Effect of Zirconium Dibromide and Aluminum Oxide Hybrid Particle Reinforcement on the Mechanical, Microstructure and Wear Properties of AA6063 Surface Metal Matrix Composite

R. Raja¹, Sabitha Jannet ¹*, Christo joy², Jeffin Johnson³

¹Assistant Professor, Mechanical Department, Karunya Institute of Technology and Sciences, Coimbatore-641114, Tamilnadu, India.
²UG Scholar, Mechanical Department, Karunya Institute of Technology and Sciences, Coimbatore-641114, Tamilnadu, India.
³Assistant Professor, Mechanical Engineering Department, Rajagiri School of Engineering & Technology, Kochi, Kerala, India.

*Corresponding author Email: sabithajannet@gmail.com

Abstract. In the present study Aluminum 6063 as the matrix and with Zirconium dibromide and Aluminum oxide as the reinforcement particle Metal Matrix surface composites were fabricated by friction stir processing. By the addition of reinforcements such as Zirconium Dibromide and Aluminum Oxide used as the strengthening agents during FSP process certainly made the MMC more wear resistant and harder than the base matrix. The effect of varying reinforcement percentage on the Mechanical wear and microstructure properties were studied. The Micro hardness showed an increasing trend in the nugget zone. The wear rate decrease with increase in volume percentage of hybrid reinforcement. FESEM images of the samples displayed uniform distribution of the particle in the matrix. And also reiterated the formation of hybrid particles.

Keywords: Friction stir processing, Hybrid surface composite, Wear, Microhardness, FESEM

1. Introduction

Aluminum alloys are the answer for the culmination of searches made by material scientist for the cost effective functional material. Aluminum Metal Matrix has been replacing the conventional engineering materials because of its properties which could match the anticipations of the industrial requirements. Friction stir processing is a derivative of FSW and has been extensively tried to fabricate surface composites. The proper dispersion of the strengthening agents while processing the metal matrix composites is very much required since it will ensure not only its upgradation over various characteristics like improved wear resistance and hardness but also over its metallurgical attributes. Q. Liu et al[1] reported that with increase in the addition of MWCNTs there was gradual increase in the tensile strength and microhardness. H. I. Kurt et al[2] inferred the effect of various proportion of hybrid particles and the process parameters such tool traverse speed, rotational speed and tool profile’s effect on the properties. I Dinaharan, et al[3] analyzed the mechanical and wear properties of aluminum copper cast. H. I. Kurt et al[4] studied the wear behaviour of AA6061 T6
reinforced with Graphite and Titanium Carbide microparticles. S. J. Abraham et al [5] reported wear mechanical behaviour and thermo mechanical studies on the AA6063 reinforced with Quartz particles. M. Balakrishnan et al [6] studied the tensile behaviour and microstructure analysis of Aluminum ferrite reinforced AA 6061.

The micro features of metals can be enhanced through friction stir processing method. The processing factors, tool's shape and size and associated joint structure make use of the prominent effect on heat dissipation and the dispersion of material, consequently enhancing the interior of the metal matrix body even from the atomic level. For that purpose a fast moving tool which is rotated and forced against the metal matrix along with the reinforcements so that the region which is exposed to the vigorously acted tool would undergo plastic deformation uniformly under the frictional heat. Properties of materials like aluminum, copper, magnesium have been upgraded by the process of FSP extensively. The groove size and the fineness of the strengthening agents affect and even could predict the final characteristic of the composite. R Beygi et al [11] found out that the fineness of the titanium carbide powder increased drastically the yield strength of the aluminum composite. Size of the reinforcements largely aided the formation of a aluminum composite with superior strength than the base matrix.

In this present study Aluminum alloy 6063 is reinforced with Zirconium dibromide and aluminum oxide micro particles and material and mechanical characterization were conducted.

2. Materials and Methods
Hybrid reinforcement was achieved by a Magnetic stirrer. Aluminum oxide with zirconium dibromide was used in equal percentage. Acetone was used for the mixing in a magnetic stirrer which was stirred 1560 rpm to obtain hybrid particles. V shaped grooves were machined using EDM of 0.3mm, 0.6mm, 0.9mm widths and 5mm depth and the particles were packed into them. A vertical milling machine was used to carry out the FSP at Vigshan tools, Coimbatore. The samples thus prepared underwent a single run of FSP with a pinless tool. The pinless tool solves the purpose of the powder being intact in the groove. Subsequently 3 runs of FSP were done on the samples with a cylindrical tool of shoulder diameter 18 mm and pin diameter of 6 mm with a pin length of 5 mm. The FSPed samples were then cut in dimensions of 30 mm X 30 mm for wear and microhardness tests. The wear tests were conducted on Pin on Disc apparatus. The microhardness tests were also conducted using Vickers hardness testing machine. The samples were then polished and etched to obtain detailed microstructure from FESEM images. The various compositions of the reinforcement and matrix is shown in detail in Table 2.

| Elements | Si  | Fe   | Cu  | Mn  | Mg  | Cr  | Zn  | Ti  | Al  | others |
|----------|-----|------|-----|-----|-----|-----|-----|-----|-----|--------|
| Weight % | 0.2 | 0.35 | 0.10| 0.10| 0.45| 0.10| 0.10| 0.10| 98.75| 0.15   |

Table 1. Chemical composition of Al6063

| SI No | Sample | AA6063(%) | Zirconium Dibromide + Aluminum Oxide(%) |
|-------|--------|-----------|----------------------------------------|
| 1     | A1     | 95        | 5                                      |
| 2     | A2     | 90        | 10                                     |
| 3     | A3     | 85        | 15                                     |
3. Results and Discussion

3.1. Microhardness

The three samples which were prepared with 5%, 10% and 15% of ZrBr$_2$+Al$_2$O$_3$ had undergone microhardness testing in order to analyze whether any enhancement has obtained in the regions nearby and within the stir zone.

