Investigation on Mechanical Properties and Wear Behavior of Al-Si-SiC-Graphite Composite using SEM and EDAX

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Abstract: In this research article mechanical properties and wear performance with regard to the tribological behavior of aluminum metal matrix composites reinforced with silicon carbide particulates and added with graphite particulates as a second reinforcement has been analysed. The method of stir casting procedure was used for the preparation of composite samples for analysis and those samples were tested for the presence of reinforcement particles using scanning electron microscope and EDAX. Uniform distribution of reinforcements and their presence was well established using characterization. The different mechanical properties have been tested and found to be better than the base alloy. Wear tests were performed to study the influence of graphite particulates and SiC particles through pin on disc tester. The experimental results of wear test reveal that, the formation of lubricate film with 4 kg of load establish the influence of graphite in the composite materials.

Keywords: Metal Matrix Composite, SiC Particulate, Graphite Flake, SEM, EDAX

1. INTRODUCTION

Aluminum is a light weight metal used extensively in the automobile sector. The addition of silicon provides enough strength but with certain limitations. Hence, addition of hard particles like silicon carbide (SiC) was aimed at. Aluminum metal matrix composites with multiple reinforcements are found to be most suitable for many applications due to its various enhanced properties and it is a best alternate material for single reinforced composites, graphite (Gr) was also added as a multiple reinforcements [1], [2]. Over the last three decades different composites, plastic and ceramic materials have emerged as manufacturing materials in different disciplines. The effect on erosion performance and various properties of SiC duly filled with glass fibers on polymer reinforced composites were scientifically studied. From the results it was found that the filled composite gives more erosion resistance than unfilled composite [3], [4]. Glass epoxy composite with filler material of granite and fly ash were prepared to evaluate the frictional performance using different water proof abrasive papers under multi pass state. The obtained results indicated that the wear loss increases when the abrading distance increases and also the major specific wear rate reduction occurred after amalgamation fillers were introduced into composite [5]. The erosion performance of the different hybrid composites with changeable surface impact velocity under different times was carried out to find the different mechanical properties. From the results it was concluded that the hybrid composite has more strength as compared with unfilled composites [6]. It is necessary to put integrated effort during the various process of design and development and also different manufacturing process including management program for preparation of composites which become competitive with metals. The different mechanical parameters and image value of Al/10.5Si/2.0Cu recycled die casting alloy with the effect of Strontium (Sr) addition were examined which revealed that the addition of Sr changed the micro structure of the eutectic silicon from an acicular to lamellar shape [7]. When the refining performance and microstructure of a master alloy of Al/18Si/2.5P and its consequence on quick solidification were studied and the results stated that when the size of alkaline phosphates particles was reduced, the solidification rate increased [8]. To expand the low cost aluminum alloys with high temperature for different applications like aeronautical and automotive sectors were planned during the effect of replacement on Erbium (Er) for Scandium (Sc) with 0.01% or 0.02% in an Al with 0.06% of Zirconium (Zr) and 0.06% of Sc alloy and toughness of the alloy is a significant mechanical property [9], [10]. The results of cooling rate and the range of aging temperatures and time were studied for Sr with Manganese (Mn) in addition with a composite alloy with regular samples in order to emphasize the different functions of metallurgical constraints on both crack initiation and promulgation processes [11].

The Al/Gr composites showed a less frictional coefficient and wear behaviour compared with base alloy during the sliding of both dry and oil impregnated. On the other hand the base alloy and Al/Gr composite containing various graphite accompaniments, the coefficient of friction in the oil impregnated sliding was not affected by the amount of graphite and was lower as compared to that of dry sliding attributable to formation of an oil film between the two contacting surfaces [12]-[14]. An analysis was done in Al/SiC/Gr mixed with reinforcement and found that the sliding speed, load and distance were distressing the wear performance and also internal contacts occurred between those parameters in Al/Si/Gr hybrid composites. Generally for tribological purposes the most excellent suited hybrid composites are Al/SiC compared with composite of aluminium with silicon carbide due to the lesser amount of wear performance [15]-[17]. LM25/SiC/Al_2O_3 hybrid composite specimens with reinforcements were produced to find out the wear performance by liquid metallurgy method. From the results it was found that, the wear resistance was increased when the reinforcement weight percentage was increased [18], [19]. Aluminum alloy with SiC and Al_2O_3 reinforcements was subjected to dry wear performance over a range of 29 to 49N weight. The observed results concluded that reinforced composite particle reduces the wear rate of the prepared composite up to 25% of volume fraction [20]-[22]. The strengthening of composite depends upon particle size, shape, volume fraction and distribution. The composite strengthening depends upon particles closure in the composite matrix. The interface between the reinforcing particles and the matrix are responsible for the raise in mechanical properties of composite [23], [24]. With the above literature an attempt was made to prepare Al/Si/SiC/Graphite composite using stir casting process and investigate the mechanical properties and wear behavior with different techniques.

