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# Mechanical Properties of Al 6061-SiCp Metal Matrix Composite Weld Joints Made using Friction Stir Welding

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***Abstract***:- Al 6061 metal matrix composites with SiCp are increasingly becoming popular in automobile, aerospace and electronics industries, in view of their excellent mechanical properties and wear resistance. The present study is focussed on weld joint characteristics of Al 6Al 6061+ 20% SiC metal matrix composite of 6mm thickness plates welded with Friction Stir Welding process. A number of welding trials with rotational speedsin the range of 1000-1500 rpm and with a constant welding speed (1.25mm/min) and axial load (7 KN) were made. The joints were assessed for their mechanical properties. Weld joints made with a rotational speed of 1200 rpm showed significantly higher strength as compared to joints with other rotational speeds. The reason for higher strength has also been explained based on micro-structural characteristics.

***Key words***:*-Al 6061-SiC Composite, Friction Stir Welding, Mechanical properties*

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## I. INTRODUCTION

The quest for new light weight structures made of metal matrix composites with Al as the base is ever increasing in almost all industrial sectors like aerospace, defence, nuclear, petro-chemical, power plant, automobile and structural applications. It is well known that the tensile strength of welded joints of aluminium alloys decreases significantly. Hashim and Dawes et al [1&2] have described the reasons for lowering of tensile properties of the weld joints. Paul et al [3] were the pioneers in the application of friction stir welding in aerospace. Hashim et al [1] have explained the liquid metallurgy techniquefor producing metal matrix composites and is highly economical as compared to other methods such as powder metallurgy.McDaniel et al [4] in their study have found that the silicon carbide particle in the range beyond 30% volume fraction is detrimental to the tensile strength.Das et al, [5] have described Al-based metal matrix composites produced by means of pressurized liquid metal infiltration (squeeze casting). Sahin et al, [6] also studied aluminium alloy composites containing various particle sizes of 10 and 20 weight.%SiC particles which were prepared by molten metal mixing and squeeze casting method under pressure with argon gas shield. Dupont[7]has described the effect of welding parameters and process type on arc and melting efficiency using gas metal arc welding. Thermal efficiency has been described in two ways, namely arc efficiency and melting efficiency. Buffa et al [8] haveexplained the concept of friction stir welding. In this process coalescence is achieved through frictional heating between the tool and the sheet, plasticizing, mixing and extrusion of a rotating pin-shoulder tool that moves between two parts being joined. Ouyang et al [9] in their investigation have focused on the forces exerted by the tool, especially the shoulder force that is directly responsible for the plunge depth to the tool pin into the work piece.Oosterkamp et al [10] have identified the role of tool pin in the friction stir welding wherein the tool pin brings the material at both sides of the joint line to the plastic state, aided by frictional heat input of the shoulder.Reynolds et al, [11] have observed that the material that was stirred originates from the upper portion of the path of the welding. Further with higher pitch, the tool acted like a drill rather than stirrer and compelled the weld metal outward in the form of chips. Beat Heinz and BirghtSkrotzki [12] have shown that FSW is an environmentally cleaner process due to the absence of melting consumable filler material. Attallah and Hanadi [13] have shown that the material flow behaviour is influenced by the FSW tool profile and FSW process parameters. Further, he has inferred that the dependence of microstructure, mechanical properties and residual stresses on welding speed and the weld properties are clearly dominated by thermal input rather than mechanical deformation by the tool.Hassan [14] in his work studied the tensile properties of the AA7010 joints made with different welding conditions. He found that low tensile strength and low ductility were obtained at low spindle speed.Thomas [15] has shown that the welds were characterized by well defined weld nuggets and flow contours, almost spherical in shape.Dieter [16] studied the effect of friction stir welding on the microstructure and mechanical properties of the AA6056 alloy for both T4 and T8 heat treatment condition.The present work is to investigate the mechanical properties of Al 6061-SiCp using friction stir welding process with Al 6061 plates of 6 mm thickness at various rotational speeds ranging from 1000-1500 rpm.

