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Study of Wear Properties of SiC Particulate And E-Glass Fiber Reinforced Al 3003 Hybrid Metal Matrix Composites

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ABSTRACT

Composite materials play a vital role at the present modern industrial sectors. Metal matrix composites are light weighted, high strength, extremely hard materials which are useful in various industrial areas like aerospace, automotive, machine building due to their advantageous properties like light weight, flexibility, hardness, simplicity and easy applicability and so on. At the centre of research and growth of these sectors this paper emphasizes the production of metal-matrix Al-SiC & E-Glass composites using the stir-casting method with varying percentile compositions of SiC & E-Glass with aluminium. In the present investigation a study on wear behavior of Aluminium metal matrix composite reinforced with SiC and E-Glass (produced by stir casting process) has been carried out. In this study wear performance is carried out by varying the percentage of reinforcements in the matrix. All experiments were conducted under room temperature condition. To assess the wear characteristics of aluminium alloy 3003 with SiC & E-Glass a computerized pin-on-disc machine was used. The specimen was studied under scanning electron microscope to get an idea about the distribution of pattern of the reinforcement in the matrix alloy and effect of these reinforcements on the wear behavior of the composites. Dispersion of reinforcements in the aluminium matrix improves the wear behavior of the composites.

Keywords: E-Glass Fiber, Silicon Carbide, Aluminium 3003 Alloy, Stir Casting.

I. INTRODUCTION

Metal Matrix composites (MMCs) are made of a continuous metallic matrix and one or more discontinuous reinforcing phases. The reinforcing phase may be in the form of fibers, whiskers or particles. In particular, Particle-reinforced aluminium alloys have the potential to be used in the wide range of engineering applications due to their higher stiffness and strength when compared with conventional aluminum alloys. For these composite materials, Silicon Carbide (SiC), a commercially pure material, has become the main type of reinforcement. Most of the research work carried out on aluminium based composite materials involved in silicon carbide as its reinforcing material. Hence forth it is essential to look for the possibilities of fabricating aluminium based composite materials using alternative materials such as E-Glass.

Metal matrix composites are produced economically by stir casting techniques, with substantial increase in the stiffness, hardness and strength to weight ratio of cast MMCs; but however there is a reduction in ductility. It has been observed that some improvements in strength and ductility can be achieved with the application of plastic forming processes i.e. forging of the cast composites. The forged MMCs in general have better mechanical properties compared to cast MMCs, such as improved density, hardness and tensile strength etc. The forging process also avoids the use of secondary operation like machining.

II. METHODS AND MATERIAL

EXPERIMENTATION

A. MATERIALS

Reinforcement compositions are selected based on the previous work done by many researchers. In many literatures authors have mentioned the reinforcement percentage should be less than 10% for E-Glass and 2%

for SiC, if it is more than 10% reinforcement will not mix with the casting properly and there is a chance of agglomeration of particles. So, in the present study reinforcement compositions are limited to above mentioned wt.%.

i. ALUMINIUM 3003 ALLOY

Fig. 1 shows Al 3003 Ingots used in the experiments to prepare samples.

Fig. 1. Al 3003 Ingots

ii. E-GLASS FIBER

E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiber glass.

Fig. 2. Chopped E-Glass Fiber

iii. SILICON CARBIDE

Silicon carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics and numerous high performance applications. This material has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developing.

Fig. 3. Silicon carbide

B. FABRICATION OF TEST SPECIMEN

The microstructure of any material is a complex function of the casting process, subsequent cooling rates. Therefore composites fabrication is one the most challenging and difficult task. Stir casting technique of liquid metallurgy was used to prepare Al 3003 Hybrid composites.

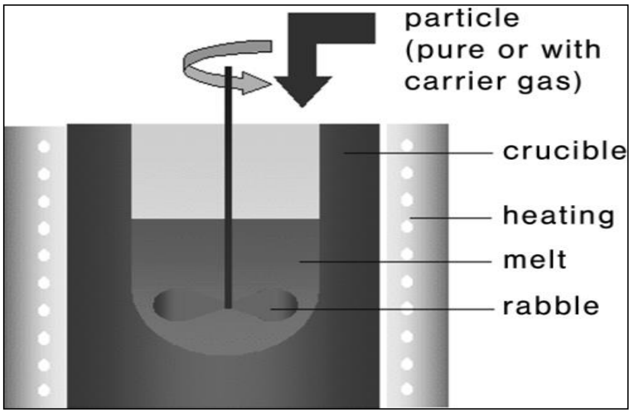

Fig. 4. Graphical representation of stir casting.

i. Preheating of reinforcement & melting of Matrix alloy:

Muffle furnace, shown in Fig. 8 was used to preheat the particulate to a temperature of 500^0C. It was maintained at that temperature till it was introduced into the Al 3003 alloy melt. The preheating of reinforcement is necessary in order to reduce the temperature gradient and to improve wetting between the molten metal and the particulate reinforcement. The melting range of Al 3003 alloy is of 700 – 800^0C. A known quantity of Al 3003 ingots were loaded into the Graphite crucible of the furnace for melting. The melt was super-heated to a temperature of 800^0C and maintained at that temperature. The molten metal was then degassed using Hexo chloro ethane tablets for about 8min. Fig. 6 and Fig. 7 indicates loading Al 3003 in to furnaces with crucible and Molten Metal respectively.



