# Friction Stir Welding on Dissimilar Metals Aluminum 6061 & Pure Copper

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*Abstract*— Friction Stir Welding (FSW) is an innovative solid-state joining process in which a non-consumable rotating cylindrical tool with a shoulder and a specially designed pin, harder than the material to be welded is inserted into the butt lines of the base metal plates and subsequently travelled along the joint line. In this work an attempt is made to join Al6061 with pure Copper using H13 as tool material. An experiment has been conducted based on three process parameters shoulder diameter (mm), tool rotational speed(rpm) and travel speed(mm/min). The tensile test has been conducted on UTM the maximum load can be applied on test specimen, the resulting tensile strength was estimated the 140MPa. The tool design is affecting the properties of weld butt joint, the microstructure is changing by varying the tool rotational speed and axial loads.

***Key words:*** FSW, Tool design, Tensile strength and Microstructure

## I. INTRODUCTION

Friction stir welding is a solid state welding process [5], is the newest addition to friction welding (FRW), a solid state welding process. Solid state welding, as the term implies, is the formation of joints n the solid state, without fusion [3]. Solid state welding includes processes such as cold welding, explosion welding, ultrasonic welding, roll welding, and forge welding.

The process uses a rotating, non-consumable weld tool that plunges into the base material and moves forward. Friction heat caused by the rotating pin creates a plasticized tubular shaft around the pin [4]. Pressure provided by the weld tool forces the plasticized material to the back of the pin, cooling and consolidation. Al alloy is difficult to weld by traditional methods, due to high thermal conductivity, resulting in defects like porosity, cracks etc. Hence FSW is being increasingly used. The process is especially well suited to butt and lap joint in aluminum, since aluminum is difficult to weld by arc process, but is very simple to weld by FSW.

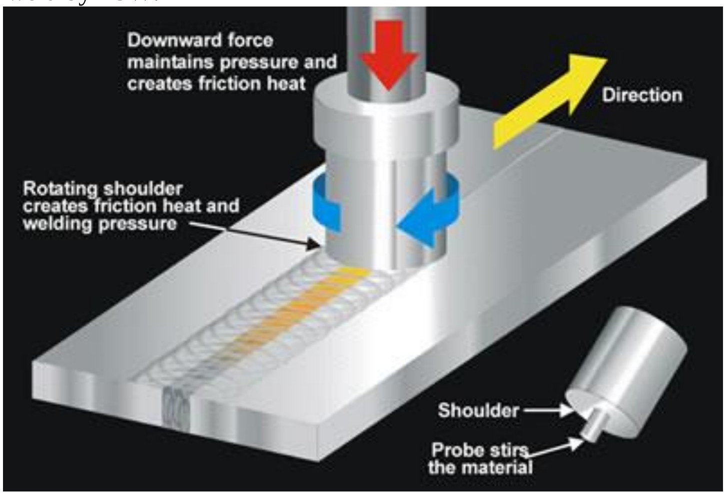


Fig. 1: Friction Stir Welding

Esther T. Akinlabi Member, Mukuna P.mubiayi [4], 2013 Butt welds of aluminium alloy and copper alloy were produced by Friction Stir Welding by varying the feed rate and keeping all other parameters constant. The final weld matrix was composed of welds produced by a constant rotational speed of 600 rpm and the feed rate varied between 50 and 300mm/min. The microstructure and fracture surfaces of the joint interfaces were investigated. The results revealed that the joint interface was characterised with mixed layers of both materials joined. The strongest weld was produced at the highest feed rate employed at 300 mm/min. The fracture surfaces were characterised with thin layers of intermetallic compounds and can be considered fit for practical applications.

## II. EXPERIMENTATION

In this investigation an attempt was made to find out the Mechanical properties of weld join of Al6061 and Pure copper. Process parameters considered are Tool design, tool rotation speed, and axial load and feed rate. Threaded tool is drawn is two dimensions with specified dimensions as shown in fig.3. Using dimensions tool was modeled using UNIGRAPHICS.

