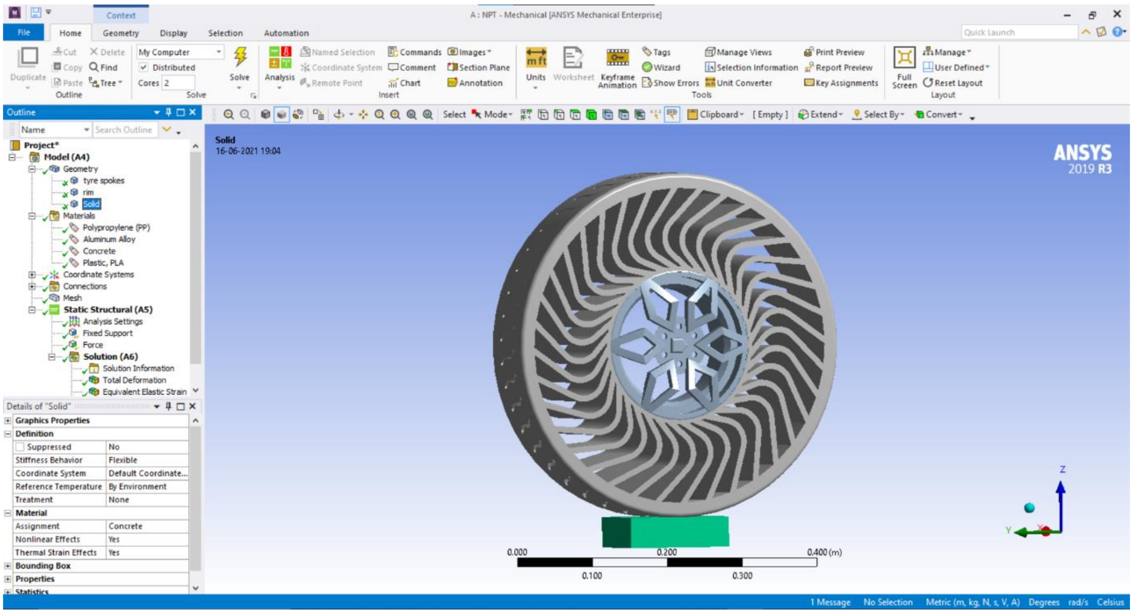


Fig 29: Geometry of The Solid

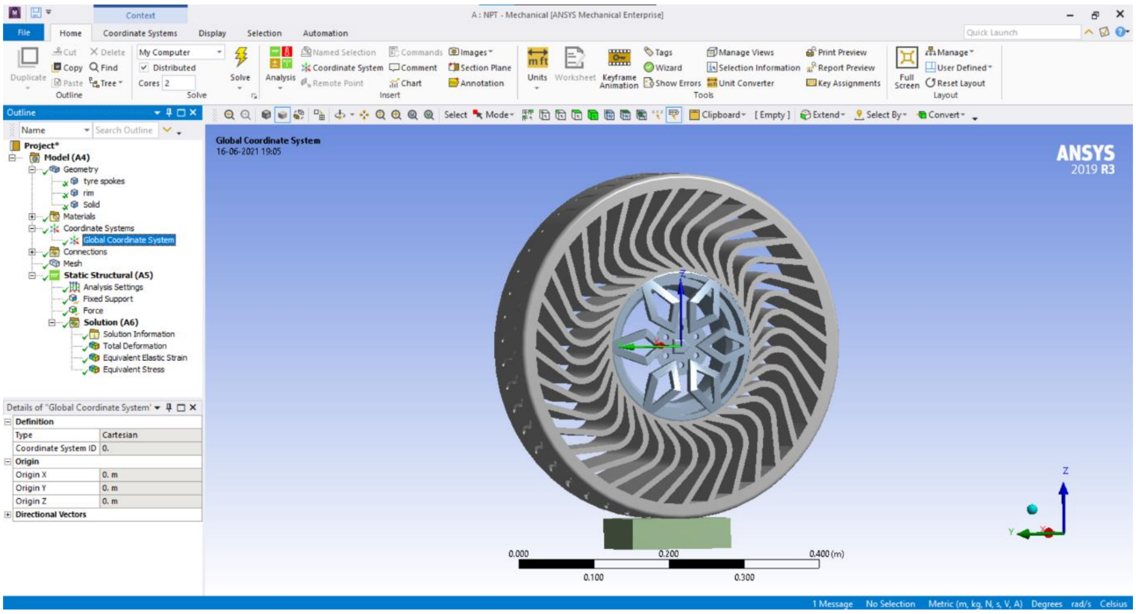


Fig 30: Coordinate Axes Along the Tyre

After assigning the materials for each part off the product under materials tool, we can see the connection parts in the product. There are two connection regions in our product. Red colour region indicates the contact bodies and the blue colour region indicates the target bodies. They are shown in the below figures.

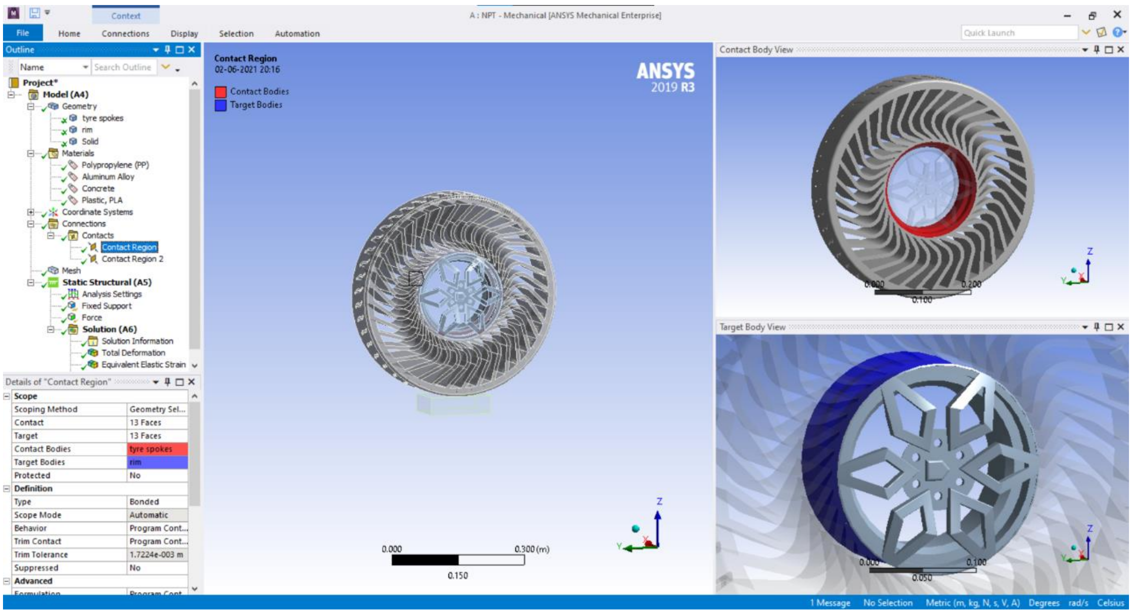


Fig 31: Contact Region-1 (Tyre Spokes and The Rim)

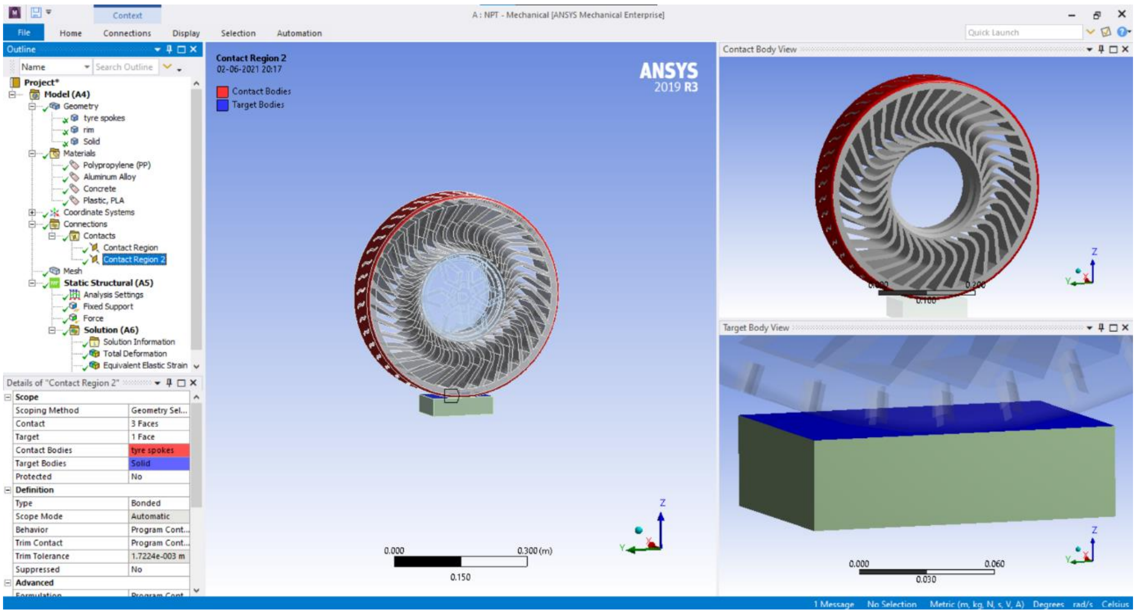


Fig 32: Contact Region 2 (Solid and The Tyre Spokes)

Generation of mesh: to generate the mesh model, a fixed support and the required force in the specific direction has to be defined in the static structural. After assigning the support and the force, we should solve the model to generate the mesh.

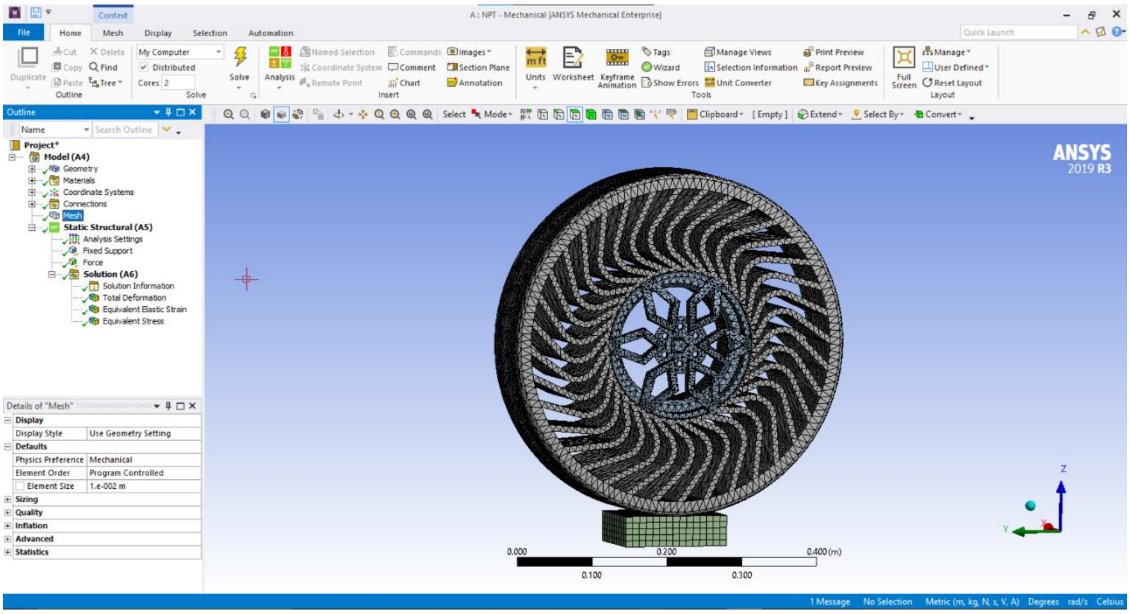


Fig-33: Mesh Model

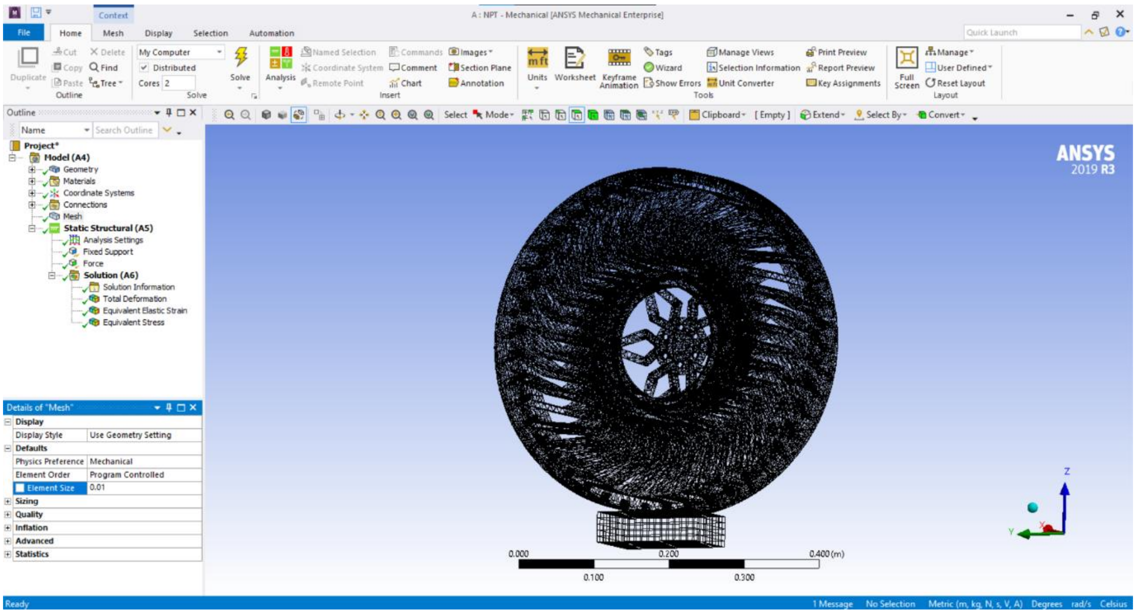


Fig-34: Wire Frame Model

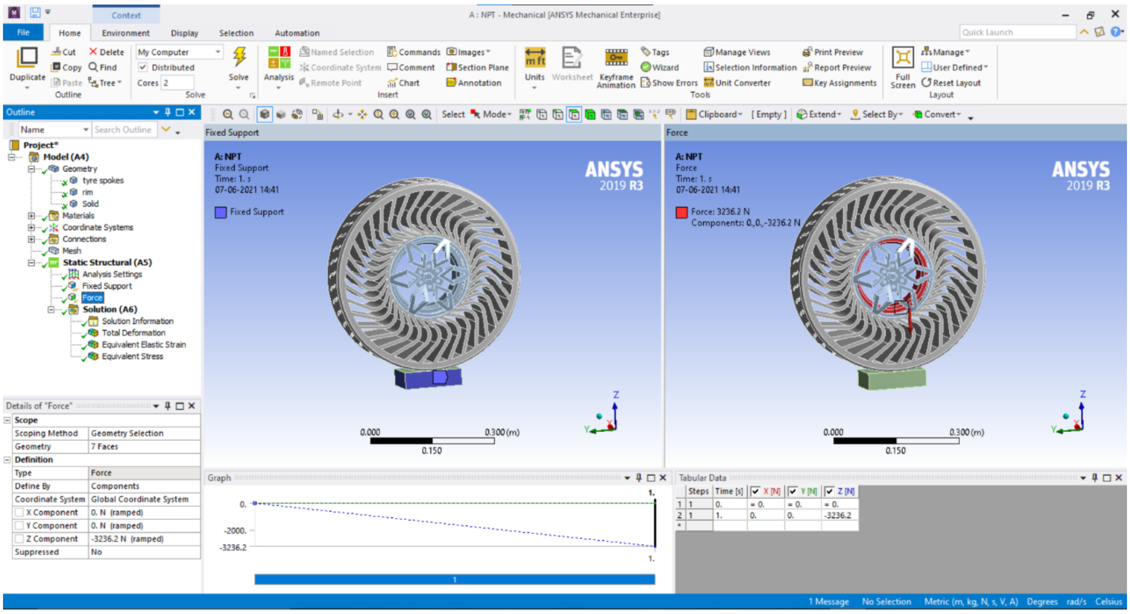


Fig 35: Static Structural

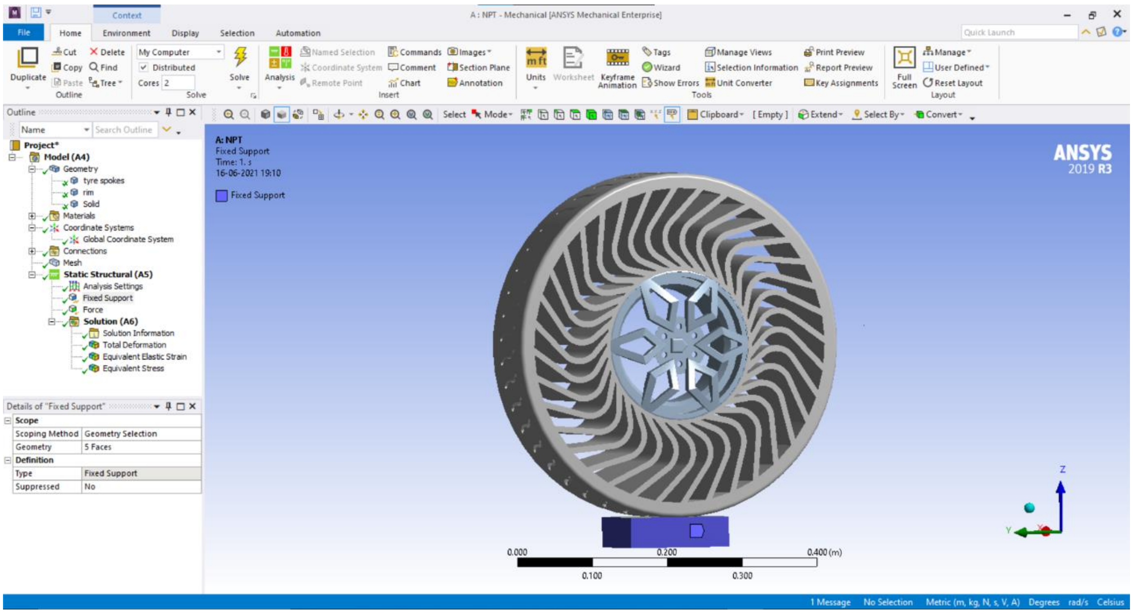


Fig 36: Fixed Support of The Tyre

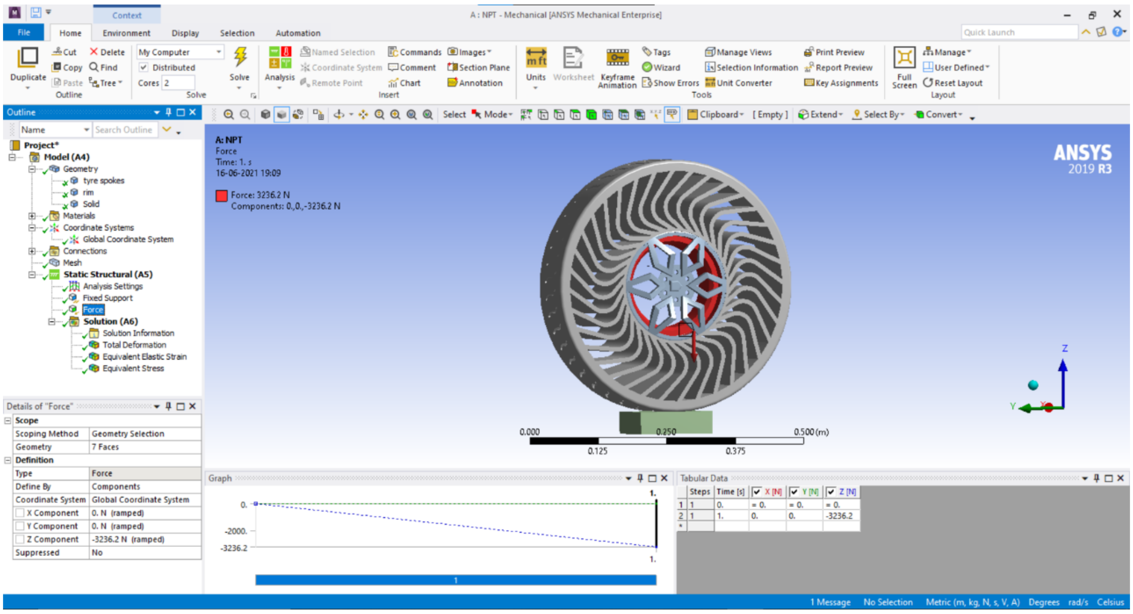


Fig 37: Force on The Tyre

(F=3236.2n)

S.No	Weight	Kilograms	Distribution of Force on One Tyre	Distribution of Weight on One Tyre (Newtons)
1	Compact car	1040	260	2,549.729
2	Four Passengers (Approx.)	210	70	686.4655
3	Total weight	1250	330	3236.2

Table-4 Forces on theTyre

Now the solution for the model is done and required solutions should be added. After solving the model, the total deformation, equivalent stress and Equivalent elastic strain results can be seen under the solution.

4.6 Analysis Solution

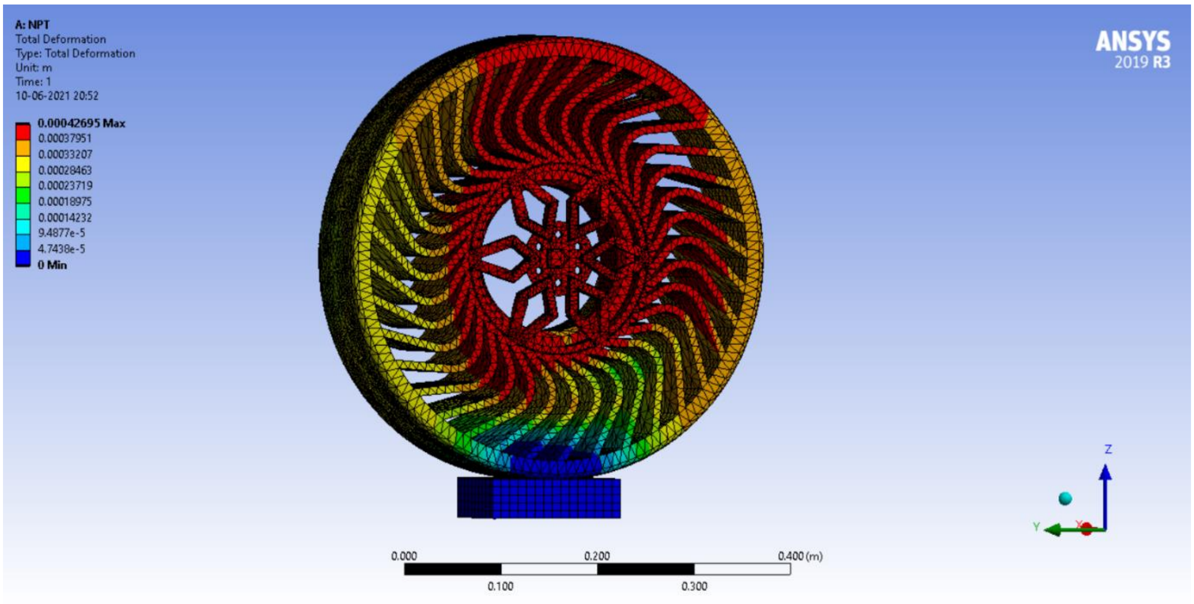


Fig 38: Total Deformation

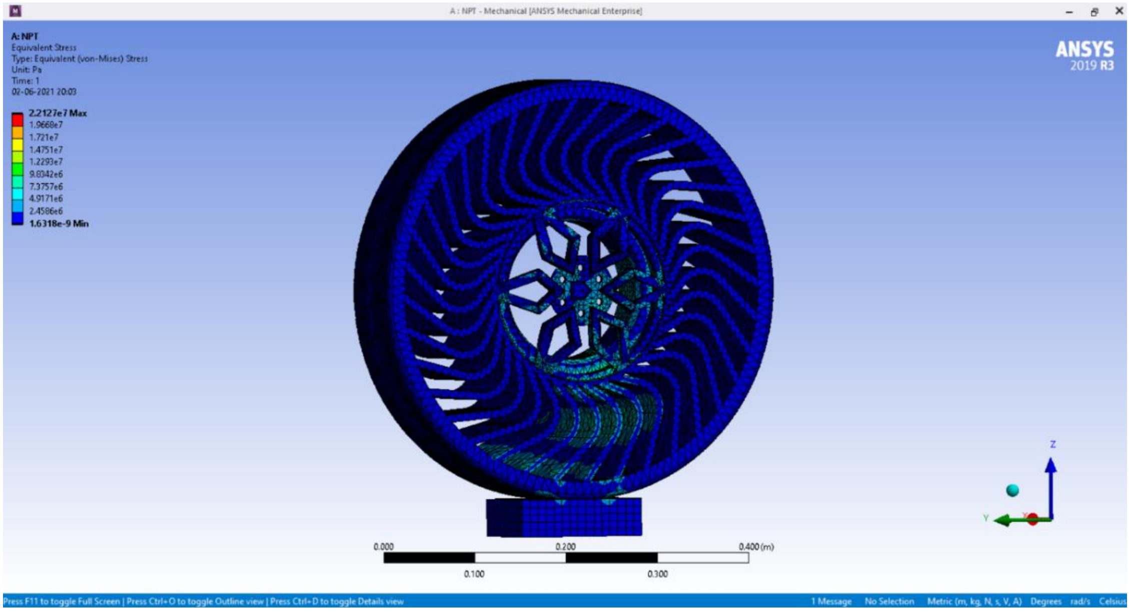


Fig 39: Equivalent Stress

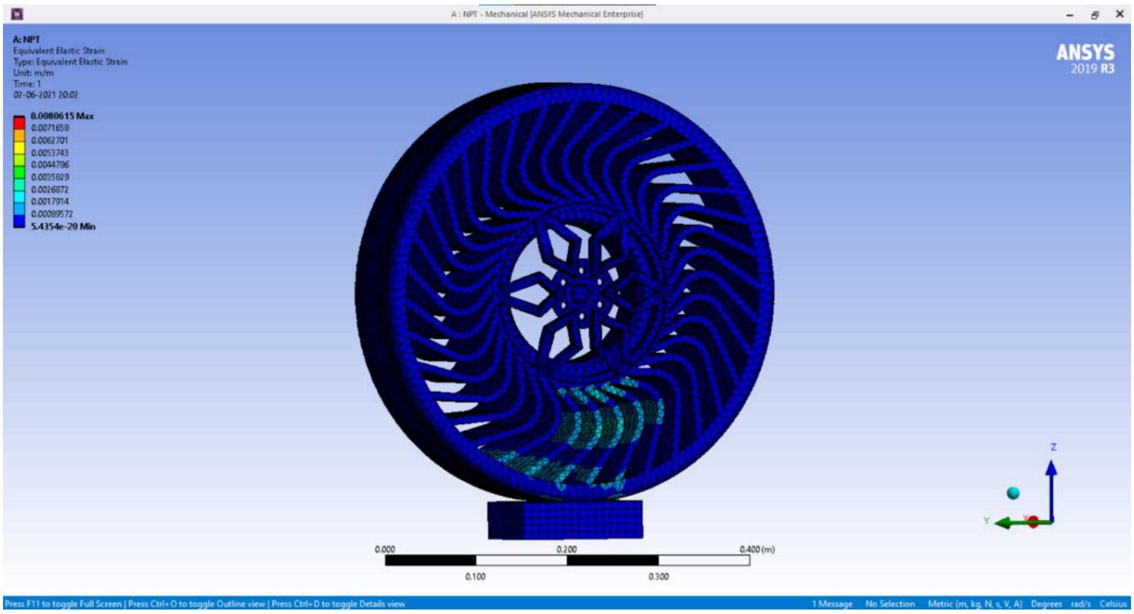


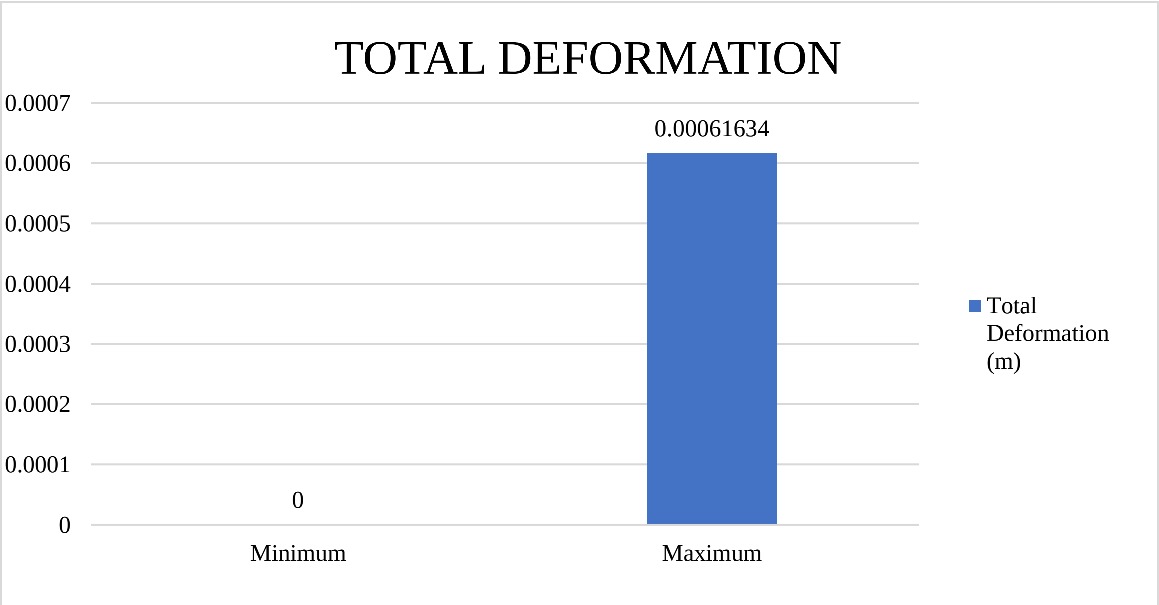
Fig 40: Equivalent Elastic Strain

4.7 Result

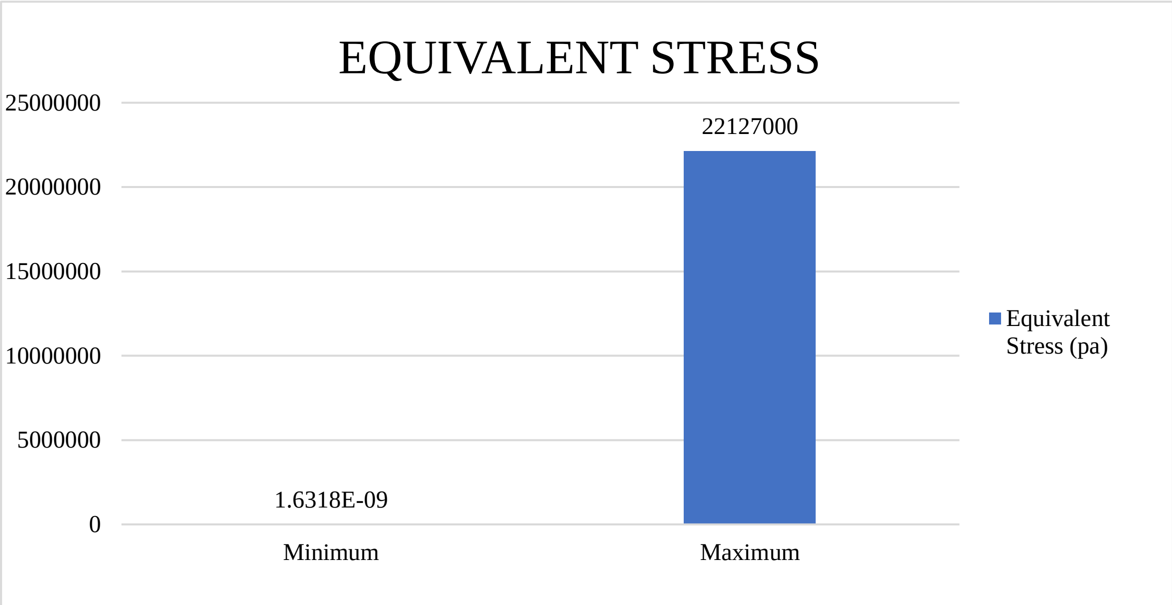
S. No	Type	Minimum	Maximum
1	Total Deformation(m)	0	0.00061634
2	Equivalent stress	1.6318e-9	2.2127e7
3	Equivalent elastic strain	5.435e-20	0.0080615

Table 4: Result

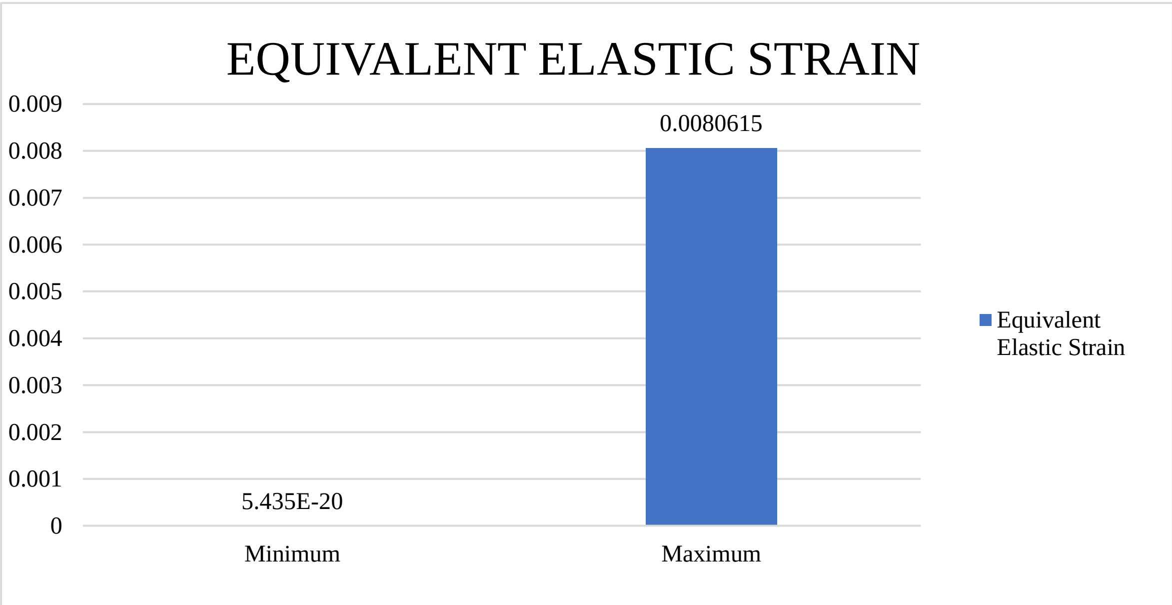
4.8 Graphs



Graph 1: Total Deformation



Graph 2: Equivalent Stress



Graph 3: Equivalent Elastic Strain

CHAPTER 5 PROTOTYRE

5.1 Prototype of The Product By 3d Printing

3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as plastics, liquids or powder grains being fused together), typically layer by layer.

By considering the design and the analysis the product prototype of the tyre is 3D printed.

5.1.1 Specifications of 3d Printer:

Process: Fused Deposition Modelling

Bed size: 200*200*200

X, Y Axis Positioning Resolution = 0.02mm

X, Y Axis Maximum Speed = 5000mm/min

Z Axis Positioning Resolution = 0.005mm

Z Axis Max Speed = 1000mm/min

Material Support = PLA

Position Resolution = 0.1mm

Filament Temperature = 210

Maximum Temperature = 260C

Software format = STL, G Codes

Total Print Time = 40hrs

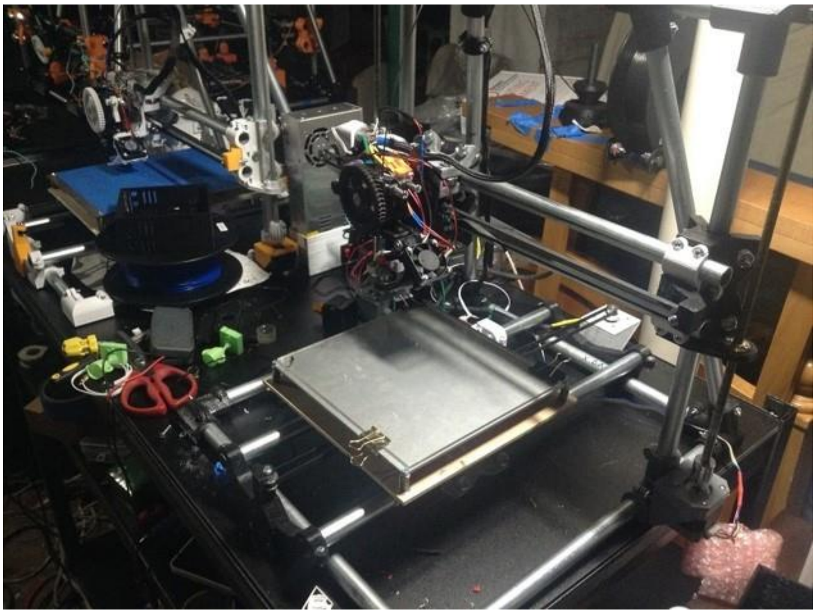


Fig 41: 3D Printer

5.2 Final Prototype of The Tyre:

Fig 42: Prototype of Tyre

Fig 43: Prototype of Rim

Fig 44: Assembly of the Tyre

CHAPTER 6 CONCLUSION AND FUTURE ENHANCEMENT

Conclusion

- The design of the tyre is done in NX cad software and the deformation analysis of the tyre is done in Ansys Workbench. The deformation of the tyre after the analysis with the PLA material to the tyre is 0.00061634. The dimensions are considered from the original equipment manufacturers standards. The structural analysis is carried out by considering the force applied to the tyre.

  The references taken for the load on the tyre is a curb weight of the compact car and applying the force on the required part. The Air-less tyre with deformable spokes would be able to replace the existing traditional pneumatic tyres in the present market.

- The prototype of the model is done by 3D printing. The creation of 3D printed object is achieved using additive process. In an additive process an object is created by layering down successive layers of material until the object is created.

- The properties of NPT like contact pressure, rolling resistance and load carrying can be varied by altering the dimensions or different materials used to manufacture NPT.

Future Enhancement

- The concept of Airless tyres will increase the safety of cars by limiting the speed of the vehicle as well as have a positive impact environmentally. Many Organizations like Micheline and Bridgestone are developing and readily looking forward to launching airless tyres by 2024.

- The tyres require less maintenance and the worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheelchairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement. Airless tyres can be a revolutionary concept in the future.

Publication

- Conference
- ICRIM-2021
- “Online International Conference on “Robotics and Intelligent Manufacturing”

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A Major Project Report

On

TAILORING THE THERMO MECHANICAL PROPERTIES OF HIGH-PERFORMANCE AEROSPACE & AUTOMOTIVE COMPOSITE MATERIALS

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled "**Tailoring The Thermomechanical Properties Of High-Performance Aerospace And Automotive Composite Materials**", is being submitted BY **Teja Sai Sumanth Gannamaneedi (17K81A0322), Abhinav Jeevan Gittingula (16K81A0361), M. Ashish Calvin (17K81A0335), Y. Sai Kiran (15K81A03E8)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Signature of Guide

Mr. DILEEP PANCHAL
Assistant Professor,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology in Department of MECHANICAL ENGINEERING**, Academic Year: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **Tailoring the Thermomechanical Properties of High-Performance Aerospace And Automotive Composite Materials** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

TEJA SAI SUMANTH GANNAMANEEDI -17K81A0322
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ABSTRACT

There is a rising need to create high performance, lightweight and strong yet tough materials for use in various industries including aerospace (civil, military aircraft), automotive (sports, utility, emergency vehicles) and others (civil engineering etc.). The use of composite materials to meet this need is now commonplace for several reasons. These include significant weight savings over traditional materials and design flexibility (load bearing only where required/reduced number of parts). In this project we modelled such multiple composite sheets and experimented with their mechanical properties by changing materials and defined which material composite is safe to use in automobile and aerospace industry.

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CHAPTER 1
INTRODUCTION

1.0 OVERVIEW OF THE PROJECT

There is a rising need to create high performance, lightweight and strong yet tough materials for use in various industries including aerospace (civil, military aircraft), automotive (sports, utility, emergency vehicles) and others (civil engineering etc.). The use of composite materials to meet this need is now commonplace for several reasons. These include significant weight savings over traditional materials and design flexibility (load bearing only where required/reduced number of parts).

In this project we started doing research on the materials and later continued with the design phase of the project and by deciding what type and composition of the alloys would be better in use. Then for results of the materials which we decided would be better in our theoretical study will be applying the material on the designs which we did for their respective industries parts (Aeroplane wing for Aerospace Industry and Sedan Car Door panel for the automobile industry) and also stimulating the real-life scenario of constraints on the design and analyzing using ANSYS software for practical results.

1.1 OBJECTIVES OF THE STUDY

In this project we will model such multiple composite sheets and experiment with their mechanical properties by changing materials and define which material composite is safe to use in automobile and aerospace industry by analyzing in the ANSYS software.

By separating every goal of the project step by step. Following the steps of procedure, we followed in our project

> Study the previous existing materials in Aerospace and Automobile Industries.

> Design a Surface design of Car Door Panel based on the standards to be followed.

> Design a Surface design of Aeroplane wing based on the standards to be followed.

> Analyze the Car Door Panel Design in ANSYS software.

> Analyze the Aeroplane wing Design in ANSYS software.

1.2 SCOPE OF THE PROJECT

From this study project we will try to bring out other existing alloy materials which already exists in this industries and prove them that they can be used in the vehicles of the industries for better performance and also betterment in other perspectives which we consider while manufacturing and designs the vehicles for these industries.

So that we can make more reliable fast and lightweight materials in Aeroplane and automobile industry.

1.3 MATERIAL REQUIREMENT

In our study project we kept our most concentration towards the materials and alloys which we used which are aluminium, titanium and zinc.

We used two materials for the final test in this project they are

1) AL-7075-T6
2) TI-6AL-V4

1. **AL-7075-T6:** 7075 aluminium alloy (AA7075) is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminium alloys because of microsegregation but has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most used aluminium alloys for highly stressed structural applications and has been extensively used in aircraft structural parts.

2. **TI-6AL-V4:** Ti-6Al-4V (UNS designation R56400), also sometimes called TC4, Ti64, or ASTM Grade 5, is an alpha-beta titanium alloy with a high specific strength and excellent corrosion resistance. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and excellent corrosion resistance are necessary

such as e.g. aerospace industry and biomechanical applications (implants and prostheses).

1.4 PROCUMENT OF EQUIPMENT

The equipment we used are

1. ANSYS software:(Version-2019 R3): Ansys, Inc. is an American company based in Canonsburg, Pennsylvania. It develops and markets multiphysics engineering simulation software for product design, testing and operation and offers its products and services to customers worldwide. Ansys was founded in 1970 by John Swanson. Swanson sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, Ansys acquired numerous other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and other physics analysis

2. SOLIDWORKS software: (Version 2020): SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systèmes, that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on an Intel-based Mac with Windows installed, the application's developer recommends against this

3. Windows 10 Computer: To perform both designing and analysis operations by running ANSYS and SolidWorks Softwares. We performed on a 8GB RAM and 4GB GPU with Intel i5 7th generation CPU computer.

1.5 ORGANIZATION OF CHAPTERS

Below from chapter 1.5.0 – 1.5.5 are the summary of how we organized our chapters to Chapters 1 to 6.

1.5.0 INTRODUCTION

In Introduction chapter of this report, we have summarized every phase of the project like Overview, Objectives, Scope of this project.

1.5.1 LITERATURE SURVEY

In literature survey chapter we will be discussing how we started our study at the theoretical stage of the project.

1.5.2 PROJECT DESIGN

In this chapter we will be discussing every part of the design phase how we decided the designs and steps of the designing.

1.5.3 PROJECT IMPLEMENTATION

In this phase we will be discussing how we implemented the design with the analysis.

1.5.4 PROJECT TESTING

In this we chapter we will be showing and discussing the analysis phase of the project and their numerical.

1.5.5 CONCLUSION AND FUTURE ENHANCEMENT

In Conclusion chapter we can have the result statement and the future development and usage.

CHAPTER 2
LITERATURE SURVEY

In this chapter we will be providing the information we gone through while researching for perfect material and also better designs to test on.

2.1 LITERATURE REVIEW ON COMPOSITES

Composites exist in nature. A piece of wood is a composite, with long cellulose fibres held together by a substance called lignin. Composite materials are formed by combining two or more materials that have quite different properties, and they do not dissolve or blend into each other. The different materials in the composite work together to give the composite unique properties. Humans have been using composite materials for thousands of years in different areas. The first uses of composites date back to the 1500 BC, when early Egyptians and Mesopotamian settlers used a mixture of mud and straw to create strong and durable buildings. The combination of mud and straw in a block of brick provides it a strong property against both squeezing and tearing or bending. The straw continued to provide reinforcement to ancient composite products, including pottery and boats. In 1200 AD, the Mongols invented the first composite bow using a combination of “animal glue”, bone, and wood. The bows were pressed and wrapped with birch bark. These bows were powerful and accurate. Composite Mongolian bows helped to ensure Genghis Khan’s military dominance. Due to their advantages such as being light weight and strong, many of the greatest advancements in composites were the result of wartime needs. During World War II, many composite materials were developed and moved from the laboratory into actual production.

The development and need for composite materials also result in the fibre-reinforced polymers (FRP) industry. By 1945, more than 7 million pounds of glass fibres were used for various products, primarily for military applications. Composite materials continued to take off after the war and grew rapidly through the 1950s. The composite innovators were ambitiously trying to introduce composites into other markets such as aerospace, construction, and transportation. Soon the benefits of FRP composites, especially its corrosion resistance, became known to the public sector. Boats were one obvious product that benefited. The first composite commercial boat hull was introduced in 1946. A full automobile body was made from composite and tested in 1947. This led to the development of the 1953 Chevrolet Corvette. The advent of the automobile age gave rise to several new methods for moulding such as compression moulding of bulk moulding compound (BMC) and sheet moulding compound (SMC). The two techniques emerged as the dominant method of moulding for the automotive industry and other industries. In the early 1950s, manufacturing methods such as large-scale filament winding, pultrusion, and vacuum bag moulding were developed. In the 1960s, the marine market became the largest consumer of composite materials. In 1961, the first carbon fibre was patented and several years later became commercially available. In the 1970s the composites industry began to mature. Many better resins and improved reinforcing fibres were developed during this period for composite applications. In the 1970s, the automotive market surpassed marine as the number one market—a position it retains today. During the late 1970s and early 1980s, composites were first used in infrastructure applications in Asia and Europe. The first all-composites pedestrian bridge was installed in Aberfeldy, Scotland, in the 1990s. In this period, the first FRP-reinforced concrete bridge deck was built in McKinleyville, West Virginia, and the first all-composites vehicular bridge deck was built in Russell, Kansas. Composites continue to find applications today. Nanomaterials are incorporated into improved fibres and resins used in new composites. Nanotechnology began to be used in commercial products in the early 2000s. Bulk carbon nanotubes can be used as composite reinforcement in polymers to improve the mechanical, thermal, and electrical properties of the bulk product.

Nowadays, the composite industry is still evolving, with much of the growth now focused on renewable energy. Wind turbine blades, especially, are constantly pushing the limits on size and require advanced composite materials, for example, the engineers can design to tailor the composite based on the performant requirements, making the composite sheet very strong in one direction by aligning the fibres that way, but weaker in another direction where strength is not so important. The engineers can also select properties such as resistance to heat, chemicals, and weathering by choosing an appropriate matrix material. In recent years, an increasing environmental consciousness and awareness of the need for sustainable development have raised interest in using natural fibres as reinforcements in composites to replace synthetic fibers. This chapter seeks to provide an overview of the science and technology in relation to the composite material, manufacturing process, and utilization.

2.1.0 LITERATURE REVIEW ON ALUMINIUM ALLOY:

7075 aluminium alloy (**AA7075**) is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminium alloys because of microsegregation, but has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most used aluminium alloys for highly stressed structural applications and has been extensively used in aircraft structural parts.

7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are **7075-0**, **7075-T6**, **7075-T651**.

The first 7075 was developed in secret by a Japanese company, Sumitomo Metal, in 1935,[3] but introduced by Alcoa in 1943 and was standardized for aerospace use in 1945.[4] 7075 was eventually used for airframe production in the Imperial Japanese Navy.

Aluminum and its alloys are used in a wide range of applications, from packaging to aerospace industries due to their high specific strength, fracture strength, and corrosion resistance. Al alloys with high strength to weight ratio provide superior mechanical properties as compared to steels and can operate under severe fatigue environments. Hence, they maintain pre-eminence as key structural materials in aircraft industry. This has led to continuous developments in thermomechanical processing of light metals and alloys for improving their structural properties. 7000 series aluminum alloys constitute aluminum, copper, zinc, and magnesium making it the strongest of all the aluminum wrought alloys. Among 7000 series aluminum alloys, 7075 is extensively used in aircraft and ordnance industries because of its superior strength. Usually, the mechanical properties of 7075 alloy are improved by reducing its iron and silicon contents and altering quenching and aging conditions. It exhibits good damage tolerance and high resistance to fatigue crack propagation in T6 aged condition.

T6 temper 7075 has an ultimate tensile strength of 510–540 MPa (74,000–78,000 psi) and yield strength of at least 430–480 MPa (63,000–69,000 psi). It has a failure elongation of 5–11%.

The T6 temper is usually achieved by homogenizing the cast 7075 at 450°C for several hours, quenching, and then ageing at 120°C for 24 hours. This yields the peak strength of the 7075 alloys. The strength is derived mainly from finely dispersed eta and eta' precipitates both within grains and along grain boundaries.

2.1.1 LITERATURE REVIEW ON TITANIUM ALLOY:

Ti-6Al-4V (UNS designation R56400), also sometimes called TC4, Ti64,[1] or ASTM Grade 5, is an alpha-beta titanium alloy with a high specific strength and excellent corrosion resistance. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and excellent corrosion resistance are necessary such as e.g. aerospace industry and biomechanical applications (implants and prostheses).

Studies of titanium alloys used in armors began in the 1950s at the Watertown Arsenal, which later became a part of the Army Research Laboratory.

Originally named gregorite, after the British chemist, Reverend William Gregor who discovered it in 1791, titanium was independently discovered by the German chemist M.H. Klaproth in 1793. He named it Titanium after the Titans of Greek mythology; “the incarnation of natural strength.” In 1797 he discovered that his titanium was the same as Gregor’s newly found element. However, the element was not successfully isolated until 1910.

Titanium is the 22nd element on the periodic table. Its atomic weight is 47.867amu. It is a low-density element (4510 kg/m3); approximately 60% less dense than that that of steel. It is nonmagnetic, and transfers heat well. Its melting point (1993 K [3020 degrees F and 1650 degrees C]) is also higher than that of steel. Titanium has high passivity; therefore, it exhibits high levels of corrosion resistance to most mineral acids and chlorides. It is also nontoxic and biologically compatible with human tissue and bone, making it an ideal material for medical implant products.

Rutile and ilmenite, the 2 primary minerals which contain titanium, make up 24% of the earth’s crust, thus making titanium the ninth most abundant element on the planet. However, it occurs in nature only in chemical combinations; the most common of which are oxygen and iron.

Ti-6Al-4V titanium alloy commonly exists in alpha, with hcp crystal structure, (SG : P63/mmc) and beta, with bcc crystal structure, (SG : Im-3m) phases. While mechanical properties are a function of the heat treatment condition of the alloy and can vary based upon properties, typical property ranges for well-processed Ti-6Al-4V are shown below. Aluminum stabilizes the alpha phase, while vanadium stabilizes the beta phase.

Ti-6Al-4V has a very low thermal conductivity at room temperature, 6.7 - 7.5 W/m·K, which contributes to its relatively poor machinability.

2.2 CONCLUSIONS ON REVIEWS

So, after seeing all these options on the way they use I decided to go with most light-weight materials and tough alloys to apply in aerospace and automobile industry. Then we decided to go with the Aluminium and Titanium major materials because they are the lightest in weight and when we add other materials and make them composite alloys, we can make strong and can give better performance for the purpose.

Hence, we decided to use AL-7075-T6 and TI-6Al-4V composite alloy materials to implement on our designs.

CHAPTER 3
PROJECT DESIGN

3.1 INTRODUCTION TO SOLIDWORKS:

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on an Intel-based Mac with Windows installed, the application's developer recommends against this. SolidWorks does not support macOS. According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, fiscal year 2011–12 revenue for SolidWorks totaled $483 million.

Fig3.1: *Solidworks Logo*

3.2 HISTORY OF SOLIDWORKS:

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD 8 software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product SolidWorks 95, in November 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired. SolidWorks for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company.

SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

SolidWorks was headed by John McEleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who is promoted Vice President Sales of Dassault Systems' Value Solutions sales channel.

3.3 SOLIDWORKS USES

- SolidWorks is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings.
- Designing in a modeling package such as SolidWorks is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design.

3.4 SOLIDWORKS COMPONENT

Before we begin looking at the software, it is important to understand the different components:

3.4.1 Part

- The first, and most basic element of a SolidWorks model is a Part.
- Parts consist of primitive geometry and features such as extrudes, revolutions, lofts, sweeps, etc.
- Parts will be the building blocks for all of the models that you will create.

3.4.2 Assemblies

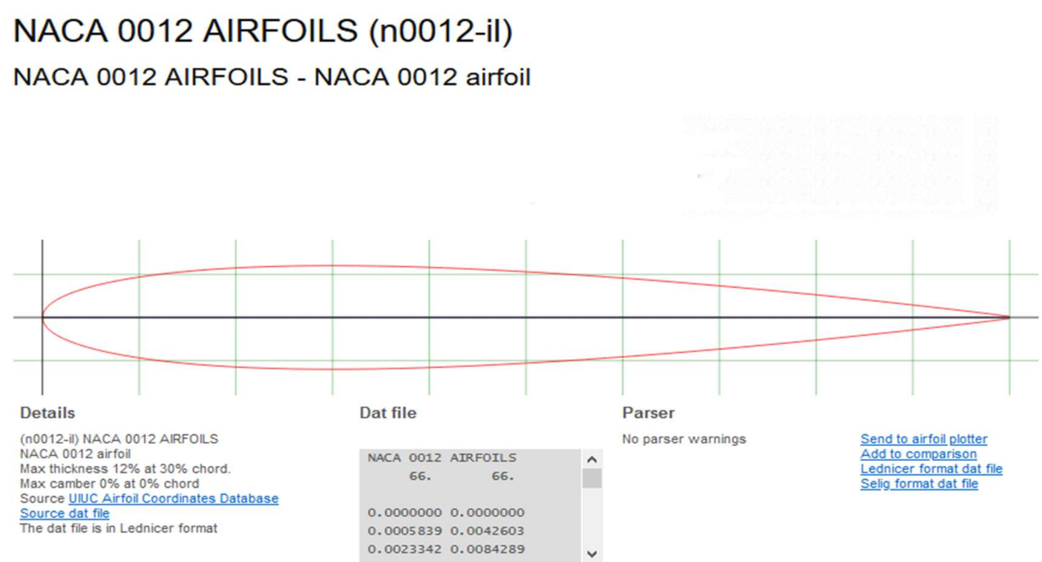
- The second component is the assembly. Assemblies are collections of parts which are assembled in a particular fashion using mates (constraints).
- Any complex model will usually consist of one, or many assemblies.

3.4.3 Drawings

- The third, and final component in SolidWorks is the Drawing.
- A drawing is the typical way to represent a 3D model such that any engineer (or manufacturer) can recreate your part.
- Drawings are important because they provide a standard way of sharing your design.

3.5 DESIGN PROCEDURE OF AEROPLANE WING

We used dimensions of NACA0012 airfoil for airplane wing design



<u>Figure 3.2:</u> *Wing Dimensions Source website layout*

Procedure:

1. Steps to design the Airplane wing surface design procedure.
2. First, we visit the curve dimensions of the NACA0012 airfoil dimensions and import (copy and paste the dimensions) to excel sheet. And separate the x and y dimensions in separate rows.
3. Then later include z dimensions with 0 in every curve point.
4. Then in the SolidWorks and open the sketch in the SolidWorks

5. Then start the curve with importing dimensions from the excel file we saved in the previous steps.

6. Now mirror the curve points by creating another plane 1000mm distance from this importing curve plane.

7. Then scale the mirrored plane to 0.4.

8. Now join both the curve and scaled curve. So, u can make it as a surface.

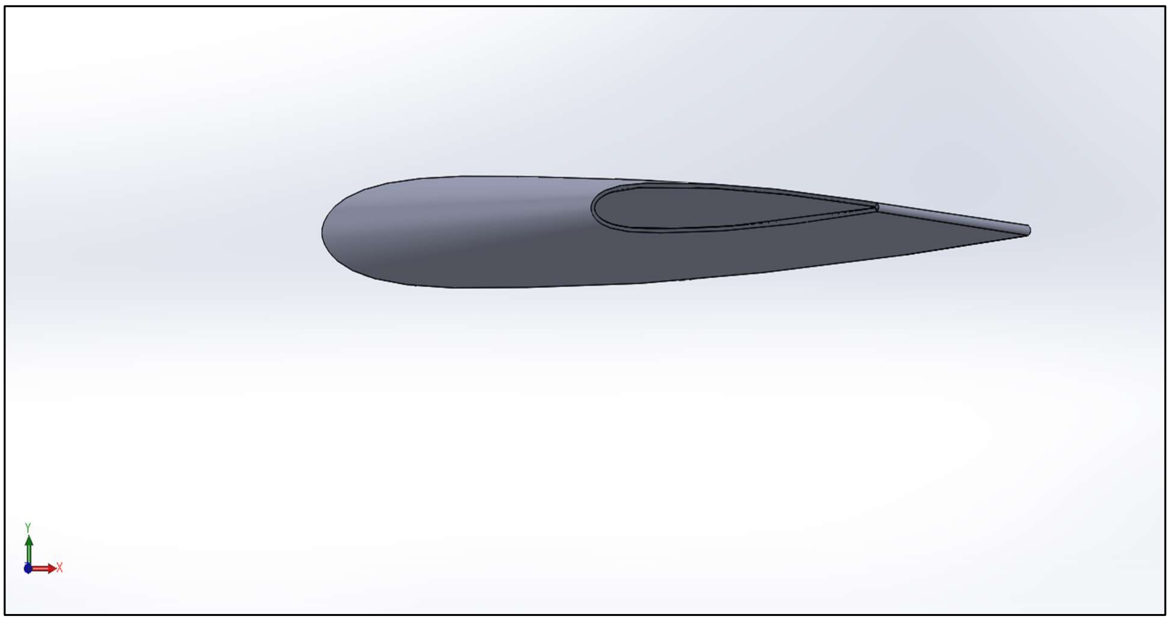


Figure 3.3 : *Wing Designing Scaling Down*

9. Now finally we get the surface model of the wing.

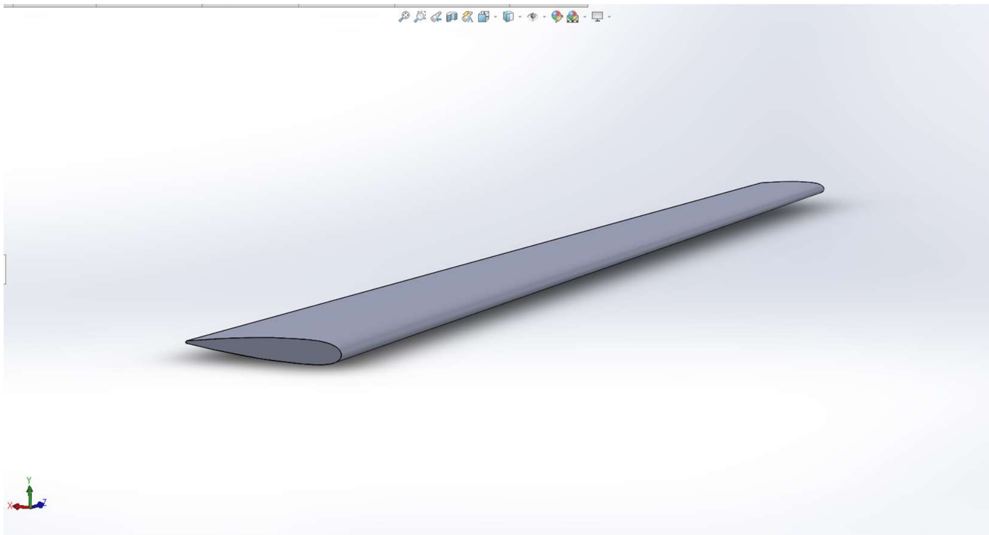


Figure 3.4: *Final Aeroplane Wing*

4.4 CAR DOOR SURFACE DESIGN PROCEDURE

Steps to design the Car Door Surface Design Procedure

1. Select YZ plane and start drawing side surface of the door panel using the following tools and dimensions shown in the figure.

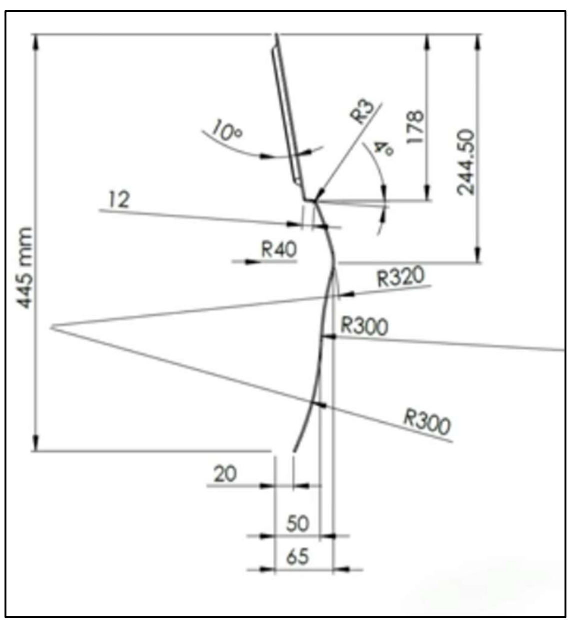


Figure 3.5: *Door Panel Side Dimensions*

2. Now exit the YZ plane and extrude the surface from the curve with draw.
3. Now we can draw a front view of the door by using the dimension in the fig and using the appropriate tools on the surface.
4. Then extrude outside the drawn FV dimensions.

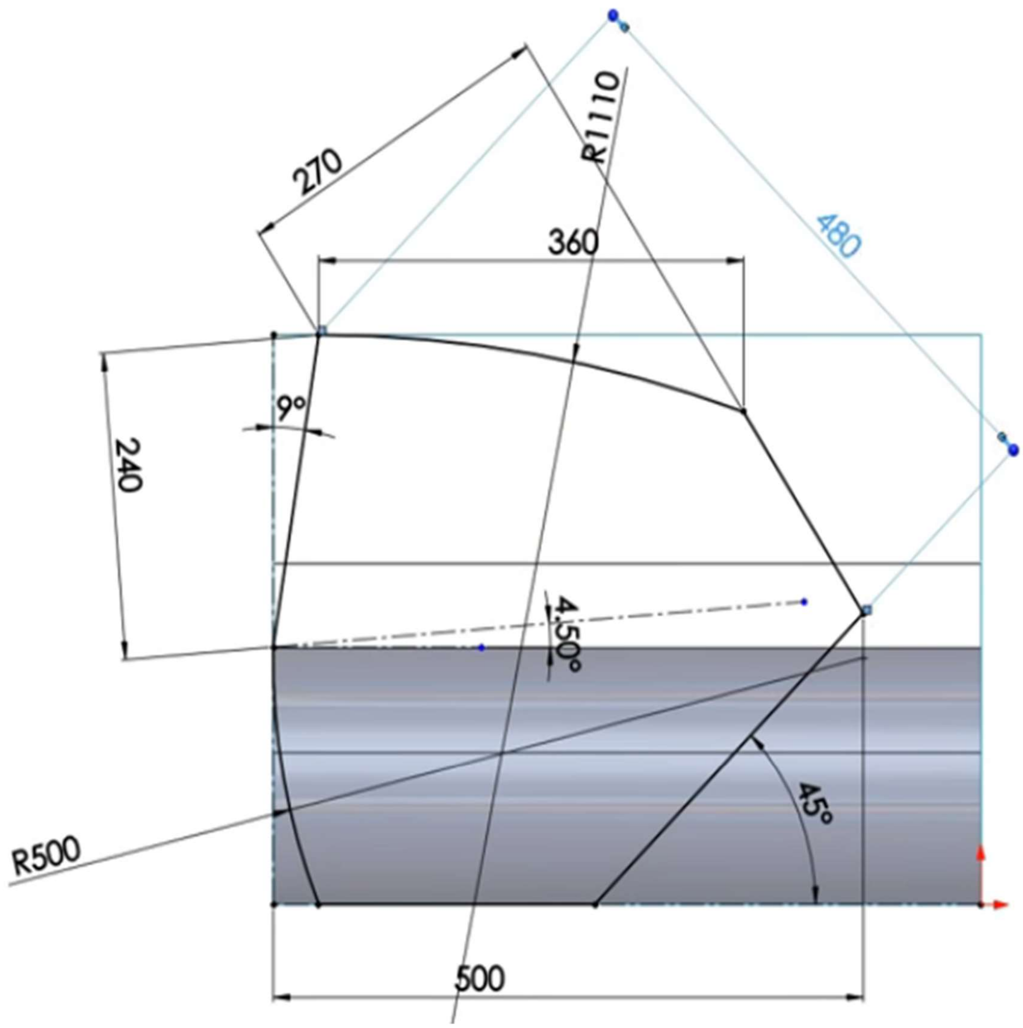


Figure 3.6: *Panel after extruding*

5. Now we can see the outline of the dimensions.

6. Then we cut the window outline.

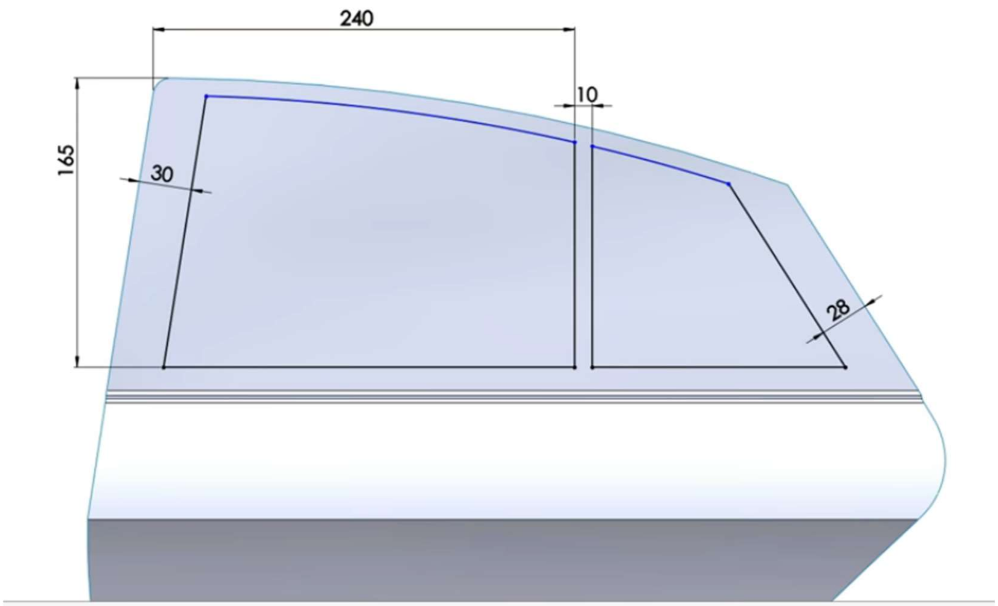


Figure 3.7: *Car Door after the trimming*

7. At last, we get the Door panel as shown in the fig.

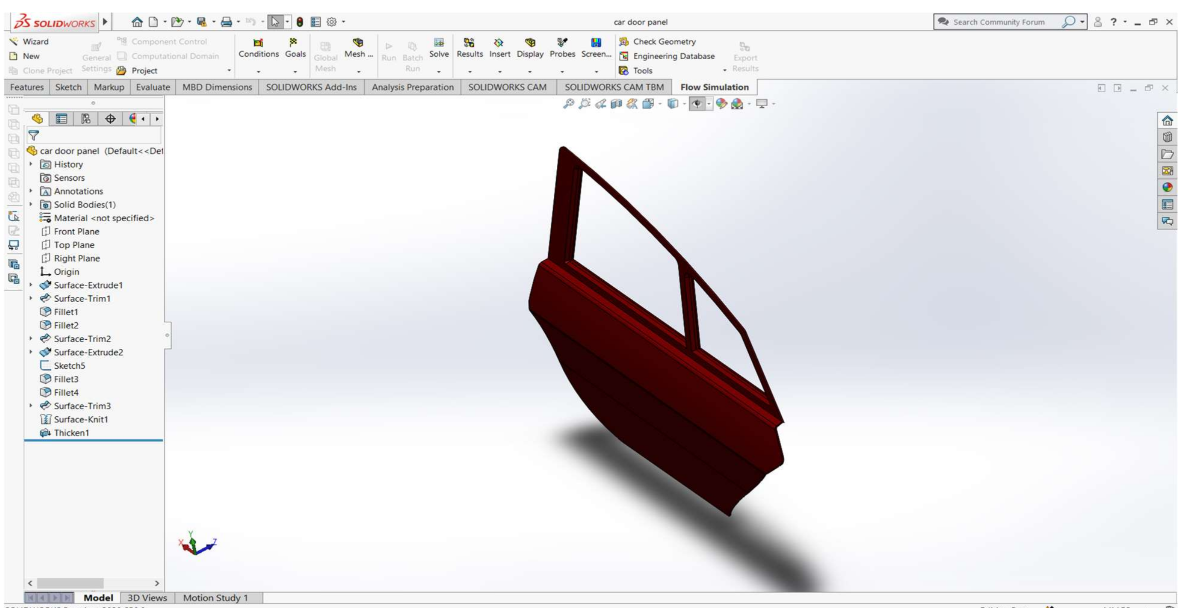


Figure 3.8: *Final Design of the Car Door Panel*

CHAPTER 4
PROJECT IMPLEMENTATION

4.1 INTRODUCTION TO ANSYS

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

• Apply design performance conditions or other operating loads.
• Build computer model or transfer models of structures, components, products, or system.
• Testing prototype in environments where it otherwise would be impossible or undesirable.
• Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
• Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both. A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

Fig 4.1: *ANSYS logo*

4.2 HISTORY OF ANSYS

The first commercial version of Ansys software was labeled version 2.0 and released in 1971. At the time, the software was made up of boxes of punch cards, and the program was typically run overnight to get results the following morning. In 1975, non-linear and thermoelectric features were added. The software was exclusively used on mainframes, until version 3.0 (the second release) was introduced for the VAXstation in 1979. Version 3 had a command line interface like DOS.

Released in January 2020, Ansys R1 2020 updates Ansys' simulation process and data management (SPDM), materials information and electromagnetics product offerings. In early 2020, the Ansys Academic Program surpassed one million student downloads.

In November 2020, South China Morning Post reported that Ansys software had been used for Chinese military research in the development of hypersonic missile technology.

4.3 INTRODUCTION TO ANSYS WORKBENCH:

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.

fig 4.2: *ANSYS Workbench logo*

4.4 INTRODUCTION TO ANSYS MECHANICAL:

Ansys Mechanical is a finite element analysis (FEA) tool that enables you to analyze complex product architectures and solve difficult mechanical problems. You can use Ansys Mechanical to simulate real world behavior of components and sub-systems, and customize it to test design variations quickly and accurately.

Fig 4.3: *ANSYS Mechanical Module*

4.5 PREREQUISITE DATA FOR ANALYSIS PROCEDURE:

1) Before starting procedure first we should convert the SolidWorks default file format SLDPRT to IGES which is an universally used format which can be recognized by any designing softwares.

2) Properties of Materials which are

a. Material Properties of AL-7075-T6

Property	**Value**
Density	2.81g/cc
Young's Modulus(E)	71.7GPa
Tensile Strength(σt)	572MPa
Elongation(€) at break	11%
Poission's Ratio	0.33
Hardness—Rockwell	87HRB
Melting Temperature(Tm)	477°C
Thermal Conductivity(k)	130-150 W/m*K
Linear thermal expansion coefficient (α)	2.36* 10^{-5} K^{-1}

Specific heat capacity (c)	714.8J/kg*K
Volume resistivity (ρ)	51.5nOhm*m

Table4.1*: Material Properties of AL-7075-T6*

b. **Materials Properties of *TI-6AL-4V***

Property	**Value**
Density	4.41g/cc
Young's Modulus	110GPa
Shear Modulus	42GPa
Bulk Modulus	124.9GPa
Poisson's Ratio	0.33
Yield Stress MPa (Tensile)	900MPa
Ultimate Stress (Tensile)	925MPa
Hardness, Rockwell C	36
Uniform Elongation	11.5%

Table4.2*: Material Properties of TI-6AL-4V*

4.6 ANALYSIS PROCEDURE ON WING:

1. Now start by selecting and dragging Static Structure tool module in Analysis Systems into the dashboard.

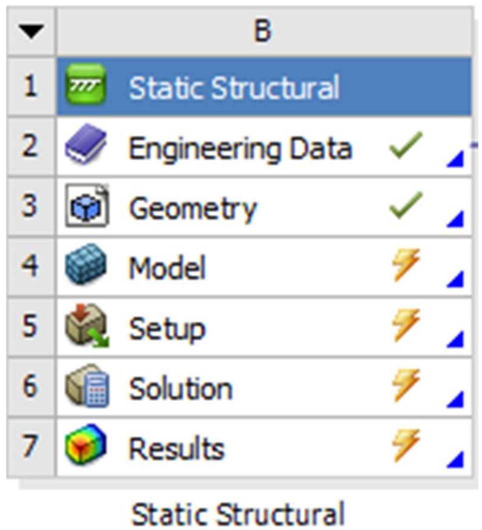


Fig 4.4: *Static Structural Module*

2. Now as the module shows in sequence numbers import the Engineering Data which is the materials information by double clicking on it from *Table4.1 and Table 4.2*.

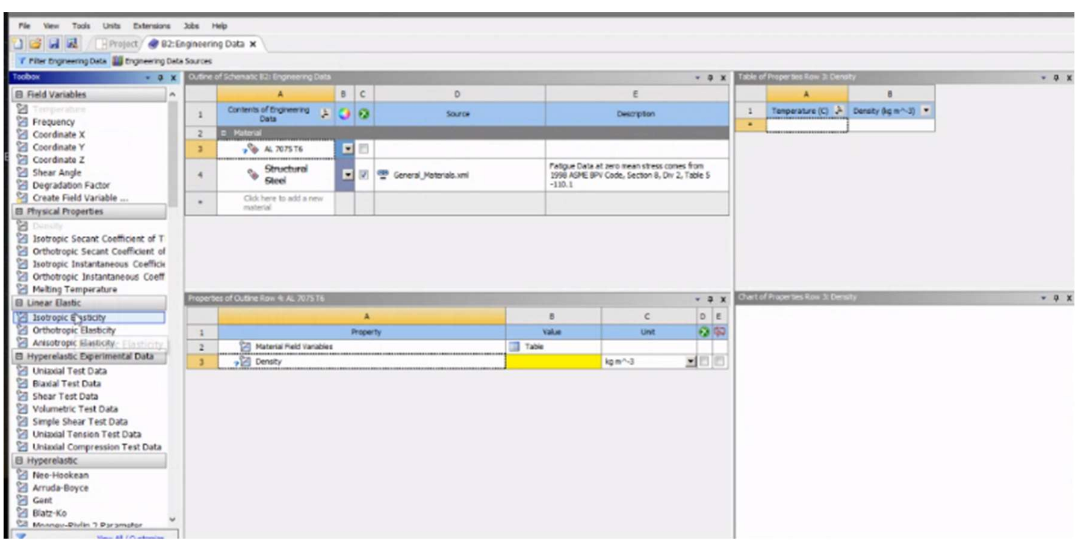


Fig 4.5: *Engineering Data input*

3. Now in the next sequence Geometry import the IGES format of Surface Design into the module now.

4. Then we go to model to enter Workbench of the Geometry by double clicking on the Model step in module.
5. In the workbench select the geometry and apply materials which we input.

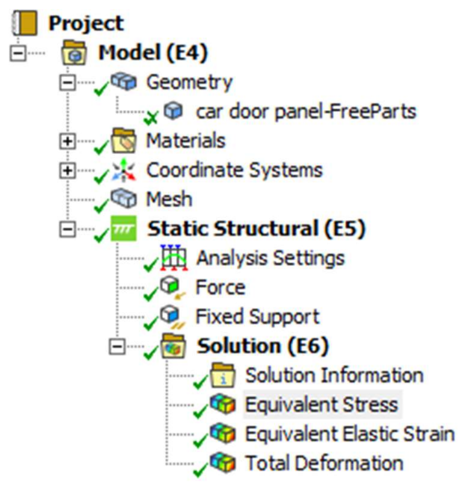


Fig 4.6: *Project model tree in ANSYS workbench*

6. Now mesh the design by clicking on Generate Mesh.

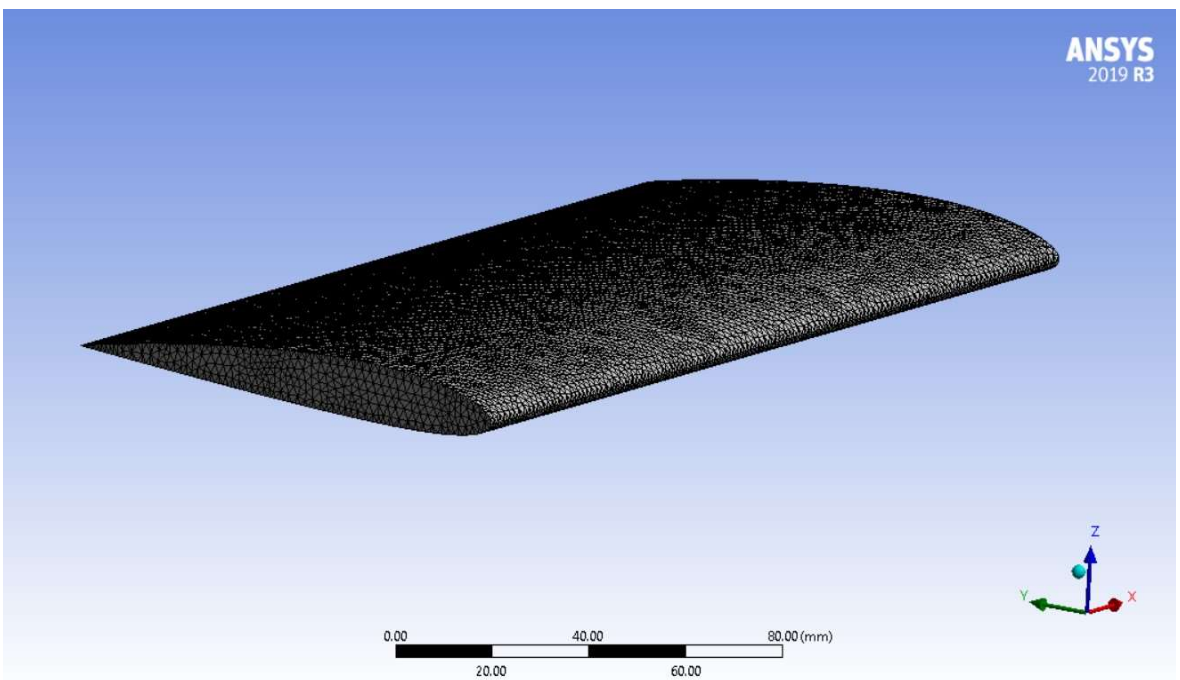


Fig 4.7: *Mesh Design of the Wing design*

7. Then in Static structural add the support and real life force simulation in our case we add fixed support on one end of the wing and also add force along the front line which is connecting both edge curves.
8. Then in solution section add which type of solution we need in our case we add Total Deformation, Equivalent Elastic Strain, Equivalent Stress.

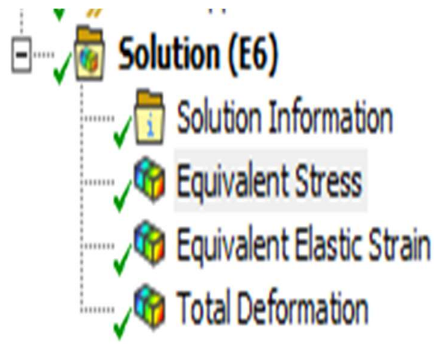


Fig 4.8: *Solution Options tree to be selected*

9. Now by clicking on Solve we can get the result of this analysis.
10. Repeat the same steps by applying different materials.

4.7 WING ANALYSIS VISUAL RESULT:

1. Mesh of the wing surface design:

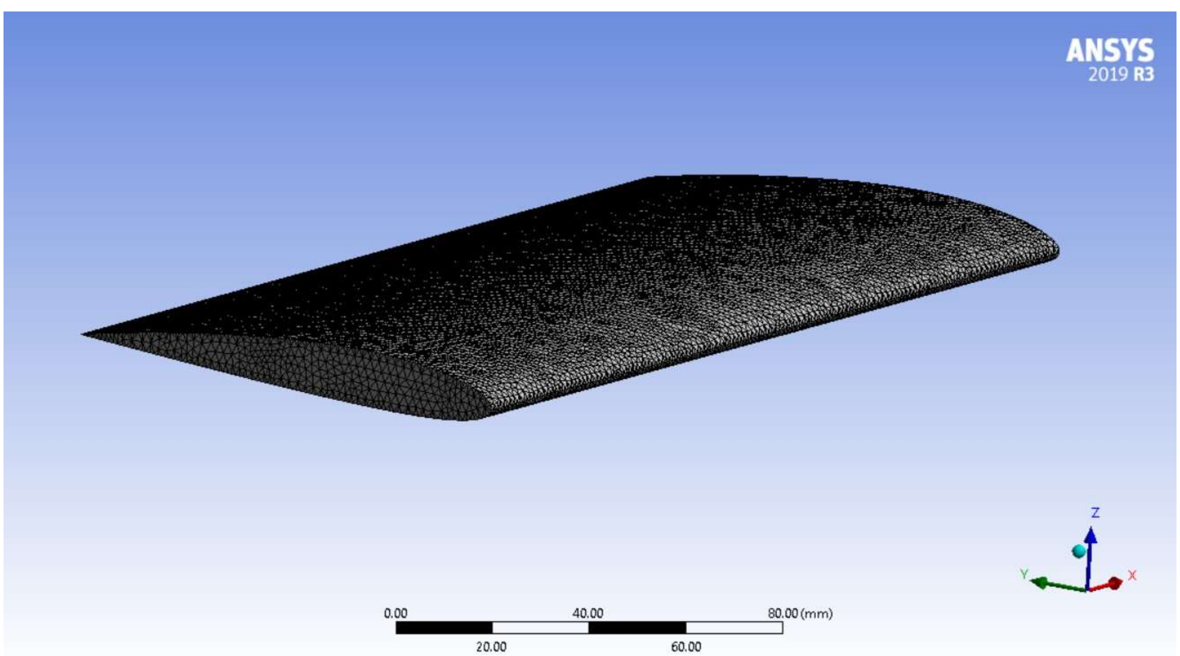


Fig 4.9: *Mesh Design of the Wing Design*

2. Total deformation of the Wing surface design by applying TI-6AL-4V.

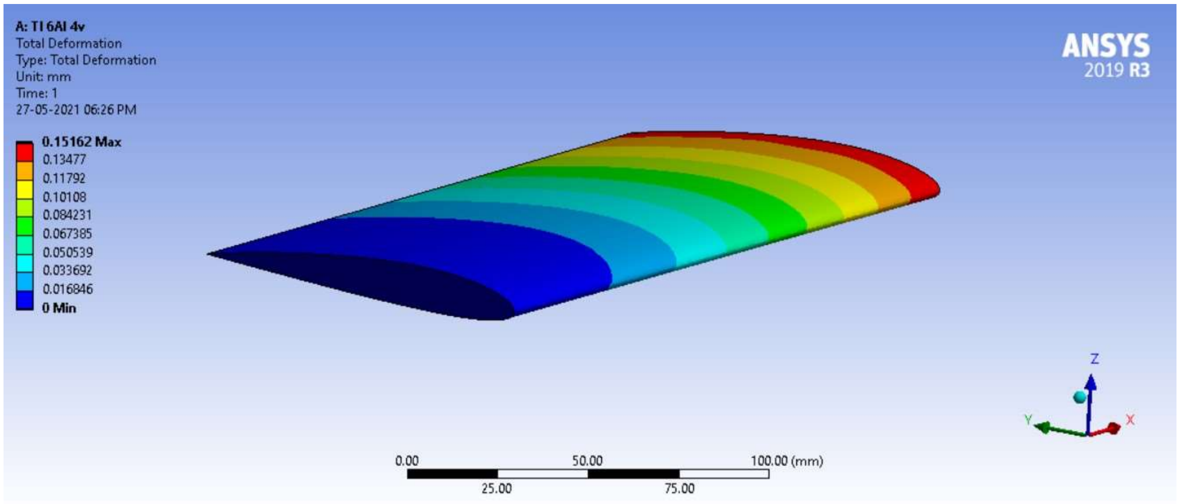


Fig 4.10: Total deformation of the Wing surface design by applying TI-6AL-4V.

3. Equivalent Stress of the Wing surface design by applying TI-6AL-4V.

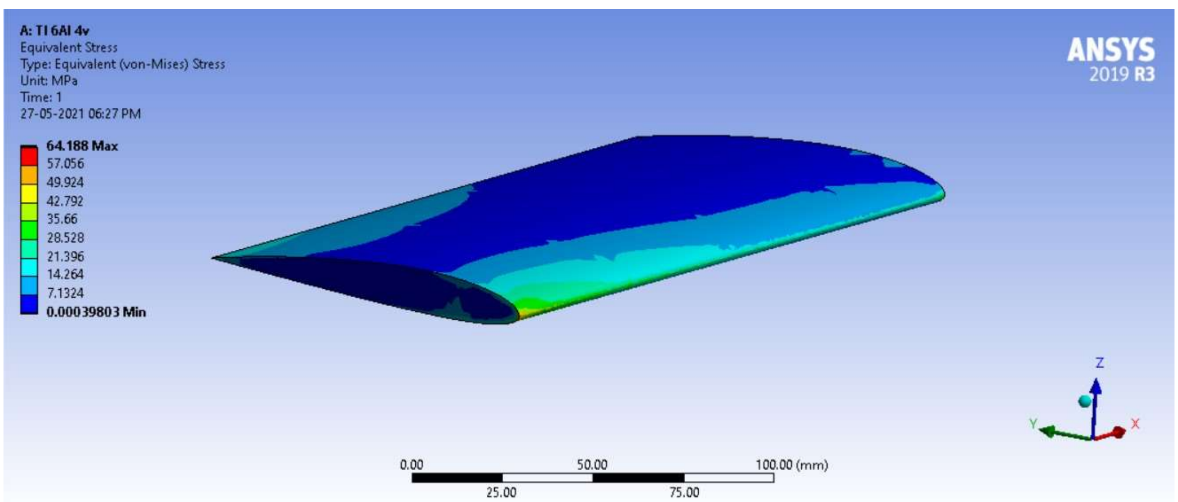


Fig 4.11: Equivalent Stress of the Wing surface design by applying TI-6AL-4V

4. Equivalent Elastic Strain of the Wing surface design by applying TI-6AL-4V

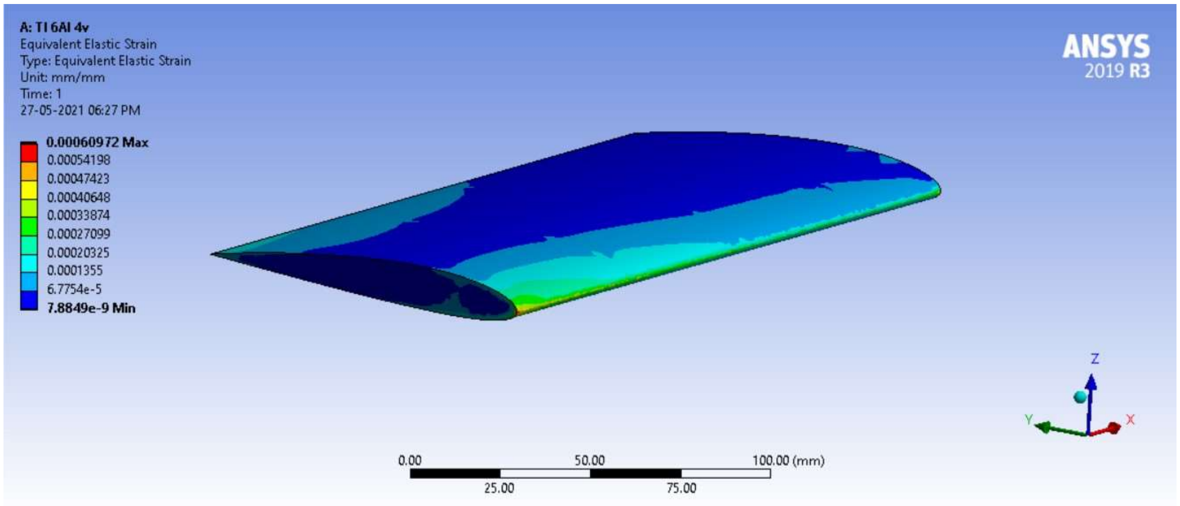


Fig 4.12: *Equivalent Elastic Strain of the Wing surface design by applying TI-6AL-4V*

5. Total deformation of the Wing surface design by applying AL-7075-T6

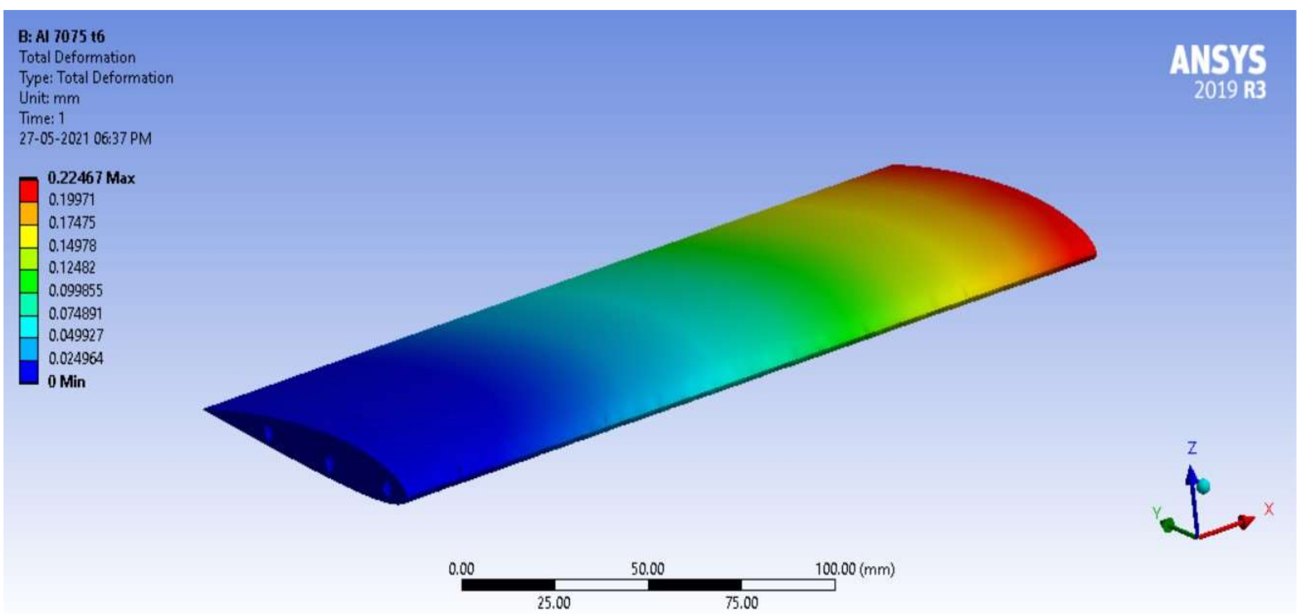


Fig 4.13: *Total deformation of the Wing surface design by applying AL-7075-T6*

6. Equivalent Stress of the Wing surface design by applying AL-7075-T6.

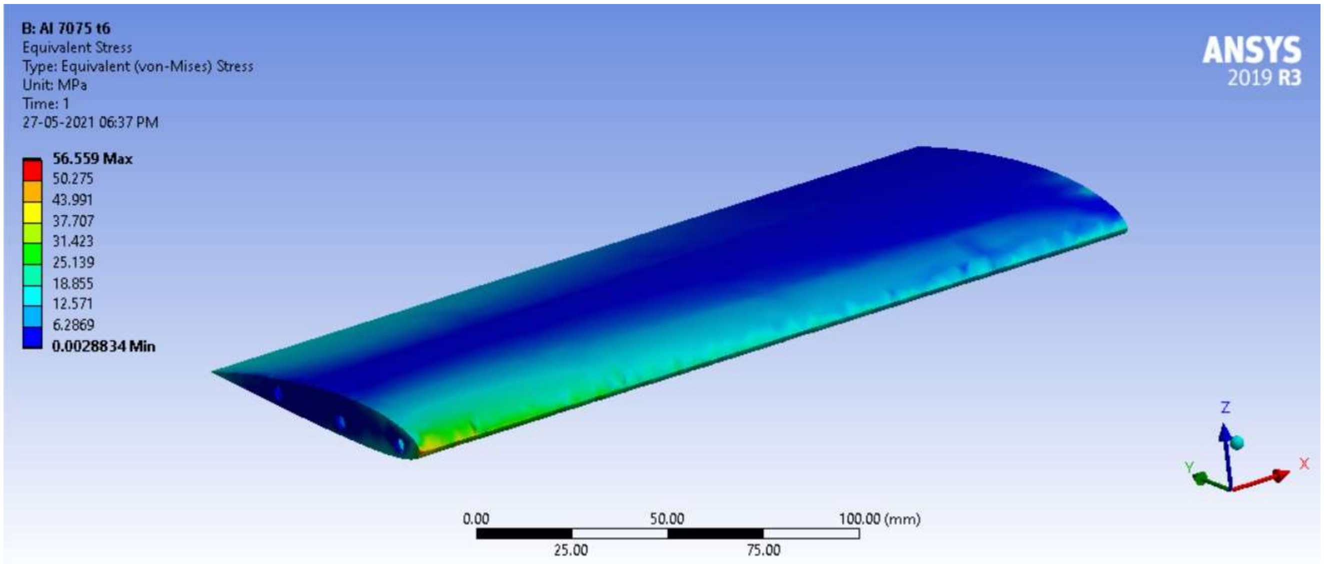


Fig 4.14: *Equivalent Stress of the Wing surface design by applying AL-7075-T6*

7. Equivalent Elastic Strain of the Wing surface design by applying AL-7075-T6.

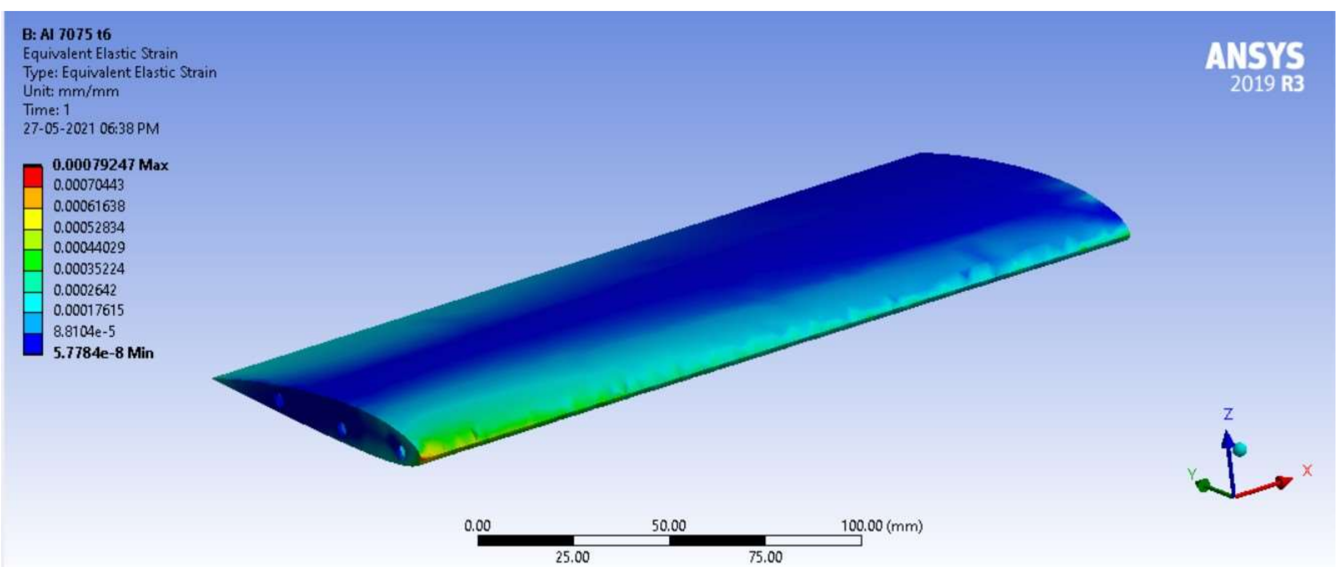


Fig 4.15: *Equivalent Elastic Strain of the Wing surface design by applying AL-7075-T6*

4.8 ANALYSIS PROCEDURE FOR CAR DOOR PANEL:

1. Now start by selecting and dragging Static Structure tool module in Analysis Systems into the dashboard.

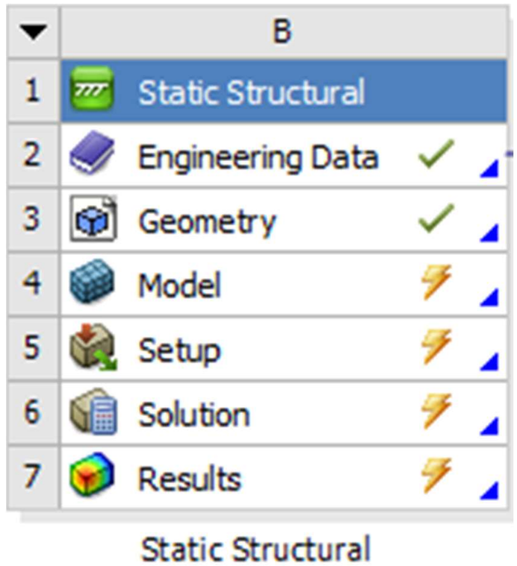


Fig 4.16: *Static Structure Module*

2. Now as the module shows in sequence numbers import the Engineering Data which is the materials information by double clicking on it from *Table4.1 and Table 4.2*.

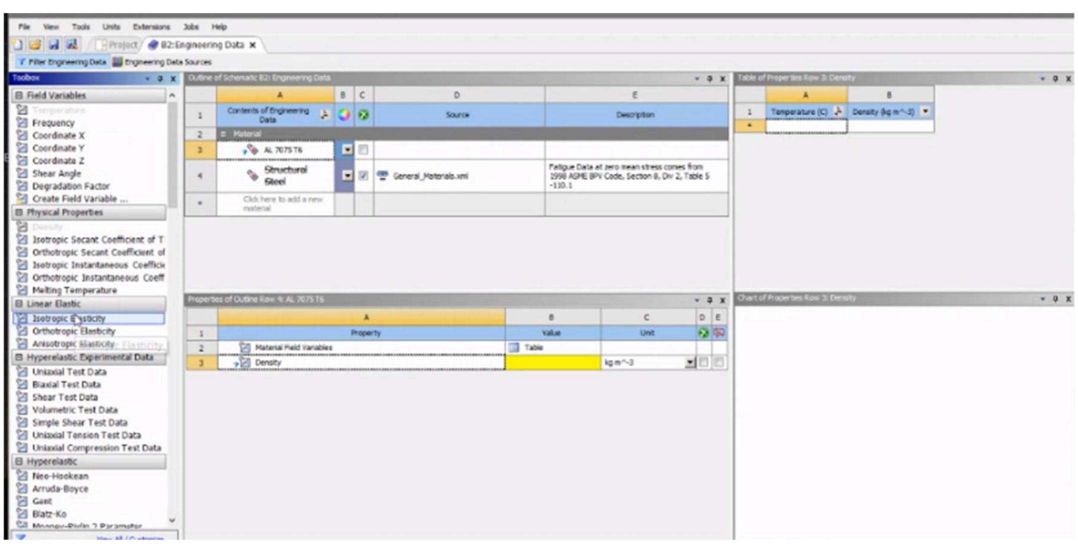


Fig 4.17: Engineering Data Material Input

3. Now in the next sequence Geometry import the IGES format of Surface Design into the module now.
4. Then we go to model to enter Workbench of the Geometry by double clicking on the Model step in module.
5. In the workbench select the geometry and apply materials which we input.

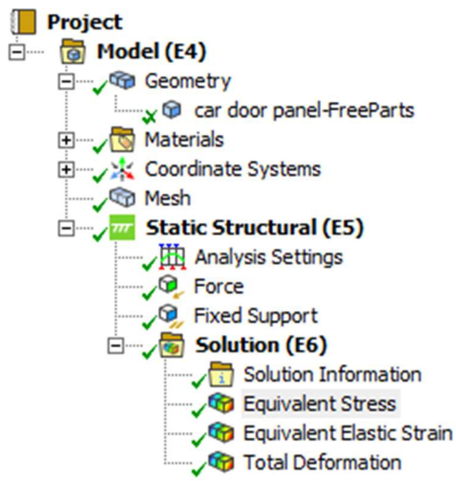


***Fig 4.18**: Model Tree of Project in ANSYS workbench*

6. Now mesh the design by clicking on Generate Mesh.
7. Now add force on the front face of the door panel and also add Fixed support on the all around the edge of the car door panel as shown in fig.

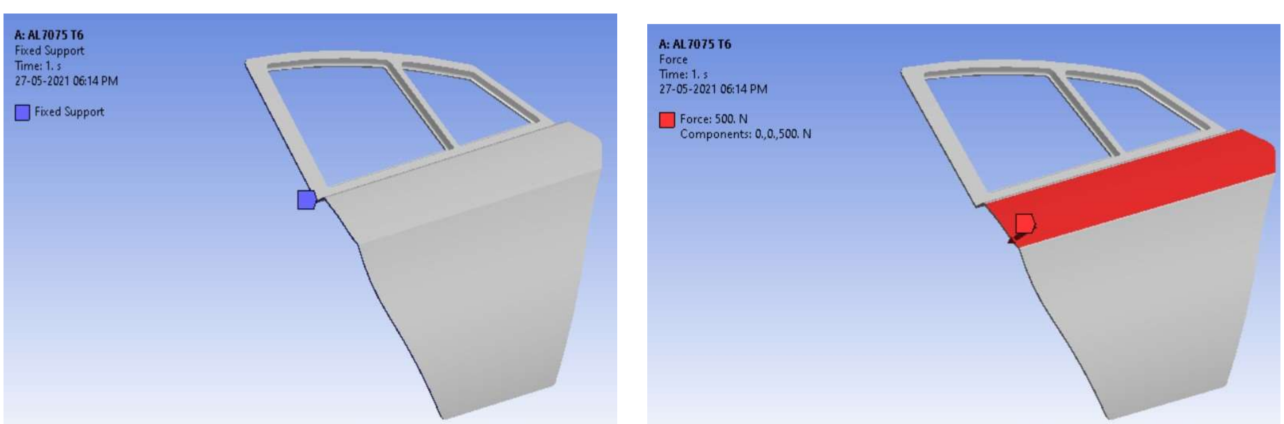


***Fig 4.19:** Car Door Design Applying Force and Support*

8. Then in solution section add which type of solution we need in our case we add Total Deformation, Equivalent Elastic Strain, Equivalent Stress.

Fig 4.20: *Solution tree list*

9. Now by clicking on Solve we can get the result of this analysis.
10. Repeat the same steps by applying different materials.

4.9 CAR DOOR ANALYSIS VISUAL RESULT:

1. Mesh of the car door panel.

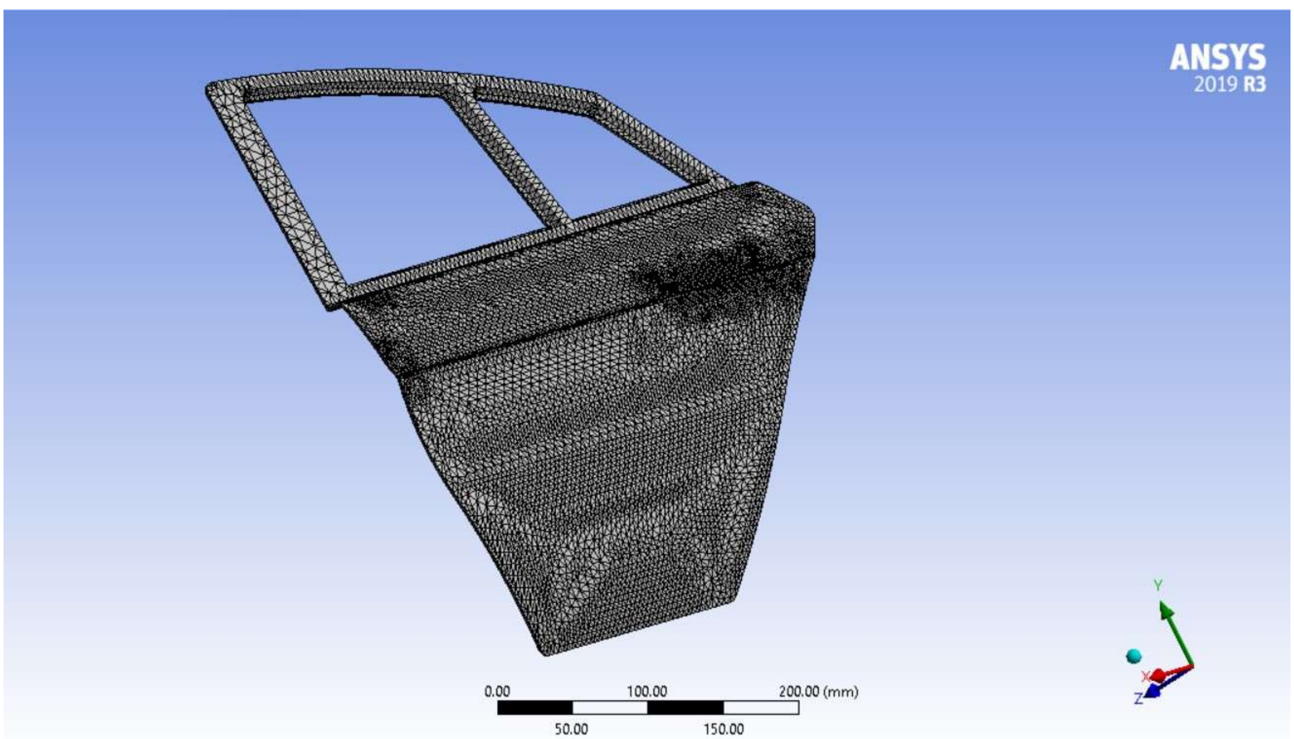


Fig 4.21: *Mesh of the car door panel*

2. Total deformation of the car door panel by applying TI-6AL-4V.

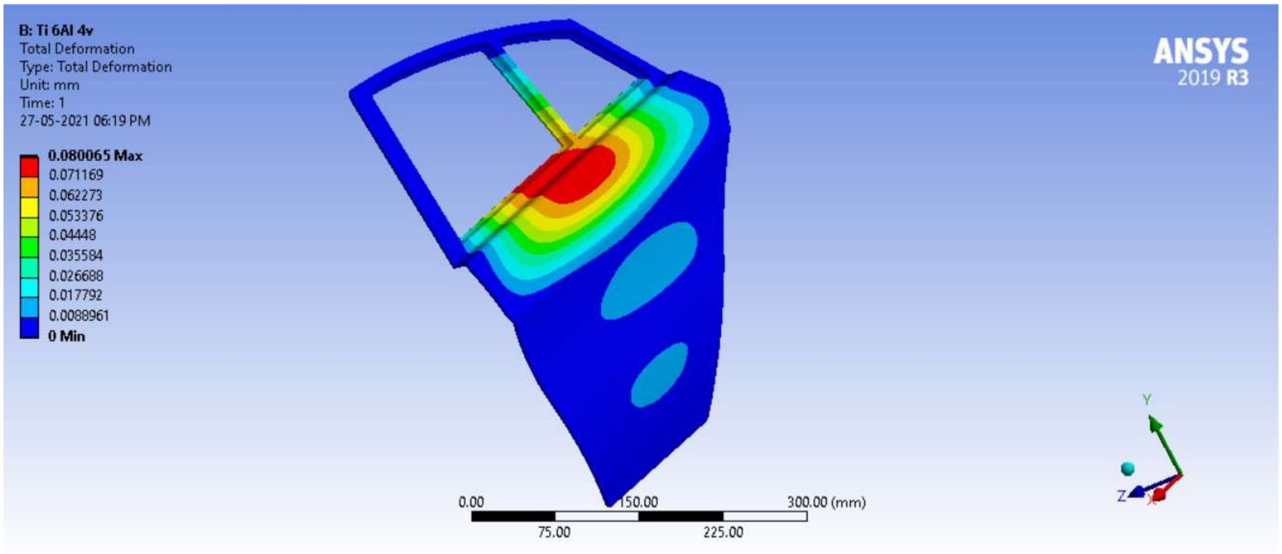


Fig 4.22: Total deformation of the car door panel by applying TI-6AL-4V

3. Equivalent Stress of the car door panel by applying TI-6AL-4V.

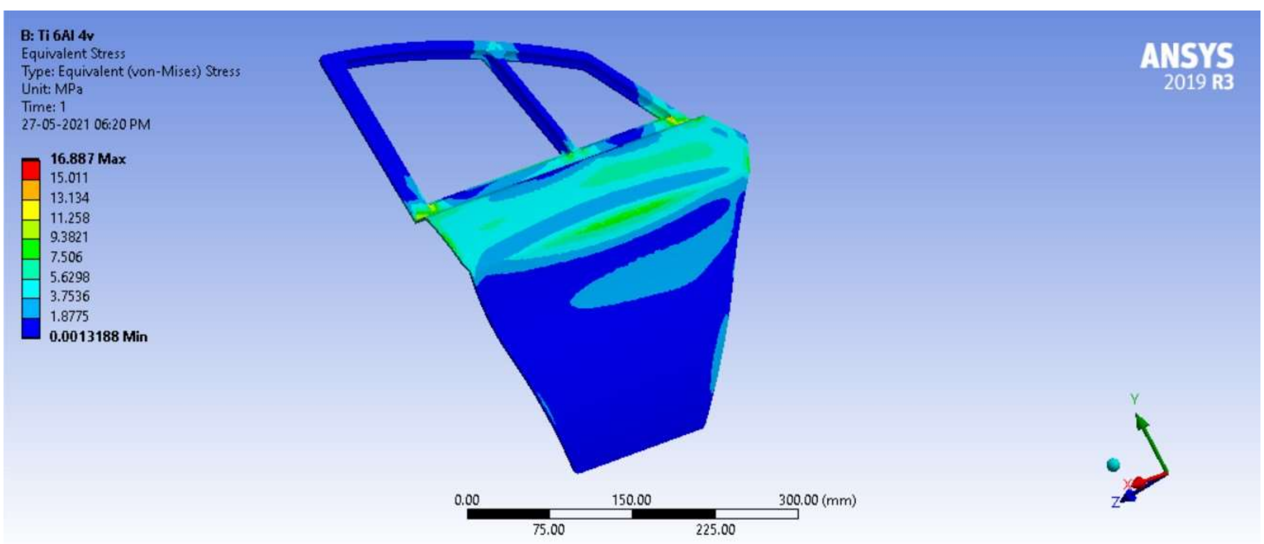


Fig 4.23: Equivalent Stress of the car door panel by applying TI-6AL-4V

4. Equivalent Elastic Strain of the car door panel by applying TI-6AL-4V

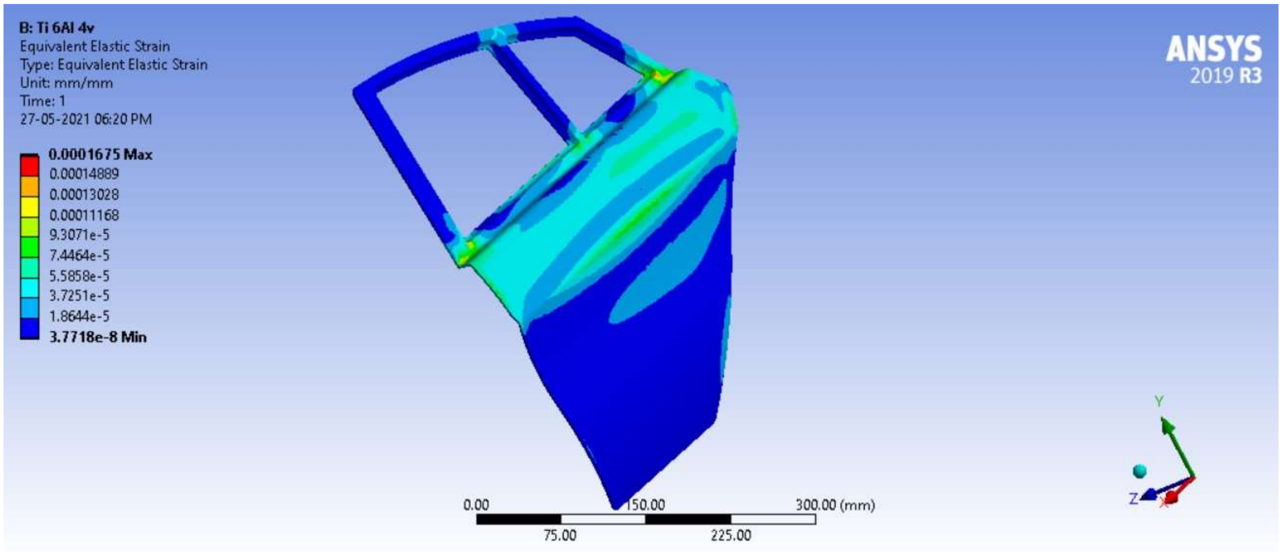


Fig 4.24: *Equivalent Elastic Strain of the car door panel by applying TI-6AL-4V*

5. Total deformation of the car door panel by applying AL-7075-T6.

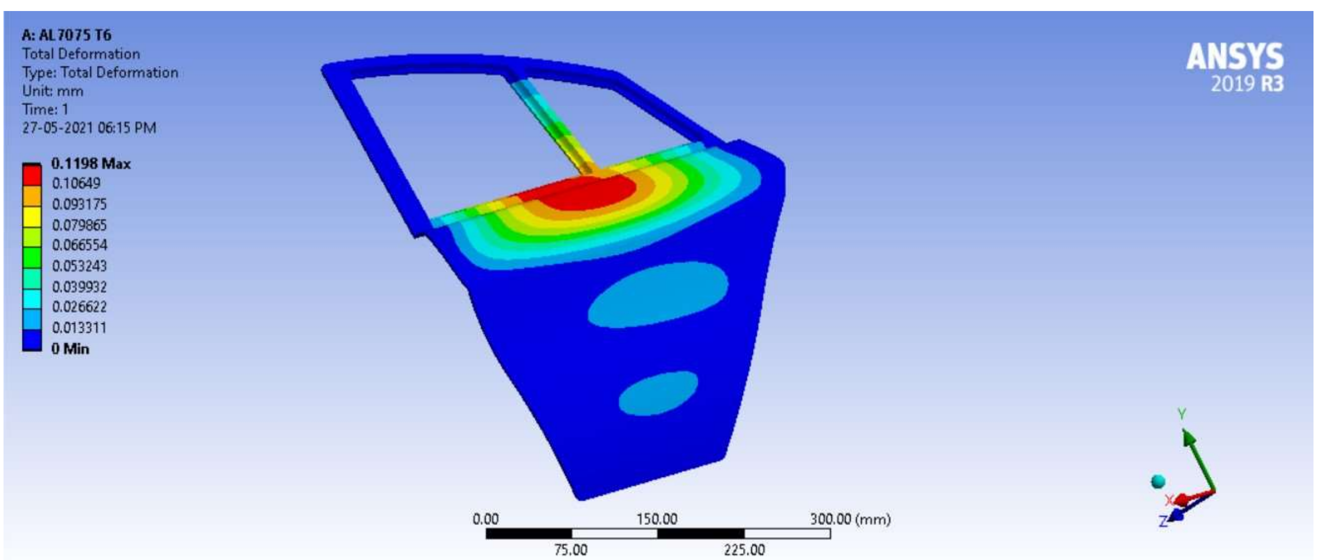


Fig 4.25: *Total deformation of the car door panel by applying AL-7075-T6*

6. Equivalent Stress of the car door panel by applying AL-7075-T6

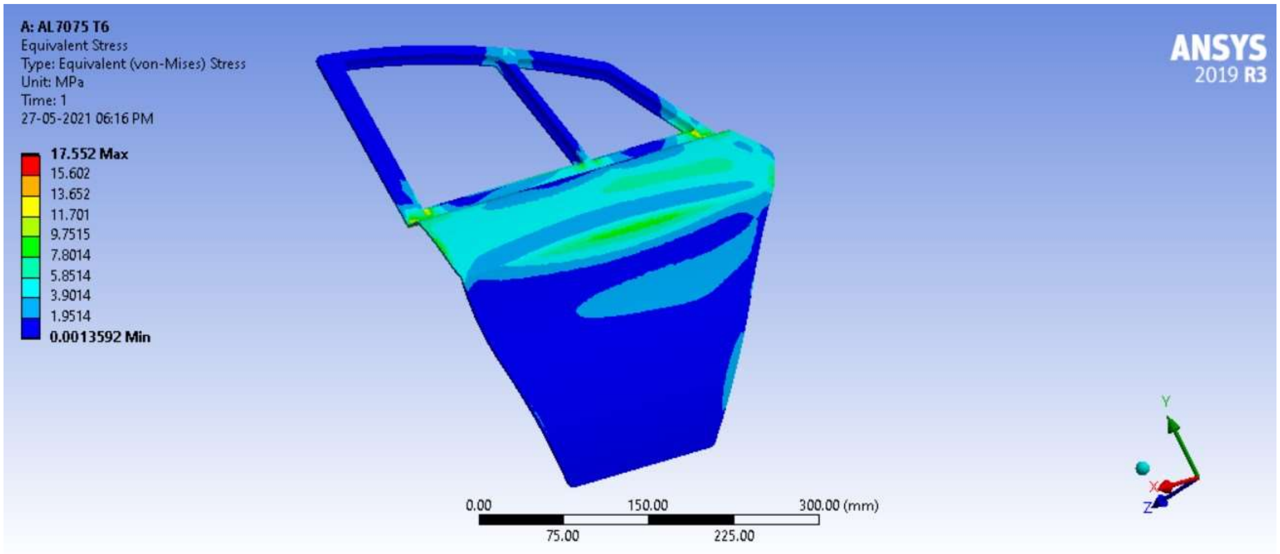


Fig 4.26: Equivalent Stress of the car door panel by applying AL-7075-T6

7. Equivalent Elastic Strain of the car door panel by applying AL-7075-T6.

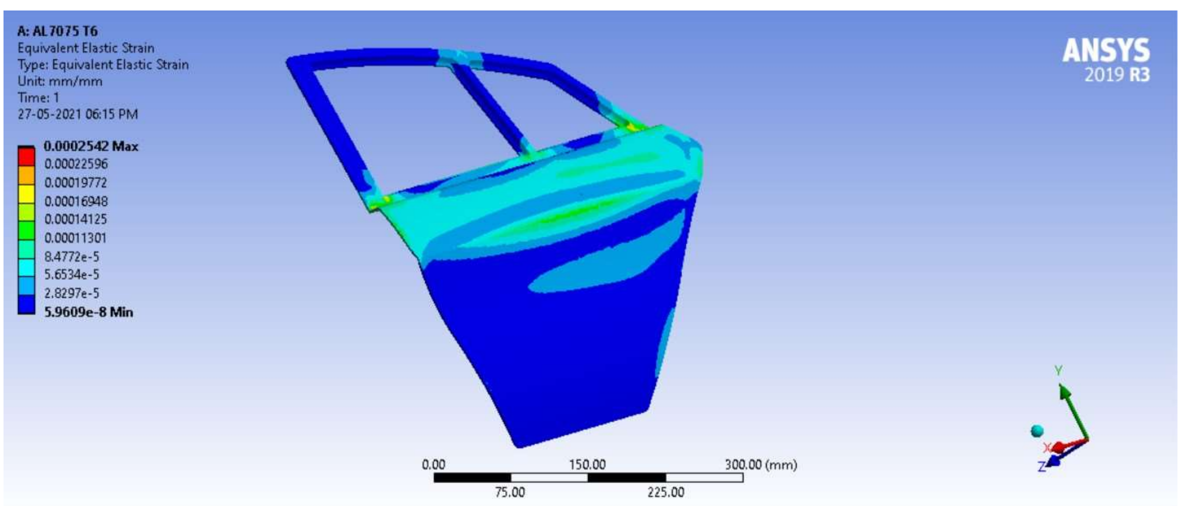


Fig 4.27: Equivalent Elastic Strain of the car door panel by applying AL-7075-T6

CHAPTER 5
CONCLUSION AND FUTURE ENHANCEMENT

5.1 RESULT:

From the analysis of Aeroplane wing and Car Door Panel in ANSYS software. The numerical data collected by changing material usage in both the designs is shown below in the *Table 7.1 and Table 7.2.*

	AeroPlane Wing Total Deformation With Al-7075-T6 In mm(milli meter)	AeroPlane Wing Equivalent Stress With Al-7075-T6 In MPa	AeroPlane Wing Equivalent Elastic Strain With Al-7075-T6 In mm/mm	AeroPlane Wing Total Deformation With TI-6AL-V4 In mm(milli meter)	AeroPlane Wing Equivalent Stress With TI-6AL-V4 In Mpa	AeroPlane Wing Equivalent Elastic Strain With TI-6AL-V4 In mm/mm
Minimum	0	0.00039	7.88*e^-4	0	0.00038	7.9*e^-4
Maximum	0.156	65.12	0.0006	0.17	64.18	0.0006

Table 5.1 : *Aeroplane wing analysis numerical outcomes by applying* Al-7075-T6 and TI-6AL-V4

	Car Door Panel Total Deformation With Al-7075-T6 In mm(milli meter)	Car Door Panel Equivalent Stress With Al-7075-T6 In MPa	Car Door Panel Equivalent Elastic Strain With Al-7075-T6 In mm/mm	Car Door Panel Total Deformation With TI-6AL-V4 In mm(milli meter)	Car Door Panel Equivalent Stress With TI-6AL-V4 In Mpa	Car Door Panel Equivalent Elastic Strain With TI-6AL-V4 In mm/mm
Minimum	0	0.00039	7.88*e^-4	0	0.00038	7.9*e^-4
Maximum	0.156	65.12	0.0006	0.17	64.18	0.0006

Table 5.1 : *Car Door Panel analysis numerical outcomes by applying* Al-7075-T6 and TI-6AL-V4

5.2 CONCLUSION

After completing the thermo analysis on both car door and aero plane wing we have found out different thermo mechanical properties and also the amount of deformation when force is applied. We have noticed that during the deformation analysis the AL-7075-T6 which is an alloy of Aluminum and Zinc materials withstood more than TI-6AL-V4 which is an Titanium alloy material proving to have more strength.

From this Analysis we also can say that AL-7075-T6 material and TI-6AL-V4 can perform much better job the than the present conventional materials used in Automobile and AeroSpace Industry.

5.3 FUTURE ENHANCEMENTS:

From this complete analysis we can say that both AL-7075-T6 and TI-6AL-V4 materials can be used the following Industries for better performance and lifespan in future. And can also see some improvements by adding more materials by increasing the count of the materials in the composite materials

5.4 PUBLICATIONS:

- (ICRIM-2021)
- "Online International Conference on "Robotics and Intelligent Manufacturing"

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A Major Project Report
On

WEIGHT OPTIMIZATION OF CHASSIS FRAME BY USING TOPOLOGY OPTIMIZATION TO REDUCE THE POLLUTION IN THE ENVIRONMENT

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

ABDUL HUQ	**-**	**(17K81A0303)**
MUFAN AKASH	**-**	**(17K81A0344)**
SISIR CHANDRA K	**-**	**(17K81A0352)**
YATISH YADAV	**-**	**(17K81A0359)**

Under the Guidance of

Mr. A. RANJITH
Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)
Dhulapally, Secunderabad – 500 100

JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Weight Optimization of Chassis Frame by Using Topology Optimization to Reduce the Pollution in The Environment**, is being submitted by **Abdul Huq (17K81A0303), Mufan Akash (17K81A0344), Sisir Chandra K (17K81A0352), Yatish Yadav (17K81A0359)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Mr. A. RANJITH
Assistant Professor,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor& Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Weight Optimization of Chassis Frame by Using Topology Optimization to Reduce the Pollution in The Environment** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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MUFAN AKASH	-17K81A0344
SISIR CHANDRA K	-17K81A0352
YATISH YADAV	-17K81A0359

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YATISH YADAV	-17K81A0359

ABSTRACT

Since past few years major cities across the world have been witnessing an upsurge in pollution levels. The smoke released from automobile and especially high fuel consuming heavy vehicles like trucks and building machinery constitutes to a major portion of these pollution levels. Decreasing the weight of such heavy vehicles can reduce the fuel consumption and can also indirectly reduce the smoke emitted and will have a positive impact on the environment. Chassis is one such part of automobiles whose weight can be decreased to achieve this feat. The automotive chassis is a skeletal frame on which several mechanical parts are bolted. The main purpose of trailer chassis is to withstand all the loads acting on it. Usually, chassis frame of trailers has heavy weight that causes high fuel consumption and emission which pollutes the environment.

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CHAPTER-1 INTRODUCTION

The car chassis presents the power essential to assist the vehicular factors and the payload positioned upon it. The suspension gadget includes the springs, the shock absorbers, and different factors that enable the car to pass by over uneven terrain except an immoderate quantity of shock achieving the passengers or the cargo. The steerage mechanism is a vital component of the chassis, as it gives the operator with a capacity of controlling the path of travel. The tyres grip the avenue floor to furnish top traction that allows the car to accelerate, brake, and make turns except skidding. Working in conjunction with the suspension, the tyres take in most of the shocks induced by means of avenue irregularities. The physique of the car encloses the mechanical factors and passenger compartment. It is made of highly mild sheet metallic or composite plastics. The factors which make up the chassis are held collectively in perfect relation to every different via the frame.

Ladder Frame (Truck Frame)

The truck frame allows different types of truck beds or enclosures to be attached to the frame. For larger trucks, the frames are simple, rugged, and of channel iron construction. The side rails are parallel to each other at standardized widths to permit the mounting of stock transmissions, transfer cases, rear axles, and other similar components. Trucks that are to be used as prime movers have an additional reinforcement of the side rails and rear cross members to compensate for the added towing stresses.

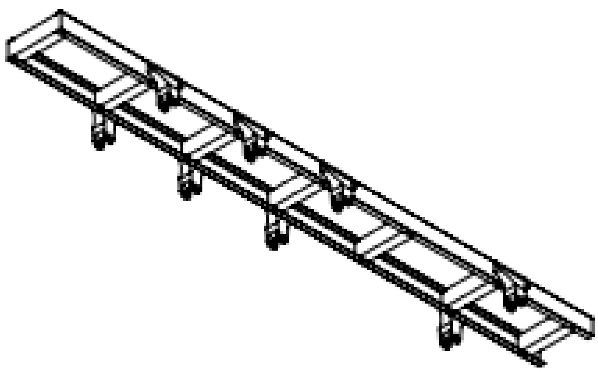


Fig 1: Ladder Chassis

1.1 Overview of The Project

Since past few years major cities across the world have been witnessing an upsurge in pollution levels. The smoke released from automobile and especially high fuel consuming heavy vehicles like trucks and building machinery constitutes to a major portion of these pollution levels. Decreasing the weight of such heavy vehicles can reduce the fuel consumption and can also indirectly reduce the smoke emitted and will have a positive impact on the environment. Chassis is one such part of automobiles whose weight can be decreased to achieve this feat. The basic outline of the project is to design the existing chassis frame by using solid works considering the dimensions of draft sheet. So, SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. After design the existing part, the design has been analyzed in Ansys. So, Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. After structural analysis has been completed the design is then topologically optimized using same Ansys workbench. So, topology optimization is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. The design is then remodeled for manufacturing purposes Which is optimized in weight, thereby achieving our sole purpose of the project to reduce the weight in order to reduce the environmental pollution.

1.2 Objectives of The Study

- Design the chassis by considering its existence dimensions. It will give the magnitude of stresses and deflection which is generating in the chassis.

- To analyze the chassis frame structurally with selected material for deflection and reduction in weight so as to decrease the fuel consumption as well as emissions to prevent the environment from vehicular pollution.

- Calculate amount of weight reduction after reducing the area.

1.3 Scope of The Study

- We are going to do the optimization of the chassis members.

- Optimization will contribute to reduction of weight without compromising over the strength of the chassis.

1.4 Material Requirement

1.4.1 Structural Steel ASTM A36

ASTM A36 is the most commonly used mild and hot-rolled steel. It has excellent welding properties and is suitable for grinding, punching, tapping, drilling and machining processes. Yield strength of ASTM A36 is less than that of cold roll C1018, thus enabling ASTM A36 to bend more readily than C1018.

S. No	Property	Value
1	Density	7850 kg/m^3
2	Young’s Modulus	2x10^{11} Pa
3	Poisson’s Ratio	0.3
4	Bulk Modulus	1.6667x10^{11} Pa
5	Shear Modulus	7.6923x10^{10} Pa
6	Compressive Ultimate Strength	0 Pa
7	Compressive Yield Strength	2.5x10^8 Pa
8	Tensile Ultimate Strength	4.6x10^8 Pa
9	Tensile Yield Strength	2.5x10^8 Pa

Table 1: Material Properties

S. No	Element	Content
1	Carbon, C	0.25- 0.290 %
2	Copper, Cu	0.20 %
3	Iron, Fe	0.3
4	Manganese, Mn	1.03 %
5	Phosphorous, P	0.040 %
6	Silicon, Si	0.280 %
7	Sulphur, S	0.050 %

Table 2: Chemical Composition

CHAPTER-2 LITERATURE SURVEY

2.1 Literature Review

- Joel Galos et al. [1] diagnosed double-deck trailers for weight over axle as they may be beneficial in mild weighting the trailer and observed that double-deck trailers can't be used on roads due to its bad height clearance in tunnels and beneath bridges. They designed a lightweight heavy duty goods automobile trailer and advised most a hit composite answers for creating a balance among value, overall performance and weight loss.

- Divyanshu Sharma and Y D Vora [2] studied the chassis layout, recognized different kinds of chassis, designed and analyzed a heavy-duty trailer chassis the usage of finite detail evaluation software program and reduced the weight of the trailer for proposed sections with same stiffness and tension and determined negligible deformation at the rear aspect of the chassis.

- Divyanshu Sharma and Y D Vora [3] designed and analyzed a heavy duty trailer for vibration by using appearing modal evaluation the use of FEA software and concluded that the chassis vibrations are capable of inflicting deformation and counseled that those chassis vibrations may be sustained through optimization of chassis design via herbal frequency.

- Gajanan S. Datar et al. [4] analyzed a 40-tonne heavy duty trailer for static as well as dynamic conditions for observing the behaviour of the masses on body. It has been concluded that the shape became secure with almost least deflection.

- Ahmad O. Moaaz and Nouby M. Ghazaly [5] explained the fatigue evaluation of a heavy responsibility truck body by way of exploring special analytical and numerical analysis techniques available for the fatigue analysis by way of thinking about dynamic masses acting on the essential additives of a heavy obligation truck frame.

- Hemant B. Patil et al. [6] analyzed a ladder kind low loader truck chassis shape having Cbeams for structural analysis for 7. Five tonne software the use of finite detail analysis software. The aspect member thickness, cross member thickness and role of cross member from rear quit had been changed for reducing the pressure magnitude at vital factor of the chassis body.

- AnandGosavi et al. [7] designed a six-axle trailer frame and analyzed it structurally for discount in weight of the body. It turned into noticed that the weight of chassis body become decreased by way of 37% (approx.). They concluded that the burden of chassis frame may be optimized for sixaxle car through the use of finite element analysis.

- Kurdi et al. [8] analyzed the heavy-duty truck chassis for stress analysis using FEA for the positioning of critical point having highest stress. They observed that the critical point was located at the chassis opening which was connected with a bolt. It has been concluded that the reduction in the magnitude of stress at this critical point was needed. Akash Singh Patel and

2.2 Review on Related Literature

The following are the overview of different research of different authors on similar content of our project:

Joel Galos et al, they designed a lightweight heavy duty goods automobile trailer and advised most a hit composite answers for creating a balance among value, overall performance and weight loss. Divyanshu Sharma and Y D Vora, the chassis vibrations are capable of inflicting deformation and counseled that those chassis vibrations may be sustained through optimization of chassis design via herbal frequency. Gajanan S. Datar et al, it has been concluded that the shape became secure with almost least deflection. AnandGosavi et al, they concluded that the burden of chassis frame may be optimized for sixaxle car through the use of finite element analysis.

2.3 Conclusions on Reviews

These are the following conclusion of the above authors whom we have taken for the reference of the content of a project:

Joel Galos et al, they designed a lightweight heavy duty goods automobile trailer and advised most a hit composite answers for creating a balance among value, overall performance and weight loss. Divyanshu Sharma and Y D Vora, the chassis vibrations are capable of and counseled that those chassis vibrations may be sustained through optimization of chassis design via herbal frequency. Gajanan S. Datar et al, it has been concluded that the shape became secure with almost least deflection. AnandGosavi et al, they concluded that the burden of chassis frame may be optimized for sixaxle car through the use of finite element analysis.

CHAPTER-3 PROJECT DESIGN

3.1 Introduction to Solidworks

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on an Intel-based Mac with Windows installed, the application's developer recommends against this. SolidWorks does not support macOS.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, fiscal year 2011–12 revenue for SolidWorks totaled $483 million.

Fig 2: Solidworks Icon

3.2 History of Solidworks

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product *SolidWorks 95*, in

November 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired. SolidWorks for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company.

SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

SolidWorks was headed by John McEleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who is promoted Vice President Sales of Dassault Systems' Value Solutions sales channel.

3.3 Solidworks Uses

- SolidWorks is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings.

- Designing in a modeling package such as SolidWorks is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design.

3.4 Solidworks Component

Before we begin looking at the software, it is important to understand the different components:

3.4.1 Part

- The first, and most basic element of a SolidWorks model is a Part.

- Parts consist of primitive geometry and features such as extrudes, revolutions, lofts, sweeps, etc.

- Parts will be the building blocks for all of the models that you will create.

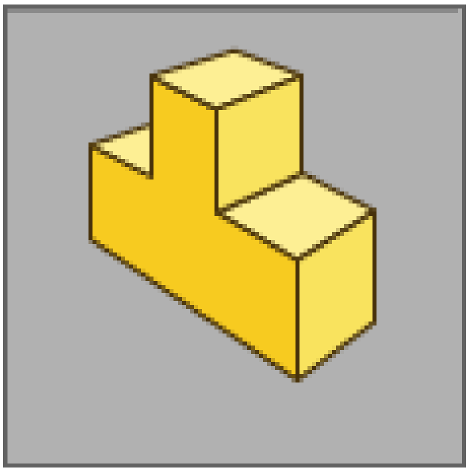


Fig 3: Part

3.4.2 Assemblies

- The second component is the assembly. Assemblies are collections of parts which are assembled in a particular fashion using mates (constraints).

- Any complex model will usually consist of one, or many assemblies.

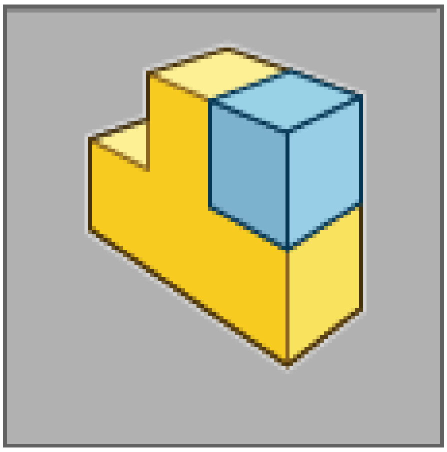


Fig 4: Assembly

3.4.3 Drawings

- The third, and final component in SolidWorks is the Drawing.

- A drawing is the typical way to represent a 3D model such that any engineer (or manufacturer) can recreate your part.

- Drawings are important because they provide a standard way of sharing your design.

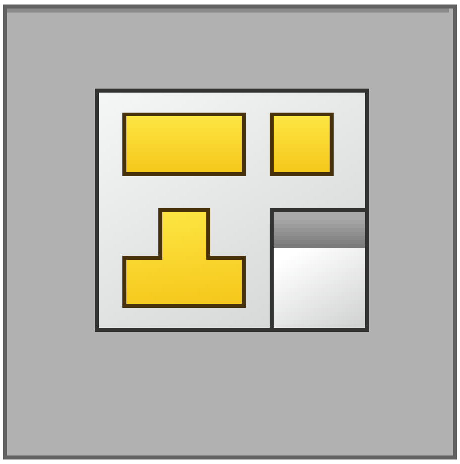


Fig 5: Drawing

3.5 Design Procedure of Existing Chassis Frame in Solidworks

3.5.1 2D Draft Sheet

By considering the 2D draft sheet of the existing frame, we have designed the model by using Solidworks software.

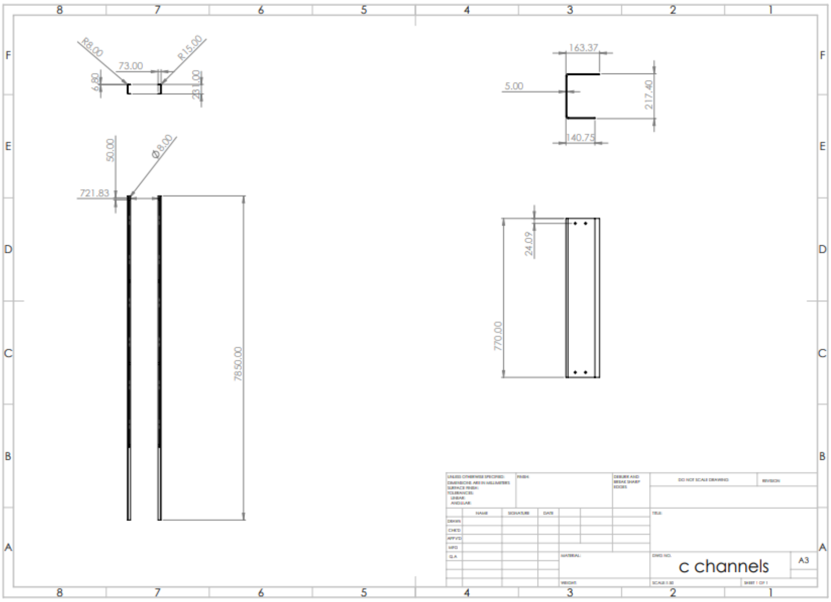


Fig 6: Draft Sheet of C-Channel & Cross Bar

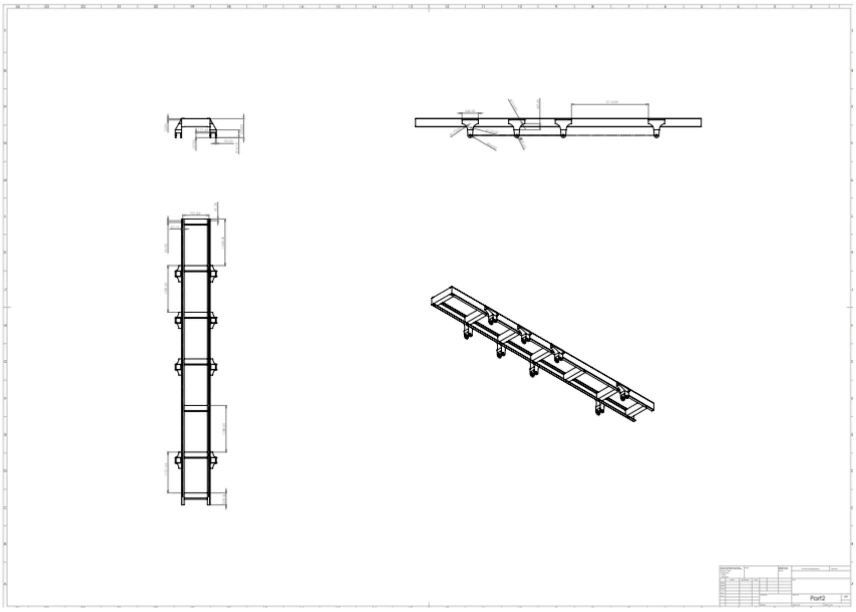


Fig 7: Draft Sheet of Axle Support & Final 2D Design

3.5.2 Solidworks Window

The main section of the window, where the model or drawing is displayed, is the graphics area.

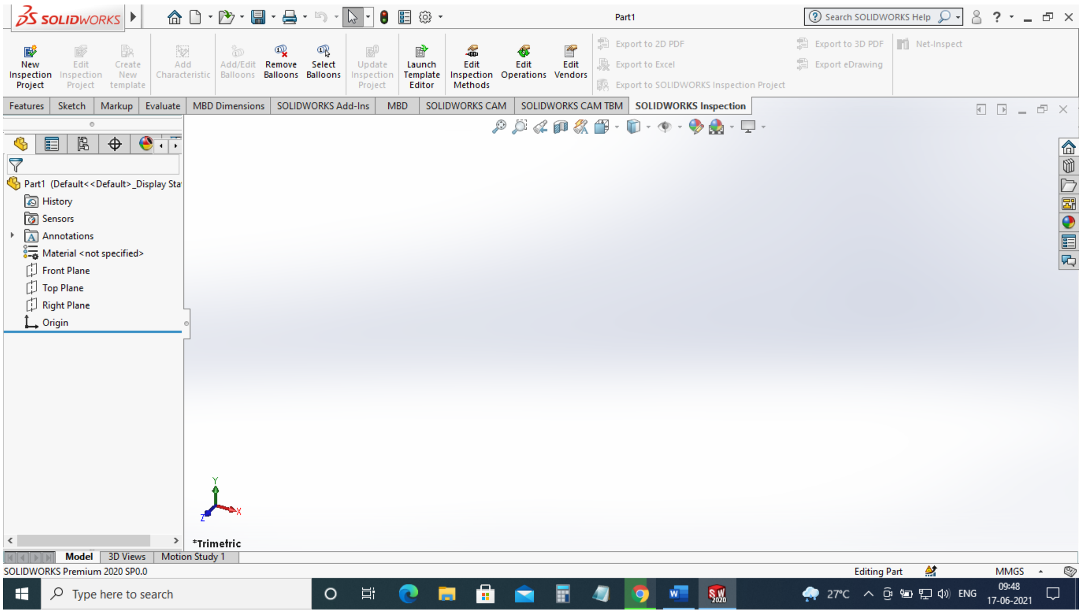


Fig 8: Solidworks Window

3.5.3 Sketch Window

After selecting the component, we have to select the plane in which we are going to design our model.

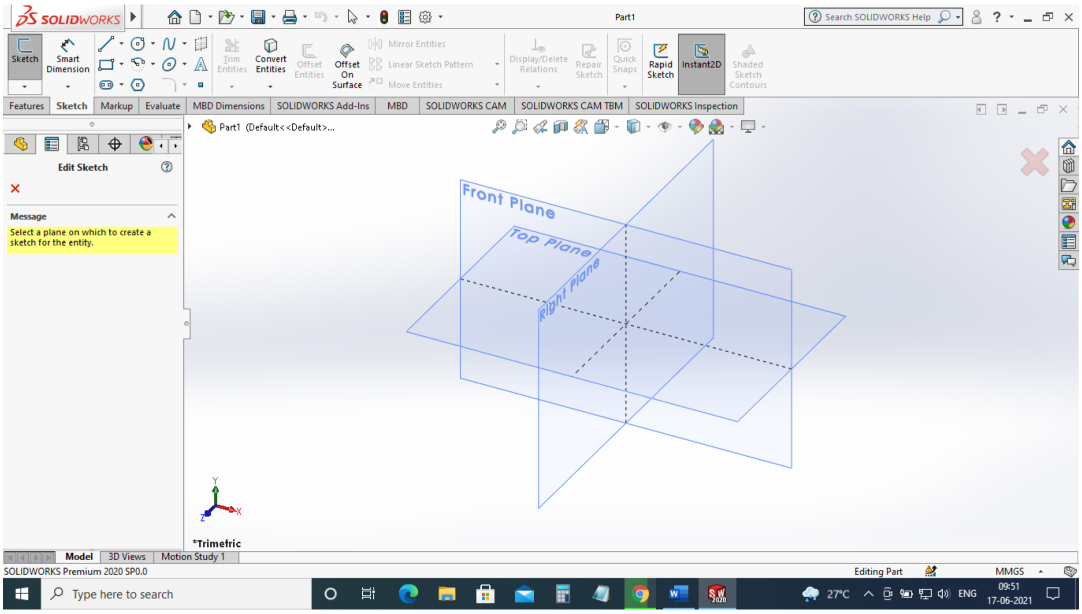


Fig 9: Sketch Window

3.5.4 C-Channel

After selecting the front plane, first, we have drawn the rough sketch of the C-Channel using the line tool and applied the dimension by using the smart dimension command. After applying the dimension, we have used the centerline tool and mirror command to mirror it along the centerline and Front Plane. After all, this is done, we have used the boss extrude command to extrude it.

Dimensions

- Length – 231 mm
- Thickness – 6.80 mm
- Breadth – 73 mm
- Mirror – 385 mm
- Distance between C-Channels – 770 mm
- Extrude length – 7850 mm

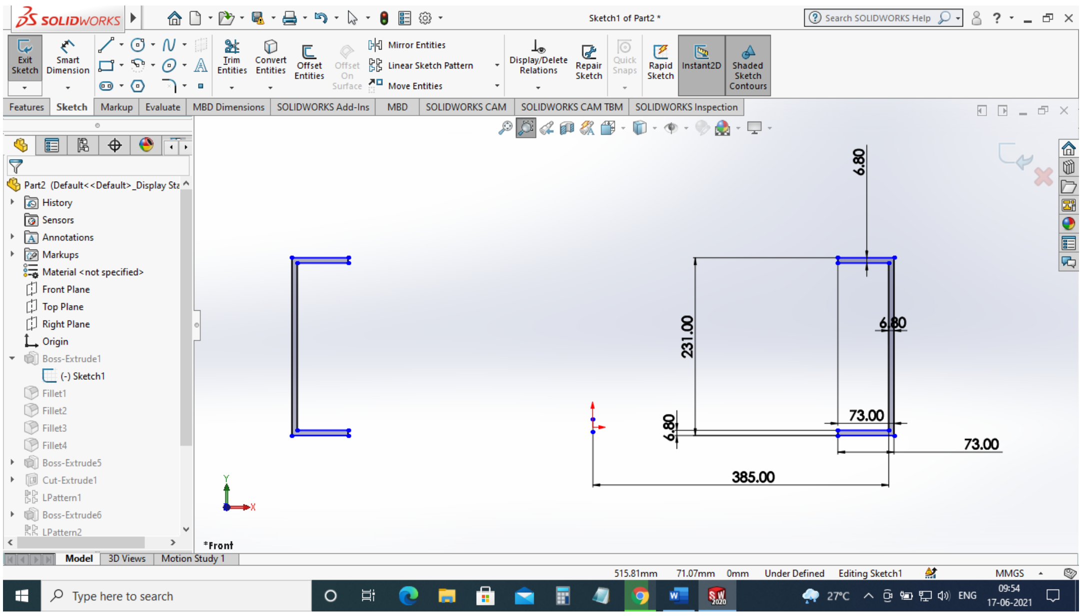


Fig 10: Sketch 1

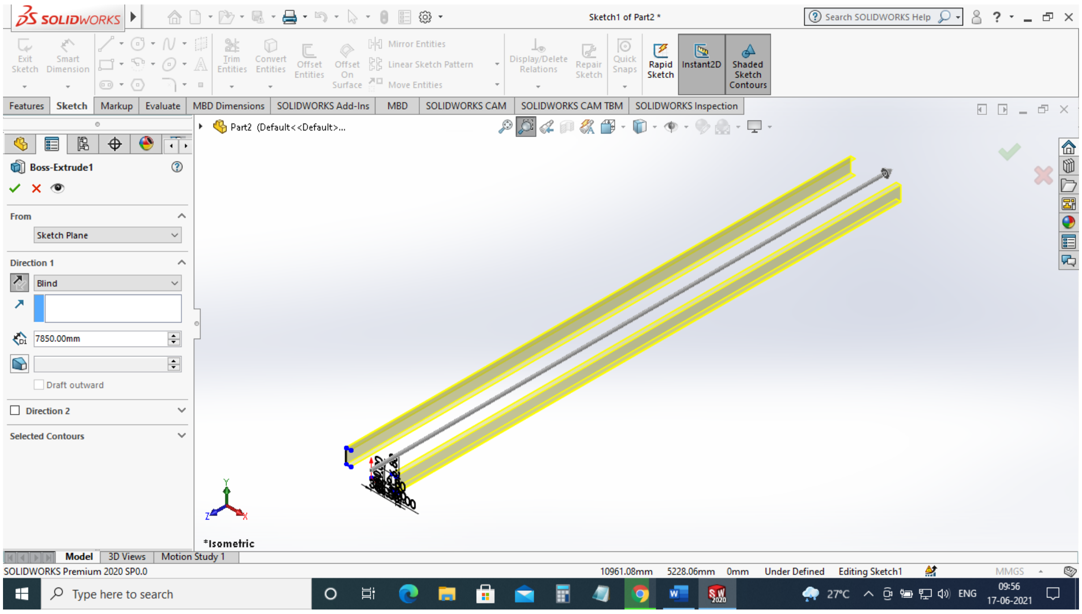


Fig 11: Boss Extrude 1

3.5.5 Crossbar

After Sketching and extrusion of C-Channel, we have drawn the rough sketch of the Crossbar using the line tool and applied dimension by using the smart dimension command. After applying the dimension, we have used the boss extrude command to extrude it up to the next surface. After all, this is done, we have used the pattern command to divide the same crossbars along the length of the C-Channel.

Dimensions

- Length – 217.40 mm
- Thickness – 5 mm
- Upper Breadth – 167.37 mm
- Lower Breadth – 140.75 mm
- Linear Pattern Spacing – 1280 mm
- Total instances – 7

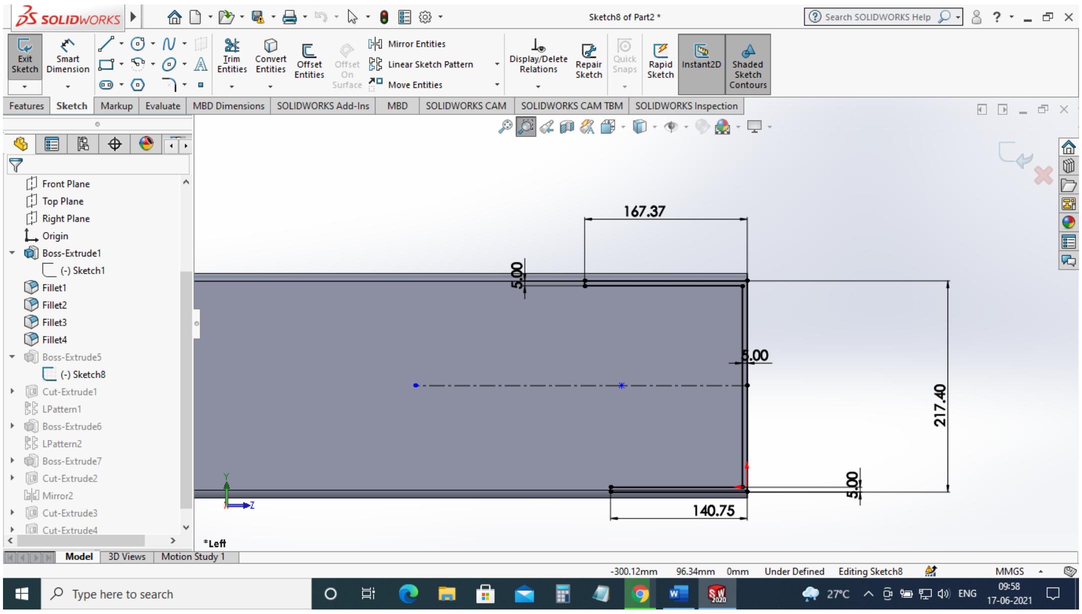


Fig 12: Sketch 8

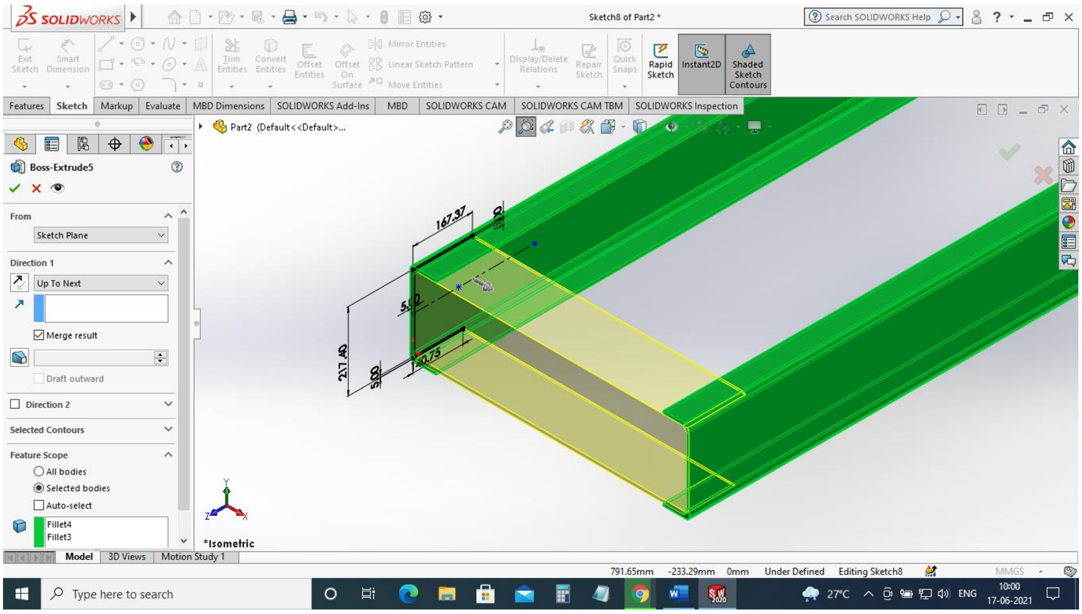


Fig 13: Boss Extrude 5

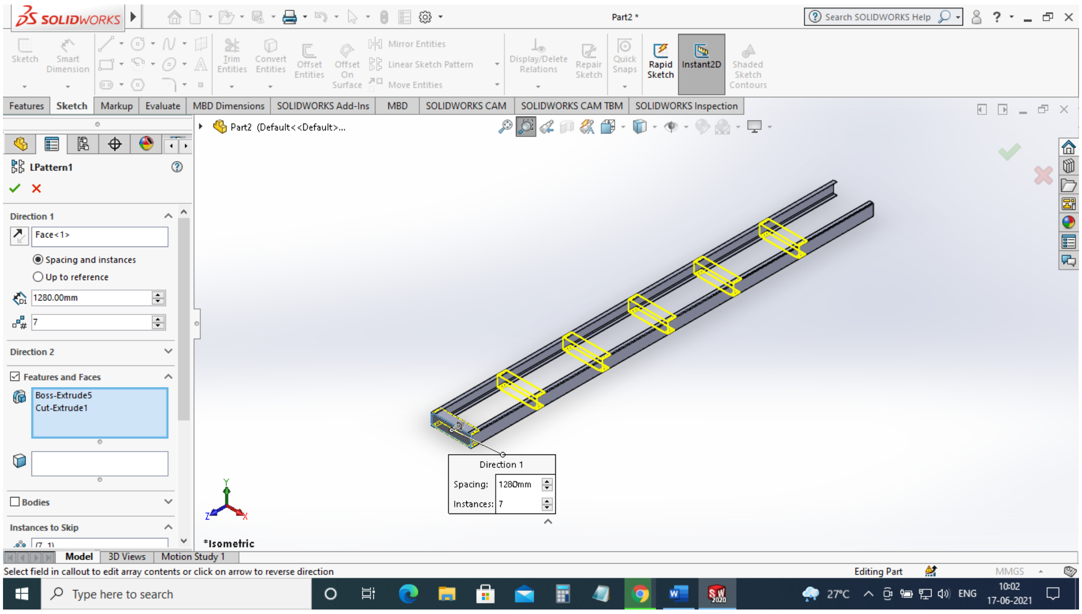


Fig 14: Pattern 1

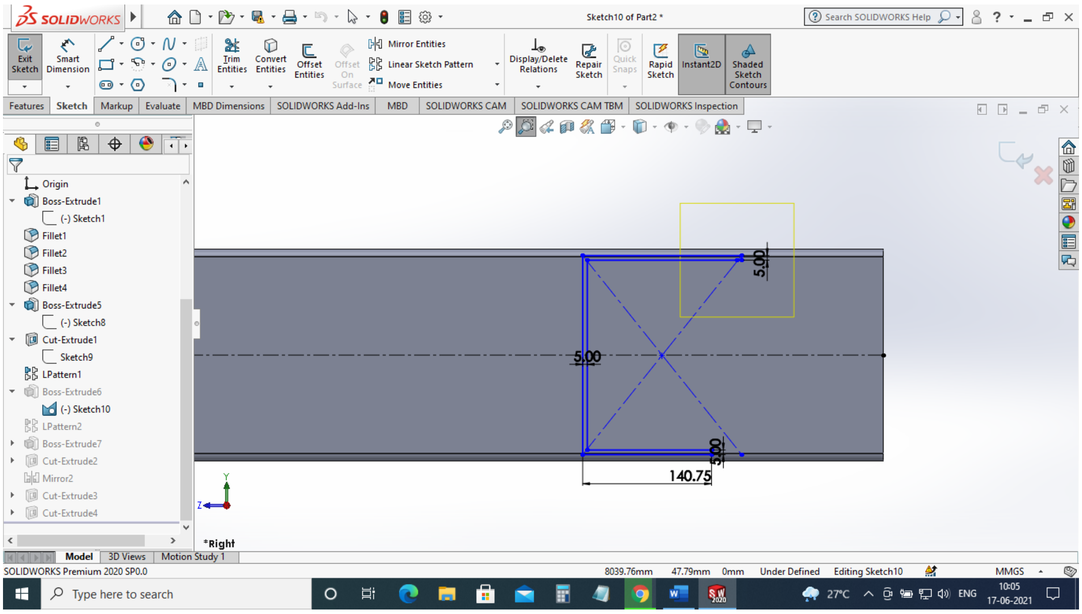


Fig 15: Sketch 10

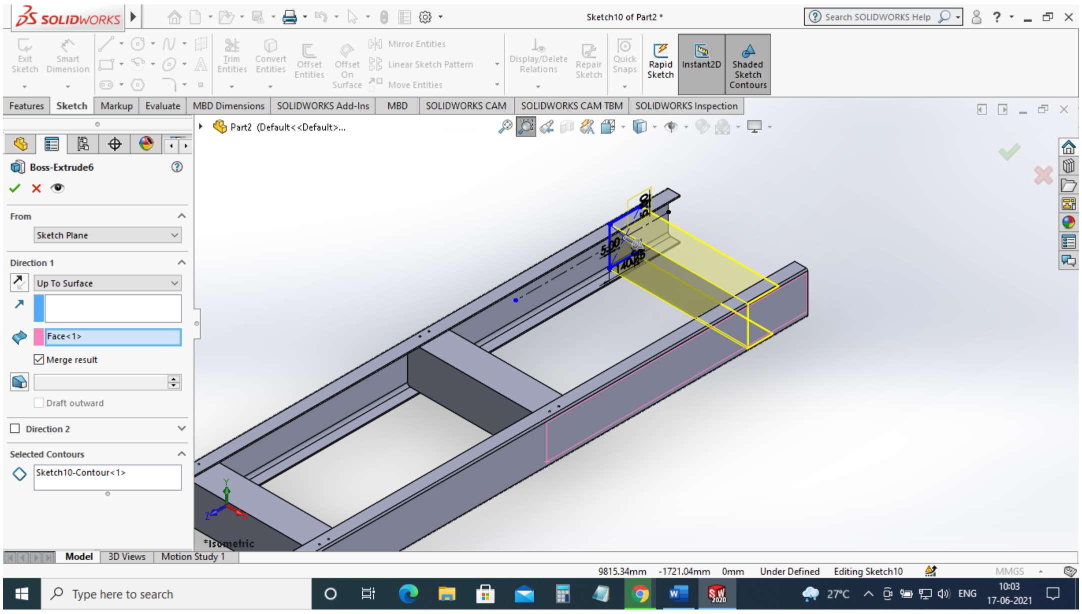


Fig 16: Boss Extrude 6

3.5.6 Axle Support

After Sketching and extrusion of Crossbars, we have drawn the rough sketch of Axle Support using the line tool and applied dimension by using the smart dimension command. After applying the dimension, we have used the boss extrude command to extrude it. Then, by using the circle& tool and extrude cut command we have cut it. After all, this is done, by using the mirror command we have to mirror it and using pattern command to divide the same axle support.

Dimensions

- Length – 520 mm, 127 mm, 215.90 mm
- Thickness – 22.23 mm, 14.90 mm
- Breadth – 171.45 mm
- Extrude Length – 446 mm
- Linear Pattern Spacing – 1280 mm
- Instances – 3

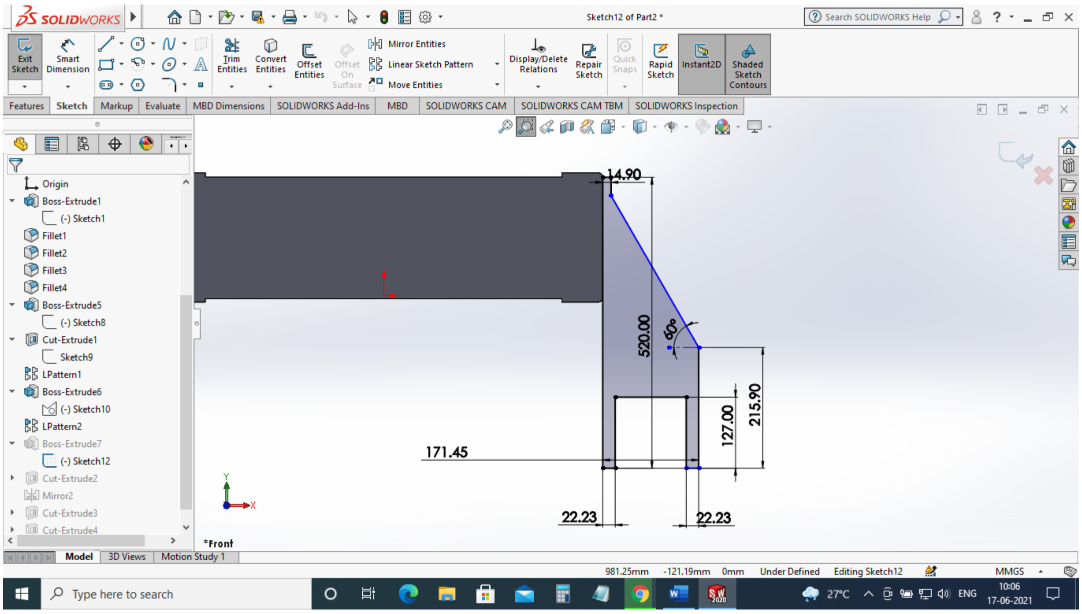


Fig 17: Sketch 12

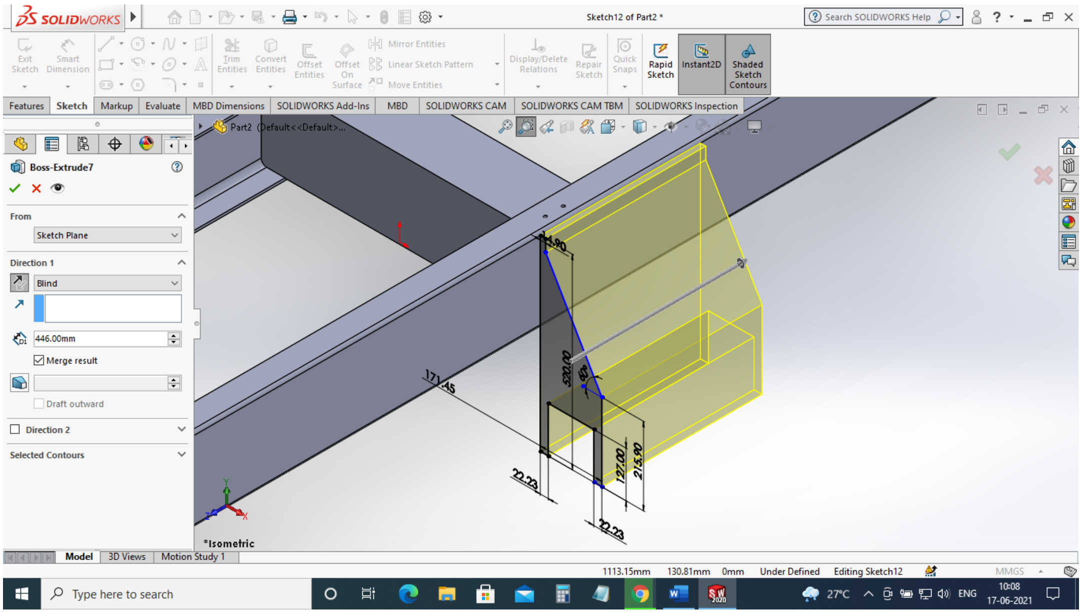


Fig 18: Boss Extrude 7

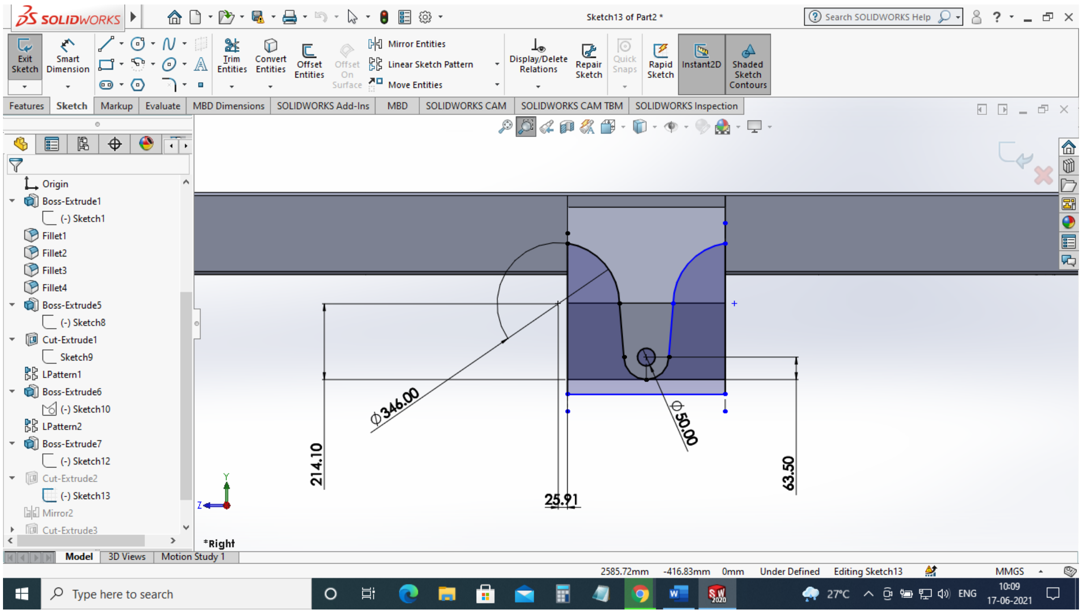


Fig 19: Sketch 13

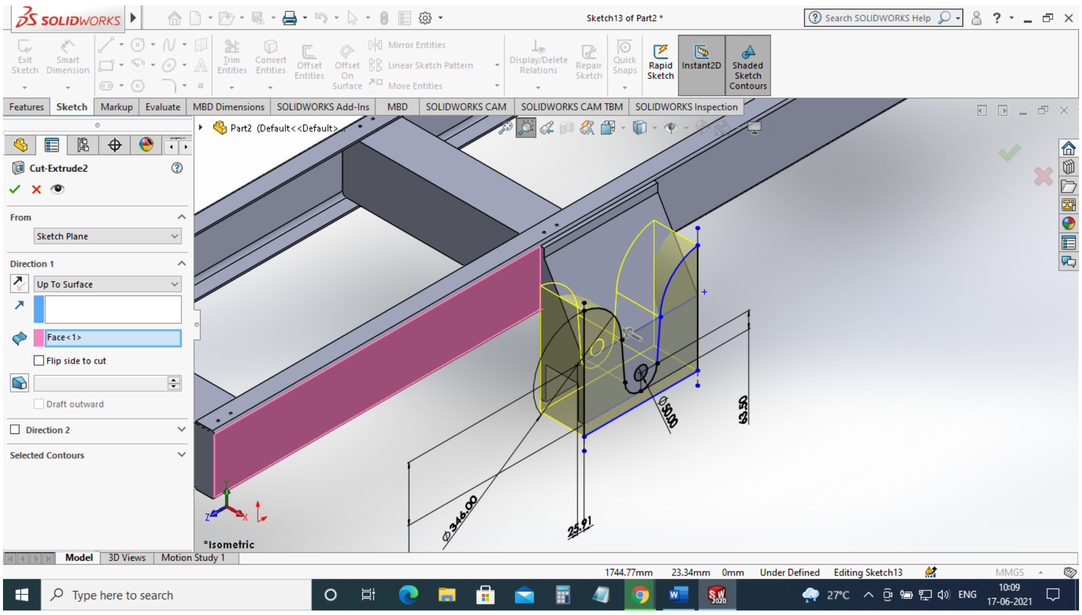


Fig 20: Cut Extrude 2

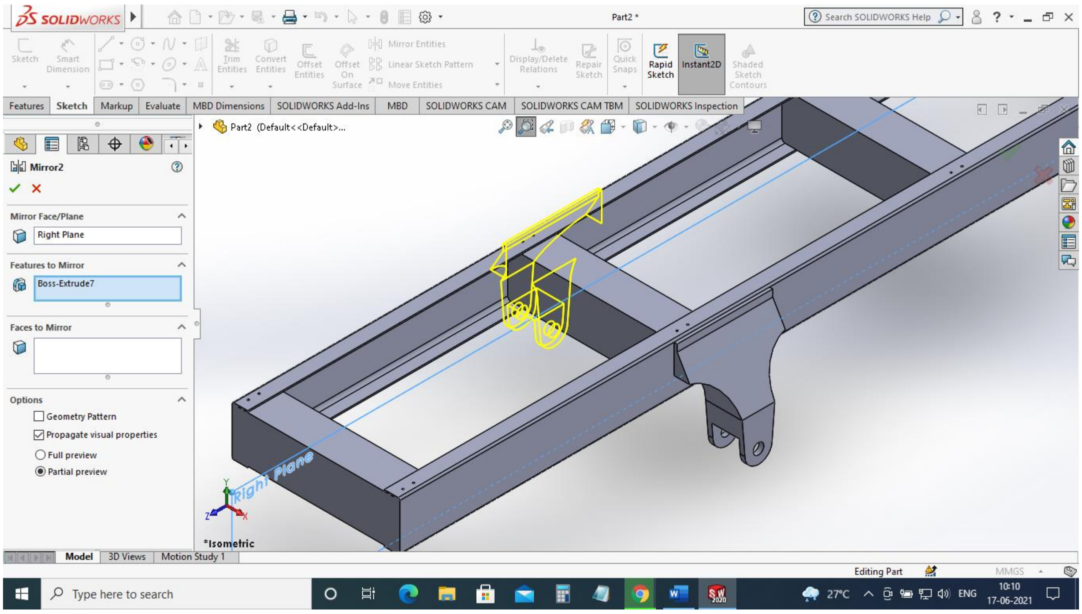


Fig 21: Mirror 2

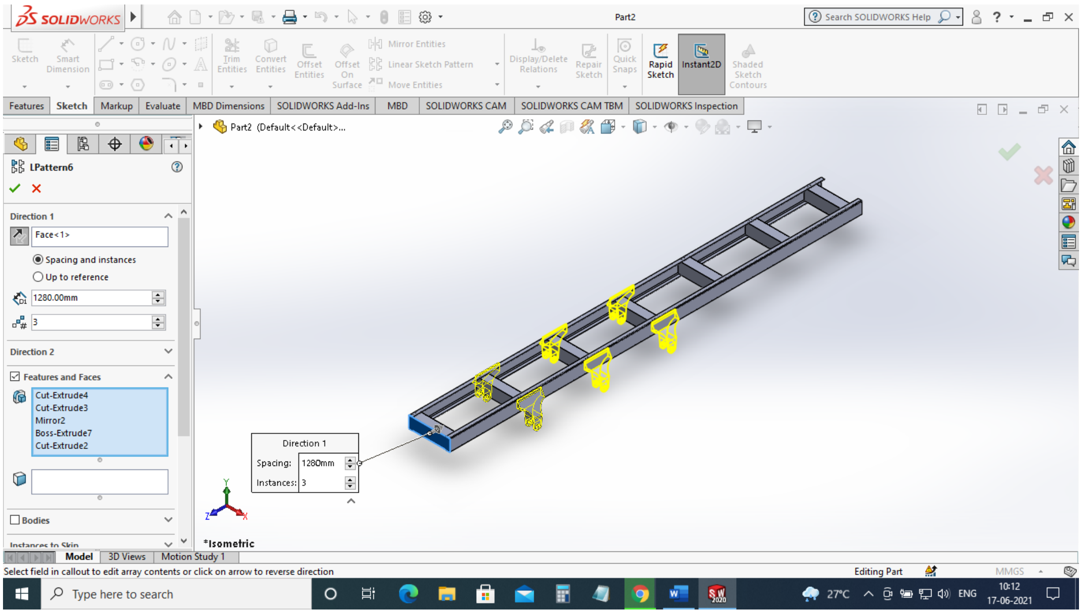


Fig 22: Pattern 6

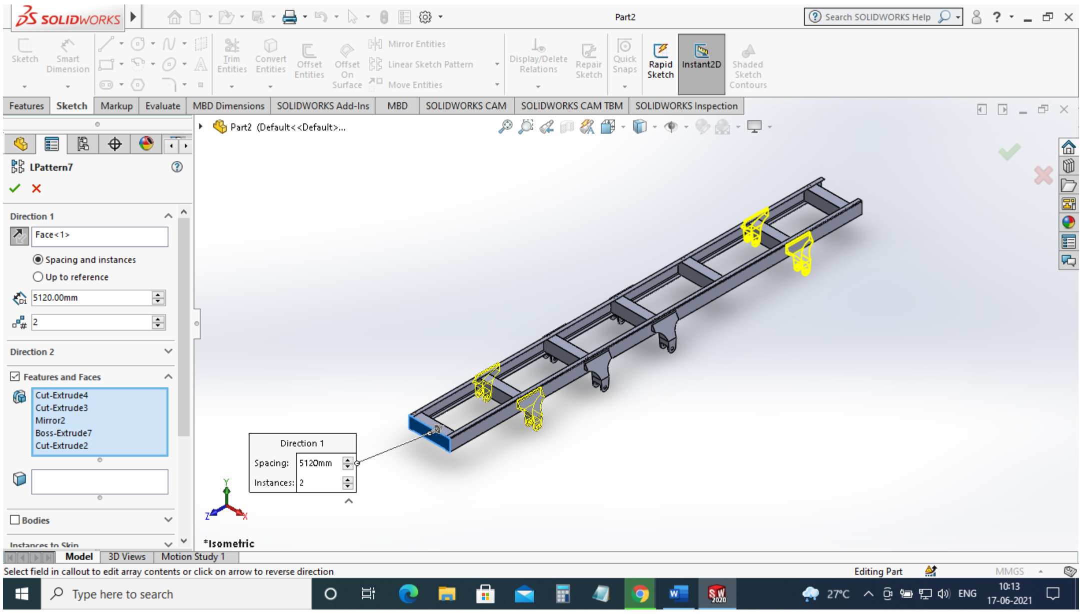


Fig 23: pattern 7

3.5.7 Final model

By considering the draft sheet of the existing chassis frame, we have used various tools like line, circle, centerline, and the commands like boss extrude, boss cut, linear pattern, mirror, fillet, etc. we have designed our final model of the existing chassis frame.

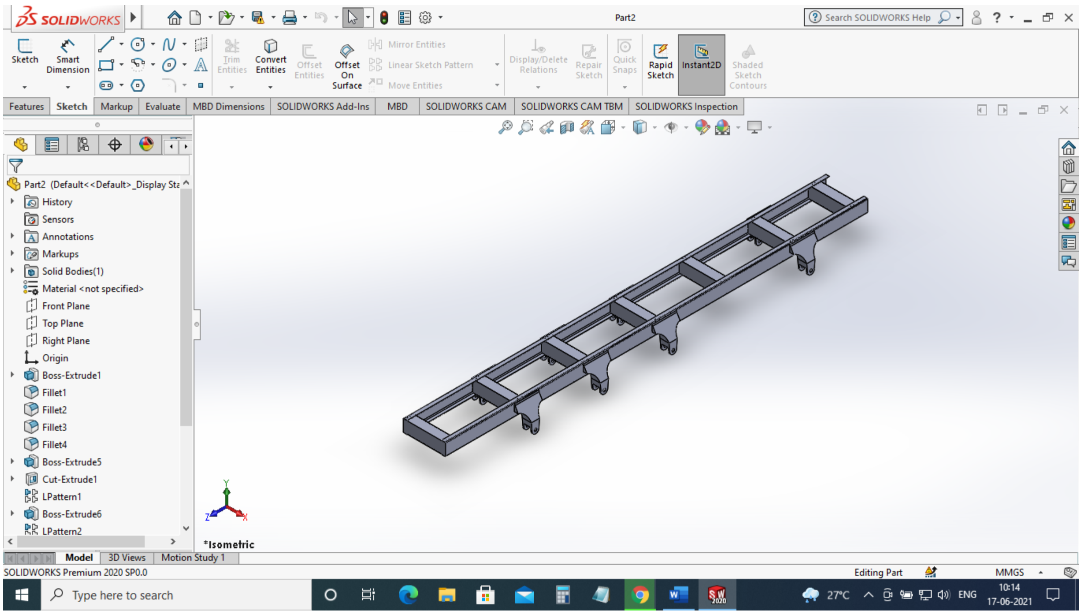


Fig 24: Final Model

CHAPTER-4 PROJECT IMPLEMENTATION

4.1 Introduction to Ansys

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable.
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.

A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

Fig 25: ANSYS Logo

4.2 History of Ansys

The first commercial version of Ansys software was labeled version 2.0 and released in 1971. At the time, the software was made up of boxes of punch cards, and the program was typically run overnight to get results the following morning. In 1975, non-linear and thermo-electric features were added. The software was exclusively used on mainframes, until version 3.0 (the second release) was introduced for the VAXstation in 1979. Version 3 had a command line interface like DOS.

Released in January 2020, Ansys R1 2020 updates Ansys' simulation process and data management (SPDM), materials information and electromagnetics product offerings. In early 2020, the Ansys Academic Program surpassed one million student downloads.

In November 2020, South China Morning Post reported that Ansys software had been used for Chinese military research in the development of hypersonic missile technology.

4.3 Introduction to Ansys Workbench

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.

Fig 26: Ansys Workbench Logo

4.4 Introduction to Ansys Mechanical

Ansys Mechanical is a finite element analysis (FEA) tool that enables you to analyze complex product architectures and solve difficult mechanical problems. You can use Ansys Mechanical to simulate real world behavior of components and sub-systems, and customize it to test design variations quickly and accurately.

Fig 27: Ansys Mechanical Logo

4.5 Static Structural and Topology Optimization Analysis Procedure of Existing Chassis Frame

4.5.1 Ansys Window

In this section, the analysis of the existing chassis frame is discussed. Start the ANSYS Product Launcher. Select a working directory for storing your model data and launch ANSYS Workbench. You will see the software outfit.

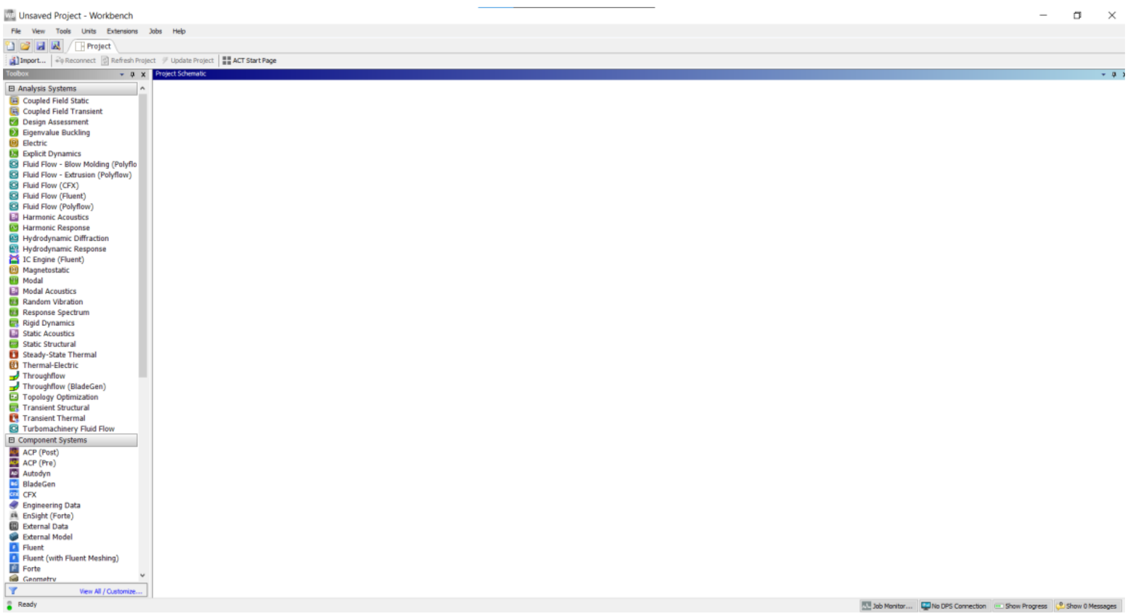


Fig 28: Ansys Window

4.5.2 Static Structural Analysis

In order to perform static structural analysis. First, we need to begin with a double click on static Structural to bring it into the project schematic window.

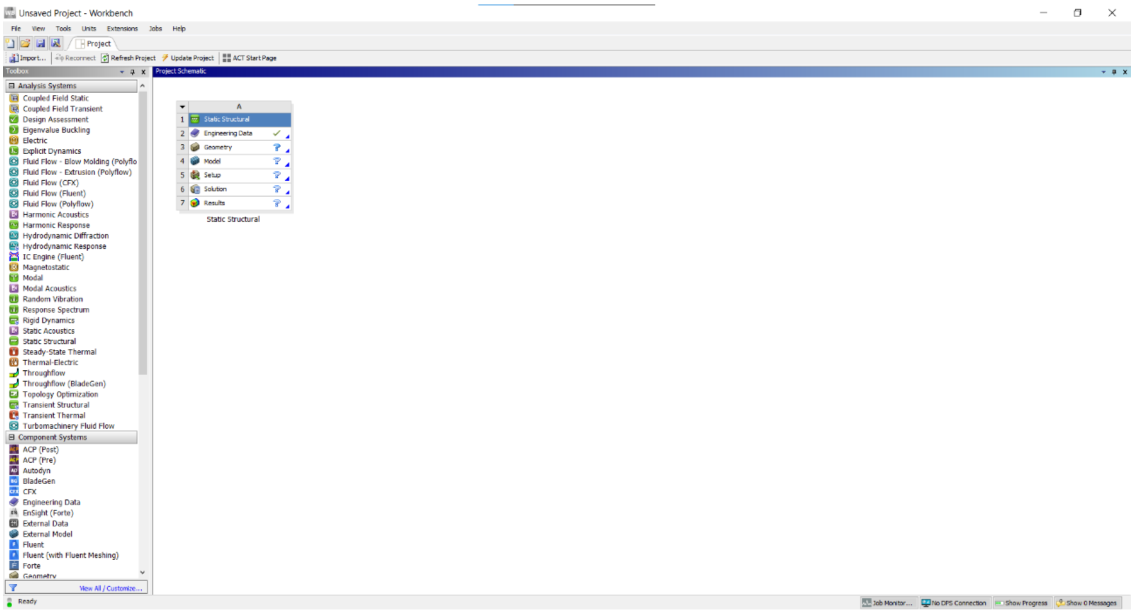


Fig 29: Static Structural Analysis

Next, we should always with looking at the engineering data. So, we have selected structural steel for our analysis. We can either change our material by clicking on engineering data sources.

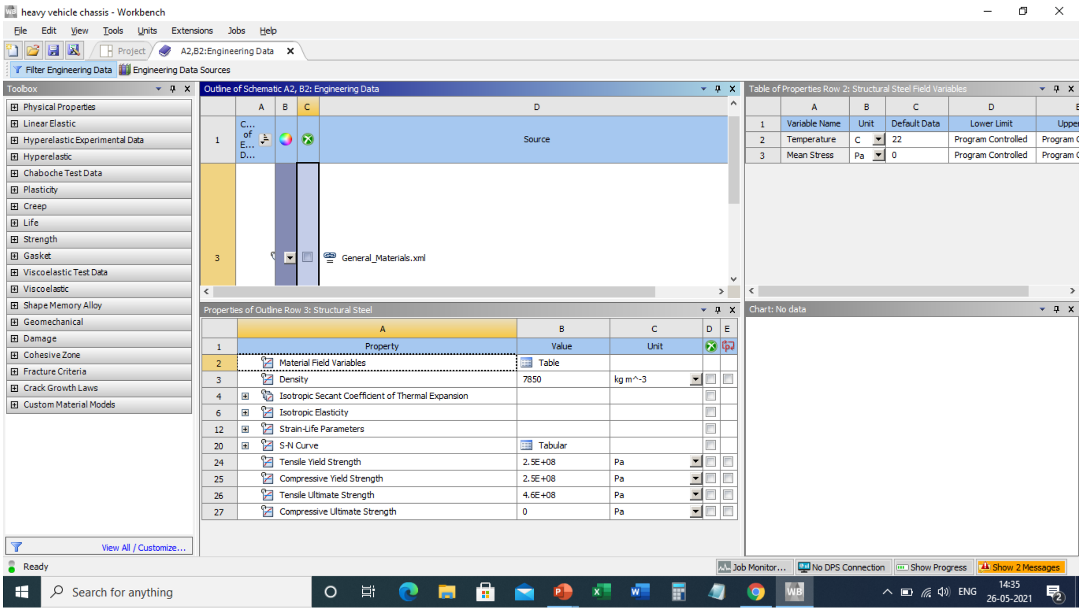


Fig 30: Engineering Data

Then, we can import our Solidworks model by changing file extension i.e., from (. prt to .stp). After importing the geometry, we will go ahead and double click on model or cell no 4 to open up Ansys mechanical.

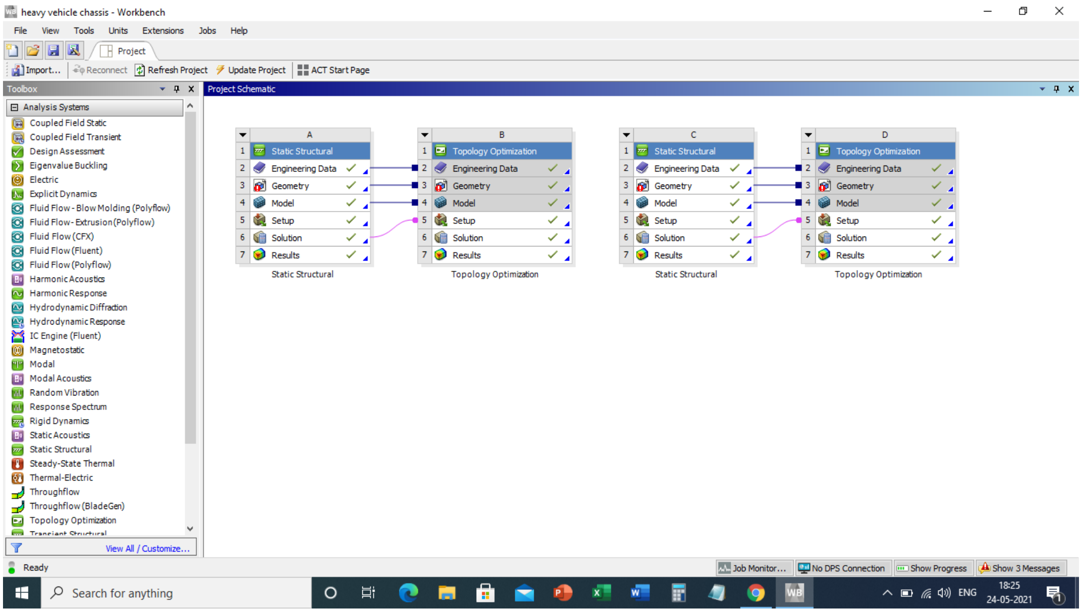


Fig 31: Analysis Detail

So, once mechanical will open, we will go ahead and see Ansys model of Solidworks.

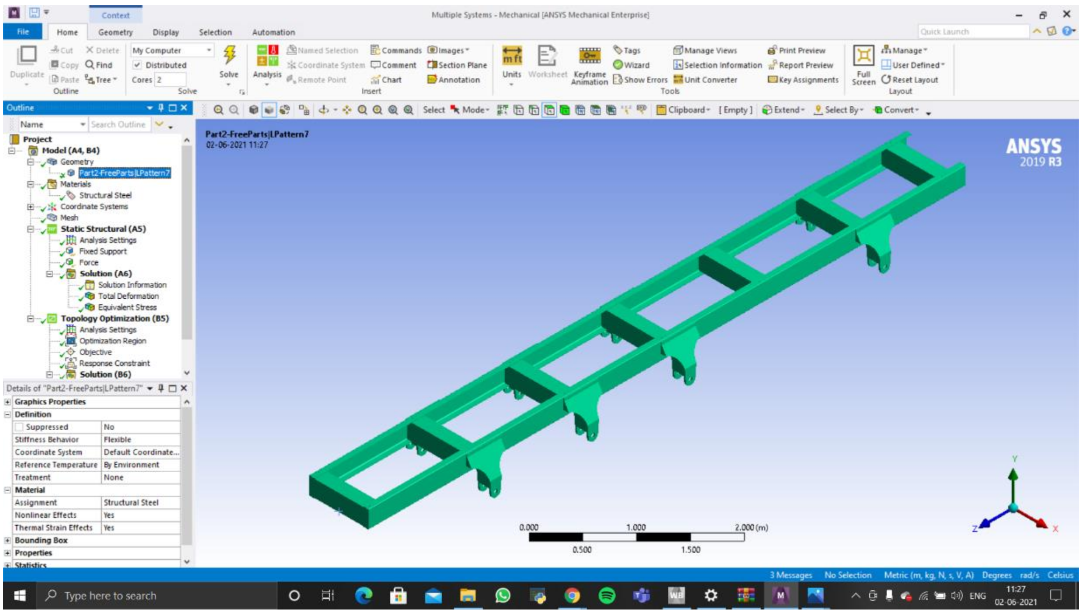


Fig 32: Ansys Geometry Model

Then, we will go ahead and right-click on a mesh and click on generate mesh. In our model, we have applied the mesh size of 75mm. So, after generating a mesh we have observed that there are a total of 211735 nodes and 101651 elements in our model.

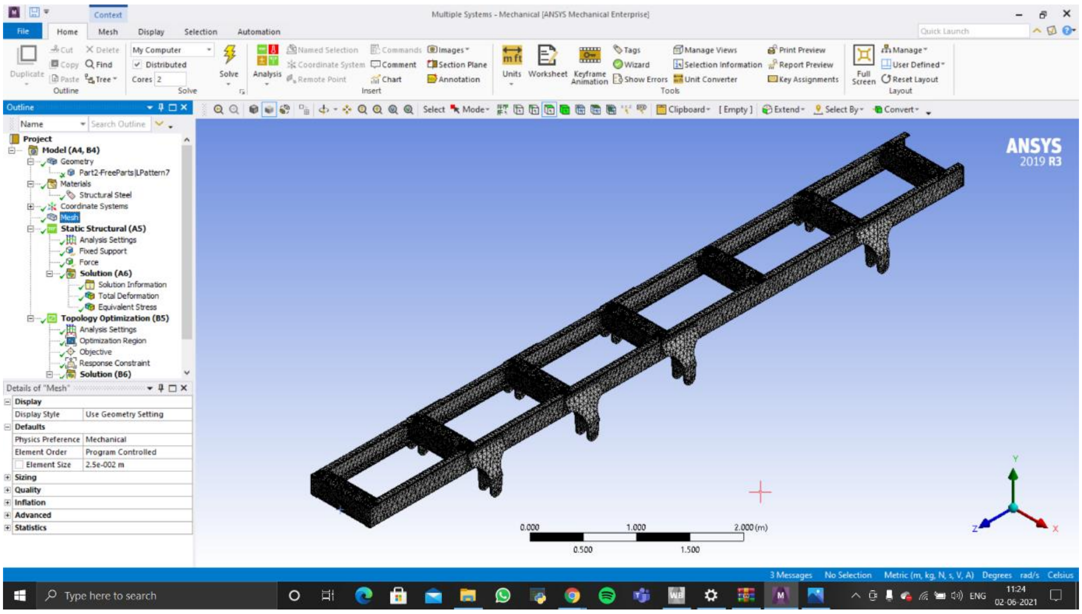


Fig 33: Mesh Model

After generating a mesh, we will go to static structural and right-click and select boundary condition. We have fixed 32 supports in our model.

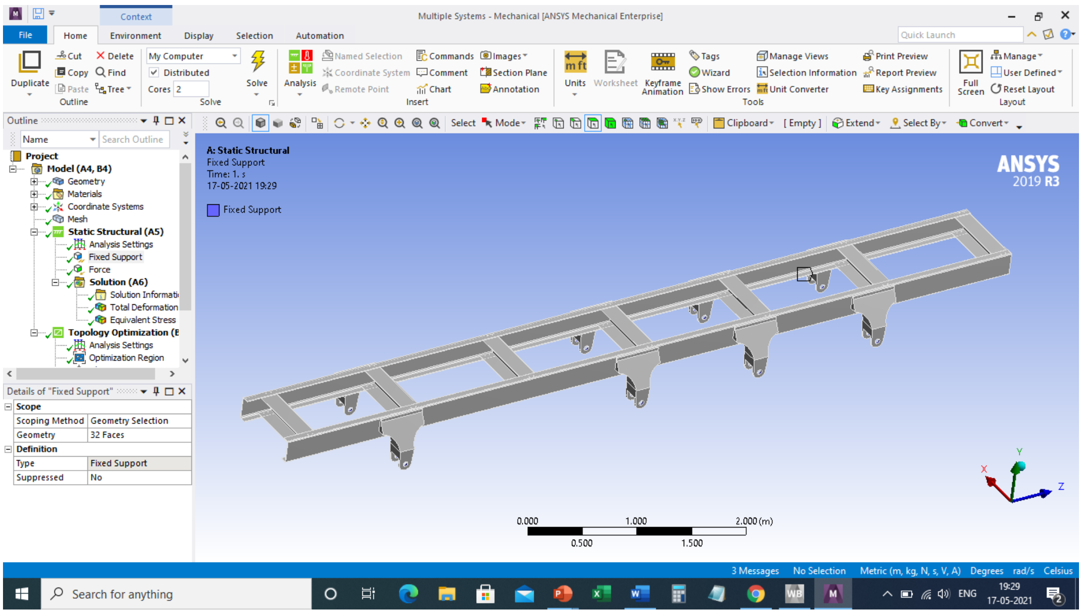


Fig 34: Fixed Support

After fixing the supports. Next, we will go and right-click on static structural and apply force. We have applied the force of 58,840 n in the negative y-direction. So, the load which is acting on the chassis is 6 tones. After converting it into newton we have come across 58,840 N.

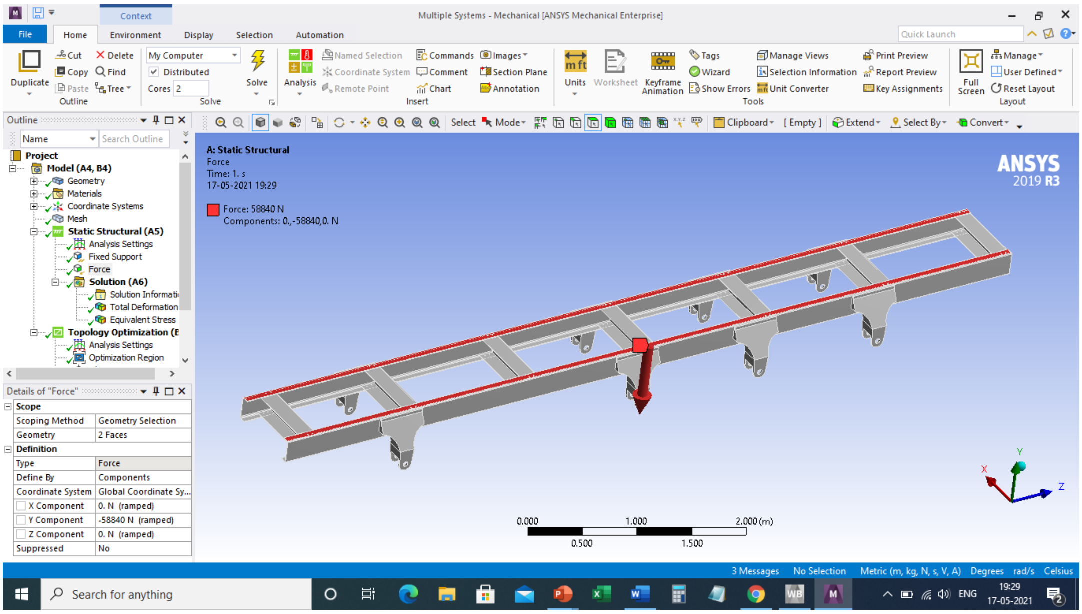


Fig 35: Force Applied

So, once the boundary condition is set. All we need to do is to add the solution. So, we go and insert a total deformation. So then, we right-click and solve to get the result. So, we have observed min and max total deformation of 0 mm and 0.00065796 mm respectively.

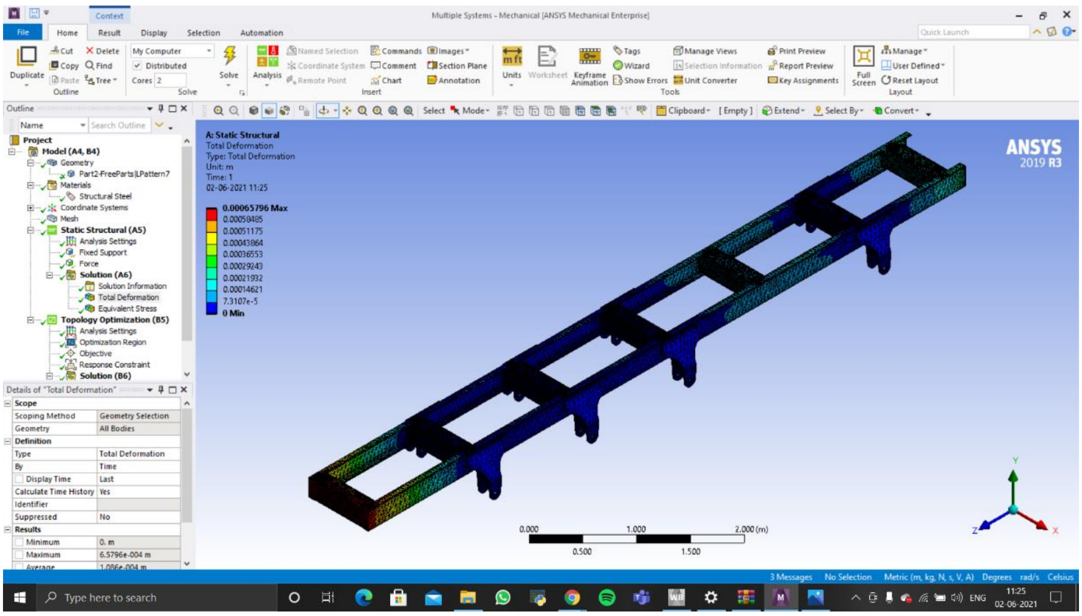


Fig 36: Total Deformation

So next, we go and insert equivalent stress. Now we are ready to go and solve. So, we right-click and solve to get the result. So, we have observed min and max equivalent Stress of 3529.2 Pa and 3.8192*10^7Pa respectively.

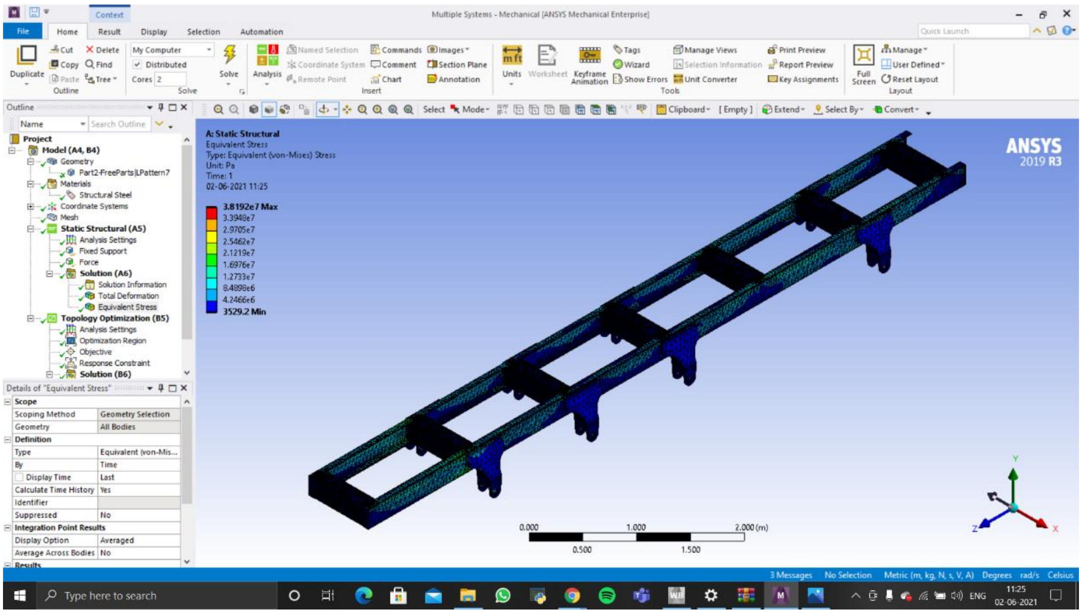


Fig 37: Equivalent Stress

4.5.3 Topology optimization Analysis

So, topology optimization (TO) is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints to maximizing the performance of the system. So, to perform topology optimization. First, we drag topology optimization over the solution. It will share the information from the static analysis which we have completed and create a topology optimization analysis. Once it’s done. We will go ahead and double click on setup to launch mechanical interface with topology optimization. So, now you can see as static structural analysis as well as the topology optimization analysis. So, right you can see that, topology optimization already excluded the regions of the boundary conditions. So, next going into optimization regions. As you can see blue region is part where we did optimization and excluded region are defined by the boundary conditions.

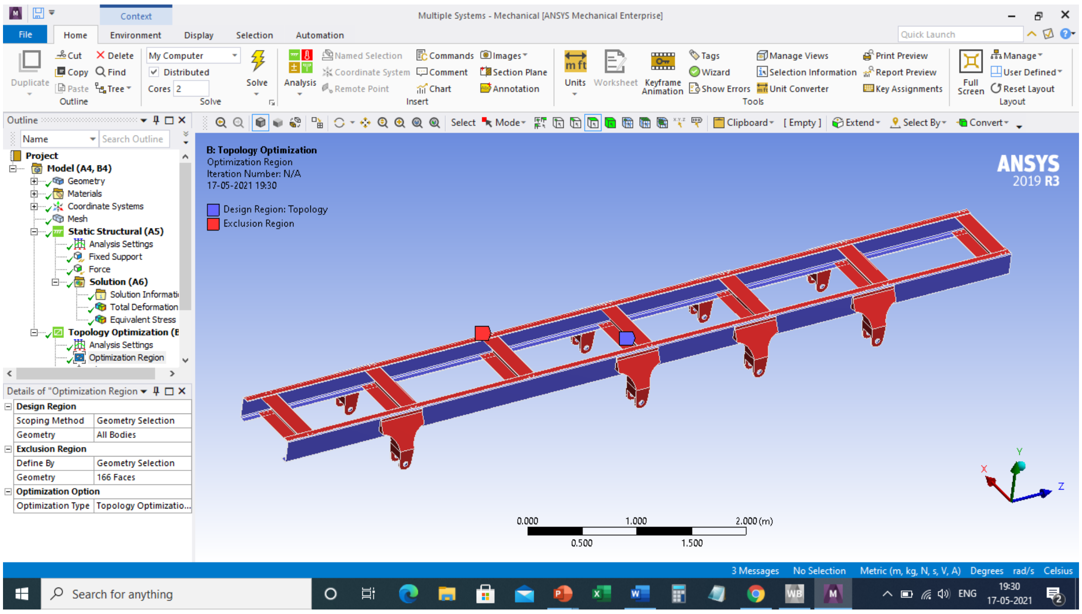


Fig 38: Optimization Region

So next, under response constraint. we can choose exactly what we are going to optimize. In our case, we are optimizing the mass by taking a response constraint of 25%.

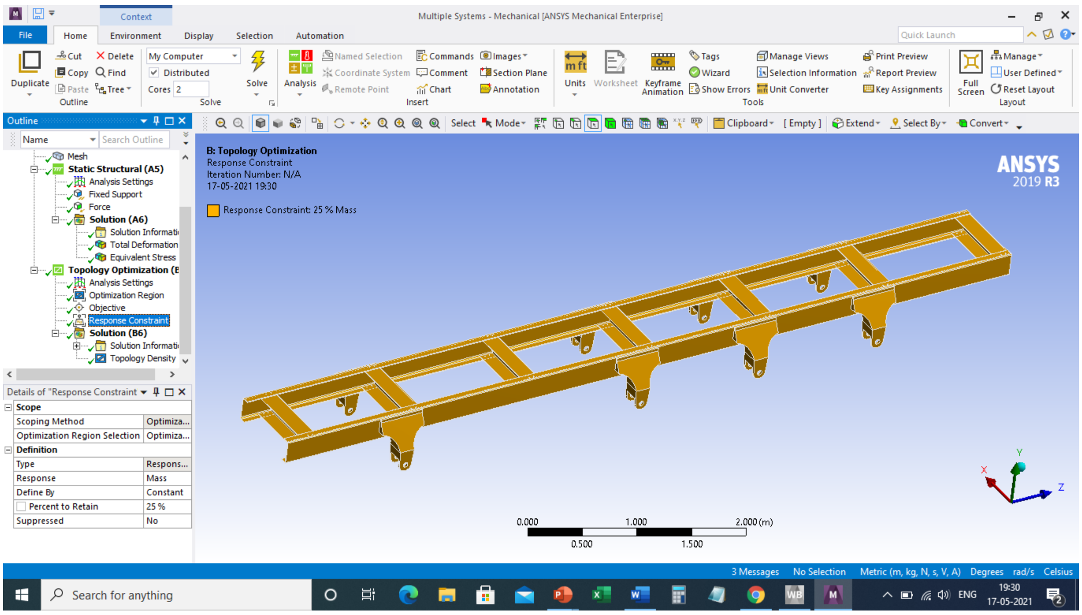


Fig 39: Response Constraint

Apply to solve the optimization of 25%. We came across the topology density, where we have observed that the mass of original mass before optimization was 1006.3 Kg, and the mass we have got after topology optimization was 798.16 Kg.

So basically, we have to remodel it. So that, the optimized part should be converted into perfect shapes. Which is easy for manufacturing.

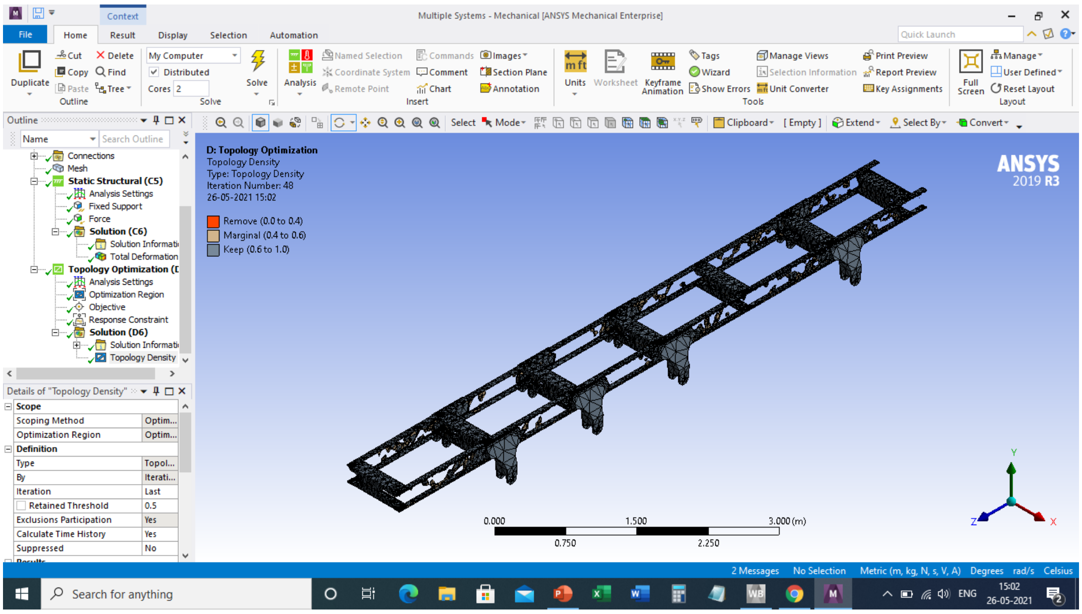


Fig 40: Topology Density

4.6 Remodeled Design of Existing Chassis Frame

To remodel the design first we need to convert the result into a design validation system. After the conversation, we need to update our results. After updating while double-clicking on geometry. SpaceClaim will open where we will be remodeling our design by using a select and smooth command. Along with perfect shapes like squares and rectangles.

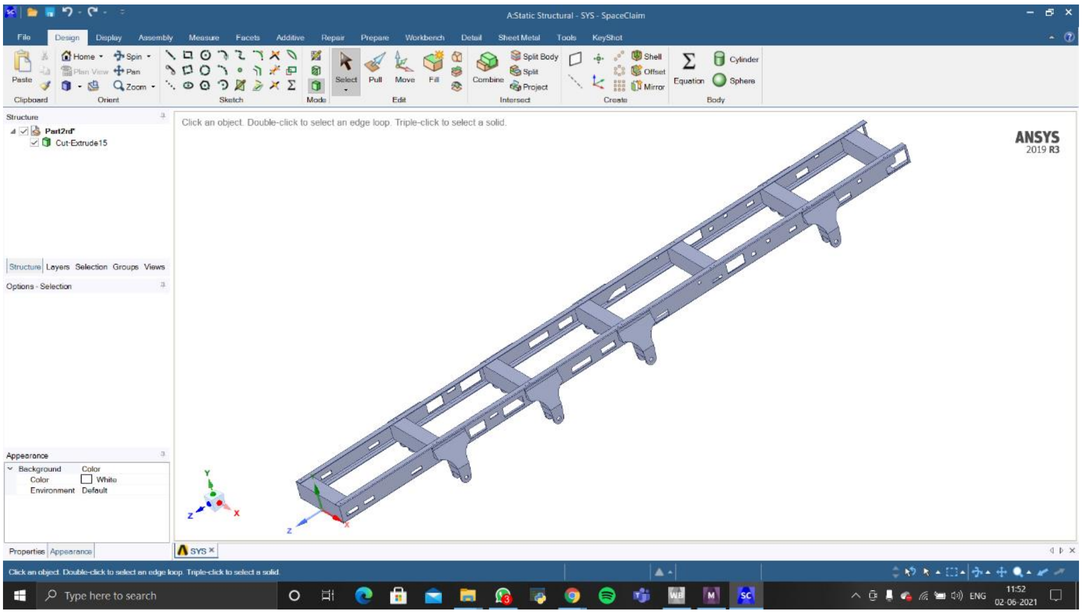


Fig 41: Modified Chassis Frame

4.7 Static Structural Analysis of Modified Chassis Frame

In this section, the Static structural analysis of the modified chassis frame is discussed. Start the ANSYS Product Launcher. Select a working directory for storing your model data and launch ANSYS Workbench. You will see the software outfit. To perform static structural analysis. First, we need to begin a with double click on static Structural to bring it into the project schematic window. Next, we should always with looking at the engineering data. So, we have selected the same material that is structural steel for our analysis. We can either change our material by clicking on engineering data sources. Then, we can import our remodeled chassis frame. After importing the geometry, we will go ahead and double click on model or cell no 4 to open up Ansys mechanical. So, once mechanical will open, we will go ahead and see the Ansys model of the modified chassis frame.

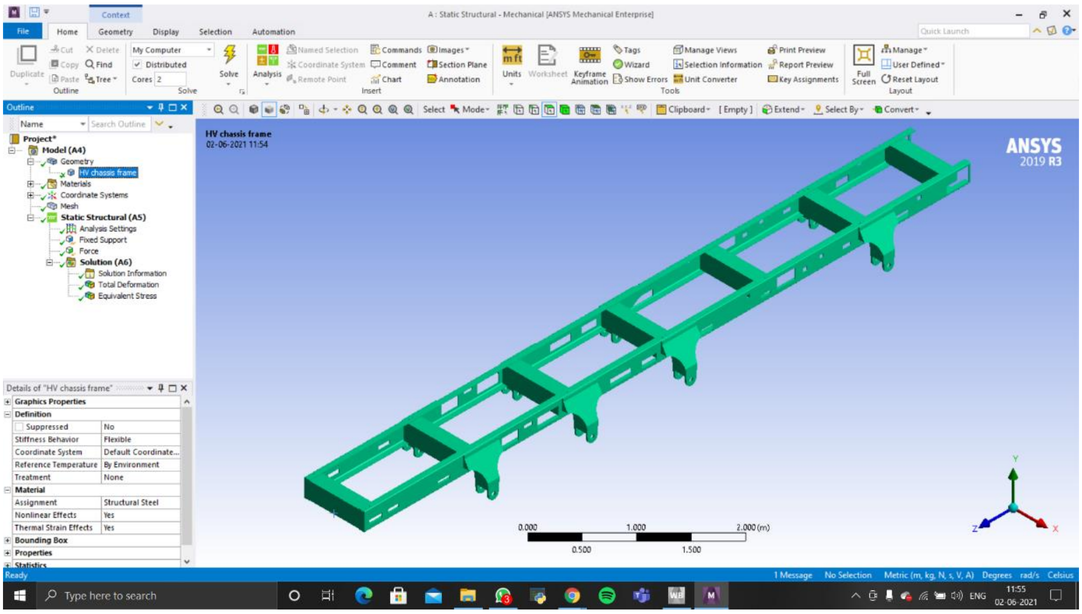


Fig 42: Ansys Geometry Model

Then, we will go ahead and right-click on a mesh and click on generate mesh. In our model, we have applied the same mesh size of 75mm. So, after generating a mesh we have observed that there are a total of 222873 nodes and 105608 elements in our model.

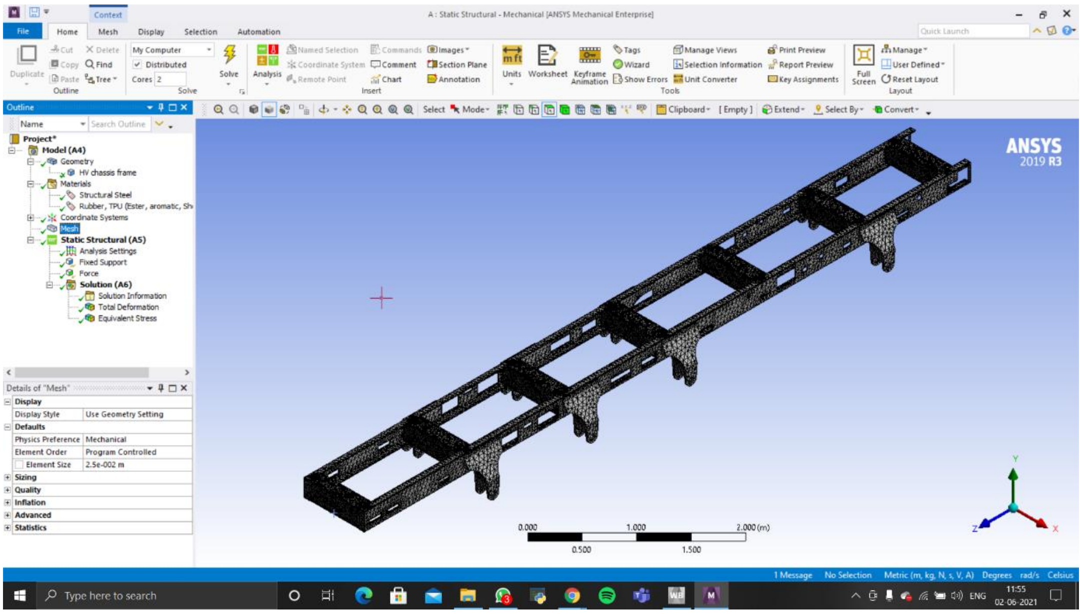


Fig 43: Mesh Model

After generating a mesh, we will go to static structural and right-click and select boundary condition. We have fixed 32 supports in our model.

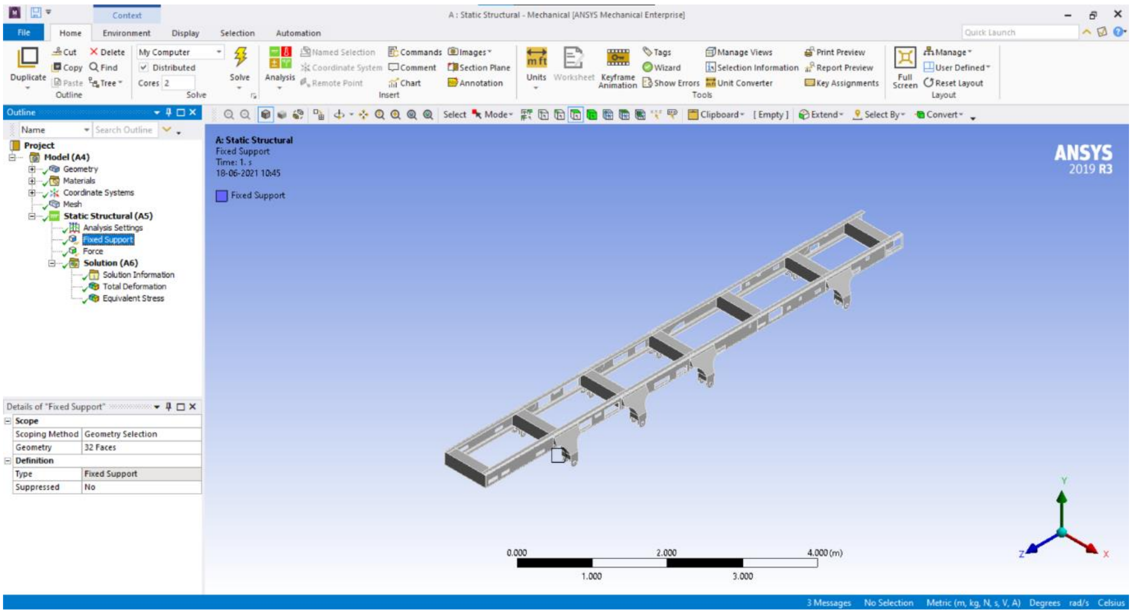


Fig 44: Fixed Support

After fixing the supports. Next, we will go and right-click on static structural and apply force. We have applied the force of 58,840 N in the negative y-direction. So, the load which is acting on the chassis is 6 tones. After converting it into newton we have come across 58,840 N.

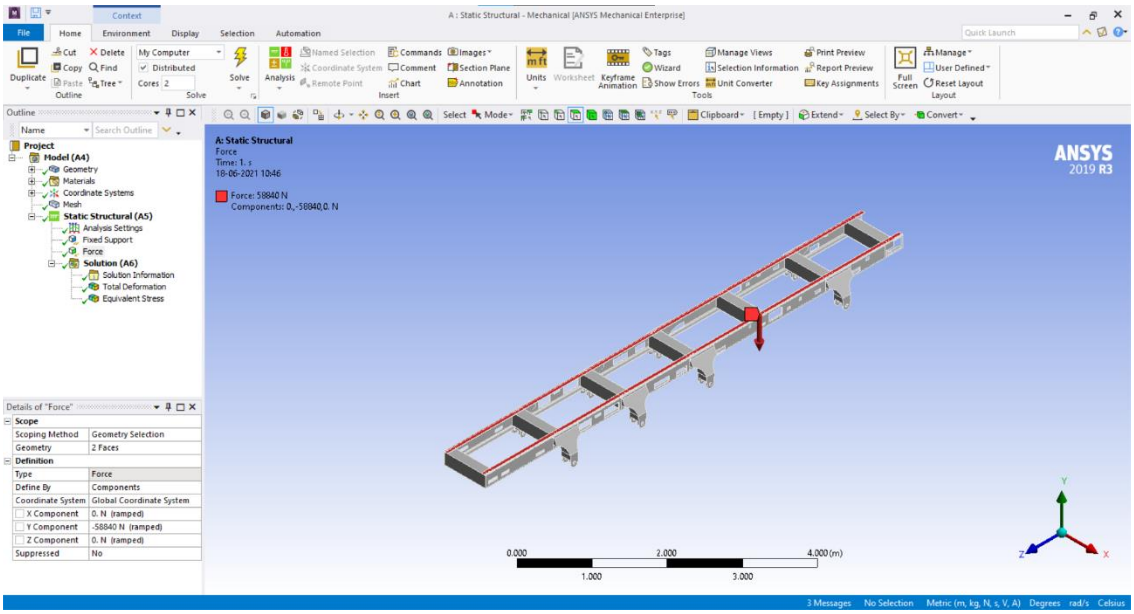


Fig 45: Force Applied

So, once the boundary condition is set. All we need to do is to add the solution. So, we go and insert a total deformation. So then, we right-click and solve to get the result. So, we have observed min and max total deformation of 0 mm and 0.00072656 mm respectively.

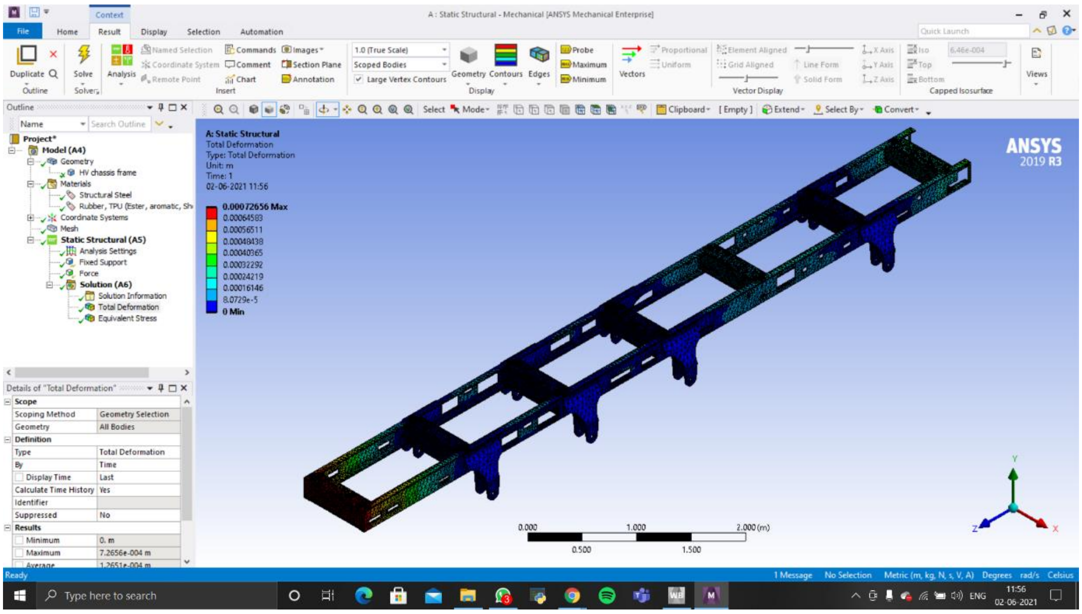


Fig 46: Total Deformation

So next, we go and insert equivalent stress. Now we are ready to go and solve. So, we right-click and solve to get the result. So, we have observed min and max equivalent Stress of 1867.5 Pa and 3.8967*10^7Pa respectively.

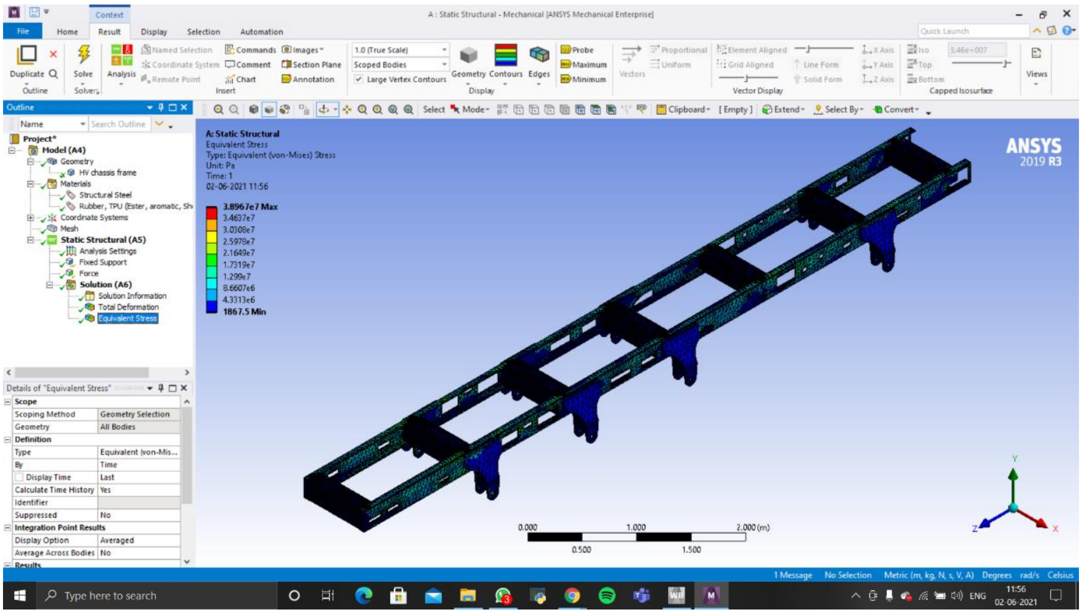


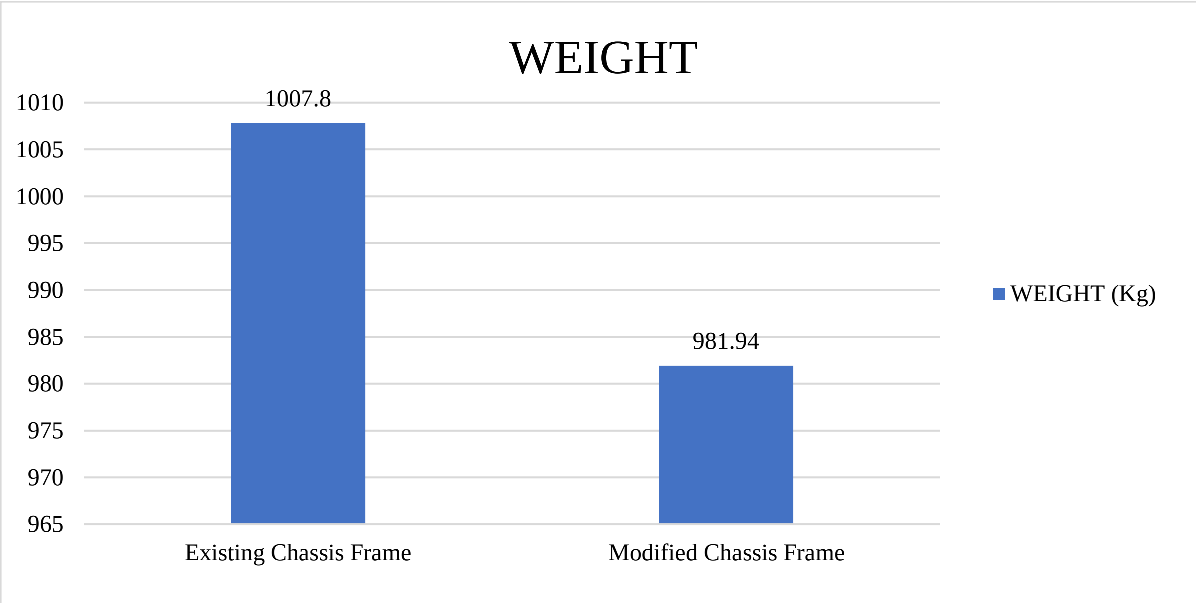
Fig 47: Equivalent Stress

4.8 Result

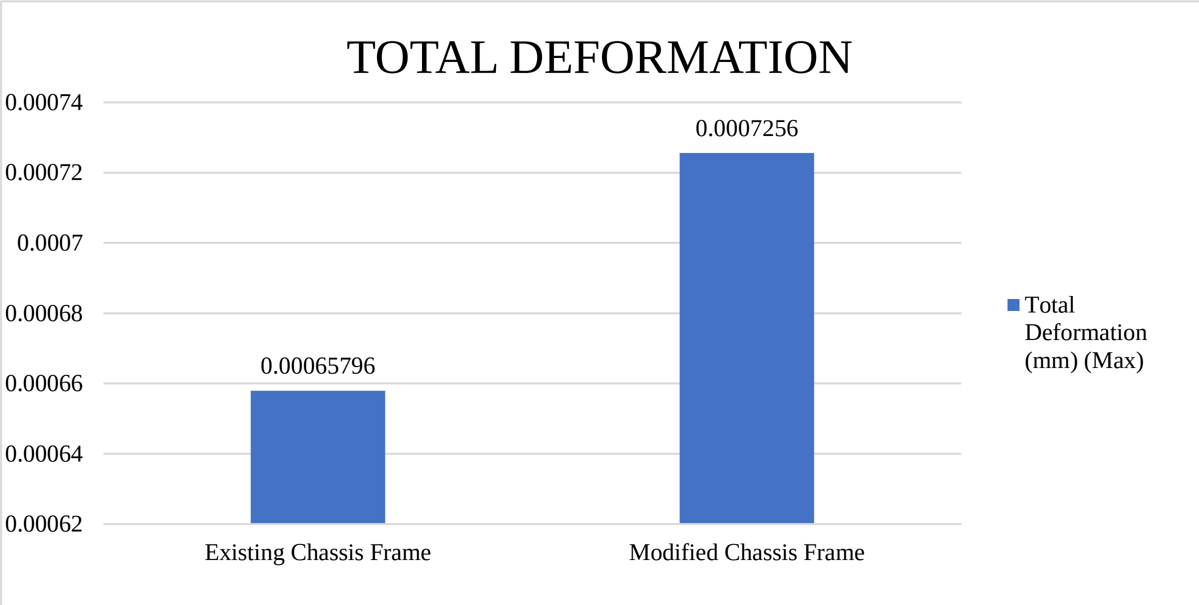
S. No	Parameters/Sections	Existing Chassis Frame	Modified Chassis Frame	Difference
1	Weight (Kg)	1007.8	981.94	-25.86
2	Total Deformation (mm) (Max)	0.00065796	0.0007256	+0.0000686
3	Equivalent Stress (N/mm2 or Mpa) (Max)	38.192	38.967	+0.775

Table 3: Result and Comparison

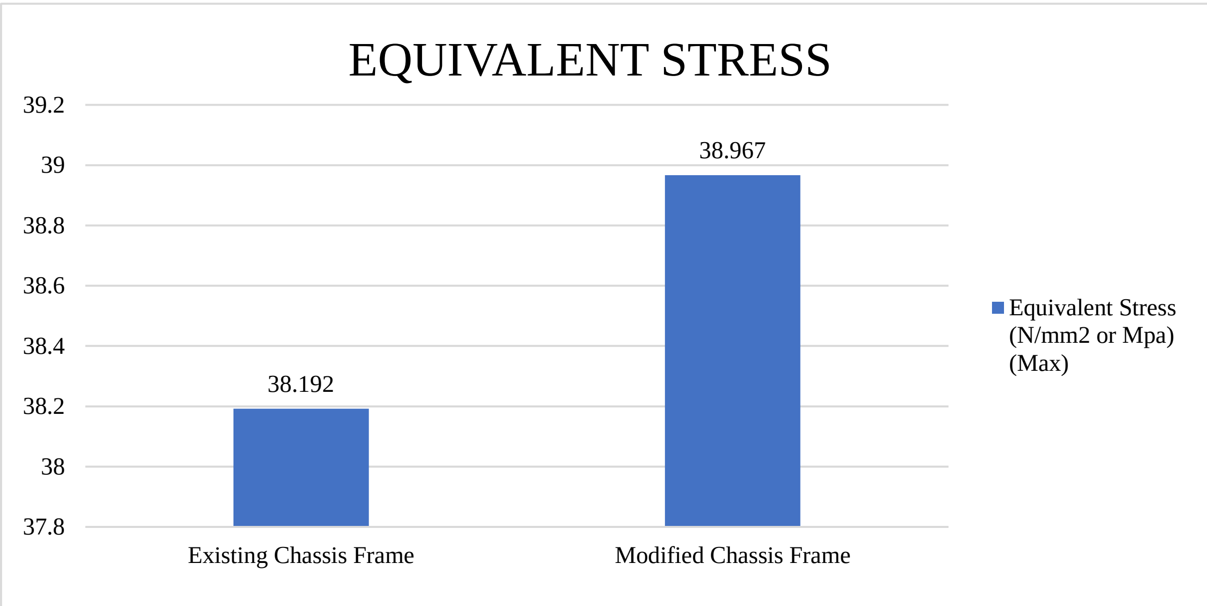
4.9 Graphs



Graph 1: Weight Comparison



Graph 2: Total Deformation



Graph 3: Equivalent Stress

CHAPTER-5 CONCLUSION AND FUTURE ENHANCEMENT

Conclusion

- By considering the above values. We can say that we have achieved a 25.86 kg amount of weight reduction without a considerable increase in the deformation and stress developed.
- So, 25.86 kg amount of weight removed from the existing chassis model can drastically decrease the fuel intake which in return will decrease the exhaust from the engine.
- In other words, we can say that the mileage of vehicles can be increased which will decrease the effect on the environment.

Future Enhancement

As a future scope of the study, manufacturing techniques for HINO 500 SERIES chassis frame could be explored with better quality with less cost, and with less weight compared to the existing chassis.

Publication

Conference

- (ICRIM-2021)
- “Online International Conference on “Robotics and Intelligent Manufacturing”

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A Major Project Report
On

NATURAL CONVECTIVE HEAT TRANSFER FROM INCLINED NARROW PLATES WITH GEOMETRY VARIATION

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

by

A.N. KUMAR KARTHIK	**- (17K81A0301)**
B. RAJESH	**- (17K81A0310)**
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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled "**NATURAL CONVECTIVE HEAT TRANSFER FROM INCLINED NARROW PLATES WITH GEOMETRY VARIATION**", is being submitted by **'A.N. Kumar Karthik (17K81A0301), B. Rajesh (17K81A0310), K. Vamshi Krishna(17K81A0332), M. Surender Reddy(17K81A0342)'**in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** MECHANICAL ENGINEERING is recorded of bonafide work carried out by them. The result embodied in this report have been verify and found satisfactory.

Signature of guide

Mr. Mukunda Dabair
Assistant Professor
Department of Mechanical Engineering

Signature of Head of the Department

Dr.D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of 'MECHANICAL ENGINEERING', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled "NATURAL CONVECTIVE HEAT TRANSFER FROM INCLINED NARROW PLATES WITH GEOMETRY VARIATION" is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density Differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Steady state natural convection from heat sink with narrow plate-fins having parallel arrangement mounted on inclined base was experimentally investigated. Aluminum heat sink with different lengths and fin thicknesses are modelled and analyzed. Few models of tapered fins are also modelled. And also comparing these results with original heat sink properties, finally we can conclude how the temperature and heat flux is varying while changing fins height and also which material is most suitable for these thermal boundary conditions.

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CHAPTER-1 INTRODUCTION

A heat sink (also commonly spelled heatsink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light-emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.

A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal paste improve the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device. A heat sink is usually made out of aluminum or copper.

Heat Transfer principle

A heat sink transfers thermal energy from a higher-temperature device to a lower-temperature fluid medium. The fluid medium is frequently air, but can also be water, refrigerants or oil. If the fluid medium is water, the heat sink is frequently called a cold plate. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction. The power supplies of electronics are not absolutely efficient, so extra heat is produced that may be detrimental to the function of the device. As such, a heat sink is included in the design to disperse heat.

To understand the principle of a heat sink, consider Fourier's law of heat conduction. Simplified to a one-dimensional form in the *x* direction, it shows that when there is a temperature gradient in a body, heat will be transferred from the higher-temperature region to the lower-temperature region. The rate at which heat is transferred by conduction, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred:

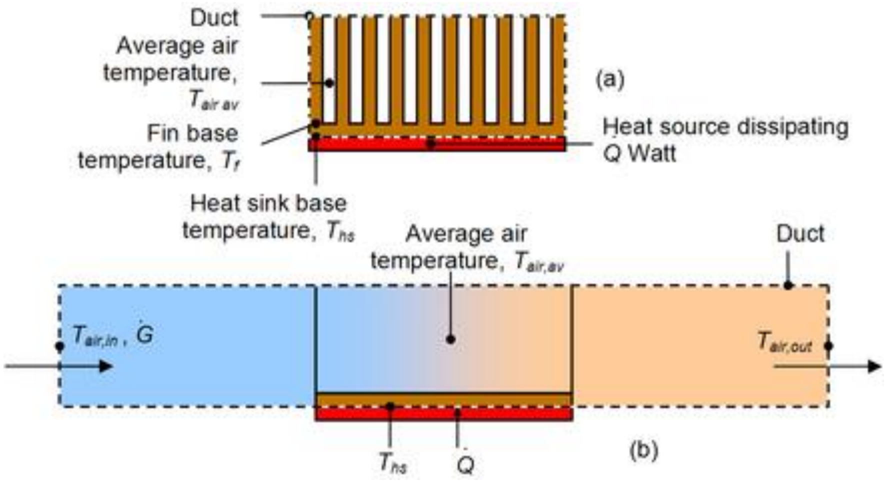


Fig1

Fig1 Sketch of a heat sink in a duct used to calculate the governing equations from conservation of energy and Newton's law of cooling

Consider a heat sink in a duct, where air flows through the duct. It is assumed that the heat-sink base is higher in temperature than the air. Applying the conservation of energy, for steady-state conditions, and Newton's law of cooling to the temperature nodes shown in the diagram gives the following set of equations:

$$\dot{Q} = \dot{m}c_{p,\text{in}}(T_{\text{air,out}} - T_{\text{air,in}}),$$
$$\dot{Q} = \frac{T_{\text{hs}} - T_{\text{air,av}}}{R_{\text{hs}}},$$

Were,

$$T_{\text{air,av}} = \frac{T_{\text{air,in}} + T_{\text{air,out}}}{2}.$$

Using the mean air temperature is an assumption that is valid for relatively short heat sinks. When compact heat exchangers are calculated, the logarithmic mean air temperature is used. the air mass flow rate in kg/s.

The above equations show that:

- When the air flow through the heat sink decreases, this results in an increase in the average air temperature. This in turn increases the heat-sink base temperature. And additionally, the thermal resistance of the heat sink will also increase. The net result is a higher heat-sink base temperature.

- The increase in heat-sink thermal resistance with decrease in flow rate will be shown later in this article.
- The inlet air temperature relates strongly with the heat-sink base temperature. For example, if there is recirculation of air in a product, the inlet air temperature is not the ambient air temperature. The inlet air temperature of the heat sink is therefore higher, which also results in a higher heat-sink base temperature.
- If there is no air flow around the heat sink, energy cannot be transferred.
- A heat sink is not a device with the "magical ability to absorb heat like a sponge and send it off to a parallel universe".[4]

Natural convection requires free flow of air over the heat sink. If fins are not aligned vertically, or if fins are too close together to allow sufficient air flow between them, the efficiency of the heat sink will decline.

1.1 OVERVIEW OF THE PROJECT

The basic outline of the project is to design the existing heat sink by using solid works considering the dimensions of draft sheet. A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light-emitting diodes, where the heat dissipation ability of the component itself is insufficient to moderate its temperature. So, SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. After design the existing part, the proposed new heat sink designs are been designed and analyzed in solid works simulation. So, solid works simulation analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. So, solid works simulation a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. The design is then remodeled for manufacturing purposes Which is optimized in weight, thereby achieving our sole purpose of the project to select a better heat sink then the existing one.

1.2OBJECTIVES OF THE STUDY

- To design the existing heat sink considering the existing dimension
- To design the proposed new heat sink
- To perform analysis to the existing heat sink and the proposed new heat sinks under the certain boundary conditions
- To determine the heat sink which has better performance when compared to others

1.3SCOPE OF STUDY

- To optimize the best heat sink by performing analysis under certain boundary conditions
- The heat sink determined from the analysis will have a better performance when compared to the existing design

1.4MATERIAL REQURIMENT

The most common heat sink materials are aluminum alloys.[7] Aluminum alloy 1050 has one of the higher thermal conductivity values at 229 W/(m·K),[8] but is mechanically soft. Aluminum alloys 6060 (low-stress), 6061, and 6063 are commonly used, with thermal conductivity values of 166 and 201 W/(m·K) respectively. The values depend on the temper of the alloy. One-piece aluminum heat sinks can be made by extrusion, casting, skiving or milling. Copper has excellent heat-sink properties in terms of its thermal conductivity, corrosion resistance, biofouling resistance, and antimicrobial resistance (see also Copper in heat exchangers). Copper has around twice the thermal conductivity of aluminum, around 400 W/(m·K) for pure copper. Its main applications are in industrial facilities, power plants, solar thermal water systems, HVAC systems, gas water heaters, forced air heating and cooling systems, geothermal heating and cooling, and electronic systems. Copper is three times as dense and more expensive than aluminum. One-piece copper heat sinks can be made by skiving or milling. Sheet-metal fins can be soldered onto a rectangular copper body. Copper is less ductile than aluminum, so it cannot be extruded into heat sinks

Fig2Image of copper

Properties	Value Measured
Melting point	1083°C
Density	8.94 X 10^3 kg/m^3 at 20°C
Thermal expansion coefficient	17.7 X 10^{-6} per °K
Thermal conductivity	305 – 355 W/(m.K)
Specific heat capacity	0.385 kJ/(kg.K)
Electrical conductivity (annealed)	75 – 90% IACS
Electrical resistivity (annealed)	0.0192 – 0.0230 microhm at 20°C
Modulus of elasticity	117 Gpa
Modulus of rigidity	44 Gpa

Table 1

CHAPTER-2 LITERATURE SURVEY

2.1 Literature Review

1. Lívia M. Corrêa Daniel J. N. M. Chalhub in their paper presented the thermal analysis of a heat sink dissipating heat from a solid-state electronic, solved utilizing the Classical Integral Transform Technique, which has shown to be a good alternative method for this kind of problem. The parallel plate fins were described as two-dimensional and the base was formulated as three-dimensional. First, it was solved the formulation for the fin using the CITT single transformation. After obtained the analytical solution for the 2D-fin, the formulation for the 3D-base was solved using double transformations of the CITT and also achieved an analytical approach. Both solutions were coupled considering perfect contact assumptions and the interface contact heat flux between fin and base was found. Finally, this heat flux was applied to the fins and base solutions. Different layouts of heat sinks, consequently, promote different heat fluxes between fin-base. The temperature field for both base and fins are not symmetric because of the non-symmetrical interface contact heat flux. The increase in the number of fins or convection enhances the heat dissipation on heat sinks. However, it was shown that is more profitable to add fins than enhance the heat transfer convection coefficient. Finally, the addition of fins performed the expected solution, which was the progressive reduction of the temperature as the number of fins increased. The six-fin layout was the most efficient for dissipating the oncoming heat flux and reducing the temperature.

2. M. Chandra Sekhar Reddy Associate Professor, Department of Mechanical Engineering, UCE (A), Osmania University, Hyderabad studied and concluded in his paper that the results of the simulation of natural convection at ambient conduction are 88^{O}C. Then by forced convection using a heat sink and fan of 7cfm the temperature is reduced to 50^{O}C which is under allowable limits. The temperature is reduced by 43%. Therefore, the PCB is working under a given temperature range of 85oC. From this we can say that the component is desirable in working for a given Heat sink design.

3. Some Considered facts from the blog published by Wakefield-Vette **"Heat sink Design facts and guidelines for thermal analysis"**. Heat Sink Thermal Performance and Heat Sink Cost are directly proportional … Increased Heat Sink Thermal Performance comes at a Higher Price. The Higher Heat Sink Price is a result of the Manufacturing Method and associated cost:

• Stamped Heat Sinks are inexpensive and provide minimal performance

• Extruded Heat Sinks a moderately priced and provide mid-level performance

• Bond-Fin Heat Sinks are high priced and provide the better performance

4. This paper presents a new fin profile i.e. straight corrugated heat sink, which is modeled as well as thermal analysis have been done .The performance of the heat sink under same working conditions of existing heat sink operating conditions has been analyzed and compared .The outcome was better than the existing model and with a reduced weight is an advantage as the cost can be minimized .Through simulation works best effect is seen in tapered heat sink with much better rate of heat dissipation. Fin efficiency and fin effectiveness of corrugated and tapered heat sink are high compared to base model. Further additional research work can be done by varying heat flux and taking other thermal parameters in account for analysis.

5. W. Elenbass investigated experimentally, the heat transfer performance of rectangular fins on a vertical base in free convection heat transfer. The effects of geometrical parameters and base-to ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined.

6. E.M Sparro investigated the heat transfer performance of rectangular fins on a vertical base in free convection heat transfer. The effects of geometric parameters and base-to-ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined.30 fin configurations were tested.

7. J.R Bodoia investigated steady state natural convection from heat sink of rectangular fins on a vertical base. The effects of geometric parameters and base-to-ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined. 30 fin configurations were tested.

8. A. De Lieto Vollaro tested heat sink for wide range of angle of inclination with upward and downward orientations. By modifying Grashoff number with cosine of inclination angle, they suggested the modified correlation, which is best suited for inclination angle interval of $-60° \leq \theta \leq +80°$. It was also observed that the flow separation inside the fin channels of the heat sink is an important.

CHAPTER-3 PROJECT DESIGN

3.1 Introduction to Solidworks

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on an Intel-based Mac with Windows installed, the application's developer recommends against this. SolidWorks does not support macOS.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, fiscal year 2011–12 revenue for SolidWorks totaled $483 million.

Solidworks Icon

3.2 History of Solidworks

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product *SolidWorks 95*, in

November 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired. SolidWorks for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company.

SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

SolidWorks was headed by John McEleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who is promoted Vice President Sales of Dassault Systems' Value Solutions sales channel.

Solid works Uses

- SolidWorks is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings.

- Designing in a modeling package such as SolidWorks is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design.

Solid works Component

Before we begin looking at the software, it is important to understand the different components:

Part

- The first, and most basic element of a SolidWorks model is a Part.

- Parts consist of primitive geometry and features such as extrudes, revolutions, lofts, sweeps, etc.

- Parts will be the building blocks for all of the models that you will create.

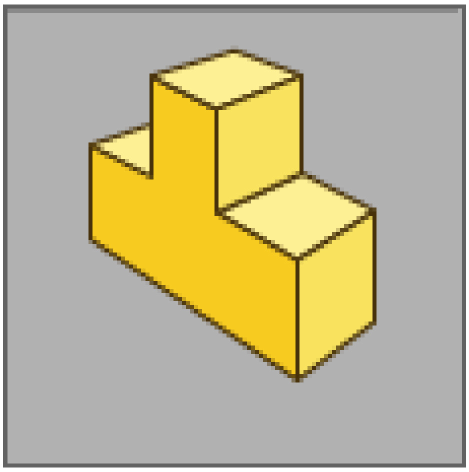


Fig 3: Part

Assemblies

- The second component is the assembly. Assemblies are collections of parts which are assembled in a particular fashion using mates (constraints).

- Any complex model will usually consist of one, or many assemblies.

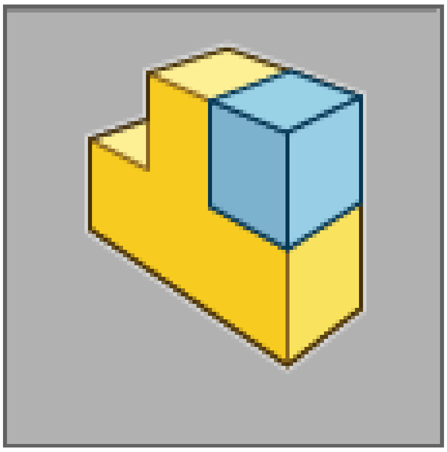


Fig 4: Assembly

Drawings

- The third, and final component in SolidWorks is the Drawing.

- A drawing is the typical way to represent a 3D model such that any engineer (or manufacturer) can recreate your part.

- Drawings are important because they provide a standard way of sharing your design.

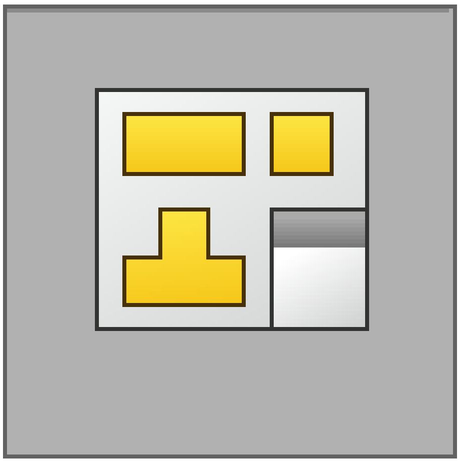


Fig 5: Drawing

CONCEPT

Parts are the basic building blocks in the SOLIDWORKS software. Assemblies contain parts or other assemblies, called subassemblies. A SOLIDWORKS model consists of 3D geometry that defines its edges, faces, and surfaces. The SOLIDWORKS software lets you design models quickly and precisely. SOLIDWORKS models are: • Defined by 3D design • Based on components

TERMINOLOGY

These terms appear throughout the SOLIDWORKS software and documentation.

Origin: Appears as two blue arrows and represents the (0,0,0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0,0,0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin.

Plane: Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature, for example.

Axis: Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The SOLIDWORKS application creates temporary axes implicitly for every conical or cylindrical face in a model.

Face: Boundaries that help define the shape of a model or a surface. A face is a selectable area (planar or nonplanar) of a model or surface. For example, a rectangular solid has six faces.

Edge: Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning, for example.

Vertex: Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning, for example.

User Interface

The SOLIDWORKS application includes user interface tools and capabilities to help you create and edit models efficiently, including:

Windows Functions

The SOLIDWORKS application includes familiar Windows functions, such as dragging and resizing windows. Many of the same icons, such as print, open, save, cut, and paste are also part of the SOLIDWORKS application.

SOLIDWORKS Document Windows

SOLIDWORKS document windows have two panels. The left panel, or Manager Pane, contains:

Feature manager design tree:

Displays the structure of the part, assembly, or drawing. Select an item from the Feature Manager design tree to edit the underlying sketch, edit the feature, and suppress and unsuppressed the feature or component, for example.

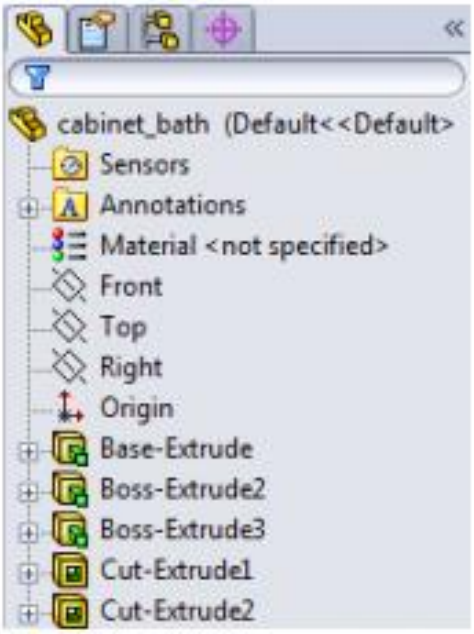


Fig3

Property manager:

Provides settings for many functions such as sketches, fillet features, and assembly mates.

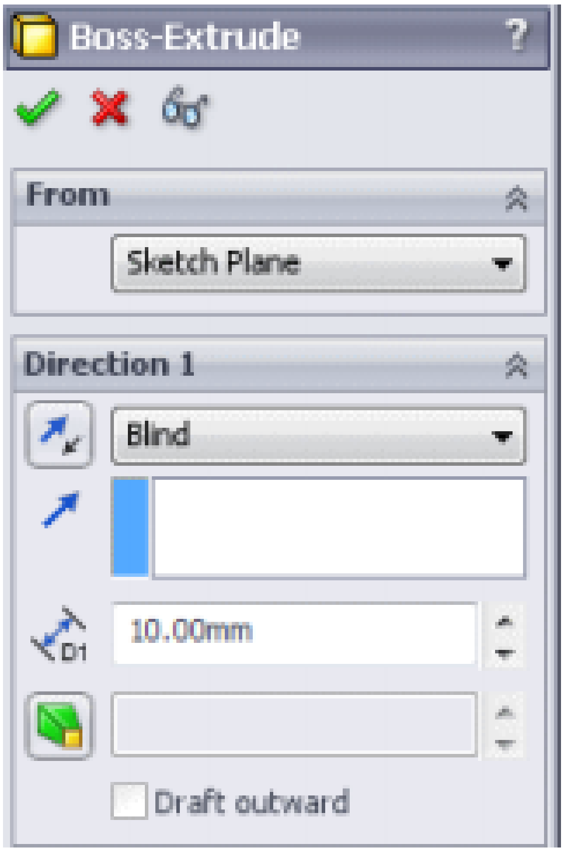


Fig4

Configuration manager:

Let's you create, select, and view multiple configurations of parts and assemblies in a document. Configurations are variations of a part or assembly within a single document. For example, you can use configurations of a bolt to specify different lengths and diameters.

