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INVESTIGATION OF FRICTION STIR WELDING OF DISSIMILAR MATERIALS

[1*] Dhanaraj Savary Nasan, [2] Jilalla Kumar & [3]Nagamani Lingala.

[1,2,3] Department of Mechanical Engineering, St. Martin's Engineering College ,Dhulapally, Secunderabad, India – 500100.

Abstract

In many fields, such as the aerospace industry, acquiring high-quality weld is considered challenging with conventional joining techniques. This issue appears for some materials, especially those that have low melting temperature.

Friction stir welding (FSW) is counted as one of the most significant developments in welding techniques. FSW process is an innovative solid-state joining technique which is also an environmentally friendly technique. The process involves versatility and energy efficiency used to generate a good collection of mechanical properties. FSW processes were first applied on aluminium alloys because of their low melting temperatures and were found to be an effective technique.

The objective of the current work is to develop a model to form the aluminium weldments of AA 5052 & AA 6061 to investigate the mechanical properties of the weldments. In the present work, parameters were studied for friction stir welding of AA 5052 & AA 6061 and welding properties were evaluated on the basis of tensile strength, impact strength and micro-hardness of welding joint.

Keywords: Friction stir welding; tensile test; Impact test, AA 5052; AA 6061; micro hardness test.

1. Introduction

Friction stir welding is a welding process invented in 1991 at The Welding Institute. This is a solid-state welding [1] and the material will not be subjected to its melting point temperature. This process is used specially in joining of high strength aluminum alloys [2]. Good quality welds can be formed using this technique, which sets this process apart from the other fusion joining processes. This process is mainly used for butt joints of aluminium alloys. As there is no emission of gases and less utilization of energy, this technique is considered as eco-friendly process and green technology in welding. There is lot of development in this technique for the past decade. In friction stir welding, any kind of materials can be joined which are not possible to join in the conventional fusion welding techniques. Many basic weld defects in the fusion welding can be avoided with the help of friction stir welding. The apparatus set up for FSW is shown in Fig. 1.

1.1 . *Materials used*

The work piece materials used are dissimilar aluminium alloys AA5052 and AA6061 .Their chemical composition is shown in Table 1 & 2. The work piece materials used are dissimilar aluminium alloys AA5052 and AA6061. Their chemical composition [3, 4] is shown in Table 1 & 2.

* Corresponding author. Tel.: +91–7702716982
drdhanarajme@smec.ac.in

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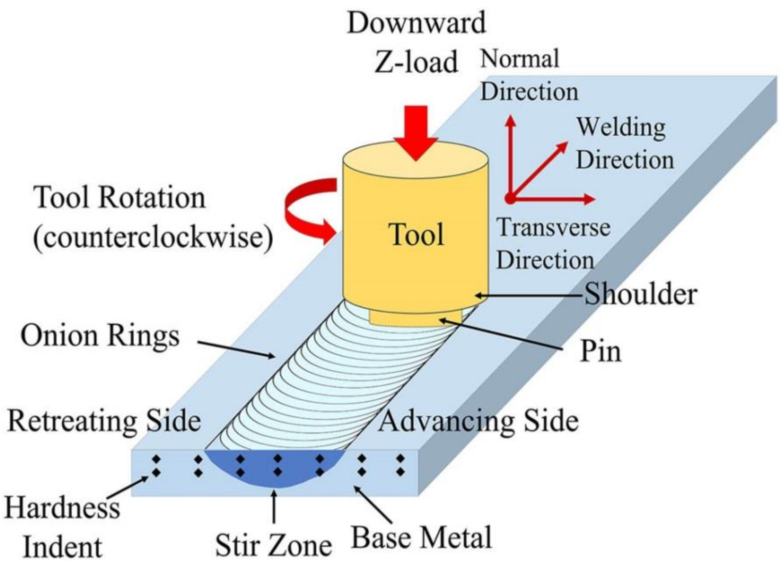


Fig. 1. Friction Stir Welding Apparatus.

