# MECHANICAL PROPERTIES OF THE FRICTION STIR WELDED DISSIMILAR ALUMINIUM ALLOY JOINTS

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**Abstract-** The present investigation aims in assessment of the mechanical properties of friction stir welded dissimilar metal alloy joints. The optimized process parameters have been predicted for obtaining the strength of the joints in comparable to the base metal. Aluminum 5083 and aluminum 6061 sheets of 5mm thick have been considered for fabricating the dissimilar joints due to their range of usage in most of the engineering applications. Dissimilar FS welded joints were fabricated by varying the process parameters like rotational speed, traverse speed and axial force fixing the Al 5083 on the advancing side and Al 6061 on the retreating side. Two levels of these parameters have been chosen at 1000 rpm and 1600 rpm, 40mm/min and 160 mm/min and 2.5kN and 3.5kN for rotational speed, traverse speed and axial force respectively. Taguchi technique was used to optimize the process parameters by selecting an L-8 orthogonal array consisting of 8 experimental runs. The mechanical properties like the yield strength, elongation, tensile strength and micro hardness of these joints fabricated has been evaluated at all these process parameters.

**Keywords-** Dissimilar alloy Joints, Friction Stir Welding, Tensile Strength, Hardness, Optimization of Process Parameters, Taguchi Technique.

## I. INTRODUCTION

Friction stir welding, since its invention has been extensively used in studied in many engineering applications. FSW on joining of metals can be seen in . Joining of dissimilar metals by conventional methods results in large plastic deformations, unwanted thermal stresses and poor mechanical properties. FSW offers an efficient solution to this challenging task since the joining takes place much below the melting temperatures and results in less distortion, lower residual stresses and fewer defects.

Joining of dissimilar aluminium alloys is gaining research importance by FSW. FSW on aluminium copper, aluminium steel, Ti-6Al-4V has been studied in. Since the metal is deformed by the frictional heat generated by rotating the too l The stirring action of the pin plasticizes the material and the joint is produced by plastic deformation of the material.

The pin not only rotates but also traverses along the length of the weld, enabling to weld the two plates.

The tool rotation and weld direction are similar on one side called as Advancing Side (AS) and opposite on the other called as Retreating Side(RS).

Due to this in an FSW joint there exists an asymmetry which is the unique characteristic of the joint.

By observing the physical phenomenon of the process one can easily understand the important process parameters that influence the strengthof the joint. Out of those influencing parameters are considered as tool rotational speed, traverse speed and axial force. One of the considerations in producing effective joints by FSW is choosing the process parameters.

Hence in the present investigation these parameters have been identified and selected at two levels and their influence on the mechanical properties has been investigated. Studies on the effect of process parameters on the tensile behavior and micro structural studies and developing mathematical models for the same can be seen in.

In all the studies reported earlier on FSW method the effect of the process parameters on the joints has been studied; however there is a necessity to study the effect of the same on producing dissimilar alloy joints of AL5083 and Al6061 due to their heavy usage in marine, aerospace, mechanical and nuclear applications. With this motive the research has been carried out to study the effect of process parameters on producing high strength dissimilar alloy joints.

## II. EXPERIMENTATION

The friction stir welded joints of dissimilar aluminium5083 and aluminium6061 were fabricated using a FSW machine. A total of 8 joints were fabricated as per the design plan from the Taguchi technique.

The chemical compositions and the mechanical properties of the metals are given in Table 1 and 2. The process parameters selected for the present investigation are given in Table 3.

**Table 1 Chemical Composition of AL5083 and AL6061 alloys**

| AL5083 | | AL6061 | |
|---|---|---|---|
| Component | Wt. % | Component | Wt. % |
| Al | 92.4 - 95.6 | Al | 95.8 - 98.6 |
| Cr | 0.05 - 0.25 | Cr | 0.04 - 0.35 |
| Cu | Max 0.1 | Cu | 0.15 - 0.4 |
| Fe | Max 0.4 | Fe | Max 0.7 |
| Mg | 4 - 4.9 | Mg | 0.8 - 1.2 |
| Mn | 0.4 - 1 | Mn | Max 0.15 |
| Other, each | Max 0.05 | Other, each | Max 0.05 |
| Other, total | Max 0.15 | Other, total | Max 0.15 |
| Si | Max 0.4 | Si | 0.4 - 0.8 |
| Ti | Max 0.15 | Ti | Max 0.15 |
| Zn | Max 0.25 | Zn | Max 0.25 |