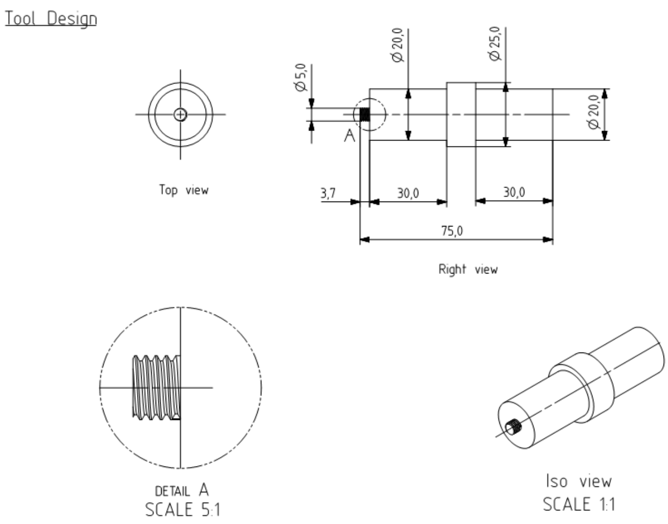


Fig. 3: Tool Design in 2-D

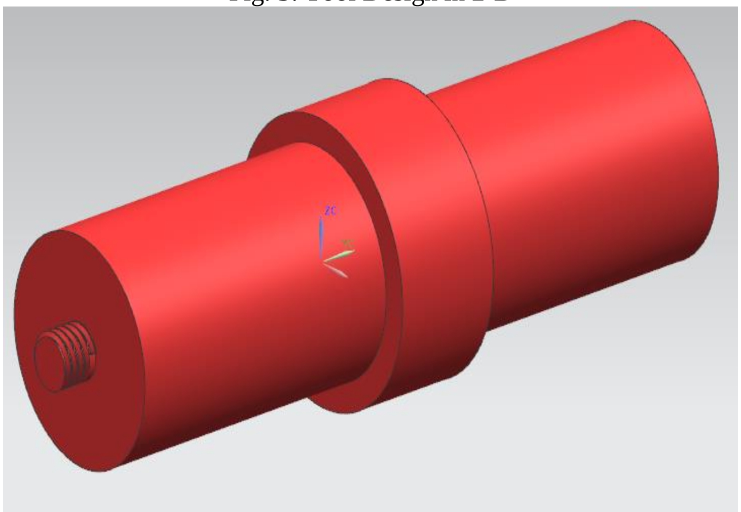

Fig. 4: Tool Modeling using Uni-Graphics

Using CNC lathe machine, the tool with threads is manufactured which is designed on UNIGRAPHICS tool. Material on the advancing front side of a weld enters into a zone that rotates and advances with the pin. This material was very highly deformed and sloughs off behind the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it was broken up into fragments. These fragments were only found in the arc shaped features of material behind the tool.

## III. PROPERTIES OF WORKPICES

| Element | Al | Si + Fe | Mg | Cu | Mo | Other elements |
|---|---|---|---|---|---|---|
| Weight %age | 97.56 | 0.8 | 0.15 | 0.15-0.40 | 0.05 | 0.15max |

Table 1: Properties of Al6061

| Name of the Al Alloy | Yield Strength in MPa | Ultimate Strength In MPa | Elongation % | Hardness in HV |
|---|---|---|---|---|
| AA 6061 | 110 | 207 | 16 | 75 |

Table 2: Mechanical Properties of Al6061

| Cu | P | Bi | Sb | As | Fe | Ni | Pb | Sn | S | Zn | O |
|---|---|---|---|---|---|---|---|---|---|---|---|
| balance | — | 0.001 | 0.002 | 0.002 | 0.005 | — | 0.005 | — | 0.005 | — | — |

Table 3: Properties of Copper

Fig. 5: CNC Lathe Machine

## IV. SPECIFICATIONS OF MILLING MACHINE

The two materials were joined by using Milling Machine, the following specifications of milling machine has been consider for producing sound weld.

Motor capacity: 10 HP
Milling machine rpm: 35-1800 rpm
Feed rate: 16-800mm/min
X-direction bed length: 1meter
Y-axis movement: 400mm
Z-axis movement: 450mm

The plate size of aluminum and copper PURE COPPER are same and having 100 mm length, 75 mm width and 4 mm thickness. EN19 having shoulder diameter of 18 mm and pin diameter of 5 mm.


Fig. 6: 4-Axies Milling Machine

## V. EXPERIMENTAL WORK

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The Al6061and pure copper Al plates were welded using three different tool rotation speeds [2], tool traverse speeds and three shoulder diameters. These designed process parameters are given in table.4

Fig. 7: Friction stir welding process

| Process Parameters | Rotational Speed(rpm) | Transverse Speed (mm/min) | Shoulder dia (mm) |
|---|---|---|---|
| 1 | 680 | 7 | 20 |

Table 4: Process Parameters

## VI. RESULTS AND DISCUSSIONS

### *A. Tensile Test*

Tensile samples were cut from sections of the weld outside of the transient zones of size specimen width 12.5mm and specimen thickness 3.97mm and initial gauge length 50 mm. tensile tests is conducted on UTM.