Fig5

The right panel is the graphics area, where you create and manipulate a part, assembly, or drawing.

Function Selection and Feedback

The SOLIDWORKS application lets you perform tasks in different ways. It also provides feedback as you perform a task such as sketching an entity or applying a feature. Examples of feedback include pointers, inference lines, and previews.

Menus

You can access all SOLIDWORKS commands using menus. SOLIDWORKS menus use Windows conventions, including submenus and checkmarks to indicate that an item is active. You can also use context-sensitive shortcut menus by clicking the right mouse button.

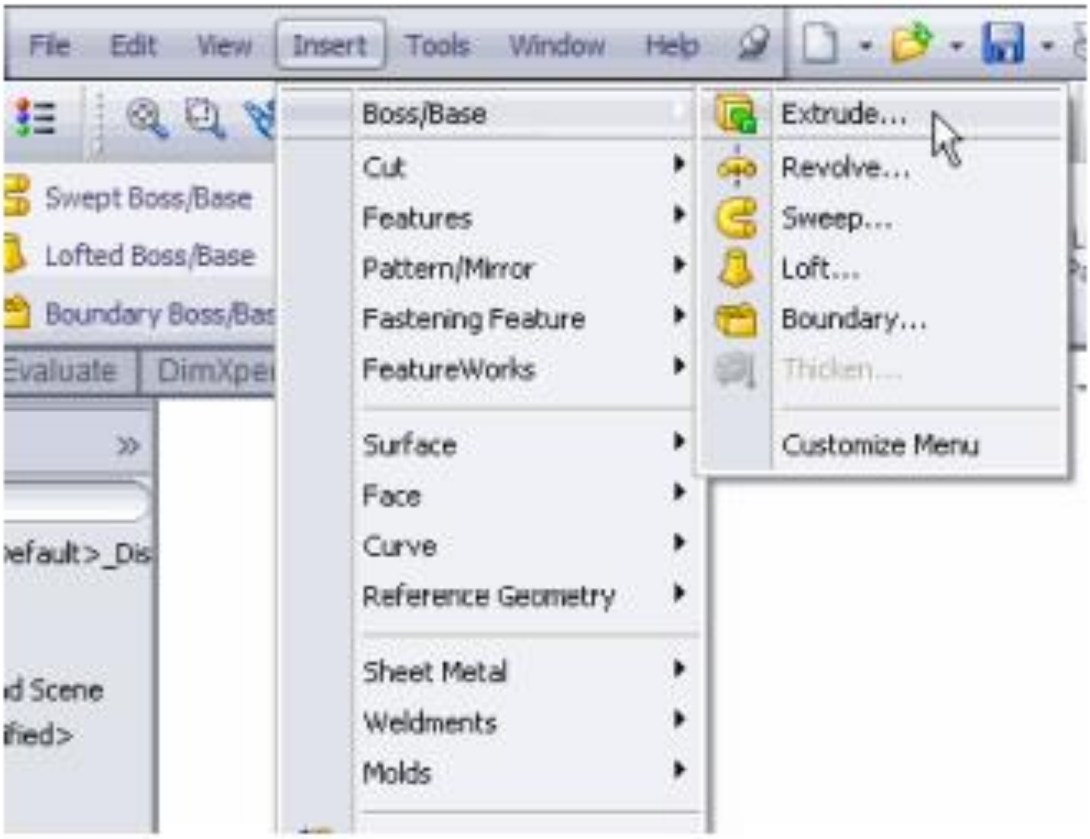


Fig6

Toolbars

You can access SOLIDWORKS functions using toolbars. Toolbars are organized by function, for example, the Sketch or Assembly toolbar. Each toolbar comprises individual icons for specific tools, such as Rotate View, Circular Pattern, and Circle.

You can display or hide toolbars, dock them around the four borders of the SOLIDWORKS window, or float them anywhere on your screen. The SOLIDWORKS software remembers the state of the toolbars from session to session. You can also add or delete tools to customize the toolbars. Tooltips display when you hover over each icon.

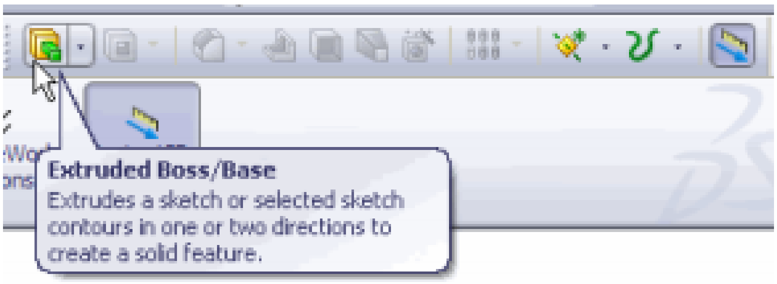


Fig7

Command Manager

The Command Manager is a context-sensitive toolbar that dynamically updates based on the active document type.

When you click a tab below the Command Manager, it updates to show the related tools. Each document type, such as part, assembly, or drawing, has different tabs defined for its tasks. The content of the tabs is customizable, similar to toolbars. For example, if you click the Features tab, tools related to features appear. You can also add or delete tools to customize the Command Manager. Tooltips display when you hover over each icon.

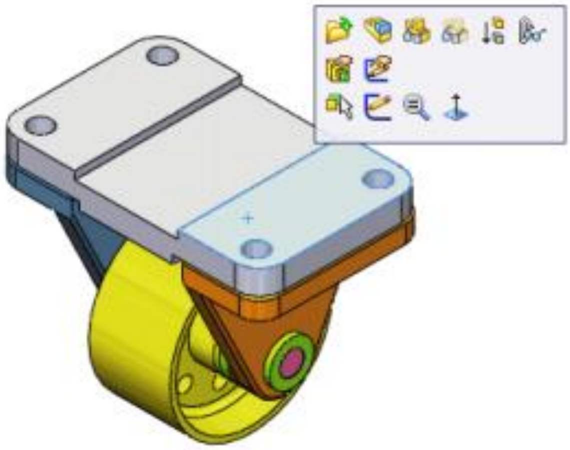
Fig8

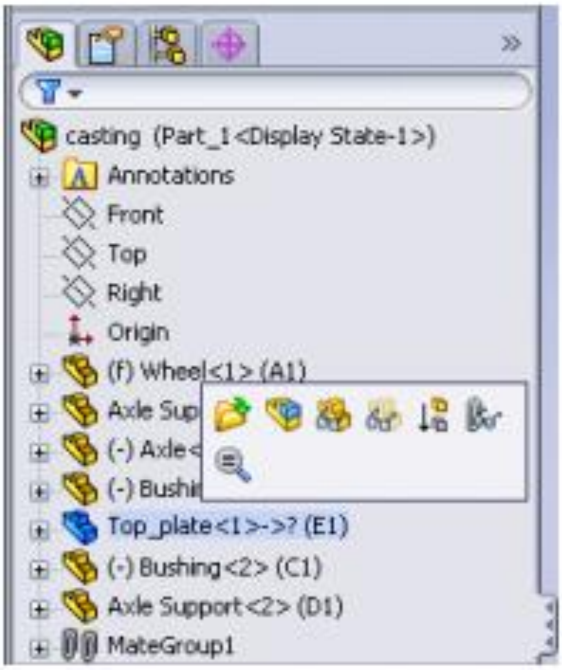
Shortcut Bars

Customizable shortcut bars let you create your own sets of commands for part, assembly, drawing, and sketch mode. To access the bars, you press a user-defined keyboard shortcut, by default, the S key.

Context Toolbars

Context toolbars appear when you select items in the graphics area or Feature Manager Design tree. They provide access to frequently performed actions for that context. Context toolbars are available for parts, assemblies, and sketches.





Handles

You can use the Property Manager to set values such as the depth of an extrude. You can also use graphic handles to drag and set parameters dynamically without leaving the graphics area.

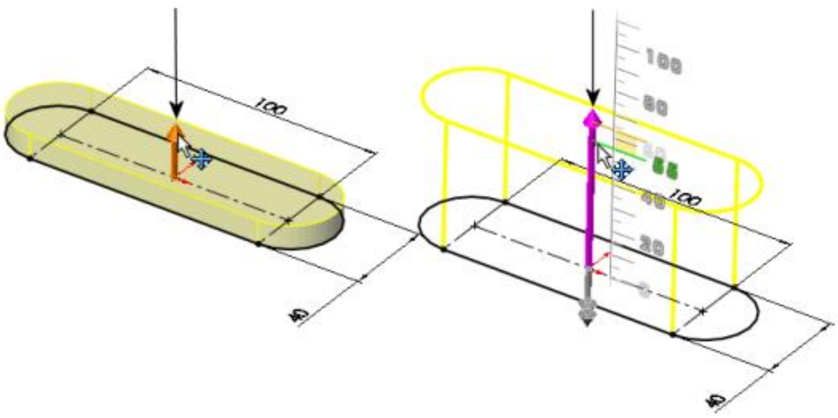


Fig 9

3.1 DESIGN OF EXISTING HEAT SINK

Design of Existing Heat Sink

By considering the existing design dimension we have designed the heat sink in the SOLIDWORKS with the help of commands like line, circle, arc, pan, etc. After designing the parts of the heat sink, we have extruded the design with the help of the extrude command. The design is shown in the fig10 and design dimension in table1

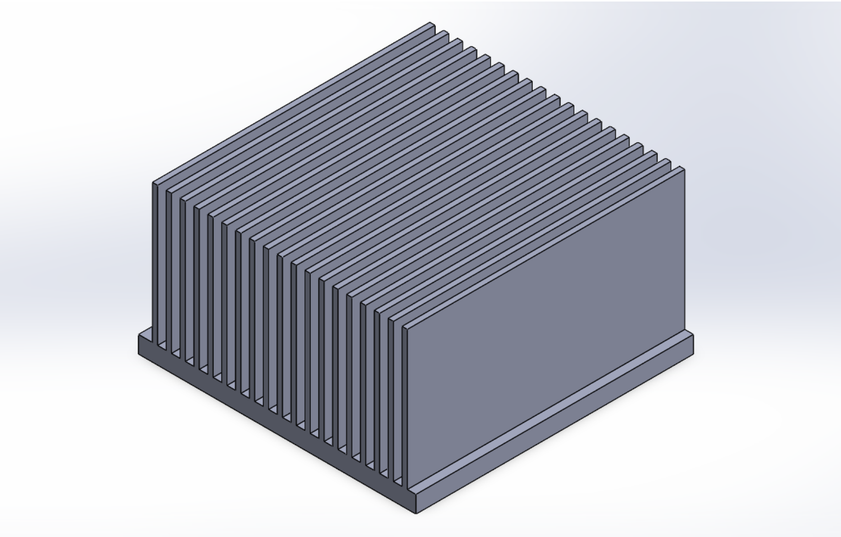


Fig10

PARAMETERS	MM	IN
LENGTH	50.8	2.00
WIDTH	50.8	2.00
HEIGTH	25.4	1.00
BASE THICKNESS	3.18	0.125
FIN THICKNESS	0.97	0.038
FIN SPACING	2.54	0.10

Table2

3.2 DESIGN OF THE PROPOSED HEAT SINKS

Proposed designs

We have proposed 7 new heat sink designs as mentioned below and all the changes in the dimension are with respective to the existing heat sink dimension.

- Heat sink with increased fin thickness
- Heat sink with decreased fin thickness
- Heat sink with tapered fin
- Heat sink with increased fin thickness having holes
- Heat sink with decreased fin thickness having holes
- Heat sink with tapered fin having holes
- Existing heat sink with holes

3.2.1 Heat sink with increased fin thickness

In this proposed design we have increased the fin Thickness from 0.97mm to 1.37mm anticipating that the increase in surface area increases the heat flow rate on the fin. The design is shown in fig3.1.3

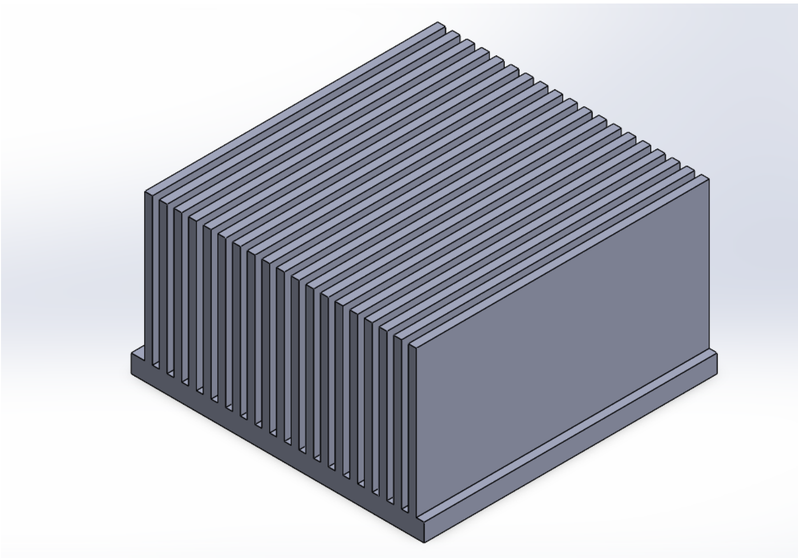


Fig11

3.2.2 Heat sink with decreased fin thickness

In this proposed design we have decreased fin thickness from 0.97mm to 0.57mm anticipating that the decrease in thickness increases the fin efficiency. The design is shown fig3.1.4

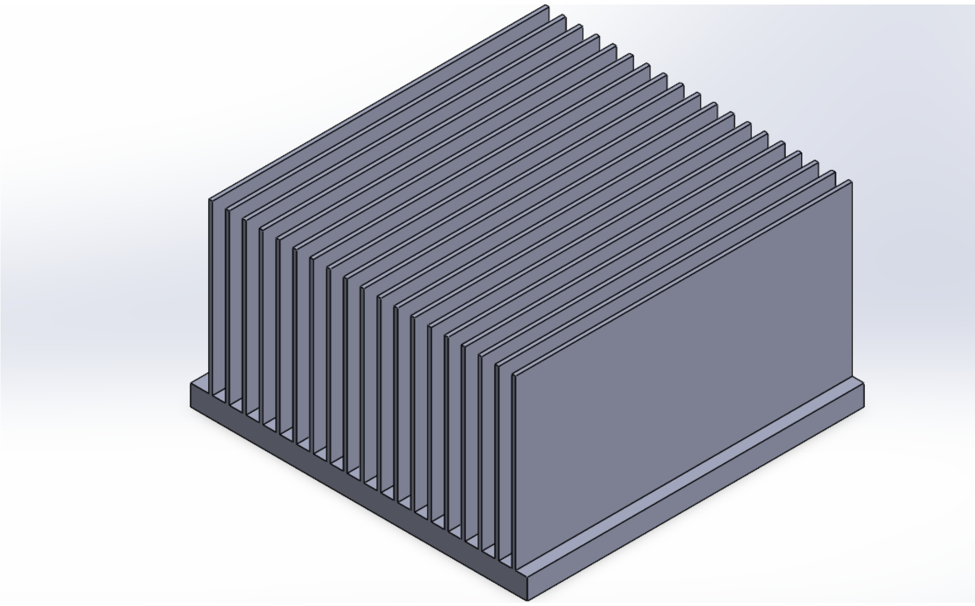


Fig12

3.2.3 Heat sink with tapered fins

The fin thickness of 0.97mm is tapered in Anticipation that the taper provides a decrease in the Manufacturing cost with the same efficiency.

The design is shown in the fig 3.1.5

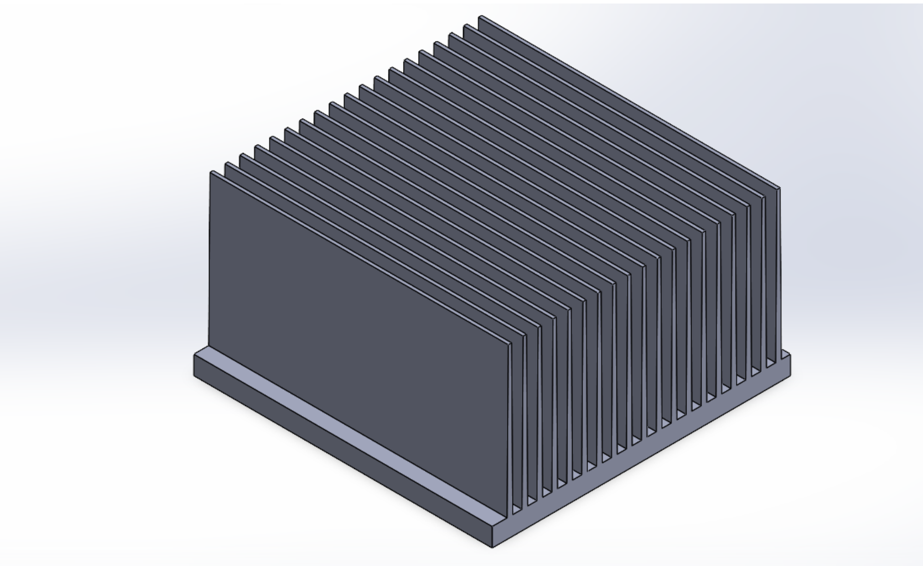


Fig13

3.2.4 Heat sink with holes

We have designed the same above proposed heat sink with holes in anticipation that the holes provide more efficient heat flow in the heat sink and we have placed the holes at the top in the anticipation that the heat flow occurs more at the top when compared to its bottom.

The fig 3.1.6 shows heat sink with increased fin thickness with holes

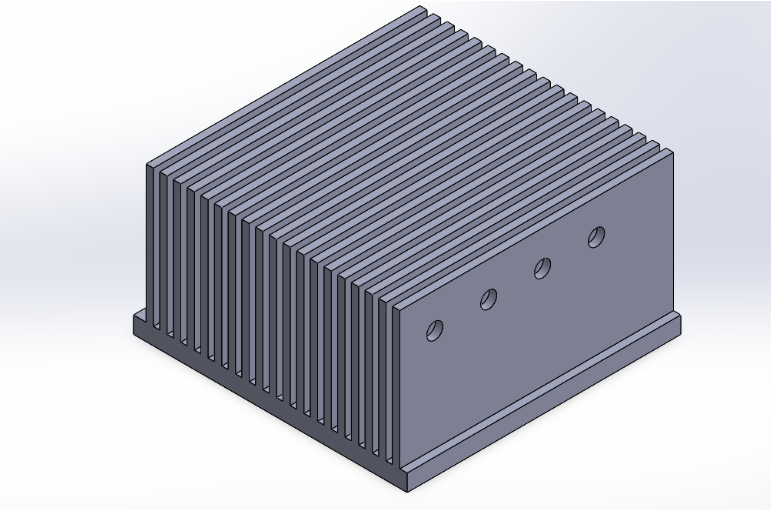


Fig14

The fig 3.1.7 shows heat sink with decreased fin thickness with holes

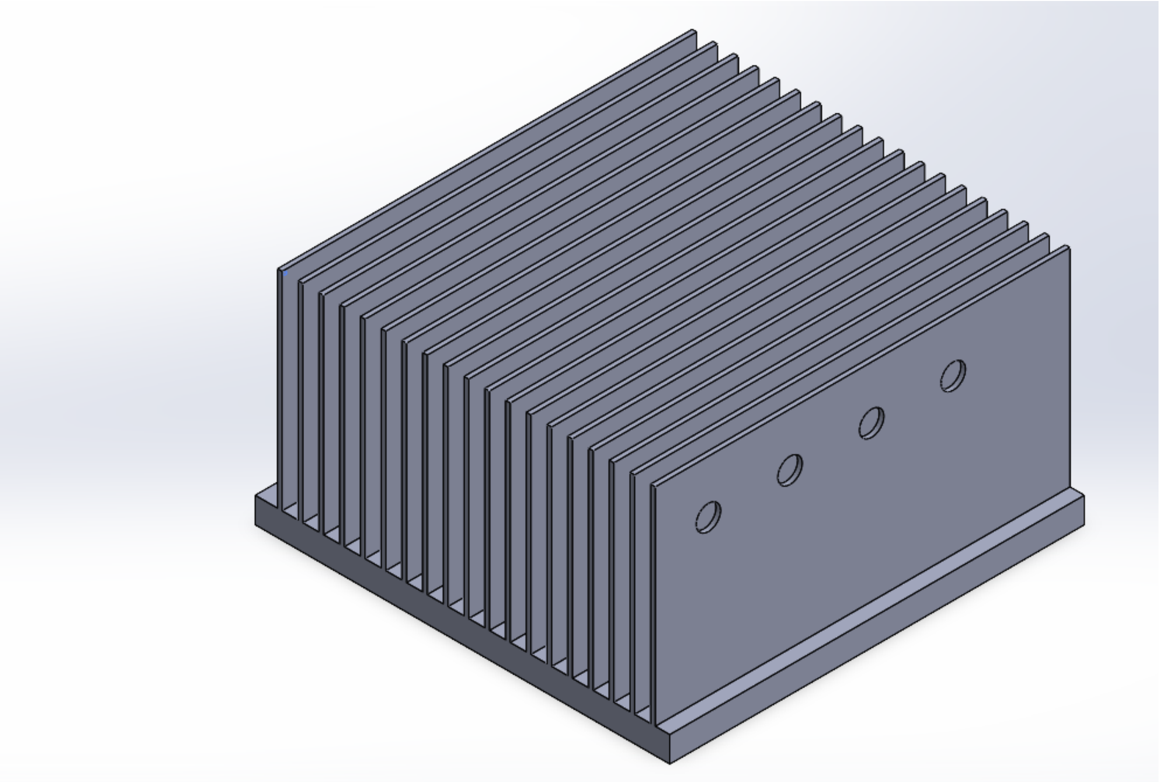


Fig15

The fig 3.1.8shows heat sink with tapered fin with holes

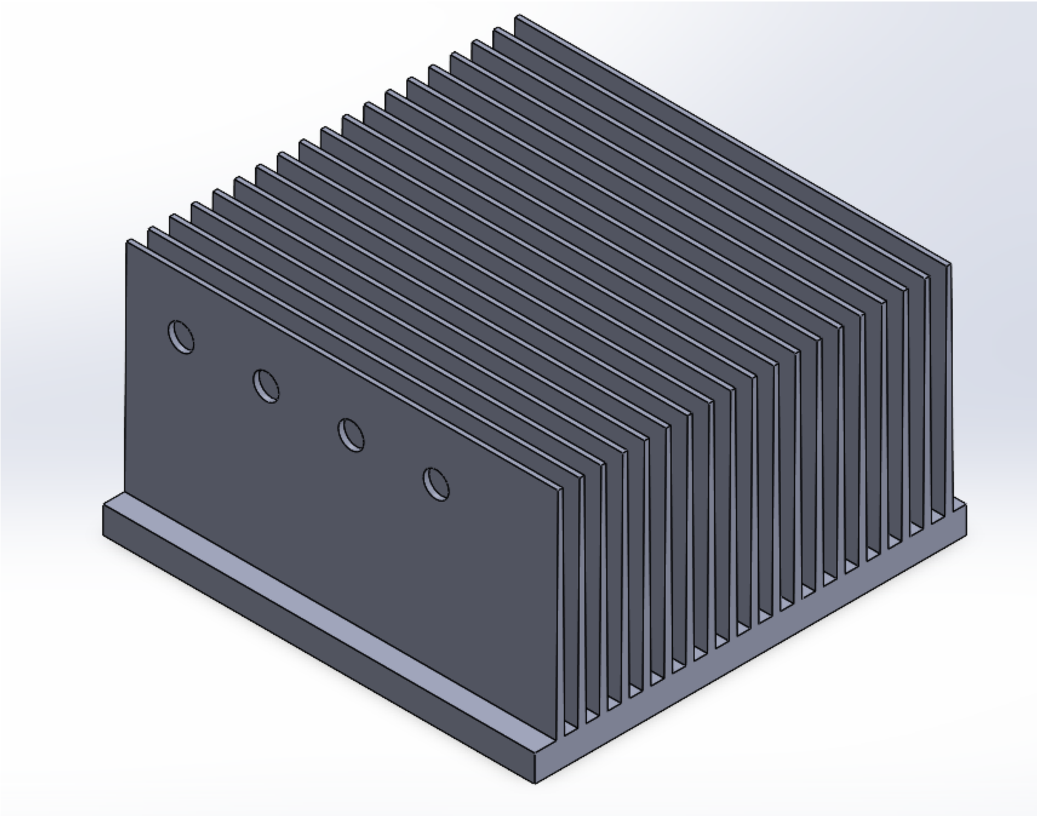


Fig16

The fig 3.1.9 shows existing heat sink with holes

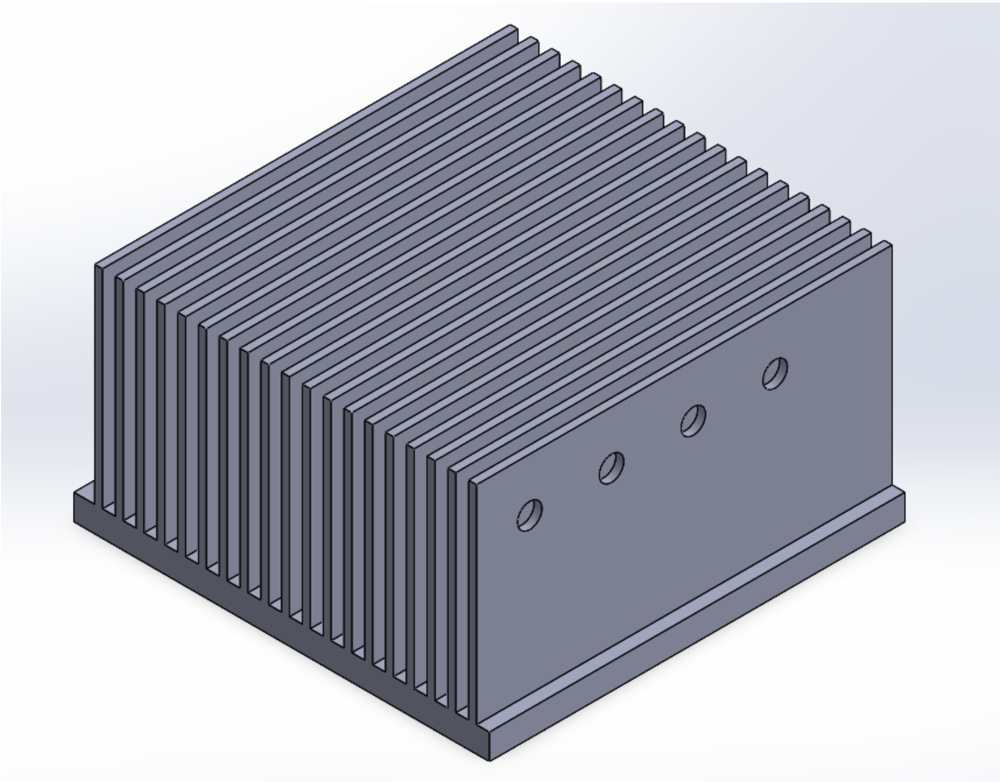


Fig17

CHAPTER-4 PROJECT IMPLEMENTATION

Introduction to finite element analysis:

The essential idea in fem is that the body or structure may be separated into littler components of limited measurements called "Finite Elements". The first body or the structure is then considered as a gathering of these components associated at a limited number of joints called "nodes" or "nodal points"

Basic capacities are approximated the relocations over each limited component. Such accepted capacities are called "shape capacities". This will speak to the uprooting within the component as far as the remit Element technique is a scientific apparatus for illuminating common and fractional at the hubs of the components. The Final differential comparison in light of the fact that it is a numerical instrument, it can take care of the unpredictable issue that can be spoken to in differential mathematical statement from. The use of FEM is boundless as respects the arrangement of common-sense configuration issues.

FEM has good efficiency to solve problems and cost critical problems as the cost for computing power is high.

The finite element method can be utilized to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mould flow simulations

Now a days, even the simplest of products rely on the finite element method for design evaluation. This is on account of contemporary configuration issues normally can't be understood as precisely and inexpensively utilizing some other system that is at present accessible. Physical testing was the standard in the years passed by, however now it is just excessively costly and tedious too.

ESSENTIAL CONCEPTS:

The limited component technique depends on building an entangled article with basic squares or driving a confounded item into little and sensible pieces. Use of this basic thought can be discovered all over the place in ordinary life and building. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

Area of one triangle: Si=1/2*R2*sin θI.

Area of the circle: SN=1/2*R2*N*Sin (2∏/N) →∏R2 as N→∞.

Where N= total number of triangles (elements)

To calculate the area of circle without using conventional formula, one of the approaches could be dividing the area into number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

A BRIEF HISTORY OF THE FEM:

1. WHO:

The reference credited is to Courant (Mathematician), Turner (air craft industry), Clough (California University), Martin (air craft industry), Argyris (German university), etc. However, it was probably established by several pioneers independently.

2. WHEN:

- Initial idea in mathematical terms was put in 1940s.
- Application to simple engineering problems in 1950s.
- Implementation in large computers in 1960s.
- Development of pre and post processors in 1980s.
- Analysis of large structural problems in 1990s.

3. WHERE:

Implementation and application were mainly in aircraft industry and automobile sectors (large and fast computers were available only in these industries).

4. WHAT:

Field problems in the form matrix of organizing large numbers of algebraic equations are used and matrix equations are solved. Differential equations are changed into an algebraic form.

Blocks with different geometry are hooked together for creating complex geometry of the engineering problem.

5. WHY:

The advantage of doing FEM analysis is that it is fairly simple to change the geometry, material and loads recomputed stresses for modified product rather than build and test. The method can be used to solve almost any problem that can be formulated as a field problem. The entire complex problem can be cast as a larger algebraic equation by assembling the element matrices within the computer and solved.

MORE ABOUT FEA:

Finite Element Analysis was first initially produced for use in the nuclear and aerospace industries where the safety of the structures is critical. Today, the growth in usage of the method is directly attributable to the rapid advances in computer technology in recent years. As a result, not just structural analysis most sophisticated problems can also be solved. Be that as it may, utilized for a wide variety of uses for example, consistent state and transient temperature appropriations, liquid stream re-enactments furthermore recreation of assembling procedures, for example, infusion mounding and metal framing.

FEA comprises a computer model of a material or design that is analyzed by applying the loads for specified results. It is utilized as a part of new item plan, and existing item refinement. An outline specialist should have the capacity to confirm the proposed plan, which is planned to meet the client prerequisites preceding the assembling. For example, adjusting the outline of a current item or structure so as to qualify the item or structure for another administration condition.

Can likewise be proficient if there should arise an occurrence of auxiliary disappointment, FEA may be utilized to decide the configuration adjustments to meet the new condition.

THE BASIC STEPS INVOLVED IN FEA:

Numerically, the structure to be examined is subdivided into a cross section of limited estimated components of straightforward shape. Inside of every component, the variety of dislodging is thought to be dictated by basic polynomial shape capacities and nodal relocations. Comparisons for the strains and hassles are created as far as the obscure nodal relocations. From this, the mathematical statements of the balance are amassed in a grid from which can be effortlessly being customized and illuminated on a PC. In the wake of applying the proper limit conditions, the nodal relocations are found by understanding the framework firmness mathematical statement.

Once the nodal relocations are known, component hassles and strains can be figured

BASIC STEPS IN FEA:

- Discretization of the domain.
- Applying the boundary conditions.
- Assembling the system equations.
- Solution for system equations.
- Post processing the results.

DISCRITIZATION OF THE DOMAIN:

The task is to divide the continuum under study into a number of subdivisions called element. Based on the continuum it can be categorized into line or area or volume elements.

APPLICATION OF BOUNDARY CONDITIONS:

From the physics of the problem, we have to apply the field conditions i.e., loads and constraints, which will help us in solving for the unknowns.

SYSTEM EQUATIONS ASSEMBLING:

The formulation of respective characteristic (Stiffness in case of structural) equation of matrices and assembly is involved in this.

SOLUTION FOR SYSTEM EQUATIONS:

Solve the equations to know the unknowns. This is basically the system of matrices which are nothing but a set of simulations equations are solved.

VIEWING THE RESULTS:

- After the completion of the solution, we have to review the required results.
- The first two steps of the above said process is known as pre-processing stage, 3rd and 4th steps are the processing stage and the final step is known as post-processing stage.

What is an element?

The entity in which system under study can be divided is called an Element. An element definition can be specified by nodes. The shape (area, length and volume) of the element depends upon the nodes with which it is made up of.

What are nodes?

Nodes are the vertex points of the element. Independent entities in the space are nodes. Points in geometry and nodes are common. The element can be changed by moving a node. This is a volume element, can take the shape of a Hexahedron or a wedge or a Tetrahedron order elements. For linear elements the linear function defines edge called shape function whose degree is one.

For the components having mid side nodes on the edge quadratic capacity called shape work whose degree is two is utilized. The higher request components when over lapped in geometry can speak to complex shapes exceptionally well inside of couple of components. The arrangement exactness will be more with the high request components. Be that as it may, higher request components will require more computational exertion and time

4.1SIMULATION

Simulation is the study of effects caused on an object due to real-world loading conditions. Computer Simulation is a type of simulation which uses CAD models to represent real objects and it applies various load conditions on the model to study the real-world effects. SolidWorks Simulation is one of the Computer Simulation programs available in the market. In SolidWorks Simulation, we apply loads on a constrained model under predefined environmental conditions and check the result (visually and/or in the form of tabular data). The types of analyses that can be performed in SolidWorks are given next. TYPES OF ANALYSES PERFORMED IN SOLIDWORKS SIMULATION SolidWorks Simulation performs almost all the analyses that are generally performed in Industries. These analyses and their use are given next. Static Analysis This is the most common type of analysis we perform. In this analysis, loads are applied to a body due to which the body deforms and the effects of the loads are transmitted throughout the body. To absorb the effect of loads, the body generates internal forces and reactions at the supports to balance the applied external loads. These internal forces and reactions cause stress and strain in the body. Static analysis refers to the calculation of displacements, strains, and stresses under the effect of external loads, based on some assumptions. The assumptions are as follows. • All loads are applied slowly and gradually until they reach their full magnitudes. After reaching their full magnitudes, load will remain constant (i.e., load will not vary against time). • Linearity assumption: The relationship between loads and resulting responses is linear. For example, if you double the magnitude of loads, the response of the model (displacements, strains and stresses) will also double. You can make linearity assumption if: 1. All materials in the model comply with Hooke’s Law that is stress is directly proportional to strain. 2. The induced displacements are small enough to ignore the change is stiffness caused by loading. 3. Boundary conditions do not vary during the application of loads. Loads must be constant in magnitude, direction and distribution. They should not change while the model is deforming. If the above assumptions are valid for your analysis, then you can perform Linear Static Analysis. For example, a cantilever beam fixed at one end and force applied on another end; refer to Figure-4.1.1

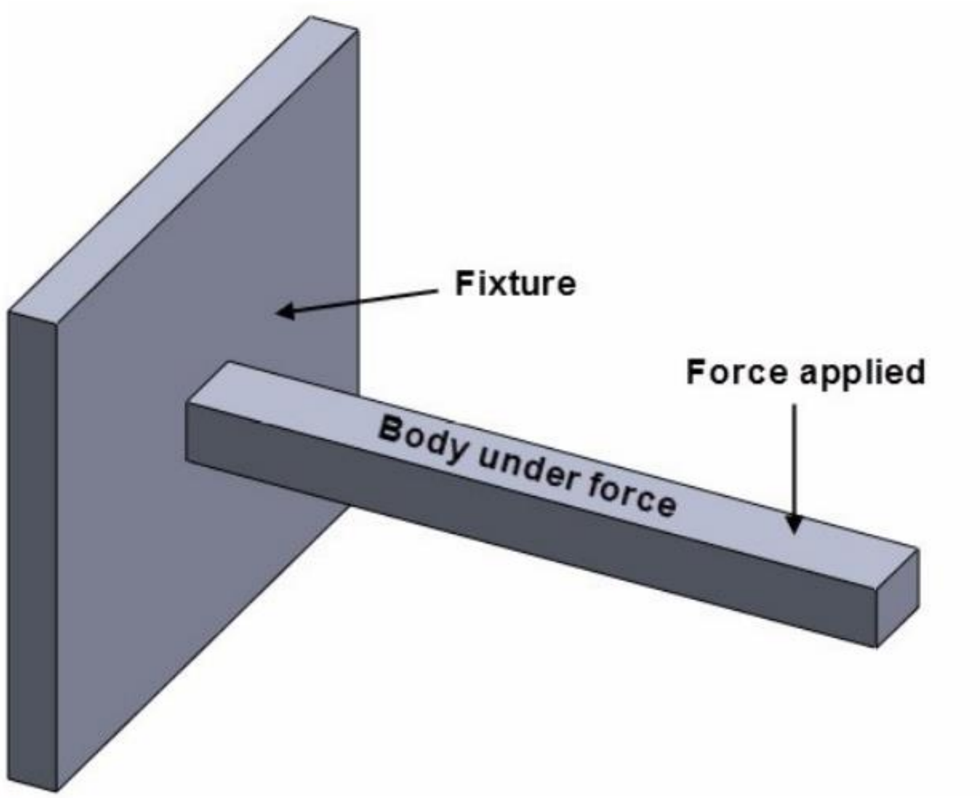


Fig18

If the above assumptions are not valid, then you need to perform the Nonlinear Static analysis. For example, an object attached with a spring being applied under forces; refer to Figure-4.1.2.

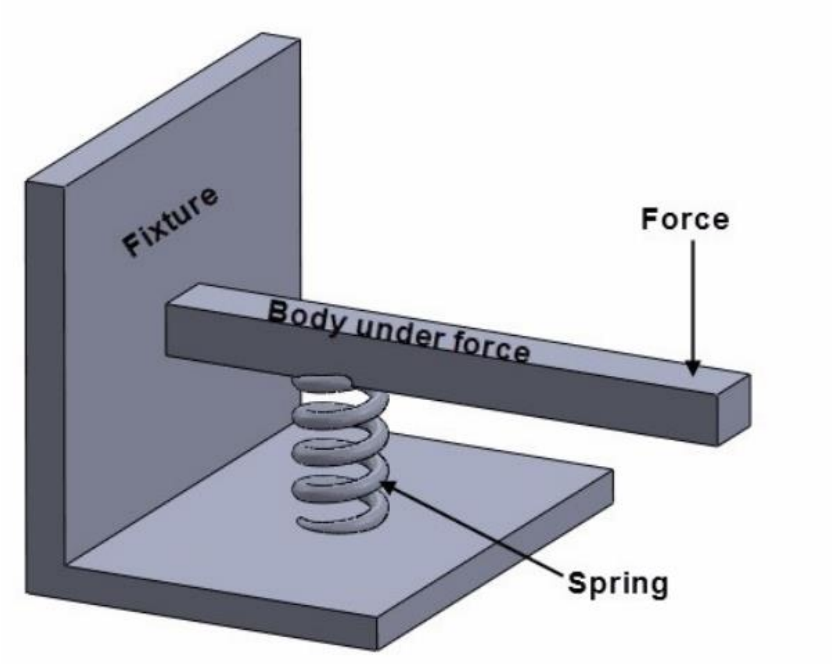


Fig19

Dynamic Analysis In general, we have to perform dynamic analysis on a structure when the load applied to it varies with time. The most common case of dynamic analysis is the evaluation of responses of a building due to earthquake acceleration at its base. Every structure has a tendency to vibrate at certain frequencies, called natural frequencies. Each natural frequency is associated with a certain shape, called mode shape that the model tends to assume when vibrating at that frequency. When a structure is excited by a dynamic load that coincides with one of its natural frequencies, the structure undergoes large displacements. This phenomenon is known as 'resonance'. Damping prevents the response of the structures to resonant loads. In reality, a continuous model has an infinite number of natural frequencies. However, a finite element model has a finite number of natural frequencies that is equal to the number of degrees of freedom considered in the model. The first few modes of a model (those with the lowest natural frequencies), are normally important. The natural frequencies and corresponding mode shapes depend on the geometry of the structure, its material properties, as well as its support conditions and static loads. The computation of natural frequencies and mode shapes is known as modal analysis. When building the geometry of a model, you usually create it based on the original (undeformed) shape of the model. Some loading, like a structure's self-weight, is always present and can cause considerable changes in the structure's original geometry. These geometric changes may have, in some cases, significant impact on the structure's modal properties. In many cases, this effect can be ignored because the induced deflections are small. The following few topics – Random Vibration, Response Spectrum analysis, Time History analysis, Transient vibration analysis and Vibration modal analysis are extensions of dynamic analysis. Random Vibration Engineers use this type of analysis to find out how a device or structure responds to steady shaking of the kind you would feel riding in a truck, rail car, rocket (when the motor is on), and so on. Also, things that are riding in the vehicle, such as on-board electronics or cargo of any kind, may need Random Vibration Analysis. The vibration generated in vehicles from the motors, road conditions, etc. is a combination of a great many frequencies from a variety of sources and has a certain “random” nature. Random Vibration Analysis is used by mechanical engineers who design various kinds of transportation equipment. Response Spectrum Analysis Engineers use this type of analysis to find out how a device or structure responds to sudden forces or shocks. It is assumed that these shocks or forces occur at boundary points, which are normally fixed. An example would be a building, dam or nuclear reactor when an earthquake strikes. During an earthquake, violent shaking occurs. This shaking transmits into the structure or device at the points where they are attached to the ground (boundary points). Mechanical engineers who design components for nuclear power plants must use response spectrum analysis as well. Such components might include nuclear reactor parts, pumps, valves, piping, condensers, etc. When an engineer uses response spectrum analysis, he is looking for the maximum stresses or acceleration, velocity and displacements that occur after the shock. These in turn lead to maximum stresses. Time History Analysis This analysis plots response (displacements, velocities, accelerations, internal forces etc.) of the structure against time due to dynamic excitation applied on the structure. Transient Vibration Analysis When you strike a guitar string or a tuning fork, it goes from a state of inactivity into a vibration to make a musical tone. This tone seems loudest at first, then gradually dies out. Conditions are changing from the first moment the note is struck. When an electric motor is started up, it eventually reaches a steady state of operation. But to get there, it starts from zero RPM and passes through an infinite number of speeds until it attains the operating speed. Every time you rev the motor in your car, you are creating transient vibration. When things vibrate, internal stresses are created by the vibration. These stresses can be devastating if resonance occurs between a device producing vibration and a structure responding to. A bridge may vibrate in the wind or when cars and trucks go across it. Very complex vibration patterns can occur. Because things are constantly changing, engineers must know what the frequencies and stresses are at all moments in time. Sometimes transient vibrations are extremely violent and short-lived. Imagine a torpedo striking the side of a ship and exploding, or a car slamming into a concrete abutment or dropping a coffeepot on a hard floor. Such vibrations are called “shock, “which is just what you would imagine. In real life, shock is rarely a good thing and almost always unplanned. But shocks occur anyhow. Because of vibration, shock is always more devastating than if the same force were applied gradually. Vibration Analysis (Modal Analysis) By its very nature, vibration involves repetitive motion. Each occurrence of a complete motion sequence is called a "cycle." Frequency is defined as so many cycles in a given time period. "Cycles per seconds" or "Hertz". Individual parts have what engineers call "natural" frequencies. For example, a violin string at a certain tension will vibrate only at a set number of frequencies, which is why you can produce specific musical tones. There is a base frequency in which the entire string is going back and forth in a simple bow shape. Harmonics and overtones occur because individual sections of the string can vibrate independently within the larger vibration. These various shapes are called "modes". The base frequency is said to vibrate in the first mode, and so on up the ladder. Each mode shape will have an associated frequency. Higher mode shapes have higher frequencies. The most disastrous kinds of consequences occur when a power-driven device such as a motor for example, produces a frequency at which an attached structure naturally vibrates. This event is called "resonance." If sufficient power is applied, the attached structure will be destroyed. Note that ancient armies, which normally marched "in step," were taken out of step when crossing bridges. Should the beat of the marching feet align with a natural frequency of the bridge, it could fall down. Engineers must design so that resonance does not occur during regular operation of machines. This is a major purpose of Modal Analysis. Ideally, the first mode has a frequency higher than any potential driving frequency. Frequently, resonance cannot be avoided, especially for short periods of time. For example, when a motor comes up to speed it produces a variety of frequencies. So, it may pass through a resonant frequency. Buckling Analysis If you press down on an empty soft drink can with your hand, not much will seem to happen. If you put the can on the floor and gradually increase the force by stepping down on it with your foot, at some point it will suddenly squash. This sudden scrunching is known as "buckling." Models with thin parts tend to buckle under axial loading. Buckling can be defined as the sudden deformation, which occurs when the stored membrane(axial) energy is converted into bending energy with no change in the externally applied loads. Mathematically, when buckling occurs, the total stiffness matrix becomes singular. In the normal use of most products, buckling can be catastrophic if it occurs. The failure is not one because of stress but geometric stability. Once the geometry of the part starts to deform, it can no longer support even a fraction of the force initially applied. The worst part about buckling for engineers is that buckling usually occurs at relatively low stress values for what the material can withstand. So, they have to make a separate check to see if a product or part thereof is okay with respect to buckling.

Slender structures and structures with slender parts loaded in the axial direction buckle under relatively small axial loads. Such structures may fail in buckling while their stresses are far below critical levels. For such structures, the buckling load becomes a critical design factor. Stocky structures, on the other hand, require large loads to buckle, therefore buckling analysis is usually not required. Buckling almost always involves compression; refer to Figure-3. In mechanical engineering, designs involving thin parts in flexible structures like airplanes and automobiles are susceptible to buckling. Even though stress can be very low, buckling of local areas can cause the whole structure to collapse by a rapid series of ‘propagating buckling’. Buckling analysis calculates the smallest (critical) loading required buckling a model. Buckling loads are associated with buckling modes. Designers are usually interested in the lowest mode because it is associated with the lowest critical load. When buckling is the critical design factor, calculating multiple buckling modes helps in locating the weak areas of the model. This may prevent the occurrence of lower buckling modes by simple modifications.

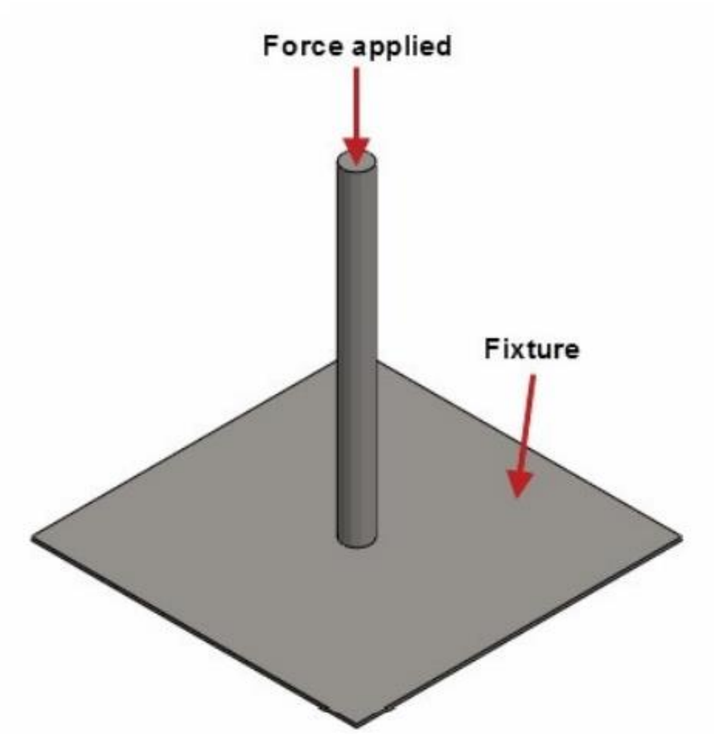


Fig20

Thermal analysis There are three mechanisms of heat transfer. These mechanisms are Conduction, Convection and Radiation. Thermal analysis calculates the temperature distribution in a body due to some or all of these mechanisms. In all three mechanisms, heat flows from a higher-temperature medium to a lower temperature one. Heat transfer by conduction and convection requires the presence of an intervening medium while heat transfer by radiation does not. There are two modes of heat transfer analysis. Steady State Thermal

Analysis In this type of analysis, we are only interested in the thermal conditions of the body when it reaches thermal equilibrium, but we are not interested in the time it takes to reach this status. The temperature of each point in the model will remain unchanged until a change occurs in the system. At equilibrium, the thermal energy entering the system is equal to the thermal energy leaving it. Generally, the only material property that is needed for steady state analysis is the thermal conductivity.

Transient Thermal Analysis In this type of analysis, we are interested in knowing the thermal status of the model at different instances of time. A thermos designer, for example, knows that the temperature of the fluid inside will eventually be equal to the room temperature (steady state), but he is interested in finding out the temperature of the fluid as a function of time. In addition to the thermal conductivity, we also need to specify density, specific heat, initial temperature profile, and the period of time for which solutions are desired. Till this point, we have learned the basics of various analyses that can be performed in SolidWorks. Now, we will learn about the studies that can be performed in SolidWorks.

DROP TEST STUDIES

Drop test studies simulate the effect of dropping a part or an assembly on a rigid or flexible floor. To perform this study the floor is considered as planar and flat. The forces that are considered automatically for this study are gravity and impact reaction. FATIGUE ANALYSIS The fatigue is more over a study then analysis. But it is generally named as analysis.

This analysis is used to check the effect of continuous loading and unloading of forces on a body. The base element for performing fatigue analysis are results of static, nonlinear, or time history linear dynamic studies.

PRESSURE VESSEL DESIGN STUDY

Pressure Vessel Design study allows you combine the results of static studies with the desired factors and interpret the results. The Pressure Vessel Design study combines the results of the static studies algebraically using a linear combination or the square root of the sum of the squares.

DESIGN STUDY

Design Study is used to perform an optimization of design. Using the Design Study, you can:

• Define multiple variables using simulation parameters, or driving global variables.

• Define multiple constraints.

• Define multiple goals using sensors

• Analyze models without simulation results. For example, you can minimize the mass of an assembly with the variables, density and model dimensions, the constraint, and volume. • Evaluate design choices by defining a parameter that sets bodies to use different materials as a variable. Till this point, you have become familiar with the analyses that can be performed by using SolidWorks. But, do you know how the software analyses the problems. The answer is FEA. FEA FEA, Finite Element Analysis, is a mathematical system used to solve real-world engineering problems by simplifying them. In FEA by SolidWorks, the model is broken into small elements and nodes. Then, distributed forces are applied on each element and node. The cumulative result of forces is calculated and displayed in results.

4.2 STARTING SOLIDWORKS SIMULATION

Before you try to start SolidWorks Simulation, make sure that you have installed it with SolidWorks and you applied the serial key for it during installation. Then, follow the steps given next.

• Start SolidWorks and open the model for which you want to perform the analyses

. • Click on the SolidWorks Add-Ins tab and select the SolidWorks Simulation button

• On clicking this button, Simulation tab will be added in the Ribbon.

• Click on the Simulation tab, the New Study drop-down will be displayed in the Ribbon. There are two buttons available in this drop-down; Simulation Advisor and New Study. We will start with Simulation Advisor as it is good for novices to the software.

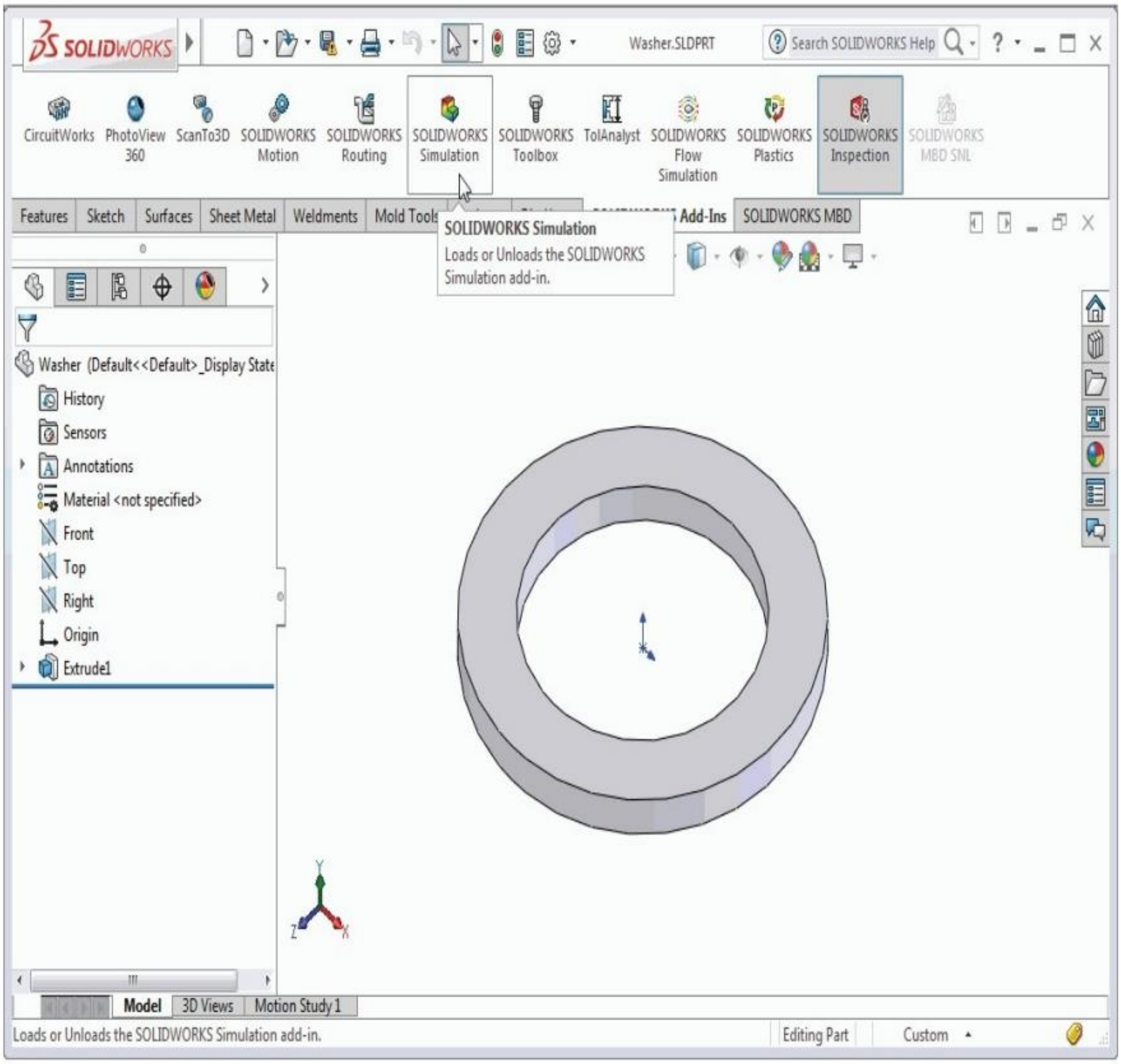


Fig21

On clicking Simulation Advisor

• Click on the Simulation Advisor button from the drop-down. The Simulation Advisor pane will display in the right of the SolidWorks window

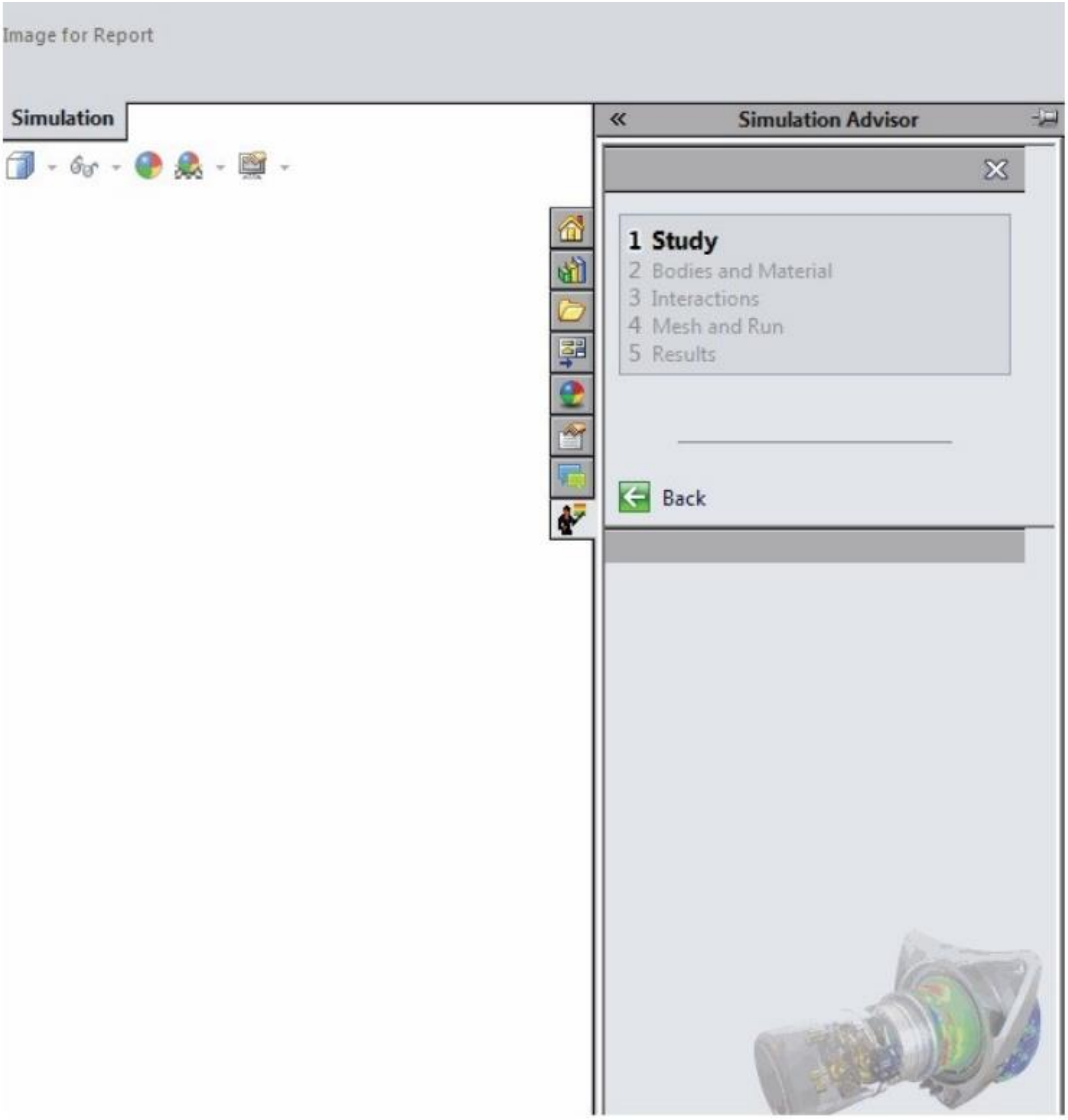


Fig22

Read the text in the Advisor and perform the actions accordingly. This is a guided process so it is recommended to perform some tricks on software by yourself. We will learn more about the advisor later in the book. On clicking New Study

• Click on the New Study button from the drop-down. The Study Property Manager will display

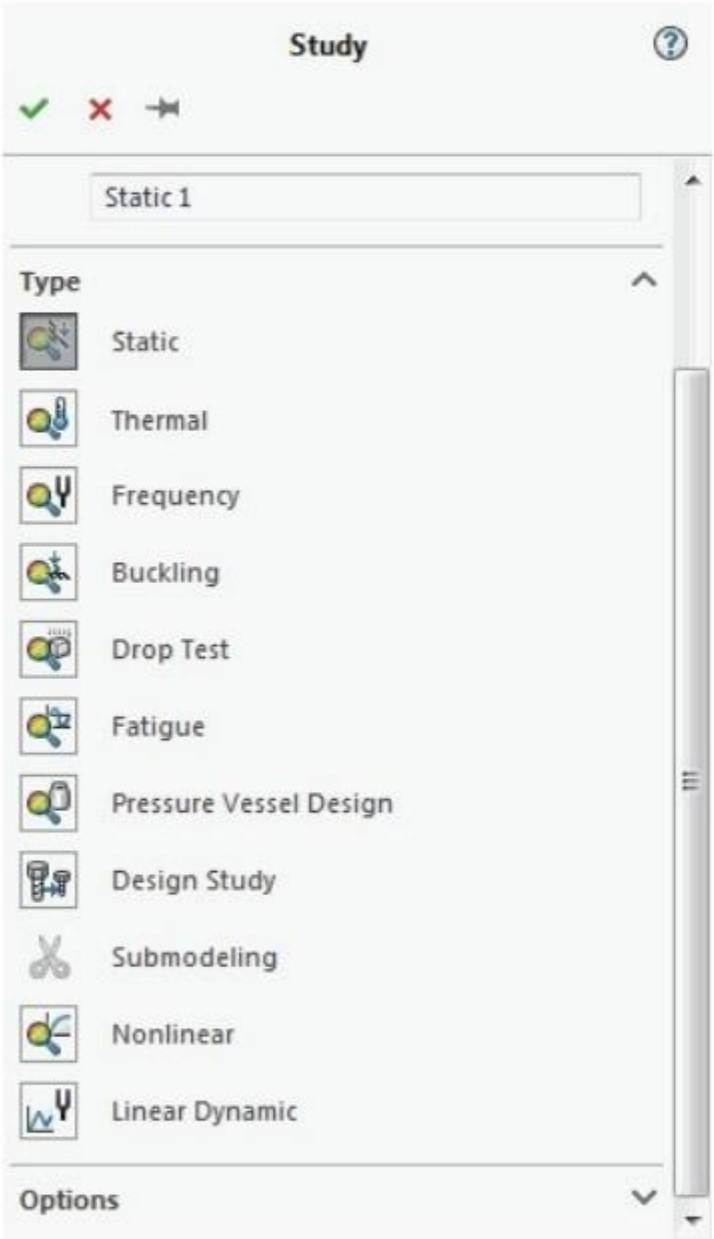


Fig23

- The buttons available in the Type rollout of the Property Manager refer to different type of analyses.
- Then we click on thermal analysis

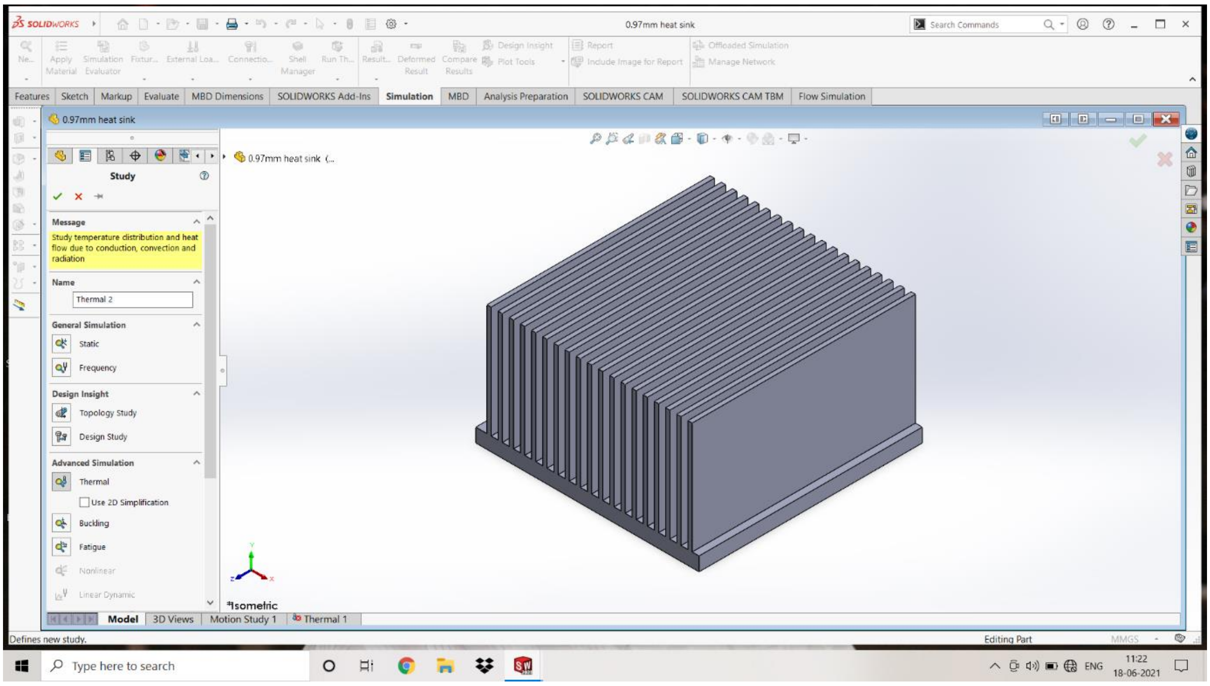


Fig24

- Then we apply the material as show in the figure below

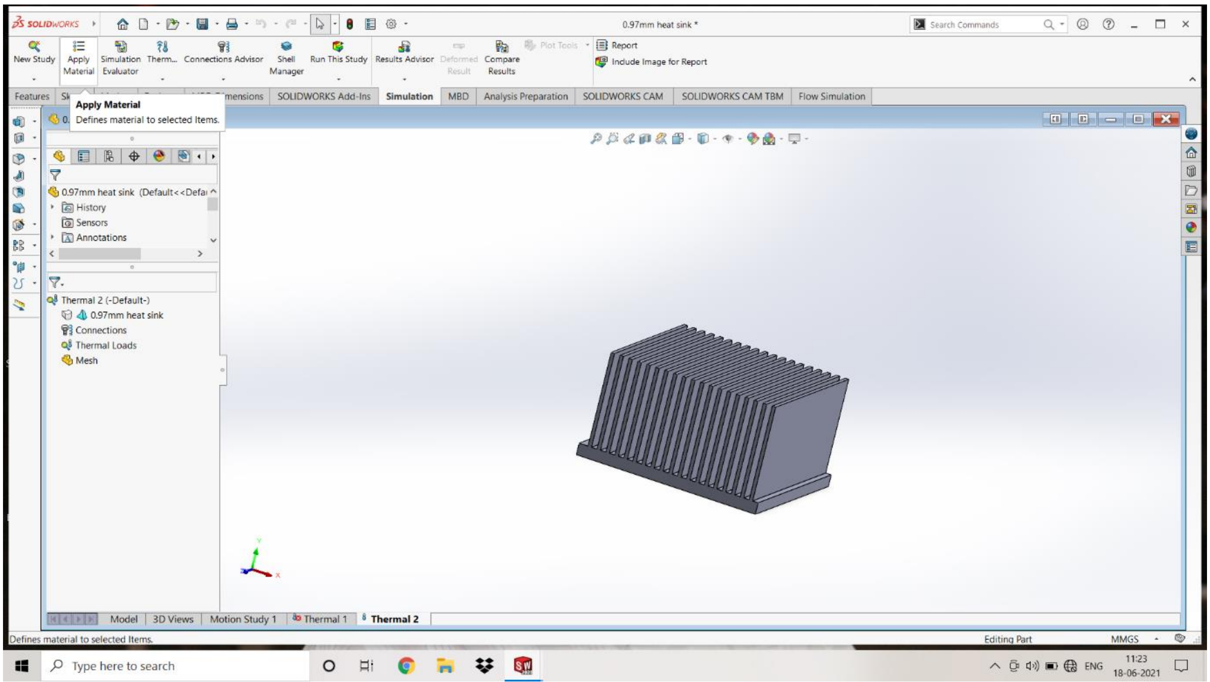


Fig25

- We select the material required as show in the figure

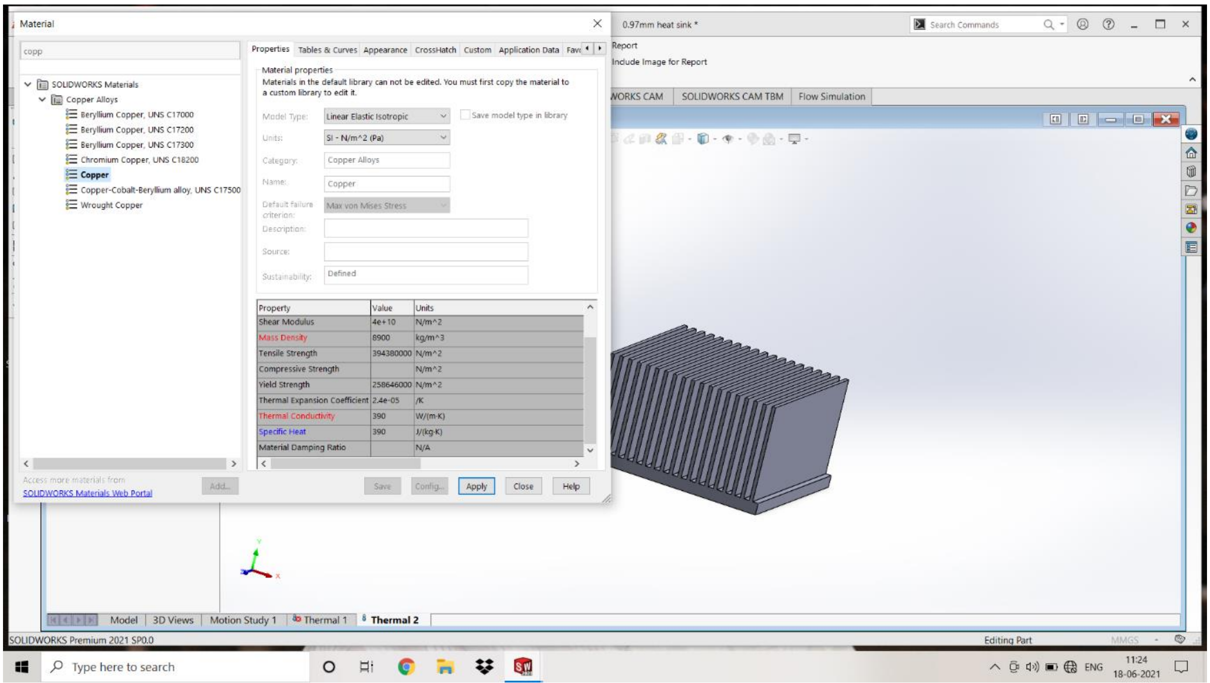


Fig26

- We click on temperature to apply the temperature conditions
- We select the thermal load in the drop-down list and select the heat power as show in the figure below

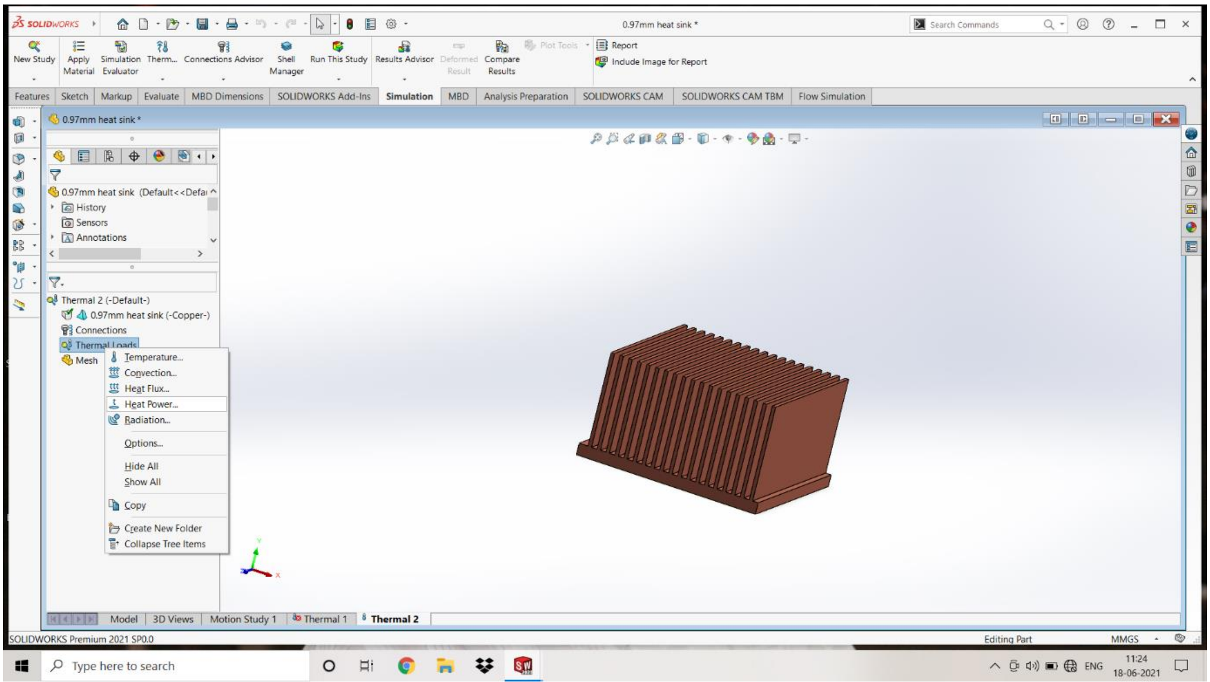


Fig27

- We applied a load of 50W at the base of the heat sink as shown in the figure below

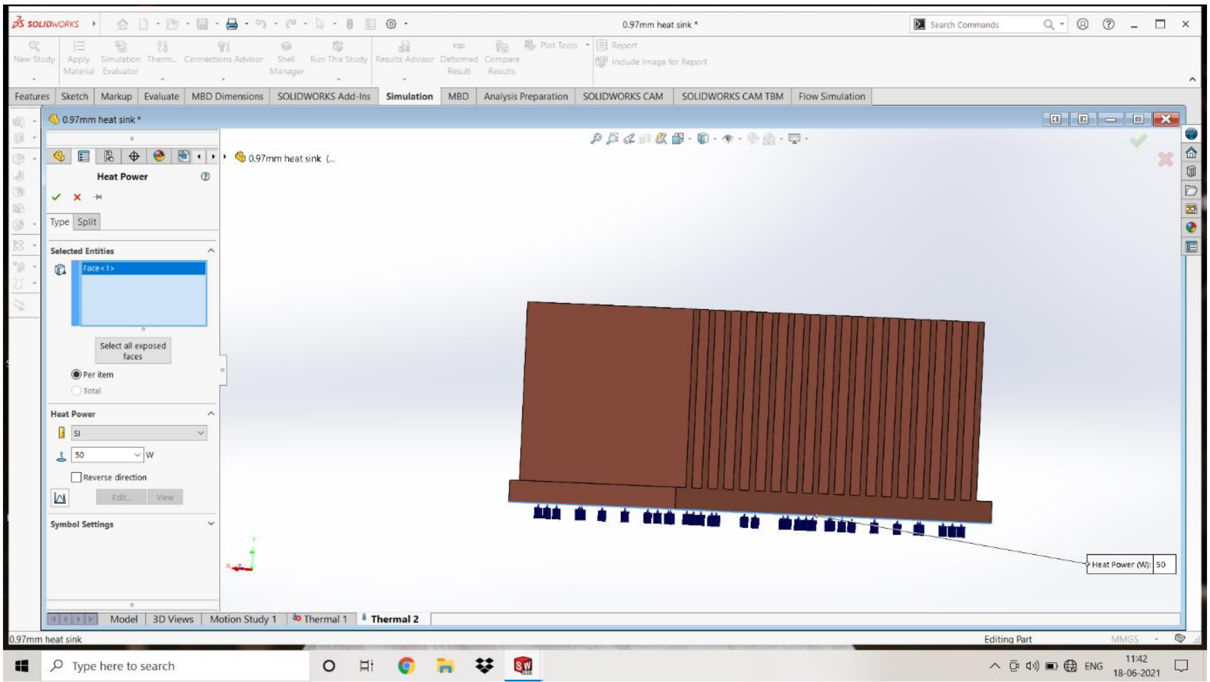


Fig28

- In the same drop-down list, we select the convection to add the convection given to the heat sink

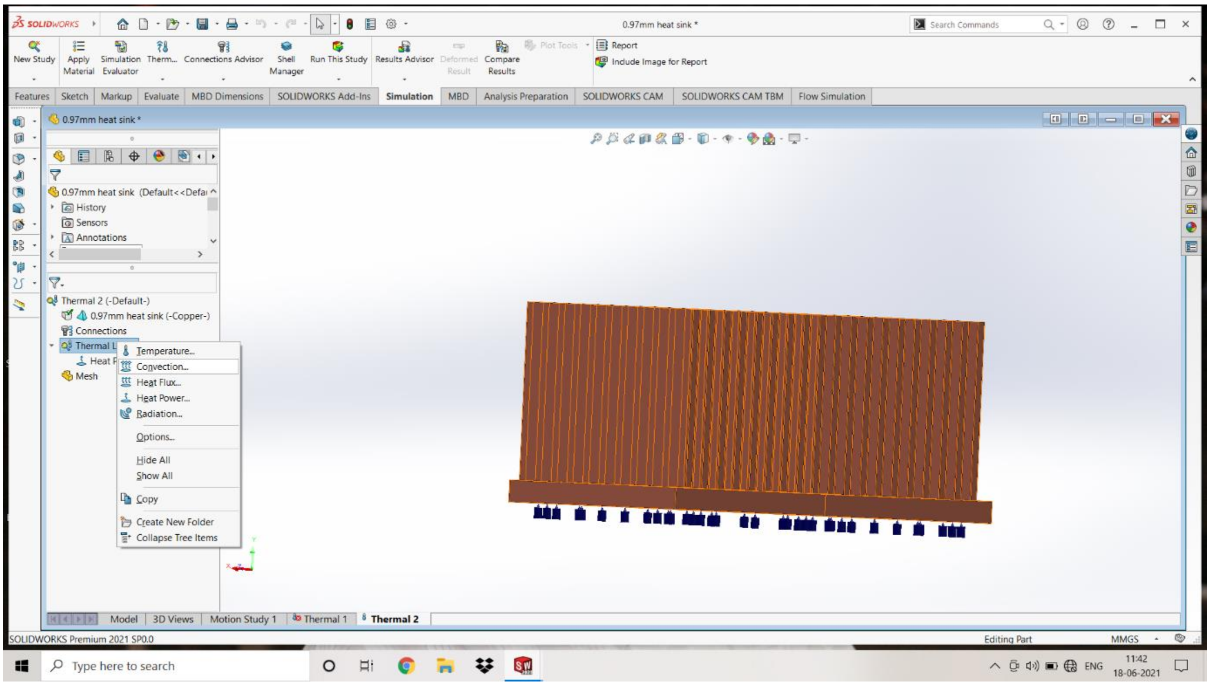


Fig29

- We have given a convection of 15W/m^{2}K to all the exposed faces expect the base of the heat sink

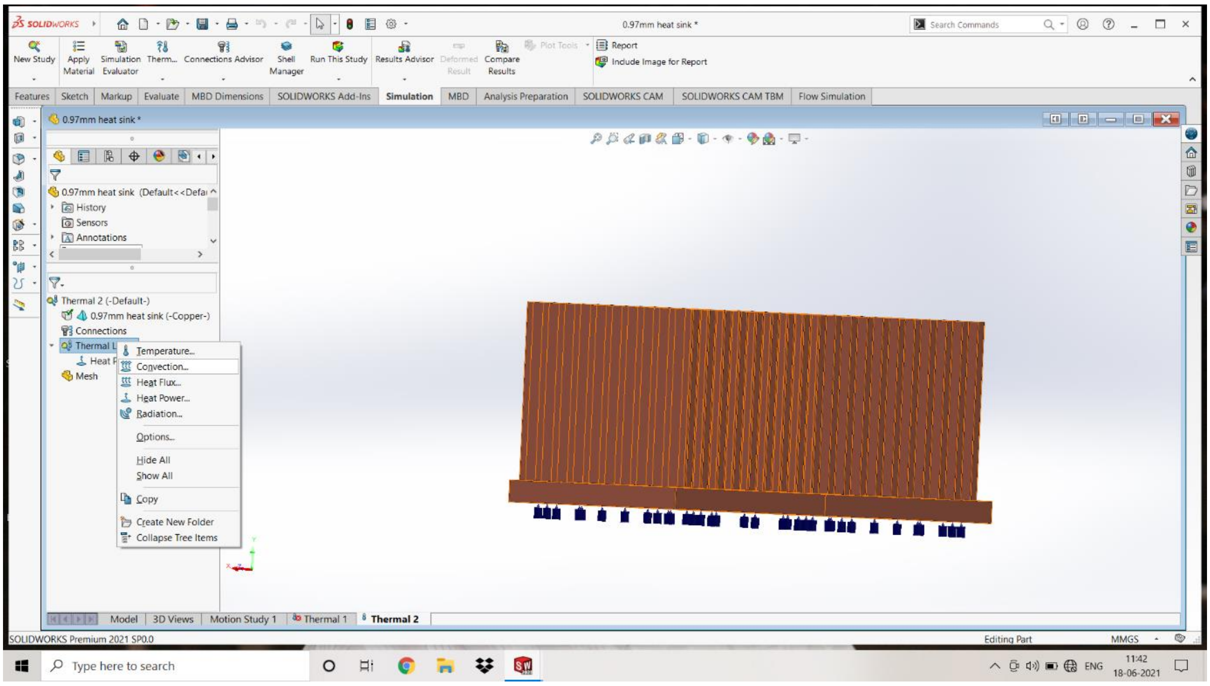


Fig30

- Then we run the study to get the results

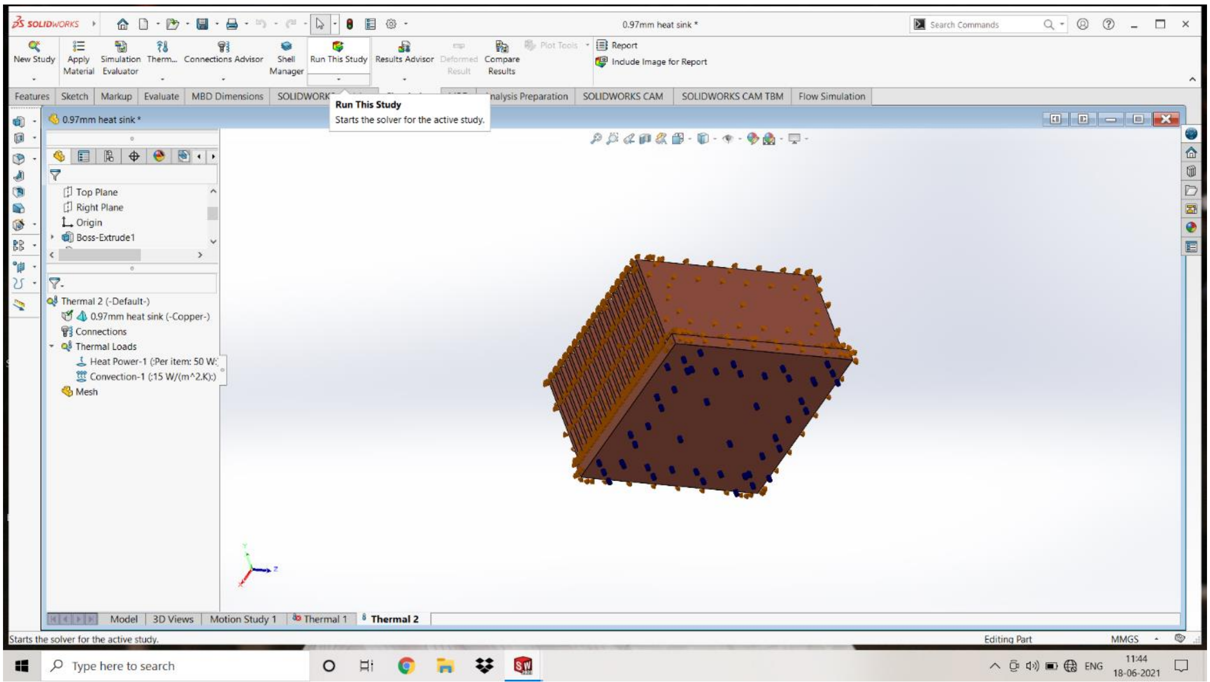


Fig31

4.3 Analysis

After designing the heat sink in the SOLIDWORKS we have use the SOLIDWORDS SUMILATION to study the proposed heat sinks. The material used in the heat sink is copper which has a better thermal conductivity of 400W/m. K and volumetric heat capacity of 3.45J/cm^3. K. The input conditions for heat sinks are the average minimum heat power is 50Watts. The Convection coefficient ranges from 2.5 -25 w/m^2 k so have we have considered average as 15 w/m^2 K and we have considered the room temperature are bulk temperature of 300.15 K. The above conditions are applied to all the proposed heat sinks and the results obtained are shown in the following figures

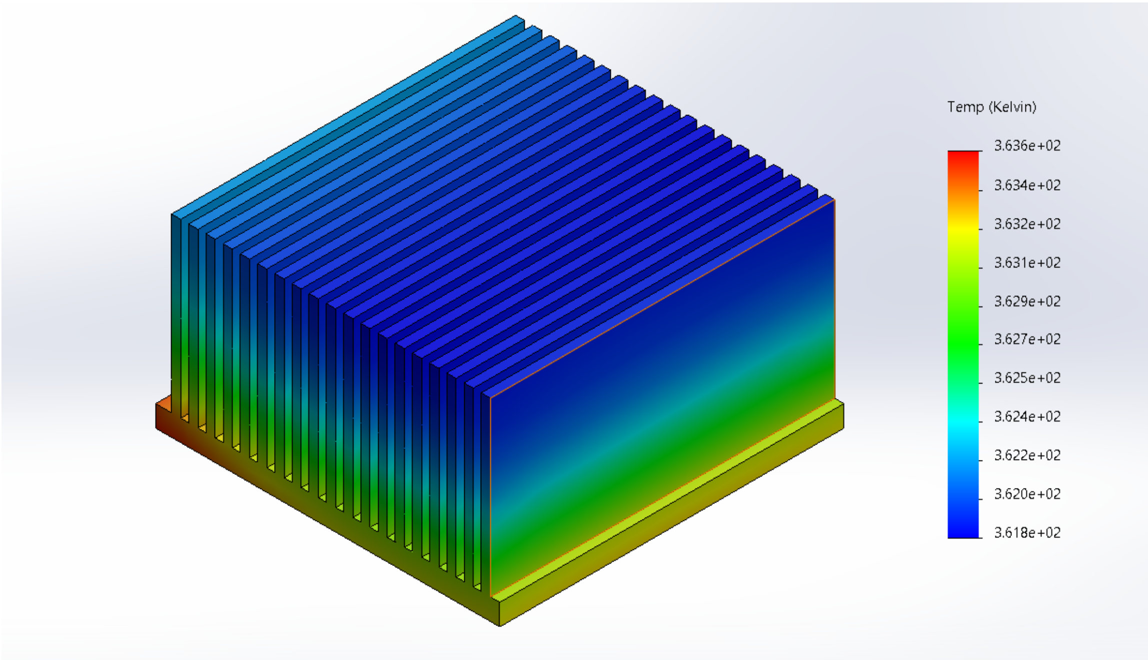


Fig32

The above figure shows the result of heat sink with 1.37mm fin thickness indicating 90.45^{0}C

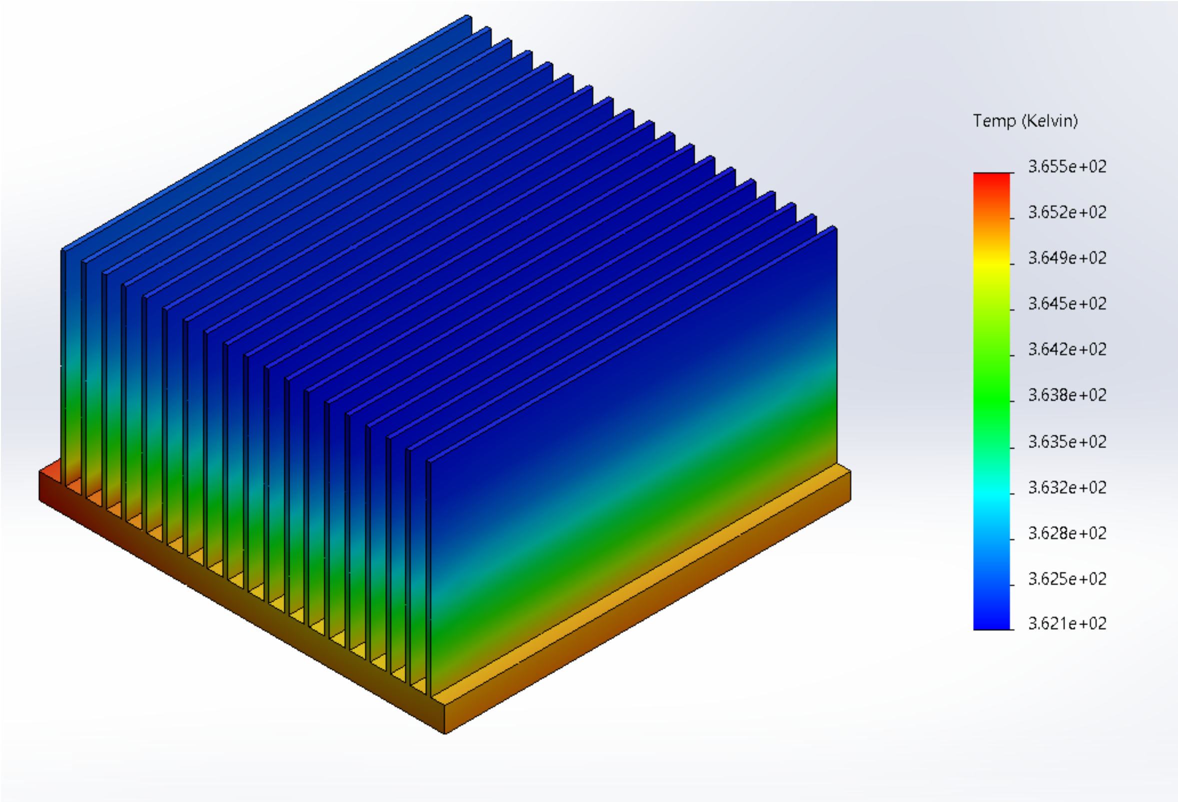


Fig33

The above figure shows the result of heat sink with 0.57mm fin thickness indicating 92.37^{0}C

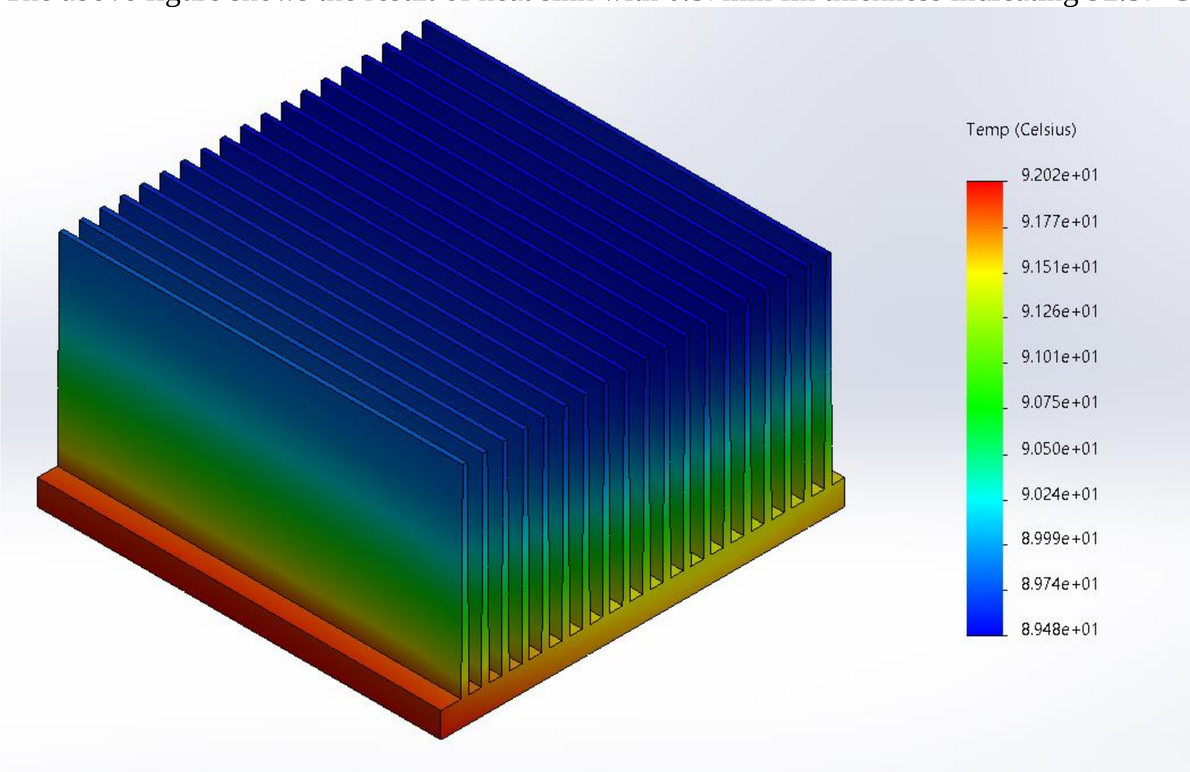


Fig34

The above figure shows the result of heat sink with tapered fins indicating 92.02^{0}C

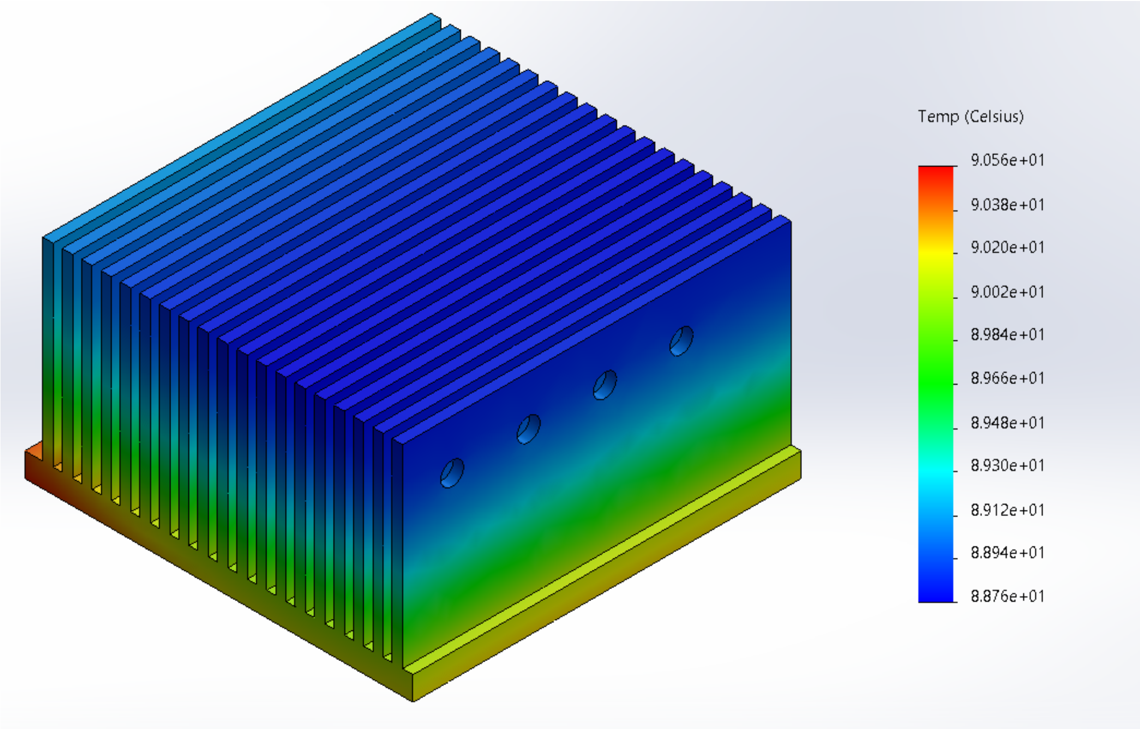


Fig35

The above figure shows the result of heat sink with 1.37mm fin thickness with holes indicating90.56^{0}C

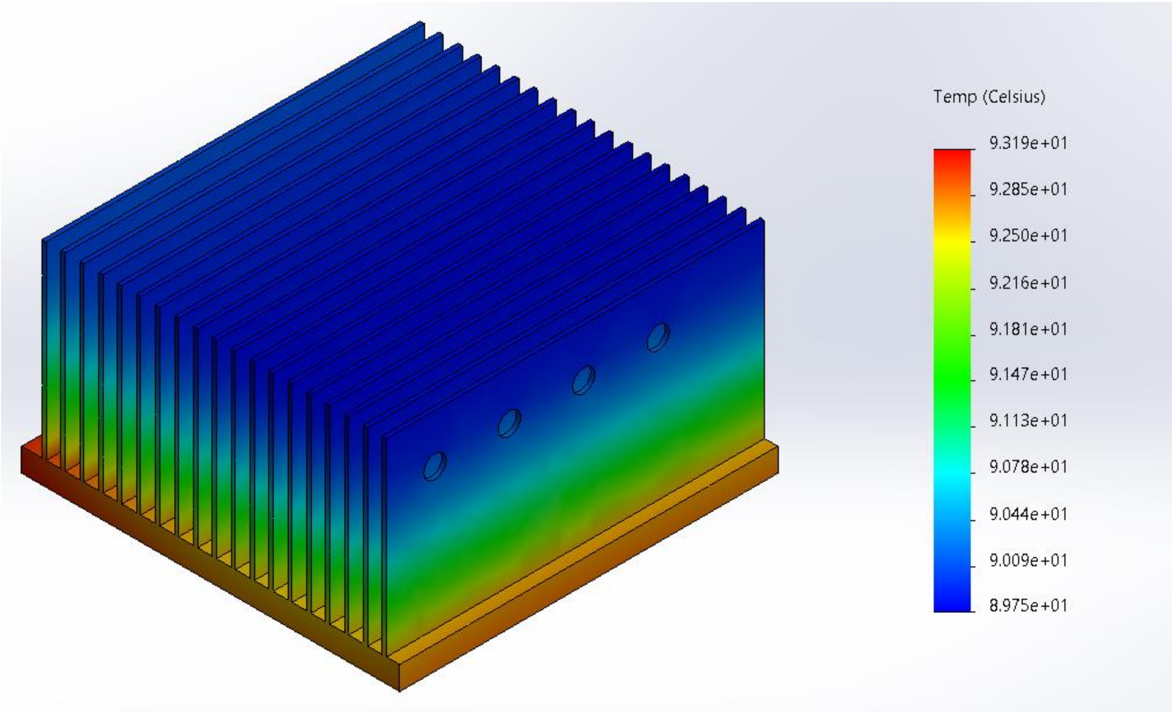


Fig36

The above figure shows the result of heat sink with 0.57mm fin thickness with holes indicating 93.19^{0}C

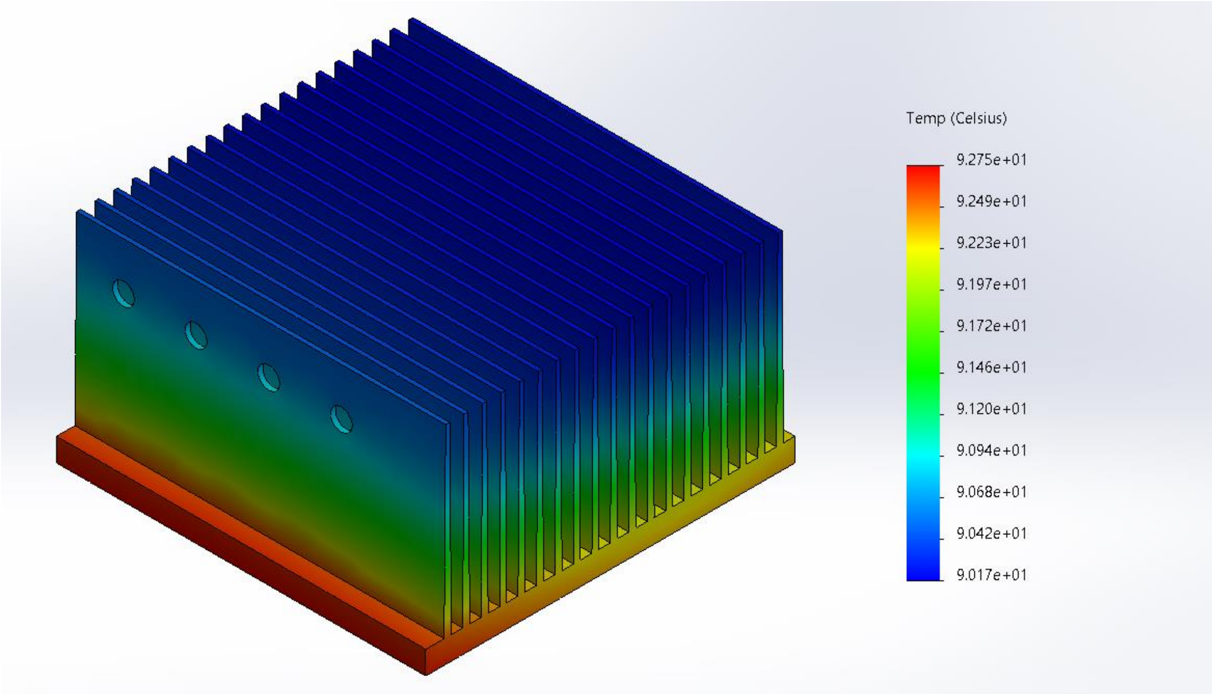


Fig37

The above figure shows the result of heat sink with tapered fins with holes indicating 92.21^{0}C

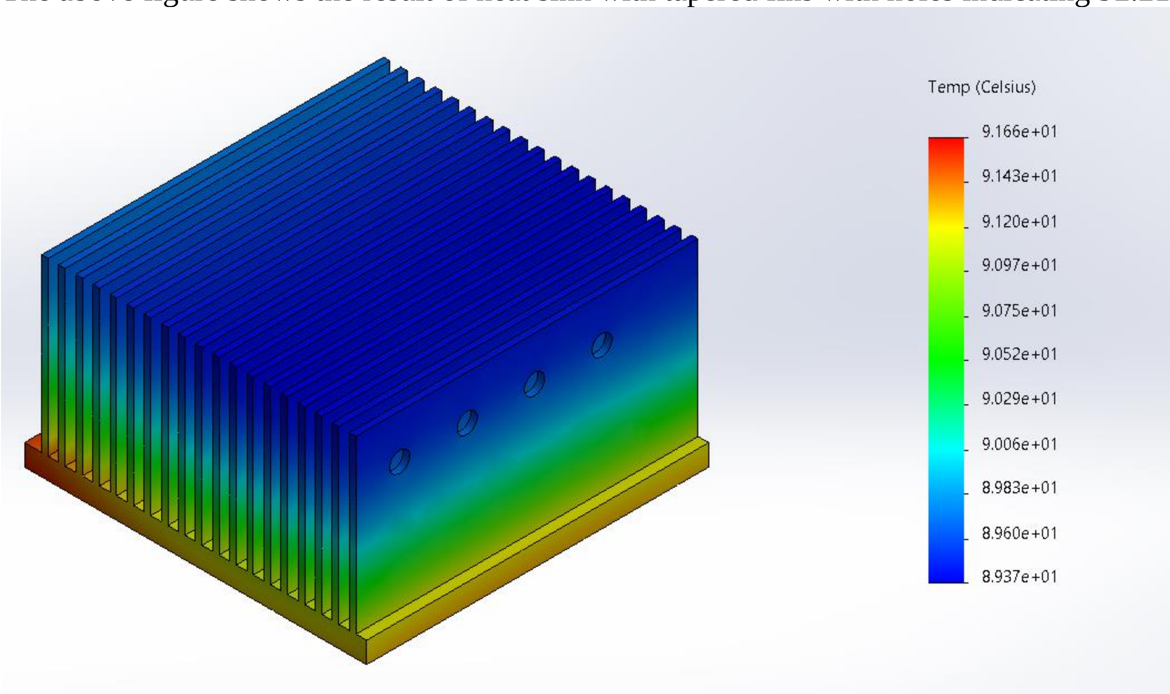


Fig38

The above figure shows the result of heat sink with 0.97mm fin thickness with holes indicating 91.66^{0}C

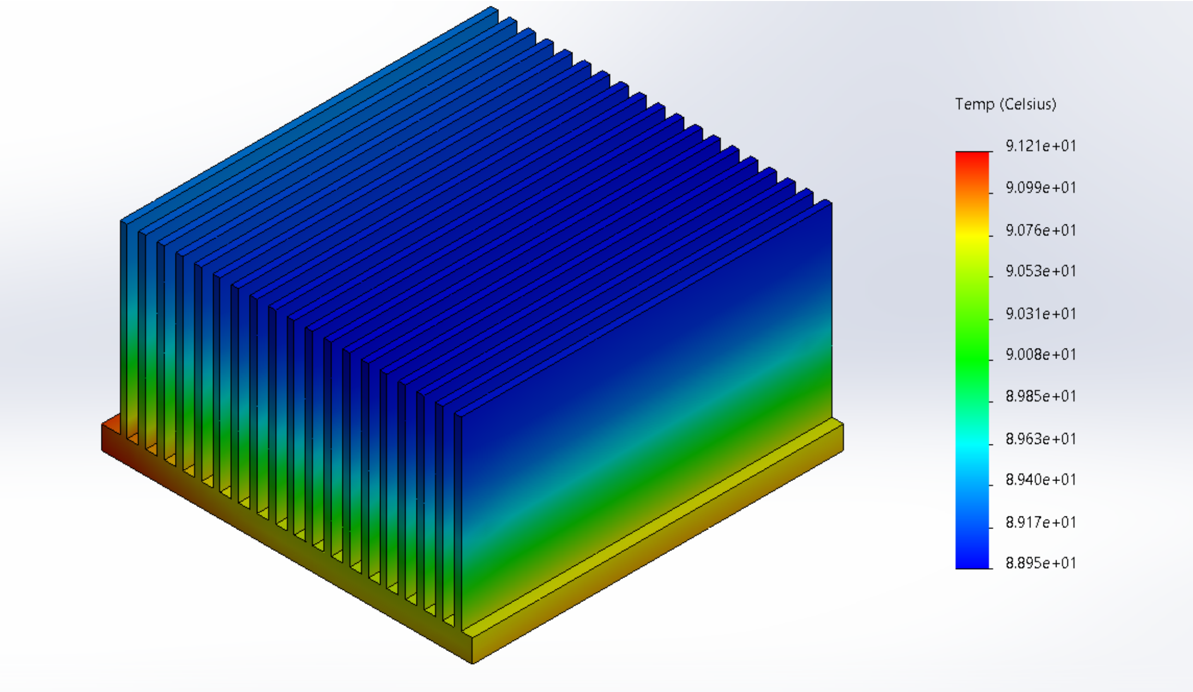


Fig39

The above figure shows the result of heat sink with 0.97mm fin thickness indicating 91.21^{0}C

CHAPTER-5 RESULT AND COMPARISON

From the above analysis of the heat sinks the following results are been observed and tabulated as shown below and we have noticed the following changes in the heat sink temperature

INPUT POWER (W)	HEAT SINK TEMPERATURE (°C)							
	1.37mm Fins	0.57mm Fins	Tapered Fins	1.37mm Fins with holes	0.57mm Fins with holes	Tapered Fins with holes	0.97mm Fins	0.97mm Fins with holes
50	90.45	92.39	92.02	90.56	93.19	92.75	91.21	91.66

TABLE 3

CHAPTER-6 CONCLUSIONS AND FUTURE ENHACEMENT

The main of the project is to design a better heat sink then the existing heat sink. We have used the material copper which a has a better thermal conductivity when compared to other materials We have designed the heat sinks in CAD software named SOLIDWORKS and analysis is been done in the SOLIDWORKS SUMULATION under the required boundary conditions We have observed that the heat sink of fin thickness of 1.37mm without holes shows better results when compared to other proposed heat sinks and the heat sink of fin thickness of 1.37mm with holes can be considered as an alternative to the existing heat sink as the production cost of the heat sink with 1.37mm fin thickness with holes is less when compared to the heat sink of 1.37mm fin thickness without holes as the mass is lesser.

6.1 PUBLICATION

- ICRIM-2021
- online international conference on “ROBOTICS AND INTELLIGENT MANUFACTURING”.

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A Major Project Report

On

EXPERIMENTAL STUDY ON DISCHARGING PERFORMANCE OF VERTICAL MULTI-TUBE SHELL AND TUBE LATENT HEAT THERMAL ENERGY STORAGE

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

CH. SAI KRUPA - 17K81A0315

J. DILEEP VARMA - 17K81A0326

S. UDAY KIRAN - 17K81A0353

Under the Guidance of

Mr S. Amith Kumar

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DEPARTMENT OF MECHANICAL ENGINEERING

St. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled “**EXPERIMENTAL STUDY ON DISCHARGING PERFORMANCE OF VERTICAL MULTI-TUBE SHELL AND TUBE LATENT HEAT THERMAL ENERGY STORAGE**”, is being submitted by **CH. SAI KRUPA (17K81A0315), J. DILEEP VARMA (17K81A0326), S. UDAY KIRAN (17K81A0353),** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** MECHANICAL ENGINEERING is recorded of bonafide work carried out by them. The result embodied in this report have been verify and found satisfactory.

Signature of Guide	**Signature of HOD**
Mr S. AMITH KUMAR	**Dr.D.V. SREEKANTH**
Assistant Professor,	**Professor & Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of 'MECHANICAL ENGINEERING', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled "**EXPERIMENTAL STUDY ON DISCHARGING PERFORMANCE OF VERTICAL MULTI-TUBE SHELL AND TUBE LATENT HEAT THERMAL ENERGY STORAGE"** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Heat transfer is phenomena that rate of heat exchange between the two different body’s for this heat transformat Heat t ion in industries are large number of body’s we will use. A device which will used to transform heat form one fluid to and another fluid that the device called heat exchanger. we have various industries which are using the heat exchanger like engineering process, refrigeration, air-conditions systems power system, food processing units and chemical reactors. In this project we did design of shell and heat exchanger by using the catia v5 r20 after the design we did analysis of heat exchanger by using the ansys14.5 with different materials we calculate the heat flow over the shell and tube heat exchanger.
Keywords: heat exchanger, heat transfer, nano fluids, periodic flow, mass flow rate, nusselt number & reynolds number

.

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INTRODUCTION

1.1. Introduction to heat transfer:

The science of thermodynamics deals with the quantitative transitions and rearrangements of energy as heat in bodies of matter. Heat transfer is the science that deals with the rate of exchange of heat between hot and cold bodies called the source and receiver. When one Kg of water is vaporized or condensed, the energy change in either process is identical. However, the rates at which either process proceed is different, vaporization being much more rapid than condensation.

The major difference between thermodynamics and heat transfer is that the former deals with the relation between heat and other forms of energy, whereas the latter is concerned with the analysis of the rate of heat transfer. Thermodynamics deals with systems in equilibrium so it cannot be expected to predict quantitatively the rate of change in a process, which results from non-equilibrium states. Heat transfer is commonly associated with fluid dynamics and it also supplements the laws of thermodynamics by providing additional rules to establish energy transfer rates.

Process heat transfer deals with the rates of heat exchange as they occur in the heat transfer equipment of the engineering process. This approach brings to better focus the importance of the temperature difference between the source and the receiver, which is, after all, the driving force whereby the transfer of heat is accomplished. A typical problem of process heat transfer is concerned with the quantities of heat to be transferred, the rates at which they may be transferred because of the natures of the bodies, the driving potential, the extent and arrangement of the surface separating the source and the receiver, and the amount of mechanical energy which may be expanded to facilitate the transfer. Since heat transfer involves an exchange in the system, the loss of heat by the one body will equal the heat absorbed by another within the confines of the same system

1.2. Principles of heat transfer:

The heat exchange process in a heat exchanger can be described by the principles of conduction, convection, and radiation.

CONDUCTION

Heat conduction is the mode of heat transfer accomplished by the mechanism of molecular interaction. The energy exchange takes place by the kinetic motion or direct impact of molecules. Molecules at relatively higher energy level impart energy to adjacent molecules at lower energy levels. This type of heat transfer occurs, as there is a temperature gradient in the system comprising of solid, liquid or gas. Conduction is proportional to the area-measured normal to the direction of heat flow and to the temperature gradient measured in that direction.

$$Q = -KA\,(dt/dx)$$

K= Coefficient of thermal conductivity

CONVECTION

Convection is possible only in the presence of a fluid medium. When a fluid flows inside a duct or over a solid body and the temperatures of fluid and solid surfaces are different, heat transfer between the fluid and the solid surfaces takes place. This is due to the motion of the fluid relative to the surface. The heat transfer by convection is always accompanied by heat transfer by conduction for a fluid flowing at a mean temperature Tm over a surface of temperature Ts. Newton proposed the following convection equation.

q = Q/A = h (Ts-Tm)

Where,

q= heat flux at the wall in W/m2

h = heat transfer coefficient in W/m2c

Ts = surface temperature in c

Tm = mean temperature in c

RADIATION

If two bodies at different temperatures are placed in an evacuated adiabatic enclosure so that they are in contact through a solid or fluid medium, the temperature of two bodies will tend to become equal. The mode of heat transfer by which this equilibrium is achieved is called as Thermal Radiation. Radiation is an electromagnetic wave phenomenon and medium is required for its propagation. According to Stefan-Boltzmann law the radiation emitted by a body is proportional to the fourth power of absolute temperature.

Q= T14

Where,

= Stefan-Boltzmann constant

T1= Surface temperature in Kelvin

CHAPTER – 2

HEAT EXCHANGERS

2.1. Introduction to heat exchangers:

A Heat Exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat Exchangers are useful in many engineering processes those in refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors and space or aeronautical applications.

2.2. Classifications of heat exchangers:

CLASSIFICATION BASED ON WORKING FEATURES:

The heat exchangers are mainly divided into three categories according to their working features.

1. Closed type exchanger
2. Regenerators
3. Open type exchangers or mixed type

(1). CLOSED TYPE EXCHANGER

Closed type exchangers are those in which heat transfer occurs between two fluids, which do not mix, or physically in contact with each other. The fluids involved are separated from each one other by a pipe or a tube wall or any other surface, which may be involved in heat transfer path. Heat transfer will occur by convection from the hotter fluid to the solid surface, by conduction through the solid and again by convection from the solid surface to the cooler fluid. Most of the heat exchangers come under this category. Our discussion will be related to this type.

(2). REGENERATORS

The regenerators are storage type heat exchangers. The heat transfer surface or elements are usually referred to as a matrix in the regenerator. Regenerators are exchangers in which a hot fluid, then a cold fluid, flows through same space alternatively with as little mixing as possible occurring between the two streams. The surface that receives releases thermal energy. Such a device is important.

Material properties of surfaces involved as well as fluid flow properties of the stream along with geometry are qualities that must be known. The analysis needs knowledge of unsteady state convection and conduction. In steam power plants, the air pre-heaters are usually rotor regenerator type.

(3). OPEN TYPE OF EXCHANGERS OR MIXED TYPE

Open type heat exchangers, as the name implies are devices where in the entering fluid stream flow into the open chamber and complete mixing of the two streams occurs. Hot and cold fluids entering such an exchanger will leave as a single stream.
Analysis of open type involves the law of conservation of mass and laws of thermodynamics. Jet condensers used for cooling the water circulated through the condensers in power plants come under this category.

CLASSIFICATION BASED ON FLUID FLOW ARRRANGEMENTS

Mostly heat exchangers are classified on the basis of configuration of the fluid flow paths through the heat exchangers. The choice of particular flow arrangement is dependent upon the required exchanger effectiveness, available pressure drops, minimum and maximum velocities allowed, fluid flow paths, packing envelope, allowable thermal stresses, temperature levels, piping and plumbing considerations, and other design considerations and criteria.

COUNTER FLOW EXCHANGER:

In counter flow exchanger the two fluids flow parallel to each other but in opposite directions within the core. The counter flow arrangements are thermodynamically superior to any other flow arrangements. It is the most efficient flow arrangements for given overall thermal conductance (UA), fluid flow rates and inlet temperatures.

PARALLEL FLOW EXCHANGER:

In parallel flow exchanger the fluid streams enter together at one end, flow parallel to each other in the same direction and leave together at other end. This arrangement has lowest exchanger effectiveness among the single pass exchanger for given overall thermal conductance and fluid flow rates. In a parallel flow exchanger, a large temperature difference between inlet temperatures of hot and cold fluid exists at the inlet side, which may include high thermal stresses in the exchanger wall at the inlet. This flow arrangement is not used for applications requiring high temperature effectiveness.

CROSS FLOW EXCHANGER:

In this type of exchanger the fluids flow normal to each other. Thermodynamically, the effectiveness of the cross flow exchanger falls between the parallel and counter flow exchangers. This is one of the most common flow arrangements used for extended surface heat exchanger, because it greatly simplifies the header design at the exit of each fluid.

FIGURE 2.2. A CLASSIFICATION BASED ON FLUID FLOW ARRANGEMENTS

CLASSIFICATION BASED ON APPLICATIONS:

Heat exchangers are classified on the basis of the applications for which they are intended and special terms are employed for major types.

These terms include

- Boiler
- Condenser
- Oil cooler

BOILERS:

Steam boilers have been used to produce power and constitute one of earliest applications of the engineering principles to heat exchangers. They consist of a number of small diameter tubes interconnected to the boiler drum. Water is allowed to flow through these tubes. The head from the flue gases passing over the tubes is transferred to the water through the tube surface.

CONDENSERS:

Condensers are used in power plants, chemical plants and refrigeration systems. Large power plant condensers are called surface condensers. Steam condensers consist of a bundle of small diameter tubes laced inside a metal shell. The exhaust steam from the turbines passes over the tubes and cooling water in the tubes.

COOLERS:

When a fluid at high temperature is to be cooled to a lower temperature, coolers are used. For example oil coolers and air coolers are used to cool the lube oil that is to cool the bearings and other surfaces of the large machinery like turbines. The most common type used is the shell and tube type of heat exchanger.

2.3. Types of heat exchangers:

The three main types of heat exchangers are,

(1). AIR COOLED HEAT EXCHANGER

It is tubular heat transfer equipment in which ambient air passes over the tubes and thus acts as the cooling medium. Air is available in unlimited quantities compared to water. The airside fouling is frequent problem. But the heat transfer coefficient of air is less than that of water.

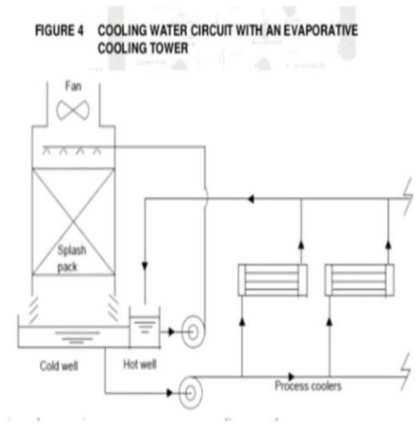

Fig:1 Cooling tower

(2). PLATE TYPE HEAT EXCHANGER

The plate type of heat exchanger consists of a thin rectangular metal sheet upon which a corrugated pattern has been formed by precision pressing. One side of each plate mounted on the frame and clamped together. The space between adjacent plates forms a flow channel. The cold and hot fluids flow through channels.

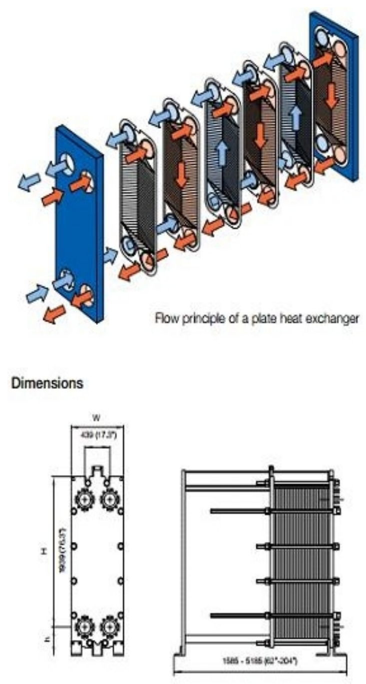

Fig:2 Flow principle

(3). SHELL AND TUBE TYPE HEAT EXCHANGER

Shell and tube type heat exchangers are the most versatile and suitable for almost all applications, irrespective of duty, pressure and temperature. Shell and tube type exchanger consists of a cylindrical shell containing a nest of tubes that run parallel to the longitudinal axis of the shell and are attached to perforated flat plates called tube sheets at each end. There are a number of perforated plates, through which the tube passes called as baffles. This assembly of tubes and baffles is called a tube bundle and is held together by tie rods and spacer tubes for spacing the baffles.

FIGURE: 2.3 A SHELL AND TUBE HEAT EXCHANGER

There are mainly three types of shell and tube heat exchangers.
1.Fixed tube sheet
2.U-tube type
3.Floating tube sheet type

(1). FIXED TUBE SHEET TYPE

Tube sheets are welded to shell to form a box. Inside of the tubes may be mechanically cleaned after removing the channel cover, but because the tube bundle cannot be removed, cleaning of the outside tubes can only be achieved by chemical means. The combination of the thermal expansion coefficient of the shell tubes and temperature during service may cause a differential expansion between them, which if excessive might loosen the tube sheet joints. The principle advantage of the fixed tube sheet construction is its low cost because of the simple construction.

(2). U-TUBE TYPE

U-tube type heat exchanger has only one tube sheet and as each tube is free to move with respect to shell, the problem of the differential movement is eliminated. Tubes can be cleaned mechanically, in applications where the tube side fluid is virtually non-fouling fluid. The advantage of U-tube heat exchanger is, as one end is free the bundle can expand or contract in response to the stress differentials. The disadvantage of U-tube construction is that the inside of the tube cannot be cleaned effectively since the U bends require flexible end drill shafts for cleaning.

(3). FLOATING HEAD TYPE

The floating head type heat exchanger is the most versatile type of heat exchanger. In this type of heat exchanger one tube sheet is fixed relative to the shell, Although this type of exchanger is widely used, it has an internal joint at the floating head and careful design is asserted to prevent the leakage of one fluid to another. Also, the design accommodates a smaller number of tubes than the fixed tube sheet or U-tube type having the same shell inside diameter.

2.4. Types of shell and tube heat exchangers:

- Surface condenser
- Steam jet air ejector condenser
- Gland steam condenser
- Drain cooler
- LP heaters
- Deaerators
- HP heaters
- Oil cooler

- **Surface condenser (rectangular):-** The condenser is surface type, fabricated construction and single shell. The condenser is mounted on saddles. A set of springs at the support or an expansion bellow at the condenser neck is provided to take care of thermal expansion in vertical direction. The condenser is firmly connected to the exhaust side of the turbine.

- **Ejector condenser:-** The ejector condenser extracts non-condensable gases from condenser and there by creates and maintains vacuum in the system.

- **Gland steam condenser:-** The gland steam condenser is used to condense the gland steam extracted from turbine glands, in a regenerative cycle, this besides condensing the glands steam, heats the condensate from the condenser. In case of very low condensate flows or non-condensing sets, GSC steam will be cooled by cooling water the condensate or cooling water passes through the tubes and steam/drain passes over the tubes. The gland steam condenser is of surface, horizontal/vertical mounting type.

- **Drain cooler:-** This sub cools the drain from the low-pressure heater to improve the cycle efficiency by heating the feed water flowing in the drain cooler.

- **L.P Heater:-** The low-pressure heaters are used to heat the condensate from the condenser, by extracting steam from turbine in a regenerative heat cycle.

This, besides effecting an improvement in the thermal efficiency removes moisture from the low-pressure stage of the turbine there reducing the problems of blade corrosion in the turbine. The condensate passes through the u tubes and steam/drain passes over the tubes. The LP heaters are of surface type with either horizontal or vertical mounting.

- **H.P. Heater:-** The high pressure feed water heaters are employed to increase the overall efficiency of the regenerative cycle by heating the feed water by the steam extracted from suitable stages of the turbine.

- **Deaerators:-** Deaerators are used to remove oxygen (corrosive gases) mechanically from the water used for generating steam in the boilers. The oxygen is reduced to 0.005cc/litre or less.

- **Oil cooler :-** Oil cooler is basically a heat exchanger and is an essential equipment to cool the lube oil that is to cool the bearings and other surfaces of the large machinery like turbines.

CHAPTER - 3

DESCRIPTION OF THE EQUIPMENT

3.1. Introduction to oil cooler:

Large amount of heat is generated at the bearings of rotating machinery. In addition to this, heat from working steam/fluid is conducted by the rotating shaft. To remove this excess heat lubricating oil is circulated through the bearings.

In the closed cycle operation of oil circuit one or more coolers are placed on the discharge side of the oil pump. The oil coolers that receive oil, absorb the waste heat, cools it to the temperature that is required at the bearings. The cooling water for the oil coolers is the same as that for the main condenser. It is usual to provide two coolers of 100% capacity such that one is always available as a standby. The coolers are mounted vertically/horizontally for easy removal of the tube nest. A change over valve of three-way type is provided to direct the flow of oil into one of the operating coolers as desired.

3.2. Construction of oil cooler:

The oil cooler is a shell and tube nest arrangement. The tube nest consists of two tube sheets into which the tubes are roller expanded. One tube sheet is fixed while the other slides on an annular seal to allow for thermal expansion. The tube nest has a number of baffles arranged in segmental type spaced at intervals such that oil that enters the coolers at inlet nozzle of the shell is made to flow in a zigzag manner & exits at the outlet nozzle of the shell.

The cooling water flows through the tubes in a two-pass/four pass arrangement by the provision of partition plate in the water boxes. The tube nest is housed in a fabricated cylindrical shell.
For inspection of tube nest it is enough to remove the rear end water chamber as well as the inspection cover on the inlet/outlet water chamber. For cleaning of the tubes as well as for attending to repairs, the tube nest along with the water chamber can be withdrawn from the shell.

Oil can be drained from the cooler through a drain connection at the bottom of the shell. Air accumulated in the oil space can be expelled through a vent. Likewise on the waterside of the cooler also, the air vent is provided at the top and a drain connection at the bottom. The oil inlet and outlet nozzles are provided with screwed thermometer connections. Thermometer pockets are also provided in the water boxes for measurement of cooling water.

3.3. Operations of oil cooler:

Open the water inlet valve and open the air vent lock on the water box cover. Close the air vent when there is a steady stream of water through the vent. Open oil inlet and outlet of the cooler and vent the oil side completely as before. When the temperature of the oil at the outlet from the cooler has reached the required value, regulates the flow of working water through the cooler by adjusting the outlet valve.

To bring the stand-by cooler into operation, On waterside operate the stand-by cooler as before. Now open the change over valve to bring the oil side of the stand-by cooler into operation and shut down the oil side of the running cooler. For shutting down running cooler, close oil outlet, closing water outlet, oil inlet and finally closing water inlet in that order.

3.4 Advantages of oil cooler:

- Effectiveness of cooling is more since the area of cross flow is more.
- Percentage of pressure drop is low.
- Heat transfer coefficient is more.
- Tubes are readily available in indigenous market.
- Replacement of tube incase of tube failure is very easy.
- Maintenance cost of the cooler is easy.

3.5. Description of oil cooler:

TUBES

Heat exchanger tubes are available in variety of materials, which include both ferrous and non-ferrous materials such as carbon steel, stainless steel, copper, admiralty brass, 90-10 copper-nickel, muntz etc. They are available in a number of wall thickness defined by BWG. The tubes are made with the strict tolerance on the outside diameter and as per specification of ASME, BS, IS standards. Most common diameters used are 15.875mm, 19.05mm, and 25.4mm.The tubes are expanded into the tube sheet, which forms a very good seal, which does not leak under reasonable operating conditions. Round tubes of different shapes are used in shell and tube exchangers.

TUBE PITCH

The tube pitch is the shortest distance between two adjacent tubes. Tube holes cannot be drilled very close together since too small width of metal between the adjacent tubes structurally weakens the tube sheet. The shortest distance between the two tube holes is the clearance or ligament and these are now fairly standardized.

Tubes are laid out either square pitch or triangular pattern. If the triangular pitch is rotated by 30 degrees, it is termed as rotated triangular pitch. If square pitch is rotated by 45 degrees, it is called rotated square pitch.Tube lay out is characterized by the included angle between tubes as shown in Figure

Flow Flow Flow

Triangular (300 C) Square (900 C) Square (600 C)

FIGURE 3.5. A TUBE LAYOUTS TUBE SHEET

They are used to hold the tubes at the ends. A tube sheet is generally a circular metal plate with holes drilled through for the desired tube pattern, holes for the tie rods, grooves for the gaskets and bolt holes for flanges to the shell and channel. In order to prevent leakage of the shell fluid at the tube sheet through clearance between the tube hole and tube, the tube to the tube sheet joints are made by many methods such as expanding the tubes, rolling of the tubes, hydraulic expansion of tubes, explosive welding of the tubes, or welding or brazing of tubes to the tube sheet.

BAFFLES

It is apparent that higher heat transfer coefficient results when the liquid is maintained in the state of turbulence. To induce turbulence outside the tube it is customary to employ baffles, which cause the liquid to flow through the shell at right angles to the exit of the tubes. Baffles are used to support tubes, enable a desirable velocity to be maintained for the shell side fluid, and prevent failure of tubes due to flow-induced vibration.

FLUID A	2 TUBES – PASSES 1 SHELL - PASSES
FLUID B	4 TUBES – PASSES

FIGURE: 3.5. B SHELL AND TUBE ARRANGEMENT

NOZZLES

The entrance and exit ports for the shell fluid and tube fluid are referred to as "Nozzles". These nozzles are pipes of constant cross section welded to the shell and channels. They are used to distribute or collect the fluid uniformly on shell and tube sides.

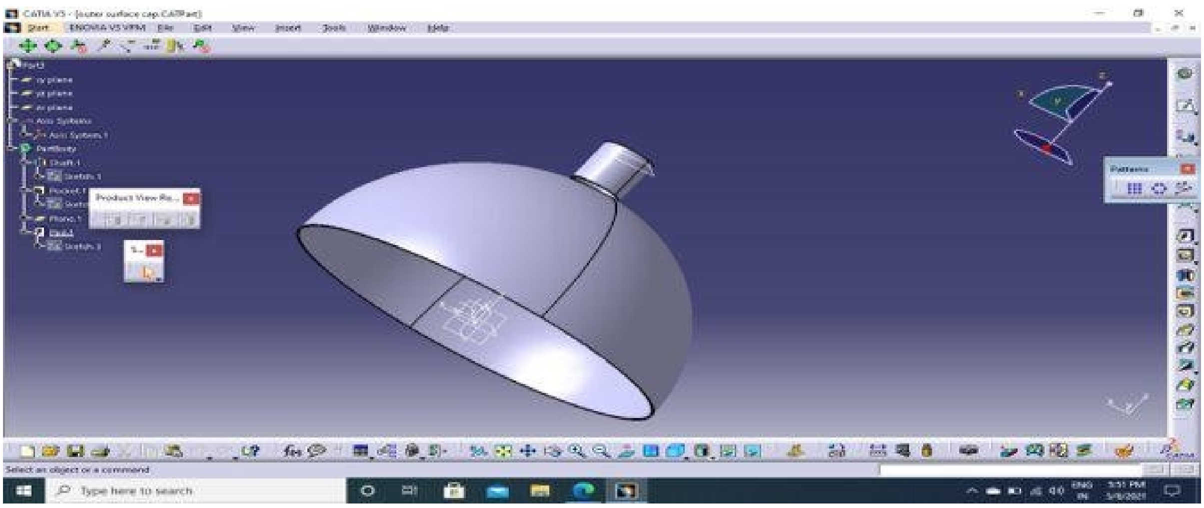

Fig:3 Front and Rear end covers

FRONT-END AND REAR END COVERS

They are containers for tube fluids for every pass. In many rear end head designs, a provision has been made to take care of thermal expansion of whole tube bundle. The front-end head is stationery while the rear end head could be either stationary or floating depending upon the thermal stresses between the tubes and shell.

TIE RODS AND SPACERS

Tie rods and spacers are other equivalent means of tying baffle system together. They should be provided to retain all transverse baffles and tube support plates securely in position. They serve two purposes; one to maintain the spacing between the baffles and second function is to reduce the fluid by-passing.

SHELL

The cylindrical shell made of rolled carbon steel plate or pipe carries flanged connection for water inlet, water outlet, plug and couplings for shell drain and vent. Suitable provisions are made for pressure and temperature measurement. The exterior of the shell also carries supporting feet and lifting lugs.

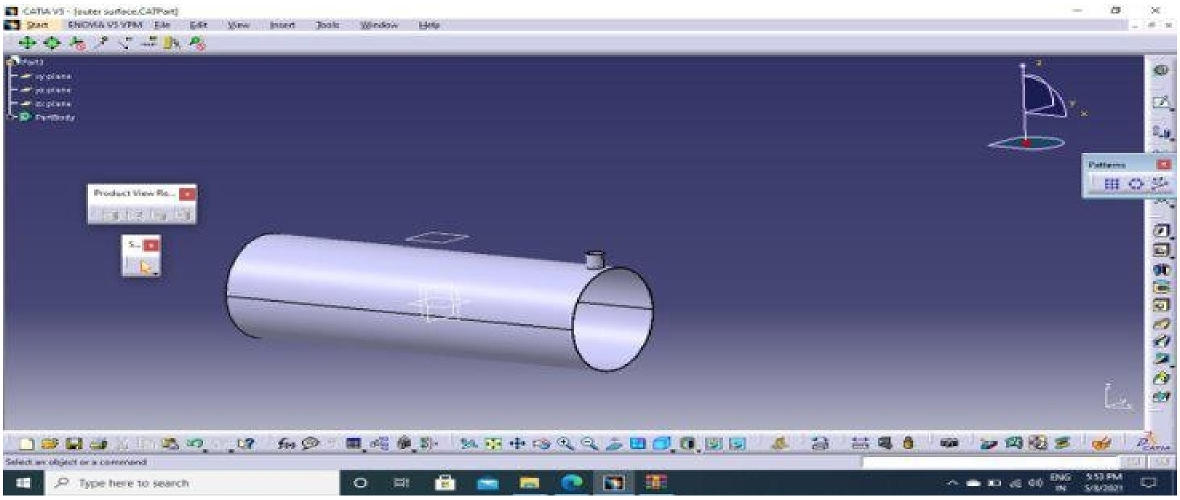

Fig:4 Cylindrical shell

WATER CHAMBERS

Both the inlet and outlet and rear end water chambers are fabricated from rolled carbon steel plate or a pipe and are of adequate proportions to minimize pressure drop and turbulence. The inlet and outlet water chamber carries water and inspection cover is divided internally into inlet and outlet chambers each having a flanged connection. The rear end water chamber consists of a simple dished cover or a flat end cover. If the water passes are more than two it is divided accordingly.

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TUBE PLATES

The tube plate material is selected depending on the type of cooling water application. Both the tube plates are drilled and tapped to receive the bolts securing water chamber. The tube holes are internally reamed to a finish suitable for the roller expansion into tube plates.

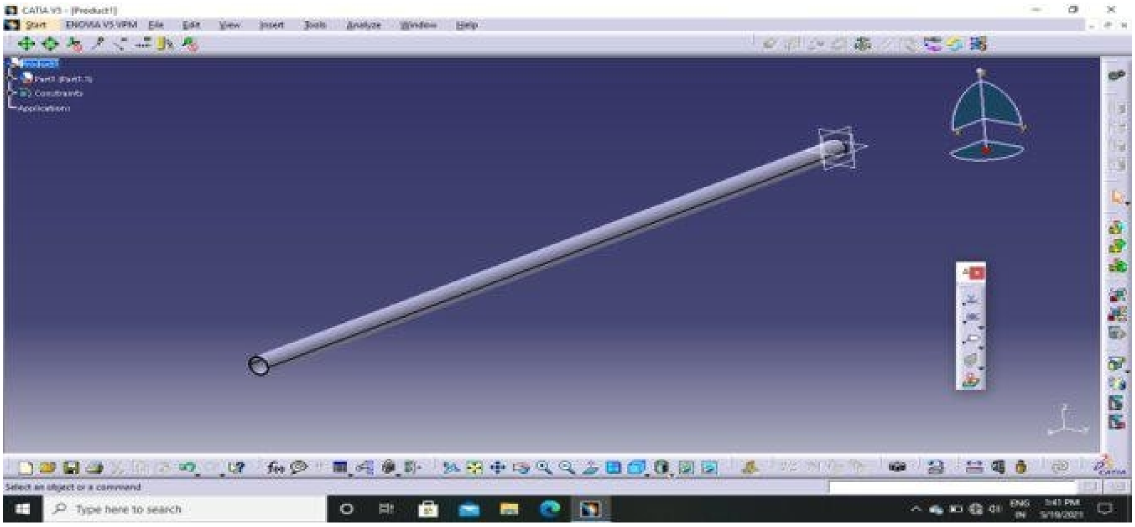


Fig:5 Tube plate

SELECTION OF HEAT EXCHANGERS

From the design point of view, Heat exchangers are complicated equipments. For example, if the overall heat transfer coefficient U is kept throughout the heat exchanger, and that the convection heat transfer coefficient can be predicted using the convection correlation's, however, the uncertainty in the predicted value of U can even exceed 30 percent. Thus it is natural to tend to over design the heat exchanger in order to avoid unpleasant surprises.

Heat transfer enhancement in heat exchangers is usually accompanied by increasing pressure drop and thus higher pumping power. Therefore any gain in the enhancement in heat transfer should be weighed against the cost of the accompanying pressure drop. Also, some thought should be given to which fluid should pass through the tube side and which should pass through the shell side. Usually, the more viscous fluid passes is for the shell side (larger passage area and thus lower pressure drop) and the fluid with higher pressure for the tube side. The rate of heat transfer in the prospective heat exchanger is

$Q_{max} = m. C_p.(T1 - T0)$

This gives the heat transfer requirement of the heat exchanger before having any idea about the heat exchanger itself.

The proper selection depends on several factors. They are:

- **Heat transfer rate:**

This is the most important quantity in the selection of heat exchanger. A heat exchanger should be capable of transferring heat at the specified rate in order to achieve the desired temperature change of the fluid at the specified mass flow rate.

- **Cost:**

Budgetary limitation usually plays the most important role in the selection of heat exchanger, except for some specialized cases where “money is no object”. An off the shell heat exchanger has a definite advantage over those made to order. However, in some cases, none of the existing heat exchangers will do, and it may be necessary to undertake the expensive and time-consuming task of designing and manufacturing a heat exchanger to suit the needs. This is often the case when the heat exchanger is an integral part of the overall device to be manufactured.

- **Pumping power:**

In a heat exchanger, both fluids are usually forced by pumps, which consume electrical power. The annual cost of electricity associated with the operation of the pumps can be determined. Minimizing the pressure drop and the mass flow rate of the fluid will minimize the operating cost of the heat exchanger, but will maximize the size of the heat exchanger and thus the initial cost.

- **Size and weight:**

Normally, the smaller and lighter the heat exchanger, the better is it. The space available for the heat exchanger in some cases limits the length of the tubes that can be used.

- **Type:**

The type of heat exchanger to be selected depends primarily on the type of fluid involved, the size and weight limitations, and the presence of any phase change processes. A heat exchanger is suitable to cool a liquid by the gas if the surface area on the gas side is many times that on the liquid side. On the other hand, a shell and tube heat exchanger is very suitable for cooling a liquid by another liquid.

- **Materials:**

The materials used in the construction of the heat exchanger may be and important consideration in the selection of heat exchanger. A temperature difference of 50oC or more between the tubes and the shell will probably pose differential thermal expansion problems and the need to be considered. The case of corrosive fluids, corrosive-resistant materials such as stainless steel and titanium alloy can be selected.

Tube Plate Material: In general the tube plate should be of a harder material than the tube so that it does not deform and affect the tightness of completed joints adjacent to it. It should however be ductile enough to take up discrepancies in locality of the hole or tubes during expansion. After expansion the material shall be still within its elastic limits.

- **Tube expansion:**

In surface condensers, the tubes are normally roller expanded in the tube plate to form a leak proof joint. The strength of the roller-expanded joint shall be sufficient to overcome the pressure of water acting over the tubes. The expansion joint should therefore be strong and carried with meticulous care.

- **Tube-to-Tube sheet joint:-**

Tubes are secured to tube plates by roller expansion, which form a tight joint between tube and tube plate. This will provide a good sealing arrangement against the penetration of circulating water into the steam space. The strength of the tube to tube sheet joint is such that an expansion bellow on shell side due to differential expansion between tube and shell is not required (i.e.) the force exerted by the tube due to differential expansion with shell will be less than the strength of the joint.

CHAPTER - 4

CATIA V5 INTRODUCTON

4.1 CATIA V5 R20 (Computer Aided Three Dimensional Interactive Application)

As the world's one of the supplier of software, specifically intended to support a totally Integrated product development process. Dassault Systems (DDS) in recognized as a strategic partner which can help a manufacturer to the turn a process into competitive advance, greater market share and higher profits and industrial and mechanical design to functional simulation manufacturing and information management.

CATIA Mechanical design solution will improve our design productivity. CATIA is a suit of programs that are used in design, analysis and manufacturing of a virtually unlimited range of the product.

" Feature based" means that we create parts and assemblies by defining feature like extrusion sweeps, cuts, holes, round and so on instead of specifying low level geometry like lines, areas circles. This means that the designer can think of the computer model at a very high level and leave all low geometry detail for CATIA to figure out.

"Parametric" means that the physical shape of the part as assembly is driven by the value assigned to the attributes of its features. We may define or modify a feature dimension or other attributes at any times. Any changes will automatically propagate through the model.

"Solid Modeling "means that the computer model we create is able to contain all the information that a real solid object would have. It has volumes and therefore, if you provide a value for the density of the material it has mass and inertia.

4.2 Benefits of CATIA

1. It is much faster and more accurate than any CAD system.
2. Once design is complete, 2-D and 3-D views are readily obtainable.
3. The ability to change in late design process is possible.
4. It provides a very accurate representation of model specifying all the other dimensions hidden geometry.
5. It provides a greater flexibility for change, for example, if we like to change the dimensions in design assembly, manufacturing etc. will automatically change.
6. It provides clear 3-D Model which are easy to visualize or model created and & it Also decrease the time required for the assembly to a large extent etc.

4.3. CATIA Applications:

Feature and Capabilities: Commonly referred as a 3D product lifecycle management software suite. CATIA support multiple stages of product development (CAD). The stages range from conceptualization, through design (CAD) and manufacturing (CAM) until analysis (CAE), as of 2007 the latest release is V5 release20 (V5R 20)

4.3.1 Industries using CATIA:

CATIA is widely used through the engineering industry, especially in the automotive and aerospace sectors, CATIA V5, VATIA V5 are the dominant systems.

4.3.2. AEROSPACE:

The Boeing Company used CATIA to develop its 777 airliner, and is currently using CATIA V5 for the 787 series aircraft. European aerospace giant airbus has been using CATIA since 2001. In 2006 airbus announced that the reduction of it airbus 380 using CATIA. Canadian aircraft maker bombardier aerospace has done all if its designing on CATIA.

4.3.3. AUTOMOTIVE

Automotive Companies that use CATOA to varying degrees are BMW. Porsche, Daimler, Chrysler, Audi, Volvo, fiat, Gestamp Automaocian, benteler AG PSA, Pevgcot Citroen, Penault, Toyota, Honda, ford Scania, Hyundai proton (company), TATA motors and Mahindra Goodyear uses it in making tires for automotive and aerospace and also uses a customized CATIA for its design and development. All automotive companies sue CATIA for car structures door beams IP supports, bumper beams root rails, side rails, body components because CATIA is very good in surface creation and computer representation of surfaces.

4.3.4. SHIPBULIDING:

Dassault system has begun serving shipbuilders with CATIA V5 release 8. which includes special features useful to shipbuilders, GD Electric boat used CATIA to design the latest fast attack submarine class for the united states Navy, the virgina class, Northrop Grumman Newport news also used CATIA to design the Gerald R.Ford class of supper carries for us navy.

4.3.5. FUTURE IMPLEMENTATION

Dassualt system has announced plans to release CATIA version 6 (V6) in mid-2008. The new interface allows designer to work directly with the 3D solid model rather than the feature based design approach employed in CATIA V5. This version will also improve the product life cycle management in a revolutionary way. This concept is called PLm.2. (in reference of the so called revolution in the internet called web 2.0)

4.4 Applications of catia in modelling:

CATIA Mechanical design solutions offer a modeler a robust supporting unlimited geometric complex ability and advanced surfacing capabilities ensuring an accurate representation of our design.

CATIA automatically embeds design intent into models providing the flexibility to optimized designs easily and effectively, as we need. CATIA offers intelligent product modeling consisting of familiar parametric features that react predictably to any change. This enables rapid alternatives all in a logical engineering environment.

Full associatively guaranties the propagations of design changes automatically throughout the entire system providing the update deliverables such as assemblies, drawing, finite element models, mold process plans and complete manufacturing data.

CATIA total product representation enables part to part modeling by capturing all engineering data throughout the development process, allowing us to fully visualize accurate product molds, as they will appear when manufacture.

4.5 Geometric modelling:

There are number of applications of the CAD software, one of the most popular applications being geometric modeling. First of all let us see what is geometric modeling? The computer compatible mathematical description of the geometric of this is called as geometric modeling. The CAD software allows the mathematical description of the object to be displayed as the image on the monitor of the computer.

4.5.1 Steps for Creating the Geometric Model

There are three steps in which the designer can create geometric models by using CAD software, these are:

- **Creation of basis geometric objects:**
  In the steps the designer creates basic geometric elements by suing commands like points, lines and circles.

- **Transformations of the elements:**
  In the second step the designer uses commands like achieve scaling, rotation and other related transformation of the geometric elements.

Creation of the geometric model:
During the final step the designer uses various commands to that cause integration of the objects or elements of the geometric model to form the desired shape.
During the process of geometric modeling the computer converts various commands given from within the CAD software into mathematical models, stores them as the files; and finally displays them as the image. The geometric models created by the designer can open at any time for reviewing, editing or analysis.

4.5.2. Representation of the Geometric Models

Of the various forms of representing the objects in geometric models, the most basic is wire frames. In this form the object is displayed by interconnected lines as shown in the figure below. There are three types of wire frame geometric modeling, these are: 2D, 2.1/2D and 3D.

They have been described below:

- 2D: It is stands of two dimensional view and is useful for flat objects.
- 2.1/2D: It gives views beyond the 2D view and permits viewing of 3D object

That has no sidewall details:

- 3D: The three dimension representation allows complete three-dimensional viewing Of the model with highly complex geometry. Solid modeling is the most advanced method of geometric modeling in three dimensions.

4.6 MODULES IN CATIA

Sketch module:
Enables us to create sections. Sketcher technique is used in many areas of CATIA. Using Sketcher mode, we can create geometry without regard to the exact relationships between parts of sketch or the exact value of dimensions, when we generate the sections, CATIA makes explicit assumptions. For example if we draw nearly horizontal line, it becomes exactly horizontal and all these assumptions are displayed graphically.

Part Design:

The most essential workbench needed for solid modeling. If you know this module then it would be extremely convenient to adapt to other modules. Also, I would recommend learning this module first completely before you try your hand at others.

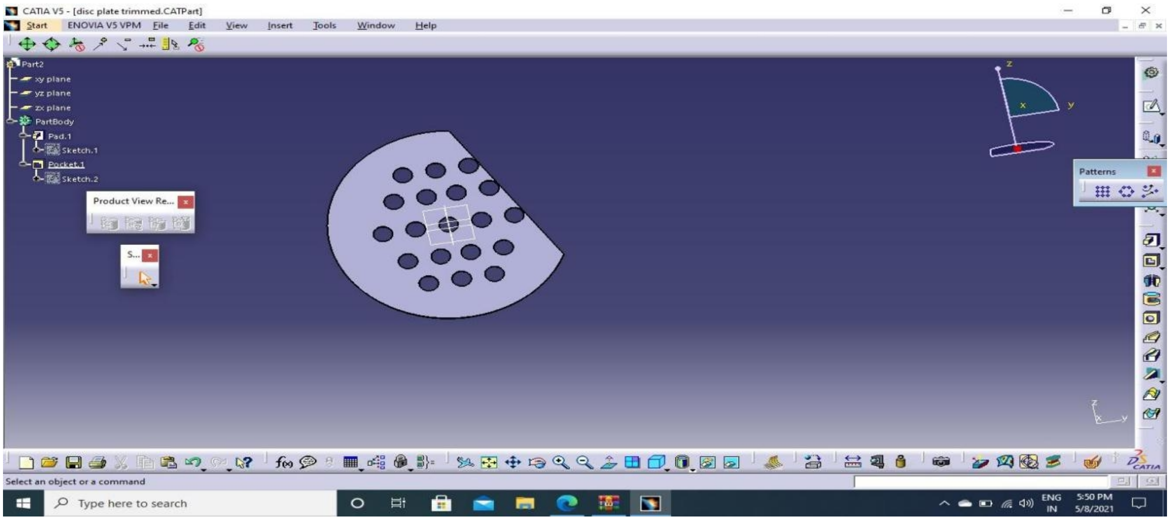


Fig:6 Half disc plate

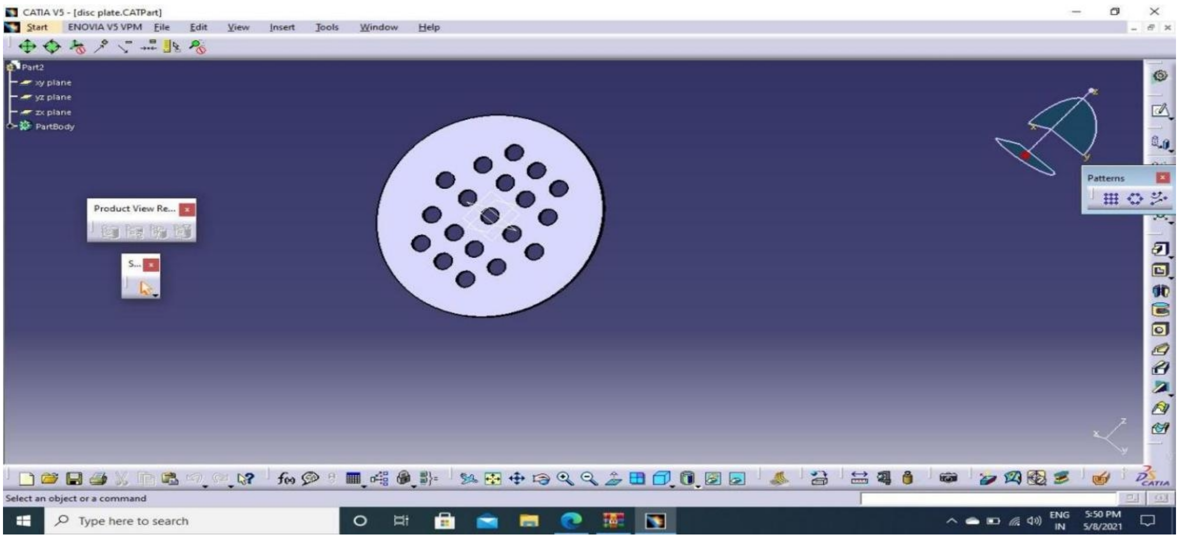


Fig:7 Disc plate

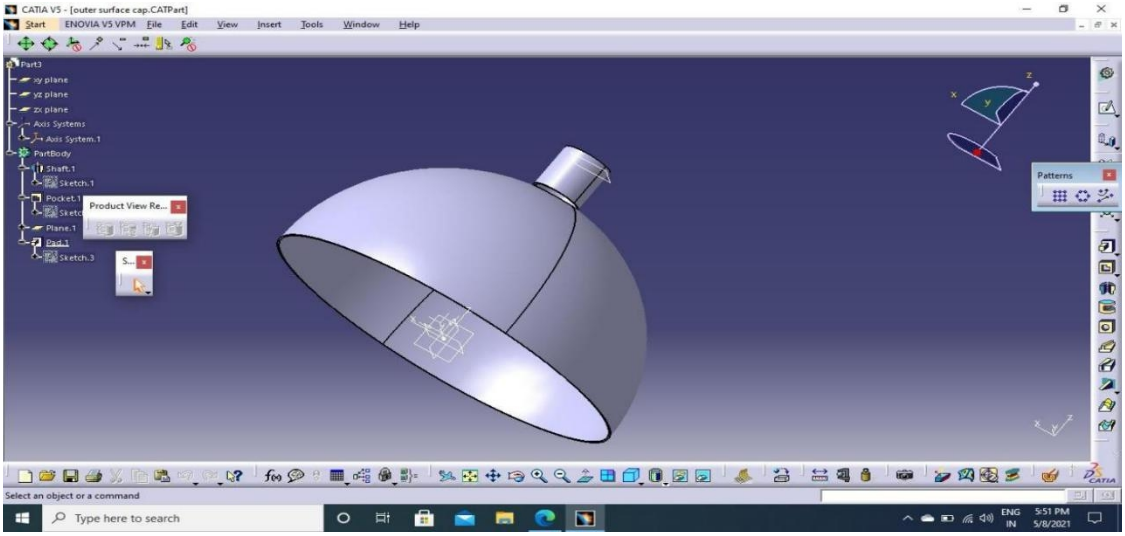


Fig:8 Nozzle

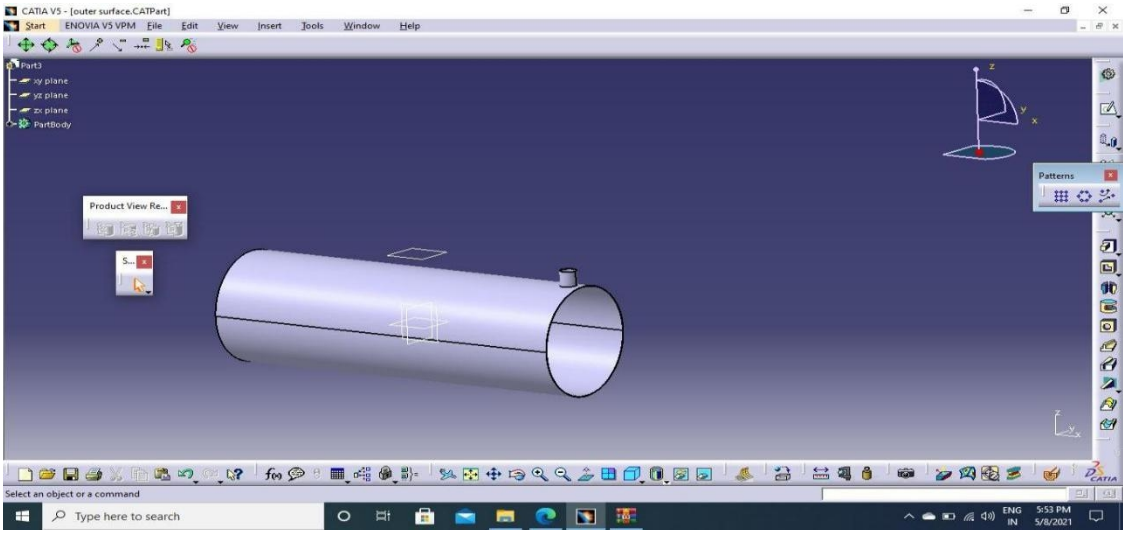


Fig:9 Cylindrical shell

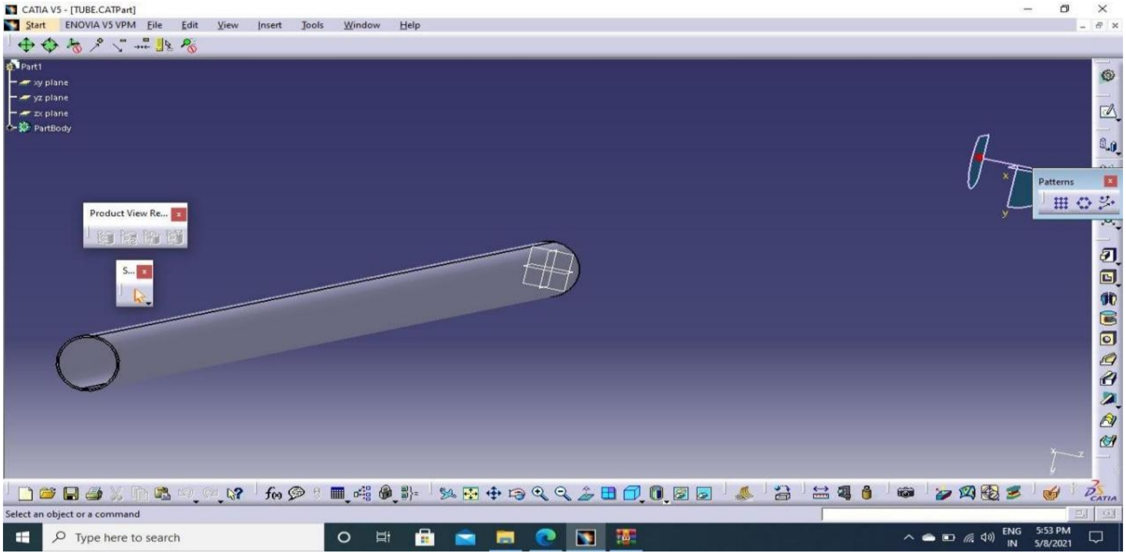


Fig:10 Tube plate

Generative Shape Design:
Probably the most important and the workbench for which CATIA is known. This module will allow you to create various shapes and the combinations that you can create are limitless. But strong knowledge of Part Design will improve your understanding of this module.

Assembly:
This is the workbench that allows to connect all the parts to form a machine or a component or anything like that. But condition is that you must first create individual parts to put them to together in a big assembly for which the above two workbenches are needed.

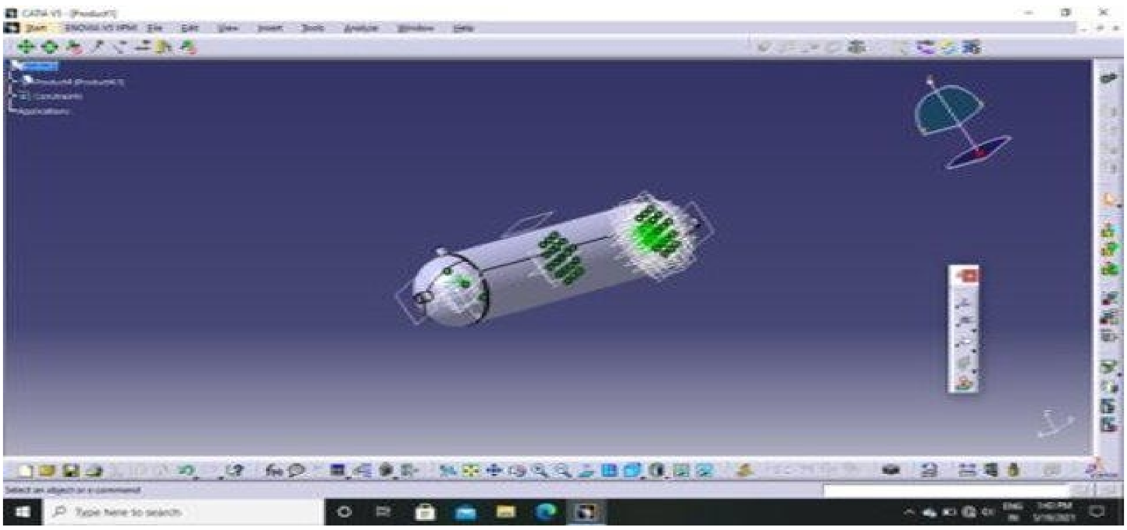
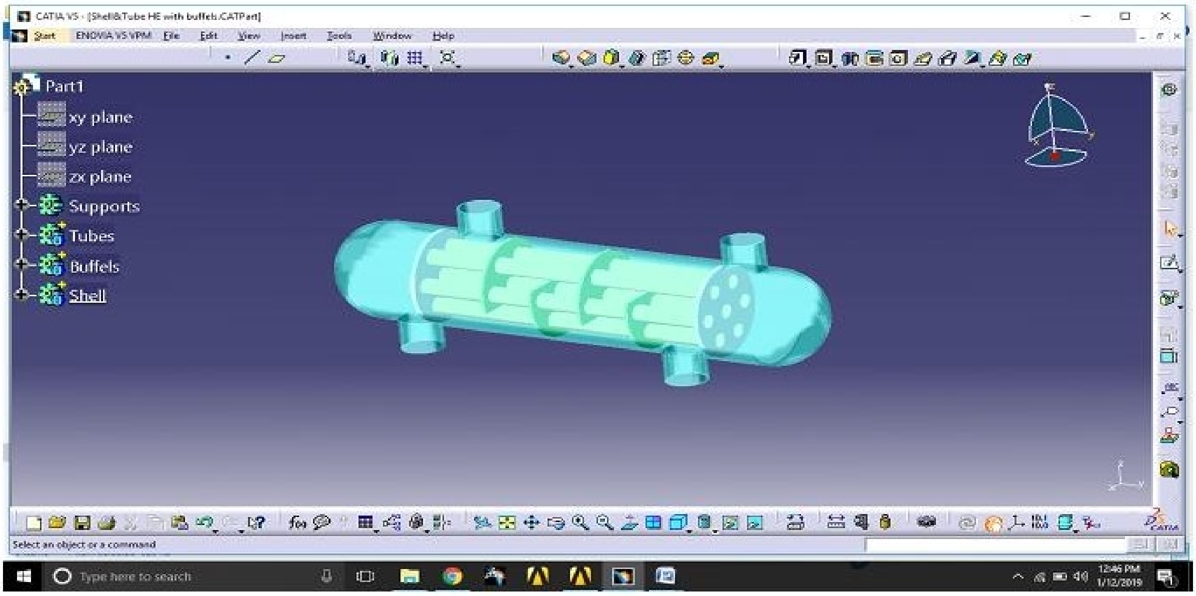


Fig:11 Model on catia

Kinematic Simulation:
In this, you can simulate, that is you can actually animate the motion of the entire assembly to see how it will move and also check for tolerances, clashes, etc. Hence this workbench will show you how a machine moves in the actual world if it is built. You can also generate velocity - acceleration - time graphs for the entire motion.



Shell and tube heat exchanger

CHAPTER - 5

INTRODUCTION TO ANSYS

5.1 History:

The association was built up in 1970 by Dr. John A Swanson Analysis frameworks, Inc. SASI. Its essential job was to make and feature limited component examination programming for auxiliary material science that could reproduce static (stationary), dynamic (moving) and warm trade (warm) issues. SASI developed its business in parallel with the improvement in PC advancement and structuring needs. The association created by 10 to 20 percent year, and in 1994 it was sold to TA Associates. The new owners took SASI's driving programming called ANSYS as their pioneer thing and doled out ANSYS, Inc as the new association name.

5.2 Introduction:

The ANSYS program is a PC program for a limited component investigation and plan. The ANSYS program can in like manner be used to process the perfect structure for given working conditions using the plan improvement feature.

ANSYS is business limited component examination programming with the ability to separate a broad assortment of different issues. ANSYS holds running under a collection of circumstances, including IRIX, Solaris, and Windows NT. Like any limited component programming, ANSYS unwinds speaking to differential conditions by breaking the issue into little components. The speaking to states of flexibility, fluid stream, warm trade, and electro-fascination would all have the capacity to be comprehended by the Finite component procedure in ANSYS. ANSYS can handle transient issues and moreover nonlinear issues. This report will focus on the basics of ANSYS using generally fundamental delineations.

The ANSYS program is a multi-reason program, suggesting that you can use it for a limited component investigation in for all intents and purposes any industry - vehicles, flying, railways, mechanical assembly, equipment, wearing stock, control time, control transmission, and biomechanics, to indicate just a couple. "Multi-reason" in like manner suggests the manner in which that the program can be used as a piece of all controls of structure – assistant, mechanical, electrical, electromagnetic, electronic, warm, fluid, and biomedical. The ANSYS program is moreover used as an enlightening gadget in schools and other academic foundations.

ANSYS writing computer programs is available on numerous sorts of PCs – (PCs), workstations, minicomputers, super minis, concentrated PCs, very unified PCs, etc. A couple of working systems are maintained, much the same as various of reasonable contraptions.

An aggregate of six windows are opened when you begin ANSYS.

1. Utility Menu (top) – contains limits that are available for all through the ANSYS session „ for instance, record controls, decisions, sensible controls and parameters. You moreover leave the ANSYS program from the rub pull down menu.

2 .Main Menu (base left) – contains the fundamental ANSYS limits, dealt with by the preprocessor, game plan, general, postprocessor, structure analyzer.

3. Toolbar (Middle Right) – contains push gets that execute usually used ANSYS summons. More push gets can be incorporated.

4. Information window (center left) – exhibits program impel messages and empower you to sort in summons explicitly.

5. Realistic window (base right) – a window where plans are showed up and graphical picking are made.

6. Yield window (not appeared) – shows content yield from the program, for instance, posting of data, etc. It is regularly arranged behind the other window and can be put to the front when key.

The methods in any limited component investigation can be secluded in three phases:

1. Preprocessing – characterize the model, for example, mesh, burdens, and limit conditions

2. Solution – amassing and illuminating the arrangement of condition.

3. Post preparing – removing applicable outcome from the arrangement

5.2.1 SOLUTION STEPS

Apply removal limitation.

- Apply pressure load.
- Solve

5.2.2 POST PROCESSING STEPS

- Enter the general post processor.
- Plot twisted shape.
- Plot the von misses equal pressure.
- List responses at obliged hubs.
- Exit the ANSYS program.

5.3 Element characteristics:

5.3.1 LISTS OF ELEMENT TYPES:

The ANSYS program has a considerable library of component sorts. A segment of the properties of the component sorts, and their groupings, are depicted in this part to make component sort assurance less requesting.

The ANSYS component library contains in excess of 100 unmistakable component plans or sorts. A component sort is perceived by a name (8 characters most extraordinary, for instance, BEAM3, including a social event mark (BEAM) and an uncommon distinctive number (3). The component is browsed the library for use in the examination by contributing its name on the component sort bring

5.3.2 TWO-DIMENSIONAL VERSUS THREE-DIMENSIONAL MODELS:

ANSYS models may be either two-dimensional or three-dimensional depending on the component sorts used. Two-dimensional models must be described in a X-Y plane. They are less requesting to set up, and run speedier than relative three-dimensional models. Rotate Symmetric models are furthermore thought to be two-dimensional.

If any three-dimensional component sort, (for instance, BEAM4) is consolidated into the component sort set, the model winds up doubtlessly three-dimensional. Some component sorts, (for instance, COMBIN14) may be a couple of dimensional, dependent upon the KEYOPT regard picked. Other component sorts, (for instance, COMBIN40) have no effect in choosing the model estimations. Two-dimensional component sorts may be used (with caution) in three-dimensional models.

5.3.3 FINITE COMPONENT TECHNIQUE:

The limited component system (FEM) (its sensible application routinely known as limited component investigation (FEA) is a numerical technique for finding inferred plans of inadequate differential conditions (PDE) and furthermore of essential conditions. The course of action approach is develop either in light of getting rid of the differential condition absolutely (steady state issues), or rendering the PDE into an approximating game plan of customary differential equations. Then numerically joined using standard methodology for instance is Euler's procedure, Runge-Kutta, etc.

In handling partial differential conditions, the fundamental test is to make a condition that approximates the condition to be thought about, yet is numerically enduring, inferring that goofs in the data and center estimations don't total and make the resulting yield be unimportant. There are various strategies for doing this, all with good conditions and shortcomings. The Finite Element Method is a not too bad choice for settling partial differential conditions over tangled spaces (like cars and oil pipelines), when the territory changes (as in the midst of a solid state reaction with a moving point of confinement), when the pined for exactness varies over the entire zone, or when the course of action needs smoothness. For instance, in a frontal accident multiplication it is possible to extend conjecture precision in "fundamental" areas like the front of the auto and decrease it in its back (as such reducing cost of the reenactment). Another outline would be in Numerical atmosphere estimate, where it is progressively basic to have definite desires over developing extremely nonlinear wonders, (for instance, tropical brutal breezes in the earth, or whirls in the ocean) instead of by and large calm locales

5.3.4 LAYOUT OF ANSYS WINDOW:

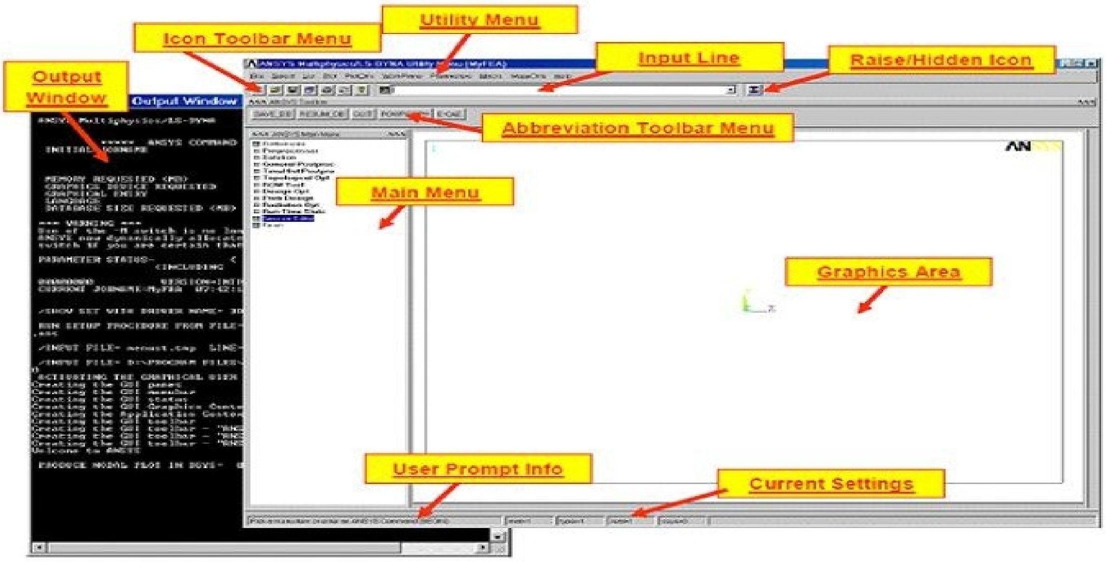


Fig:13 Screen ANSYS window

5.3.5 MOUSE

Left mouse get picks (or unpicks) the component or region closest to the mouse pointer. Pressing and hauling empowers you to "survey" the thing being picked (or unpicked).Middle mouse get completes an Apply. Recuperations the time required to move the mouse over to the Picker and press the Apply get. Use Shift-Right catch on a two-get mouse.

Right mouse get flips among pick and unpick mode. Note, the Shift-Right catch on a two catch mouse is indistinguishable to the Middle mouse get on a three-get mouse.

5.3.6 DATABASE AND FILES

The term ANSYS database suggests the data ANSYS keeps up in memory as you collect, comprehend, and post process your model. The database stores both your data and ANSYS comes about data:

– Input data - information you ought to enter, for instance, estimations, material properties, and burden data.
– Results data - sums that ANSYS determines, for instance, migrations, stresses and temperature.

5.4 Defining the jobname:

Utility Menu > File> Change Job name

The occupation name is a name up to 32 characters that recognizes the ANSYS work. When you portray a livelihood name for an investigation, the occupation name transforms into the underlying section of the name of all records the examination makes. (The enlargement or postfix for these records' names is a report identifier, for instance, .DB.) By using work name for each investigation, you ensure that no archives are overwritten.

jobname.log: Log record, ASCII. Contains a log of each request issued in the midst of the session. If you start a minute session with the equivalent jobname in a comparative working library, ANSYS will add to the past log archive (with a period stamp).

5.4.1 FILE MANAGEMENT TIPS

Run each examination stretches out in an alternate working index.

Use assorted business names to isolate distinctive examination runs.

You should keep the going with records after any ANSYS examination:

Log record (.log); database report (.db); comes about archives (.rst, .rth,); stack step reports, accepting any (.s01, .s02, ...)

Portraying an Analysis Title: Utility Menu> File> Change Title

This will portray a title for the investigation. ANSYS fuses the title on all representations appears and on the game plan yield. (In the event that it's not all that much inconvenience join your name and understudy ID in the investigation title for each and every one of a kind diagram)

5.5 ANSYS Graphical User INTERFACE (OUT PUT WINDOW)

After starting ANSYS, two windows will appear. The first is the ANSYS 8.1 Output Window:

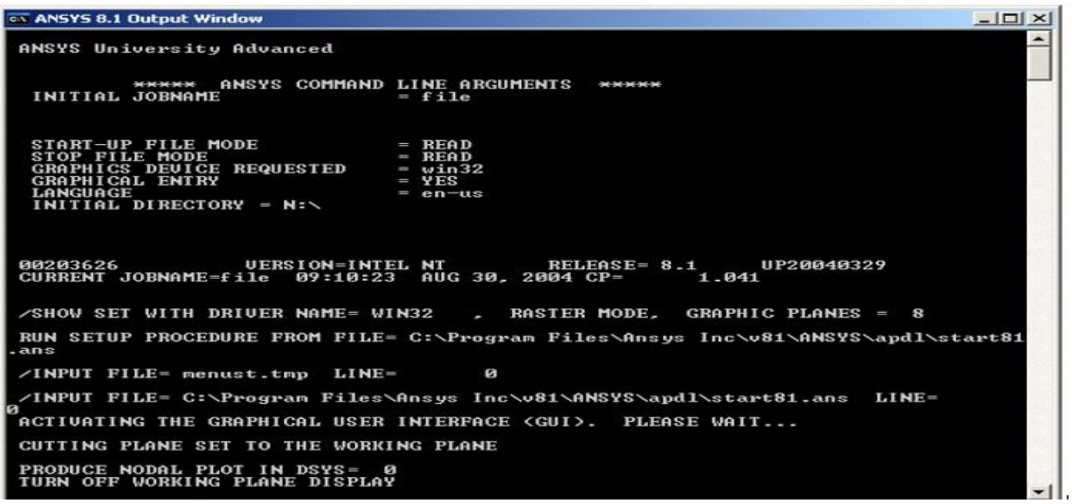


Fig:14 Screen output windows

This window demonstrates a posting of each request that ANSYS executes. If you experience issues, this is a conventional spot to plan to see what ANSYS is doing or has one. This is one zone where you will find most of the notification and bumble messages that appear and the gather that created the notice/botch.

The second window is the ANSYS Research FS graphical UI. This is isolated into 4 sections (showed up on next page): ANSYS Utility Menu

- ANSYS Toolbar Menu
- ANSYS Main Menu
- Display window

Each segment will be talked about in further detail beneath.

5.6 ANSYS UTILITY MENU
Inside this menu, you can perform record activities, rundown and plot things, and change show alternatives

5.6.1 FILE DROP-DOWN MENU
The File drop-down menu incorporates the choices to clear the database, change, resume, and spare the present model

5.6.2 LIST PULL-DOWN MENU
The r destroy down menu empowers you to see the log and slip-up reports, get a posting of geometric substances, components and their properties, center points, and farthest point conditions and loads associated with the model.

5.6.3 PLOT PULL-DOWN MENU
This draw down menu enables you to plot the different parts of the model, for example, key points, areas, volumes and elements

5.6.4 PLOT CTRLS PULL-DOWN MENU
This menu incorporates the controls to skillet/zoom/pivot your model, select the numbering alternatives, change styles and create printed copies of the plots.

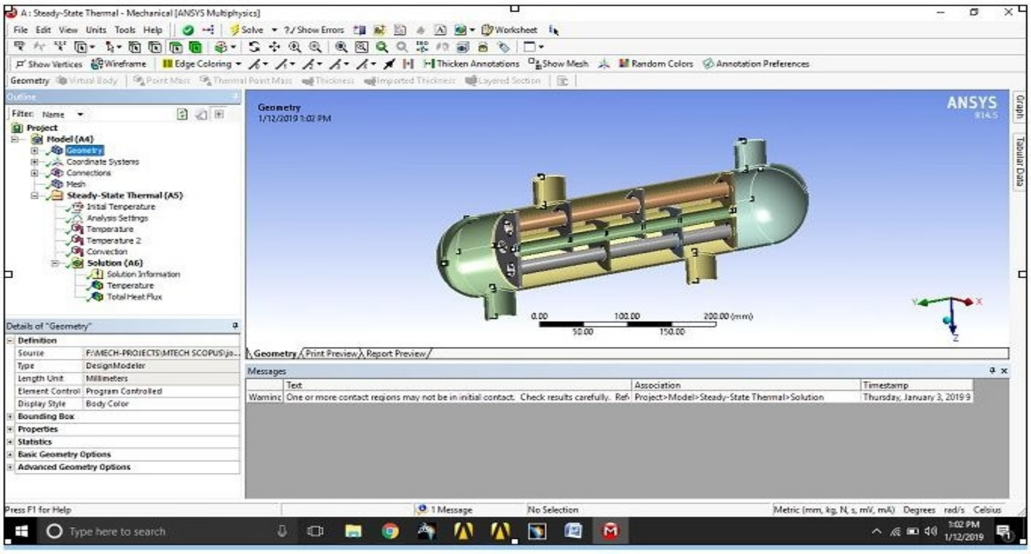


Fig:15 Heat exchanger

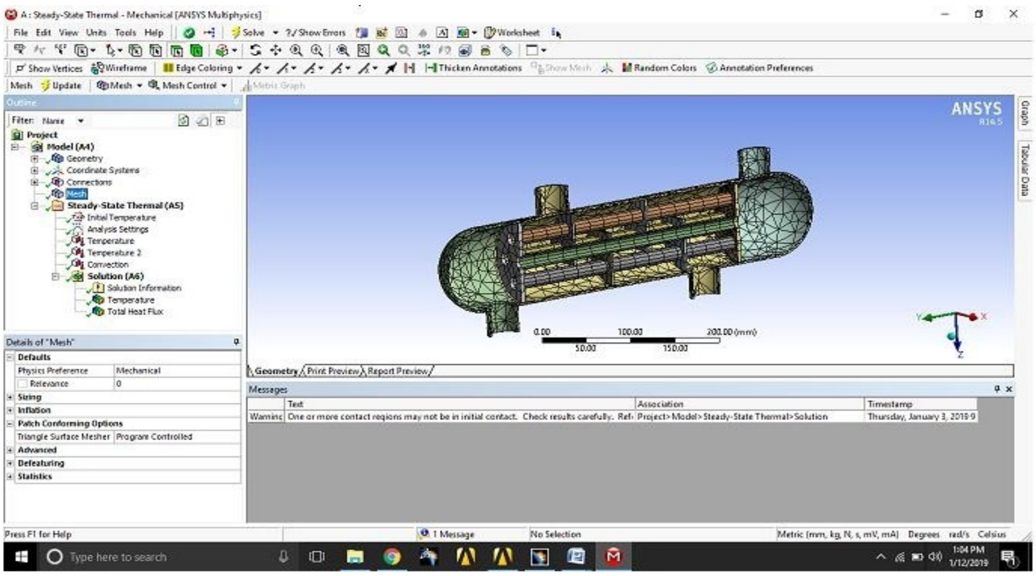


Fig:16 Mesh model in AnsysZ

5.7 RESULT AND DISCUSSION

Structural steel

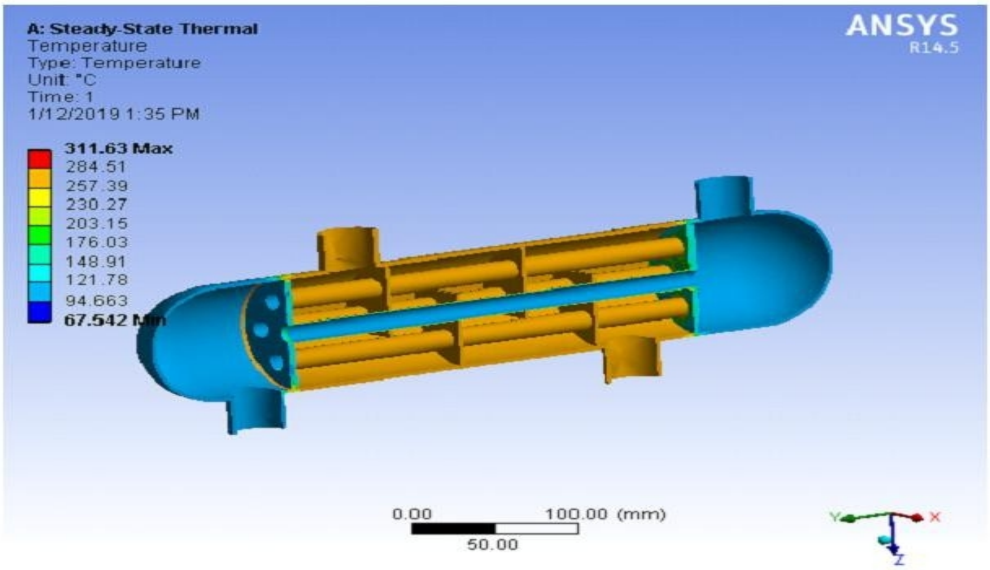


Fig:17 Total temperature

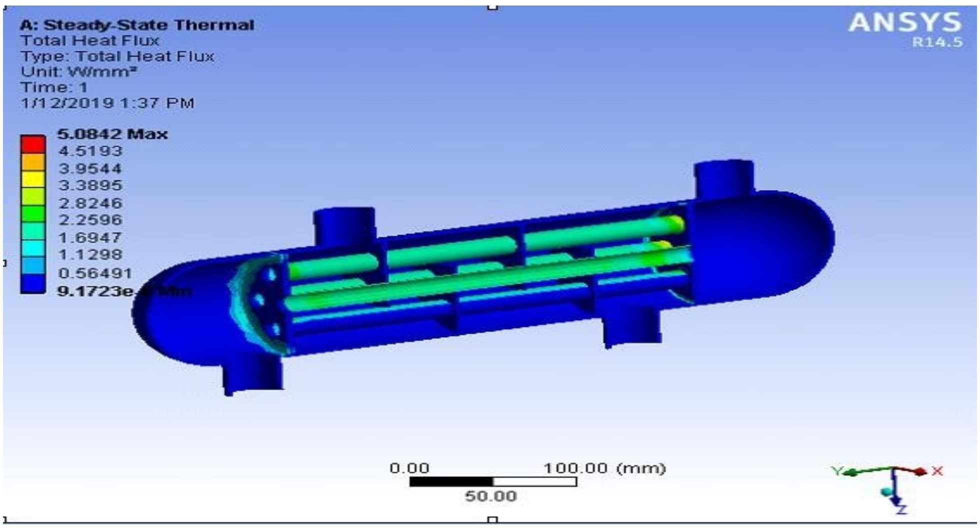


Fig:18 Total heat flux

Titanium alloy

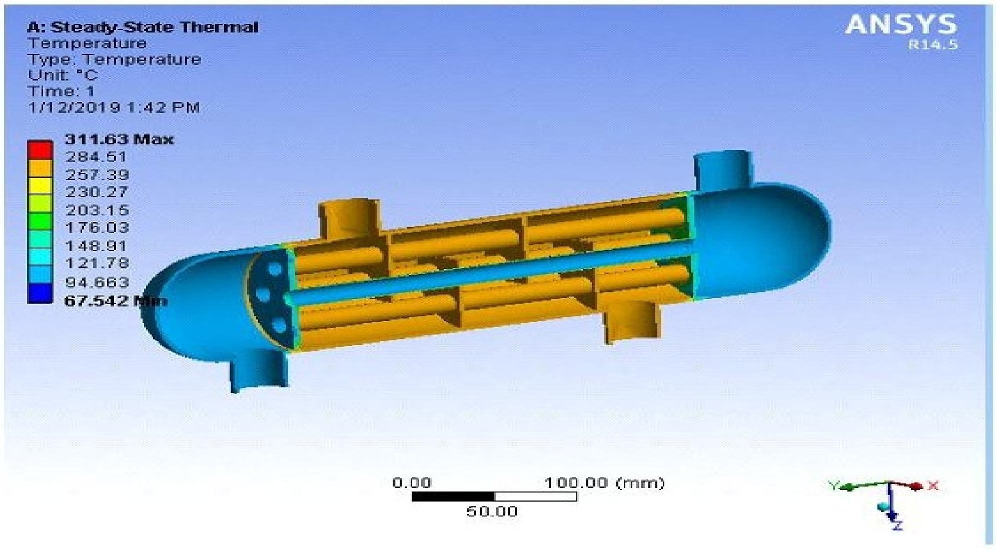


Fig:19 Total temperature

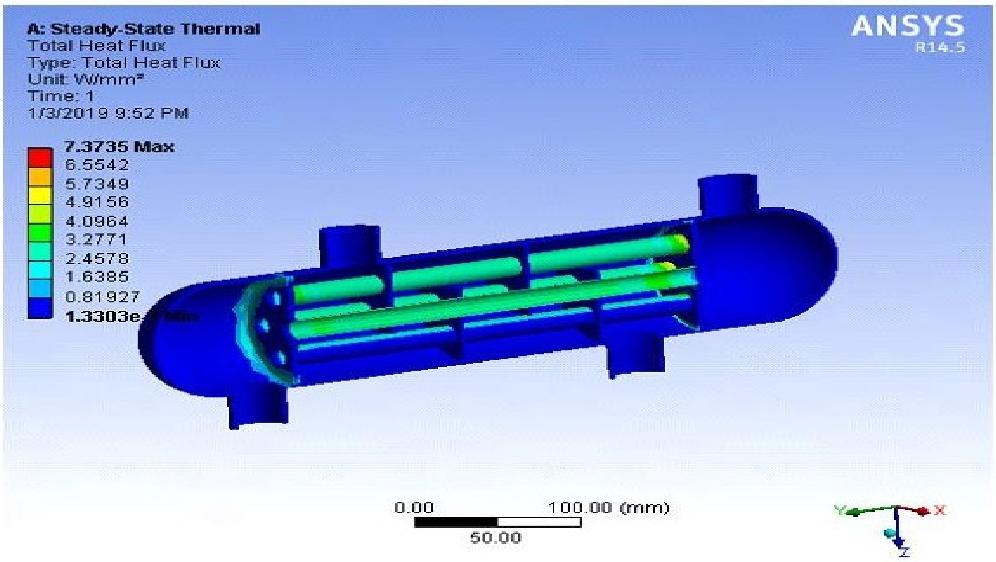


Fig:20 Total heat flux

5.8 Comparison Table For steady state thermal analysis:

	STRUCTURAL STELL	TITANIUM ALLOY
Conduction temperature,(c)	311.63	5.0842
Total heat flux,(w/m^2)	311.63	7.3735

CHAPTER-6: CONCLUSION & FUTURE ENHANCEMENT

Conclusion:
Our project is to plan and examination of state thermal on shell and tube exchanger. We have planned piston utilizing cad programming specifically CATIA V5 and investigation is finished utilizing ANSYS 14.5 and the thermal and static examination is drawn under required limit conditions.we broke down structural steel and titanium alloy for better thermal conditions and distortion factors.

We have seen that combination material subsequent to including titanium alloy indicates great outcomes when contrasted with standard composite material

Future enhancement:
Because the process industry has become more competitive, with product development process Contruction and product life time drastically shortened, designers and engineers have less time between initial design and final fabrication. Fastback construction has become more the rule than the exception. Design changes are typically made after the start-up date, and constant improvements continue until demand for the product has diminished. At this point, a company must assess its manpower and equipment to tailor them to new market demands.

The Shell and Tube Heat Exchanger Market report analyzes insights related to market developments, trends and demand changes across numerous regions across the world. It outlines market dynamics entailing market restraints, drivers, trends, and opportunities trailed by pricing analysis and value chain analysis.The report provides a close analysis of the numerous segments within the market supported product kind, application, and end-use across various countries around the world.

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A Major Project Report
on

PREDICTION OF HEAT AFFECTED ZONE IN SUBMERGED ARC WELDING (SAW) OF LOW CARBON ALLOY STEEL JOINTS WITH VARIOUS METAL FLUXES

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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MOHAMMED RAUOOF	**-**	**(16K81A0397)**
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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Prediction of Heat Affected Zone in Submerged Arc Welding (Saw) Of Low Carbon Alloy Steel Joints with Various Metal Fluxes**, is being submitted by **Dastagir Khan (16K81A0313), Mohammed Rauoof (16K81A0397), Chandak Ankit (16K81A03C4), Sai Dinesh Reddy (16K81A03D1)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Y. CHANDRASHEKAR YADAV
Assistant Professor,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor& Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Prediction Of Heat Affected Zone In Submerged Arc Welding (Saw) Of Low Carbon Alloy Steel Joints With Various Metal Fluxes** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

DASTAGIR KHAN	(16K81A0313)
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CHANDAK ANKIT	(16K81A03C4)
SAI DINESH REDDY	(16K81A03D1)

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ABSTRACT

The project has been made to realize the effect of submerged arc welding (SAW). Submerged arc welding is a fusion joining process, known for its high deposition capabilities. This process is useful in joining thick section components used in various industries. Heat Affected Zone (HAZ) produced within the base metal as a result of tremendous heat of arc is of big concern as it affects the performance of welded/surfaced structure in service due to metallurgical changes in the affected region. This work was carried out to investigate the effect of polarity and other SAW parameters on HAZ size and to establish their correlations. Welding flux constitutes nearly half of the cost in SAW process. Over the years, development of better welding flux compositions in terms of mechanical properties and productivity, which are economically cost effective too, has caught the eye of many researchers.

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CHAPTER- 1 INTRODUCTION

1.1 Overview of the project:

Submerged arc welding (SAW) is widely used to weld relatively thick plates at high metal deposition rates . Heat for this process is derived from an arc between a bare metal electrode and the work. SAW differs from other arc welding processes in that the arc is not visible. It is shielded by a blanket of granular fusible material called flux, which is placed over the joint area ahead of the arc. Pressure is not used, and filler metal is obtained primarily from the bare electrode wire that is continuously fed through the blanket of flux into the arc and the pool of molten flux. A unique feature of SAW is that the granular flux material covers the weld area and prevents emission of arc radiation, sparks, spatter, and fumes. In addition to shielding the arc from view, the flux produces a slag that protects the weld metal, reducing the cooling rate and helping shape the weld contour .

Most sheet metal cutting techniques are based on localized melting of the material (see Figure 1). The area between the melted part and the unaffected base metal undergoes chemical and structural modifications. It's called the heat-affected zone (HAZ).It often can be recognized by a series of brightly colored bands, also visible near welds. Colors, caused by surface oxidation, are an approximate indicator of the temperature the metal reaches.

This project is done to increase the heat flow in the metal by which the affected zone get reduced in submerged arc welding process by changing the flux in the welding process.

1.2 Objectives of the project:

- Designing the welded plate by using CATIA software of 100x100 with 10mm of thickness.
- To analyze the heat affected zone and heat flux rate by using three different metallic fluxes.
- The software which we have used for analyze are HyperMesh and Ansys.

1.3 Scope of the project:

- The scope of the project is to reduce the heat affected zone in submerged arc welding of low carbon steel joints with various metal flux to increase the life of the welded piece.

1.4 Materials selection:

1.4.1 Low Carbon Alloy Steel :

Low alloy steels are similar to carbon steels but have additional alloying elements like chromium, molybdenum, etc., to improve their heat treat response. With heat treating, ultimate strengths from about 60 – 300 ksi are possible within this group of materials. Utilizing specialized heat-treating processes, it is possible to engineer parts with specific properties in different areas of the same part. An example of this would be first heat treating the casting to a very tough condition for impact resistance, then applying a second surface hardening heat treatment to make the surface wear resistant.

1.4.2 Various Metal Fluxes :

- Aluminum-Rutile
- Calcite
- Dolomite

1.5 Introduction of Submerged Arc Welding (SAW) & Heat Affected Zone(HAZ):

1.5.1 History of Submerged arc welding:

This is a well-established and extremely versatile method of welding. Submerged-arc welding (SAW) involves the formation of an arc between a continuously fed electrode and the workpiece. A blanket of powdered flux, which generates a protective gas shield and a slag (and may also be used to add alloying elements to the weld pool), protects the weld zone. A shielding gas is not required. The arc is submerged beneath the flux blanket and is not normally visible during welding.

Although in the late 1920s numerous patents were filed for specialized fluxes and a process with no visible arc, credit goes to the National Tube Works Co., McKeesport, Pa., for developing in 1930 what is today known as submerged arc welding. The company needed to achieve higher deposition rates in welding pipe seams.

In the late 1930s the development of the process ramped up with the demand for battle ships and other military equipment to support the war. It is reported that a letter from then President Roosevelt to Winston Churchill even mentioned 'a welding technique which enables us to construct merchant ships with a speed unequaled in the history of merchant shipping," and that this welding process was 'up to 20 times faster" than previous welding processes. Since ship hull construction favored this process, wartime manufacturing pushed the newly born sub-arc technology to the forefront of the welding world.

Fast-forward to the year 2000, and the stage is set for the modern evolution of SAW. There is no question that manufacturers need to make better use of resources in today's ultracompetitive manufacturing environment. With the industrialized world growing exponentially, the need to manufacture with both speed and efficiency stands greater than at any other period in history. Add into the climate more demands to ship products worldwide; growing infrastructure projects like bridge-building, steel construction, and spiral pipe; and anything to do with energy, such as wind towers, offshore oil rigs, and mining equipment, and the time is ripe for the SAW process to become all that it can be.

Driven by modern welding requirements, SAW advances in the last five to 10 years have created significant advantages. Deposition rates of more than 100 lbs. per hour are now reported in certain cases. It is also possible to weld very large joint areas with fewer passes and minimal preparation. SAW users have partnered with the equipment manufacturers to create an industry that has responded to its own needs.

SAW naturally lends itself to the more civilized surroundings. It has always been an environmentally friendly, safe process with minimal fume to be ingested and no arc rays to be shielded from, making it one of the more pleasant welding environments to work in. It is the technology advances in the power equipment and controls that have made it a reality to perform SAW with greater ease and precision than previously possible.

Introduction to Submerged Arc Welding:

Submerged Arc Welding (SAW) was discovered in the year 1935 by Rothermund and Jones, Kennedy. This welding can be operated in semi-automatic mode otherwise in automatic mode. But generally, the operation of this SAW can be done in automatic mode. Submerged-arc welding method is fixed and extremely adaptable. This kind of welding involves in arranging the arc among a constantly fed electrode as well as the workpiece. A layer of powdered flux generates a protecting gas shield as well as a slag to protect the weld region. The arc can be submerged below the flux layer & in general, is not noticeable throughout the welding process. In this, the weld quality is extensively influenced by the submerged arc welding parameters like welding speed, welding current, arc voltage, electrode stick out which are closely related to the calculation of the weld bead, this article discusses an overview of submerged Arc welding method.

The definition of submerged arc welding is, it is one type of welding method where this welding arc can travel under a layer of granular flux. In this type of welding, a tubular electrode otherwise consumable solid can be fed constantly to the weld region. At the same time, a layer of granular fusible flux can be poured over the weld zone which immersed the welding arc as well as defends it from atmospheric pollution.

The granulated flux includes compounds like lime, silica, manganese oxide, calcium fluoride, etc. Whenever the flux is melted, then it turns into conductive as well as offers a current lane among the workpiece & electrode. The solid layer of flux wraps the melted metal totally and stops the sprinkle and covers the strong ultraviolet (UV) radiation vapors generated during the procedure.

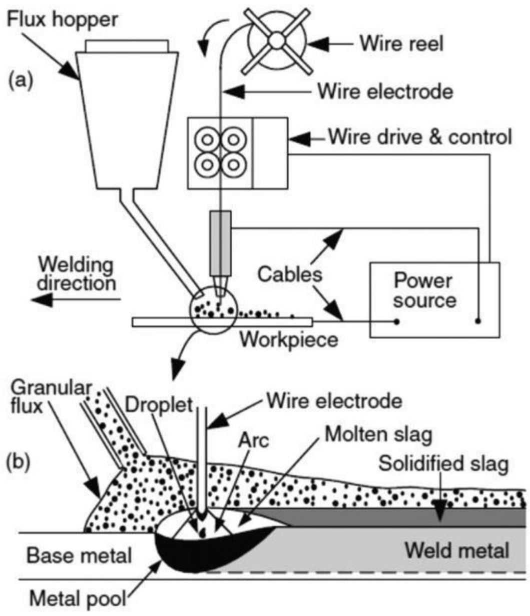


Figure-1 Submerged Arc Welding

Equipment of Submerged Arc Welding:

The submerged arc welding can be built with main parts or equipment like Welding head, Flux hopper, Flux, Electrode wire feed unit, Electrode, and Flux recovery unit. Welding head can be used to supply filler as well as flux metal to the joint for welding

In Flux hopper, the flux can be stored as well as deliver to the welding joint. It controls the rate of deposition of flux to the welding joint.

The granular flux is used to shield the welding arc, and it includes silica, lime, calcium fluoride, oxides of calcium, manganese oxide, etc. It fed into the weld zone with the flow of gravity during the welding head nozzle. Whenever it is melted, then it turns into conductive as well as conducts the current among the workpiece & electrode.

The granular flux's solid layer wraps the melted metal totally & stops the sprinkle and flash. It covers up the UV radiations which is the characteristic of SMAW method. The minor part of the flux obtains melted & shapes slag on the weld pond. It is detached after the welding method obtains completed. The higher element of the flux performs like an insulator & encourages the deep transmission of heat toward the work piece.

Electrode wire feed unit offers nonstop electrode wire feed toward the welding joint, and it includes a reel on which the electrode wire can be injured.

A consumable electrode can be used by the submerged arc welding which is a loop of bare round wire with 1.5 mm to 10 mm diameter. It can be fed routinely throughout the welding gun, and the submerged arc welding electrode composition depends on the welded material. The electrodes are available to weld high carbon steel, mild steel, low and special alloy steels, stainless steel, etc. Generally, the electrodes are covered by the copper to stop rusting & amplify electrical conductivity. They are obtainable within straight length & coils.

Flux recovery unit is used to gather the not used flux present after welding, and after recovery, it can be used another time for the joining.

Working of Submerged Arc Welding:

In this kind of welding, the flux begins for depositing on the joint to be welded. Whenever the flux is cold, then it acts as an insulator. The arc can be started by moving the tool by the work portion. The arc struck will constantly remain below a wide coating of flux, and the generated heat by the arc softens the granular flux.

Once the flux is melted by the heat of the arc, then it will become highly conductive. The flow of current begins to flow the electrode through the melted flux that can be in contact by the atmosphere. The minor dissolved flux alters to wastage slag & which is detached after welding method finished.

At a fixed speed, the electrode from the roll is constantly fed toward the joint to be linked. If linking is partially automatic, then the top of the welding can be moved physically along with the connection. In an automatic submerged arc welding, a separate drive can be used to move the welding top above the stationary job otherwise job moves beneath the head of the stationary welding.

Heat-affected zone:

Introduction to Heat Affected Zone:

The heat affected zone (HAZ) is a non-melted area of metal that has undergone changes in material properties as a result of being exposed to high temperatures. These changes in material property are usually as a result of welding or high-heat cutting. The HAZ is the area between the weld or cut and the base (unaffected), parent metal.

The HAZ area can vary in severity and size depending on the properties of the materials, the concentration and intensity of the heat, and the welding or cutting process used

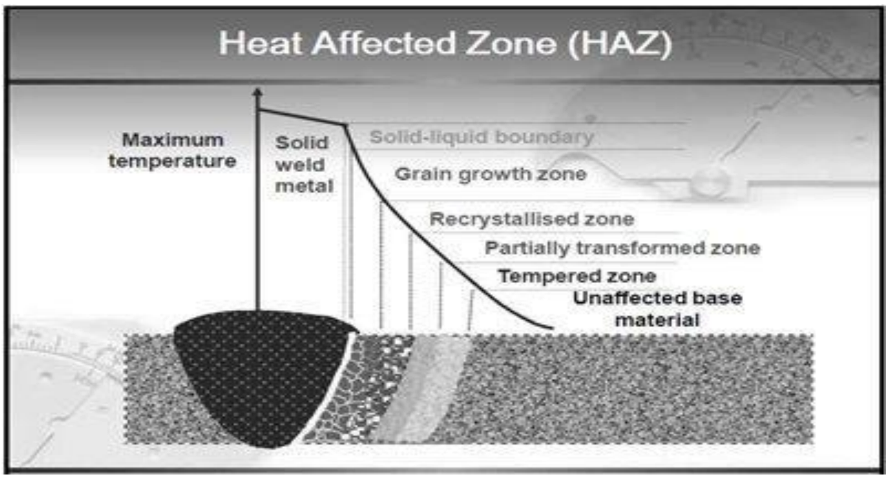


Figure-2 Heat Affected Zone

Causes of Heat-Affected Zones:

The heating associated with welding and/or cutting generally uses temperatures up to and often exceeding the temperature of melting of the material in question, depending on the welding process used. However, the heating and cooling thermal cycle associated with these processes is different to whatever processing has occurred with the parent material previously. This leads to a change in microstructure associated with the heating and cooling process.

The size of a heat affected zone is influenced by the level of thermal diffusivity, which is dependent on the thermal conductivity, density and specific heat of a substance as well as the amount of heat going in to the material. Those materials with a high level of thermal diffusivity are able to transfer variations of heat faster, meaning they cool quicker and, as a result, the HAZ width is reduced. On the other hand, those materials with a lower coefficient retain the heat, meaning that that the HAZ is wider. Generally speaking, the extension of the HAZ is dependent on the amount of heat applied, the duration of exposure to heat and the properties of the material itself. When a material is exposed to greater amounts of energy for longer periods the HAZ is larger.

With regard to welding procedures, those processes with low heat input will cool faster, leading to a smaller HAZ, whereas high heat input will have a slower rate of cooling, leading to a larger HAZ in the same material. In addition, the size of the HAZ also grows as the speed of the welding process decreases. Weld geometry is another factor that plays a role in the HAZ size, as it affects the heat sink, and a larger heat sink generally leads to faster cooling.

High temperature cutting operations can also cause a HAZ and, similarly to welding procedures, those processes that operate at higher temperatures and slow speeds tend to create a larger HAZ, while lower temperature or higher speed cutting processes tend to reduce the HAZ size. The width of the HAZ from the cut edge is determined by the cutting process, cutting speed, and the material properties and thickness.

Different cutting processes have differing effects on the HAZ, regardless of the material being cut. For example, shearing and waterjet cutting do not create a HAZ, as they do not heat the material, whilst laser cutting creates a small HAZ due to the heat only being applied to a small area. Meanwhile, plasma cutting leads to an intermediate HAZ, with the higher currents allowing for an increased cutting speed and thereby a narrower HAZ, while oxyacetylene cutting creates the widest

HAZ due to the high heat, slow speed and flame width. Arc welding falls between the two extremes, with individual processes varying in heat input.

In welding, the heat-affected zone (HAZ) is the area of base material, either a metal or a thermoplastic, which is not melted but has had its microstructure and properties altered by welding or heat intensive cutting operations. The heat from the welding process and subsequent re-cooling causes this change from the weld interface to the termination of the sensitizing temperature in the base metal. The extent and magnitude of property change depends primarily on the base material, the weld filler metal, and the amount and concentration of heat input by the welding process.

The thermal diffusivity of the base material plays a large role—if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small. Alternatively, a low diffusivity leads to slower cooling and a larger HAZ. The amount of heat input during the welding process also plays an important role as well, as processes like oxyfuel welding use high heat input and increase the size of the HAZ. Processes like laser beam welding and electron beam welding give a highly concentrated, limited amount of heat, resulting in a small HAZ. Arc welding falls between these two extremes, with the individual processes varying somewhat in heat input.

Figure-3 Heat Affected Zone

HAZ Areas:

While the HAZ occurs between the weld or cutting zone and the unaffected parent metal, the HAZ itself has different areas according to how close they are to where the cutting or welding heat was applied to the material.

The cutting or weld zone is the liquid region where the process itself takes place and is adjoined by the fusion boundary. The fusion boundary is the border of the fusion zone where the liquid and solid phases of the metal coexist. Further from the weld or cutting zone is the HAZ itself, which is where the non-melted parent metal has experienced changes to the microstructure. In conventional steels, the HAZ can be broken down into the grain coarsened zone (closest to the heated area), the grain refined zone, the partially transformed (interstitially heated) zone and the tempered zone. In other materials, which do not undergo a solid-state phase transformation during cooling, it is common to see a grain growth zone and a recrystallized zone, with some evidence of a tempered zone. Outside of these HAZ areas is the unaffected base material.

The various HAZ areas are formed by differing temperatures in the base metal further from the weld or cut itself. This should not be mistaken for the series of visible colored bands, caused by surface oxidation, near a weld in stainless steel. The 'temper colors' represent much lower temperatures than those which form the heat affected zone, and extend for some distance beyond the actual heat affected zone. These different colors, also known as heat tint, offer an approximate indication of the temperature reached by the metal. In the case of stainless-steel type 1.4301 (AISI 304) heated in open air, the band colors and associated temperatures are as follows:

Color	Temperature
Light Yellow	550 degrees F/290 degrees C
Straw Yellow	640 degrees F/340 degrees C
Yellow	700 degrees F/370 degrees C
Brown	735 degrees F/390 degrees C
Purple Brown	790 degrees F/420 degrees C
Dark Purple	840 degrees F/450 degrees C
Blue	1,000 degrees F/540 degrees C
Dark Blue	1,110 degrees F/600 degrees C

Table 1 Heat Effected Zone Color Range

The heat tint colors depend on the material’s resistance to oxidation, with those metals with a higher steel chromium content showing less intense coloration as they are more resistant to oxidation. The use of protective gas and electrode coatings can also reduce heat tint as they partially shield the metal from oxidation. Conversely, rougher surfaces oxidize faster, causing darker colors. In addition, paint, oil, rust and even fingerprints can alter the heat tint, although they do not impact the extent of the HAZ itself.

CHAPTER- 2 LITERATURE SURVEY

2.1 LITERATURE REVIEW:

A brief review on development of submerged arc welding fluxes has been provided for the methods for development of fluxes fresh fluxes constituents for optimization, recycling of fluxes and hard facing.

The conventional approach to welding flux development is by experimental optimization. The extensive and expensive trial and error experimentation was needed because it is often difficult to know a priori how the flux ingredients interact to determine the operational characteristics of the flux and the final performance of the welded structure. For development of welding fluxes by hit and trial methods, many investigators tried to understand the role of each flux ingredients on the weld-metal properties and operational characteristics of the process by varying only the individual flux ingredient in a given flux system (Farias et al., 2004; Du Plessis et al. 2007).Kanjilal et al., (2004) observed that this approach by its very nature failed to take into account the simultaneous variation of the flux ingredients as well as their interaction effects. Assessment of flux ingredient interaction has been recognized as increasingly important in welding flux design where it may be necessary to determine the combined synergetic and antagonistic effects of many flux ingredients (Kanjilal et al., 2004, 2006, 2007).Factorial design, which has been widely used in other areas of arc welding technology, is inadequate for welding flux formulation because flux properties depend on the relative proportions of the flux ingredients (Anderson et al, 2002).Ren et al, (2010) used a design of experiment method (DoE) known as uniform design (UD) to develop a new agglomerated flux for high speed and multi-arc SAW. In the UD, the only thing to be considered is the uniform dispersion of the experimental points in the experimental space. Although the UD method has advanced the traditional experimental optimization, the result may be suboptimal or at best near optimal. Kanjilal et al, (2004, 2005, 2007a, 2007b) used another form of DoE technique known as the extreme vertices design (XVERTD) proposed by McLean and Anderson (1966). In the XVERTD technique, the constraints on the q flux ingredients define the experimental region, which is usually a (q – 1) dimensional simplex. The extreme vertices of the simplex, the centroids of each of the faces and the centroid of the entire simplex are determined and used as the experimental points or treatment combinations. Kanjilal and his co-investigators used their experimental data to develop prediction models for the measured responses such as weld-metal composition, mechanical properties, microstructure and element transfer characteristics of the flux. Standard mixture designs such as simplex-lattice and simplex-centroid will have limited applications in welding flux research because flux ingredients usually vary between a lower bound greater than 0 and an upper bound lesser than (100%). Extreme Vertices Designs are most appropriate when the researcher is interested in the effect of flux ingredients proportions on the responses.(Mclean and Anderson, 1966; Snee and Marquardt, 1974; Ding et al, 1999; Adeyeye et al, 2008).Development of models should not be limited to process factors because studies have shown that flux formulation plays a prominent role in the productivity of the welding process and the quality of the welded structure (Du Plessis et al, 2006, 2007).

2.2 REVIEW ON RELATED LITERATURE:

Various researchers have studied the effect of flux composition on element transfer and weld metal chemistry. Different ingredients in the flux system provide the process with different pyro-metallurgical characteristics and thus different microstructure and weld metal chemistry. The weld composition does not depend only on its concentration in the flux or wire but it is also affected by the other additions or alloys which are present in the flux. To understand the weld composition, it is essential to design fluxes for a particular electrode, base plate combination with the help of ternary phase diagrams. The design methodology decides the flux composition, which should melt at approximately 50oC lower temperature than the parent metal for proper fluxing action. The weld metal composition in SAW cannot be described only on the basis of equilibrium conditions, because during SAW the temperature is so high and the process is so fast, that the equilibrium cannot be established in such a short duration. For those reactions which are having very high equilibrium constant, the reaction for these elements can be neglected e.g. elements like Ca, Mg, AL are not transferred to the weld material during SAW. On the basis of the above literature review it can be safely inferred that weld composition is greatly influenced by flux composition and by the welding conditions. Stability of metal oxides present in the flux, network formers present in the flux, basicity index, oxidation and reduction reactions, oxygen potential of flux, FeO activity of slag, ratio of slag and molten metal, CO and MnO reactions, rate of heat input, rate of evaporation of various elements, physical and chemical properties of flux, electrochemical and thermo chemical reactions, chemical potential of the flux, physical properties of flux, chemical partitioning between slag and weld metal, electrode polarity, welding process parameters, thermodynamic and kinetic factors play an important role in determining transfer behavior of flux.

2.3 CONCLIUSION OF REVIEW:

After going through the research work carried out in the field of welding flux development it has been concluded that the welding flux can be designed by using statistical and design of experiment methods such as mixture designs etc. instead of lengthy trial and error methods. Various researchers have used different methods and different ingredients for improving the quality of flux and optimizing its properties, thus there is a vast scope for research work in the field of development of high performance and cost-effective fluxes.

CHAPTER – 3 PROJECT DESIGN

3.1 HISTORY TO CATIA:

French organization Dassault systems created multi-stage cad/cam/cae business programming CATIA(computer aided three-dimensional interactive application). this is composed in the C++ programming language, CATIA is the primary result of the Dassault systems item lifecycle administration programming suite.

Figure-4 Logo

- CATIA competes with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others in the CAD/CAM/CAE market.

Developer(s)	Dassault Systems
Stable release	V6R2011x / November 23, 2010
Operating system	Unix / Windows
Type	CAD software
License	Proprietary
Website	WWW.3ds.com

Table 2 Details of CATIA

- In 1977 a French air craft maker Avions Marcel Dassault, began CATIA as an in-house advancement around then client of the CADAM CAD programming to build up Dassault's Mirage contender plane, then was embraced in the shipbuilding, car, aviation and different commercial ventures.
- At first named CATI (Conception Assisted Tridimensionnelle Interactive - French for Interactive Aided Three-dimensional Design) - it was renamed CATIA in 1981, when Dassault made an auxiliary to create and offer the product, and marked a non-selective circulation concurrence with IBM.
- In 1984, CATIA is picked as its principle 3D CAD apparatus by Boeing Company, turning into its biggest client.
- In 1988, CATIA adaptation 3 was ported from centralized server PCs to UNIX.
- In 1990, CATIA is picked as its primary 3D CAD apparatus by General Dynamics Electric Boat Corp, to plan the U.S. Naval force's Virginia class submarine.
- In 1992, IBM acquired CADAM and the following year CATIA CADAM V4 was distributed.
- In 1996, it was ported from one to four UNIX working frameworks, including IBM AIX, Sun Microsystems SunO , Silicon Graphics IRIX and Hewlett-Packard HP-UX.
- In 1998, CATIA V5 was discharged a completely modified variant of CATIA, with backing for Windows NT, UNIX and Windows XP since 2001.
- In 2008, Dassault released CATIA V6. While the server can keep running on Microsoft Linux or AIX, Windows, customer backing for any working framework other than Microsoft Windows is dropped.

Name/Version	Latest Build Number	Original Release Date	Latest Release Date
CATIA v4	R25	1993	January 2007
CATIA v5	R20	1998	February 2010
CATIA v6	R2012	29/05/2008	May 2011

Table-3 Versions of CATIA

3.2 SCOPE OF APPLICATION:

3D Product Lifecycle Management suite available in CATIA, multiple stages of product development (CAx), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE) can be performed.

CATIA facilitates mutual engineering across disciplines, mechanical engineering, including shape design & surfacing, systems engineering and equipment.

Surfacing & Shape Design:

CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From styling, subdivision, and Class A surfaces to mechanical functional surfaces.

Mechanical Engineering:

Modules like 3D sketches, sheet metal work bench, forged or tooling parts for creation of 3D parts like assemblies and molded are available in CATIA. The tools in the CATIA enable functional tolerances, Kinematics definition and product definition.

Equipment Design:

The design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing can be done by CATIA.

Systems Engineering:

CATIA solves intelligent products and Model complex through the systems engineering approach. It covers the requirements definition, the systems architecture, the behavior modeling and the virtual product or embedded software generation. It can be customized via application programming interfaces (API). Visual Basic and C++ programming languages via CAA (Component Application Architecture); a component object model (COM)-like interface are adapted using CATIA V5 & V6.

Although later versions of CATIA V4 implemented NURBS, V4 principally used piecewise polynomial surface. Non-manifold solid engine is used in CATIA V4.

Parametric solid/surface-based package which uses NURBS available in CATIA as the core surface representation and has several workbenches that provide KBE support.

Enova, Smarteam, and various CAE Analysis applications can work with V5.

3.3 SUPPORTED OPERATING SYSTEMS AND PLATFORMS:

CATIA V6 runs only on Microsoft Windows and Mac OS with limited products.

CATIA V5 runs on Microsoft Windows (both 32-bit and 64-bit), and as of Release 18Service Pack4 on Windows Vista 64.IBM AIX, Hewlett Packard HP-UX and Sun Microsystems Solaris are supported.

CATIA V4 is supported for IBM MVS, UNIXs VM/CMS and mainframe platforms up to release 1.7.

CATIA V3 version and earlier versions run on the mainframe platforms.

3.4 INDUSTRIES USING CATIA:

CATIA can be connected to a wide variety of commercial enterprises, from aviation and defense, car, and modern gear, to cutting edge, shipbuilding, shopper merchandise, plant outline, purchaser bundled products, life sciences, building design and development, procedure force and petroleum, and administrations. CATIA V4, CATIA V5, Pro/E, NX (once in the past Unigraphics), and Solid Works are the predominant frameworks.

Aerospace:

Aviation the Boeing Company utilized CATIA V3 to create its777 carrier, and is at present utilizing CATIA V5 for the787 arrangement air ship. They have utilized the full scope of Dassault Systems' 3D PLM items — CATIA, DELMIA, and ENOVIALCA — supplemented by Boeing created applications.

Chinese Xian JH-7 is the first plane made by CATIA V5, when the blueprint was done on September 26, 2000.European aviation monster Airbus has been utilizing CATIA since 2001. Canadian air ship creator Bombardier Aerospace has done the majority of its flying machine outline on CATIA.

Westland is currently some portion of an Italian organization called Finmeccanica the joined organization calls them AgustaWestland. The primary supplier of helicopters to the U.S Military powers, Sikorsky Aircraft Corp., utilizes CATIA.

Automotive:

Many automotive companies utilize CATIA to varying degrees, including BMW, Audi, Jaguar Land Rover, Volkswagen, Porsche, Daimler AG, Chrysler, Honda Bentley, Volvo, Fiat etc. Goodyear uses it in making tires for automotive and aerospace and also uses a customized CATIA for its design and development. They use CATIA to make design components like car doors, car roofs etc.

Ship building:

Dassault Systems has started serving shipbuilders with CATIA V5 discharge 8, which incorporates exceptional components valuable to shipbuilders. GD Electric Boat utilized CATIA to plan the most recent quick assault submarine class for the United States Navy, the Virginia class. Northrop Grumman Newport News likewise utilized CATIA to plan the Gerald. Portage class of super bearers for the US Navy.

Industrial Equipment:

CATIA has number vicinity in the Industrial Equipment industry. Mechanical Manufacturing apparatus organizations like Schuler and Metso use CATIA , and also substantial portable hardware and gear organizations like Claus, furthermore different modern hardware item organizations like Alstom Power and ABB Group

Other:

Other Architect Frank Gehry has utilized the product, through the C-Cubed Virtual Architecture organization, now Virtual Build Team, to plan his recompense winning curvilinear structures. His innovation arm, Gehry Technologies, has been created programming in view of CATIA V5 named

Digital Project. Computerized Project has been utilized to outline structures and has effectively finished a modest bunch of undertakings.

As per the depicted strategy the gear pair with the accompanying parameters was displayed utilizing CATIA V5R12. Demonstrating of gear utilizing the CATIA comprises of two stages, one is part outline and another Assembly plan. Part and Shape outline are the fundamental modules of configuration in CATIA programming.
They depend on a few instruments for simple and subjective displaying of any sort of machine components. Initial step of outline any part is to characterize position (plane) of Sketch and to attract profile picked Sketch. A few operations comprise in including material, others in evacuating material for instance Create a Pad, Pocket, Shaft, Groove, Hole, Slot, and Loft and so forth.

3.5 MODELING OF WELDING PLATE:

Procedure:

1) Modeling of ocean turbine blade is done through CATIA V5R16 by considering all the specifications of the blade as mentioned above.
2) Open CATIA and from start menu select the mechanical design and then part design.

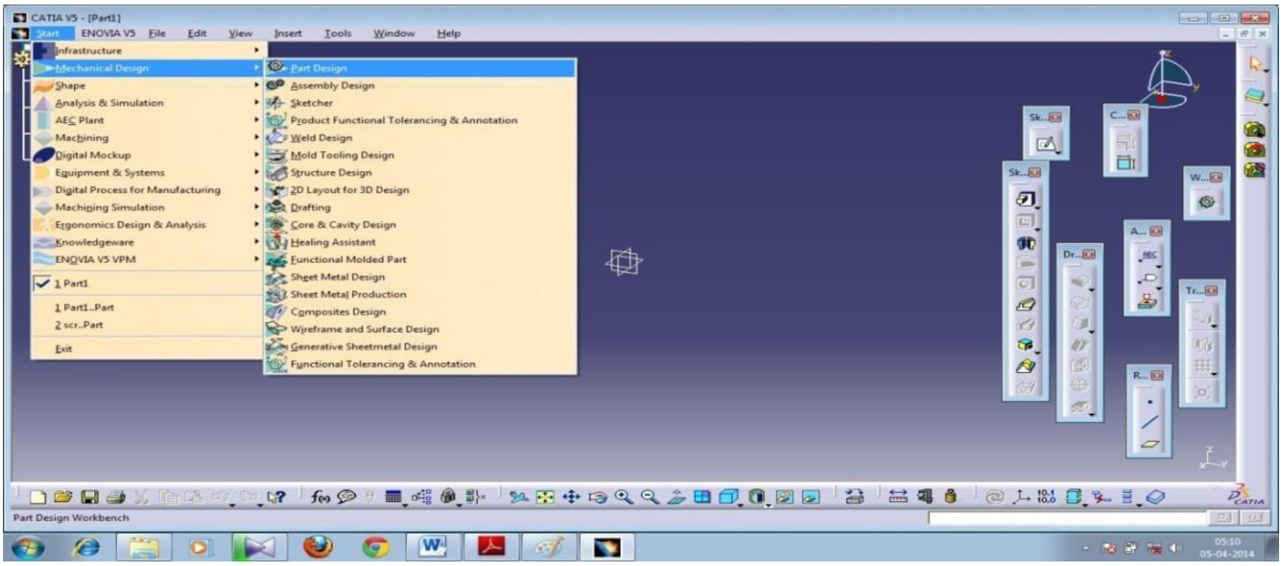


Figure-5 Selection of Mechanical Design

3) From the coordinate system select the X-Y plane and click on sketcher

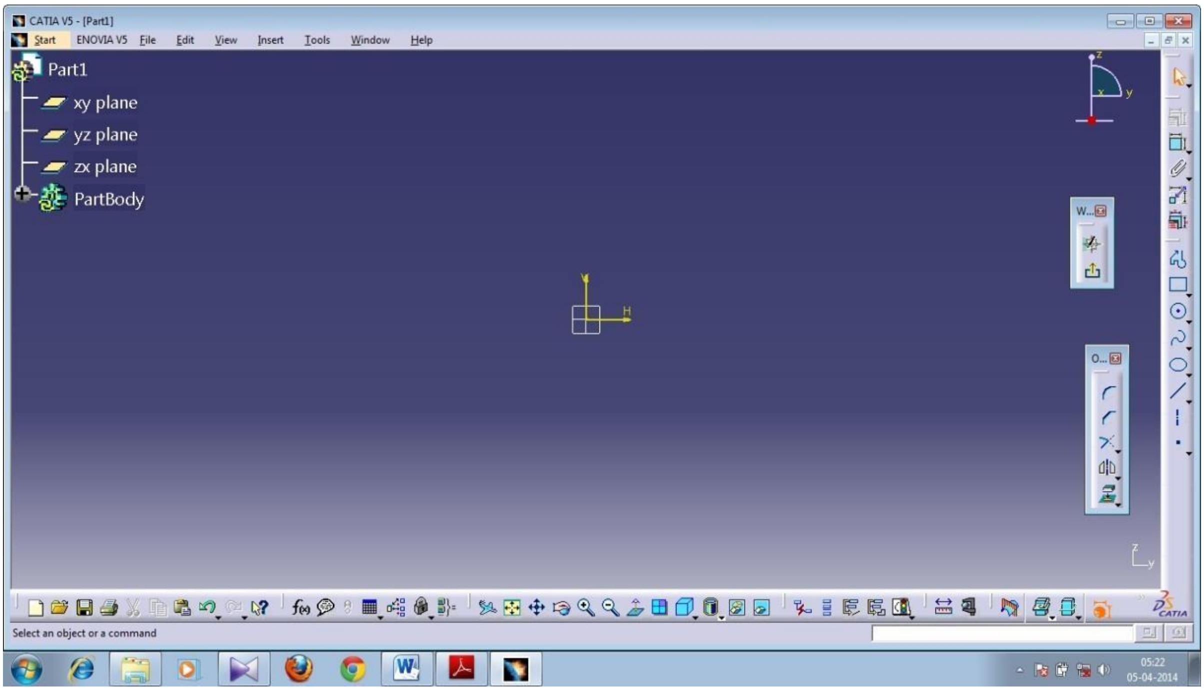


Figure-6 Selecting one plane to draw

4) By using sketch tool, we have drawn a Plate 1 of 100x100mm with thickness 10mm.

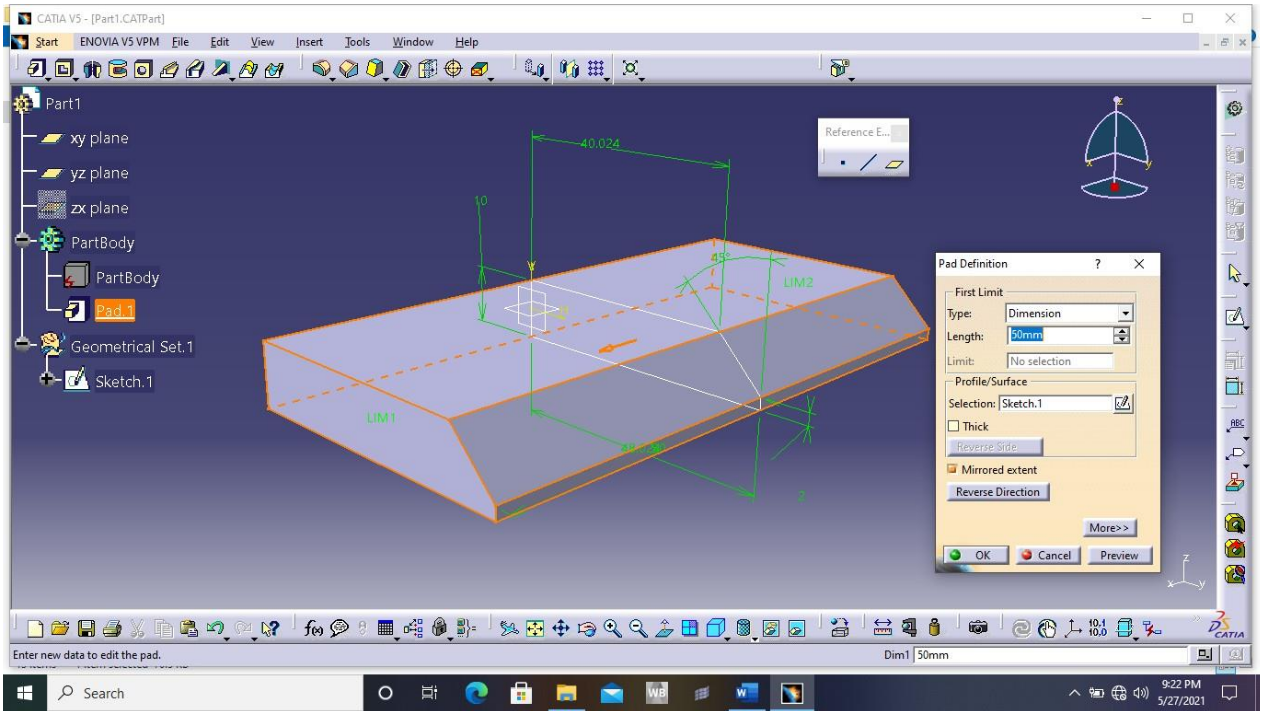


Figure-7 Designing Plate 1

5) By using mirror tool, we designed Plate 2.

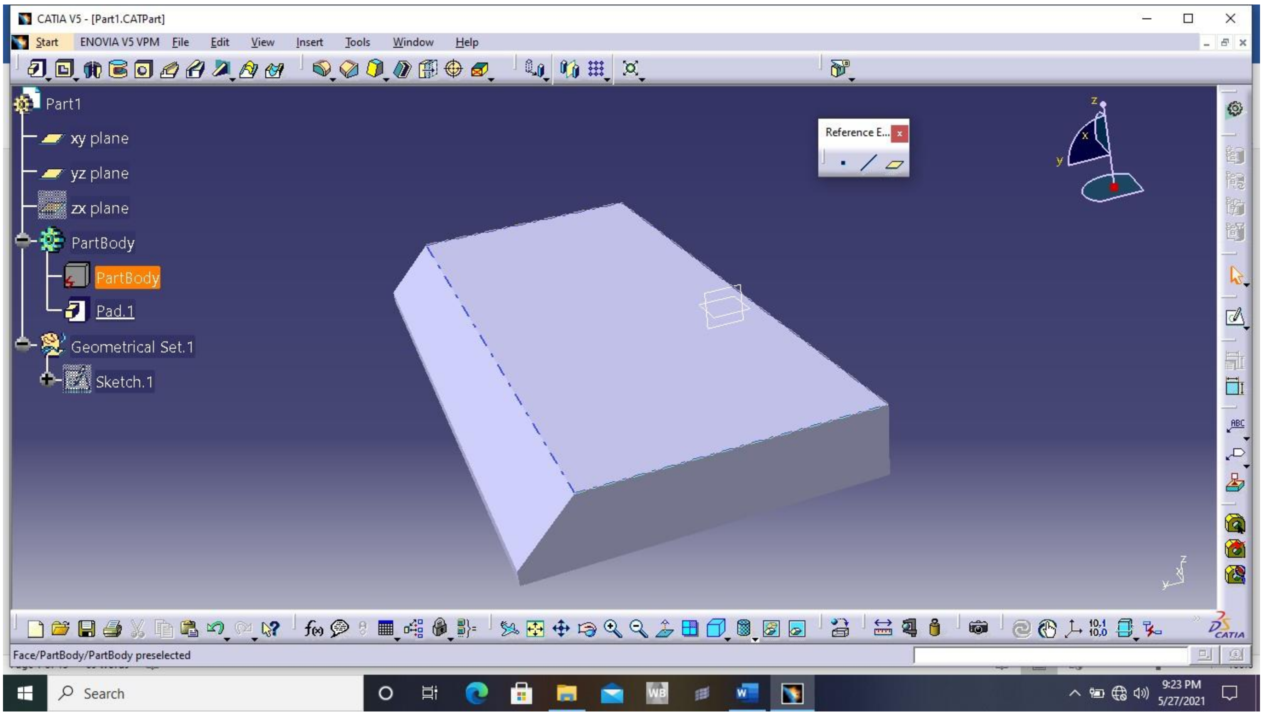


Figure-8 Designing Plate 2

6) By taking 45^o of weld arc, we have designed weld area

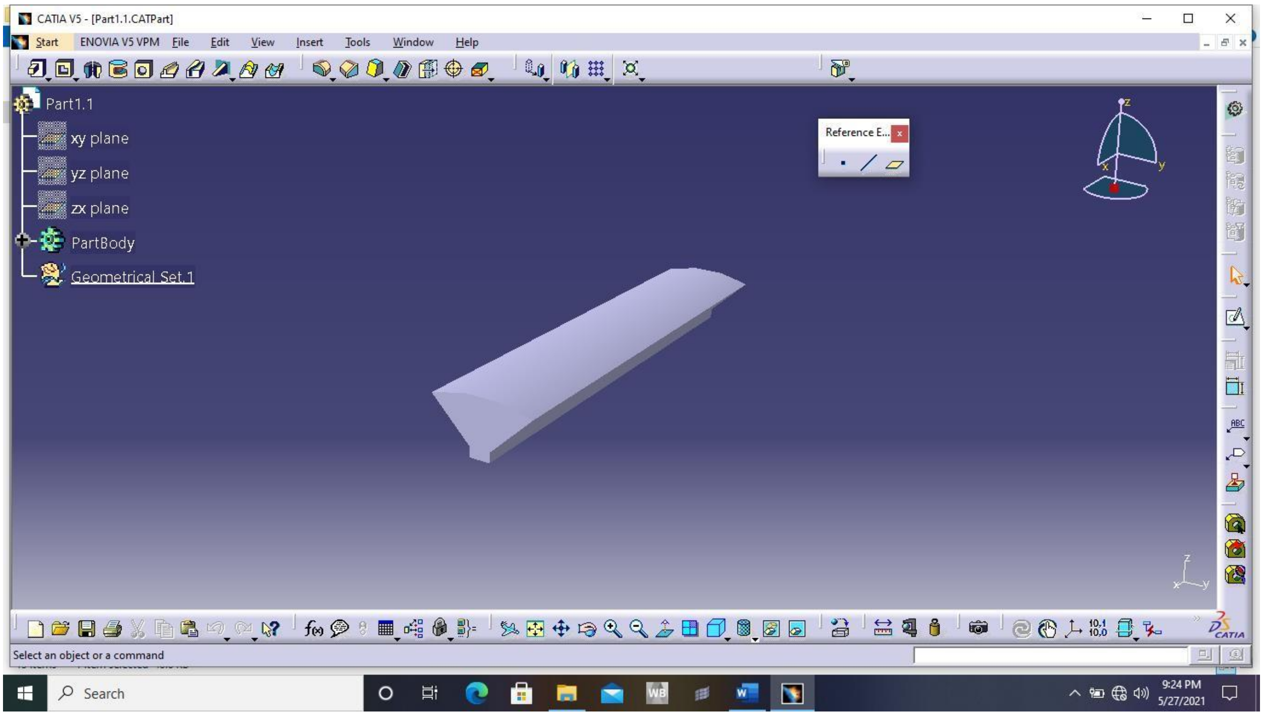


Figure-9 Weld Area

7) By assembling the three parts together we get the welded plate design

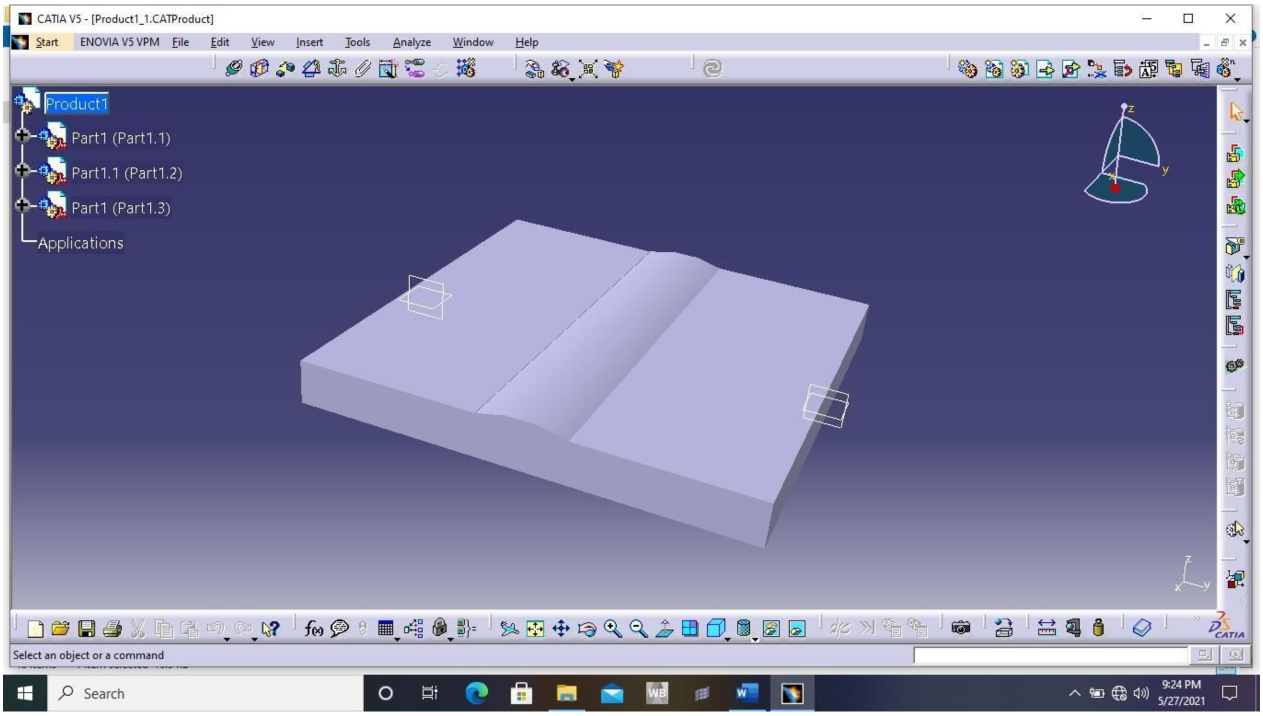


Figure-10 Welded Plate

CHAPTER – 4 PROJECT IMPLEMENTATION

4.1 INTRODUCTION TO HYPERMESH:

Its software also found uses in other sectors, including aerospace (NASA), aviation (Airbus), consumer electronics (Nokia), and toy manufacturing (Mattel), among others. In 2002, Altair software aided in the design of the Airbus A380 by weight optimizing the aircraft wing ribs. That year, the company moved into a new headquarters in Troy, Michigan. It maintained separate offices in Allen Park, Michigan. Also, in 2002, Altair opened offices in Seongnam, South Korea and Shanghai, China, adding those locales to its international footprint alongside India where it had begun investment in 1992.

4.1.1 HISTORY:

In addition to its software production, Altair continued hiring out engineering consultants to its corporate clientele. Its consultancy services accounted for the majority of the company's revenue until 2004, when the sale and licensing of software overtook that. In October of that year, General Atlantic invested $30 million in Altair. Also in 2004, Altair partnered with General Motors and the United States Department of Defense on the design and construction of a new military vehicle.

Altair also branched out into the life sciences, finance, and pharmaceutical industries with its high-performance computing software, PBS Pro, which it had acquired the rights to in 2003. In June 2006, Altair acquired the French CAE software company, Mecalog, and its Radio’s technology suite. In 2007, it spun off a new wholly-owned subsidiary called Ilumisys, which would focus on light-emitting diode (LED) lamps designed to be used as direct replacements for fluorescent light tubes. Ilumisys' operations were moved to Michigan in 2011, and it was rebranded as TOGGLED in 2012.

4.1.2 SCOPE OF THE APPLICATION:

Hyper Mesh is a solver neutral environment with the broadest set of direct interfaces to commercial CAD and CAE systems and a rich suite of easy-to-use tools to build and edit CAE models. The advanced geometry and meshing capabilities provide an environment for rapid model generation. The ability to generate high quality mesh quickly is one of Hyper Mesh’s core competencies. With automatic and semi-automatic shell, tetra, and hexa meshing capabilities, HyperMesh simplifies the modeling process of complex geometries.

HyperMesh has advanced model assembly tools capable of supporting complex sub-system generation and assembly, in addition, modeling of laminate composites is supported by advanced creation, editing and visualization tools. Design change is made possible via mesh morphing and geometry dimensioning. A flexible set of morphing tools allows users to modify mesh without re-meshing to automate the investigation new design proposals. It also has an extensive API which allows for advanced levels customization.

4.1.3 Using of HyperMesh:

- Import the file which we have design in CATIA

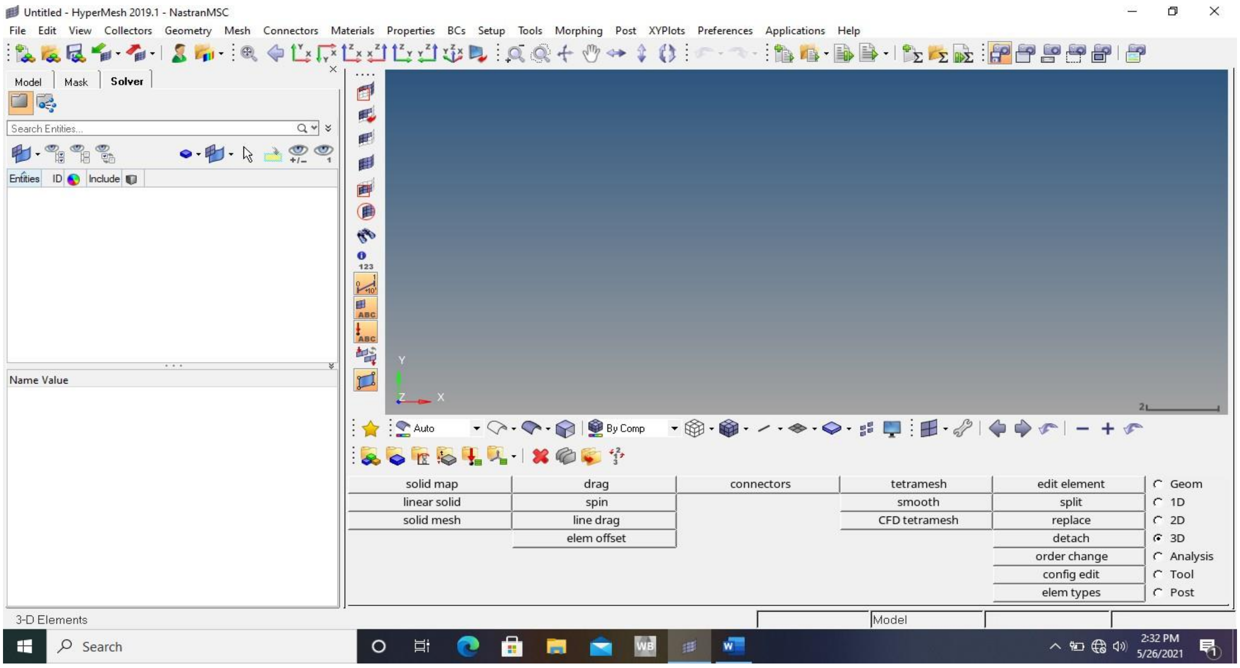


Figure-11 HyperMesh Window

- We have to Select the solver:

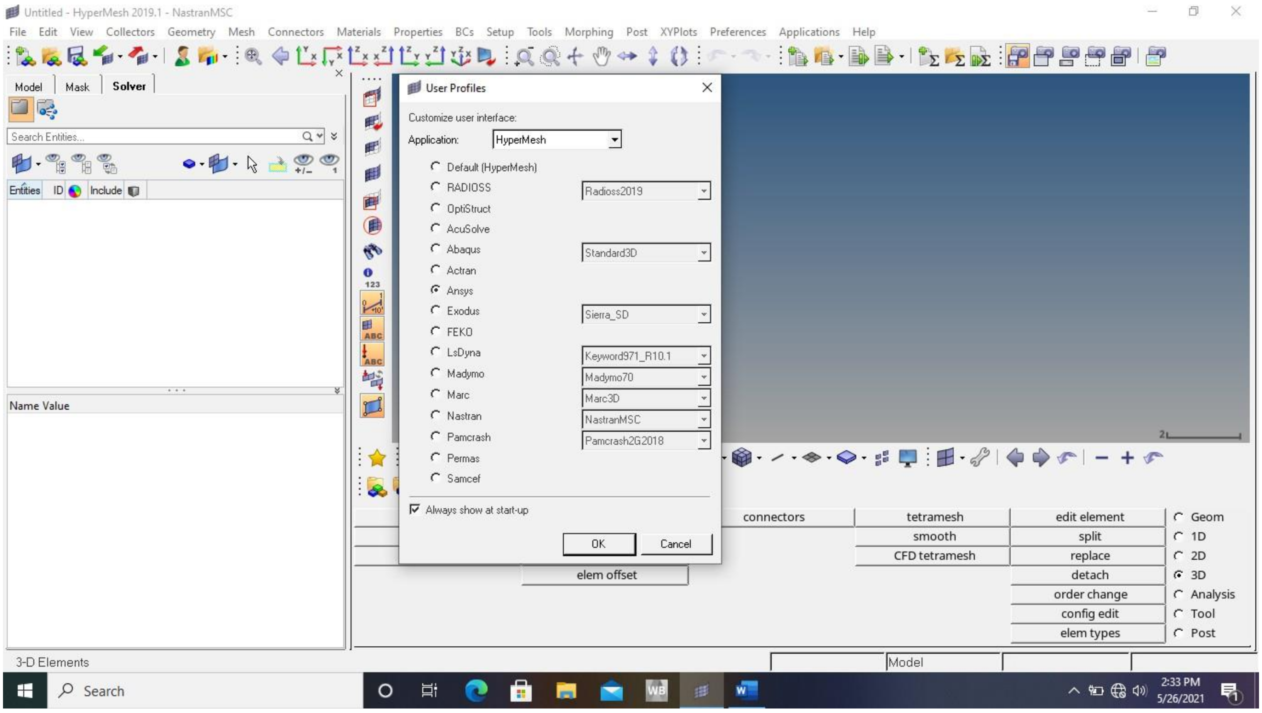


Figure-12 Selecting of solver

- Import the file from the system

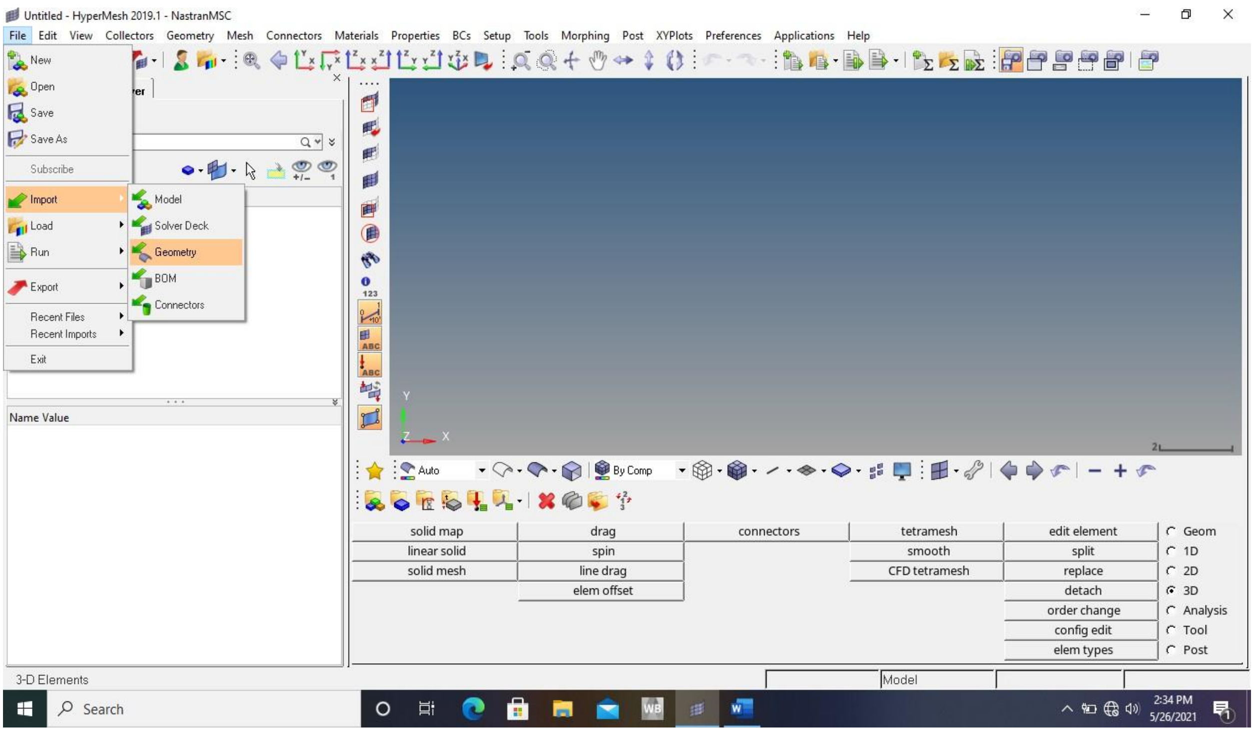


Figure-13 Import

- Select the file from the folder

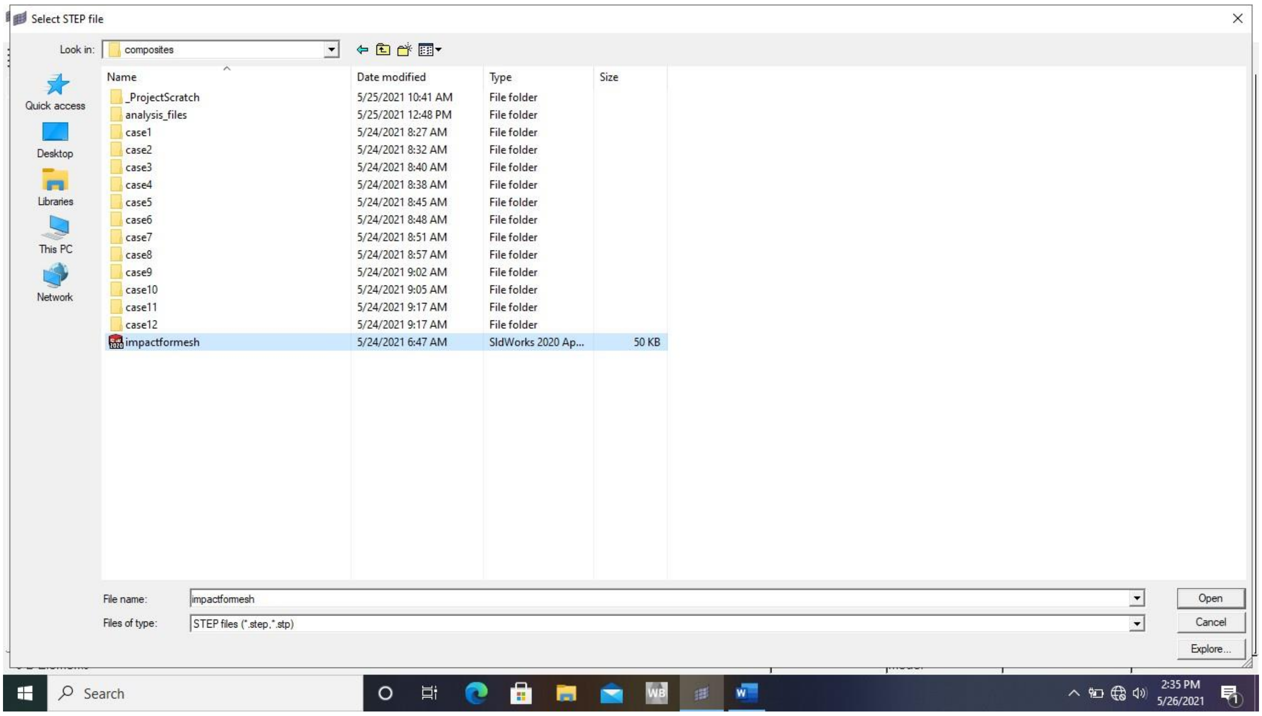


Figure-14 Select file

- Give Imported Geometry to the system

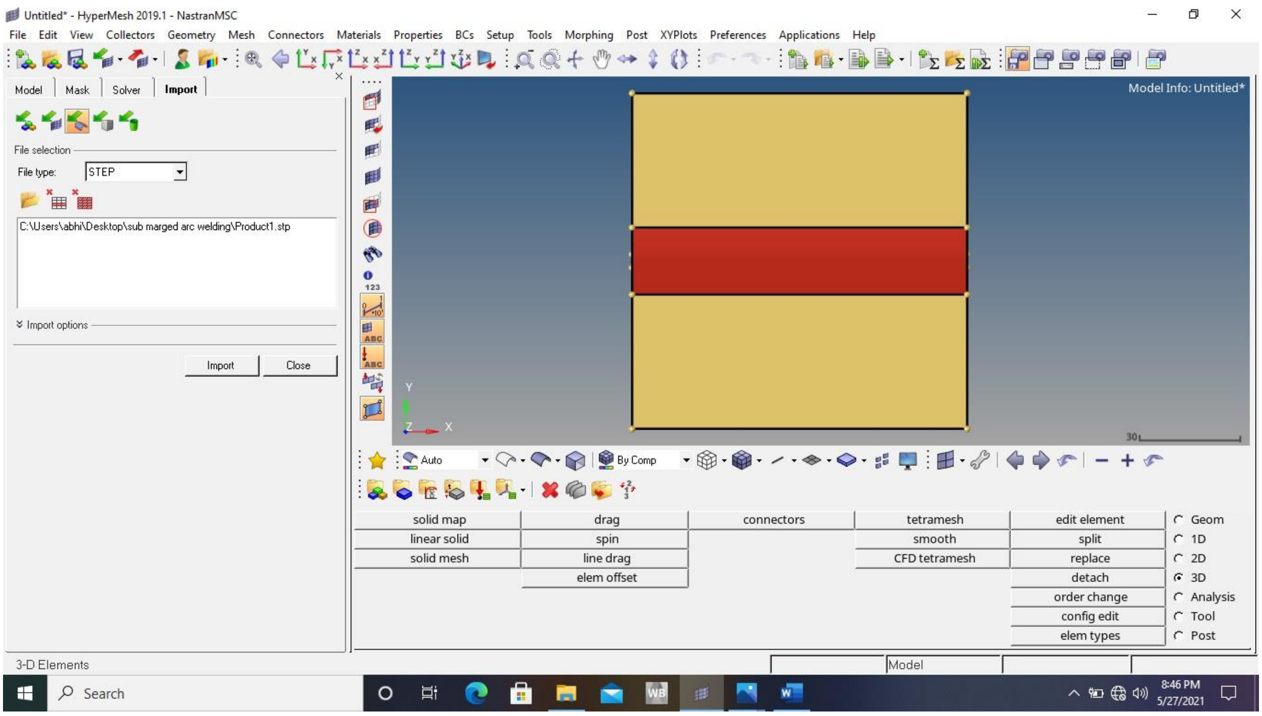


Figure-15 Imported geometry

- Now clean off the geometry

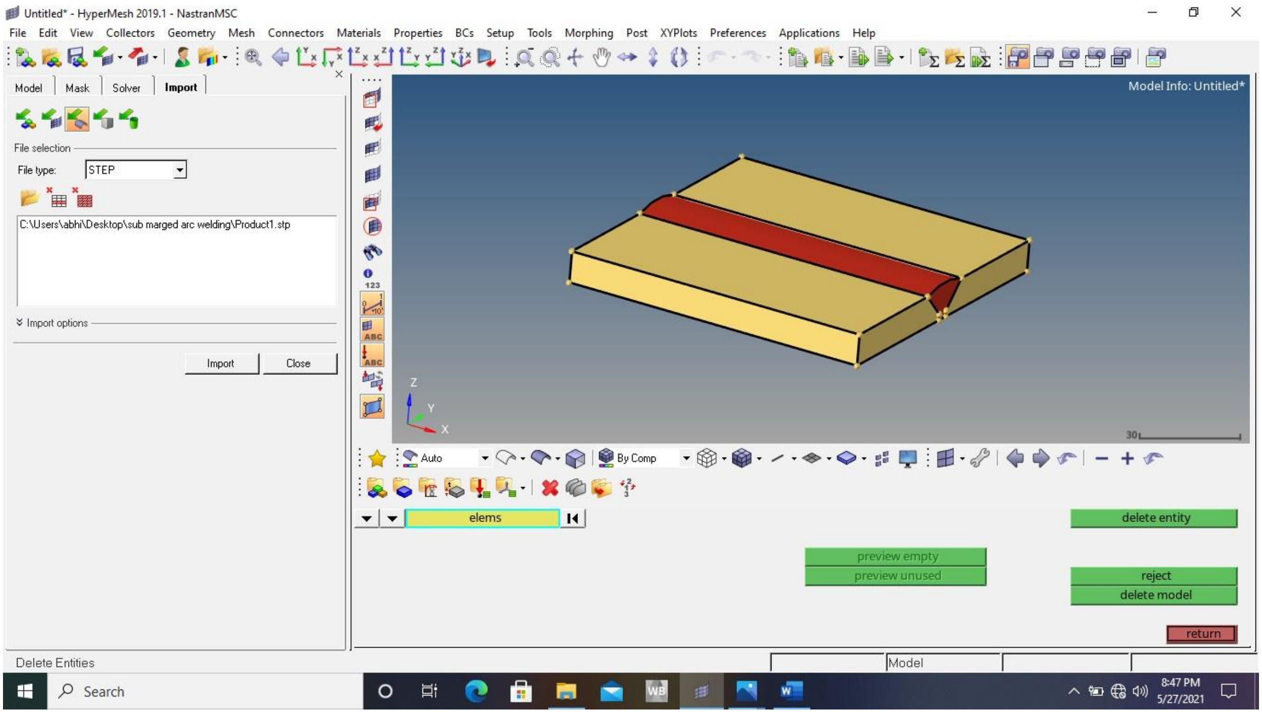


Figure-16 Clean off geometry

- After clean off geometry next cleaning of solid

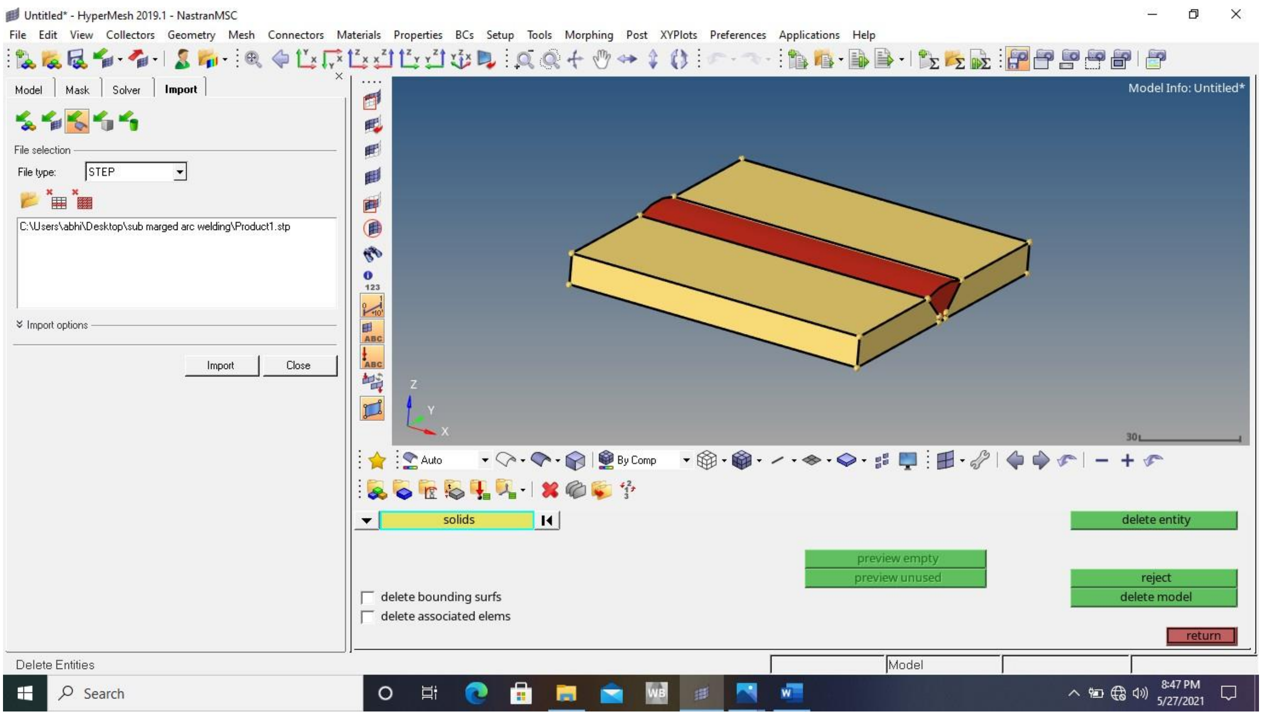


Figure-17 Solid cleaning

- Now we have to do 2D meshing-r-trias.

