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# Fabrication and Analysis of Friction Stir Welded Joints of Two Dissimilar Aluminium Alloys At Different Tool Profiles

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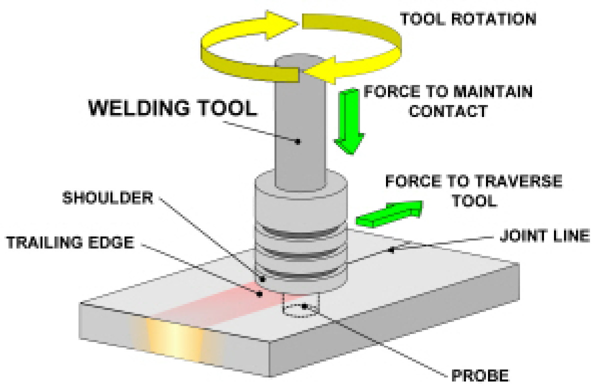
## Abstract:

Now a day the use of friction stir welding (FSW) continues to grow. It is now a mature process for joining aluminum and is seeing rapid progress in many other engineering alloys. FSW is a solid state technique has become field of interest of many researchers due to increase in the demand in joining process in the aerospace, railway and ship building industries especially in the fabrication of aluminum alloys. A Vertical Milling Machine is used in this project weld the parts together. The parts being welded are made up of dissimilar aluminum alloys and welding parameters like tool rotation speed is varied while the welding speed is constant. The parts which are welded to form a butt joint. Different tool pin profiles considered are circular/round and square. The tools are designed using Pro/E and are manufactured on a Lathe machine. After the parts are welded, good samples are selected and small specimens are cut from it perpendicular to the weld direction for hardness and tensile tests.FEA analysis will be performed for friction stir welding of dissimilar aluminum alloys at various thickness Structural and thermal analysis will also done in SOLIDWORKS. Finally we conclude as which tool more effective at various welding parameters from FEA results.

## I.INTRODUCTION:

Friction Stir Welding is one of the new entrants to the solid state joining technique which have made a remarkable progress in welding technology. Fsw was invented by Wayne Thomas at TWI in 1991has become field of interest of many researchers due to increase in the demand in joining process in the aerospace, railway and ship building industries especially in the fabrication of aluminum alloys. FSW is an eco-friendly process that conducted various butt and lap welding for ferrous and non-ferrous metals and plastics. Friction Stir Welding (FSW) is a simple process in which a rotating cylindrical tool with a shoulder and a profiled pin is plunged into the abutting plates to be joined and traversed along the line of the joint. A schematic of the friction stir welding process is shown in Fig. 1.The plates are tightly clamped on to the bed of the vertical milling machine equipment to prevent them from coming apart during welding. A cylindrical tool rotating at high speed is slowly plunged into the plate material, until the shoulder of the tool touches the upper surface of the material. A downward force is applied to maintain the contact. Frictional heat, generated between the tool and the material, causes the plasticized material to get heated and softened, without reaching the melting point. The tool is then traversed along the joint line, until it reaches the end of the weld. It should be noted that, in order to achieve complete through-thickness welding, the length of the pin should be slightly less than the plate thickness, since only limited amount of deformation occurs below the pin. Upon reaching the end of the weld, the tool is withdrawn, while it is still being rotated. As the pin is withdrawn, it leaves a keyhole at the end of the weld.




**Fig(1) Schematic representation of Friction Stir Welding.**

## II.MATERIALS AND METHODS:

A. MATERIALS: In this work the materials that have been used are two dissimilar aluminum alloys that are AA 6061-T6 and AA 5083-H111-O.hen compared to other material aluminum is softer metal and very light weight, mostly used in all industries.

The density of Al 6061 is 2.7g/cm3 and ultimate tensile strength is 275-350 Mpa.AA 5083 is 2.65g/cm3, Ultimate tensile strength is 300Mpa.High speed steel is used as a tool material. Thermal Cond of steel is 19 w/mk.specific heat is 0.640 j/g c.

### B. METHODS:

When the dissimilar aluminum alloys are welding with other fusion welding processes the material properties mostly may differ. Because the electrode which is using is the opposite material to the plate. It was proved that these materials could be efficiently welded by using the Friction Stir Welding process. And mostly the material properties will not change .FSW has various advantages over other welding processes like no hot cracking of the welded very less residual stresses, safe and environment friendly apart from others.