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2. MATERIALS AND METHODS

2.1 Aluminum Silicon Alloy

Aluminum silicon alloy and graphite powder were used as matrix alloy and reinforcement phase respectively. 10%, 0.10%, 0.10%, 0.50%, 0.60%, 0.20% of Si, Mg, Cu, Mn, Fe, Ti respectively were taken with Al of remaining portions are the mixture to prepare Al-Si alloy. The composite required for the investigation was fabricated by gravity die stir casting procedure. The final composites were cast to the size of 25 mm diameter and 250 mm length. Mineral graphite is one of the allotropes of carbon. Graphite is the most stable form of carbon under standard conditions. SiC particles are present in the molten Al/Si alloy.

2.2 Stir Casting Process

The melting process was carried out in a stainless steel crucible using electric resistance set up .The steel crucible and base ingot were preheated to 150˚C and 200˚C respectively. The pouring temperature was maintained at 760˚C and necessary molten treatment such as fluxing, degassing was carried out. The muffle furnace was heated up to 800˚C and once it reached the set temperature, SiC and graphite were added. The whole material reached the molten state. The stirrer at 350 rpm was used for mixing of the reinforcement of all the material into pure aluminium matrix. The composite materials melt at 658˚C and when mixing was completed then mould was heated to 400˚C by flame gas and then molten metal was poured into this mould. When the material had come in contact with atmosphere, a sparking sound created by the molten material due to huge temperature difference. The composite was taken out from the split mould for further machining and specimen preparation. The composition of prepared composite was with 66 grams of SiC, 66 grams of graphite and 2000 grams of aluminium.

3. EXPERIMENTAL METHODS

3.1 Tribology Tests

To characterize the tribological properties of the prepared composite, the experiments were performed using a computer controlled pin-on-disc tribometer under ambient conditions of room temperature and humidity as per ASTM test standards and as shown in Fig. 1. EN31 steel disc with the hardness of 60 HRC and ground to surface finish of 1.6 Ra was mounted and secured tight perpendicular to the axis of rotation. The wear test specimens were machined into pins of size 10 mm diameter, 25 mm length using a lathe from the cast composite. The end of specimens were polished with abrasive papers of grade 1\0 and followed by grade 4\0. The pins were cleaned with acetone and weighed before and after testing to an accuracy of ±0.0001g to calculate the wear value. The sliding end of the pin and the disc surface were cleaned with acetone before testing. The pin specimen was inserted in its holder and adjusted, so that the specimen was perpendicular to the disc surface during contact. Appropriate load from 1 kg to 4 kg were added to the system lever to develop the selected force pressing the pin against the disc. The counter balance weights were accustomed, so that the whole cross section of the specimen was mounted with load. The load acting tangentially on the disc and the depth of wear were noted through the electrical display unit, which increases with the application of load. Initially the displacement sensor and the tangential force sensor were adjusted and set to zero, which measures the

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tangential force and the pin displacement. This tangential component was used for calculating the friction component. The signals from sensors after processing in controller were used to investigate the wear mechanisms and characteristics of transfer layer and the pins were analyzed using Scanning Electron Microscope (SEM).

Fig. 1 Pin-on-Disc Tribometer

4. RESULTS AND DISCUSSIONS

The prepared composite was subjected to various mechanical and wear tests. From the observed results the following several inferences were drawn.

4.1 Microstructure Analysis

The microstructure image of the prepared specimen was observed and is shown in Fig. 2. The image shows the random distribution of an intermetallic spacing in the matrix and it also notifies about the grain orientation and distribution. It was found that the specimen contains 10% by weight as reinforcement had more randomness. It was observed that alumina particles were deposited on the aluminum matrix. Alumina has a certain attraction towards aluminum. The microstructures of the specimen are classified, where white back ground is aluminum, dark portion is graphite, light black portion is silicon and grey portion is primary silicon crystal.

