INVESTIGATION ON THE PROPERTIES OF Al6063/Al_2O_3 SURFACE COMPOSITE FABRICATED BY FRICTION STIR PROCESSING

M. Appas Muthu[1], V. Sritharan[2],R. Surendran[3] Aby Kurian [4]

[14]*PG Scholar, Government college of Technology, Coimbatore*
[2]*Professor of Production Engineering, Government College of Technology, Coimbatore*
[3]*Assistant Professor Mechanical Engineering, Government College of Technology, Coimbatore*

Abstract - *Friction stir processing (FSP), a solid state technique based on the principle of friction stir welding, is used for material processing in order to modify the microstructures and mechanical properties of surface composites. In this investigation, the influence of tool rotational speed, traverse speed and volume percentage (10%, 17% and 22%) of Al_2O_3 reinforcement particles on wear characterization and hardness of aluminium alloy (Al 6063) based surface composites fabricated via Friction stir processing (FSP) was studied. For various combinations of rotational speed and traverse speed, the average hardness on top surface of processed samples was evaluated. It was found that maximum hardness has been obtained at rotational speed of 1400 rpm and traverse speed of 80 mm/min. The wear rate decreases with increase in the volume fraction of Al_2O_3 particles.*

***Key Words*: Friction Stir Processing, Surface composite, Hardness, Microstructure, Wear Resistance**

1.INTRODUCTION

Friction stir processing (FSP), a solid state technique based on the principle of friction stir welding, is used for material processing in order to modify the microstructures and mechanical properties of surface composites and to fabricate the surface composites. Firstly the tool without pin is used and traverses along the groove consisting of reinforcement particles thus forging it. Later the tool with pin is used and moves along the desired line to cover the region underneath the shoulder. Friction between the tool and work piece results in localized heating that softens and plasticizes the work piece. During this process, the material undergoes plastic deformation, thus resulting in grain refinement to improve its mechanical properties.

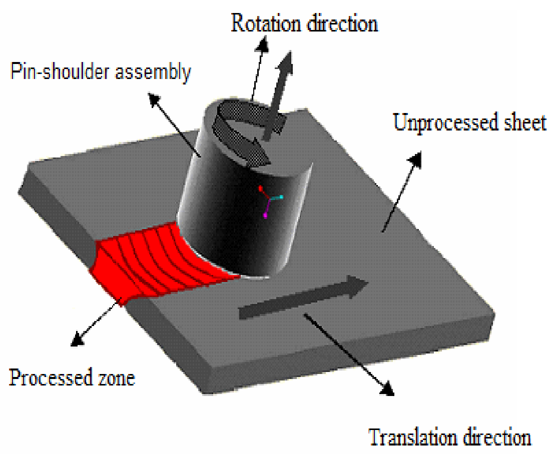


Fig-1 Principle of Friction Stir Processing

1.1 ALUMINIUM ALLOY MATERIALS

Aluminium is not just a single material, but a family of a variety of alloys grouped according to the alloy elements added and that provide the best combination of properties for a particular application. Alloy requirements may include strength, corrosion resistance enhancement and ductility, ease of welding, formability or combinations of some of these properties. Aluminium 6 series contains additions of silicon and manganese up to 1.7% and 1.2% respectively. Used extensively for extruded sections of all shapes and sizes. Common alloys are 6063, 6082 and 6061. Al6063 is an aluminium alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by the association. It's generally good mechanical properties and is heat treatable and weldable. 6063 is the most common used alloy used for aluminium extrusion. It allows complex shapes to form with very smooth surfaces fit for anoidizing and so is popular for visible architectural application window frames, door frames, roofs, and sign frames.

REINFORCEMENT MATERIAL (Al_2O_3)

Aluminium oxide is chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium (III) oxide. It is commonly called alumina, and may also be called Al oxide, or alundum depending on particular forms or applications. It occurs naturally in its crystalline polymorphic phase α-Al_2O_3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

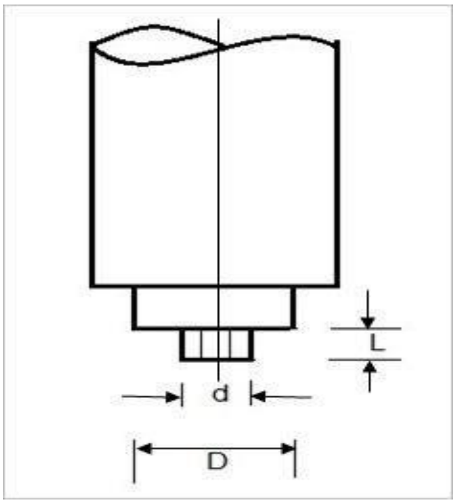
2. EXPERIMENTAL PROCEDURE

Aluminium was used as substrate plates. The plates were cut into dimensions of 200 mm x 150 mm x 6 mm (thickness). The friction stir processing was done using the machine made by GCT, Coimbatore, India. The normal load was kept constant as 10 kN, rotation speed was varied as 1400, 1600 and 1800 rpm and transverse speed was varied as 40 mm/min, 80mm/min and 120 mm/min respectively for all samples. For convenience, the samples were labeled as 1, 2, 3…. And 9 they are listed in table no 1.

Table -1: Experimental design parameters

S. No	Rotational Speed (Rpm)	Traverse Speed (mm/min)	Plunge Depth (mm)
1	1800	40	0.15
2	1800	80	0.15
3	1800	120	0.15
4	1600	40	0.15
5	1600	80	0.15
6	1600	120	0.15
7	1400	40	0.15
8	1400	80	0.15
9	1400	120	0.15

The non consumable tools made of high carbon steels have been used to fabricate the surface composite. The tool dimensions are shown in figure 2 One pin profiles and shoulder profile, has been fabricate surface composite.