## II. EXPERIMENTAL SET-UP

A schematic of Friction Stir welding process is shown in Figure 1 where the Al-6061 plates are clamped to the holder.

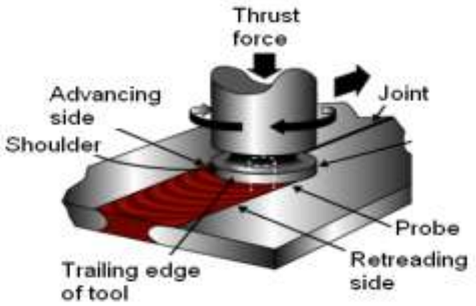
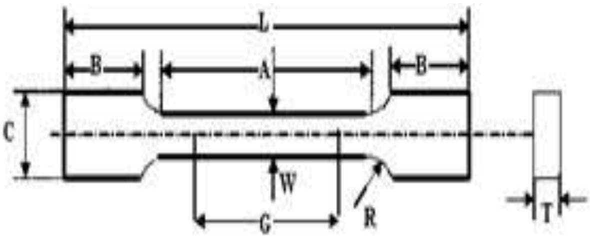



**Figure 1: Friction Stir Welding set-up**

A cylindrical-shouldered tool with a probe is constantly rotated with a uniform speed into a butt joint between two fixed clamps. A tool (Figure 2)which is slightly shorter than the weld depth has been used for the study.In the present study three rotational speeds: 1000, 1200 & 1500 rpm respectively were used.

**Figure 2: Cylindrical probe**

Metal Matrix Composite castings of Al 6061/SiCp made by liquid metallurgy route were sliced to a dimension of 120 x 6mm. The tensile test specimen has been prepared as per ASTM E-8 with a gauge length of 25 ± 0.1 mm as shown in Figure 3. The tensile test specimen has been prepared as per ASTM E-8. Tensile specimens after the tests were done are indicated in Figure 4.




L = 100 mm : G = 25 mm : B = 30 mm
C = 10 mm : A = 32 mm : T = 6 mm

**Figure 3: Tensile test specimen**

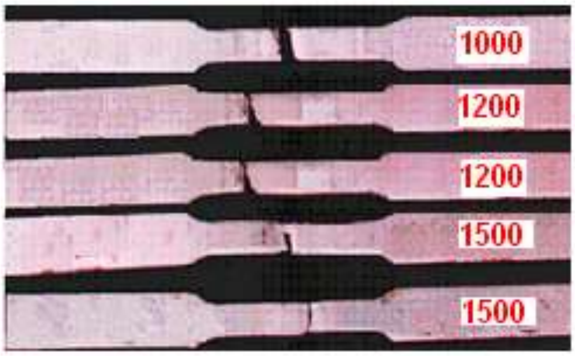



**Figure4: Al 6061 + 20wt.%SiC specimens after fracture.**

## III. RESULTS AND DISCUSSIONS

Table1 indicates tensile strength of the joints with various rotational speeds of 1000 – 1500 rpm with Al 6061 and Al 6061+20%SiC. Tensile strength of Al 6061+20%SiC at 1200 rpm shows higher value compare to 1000 & 1500 rpm.

The mechanical properties of the Al 6061+ 20% SiC joints welded at a various rotational speeds of 1000 rpm to 1500 rpm are indicated in Table 1. At a rotational speed of 1200 rpm, higher tensile strength has been noticed. The presence of SiC particles have contributed for higher strength. Moreover, a higher rotational speed causes excessive release of stirred materials to the upper surface.As the rotational speed increases to 1500 rpm, the tensile strength is lower.

