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THE ROLE OF SiCp ON MICROSTRUCTURE AND MECHANICAL BEHAVIOUR OF ALUMINIUM ALLOY USING FRICTION POWDER PROCESSING

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Abstract- **Friction Powder Processing (FPP) is a new innovative technology developed based on the principle of Friction Stir Welding (FSW) technique. In FPP, the ceramic particulates are reinforced into the base metal by adding it into the groove and Friction Stir Processing (FSP) is performed. In this study, the aluminium alloy 6016 is chosen as the base metal and SiC particulate as reinforcement material. The process parameters such as axial load of 8 KN, traverse speed of 60 mm/min and the tool rotational speed of 1600 rpm were selected. The Friction Powder Processing was carried out on indigenously developed Friction Stir welding machine. The microstructure analysis was carried out using optical microscope (OM) and Scanning Electron Microscopy (SEM). The mechanical characteristics of Friction Powder Processed plates were analyzed using computerized universal tensile testing machine. The micrograph results revealed that SiC particulates were evenly distributed in the stir zone and reduction in grain size also observed. The reason for the grain size reduction was stirring action of the FPP tool's pin. The tensile strength results showed the significant improvement in strength of FPP plates when SiC particulates were reinforced into the base metal plates.**
Key words: Friction Powder Processing, FPP Parameters, FPP tool, Microstructure, Tensile test

I. INTRODUCTION

Friction Stir Welding (FSW) is the solid state joining process invented by The Welding Institute (TWI) in the year 1991 [1]. Due to the rapid development of this technique and implement of high strength and long durable tools, the use of FSW has been expanded to many other materials such as Mg, Cu, Ti, steels and Ni alloys etc., [2-6].

The FSW process involves the non consumable rotating tool is inserted into the workpiece at the gap between two plates to be joined and then the tool is moved along the gap. The frictional heat will be generated primarily from the tool shoulder and also from the pin. The heat generated is used to soften the materials to be joined. Due to the plastic deformation and extrusion process around the FSW tool, the workpiece is joined [7].

The process of FSW has been widely used from aerospace industries to ship building industries. It has some beneficial advantages such as no fumes, no need of filler materials or shielding gas, no need of surface treatment free from pores and blow holes.

The major disadvantage of FSW process is the exit hole left behind at the end of the welding process when the tool is withdrawn from the work piece. During FSW process, plastic deformation has been occurred on the welded zone leads to reduction in the strength and hardness of the material.

Friction Stir Processing (FSP) is a solid state process developed based on the principle of FSW process to modify the microstructure and to improve the mechanical properties of the base metal. In FSP process, the frictional heating will be generated and resulted in intense plastic deformation occurrence in the surface of the metal matrix. In recent years FSP technique is used in many industrial applications such as shipping industries, aerospace industries, etc, [8].

The localized thermo mechanical cycle of FSP homogenous and refines stir zone microstructure, leading to improve the material properties in the processed layers [9].The FPP is the advanced technique to design the properties of the processed area by performing FSP after adding powder with a controlled composition is placed in the gap between plates [10].

II. EXPERIMENTAL PROCEDURE

In this study, FPP is performed by reinforcing SiC particulate into the Aluminium alloy AA 6016. The tensile behaviour and microstructure of the material has been examined. The micro hardness of the material also considered for the analysis purpose. The chemical composition of AA 6016 is shown in Table 1. The process was carried out on 3 axis FSW machine. The length in the X axis is 780 mm, Y axis is 370 mm and Z axis of 180 mm. The power delivered by the spindle is 3.5 KW. The maximum axial force applied on the work piece is 15 KN. The maximum welding speed of the FSW machine is 3000 mm/minute. The variable vector drive has maximum rotational speed of 3000 rpm.

Element	Mg	Mn	Si	Fe	Cu	Mg	Cr	Zn	Al
% Wt.	0.60	0.24	1.50	0.50	0.16	0.02	0.10	0.18	96.4

Table 1. Chemical composition of AA 6016

A groove of size 0.5X 5 mm was taken on surface of the AA 6016 plate has dimension of 100 mm X 100 mm X 6 mm and SiC particulate was filled in that groove has shown in the Fig 1.

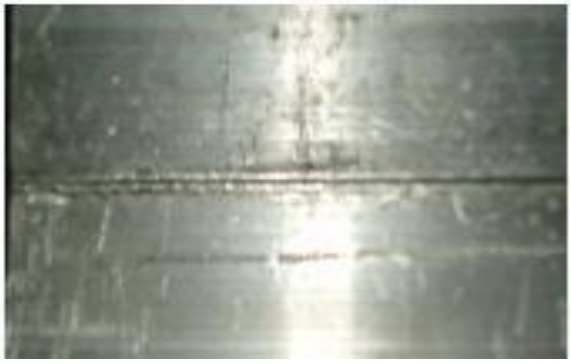

Fig 1. Groove on the AA 6016 plate

The SiC particulate of size 10 micron was filled in the groove manually and top surface of the groove was closed with pin less tool on FSW machine. The tool used for the FPP process was made of High Carbon High Chromic (HCHCr) steel with cylindrical threaded profile, has the shoulder diameter of 18 mm, pin diameter of 6 mm and pin length of 5.7 mm as shown in Fig 2.

