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Investigation of Wear Loss in Aluminium Silicon Carbide Mica Hybrid Metal Matrix Composite

S Sharath Kumar[1], M Shanmuga Priyan[2], P Saravanan[3], R Raghuram[4], T Anand[5]

[1,2,3,4,] *B.EMechanical, department of mechanical engineering, Sri Muthukumaran Institute of Technology, India*
[5]*Associate professor, department of mechanical engineering, Sri Muthukumaran Institute of Technology, India*

Abstract: *Aluminium which is one of the most widely available materials in the world has proven a lot of use in modern technological developments. Aluminium 6061 T6 is a tempered alloy of aluminium containing different compositions of various materials together with it. Aluminium is used as alloys and also as composites for various applications such as aircrafts, automobile body parts, engine parts, SCUBA tanks, yacht construction etc. Even though aluminium alloys are used in various fields due to its unique and specific properties, certain properties like wear resistance can be improved to obtain a broader base of applications. A hybrid metal matrix composite is formed combining aluminium silicon carbide and mica in three different compositions keeping silicon carbide constant and increasing the mica percentage. A drum type wear apparatus is used to determine the percentage of wear loss in different compositions using different loads and it is found that the wear loss decreases linearly as the mica percentage is increased.*

Keywords: *Aluminium, Silicon Carbide, Mica, Hybrid Metal Matrix Composites, Wear Loss, Drum Type Wear Apparatus*

I. Introduction

A composite material is composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents. One of the many advantages of using a composite material is that we can change the properties of the material on our own will and wish. Composites can be very strong and stiff and yet very light in weight therefore the ratios of strength to weight and stiffness to weight are several times greater than steel or aluminium, there are many other benefits of using a composite material such as increased toughness, stiffness, tensile strength, thermal and electrical properties which may prove useful in various applications.

There are various ways of classifying composite materials. One of which is based on the matrix phase. If the material is formed with a metal as the matrix phase and ceramics or metals as the reinforcing phase then it is known as a metal matrix composite. Metal matrix composites have found various uses such as in drills, tank armours, high end sport equipments and also in aerospace applications such as jet landing gears etc. However the main application of metal matrix composites lie in automobile field where it is used as driveshaft's, disc brakes, push rods, cylinder linings and also as a reinforcing in cylinder sleeves. All the above applications have a direct relationship with wear of the component. Thus improvement in the wear loss found finds itself very useful. We have gone though different journal papers in which the addition of silicon carbide and mica has been made and has a significant impact in the wear loss.

Suptal (2013) has studied the influence of reinforcing silicon carbide with aluminium and has found that increase in silicon carbide percentage (5%) increases the wear resistance.

Rajmohan (2013) has studied the result of forming a hybrid composite of aluminium (Al 356) with silicon carbide (10%) and mica (3%) and has found out that there is a reduction in wear loss as the percentage of mica and silicon carbide are increased.

Similarly various papers published by different authors relating to the effect of silicon carbide and mica reinforcements were studied and it indicates that there is a reduction in wear loss. Efforts were taken to prove that the increase in percentage of mica would have a significant increase in the wear resistance.

II. Experimental Work

2.1 Materials

The materials chosen for this investigation are tempered aluminium 6061 T6, Black silicon carbide which is of 4 micron size and muscovite mica which is a natural mineral of 26 micron size. As Aluminium's applications are limitless it is mandatory to constantly improve its properties so that it could be used much more effectively and efficiently. As a result aluminium 6061T6 was selected as the base material whose

characteristics had to be improved. Silicon carbide was chosen as a reinforcing material as it is one of the hardest materials available on earth whose Mohs' hardness ranges from 9 to 10. Mica which is an easily available mineral is mainly added as a reinforcing material to increase the machinability. Aluminium Silicon carbide composites exhibit properties such as High tensile and shear strength, Good fatigue and fracture properties, Good erosion and corrosion resistance. Dimensional stabilities etc. whereas mica exhibits some unique properties such as high Chemical inertness, Elasticity, flexibility etc

This study concerns the effect of wear resistance when the percentage of mica is increased; therefore 3 different compositions are formed keeping silicon carbide (4%) as a constant and mica (1, 2 and 3%) varying in each composition

2.2 Specimen Preparation

The hybrid metal matrix composite is produced by mixing the base material with the two other reinforcing materials. This can be achieved by using various fabrication techniques such as solid and liquid fabrications. Considering factors such as availability, cost, ease of preparation etc stir casting was selected which is one of the liquid fabrication techniques which involve uniform dispersion of the reinforcing materials in the base material.