**Table 2 Mechanical Properties of AL5083 and AL6061 alloys[2]**

| AL5083 | | AL6061 | |
|---|---|---|---|
| Yield Strength | 228 Mpa | Yield Strength | 276 Mpa |
| Ultimate Tensile Strength | 317 Mpa | Ultimate Tensile Strength | 310 Mpa |
| Elongation | 16 % | Elongation | 12% |
| Hardness(Vickers) | 96 | Hardness(Vickers) | 107 |

**Table 3 Process parameters[19]**

| Parameter | Level 1 | Level 2 |
|---|---|---|
| Tool Rotational Speed (rpm) | 1000 | 16000 |
| Traverse Speed (mm/min) | 40 | 160 |
| Axial Force (kN) | 2.5 | 3.5 |

The tool used for fabricating the joints is made by high carbon steel of diameter 20 mm with shoulder diameter as 12mm and with a cylindrical pin of diameter 5mm. With the identified process parameters the joints are fabricated the schematic diagram of the joint and one of the fabricated joint is shown in Figure 1a and 1b.

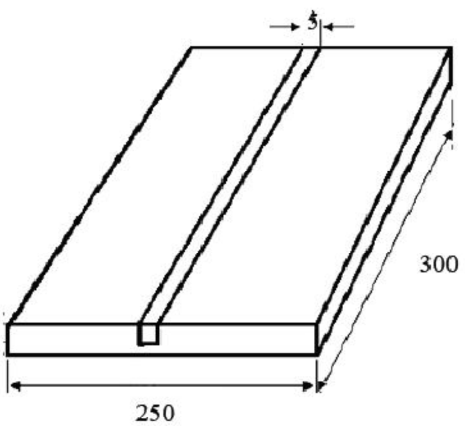



**Figure 1a Schematic Diagram FSW Joint**

**Figure 1b Joint Fabricated by FSW**

The diagram of the plates from which the samples are cut is given in Figure 2a and the tensile test specimen is given in Figure 2b.

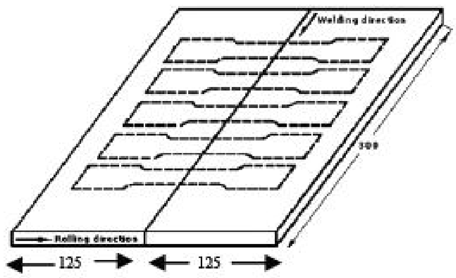



**Figure 2a Schematic Diagram Samples of FSW Joint**

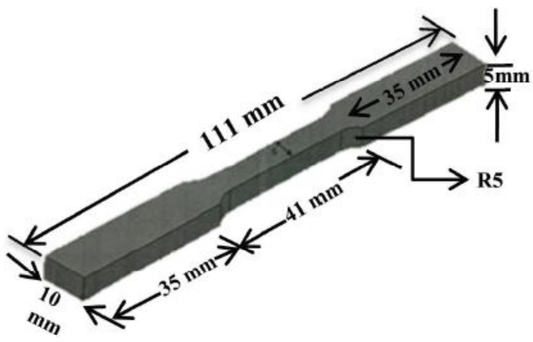



**Figure 2b Tensile Test Specimen of FSW Joint**

A set of 24 specimens for determining the mechanical properties were prepared by using a wire cut EDM machine by Mitsubishi as shown in Figure 3a and 3b.

Figure 3a Samples Cut from EDM

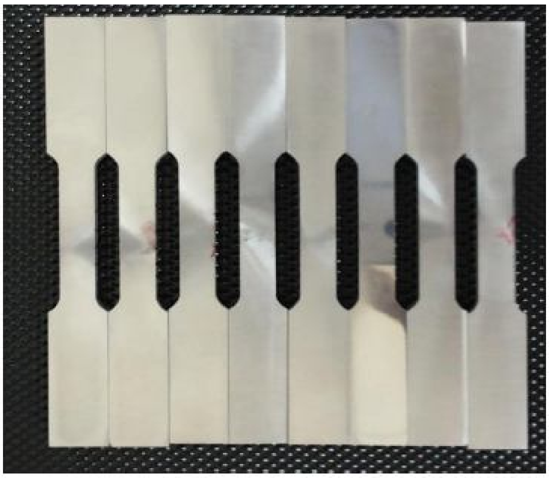


Figure 3b Samples for Tensile Test

Tensile test and hardness tests have been carried out using an Instron testing machine and Wilson Computerized Vickers hardness testers. For each fabricated plate a set of 3 samples for tensile test and 2 samples for micro harness were cut. A row of indentation tests have been conducted at each location of the sample along the longitudinal direction of the weld and the figures are given in Figure 4a, and 4b.