The process parameters employed were tool rotation speed 1600 rpm, axial load of 8kN and traverse speed of 60 mm/minute. A specimen of width 10 mm was obtained from the Friction Stir Processed plate as shown in Fig 3 by cutting at the centre of the plate perpendicular to FSP direction

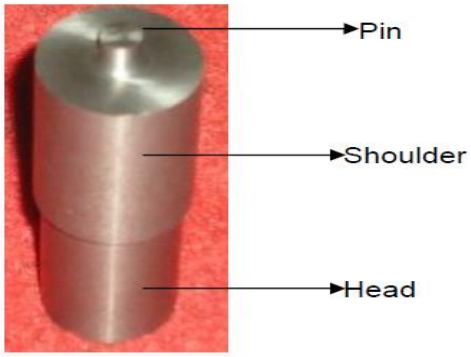

Fig 2. Photograph of FPP tool

The specimen was polished as per standard metallographic procedure and etched with Keller's reagent. The digital image of the macrostructure of the etched specimen was captured using a digital optical scanner. The microstructure was observed using scanning electron microscope.

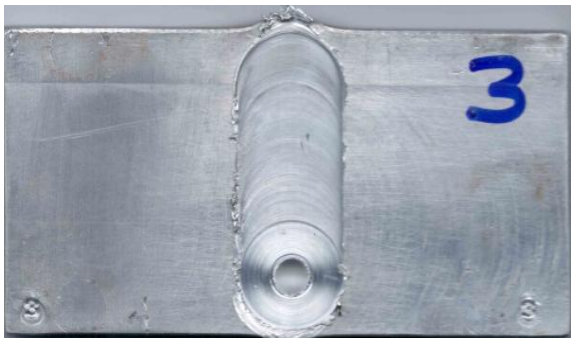

Fig 3. FPP Plate with Rotational Speed of 1600 rpm

The micro hardness of FPP plate of AA 6016 was measured using a micro hardness tester (make: Mitutoyo, Japan) at 500 g load applied for 15 seconds.

The tensile test was carried out using the computed universal Tensile Testing Machine. Initially the specimen was cut according to the American Society of Testing of Materials (ASTM) standard E8 and then testing was carried out. The dimension for the tensile specimen was shown in the Fig 4. The tensile test was carried out using computer aided Universal Testing Machine of 20 KN load.

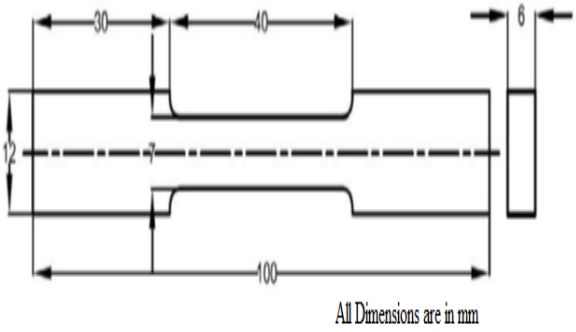

Fig 4. Dimensions of the tensile specimen

III. RESULTS AND DISCUSSION

The macrograph of the cross section of FPP zone is shown in Fig.5.

Fig 5 Macrograph of Friction Powder Plate

It is evident from the Fig that the FPP zone is free from typical FSW defects such as tunnel, pin hole, piping and worm hole.

A. Microstructural Analysis

The OM image was shown in Fig 6 revealed that SiC particles are evenly get distributed in the stir zone and also found that the grain size was considerably reduced due to stirring action of the pin.

Fig 6 OM image of Stir Zone

Fig 7 shows the OM photograph of the transition zone. In this zone the phase shift has been occurred between the stir zone and Thermo Mechanically Affected Zone (TMAZ).

The SiC particulates were completely get packed in the stir zone and few particles were spread to TMAZ zone.

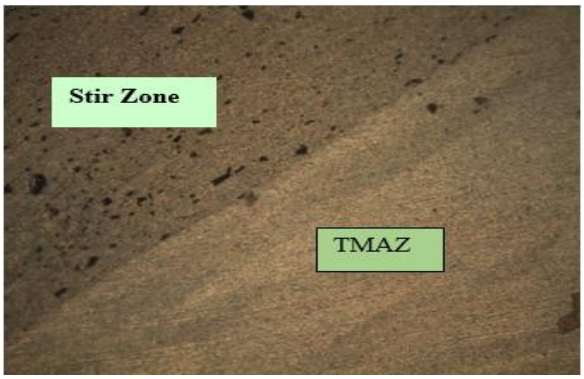

Fig 7 OM Image of Transition Zone

The SEM photograph of processed plate is shown in the Fig 8. The FPP zones revealed that SiC particles were evenly distributed in the stirred zone and get well bonded with Al alloy.