After the materials were welded, various tests like Tensile strength test, Brignell's hardness test and the microstructure tests were conducted at the welded joint. And a plate and tool designed in PRO/E. and conducted FEA Couple field analysis & Structural analysis on tools to verify the temperature distribution, thermal flux, gradient and stresses in SOLIDWORKS.

## III.EXPERIMENTAL WORK:

The Experiments have been conducted on Vertical Milling machine The Milling machine provides an alternative way to produce friction stir welds when the actual FSW machine is not available.

### A. Work piece:

The materials used in this work are AA 6061-T6 and AA 5083-H111-O the plates have been cut into the required size by shear cutting. Single pass welding procedure is used to fabricate the joints.

### Work piece specifications:

Length:100mm ; Breath: 50mm ;Thickness: 5 mm
The chemical composition and mechanical properties of base metals are given in Tables (A) and( B)

### Table (A): AA 6061-T6

| ELEMENT | % PRESENT |
|---|---|
| Magnesium(Mg) | 0.80-1.20 |
| Silicon(Si) | 0.40-0.80 |
| Iron(Fe) | 0.0-0.70 |
| Copper(Cu) | 0.15-0.40 |
| Titanium(Ti) | 0.0-0.15 |
| Zinc(Zn) | 0.0-0.25 |
| Manganese(Mn) | 0.0-0.15 |
| Others (Total) | 0.0-0.15 |
| Others(Each) | 0.0-0.05 |
| Aluminium (Al) | Balance |

Aluminum alloy 6061(used for both aerospace and marine alloys) is a medium to high strength heat-treatable alloy with strength higher than 6005A. It has very good corrosion resistance and very good weld ability although reduced strength in the weld zone. It has medium fatigue strength. It has good cold formability in the temper T4, but limited formability in T6 temper. Not suitable for very complex cross sections. Applications Alloy 6061 is typically used for heavy duty structures like rail coaches, truck frames, ship building including helicopter rotor skins.

### Table (B): AA 5083-H111-O

| ELEMENT | % PRESENT |
|---|---|
| Magnesium(Mg) | 4.00-4.90 |
| Manganese(Mn) | 0.40-4.90 |
| Iron(Fe) | 0.40 Typical |
| Silicon(Si) | 0.0- 0.40 |
| Titanium(Ti) | 0.05-0.25 |
| Chromium (Cr) | 0.05-0.25 |
| Copper (Cu) | 0.10 Typical |
| Others (Total) | 0.0-0.15 |
| Zinc (Zn) | 0.0-0.10 |
| Aluminum (Al) | Balance |

Aluminum AA5083 (used for marine alloys) is known for exceptional performance in extreme environments. 5083 is highly resistant to attack by both seawater and industrial chemical environments. Alloy 5083 also retains exceptional strength after welding. It has the highest strength of the non-heat treatable alloys.

Applications Alloy 5083 is typically used in ship building and rail cars.

### B. Tool Specifications and profile:

The design of the tool is a critical factor as a good tool can improve both the quality of the weld A non-consumable rotating is used. In this study both Round and Square pin tools are used.

### Tool specifications:

High speed steel.

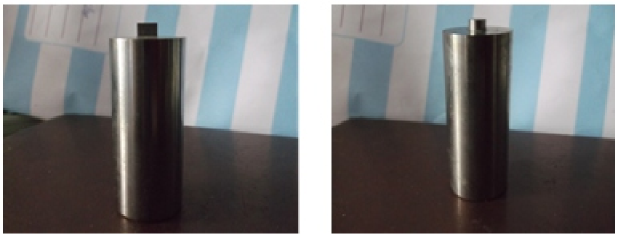


Fig (2): Round tool and square tool

### Tool Dimensions(For Square and round tool)

Shoulder Diameter: 25 mm
Shoulder length: 45 mm
Pin Diameter: 6x6 mm (for square tool)
5 mm (for round tool)
Pin Length: 4.5 mm

### C.Weld Trails:

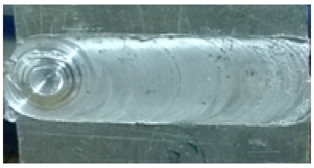
Main difficulty encountered in a FSW is the process optimization. Different parameters like tool rotation (rpm), welding speed (mm/min) axial force (N), tool design etc. are involved in deciding the sufficient heat generation for the effective (quality) solid state joining of materials. Six sets of welding trails were made at the base material only by varying tool rotation speed and keeping downward force and welding speed constant