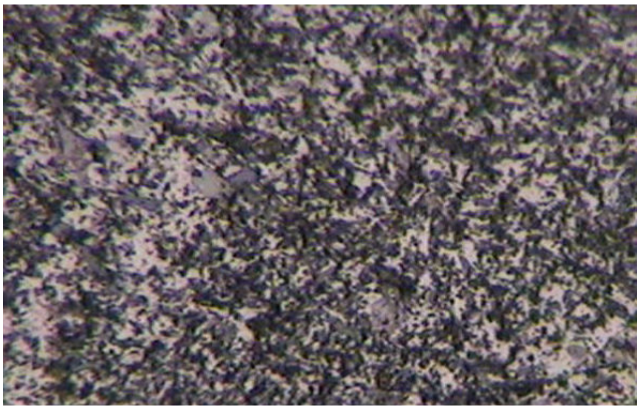

Fig. 2 Microstructure of Al-Si-SiC-Gr Composite

4.2 Hardness Investigation

The hardness value of the Al-Si alloy was calculated as per the ASTM standard by using the hardness testing machine. The alloy was mounted on the hardness testing machine and then 100 kg of force was applied on the specimen material. From the observed values it was found that the hardness of the prepared composite has been increased to 108 and the values are given in the following Table I.

Table I. Hardness Values of Various Specimens

Specimen	Diameter of Indentation (mm)	Hardness (BHN)
Pure Aluminium	1.63	59
Al-Si-Alloy	1.63	96
Al-SiC-Gr Composite	1.58	108

4.3 Tensile Test

The value of tensile strength was measured for the prepared specimen using tensometer and the result showed that the value increases on addition of silicon with aluminum. From the calculated values it was observed that the tensile strength of prepared composite was increased to 187 N/mm^2 and the corresponding values are given in the following Table II.

Table II. Tensile Properties of Various Specimens

Specimen	Tensile Strength (N/mm^2)
Pure Aluminium	145
Al-Si-Alloy	160
Al-SiC-Gr Composite	187

It was noted that the addition of SiC particulates and Gr reinforced particulates increases the composite tensile strength.

4.4 Wear Behavior Test

Wear test was conducted for base alloy and SiC graphite composite reinforced with two different particle sizes of 63 and 37 microns. Graphite was added as fine powder where as SiC was added as particles. The wear test was conducted for different loads from 1 to 4 kg by keeping sliding distance of 2 km as constant. The observed results of mass loss for varying particle size of graphite with various loading conditions for two different particle sizes of 63 and 37 microns with base alloy is shown in Fig. 3. Similarly for different particle size of graphite the wear rate with various loads were analysed and are given in Fig. 4. From the following Fig. 3 and Fig. 4, it was clearly found that the mass loss increases with increase in load during the analysis of prepared composite materials, also it was found that the base alloy shows appreciable mass loss when compared with the SiC-Gr reinforced composites. The same trend was observed for the wear rate also. As the load increases the wear rate also increases and base alloy shows the maximum wear. When the load was 4 kg, the effect of graphite was considerable which paved the way for reduction in mass loss and wear rate.

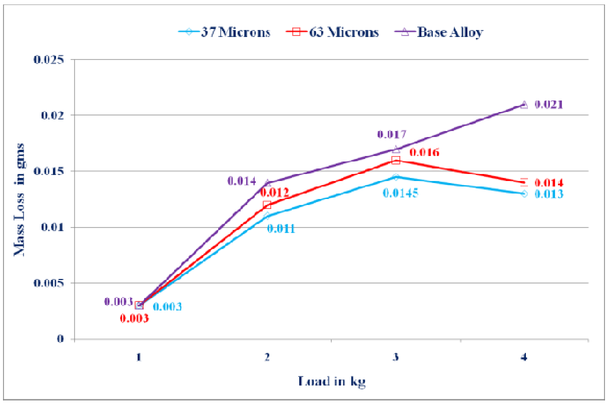

Fig. 3 Load Vs Mass Loss

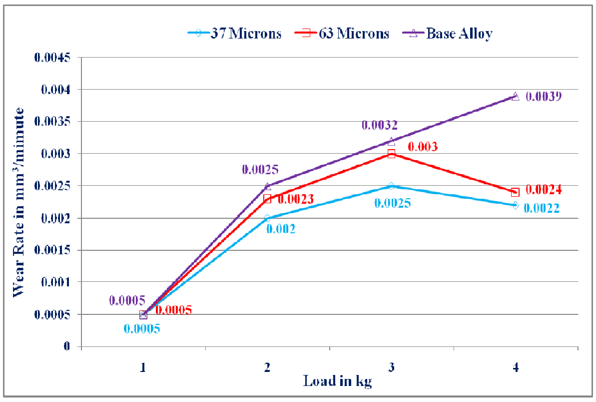

Fig. 4 Load Vs Wear Rate

4.5 Characterization through EDAX

The prepared composite specimen was also characterized using EDAX. The observed results are shown in Fig. 5 which shows the presence of Aluminium, Silicon and Carbon based on their respective percentage. Live Time: 100.0 sec, Accelerating Voltage: 15.0 kV and Off Angle: 35.0 degree