The grain size of SiC particles were gets reduced due to the stirring action of the pin. The even distribution of SiC particles on the processed zone revealed the increase of the strength of the material.

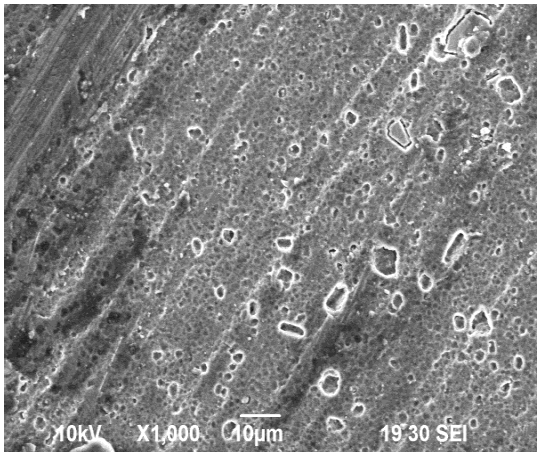

Fig 8 SEM image of Friction Powder Processed Sample

B. Mechanical Characteristics

Micro Hardness Test

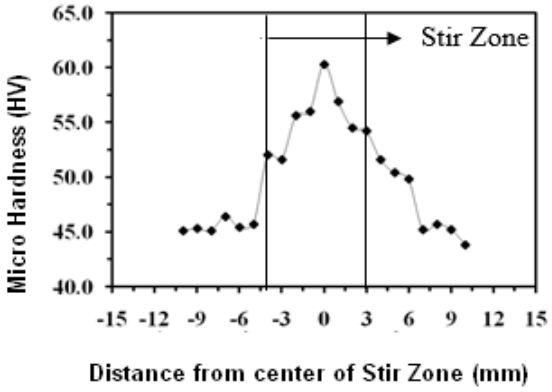

Fig 9 Micro Hardness Test

The micro hardness test for the SiC particles reinforced with aluminum alloy was shown in the Fig 9. It is evident from the figure that micro hardness values gets increased at the stirred zone and get decreased while moving away from the stirred zone. The average micro hardness value at the stirred zone is 60 HV and the value at TMAZ zone is 45 HV. centre while friction stir processing alone takes place away from the centre.

TENSILE TEST

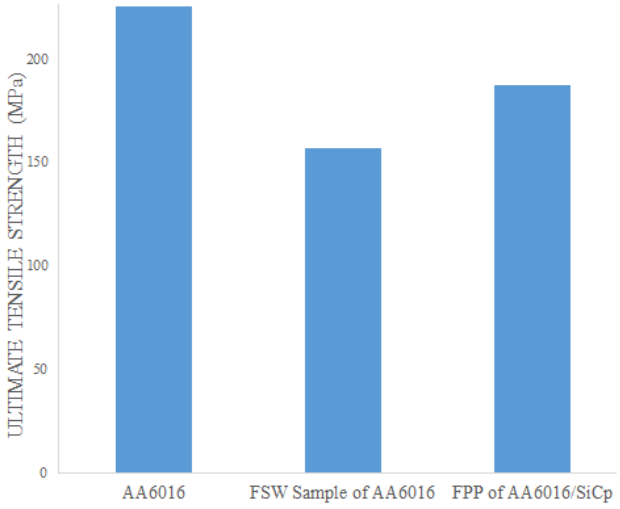

Fig 10 Tensile Characteristics of FPP Sample

The fine grain structure of SiC particles and even distribution of the particle in the stir zone contributed for the increase of hardness value in the processed zone. The factors contribute to hardening of stir zone were; SiC particles offer resistance to the movement of dislocation during plastic deformation and increase its density, uniform dispersion of SiC particles in the aluminum matrix, good bonding between SiC particles and aluminum matrix. The plasticized aluminum alloy has to flow into the groove to fill it to yield a defect free continuous stir zone. Therefore, friction stir welding and processing take place at the

Fig 10 shows the tensile strength of aluminum alloy with SiC particle. The FPP processed plate has the tensile strength of 157 MPa comparatively lesser than base metal without SiC particle. This showed that during FSW process the tensile strength of the material will get loss due to plastic deformation occurred during FSW process. Then by performing FPP after adding SiC_p, tensile strength of the sample (187 MPa) gets increased considerably.

IV. CONCLUSION

From the above study, the following conclusions can be drawn,

a) The micro sized SiC_p can be introduced into the groove made on AA 6016 plate, during FPP process, the grain size of SiC_p gets considerably reduced due to stirring action of the pin.

b) The microstructural observations revealed the even distribution of SiC_p in the stir zone and also revealed the tight bonding of SiC and base metal

c) The microhardness and tensile behavior of the FPP plate showed that reinforcing of SiC_p into the base metal resulted in increase of the material strength.

V. ACKNOWLEDGEMENT

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