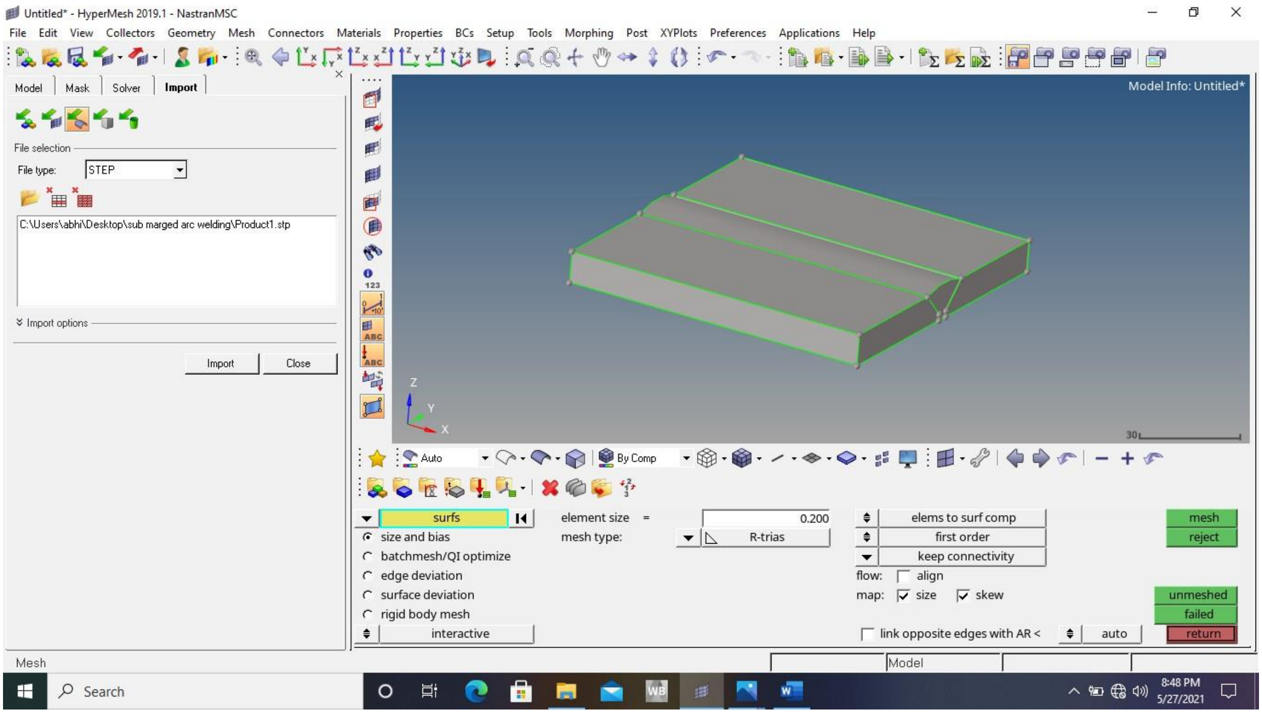


Figure-18 2d meshing -r-trias element size0. 2mm

- 2D meshed object -5392 elements

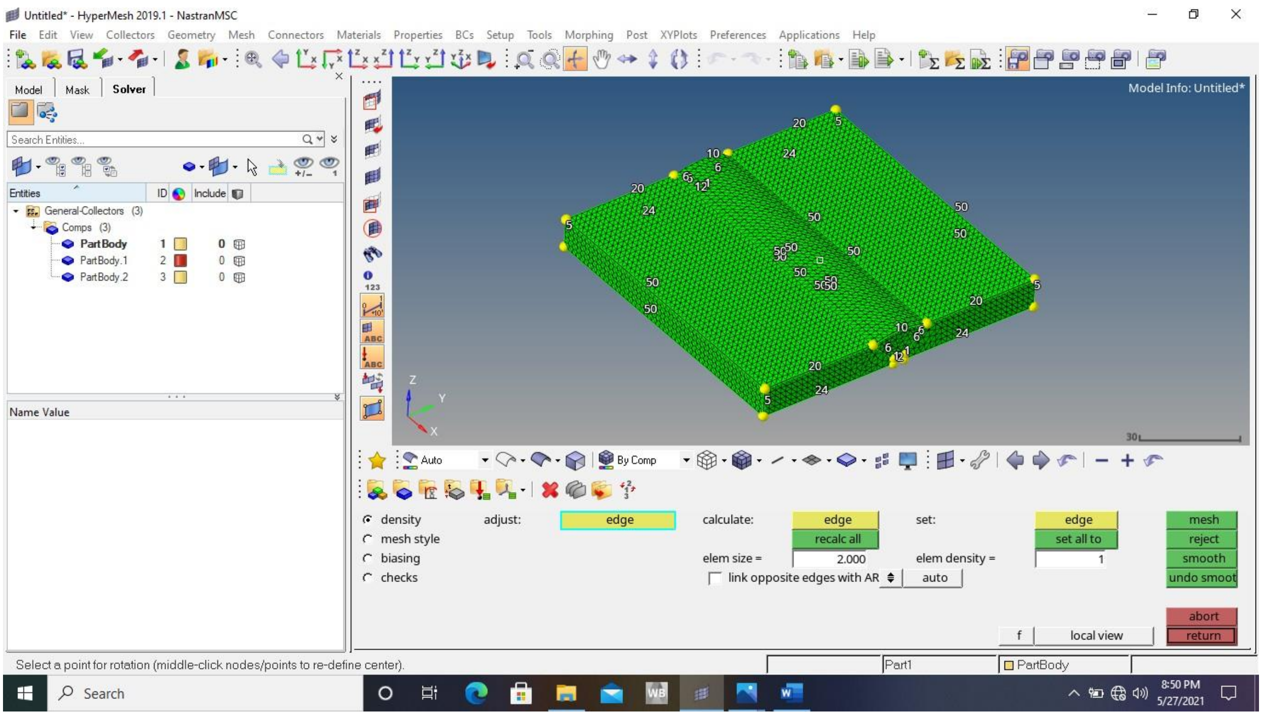


Figure-19 2d meshed object -5392 elements

- After 2D meshing we have to do 3D meshing -tetra mesh

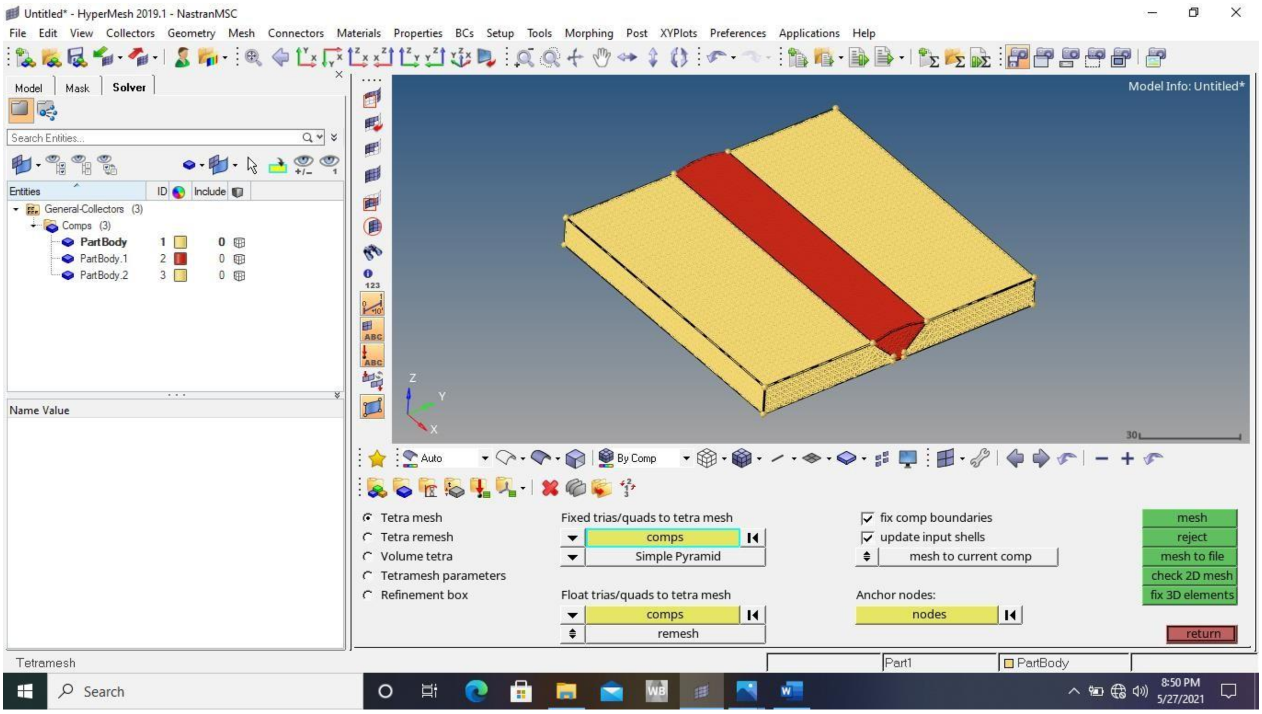


Figure-20 3d meshing -tetra mesh

- After Tetra mesh we have to do 3D mesh

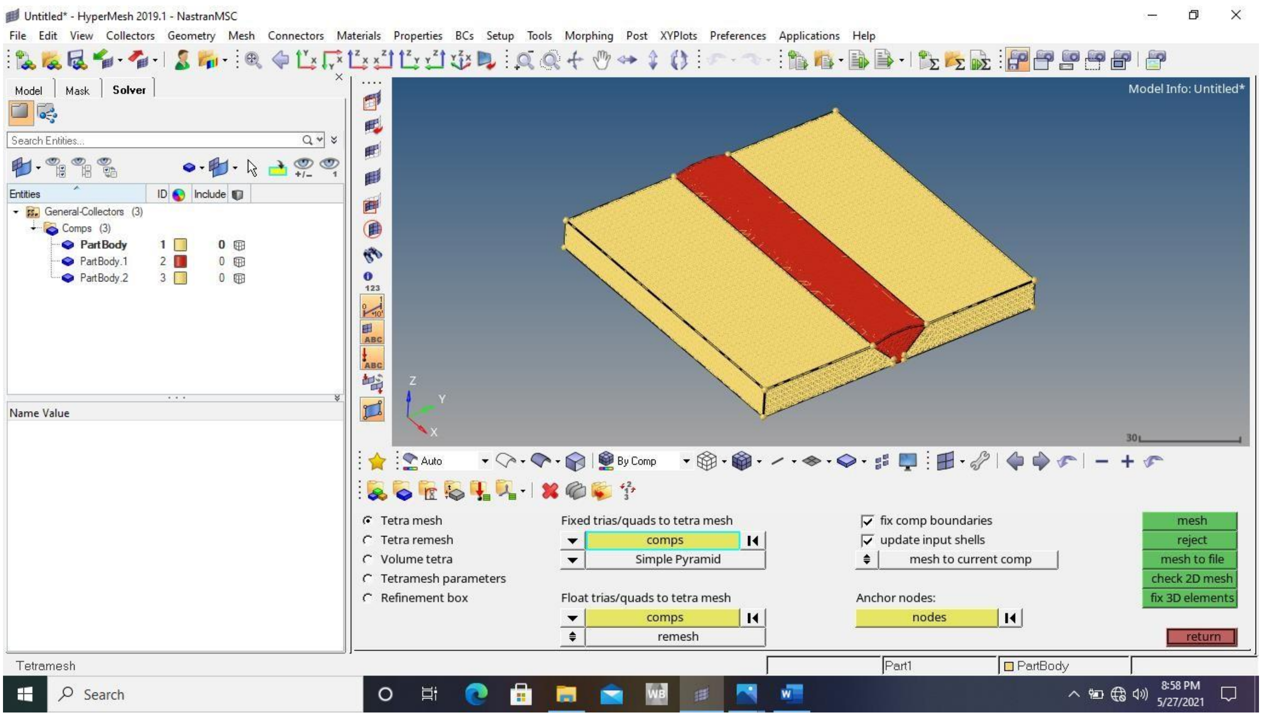


Figure-21 3d meshed

- Now we have to do cleaning of elements

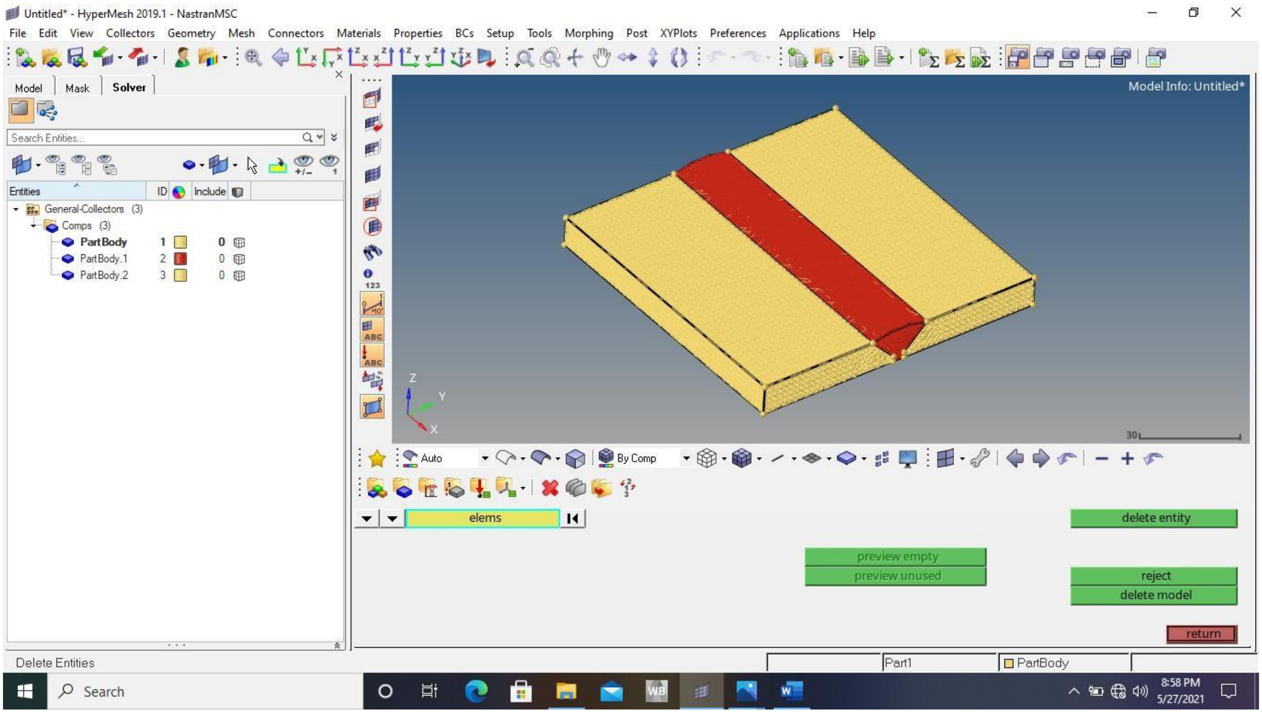


Figure-22 Cleaning of elements

- Selection of 2D elements

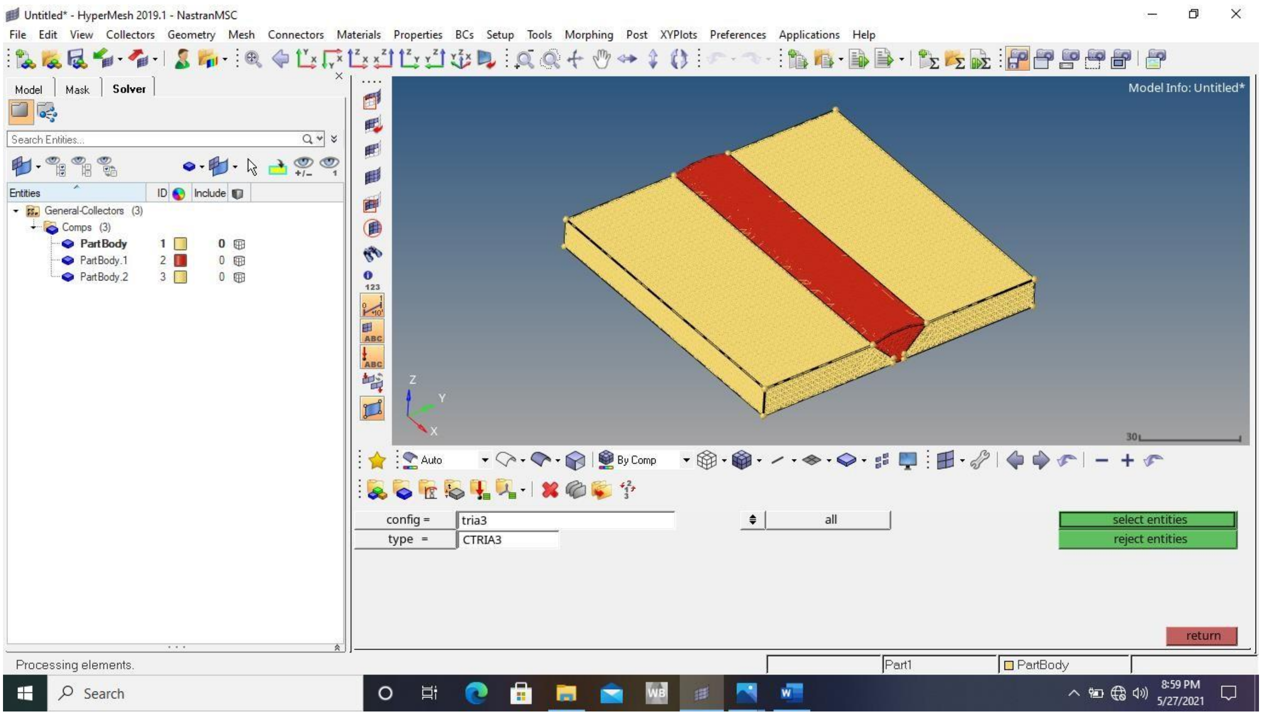


Figure-23 Selection of 2d elements

- Finally, we have got the final meshed file after running different tasks

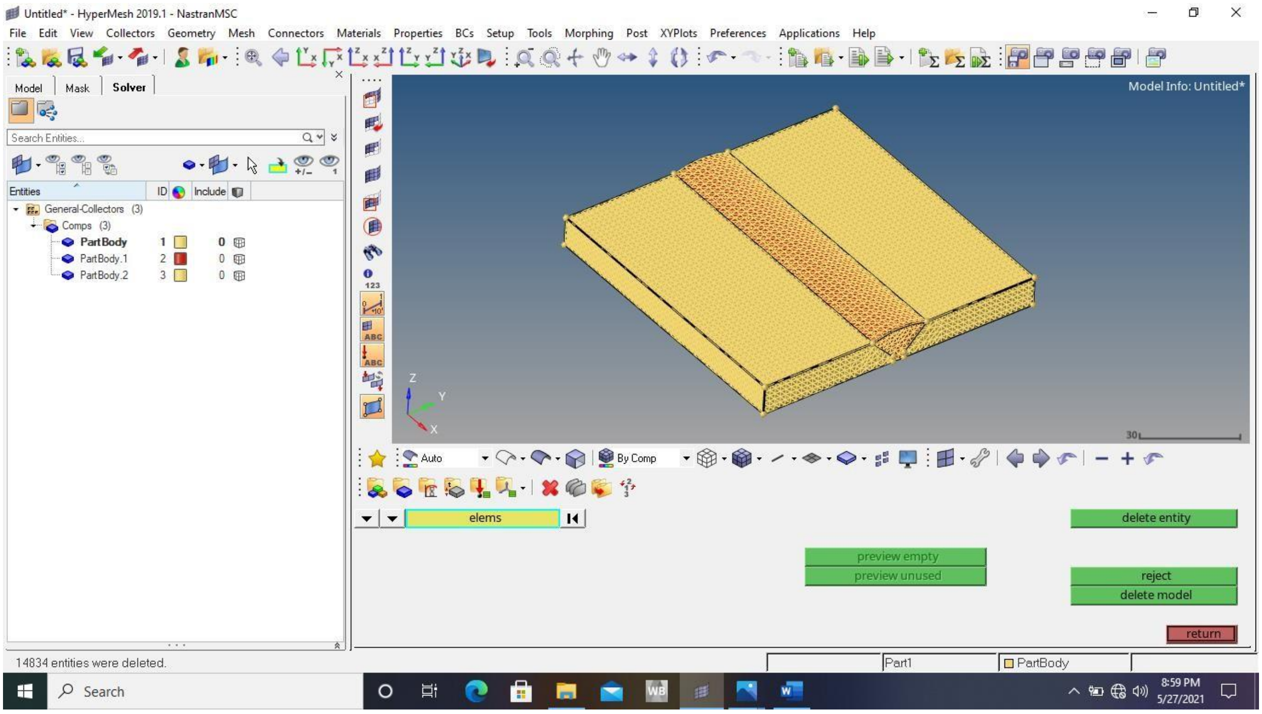


Figure-24 Final meshed file

- After final mesh we need to save this file in .nas format.

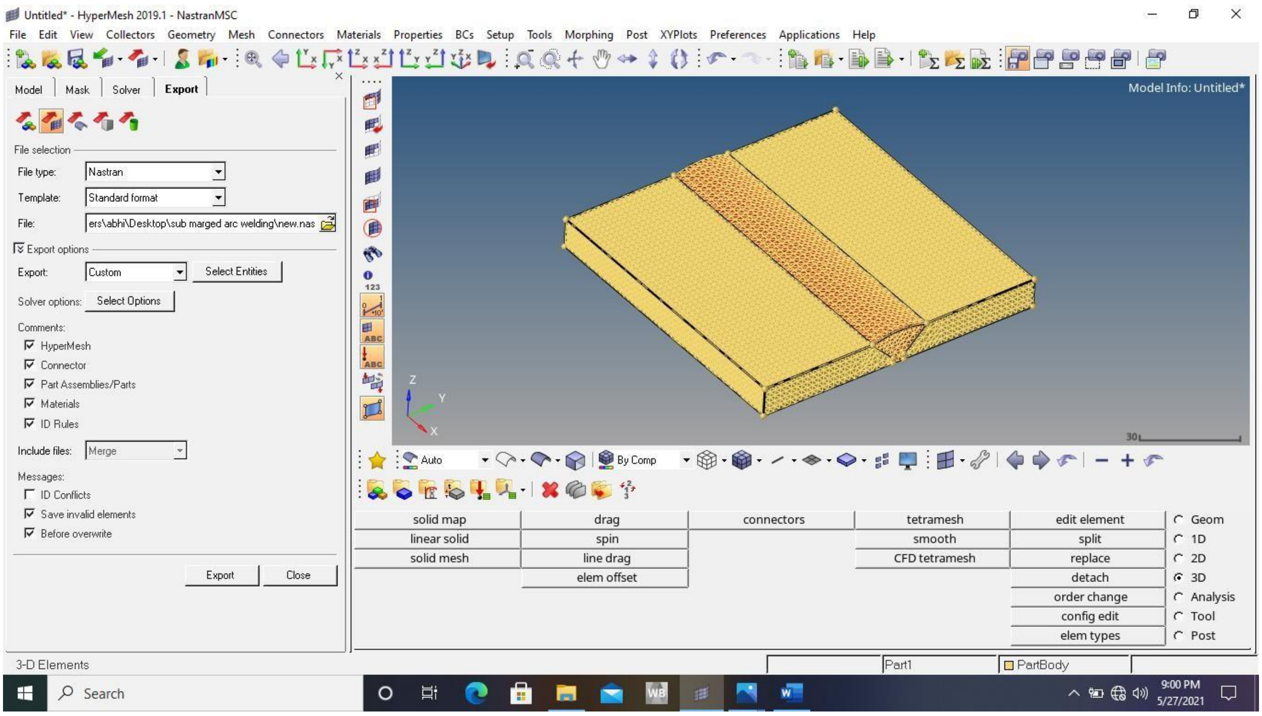


Figure-25 Exported file in .nas forma

4.2 INTRODUCTION TO ANSYS:

The ANSYS program is self-contained general-purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable.
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.

A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

Figure-26 ANSYS Logo

4.2.1 HISTORY OF ANSYS

The first commercial version of Ansys software was labeled version 2.0 and released in 1971. At the time, the software was made up of boxes of punch cards, and the program was typically run overnight to get results the following morning. In 1975, non-linear and thermo- electric features were added. The software was exclusively used on mainframes, until version

3.0 (the second release) was introduced for the VAXstation in 1979. Version 3 had a command line interface like DOS.

Released in January 2020, Ansys R1 2020 updates Ansys' simulation process and data management (SPDM), materials information and electromagnetics product offerings. In early 2020, the Ansys Academic Program surpassed one million student downloads.

In November 2020, South China Morning Post reported that Ansys software had been used for Chinese military research in the development of hypersonic missile technology.

4.2.2 INTRODUCTION TO ANSYS WORKBENCH

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.

Figure-27 Ansys Workbench Logo

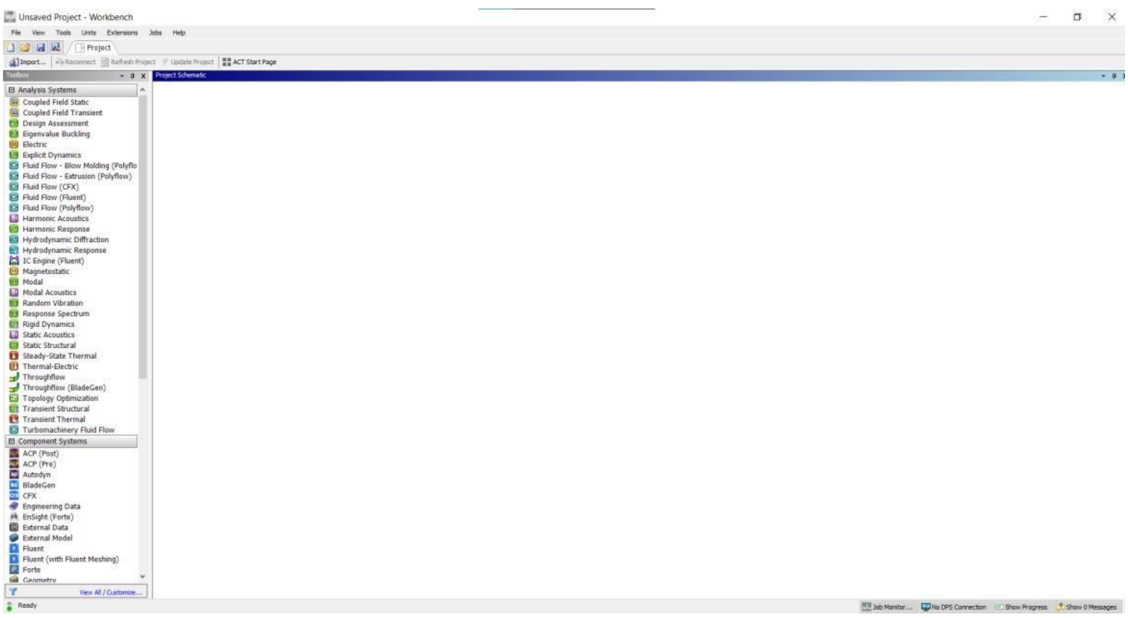
4.2.3 INTRODUCTION TO ANSYS MECHANICAL

Ansys Mechanical is a finite element analysis (FEA) tool that enables you to analyze complex product architectures and solve difficult mechanical problems. You can use Ansys Mechanical to simulate real world behavior of components and sub-systems, and customize it to test design variations quickly and accurately.

Figure-28 Ansys Mechanical Logo

4.2.4

ANALYSIS



Ansys Window:

Figure-29 Ansys Window

Static Structural Analysis:

In order to perform static structural analysis. First, we need to begin with double click on static Structural to bring in into the project schematic window.

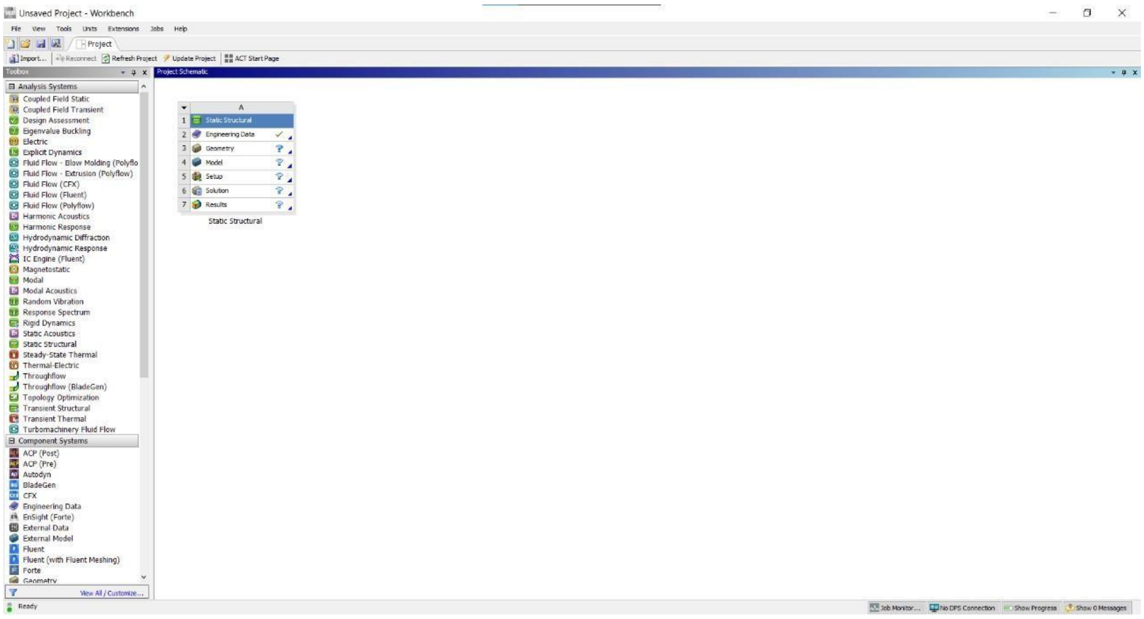


Figure-30 Static Structural Analysis

- Then, we can import our HyperMesh model by changing file extension i.e., from .nas. After importing the geometry, we will go ahead and double click on model or cell no 4 to open up Ansys mechanical.

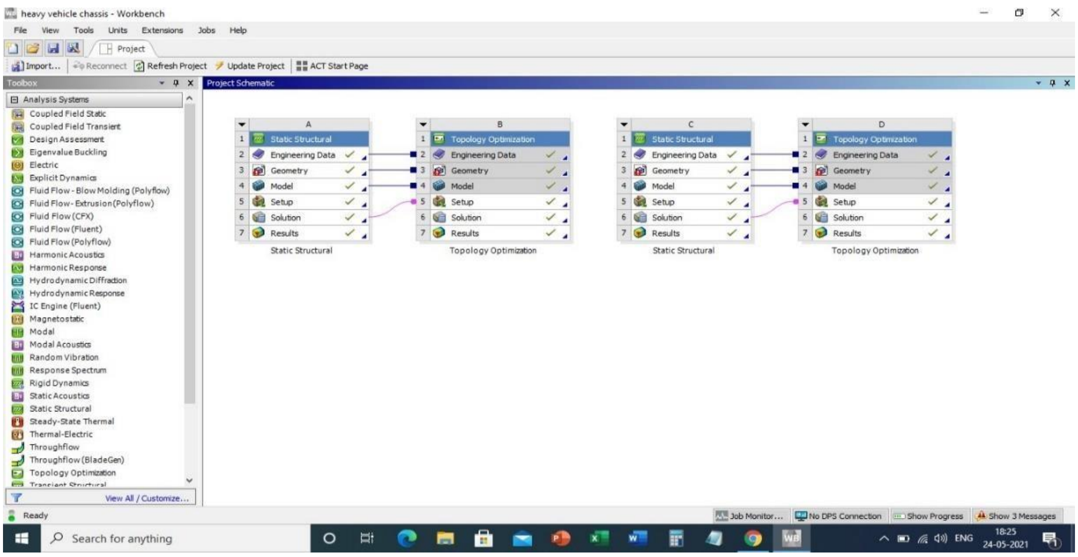


Figure-31: Extract Model

- Next, we should always with looking at the engineering data. So, we have selected structural steel for our analysis. We can either change our material by clicking on engineering data sources.

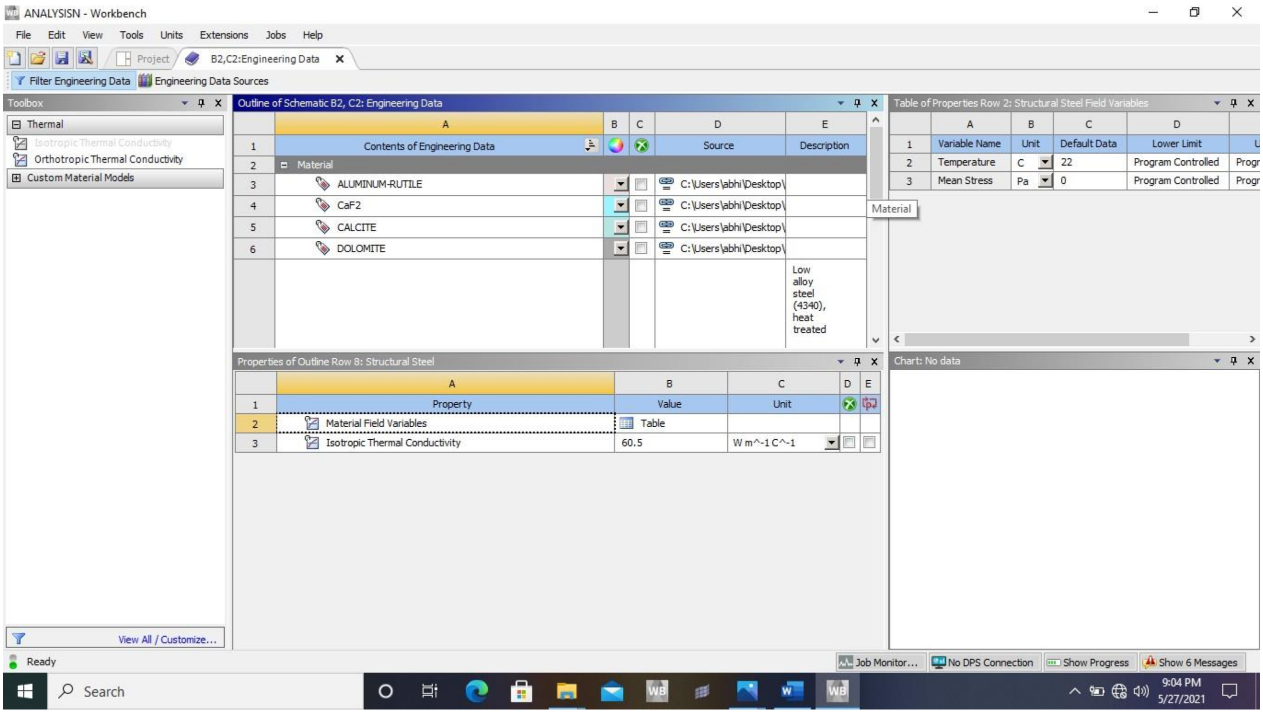


Figure-32: Eniginering dat

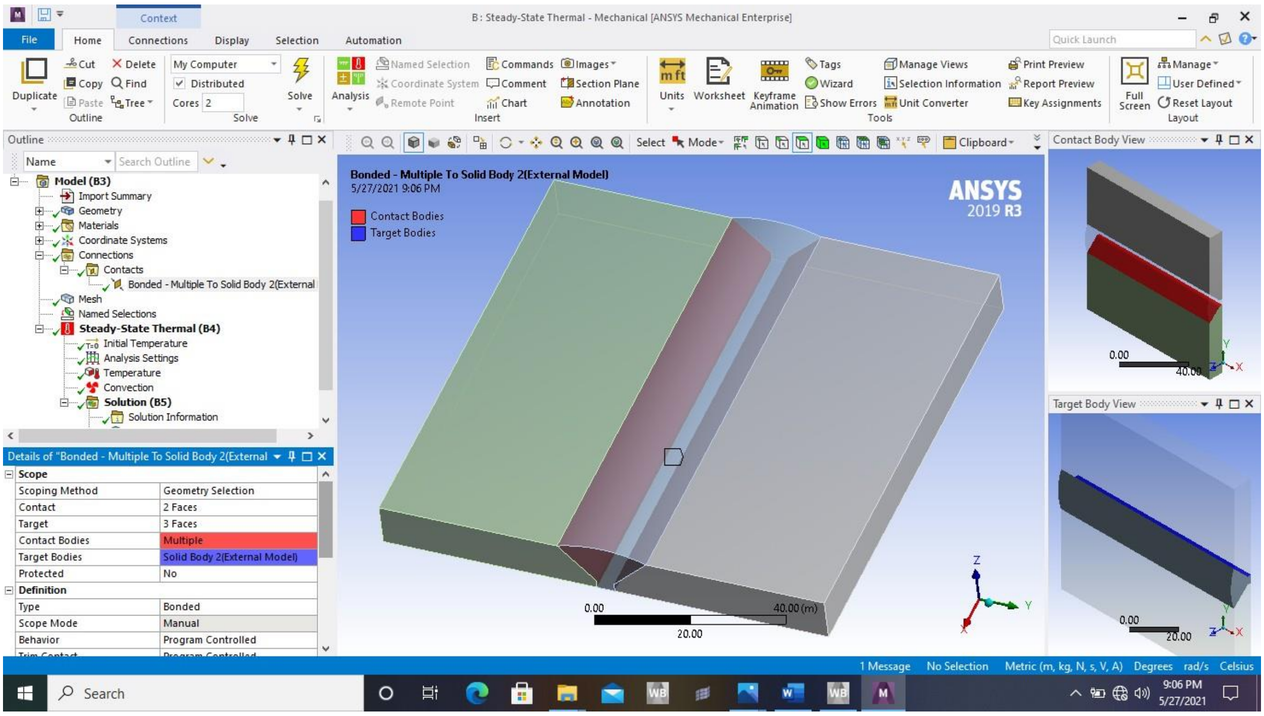


Figure-33: Contact

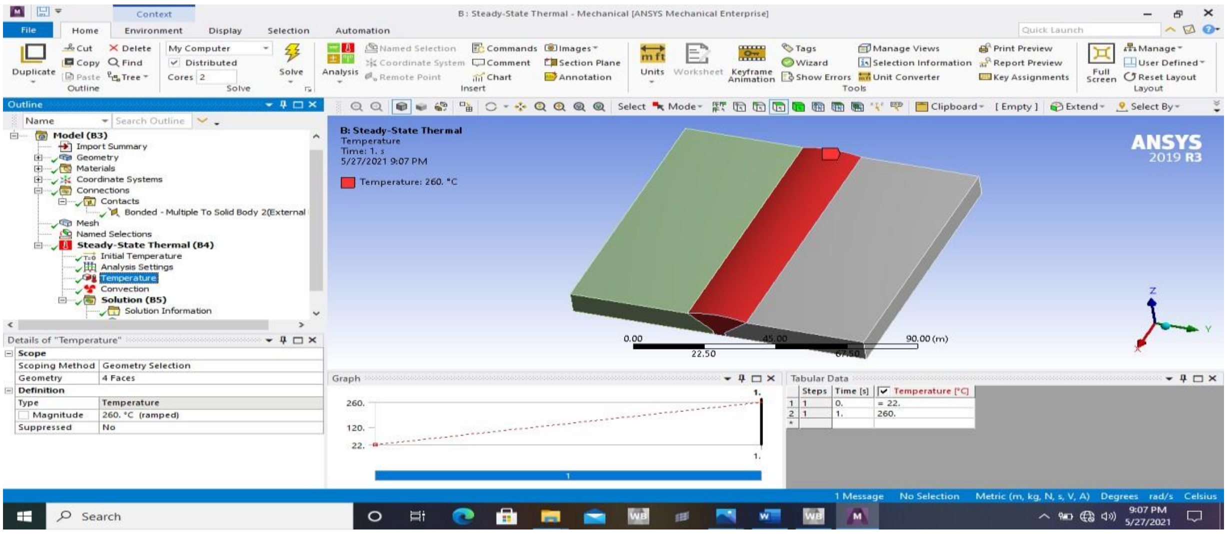


Figure-34 Temperature

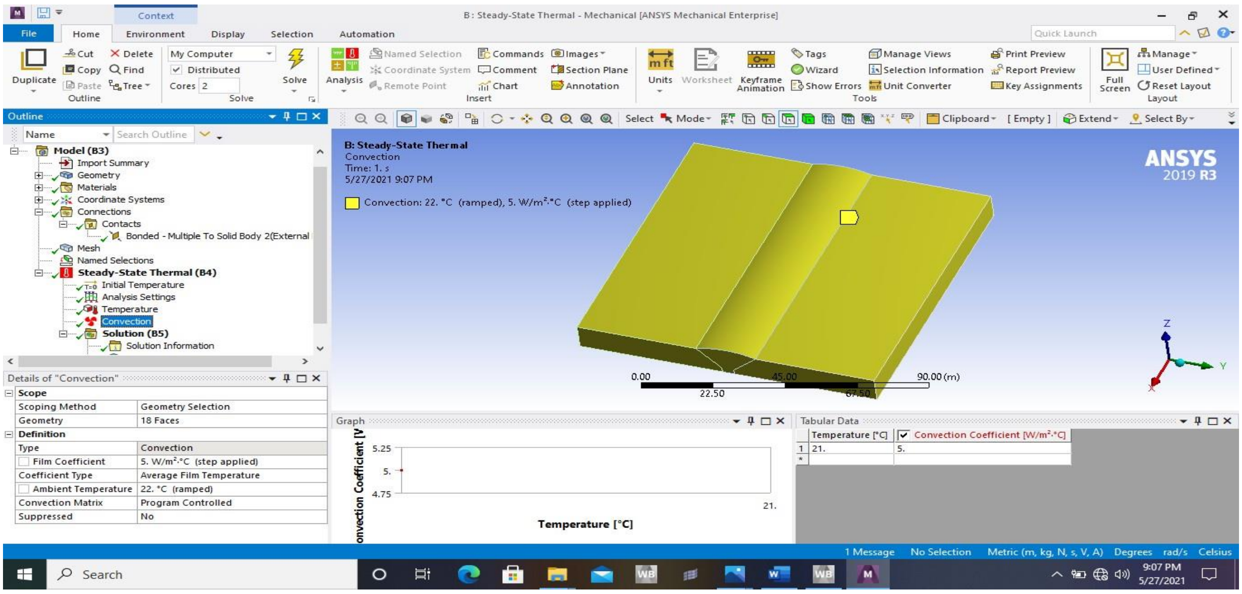


Figure-35 Convection

- Now we are using three different metallic fluxes in order to know which is more suitable.
  - i) Aluminum Rutile
  - ii) Calcite
  - iii) Dolomite
- We are checking maximum heat affect zone on welded plate by changing metallic fluxes and we are also taking the readings of heat transfer.

i) ALUMINUM-RUTILE:

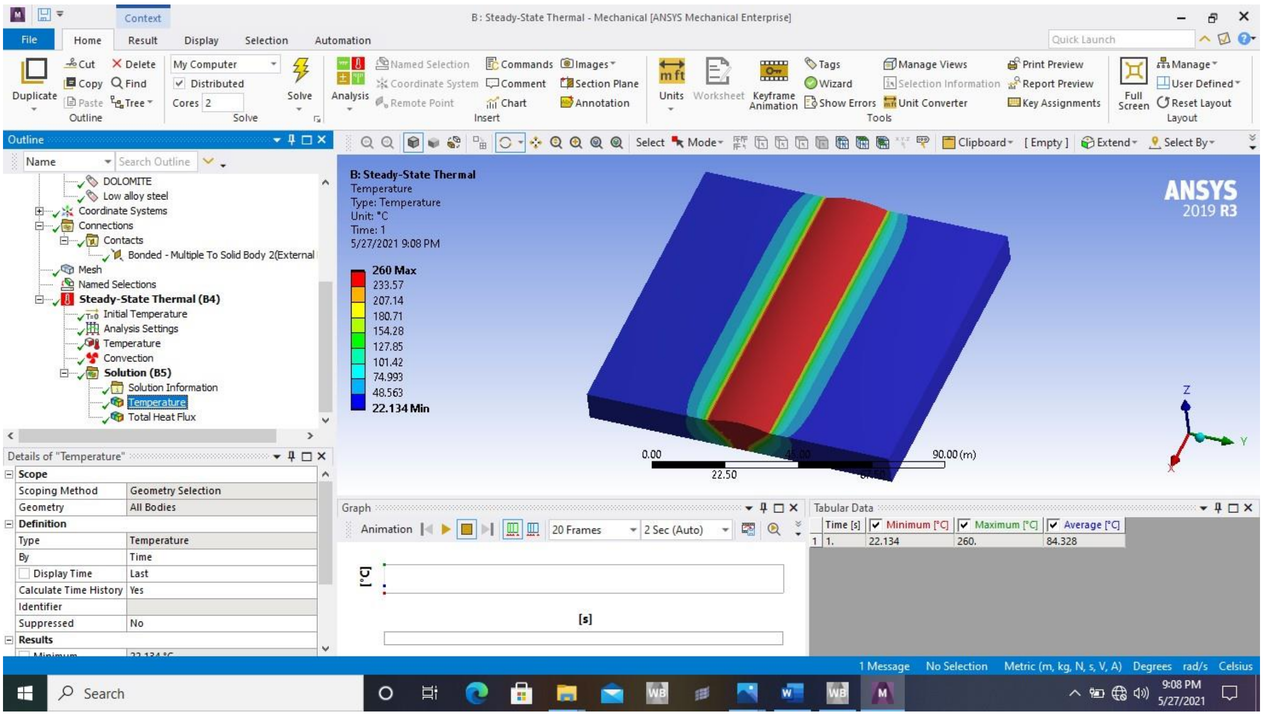


Figure-36 HEAT AFFECTED ZONE

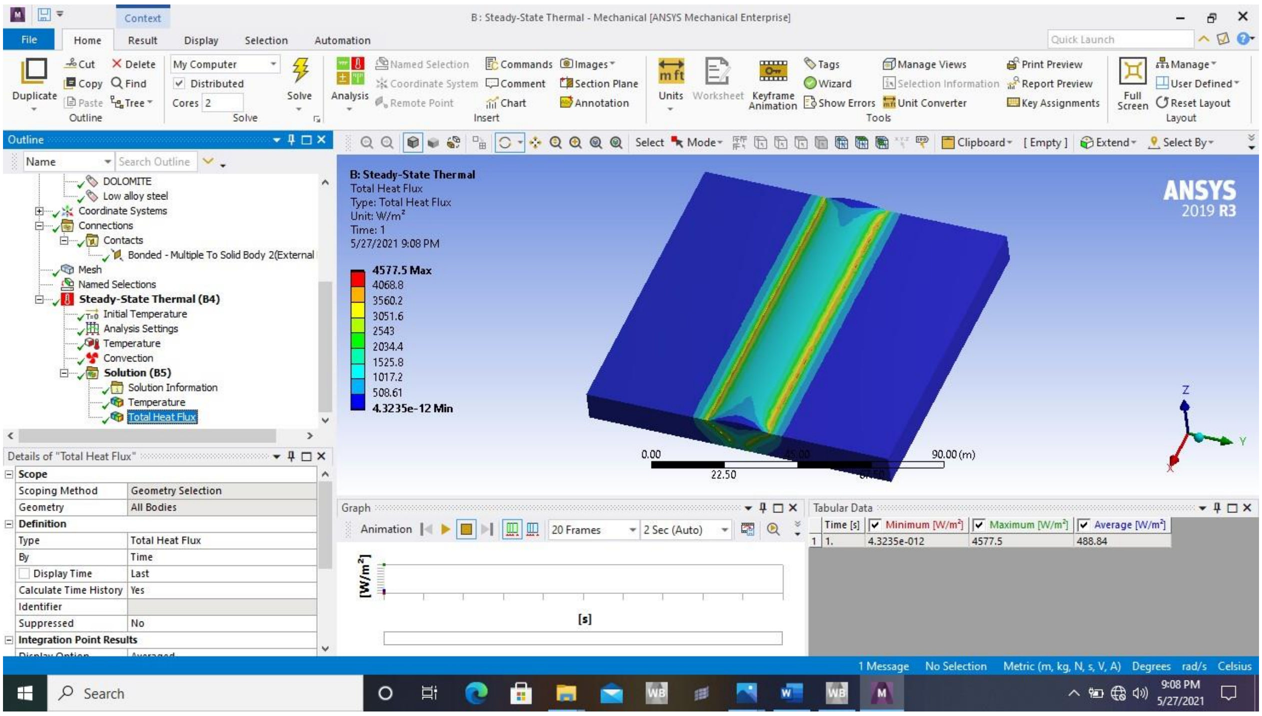


Figure-37: FLUX

- By using aluminum rutile metallic flux, we have got heat affected zone 260 max and heat flux 4577.5 max.

ii) CALCITE:

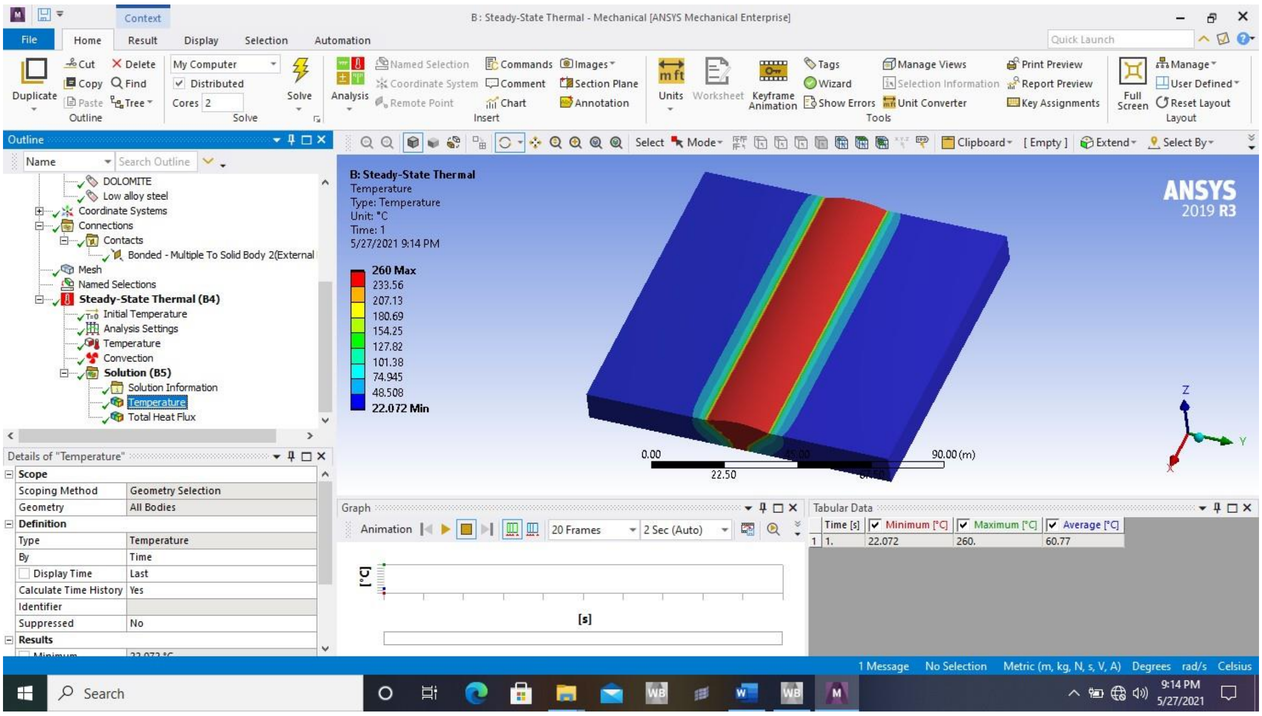


Figure-38: Calcite heat affected zone

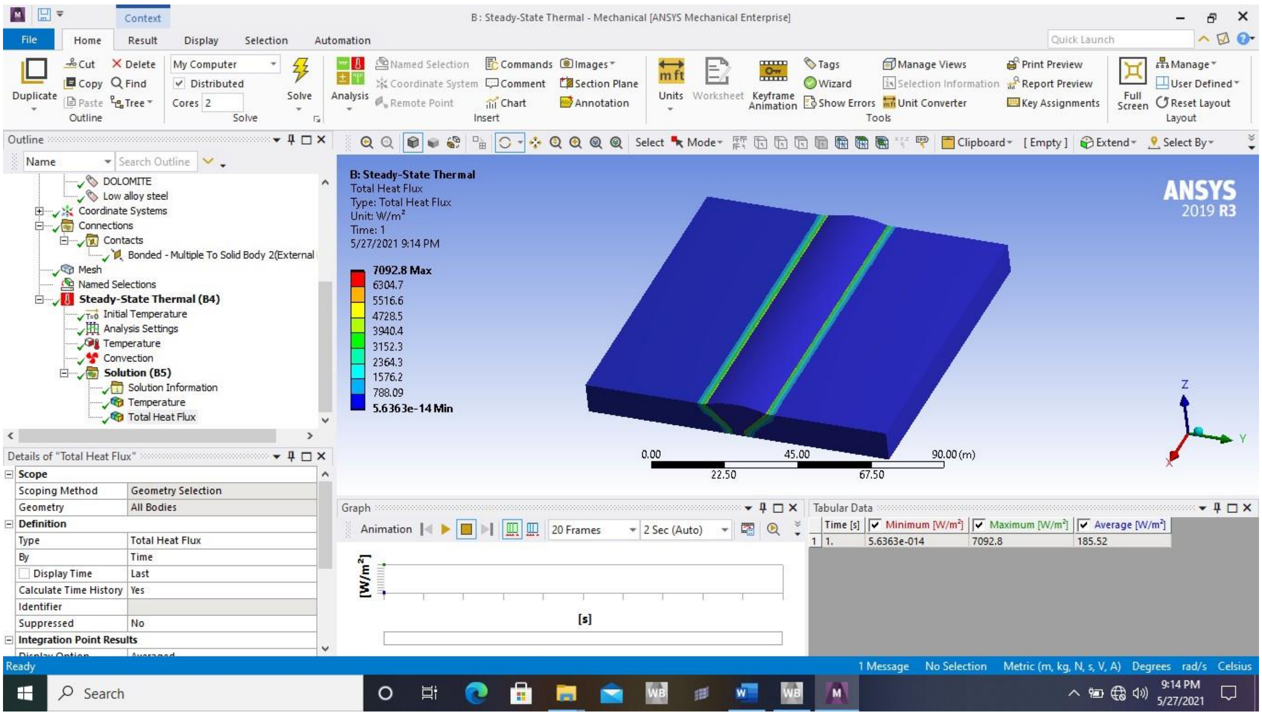


Figure-39: Calcite heat flux

- By using calcite metallic flux, we have got heat affected zone 260 max and heat flux 7092.8 max.

iii) DOLOMITE:

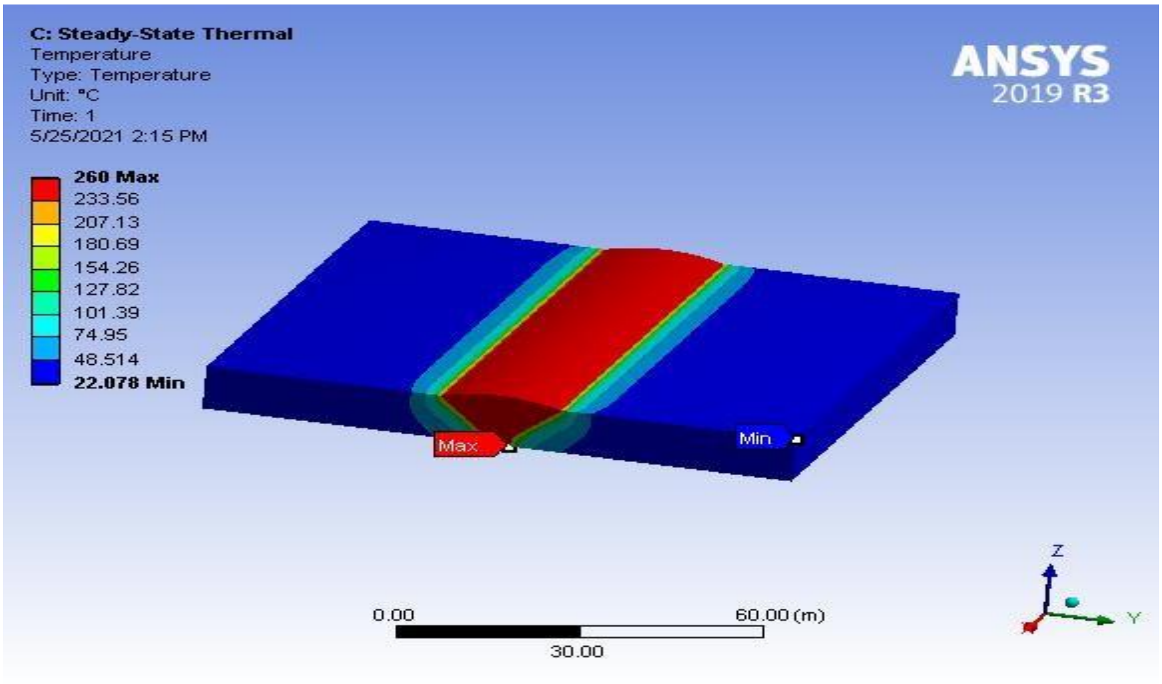


Figure-40: Dolomite Heat Affected Zone

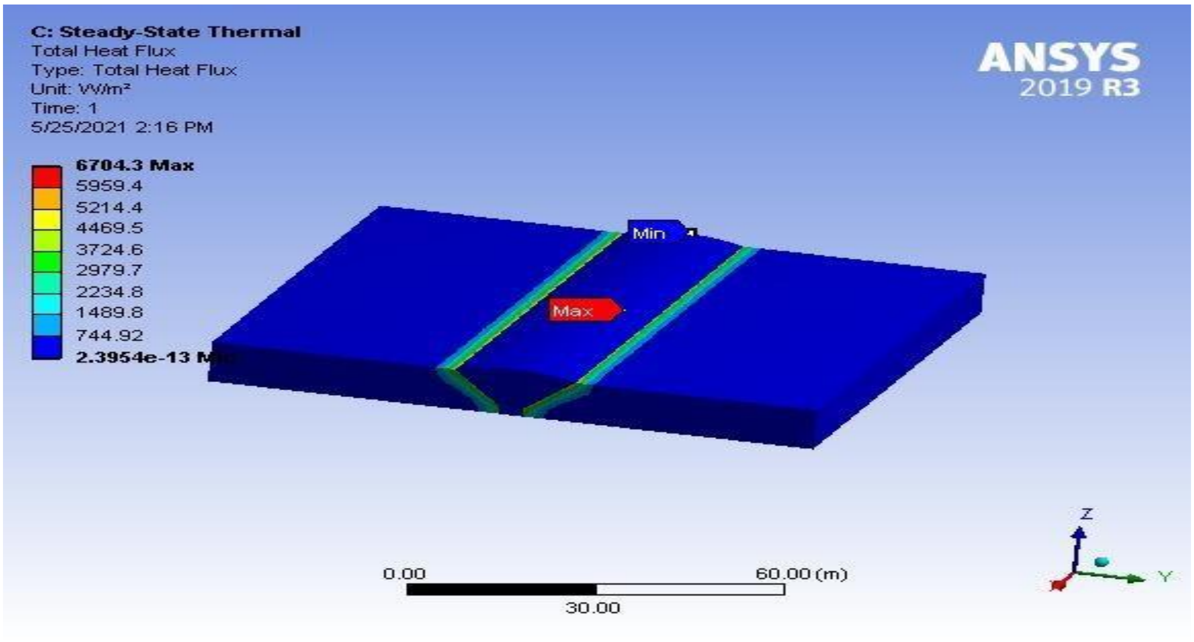


Figure-41: Dolomite Heat Flux

- By using calcite metallic flux, we have got heat affected zone 260 max and heat flux 6704.3 max.

4.3 RESULT

S.No	Metal Flux	Heat Affected Zone	Heat Flux
1.	Aluminium Rutile	260 Max	4577.5 Max
2.	Calcite	260 Max	7092.8 Max
3.	Dolomite	260 Max	6704.3 Max

Table 4: Result

CHAPTER-5 CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

The design and analysis are done through the recent software CATIA, HyperMesh and ANSYS. Which are mostly used for designing and analysis purpose.

After design we performed structural analysis with three different metallic fluxes.

Aluminum Rutile, Calcite, Dolomite.

- Hence by comparing all results of 3 different metallic flux.
- The calcite metallic flux has good heat flux rate by which heat affected zone is less.
- Maximum temperature values:

Heat Affect Zone - 260 max

Heat Flux - 7092.8max

FUTURE ENHANCEMENT

In future we can perform by using different metallic fluxes by changing it properties. In order to get maximum heat flow.

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Website:

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2. https://en.wikipedia.org/wiki/Altair_Engineering

A MAJOR PROJECT REPORT
On

EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF PROCESS PARAMETERS OF AWJM BY CFD FLOW ANALYSIS

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

By

M G SAMUEL	**-**	**(17K81A0336)**
R. DILIP KUMAR	**-**	**(17K85A0301)**
P. MADHU	**-**	**(17K85A0310)**
P. SAKETH KUMAR	**-**	**(17K85A0344)**

Under the Guidance of

Mr. T. PARAMESH
Associate Professor

DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)
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JUNE 2021

ST. MARTIN'S ENGINEERING COLLEGE

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(Approved by A.I.C.T.E, New Delhi, Affiliated to JNTU Hyderabad)

Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Experimental Investigation and Optimization of process parameters of AWJM by CFD flow analysis**, is being submitted by **M G Samuel (17K81A0336), R.Dilip Kumar (17K85A0301), P.Madhu (17K85A0310), P.Saketh Kumar (17K85A0344)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OFTECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Mr. T. PARAMESH
Associate Professor,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor& Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021,St. Martin’s Engineering College,Dhulapally,Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Experimental Investigation and Optimization of process parameters of AWJM by CFD flow analysis** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

M G SAMUEL	(17K81A0336)
R. DILIP KUMAR	(17K85A0301)
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P. SAKETH KUMAR	(17K85A0344)

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ABSTRACT

Here we need to run analysis on fluid dynamics and flow characteristics using Computational Fluid Dynamics (CFD), which is a science that uses data structures to solve issues of fluid flow like velocity, density, and chemical compositions. Here in CFD analysis we need to run experimental investigation of the general nature of flow through the nozzle and its results in rapid wear of the nozzle which affects the cutting performance. And we need to investigate how the flow is effected in mixing chamber which is connected with abrasive supply pipe and the nozzle

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CHAPTER-1. INTRODUCTION

1.1 Overview of the project:

Abrasive waterjet machining offers the potential for the development of a tool which is less sensitive to material properties, has virtually no thermal effects, and imposes minimal stresses. This process was first introduced as a commercial system in 1983 for cutting of glass. Nowadays, this process is being widely used for machining of hard to machine materials like ceramics, ceramic composites, fiber-reinforced composites, and titanium alloys where conventional machining is often not technically or economically feasible. The fact that it is a cold process has important implications where heat-affected zones are to be avoided. The heart of the abrasive waterjet system is the abrasive jet nozzle as shown. Water is pressurized up to 400 Mpa and expelled through a sapphire nozzle to form a coherent high-velocity jet. Abrasives are added into a specially shaped abrasive-jet nozzle from separate feed ports. Part of the waterjet's momentum is transferred to the abrasives

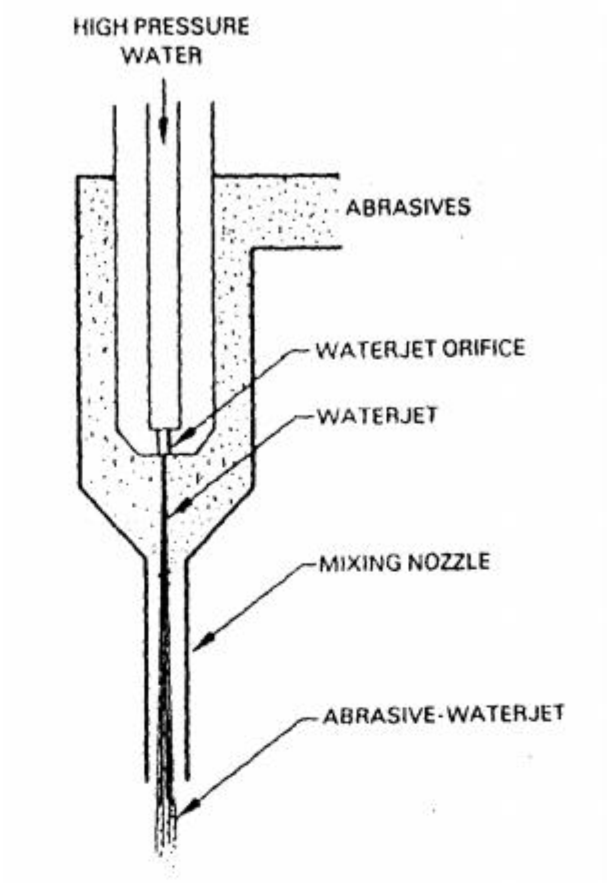


Fig.1 Schematic of abrasive waterjet nozzle

Whose velocities rapidly increase, as a result, a focused, high-velocity stream of abrasives exits the nozzle and performs the cutting action of the workpiece surface. The abrasive water jet machining system is composed of the following components: high pressure intensifier, waterjet, abrasive feed system, abrasive-jet nozzle, abrasive and water catcher, and supporting accessories such as hoses and control valves. There are several parameters that affect the cutting performance of the abrasive waterjet; hydraulic parameters; waterjet nozzle diameter and supply pressure, abrasive parameters; abrasive material, abrasive size and abrasive flow rate, mixing parameters; mixing tube dimensions and nozzle material, cutting parameters; traverse rate, standoff distance, impingement angle and depth of cut and material to be cut. Advantages of the process include the following minimal dust specially when cutting of asbestos, less thermal or deformation stresses i.e. the workpiece is cold cut, decreased power consumption, striation is reduced, high accuracy due to little workpiece deformation, no fire hazards because water is inflammable, the ability to cut almost any material, deep kerfing capability, high edge surface quality, and no heavy clamping of workpiece is needed. The following limitations are relevant to abrasive waterjet machining: high capital investments are required, high cutting power is required, delamination occasionally occurs, the jet has only a limited stability perpendicular to its own axis, and the process is noisy and produces a great deal of spray. The process has been extensively used in diverse fields of applications. An early study on practical applications of AWJM provided a comprehensive list of potential candid at materials that were successfully machined. Examples of industrial applications of AWJM are found. Machine tools for AWJM have been extensively developed in several companies for the last two decades. Several machine tools' designs are found. This paper is a review of recent developments in AWJM research. An attempt will be made to assess the present situation; namely, to find out what new knowledge is available today, what is lacking in research and applications, and how the situation could be improved. The paper will concentrate on new research findings obtained during the last two decades, which had produced many useful theoretical as well as experimental findings. Much of the research has dealt with mechanisms of material removal in different work materials, productivity and surface quality and some reviews on AWJM have been conducted so far. Comparison studies, especially between AWJM and laser, have also been conducted.

1.2 Objectives of study

To evaluate and optimize Inlet Pressure of water, Velocity of water, Mass flow rate of water, Mass flow rate of abrasive particles, velocity of water abrasive mixture. Here we need to run analysis on fluid dynamics and flow characteristics using Computational Fluid Dynamics (CFD), which is a science that uses data structures to solve issues of fluid flow like velocity, density, and chemical compositions. Here in CFD analysis we need to run experimental investigation of the general nature of flow through the nozzle and its results in rapid wear of the nozzle which affects the cutting performance. And we need to investigate how the flow is affected in mixing chamber which is connected with abrasive supply pipe and the nozzle Abrasive water jet cutting is highly used in aerospace, automotive and electronics industries. In aerospace industries, parts such as titanium bodies for military aircrafts, engine components (aluminium, titanium, and heat resistant alloys), aluminium body parts and interior cabin parts are made using abrasive water jet cutting. In automotive industries, parts like interior trim (head liners, trunk liners, and door panels) and fibre glass body components and bumpers are made by this process. Similarly, in electronics industries, circuit boards and cable stripping are made by abrasive water jet cutting. Surface roughness testing was carried out by surf-test stylus instrument. They found that the first texture was located at the top of the cut having smooth surface. The second texture was located at bottom of the cut having rough surface and also concluded that when the thickness was increased the surface roughness was increased. When the traverse speed increased the surface become rougher, And while the depth of cut increases, the surface roughness also increased. Surface roughness slightly changes by increasing the abrasive mass flow rate. The higher productivity with nominal surface roughness can achieve by minimum traverse speed. By increases in abrasive mass flow rate, smooth surface can be achieved

1.3 Scope of study

AWJM replace the conventional machining of hard and difficult to cut materials, namely the Ultrasonic Machining, Laser Beam Machining and Electro Discharge Machining, which are slow machining process and also damage the surface integrity of the material. The AWJM process has sought the benefits of combining with other material removal methods to further expand its applications and improve the machining characteristics. Many researchers excluded influence of nozzle size and orifice diameter during the study of the performance characteristics. Many research scholars done investigation on influence of input process parameters on single quality characteristic as an objective during optimization of AWJM (like MRR, SR, Kerf characteristics, depth of cut).Very few literature is available on Multi objective optimization process. Now present scholars found it as the direction of future investigation work. No literature available so far for multi response optimization of process variables and more work is required to be done in this area. Also, various experimental tools used for optimization (such as Taguchi method and RSM) can be integrated together to incorporate the advantages of both simultaneously. Very little research literature was available on nozzle wear.

Research may be carried on the optimization for the power consumption, dimension accuracy and multi objective optimization of AWJM process. The scope of applications of CFD thus seem to be wide in the engineering disciplines in mechanical and aerospace engineering involving primarily flow and thermal analysis studies. Hence mathematics, flow physics, advanced numerical method are paramount for modeling. As technology advances, understanding the mechanism behind hybrid nontraditional processes is prerequisite for its effective commercial application. So many investigations so far had done on AWJM process. Study of process parameters such as abrasive flow rate, traverse speed, standoff distance, pressure, abrasive size, orifice diameter and performance measures as Surface roughness (SR), Material removal rate (MRR), kerf width, Depth of cut (DOC) is carried out more by researchers we can see many different materials can be taken as target material and different abrasives can be used. Work can be extended in terms of micro-structure and hardness of materials. Also it can be work to identify suitable abrasives. We can see many different materials can be taken as target material and different abrasives can be used. Work can be extended in terms of micro-structure and hardness of materials. Also it can be work to identify suitable abrasives. The erosive jet spread over a larger effective footprint in air compared to water. Moreover, the instantaneous centerline erosion rate and volumetric erosion rates reduced with channel depth. The decrease in erosion rate due to the stagnation zone was shown to be only a function of channel geometry, and was independent of the standoff distance, jet angle, jet direction (forward or backward machining) and whether the jet was submerged or in air. Width of the channel machined in water was thin compared to the air. It is shown that submerged AWJM results in narrower features than those produced while machining in air, without a decrease in centerline etch rate Submerged AWJ micro machining also has the great benefits that it releasing less abrasive debris to the air and noise can be reduced. Because of these capabilities, this cutting process is more cost-effective than traditional and some non-traditional machining processes the cut geometry depends on the type of abrasive grit and cutting parameters. Different types of abrasives are used in AWJM like garnet, olivine, Aluminum oxide (Al_2O_3), silicasand, glass bead, silicon carbide (SIC), zirconium, etc. But a survey shows that 90% of the AWJM is done using garnet as an abrasive. The hardness of the abrasive particles is an important characteristic which strongly influences the cut geometry and that the depth of jet penetration depends strongly on the ratio of the hardness of the target material to the hardness of the abrasive. AWJM involves quite a few parameters that can affect the cutting performance like cutting parameters stand of distance, traverse speed, impact angle and number of passes. Hydraulic parameters like water pressure, orifice diameter, water Jet etc.

1.4 Material requirement

- **Advanced Composite**

Materials Advanced composite materials (ACMs) are also known as advanced polymer matrix composites. These materials are having high strength, dimensional stability, light weight with high stiffness, temperature and chemical resistance and easily process as compared with other materials done investigation on the influence of different parameters like Pressure, SOD, Time, Abrasive grain size, nozzle diameter on the Metal removal of FRP (Fiber Reinforced Polymer) composite by Abrasive jet machining. Investigation on machinability of SiC Particle Reinforced Metal Matrix Composites by non-conventional machining process such as Electro Discharge Machining (EDM), laser cutting and Abrasive Water Jet (AWJ).The surface integrity of the different machining processes are examined and compared. Research work on Electro discharge machining of metal matrix composites. Research on Laser cutting of titanium metal matrix composites.

- **Granite/Marbles**

Granite is a common type of felsic intrusive igneous rock that is granular and phaneritic in texture. Granites can be predominantly white, pink, or gray in color, depending on their mineralogy investigations on the behavior of five artificial rocklike materials subjected to abrasive water jet cutting. The effects of the AWJ operating variables on the kerf width were studied and the rock properties were correlated with the kerf widths. From the experimental results they observed that standoff distance and traverse speed are significant effect on the kerf widths. Due to their unique characteristics such as excellent resistance to environmental effects and attractive decorative properties, granites has a special interest among natural stones. Abrasive Water Jet (AWJ) cutting is being increasingly seen as a most promising machining method

- **Advanced Ceramic Materials**

Latest ceramic materials are silicon carbide, aluminum nitride, silicon nitride, zirconium, alumina, and titanium-based materials, which are offering high performance characteristics as compared with unconventional materials. Investigation conducted to assess the influence of Abrasive jet machining process parameters on MRR and Kerf of fiber glass. Research investigation on machining of Alumina ceramics by varying the Ultra sonic machining process parameters such as abrasive grit size, slurry concentration, power rating, tool feed rate and slurry flow rate. Experiments by laser machining for shaping ceramic, defocused laser beam is applied throughout the length of the groove-cracks to generate a great thermal stress, which makes the two groove cracks link together. The material removal is due to the linkage of the groove-cracks from the experimental results they observed surface roughness and the inspection of crack defects. Additive manufacturing (AM) has the potential to disrupt the ceramic industry by offering new opportunities to manufacture advanced ceramic components without the need for expensive tooling, thereby reducing production costs and lead times and increasing design freedom. Whilst the development and implementation of AM technologies in the ceramic industry has been slower than in the polymer and metal industries, there is now considerable interest in developing AM processes capable of producing defect-free, fully dense ceramic components. A large variety of AM technologies can be used to shape ceramics, but variable results have been obtained so far. Selecting the correct AM process for a given application not only depends on the requirements in terms of density, surface finish, size and geometrical complexity of the part, but also on the nature of the particular ceramic to be processed. This paper provides a detailed review of the current state-of-the-art in AM of advanced ceramics through a systematic evaluation of the capabilities of each AM technology, with an emphasis on reported results in terms of final density, surface finish and mechanical properties. An in-depth analysis of the opportunities, issues, advantages and limitations arising when processing advanced ceramics with each AM technology is also provided.

- **A. Glass**

Glass is a non-crystalline amorphous solid material. This is widely used in decorative usage for tableware, window panes and decorative usage. Silicate glass is the oldest glass. Anixter, E Glass products have applications in design engineering, and they can solve many special problems. These materials can work in situations in which plastics and metals would fail and need to be part of designer’s repertoire. Investigation on drilling of soda lime glass by abrasive hot air jet machining to find the effect on MRR and Ra. J.M. Fan et al, developed mathematical model for micro-hole drilling and micro-channel cutting on glass. They compared predictive models results with experimental investigation results and concluded that both are in good in agreement with experimental results

- **B. Alloys**

An alloy is a mixture of a metal and another element. Alloys are defined by a metallic bonding character. An alloy may be a solid solution of metal elements (a single phase) or a mixture of metallic phases (two or more solutions) Examples of alloys are brass, bronze, solder, steel, duralumin and bronze. Vasanth’s et al, done investigation on machine ability of titanium alloy. They find the influence of process parameters on surface roughness and topography for enhancing the process. From the experimental results it has been observed that the abrasive flow rate and standoff distance has the most significant role on determining surface quality. M. Uthayakumar et al research work done on machinability of nickel-based super alloys. Selected process parameters are water jet pressure, traverse speed of jet nozzle, and standoff distance. By varying the selected process parameters they evaluated difference in kerf width, kerf wall inclination, and material removal rate (MRR).from the experimental results they observed that jet pressure is the most significant factor influencing the surface morphology and surface quality. K.S. Jai Aultrin et al done research work on effect of process parameters on Material removal Rate and Surface roughness, while machining of copper iron alloys. They developed a predictive model for MRR and SR by regression analysis. From the experimental results they found that water pressure, abrasive flow rate, orifice diameter, nozzle diameter and standoff distance and along with their interactions have significant effect on the MRR and SR. pure aluminum and Al 6061 aluminum alloy as a target material. Adnan Akkurt uses the conventional and various nontraditional machining processes to investigate Microstructures and hardness variations of cut surfaces of the material. Target material had been cut with saw, milling, submerged plasma, plasma, laser, wire electric discharge machining, and oxy-fuel and Abrasive water jet. Adnan Akkurt uses GMT Garnet (80mesh) as an abrasive material having hardness 7.5-8 Mohs in AWJM. The aluminum alloy plate having thickness of 20 mm. The abrasive mass flow rate 250 g/min was taken. The study shows that the hardness and surface quality of the cut surface is affected from the kind of cutting process.

1.5 Procurement equipment

A schematic layout of AJM is shown in Fig-1.The filtered gas supplied under pressure to the mixing chamber containing the abrasive powder and vibrating at 50c/s, entrains the abrasive particle and is the passed into a connecting hose. This abrasive and gas mixture emerges from a small nozzle at high velocity. The abrasive powder federate is controlled by the amplitude of vibration of the mixing chamber. A pressure regulator controls the gas flow and pressure.
The nozzle is mounted on a fixture. Either the work piece or the nozzle is moved by cams pantograph or other suitable mechanisms to control the size and shape of the cut. Hand operation is sometimes adequate to remove surface contaminations or in cutting where accuracy is not very critical. Dust removal equipment is necessary to protect the environment. Commercial bench mounted units including all controls, motion producing devices, and dust control equipment are available.

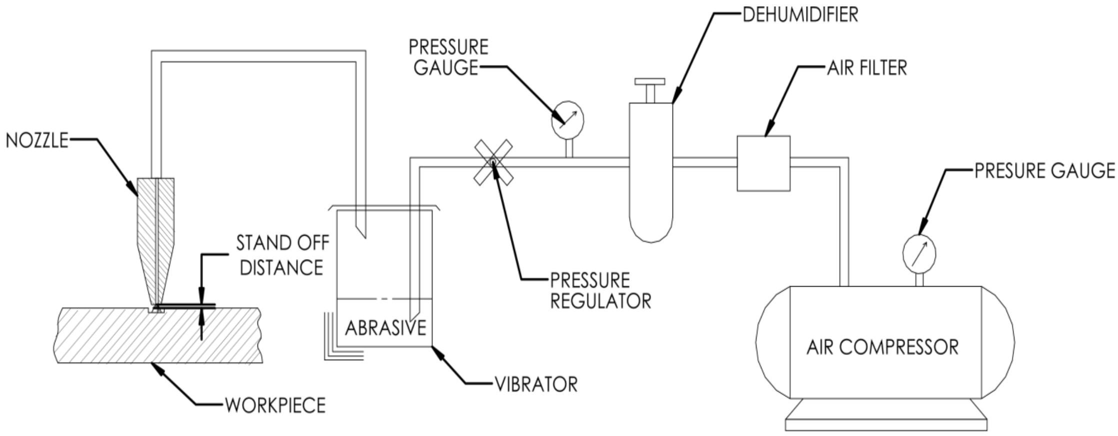


Fig 2: SCHEMATIC LAYOUT OF ABRASIVE JET MACHINE

The major components are:

1. Air compressor.

2. Air filter.

3. Dehumidifier.

4. Pressure Gauge.

5. Pressure Regulator.

6. Vibrator or Mixer.

7. Nozzle.

8. Horizontal and vertical motion module (for xyz motion).

9. Arrangement to hold the workpiece.

10. Types of abrasive

11. Size of abrasive grain

12. Velocity of abrasive jet

13. Flow rate of abrasive

14. Work material

15. Geometry, composition and material of nozzle

16. Nozzle work distance (standoff distance)

17. Carrier gas

Characteristics of different Variables:

Medium	Water
Abrasive	Silicon carbide
Flow rate of abrasive	0.0042kg/s
Pressure	100kpa
Material of nozzle	Tungsten Carbide
Nozzle life	10-15 hrs.
Work material	Non Metals like glass, ceramics, and granites. Metals and alloys of hard materials like germanium, silicon etc.
part application	Drilling, cutting, deburring, cleaning

Table 1. Characteristics of different variables

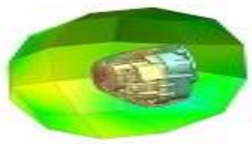
1.6 Introduction to Uni Graphics:

NX, formerly known as NX Unigraphics or usually just UG, is an advanced high-end CAD/CAM/CAE software package originally developed by Unigraphics, but since 2007 by Siemens PLM Software. It is used, among other tasks, for Design (parametric and direct solid/surface modelling)Engineering analysis (static; dynamic; electro-magnetic; thermal, using the finite element method; and fluid, using the finite volume method).Manufacturing finished design by using included machining modules. NX is a direct competitor to TopSolid, CATIA, Creo, Autodesk Inventor, and SolidWorks. NX for Design is an integrated product design solution that streamlines and accelerates the product development process for engineers who need to deliver innovative products in a collaborative environment. Unlike CAD-only solutions and closed enterprise solutions, NX for Design offers the highest level of integration between development disciplines in an open, collaborative environment.NX11 Product Engineering Software Revolutionizes Development

NX 11 for Design: Transform Product Engineering

Better design starts with better software. Transform your product engineering processes with NX 11. The latest release of NX introduces capabilities for convergent modeling, rapid manufacturing, with improved annotation, drafting and documentation, and rendering. Active Workspace in NX 11 is built around these items to provide seamless access to PLM capabilities right within NX.

NX 11 for Design



Simcenter 3D now powers all of Siemens' simulation capabilities for predicting product performance. You have all of the capabilities of NX CAE, along with new ones for acoustics, motion tire models, advanced report writing, and more. Simcenter 3D delivers a unified, scalable, and open environment for 3D CAE with connections to design, 1D simulation, test and data management. Speed your simulation process with Simcenter 3D.

NX 11 for Manufacturing: Digitalize Production

The new robotics machining and groundbreaking hybrid additive manufacturing capabilities in NX CAM let you produce new categories of parts. With Line Designer you can easily compare the physical plant with the virtual layout model by using the cloud data. NX CAM provides a new-level of efficiency to program any job, reduce machining cycle and improve quality. NX CMM now lets you create high-speed inspection methods. NX Tooling Design provides increased productivity when designing molds and progressive dies.

1.7 Ansys introduction:

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable.
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.
- The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material.

- A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.
- A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

Organization of Ansys program

The ANSYS program is organized into two basic levels:

- Begin level (Start level)
- Processor (or routine) level

Begin level acts as a gateway into and out of the ANSYS program. Changing the name of job, database clearing, and binary files copying are program controls used. When we first enter the program, we at the begin level.

At the processor level, several processors are available; each processor is a set of functions that specific analysis task perform. For instance, the general preprocessor (PREP7) is the place we fabricate the model, the arrangement processor (SOLUTION) is the place we apply stacks and get the arrangement, and the general postprocessor(POST1) is the place we assess the outcomes and acquire the arrangement. An extra postprocessor (POST26), empowers we to assess arrangements results at particular focuses in the model as an element of time.

CHAPTER-2. LITERATURE REVIEW

2.1 Literature review

Abrasive Waterjet Machining System

In the AWJM system, materials are removed using erosion processes. Erosion is a type of wear with the manifestation of accelerating and the continuous collision of abrasive particles in a high velocity in liquid form. An example of a typical AWJM is shown in Figure 1. The underlying operating structure of AWJM includes a high-pressure pump system, a cutting head, a table and a computer-based controller

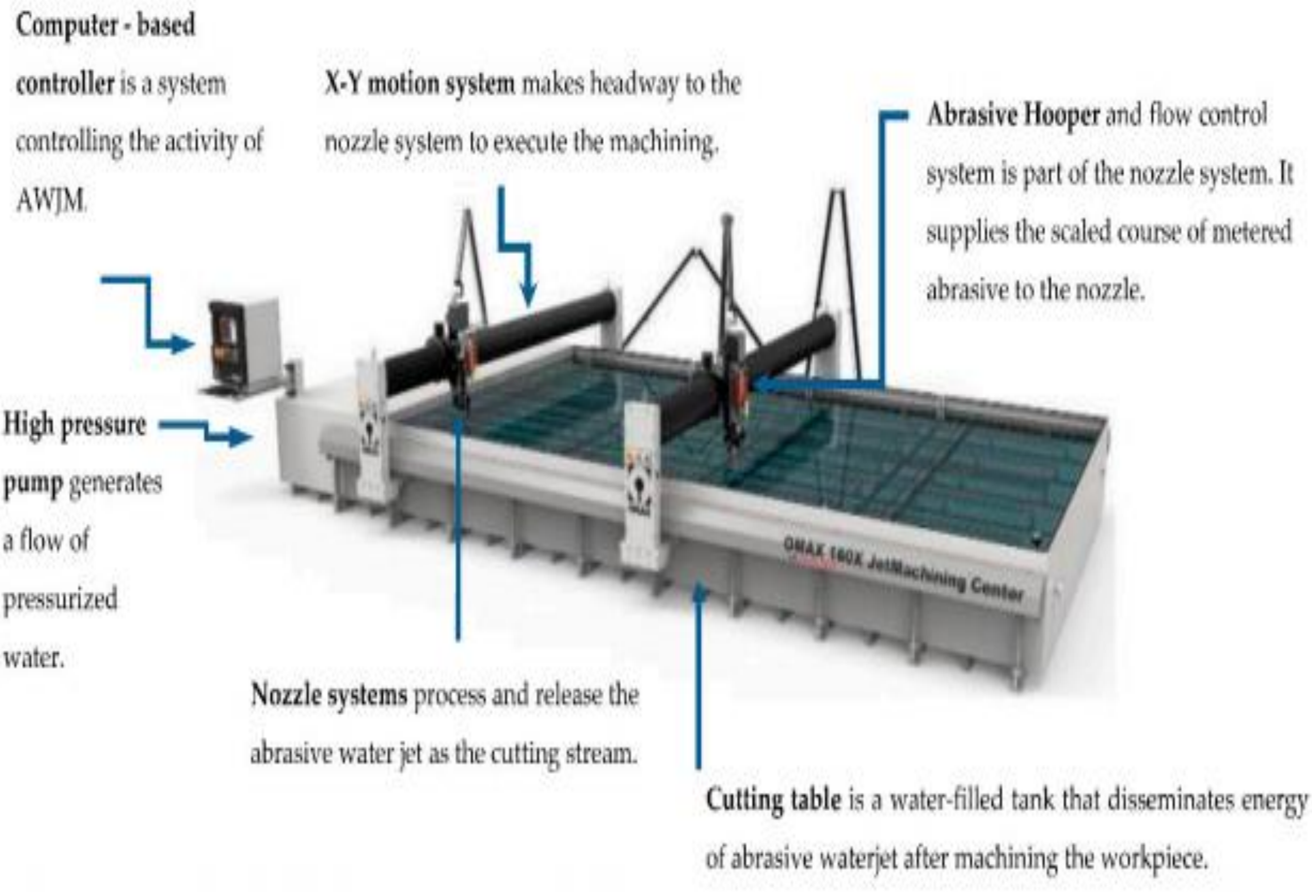


Fig no.3 AWJM mechanism and components

The computer-based controller is incorporated into the AWJM system, functioning independently, which enables to download varied types of diagram programs. This comprises tools that are distinct to AWJM, such as manual or automatic cut in/out tools, tools for the generation of cutting paths, collision prediction and resolution, tool assignment for surface quality, etc. Mixing the granular abrasive with a high-pressure waterjet stream makes the AWJM capable of machining. A high-pressure pump drives the pressurized water in the nozzle system. This system includes an abrasive hopper, orifice, mixing chamber and focusing tube. The water travels with a high level of velocity and is forced out of the orifice in a very thin stream structure. A hopper that includes a plastic tube holds abrasive particles and dispenses them to the cutting head, where particles are then drawn into a waterjet stream in the mixing chamber. The high-speed waterjet, set alongside abrasive particles, is compounded and accelerated to create an abrasive waterjet. The focusing tube directs the abrasive waterjet to its focal point when cutting a working piece

Abrasive Waterjet

Erosion Mechanism the AWJM process of removing material from a target workpiece emerges through an erosive venture of abrasive particles travelling with high velocity. Material removal rates in AWJM transpire across two primary models, such as cutting and deformation/ploughing deformation wear mechanism. Erosion mechanisms vary depending on workpiece material and properties. A workpiece can be categorized as ductile, brittle or composite. In ductile materials, erosion can occur using two procedures, i.e., repeated plastic deformation and cutting action. In general, ductile erosion is applicable to metals and other similar materials that are capable of a significant plastic deformation process. For the brittle materials erosion process, removal of material occurs through crack propagation and chipping, resulting in contact stresses caused during the impact of abrasive particles, which is then defined as the cracking method. In the case of composite materials, abrasives penetrate the material and produce breakages that initiate the formation of cracks, which in turn results in delamination

AWJM Process and Advantages

The cutting process is a core method in the manufacturing industry. AWJM is highly capable of machining from hard to soft materials at a very low machining force, which avoids the destruction of the target workpiece's properties. Abrasive waterjet machining is a non-conventional cold processing technology used for material processing with significant advantages which has been the reasoning behind the rapidly progressing application of AWJM, particularly in metallic materials. The reduction of temperature is carried through the presence of cooling water due to the presence of cooling water, which renders AWJM's superiority compared to other non-conventional machines based on experimental studies on various workpieces. It substantiates AWJM compared to other technologies, indicating versatility in cutting diverse material with a wide range of thickness, absence of tool wear and flexibility in cutting intricate geometries. Other machines such as EDM and ECDM involve the use of high-intensity energy to cut hard metals and materials that are difficult to machine. However, the usage of high thermal heating sources causes craters, cracks, thermal damages, and destructively tensile residual stresses; hence, materials that are low conductors of heat are very applicable. In AWJM applications, the absence of thermal distortion is achieved due to its cold cutting process since the material temperature will not exceed 70 ◦C. EDM and ECDM generate hazardous solid, liquid, and gaseous products resulting in sludge containing metal ions, acids, nitrate, oils and even traces of heavy metal ions due to anodic electrochemical dissolution, which are very harmful to humans and the environment AWJM is also considered environmentally friendly and sustainable as it does not omit any hazardous vapor; hence, AWJM generates waste such as abrasives that adversely affect the environment. Sustainable manufacturing aims to achieve an efficient operation at the same time, reducing the environmental effect. Recycling and reusing these abrasives make AWJM more economical, effective, and environmentally friendly. The discussed competitive advantages of AWJM have been the rational reason behind its expanding utilization and continuous progression.

Abrasive Waterjet Cutting Process Parameters and Influences

The abrasive waterjet (AWJ) cutting process incorporates several independent process parameters that directly affect the machine's performances. As illustrated in the cause and-effect diagram of the AWJM process parameters given in Figure 4, the input process parameters are categorized as follows (1) hydraulic, (2) nozzle, (3) material, (4) abrasive, and (5) cutting. The input process parameters primarily affect the machining performance or output parameters of AWJM application learning the variables will be fundamental towards development and improvement initiatives of quality and efficiency of the entire cutting process.

Various materials used in 2017-2020 In the past and recent years, AWJM has gained high interest amongst researchers, as it is a versatile tool that is used in almost all manufacturing processes and materials. Figure 2 presents the statistics of various workpieces utilized in AWJM applications, as established from several reviewed publications [25–66]. The first chart (a) shows a generated summary of various workpieces that have been employed in AWJM applications, while the second chart (b) represents created synopsis material types for enhanced analysis based on several research studies used from the year 2017 to 2020

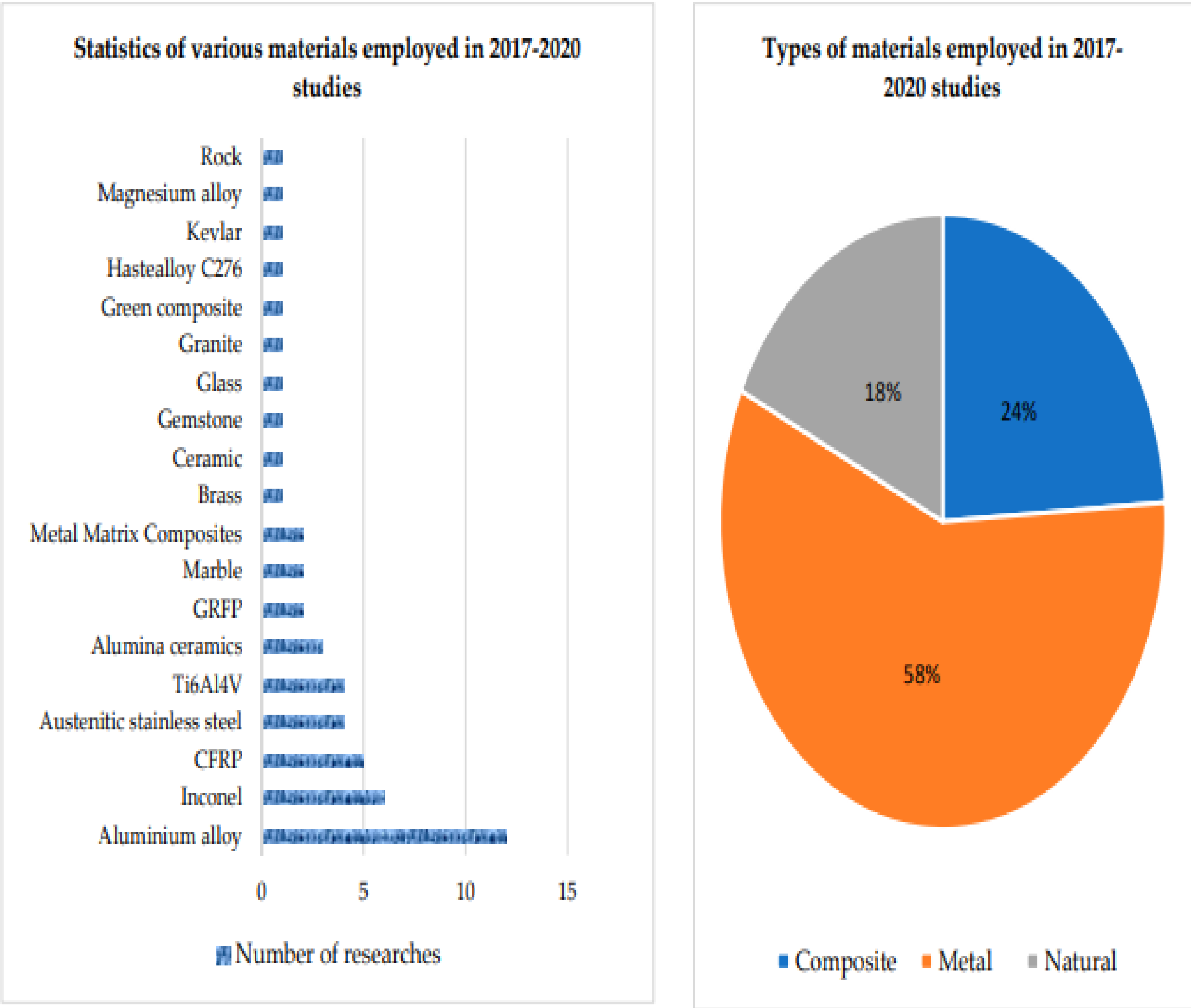


Fig no.4 Various materials used in 2017-2020

2.2 Literature survey

1. Pure water jet cutting

With pure water, both soft and stronger, tough materials can be processed. In this process, the individual parts are separated by pure, filtered water. Since no dust or chips are generated or toxic gases are released, this variant of water jet cutting is environmentally friendly. After completion of the cutting process, the water can continue to be used and finally fed into the water cycle. The diameter of the water jet is relatively small, which prevents the formation of drops. It can be less than 0.1 mm. especially with materials of only small thickness, optimum, precisely fitting cutting results can be achieved. As a rule, machines with several nozzles are used, which are mounted on one or more traverses. If a pressure of 4000 bar is built up during the cutting process, it is possible to accurately separate textiles up to a thickness of 30 mm.

2. Components of water jet cutting

A water jet cutting machine consists of the following main components, which can be combined in different ways:

Memory
Guiding machine (CNC-controlled)
High-pressure piping
Oil tank and oil pump
Pressure intensifier
Electric motor
Water treatment for desalting and filtering
Nozzle with diameter between 0.1 and 0.5 mm and valve

In addition, a machine for water jet cutting is constructed as follow:

Machine frame: The axes of the machine are supported by steel tubes. The guides are milled, scraped, ground or annealed with low tension. A laser interferometer checks the frame and the guide for correct alignment and aligns them with dowels. For water jet cutting, a portal design is generally preferred, whereby a distinction is made between flat boards for normal work and high portal systems for special dimensions. In this way, it is also possible to design very large machines with a gantry span of up to 5000 mm. The two guide axes can be coupled via a CNC control, which means that both axes act as one. There are also variants as support arms with a one-sided cross beam guide. This simplifies access to the cutting area, and the purchase price of these machines is also lower. In the past, water jet cutting worked more precisely with the portal design, as there were fewer vibrations. However, newer support arm systems are now vibration-reduced, so you can achieve the same performance as with a portal machine.

Jet destroyer: After the water jet has fulfilled its task, there is still a high residual energy in the jet itself. Water basins are often used as a kind of jet catcher to reduce this energy. A water column of 600 mm is recommended so that this residual energy can be converted into heat. This water basin should be separated from the machine itself, otherwise the water can heat up to two-digit temperatures after a few hours of work. If the pool and the machine are coupled, there may be long-term displacements that affect the cutting precision. In addition, there are the so-called catcher, which in water jet cutting refers to a catch basin that is adapted to the movements of the cutting axis. Catchers have an extreme sound emission, in addition a lot of splash water occurs. The residual energy is converted by integrated ceramic balls. There are only small amounts of water in circulation. For this reason, the heating takes place faster, but is decoupled from the workpiece.

High-pressure pump: A high-pressure pump is used to ensure that the water jet is as pulsation-free as possible when cutting water. Simple models are only operated with compressed air, which can lead to poor efficiency. High pressure pumps, which generate a **pressure of up to 200 bar** using oil hydraulics, are more common for water jet cutting. A proportional valve enables pressure control. Compressed oil is first pumped into the high-pressure booster. There it acts with transmission ratios of 20:1-40:1 on the water surface. This enables a pressure of **up to 6200 bar**. The water then passes into a pulsation damper, which functions like a high-pressure gas accumulator as a kind of buffer cylinder with 1 to 2 l volume. This dampens pressure fluctuations when the hydraulic piston is reversed. The larger these buffers are designed, the better the cutting performance. Today's systems have an output of between 11 and 149 kW at a flow rate of up to 15.2 l per minute. Newer machines use cutting pump units with plunger pumps that can directly generate a pressure of **4100 bar**. This eliminates the need for hydraulics and the pulsation damper due to the low pulsation. The volume flow generated is up to 100 l/m at a pressure of 3800 bar and a drive power of 7450 kW. In addition, there are different drive concepts for the high-pressure pumps for water jet cutting in comparison.

Hydraulic power pack: The hydraulic power pack delivers the hydraulic oil to the intensifier at a pressure. The ratio of cross-section of the two cylinders in the intensifier is say A ratio (A = A large / A small). Thus, pressure amplification would take place at the small cylinder as follows. Thus, if the hydraulic pressure is set as 100 bar and area ratio is 40, pw = 100 x 40 = 4000 bar. By using direction control valve, the intensifier is driven by the hydraulic unit. The water may be directly supplied to the small cylinder of the intensifier or it may be supplied through a booster pump, which typically raises the water pressure to 11 bar before supplying it to the intensifier. Sometimes water is softened or long chain polymers are added in “additive unit”. Thus, as the intensifier works, it delivers high pressure water (refer Fig. 6). As the larger piston changes direction within the intensifier, there would be a drop in the delivery pressure. To counter such drops, a thick cylinder is added to the delivery unit to accommodate water at high pressure. This is called an “accumulator” which acts like a “fly wheel” of an engine and minimizes fluctuation of water pressure High-pressure water is then fed through the flexible stainless steel pipes to the cutting head. It is worth mentioning here that such pipes are to carry water at 4000 bar (400 MPa) with flexibility incorporated in them with joints but without any leakage. Cutting head consists of orifice, mixing chamber and focusing tube or insert where water jet is formed and mixed with abrasive particles to form abrasive water jet. The potential or pressure head of the water is converted into velocity head by allowing the high-pressure water to issue through an orifice of small diameter (0.2 – 0.4 mm). The velocity of the water jet thus formed can be estimated, assuming no losses as using Bernoulli’s equation where, the water pressure and the density of water are evaluated. The orifices are typically made of sapphire. In commercial machines, the life of the sapphire orifice is typically around 100 – 150 hours. In WJM this high velocity water jet is used for the required application where as in AWJM it is directed into the mixing chamber. The mixing chamber has a typical dimension of inner diameter 6 mm and a length of 10 mm. As the high velocity water is issued from the orifice into the mixing chamber, low pressure (vacuum) is created within the mixing chamber. Metered abrasive particles are introduced into the mixing chamber through a port. The abrasive particles are metered using different techniques like vibratory feeder or toothed belt feeder. The reader may consult standard literature on transportation of powders.

Mixing: During mixing process, the abrasive particles are gradually accelerated due to transfer of momentum from the water phase to abrasive phase and when the jet finally leaves the focusing tube, both phases, water and abrasive, are assumed to be at same velocity. The mixing chamber, as shown in Fig. 7 and Fig. 8, is immediately followed by the focusing tube or the inserts. The focusing tube is generally made of tungsten carbide (powder metallurgy product) having an inner diameter of 0.8 to 1.6 mm and a length of 50 to 80 mm. Tungsten carbide is used for its abrasive resistance. Abrasive particles during mixing try to enter the jet, but they are reflected away due to interplay of buoyancy and drag force. They go on interacting with the jet and the inner walls of the mixing tube, until they are accelerated using the momentum of the water jet.

Disposal of the cutting water: In the abrasive process, the cutting water is mixed with various substances, which is why the water must be removed from the jet shredder. Scratch conveyors are available for this purpose, which continuously remove residues from the jet shredder. There are also models in which the water is removed manually. After the water has been filtered, it can be used again for water jet cutting. Abrasive recycling can save costs and resources in water jet cutting.

Control components: Water jet cutting is carried out exclusively with a **CNC control**. Simple machines have a **plotter control**. On high quality models you will find controls with adapted feed speeds at which the axes are also interpolated. In addition to a CAD interface, these machines also have a CAM connection for water jet cutting. Some models are equipped with a PC control, which allows even CNC-untrained users to perform water jet cutting.

Possible alternatives to water jet cutting: Direct contact with water is not desired for a large number of materials. These alternatives to water jet cutting are at your disposal:

CNC control: The experiments were performed on S-3015 AWJM CNC machine, manufactured by Water Jet Germany Private Limited. Water jet cutting uses high pressure water to cut softer material like rubber and abrasive jets adds abrasive to water to cut harder material like steel, glass and titanium. The high pressure water is forced through a tiny orifice to concentrate high energy in a tiny area to cut. Later conducted experiments on EDM using the copper and brass sheets as tools which was generated by AWJM in order to machine stainless steel and titanium alloy. Since this process is neither chemical and nor thermal, therefore it does not cause any change in physical and metallurgical properties of the workpiece.

Plasma cutting: A special gas is used in this system, which becomes plasma at 30,000 °C. The gas is then used to cut the water. Compressed air leads the molten material out of the kerf. The process is popular with steel up to 15 mm thick. The cutting speed is a great advantage of this process.

Laser cutting: The laser cutting process uses light to focus energy on the material to be processed. Thus the material evaporates selectively. The cutting gap of high-quality machines is almost invisible. Complex and acute-angled cuts are thus feasible. It is one of the most precise processes ever.

Plotter: With the aid of a tangential or drag knife, the material is cut with a knife plotter. Cutting inserts are interchangeable so that a variety of materials can be cut. The acquisition costs are low. However, milling and new cutting inserts incur costs in the long term. A plotter is only interesting for you if you have to cut very thin materials such as foils and textiles.

2.3 Conclusions on Reviews

AWJM is a comparatively recent machining process. It is mainly used for machining of high strength and difficult-to-cut materials due to its low cutting temperature, no heat damage to the surface, and low cutting forces. In recent years the process has been applied to different materials such as ceramics, composites, titanium alloys and even amorphous alloys. As a result of the present review, the following conclusions could be drawn. The abrasive waterjet material removal process is a complex erosion process where more than one mode contributes to the erosion results. Two mechanisms have been identified for ductile materials as the dominant modes for material removal, cutting wear mode and deformation wear mode. High surface quality was obtained with abrasive waterjet cutting by using high pressures and low traverse rates. The process does not generally affect the integrity of the surface. The depth of cut varies linearly with the abrasive flow rate and pressure. Low traverse rates are more efficient for deep cuts. The smaller the standoff distance, the deeper the cut. It was shown that the maximum temperature occurs in the immediate vicinity of the cutting interface and decays rapidly thereafter with increasing distance from the cutting interface. The hardness and toughness of the abrasive waterjet nozzle material should both exceed certain threshold values for effective performance

AWJ Abrasive waterjet cutting process parameters are factors that impact the effectiveness of machining performance. Defects such as the surface quality, kerf geometric inaccuracies and low material removal rate are directly correlated to transverse speed, standoff distance, waterjet pressure, and abrasive mass flow rate as well as material properties and material thickness. Therefore, nominating suitable values for these factors should be managed appropriately. Functional relations between these responses and input parameters of AWJ cutting were obtained and studied by many experimental results of numerous authors. Table 8 details a number of experimental investigations from recently published research, providing evaluations of correlations between input and output process parameters of AWJM, particularly in cutting operations. Based on the studies summarized in Table 8, water pressure at a high level provided a higher depth of cut and higher material removal rate [33, 58]. A lower value of traverse speed ranging from 60 to 90 mm/min was favorable in achieving a lower surface roughness, and a higher material removal rate and depth of cut. AWJ cutting of hard-to-cut workpieces such as metallic materials including tungsten carbide, tool steel, and Inconel alloys have demonstrated distinct characteristics such as the fast speed at a rate of 2 to 3 mm3/s, versatility in cutting with thickness ranging from ≤304.8 mm, the ability to machine complicated shapes, and environmentally sustainable qualities. These characteristics explain their wide range of current applications across various industries. • Cutting metallic materials with low machinability, i.e., stainless steel, Inconel and titanium, can attain lower surface roughness, higher depth of cut and material removal rate at a waterjet pressure ranging from 201 to 300 MPa. A traverse speed ranging from 60 to 90 mm/min, abrasive mass flow rate of 401 to 500 g/min, and stand-off distance ranging from 1.0 to 3.0 mm were established to achieve a lower surface roughness, lower kerf taper angle, and higher material removal rate applicable to various metals.

CHAPTER-3 PROJECT DESIGN

3.1 Overview of design

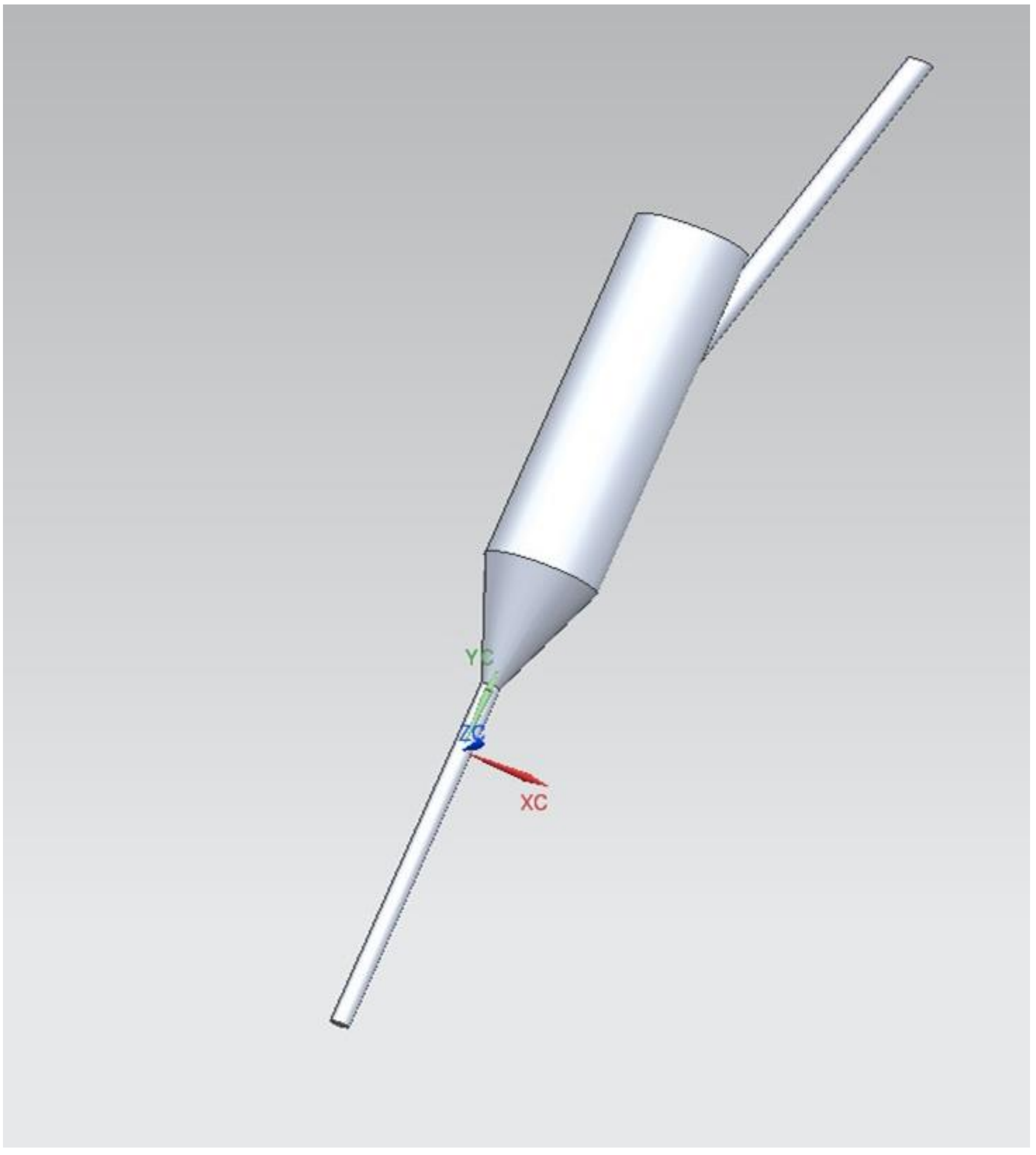


Fig no.5 ISOMETRIC VIEW

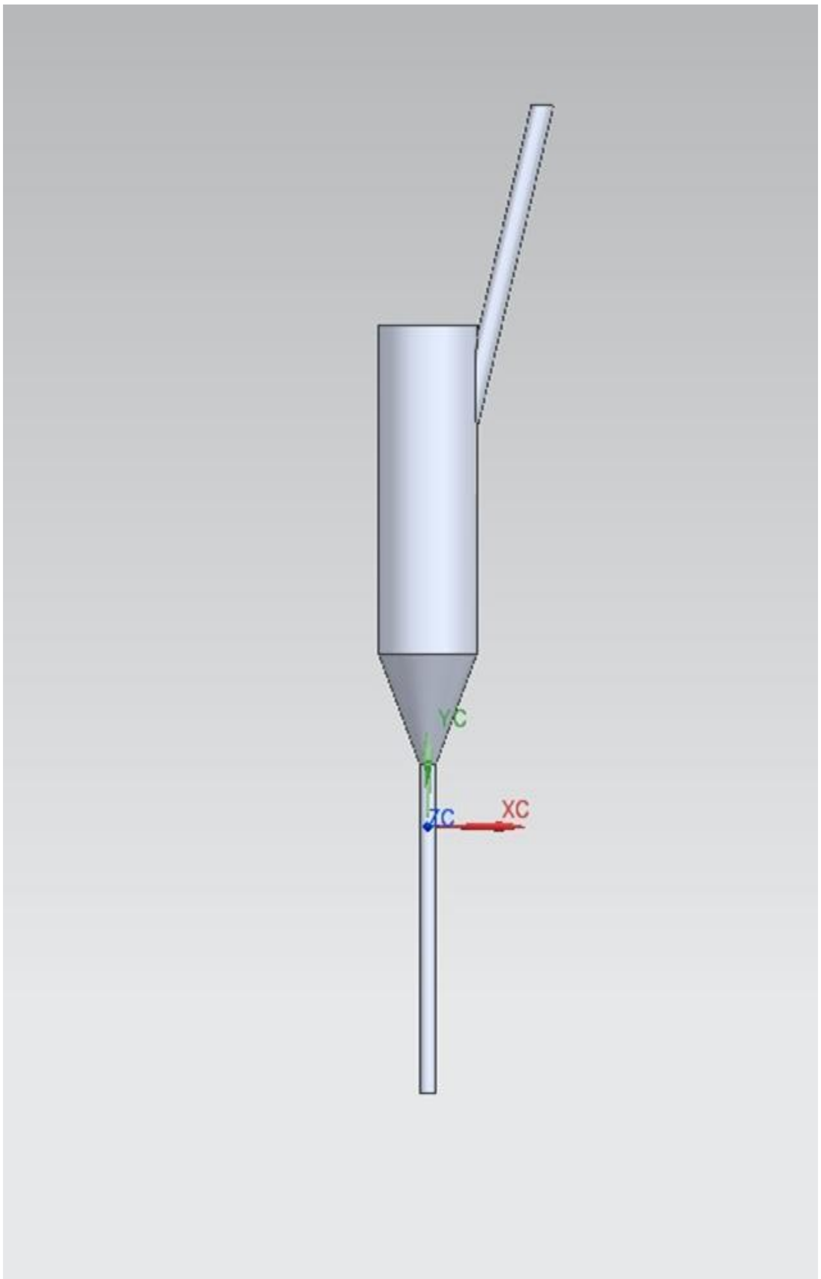


Fig no.6 FRONTVIEW

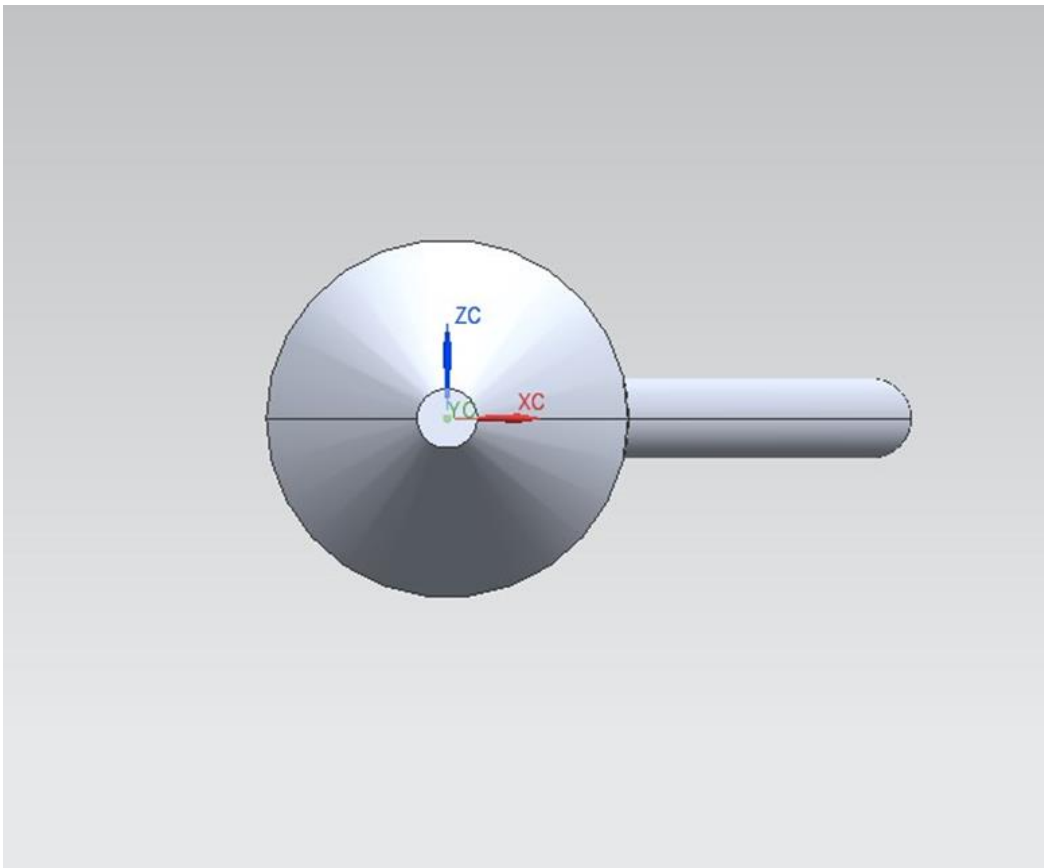


Fig no.7 TOP VIEW

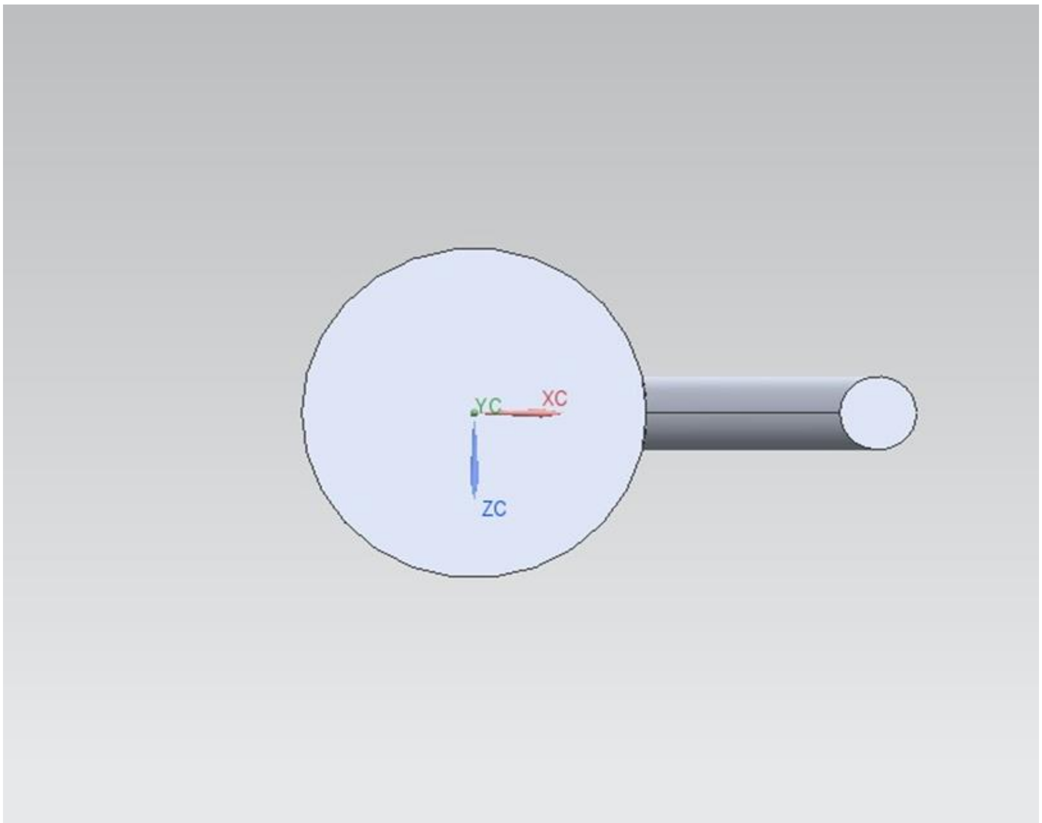


Fig no.8 BOTTOM VIEW

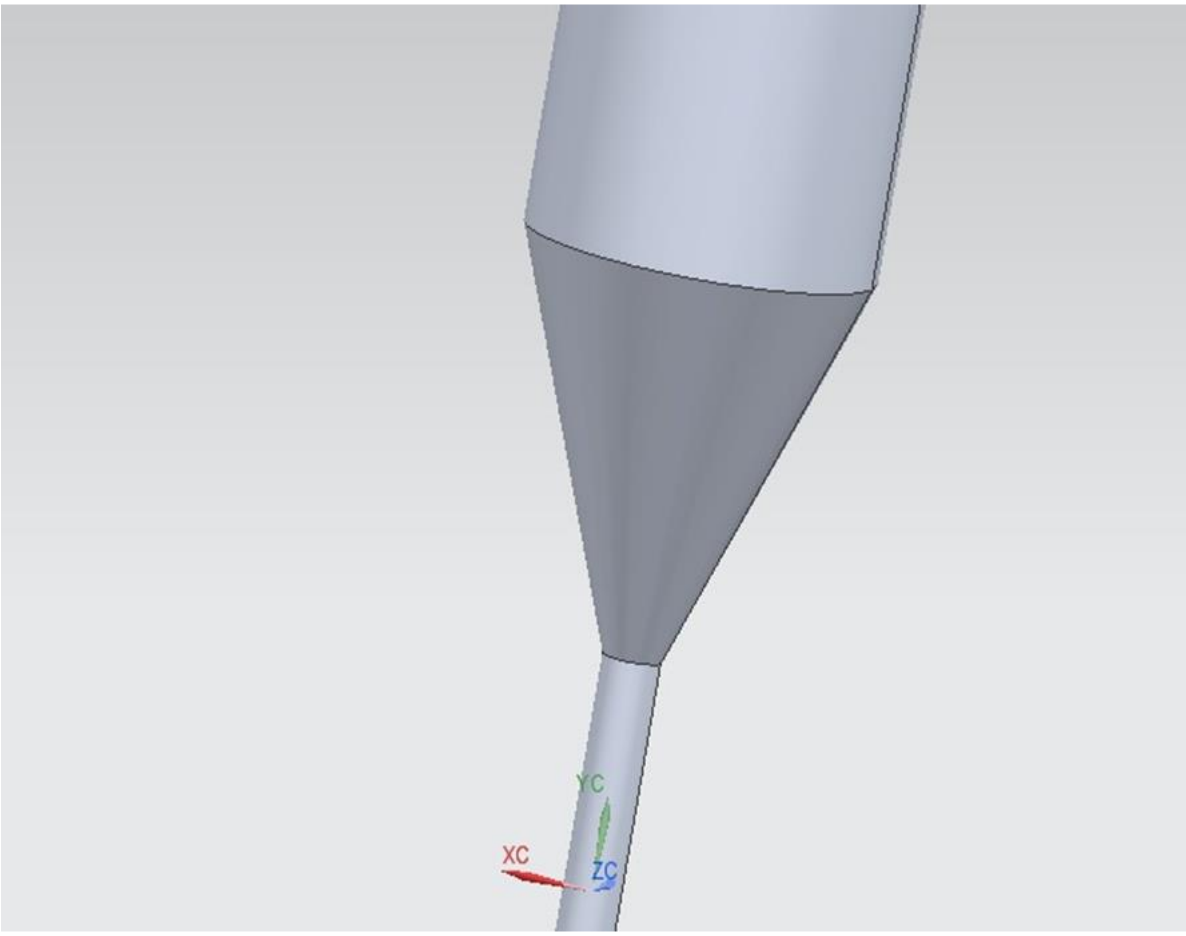


Fig no 9 CUTTING HEAD

3.2 Equipment analysis

Assembly

Nozzle:

AJM nozzle is usually made of tungsten carbide or sapphire (usually life – 300 hours for sapphire, 20 to 30 hours for WC) which has resistance to wear. The nozzle is made of either circular or rectangular cross section and head can be head can be straight, or at a right angle. It is so designed that loss of pressure due to the bends, friction etc. is minimum possible. In integration manufacturing technology abrasive jet finishing combined with grinding gives rise to a precision finishing process, in which slurry of abrasive and liquid solvent is introduced to grinding area between wheel and work surface under no radial feed [1]. The particles are driven and energized by the rotating grinding wheel and liquid pressure and increased slurry speed between grinding wheel and work surface accomplishes micro removal finishing. The study of the results of machining under various operating conditions approves that a commercial AJM machine was used, with nozzles hiving diameter ranging from 0.45 to 0.65 mm, the nozzle materials being either tungsten carbide or sapphire, which have high tool lives. SIC and aluminum oxides were the two abrasives used. Other parameters studied were standoff distance (5–10 mm), spray angles (60◦ and 90◦) and pressures (5 and 7 bars) for materials like ceramics, glass, and electro-discharge machined (EDM) die steel. The holes drilled by AJM may not be circular and cylindrical but almost elliptical and bell mouthed in shape. High material removal rate conditions may not necessarily r small narrow clean-cut machined areas. Studies show that AJM is a good micro-machining method for ceramics. The machinability during the AJM process can be associated to that given by the established models of solid particle erosion, in which the material removal is assumed to initiate in the ideal crack formation system. However, it was explained that the erosion models are not applicable to the AJM test results, because the relative hardness of the abrasive particles against the target material, which is not taken into account in the models, is important in the micro-machining process. No degradation in strength took place for the AJM ceramic surfaces. This is attributed to the fact that radial cracks did not propagate downwards by impacts during the machining process. Quality of the surface produced during abrasive water jet machining of aluminum has been investigated in recent years. The abrasive used was garnet of mesh size 80. The variables were stand-off distance (SOD) of the nozzle from the work piece surface; feed rate and jet pressure. The evaluating criteria width of cut, taper of the cut slot and work surface roughness. It was found that in order to reduce the width of cut; the nozzle should be placed close to the work piece surface. Increase in jet pressure effects in widening of the cut both at the top and at exit of the jet from the work piece

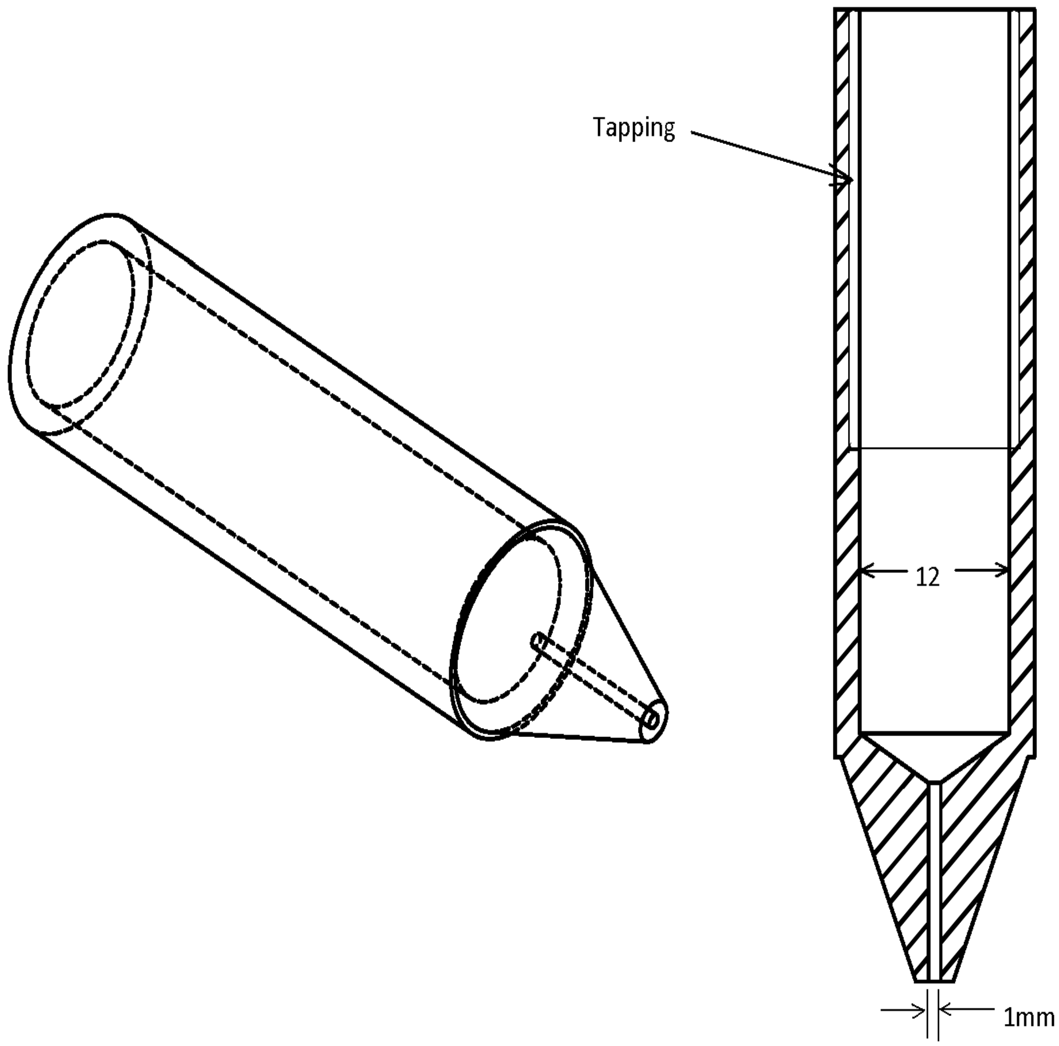


Fig no.10 Nozzle

Surface texture

The effects of AWJM on the surface quality of the produced surfaces, hence helped to obtain better surface quality than ten years ago. The surface texture that may be associated with abrasive waterjet machining include: surface waviness, burr formation, surface finish and lay. The finish of a surface machined by abrasive waterjet exhibits two distinct contributions from the process: roughing occurring at the upper portion of the kerf, due to the micro effects of each impacting particle and waviness or striation, occurring at the lower portion of the kerf, due to jet penetration and loss of stability as the cutting depth increases. A smooth cut can be obtained by extending the cutting wear over the entire thickness of the material. This can be achieved by increasing the jet cutting power or by reducing the traverse rate [73]. The surface roughness was found to depend on the micromachining process of particle-material interaction. As the traverse rate and abrasive particle size increase, the surface roughness increases as shown in Fig. It is clear that an increase in the abrasive flow rate produces better surface finish, Fig. 16 (b). In a study on AWJM of metal and ceramic matrix composite materials using scanning electron microscopy, obtained relatively smooth surfaces with minimum subsurface microstructural damage. Blickwedel developed a semi-empirical equation for the prediction of surface roughness as a function of both traverse rate and pressure using regression analysis. Another mathematical model for the prediction of surface roughness of graphite/epoxy composite was developed by Ramulu and Arola [40] using ANOVA regression techniques and can be used for determining cutting parameters for tailored surface quality. Chao et al [67] evaluated generated surfaces using surface topography analysis. It was found that the smooth zone has a random, moderately isotropic texture. The extent of the smooth zone depends on the cutting conditions e.g. traverse rate, depth of cut and cutting direction. Surface roughness was shown to strongly depend on depth of cut and traverse rate in the striation zone. An oscillation applied to the abrasive waterjet nozzle head was found to produce superior surface texture results for cutting of ceramics. The smooth zone depth increased by more than 30% as compared to that without oscillation. Also the striations were observed to decrease the surface waviness was found to depend primarily on the dynamic parameters, i.e. pressure, abrasive flow rate, and traverse rate. Figure 17 shows the effect of traverse rate and abrasive flow rate on surface waviness. As can be seen, the surface waviness is critically dependent on the traverse rate Burrs may form at the exit side of thin sheet metal cut with an abrasive waterjet. Figure 18 shows data on the height of burrs formed at different traverse rates and abrasive flow rates. The mechanism causing burr formation is similar to that in mechanical sawing, i.e. the material at the bottom of cut is bent rather than removed.

Surface integrity

The surface integrity effects are defined as particle deposition, delamination, gouging, cracking, work hardening and heat affected zones. Particle deposition increases with increasing angle of attack and decreasing particle velocities. A recommended practice in using abrasive waterjet is that the abrasive supply be turned off after a surface has been generated by linear cutting, turning and milling, so that the waterjet alone can be used to clean the surface of particles that may have been imbedded. Delamination may be observed when machining layered materials such as graphite epoxy composites and Kevlar. Delamination occurs only if the deformation wear mode of erosion exists. On the other hand, delamination is a major concern in AWJM of composite materials. The mechanism of delamination was studied using fracture mechanics and the optimum waterjet pressure for no delamination is now predictable. Gouging are dimples about 10 microns in diameter observed microscopically. These dimples are particles pulled from the surface. The surfaces produced with abrasive waterjet are free from microstructural distortion. For brittle materials such as glass, cracks may be evident on the kerf edge. It was observed that micro cracks less than one micron deep may form when abrasive particles less than 10 microns in size are used. Changes in hardness due to abrasive waterjet machining are insignificant. Also abrasive waterjet process does not affect the mechanical characteristics of the material. Strains occurring in erosion must be very large, and in addition, the surface will become work-hardened by the eroding particle. Erosion also involves very high strain rates. This tends to increase the flow stress. In a recent research work, Tönshoff et al observed that the high-frequency impact of pure waterjet on the surface of steel, using pressures up to 100 Mpa, causes local plastic deformation. As a result, high compressive residual stresses are induced in the surface-near layers. Fatigue strength was also shown to increase. The effect on the depth only reaches the surface-near material within distances from the surface of up to approximately 30 microns. The inspection of abrasive waterjet machined surfaces indicated that no heat affected zones are associated with the cutting process. Even if high temperatures occur for very short periods of time upon the impact, these are removed as the kerf is generated.

Nozzle Wear

The mixing tube, where the abrasives are mixed, accelerated and focused with the high-pressure waterjet, is the component of the abrasive waterjet that receives the greatest wear. Hashish tested a wide range of candidate nozzle materials. The tungsten carbide grades exhibited more longevity than the hard ceramics such as boron carbide, when garnet abrasives were used. The reverse trend was observed with aluminium oxide abrasives. Wear mechanisms along the mixing tube change from erosion at the upstream to abrasion at the downstream sections. The development of nozzle wear as a function of operating time shows a 50 % increase in the nozzle diameter after only 80 minutes of operation as observed by König and Schmelzer. A slight increase in the nozzle wear is also observed when the pressure increases from 200 Mpa to 300 Mpa. On the other hand, surface roughness and kerf taper progressively increase as the nozzle wear increases. The effect of mixing tube length on nozzle wear is shown. The longer the mixing tube, the slower the wear rate. The reason is that the velocity vectors of the particles become parallel to the wall when the tube length increases and only the abrasion mode exists. Figure shows the effect of mixing tube material on wear. The boron carbide tube exhibited a faster wear rate than the tungsten carbide tube. The reverse trend is observed when using aluminium oxide abrasives. A recent research work on the wear of mixing tube materials has shown the superiority of a new nozzle material, composite carbide over tungsten carbide and boron carbide, due to its particular combination of hardness and toughness. Schwetz et al suggest the use of boron carbide nozzles with hard abrasives such as aluminium oxide for machining of very hard and tough workpieces such as ceramics and cermets.

Control and monitoring

Researchers have been becoming more interested and active in this field. Kovavevic developed a wear sensor system for on line tracking of abrasive water jet nozzle wear based on conductive loops placed on ceramic substrate and embedded in the tip of the nozzle. Hence, compensation for the increase in AWJ nozzle diameter could be made. Afterwards, he showed that the workpiece normal force generated by the abrasive water jet could be used as an indicator of the jet penetration, and that a force-feed back control holds a promise as an effective way to regulate the depth of jet penetration. A correlation between depth of cut and process variables, based on experimentation, was derived using multiple regression analysis. Another monitoring system for the AWJ nozzle wear based on acoustic signals generated by the AWJ was derived by Kovacevic et al. This model has the possibility of monitoring and compensating nozzle wear using the frequency domain acoustic signals generated by the jet exiting the nozzle. An artificial neural network is capable of determining the nozzle diameter corresponding to any unknown sound signal. Kovacevic and Fang showed that fuzzy rules could be applied in AWJM to determine WJ cutting parameters for milling instead of the tedious and time consuming experimentation. A more recent study derived a mathematical model for the estimation of the energy absorption capability of materials during AWJM based on the energy balance inside the workpiece. It is shown that the energy absorption depends on the depth of cut.

AWJM is a comparatively recent machining process. It is mainly used for machining of high strength and difficult-to-cut materials due to its low cutting temperature, no heat damage to the surface, and low cutting forces. In recent years the process has been applied to different materials such as ceramics, composites, titanium alloys and even amorphous alloys.

Abrasive container:

The high-pressure air from the compressor is passed through a FRL unit to remove any impurities. Then it is fed to the abrasive chamber which has one inlet for the incoming compressed air and outlet for mixture of abrasive particles and air. The abrasive particles are introduced from the side so to form a cyclone to facilitate better mixing. The chamber is of cylindrical shape made up of mildsteel

Fig no.11 Abrasive container

The vibrator assembly:

Vibrating Unit is used for mixing the air with the abrasive particles (Al_2O_3). The Abrasive particles are stored in a container through which air is flown.

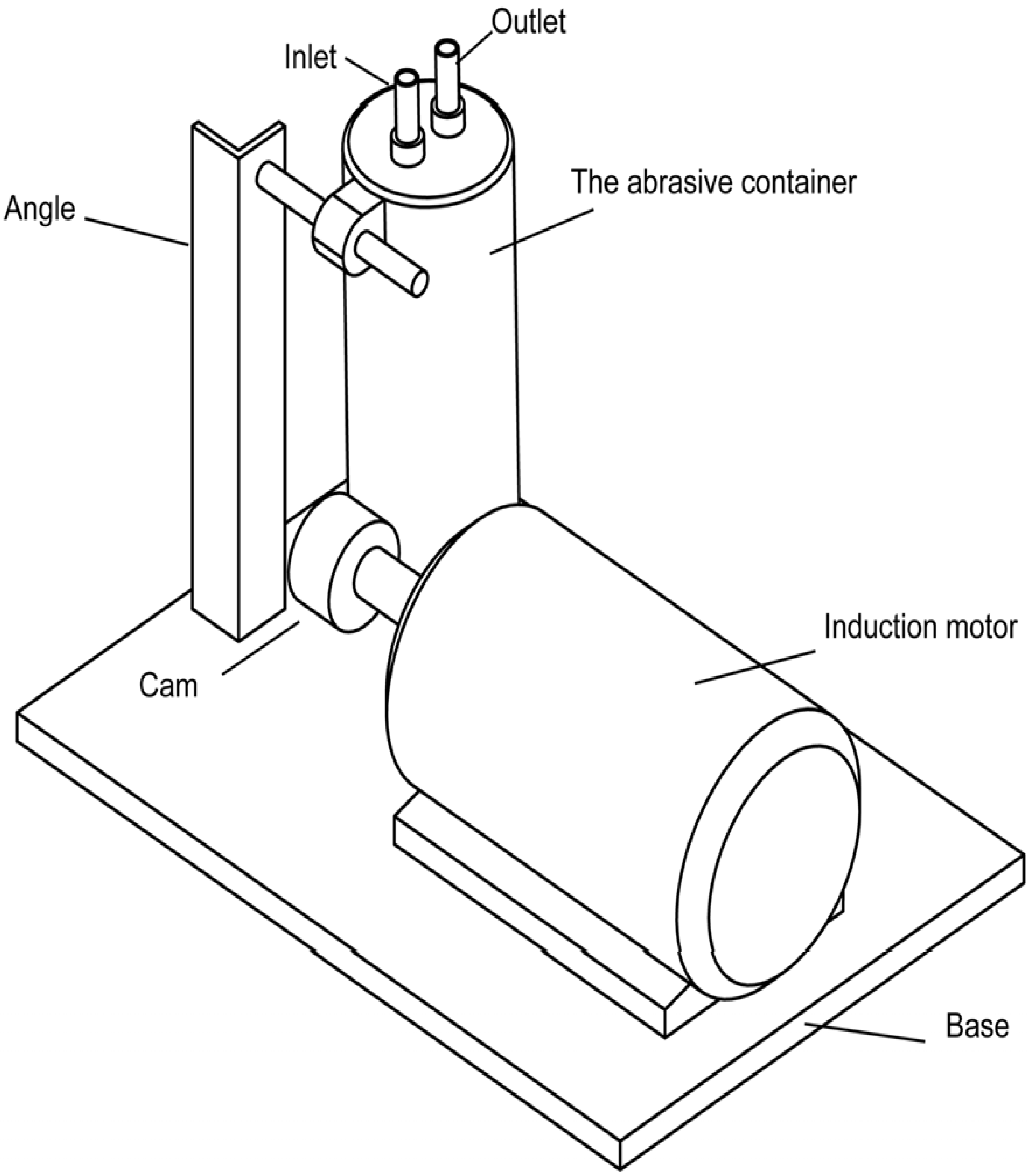


Fig no.12

The particles are agitated by means of a cam and motor arrangement. The rotation of cam results in vibration in the abrasive container. The flow rate of abrasive materials can be controlled by manipulating the rotational speed of the motor. The abrasive container will have one inlet and one outlet for air passage and will be vertically suspended from a hinged joint. So, the vibrating unit consists of following part

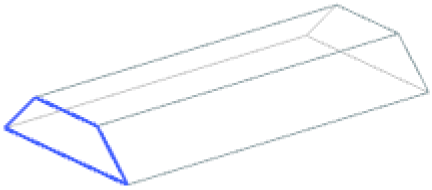
1. Motor (Induction type)
2. Cam

3.3 Define the modules

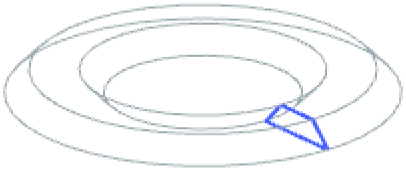
Simple Solids and Surfaces

Once you have a sketch, or several sketches, there are four basic types of bodies that you can create from those sketches using solid modeling operations.

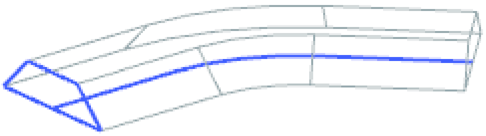
- Extruded – an extruded body is obtained by sweeping an input section string along a vector, with specified start and end distance limits. The Extrude command creates this kind of body in NX.



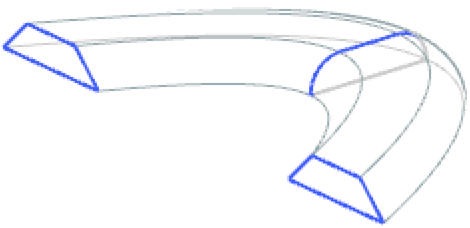
- Revolved – a body of revolution is obtained by sweeping an input section string around an axis, with specified start and end angle limits. The Revolve command creates bodies of revolution in NX.



- Swept – a swept body is obtained by sweeping the input section string along a guide curve. The Sweep Along Guide
Command produces general swept bodies in NX.



- Lofted – lofted bodies are obtained by specifying non-intersecting section strings (not necessarily the same shape!), which the lofted body must pass through. The Through Curves command produces general lofted bodies in NX.



More sophisticated surfaces are built by combining multiple sections with multiple guides –these are called mesh surfaces in NX, and there are a variety of sweep and loft tools that produce them.
In addition to these four basic types of bodies shown above, you can also build simple primitive shapes from scratch. The primitive design features in NX include Block, Cylinder, Cone, and Sphere.

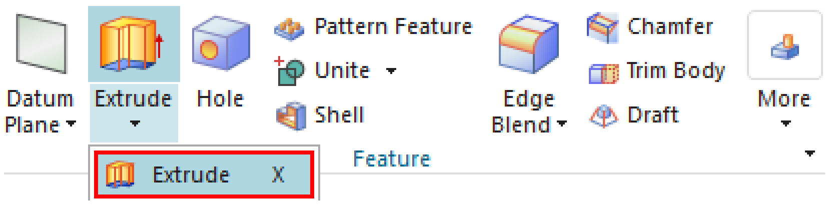
These commands are found in the more gallery in the Feature group on the Home tab. In the exercises below, we illustrate these fundamental tools, as well as a few others for creating simple solids and surfaces.

3.4 &3.5 Modules functionalities and design/graphs

Extrude

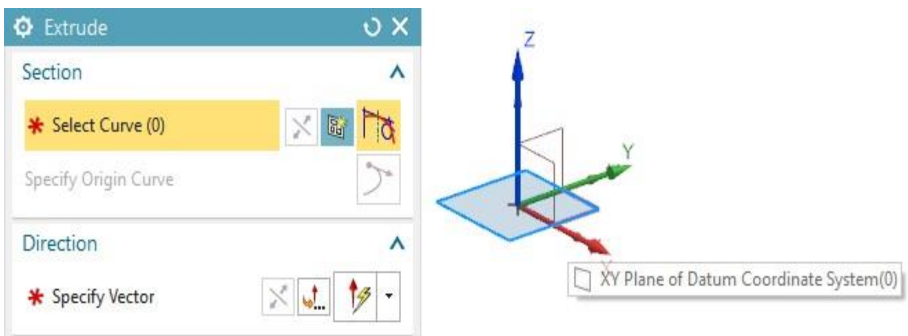
The Extrude command is fundamental to solid modeling. The Extrude function takes a set of curves (called the section string) and sweeps them along a vector to create a solid or sheet body. If your section string is closed, the result will be

Solid body, and if the section string is open, the result will be a sheet body. The Extrude command is found in the Feature
Group on the Home tab.



While most extrusions involve a planar section string (or at least curves from parallel planes), it is possible for the curves in the string to be twisted in three-dimensional space, and although you must take care to ensure that the resulting body will not have self-intersections.

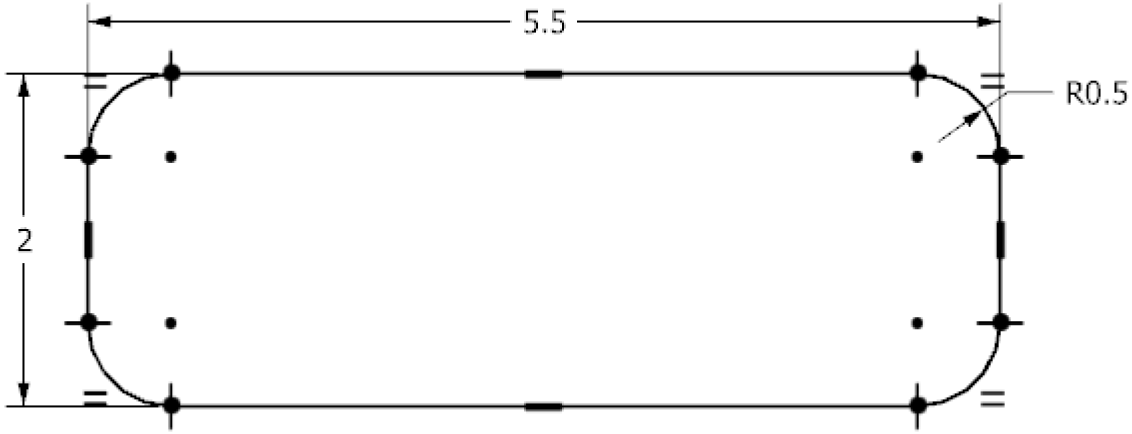
- Create a new file called "Extrude.prt" and place it in "C:\My NX Files".
- Select the Extrude tool. The Extrude dialog box will then appear. The red asterisk in the Section field indicates that NX wants you to specify a



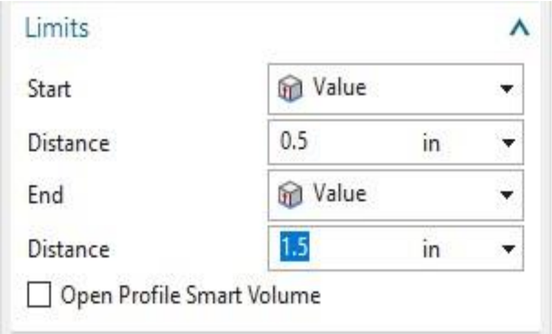
- Curve. Since the Sketch Section icon is present, if you click on the XY plane of the datum coordinate system, you will enter the Sketch Task Environment on that plane. The Direction will automatically become a normal vector to the sketch plane, as well. Go ahead and select the XY plane.

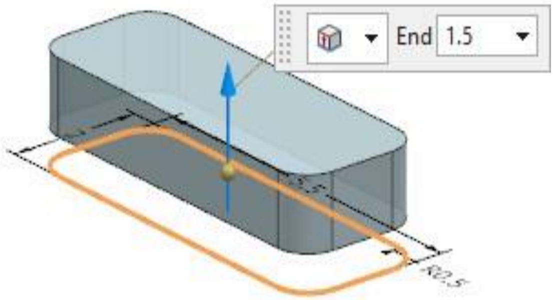
- In the Sketch Task Environment, create the sketch shown below. Finish the sketch to return to the

Extrude dialog.

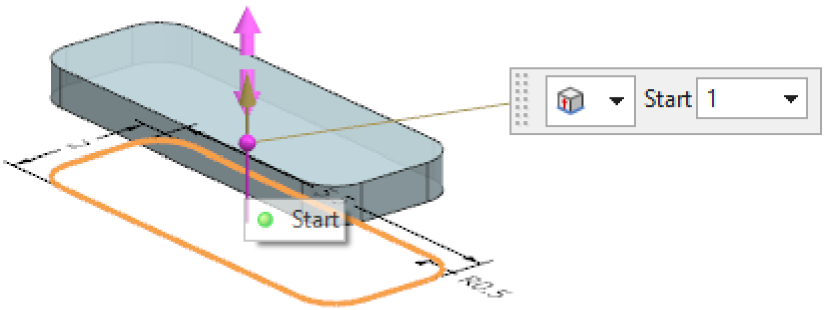


- When the selection is a closed string, the preview shows a solid body defined by Start and End Limit values. You can modify these values in the Extrude dialog and the preview will update when you push [Tab] or [Enter].

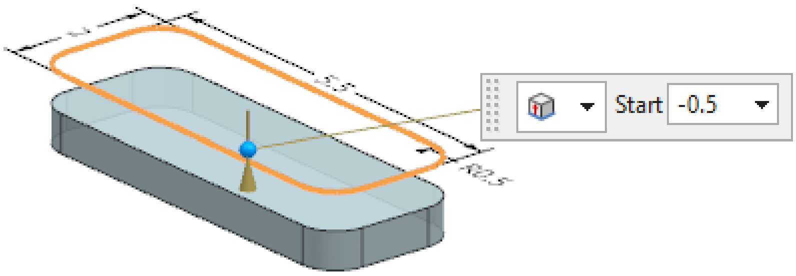




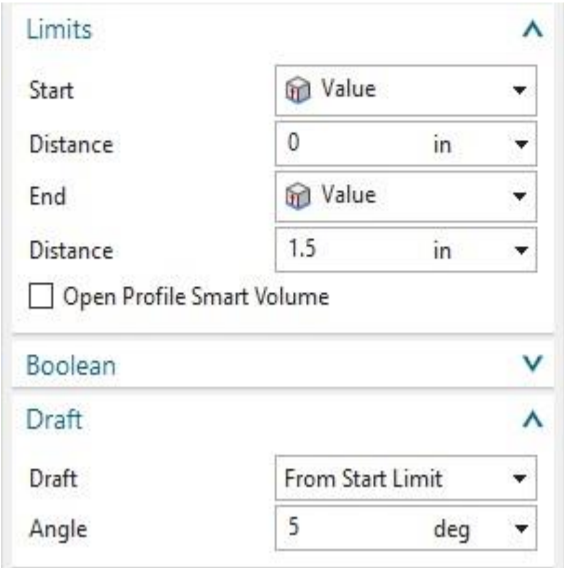
- You can also use the handles to dynamically modify your extruded body – the arrow controls the End, and the spherical handle controls the Start. Simply click-and-hold-and-drag either handle to change the value dynamically.

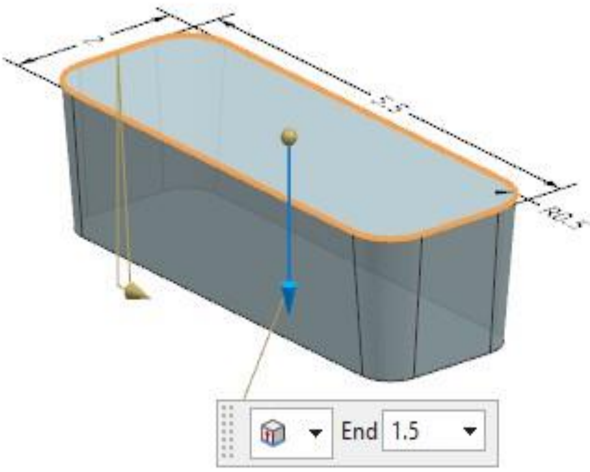


- There are no restrictions on the relation between the Start and End values – NX doesn't care if you use negative values, or whether the End value is greater than the Start value, or if they are the same – go wild!

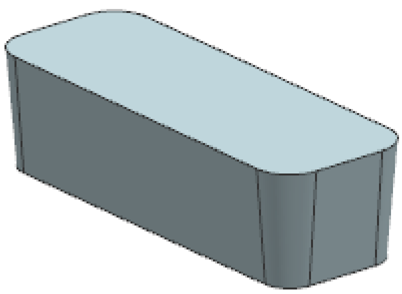


There are some additional options within the Extrude dialog that are very useful. For instance, you can apply a Draft angle to the walls of the extruded body. When you specify a Draft, the draw direction is necessarily the same as the extrusion direction, and so whether the Start Limit Value is greater than the End Limit Value or not will impact how the Angle parameter is interpreted. Use the Reverse Direction button to Extrude in the -ZC direction, then set the Start to 0 in and the End to 1.5 in and specify Draft Angle of 5 degrees





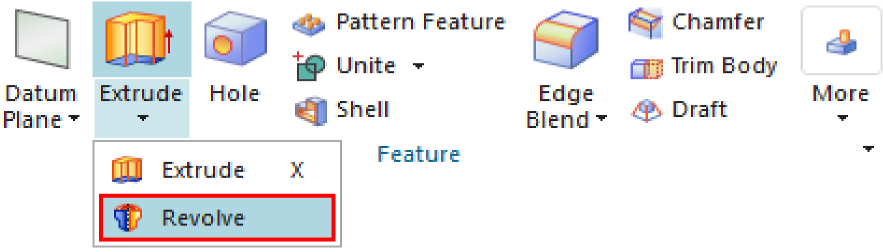
- Click OK to create the Extrude feature. Since the sketch was created internally to the feature, it appears in neither the Model History, nor the Graphics Window.

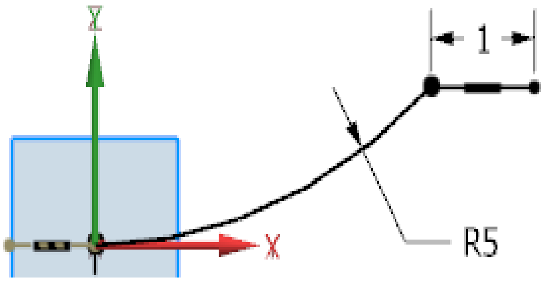


- Save your part file!

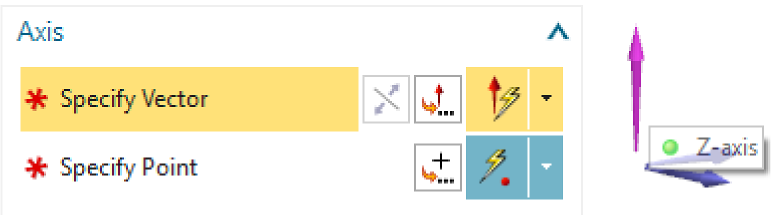
Revolve

The Revolve tool creates a body of revolution from a section string, which is not required to be closed. The axis of revolution can be a curve, edge, existing axis, or you can specify it by giving a direction vector and a point entity.

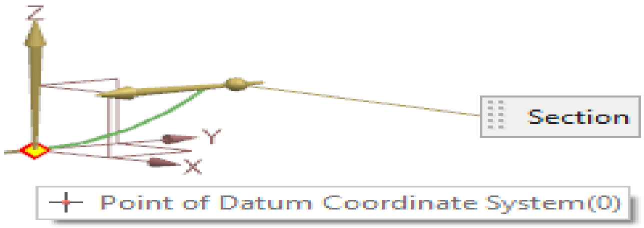


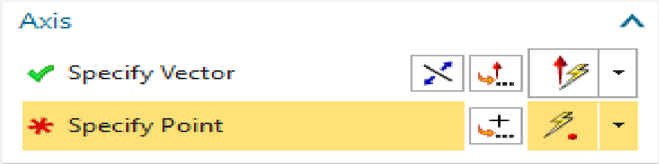
- Create a new file called “Revolve.prt” and place it in “C:\My NX Files”.
- Create the sketch shown below on the YZ plane of the datum coordinate system.
- 

- Select the Revolve tool and choose your sketch as the Section. For the Axis, use the Z axis of the OrientXpress, as shown below.



- A common point of confusion for new NX users is the role that the Point plays in determining the Axis. Notice that after selecting the Vector, you still need to specify a Point.

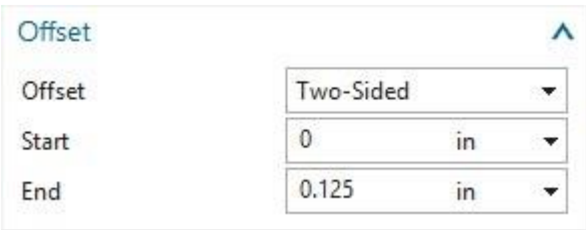


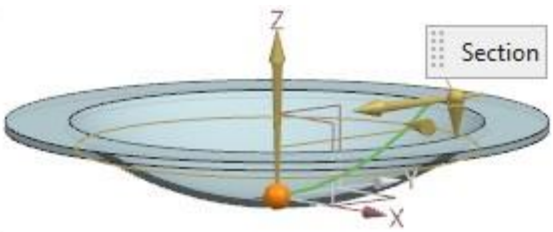


- The vector gives the axis its direction, but it is still not anchored in three-dimensional space – this is the role of the

  Point. Click on the point of the datum coordinate system.

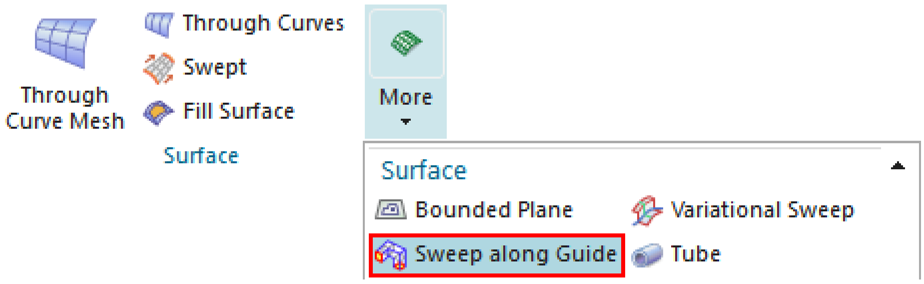
- Now that the vector is required to pass through a specific point, there is enough data to determine an axis! When prompted for the Vector, if you select an existing line, edge, or axis, NX will infer a point based on the input.
- Specify a two-sided offset from 0 in to 0.125 in so that the body of revolution is a solid of uniform thickness.





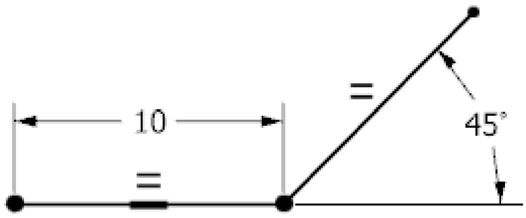
- Save your part file!

Both Extrude and Revolve are special cases of sweep operations. There are a number of sweep tools in NX, the most basic and general of which is the Sweep along Guide tool. The Sweep along Guide tool requires that you specify a section string and a guide string, and the resulting body has cross section identical to the section at each plane normal to the guide.
Sweep along Guide is found in several places on the ribbon, the most convenient of which is in the More gallery from the
Surface group on the Home tab.

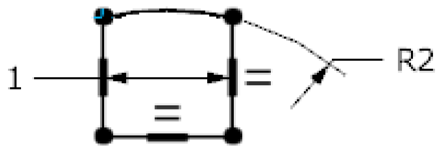


The Sweep along Guide has several noteworthy features not present in other sweep tools: it has a Boolean option (see Chapter 9.3), and both the section and guide strings can have sharp corners (most sweeps require tangent-continuous guide strings).

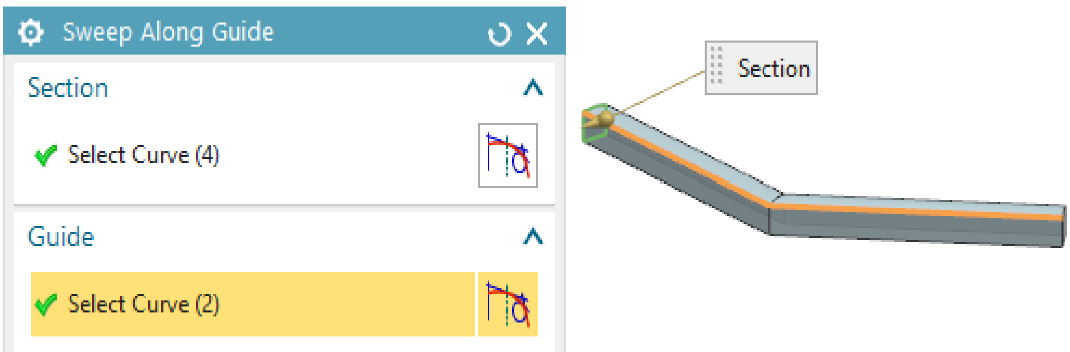
- Create a new file (Units: Inches) called "Sweep AlongGuide.prt" and place it in "C:\My NX Files".
- Create the sketch shown below on the XY plane, and name it "GUIDE".



- Create the sketch shown below as a sketch of Type On Path attached to "GUIDE" at 0% arc length. Name it "SECTION".



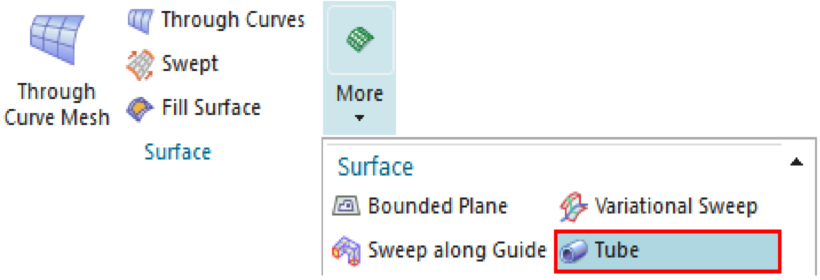
- Select the Sweep Along Guide tool, and choose the sketch "SECTION" as the Section, and the sketch "GUIDE" as the
Guide. Click OK to create the solid body shown below.



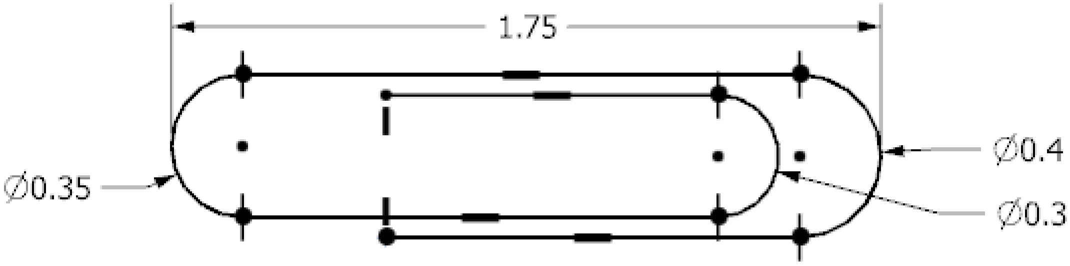
- Save your file!

Tube

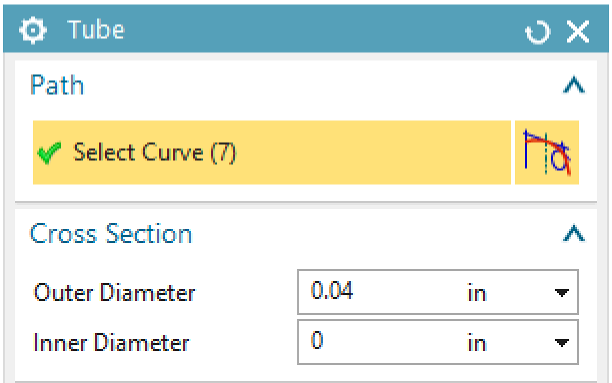
The Tube command is the only sweep command that does not require a section as input – the section is always a pair of circles, specified by an Outer Diameter and Inner Diameter. Instead, the Tube command asks only for the Guide curve. The Inner Diameter is allowed to be zero if you wish to model an entirely solid tube. The Tube command is found in several places on the ribbon, the most convenient of which is in the More gallery from the Surface group on the Home tab.

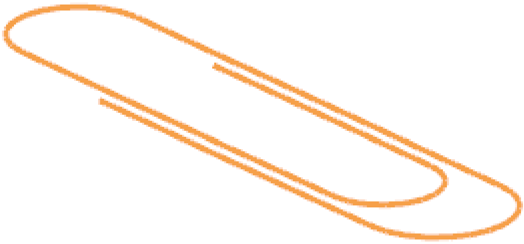


- Create a new file (Units: Inches) called "Tube.prt" and place it in "C:\My
- NX Files".
- Create the sketch shown below in the XY plane.



- Select the Tube command and choose the sketch as the Path. Enter the parameters shown below and click OK.



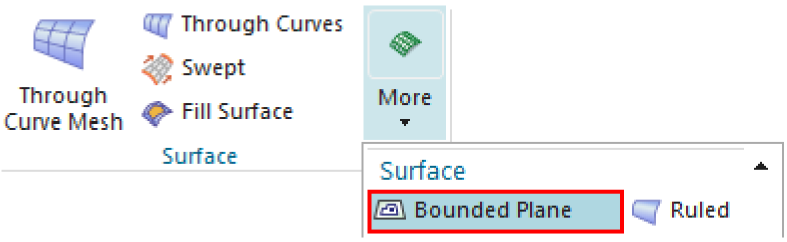


- In the Settings panel on the dialog, set the Output to Single Segment.

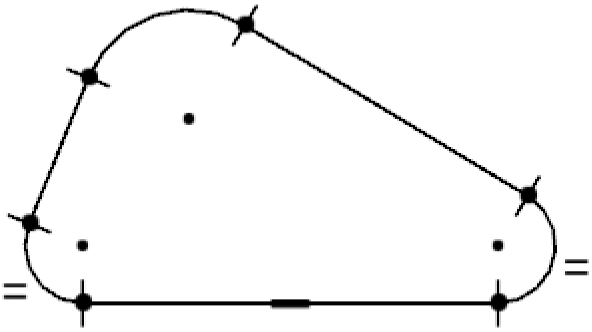
- Your model should look like a paper clip. Save your file!

Bounded plane

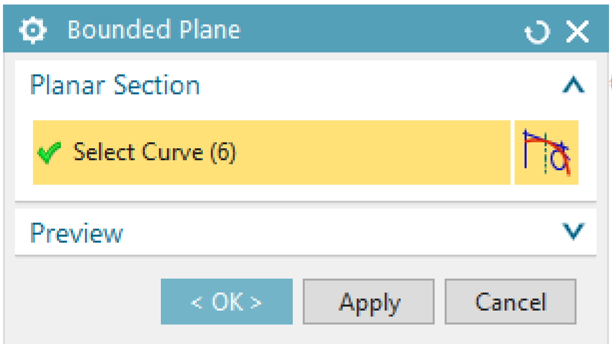
In general, when you have a closed, chain-connected set of curves in three-dimensional space, there is no unique or obvious way to build a surface that has them as the boundary – typically more data is required to define a surface. However,
When the curves are coplanar, the planar region enclosed by the curves is an especially simple and useful surface that NX can generate from only the boundary curves. The Bounded Plane tool does exactly that, and it is found in the More gallery in the Surface group on the Home tab.

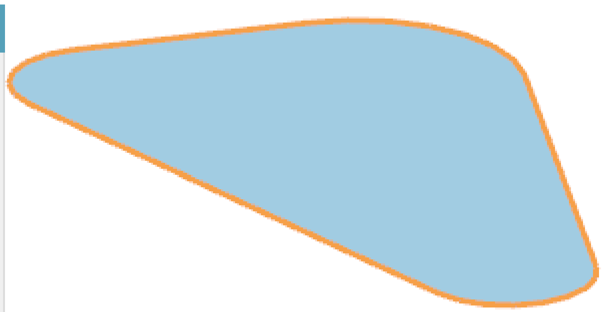


- Create a new file (Units: Inches) called "Bounded Plane.prt" and place it in "C:\My NX Files".
- Create the sketch shown below in the XY plane.



- Select the Bounded Plane tool and choose the sketch as the Planar Section. Click OK to generate the surface.





- Save your file!

CHAPTER-4. PROJECT IMPLEMENTATION

4.1 Implementation of stages:

Meshing:

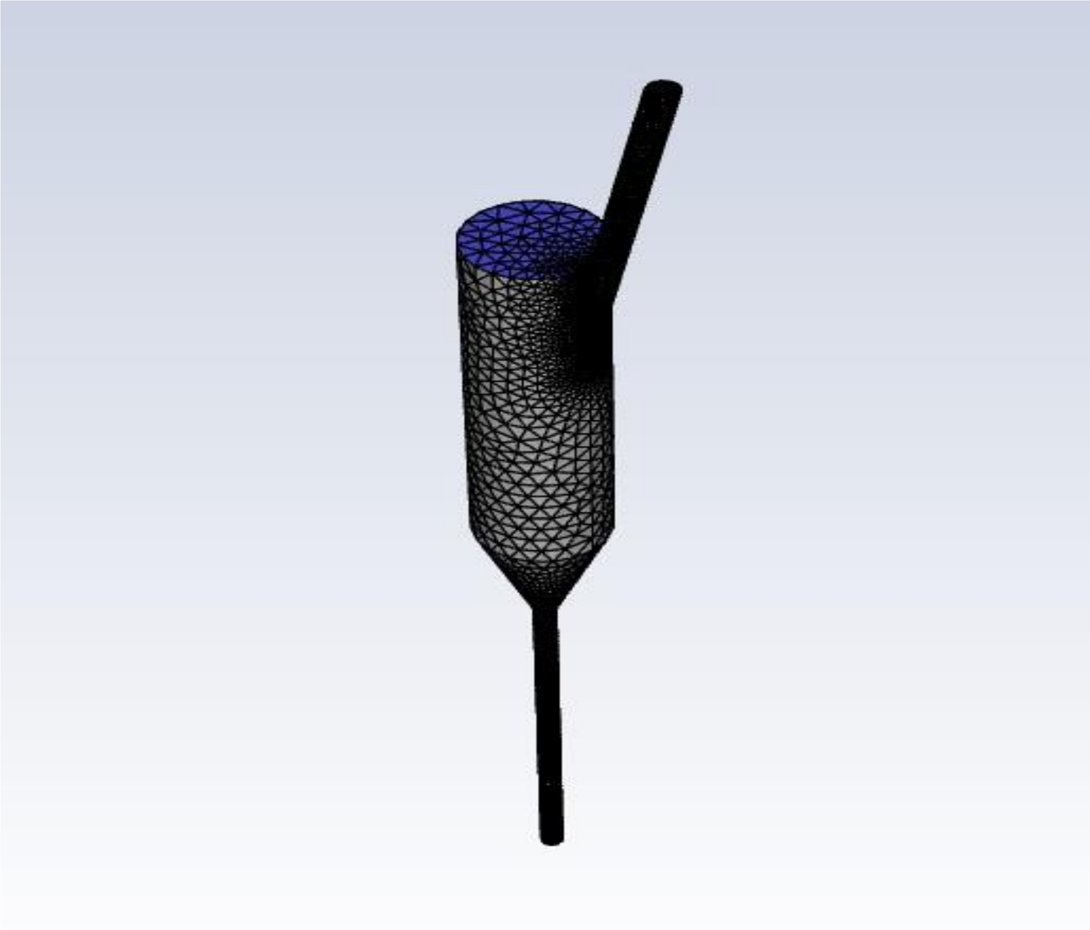


Fig no.13 Mesh analysis of nozzle

Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components. In the event that we need this kind of lattice, we must form the geometry as arrangement of genuinely normal volumes and/or regions that can acknowledge a mapped network.

Structural static analysis:

The load effects can be calculated on a structure by ignoring the damping and inertia effects, such as those caused by time varying loads can be calculated by structural static analysis. Steady equivalent loads like steady inertia loads and time varying loads are included in Static analysis. Static analysis is utilized to decide the removals, burdens, strains and powers in structures or segments brought about by burdens that don't instigate noteworthy dormancy and damping impacts. Enduring stacking and reaction conditions are accepted, i.e. the stress and the structure's reactions are expected to differ gradually as for time. The kinds of load can be applied in static analysis include:

- Force and pressure application on body.
- Steady state inertial forces.
- Displacement.
- Thermal behavior.

Analysis Steps:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:
Create a study defining its analysis type and options.
If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.

- Define material properties.
- Specify restraints and loads.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.

Analysis work

Velocity contours

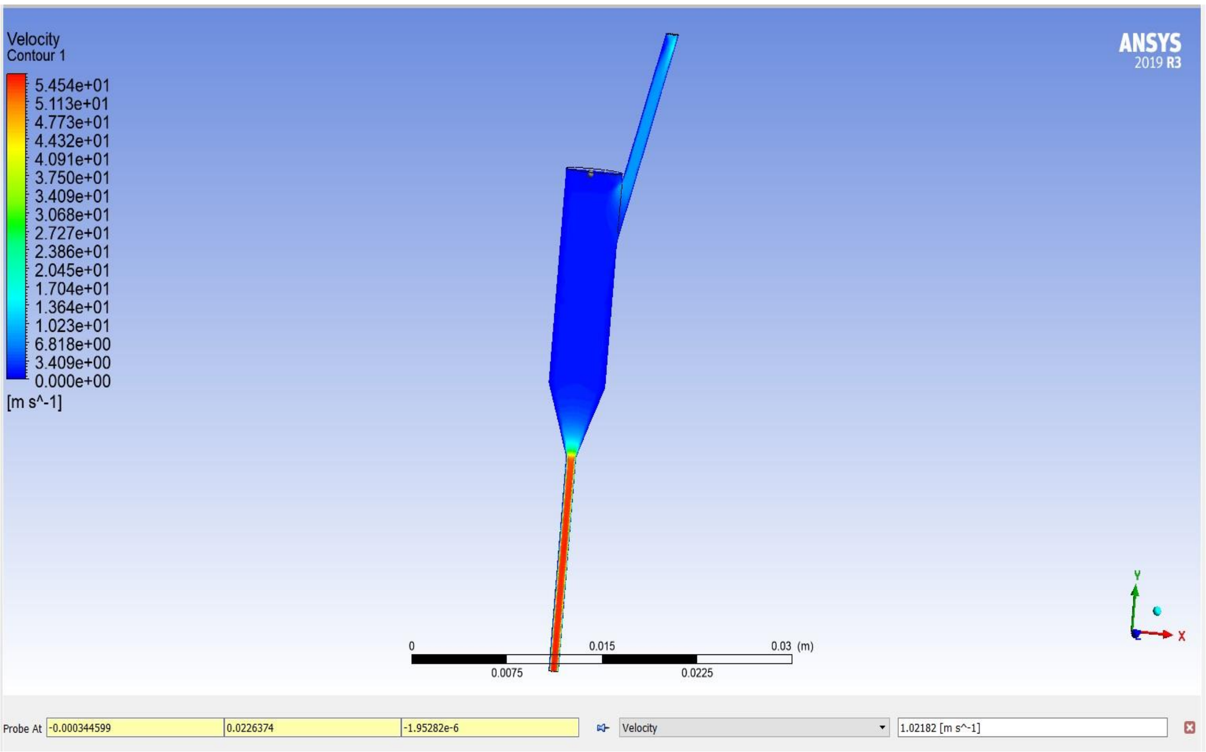


Fig no.14 Velocity at water inlet

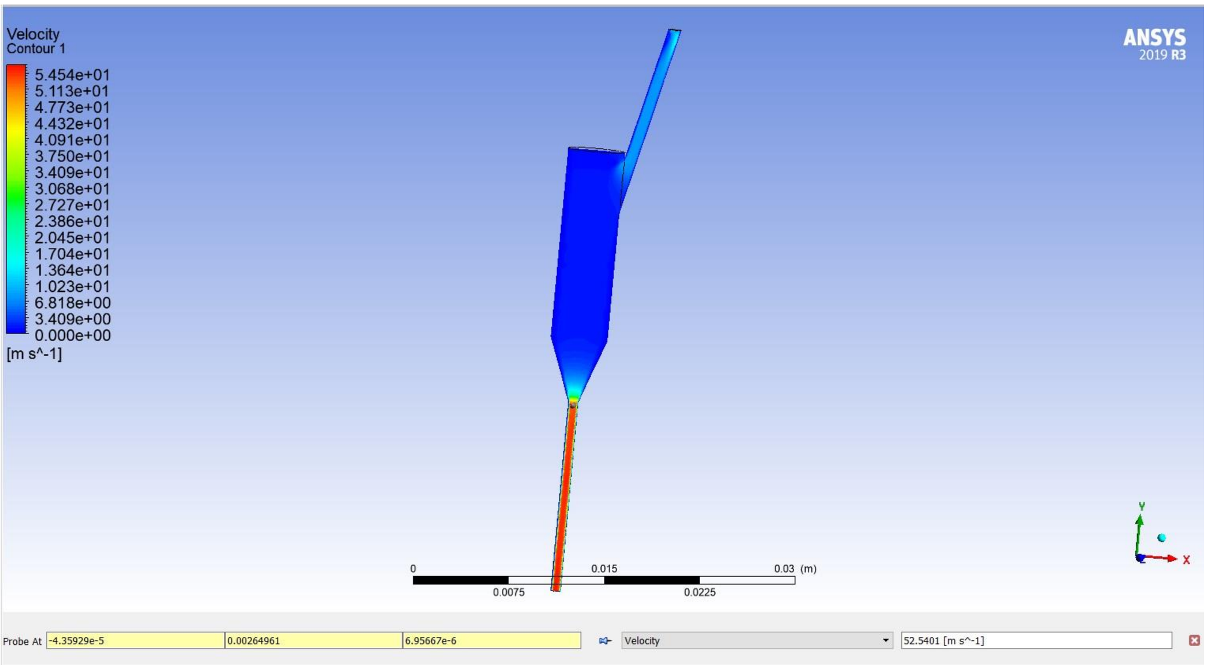


Fig no.15 Velocity at outlet

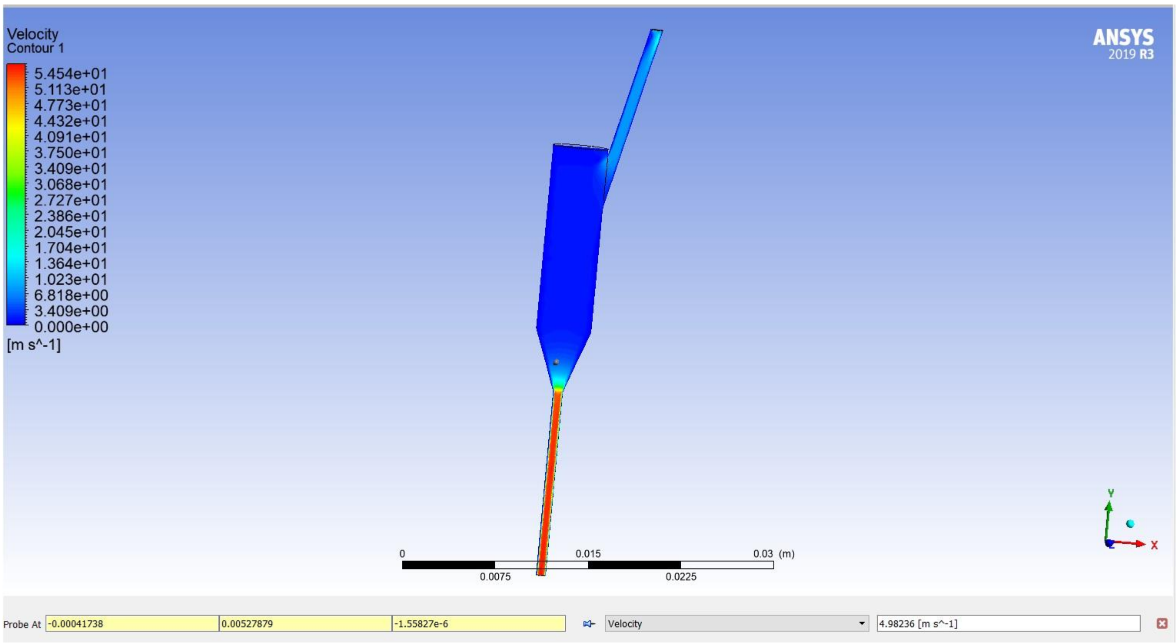


Fig no.16 Velocity at mixing chamber

Wall shear stress

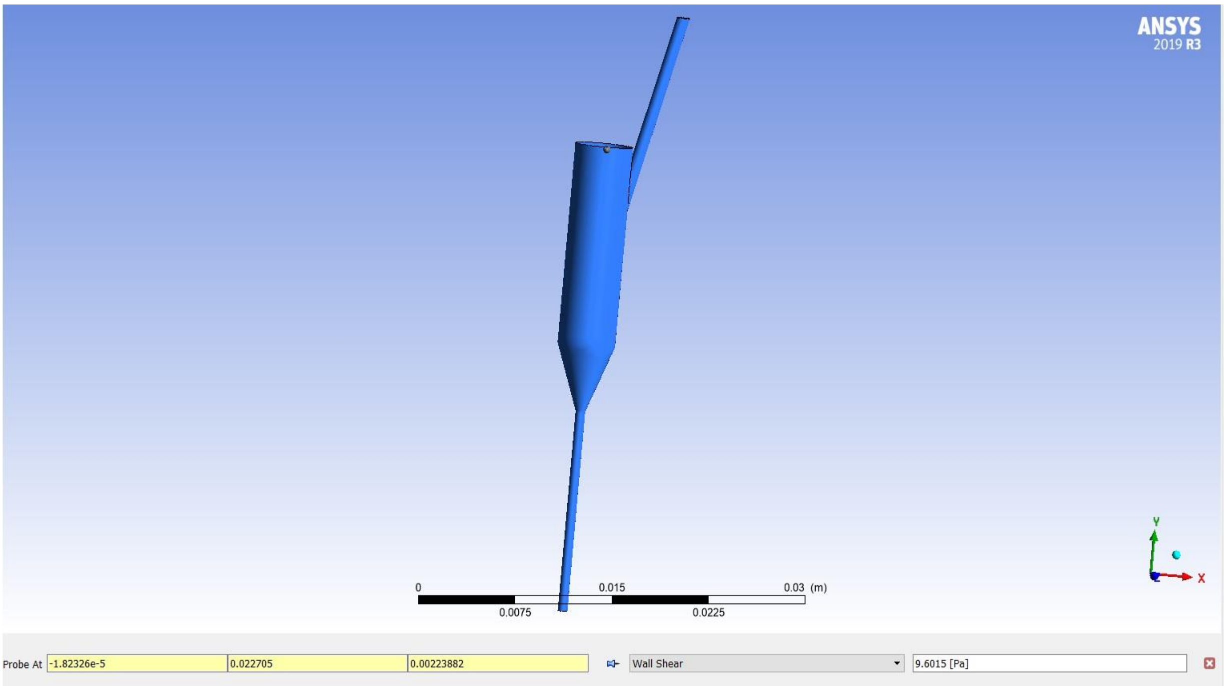


Fig no.17 Wall shear at inlet

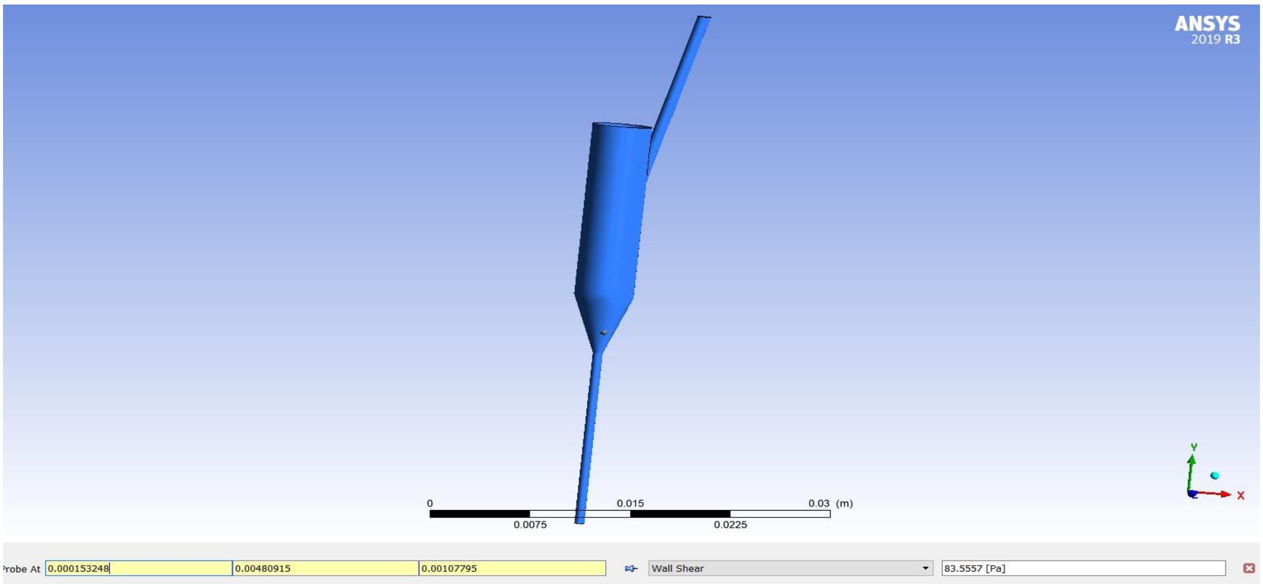


Fig no.18 Wall shear at outlet

Presssure contours

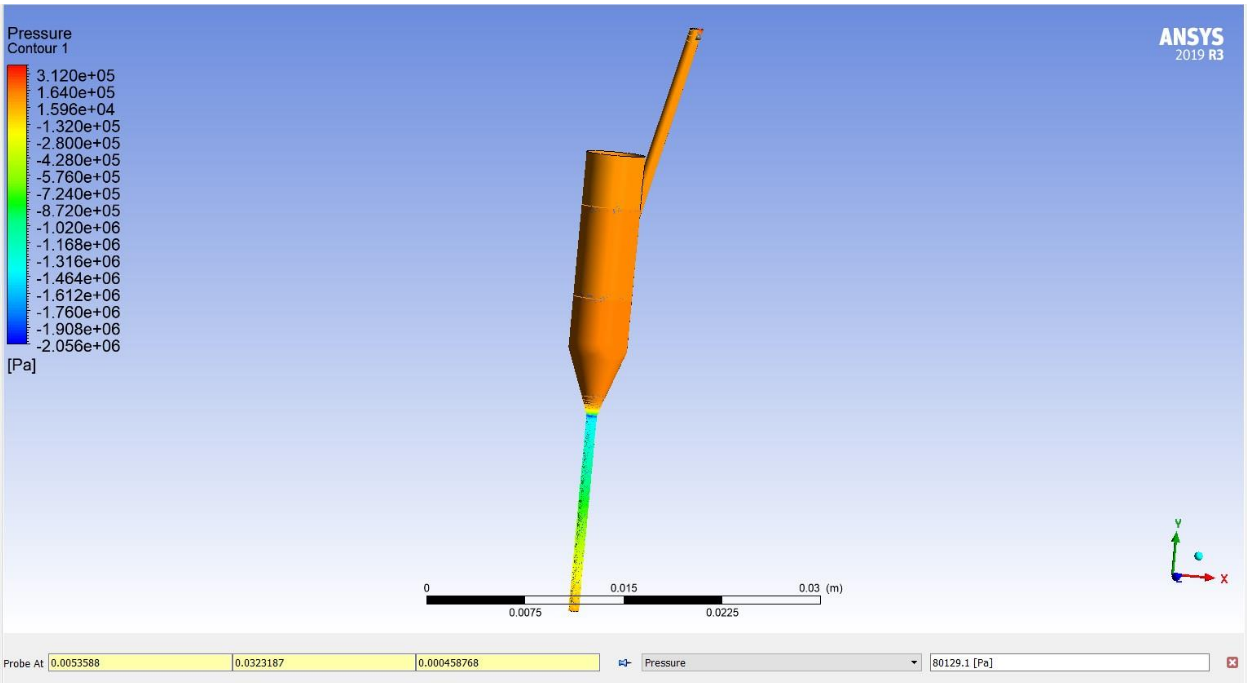


Fig no.19 Pressure at abrasive inlet

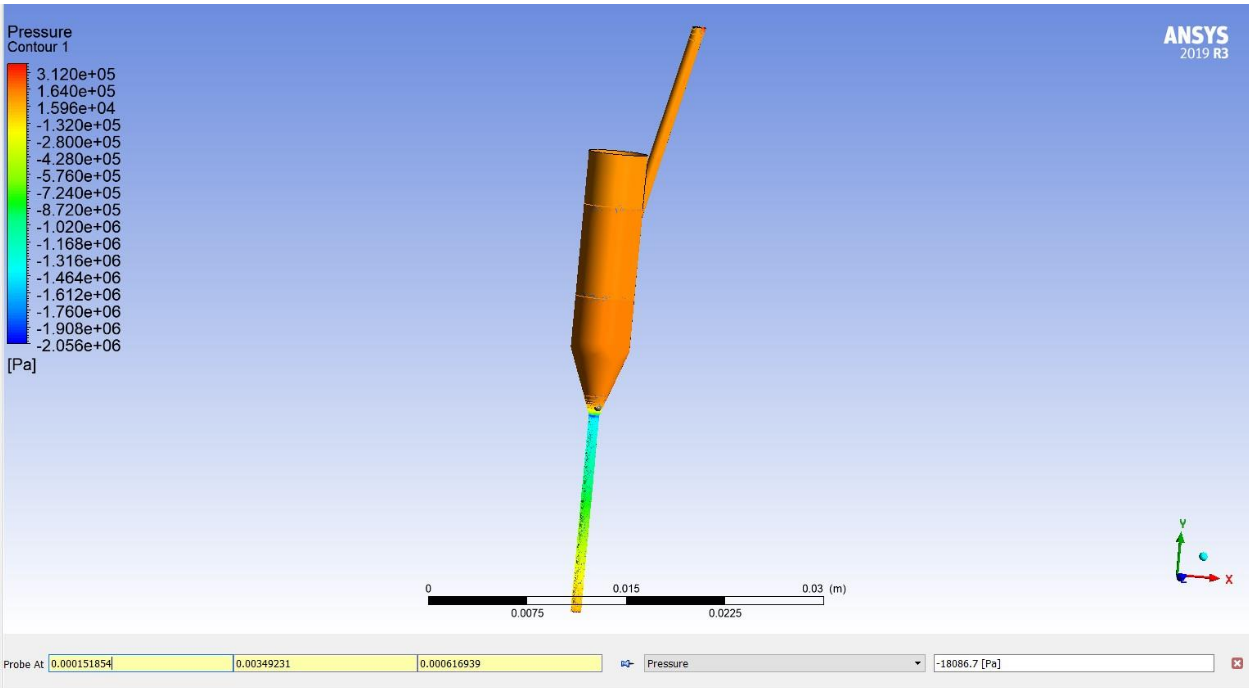


Fig no.20 Pressure at oulet

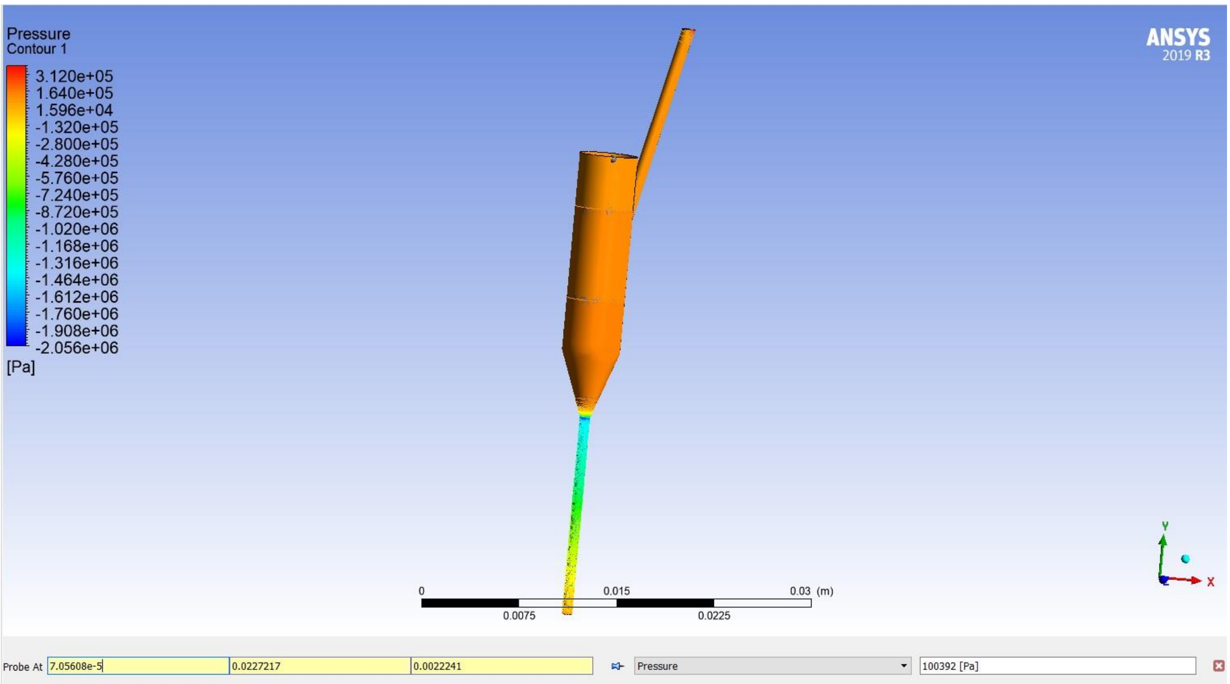


Fig no.21 Pressure at water inlet

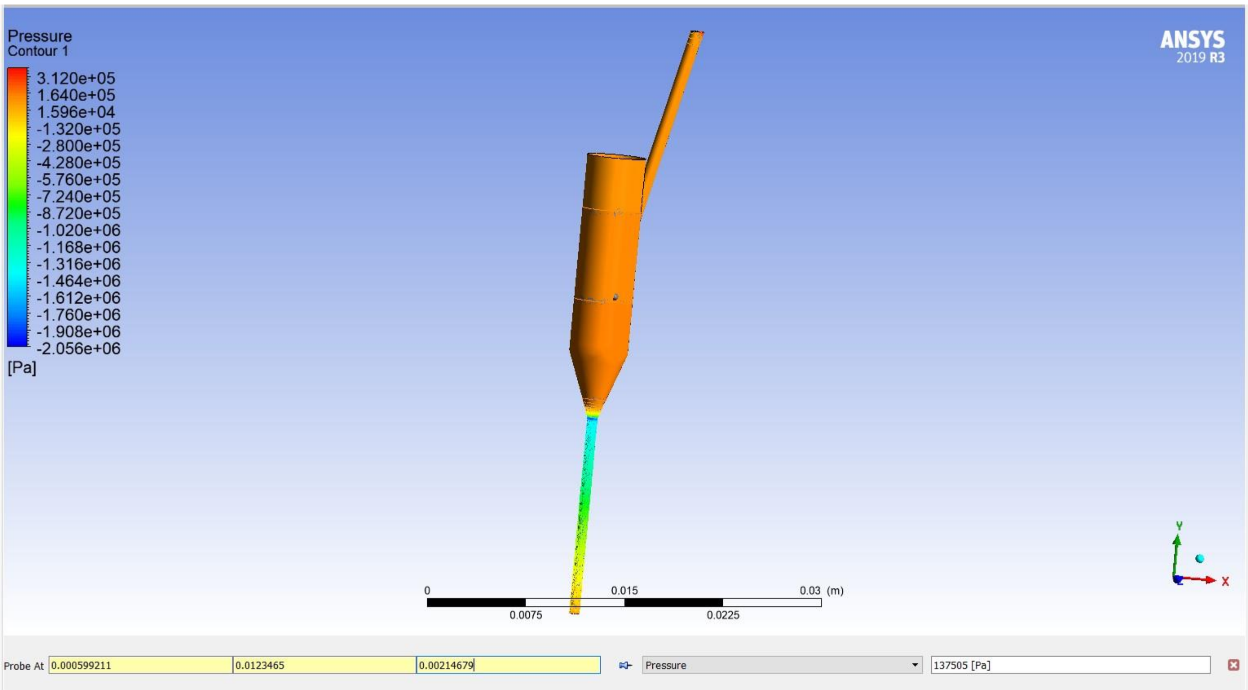


Fig no.22 Pressure at mixing chamber

- Analysis done with inlet pressure of 150 Kpa
  Mass flow rate of abrasive is 0.0042 kg/s

Velocity vectors

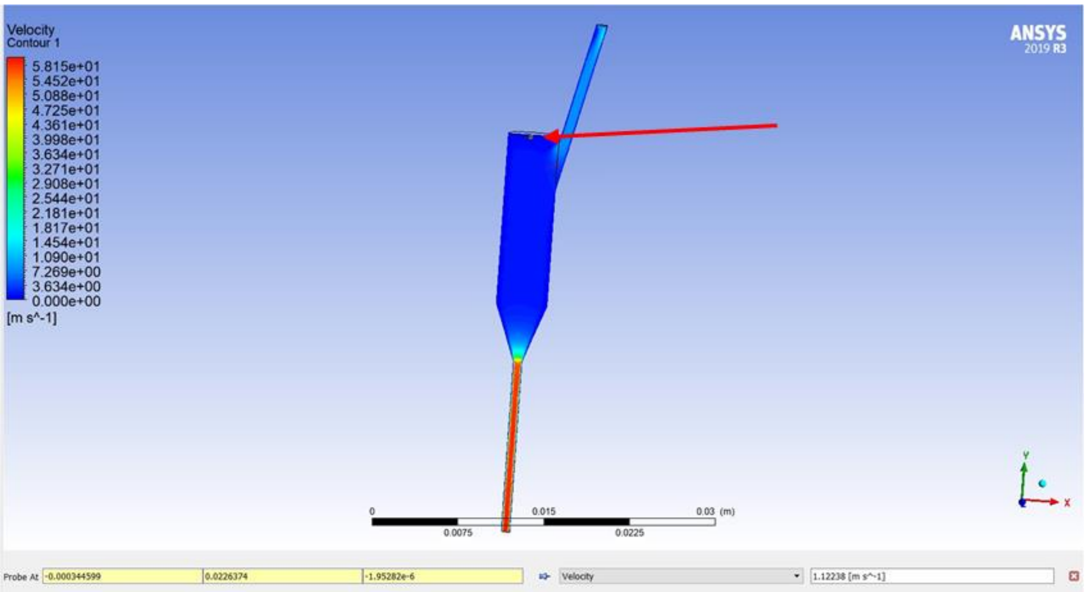


Fig no.23 Water inlet velocity

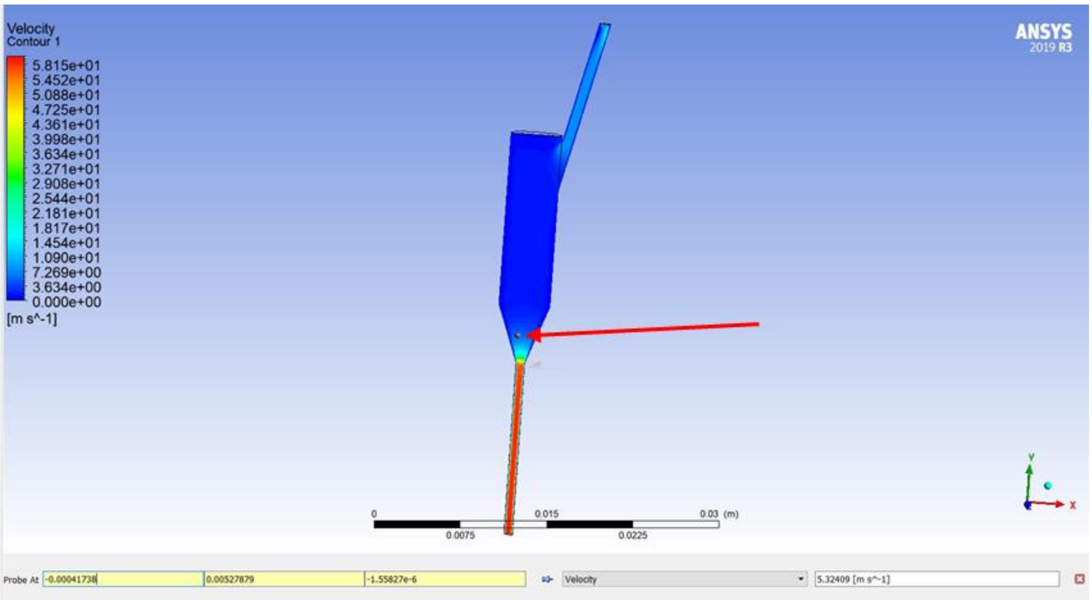


Fig no.24 Suspension velocity before exit

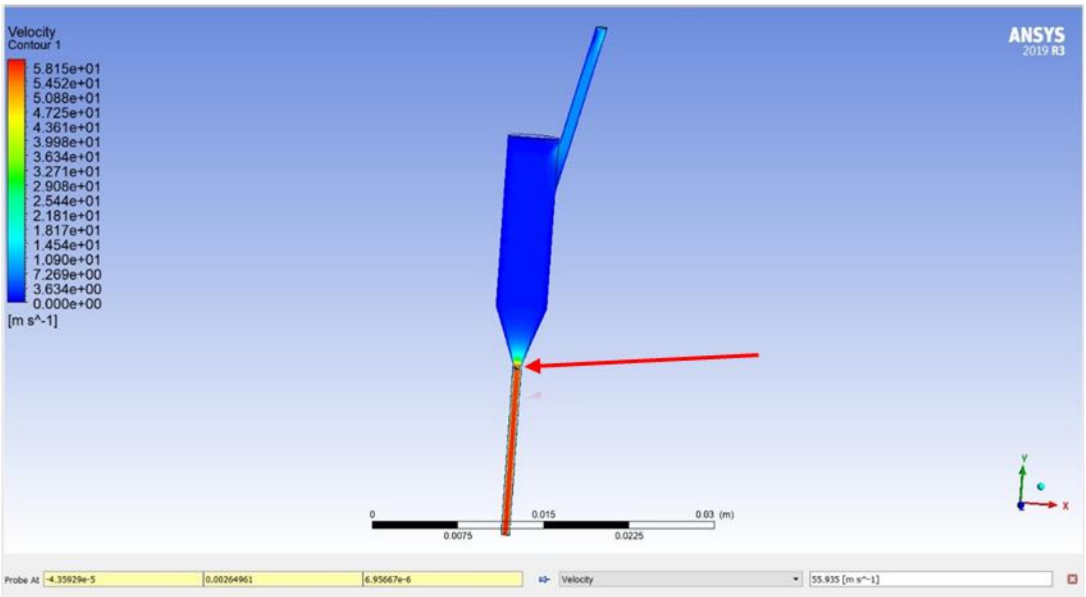


Fig no.25 Suspension velocity at exit

Pressure coutours

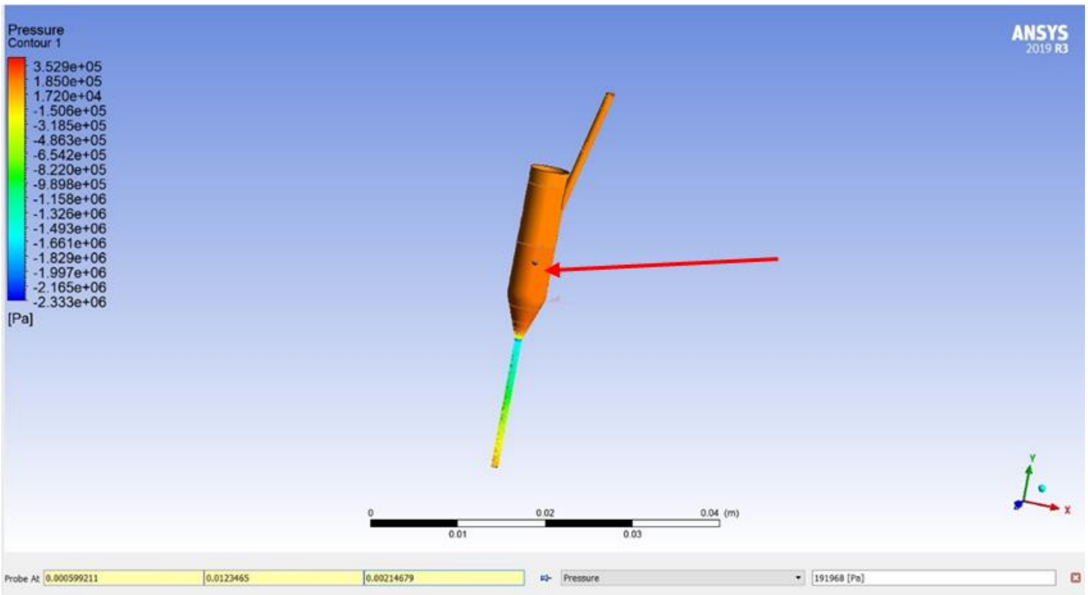


Fig no.26 Mixing chamber pressure

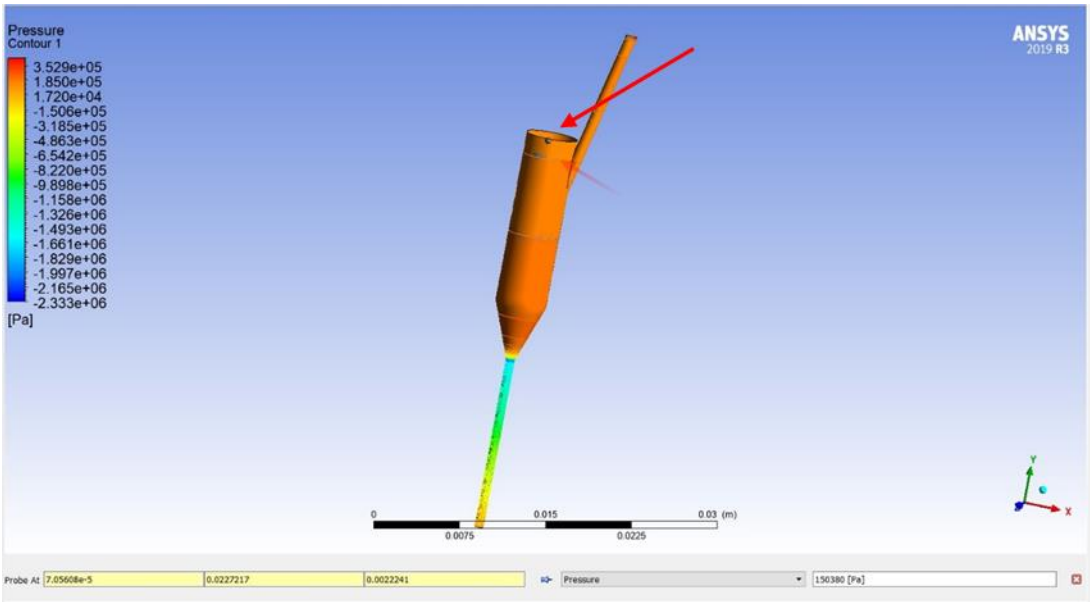


Fig no.27 Water inlet pressure

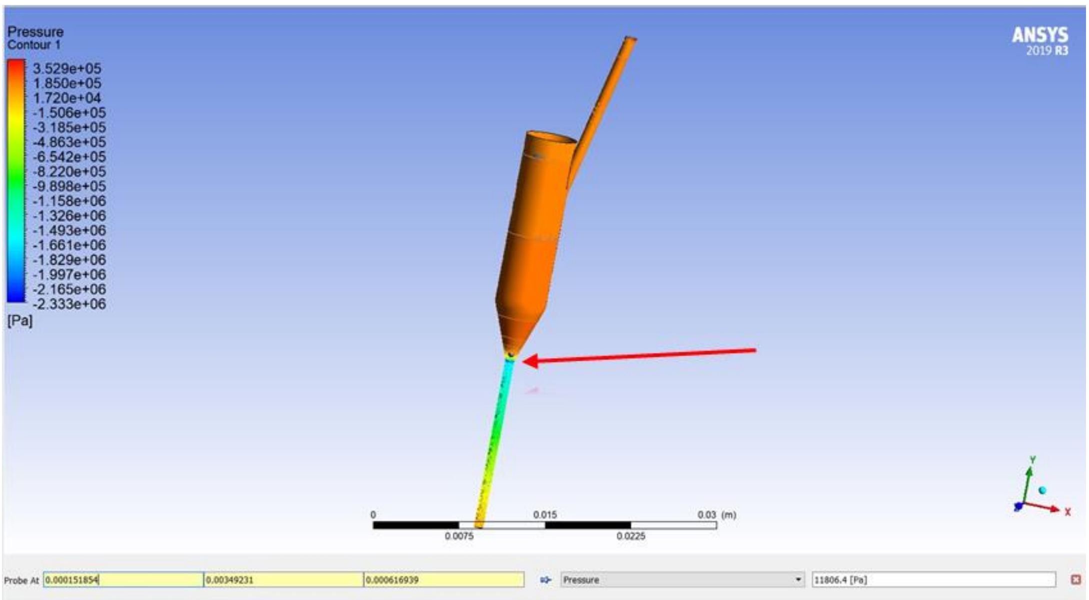


Fig no.28 Suspension pressure at the exit

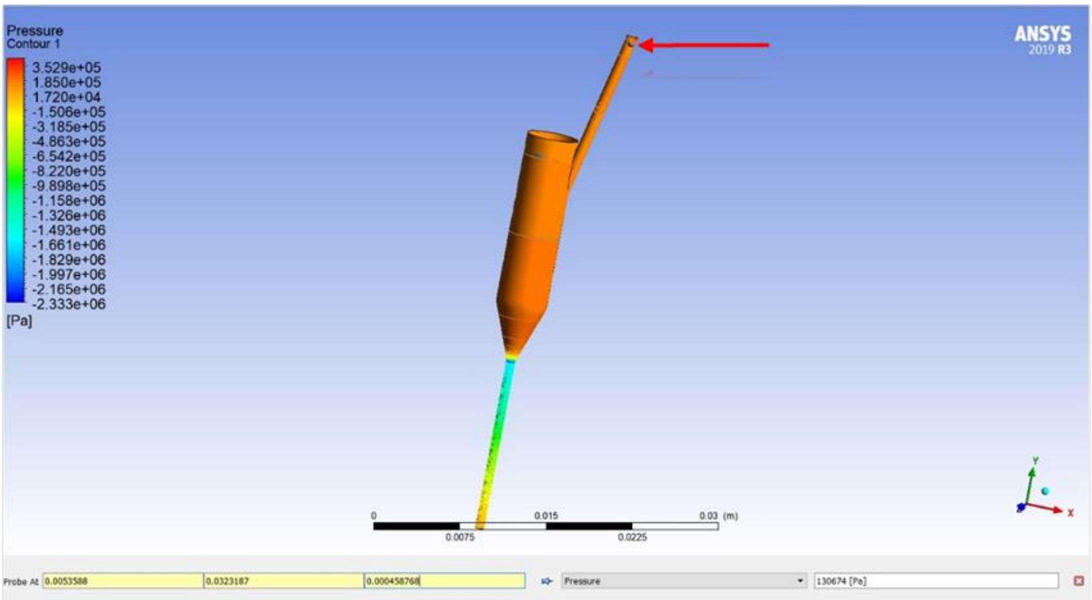


Fig no.29 Abrasive pressure at inlet

Wall shear contours

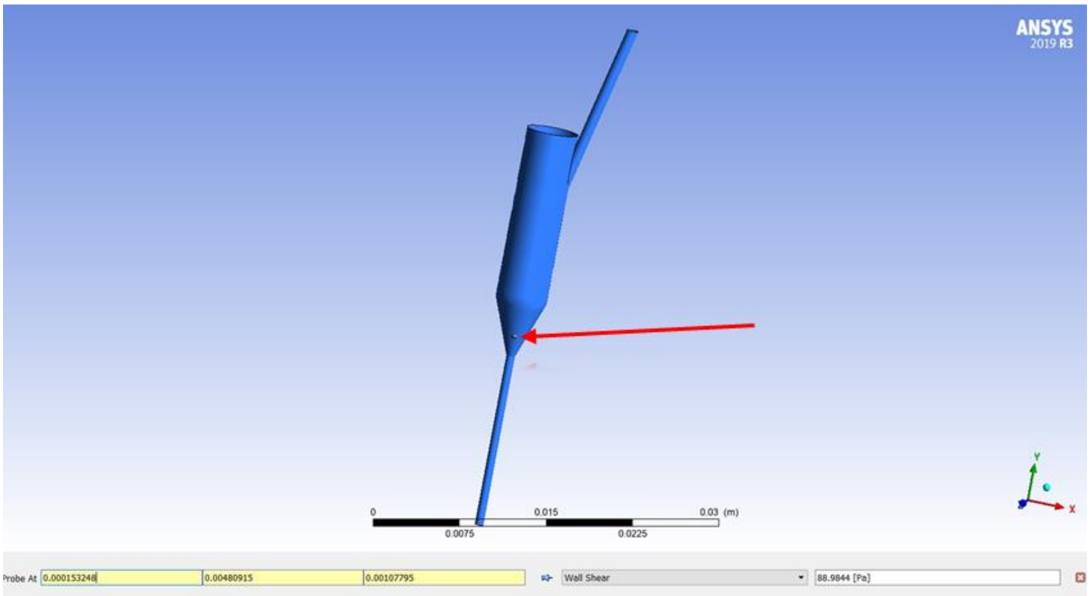


Fig no.30 Wall shear at nozzle

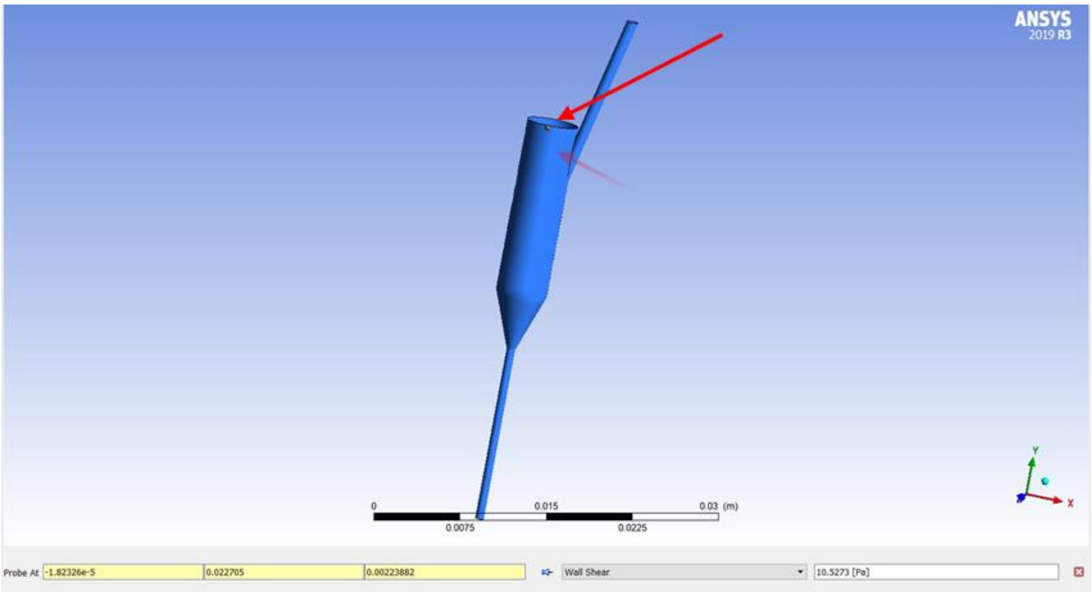


Fig no.31 Wall shear at inlet

Analysis done with inlet pressure of 200 Kpa
Mass flow rate of abrasive is 0.0042 kg/s

Velocity contours

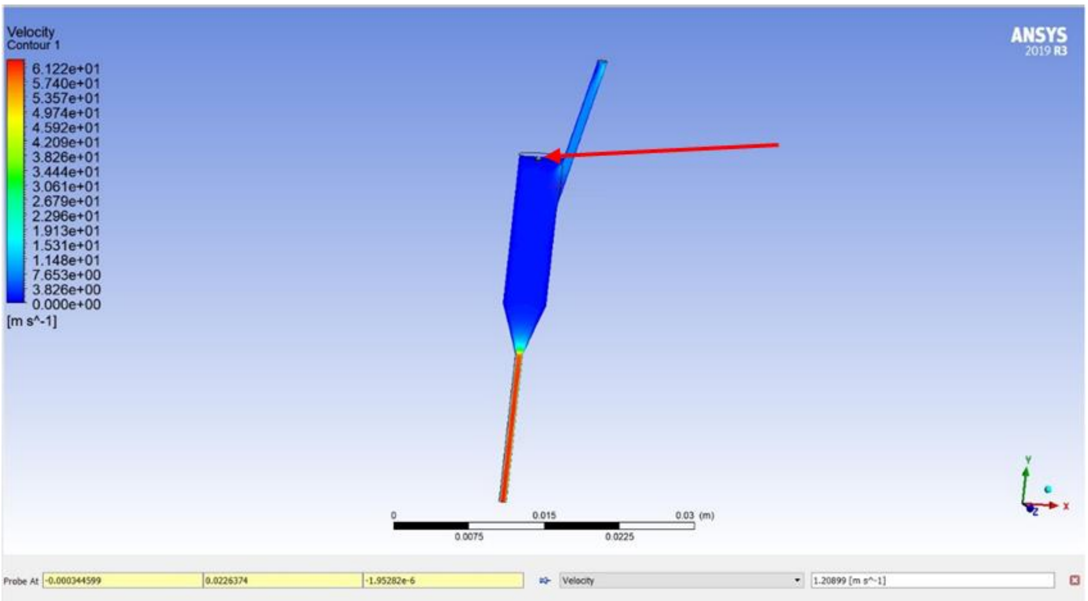


Fig no.32 Water inlet velocity

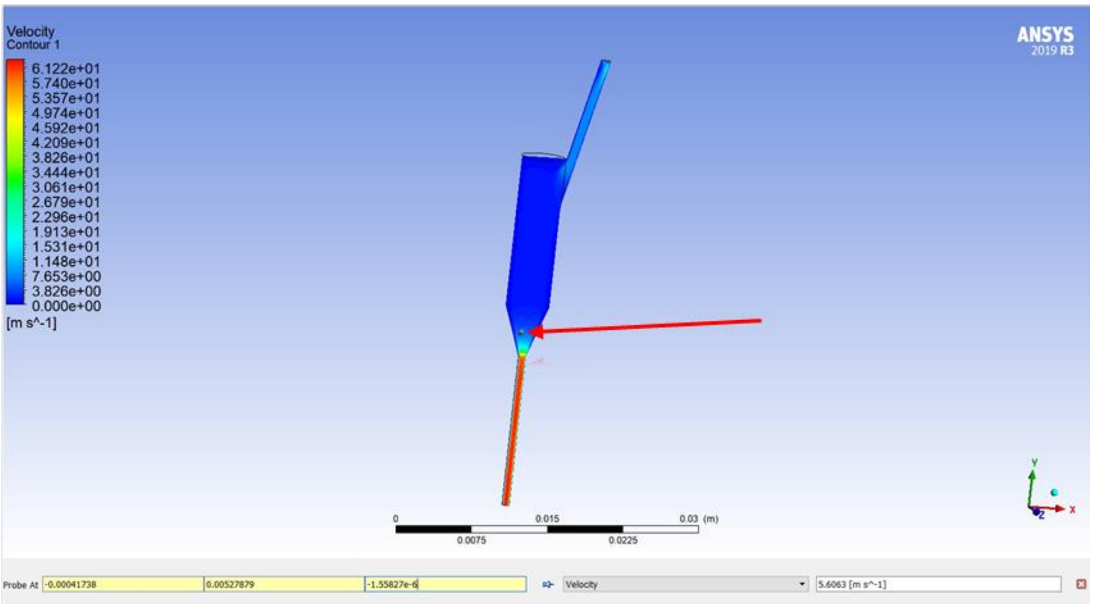


Fig no.33 Suspension velocity before exit

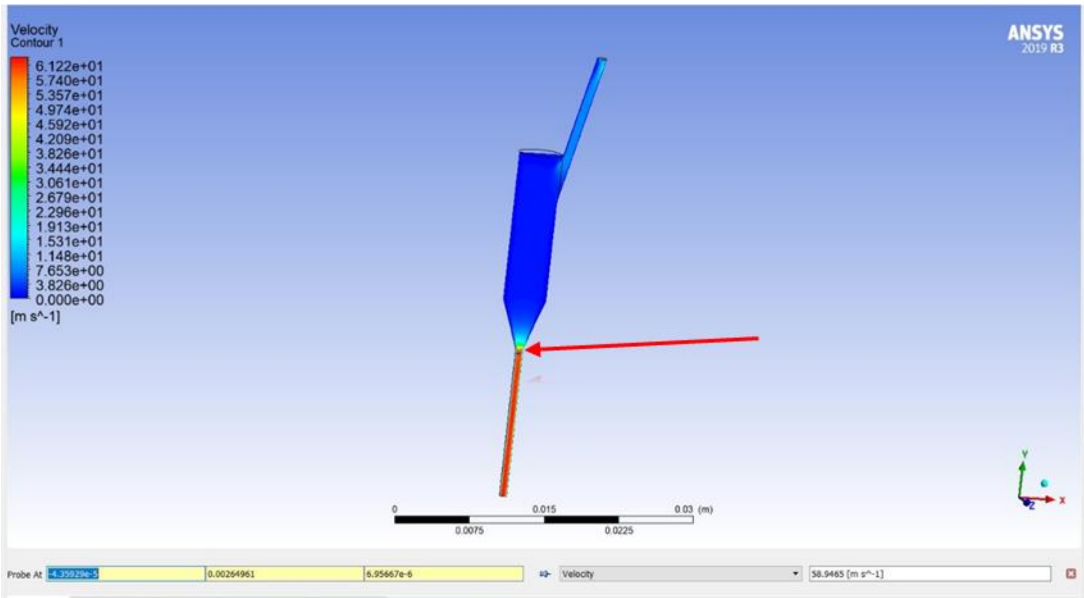


Fig no.34 Suspension velocity at exit

Pressure contours

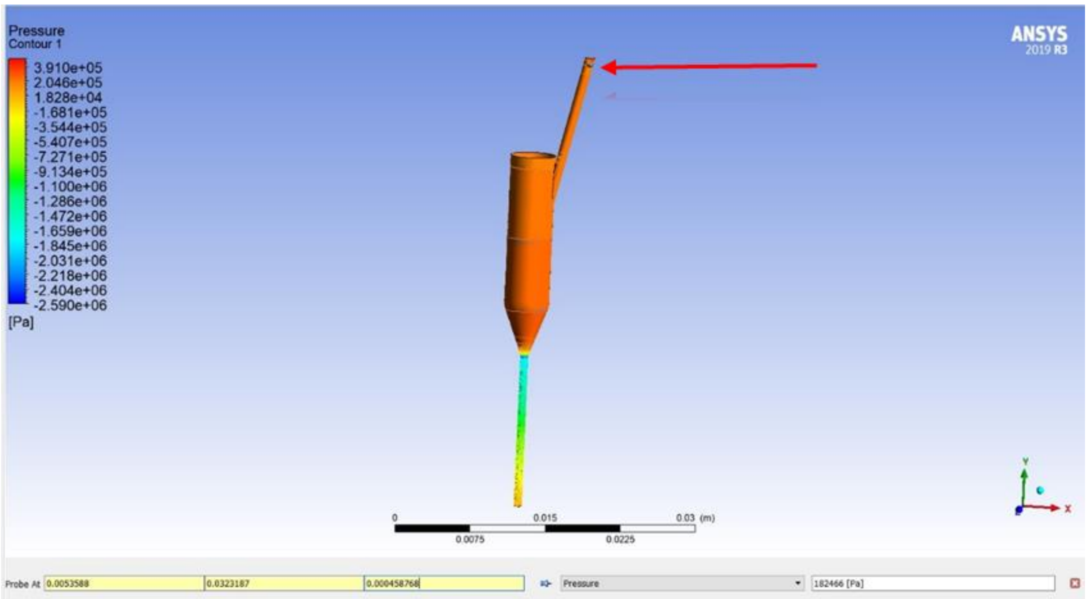


Fig no.35 Abrasive pressure at inlet

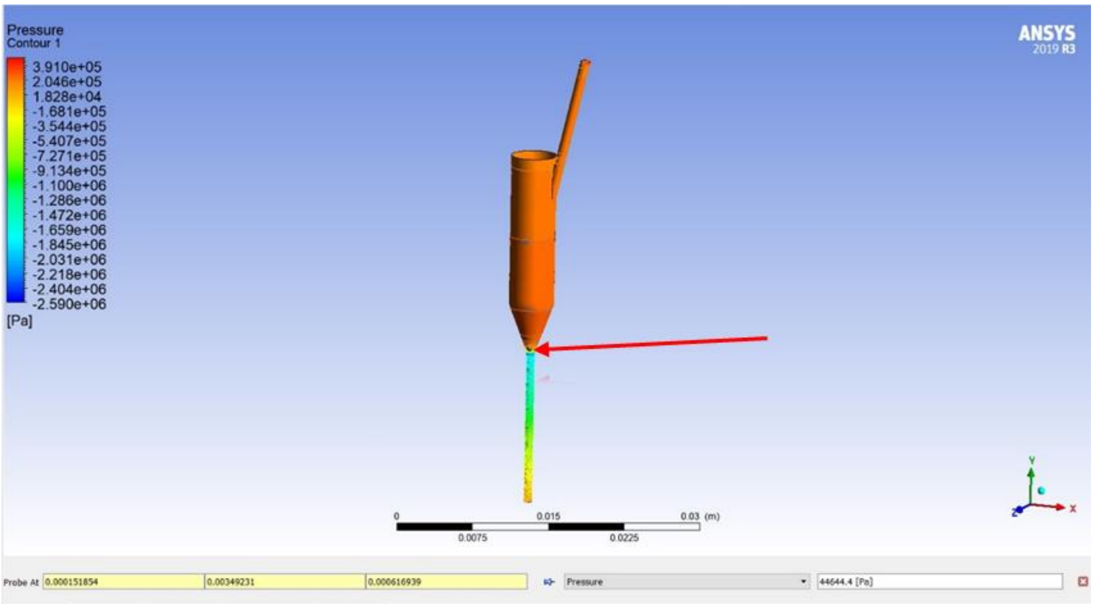


Fig no.36 Suspension pressure at the exit

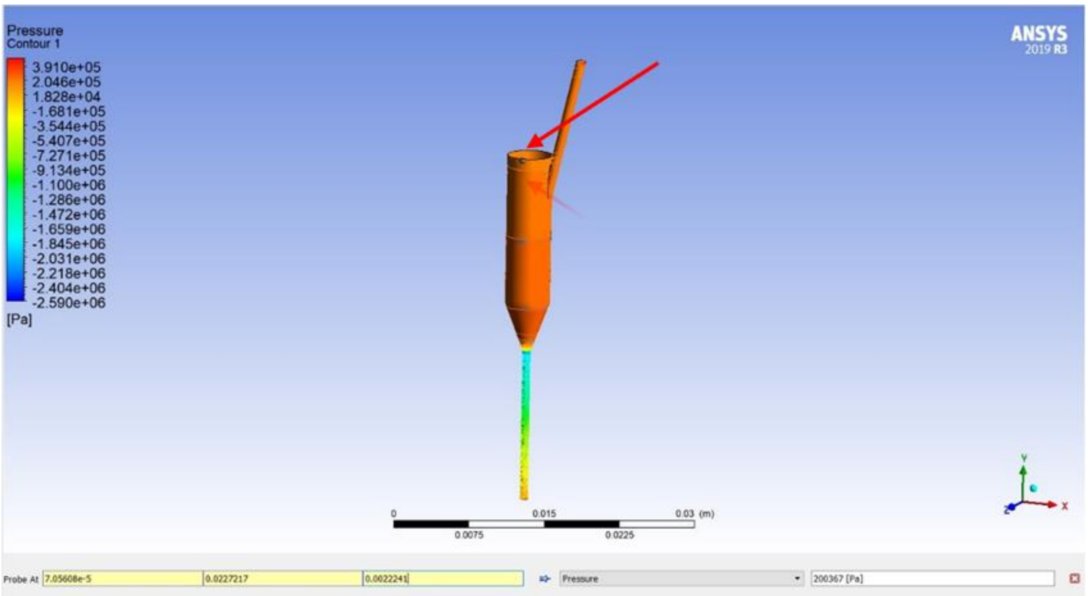


Fig no.37 Water inlet pressure

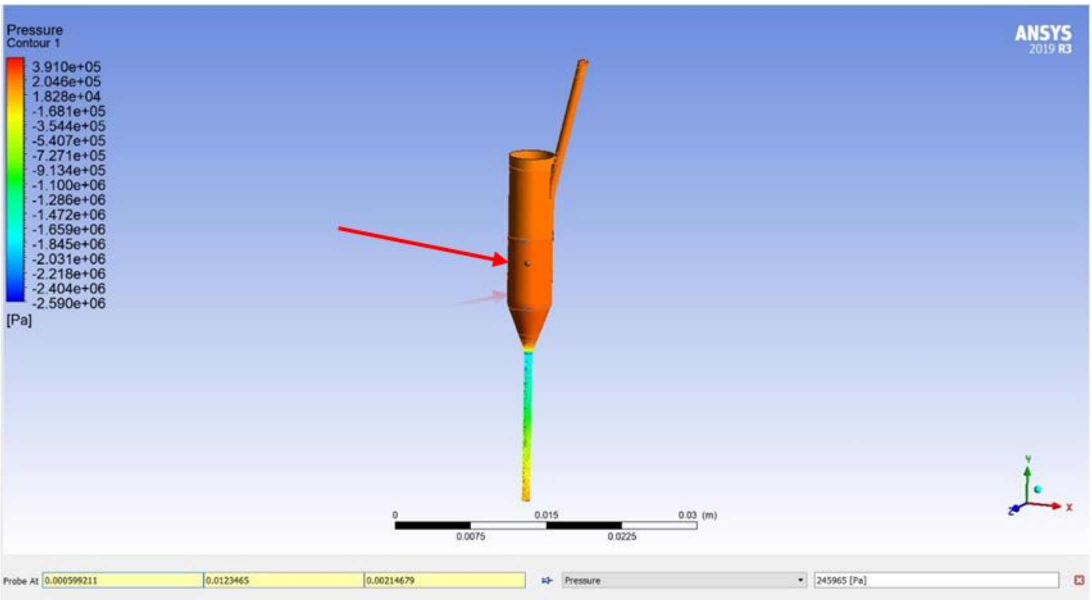


Fig no.38 Mixing chamber pressure

Wall shear contours

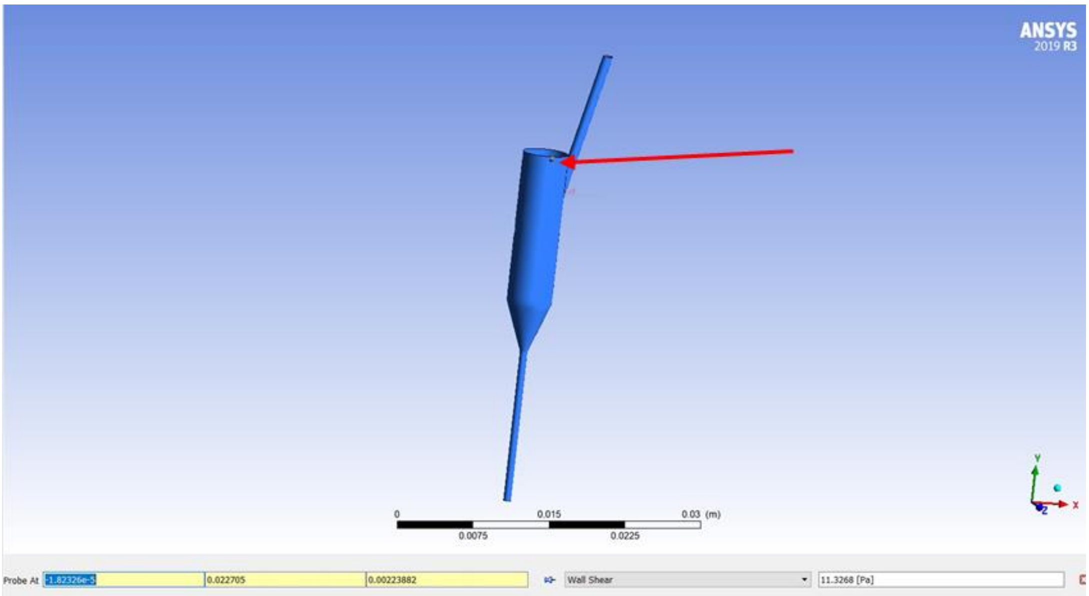


Fig no.39 Wall shear at inlet

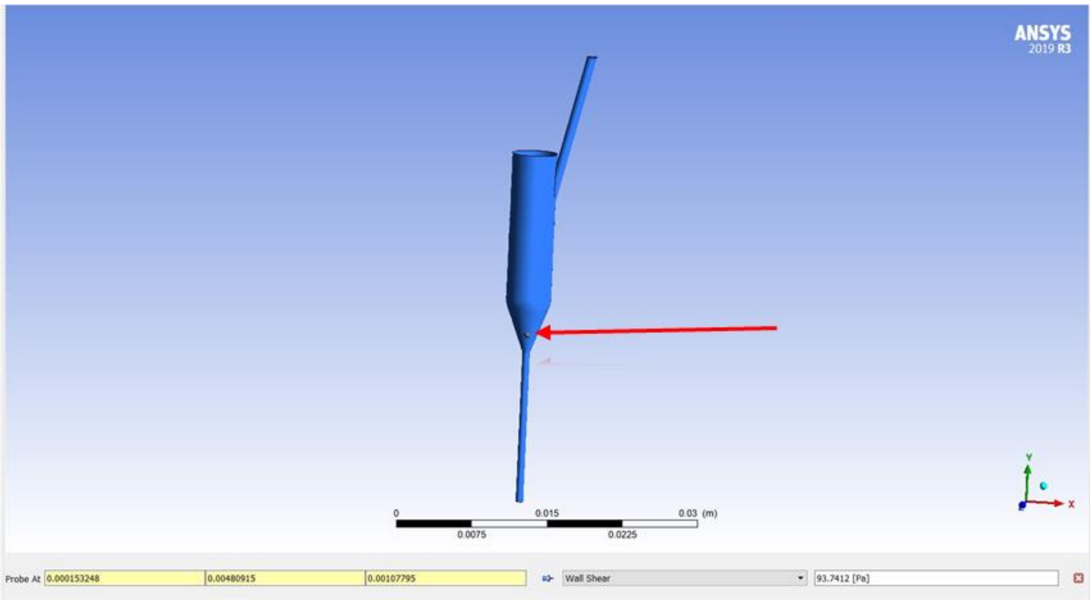


Fig no.40 Wall shear at nozzle

4.2 Results obtained

Sl no.	Total gauge pressure (kpa)	Mass flow rate (kg/s)	Water Inlet pressure at (pa)	Abrasive inlet Pressure (pa)	Pressure at mixing chamber (pa)	Pressure at outlet (pa)	Velocity at Inlet (m/s)	Velocity before exit (m/s)	Velocity at exit (m/s)	Wall shear at Inlet (pa)	Wall shear at Outlet (pa)
1	100	0.0042	100,392	80,129.1	137,505	-18,086.7	1.02182	4.98236	52.5401	9.6015	83.5557
2	150	0.0042	150,380	130,674	191,968	11,806.4	1.12238	5.32409	55.935	10.5273	88.9844
3	200	0.0042	200,367	182,466	245,965	44,644.4	1.20899	5.6063	58.9465	11.3268	93.7412

Table 2. Results obtained

5. PROJECT TESTING

5.1 Overview of testing methods

Organization of Ansys program

The ANSYS program is organized into two basic levels:

- begin level (Start level)
- Processor (or routine) level

Begin level acts as a gateway into and out of the ANSYS program. Changing the name of job, database clearing, and binary files copying are program controls used. When we first enter the program, we at the begin level.

At the processor level, several processors are available; each processor is a set of functions that specific analysis task perform. For instance, the general preprocessor (PREP7) is the place we fabricate the model, the arrangement processor (SOLUTION) is the place we apply stacks and get the arrangement, and the general postprocessor(POST1) is the place we assess the outcomes and acquire the arrangement. An extra postprocessor (POST26), empowers we to assess arrangements results at particular focuses in the model as an element of time.

PERFORMING A TYPICAL ANSYS ANALYSIS

The ANSYS system has numerous limited component investigation capacities, extending from a straightforward, direct, static examination to a nonlinear, transient element investigation. The investigation guide manuals in the ANSYS documentation set portray particular systems for performing examination for diverse building controls.

ANSYS analysis has three distinct steps:

- construct the model
- Apply loads and boundaries
- Obtain the solution
- Review the results

The following table shows the brief description of steps followed in each phase.

Pre-processor	Solution processor	Post processor
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graphs
Assigning real constants	load definition	view animated results
Material definition	Solve	
Mesh generation		
Model display		

Table 3. ANSYS analysis steps

Pre-processor

Preprocessor prepares the input data for ANSYS analysis. The general preprocessor (PREP 7) contains solid modeling and mesh generation capabilities, and is also used to define all other analysis data with the benefit of data base definition and manipulation of analysis data. Parametric input, user files, macros and extensive online documentation are also available, providing more tolls and flexibility for the analyst to define the problem. Extensive graphics ability is available throughout the ANSYS program, including isometric, perceptive, section, edge and hidden-line displays of three-dimensional structures-y graphs of input quantities and results, and contour displays of solution results.

The preprocessor stage involves the following:

- Specify the title, which is the name of the issue. This is discretionary yet exceptionally valuable, particularly if various configuration cycles are to be finished on the same base mode.
- Analysis types thermal analysis, modal analysis, Harmonic analysis etc.
- Creating the model: The model may be made in pre-processor, or it can be imported from other design software by changing the file format.
- Defining element type: these chosen from element library.
- Assigning real constants and material properties like young`s modules, Poisson's ratio, density, thermal conductivity, damping effect, specific heat, etc.
- Apply mesh: Meshing is nothing but dividing the whole area into discrete number of particles.

Solution processor

Here we create the environment to the model, i.e. applying constraints & loads. This is the main phase of the analysis, where the problem can be solved by using different solution techniques. Here three major steps involved:

- Solution type required, i.e. static, modal, or transient etc. is selected.
- Defining loads: The loads may be surface loads, point loads; thermal loads like temperature, or fluid pressure, velocity are applied.
- Solve FE solver can be logically divided into three main steps, the pre-solver, the solution and post-solver. Model read by pre solver which is created by the pre-processor and makes the arithmetical representation of the model and calls the mathematical-engine, which calculates the result. The result return to the solver and the strains, stresses, etc. for each node within the component or continuum are calculated by post solver.

Post processor

Post processing means the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affects the design, how the meshing is done.

Post processor analyzes results, which display stress and strain contours, distorted geometries, flow fields, safety factor contours, contours of potential field results; vector field displays shapes of mode and graphs related to time history. The post processor can also be used for algebraic operations, database manipulators, differentiation and integration of calculated results.

Review the results

Once the solution has been calculated, results can be reviewed in post processor. Two post processors are available: POST 1 and POST 26. We use POST 1, the general post processor to review the results at one sub step over the entire model or selected portion of the model. We can obtain contour displays, deform shapes and tabular listings to review and interpret the results of the analysis. POST 1 offers many other capabilities, including error estimation, load case combination, calculation among results data and path operations.

- We use POST 26, the time history post processor, to review results at specific points in the model over all tome steps. We can obtain graph plots of results, data vs. time and tabular listings. Other POST 26 capabilities include arithmetic calculations and complex algebra.
- The simultaneous set of equations that the finite element method generates the solution taken by the computer, the results of the solution are:
- Nodal degree of freedom values, which form the primary solution.
- Derived values which frame the component arrangement

5.2 Analysis

Introduction to finite element analysis

The essential idea in fem is that the body or structure may be separated into littler components of limited measurements called "Finite Elements". The first body or the structure is then considered as a gathering of these components associated at a limited number of joints called "nodes" or "nodal points"

Basic capacities are approximated the relocations over each limited component. Such accepted capacities are called "shape capacities". This will speak to the uprooting within the component as far as the remit Element technique is a scientific apparatus for illuminating common and fractional at the hubs of the components. The Final differential comparison in light of the fact that it is a numerical instrument, it can take care of the unpredictable issue that can be spoken to in differential mathematical statement from. The use of FEM is boundless as respects the arrangement of commonsense configuration issues.

The finite element method can be utilized to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mold flow simulations

Now a days, even the most simple of products rely on the finite element method for design evaluation. This is on account of contemporary configuration issues normally can't be understood as precisely and inexpensively utilizing some other system that is at present accessible. Physical testing was the standard in the years passed by, however now it is just excessively costly and tedious too.

Essential concepts: The limited component technique depends on building an entangled article with basic squares or driving a confounded item into little and sensible pieces. Use of this basic thought can be discovered all over the place in ordinary life and building. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

Area of one triangle: Si=1/2*R2*sin θI.

Area of the circle: SN=1/2*R2*N*Sin (2∏/N) →∏R2 as N→∞.

Where N= total number of triangles (elements)

To calculate the area of circle without using conventional formula, one of the approach could be dividing the area into number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle

CHAPTER-6.0 CONCLUSION AND FUTURE ENHANCEMENT

The experimentation investigation and optimization of process parameters of AWJM is done and obtained by CFD analysis using ANSYS software.The variations in the flow is obtained in the process parameters of AWJM.

Quality of cut surface in AWJM is dependent on so many process parameters. Process parameter which affect less or more on quality of cutting in AWJM are water pressure, size of abrasives, Standoff distance, abrasive flow rate, types of abrasive, orifice size, nozzle diameter, and traverse speed. Quality of machining is measured by material removal rate, kerf width surface roughness, and taper ratio. From the literature survey compare to above all cited parameter traverse speed is most active parameter for MRR. Abrasive flow rate is too an important parameter for increasing MRR. But further than some limit with rise in abrasive flow rate and traverse speed the surface roughness falls. Increasing traverse speed also upsurge the kerf geometry. So it is essential to discover optimum condition for process parameter to give improved quality of cutting surface. Traverse speed is directly proportional to output (productivity) and should be selected as high as possible deprived of compromising kerf quality and surface roughness.

Abrasive waterjet machining is a new machining process, the advantages of which include low cutting temperatures, no heat damage to the material being cut, minimal dust, and low cutting forces. This paper presents a state of the art review of research in this new process. The main topics discussed are mechanics of material removal, productivity, cutting forces, surface quality and nozzle wear.

Future enhancements:

Current design requirements have necessitated the need for a class of engineering materials that possess high stiffness and reduced weight, especially at elevated service temperatures. Due to the rapid developments in the aerospace and the automotive industries, traditional machining of ceramics and composite materials are becoming inadequate and inefficient because of the excessive tool wear, and the brittle nature of these materials. Abrasive waterjet machining offers the potential for the development of a tool which is less sensitive to material properties, has virtually no thermal effects, and imposes minimal stresses. This process was first introduced as a commercial system in 1983 for cutting of glass. Nowadays, this process is being widely used for machining of hard to machine materials like ceramics, ceramic composites, fibre-reinforced composites, and titanium alloys where conventional machining is often not technically or economically feasible. The fact that it is a cold process has important implications where heat-affected zones are to be avoided. The heart of the abrasive waterjet system is the abrasive jet nozzle as shown in. Water is pressurized up to 400 Mpa and expelled through a sapphire nozzle to form a coherent high-velocity jet. Abrasives are added into a specially shaped abrasive-jet nozzle from separate feed ports. Few researchers were concerned with cutting forces and temperature. This may be attributed to the fact that AWJM is a cold cutting process and cutting forces are very low.No literature available so far for multi response optimization of process variables and more work is required to be done in this area.

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A Major Project Report
on

MODELLING AND EXPERIMENTAL STUDY OF LATENT HEAT THERMAL ENERGY STORAGE WITH ENCAPSULATED PCMS FOR SOLAR THERMAL APPLICATIONS

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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JUNE 2021

ST. MARTIN’S ENGINEERING COLLEGE

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Modelling and Experimental Study of Latent Heat Thermal Energy Storage With Encapsulated PCMs For Solar Thermal Applications**, is being submitted by **M. Goutham (15K81A0332), A. Rakesh Reddy (17K81A0302), B. Vinay (17K81A0308), K. Phani Ganesh (17K81A0330)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

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Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Modelling And Experimental Study Of Latent Heat Thermal Energy Storage With Encapsulated PCMs For Solar Thermal Applications** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

The world generates major energy from fossil fuel based thermal power plant which uses coal, oil and natural gas. The fossil fuel-based energy sources have a major impact on the climate change. As a result, the usage of renewal energy sources such as solar, wind and tidal has emerged as an alternative. Among these, solar energy is available in abundance in many parts on the earth and has zero global warming potential (GWP), which can be used as heat source in thermal power plant. The variability in solar radiation creates a gap between energy demand and supply, which necessitates the use of efficient thermal energy storage for bridging the gap to make the solar thermal power plant a viable solution for continuous power generation. In this work, a model of encapsulated phase change materials (PCMs) based latent heat thermal energy storage (LHTES) is developed to analyse the transient variation in heat transfer fluid (HTF) temperature at the outlet of LHTES and PCM temperature. Experiments on a spherical capsule reveal melting and solidification behaviour of PCM from the measured temperature field.

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CHAPTER 1
INTRODUCTION

Thermal Energy Storage (TES) has become one of the most pressing topics worldwide. The serious concern of public regarding greenhouse gases emissions, limited reserves of fossil fuel, and rapid growth of global energy have shed the light on the effective utilization of thermal energy. According to the U.S energy information administration, the global world energy use is estimated to increase from 1.7×1011 MWh in 2015 to 2.2x1011 MWh in 2040, an increase of 29%. Thermal energy storage provides a key method to reduce energy consumption and dependency on fossil fuels. Efficient utilization of energy can be achieved by matching the energy supply with demand by means of thermal energy storage systems. For instance, power plants can run at maximum power, and excess heat from production can be transferred to thermal storage systems where it is stored for later utilization during peak demand, increasing efficiency and reducing the mismatch between energy supply and demand. In this context, thermal energy storage using Phase Change Materials (PCMs) present a unique opportunity to reduce the need to fossil fuel and suppress greenhouse gases emission.

According to the report from the U.S. Energy Information Administration in 2016, 41% of worldwide energy was consumed for residential buildings, especially, 60% of that value was consumed for heating and cooling applications (The U.S. Energy Information Administration [2016]). The United Kingdom's Government Department for Business, Energy & Industrial Strategy reported the energy use in the United Kingdom from 1970 to 2015 in 2016. The report released about 30% of energy was consumed by residential sector. Heating system consumed 56% of such value (The United Kingdom's Government Department [2016]). From the results, the biggest potential for energy saving in residential sector was in heating or cooling applications.

A Thermal Energy Storage (TES) system is an important technological system to provide energy savings as well as the efficient and optimum energy use because a TES can hold thermal energy of materials in the solid state or in the liquid state. Therefore, a TES is an efficient energy storage, which can improve the performance of energy systems, and a TES can correct the gap between the demand and supply of energy. The main types of a TES are a sensible heat storage and a latent heat storage. The latent heat storage is a very efficient method to store and release thermal energy because it has a high-energy storage density at constant temperatures. A latent heat storage material can store 5-14 times more heat per unit volume than a sensible heat storage material can.

1.1 Overview of the Project:

The world generates major energy from fossil fuel based thermal power plant which uses coal, oil and natural gas. The fossil fuel-based energy sources have a major impact on the climate change. As a result, the usage of renewal energy sources such as solar, wind and hydel has emerged as an alternative. Among these, solar energy is available in abundance in many parts on the earth and has zero Global Warming Potential (GWP), which can be used as heat source in thermal power plant. One of the drawbacks with this source is its high equipment cost and initial investment, however with the advancement in technology, it is expected to decline in future. Another problem is unavailability of this source during night and intermittency throughout the day. Therefore, thermal energy storage (TES) can be a solution, as it can store energy in the form of sensible heat or/and latent heat for later utilization. Various types of thermal energy storage are

(i)sensible heat storage,

(ii) latent heat storage and

(iii) thermo-chemical storage.

Latent heat storage offers greater storage density per unit volume than sensible storage because of its latent heat content. Phase change materials (PCMs) are used in latent heat thermal energy storage (LHTES). PCM can store and release energy within a small temperature difference and can undergo various melting and solidification cycles without losing stability [3]. There are many factors to be considered while selecting a PCM, viz. nontoxic, low sub cooling, non-corrosive, non-flammable and high thermal conductivity, specific heat and latent heat [4]. However, one of the disadvantages of organic and inorganic PCMs is their low thermal conductivity, which can lead to poor heat transfer and long hours of charging and discharging of LHTES. The heat transfer enhancement techniques in LHTES are broadly categorized as (i) increase of heat transfer surface area, such as using encapsulated PCM and (ii) improvement of effective thermal conductivity of PCM, such as using fins, metal matrix and metallic fillers [5]. In this context, encapsulated PCM is a potential method to improve heat transfer between PCM and HTF because of the higher heat transfer area compared to the volume. Encapsulated PCMs based latent heat thermal energy storage is used in different applications, such as concentrated solar thermal power plant, solar cooling, energy efficient building and waste heat recovery system.