**Table 1: Tensile strength of welds**

| Material | Speed (rpm) | Tensile Strength, MPa |
|---|---|---|
| Al 6061-T0 | - | 110 |
| Al 6061+ 20% SiC | - | 130 |
| Al 6061 weld joint | 1000 | 110 |
| | 1200 | 131 |
| | 1500 | 120 |
| Al 6061+ 20% SiC | 1000 | 120 |
| | 1200 | 208 |
| | 1500 | 145 |

As rotational speed increased, heat input per unit length of joint increased, resulting in inferior tensile properties due to rise in temperature, which increases grain growth. Considerable increase in turbulence which destroys the regular flow behaviour available at lower speed is also observed.

The microstructure of the weld joints made with different rotational speeds are indicated in Figure 5a to 5c. Fractographs of weld joints with different rotational speeds are also indicated in Figure 6a to 6c. From the microstructures and fractographs, it is quite apparent that rotational speeds of 1200

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rpm gives much smoother flow pattern and more plasticized regions as evident from dimple formation.

It is also evident that the strength of joints with this speed are much higher than that of the base material which could be due to work hardening during friction stir welding. It is also clear from Table 1 that the strength of the joint is also higher compared to weld strength without SiC reinforcement.

**Figure 5a**: Flow pattern: 1000 rpm [40x]

**Figure 5b**: Flow pattern: 1000 rpm [40x]

**Figure 5c**: Flow pattern: 1000 rpm [40x]

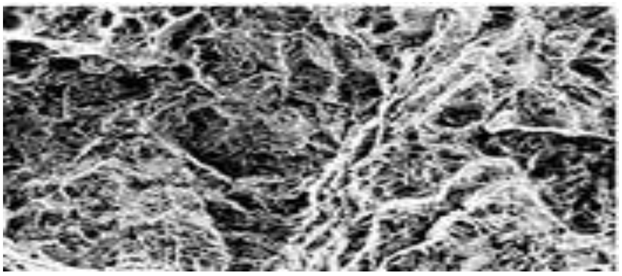

**Figure 6a**: Fractograph Al6061 + SiC – 1000 rpm [500x]

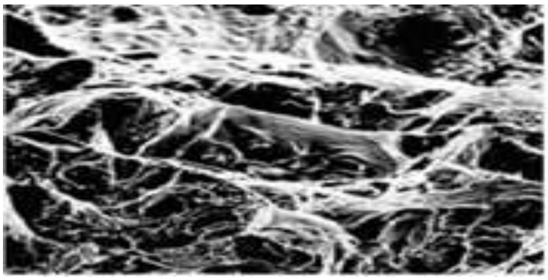

**Figure 6b**: Fractograph Al6061 + SiC – 1200 rpm [500x]

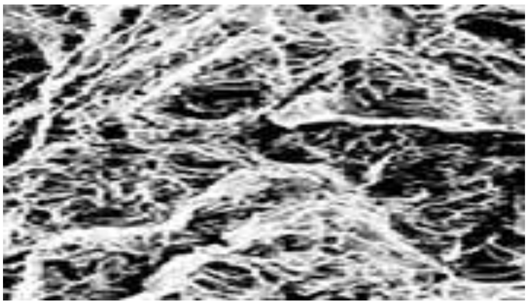

**Figure 6c**: Fractograph Al6061 + SiC – 1400 rpm [500x]

Finally it can be summarized that the welding parameters for producing defect free Al 6061-SiCp MMC plates lies in using straight cylinder pin profiled toolwith a rotational speed 1200 rpm 1.25 /sec and axial force of 7 kN.

## IV. CONCLUSIONS

Friction Stir Welding with a rotational speed of 1200 rpm enables much smoother mechanical working and plasticizing of the weld zone. SiC particles do not interfere with plasticizing of the weld zone.At higher rotational speed the weld nugget is irregular in shape as compared to the preferred elliptical shape. Further, the tensile strength of the weldment is also lowered.Fracture surface examination on weldment of Al 6061+ 20% SiCp revealed the presence of extensive distribution of dimples indicating ductile nature of the weld zone.

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