

# Further Improvements in Mechanical Properties and Micro Structural Studies of Al-Mg-Si Age Hardening Alloy via Friction STIR Welding

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## Abstract

Recently many reports on Friction Stir Welding (FSW) of various similar systems such as aluminium alloy AA6061-T6 has been reported. FSW of Aluminium alloys has captured important attention from manufacturing industries, such as Shipbuilding, Automotive, Railway and Aircraft production. Dissimilar welds which include welds between the different series of aluminium alloys has been successfully produced by many researchers. In FSW process, a so-called welding-head pin rotating at speeds usually in excess of a few hundred rpm, travels down the length of contacting metal plates, creating a highly plastically deformed zone through the associated force and frictional heating. Aluminium and its alloys are widely used in industrial applications due to their excellent electrical & thermal conductivities, good strength, corrosion & fatigue resistance. The aim of present study was analogy of the microstructures and mechanical properties of friction stir welded joint of Aluminium alloy AA 6061-T6 plates in 3mm thickness.

**Keywords** - Aluminium alloy, Similar Materials, Microstructure, SEM analysis, Micro hardness and Mechanical Properties, FSW.

## I. INTRODUCTION

Friction stir welding (FSW) has now become an important process in the joining of aluminium alloys which are soft relative to the material used as the tool for stirring the metal. [1-3] since there is no macroscopic melting involved, the controls needed in fusion welding to avoid phenomena such as solidification and liquation cracking, porosity, and loss of volatile solutes can be avoided.

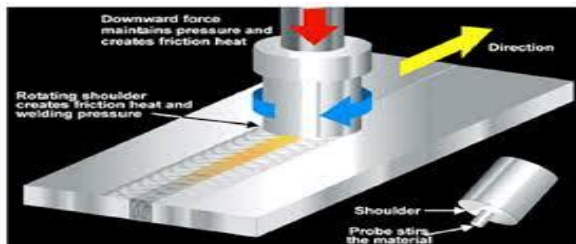


Fig 1: A Schematic Friction Stir Welding

The aim of the present paper is to make a detailed assessment of the microstructures of friction stir welds in two aluminium alloys, AA6061-T6 (an age hardening alloy) using optical microscopy. The technique allows changes in both the size and structure of grains, and effects on coarser particles are observed. By combining this information with mechanical data, a comprehensive description of friction stir welds aluminium alloy is presented.

## II. EXPERIMENTAL PROCEDURE

### A. Welding and materials

Friction stir welds were produced with AA6061-T6 (Al-Mg-Si alloy) chemical composition for 6061-T6 shown in table 1. The rolled plates were cut into rectangular samples of 100 x 75 x 3 mm and welding was carried out using vertical milling machine. The welding tool used in this study was AISI H13 tool steel, which has high resistance to thermal fatigue. The pin profile used in this work is conical tapered pin. Table 2 shows different combinations of plate thickness and welding speed. To study the microstructure of the weldments of these dissimilar aluminium alloys Keller's reagent was used. Optical microscopy with Micro and Macrostructures to evaluate the metallurgical characterization [4]. For tensile studies, the samples were prepared according to the ASTM E8 standards and the tests were carried at a strain rate of 0.8mm/min. Micro Hardness were carried out at a load of 100gf with dwell time 10secs and distance of 0.25mm interval across the weldment.

Table 1 Chemical composition of 6061 Aluminium

<b>6061 Al</b>	Si 0.80	Fe 0.70	Cu 0.40	Mn 0.15
	Mg 1.2	Cr 0.35	Zn 0.25	Ti 0.15
	Al balance			

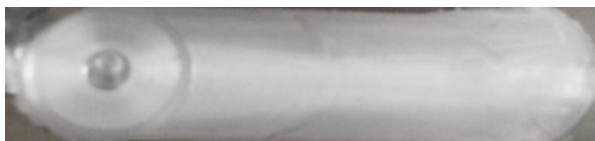
**Table 2: Process parameters**

	Unit	Experiment 1
Rotation Speed	rpm	800 ,1200
Transverse speed	mm/min	30-60
Offset	mm	1
Plunge depth	mm	3
Tilt angle degree	2°	2°

### III. RESULTS AND DISCUSSION

#### A. Surface Morphology of weld

The surface morphology of the weld fabricated using conical tapered pin profile shown in fig 2. The rotational speed and the traverse speed were maintained at 800 rpm, 32mm/min and 1200 rpm, 60mm/min respectively. By varying the process parameters, no external defects were found on the weld