D=15mm (Shoulder Diameter)
d=6 mm (Pin diameter)
L=5.5 mm (Pin Length)

Fig -2: FSP Tool Dimensions

An inverted microscope is a microscope with its light source and condenser on the top, above the stage pointing down, while the objectives and turret are below the stage pointing up. The stage of an inverted microscope is usually fixed, and focus is adjusted by moving the objective lens along a vertical axis to bring it closer to or further from the specimen.

The Brinell hardness test method as used to determine Brinell hardness, is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high test load (3000 kgf) and a 10mm wide indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies. The Brinell method 24 applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured across at least two diameters – usually at right angles to each other and these result averaged (d). A chart is then used to convert the averaged diameter measurement to a Brinell hardness number. Test forces range from 500 to 3000 kgf. A Brinell hardness result measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load, for a given length of time.

Fig -3: Experimental Setup of Friction Stir Processing

The weld samples were cut into transverse direction the cross section surface has been prepared for metallographic examination. Before going to take the microstructure, standard metallographic procedures are carried out on processed specimen. Polishing with emery sheets of silicon carbide (SiC) with grit size varying from 220 to 2000 followed by disc polishing. The electrolytic etching techniques are used to observe the microstructure of processed area.

The processed samples are sliced using power hacksaw and then machined to required dimension to prepare hardness specimen as shown in figure 4 , these specimen are taken in the normal direction of the weld. The specimen is loaded and hardness specimen undergoes penetration. The hardness test of processed samples was conducted by using a hardness testing machine.

Fig -4: Specimen for hardness Testing

The processed samples are sliced using power hacksaw and then machined to required dimension to prepare wear specimen as shown in figure 5, these specimen are taken in the normal direction of the weld.

DUCOM pin-on-disc test apparatus was used to investigate the dry sliding wear characteristics of aluminium composite specimens. Dry sliding wear tests were conducted as per ASTM G99 standards. Wear specimen of 9 mm side square and 40mm length were machined from FSP samples and then polished metallographically. Cleaned pins of unreinforced aluminium alloy and composites were pressed against a rotating EN32 steel disc (hardness 65 HRC) of diameter 165 mm and thickness 8 mm by applying the load at room temperature for 2 minutes. Surface roughness of disc was 1.6μm RA and all the specimens were ground using 600-grid emery paper to have test specimens with uniform standard surface finish. The experiments were conducted at room temperature (25 °C and relative humidity 65%). Load is applied through a dead weight loading system to press the pin against the disc. During experiment the specimens remains fixed and disc rotates. Wear test was carried out at sliding velocities of 2 m/sec, 3 m/sec and 4 m/sec against normal loads of 20 N, 50 N and 70 N. In this work, wear rate was calculated after a time period of 2 minutes. Care has been taken that the specimen under test was continuously cleaned with woolen cloth to avoid the entrapment of wear debris and to achieve uniform experimental procedure. After each test the disc was cleaned using acetone solution.

Fig -5: Specimen for Wear Test

3. RESULT AND DISCUSSIONS

In order to view the distribution of the reinforcement in the base metal, an inverted microscope is used. The specimen is etched by keller's reagent and is immersed for about 15 seconds. The photo micrographs of the composites at 50 X magnification are shown below.

The microstructure of the various specimens at the processed zone has been observed. The compounds are uniformly distributed over the processed region. The increase in volume percentage provides effective intermixing of compounds.

Brinell hardness values of composite specimens show an increase in hardness with decrease in rotational speed. Hardness value of pure aluminum matrix was 55 BHN. Composites rotational speed at 1800rpm shows the lowest hardness value (64 BHN) while composites rotational speed at 1400rpm shows the highest hardness (72 BHN). This is due to the high heat generation that causes matrix softening which decreases the macrohardness. This softening of the nugget zone resulted in coarsening and/or dissolution of strengthening precipitates in the aluminum matrix which occurs especially in heat treatable aluminum alloys.

4. CONCLUSIONS

Al6063/Al_2O_3 AMCs were fabricated using FSP and the effect of Rotational Speed, Traverse Speed, Al_2O_3 particles and its volume fraction on microstructure, hardness and sliding wear behaviour were analyzed. The following conclusions are derived from the present work.

- The distribution of Al_2O_3 particles was fairly homogenous in the composite irrespective of the volume fraction. Al6063/Al_2O_3 AMCs exhibited a reduction in the average grain size during FSP. A clean interface was noticed between Al_2O_3 particles and the Al6063 aluminium matrix.

- It was observed that the hardness increases when decreasing the rotational speed and showed higher hardness value in Al6063/Al_2O_3 surface composite due to the high heat generation that causes matrix softening which decreases the macrohardness. This softening of the nugget zone resulted in coarsening and/or dissolution of strengthening precipitates in the aluminum matrix which occurs especially in heat treatable aluminum alloys. It was found that maximum hardness has been obtained at rotational speed of 1400 rpm and traverse speed of 80 mm/min.

- Al_2O_3 particles improved the wear resistance of Al_2O_3 particles is increased. The rate of wear was found to be 0.00071 mm^3/m at 10 vol.% and 0.00053 mm^3/m at 22 vol. %. It was also observed that high wear resistance exhibited in the Al6063/ Al_2O_3 surface composites due to presence of Al_2O_3 acted as load bearing elements and solid lubricant respectively.

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