Plates with dimensions of 125mm × 75mm × 5mm each of AA5052 and AA6061 are butt welded and plates with dimensions of 125mm × 75mm × 8mm each of AA5052 and AA6061 are joined using FSW technique. The combined application of the dissimilar aluminium alloys is widely used in the field of marine, automobile, pipelines and structural applications

Table 1. Chemical Composition of AA 5052

Element	Content (%)
Aluminum, Al	95.9
Magnesium, Mg	2.2-2.8
Chromium Cr	0.15-0.35
Iron, Fe	0.4
Manganese, Mn	0.1
Copper, Cu	0.1
Silicon, Si	0.25
Zinc, Zn	0.1

Table 2. Chemical Composition of AA6061

Element	Content (%)
Aluminum, Al	97.9
Copper, Cu	0.28
Chromium (Cr)	0.2
Silicon (Si)	0.6
Magnesium (Mg)	1

2. Methodology

Samples prepared for welding are cut into the required plate sizes (125mm x 75mm x 5mm, and 125mm x 75mm x 8mm) by power hacksaw. Then these plates were grinded and polished for good dimensional accuracy and finish. The FSW of the prepared specimens was done using vertical milling machine. Welding parameters [5, 6, 7] for two samples are depicted in Table 3. Welded material is shown in Fig. 2.

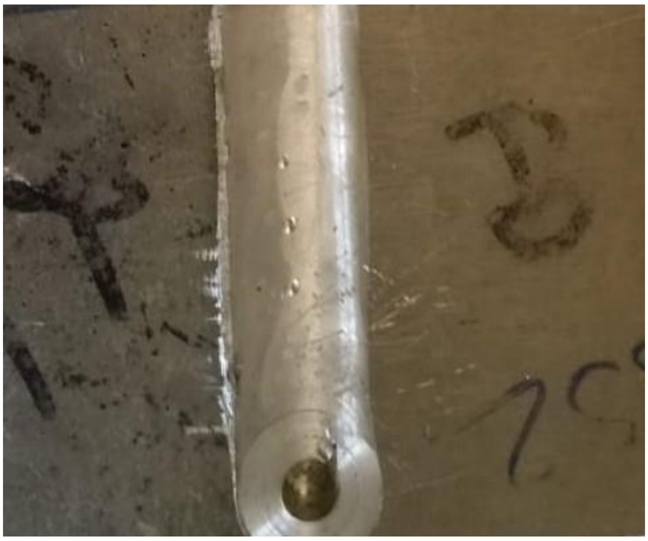


Fig. 2. Welded material.

Table 3. Welding parameters

Sample	Thickness (mm)	Speed (RPM)	Feed (mm/min)	Tilt angle (Degrees)	Tool
A	5	710	16	2	Triangular
B	8	900	20	2	Triangular

3. Testing of material

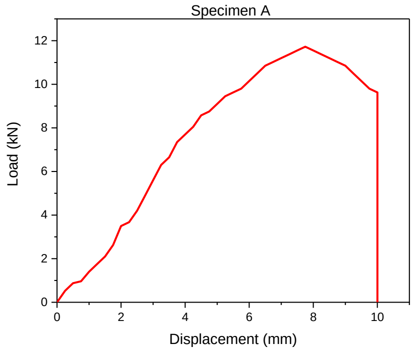
To study the welding characteristics of the welded specimens the following tests [9, 10] were conducted.

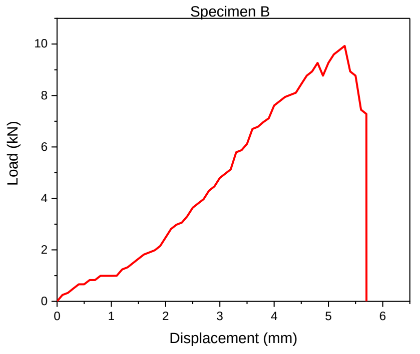
- Tensile testing
- Impact testing
- Hardness testing
- Micro structural testing

3.1 *Tensile Test*

The tensile properties of the welded specimens were determined by universal testing machine of 40 Ton capacity. After the testing, the specimen is shown in the Fig. 3**.** Based on test data, the curve of load versus displacement of the specimen is plotted and same is displayed in the Fig. 4. The final results are tabulated in the Table 4.

Fig. 3. Specimen after testing





Specimen A Specimen B

Fig. 4. Tensile graph

Table 4. Tensile test results

Thickness (mm)	Speed (rpm)	Ultimate Load (KN)	Ultimate Tensile Strength (MPa)	Elongation %
5.05	710	11.680	184.722	10.800
8.04	900	9.880	100.396	6.200

3.2 *Brinell hardness test*

The hardness of the welded specimens is measured using the Brinell hardness tester. The result obtained from the hardness test is shown in the Table 5.