The study of LHTES containing encapsulated PCMs as a system, is also important to overcome the technological and economical barrier of this technology. Few authors experimentally and numerically studied the effect of different operating and geometrical parameters on the thermal performance of LHTES. Panesi performed heat transfer analysis of packed bed LHTES for air-conditioning application with water mixed with nucleation agent as a PCM and the aqueous solution of ethanol as (HTF). Simplified energy equations were used for the analysis of spherical capsule and the numerically predicted charging time was compared with the experimental results. Hawaladar et al. conducted experiments on a lab scale setup of packed bed latent heat thermal energy storage to determine the thermal performance. The coacervation technique was used for the manufacturing of the encapsulated PCM. Authors reported that the energy stored and release capacity is higher for encapsulated PCM. Cheng et al. designed and studied a packed bed cold storage unit for a high temperature solar application. They concluded that the effect of inlet HTF temperature is pronounced on the rate of charging and the maximal charging capacity, compared to the energetic efficiency, whereas the inlet HTF flow rate has limited influence on the charging rates than on the energetic efficiency. Few studies on the effect of different operating parameters and geometrical parameters on the thermal performance of the encapsulated PCMs based LHTES were reported in the literature. Nallusamy et al. considered packed bed thermal energy storage system consists of both sensible heat storage material and latent heat storage (SHS) material. Experimental studies were performed with varying inlet temperatures and varying mass flow rates, and constant inlet temperature.

The sun has been a powerful presence and force throughout the history of human existence on earth. It has been regarded by many cultures as a god of one form or another, and understood by most to be the ultimate source of life on this planet. It has also been intentionally exploited by many clever means over the centuries, in order to better utilize this life-giving energy. As far as renewable energy sources go, the sun represents the best and most stable we have. It is infinite with respect to all practical timescales, immensely powerful, understood and predictable in its overall trends and patterns, and for the foreseeable future beyond anthropogenic effects. In short, the perfect energy source; but it is not without difficulties. Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Modern systems designed for capturing the suns energy and transferring it to water, either for immediate use or as a storage medium, have been studied and put to use since the 1970’s, when they were first used for pool heating in California. Continued research and innovation has resulted in products feasible in much colder and less sunny climates today.

1.2 Objectives of the Study:

A Thermal Energy Storage (TES) system is an important technological system to provide energy savings as well as the efficient and optimum energy use because a TES can hold thermal energy of materials in the solid state or in the liquid state. Therefore, a TES is an efficient energy storage, which can improve the performance of energy systems, and a TES can correct the gap between the demand and supply of energy. The main types of a TES are a sensible heat storage and a latent heat storage. The latent heat storage is a very efficient method to store and release thermal energy because it has a high-energy storage density at constant temperatures. A latent heat storage material can store 5-14 times more heat per unit volume than a sensible heat storage material can.

Phase Change Materials (PCMs) are well known as latent heat storage materials. PCMs can save thermal energy, and use energy efficiently, because PCMs can absorb thermal energy in the solid state, and the thermal energy can be released in the liquid state at a constant temperature. Therefore, PCMs as new materials for saving energy can be applied into building applications.

The objective of this study is to develop a methodology and procedure to accurately determine material properties of PCMs based on salt hydrates because inaccurate materials properties are measured by existing methodology. The materials properties of the PCMs are presented by various methods, such as DSC method and heat flow method, because information about the properties of the PCMs is not accurate and detailed. In order to determine and assess the TES systems of the PCMs over a variety temperature range, the results, such as the dynamic/isothermal results, the thermal conductivities, and the enthalpy changes of the PCMs were compared and analyzed. In addition, this study demonstrates how to design building roofs incorporating PCMs to save energy using FEA. Therefore, this study proposes the developed methodology to analyses accurately the material properties of the PCMs. The developed methodology can be used to analyses accurately the TES systems of PCMs.

- To design solar water heating system.
- To perform analysis on copper tube.
- Integrating PCMs into the solar water heating system.
- To know the inlet and outlet temperature of HTF.

1.3 Scope of the Study:

- Solar water heating systems has the potential to save millions of energy costs. It replaces the domestical water heating systems like electric water heating systems, gas water heating systems.
- PCMs have so many uses in the sector of solar thermal applications like solar water heating systems. To store extra amount of radiation energy in the phase change materials and to use that energy during night times.
- PCMs are integrated in the solar water heating system. To store thermal energy in phase change materials and to use it when there is no availability of sun. like this the efficiency of solar water heating systems can be increased.
- Electricity can be saved during even night times. Instead of using electricity for water heating purposes, we can use thermal energy stored in the phase changing materials for these purposes.
- Usage of wood or electricity can be decreased.

1.4 Material Requirement:

Absorber plate - copper.

Transparent cover – tempered glass.

Casing – aluminum.

Insulation – polyurethane foam.

Tank – stainless steel 304.

Material	Temperature (°C)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Heat capacity ($J.kg^{-1}.K^{-1}$)	Density ($kg.m^{-3}$)	Thermal expansion ($\times10^{-6}$ K^{-1})	Young's modulus (GPa)	Yield stress (MPa)	Poisson's Ratio	Melting point (°C)
Aluminum alloy 6061-T6	0	162	917	2703	22.4	69.7	277.7	0.33	582-652
	98	177	978	2685	24.61	66.2	264.6		
	201	192	1028	2657	26.6	59.2	218.6		
	316	207	1078	2630	27.6	47.78	66.2		
	428	223	1133	2602	29.6	31.72	17.9		
	571	253	1230	2574	34.2	0	0		

Table 1 properties of aluminum alloy 6061-T6

Properties	Value Measured
Melting point	1083°C
Density	8.94 X 10^3 kg/m^3 at 20°C
Thermal expansion coefficient	17.7 X 10^{-6} per °K
Thermal conductivity	305 – 355 W/(m.K)
Specific heat capacity	0.385 kJ/(kg.K)
Electrical conductivity (annealed)	75 – 90% IACS
Electrical resistivity (annealed)	0.0192 – 0.0230 microhm at 20°C
Modulus of elasticity	117 Gpa
Modulus of rigidity	44 Gpa

Table 2 physical properties of copper

Insulating material	Density (kgm^{-3})	Thermal conductivity (W/mK) at 10°C	Compressive strength (Kpa)	Relative moisture absorption
Expanded polystyrene 15	15	0.04	35	Medium
Expanded polystyrene 30	30	0.037	110	Medium
Extruded polystyrene	32	0.27	300	Medium
Polyurethane foam	36	0.018	200	Low
Phenolic foam	32	0.027	170	Low
Cellular foam	125	0.41	700	Low
Mineral wool	24	0.045	Negligible	Very high

Table 3 Properties of common insulation materials

Element	Weight percentage
Carbon	0.08 max
Manganese	2.00 max
Phosphorus	0.045 max
Sulphur	0.030 max
Silicon	0.75 max
Chromium	18.00-20.00
Nickel	8.00-12.00
Nitrogen	0.10 max
Iron	67-71

Table 4 composition of stainless steel 304

Parameters	Values	Parameters	Values
Density	8030 Kg/m^3	Poisons Ratio	0.29
Elastic modulus	193 G Pa	Melting point	1723K
Mean coefficient of Expansion	18.4 µm/m/ºC	Refractive index	3.81Fe
Thermal conductivity	20 W/m K	Enthalpy	8.7 J/mm^3
Specific Heat	500 J/Kg K	Diffusivity	5.7 mm^2/s

Table 5 properties of stainless steel 304

Thermal and Physical Properties of PCM:

PCM: - calcium chloride hexahydrate.

Physical properties:

- Physical appearance: It is available in white powder or granules.
- Solubility: It is freely soluble in water.

Thermal properties:

- Latent heat of transition: 190 KJ/Kg.
- Temperature of transition: 29-30 °C.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Review:

Thermal energy storage is a key technology for an effective utilization of energy. The applications of phase change materials for thermal energy storage have been the focus of extensive research in recent decades. Their use can reduce the size and cost of the system, offering higher thermal storage capacity and the ability to be used as a thermal management tool. The following sections present the fundamentals of phase change materials including the details of their physical behavior, design issues, and applications for thermal energy storage.

2.1.1 Thermal energy storage:

Thermal Energy Storage (TES) is defined as the temporary holding of thermal energy in the form of hot or cold substances for later utilization (Abedin and Rosen [2011]). A Thermal Energy Storage (TES) system is an important technology to provide energy savings and the efficient and optimum energy use in very specific areas such as security energy supply or thermal inertia and thermal protection (Abedin and Rosen [2011]; Zalba et al. [2003]). Also, a TES system is an efficient energy storage, which can improve the performance of energy systems, and the TES can reduce the mismatch between the supply and demand of energy. A TES system is classified as a sensible heat thermal energy storage, a latent heat thermal energy storage, and a chemical energy storage.

In sensible heat, energy is stored/released by raising/reducing the temperature of a storage material without changing the phase. Besides the mass of storage material, the amount of sensible heat storage is limited by the temperature change of the system as seen in equation.

$$Q = m\int_{T1}^{T2} C_P . dT$$

Where Q is the sensible heat stored, m: is the mass of storage material, T1 and T2 are the temperature range which the process operates. In latent heat storage systems, thermal energy is stored or released by the material while it experiences a phase transition from solid to liquid during a charging period, or liquid to solid during a discharging period. Phase change may also occur in form of liquid-gas phase transition characterized by even higher latent heat than solid-liquid. liquid-gas phase transition however is not commonly used for energy storage

applications due to the higher pressure and the impractical large volume involved.
Unlike sensible heat, latent heat storage is attractive in that it stores larger amount of energy at constant temperature during phase transition. The storage capacity of a latent heat system is given by:

$$Q = m\left[\int_{T1}^{Tm} C_{P\_Solid}.dT + \Delta h + \int_{Tm}^{T2} C_{P\_Liquid}.dT\right]$$

Where Q is the latent heat stored in the system, m is the mass of storage material, Tm is melting temperature of storage material, Δh is the enthalpy or latent heat of storage material, T1 and T2 represent the temperature range and Cp is the specific heat capacity at constant pressure.

In thermo-chemical energy storage, heat is absorbed or released through a completely reversible chemical reaction when the molecular bonds are reformed and broken during an endothermic or exothermic reaction as given in equation 3. Due to the high cost of such systems, their applications are very limited. The storage capacity of a thermo-chemical system is given by:

$$Q = ma_r\Delta h$$

Where Q is the thermo-chemical energy stored, m is the mass of storage material, ar is the extent of conversion and Δh is the endothermic heat of the reaction.

2.1.2 Phase Change Materials:

Phase Change Materials (PCMs) are latent heat energy storage materials that undergo solid-liquid phase transition at specific temperature known as the phase transition temperature. As the PCM absorbs energy from the surrounding, the material changes its phase from solid to liquid while maintaining nearly constant temperature that corresponds to the phase transition temperature of the PCM. The absorbed energy is stored in the constituent atoms or molecules in the form of vibrational energy. When PCM absorbs its maximum energy storage capacity, the atomic bonds are loosened, and the PCM completes its transition from solid to liquid. This amount of energy absorbed during phase transition is known as the latent heat or enthalpy of fusion. Solidification, also known as freezing or crystallization, is the reverse of this process during which the energy is released, molecules are reordered, and the material transitions from liquid to solid at nearly constant temperature. This process can be seen in Figure 1.1.

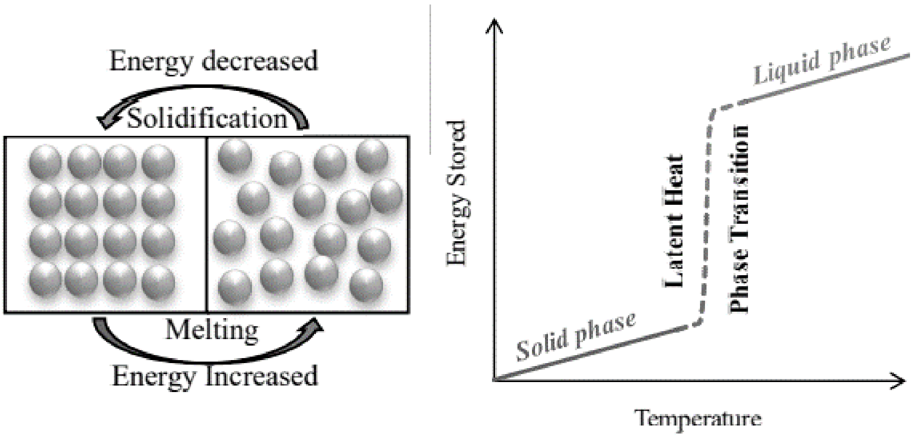

Fig.1 Thermal energy storage in PCM

When choosing a PCM for a given application the main considerations are the phase transition temperature and the latent heat of fusion. The phase transition temperature needs to be within the operating range of the application, or within the temperature range at which the system needs to be maintained. The latent heat of fusion should be as high as possible. When compared to sensible heat storage materials, the main benefits of PCMs are the ability to maintain the system at nearly constant temperature during the phase transition in a passive way regardless of the applied heat flux. Therefore, efficient thermal management is only possible using PCMs, while sensible storage material can only store thermal energy over a temperature range. Moreover, PCMs have much higher energy storage density, reducing the volume of the system, and resulting in less material mass. PCMs, however, do not fully meet the requirements for all thermal energy storage systems. A wide range of technical solutions have been developed. For instance, current existing PCMs are only available at particular phase transition temperatures. Therefore, eutectic PCM mixtures can be developed to create new PCMs with improved properties and new phase transition temperatures. In addition, finding materials with very high latent heat as well as excellent heat transfer characteristics has been challenging. The low thermal conductivity and thermal diffusivity of PCMs prevent rapid system transients. Currently, the enhancement of heat transfer in PCMs is one of the most pressing topics. A PCM based system can have a heat storage capacity that is 4-50 times larger than sensible heat storage materials [5]. For instance, water is a common storage medium for solar water heating systems in the range of 45°C to 60°C. In Figure 1.2, the theoretical energy storage of a PCM tank Myristic Acid with phase transition temperature of 54°C and latent heat of 220J/g - is compared to that of water.

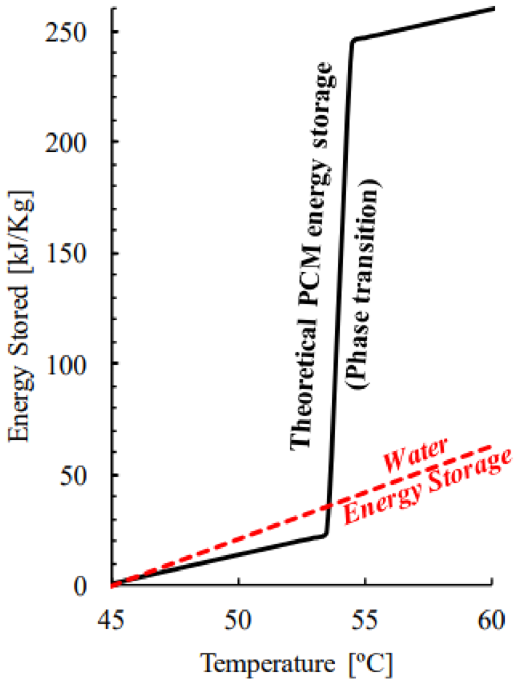

Fig.2 Comparison between thermal energy storage of Myristic Acid PCM and water.

Theoretically, the PCM tank can store 260 Joules per 1 Kg of PCM compared to 63 Joules per 1 Kg of water, an increase of 313% in energy storage capacity over a temperature range of 15°C. For a storage temperature of 55°C and temperature range of 5°C, the energy storage of the PCM system is 11 times larger than a sensible heat storage system. In other words, a solar system with PCMs can be 4-11 times smaller than water systems and still able to store the same amount of thermal energy. Moreover, the PCM tank can store most of the energy at 54-55 °C, illustrating a higher useful quality for energy. The same concept can also be applied in larger solar energy power plants. PCMs can be integrated in the system to store the excess solar energy during periods of lower demand and utilize it later when the demand exceeds the supply. PCMs are typically separated into three categories: organic, inorganic, and eutectics. A classification is given in Figure 1.3.

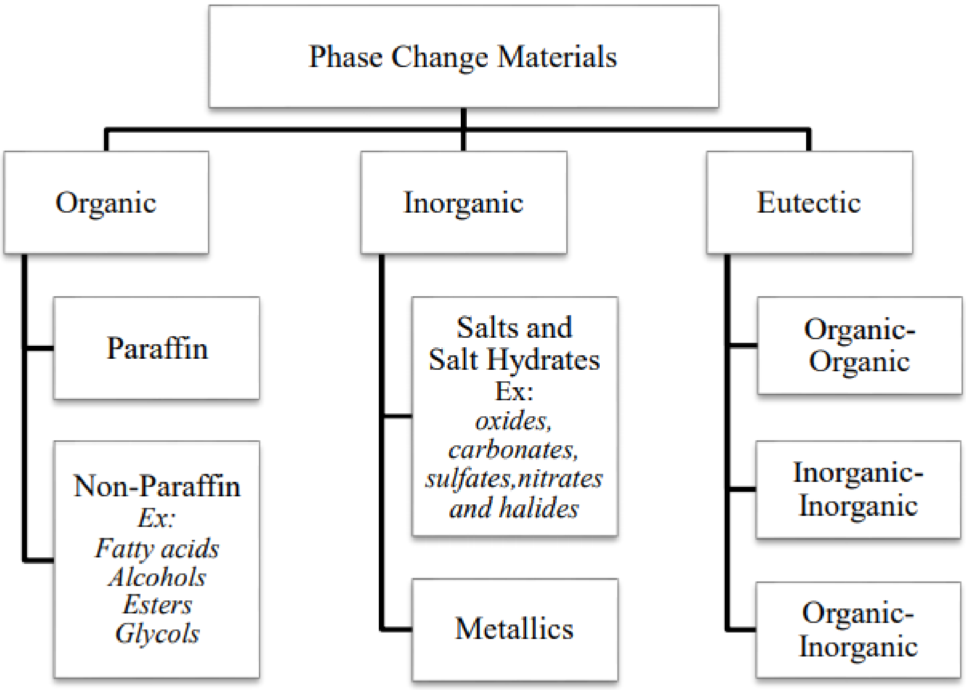

Fig.3. Classification of PCMs

In general, organic PCMs are the most popular type of PCMs, classified as Paraffin (CnH2n+2) and the non-paraffin such as fatty acids (CH3(CH2)2nCOOH). Depending on the hydrocarbon chain structure, each PCM has its particular phase transition temperature and latent heat of fusion. Most organic PCMs are characterized by excellent thermal stability, non-corrosiveness, non-toxicity, and little or no supercooling. Their major limitation is the very low thermal conductivity, relatively higher cost, and flammability. Inorganic PCMs are classified as salts and metallic alloys. Salt hydrates consist of a crystal matrix of water and salt solution. The high latent heat of some mixtures, low cost, ease of availability, high specific heat, and high thermal conductivity of salt hydrates are very attractive for practical application, however the supercooling and poor thermal stability upon cycling due to phase separation and dehydration are their main drawbacks. Metallic alloys possess attractive thermo-physical properties such as high thermal conductivity and specific heat, however they are mostly available with very high phase transition temperatures, limiting their applications. Eutectic PCMs are two or more components that melt and freeze simultaneously. A comparison between different PCMs is given in Table 1.1.

	Organics	Salts/Salt hydrates	Metallics
Latent heat	Fatty acids: 100–240 J/g Methyl esters: 200-250 J/g Sugar Alcohols: 200-300J/g Paraffins: 170-270 J/g	90 – 492 J/g	16-560 J/g
Cost	Moderate	Low	Low to high
Availability	Widely available	Widely available	varies
Conductivity	0.15 - 0.4 W/m.K	0.5-1.2 W/m.K	8-237 W/m.K
Specific heat	1.5 – 2.8 J/g.K	2.5 – 4.5 J/g.K	0.2-1.5 J/g.K
Density	0.7-0.96 kg/m^3	1.3-2.5 kg/m^3	1740-7030 kg/m^3
Supercooling	Minimal to Self-nucleating	High	Minimal
Melting	Very sharp	Wide-sharp	Very sharp
Phase separation	No phase separation	Separates	No separation
Thermal stability	Mostly stable	Mostly unstable	Stable
Flammability	Some are Flammable	Non-flammable	Non-flammable
Corrosiveness	Mostly Non-corrosive	Corrosive	Non-corrosive

Table 6 Comparison between different families of PCMs

2.2 Review on Related Literature:

There are two main types of solar water heater systems: passive and active. Active systems integrate pumps and rotary elements and are therefore very expensive. Passive systems use natural water circulation, gravity, and/or pressurized water systems. Passive solar water heater systems are much less expensive than their active counterparts and are easier to maintain and repair.

(Soteris A. Kalogirou, 2004) presents a survey of the various types of solar thermal collectors and applications. All the solar systems which utilize the solar energy and its application depends upon the solar collector such as flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors which are used in this system. The solar collectors are used for domestic, commercial and industrial purposes. These include solar water heating, which comprise thermosyphon, integrated collector storage, direct and indirect systems and air systems, space heating and cooling, which comprise, space heating and service hot water, air and water systems and heat pumps, refrigeration, industrial process heat, which comprise air and water systems and steam generation systems, desalination, thermal power systems, which comprise the parabolic trough, power tower and dish systems, solar furnaces, and chemistry applications.

Motion	Collector type	Absorber type	Concentration ratio	Temperature range (°C)
Stationary	FPC	Flat	1	30-80
	ETC	Flat	1	50-200
	CPC	Tubular	(1-5)	60-240
Single-axis tracking	LFR	Tubular	(15-45)	60-250
	PTC	Tubular	(15-45)	60-300
	CTC	Tubular	(10-50)	60-300
Two-axis tracking	PDR	Point	(100-1000)	100-500
	HFC	Point	(100-1500)	150-2000

Table 7 Comparison of the Collectors

(K. Sivakumar) represent the design of Elliptical heat pipe flat plat solar collector and tested with a collector tilt angle of 11° to the horizontal. Experimental analysis of the effect of condenser length/evaporator length (Lc/Le) ratio of the heat pipe, different cooling water mass flow rates and different inlet cooling water temperature were analyses. Five numbers of elliptical heat pipes with stainless steel wick have been fabricated and used as transport tubes in the collector. Copper tube has been used as container material with methanol as working fluid of the heat pipe. These heat pipes were fixed to the absorber plate of the solar collector and the performance of elliptical heat pipe solar collector has been studied and results were compared. It has been found from the experimental trials that the elliptical heat pipe solar collector having Lc/Le ratio of 0.1764 achieved higher instantaneous efficiency.

(B Sivaraman and N Krishna Mohan, 2005) represents experiments on the effect of L/d ratio of heat pipe on heat pipe solar collector. Two solar collectors with different L/di have been designed and fabricated. A heat pipe with stainless steel wick replaces the transport tubes of the solar collector. Copper and stainless steel were used as container and wick material and methanol was used as working fluid of heat pipe. Heat pipes are designed to have heat transport factor of around 194 W and 260 W of thermal energy. Experiments were conducted during summer season with a collector tilt angle of 13o to the horizontal. The collector with L/di ratio of 52.63 was found to be more efficient than the collector with L/di ratio of 58.82. This improved efficiency is due to increase in heat transport factor of heat pipe, which increase with decrease in L/di ratio.

(Hussain Al-Madani, 2006) studied a batch solar water heater in Bahrain consisting of an evacuated, cylindrical glass tube. Water runs through copper coils, which act as collectors, located within the glass tube. Side-by-side testing of prototypes resulted in a maximum temperature difference between the inlet and outlet of the cylindrical batch system of 27.8°C with a maximum efficiency of 41.8%. Al-Madani determined the cost of manufacturing the cylindrical batch system to be $318, slightly less expensive than typical flat plate collectors of $358.

(Dharamvir Mangal, Devander Kumar Lamba, Tarun Gupta, Kiran Jhamb, 2010) presents acknowledgement to one of the latest solar water heaters which is evacuated solar water heater based on a thermo siphon principle used for heating water for domestic purposes in household by utilizing solar radiations. As the air is evacuated from the solar tube to form a vacuum, this greatly reduces conductive and convective heat loss from the interior of tube. As a result, wind and cold temperature have less effect on the efficiency of evacuated solar water heater. Result of less heat loss is fast heating of water as compared to flat plate solar water heater/collector. This paper introduced the benefits of evacuated tube solar water heater. In India, it is still new model of solar water heater which can be used in our household to face the challenge of climate change, global warming, energy crisis etc. When comparing peak efficiency levels, it may seem that there is little difference between flat plate and evacuated tubes, in fact flat plate may actually be higher, but this is during minimal heat loss conditions. When averaged over a year evacuated tube collector have a clear advantage.

(K. S. Ong and W. L. Tong, 2011) presents a System performance of solar water heaters depend upon collector and storage tank design and sizing and weather conditions (solar radiation intensity and ambient temperature). Short- and long-term performance tests were conducted on natural and force convection U-tube and heat pipe evacuated tube solar water heaters. The test procedures employed enabled comparative performances of solar water heating systems to be made even when they were tested at different times of the year. The experimental results showed that the natural convection heat pipe system was capable of heating water to 100˚C and performed best among the systems tested.

Sharma, A. et al (2009), established that the use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. CMS have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. There are large numbers of Costate melt and solidify at a wide range of temperatures, making them attractive in a number of applications.

Demirbas, M. F. (2006), reported that, the storage of thermal energy in the form of sensible and latent heat has become an important aspect of energy management with the emphasis on efficient use and conservation of the waste heat and solar energy in industry and buildings Latent heat storage is one of the most efficient ways of storing thermal energy. Solar energy is a renewable energy source that can generate electricity, provide hot water, heat and cool a house, and provide lighting for buildings. Paraffin waxes are cheap and have moderate thermal energy storage density but low thermal conductivity and, hence, require a large surface area. Hydrated salts have a larger energy storage density and a higher thermal conductivity. In response to increasing electrical energy costs and the desire for better lad management, thermal storage technology has recently been developed. The storage of thermal energy in the form of sensible and latent heat has become an important aspect of energy management with the emphasis on the efficient use and conservation of the waste heat and solar energy in the industry and buildings. Thermal storage has been characterized as a kind of thermal battery.

Akgun, M. et al (2008), in their study, analyzed Thermal energy storage performance of paraffin in a novel tube-in-shell system. A novel design for the storage unit whose geometry is consistent with the melting/solidification characteristics of phase change materials (PCMs)is introduced. Three kinds of paraffin with different melting temperatures are used as PCMs.Water is used as the heat transfer fluid (HTF). At first, the thermo-physical properties of the paraffin used are determined through the differential scanning calorimeter (DSC) analysis. The effects of the Reynolds number and the Stefan number on the melting and solidification behaviors are determined. It is disclosed the novel tube-in-shell storage geometry introduced in this study suggests promising results.

Brian James and Paul Delaney (2012), investigated current PCM market trends and assess their future potential application in commercial buildings. The goal is to determine their efficacy in peak demand reduction and energy savings. Discussions with PCM manufacturers provided a better understanding of the technical potential and current market availability office products. Evaluation of PCM products for certain applications determined their energy-efficiency potential. Comparisons were drawn to determine mass equivalents between PCM and conventional thermal mass, such as stone, concrete, and brick. In addition, temperature and sensible cooling profiles were developed for a prototypical building based on energy simulations using Energy Plus. Next, it was determined which climate zones were most appropriate for PCM installations. This was based on the day-to-night temperature variation required to regenerate a phase change.

2.3 Conclusions:

The following conclusions are made from the literature review:

- Use of phase change material is an effective way of storing thermal energy and has advantages of high storage density and isothermal nature of energy storage.
- Use of phase change material is an important aspect of energy management, by utilization excess available energy.
- A vertical tube in shell type storage system is a simple and effective way of storing thermal energy using phase change material.
- The geometry of tube in shell type storage system can be made consistent with melting and solidification characteristics.
- Paraffin wax is a good choice of phase change material, for solar water heating application, due to its easy workability, melting temperature and availability.
- Phase change material is an important part of energy efficient future.

CHAPTER 3
PROJECT DESIGN

3.1 Overview of the Design:

Solid works user interface:

User interface:

The SOLIDWORKS application includes user interface tools and capabilities to help you create and edit models efficiently, including:

Windows functions:

The SOLIDWORKS application includes familiar Windows functions, such as dragging and resizing windows. Many of the same icons, such as print, open, save, cut, and paste are also part of the SOLIDWORKS application.

Solid works document windows:

SOLIDWORKS document windows have two panels. The left panel, or Manager Pane, contains:

Feature manager design tree:

Displays the structure of the part, assembly, or drawing. Select an item from the Feature Manager design tree to edit the underlying sketch, edit the feature, and suppress and unsuppressed the feature or component, for example.

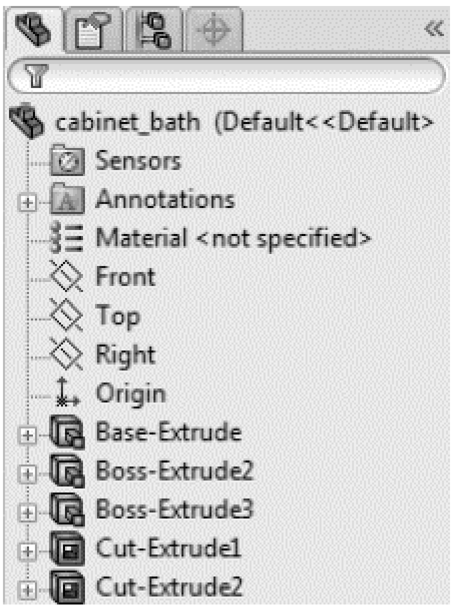

Fig.4 Feature manager design Tree

Property manager:

Provides settings for many functions such as sketches, fillet features, and assembly mates.

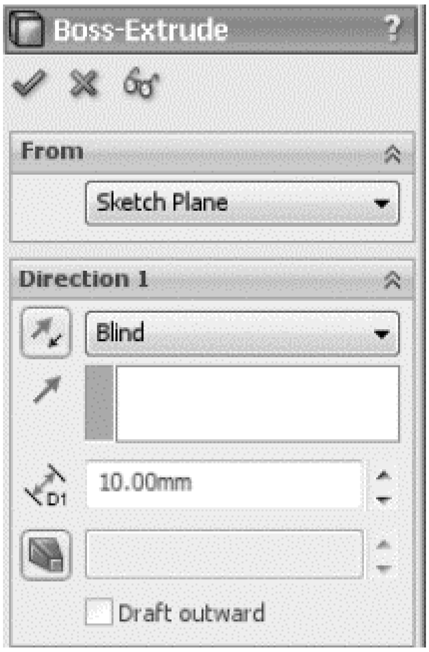

Fig.5 Property Manager

Configuration manager:

Let's you create, select, and view multiple configurations of parts and assemblies in a document. Configurations are variations of a part or assembly within a single document. For example, you can use configurations of a bolt to specify different lengths and diameters.

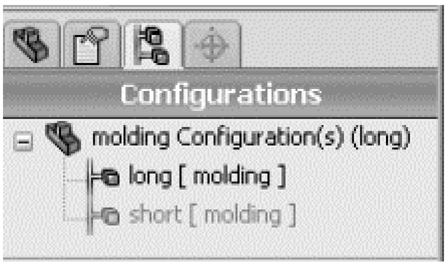

Fig.6 Configuration Manager

Function selection and feedback:

The SOLIDWORKS application lets you perform tasks in different ways. It also provides feedback as you perform a task such as sketching an entity or applying a feature. Examples of feedback include pointers, inference lines, and previews.

Menus:

You can access all SOLIDWORKS commands using menus. SOLIDWORKS menus use Windows conventions, including submenus and checkmarks to indicate that an item is active. You can also use context-sensitive shortcut menus by clicking the right mouse button.

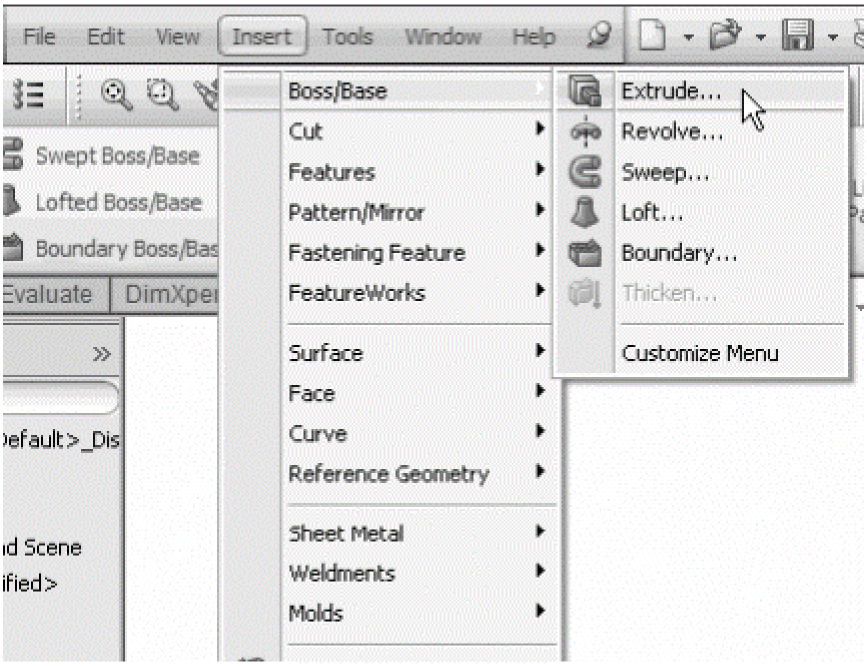

Fig.7 Menu

Toolbar:

You can access SOLIDWORKS functions using toolbars. Toolbars are organized by function, for example, the Sketch or Assembly toolbar. Each toolbar comprises individual icons for specific tools, such as Rotate View, Circular Pattern, and Circle. You can display or hide toolbars, dock them around the four borders of the SOLIDWORKS window, or float them anywhere on your screen. The SOLIDWORKS software remembers the state of the toolbars from session to session. You can also add or delete tools to customize the toolbars. Tooltips display when you hover over each icon.

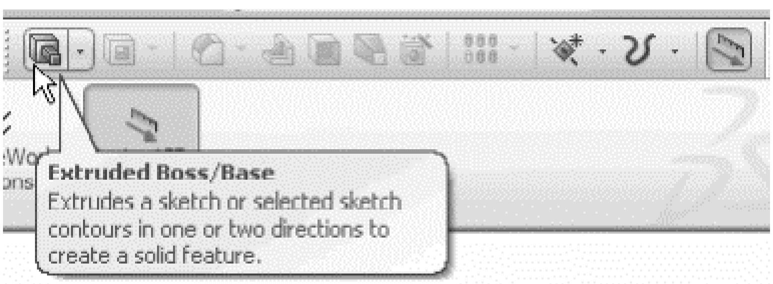

Fig.8 Toolbar

Command manager:

The Command Manager is a context-sensitive toolbar that dynamically updates based on the active document type. When you click a tab below the Command Manager, it updates to show the related tools. Each document type, such as part, assembly, or drawing, has different tabs defined for its tasks. The content of the tabs is customizable, similar to toolbars. For example, if you click the Features tab, tools related to features appear. You can also add or delete tools to customize the Command Manager. Tooltips display when you hover over each icon.

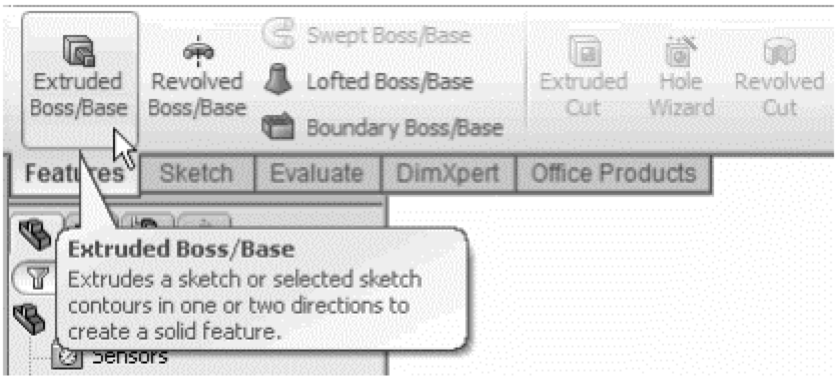

Fig.9 Command Manager

Shortcut bars:

Customizable shortcut bars let you create your own sets of commands for part, assembly, drawing, and sketch mode. To access the bars, you press a user-defined keyboard shortcut, by default, the S key.

Fig.10 Shortcut Bars

Context toolbar:

Context toolbars appear when you select items in the graphics area or Feature Manager design tree. They provide access to frequently performed actions for that context. Context toolbars are available for parts, assemblies, and sketches

3.1.1 Flat plate Collector:

Flat-plate collectors are an extension of the basic idea to place a collector in an ‘oven’-like box with glass in the direction of the sun. Most flat-plate collectors have two horizontal pipes at the top and bottom, called headers, and many smaller vertical pipes connecting them, called risers. The risers are welded (or similarly connected) to thin absorber fins. Heat-transfer fluid (water or water/antifreeze mix) is pumped from the hot water storage tank (direct system) or heat exchanger (indirect system) into the collectors’ bottom header, and it travels up the risers, collecting heat from the absorber fins, and then exits the collector out of the top header. Serpentine flat-plate collectors differ slightly from this ‘harp’ design, and instead use a single pipe that travels up and down the collector. However, since they cannot be properly drained of water, serpentine flat-plate collectors cannot be used in drain back systems. The type of glass used in flat-plate collectors is almost always low-iron, tempered glass. Being tempered, the glass can withstand significant hail without breaking, which is one of the reasons that flat-plate collectors are considered the most durable collector type.

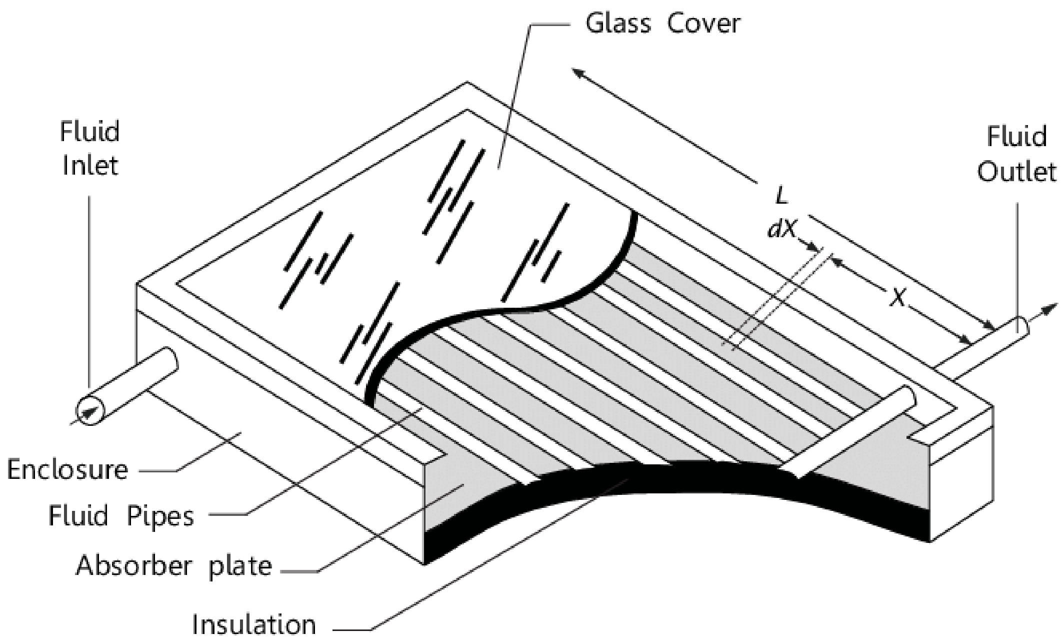

Fig.11 Flat plate collector Structure

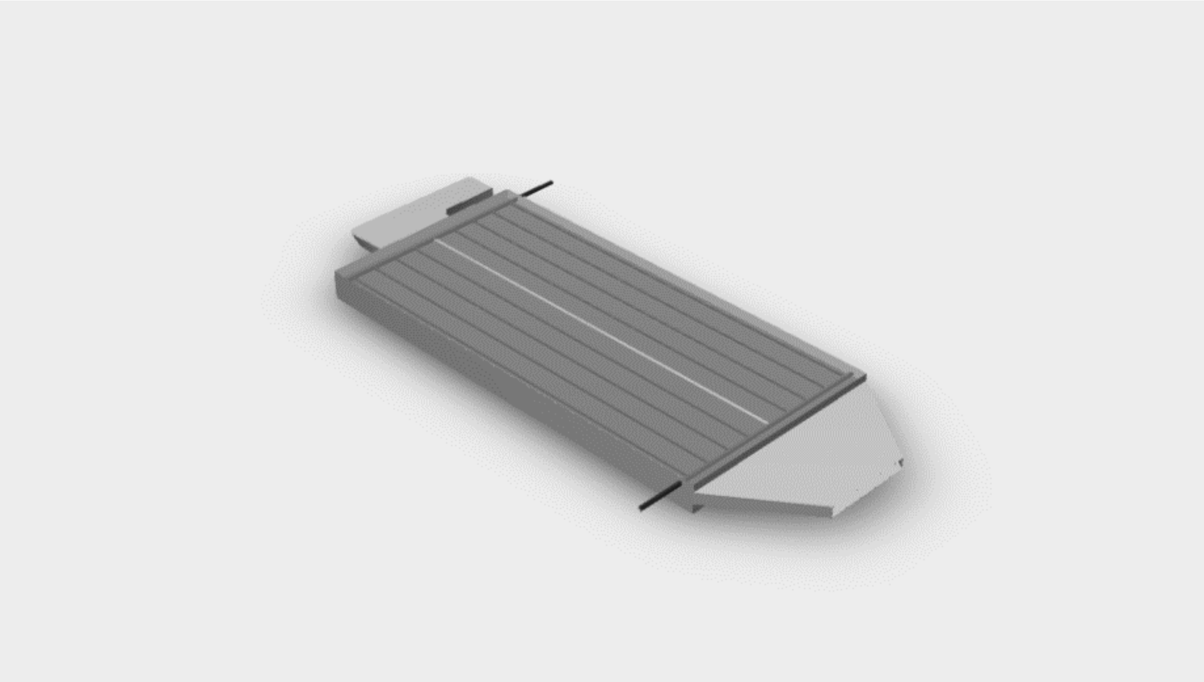

Fig.12 Design of flat plate Collector

Flat plate collector consists of different components they are: -

- Transparent cover.
- Absorber plate.
- Copper tube.
- Casing.
- Insulation.

Transparent cover:

The transparent cover has the function of isolating the solar collector from the external environmental conditions - although it allows solar radiation to pass - that cause the greenhouse effect. Normally it is formed by a single sheet of tempered glass (resistant) with low iron content (very transparent) of approximately 4 mm thickness.

Absorber Plate:

Absorber plate is usually metallic or coated in black surface which is used for absorbing radiation energy. The absorber plate's coating directly affects how efficient the collector is.

Insulation:

The insulation is the element, as it happens in the rest of applications, fulfils the function of avoiding the losses of heat of the interior of the collector -specifically of the absorber- to the outside and is usually formed by plates of synthetic foams (polyurethane, cyanide, fiberglass, etc.) located on the sides and on the back of the solar panel.

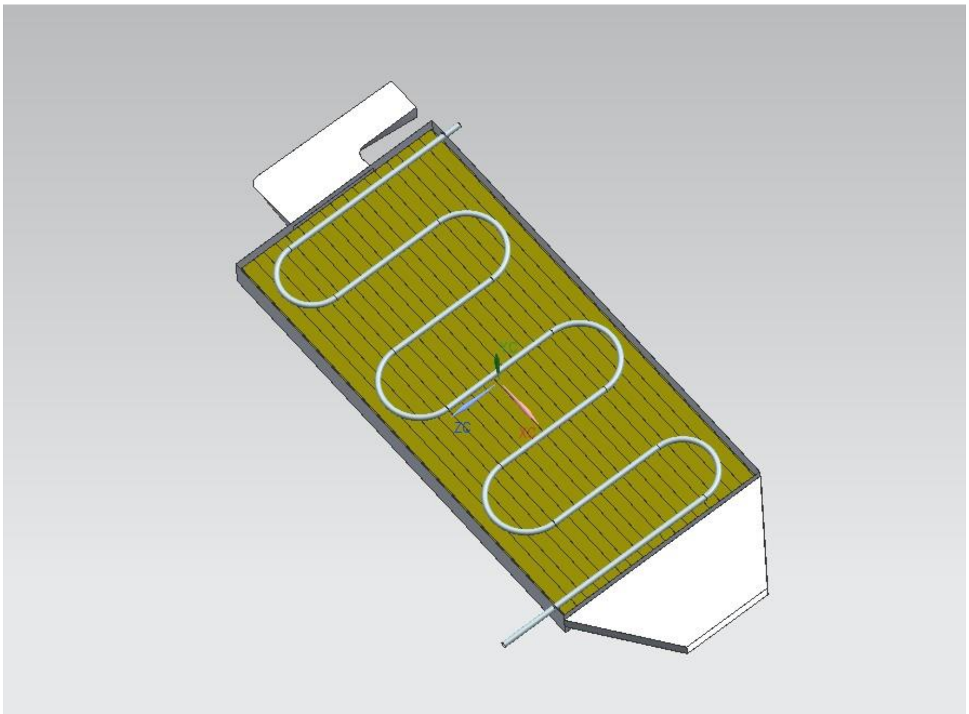

Fig.13 Internal design of flat plate Collector

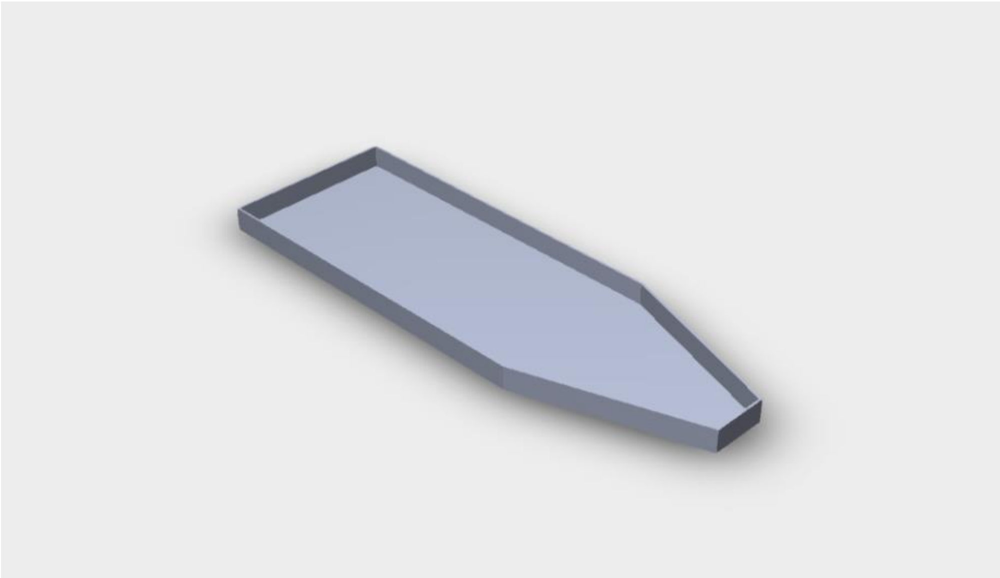

Fig.14 Casing

Casing:

The case of the flat solar collector has the function of housing the rest of the components. This closure is usually formed by an anodized aluminium profile that will guarantee a resistance of the assembly, even in extreme working conditions. Likewise, the casing will have condensate drainage holes in the lower part.

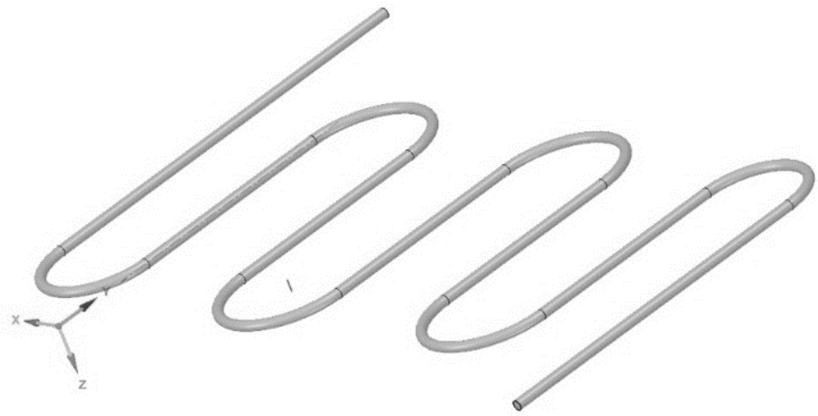

Fig.15 Copper Tube

3.1.2 Materials used for flat plate Collector:

Absorber plate - copper.

Transparent cover – tempered glass.

Casing – aluminum.

Insulation – polyurethane foam.

Material	Temperature (°C)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Heat capacity ($J.kg^{-1}.K^{-1}$)	Density ($kg.m^{-3}$)	Thermal expansion ($\times10^{-6}$ K^{-1})	Young's modulus (GPa)	Yield stress (MPa)	Poisson's Ratio	Melting point (°C)
Aluminum alloy 6061-T6	0	162	917	2703	22.4	69.7	277.7	0.33	582-652
	98	177	978	2685	24.61	66.2	264.6		
	201	192	1028	2657	26.6	59.2	218.6		
	316	207	1078	2630	27.6	47.78	66.2		
	428	223	1133	2602	29.6	31.72	17.9		
	571	253	1230	2574	34.2	0	0		

Table 8 Properties of aluminum Alloy 6061-T6

Properties	Value Measured
Melting point	1083°C
Density	8.94 X 10^3 kg/m^3 at 20°C
Thermal expansion coefficient	17.7 X 10^{-6} per °K
Thermal conductivity	305 – 355 W/(m.K)
Specific heat capacity	0.385 kJ/(kg.K)
Electrical conductivity (annealed)	75 – 90% IACS
Electrical resistivity (annealed)	0.0192 – 0.0230 microhm at 20°C
Modulus of elasticity	117 Gpa
Modulus of rigidity	44 Gpa

Table 9 Physical properties of Copper

Insulating material	Density (kgm^{-3})	Thermal conductivity (W/mK) at 10°C	Compressive strength (Kpa)	Relative moisture absorption
Expanded polystyrene 15	15	0.04	35	Medium
Expanded polystyrene 30	30	0.037	110	Medium
Extruded polystyrene	32	0.27	300	Medium
Polyurethane foam	36	0.018	200	Low
Phenolic foam	32	0.027	170	Low
Cellular foam	125	0.41	700	Low
Mineral wool	24	0.045	Negligible	Very high

Table 10 Properties of common insulation Materials

DIMENSIONS:

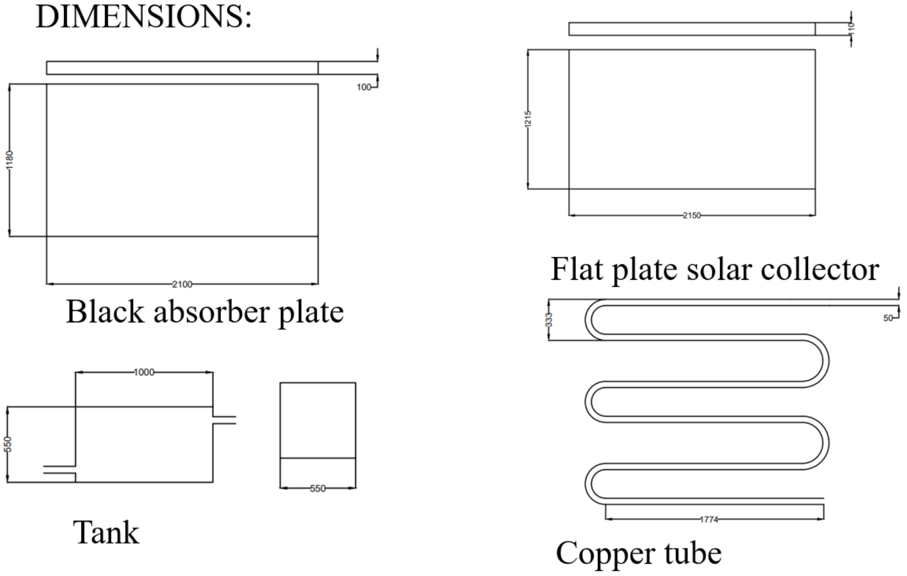

Fig.16 Dimensions of solar water Heater

3.1.3 Tank:

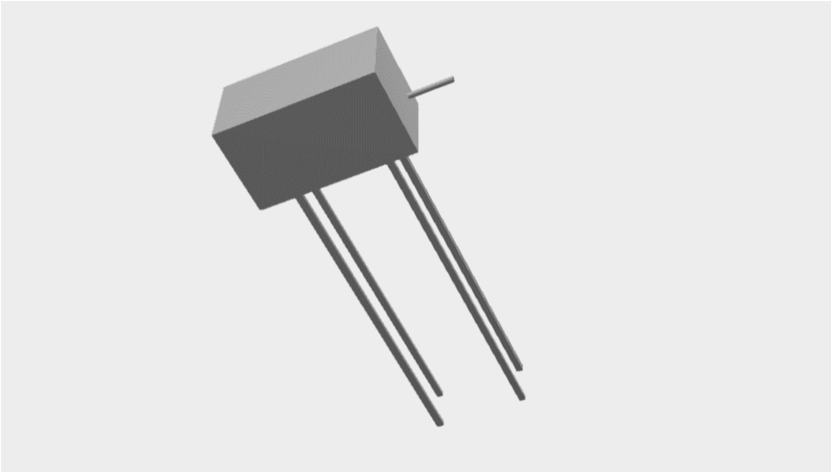

Fig.17 Design of Tank

Tank of solar water heater is used to store water. Cold water is supplied to solar flat plate collector and it collects hot water coming from solar flat plate collector. The water is supplied and received using pump.

Material used – stainless steel 304.

Element	Weight percentage
Carbon	0.08 max
Manganese	2.00 max
Phosphorus	0.045 max
Sulphur	0.030 max
Silicon	0.75 max
Chromium	18.00-20.00
Nickel	8.00-12.00
Nitrogen	0.10 max
Iron	67-71

Table 11 Composition of stainless Steel 304

Parameters	Values	Parameters	Values
Density	8030 Kg/m^3	Poisons Ratio	0.29
Elastic modulus	193 G Pa	Melting point	1723K
Mean coefficient of Expansion	18.4 µm/m/°C	Refractive index	3.81Fe
Thermal conductivity	20 W/m K	Enthalpy	8.7 J/mm^3
Specific Heat	500 J/Kg K	Diffusivity	5.7 mm^2/s

Table 12 Properties of stainless Steel 304

Assembled Design:

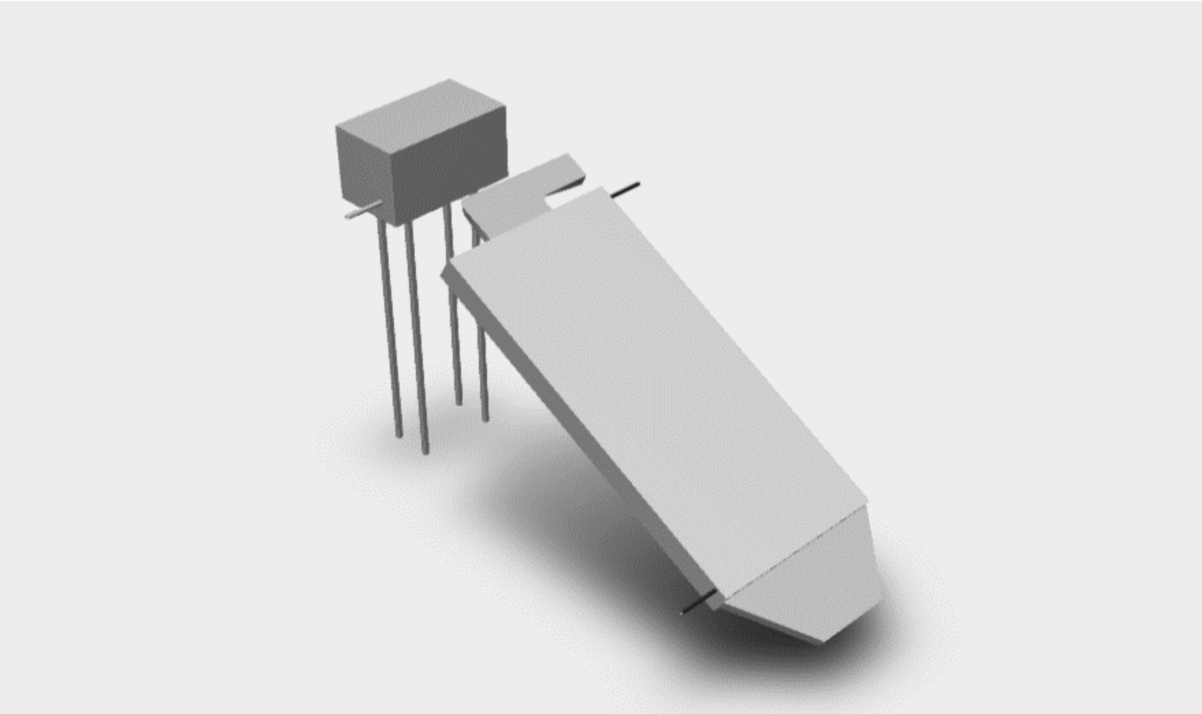

Fig.18 Assembled Design

3.2 Equipment Analysis:

Ansys Introduction:

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc. ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable.
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients

simple intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.
A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

Organization of the program:

ANSYS program is organized into two basic levels:

- begin level (Start level)
- Processor (or routine) level

Begin level acts as a gateway into and out of the ANSYS program. Changing the name of job, database clearing, and binary files copying are program controls used. When we first enter the program, we at the begin level.
At the processor level, several processors are available; each processor is a set of functions that specific analysis task perform. For instance, the general preprocessor (PREP7) is the place we fabricate the model, the arrangement processor (SOLUTION) is the place we apply stacks and get the arrangement, and the general postprocessor (POST1) is the place we assess the outcomes and acquire the arrangement. An extra postprocessor (POST26), empowers we to assess arrangements results at particular focuses in the model as an element of time.

Performing a typical Ansys analysis:

The ANSYS system has numerous limited component investigation capacities, extending from a straightforward, direct, static examination to a nonlinear, transient element investigation. The investigation guide manuals in the ANSYS documentation set portray particular systems for performing examination for diverse building controls. A typical ANSYS analysis has three distinct steps:

- construct the model
- Apply loads and boundaries
- Obtain the solution
- Review the results

The following table shows the brief description of steps followed in each phase.

Pre-processor	Solution processor	Post processor
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graphs
Assigning real constants	load definition	view animated results
Material definition	Solve	
Mesh generation		
Model display		

Pre-processor:

Preprocessor prepares the input data for ANSYS analysis. The general preprocessor (PREP 7) contains solid modeling and mesh generation capabilities, and is also used to define all other analysis data with the benefit of data base definition and manipulation of analysis data. Parametric input, user files, macros and extensive online documentation are also available, providing more tolls and flexibility for the analyst to define the problem. Extensive graphics ability is available throughout the ANSYS program, including isometric, perceptive, section, edge and hidden-line displays of three-dimensional structures-y graphs of input quantities and results, and contour displays of solution results.

Post processor:

Post processing means the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affects the design, how the meshing is done. Post processor analyzes results, which display stress and strain contours, distorted geometries, flow fields, safety factor contours, contours of potential field results; vector field displays shapes of mode and graphs related to time history. The post processor can also be used for algebraic operations, database manipulators, differentiation and integration of calculated results

Meshing:

Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components. In the event that we need this kind of lattice, we must form the geometry as arrangement of genuinely normal volumes and/or regions that can acknowledge a mapped network.

3.2.1 Analysis:

In this project we did thermal analysis on serpentine copper tube.

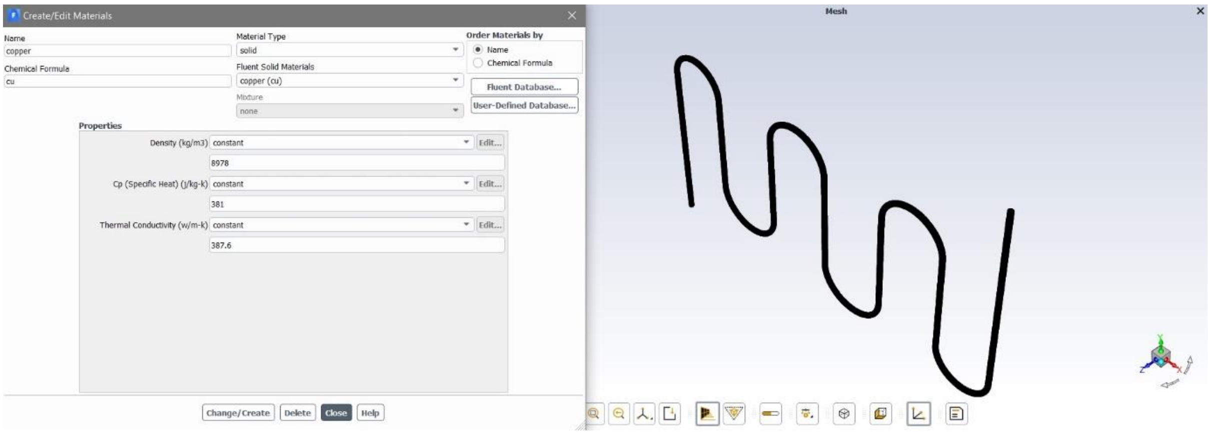

Fig.19 Applying copper Material

In fig.19 it is clear that the copper properties are applied to the serpentine tube. The following are the properties that are applied to the copper serpentine tube.

- Density – 8978 kg/m³.
- Thermal conductivity – 387.6 W/m-K.
- Specific heat – 381 J/kg-K.

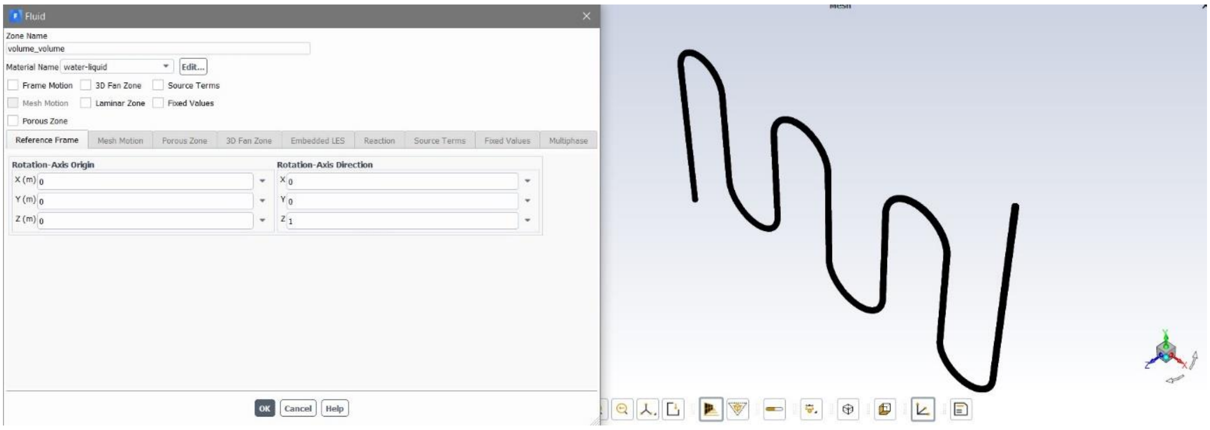

Fig.20 Selection of HTF

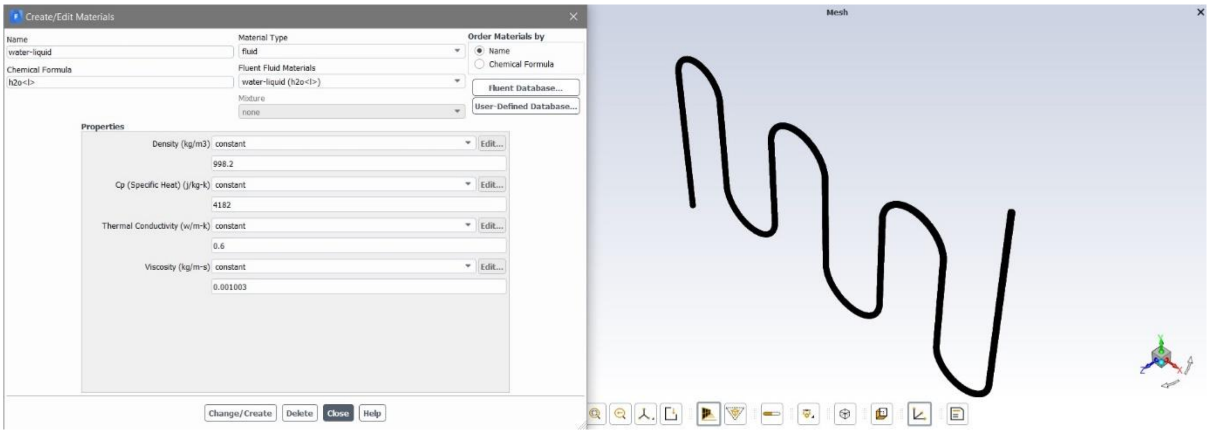

Fig.21 Applying HTF Material

Fig.21 shows that the properties of heat transfer fluid. Water is the heat transfer fluid that is applied. Following are the properties of the water fluid.

- Density – 998.2 kg/m^3.
- Thermal conductivity – 0.6 W/m-K.
- Specific heat – 4182 J/kg-K.
- Viscosity – 0.001003 kg/m-s.

Above are the properties that are applied. This water will flow inside the serpentine copper tube.

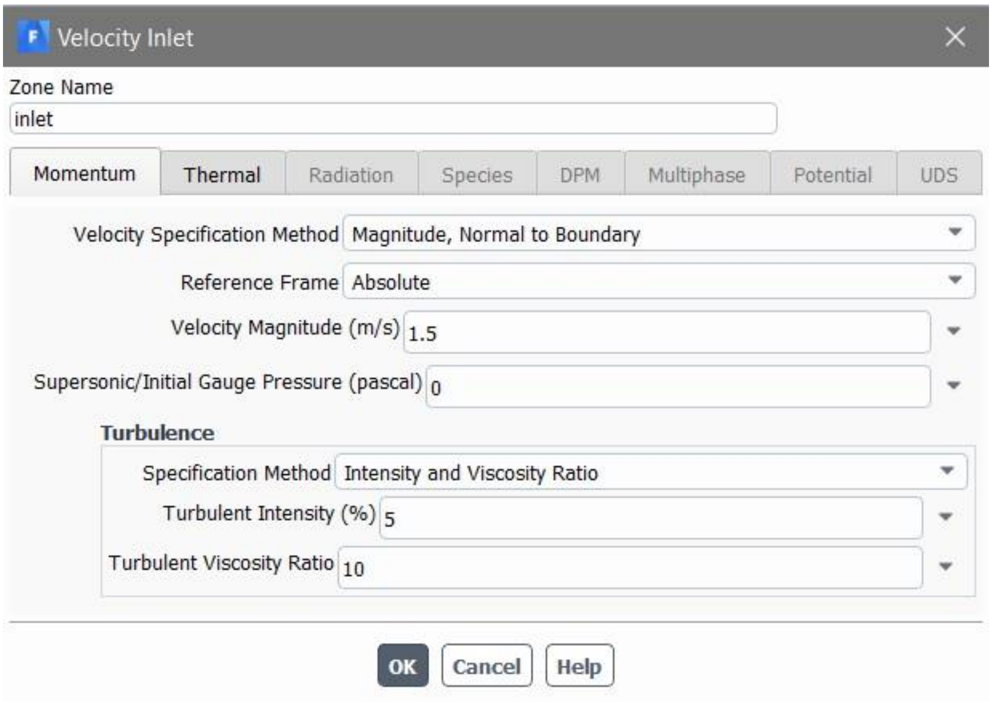

Fig.22 Velocity Inlet

Fig.22 represents the properties of velocity inlet of heat transfer fluid.

Velocity magnitude – 1.5 m/s.

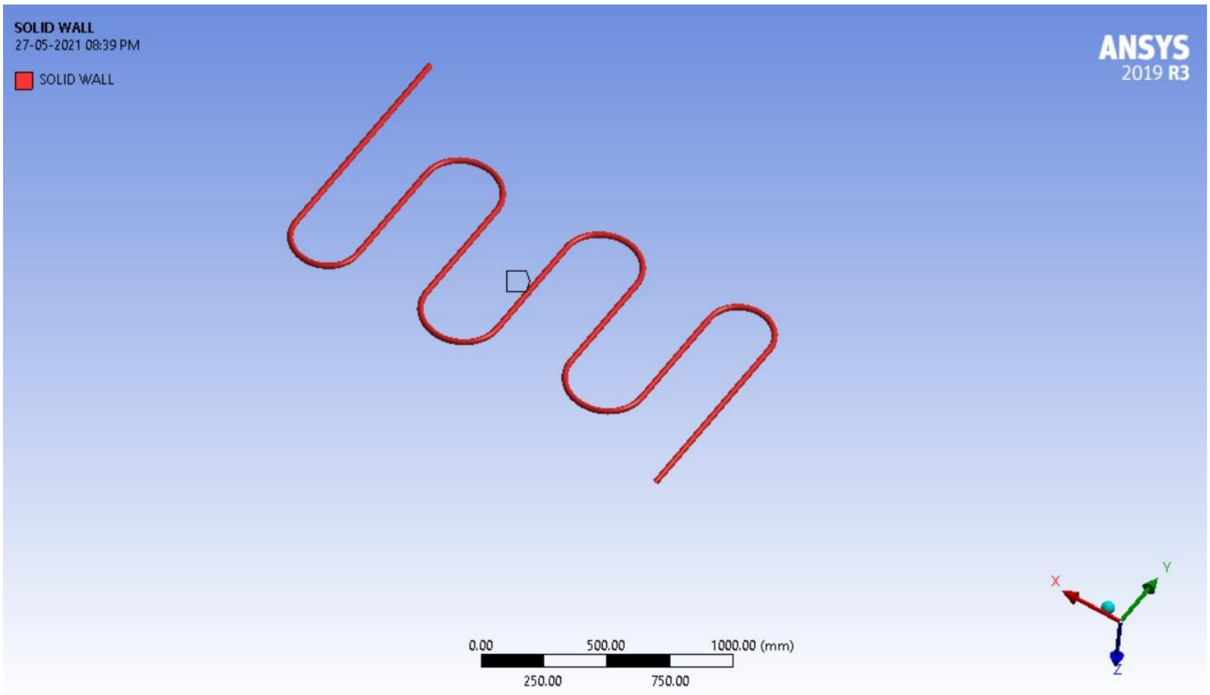

Fig.23 Solid Wall

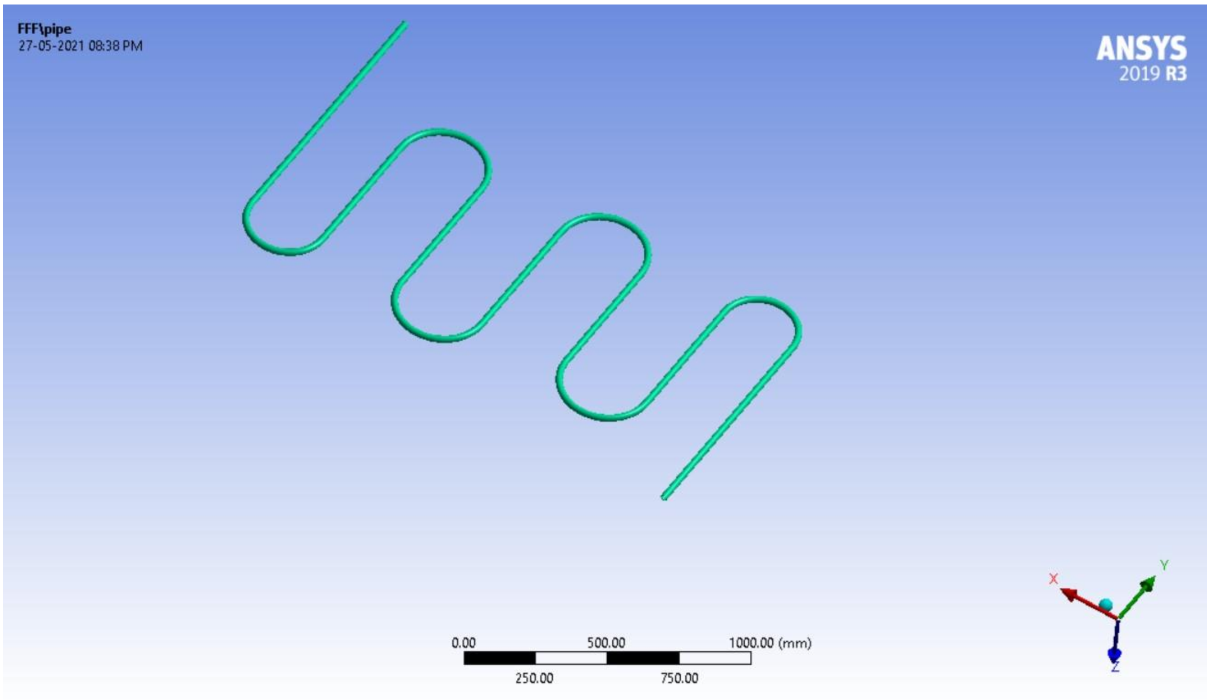

Fig.24 Pipe

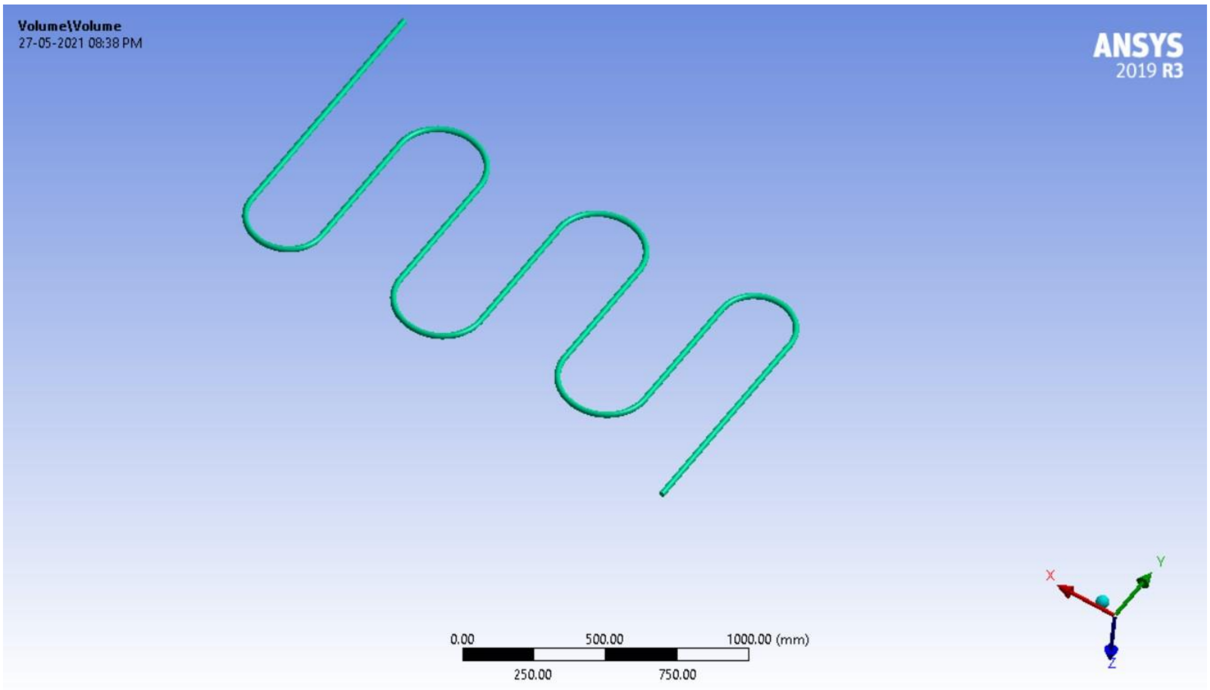

Fig.25 Volume of Pipe

Fig.23,24,25 represents solid wall ,volume of the copper pipe.

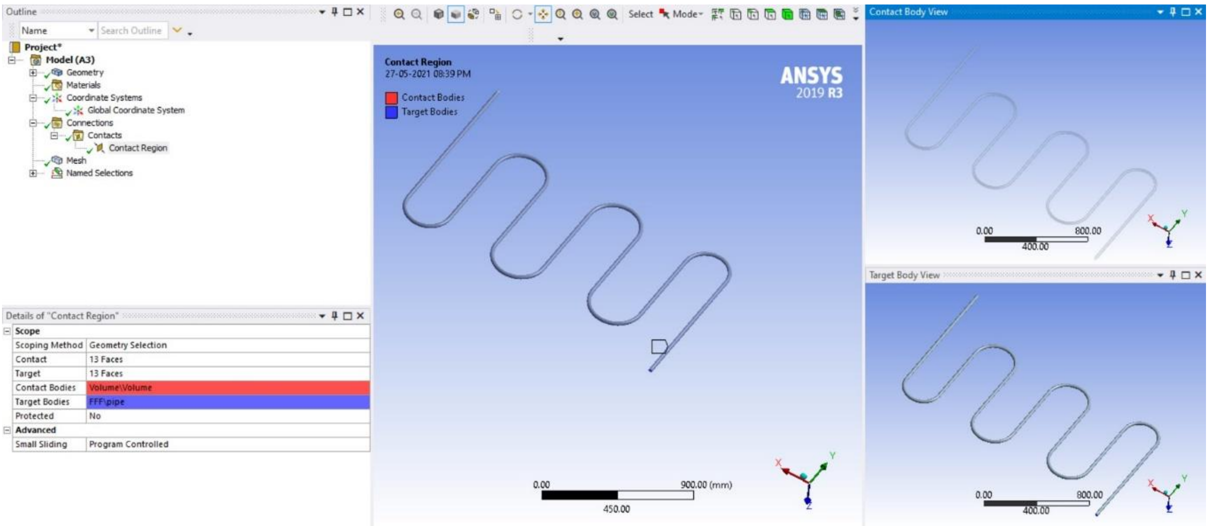

Fig.26 Contact Region

Fig.26 consists of contact region, contact body view and target body view.

Contact analysis – when one surface comes into contact with the other, ansys numerically puta a spring of stiffness KN between the two. Ansys recommends a value between 0.01 and 100 young's modulus for the material.

Contact and target view – if a convex surface comes into contact with a flat or concave surface, the flat or concave surface should be the target surface. If one surface has a coarse mesh and the other a fine mesh, the surface with the coarse mesh should be the target surface.

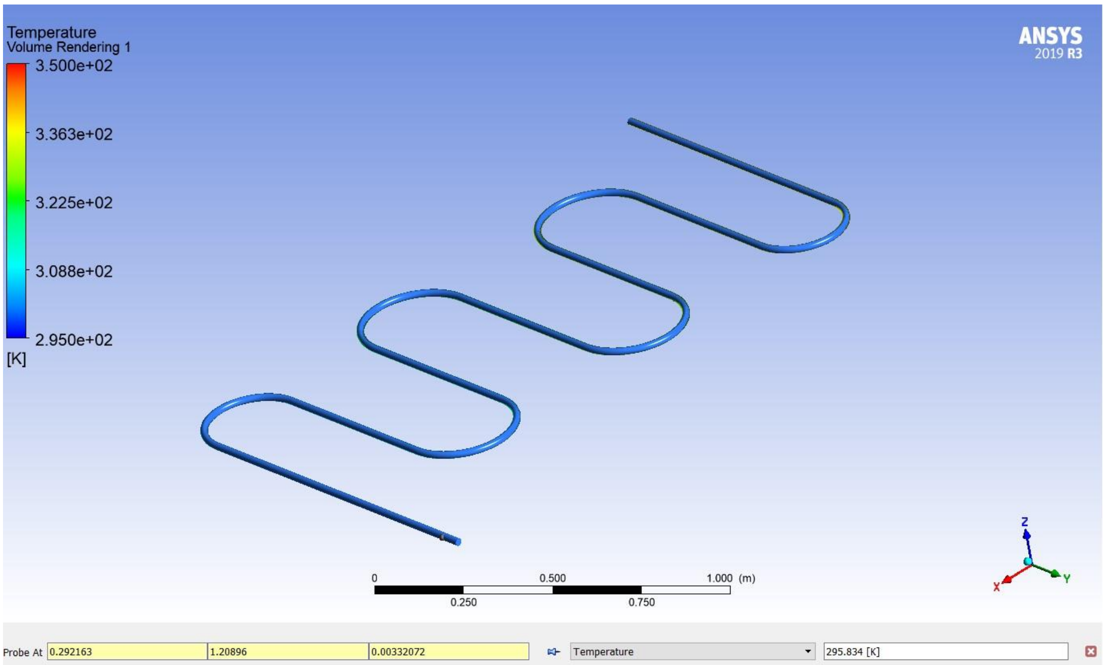

Fig.27 Thermal analysis of copper tube

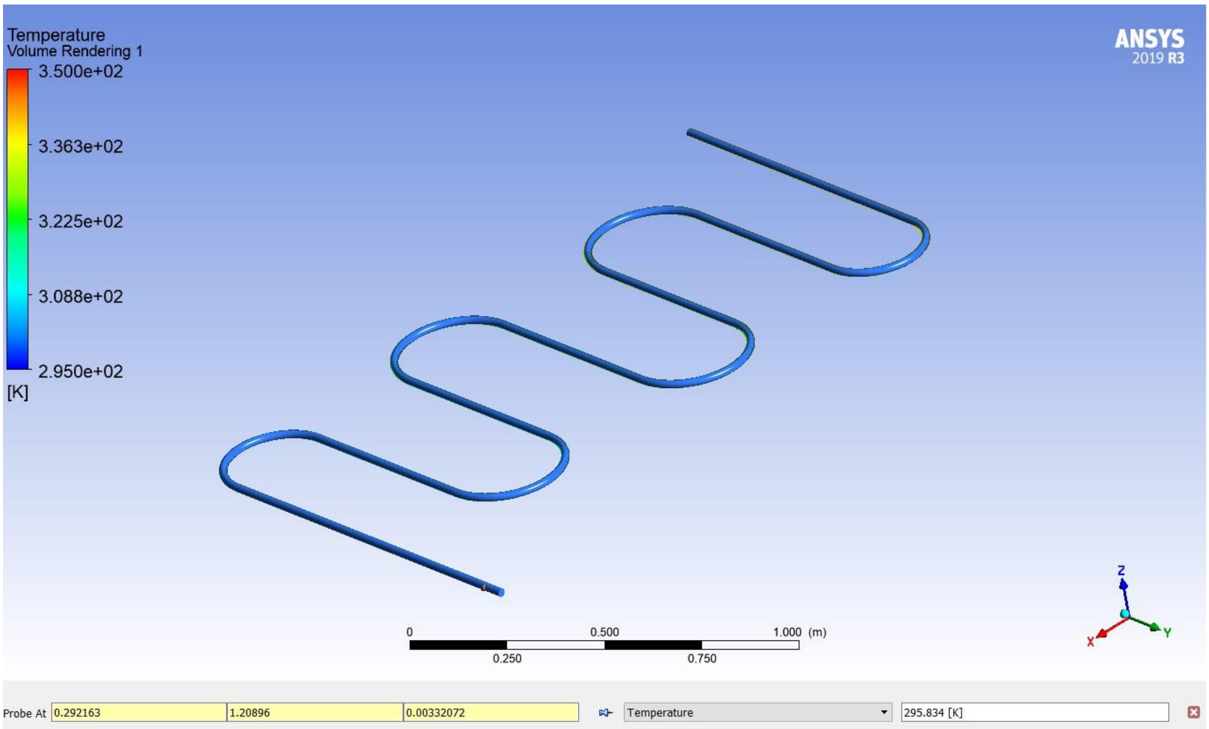

Fig.28 Thermal analysis of copper tube at 295.834K

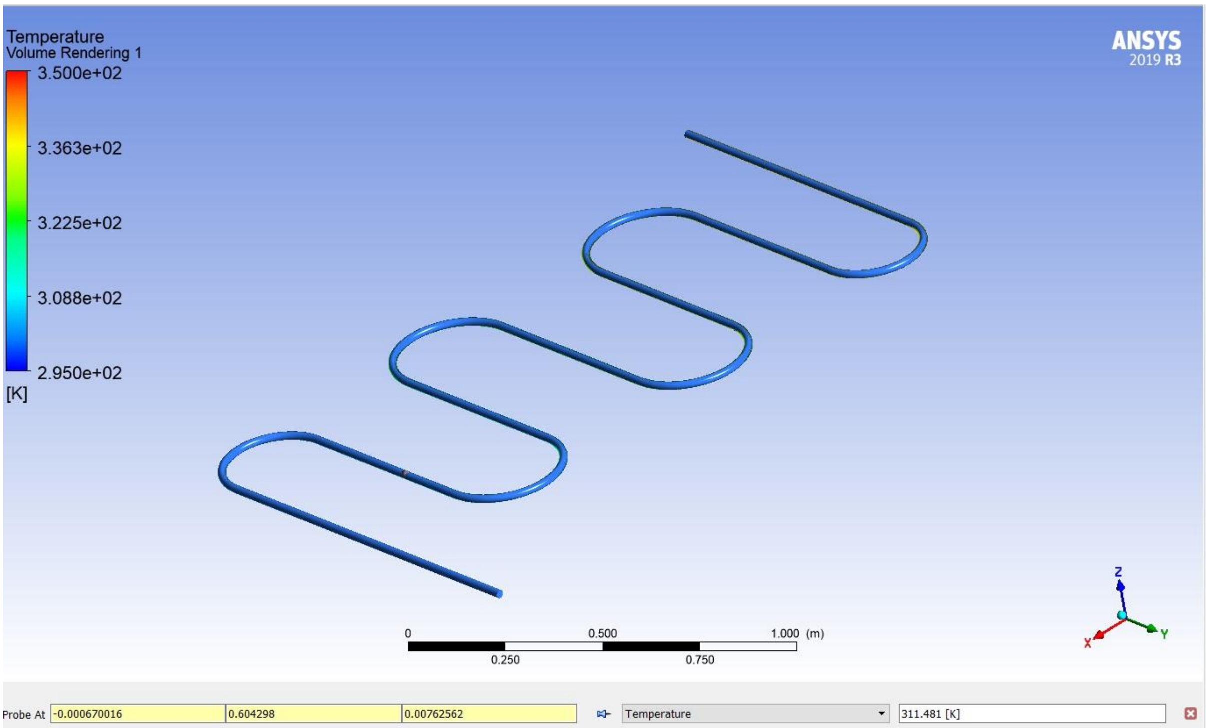

Fig.29 Thermal analysis of copper tube at 311.481K

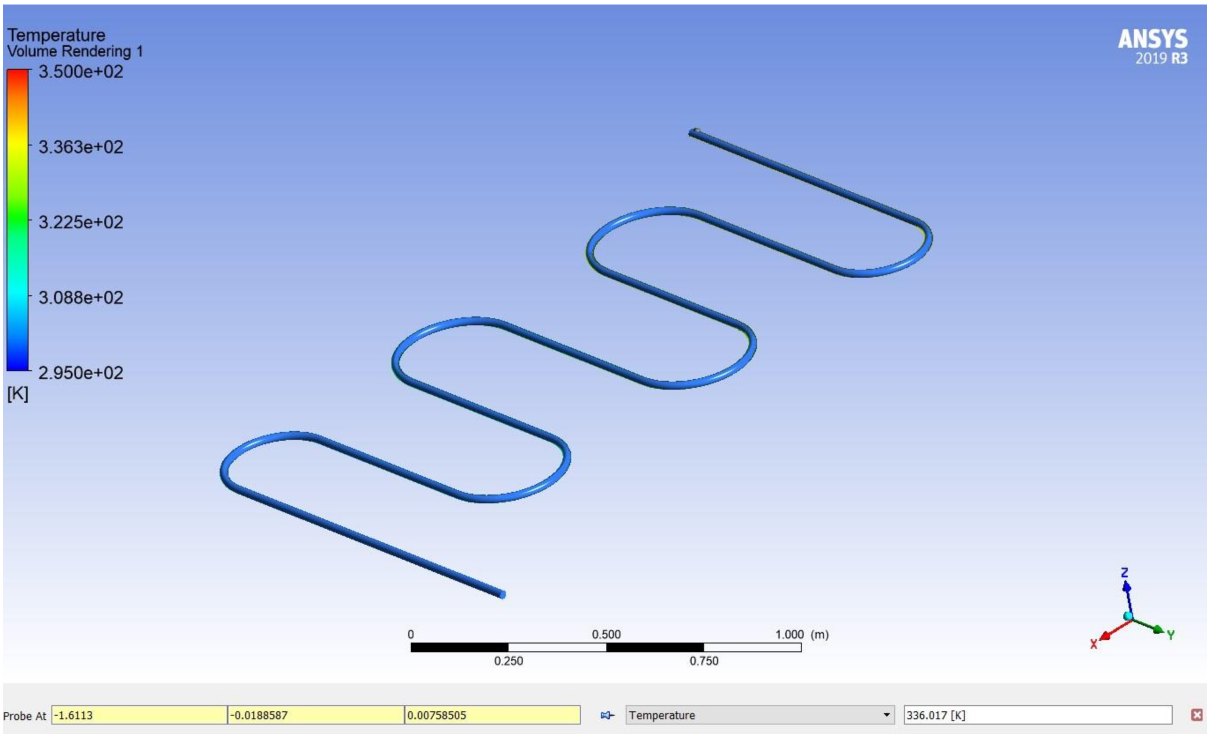

Fig.30 Thermal analysis of copper tube at 336.017K

Fig.27,28,29,30 represents the thermal analysis on serpentine copper tube at various temperatures. In the figures it is clear that the serpentine copper tube maintains the same temperature throughout the length. Thermal analysis is performed at different temperatures they are- 295.834K, 311.481K, 336.017K.

3.3 Modules:

Module in CAD software is an environment for design like piping, sheet metal etc. Module is the term in software customization. There are many companies using software's which does not require suppose piping environment. So that company prefer to buy solid works without piping module or any other module.

- sheet metal
- weldments
- Advanced Surface Modelling
- Mold Design Using SolidWorks
- Simulation

Weldments:

weldments are typically structural sections cut size and held together by the welding process**.** This is a very common process for structural members and parts. Let’s consider the following example of a simple frame.

The Weldment package within SolidWorks allows you to create some amazing fabricated structures, with just a few either 2D or 3D sketches and some pre-loaded shapes. The sketch lines define where and how the structural pieces are laid out.

Sheetmetal:

Sheet metal is the metal formed into thin and flat pieces, which uses sheets of thickness less than 6 mm. It is one of the main and basic forms of metal working. You can cut or bend into various shapes using sheet metal. The greatest feature of sheet metal is that it’s having ability to be formed and shaped by no of process.

Sheet metal bending or unbending is easy to do in real scenario with helps of various machine tools and experienced machinist. But it is computer CAD program like SolidWorks is analytical in nature. So, you should have to represent bending process analytically. For representing that, SolidWorks provided bend allowance, bend deduction, k-factor etc.

Surface modelling:

surface modeling is SolidWorks’ primary solution to modeling freeform shapes. Surface modeling allows adjustment of topology and profile of any object drawn with parametric accuracy i.e., the engineer can mold the surface precisely as per any dimension manually set according to design constraints.

Mold design:

Mold tools span from initial analysis to creating the tooling split. The result of the tooling split is a multibody part containing separate bodies for the molded part, the core, and the cavity, plus other optional bodies such as side cores. The multibody part file maintains your design intent in one convenient location. Changes to the molded part are automatically reflected in the tooling bodies.

Solid works simulation:

Solid works simulation is a virtual testing environment to analyze your design, evaluate its performance and make decisions to improve product quality. the software employs a numerical technique called Finite Element Analysis, or FEA.

The concepts behind FEA were developed in the early 1940's, but the method became more mainstream in the 1980's and 90's when it was implemented on desktop computers. Today, FEA is a powerful tool that is widely used by designers across many industries. It's used for solving structural, vibrational and thermal problems virtually before they pose a real problem in reality.

3.4 Modules Functionalities:

Weldments:

Weldment's functionality enables you to design a weldment structure as a single multibody part.

You use 2D and 3D sketches to define the basic framework. Then you create structural members containing groups of sketch segments. You can also add items such as gussets and end caps using tools on the Weldments toolbar.

- Can transfer the material properties of a library profile when you use it as a structural member.
- The weldment feature designates the part as a weldment and enables the weldment environment.
- You can create your own weldment profiles to use when creating weldment structural members.
- You create the profile as a library feature part, then file it in a defined location so it is available for selection.
- The pierce point defines the location of the profile, relative to the sketch segment used to create the structural member.
- can use segments and other solid bodies to trim segments so they butt up correctly in the weldment part.
- To close off open structural members, you can add end caps, including internal end caps.
- You can add weld beads to weldment parts and assemblies, and multibody parts.
- You create sub-weldments to segment complex weldment models into more manageable entities.

Surface Modelling:

Surface modeling is crucially important in design of industrial equipment which is directly related to the quality and price of the said equipment in any industry or fabrication. Some applications of SolidWorks surface modeling are listed as follows:

Automotive and Aeronautical Design:

Aerodynamic properties of a vehicle are often the differentiating factor between a model with low fuel efficiency and a model with efficient fuel consumption. The profile of a car or a plane is designed using surface modelling – SolidWorks, being the user-friendly software that it is, allows the engineer to freely control the profiles of a car or a plane, thus enabling multiple iterations leading up to the most optimal design.

Furniture Design:

Furniture industry keeps coming up with innovative designs in different styles crafted with wood, plastic, steel and synthetic materials. These designs can be modelled very conveniently with SolidWorks surface modelling.

Spacecrafts and Satellites:

The "weird" profiles of rockets sent into space by government projects and private space research companies like Space-X are modelled with the same profiling techniques as automotive – surface modelling can help design the aerodynamic profiles of space equipment.

Auxiliaries:

While large scale, gigantic equipment like space-shuttles and airplanes are commonly modelled using this technique, smaller equipment like computer mouse, clothing iron, bottles and toys are also modelled with SolidWorks surface modeler.

Mold Design:

- Mold analysis tools are used by designers of moulded plastic parts and by designers of the mold tools used to manufacture those parts.
- Parting lines lie along the edge of the moulded part, between the core and the cavity surfaces. They are used to create the parting surfaces, and to separate the surfaces. You create the parting lines after the model is scaled and proper draft is applied.

- To cut a tooling block into two pieces, you need two complete surfaces (a core surface and a cavity surface) without any through holes. Shut-off surfaces close up the through holes. You create shut-off surfaces after you create the parting lines.
- You can extract geometry from a tooling solid to create a core feature. You can also create lifters and trimmed ejector pins.
- You can insert a tooling split to create the core and cavity blocks for a mold.
- Set analysis parameters and colour settings to identify and visualize trapped areas on moulded parts that would prevent the part from ejecting from the mold.
- Set analysis parameters and colour settings to identify and visualize areas with insufficient draft on moulded parts.
- You can merge multiple edges into a single edge. This is useful on imported parts, where edges sometimes import as multiple short edges.

- When you use various mold tools, the software automatically creates the following folders and adds the appropriate surfaces to them:

- **Automatically Selecting a Different Chain of Edges**
- **Manually Selecting Each Edge**

Sheet Metal:

Sheet metal parts are generally used as enclosures for components or to provide support to other components.

You can design a sheet metal part on its own without any references to the parts it will enclose, you can design the part in the context of an assembly that contains the enclosed components, or you can design the part within another part document in a multibody environment.

- Forming tools are parts that act as dies that bend, stretch, or otherwise form sheet metal to create form features such as louvers, lances, flanges, and ribs.
- SOLIDWORKS multibody part functionality lets you work with several bodies in one part to create complex sheet metal designs.
- Sheet metal Property Managers help you create and modify sheet metal parts.
- A base flange is the first feature in a new sheet metal part.
- The Bends Property Manager allows you to convert a shelled part to a sheet metal part.

- The depth of a tab feature is automatically set to the thickness of the sheet metal part. The direction of the depth automatically coincides with the sheet metal part to prevent a disjoint body.
- A mitre flange feature adds a series of flanges to one or more edges of a sheet metal part.
- You can create compound bends in sheet metal parts using the Swept Flange tool.
- The Jog tool adds material to a sheet metal part by creating two bends from a sketched line.
- Lofted bends in sheet metal parts use two open-profile sketches that are connected by a loft. The Base-Flange feature is not used with the Lofted Bend feature.
- The Welded Corner Property Manager allows you to add a weld bead to the corners of a folded sheet metal part, including mitre flanges, edge flanges, and closed corners.

Simulation:

Accelerated Simulation Calculations:

Benefits: Validate designs more quickly while still capturing accurate results for critical components.

Combine linear elements for faster solution and quadratic elements for higher accuracy in the same simulation study.

Simulation Evaluator:

Benefits: Be confident that you have the correct simulation setup and results.

Check for common errors in simulation, such as result location, material, and mesh volume.

Distributed Coupling for Pins and Bolts:

Benefits: Achieve a more realistic representation of a connector's behavior.

Allow faces attached to Pin and Bolt connectors to deform.

Thermal Loads for Beams:

Benefits: Save a substantial amount of time and computer resources by using beams instead of shells and solids.

Import temperatures from thermal analysis on models with beams as load to perform stress analysis.

Free-Body Forces for Nonlinear Studies:

Benefits: Help users quickly obtain results such as Reaction Forces.

Now you can calculate free-body forces for contact, external loads, restraints, and more in nonlinear studies.

CHAPTER 4

PROJECT TESTING

4.1 Overview of Testing Methods:

4.1.1 Testing Surface Shape of Solar Radiation Absorber Plate:

The study of testing the absorber plate surface shape on the solar heater comprises a double plate of the intensity of solar radiation, temperature of incoming water, temperature of the water out, the temperature of the absorber plate, cover glass temperature and ambient temperature. Intensity of total solar radiation on average have the same pattern with the average temperature (the temperature of the cover glass, the temperature absorber plate, the temperature of incoming water temperature and the water out). Thus, the amount of energy absorbed by the solar water heater will be in accordance with the energy source is solar radiation energy. For ambient temperatures not entirely solar radiation pattern, it is because there are other factors that affect the temperature, the wind speed and air humidity. the efficiency of solar water heater with a double plate absorber plate surface can generate waveforms solar water heater efficiency is higher and more gentle decline in efficiency compared with the efficiency of solar water heater with flat plate surface absorbent form. These conditions are caused by a different surface area, so that the heat energy of solar radiation that is absorbed is greater. Thus, the wave-shaped absorber plate surface can increase the efficiency of solar water heater.

A solar collector is required to absorb solar radiation and to transfer the absorbed energy into a heat transfer fluid with a minimum of heat loss. In assessing the performance of a collector, it is therefore important both to determine its ability to absorb solar radiation and to characterize its heat losses. The ability of a collector to absorb solar radiation is largely determined by the optical properties of its cover and absorber surface. However, there are also losses, which may be considered as input losses, associated with the transfer of heat from the absorber surface into the heat transfer fluid. These are influenced by the design of the absorber fluid passageways.

Factor Affects Efficiency of a Flat Plate Collector:

Efficiency of flat plate collector can be improving by:

1. Increase transmission of energy through the collector to the working fluid by

a. Improve transparent covers

b. Improve absorber plate to incident solar radiation

c. Improve heat transfer coefficient from absorbing surface to the working fluid.

2. Reducing thermal losses from absorber plate to outside air. This can be minimizing by reducing conductive, convective and radiation losses

a. Conduction losses: A collector loses heat from its front, its back and its sides. The back and side losses from a flat plate collector can be minimized by the use of insulation.

b. Convection & Radiation losses: The heat losses from the front of a flat plate collector are usually the largest component of the overall heat losses. They occur in the form of convection and thermal radiation from the front cover to the environment and can be reduced by designing the collector in such a way that the temperature of the front cover is kept low. This can be achieved by minimizing the heat transfer between the absorber and the outer cover. The convective heat transfer between the absorber and the outer cover can be reduced by using a multiple glazing system or by evacuating the space over the absorber. The radiative heat transfer from the absorber to the cover can be reduced by the use of selective surfaces

3. The heat loss coefficient of a collector increases with collector operating temperature and with the local wind speed

Testing Procedure:

Standardized testing and rating procedure provides a basis for comparing the efficiency of different type of collector also it is basis for selection of a solar collector for given application as well as their design improvement. The main functions of collector testing are

1. To get requisite data for predicting the performance of solar collector system in given meteorological condition.

2. To get requisite data to study and develop the design of solar water heater collector

3. To compare performance of different design solar collector for their better commercial use
4. To get performance standard.

Test set up consisting of flat plate collector under test, a liquid pump, a heat exchanger with a cooling coil and a storage tank with an electric immersion heater. A bypass is provided for control mass flow rate. The purpose of heat exchanger with a cooling coil is to remove heat. Thus, the combination of storage tank with electric heater and heat exchanger provides a mean for adjusting the fluid inlet temperature to collector to a desire value. There are number of collector models appearing in the market for improving the efficiency of solar water heating system requires some unified approach or testing method that will compare and determine the performance of different solar water heating collector models under given climatic and operating conditions. On any given day data is recorded under steady state condition for fixed value of m and It. for each set of fixed value number of tests be conducted symmetrically. The principal measurements made in each data set are the fluid flow rate m, the fluid inlet and outlet temperature of collector (It & To), the solar radiation incident on the collector plane (G), the ambient temperature Ta and wind speed V. The efficiency of solar collector is given by

Collector Efficiency Collector panel efficiency is the ratio between the rates of heat (Q) is transferred to a fluid divided by solar radiation on the cover plate.

$$\eta = \frac{Q}{A\,G}$$

$$\eta = \frac{mC_p(T_{out} - T_{in})}{A\,G}$$

Description: Q = The energy absorbed by the collector, (W/m^2)
A = Area of the collector, (m^2) , G = Total solar radiation intensity (W/m^2)
T_{in} & T_{out} = The temperature of the incoming & outgoing water (^0C)

4.1.2 Charging and Discharging of PCM:

Efficient and economical technology that can be used to store large amounts of heat in a reduced volume is the subject of research for a long time. PCM plays an important role in energy conservation, which is very attractive because of its high storage density with small temperature change. It has been demonstrated that the development of a latent heat in thermal energy storages system which store heat during peak power operation and release the same during reduced power operation. Phase change material is one of the thermal storage devices. Thermal energy storage system enhanced by encapsulating with suitable PCM materials, within these surfaces heat can absorb or capture solar thermal energy through natural convection. The amount of stored heat energy depends on the specific heat of the medium, the temperature change and the amount of storage material. Latent Heat Storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice - versa. This system provides a valuable solution for correcting the difference between the supply and demand of energy. Many phase change materials have been studied and tested for different practical uses by many scientists.

Charging and discharging of phase change material are the test methods that are performed on selected phase change material.

During charging process the selected phase change material absorbs thermal energy and undergoes melting process. The selected phase change material is calcium chloride hexahydrate whose temperature is between 29-30°c. thus the melting process is known as charging process. The temperature of the phase change material is within requirements of the project.

During discharging process, the selected phase change material undergoes solidification process by rejecting thermal energy. This is known as the solidification process. Charging and discharging process are important process that involves with phase change materials.

CHAPTER 5

CONCLUSION AND FUTURE ENHANCEMENT

Conclusions:

Solar water heating system plays an important role in sustainable energy management in Indian households as well as worldwide. Such an effort will not only be useful in improving the quality of life but also in environmental protection. This review paper is focused on the past & current research of energy storage through PCMs for solar water heating systems. This paper will also help to find the suitable PCM and provide the various designs for solar water heating systems to store the solar thermal energy.

calcium chloride hexahydrate is a good PCM for energy storage in latent heat storage system. It has a suitable transition temperature range of 29-30°C and a relatively high latent heat of 190kJ/kg. In addition, it does not exhibit any sub-cooling. A simple system can be used for energy storage with reasonable charging and discharging times. The melting was more at the top and nearer to the inner tube. The solidification was rapid at the point which was nearer to the inner tube carrying heat transfer fluid. During charging, the energy stored in LHTES increases with the increase in inlet HTF temperature.

Renewable energy research has become increasingly important since the signing of the Kyoto Protocol. Solar water heating (SWH) is one of the most effective technologies to convert solar energy into thermal energy and is considered to be a developed and commercialized technology. However, there exist opportunities to further improve the system performance to increase its reliability and efficiency. A concise review primarily on the design features and related technical advancements of the SWH systems in terms of both energy efficiency and cost effectiveness has been presented. Several solar water heating designs have been introduced in the market and are more commonly utilized in the tropical regions of developing countries. Recent developments in heat pipe based solar collector technology exhibit a promising design to utilize solar energy as a reliable heating source for water heating applications in solar adverse regions. Heat pipe based solar water heating is influenced by many factors including the nature of the refrigerant, due to the environmental concerns.

Thermal energy storage using Phase Change Materials (PCMs) presents a unique solution to reduce energy consumption, greenhouse gases emission and dependency on fossil fuels. While PCMs are being introduced into many applications for thermal energy storage, continuous refinements and improvements are needed to match the requirements of the vast number of their applications of PCMs.

Energy storage is very appealing to many parties because of its ability and potential to improve system performance. Storing excess energy for future use makes the development of technology more effective and viable compared to building new power plants. PCMs can play a significant role in storing higher amounts of energy, which is linked with the latent heat of the phase change. Also, PCMs support a target-oriented settling temperature by the fixed temperature of the phase change. The energy storage capacity of PCMs in the heat recovery of solar power plants is affected by several factors. Two forms of heat transfer, heat conduction and convection occur during the phase change process inside the PCMs. Improve heat transfer techniques can increase heat conduction and suppress heat convection. To ensure better and more cost-effective PCM performance in energy storage applications, it is recommended that the available information be consolidated to provide better facilities to end-users. Also, social awareness, along with the technological development of solar stills can significantly motivate people to use PCM-based energy storage systems. However, future research should focus on techniques to improve and optimize the heat transfer of PCMs. Further research on the development of efficient and cost-effective PCMs with less ageing effects for solar thermal energy storage applications is needed to ensure significant and positive social impacts.

Future Enhancements:

The system further can be improved by using different type of PCMs and by placing PCMs at different locations in solar water heater system. Its efficiency can also be increased by using different type of materials for absorber plate, tube, water tank etc.

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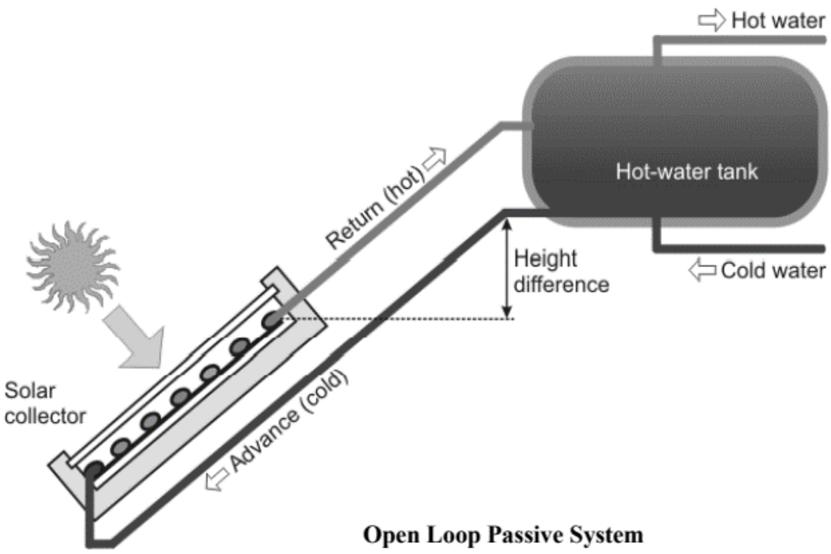
APPENDICES

Open and Closed Loop Passive Systems:

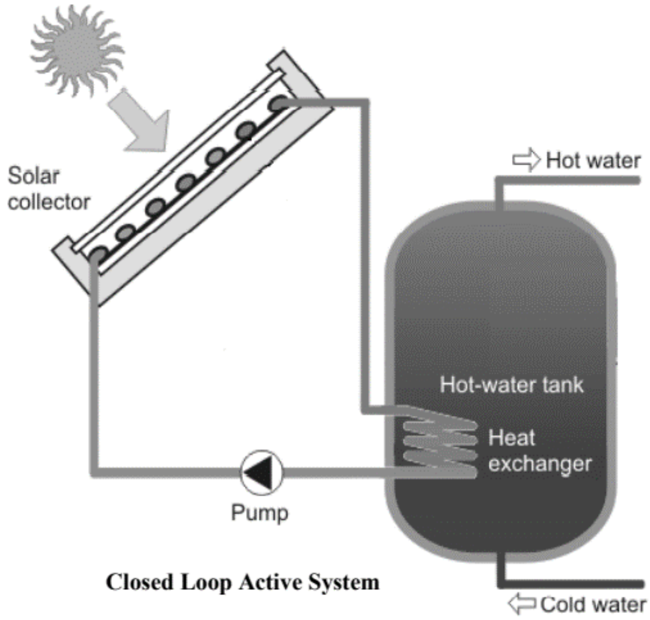
Passive systems move domestic water or a heat-transfer fluid through the system without pumps. These systems are usually less expensive than active systems, but are also generally less efficient due to slower liquid flow rates through the system. Thermosyphon system is an example of Open Loop Passive System. It is based on natural convection to circulate water through the solar absorber and to the tank. The tank is located above the collector. As water in the collector heats, it becomes lighter and naturally rises into the tank above. Meanwhile, cooler water in the tank flows downwards into the solar collector, causing circulation throughout the system.



Open Loop Passive System

Open and Closed Loop Active Systems:

Closed loop systems use pumps to transfer the fluid (usually a glycol-water antifreeze mixture) through the solar water heater. Heat exchangers transfer the heat from the fluid to the water that is stored in tanks. Thick-walled heat exchangers prevent the mixture from the domestic water. Closed-loop systems are popular in areas with low temperatures because they offer good antifreeze protection. However, glycol antifreeze systems are more expensive to purchase and install and the glycol must be checked every year and replaced every few. Open-loop active systems use pumps to circulate domestic water through the collectors. This design is efficient and lowers operating costs but it is not appropriate if water is hard or acidic because corrosion will damage the system. Open loop active systems are popular in regions that do not experience freezing temperatures.



Closed Loop Active System

Batch water heaters

Batch water heaters, also known as ‘breadboxes’ are very simple passive systems for heating water using solar energy and have been used since the early 1900’s. Batch systems consist of black storage tanks contained within an insulated box that has a transparent cover. Cold water is added to the hot water stored in the tanks whenever hot water is removed. Modern batch systems are used as preheating systems, where the water is then heated further by conventional gas, electric or wood systems. To retain the heat within the water, the system requires insulated covering to be placed over the glazing at night to prevent the heat being lost to the environment.

A Main Project Report
on

DESIGN OF GREASE INTERCEPTOR

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

By

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ST. MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)
Dhulapally, Secunderabad – 500 100

JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Design of Grease Interceptor**, is being submitted by **G. Vineeth(17K81A0373) and Nichenametla Sai Siddarth(17K81A03A0)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Dr. D. V. SREEKANTH
Professor & Head of the Department,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Design of Grease Interceptor** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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The satisfaction and euphoria that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible and whose encouragements and guidance have crowded effects with success.

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ABSTRACT

The aim of project was to design and fabricate i.e., to develop a grease interceptor. A grease interceptor is a plumbing device designed to intercept most greases and solids before they enter a wastewater disposal system. Grease interceptors are generally used to prevent clogging of pipelines with grease, fat and oils. They are also used to prevent large amount of grease accumulating in sewage systems. The separation of gasoline and oils from waste water is also accomplished by use of this fixture installed in the plumbing systems. A properly installed and maintained grease interceptor can prevent upto 99% of grease and oils from entering sewage systems. We mainly focus on making our product cost effective. We designed our project using solidworks, maintaining all the dimensions as required to with stand high pressure and flow rate. We have fabricated prototype using fibre- reinforced plastic (FRP) material. After testing and making changes as required, the final product has been manufactured using stainless steel Material.

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CHAPTER-1 INTRODUCTION

1.1 Introduction

We are very well aware of the fact that grease and water don't mix, especially when they travel through the sewer lines. Yet, we at our homes tend to pour down oils we used for cooking down the drain. Which generally tend to block our drains pipes or on large scale cause issues to the sewage system. We can easily clean our house drain pipes but it is near to impossible to clean when it comes to large industries and restaurant food chains. High-viscosity fats and cooking grease such as lard solidify when cooled, and can combine with other disposed solids to block drain pipes.

Restaurants and large industries use huge quantities of fats, oils and grease. Large amounts of oil from food preparation in restaurants can overwhelm a septic tank or treatment facility, causing release of untreated sewage into the environment. Fat, Oils and grease also causes big problems within commercial kitchens, with fat, oil and grease from wastewater causing blockages in internal pipes leading to expensive repairs and potential equipment downtime. According to the International Building Norm 1825, commercial kitchens generating wastewater must have pre-treatment plants to ensure that fat, oil and grease (FOG) are not discharged into the public sewerage network. Otherwise, very greasy wastewater puts the pipe systems and drainage equipment at risk. Grease and oils are deposited with other wastewater components on the walls of the pipes and can lead to corrosion, blockages and noxious smells.

Nearly half a million tons of grease and fat enter the sewerage system every year. Grease accumulation causes sewer blockages and overflows. Grease sticks to pipe walls, which can eventually lead to blockages while fats and oils damage waste water treatment equipment, costing municipalities millions in repairs every year. If allowed to enter a natural water course, fats, oils and grease can cause serious damage to the environment. Fats, oil, and grease (FOG) can have serious consequences when introduced to the sewer system. FOG entering the sewer system from food preparation and dishwashing can and will harden and build up eventually leading to a blockage in the city sewer or your own line. When a blockage occurs, the sewage coming from upstream backs up and finds another way out. It could exit through a manhole then run down the street or through a drain or clean out in your home or business.

From our research we estimated there are over 40,000 sanitary sewer overflows/year. The untreated sewage from these overflows contaminate water and the environment, cause serious water quality issues, property damage and threaten public health. Sewer collection systems take wastewater to a treatment plant, but there are some things they're not designed to handle. One of those is grease.

Grease, especially grease with animal fats (think bacon grease), cools and solidifies at normal temperatures in pipes. That cooling, as well as other chemical reactions in sewer lines, causes blockages in the sewer pipes, eventually causing backups called sanitary sewer overflows. Overflows are a significant public health risk and require specialized equipment, time and manpower to clear.

For this reason, many cities require the use of grease traps, or called grease interceptors, at locations that prepare food items to ensure grease doesn't block sewer lines and result in sanitary sewer overflows.

In some situations, a grease interceptor can save the food service establishment money as well. Any location with long plumbing runs to the sewer collections system, such as a mall, hospital, or restaurant inside of a large building runs the risk of blockages in internal pipes. Those blockages could lead to backups, fines and even downtime while internal plumbing is repaired.

A Grease interceptor is easy-to-fit plumbing devices designed to capture (or trap) fats, oils and grease (FOG) before they enter the main drainage system. A grease trap plays a critical role in your foodservice operation. When installed and maintained properly, the grease trap interceptor is a safe, clean way to rid your restaurant of fats, oil and grease (FOG). When there's a glitch in your grease trap system, it can lead to sewer or drain backups and noxious odors. Grease traps are important for keeping fats, oil, and grease from food production from entering the sewer line with waste water. When waste water enters the grease trap, a system of baffles causes the oils and grease to rise from the water and become trapped within the receptacle. Grease traps have been around for more than 100 years and are also known as grease interceptors, converters, catchers, grease recovery management devices or FOG traps.

They're used in in a wide range of environments including:

- Restaurants
- Cafes
- Takeaways
- Pubs, bars and inns
- Hotels
- Schools and colleges
- Bakeries

To put it simply, a grease trap is a receptacle into which wastewater containing FOG flows through before entering a drainage system. The receptacle is designed to intercept or "trap" the FOG while allowing clear water to escape.

One factor that’s important when choosing a grease trap is efficiency. More efficient grease traps can remove and store more grease from your kitchen waste water. That means a much lower chance of blockages and overflows. Higher grease storage capacity keeps your interceptor functioning properly and makes it simpler and less expensive to maintain.

Grease traps have been around since the 1880s, and many grease interceptors still use the same basic design as those early models. But design and engineering innovations in more recent years have allowed companies to develop new designs that are more efficient, longer lasting and easier to use and maintain.

Early grease traps were made of concrete, which tends to degrade over time and eventually fails. Modern grease interceptors come in a variety of materials, including concrete, steel, fibreglass and plastic. The material used in grease interceptors affects their cost, their weight, how easy or difficult they are to install or move, and how often they must be replaced.

Concrete can degrade, as can metal in some circumstances. fibreglass tends to crack if moved. Modern plastics are lightweight and highly durable, and can make for long-lasting, highly efficient grease traps.

Compact, highly efficient grease interceptors, such as Thermaco's Trapzilla systems, are engineered so they never lose efficiency. They can hold upwards of 90 percent of their volume in grease before they must be cleaned out.

A grease interceptor is located between kitchen drain lines and sanitary sewer lines. Grease interceptors capture the FOG that enters sink drains from food service activities such as food preparation, dishwashing and cleaning.

Grease is a huge problem. With more people eating out than ever before and more restaurants being built, more grease needs to be disposed of. FOG are approximately 10 to 15 per cent less dense than water, and once cooled FOG will begin to congeal and harden, this is when it becomes a significant problem. At the time when you are pouring grease into the drainage system it won't seem like a problem, however as time passes grease will cause blockages and overflows that can potentially damage property and cause environmental contamination of local bodies of water. Grease traps trap the grease and ensure grease does not become a problem.

If you are a larger organization or a commercial company, you are required by law to have a grease trap in your premises. Although grease interceptors are relatively simple devices they serve a huge purpose and can save you a lot of time and money in the long-run. If you buy a grease trap from a reputable company like Grease Trap Store you'll receive great quality at an affordable price. The grease trap will pay for itself ten-fold compared to what you may pay for in plumbing costs should a serious problem arise from a grease-related blockage or overflow.

1.2 Background and History

Grease traps were invented in the 1880's, and the technology has reminded nearly unchanged ever since. Whether the unit is a grease trap or grease interceptor, the technology works the same. Fats, oil and grease (FOG) float to the surface, leaving the wastewater to flow into the sewage system.

Nathanial Whiting, an American visionary patented the first rudimentary grease trap in the late 1884. Although basic and crude in design, this original patent is what all modern systems derive from. The first documentation for the use of grease traps was in the Victorian period when the sewer system was invented and put into action. This fact clearly shows that the negative impact that FOG has on sewers was evident even then. Although use was sporadic and not obligatory, the roots of the war against grease had taken hold, roots that have continued to grow and broaden over the last 100 years.

The boom in the growth of the foodservice and catering industry coupled with changing diets and cooking techniques greatly contributed to increasing fatberg concerns. As more commercial kitchen waste was being disposed of directly into sinks and drains, without any form of protection against nasty build-ups, it became evident that something needed to be done. Between 1990 and 1991 legislation was drawn up and enforced stipulating strict guidelines in reference to the disposal of kitchen waste, especially in commercial premises. All commercial businesses that prepare and distribute food are now required to install and regularly maintain appropriate grease traps with correct, up-to-date documentation available to substantiate procedures. With water authorities clamping down on irresponsible practices, grease traps have never been more in the limelight.

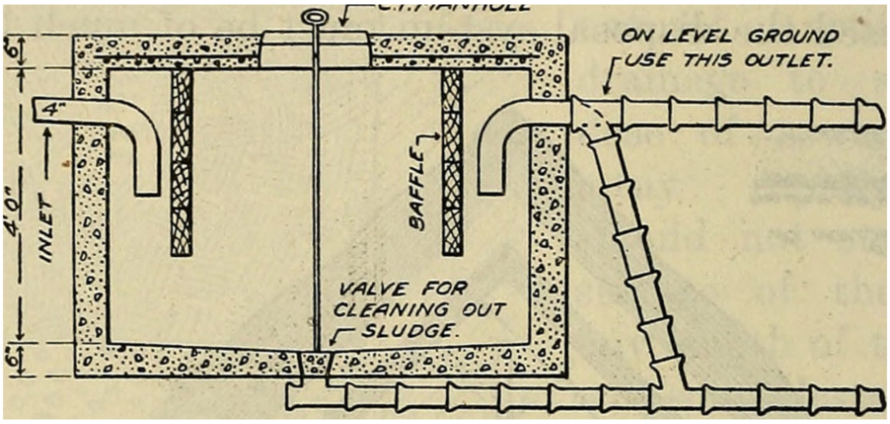


Fig1. Drawing of First working Grease Interceptor

The "25% Rule" also known as the One-Quarter or 1/4th rule. This rule (which in many states and counties is an actual rule enforced by health inspectors) states that the total depth of the "brown grease" layer in an inceptor – which is usually floating on the top and a combination of food matter, grease, and oil – including any solids that have settled to the bottom should not be more than one-quarter of the total depth of the inceptor.

While grease traps have been around for a long time (seeing a rise in popularity in WWII), the first instance found of the one-quarter rule appeared in Honolulu in the 1990s by the head of the Regulatory Control Branch Head or the Department of Environmental Services, James Baginski. All the Hawaiian Islands have slim margins when it comes to FOGS in wastewater, and James did multiple tests to see what the total volume of grease traps in those days could hold before FOGS started leaking out with the wastewater. 25 to 35 percent is what he found, and so he placed his recommendations for cleaning at the lower number.

1.3 Working Principle

Grease traps work on the basis that animal fats and vegetable oils (grease) are 10 to 15 percent less dense than water and that grease won't mix with water. Thus, fats and oils float on top of water. The FOG fills the grease trap from the top down, displacing the wastewater from the middle of the grease trap and into the sanitary sewer or septic system.

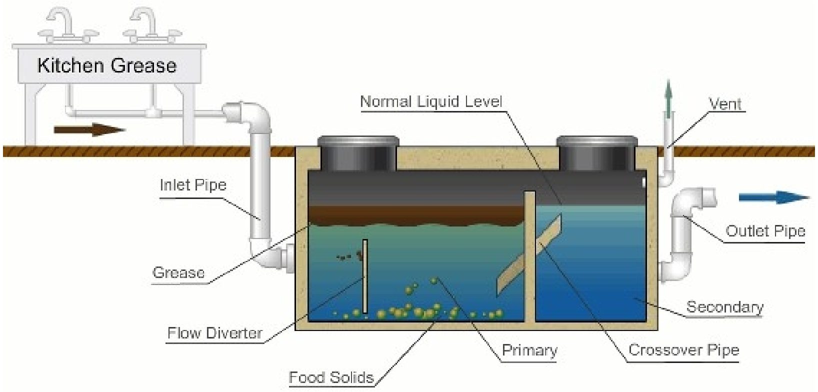


Fig2. Modern Grease Interceptor with components

When wastewater enters a grease trap, the flow rate is reduced enough so the wastewater is given enough time to cool and separate into 3 layers. The grease rises to the top inside the interceptor and is trapped using a system of baffles. Solids settle at the bottom and the separated clear water escapes under an outlet baffle. Many grease traps also have strainers for collecting solid debris, which reduces the amount of solids that settle at the bottom of the trap. The relatively grease-free water is then fed into the normal septic system. grease thus collected will be contaminated and is unsuitable for further use. This type of grease is called brown grease.

Over time, solids and grease build-up, and if left to accumulate for long enough they can start to escape through the outlet and in some circumstances, they can back-up through the inlet. For this reason, the trap must be cleaned / pumped out on a regular basis.

Fig3. Grease Interceptor used in kitchen

- STEP 1 - Flow from under sink grease traps or directly from plumbing fixtures enters the grease interceptor.
- STEP 2 - An approved flow control or restricting device is installed to restrict the flow to the grease interceptor to the rated capacity of the interceptor.
- STEP 3 - FOG floats on the water surface and accumulates behind the grease retaining fittings and the wall separating the compartments. FOG will be removed during routine grease interceptor cleaning.
- STEP 4 - Solids in the wastewater that do not float will be deposited on the bottom of the grease interceptor and will need to be removed during routine grease interceptor cleaning.
- STEP 5 - Flow exits the interceptor through the outlet pipe and continues on to the sanitary sewer system.

NOTE - Some interceptors have a sample box so that inspectors or employees of the food service establishment can periodically take effluent samples.

Waste from passive grease traps and gravity interceptors is called brown grease. Brown grease is rotted food solids in combination with fats, oils, and grease (FOG). Brown grease is pumped from the traps and interceptors by grease pumping trucks. Unlike the collected yellow grease, the majority of brown grease goes to landfill sites. New facilities (2012) and new technology are beginning to allow brown grease to be recycled.

1.4 Application

Restaurant and foodservice kitchens produce a lot of waste grease which is present in the drain lines from the various sinks dishwashers and cooking equipment such as combi ovens and commercial woks. If not removed the grease will congeal within the sewer and cause blockages and back-ups.

In the United States, sewers back up annually “an estimated 400,000 times and municipal sewer overflows on 40,000 occasions”. The EPA has determined that sewer pipe blockages are the leading cause of sewer overflows, and grease is the primary cause of sewer blockages. Even if accumulated FOG does not escalate into blockages and sanitary sewer overflows, it can disrupt wastewater utility operations and increase operations and maintenance requirements”

For these reasons, depending on the country, nearly all municipalities require commercial kitchen operations to fit some kind of interceptor device to collect the grease before it enters the sewer. Additionally, where FOG is a concern in the local wastewater collection system communities have set up inspection programs to ensure that these grease traps and/or interceptors are being maintained on a routine basis.

It is estimated 50% of all sanitary sewer overflows are caused by grease blockages with over 10 billion gallons of raw sewage spills annually. The answer to this question lies in the above explanation. As established water and oil do not mix therefore when it is washed down the sink it

will clog pipes because it is thicker than water. Even if oil is poured down the sink as a hot substance (then it is like a liquid) once it cool its will re-solidify and the same problem presents.

The main argument for grease traps is that if grease increases in pipework eventually blockages and backup will occur. These problems can then spread into the main sewers and cause issues for water treatment facilities as grease interferes with chemicals that clean waste water. In the end this costs time and money as well as unnecessary inconvenience for individuals or even the country as a whole.

Other reasons why grease traps are necessary:

* Required by law.

Bigger organizations and corporate companies actually have a legal obligation to have a grease trap. This is true of restaurants or caters for example.

* Fast acting.

Grease trap systems work from the outset and start trapping grease as soon as

they are used. The most effective ones trap a high rate of grease per hour and per day. Imagine the efficiency to your own pipes or the water system generally?

* Helps the environment.

Many grease traps use little power which makes them environmentally friendly. Equally the grease which is trapped can be recycled which means it does not go to waste.

1.5 Limitations

The design of a grease trap reminds me of making a pot of homemade chicken soup. You put in a whole chicken, a bunch of vegetables and then let it cook for a few hours. Remove the chicken and let it cool. What you will find is this – The fat from the chicken has floated to the top and solidified. The veggies (solids) will settle on the bottom of the pot, and the broth takes up the space in between. A grease trap works the same way. Food and water go down the drain and into the grease trap – The solids settle to the bottom, the Fats float on top, and in between the waste water drains into the city water supply – capturing the FOG (fats, oil and grease) in your grease trap.

How often should you clean your grease trap? The standard rule is that a grease trap should be maintained at a frequency that will guarantee that your fats, oil, and grease (FOG) do not exceed 25% of the trap's capacity. A general rule of thumb is that inside grease traps need monthly cleaning and external grease traps must be cleaned at least every 12 weeks. Check with your municipality to confirm their specific requirements.

Your best starting point is to hire a licensed grease trap service provider that has well trained employees. Your provider must ensure that all manifests are properly completed and include the size of the trap, the amount of FOG material removed, and where the trap materials will be disposed. This manifest is not only the store's proof of compliance, but it also follows the train of the material to make certain that it is disposed of legally – guaranteeing it does not wind up in public waterways.

1.6 Summary

The purpose of a grease trap is to collect and therefore reduce the amount of fats, oils and greases (FOG's) that enter the main sewers. Grease entering the main sewer system will over time create blockages, foul odours and pest infestation. Grease traps have been in use since Victorian days and in simple terms are boxes positioned within the wastewater drain run from the sinks and appliances in a kitchen to the foul sewer system. They are designed only to have kitchen wastewater flowing through them and should never have wastewater from other drainage system sources such as toilets.

They can be made from a number of different materials including Stainless Steel, Mild Steel, Plastics, Concrete and our own patented new innovative disposable G-Bag System. Effective commercial models range from 40 litres capacity to 45000 litres and above. They can be located above ground, below ground, inside the kitchen or outside the building.

CHAPTER-2 LITERATURE SURVEY

2.1 Introduction

Fat, oil, and grease (FOG) blockages are the primary cause in 40-50% of all sanitary system overflows (SSOs) (Southerland, 2002). Sewer collection utilities are required to properly manage, operate, and maintain the collection system (Code of Federal Regulations, 2002). Currently, the primary means of controlling FOG blockages is to capture and retain FOG materials through passive and mechanized grease interceptor devices (Figure 1-1). The performance of these devices in real-world environments is being questioned and needs further examination. Limited scientific studies have been done evaluating these devices, and many claims of enhanced performance made in marketing strategies by manufacturers of grease and oil interception devices need to be verified by objective and unbiased research protocols. Visual observation of grease interceptors has shown numerous occurrences of hydraulic short circuiting due to either high FOG concentration discharges from the kitchen or high temperature FOG discharges. Recent discussions with a variety of grease interceptor manufacturers indicate a lack of consistency in design geometry and considerations (i.e., tank sizing variability, effect of depth, width, and length ratios). Moreover, grease interceptor manufactures were unable to support their design configurations with scientific data or research study results.

2.2 Literature Survey

Grease traps have been used since Victorian days: Nathaniel Whiting obtained the first patent in the late 1800s. The traps reduce the amount of fats, oils, greases and solids (FOGS) that enter sewers. They comprise boxes within the drain run that flows between the sinks in a kitchen and the sewer system. They only have kitchen waste water flowing through them, and do not serve any other drainage system, such as toilets. They can be made from many different materials, such as stainless steel, plastics, concrete & cast iron. They range from 35 liter capacity to 45,000 liters and greater. They can be located above ground, below ground, inside the kitchen or outside the building.

Current grease interceptor evaluations use animal fat as a test medium for finding minimum retention time. These tests do not consider that many restaurants use detergents, sanitizers, and vegetable oils. These factors can influence emulsification characteristics (e.g. droplet size) of FOG discharges, and thus influence separation efficiencies.

As Per the American Society of Plumbing Engineers, "grease interceptors are sized according the volume of effluent expected, the retention time necessary for separation at the temperature of the waste, the frequency of cleaning, and the quantity of emulsified grease (ASPE, 1999). “Grease” is being referred to as a “catch-all” phrase by the utility industry for FOG and include some waxes and paraffin. Each of these categories of FOG exhibit different chemical and physical properties.

Presently, the universal plumbing standards are based solely on effluent measurements. These standards do not consider chemical composition of FOG, baffle arrangement, maintenance, and geometry criteria. For example, the Uniform Plumbing Code (UPC) requires one baffle. However, jurisdictions such as Austin, Texas recommend two baffles, citing increased grease interceptor efficiency. The geometry criterion for interceptors also varies significantly among regulating authorities. Many authorities believe length of the interceptor is more significant for separation than depth. In the case of cleaning frequency, the U.S. EPA recommends cleaning of interceptors when the volume is at 75% of maximum. However, many cities recommend cleaning frequencies between 60 and 120 days (Fankel, 2004).

Stoll and Gupta (1997) developed management strategies for FOG collection, treatment, and disposal. In their work, Stoll and Gupta mentioned that grease interceptors could achieve higher FOG and solids removal efficiencies by assuring
the following:

♦ Avoid the use of emulsions, and use cleaning agents sparingly.

♦ Drain surfactant-laden food wastes only at the end of the day to provide longer periods in the grease interceptor and improve separation.

♦ Encourage intermediate machine cleaning to working surfaces and floors with hot water at high pressure, without cleaning agents, and drain scalding and boiling containers slowly after cooling first.

♦ Train and keep an eye on kitchen staff.

This research will greatly benefit the wastewater community by being the first to develop a link between how the influent and effluent designs impact the food solids and grease separation thickness. This research will also be the first to develop a 3-D two-phase (fat/oil and water) flow model of a grease interceptor. This model will be used to evaluate design changes, and operation and maintenance (O&M) conditions on the removal of FOG from foodservice waste. The model will be validated using a laboratory-scale grease interceptor. The results of this research will then be used to develop an alternative grease interceptor sizing methodology that can be used by the International Association of Plumbing and Mechanical Officials (IAPMO) for inclusion to the Uniform Plumbing Code (UPC).

In a recent study, Lesikar et al. (2006) performed the field analysis of grease interceptors for 28 restaurants ranging in size of the restaurant, fast food versus full fare, and cuisine types. Five day biochemical oxygen demand (BOD5), total suspended solids (TSS), FOG concentration, and flow (in the form of total gallons accumulated per day) measurements were performed for six consecutive days around the same time per day. A second set of BOD5, TSS, FOG, and flow measurements were performed at the same sites after a two week break. All samples were collected in the grease interceptor effluent.

Lesikar et al. found higher BOD5 and average flow values found previously in the literature. As shown in the Table 1-1, mean values for BOD5, TSS, FOG, and flow were 1040 mg/L, 358 mg/L, 123 mg/L, and 68 L/(day-seat), respectively. A large variance was found for all the parameters measured suggesting significant variability over the operation period of the restaurants investigated. The BOD5, TSS, and FOG variability is likely to be larger in the influent stream of the grease interceptor. However, no measurements were made in the grease interceptor influent. Moreover, Lesikar et al. made no mention of when the grease interceptor was last cleaned prior to the sampling time.

Lesikar and coworkers (Garza et al., 2005) also investigated how these measurement parameters were influenced by the restaurant's management practices and cuisine type. In Garza et al., a multiple regression with backward elimination (MRBE) statistical analysis was used to determine the degree that the specific management practice or parameter can be used as a predictor for the change in magnitude of the grease interceptor effluent TSS, BOD5, FOG, and flow data. If the parameter passed the MRBE test, a follow up repeated measure analysis with stepwise elimination (RMASE) test was performed to determine the final degree of correlation between the parameter and the effluent grease interceptor measurements. The restaurant management practices were collected using a self reported survey sent out by Garza et al. Parameters that were investigated are displayed in Table 1-2. The highlighted values in Table 1-2 display the highest degree of correlation after the RMASE test.

Garza et al. results suggest that several factors provided the greatest impact on the grease interceptor effluent TSS, BOD5, FOG, and average flow values. These factors are: cuisine type (in particular Mexican, Asian, seafood, single-service and full-service American); the operation of self service salad bars; and the number of seats. As discussed in Garza et al. (2005), the use of seat number in the sizing of grease interceptors seems appropriate due to the degree of importance from the RMASE results. In addition, Garza et al. concluded that self service salad bars are a likely source of uncontrolled patron usage of salad dressing with a range of FOG content as well as a higher disposal rate of unconsumed salad. However, no information was provided about the extent of variety that the salad bar offers (i.e., anti pasta salads, vegetable salads, range of salad dressings, meat toppings, etc.). In addition, Garza et al. (2005) did not include other variables such as detergent types and dishwashing methods, grease interceptor size and pump-out schedule, cleaning water disposal, wash and rinse water temperature, and sampling location relative to commingling of wastewater lines. Variables were not included, due to either unreliable survey responses or being classified as not a restaurant management practice. Some or all of these unreported variables may also influence the effluent grease interceptor TSS, BOD5, FOG and average flow values. Consequently, inappropriate conclusions may be drawn from the importance of certain parameters on the effluent grease interceptor values due to other non-evaluated parameters.

Research Scope and Objectives

This study had two specific research objectives:

1) Determine the optimal design, sizing, and operations and maintenance criteria for grease interceptors. Researchers employed experimental and numerical techniques to understand and quantify the performance of grease interceptors. They developed alternative designs using

numerical models followed by physical models of the most promising alternative designs, which were tested on a laboratory scale grease interceptor. Researchers examined different theoretical residence times to quantify the increase in FOG removal performance with reactor size. In addition, they investigated the impact of temperature and detergents to determine how food service establishments' operational conditions influence the FOG removal process within grease interceptors. The research team conducted field measurements of grease interceptors to understand the dynamics of FOG separation when food solids are also discharged into the grease interceptor.

2) Develop a grease interceptor design methodology that can be submitted to the International Association of Plumbing & Mechanical Officials (IAPMO) for consideration for inclusion into the Uniform Plumbing Code (UPC).

2.3 Global Survey

FOG management programmes are often run by water service authorities and results are frequently not readily available or published. Details various international FOG management programmes which have been studied, from city scale pilot programmes to multi-country initiatives. There are very few homogenous national approaches, with the positive Swedish and Norwegian approach varying between several water service authorities. The management approaches are often pilot programmes in areas with historic detrimental FOG problems, which react to the areas with high level of sewer problems.

The campaigns mentioned in the previous section may require GTSs but standards are rarely included to regulate the installation of properly sized GTSs or the maintenance of the units. Successes are often recorded by the reduction of blockages but the benefits to the sewers and WWTPs are rarely assessed. The following sections will detail some approaches that various countries have taken, from the multi country RecOil Project to the various methods that other countries have integrated to various degrees of success

Food Service Establishments meeting any of the above criteria shall be required to submit to EWSU a FOG Discharge Questionnaire. The data contained therein will be used to assess the size required to effectively control the discharge of undesirable materials into the wastewater collection system. The same process will occur where any existing establishments are found to be in violation of this policy. Existing establishments shall not be exempt from the requirements of this policy. “Grandfathering” of existing establishments that do not meet the FOG discharge requirements will not be permitted.

In addition to submitting a FOG Discharge Questionnaire, a user must submit plans to EWSU for approval to install a new grease interceptor or to make modifications to an existing FOG Removal System. The plans shall include the location of the grease interceptor, its capacity (in gpm or gallons), the connecting pipes, the capacities of the fixtures draining to the interceptor, and any other information deemed necessary.

Applicability:

These requirements are applicable to all commercial establishments, including those that are undergoing: 1. New Construction 2. Interior remodeling to accommodate expansion or operational modifications 3. Changes of ownership/occupancy 4. Establishments experiencing difficulty in achieving compliance with maintenance and/or wastewater discharge limitations 5. A change in menu or hours of operation that could significantly affect the amount of fats, oils, and grease discharged into the establishment’s FOG removal system

CHAPTER-3 TYPES OF GREASE INTERCEPTORS

3.1 Introduction

In order to meet the widely varying applications, several types of grease interceptor have been developed which are classified on the basis of nature of grease trapping process, relative direction of fluid motion, design and constructional feature and physical state of fluids.

A grease trap (also known as grease interceptor, grease recovery device, grease capsule and grease converter) is a plumbing device (a type of trap) designed to intercept most greases and solids before they enter a wastewater disposal system. Common wastewater contains small amounts of oils which enter into septic tanks and treatment facilities to form a floating scum layer. This scum layer is very slowly digested and broken down by microorganisms in the anaerobic digestion process. Large amounts of oil from food preparation in restaurants can overwhelm a septic tank or treatment facility, causing release of untreated sewage into the environment. High-viscosity fats and cooking grease such as lard solidify when cooled, and can combine with other disposed solids to block drain pipes.

Grease traps have been used since Victorian days: Nathaniel Whiting obtained the first patent in the late 1800s. The traps reduce the amount of fats, oils, greases and solids (FOGS) that enter sewers. They comprise boxes within the drain run that flows between the sinks in a kitchen and the sewer system. They only have kitchen waste water flowing through them, and do not serve any other drainage system, such as toilets. They can be made from many different materials, such as stainless steel, plastics, concrete & cast iron. They range from 35 liter capacity to 45,000 liters and greater. They can be located above ground, below ground, inside the kitchen or outside the building.

3.2 Types of Grease Interceptors

There are three primary types of device. The most common are those specified by ASME (American Society Of Mechanical Engineers), utilizing baffles, or a proprietary inlet diffuser. Grease trap sizing is based on the size of the 2- or 3-compartment sink, dishwasher, pot sinks, and mop sinks. The cumulative flow rates of these devices, as well as overall grease retention capacity (in pounds or kilograms) are considered. Currently, ASME Standard (ASME A112.14.3) is being adopted by both of the National Model Plumbing Codes that cover most of the US. This standard requires that grease interceptors remove a minimum of 90% of incoming FOGs. It also requires that grease interceptors are third-party tested and certified to 90 days compliance with the standard pumping. This third-party testing must be conducted by a recognized and approved testing laboratory.

The most common passive grease traps are smaller, point-of-use units used under three-compartment sinks or adjacent to dishwashers in kitchens. The second most common type of interceptor is the large in-ground tank, which is usually 500–2,000 US gallons (2,000–8,000 L). These units are constructed of concrete, fibreglass or steel. They have greater grease and solid storage capacities for high-flow applications such as a restaurant or hospital store. They are commonly called gravity interceptors. Interceptors require a retention time of 30 minutes to allow the fats, oils, grease and food solids to settle in the tank. As more waste water enters the tank, the grease-free water is pushed out of the tank. The rotting brown grease inside a grease trap or grease interceptor must be pumped out on a scheduled basis. The brown grease is not recycled and goes to landfill. On average 300 to 400 pounds (140 to 180 kg) of brown grease goes to landfill annually from each restaurant.

A third system type, GRDs (grease recovery devices), removes the grease automatically when trapped. The recovered grease or "yellow grease" is recycled with the waste vegetable oil from the kitchen's deep-fryers. Restaurants need not effect grease trap pumping as do restaurants with conventional grease traps or grease interceptors.

Passive grease traps and passive grease interceptors must be emptied and cleaned when 25% full. As the passive devices fill with fats, oils, and grease, they become less productive for grease recovery. A full grease trap does not stop any FOG from entering the sanitary sewer system. The emptied contents or "brown grease" is considered hazardous waste in many jurisdictions.

3.3 Hydromechanical Grease Interceptor (HGI)

A hydromechanical grease interceptor (HGI) (also known as a grease trap) is a flow-based grease interceptor that is usually installed in ground or above ground, inside or outside of the facility, and has a typical capacity of less than 250 gallons. FSEs generally prefer HGIs over gravity grease interceptors (GGIs) because HGIs are less expensive to install, can fit in smaller spaces, and can be easier to maintain. A typical conceptual HGI design is illustrated in Figure 1-2, Conceptual Design of a Typical Hydromechanical Grease Interceptor.

Fig4.Hydromechanical Grease Interceptor

Design and Sizing :-

HGIs are made of steel, fibreglass or polyethylene, typically consisting of a single compartment with baffles, and sized according to the Uniform Plumbing Code (UPC). Chapter 10, Table 102 of the 2006 UPC and the 2009 UPC provide two different sizing methods for HGIs. Regardless of the sizing method, HGIs are sized based on flow rate and the pounds of FOG that they can store. Typically, they treat 2050 gallons per minute (GPM), store 40100 pounds of FOG, and are 1560 gallons in volume. Vented flow control devices must be installed upstream of HGIs to control the wastewater flow to match the certified flow rate of the HGI. If this flow control device is not installed, the HGI may not perform properly when the flow exceeds the certified flow rate.

Proper Maintenance:-

HGIs should be cleaned before the floating FOG and settled solids accumulation exceeds 25% of the HGI's capacity. In order to prevent this, daily to weekly cleaning of the HGI by kitchen staff or pumping contractors may required to ensure proper operation. If performed by kitchen staff, solids and FOG should be dewatered (e.g., mixed with kitty litter) and discarded in the trash.

Fig5. Cleaning of hydromechanical grease interceptor

3.4 Gravity Grease Interceptor (GGI)

Gravity grease interceptors (GGIs) treat kitchen wastewater from food service establishments (FSEs) using gravity separation. They accumulate fats, oil and grease (FOG) and solids over time allowing the treated wastewater to discharge to the sanitary sewer.

The International Association of Plumbing and Mechanical Officials defines a GGI as a "plumbing appurtenance identified by volume and intended to be installed in a sanitary drainage systemto intercept,using gravity only,nonpetroleum fats,oils,and greases from a waste water discharge".It is usually installed underground outside food service establishments, where it can be properly serviced and maintained by qualified personnel. Installing the unit in this location also removes the risk of having used grease stored within the same area where food is prepared and served. The tank can be made in different shapes and configurations, but must be effective in intercepting the grease. Many factors contribute to the efficiency of a GGI.

Design and Sizing:-

GGIs are made of precast concrete, steel, fibreglass or PVC and are sized according to the Uniform Plumbing Code (UPC). Chapter 10, Table 103 of the 2006 and 2009 UPC sizes GGIs based on the number of drainage fixture units (DFUs) connected to the interceptor. Typically, GGIs are 500 1,500 gallons in volume, depending upon the number of kitchen drains connected.

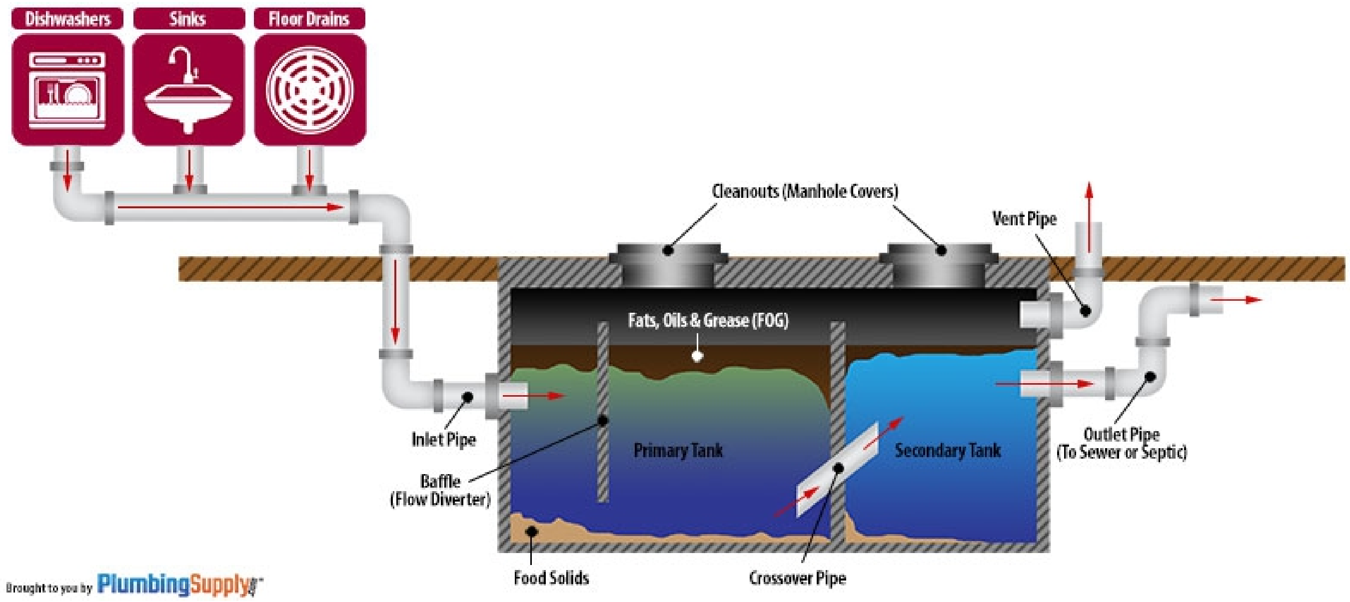


Fig6. Working of Gravity grease interceptor

Proper Maintenance and The 25% Rule:-

Many California sewering agencies require that GGIs be cleaned (pumped) out completely at a mandatory minimum frequency of once every 90 days to prevent the overaccumulation of floating FOG and settled solids. A complete pumpout means that all of the contents of the interceptor must be pumped out and no liquids can be returned to the interceptor unless specific permission has been granted in writing by the sewering agency for this practice. Some GGIs may need to be pumped out more frequently than once every 90 days if the floating FOG and settled solids accumulation exceeds 25% of the overall capacity of the interceptor prior to the 90 day period (i.e, the 25% Rule)

Fig7. Cleaning of Gravity grease interceptor

3.5 Automatic Grease Interceptor(AGI)

Automatic Grease Interceptors are designed to intercept and remove large quantities of fats, oils, and grease (FOG) discharged from food service facilities and large commercial/institutional kitchens. They are suitable for aboveground or vaulted underground installations. The larger volume, end-of-pipe AGI units are usually installed in the building's basement and service an entire facility's kitchen fixtures, including all floor drains.

Automatic systems, also known as AGRU's (automatic grease removal units), perform many of the same operations as a manual grease trap. Much like a manual system the flow of wastewater is slowed to allow it to cool and separate though automatic systems almost always feature the addition of a removable strainer basket for solids collection. This means the wastewater inside the unit willmainly contain FOG with only small amounts of solid waste escaping the strainer and settling at the bottom of the unit.

Fig8. Automatic Grease Interceptor

CHAPTER-4 MATERIAL SELECTION

4.1 Introduction

Material is a substance or mixture of substances that constitute an object. Materials can be pure or impure, living or non-living matter. Materials can be classified based on their physical and chemical properties, or their geological origin, or biological function. Materials science is the study of materials and their applications.

Raw materials can be processed in different ways to influence their properties, by purification, shaping, or the introduction of other materials. New materials can be produced from raw materials by synthesis. In industry, materials are inputs to manufacturing processes to produce products or more complex materials.

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Systematic selection of the best material for a given application begins with the properties and costs of candidate materials. Material selection is often benefited by the use of a material index or performance index relevant to the desired material properties. For example, a thermal blanket must have poor thermal conductivity to minimize heat transfer for a given temperature difference. A designer must have a thorough knowledge of the properties of the materials and their behavior under working conditions. Some of the important characteristics of materials are strength, durability, flexibility, weight, resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity, etc.

Systematic selection for applications requiring multiple criteria is more complex. For example, when the material should be both stiff and light, for a rod a combination of high Young's modulus and low density indicates the best material, whereas for a plate the *cube root* of stiffness divided by density is the best indicator since a plate's bending stiffness scales by its thickness cubed. Similarly, again considering both stiffness and lightness, for a rod that will be pulled in tension the specific modulus or modulus divided by density should be considered, whereas, for a beam that will be subject to bending, the material index is the best indicator. Reality often presents limitations, and the utilitarian factor must be taken into consideration. The cost of the ideal material, depending on the shape, size, and composition, may be prohibitive, and the demand, the commonality of frequently utilized and known items, its characteristics, and even the region of the market dictate its availability.

4.2 fibre-Reinforced Plastic

The type of fibre used for the manufacturing of the prototype is 450GSM fibre which is also 450E chopped standard fibre. The general purpose resin that is used to bind the fibre parts together and MEKP(methyl ethyl ketone peroxide) is added 2% in a mixture of general-purpose resin + accelerator. The Fibre to resin ratio is 1:2.

The fibre that is used for the manufacturing of the prototype is Glass-reinforced plastic. Glass-reinforced plastic (GRP) is a composite material or fibre-reinforced plastic made of plastic reinforced by fine glass fibres. Like graphite-reinforced plastic, the composite material is commonly referred to as fibreglass. The glass can be in the form of a chopped strand mat or a woven fabric.

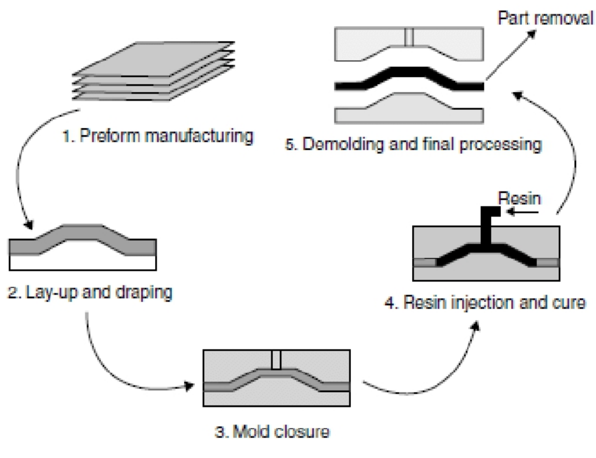


Fig9. FRP modelling Process cycle

As with many other composite materials (such as reinforced concrete), the two materials act together, each overcoming the deficits of the other. Whereas the plastic resins are strong in compressive loading and relatively weak in tensile strength, the glass fibres are very strong in tension but tend not to resist compression.

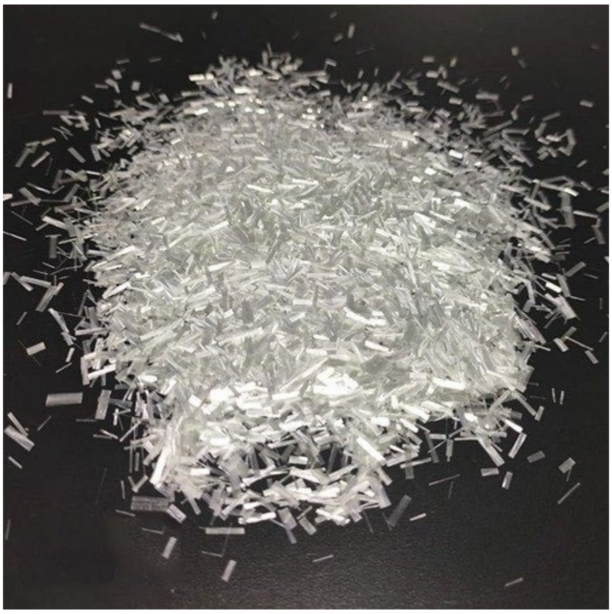


Fig10. Glass fibre

By combining the two materials, GRP becomes a material that resists both compressive and tensile forces well. The two materials may be used uniformly or the glass may be specifically placed in those portions of the structure that will experience tensile loads.

Uses

Uses for regular glass fibre include mats and fabrics for thermal insulation, electrical insulation, sound insulation, high-strength fabrics, or heat- and corrosion-resistant fabrics. It is also used to reinforce various materials, such as tent poles, pole vault poles, arrows, bows and crossbows, translucent roofing panels, automobile bodies, hockey sticks, surfboards, boat hulls, and paper honeycomb. It has been used for medical purposes in casts. Glass fibre is extensively used for making FRP tanks and vessels.

Open-weave glass fibre grids are used to reinforce asphalt pavement. Non-woven glass fibre/polymer blend mats are used saturated with asphalt emulsion and overlaid with asphalt, producing a waterproof, crack-resistant membrane. The use of glass-fibre reinforced polymer rebar instead of steel rebar shows promise in areas where avoidance of steel corrosion is desired.

Glass fibre use has recently seen use in biomedical applications in the assistance of joint replacement where the electric field orientation of short phosphate glass fibres can improve osteogenic qualities through the proliferation of osteoblasts and with improved surface chemistry. Another potential use is within electronic applications as sodium-based glass fibres assist or replace lithium in lithium-ion batteries due to their improved electronic properties.

Manufacturing processes

There are two main types of glass fibre manufacture and two main types of glass fibre products. First, fibre is made either from a direct melt process or a marble remelt process. Both start with the raw materials in solid form. The materials are mixed and melted in a furnace. Then, for the marbling process, the molten material is sheared and rolled into marbles which are cooled and packaged. The marbles are taken to the fibre manufacturing facility where they are inserted into a can and remelted. The molten glass is extruded to the bushing to be formed into a fibre. In the direct melt process, the molten glass in the furnace goes directly to the bushing for formation.

4.3 Composition of Fibre-Reinforced Plastic

Methyl Ethyl Ketone Peroxide

Methyl ethyl ketone peroxide is an organic peroxide, a high explosive similar to acetone peroxide. MEKP is a colorless, oily liquid whereas acetone peroxide is a white powder at STP; MEKP is slightly less sensitive to shock and temperature, and more stable in storage.

Fig11. Methyl Ethyl Ketone Peroxide

MEKP (Methyl Ethyl Ketone Peroxide) is the catalyst added to polyester resins and vinyl ester resins. As the catalyst mixes with the resin, a chemical reaction occurs, creating heat that cures (hardens) the resin. Use approximately 1/2 oz per quart of resin.

General Purpose Resin

Fig12. General Purpose Resin

1. Usage:

The general purpose polyester resins perform best if the laminate is completely post cured. The quantity of catalyst and accelerator can be adjusted to get a shorter or longer gel time. The accelerator must be completely mixed before the catalyst is added to avoid a direct blending which may cause an explosion.

The general purpose polyester resin is a quick curing unsaturated polyester resin based on Orthophthalic raw material for laminating purposes. It is un-accelerated. Suitable for both hand layup and gun spray-up. The resin offers excellent mechanical properties, impact, and water resistance.

2.Post Curing:

It is recommended to mature the products for 24 hours and post-curing should be done for at least three hours at 800C or 2-3 weeks at room temperature. This is essential for getting the optimum properties.

3.Storage / Handling:

The polyester resin remains stable for 3 months at 300C in the dark and 4 months at 250C. The resin stability deteriorates markedly at elevated temperatures, especially when exposed to direct sunlight. Espanol 12.00 has a flashpoint of 340C and is classified as flammable. "NO SMOKING" rules should be strictly followed. In case of spillage, use sand or earth to absorb and shovel off for disposal as per local regulations, In case of fire, use dry chemical foam, Carbon dioxide, or water spray to extinguish the flame.

4.Packing:

The Polyester resin is packed in HDPE carboys (30, 35, 40 & 45 kgs) and epoxy coated steel drums HDPE barrels (220 kgs) of standard size net weight. Special packing size offered for projects on returnable containers. Technical services are also provided to compliance standards.

5.Health & Safety:

Never add metal salts (Accelerator) or Pre Acceleratorated resin to Peroxides when adding peroxides to a resin solution, mix thoroughly the resulting product Do not add organic peroxides to a hot diluent or process. Prevent contamination of Accelerator, the promoter from materials like (Iron Copper, Cobalt) salts, storing acids and sanding bags of dust. Suggested containers are glass, polypropylene, Teflon, Poly-ethylene, or stainless steel to prevent contamination of material during its handling.

Accelerator

An accelerator is added to the catalyzed resin to enable the reaction to proceed at workshop temperature and/or at a greater rate. Since accelerators have little influence on the resin in the absence of a catalyst they are sometimes added to the resin by the polyester manufacturer to create a ‘pre accelerated resin.

Cobalt is used to accelerate the curing of unsaturated polyester resins and may be used on its own or in conjunction with other metals like Potassium, Sodium, and Copper to obtain optimal results. COMACC Cobalt accelerators can be supplied at various concentrations and solvents according to customers needs

4.4 Stainless Steel

Stainless steel is a generic term referring to a variety of steel types. Like all other kinds of steel, stainless steel is made primarily from iron and carbon in a two-step process. What makes stainless steel different is the addition of chromium (Cr) and other alloying elements such as nickel (Ni) to create a corrosion-resistant product.

Steel corrodes because iron, the metal used to make steel, occurs in nature in combination with other elements. When iron ore is artificially manipulated into a pure form to make steel, it becomes unstable and will readily recombine with oxygen.

When chromium is added to steel, it forms chromium oxide, which acts as a protective surface to prevent air and moisture from causing rust, as happens with ordinary steel. Chromium is added in quantities ranging from 10.5 to 30%, depending on the application or environment in which the steel is to be used. There are more than 100 different grades of stainless steel but they can be grouped into five major types:

Austenitic is the most widely used type of stainless steel. It has excellent corrosion and heat resistance with good mechanical properties over a wide range of temperatures. Austenitic steel is used in housewares, industrial piping and vessels, construction, and architectural facades.

Stainless character

Corrosion resistance is the main advantage of stainless steel, but it certainly isn't the only one. Stainless steel is also:

1.High and low-temperature resistant
2.Easily fabricated
3.Strong and durable
4.Easy cleaned and maintained
5.Long-lasting, with a low lifecycle cost
6.Aesthetically attractive
7.Environmentally friendly and recyclable.

In addition to chromium, stainless steels are made with alloys of silicon, nickel, carbon, nitrogen, and manganese. Nitrogen, for example, improves tensile properties like ductility. Nickel is added to austenitic steel to improve flexibility. These alloys are added in varying amounts and combinations to meet specific end-use applications, which is why stainless steel manufacturers need to verify that the correct percentages of each alloy are being used. Two technologies provide the elemental analysis needed to produce high-quality stainless steel: X-Ray Fluorescence (XRF) and Optical Emission Spectroscopy (OES).

OES is a robust, reliable, and widely-used technology for the analysis of metals and alloys in the lab. Compared with traditional combustion analyzers, OES provides faster elemental analysis with high precision and accuracy in iron and steel, aluminum, copper, magnesium, precious metals, and other specialty metals/alloys. OES has demonstrated its capability to provide more efficient control of steel production by providing accurate sample analysis during the manufacturing process.

4.5 Composition of Stainless Steel

SAE 304 stainless steel is the most common stainless steel. The steel contains both chromium (between 18% and 20%) and nickel (between 8% and 10.5%) metals as the main non-iron constituents. It is an austenitic stainless steel. It is less electrically and thermally conductive than carbon steel and is essentially-magnetic but less magnetic than steel. It has a higher corrosion resistance than regular steel and is widely used because of the ease in which it is formed into various shapes.

Chemical Composition

Type 304 stainless steel chemical composition, in %

Standard	AISI (UNS)	C, ≤	Si, ≤	Mn, ≤	P, ≤	S, ≤	Cr	Ni
ASTM A276/A276M	304 (S30400)	0.08	1.00	2.00	0.045	0.030	18-20	8-11

Table 4.5.1 Chemical composition of stainless steel

4.6 Properties of Stainless Steel 304

Mechanical Properties of Stainless Steel 304

Table 4.6.1. Mechanical properties for 304 stainless steel alloys - sheet up to 8 mm thick

Grade	304	304L	304H
Tensile strength(MPa)	540-570	520-700	-
Proof Stress(MPa)	230min	220min	-
Elongation A50mm	45Min%	45Min%	-

Table 4.6.2. Mechanical properties for 304 stainless steel alloys - plate from 8 - 75 mm thick

Grade	304	304L	304H
Tensile strength(MPa)	520-720	500-700	-
Proof Stress(MPa)	220min	200min	-
Elongation A50mm	45Min%	45Min%	-

Table 4.6.3. Mechanical properties for 304 stainless steel alloys - bar and section up to 160 mm diameter / thickness

Grade	304	304L	304H
Tensile strength(MPa)	540-570	520-700	-
Proof Stress(MPa)	230min	220min	-
Elongation A50mm	45Min%	45Min%	-
Hardness Brinell	215 Max HB	215 Max HB	-

Physical Properties of Stainless Steel 304

Table 4.6.4. Physical properties for 304 stainless steel alloys

Property	Value
Density	8.00 g/cm^3
Melting Point	1450 °C
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.72 x 10^{-6} Ω.m
Thermal Conductivity	16.2 W/m.K
Thermal Expansion	17.2 x 10^{-6}/K

Alloy Designations

Stainless steel 304 also corresponds to the following standard designations and specifications:

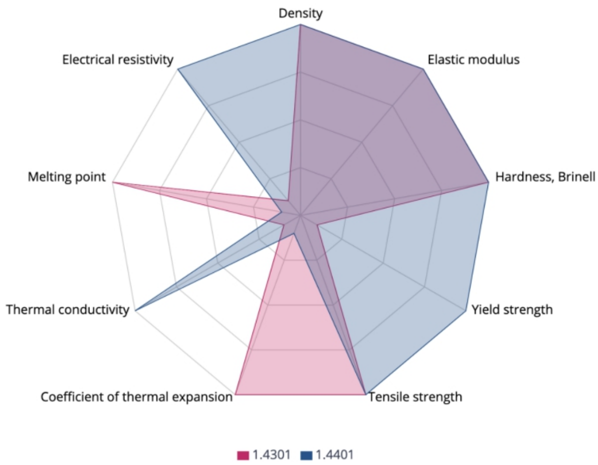


Fig13. Combined Diagram of Stainless Steel Properties

Heat Resistance

Maximum service temperature in air

- Intermittent service temperature: 870 °C
- Continuous service temperature: 925 °C

Sensitization occurs when type 304 austenitic stainless steel is heated between 425 and 815 °C. Carbon and chromium combine to form chromium carbide, which precipitates at the crystal boundary, so the Cr content near the grain boundary is greatly reduced, and becomes a Cr-depleted region. Therefore, its corrosion resistance is lowered.

In order to prevent sensitization, the following methods can be used for AISI 304 stainless steel:

- Rapidly passing the sensitized temperature range 425-815°C, thus Cr does not have enough time to combine with C, and it is impossible to precipitate chromium carbide.
- The sensitized stainless steel is reheated to a temperature 1040-1065°C sufficient to decompose the chromium carbide, and then rapidly cooled to make the chromium carbide less likely to precipitate.
- Use ultra-low carbon austenitic stainless steels 304L can reduce the formation of chromium carbide and reduce the probability of chromium-depleted envelope.

Machining

Type 304 stainless steel is more difficult to machine than carbon steel and low alloy steel because of its higher strength and higher work hardening rate. Therefore, more power and lower processing speed are required, resulting in shortened tool life and difficulty in obtaining a smooth surface.

Welding

SS 304 stainless steel has excellent welding performance and does not require preheating, but requires similar filler material composition but high alloy content. Ensure that the weld contains 5-10% ferrite during welding to avoid cracking of the weld. Reduce the carbon content, such as using 304L, stabilized stainless, or adding niobium Nb, to avoid weld corrosion. 304 may require subsequent reannealing after soldering or heat treatment to achieve optimum corrosion resistance, softness and ductility. Because intergranular corrosive chromium carbide is dissolved during the annealing process. Postweld heat treatment: 949-1149 °C if undertaken, or stress relieve below 649 °C to avoid weld corrosion.

Corrosion Resistance

The reason why AISI 304 grade stainless steel has excellent corrosion resistance in the atmosphere is due to the formation of a chromium passivation film on its surface. But when SS304 is in a warm chloride environment, the corrosion is even faster than non-alloy mild steel. Below is the application range of stainless steel in chloride ion medium for reference.

Applications

AISI 304 stainless steel is widely used in petroleum & chemical industry, metallurgical machinery, aerospace industry, food processing equipment, instruments, household appliances and hardware manufacturing industries.

SS304 material is made into a great many intermediate products such as steel sheet & plate, steel tube & pipe, steel bar & flat, rod & wire, etc.

Final products such as all kinds of kitchen ware, tableware, medical device, machinery and parts, wire mesh, filters, architectural and decorative products, etc.

CHAPTER-5 NEEDS FOR MAINTAINANCE

5.1 Introduction

Restaurant owners and operators are responsible for properly maintaining their outdoor underground grease interceptors. A reputable Grease Hauler can help with maintenance by recommending an appropriate cleaning schedule and notifying you of any mechanical problems with the grease interceptor.

The Fats, Oils, Greases & Grease Haulers are present in the grease haulers. Grease haulers pump out the contents of grease removal devices and dispose of the grease at sewage treatment facilities. Unfortunately, many grease hauling companies have been caught illegally dumping grease from their clients' grease removal devices into sewer manholes or storm drains.

To Protect Your Business of the food processing and food preparations and food services. Food service facilities will be held responsible when grease from their facilities is improperly handled, and can face large fines as a result. To protect your business and the environment you should closely monitor the activities of the grease hauling companies you hire to be certain that they are acting responsibly.

It is recommended that an employee be assigned to supervise the grease hauler. Ask questions about how the hauler handles the grease waste from your facility. Very low prices for grease pumping and hauling services may be an indication that the hauler is not properly disposing of the grease. It is also important that grease removal devices be cleaned out often.

Proper disposal of used cooking grease is required by law. When retail food establishments disregard sewer use regulations and improperly dispose of grease, fat or oil, sewer lines can become clogged and sewage can back up into homes and businesses, or flows into the storm drain system where it can reach the ocean and cause significant health and environmental problems. When that happens, the entire community suffers.

Sewer problems can also affect public health. In some areas, backups are frequently caused by grease clogging the local sewers. Use a trash can for food scraps. Solid waste can accommodate 20 percent liquid so even your gravies and other oily sauces can be sent to the dumpster. Handle solid waste wisely for health safety: secure trash bags, dump daily, and keep the dumpster lid secured.

Posting "No Grease" signs will remind your employees not to pour used cooking grease, hood-vent grease, or any other used fats and oils down the sink drain. Contrary to popular belief, adding hot water, detergent, or even commercial degreasers does not liquefy the grease long enough to escape your drains. Posting signs will remind employees to use the recycle container.

5.2 Selection of Grease Haulers

The selection process should include the requirements and other important aspects also

1. Receive the service you paid for
2. Ensure grease is properly managed
3. Avoid illegal dumping and under bidding
4. Reduce the chance of experiencing a sewer overflow
5. Avoid sewer and stormwater fines or penalties

Services that should be included

1. Complete removal of grease layer, settled solids and wastewater. Do not accept skimming the top layer of grease only, as debris also collects at the bottom of the interceptor.
2. A thorough cleaning, including removing baffle and lid if possible, scraping the sides, lid and baffles to remove as much of the grease as possible and replacing the baffle and lid.
3. Proper disposal of grease waste and water at an approved location.
4. A contract which states disposal will comply with all federal, state and local laws and regulations.
5. A receipt with the date and volume removed.

Tips

Ask the hauler/pumper to describe their pumping process. Compare costs of service, availability and scheduling. The cost of hauling is charged per gallon of waste and costs will vary so check with different companies. Ask other restaurants for their opinions and experiences with Grease Haulers/Recyclers. When possible, witness/observe all activities performed by the Grease Hauler. If the Grease Hauler does not provide adequate answers to your questions, you may want to consider interviewing additional Grease Haulers. Enforcement actions against waste haulers for improperly disposing of waste do occur and many times restaurant owners pay for improper pumping and disposal.

5.3 Best Management Practices

Proper grease interceptor maintenance is necessary to prevent sewer line interference, blockages, and sanitary sewer overows.

Fig14. Clogged Sewage Pipe Due to the heavy oil.

1. Maintain grease interceptor in accordance with the 25% rule.
2. Recycle waste cooking oil. Do NOT pour down sinks or any drains. Do NOT pour into any storm grates or onto the ground.

3. “Dry wipe” and scrape all pots, pans, and plates into a trash container to remove residual oil, grease, and food particles.

4. Use Strainers in sink drains and floor drains.Periodically empty contents into trash container.

5. Post “No Grease” signs above sinks.

6. Educate and train employees on grease control.

7. If an oil or grease spill occurs: Clean up using a dry, oil-absorbing material or use ice. Do NOT wash into drains.

8. Food grinder use is discouraged due to build up of solids.

9. Keep records of interceptor pumpings or cleanings.

Fig15. Over Flow of the Sewage system

Fig16. Clogged Manhole of the Sewage system

5.4 Required Grease Interceptor Maintenance

The 25% Rule of the Grease control device must be cleaned before volume of floating grease and settled solids reaches more than 25% of tank volume.

1. Clean or pump complete contents of interceptor at a minimum of every 90 days. Some facilities may need to clean monthly or every two months to prevent exceeding 25% of capacity of interceptor with grease and food solids. Check with your grease waste hauler to determine if your interceptor pump frequency needs to be 30, 60, or 90 days.
2. Make sure that complete contents of interceptor are pumped. No partial pumping (grease layer only) is allowed. Contact your grease waste hauler to make sure complete contents are pumped.
3. Keep records on site of interceptor pumping or cleaning for inspectors. Pump records must include date pumped, volume pumped, and grease waste hauler ID information.

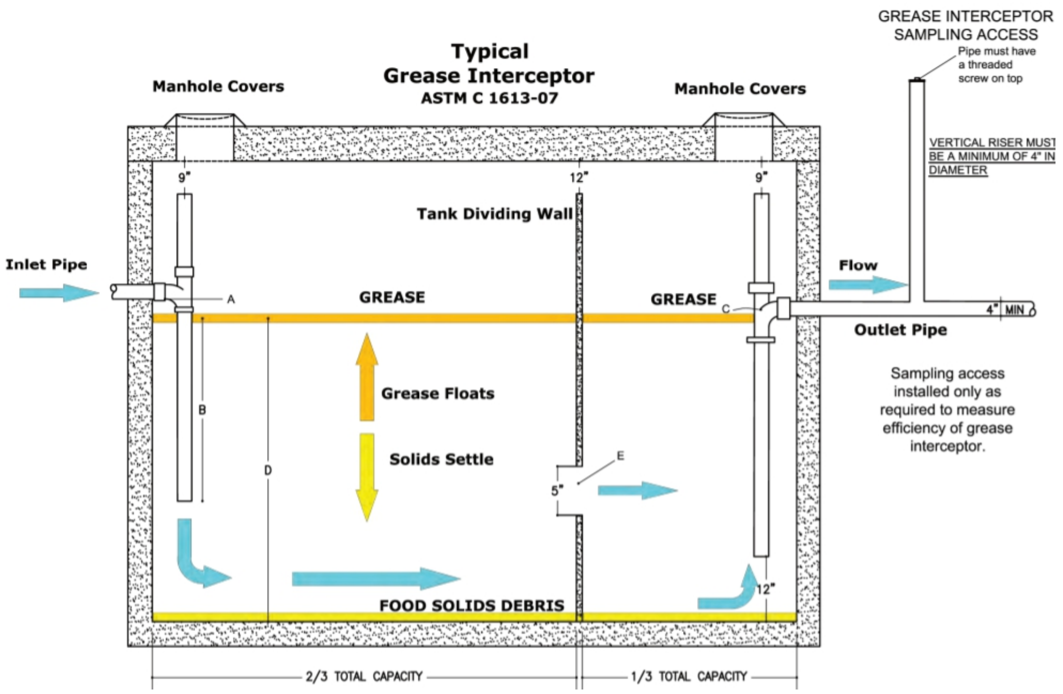


Fig17. Typical layout of the Grease interceptor to define waste materials

4. Correct any deficiencies, especially missing outlet T or deterioration of the interceptor.
5. Do NOT dump any oils or grease into floor drains, kitchen sink drains, mop sinks, sanitary sewer connections, or storm water grates. Properly dispose of oils and grease in recycle bins or containers.
6. Review the Best Management Practices (BMPs) located on the back of this brochure with all employees.

CHAPTER-6 PROTOTYPE DESIGN

6.1 Introduction

The designing of the grease interceptor has been done in the solidworks software. The measurements of the grease interceptor have been taken through the standard values and then they have been customized according to the requirement. In the very first stage of the designing process the capacity has be taken to be 10gpm(gallon per minute), which is very large in the household purposes as the bearing capacity of the heat exchanger is 60litres. So, the dimensions are being calculated according to the volume required so that the grease interceptor will be compatible to use. A grease trap is a plumbing device designed to intercept most greases and solids before they enter a wastewater disposal system. Common wastewater contains small amounts of oils which enter into septic tanks and treatment facilities to form a floating scum layer.

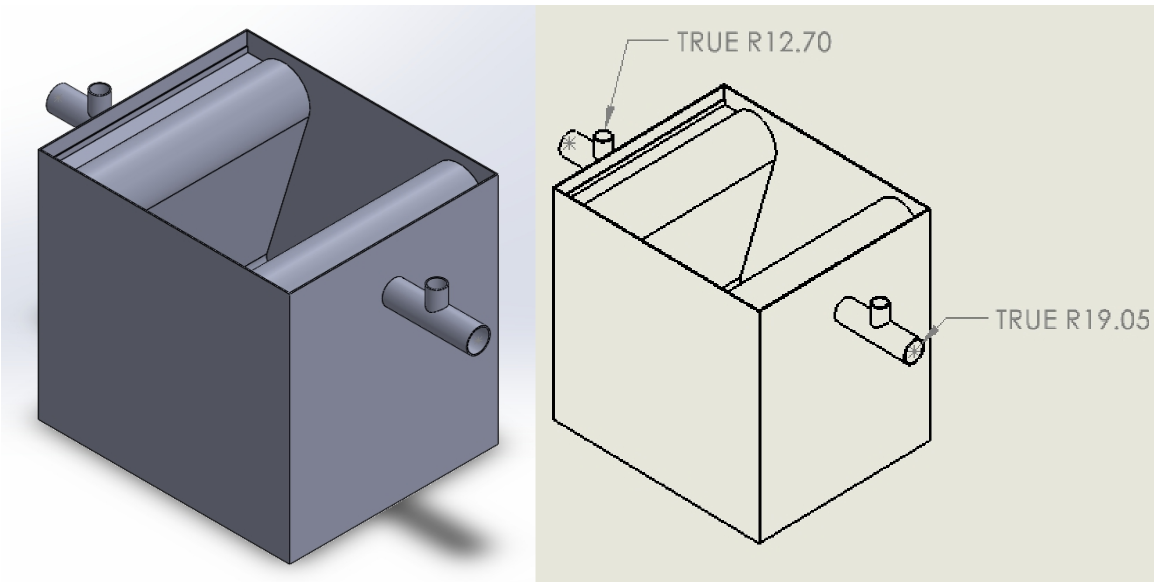


Fig18. Isometric views of the Grease interceptor

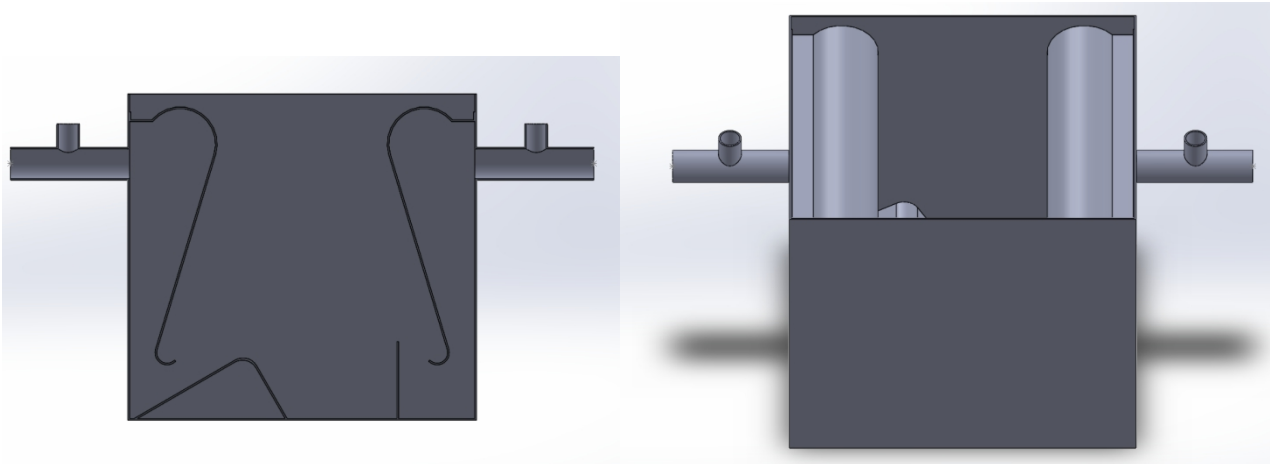


Fig19. Section view of the Grease interceptor

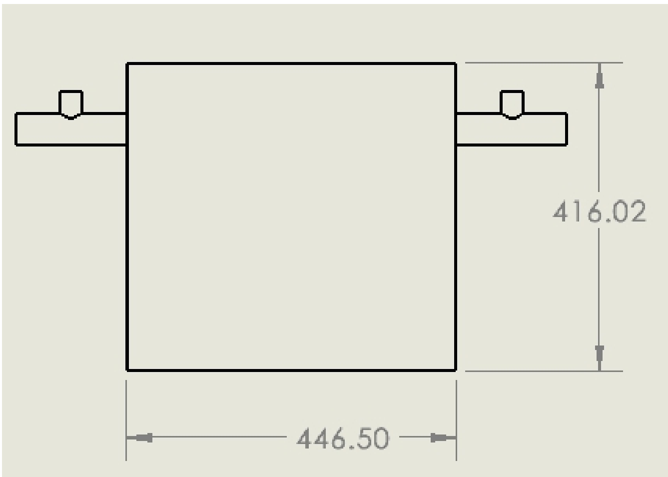


Fig20. Dimensions of the Grease Interceptor

6.2 Software Description

6.2.1 Introduction

Mechanical engineering software is a collection of programs, processes and information that allows engineers to calculate, model, and depict multifaceted engineering problems and to save calculations for future use. There are two main functions of mechanical engineering software – calculation management and design. Mechanical engineers design power-producing machines, such as electric generators, internal combustion engines, and steam and gas turbines, as well as power-using machines, such as refrigeration and air-conditioning systems. Mechanical engineers design other machines inside buildings, such as elevators and escalators.

The most used mechanical software are

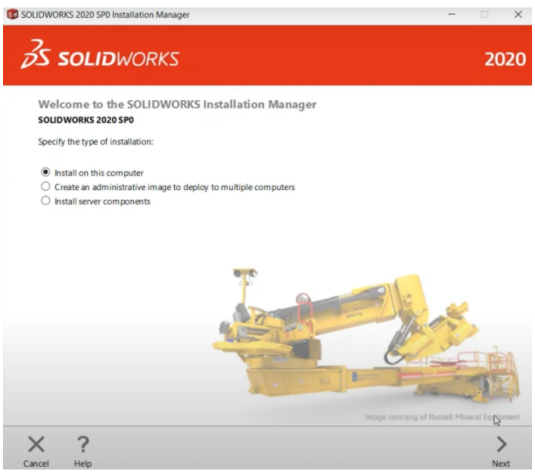
1. AutoCAD
2. Catia V5
3. Solidworks
4. NX CAD
5. Pro-E
6. Ansys and so on

6.2.2 DS Solidworks

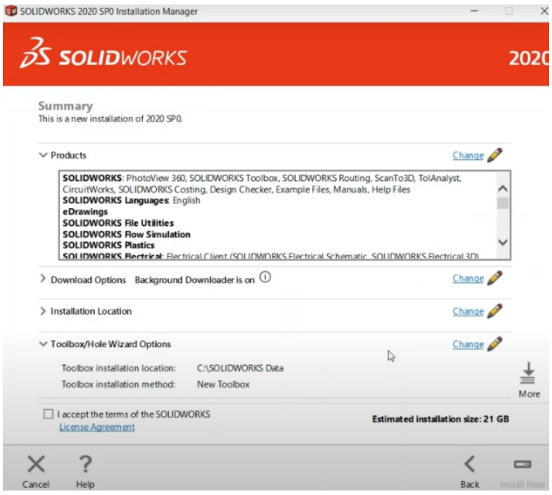
Solidworks was developed by MIT graduate Jon Hirschtick and was bought by Dassault Systems in 1997. The software now encompasses a number of programs that can be used for both 2D and 3D design. Solidworks is used to develop mechatronics systems from beginning to end. The solidworks software solutions are used by mechanical, electrical, and electronics engineers to form a connected design. The suite of programs is aimed at keeping all engineers in communication and able to respond to design needs or changes. Solidworks continues to adapt their solutions to include new capabilities based on the feedback of users. Solidworks 2020 features a number of enhancements, such as improved performance, streamlined workflows, and 3DExperience, a cloud-based platform.

Installation:

1.Download SolidWorks from **https://www.solidworks.com/sw/support/downloads.htm**



2. Run Solidworks installation manager.



3. Propulate the serial number and select the required modules.

4. During installation, basic features of the products are presented in the Install window. See image below for the details.

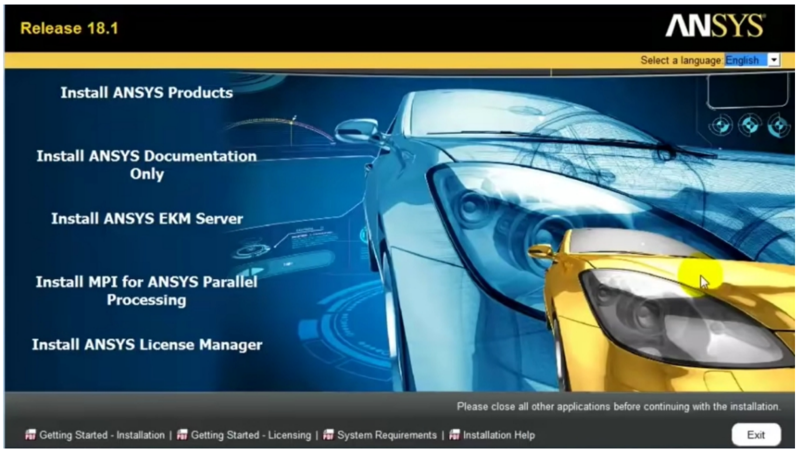
6.2.3 Ansys

Ansys software develops and markets multiphysics engineering simulation software for product design, testing and operation and offers its products and services to customers worldwide. It is an American based company. Ansys was found in 1970 by john Swanson. Swanson sold his company interest in the company to venture capitalists in 1993. This software is mainly used for the analysis and the simulation purposes to know whether the given geometry or the structure works as per the required conditions.

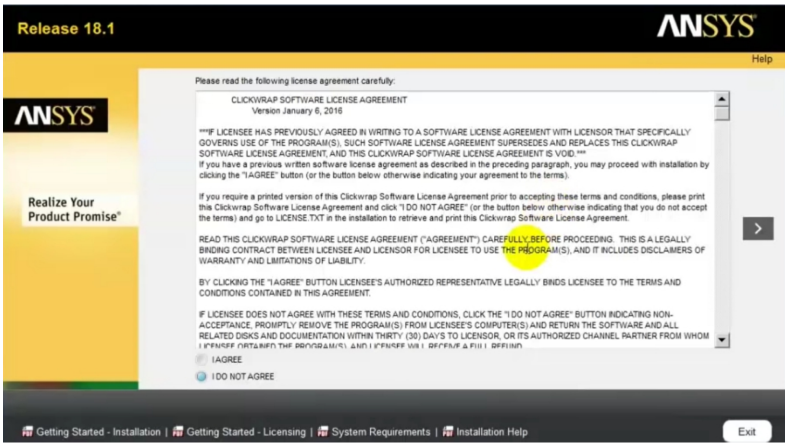
Installation:

1. Extract the zipped file.

2. Run the setup as the administrate.



3. Read and accept the terms.



4. Install the software and license file required.

6.3 Creation of Fluid Domains

The grease interceptor design is done in the solidworks design module itself and has been saved in .stp format(step format). Then the step file is imported to fluent solver of ansys workbench and the fluid enclosures are been created using design modular of ansys. The fluid domains are created by formation of surfaces and the fill command in the ansys workbench.

The volume can also be calculated with the help of the design modular in ansys software. The inlet and the outlets of the grease interceptor are as mentioned below.

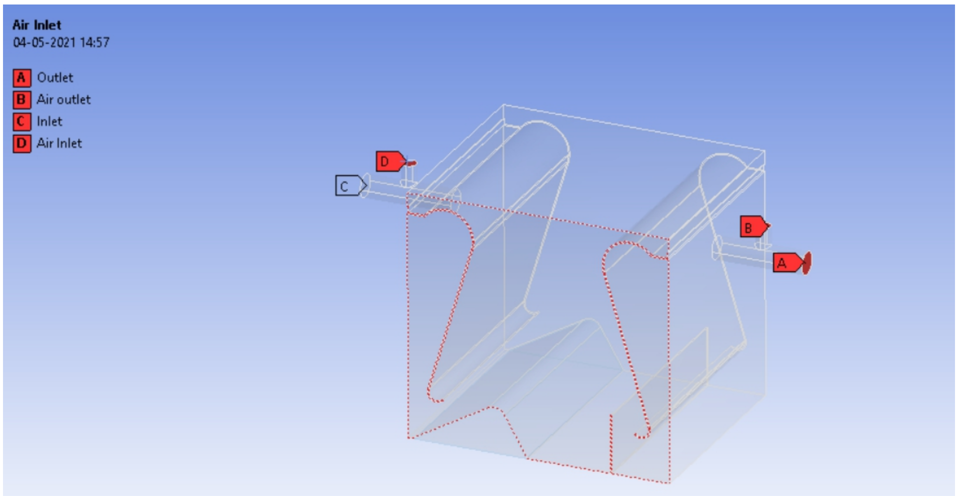


Fig21.Fluid Domains of Grease interceptor

6.4 Design Procedure

The design procedure of the final prototype has been done by considering the previous calculations and the FRP prototype. The steps of the first designed model are as follows

- Step 1 – Open solidworks software and select part design.
- Step 2 – Select Top plane.
- Step 3 – Draw a rectangle with base dimensions using rectangle tool and by the help of smart dimensions give the rectangle the dimensions of 446.50 x 370.30mm and extrude it to height of 416.02mm using Extruded Boss/ Base feature.

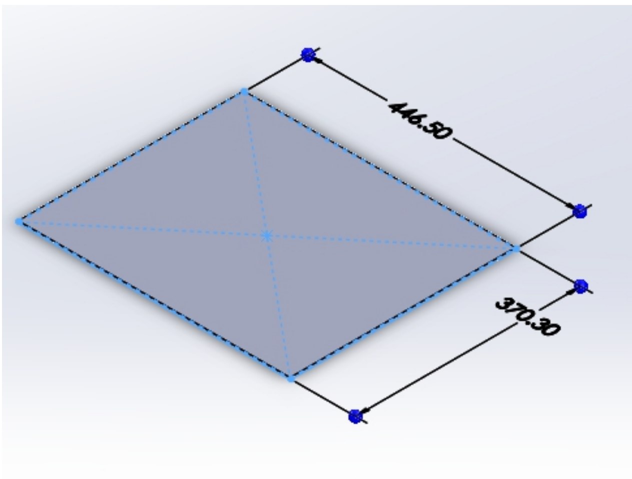


Fig22. Base plate Design

- Step 4 – Using shell operation create a shell by selecting the top face with a clearance dimension 2 mm wall thickness.

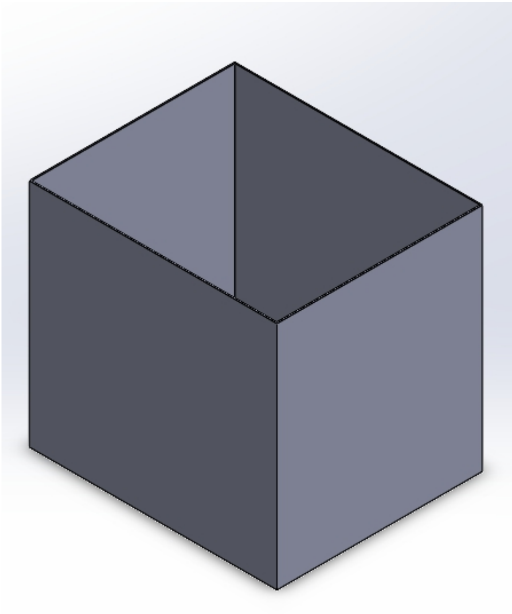


Fig23. Creation of Tank

- Step 5 – Add the weldments as per required diameter on both sides using weldments tool.

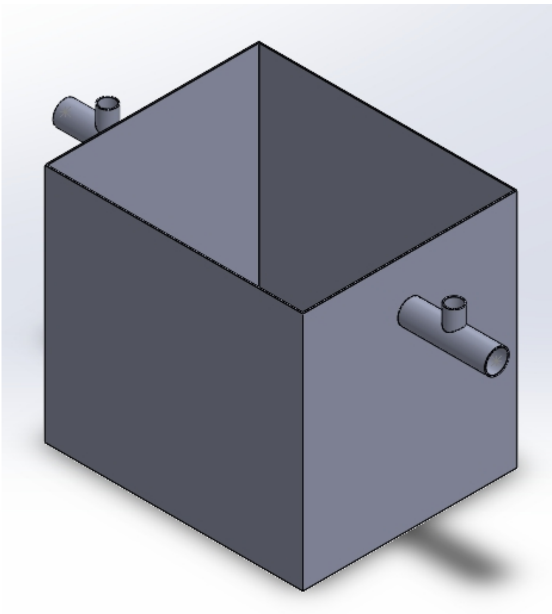


Fig24. Creation of Weldments

- Step 6 – Draw the profiles of the vanes and guiding elements on the front plane.
- Step 7 – Using Extrude Boss/ Base feature, extrude the vanes and other guiding elements.

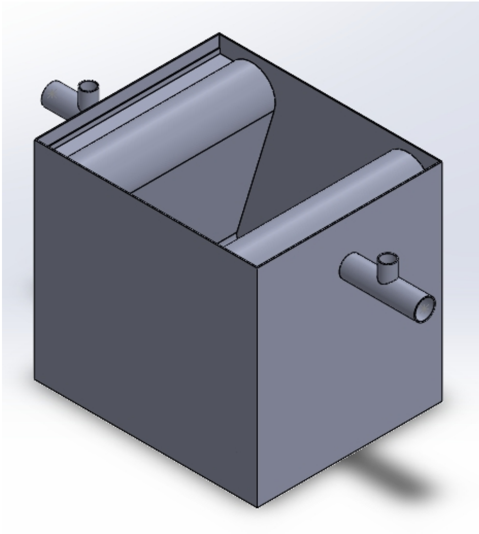


Fig25. Creation of Guide Bladed and Guide Vanes

6.5 Design for Prototype using FRP

Before the manufacturing of the actual prototype, the model has been created using Fibre Reinforced Plastic. To check the performance and the efficiency of the grease interceptor. This prototype has been manufactured with the dimensions considered after calculation of the initial design made in solidworks software. The reduction of the dimensions to the initial dimensions are done because of the initial bearing capacity I.e., 60litres. The efficiency and the performance remains same as there is no change in the length. As the materials selection has already been discussed before the joining of the FRP Sheets are done with the help of the resin and the matrix. Also the accelerator is added to the matrixs and resin mixture to make the hardening process faster.

Methyl ethyl ketone peroxide is an organic peroxide, a high explosive similar to acetone peroxide. MEKP is a colorless, oily liquid whereas acetone peroxide is a white powder at STP, MEKP is slightly less sensitive to shock and temperature, and more stable in storage.

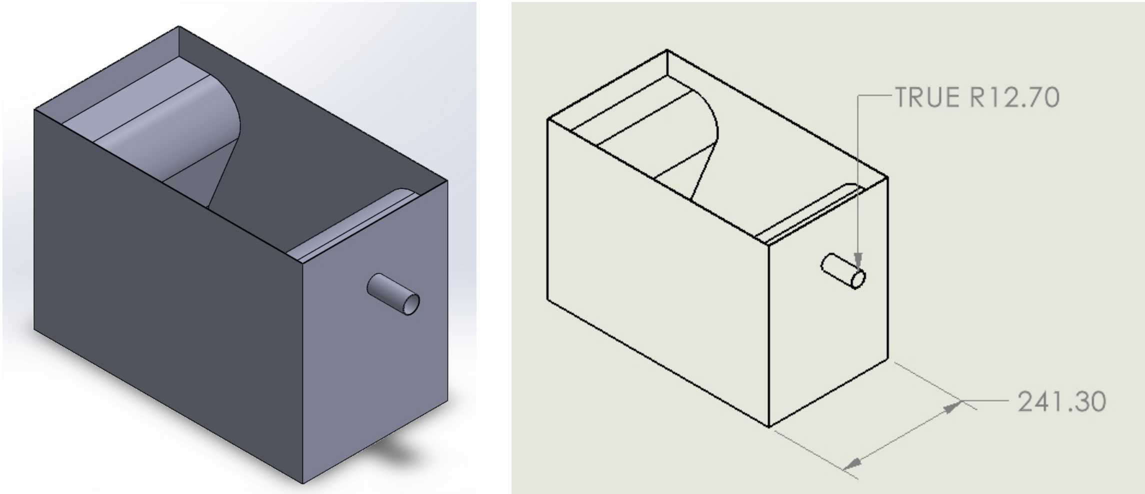


Fig26. Isometric Views of Design for FRP model

The general purpose polyester resin is a quick curing unsaturated polyester resin based on Orthophthalic raw material for laminating purpose. It is un-accelerated. Suitable for both hand lay up and gun spray up. The resin offers excellent mechanical properties, impact and water resistance.

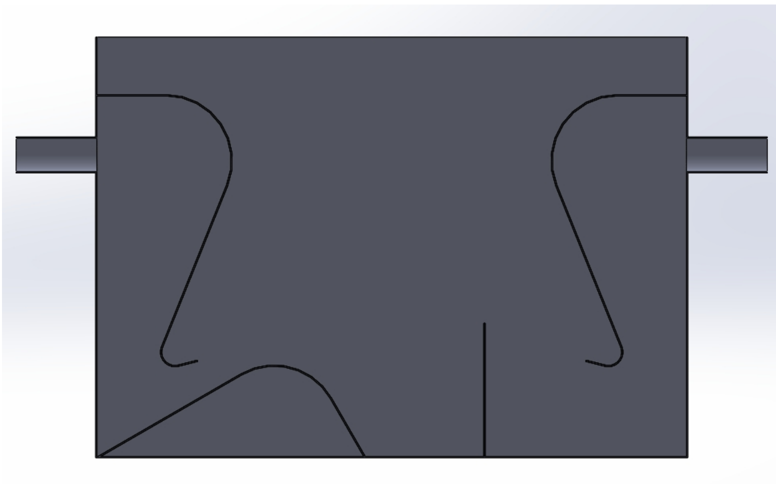


Fig27. Section view of design for FRP model

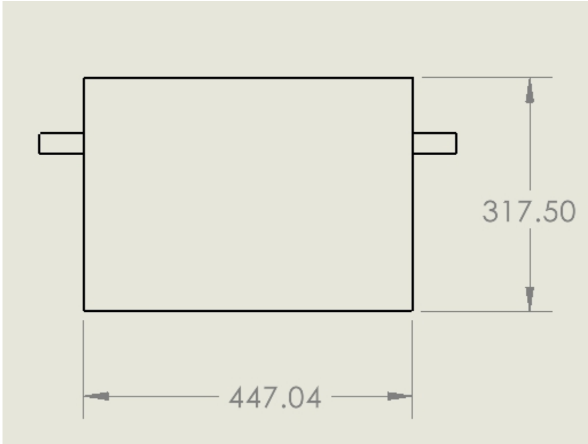


Fig28. Dimensions of design for FRP model

Cobalt is used to accelerate the curing of unsaturated polyester resins and may be used on its own or in conjunction with other metals like Potassium, Sodium and Copper to obtain optimal results. COMACC Cobalt accelerators can be supplied at various concentrations and solvents according to customers needs.

The width of the design has been reduced to 10inches in the FRP prototype. This reduction has been done on the design is to reduce the bearing capacity of the grease interceptor, the bearing capacity is known as the volume that can be maintained in the grease interceptor without any input fluid sent through the inlet of the grease interceptor. The bearing capacity of the grease interceptor that has be designed first is 60liters and the bearing capacity of the FRP prototype is 47litres.

Then the fluid domain of the design made for the FRP prototype has also followed the procedure of the initial design itself. The fluid domain has been created in the ansys design modular only. The Inlet is on the left of the grease interceptor and the outlet is on the right. At the inlet there is a guide vane that helps the fluid to movie toward the top of the grease interceptor.

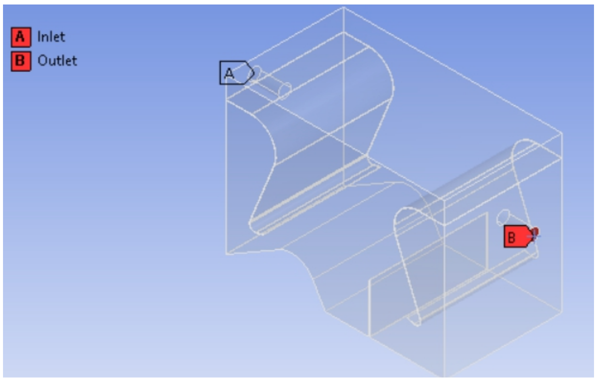


Fig29. Fluid Domain of FRP model

Then due to the reduction of the dimensions in the design, the bearing capacity of the FRP model is 47litres.

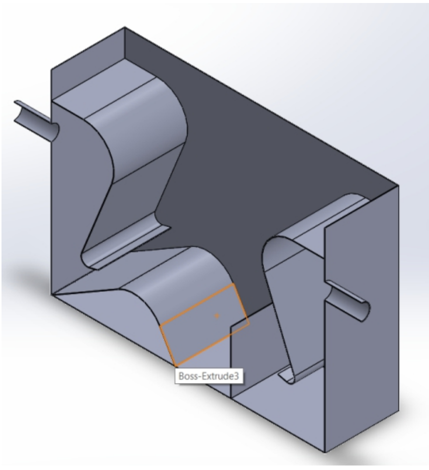


Fig30. Sectional Isometric View of FRP model

6.6 Design for Prototype using Stainless Steel

By considering the size and the capacity of the FRP model, to make it more compatible to use in the household purposes the width is further reduced. The efficiency and the performance are not effected by reducing the width of the grease interceptor. The bending of the guide blades and the guide vanes are are done as per the diagram given. And welding is done

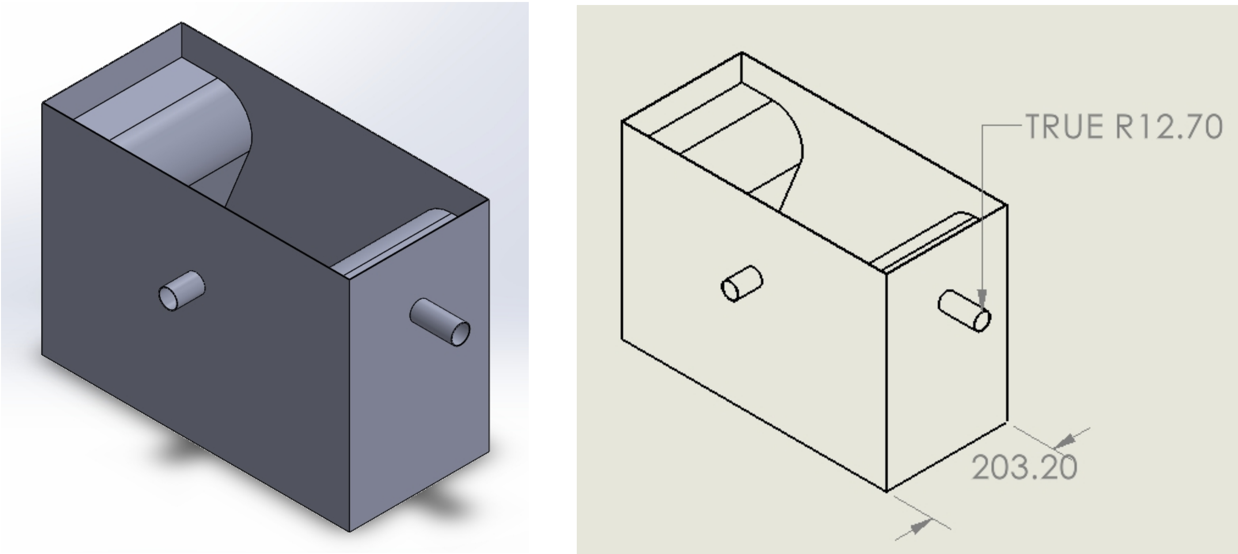


Fig31. Isometric view of the design for Stainless Steel model

across the each contact point of the edges of the guide blade and guide vanes. Then the other parts are been welded to it to form the vessel like structure.

Stainless Steel is a corrosion- resistant ally of iron, chromium and in some cases, nickel and other metals. Completely and infinitely recyclable, stainless steel is the “green material” par excellence. In fact, within the construction sector, its actual recovery rate is close to 100%. Stainless

Steel is also environmentally neutral and inert, and its longevity ensures to meets the needs of sustainable construction. Furthermore,it does not leach compounds that could modify its composition when it contact with elements like water.

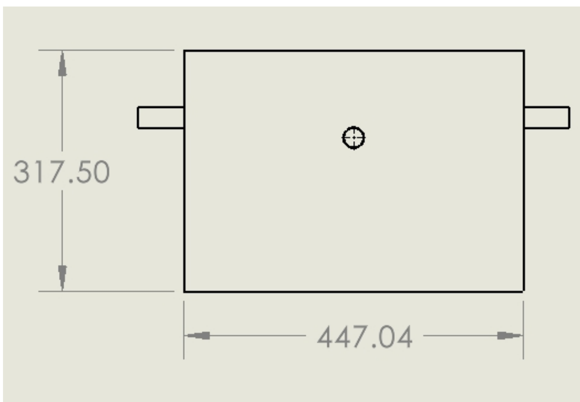


Fig32. Dimensions of the Stainless Steel model

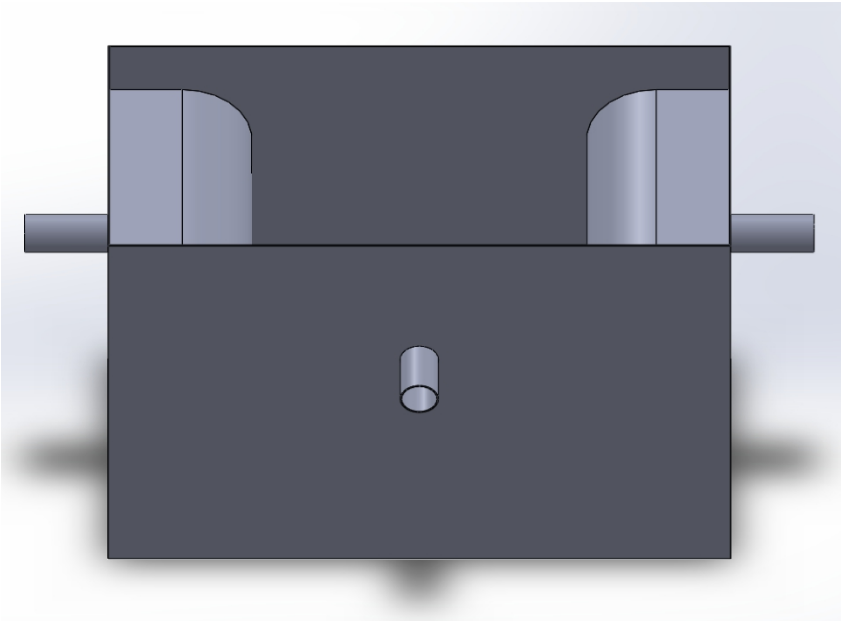


Fig33. Angular view of the Stainless Steel model

In addition to these environmental benefits, stainless steel is also aesthetically appealing, extremely hygienic, easy to maintain, highly durable and offers a wide variety of aspects. As a result, stainless steel can be found in many everyday objects. It also plays a prominent role in an array of industries, including energy, transportation, building, research, medicine, food and logistics.

Then the fluid domain of the design made for the Stainless Steel prototype has also followed the procedure of the initial design itself. The fluid domain has been created in the ansys design modular only. The Inlet is on the left of the grease interceptor and the outlet is on the right. At the inlet there is a guide vane that helps the fluid to movie toward the top of the grease interceptor.

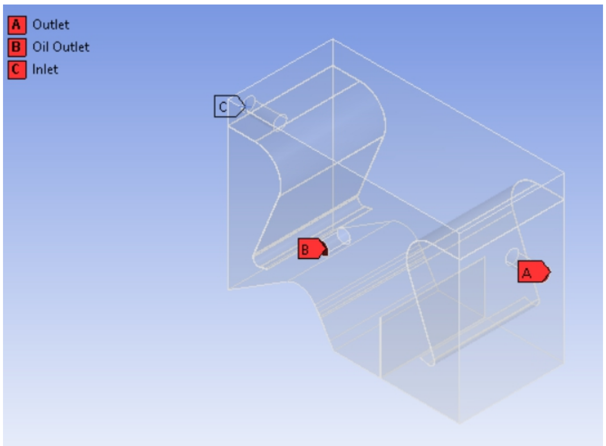


Fig34. Fluid Domain of Stainless Steel model

Then due to the reduction of the dimensions in the design, the bearing capacity of the, the bearing capacity of the Stainless Steel model is 35litres.

CHAPTER-7 CONCLUSION AND FUTURE ENHANCEMENT

7.1 Result

The design of the grease interceptor has been done for the Stainless steel is done in the solidworks software. But before concluding the design for the stainless steel prototype, the manufacturing of the FRP prototype. The design for the FRP prototype is done in such a way that the its bearing capacity is 47litres and the bearing capacity of the Stainless steel prototype is 35litres.

On the observation and experimentation, the grease interceptors work on the load which is more than that of the bearing capacity. Grease traps, also known as grease interceptors, grease arrestors, grease recovery devices and grease converters stop fat and oil residues from entering the waste water network. They provide a receptacle where more than 90% of FOG residues can be temporarily
stored.

Design for FRP Prototype

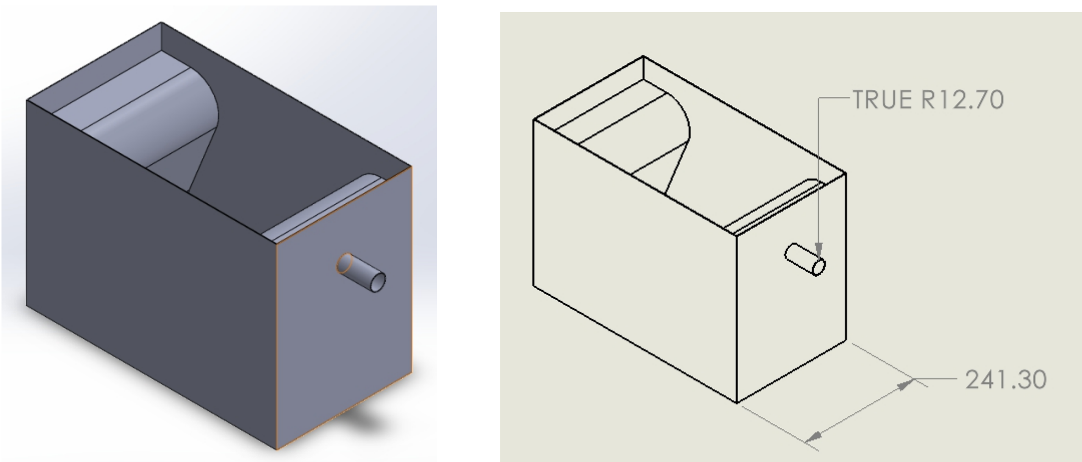


Fig35. Isometric view of Design done of FRP Model

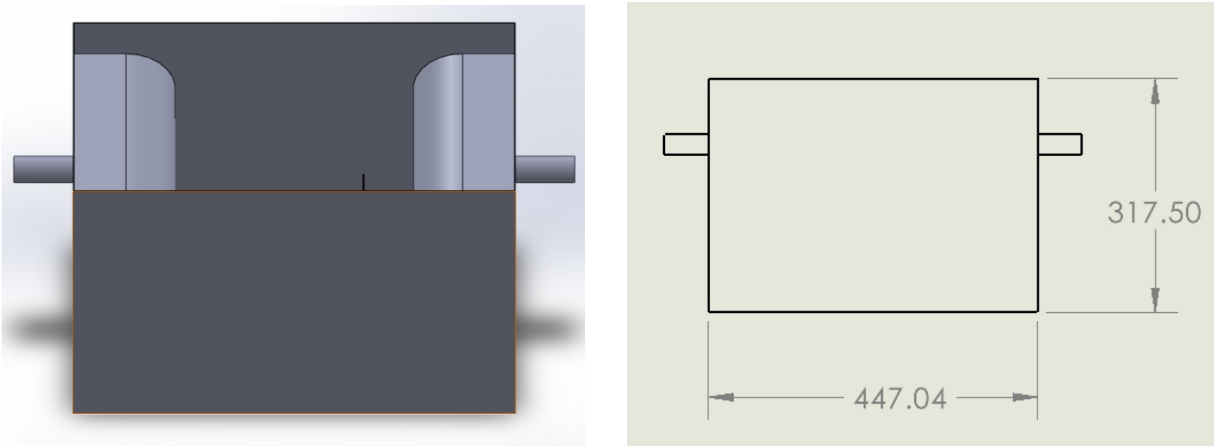


Fig36. Dimension of Design done for FRP model

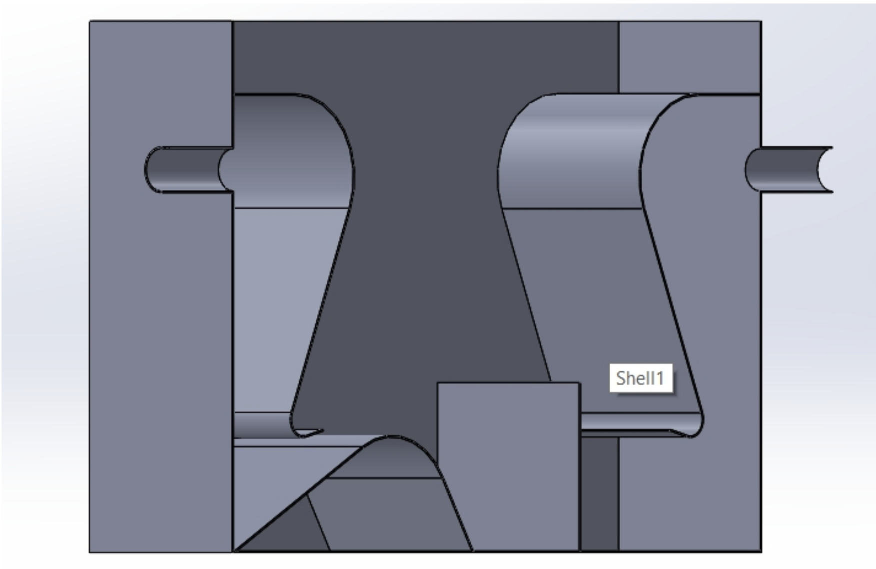


Fig37. Sectional view of Design done for FRP model

Design for Stainless Steel Prototype

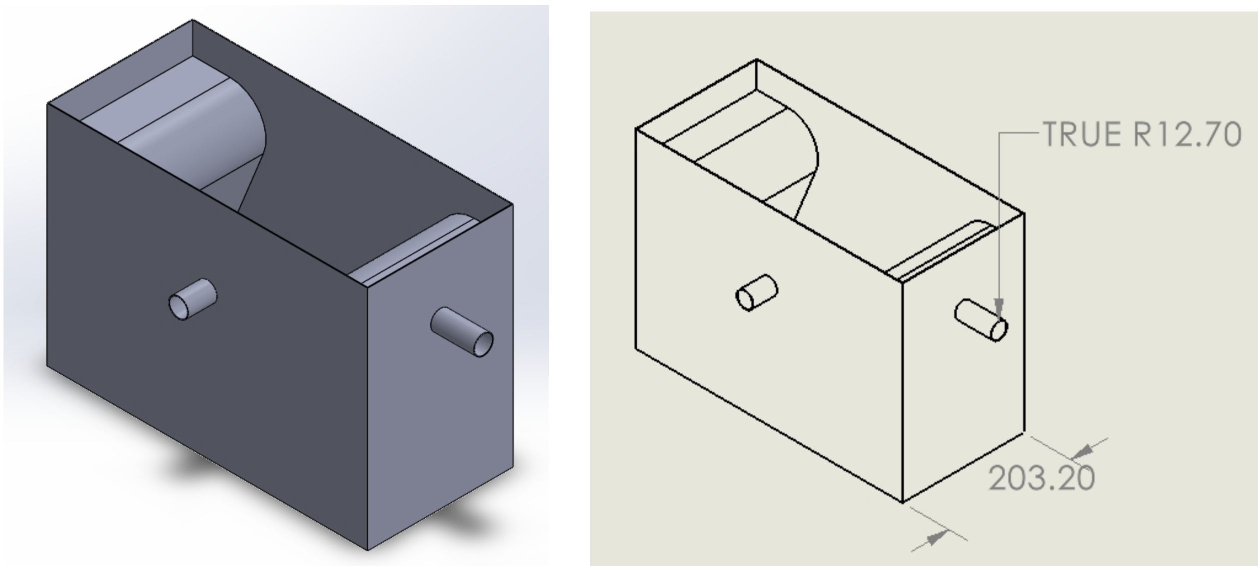


Fig38. Isometric view of Design done for Stainless Steel Model

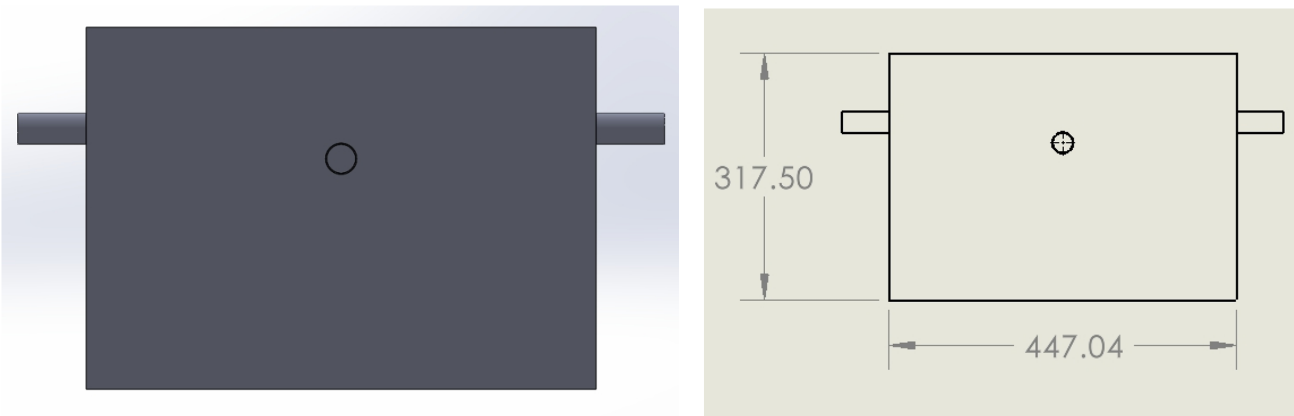


Fig39. Dimension of Design done for Stainless Steel Model

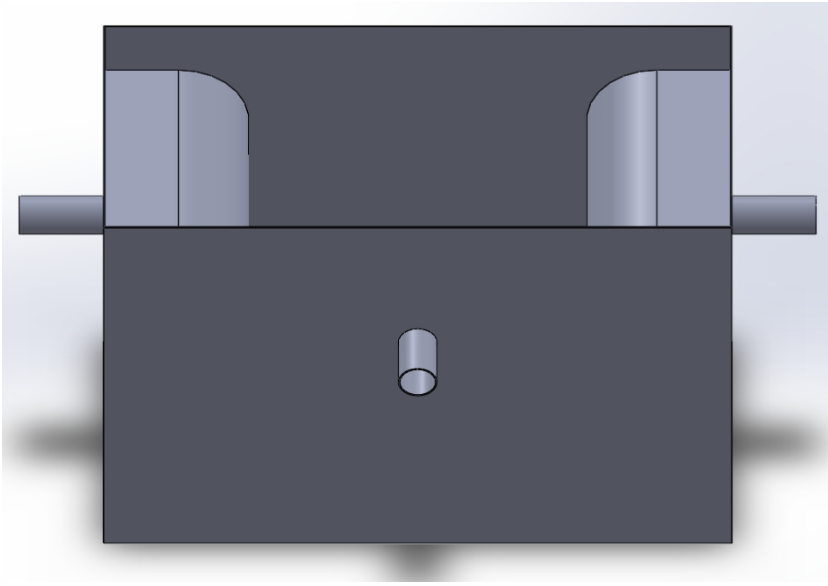


Fig40. Angular view of Design done for Stainless Steel Model

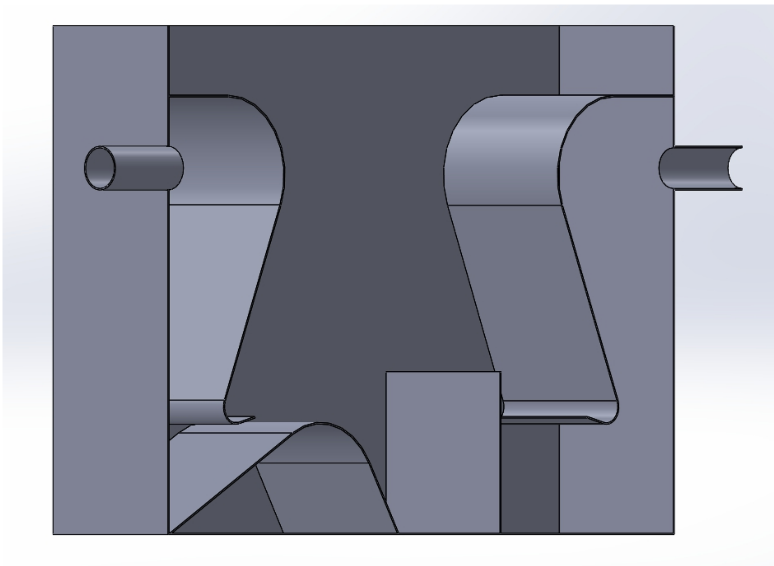


Fig41. Sectional view of Design done for Stainless Steel Model

In a busy restaurant, for example, small droplets of oil and particles of food which escape being scraped into the solid waste bin are washed off and enter the waste water system. To prevent these fats and oils from entering the main waste water system, grease traps are installed, usually underground.

A grease trap is a water-containing concrete, steel or obre glass box with an inlet pipe and a raised outlet. As waste water passes into the grease trap, the Uow rate is slowed. This allows food articles sink to the bottom of the trap, while oil and grease rise to the surface of the water within the trap. Baffles set inside the box allow water to Uow underneath, but provide one or more solid walls as an additional barrier to FOG waste.

A grease trap should be cleaned when it is 25% – 30% full. When levels exceed this amount, the trap becomes less effective and higher levels of FOG enter the main waste water system. How regularly a grease trap is maintained depends on business type, waste levels, waste sorting techniques, and the size, type and age of the grease trap.

Domestic grease traps might not have the scope of commercial and industrial businesses, but residential grease interceptors also require maintenance. Household FOG (fats, oils and grease) waste is the number one cause of drain blockage. Apartment blocks are particularly susceptible to grease trap overÙow into shared waste water networks, where a JJ's Waste & Recycling automated grease trap maintenance service can provide the perfect solution and complete peace of mind.

Waste & Recycling offers a rapid and reliable domestic grease trap cleaning service for individual homes or apartment blocks. We also provide advice on grease trap sizing and placement for renovations and new-builds, as well as countless other aspects of domestic waste disposal.

7.2 Conclusion

Wastewater characteristics are depending on wastewater source that may increase and becoming more toxic in recent times. The concentrations of oil and grease in wastewater streams have been observed to increase adverse effects on the ecology. This results from the increasing oil and grease use, high-demanded oil processed foods, establishment, expansion of oil mills and refineries worldwide, as well as indiscriminate discharge of oil and grease into the water drains, domestically and industrially.

This study reported the applications, efficiencies, and challenges of oil and grease wastewater treatment from industrial wastewater and municipal water stream. The results showed that the concentrations of oil and grease discharged into the ecosystem lead to increase environmental impact. The desired development for effective removal of oil and grease is discussed as emerging pollutants.

Lipase and adsorbent material zeolite (mixture of laterite and amorphous) were selected to eliminate O&G concentration from industrial wastewater.

7.3 Future Scope of Work

The Grease interceptor is the most effective component in the sewage system to separate the Fats, Oils, Solid wastes and other undissolved salts in the water. This is used to trap them and maintain the pipe line without clogging. Transnet Port Terminals (TPT) is a division of Transnet Limited is seeking a service provider to maintain the Fat Trap and Extractor Fan Canopy at Pier 1 Durban Container Terminal Bhekulwandle facility, Pier 2 and Head Office Canteen. The successful service provider will be required to provide Transnet with quick, effective, cost-saving service methods to ensure monthly maintenance of Extractor Fan Canopy and Fat traps and Fat carrying lines are maintained to a specific hygiene level. Including elimination thereof.

The successful service provider will be required to conduct as assessment, clean and issue a Compliance Certificate according to Extractor Fan Canopy and Fat Traps Health and Safety, Environment Regulations. Proper extractor fan and fat trap maintenance should ensure that the canteen is running smoothly, without getting any of the smelly backups that occurs due to lack of proper maintenance plan for oils and grease before they block the sewer line.

Scope inclusions:

a) Clean, Treat, Remove and Dispose of content in the Fat Trap, in accordance with all applicable laws and regulations.
b) Clean, Treat, Remove and Dispose of content in the Extractor Fan Canopy, in accordance with all applicable laws and regulations.
c) Manage and treat all spillages that happen during cleaning operation

Interceptors which have been properly designed and certified must be required and used. They must be installed as they were tested and were intended to be installed. Staff must be given adequate BMP and practice them on a consistent basis. And last, but not least, the devices must be maintained according to the codes and the manufacturer’s requirements.

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A Major Project Report
On

DESIGN, ANALYSIS AND PROTOTYPE OF AIR-LESS TYRE BY ADDITIVE MANUFACTURING PROCESS

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

BHUDHAVARAPU SAI ROHIT	**-17K81A0312**
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Under the Guidance of

Prof. C.H RANGARAO
Associate Professor

DEPARTMENT OF MECHANICAL ENGINEERING

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Dhulapally, Secunderabad – 500 100

JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Design, Analysis and Prototype of Air-Less Tyre by Additive Manufacturing Process**, is being submitted by **Bhudhavarapu Sai Rohit (17K81A0312), Neeli Vishnudeep (17K81A0347), Taravath Vishal (17K81A0355), Vontari Sai Ritesh Reddy (17K81A0357)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

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Signature of HOD

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Internal Examiner

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Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Design, Analysis and Prototype of Air-Less Tyre by Additive Manufacturing Process** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Non-Pneumatic Tyre (NPT) as the name suggests is a type of tyre that doesn't use air to support the load. The main principle involved in the airless tyre is, the flexible tread and shear bands deform temporarily as the spokes bend, then quickly going back to the initial shape. The NPT discussed here consists of mainly three parts. A rigid hub, Deformable spokes that support vertical load, Reinforced shear band and tread made out of rubber which comes into contact with the surface. Several types of research are being carried out all over the globe to make NPT an alternative to the conventional pneumatic tyre. This project consolidates an overview of the design and analysis of the Non-Pneumatic Tyre. The model of the tyre is designed in NX Cad software and Analysis is to be done in the Ansys workbench. The prototype of the model is done by 3D printing.

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CHAPTER-1 INTRODUCTION

Conventional pneumatic (air-inflated) tyres have dominated the tyre market for over a century. Since the earlier invention of the non-pneumatic wheel in the 1920s, the non-pneumatic tyre (NPT) is getting more attention due to its advantages over the pneumatic counterpart.

As far as automobiles are concerned, the engine, transmission and all other powertrain parts are only good as the tyres are. Since its invention in 1888 by Dunlop, the pneumatic tyre has been the primary choice for use in automobile subjected to different operating conditions due to the several advantages offered by it mainly:

1. Low energy loss while rolling
2. Low vertical stiffness which produces cushioning effect.
3. Low contact pressure and
4. Low mass.

Even though several advantages exist for a pneumatic tyre which resulted in its widespread acclaim, there exists a chance for it to go flat during operation which is its greatest drawback to date. In the case of vehicles that are subjected to extreme conditions like tractors, solid tyres are used to avoid this issue but this deteriorates ride quality. Researchers have been trying long back as 1920s to build a non-pneumatic tyre (NPT) that has sufficient resilience. With advancement in material science and manufacturing technologies, researchers were able to create NPTs having sufficient compliance. Modern NPT designs integrate wheel and tyre into a single component. The NPT consists of a rigid hub, flexible spokes, shear band and tread which is made up of rubber as shown in Figure. The flexible spokes and shear band are the components that support the load acting on an NPT like air in the case of a pneumatic tyre. Several researches are going on to optimize the design of spokes and shear band of an NPT and some of them are discussed below. Akshay Narasimhan et al studied the effect of material properties on static behavior of an NPT having radial spokes and shear band made of polyurethane and concluded that increase in shear modulus increased the stiffness of the NPT. Hysteresis loss due to the viscoelastic nature of rubber accounts for 90 % of energy loss. The spokes and shear band of NPT are usually made of polyurethane which also exhibits viscoelasticity.

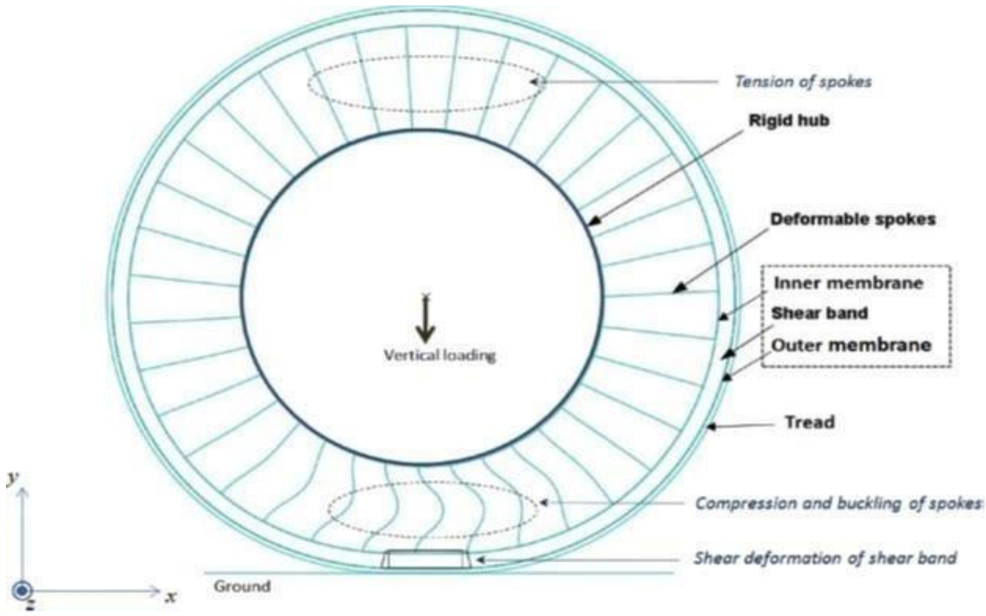


Fig 1: Schematic Representation of Airless Tyre

Non-Pneumatic Tyres

Airless tires, non-pneumatic tires (NPT), or flat-free tyres are tyres that are not supported by air pressure. In 2005, Michelin started developing an integrated tire and wheel combination, the "Tweel" (derived from "tyre" and "wheel," which, as the name "Tweel" suggests, are combined into one new, fused part), which operates entirely without air. Michelin claims its "Tweel" has load carrying, shock absorbing, and handling characteristics that compare favorably to conventional pneumatic tyres. In 2019 however Michelin and GM announced that, their goal of making a new airless tyre for passenger vehicles available in 2024.

Big Tyre Pvt Ltdin Australia is developing a "non-pneumatic, non-solid wheel", which is designed to handle high working loads, such as those found in underground mines. A non-pneumatic or airless tyre for passenger vehicles can be more efficient than the traditionally used pneumatic tyres. One or the other way there are many advantages over using pneumatic tyres. The main advantage of airless tyres is that they do not go flat. Other advantages are that airless tyres need to be replaced less, resulting in savings. Heavy equipment outfitted with airless tyres will be able to carry more weight and engage in more rugged activities.

Fig 2: Michelin Twill

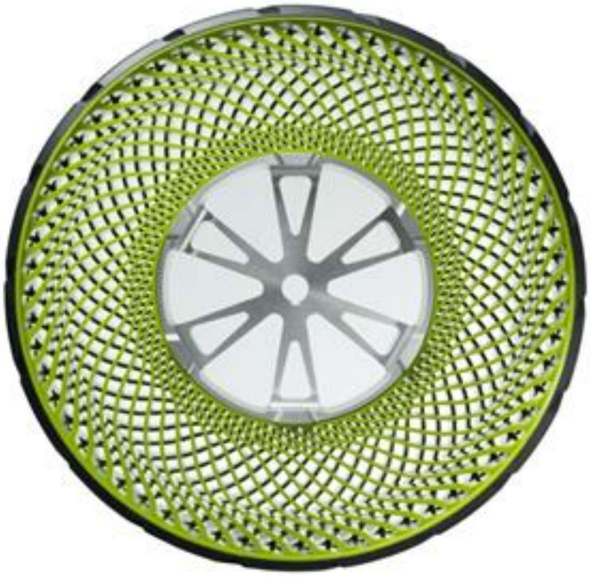


Fig 3: Bridgestone

Advantages of Air-Less Tyre:

For one thing, there are huge safety benefits. Having an airless tyre means there is no possibility of a blowout, which, in turn, means the number of highway accidents will but cut significantly. Even for situations such as Humvees in the military, utilizing non-pneumatic tyres has a great positive impact on safety

1.1 Overview of The Project

The basic outline of the project is to bring out the airless tyre design and to do the deformation analysis. Non-Pneumatic Tyre (NPT) as the name suggests is a type of tyre that doesn't use air to support the load. Even though tyres made out of solid rubber exists, they don't have enough compliance and will not provide a supple ride if used in normal vehicles. Heavy equipment outfitted with airless tyres will be able to carry more weight and engage in more rugged activities. In this project we designed and analyzed the design and suitable pattern is prototyped. The flexible tread and shear bands deform temporarily as the spokes bend, then quickly go back to the initial shape. There is additionally an environmental profit to victimization this sort of tyre. Since they never go flat and may be rethreaded, unventilated tyres won't ought to be thrown away and replaced nearly as usually as gas tyres. This can weigh down lowland mass considerably.

1.2 Objectives of The Study

According to NPT, the main component contributing to the energy loss of the NPT is the shear band due to the shear loading at the contact area. With Non pneumatic tyres or airless tyres, you never have to worry about your tires leaking because you knew this was coming--non-pneumatic tires have no air to leak. For most drivers, this feature will sound nothing short of revolutionary. When you run over a sharp object in the road, you won’t have to worry about a flat tire because tires without air can’t go flat. An end to the days of changing a tire on the highway shoulder would be welcome to drivers everywhere. Since you won’t be changing or repairing a flat, you don’t need to carry a spare. Just like cars using run-flat tires, this feature could free up trunk space. No spare also means less weight and less weight means better fuel economy. The airless concept tire is one of the initiatives aimed toward Bridgestone’s long-term vision of the use of sustainable materials. The materials used in the tire are recyclable, contributing to the efficient use of resources

Airless tires will be among the first for which this process is a reality. It is the design of shear beam and spokes which allows for the potential to achieve a relatively uniform surface contact distribution with the ground under load. The spokes and ring are manufactured in a mold with imbedded reinforcements. A rubber tread is bonded to the outer ring to provide traction. Use of PLA for the spokes and the shear band having low viscoelastic energy loss than rubber may result in design of NPT with low rolling resistance. The use of hyper elastic materials such as PLA is important because of their shearing properties that contribute to the flexibility, energy loss, damping, and the pressure distribution between the NPT and the road. When the NPT is loaded at the hub center, the composite ring flattens in the contact area, forming a contact patch. The deformable spokes buckle due to the applied load. The spokes out of the contact area do not undergo deformation and remain in tension. The airless concept can lead to reduced CO2 emissions because of their low rolling resistance. While the load-carrying structure is made of composite materials such as polyurethane, thermoplastics, fiberglass and epoxy laminates, but also eco-friendlier and bio-degradable materials have been proposed.

1.3 Scope of The Study

Our tires require less maintenance and worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheel chairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement.

This can be the revolutionary concept in the future.

1.4 Material Requirement

The materials required for the Analysis and Fabrication is Aluminum Alloy and PLA (Poly lactic acid).

RIM-Aluminum Alloy,

TYRE-PLA (Poly-Lactic Acid).

1.4.1 Aluminum Alloy:

In the automotive industry alloy wheels are wheels that made from an alloy of aluminum or. Alloys are mixtures of a metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of aluminum are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels.

S. No	Property	Value
1	Density	2770 kg/m^3
2	Young's Modulus	7.1e+ 10 Pa
3	Poisson's Ratio	0.33
4	Bulk Modulus	6.9608e+ 10 Pa
5	Shear Modulus	2.6692e+ 10 Pa
6	Compressive Ultimate Strength	0 Pa
7	Compressive Yield Strength	2.8e+ 08 Pa
8	Tensile Ultimate Strength	3.1e+ 08 Pa
9	Tensile Yield Strength	2.8e+ 08 Pa

Table 1: Properties of Aluminium Alloy

1.4.2 Poly Lactic Acid:

Polylactic Acid (PLA) is different than most thermoplastic polymers in that it is derived from renewable resources like corn starch or sugar cane. Most plastics, by contrast, are derived from the distillation and polymerization of non-renewable petroleum reserves. Plastics that are derived from biomass (e.g., PLA) are known as “bioplastics.”

Polylactic Acid is biodegradable. It can be produced from already existing manufacturing equipment (those designed and originally used for petrochemical industry plastics). This makes it relatively cost efficient to produce.

S. No	Property	Value
1	Density	1255 kg/m^3
2	Young’s Modulus	3.447e+ 09 Pa
3	Poisson’s Ratio	0.3899
4	Bulk Modulus	5.218e+ 09 Pa
5	Shear Modulus	1.24e+ 09 Pa
6	Tensile Ultimate Strength	6.293e+ 07 Pa
7	Tensile Yield Strength	5.244e+ 07 Pa
8	Isotropic Thermal Conductivity	0.1442 W/m^{o}C
9	Specific Heat Constant Pressure	1195 J/kg^{0}C
10	Isotropic Resistivity	4.313e+ 09 ohm.m

Table 2: Properties of Pla

CHAPTER 2 LITERATURE SURVEY

2.1 Literature Review on Research Area

Mohammad Fazelpour et al, [1] stayed considered about the evolution of meso-structures in the development of the shear band of non-pneumatic tyre and he concluded as follows below. To increase fuel efficiency in NASA manned exploration system. They replaced elastomeric material with shear of shear band with materials which can tolerate harsh temperatures and shear loads or to replace the materials with linear elastic low-hysteretic loss materials. Topologies were created such as honeycombs; new shapes like s-type meso-structures and the structural analysis were carried out of shear band of non-pneumatic tyre with meso-structure was investigated through shear flexure, shear strain, and contact pressure. At the end of research, they set up guidelines on custom designing meso-structures for challenging applications such as non-pneumatic tyre and passive morphing air foils which will be addressed in future research. A.M. Abdul-Yazid et al, [2] examined three dissimilar structures of the Tweel, resistant technologies, and NPT by seeking yielding spoke structures. He conducted the quasi-static, 2D analysis on contact pressure, vertical tire stiffness and stress which are affected by spoke structures and shear band by creating two NPTs, a tire with a composite ring and another without composite ring. The results showed that shape and size of spokes has effect on tire behaviour and the shear layer reduces the impact of the deformed spokes shape in contact pressure distribution. Bert Bras et al, [3] discussed about the ecological effect of the Tweel tyre amid its lifecycle from assembling, through use and transfer. Since the Tweel tyre is as of now still in the examination stage and is most certainly not made and utilized on a vast scale, there are instabilities as for end-of-life situations and rolling resistance evaluates that will influence the LCA.

2.2 Review on Related Literature

Development of a two-dimensional model of a compliant non-pneumatic tire Amir Gasmi a, Paul F. Joseph a, Timothy B. Rhyne b, Steven M. Cron b an analytical model for a compliant non-pneumatic tire on frictionless, rigid ground is presented. The tire model consists of a thin flexible annular band and spokes that connect the band to a rigid hub. The annular band is modelled using curved beam theory that takes into account deformations due to bending, shearing and circumferential extension. The effect of the spokes, which are distributed continuously in the model and act as linear springs, is accounted for only in tension, which introduces a nonlinear response. The quasi-static, two-dimensional analysis focuses on how the contact patch, vertical tire stiffness and rolling resistance are affected by the stiffness properties of the band and the spokes. A Fourier series representation of the shear strain in the annular band and the complex modulus of the material were used to predict rolling resistance due to steady state rolling. From the analysis point of view, when the wheel is loaded at its hub, the following three distinct regions develop: (1) a support region where the hub hangs by the spokes from the upper part of the flexible band, (2) a free surface region where the spokes buckle and have no effect, and (3) a contact region where the flexible band is supported by the ground without the effect of the spokes. The angular bounds of these three regions are determined by the spoke angle and the contact angle, which are respectively the angle at which the spokes start to engage in tension and the angle that defines the edge of contact. Closed-form expressions of contact stress, stress-resultants and displacements at the centroids of the cross-sections of the flexible band are expressed in terms of these angles, which must be determined numerically. A thorough parametric analysis of quantities of interest for the tire is presented, which can be used to help support the optimal and rational design of compliant nonpneumatic tires. The model was validated by comparison with two computational models using the commercial finite element software ABAQUS and by experimental rolling resistance data.

2.3 Conclusion on Review

Air-less tyres or Non-Pneumatic Tyres require less maintenance and worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheel chairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement.

CHAPTER 3 PROJECT DESIGN

3.1 Over View Of the Design

The design of the tyre is done in NX Cad software. The basic requirement for the design is to know the different pattern to design and the dimensions to consider. By considering the original equipment manufacturers standards the dimensions are taken for the design. The dimensions are, the outer diameter of the tyre is 460mm, the inner diameter of the tyre is 420mm. At this point the spokes will be in the contact to the inner core of the tyre. The diameter of the outer part of the is 210mm. The spokes will be attached to the outer part of the rim and the inner core of the tyre.

3.2 Introduction to NX Cad

The design is carried out in NX Cad software. NX, formerly known as "Unigraphics", is an advanced high-end CAD/CAM/CAE, which has been owned since 2007 by Siemens PLM Software. In 2000, Unigraphics purchased SDRC I-DEAS and began an effort to integrate aspects of both software packages into a single product which became Unigraphics NX.

Fig 4: NX Cad Icon

It is used, among other tasks, for:

- Design (parametric and direct solid/surface modelling)
- Engineering analysis (static; dynamic; electro-magnetic; thermal, using the finite element method; and fluid, using the finite volume method.
- Manufacturing finished design by using included machining modules.

NX CAD is very useful platform for design engineer. It's providing many applications like sheet modelling and modelling; drafting is also there but most important thing is synchronous modelling through which you can work on solid dump body. It is used for mechanical simulation, electromechanical systems design, tooling and fixture design, package design and mechanical design. Siemens NX is a cutting-edge software which is highly useful for the manufacturing sectors. The most powerful, flexible, and innovative product development solution in the industry, NX for Design has the features, performance, and capabilities to help you get a product to market faster than ever before. NX generally provides the users with the most effective possibilities to fasten the production process resulting with excellent quality products.

NX can be more helpful for easy product tracking through various phases across the entire production lifecycle.

3.3 Uses of NX Cad

Surfacing & Shape Design

NXCAD provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From styling, subdivision, and Class A surfaces to mechanical functional surfaces.

Mechanical Engineering

Modules like 3D sketches, sheet metal work bench, forged or tooling parts for creation of 3D parts like assemblies and moulded are available in NXCAD. The tools in the NXCAD enable functional tolerances, Kinematics definition and product definition.

Equipment Design

The design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing can be done by NXCAD.

Systems Engineering

NX CAD solves intelligent products and Model complex through the systems engineering approach. It covers the requirements definition, the systems architecture, the behaviour modelling and the virtual product or embedded software generation. It can be customized via application programming interfaces (API). Visual Basic and C++ programming languages via CAA (Component Application Architecture); a component object model (COM)-like interface is adapted using NX CAD.

3.4 Modelling of The Tyre in NX Cad Software

3.4.1 Design Procedure:

Modelling of a TYRE is done through NX CAD by considering all the specifications of the design and Dimensions of TYRE. Draft sheet of the design can be seen in the following figure.

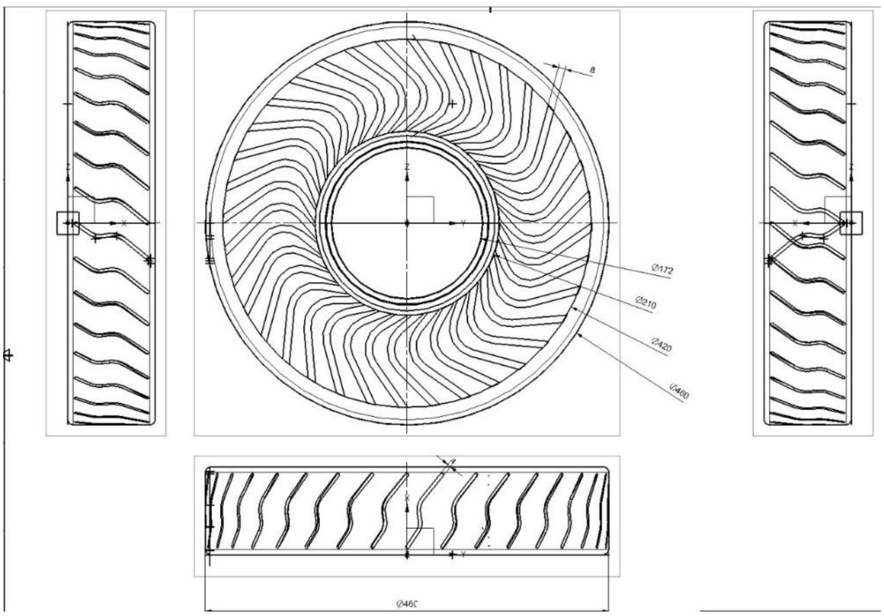


Fig 5: 2D Draft Sheet of The Tyre

Dimensions of the Tyre:

- Outer diameter of the tyre (460mm)
- Inner diameter of the tyre (420mm)
- Thickness of a spoke (8mm)
- Outer diameter of the rim (210mm)
- Inner diameter of the rim (172mm)
- Angle of a grooves (46^{0})
- Thickness of the grooves (4mm)
- Thickness of the tyre (100mm)

3.4.2 Part Design:

Open the New window on the screen, select model and select assembly for the design. From the coordinate system select the X-Y plane and click on sketch. By taking the rim design and the references the outer part of the tyre and the inner part of the tyre is modelled.

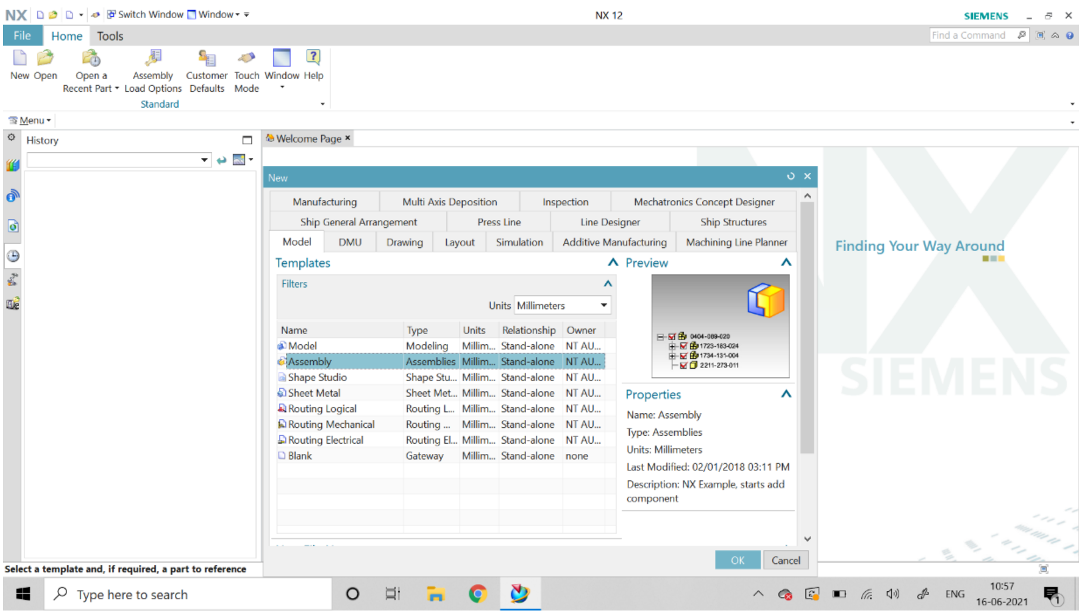


Fig 6: Part Design Model.

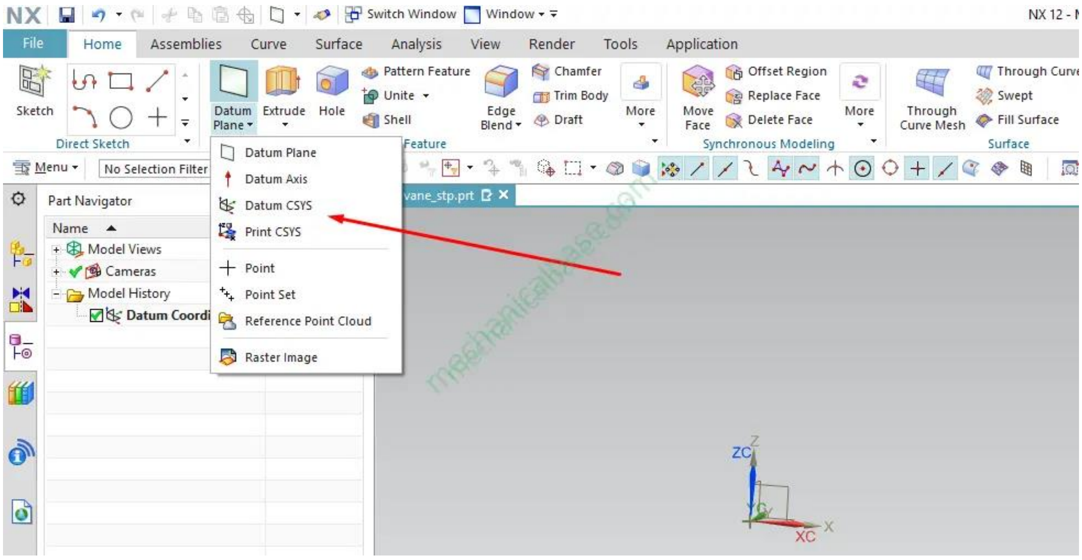


Fig 7: Selection of Coordinate System

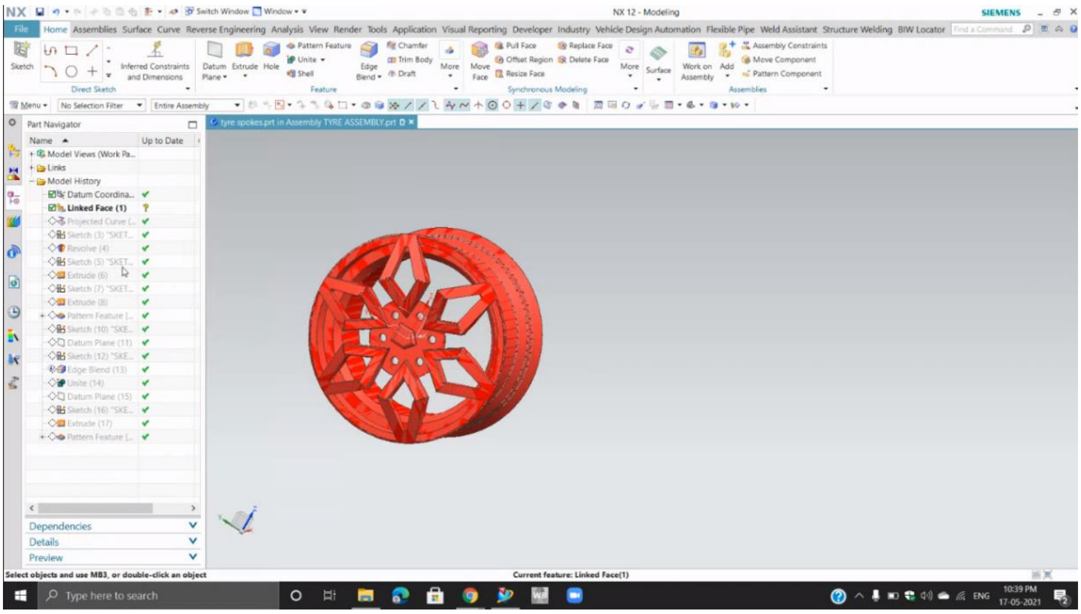


Fig 8: Design of The Rim

3.4.3 Sketching

After importing the designed rim, now use the wave geometry linker and the part is shown in side view. Then select extract geometry. After take the references through the edges of the RIM. Project curves tool helps us to join the references of the rim as shown in below figures. The references of the rim can be seen in the figure. By using revolve command, Sketch the inner part of the tyre and the outer part of the Tyre.