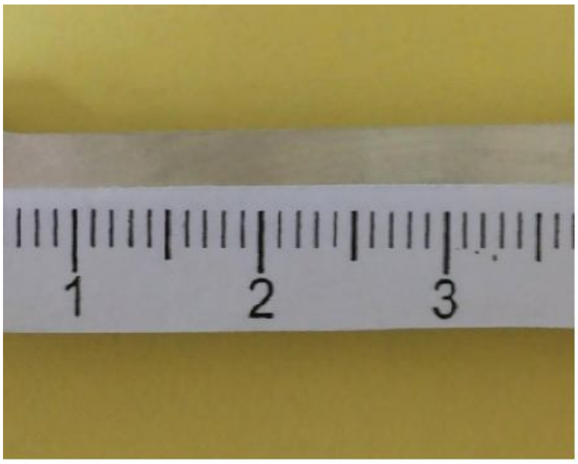



Figure 4a Samples for Micro Hardness

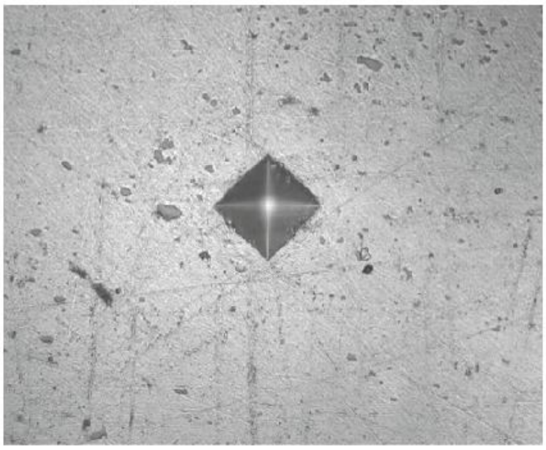


Figure 4b Indentation sample of the Diamond Indenter

The failure of the tensile specimens occurred either on the retreating side or the advancing side of the fabricated joint and is shown in Figure 5. The graphs indicating the tensile strength and micro hardness are given in Figure 6a and 6b.

Figure 5 Fractured specimens from Tensile Testing

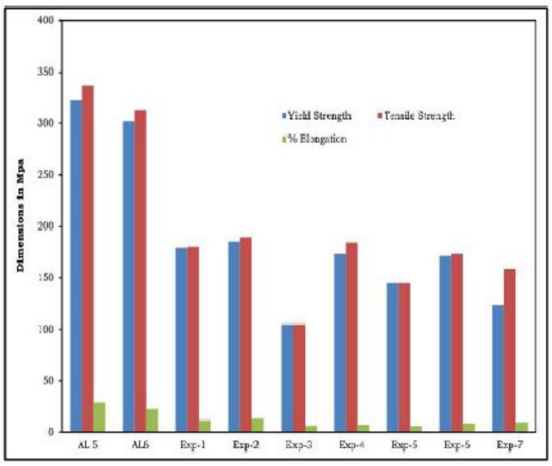



Figure 6a Yield Strength, Tensile Strength and elongation of the specimens from Tensile Test

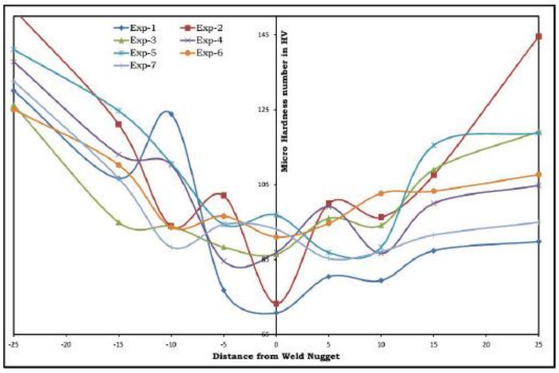



**Figure 6b Micro hardness perpendicular to the weld line from Hardness Test**

## III. OPTIMIZATION

The optimization of process parameters has been performed by using Taguchi technique and Qulaitek4 Software. The process parameters identified at two levels are rotational speed, traverse speed and axial force. Two levels of these parameters chosen are 1000 rpm, 1600rpm, 40mm/min, 160mm/min, 2.5kN and 3.5kN for rotational speed, traverse speed and axial force respectively. An L8-Orthogonal array has been selected. The trail runs for the experiments is given in the Table 4 below.