Stir casting is the most popular commercial method for producing aluminium composites. In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix a composite was initiated in 1968.Mechanical stirring in the furnace is a key element for the process. The resultant molten alloy along with ceramic particles can be used for die casting, sand casting etc. It is suitable for producing composites with up to 30% volume fractions of reinforcement there are various parameters that have to taken into considerations while doing stir casting such as stirring speed, Time, Temperature, preheated mould temperature, blade angle, pouring temperature etc.

Stir casting was done using a furnace with a maximum temperature settable as 1000°C. A graphite crucible of 2KG capacity was selected according to the furnaces dimensional specifications. The base material that is aluminium was placed inside the graphite crucible and was kept into the furnace at a temperature of 850°C which is higher than the melting point of aluminium which is around 630 °C so as to obtain the molten state. The reinforcements were also kept at the same temperature to improve its wetability with aluminium.

Fig.1 shows mica

Fig.2 shows SiC

Fig.3 shows aluminium

Fig.4 shows stir casting

The dies were cleaned using emery paper, and graphite was applied along with kerosene to prevent the material from sticking to the dies surface. The dies were preheated to a temperature of 500°C to reduce shrinkage and blow holes formation when molten metal was poured into it. Three different compositions were taken keeping % of silicon carbide a constant 4% and increasing the mica percentage from 1, 2 and 3 % respectively in each composition. Cylindrical dies of sizes 20mm diameter and 175mm length were taken so as to prepare the specimens for wear analysis as per ASTM standards. Magnesium was added to compensate for the loss during heating and also to increase the wetability between the materials. As the temperature set in the furnace was achieved the crucible was taken out, degasser and coverall were added to the molten metal to remove the impurities of the material. The reinforcement materials were added with the molten aluminium and were again kept inside the furnace to obtain a temperature of 850°C. After achieving the temperature a stirrer was introduced inside the furnace which rotated at 300rpm so as to distribute the reinforcement equally. The stirring was done keeping the temperature constant and was carried out for approx 10minutes. Then the molten material obtained was poured into the cylindrical die and was set to cool off for three hours after which the die was opened to obtain the specimen for wear analysis.

2.3 Testing of Wear Properties

Wear is one of the important tribological properties that play a major role in deciding the use of the material. There are various methods used to check wear loss in a material, of which a pin on drum type apparatus was selected. This test simulates the wear that occurs during crushing and grinding action which happens to produce a more realistic result when compared to other methods. The wear resistance is measured by moving a test piece across the surface of an abrasive sheet mounted to a revolving drum and is expressed as volume in mm^3. The test samples are machined as per the ASTM standard D 5963-96 according to which a cylindrical sample of 15.8 mm diameter and 10mm thickness is required.

Fig.5 shows the wear samples before and after testing

Fig.6 shows the drum type wear apparatus

The test method is performed under specified conditions using a cylinder drum of 150mm diameter, sliding distance of 500mm, equivalent revolution of 84 times, rotational frequency of 40 rpm, and different contact pressures of 1,2 and 3kg. The abrasion tester consists of a machine frame holding a laterally movable test piece holder, a rotary cylindrical drum to which an abrasive sheet can be fastened. Aluminum oxide or corundum is used as the abrasive paper with a grit size of 60. The test piece is initially weighed and then fitted in the holder which is loaded with the given contact pressure. The drive system is operated to rotate the drum in clockwise direction. The holder is made to move laterally from right to left so that the material comes in contact with the grain faces of the abrasives. After the test piece reaches the end of the drum, it is removed and is weighed. The difference in the weight gives us the weight loss of the material due to wear. When the difference in weight is divided by the initial weight of the material before wear, the wear loss of the material can be determined.