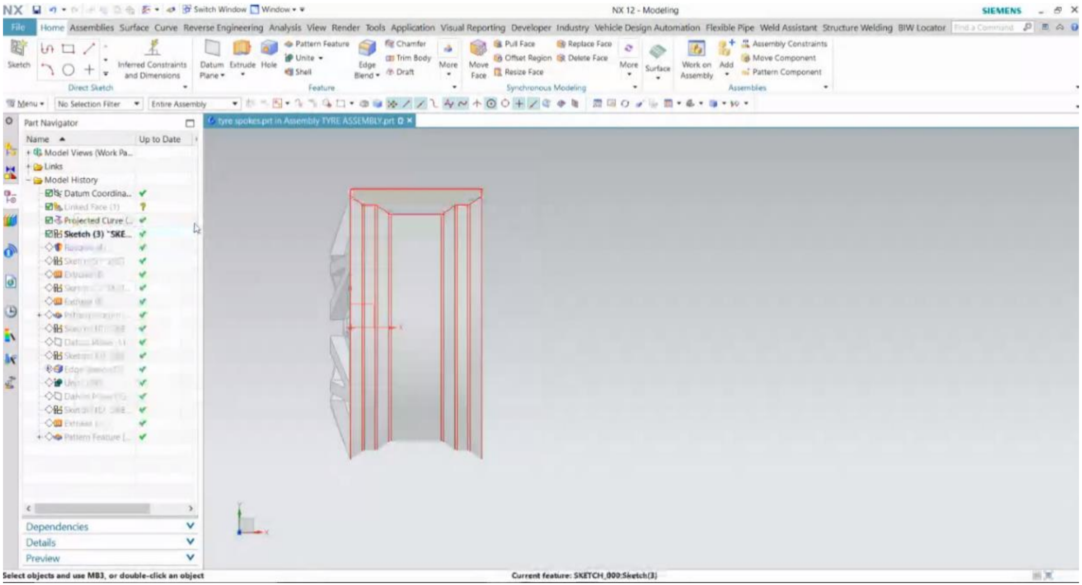


Fig 9: Sketching of The Rim

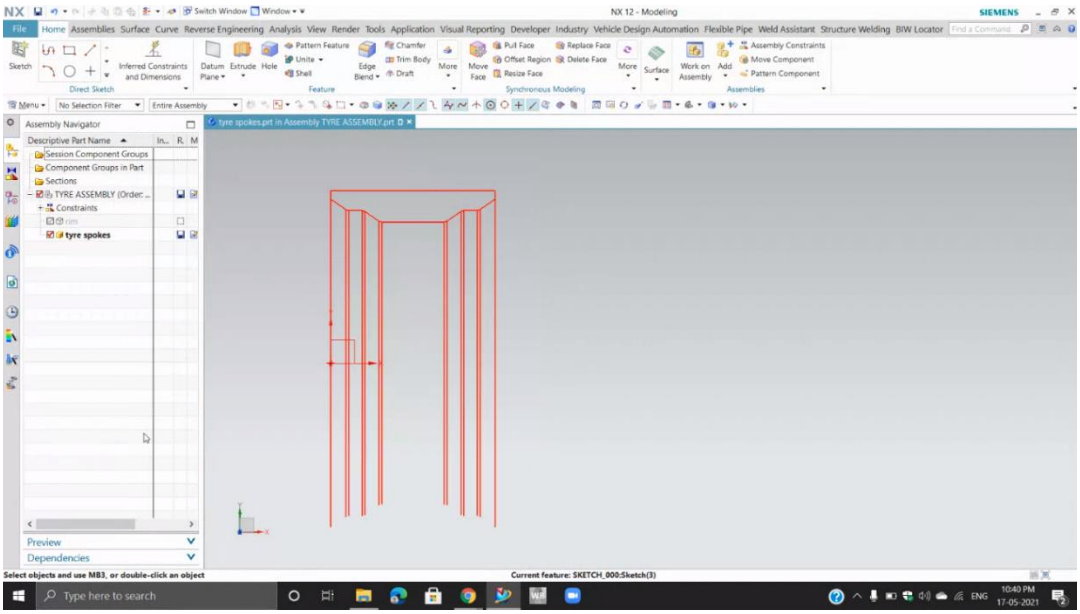


Fig 10: Joining the References

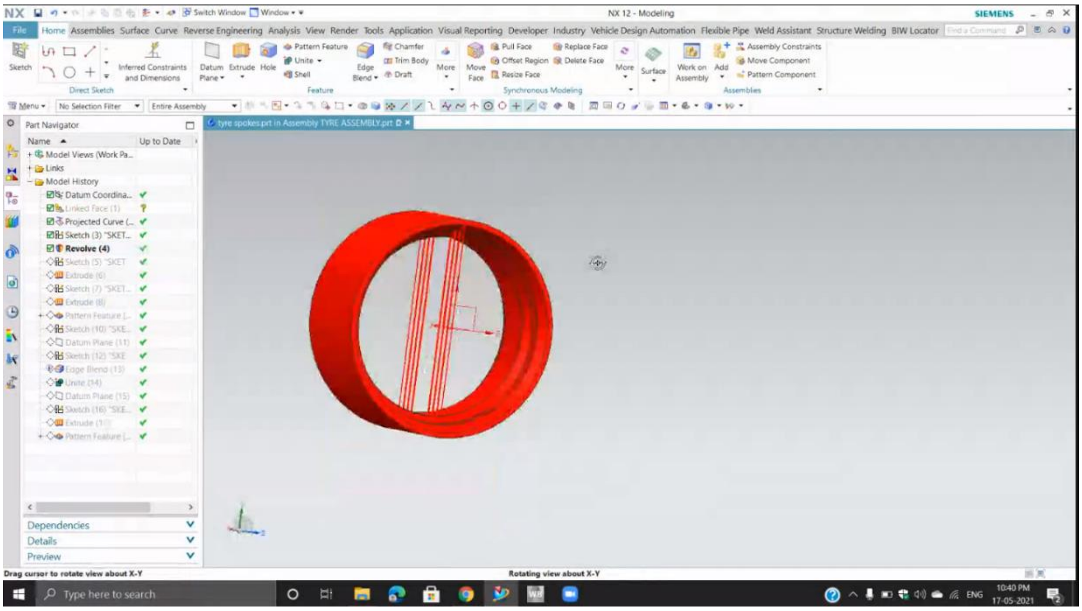


Fig 11: Outer Core of The Rim

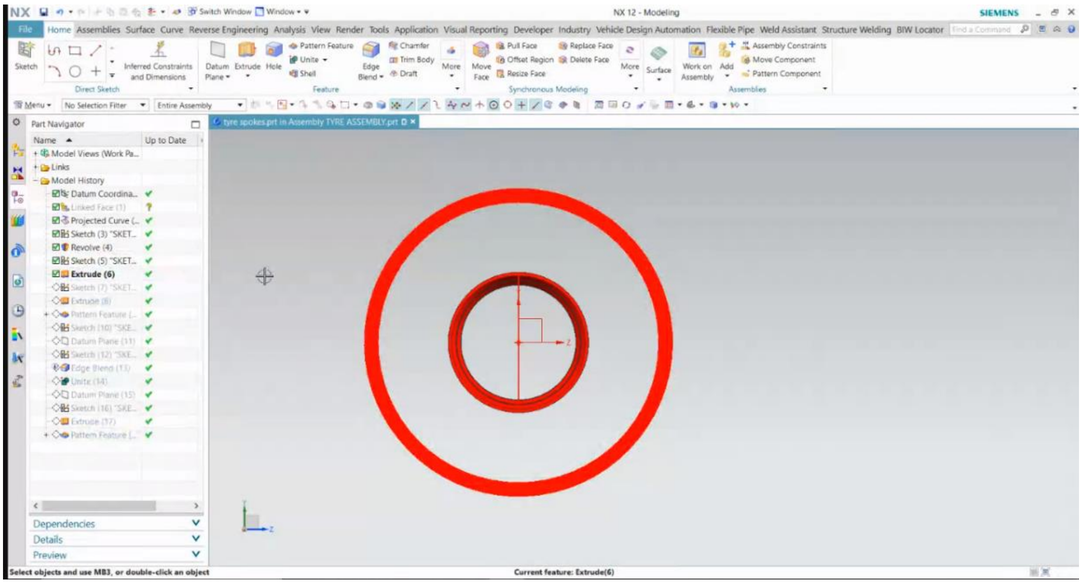


Fig 12: Sketching of Tyre

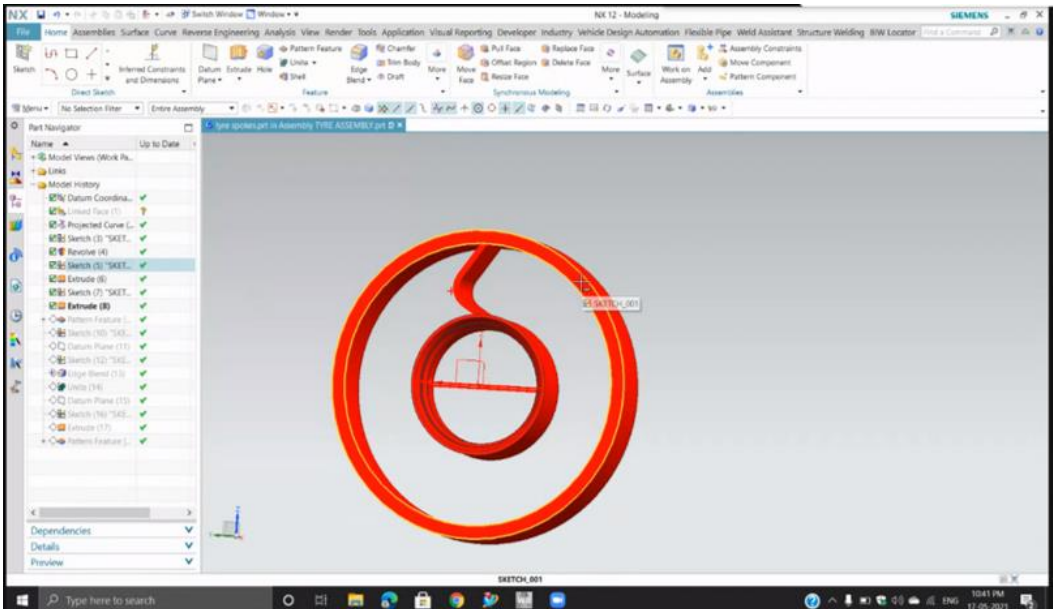


Fig 13: Sketching of a Spoke

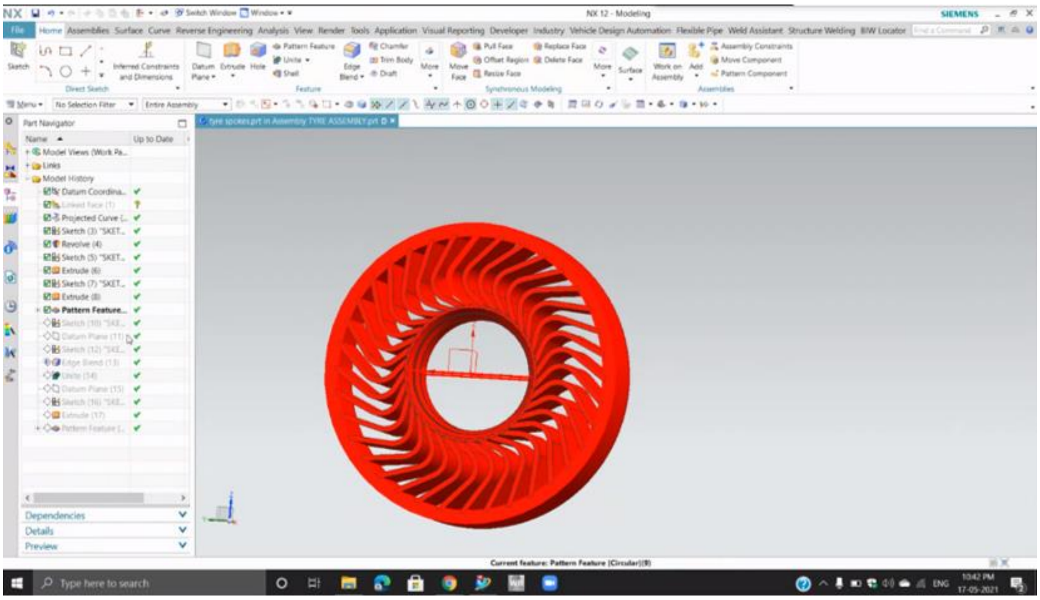


Fig 14: Modelling of The Spokes

Through pattern feature, design the spokes along the inner core of the tyre i.e., the spokes should attach between the inner core of the tyre and the exterior of the rim. Now design the grooves on the outer part of the tyre.

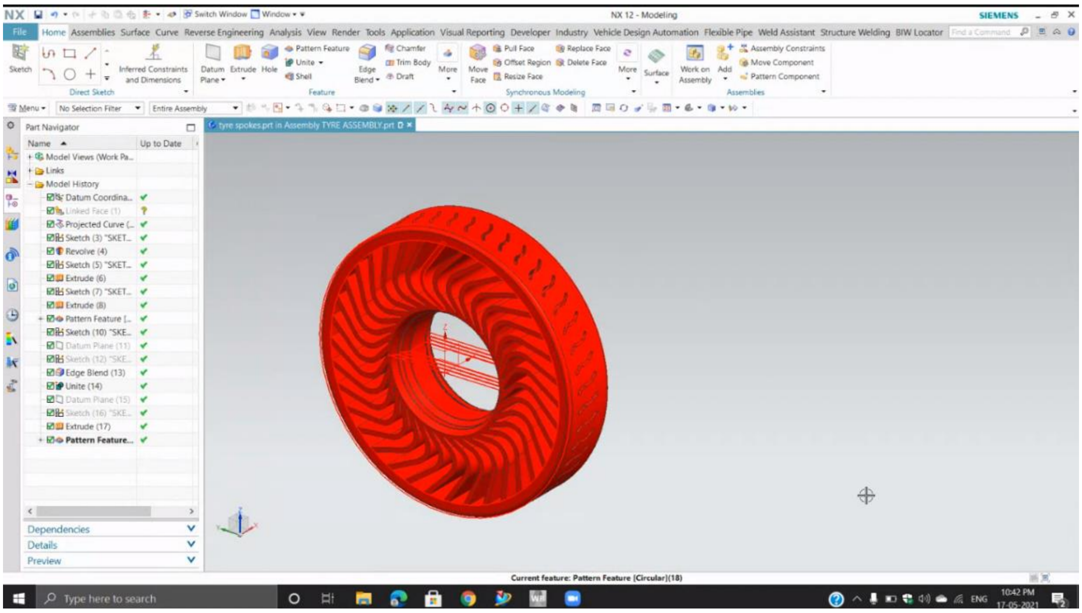


Fig 15: Modelling of The Grooves

3.4.4 Final Design:

By assembling the rim part and the sketched outer and inner part of the tyre with spokes attached, we can see the final design.

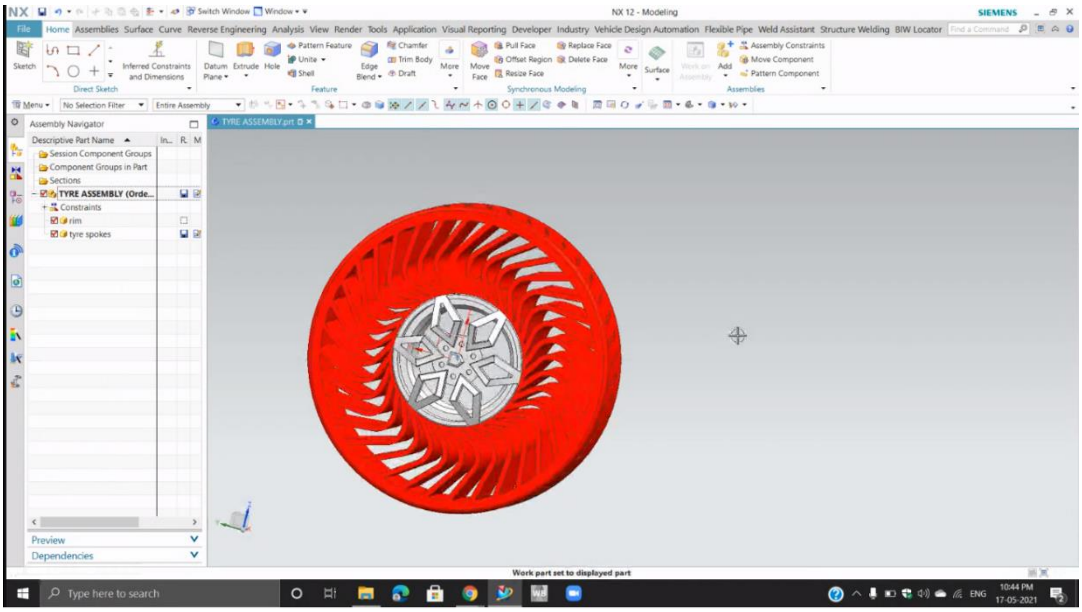


Fig 16: Final Design of Air-Less Tyre

CHAPTER 4 PROJECT IMPLEMENTATION

4.1 Introduction to Ansys:

The ANSYS program is self-contained general purpose finite element program. This is developed and maintained by Swason analysis systems Inc.

ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.
- Testing prototype in environments where it otherwise would be impossible or undesirable
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.

A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

4.2 Organization of Ansys Program

The ANSYS program is organized into two basic levels:

- Begin level (Start level)
- Processor (or routine) level

Begin level acts as a gateway into and out of the ANSYS program. Changing the name of job, database clearing, and binary files copying are program controls used. When we first enter the program, we at the begin level.

At the processor level, several processors are available; each processor is a set of functions that specific analysis task perform. For instance, the general preprocessor (PREP7) is the place we fabricate the model, the arrangement processor (SOLUTION) is the place we apply stacks and get the arrangement, and the general postprocessor (POST1) is the place we assess the outcomes and acquire the arrangement. An extra postprocessor (POST26), empowers we to assess arrangements results at particular focuses in the model as an element of time.

4.3 Performing A Typical Ansys Analysis:

The ANSYS system has numerous limited component investigation capacities, extending from a straightforward, direct, static examination to a nonlinear, transient element investigation. The investigation guide manuals in the ANSYS documentation set portray particular systems for performing examination for diverse building controls.

ANSYS analysis has three distinct steps:

- Construct the model
- Apply loads and boundaries
- Obtain the solution
- Review the results

The following table shows the brief description of steps followed in each phase.

Pre-processor	Solution processor	Post processor
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graphs
Assigning real constants	load definition	view animated results
Material definition	Solve	
Mesh generation		
Model display		

Table 3: Phases of ANSYS

4.3.1 Pre-Processor

Preprocessor prepares the input data for ANSYS analysis. The general preprocessor (PREP 7) contains solid modeling and mesh generation capabilities, and is also used to define all other analysis data with the benefit of data base definition and manipulation of analysis data. Parametric input, user files, macros and extensive online documentation are also available, providing more tolls and flexibility for the analyst to define the problem. Extensive graphics ability is available throughout the ANSYS program, including isometric, perceptive, section, edge and hidden-line displays of three-dimensional structures-y graphs of input quantities and results, and contour displays of solution results.

The preprocessor stage involves the following:

- Specify the title, which is the name of the issue. This is discretionary yet exceptionally valuable, particularly if various configuration cycles are to be finished on the same base mode.
- Analysis types thermal analysis, modal analysis, Harmonic analysis etc.
- Creating the model: The model may be made in preprocessor, or it can be imported from other design software by changing the file format.

- Defining element type: these chosen from element library.
- Assigning real constants and material properties like young`s modules, Poisson's ratio, density, thermal conductivity, damping effect, specific heat, etc.
- Apply mesh: Meshing is nothing but dividing the whole area into discrete number of particles.

4.3.2 Solution Processor:

Here we create the environment to the model, i.e., applying constraints & loads. This is the main phase of the analysis, where the problem can be solved by using different solution techniques. Here three major steps involved:

- Solution type required, i.e., static, modal, or transient etc. is selected.
- Defining loads: The loads may be surface loads, point loads; thermal loads like temperature, or fluid pressure, velocity is applied.
- Solve FE solver can be logically divided into three main steps, the pre-solver, the solution and post-solver. Model read by presolver which is created by the pre-processor and makes the arithmetical representation of the model and calls the mathematical-engine, which calculates the result. The result return to the solver and the strains, stresses, etc. for each node within the component or continuum are calculated by post solver.

4.3.3 Post Processor:

Post processing means the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affects the design, how the meshing is done.

Post processor analyzes results, which display stress and strain contours, distorted geometries, flow fields, safety factor contours, contours of potential field results; vector field displays shapes of mode and graphs related to time history. The post processor can also be used for algebraic operations, database manipulators, differentiation and integration of calculated results.

4.3.4 Review

Once the solution has been calculated, results can be reviewed in post processor. Two post processors are available: POST 1 and POST 26. We use POST 1, the general post processor to review the results at one sub step over the entire model or selected portion of the model. We can obtain contour displays, deform shapes and tabular listings to review and interpret the results of the analysis. POST 1 offers many other capabilities, including error estimation, load case combination, calculation among results data and path operations.

The simultaneous set of equations that the finite element method generates the solution taken by the computer, the results of the solution are:

- Nodal degree of freedom values, which form the primary solution.
- Derived values which frame the component arrangement.

Meshing:

Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components.

4.4 Static Structural Analysis:

The load effects can be calculated on a structure by ignoring the damping and inertia effects, such as those caused by time varying loads can be calculated by structural static analysis. Steady equivalent loads like steady inertia loads and time varying loads are included in Static analysis. Static analysis is utilized to decide the removals, burdens, strains and powers in structures or segments brought about by burdens that don't instigate noteworthy dormancy and damping impacts. Enduring stacking and reaction conditions are accepted, i.e. the stress and the structure's reactions are expected to differ gradually as for time. The kinds of load can be applied in static analysis include:

- Force and pressure application on body.
- Steady state inertial forces.
- Displacement.
- Thermal behavior.

Analysis Steps:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties.
- Specify restraints and loads.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.
- View results.

4.4.1 Process for Analysis of The Tyre

In this section, the modeling and analysis of the Air-less Tyre or Non-pneumatic tyre is discussed. Start the **ANSYS Product Launcher**. Select a working directory for storing your model data and launch **ANSYS Workbench**. You will see the software outfit as Fig. 1

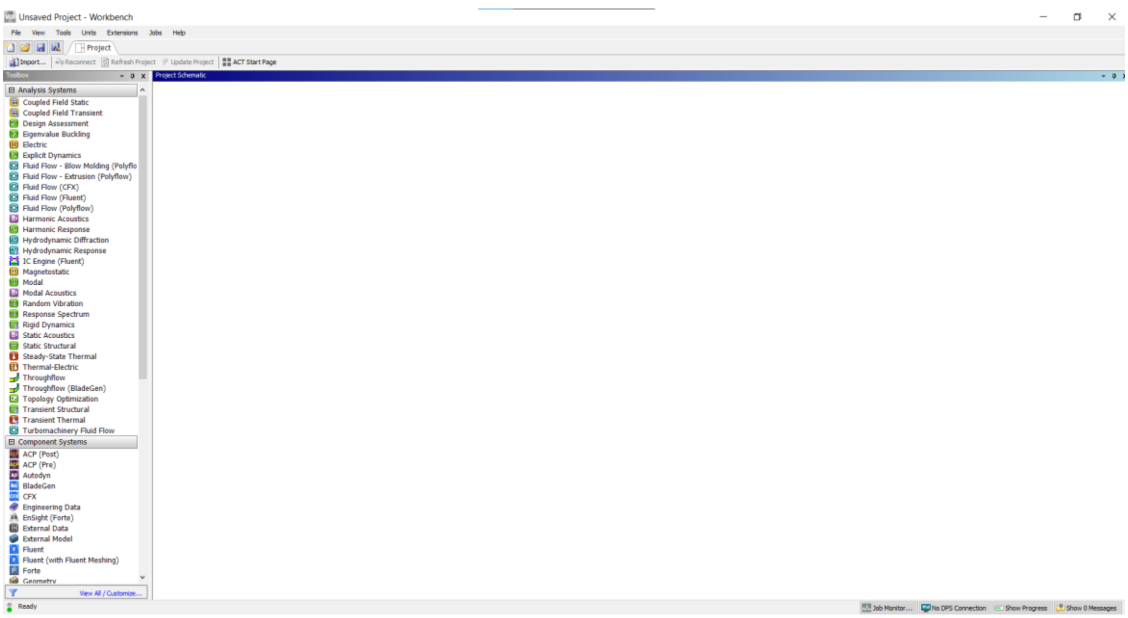


Fig 17: Ansys Workbench Software Outfit

Drag Static Structural (ANSYS) tab from Analysis Systems of Toolbox window to the Project Schematic window. Now, your static structural analysis model should be in the Project Schematic.

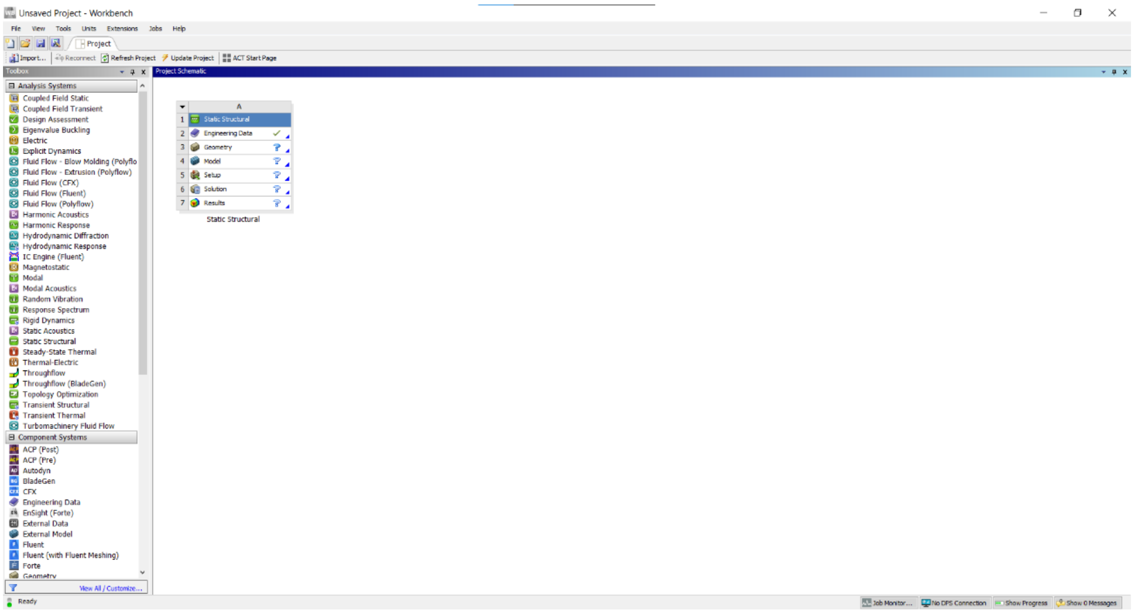


Fig 18: Tool Box View

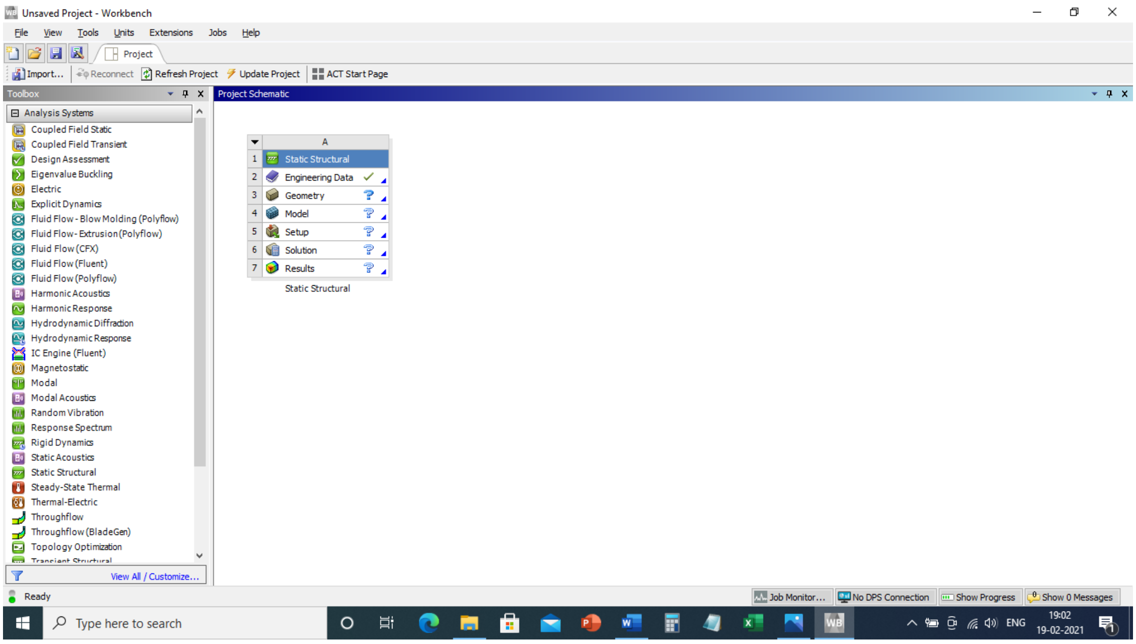


Fig 19: Static Structure

Now, the Engineering Data of the materials should be added to your project to assign during modelling the product. To select more materials under different sources, we should select engineering data sources tab which is adjacent to filter engineering sources.

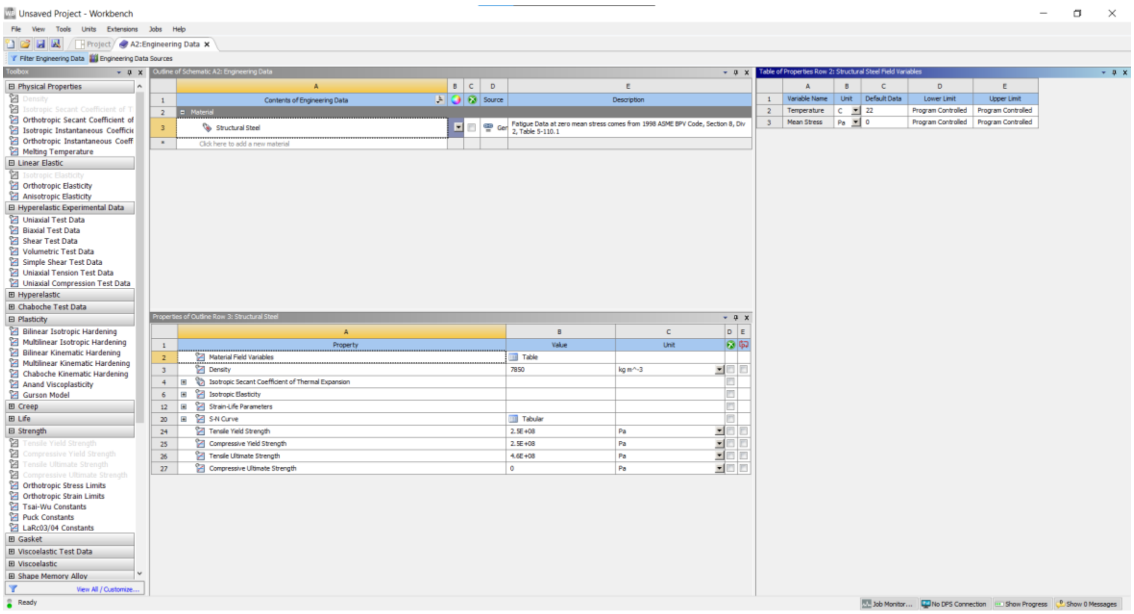


Fig 20: Engineering Data Materials

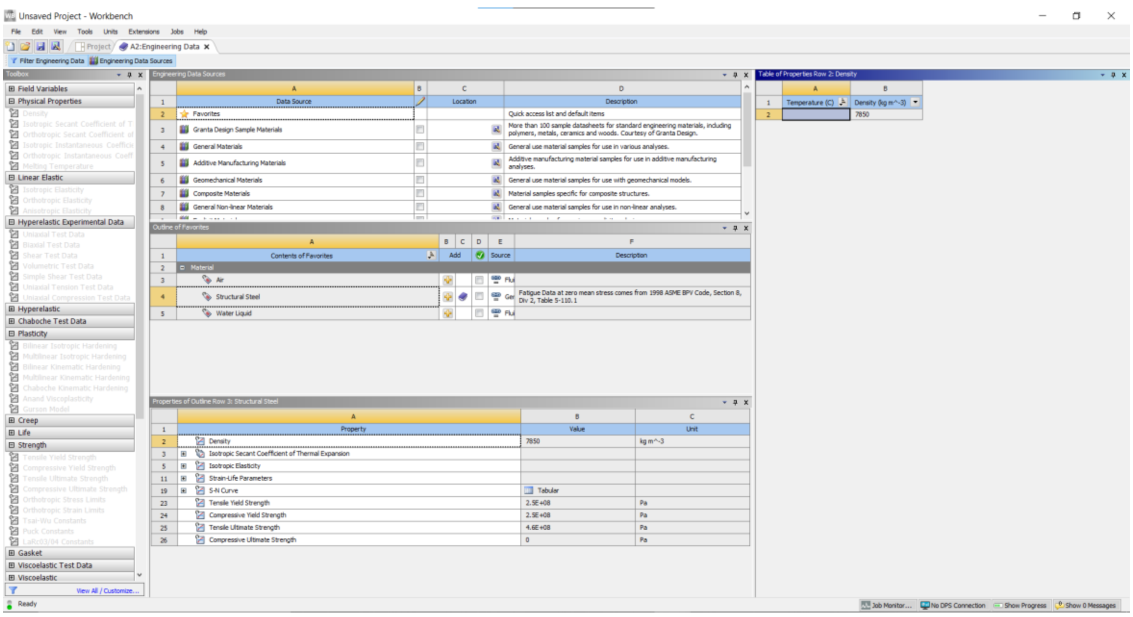


Fig 21: Engineering Data Sources

After completion of Engineering data tools, the designed product should be imported to the project Geometry.

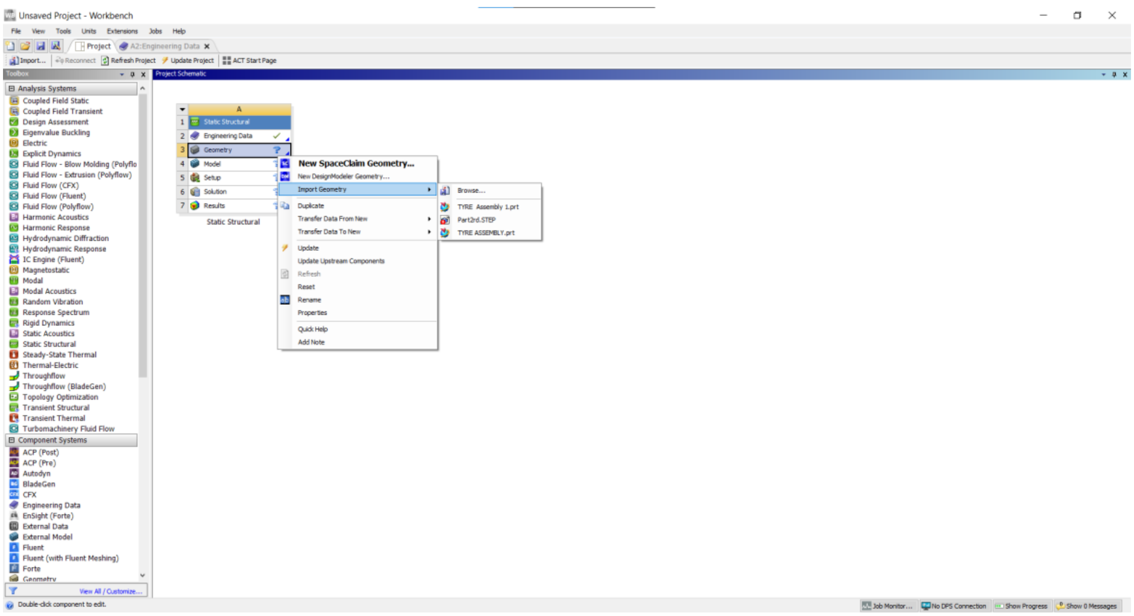


Fig 22: Importing the Geometry

In design modeler, road surface to the tyre is been sketched. By selecting the coordinate axis and the required direction for the sketch and extruding the sketch for required dimension is done.

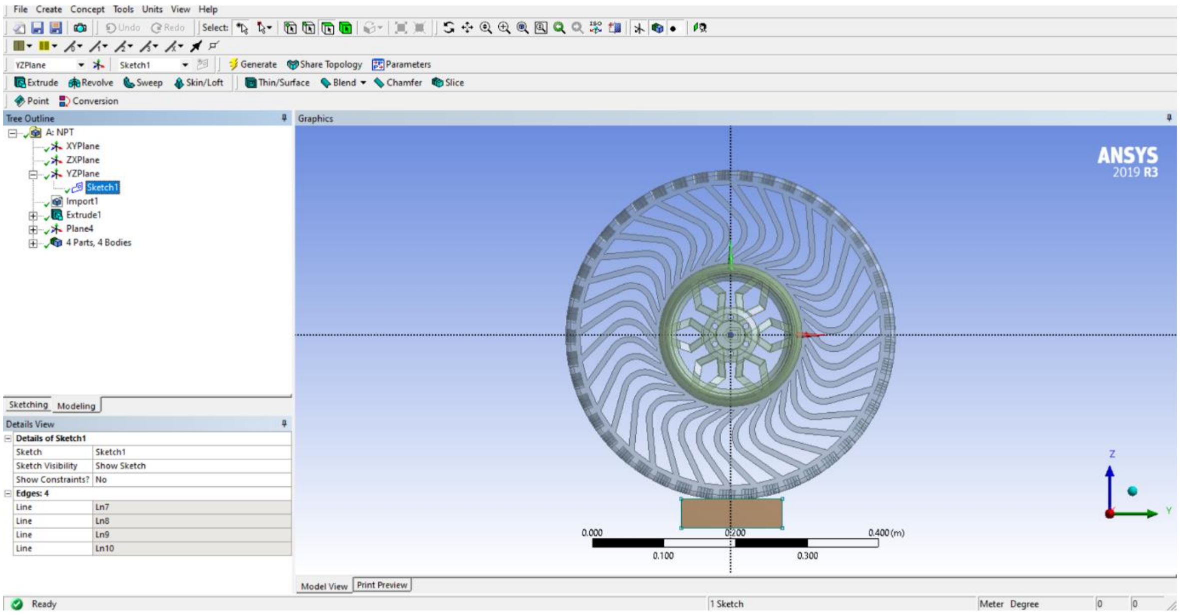


Fig 23: Selecting the sketch

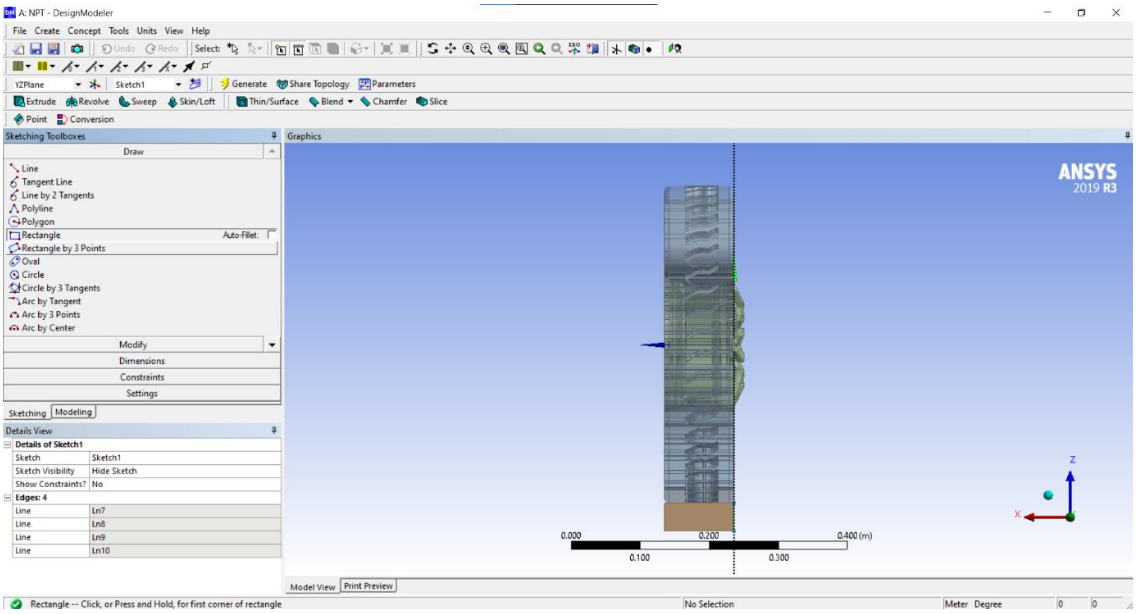


Fig 24: Sketching and Extruding the Road Surface

4.5 Static Structural of The Model

In the model tool, the material assignment for different parts of the product, assigning of force, fixed support to the tyre, meshing and solving the model for Deformation Analysis is carried out.

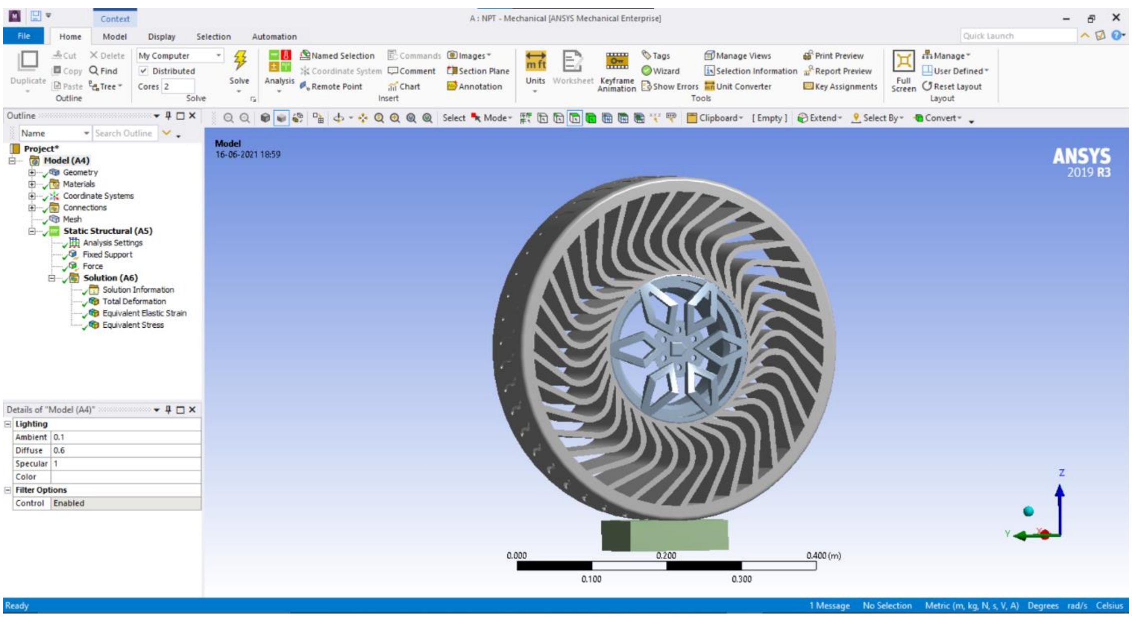


Fig 25: Model of the Type

Under the project tool the model is displayed. The model consists of geometry, materials, coordinate system, connections, mesh, static structural and solution.

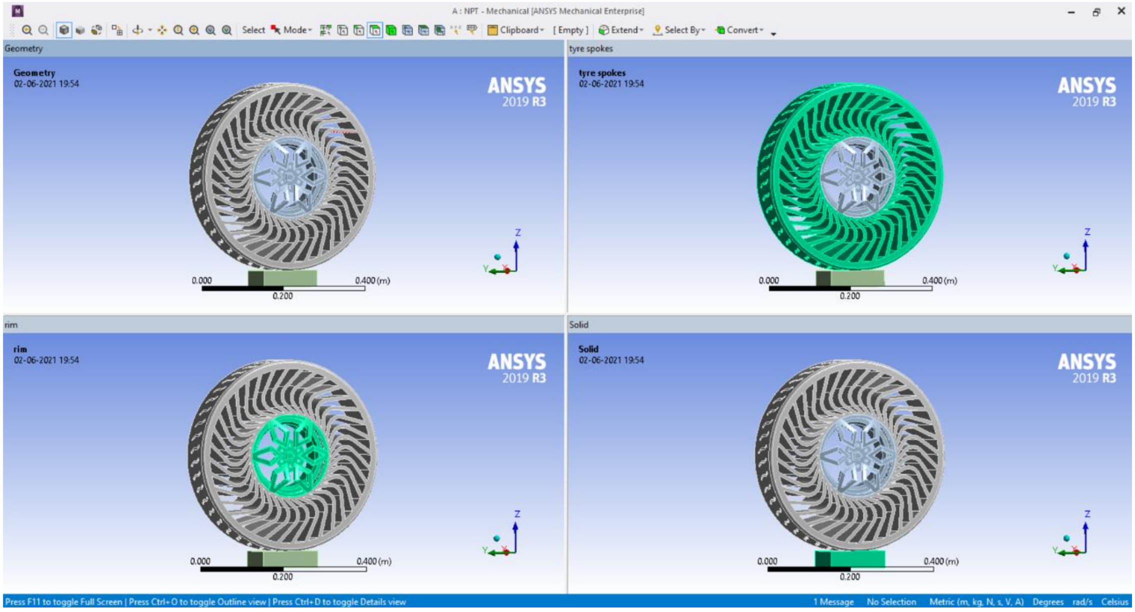


Fig 26: Geometry of The Mode

In the below figures we can see the geometry of each part of the tyre and the coordinate system.

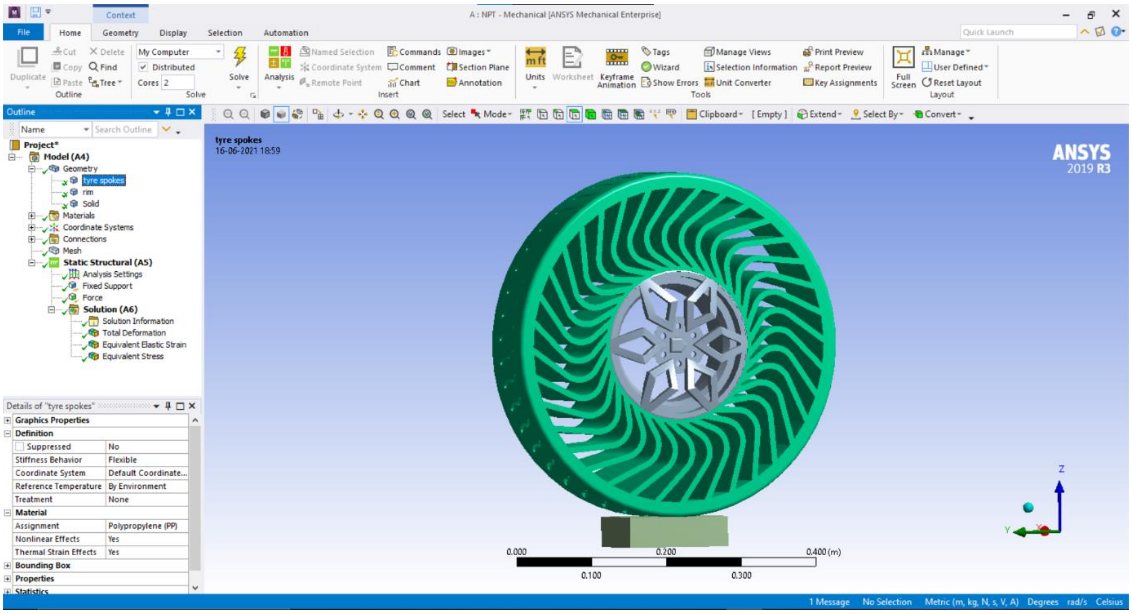


Fig 27: Geometry of Tyre Spokes

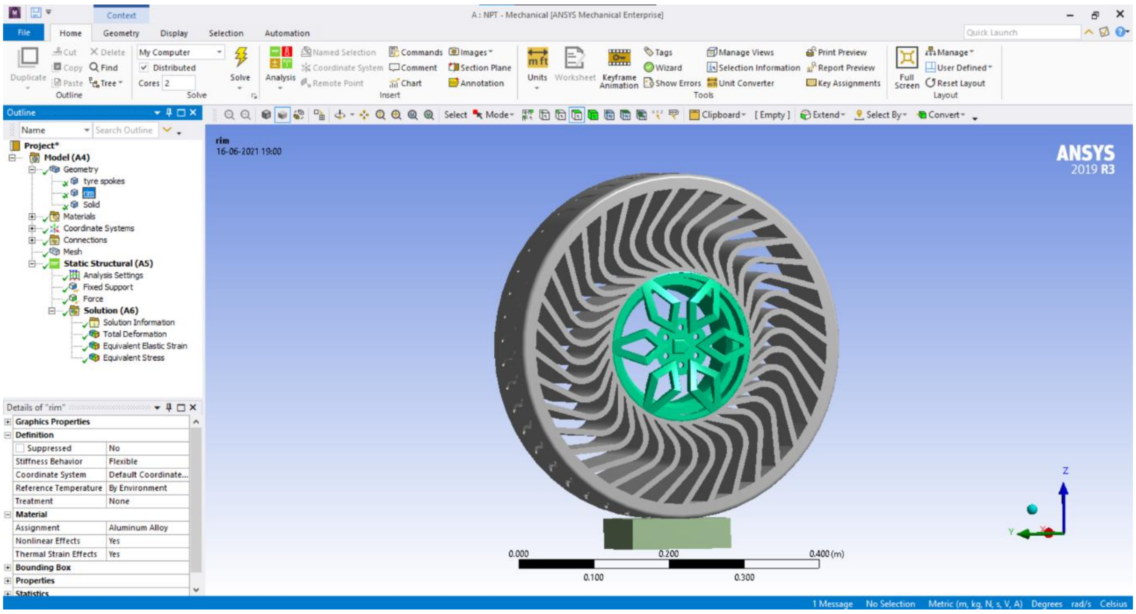


Fig 28: Geometry of The Rim

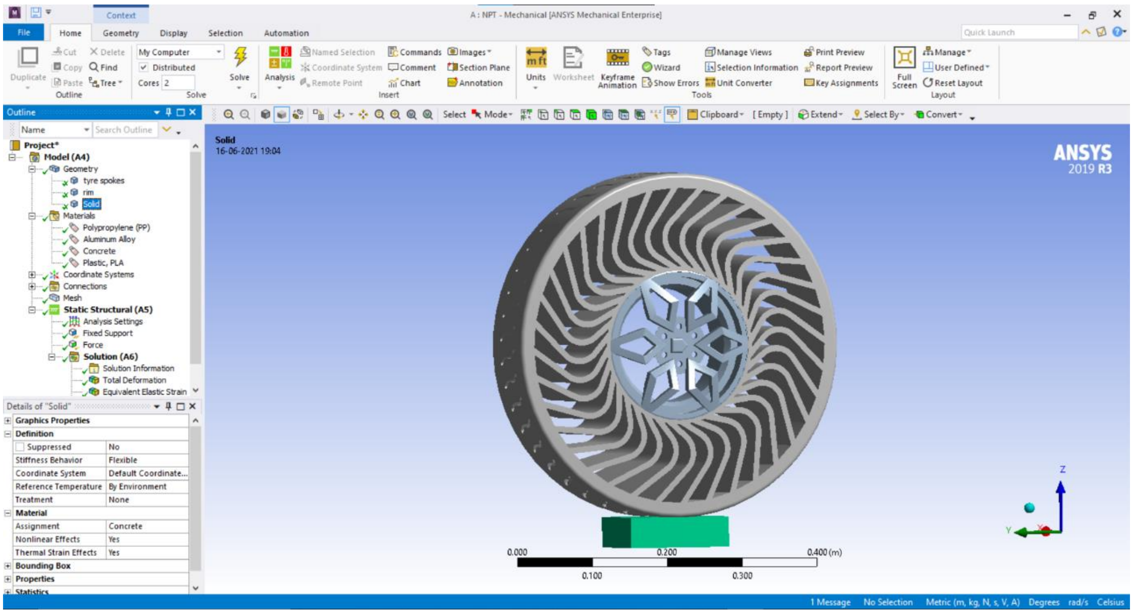


Fig 29: Geometry of The Solid

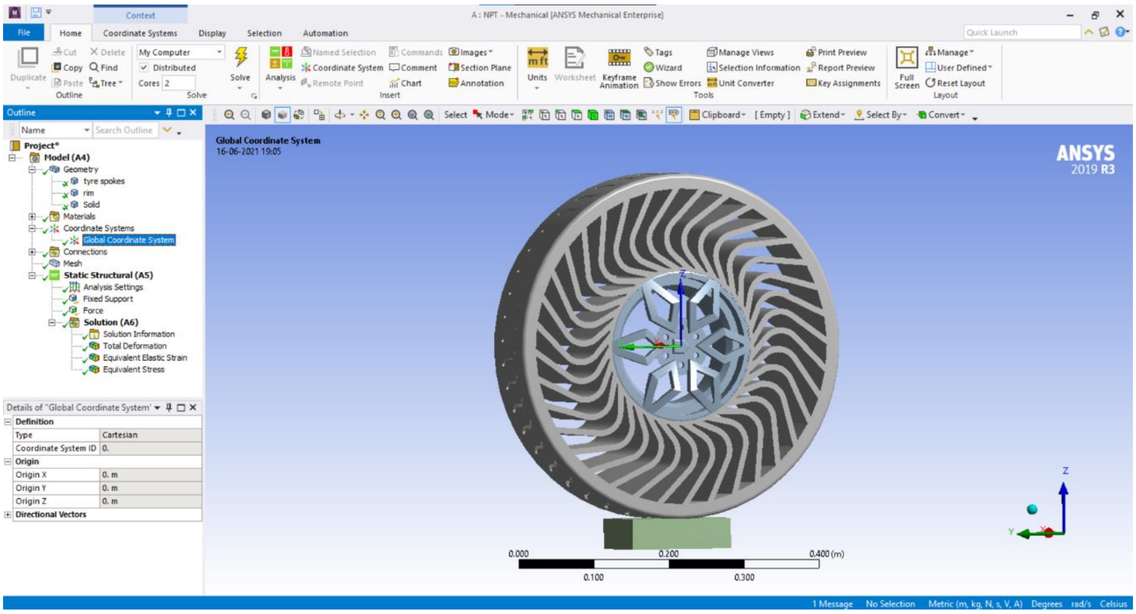


Fig 30: Coordinate Axes Along the Tyre

After assigning the materials for each part off the product under materials tool, we can see the connection parts in the product. There are two connection regions in our product. Red colour region indicates the contact bodies and the blue colour region indicates the target bodies. They are shown in the below figures.

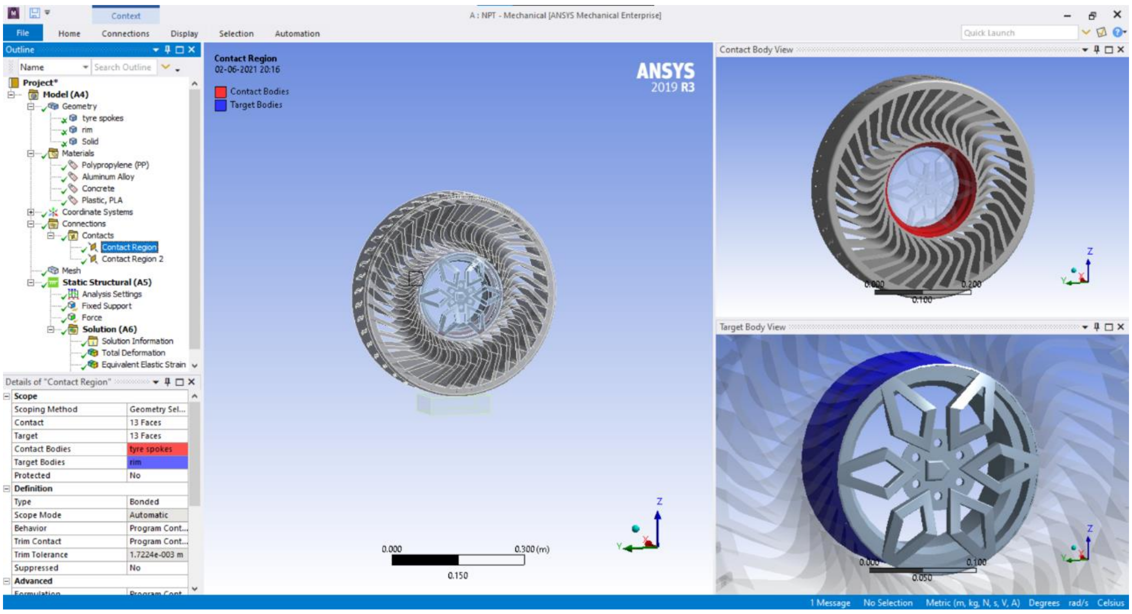


Fig 31: Contact Region-1 (Tyre Spokes and The Rim)

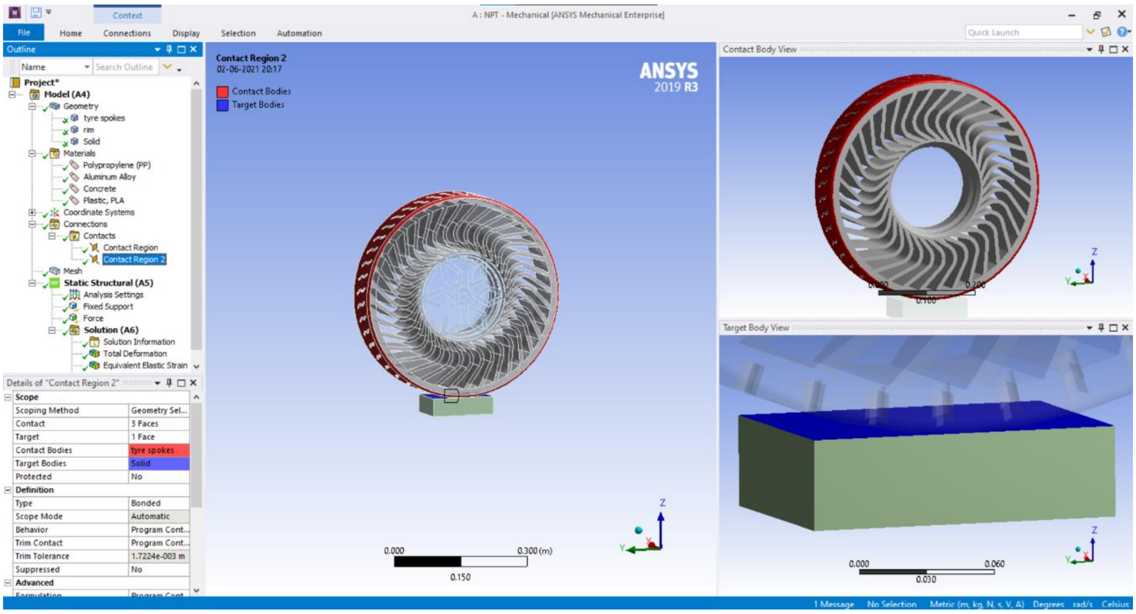


Fig 32: Contact Region 2 (Solid and The Tyre Spokes)

Generation of mesh: to generate the mesh model, a fixed support and the required force in the specific direction has to be defined in the static structural. After assigning the support and the force, we should solve the model to generate the mesh.

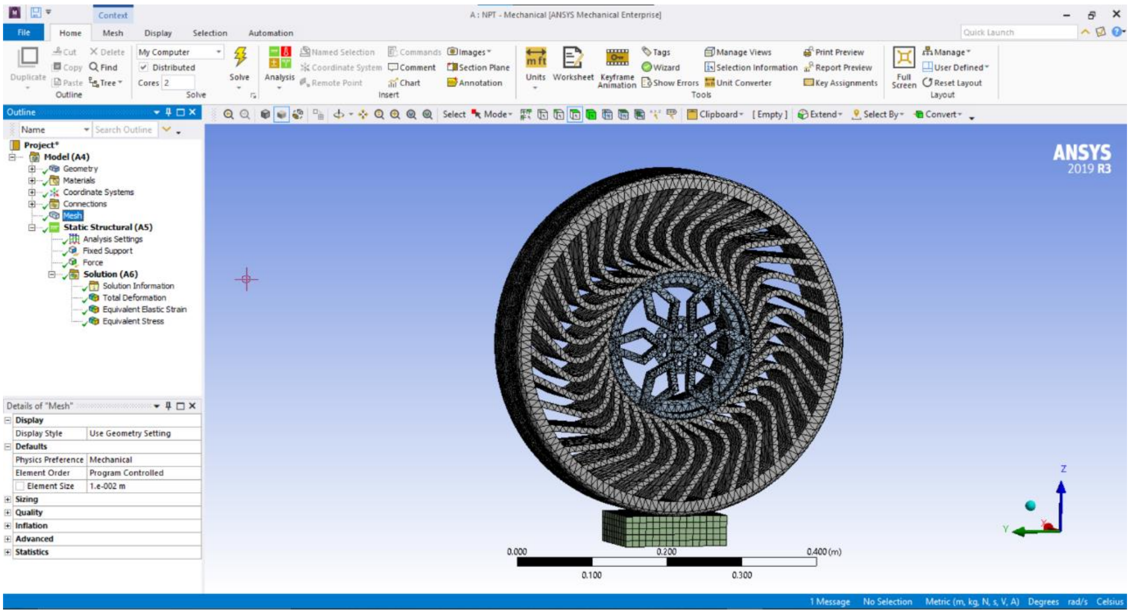


Fig-33: Mesh Model

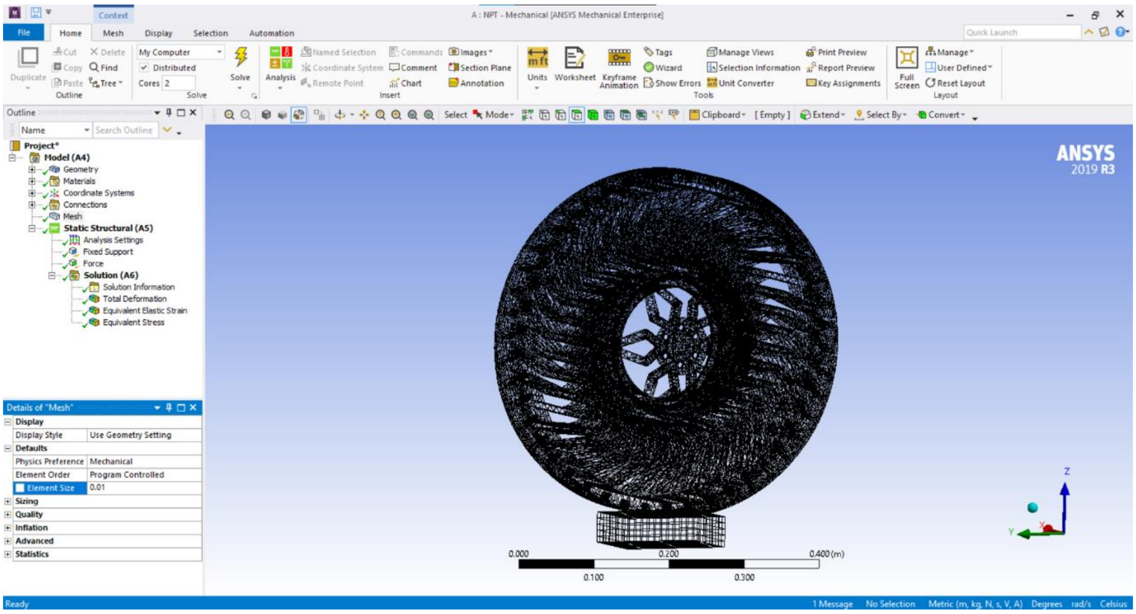


Fig-34: Wire Frame Model

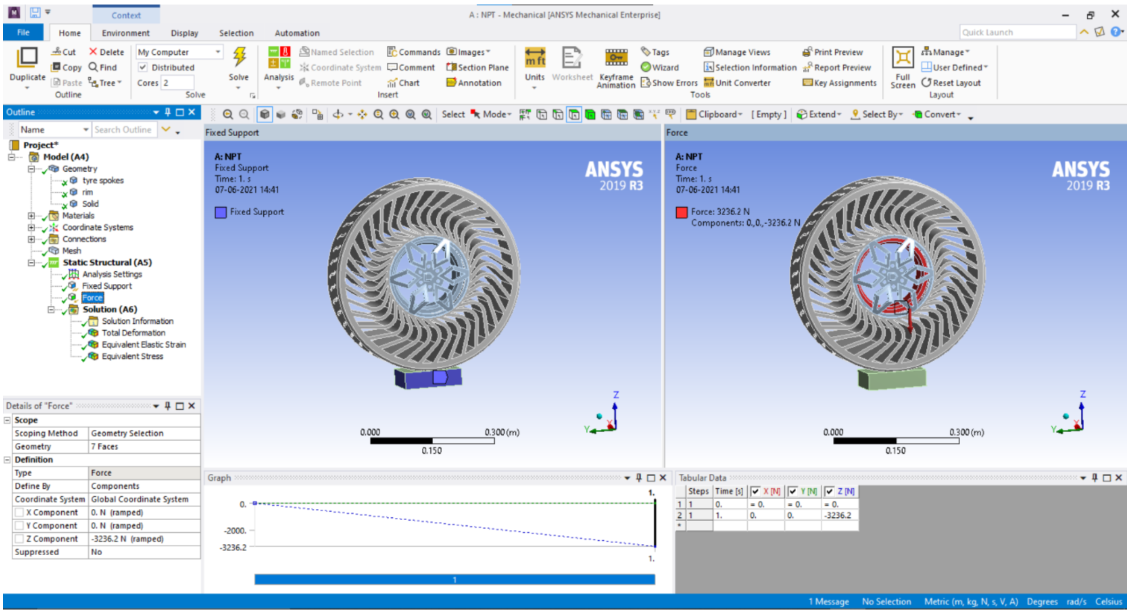


Fig 35: Static Structural

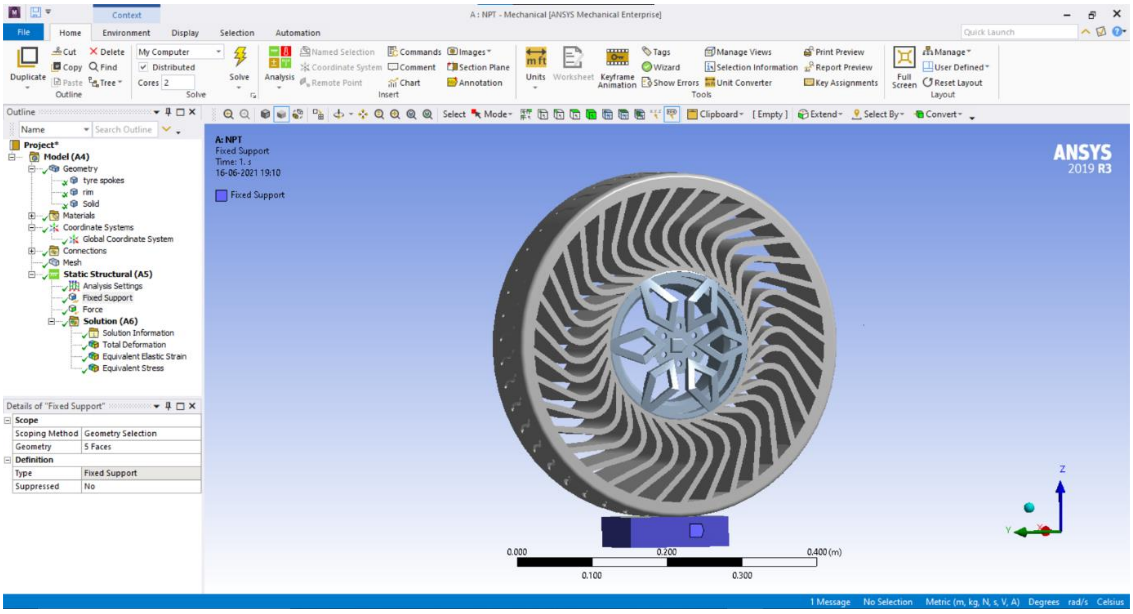


Fig 36: Fixed Support of The Tyre

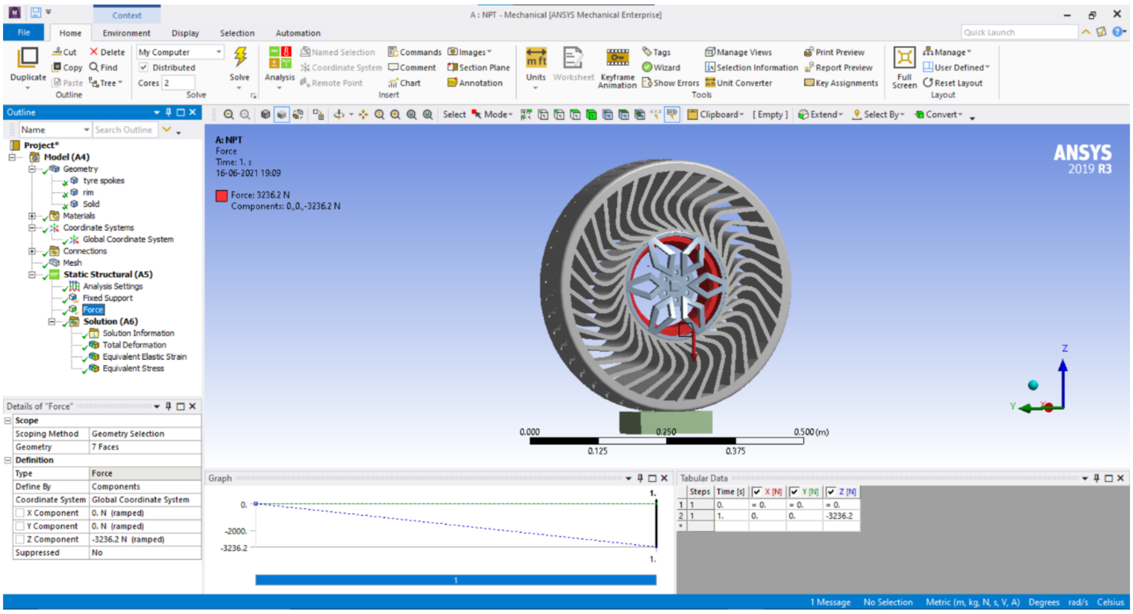


Fig 37: Force on The Tyre

(F=3236.2n)

S.No	Weight	Kilograms	Distribution of Force on One Tyre	Distribution of Weight on One Tyre (Newtons)
1	Compact car	1040	260	2,549.729
2	Four Passengers (Approx.)	210	70	686.4655
3	Total weight	1250	330	3236.2

Table-4 Forces on theTyre

Now the solution for the model is done and required solutions should be added. After solving the model, the total deformation, equivalent stress and Equivalent elastic strain results can be seen under the solution.

4.6 Analysis Solution

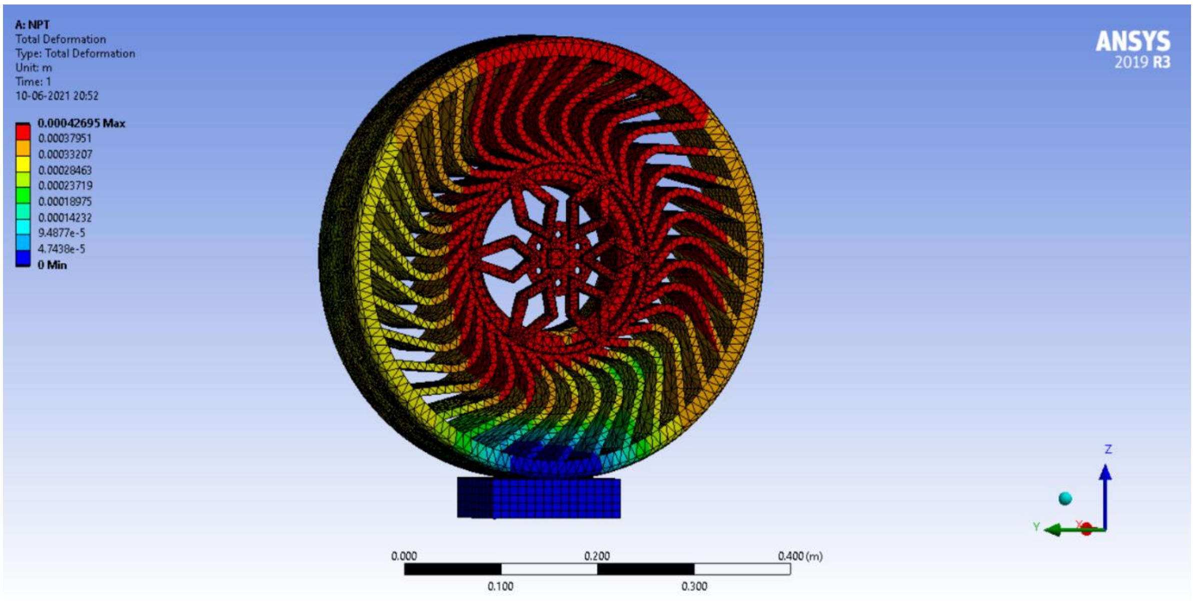


Fig 38: Total Deformation

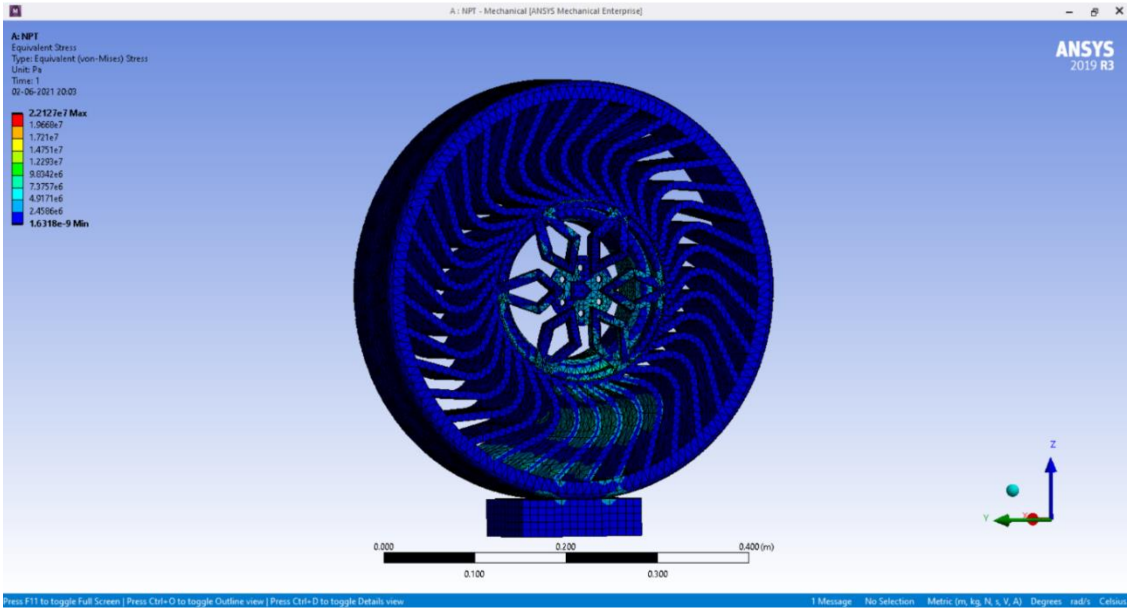


Fig 39: Equivalent Stress

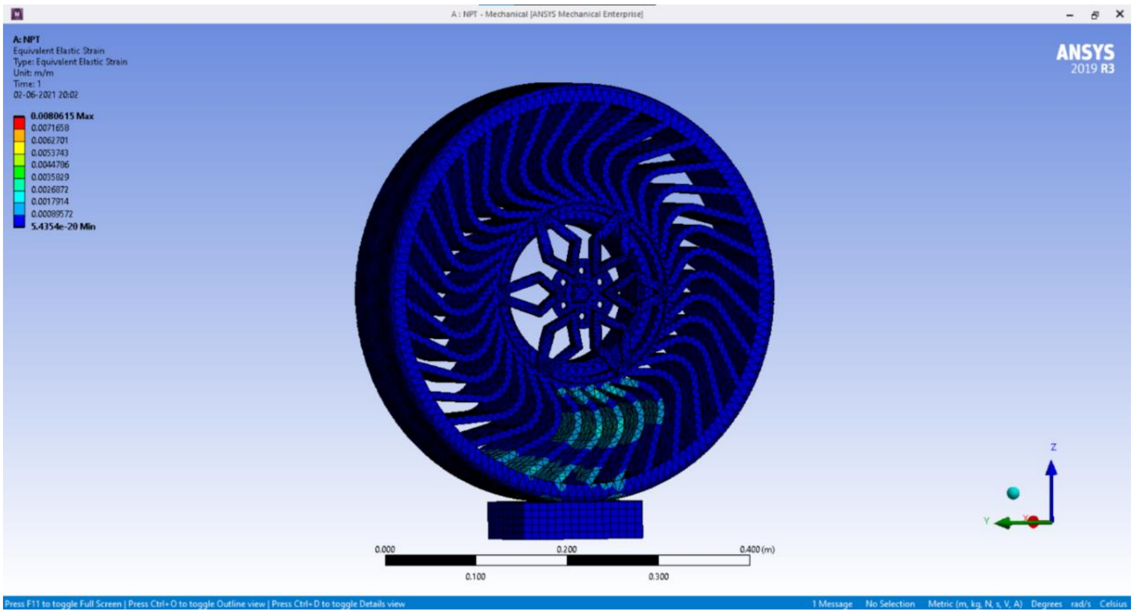


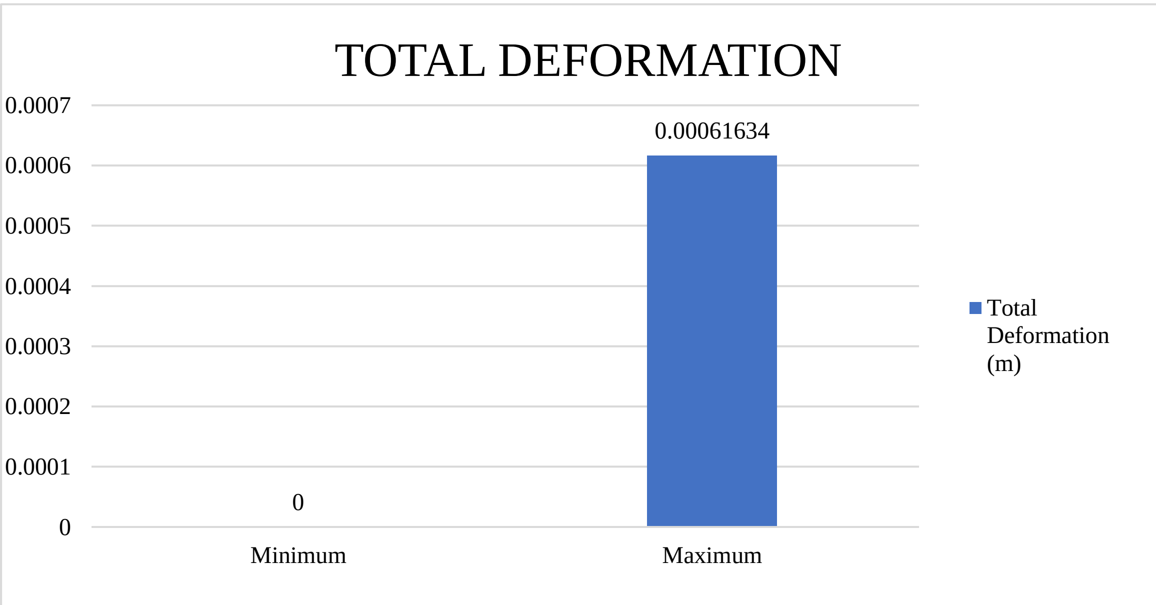
Fig 40: Equivalent Elastic Strain

4.7 Result

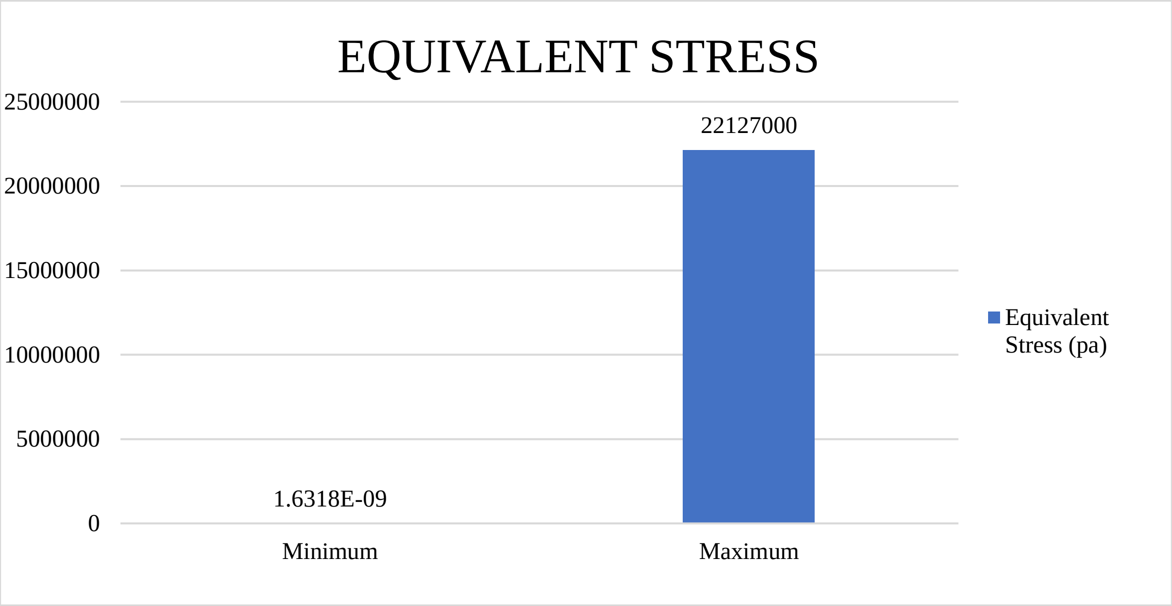
S. No	Type	Minimum	Maximum
1	Total Deformation(m)	0	0.00061634
2	Equivalent stress	1.6318e-9	2.2127e7
3	Equivalent elastic strain	5.435e-20	0.0080615

Table 4: Result

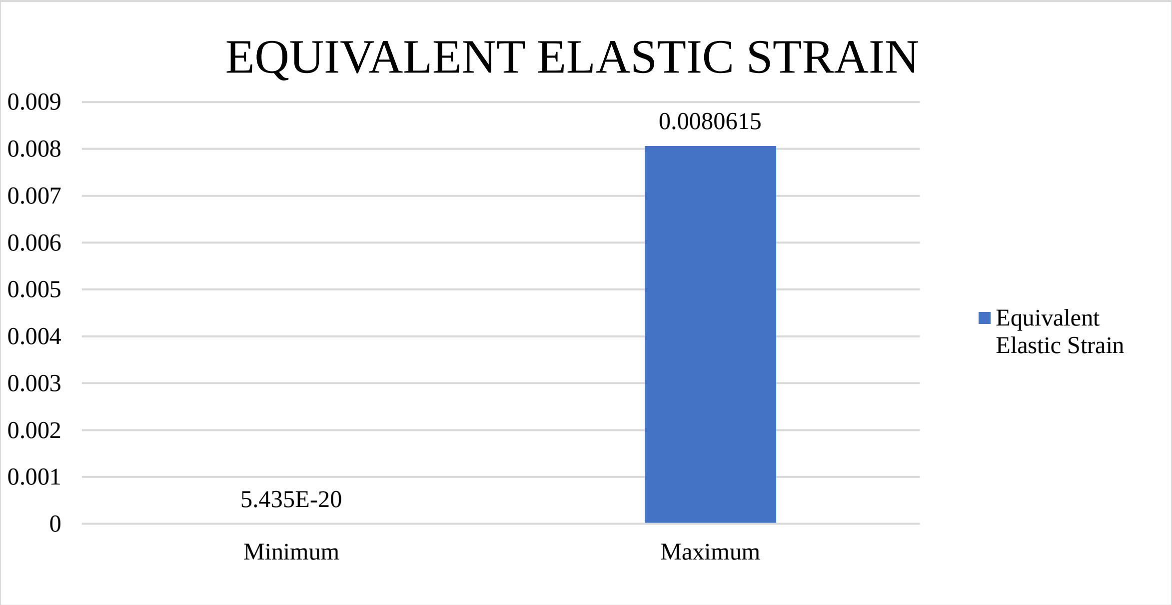
4.8 Graphs



Graph 1: Total Deformation



Graph 2: Equivalent Stress



Graph 3: Equivalent Elastic Strain

CHAPTER 5 PROTOTYRE

5.1 Prototype of The Product By 3d Printing

3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as plastics, liquids or powder grains being fused together), typically layer by layer.

By considering the design and the analysis the product prototype of the tyre is 3D printed.

5.1.1 Specifications of 3d Printer:

Process: Fused Deposition Modelling

Bed size: 200*200*200

X, Y Axis Positioning Resolution = 0.02mm

X, Y Axis Maximum Speed = 5000mm/min

Z Axis Positioning Resolution = 0.005mm

Z Axis Max Speed = 1000mm/min

Material Support = PLA

Position Resolution = 0.1mm

Filament Temperature = 210

Maximum Temperature = 260C

Software format = STL, G Codes

Total Print Time = 40hrs

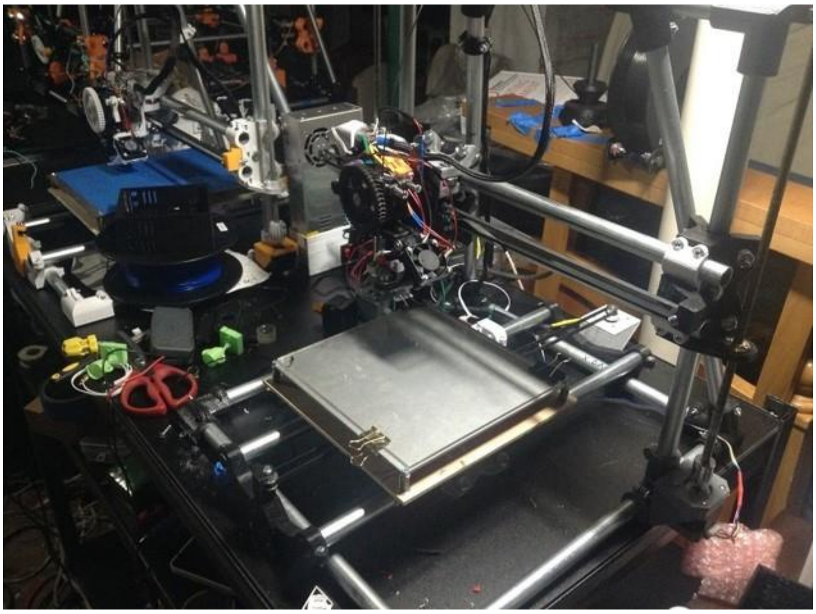


Fig 41: 3D Printer

5.2 Final Prototype of The Tyre:

Fig 42: Prototype of Tyre

Fig 43: Prototype of Rim

Fig 44: Assembly of the Tyre

CHAPTER 6 CONCLUSION AND FUTURE ENHANCEMENT

Conclusion

- The design of the tyre is done in NX cad software and the deformation analysis of the tyre is done in Ansys Workbench. The deformation of the tyre after the analysis with the PLA material to the tyre is 0.00061634. The dimensions are considered from the original equipment manufacturers standards. The structural analysis is carried out by considering the force applied to the tyre.

  The references taken for the load on the tyre is a curb weight of the compact car and applying the force on the required part. The Air-less tyre with deformable spokes would be able to replace the existing traditional pneumatic tyres in the present market.

- The prototype of the model is done by 3D printing. The creation of 3D printed object is achieved using additive process. In an additive process an object is created by layering down successive layers of material until the object is created.

- The properties of NPT like contact pressure, rolling resistance and load carrying can be varied by altering the dimensions or different materials used to manufacture NPT.

Future Enhancement

- The concept of Airless tyres will increase the safety of cars by limiting the speed of the vehicle as well as have a positive impact environmentally. Many Organizations like Micheline and Bridgestone are developing and readily looking forward to launching airless tyres by 2024.

- The tyres require less maintenance and the worry of puncture is eliminated. The materials used in the tyre and the spokes are 100% recyclable. The airless tires may be successfully implemented especially in the design of electric road vehicles and also in many fields such as outer space mission rovers, military appliances, wheelchairs etc. In the farming, mining, and construction industries, tyre failure can cause a loss of productivity and efficiency. Tyres that never leak or puncture would be a welcome advancement. Airless tyres can be a revolutionary concept in the future.

Publication

- Conference
- ICRIM-2021
- "Online International Conference on "Robotics and Intelligent Manufacturing"

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A Major Project Report
On

DESIGN AND DEVELOPMENT OF AIR PURIFICATION SYSTEM

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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M. KAVYA SRI	–17K81A0386
M. YASHWANTH KUMAR	–17K81A0396
P. SHIVA SAI KRISHNA	–17K81A03A5

Under The Guidance of

Dr. D. V SREEKANTH

Professor & Head of the Department

DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

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Dhulapally, Secunderabad – 500 100

JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the major project report entitled **"DESIGN AND DEVELOPMENT OF AIR PURIFICATION SYSTEM"** is being submitted by **"B. NITHIN GOUD (17K81A0366), M. KAVYA SRI (17K81A0386), M. YASHWANTH KUMAR (17K81A0396), P. SHIVA SAI KRISHNA (17K81A03A5)"** in partial fulfilment of the requirements for the award of the Degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Signature of Guide

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place :

Date :

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical engineering**, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **"DESIGN AND DEVELOPMENT OF AIR PURIFICATION SYSTEM"**, is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

In present scenario due to increase in industrialization air pollution is one of the biggest problems all over the world. Air pollution is mixture of industrial smog, solid dust particles, harmful bacteria and harmful gases in the air. Air pollution isn't just outside but also inside buildings. Polluted indoor air is most commonly found in homes in larger cities. The dust mites, smog, smoke from kitchen, outdoor pollutants together pollute the air inside building. Breathing air with contaminants like this can adversely affect person's health. There are several methods to purify the polluted air, some are using HEPA filters, chemical ionizers, ozone generators etc. These methods works great but worried about by-products released like ions and ozone in ionizers and ozone generators are harmful and can cause health hazards. This project works for a solution to these problems and developed an air purifier which can remove contaminants without producing any by-products. In this project, the main objective is to build an air purifier with maximum efficiency which supplies purified air at high CFM (cubic feet per minute). In this project a fan with high air extraction capacity is used to extract the air from surroundings through filter components to filter and deliver purified air at required speed. This purifier comes with a 3-stage purification system includes pre-filter trap dust particles (like hair, paper, wood dust, tiny particles), a true HEPA filter trap PM2.5, PM0.3, pollen, an activated carbon filter trap chemical waste, domestic waste, bad smells and harmless UV light to kill bacteria and viruses. A regulator is used to control the speed of purified air and a sensor with display unit is used to detect the air quality and display air quality index.

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CHAPTER-1
INTRODUCTION

1. Introduction:

Factories, vehicles and use of non-renewable energy pollutes the air around the cities. In India and most of the populated countries this is a major problem, the polluted cities in these countries are home to more than 1 billion citizens. The solution that peoples use to clean the indoor air in the polluted areas are called air purifiers. It is a device that most people that are affected by poor air quality keep in their homes and offices. The air purifier's function is usually to create an airflow in the home by suction from a fan inside the device. The air then passes through some sort of filter media which traps the polluted particles, and out comes clean air. However, most air purifiers on the market today are using only HEPA filter, which doesn't remove all the pollutants. Some air purifiers using ionizers, ozone generators as filter media which release ions and ozone into atmosphere which is unhealthy. This solution is rather costly and is not suitable for everyone.

1.1. Background

Most people have the apprehension that air pollution, at a dangerous level, only occur in parts of Asia and in the very largest cities. But now larger cities in India are facing the same kind of problem. Drastic solutions are done in Mumbai and Delhi where they occasionally have turned down traffic to reduce air pollution. In China, it is very common to have an air purifier at home to prevent living in polluted air. In India, this is still not common but a growing awareness may lead to an increased demand for air purifiers. The project brief was to develop an air purifier with high performance index at low cost. As mentioned earlier, most air purifiers that are available today function and look more or less the same, and most of them uses HEPA filter technology for cleaning the air. In this project uses triple layer filtration technology which include removing bad odours and bacteria rather than removing only dust mites, smoke etc. The function of all active components and their working principles is described in detail in next chapter.

1.2. Motivation:

Living in a house with pollutants is very dangerous. With increasing population, we cannot stop the industrialization and usage of automobiles, Non-renewable energy sources which produce pollutants. But we cannot leave this issue a side because it can be dangerous to us, an alternate option has to be determined and should be implanted as soon as possible to avoid problems and huge loss to mankind.

Thus, there is a need of developing an air purifier which can filter air from pollutants. The air purifier should be portable, efficient and easy to operate. In this project we are developed an air purifier with triple layer filtration technology which provide high performance index.

1.3. Problem Statement:

Air pollution in India is a serious health issue. Out of the 30 most polluted cities in the world, 21 were in India in 2019. As per a study based on 2019 data, at least 140 million people in India breathe air that is 10 times or more over the WHO safe limit. The 51% of pollution is caused by the industrial pollution, 27 % by vehicles, 17% by crop burning and 5% by fireworks. The quality of indoor air is concerned more and more by the government and the Public in India nowadays. The indoor air regarding the health effects is becoming a serious challenge in both urban and rural areas of country. In order to further study the factors which effects of the indoor air quality it is very important for us to know clearly what the major indoor airborne particulate pollutants.

Adherence to the increasing awareness towards protecting the environment in development, this project emerges as a tool to help and enable the determination of the factors that increase of PM (particulate matter) levels within the house and controlling them.

Various studies have shown that presence of occupants, outdoor air speed, location characteristics and quality of ventilation system are large contributor to the generation of particulate matters concentration. In order to improve the quality of indoor air, existing research works will be developed on the methods which will be discussed in the following chapter.

1.4. Project Objectives:

The main objective of the project is to design, develop and test a portable air purification system, to provide best output in improving indoor air. Design an Air Purifier which operates with 3 advanced stages of filtration using: a cellular-activated carbon filter, a HEPA filter, and a UV sterilizer.

According to data in 2017, 1.2 million deaths are caused in India due to air pollution". Nowadays cleaning of air becomes mandatory in the Sense of public health. It helps in preventing air pollution.

1.5. Methodology:

The well implemented project needs a plan of action and specified steps for its completion. The project started with gathering the information regarding pollutants in indoor air and their effects on health and finding the problem statement for the project. Then the literature survey was made to gather the information on the devices already existed relating to our project. Then the main objectives were identified along with the scope. Based on the gathered information different assumptions and ideas were developed and the best alternative was chosen.

After finalizing the idea, different rough sketches were drawn and a best sketch was selected. This sketch was converted into 3D model using SolidWorks and analyzed for stress and strains develop for different forces applied on it. The 3D model is converted into physical state using 3D printing method which is the outer casing of the project. The necessary components like filters were manufactured, sensors and display units were purchased. Physical structure of purifier consists of hollow cylindrical with several holes in lower portion for air to enter into it and the upper portion is used to place sensors, circuits, display unit and other control systems. The 3 filters specified were placed in lower portion and an axial fan was kept at the upper portion of the body. Arduino code was developed for air quality sensor and UV sensor and uploaded to Arduino module to sense the values.

CHAPTER-2
LITERATURE REVIEW

2.1.Introduction:

To gather relevant information for this project a literature review was conducted to act as a framework for the project. This is done to find useful relevant information from reliable sources about the intended subject of research. The literature review consisted of articles and books mainly touching areas of green product development and air purification technologies.

2.2.Literature Review:

Germany, brothers Klaus and Manfred Hammes purchased a patent for a simple air filtration system. Using a fiberglass pad attached with small magnets to the air outlet of a residential oil oven, the Hammes brothers were able to filter soot from the air. In 1963, the 31 Hammes brothers simple but effective filter became the first air cleaner to be utilized in homes across Germany.

In the same year, US Congress passed the Clean Air Act of 1963 to set standards for the reduction of air pollution through fuel emissions standards. Although it was not Congress first attempt at reducing air pollution, the Clean Air Act of 1963 alerted scientists and consumers of the need to protect our lungs from pollutants such as perfumes, building materials, chemicals, pesticides, and allergens.

No longer classified as top-secret, HEPA air filters became popular in the 1970s and 1980s as more consumers became concerned about air pollution. With the introduction of dozens of products featuring HEPA filters, new and exciting ways to control allergies and asthma finally became widely available for residential use. Originally, the first HEPA air purifiers were bulky, difficult to operate, and traditionally used only in hospital and pharmaceutical settings and among computer chip manufacturers. Then businesses began to take notice of indoor air quality concerns among residential consumers.

In response to the growing demand for clean air, Incent AG, the Hammes brothers newly formed company moved to Switzerland and began developing and manufacturing residential air purifiers in 1971. After many years of international success for Incent AG, Frank Hammes, son of Klaus Hammes, began to distribute cabin air filters as add-on accessories for Mercedes-Benz automobiles in 1990.

In 1991, Frank Hammes formed IQ Air North America, which has promoted the continual growth and success of the air purification industry. In 1991, through the amazing technology of True Medical HEPA and Activated Carbon, Richard Taylor created a filter that addressed the issues of environmental particulate contamination, chemical toxicity, and odors. It was then that he and his wife Joyce founded Austin Air Systems Limited. Based out of Buffalo, NY, Austin Air introduced a pre-filter that ensured a HEPA filter life unequaled to anything in the industry. Austin Airs 360-degree intake system draws air into all sides of the air cleaner, maximizing efficiency and delivering more clean air faster. With the largest air cleaner manufacturing facility in the world, Austin Air continues to produce all the parts for their fantastic air purifiers. • Established in 1992, Aller Air quickly became a trusted name in air purification. After a family member of Aller Air founder Sam Teitelbaum developed Multiple Chemical 32 Sensitivity (MCS), Teitelbaum and partner Wayne Martin decided to develop their own air cleaner. Using the combination of true HEPA filters and a MAC-B (mass activated carbon bed) filters, which contain pounds of carbon, Aller Air created an air purifier that safely and effectively removes chemicals, gases, and odors from the air. With offices in the United States, Italy, and Canada, Aller Air purifiers are used by the Mayo Clinic, IBM, Gucci, Prada, and the U.S. Army. With more than 100 model to choose from, Aller Air cleaners are efficient, practical, and cost effective.

With headquarters in Stockholm, Sweden, and Chicago, the Blue-air air purifier company is committed to creating a healthier environment both indoors and out. Founded in Sweden in 1996, Blue-air quickly earned a reputation for high performance, technological innovation, and quality design. A revolutionary combination of mechanical and electrostatic filtration allows Blue-air purifiers to capture 99.97% of irritating particles, gases, and odors. With more than five different models, these powerful yet near-silent air cleaners provide a visually-pleasing form and highly effective function.

Now a global leader in the production of specialty products and chemicals and a subsidiary brand of Katz, Honeywell started as a hot water heater company in 1906 and has a longstanding tradition of supplying safe, reliable, and high-quality products. Acquired by Katz in July of 2002, Honeywell’s indoor air quality products continually meet and exceed the American Lung Associations Health House guidelines with meaningful innovations based on consumer research and insights. With the use of permanent, lifetime HEPA filters, Honeywell air cleaners remove 99.97% of all common, household particles such as dust, pollen, tobacco, smoke, and cat dander. The Honeywell glass-fiber HEPA material helps remove airborne particles without the use of expensive ultraviolet bulbs, chemicals, or other treatments. With a diversity of products to fit your needs, Honeywell offers a series of Home Comfort and Indoor Air Quality Solutions.

In 2002, IQ-Air air purifiers became the first air cleaners to incorporate H13 class certified HEPA filters, which capture up to 100 times more particles than conventional HEPA filters. H13 class certified HEPA filters, up to that point, had only been used in hospital clean rooms.

Although no longer a top-secret government project, air purifiers still hold the secrets to cleaner air and healthier environments for many asthma and allergy sufferers. Today HEPA air purifiers and filters are used in a variety of critical filtration applications in nuclear, electronic, aerospace, pharmaceutical and medical fields, as well as in homes around the world.

CHAPTER-3
DESIGN AND ANALYSIS

3.1 Introduction to Solid works:

The SolidWorks® is a CAD software which is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

CONCEPTS

Parts are the basic building blocks in the SolidWorks software. Assemblies contain parts or other assemblies, called subassemblies. A SolidWorks model consists of 3D geometry that defines its edges, faces, and surfaces. The SolidWorks software lets you design models quickly and precisely.

SolidWorks models are:

• Defined by 3D design

• Based on components

3D DESIGN

SolidWorks uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies. When designing a model using SolidWorks, you can visualize it in three dimensions, the way the model exists once it is manufactured.

COMPONENT BASED

One of the most powerful features in the SolidWorks application is that any change you make to a part is reflected in all associated drawings or assemblies.

SOME IMPORTANT SKETCH TOOLS:

A part is the basic building block in the SolidWorks software. In this procedure, you open a new part document where you will build a model.

1. Click **New** (Standard toolbar) or **File** > **New**.

2. In the New SolidWorks Document dialog box, click **Part** and click **OK**.

SKETCH- This command is used to create the new sketch like circle, line, rectangle, ellipse, etc,

The SOLIDWORKS window selects the sketch icon and selects the plane or surface want to sketch.

CIRCLE- This command is used to create the circle. Create circle by picking the centre point and a point on the circle from Right Tool chest. Pick the origin for the circle's centre -pick a point on the circle's edge-click ok

LINE- This command is used to create the line. Create the line by start point and end point.

FILLET- This command is used to create the round corners. Create the round corners by selecting the required edges to be rounded. Chamfer is also same as fillet but creates slope edge instead of round corners.

RECTANGLE- This command is used to create the rectangle and square.

Click the rectangle icon in the right Tool chest –click the lower left point of the rectangle and higher right corner of the rectangle we want to draw.

After drawing the rectangle, the dimension of the rectangle is provided by the pick the dimension command from the dimension icon in the right tool chest of the pro-e software.

DIMENSION- This command is used to provide the dimension of the sketched entities the entities may be circle, line, rectangle, ellipse, etc,

The dimension is providing to the sketch by select the dimension icon from the right tool chest then select the sketched entities and press the middle mouse button to finish the dimensioning.

To change the dimension of the sketched entities by just double clicks the dimension line of created sketch.

EXTRUDE – This command is used to create the material (to make 3D object from 2D sketch) from the sketched entities. The entities may be circle, line or rectangle.

Select the extrude icon from the right tool chest then select the sketched part in the window, enter the extrude length and press the middle mouse button to finish the extrude command. There is a provision for removing material in pro –e which is called cut. The main condition to create the solid model is the sketched section must be closed.

REVOLVE- This command is used to create the material from taking the one axis and sketched entities. The axis is the centre of the revolved part. The revolve angle should between 0 degree to 360 degree.

3.2 Design of Air Purifier:

An Air purifier was designed with 3 stages of filtration : a True HEPA filter, an Activated carbon filter and UV sterilizer. In addition to this another stage namely pre-filter was used for enhancing the life of HEPA filter.

Activated Carbon Filter: Absorbs and collects dust, pet hair, allergens, smoke fumes and harmful gases.

HEPA Filter: Captures 99.97% of airborne contaminants like dust, bacteria, fungi, viruses, and allergens.

UV Light: Destroy micro-organisms such as germs, viruses, fungi and bacteria.

3.3 3D Model:

The below design is done in solid works and analysed in Ansys for various loads to test stress and vibrations it can withhold. In below figures shows the different views of design.

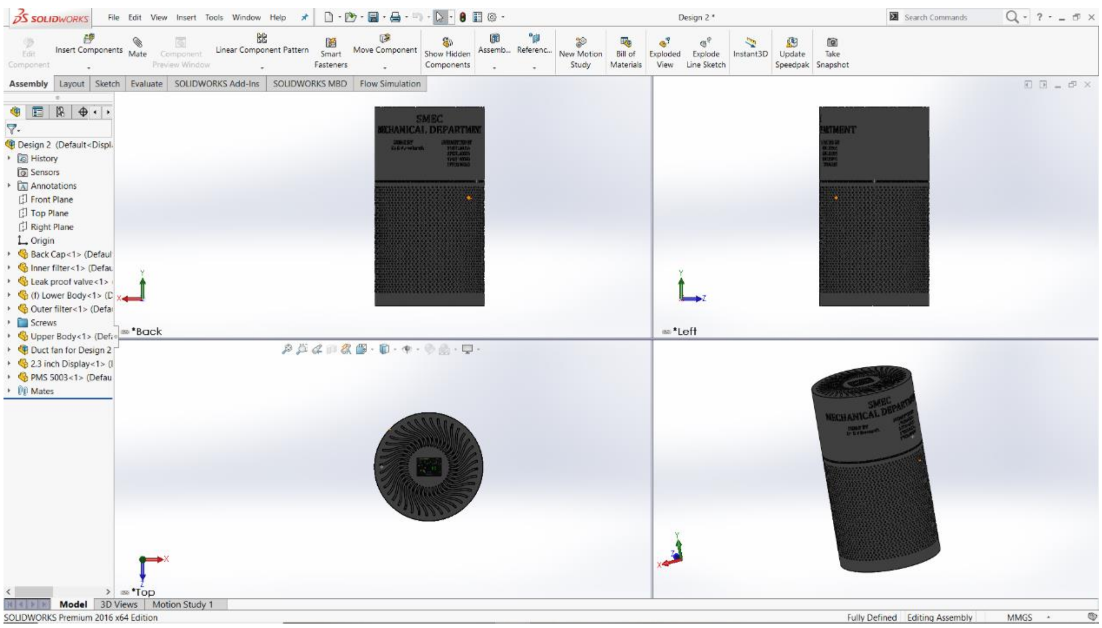

Fig 1 : Different views of 3D model

The above design was done in Solidworks using a list of tools like Circle, Dimensions, Extrude feature, Hole feature, Circular pattern, Filets and Text Wrap etc.,

Fig 2 : Photo Rendered view of 3D model

3.4 Draft Sheet:

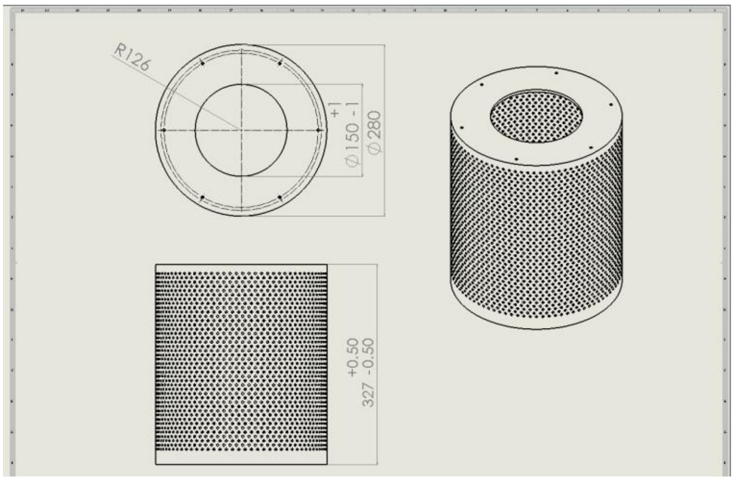

Fig 3 : Draft sheet of Lower Body

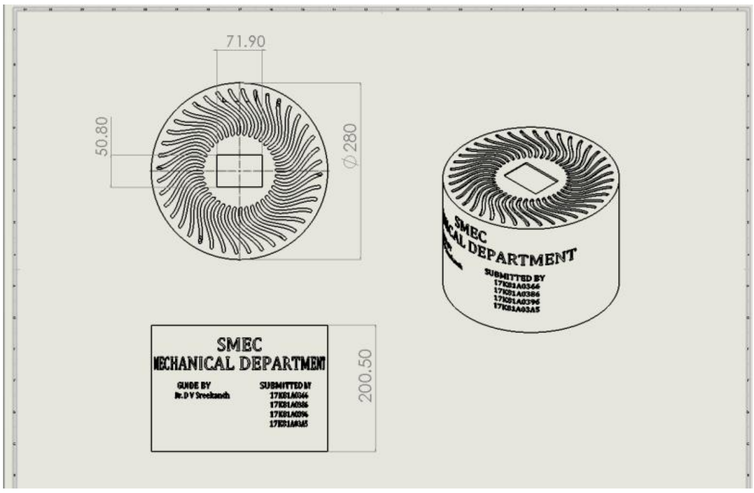

Fig 4 : Draft Sheet of Upper Body

3.5 SOLIDWORKS SIMULATION:

SOLIDWORKS Simulation is an easy-to-use portfolio of structural analysis tools that use Finite Element Analysis (FEA) to predict a product's real-world physical behavior by virtually testing CAD models. The portfolio provides linear, non-linear static and dynamic analysis capabilities.

Structural Simulation:

Structural Simulation solutions available to SOLIDWORKS users provide a comprehensive set of structural analysis capabilities to guide design decisions and improve product performance and quality

- CAD-embedded structural analysis solutions using Finite Element Analysis (FEA) to predict real-life performance
- Easy to use, comprehensive capabilities solve everything from a simple linear analysis of single components to complete simulations of full assemblies with contact and non-linearities
- Cloud-enabled solutions deliver access to powerful, proven, and scalable Abaqus technology from SIMULIA
- Understand product performance early in the design process to innovate more and avoid rework

Computational Fluid Dynamics:

Perform fluid flow and heat transfer simulation to improve quality and avoid manufacturing issues

- Explore fluid flow and thermal performance of products to accelerate product innovation
- A wide range of capabilities provides tools to easily predict steady-state and long transient flow and thermal behaviour of products
- Fully integrated multidisciplinary environment to quickly and easily conduct CFD analyses
- Collaborate with project stakeholders around fluid flow simulation results for informed decisions

3.6 FINITE ELEMENT ANALYSIS:

FEA consists of a computer model of a material or design that is stressed and analysed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

Stresses and Strains:

The mechanical structure is subjected to various pressure loads to observe the deformation due to the suction pressure developed by the fan. They have shown good results for a wide range of pressure < 15Mpa.

A Convergent-Divergent nozzle is used to increase speed of air at outlet. Fluid flow analysis is performed on nozzle to study the behaviour of nozzle. Fig shows the velocity, temperature and pressure trajectories starting from inlet to outlet

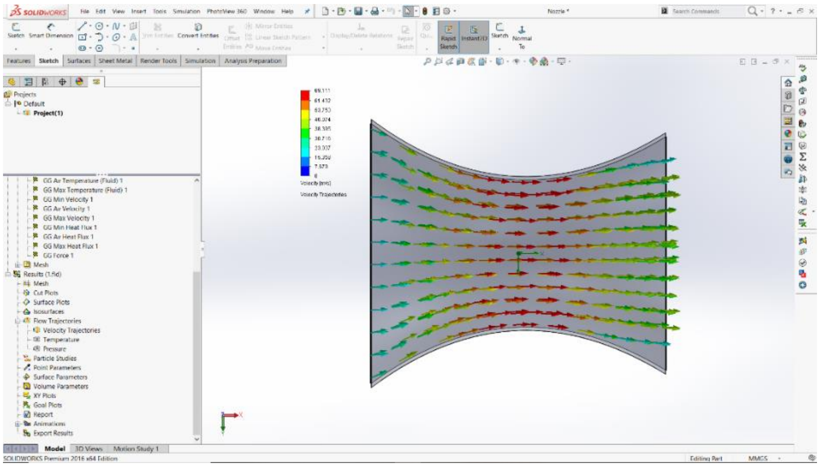

Fig 5: Velocity Profile

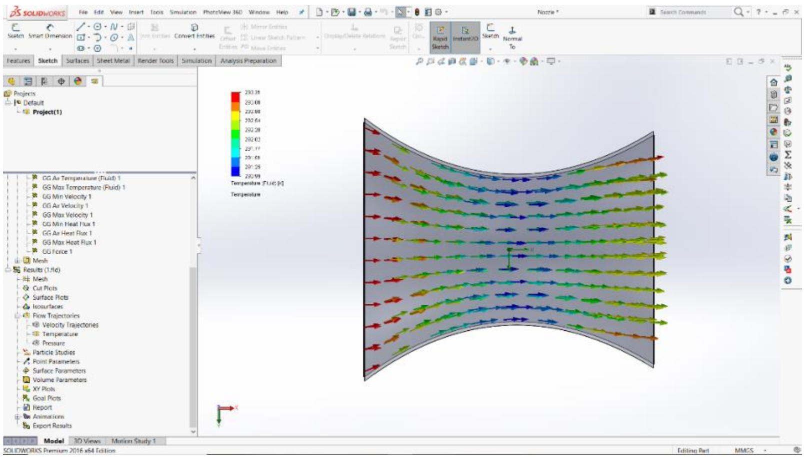

Fig 6: Temperature Profile

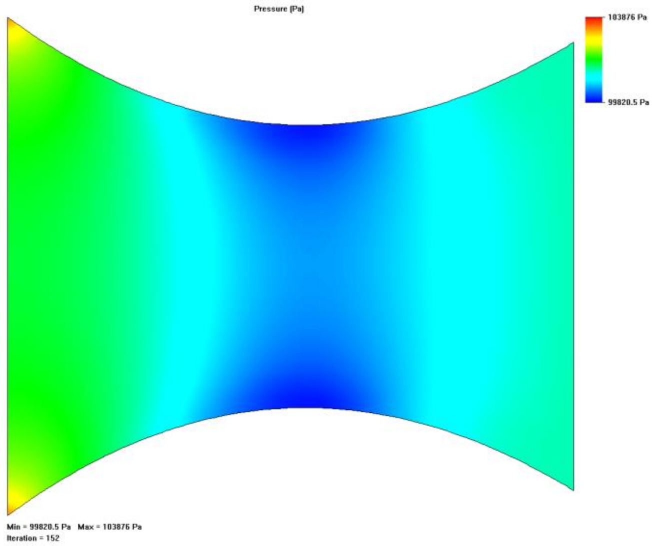

Fig 7: Pressure Contour

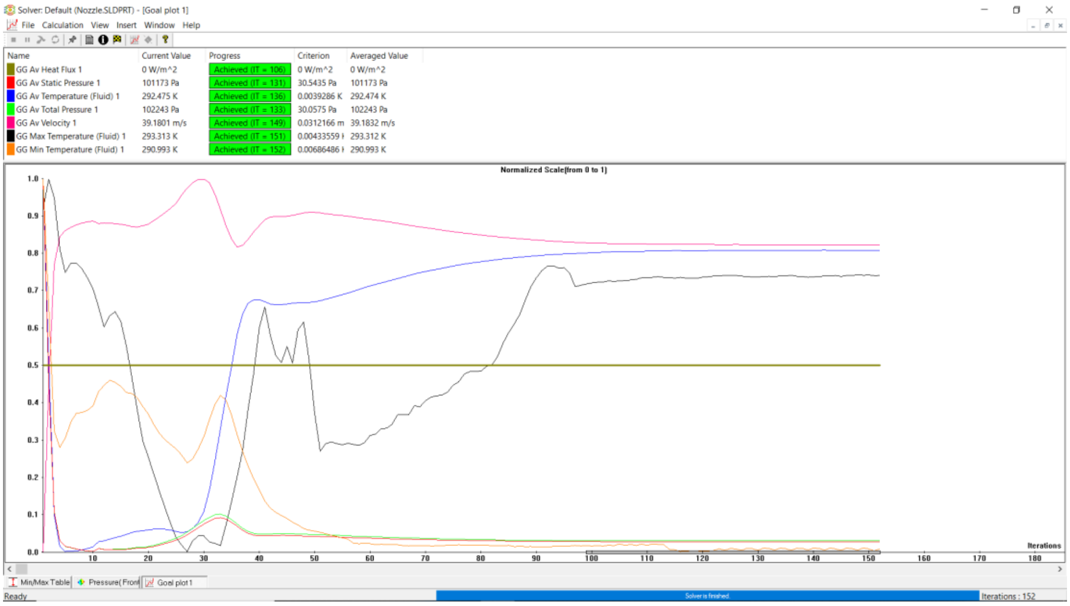

Fig 8: Graph distribution for pressure, temperature, velocity v/s No. of. Iterations

CHAPTER – 4

FABRICATION OF AIR PURIFIER

4.1 Fabrication Process:

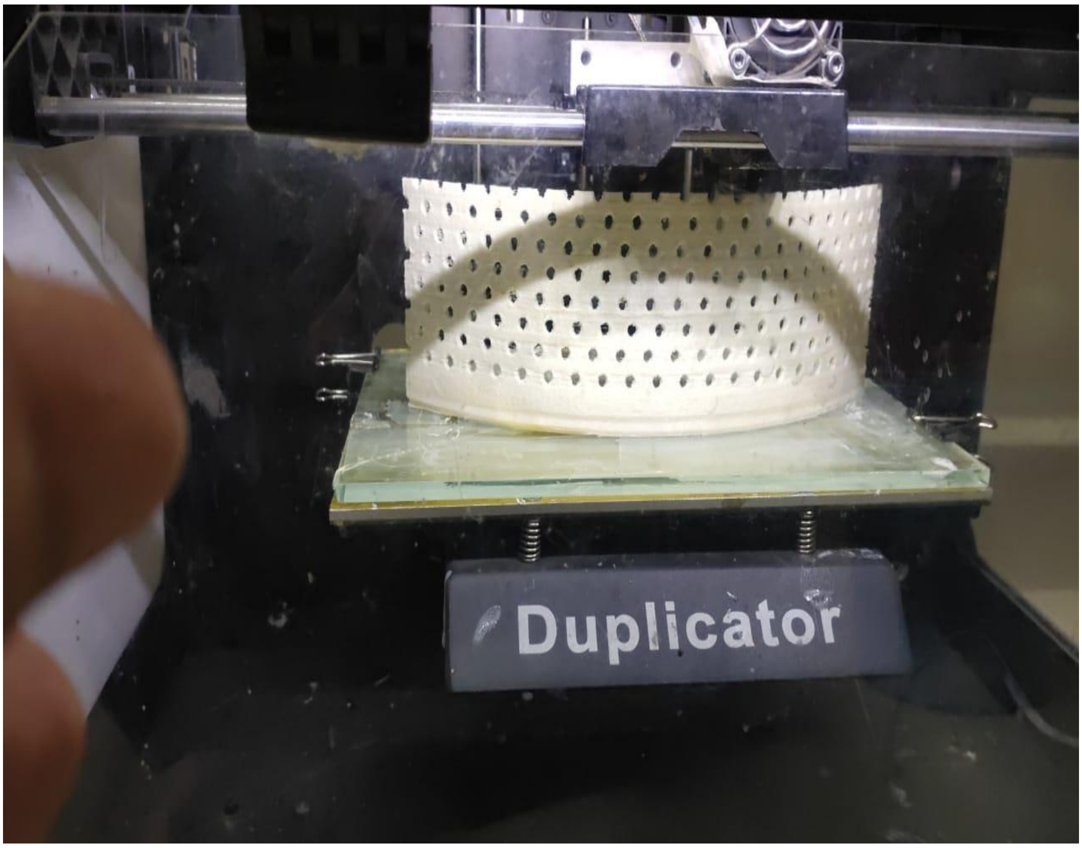

Fig 9: Fabrication Process

The figure above shows the fabrication of purifier body using 3D printing. The purifier body is fabricated by using FDM process and all the electronic and filter components are implanted inside the body at specified locations.

4.2 3D printing:

The outer body of air purifier is divided into 2 parts namely lower body where filters are placed and upper body where display unit and electronic components are placed. These parts printed using FDM (Fusion Deposition Modelling) process using ABS material.

The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as plastics, liquids or powder grains being fused together), typically layer by layer. 3D printable models are designed using CAD software and saved them in STL file format, then this STL file is examined for errors because most CAD software produce errors.

Fusion Deposition Modelling (FDM) is a 3D printing process in which an extruder is used to melt the material and deposit it on location specified in 3D model. It creates the 3D model directly from 3D CAD data.

4.3 Components:

The list of components and used for fabricating an Air Purifier is mentioned below.

1. Body:

The body was designed in Solidworks and fabricated using 3D printing. The most popular process of 3D printing was FDM it was widely used method because of it’s flexibility and easy usage. The body is divided into 2 parts namely Lower body and Upper body.

In Lower body all the three filters and the axial fan to extract the fresh air from chamber were implanted the main part of the project and it bears the load of all components. Since the components are too less in wait the load acted on the lower body was negligible.

The Upper body where the all sensors and circuits were implanted and the purified air comes out from this region. The electronic components are very small and produce less heat while working. The figure below shows the printed parts and assembled parts.

Fig 10: Upper Body

Fig 11: Lower Body

2. Filters:

- **HEPA Filter:**

HEPA TECHNOLOGY

HEPA is an acronym for High Efficiency Particulate Air and is a technology that has been used for many years to filter particles. HEPA filters must meet a standard of trapping at least 99.97% of all particles larger than 0.3 microns. The human eye can only see particles larger than 10 microns; so particles caught in a HEPA filter such as chemicals, bacteria and viruses cannot be seen. Because HEPA filters are able to trap mold and bacteria, they create a more sanitary environment. Additionally, this does not generate ozone or any other harmful byproducts.

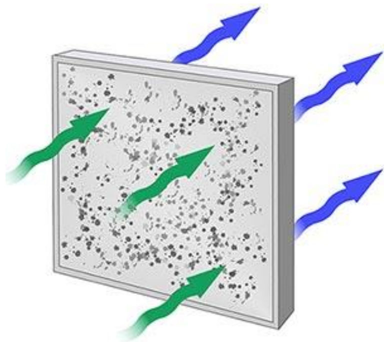

Fig 12: HEPA Filter Working

The HEPA filter is a very fine fiber-like material that has been folded back and forth to create the shape of an accordion. This accordion shape creates a maze of randomly arranged fibers and presents a very large surface for air to be pushed through by the air purifier fan. Airflow must have an opportunity to pass through the filter in order for it to be cleaned. 25 The more times airflow passes through the filter in an hour, the cleaner the air will become. As the HEPA filter becomes full, air will no longer be able to pass through and a new filter will be needed; however, a HEPA filter will typically last 2 to 4 years.

HEPA filters are made of boron silicate microfibers formed into a flat sheet by a process similar to making paper. Round filter sheets are pleated to increase the overall surface area. Pleats are separated by baffles which direct the airflow through the filter. Filter media is very delicate and should never be touched.

Fig 13: HEPA Filter

How HEPA filter Operates:

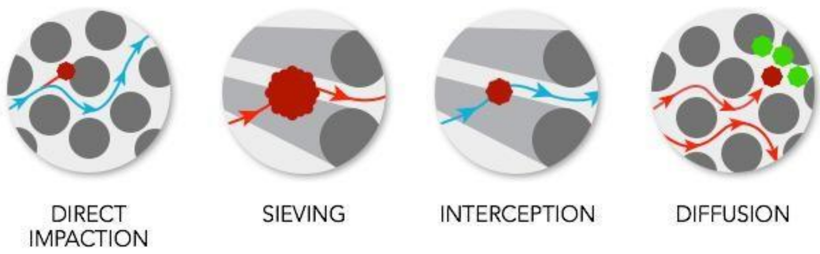

Fig 14: Filtration Methods

- Direct Impaction: Large contaminants, such as certain types of dust, mold, and pollen, travel in a straight path, collide with a fiber, and stick to it.
- Sieving: The air stream carries a particle between two fibers, but the particle is larger than the gap, so it becomes ensnared.
- Interception: Airflow is nimble enough to reroute around fibers, but, thanks to inertia, particles continue on their path and stick to the sides of fibers.
- Diffusion: Small, ultrafine particles move more erratically than larger ones, so they're more likely to hit and stick to fibers.

HEPA air purifiers are the most effective at trapping airborne particles; however, they do not remove odours, chemicals or gases. Therefore, most HEPA air purifiers have some level of activated carbon-based material to absorb odours and chemicals not caught by the HEPA filter.

- **Activated Carbon Filter:**

Elements like activated carbon, zeolite, or potassium permanganate are added to air purifier filters to increase efficiency to the filtering system. These elements work to absorb smoke, gases, chemicals, and odours that are present in the air. Activated carbon neutralizes odours and traps harmful chemicals and gases in its pores to provide relief from activities like secondhand smoke, off-gassing from plastics, and harmful fumes produced from renovations. An effective filtering system that is also equipped with chemical adsorption materials can produce cleaner and fresher-smelling air.

Fig 15: Activated Carbon Filter

- **UV Light:**

Ultraviolet light (UV) technology is key to neutralizing viruses and bacteria that accumulate on air purifier air filters. It is important to use the UV technology in combination with HEPA air filters and possibly activated carbon. Without a particulate filter system like a HEPA air filter, too many microorganisms may be hidden from the UV light, since it is not easily located on an air filter.

Fig 16: UV Light

3. **Axial Fan:**

An electric fan is used to pull air through the air purifier. The fan is usually purchased from a small-parts supplier. The fan consists of a small electric motor with metal fan blades attached to the motor's power take-off. The fan blades are usually spot welded to a collar, which is slipped onto the power take-off and bolted in place. The fan is usually attached to the case with steel screws.

Fig 17: Axial Fan

4. **Arduino UNO:**

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE

(Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo.

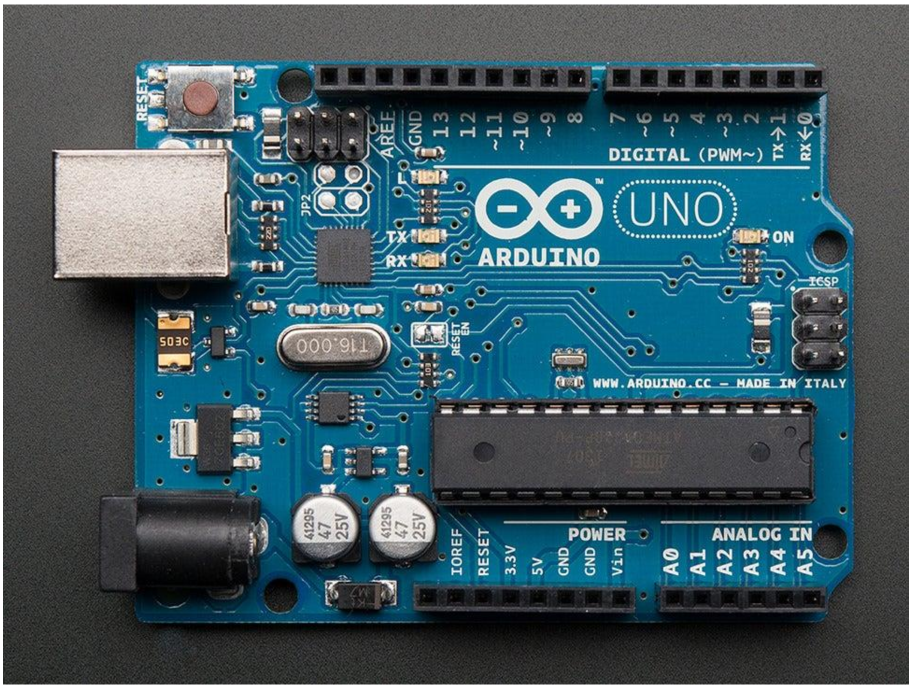

Fig 18: Arduino UNO

<u>Technical specifications:</u>

Microcontroller: Microchip ATmega328P

Operating Voltage: 5 Volts

Input Voltage: 7 to 20 Volts

Digital I/O Pins: 14 (of which 6 can provide PWM output)

UART: 1

I2C: 1

SPPI: 1

Analog Input Pins: 6

DC Current per I/O Pin: 20 mA

DC Current for 3.3V Pin: 50 mA

Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

Length: 68.6 mm

Width: 53.4 mm

Weight: 25 g

General pin functions:

LED: There is a built-in LED driven by digital pin 13. When the pin is high value, the LED is on, when the pin is low, it is off.

VIN: The input voltage to the Arduino/Genuine board when it is using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

3V3: A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins.

IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source, or enable voltage translators on the outputs to work with the 5V or 3.3V.

Reset: Typically used to add a reset button to shields that block the one on the board.

Special pin functions:

Each of the 14 digital pins and 6 analog pins on the Uno can be used as an input or output, under software control (using pinMode(), digitalWrite(), and digitalRead() functions). They operate at 5 volts. Each pin can provide or receive 20 mA as the recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50K ohm. A maximum of 40mA must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller. The Uno has 6 analog inputs, labeled A0 through A5; each provides 10 bits of resolution (i.e., 1024 different values). By default, they measure from ground to 5 volts, though it is possible to change the upper end of the range using the AREF pin and the analogReference() function.

In addition, some pins have specialized functions:

Serial / UART: pins 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL serial chip.

External interrupts: pins 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

PWM (pulse-width modulation): pins 3, 5, 6, 9, 10, and 11. Can provide 8-bit PWM output with the analogWrite() function.

SPI (Serial Peripheral Interface): pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK). These pins support SPI communication using the SPI library.

TWI (two-wire interface) / I²C: pin SDA (A4) and pin SCL (A5). Support TWI communication using the Wire library.

AREF (analog reference): Reference voltage for the analog inputs.

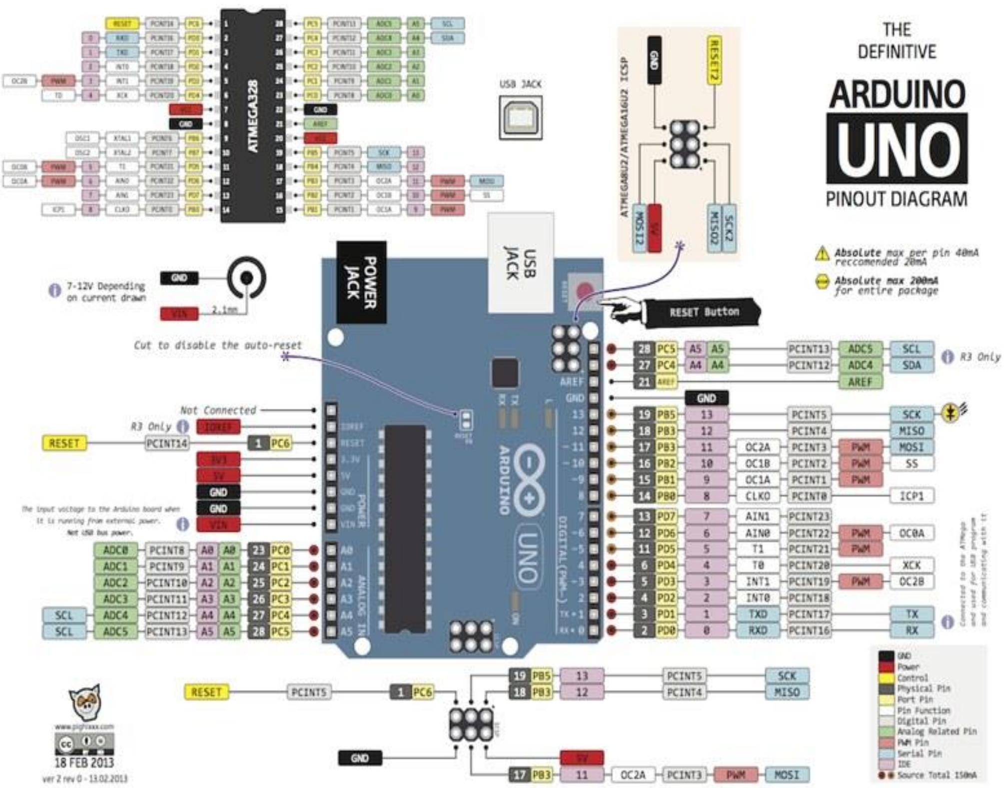

Fig 19: Arduino UNO Pin diagram

5. PMS5003 Particulate Sensor:

The Plantower PMS5003 is a low-cost laser particle counter, one of a range of sensors by Plantower that also include the PMS1003, PMS3003, and PMS7003. PMS5003 is a kind of digital and universal particle concentration sensor, which can be used to obtain the number of suspended particles in the air, i.e., the concentration of particles, and output them in the form of a digital interface. This sensor can be inserted into variable instruments related to the concentration of suspended particles in the air or other environmental improvement equipment to provide correct concentration data in time.

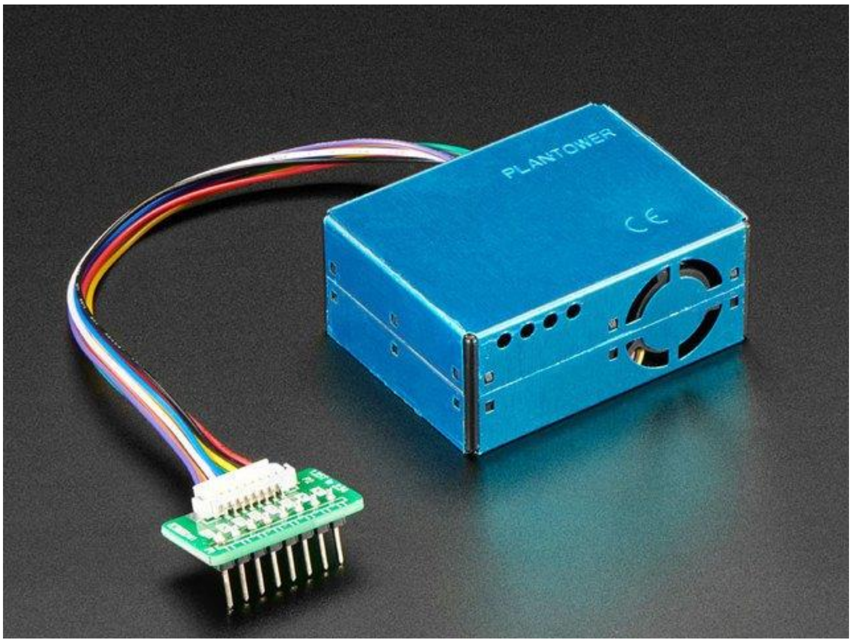

Fig 20: PMS5003 Sensor

PMS5003 Pins:

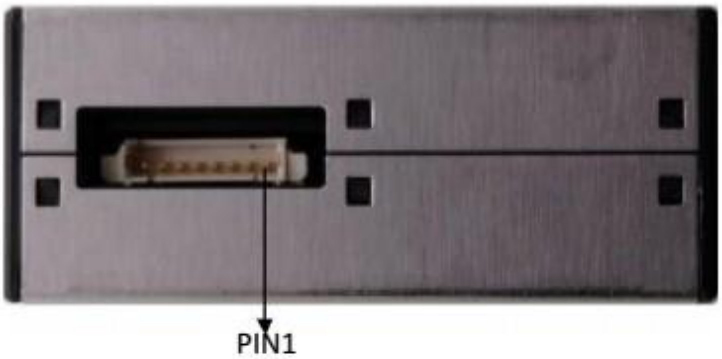

Fig 21: Pin Configuration

Some of the PM2.5 pins are numbered from left to right as 1, 2, 3……8. But in case of **PM5003**, the pins are named from right to left. Be careful while connecting **PM5003 pins** as you might connect it reversely.

PIN	FUNCTION	DESCRIPTION	REMARKS
1	**VCC**	Supply voltage 5V	4.5 – 5.5V
2	**GND**	Ground	
3	**SET**	HIGH or SUSPENDED – work mode LOW – sleep mode	3.3Vlogic
4	**RXD**	UART/TTL data receive	3.3Vlogic
5	**TXD**	UART/TTL data transmit	3.3Vlogic
6	**Reset**	LOW to reset	3.3Vlogic
7	**NC**	Not connected	
8	**NC**	Not connected	

Table 1: PMS5003 Pin Configuration

6. ML8511 UV Sensor:

The ML8511 UV sensor is easy to use the ultraviolet light sensor. The MP8511 UV (ultraviolet) Sensor works by outputting an analog signal in relation to the amount of UV light that’s detected. This breakout can be very handy in creating devices that warn the user of sunburn or detect the UV index as it relates to weather conditions.

This sensor detects 280-390nm light most effectively. This is categorized as part of the UVB (burning rays) spectrum and most of the UVA (tanning rays) spectrum. It outputs an analog voltage that is linearly related to the measured UV intensity (mW/cm2). If your microcontroller can do an analog to digital signal conversion then you can detect the level of UV!

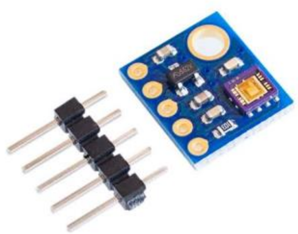

Fig 22: ML8511 UV Sensor

Block Diagram:

The UV Sensor ML8511 has **Photodiode** sensitive to **UV-A** and **UV-B**. Then it has an internal Embedded **operational amplifier** which will convert photocurrent to voltage output depending on the **UV light intensity**.

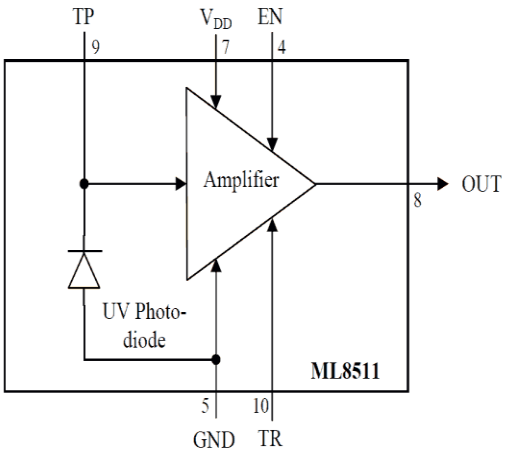

Fig 23: Block Diagram

The output is always in the form of Analog voltage. Through the voltage output, it is easy to interface with external microcontrollers and ADC.

UV Characteristics:

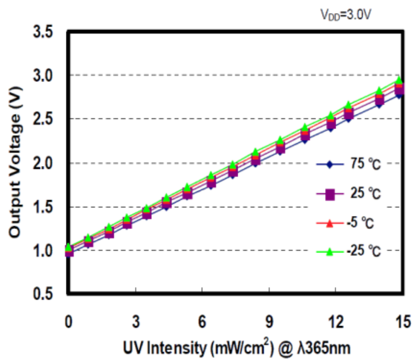

Fig 24: UV Characteristics

7. 20x4 LCD Module:

The LCD stands for liquid crystal display, that works on the light modulation features of liquid crystals. It is available in electronic visible display, video display and flat panel display. There are numerous categories and features are exits in markets of LCD and you can see it on your mobile, laptop, computer and television screen. The invention of LCD gives new life to electronic industries and replaces LED and gas plasma techniques. It also replaces the CTR (cathode ray) tube that used for visual display. The input power consumed by the liquid crystal display is less then light-emitting diode and plasma display. In today's post, we will have look at 20 x 4 LCD, its features, working, applications, and practical implementation in different electronic devices. So, let's get started with the Introduction to 20x4 LCD Module.

- In a **20x4 LCD** module, there are four rows in display and in one row twenty character can be displayed and in one display eighty characters can be shown.
- This liquid crystal module uses HDD44780 (It is a controller used to display monochrome text displays) parallel interfacing.
- The liquid crystal display interfacing code is easily accessible. We just required eleven input and output pinouts for the interfacing of the LCD screen.
- The input supply for this module is three volts or five volts, with that module other components like Arduino Mega.
- Thie electronic device can be used in different embedded systems, industries, medical devices, and portable devices like mobile, watches, laptops.
- Liquid crystal display works on two types of the signal first one is data and the second one is for control.
- The existence of these signals can be identified through the on and off condition of RS pinout. Data can be read by pushing the Read/write pinout.
- These are some pinouts of 20x4 LCD modules that are described here with the detailed.

Pin Configuration:

Pin No:	**Pin Name:**	**Parameters**
Pin#1	It denoted as Vss	It is ground pinout potential at this pinout is zero.
Pin#2	It denoted as Vdd	At this pinout, five volts are provided.
Pin#3	This pinout denoted as Vo	This pinout is used to set the contrast of the screen.

Pin#4	This pin denoted as RS	It used to H/L register select signal.
Pin#5	It denoted as R/W	It used for H/L read/write signal.
Pin#6	This pinout denoted as E	It used for H/L enable signal.
Pin#7-14	The pinouts from seven to fourteen denoted as DB0 – DB7.	It used for H/L data bus for 4 bit or 8-bit mode.
Pin#15	It identified as A (LED+)	It used to set backlight anode.
Pin#16	It recognized as K (LED-).	It used to set backlight cathode.

Table 2: LCD Pin Configuration

8. UV Choke:

UV Choke is designed to provide all the power requirements for Residential RO UV Water Purifiers with high frequency switching technology. Features: It is most useful for all type of UV tube which is use in domestic water purifier. Compact size and light weight.

Fig 25: UV Choke

9. DC Power Module:

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. As a result, power supplies are sometimes referred to as electric power converters. Some power supplies are separate standalone pieces of equipment, while others are built into the load appliances that they power. Examples of the latter include power supplies found in desktop computers and consumer electronics devices. Other functions that power supplies may perform include limiting the current drawn by the load to safe levels, shutting off the current in the event of an electrical fault, power conditioning to prevent electronic noise or voltage surges on the input from reaching the load, power-factor correction, and storing energy so it can continue to power the load in the event of a temporary interruption in the source power (uninterruptible power supply).

An AC-to-DC power supply operates on an AC input voltage and generates a DC output voltage. Depending on application requirements the output voltage may contain large or negligible amounts AC frequency components known as ripple voltage, related to AC input voltage frequency and the power supply's operation. A DC power supply operating on DC input voltage is called a DC-to-DC converter. This section focuses mostly on the AC-to-DC variant..

Fig 26: DC Power Supply Module

4.4 Materials Used:

4.4. 1. ABS:

ABS (Acronitrile Butadiene Styrene) used as material for printing the body. It is a common thermoplastic polymer made by polymerizing styrene and Acronitrile in the presence of polybutadiene. The proportions can vary from 15% to 35% acrylonitrile, 5% to 30% butadiene and 40% to 60% styrene. The result is a long chain of polybutadiene crisscrossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The acrylonitrile also contributes chemical resistance, fatigue resistance, hardness, and rigidity, while increasing the heat deflection temperature. The styrene gives the plastic a shiny, impervious surface, as well as hardness, rigidity, and improved processing ease. The polybutadiene, a rubbery substance, provides toughness and ductility at low temperatures, at the cost of heat resistance and rigidity. For the majority of applications, ABS can be used between −20 and 80 °C (−4 and 176 °F), as its mechanical properties vary with temperature.

Properties:

ABS provides favorable mechanical properties such as impact resistance, toughness, and rigidity when compared with other common polymers.

<u>Mechanical Properties:</u>

Young's Modulus (GPa) : 2.28

Tensile Strength (MPa) : 43

Flexural modulus (GPa) : 2.48

Flexural Strength (MPa) : 77

<u>Physical properties:</u>

Density (ρ) : 0.9–1.53 g/cm3;

Flammability : 1.00

<u>Thermal properties:</u>

Thermal conductivity (k) : 0.1 W/(m·K)

Linear thermal expansion coefficient (α) : 12×10−5 K−1

4.4. 2. Polypropylene Fabric:

Polypropylene fabric is used to fabricate HEPA filter. Polypropylene fiber, also known as polypropene or PP, is a synthetic fiber, transformed from 85% propylene, and used in a variety of applications. It is used in many different industries, but one of the most popular is the manufacturing of carpet yarns. For example, most of the economical carpets for light domestic use are made from this fiber. The fiber is thermoplastic, resilient, light weight and resistant to mildew and many different chemicals. As a fiber, polypropylene is strong, fade-resistant, and inherently stain resistant. This is because polypropylene has no active dye sites after it is synthesized. If you do a search for dying polypropylene, you will find that it is impossible to dye or change the color of the polypropylene after it has been extruded. Only when polypropylene is in a hot liquid form is it able to change colors with organic and inorganic pigments.

Some of the main PP fiber characteristics:

- colorfast
- quick drying
- anti-static behavior
- thermally bondable
- strong
- dry hand
- comfortable and lightweight

4.4. 3. Activated Charcoal:

Activated carbon, also called activated charcoal, is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Due to its high degree of microporosity, one gram of activated carbon has a surface area in excess of 3,000 m2 (32,000 sq ft) as determined by gas adsorption. An activation level sufficient for useful application may be obtained solely from high surface area. Further chemical treatment often enhances adsorption properties. Filters with activated carbon are usually used in air and gas purification to remove oil vapors, odor, and other hydrocarbons from the air. The most common designs use a 1-stage or 2 stage filtration principle in which activated carbon is embedded inside the filter media.

Activated carbon filters are used to retain radioactive gases within the air vacuumed from a nuclear boiling water reactor turbine condenser. The large charcoal beds adsorb these gases and retain them while they rapidly decay to non-radioactive solid species. The solids are trapped in the charcoal particles, while the filtered air passes through.

4.4. 4. UV-C light:

UVC radiation is a known disinfectant for air, water, and nonporous surfaces. UVC radiation has effectively been used for decades to reduce the spread of bacteria, such as tuberculosis. For this reason, UVC lamps are often called "germicidal" lamps. UVC radiation has been shown to destroy the outer protein coating of the SARS-Coronavirus, which is a different virus from the current SARS-CoV-2 virus. The destruction ultimately leads to inactivation of the virus efficiently and safely inactivates airborne human coronaviruses. UVC radiation may also be effective in inactivating the SARS-CoV-2 virus, which is the virus that causes the Coronavirus Disease 2019 (COVID-19). UVC radiation can only inactivate a virus if the virus is directly exposed to the radiation. Therefore, the inactivation of viruses on surfaces may not be effective due to blocking of the UV radiation by soil, such as dust, or other contaminants such as bodily fluids. Many of the UVC lamps sold for home use are of low dose, so it may take longer exposure to a given surface area to potentially provide effective inactivation of a bacteria or virus.

4.5 Working Principle:

Fig 27: Working Principle

As soon as we turn on the motor implanted in the body the air extraction process begins. The design was made in a such a way that air enters the purifier all around the 360° and passes through the preliminary filter which traps the large particles, then the enters into the actual filtering stage.

In this stage the air enters through the True HEPA filter at first where wetness in the air, dust mites, pollen, etc., were trapped and then the air is allowed to pass the Activated carbon filter, the second stage where smoke, bad odours, some types of microbial dust were trapped in this stage. Then the air was sent into a chamber where UV light was equipped which disinfects the air and removes all kinds of bacteria and viruses.

Then this purified air was extracted out from the chamber and sent to atmosphere (Room air) using an axial fan implanted above the chamber. Thus, the air was purified.

A PMS5003 Particulate sensor was placed in the upper chamber where it’s inlet and outlet facing outside the purifier to collect the air from atmosphere for testing the particulate matter. The output of the sensor was in digital signal which converted into numeric system using Arduino UNO.

A ML8511 UV sensor was used to detect the intensity of UV light used. The output of the sensor is analog which is converted into digital using ADC (Analog to Digital Converter) of Arduino UNO and the signal was sent to display in numerical data. Arduino UNO was programmed for reading the values from sensors and displaying them on the display module provided. The Arduino UNO program was done in Arduino IDE, a software which is used to write different Arduino programs.

Working Principle of PMS5003 Sensor:

Laser scattering principle is used for such sensor, i.e., produce scattering by using a laser to radiate suspending particles in the air, then collect scattering light in a certain degree, and finally obtain the curve of scattering light change with time. In the end, equivalent particle diameter and the number of particles with different diameters per unit volume can be calculated by microprocessor-based on MIE theory.

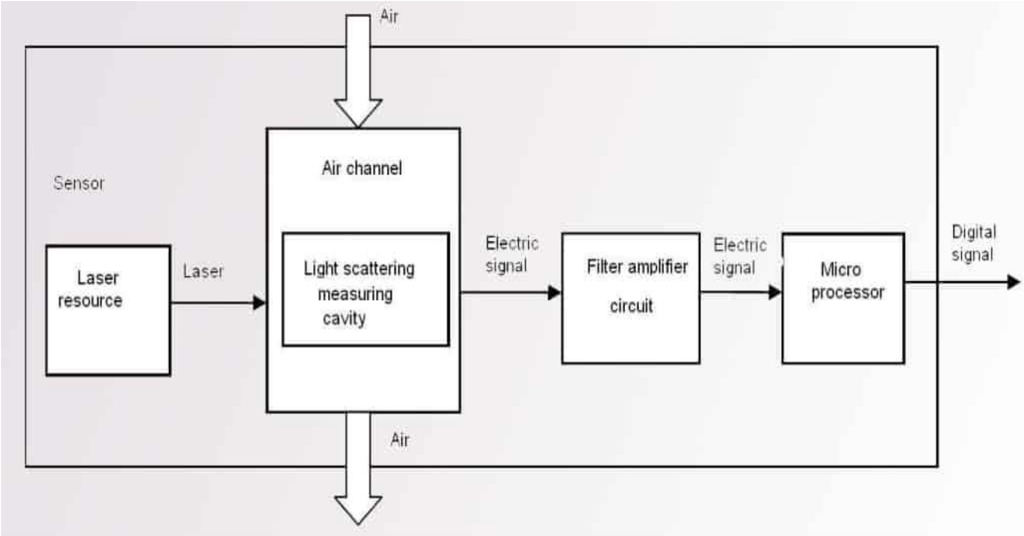

Fig 28: Working principle of PMS5003 Sensor

Working Principle of ML8511 Sensor:

UV sensors work by detecting the UV radiation emitted by the flame and are sensitive to a wide range of flammable fuels including hydrocarbons, sulphur, hydrazine and ammonia**.**

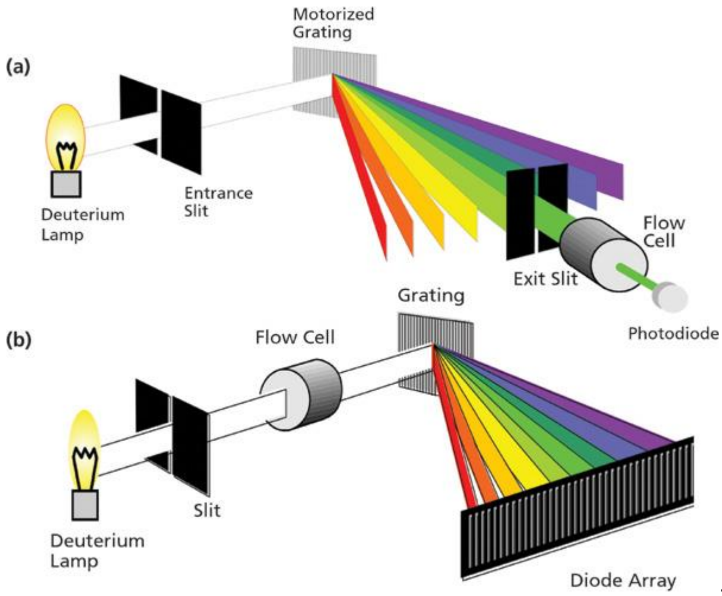

Fig 29: Working principle of ML8511 UV sensor

4.6 Circuit Diagram:

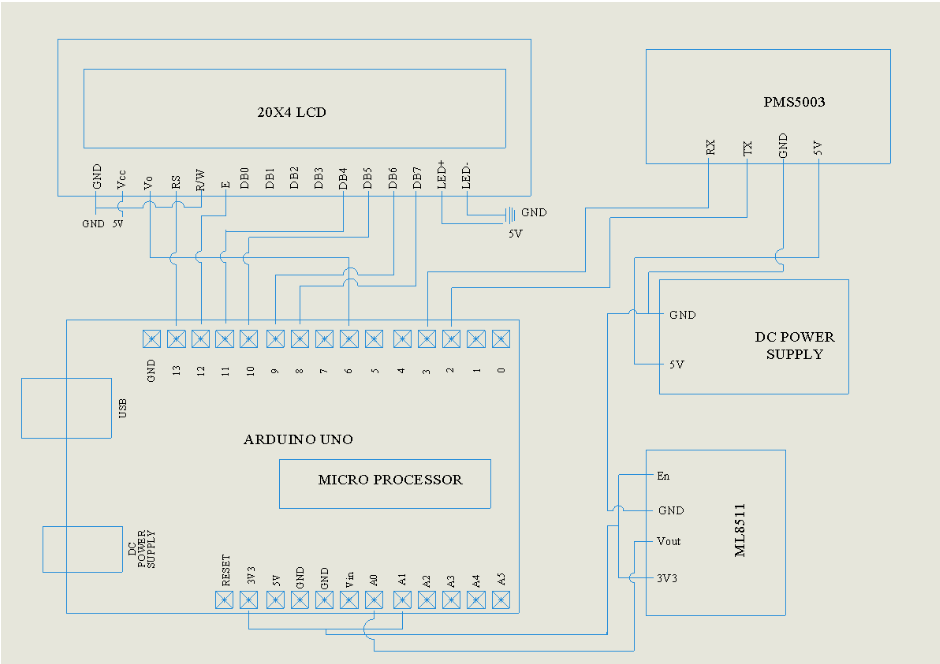

Fig 30: Circuit Diagram

The above figure shows the circuit diagram for interfacing PMS5003 and ML8511 sensors with Arduino UNO Board.

The detailed pin to pin connection is described in the table below and the detail pin configuration and datasheet of LCD Module, PMS5003, ML8511 Sensors is mentioned in chapter 4 components section.

Pin Configuration:

Sl.No	Sensor Pins	Arduino Pins
	LCD Module	
1.	Pin 1 (Vss)	GND
2.	Pin 2 (Vcc)	5V
3.	Pin 3 (Vo)	Pin 6 (Digital)
4.	Pin 4 (Rs)	Pin 13 (Digital)
5.	Pin 5 (R/W)	GND
6.	Pin 6 (E)	Pin 12 (Digital)
7.	Pin 11 (DB4)	Pin 11 (Digital)
8.	Pin 12 (DB5)	Pin 10 (Digital)

9.	Pin 13 (DB6)	Pin 9 (Digital)
10.	Pin 14 (DB7)	Pin 8 (Digital)
11.	Pin 15 (LED+)	5V
12.	Pin 16 (LED-)	GND
	PMS5003 Sensor	
1.	Pin 1 (Vcc)	5V
2.	Pin 2 (GND)	GND
3.	Pin 4 (RXD)	Pin 3 (Digital)
4.	Pin 5 (TXD)	Pin 2 (Digital)
	ML8511 Sensor	
1.	Pin 2 & 5 (Clubded)	Pin 3V3 & A1
2.	Pin 3 (GND)	GND
3.	Pin 4 (OUT)	A0

Table 3: Sensors To Arduino Pin Alignment

Software Used:

The software used for writing the code for sensors is Arduino IDE. It is user friendly and easy to understand. To start with coding we have to install certain libraries required for reading values from sensor and displaying them on display. The list of libraries to be installed are mentioned below, these libraries can be downloaded in Arduino IDE software itself by navigating to **Tools → Manage libraries → Search the library and install suitable version.**

Arduino IDE:

- Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module.
- It is an official Arduino Software, making code implementaion and compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.
- It is easily available for operating systems like MAC, Windows, Linux and runs on the Java platform that comes with inbuilt commands and functions that play a vital role for debugging, editing and compling the code in the environment.

- A range of Arduino modules available including Arduino UNO, Arduino Mega, Arduino Lenardo, Arduino Micro and many more.
- Each of them contains a microcontroller on the board that is actually programmed and aspects the information in the form of code.
- The main code, also known as a sketch, created on the IDE platform will ultimately generate a HEX file which is then transferred and uploaded in the controller on the board.
- The IDE environment mainly contains two basic parts : Editor and Compiler where former is used for writing the required code and later is used for compling and uploading the code into the given Arduino Module.
- The environment supports both C and C++ language.

The IDE environment is mainly distrubuted into three sections

- Menu Bar
- Text Editor
- Output Pane

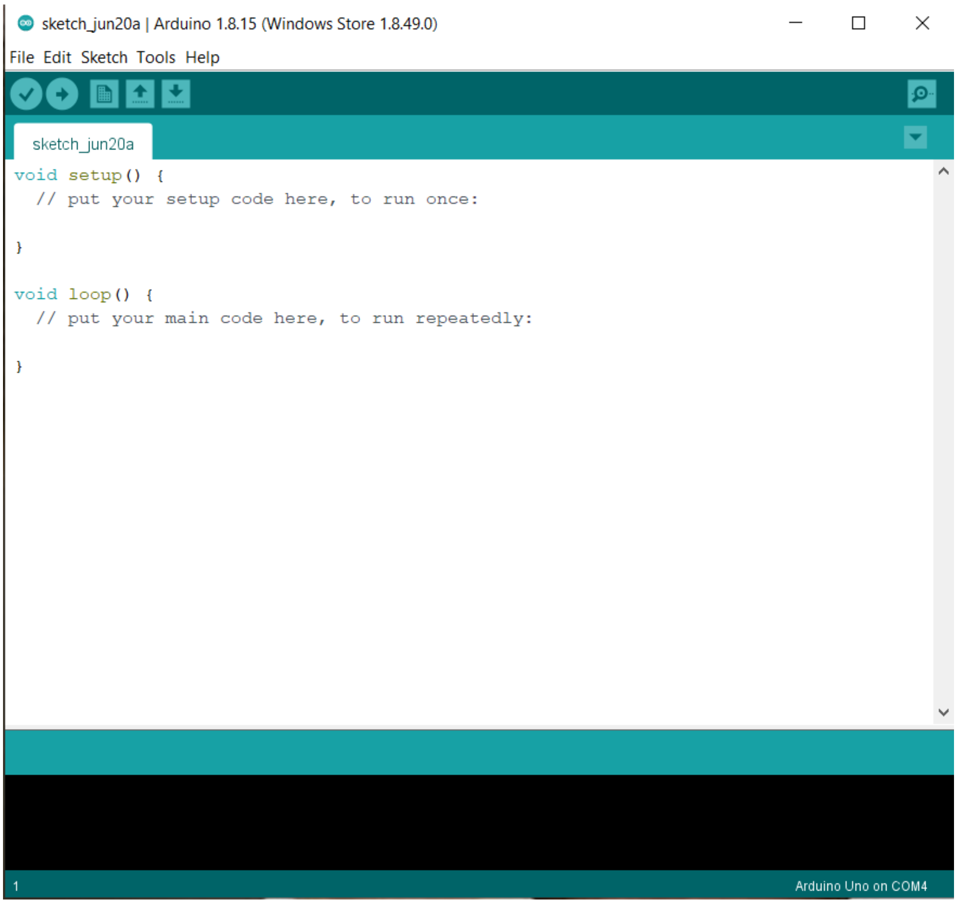

Fig 31: Arduino IDE

Advantages:

- Really open source software and hardware.
- Huge community
- Low cost boards and peripherals (when source from China)
- It's Simple (i.e., add abstraction to underlying MCU's "nuts & bolts" many times for the sake of efficiency/processing speed), but not too simple so called sketches are actually C/C++ code and you need some real programming skills for some real job.

Disadvantages:

- It's mostly still AVR (8-bit) "eco-system" (and +5V). There is many claims that other (e.g. ARM) architecture are supported but you'll find pretty soon that even 32-bit boards designed by Arduino team (e.g. Due, Zero, MKR) are not supported in a similar way to 8-bit (Uno, Lenardo, Mega2560); they are still second choice.
- If you need more peocessing power and working memory be ready to say goodbye Arduino environment pretty soon.

4.7 Project Code:

```
#include "PMS.h"

#include "SoftwareSerial.h"

#include <LiquidCrystal.h>

LiquidCrystal lcd(13, 12, 11, 10, 9, 8);

 int Con = 140;

//PMS5003 sensor

SoftwareSerial Serial1(2, 3); // RX, TX

 PMS pms(Serial1);

PMS::DATA data;

// UV Sensor

int UVOUT = A0; //Output from the sensor

int REF_3V3 = A1; //3.3V power on the Arduino board
```

```
 void setup()
{
  analogWrite(6, Con);
  Serial1.begin(9600);
  lcd.begin(20,4);
  pinMode(UVOUT, INPUT);
  pinMode(REF_3V3, INPUT);
    lcd.setCursor(4, 0);
  lcd.print("Welcome SMEC");
  lcd.setCursor(2, 1);
  lcd.print("Mechanical Dept");
  lcd.setCursor(5, 2);
  lcd.print("Guided by");
  lcd.setCursor(2, 3);
  lcd.print("Dr D V Sreekanth");
  delay(6000);
  lcd.clear();
}
 void loop()
{
  if (pms.read(data))
  {    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Air Quality Index :");
    lcd.setCursor(0, 1);
    lcd.print("PM1.0 :" + String(data.PM_AE_UG_1_0) + "(ug/m3)");
```

```
  lcd.setCursor(0, 2);

  lcd.print("PM2.5 :" + String(data.PM_AE_UG_2_5) + "(ug/m3)");

//lcd.setCursor(0, 3);

 //lcd.print("PM10  :" + String(data.PM_AE_UG_10_0) + "(ug/m3)");

 AQI();

 delay(3000);

 lcd.clear();

 //delay(4000);

// UV Code

 lcd.clear();

int uvLevel = averageAnalogRead(UVOUT);

int refLevel = averageAnalogRead(REF_3V3);


//Use the 3.3V power pin as a reference to get a very accurate output value from sensor

float outputVoltage = 3.3 / refLevel * uvLevel;

  float uvIntensity = mapfloat(outputVoltage, 0.99, 2.8, 0.0, 15.0); //Convert the voltage to
a UV intensity level

lcd.setCursor(0, 0);

lcd.print("UVIndex:");

lcd.setCursor(8, 1);

lcd.print(uvIntensity);

lcd.print(" mW/cm2");

lcd.setCursor(0,2);

lcd.print("UV BandWidth : ");

lcd.setCursor(14,3);

lcd.print("280nm");

delay(3000);  }    }
```

```
  //Takes an average of readings on a given pin
//Returns the average
int averageAnalogRead(int pinToRead)
{  byte numberOfReadings = 8;
  unsigned int runningValue = 0;
   for(int x = 0 ; x < numberOfReadings ; x++)
    runningValue += analogRead(pinToRead);
  runningValue /= numberOfReadings;
   return(runningValue);}
float mapfloat(float x, float in_min, float in_max, float out_min, float out_max)
{  return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;}
void AQI ()
{    int Y = (data.PM_AE_UG_2_5);
if (0 < Y < 31 )
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
    lcd.print("AQI : ");
  lcd.setCursor(12,3);
  lcd.print(Z);}
if (30 < Y < 61 )
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
   lcd.print("AQI : ");
  lcd.setCursor(12,3);
  lcd.print(Z);}
if (60 < Y < 91 )
```

```
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
    lcd.print("AQI : ");
  lcd.setCursor(12,3);
  lcd.print(Z);}
if (90 < Y < 121 )
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
    lcd.print("AQI : ");
  lcd.setCursor(12,3);
  lcd.print(Z);}
if (120 < Y < 251 )
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
  lcd.print("AQI : ");
    lcd.setCursor(12,3);
  lcd.print(Z);}
if ( Y > 250 )
{  int Z = 1.67 * Y;
  lcd.setCursor(6,3);
  lcd.print("AQI : ");
  lcd.setCursor(12,3);
  lcd.print(Z);}  }
```

4.8 Calculation:

1. Clean Area Delivery Rate (CADR) :

CADR is the abbreviation of Clean Air Delivery Rate. It is either measured as cubic meter of air delivered in hour or cubic foot of air delivered in a minute. Essentially, it is the indicator of how much air the purifier cleans in a given time. Obviously, higher the better. The Association of Home Appliance Manufacturers suggest having three CADR numbers mentioned on each purifier, namely CADR for tobacco smoke, dust and pollen.

Smoke CADR value = Square Feet of Room / 1.55 (here 1.55 = AHAM's 2/3 rule)
Square feet of room = 275 sq.ft.
Smoke CADR value = 275 / 1.55 = 177.41 m3/hr

2. Air Change per Hour (ACH):

ACH simply is the number of times an air purifier filters all of the air in a room in one hour. So, an ACH rating of 4 means that the purifier filters the air in the room four times an hour. As you would have already figured out by now, it is one of the most important factor that signifies the effectiveness of the air purifier.

CADR = 177.19 m3/hr

CADR in cubic feet per minute = 300 x 0.588 = 104.19 cfm (here 0.588 is the conversion constant)

Air changed in an hour = 104.19 x 60 = 6251.4 (CADR in CFM x number of minutes in an hour)

Room volume = 2475 cubic feet [275 x 9 as Room height is assumed to be 9 ft.]

ACH rating = Air changed in an hour / Room Volume

ACH rating = 6251.4 / 2475 = 2.56

4.9 Application:

Medical, Commercial, Institutional, Industrial, and Military Applications. Since 1985 Pure Air Systems, Inc. has been manufacturing commercial grade HEPA and carbon-based air filtration systems for the commercial and residential markets. Here are some of the applications where are products are being used:

1. **Medical**

Hospitals: Use of HEPA systems in patient care rooms where either a positive or negative HEPA filtered environment is required. Typically used for infection control or isolation for communicable disease control.

Clinics: Use of HEPA systems for reduction/removal of airborne pathogens, allergens and bacteria to maintain clean environment for outpatient procedures.

Laboratories: Use of HEPA systems in medical labs and dental labs

Pharmaceutical Manufacturing: Use of HEPA systems for containment of chemical compounds during the manufacture and development of pharmaceutical drugs.

2. **Institutional**

Universities: Use of HEPA and Carbon systems for R&D labs for reduction/removal of airborne contaminants and/or pathogens during various phases of the research cycle.

Pre-Schools and Secondary Educational Facilities: Use of HEPA systems in pre-schools to reduce levels of airborne pathogens and minimize spread of communicable disease. Use of HEPA systems in High Schools for overall air filtration of occupied areas.

3. **Commercial**

Household Health and Personal Care Products: Use of HEPA and Carbon-based systems for reduction/removal of contaminants associated with the design and development of various chemical and compound-based health care and cosmetic products.

Food Products and Beverages: Use of HEPA systems to maintain mid-level clean room environment for packaging and processing of food grade products. This includes the bottling process for many alcoholic and non-alcoholic beverages.

Retail–Restaurant: Use of HEPA and Carbon systems for removal of odours and airborne particulates in food service and various retail facilities. Also used for removal of cigarette and cigar smoke in those bars and restaurants that allow smoking.

Apartments and Hotels: Use of HEPA systems in apartment complex HVAC systems (where individual air handlers are used) and in high end Hotels for meeting and conference rooms.

4. **Industrial**

Microelectronics: Use of HEPA and Carbon systems in the manufacture of microchips and other dust sensitive electronic components. Typically, these types of products have to be fabricated in a clean-room type of environment.

Optics: Use of HEPA systems to maintain clean room environment in the manufacture of precision optics for commercial and military use.

Precision Component Manufacturing: Use of HEPA systems for reduction/removal of fine dust generated in the manufacturing of precision components to minimize maintenance issues with particulate getting into process equipment.

Testing Laboratories: Use of HEPA systems to remove fine airborne particulate generated during various phases of compound testing (i.e., mineral labs, precious metal labs).

Automotive: Use of HEPA systems in the paint and coatings labs and R & D facilities.

5. Military

Aerospace Guidance Systems: Use of HEPA systems in the manufacture and assembly of highly sophisticated, precision guidance systems for all military aircraft, satellites and unmanned systems. These systems are always assembled in clean room environments.

Chemical and Biological Systems: Use of HEPA systems for protection of occupants in the development and testing of certain chemical and biological compounds.

CHAPTER-5
PROJECT TESTING

The testing of the project was done after the fabrication process. The project was done in a room of 2475 cubic feet volume. Several testings was done with different impurities and with different values and all the results found satisfactory. It took an average of 25mins to purify air to an AQI value of 20 from an AQI value of 150.

Fig 32: Final Output

CHAPTER-6

CONCLUSION AND FUTURE ENHANCEMENT

6.1 Conclusion:

The Design and Development of Air Purification System was designed using Solidworks and analyzed using Solidworks Simulation platform. Once design was completed, we run several simulations to get good results. The simulation was done and appropriate material and fabrication process was chosen then we dived into real process i.e., Fabrication process

We fabricated the outer body of the project using 3D printing and all the components including filters and sensors kept at desired positions. Then we tested the project in a room of 275sq.ft and found results as appreciable. It took around 20-30mins to get fresh air of AQI 20 from an AQI of 150.

6.2 Future Scope:

Increase in vehicular population, severe construction activities, and industries are largely contributing to an increase in outdoor pollution across Indian cities. It is quite evident that, with a growing economy and over 125 billion people to feed, the destruction will continue and more forests will be cut and space created for infrastructure. So, there will be consequences for these actions. Starting from groundwater, the crops and the air – they are all becoming toxic. Obviously, the coming generations will pay heavily for this irresponsible action by us. What we need are consciousness and actions that can at least reduce the burden to the only planet that we have.

In future Air purification will become the biggest goal and growing technology and moreover air purifiers the devices which purify the air becomes a common device like TV, Fridge, Cooler etc., The purifier can be upgraded as movable all over corners in the room for better purification using motion sensors and servo motors. The HEPA filters can be replaced with washable filters with higher efficiency.

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A MAJOR PROJECT REPORT
On

MACHINING OF CFRP USING AWJM AND ANALYSING THE LIFE OF NOZZLE USING CFD

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

by

ANIKETH KUMAR	**- (17K81A0363)**
MADHU REDDY	**- (17K81A0384)**
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Under the guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled "**MACHINING OF CFRP USING AWJM AND ANALYSING THE LIFE OF NOZZLE USING CFD**" is being submitted by "**ANIKETH KUMAR (17K81A0363), MADHU REDDY (17K81A0384), VYSHNAVI MANDA (17K81A0387), AKHIL KUMAR (17K81A0398)"** in partial fulfilment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Signature of Guide	**Signature of HOD**
Dr. D.V. SREEKANTH	**Dr. D.V. SREEKANTH**
Professor& Head of the Department	**Professor& Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the student of Bachelor **of Technology** in Department of **'MECHANICAL ENGINEERING'**, session 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled""**MACHINING OF CFRP USING AWJM AND ANALYSING THE LIFE OF NOZZLE USING CFD**" is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

Aniketh Kumar	- (17K81A0363)
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ABSTRACT

Computational fluid dynamics (CFD) Models for ultra-high velocity by abrasive water jet machine. The present experimental study is about drilling of carbon fiber at different stand of distance as input parameter. The abrasive water jet machine is a non-conventional machining process in which abrasive and water are mixed required ratio to impinge on the work material at high velocity. CFD analysis is a branch of fluid mechanics that uses of numerical analysis and data structure and analyse and solve problem that involve fluid flows. Here we are finding the output velocity of the nozzle.The main experimental results demonstrated that the stand-off distance and the abrasive flow rate were the major parameters affecting the surface roughness (Ra) and the hole taper.

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CHAPTER-1

INTRODUCTION

Abrasive water jet cutting is an extended version of water jet cutting; in which the water jet contains abrasive particles such as silicon carbide or aluminium oxide in order to increase the material removal rate above that of water jet machining. Almost any type of material ranging from hard brittle materials such as ceramics, metals and glass to extremely soft materials such as foam and rubbers can be cut by abrasive water jet cutting. The narrow cutting stream and computer-controlled movement enables this process to produce parts accurately and efficiently. This machining process is especially ideal for cutting materials that cannot be cut by laser or thermal cut. Metallic, non-metallic and advanced composite materials of various thicknesses can be cut by this process.

This process is particularly suitable for heat sensitive materials that cannot be machined by processes that produce heat while machining. In this process, high velocity water exiting the jewel creates a vacuum which sucks abrasive from the abrasive line, which mixes with the water in the mixing tube to form a high velocity beam of abrasives.

1.1 WORKING PRINCIPLE OF AWJM

The cutter is commonly connected to a high-pressure water pump where the water is then ejected from the nozzle, cutting through the material by spraying it with the jet of high-speed water.Additives in the form of suspended grit or other abrasives, such as garnet and aluminium oxide can assist in this process.An abrasive jet starts out the same as a pure water jet.As the thin stream of water leaves the nozzle, abrasive is added to the stream and mixed.The beam of water accelerates abrasive particles to speeds fast enough to cut through much harder materials.Silicon carbide, sand, corundum, and glass beads of grain size 10 to 150 μm are often used as abrasive materials.The mixing of abrasive particles in water jet is in such a manner that water jet's momentum is transferred to the abrasives. The coherent, abrasive water jet that exits the AWJM nozzle has the ability to cut various materials, such as metals, glass, ceramics and composites. Generally, AWJM cuts 10 times faster than the conventional machining methods of composite materials.

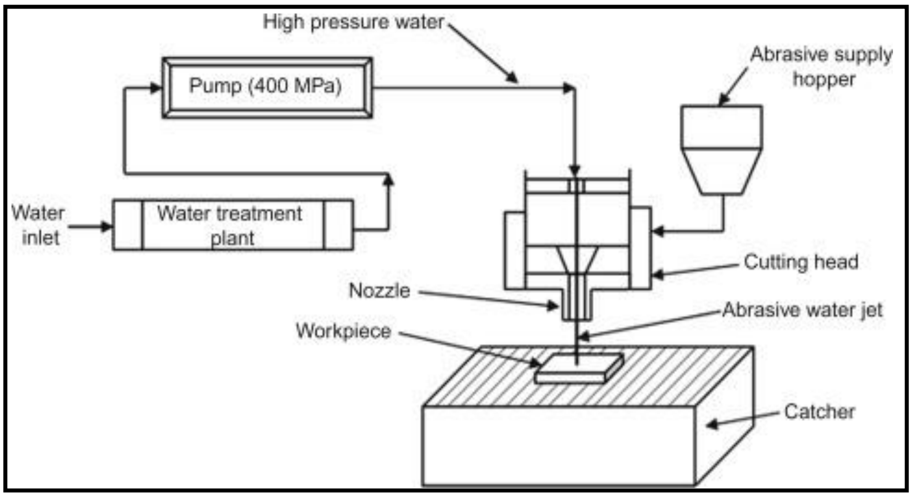


Fig 1

Sketch of AWJM

This process works on basic principle of water erosion. In this process, a high speed well concentrated water jet is used to cut the metal. It uses kinetic energy of water particle to erode metal at contact surface. The jet speed is almost 600 m/s. It does not generate any environmental hazards. For cutting hard materials, abrasive particles are used in water jet These abrasive particles erode metal from contact surface

- Abrasive water jet (AWJM) machining process utilized increasingly in industrial applications. It is a non-traditional machining process and involves complex mechanics. A nozzle is required to perform abrasive water jet machining for material removal with the help of very high velocity of water jet. The main problem of AWJM machining process is nozzle wear during the process. The wear depends on various parameters such as water jet characteristics, abrasive size and nozzle geometry, etc. The nozzle wear is not fully understood experimentally; also, the uncontrolled nozzle wear can affect the effectiveness and surface finish obtained through the AWJM machining process.
- In the present work, the effect of geometrical parameters of single step nozzle and abrasive size on skin friction coefficient at the wall of nozzle due to wall shear stress and jet exit kinetic energy has been analysed by ANSYS software. This analysis is totally depending on nozzle geometry and nozzle material is taken same for all cases. This analysis can be highly helpful for understanding nozzle wear during the AWJM machining process.

1.2 OVERVIEW OF THE PROJECT

The basic outline of the project is to machine the work piece i.e., CFRP using AWJM to find material removal rate (MRR) and to find the life of the nozzle using CFD analysis by ANSYS. IN the machining process, the parameters such as SOD, abrasive flow rate, jet transfer speed are given to the system and placing the work material perpendicular to the nozzle for the jet impingement. Calculating the material removal rate considering the values obtained while machining.

In the analysing process,the life of the nozzle is to be calculated.That can be done by comparing velocity,pressure and eddy’s viscosity at varying parameters.The model of the nozzle is drawn using CAD software and uploaded in the ANSYS workbench.The parameters are given,then running the program and obtaining the simulations.Comparing all these simulations nozzle life is calculated.

1.3 OBJECTIVES OF THE PROJECT

- To erode the material using abrasives such as silicon carbide,sand,garnet,aluminium oxide.
- To calculate the material removal rate (MRR).
- Optimization was performed to simultaneously optimize two objectives (productivity and operating cost) with three factors

(traverse speed, abrasive mass flow rate and standoff distance) and three constraints (perpendicular tolerance, surface roughness limit and traverse speed for separation cut).

- Analysing the life of nozzle using CFD by ANSYS.

1.4 SCOPE OF STUDY

By using dust collecting system and air filter, the environmental loading and hazards can be eliminated for eco-friendly machining. Beyond a number of traditional applications, some futuristic applications of abrasive jet are,

- Cutting tools blasting after grinding.
- Abrasive jet etching.
- Surface cleaning prior to welding.
- Cryogenic abrasive jet for machining polymers.

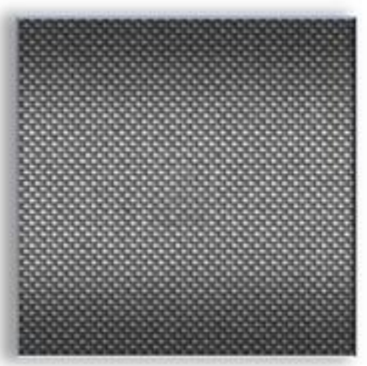
1.5 MATERIAL REQUIREMENT

(A)Composite Materials

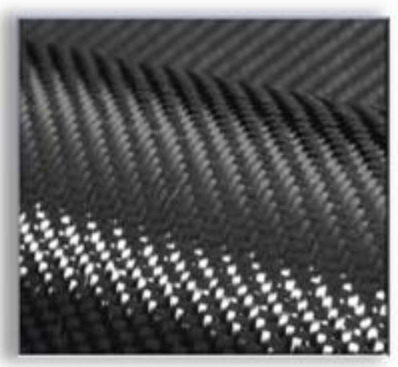
A composite material is a material made from two or more elements with significantly different physical or chemical properties which, when combined, produce a material with characteristics different from the individual components. Generally, a composite material is composed of reinforcement (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). Composite materials are mainly classified into three types based on matrix I) Polymer Matrix Composites (PMC) ii) Metal Matrix Composites (MMC) iii) Ceramic Matrix Composites (CMC). Composites are also classified into three types based on their reinforcements, namely, (i) Fibrous composite (ii) Particulate composite and (iii) Structural composite orlaminate.

(B)Carbon fibre reinforced polymer

Carbon fibre is a synthetic material that offers a unique combination of qualities -- high strength, high stiffness and low weight. Carbon fibre composites are about 10 times stronger and 5 times lighter than steel, and about 1.5 times lighter than aluminium. Together with the right resin systems, carbon fibre composites are also known for being extremely corrosion resistant and able to withstand high wear.



(a) PlainWeave



(b)2x2Twill

Fig 2 carbon fiber reinforced polymer

Those qualities make it useful in a wide variety of aesthetic and structural applications.Carbon fibre starts with a precursor polymer material called PAN (Polyacrylonitrile) which is heated until it becomes carbonized. It's spun into extremely fine fibres (thinner than a human hair) which are washed and stretched to obtain the desired fibre diameter. This process also helps align the molecules within the fibre and helps create tightly bonded carbon crystals.

DENSITY	**1.8 -2.0 gm/cm3**
MELTING POINT	**3652 –3697C**
COEFFICIENT OF EXPANSION	**9.0Mm/mc**
TENSILE STRENGTH(MPA)	**2000 KN/mm2**
YOUNG'S MODULUS	**250.7 KN/mm2**

Table 1 properties of CFRP

CHAPTER-2

LITERATURE SURVEY

2.1 History of Water jet machine

Waterjet cutting technique uses a high-pressure stream of water to cut different materials. The early usage dates back to Roman Empire, who used it for hydraulic mining and land development. In the early 1930's, a Paper Patent Company used relatively low-pressure water for cutting soft metals. The first reliable ultra-high-pressure pump was developed in 1970 by OMAX Corporation.

2.2 Evolution of Water jet Machine:

The early waterjets only managed to cut soft materials. However, the modern waterjet machines use garnet abrasive, which are capable of cutting hard materials like steel, stone, and glass.

- **1940's**: By this time, advanced high pressure water jet machines started gaining popularity. These machines were specifically developed for aviation & automotive hydraulics.
- **1950's:** Liquid jet machines in the pressure range of (100000 PSI, 6900 bar) were used to cut plastic and aerospace metals. The first liquid jet machine was developed by John Parsons.
- **1960's**: Ultra high-pressure hydro jet machines up to 50,000(3,450 bar) were used to cut metal and stone. They were also used in polyethylene industry.
- **1970's**: The first commercial water jet cutting machine system developed by Bendix Corporation was introduced in the market.

- **1980's:** First abrasive water jet nozzles ROCTEC ceramic tungsten carbide composite mixing tubes were developed by Boride Corp. These nozzles were made from a patented carbide material.
- **1990's**: OMAX Corporation developed patented 'Motion Control Systems'. It was also used to locate the waterjet stream.
- **2000's:** The introduction of zero tapper waterjet improved the precision cutting of parts with square, taper-free edges, including interlocking pieces and dove tail fittings.
- **2010's:** The technology in 6 axis machines greatly improved the credibility of Water jet cutting tools.

Throughout the history of Waterjet cutting, technology has evolved, became more reliable, more accurate, and much faster. If you are looking for a reliable waterjet cutting for your next project, you can always consider industry expert like Hydro-Laser.

Waterjet technology evolved in the post-war era as researchers around the world searched for new methods of efficient cutting systems. In 1956, Carl Johnson of Durox International in Luxembourg developed a method for cutting plastic shapes using a thin stream high-pressure waterjet, but those materials, like paper, were soft materials. In 1958, Billie Schwacha of North American Aviation developed a system using ultra-high-pressure liquid to cut hard materials. This system used a 100,000 psi (690 MPA) pump to deliver a hypersonic liquid jet that could cut high strength alloys such as PH15-7-MO stainless steel.

While not effective for the XB-70 project, the concept was valid and further research continued to evolve water jet cutting. In 1962, Philip Rice of Union Carbide explored using a pulsing water jet at up to 50,000 psi (340 MPA) to cut metals, stone, and other materials. Research by S.J. Leach and G.L. Walker in the mid-1960s expanded on traditional coal waterjet cutting to determine ideal nozzle shape for high-pressure waterjet cutting of stone, and Norman Franz in the late 1960s focused on waterjet cutting of soft materials by dissolving long chain polymers in the water to improve the cohesiveness of the jet stream. In the early 1970s, the desire to improve the durability of the waterjet nozzle led Ray Chadwick, Michael Kurko, and Joseph Corriveau of the Bendix Corporation to come up with the idea of using corundum crystal to form a waterjet orifice, while Norman Franz expanded on this and created a waterjet nozzle with an orifice as small as 0.002 inches (0.051 mm) that operated at pressures up to 70,000 psi (480 MPA). John Olsen, along with George Hurlburt and Louis Kapcsandy at Flow Research (later Flow Industries), further improved the commercial potential of the waterjet by showing that treating the water beforehand could increase the operational life of the nozzle.

CHAPTER-3

PROJECT DESIGN

3.1 Individual Part Design

The speed at which an abrasive waterjet can cut depends on the shape of the part. Fine, sharp features cut more slowly than large, rounded features. Smooth, striation-free edges take longer to cut than rough severance cuts. Some guidelines follow for designing parts to save time later.

1. **Internal corners.** An abrasive waterjet must slow down to make precise, sharp internal corners. By closing a slot with an arc rather than a square end, the cutting time can be reduced. This is true even when the path length is increased.
2. **External Corners**. The correct strategy for cutting external corners previously was the same as for internal corners; namely, radius the corners to decrease cutting time. Recently, however, the concept of corner passing has made it possible to make sharp corners by moving past the corner into the scrap at the full cutting speed until the lagging bottom portion of the jet has passed the corner. Then the jet is moved back to the corner quickly and started on its new path. The result is a quickly cut, high-quality corner.Check whether the machine you use has corner passing.

3. **Piercing**. With each pierce of the material, you must wait for the jet to turn off from the previous cut, restart for the new cut, and then pierce the material. If there are holes near the periphery of a part, it often is faster simply to connect them to the outside rather than pierce them.
4. **Taper.** An abrasive water jet is tapered. When the jet moves slowly, the kerfis widest at the bottom. When it moves fast, the kerf is widest at the top. The jet cuts thin materials at a high speed, and for this reason, thin materials have greater edge taper than thicker materials. Be sure that your design can tolerate this edge taper. If not, you can move slowly along the portion of the path that must be taper-free, or use a more sophisticated machine that tilts the head to remove taper while cutting at normal speed.
5. **Tabbing**. Tabs on the part edge are used most commonly to hold the part in place while it is being cut. By using tabs, hundreds of small parts can be cut from a single plate unattended without the finished parts snagging the nozzle or falling into the catcher, where they are easily lost.

   Tabs also are a useful way to store small parts to minimize handling. Storing in inventory, anodizing, and plating all can be performed on a single sheet of tabbed parts. Then, when the parts are needed, they are broken free like parts in a plastic toy model kit.

3.2 Assembly and Weldment Design

Forethought about the entire design as an assembly or weldment also can save manufacturing time. The shape flexibility and the precision possible with abrasive waterjet cutting permit self-jigging assemblies and other useful features for easing assembly.

1. Use tabs and slots to aid assembly. Some of the assembly techniques used in sheet metal work can be used with heavy plates cut with abrasive jets. Slots can be used to precisely receive tabs cut on the mating part. Joining is then achieved by one of three methods:

   a) The tab extends through the mating plate and is twisted with a wrench to lock the two pieces together.

   b) The tab is somewhat shorter than the plate thickness and is plug-welded into place.

   c) The tab is somewhat shorter than the plate thickness and is tapped for bolting into place.

2. Use a constant thickness. If all pieces of a weldment or assembly are the same material and thickness, they all can be cut from the same plate. Small parts can be nested within holes in large parts to save material, and parts for the entire assembly can be made in one setup, saving shop time.

3. Make holes for fasteners and bearings. Abrasive jets make clean, precise holes that either can be tapped or reamed as soon as the part is removed from the machine. Bearings can be pressed directly into reamed holes. Tapped holes provide accurate location and eliminate the need to handle nuts and second wrenches during assembly.
4. Square holes can be used in combination with carriage bolts as another method for eliminating second wrenches at assembly.

Time can be saved in piece-part manufacturing, assembly, and welding by using knowledge of the cutting process to its fullest during the design phase.

3.3Parameters

The general domain of parameters in entrained type AWJ machining system is given below:

• Orifice – Sapphires – 0.1 to 0.3 mm

• Focussing Tube – WC – 0.8 to 2.4 mm

• Pressure – 2500 to 4000 bar

• Abrasive – garnet and olivine - #125 to #60

• Abrasive flow - 0.1 to 1.0 Kg/min

• Standoff distance – 1 to 2 mm

• Machine Impact Angle – 90 degrees

• Traverse Speed – 100 mm/min to 5 m/min

• Depth of Cut – 1 mm to 250 mm.

Mechanism of material removal in machining with water jet and abrasive water jet is rather complex. In AWJM of ductile materials, material is mainly removed by low angle impact by abrasive particles leading to ploughing and micro cutting. Such process has been studied in detail initially by Finnie as available in the edited volume by Engels. Further at higher angle of impact, the material removal involves plastic failure of the material at the sight of impact. It unified such models as applicable under AWJM at a later stage. In case of AWJM of brittle materials, other than the above two models, material would be removed due to crack initiation and propagation because of brittle failure of the material.

CHAPTER-4

PROJECT IMPLEMENTATON

Abrasive water jet machining (AWJM), also knownas abrasive micro-blasting, pencil blasting and micro-abrasive blasting, is an abrasive blasting machining process that uses abrasive propelled by a high velocity gas to erode material from the work piece. Brittle materials such as glass, ceramics, silicon, and germanium, have been widely used in semiconductor, optical, biosensors, micro-electronics, micro-fluidic devices and other fields. Traditional machining approaches such as milling and drilling are not very effective at machining brittle materials. Abrasive water jet micromachining (AWJM) is a promising non-traditional machining technology for the cost-effective fabrication of micro-structures on brittle and hard materials. The AWJM process is based on the erosion of substrate by an abrasive-laden air jet or abrasive air jet (AAJ). The abrasive particles are accelerated to a high velocity by applying pressurized air in a fine nozzle, and the nozzle moves relative to the work substrate for making a structure on it. The removal of materials in AWJM is achieved by means of micro plastic deformation and/or brittle fracture. For hard andbrittle materials, the impact force of the abrasive particle causes localized cracks at the work surface.

The target material is removed by the formation and propagation of cracks with the subsequent impact events (Slikkerveer et al, 2000;

Ligthart et al, 1996; Li et al, 2008). Modelling of the erosion rate is usually based on the studies of deformation caused by sharp indenters for brittle materials. According to the well-established erosion model for brittle materials (Ligthart et al, 1996; Lawn et al, 1980; Marshall et al, 1982; Marshall, 1984; Chiang et al, 1982), when a brittle material is loaded by a sharp indenter, a plastic zone is formed beneath the indent. At higher loads, a radial crack may propagate downwards from the base of the plastic zone. This crack does not contribute to the material removal but can degrade the material strength. On unloading, a lateral crack propagates at the base of the plastic zone. The lateral crack formation literally takes place parallel to the material surface, and strongly relates to the material removal phenomenon. It is believed that the normal component of impact energy is responsible for material removal in the brittle nature. In the 1930s, a low-pressure water jet system was patented and successfully used to cut paper. Twenty years later, a high- pressure hydraulic seal from aviation industry was adopted to water jet machining, that noticeably increased the process productivity. The continuous increase of working pressure in the next few decades allowed the cutting of hard alloys and carbides. On the other hand, a high pressure led to severe nozzle wear, making abrasive jet machining (AJM) economically non-competitive. From the 1970s, after ceramic nozzles were introduced, abrasive jet systems became commercially available and, within a short span of time, became the industrial mainstream and were mainly utilised for cutting and cleaning purposes. Further developments of AJM technology have been made, mainly based on material science progress and CNC conception. In the 21st century, AJM development deviated its track to technology miniaturization, wherein the nozzle diameter plunged from macro to micro scale. Today, sapphire orifice, super- hard abrasives and reliable high-pressure pumps combined with a 6-axis, precisely manage and process monitored systems, making AJM one of the most promising micro-manufacturing technologies despite the fact that it has been used for a century. In the last 25 years, there is a solid growing trend of industrial interest in micro-AJM.

4.1ESSENTIAL CONCEPTS:

(A) MATERIAL REMOVAL MECHANISM:

Erosion is conventionally considered as a negative phenomenon-non, producing damage to structures. In the conception of free abrasive machining, erosion becomes an instrument, where AJM is a manufacturing technology, which is based on erosion localization and intensification. Directed flow of hard micro-particles splits-off the tiny chips from the substrate, removing workpiece mass to required geometrical conditions. Depending on materials proper- ties and process parameters, ductile or brittle removal mechanisms may dominate during erosion. The third one, namely elastic removal mode was discovered recently. The understanding of material removal mechanism is essential for machining efficiency enhancement.

(B) PROCESS PARAMETERS:

AJM process is affected by the number of settings. Some factors may contribute differently depending on the combination of other factors and materials properties. Although, several dominating tendencies can be underlined. The independent process parameters involved in AAJM were classified by Hashish into two general groups and later into three groups by the Nouraei et al., which are discussed below.

1.Nozzle pressure: Pressure directly affects flow velocity and, as an aftermath, the kinetic energy of the in-flow particles. Thus, an increase in pressure leads to the growth of MRR and surface roughness. In AAJM, working pressure may vary from 0.2 to 1 MPa, that usually corresponds to 100- 300 m/s of particle velocity. During pre-coating machining for improvement of coated layer bonding to zirconia substrate, a working pressure less than 1 MPa was recommended.

2.Jet velocity: Due to boundary conditions between air jet and stable surroundings, abrasive jet velocity is non- uniform in both radial or axial direction. Li et al. conditionally divided air flow into three velocity regions. In the initial region, jet velocity preserves its speedinaformofconuswith abaseatthenozzleexit.Thehighness of the conus is independent of the jet velocity at the nozzle exit. Instead, it is proportional to its diameter and flow viscosity.

3.Traverse speed: Traverse speed is a speed of the reciprocal motion of the blasting nozzle relative to the machined surface. The speed selection is based on requirements of feature geometry. In precise etching by micro-blasting, the speed may fall down to 0.25 mm/s. The slower speed provides deeper erosion spot. Particle distribution in a flow cross section has normal character, consequently, the abrasive jet produces Gaussian shape footprint with a bottom at the distribution centre. However, at some conditions, the machined profile can turn to the flat or even convex pattern, as was reported recently.

4.Stand-off-distance: Stand-off-distance is the distance between the nozzle exit and machined surface. Moving from conventional sand-blasting to powder-blasting, SOD was shortened from a few meters to several hundreds of micrometres.

5.Flow rate: Abrasive flow rate is the mass of abrasive powder supplied to a mixing chamber per unit time. Typically, flow rate varies from around 1 g/min to 1 kg/min, depending on nozzle diameter and pressure.

6.Nozzle Wear mechanism: Like most of the other machining technologies, all AWJM methods are related to the issue of tool wear. The nozzle is the most vulnerable component of any abrasive water jet system. The typical working scheme of the nozzle with a mixing chamber is presented in Figure. High pressured energy carrier moves through the orifice to the inner chamber, where it is mixed with abrasive particles. Then, the mixture enters the nozzle tube, obtaining a directed motion and exits in a form of an abrasive water jet. The wall of the mixing tube is multiply impacted by particles during the process, that leads to internal nozzle erosion and changes in the tube profile. Continuous increase of nozzle hole diameter leads to process instability due to rise in air flow rate, jet divergence, and footprint size. Such circumstances affect the MRR, surface waviness and preciseness in general. Therefore, the nozzle wear mechanism became an important technological topic in the improvement of AWJM economic indicators.

4.2 MRR EVALUATION:

MRR can be evaluated by the weight loss over the test period is divided by the time of the test in minutes.

MRR = (wb-wa) t (g/min)

Where wb is the mass of work piece before the process began, wa is the mass of work piece after the process ended, and t is the machining time in minutes. The machining time for each trial was the time taken to obtain a hole completely through thetest piece. This, of course,varied depending on the given cutting conditions.

4.3WORKING AND PARTS INVOLVED IN THE MACHINING:

Abrasive Water jet cutting works by forcing a large volume of water with high pressurethrough a small orifice in the nozzle. The constant volume of water travelling through a reduced area causes acceleration in the particles. This accelerated stream leaving the nozzle impacts the material to be cut. The extreme pressure of the accelerated water particles contacts a small area of the work piece. In this small area, the work piece develops small cracks due to stream impact. The water jet washes away the material that "erodes" from the surface of the work piece. The crack caused by the water jet impact is now exposed to extreme pressure and impact of particles in the following streamcause the small crack to propagate until the material is cutthrough.

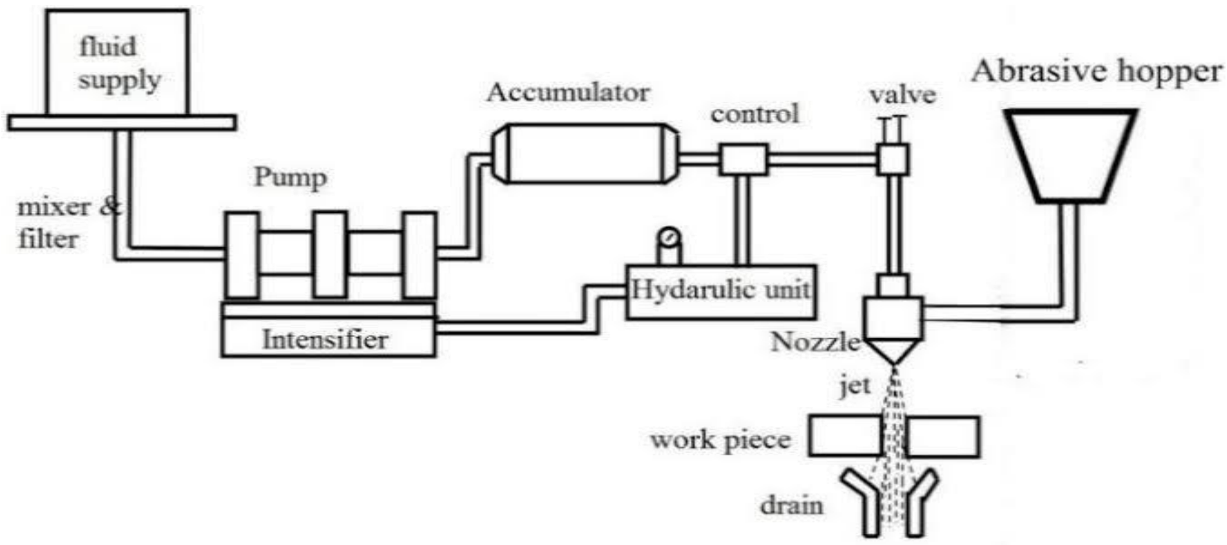


Fig 3 schematic diagram of AWJM

AWJM is a mechanical material removal process used for the erosion of holes and cavities by the impact of abrasive particles and pressurized water that exits from the jet forming a slurry on hard and brittle material. The process does not involve any electrical, chemical and thermal process as it there is no change in the metallurgical and physical properties of the work piece. The schematic diagram of AWJM is shown in Figure.

The water from the water source is pumped up by a high-pressure water pump and passes through a R-O plant. Then the water is treated and its TDS (totally dissolved solvents) is reduced. The water is than put to storage tank. The air is compressed by an air compressor and passes it through a reservoir. In general, the compressed air has high temperature and so its temperature is reduced by the chiller plant. Then the water and air are mixed at the spindle. At the other side, the abrasive is added to the spindle. The water exits from the jet with higher pressure and the machining process is carried out.The parts of the abrasive water jet machine are mentioned in Figure 1.4 (a-g).

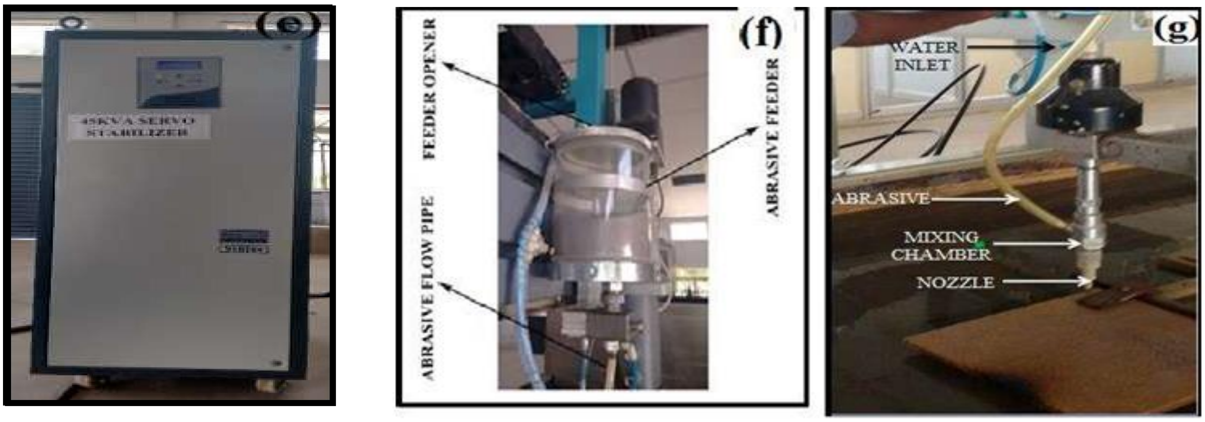


Fig. 4 parts of the abrasive water jet machine
(a)air compressor, (b)chiller plant, (c)RO plant, (d)rooster pump, (e)stabilizer, (f)abrasive feeder, (g)nozzle

(a) Air Compressor

The air compressor which is used for compressing the air. The pressurized air is allowed to pass through a nozzle with high velocity and mix with water at a chamber to carry out machining.

(b) Chiller Plant

the chiller plant, placed next to the compressor. The air compressed by the compressor has a higher temperature so to reduce the temperature a chiller plant is placed.

(c) Reverse Osmosis Plant

Figure 1.4 (c) shows the reverse osmosis plant. Plant is used for the treatment of water used for water jet machining. This plant is used for the removal of the totally dissolved solvents present in the water. This plant also reduces the hardness of the water used for machining. This plant plays a vital role in this machining process because the tool that is used for machining is water is to do the treatment to treat without causing any dust andimpurities.

(d) Pump

The rooster pump, water is pressurized from the water source and exits at the nozzle. The pump plays a major role because the flow of water is carried out by it.

(e) Abrasives and Nozzle

Figure 1.4 (e-g) shows the 45KVA servo stabilizer, Abrasive feeder unit, and a nozzle set up. The abrasives are used as tools in water jet machining as they create a sharp cutting surfaces on the work piece and makes the surface to erode. The nozzle is the place where the high pressurized water is sprayed to do the machining.

Fig. 5 Abrasive water jet machine

4.4 AWJ MACHINING OF COMPOSITE MATERIALS

Advanced machining is the emerging technology that has contributed to the manufacture of numerous engineering components in the field of aerospace, marine, architectural and automobile sectors. AWJM is an eco-friendly modern technique renowned for machining hard and orthotropic materials without causing any thermal distortion and residual stress. The AWJ cutting of heterogeneous composite laminates faces numerous challenges. Problems like delimitation arising from the impact of the water jet, and time consumption while machining features such as slots and holes need more attention towards the selection of the process parameters. Hence, it is important to develop a methodology for the selection of the process parameters for fiber reinforced composite materials. Till now, no machine manufacturers have provided good adequate database for composite cutting especially for NFRPCs. This research work aims at the study of the behaviour of AWJM processes of a natural fibre based thermo-set polyester matrix composite. The influence of the various AWJ cutting parameters, such as the roles of abrasive particles, water pressure, stand-off distance, and feed rate have been analysed.

1.Advantages of AWJM

AWJMs have certain beneficial characteristics, which help achievement of a significant penetration into manufacturing industries.

- Extremely fast set-up and programming, Machine virtually for any 2D shape on any material.
- practically no heat generated on the part,Machines plates of large thickness.Time taken for clamping the work piece is reduced.
- High accuracy, good surface finish, Fully and semi-automated. Pressure of the water can be adjusted easily, Good mechanical controllability.

Item	Identification
Machine model	s3015
Intensifier	KMT-SLV 50 HP
Table size	3 * 1.5 m
Nozzle diameter	1 mm
Jetimpingement/Impactangle	90
Max. pressure	3800 bars
Table size	3 * 1.5 m
Max. feed	4000 mm/min
Max. abrasive flow rate	700 g/min
Standoff distance	More than 1 mm
Vertical cut height	300 mm
Abrasive type	Garnet sand
Abrasive size	80 mesh
Avg dia of abrasives	0.20 mm

Table 2 properties of abrasive water jet machine

2. MATERIALS:

- Polymers, Honeycombs, PMC, MMC, CMC, Reinforced plastics
- Steels, Non-ferrous alloys, Ti alloys, Ni-alloys
- Metal Polymer Laminates, Glass Fiber Metal Laminates
- Concrete, Stone – Granite, Wood.

3. APPLICATIONS OF AWJM

- Paint removal
- Cleaning, Penning, Cutting, Drilling, Turning, Pocket Milling
- Cutting soft materials, Cutting frozen meat
- Textile, Leather industry, Mass Immunization, Surgery
- Nuclear Plant Dismantling.

4.5 EXPERIMENTAL SETUP

The carbon & glass fibre-reinforced polyester composite was fabricated, using the compression moulding method (Figure 3.4). The carbon &glass mats were cut into square pieces of size 300x300mm^2 as per the dimension of mould cavity. The resin mixture was prepared

Fig 6 Fabrication of composites by Compression moulding Machine

with the proportionate quantity of 100 ml of UPR with 1.5 ml of catalyst and accelerator respectively, as per the recommendations of the resin manufacturer. The resin mixture was poured over the fibre mats inside the mould placing the fibre mats one over the other alternately, in such a way as to attain the fibre content of 50±2wt.%.
The split mould was closed by applying 15MPa of pressure in such a way as to attain a 12mm thick plate. Finally, the mould with the composite was kept at a constant pressure for 24 hours at room temperature for curing. Mansion wood polishing (white) wax was applied around the mould cavity, to enable easy removal of the composite laminate.

4.6 COMPUTATIONAL FLUID DYNAMICS(CFD) ANALYSIS:

Computational fluid dynamics or CFD is the analysis of systems involving
mats inside, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. The technique is very powerful and spans a wide range of industrial and non-industrial application areas. Some examples are:

- aerodynamics of aircraft and vehicles: lift and drag
- hydrodynamics of ships
- power plant: combustion in internal combustion engines and gas turbines
- turbo machinery: flows inside rotating passages, diffusers etc.

The variable cost of an experiment, in terms of facility hire and/or person- hour costs, is proportional to the number of data points and the number of configurations tested.In contrast, CFD codes can produce extremely large volumes of results at virtually no added expense, and it is very cheap to per- form parametric studies, for instance to optimize equipment performance.

Below we look at the overall structure of a CFD code and discuss the role of the individual building blocks. We also note that, in addition to a substantial investment outlay, an organization needs quailed people to run the codes and communicate their results, and briefly consider the modelling skills required by CFD users. We complete this otherwise upbeat section by wondering whether the next constraint to the further spread of CFD amongst the industrial community could be a scarcity of suitably trained personnel instead of availability and/or cost of hardware and software.

4.7 CAD DRAWING OF NOZZLE AND ITS DIMENSIONS

(a)Nozzle-material used:

Wear of the nozzle becomes a major problem since it may affect the performance of water jet machining.

Design, materials, and life of the nozzle give significance effect to the nozzle wear.

various parameters that may influence the wear rate of the nozzle such as nozzle length, nozzle inlet angle, nozzle diameter, orifice diameter, abrasive flow rate and water pressure.

The high pressure of the water and hard abrasive particles may erode the nozzle wall.

A nozzle using a tungsten carbide-based material has been developed to reduce the wear rate and improve the nozzle life.

Focusing tube diameter	0.76 mm
Focus tube length	76mm
Nozzle angle	45 degrees
Mixing chamber diameter	6mm
Mixing chamber length	12mm
Orifice diameter	0.2mm
Water inlet diameter	2.5mm
Abrasive inlet diameter	3mm

Table 3 dimensions of nozzle head

(b) Numerical Model and Assumptions

- The abrasive water suspension mixture is let into the nozzle at inlet and carried through converging cone to focus tube and exits at nozzle, in which the focus tube is used for guiding the flow. The numerical model adopted closely follows the work at Huet al which liquid-solid two-phase flow is considered. Water is a continuous medium and incompressible.Flow is considered as two-phase flow mixture in which water is liquid phase and abrasives is solid phase, but mixed with the liquid phase.

Two phase flow is steady and possesses turbulent flow characteristics. The nozzle head of AWJM ismodelled by using pro/E software and it is saved. We modelled the nozzle head of varying inlet pressure of nozzle, then it is imported in ICEM meshing software for meshing the model. Tetrahedron is used for fine meshing. Then it is imported in CFX Pre for giving input parameters and properties of water and abrasive by impact erosion of high-pressure high velocity of water and entrained high velocity of grit abrasives on a work piece. The invention of the abrasive water jet by impact erosion of high-pressure high velocity of water and entrained high velocity of grit abrasives on a workpiece.

(c) Material Domain Input

For the meshed model computational domain input should be given in the first. You have to create a water inlet, abrasive inlet and mixture outlet to the meshed model. In CFX pre-processor, you have to give the thermodynamic properties of water and abrasive. The water is taken as continuous liquid, and dispersed solid abrasive size is 1mm. In boundary condition you have to give domain type, name of nozzle head and mixing chamber.

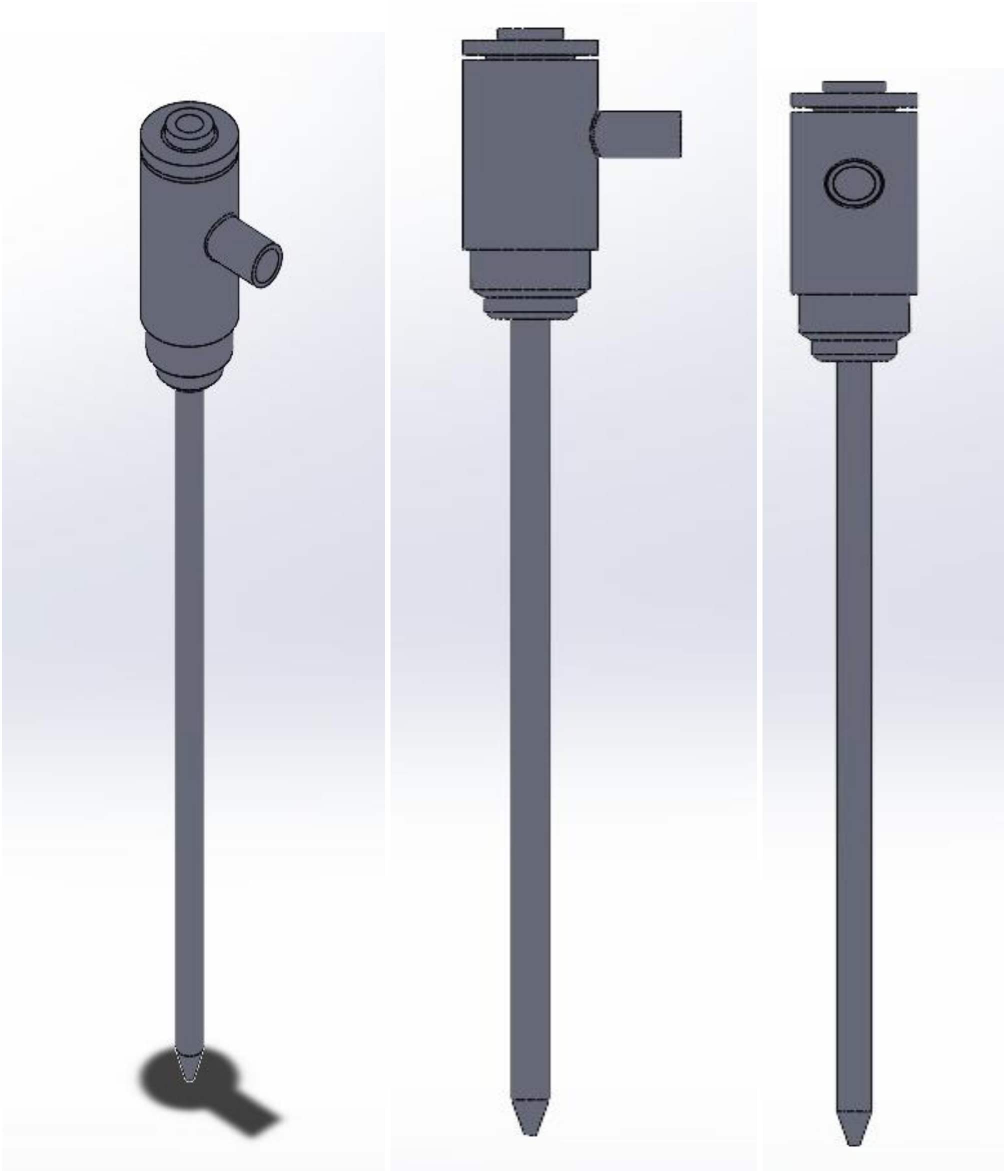


Fig 7 CAD drawings of nozzle head

You have to name the liquid domain and solid domain of nozzle head and mixing chamber.Then you have to tell at water inlet, water enters and at abrasive inlet abrasive enters and also give the boundary details. Then you have to give domain interface between solid and liquid domain. The outlet will be the velocity. In CFX Solver, the model is imported and no of equations is performed and you have to give no of iterations and run solver and monitor. In CFX post, the models are imported and post process the results.

4.8SIMULATIONS OBTAINED ON PERFORMING ANALYSIS

After drawing the CAD model of nozzle head according to the dimensions mentioned and uploading the design to the ANSYS workbench. The obtained simulations are discussed below. The high pressure of the water and hard abrasive particles may erode the nozzle wall. A new nozzle using a tungsten carbide-based material has been developed to reduce the wear rate and improve the nozzle life. Apart from that, prevention of the nozzle wear has been achieved using porous lubricated nozzle.On varying the parameters like abrasive flow rate, jet transfer speed, pressure, velocity the simulations are obtained.

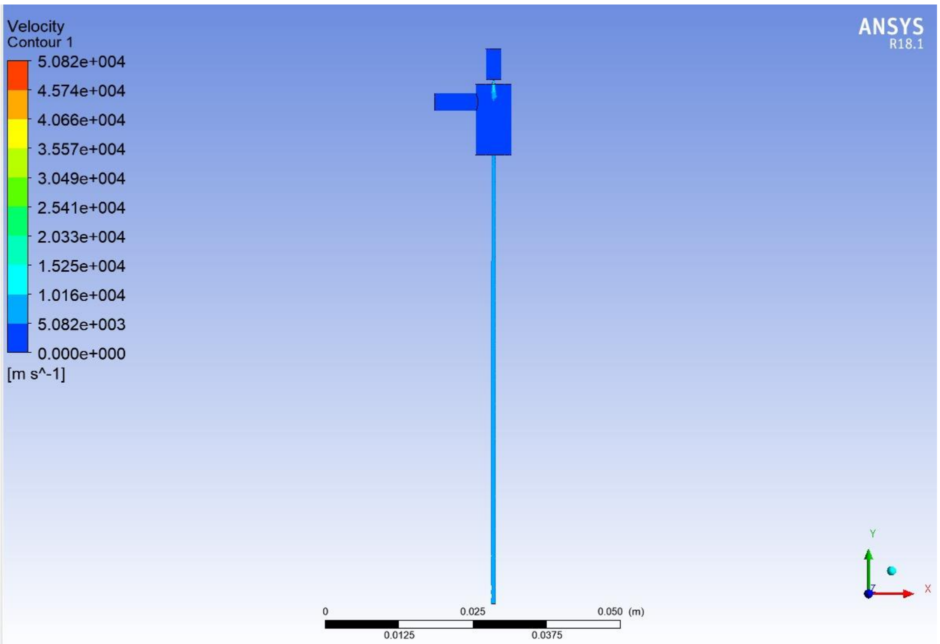


Fig 8

The above figure shows the result of nozzle velocity at 40MPA,180mm/min jet transfer speed,250g/min abrasive flow rate and stand-off distance at 1mm.we can observe from the above fig, that the velocity at the orifice is quite high but at the orifice the water jet have to maintain according to the diameter of orifice, at this level the water jet maintains high velocity.

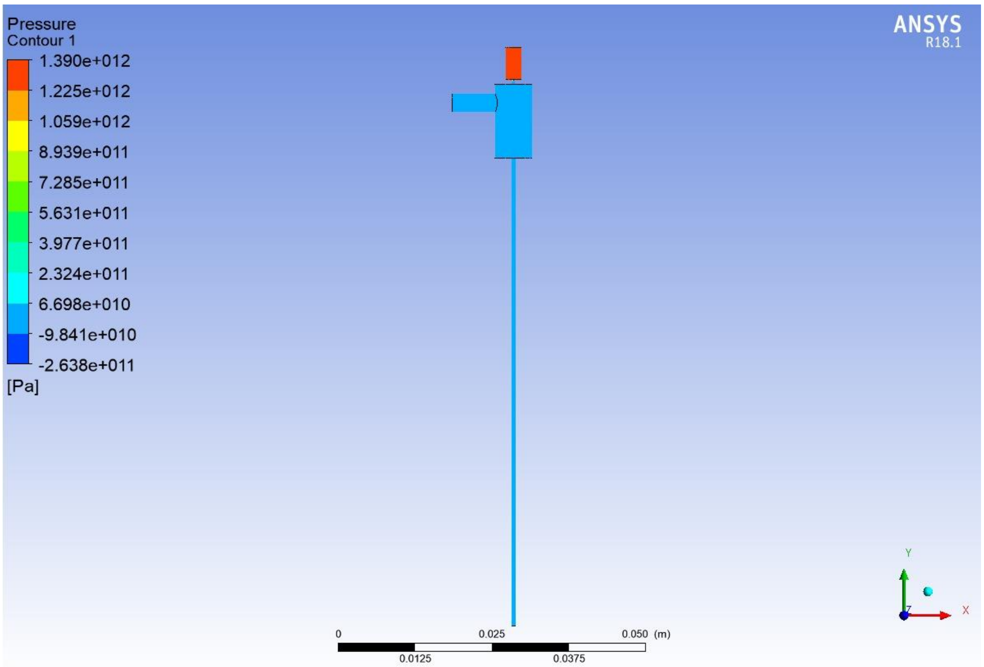


Fig9

The above figure shows the result of nozzle pressure at 40MPA,180mm/min jet transfer speed,250g/min abrasive flow rate and stand-off distance at 1mm.As we supply the high pressurized water to the orifice and is obvious that the pressure of water before entering the orifice is very high.

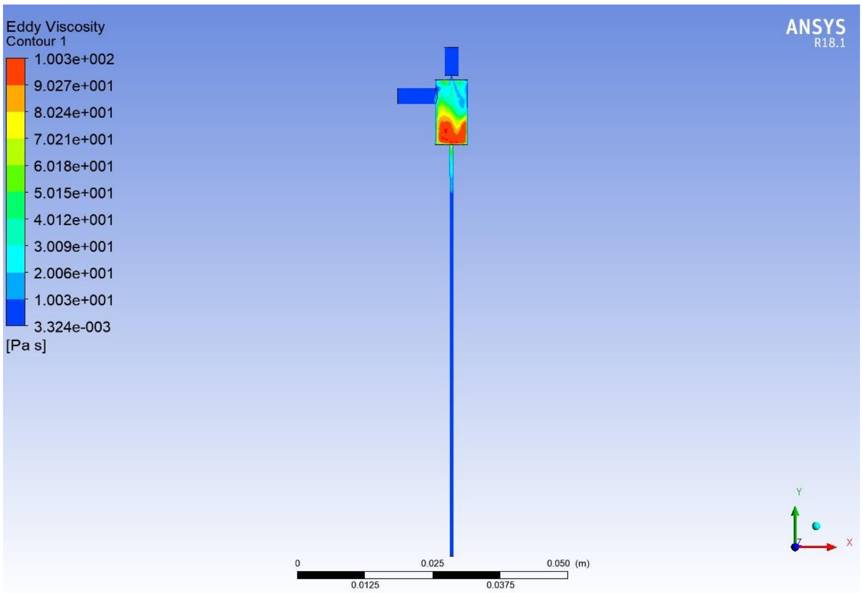


Fig 10

The above figure shows the result of nozzle's eddy viscosity at 40MPA,180mm/min jet transfer speed,250g/min abrasive flow rate and stand-off distance at 1mm.as we can observe, after entering into the mixing chamber through orifice, the water jet is allowed to mixed with the abrasive particles so the fluctuations are observed in the eddy viscosity. And maintains the cutting pressure at the tip of nozzle to erode the work material.

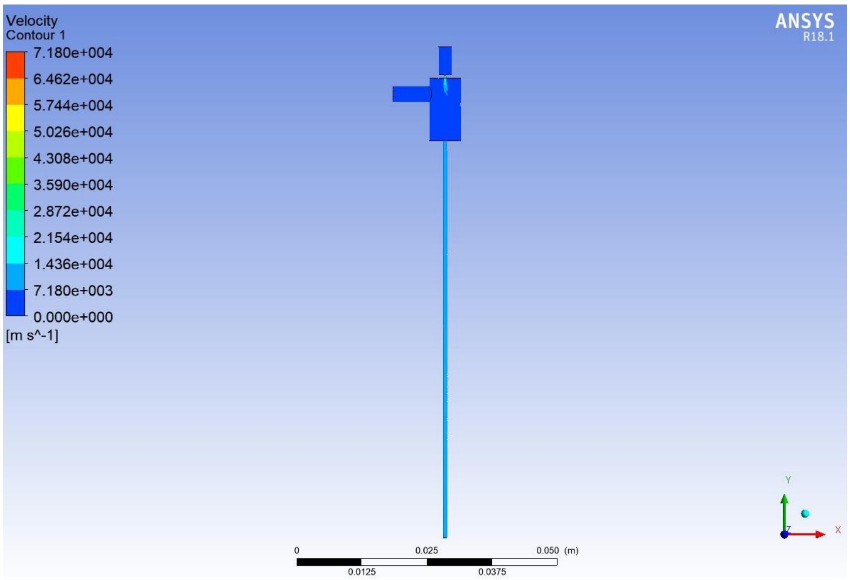


Fig 11

The above figure shows the result of nozzle velocity at 80MPA,250mm/min jet transfer speed,400g/min abrasive flow rate and stand-off distance at 1.5mm.

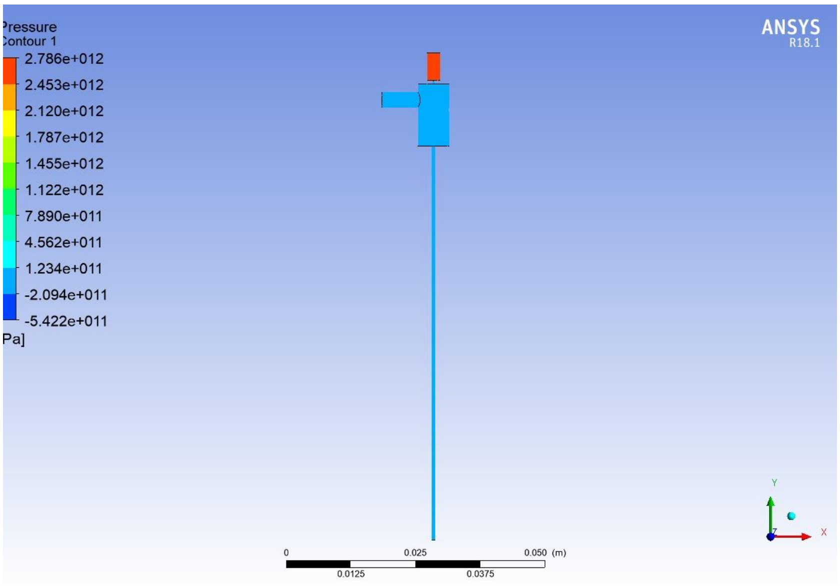


Fig 12

The above figure shows the result of nozzle pressure at 80MPA,250mm/min jet transfer speed,400g/min abrasive flow rate and stand-off distance at 1.5mm.

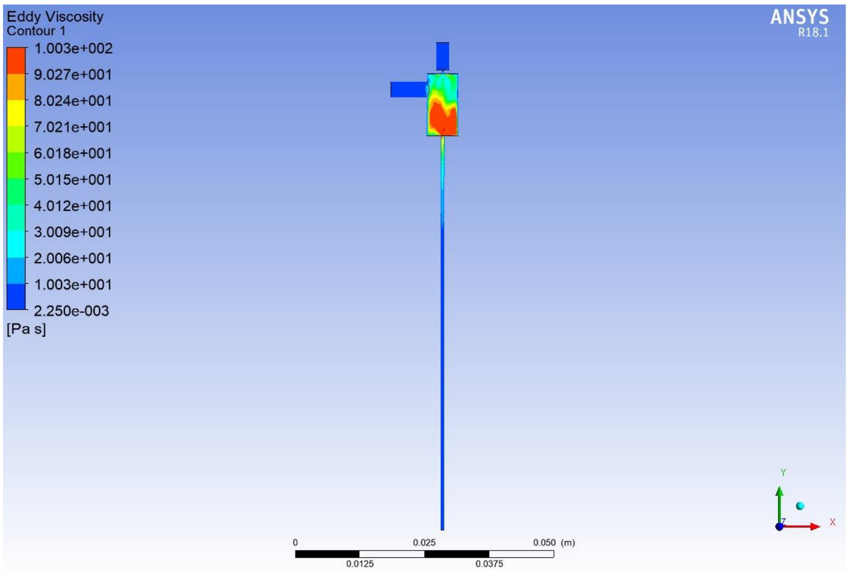


Fig 13

The above figure shows the result of nozzle's eddy viscosity at 80MPA,250mm/min jet transfer speed,400g/min abrasive flow rate and stand-off distance at 1.5mm.

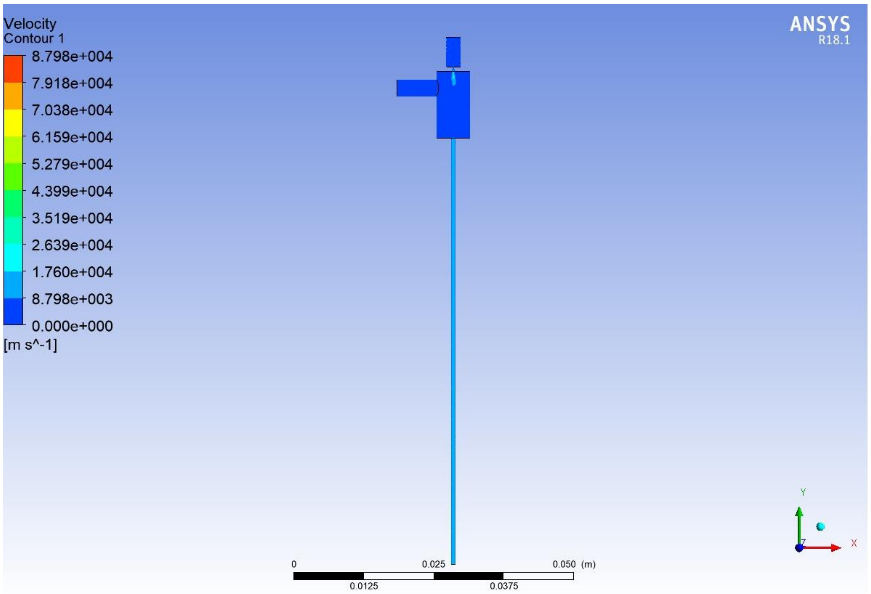


fig 14

The above figure shows the result of nozzle velocity at 120MPA,315mm/min jet transfer speed,500g/min abrasive flow rate and stand- off distance at 2mm.

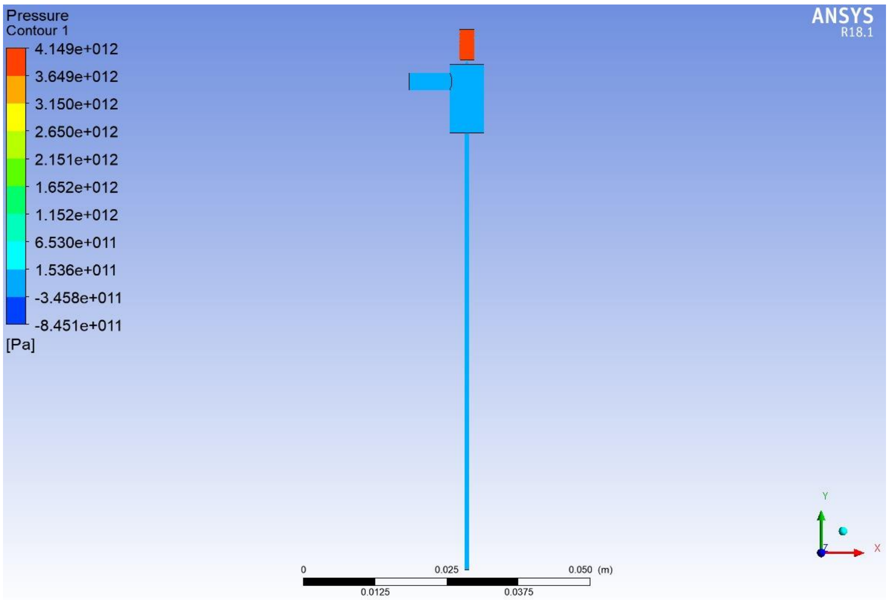


fig 15

The above figure shows the result of nozzle pressure at 120MPA,315mm/min jet transfer speed,500g/min abrasive flow rate and stand-off distance at 2mm.

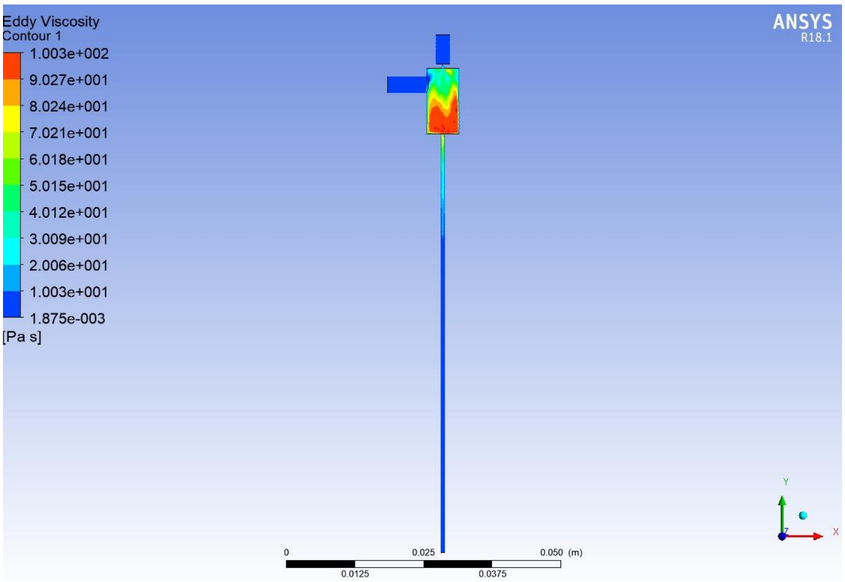


Fig 16

The above figure shows the result of nozzle's eddy viscosity at 120MPA,315mm/min jet transfer speed,500g/min abrasive flow rate and stand-off distance at 2mm.

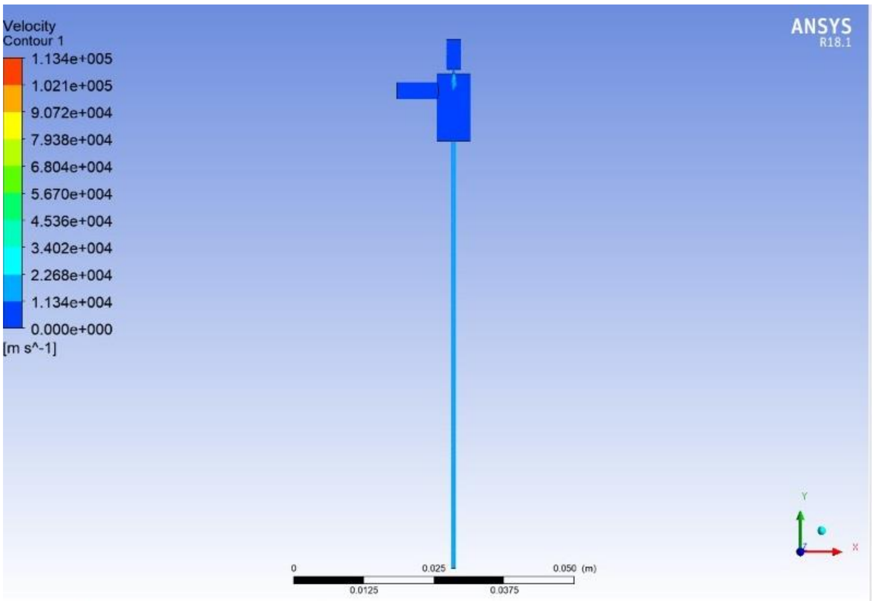


Fig 17

The above figure shows the result of nozzle velocity at 240MPA,380mm/min jet transfer speed,600g/min abrasive flow rate and stand-off distance at 1mm.

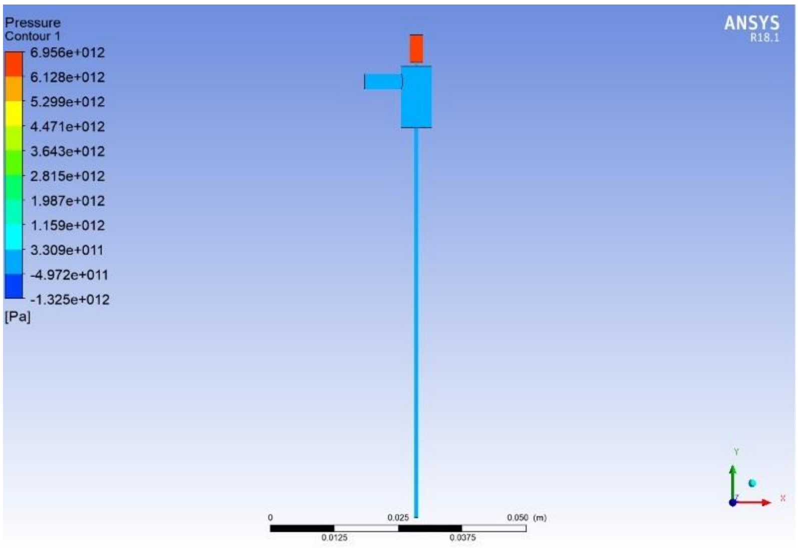


Fig 18

The above figure shows the result of nozzle pressure at 240MPA,380mm/min jet transfer speed,600g/min abrasive flow rate and stand-off distance at 1mm.

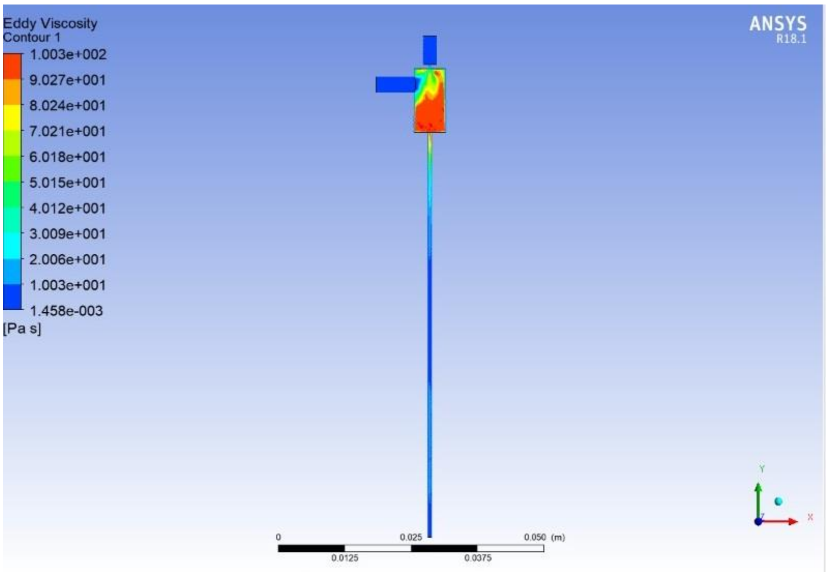


Fig 19

The above figure shows the result of nozzle's eddy viscosity at 240MPA,380mm/min jet transfer speed,600g/min abrasive flow rate and stand-off distance at 1mm.

In the case of mixing tube, the velocity reduces gradually and it reaches maximum in the mixing region and then gradually decreases when it reaches at the end of tube. The magnitude of velocity is high at higher water inlet pressure. In the case of focus tube length, the gain in velocity is observed when the flow past the nozzle. The velocity gain is more for 240 MPA pressure. Further kinetic energy lost is observed when the flow is along the focus tube for all the cases. This may be due to some of the abrasive particles do collide with the focusing tube wall.

The effect of pressure of the abrasive fluid suspension has significant effect on the erosion characteristics of the inner surface in the nozzle. The general nature of flow through the abrasive fluid jet machining, results in rapid wear of the nozzle which affects the cutting performance. High pressure of water and abrasive particles may cause severe wall shear stress due to wear.Various flow parameters are considered wall shear stress, velocity, shear strain rate. While taking parameters, the outlet velocity should be high and wall shear stressdue to wall shear, and shear strain rate should be low. The water inlet pressure increases, its velocity increases, wall shear stress also increases and all parameters increases. Without affecting wall shear stress, we take inlet pressure.

CHAPTER-5

RESULTS AND COMPARISION

From the analysis we noticed that for every 200 hours the nozzle starts wearing, we need to change the nozzle for every 200 hours. In the machining process,it was observed that increasing reinforcement increasing the Material Removal Rate under the significant contribution of reducing mesh size of abrasive particles and inclined velocity.

Trial number	**Jet transfer speed(mm/min)**	**Abrasive flow rate(g/min)**	**Stand of distance(mm)**	**MRR (gm/sec) (Wb – Wa) t**
1.	180	250	1	0.879
2.	180	300	1	0.889
3.	180	250	1.5	0.852
4.	180	300	1.5	0.863
5.	180	250	2	0.799
6.	180	300	2	0.815
7.	250	350	1	1.129
8.	250	400	1	1.136
9.	250	350	1.5	1.011
10.	250	400	1.5	1.125
11.	250	350	2	0.969
12.	250	400	2	0.994

Trial number	Jet transfer speed(mm/min)	Abrasive flow rate(g/min)	Stand of distance(mm)	MRR (gm/sec) (Wb – Wa) t
13.	315	450	1	1.567
14.	315	500	1	1.672
15.	315	450	1.5	1.248
16.	315	500	1.5	1.370
17.	315	450	2	1.091
18.	315	500	2	1.117
19.	380	550	1	2.898
20.	380	600	1	2.976
21.	380	550	1.5	2.546
22.	380	600	1.5	2.738
23.	380	550	2	2.087
24.	380	600	2	2.121

Table 4 experimental results

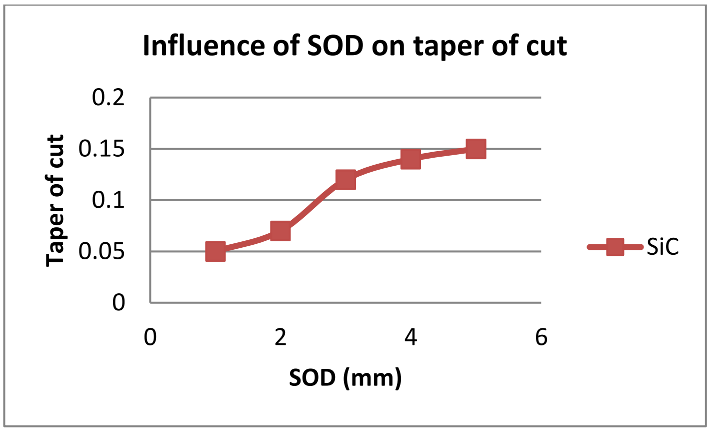
5.1 Material removal rate (MRR):

The metal removal rate in AWJM can be expressed as= {[volume of material removed per grit per cycle] * rate (impacts made by abrasives per second}

$$MRR = u \times c_d \times \frac{\Pi}{4} d_o^{\,2} \times \sqrt{\frac{2p_w^{\,3}}{\rho_w}}$$

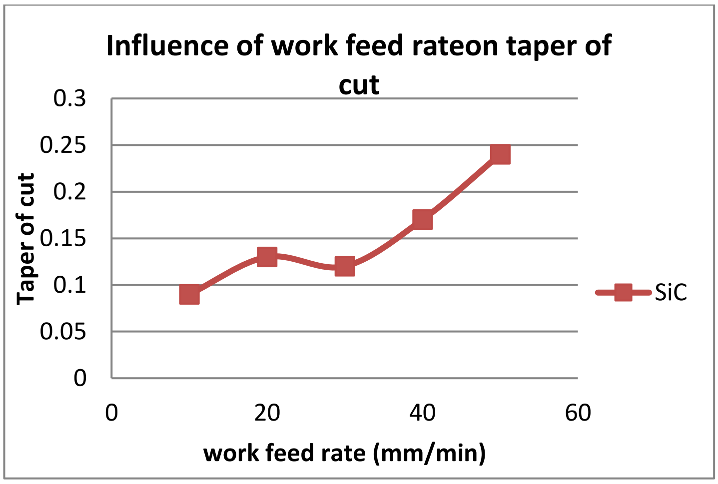
Were,**ρ-** density of water
u – constant that depends on the work material
Cd – discharge coefficient of the orifice
d – diameter of the orifice
Pw – pressure of water, Units: gm/sec

5.2 PERFORMANCE EVOLUTION



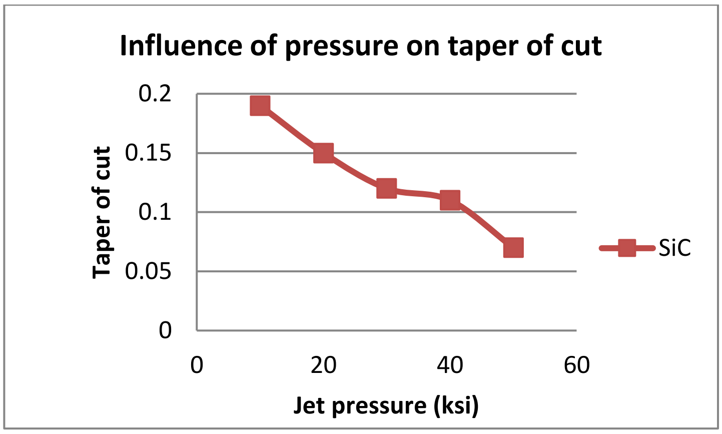
Graph 1

The above graph shows that, as the SOD increases the taper of cut also increases.



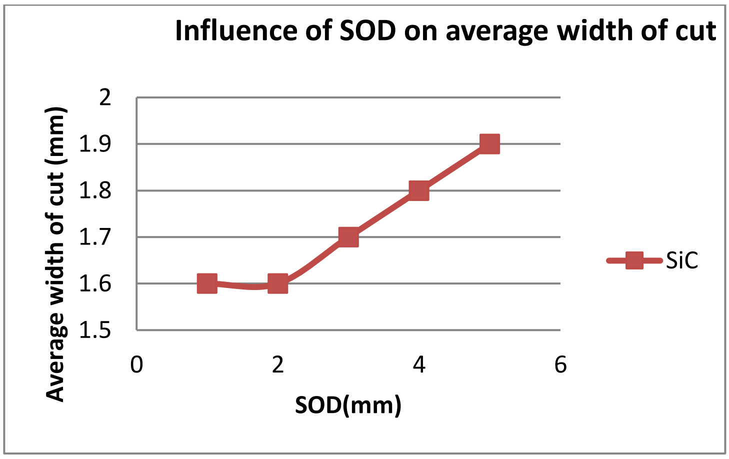
Graph 2

The above graph we can observe that, at first the fluctuations are observed and then the graph increases gradually, as the work feed rate increases taper cut also increases.



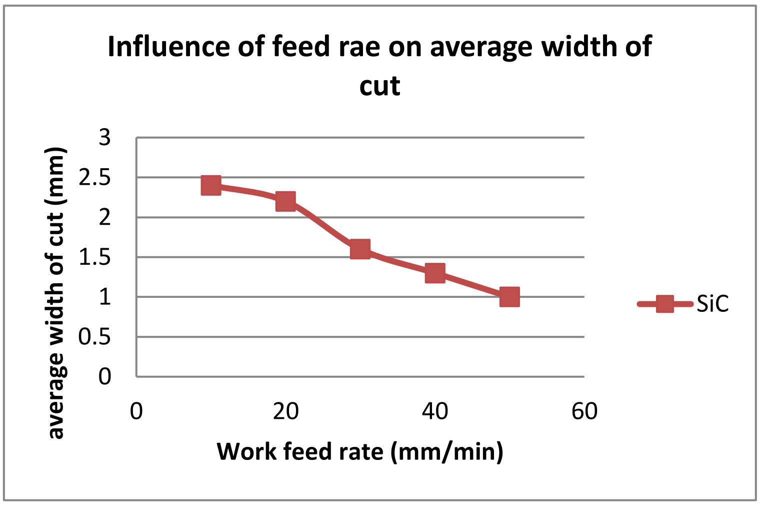
Graph 3

On observing the graph, we can say that, as the pressure on taper of cut increases, the taper of cut decreases.



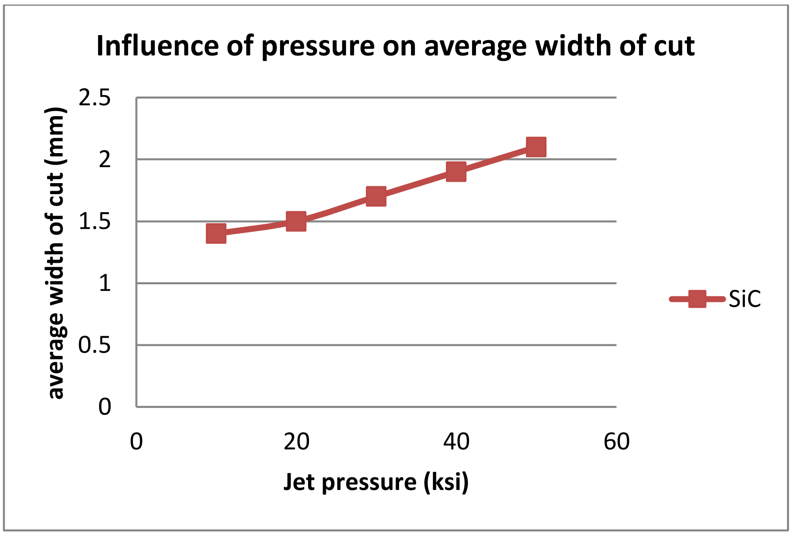
Graph 4

The above graph shows that, as SOD increases the width of cut also increases.



Graph 5

After noticing the above graph, we can say that, as the work feed rate increases the average width of cut decreases.



Graph 6

From the above graph we can observe that, the jet pressure is directly proportional to average width of cut, as the jet pressure increases the width of cut also increases.

fig 20 images of work material while machining

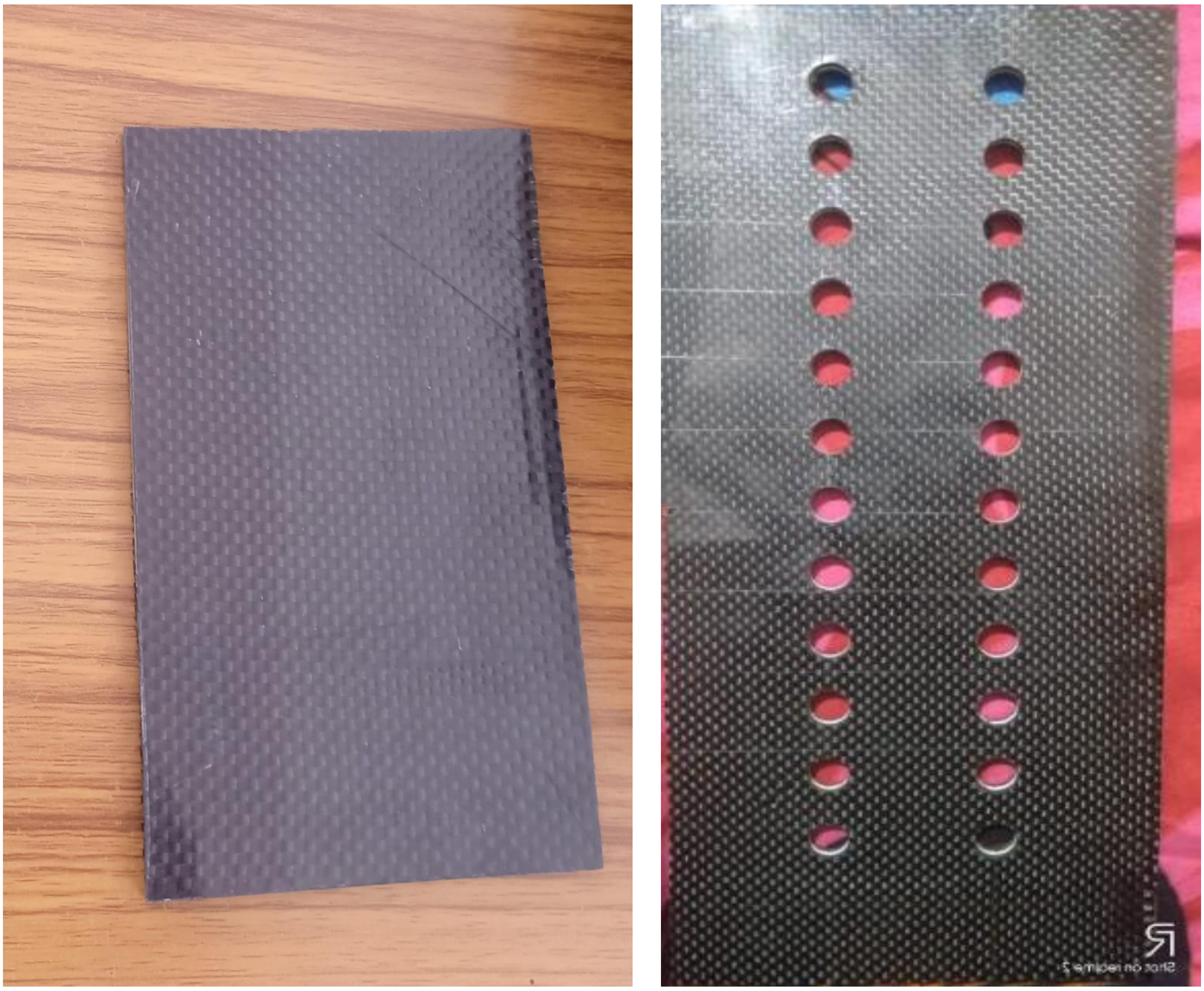


Fig. 21images of work material before machining and after machining

CHAPTER-6

CONCLUSION AND ENHANCEMENT

AWJM is an emerging technology for material processing.It is environment friendly and relatively inexpensive process with reasonably high material removal rate.

And also helps in finding material removal rate&in optimizing process parameters.

The machining is done using AWJM and obtained the parameters accordingly.

Analysis is done using CFD(computational fluid dynamics) and obtained the life of nozzle.

Various statistical and modern processes can be applied to optimize the parameters.

6.1 PUBLICATIONS

- ICRIM-2021
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6.2 REFERENCES

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A Major Project Report
on

DEVELOPMENT OF METAL MATRIX COMPOSITE MATERIAL USING SAND CASTING

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **DEVELOPMENT OF METAL MATRIX COMPOSITE MATERIAL USING SAND CASTING**, is being submitted by **I. Sahiti (17K81A0378), J. Pavan Teja (17K81A0379), K. Sanjay Reddy (17K81A0380), T. Vinitha Reddy (17K81A03B6)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

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DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **DEVELOPMENT OF METAL MATRIX COMPOSITE MATERIAL USING SAND CASTING** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

There is a growing interest worldwide in manufacturing hybrid metal matrix composites [HMMCs] which possesses combined properties of its reinforcements and exhibit improved physical, mechanical and tribological properties. Aluminum-based Metal Matrix Composites (MMCs) have received increasing attention in recent decades as engineering materials.

Composite materials are known as advanced materials for their high strength, high wear resistance, good damping characteristic and their enhanced high temperature performance. The hybrid metal matrix composite (HMMCs) materials are prepared by using sand casting technique.

In this project, The Development of Al7075alloy based metal matrix Hybrid composite reinforced with different compositions such as BFS 3 % + SiC 10% weight, BFS 6% + SiC 14% weight and BFS 12 % + SiC 18%. Experimental study was carried out to investigate the mechanical properties such as hardness, tensile strength, and microstructure.

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CHAPTER-1
INTRODUCTION

1.1 INTRODUCTION

Current engineering applications require materials that are stronger, lighter, and less expensive. A good example is the current interest in the development of materials that have good strength to weight ratio suitable for automobile applications where fuel economy with improved engine performance is becoming more critical. In-service performance demands for many modern engineering systems require materials with broad spectrum of properties, which are quite difficult to meet using monolithic material systems.

Metal matrix composites (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications. Some of these property combinations include: high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance.

Aluminum hybrid matrix composites have become better substitutes for the conventional aluminum alloys because of their characters like improved strength to weight ratio, energy saving, and better wear resistance. Reinforced aluminum hybrid matrix, a composite for the use of the automotive industry and other structural applications, has been increased because of the physical and mechanical properties it possesses. Aluminum based hybrid matrix composites with a variety of particulate reinforcements such as Al_2O_3, TiC, Ti_2B, B_4C, TiN, Si_3N_4, graphite, and industrial waste byproduct have been conceived and developed for various potential applications.

1.2 Objective

The present study involves the development of hybrid metal matrix composite reinforced with particulate BFC, Sic and Al 7075 by sand casting method. Weight fraction of 3, 6 and 12% of BFS is reinforced with base Aluminum Alloy 7075 matrix. The fabricated aluminum alloy was solution treated and then precipitation treated for T-6 condition. Casted composite and heat treated composite machined carefully to prepare specimens for micro hardness, tensile strength and microstructure as per the ASTM standards. Mechanical properties include hardness; microstructure and tensile properties were evaluated.

1.3 COMPOSITE MATERIALS

Composite materials emerged in the middle of the 20th century as a promising class of engineering materials providing new prospects for modern technology. Generally, any material consisting of two or more components with different properties and distinct boundaries between the components can be referred to as a composite material. Moreover, the idea of combining several components to produce a material with properties that are not attainable with the individual components has been used by man for thousands of years. Correspondingly most natural materials that have emerged because of a prolonged evolution process can be treated as composite materials.

Composite materials are anisotropic and inhomogeneous materials. Composite material is made by combining a minimum of two or more materials, often with different properties. Composite materials usually present unique properties in which the strength-to-weight ratio is high. Another advantage of composite material is that it provides flexibility in design because the composites can be molded into complex shapes. There are many types of composite materials such as carbon-reinforced fiber plastic, glass fiber–reinforced aluminium, composites with carbon nanotubes, and many more. Other types of composite include metal-matrix and ceramic-matrix composites.

Composites have vast usage in engineering applications. Currently, laminated composite is becoming very popular in the area of aeronautics, wind energy, as well as in the automotive industry.

USES OF COMPOSITE MATERIALS

The wide range of property values attained with composites and the ability to tailor the properties is an advantage. Composite materials also generally have higher strength- and modulus-to-weight ratios than traditional engineering materials. These features can reduce the weight of a system by as much as 20 to 30%. The weight savings translates into energy savings or increased performance. Advanced composites exhibit desirable dynamic properties and have high creep resistance and good dampening characteristics. In fact, the superior fatigue performance of composite materials enables them to be used to repair metallic airframes with fatigue damage.

Since composite materials can be manufactured into almost any shape, they allow great design flexibility and offer reduced parts count for articles. The opportunity to select the constituents, tailor them to obtain the required properties, and then through design make the optimum use of the properties is a situation that makes composites very attractive to many industries.

APPLICATIONS

1. Aerospace

Thermoset composites are being specified for wings, fuselages, bulkheads, and other applications in commercial, civilian, and military aerospace applications.

2. Appliance/ Business

Composites are being used in frames, equipment panels, handles, and trims in applications. Power tools, business equipment etc.

3. Automotive/ Transportation/ Farm/ Construction

Composites are now being used in vehicle and equipment applications, including panels, interior components and buildings , roads, bridges etc.

1.4 METAL MATRIX COMPOSITE

Metal matrix composites (MMCs) are group of materials (such as metals, alloys or intermetallic compounds) incorporated with various reinforcing phases, such as particulates, whiskers or continuous fibers.

Classification of MMCs based on the matrix material

MMCs are classified into different categories depending upon their matrix materials. Some examples of most used metallic matrix configurations are:

- Aluminium-based composites; aluminium as matrix can be either cast alloy or wrought alloy (i.e., AlMgSi, AlMg, AlCuSiNn, AlZnMgCu, AlCu, AlSiCuMg.
- Magnesium – based composites.
- Titanium – based composites.
- Copper – based composites.
- Super alloy- based composites.

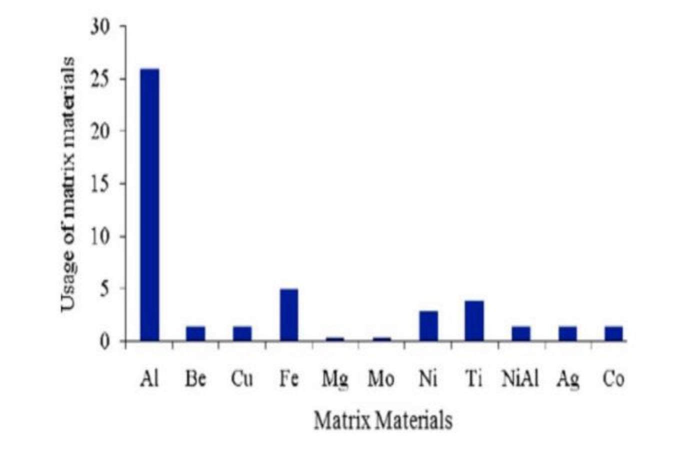


Fig 1: Usage volume of matrix materials

Figure 1 shows the usage volume of different matrix materials in MMCs. As seen, aluminum is the most used matrix material in MMCs.