**Fig 2 Surface morphologies of weld without defects**

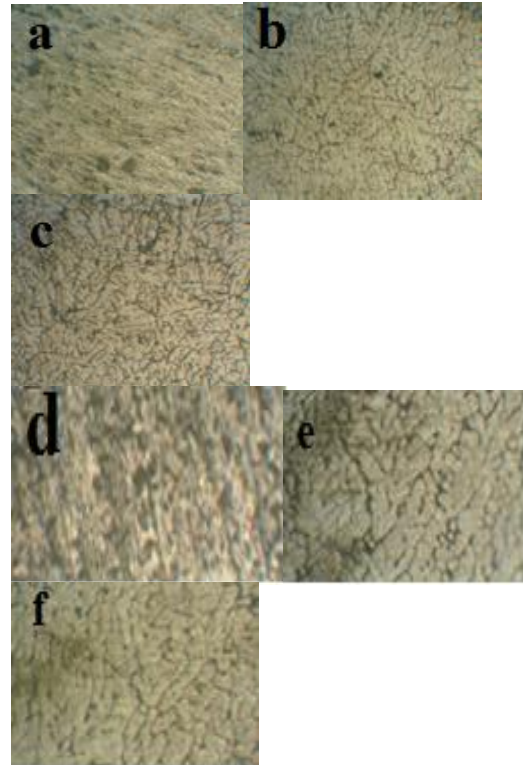
#### B. Microstructure Analysis:

##### Macrostructure

From the macro-graphic studies, different regions of weldments are identified and it represents the effective stir of both base material in the stir zone in fig 3. Defect free welds were produced on using conical tapered pin with process parameter of 710 rpm, 28mm/min.



**Fig 3 Macrostructure conical threaded pin**



**Fig 4 Microstructure of the different regions, a-6061-T6 BM, b-HAZ of 6061-T6, c-TMAZ of 6061-T6, d-NZ, e-THAZ of 6061-T6, f-HAZ of 6061-T6, g-BM of 6061-T6**

Material (Dissimilar)	Tool design Constant	Speed (rpm)	Travel speed (mm/min)	Tilting angle (degree)	(H V)
AA6061-T6	Conical tapered pin	800	32	2°	34 5
AA6061-T6	Conical tapered pin	1200	60	2°	27 5

#### C. Microstructure

The microstructure of the different regions of the welded dissimilar material is shown in fig 4. Though the weld undergoes considerable amount of thermal cycle, there is no significant changes in the microstructures of the base metals. On the other hand, the thermal cycle, has considerably influenced the heat affected zone (HAZ), which is evident from the microstructure. However, there is no plastic deformation occurring in this area. In the thermomechanically affected zone (TMAZ), there is considerable growth in the grain boundaries which could be due to the plastic deformation and the less heat developed during the process. Also, it is evident from the microstructures that a distinct grain boundary separates the recrystallized zone (weld nugget) from the deformed zones of the TMAZ. The dynamically recrystallized zone is the stirred zone, where the material has undergone severe plastic deformation resulting in fine equiaxed grains [5].

#### D. Microhardness

The samples were polished using different size of emery paper and cloth polished also the Vicker's hardness of the final polished samples were measured by indentation test, with square diamond base indenter which under the application of 5kg load with a dwell time of 10 sec. Then the diagonals of the indent formed on the material surface (Dissimilar) were measured.

#### E. Tensile test

Maximum weld strength of 1200 rpm ultimate tensile strength 198.19 MPa and Yield strength 175.54 MPa and % elongation 0.80 were obtained for conical tapered pin, the tool pin geometry fracture occurred at the HAZ of 6061-T6 side. The welded specimen shows lower strength compared to both the base material. Joint efficiency obtained is 80%.

### IV. CONCLUSION

In conclusion, an overview of friction stir welding of dissimilar materials focusing on aluminium AA6061-T6 has been conducted, and it was successfully accomplished under different parameters by using a conical tapered pin tool. All welds were defect free. Microstructure of weld and Micro hardness were shown at centre of weld. Tensile strength was good. Microstructural changes induced by the friction stir welding process were clearly identified in this study. Also, in the analysis of the dissimilar joint the mixture of the two alloys is easily identified by the etching response of both alloys.

### V. SCOPE OF FUTURE WORK

We have seen that, we can join dissimilar materials/alloys by FSW. But there is always present a need in everything to become more suitable and reliable in use. In this regard we can say that, we have to find more suitable tactics to join different

materials/alloys economically by FSW, as we can get the best joint with good strength and research of joining different materials/alloys in future with following points:

- Selection of tool material and design of tool for the welding.
- To get the joint having good strength to weight ratio.
- Application of special coating materials or powder to get the high strength welds.
- To join aluminium alloys and aluminium metal matrix composites.
- To join of aluminium to steel reliably and cost effectively.

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