III. Results and Discussion

3.1 Microstructure Study

Uniform distribution of reinforcement materials in the base matrix is required in order to obtain perfect results in testing. To verify whether the distribution is uniform, a microstructure study is to be conducted. A scanning electron microscope was selected based on its superior magnification of 5X to 300,000X. Before conducting the microstructure study, the surface of the specimen is to be cleaned, polished and etched perfectly.

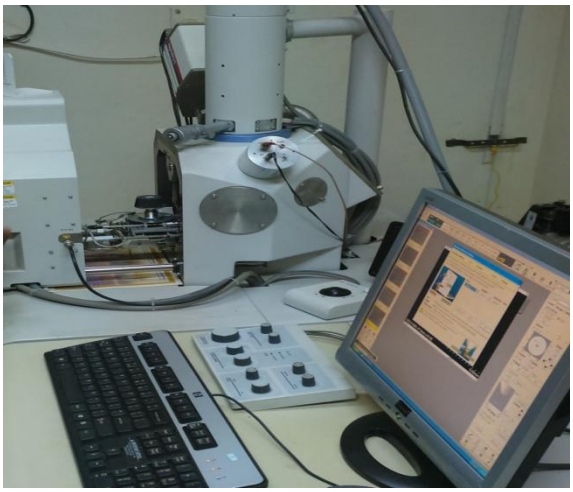


Fig.7 shows the scanning electron microscope

Fig.8 shows the etched sample for SEM analysis

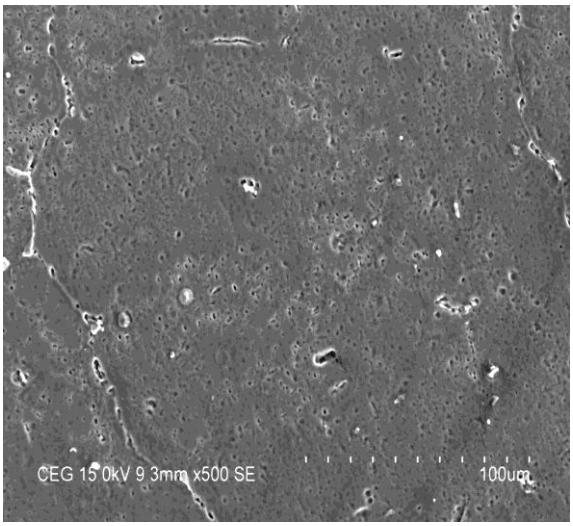


Fig.9 shows Al + SiC (4%) + mica (1%)

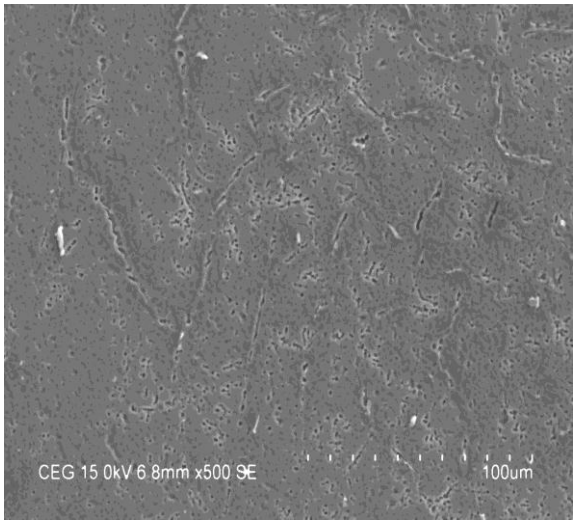


Fig.10 shows Al + SiC (4%) + mica (2%)