Aluminium – matrix composites are widely used in the automotive and aerospace industry. Reinforcement compounds such as SiC, Al_2O_3, and B_4C can be mixed easily and effectively in molten aluminum. Magnesium–matrix composites have similar advantages, but due to limitations in fabrication and lower thermal conductivity, they are not widely used as compared with aluminum-based MMCs.

APPLICATIONS OF MMCs

MMCs are good alternatives to traditional materials, due to their hardness, specific strength, and creep resistance. The special properties of these materials have enlarged its application to other interesting areas as sports and electronic applications, where the thermal properties and the right value of coefficient of thermal expansion are essential.

In the early 1970s, the attention was focused on increasing the creep resistance of the rotor blades through the reinforcement of aluminum alloys by boron fibers. Recently, interest has shifted to asymmetrical components for aircraft engines, many of which are ideally equipped with unidirectional high-performance properties that are especially exploited in titanium matrix composites. These properties have made MMC an interesting alternative to traditional materials. In fact, there is an increasingly important MMC presence in engines (engine block and pistons), drive shaft, and disk brakes.

1.5 HYBRID METAL MATRIX COMPOSITE

Ages are related with material growth and the enhancement of each material to its superclasses has been the prime requirement of research. Combinations of material form the present era of exploring metallurgy field. Composites are one such that evolved during its process from 1500 BC. The advancement in the composites has uplifted itself from primitive to its next stage. The hybrid composites navigated for purpose of lightweight, wear resistance and for combining advantages of the reinforces based upon the necessity and need of applications. Hybrid composites are developing as an improvement over previously existing conventional composite.

The sustainable industry growth and people's life improvement greatly depend on the use of alternative product in various fields. Hybridization is a process of incorporating two or more reinforcements to yield better stiffness, strength, high strength to weight ratio and other mechanical properties. Hybrid composites primarily consist of one matrix and two or more reinforcement. Hybrid Composite materials are formed by reinforcing two or more materials of varying properties with matrix phase.

ADVANTAGES OF HMMC'S

1. Hybrid Composites are materials that are fabricated by combining two or more different types of fibers within a common matrix.
2. It can be used for primary structures in commercial, industrial, aerospace, marine and recreational structures.
3. It has wide array of benefits in aerospace industry, such as great fatigue and corrosion resistance.
4. The most significant advantage is weight reduction, where it could generate savings in the range of 20% to 50%.
5. The mechanical properties can be tailored by "lay-up" design, with tapering thickness of reinforcing and changing orientation.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

Processing and Characterization of Hybrid Metal Matrix Composites [1] J. Mater. Environ. Sci., 2018, Volume 9, Issue 7,[1]

The present paper reports a review on the structural and mechanical behavior of aluminium hybrid metal matrix composite. Aluminium matrix composites (AMC) are modern and advanced metal matrix composites (MMC) that can meet the recent increasing demands of various industries. The physical, structural and mechanical properties of aluminium matrix composites have made them useful in fields of aerospace, marines etc. It is necessary to select the right combination of compounds or minerals to reinforce with the metal as it will directly affect the properties of metal matrix composite thus formed. Selection of different constituents will affect the properties of MMC differently and the composition of constituents can also be varied to observe the changing properties of MMCs. This paper describes the various processing techniques and the various research and development activities taking place in the field of hybrid metal matrix composites.

Characterization of hybrid aluminum matrix composites for advanced applications – A review April–June 2016, [2]

Hybrid aluminum matrix composites (HAMCs) are the second generation of composites that have potential to substitute single reinforced composites due to improved properties. This paper investigates the feasibility and viability of developing low cost-high performance hybrid composites for automotive and aerospace applications. Further, the fabrication characteristics and mechanical behavior of HAMCs fabricated by stir casting route have also been reviewed. The optical micrographs of the HAMCs indicate that the reinforcing particles are fairly distributed in the matrix alloy and the porosity levels have been found to be acceptable for the casted composites. The density, hardness, tensile behavior and fracture toughness of these composites have been found to be either comparable or superior to the ceramic reinforced composites. It has been observed from the literature that the direct strengthening of composites occurs due to the presence of hard ceramic phase, while the indirect strengthening arises from the thermal mismatch between the matrix alloy and reinforcing phase during solidification.

Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum Disulphide 2016 G. Pitchayyapillai,1 P. Seenikannan,1 K. Raja,2 and K. Chandrasekaran [3]

Aluminum Hybrid Reinforcement Technology is a response to the dynamic ever-increasing service requirement of industries such as transportation, aerospace, automobile, and marine, due to its attractive properties like high ductility, highly conductivity, light weight, and high strength to weight ratio. In this evolution, an attempt has been made to investigate the wear rate of Al6061 hybrid metal matrix composite reinforced with the hard ceramic alumina (4, 8, and 12 wt.% of Al_2O_3) and soft solid lubricant of molybdenum disulphate (2, 4, and 6 wt.% of MoS_2) is fabricated by using stir casting method.

Aluminium matrix hybrid composites: a review of reinforcement philosophies; mechanical, corrosion and tribological characteristics October–December 2015 [4]

This paper attempts to review the different combination of reinforcing materials used in the processing of hybrid aluminium matrix composites and how it affects the mechanical, corrosion and wear performance of the materials. The major techniques for fabricating these materials are briefly discussed and research areas for further improvement on aluminium hybrid composites are suggested.

Preparation and Testing of Hybrid Metal Matrix Composite-A Case Study [5] Number 2013 [5]

Aluminum metal matrix composites are light weight, cost competitive and have high performance properties. The present study deals with the preparation of the optimized hybrid metal matrix composite Al356 + 3% graphite + 6% silicon carbide after conducting wear tests. The proposed composite is further subjected to tensile test, compression test, and hardness tests. The findings suggest that the conventional brake disc made of Grey Cast Iron can be replaced by the proposed hybrid metal matrix composite for better performance.

Development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications 2011 [6]

The present study deals with the investigation of dry sliding wear behavior of aluminium alloy-based composites, reinforced with silicon carbide particles and solid lubricants such as graphite/antimony tri sulphide (Sb2S3). The first one of the composites (binary) consists of Al. with 20% Silicon Carbide particles (Sic) only. The other composite has Sic and solid lubricants: Graphite + Sb2S3 (hybrid composite) at solid state. Both composites are fabricated through P/M route using "Hot powder perform forging technology". The density and hardness are measured by usual methods. The pin-on-disc dry wear tests to measure the tribological properties are conducted for one hour at different parameters namely load: 30, 50 and 80N and speed: 5, 7 and 9m/s. The tested samples are examined using scanning electron microscope (SEM) for the characterization of microstructure and tribulate on worn surface of composites.

Aluminum hybrid metal matrix composites, Volume 48 Number 6 June 2017 [7]

Silicon carbide-Graphite-Al6061alloy composite having 10 to 20% of silicon carbide and 5 to 10% graphite fiber were fabricated by liquid metallurgy (stir cast) method. The casted composite specimens were machined as per test standards. The specimens were tested to know the characteristics of the Hybrid Metal Matrix Composites (HMMc). Experimental study was carried out to investigate the mechanical properties such as hardness, tensile strength, shear test and impact test. As a result, hardness decreases with the increase in the percentage of Gr, tensile strength, and shear test.

A Study on Mach inability of Hybrid Metal Matrix Composites-A Review National Conference on Advances in Mechanical Engineering Science (NCAMES-2016) [8]

In the present study, based on the literature review, the machining of hybrid Aluminum metal matrix composite is discussed. These hybrid HMMCs can easily be machined by conventional machining and good surface quality can be obtained by controlling the machining parameters. These Aluminum metal matrix composites with multiple reinforcement are finding increased applications because of improved mechanical and tribiological properties and hence are better substitutes for reinforced composites. These materials are developed for bushes, bearings, and cylinder liners in cast Aluminum engine blocks. The problems encountered during machining of hybrid MMCs and their amendments using conventional machining are discussed.

Research Significance, Applications and Fabrication Of Hybrid Metal Matrix Composites International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 5, May 2015 [9]

The reinforcement of light metals will have profuse prospect of application areas where weight reduction has priority. This material group becomes motivating for the utilization as constructional and functional materials, if the property contour of the conventional materials either does not arrive at the increased standards of explicit demands or is the solution of the problem. However, the appreciative technology of MMCs is in competition with other modern material technologies. In the present scenario, researchers and scientists are fascinated and involved in exploring new developments pertaining to metal matrix composite materials. Numerous scientists and researchers have carried out an extensive research work on mechanical and tribological behaviors of composite materials because of appreciative and advantageous properties. In present circumstances, Metal Matrix Composites are primarily important for military, automotive and aerospace applications. In the research work, Aluminium based composites reinforced with Silicon Carbide and Graphite particles have been prepared by stir casting technique.

Aluminium Metal Matrix Composites - A Review Received: October 19, 2013 [10]

Aluminium matrix composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the stiffness, specific strength, wear, creep and fatigue properties com- pared to the conventional engineering materials. This paper presents the overview of the effect of addition on different reinforcements in aluminium alloy highlighting their merits and demerits. Major issues like agglomerating phenomenon, fiber-matrix bonding and the problems related to distribution of particles are discussed in this paper. Effect of different reinforcement on AMCs on the mechanical properties like tensile strength, strain, hardness, wear and fatigue is also dis- cussed in detail. Major applications of different AMCs are also highlighted in this work.

A Review of the Aluminum Metal Matrix Composite and its Properties Volume: 04 Issue: 02 | Feb -2017 [11]

The present study deals with the addition of reinforcements such as graphite, fly ash, silicon carbide, red mud, organic material etc. to the Aluminium matrix in various proportions. Each reinforced material has an individual property which when added improves the properties of the base alloy. An effort has been made to review the different combinations of the composites and how they affect the properties of the different alloys of aluminum. A comprehensive knowledge of the properties is provided to have an overall study of the composites and the best results can be employed for the further development of the Aluminum reinforced composed.

The investigation shows that Al metal matrix composites can be replaced with other conventional metals for better performance and longer life.

Hardness and impact behavior of aluminum metal matrix composite, The 3rd International Conference on Materials and Manufacturing Engineering 2018 [12]

In this study four samples of different compositions of Silicon Carbide are prepared and studied. The fabrication process is done by Stir casting carries out by adding the required additives into the molten mixture of aluminum followed by continuous stirring. After solidification for a period of time the samples are cut according to standard dimensions for carrying out the testing procedures. The various test procedures like hardness and impact tests were conducted to study the mechanical properties of obtained metal matrix composite. The various results inferred from the tests are analyzed and subjected to comparison with each other in this study.

An Overview on Development of Aluminum Metal Matrix Composites with Hybrid Reinforcement [13] Volume 1 Issue 3, December 2012

Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. This review article is written for initiating new research on development of aluminium metal matrix composites with hybrid reinforcement.

Aluminum Metal Matrix Composites – A Review, August 2017; [14]

A composite material is a combination of two or more chemically distinct and insoluble phases; its properties and structural performance are superior to those of the constituents acting independently. Metals and ceramics, as well, can be embedded with particles or fibers, to improve their properties; these combinations are known as Metal-Matrix composites. Aluminum alloy constitutes a very important engineering material widely employed in the aircraft and aerospace industry for the manufacturing of different parts and components. It is due to its high strength to density ratio that it a sought after metal matrix composite. Various processing techniques for the fabrication of Aluminum matrix composites, testing of their mechanical properties are available.

Mechanical Properties of Al-SiC Metal Matrix Composites Fabricated by Stir Casting Route November 09, 2017; [15]

Aluminum and its alloys possess excellent properties such as low density, good plasticity, and ductility. They find extensive applications in aeronautics, astronautics, and automobile and high speed train fields. The matrix alloy, the reinforcement material, the volume and shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties [1]. Metal matrix composites (MMCs), such as SiC particle reinforced Al, are one of the widely known composites because of their superior properties such as high strength, hardness, stiffness, wear and corrosion resistance. SiC particle reinforced Al based MMCs are among the most common MMC and available ones due to their economical production.

Stir Casting Process in Particulate Aluminium Metal Matrix Composite: A Review Volume 12, Number 1 (2017); [16]

The enhancement of manufacturing sector has somewhere advance to the increase in the use of particulate aluminium metal matrix composites (PAMMCs). PAMMCs are attracting considerable interest worldwide for automotive, architectural and aerospace sectors because of their superior mechanical and tribological properties. PAMMCs possess high specific strength, greater strength to weight ratio at elevated temperature, greater wear resistance as compared to matrix phase. Numerous types of reinforcements in particulate like SiC, Al2O3, B4C, TiC and ZrSiO4 is used to improve the metallurgical as well as mechanical properties as compared to its base matrix. Besides, authors also used industrial and agro waste like fly ash, bauxite residue, groundnut shell, rice husk ash and bags ash as reinforcement in matrix phase. Various fabrication processes like solid state (Powder Metallurgy) and liquid state processes (Stir casting, Compo-casting, Squeeze Casting, in situ casting routes) were adopted by authors to fabricate PAMMCs. Among these processes stir casting is cheapest and simple route for fabrication of AMMCs. This review article elaborates the latest trend in stir cast process to fabricate different types of PMMCs.

Effect of Particulate Reinforced Aluminium Metal Matrix Composite–A Review, Vol. 19, No. 1 (2015) 23–30; [17]

The combined effect of reinforcements on Aluminium Metal Matrix composites with individual and multiple particulate reinforcements like Hybrid Metal matrix composites are finding increased applications in aerospace, automobile, space, underwater, and transportation applications. This is mainly due to improved mechanical and tribological properties like strength, stiffness, abrasion, impact resistance and wears resistance. In the present scenario, a lot of research activities were on pipeline. This paper guides the researchers and engineers towards proper selection of materials by their properties in the relevant field and different techniques involved in manufacturing of metal matrix composites, particularly on the liquid state metal processing technique.

A Study of Microstructure And Tribological Properties Of Stir Cast Al Metal Matrix Composite, Volume- 5, Issue-4, April -2017 [18]

An attempt has been made to develop and characterize Al 5083 alloy with SiC reinforcement by using stir casting technique. In case of MMC' aluminum matrix composite dues, their high strength to weight ratio, low cost and high wear resistance are widely manufactured and used in structural applications along with aerospace and automobile industry. The study of wear characteristics and mechanical properties on Aluminium Matrix Composites (AMCs) reinforced with silicon carbide (SiC) particles are carried out. In this composite Al 5083 is used as matrix material with varying quantity of SiC of 3%,5% and 7 Wt%. The composite was fabricated by using Friction stir casting (FSC) method. The friction and wear characteristics of the composite is investigated under dry sliding condition and compared with original aluminium alloy. The wear test is carried out by using pin on disk method at normal loads and at constant velocity. The wear mechanism of composites and original alloy is compared by using scanning electron microscope (SEM) image of the worn surfaces.

2.2 SUMMARY

Aluminum alloy matrix composites reinforced with Hybrid can be successfully synthesized by the stir casting method. For synthesizing of hybrid composite by stir casting process, stirrer design and position, stirring speed and time, melting, and pouring temperature, particle-preheating temperature, particle incorporation rate, mold type and size, and reinforcement particle size and amount are the important process parameters. With the addition of hybrid reinforcement instead of single reinforcement the hardness, toughness, strength, corrosive, and wear resistance of the composite will be increasing further increased.

CHAPTER 3

MATERIAS AND METHODS

3.1 MATERIALS

3.1.1 ALUMINUM ALLOY 7075

7075 aluminum alloy is an aluminum alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average mach- inability. It has lower resistance to corrosion than many other aluminum alloys but has significantly better corrosion resistance than the 2000 alloys. Its relatively high cost limits its use.

7075 aluminum alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651.

The first 7075 was developed in secret by a Japanese company, Sumitomo Metal, in 1943.[1] 7075 was eventually used for airframe production in the Imperial Japanese Navy. **Aluminum alloys** (or) **aluminum alloys** are alloys in which aluminum (Al) is the predominant metal.

The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys.

The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics.

Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Alloys composed mostly of aluminum have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. Aluminum-magnesium alloys are both lighter than other aluminum alloys and much less flammable than alloys that contain a very high percentage of magnesium.

Aluminum alloy surfaces will develop a white, protective layer of aluminum oxide if left unprotected by anodizing and/or correct painting procedures. In a wet environment, galvanic corrosion can occur when an aluminum alloy is placed in electrical contact with other metals with more positive corrosion potentials than aluminum, and an electrolyte is present that allows ion exchange. Referred to as dissimilar-metal corrosion, this process can occur as exfoliation or as intergranular corrosion. Aluminum alloys can be improperly heat treated. This causes internal element separation, and the metal then corrodes from the inside out.

Aluminum alloy compositions are registered with The Aluminum Association. Many organizations publish more specific standards for the manufacture of aluminium alloy, including the Society of Automotive Engineers standards organization, specifically its aerospace standards subgroups, and ASTM International

Aluminum alloy the matrix material is chosen as 7075 Aluminum alloy and it is highly dense, corrosion resistance and very soft ductile material belonging to the boron group of chemical elements. The typical compositions of 7075 Al-alloy

USES

Due to their high strength-to-density ratio 7000 series alloys such as 7075 are often used in transport applications, including marine, automotive and aviation. These same properties lead to its use in rock climbing equipment, bicycle components, inline skating-frames and hang glider airframes are commonly made from 7075 aluminum alloy.

Hobby grade RC models commonly use 7075 and 6061 for chassis plates. 7075 is used in the manufacturing of M16 rifles for the American military as well as AR-15 style rifles for the civilian market. In particular high quality M16 rifle lower and upper receivers as well as extension tubes are typically made from 7075-T6 alloy. Desert Tactical Arms, SIG Sauer, and French armament company PGM use it for their precision rifles. It is also commonly used in shafts for lacrosse sticks, such as the STX Sabre, and camping knife and fork sets. It is a common material used in competition yo-yos as well.

Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mold tool manufacturing. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020.

APPLICATIONS

It is a common material used in competition yo-yos as well. Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mold tool manufacturing. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020.

3.1.2 BLAST FURNANCE SLAG

(a) Ca O: 30 to 38 %

(b) Si O2: 30 to 40 %

(c) $Al_2 O_3$: 15 to 222%

(d) Mg O: 8 to 11%

(e) Fe O: 0.49 %

(f) Mn O: 2%

Blast furnace slag is used successfully in mud-to-cement conversion worldwide because of its economic, technical, and environmental advantages (Pessier et al., 1994). Slag-mix slurries were used as primary, temporary abandonment and sidetrack plug cements during prospect predrilling in the Gulf of Mexico. However, the penetration rates were slower than expected when these plugs were drilled out, hence a basic study of its drilling properties was initiated.

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminates impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production, the flux consists mostly of a mixture of limestone and for sterile or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an uncreative crystalline material consisting of an assemblage of Ca-Al-Mg silicates.

To obtain a good slag reactivity or hydraulicity, the slag melt needs to be rapidly cooled or quenched below 800 °C to prevent the crystallization of marinate and melilite. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. To obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement.

The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al2O3 (8-24%), and MgO (1-18%). In general, increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength. The MgO and Al2O3 content show the same trend up to respectively 10-12% and 14%, beyond which no further improvement can be obtained. Several compositional ratios or so-called hydraulic indices have been used to correlate slag composition with hydraulic activity; the latter being mostly expressed as the binder compressive strength.

The glass content of slags suitable for blending with Portland cement typically varies between 90-100% and depends on the cooling method and the temperature at which cooling is initiated. The glass structure of the quenched glass largely depends on the proportions of network-forming elements such as Si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al. Increased amounts of network-modifiers lead to higher degrees of network depolymerization and reactivity.

Common crystalline constituents of blast-furnace slags are merwinite and melilite. Other minor components which can form during progressive crystallization are belite, monticellite, rankinite, wollastonite and fosterage. Minor amounts of reduced Sulphur are commonly encountered as old Hamite.

APPLICATIONS

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

Use of GGBS significantly reduces the risk of damages caused by alkali–silica reaction (ASR), provides higher resistance to chloride ingress — reducing the risk of reinforcement corrosion — and provides higher resistance to attacks by sulfate and other chemicals**.**

USES

Pelletized blast furnace slag has been used as lightweight aggregate and for cement manufacture. Foamed slag has been used as a lightweight aggregate.

Granulated blast furnace slag has been used as a raw material for cement production and as an aggregate and insulating material. and granulated slag have also been used as sand blasting shot materials.

3.1.3 SILICON CARBIDE POWDER

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high-quality technical grade ceramic with very good mechanical properties.

It is used in abrasives, refractoriness, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material.

Properties of Silicon Carbide

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness.

3.2 METHODS

3.2.1 SAND CASTING

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand-casting process. Sand castings are produced in specialized factories called foundries. Over 60% of all metal castings are produced via sand casting process.

Molds made of sand are relatively cheap, and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened, typically with water, but sometimes with other substances, to develop the strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known as a flask. The mold cavities and gate system are created by compacting the sand around models called patterns, by carving directly into the sand, or by 3D printing.

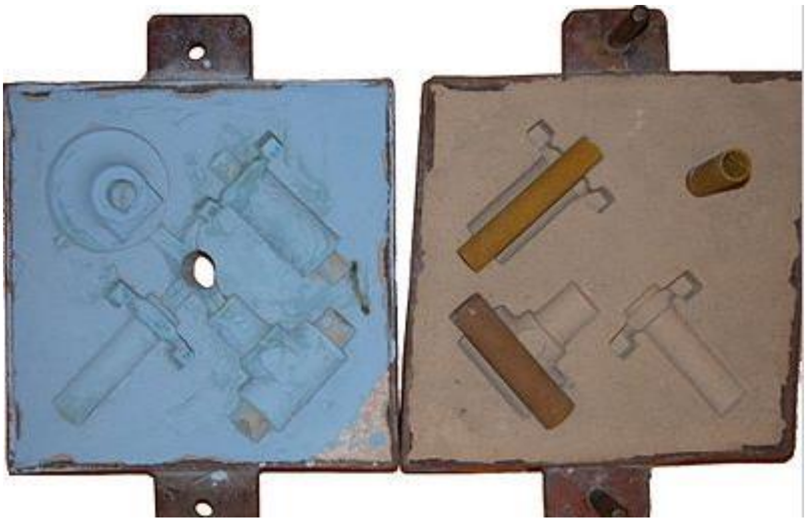


Fig 2: Sand casting mold

GREEN SAND

These castings are made using sand molds formed from "wet" sand which contains water and organic bonding compounds, typically referred to as clay.[4] The name "Green Sand" comes from the fact that the sand mold is not "set", it is still in the "green" or uncured state even when the metal is poured in the mould. Green sand is not green in color, but "green" in the sense that it is used in a wet state (akin to green wood). Unlike the name suggests, "green sand" is not a type of sand on its own (that is, not greensand in the geologic sense), but is rather a mixture of:

Silica sand (SiO_2), chromate sand ($FeCr_2O_4$), or zircon sand ($ZrSiO_4$), 75 to 85%, sometimes with a proportion of olivine, staurolite, or graphite.

- betonies (clay), 5 to 11%
- water, 2 to 4%
- inert sludge 3 to 5%
- anthracite (0 to 1%)

There are many recipes for the proportion of clay, but they all strike different balances between mold ability, surface finish, and ability of the hot molten metal to degas. Coal, typically referred to in foundries as sea-coal, which is present at a ratio of less than 5%, partially combusts in the presence of the molten metal, leading to off gassing of organic vapors. Green sand casting for non-ferrous metals does not use coal additives, since the CO created does not prevent oxidation. Green sand for aluminum typically uses olivine sand (a mixture of the minerals forsterite and fayalite, which is made by crushing dunnite rock).

3.2.2 MATERIAL PROPERTIES

Aluminum, Al	88.5 - 91.5 %	88.5 - 91.5 %
Chromium, Cr	0.18 - 0.25 %	0.18 - 0.25 %
Copper, Cu	1.2 - 1.9 %	1.2 - 1.9 %
Iron, Fe	<= 0.12 %	<= 0.12 %
Magnesium, Mg	1.9 - 2.6 %	1.9 - 2.6 %
Manganese, Mn	<= 0.06 %	<= 0.06 %
Other, each	<= 0.05 %	<= 0.05 %
Other, total	<= 0.15 %	<= 0.15 %
Silicon, Si	<= 0.10 %	<= 0.10 %
Titanium, Ti	<= 0.06 %	<= 0.06 %
Zinc, Zn	5.2 - 6.2 %	5.2 - 6.2 %

Table 1: Chemical properties of Al7075

Physical Properties	**Metric**	**English**
Density	2.81 g/cc	0.102 lb/in³
Mechanical Properties	**Metric**	**English**
Hardness, Brinell	148	148
Hardness, Knoop	188	188
Hardness, Rockwell A	53.2	53.2
Hardness, Rockwell B	87	87
Hardness, Vickers	173	173
Tensile Strength, Ultimate	565 MPa	82000 psi
	11.0 MPa @Thickness 1.00 - 6.35 mm, Temperature 538 °C	1600 psi @Thickness 0.0394 - 0.250 in, Temperature 1000 °F
	18.0 MPa @Thickness 1.00 - 6.35 mm, Temperature 482 °C	2610 psi @Thickness 0.0394 - 0.250 in, Temperature 900 °F
	552 MPa @Thickness 1.00 - 6.35 mm, Temperature 24.0 °C	80100 psi @Thickness 0.0394 - 0.250 in, Temperature 75.2 °F
	579 MPa @Thickness 1.00 - 6.35 mm, Temperature -28.0 °C	84000 psi @Thickness 0.0394 - 0.250 in, Temperature -18.4 °F
	607 MPa @Thickness 1.00 - 6.35 mm, Temperature -80.0 °C	88000 psi @Thickness 0.0394 - 0.250 in, Temperature -112 °F
	683 MPa @Thickness 1.00 - 6.35 mm, Temperature -196 °C	99100 psi @Thickness 0.0394 - 0.250 in, Temperature -321 °F
Tensile Strength, Yield	490 MPa	71000 psi
	9.00 MPa @Thickness 1.00 - 6.35 mm, Temperature 538 °C	1310 psi @Thickness 0.0394 - 0.250 in, Temperature 1000 °F
	15.0 MPa @Thickness 1.00 - 6.35 mm, Temperature 482 °C	2180 psi @Thickness 0.0394 - 0.250 in, Temperature 900 °F
	496 MPa @Thickness 1.00 - 6.35 mm, Temperature 24.0 °C	71900 psi @Thickness 0.0394 - 0.250 in, Temperature 75.2 °F
	517 MPa @Thickness 1.00 - 6.35 mm, Temperature -28.0 °C	75000 psi @Thickness 0.0394 - 0.250 in, Temperature -18.4 °F
	545 MPa	79000 psi

Table 2: Physical and mechanical properties of A17075

Main Characteristics	Property/Parameter	Technique
1.1. Particle and crystallite size	1.1.1. Crystallite size - average - individual	 X-ray line broading TEM
	1.1.2. Primary particle size - average - individual	 partly by FSSS, BET TEM, SEM Microscopy
	1.1.3. Aggregate particle Size - average	 FSSS = Permeability (ASTM B-330) calc. from BET and size distributions
	- distributions	Sieving, wet microsieving Sedimentation, centrifuge, light scattering
	1.1.4. Specific Surface Area	BET (gas adsorption)
1.2. Particle shape	Crystallite/Particle shape	TEM, SEM Powder Micrograph
1.3 Microstructure of particles		TEM, SEM Microscopy

Table 3: Characteristics of Silicon Carbide Powder

Item	Unit	Data
Maximum service temperature	°C	1,380
Density	g/cm^3	3.02
Open porosity	%	<0.1
Bending strength	Mpa	250 (20°C)
	Mpa	280 (1,200°C)
Elastic modulus	Gpa	330 (20°C)
	Gpa	300 (1,200°C)
Thermal conductivity	W/m k	45 (1,200°C)
Thermal expansion coefficient	$K^{-1}\times10^{-6}$	4.5
Mohs hardness		13
Acid and alkali resistance		Excellent

Table 4: Physical and Mechanical properties of SiC powder

compositions

Oxide/Metal	Approximate Weight %
Calcium Oxide (CaO)	35 – 55
Silica (SiO_2)	10 – 35
Aluminum Oxide (Al_2O_3)	0.1 – 10
Iron Oxide (FeO) (70 – 80% FeO & 20 -30 Fe_2O_3)	0.1 – 40
Magnesium Oxide (MgO)	3 – 10
Manganese Oxide (MnO)	3 – 10
Sulfate (SO_3)	0.01 – 15
Phosphate (P_2O_5)	0.01 - 1
Metallic Iron	0.5 – 10

Table 5: Compositions of Blast Furnace Slag

Parameter	ASTM C989 Limit	Test Result	Parameter	ASTM C989 Limit	Test Result
SiO_2, %	-	33.4	Specific Gravity	-	3.01
Al_2O_3, %	-	10.1	7 Days Strength Activity Index, %	75 min	88.1
Fe_2O_3, %	-	0.7			
SO_3, %	4.0 max	2.5			
CaO, %	-	42.8			
MgO, %	-	10.0			
K_2O, %	-	0.4			
Na_2O, %	-	0.3			
Loss on Ignition, %	-	1.0			

Table 6: Chemical Composition and Physical Properties

CHAPTER-4

EXPERIMENTAL SETUP

4.1 MATERIAL COMPOSITION

- Aluminum alloy 7075+ BFS 3 % + SiC 10%.
- Aluminum alloy 7075 + BFS 6% + SiC 14%.
- Aluminum alloy 7075 + BFS 12% + SiC 18%.

4.2 RAW MATERIALS USED

Fig 3: Aluminium (Al707)

Fig 4: Silicon Carbide Powder

Fig 5: Blast Furnace Slag

4.3 CASTING

Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

SAND CASTING

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand-casting process. Sand castings are produced in specialized factories called foundries. Over 60% of all metal castings are produced via sand casting process.

Molds made of sand are relatively cheap, and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened, typically with water, but sometimes with other substances, to develop the strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known as a flask. The mold cavities and gate system are created by compacting the sand around models called patterns, by carving directly into the sand, or by 3D printing.

PATTERN PREPARATION

In casting, a pattern is a replica of the object to be cast, used to prepare the cavity into which molten material will be poured during the casting process. Patterns used in sand casting may be made of wood, metal, plastics, or other materials. Patterns are made to exacting standards of construction, so that they can last for a reasonable length of time, according to the quality grade of the pattern being built, and so that they will repeatably provide a dimensionally acceptable casting.

Melting of aluminum alloy 7075

aluminum alloy 7075 temperature has an ultimate tensile strength of 510–540 MPa (74,000–78,000 psi) and yield strength of at least 430–480 MPa (63,000–69,000 psi). It has a failure elongation of 5–11%.

The aluminum alloy 7075 temperature is usually achieved by homogenizing the cast 7075 at 450 °C for several hours, quenching, and then aging at 120 °C for 24 hours. This yields the peak strength of the 7075 alloy. The strength is derived mainly from finely dispersed eta and eta' precipitates both within grains and along grain boundaries.

4.4 SELECTION OF OPTIMUM CONDITION

Desirable properties of metal

1. Tensile strength

Tensile properties dictate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties.

The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Since both, the engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (specimen geometry information), the load-elongation curve will have the same shape as the engineering stress-strain curve.

The stress-strain curve relates the applied stress to the resulting strain and each material has its own unique stress-strain curve. A typical engineering stress-strain curve is shown below If the true stress, based on the actual cross sectional area of the specimen, is used, it is found that the stress-strain curve increases continuously up to fracture. They are tabulated for common materials such as alloys, composite materials, ceramics, plastics, and wood, tensile strength is measured as force per unit area.

2. Hardness

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting, or bending. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface. For elastomers and some polymers, hardness is defined at the resistance to elastic deformation of the surface. The lack of a fundamental definition indicates that hardness is not a basic property of a material, but rather a composite one with contributions from the yield strength, work hardening, true tensile strength, modulus, and other factors. Hardness measurements are widely used for the quality control of materials because they are quick and considered to be non-destructive tests when the marks or indentations produced by the test are in low stress areas. There are a large variety of methods used for determining the hardness of a substance. A few of the more common methods are introduced below.

3. Microstructure

When describing the structure of a material, we make a clear distinction between its crystal structure and its microstructure. The term ‘crystal structure’ is used to describe the average positions of atoms within the unit cell and is completely specified by the lattice type and the fractional coordinates of the atoms (as determined, for example, by X-ray diffraction). In other words, the crystal structure describes the appearance of the material on an atomic (or Å) length scale. The term ‘microstructure’ is used to describe the appearance of the material on the nm-cm length scale.

4.5 EXPERIMENTAL PROCEDURE

Al7075 hybrid metal matrix is fabricated by sand casting method. It is an attractive and economical casting technique which allows conventional metal processing route.

Al 7075 melted above 850 ºC in a graphite crucible and the reinforcements were preheated up to same temperature for proper mixing. Preheated BFS and graphite were mixed in the metal slurry manually at 850 ºC. The molten metal poured in preheated molds and allowed to cool. Casted metal matrix was machined to remove cluster formation on the surface and then cut into required dimension by using fan-saw cutting machine.

CASTING IMAGES

Fig 6: Raw material heated at furnace

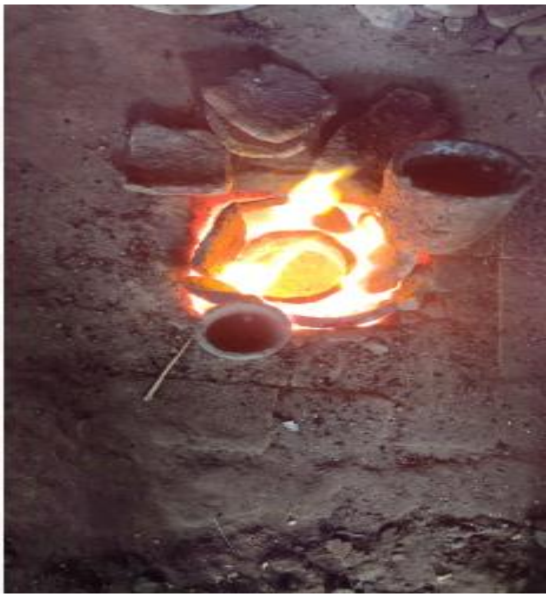


Fig 7: heated up to 850^0C

Fig 8: Mixing the powders (Stirring)

Fig 9: Pouring the Molten Metal

Fig 10: After pouring the molten metal (Filling)

4.6 CASTING COMPONENTS

A. At composition Aluminum alloy 7075+ BFS 3 % + SiC 10%

Fig 11: Composite material (sample 1)

B. At composition Aluminum alloy 7075 + BFS 6% + SiC 14%

Fig 12: Composite material (sample 2)

C. At composition Aluminum alloy 7075 + BFS 12 % + SiC 18%.

Fig 13: Composite material (sample 3)

D. Machining Process for dumble shape

Fig 14: Machining process

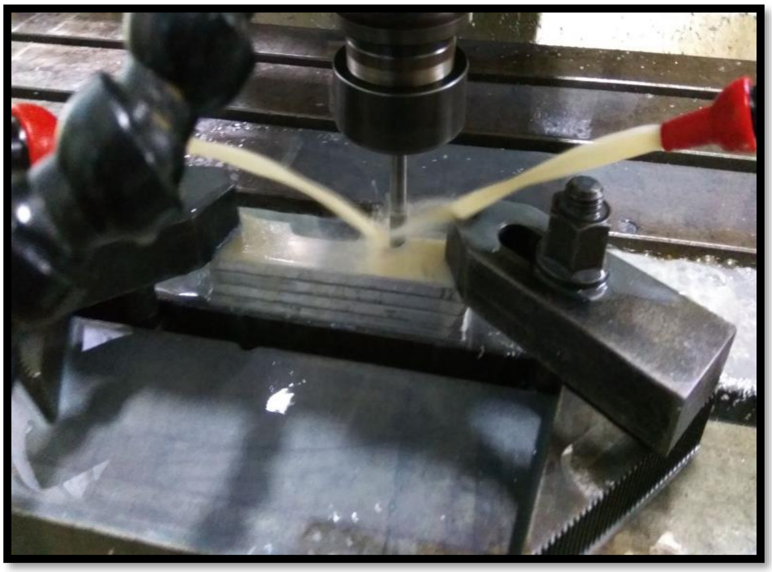


Fig 15: Machining for Dumble shape

E. Final Dumble Shape according to ASTM standards

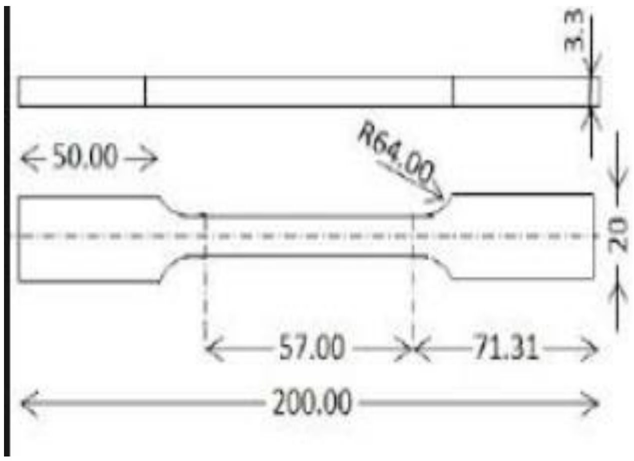


Fig 16: Final shape according to ASTM

Fig 17: Final dumble shape Composite

CHAPTER 5

RESULTS AND DISCUSSION

5.1 TESTS CONDUCTED

A. Tensile Test:

Type of test – Tensile

Machine Model – TUE-C-600

Fig 18: Ultimate tensile testing machine

Tensile testing, also known as tension testing is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under normal forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area.

From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. For anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required.

B. HARDNESS TEST REULTS

MACHINE DETAILS

Name –HARDNESS

Fig 19: Hardness testing machine

5.2 HARDNESS TEST DETAILS

Test Reference – IS 1586:2000

Type of Hardness – HRC

Machine Model – 2008/073, MRB 250

Sample ID – Hardness Test at Weld Zone

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the machine. Indentation hardness value is obtained by measuring the depth or the area of the indentation using one of over 12 different.

The **Brinell hardness test method** as used to determine Brinell hardness, is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high-test load (3000 kg.) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The **Rockwell hardness test method**, as defined in ASTM E-18, is the most used hardness test method. You should obtain a copy of this standard, read and understand the standard completely before attempting a Rockwell test.

5.3 SEM INTRODUCTION

Scanning Electron Microscopy - SEM - is a powerful technique in the examination of materials. It is used widely in metallurgy, geology, biology and medicine.

The user can obtain high magnification images, with a good depth of field, and can also analyze individual crystals or other features. A high-resolution SEM image can show detail down to 25 Angstroms, or better. When used in conjunction with the closely related technique of energy-dispersive X-ray microanalysis, the composition of individual crystals or features can be determined.
There are many ways that scanning electron microscopy and X-ray microanalysis can aid studies of materials.

THE MODERN SCANNING ELECTRON MICROSCOPE

Invented some 50 years ago, SEM is now a mature technique and is applied widely in many scientific applications.

Figure 20: SEM equipment

A normal scanning electron microscope operates at a high vacuum. The basic principle is that a beam of electrons is generated by a suitable source, typically a tungsten filament or a field emission gun. The electron beam is accelerated through a high voltage (e.g.: 20 kV) and pass through a system of apertures and electromagnetic lenses to produce a thin beam of electrons., then the beam scans the surface of the specimen by means of scan coils (like the spot in a cathode-ray tube "old-style" television).Electrons are emitted from the specimen by the action of the scanning beam and collected by a suitably-positioned detector.

The microscope operator is watching the image on a screen. Imagine a spot on the screen scanning across the screen from left to right. At the end of the screen, it drops down a line and scans across again, the process being repeated down to the bottom of the screen. The key to how the scanning electron microscope works (and this is the clever bit) is that the beam scanning the specimen surface is exactly synchronized with the spot in the screen that the operator is watching. The electron detector controls the brightness of the spot on the screen - as the detector "sees" more electrons from a particular feature, the screen brightness is increased. When there are fewer electrons, the spot on the screen gets darker.

These days, the screen is generally a digital monitor, not a glass crt, but the principle is the same. The magnification of the image is the ratio of the size of the screen to the size of the area scanned on the specimen. If the screen is 300 mm across and the scanned area on the specimen is 3 mm across, the magnification is x100. To go to a higher magnification, the operator scans a smaller area; if the scanned area is 0.3 mm across, the magnification is x 1000, and so on.

There are different types of electron image. The two most common are the secondary electron image (SEI) and the backscattered electron image (BEI). The sei is used mainly to image fracture surfaces and gives a high resolution image. The BEI is used typically to image a polished section; the brightness of the BEI is dependent on the atomic number of the specimen (or, for compounds, the average atomic number). For example, lead will appear brighter than iron and calcium oxide will appear brighter than calcium carbonate. The BEI is, in essence, an atomic number map of the specimen surface.

All SEM images are in black-and-white, although they may subsequently have false colors applied to them for aesthetic reasons or to aid interpretation. A development of the normal high-vacuum scanning electron microscope is the ESEM, or Environmental SEM. The ESEM can operate with air in the specimen chamber - the pressure is lower than atmospheric pressure but higher that the high-vacuum of a normal SEM. This has the advantage that wet specimens can be examined without them dehydrating and is especially useful for biological specimens and other specimens containing water, such as freshly mixed cement paste.

5.4 TEST SAMPLES

A. Tensile test

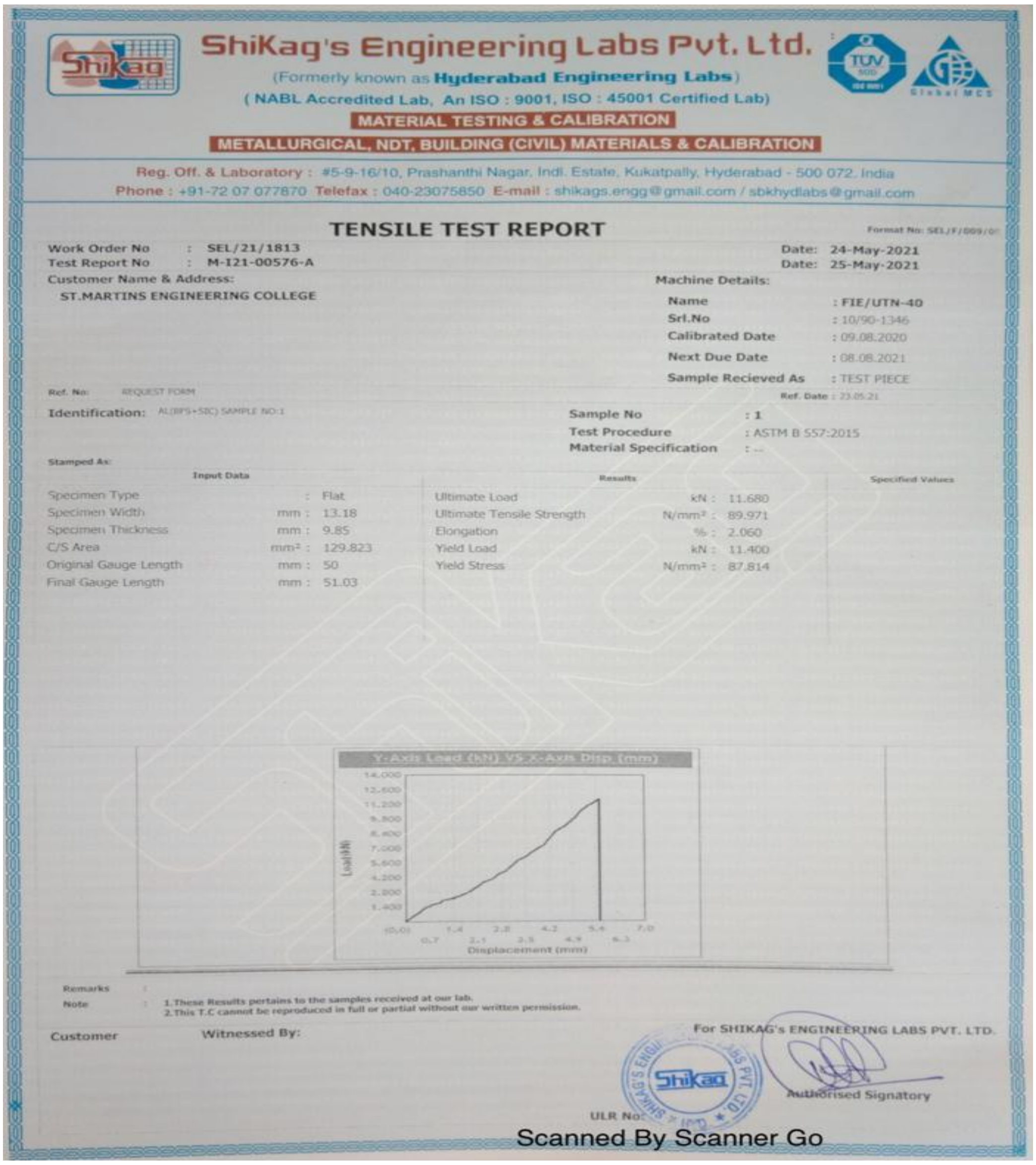
Fig 21: Testing sample 1

Fig 22: Testing sample 2

Fig 23: Testing sample 3

5.4 TEST RESULT

5.4.1 Tensile test



ShiKag's Engineering Labs Pvt. Ltd.
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(NABL Accredited Lab, An ISO : 9001, ISO : 45001 Certified Lab)
MATERIAL TESTING & CALIBRATION
METALLURGICAL, NDT, BUILDING (CIVIL) MATERIALS & CALIBRATION

Reg. Off. & Laboratory : #5-9-16/10, Prashanthi Nagar, Indl. Estate, Kukatpally, Hyderabad - 500 072. India
Phone : +91-72 07 077870 Telefax : 040-23075850 E-mail : shikags.engg@gmail.com / sbkhydlabs@gmail.com

TENSILE TEST REPORT

Format No: SEL/F/009/0

Work Order No : SEL/21/1813 — Date: 24-May-2021
Test Report No : M-I21-00576-A — Date: 25-May-2021

Customer Name & Address:
ST.MARTINS ENGINEERING COLLEGE

Machine Details:
Name : FIE/UTN-40
Srl.No : 10/90-1346
Calibrated Date : 09.08.2020
Next Due Date : 08.08.2021
Sample Recieved As : TEST PIECE

Ref. No: REQUEST FORM — Ref. Date : 23.05.21

Identification: AL(BFS+SIC) SAMPLE NO:1

Sample No : 1
Test Procedure : ASTM B 557:2015
Material Specification : --

Stamped As:

Input Data			Results			Specified Values
Specimen Type	:	Flat	Ultimate Load	kN :	11.680	
Specimen Width	mm :	13.18	Ultimate Tensile Strength	N/mm² :	89.971	
Specimen Thickness	mm :	9.85	Elongation	% :	2.060	
C/S Area	mm² :	129.823	Yield Load	kN :	11.400	
Original Gauge Length	mm :	50	Yield Stress	N/mm² :	87.814	
Final Gauge Length	mm :	51.03				

Remarks :
Note : 1.These Results pertains to the samples received at our lab.
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For SHIKAG's ENGINEERING LABS PVT. LTD.
Authorised Signatory

ULR No:

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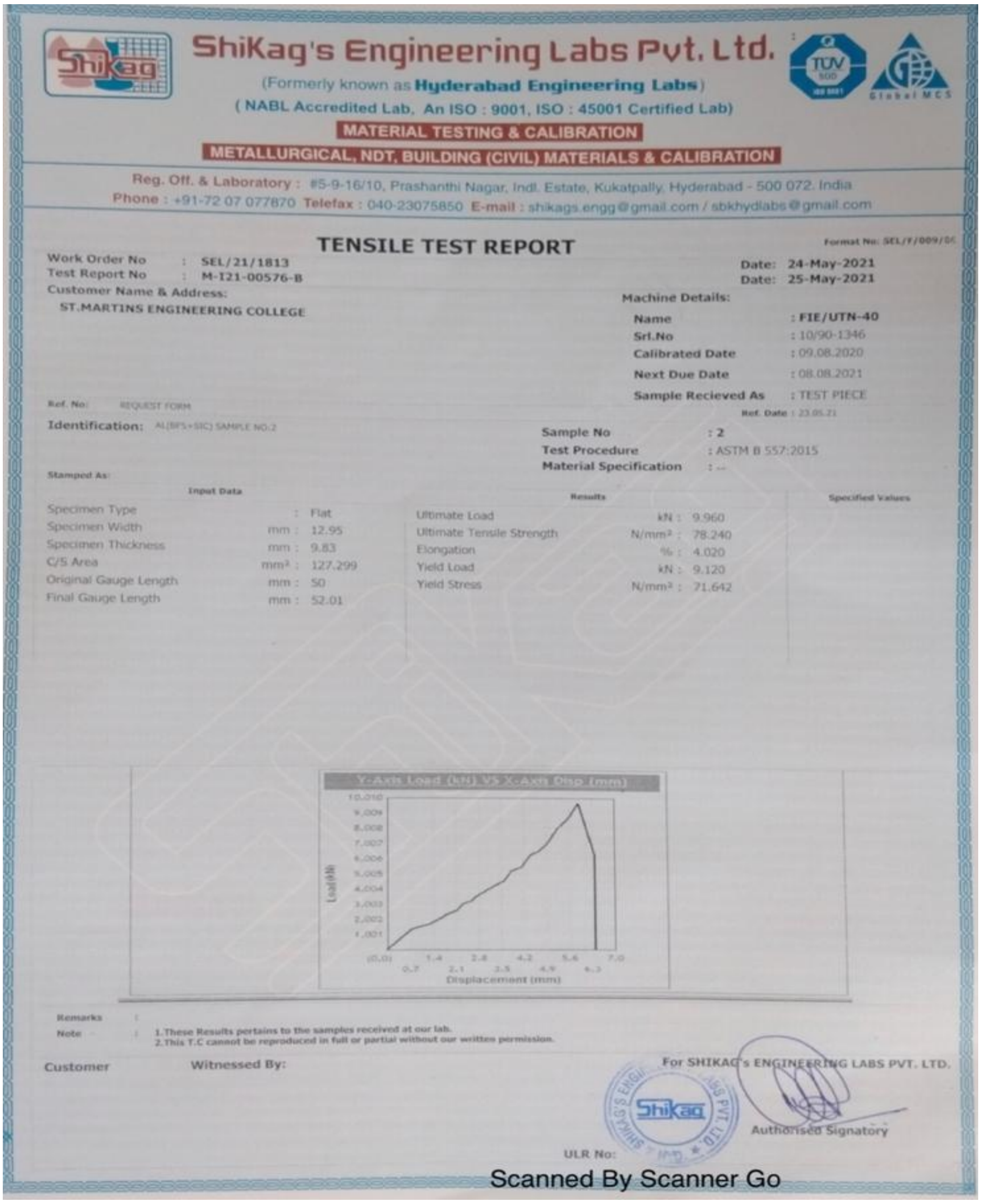
Fig 24: Tensile Test Report 1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Phone : +91-72 07 077870 Telefax : 040-23075850 E-mail : shikags.engg@gmail.com / sbkhydlabs@gmail.com

TENSILE TEST REPORT

Format No: SEL/F/009/0(

Work Order No : SEL/21/1813 Date: 24-May-2021
Test Report No : M-I21-00576-B Date: 25-May-2021
Customer Name & Address:
ST.MARTINS ENGINEERING COLLEGE

Machine Details:
Name : FIE/UTN-40
Srl.No : 10/90-1346
Calibrated Date : 09.08.2020
Next Due Date : 08.08.2021
Sample Recieved As : TEST PIECE

Ref. No: REQUEST FORM
Ref. Date : 23.05.21
Identification: AL(BFS+SIC) SAMPLE NO:2

Sample No : 2
Test Procedure : ASTM B 557:2015
Material Specification : --

Stamped As:

Input Data			Results			Specified Values
Specimen Type		Flat	Ultimate Load	kN	9.960	
Specimen Width	mm	12.95	Ultimate Tensile Strength	N/mm²	78.240	
Specimen Thickness	mm	9.83	Elongation	%	4.020	
C/S Area	mm²	127.299	Yield Load	kN	9.120	
Original Gauge Length	mm	50	Yield Stress	N/mm²	71.642	
Final Gauge Length	mm	52.01				

Remarks :
Note : 1.These Results pertains to the samples received at our lab.
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Fig 25: Tensile Test Report 2

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Phone : +91-72 07 077870 Telefax : 040-23075850 E-mail : shikags.engg@gmail.com / sbkhydlabs@gmail.com

TENSILE TEST REPORT

Format No: SEL/F/009/0

Work Order No : SEL/21/1813 Date: 24-May-2021
Test Report No : M-I21-00576-C Date: 25-May-2021

Customer Name & Address:
ST.MARTINS ENGINEERING COLLEGE

Machine Details:

Name	: FIE/UTN-40
Srl.No	: 10/90-1346
Calibrated Date	: 09.08.2020
Next Due Date	: 08.08.2021
Sample Recieved As	: TEST PIECE

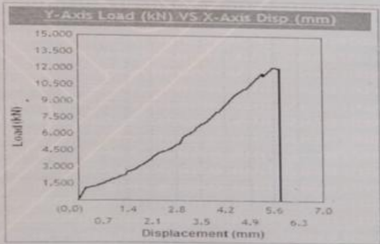
Ref. No: REQUEST FORM Ref. Date : 23.05.21

Identification: AL(BFS+SIC) SAMPLE NO:3

Sample No	: 3
Test Procedure	: ASTM B 557:2015
Material Specification	: --

Stamped As:

Input Data			Results			Specified Values
Specimen Type	:	Flat	Ultimate Load	kN :	12.480	
Specimen Width	mm :	13.52	Ultimate Tensile Strength	N/mm^2 :	94.189	
Specimen Thickness	mm :	9.8	Elongation	% :	3.800	
C/S Area	mm^2 :	132.496	Yield Load	kN :	8.960	
Original Gauge Length	mm :	50	Yield Stress	N/mm^2 :	67.623	
Final Gauge Length	mm :	51.9				



Remarks :
Note : 1.These Results pertains to the samples received at our lab.
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Customer Witnessed By: For SHIKAG's ENGINEERING LABS PVT. LTD.

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Fig 26: Tensile Test Report 3

5.5.2 HARDNESS TEST

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Phone : +91-72 07 077870 Telefax : 040-23075850 E-mail : shikags.engg@gmail.com / sbkhydlabs@gmail.com

HARDNESS TEST REPORT

Work Order No : SEL/21/1813
Test Report No : M-I21-00578-D
Work Order Date :24-May-2021
Test Report Date :25-May-2021

Customer Name & Address:
ST.MARTINS ENGINEERING COLLEGE

Sample No :1
Sample Received Date :24-May-2021
Tested Date :25-May-2021
Sample Stamped As :

Ref.No: REQUEST FORM
Ref. Date: 23.05.21

Machine Details
Name : ROCKWELL CUM BRINELL HARDNESS
Model No/Srl.No : 15/08/014 RAB-250
Calibration on Date : 09.08.2020
Calibration Due Date : 08.08.2021

Test Details
Test Procedure : IS 1500:2005
Type of Hardness : BHN
Indentor : 5 mm
Load Applied : 250 Kgf

Material Identification:
AL(BFS+SIC) SAMPLE NO: (3NOS)

Material Specification:
--

Sl.No	Location	Observed Values in BHN			
		Impression 1	Impression 2	Impression 3	Average
1	AL(BFS+SIC) SAMPLE NO:1	51.9	51.0	51.0	51.30
2	AL(BFS+SIC) SAMPLE NO:2	56.8	56.3	57.3	56.80
3	AL(BFS+SIC) SAMPLE NO:3	62.4	63.0	61.20	62.20

Specified Values: --

Result :
Remarks : 1.These Results pertains to the samples received at our lab.

Verified By:
Witnessed By:
For SHIKAG's ENGINEERING LABS PVT. LTD.
Authorised Signatory
ULR No:

Format No: SEL/F/009/00
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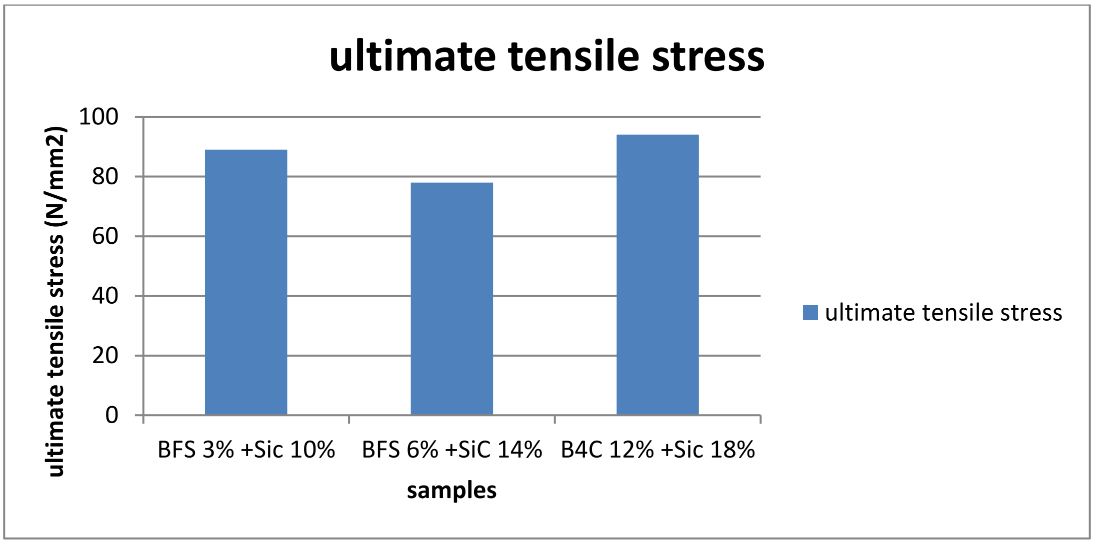
Fig 27: Hardness Test Report

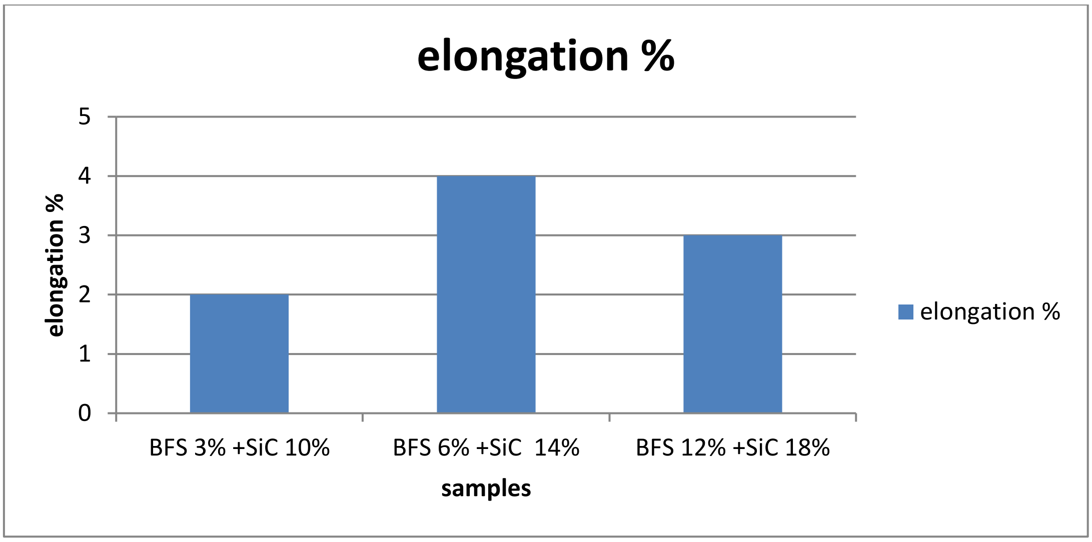
5.6 Graphs



Graph 1: Ultimate tensile stress

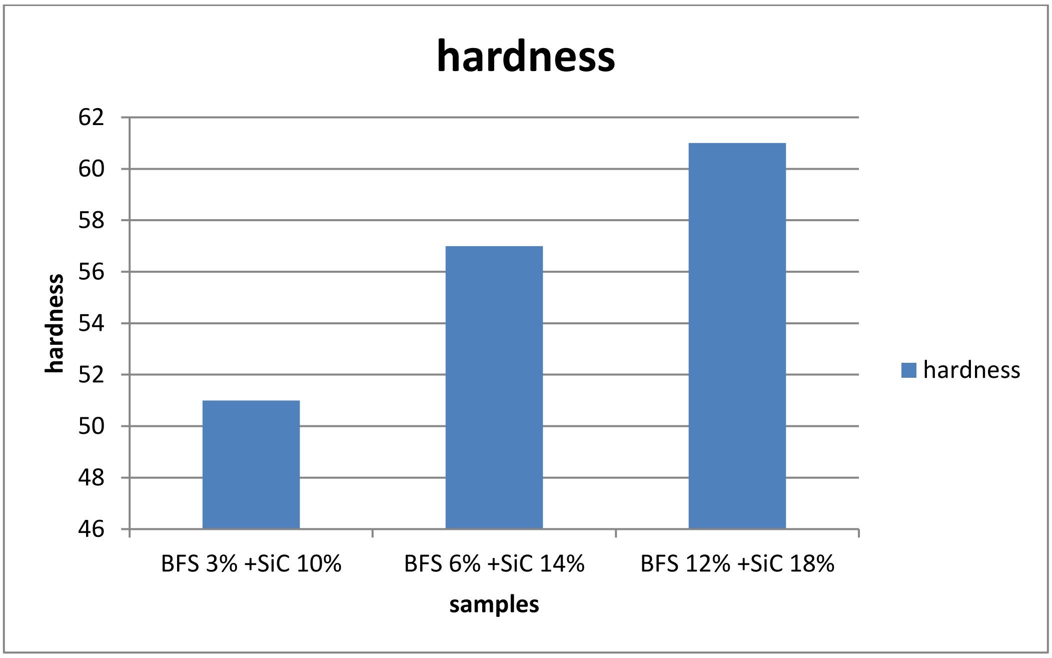
According to the plot, the ultimate tensile stress increases at BFS 12% + SiC 18% compared to other two samples because of the powder average mixed in the sample.

The above graph shows BFS, SiC compositions(samples) with different weight on X-axis and ultimate tensile stress is shown on the Y- axis. According to the graph blue color bar indicates Ultimate tensile stress.



Graph 2: elongation %

According to the plot, the elongation increases at BFS 6% + SiC 14% compared to other two samples because of the powder average mixed in the sample.

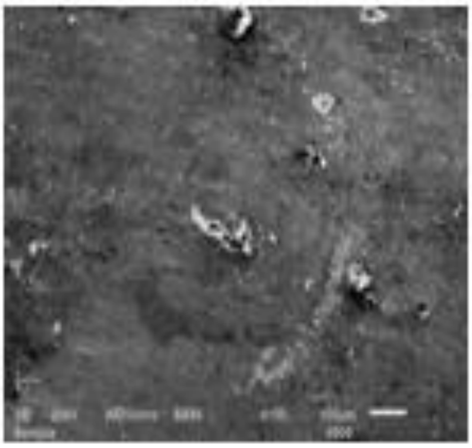


Graph 3: Hardness

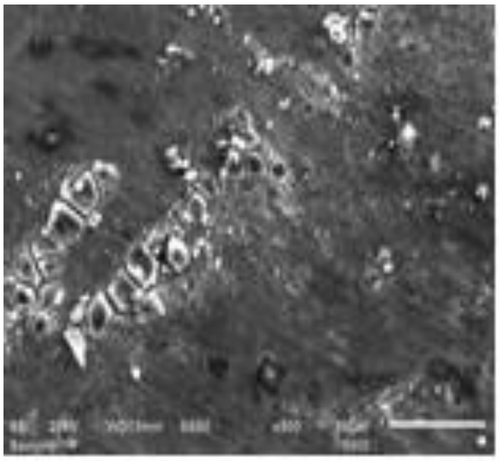
According to the plot, the ultimate load increases at BFS 12% + SiC 18 % compared to other two samples because of the powder average mixed in the sample.

5.7 METALLOGRAPHIC ANALYSIS

Metallographic weld specimens were cut, mounted, polished, and examined by optical and scanning electron microscopy (SEM). SEM microscope used was a JEOL JSM-6460 equipped with Oxford Instruments INCA-350 energy-dispersive spectroscopy system.

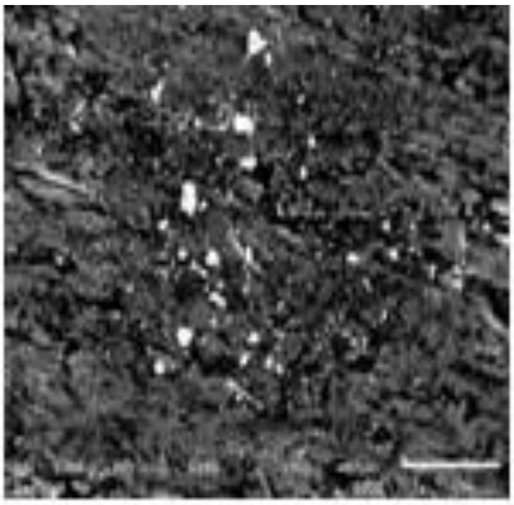


Al 7075



At BFS 3 % + SiC 10%

At BFS 6% + SiC 14%



At BFS 12 % + SiC 18%

Fig 28: Microstructure Analysis

Microstructure of a prepared surface specimens tested by inverted metallurgical microscope range of 25X -100X magnification. Microstructure of polished surface resulted cluster formation of reinforcement particles as shown in the sample.

1. Clear identification of non-metallic particles distribution in between metallic particles resulted by etching process as shown in the sample.

2. The formation of dendritic structure resulted by solidification process observed before heat treatment of composite. BFS, SiC and Al particles melted and mixed homogeneously by heat treatment and uniform distribution of reinforcements.

The above Figures are presented with the microphotographs of Cast al 7075 -SiC and BFS composites, respectively. From figures it can be observed that, the distributions of reinforcements in the respective matrix are fairly uniform. Further these figures reveal the homogeneity of the cast composites. The microphotograph also clearly revels the increased filler contents in the composites. Cracks are also seen in the microstructure.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In this project, considered the potential of use hybrid metal matrix composite (MMC) with reference to the aerospace industry. Initially, the required properties are identified, after which, the work explores pure aluminum and its importance in the industry along with its limitations.

The Development of Al7075alloy based metal matrix Hybrid composite reinforced with different compositions such as BFS 3 % + SiC 10% weight , BFS 6% + SiC 14% weight and BFS 12 % + SiC 18% .

Hybrid Al7075 MMC fabricated by sand casting method effectively. The experimental study reveals the enhanced mechanical properties hardness, tensile strength, and microstructure.

The micro hardness improved by adding reinforcements to the base alloy. The addition of BFS particles improved the hardness and the improved wear properties results by the addition of Al+SiC. Further the mechanical properties enriched by heat treatment. Hardness and tensile strength improved by Aluminum alloy 7075 + BFS 6% + SiC 14% Homogeneous mixture of the reinforcement particles with molten metal was observed in the microstructure.

6.2 FUTURE SCOPE

Process parameters plays a vital role on properties of Al based HMC. In case of sand casting Stir casting, process parameters like stirring rate, stirring temperature, pouring temperature etc., are to be maintained for achieving better properties of HMC. For manufacturing of composite material by stir casting, knowledge of its operating parameters, different fabrication techniques such as solid state processes including powder metallurgy (PM Route), high energy ball milling, friction stir process, diffusion bonding and vapor deposition techniques are very essential. If the process parameters are properly controlled, it could lead to the improved properties in composite material.

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Name of the author - Subra Suresh

Published by - Elsevier, 2013

Metal-Matrix Composites are being used or considered for use in a variety of applications in the automotive, aerospace, and sporting goods industries.

This book contains sixteen chapters, all written by leading experts in the field , which focus on the processing, microstructure and characterization, mechanics and micromechanics of deformation, mechanics and micromechanics of damage and fracture, and practical applications.

A particularly noteworthy feature of this authoritative volume is its collection of state-of-the-art reviews of the relationships among processing, microstructural evolution, micromechanics of deformation and overall mechanical response.

2.Aluminium matrix composites: Challenges and opportunities

Name of the author – M.K Surappa

Sadhana, **8**, pages319–334 (2003)

Published – February 2003

This book contains 8 pages, all are written by experts in the field, which focuses on the challenges and opportunities of Aluminum metal matrix composite.

The book has 4020 access, 599 citations and 3 almetrics

3.Particle reinforced aluminium and magnesium matrix composites

Name of the author – D.J. Lloyd

Published – 18th July 2013

This book contains 23 pages, all are written by experts in the field, mainly focuses on particle reinforced and magnesium metal matrix composite.

The book has 1422 citation , 4 almetrics.

3.The production and application of metal matrix composite materials

Name of the author - J.W. Kaczmar, K. Pietrzak, W. Wlosinski

Published – Elsevier, 2000

This book contains 106 pages and 3 chapters, all are written by experts in the field, mainly focusses on production and application of metal matrix composite materials.

4.Mechanical Metallurgy

Name of the author - G.E. Dieter

Published – MC Graw- Hill book company, 1961

This book contains more than 600 pages and 22 chapters. And this book is about Mechanical Metallurgy which deals with behavior and response of materials of applied force.

5. General Overview and Applications of Ceramic Matrix Composites (CMC's)

Name of the author – Zivic, Fathima

Published – 2021

This book contains is written by experts in the field and deals about ceramic matric composites.

A Major Project Report
on

LPG REFRIGERATION SYSTEM WITH ZERO OPERATING COST

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

D. RAMA KRISHNA VAMSHI - (17K81A0370)

E. RAMYA - (17K81A0371)

G. SAI KRISHNA - (17K81A0375)

V. SATISH KUMAR - (17K81A03B8)

Under the Guidance of

Mr. CH. RANGA RAO
Associate Professor

DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled "**LPG REFRIGERATION SYSTEM WITH ZERO OPERATING COST**", is being submitted by **D. RAMA KRISHNA VAMSHI (17K81A0370), E. RAMYA (17K81A0371), G. SAI KRISHNA (17K81A0375), V. SATISH KUMAR (17K81A03B8)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

CH. RANGA RAO
Associate Professor
Department of Mechanical Engineering

Signature of HOD

Dr.D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017–2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this project entitled "**LPG REFRIGERATION SYSTEM WITH ZERO OPERATING COST**" is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

D. RAMA KRISHNA VAMSHI	-17K81A0370
E. RAMYA	-17K81A0371
G.SAI KRISHNA	-17K81A0375
V. SATISH KUMAR	-17K81A03B8

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We especially would like to express my deep sense of gratitude and indebtedness to **Dr. P. Santosh Kumar Patra**, **our beloved Principal, St. Martin's Engineering College** for his invaluable encouragement, suggestions and support from an early stage of this research and providing me extraordinary experiences throughout the work. Above all, his priceless and meticulous supervision at each and every phase of work inspired me in innumerable ways.

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D.RAMAKRISHNA VAMSHI - 17K81A0370

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V.SATISH KUMAR - 17K81A03B8

ABSTRACT

Supply of continuous electricity is still not available in several areas of the country and the world. At such places, this work will be helpful for refrigeration of food, medicines, etc... This paper investigates the result of an experimental study carried out to determine the performance of domestic refrigerator when a liquefied petroleum gas (LPG) which is locally available which comprises of 24.4% propane, 56.4% butane and 17.2% isobutene which is varied from company to company is used as a Refrigerant. The LPG is cheaper and possesses an environmental friendly nature with no Ozone Depletion Potential (ODP) and no Global Warming Potential (GDP). It is used in world for cooking purposes. The refrigerator used in the present study is designed to work on LPG. The performance parameters investigated is the refrigeration effect in certain time. The refrigerator worked efficiently when LPG was used as a refrigerant instead of R134a.Also from the experiment which done in atmospheric condition, we can predict the optimum value of cooling effect with the suitable operating condition of regulating valve and capillary tube of the system. The use of LPG for refrigeration purpose can be environment friendly since it has no ozone depletion potential (ODP). Usually LPG is used as a fuel for cooking food in houses, restaurants, hotels, etc. and the combustion products of LPG are CO2 and H2O.

In this project we have designed and analyzed a refrigerator using LPG as refrigerant. LPG is available in cylinders at high pressure. When this highpressure LPG is passed through the capillary tube of small internal diameter, the pressure of LPG is dropped due to expansion and phase change of LPG occurs in an isoenthalpic process. Due to phase change from liquid to gas latent heat is gained by the liquid refrigerant and the temperature drops. In this way LPG can produce refrigerating effect for a confined space.

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CHAPTER - 1

INTRODUCTION

Due to the huge demand of electricity over the world, we think of recovering the energy which is already spent but not being utilized further, to overcome this crisis with less investment. The climatic change and global warming demand accessible and affordable cooling systems in the form of refrigerators and air conditioners. Annually Billions of dollars are spent in serving this purpose. Hence forth, we suggest COST FREE Cooling Systems. Although government agencies are not able to continuously supply a major portion of electricity in both the urban as well as in rural areas. Still the people in these regions require refrigeration for a variety of socially relevant purposes such as cold storage or storing medical supplies and domestic kitchens this project has the novelty of using LPG instead of electricity for refrigeration. This solution is convenient for refrigeration in regions having scares in electricity.

The term 'refrigeration' in a broad sense is used for the process of removing heat (i.e. Cooling) from a substance. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body, whose temperature is already below the temperature of its surroundings. For example, if some space (say in cold storage) is to be kept at -2 ^{o}C, we must continuously extract heat which flows into it due to leakage through the walls and also the heat, which is brought into it with the articles stored after the temperature is one reduced to -2 ^{o}C. Thus in a refrigerator, heat is virtually being pumped from a lower temperature to a higher temperature. The refrigeration system is known to the man, since the middle nineteenth century. The scientist, of the time, developed a few stray machines to achieve some pleasure. But it paved the way by inviting the attention of scientist for proper studied and research.

They were able to build a reasonably reliable machine by the end of nineteenth century for the refrigeration jobs. But with the advent of efficient rotary compressors and gas turbines, the science of refrigeration reached its present height. Hebrews, Greeks, and Romans places large amounts of snow into storage pits dug into the ground and insulated with wood and straw. The ancient Egyptians filled earthen jars with boiled water and put them their roofs, thus exposing the jars to the night's cool air. In India, evaporating cooling was employed.

When a liquid vaporizes rapidly, it expands quickly. The rising modules of vapor abruptly increase their kinetic energy and this increase is drawn from the intermediate surroundings of the vapor. These surroundings are therefore cooled. The intermediate stage in the history of cooling foods was to add chemicals like sodium nitrate or potassium nitrate to water causing the temperature to fall. Cooling wine via above method was recorded in 1550.

According to the second law thermodynamics, this process can only be performed with the supply of some external work. It is thus obvious, that supply of power (say electrical motor) is regularly required to drive a refrigerator. The substance which work in a heat pump to extract heat from a cold body and to deliver it to a hot body is called “refrigerant”.

When we think about refrigerator we only remember refrigeration in kitchen, but actually it is divided in types in which each type having their own type of functioning. One which used I industrial purpose is called industrial refrigerator, which is used as food processing, chemical processing, and cold storage. Industrial refrigeration, which frequently uses ammonia refrigeration to maintain temperature, is necessary for computer, foodstuffs, blood vaccines, and quite a few other goods that must maintain a constant and steady temperature at all times.

It works on the principle that during the conversion of LPG into gaseous form, expansion of LPG takes place. Due to this expansion there is a pressure drop and increase in volume of LPG that results in the drop of temperature and a refrigerating effect is produced. This refrigerating effect can be used for cooling purposes. So this work provides refrigeration for socially relevant needs as well as replaces global warming creator refrigerants. While going through the literature review in LPG refrigeration system, Conventional VCR (Vapour Compression Refrigeration System) uses LPG as refrigerant and produced the refrigerating effect. But in our proposed very simple type of refrigeration system in which the high pressure LPG is passing through a capillary tube and expands. After expansion the phase of LPG is changed and converted from liquid to gas and then it passes through the evaporator where it absorbs the heat and produces the refrigerating effect. After evaporator it passes through the gas burner where it burns.

1.0 OVERVIEW OF THE PROJECT

The basic idea behind LPG refrigerator is to use the LPG to absorb heat. LPG is stored in the LPG cylinder under high pressure. When the gas tank of regulators is opened then high pressure. LPG passes through the high pressure pipe. This LPG is going by high pressure gas pipe to capillary tube. High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant. After capillary tube, low pressure LPG is passed through the evaporator. LPG is converted into low pressure and temperature vapour from and passes the evaporator which absorbs heat from the chamber. Thus the chamber becomes cool down. Thus we can achieve cooling effect in refrigerator. After passing through the evaporator low pressure LPG is passed through the pipe to burner. Ans we can use the low pressure of LPG in burning processes.

Fig 1.0 Equipment set up of LPG refrigeration system

1.1 OBJECTIVE OF THE STUDY

1. To identify the form of residual waste in traditional Refrigeration system.
2. Compare the important characteristics between LPG Refrigeration system and traditional refrigeration system.
3. To distinguish between the current existing refrigerator Cost and estimated cost of LPG refrigerator.
4. The performance of existing refrigerator and LPG Refrigerator is to be compared.
5. To determine the COP of refrigerator using LPG as refrigerant.

To make a Refrigeration system without causing Ozone depletion. Generally the refrigeration effect is done by some fluorocarbons especially chlorofluorocarbons, but it is the main reason for ozone depletion effects and other common refrigerants are ammonia, Sulphur dioxide and propane. To avoid ozone depletion, we are using LPG for refrigeration instead of other gases. To provide refrigeration effect without using electricity.

1.2 SCOPE OF THE STUDY

1) The future scope of this project is to focus in implementation of the project in the restaurant and community hall for preserving vegetables, dairy products with the refrigeration, where it serves the purpose of preservation.
2) This kind of system can be implemented on the food trucks as well where it can store in various quantities.
3) To create working model for LPG refrigeration.

1.3 MATERIALS REQUIRED

1) Copper tube
2) Refrigerator box
3) LPG cylinder
4) Burner
5) LPG hose
6) Copper welding
7) Brazing material
8) Pressure gauges
9) Temperature sensor

1.4 PROCUREMENT OF EQUIPMENT

NO.	COMPONENTS	PRICE
1	REFRIGERATION BOX	3000
2	EVAPORATOR BOX	2500
3	GAS PIPE, GAS CYLINDER	1300
4	CAPILLARY TUBE	1200
5	BURNER	1000
6	INSULATED THERMOCOL	200

7	RUBBER GASKET MAGNET	400
8	HANDLE CLAMP	100
9	BRAZING MATERIAL	600
10	SUCTION PIPE	400
11	C U ‘T’ CONNECTOR	200
12	BRASS NUT	200
13	HIGH PRESSURE VALVE, PIPE CLAMP	650
14	PRESSURE GAUGE	700
15	STRAIGHT CONNECTOR	80
16	TEMPERATURE SENSOR	200
17	SCREW, NUT, BOLT	100

Tab 1.4 Procurement of equipment

ORGANIZATION OF CHAPTERS

INTRODUCTION

The science of maintaining the temperature of a substance below the atmospheric temperature is generally termed as refrigeration or it can be said that it is the science of producing and maintaining the temperatures of the substance below that of the surroundings atmosphere. In simple, refrigeration means the cooling or removal of heat from a system or substance that needs to be cooled. Looking into the current scenario of domestic refrigeration system, electricity and Chlorofluorocarbon is generally used to produce the refrigeration effect. But the use of Chlorofluorocarbon is not at all free of harm. It has contributed to the ozone layer depletion which is considered as a threat to the mankind. As electricity is (abundant) in our country, the need of an alternate to the existing system has arisen. In such cases, LPG refrigeration system has proven to be an effective for areas such as research sites, mines & deserts and also free of pollution. The LPG that is coming out of the system can be directly be used on the cooking stoves. It works on the principle that as LPG expands there is pressure drop and increase in volume of LPG that results in drop of temperature and produces the refrigeration effect. The system eliminates the use of compressor and condenser. As it has no Ozone Depletion Potential it can be said as eco-friendly. Though many engineering analysis gas been done in recent years regarding LPG refrigeration system, the practical implications of such study yet to be reported in details. In the current work an attempt has been made to analysis the performance of a LPG powdered refrigeration system and to evaluate the effect of inlet pressure on performance of the system.

LITERATURE SURVEY

Thermodynamically Evolution of LPG Refrigerator

LPG with 64% Propane and 36% Butane by mass is suitable replacement for R-12 and 60% Propane and 40% commercial Butane is suitable replacement for R 134a in a domestic refrigerator with single evaporator coil. Enthalpy of gas remains constant when it expands inside the capillary tube. When there is an increase in inner diameter of capillary tube and coil diameter there will be increase in mass flow rate of gas and when there is an decrease in inner diameter of capillary tube and coil diameter there will be a decrease in mass flow rate of gas.

Refrigeration effect

High pressure gas is basic requirement for producing refrigeration effect. A comparative study on COP's of different Refrigerants are done and it is concluded that R744 (carbon dioxide) requires high operating pressure. R717 can be used as a green refrigerant in home.

A Study Paper on LPG as an Alternative Refrigerant for Refrigeration

Least possible temperature attained by LPG refrigeration system is -20 degree Celsius and with COP of 6.4 which is greater than other domestic refrigerants. In average its COP varies between 6 and 13.

PROJECT DESIGN

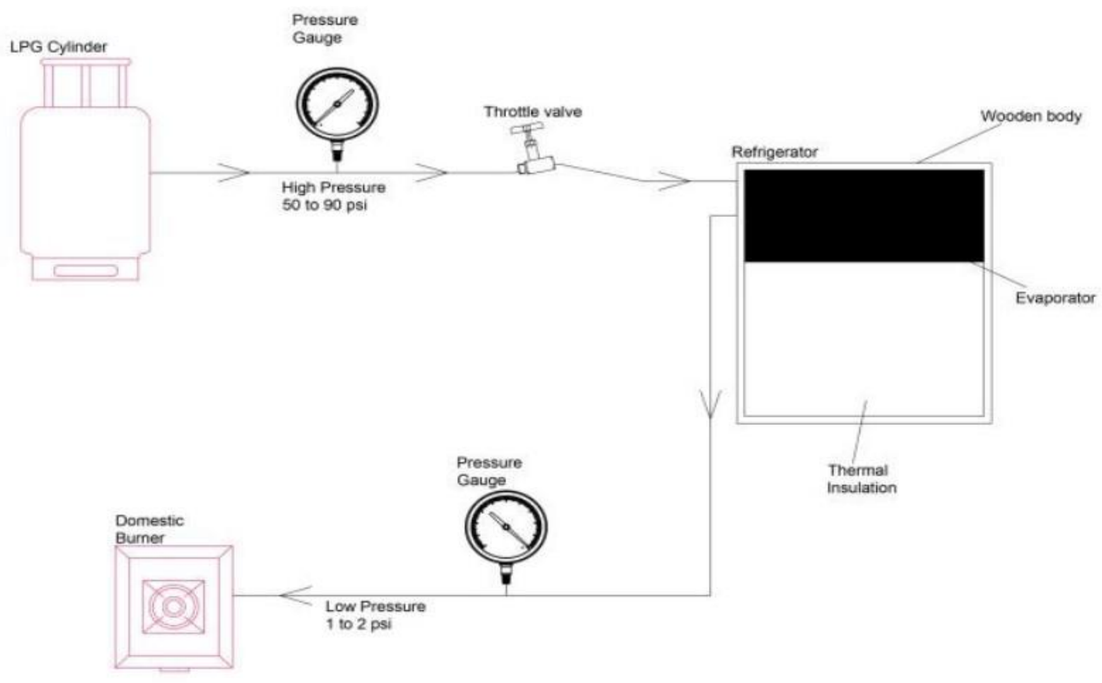

Fig1.4.a Design of LPG refrigeration system

PROJECT IMPLEMENTATION

The basic idea behind LPG refrigeration system is to use the evaporator of a LPG to absorb heat. LPG is stored in the LPG cylinder under high pressure when the gas tank of regulators is opened then high pressure LPG passes in gas pipe. This LPG is going by high pressure gas pipe in capillary tube. It works on the principle that during the extraction of heat the LPG expanded there is a pressure drop and increase in volume of LPG that results in the drop of temperature and a cooling effect.

PROJECT TESTING

The following test are to be on the machine.

1. Cooling rate.
2. Velocity of gas flow.
3. Expansion of gas.
4. Pressure regulation.
5. Testing for leaks and deformities.

CONCLUSION AND FUTURE ENHANCEMENT

1. In the future, however, the result may vary from the energy audit of any refinery if energy input for 1kg of LPG production was taken.
2. At both original and operating costs, this model is cheaper.
3. Maintenance costs are therefore also minimal. This model is best suited for the restaurants, industry, the factory, chemical sectors with very high LPG usage.
4. LPG is supplied in pressurized cylinders to keep it liquefied. The LPG cylinders, from past many years, are being manufactured in our country from the very conventional metallic material such as steel.
5. The weight of the cylinder becomes more as density of steel is higher compared to other light weight material. In household applications, thrust should be given towards use of low density materials so that the weight will come down. With the advancement of low density materials like GFRP (Glass Fiber Reinforced Polymer) composites, we can think of producing LPG cylinders with GFRP to reduce its weight in future, to increase safety, for measuring the amount of liquid consumption.

CHAPTER - 2

LITERATURE SURVEY

2.0 LITERATURE SURVEY

1 A. Baskaran & P. Koshy Mathews

A performance Comparison of Vapour Compression Refrigeration System. Using eco-friendly refrigerant of low Global Warming Potential (GWP) Vapour Compression Refrigeration System with the new R290/R600a refrigerant mixture as a substitute refrigerant for CFC12 and HFC 134a. The refrigerant R290/R600a had a refrigerating capacity 28.6% to 87.2% higher than that of R134a.

2 A. Baskaran & P. Koshy Mathews

A performance Comparison of Vapour Compression Refrigeration System. Using eco-friendly Refrigerants of Low Global Warming Potential. R600a performance have a slightly higher than coefficient (COP) R134a for the condensation temperature of 50 C and evaporating temperatures ranging between -30˚C and 10˚C. Hence, the coefficient of performance (COP) of this mixture was up to 5.7% higher.

3 M. Mohanraj et. al., have studied experimentally the dropin substitute for R134a with the environment friendly, energy efficient hydrocarbons (HC) mixture which consists of 45% HC290 and 55% R600a at various mass charges of 50g, 70g and 90g in domestic refrigerant. The experiments were carried out in 165 liters domestic refrigerator using R134a with POE oil as lubricant. The discharge temperatures of HC mixtures are found to be lower then R134a by 13.76%, 6.42% and 3.66% for 50g,70g and 90g respectively. The power consumption of HC mixture at 50g and 70g are lower by 10.2% and 5.1% respectively and 90g shows higher power consumption by 1.01%. The percentage reduction in pull down time is 18.36%, 21.76% and 28.57% for 50,70 and 90g mass charges respectively when compared to R134a. The HC mixture because of its high energy efficiency will also reduce the indirect global warming. In conclusion HC mixture of 70g is found to be an effective alternative to R134a in165 liters domestic refrigerator.

4 B.O. Balaji, have Experimental study of R152a/R32 to replace R134a in a domestic refrigerator and find out that COP obtained by R152a is 4.7% higher than that of R134a. COP of R32 is 8.5% lower than that of R134a and propane is an attractive and environmentally friendly to CFC’s used currently.

5 R.W.James & J.F.Missenden, have use of propane in domestic refrigerators and conclude that he implications of using propane in domestic refrigerators are examined in relation consumption, compressor costs, availability, to energy lubrications, environmental factors and safety propane is an attractive and environmentally friendly alternative to CFC's used currently.

6 Bilal A. Akash et. al, has conducted performance tests on the performance of liquified petroleum gas (LPG) as a possible substitute for R12 in domestic refrigerators. The refrigerator which is initially designed to work with R12 is used to conduct the experiment for LPG (30% propane, 55% n-butane and 15% isobutane). Various mass charges of 50,80 and 100g of LPG were used during the experimentation. LPG compares very well to R12. The COP was higher for all mass charges at evaporator temperatures lower than -15˚C. Overall, it was found that at 80g charge, LPG had the best results when used in this refrigerator. The condenser was kept at a constant temperature at 47˚C. Cooling capacities were obtained and they were in the order of about three to fourfold higher for LPG than those for R12.

7 M. Fatouh et. al. investigated substitute for R134a in a single evaporator domestic refrigerator with a total volume of 0.283 m3 with Liquefied petroleum gas (LPG) of 60% propane and 40% commercial butane. The performance of the refrigerator, tests were conducted with different capillary lengths and different charges of R134a and LPG. Experimental results of the refrigerator using LPG of 60g and capillary tube length of 5 m were compared with those using R134a of 100g and capillary tube length of 4 m. Pull-down time, pressure ratio and power consumption of LPG refrigerator were lower than those of R134a by about 7.6%, 5.5% and 4.3%, respectively. COP of LPG refrigerator was 7.6% higher than that of R134a. Lower on-time ratio and energy consumption of LPG refrigerator was lower than 14.3% and 10.8%, respectively, compared to R134a. In conclusion, the proposed LPG is drop in replacement for R134a, to have the better performance, optimization of capillary length and refrigerant charge was needed.

2.1 CONCLUSION OF LITERATURE SURVEY:

1. According to literature survey the performance of propane (LPG) refrigerator are higher than domestic R134a refrigerator.
2. There is less oxygen layer depletion compare to domestic refrigerator.
3. LPG (Liquified Petroleum Gas) refrigerators are less in maintenance, more eco-friendly, less cost to build.
4. Cooling capacity of LPG refrigerators is higher than R134a refrigerator.

CHAPTER - 3

PROJECT DESIGN

3.0 OVERVIEW OF THE DESIGN

The actual system is the process which have been used in the Domestic Refrigerator and most commonly used refrigerator is R134a. In the domestic refrigerator we use the compressor, condensor and these compressor and condensor plays a vital role in R134a refrigeration system. Whereas, in the LPG refrigeration system we eliminate the compressor and condensor and we make use Liquified Petroleum Gas as the major source and a burner. The below figure shows the modification of the Vapour Compression Cycle which we have used in this experiment.

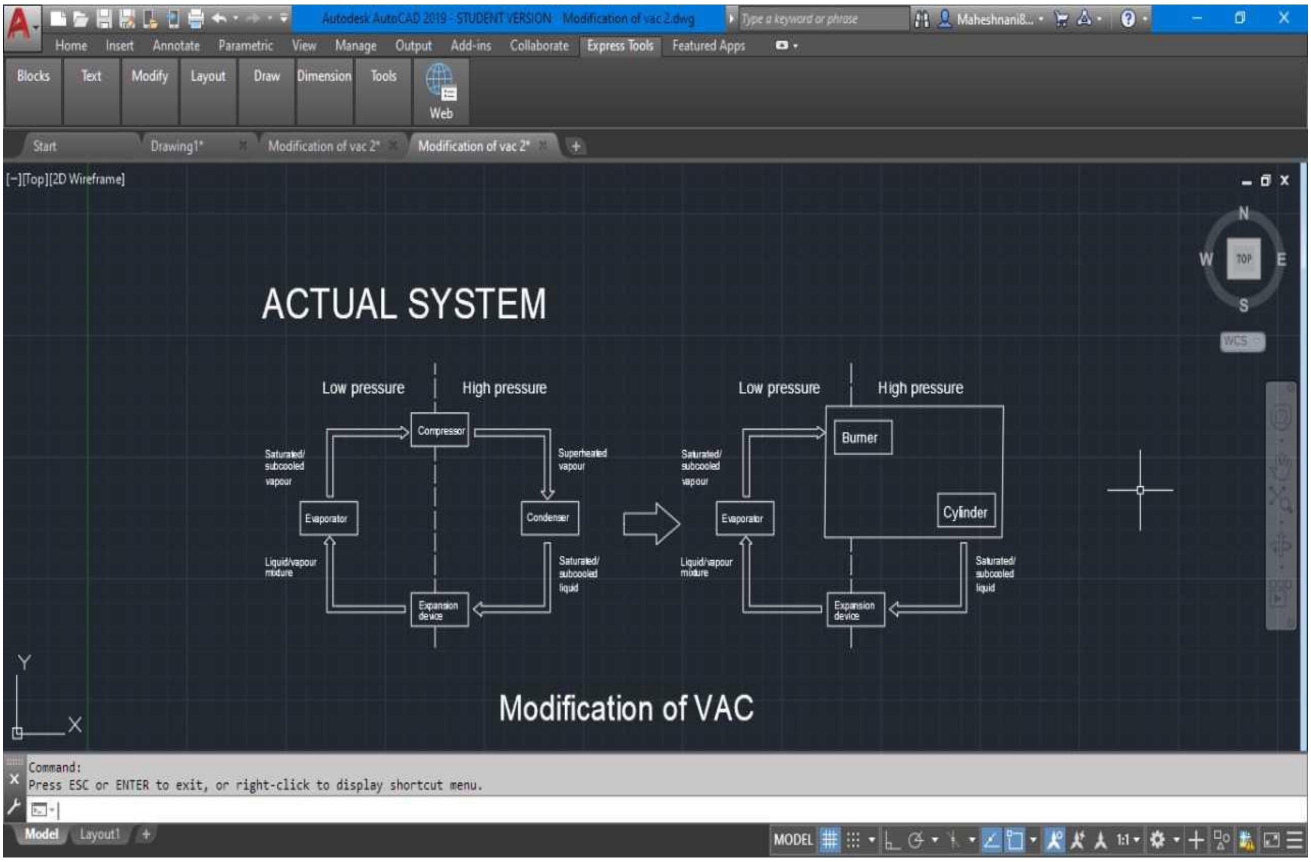

Fig3.0 a: Modification of Vapour Absorption cycle

In the below figure we have LPG cylinder, Pressure gauge, Throttle valve, Capillary tube, Evaporator, Temperature probe and the Burner.

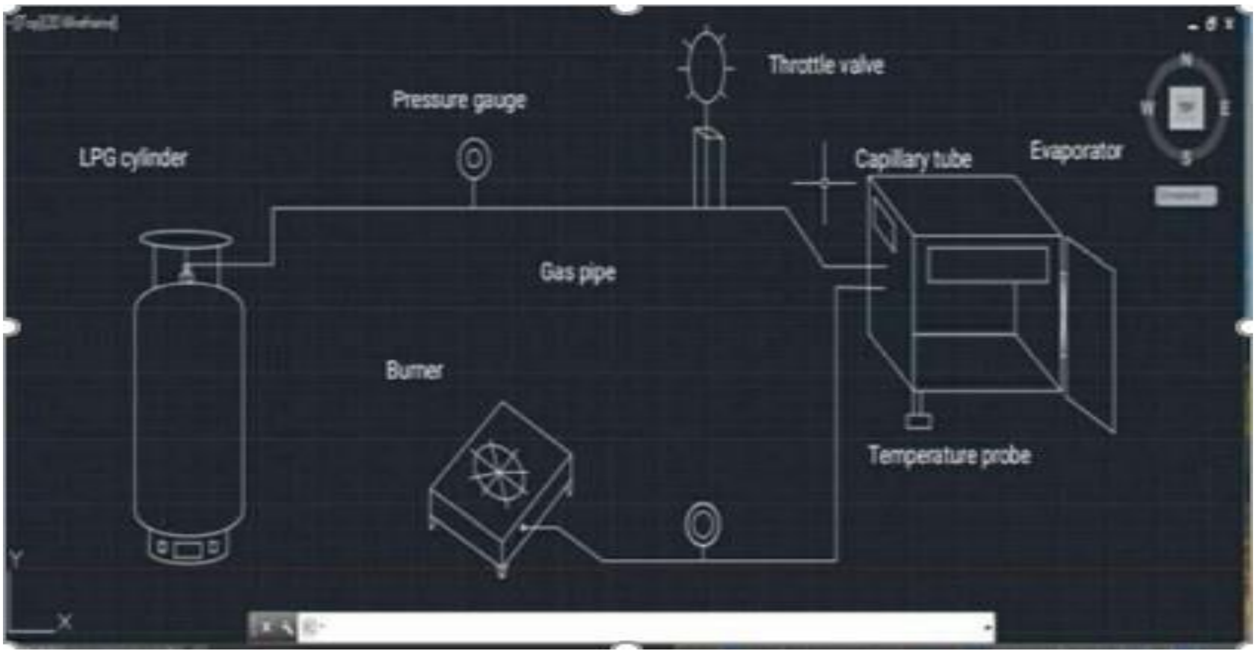

Fig3.0 b: Design of LPG Refrigeration System

The design of LPG refrigeration system with zero operating cost is as shown in the above and below figures respectively.

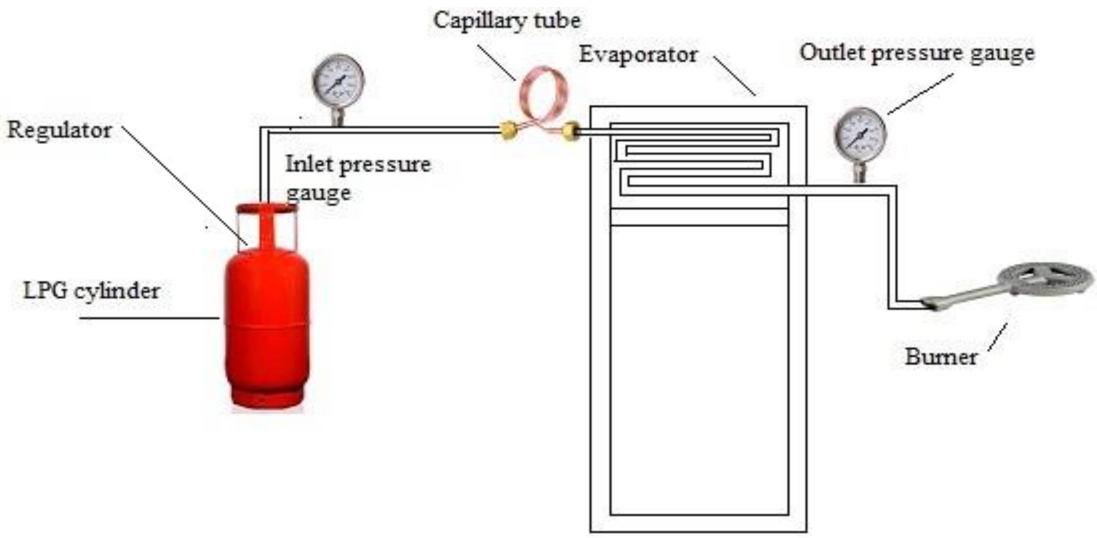

Fig3.0 c: Schematic diagram of LPG refrigeration system

SPECIFICATIONS:

Refrigerator Box - 476*362*600 mm3

Evaporator - 355*236*157 mm3

Thickness of the Box - 12mm

Thickness of Thermocol - 20mm

Diameter of Capillary tube - 2.28mm

Length of Capillary tube - 1.5mm

Diameter of High pressure pipe - 8.5mm

Diameter of the cylinder - 315mm

Height of the cylinder - 825mm

3.1 MODULE DEFINITION & ITS FUNCTIONALITIES

1. LPG Gas Cylinder:

Liquefied Petroleum Gas is combination of Propane (C_3H_8) and Butane (C_4H_{10} It is generally stored at 12.7 bar for house hold purpose cylinder. By using a suitable regulator LPG is sent into capillary tube. LPG is used as a fuel for domestic, industrial, horticultural, agricultural, cooking, heating and drying processes. LPG can be used as an automotive fuel or as a propellant for aerosol, in addition to other specialist applications LPG can also be used to provide lighting through the use of pressure lanterns.

Fig3.1.1: LPG Gas Cylinder

2. Capillary Tube:

The main function of capillary is to lower the pressure. As the capillary tube, the capillary tube downs the pressure up to 1.4bar its diameter is less then 3mm. The capillary refrigerant enters through the capillary tube, its pressure drops down suddenly due to its small diameter.

Fig3.1.2: Capillary Tube

3. Evaporator:

The evaporator is an important part where the actual cooling effect takes place in the refrigeration systems. The evaporators are heat exchanger surface that transfer the heat from the substance to be cooled to the refrigerant, evaporators refrigeration thus removing the heat from the cabin are used for wide variety and hence the available form of the substance. This cooling effect in the vapour form at low pressure and temperature.

Fig3.1.3: Evaporator

4. Pressure gauges:

Many techniques have been developed for the measurement of pressure and vaccums. Instruments that are used to measure pressure are called pressure gauges or vacuum gauges. These gauges are available in 63mm, 100mm, and 150mm sizes and can be customized as per client. A Bourdon gauge uses a coiled tube, which, as expands due to pressure increases cases a rotation of an arm connected to the tube.

Fig3.1.4: Pressure Gauge

5. Digital Temperature probe:

A digital temperature probe is a device that gives the temperature measurement through an electrical signal.

6. Gas Burner:

A **burner** is a device which produces heat or a flame, especially as part of a stove or heater.

Fig3.1.5: Burner

Fig3.1.6: Temp. sensor

7. High Pressure pipes: The range of high pressure pipes covers most application where there is a requirement to transfer gas at high pressure. They consist of a steel pipe with a steel ball fitted to both ends. All pipes are pressure tested to 100 MPa (200 psi).

Fig3.1.7: High Pressure Pipe

3.2 RELATED DESIGNS/GRAPHS

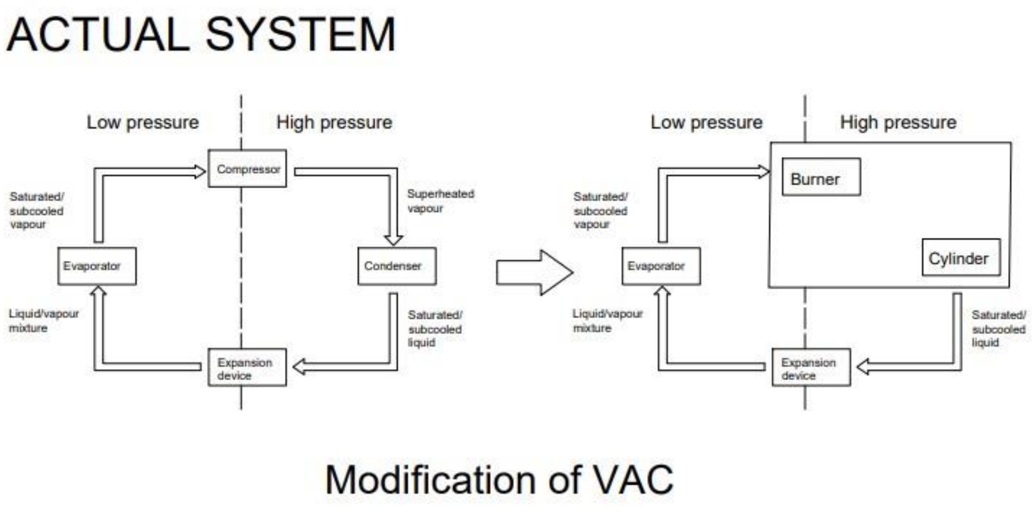

Fig3.2.1: Modification of Vapour Compression Cycle

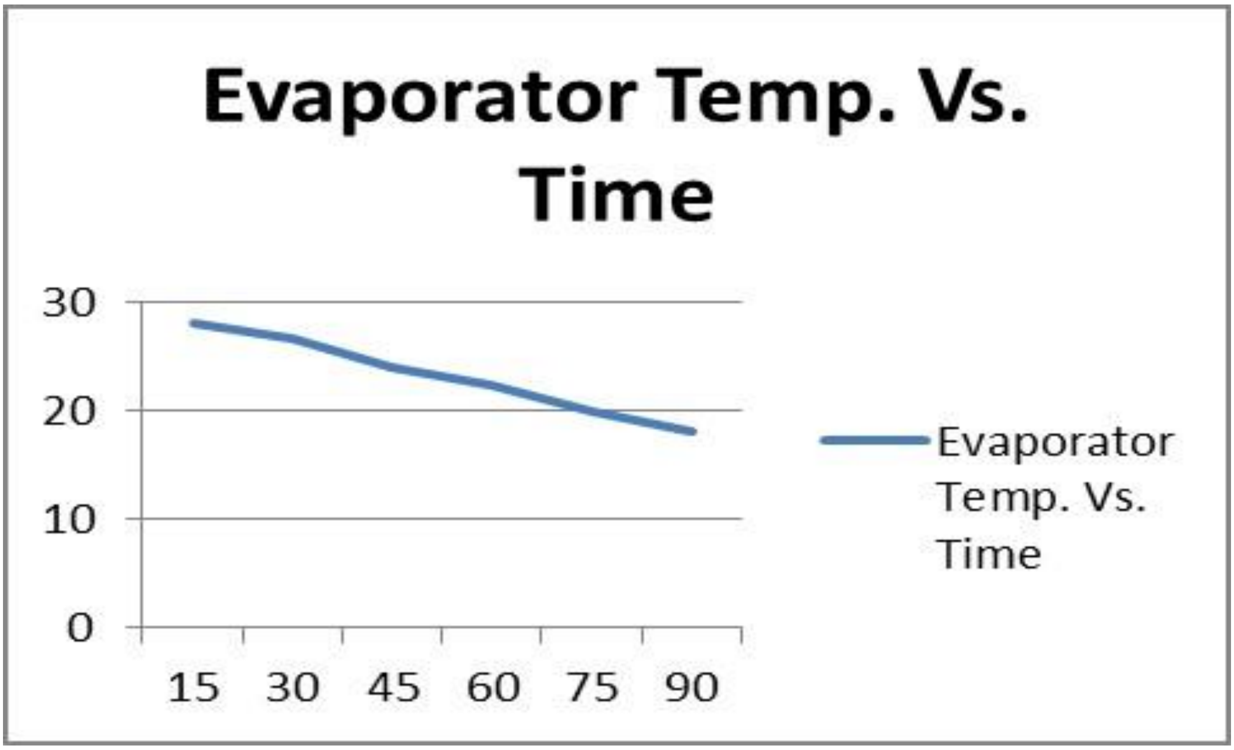

Fig3.2: Evaporator Temp. vs Time

The above graph is drawn between the Evaporator temperature and the Time taken for the cooling of the evaporator. We can see that as the time increases the temperature in the evaporator decreases.

CHAPTER – 4

PROJECT IMPLEMENTATION

4.0 DOMESTIC REFRIGERATION:

A household or domestic refrigerator has become one of the most important household appliances all over the world. Every year millions of domestic refrigerators are manufactured. A domestic refrigerator is essentially a small cold storage where several food products such as ice cream, meat, fish, milk, fruits, vegetables, water etc. can be stored at reduced temperatures. The most common domestic refrigerator uses a vapour compression refrigeration system for maintaining required storage conditions, even though a small number of refrigerators use the principle of triple fluid vapour absorption refrigeration system. Domestic refrigerators are available in wide range of sizes and designs. The domestic refrigerator is normally specified by the storage volume (gross or net), e.g. a 300 litre refrigerator means a domestic refrigerator with an internal storage volume of 300 litres. The sizes of the domestic refrigerators vary from about 100 litres to about 600 litres. Now-a-days, most of these units use either HFC-134a or hydrocarbons as refrigerants. They use a sealed (hermetic) compressor with a capillary tube as an expansion device. The condenser of small refrigerators are of natural convection type, while larger refrigerators may have a fan for forced air circulation over the condenser.

4.1 WORKING OF VCR SYSTEM:

A vapour compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant is used. It condensed and evaporates at temperatures and pressures close to the atmospheric conditions. The refrigerants usually used for this purpose are ammonia, carbon dioxide and sulphur dioxide.

Comparison between gas cycles and vapor cycles

Thermodynamic cycles can be categorized into gas cycles and vapour cycles. In a typical gas cycle, the working fluid (a gas) does not undergo phase change, consequently the operating cycle will be away from the vapour dome. In gas cycles, heat rejection and refrigeration take place as the gas undergoes sensible cooling and heating. In a vapour cycle the working fluid undergoes phase change and refrigeration effect is due to the vaporization of refrigerant liquid. If the refrigerant is a pure substance then its temperature remains constant during the phase change processes. Hence, the required mass flow rates for a given refrigeration capacity will be much smaller compared to a gas

cycle. Vapour cycles can be subdivided into vapour compression systems, vapour absorption systems, vapour jet systems etc.
Among these the vapour compression refrigeration systems are predominant.

Mechanism of simple vapour compression refrigeration system:

Compression refrigeration cycles take advantage of the fact that highly compressed fluids at a certain temperature tend to get colder when they are allowed to expand. If the pressure change is high enough, then the compressed gas will be hotter than our source of cooling (outside air, for instance) and the expanded gas will be cooler than our desired cold temperature. In this case, fluid is used to cool a low temperature environment and reject the heat to a high temperature environment. Vapour compression refrigeration cycles have two advantages. First, a large amount of thermal energy is required to change a liquid to a vapor, and therefore a lot of heat can be removed from the airconditioned space. Second, the isothermal nature of the vaporization allows extraction of heat without raising the Simple Vapour Compression Refrigeration System temperature of the working fluid to the temperature of whatever is being cooled. This means that the heat transfer rate remains high, because the closer the working fluid temperature approaches that of the surroundings, the lower the rate of heat transfer.

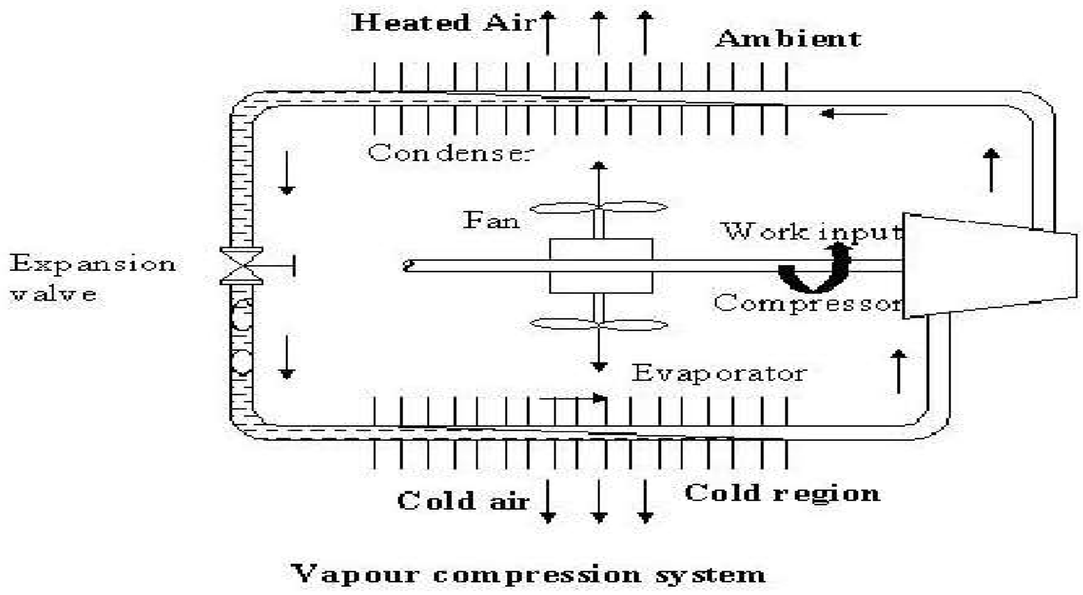

Fig4.1 a: Simple Vapour Compression system

The refrigeration cycle is shown in Figure below and can be broken down into the following stages:

1 – 2 Low-pressure liquid refrigerant

In the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 – 3 The superheated vapour

Enters the compressor where its pressure is raised. The temperature will also increase, because a proportion of the energy put into the compression process is transferred to the refrigerant.

3 – 4 The high pressure superheated gas

Passes from the compressor into the condenser. The initial part of the cooling process (3-3a) superheats the gas before it is then turned back into liquid (3a-3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid

Passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.

Simple Vapor Compression Refrigeration Cycle

It is shown on T-S below at point 1, let T1, P1, and s1 be the properties of vapour refrigerant. the four processes of the cycle are as follows:

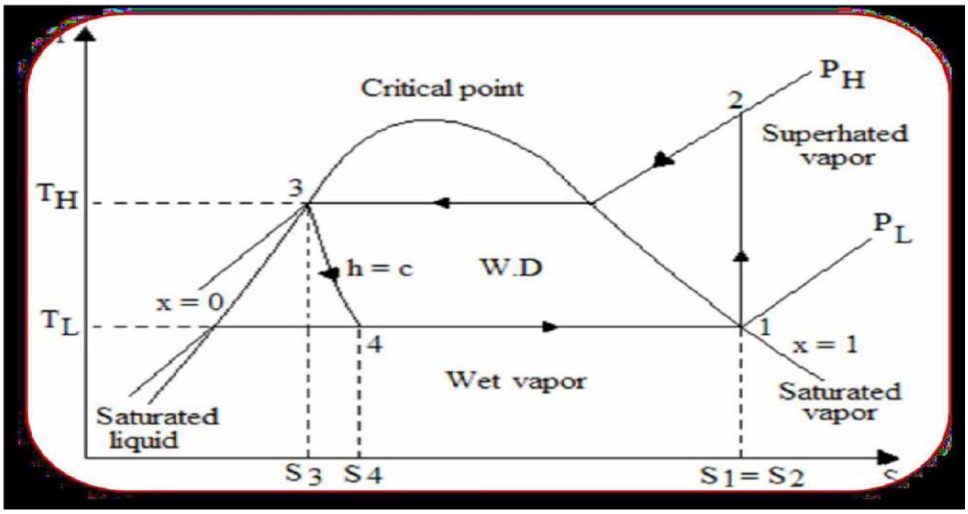

Fig4.1 b: T-s diagram of simple vapor compression refrigeration cycle

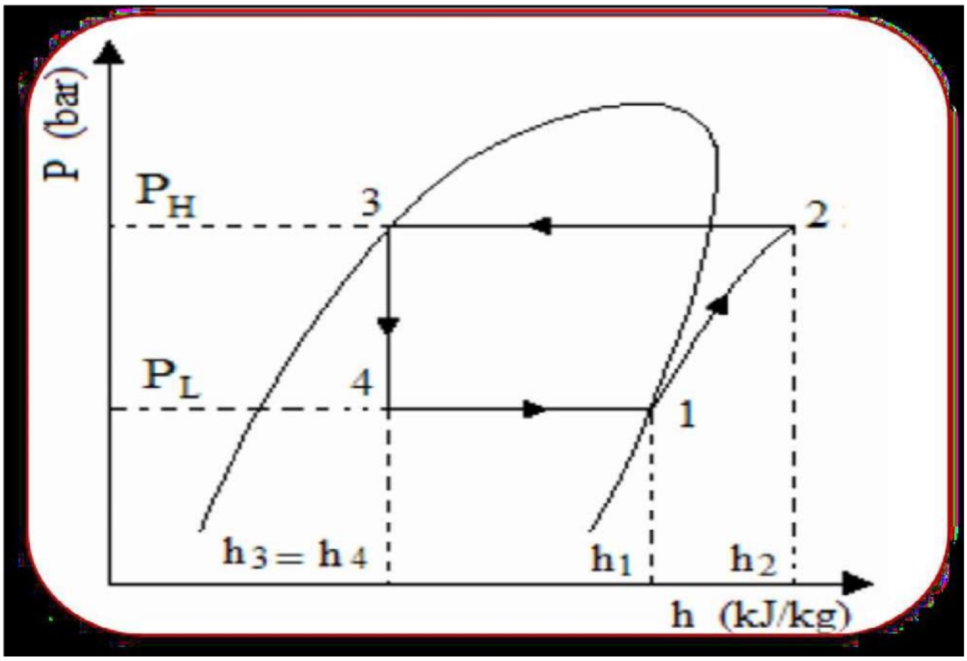

Fig4.1 c: P-h diagram for simple vapor compression refrigeration cycle

1. Compression process:

The vapour refrigerant at low pressure p1 and temperature T1 is compressed isentropically to dry saturated vapour as shown by the vertical line 1-2 on T-s diagram and by the curve 1-2 on p-h diagram. The pressure and temperature rises from 1 to 2.

The work done during isentropic compression is given by:

W=h2-h1……………………………………….1

2. Condensing process

The high pressure and temperature vapour refrigerant from the compressor is passed through the condenser where it is completely condensed at constant pressure p2 and temperature T2. The vapour refrigerant is changed into liquid refrigerant. The refrigerant while passing through the condenser, gives its latent heat to the surrounding condensing medium.

3. Expansion process:

The liquid refrigerant at pressure p3=p2 expanded by throttling process through the expansion valve to a low pressure p4=p1 and temperature T4=T1. Some of the liquid refrigerant evaporates as it passes through expansion valve, but the greater portion is vaporized in the evaporator. During the throttling process no heat is absorbed or rejected by the liquid refrigerant.

4. Vaporizing process:

The liquid vapour mixture of the refrigerant at pressure p4=p1 and temperature T4=T1 is evaporated and changed into vapour refrigerant at constant pressure and temperature. During evaporation, the liquid vapour refrigerant absorbs its latent heat of vaporization from medium (air, water or brine) which is to be cooled. The heat absorbed or extracted by the liquid vapour refrigerant during evaporation is given by: RE=h1-h4=h1-hf3……………………………….2

Where hf3 is sensible heat at T3 (enthalpy of liquid refrigerant leaving the condenser). The coefficient of performance is ratio of refrigerating effect to the work done.

C.O.P = (h1-h4) / (h1-hf3)

= (h1-hf3) / (h2-h1)

Types of refrigerant used in vapour compression systems:

A variety of refrigerants are used in vapor compression systems. The required cooling temperature largely determines the choice of fluid. Commonly used refrigerants are in the family of chlorinated fluorocarbons (CFCs, also called Freons): R-11, R-12, R-21, R-22 and R-502. The properties of these refrigerants are summarized in Table 1 and the performance of these refrigerants is given in Table 2 below.

Tab4.1 d: Properties of commonly used refrigerants

Refrigerant	Boiling Point ** (°C)	Freezing Point (°C)	Vapor Pressure * (kPa)	Vapor Volume * (m^3 / kg)	Enthalpy *	
					Liquid (kJ / kg)	Vapor (kJ / kg)
R – 11	-23.82	-111.0	25.73	0.61170	191.40	385.43
R – 12	-29.79	-158.0	219.28	0.07702	190.72	347.96
R – 22	-40.76	-160.0	354.74	0.06513	188.55	400.83
R – 502	-45.40	---	414.30	0.04234	188.87	342.31
R – 7 (Ammonia)	-33.30	-77.7	289.93	0.41949	808.71	487.76

Tab4.1 e: Performance of commonly used refrigerants

Refrigerant	Evaporating Press (kPa)	Condensing Press (kPa)	Pressure Ratio	Vapor Enthalpy (kJ / kg)	COP^{**}_{carnot}
R – 11	20.4	125.5	6.15	155.4	5.03
R – 12	182.7	744.6	4.08	116.3	4.70
R – 22	295.8	1192.1	4.03	162.8	4.66
R - 502	349.6	1308.6	3.74	106.2	4.37
R - 717	236.5	1166.5	4.93	103.4	4.78

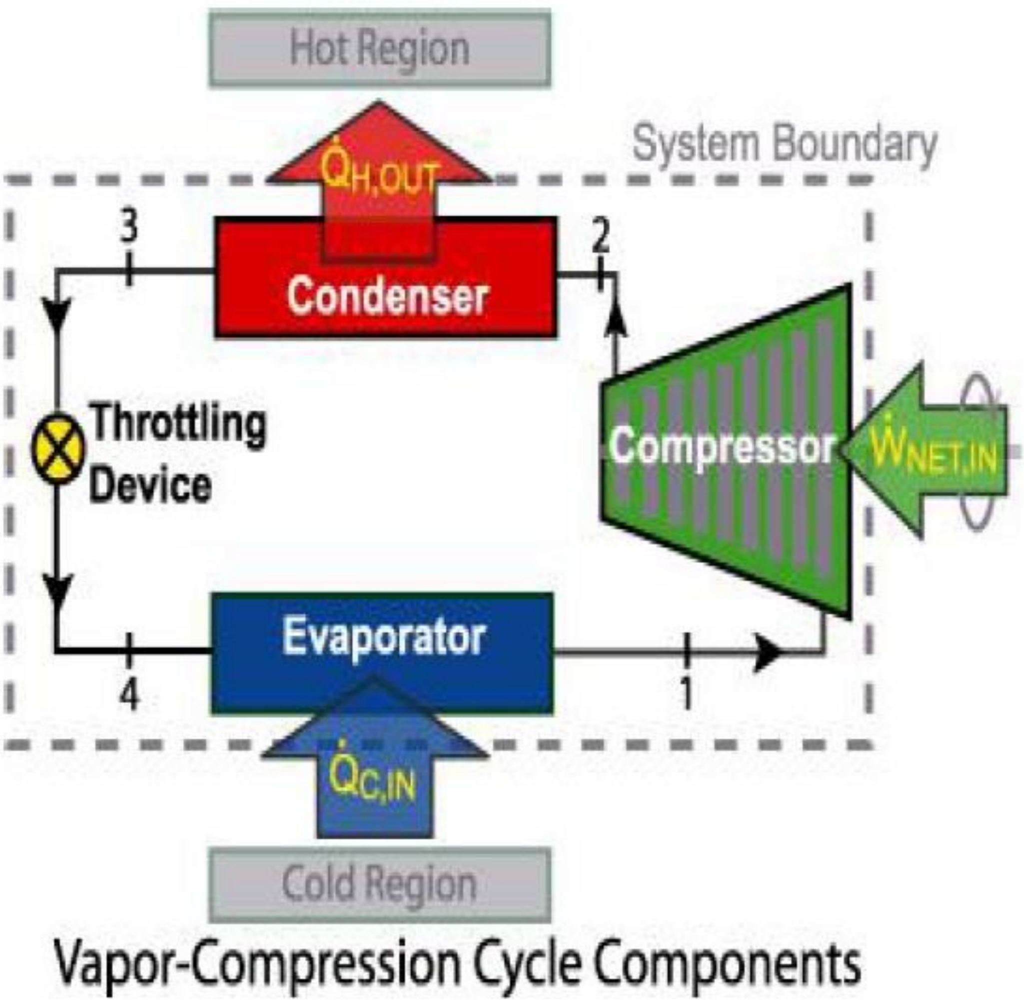

Fig4.1 f: Vapor Compression Cycle

Advantages:

- Capable of large refrigerating loads at lower initial purchase and operating cost.
- Very efficient.
- Very compact system for small to very large heat loads.
- Cycle can be reserved for heat pump operation.

Disadvantages:

- Parts can wear out.
- Noise
- Potential refrigerant leaks.
- Operates in limited orientation.

Applications of VCR:

- Household refrigerator.
- Air conditioners.
- Water coolers.
- Ice and Ice cream makers.
- Deep freezers.
- Large industrial refrigeration.
- Air conditioning systems.

4.2 Fundamentals of Refrigeration

Refrigeration and Second Law of Thermodynamics:

Refrigeration is the removal of heat from a space at a temperature lower than the surrounding temperature. Due to the natural frequency of heat to flow from higher to lower temperature, the rushes to replace the heat removed. But a refrigerator rejects the heat that is entering into the system back to the atmosphere. Hence input of work is essential, according to second law of thermodynamics systems for pumping heat from lower to higher temperatures.

Second Law of Thermodynamics:

The second law of thermodynamics is a limit law. It gives the upper limit of efficiency of a system. The second law also acknowledges that processes follow in a certain direction but not in the opposite direction. It also defines the important property called entropy. It is common sense that heat will not flow spontaneously from a body at lower temperature to a body at higher temperature. In order to transfer heat from lower temperature to higher temperature continuously (that is, to maintain the low temperature) a refrigeration system is needed which requires work input from external source. This is one of the principles of second law of thermodynamics, which is known as Clausius statement of the second law.

Clausius Statement of Second Law: It is impossible to transfer heat in a cyclic process from low temperature to high temperature without work from external source. It is also a fact that all the energy supplied to a system as work can be dissipated as heat transfer. On the other hand, all the energy supplied as heat transfer cannot be continuously converted into work giving a thermal efficiency of 100 percent. Only a part of heat transfer at high temperature in a cyclic process can be converted into work, the remaining part has to be rejected to surroundings at lower temperature. If it were possible to obtain work continuously by heat transfer with a single heat source, then automobile will run by deriving energy from atmosphere at no cost. A hypothetical machine that can achieve it is called Perpetual Motion Machine of second kind. This fact is embedded in Kelvin-Planck Statement of the Second law.

Kelvin-Planck statement of second law: It is impossible to construct a device (engine) operating in a cycle that will produce no effect other than extraction of heat from a single reservoir and convert all of it into work.

Mathematically, Kelvin-Planck statement can be written as: cycle ≤ 0W (for a single reservoir) Reversible and Irreversible Processes:

Irreversible Processes: A process is reversible with respect to the system and surroundings if the system and the surroundings can be restored to their respective initial states by reversing the direction of the process, that is, by reversing the heat transfer and work transfer. The process is irreversible if it cannot fulfill this criterion. If work is done in presence of friction, say by movement of piston in a cylinder then a part of the work is dissipated as heat and it cannot be fully recovered if the direction of process is reversed. Similarly, if heat is transferred through a temperature difference from higher temperature to a lower temperature, its direction cannot be reversed since heat transfer from lower temperature to higher temperature would require external work input. These are two examples of irreversible processes.

Reversible process: It is a hypothetical process in which work is done in absence of friction and heat transfer occurs isothermally. Irreversibility leads to loss in work output and loss in availability and useful work.

Heat engines, Refrigerators, Heat pumps:

Heat engines: A heat engine may be defined as a device that operates in a thermodynamic cycle and does a certain amount of net positive work through the transfer of heat from a high temperature body to a low temperature body. A steam power plant is an example of a heat engine.

Refrigerators: A refrigerator may be defined as a device that operates in a thermodynamic cycle and transfers a certain amount of heat from a body at a lower temperature to a body at a higher temperature by consuming certain amount of external work. Domestic refrigerators and room air conditioners are the examples. In a refrigerator, the required output is the heat extracted from the low temperature body.

Heat pumps: A heat pump is similar to a refrigerator, however, here the required output is the heat rejected to the high temperature body.

Carnot's theorems for heat engines:

Theorem 1: It is impossible to construct a heat engine that operates between two thermal reservoirs and is more efficient than a reversible engine operating between the same two reservoirs.

Theorem 2: All reversible heat engines operating between the same two thermal reservoirs have the same thermal efficiency. The two theorems can be proved by carrying out a thought experiment and with the help of second law. Carnot's theorems can also be formed for refrigerators in a manner similar to heat engines. Carnot efficiency: The Carnot efficiencies are the efficiencies of completely reversible cycles operating between two thermal reservoirs.

According to Carnot's theorems, for any given two thermal reservoirs, the Carnot efficiency represents the maximum possible efficiency.

If we consider a combined system that includes the system and its surroundings, then the combined system becomes an isolated system. Then one can write: Δ system + ΔSS surroundings = σisol > 0 since entropy is produced in all actual processes, only processes that can occur are those for which the entropy of the isolated system increases. Energy of an isolated system is conserved whereas entropy of an isolated system increases. This is called the principle of increase of entropy.

Units of Refrigeration:

A unit is used in the field of refrigeration is known as Ton of Refrigeration. A Ton of Refrigeration is defined as the quantity of the heat required to be required to be removed from one ton of ice within 24 hours when the initial condition of water is 0 ^{o}C, because same cooling effect will be given by melting the same ice.

4.3 REFRIGERANTS:

The thermodynamic efficiency of refrigeration system mainly depends on its operating temperatures. However, important practical issues such as system design, size, initial and operating costs, safety, and serviceability etc.; depend very much on the type of the refrigerant selected for given application. Due to several environmental issued such as ozone layer depletion and global warming and their relation to the refrigerants used, the selection of suitable refrigerant has become one of the important issues in recent times.

Replacement of an existing refrigerant by a completely new refrigerant, for whatever reason, is an expensive proposition as it may call for several changes in the design and manufacturing of refrigeration systems. Hence it is very important to understand the issues related to the selection and the use of refrigerants. In principle, any fluid can be used as a refrigerant in vapor compression refrigeration systems only.

Refrigeration Applications	Short description	Typical HFC's used
Domestic Refrigeration	Applications used for keeping food in dwelling units	HFC-134a
Commercial Refrigeration	Holding and displaying frozen and fresh food in retail outlets.	R404A, R507, HFC-234a
Food processing and cold storage	Equipment to preserve, process and food from its source to the wholesale and cooling.	R410A, R 407C, R 507, HFC-134a
Industrial Refrigeration	Large equipment, typically 25KW to 30MW, used for chemical processing cold storage, food processing and district heating and cooling.	HFC-134a, R-404A, R-507
Transport Refrigeration	Equipment to preserve and store goods, foodstuffs, during transport by road, rail, air and sea.	R410A, R407C, HFC-134A

Tab 4.3 Types of Refrigerants

Primary and Secondary Refrigerants:

Fluids suitable for refrigeration purpose can be classified into primary and secondary refrigerants. Primary refrigerants are those fluids, which are used directly as working fluids, for example in vapor compression and vapor compression refrigeration systems. When used in compression or absorption systems, these fluids provide refrigeration by undergoing phase changing process in the evaporator. As the name implies, secondary refrigerants are those fluids, which are used for transporting thermal energy from one location to other. Secondary refrigerants are also known under the name brines or antifreezes. Of course, if the operating temperatures are above $0^{o}C$, then pure air blower can also be used as secondary refrigerant, for example in large air conditioning systems. The secondary refrigerants do not undergo phase change as they transport energy from one location to other.

An important property of secondary refrigerant is its freezing point. Generally, the freezing point of brine will be lower than the freezing point of its constituents. The temperature at which the freezing point of brine takes place depends on its concentration. The concentration at which a lowest temperature can be reached without solidification is called as eutectic point. The commonly used secondary refrigerants are the solution of air blower and ethylene glycol, propylene glycol or calcium chloride. These solutions are known under the general name of brines. In vapor absorption system, a refrigerant and absorbent combination is used as the working fluid.

OZONE DEPLETION POTENTIAL:

The product is a green technology and is eco-friendly, as if eliminates the use of ozone-depletion refrigerants.

TRANSPORTATION:

On the other hand the technology if implemented in heavy utility vehicles or transportation, it would help in distant transportation, it would help in distant transportation of eatables as the refrigeration system inside the vehicle can be brone simultaneously. Cooling and storage of essentials in remote areas and in emergency vehicles, such as storage of essentials bio-chemicals, injections, etc which have their own gas turbine power-plants.

ELECTRICITY IS NOT AVAILABLE:

This system is cheaper at initial and running cost is almost zero. It does not require an external energy sources to run the system an no moving part in the system. So maintenance cost is also very low. No outside energy source is required to run the system. As well no moving components are present in the system which future reduces the maintenance cost as well. This LPG refrigeration system has wide scale application in hotel industries, chemical industries where the LPG consumption is at a higher level.

4.4 PHYSICAL PROPERTIES AND CHARACTERISTICS OF LPG:

DENSITY

LPG at atmospheric pressure and temperature is a gas which is 1.5 to 2.0 times heavier than air. It is readily liquefied under moderate pressures. The density of the liquid is approximately half that of water and ranges from 0.525 to 0.580 @ 15 deg. C. Since LPG vapour is heavier than air, it would normally settle down at ground level/ low lying places, and accumulate in depressions.

VAPOUR PRESSURE

The pressure inside a LPG storage vessel cylinder will be equal to the vapour pressure corresponding to the temperature of LPG in the storage vessel. The vapour pressure is dependent on temperature as well as on the ratio of mixture of hydrocarbons. At liquid full condition any further expansion of the liquid, the cylinder pressure will rise by approx. 14 to 15 kg./sq.cm. for each degree centigrade. This clearly explains the hazardous situation that could arise due to overfilling of cylinders.

FLAMMABILITY

LPG has an explosive range of 1.8% to 9.5% volume of gas in air. This is considerably narrower than other common gaseous fuels. This gives an indication of hazard of LPG vapour accumulated in low lying area in the eventuality of the leakage or spillage. The auto-ignition temperature of LPG is around 410-580 deg. C and hence it will not ignite on its own at normal temperature. Entrapped air in the vapour is hazardous in an unpurged vessel/ cylinder during pumping/ filling-in operation. In view of this it is not advisable to use air pressure to unload LPG cargoes or tankers.

COMBUSTION

The combustion reaction of LPG increases the volume of products in addition to the generation of heat. LPG requires upto 50 times its own volume of air for complete combustion . Thus it is essential that adequate ventilation is provided when LPG is burnt in enclosed spaces otherwise asphyxiation due to depletion of oxygen apart from the formation of carbon-dioxide can occur.

ODOUR

LPG has only a very faint smell, and consequently, it is necessary to add some odourant, so that any escaping gas can easily be detected. Ethyl Mercaptan is normally used as stenching agent for this purpose. The amount to be added should be sufficient to allow detection in atmosphere 1/5 of lower limit of flammability or odour level 2 as per IS : 4576.

COLOUR

LPG is colourless both in liquid and vapour phase. During leakage the vapourisation of liquid cools the atmosphere and condenses the water vapour contained in them to form a whitish fog which may make it possible to see an escape of LPG.

TOXICITY

LPG even though slightly toxic, is not poisonous in vapour phase, but can, however, suffocate when in large concentrations due to the fact that it displaces oxygen. In view of this the vapour poses mild anaesthetic properties.

SAFETY

LPG is just as safe as any other fuel. In fact, it is safer than most of the fuels because neither LPG itself nor the end products that are produced by burning LPG in a suitable appliance, are poisonous to inhale. Since LPG cannot burn without air, there can never be a 'Flash-back' into the cylinder.

4.5 WORKING OF LPG REFRIGERATOR

The basic idea behind LPG refrigerator is to use the LPG to absorb heat. The simple mechanism of the LPG refrigeration working is shown in the figure below.

- LPG is stored in the LPG cylinder under high pressure. When the gas tank of regulators is opened then high pressure LPG passes through the high pressure pipe. This LPG is going by high pressure gas pipe to capillary tube.
- High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant.
- After capillary tube, low pressure LPG is passed through the evaporator. LPG is converted into low pressure and temperature vapor from and passes the evaporator which absorbs heat from the chamber. Thus the chamber becomes cool down. Thus we can achieve cooling effect in refrigerator.
- After passing through the evaporator low pressure LPG is passed through the pipe to burner. And we can use the low pressure of LPG in burning processes.

The LPG Refrigerator is work on the simple Vapour Compression Refrigeration system. The working of VCR system is as follows:

Process 2-3: When the compressor is started, it draws the low pressure vapour from the evaporator at state 2 and compresses it isentropically to sufficiently high pressure up to state 3. Since in compression work is done on the vapour, its temp also increases and hence it is converted into low pressure adiabatically i.e. enthalpy remains constant.

After capillary tube, this low pressure LPG is passed through evaporator. In the evaporator LPG is converted into low pressure and temperature form which it absorbs the heat from the cooling chamber.

Thus the cooling chamber cools down.

Process 3-4: Hot vapour from compressor under pressure is discharged into the condenser where condenser cooling medium usually water or surrounding air is absorb the heat from hot vapour. This converts the hot vapour into liquid and the liquid is collected in liquid receiver at state 4.

Process 4-1: The liquid from the liquid receiver at high pressure is then piped to a refrigerant control valve which regulates the flow of liquid into the evaporator. This control valve, while restricting the flow, also reduces the pressure of the liquid with the result the liquid change into vapour of low dryness fraction represented by state 1. During this process the temperature of the refrigerant reduces corresponding to its pressure.

Process 1-2: Finally, the low pressure, low temperature refrigerant passes through the evaporator coil where it absorb its latent heat from the cold chamber or from brine solution at constant pressure and converts into vapour at state 2. It is again supplied to compressor. Thus, the cycle is completed.

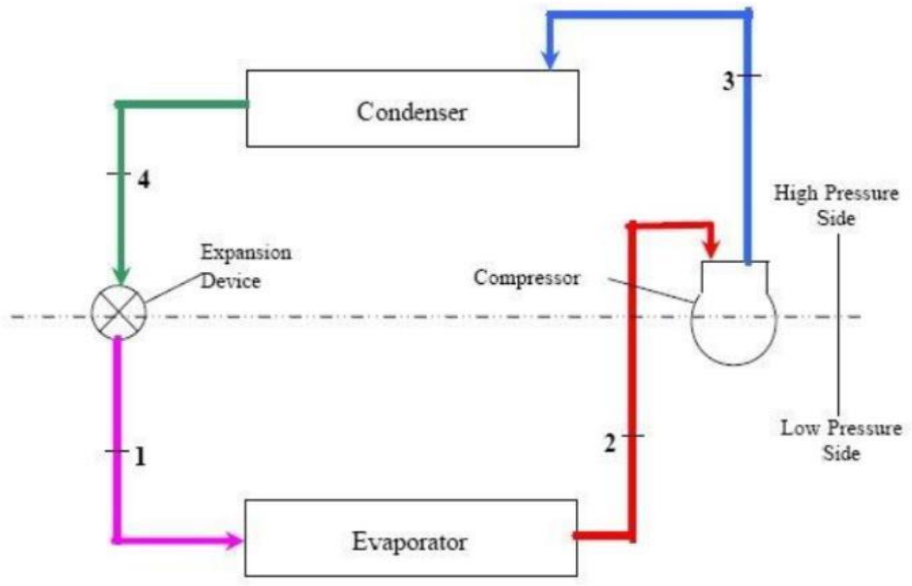

Fig4.5 a: Schematic diagram of simple VCRs

The idea behind working of LPG refrigeration is to absorb heat from surrounding by using the evaporation of a LPG. The pressure of LPG which is stored in cylinder is at about 80 psi. We are lowering this pressure of LPG up to pressure 15 psi by using capillary and so that cooling is done on surrounding by absorbing heat isentropically.

Pressure of LPG in cylinder is high, when the regulator of gas tank is opened then high pressure LPG passes through gas pipe. After that this high pressure LPG goes in the capillary tube from high pressure pipe. In the capillary tube this high pressure LPG is converted into low pressure and hence low temperature because of expansion of LPG gas in capillary tube.

Thus we can get refrigerating effect in refrigerator. After that the low pressure LPG from evaporator is passed to the burner through high pressure pipe and we can use this low pressure LPG for burning for further application. In this project we use recompressed LPG cylinder instead of compressor. In this way we can achieve refrigerating effect from this system.

The actual setup and construction of LPG refrigeration system is shown in the following figure.

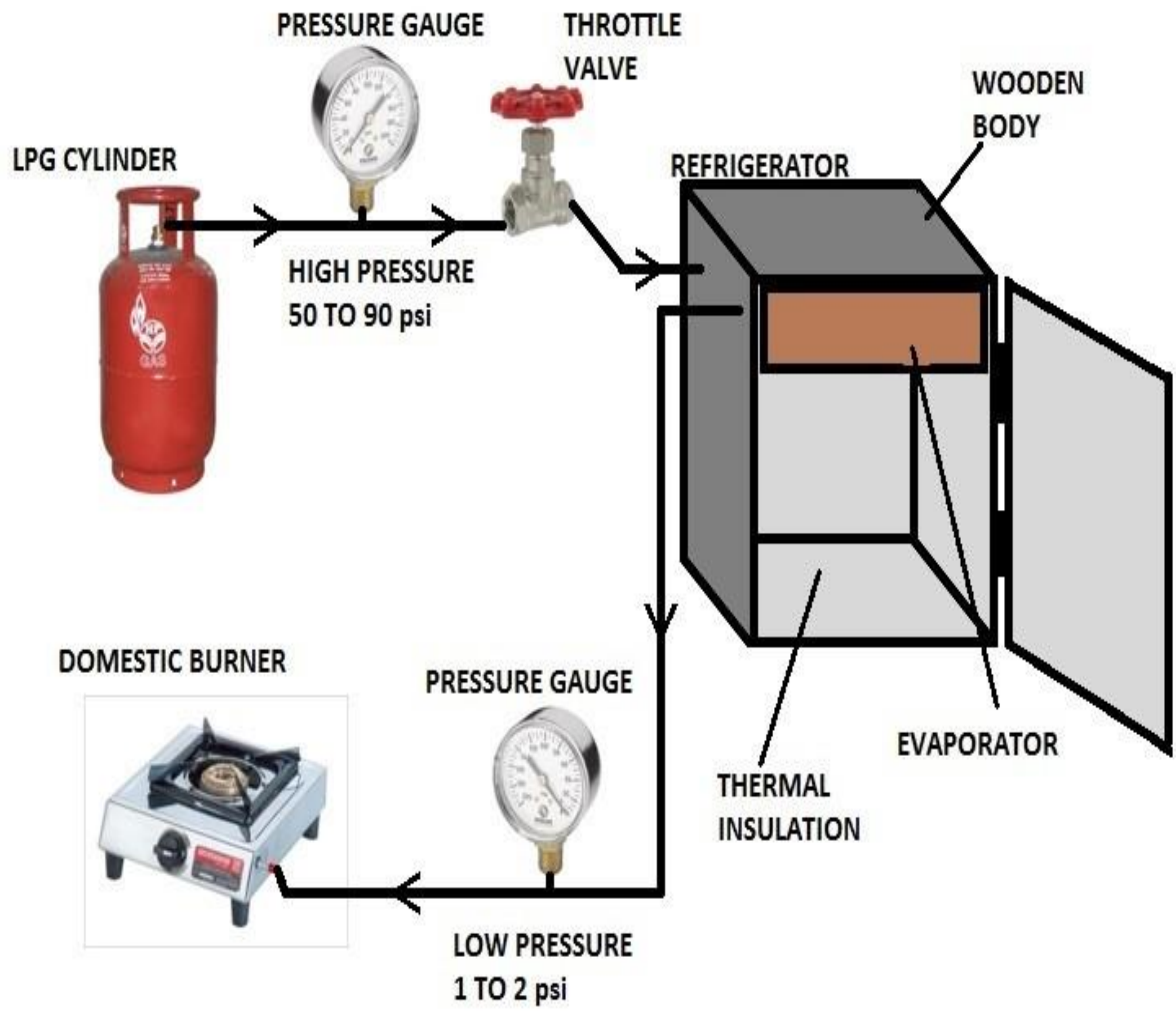

Fig4.5 b: LPG Refrigeration and Heating System

OPERATIONAL PARAMETERS:

The experiment of this project was done and the readings were taken under ten minutes intervals which are as follows:

Sl. No.	**Inlet Pressure (Bar)**	**Outlet Pressure (Bar)**	**Time (mins)**	**Evaporator Temp. (deg C)**
1	5.525	1.2	0	33.2
2	5.525	1.2	15	30.3
3	5.525	1.2	30	27.5
4	5.525	1.2	45	21.5
5	5.2	1.2	60	18.3
6	5.2	1.2	75	16.4
7	5.2	1.2	90	14.8
8	5.2	1.2	105	12.2
9	5.2	1.2	120	9.4

Tab 4.5: Experimental Readings

4.6 RESULT:

The properties of LPG at 5.525 bar

Enthalpy, h = 430.3 kJ/kg

The properties of LPG at 1.2 bar

hf = 107.3 kJ/kg

Initial Temp Tsat = -33.2ºC

Heat extracted from evaporation in 1.5 hours,

Qeva = heat absorbed by LPG (Qlpg)

(Qeva) = heat absorbed from (surrounding air inside of evaporater + leakage)

X lpg = Dryness fraction of LPG from graph = 0.5

Q eva = Q air + Q L = ma Cpa (ΔT) + Q L

Since there is very less amount of air so it is neglected.

Heat observed by LPG,

(Q lpg) = Latent heat absorbed (Q L) LPG + Sensible heat gain (Q sen) LPG

We have volume of rate of LPG 0.1 lit/min &

Sp. volume of LPG at 1.22 bar is $1.763*10^{-3}$ m^3 / kg

Mass flow rate of LPG = $0.0001/1.763*10^{-3}$ = 0.567 kg/min

m = $9.448*10^{-4}$ kg/ sec

(Q LPG) =$m_{lpg} * (X_{lpg}) * hfg + m_{lpg} * Cp_{lpg} * (T sup – T sat)$

$= 9.448*10^{-4}*0.5*375*103*5400+9.448*10^{-4}*1.67*42.6$

= 0.985308 MJ/hr

h2 = hf+ X hfg

= 107.3+0.5*375= 294.8 kJ/kg

hg = hf+ hg

= 107.3+375=482.3 KJ/kg

h3 = hg +Cp ΔT

= 482.3 + 1.67* 50.3 kJ/ kg

= 566.301 kJ/kg

So that refrigerating effect is

Re = h3- h2

= 566.301- 294.8

= 271.501 kJ/kg

For calculating COP, we require the work i/p, for work input we have 14.5 kg LPG cylinder.

Hence, input work is the amount of power required for filling one cylinder.

From PCRA energy audit report, power required to refill 1 cylinder is 3.1354 kwh.

Therefore, for filling 1 kg of LPG power required

= 3.1354 /14.5 = 0.2162 kwh

We run the setup for 1.5 hr, for that power is

= 0.2162*1000/(9.85*5400)/10000 = 42.36 watts

COP OF REFRIGERATION SYSTEM:

COP = R.E/Work Input

= 271.501/42.36 = 6.40

After finding out the cop of LPG refrigerator we find out the heat liberated by LPG after burning in the burner with efficiency of 92%.

Heat liberated by LPG to atmosphere Q l = m*Cv

The volume flow rate of LPG is 0.1 lit/ min & sp. volume of

LPG at 1.225 bar pressure is 1.763* 10^{-3} m^3 /kg

Mass flow rate of LPG= 0.0567 kg/ min

$m = 9.448 * 10^{-4}$ kg/sec

C_v = 46.1 mJ/kg

Q L = $9.448 * 10^{-4} * 46.1 * 103$

= 43. 56 W

Hence we got the Refrigeration effect as well as the heat from the LPG system. Here the COP of the LPG refrigeration system is high when compared with the domestic refrigerator.

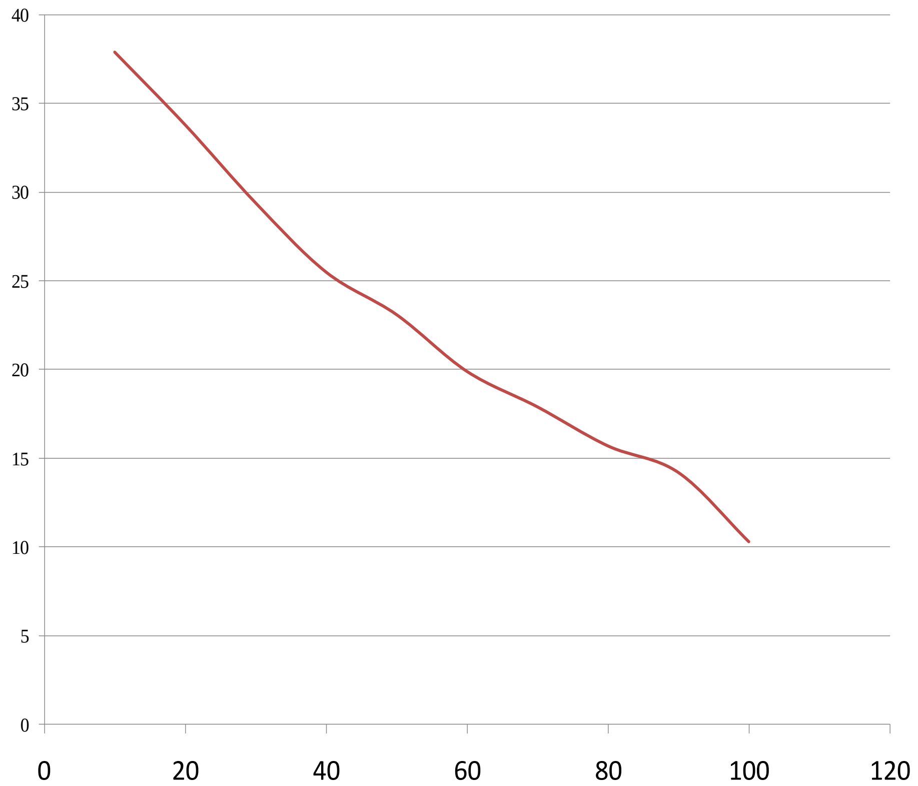

Fig 4.6: Evaporator temp. vs Time

COMPARE WITH DOMESTIC REFRIGERATOR:

Cop of a domestic refrigerator is normally up to 2.7 which is lesser than the LPG refrigerator. Domestic refrigerator required high input power than LPG refrigerator. Also there are more moving parts in domestic refrigerator and not eco-friendly. Domestic refrigerator requires more maintenance and operation is noisy.

ADVANTAGES:

- The cooling capacity of LPG is 10% higher than R-12 and the vapour pressure is approximate.
- LPG is naturally occurring and non-toxic.
- Use of LPG as a refrigerant also improves the overall efficiency by 10 to 20%.
- The ozone depletion potential (ODP) of LPG is 0 and Global Warming Potential (GWP) is 8 which is significantly negligible as compared to other refrigerant.
- Apart from environment friendly, use of also LPG gives us lot of cost advantages.
- LPG does not form acids and thereby eliminates the problem with blocked capillaries.
- There is 60% reduction in weight of the system due to higher density of LPG.
- The fridge works when there is no electricity.
- It is efficient to save fuel.
- No pollution.
- The units are effectively silent in operation.
- Running cost is zero.
- Eliminates the compressor and condenser.

DISADVANTAGES:

- LPG is explosive in nature.
- After the refrigeration processes, the exhaust of LPG is burn into burner. Because of the exhausted vapour LPG cannot converted again into liquid phase, because this process is very costly.
- The preservation of leakages of the LPG is the major problem in LPG refrigeration system. Because of the LPG is highly flammable.

CHAPTER – 5

PROJECT TESTING

5.0 OVERVIEW OF TESTING METHODS

LPG - Propane Quality Assurance – LPG Standards & Testing:

A lot of effort goes into making sure that the LPG you receive is of the highest propane quality, and it shows. Propane quality problems with LPG are very rare.

Why is LPG Tested?

LPG is tested to assure composition, energy content, performance, octane rating, dryness and safety. The testing also serves to limit toxicity and emissions in use.

WHAT LPG PROPERTIES ARE QUALITY TESTED ?

1. LPG Vapour Pressure
2. Wobbe Index
3. Motor Octane Number
4. LPG Odour
5. Corrosion - Copper Strip Test
6. Dienes Limit Test
7. LPG Dryness
8. Free Water Test
9. Fluorine Test
10. Hydrogen Sulfide Test
11. Residue on Evaporation at 105°C
12. Sulphur (Sulfur) Test
13. Volatile Residue Test

Each property has specified test method and pass-fail parameters.

Each one is fully explained below.

The LPG Quality Standards - Propane Quality:

Propane quality is very important for proper results. There are two sets of propane quality standards for LPG in Australia. We will just look at the propane quality specification, as butane use is extremely rare in Australia. One set of propane quality standards is for LPG used in homes and businesses for various heating applications. The industry Standards for this are the Gas Energy Australia LPG for Heating Use Specification 2013 and Australian Standard AS4670-2006 "Commercial propane and commercial butane for heating". The second propane quality Standard is the Fuel Standard (Autogas) Determination 2003.This regulates the quality of LPG supplied in Australia for automotive use. The two propane quality Standards are very similar but we'll focus on the 2013 heating use specification, as it contains everything included in the autogas specification and more. The following explains the thirteen LPG properties tested, why they are tested, test methods and pass-fail parameters…

LPG Vapour Pressure:

When LPG is stored in a gas bottle, it is under pressure. The term "pressure" refers to the average force per unit of area that the gas exerts on the inside walls of the gas bottle. LPG vapour pressure is measured in kilopascals (kPa). LPG pressure can vary greatly based on temperature, so a specific temperature is specified for the test.

Wobbe Index for LPG:

The Wobbe Index is used to compare the energy output of fuel gases in heating applications. It is often used as an indicator of the interchangeability of fuel gases, including LPG and natural gas. Wobbe Index is measured in megajoules per cubic metre of gas – MJ/m3. The standard sets both a minimum and maximum value for the test at 84.0MJ/m3 minimum and 88.0MJ/m3 maximum.

LPG Motor Octane Number:

High compression engines require high compressibility of the fuel without pre-ignition. Octane ratings are indicative of this compressibility. Motor Octane Number (MON) is one of a number of octane standards in use. MON is a standard measure for the performance of motor fuel in resisting pre-ignition and knocking. The composition of the LPG affects the MON results, as olefins have lower octane numbers. So, this test is one way of regulating the composition of the LPG, by using performance criteria. Whilst the autogas specification sets a minimum MON of 90.5, the heating specification has no minimum, as it has no relevance for heating.

LPG Odour:

In its natural state, LPG is an odourless and colourless gas. The distinctive smell that people associate with LPG is actually added to it as a safety measure. Without the addition of an odourant, leaking gas could collect without being detected. The specification is based on a person with a normal sense of smell being able to detect the distinct smell of the odourant at a specific percentage of LPG in air, simulating a leak. The percentage is based on the lower flammable limit (LFL), which is the lowest concentration of a gas, in air, capable of producing a flash of fire in presence of an ignition source. The LPG specification is to be able to detect the LPG vapour at 20% LEL in air, using test method EN 589 Annex A - Automotive Fuels LPG Requirements and Test Methods. Test Method for Odour of LPG. To achieve this a suitable odourant, Ethyl Mercaptan, is added to the LPG at 25 ppm. Maintaining a guideline value of 6 ppm, measured in vapour downstream from odourant injection, is considered to be a suitable. LPG terminal systems often include a fail-safe mechanism that stops the LPG pump if the odourant injection malfunctions. This level should markedly exceed the requirement to detect LPG vapour at 20% LEL in air.

Corrosion, Copper Strip Test for LPG:

LPG piping and fittings are often made of copper or a copper alloy – brass. In fact, brass (a copper-zinc alloy) is the preferred metal for LPG fittings, as it is non-sparking. For this reason, it is important that the LPG be non-corrosive with regard to copper and brass. The composition of the LPG affects the corrosion results and especially the presence of sulphur compounds. So, as with MON, this test is one way of regulating the composition of the LPG. The copper strips and colour comparison chart used in the testing are shown. The test result must be Class 1 under test method ISO 6251 - Liquefied petroleum gases - Corrosiveness to copper - Copper strip method.

Dienes Limit Test for LPG:

Dienes, including butadiene, are hydrocarbon gases containing two carbon double bonds. Excessive diene content can increase the likelihood of residue problems in regulators and vaporisers. Dienes can also reduce the octane rating of autogas. The composition analysis is done using a gas chromatograph. Dienes are limited to a maximum of 0.3 mol percent, as tested under the ISO 7941 test method - Commercial propane and butane - Analysis by gas chromatography.

LPG Dryness:

The dryness test is only applicable to propane and not butane. Dryness is important in relation to freezing in pressure reducing regulators. Propane must pass the dryness test, which is the valve freeze method applied for 60 seconds duration which is ISO 13758 - Liquefied petroleum gases- Assessment of the dryness of propane - Valve freeze method. This is equivalent to less than 160 ppmv (parts per million of volume) of water at 0°C.

Free Water Test:

The Free Water Test only applies to butane. As with the dryness test, this relates to freezing in regulators. Water promotes rust on internal surfaces of steel storage tanks and iron piping systems. Rust caused by free water can also cause odourant fade and can block small openings. In cold weather or in pressure This can impair the functionality or damage valves, pumps, piping, and regulators. LPG cannot contain any free water at 0°C.

Fluorine Test:

This test is only require if any component of the LPG has been sourced from a HF Alkylation Unit within a refinery. Fluorine compounds, and particularly hydrofluoric acid (HF) and its combustion products, may be extremely destructive in any environment. As a result, fluorine content is limited to a maximum of 10mg/kg. No specific test method is specified.

Who Does the Testing?

Some facilities use their own lab, some use independent labs and some a combination of the two. All are normally NATA accredited – National Association of Testing Authorities, Australia.

Final Thoughts:

LPG quality is closely monitored and controlled to make sure it meets quality standards. The result is that the LPG customers receive meets all specifications and will perform as expected.

5.1 COOLING RATE:

In the process of refrigeration, adiabatic expansion of LPG takes place 100 psi to 10 psi. And due to this thermodynamically it absorbs heat from surrounding and cooling effect can be achieved.

TO FIND TEMPERATURE INTERVAL:

What are temperature intervals?

Temperature interval is the difference between two temperatures. It is measured in degrees Celsius (°C), kelvins, degrees Fahrenheit (°F), degree Reaumur (°Re) or degree Rankine (°R or °Ra).

How do you find the temperature interval?

This means that if the temperature is raised from 0 °C to 5 °C, on the Fahrenheit scale, it will raise from 32 °F to 32 + 9 = 41 °F. Similarly, the interval of 100 °C is equivalent to an interval of 180 °F, so the temperature from 0 °C to 100 °C will rise in Fahrenheit scale from 32 °F to 32 + 180 = 212 °F.

In this experiment, the temperature goes on decreasing as the pressure in the gas pipe passes through the capillary tube decreases the pressure and cools the evaporator in isenthalpic process where enthalpy is constant.

5.2 VELOCITY OF GAS FLOW:

The velocity in the gas lines should be less than 60 to 80 ft/sec to minimise noise and allow for corrosion inhibition. A lower velocity of 50 ft/sec should be used in the presence of known corrosives such as CO2. The minimum gas velocity should be between 10 and 15 ft/sec, which minimizes liquid fall out.

EXPANSION OF LPG:

LPG expansion is 270 times the volume of gas to the volume of liquid. In other words, LPG expansion is to 270 times the volume when it goes from liquid to gas. So, 1L of liquid LPG (propane) expands to equal 270L of gaseous LPG expansion.

LPG – Propane Boiling Point: -42deg C or -44 deg F.

5.3 PRESSURE REGULATION

TEST A PRESSURE GAUGE:

- Isolate the pressure gauge from the process using valves, or by removing the gauge from the process.

- Connect the gauge to the calibrator or reference gauge. For hydraulic pressure gauges it’s important to remove any gas that might be trapped in the fluid in the gauge, calibrator, and connections by priming the system. When generating pressure allow a few moments for stability. Compare the reading of the gauge under test with the master gauge or calibrator.
- For hydraulic pressure gauges it’s important prime the system. This will remove any gas that might be trapped in the fluid in the gauge, calibrator or connections.
- When generating pressure allow a few moments for the measurement to stabilize. When using a hydraulic hand pump as a source it can take several minutes for the pressure to stabilize due to the thermodynamic effect of fluids.
- Compare the reading of the gauge under test with the master gauge or calibrator.

5.4 TESTING FOR LEAKS AND DEFORMITIES:

How do you make soapy water for leak detection?

Combine 1 cup water with 1 cup liquid dish soap in a spray bottle and swirl gently to mix.Set the spray bottle to a direct stream spray.Spray the item you are checking for leaks thoroughly with the homemade leak detector solution. The air or gas leaking out will cause bubbles out will cause bubbles to form at the leak site.

Difference between leak test and pressure test:

Leak testing is usually conducted at pressure levels at or below the system operating pressure. A leak test as prescribed by design codes is performed at a factor times the design pressure of the piping system. The pressure test is usually performed at 1.1 to 1.5 times the design **pressure** of the system.

Why leak test is done?

A leak test is performed to identify weak spots as well as to improve product design. The test is performed by using high pressure to check if there is a pressure drop caused by an unintended crack or hole.

BRAZING PORTINS ARE TESTED

What is the proper clearance for brazing?

So when you're brazing, maintain a clearance between the base metals to allow capillary action to work most effectively. In almost all cases, this means a close clearance. Optimal clearance or joint gap for most filler metals is 0.0015 inch, but typical clearances range from 0.001 to 0.005 in.

Why it is important to inspect a brazed joint?

Once the parts are finally brazed, Brazing-inspection is called to verify that all joints are correctly made to meet all requirements. The search is for discontinuities in the joint, meaning lack of metallurgically bonded filler metal or presence of cracks or voids, caused by entrapment of flux or gas.

What temperature you need for brazing?

Brazing, when performed correctly, is a joining process that produces a permanent bond between two or more materials by heating them to a temperature above 450°C (840°F), but lower than the melting-temperature of any of the materials being joined.

CHAPTER - 6

CONCLUSION AND FUTURE ENHANCEMENT

Conclusion:

1. The aim of LPG refrigerator was to use LPG as a refrigerant and utilizing the energy of the high pressure LPG cylinder for producing the refrigeration effect. We also conclude that, we are trying to burn the exhaust LPG, the pressure of exhaust gas is less then 10psi, so that the flame produce by the burner is spreading outside.
2. This system is cheaper at initial and running cost is almost zero. It does not require an external energy sources to run the system and no moving parts in the system. So maintenance cost is also very low.
3. This system is most suitable for hotels, industries, refinery, chemical industries where consumption of LPG is very high.
4. Propane is an attractive and environmentally friendly alternative to CFCs used currently.
5. Mass flow rate increases with increase in capillary inner diameter and coil diameter where as mass flow rate decreases with increase in length. It was observed that the COP of system increases with similar change in geometry of capillary tube.
6. High COP values were obtained. No operation problems have been encountered compressor. The use of LPG as a replacement refrigerant can contribute to the solution of Ozone Depletion Potential problem and global warming potential.

Future Enhancement:

LPG (Liquified Petroleum Gas) is supplied in pressuried cylinders to keep it liquified. The LPG cylinders, from past many years, are being manufactured in our country from the very conventional metallic materials such as steel. The weight of the cylinder becomes more as density of steel is higher compared to other light weight materials. In household applications, thrust weight will come down. With the advancement of low density materials like GFRP (Glass Fibre Reinforced Polymer) composites, we can think of producing LPG cylinders with GFRP to reduce its weight in future, to increase safety, for measuring the amount of liquid consumptions etc.

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A Major Project Report
On

FATIGUE ANALYSIS AND DESIGN OPTIMIZATION OF EXCAVATOR BUCKET

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Fatigue Analysis and Design Optimization of Excavator Bucket**, is being submitted by **B.Naveen Kumar (17K81A0365), M.Sri Sai Teja (17K81A0389), M.Sai Vineeth (17K81A0392), M.Vinod kumar (17K81A0393)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Mr. P NEIL MOSES
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Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor& Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Fatigue Analysis and Design Optimization of Excavator Bucket** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

As we see there's climb within the earth moving machine industries because the construction work is rapidly growing is understood through the high performance of construction machines. An excavator may be a typical hydraulic heavy-duty human operated machine utilized in general versatile construction operations, like digging, ground levelling, carrying loads, dumping loads. Normally backhoe excavators are working under worst working conditions. Due to severe working conditions, excavator parts are subjected to high loads and must work reliably in the unpredictable working conditions. Thus, it's necessary for the engineers to provide an equipment of maximum reliability.

In this project we focused on reducing the weight of one such excavator bucket keeping in mind the stresses developed in the bucket during operation. A 3d model of an excavator bucket is modelled and structural analysis is performed to determine its initial parameters. Then the weight of same model is reduced using topology optimization and then reanalyzed to make sure the stresses in the bucket are not increased. Then both the models are compared and the best one is defined.

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CHAPTER-1 INTRODUCTION

Excavators are arguably the most recognized piece of Plant on this Planet. Used across an array of earthmoving activities and sectors, the Excavator is integral to the Plant Machinery Industry. This week, we‘re delving into the history of Excavators and looking at how they‘re evolved over the years.

1.1 THE FIRST HYDRAULIC EXCAVATORS:

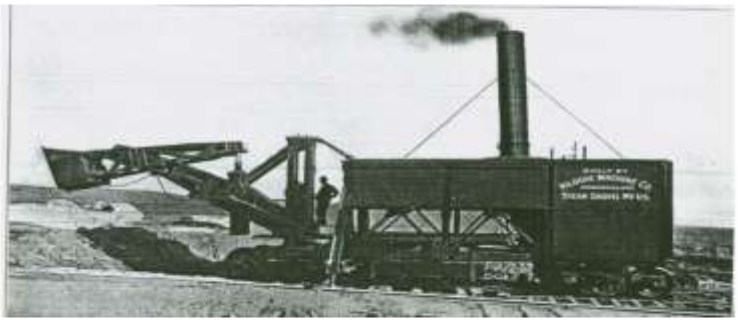


Fig-1 First hydraulic excavator

The excavators we know and love to dig with today have grown out of 140 years of development. The late 1800s saw the realization that hydraulic force can aid digging applications. From there, what might be considered a descendant of modern excavators was developed.

Before the 1880s, excavators were cabled. While cabled excavators were still in operation, hydraulic excavators are more widely popular for a broader range of applications. It‘s widely acknowledged that W.G. Armstrong & Co.‘s was one of the first companies to produce a hydraulic excavator used in a practical application.

In 1897, Kilgore Machine Company introduced the first _all hydraulic‘ excavator. This machine was operated using direct-action four steam cylinders and no cables. Kilgore‘s excavator was hardy, therefore hardy in operation. Furthermore, the end of each cylinder‘s stroke was cushioned; consequently there was no shock damage while in operation.

These machines were only the beginning of the excavator‘s history.

INTRODUCING THE MINI EXCAVATOR

Fast forward 60 years to the 1960s in Japan. The country is facing an economic boom and growing urbanization. As a result, the civil engineering sector was under pressure to create new houses in built up areas. The issue they face is that excavators would relieve the pressure faced by demands for shorter construction times, but the machinery won‘t fit on most of the construction sites. Consequently, laborers are forced to use pickaxes and shovels.

The YNB 300 was Yanmar Construction Company‘s answer to this issue. The wheeled self-propelled mini excavator is not only able to fit onto the tight construction sites, but is the world‘s first mini excavator. Following the success of the YNB300, Yanmar released the YNB600C. The YNB600C improved operator performance and included a swing boom. As a result, this incarnation of the mini excavator could dig against walls.

Yanmar celebrated the 50th Anniversary of the release of the YNB300C in 2018.Other companies worldwide felt the pressure. By the mid 1980s, multiple companies including JCB, Kubota, Beresford, and Manitou, had released their own mini diggers. Meanwhile, technology and machinery solutions continued to develop and improve.

1.2 TYPES OF EXCAVATORS

BASED ON WORKING MECHANISM:

- **HYDRAULIC EXCAVATORS**

Most of the heavy-duty equipment uses hydraulics for its working because of its ability to carry heavy loads and the power of the control mechanism. The major components of the excavator are a bucket, arm, rotating cab, and movable tracks; and its operations are controlled by hydraulics. The primary function of excavator in the construction industry is digging ditches, trenches, foundations, and holes and for quarrying and mining river beds in the mining industry. Also, with excavators, it is possible to safely lift and move soil or other heavy materials from one place to another. In this article, we can discuss all the important topics related to the excavator and its operation.

Important Hydraulic Excavator Types :

Fig-2 Crawler excavators

12.1 Crawler Excavators: Crawler excavators are used for mining purposes, trench digging, and landscape grading and they appear a little bit different from excavators that run on wheels. This excavator looks similar to tracked tanks that are used in the army and they run on large two endless tracks. The chain wheel system of this compact excavator provides greater balance, flexibility, and stability, but it reduces speed.

Fig-3 Dragline Excavator

1.2.2 Dragline Excavators: The dragline excavator used for underwater options, road excavation, and pile driving has a key feature of unique hoist rope and dragline system. Unlike the normal excavators, this excavator uses a hoist rope system where the bucket is attached via a hoist coupler. For raising and lowering the bucket hoist rope is used and to pull the bucket toward the driver it uses the dragline. Mostly, these excavators are assembled on-site because of their larger size and weight.

Fig-4 Suction excavators

1.2.3Suction Excavators: The suction excavator also known as a vacuum excavator is used for underground applications, delicate digging projects, and debris cleanup from holes or land. This wheeled vehicle with high-pressure vacuum and water jets has sharp teeth at the edge that creates a vacuum and takes away soil or other debris. The construction of a suction excavator is similar to that of a vacuum truck except for the width of the suction hose.

1.2.4 Skid Steer Excavators: The four-wheel skid steer excavator is a compact, rigid-frame, engine-powered machine that can be used in residential projects, and for removing spread out or piled up debris. The bucket is oriented away from the driver and this type of excavator is suitable for space-limited sites requiring maneuvering tricky turns.

Fig-5 Skid steer excavator

1.2.5 Long Reach Excavators: The long reach excavator has a 40-100 feet extendable arm that simplifies the industrial demolition and heavy-duty digging projects.

Fig-6 Long reach excavators.

1.3 HYDRAULIC EXCAVATOR IMPORTANT COMPONENTS

1.3.1 Undercarriage: Undercarriage is an essential part of heavy-equipment that contains other components necessary for the movement of the excavator. The undercarriage components that assist in excavator movement are sprocket, final drive unit, track shoe, track link, track frame, track roller, front idler. Among this, the final drive unit has key functions like transmitting power from the engine and increasing the torque.

Fig-7 Under carriage

1.3.2 Cab: The cab is the location from where the operator controls the movement of excavator and it needs to offer excellent visibility to the operator. Controls, gauges, and monitor panel

Fig-8 Cab

are located inside the cab. The operator cab can rotate 360° and makes it possible to dig, move, and dump things easily.

1.3.3 Hoe: The Hoe is constructed with three important parts like boom, dipper arm, and bucket. Boom is a hydraulically actuated arm and its hydraulic boom cylinder will enable the operator to move the dipper arm with respect to the instruction passed from the cab. The dipper arm transfers the power from boom to the bucket lowering and aligning the bucket.

The bucket is an important part of Hoe that allows digging.

Fig-9 Hoe

1.3.4 Counter Weight: Solid iron or other materials are used as counterweight in excavators to counterbalance the weight of excavated earth. There are high chances for the heavy equipment to tip over during its operation if a proper counterweight is not included. The excavators are designed in such a way that, the counterweight can be removed in some situations to ease transportation

Fig-10 Counter weight

1.3.5 Controls: Operators can control excavator operations from the cab using travel pedals, levers, and joysticks. Simple operations on these controls will help to move the dipper arm & boom and load & unload the bucket. The travel pedals and levers in the excavator will control the speed, direction, and rotation. Whereas, the two joysticks located on the left and right side of the operator will control the movements.

Fig-11 Controls

1.3.6 Attachments: Augers, compactors, hammers, rippers, grapples, etc… are some type of attachments used in excavators. The attachment augers can make the excavator function as a hole-digger. Similarly, compactors are used for hard-pounding base fill, hammers for breaking rocks, rippers for pavement work, and grapples for lifting logs, bales, or lumber.

Fig-12 Attachments

An excavator‘s design allows the construction equipment to be used for many versatile purposes. Hydraulic cylinders, booms, arms, and attachments provide digging and holding functionalities, while a house-like cab provides the driver with controls to direct the excavator. A rotating platform and wheels provide the necessary mobility to lift and remove rise from the work site.

Excavators use a variety of hydraulic attachments that serve different purposes. In addition to a bucket, other common attachments include an auger, breaker, grapple, auger, lamp, and quick coupler.

Fig-13 Types of Buckets

1.3.7 BUCKETS

Buckets are the most common attachments seen on excavators. These steel attachments have teeth-like edges that can provide digging and scooping capabilities. Buckets come in different varieties. The most common are ditching buckets — which is designed for grading stones — and trenching buckets, which are used to dig trenches.

1.3.8 AUGER

Attaching an auger allows you to bore into the ground. Powered by hydraulic circuits these helical attachment have the ability to reach over objects and drill deep holes. Augers come in different specifications and sizes for various digging conditions and terrains — they range from 4 inches to 50 inches in length and can dig up to 32 feet.

1.3.9 BREAKER

Breakers are similar to jackhammers but are much larger in size. With the ability to provide up to 1000 pounds of impact energy, these attachments are used to break into tougher surfaces like stone and concrete.

1.3.10 CLAMP

Clamps allow excavator operators to pick up large materials such as tree stumps and concrete that are too oversized for a bucket. The attachments can be used with buckets or as pieces in a grapple. Clamps are easy to attach and detach from excavators.

1.3.11 COUPLER

Couplers allow you to quickly switch between tools and attachments without a crew. This is handy when you are moving between different tasks and processes on a job site.

1.4 HYDRAULIC EXCAVATOR OPERATION

The design of the hydraulic excavator is similar to that of a human arm where it can safely perform different operations in the construction and mining industry. It is the three hydraulic cylinders that are controlled using the joysticks located inside the operator cabin, makes it possible to move the excavator hoe as per the operator instruction. The diesel power engine is an important component that produces the energy required for the excavator to rise, lower, or moves the hoe for digging or other operations.

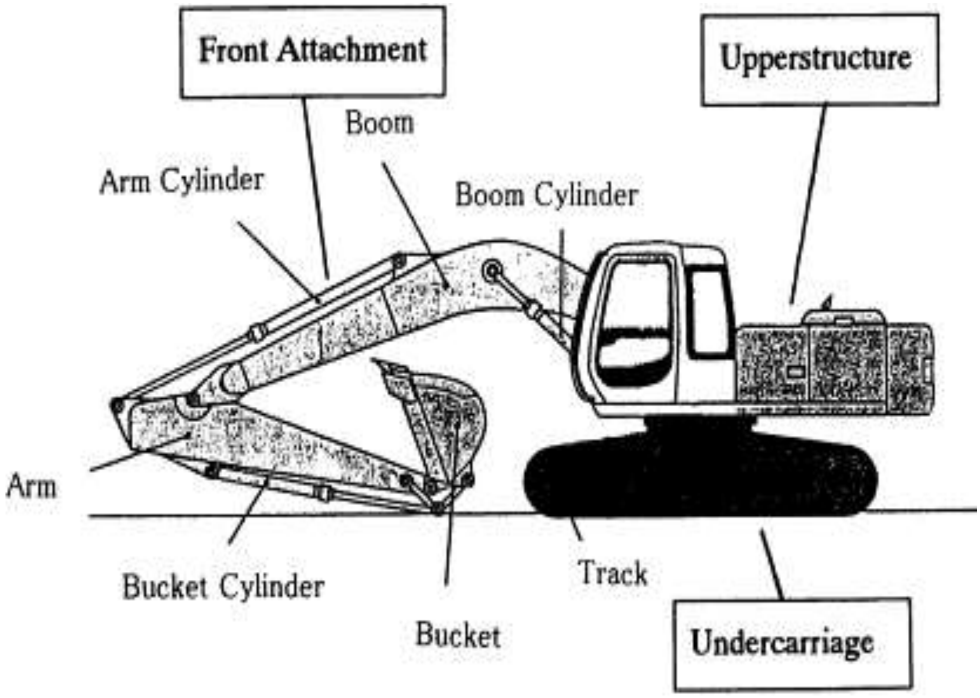


Fig-14 Hydraulic excavator operation

The hoe that consists of a boom, dipper arm and bucket is attached to the lower part of excavator chassis. The arm of the excavator has two main sections that are connected with a hinge. A hydraulic cylinder is placed at the bottom of the first section and another cylinder above the second section. When the operator works on the joystick to raise the arm, the fluid will be pumped from the reservoir into the first cylinder located below the first section of the arm. This will extend the piston rod and will raise the arm. Similarly, the second piston also extends or retracts to raise or lower the second part. The third cylinder is used to control the forward and backward movement of the bucket.

1.5 BASED ON CARRIERS

Based on the carriers they are mounted upon ,excavators can be of 4 types:

1.5.1 CRAWLER MOUNTED EXCAVATOR

Fig-15 Crawler mounted excavator

As the name suggests, crawlers provide mobility to the crawler-mounted excavators. The crawler-mounted excavators are known for carrying out heavy works in terrain regions. Although the crawler mounted excavators have a low speed, they can work effectively on wet/soft soils, sharp rocks, or any adverse conditions. Moreover, crawler-mounted excavators have a very small turning radius. It is preferable to shift the crawler-mounted excavators from one site to the other on trailers only.

1.5.2 TRUCK MOUNTED EXCAVATOR

Fig-16 Truck mounted excavator

This excavator is mounted on a truck chassis. A truck-mounted excavator can move with ease at high speed on the road. It has two separate engines and cabs for the excavator and

truck chassis. This excavator requires more operating space and firm ground to function optimally.

1.5.3 SELF PROPELLED EXCAVATOR

Fig-17 Self Propelled excavator

These excavators have rubber tires and can move without external propulsion at a speed of 10 to 30 km per hour. The self-propelled excavator has one engine and a cab.

1.5.4 BARGE/RAIL MOUNTED

Fig-18 Barge rail mounted

The excavators mounted or a barge or a rail is used for excavation works near the railway lines or in water.

EXCAVATOR BUCKET

Buckets are the most common attachments seen on excavators. These steel attachments have teeth-like edges that can provide digging and scooping capabilities. Buckets come in different varieties. The most common are ditching buckets — which are designed for grading stones — and trenching buckets, which are used to dig trenche.

1.6 TYPES OF EXCAVATOR BUCKETS:

1.6.1 DIGGING EXCAVATOR BUCKET

When one thinks of an excavator, the large, claw-looking attachment comes to mind. This attachment is colloquially known as the digging bucket. It, as its name suggests, is primarily used for digging through hard, rugged surfaces. These can range from hard soil, to even rocks in some cases.

Fig-19 Digging excavator bucket

The digging bucket is also considered to be all-purpose, meaning it can be used in numerous circumstances. These buckets also come in different sizes, in order to meet the demands of the surface in question. A knowledgeable operator will be able to dig efficiently, just as long as safety is kept in mind.

1.6.2 ROCK EXCAVATOR BUCKET

Should a digging bucket not be applicable to more hardened surfaces, a rock excavator bucket type will be required. This specific type of bucket packs a more powerful punch than its counterpart. Many rugged environments will often contain rocks that cannot be penetrated easily. A rock bucket takes care of that issue outright.

Fig-20 Rock excavator bucket

For example, the edges of the bucket are reinforced with added material, and have sharper teeth. This allows it to be pushed into rock with more force, which makes excavator jobs all the more easier.

1.6.3 CLEANUP EXCAVATOR BUCKETS

After a long, hard day of excavating, there will be numerous amounts of debris lying around. To make their job simpler, excavator operators will attach a clean-up bucket to their vehicle. Clean-up buckets don‘t have any protruding teeth, nor are they made with size in mind.

Fig-21 Cleanup excavator

They are relatively smaller, while maintaining the shape of an ordinary bucket. This comes down to its primary function; it is made for cleaning up areas that were worked on. One of the most important purposes of the bucket is that it also keeps maintenance costs low. Clean-up crews will seldom be used, so that their efforts can be moved elsewhere.

1.6.4 SKELETON BUCKETS

Not all excavating jobs were created equally. In some circumstances, a more delicate process must be employed. This is where the use of a skeleton bucket must be used, and attached to the vehicle. A skeleton bucket variation is a modified bucket, which allows for finer materials in digging to be separated.

Fig-22 Skelton bucket

Since the teeth in the bucket are separated by gaps, larger chunks of substances can fall through. When certain materials have to be excavated from a requisite surface, a skeleton bucket may be employed. This allows the specific job to move ahead, without wasting time on removing unnecessary elements from a surface.

1.6.5 V BUCKETS

For areas that require trenches to be dug, a V bucket will usually be employed. Due to its V-shaped design, an excavator will easily be able to dig an appropriately-sized trench or channel. They can also be used to make space for utility cables, so that they don‘t pose a safety hazard to the ground team.

Fig-23 V bucket

1.6.6 AUGER BUCKETS

In terms of multipurpose functionality, an auger bucket is truly one-of-a-kind. This type of excavator bucket is extremely versatile, allowing multiple digging jobs to be done altogether. When time is of the essence, many excavator operators will use an auger. Various tasks such as digging, scraping and clearing can be completed in record time, as a result.

Fig-24 Auger bucket

Since no two excavator jobs are alike, different buckets will be used in different scenarios. That is why a knowledgeable operator must be behind the wheel at all times. The right operator will know which bucket type to use, as well as its respective size. That way, the respective project can be worked on at a much more efficient rate.

1.7 NEED OF DESIGN OPTIMIZATION OF EXCAVATOR BUCKET

The bucket of any excavator is one of the major parts on which useful load is applied. So, it becomes necessary for engineers to make sure that the proposed design of any excavator bucket is able to resist high forces by retaining its shape under fatigue loads. Previously when computerized optimization tools were not available, it was near impossible for the engineers to study each and element of the structure to decide where optimization should be performed.

It is also very clear that most of the excavator buckets aren‘t weight optimized. So it becomes necessary to reduce the weight of bucket to increase the load carrying capacity or indirectly save the reduced material cost. Some of the uses of weight optimization are discussed below:

- Reduce the overall weight of the machinery
- Reduce the material costs
- Reduce labor costs
- Increase the load carrying capacity of excavator

For above reasons, the optimization of excavator bucket is necessary to directly or indirectly reduce many costs involved.

It is also necessary to make sure that the boundary conditions applied to all the models are same and stresses developed in the new model after optimizations are not considerably high.

CHAPTER-2 LITERATURE SURVEY

In reference paper, they have used reverse engineering method to study excavator bucket. During the part of challenge a static evaluation used to be carried out the use of FEA package. These paper emphases on structural weight optimization of backhoe excavator attachment the usage of FEA strategy via trial and error method, the optimization is also performed for weight and results are compared with trial and error approach which shows equal results. The FEA of the optimized mannequin also carried out and their consequences are confirmed by using making use of classical theory. Comparison two shows two that the versions in results of character components are very much less and whole version in result is of only 3.93% which mirror that the consequences of structural weight optimization carried out with the aid of trial and error approach are correct and acceptable .The variations in outcomes of the Von Mises stresses and the classical concept are very less and we can say that the effects are equal and acceptable

The Excavator bucket tooth have to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. Its tooth got damaged due to abrasive wear and impact load. This paper deals with review of Excavators bucket tooth analysis to find out its actual failure.

Excavators are used primarily to excavate below the natural surface of the ground on which the machine rests and load it into trucks or tractor. Due to severe working conditions, excavator parts are subjected to high loads.

The hydraulic excavators are widely used in construction, mining, excavation, and forestry applications. Its diversity and convenient operability make it popular. The performance of hydraulic excavator is depending on its performance of the backhoe front attachment.

An optimized bucket design is important for increasing productivity and loading performance for underground loaders. Design theories are today difficult to evaluate due to lack of verification methods. Later years development of simulation software and computers has made it possible to verify the design by simulating the loading process. The purpose with this thesis has been to both develop and use a simulation model of the loading process for one of Atlas Copco's underground loaders.

The Hydraulic excavator machines are heavy duty earth mover consisting of a boom, arm and bucket. It works on principle of hydraulic fluid with hydraulic cylinder and hydraulic motors.

A better tool design in the excavation process has been always a challenging task for the engineers. A poorly designed tool always results in poor excavation of the ground, higher wear of the tool, wastage of the time, and power. But proper understanding of the soil mechanics in context of the soil cutting process may help in a better tool design. Moreover it requires the resistive forces offered by the ground on the bucket.

Rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with complex mechanism and automation of construction activity.

In this study, static structural analysis of backhoe loader arms has been performed with the finite element method (FEM). The aim of this study is to simulate and strengthen the back and front arms of the backhoe loader concerning with stress under maximum loading condition and different boundary conditions.

A better design in excavation process has been challenging task for the engineers. Poor design gives always poor result in excavation process. Excavation tasks range from cutting a geometrically described volume of earth for atrench or foundation footing to loading a pile of soil.

CHAPTER-3 PROJECT DESIGN

3.1 INTRODUCTION TO SOLIDWORKS

SolidWorks is a solid (CAD) and computer aided engineering (CAE) computer program that runs primarily on Microsoft windows. While it is possible to run SolidWorks on Macos It is not supported by SolidWorks. SolidWorks is published by Dassault systems.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, Fiscal year 2011–12 revenue for SolidWorks total $483 million.

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jhon Hirschtick used $1 million he had made while a member of the met blackjack team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from concord Massachusetts, SolidWorks released its first product SolidWorks 95, in November 1995. In 1997 Dassault, best known for its Catia CAD software, acquired SolidWorks for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company. SolidWorks currently markets several versions of the SolidWorks CAD software in addition to Drawings, a collaboration tool, and DraftSight, a 2D CAD product. SolidWorks was headed by John Meleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Basic from Jan 2015. Gian Paolo Basic replaces Bertrand Sicot who is promoted Vice President Sales of Dassault Systems Value Solutions sales channel.

Its user base ranges from individuals to large corporations, and covers a very wide cross-section of manufacturing market segments. Commercial sales are made through an indirect channel, which includes dealers and partners throughout the world. In the United States, the first reseller of SolidWorks, in 1995, was computer aided technology LLC, headquartered in Chicago. Directly competitive products to SolidWorks include PTC Creo element/pro, Solid edge, and Autodesk Inventor. SolidWorks also partners with third party developers to add functionality in niche market applications like finite element analysis, circuit layout, tolerance checking, etc. SolidWorks has also licensed its 3D modeling capabilities to other CAD software vendors, notably ANVIL.

SolidWorks is a solid modeler and utilizes parametric feature based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on para solid -kernel.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

Name/Version	Version Number	Version History Value	Release Date
SolidWorks 95	1	46	November 1995
SolidWorks 96	2	270	Early 1996
SolidWorks 97	3	483	Late 1996
SolidWorks 97Plus	4	629	1997
SolidWorks 98	5	817	1997
SolidWorks 98Plus	6	1008	1998
SolidWorks 99	7	1137	1998
SolidWorks 2000	8	1500	1999
SolidWorks 2001	9	1750	2000
SolidWorks 2001Plus	10	1950	2001
SolidWorks 2003	11	2200	2002
SolidWorks 2004	12	2500	2003
SolidWorks 2005	13	2800	2004
SolidWorks 2006	14	3100	2005
SolidWorks 2007	15	3400	2006
SolidWorks 2008	16	3800	July 1, 2007
SolidWorks 2009	17	4100	January 28, 2008
SolidWorks 2010	18	4400	December 9, 2009
SolidWorks 2011	19	4700	June 17, 2010
SolidWorks 2012	20	5000	September, 2011
SolidWorks 2013	21	6000	September, 2012
SolidWorks 2014	22	7000	October 7, 2013
SolidWorks 2015	23	8000	September 9, 2014
SolidWorks 2016	24	9000	October 1, 2015
SolidWorks 2017	25	10000	September 19, 2016

SolidWorks 2018	26	11000	September 26, 2017
SolidWorks 2019	27	12000	October 9, 2018
SolidWorks 2020	28	13000	September 18, 2019

Table : 1 Release history of SolidWorks

DS Solid works Corp. has sold over 3.5 million licenses of SolidWorks worldwide. This includes a large proportion of educational licenses.

The Sheffield telegraph comments that Solid works is the world's most popular CAD software. Modeling technology

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded to add or cut to remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power user). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies., which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).

3.2 Material properties:

Steel is used as material for excavator bucket. It is an alloy of iron and other elements including carbon. When carbon is primary alloying element, its content in the steel is between 0.002% to 2.1% by weight. Carbon, Manganese, Phosphorous, Sulphur, Silicon and traces of Oxygen, nitrogen and Aluminium.The material considered for excavator bucket is AISI 1040 steel**.**

SL.NO.	Properties	Value
1	Density	7850 Kg/m3
2	Youngs modulus	2e+11Pa
3	Poisson's ratio	0.3
4	Tensile Yield strength	2.5e+08Pa
5	Tensile Ultimate strength	4.6+08Pa

Table : 2 Material Properties

3.3 DESIGN IN SOLIDWORKS :

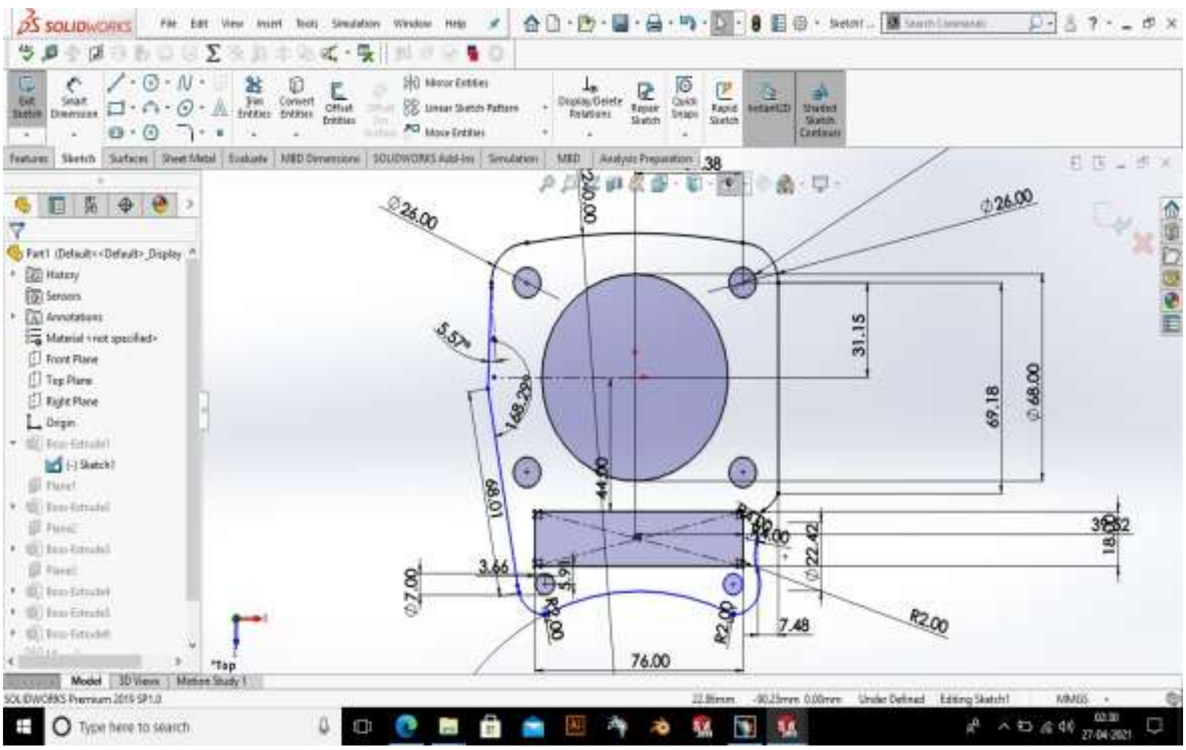


Fig 25 Dimensions of the component

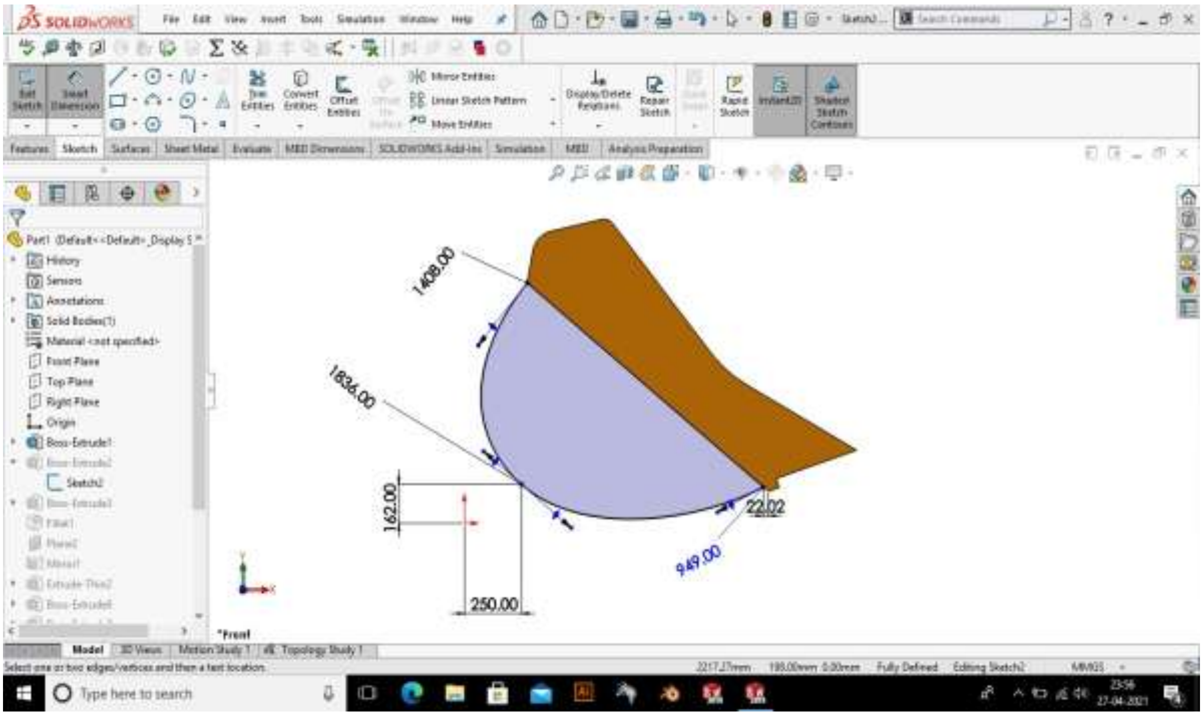


Fig 26 Design of the component

3.3.1 MESH:

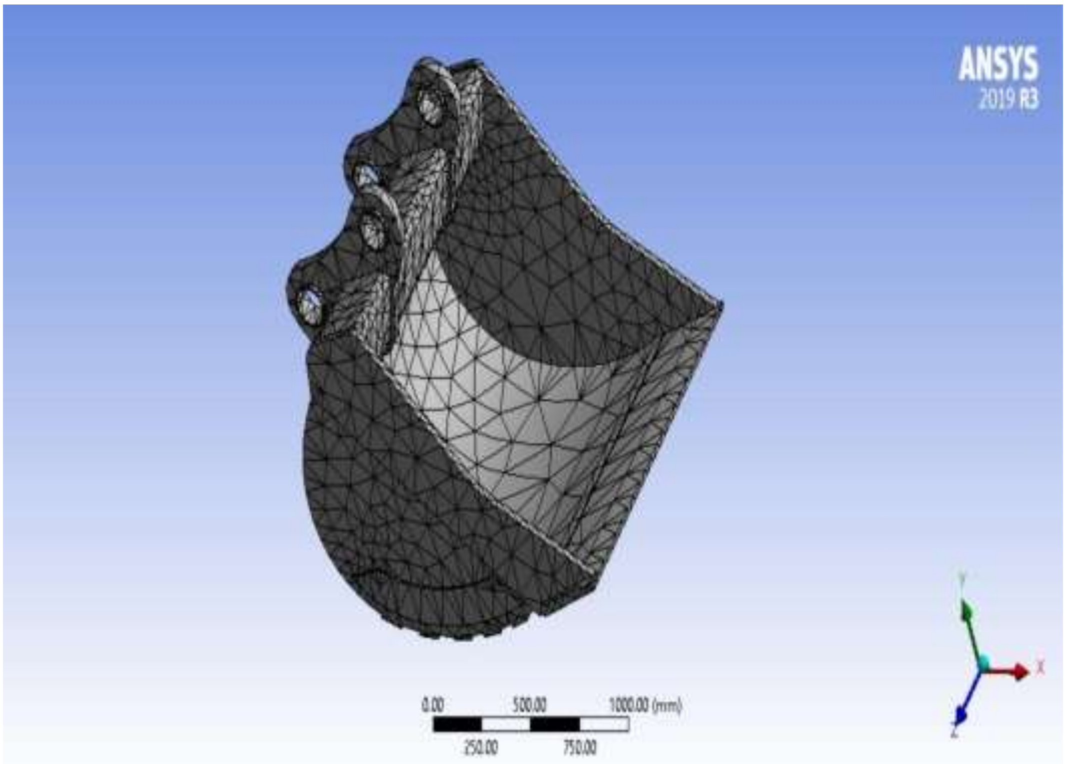


Fig 27 Component mesh

CHAPTER-4 PROJECT IMPLEMENTATION

4.1 HISTORY OF ANSYS : The association was built up in 1970 by Dr. John A Swanson Analysis frameworks, Inc. SASI. Its essential job was to make and feature limited component examination programming for auxiliary material science that could reproduce static (stationary), dynamic (moving) and warm trade (warm) issues. SASI developed its business in parallel with the improvement in PC advancement and structuring needs. The association created by 10 to 20 percent year, and in 1994 it was sold to TA Associates. The new owners took SASI's driving programming called ANSYS as their pioneer thing and doled out ANSYS, Inc as the new association name.

4.2 INTRODUCTION TO ANSYS : The ANSYS program is a PC program for a limited component investigation and plan. The ANSYS program can in like manner be used to process the perfect structure for given working conditions using the plan improvement feature.

ANSYS is business limited component examination programming with the ability to separate a broad assortment of different issues. ANSYS holds running under a collection of circumstances, including IRIX, Solaris, and Windows NT. Like any limited component programming, ANSYS unwinds speaking to differential conditions by breaking the issue into little components. The speaking to states of flexibility, fluid stream, warm trade, and electro-fascination would all have the capacity to be comprehended by the Finite component procedure in 32 ANSYS. ANSYS can handle transient issues and moreover nonlinear issues. This report will focus on the basics of ANSYS using generally fundamental delineations.

The ANSYS program is a multi-reason program, suggesting that you can use it for a limited component investigation in for all intents and purposes any industry - vehicles, flying, railways, mechanical assembly, equipment, wearing stock, control time, control transmission, and biomechanics, to indicate just a couple. "Multi-reason" in like manner suggests the manner in which that the program can be used as a piece of all controls of structure – assistant, mechanical, electrical, electromagnetic, electronic, warm, fluid, and biomedical. The ANSYS program is moreover used as an enlightening gadget in schools and other academic foundations.

ANSYS is open on all ME net Sun and SGI machines. It is available on the Linux machines by remote-login so to speak. On the right side, tattle has it that ANSYS is examining a Linux port. At the present time, ME net uses the Research/Faculty type of ANSYS 12.1. The Research/Faculty grant level gifts greater, more many-sided models than does the energy level running on the IT Labs machines. This record is proposed to be a starting stage. The material verified here is by no means whatsoever, expansive.

Frankly, we will simply start to uncover what's underneath of ANSYS's abilities. Given that, I will try to cover by far most of what I consider ANSYS and a couple of devices I have learned while using it. The record will begin with two direct cases, taking the customer through most of the methods for making a model, agreeing, including limit conditions, clarifying, and, finally, looking results. The remains of this file will over tips and snares for every one of the methods ANSYS writing computer programs is available on numerous sorts of PCs – (PCs), workstations, minicomputers, super 33 minis, concentrated PCs, very unified PCs, etc. A couple of working systems are maintained, much the same as various of reasonable contraptions.

An aggregate of six windows are opened when you begin ANSYS.

1. Utility Menu (top) – contains limits that are available for all through the ANSYS session , for instance, record controls, decisions, sensible controls and parameters. You moreover leave the ANSYS program from the rub pull down menu.

2. Main Menu (base left) – contains the fundamental ANSYS limits, dealt with by the pre-processor, game plan, general, post processor, structure analyzer.

3. Toolbar (Middle Right) – contains push gets that execute usually used ANSYS summons. More push gets can be incorporated.

4. Information window (center left) – exhibits program impel messages and empower you to sort in summons explicitly.

5. Realistic window (base right) – a window where plans are showed up and graphical picking are made

6. Yield window (not appeared) – shows content yield from the program, for instance, posting of data, etc. It is regularly arranged behind the other window and can be put to the front when key.

The methods in any limited component investigation can be secluded in three phases:

1. Pre-processing – characterize the model, for example, mesh, burdens, and limit conditions

2. Solution – amassing and illuminating the arrangement of condition. 34 3.Post preparing – removing applicable outcome from the arrangement

4.2.1 SOLUTION STEPS: i. Apply removal limitation. ii. Apply pressure load. iii .Solve

4.2.2 POST PROCESSING STEPS: i. Enter the general post processor. ii. Plot twisted shape. iii. Plot the von miss equal pressure. iv. List responses at obliged hubs. V. Exit the ANSYS program.

component sort is perceived by a name (8 characters most extraordinary, for instance, BEAM3, including a social eve

4.3 ELEMENT CHARACTERISTICS:

4.3.1 LISTS OF ELEMENT TYPES:

The ANSYS program has a considerable library of component sorts. A segment of the properties of the component sorts, and their groupings, are depicted in this part to make component sort assurance less requesting. The ANSYS component library contains in excess of 100 unmistakable component plans or sorts. A nt mark (BEAM) and an uncommon distinctive number (3). The component is browsed the library for use in the examination by contributing its name on the component sort bring .

4.3.2 TWO-DIMENSIONAL VERSUS THREE-DIMENSIONAL MODELS:

ANSYS models may be either two-dimensional or three-dimensional depending on the component sorts used. Two-dimensional models must be described in a X-Y plane. They are less requesting to set up , and run speedier than relative three-dimensional models. Rotate Symmetric models are furthermore thought to be two-dimensional.

If any three-dimensional component sort, (for instance, BEAM4) is consolidated into the component sort set, the model winds up doubtlessly three- dimensional. Some component sorts, (for instance, COMBIN14) may be a couple of dimensional, dependent upon the KEYOPT regard picked. Other component sorts, (for instance, COMBIN40) have no effect in choosing the model estimations. Two-dimensional component sorts may be used (with caution) in three- dimensional models.

4.3.3 FINITE COMPONENT TECHNIQUE: The limited component system (FEM) (its sensible application routinely known as limited component investigation (FEA) is a numerical technique for finding inferred plans of inadequate differential conditions (PDE) and furthermore of essential conditions. The course of action approach is develop either in light of getting rid of the differential condition absolutely (steady state issues), or rendering the PDE into an approximating game plan of customary differential equation , then numerically joined using standard methodology, for instance, Euler's procedure, Runge-kutta etc.

In handling partial differential conditions, the fundamental test is to make a condition that approximates the condition to be thought about, yet is numerically enduring, inferring that goofs in the data and center estimations don't total and 36 make the resulting yield be unimportant. There are various strategies for doing this, all with good conditions and shortcomings. The Finite Element Method is a not too bad choice for settling partial differential conditions over tangled spaces (like cars and oil pipelines), when the territory changes (as in the midst of a solid state reaction with a moving point of confinement), when the pined for exactness varies over the entire zone, or when the course of action needs smoothness.

For instance, in a frontal accident multiplication it is possible to extend conjecture precision in "fundamental" areas like the front of the auto and decrease it in its back (as such reducing cost of the reenactment). Another outline would be in Numerical atmosphere estimate, where it is progressively basic to have definite desires over developing extremely nonlinear wonders, (for instance, tropical brutal breezes in the earth, or whirls in the ocean) instead of by and large calm local.

4.3.4 LAYOUT OF ANSYS WINDOW:

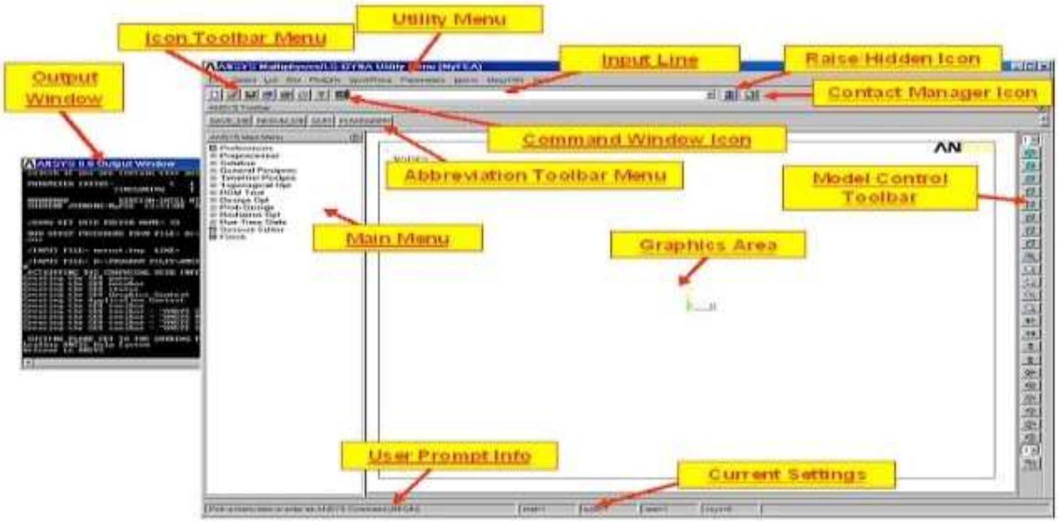


Fig-28 Screen ANSYS window

4.3.5 MOUSE:

Left mouse get picks (or unpicks) the component or region closest to the mouse pointer. Pressing and hauling empowers you to "survey" the thing being picked (or unpicked).Middle mouse get completes an Apply. Recuperations the time required to move the mouse over to the Picker and press the Apply get. Use Shift-Right catch on a two-get mouse. Right mouse get flips among pick and unpick mode. Note, the Shift-Right catch on a two catch mouse is indistinguishable to the Middle mouse get on a three-get mouse.

4.3.6 DATABASE AND FILES: The term ANSYS database suggests the data ANSYS keeps up in memory as you collect, comprehend, and post process your model. The database stores both your data and ANSYS comes about data:

– Input data - information you ought to enter, for instance, estimations, material properties, and burden data.

– Results data - sums that ANSYS determines, for instance, migrations, stresses and temperature.

4.4 DEFINING THE JOBNAME:

Utility Menu > File> Change Job name

The occupation name is a name up to 32 characters that recognizes the ANSYS work. When you portray a livelihood name for an investigation, the occupation name transforms into the underlying section of the name of all records the examination makes. (The enlargement or postfix for these records' names is a report identifier, for instance, .DB.) By using work name for each investigation, you ensure that no archives are overwritten. jobname.log: Log record, ASCII. Contains a log of each request issued in the midst of the session. If you start a minute session with the equivalent jobname in a comparative working library, ANSYS will add to the past log archive (with a period stamp).

4.5 ANSYS GRAPHICAL USER INTERFACE (OUT PUT WINDOW): After starting ANSYS, two windows will appear. The first is the ANSYS 8.1 Output Window:

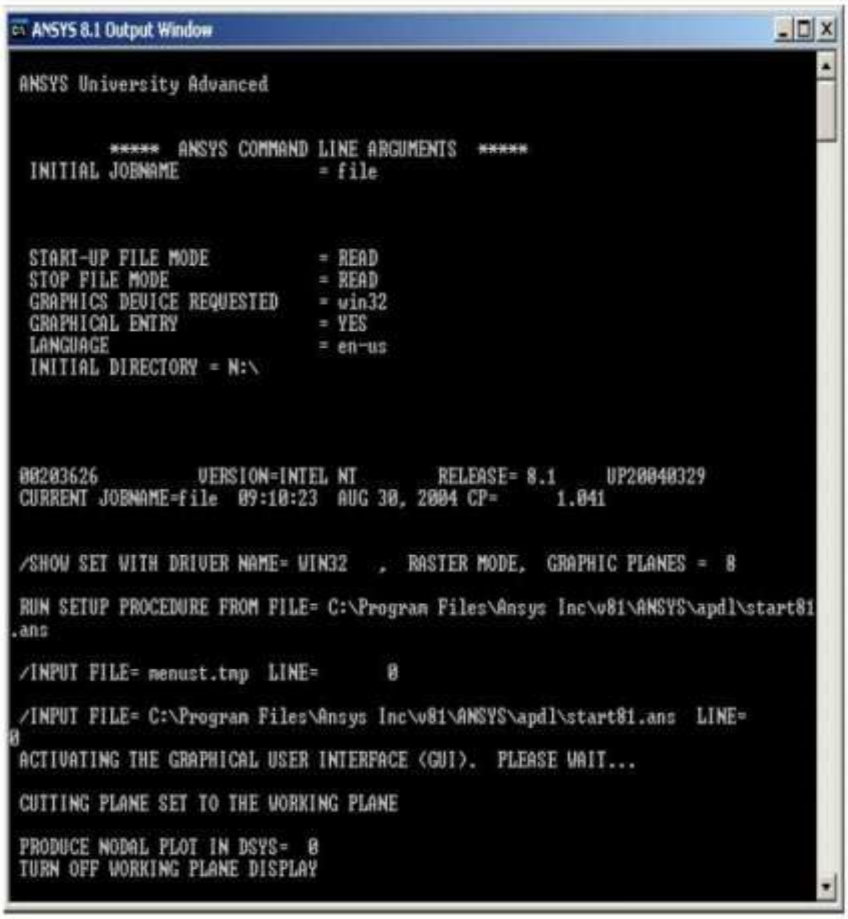


Fig- 29 Screen output window

This window demonstrates a posting of each request that ANSYS executes. If you experience issues, this is a conventional spot to plan to see what ANSYS is doing or has one. This is one zone where you will find most of the notification and bumble messages that appear and the gather that created the notice/botch.

The second window is the ANSYS Research FS graphical UI. This is isolated into 4 sections (showed up on next page):

- ANSYS Utility Menu
- ANSYS Toolbar Menu

- ANSYS Main Menu Display window

4.6 ANSYS UTILITY MENU:

Inside this menu, you can perform record activities, rundown and plot things, and change show alternatives.

4.6.1 FILE DROP-DOWN MENU:

The File drop-down menu incorporates the choices to clear the database, change, resume, and spare the present model.

4.6.2 LIST PULL-DOWN MENU:

The r destroy down menu empowers you to see the log and slip-up reports, get a posting of geometric substances, components and their properties, center points, and farthest point conditions and loads associated with the model.

4.6.3 PLOT PULL-DOWN MENU:

This draw down menu enables you to plot the different parts of the model, for example, Keypoint, areas, volumes and elements

4.6.4 PLOT CTRL PULL-DOWN MENU:

This menu incorporates the controls to skillet/zoom/pivot your model, select the numbering alternatives, change styles and create printed copies of the plots.

4.7 TOPOLOGY :

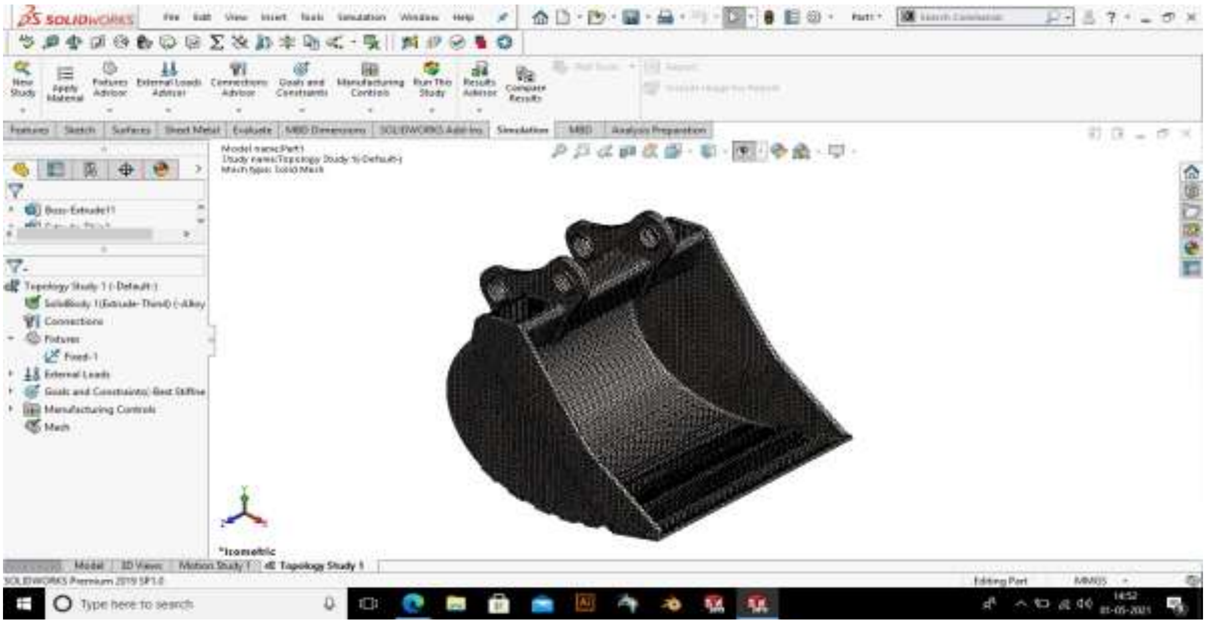
Topology optimization (**TO**) is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary condition and constraints with the goal of maximizing the performance to increase the manufacture Ability is an active field of research. In some cases results from TO can be directly manufactured using Additive manufacturing; TO is thus a key part of design for additive manufacturing. On a broad level, one can visualize that the more the material, the less the deflection as there will be more material to resist the loads. So, the system. The design is optimized using either gradient-based mathematical programing techniques such as the optimality criteria algorithm and the method of moving asymptotes or no gradient-based algorithms such as genetic algorithms.
Topology Optimization has a wide range of applications in aerospace, mechanical, bio-chemical and civil engineering. Currently, engineers mostly use TO at the concept level of a design process. Due to the free forms that naturally occur, the result is often difficult to manufacture. For that Reason the result emerging from TO is often fine-tuned for manufacturability. Adding constraints to the formulation in order the optimization requires an opposing constraint, the volume constraint. This is in reality a cost factor, as we would

not want to spend a lot of money on the material. To obtain the total material utilized, an integration of the selection field over the volume can be done.

	B	C
1	Cycles	Alternating Stress (Pa)
2	10	3.999E+09
3	20	2.827E+09
4	50	1.896E+09
5	100	1.413E+09
6	200	1.069E+09
7	2000	4.41E+08
8	10000	2.62E+08
9	20000	2.14E+08
10	1E+05	1.38E+08
11	2E+05	1.14E+08
12	1E+06	8.62E+07
*		

Table : 3 S-N Curves

- The Excavator Bucket is Designed and S-N Curves are given as Input for performing Fatigue Analysis
- Considering $\mathbf{10^6}$ cycles we get Equivalent stress value to be 86.2 Mpa



ANALYSING EXPERIMENTAL DATA :

Fig 30 : Topology study

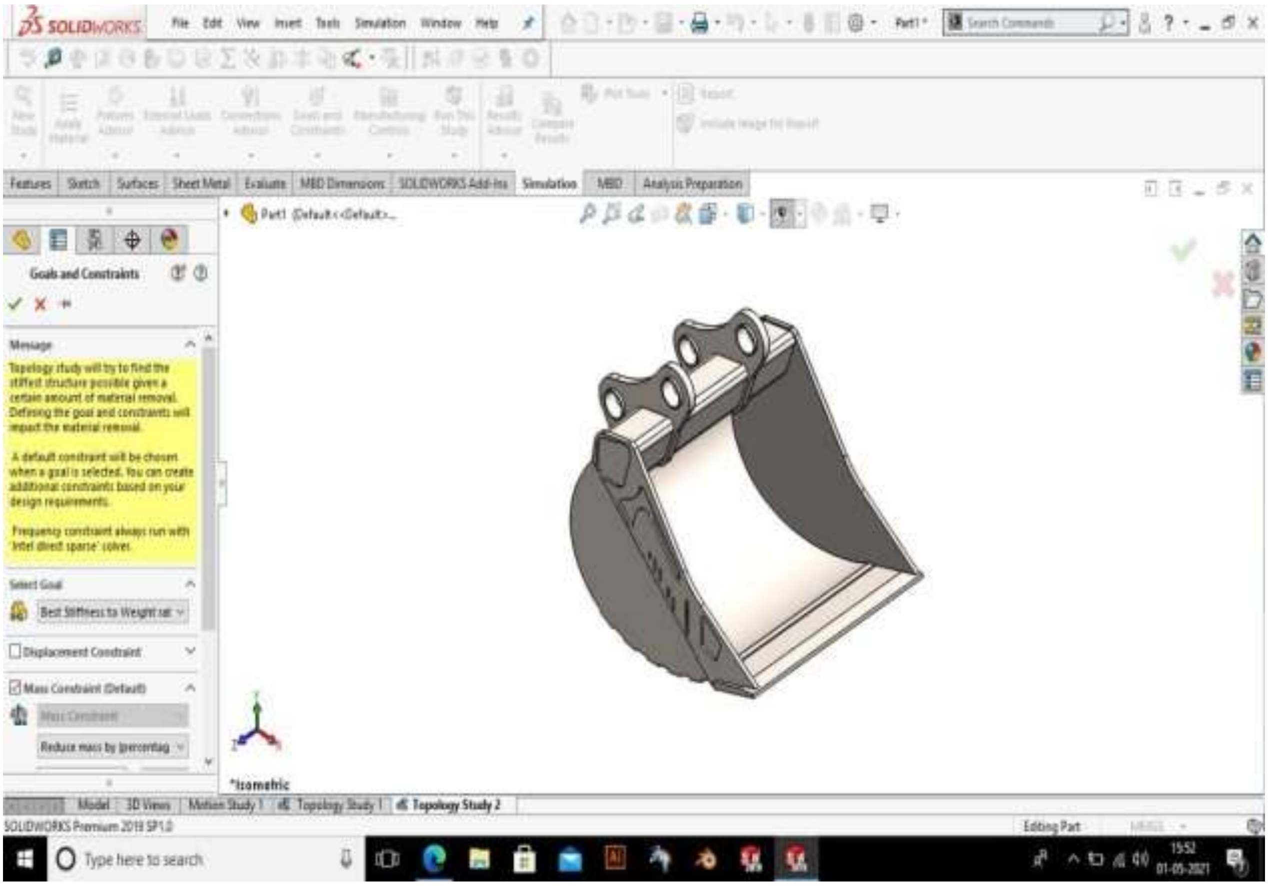


Fig 31 : Topology 2

INITIAL FIXED SUPPORT :

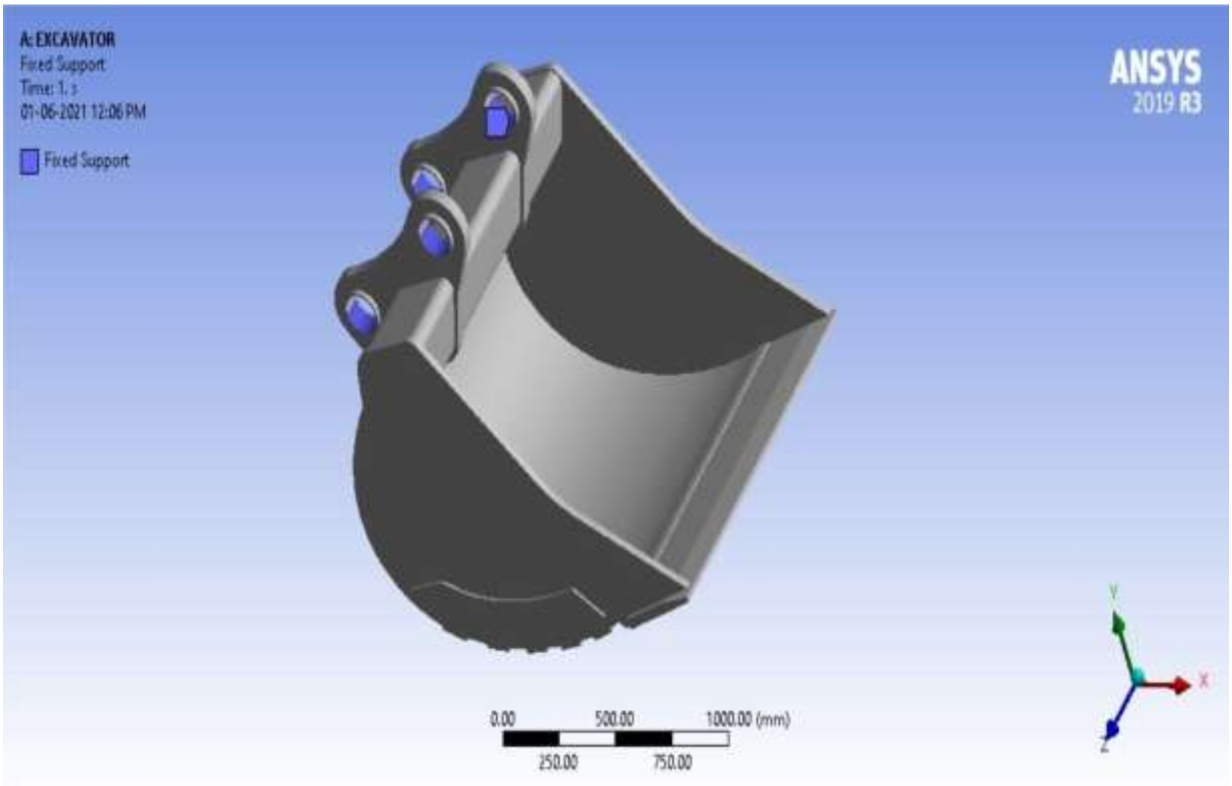


Fig 32 : Initial fixed support

INITIAL FORCE :

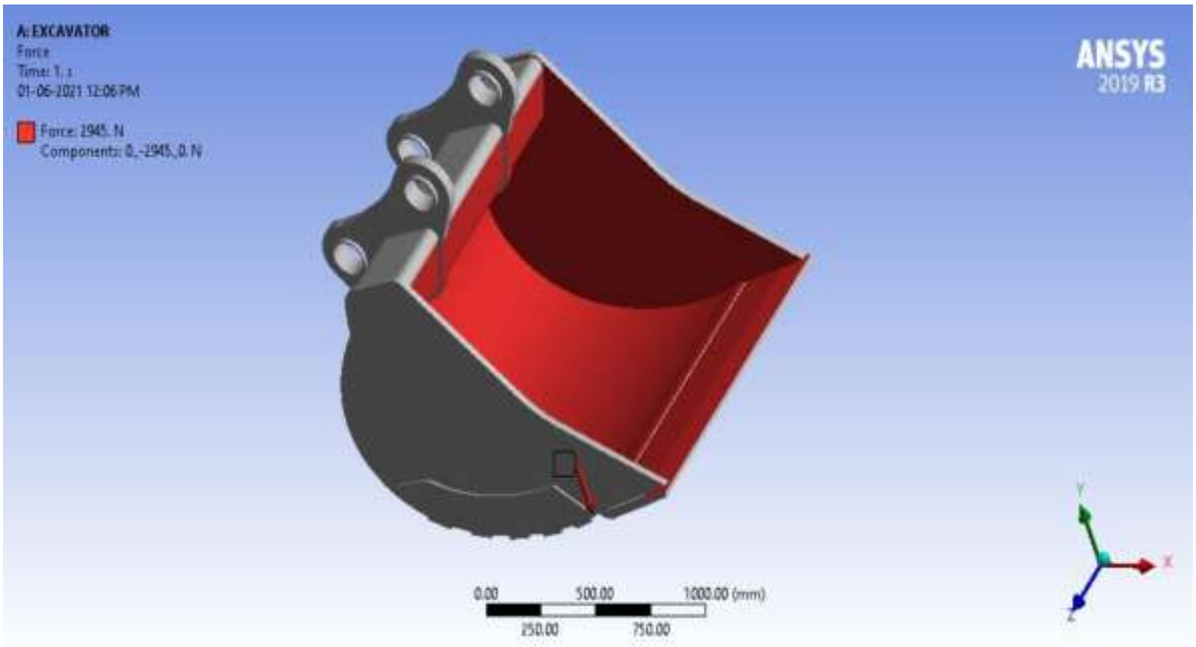


Fig 33 : Initial force

The initial force is applied on the constrained model and analyzed to determine the total deformation and equivalent stress.

INITIAL TOTAL DEFORMATION:

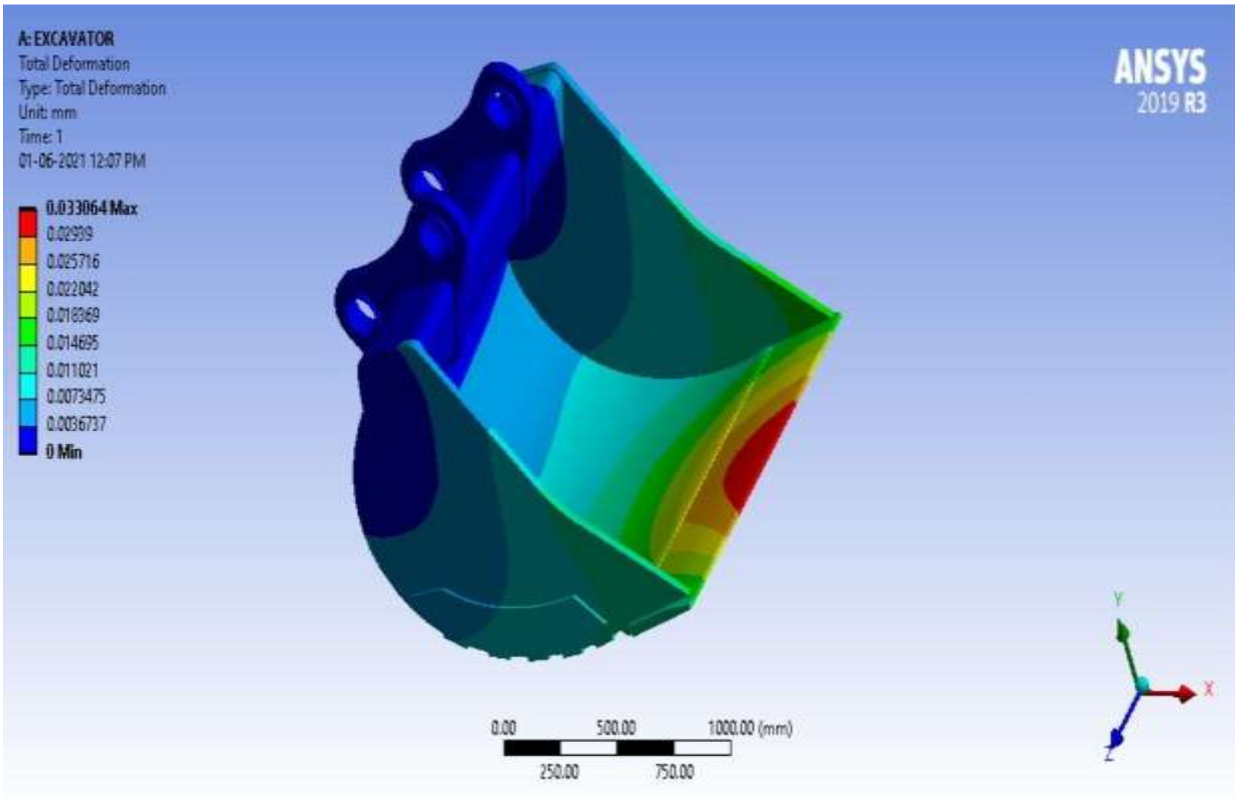


Fig 34 : Initial total deformation

INITIAL EQUIVALENT STRESS :

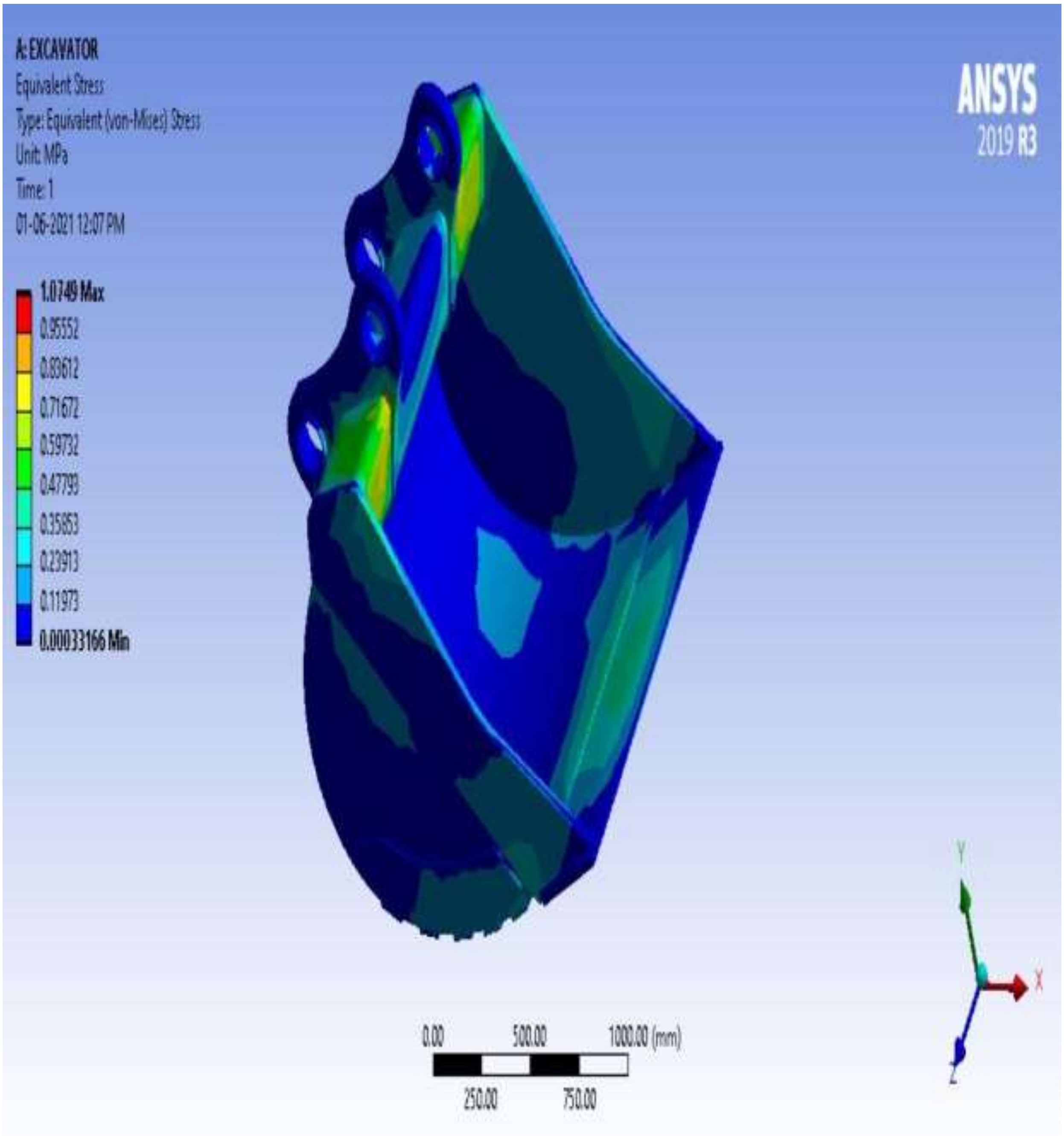


Fig 35 : Initial Equivalent Stress

- The initial deformation is calculated by applying the initial force and it comes out to be 0.03364
- The initial equivalent stress is calculated by applying the initial force and it comes out to be 1.0749.

According to the fatigue analysis results the equivalent stress for the excavator bucket comes out to be 86.2 Mpa. The initial value of equivalent stress is well within the limits.

FINAL FIXED SUPPORT:

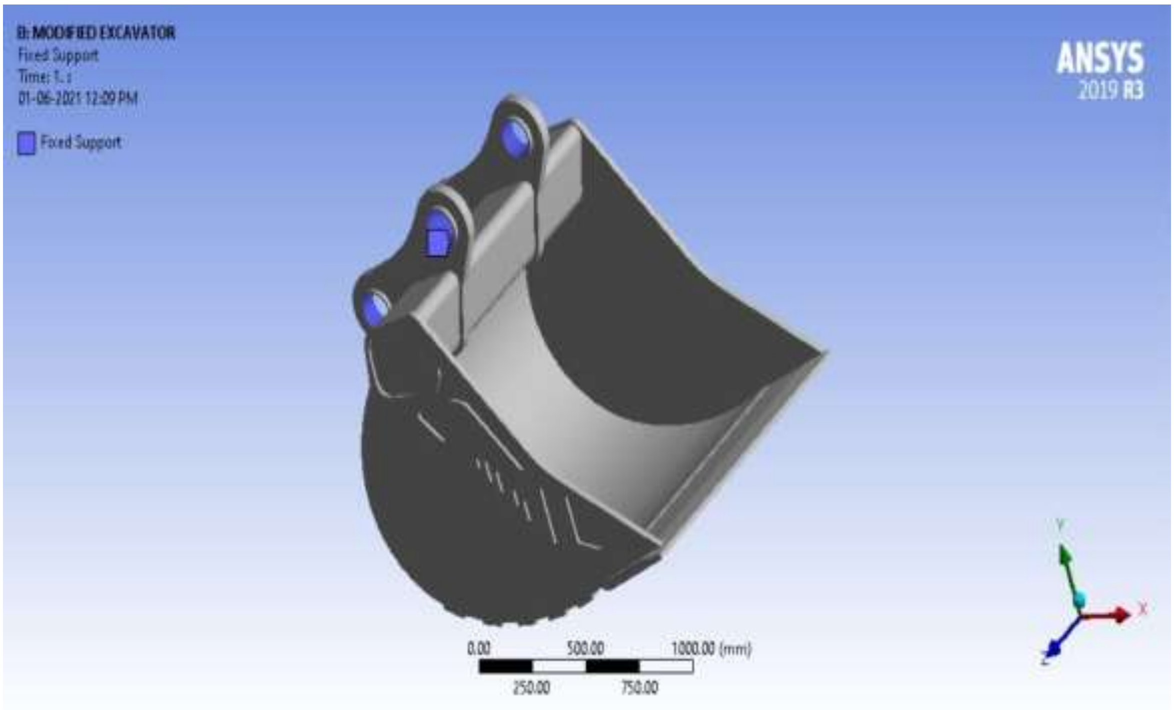


Fig 36 : Final Fixed Support

Now the Supports are removed and the component is fixed and applied with constraints and the force is applied.

FINAL FORCE:

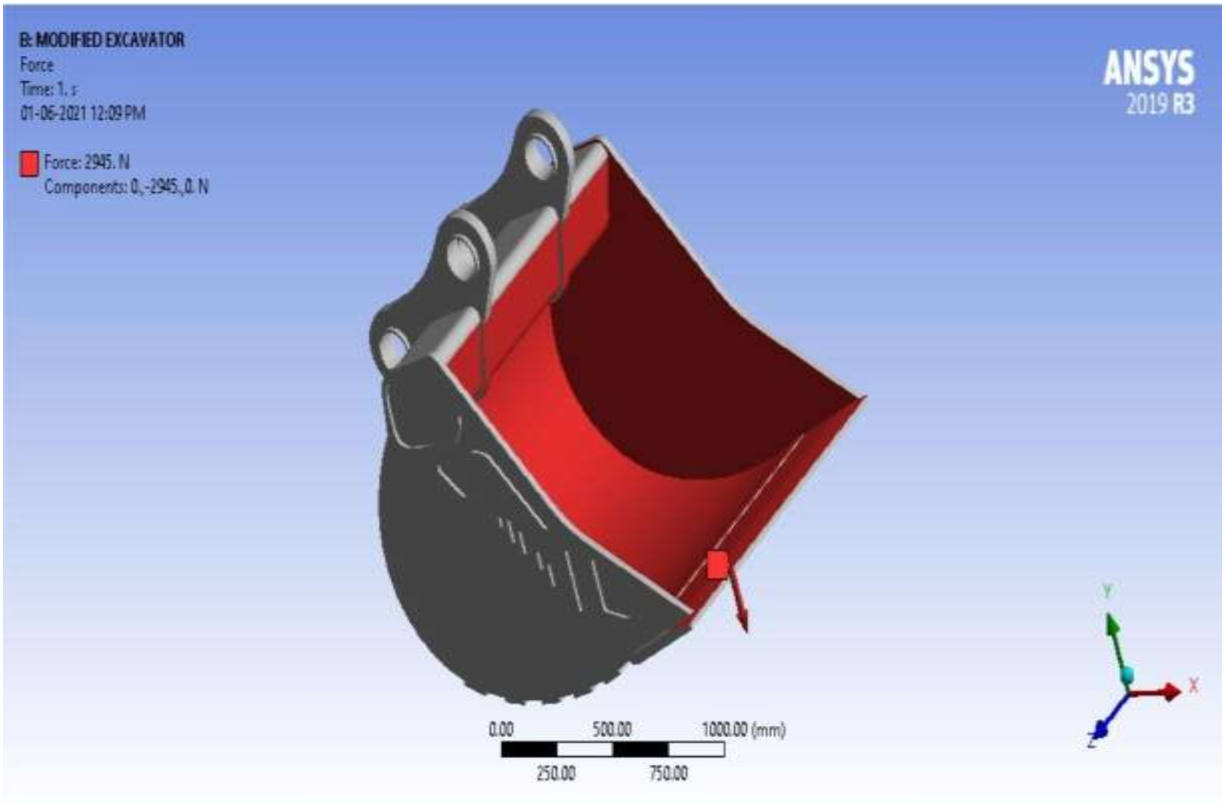


Fig 37 : Final force

FINAL TOTAL DEFORMATION:

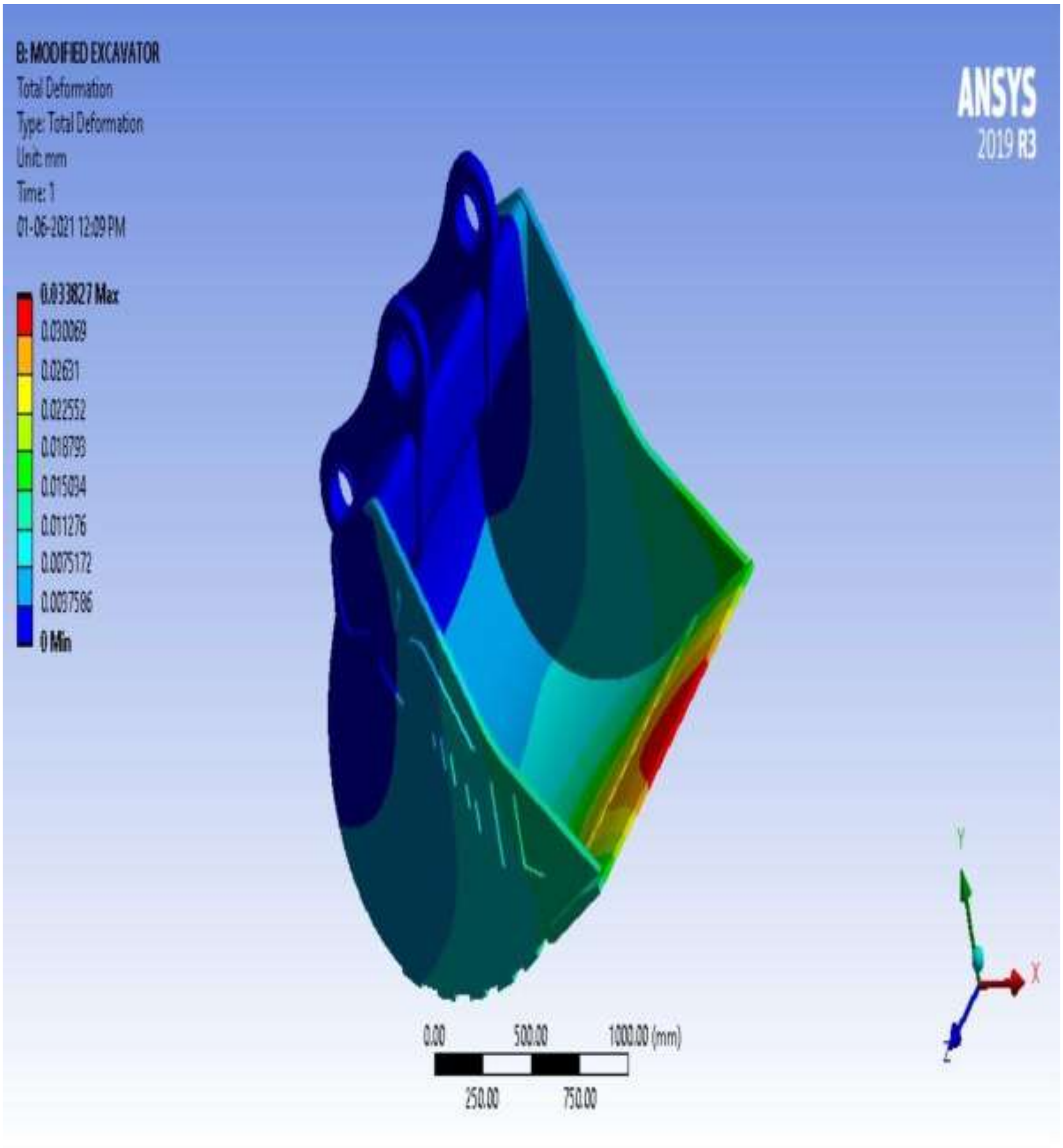


Fig 38 : Final total deformation

- The final deformation is calculated by removing the supports and applying the force and it comes out to be 0.033827.
- There is a slight increase in the deformation but it is well within the limits

FINAL EQUIVALENT STRESS:

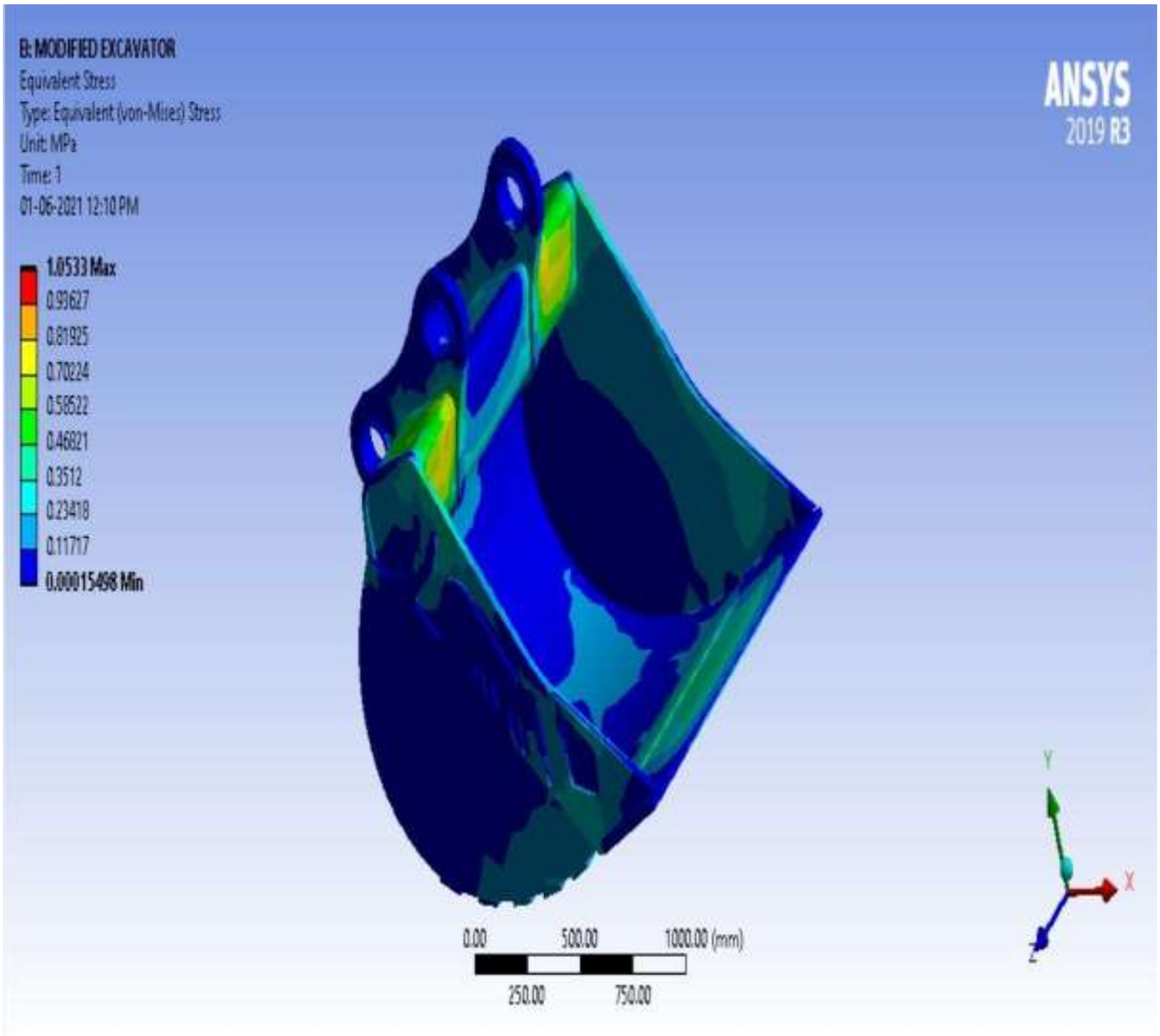


Fig 39 : Final equivalent stress

- The Final equivalent stress is calculated by applying the initial force and it comes out to be 1.0533Mpa.

According to the fatigue analysis results the equivalent stress for the excavator bucket comes out to be 86.2 Mpa. The final value of equivalent stress is well within the limits and is also less than the initial value.

Comparison Table :

Sl.no	Initial			Final		
1	Force	Total deformation	Equivalent stress	Force	Total deformation	Equivalent stress
2	2945N	0.033064 Max 0 min	1.0749 Max 0.00033166 Min	2945N	0.033827 Max 0 Min	1.0533 Max 0.00015498 Min

Table : 4 Comparison table

CHAPTER-5 CONCLUSION

5.1 CONCLUSION:

- In this project the deformation calculation for excavator bucket without support is slightly more than for excavator bucket with support and the values are well within the limits
- The equivalent stress for excavator bucket without support is less than for excavator bucket with support and the values are very minimum when compared with equivalent stress obtained by applying fatigue analysis (for S-N curve cycle of 10^9)
- With the reduction of weight by removing the supports, the excavator bucket is more flexible and agile while carrying loads.

5.2 FEATURE ENHANCEMENT:

With the experiment results it is clear that by reducing the thickness and weight of the bucket, the equivalent stress is reducing which reduces the crack generation of the component resulting in long life of the component.

This experiment can be further enhanced by using different materials and altering thickness.

5.3 REFERENCES:

1. Mc Graw Hill –Design of machine elements‖ by VB Bhandari – Textbook reference
2. –Machine Design‖ by R S Khurmi – Textbook reference
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A Major Project Report
On

COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF CONVERGENT-DIVERGENT NOZZLE

SUBMITTED TO

JawaharlalNehruTechnologicalUniversityHyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the project entitled "**COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF CONVERGENT-DIVERGENT NOZZLE"** is being submitted by **Md. Ismail Zabiullah (17K81A0390), T.Nikarsh (17K81A03B5), V.Ajay chary (17K81A03B7)** in partial fulfilment of the requirement for the award of the degree **of BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory

Signature of Guide	**Signature of HOD**
Mrs. N. SNEHA	**Dr. D.V. SREEKANTH**
Assistant Professor,	**Professor& Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of 'MECHANICAL ENGINEERING', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled "COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF CONVERGENT-DIVERGENT NOZZLE" is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

Md. Ismail Zabiullah	(17K81A0390)
T. Nikarsh	(17K81A03B5)
V. Ajay Chary	(17K81A03B7)

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ABSTRACT

The convergent-divergent nozzle finds application in many areas of industry and technology. The present work focuses on the CFD simulation of a convergent-divergent nozzle undergoing compressible flow, as there exist a few works on this topic. The work performed using a standard geometry to capture the normal shock under different exit pressure conditions. Finite volume method is to be utilized for the numerical simulations using ANSYS FLUENT. The results are to be analyzed using pressure plot, Mach number plot, different contour plots for pressure, temperature, density, velocity ,flow . The study is performed to contribute towards the fundamental knowledge and practical applications.

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CHAPTER -1

INTRODUCTION

1.1 Overview of the project

NOZZLE: A nozzle (from nose, signifying 'little gush') is a container of changing cross-sectional territory (for the most part hatchet symmetric) going for expanding the speed of a surge, and controlling its bearing and shape. Nozzle stream dependably creates powers related to the adjustment in Stream Energy, as we can feel by handholding a hose and opening the tap. In the least complex instance of a rocket nozzle, relative movement is made by shooting mass from a chamber in reverse through the nozzle, with the response powers acting chiefly on the contrary chamber divider, with a little commitment from nozzle dividers. As imperative as the propeller is to shaft-motor impetuses, so it is the nozzle to stream drive, since it is in the nozzle that warm vitality (or some other sort of high-pressure vitality source) changes into active vitality of the fumes, and its related direct energy creating push. The stream in a nozzle is extremely fast (and accordingly adiabatic to a first estimate), and with next to no frictional loses (in light of the fact that the stream is almost one-dimensional, with a great pressure angle aside from if stun waves structure, and nozzles are moderately short), so the isentropic model up and down the nozzle is adequate for starter plan.

The nozzle is said to start where the chamber distance across starts to diminish (incidentally, we expect the nozzle is hatchet symmetric, for example with round cross-areas, in dislike that rectangular cross-segments, said two-dimensional nozzles, are once in a while utilized, especially for their simplicity of bearing capacity). The meridian nozzle shape is immaterial with the 1D isentropic model; the stream is just reliant on cross-segment region proportions.

Genuine nozzle stream leaves from perfect (isentropic) stream on two viewpoints:

- Non-adiabatic effects. There is a sort of warmth expansion by non-balance radical-species recombination and a warmth evacuation by cooling the dividers to keep the quality of materials in long span rockets (for example working temperature of cryogenic SR-25 rockets utilized in Space Shuttle is 3250 K, above steel vaporization temperature of 3100 K, not simply softening, at 1700 K). Brief term rockets (for example strong rockets) are not effectively cooled but rather depend on removal; in any case, the nozzle-throat distance across can't let augment excessively, and strengthened materials (for example carbon, silica) are utilized in the throat locale.

- There is gooey scattering inside the limit layer, and disintegration of the dividers, what can be basic if the disintegration enlarges the throat cross-segment, incredibly lessening way-out territory proportion and thus push.

- Axial leave speed is lower than determined with the one-dimensional leave speed, when outspread outpouring is represented.

1.2 Objectives of the Project

The convergent-divergent nozzle finds application in many areas of industry and technology. The present work focuses on the CFD simulation of a convergent-divergent nozzle undergoing compressible flow, as there exist a few works on this topic. The work performed using a standard geometry to capture the normal shock under different exit pressure conditions. Finite volume method is to be utilized for the numerical simulations using ANSYS FLUENT. The results are to be analysed using pressure plot, Mach number plot, different contour plots for pressure, temperature, density, velocity, flow.

1.3 Scope of the Project

The study is performed to contribute towards the fundamental knowledge and practical applications. The convergent-divergent nozzle finds applications in many industries and technology. This work can be utilized for the reference and this nozzle is mostly used in rockets, jets etc to increase the velocity at the exhausts or decrease the pressure and temperature. This type of nozzles also used in turbines.

1.4 Material Selection

The material is selected based on the working and the applications of nozzle for example the rocket nozzle required a material that can with stand high melting and boiling point. So here they use the Tungsten because it is the material of choice when the solid rocket propellant flame temperatures exceed the melting point of rhenium. Because tungsten can be used to coat a lighter weight material

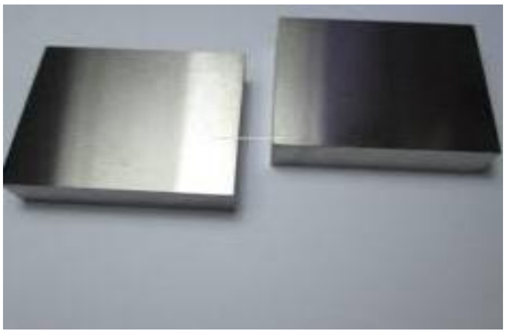

fig 1.1 Tungsten

such as graphite or carbon/carbon, the cost and weight of monolithic tungsten throat are avoided.

The compound formula of Tungsten Rhenium is WRe. Where the molecular weight is 370.04 and the appearance Gray metallic solid in various forms. The melting point is 3400 C and the boiling point is 5660 C. The density is 19.7 g/cm3. The tensile strength is 1310-2100 MPa, the thermal expansion is 4.48*10-6k-1 and the exact mass is 370.906684 where the monoisotopic mass is 370.9.

1.5 Types of Nozzles

CONVERGENT NOZZLE: Convergent nozzle is utilized to expand the speed of the liquid by diminishing the cross-sectional region of the nozzle dividers. The aera of the dividers additionally decline by proportionately in this nozzle the basic pressure proportion is lesser then the back pressure which created by fumes gasses A combining nozzle can just end up supersonic at the leave arrange; the speed increments monotonically along the nozzle. On the off chance that a uniting nozzle is encouraged from a steady pressure consistent temperature chamber, the stream rate develops as the release pressure is being diminished, until the stream winds up sonic (gagged) and the stream rate never again changes with further diminishing in release pressure (a lot of extension waves alter the leave pressure to this lower release pressure). With the exception of bygone era turbojets and military warrior flying machine, all business fly motors (after Concorde was resigned) use merging nozzles releasing at subsonic speed (both, the hot centre stream and the colder fan stream).

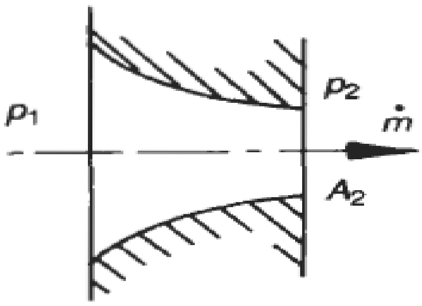

Fig 1.1 convergent nozzle

DIVERGENT NOZZLE: Divergent nozzle is utilized to diminish the speed of the liquid by expanding the cross-sectional territory of the nozzle dividers. The territory of the dividers additionally increments by comparably in this nozzle the basic pressure proportion is more prominent than the back pressure which produced by fumes gasses

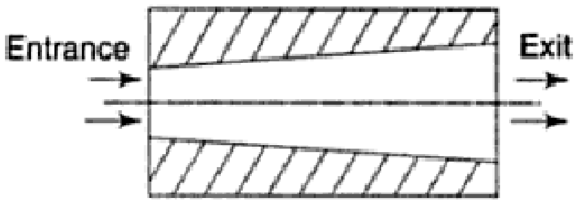

fig 1.2 divergent nozzle

CONVERGENT –DIVERGENT NOZZLE: In the convergent – divergent nozzle the cross-sectional territory of the nozzle will diminish consistently from beginning to through point after that the cross-segment region will increment persistently, the back pressure which produced is lesser then the basic pressure proportion.

