MODELING AND THERMAL ANALYSIS OF 3D PRINTER EXTRUDER IN FUSED DEPOSITION

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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.

I.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.

Planetary Gear

Figure 1: Planetary Gear

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.

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.

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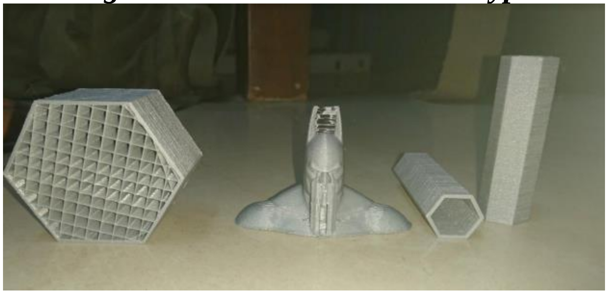
Domestic Use

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 2: Cranium Bone Prototype



II.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 modeling) 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 .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.

III. DESIGN & DEVELOPMENT

3.1 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.

3.2 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

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.

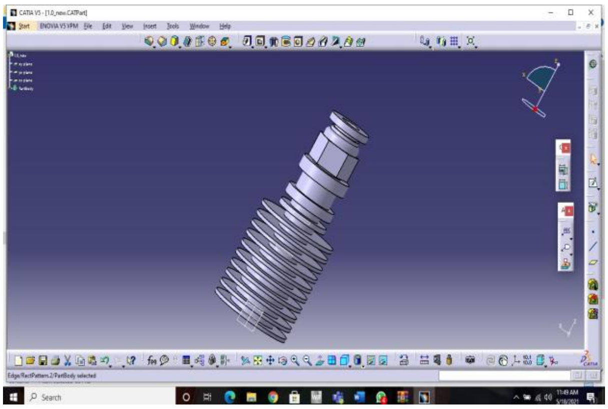
Ship building:

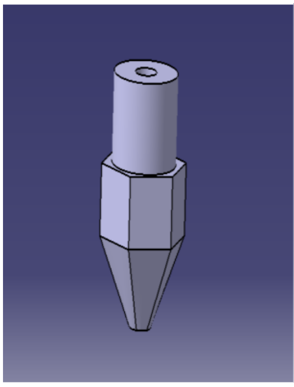
Dassault Systems has started serving shipbuilders with CATIA V5 discharge 8, which incorporates exceptional components valuable to shipbuilders. GD Electric Boat utilized CATIA to plan the most recent quick assault submarine class for the United States Navy, the Virginia class. Northrop Grumman Newport News likewise utilized CATIA to plan the Gerald. Portage class of super bearers for the US Navy.

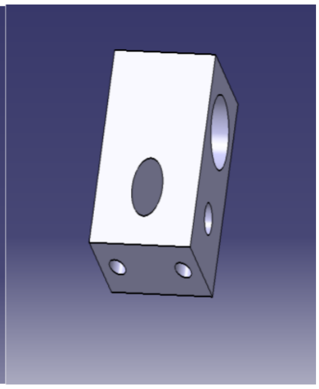
Industrial Equipment:

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.

3.3 Design of 3D printer extruder with fins:







IV.IMPLIMENTATION OF ELEMENT

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: $SN=1/2*R2*N*\sin(2\prod/N) \rightarrow \prod R2$ as $N\rightarrow\infty$. 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.

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 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 out.

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 4th 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. 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.

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 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.

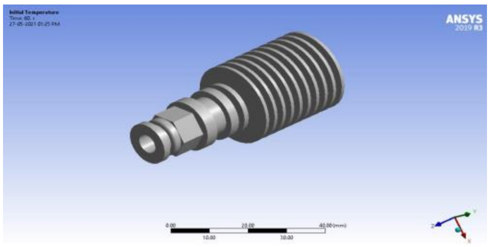
Review The Results:

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

Analysis of the extruder using ANSYS:

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.



V.CONCLUSION AND FUTURE SCOPE

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.
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.

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