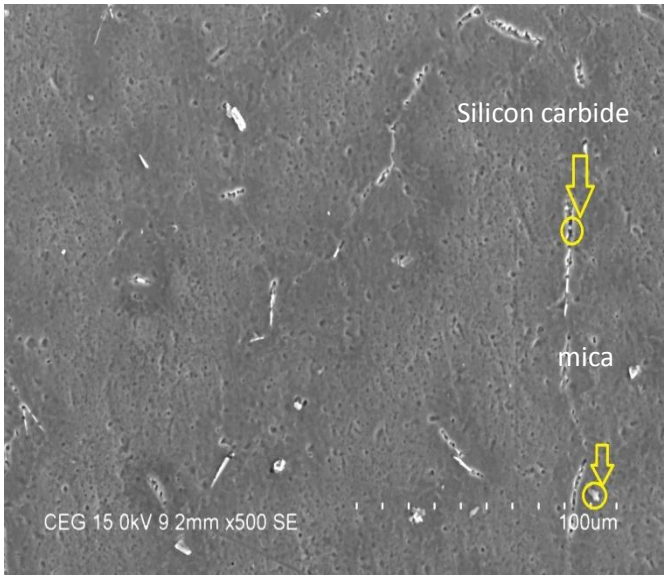


Fig.11 shows Al + SiC (4%) + mica (3%)

The SEM analysis clearly shows the distribution of silicon carbide and mica particles in aluminium. It can be obserevd that the mica concentration has increased in each successive composition.

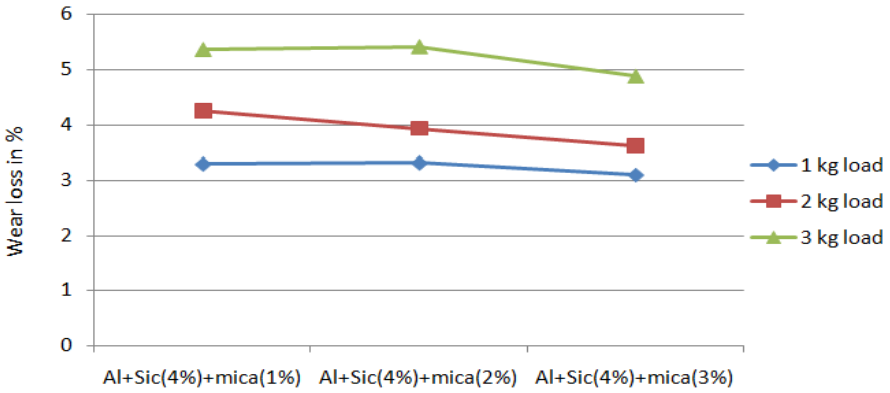
3.2 Wear Resistance Test

Three different compositions are taken in order to determine the effect of increase in mica on the wear property of aluminium silicon carbide composite. Three different loading were also done for each composition in order to determine the effect of increase in load.

3.2.1 Variation of wear loss due to loading in different compositions

s.no	loads / Compositions	Al+Sic(4%)+mica(1%)	Al+Sic(4%)+mica(2%)	Al+Sic(4%)+mica(3%)
1	1 kg load	3.29	3.31	3.09
2	2 kg load	4.26	3.93	3.61
3	3 kg load	5.37	5.42	4.88

Table.1 shows the Variation of wear loss due to loading in different compositions



Graph.1 Wear loss vs. compositions in various loading conditions

Graph.1 shows the variation of wear loss present in each composition by varying the loading conditions. It is a well known fact that as the contact pressure between any two surfaces increases, the wear loss between them also increases. This can be well seen in each of the compositions. As the contact pressure is increased the wear loss also increases. From the graph it is also observable than the wear loss decreases from 1st composition to third composition. This is mainly because of the increase in mica percentage, as the percentage of silicon carbide is kept as a constant.

IV. Conclusion

From the investigation it is observable that aluminium metal matrix composites can be fabricated using stir casting method, but the amount of reinforcements that can be added to the matrix phase is very less. As a result of which we had kept the percentage of reinforcement to be lesser than 10%. If the percentages of reinforcements are increased, uniform distribution will not be achieved and the specified percentage composition cannot be obtained. From the SEM photos it is clear that the reinforcements have been uniformly distributed in all the three compositions. From the result what we got shows that the wear loss decreases as the mica percentage is increased. Thus it is proved that mica has an effect on wear property such that when mica is added it reduces the wear loss and increases the wear resistance of the material.

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