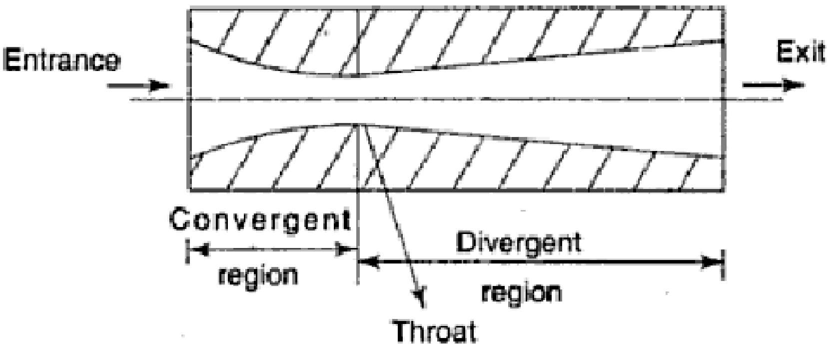

Fig1.3 convergent-divergent nozzle

The steam enters the nozzle with a high pressure, yet with an insignificant speed. In the meeting segment (for example from the bay to the throat), there is a drop in the steam pressure with an ascent in its speed. There is additionally a drop in the enthalpy or complete warmth of the steam. This drop of warmth. Isn't used in doing some outer work, however is changed over into dynamic vitality. In the divergent bit (for example from the throat to outlet), there is further drop of steam pressure with a further ascent in its speed. Once more, there is a drop in the enthalpy or complete warmth of steam, which is changed over into active vitality. It will intrigue realize that the steam enters, the nozzle with a high pressure and immaterial speed. In any case, leaves the nozzle with a high speed and little pressure. The pressure, at which the steam leaves the nozzle, is known as backpressure. Also, no warmth is provided or dismissed by the steam amid move through a nozzle. In this manner, it is considered as isentropic stream, and the comparing extension is considered as an isentropic development. Presently the coefficient of nozzle or nozzle effectiveness (normally meant by K) is characterized as the proportion of valuable warmth drop to the isentropic heat drop. Scientifically,

$$k = \frac{useful\ heatdrop}{isentropic\ drop} = \frac{ac}{ab} = \frac{h1 - h3}{h1 - h2}$$

1.6 TYPES OF FLOWS

Different stream routines are characterized dependent on the meaning of Mach number.

Subsonic Flow: When the liquid speed is lower than the acoustic speed (M<1) at that point the liquid stream is called as subsonic. Anyway, Mach number of the stream changes while disregarding an article or through a pipe. Henceforth for straightforwardness, stream is considered as subsonic if Mach number is in the scope of 0-0.8. All little plentifulness unsettling influences travel with acoustic speed and speed of the stream in the subsonic routine is not exactly acoustic speed subsequently nearness of the aggravation is felt by the entire liquid area. Along these lines subsonic stream is pre-cautioned or arranged to confront the unsettling influence.

Transonic stream: When the stream Mach number is in the range 0.8-1.2 it is called transonic stream. Profoundly temperamental and blended subsonic and supersonic streams are the primary highlights of this routine. Sonic stream: When stream Mach number is 1 it is called sonic stream.

Supersonic Flow: When the stream Mach number is all the more then wherever in the area then it is called as supersonic stream. This stream isn't pre-cautioned since the liquid speed is more than the speed of sound.

Hypersonic Flow: according to the thumb rule, when the stream Mach number is in excess of 5 then it is called as hypersonic streams. This isn't the fixed definition for hypersonic stream since hypersonic stream is characterized by specific attributes of stream.

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Early takes a shot at coaxial planes were persuaded for the most part by applications in combustion and air ship impetus. Forestall and Shapiro (1950) were the first to play out a trial examination on mass and energy exchange between the two floods of a co-streaming plane with exceptionally huge auxiliary streams in subsonic locale, and demonstrated that the speed proportion of the essential to optional stream is the central parameter deciding the state of the blending district, and proposed an exact connection for the length of the essential potential centre.

In the interim, the element of supersonic, double, coaxial fly was first examined by Love et al (1959). They made hypothetical investigations on a fly leaving into supersonic streams, and showed that a supersonic external stream can allow a crossing stun design at a lot higher pressure proportion before shaping a Mach circle which is the situation for a subsonic external stream. Shadow et al (1990) in their investigation of compressible spreading rates of supersonic coaxial planes have distinguished that axisymmetric coaxial stream's spreading rate shifts with the convective Mach number. Also, the adjustments in spreading rate rely upon the hub separate.

Various works have been made to explore the subsonic and supersonic double, coaxial stream. These works have been for the most part to explore

1) fly clam or concealment,

2) blending improvement, and

3) highlight of shockwave framework.

2.2 COAXIAL JETS

Fly Structure: One of particular highlights of the supersonic fly structure, which is connected with the execution of mechanical applications, is the stun cell framework, particularly the Mach plate.

D'Attore and Harshbarger (1965) announced first that the separation of Mach plate from the nozzle exit diminished as the external auxiliary stream speed was expanded, however the nitty gritty close recorded structure of the supersonic coaxial fly for a given stream condition is appeared by Dosanjh et al (1969). Buckley (1975) has contended that the area of the Mach circle produced in a supersonic, double, coaxial fly won't be adjusted since the hub Mach number dissemination upstream of the Mach plate is autonomous of the states of the outer streams. Masuda et al (1993, 1994) have revealed that the nearness of auxiliary annular stream has a good impact for decreasing the distance across of Mach plate which is framed in the essential internal fly.

. **Applications and Jet Noise**

Utilizations of the supersonic, double, coaxial fly to smother stream commotion were fundamentally investigated by Dosanjh et al (1969,1971). Also, examined different parameters, for example, nozzle geometry, pressure proportion, mass stream proportion between two streams, and so forth., and found that the co-pivotal arrangement lessens fly clam or outflow. They likewise watched a huge commotion decrease at specific blends of pressure 19 stun structure of the stream was essentially debilitated. Wlezien (1989) analysed the coupled communication of planes from two ostensibly indistinguishable convergent/divergent nozzles as an element of nozzle separating. The shriek methods of two coupled planes relate to those watched for single tufts, yet the modular amplitudes are emphatically reliant on nozzle separating.

Further chips away at expansive scale supersonic coaxial fly were done by Ahuja (1976), Bassiouni (1976) and Bhutiani (1976). They showed that the stuns were powerless or non-existent for an accurately extended stream condition, at which considerable in general clamour decrease was gotten. Olson and Friedman (1974) made exploratory works over numerous sorts of coaxial setups, and inferred that the clamor decreases at supersonic conditions are subjectively equivalent to that at subsonic conditions. The outcomes referenced above uncovered that the optional stream diminishes Mach wave emanation in supersonic fly, prompting the fly commotion decrease. This has been demonstrated by Papamoschou and his collaborators (1996, 1997, 1998, 2000a, 2000b, 2001, 2002, 2003, 2004).

- Convective Mach number of the stream whirlpools with respect to the coflow. This number ought to be short of what one. The lower it turns into, the quicker the constriction of the flag inside the co flow thickness.

- Convective Mach number of the co-stream swirls in respect to the surrounding gas.

This number ought to likewise be short of what one, albeit one may endure some radiation from the co-stream if the fly radiation is extraordinarily stifled.

- Co-stream thickness. The more prominent it is, the more unsettling influences need to rot sub-sonically before it achieves the surrounding gas.

- Coverage of the Mach wave-radiating area of the fly by the co-stream. On the off chance that the co-stream disperses before the finish of this district, Mach waves will even now be produced.

2.3 AXISYMMETRIC JETS AND NON-CIRCULAR JETS

Roundabout Free Jets

George Papadopoulos et al (1999) introduced the centreline speed information for a consistent thickness axisymmetric fly having a non-uniform beginning speed circulation that was completely tempestuous. The few Reynolds numbers (Re) explored indicated particularly the impact of Re on the improvement of the stream, explicitly the downstream move of the virtual root with expanding Re. This move of the centreline speed rot bends was credited to the underlying choppiness force dispersion.

Antonia et al (2001) studi 24 Valentino Todde et al (2009) broke down the highlights of a low Reynolds number free submerged fly with exceptional respect to factual amounts on the stream centerline. The outcomes demonstrated that, at low-Reynolds numbers, the underlying district of the fly is overwhelmed by very much characterized vortices in the shear layer. This outcome is substantiated by both the measurable minutes and the phantom examination.

Non-Circular Jets

Schadow et al (1988) have explored the triangular stream for use as a uninvolved gadget to upgrade fine-scale blending and to lessen the cognizance of extensive scale structures in the stream. The sharp corners in the stream injector brought high unsteadiness modes into the stream through the non-symmetric mean speed and pressure dispersion around the nozzle. While exceedingly lucid structures could be produced at the level side, the corner stream was overwhelmed by very tempestuous little scale whirlpools.

Dimitri Papamoschou and Marco Debiasi (1999) announced commotion estimations for superbly extended coaxial planes made out of a supersonic essential stream at speed of 920 m/s and a coflow stream at conditions intended to avert development of Mach waves. Both the essential and optional streams comprised of helium– air blends to re-enact around the states of hot streams. The subsequent sound field was contrasted with that radiated by a solitary fly at the states of the essential stream. It demonstrates that Mach waves represent at any rate 85% of the sound field most important to airplane commotion.

Non-Circular Coaxial Jets

There are a few deals with incompressible non-round coaxial flies and very much reported. Be that as it may, just a couple of quantities of takes a shot at compressible noncircular coaxial planes were archived.

Khodadadi et al (1989) examined the tempestuous blending of an essential fly and its encompassing liquid in a pipe. Point by point profiles of the pivotal mean and rms speeds have been estimated with a laser Doppler anemometer. Estimated spectra of hub speed variances demonstrate the nearness of sound structures.

Marco Debiasi and Dimitri Papamoschou (2001) completed investigations to portray the acoustics of axisymmetric rapid planes at an assortment of Mach numbers and speeds. Likewise at pressure-coordinated, over extended, and under extended conditions. The impact of an annular optional 27 stream on commotion discharge was additionally examined. The optional stream essentially wipes out the shriek tones, however has little effect on broadband stun commotion. With special case of confined and powerless shriek tones, the passage field spectra toward pinnacle clamor outflow (behind quadrant) are cold-hearted to nozzle leave pressure and depend exclusively on the completely extended Mach number and speed.

2.4 RECIRCULATION REGION AND VISUALIZATION

The distribution area is for all intents and purposes essential to settle a fire in a combustion chamber innovation since the re-circled combustion items make a diminished speed district where fire speed and stream speed can be coordinated.

Syred and Beer (1974), Lilley (1977), Leschziner and Rodi (1984) and Naughton et al (1997) have made test attempts to examine the twirl stream, and found that the whirl fly prompts an expansion in the spreading and rot rates of fly, along these lines expanding the entrainment rate of surrounding gas into the fly, when contrasted and the planes of no twirling.

CHAPTER 3 PROJECT DESIGN

3.1 INTRODUCTION TO NX 12

NX, formerly known as “Unigraphics”, is an advanced high-end CAD/CAM/CAE, which has been owned since 2007 by Siemens PLM Software. In 2000, Unigraphics purchased SDRC I-DEAS and began an effort to integrate aspects of both software packages into a single product which became Unigraphics NX or NX.

It is used, among other tasks, for:

- Design (parametric and direct solid/surface modelling)
- Engineering analysis (static; dynamic; electro-magnetic; thermal, using the finite element method; and fluid, using the finite volume method).

TABLE 3.1

Developer(s)	Siemens PLM Software
Initial release	October 1973; 47 years ago,
Stable release	1847 Series – 1867 monthly / June 2019; 2 years ago,
Operating system	Mac OS up to NX12, Unix-like (x64, partially), Windows (x64)
Available in	multi-language
Type	CAD/CAM/CAE/PLM
License	proprietary
Website	www.plm.automation.siemens.com/en_us/products/nx/index.shtml

3.2 HISTORY

1972: United Computing, Inc. releases UNIAPT, one of the world's first end-user CAM products.

1973: The company purchases the Automated Drafting and Machining (ADAM) software code from MCS in 1973. The code became a foundation for a product called UNI-GRAPHICS, later sold commercially as Unigraphics in 1975.

1976 McDonnell Douglas Corporation buys United Computing.

1983: UniSolids V1.0 is released, marking the industry's first true interactive Solid Modeling software offering.

1991: During a period of financial difficulties McDonnell Douglas Automation Company (McAuto) sells its commercial services organization, including the Unigraphics organization and product, to EDS which at that time is owned by GM. Unigraphics becomes GM's corporate CAD system.

1992: Over 21,000 seats of Unigraphics are being used worldwide.

1996: Unigraphics V11.0 is released with enhancements in Industrial Design and Modeling including Bridge Surface, Curvature Analysis for Curve and Surfaces, Face Blends, Variable Offset Surface, etc. In the area of Assembly Modeling the new capabilities include Component Filters, Faceted Representations, and Clearance Analysis between multiple Components. A fully integrated Spreadsheet linked to Feature-Based Modeling is also included.

2002 First release of the new "Next Generation" version of Unigraphics and I-DEAS, called NX, beginning the transition to bring the functionality and capabilities of both Unigraphics and I-DEAS together into a single consolidated product.

2007 Introduction of Synchronous Technology in NX 5.

2011 Release of NX8 on October 17-2011

2013 Release of NX9 (x64 only) on October 14-2013

3.3 RELEASE HISTORY

Name/Version	Version History Value	Release Date
Unigraphics	R1	April 1978
Unigraphics	R2	July 1978
Unigraphics	R3	October 1978
Unigraphics	R4	March 1979
Unigraphics	D1	December 1979
Unigraphics	D2	September 1980
Unigraphics	D3.0	April 1982
Unigraphics	D4.0	September 1982
Unigraphics II	1.0	August 1983
Unigraphics I	D5.0	March 1984
Unigraphics II	2.0	March 1985
Unigraphics I	D6.0	August 1985

Unigraphics II	3.0	November 1985
Unigraphics II	4.0	November 1986
Unigraphics II	5.0	October 1987
Unigraphics II	6.0	December 1988
Unigraphics II	7.0	December 1989
Unigraphics	8.0	March 1991
Unigraphics II	9.0	August 1992
Unigraphics	10.3	June 1994
Unigraphics	11.0	January 1996
Unigraphics	12.0	January 1997
Unigraphics	13.0	July 1997
Unigraphics	14	6/22/1998
Unigraphics	15.0	November 1998

Unigraphics	16.0	September 1999
Unigraphics	17.0	October 2000
Unigraphics	18.0	July 2001
Unigraphics	NX	July 2002
NX	5	4/16/2007
NX	6	5/20/2008
NX	7	5/20/2010
NX	7.5	
NX	8	10/17/2011
NX	8.5	
NX	9	10/14/2013
NX	10	12/14/2014
NX	11	09/08/2016

NX	12	10/27/2017
NX	1847	1/18/2019
NX	1872	6/26/2019
NX	1899	December 2019
NX	1926	June 2020
NX	1953	December 2020

Table 3.2

3.4 NX for Design

The most powerful, flexible, and innovative product development solution in the industry, NX for Design has the features, performance, and capabilities to help you get product to market faster than ever before for Design enables you to deliver products “right to market, first time" using more virtual product models and fewer, more costly, physical prototypes. This leads to market gains, lower development costs, and improved product quality.

3.5NX for Manufacturing

Drive efficient end-to-end part manufacturing operations and deliver high-precision parts through digitalization. Program CNC machine tools, control robotic cells, drive 3D printers and monitor quality using one software system. Digitally transform your part manufacturing business to gain productivity and increase profitability.

3.6 NX Model of Nozzle

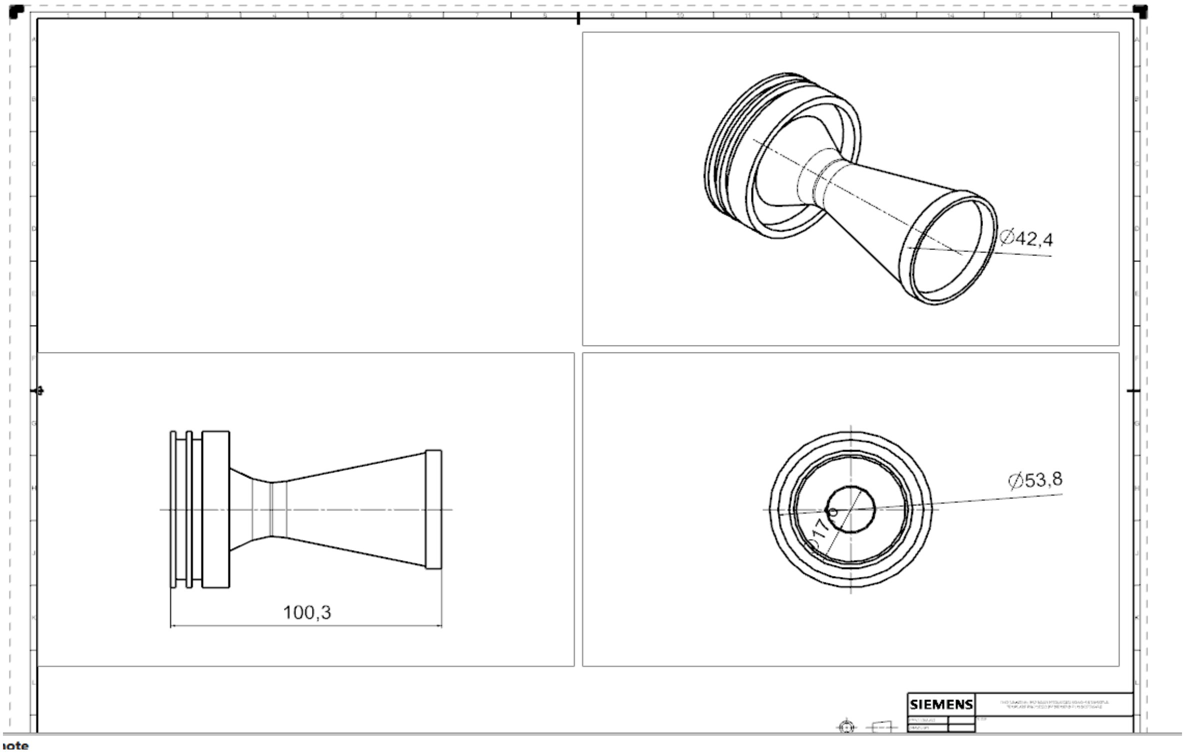

Fig 3.1DRAFT SHEET 1

DIMENSIONS:

MEASUREMENTS	VALUES
Length	**100.3 mm**
Inlet diameter	**53 mm**
Throat diameter	**17 mm**
Outlet diameter	**42 mm**

Table 3.3

Design of Nozzle 1

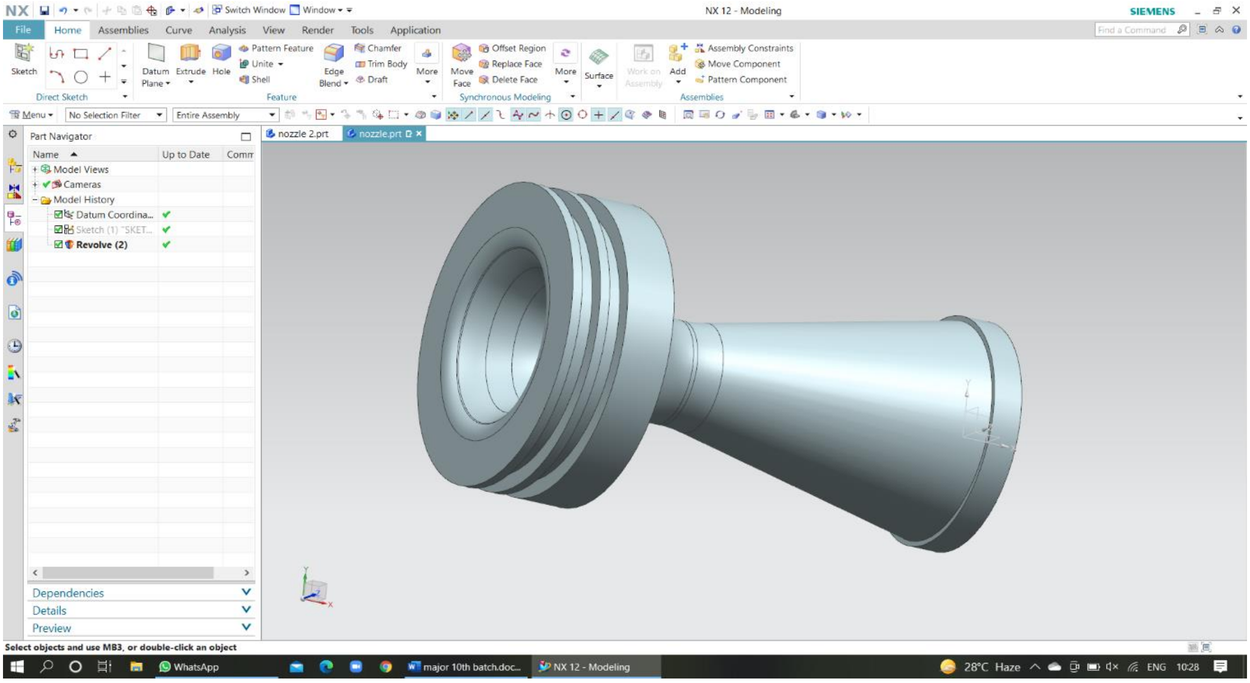

Fig 3.2 Internal flow of Nozzle 1

Internal flow of Nozzle 1

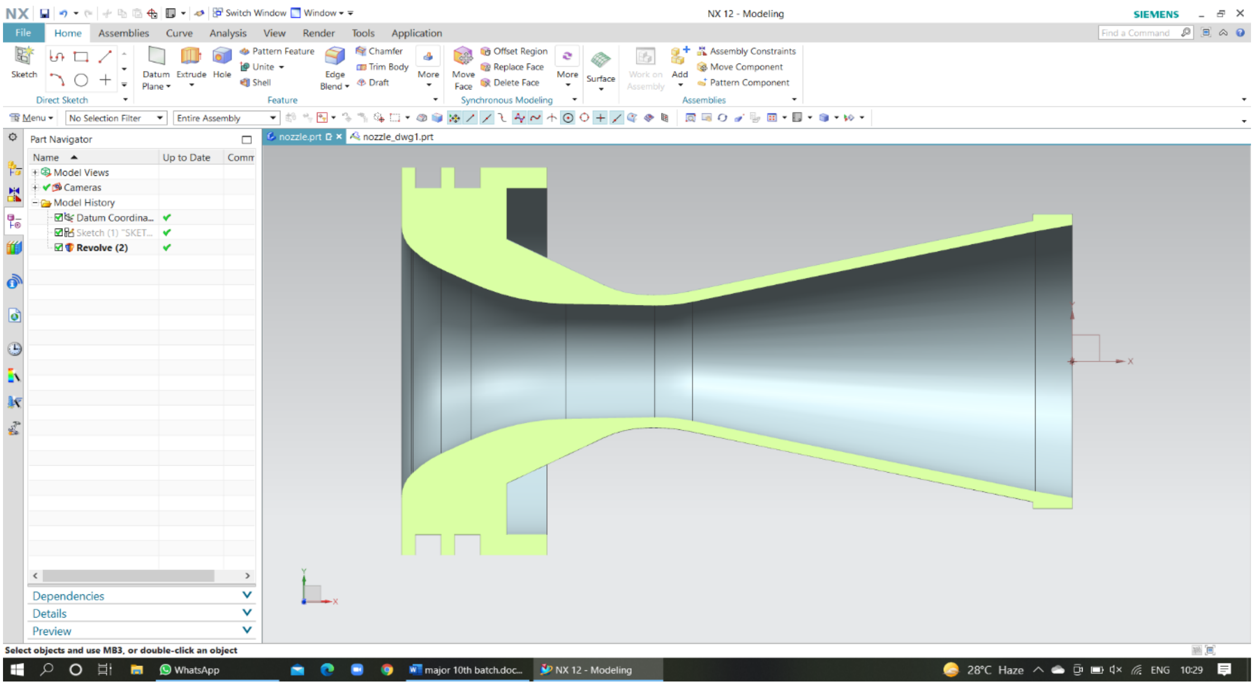

Fig 3.3 Internal flow of Nozzle 1

Draft sheet of Nozzle 2

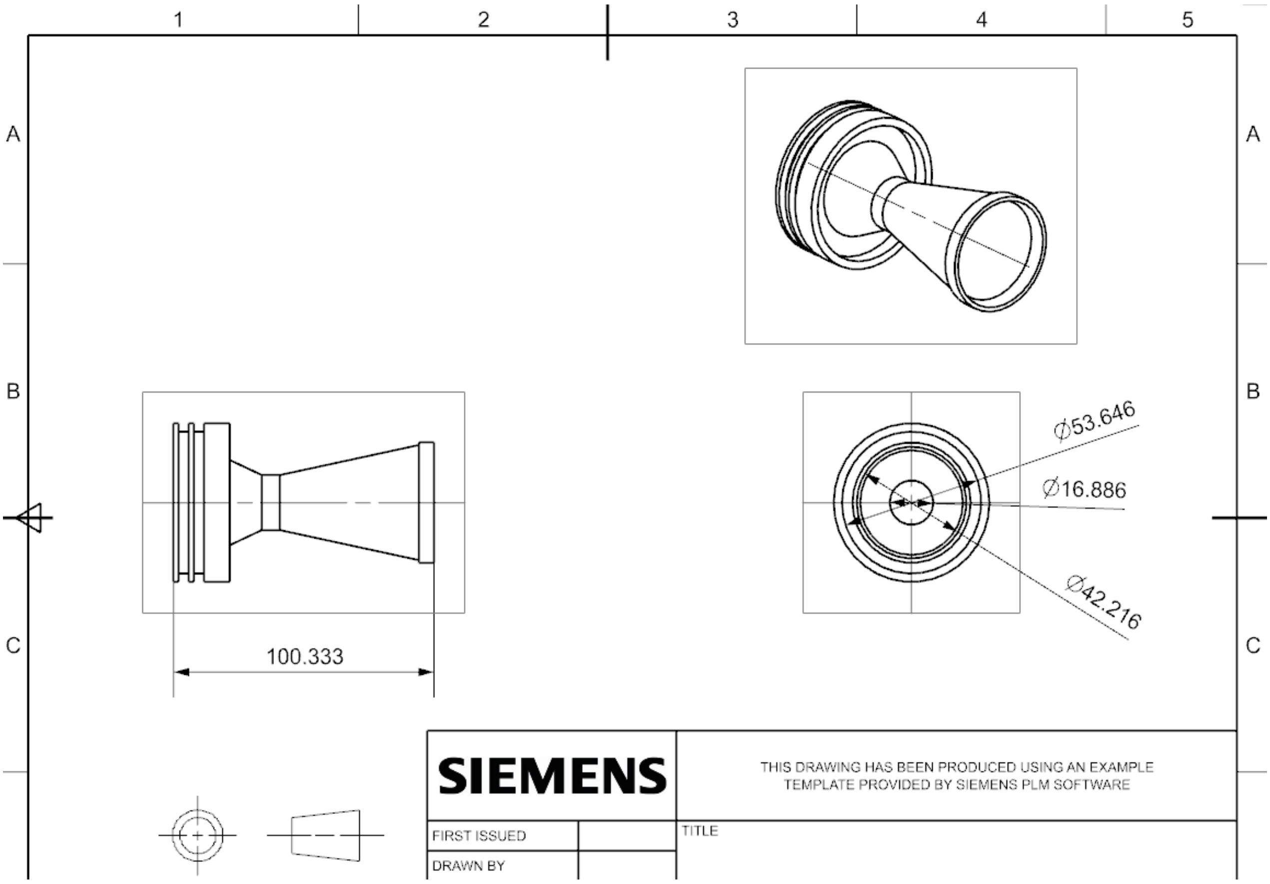

Fig 3.4

DIMENSIONS:

MEASUREMENTS	VALUES
Length	**100.3 mm**
Inlet diameter	**53 mm**
Throat diameter	**16 mm**
Outlet diameter	**42 mm**

Table 3.4

Design of Nozzle 2

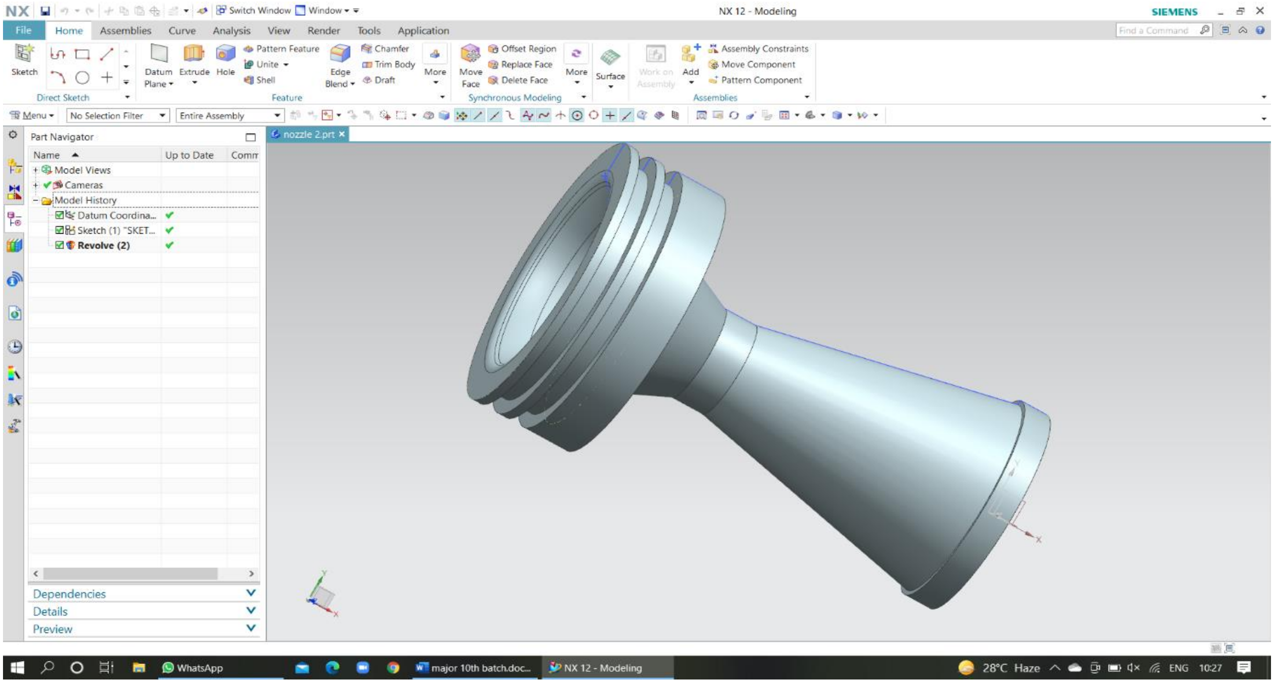

Fig 3.5 Design of Nozzle 2

Internal flow of Nozzle 2

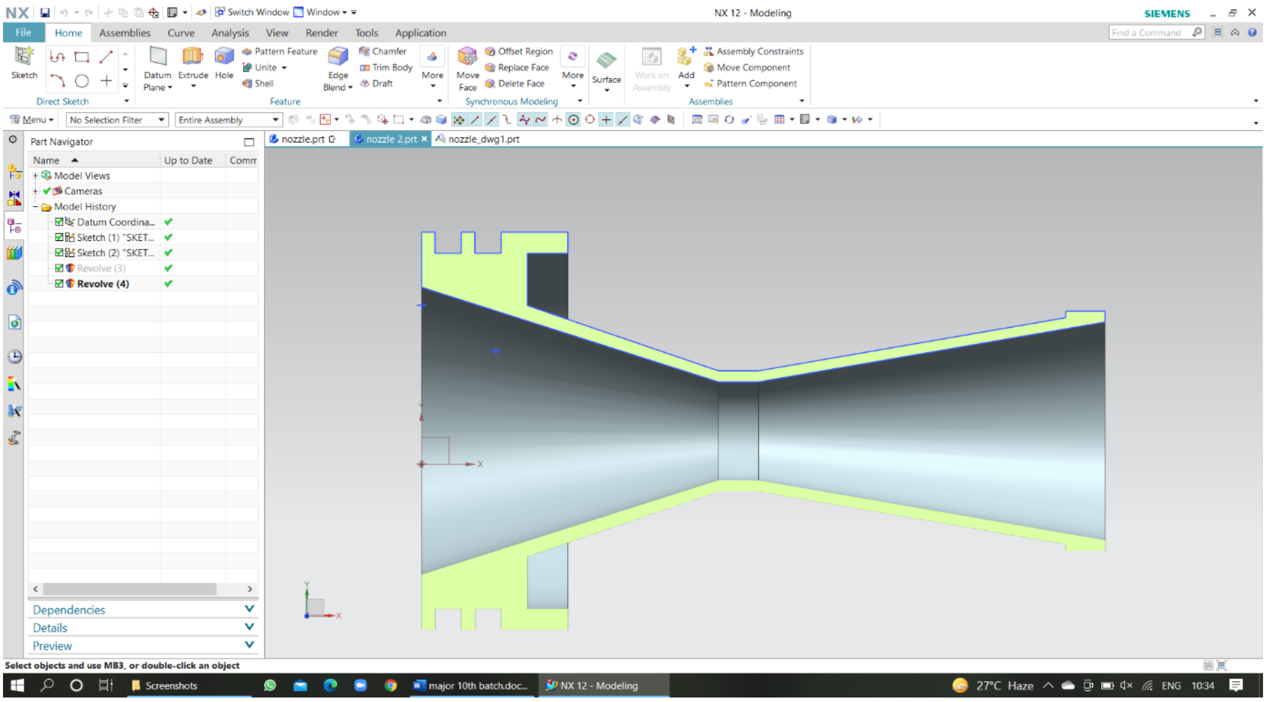

Fig 3.6 Internal flow of Nozzle 2

Chapter-4

INTRODUCTION TO ANSYS

4.1 HISTORY:

The association was built up in 1970 by Dr. John A Swanson Analysis framework, Inc. SASI. Its essential job was to make and feature limited component examination programming for auxiliary material science that could reproduce static (stationary), dynamic (moving) and warm trade (warm) issues. SASI developed its business in parallel with the improvement in PC advancement and structuring needs. The association created by 10 to 20 percent year, and in 1994 it was sold to TA Associates. The new owners took SASI's driving programming called ANSYS as their pioneer thing and doled out ANSYS, Inc as the new association name.

4.2 INTRODUCTION:

The ANSYS program is a PC program for a limited component investigation and plan. The ANSYS program can in like manner be used to process the perfect structure for given working conditions using the plan improvement feature.

ANSYS is business limited component examination programming with the ability to separate a broad assortment of different issues. ANSYS holds running under a collection of circumstances, including IRIX, Solaris, and Windows NT. Like any limited component programming, ANSYS unwinds speaking to differential conditions by breaking the issue into little components. The speaking to states of flexibility, fluid stream, warm trade, and electro-fascination would all have the capacity to be comprehended by the Finite component procedure in ANSYS. ANSYS can handle transient issues and moreover nonlinear issues. This report will focus on the basics of ANSYS using generally fundamental delineations.

The ANSYS program is a multi-reason program, suggesting that you can use it for a limited component investigation in for all intents and purposes any industry - vehicles, flying, railways, mechanical assembly, equipment, wearing stock, control time, control transmission, and biomechanics, to indicate just a couple. "Multi-reason" in like manner suggests the manner in which that the program can be used as a piece of all controls of structure – assistant, mechanical, electrical, electromagnetic, electronic, warm, fluid, and biomedical. The ANSYS program is moreover used as an enlightening gadget in schools and other academic foundations.

ANSYS is open on all ME net Sun and SGI machines. It is available on the Linux machines by remote-login so to speak. On the right side, tattle has it that ANSYS is examining a Linux port. At the present time, ME net uses the Research/Faculty type of ANSYS 12.1. The Research/Faculty grant level gifts greater, more many-sided models than does the energy level running on the IT Labs machines.

ANSYS writing computer programs is available on numerous sorts of PCs – (PCs), workstations, minicomputers, super minis, concentrated PCs, very unified PCs, etc. A couple of working systems are maintained, much the same as various of reasonable contraptions.

4.2.1 SOLUTION STEPS

- Apply removal limitation.
- Apply pressure load.
- Solve

4.2.2 POST PROCESSING STEPS

- Enter the general post processor.
- Plot twisted shape.
- Plot the von miss's equal pressure.
- List responses at obliged hubs.
- Exit the ANSYS program.

4.3 ELEMENT CHARACTERISTICS

4.3.1 LISTS OF ELEMENT TYPES:

The ANSYS program has a considerable library of component sorts. A segment of the properties of the component sorts, and their groupings, are depicted in this part to make component sort assurance less requesting.

The ANSYS component library contains in excess of 100 unmistakable component plans or sorts. A component sort is perceived by a name (8 characters most extraordinary, for instance, BEAM3, including a social event mark (BEAM) and an uncommon distinctive number (3).

The component is browsed the library for use in the examination by contributing its name on the component sort bring

4.3.2 TWO-DIMENSIONAL VERSUS THREE-DIMENSIONAL MODELS:

ANSYS models may be either two-dimensional or three-dimensional depending on the component sorts used. Two-dimensional models must be described in a X-Y plane. They are less requesting to set up, and run speedier than relative three-dimensional models. Rotate Symmetric models are furthermore thought to be two-dimensional.

If any three-dimensional component sort, (for instance, BEAM4) is consolidated into the component sort set, the model winds up doubtlessly three-dimensional. Some component sorts, (for instance, COMBIN14) may be a couple of dimensional, dependent upon the KEYOPT regard picked. Other component sorts, (for instance, COMBIN40) have no effect in choosing the model estimations. Two-dimensional component sorts may be used (with caution) in three-dimensional models.

4.3.3 Finite component technique

The limited component system (FEM) (its sensible application routinely known as limited component investigation (FEA) is a numerical technique for finding inferred plans of inadequate differential conditions (PDE) and furthermore of essential conditions. The course of action approach is developed either in light of getting rid of the differential condition absolutely (steady state issues), or rendering the PDE into an approximating game plan of customary differential equations, then numerically joined using standard methodology, for instance, Euler's procedure, Runge-Kutta, etc.

In handling partial differential conditions, the fundamental test is to make a condition that approximates the condition to be thought about, yet is numerically enduring, inferring that goof in the data and center estimations don't total and make the resulting yield be unimportant. There are various strategies for doing this, all with good conditions and shortcomings. The Finite Element Method is a not too bad choice for settling partial differential conditions over tangled.

4.3.4 Layout of ANSYS window

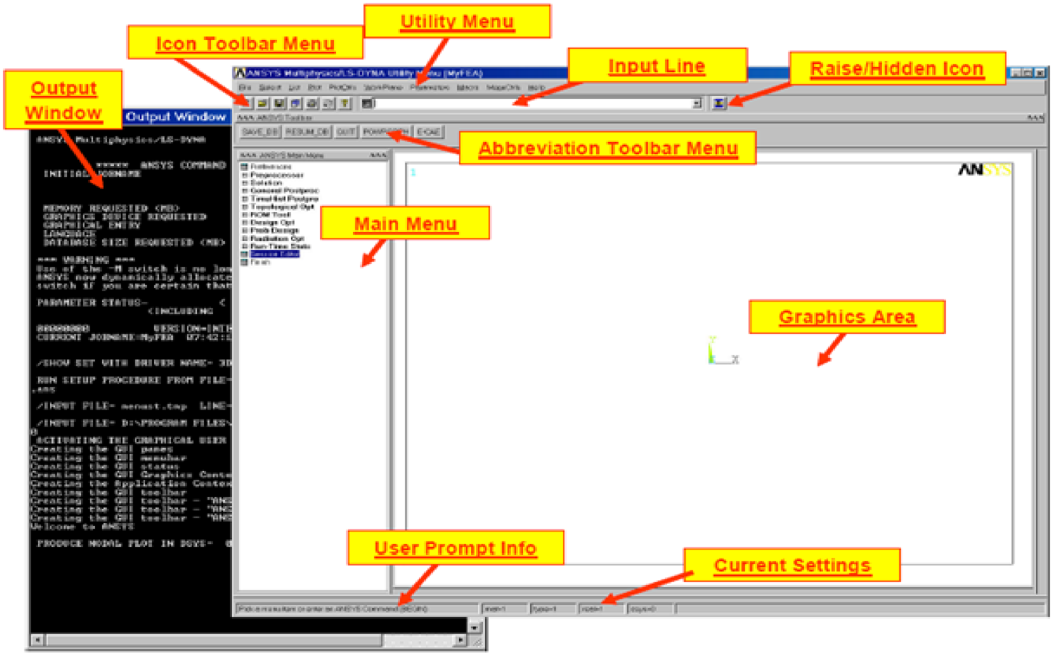

Fig:4.1Screen ANSYS window

4.3.5 MOUSE

Left mouse get picks (or unpicks) the component or region closest to the mouse pointer. Pressing and hauling empowers you to "survey" the thing being picked (or unpicked). Middle mouse get completes an Apply. Recuperations the time required to move the mouse over to the Picker and press the Apply get. Use Shift-Right catch on a two-get mouse.

Right mouse gets flips among pick and unpick mode. Note, the Shift-Right catch on a two-catch mouse is indistinguishable to the Middle mouse get on a three-get mouse.

4.3.6 DATABASE AND FILES

The term ANSYS database suggests the data ANSYS keeps up in memory as you collect, comprehend, and post process your model. The database stores both your data and ANSYS comes about data:

– Input data - information you ought to enter, for instance, estimations, material properties, and burden data.

4.4 DEFINING THE JOBNAME

Utility Menu > File> Change Job name

The occupation name is a name up to 32 characters that recognizes the ANSYS work. When you portray a livelihood name for an investigation, the occupation name transforms into the underlying section of the name of all records the examination makes. (The enlargement or postfix for these records' names is a report identifier, for instance, .DB.) By using work name for each investigation, you ensure that no archives are overwritten.

jobname.log: Log record, ASCII. Contains a log of each request issued in the midst of the session. If you start a minute session with the equivalent jobname in a comparative working library, ANSYS will add to the past log archive (with a period stamp).

4.4.1 FILE MANAGEMENT TIPS

- Run each examination stretch out in an alternate working index.
- Use assorted business names to isolate distinctive examination runs.
- You should keep the going with records after any ANSYS examination:

log record (.log); database report (.db); comes about archives (.rst, .rth, …); stack step reports, accepting any (.s01, .s02, ...)

Portraying an Analysis Title: Utility Menu> File> Change Title

This will portray a title for the investigation. ANSYS fuses the title on all representations appears and on the game plan yield. (In the event that it's not all that much inconvenience join your name and understudy ID in the investigation title for each and every one-of-a-kind diagram)

4.5 ANSYS GRAPHICAL USER INTERFACE (OUT PUT WINDOW)

After starting ANSYS, two windows will appear. The first is the ANSYS 8.1 output Window:

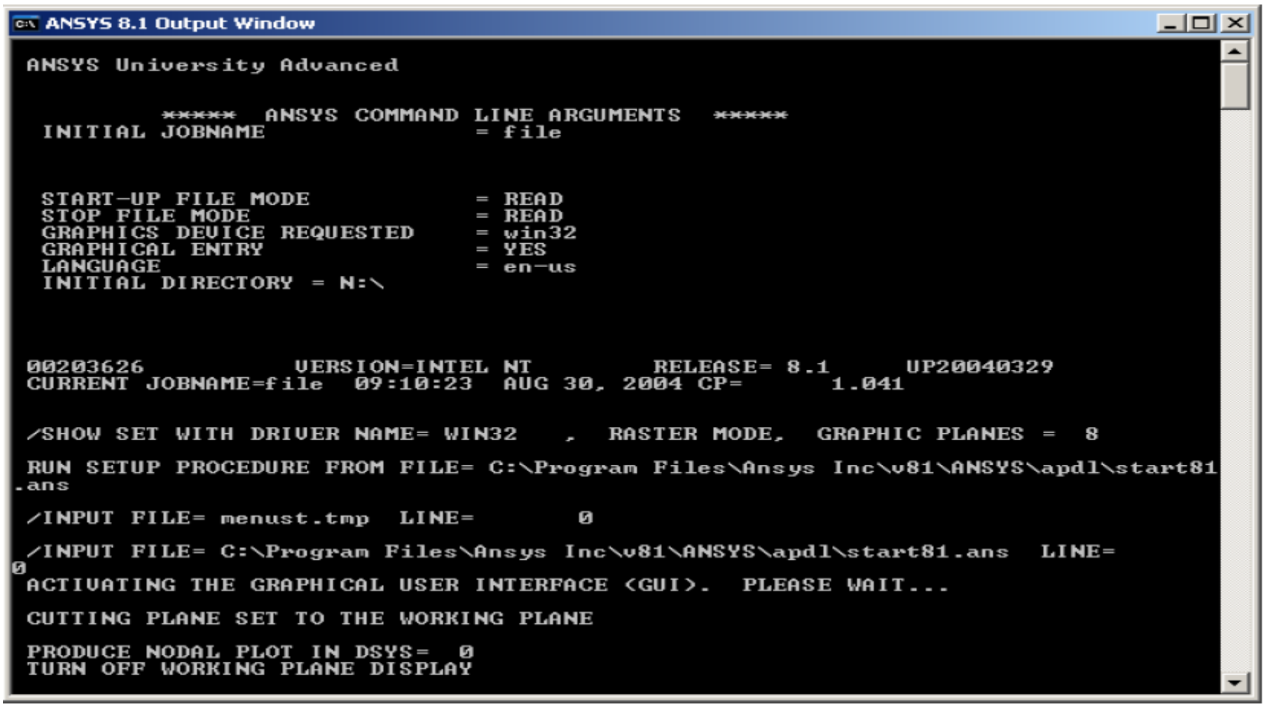

Fig:4.2Screen output window

This window demonstrates a posting of each request that ANSYS executes. If you experience issues, this is a conventional spot to plan to see what ANSYS is doing or has one. This is one zone where you will find most of the notification and bumble messages that appear and the gather that created the notice/botch.

The second window is the ANSYS Research FS graphical UI. This is isolated into 4 sections (showed up on next page): ANSYS Utility Menu

- ANSYS Toolbar Menu
- ANSYS Main Menu
- Display window

Each segment will be talked about in further detail beneath.

4.6 ANSYS UTILITY MENU

Inside this menu, you can perform record activities, rundown and plot things, and change show alternatives

4.6.1 FILE drop-down menu

The File drop-down menu incorporates the choices to clear the database, change, resume, and spare the present model.

4.6.2 List pull-down menu

The r destroys down menu empowers you to see the log and slip-up reports, get a posting of geometric substances, components and their properties, center points, and farthest point conditions and loads associated with the model.

4.6.3 Plot pull-down menu

This draws down menu enables you to plot the different parts of the model, for example, key points, areas, volumes and elements

4.6.4 Plot CTRL's pull-down menu

This menu incorporates the controls to skillet/zoom/pivot your model, select the numbering alternatives, change styles and create printed copies of the plots.

Ansys Geometry of Nozzle 1

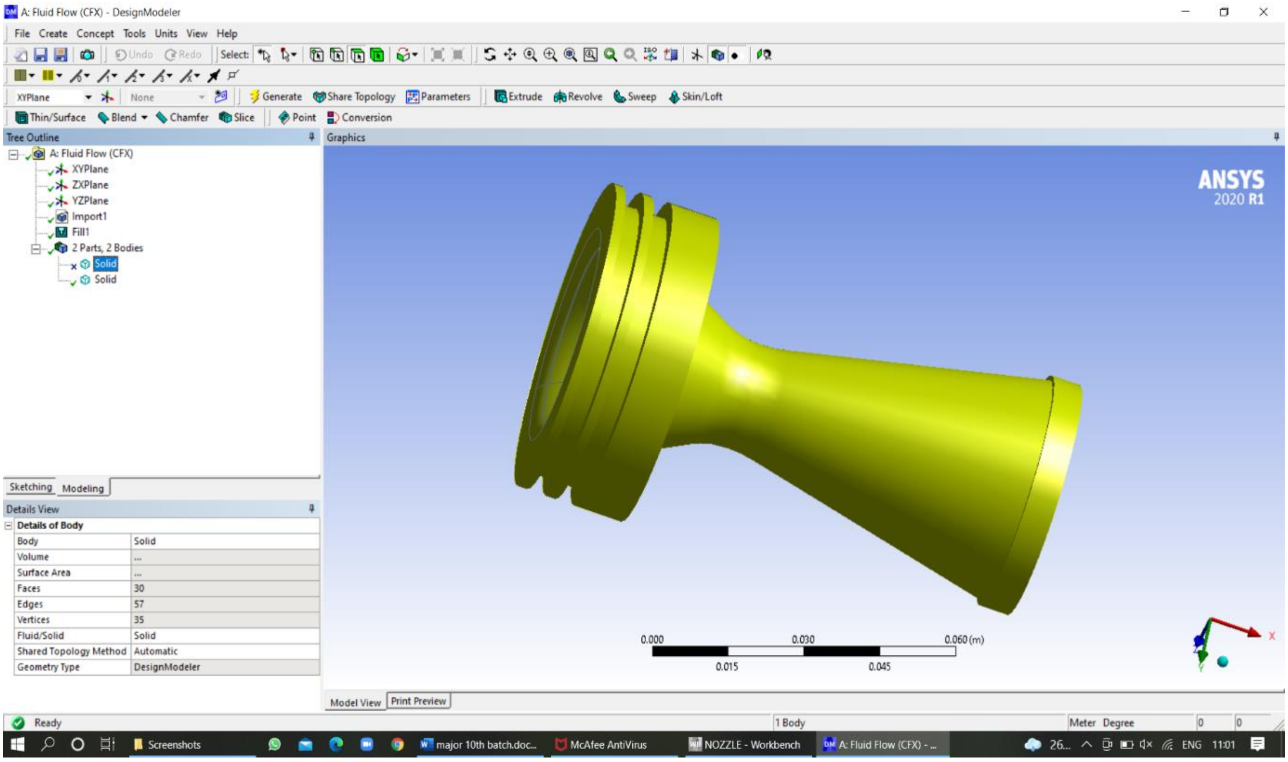

Fig 4.3 Ansys Geometry of Nozzle 1

Internal flow surface area of nozzle 1

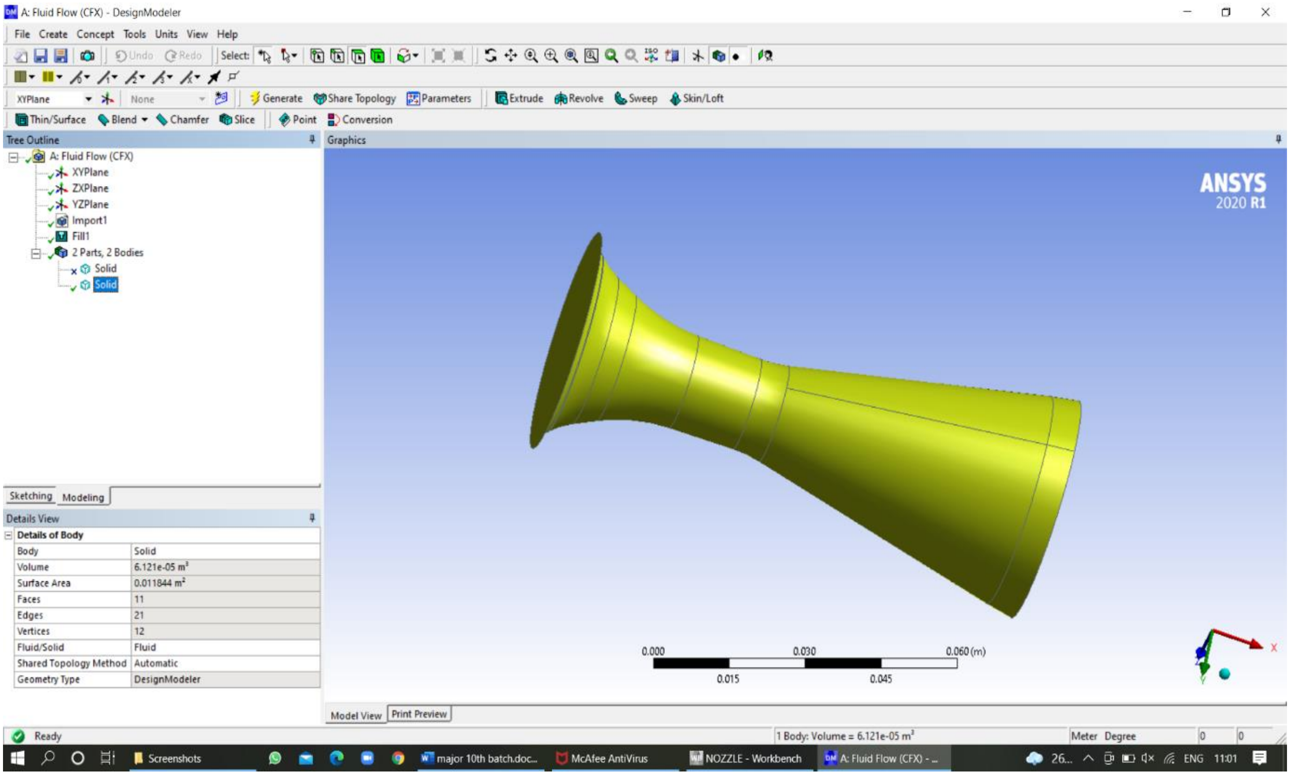

Fig 4.4 Internal flow surface area of nozzle 1

Mesh analysis of Nozzle 1

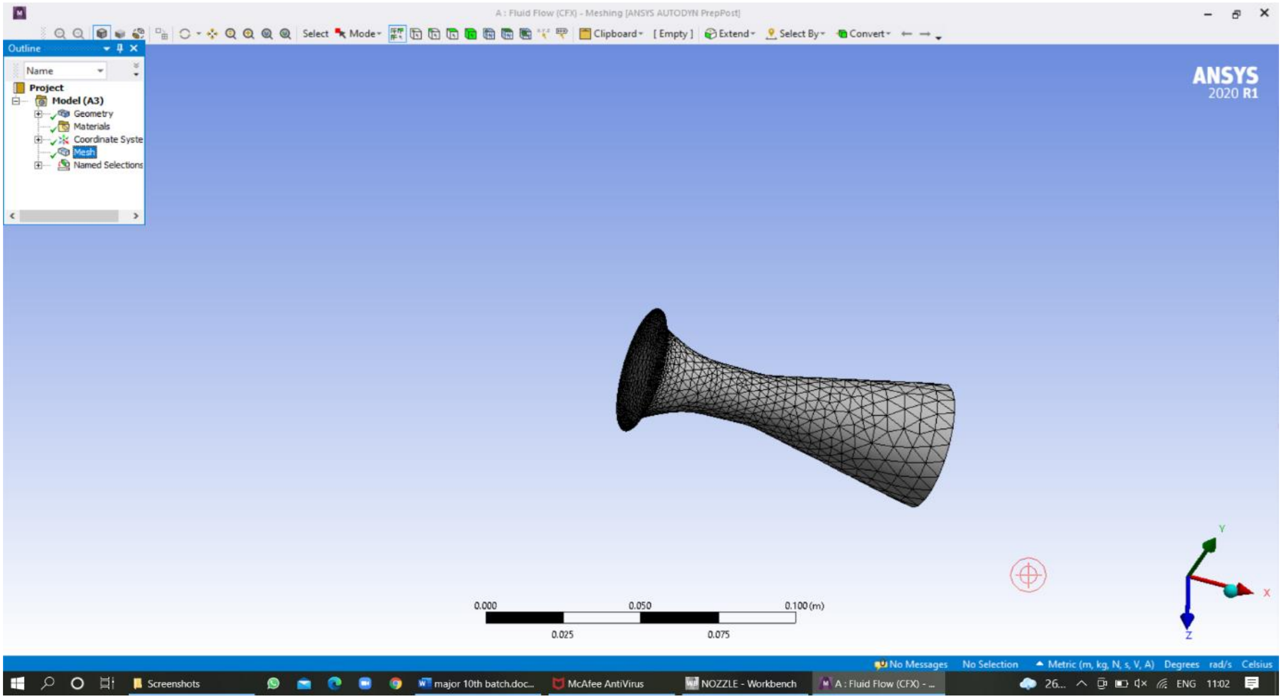

Fig 4.5Mesh analysis of Nozzle 1

Inlet of nozzle 1

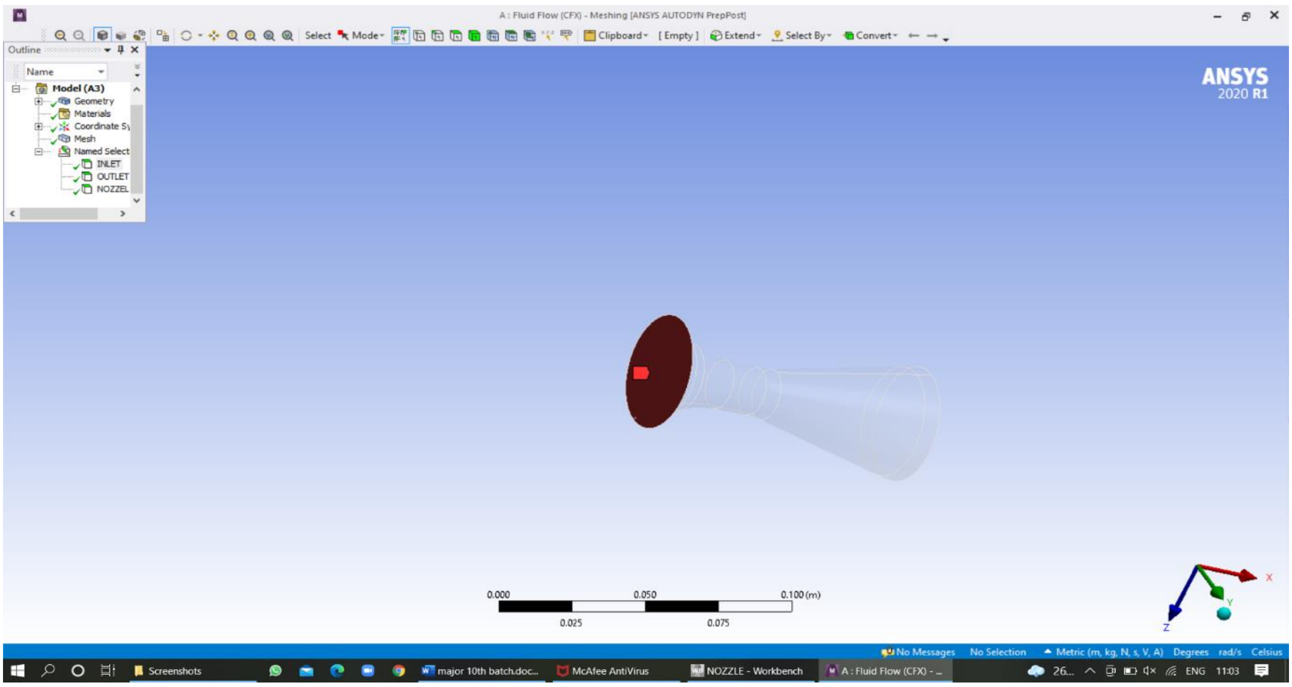

Fig 4.6 Inlet of nozzle 1

Outlet of Nozzle 1

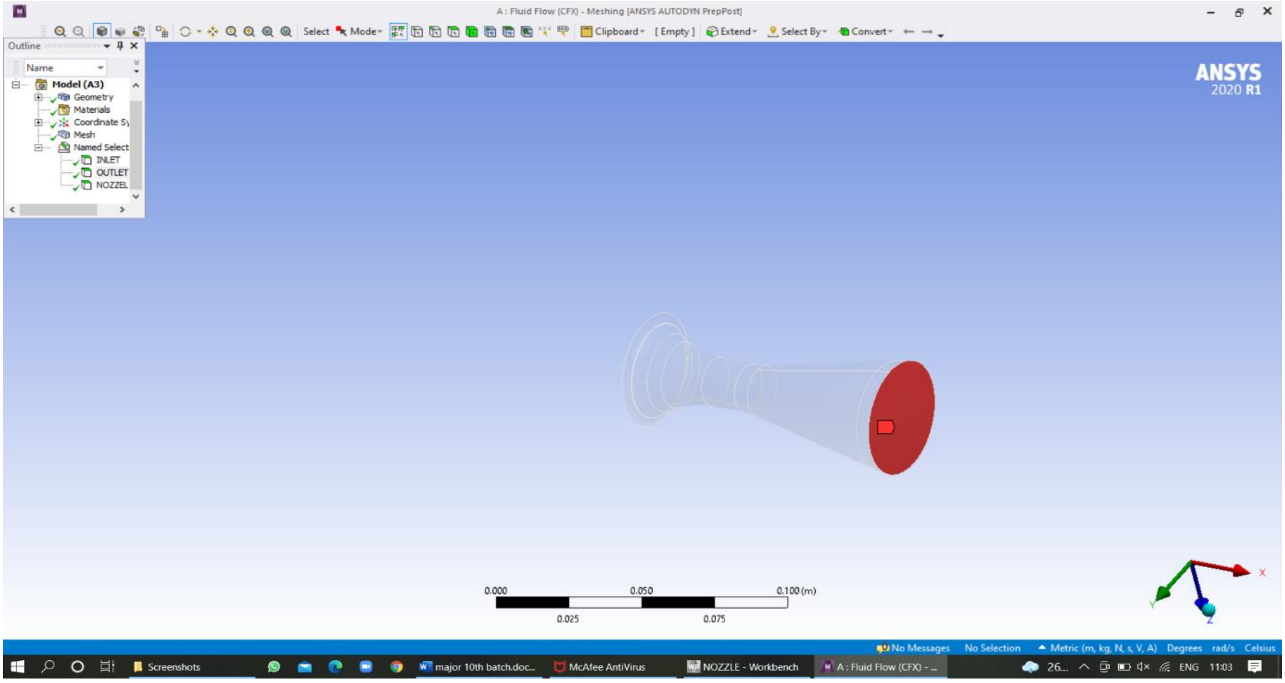

Fig 4.7 Outlet of Nozzle 1

Nozzle wall 1

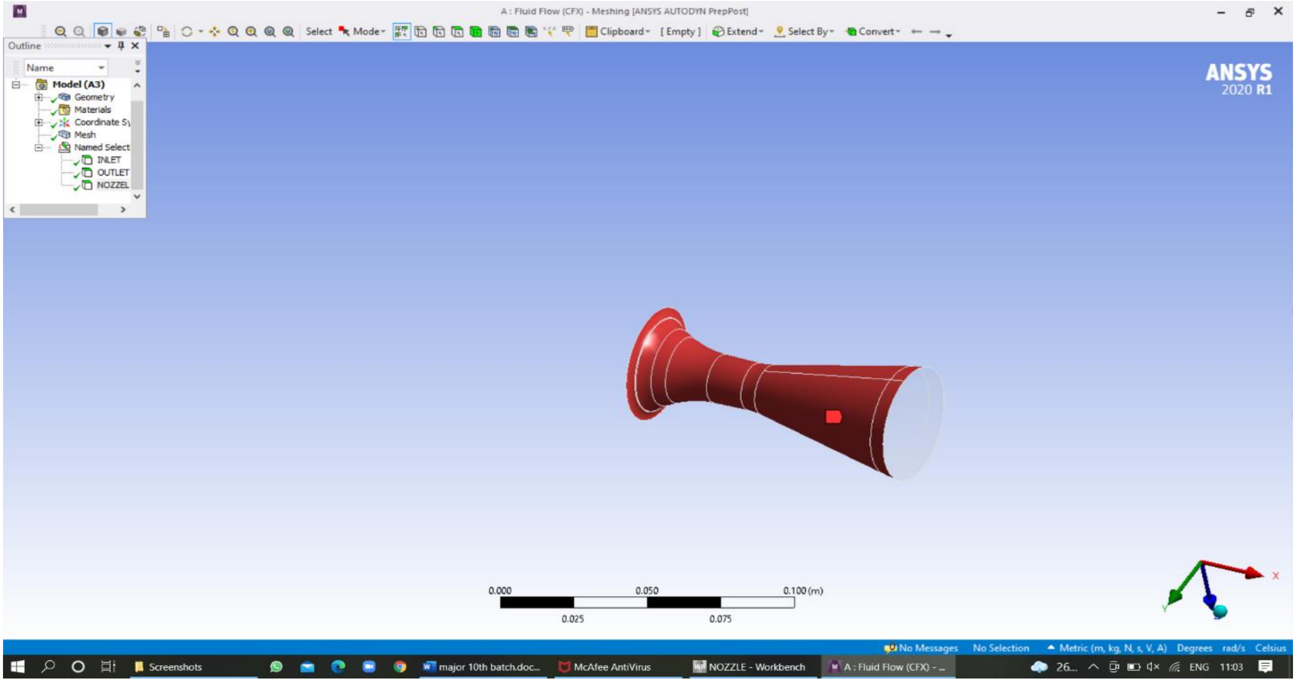

Fig 4.8 Nozzle wall 1

Velocity 1

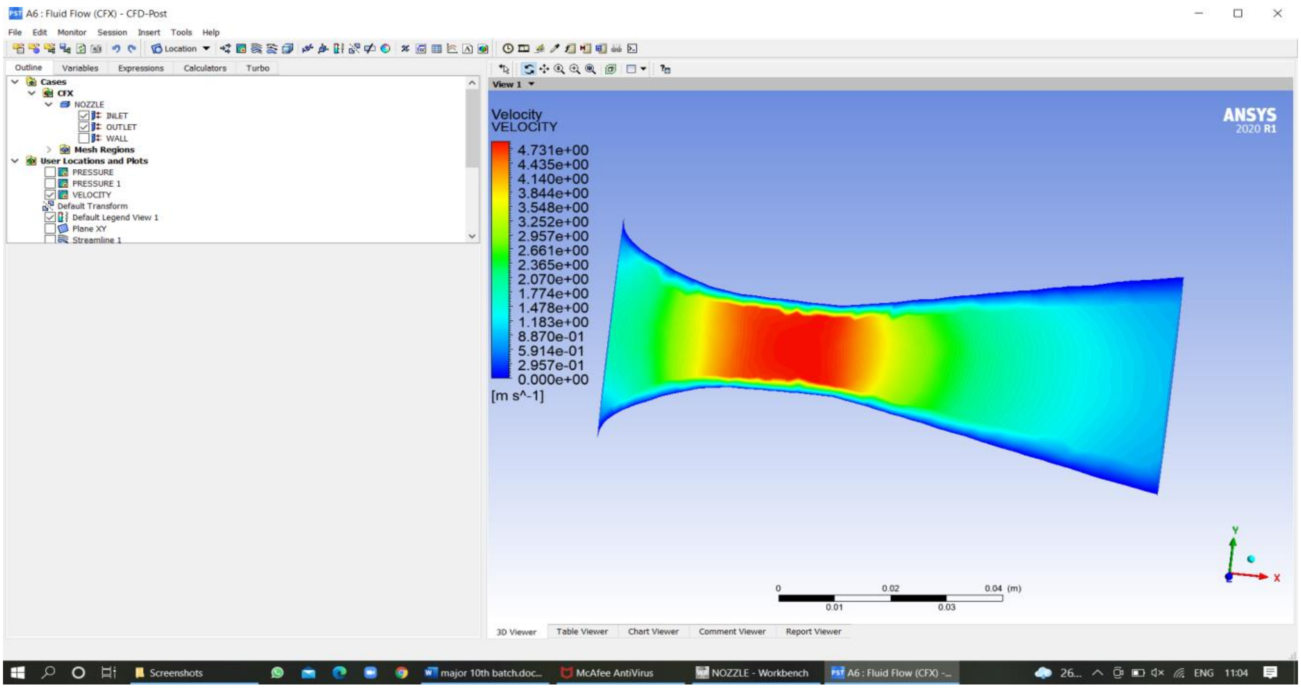

Fig 4.9 Velocity 1

Pressure 1

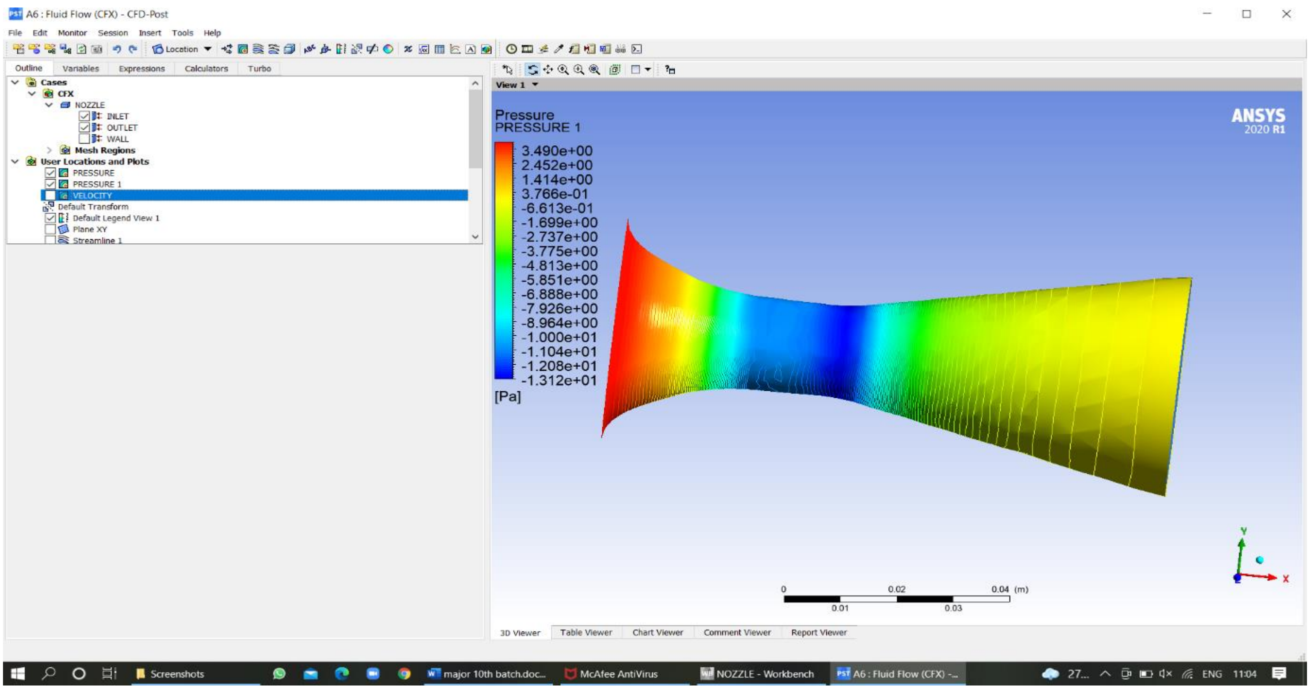

Fig 4.10 Pressure 1

Ansys Geometry of Nozzle 2

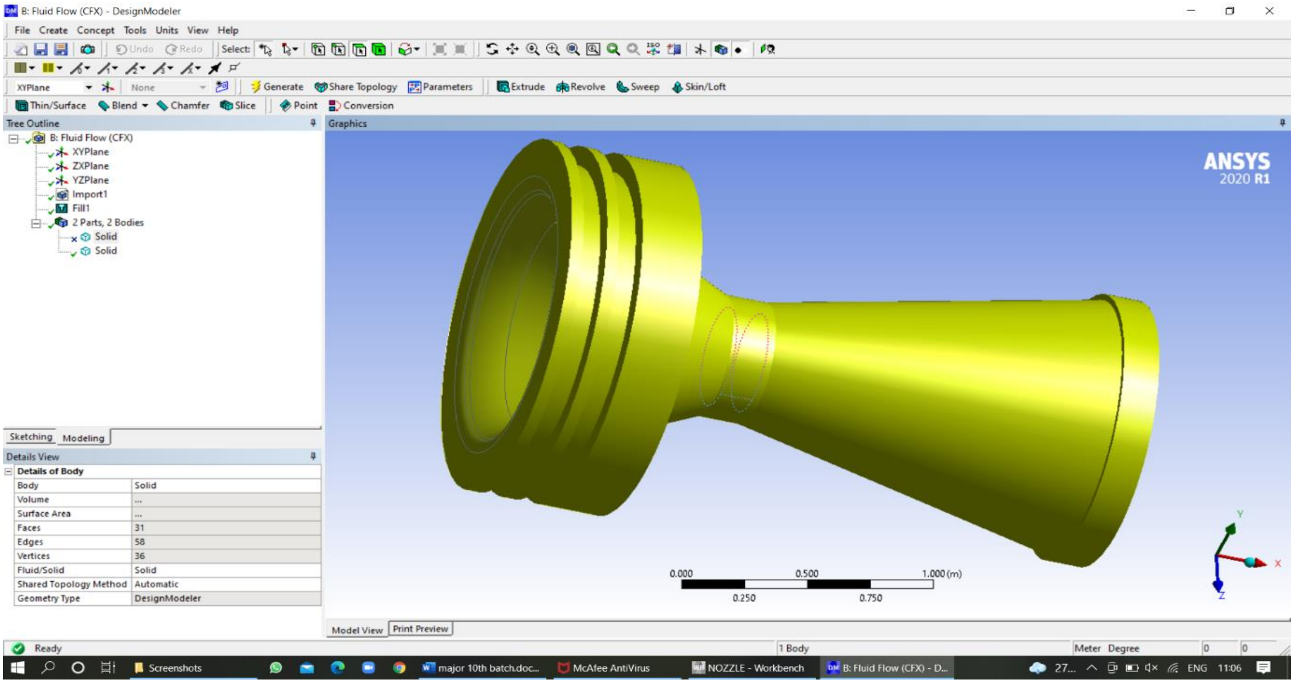

Fig 4.11 Ansys Geometry of Nozzle 2

Internal flow surface area of nozzle 2

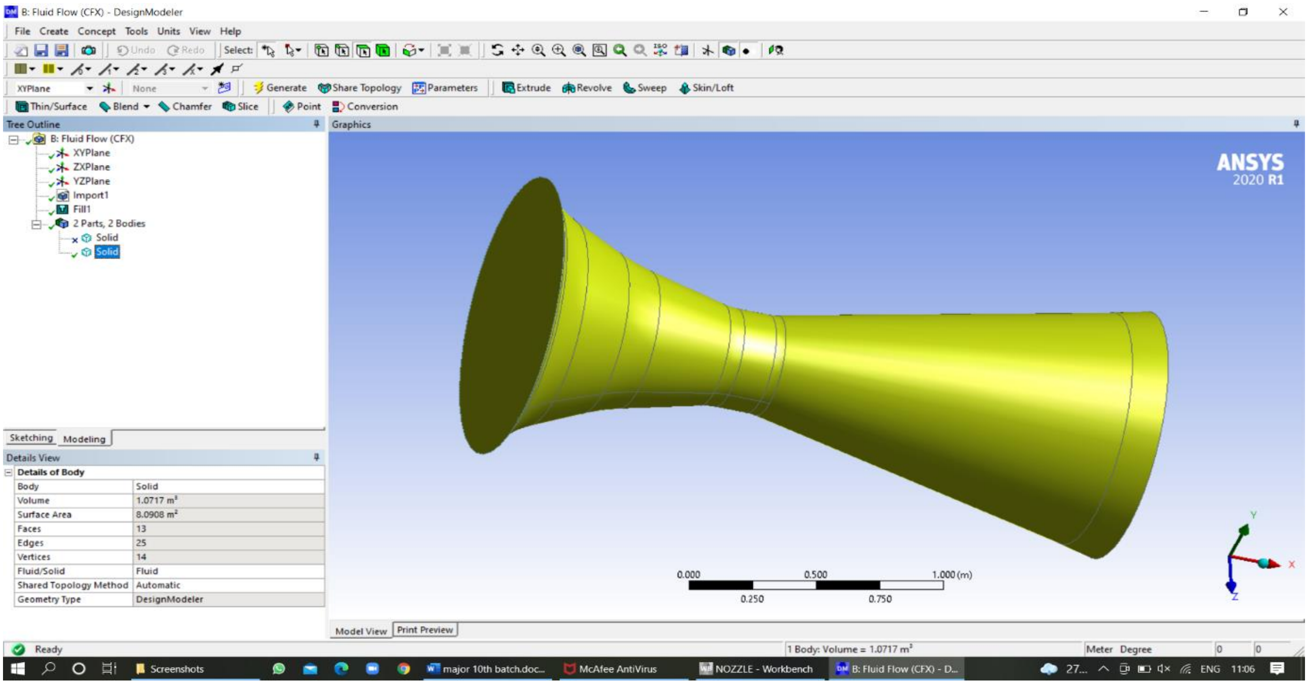

Fig 4.12 Internal flow surface area of nozzle 2

Mesh analysis of Nozzle 2

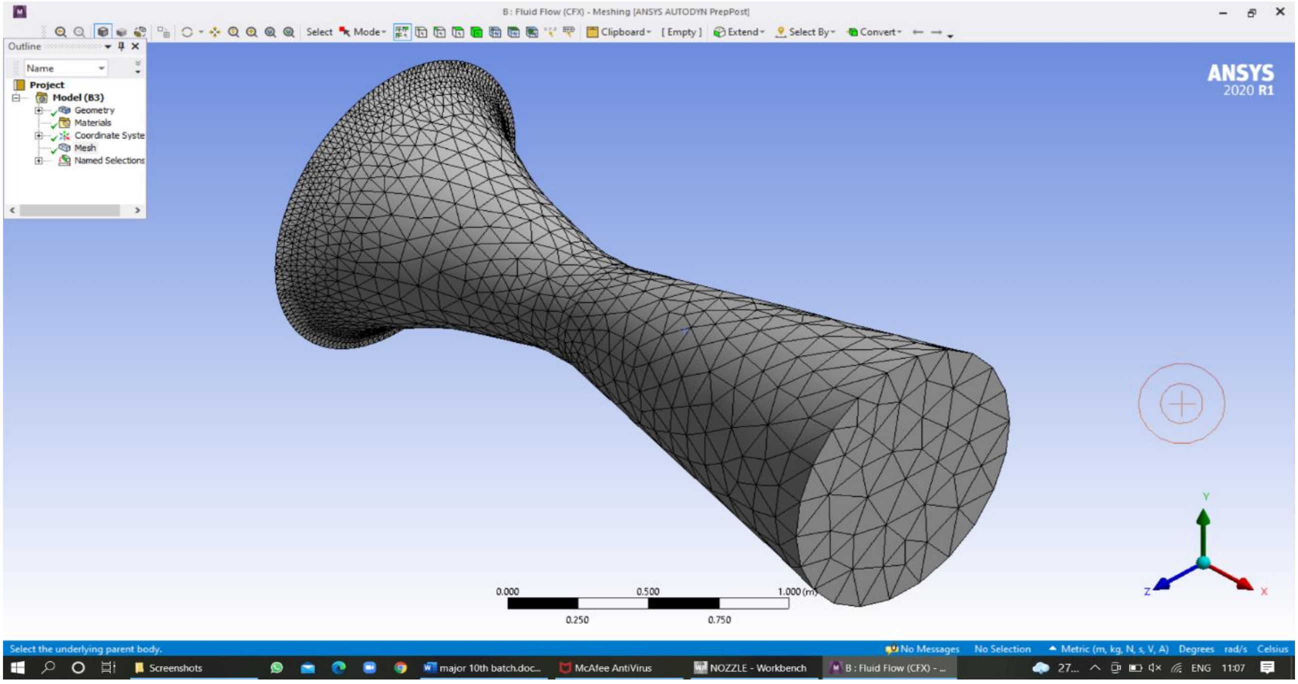

Fig 4.13 Mesh analysis of Nozzle 2

Outlet of nozzle 2

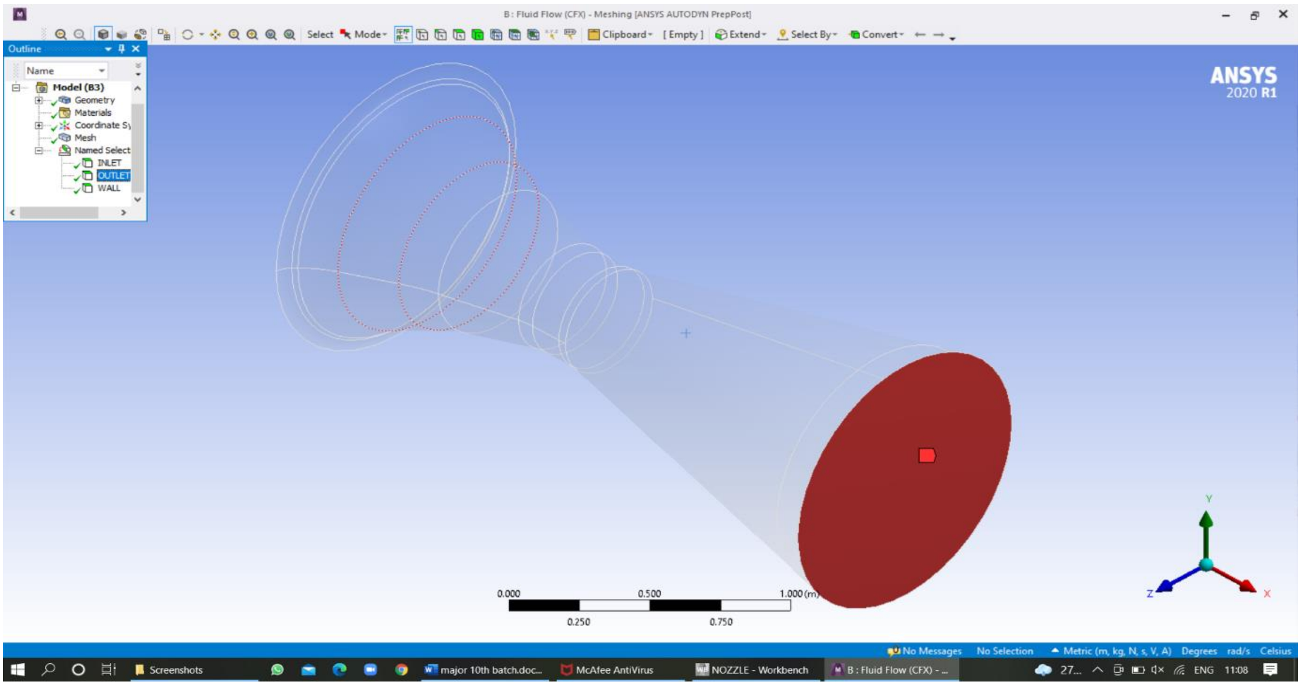

Fig 4.14 Outlet of nozzle 2

Nozzle wall 2

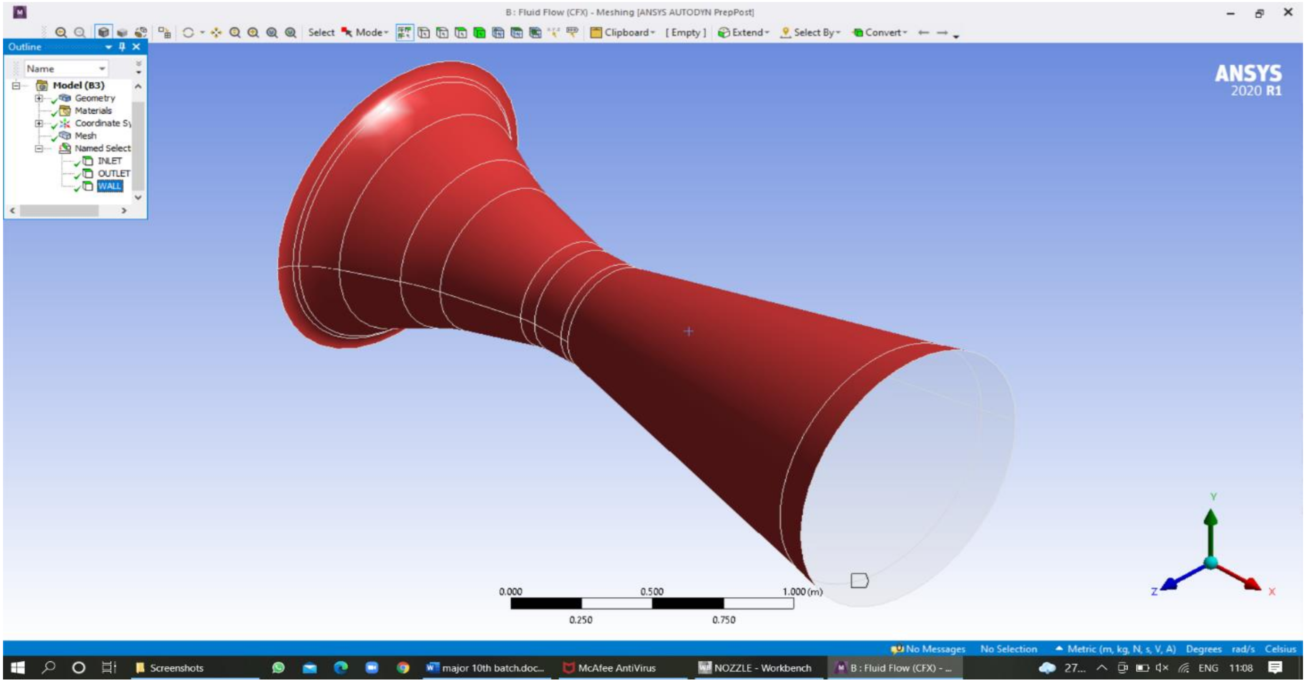

Fig 4.15 Nozzle wall 2

Inlet of Nozzle 2

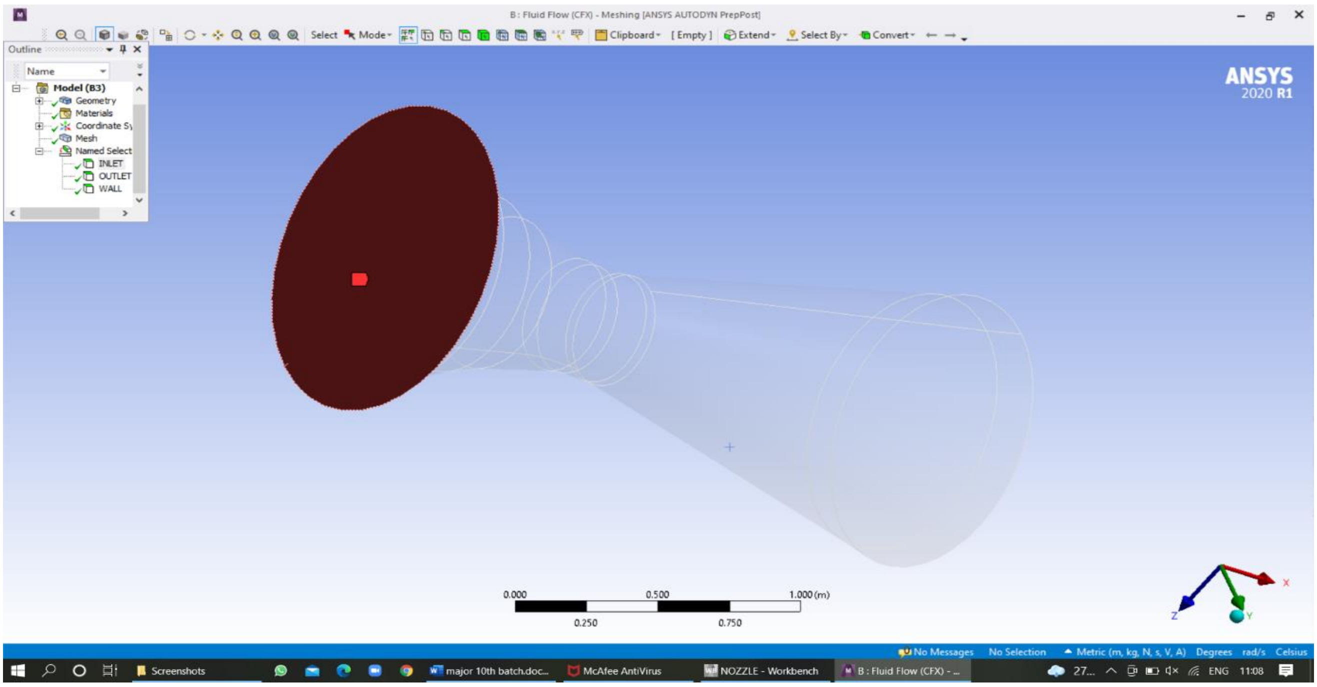

Fig 4.16 Inlet of Nozzle 2

Velocity 1

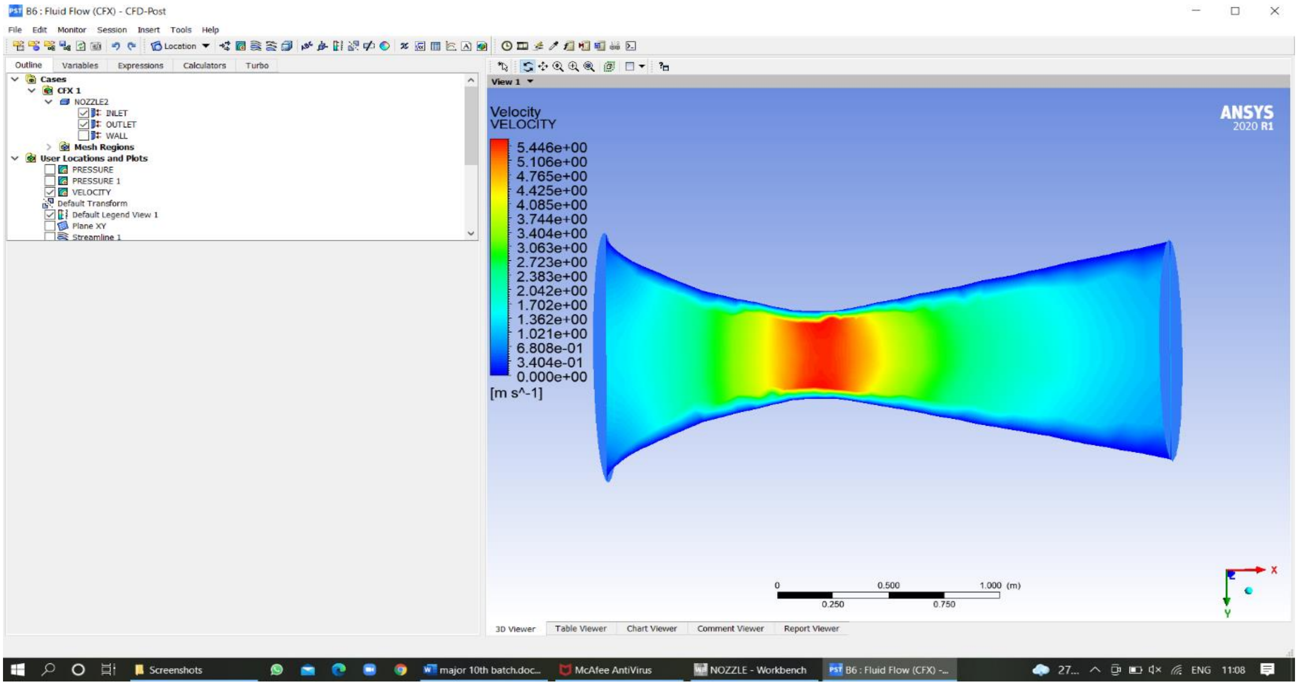

Fig 4.17 Velocity 1

Pressure 2

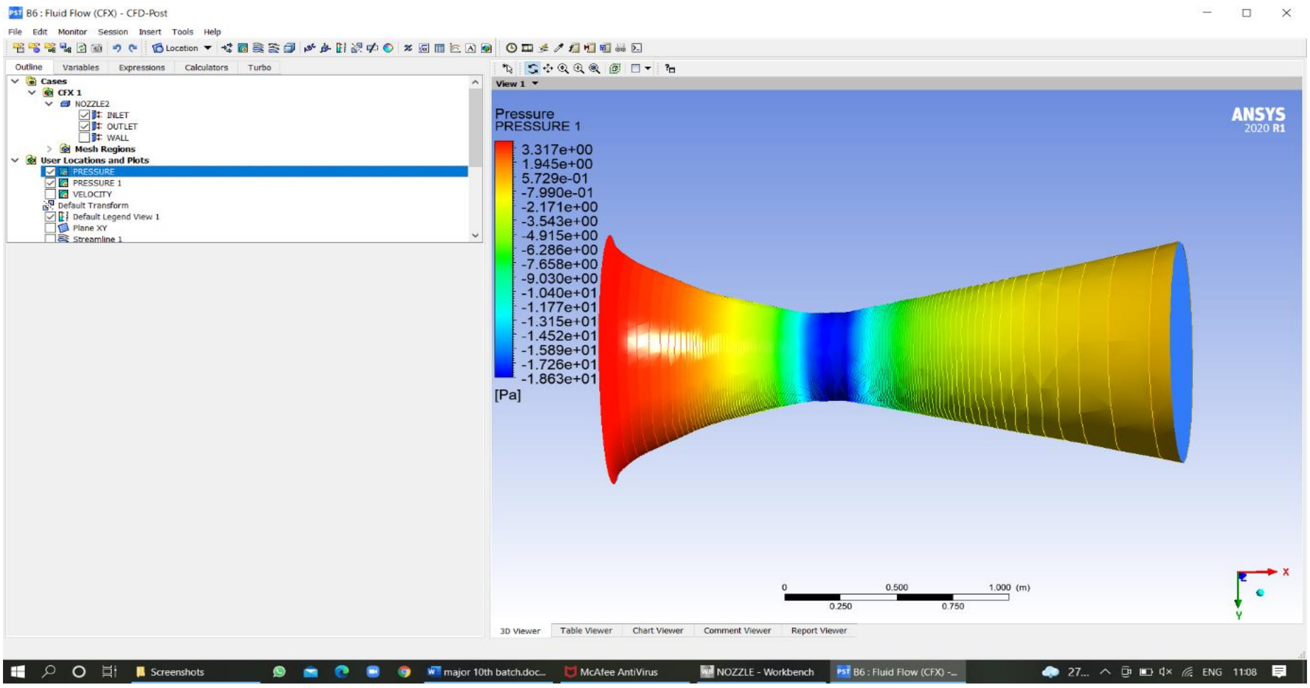

Fig 4.18 Pressure 2

CHAPTER-5
EXPERIMENTAL RESULTS

RESULT

The below table shows the difference in pressure and velocity at different points

S.NO		PRESSURE (pa)			VELOCITY(ms^-1)		
		P1 (inlet)	P2 (outlet)	P3 (throat)	V1 (inlet)	V2 (throat)	V3 (outlet)
1	NOZZLE 1	3.9	-12.61	-0.02	2.00	4.8	2.1
2	NOZZLE 2	1.3	-0.08	-18.26	1.00	1.84	1.022

Table 5

- Inlet pressure of nozzle is 3.9pa where outlet and pressure at throat is -12.61 and -0.02 respectively.
- Velocity in nozzle 1 is varying from inlet to outlet through throat is 2, 4.8, 2.1 ms^-1 respectively as shown in above table.
- When it comes to nozzle 2 the inlet pressure is 1.3pa and outlet pressure is -0.08pa and the throat pressure is-18.26.
- The velocity in nozzle 2 is, at inlet it is 1 ms^-1, at outlet is 1.002 ms^-1and at the throat is 1.84 ms^-1.

Chapter -6

CONCLUSION

- From the above table we can conclude that when we decrease the throat diameter the pressure and velocity will be changed.
- We can also observe that there will be more decreases in pressure than the decrease in velocity
- This type of nozzles has wide range of applications in aerospace industry like in ramjet engine ,rocket engine etc.

The results obtained analytically are in accordance with theoretical

relations used thus validating the results. It can be concluded that the

optimization of the design resulted in better performance that is air is

accelerated at must faster rate and reduced pressure in the CD Nozzle

model than the conventional cylindrical model.

FUTURE ENHANCEMENT

The work is to be further continued by doing fluid flow analysis for both the models and imparting rotational speed to the fan to accelerate the air at much better rate. The present study focuses only on circular geometry of the CD Nozzle and this work can be further continued by changing the geometry to rectangular and ellipse at the inlet, outlet and at the throat

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A Major Project Report

on

DESIGN OF FOOT OVER BRIDGE WITH THE VARIATION OF STIFFNESS TO WEIGHT RATIO WITH THE HELP OF TOPOLOGY OPTIMIZATION

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

Submitted by

K.SAI TEJA - (17K81A0381)

MD. MAHBOOB UR RAHMAN - (17K81A0391)

S. VIJAY KUMAR - (17K81A03A9)

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Under the Guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

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Dhulapally, Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Design of Foot Over Bridge with the variation of Stiffness to Weight ratio with the help of Topology Optimization**, is being submitted by **K. Sai Teja (17K81A0381) , MD. Mahboob Ur Rahman (17K81A0391) , S. Vijay Kumar (17K81A0A9), T. Ankith Singh(17K81A03B3)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

V. SRIPAL

Assistant Professor,

Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH

Professor & Head of the Department

Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Design of Foot Over Bridge with the variation of Stiffness to Weight ratio with the help of Topology Optimization** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

K.SAI TEJA	(17K81A0381)
MD. MAHBOOB UR RAHMAN	(17K81A0391)
S.VIJAY KUMAR	(17K81A03A9)
T. ANKITH SINGH	(17K81A03B3)

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K.SAI TEJA (17K81A0381)

MD. MAHBOOB UR RAHMAN (17K81A0391)

S.VIJAY KUMAR (17K81A03A9)

T. ANKITH SINGH (17K81A03B3)

ABSTRACT

Footbridges are needed where there is a separate pathway must be supplied for human beings to move site visitors flows or some physical impediment, along with a river. The masses they convey are, with regards to toll road or railway bridges, pretty modest, and in most circumstances a reasonably light structure is needed. They are but, often required to give a protracted clear span, and stiffness then becomes an crucial consideration. The bridges are frequently required very virtually on view to the general public and consequently the advent deserves careful attention. Steel offers financial and appealing kinds of creation which suit all of the requirements demanded of a footbridge.

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CHAPTER-1

INTRODUCTION

1.1. OVERVIEW OF THE PROJECT:

A footbridge (also a pedestrian bridge, pedestrian overpass, or pedestrian overcrossing) is a bridge designed solely for pedestrians.[1] While the primary meaning for a bridge is a structure which links "two points at a height above the ground", a footbridge can also be a lower structure, such as a boardwalk, that enables pedestrians to cross wet, fragile, or marshy land.[2] Bridges range from stepping stones–possibly the earliest man-made structure to "bridge" water–to elaborate steel structures. Another early bridge would have been simply a fallen tree. In some cases a footbridge can be both functional and artistic.

For rural communities in the developing world, a footbridge may be a community's only access to medical clinics, schools, businesses and markets. Simple suspension bridge designs have been developed to be sustainable and easily constructed in such areas using only local materials and labor.

An enclosed footbridge between two buildings is sometimes known as a skyway. Bridges providing for both pedestrians and cyclists are often referred to as green bridges and form an important part of a sustainable transport system.

Footbridges are often situated to allow pedestrians to cross water or railways in areas where there are no nearby roads. They are also located across roads to let pedestrians cross safely without slowing traffic. The latter is a type of pedestrian separation structure, examples of which are particularly found near schools.

The simplest type of a bridge is stepping stones, so this may have been one of the earliest types of footbridge. Neolithic people also built a form of a boardwalk across marshes, of which the Sweet Track, and the Post Track are examples from England that are around 6000 years old. Undoubtedly ancient peoples would also have used log bridges; that is a timber bridge that fall naturally or are intentionally felled or placed across streams. Some of the first man-made bridges with significant span were probably intentionally felled trees.

Among the oldest timber bridges is the Holzbrücke Rapperswil-Hurden crossing upper Lake Zürich in Switzerland; the prehistoric timber piles discovered to the west of the Seedamm date back to 1523 B.C. The first wooden footbridge led across Lake Zürich, followed by several reconstructions at least until the late 2nd century AD, when the Roman Empire built a 6-metre-wide (20 ft) wooden bridge. Between 1358 and 1360, Rudolf IV, Duke of Austria, built a 'new' wooden bridge across the lake that has been used to 1878 – measuring approximately 1,450 metres (4,760 ft) in length and 4 metres (13 ft) wide. On April 6, 2001, the reconstructed wooden footbridge was opened, being the longest wooden bridge in Switzerland.

A clapper bridge is an ancient form of bridge found on the moors of Devon (Dartmoor and Exmoor) and in other upland areas of the United Kingdom including Snowdonia and Anglesey, Cumbria, Yorkshire and Lancashire. It is formed by large flat slabs of stone, often granite or schist, supported on stone piers (across rivers), or resting on the banks of streams. Although often credited with prehistoric origin, most were erected in medieval times, and some in later centuries. First recorded in the 14th century, the bridge is believed to have been originally built in the 13th century to enable pack horses to cross the river. Nowadays clapper bridges are only used as footbridges.

The Kapellbrücke is a 204-metre-long (669 ft) footbridge crossing the River Reuss in the city of Lucerne in Switzerland. It is the oldest wooden covered bridge in Europe, and one of Switzerland's main tourist attractions. The bridge was originally built c. 1365 as part of Lucerne's fortifications.

An early example of a skyway is the Vasari Corridor, an elevated, enclosed passageway in Florence, central Italy, which connects the Palazzo Vecchio with the Palazzo Pitti. Beginning on the south side of the Palazzo Vecchio, it then joins the Uffizi Gallery and leaves on its south side, crossing the Lungarno dei Archibusieri and then following the north bank of the River Arno until it crosses the river at Ponte Vecchio. It was built in five months by order of Duke Cosimo I de' Medici in 1565, to the design of Giorgio Vasari.

Bank Bridge is a famous 25 metre long pedestrian bridge crossing the Griboedov Canal in Saint Petersburg, Russia. Like other bridges across the canal, the existing structure dates from 1826. The special popularity of the bridge was gained through angular sculptures of four winged lions crowning the abutments. They were designed by sculptor Pavel Sokolov (1764-1835), who also contributed lions for Bridge of Lions.

1.2. DESIGN:

Design of footbridges normally follows the same principles as for other bridges. However, because they are normally significantly lighter than vehicular bridges, they are more vulnerable to vibration and therefore dynamics effects are often given more attention in design. International attention has been drawn to this issue in recent years by problems on the Pont de Solférino in Paris and the Millennium Bridge in London. To ensure footbridges are accessible to disabled and other mobility-impaired people, careful consideration is nowadays also given to provision of access lifts or ramps, as required by relevant legislation (e.g. Disability Discrimination Act 1995 in the UK). Some old bridges in Venice re now equipped with a stair lift so that residents with a disability can cross them.

1.3. TYPES OF FOOTOVER BRIDGES

Types of footbridges include but are not limited to:

- Beam Bridge
- Boardwalk
- Clapper bridge
- Plank road
- Corduroy road
- Moon bridge
- Simple suspension bridge
- Living bridge
- Simple truss

- Stepping stones
- Zig-zag bridge

1.4. BEAM BRIDGES:

Beam bridges, also known as stringer bridges, are the simplest structural forms for bridge spans supported by an abutment or pier at each end. No moments are transferred throughout the support, hence their structural type is known as simply supported.

The simplest beam bridge could be a log (see log bridge), a wood plank, or a stone slab (see clapper bridge) lay across a stream. Bridges designed for modern infrastructure will usually be constructed of steel or reinforced concrete, or a combination of both. The concrete elements may be reinforced, pre-stressed or post-tensioned. Such modern bridges include girder, plate girder, and box girder bridges, all types of beam bridges.

Types of construction could include having many beams side by side with a deck across the top of them, to a main beam either side supporting a deck between them. The main beams could be I-beams (also known as H-beams), trusses, or box girders. They could be half-through, or braced across the top to create a through bridge.

Because no moments are transferred, thrust (as from an arch bridge) cannot be accommodated, leading to innovative designs, such as lenticular trusses and bow string arches, which contain the horizontal forces within the superstructure.

Beam bridges are not limited to a single span. Some viaducts such as the Feiyunjiang Bridge in China have multiple simply supported spans supported by piers. This is opposed to viaducts using continuous spans over the piers.

Fig-1 Beam bridge

Beam bridges are often only used for relatively short distances because, unlike truss bridges, they have no built in supports. The only supports are provided by piers. The farther apart its supports, the weaker a beam bridge gets. As a result, beam bridges rarely span more than 250 feet (80 m). This does not mean that beam bridges are not used to cross great distances; it only means that a series of beam bridges must be joined together, creating what is known as a continuous span.

1.5. BOARDWALK:

A boardwalk (alternatively board walk, boarded path, or promenade) is an elevated footpath, walkway, or causeway built with wooden planks that enables pedestrians to cross wet, fragile, or marshy land. They are also in effect a low type of bridge. Such timber track ways have existed since at least Neolithic times.

Some wood boardwalks have had sections replaced by concrete and even"a type of recycled plastic that looks like wood”

An early example is the Sweet Track that Neolithic people built in the Somerset levels, England, around 6000 years ago. This track consisted mainly of planks of oak laid end-to-end, supported by crossed pegs of ash, oak, and lime, driven into the underlying peat.

The Wittmoor bog trackway is the name given to each of two prehistoric plank roads, or boardwalks, trackway No. I being discovered in 1898 and trackway No. II in 1904 in the Wittmoor bog in northern Hamburg, Germany. The trackways date to the 4th and 7th century AD, both linked the easten and western shores of the formerly inaccessible, swampy bog. A part of the older trackway No. II dating to the period of the Roman Empire is on display at the permanent exhibition of the Archaeological Museum Hamburg in Harburg borough, Hamburg.

Fig-2 Board walk

A duckboard is a type of boardwalk placed over muddy and wet ground.During World War I, duckboards were used to line the bottom of trenches on the Western Front because these were regularly flooded, and mud and water would lie in the trenches for months on end. The boards helped to keep the soldiers' feet dry and prevent the development of trench foot, caused by prolonged standing in waterlogged conditions. They also allowed for troops' easier movement through the trench systems.

Fig-2.1Board walk

Combat troops on nearly all sides routinely wore hobnail-style trench boots that often slipped on the new duck boards when they were wet and required extra caution. Falling or slipping off the duckboards could often be dangerous, even fatal. Unfortunate soldiers were left struggling to rise under the weight of their equipment in the intractable and sometimes deep water or mud. If this happened at ground level during a tactical advance, the rising soldier could be left a defenseless target for enemy fire as well as hinder forward progress. He could also simply go unnoticed in the ensuing melee, and easily drown under his heavy equipment

1.6. CLAPPER BRIDGE:

A clapper bridge is an ancient form of bridge found on the moors of the English West Country (Bodmin Moor, Dartmoor and Exmoor) and in other upland areas of the united kingdom including Snowdonia and Anglesey , Cumbria , Yorkshire, Lancashire and Scotland. It is formed by large flat slabs of stone, often granite or schist, supported on stone piers (across rivers), or resting on the banks of streams.

Fig-3 Clapper bridge

Although often credited with prehistoric origin, most were erected in medieval times, and some in later centuries. They are often situated close to a ford where carts could cross. According to the Dartmoor National Park, the word 'clapper' derives ultimately from an Anglo-Saxon word, cleaca, meaning 'bridging the stepping stones'; the Oxford English Dictionary gives the intermediate Medieval Latin form clapus, claperius, "of Gaulish origin", with an initial meaning of "a pile of stones”.

1.7. PLANK ROAD:

A plank road is a road composed of wooden planks or puncheon logs. Plank roads were commonly found in the Canadian province of Ontario as well as the Northeast and Midwest of the United States in the first half of the 19th century. They were often built by turnpike companies.

The Wittmoor bog trackway is the name given to each of two historic plank roads or boardwalks, trackway No. I being discovered in 1898 and trackway No. II in 1904 in the Wittmoor bog in northern Hamburg, Germany. The trackways date to the 4th and 7th century AD, both linked the eastern and western shores of the formerly inaccessible, swampy bog. A part of the older trackway No. II dating to the period of the Roman Empire is on display at the permanent exhibition of the Archaeological Museum Hamburg in Harburg, Hamburg.

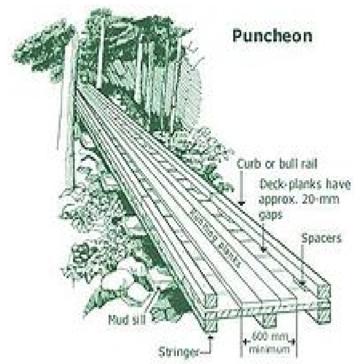

Fig-4 Plank road

This type of plank road is known to have been used as early as 4,000 BC with, for example, the Post Track found in the Somerset levels near Glastonbury, England. This type of road was also constructed in Roman times.

From the mid 1840s and to mid 1850s, the United States experienced the Plank Road Boom and a subsequent bust. The first plank road in the US was built in North Syracuse, New York, to transport salt and other goods; it appears to have copied earlier roads in Canada, which had copied Russian ones. The plank road boom, like many other early technologies, promised to transform the way people lived and worked and led to permissive changes in legislation seeking to spur development, speculative investment by private individuals, etc.

Fig-4.1 Plank road

Three plank roads, the Hackensack, the Paterson, and the Newark, were major arteries in northern New Jersey. The roads travelled over the New Jersey Meadowlands, connecting the cities for which they were named to the Hudson River waterfront.

U.S. Route 1 in Virginia follows the Boydton Plank Road from Petersburg southwards to just north of the North Carolina line.

On the U.S. West Coast the Canyon Road of Portland, Oregon was another important but short artery and was built between 1851 and 1856.

Kingston Road (Toronto) (Governor's Road) and Danforth Avenue, in Toronto, were plank roads built by the Don and Danforth Plank Road Company in the late 18th and the early 19th centuries. Highway 2 from Toronto eastwards was a plank road in the 19th century that was later paved.

Plank roads are used exclusively in the Canadian fishing outport of Harrington Harbour, Quebec because the town is built directly over a hilly, rocky shore. ATVs are the only mode of transportation there.

Fig-4.2 Plank road

1.8. CORDUROY ROAD:

A corduroy road or log road is a type of road or timber trackway made by placing logs, perpendicular to the direction of the road over a low or swampy area. The result is an improvement over impassable mud or dirt roads, yet rough in the best of conditions and a hazard to horses due to shifting loose logs.

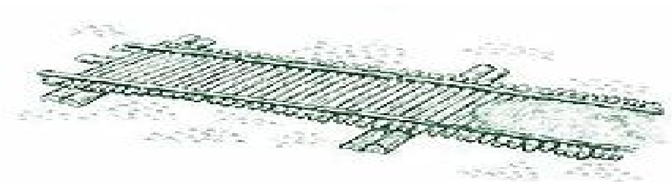

Fig-5 Corduroy Road

Corduroy roads can also be built as a foundation for other surfacing. If the logs are buried in wet, acidic, anaerobic soils such as peat or muskeg, they decay very slowly. A few corduroy road foundations that date back to the early 20th century still exist in North America. One example is the AlaskaHighway between Burwash Landing and Koidern, Yukon, Canada, which was rebuilt in 1943, less than a year after the original route was graded on thin soil and vegetation over permafrost, by using corduroy, then building gravel road on top. During the 1980s, the gravel was covered with a chip-seal. The late 1990s saw replacement of this road with modern road construction, including rerouting of the entire highway.

Fig-5.1 Corduroy road

In World War II they were used by both German and Soviet forces on the Eastern Front in slang use, corduroy road can also refer to a road in ill repair, having many potholes, ruts, or surface swellings. This should not be confused with a washboard road.

1.9. MOON BRIDGE:

A moon bridge is a highly-rounded arched pedestrian bridge associated with gardens in China and Japan. The moon bridge originated in China and was later introduced to Japan.

Fig-6 Moon bridge

This type of bridge was originally designed to allow pedestrians to cross canals while allowing the passage of barges beneath. When constructed using the climbing ascent and descent, it has the further advantage of not using space from the adjoining fields for approaches to the bridge.

In formal garden design, a moon bridge is placed so that it is reflected in still water. The high arch and its reflection form a circle, symbolizing the moon.

1.10. SIMPLE SUSPENSION BRIDGE:

A simple suspension bridge (also rope bridge, swing bridge (in New Zealand), suspended bridge, hanging bridge and catenary bridge) is a primitive type of bridge in which the deck of the bridge lies on two parallel load-bearing cables that are anchored at either end. They have no towers or piers. The cables follow a shallow downward catenary arc which moves in response to dynamic loads on the bridge deck.

Fig-7 Simple suspension bridge

The arc of the deck and its large movement under load make such bridges unsuitable for vehicular, or railroad, traffic. Simple suspension bridges are restricted in their use to foot traffic. For safety, they are built with stout handrail cables, supported on short piers at each end, and running parallel to the load-bearing cables. Sometime these may be the primary load-bearing element, with the deck suspended below. Simple suspension bridges are considered the most efficient, and sustainable design, in rural regions, especially for river crossings that lie in non-floodplain topography such as gorges.

1.11. LIVING BRIDGES:

In the northeast Indian state of Meghalaya, Khasi and Jaintia tribal people have created living root bridges, which are a form of tree shaping. Here, simple suspension bridges are made by training the roots of the Ficus elastica species of banyan tree across watercourses.[11] There are examples with a span of over 170 feet (52 m). They are naturally self-renewing and self-strengthening as the component roots grow thicker and some are thought to be more than 500 years old.

Fig-8 Living bridge

In the Iya Valley of Japan, bridges have been constructed using wisteria vines. To build such a bridge, these vines were planted on opposite sides of a river and woven together when they grew long enough to span the gap. The addition of planks produced a serviceable bridge

1.12. TRUSS:

A truss is an assembly of beams or other elements that creates a rigid structure.

In engineering, a truss is a structure that "consists of two-force members only, where the members are organized so that the assemblage as a whole behaves as a single object". A "two-force member" is a structural component where force is applied to only two points. Although this rigorous definition allows the members to have any shape connected in any stable configuration, trusses typically comprise five or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes.

Fig-9 Truss

In this typical context, external forces and reactions to those forces are considered to act only at the nodes and result in forces in the members that are either tensile or compressive. For straight members, moments (torques) are explicitly excluded because, and only because, all the joints in a truss are treated as revolutes, as is necessary for the links to be two-force members.

A planar truss is one where all members and nodes lie within a two-dimensional plane, while a space truss has members and nodes that extend into three dimensions. The top beams in a truss are called top chords and are typically in compression, the bottom beams are called bottom chords, and are typically in tension.

1.13. STEPPING STONES:

Stepping stones or stepstones are sets of stones arranged to form a simple bridge or causeway that allows a pedestrian to cross a natural watercourse, such as a river; or a water feature in a garden where water is allowed to flow between stone steps. Unlike other bridges, they have no spans. Although their origin is unknown, stepping stones, along with log bridges, are likely to have been one of the earliest forms of crossing inland bodies of water devised by humans

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Fig-10 Stepping stones

In traditional Japanese gardens, the term "iso-watari" refers to stepping stone pathways that lead across shallow parts of a pond. Using iso-watari for crossing ponds, or shallow parts of streams, one can view the fish and plants around or in the pond, like carp, turtles, and waterfowls. It works like a bridge, in a slower way of crossing.

Today, stepping stones are commonly used by mountaineers and hikers as a makeshift way of crossing uncharted or unanticipated streams and torrents. They may occur alongside a ford.

1.14. ZIG-ZAG BRIDGE:

A zigzag bridge is a pedestrian bridge composed of short segments, each set at an angle relative to its neighbors and usually with an alternating right and left turn required when traveling across the bridge. It is used in standard crossings for structural stability; and in traditional and contemporary Asian and Western landscape design across water gardens.

When constructed of wood, each segment is formed from planks and is supported by posts. When constructed of stone, the bridge will use short or long rectilinear slabs set upon stone footings

Fig-11 Zig-zag bridge

A zig-zag bridge is often seen in the Chinese garden, Japanese garden, and Zen rock garden. It may be made of stone slabs or planks as part of a pond design and is frequently seen in rustic gardens. It is also used in high art modern fountain gardens, often in public urban park and botanic garden landscapes.

The objective in employing such a bridge, constructed according to Zen philosophy and teachings, is to focus the walker's attention to the mindfulness of the current place and time moment - "being here, now". As it often has no railings, it is quite possible for an inattentive walker to simply fall off an end into the water.

The zigzag of paths and bridges also follows a principle of Chinese Feng Shui.

1.15. ADVANTAGES OF FOOT OVER BRIGES:

Much rural travel takes place on local footpaths, tracks and village roads. These provide essential access to water, firewood, farm plots and the classified road network. Communities and/or local government are generally responsible for this infrastructure.
Can be used to cross ways that aren’t meant for pedestrians such as highways, railway tracks, rivers etc.

Easy to build and dismantle whenever needed.
Maintenance cost and building costs are low.
Can last very long under favorable environmental conditions.

1.16. DISADVANTAGES OF FOOTOVER BRIDGES:

- Pedestrian overpasses over highways or railroads are expensive, especially when elevators or long ramps for wheelchair users are required.
- Without elevators or ramps, people with mobility handicaps will not be able to use the structure.
- People may prefer to walk across a busy road rather than climb a bridge, and this may be attributed to being in a hurry, perceiving the safety and security of the footbridge to be low, or simply because of feeling tiredness when climbing the stairs. It is recommended that overpasses should only be used where the number of users justifies the costs. The operational concept of the footbridge is based on the notion that pedestrians need to walk a longer distance and exert more physical effort so that the traffic flow is not interrupted.
- Narrow, enclosed structures can result in perceptions of low personal security among users. Wider structures and good lighting can help reduce this.

CHAPTER-2

LITERATURE STUDY

2.1 Literature Review:

Kao and Kou (2010) analyzed a symmetrical, fan-shaped cable-stayed bridge under sudden loss of cable as it is most critical phenomenon in the analysis of cable stayed bridge. Wolff and Starossek (2008) studied the collapse behaviour of a 3D cable-stayed bridge model and found out that the initial failure (loss) of the three cables around the pylon can trigger a zipper-type collapse associated with a large vertical deformation within the bridge deck. Jenkins and Gersten (2001) reports in FTA report that about 58% of terrorist attacks targeted the transportation sector including bridge structures. Mahoney (2007) analyzed typical highway bridges under blast loads. (Huang et al., 2011) studied the significant damage and collapse of several bridges which were occurred as the result of severe past earthquake events.

Therefore, he recommends different guidelines for response to seismic actions is considered in the design of bridges. For example, Xiaoyudong bridge in China was damaged during the May 12th 2008 Wenchuan earthquake with the magnitude of 8.0. (Kawashima et al., 2011, Hoshikuma, 2011).they studies the strong earthquake in Japan in Fukushima which created significant damage in several bridges caused by strong ground motion as well as tsunami inundation and soil liquefaction The dynamic response of cable stayed bridges is more critical due to effect of earthquake and wind loadings as compared to other types of bridges. However with increasing span length and increasing slenderness of the stiffening girder the great attention is paid not only to dynamic response of bridges under earthquake and wind loading but also to the dynamic traffic loading.

2.2 Literature Survey:

The surveyor determines the length of the bridge crossing to estimate the materials required for construction. Depending on the distance and equipment available, the surveyor measures this distance with a tape, an electronic measuring device, or by stadia method.The surveyor reports on the character and shape of the riverbanks. This includes the amount and type of vegetation; the slope, height, and composition of the banks; and pertinent dimensions of any natural dikes. The surveyor selects tentative abutment positions and measures the size and location of any usable abutments or piers for possible use in the proposed construction.

The surveyor profiles the streambed or gap to facilitate the design of intermediate supports. The profile interval is measured by a tape or cable stretched horizontally across the stream or gap or by the instrument-stadia method. Vertical measurements for the profile are referenced to the horizontal tape, cable, or water surface. For floating bridges, profiles are required only for setting trestles near the shores.

The surveyor determines stream velocity by timing a floating object over a measured course. High-water levels are determined by noting drift and marks on vegetation or piers, questioning local inhabitants, and consulting tide tables and local flood records.The surveyor observes the character of the river bottom for each site and reports information on the design of intermediate supports. If a floating bridge is to be constructed, the surveyor determines the character of the river bottom so the holding power of anchors can be estimated.

2.3 Conclusion on Review:

The literature survey indicates that most of the research is done on seismic effects, wind effects, dynamic loadings on cable stayed bridges but actual design and analysis of cable stayed bridge is not done and validation of results on various analytical software's will give us the confidence of bridge design as that of a professional structural designer.

CHAPTER-III

PROJECT DESIGN

3.1 INTRODUCTION TO CATIA :

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

Developer(s)	Dassault Systems
Stable release	V6R2011x / November 23, 2010
Operating system	Unix / Windows
Type	CAD software
License	Proprietary
Website	WWW.3ds.com

TABLE:1 DETAILS OF CATIA

3.2 HISTORY OF CATIA:

CATIA began as an in-house progress in 1977 by French air ship producer Avions Marcel Dassault, around then client of the CADAM CAD programming to build up Dassault's Mirage warrior fly, and after that was gotten a handle on in the flight, auto, shipbuilding, and particular endeavors.

At first named CATI (Conception Assisted Tridimensional Interactive - French for Interactive Aided Three-dimensional Design) - it was renamed CATIA in 1981, when Dassault made a support to make and offer the thing, and indicated a non-explicit dispersing synchronization with IBM.

- In 1984, the Boeing Company picked CATIA as its guideline 3D CAD gadget, transforming into its greatest customer.
- In 1988, CATIA version 3 was ported from concentrated PC PCs to UNIX.
- In 1990, General Dynamics Electric Boat Corp picked CATIA as its guideline 3D CAD instrument, to structure the U.S. Maritime power's Virginia class submarine.

- In 1992, CADAM was purchased from IBM and the next year CATIA CADAM V4 was appropriated.
- In 1996, it was ported from one to four UNIX working structures, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS and Hewlett-Packard HP-UX.
- In 1998, a by and large changed adjustment of CATIA, CATIA V5 was released, with assistance for UNIX, Windows NT and Windows XP since 2001. In 2008, Dassault proclaimed and released CATIA V6. While the server can continue running on Microsoft Windows, Linux or AIX, client support for any working system other than Microsoft Windows is dropped.

3.2.1 Release History:

Name/Version	Latest Build Number	Original Release Date	Latest Release Date
CATIA v4	R25	1993	January 2007
CATIA v5	R20	1998	February 2010
CATIA v6	R2012	29/05/2008	May 2011

Table:2 Versions of CATIA

3.3 SCOPE OF APPLICATION:

Commonly implied as 3D Product Lifecycle Management programming suite, CATIA supports various periods of thing improvement (from conceptualization, plan (CAD), manufacturing (CAM), and building (CAE). CATIA empowers network arranged structure transversely over orders, including surfacing and shape layout, mechanical planning, apparatus and systems engineering.Commonly suggested as 3D Product Lifecycle Management programming suite, CATIA reinforces diverse periods of thing progression (from conceptualization, plan (CAD), creating (CAM), and structuring (CAE). CATIA empowers network arranged structure across over controls, including surfacing and shape layout, mechanical planning, apparatus and systems structuring.

3.3.1 Surfacing and shape design:

CATIA gives a suite of surfacing, making sense of, and discernment answers for make, change, and support complex innovative shapes. From subdivision, styling, and Class A surfaces to mechanical down to earth surfaces.

3.3.2 Mechanical engineering:

CATIA engages the generation of 3D segments, from 3D draws, sheet metal, composites, and shaped, designed or tooling parts up to the importance of mechanical social affairs. It offers devices to complete thing definition, including pragmatic protections, and furthermore kinematics definition.

3.3.3 Equipment design:

CATIA engages the development of 3D segments, from 3D draws, sheet metal, composites, and formed, produced or tooling parts up to the significance of mechanical social affairs. It offers instruments to complete thing definition, including utilitarian protections, and also kinematics definition.CATIA supports the layout of electronic, electrical and moreover passed on systems, for instance, fluid and HVAC structures, the separation to the production of documentation for amassing.

3.3.4 Systems engineering:

CATIA offers a response for presentation complex and sharp things through the structures building approach. It covers the requirements definition, the systems designing, the direct showing and the virtual thing or embedded programming period. CATIA can be revamped by methods for usage programming interfaces (API). CATIA V5 and V6 can be balanced using Visual Basic and C++ programming tongues through CAA (Component Application Architecture); a portion challenge appear (COM)- like interface.

Though later types of CATIA V4 completed NURBS, V4 basically used piece wise polynomial surface. CATIA V4 uses a non-complex solid engine. Catia V5 features a parametric solid/surface-based group which uses NURBS as the inside surface depiction and has a couple of workbenches that give KBE reinforce. V5 can work with various applications, including Enova, Smarteam, and distinctive CAE Analysis applications.

3.4 SUPPORTED OPERATING SYSTEMS AND PLATFORMS:

CATIA V6 runs just on Microsoft Windows and Mac OS with restricted items. CATIA V5 keeps running on Microsoft Windows (both 32-bit and 64-bit), and as of Release 18Service Pack4 on Windows Vista 64.IBM AIX, Hewlett Packard HP-UX and Sun Microsystems Solaris are upheld.

CATIA V4 is upheld for those Unixes and IBM MVS and VM/CMS centralized computer stages up to discharge 1.7. CATIA V3 and prior keep running on the centralized server stages.

3.5 APPLICATIONS OF CATIA:

CATIA can be associated with a wide collection of endeavors, from flying and obstruction, vehicle, and mechanical rigging, to bleeding edge, shipbuilding, customer items, plant layout, purchaser packaged stock, life sciences, designing and improvement, process power and oil, and organizations. CATIA V4, CATIA V5, Pro/E, NX (in the past Unigraphics), and Solid Works are the staggering systems.

3.5.1 Aerospace:

The Boeing Company used CATIA V3 to make its777 bearer, and is starting at now using CATIA V5 for the787 game plan plane. They have used the full extent of Dassault Systems' 3D PLM things — CATIA, DELMIA, and ENOVIALCA — enhanced by Boeing made applications.

- The progression of the Indian Light Combat Aircraft has been using CATIA V5.
- Chinese Xian JH-7 An is the main plane made by CATIA V5, when the arrangement was done on September 26, 2000.
- European avionics beast Airbus has been using CATIA since 2001.
- Canadian carrier maker Bombardier Aerospace has done most of its plane blueprint on CATIA.
- The Brazilian flying machine association, EMBRAER, use Catia V4 and V5 to create all planes.
- Vought Aircraft Industries use CATIA V4 and V5 to make its parts.
- The British Helicopter association, Westland, use CATIA V4 and V5 to convey all their flying machine. Westland is as of now part of an Italian association called Finmeccanica the joined association calls themselves AgustaWestland

3.5.2 Automotive:

Various car associations use CATIA to evolving degrees, including BMW, Porsche, Daimler AG, Chrysler, Honda, Audi, Jaguar Land RoverVolkswagen, Bentley Motors Limited, Volvo, Fiat, Benteler AG, PSA Peugeot Citroën, Renault, Toyota, Ford, Scania, Hyundai, Skoda Auto, Tesla Motors, Valmet Automotive, Proton, Tata motors and Mahindra and Mahindra Limited.

Goodyear uses it in making tires for vehicle and flight and besides uses a changed CATIA for its arrangement and headway. Various vehicle associations use CATIA for vehicle structures — gateway columns, IP supports, watch bars, housetop rails, side rails, body parts — in light of the way that CATIA is incredible in surface creation and Computer depiction of surfaces.

Dassault Systems has begun serving shipbuilders with CATIA V5 release 8, which fuses unprecedented segments important to shipbuilders. GD Electric Boat used CATIA to design the latest fast attack submarine class for the United States Navy, the Virginia class. Northrop Grumman Newport News moreover used CATIA to design the GeraldR. Portage class of super bearers for the US Navy.

3.5.3 Industrial equipment:

CATIA has a strong closeness in the Industrial Equipment industry. Present day Manufacturing equipment associations like Schuler and Metso use CATIA , and also significant compact contraption and rigging associations like Claas, and moreover unique mechanical apparatus thing associations like Alstom Power and ABB Group.

3.5.4 Other:

Sketcher Frank Gehry has used the item, through the C-Cubed Virtual Architecture association, presently virtual Build Team, to design his respect winning curvilinear structures. His development arm, Gehry Technologies, has been making programming in light of CATIA V5 named Digital Project. Propelled Project has been used to layout structures and has viably completed an unobtrusive cluster of exercises.

3.6 MEASUREMENTS:

MEASUREMENTS	VALUES
Length	30m
Width	5m
Height	3m
Thickness	0.3m
Force	41678N

Table No. 3 Measurements.

3.7 DESIGN:

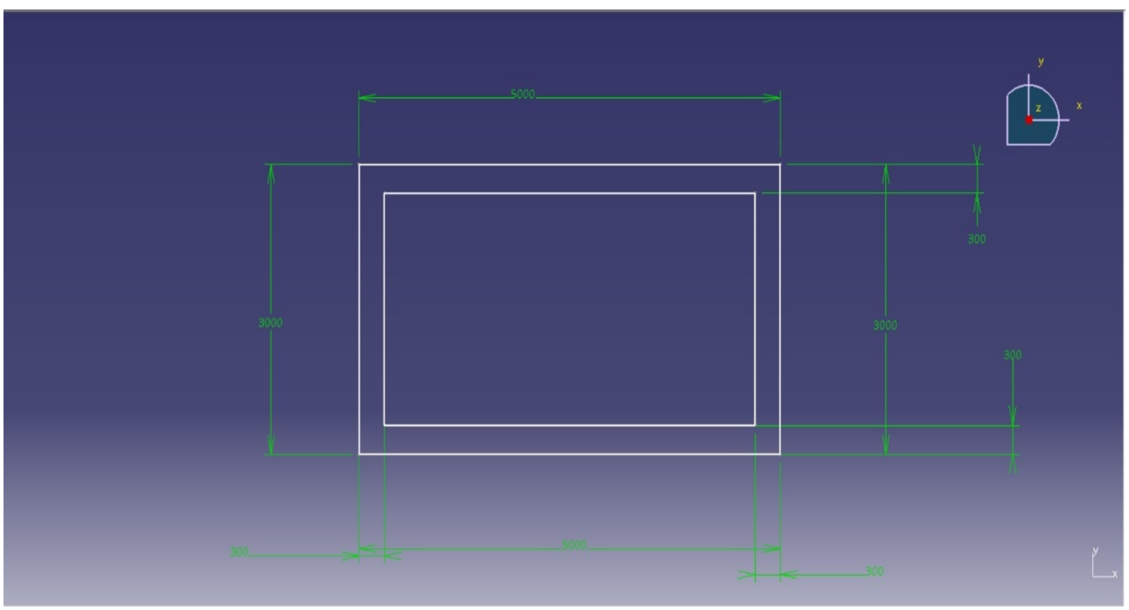


Fig-12 Design

3.7.1Pad(extrude):

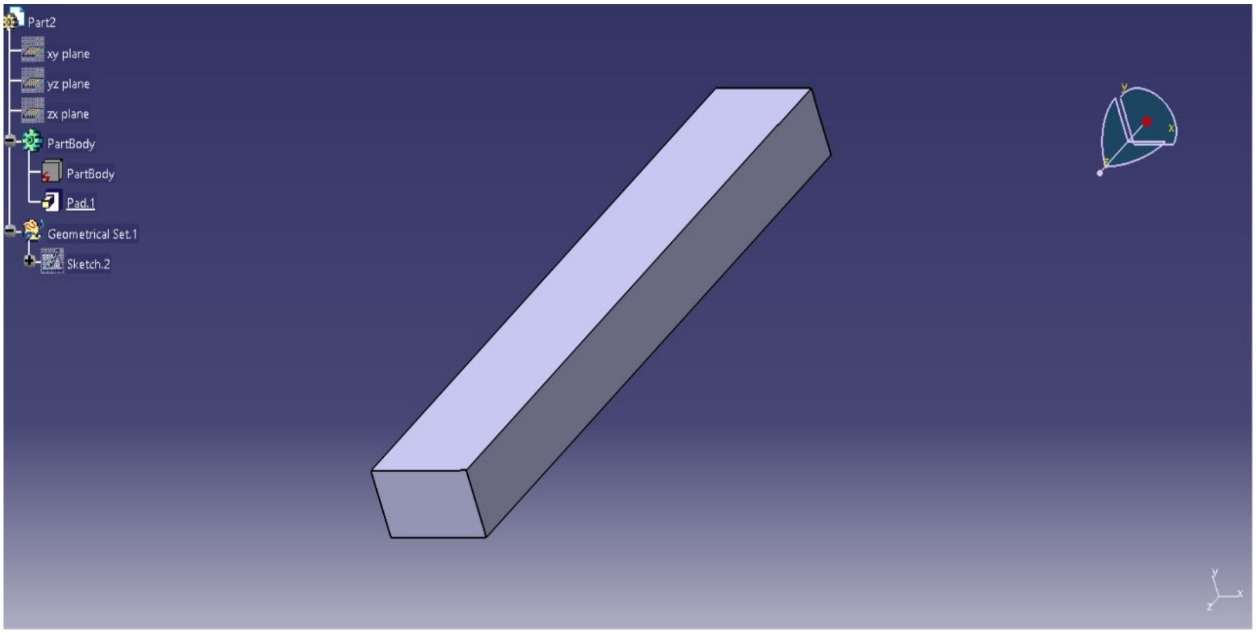
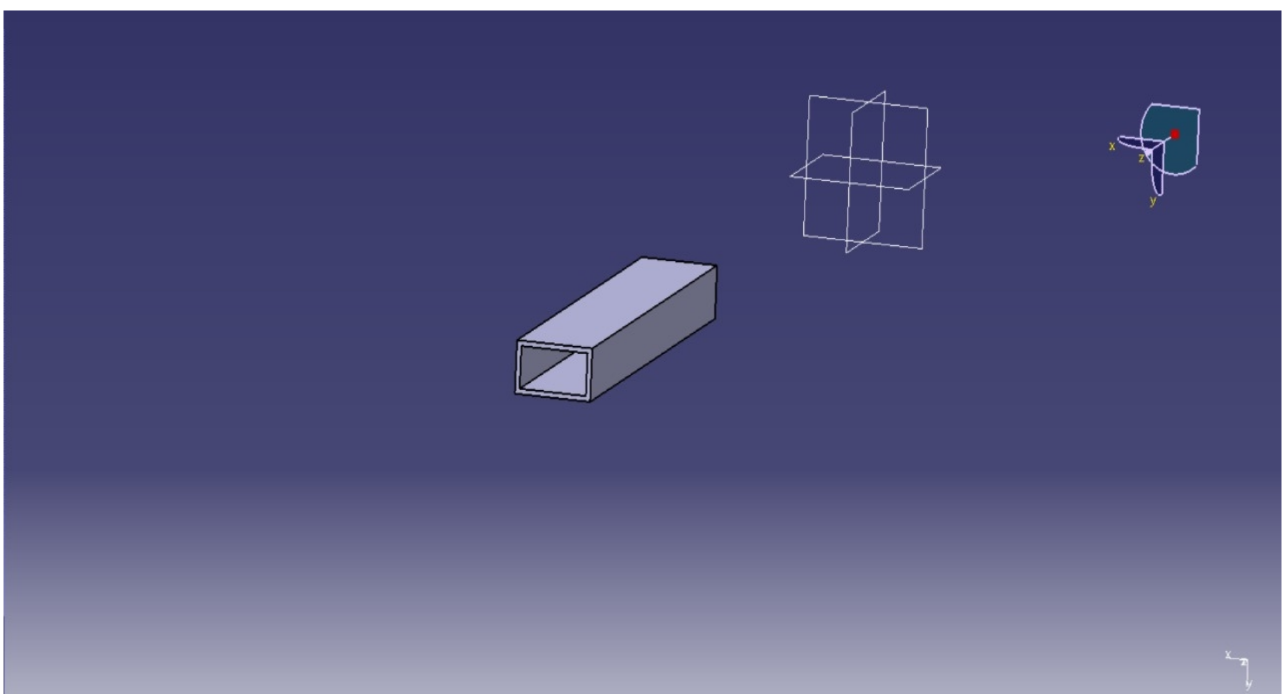


Fig-13 Pad(extrude)

3.7.2Pocket(hole):



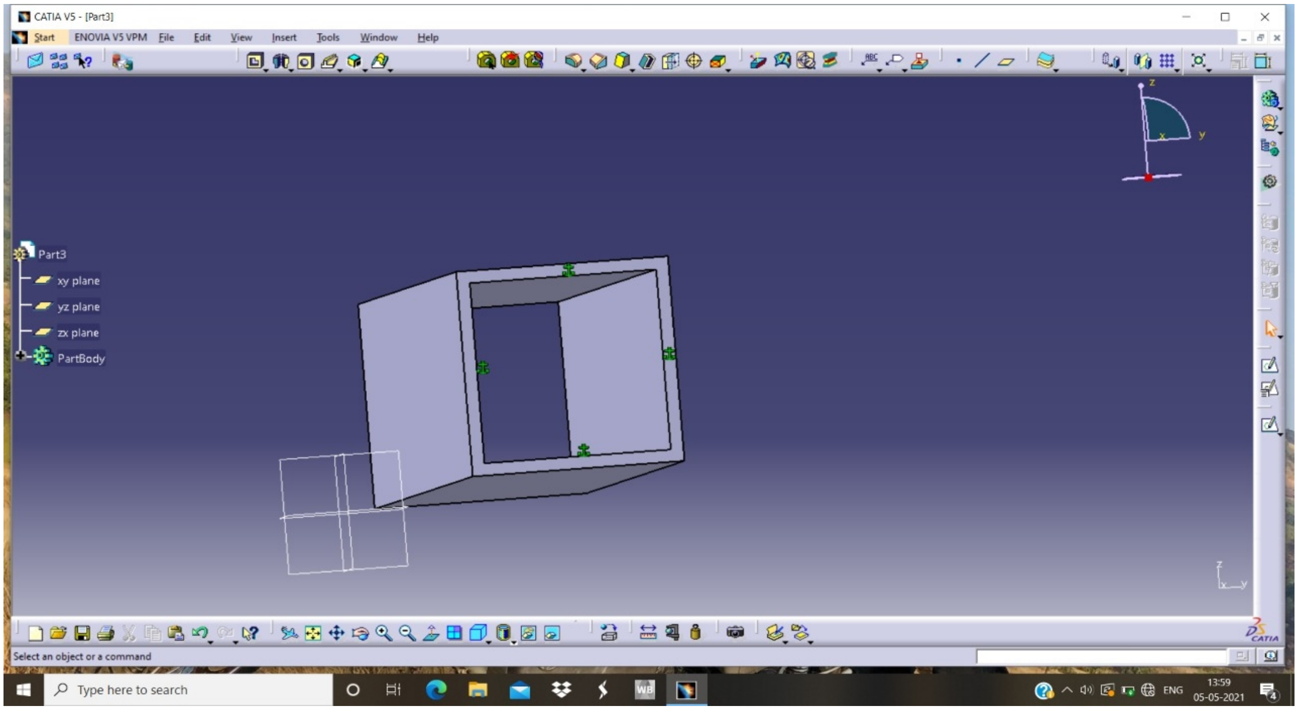


Fig-14 Pocket(hole)

CHAPTER-4

PROJECT IMPLEMENTATION

4.1 HISTORY OF ANSYS :

The association was built up in 1970 by Dr. John A Swanson Analysis frameworks, Inc. SASI. Its essential job was to make and feature limited component examination programming for auxiliary material science that could reproduce static (stationary), dynamic (moving) and warm trade (warm) issues. SASI developed its business in parallel with the improvement in PC advancement and structuring needs. The association created by 10 to 20 percent year, and in 1994 it was sold to TA Associates. The new owners took SASI's driving programming called ANSYS as their pioneer thing and doled out ANSYS, Inc as the new association name.

4.2 INTRODUCTION TO ANSYS :

The ANSYS program is a PC program for a limited component investigation and plan. The ANSYS program can in like manner be used to process the perfect structure for given working conditions using the plan improvement feature.

ANSYS is business limited component examination programming with the ability to separate a broad assortment of different issues. ANSYS holds running under a collection of circumstances, including IRIX, Solaris, and Windows NT. Like any limited component programming, ANSYS unwinds speaking to differential conditions by breaking the issue into little components. The speaking to states of flexibility, fluid stream, warm trade, and electro-fascination would all have the capacity to be comprehended by the Finite component procedure in ANSYS. ANSYS can handle transient issues and moreover nonlinear issues. This report will focus on the basics of ANSYS using generally fundamental delineations.

The ANSYS program is a multi-reason program, suggesting that you can use it for a limited component investigation in for all intents and purposes any industry - vehicles, flying, railways, mechanical assembly, equipment, wearing stock, control time, control transmission, and biomechanics, to indicate just a couple. "Multi-reason" in like manner suggests the manner in which that the program can be used as a piece of all controls of structure – assistant, mechanical, electrical, electromagnetic, electronic, warm, fluid, and biomedical. The ANSYS program is moreover used as an enlightening gadget in schools and other academic foundations.

ANSYS is open on all ME net Sun and SGI machines. It is available on the Linux machines by remote-login so to speak. On the right side, tattle has it that ANSYS is examining a Linux port. At the present time, ME net uses the Research/Faculty type of ANSYS 12.1. The Research/Faculty grant level gifts greater, more many-sided models than does the energy level running on the IT Labs machines. This record is proposed to be a starting stage. The material verified here is by no means whatsoever, expansive. Frankly, we will simply start to uncover what's underneath of ANSYS's abilities. Given that, I will try to cover by far most of what I consider ANSYS and a couple of devices I have learned while using it. The record will begin with two direct cases, taking the customer through most of the methods for making a model, agreeing, including limit conditions, clarifying, and, finally, looking results. The remains of this file will over tips and snares for every one of the methods ANSYS writing computer programs is available on numerous sorts of PCs – (PCs), workstations, minicomputers, super minis, concentrated PCs, very unified PCs, etc. A couple of working systems are maintained, much the same as various of reasonable contraptions.

- An aggregate of six windows are opened when you begin ANSYS.

1. Utility Menu (top) – contains limits that are available for all through the ANSYS session , for instance, record controls, decisions, sensible controls and parameters.You moreover leave the ANSYS program from the rub pull-downmenu.

2. Main Menu (base left) – contains the fundamental ANSYS limits, dealt with by the pre-processor, game plan, general, post processor, structure analyzer.

3. Toolbar (Middle Right) – contains push gets that execute usually used ANSYS summons. More push gets can be incorporated.

4. Information window (center left) – exhibits program impel messages and empower you to sort in summons explicitly.

5. Realistic window (base right) – a window where plans are showed up and graphical picking are made.

6. Yield window (not appeared) – shows content yield from the program, for instance, posting of data, etc. It is regularly arranged behind the other window and can be put to the front when key.

- The methods in any limited component investigation can be secluded in three phases:

1.Pre-processing – characterize the model, for example, mesh, burdens, and limit conditions

2.Solution – amassing and illuminating the arrangement of condition.

3.Post preparing – removing applicable outcome from the arrangement

4.2.1 Solution steps:

- Apply removal limitation.
- Apply pressure load.
- Solve

4.2.2 Post processing steps:

- Enter the general post processor.
- Plot twisted shape.
- Plot the von miss equal pressure.

- List responses at obliged hubs.
- Exit the ANSYS program.

4.3 ELEMENT CHARACTERISTICS:

4.3.1 Lists of element types:

The ANSYS program has a considerable library of component sorts. A segment of the properties of the component sorts, and their groupings, are depicted in this part to make component sort assurance less requesting.

The ANSYS component library contains in excess of 100 unmistakable component plans or sorts. A component sort is perceived by a name (8 characters most extraordinary, for instance, BEAM3, including a social event mark (BEAM) and an uncommon distinctive number (3). The component is browsed the library for use in the examination by contributing its name on the component sort bring

4.3.2 Two-dimensional versus three-dimensional models:

ANSYS models may be either two-dimensional or three-dimensional depending on the component sorts used. Two-dimensional models must be described in a X-Y plane. They are less requesting to set up , and run speedier than relative three-dimensional models. Rotate Symmetric models are furthermore thought to be two-dimensional.

If any three-dimensional component sort, (for instance, BEAM4) is consolidated into the component sort set, the model winds up doubtlessly three-dimensional. Some component sorts, (for instance, COMBIN14) may be a couple of dimensional, dependent upon the KEYOPT regard picked. Other component sorts, (for instance, COMBIN40) have no effect in choosing the model estimations. Two-dimensional component sorts may be used (with caution) in three-dimensional models.

4.3.3 Finite component technique:

The limited component system (FEM) (its sensible application routinely known as limited component investigation (FEA) is a numerical technique for finding inferred plans of inadequate differential conditions (PDE) and furthermore of essential conditions. The course of action approach is develop either in light of getting rid of the differential condition absolutely (steady state issues), or rendering the PDE into an approximating game plan of customary differential equation , then numerically joined using standard methodology, for instance, Euler's procedure, Runge-kutta , etc.

In handling partial differential conditions, the fundamental test is to make a condition that approximates the condition to be thought about, yet is numerically enduring, inferring that goofs in the data and center estimations don't total and make the resulting yield be unimportant. There are various strategies for doing this, all with good conditions and shortcomings. The Finite Element Method is a not too bad choice for settling partial differential conditions over tangled spaces (like cars and oil pipelines), when the territory changes (as in the midst of a solid state reaction with a moving point of confinement), when the pined for exactness varies over the entire zone, or when the course of action needs smoothness. For instance, in a frontal accident multiplication it is possible to extend conjecture precision in "fundamental" areas like the front of the auto and decrease it in its back (as such reducing cost of the reenactment). Another outline would be in Numerical atmosphere estimate, where it is progressively basic to have definite desires over developing extremely nonlinear wonders, (for instance, tropical brutal breezes in the earth, or whirls in the ocean) instead of by and large calm local

4.3.4 Layout of ansys window:

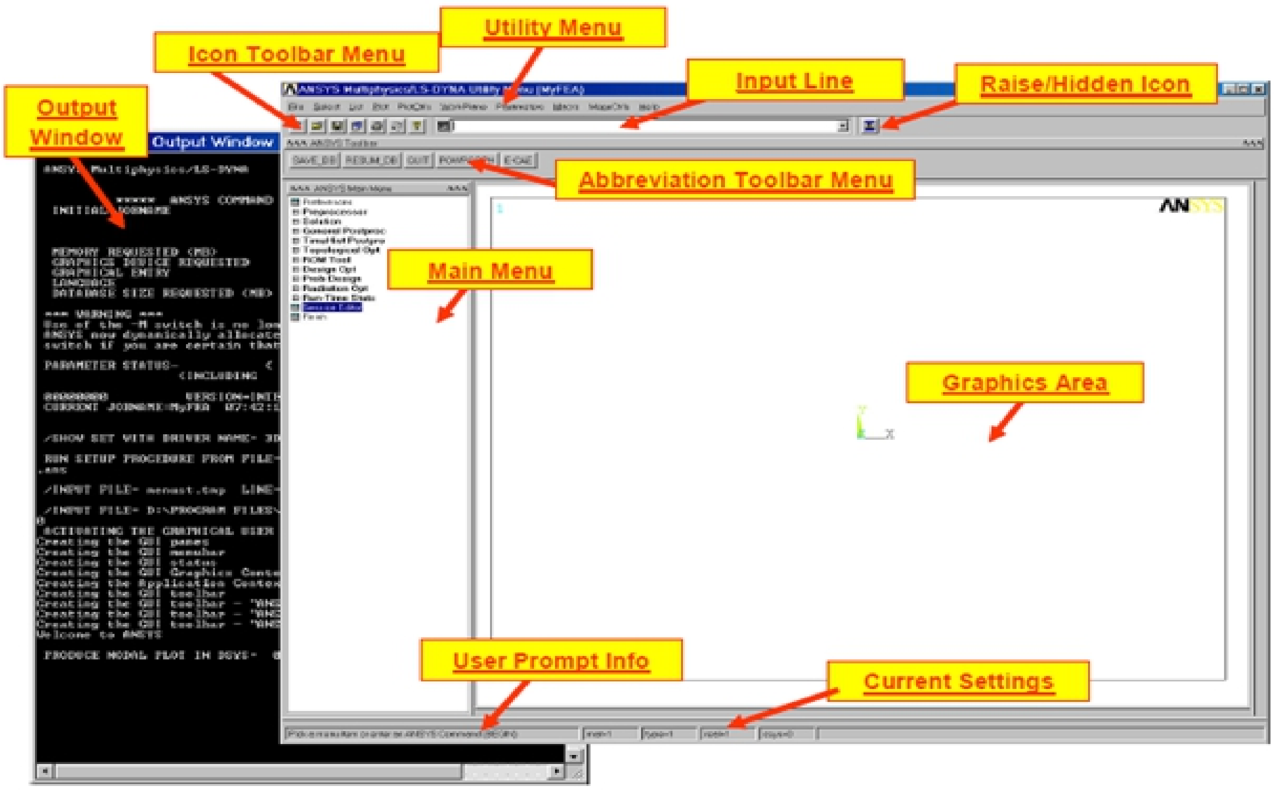


Fig-15 Screen ANSYS window

4.3.5 Mouse:

Left mouse get picks (or unpicks) the component or region closest to the mouse pointer. Pressing and hauling empowers you to "survey" the thing being picked (or unpicked).Middle mouse get completes an Apply. Recuperations the time required to move the mouse over to the Picker and press the Apply get. Use Shift-Right catch on a two-get mouse.

Right mouse get flips among pick and unpick mode. Note, the Shift-Right catch on a two catch mouse is indistinguishable to the Middle mouse get on a three-get mouse.

4.3.6 Database and files:

The term ANSYS database suggests the data ANSYS keeps up in memory as you collect, comprehend, and post process your model. The database stores both your data and ANSYS comes about data:

– Input data - information you ought to enter, for instance, estimations, material properties, and burden data.

– Results data - sums that ANSYS determines, for instance, migrations, stresses and temperature.

4.4 DEFINING THE JOBNAME:

➢ Utility Menu > File> Change Job name

The occupation name is a name up to 32 characters that recognizes the ANSYS work. When you portray a livelihood name for an investigation, the occupation name transforms into the underlying section of the name of all records the examination makes. (The enlargement or postfix for these records' names is a report identifier, for instance, .DB.) By using work name for each investigation, you ensure that no archives are overwritten. jobname.log: Log record, ASCII. Contains a log of each request issued in the midst of the session. If you start a minute session with the equivalent jobname in a comparative working library, ANSYS will add to the past log archive (with a period stamp).

4.5 ANSYS GRAPHICAL USER INTERFACE (OUT PUT WINDOW):

➢ After starting ANSYS, two windows will appear. The first is the ANSYS 8.1 Output Window:

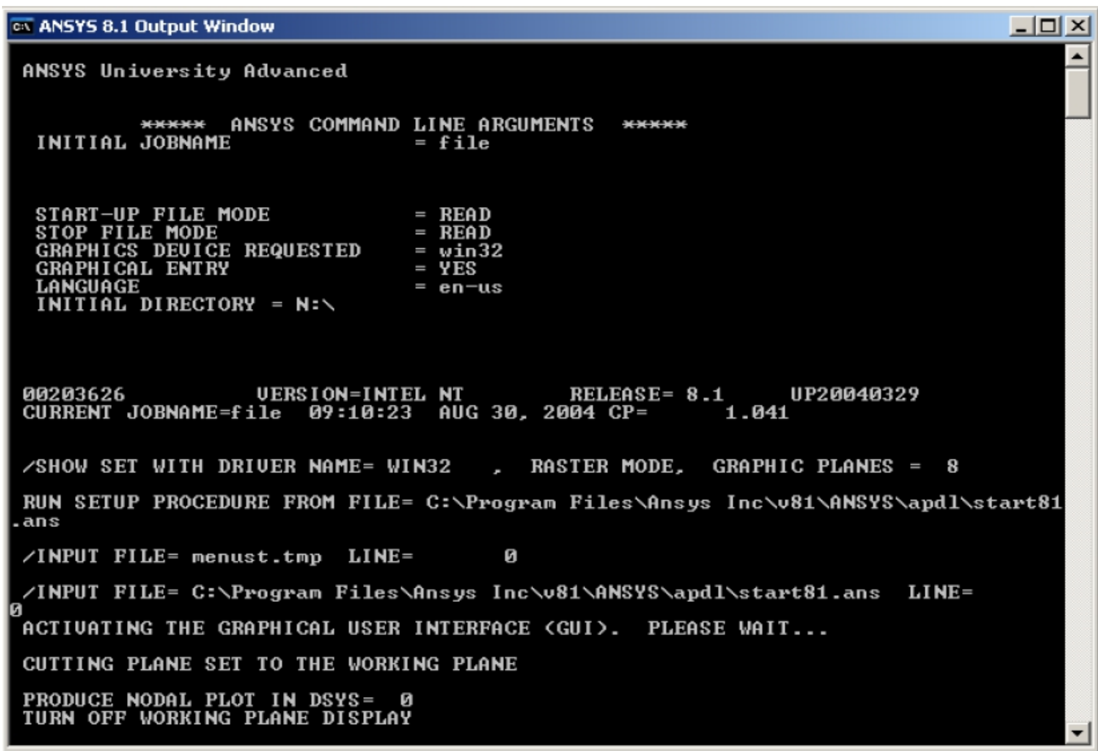


Fig-16 Screen output window

This window demonstrates a posting of each request that ANSYS executes. If you experience issues, this is a conventional spot to plan to see what ANSYS is doing or has one. This is one zone where you will find most of the notification and bumble messages that appear and the gather that created the notice/botch.

➢ The second window is the ANSYS Research FS graphical UI. This is isolated into 4 sections (showed up on next page):

- ANSYS Utility Menu
- ANSYS Toolbar Menu

- ANSYS Main Menu
- Display window

Each segment will be talked about in further detail beneath.

4.6 ANSYS UTILITY MENU:

Inside this menu, you can perform record activities, rundown and plot things, and change show alternatives.

4.6.1 File drop-down menu:

The File drop-down menu incorporates the choices to clear the database, change, resume, and spare the present model.

4.6.2 List pull-down menu:

The r destroy down menu empowers you to see the log and slip-up reports, get a posting of geometric substances, components and their properties, center points, and farthest point conditions and loads associated with the model.

4.6.3 Plot pull-down menu:

This draw down menu enables you to plot the different parts of the model, for example, Keypoint, areas, volumes and elements

4.6.4 Plot ctrl pull-down menu:

This menu incorporates the controls to skillet/zoom/pivot your model, select the numbering alternatives, change styles and create printed copies of the plots.

4.7 ANALYSING EXPERIMENTAL DATA:

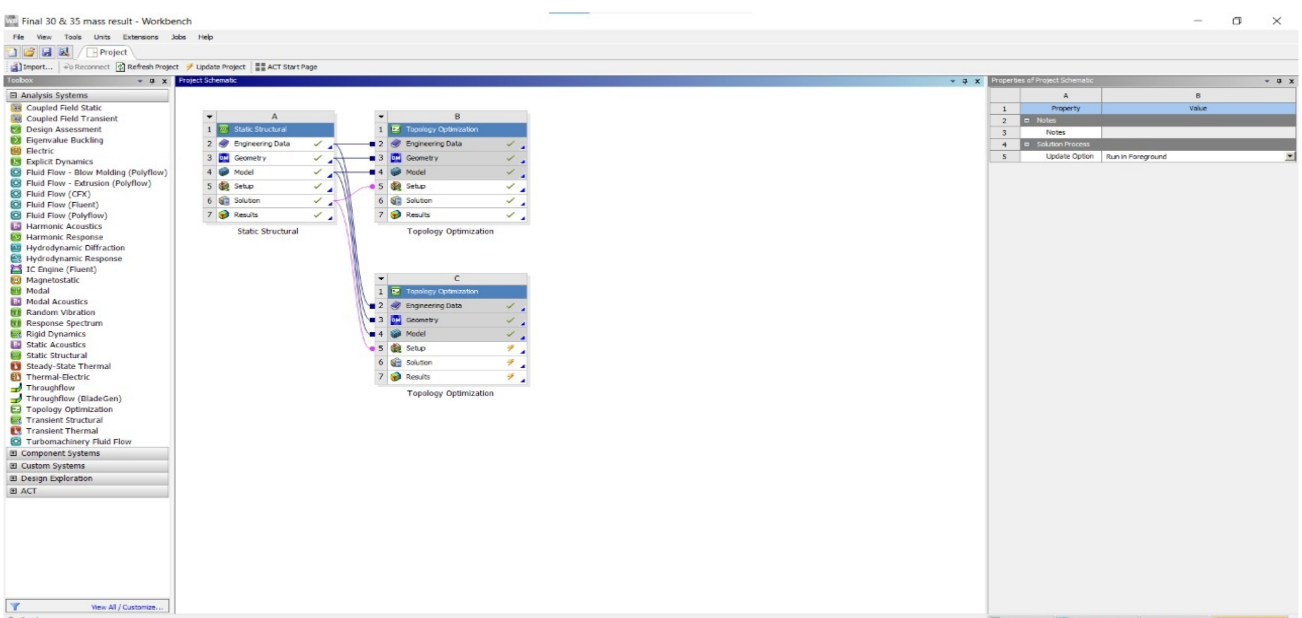


Fig-17 Analysing experimental data

4.8 MESH:

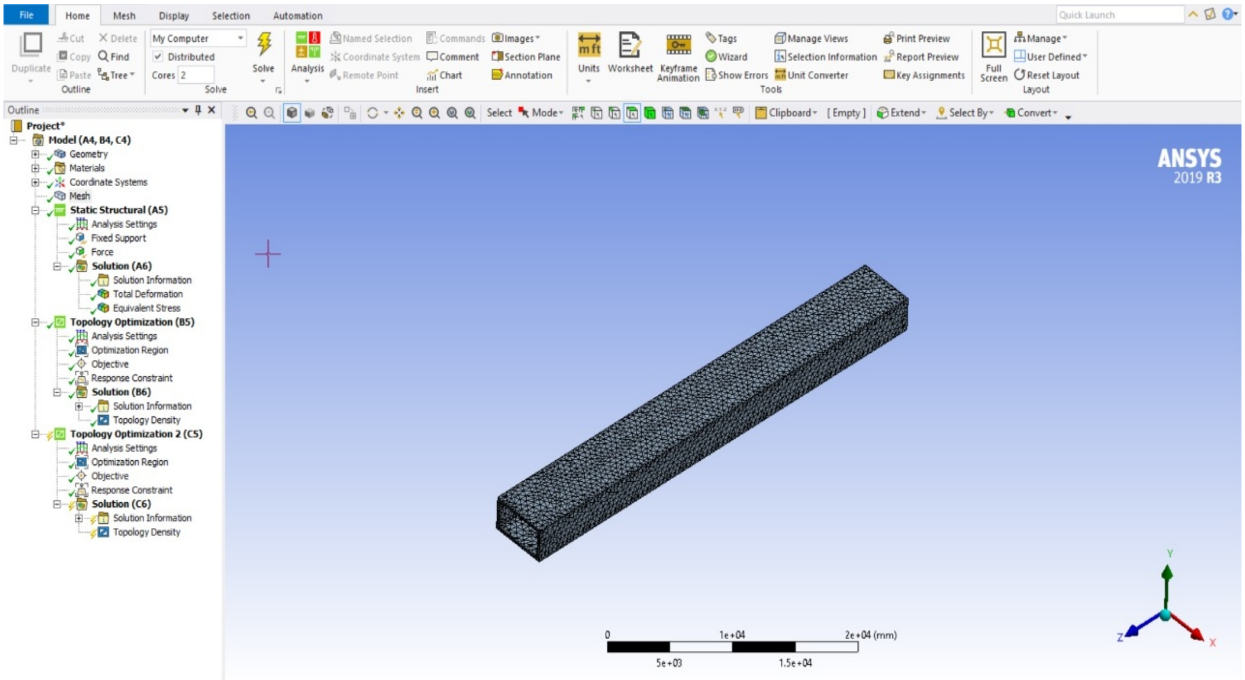


Fig-18 Mesh

4.9 FIXED SUPPORT:

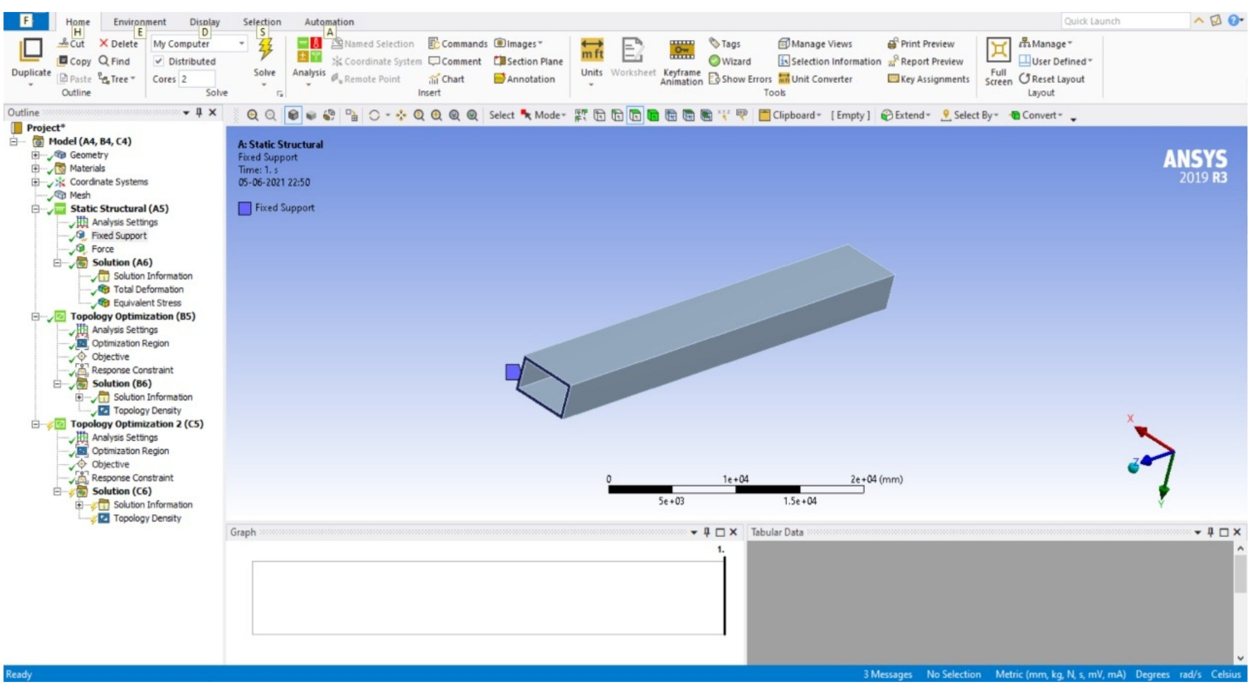


Fig-19 Fixed support

4.10 LOAD ACTING:

Average weight x No.of people x Gravitational force = Force(Load)

85kgs x 50 x 9.81 = 41678N

Force(Load) = Deformation

41678N = 0.0085297ra

4.11 FORCE:

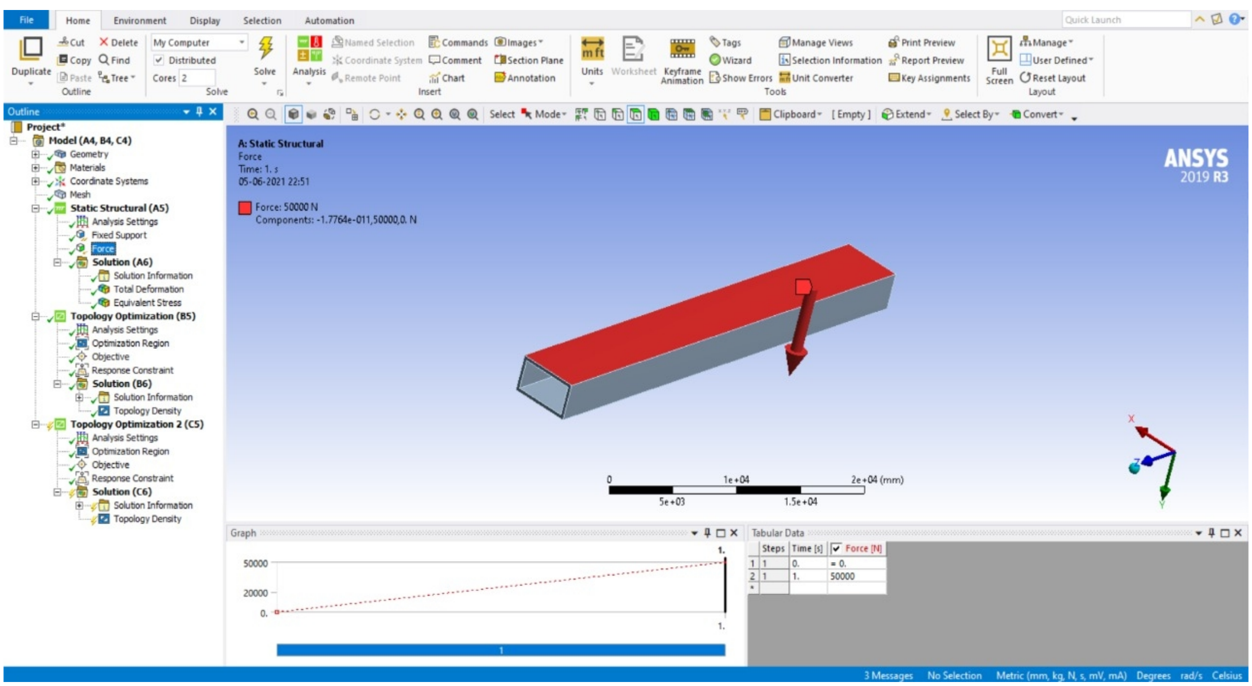


Fig-20 Force

4.12 EQUIVALENT STRESS:

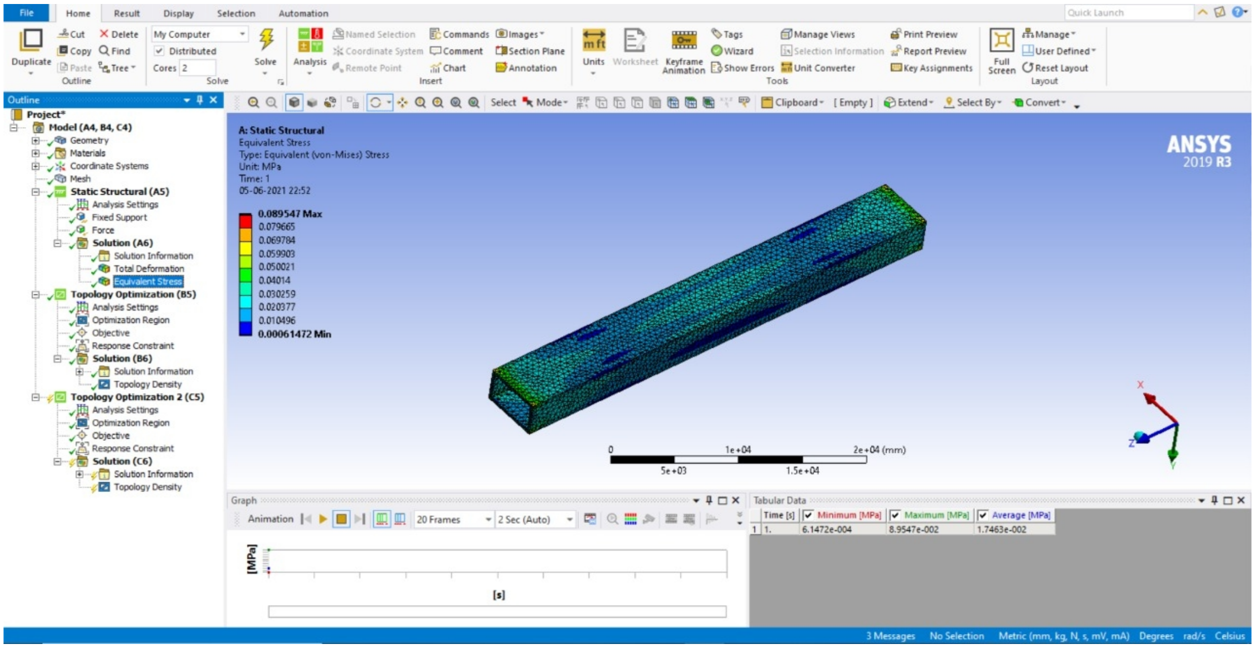


Fig-21 Equivalent stress

4.13 TOTAL DEFORMATION:

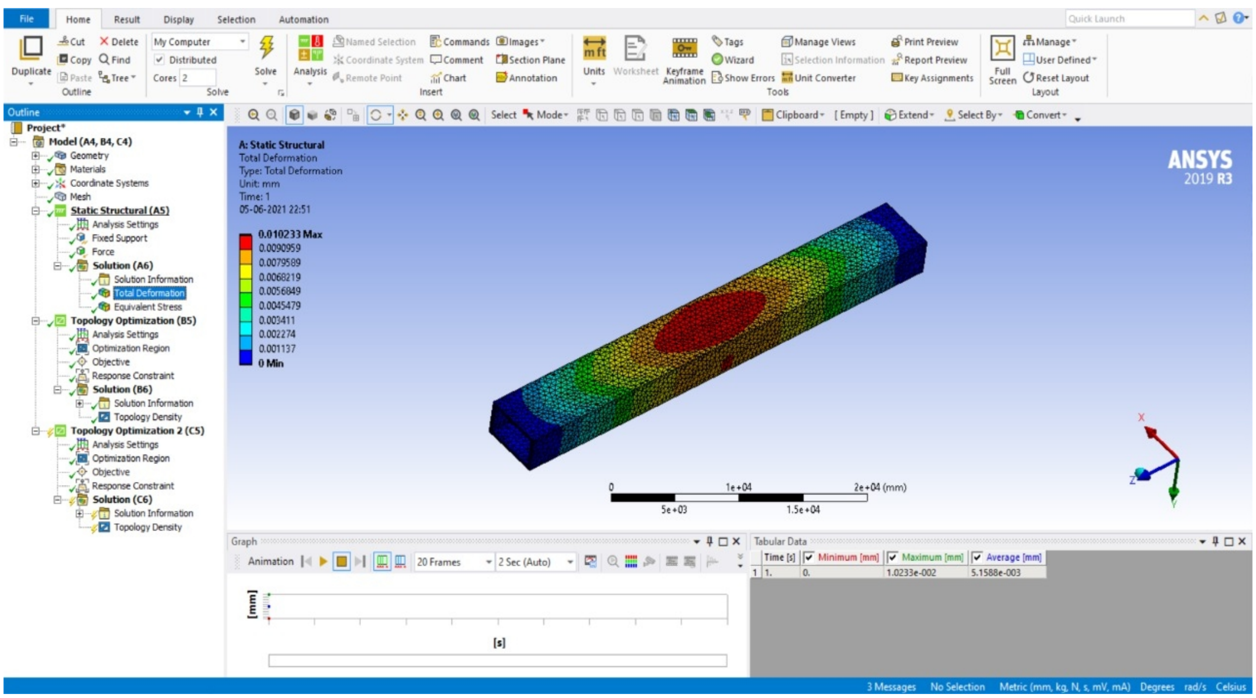


Fig-22 Total deformation

4.14 DEFORMATION SAMPLES:

LOAD	DEFORMATION
40000N	0.0081863
42000N	0.0085956
44000N	0.0090049
46000N	0.0094143
48000N	0.0098236
50000N	0.010233

Table No. 4 Deformation

4.15 TOPOLOGY OPTIMIZATION:

The study of topology optimization is making difference in weight(mass) without any change in dimensions.

Removal of excess material where there is no stress acts on it,i also called topology optimization.

It is also used to reduce the weight(mass) in case of getting good performance.

4.16 OPTIMIZATION REGION:

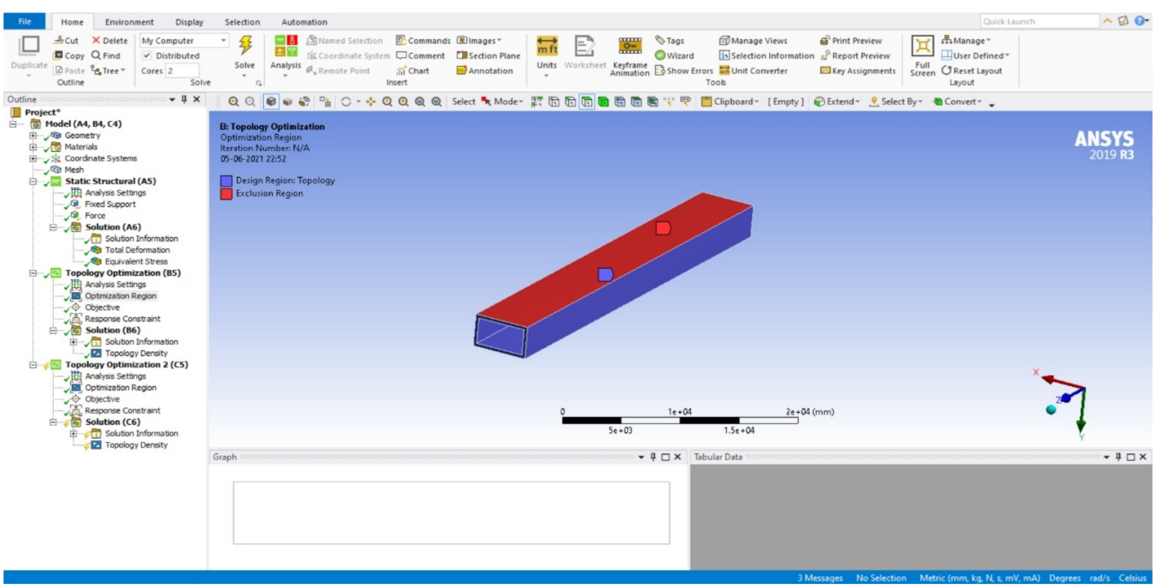


Fig-23 Optimization region

4.17 RESPONSE CONSTRAINT:

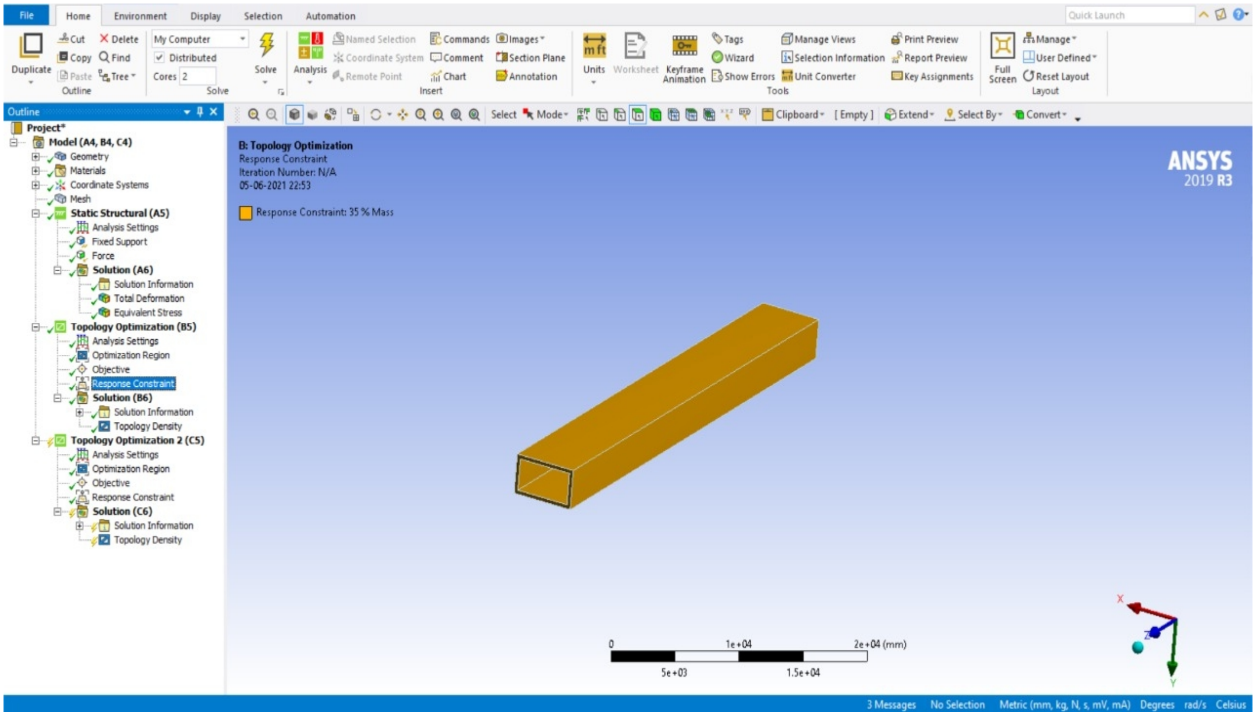


Fig-24 Response constraint

4.18 TOPOLOGY OPTIMIZATION RESULT:

S.NO	MATERIAL	DENSITY	RESPONSE CONSTRAINT	ORIGINAL MASS	MASS AFTER TOPOLOGY OPTIMIZATION	PERCENTAGE OF MASS REDUCED
1.	Structural steel	8654.9kg	30%	1537.15kg	868.88kg	43.408%
2.	Structural steel	8654.9kg	35%	1537.15kg	919.06kg	40.208%

Table No. 5 Topology Optimization Result

4.19 ANALYSING EXPERIMENTAL RESULT(FINAL RESULT):

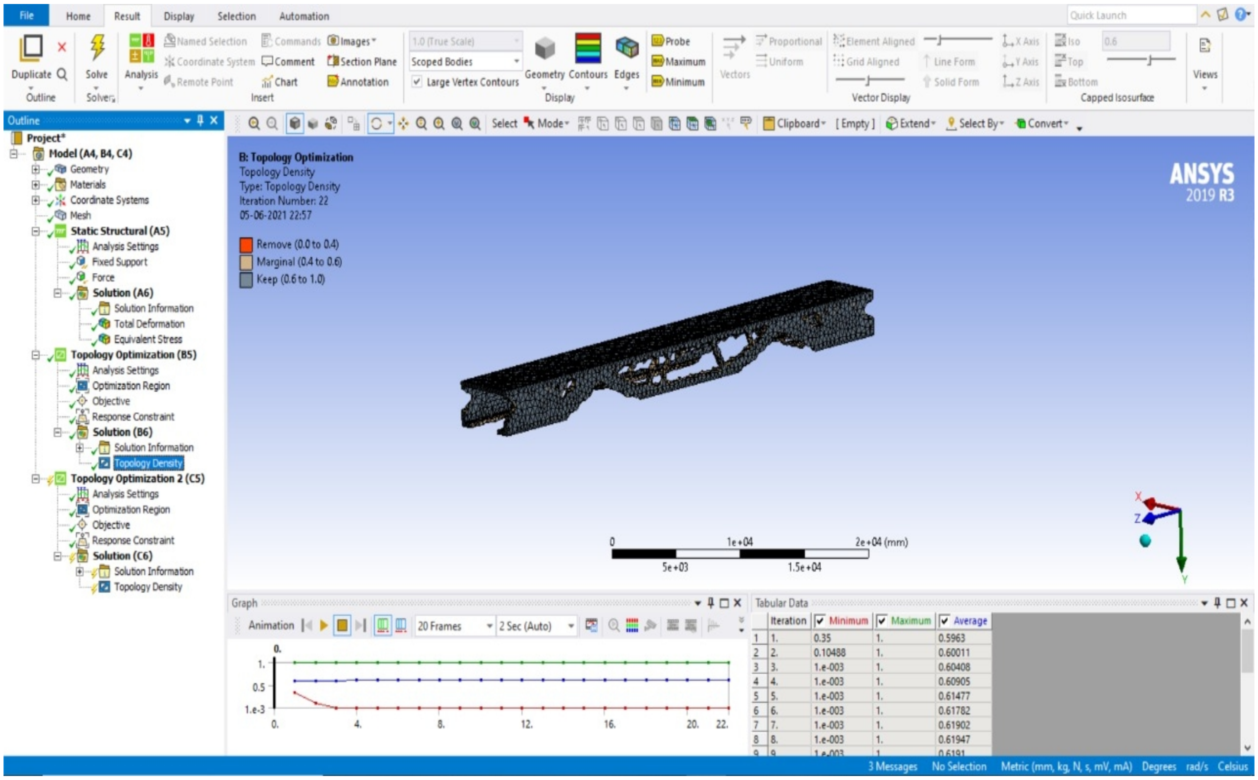


Fig-25 Final model

CHAPTER-5

CONCLUSION & FUTURE ENHANCEMENT

5.1 CONCLUSION:

In this project we did design of a footover bridge by using CATIA-V5-R2011.

After the completion of design , we did analysis by using ANSYS Workbench with help of Topology optimization.

We got a good performance of the footover bridge by giving the measurements which we used in this Project.

And we also done the variation of Stiffness to Weight(mass) ratio.

5.2 FUTURE ENHANCEMENT:

As a future scope of study, manufacturing techniques for Foot over Bridge could be used in all the heavy traffic routes,and also be able to construct strong enough to with-stand more and more pedestrians on it .

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5. https://www.satec.co.in/foot-over-bridge

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5.6 BOOKS:

1. Guide Lines for Bridge Design

2. SCDOT - Bridge Design Manual

3. Steel Bridge Bearing Design and Detailing Guidelines

A MAJOR PROJECT REPORT

On

MODELING AND THERMAL ANALYSIS OF 3D PRINTER EXTRUDER IN FUSED DEPOSITION MODELLING

SUBMITED TO

Jawaharlal Nehru Technological University Hyderabad

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

SUBMITTED BY

G. AMARNATH REDDY - (17K81A0374)

MD.MUDASSIR HUSSAIN - (17K81A0394)

MOHAMMED IMRAN - (17K81A0395)

NUTAKKI ABHISHEK - (17K81A03A2)

Under the Guidance of

Mrs. K. SUNITHA

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

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JUNE 2021

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BONAFIDE CERTIFICATE

This is to certify that the major project entitled **"MODELING AND THERMAL ANALYSIS OF 3D PRINTER EXTRUDER IN FUSED DEPOSITION MODELLING"** is being submitted by **"G. AMARNATH REDDY -17K81A0374, MD. MUDASSIR HUSSAIN -17K81A0394, MOHAMMED IMRAN -17K81A0395, NUTAKKI ABHISHEK -17K81A03A2"** in partial fulfillment of the requirements for the award of the Degree of *Bachelor of Technology in Mechanical Engineering*. To the Jawaharlal Nehru Technological University, Hyderabad as a record of bona fide work done by them. The result embodied in this report have been verified and found satisfactory.

Signature	Head of the Department
K. SUNITHA	Dr. D.V. SREEKANTH
Associate professor	Head of the department
Mechanical department	Mechanical department

Internal Examiner | External Examiner

Place:

Date:

DECLARATION

We, the students of **bachelor of technology** in department of mechanical, session: 2017 – 2021, St. Martin's engineering college, Dhulapally, Kompally, Secunderabad, here by declare that work presented in this Project Work entitled "Modeling and Thermal Analysis of 3D Printer extruder in FDM" is the outcome of our own bonafied work and is to correct the best of our knowledge and this work has been undertaken care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

G. AMARNATH REDDY - (17K81A0374)
MD MUDASSIR HUSSAIN - (17K81A0394)
MOHAMMED IMRAN - (17K81A0395)
NUTAKKI ABHISHEK - (17K81A03A2)

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ABSTRACT

Fused Deposition modeling is the prime method of Additive manufacturing process used for the polymer manufacturing. As in this process the polymer filament enter into heat sink through feed filament where it gets melts and extruded from nozzle and deposited layer by layer to build the component.so to extrude the PLA melt, the feed polymer in solid form is used as plunger. In order to remain feed filament in solid state it is necessary to remain the temperature of the heat sink much below the melting temperature of polymer. Therefore fins are provided on the heat sink to increase the surface area. Here in this way thermal behavior of heat sink is analyzed, in this analysis heat sink having circular, elliptical and rectangular having fins are analyzed for working material that is poly – Latic – acid.

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LIST OF FIGURES

LIST OF TABLES

Chapter – 1
INTRODUCTION

1.1 Introduction:

A 3d printer is an additive manufacturing technique where 3D objects and parts are made by the addition of multiple layers of material. It can also be called as rapid prototyping. It is a mechanized method where 3D objects are quickly made as per the required size machine connected to a computer containing blueprints of any object.

The additive method may differ with the subtractive process, where the material is removed from a block by sculpting or drilling. The main reason to use 3d printer is for 90% of material utilization, increase product life, lighter and stronger. 3D printing is efficiently utilized in various fields such as aerospace, automobile, medical, construction and in manufacturing of many household products.

The term 3D printing covers a host of processes and technologies that offer a full spectrum of capabilities for the production of parts and products in different materials. Essentially, what all of the processes and technologies have in common is the manner in which production is carried out layer by layer in an additive process which is in contrast to traditional methods of production involving subtractive methods or casting processes.

Applications of 3D printing are emerging almost by the day, and, as this technology continues to penetrate more widely and deeply across industrial, maker and consumer sectors, this is only set to increase. Most reputable commentators on this technology sector agree that, as of today, we are only just beginning to see the true potential of 3D printing. 3DPI, a reliable media source for 3D printing, brings you all of the latest news, views, process developments and applications as they emerge in this exciting field.

This overview article aims to provide the 3DPI audience with a reliable backgrounder on 3D printing in terms of what it is technologies, processes and materials, its history, application areas and benefits.

1.2 3D Printing Applications:

Education

New learning material: often you must want new teaching materials but may not be able to afford to budget for them. Now their resources can be made using a 3D printer, saving money on your department budget. When we will be Printing our own learning, materials is not only cheaper but it will be almost always quicker too. Even though students are traditionally taught through books and theory, kinesthetic learners prefer to learn through using aids and materials. 3D printing which also allows you to bring any of the subject matter to life as the physical aid to engage all of your students for a very long period of time increasing that their learning and improving their problem solving and critical thinking capabilities.

Figure 1.1: Planetary Gear

Apparel

3D printing has spread into the world of clothing with fashion designers experimenting with 3D-printed bikinis, shoes, and dresses. When we talk about the commercial production, Nike is using 3D printing to prototype and manufacture the very same football shoe for the American football players and the company New Balance is 3D manufacturing custom fit shoes for all the athletes.

3D printing has come to the point where companies are printing consumer grade eyewear with on demand custom fit and styling (although they cannot print the lenses). On demand customization of glasses is possible with rapid prototyping.

Construction

With the help of 3D printers, we are able to build civil models like prototype of building or plan structures. So that the customers can easily visualized the models.

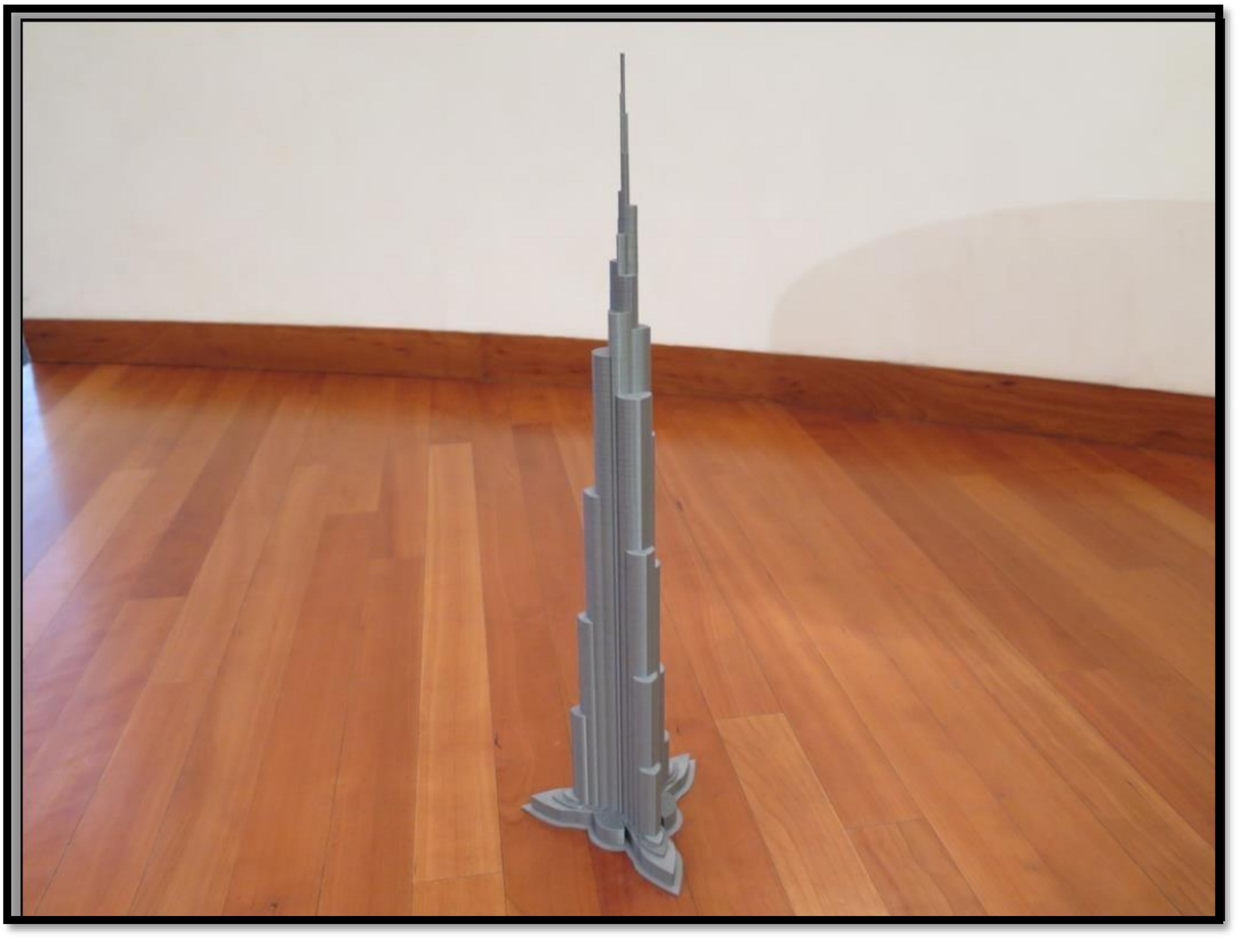

Figure 1.2: Building Prototype Printed

Medical

Medical applications for 3D printing are expanding rapidly and are expected to revolutionize health care. Medical uses for 3D printing, both actual and potential, can be organized into several broad categories, including: tissue and organ fabrication; creation of customized prosthetics, implants, and anatomical models; and pharmaceutical research regarding drug dosage forms, delivery, and discovery. The application of 3D printing in medicine can provide many benefits, including: the customization and personalization of medical products, drugs, and equipment; cost-effectiveness; increased productivity; the democratization of design and manufacturing; and enhanced collaboration. However, it should be cautioned that despite recent significant and exciting medical advances involving 3D printing, notable scientific and regulatory challenges remain and the most transformative applications for this technology will need time to evolve

Figure 1.3: Cranium Bone Prototype

Domestic Use

The domestic market of the 3D printing was mainly practiced by hobbyists and enthusiasts and was very little used for many of the practical household applications which are inapplicable. A working clock was made and gears were printed for home woodworking machines among other purposes. 3D printing was also used for ornamental objects. Websites associated with home 3Dprintins include coat hooks, doorknobs etc.

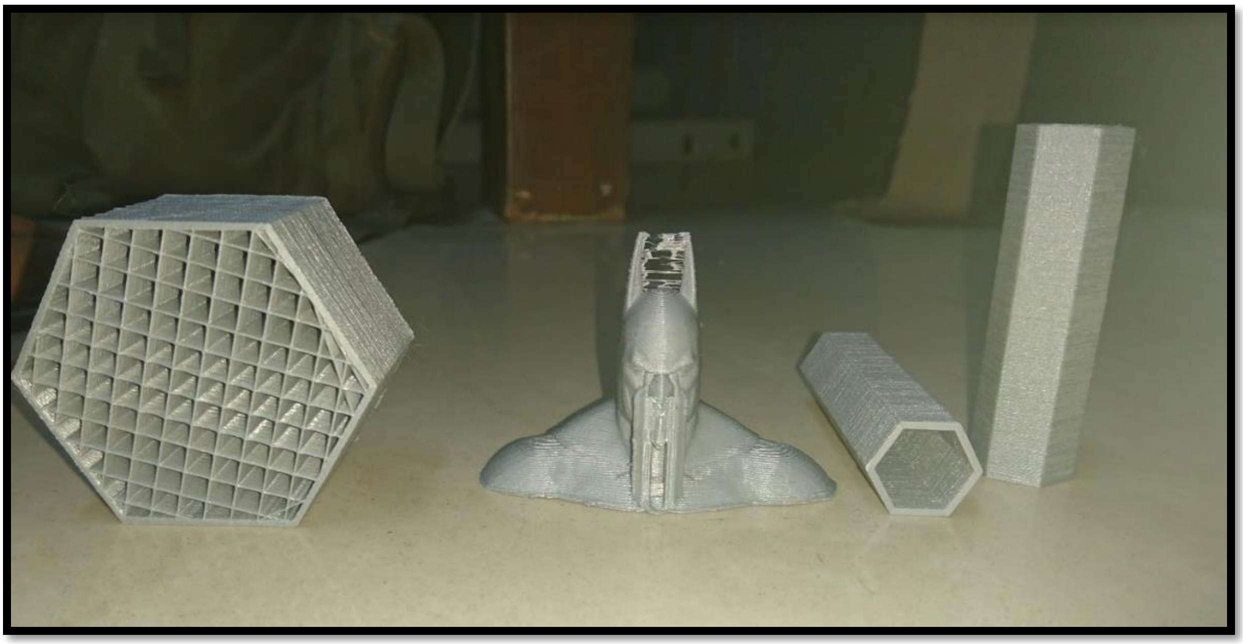

Figure 1.4: Domestic Items

1.3 Overview of the project:

In this project we 3D printer extruder heat sink with necessary dimensions. Initially we have designed extruder heat sink with circular fins by using three different thicknesses of circular fins i.e 0.8mm,1mm,1.2mm by using CATIA V5 software.

Then performed the thermal analysis on these three (0.8mm,1.0mm,1.2mm thickness fins) and find out which one of these three designs is more effective in terms of heat dissipation. The input parameters considered for the analysis are Initial Temperature, Heat flow and Convection. The parameters considered for results are Total Heat Flux and Temperature Distribution.

The thickness which is more effective is taken as reference and used to design extruder heat sink fins with rectangular and elliptical shapes. Then perform the thermal analysis on the extruder sink with rectangular and elliptical fins using ANSYS software.

After completion of the analysis of the extruder sink with different fin shapes compare the analysis results (Total Heat Flux and Temperature Distribution) obtained for different shapes of fins and then determine the shape of fin which is more effective.

1.4 Objectives of the study:

The main objective of our project is to design 3D printer extruder sink with different shapes of fins and then do the thermal analysis on them with input boundary condition being Initial Temperature, Heat flow, Convection.

We have considered three different shapes for the extruder heat sink fins, they are

- Circular
- Elliptical
- Rectangular

Also to study the properties like Total Heat Flux distribution and Temperature distribution for various shapes of extruder heat sink fins.

To compare the thermal analysis result values i.e Total Heat Flux distribution values and Temperature distribution values and then determine the shape of fin which is more effective.

To avoid the excess preheating of the 3D printing filament so that it does not melt before entering the heat box.

1.3 Scope of the study:

3D printing has long passed the point of being viewed only as a prototyping solution. Everyday, companies are finding new ways to incorporate the technology into their production, with applications ranging from tooling to spare/replacement parts and some end-use components.

So as the 3D printing usage is increasing rapidly we also need to improve the design of the components to make the 3D printing more effective and assessable. So our project aims to design an extruder with fins to increase heat dissipation.

This project can be further used to fabricate the 3D printer extruder sink with the appropriate shape of the fin which is more effective in terms of Heat Dissipation.

I future these results that we have obtained for extruder sink with various shapes of fins will be helpful to design extruder sink with various other fin shapes which maybe even more effective than the ones we used for our study.

1.5 Materials used:

Thermal properties of the materials (PLA, aluminum alloy) are taken from literature survey and used in this analysis. The thermal conductivity of PLA is assumed to be constant as 0.195 W/m-°C [25]. Specific heat capacity for PLA as a function of temperature is determined by Pyda et al. [21] based on differential scanning calorimetric and adiabatic calorimetric. The temperature and specific heat capacity relationship of PLA are based on the work of Pyda et al. [21] (for a molar mass of 72.06 g/mol) and are provided in table 1.1.

It is shown that the specific heat capacity of PLA in FDM follows two different approximately linear portions for temperatures above and below 332.5 °C , which is stated to be the glass transition temperature.

Within the model the temperature dependent values based on Fig. are used. For temperature below than 332.5 °C , the specific heat capacity is assumed to be (4.4T + 58) J/Kg °C and for 332.5 °C and above, the specific heat capacity value is assumed to be (1.05 T + 1668) J/Kg-°C

Thermal Property of PLA	**Value**
Specific Heat	(1.05 T + 1668)
Thermal conductivity	0.19 W/m °C
Solidification Temperature	175 °C
Melting temperature	175°C
Viscosity	Follow Power law
Density	1250 $m3\ /K$
Enthalpy of Melting	45000 J/Kg

Table 1.1: Thermal properties of PLA.

Thermal properties of Aluminum alloy	**Value**
Thermal Conductivity	237 W/m °C
Specific Heat	903J/Kg °C
Density	2702 kg/$m3$

Table 1.2: Thermal Properties of Aluminum alloy.

CHAPTER 2
LITERATURE SURVEY

2.1 Literature review:

1. Yang et.al [2015] presented in his paper a novel method to produce 3D objects using smart memory polymer [SMP] as a material so that all the parameters involved in the quality production of the components can be optimized. The practical utility products involve lots of minute hurdles. After making a sample SMP product its surface finish, dimensional accuracy tenacity and other parameters were verified. The fabrication method basically includes FDM (fused deposition modelling) in which the effect of printing parameters such as temperature of extruder, scanning speed and other parameters are studied. The specialty of the SMP material lies with its sensitivity to the thermal stimuli which have potential application in the field of aerospace applications.

2. Vaezi et.al [2012] has analyzed the various processes involved in the aided manufacturing (AM) process by classifying them in three broad categories, scalable micro-AM systems, 3D direct writing and hybrid processes and detail analysis is done. The results of individual processes and their advantage and disadvantage were plotted on single platform. The conclusion debunked the need of the society to keep abreast with the growing trend. Among the numerous papers and intensive research the optimized MSL and EFAB processes have shown the promising potential and satisfactory results for the AM 3D modelling.

3. Taufik et.al [2015] it has done Surface roughness calculation studies in fused deposition modelling (FDM) process. The deposited layers were analyzed with main focus on the profile perimeter of material. Basically, the build edge profiles were scanned under categories to reduce any possibility of errors in the roughness models. The methodology involved some combinations of theoretical and empirical approaches to determine the randomness in the profile. Further a detailed comparison was made between the existing and proposed models to analyze the pros and cons of the process. The results reveal that variations in the built edge profile causes roughness in the FDM process and also their profiles vary from each other too in different orientation. Most important conclusion is the variation in height and base length are the major factors contributing roughness in FDM.

4.Casavola et.al [2015] in this paper orthotropic mechanical property of fused deposition modelling is analyzed using classical laminate theory. A feed stock wire is used in layer by layer form by FDM process to produce 3D object rapid prototyping. The mechanical behavior of the produced parts were analyzed by using CLT (classical laminate theory) in which the properties were evaluated such as elastic modulus in transverse direction, Poisson’s ratio and shear modulus. The specimens having significant vertical dimensions are not included due to the limitation of

FDM techniques to produce vertical specimens. Ultimately two different materials ABS and PLA were used to validate the authenticity of CLT. The results reveal that PLA has young's modulus and UTS values computed were almost double to that of the ABS even PLA being brittle nature.
5.Yardimci et al. [25] Fused Deposition processes involve successive melting, extrusion and solidification of thermoplastic polymer melts. Fluid mechanics and heat transfer of neat or particle-filled polymeric melts, viscoelastic deformation and solidification of the roads that are being produced, and repetitive thermal loading of the growing part are important physical processes that control the final quality of the part. Previous computational process models investigated deposition and cooling processes for single and multiple filaments. In the current study, complimentary computational models are presented for the extrusion phase of the process. Impact of liquefier and nozzle design on thermal hardware behavior and operational stability has been quantified.
6.Pyda et al. [2004] The heat capacity of poly (lactic acid) (PLA) is reported from T¼(5 to 600) K as obtained by differential scanning calorimetry (d.s.c.) and adiabatic calorimetry. The heat capacity of solid PLA is linked to its group vibrational spectrum and the skeletal vibrations.
7. Bellini et.al [2004] they have studied the liquefier dynamics in the fused deposition modelling which is a sub branch of layered manufacturing technique. In FDM technique the building blocks are deposited on the surface in the vector style. In recent development domain the process has reached beyond the building of model to a finished product. In this paper the liquefier dynamics is studied to synchronize the flow control with the control strategies in the extrusion phase. The results reveal that there is a good agreement between the applied flow rate i.e. theoretical curve and the physical response of the system i.e. experimental curve for small magnitudes. The suggestion of the paper reveal that A shift from ‘‘prototyping’’ to ‘‘manufacturing’’ necessitates the following improvements such as to meet the desired specification there should be an agreement between the core part input parameters, improved surface quality. To have a clear image of the peculiar phenomena that happens in the liquefier, a mathematical model based on physical assumptions was developed. After comparison of the results with the experimental devices the slip phenomena between the roller and the filament at top is the reason for the error in the steady deposition rate of the material.
8. Noriega et.al [2013] has made the use of artificial neural networks and an optimization algorithm to improve dimensional accuracy of FDM square cross section. In FDM technique a consecutive fused layer of liquid in layer by layer form makes final geometry. Due to characteristic process however it is not possible to produce good dimensional tolerance. This paper has made some attempt to overcome these drawbacks. For this purpose, a model was developed to forecast the dimensions of the manufactured parts, based on available design characteristics. Particularly, this work has used an artificial neural network combined with an optimization algorithm, to determine

the optimal dimensional values for the CAD model. Further according to the algorithm provided the CAD model was revamped. The analysis of then result shows that errors in the manufacturing are reduced drastically it was 50 and 30% for external and internal dimensions respectively

2.2Conclusion of the Review:

Based on the previously written papers it is evident that there is not much work done on the extruder heat sink's thermal properties which is essential to avoid the too much preheating of the filament (PLA, ABS, etc.).so our project aims to address this problem by analyzing the thermal properties of the extruder sink with fins and determine which is effective.

CHAPTER 3

PROJECT DESIGN

3.1 INTRODUCTION TO CATIA:

fig 3.1 : CATIA

French organization Dassault Systems created multi-stage CAD/CAM/CAE business programming CATIA (Computer Aided Three-dimensional Interactive Application). This is composed in the C++ programming language, CATIA is the primary result of the Dassault Systems item lifecycle administration programming suite.

CATIA competes with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others in the CAD/CAM/CAE market.

Developer(s)	Dassault Systems
Stable release	V6R2011x / November 23, 2010
Operating system	Unix / Windows
Type	CAD software
License	Proprietary
Website	WWW.3ds.com

Table 3: Details of CATIA

3.2 History of CATIA:

In 1977 a French air craft maker Avions Marcel Dassault, began CATIA as an in-house advancement around then client of the CADAM CAD programming to build up Dassault's. Mirage contender plane, then was embraced in the shipbuilding, car, aviation and different commercial ventures.

At first named CATI (Conception Assisted Three Dimensional Interactive - French for Interactive Aided Three-dimensional Design) - it was renamed CATIA in 1981, when Dassault made an auxiliary to create and offer the product, and marked a non-selective circulation concurrence with IBM.

In 1984, CATIA is picked as its principal 3D CAD apparatus by Boeing Company, turning into its biggest client.

In 1988, CATIA adaptation 3 was ported from centralized server PCs to UNIX.

In 1990, CATIA is picked as its primary 3D CAD apparatus by General Dynamics Electric Boat Corp, to plan the U.S. Naval force's Virginia class submarine.

In 1992, IBM acquired CADAM and the following year CATIA CADAM V4 was distributed.

In 1996, it was ported from one to four UNIX working frameworks, including IBM AIX, Sun Microsystems SunOS, Silicon Graphics IRIX and Hewlett-Packard HP-UX.

In 1998, CATIA V5 was discharged a completely modified variant of CATIA, with backing for Windows NT, UNIX and Windows XP since 2001.

In 2008, Dassault released CATIA V6. While the server can keep running on Microsoft Linux or AIX, Windows, customer backing for any working framework other than Microsoft Windows is dropped.

Release History

Name/Version	Latest Build Number	Original Release Date	Latest Release Date
CATIA v4	R25	1993	January 2007
CATIA v5	R20	1998	February2010
CATIA v6	R2012	29/05/2008	May 2011

Table 4: versions of CATIA

3.3 SCOPE OF APPLICATIONS:

3D Product Lifecycle Management suite available in CATIA, multiple stages of product development (CAx), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE) can be performed.

CATIA facilitates mutual engineering across disciplines, mechanical engineering, including shape design & surfacing, systems engineering and equipment.

Surfacing & Shape Design

CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From styling, subdivision, and Class A surfaces to mechanical functional surfaces.

Mechanical Engineering

Modules like 3D sketches, sheet metal work bench, forged or tooling parts for creation of 3D parts like assemblies a molded are available in CATIA. The tools in the CATIA enable functional tolerances, Kinematics definition and product definition.

Equipment Design

The design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing can be done by CATIA.

Systems Engineering

CATIA solves intelligent products and Model complex through the systems engineering approach. It covers the requirements definition, the systems architecture, the behavior modeling and the virtual product or embedded software generation. It can be customized via application programming interfaces (API). Visual Basic and C++ programming languages via CAA (Component Application Architecture); a component object model (COM)-like interface is adapted using CATIA V5 & V6.

Although later versions of CATIA V4 implemented NURBS, V4 principally used piecewise polynomial surface. Non-manifold solid engine is used in CATIA V4.

Parametric solid/surface-based package which uses NURBS available in CATIA as the core surface representation and has several workbenches that provide KBE support. Enova, Smart team and various CAE Analysis applications can work with V5.

Supported Operating Systems And Platforms

CATIA V6 runs only on Microsoft Windows and Mac OS with limited products.

CATIA V5 runs on Microsoft Windows (both 32-bit and 64-bit), and as of Release 18Service Pack4 on Windows Vista 64.IBM AIX, Hewlett Packard HP-UX and Sun Microsystems Solaris are supported.

CATIA V4 is supported for IBM MVS, UNIXs VM/CMS and mainframe platforms up to release 1.7.

CATIA V3 version and earlier versions run on the mainframe platforms.

3.4 NOTABLE INDUSTRIES USING CATIA

CATIA can be connected to a wide variety of commercial enterprises, from aviation and defense, car, and modern gear, to cutting edge, shipbuilding, shopper merchandise, plant outline, purchaser bundled products, life sciences, building design and development, procedure force and petroleum, and administrations. CATIA V4, CATIA V5, Pro/E, NX (once in the past Unigraphics), and Solid Works are the predominant frameworks.

Aerospace:

Aviation the Boeing Company utilized CATIA V3 to create its777 carrier, and is at present utilizing CATIA V5 for the787 arrangement air ship. They have utilized the full scope of Dassault Systems' 3D PLM items — CATIA, DELMIA, and ENOVIALCA — supplemented by Boeing created applications.

Chinese Xian JH-7 is the first plane made by CATIA V5, when the blueprint was done on September 26, 2000.European aviation monster Airbus has been utilizing CATIA since 2001. Canadian air ship creator Bombardier Aerospace has done the majority of its flying machine outline on CATIA.

Westland is currently some portion of an Italian organization called Finmeccanica the joined organization calls them AgustaWestland. The primary supplier of helicopters to the U.S Military powers, Sikorsky Aircraft Corp., utilizes CATIA.

Automotive:

Many automotive companies utilize CATIA to varying degrees, including BMW, Audi, Jaguar Land Rover, Volkswagen, Porsche, Daimler AG, Chrysler, Honda Bentley Motors Limited, Volvo, Fiat etc. Goodyear uses it in making tires for automotive and aerospace and also uses a customized CATIA for its design and development. They use CATIA to make design components like car doors, car roofs etc.

Ship building:

Dassault Systems has started serving shipbuilders with CATIA V5 discharge 8, which incorporates exceptional components valuable to shipbuilders. GD Electric Boat utilized CATIA to plan the most recent quick assault submarine class for the United States Navy, the Virginia class. Northrop Grumman Newport News likewise utilized CATIA to plan the Gerald. Portage class of super bearers for the US Navy.

Industrial Equipment:

CATIA has number vicinity in the Industrial Equipment industry. Mechanical Manufacturing apparatus organizations like Schuler and Metso use CATIA, and also substantial portable hardware and gear organizations like Class, furthermore different modern hardware item organizations like Alstom Power and ABB Group.

3.5 Design of 3D printer extruder with fins:

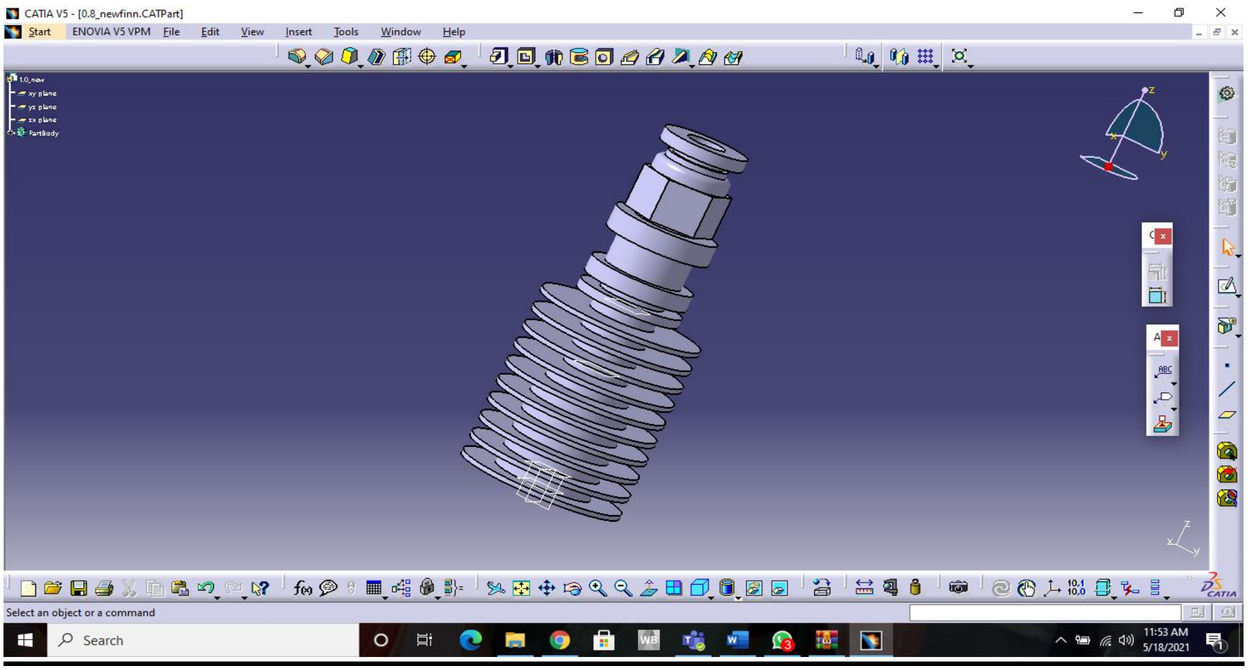

Fig 3.2 :Extruder sink with 0.8mm thickness fins

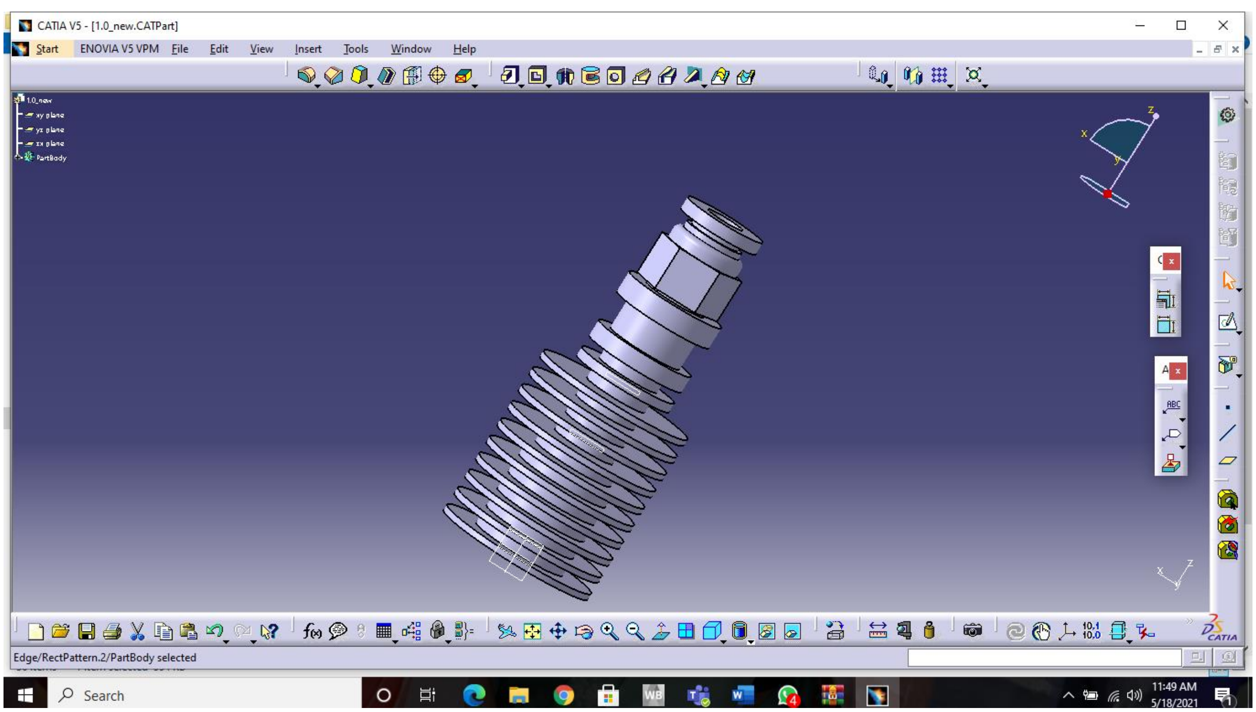

Fig 3.3 : Extruder sink with 1mm thickness fin

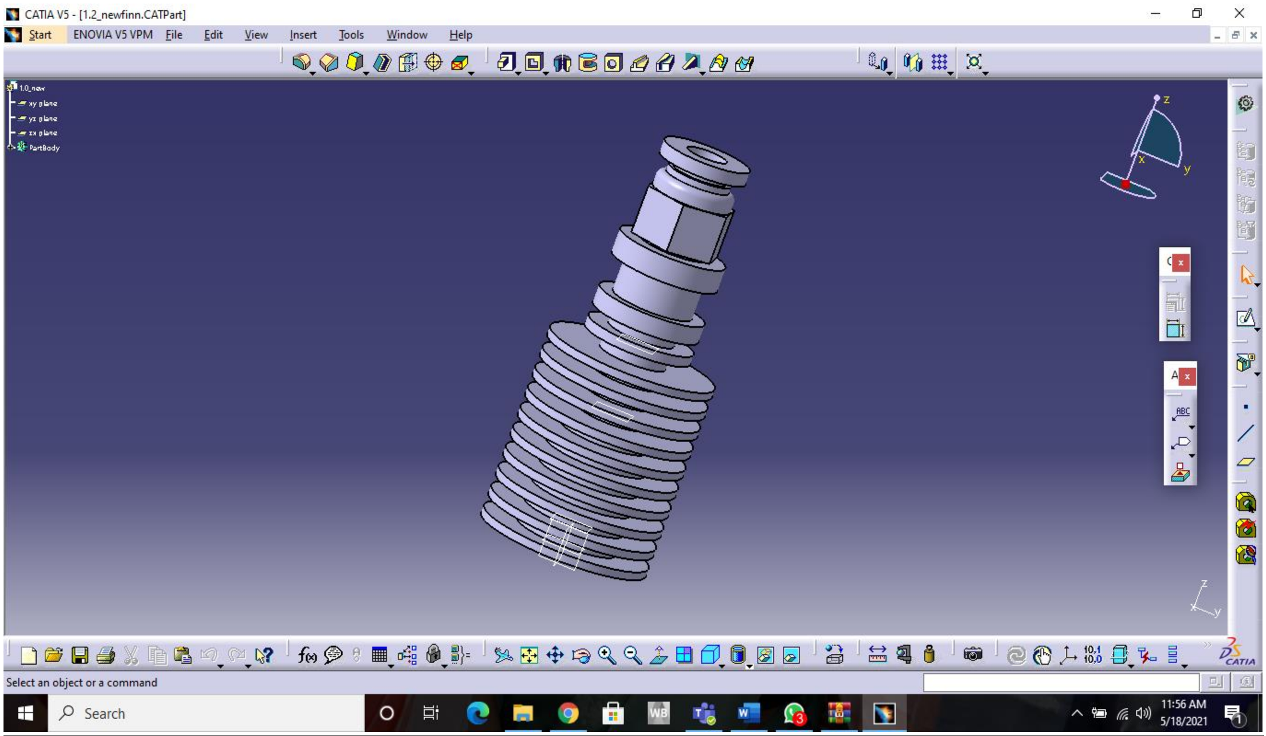

Fig 3.4 : Extruder sink with 1.2 mm thickness circular fins

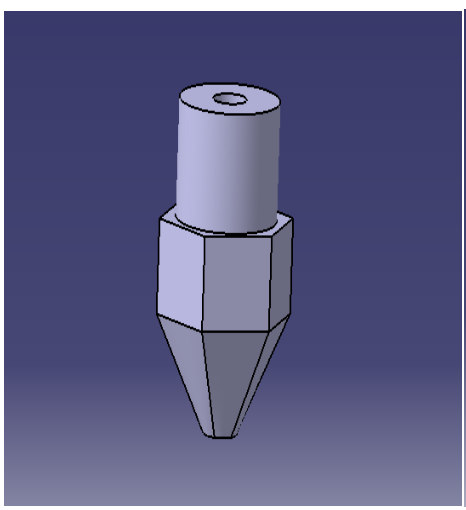

Fig 3.5: 3D Printer Nozzle

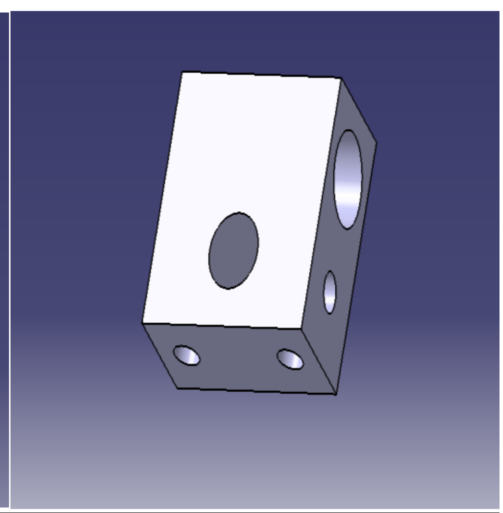

Fig 3.6: Heat Block

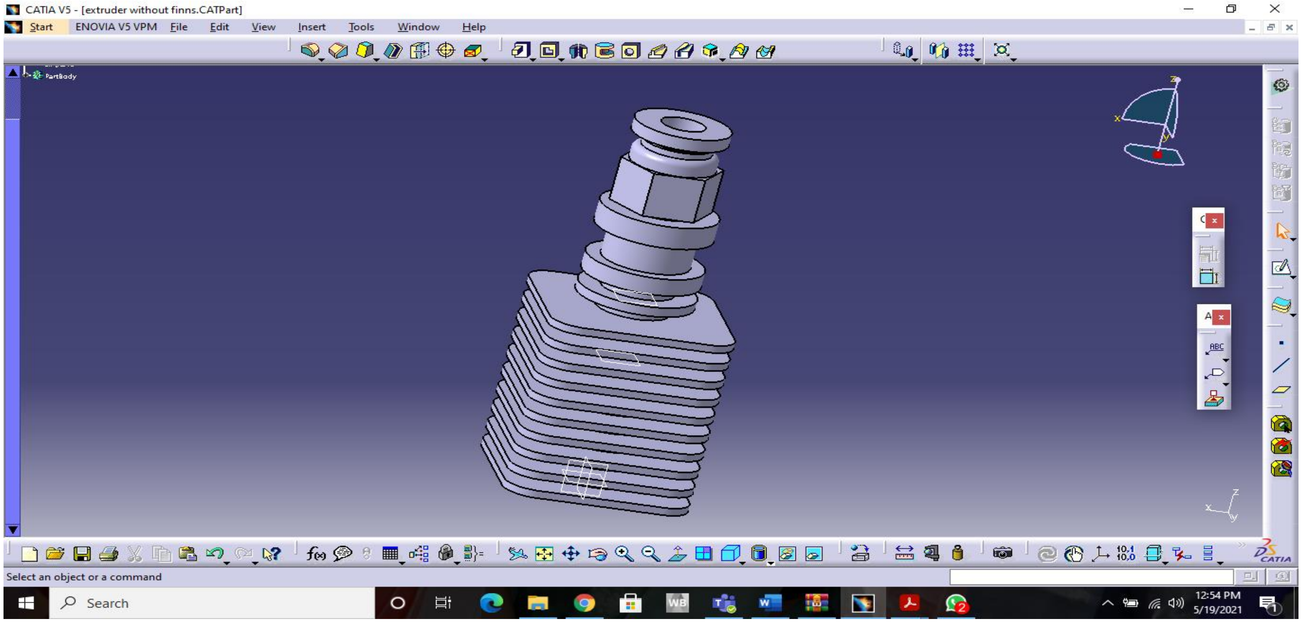

Fig 3.7: Extruder sink with rectangular(1.2mm thickness) fins.

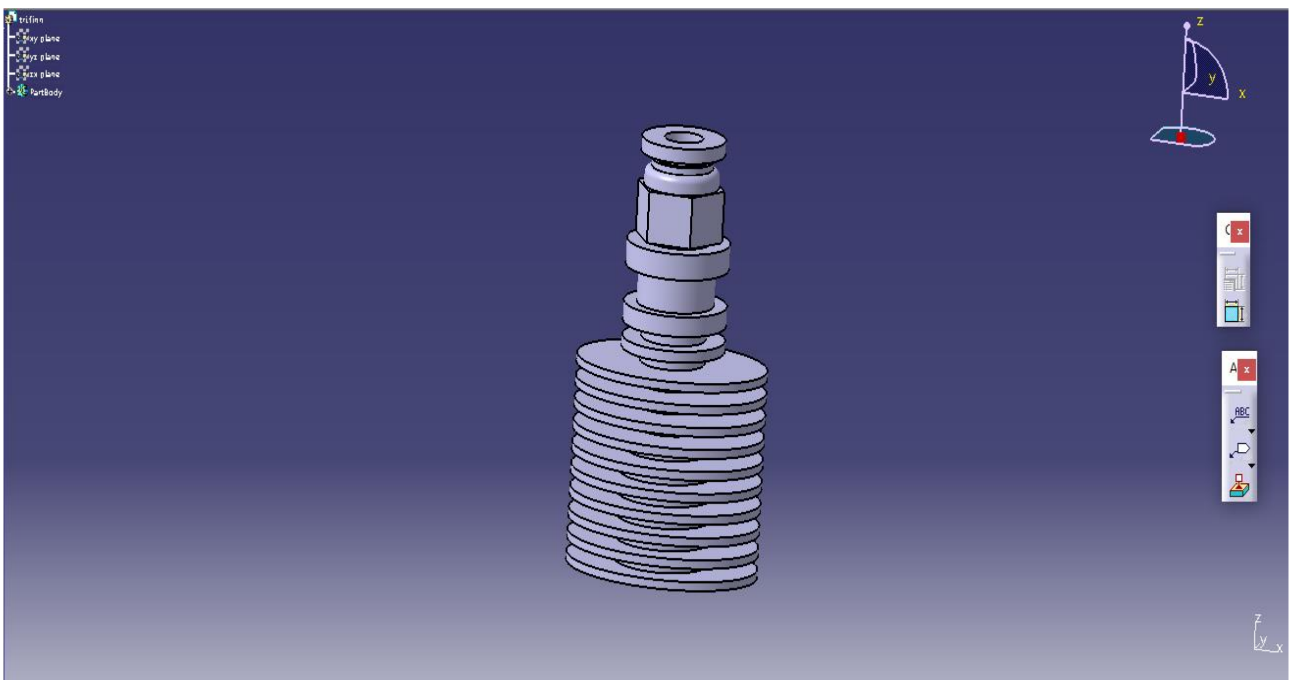

Fig 3.8: Extruder sink with elliptical(1.2mm thickness) fins.

CHAPTER 4

PROJECT IMPLIMENTATION

4.1 INTRODUCTION TO FINITE ELEMENT ANALYSIS

The essential idea in fem is that the body or structure may be separated into littler components of limited measurements called "Finite Elements". The first body or the structure is then considered as a gathering of these components associated at a limited number of joints called "nodes" or "nodal points"

Basic capacities are approximated the relocations over each limited component. Such accepted capacities are called "shape capacities". This will speak to the uprooting within the component as far as the remit Element technique is a scientific apparatus for illuminating common and fractional at the hubs of the components. The Final differential comparison in light of the fact that it is a numerical instrument, it can take care of the unpredictable issue that can be spoken to in differential mathematical statement from. The use of FEM is boundless as respects the arrangement of commonsense configuration issues.

FEM has good efficiency to solve problems and cost critical problems as the cost for computing power is high.

The finite element method can be utilized to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mold flow simulations

Now a days, even the simplest of products rely on the finite element method for design evaluation. This is on account of contemporary configuration issues normally can't be understood as precisely and inexpensively utilizing some other system that is at present accessible. Physical testing was the standard in the years passed by, however now it is just excessively costly and tedious too.

ESSENTIAL CONCEPTS: The limited component technique depends on building an entangled article with basic squares or driving a confounded item into little and sensible pieces. Use of this

FEA can be explained with a small example such as measuring the area of a circle.

Area of one triangle: Si=1/2*R2*sin I.

Area of the circle: SN=1/2*R2*N*Sin (2∏/N) →∏R2 as N→∞. Where N= total number of triangles (elements)

To calculate the area of circle without using conventional formula, one of the approaches could be dividing the area into number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

4.2 A BRIEF HISTORY OF THE FEM:

WHO

The reference credited is to Courant (Mathematician), Turner (air craft industry), Clough (California University), Martin (air craft industry), Argyris (German university), etc. However, it was probably established by several pioneers independently.

WHEN

- Initial idea in mathematical terms was put in 1940s.
- Application to simple engineering problems in 1950s.
- Implementation in large computers in 1960s.
- Development of pre- and post-processors in 1980s.

Analysis of large structural problems in 1990s. basic thought can be discovered all over the place in ordinary life and building. The philosophy

WHERE

Implementation and application were mainly in aircraft industry and automobile sectors (large and fast computers were available only in these industries).

WHAT

Field problems in the form matrix of organizing large numbers of algebraic equations are used and matrix equations are solved. Differential equations are changed into an algebraic form. Blocks with different geometry are hooked together for creating complex geometry of the engineering problem.

WHY

The advantage of doing FEM analysis is that it is fairly simple to change the geometry, material and loads recomputed stresses for modified product rather than build and test. The method can be used to solve almost any problem that can be formulated as a field problem. The entire complex problem can be cast as a larger algebraic equation by assembling the element matrices within the computer and solved.

5.3 BASIC STEPS INVOLVED IN FEA:

Numerically, the structure to be examined is subdivided into a cross section of limited estimated components of straightforward shape. Inside of every component, the variety of dislodging is thought to be dictated by basic polynomial shape capacities and nodal relocations.

Comparisons for the strains and hassles are created as far as the obscure nodal relocations. From this, the mathematical statements of the balance are amassed in a grid from which can be effortlessly being customized and illuminated on a PC. In the wake of applying the proper limit conditions, the nodal relocations are found by understanding the framework firmness mathematical statement. Once the nodal relocations are known, component hassles and strains can be figured.

Basic Steps In FEA:

- Discretization of the domain.
- Applying the boundary conditions.
- Assembling the system equations.
- Solution for system equations.
- Post processing the results.

a) Discretization of the Domain:

The task is to divide the continuum under study into a number of subdivisions called element. Based on the continuum it can be categorized into line or area or volume elements.

b) Application of Boundary Conditions:

From the physics of the problem, we have to apply the field conditions i.e., loads and constraints, which will help us in solving for the unknowns.

c) Assembling System Equation:

The formulation of respective characteristic (Stiffness in case of structural) equation of matrices and assembly is involved in this.

d) Solution for System Equation:

Solve the equations to know the unknowns. This is basically the system of matrices which are nothing but a set of simulations equations are solved.

e) Viewing the Results:

After the completion of the solution, we have to review the required results.The first two steps of the above said process is known as pre-processing stage, 3rd. and 4the steps are the processing stage and the final step is known as post-processing stage.

f) What is an element?

The entity in which system under study can be divided is called an Element. An element definition can be specified by nodes. The shape (area, length and volume) of the element depends upon the nodes with which it is made up of.

g) What are nodes?

Nodes are the vertex points of the element. Independent entities in the space are nodes. Points in geometry and nodes are common. The element can be changed by moving a node. This is a volume element, can take the shape of a Hexahedron or a wedge or a Tetrahedron order elements. For linear elements the linear function defines edge called shape function whose degree is one. For the components having mid side nodes on the edge quadratic capacity called shape work whose degree is two is utilized. The higher request components when over lapped in geometry can speak to complex shapes exceptionally well inside of couple of components. The arrangement exactness will be more with the high request components. Be that as it may, higher request components will require more computational exertion and time

5.4 ANSYS INTRODUCTION:

The ANSYS program is self-contained general purpose finite element program.
This is developed and maintained by Swanson analysis systems Inc.
ANSYS finite element analysis software enables following tasks:

- Apply design performance conditions or other operating loads.
- Build computer model or transfer models of structures, components, products, or system.

- Testing prototype in environments where it otherwise would be impossible or undesirable.
- Studying physical responses such as temperature distributions, stress levels or electromagnetic fields.
- Reducing the productions cost by optimizing design early in the development process.

The ANSYS project has a compressive graphical client interface (GUI) that gives clients simple, intelligent access to program capacities, orders, documentation and reference material. A natural menu framework offers clients some assistance with navigating through the ANSYS program. Clients can enter information utilizing a mouse, a console, or a blend of both.
A graphical client interface all through the project, to direct new clients through the learning process and furnish more experienced clients with different windows, draw down menus, dialog boxes, apparatus bar and online documentation.

5.5 PERFORMING A TYPICAL ANSYS ANALYSIS

The ANSYS system has numerous limited component investigation capacities, extending from a straightforward, direct, static examination to a nonlinear, transient element investigation. The investigation guide manuals in the ANSYS documentation set portray particular systems for performing examination for diverse building controls. A typical
ANSYS analysis has three distinct steps:

- construct the model
- Apply loads and boundaries
- Obtain the solution
- Review the results

The following table shows the brief description of steps followed in each phase.

Pre-processor	Solution processor	Post processor
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graphs
Assigning real constants	load definition	view animated results
Material definition	Solve	
Mesh generation		
Model display		

Table: 8 Steps followed in ANSYS

Pre-Processor:

Preprocessor prepares the input data for ANSYS analysis. The general preprocessor (PREP 7) contains solid modeling and mesh generation capabilities, and is also used to define all other analysis data with the benefit of data base definition and manipulation of analysis data. Parametric input, user files, macros and extensive online documentation are also available, providing more tolls and flexibility for the analyst to define the problem. Extensive graphics ability is available throughout the ANSYS program, including isometric, perceptive, section, edge and hidden-line displays of three-dimensional structures-y graphs of input quantities and results, and contour displays of solution results.

The preprocessor stage involves the following:

- Specify the title, which is the name of the issue. This is discretionary yet exceptionally valuable, particularly if various configuration cycles are to be finished on the same base mode.
- Analysis types thermal analysis, modal analysis, Harmonic analysis etc.
- Creating the model: The model may be made in pre-processor, or it can be imported from other design software by changing the file format.
- Defining element type: these chosen from element library.
- Assigning real constants and material properties like young`s modules, Poisson’s ratio, density, thermal conductivity, damping effect, specific heat, etc.
- Apply mesh: Meshing is nothing but dividing the whole area into discrete number of particles.

Solution Processor:

Here we create the environment to the model, i.e., applying constraints & loads. This is the main phase of the analysis, where the problem can be solved by using different solution techniques. Here three major steps involved:

- i.e., static, modal, or transient etc. is selected.
- Defining loads: The loads may be surface loads, point loads; thermal loads like temperature, Solution type required or fluid pressure, velocity is applied.
- Solve FE solver can be logically divided into three main steps, the pre-solver, the solution and post-solver. Model read by pre solver which is created by the pre-processor and makes the arithmetical representation of the model and calls the mathematical-engine, which calculates the result. The result return to the solver and the strains, stresses, etc. for each node within the component or continuum are calculated by post solver.

Post Processor:

Post processing means the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affects the design, how the meshing is done.

Post processor analyzes results, which display stress and strain contours, distorted geometries, flow fields, safety factor contours, contours of potential field results; vector field displays shapes of mode and graphs related to time history. The post processor can also be used for algebraic operations, database manipulators, differentiation and integration of calculated results.

Review The Results:

Once the solution has been calculated, results can be reviewed in post processor. Two post processors are available: POST 1 and POST 26. We use POST 1, the general post processor to review the results at one sub step over the entire model or selected portion of the model. We can obtain contour displays, deform shapes and tabular listings to review and interpret the results of the analysis. POST 1 offers many other capabilities, including error estimation, load case combination, calculation among results data and path operations. We use POST 26, the time history post processor, to review results at specific points in the model over all tome steps. We can obtain graph plots of results, data vs. time and tabular listings. Other POST 26 capabilities include arithmetic calculations and complex algebra.

The simultaneous set of equations that the finite element method generates the solution taken by the computer, the results of the solution are:

- Nodal degree of freedom values, which form the primary solution.
- Derived values which frame the component arrangement

Meshing:

Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components. In the event that we need this kind of lattice, we must form the geometry as arrangement of genuinely normal volumes and/or regions that can acknowledge a mapped network.

Analysis Steps:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, Material property, force value, or any other input.
- Define material properties.
- Specify input thermal properties..
- The program automatically creates a mixed mesh when different geometries (solid, shell, Structural members etc.) Exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and Optimization studies use the meshes in referenced studies.
- Run the study.
- View results.

4.6 Analysis of the extruder using ANSYS:

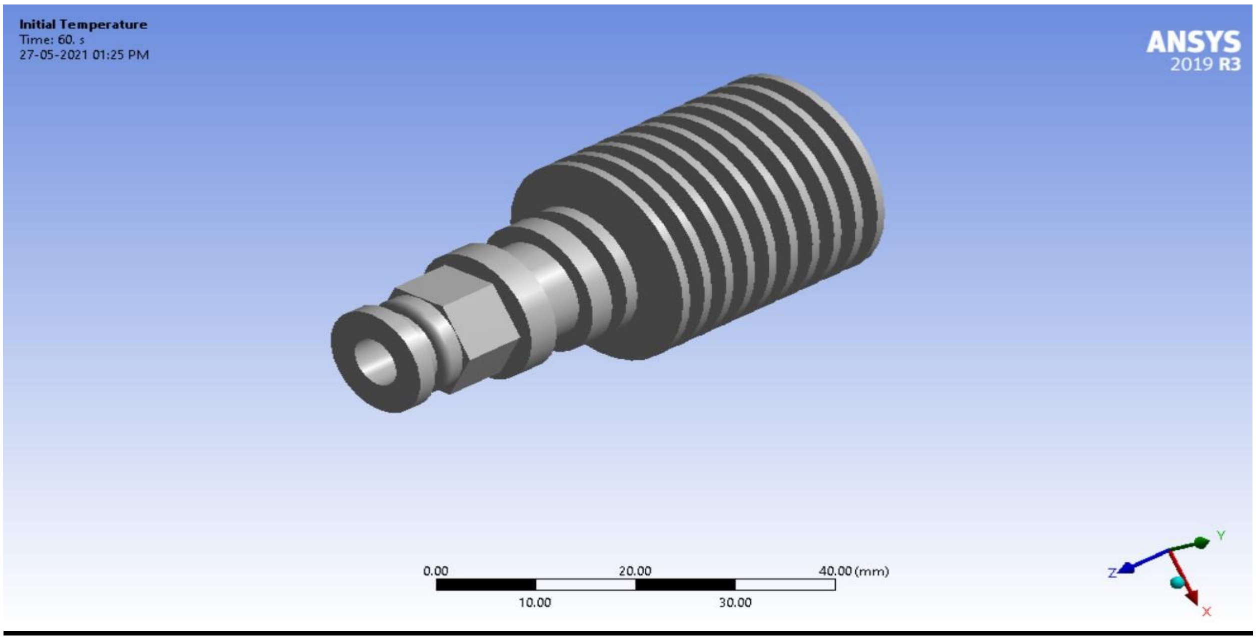

Fig 4.1: Initial Temperature(27°C)

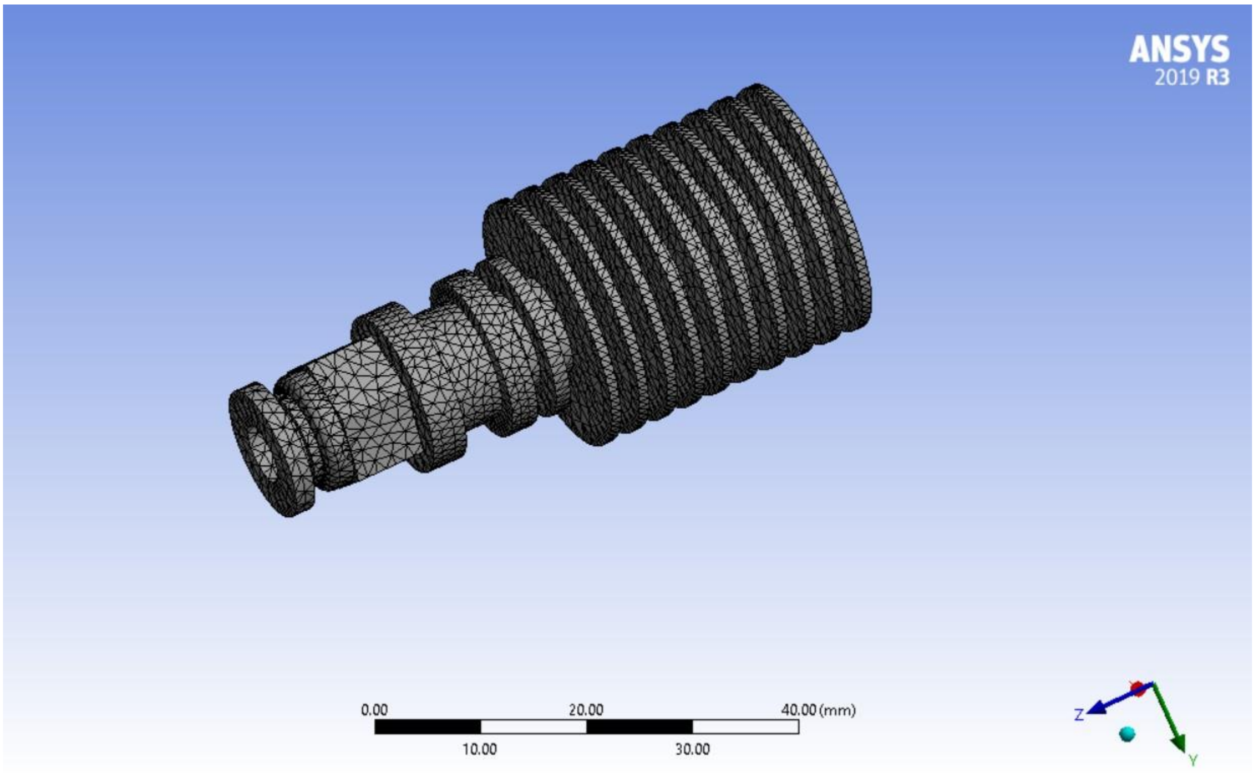

Fig 4.2: meshing (tetrahedral)

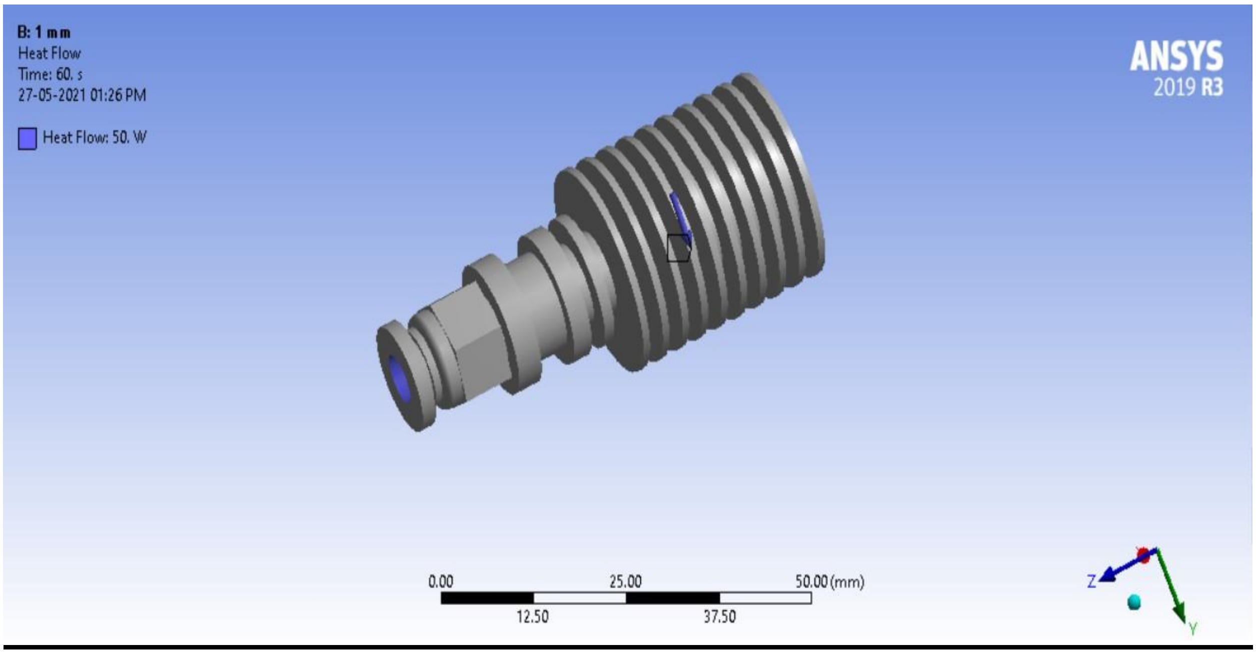

Fig 4.3: Heat flow

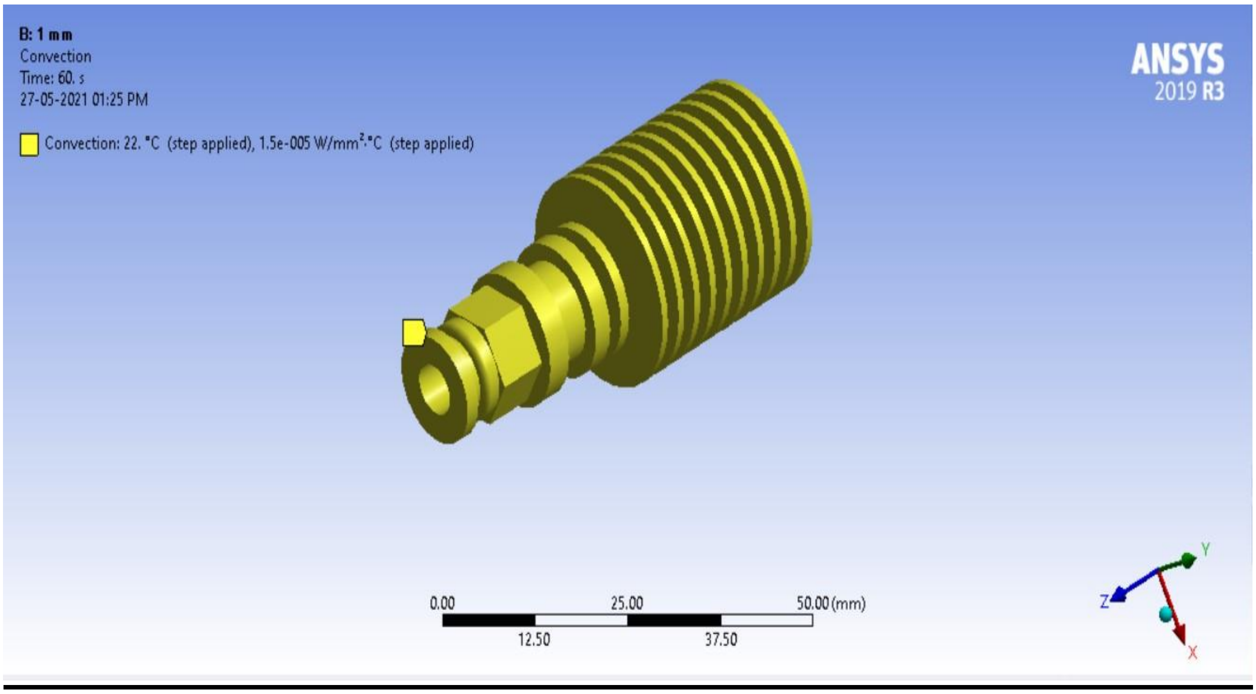

Fig 4.4: Convection

Results:

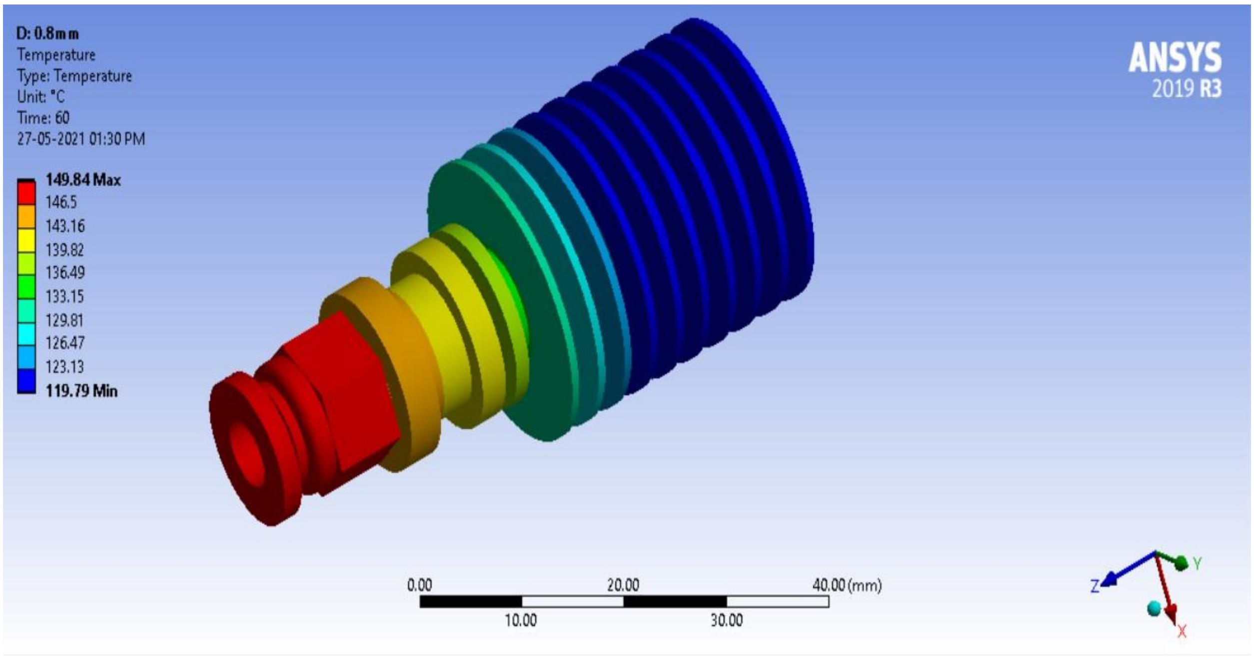

Fig 4.5: Temperature distribution

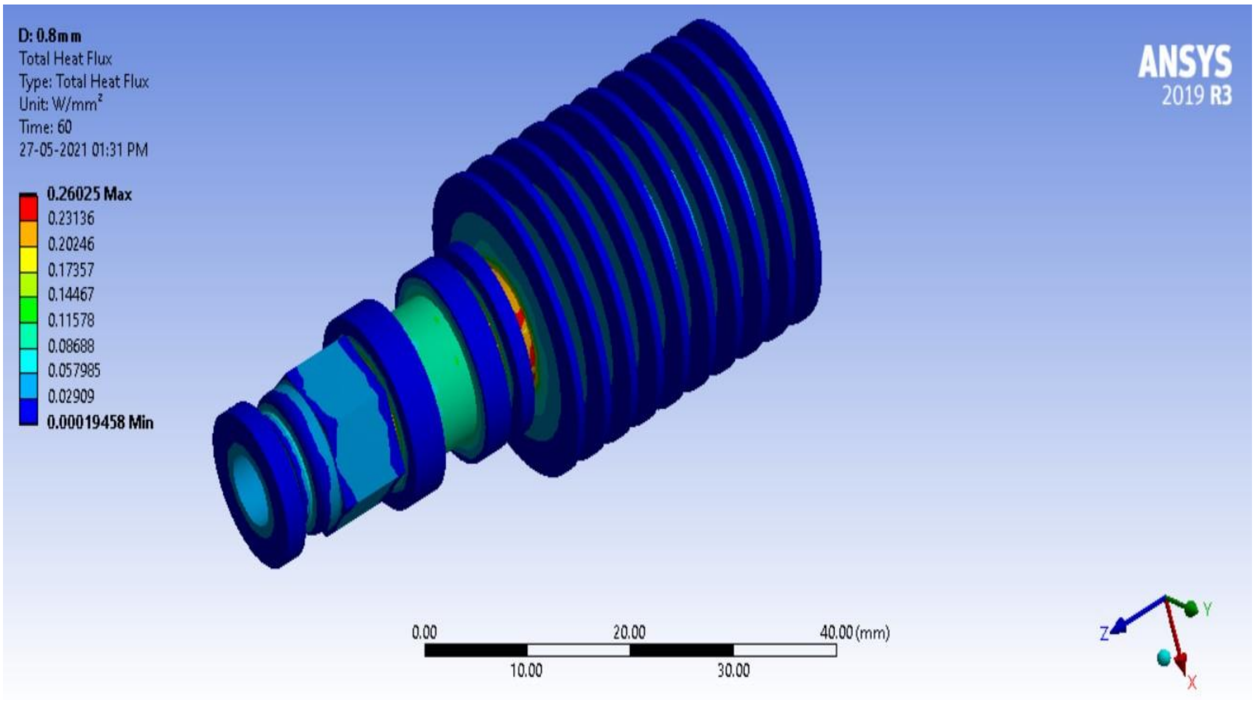

Fig 4.6: Total Heat flux

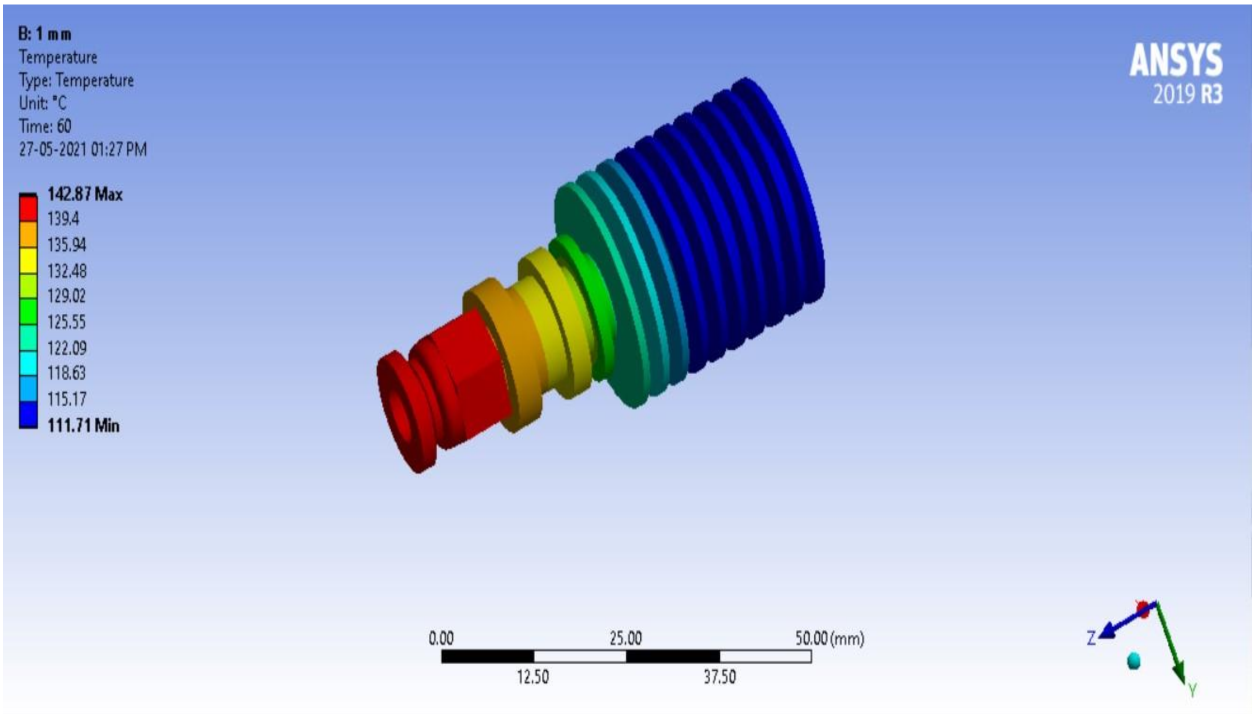

Fig 4.7: Temperature distribution

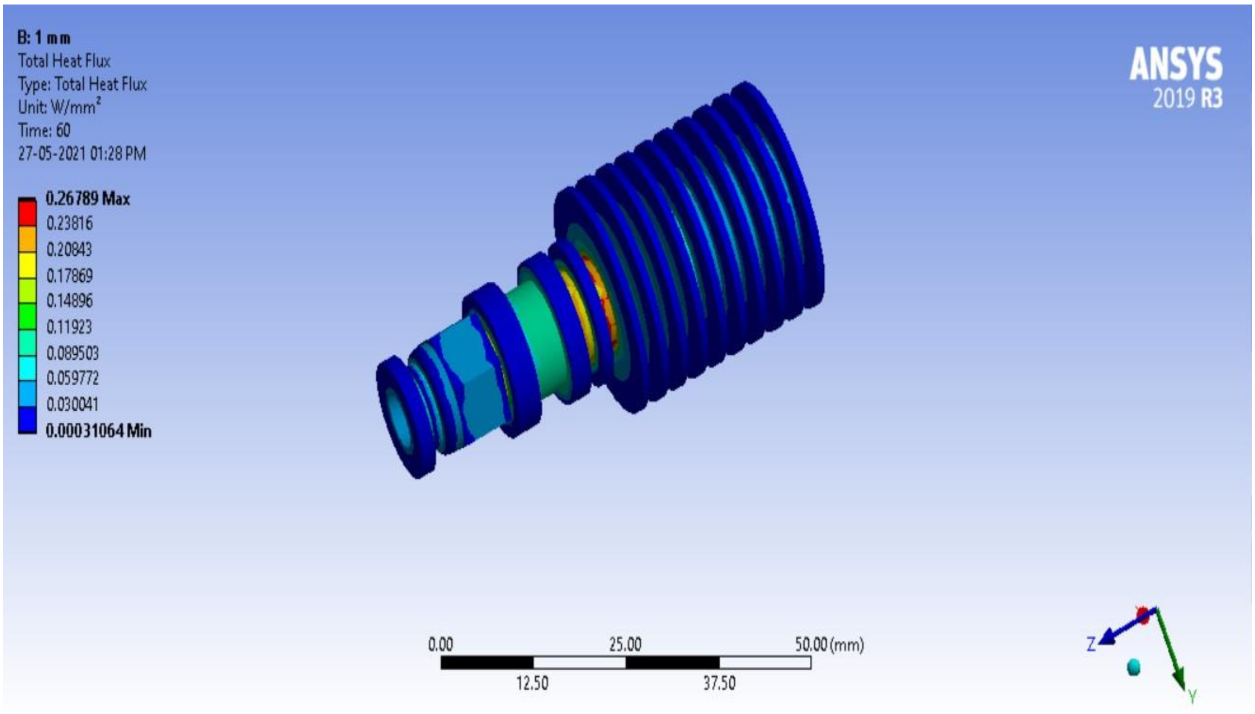

Fig 4.8: Total Heat flux

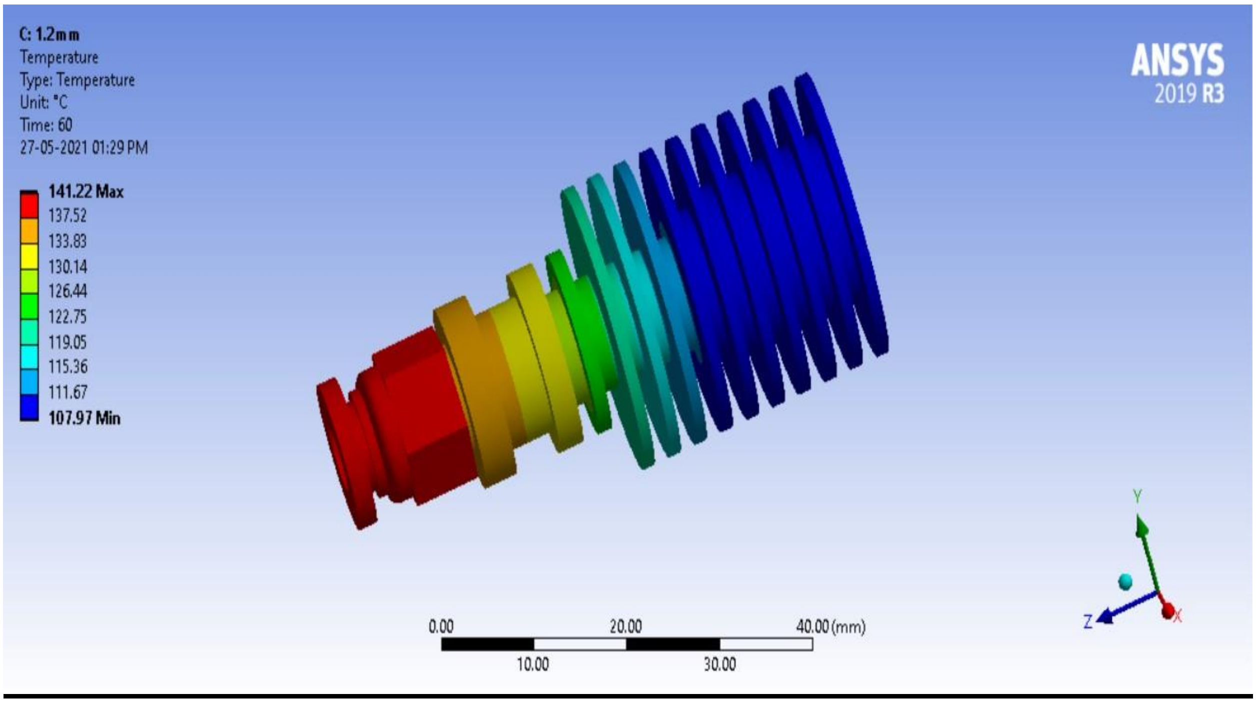

Fig 4.9: Temperature distribution

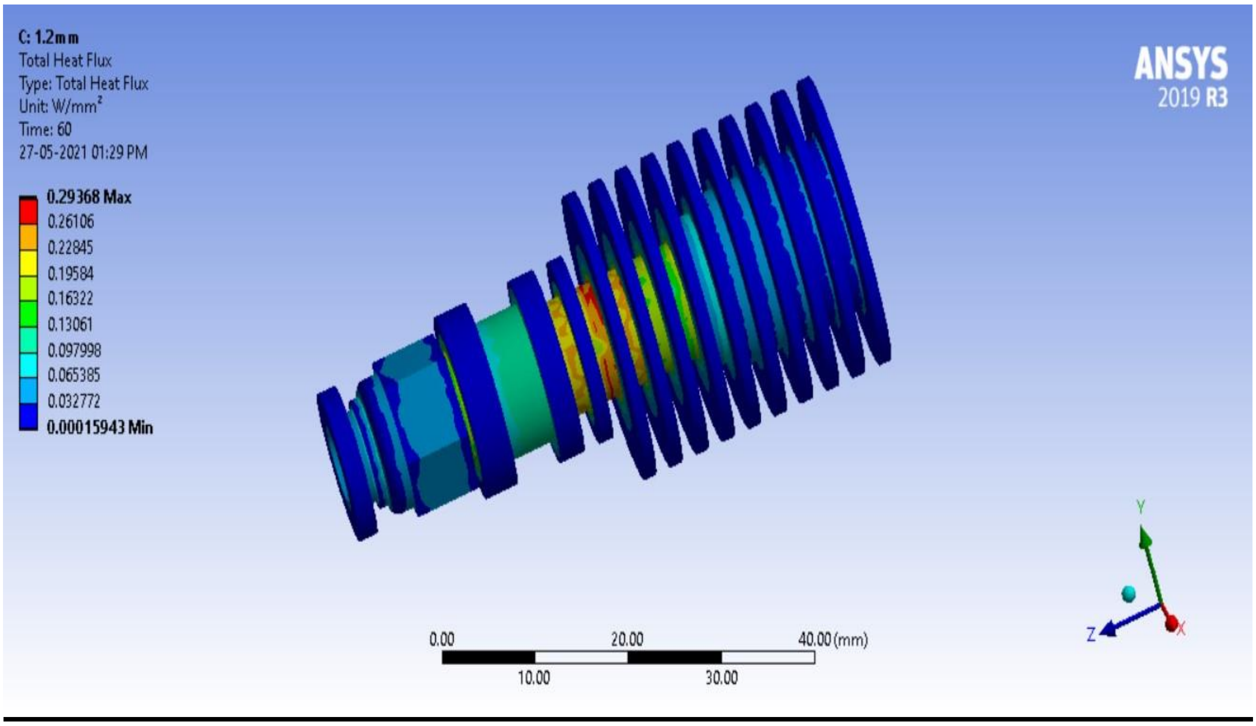

Fig 4.10: Total Heat flux

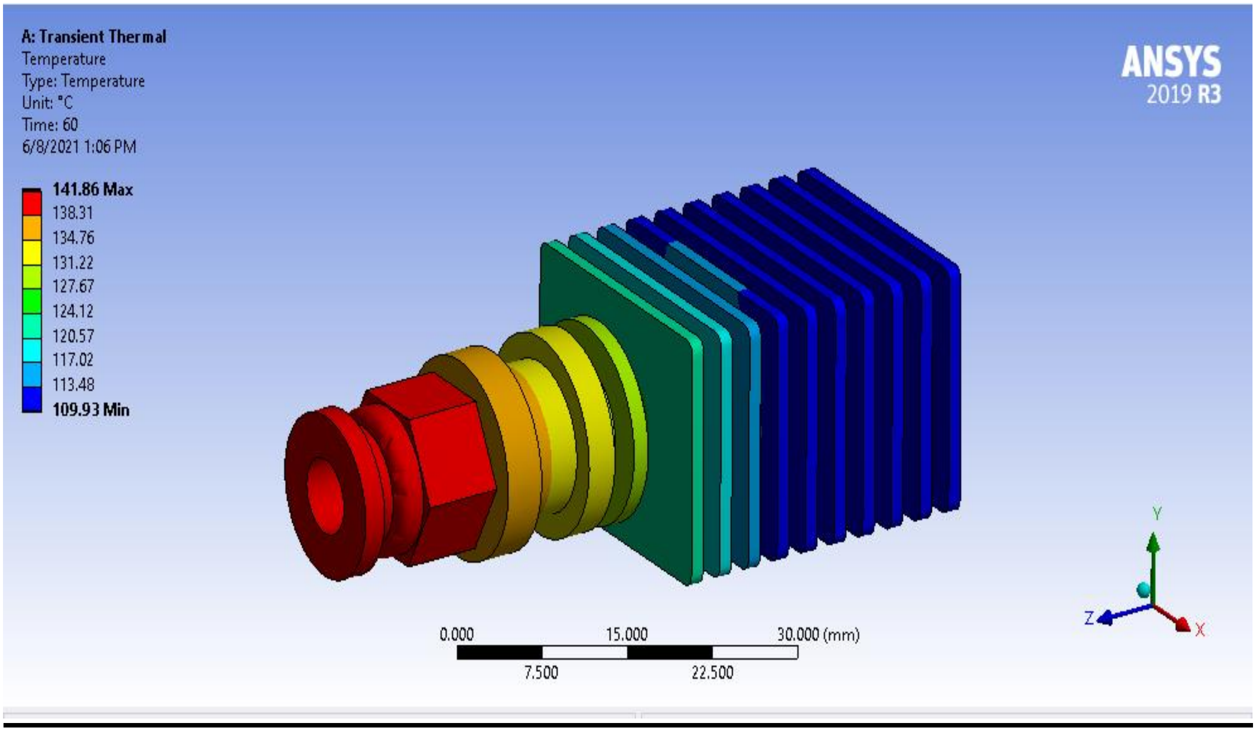

Fig 4.11: Temperature distribution

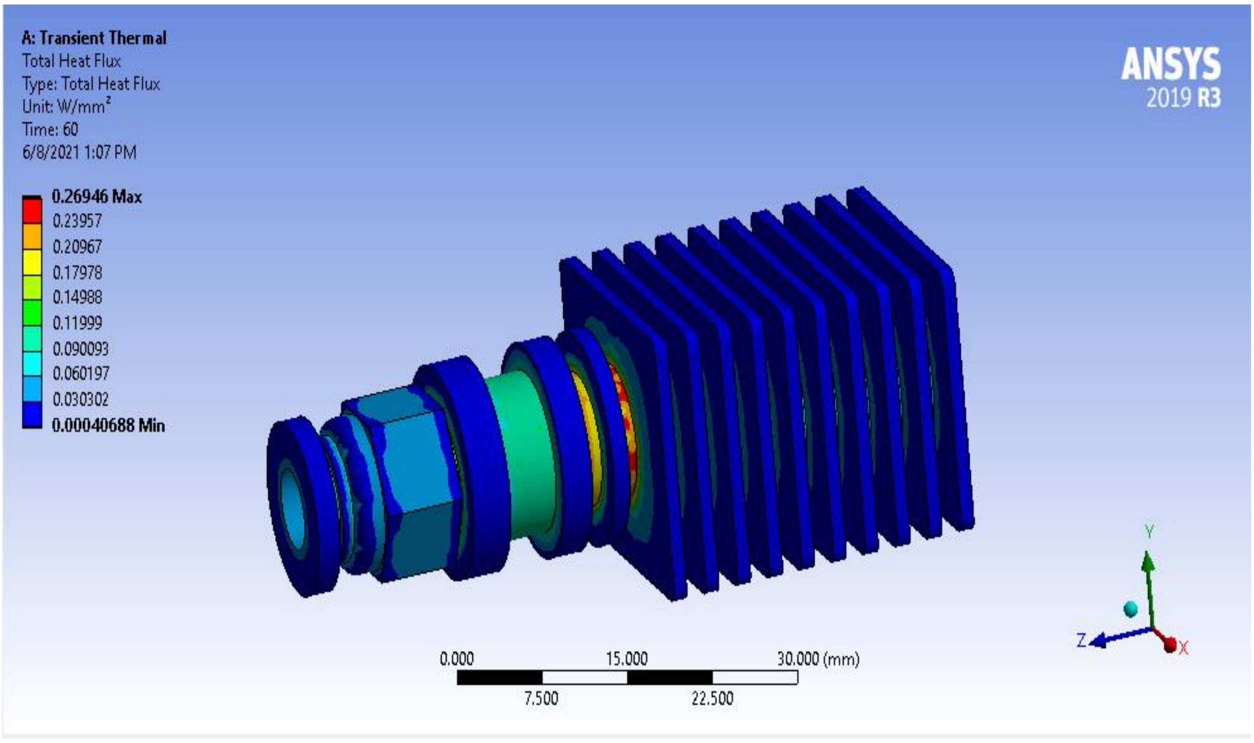

Fig 4.12: Total Heat flux

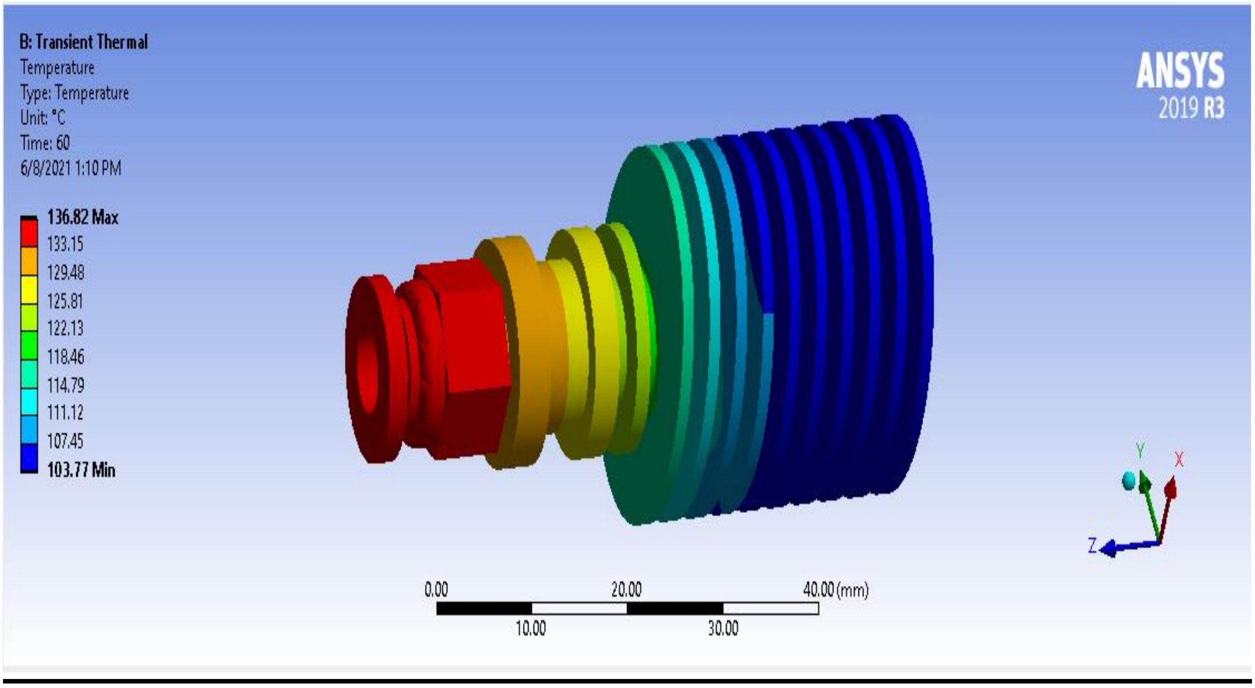

Fig 4.13: Temperature distribution

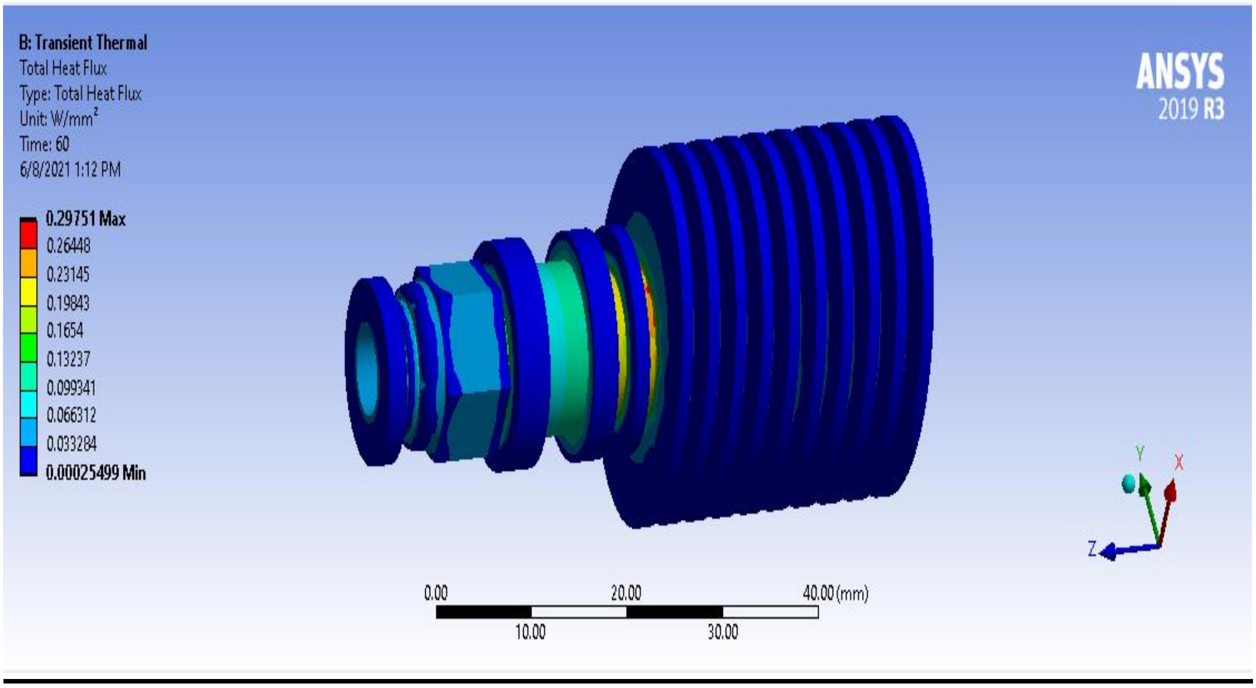

Fig 4.14: Total Heat flux

4.7 Result table:

S.no	Thermal property	Extruder with circular fin (0.8mm)	Extruder with circular fin (1.0mm)	Extruder with circular fin (1.2mm)	Extruder with rectangular fin (1.2mm)	Extruder with elliptical fin (1.2mm)
1	**Temperature (maximum) °C**	**149.84**	**142.87**	**141.22**	**141.84**	**136.82**
- 2	**Temperature (minimum) °C**	**119.79**	**111.71**	**107.97**	**109.93**	**103.77**
3	**Heat flux (maximum)W/mm2°C**	**0.26025**	**0.26789**	**0.29368**	**0.26949**	**0.29751**
4	**Heat flux (maximum)W/mm2°C**	**0.00019**	**0.00031**	**0.00015**	**0.00040**	**0.00025**

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 Conclusion:

Initially we have designed extruder with circular fins with varying thicknesses(0.8mm,1.0mm,1.2mm) and perform analysis and found that fin thickness of 1.2mm is more effective when compared to other shapes of fins. Further we used this 1.2 mm thickness and designed extruder sink with rectangular and elliptical shaped fins and performed analysis on them.