**Table 4 Indicating the Trail Runs by varying the process Parameters**

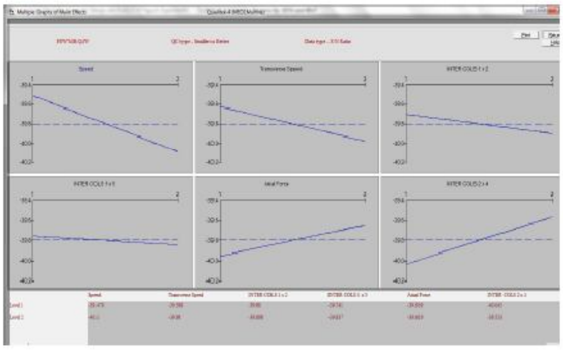
| Exp .no | Rotational speed rpm (A) | Traverse Speed mm/min(B) | AxB =C | AxD =E | Axial Force(D) | BxL =F | BxD =G |
|---|---|---|---|---|---|---|---|
| 1 | 1000 | 40 | 1 | 1 | 2.5 | 1 | 1 |
| 2 | 1000 | 40 | 1 | 2 | 3.5 | 2 | 2 |
| 3 | 1000 | 160 | 2 | 1 | 2.5 | 2 | 2 |
| 4 | 1000 | 160 | 2 | 2 | 3.5 | 1 | 1 |
| 5 | 1600 | 40 | 2 | 1 | 3.5 | 1 | 1 |
| 6 | 1600 | 40 | 2 | 2 | 2.5 | 2 | 2 |
| 7 | 1600 | 160 | 1 | 1 | 3.5 | 2 | 2 |
| 8 | 1600 | 160 | 1 | 2 | 2.5 | 1 | 1 |

**The results given as input for each sample are given in Table 5.**

**Table 5 Results of the Micro Hardness**

| | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| Trial 1 | 92.34 | 94.17 | 98.28 | 98.28 |
| Trial 2 | 85.07 | 90.56 | 84.17 | 85.53 |
| Trial 3 | 110 | 89.08 | 91.83 | 88.11 |
| Trial 4 | 97.16 | 112.7 | 92.09 | 96.05 |
| Trial 5 | 97.16 | 112.7 | 92.09 | 96.05 |
| Trial 6 | 101.5 | 107 | 89.82 | 103.3 |
| Trial 7 | 107.7 | 96.61 | 100 | 84.17 |
| Trial 8 | 120.8 | 96.33 | 106.1 | 103.1 |

The effect of each process parameters on the micro hardness is shown in the Figure 7a and 7b. The S/N analysis has been selected since the input data from the experiments is more than one set for each trial. The optimized parameters have been obtained as rotational speed as 1000rpm, traverse speed 40mm/min and axial force of 3.5kN.



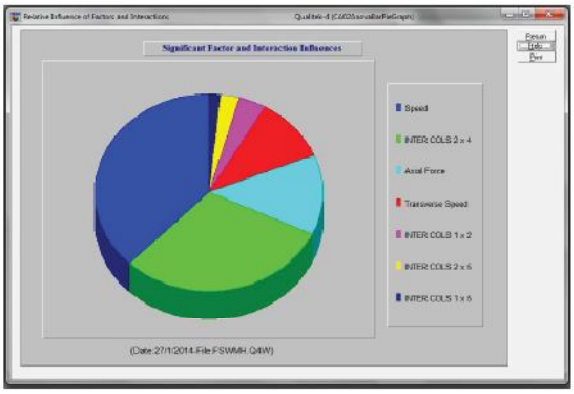



**Figure 7a and 7b Influence of each process parameter on the micro hardness**

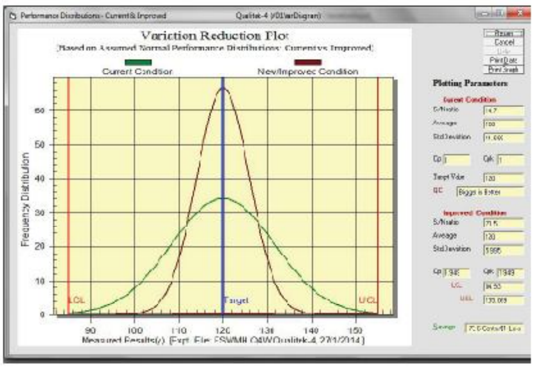



**Figure 7c. Graph indicating the current condition and Improved Conditions**

## 4. DISCUSSION

The tensile behavior and hardness values from the experiments show that there is an increase in the same when the rotational speed and axial force is increased keeping the weld speed constant. There is a decrease in the same when the weld speed is increased keeping the other parameters constant. However, when the axial force is increased the tensile strength is increased. This behavior is due to the increased frictional heat and insufficient frictional heat. Higher weld speeds results in poor heat generation and plastic flow of the material. This may have resulted in a week interface at the joint. Higher the weld speeds lower the heat generation which results in fasters cooling of the welded joints. It can also be inferred that when the welding speeds are higher there exists lower metallurgical transformations and lower strengths.

However, in the present investigation the tensile strength and the hardness are observed to be more due to the ageing of the welded joints. From the optimization technique the optimized process parameters are obtained the results from the current condition and improved condition are given in Figure 7.

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