![Microhardness variation on the three zones of the hybrid surface composite](image)

Figure 1. Micro hardness variation on the three zones of the hybrid surface composite

The micro hardness test indicated that the samples showed an increase in the micro hardness in the stir zone. From the figure 1 it can be inferred that the increase in the micro hardness in the stir zone compared to the advancing and retreating side is majorly due to the grain size reduction. Cao R. et al, this would have occurred due to reinforcement of hybrid particles and the severe plastic deformation which the samples would have undergone during FSP process. In the FSP zone hardness increases due to high heat produced in the zone and because of high heat, dispersion of reinforcement has taken place in a homogeneous manner and thereby no chance for porosity in that particular region it enables the FSP zone to have high hardness compared to the other zone.

A considerable variation in the hardness of the composite and the base matrix was observed, in addition, the micro hardness of material away from the stir zone was found out to be 27 VHN whereas that within the stir zone is as high as 66 VHN. By FSP due to the controlled rotation of the processing tool had ensured grain refinement and thereby led to an increase in the micro hardness of the composite. There was a considerable mix up of the reinforcements to strengthen up the composite during the dispersion and led to the uniform distribution of the elements within the nugget zone.

3.2. Wear Rate

Using the pin on disc apparatus, the wear rate of the three samples were measured, in addition, it was observed that the wear rate gradually decreased with increase in % of ZrBr$_2$+Al$_2$O$_3$ and finally the sample with 15% showed the least wear rate among the taken samples.
The appreciable interfacial bonding between the reinforcement and the matrix in advents the sliding of the surface. The contact surface between the pin and the aluminum alloy 6063 is reduced due to the presence of hybrid particles can be one of the reasons for reduced wear rate also reported by Maurya S et al[8] and Vijayan et al[9], this can also be attributed to the reason that hard materials usually have lesser wear rate compared to soft materials.

Usually, aluminum being a softer material tends to wear out more than other materials in use even though it has a better possibility in aircraft and automobile applications if its wear rate could be controlled by the addition of proper reinforcements. Consequently, the particles will get into the aluminum matrix especially in areas where it would wear out more easily thereby enhancing the resistance to wear against the contact.

3.3. Microstructure Analysis

The microstructure from the FESEM images shown in Figure 3 (a-c) indicates the distribution of the reinforcement particle at various volume percentages. The images displayed show an uniform distribution of the particles also analyzed by A Sert et al[10].The matrix underwent severe plastic deformation leading to the stirring and uniform distribution of the particles. It was also observed a few cracks in the images which might be due to non-uniform cooling after the process.

The severe plastic distortion by the rotating tool had brought the reinforcements into the matrix especially in the stir zone where dynamic recrystallization had taken place during the FSP process. When the temperature rose above recrystallization temperature because of the friction between tool and substrate made the material more plastic rather than liquid which led to uniform as well as proper dispersion of the strengthening agents in to the aluminum matrix.
4. CONCLUSION

Zirconium dibromide along with Aluminum oxide micro particles were used to reinforce Aluminum alloy 6063. Friction stir processing was implemented to fabricate the Aluminum Metal Matrix surface composites.

1. The wear test for the composites were conducted and the result shows that wear rate decreases as the volume percentage of the reinforcement added into the composite increases, what's more, it was found out that Al6063 with 15% of ZrBr$_2$+Al$_2$O$_3$ reported least wear rate among the samples due to the considerable presence of hybrid particles within the fabricated composite.

2. The result for the micro hardness test clearly shows that hardness value increases as the volume percentage of the reinforcement added to the composites increases, in fact the grain refinement which had taken place because of the rotation of the tool against the solid substrate with the strengthening elements supported the case for such an improvement in the mechanical characteristics. The microhardness of the sample with 15% of ZrBr$_2$+Al$_2$O$_3$ was observed to be the largest among the samples due to the fact that added hybrid particles which dispersed uniformly within the matrix had kept the entire fabricated composite intact without any further dislocation towards the slipping plane. The microhardness was raised to above 65 VHN from 25 VHN in the nugget zone and it is considered to be an appreciable amount of enhancement happened to the property after FSP.

3. The FESEM analysis indicates the presence and uniform distribution of reinforcement particles in the matrix metal. Being a solid state process, due to the intense plastic deformation under frictional heat led to the dynamic recrystallization of the material and thereby distributes the hybrid micro particles uniformly especially for the sample with 15% of ZrBr$_2$+Al$_2$O$_3$ which was observed from the FESEM images.

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