500 RPM

700 RPM

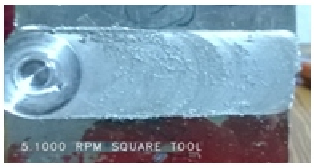

1000 RPM

Fig(3): Welded with Rounde pin tool



500 RPM

700 RPM




1000 RPM

Fig (4): Welded with Round pin tool

### Six Sets of welding trails made at work by varying tool rotation speed and welding speed kept constant.

| S.No | Tool Rotation Speed(rpm) | Welding Speed (mm/min) | Tool Profile |
|---|---|---|---|
| 1 | 1000 | 25 | Round |
| 2 | 1000 | 25 | Square |
| 3 | 700 | 25 | Round |
| 4 | 700 | 25 | Square |
| 5 | 500 | 25 | Round |
| 6 | 500 | 25 | Square |

Adequate Welding quality was obtained at rotational speed of 500 rpm, weld speed of 25 mm/min, and 1000 rpm at weld speed 25 mm/min and pressure 5 MPa as there are cracks occurred when observed with naked eye.

## IV.ANALYSIS WORK:

FEA Couple field analysis & Structural analysis on tools to verify the Stresses and displacements in structural analysis and in Thermal analysis temperature distribution, thermal flux, gradient in SOLIDWORKS (2012) version.

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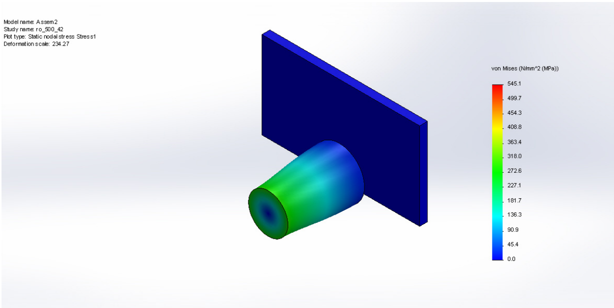
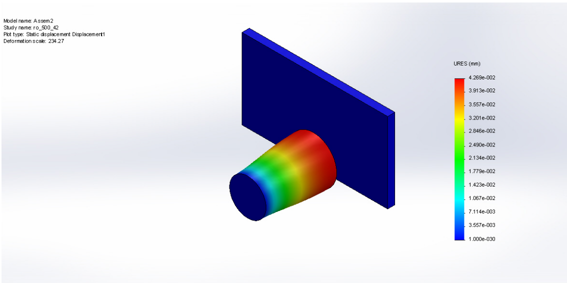
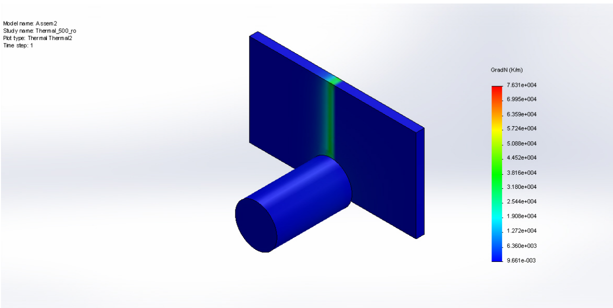
### A. Stress



### B. Displacement



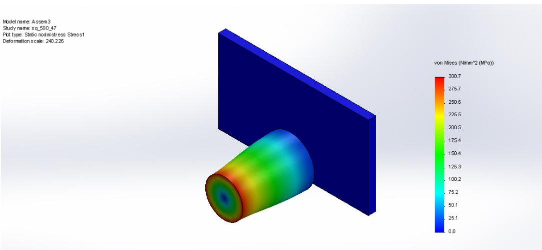
### C.Temparature Gradient



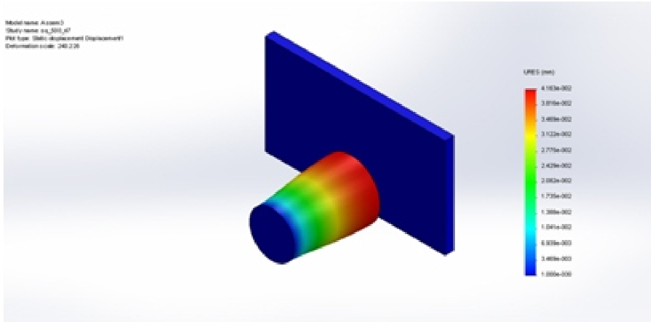
| | |
|---|---|
| Temperature(K) | 543 |
| Thermal Gradient(K/mm) | 76313.9 |
| Resultant Heat Flux (W/mm$^2$) | 1.31E +06 |
| Stress N/mm$^2$ | 545.131 |