So after comparing the results of the rectangular and elliptical fins we finally conclude that elliptical fins are more effective than any other shape of fins as the results (Temperature distribution, Total Heat flux) are better than the others.

5.2 Future Scope:

This project can be further used to fabricate the 3D printer extruder sink with the appropriate shape of the fin which is more effective in terms of Heat Dissipation.

I future these results that we have obtained for extruder sink with various shapes of fins will be helpful to design extruder sink with various other fin shapes which maybe even more effective than the ones we used for our study.

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A Main Project Report

On

TOPOLOGY OPTIMIZATION OF FOUR STROKE ENGINE BLOCK TO CONVERT IN TO SIX STROKE ENGINE

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfilment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

CH. PREM KUMAR - (17K81A0369)

N. HARSHITH - (17K85A0397)

P. SAIPRASAD - (17K85A03A8)

Under the Guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

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Secunderabad, Telangana (India)-500100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Topology Optimization Of Four Stroke Engine Block To Convert In To Six Stroke Engine**, is being submitted by **CH. Prem kumar(17K81A0369), N. Harshith(17K85A0397), P. Saiprasad (17K85A03A8)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OFTECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide	**Signature of HOD**
P. RAJAMANI	**Dr. D.V. SREEKANTH**
Assistant Professor,	**Professor & Head of the Department**
Department of Mechanical Engineering	Department of Mechanical Engineering

Internal Examiner **External Examiner**

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year:2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Topology Optimization of Four Stroke Engine Block To Convert In To Six Stroke Engine** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

CH. PREM KUMAR	(17K81A0369)
N. HARSHITH	(17K85A0397)
P. SAIPRASAD	(17K85A03A8)

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ABSTRACT

In six stroke engine, there are additional two strokes, namely another power and exhaust strokes. The engine works through harnessing wasted heat energy created by the fuel combustion. After the combustion stage water is injected into the superheated cylinder. The water explodes into steam and force the piston down. It in turn helps to cool the engine. That resulted in normal levels of power but using much less fuel. It also has the advantage of not requiring an external cooling system. In these six stroke engines an additional water tank is added which stores water in it. In order to counter this extra weight, the weight of the original engine must be decreased. In this project, one such four stroke engine is modelled and its weight is decreased by removing unnecessary material by using topology optimization. Weight of water tank completely filled with water is assumed and equivalent amount of weight is decreased from the engine to convert it into a six stroke engine block.

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Chapter 1 Introduction

1.0 Overview of the Project:

We are going to design a four stroke engine block in Solidworks software and perform Topology Optimization in Solidworks. In a six stroke engine additional two strokes must be added namely a power stroke and an exhaust stroke. For this a water tank must be added so that addidtional two strokes can be taken place. When the water tank is filled with water and the water will be injected into the cylinder and due to the heat produced in the engine will turn the water into steam, So that the steam will be performing additional two strokes. In an engine the main component is engine block, So we are going to decrease the weight from the engine block by Topology Optimization.

1.1 objective of the Project:

• The 4-stroke engine design is modified to design 6-stroke engine.
• It improves efficiency and reduce emissions with less fuel consumption.
• There are total 6 cycles with two power strokes.
• The 6-stroke engines are categorized into single piston type and opposed piston type.
• It delivers higher output power and torque.
• There are two expansions (work/power stroke) in the six strokes.

1.2 Scope of the Project:

➡Power output is higher. It is increased by 35% compare to 4-stroke engine.

➡Emission is less and hence air pollution is lower by up to 65%.

➡Thermal efficiency is higher.

➡Fuel consumption is less. It is reduced by 40% compare to 4-stroke engine.

➡Lower engine temperature and noise level.

➡Due to more air intake, the cooling system is improved. Hence external cooling is not required.

➡The output torque is increased by 35% compare to 4-stroke engine.

1.3 IC engine

The first successfully working internal combustion engine used in an automobile was built by Siegfried Marcus in approximately 1864. It was an upright single-cylinder, two-stroke petroleum-fuelled engine that also utilized a carburettor to deliver fuel to the engine. The engine was placed on a cart with four wheels and successfully ran under its own power. Not only has Marcus produced the first engine that is the direct predecessor to today's engines, he had also built the first automobile in history, some 20 years before Gottlieb Daimler's automobile.

Today's engines are an integral component of an automobile that are built in a number of configurations and are considerably more complex than early automotive engines.

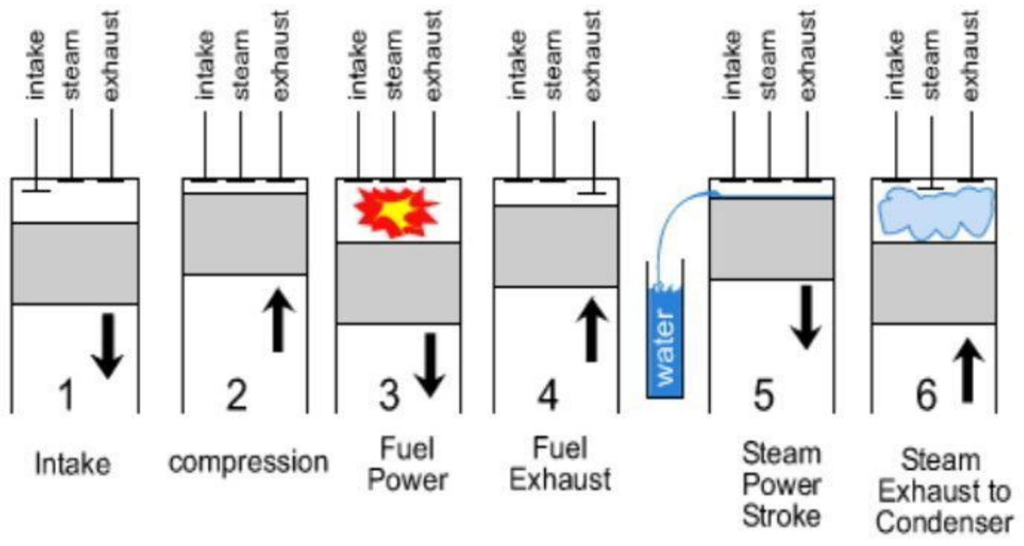
Technological innovations such as electronic fuel injection, drive-by-wire (i.e., computer controlled) throttles, and cylinder-deactivation have made engines more efficient and powerful.

The use of lighter and stronger engineering materials to manufacture various components of the engine has also had an impact; it has allowed engineers to increase the power-to-weight of the engine, and thus the automobile.

Common components found in an engine include pistons, camshafts, timing chains, rocker arms, and other various parts. When fully stripped of all components, the core of the engine can be seen: the cylinder block. The cylinder block (popularly known as the engine block) is the strongest component of an engine that provides much of the housing for the hundreds of parts found in a modern engine. Since it is also a relatively large component, it constitutes 2025% of the total weight of an engine . Thus there is much interest in reducing the block's weight.

Many early engine blocks were manufactured from cast iron alloys primarily due to its high strength and low cost. But, as engine designs became more complicated, the weight of the engine (and the vehicle) had increased. Consequently, the desire among manufacturers to use lighter alloys that were as strong as cast irons arose. One such material that was being used as a substitute was aluminium alloys. Used sparingly in the 1930's (due to problems with durability) ,aluminium alloy use in engine blocks increased during the 1960's and 1970's as a way to increase fuel efficiency and performance. Together, these two metals were used exclusively to fabricate engine blocks. As of late, however, a new material process has made magnesium alloy suitable for use in engines. The alloy, called AMC-SC1, weighs less than both cast iron and aluminium alloys and represents new possibilities in engine manufacturing. A new manufacturing process have made compacted graphite cast iron (CGI) a viable alternative to gray cast iron for the manufacture of diesel engine blocks. Like magnesium alloys, this material offers a higher strength and lower weight than gray cast iron.

1.4Working of Six-Stroke Engine :



The six strokes of the six stroke cycles are as follows:

1. Intake stroke
2. Compression stroke
3. Ignition stroke
4. Recompression stroke
5. Steam expansion stroke and
6. Exhaust stroke

In a general six stroke engine, the first 4 strokes are similar to those in 4-stroke Otto cycle engine. In the first stroke i.e. the Intake stroke, air-fuel mixture, by the carburettor is supplied in the intake valve, whereas the exhaust valve is closed and the piston is said to move from TDC (Top SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume 2 Issue 10 – October 2015 ISSN: 2348 – 8360 www.internationaljournalssrg.org Page 20 Dead Center) to BDC (Bottom Dead Center). The second stroke is of Compression, wherein the intake as well as the exhaust valves is closed, consists of compression of the air fuel mixture and the piston moves from BDC to TDC. In the third stroke, Ignition takes place as a spark plug is used to ignite the compressed mixture and thereby begins the second revolution wherein the piston again moves from TDC to BDC. In the fourth stroke, these burnt gases are led out from the cylinder through exhaust valve and reed valve which then completes the second revolution and the fourth stroke as the piston moves from BDC to TDC. The differentiating points are the latest two strokes i.e, the 5th and the 6th stroke. The fifth stroke initiates the power stroke, wherein instead of air- fuel mixture only air is sucked into the cylinder from the air filter through the secondary air induction line and the piston moves from TDC to BDC. In the sixth stroke, the exhaust air from the cylinder is led to the atmosphere by the exhaust valve. In some cases, the sixth stroke is also known as Scavenging Stroke.

Cylinders integrated into one or several cylinder blocks

A **cylinder block** is a unit comprising several cylinders (including their cylinder walls, coolant passages, cylinder sleeves if any, and so forth). In the earliest decades of internal combustion engine development, monobloc cylinder construction was rare; cylinders were usually cast individually. Combining their castings into pairs or triples was an early win of monobloc design.

Each **cylinder bank** of a V engine (that is, each side of the V) typically comprised one or several cylinder blocks until the 1930s, when mass production methods were developed that allowed the modern form factor of having both banks plus the crankcase entirely integrated.

A **wet liner** cylinder block features cylinder walls that are entirely removable, which fit into the block by means of special gaskets. They are referred to as "wet liners" because their outer sides come in direct contact with the engine's coolant. In other words, the liner is the entire wall, rather than being merely a sleeve.

Wet liner designs are popular with European manufacturers, most notably Renault and Peugeot, who continue to use them to the present. **Dry liner** designs use either the block's material or a discrete liner inserted into the block to form the backbone of the cylinder wall. Additional sleeves are inserted within, which remain "dry" on their outside, surrounded by the block's material. With either wet or dry liner designs, the liners (or sleeves) can be replaced, potentially allowing overhaul or rebuild without replacement of the block itself; but in reality, they are difficult to remove and install, and for many applications (such as most late-model cars and trucks), an engine will never undergo such a procedure in its working lifespan. It is likelier to be scrapped, with new equipment—engine or entire vehicle—replacing it.

This is sometimes rightfully disparaged as a symptom of a throw-away society, but on the other hand, it is actually sometimes more cost-efficient and even environmentally protective to recycle machinery and build new instances with efficient manufacturing processes (and superior machine performance and emission control) than it is to overvalue old machinery and craft production.

Cylinder head

The head gasket is the most highly stressed static seal in an engine and was a source of considerable trouble in early years. The monobloc cylinder head forms both cylinder and head in one unit, thus avoiding the need for a seal.

Along with head gasket failure, one of the least reliable parts of the early petrol engine was the exhaust valve, which tended to fail by overheating and burning. A monobloc head could provide good water cooling, thus reduced valve wear, as it could extend the water jacket uninterrupted around both head and cylinder. Engines with gaskets required a metal-to-metal contact face here, disrupting water flow.

The drawback to the monobloc head is that access to the inside of the combustion chamber (the upper volume of the cylinder) becomes difficult. Access through the cylinder bore is restricted for machining the valve seats, or simply for inserting angled valves. An even more serious restriction is that for the maintenance task of de-coking and re-grinding the valve seats, a regular task on older engines. Rather than removing the cylinder head from above, the mechanic must now remove pistons, connecting rods and the entire crankshaft from beneath.

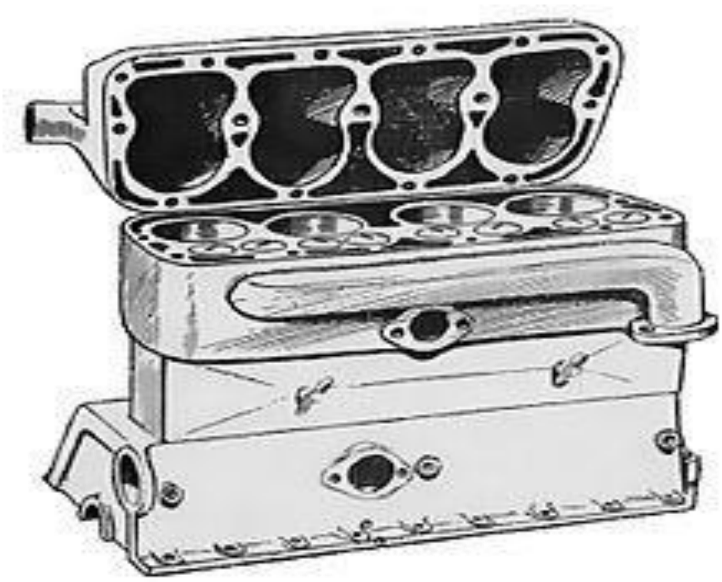
One solution to this for side-valve engines was to place a screwed plug directly above each valve, and to access the valves through this (illustrated). The tapered threads of the screwed plug provided a reliable seal. For low-powered engines this was a popular solution for some years. It was difficult to cool this plug, as the water jacket didn't extend into the plug. As performance increased, it also became important to have better combustion chamber designs with less "dead space". One solution was to place the spark plug in the centre of this plug, which at least made use of the space. However this also placed the spark plug further away from the main combustion chamber, leading to long flame paths and slower ignition.

During World War I, development of the internal combustion engine progressed enormously. After the war, as civilian car production recommenced, the monobloc cylinder head was required less frequently. Only high-performance cars such as the Leyland Eight of 1920 persisted with it. Bentley and Bugatti were other racing marques who notably adhered to them, through the 1920s and into the 1930s, most famously being used in the purpose-built American Offenhauser straight-four racing engines, first designed and built in the 1930s.

Aircraft engines at this time were beginning to use high supercharging pressures, increasing the stress on their head gaskets. Engines such as the Rolls-Royce Buzzard used monobloc heads for reliability.

The last engines to make widespread use of monobloc cylinder heads were large air-cooled aircraft radial engines, such as the Wasp Major. These have individual cylinder barrels, so access as a monobloc is less restricted than on inline engine. As they are also of high specific power and require the utmost reliability, the advantages of the monobloc remained attractive.

The difficulties of machining, and maintaining, a monobloc cylinder head were always a severe drawback to it. As head gaskets became able to handle the heat and pressure necessary, the technique went out of use. It is almost unknown today, but has found a very few "Niche" uses, as the technique of monobloc cylinder heads was adopted by the Japanese model engine manufacturer Saito Seisakusho for their glow fuelled and spark ignition model four stroke engines for RC aircraft propulsion needs.



1.5Technology used in engine block manufacturing

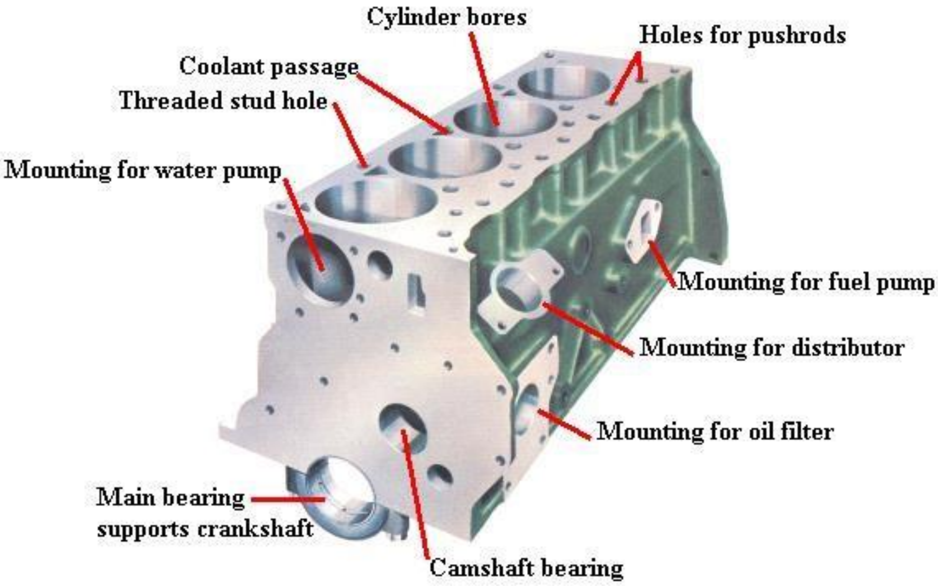
Casting technology at the dawn of the internal combustion engine could reliably cast either large castings, or castings with complex internal cores to allow for water jackets, but not both simultaneously. Most early engines, particularly those with more than four cylinders, had their cylinders cast as pairs or triplets of cylinders, then bolted to a single crankcase.

As casting techniques improved, the entire cylinder block of four, six or even eight cylinders could be cast as one. This was a simpler construction, thus cheaper to make, and the communal water jacket permitted closer spacing between cylinders. This also improved the mechanical stiffness of the engine, against bending and the increasingly important torsional twist, as cylinder numbers and engine lengths increased. In the context of aircraft engines, the non-monobloc precursor to monobloc cylinders was a construction where the cylinders (or at least their liners) were cast as individuals, and the outer water jacket was applied later from copper or steel sheet. This complex construction was expensive, but lightweight, and so it was only widely used for aircraft.

V engines remained with a separate block casting for each bank. The complex ducting required for inlet manifolds between the banks were too complicated to cast otherwise. For economy, a few engines, such as the V12 Pierce-Arrow, were designed to use identical castings for each bank, left and right. Some rare engines, such as the Lancia 22½° narrow angle V12 of 1919, did use a single block casting for both banks.

Modern cylinders, except for air-cooled engines and some V engines, are now universally cast as a single cylinder block.

Until recently, cast iron and aluminium alloys have been the preferential materials used to manufacture most diesel and conventional gasoline-powered engine blocks. However, with a greater emphasis on increasing the efficiency of the engine via weight reduction, manufacturers have began to look for alternative alloys that are lighter than cast iron and aluminium alloys, while retaining the necessary strength to withstand the forces of an engine. As of late, new manufacturing processes have been developed that have engendered two new alloys suitable for use in an engine block, magnesium alloy AMC-SC1 and compacted graphite cast iron (CGI). In this paper, the functional requirements of the engine block, the processes used to manufacture the part, and the mechanical properties of the alloys will be discussed.



1.6 TYPES OF ENGINE BLOCK

The internal combustion engine takes many forms, and many efforts have been made to optimize the performance of every component from oil-pan to air-cleaner. The engine block itself is no exception, and of all the different designs experimented with over the years, the following are the most popular and prolific.

The V Engine

This is probably the most popular engine block on the market and comes in several iterations. From massive Cadillac V16s, to classic V8s to the tiny V4s used on motorcycles; the V engine has a long history and time-tested record of reliability. The primary advantage of a V engine is its compact nature. Because it uses a pair of cylinder banks running parallel to each other, a V-16 engine is almost the same length as an inline-eight and only a bit wider. The only downside of a V engine is smoothness, which can be quite bad due to the fact that the pistons are set at odd angles to the engine center-line. This effect can be offset by adding more cylinders, which is why luxury cars often have 10 cylinders or more.

FLAT ENGINE

A flat engine, also known as a horizontally opposed engine, is a piston engine where the cylinders are located on either side of a central crankshaft. A flat engine should not be confused with the opposed-piston engine, in which each cylinder has two pistons sharing a central combustion chamber.

Inline Engine

Inline-block engines use a series of cylinders that run in a single line from the back of the engine to the front. Because these engines typically run smoothly, they are often used in applications that require high-rpm power, which makes the configuration ideally suited to the small-displacement engines used in most passenger cars. It is for this reason that almost all four-cylinder engines use an inline-block configuration. Additionally, an inline configuration by design lends itself to the usage of an overhead cam (OHC) cylinder head, which also helps to increase high-rpm horsepower. This inline-four/OHC cylinder head combination is used to good effect on practically all four-cylinder cars currently in

production.

Boxer Engines

Boxer engines are used primarily by Porsche and Subaru and are some of the most highly developed engines around. The easiest way to understand the boxer engine is to think of it as a V engine that has been pressed flat, so that the cylinder heads are directly opposite each other. The boxer engine has a number of advantages. Because the pistons on one bank effectively serve as counterweight for the other side, the crankshaft does not require counterweights of its own. This makes for a shorter, lighter crankshaft and a higher revving and more powerful engine. Boxer engines are also relatively light and are low to the ground. This can lower a car's centre-of-gravity by several inches, making for a better-handling chasis.

1.7 Manufacturing of cylinder block

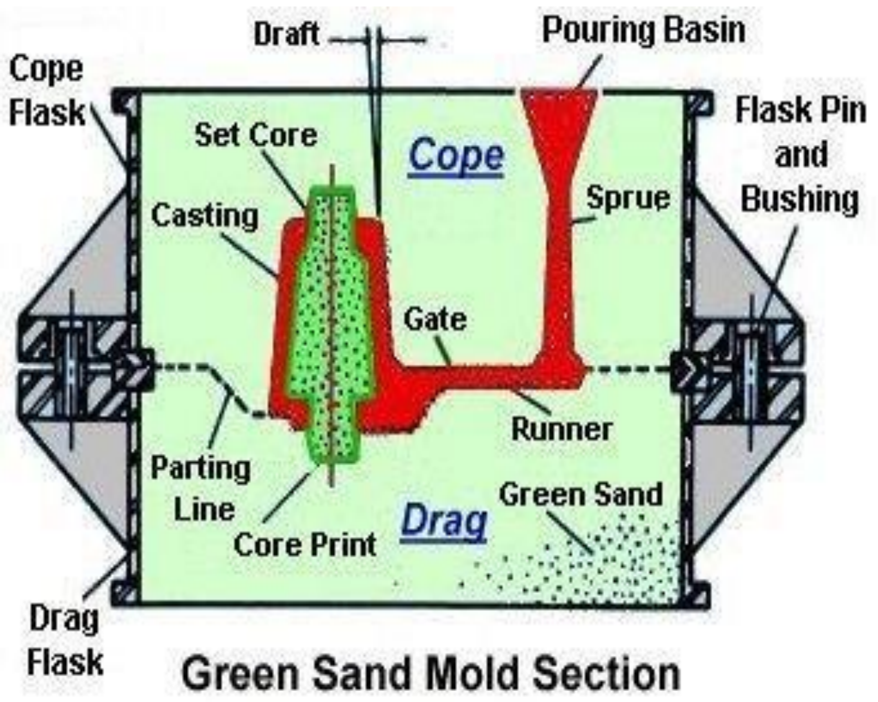
There are two methods used to cast engine blocks for all materials: green sand moulding or lost foam casting. The latter, pioneered by General Motors for their Saturn vehicles, have become more popular due to its capability to produce near net shape components, provide tight tolerances for critical components, and reduce machine maintenance and cost.

Green sand moulding, however, is still widely used in industry as material costs are low and most metals can be cast by this method.

Green Sand Moulding

Apart of the sand casting family that also includes dry-sand moulds and skin-dried moulds, green sand moulding the common method to cast engine blocks. The term “green” denotes the presence of moisture in the moulding sand.

Figure 2 demonstrates the first stage of green sand moulding. From Figure 2, a combination of silica sand, clay, and water poured in one-half of the block pattern with a wood or metal frame. The mould is then compacted by squeezing or jolting, and the process is repeated for the other half of the mould. A core consisting of hardened sand is used for support. Then, molten cast iron, aluminium, or magnesium alloy is poured into the combined moulds and solidifies. Once the latter part has been completed, the moulds are removed, and the cylinder block is cleaned and inspected. Heat treatment of the block is then undertaken to improve the mechanical properties of the alloy for suitable use.



The first stage of green sand moulding, a mixture of silica sand, clay, and water is poured into a defined pattern framed with metal

Lost Foam Casting

Lost foam casting is a more reliable and efficient casting technique of the manufacture of engine blocks than green sand moulding. The technique begins with the use of polystyrene beads placed in pre expanders for wet expansion to control bead size and density to produce four separate block mouldings to be glued together to form the final mould. Next, the metal tool is preheated to remove any moisture and then filled with the beads. The tool is then heated via steam and placed in an autoclave, where it is subjected to high pressures in order to create the moulds.

The tool is removed from the autoclave and immersed in water to finish the mouldings. Precise control over the heating and cooling aspect ensures dimensionally accurate, smooth and strong moulds.

If the tool was not heated before the beads were injected, the results would be rough finishes in the moulds with low-strength sections. If the tool and beads stay heated for an extended period of time, or is not cooled enough, the beads become "overused," which produces surface variations in the mouldings. If the tool has been inadequately cooled, the moulds will contain variations in dimensions.

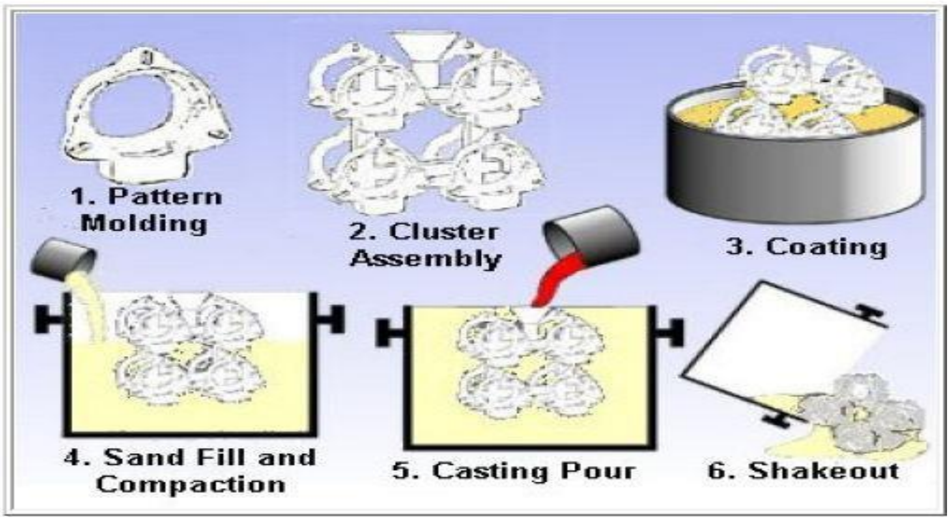


Figure 6: Graphical description of the last 6 of 7 methods of the lost foam casting method

From above fig once the individual moulds are glued together, the assembly is placed in a vat with water-based ceramic liquid to prevent molten metal from destroying the mould, stiffen the assembly, and provide a smooth finish. The assembly can also be sprayed with the ceramic liquid, but is a time-consuming process. Next, the coated foam engine block is filled with sand, compacted, and immersed in the molten metal alloy. Once cooled, sand is removed from the metal casting, cleaned, and undergoes heat treatment to increase the mechanical properties of the block. Finally, coolant and oil passages are machined into the block.

1.8 Advantages of Six-Stroke Engine :

a) **No external cooling required**:

In the two additional stokes, the exhaust heat energy present in the cylinders is used up by the air or water to do work. Thereby decreasing the engine temperature and ruling out the need for heavy external cooling systems& radiators.

b) **Increased Stroke Volume:**

In six stroke engine the change in volume during the compression stroke is slightly higher than four stroke engine after the ports are closed. Also, the expansion stroke is much greater in six strokes than four strokes, both from T.D.C. to B.D.C. and from T.D.C. till the exhaust port is open. Therefore, large volume in the cylinder is obtained, thereby increasing power. Better filling of the cylinder on the intake due to the lower temperature of the cylinder walls and the piston head.

c) **Reduction in fuel consumption:**

The operating efficiency of a 4-stroke petrol engine is approximately 30%. Whereas that of the six-stroke will be of order of 50%. For the same amount of fuel, we get additional two strokes (using air/water) thereby reducing the overall fuel consumption of six-stroke engines. The increase in thermal efficiency compensated for any reduction in specific power. It has less inertia due to the lightness of the moving parts which is another contributing factor.

d) **Two work cycles in six strokes**:

As the work cycles occur on two strokes i.e., 8% more than in a 4-stroke engine, the fluctuations in torque is minimal. This lead to very smooth operation at low speed, thereby improving performance in stop and go situations as in heavy traffic in a city. Also there is increase in torque by 35% in six stroke engine.

e) **Reduction in pollution:**

Significant reduction in chemical, noise and thermal pollution are reduced. There occurs no problem in combustion due inflammability difference in six stroke engine. Also the emissions of HC, CO, NOx are reduced.

f) **Adaptability to various fuels**:

It can use the variety of fuels, of any origin which maybe fossil or vegetable, from diesel to L.P.G. or animal grease. It’s light, standard petrol engine construction, and the low compression ration of the combustion chamber; do not exclude the possibility of use of diesel fuel. The above advantage of adaptability to various fuels is the prime motivating behind the idea for using alternative fuels with higher calorific value in the two strokes other than water or air.

Chapter 2

MATERIALS

2.1Gray Cast Iron Alloys

Gray cast iron alloy have been the dominant metal that was used to manufacture conventional gas-powered engine blocks. Though extensive use of aluminium alloys has diminished the popularity of this material, it still finds wide use in diesel-fuelled blocks, where the internal stresses are much higher. Gray cast iron alloys typically contains 2.5-4 wt.% carbon and 1-3 wt.% silicon, 0.2-1.0 wt.% manganese, 0.02-0.25 wt.% sulphur, and 0.02-1.0 wt.% phosphorus . It has excellent damping capacity, good wear and temperature resistance, is easily machinable, and is inexpensive to produce. However, gray cast irons are relatively weak and are prone to fracture and deformation. Due to these problems, compacted graphite iron has recently begun to compete with gray cast iron as the choice material to produce diesel engine blocks. Figure 2 shows the BMW S54 inline-6 used in their high performance M3 coupe. It is interesting to note that the cylinder block for this engine is constructed from gray cast iron, whereas the block for the BMW M54 engine, the basis of architecture of the S54, was made of aluminium alloy. One possible reason why the S54 block was made from gray cast iron was the need for a stronger material that could tolerate the higher performance levels (the S54 produces 333 brake horsepower and has a maximum engine speed of 8000 rpm, whereas the M54 produces 184-225 brake horsepower with a maximum engine speed of 6500 rpm).

BMW’s S54 inline-6 engine, which uses a gray cast iron engine block

2.2Aluminum Alloys

One of the key weight saving features in the engine design is the use of a cast aluminium cylinder block with cast iron cylinder liners.The cast iron liners (with ground outsidediameter) are press-fit into the precision bored aluminium cylinder block. This provides optimal heat transfer into the cylinder block.

The iron liners provide the wear resistance needed for improved durability.

The installation process for the liners includes chilling the liner prior to placement and sophisticated precision force monitoring to ensure proper installation.

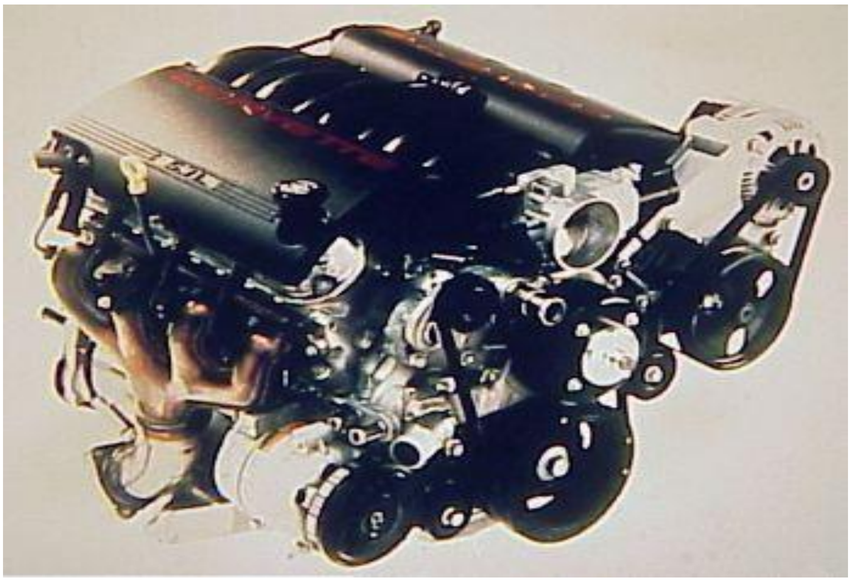
After installation, the ID of the iron liner is bored to a mass-saving 1.5 millimetre wall thickness.

Aluminium alloy use has gained popularity since the 1960’s as a way to reduce the overall weight of the vehicle. There are two practical implications: improved performance-to-weight ratio and increased fuel efficiency. The drawbacks of using aluminium in engine blocks are that they are more expensive to manufacture than cast iron alloys.

However, the strength-to-weight ratio of aluminium alloys is hard to ignore, and manufacturing processes developed throughout the years have minimized the cost disparity between aluminium and cast iron.

There are two aluminium alloys that are mainly used in the manufacture of cylinder blocks: 319 and A356. Aluminium alloy 319 has a composition of 85.8-91.5 wt.% aluminium, 5.5-6.5 wt.% silicon, 3-4 wt.% copper, 0.35 maximum wt.% nickel, maximum 0.25 wt.% titanium, maximum 0.5 wt.% manganese, maximum 1% iron, maximum 0.1 wt.% magnesium, and maximum 1 wt.% zinc.

The alloy has good casting characteristics, corrosion resistance, and thermal conductivity. When heat treated with the T5 process, it possesses high strength and rigidity for engine block use. The LS1 engine of the 5th generation Chevrolet Corvette (1997-2004) is an example of an engine that utilizes aluminium alloy .



The Chevrolet Corvette LS1 V8 engine which utilizes an aluminium alloy 319-T5 cylinder block

Aluminium alloy A356.0 F has a composition of 91.1-93.3 wt.% aluminium, 6.5-7.5 wt.% silicon, 0.25-0.45 wt.% magnesium, and maxima of 0.2 wt.% copper, 0.2 wt.% titanium, 0.2 wt.% iron, and 0.1 wt.% zinc. Aluminium alloy 5454 H32 has a composition of 94.5-97.1 wt.% aluminium, 0.25 wt.% silicon, 2.4-3.0wt.% magnesium, and maxima of 0.1 wt.% copper, 0.2 wt.% titanium, 0.4 wt.% iron, and 0.15 wt.% zinc,0.05-0.20 wt.% chromium and 0.5-1.0 wt.% manganese.

Table 1 strength of materials

	Aluminium A356.0F	Aluminium 5454 H32
Tensile Strength	160 MPa	275 MPa
Yield Strength	100MPa	205MPa

General Motor’s inline-5 engine which uses aluminium alloy A356-T6 as its engine block.

2.3 Magnesium Alloys

Magnesium alloys have been used in engines before, but not for cylinder blocks. Rather, they were used as valve covers, cylinder head covers, intake manifolds, rocker arm covers, air intake adaptors, induction systems, and accessory drive brackets.

The biggest attraction for manufacturers is that the material is much lighter than cast iron and aluminium alloys and has the same strength as cast iron and aluminium alloys. Material scientists and engineers were determined to exploit these characteristics of magnesium alloy and use it to fabricate engine blocks.

There were a number of magnesium alloys available that met or exceeded the requirements demanded by manufacturers for an engine block, but insufficient material stability at high temperatures hindered their actual use. However, in 2003 material scientists and engineers from the Cooperative Research Centre for Cast Metals Manufacturing and the Australian Magnesium Corporation presented their discovery of sand-cast AMC-SC1 magnesium alloy.

This grade of magnesium alloy contains two rare earth elements, lanthanum and cerium, and was heat-treated with T6. This stabilizes the strength of the alloy at high engine operating temperatures, which is a necessary requirement for a cylinder block material. Bettles et al. had performed experiments to determine the yield and creep strengths of AMC-SC1 and their results are shown in Table 3. From Table 3, the most significant point is that the yield strength of AMC-SC1 essentially stays the same at 177ºC as it does at room temperature.

This means that the material is able to tolerate a wide range of operating temperatures without a loss in strength. Other properties of the magnesium alloy
include good thermal conductivity, excellent machining and casting qualities, and excellent damping characteristics.

To demonstrate the significant weight savings of magnesium alloy over cast iron and aluminium alloy, consider BMW’s inline-6 R6 (shown in Figure 4), which replaced the company’s M54 aluminium engine. Its cylinder block is made of AMC-SC1 and is said to have decreased the weight of a comparably-built gray cast iron and aluminium alloy block by 57% and 24% . So far, BMW is the only company to have used magnesium alloy cylinder blocks in production vehicles. But, with a significant weight advantage over the current alloys used today and negligible increase in cost, other manufacturers will begin to consider the use of AMC-SC1 and possibly other grades of magnesium alloys for engine blocks.

BMW’s 6-cylinder R6 power plant uses a magnesium alloy AMC-SC1-fabricated cylinder block

Chapter 3

INTRODUCTION TO SOLIDWORKS

3.1

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systemes, that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on an Intel-based Mac with Windows installed, the application's developer recommends against this SolidWorks does not support macOS.

3.2 History

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product *SolidWorks 95*, in November 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired SolidWorks for $310 million in stock. Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company.

SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

SolidWorks was headed by John McEleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who is promoted Vice President Sales of Dassault Systèmes' Value Solutions sales channel.

Release history

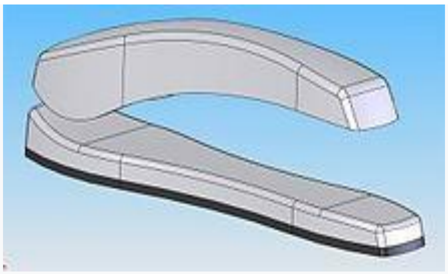
Name/Version	Version Number	Version History Value	Release Date
SolidWorks 95	1	46	November 1995[1]
SolidWorks 96	2	270	Early 1996
SolidWorks 97	3	483	Late 1996
SolidWorks 97Plus	4	629	1997
SolidWorks 98	5	817	1997
SolidWorks 98Plus	6	1008	1998
SolidWorks 99	7	1137	1998
SolidWorks 2000	8	1500	1999
SolidWorks 2001	9	1750	2000
SolidWorks 2001Plus	10	1950	2001
SolidWorks 2003	11	2200	2002
SolidWorks 2004	12	2500	2003
SolidWorks 2005	13	2800	2004
SolidWorks 2006[9]	14	3100	2005
SolidWorks 2007	15	3400	2006
SolidWorks 2008	16	3800	July 1, 2007
SolidWorks 2009	17	4100	January 28, 2008
SolidWorks 2010	18	4400	December 9, 2009
SolidWorks 2011	19	4700	June 17, 2010
SolidWorks 2012	20	5000	September, 2011
SolidWorks 2013	21	6000	September, 2012
SolidWorks 2014	22	7000	October 7, 2013
SolidWorks 2015	23	8000	September 9, 2014
SolidWorks 2016	24	9000	October 1, 2015
SolidWorks 2017	25	10000	September 19, 2016
SolidWorks 2018	26	11000	September 26, 2017
SolidWorks 2019	27	12000	October 9, 2018
SolidWorks 2020	28	13000	September 18, 2019
SolidWorks 2021			September 22, 2020[

Market

DS Solidworks Corp. has sold over 3.5 million licenses of SolidWorks worldwide.[1] This includes a large proportion of educational licenses.

Its user base ranges from individuals to large corporations, and covers a very wide cross-section of manufacturing market segments. Commercial sales are made through an indirect channel, which includes dealers and partners throughout the world. In the United States, the first reseller of SolidWorks, in 1995, was Computer Aided Technology, LLC, headquartered in Chicago. Directly competitive products to SolidWorks include PTC Creo Elements/Pro, Solid Edge, and Autodesk Inventor. SolidWorks also partners with third-party developers to add functionality in niche market applications like finite element analysis, circuit layout, tolerance checking, etc. SolidWorks has also licensed its 3D modeling capabilities to other CAD software vendors, notably ANVIL.

3.3 Modeling technology



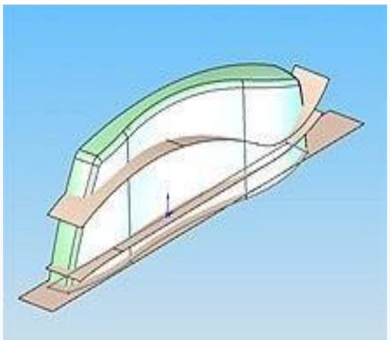
screen shot captured from a SolidWorks top-down design approach

SolidWorks is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded to add or cut to remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc. screen shot captured from a



SolidWorks top-down design approach

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, *assembly mates* define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).

File format

SolidWorks files (previous to version 2015) use the Microsoft Structured Storage file format. This means that there are various files embedded within each SLDDRW (drawing files), SLDPRT (part files), SLDASM (assembly files) file, including preview bitmaps and metadata sub-files. Various third-party tools (see COM Structured Storage) can be used to extract these sub-files, although the subfiles in many cases use proprietary binary file formats.

SolidWorks allows saving 3D Model information in *step format, which lets the model be displayed and modified in other platforms from other ve.

Associated products

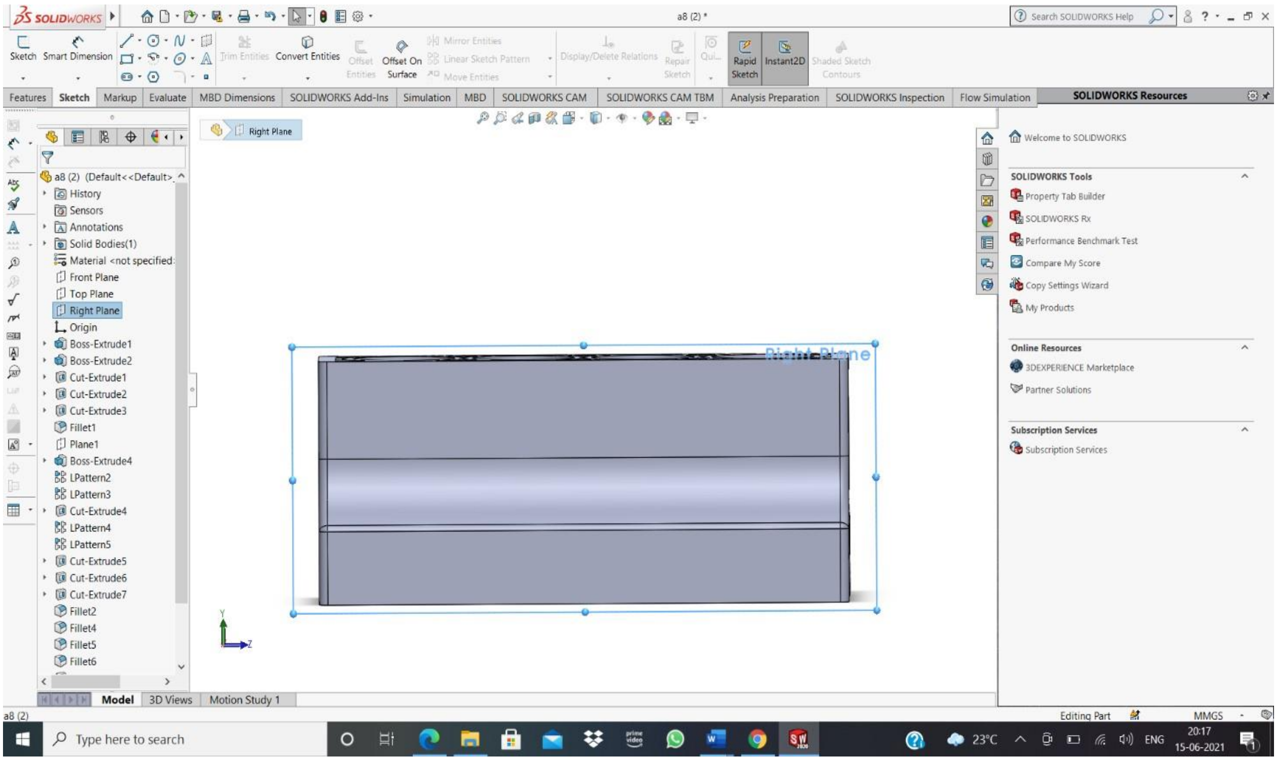
SolidWorks has developed also various complementary add-ins, including:

- PhotoWorks : 3D photorealistic rendering engine.
- SOLIDWORKS Composer : content creation software for documentation, technical illustration, catalogs, commercial brochures, training documents, maintenance manuals ... from CAD data with updates of CAD changes.
- 3DEXPERIENCE Marketplace : an add-in allowing users to download 3D parts from an online catalog on make 3D printed parts on-demand.

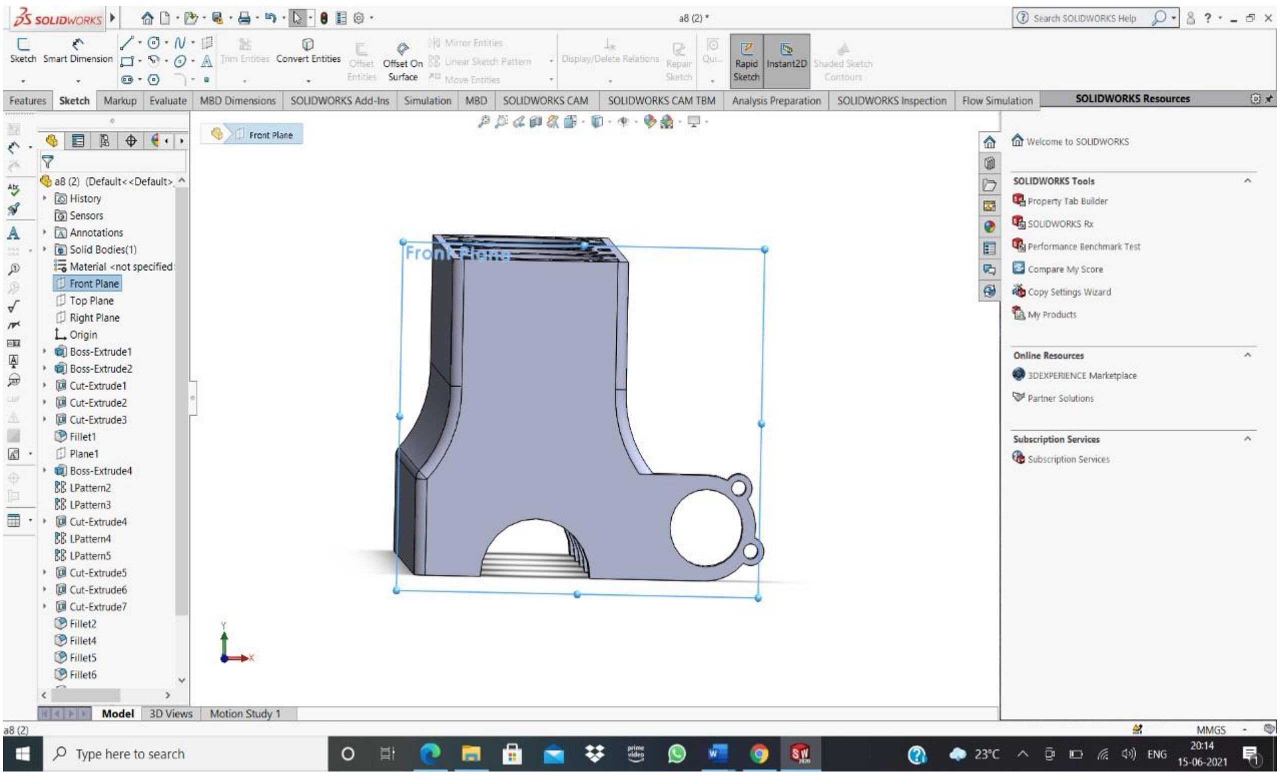
Chapter 3

3.4Design of four stroke engine block

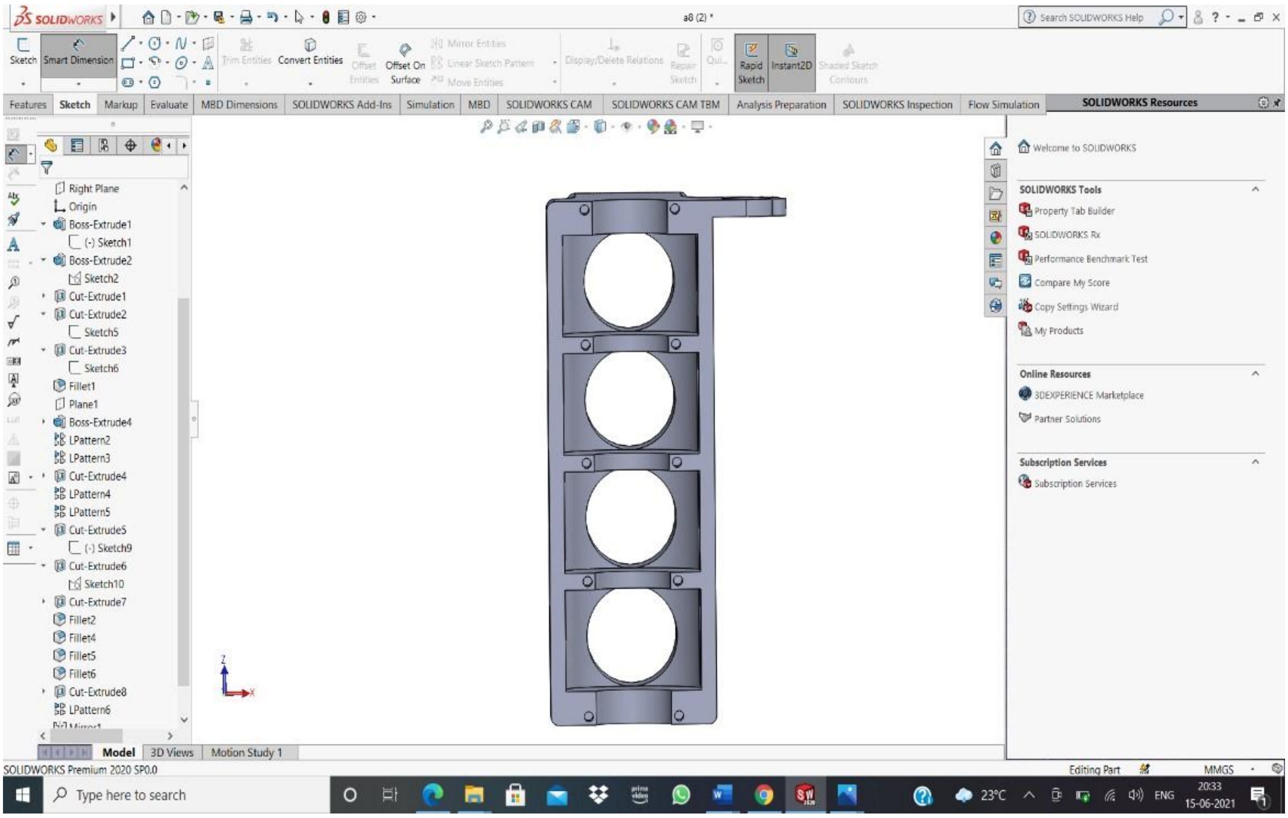
RIGHT PLANE



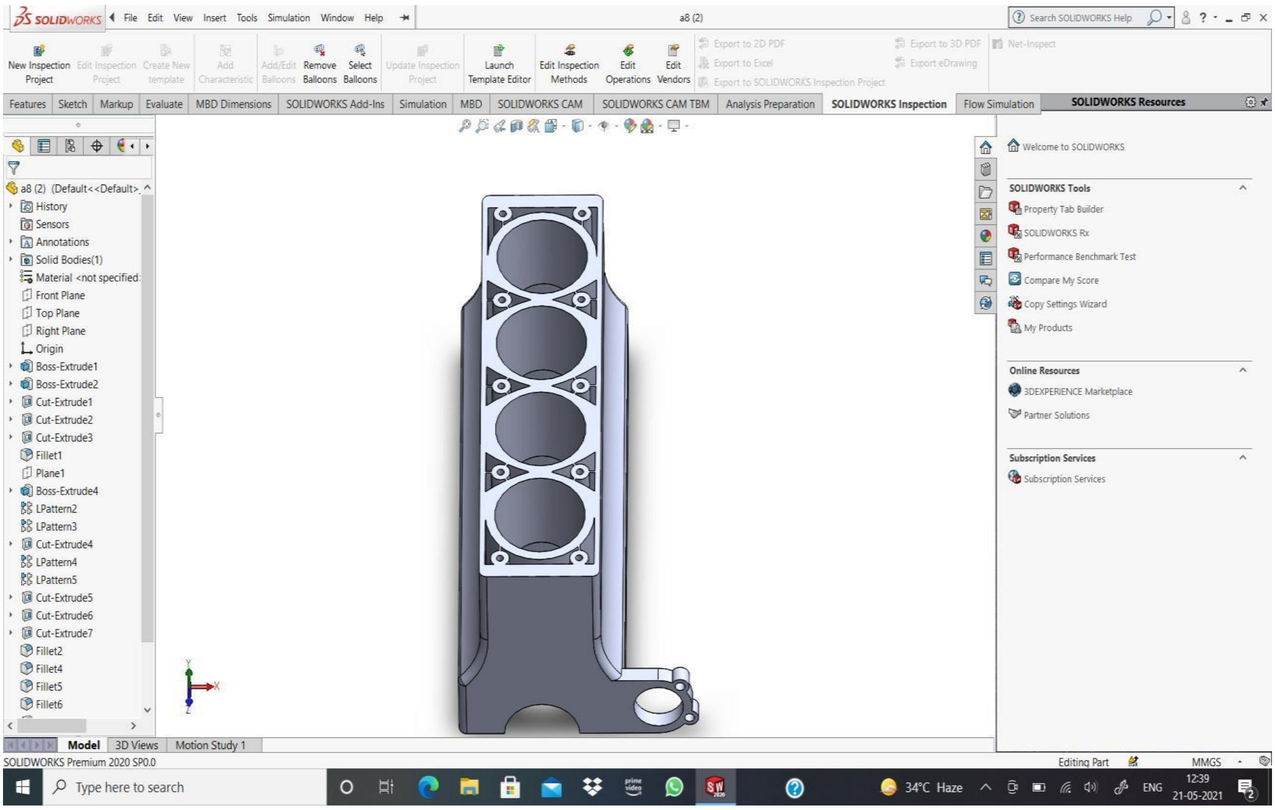
FRONT PLANE

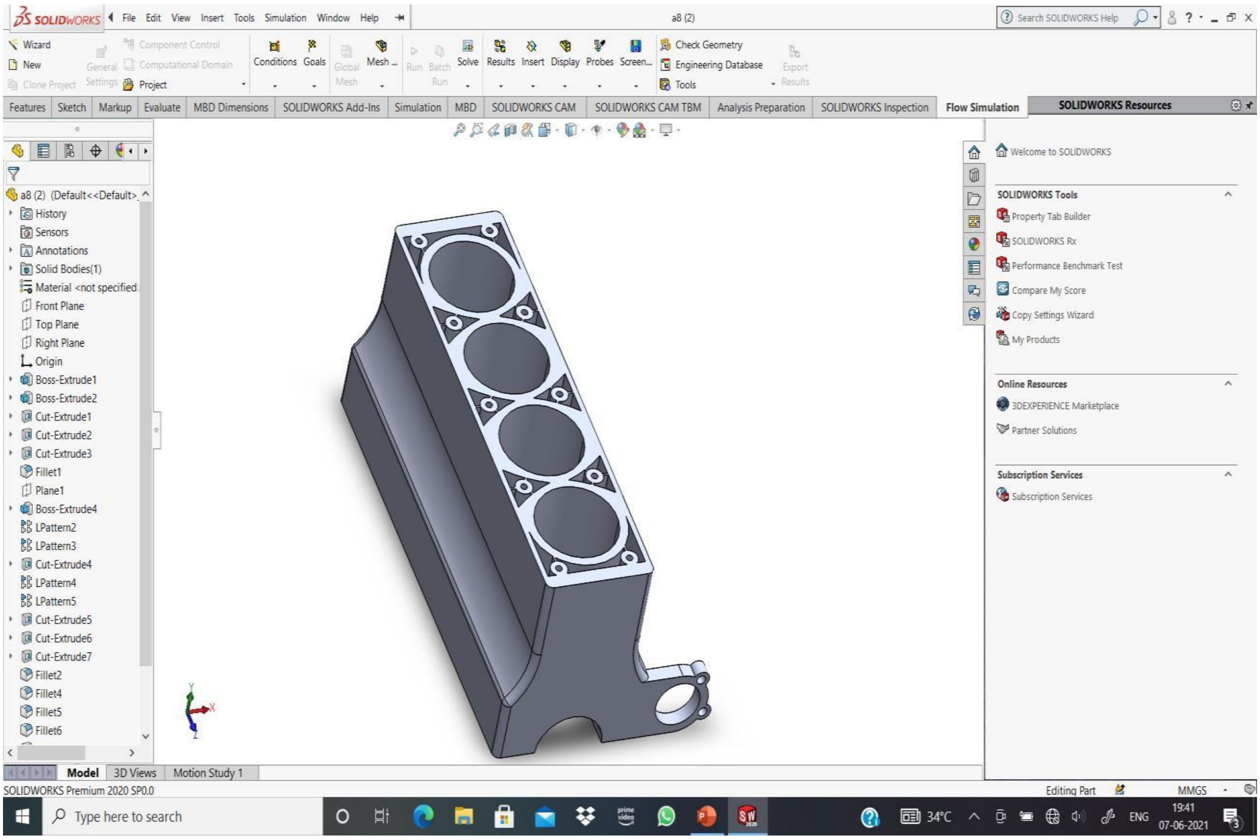


BOTTOM PLANE



FINAL DESIGN




SOLIDWORKS
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Cut-Extrude1
Cut-Extrude2
Cut-Extrude3
Fillet1
Plane1
Boss-Extrude4
LPattern2
LPattern3
Cut-Extrude4
LPattern4
LPattern5
Cut-Extrude5
Cut-Extrude6
Cut-Extrude7
Fillet2
Fillet4
Fillet5
Fillet6
Welcome to SOLIDWORKS
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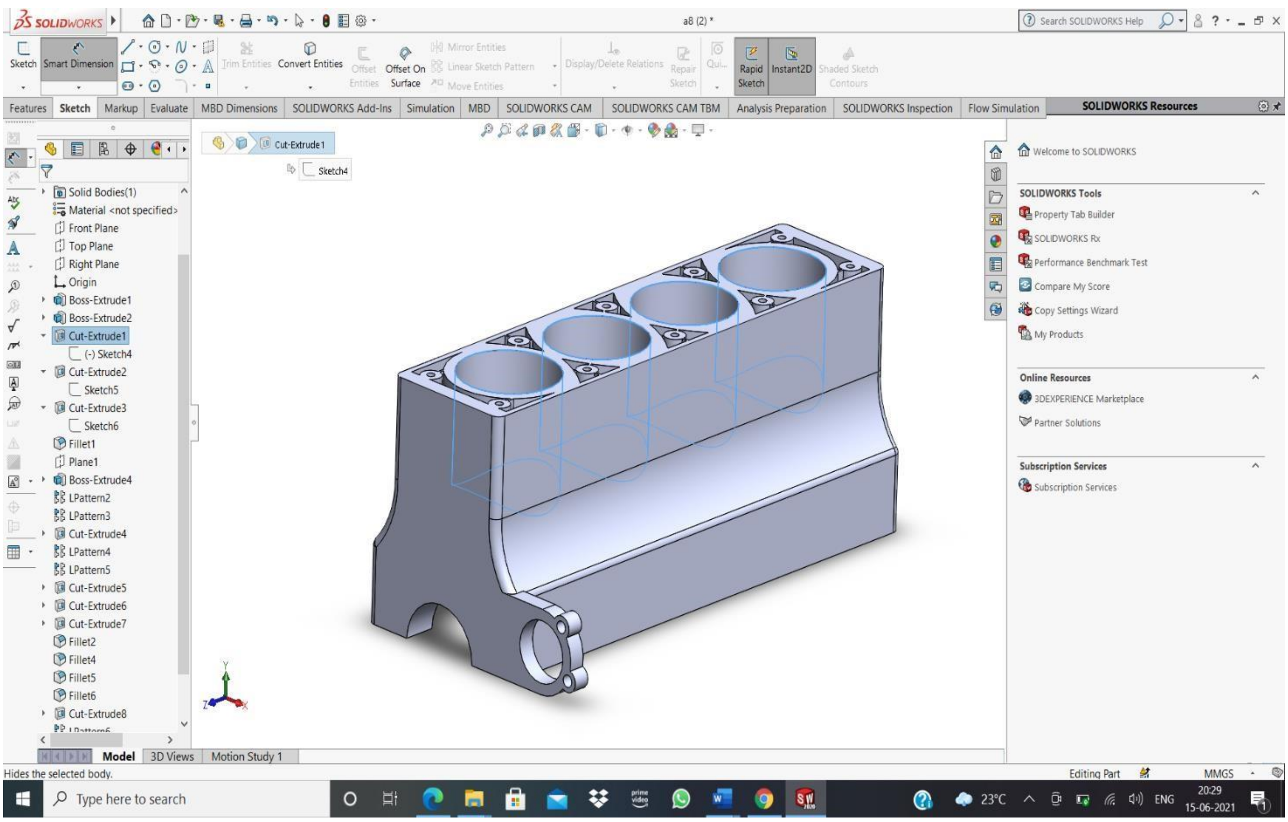
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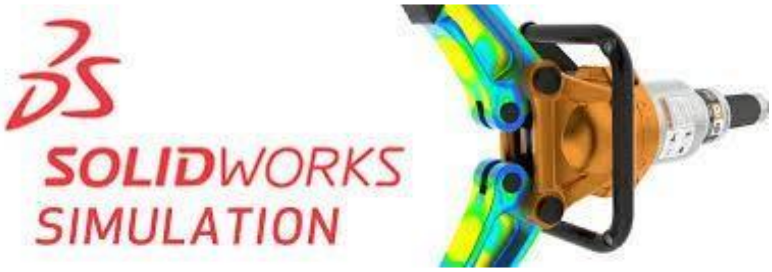
Chapter 4

Solidworks Simulation



4.1

SOLIDWORKS Simulation is a virtual testing environment to analyze your design, evaluate its performance and make decisions to improve product quality. But how does it accomplish this? Behind the scenes, the software employs a numerical technique called Finite Element Analysis, or FEA.

The concepts behind FEA were developed in the early 1940's, but the method became more mainstream in the 1980's and 90's when it was implemented on desktop computers. Today, FEA is a powerful tool that is widely used by designers across many industries. It's used for solving structural, vibrational and thermal problems virtually before they pose a real problem in reality.

Here is a fun fact you might not be aware of. Every seat of SOLIDWORKS CAD includes a free tool called Simulation Xpress, which can be used to analyze a single body part with simple loads and supports. You can activate by navigating to the Tools Menu, then Xpress Products.

For additional analysis capabilities, SOLIDWORKS offers three simulation packages designed to meet the needs of different users:

Simulation Standard is used for structural, motion and fatigue analysis of parts and assemblies.

Simulation Professional adds more capabilities including frequency, thermal, buckling, drop test and optimization studies. It also includes a full set of productivity tools that allow you to work faster and achieve greater accuracy in your results.

Finally, the Simulation Premium package is capable of analyzing plastic and rubber components, metal forming operations, composite materials, and dynamic loads such as oscillating or vibrating structures.

Regardless of the specific design being tested, the fundamental steps of any FEA study are always the same.
We start with a geometric model. This could be a native SOLIDWORKS part, multi-body part, or an assembly. It could also be a file from another CAD system, or even a neutral format such as a STEP, IGES, or a Parasolid. SOLIDWORKS Simulation is capable of analyzing all of these file types.

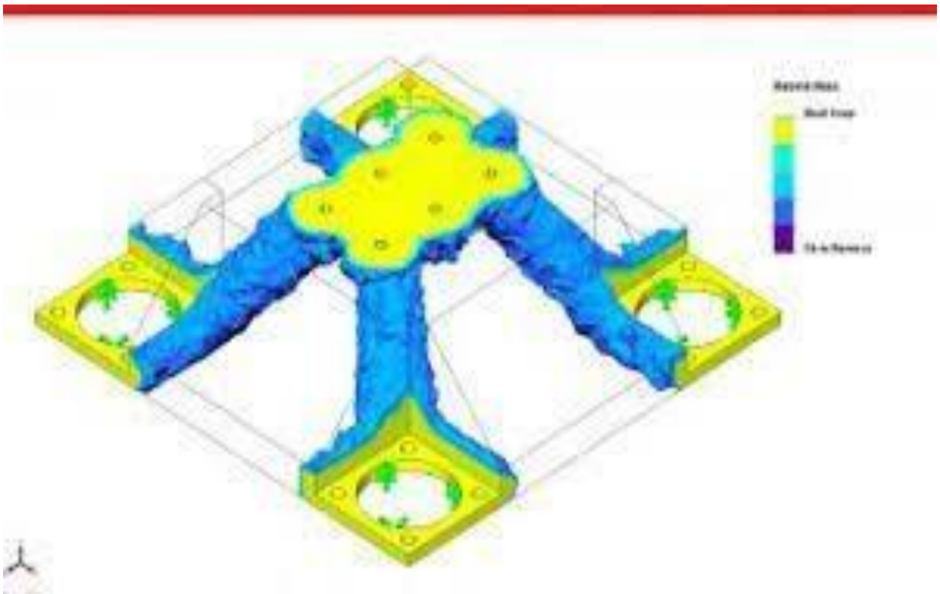
Next, we assign materials to all the components, define the loads acting on the structure and apply restraints to describe how it's anchored or held in place.

Lastly, we approximate the geometry by splitting it into smaller and simpler entities known as elements. This process is called "meshing", and it can be automated by the software. For advanced users who would prefer more control over the meshing process, there are built-in tools that allow for additional refinement.

After running the study, we can view the results using a variety of colour plots, graphs, animations and reports.

In the upcoming videos, we will explore each step of the FEA process in greater detail.

TOPOLOGY OPTIMIZATION



Topology Optimization

4.2

Topology optimization (TO) is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. TO is different from shape optimization and sizing optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations.

The conventional TO formulation uses a finite element method (FEM) to evaluate the design performance. The design is optimized using either gradient-based mathematical programming techniques such as the optimality criteria algorithm and the method of moving asymptotes or non gradient-based algorithms such as genetic algorithms.

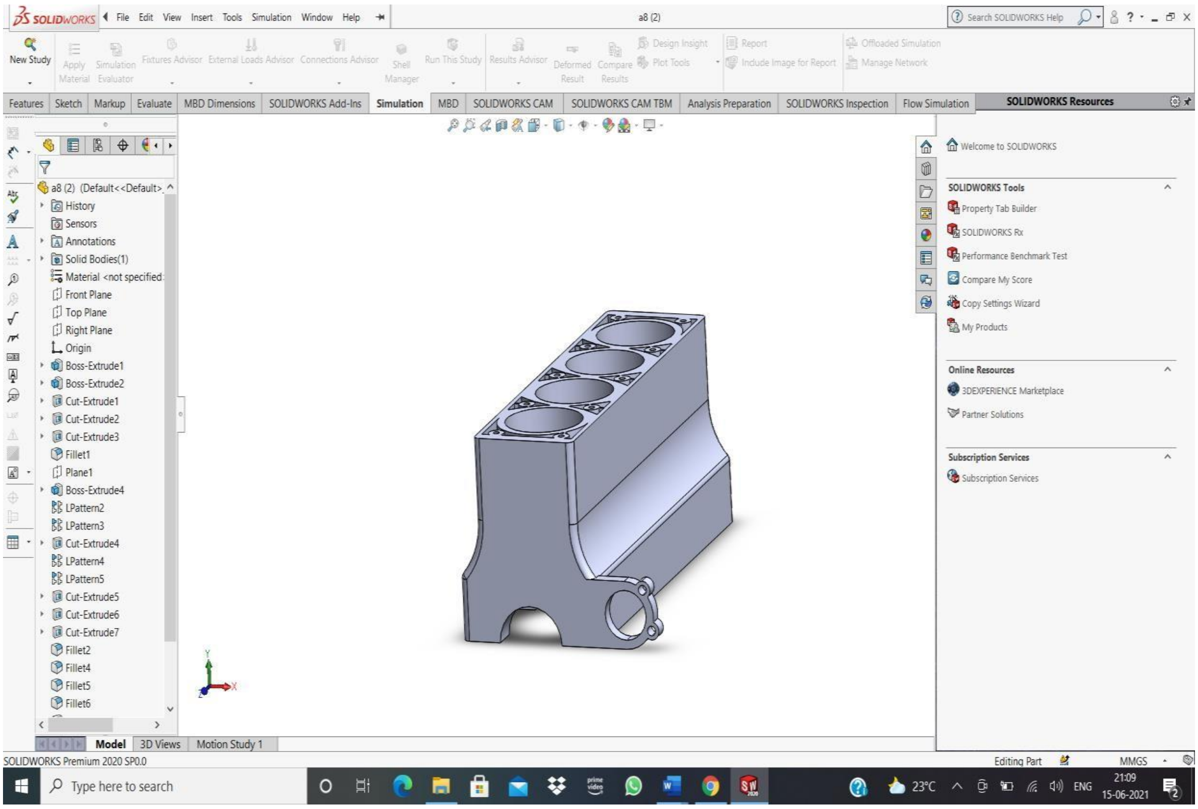
Topology Optimization has a wide range of applications in aerospace, mechanical, biochemical and civil engineering. Currently, engineers mostly use TO at the concept level of a design process. Due to the free forms that naturally occur, the result is often difficult to manufacture. For that reason the result emerging from TO is often fine-tuned for manufacturability. Adding constraints to the formulation in order to increase the manufacturability is an active field of research. In some cases results from TO can be directly manufactured using additive manufacturing; TO is thus a key part of design for additive manufacturing.

4.3 PROCESS OF TOPOLOGY OPTIMIZATION

Preparation

Load up SOLIDWORKS 2020, and then load up the bracket.

Now, go to the SOLIDWORKS Add-ins tab at the ribbon at the top of the screen and load up the Simulation add-in. Then, locate the Simulation tab on the ribbon, click the New Study icon, and select New Study from the drop-down menu.



This will open up the study pane on the left-hand side of the screen. In the study pane, find the Design Insight section, and click Topology Study. You can rename your study here if you would like. I have left it as the default name (Topology Study 1). Then, click the green check mark. This will open a new study pane in the left-hand pane under the design tree.

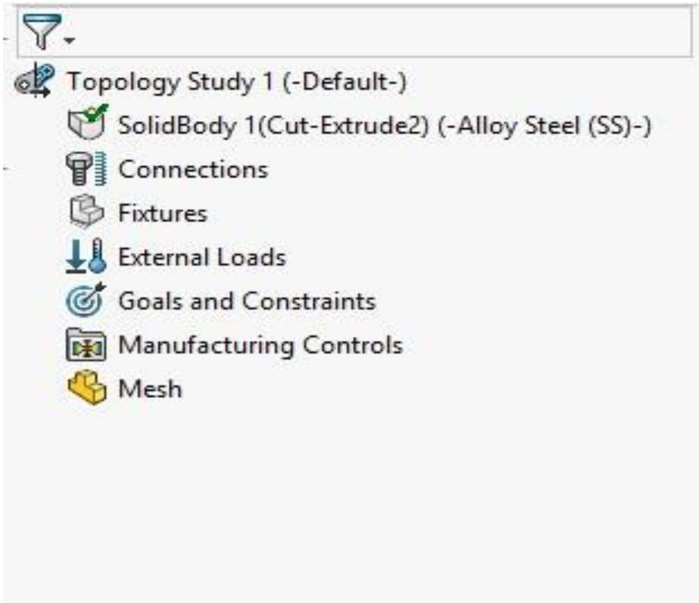
Before you begin the study, you need to define a material so that SOLIDWORKS will know how to define the material parameters from its material database.

From the top ribbon, in Simulation tab, select Apply Material. From this list, select Aluminium A356.0F , and then click Apply.

4.4 Defining the Simulation Parameters

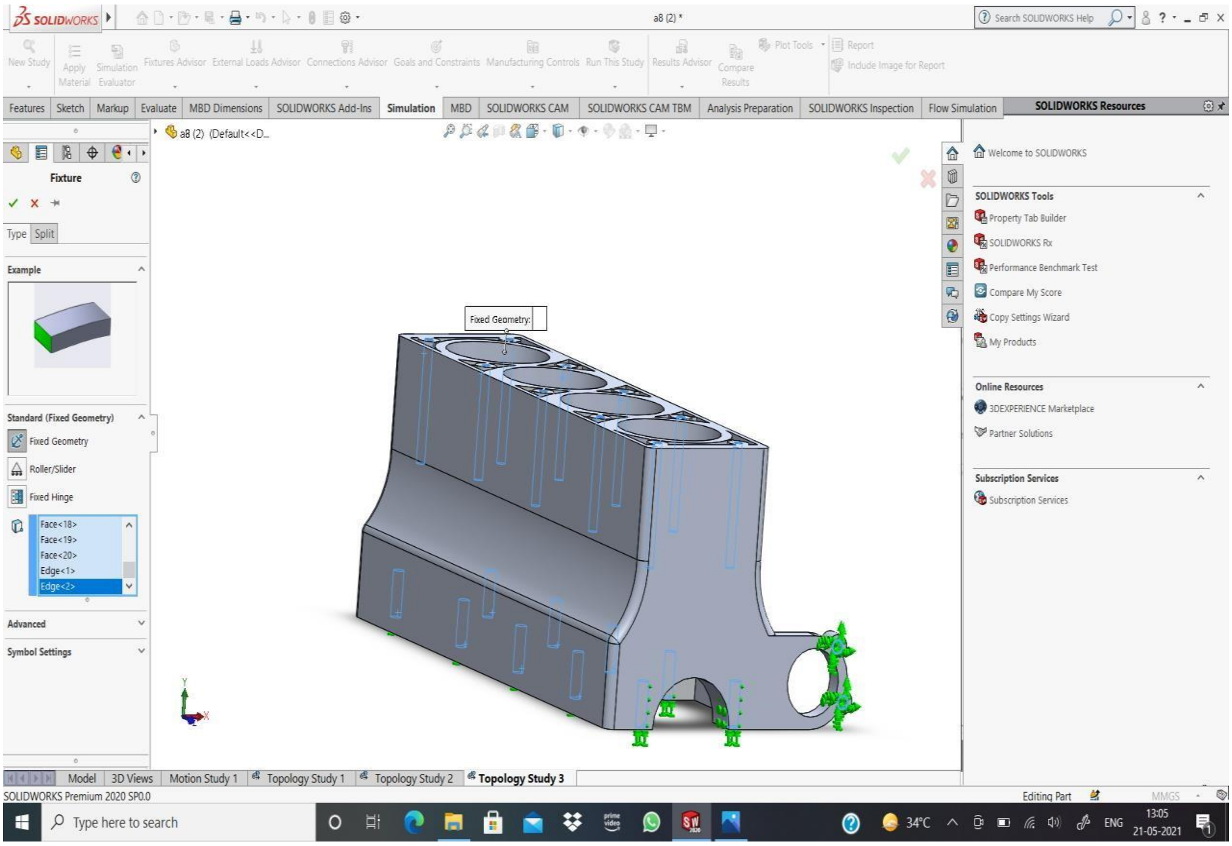
Now that the model is loaded, the type of study has been defined, and a material has been selected for use in the study, you can begin to define the parameters of the study, such as loads, fixtures and design constraints.

Take a look at the Topology Study 1 panel in the left-hand pane. It should look like what is shown in Figure 2.



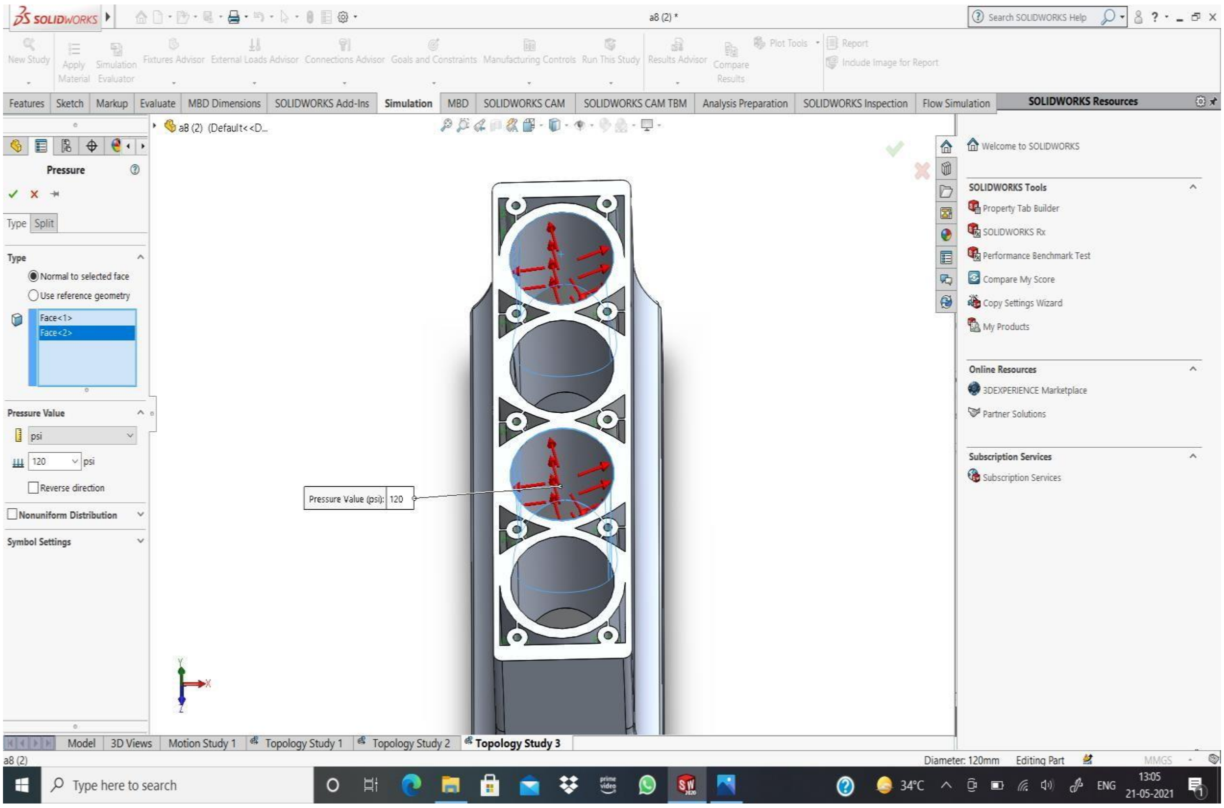
Topology Study pane.

Next, you will define the fixtures. These will represent the mounting points where bolts will hold the bracket to a wall. Right-click on Fixtures in the Topology Study pane and select Fixed Geometry from the drop-down menu. Spin the bracket around to the rear side, and then select the inner faces of the eight bolt holes. Seven holes are selected in the example shown in Figure 3. When you have selected all eight bolt holes, you can click the green check mark in the Fixture panel.



Now, you want to apply a load. The plates that make up the bracket are 10mm thick and made from steel. They are also fairly strong (to put it mildly).

For the purposes of this example, let's assume that you wish to hang something fairly heavy on this bracket. Maybe it's part of a vehicle inspection ramp, for instance. The application doesn't really matter, but let's assume that you want it to be heavy and distributed across the top face of the bracket. Right-click the External Loads option in the Topology Study pane, select Force from the drop-down menu, and enter 1000 kg of force in the Force Value text entry box. Before you close the Force/Torque pane, you must select a face where you wish to apply this mass. I selected the top face of the bracket (the one with four holes on).



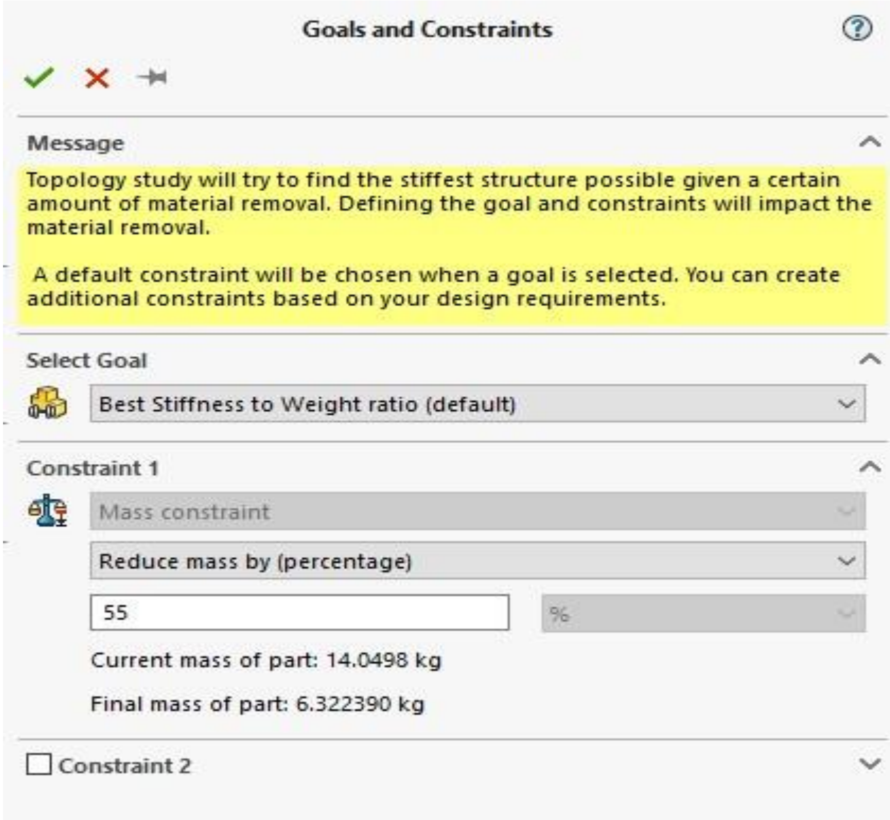
Goals and Constraints:

This is probably the most important part of topology optimization in SOLIDWORKS 2018 because this is where you tell the software your design targets in terms of optimization.

Right-click the Goals and Constrains option in the Topology Study pane, and from here you will see three types of optimization options:

- Best Stiffness to Weight Ratio (default)
- Minimize Maximum Displacement
- Minimize Mass with Displacement Constraint

Choose the first option, Best Stiffness to Weight Ratio. This will open the Goals and Constraints pane.



Instantly, you can see that the current mass of the non optimized part is 14.05kg. That's a big old bracket! You could probably build a road bridge with that. I'm thinking that maybe I should have created bigger bolt holes.

Oh well, we won't worry about it. It's just an example after all. And, anyway, it will be fun to see how much we can reduce the weight by. That's what optimization is all about!

Next, go into the Constraint 1 box and type 55 percent into the text box, as shown in Figure 4. This gives a Final Mass of Part equal to 6.3 kg. This value will act as the mass target while the computer runs its iterations.

If you wanted to, you could also activate a second constraint by selecting the Constraint 2 check box. But for now, just use the single constraint, and click the green check mark to exit the Goals and Constraints pane.

Manufacturing Controls

Next down the list in the Topology Study pane is the Manufacturing Controls option.

These add constraints that assist with the manufacturability of the part and can be used to keep regions of material that you don’t want removed by the optimization process.

Right-click on the Manufacturing Controls option, and you can see several options, as shown in Figure 5.

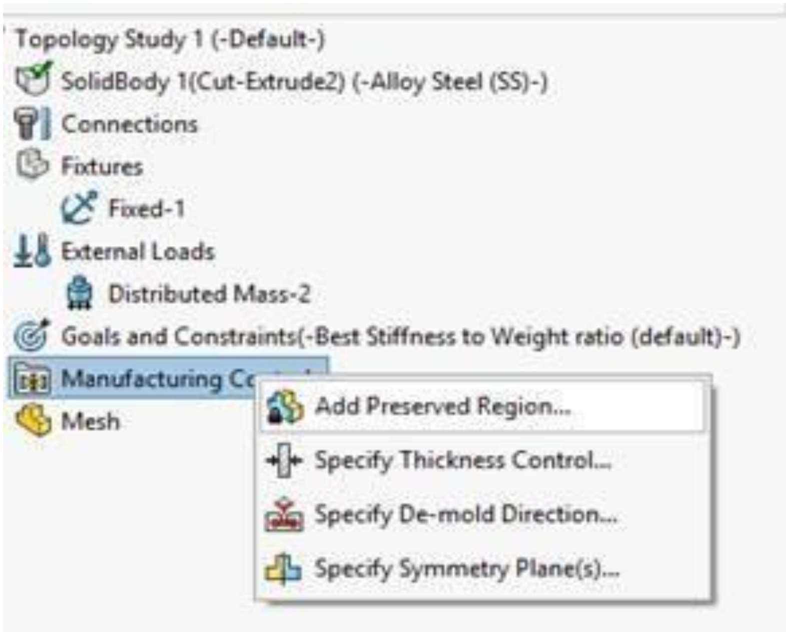
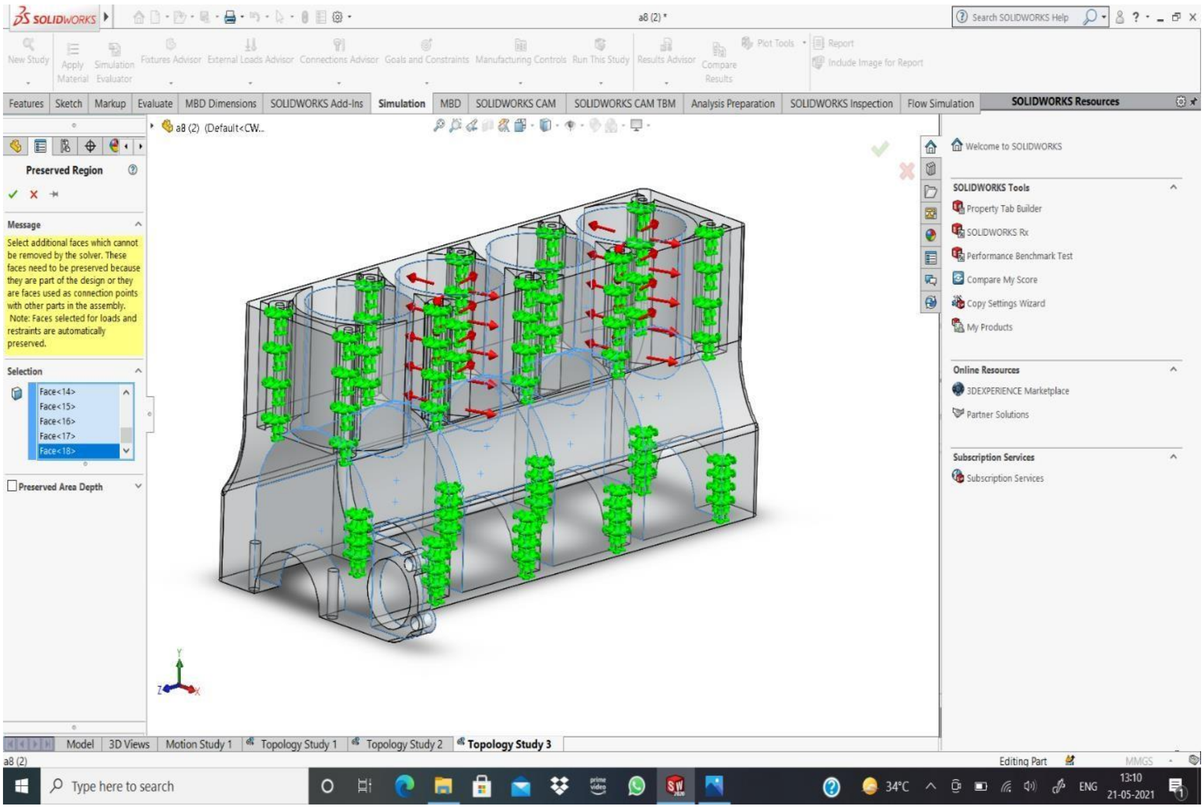


Figure 5. Manufacturing Controls

For this part, you want to choose Add Preserved Region. Clicking this option will open the Preserved Region pane.



With the Selection box active, you can now go into the main design window and select the faces that you wish to preserve. For this example, select the inner face of each and every hole on the part. This will preserve the regions around the holes. If you look down at the bottom of the Preserved Region pane, you can see an option labeled Preserved Area Depth. By default, this is switched off. But for this example, you want to specify the depth of the face that you will preserve, so activate it with the check box, and select depth. This will preserve a cylindrical region that extends from the perimeter of the bolt hole.

You have finished with these preserved regions now, so you can click the green check mark to exit.

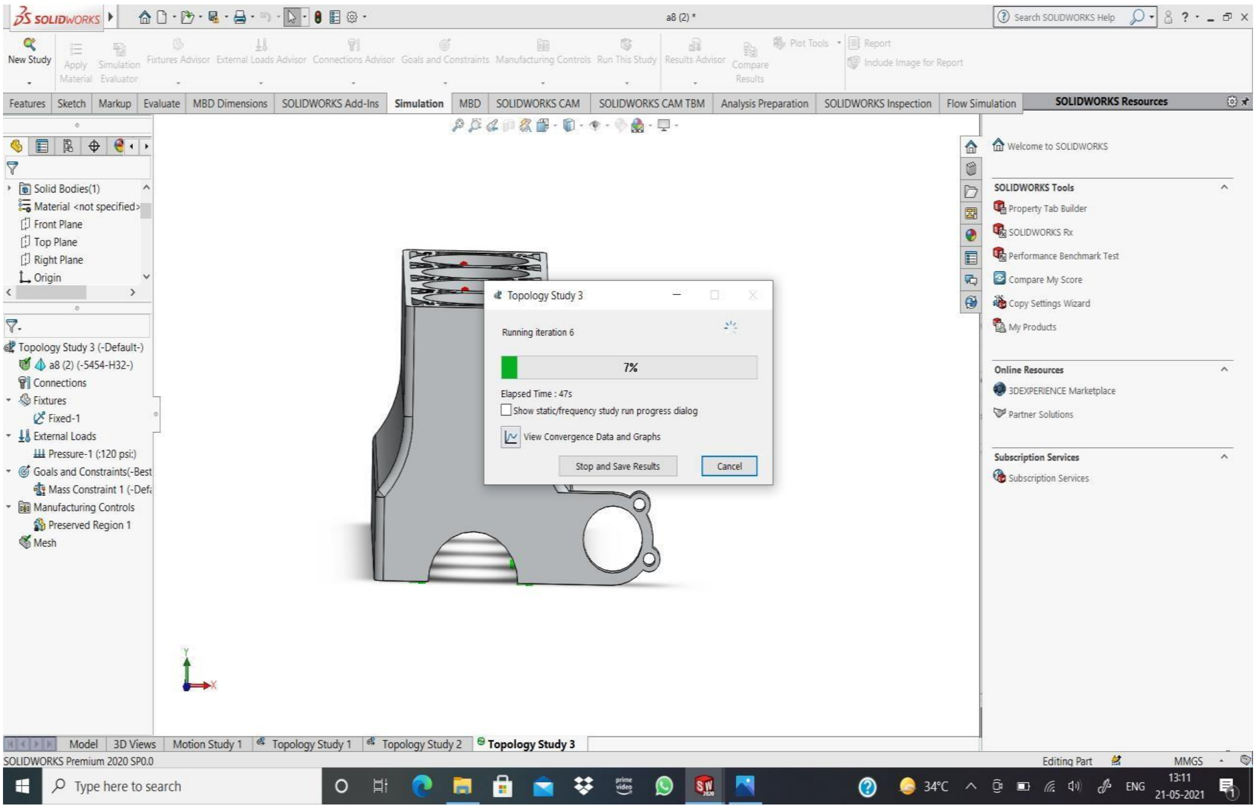
Next, go back to the Thickness Control option and select a minimum thickness of 8mm. This just means that no section will be reduced below 8mm.

And, finally, go to the Specify Symmetry Planes option, and select half symmetry along the longitudinal plane. This will ensure that the optimization process is mirrored on both sides. Without it, the process will produce somewhat random results. As the forces are acting downward, and there is no torque to worry about, you can select this option.

Mesh and Run:

All of the basic constraints are set, and you are ready to mesh.

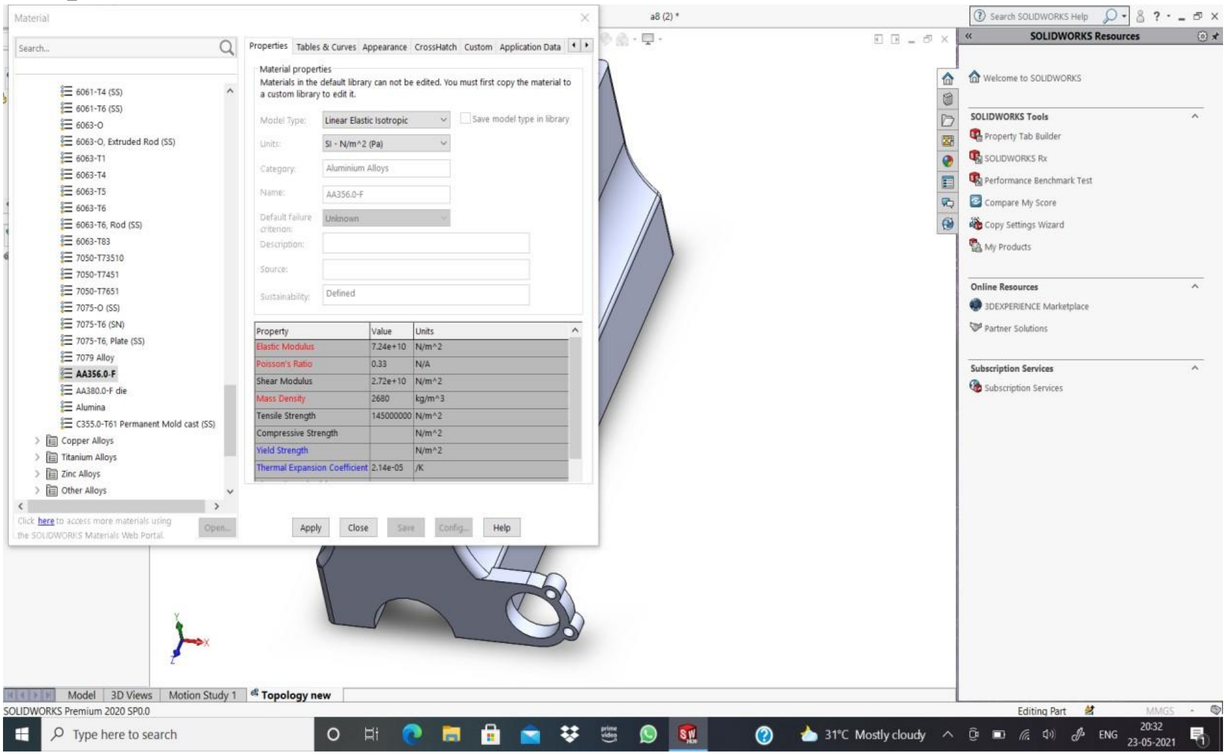
Go to the Mesh option at the bottom of the Topology Study pane, right-click it, and select Create Mesh. This will open the Mesh pane (see Figure 8). From here, you can control the Mesh Density. A finer mesh will create a more accurate study, but will take longer to mesh. The opposite is true for a coarse mesh (it will take a shorter time to simulate, but may not be as accurate). So, select Fine mesh, because this is a simple model and it won’t take too long.



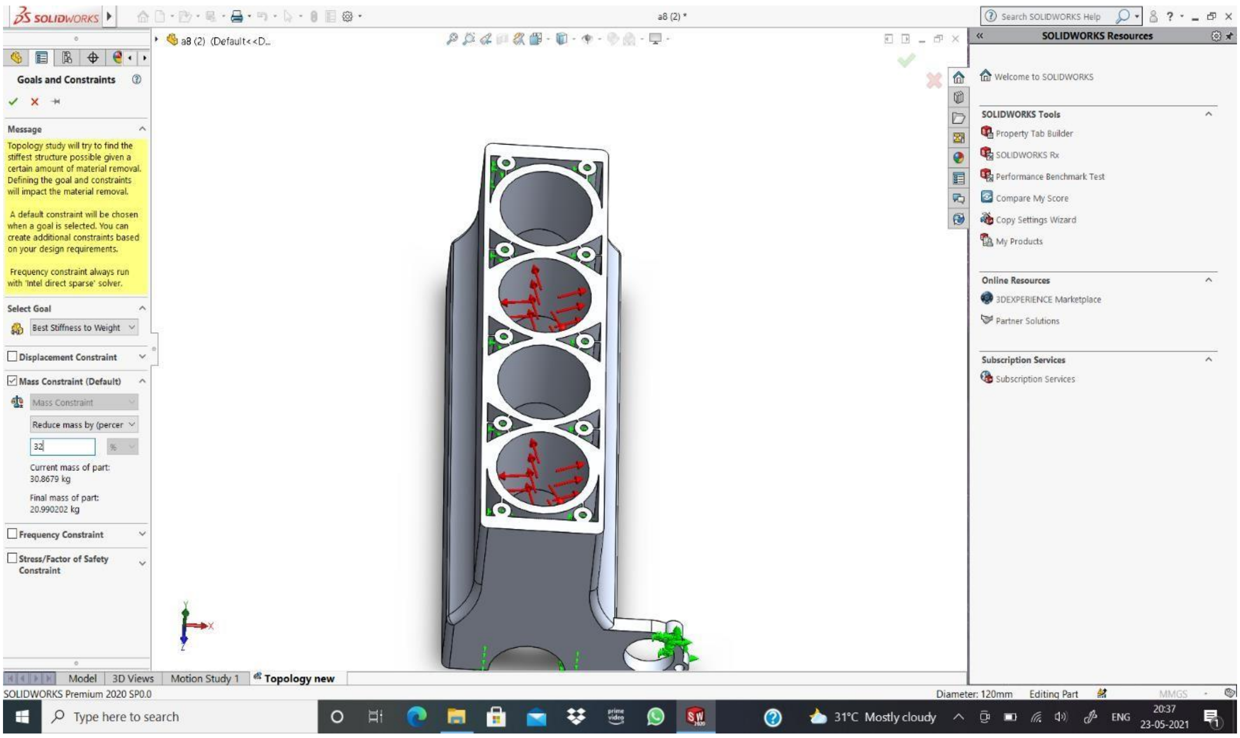
Topology Optimization

4.5 Al 356.0F

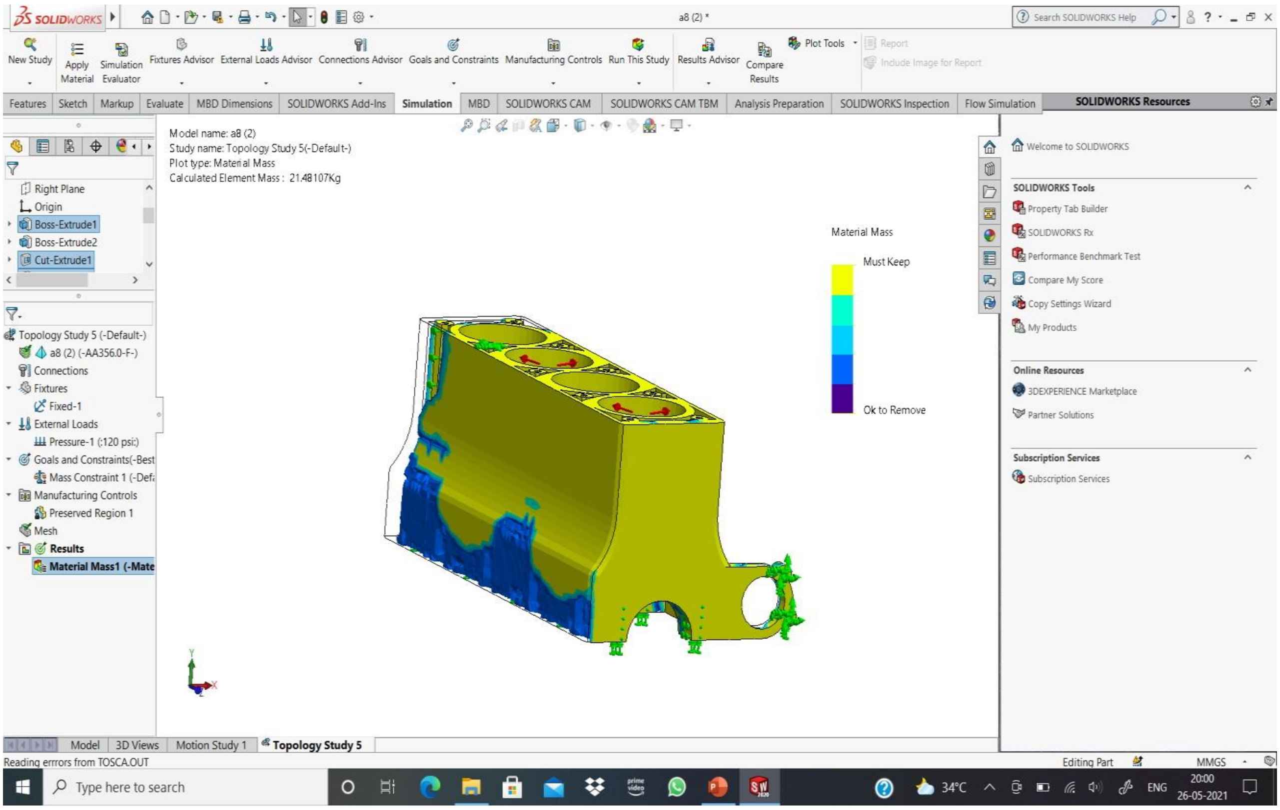
Properties of Al 356.0F



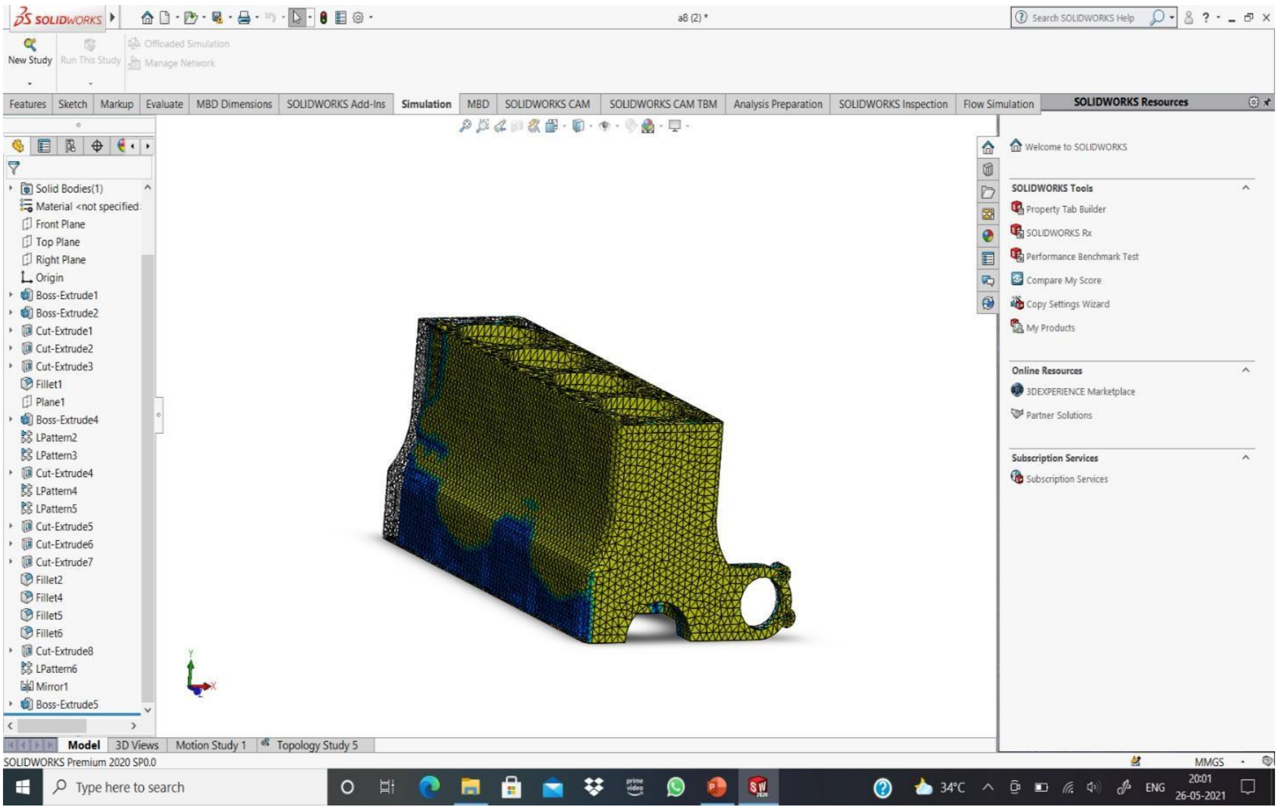
Goals and Constraints



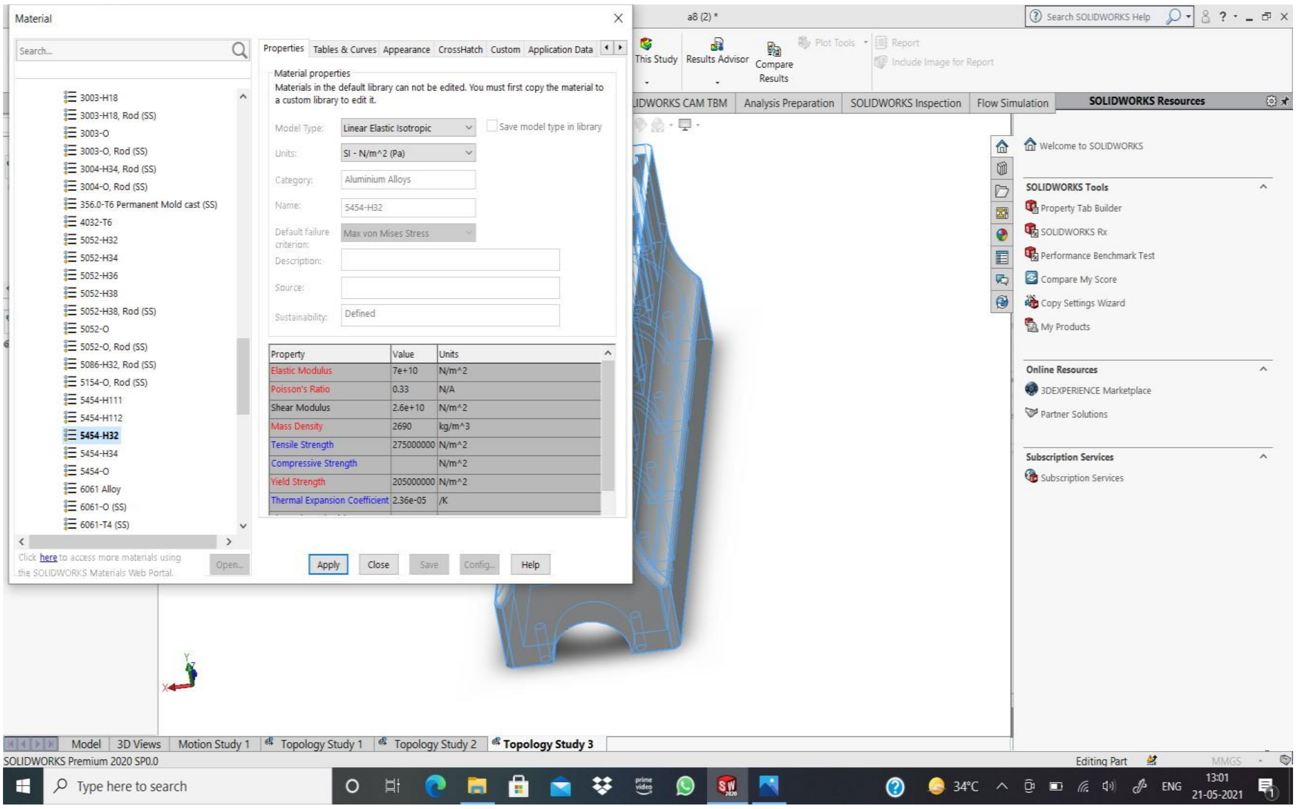
Results



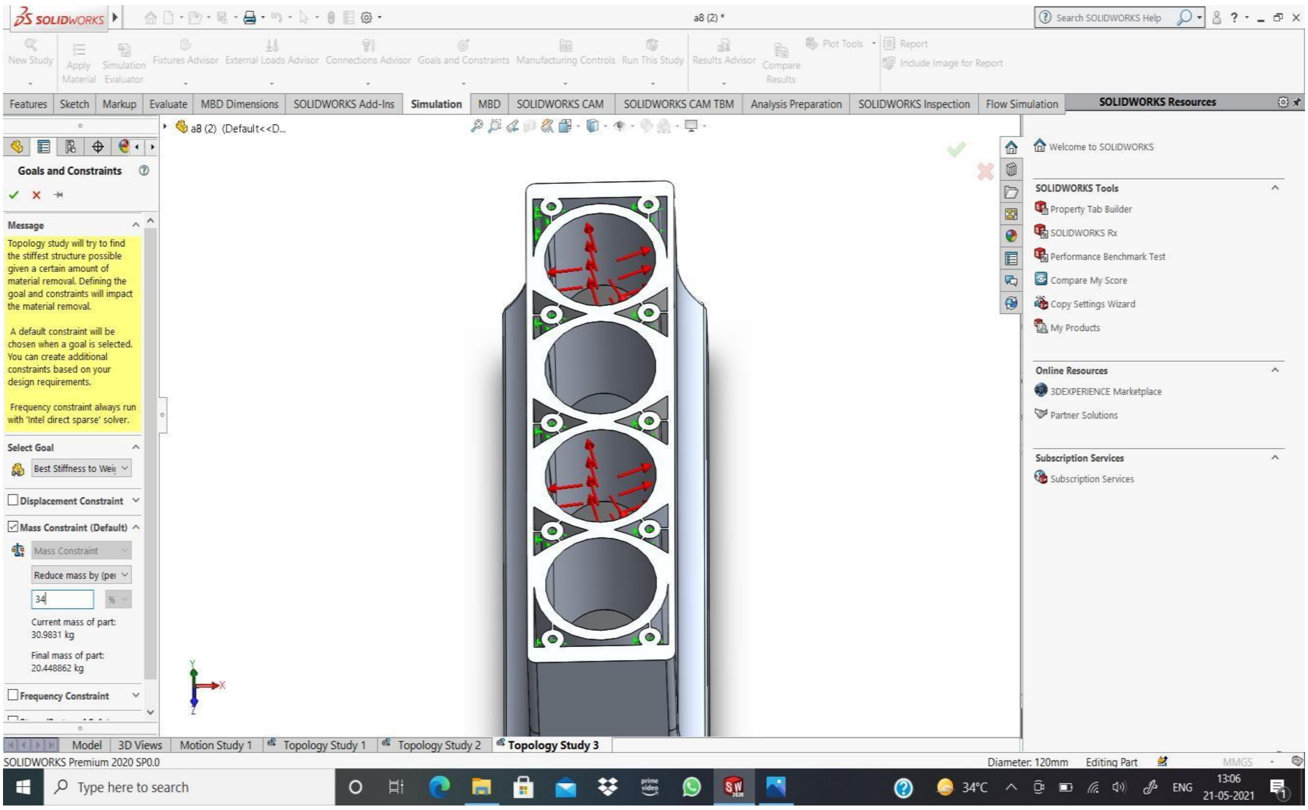
Mesh



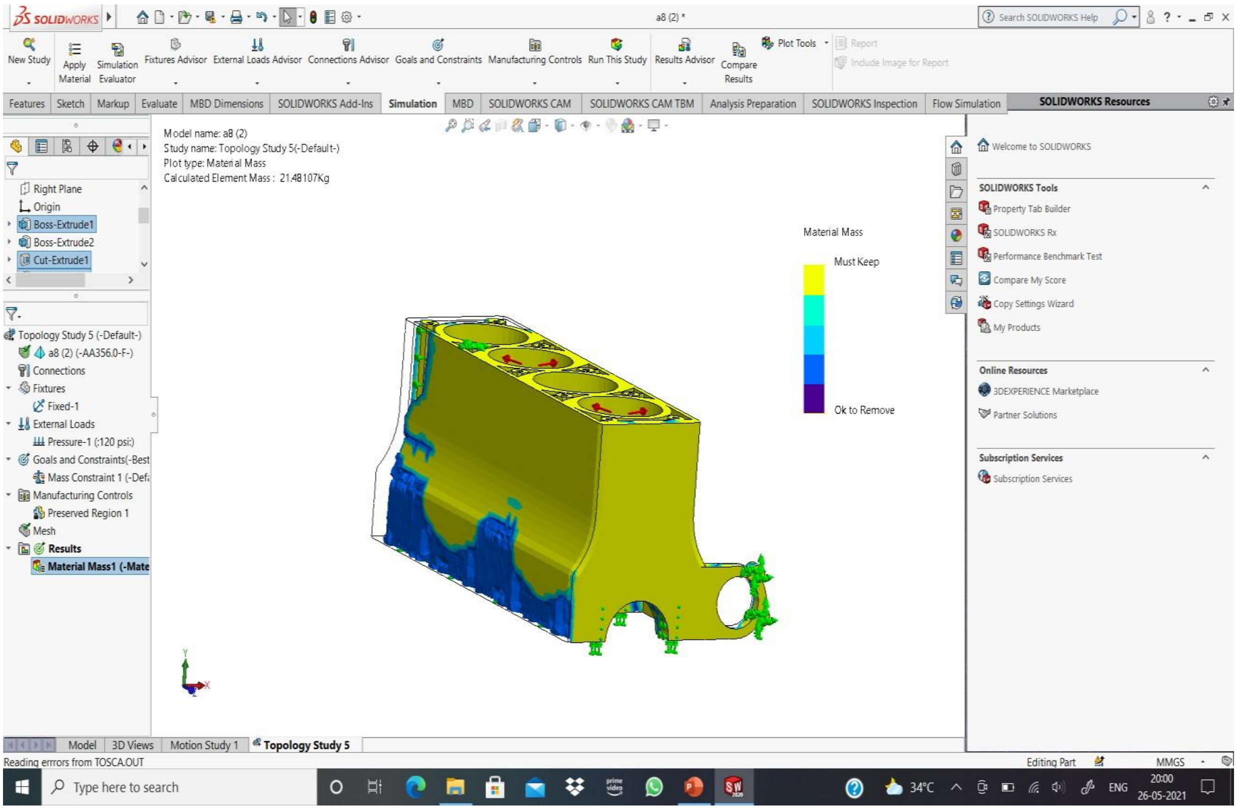
4.6 Al 5454 H32



Goals and Constraints



Results



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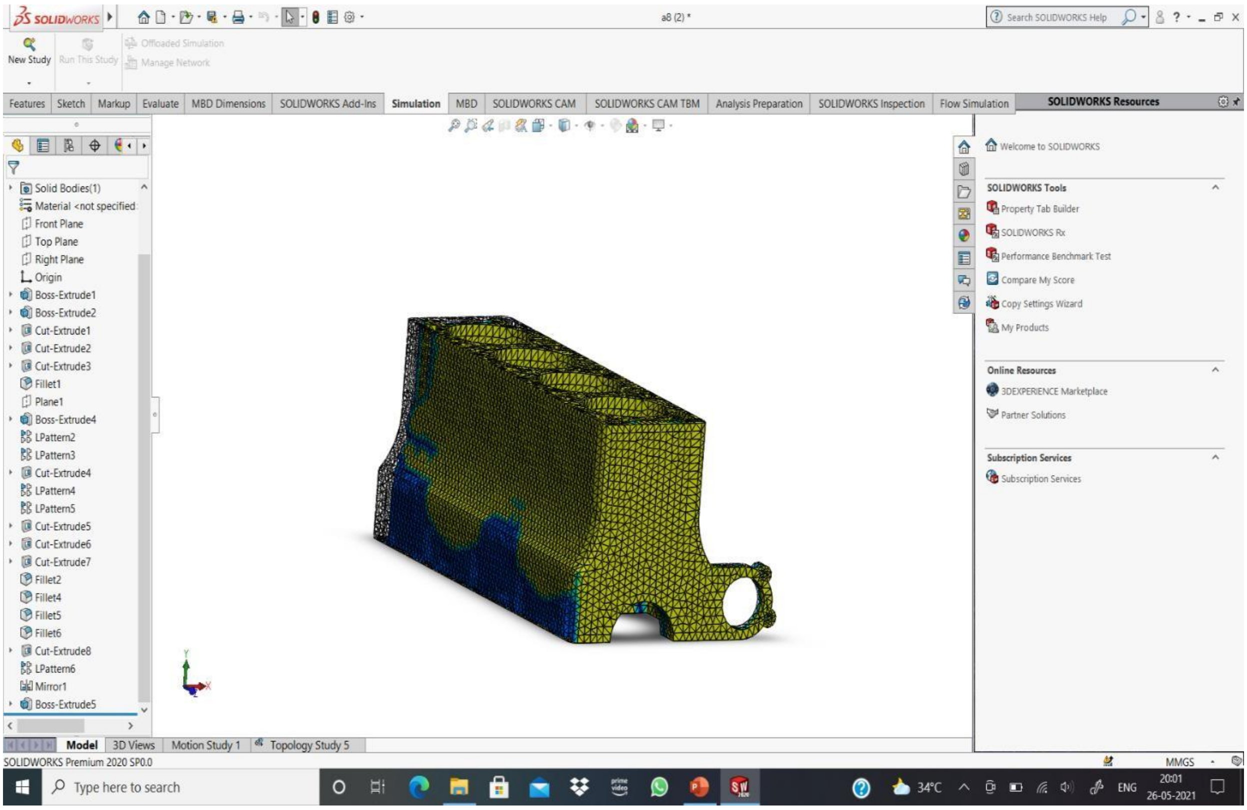
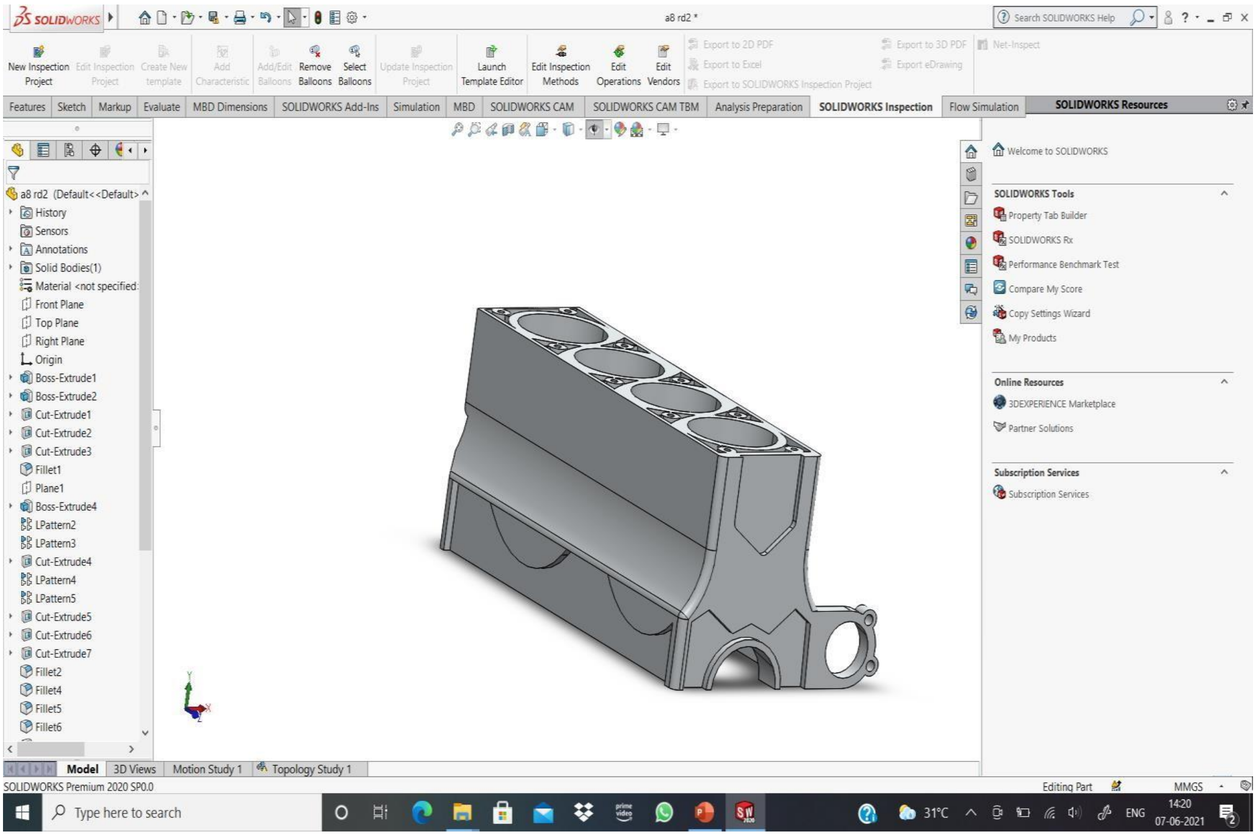


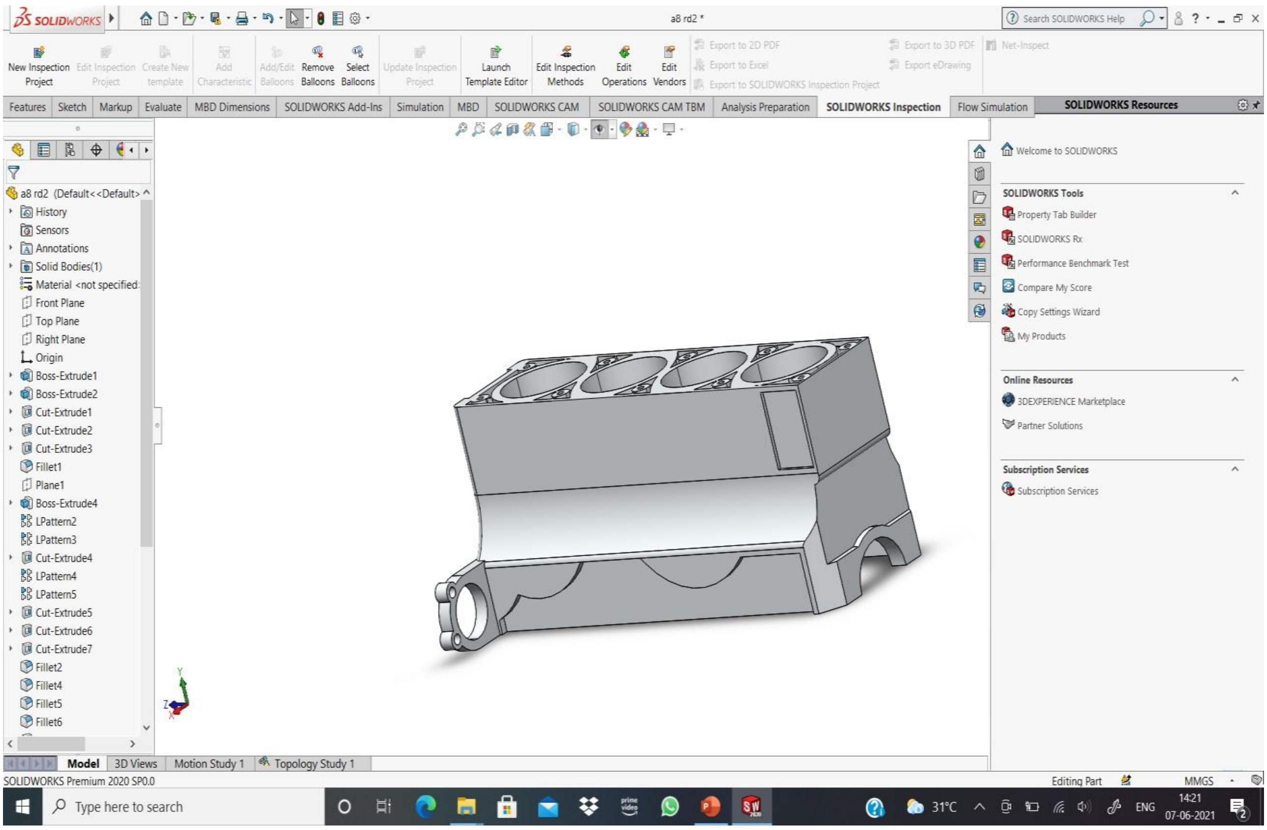
Results of Topology Optimization

Material Mass	Before	After
Al 356.0 F	30.8679kg	21.48107kg
Al 54564 H32	30.9011kg	20.96959kg

4.7 Remodeling

Al 5454 H32





Results After Remodeling

Material	Before	After
Al 5454 H32	30.9011kg	24.9011kg

CHAPTER 5

CONCLUSION AND FUTURE ENHANCEMENT

- We are going to design Four stroke engine block in the software Solidworks and perform Topology Optimization in Solidworks.

- The material mass of Al A-356.0F is reduced from 30.8679Kg to 21.48107Kg and another Al alloy 5454 H32 of material mass is reduced from 30.9011Kg to 20.96959kg .

- After remodeling of the Al 5454 H32 weight reduced is 6kgs . Due to the reduce of the material mass the engine efficiency will be increased and power will be higher compared to the four stroke engine.

- As a future scope of study, six stroke engine is used in automobile industry to increase efficiency and power.

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A Major Project Report
on

DESIGN AND DEVELOPMENT OF WIRELESS ARTIFICIAL ARM

SUBMITTED TO

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

by

B. SANDEEP	**-17K81A0367**
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Under the Guidance of

Dr. M. LAVANYA
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DEPARTMENT OF MECHANICAL ENGINEERING

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Dhulapally, Secunderabad – 500 100

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **Design and Development of Wireless Artificial Arm**, is being submitted by **B. Sandeep (17K81A0367), K. Vishal (17K81A0382), S. Tanveer singh (17K81A03B0), V. Mani teja (17K81A03B9)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report has been verified and found satisfactory.

Signature of Guide

Dr. M. LAVANYA
Associate Professor,
Department of Mechanical Engineering

Signature of HOD

Dr. D.V. SREEKANTH
Professor & Head of the Department
Department of Mechanical Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in **Department of Mechanical Engineering**, of the Academic Year: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project entitled **Design and Development of Wireless Artificial Arm** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been carried by taking care of Engineering Ethics. The result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

Today's technology increased the interest in robotic systems thus, increasing the number of studies conducted in this area. There are many studies on robotic systems in several fields to facilitate human life. In this project, a robot hand is designed to imitate finger movements using the flex sensors mounted on a wearable glove. Various sensors that detect the finger movement are used. The sensor that detects the angle of the fingers has been shown to provide accurate values. Various servo motors are placed on the robotic hand in order to mimic the muscle movements depending upon the data transmitted by the flex sensors. Thus, in this project an Animatronic hand is developed using ZigBee module and Arduino UNO. As the whole body of the robot would have been expensive, we only developed a hand which will act as shadow hand. The main aim of this project is to highlight the use of wireless communication and its application by developing Robotic Hand which can be used in many fields like medical, defence, chemical industries.

Keywords - Arduino, Servomotors, Flex sensors, Programming of the Arduino.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO EMBEDDED SYSTEMS:

An Embedded System is a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a specific function. A good example is the microwave oven. Almost every household has one, and tens of millions of them are used every day, but very few people realize that a processor and software are involved in the preparation of their lunch or dinner.

An embedded system is a controller with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today. Ninety-eight percent of all microprocessors manufactured are used in embedded systems.

Modern embedded systems are often based on microcontrollers (i.e. CPUs with integrated memory or peripheral interfaces), but ordinary microprocessors (using external chips for memory and peripheral interface circuits) are also common, especially in more complex systems. In either case, the processor(s) used may be types ranging from general purpose to those specialized in certain class of computations, or even custom designed for the application at hand. A common standard class of dedicated processors is the digital signal processor (DSP).

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, programmable logic controllers, and largely complex systems like hybrid vehicles, MRI, and avionics. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

1.2 REAL TIME SYSTEMS:

One subclass of embedded is worthy of an introduction at this point. As commonly defined, a real time system is a computer system that has timing constraints. In other words, a real-time system is partly specified in terms of its ability to make certain calculations or decisions in a timely manner. These important calculations are said to have deadlines for completion. And, for all practical purposes, a missed deadline is just as bad as a wrong answer.

The issue of what if a deadline is missed is a crucial one. For example, if the real-time system is part of an airplane's flight control system, it is possible for the lives of the passengers and crew to be endangered by a single missed deadline. However, if instead the system is involved in satellite communication, the damage could be limited to a single corrupt data packet. The more severe the consequences, the more likely it will be said that the deadline is "hard" and thus, the system is a hard real-time system. Real-time systems at the other end of this discussion are said to have "soft" deadlines.

All of the topics and examples presented in this book are applicable to the designers of real-time system who is more delight in his work. He must guarantee reliable operation of the software and hardware under all the possible conditions and to the degree that human lives depend upon three system's proper execution, engineering calculations and descriptive paperwork.

1.3 APPLICATION AREAS:

Nearly 99 per cent of the processors manufactured end up in embedded systems. The embedded system market is one of the highest growth areas as these systems are used in very market segment- consumer electronics, office automation, industrial automation, biomedical engineering, wireless communication, data communication, telecommunications, transportation, military and so on.

Consumer appliances:

At home we use a number of embedded systems which include digital camera, digital diary, DVD player, electronic toys, microwave oven, remote controls for TV and air-conditioner, VCO player, video game consoles, video recorders etc. Today's high-tech car has about 20 embedded systems for transmission control, engine spark control, air-conditioning, navigation etc. Even wristwatches are now becoming embedded systems. The palmtops are powerful embedded systems using which we can carry out many general-purpose tasks such as playing games and word processing.

Office automation:

The office automation products using embedded systems are copying machine, fax machine, key telephone, modem, printer, scanner etc.

Industrial automation:

Today a lot of industries use embedded systems for process control. These include pharmaceutical, cement, sugar, oil exploration, nuclear energy, electricity generation and transmission. The embedded systems for industrial use are designed to carry out specific tasks such as monitoring the temperature, pressure, humidity, voltage, current etc., and then take appropriate action based on the monitored levels to control other devices or to send information to a centralized monitoring station. In hazardous industrial environment, where human presence has to be avoided, robots are used, which are programmed to do specific jobs. The robots are now becoming very powerful and carry out many interesting and complicated tasks such as hardware assembly.

Medical electronics:

Almost every medical equipment in the hospital is an embedded system. These equipment's include diagnostic aids such as ECG, EEG, blood pressure measuring devices, X-ray scanners; equipment used in blood analysis, radiation, colonscopy, endoscopy etc. Developments in medical electronics have paved way for more accurate diagnosis of diseases.

Computer networking:

Computer networking products such as bridges, routers, Integrated Services Digital Networks (ISDN), Asynchronous Transfer Mode (ATM), X.25 and frame relay switches are embedded systems which implement the necessary data communication protocols. For example, a router interconnects two networks. The two networks may be running different protocol stacks. The router's function is to obtain the data packets from incoming pores, analyze the packets and send them towards the destination after doing necessary protocol conversion. Most networking equipment's, other than the end systems (desktop computers) we use to access the networks, are embedded systems.

Telecommunications:

In the field of telecommunications, the embedded systems can be categorized as subscriber terminals and network equipment. The subscriber terminals such as key telephones, ISDN phones, terminal adapters, web cameras are embedded systems. The network equipment includes multiplexers, multiple access systems, Packet Assemblers Dissemblers (PADs), sate11ite modems etc. IP phone, IP gateway, IP gatekeeper etc. are the latest embedded systems that provide very low-cost voice communication over the Internet.

Wireless technologies:

Advances in mobile communications are paving way for many interesting applications using embedded systems. The mobile phone is one of the marvels of the last decade of the 20’h century. It is a very powerful embedded system that provides voice communication while we are on the move. The Personal Digital Assistants and the palmtops can now be used to access multimedia services over the Internet. Mobile communication infrastructure such as base station controllers, mobile switching centers are also powerful embedded systems.

Insemination:

Testing and measurement are the fundamental requirements in all scientific and engineering activities. The measuring equipment we use in laboratories to measure parameters such as weight, temperature, pressure, humidity, voltage, current etc. are all embedded systems. Test equipment such as oscilloscope, spectrum analyzer, logic analyzer, protocol analyzer, radio communication test set etc. are embedded systems built around powerful processors. Thank to miniaturization, the test and measuring equipment are now becoming portable facilitating easy testing and measurement in the field by field-personnel.

Security:

Security of persons and information has always been a major issue. We need to protect our homes and offices; and also, the information we transmit and store. Developing embedded systems for security applications is one of the most lucrative businesses nowadays. Security devices at homes, offices, airports etc. for authentication and verification are embedded systems. Encryption devices are nearly 99 per cent of the processors that are manufactured end up in~ embedded systems. Embedded systems find applications in every industrial segment-consumer electronics, transportation, avionics, biomedical engineering, manufacturing, process control and industrial automation, data communication, telecommunication, defense, security etc. Used to encrypt the data/voice being transmitted on communication links such as telephone lines. Biometric systems using fingerprint and face recognition are now being extensively used for user authentication in banking applications as well as for access control in high security buildings.

Finance:

Financial dealing through cash and cheques are now slowly paving way for transactions using smart cards and ATM (Automatic Teller Machine, also expanded as Any Time Money) machines. Smart card, of the size of a credit card, has a small micro-controller and memory; and it interacts with the smart card reader! ATM machine and acts as an electronic wallet. Smart card technology has the capability of ushering in a cashless society. Well, the list goes on. It is no exaggeration to say that eyes wherever you go, you can see, or at least feel, the work of an embedded system.

1.4 OVERVIEW OF EMBEDDED SYSTEMS ARCHITECT:

Every embedded system consists of custom-built hardware built around a Central Processing Unit (CPU). This hardware also contains memory chips onto which the software is loaded. The software residing on the memory chip is also called the ‘firmware’. The embedded system architecture can be represented as a layered architecture as shown in Fig.

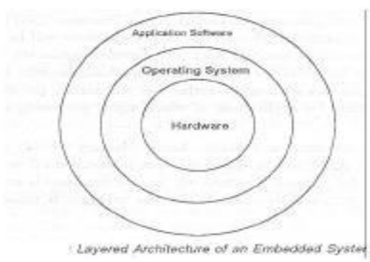

Fig 1: Layered architecture of an embedded system

The operating system runs above the hardware, and the application software runs above the operating system. The same architecture is applicable to any computer including a desktop computer. However, there are significant differences. It is not compulsory to have an operating system in every embedded system. For small appliances such as remote-control units, air conditioners, toys etc., there is no need for an operating system and you can write only the software specific to that application. For applications involving complex processing, it is advisable to have an operating system. In such a case, you need to integrate the application software with the operating system and then transfer the entire software on to the memory chip. Once the software is transferred to the memory chip, the software will continue to run *for* a long time you don't need to reload new software.

Now, let us see the details of the various building blocks of the hardware of an embedded system.

As shown in Fig. the building blocks are;

· Central Processing Unit (CPU)

· Memory (Read-only Memory and Random-Access Memory)

· Input Devices

· Output devices

· Communication interfaces

· Application-specific circuitry

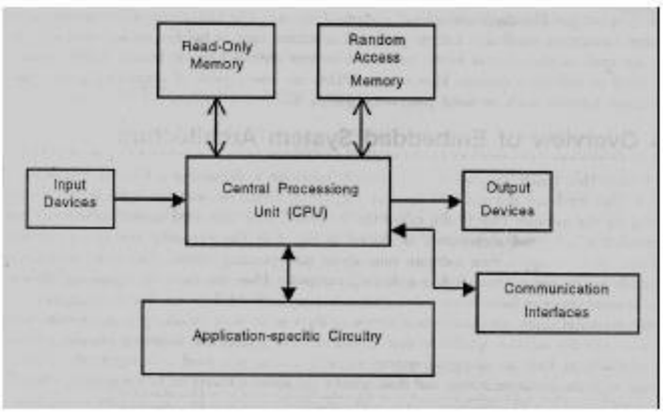

Fig 2: Block diagram of hardware components of embedded system

1.4.1: Central Processing Unit (CPU):

The Central Processing Unit (processor, in short) can be any of the following: microcontroller, microprocessor or Digital Signal Processor (DSP). A micro-controller is a low-cost processor. Its main attraction is that on the chip itself, there will be many other components such as memory, serial communication interface, analog-to digital converter etc. So, for small applications, a microcontroller is the best choice as the number of external components required will be very less. On the other hand, microprocessors are more powerful, but you need to use many external components with them. D5P is used mainly for applications in which signal processing is involved such as audio and video processing.

1.4.2: Memory:

The memory is categorized as Random Access 11emory (RAM) and Read Only Memory (ROM). The contents of the RAM will be erased if power is switched off to the chip, whereas ROM retains the contents even if the power is switched off. So, the firmware is stored in the ROM. When power is switched on, the processor reads the ROM; the program is program is executed.

1.4.3: Input devices:

Unlike the desktops, the input devices to an embedded system have very limited capability. There will be no keyboard or a mouse, and hence interacting with the embedded system is no easy task. Many embedded systems will have a small keypad-you press one key to give a specific command. A keypad may be used to input only the digits. Many embedded systems used in process control do not have any input device *for* user interaction; they take inputs *from* sensors or transducers

1’fnd produce electrical signals that are in turn fed to other systems.

1.4.4: Output devices:

The output devices of the embedded systems also have very limited capability. Some embedded systems will have a *few* Light Emitting Diodes (LEDs) *to* indicate the health status of the system modules, or *for* visual indication of alarms. A small Liquid Crystal Display (LCD) may also be used to display *some* important parameters.

1.4.5: Communication interfaces:

The embedded systems may need to, interact with other embedded systems at they may have to transmit data to a desktop. To facilitate this, the embedded systems are provided with one or a few communication interfaces such as RS232, RS422, RS485, Universal Serial Bus (USB), IEEE 1394, Ethernet etc.

1.4.6: application-specific circuitry:

Sensors, transducers, special processing and control circuitry may be required fat an embedded system, depending on its application. This circuitry interacts with the processor to carry out the necessary work. The entire hardware has to be given power supply either through the 230 volts main supply or through a battery.

1.5 OBJECTIVES OF THE PROJECT:

- To Make the arm structure using 3D printed material.
- To built it at a lower cost than the currently available robotic arms.
- To make the arm as light weighted as possible by using 3D printed materials.
- To design the arm which is not only to be used as prosthetic hand but also for various other industrial uses.
- To make it accessible for all those needy and disabled persons who cannot afford costly Robotic Hand/Arm.

1.6 SCOPE OF THE PROJECT:

- With 3D printing advancing and becoming more affordable, the possibility of anyone being able to easily design and print a prosthetic limb could soon become a reality. New 3D scanning and body modelling technology could also enable people to 3D scan their limbs and have prosthetics modelled after them, making for more natural fitting and appearance.
- Even more impressive, researchers are developing versions of bionic limbs, controlled by thought. They attach to an implant inserted directly into the bone, and nerve reassignment surgery then allows brain signals to directly control movement.

CHAPTER 2

LITERATURE SURVEY

[1] Pushkar shukla, Bhumik gupta, Shailesh Bilsht, proposed MIMIC. The project is basically a robotic arm. They have attempted to propose an algorithm to control the mimicing action of the robotic arm that copy's the human arm movement. Algorithm as two steps, first is reading from the sensor and converted into mechanical movement into robotic arm using an estimation algorithm. Second step is an algorithm to eliminate the noise. One of the main advantage of this robotic arm is that it can completely replace human operations like bomb diffusion etc. Arm is constructed using acrylic glass. Arm have 5 degree of freedom. It uses six servomotors to control movement. This Arm can mimic flexion and extension. Mimic is done in 2 ways, either by using camera and other visual sensors like "kinetic", or by attaching colour bands to human arms for better recognition of different parts of human arm. Accelerometer , flux sensor, potentiometer are used for tracking movements of robotic arm.

[2] Gargi Saha, Jit Rakshit, Srijita Das proposed MIMICING ROBOTIC ARM. This robotic arm can copy the human arm movement with certain accuracy where human intervention is not possible. This paper shows the design and execution of a mechanical robotic arm using Arduino UNO which mimic the of human arm gesture. Here human machine interface is used for robots by using a DIY bend sensor, which works on basics of actual muscular movement. The Arduino UNO uses atmega 328 microcontroller. The working principle involves interfacing potentiometer and motors achieved by using Arduino board the bend sensor converts mechanical movement into electrical output. The microcontroller convert the signal from the potentiometer and generate digital pulses for activing the servo motors. The motor rotate as per the pulses and thus movement of the arm is achieved.

[3] Edwin Basil Mathew, Dushyant Khanduja, Bhavya Sapra, Bharat Bushan proposed ROBOTIC ARM CONTROL THROUGH HUMAN ARM MOVEMENT DETECTION USING POTENTIOMETERS. In this projects a number of situations exist where it is not possible for a human operations to do an activity on his /her own, due to level of danger of difficulty involved. The danger involves taking reading from active volcano entering buildings on fire, diffusion of a bomb or collecting a radio active sensor. The robotic are can be autonomous and controlled manually which adds up the characteristics to be used to perform various task with great accuracy the robotic arm can be fused on a mobile (wheeled) and can be designed for industrial or home application. There are so many ways in which a robotic arm cab be controlled and manipulated. Apart from this many researches have worked to operates robotic arm through computer terminals, joystick even interfacing them with internet so that they can be controlled and operated from any. A robotic arm by definition is a robot manipulator, usually programmed with function similar to a human arm. This project requires potentiometer, servomotor, Arduino Uno, power supply, frame. The robot require no training since robotic arm is controlled by user. This robotic arm can be provided with a camera so that the user controlled the robotic arm doesn't have to be in direct line of sight of the robot to be able to control it.

[4] Ahasan Ulla Rahul,M Tanseer Ali and Rakibull Ahasan proposed GESTURE BASED WIRELESS SHADOW ROBOT. In this project they presented an application of gesture mimic human robot interaction which has developed using kinetic sensors. The project contains a robotic body that mimics the hand gesture of the user body using kinetic sensor. The project mainly focusses on human hand gesture mimicing by a 17 degree of freedom humanoid. The project includes implementation and evaluation and simply joints angle calculation, utilizing wireless control for robot movements. Developing training mode to store and utilize repetitive robot movements, development of basic non-feedback static walking sequence for the forward walking of the shadow robot etc.

[5] Rahul sekhar, Rakesh Kiran Musalay, Yashwanth Krishnamurthy and shreenivas B, Proposed INERTIAL SENSOR BASED WIRELESS CONTROL OF A ROBOTIC ARM. The project involves the development of a wireless motion sensing control unit, the operation of which is based on inertial sensors, and extends its application to the control of an anthropomorphic robotic arm. MEMS inertial sensors are used in the system and accelerometer and gyroscope are used in the control unit. An additional accelerometer is strapped to the users arm. An accelerometer is used for measuring acceleration through an inertial frame of reference. This can be used to measure its orientation. Thus the orientation of the lower arm of the user is measured and this data is transmitted wirelessly to a receiver where processing is carried out. The robotic arm is programmed in such a way that it mimic the hand gesture of the users. Data processing is carried out on a low-cost microcontroller.

CHAPTER 3
PROJECT DESIGN

3.1 INTRODUCTION TO SOLIDWORKS:

SOLIDWORKS is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems, that runs primarily on Microsoft Windows. While it is possible to run solidworks on an intel-based Mac with windows installed, the application's developer recommends against this. Solidworks does not support macOS.

According to publisher, over two million engineers and designers at more than 165,000 companies were using solidworks as of 2013. Also, according to the company, fiscal year 2011-12 revenue for solidworks totaled $483 million.

3.2 HISTORY OF SOLIDWORKS:

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, United States, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product SolidWorks 95, in November 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired SolidWorks for $310 million in stock Jon Hirschtick stayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenue company.

Name/Version	Version Number	Version History Value	Release Date
SOLIDWORKS 2017	25	10000	September 19, 2016
SOLIDWORKS 2018	26	11000	September 26, 2017
SOLIDWORKS 2019	27	12000	October 9, 2018
SOLIDWORKS 2020	28	13000	September 18, 2019
SOLIDWORKS 2021			September 22, 2020

Table 1: Release History of SOLIDWORKS

3.3 APPLICATION OF SOLIDWORKS (DRAFTING):

Solidworks can draw vivid 3D model, it can dynamically show the cut process and can get virtual assembly and assembly exploded view. It start from the perspective of the classroom, examples discussed the ability of solidworks to establish basic volume model, dynamic display the difficult issues in the course of mechanical design and drafting, such as plane intersects with the basic volume model, assembly and exploded view. It is also investigated the role of solidworks enrich the teaching content, improve students' ability of spatial imagination and design skills, stimulate students' interest in learning, enhance the ability of student drawings and identify drawings. It is demonstrated that the using of solidworks for classroom can effectively reduce teaching and learning difficulty, enhance students' interest in learning and helps to achieve good teaching results.

3.4 PROPOSED DESIGN USING SOLIDWORKS:

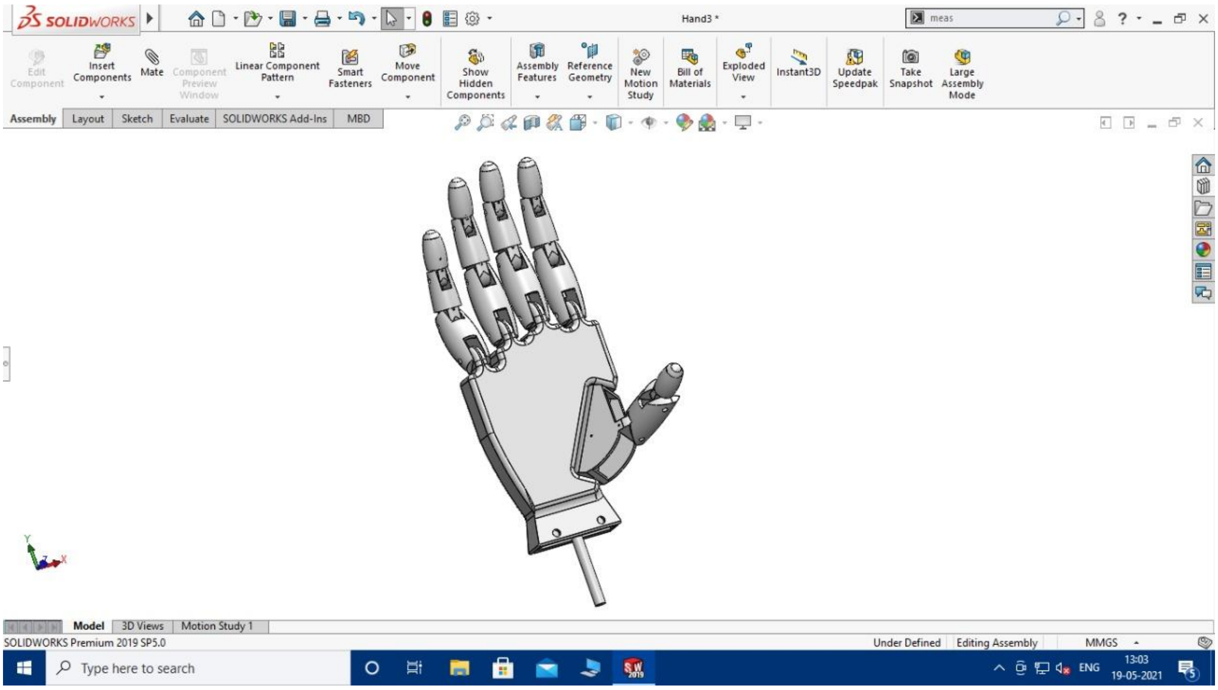

Fig. 3 Hand design

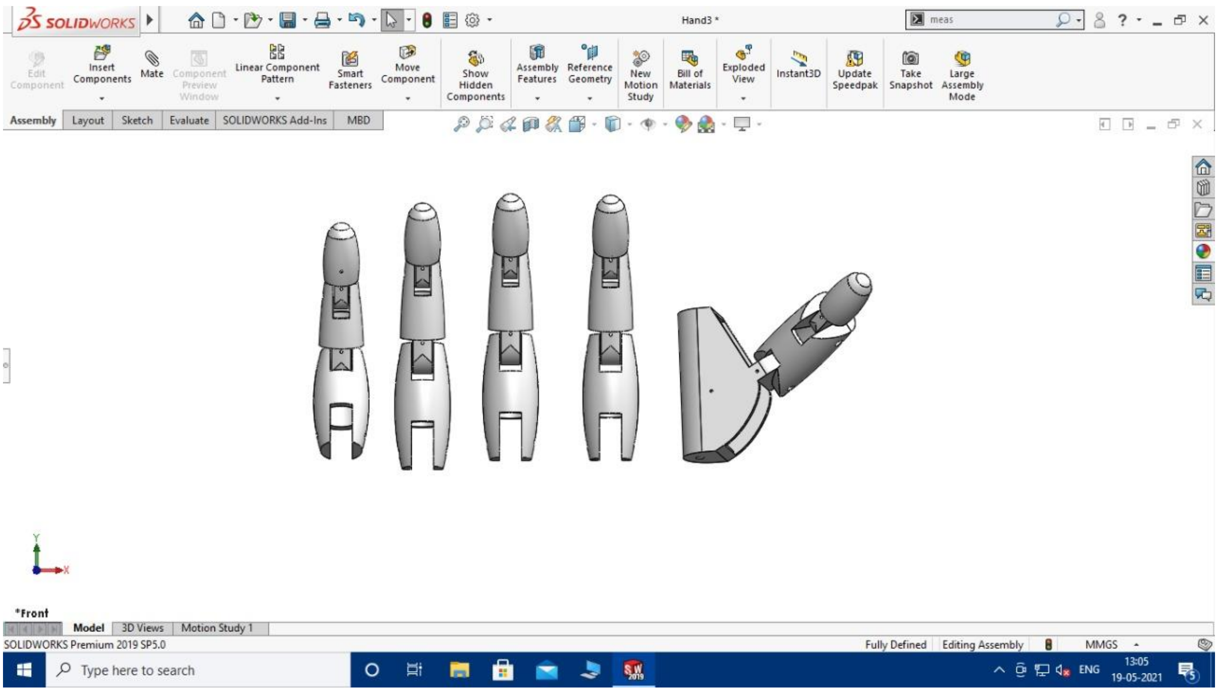

Fig. 4 Fingers Design

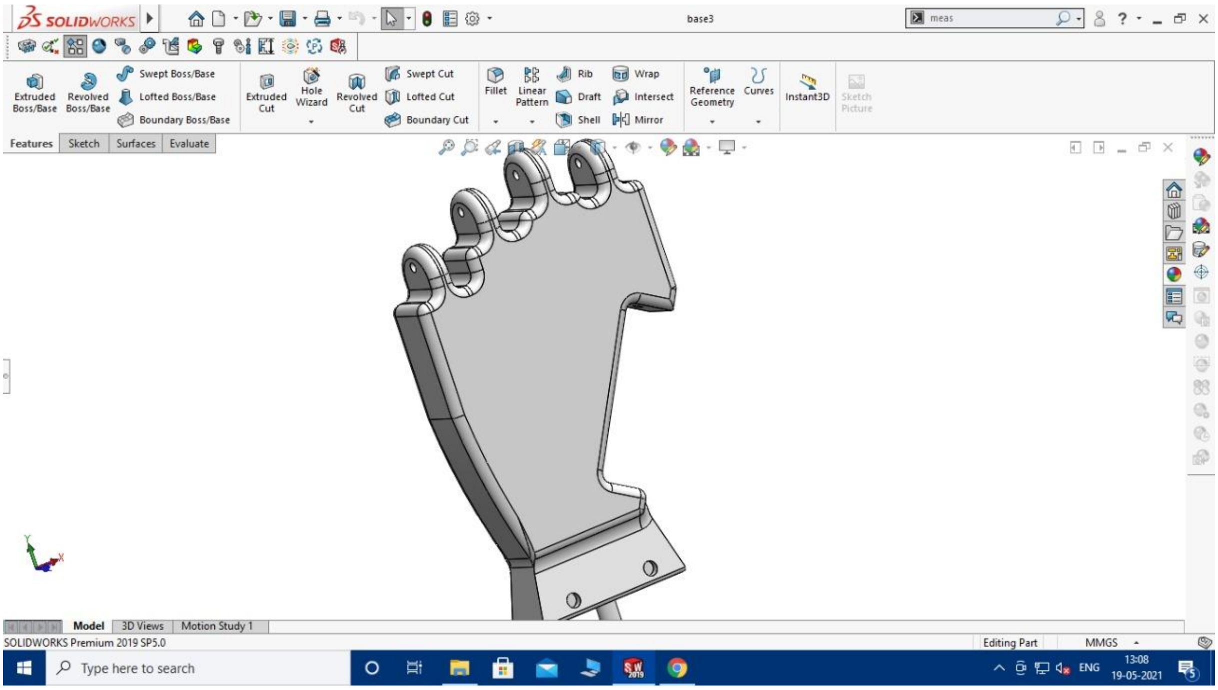

Fig. 5 Palm Design

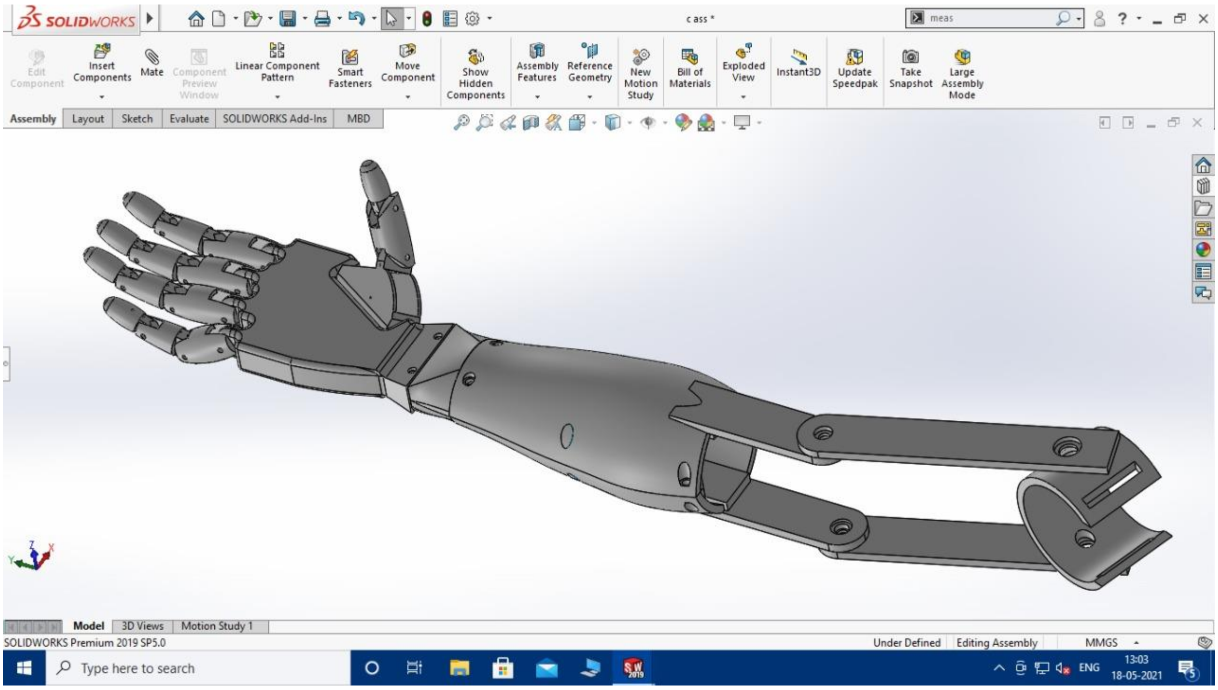

Fig. 6 Hand Design

The Above Figures are Designed using SOLIDWORKS 2020 Software.

3.5 PART DIMENSIONS:

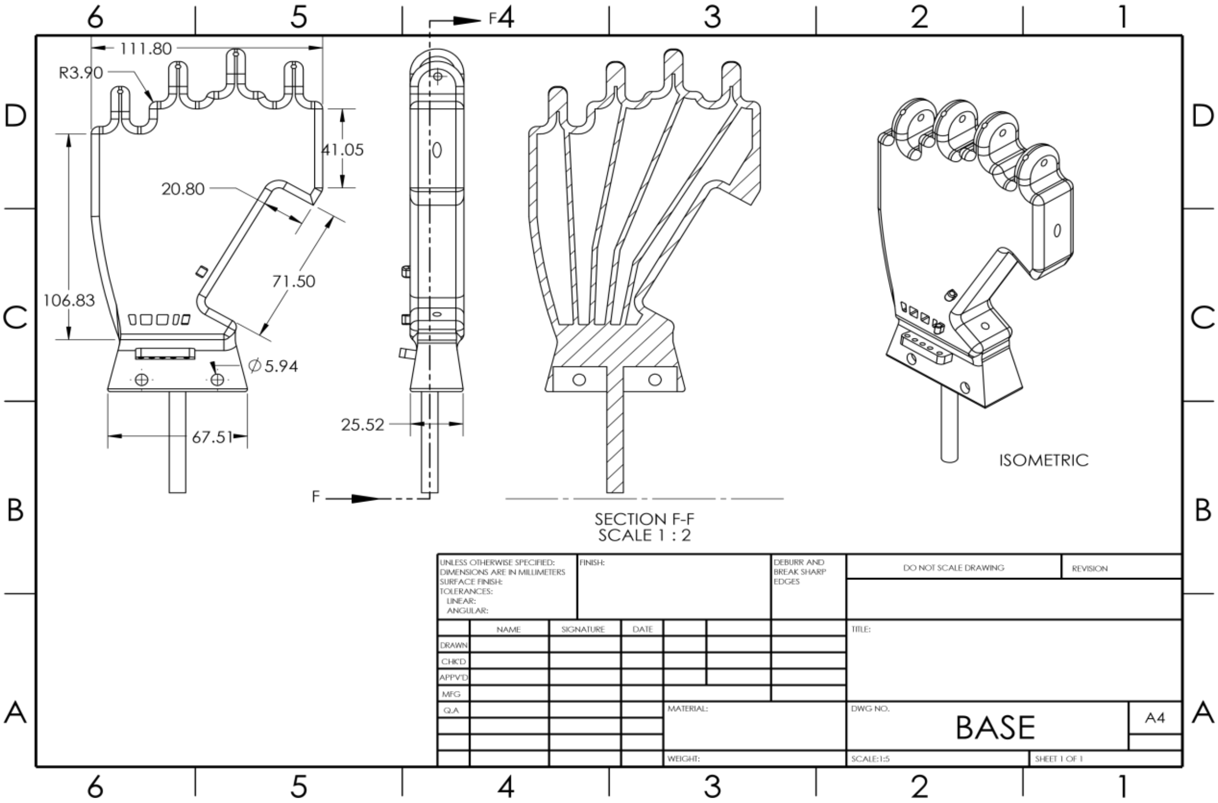

Fig. 7 Dimensions of Palm

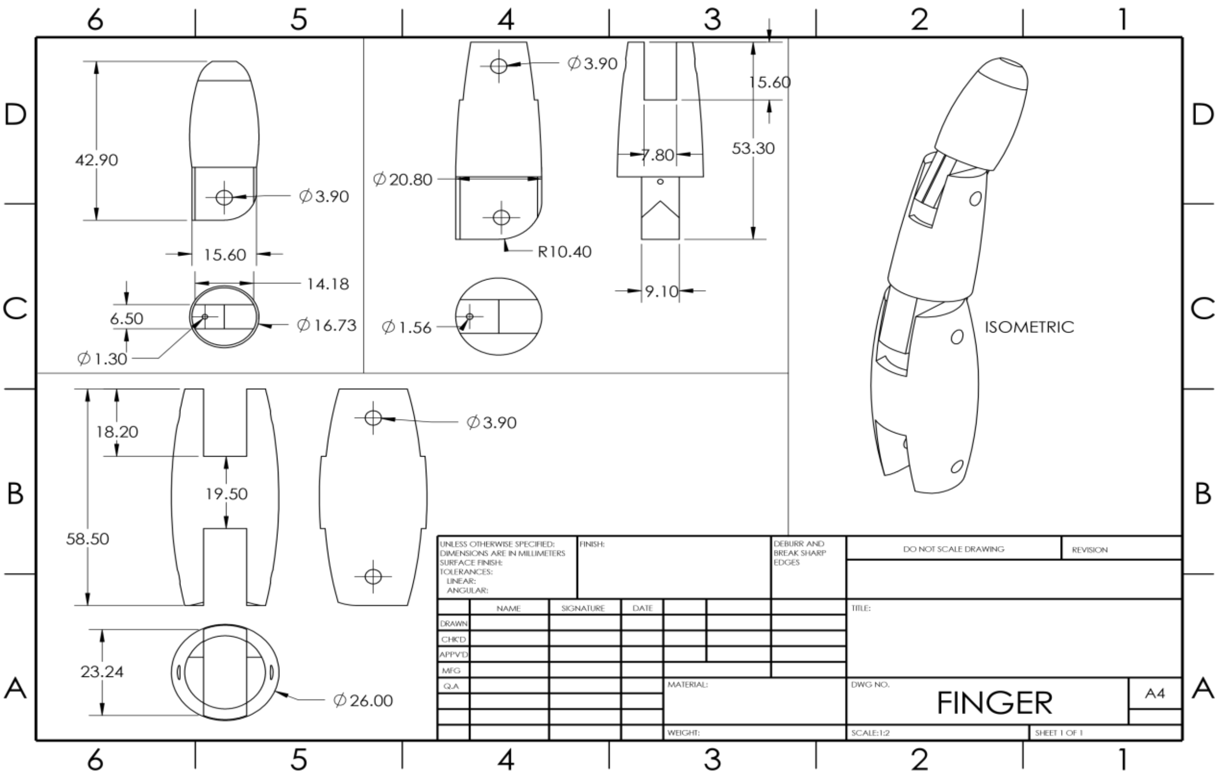

Fig. 8 Finger Dimensions

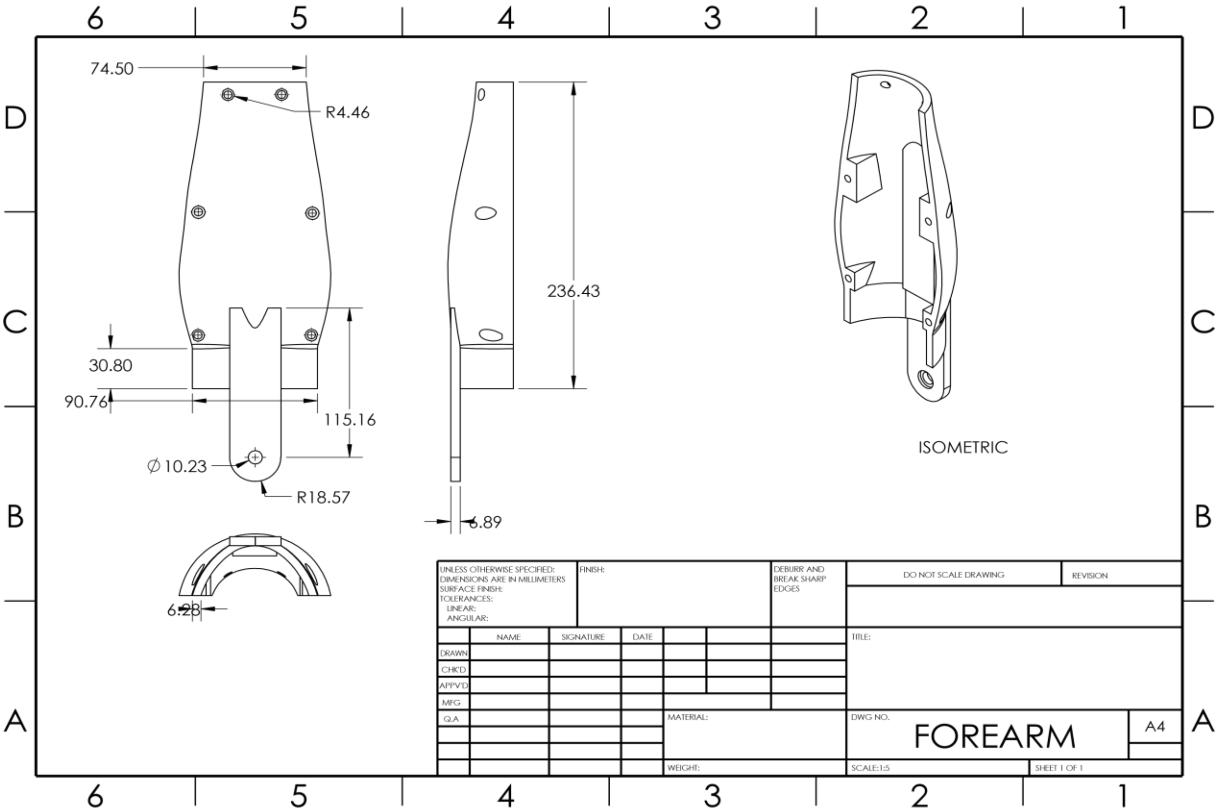

Fig. 9 Forearm Dimensions

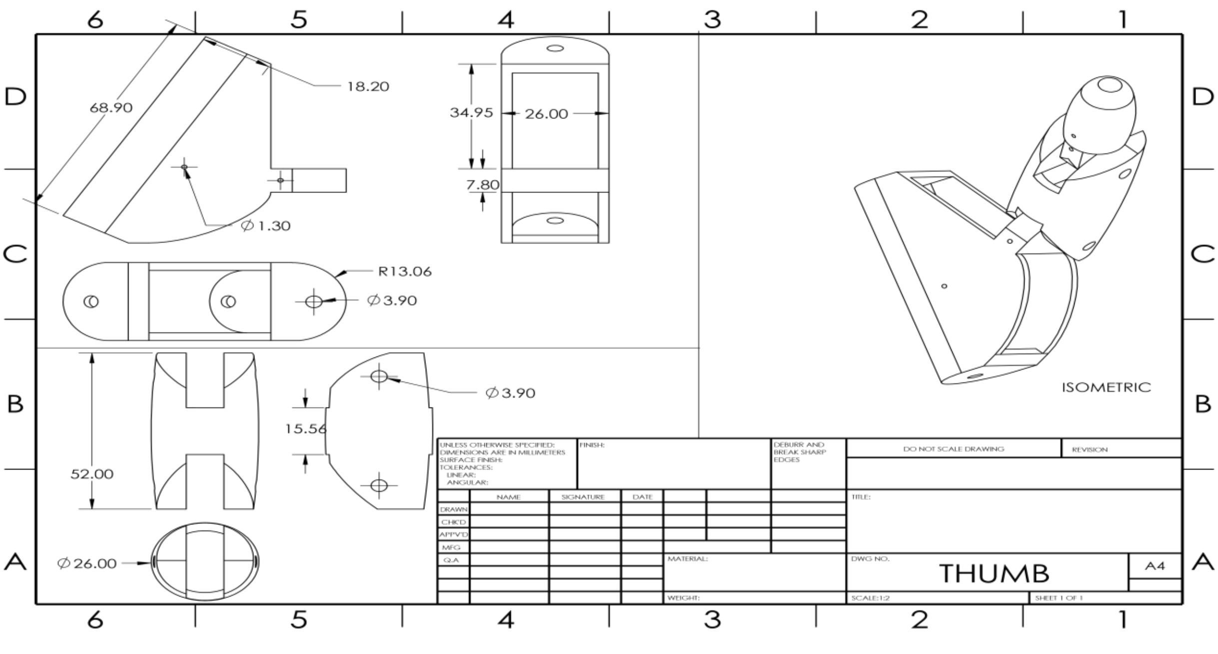

Fig. 10 Thumb Dimensions

The Dimensional view of the Parts has been done using SOLIDWORKS 2020 Software.

3.6 SECTIONAL VIEW OF PALM:

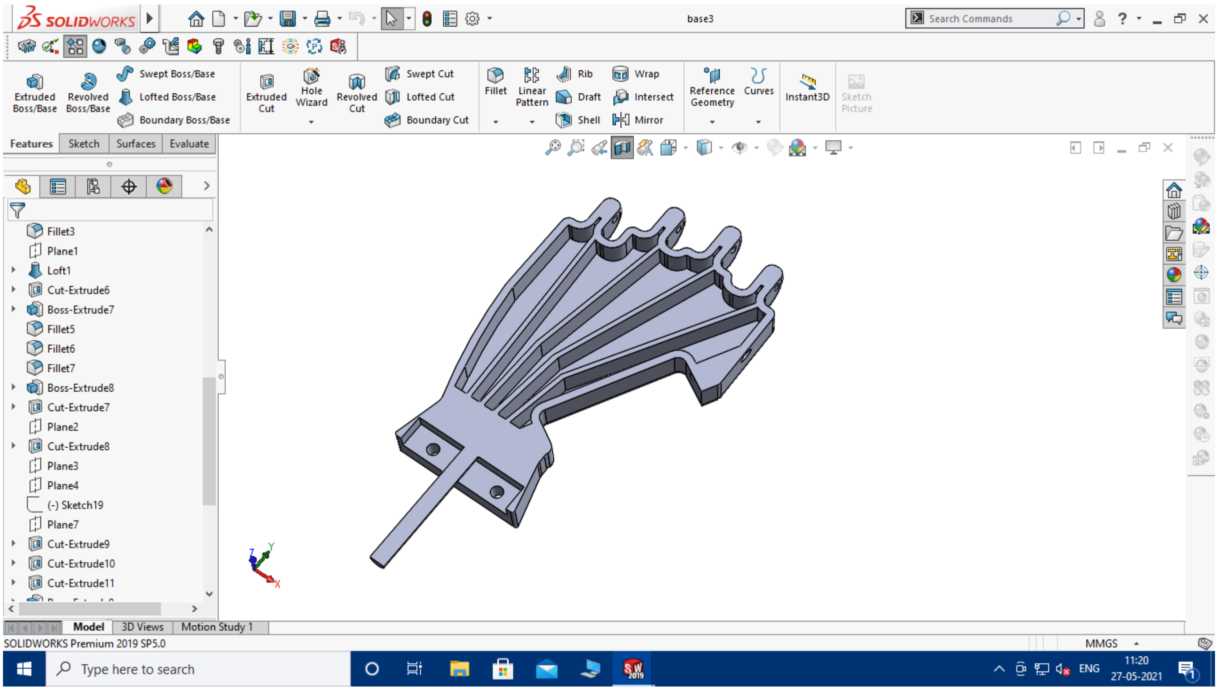

Fig. 11 Sectional view of Palm

As shown in the fig.2.2 the sectional view represents the gaps designed Purposely to make space for the Wiring and Connections that are to be provided to the Servo motors.

CHAPTER 4
PROJECT IMPLEMENTATION

4.1 HISTORY:

Robotics is one of the most researched fields in modern technology. Every year there has been an increase in the number of robots working for us in different fields from love to war. The research in this field of robotics is geared towards achieving a design and control algorithm that resembles the living organisms that exist in nature. In this endeavour, the human hand has proved to be the most intricate mechanisms that exist in nature. It consists of several bones, in a variety of sizes, which are required to act in unison to perform complex motions.

The first robotic hand was developed in the 1950s by a scientist named George Devil, Jr., before which robotics were largely the product of science fiction and the imagination. The development of robotics was slow for a while, with many of the most useful applications being involved with space exploration. The use of robots to aid in industrialization weren't fully realized until the 1980s, when robotic hand began to be integrated in automobile and other manufacturing assembly lines.

4.2 BACKGROUND RESEARCH:

There are many artificial hands in the market, some of which are faster and even stronger than the human hand. But in the broader spectrum of dexterous manipulation, sense, weight and even size, there hasn't been designed an artificial hand that can match the human hand. It is therefore natural for any researcher to take inspiration and build a hand that can achieve, though partially, such capabilities.

In this proposed project, the robotic hand system will work in a master- slave configuration. A master is a human operator that is used to control the slave (robotic hand). Both the master and the slave make use microcontrollers attached to Arduino Uno for signal processing, and ZIGBEE module for communication. The master will use flex sensors to monitor the movement of the fingers, while the slave will use servo motors to actuate individual fingers.

4.3 HARDWARE COMPONENTS SPECIFICATIONS:

Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button.

Fig. 12 Arduino UNO Board

Servo Motors

A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Fig. 13 Servo motor S90gs

3D Printed Hand

It is a mechanical hand made up of plastic. Separate parts of a hand like fingers, palm are 3d printed and joined together. In order to achieve movement in hand each finger in connected to a servo motor via a thread.

Fig. 14 3D Printed Hand

Zigbee

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low bandwidth needs, designed for small scale projects which need wireless connection. Hence, ZigBee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.

Fig. 15 Zigbee

Arduino NANO

Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a smallest, complete, and breadboard friendly. Physically, it is missing power jack. The Nano is automatically sense and switch to the higher potential source of power, there is no need for the power select jumper.

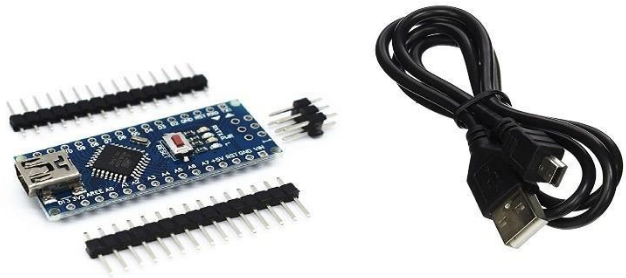

Fig. 16 Arduino Nano

Flex Sensors

A flex sensor or bend sensor is a sensor that measures the amount of deflection or bending. Usually, the sensor is stuck to the surface, and resistance of sensor element is varied by bending the surface. Since the resistance is directly proportional to the amount of bend it is used as goniometer, and often called flexible potentiometer.

Fig. 17 Flex Sensor

4.4 BLOCK DIAGRAM OF TRANMITTER AND RECIEVER:

4.4.1 Transmitter:

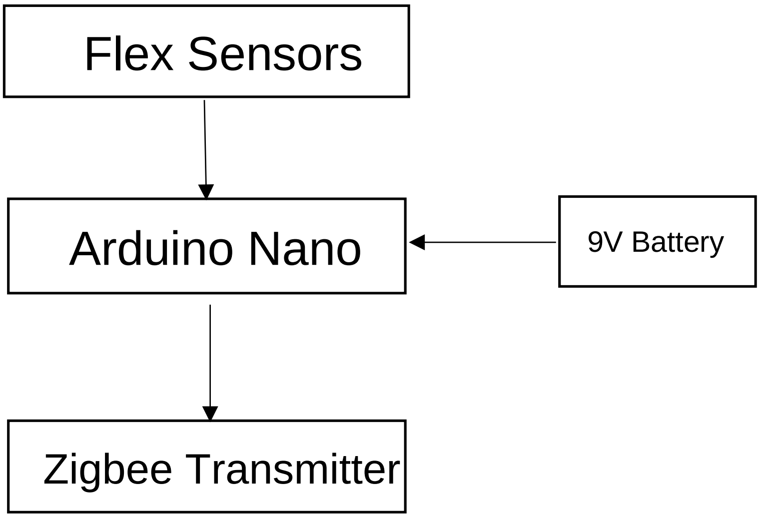

Fig. 18 Transmitter block diagram

The receiver portion of the project kit consists of various components. Arduino nano, 9v battery, flex sensors, glove and a Zigbee transmitter have been used. The data of movements of the flex sensors is given to Arduino nano. The data is basically in analog form.

4.4.2 Reciever:

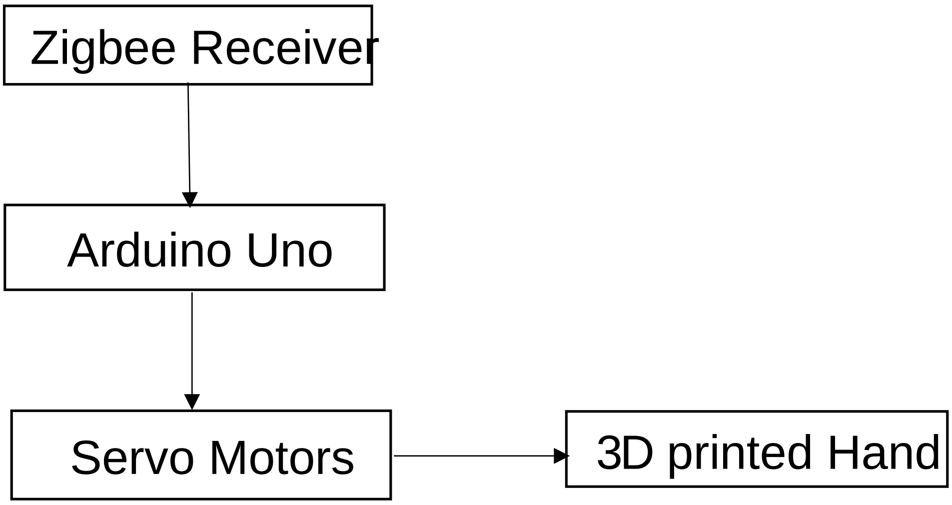

Fig. 19 Reciever block diagram

The receiver portion of the project kit consists of various components. Arduino nano, 9v battery, flex sensors, glove and a Zigbee transmitter have been used. The data of movements of the flex sensors is given to Arduino nano. The data is basically in analog form.

4.5 CONSTRUCTION OF SETUP:

4.5.1 Construction of Glove:

- To make the control glove we settled up first the right position of the different components, then connect everything with the proper length of wire.

- To make an analog read with Arduino Nano we made a voltage divider, since that flex sensors don't work like potentiometers (they have only 2 contacts).

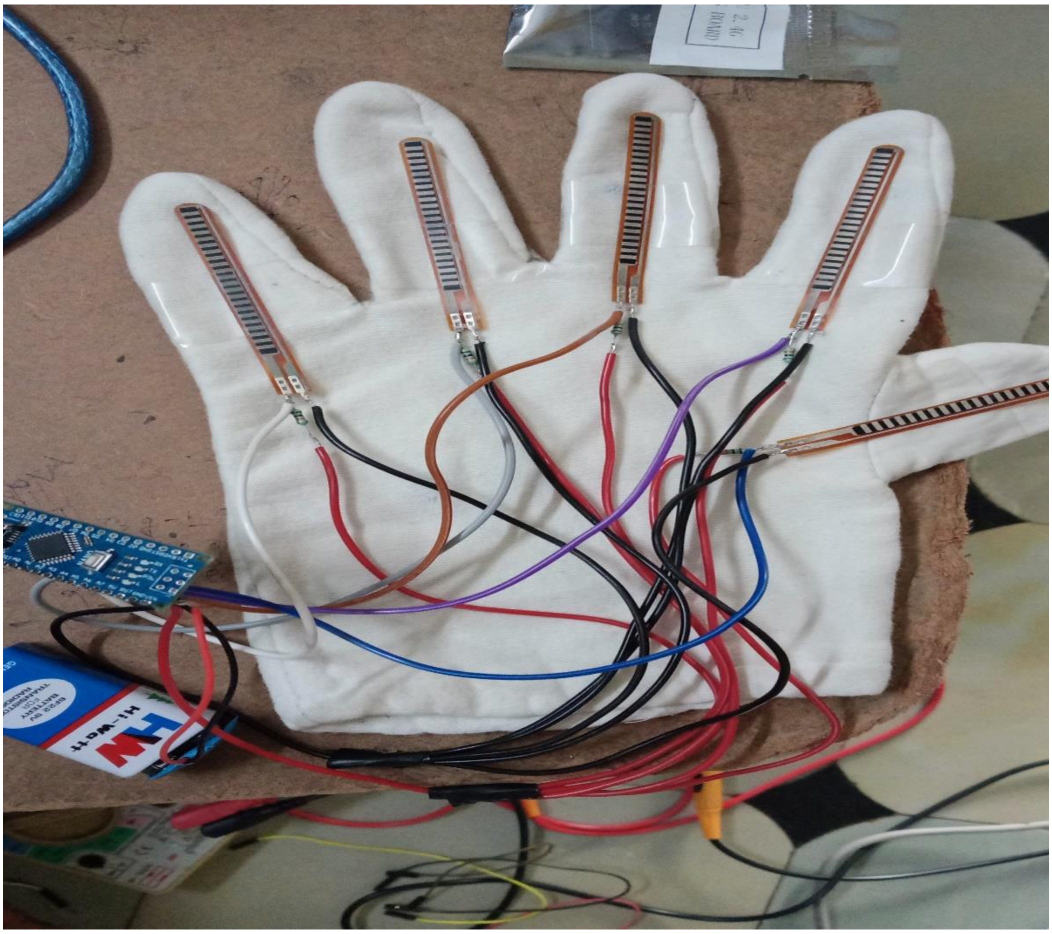

Fig. 20 Construction of Glove

By following the scheme, first we soldered 5 resistors on the Nano board, one side to the 5 different Analog pins, the other in common to the ground. Then the flex sensors are soldered, one side to the 5 different Analog pins and the other in common to the positive.

- Then connect the zigbee: two wires for the power, the other two for the signal. Solder the Tx pin to the Rx and vice versa.
- Now connect the battery pack, and the glove it's done.

4.5.2 Construction of 3D Printed Hand:

This is the most complicated part, because we had to choose the proper materials to make the hand, but we have opted to use a 3D printed hand.

Fig. 21 Assembly of Fingers

Fig. 22 Assembly of Palm

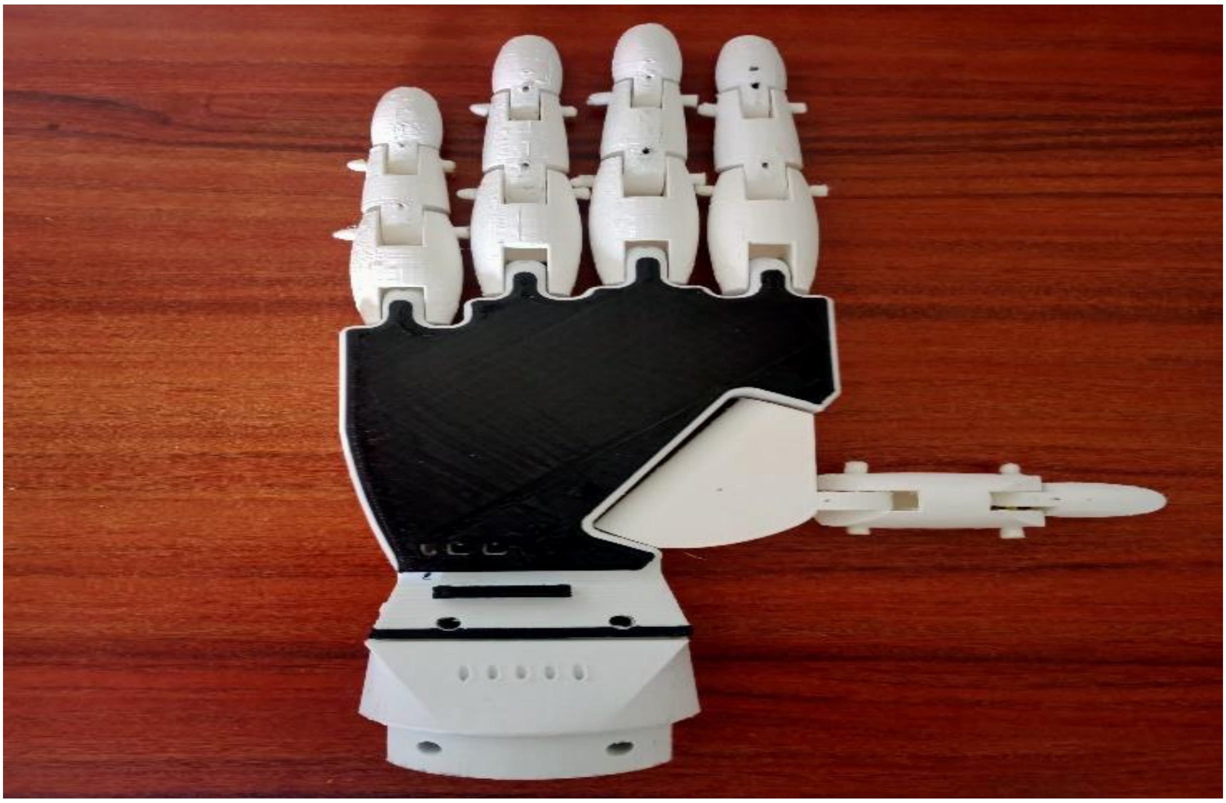

Fig. 23 Assembly of wrist and Palm

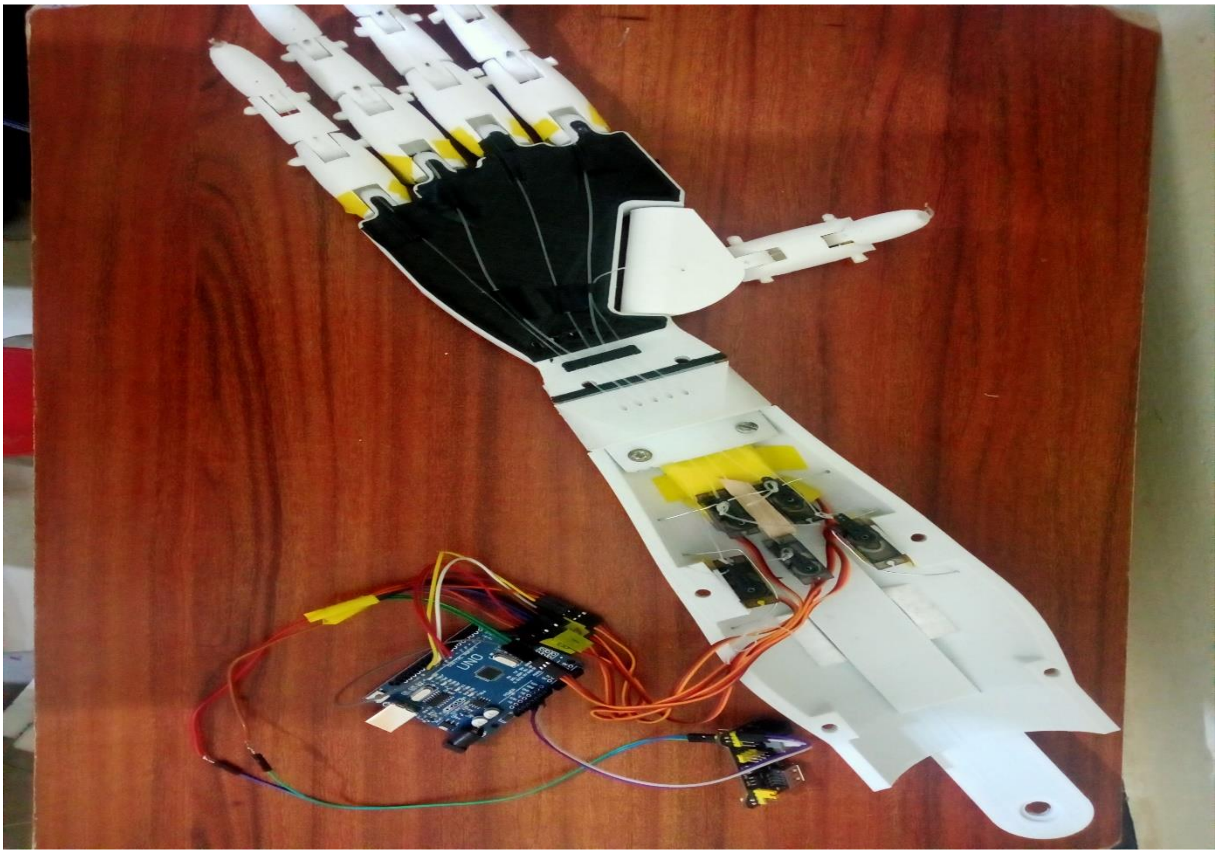

Fig. 24 Assembling of motors

4.6 HARDWARE WORKING AND PROGRAMMING

4.6.1 Power Supply

Description of Power Supply:

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

This power supply section is required to convert AC signal to DC signal and also to reduce the amplitude of the signal. The available voltage signal from the mains is 230V/50Hz which is an AC voltage, but the required is DC voltage (no frequency) with an amplitude of +5V and +12V for various applications.

In this section we have Transformer, Bridge rectifier, are connected serially and voltage regulators for +5V and +12V (7805 and 7812) via a capacitor (1000µF) in parallel are connected parallel as shown in the circuit diagram below. Each voltage regulator output is again is connected to the capacitors of values (100µF, 10µF, 1 µF, 0.1 µF) are connected parallel through which the corresponding output (+5V or +12V) are taken into consideration.

Power supplies can be broadly divided into linear and switching types. Linear power converters process the input power directly, with all active power conversion components operating in their linear operating regions. In switching power converters, the input power is converted to AC or to DC pulses before processing, by components that operate predominantly in non-linear modes.

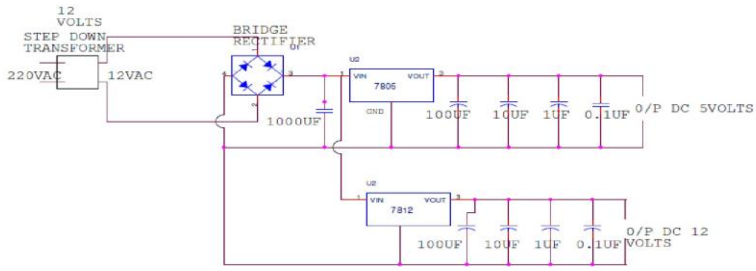

Fig. 25 Internal Circuit of power supply

4.6.2 Circuit Explanation

Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled electrical conductors. A changing current in the first circuit (the primary) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the secondary). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other.

The secondary induced voltage V_S, of an ideal transformer, is scaled from the primary V_P by a factor equal to the ratio of the number of turns of wire in their respective windings:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \qquad \text{-------------------------(1)}$$

Detailed Operation

The simplified description above neglects several practical factors, in particular the primary current required to establish a magnetic field in the core, and the contribution to the field due to current in the secondary circuit.

Models of an ideal transformer typically assume a core of negligible reluctance with two windings of zero resistance. When a voltage is applied to the primary winding, a small current flow, driving flux around the magnetic circuit of the core. The current required to create the flux is termed the magnetizing current since the ideal core has been assumed to have near-zero reluctance, the magnetizing current is negligible, although still required to create the magnetic field.

The changing magnetic field induces an electromotive force (EMF) across each winding. Since the ideal windings have no impedance, they have no associated voltage drop, and so the voltages V_P and V_S measured at the terminals of the transformer, are equal to the corresponding EMFs. The primary EMF, acting as it does in opposition to the primary voltage, is sometimes termed the "back EMF".

4.6.3 Bridge Rectifier

A diode bridge or bridge rectifier is an arrangement of four diodes in a bridge configuration that provides the same polarity of output voltage for any polarity of input voltage. When used in its most common application, for conversion of alternating current (AC) input into direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a center-tapped transformer design, but has two diode drops rather than one, thus exhibiting reduced efficiency over a centertapped design for the same output voltage.

Basic Operation

When the input connected at the left corner of the diamond is positive with respect to the one connected at the right-hand corner, current flows to the right along the upper colored path to the output, and returns to the input supply via the lower one.

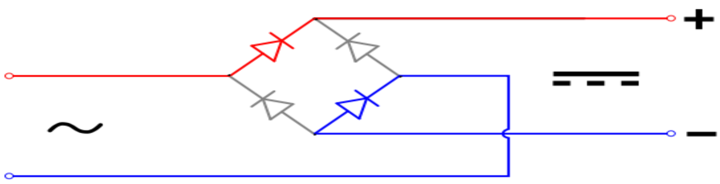

Fig 26: Current flows along upper coloured path

When the right-hand corner is positive relative to the left hand corner, current flows along the upper colored path and returns to the supply via the lower colored path.

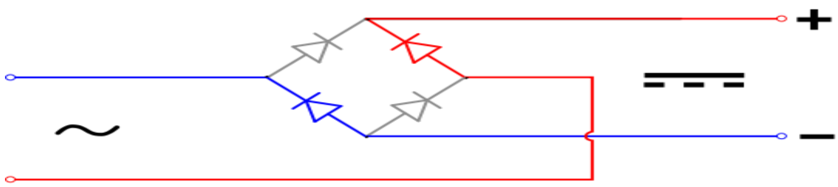

Fig 27: Current flowing along lower coloured path

In each case, the upper right output remains positive with respect to the lower right one. Since this is true whether the input is AC or DC, this circuit not only produces DC power when supplied with AC power: it also can provide what is sometimes called "reverse polarity protection". That is, it permits normal functioning when batteries are installed backwards or DC input-power supply wiring "has its wires crossed" (and protects the circuitry it powers against damage that might occur without this circuit in place).

Prior to the availability of integrated electronics, such a bridge rectifier was always constructed from discrete components. Since about 1950, a single four-terminal component containing the four diodes connected in the bridge configuration became a standard commercial component and is now available with various voltage and current ratings. For many applications, especially with single phase AC where the full-wave bridge serves to convert an AC input into a DC output, the addition of a capacitor may be important because the bridge alone supplies an output voltage of fixed polarity but pulsating magnitude (see diagram above).When input AC signal is applied across the bridge rectifier, during the positive half cycle diodes D_1 and D_3 are forward biased and allows electric current while the diodes D_2 and D_4 are reverse biased and blocks electric current. On the other hand, during the negative half cycle diodes D_2 and D_4 are forward biased and allows electric current while diodes D_1 and D_3 are reverse biased and blocks electric current. During the positive half cycle, the terminal A becomes positive while the terminal B becomes negative. This causes the diodes D_1 and D_3 forward biased and at the same time, it causes the diodes D_2 and D_4 reverse biased. Output can also be smoothed using a choke and second capacitor. The choke tends to keep the current (rather than the voltage) more constant. Due to the relatively high cost of an effective choke compared to a resistor and capacitor this is not employed in modern equipment.

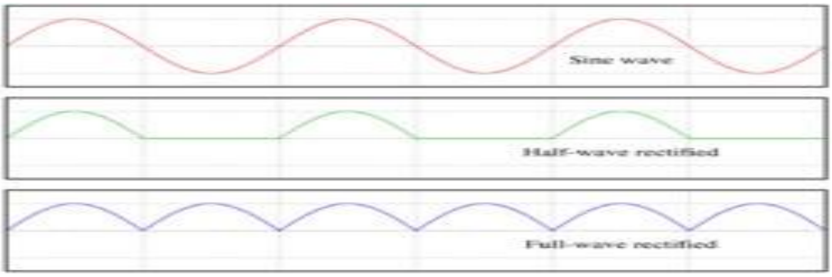

Fig 28: Output using Smoothing Capacitor

Because a breeder sets a minimum current drain, the regulation of the circuit, defined as percentage voltage change from minimum to maximum load, is improved. However, in many cases the improvement is of insignificant magnitude.

The capacitor and the load resistance have a typical time constant $\tau = RC$ where C and R the function of this capacitor, known as a reservoir capacitor (aka smoothing capacitor) is to lessen the variation in (or 'smooth') the rectified AC output voltage waveform from the bridge. One explanation of 'smoothing' is that the capacitor provides a low impedance path to the AC component of the output, reducing the AC voltage across, and AC current through the resistive load. In less technical terms, any drop in the output voltage and current of the bridge tends to be cancelled by loss of charge in the capacitor.

This charge flows out as additional current through the load. Thus, the change of load current and voltage is reduced relative to what would occur without the capacitor. Increases of voltage correspondingly store excess charge in the capacitor, thus moderating the change in output voltage / current. Also see rectifier output smoothing. The simplified circuit shown has a well-deserved reputation for being dangerous, because, in some applications, the capacitor can retain a *lethal* charge after the AC power source is removed. If supplying a dangerous voltage, a practical circuit should include a reliable way to safely discharge the capacitor. If the normal load cannot be guaranteed to perform this function, perhaps because it can be disconnected, the circuit should include a breeder resistor connected as close as practical across the capacitor. This resistor should consume a current large enough to discharge the capacitor in a reasonable time, but small enough to avoid unnecessary power waste.

In some designs, a series resistor at the load side of the capacitor is added. The smoothing can then be improved by adding additional stages of capacitor–resistor pairs, often done only for sub supplies to critical high-gain circuits that tend to be sensitive to supply voltage noise.

The idealized waveforms shown above are seen for both voltage and current when the load on the bridge is resistive. When the load includes a smoothing capacitor, both the voltage and the current waveforms will be greatly changed. While the voltage is smoothed, as described above, current will flow through the bridge only during the time when the input voltage is greater than the capacitor voltage. For example, if the load draws an average current of n Amps, and the diodes conduct for 10% of the time, the average diode current during conduction must be 10n Amps. This non-sinusoidal current leads to harmonic distortion and a poor power factor in the AC supply.

In a practical circuit, when a capacitor is directly connected to the output of a bridge, the bridge diodes must be sized to withstand the current surge that occurs when the power is turned on at the peak of the AC voltage and the capacitor is fully discharged. Sometimes a small series resistor is included before the capacitor to limit this current, though in most applications the power supply transformer's resistance is already sufficient.

Output can also be smoothed using a choke and second capacitor. The choke tends to keep the current (rather than the voltage) more constant. Due to the relatively high cost of an effective choke compared to a resistor and capacitor this is not employed in modern equipment.

Some early console radios created the speaker's constant field with the current from the high voltage ("B +") power supply, which was then routed to the consuming circuits, (permanent magnets were considered too weak for good performance) to create the speaker's constant magnetic field. The speaker field coil thus performed 2 jobs in one: it acted as a choke, filtering the power supply, and it produced the magnetic field to operate the speaker.

4.6.4 Voltage Regulator

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. The 78xx (also sometimes known as LM78xx) series of devices is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is a very popular choice for many electronic circuits which require a regulated power supply, due to their ease of use and relative cheapness. When specifying individual ICs within this family, the xx is replaced with a two-digit number, which indicates the output voltage the particular device is designed to provide. The 78xx line are positive voltage regulators, meaning that they are designed to produce a voltage that is positive relative to a common ground. There is a related line of 79xx devices which are complementary negative voltage regulators. 78xx and 79xx ICs can be used in combination to provide both positive and negative supply voltages in the same circuit, if necessary.

A simple voltage/current regulator can be made from a resistor in series with a diode (or series of diodes). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. When precise voltage control and efficiency are not important.

Internal Block Digram

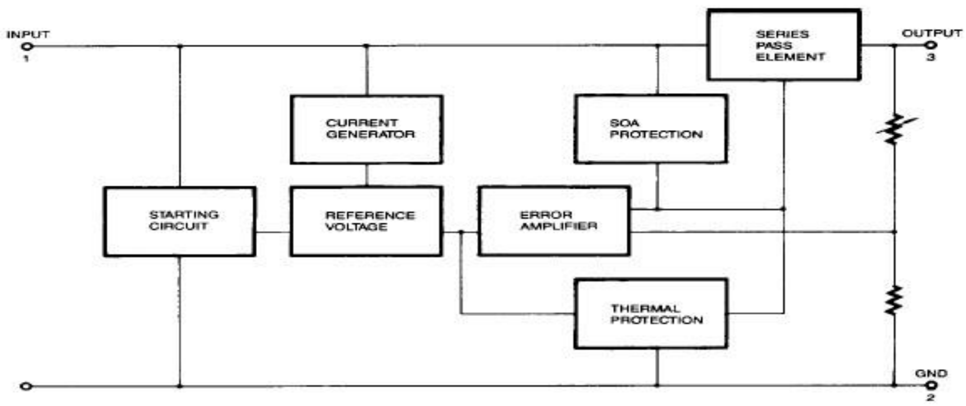

Fig 29: Internal Block Diagram of Voltage Regulator

4.7 MICROCONTROLLER (ARDUINO):

4.7.1 Introduction:

The Atmel ATmega328/P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328/P achieves throughputs close to 1MIPS per MHz. This empowers system designer to optimize the device for power consumption versus processing speed.

4.7.2 Description:

The Atmel AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in a single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ATmega328/P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6- channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run.

Atmel offers the Q Touch library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully de bounced reporting of touch keys and includes Adjacent Key Suppression technology for unambiguous detection of key events. The easy-to-use Q Touch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using Atmel's high-density non-volatile memory technology. The On chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega328/P is a powerful microcontroller that provides a highly flexible and cost-effective solution to many embedded control applications. The ATmega328/P is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, and Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

4.7.3 Configuration Summary:

Features	Atmega328/p
Pin count	28/32
Flash (bytes)	32k
SRAM (bytes)	2k
EEPROM (bytes)	1k

General purpose I/O lines	23
SPI	2
TWI(i2c)	1
USART	1
ADC	10 bit 15Ksps
ADC Channels	8
8-bit Timer counter	2
16 bit Timer counter	1

Table 2: Features of Arduino

4.7.4 Atmega 328 Architecture:

Basically, the processor of the Arduino board uses the Harvard architecture where the program code and program data have separate memory. It consists of two memories such as program memory and data memory. Wherein the data is stored in data memory and the code is stored in the flash program memory. The Atmega328 microcontroller has 32kb of flash memory, 2kb of SRAM 1kb of EPROM and operates with a 16MHz clock speed.

4.7.5 Atmega328 Pin Diagram:

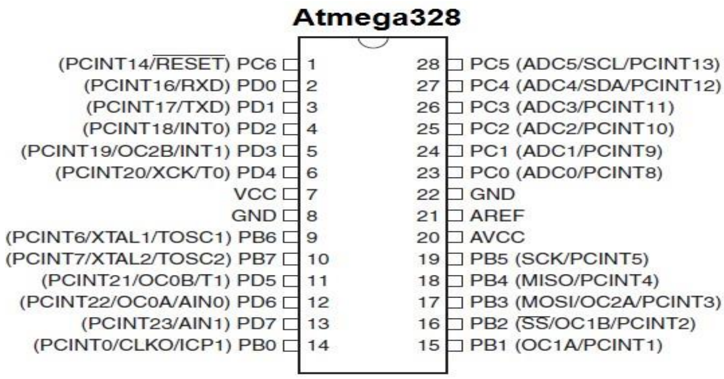

Fig 30: Pin Diagram of Atmega 328

Pin Category	**Pin Name**	**Details**
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/output Pins	Digital Pins 0 – 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Table 3 : Pin Description of Atmega 328

4.8 ARDUINO BOARD:

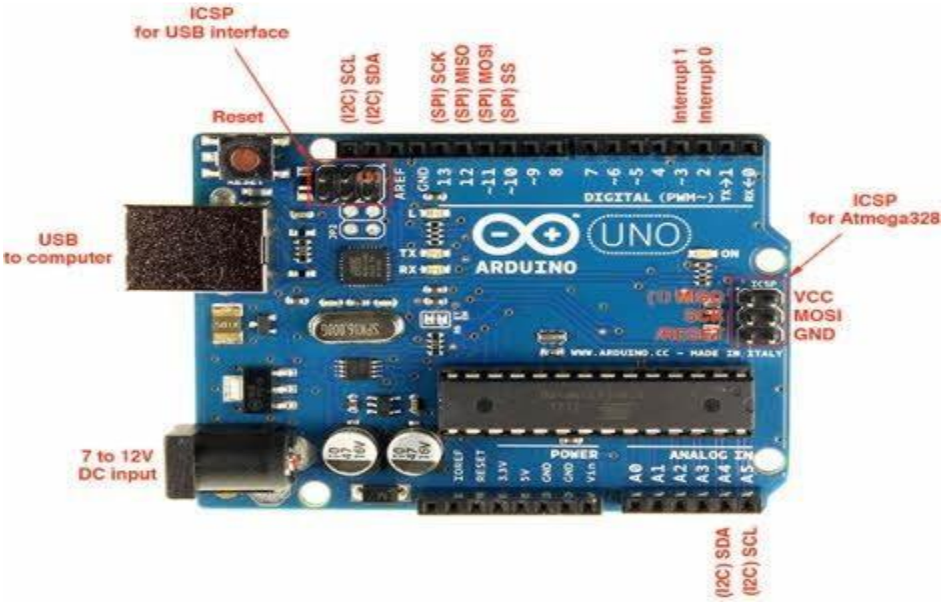

Fig 31: Arduino Board

An Arduino board is a one type of microcontroller-based kit. The first Arduino technology was developed in the year 2005 by David Cuartielles and Massimo Banzi. The designers thought to provide easy and low-cost board for students, hobbyists and professionals to build devices. Arduino board can be purchased from the seller or directly we can make at home using various basic components. The best examples of Arduino for beginners and hobbyists includes motor detectors and thermostats, and simple robots. In the year 2011, Adafruit industries expected that over 3lakhs Arduino boards had been produced. But, 7lakhs boards were in user's hands in the year 2013. Arduino technology is used in many operating devices like communication or controlling.

4.8.1 Arduino Technology:

Arduino is open source hardware. The hardware reference designs are distributed under a Creative commons Attribution Share-Alike 2.5 license and are available on the Arduino website. Layout and production files for some versions of the hardware are also available.

A typical example of the Arduino board is Arduino Uno. It includes an ATmega328 microcontroller and it has 28-pins.

The pin configuration of the Arduino Uno board consists of 14-digital I/O pins. Wherein 6 pins are used as pulse width modulation o/ps and 6 analog i/ps, a USB connection, a power jack, a 16MHz crystal oscillator, a reset button, and an ICSP header. Arduino board can be powered either from the personal computer through a USB or external source like a battery or an adaptor. This board can operate with an external supply of 7-12V by giving voltage reference through the IO Ref pin or through the pin VIN.

4.8.2 Digital Inputs:

It comprises of 14-digital I/O pins, each pin takes up and provides 40mA current. Some of the pins have special functions like pins 0 & 1, which acts as a transmitter and receiver respectively. For serial communication, pins-2 & 3 are external interrupts, 3, 5, 6,9,11 pins delivers PWM o/p and pin-13 is used to connect LED.

4.8.3 How to program an Arduino

The main advantage of the Arduino technology is you can directly load the programs into the device without the need of a hardware programmer to burn the program. This is done because of the presence of the 0.5KB of boot loader that allows the program to be dumped into the circuit. The Arduino tool window contains a toolbar with various buttons like new, open, verify, upload and serial monitor. And additionally, it comprises of a text editor (employed to write the code), a message space (displays the feedback) like showing the errors, the text console, that displays the o/p & a series of menus just like the file, tool menu & edit.

4.8.4 Arduino Program:

Programming into the Arduino board is called as sketches. Each sketch contains three parts such as Variables Declaration, Initialization and Control code. Where, Initialization is written in the setup function and Control code is written in the loop function.

The sketch is saved with .ino and any operation like opening a sketch, verifying and saving can be done using the tool menu.

The sketch must be stored in the sketchbook directory.

- Select the suitable board from the serial port numbers and tools menu.
- Select the tools menu and click on the upload button, then the boot loader uploads the code on the microcontroller.

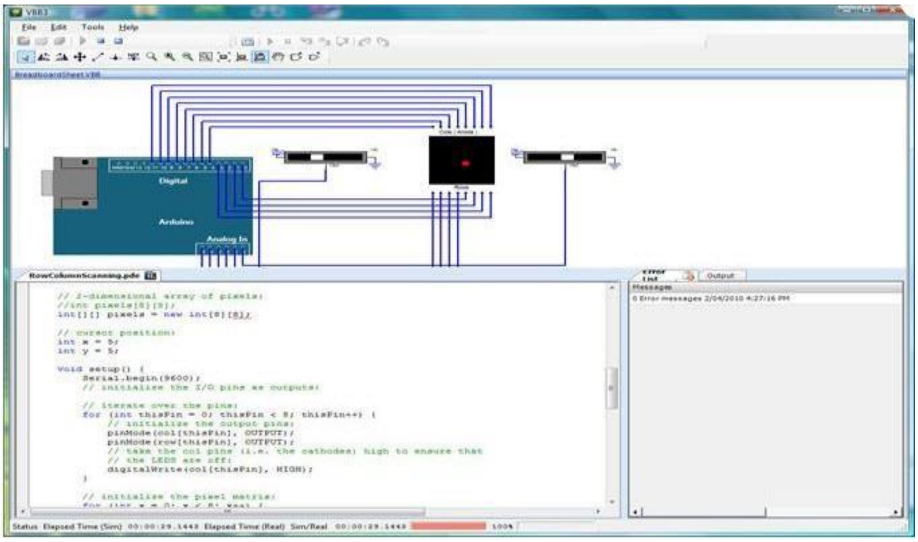

Fig.32: Programming an Arduino

4.8.5 Basic Functions of Arduino Technology:

- Digital read pin reads the digital value of the given pin.
- Digital write pin is used to write the digital value of the given pin.
- Pin mode pin is used to set the pin to I/O mode.
- Analog read pin reads and returns the value.
- Analog write pin writes the value of the pin.

- Serial. Begins pin sets the beginning of serial communication by setting the rate of bit.

4.8.6 Advantages of Arduino Technology:

- It is cheap
- It comes with an open supply hardware feature that permits users to develop their own kit
- The software of the Arduino is well-suited with all kinds of operating systems like Linux, Windows, and Macintosh, etc.

It also comes with open supply software system feature that permits tough software system developers to use the Arduino code to merge with the prevailing programing language libraries and may be extended and changed.

4.9 ARDUINO NANO:

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech.

4.9.1 Schematic and Design

Arduino Nano 3.0 (ATmega328): schematic, Eagle files.

Arduino Nano 2.3 (ATmega168): manual (pdf), Eagle files

Note: since the free version of Eagle does not handle more than 2 layers, and this version of the Nano is 4 layers, it is published here unrouted, so users can open and use it in the free version of Eagle.

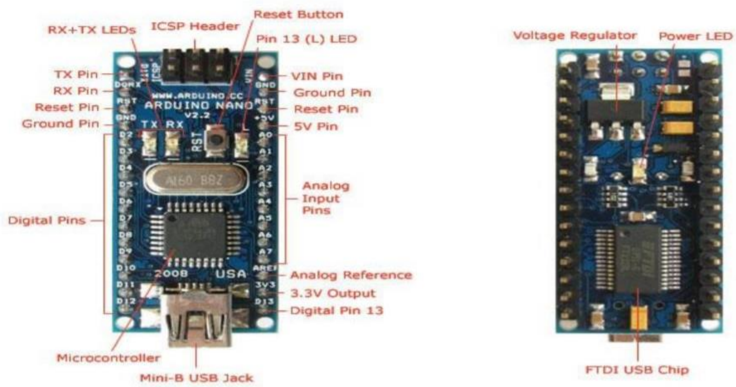

Fig: 33 Arduino Nano front and back chip.

Power :

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source. The FTDI FT232RL chip on the Nano is only powered if the board is being powered over USB. As a result, when running on external (nonUSB) power, the 3.3V output (which is supplied by the FTDI chip) is not available and the RX and TX LEDs will flicker if digital pins 0 or 1 are high.

Memory:

The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the bootloader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output:

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX): Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.

External Interrupts: 2 and 3:

These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt () function for details.

PWM: 3, 5, 6, 9, 10, and 11:

Provide 8-bit PWM output with the analogWrite () function.

SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK):

These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

LED: 13:

There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off. The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the analogReference () function.

Additionally, some pins have specialized functionality:

I2C:4(SDA) and 5(SCL):

Support I2C (TWI) communication using the Wire library (documentation on the Wiring website).

There are a couple of other pins on the board.

AREF:

Reference voltage for the analog inputs. Used with analogReference ().

Reset:

Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board. See also the mapping between Arduino pins and ATmega168 ports.

Communication:

The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A SoftwareSerial library allows for serial communication on any of the Nano's digital pins. The ATmega168 and ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details.

To use the SPI communication, please see the ATmega168 or ATmega328 datasheet.

4.9.2 Programming:

The Arduino Nano can be programmed with the Arduino software (download). Select "Arduino Diecimila, Duemilanove, or Nano w/ ATmega168" or "Arduino Duemilanove or Nano w/ ATmega328" from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials. The ATmega168 or ATmega328 on the Arduino Nano comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files). You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset:

Rather than requiring a physical press of the reset button before an upload, the Arduino Nano is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the FT232RL is connected to the reset line of the ATmega168 or ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well coordinated with the start of the upload. This setup has other implications. When the Nano is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Nano. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

4.10 ZigBee (IEEE 802.15.4)

The IEEE 802.15.4 normal may be an easy packet information protocol for light-weight wireless networks and specifies Medium Access management –MAC and the Physical-PHY layers for Multiple frequency –RF bands, together with 868 M.C., 915 MHz, and 2.4 GHz.

The IEEE 802.15.4 normal is intended to supply reliable information transmission of modest amounts of knowledge up to one hundred meters or additional whereas overwhelming little or no power. IEEE 802.15.4 is often but thirty-two K in size that includes a 64-bit address house, supply and destination.

ZigBee technology takes full advantage of the IEEE 802.15.4 normal and extends the capabilities of this new radio normal by shaping a versatile and secure network layer that supports a spread of architectures to supply extremely reliable wireless communications in harsh or dynamic RF environments.

ZigBee technology additionally offers simplicity and efficient approach to putting together, construction and re-modelling with wireless technology. ZigBee is ready to supply the customers with final flexibility, mobility, and easy use by building wireless intelligence a nd capabilities into daily devices.

ZigBee is predicted to supply low value and low power property for instrumentality that wants battery life as long as many months too many years however don't need information transfer rates as high as those enabled by Bluetooth. This type of network eliminates use of physical local area network cables. The devices might embrace telephones, hand-held digital assistants, sensors and controls settled at intervals a number of meters of every alternative.

4.10.1 ZigBee Alliance:

The ZigBee Alliance is associate degree association of corporations operating along to modify reliable, cost-effective, low-power, wirelessly networked; observance associate degree management merchandise supported an open international normal. The goal of the ZigBee Alliance is to supply the patron with final flexibility, mobility, and easy use by building wireless intelligence and capabilities into daily devices. ZigBee technology are going to be embedded in a very wide selection of merchandise and applications across shopper, commercial, industrial and government markets worldwide. For the primary time, corporations can have a standards-based wireless platform optimized for the distinctive wants of remote observance and management applications, together with simplicity, responsible inexpensive and low-power.

4.10.2 Applications:

- 2.4 Gig cycle per second IEEE 802.15.4 systems
- ZigBee systems

- Home/building automation
- Industrial management
- Wireless sensing element networks
- Computer peripherals

4.10.3 Key Features:

- True single-chip a pair of.4 gig cycle per second IEEE 802.15.4 compliant RF transceiver with baseband electronic equipment and waterproof support
- DSSS baseband electronic equipment with 2MChips/s and 250 kbps effective rate.
- Appropriate for each RFD and FFD operation
- Low current consumption (RX: eighteen.8mA, TX: 17.4 mA)
- Low offer voltage (2.1 – 3.6 V) with integrated transformer
- Low offer voltage (1.6 – 2.0 V) with external transformer
- Programmable output power
- No external RF switch / filter required
- Only a few external parts
- 128(RX) + 128(TX) computer memory unit information buffering
- Digital RSSI / LQI support
- Hardware waterproof secret writing (AES-128)
- Battery monitor
- QLP-48 package, 7x7 mm
- Powerful and versatile development tools on the market

4.10.4 ZigBee features:

The emphasis of network applications underneath the IEEE 802.15.4 / ZigBee normal embrace the options of low power consumption, required for under 2 major modes (TX/Rx or Sleep), high density of nodes per network, low prices and easy implementation. These options area unit enabled by the subsequent characteristics 2.4GHz and 868/915 Mc twin PHY modes.

This represents 3 license-free bands: a pair of.4-2.4835 GHz, 868-870 Mc and 902-928 Mc the amount of channels assigned to every waveband is mounted at sixteen channels within the a pair of.45 giga cycle per second band, ten channels within the 915 Mc band, and one channel within the 868 Mc band

- Allocated sixteen bit short or sixty-four-bit extended addresses.
- Allocation of bonded time slots (GTSs)
- Low power consumption with battery life starting from months to years.
- Energy detection (ED).

4.10.5 Device Types:

ZigBee devices area unit needed to adapt to the IEEE 802.15.4-2003 Low-Rate Wireless Personal Space Network (WPAN) normal. ZigBee wireless devices area unit expected to transmit 10-75 meters, reckoning on the RF atmosphere and therefore the power output consumption needed for a given application, and can operate within the unauthorized RF worldwide (2.4GHz international, 915MHz Americas or 868 Mc Europe).

There are a unit 3 completely different ZigBee device sorts that treat these layers in any self-organizing application network. These devices have 64-bit IEEE addresses, with choice to modify shorter addresses to cut back packet size, and add either of 2 addressing modes – star and peer-toper.

•The ZigBee (PAN) organizer node: the foremost capable device, the organizer forms the basis of the network tree and would possibly bridge to alternative networks. It's ready to store data regarding the network. There's one, and only 1, ZigBee organizer in every network to act because the router to alternative network. It additionally acts because the repository for security keys.

•The Full operate Device (FFD): The FFD is associate degree treated router transmittal information from alternative devices. It wants lesser memory than the ZigBee organizer node, and entails lesser producing prices. It will operate altogether topologies and may act as an organizer.

•The Reduced operate Device (RFD): This device is simply capable of talking within the network; it cannot relay information from alternative devices. Requiring even less memory, (no flash, little or no read-only storage and RAM), associate degree RFD can so be cheaper than associate degree FFD. This device talks solely to a network organizer and may be enforced terribly merely in network topology. Associate degree FFD will refer to RFDs or alternative FFDs, whereas associate degree RFD will speak solely to associate degree FFD. Associate degree RFD is meant for applications that area unit very simple, like a lightweight switch or a passive infrared sensor; they are doing not have the necessity to send giant amounts of knowledge and will solely go with one FFD at a time. Consequently, the RFD is enforced victimization negligible resources and memory capability.

4.11 FLEX SENSORS:

Flex sensors are usually available in two sizes. One is 2.2 inch and another is 4.5 inch. Although the sizes are different the basic function remains the same. They are also divided based on resistance. There are LOW resistance, MEDIUM resistance and HIGH resistance types. Choose the appropriate type depending on requirement. Here we are going to discuss 2.2inch Flex sensor that is FS-L-0055.

FLEX SENSOR function

FLEX SENSOR terminal resistance changes when it is bent.

4.11.1 FLEX SENSOR Pin Configuration

Flex sensor is a two-terminal device. The Flex sensor does not have polarized terminals like diode.

So, there is no positive and negative.

Pin Number	Description
P1	Usually connected to positive of power source.
P2	Usually connected to ground.

Table: 4 pin connections of flex sensor.

4.11.2 FLEX SENSOR Features and Specifications

- Operating voltage of FLEX SENSOR: 0-5V
- Can operate on LOW voltages
- Power rating: 0.5Watt (continuous), 1 Watt (peak)
- Life: 1 million
- Operating temperature: -45ºC to +80ºC
- Flat Resistance: 25K Ω
- Resistance Tolerance: ±30%
- Bend Resistance Range: 45K to 125K Ohms (depending on bend)

4.11.3 Where to Use FLEX SENSOR

For understanding the use of FLEX SENSOR consider:

Case1: Where you want to check whether the surface of a device or thing is leveled or not. Say you want a device to check whether a window or door is open or not. At that time a Flex sensor could be used. The sensor could be fixed at door edge and when the door opens the Flex sensor gets flexed. With the sensor being flexed its parameters changes which could be designed to provide an alert.

Case2: Where you want to measure the FLEX or BENT or ANGLE change of any instrument or device. The FLEX SENSOR internal resistance changes almost linearly with its flex angle. So by sticking the sensor to the instrument we can have the flex angle in electrical parameter of resistance.

4.11.4 How to Use FLEX SENSOR

As mentioned earlier, FLEX SENSOR is basically a VARIABLE RESISTOR whose terminal resistance increases when the sensor is bent. So, this sensor resistance increases depends on surface linearity. So, it is usually used to sense the changes in linearity.

Fig: 34 bending angles of flex sensors

As shown above figure, when the surface of FLEX SENSOR is completely linear it will be having its nominal resistance. When it is bent 45º angle the FLEX SENSOR resistance increases to twice as before. And when the bent is 90º the resistance could go as high as four times the nominal resistance. So the resistance across the terminals rises linearly with bent angle. So in a sense the FLEX sensor converts flex angle to RESISTANCE parameter.

For convenience we convert this RESISTANCE parameter to VOLTAGE parameter. For that we are going to use VOLTAGE DIVIDER circuit. A typical VOLTAGE DIVIDER circuit is shown below.

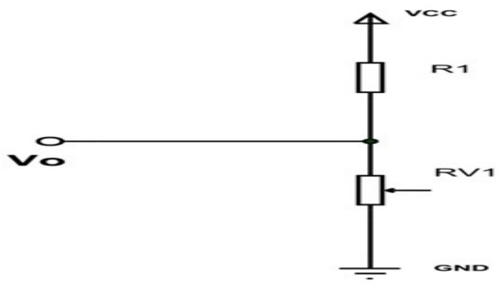

Fig: 35 Voltage divider circuit

In this resistive network we have two resistances. One is constant resistance (R1) and other is variable resistance (RV1). Vo is the voltage at midpoint of VOLTAGE DIVIDER circuit and is also the output voltage. Vo is also the voltage across the variable resistance (RV1). So, when the resistance value of RV1 is changed the output voltage Vo also changes. So, we will have resistance change in voltage change with VOLTAGE DIVIDER circuit.

Here we will replace the variable resistance (RV1) with FLEX SENSOR. The circuit will be as below.

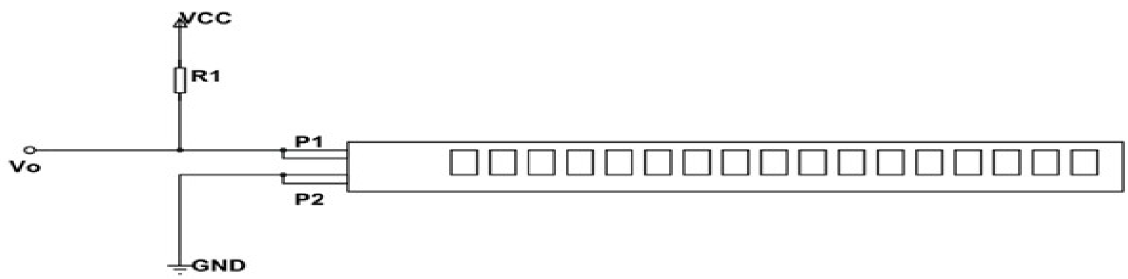

Fig: 36 Flex sensor

As shown in figure, R1 here is a constant resistance and FLEX SENSOR which acts as a variable resistance. Vo being output voltage and also the voltage across the FLEX SENSOR. Here,

Vo=VCC (Rx/ (R1+Rx)) ----------------------------- (12)

Rx - FLEX SENSOR resistance

Now, when the FLEX SENSOR is bent the terminal resistance increases. This increase also appears in VOLTAGE DIVIDER circuit. With that the drop across the FLEX SENSOR increases so is Vo. So, with increase in bent of FLEX sensor Vo voltage increases linearly. With that we have VOLTAGE parameter representing the flex. We can take this VOLTAGE parameter and feed it to ADC to get the digital value which can be used conveniently.

4.11.5 Applications

- Robotics
- Gaming (Virtual Motion)
- Medical Devices
- Computer Peripherals
- Musical Instruments
- Physical Therapy

4.11.6 2D-Model

Measurements in millimetre (inches)

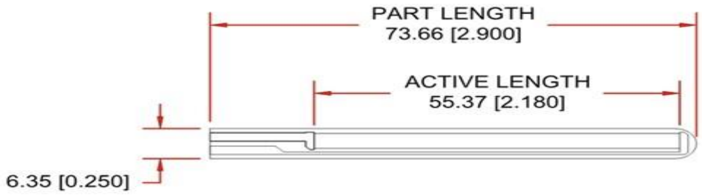

Fig: 37 2D diagram of flex sensor.

4.12 MG90 SERVO MOTOR:

MG90S is a micro servo motor with metal gear. This small and lightweight servo comes with high output power, thus ideal for RC Airplane, Quadcopter or Robotic Arms.

4.12.1MG90S Wiring Description

.

Wire Number	**Wire Colour**	**Description**
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

Table:5 Wiring pins description

4.12.2 Tower Pro MG-90S Features

- Operating Voltage: 4.8V to 6V (Typically 5V)
- Stall Torque: 1.8 kg/cm (4.8V)
- Max Stall Torque: 2.2 kg/cm (6V)
- Operating speed is 0.1s/60° (4.8V)
- Gear Type: Metal
- Rotation: 0°-180°
- Weight of motor: 13.4gm
- Package includes gear horns and screws

4.12.3 Alternative Servo Motors

SG90S Plastic Gear, MG995 High Torque Metal Gear, VTS-08A Analog Servo

Selecting your Servo Motor

There are lots of servo motors available in the market and each one has its own specialty and applications. The following two paragraphs will help you identify the right type of servo motor for your project/system. Most of the hobby Servo motors operates from 4.8V to 6.5V, the higher the voltage higher the torque we can achieve, but most commonly they are operated at +5V. Almost all hobby servo motors can rotate only from 0° to 180° due to their gear arrangement so make sure your project can live with the half circle. If no, you can prefer for a 0° to 360° motor or modify the motor to make a full circle. The gears in the motors are easily subjected to wear and tear, so if your application requires stronger and long running motors you can go with metal gears or just stick with normal plastic gear.

Next comes the most important parameter, which is the torque at which the motor operates. Again, there are many choices here but the one here is the 2.2kg/cm torque which comes with the MG90 Motor. This 2.2kg/cm torque means that the motor can pull a weight of 2.2kg when it is suspended at a distance of 1cm. So, if you suspend the load at 0.5cm then the motor can pull a load of 4.4kg. Based on the load which you use in the project you can select the motor with proper torque. The below picture will illustrate the same.

4.12.4 How to use a Servo Motor

After selecting the right Servo motor for the project, comes the question how to use it. As we know there are three wires coming out of this motor. The description of the same is given on top of this page. To make this motor rotate, we have to power the motor with +5V using the Red and Brown wire and send PWM signals to the Orange colour wire. Hence we need something that could generate PWM signals to make this motor work, this something could be anything like a 555 Timer or other Microcontroller platforms like Arduino, PIC, ARM or even a microprocessor like Raspberry Pie. Now, how to control the direction of the motor? To understand that let us a look at the picture given in the MG-90S datasheet. From the picture we can understand that the PWM signal produced should have a frequency of 50Hz that is the PWM period should be 20ms. Out of which the On-Time can vary from 1ms to 2ms. So, when the on-time is 1ms the motor will be in 0° and when 1.5ms the motor will be 90°, similarly when it is 2ms it will be 180°. So, by varying the on-time from 1ms to 2ms the motor can be controlled from 0° to 180° .

4.12.5 Applications

- Used as actuators in many robots like Biped Robot, Hexapod, robotic arm etc...
- Commonly used for steering system in RC toys
- Robots where position control is required without feedback
- Less weight hence used in multi DOF robots like humanoid robots.

4.13 ELECTRONIC CONNECTIONS

Connect the servo to the respective Arduino Uno Pins.

Servo	Servo Wire	Arduino Pin	Breadboard Pin
Thumb	Brown	GND*	Ground Rail
Thumb	Red	5V*	Power Rail
Thumb	Orange	2	–
Index	Brown	–	Ground Rail
Index	Red	–	Power Rail
Index	Orange	3	–
Middle	Brown	–	Ground Rail
Middle	Red	–	Power Rail
Middle	Orange	4	–
Ring	Brown	–	Ground Rail
Ring	Red	–	Power Rail
Ring	Orange	5	–
Pink	Brown	–	Ground Rail
Pink	Orange	6	–

Table: 6 Connections of the servomotors

CHAPTER 5

PROJECT OUTPUT

5.0 Result

5.1 Hardware outputs:

This project ‘Robotic arm using wireless gesture control’ results in a working mechanical hand which can be controlled by user’s hand gesture. As shown in the below figure the transmitter glove made up of flex sensors, Arduino and Zigbee is worn by the user. As the user moves his/her fingers the value of resistance is changed in the flex sensors these values are transmitted for every second

Representing the posture of user’s hand at that moment. In this way wireless communication has been achieved successfully.

Now, the transmitted data of the flex sensor is received by the ZigBee receiver which is connected to the mechanical arm along with Arduino and servo motors. This data is read by the microcontroller and according the program that has been dumped in it the respective servo motors starts rotating. This movement of servo motors is in sync with the gesture movements of the control glove worn by the user which results in a robotic hand that can be controlled wireless by hand gestures.

Thus, it was observed that after bending the single flex sensor at the transmitter side, the corresponding robotic finger moved in the same manner and same angle. Servo motor causes the movement of a robotic finger. With reference to this, all five servo motors moved (or controlled) by five flex sensors on a single control glove. In this way, a wireless communication has been achieved successfully. So, now it is possible that a man can control a robotic hand from a distance wirelessly.

5.2 Applications of Robotic hand using wireless gesture control:

- For use in Chemical industries for safety point of view to human hand.
- As a part of Humanoid robot to perform various tasks.

- In medical field for physically challenged patients.
- For Military use in bomb diffusing.
- For use in Robots that help deaf and dumb in chatting with sign language.

5.3 Disadvantages:

- It is difficult to construct a hand which is capable of executing similar muscle movements as a real human hand.
- Here we used a ZigBee for wireless data transmitting which has a limited range of 70m (approximately). This can be overcome by using RF module instead.

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

6.1 CONCLUSION

This project presents a wireless animatronic hand which is implemented by using a latest wireless technology. It can be widely used where there are restrictions or a hazard to a human hand. It is basically a futuristic project which will be used to make Humanoid (Human like robots). Future efforts will be made to make this hand movable (from one place to another), more flexible and more precise if possible. The proposed of the prosthetic hand is light weight. The servo motors as actuator give the hand lightweight structure and low-cost prosthetic hand. This hand can be used as prosthetic hand for trans-radial prosthesis because of its size.

6.2 FUTURE ENHANCEMENT

Digital camera can be placed on the robotic hand which will record the motions of a hand if a robotic hand is at a long distance. Besides increasing the functions and stability of the hand rehabilitation device, a virtual environment could be developed to increase the interactivity of the stroke patient and the rehabilitation device. It can also crease fun for the patient and increase the rehabilitation efficiency potentially. We will work on this project in future and make it accessible for all those needy and disabled persons who cannot afford costly Robotic Hand/Arm. Further robotic hand will be made for dangerous things when it will be wireless and can be used from far places without hindrance. Now, Sensors are used for moving fingers afterwards we will make it auto for all those works which need not variable instructions. Another form of this hand will be access from software wirelessly without sensors which will reduce cost as well.

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[8] X-CTU user's guide:

http://ftp1.digi.com/support/documentation/90001003_A.pdf

APPENDIX

Transmitter Code:

```
int fing1 = A0; int fing2 = A1; int fing3 = A2; int fing4 = A3; int fing5 = A4;



float value1,value2,value3,value4,value5;



void setup(){

  Serial.begin(9600);       //Begin serial communication

}



void loop(){    value1 = analogRead(fing1);    value2 = analogRead(fing2);    value3 = analogRead(fing3);   value4 = analogRead(fing4);   value5 = analogRead(fing5);




    Serial.print("1:");Serial.println(value1);

    Serial.print("2:");  Serial.println(value2);

    Serial.print("3:");  Serial.println(value3);

    Serial.print("4:");  Serial.println(value4);

    Serial.print("5:");  Serial.println(value5);

    Serial.println();
```

```
if(value1 > 1020) ///////////////thumb

{

 Serial.println("a");          delay(500);

  }

 if(value1 < 1020)

{

 Serial.println("b");          delay(500);

  }         if(value2 > 971)  /////////////////point

{

  Serial.println("c");          delay(500);

  }

if(value2 < 971)

{

  Serial.println("d");          delay(500);

  }

if(value3 > 1016)  /////////////middle

{

 Serial.println("e");           delay(500);

  }

if(value3 < 1016)

{
```

```
 Serial.println("f");            delay(500);

  }

 if(value4 > 1000)  //////////////4 fing

 {

  Serial.println("g");

   delay(500);

  }

 if(value4 < 1000)

 {

  Serial.println("h");            delay(500);              }         if(value5 < 990)//////////////little

 {

  Serial.println("i");           delay(500);

 }

 if(value5 < 1020)

 {

  Serial.println("j");           delay(500);

 }

Serial.println();   delay(2000);

}
```

Receiver program:

```
#include <Servo.h>

#define S1 9

#define S2 10

#define S3 11

#define S4 12   #define S5 13   int x; //String result;

Servo servo1;

Servo servo2;

Servo servo3;

Servo servo4;

Servo servo5;



void setup(){

Serial.begin(9600);

zigbee.begin(9600);

servo1.attach(S1);

servo2.attach(S2);

servo3.attach(S3);   servo4.attach(S4);

 servo5.attach(S5);

delay(2000);

 servo1.write(0);
```

```
 servo2.write(180);

 servo3.write(180);

 servo4.write(180);

servo5.write(0);

}


void loop() {

  delay(100);

 if(zigbee.available()>0)

     {

char result=zigbee.read();

Serial.println(result);

  if(result == 'a') ////////////////thumb

        {

          Serial.println("thumb open");

servo1.write(0);delay(200);

         }        if(result == 'b') //thumb

        {

 Serial.println("thumb close");

servo1.write(180);delay(200);

         }
```

```
          if(result == 'c') /////////////////point
      {
        Serial.println("point close");
 servo2.write(180);delay(200);
       }        if(result == 'd')
      {
        Serial.println("point open");
servo2.write(0);delay(200);
       }

     if(result == 'e') ////////////middle
      {
        Serial.println("middle open");
servo3.write(180);delay(200);
       }        if(result == 'f')
      {
        Serial.println("middle close");
 servo3.write(0);delay(200);
       }
```

```
      if(result == 'g') ////////////////4th
       {
         Serial.println("4th open");
 servo4.write(180);delay(200);
        }       if(result == 'h')
       {
         Serial.println("4th close");
servo4.write(0);delay(200);
        }      if(result == 'i') //////////little
       {
         Serial.println("little open");
 servo5.write(0);delay(200);
        }       if(result == 'j')
       {
         Serial.println("little close");
  servo5.write(180);delay(200);
        }


    }
}
```