Table 5. Average hardness values

Specimen No.	Impression 1 (BHN)	Impression 2 (BHN)	Impression 3 (BHN)	Average (BHN)
A	68.8	68.2	68.2	68.40
B	62.4	63.0	61.8	62.40

3.3 *Charpy impact test*

The Charpy impact test is done to measure the impact energy of the weldments. The impact test result is shown in the Table 6 and impacted tested specimen is shown in in the Fig. 5.

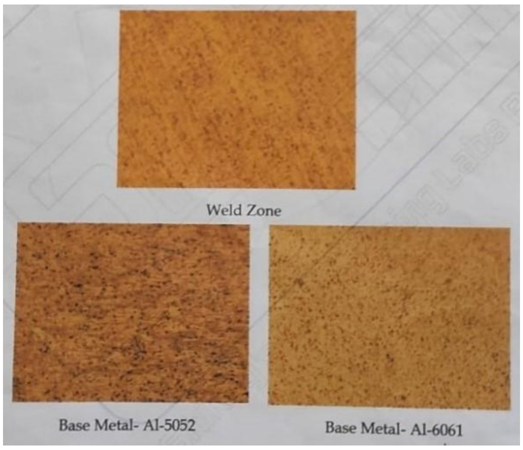
Table 6. Impact test results

Specimen No.	Impact 1 (Joules)	Impact 2 (Joules)	Impact 3 (Joules)	Average (Joules)
A	24	0	0	24.00
B	28	0	0	28.00

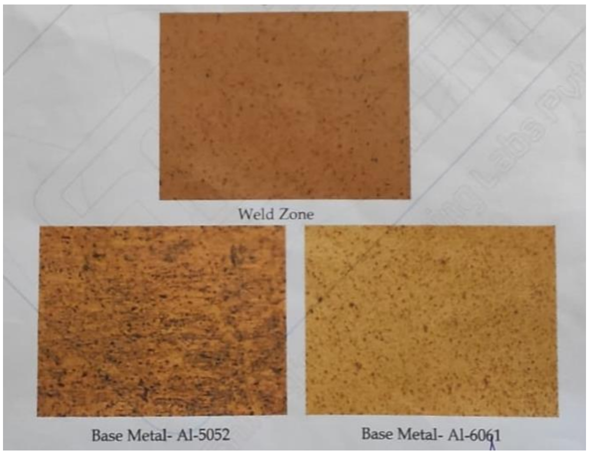
Fig . 5. Specimen after impact testing

3.4 *Microstructure test*

Microstructure analysis is a valuable tool to gain information on how the material was made and the quality of the resulting material. The microstructures were taken at various regions of the weldments for both the samples. The weld details for both the sample are illustrated in Fig .6. Apart from the above tests that is physical experiments, numerical simulations [11.12] were also carried by the various investigators.



Specimen A



Specimen B

Fig .6. Details of weld

4. Results and discussions

From the tensile test results, it was observed that the welding parameters, such as the tool rotation speed and thickness of the specimen has greatly influenced the tensile properties like ultimate tensile strength, yield tensile strength and percentage of elongation. Among the two different combinations which are taken for the welding of the specimens, the best properties are achieved at thickness of 5mm and 710 rpm. The results obtained from Brinell hardness tester shows that the tool traverse speed and the tool rotation speed are showing considerable effect on the hardness of the weldments. The best hardness properties are achieved for specimen with 5mm thickness at tool rotation speed of 710 rpm. The measurements of the impact energy carried out in the Charpy test show that there is considerable effect of the plate thickness, tool traverse speed and the tool rotation speed on the impact energy of the weldment. At 8mm thickness plate and tool rotation speed of 900 rpm, the best impact energy was observed. Based microstructure analysis, given specimen microstructure indicates particles of primary MnA16 and insoluble phases that contain Magnesium, or that contain Manganese in the Matrix.

4. Conclusions

Dissimilar AA6061 and AA5052 alloys have been friction stir welded with a variety of different process parameters. At various tool rotation speeds and dimensions, the effects of materials position and welding speed on materials flow, hardness and tensile properties of the joints were investigated. Based on the above results and discussion, the following conclusions were arrived.

- At lower rotation speeds and thickness, good tensile strength and hardness values are achieved
- The impact strength was good at higher rotational speeds, feed and thickness.
- The microstructural studies suggested that there was no rigorous mixing of both materials in the nugget.

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