Fig. 8: Universal Testing Machine

Fig. 9: Broken Test Piece

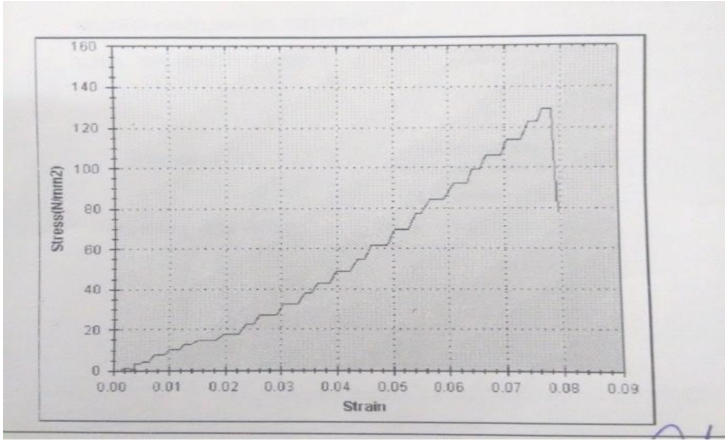


Fig. 10: Impact Test Piece

### *B. Hardness Test*

Hardness test has been conducted on Micro hardness Tester. The sample test specimen as shown in figure. Here we are calculating the hardness of Al6082, Copper PURE COPPER and weld spot. The hardness of Al6082 is 61.1 and the Copper PURE COPPER is 189.8 and finally we got the hardness of welding point 61.4. the sample value of weld point hardness value is HV0.5

### *C. Impact Strength*

The impact strength has been conducted on CHARPY IMPACT TEST. The weld point of dimensions 5*10*55mm taken for sample test piece. Making the V-Notch at a depth 2mm. Place the specimen that V-Notch line axis should be coincide with axis of checks of the tool holder. Find the initial load friction of hammer that is Joules. Place the test specimen and release the hammer with the angle of 1350 at room Temperature. The value of impact strength is calculated for one square millimeter is 2J.

Fig. 10: Impact Test Piece

### *D. Microstructure*

A typical macrostructure of the transverse cross- section at different regions of the Friction stir weld for the optimum process parameters of tool rotational speed of 900rpm, 1° tool tilt angle and travel feed of 16mm/min. The left side of the weld centre corresponds to the retreating side while the right side corresponds to the advancing side. The macrostructure of the weld cross section can be divided into three distinct regions, namely, the Stir Zone (SZ), Heat Affected Zone (HAZ), and the Base Metal (BM). Two different zones of HAZ can be observed.

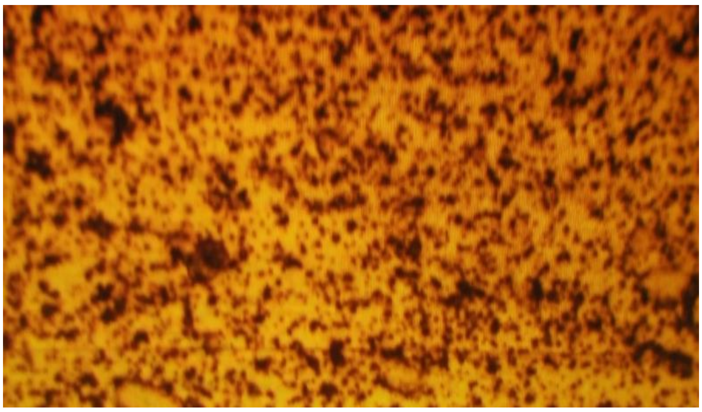

Fig. 11: Microstructure

## VII. CONCLUSIONS

Based on the results of different researchers, the tensile strength of Al6061 and Pure copper is discussed for optimum process parameters of rotational speed, welding speed and axial force. Superior tensile properties of FSW joints were observed, this is due to the formation of fine equiaxed grains and uniformly distributed very fine strengthening precipitates in the weld region. With a recent research developments in use of heat treatable aluminium alloys, it has been suggested that higher tensile Strength of these alloys, a manufacturer allow to use in the Area of aerospace and automobile industries, where the high strength to weight ratio is important.

The combination of the process parameters of 700 rpm tool Rotation rate (rpm), 7 mm/min welding speed and 18mm shoulder diameter has been predicted to give the Tensile Strength of 184.7 N/mm2.Combination of the process parameters of 680 rpm tool rotation rate (rpm), 5 mm/min welding speed and 18 mm shoulder diameter has been predicted to give the hardness of 60.4

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