### D. Analysis for Square tool.

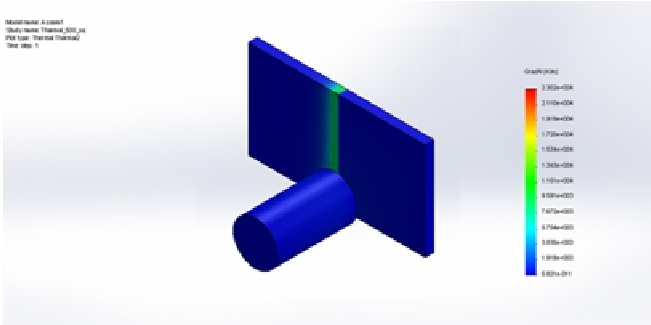
### Stress



### Displacement



### Temparature Gradient



| | |
|---|---|
| Temperature(K) | 553 |
| Thermal Gradient(K/mm) | 23017.4 |
| Resultant Heat Flux (W/mm$^2$) | 3.18 E+06 |
| Stress N/mm$^2$ | 300.711 |

## V.RESULTS AND DISCUSSIONS

### A.Tensile Strength:

Tensile Strength has been carried out with help of universal testing machine(UTM). Tensile Specimens of required dimensions are prepared.

### Specimen Dimensions:100x50x5 (in mm)

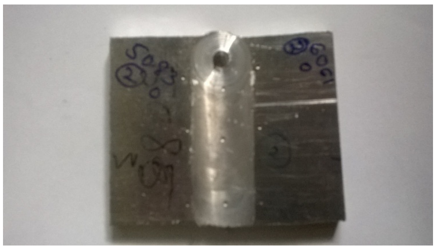
Specimens after tensile test

## Specimen Dimensions

Area for square tool: 180 N/mm2
Area for round tool: 98.17N/mm2
The Tensile Strength for specimen for a round tool is 133.79 N/mm2.The Tensile Strength for specimen square tool is 145.16 N/mm2.

## B. Rockwell Hardness Test:

The Rockwell scale is hardness scale based on the indentation hardness of material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by preload. The Rockwell hardness tests were conducted to determine the hardness values of aluminum AA6061 alloy and AA5083 friction stir weldments at different rotational speeds and feeds of the different tool in a Rockwell Hardness TesterBy using Rockwell 1/16 inch scale load value major 100 kgf and minor 10 Kgf hardness values as at 500 rpm square tool.



| | |
|---|---|
| Trail 1 | 108 HRB |
| Trail 2 | 177 HRB |
| Trail 3 | 109 HRB |

## VI.CONCLUSION:

In this investigation an attempt has been made to study the effect of tool pin profiles and welding parameters on the formation of friction stir weld and tensile properties in AA5083 and AA6061 aluminium alloy. From this investigation, the following:

1.Friction stir welding is performed to join 5mm thick plates of Aluminium alloys with varied parameters like tool rotation speed (rpm), welding speed (mm/min) and downward pressure (MPa).

2.Quality welds are produced with the tool rotation speed of 500-1000 RPM at weld speed 25mm/min and download pressure 5MPa.

3.Joints fabricated at rotational speed of 500 rpm and weld speed of 25 mm/min at Square tool profile exhibited superior tensile strength properties.

4.At high rotational speed cracks were observed by visual inspection.

5.For square tool at 500 rpm the stress values are 300.711 N/mm2 and Displacement Value 0.0416316 mm and for Thermal analysis the temperature 553 k and Heat flux 3.18e06 w/m2 at 5mm thickness

6.In FSW it is understood that increasing the welding speeds, decreasing the tool rotation speed and reduction in thickness which in turn increases the tensile properties.

From the results, the square tool is better than cylindrical tool for aluminum alloy

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