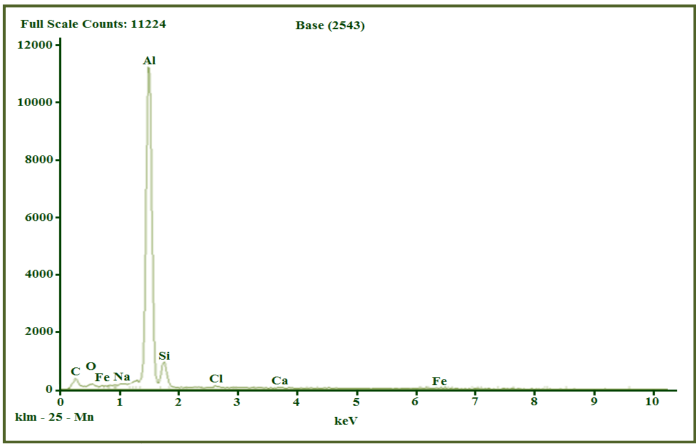

Fig. 5 EDAX Examination

***4.6** Characterization using SEM*

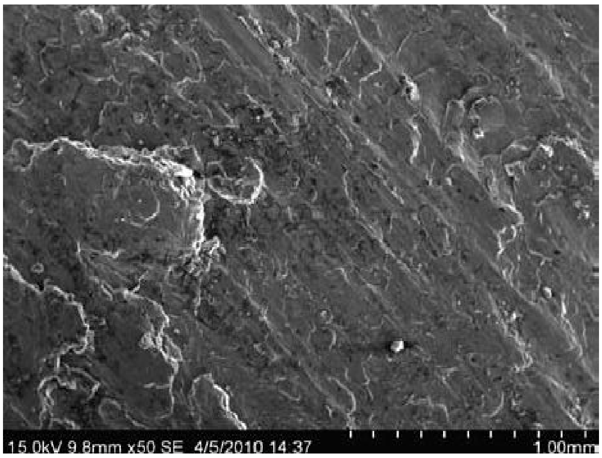

Fig. 6 SEM Image of Specimen at 50 X

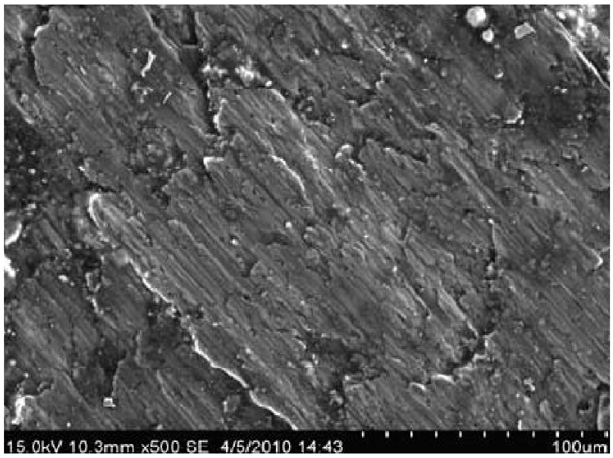

Fig. 7 SEM Image of Specimen at 500 X

The characterization of the specimen was carried out through SEM analysis on the worn surface of composite under load of 30N. The various SEM images of the prepared composite specimen are shown in the following Fig. 6 and Fig. 7. From the following SEM images it was observed that the material removal rate of the prepared specimen was occurred through micro cutting and micro chipping process only. Wide range of ploughing or abrasion marks were seen on the surface of the prepared composite and no deeper cuts occurred during the wear process.

5. CONCLUSIONS

Based on the analysis carried out on the prepared samples the following observations were made.

- Microstructural inspection showed the presence of reinforcements and also uniform distribution of elements was observed for graphite weight percent more than 10.
- The hardness of the prepared composite was about 10-15 % better than that of base alloy.
- Nearly 9 % increase in tensile strength was observed in the prepared composite sample.
- The wear behavior showed reduction in mass loss and wear rate at higher loads. The structure of film D was also seen due to the graphite presence in the composite with 4kg of load.
- SEM image revealed that the material removal is mainly due to micro cutting and micro chipping.

This research may be extended further by adding silicon carbide in the form of fine powder and subjecting the developed composite for further analysis like wear test and mechanical tests. The base metal aluminium may also be refined by the addition of suitable alloying element.

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