Fig. 5. Molten **Fig. 6.** degas tablet **Fig. 7.** Adding Metal, Degasifier reinforcent Materials

ii. Mixing and Stirring and preparation of specimen:

Alumina coated stainless steel impeller was used to stir the molten metal to create a vortex. The impeller was of centrifugal type with 3 blades welded at 45^0 inclination and 120^0 apart. The stirrer was rotated at a speed of 300 – 400 rpm and a vertex was created in the melt. The depth of immersion of the impeller was approximately one third of the height of the molten metal. From the bottom of the crucible. The preheated particulates of SiC and short E-Glass fiber were introduced into the vortex at the rate of 120gm/min. Fig. 7 shows the process of adding reinforcent material SiC and Chopped E-Glass Fiber. Stirring was continued until interface interactions between the particles and the matrix promoted wetting. The melt was superheated to temperature of (800^0C) it was poured into the preheated die.

Fig. 8. Pouring

Then after few minutes of stirring as shown in Fig. 8, the liquid metals with reinforcements are poured into the dies to get the required castings. The pouring into the dies of ASTM Mould Box is as shown in the Fig. 8. The dies were pre heated and were coated with additives to ease the process of removing the castings. The dies were coated with a mixture of china clay, water and sodium silicate to prevent iron contamination. Fig. 9 shows the process of removing the casting after cooling the casted Al 3003 hybrid composite with SiC and E-glass. After solidification the required casts are obtained which are sent for proof machining on a centre lathe to remove the scaling from the surface as shown in Fig. 10.


Fig. 9. Final Casted Product **Fig. 10.** Machining

iii. Composition of Specimens Prepared:

Table 1. Different casting composition of Al 3003 Hybrid Composites produced as part of this research work.

Specification	SiC %	E-Glass %	AL 3003 %
C1	0	0	100
C2	2	1	97
C3	2	3	95
C4	2	5	93
C5	4	1	95
C6	4	3	93
C7	4	5	91
C8	6	1	93
C9	6	3	91
C10	6	5	89
C11	8	1	91
C12	8	3	89

C13	8	5	87

III. WEAR CHARACTERISTICS

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus. Materials are tested in pairs under nominal non-abrasive conditions. The principle areas of experimental attention in using this type of apparatus to measure wear are described. The coefficient of friction may also be determined. The values stated in SI units are to be regarded as standard.

This standard does not purport to address all of the safety concerns, if any, associated with it use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Summary of Test Method

For the pin-on-disk wear test, two specimens are required. One, a pin with a reduced tip, is positioned perpendicular to the other, usually at a circular disk. A ball, rapidly held, is often used as the pin specimen. The test machine causes either the disk specimen or the pin specimen to revolve about the disk center. In either case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented either horizontally or vertically.

Fig. 11. Pin-on-disc machine

Preparation of Specimens According to ASTM Standard for Experimentation

Wear Test

The wear test was conducted using a pin-on-disc computerised wear testing machine as shown in Fig. 12 in accordance with ASTM standards G99-95. The test uses the specimens of diameter of 6mm and length 25mm machined from the cast specimens.

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Fig. 12. Specimen for wear test

FORMULAE

Wear rate = V/S

Where,

V = Volume of wear m3 = v1 – v2

V1 = πr*rL1

V2 = πr*rL2

r = radius of specimen

L1 = Initial length of specimen

L2 = final length of specimen

Or

S = Sliding distance (meter) = π*D*N*T = 2*π*R*N*T

D = Diameter of wear track in meter

R = Radius of wear track in meter

N = Speed of the wheel in rpm

T = Sliding time in minutes

Wear rate (mm^3/m) = V/S

V = Volume of wear in debri’s in mm^3

S = Sliding in meter

track diameter of 120mm in pin on disc experiment, this is because of increase in the amount of reinforcements in MMC.

IV. RESULTS AND DISCUSSION

WEAR RATE ANALYSIS

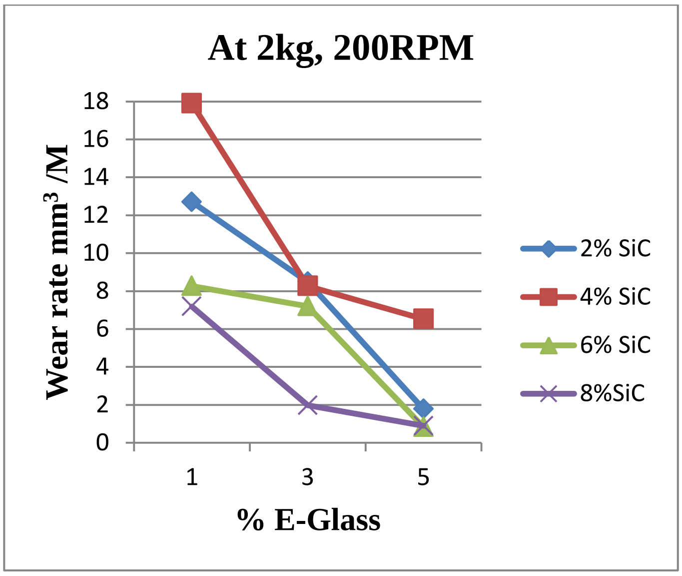

Fig. 13. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 13, the wear rate decrease as the percentage of silicon carbide and E-Glass increases from 1%, 3%, and 5% in different %SiC, E-Glass reinforced Al 3003 based hybrid MMC. At 2kg load and 200rpm at track diameter of 50mm in pin on disc experiment, this is because of increase in the amount of reinforcements in MMC.

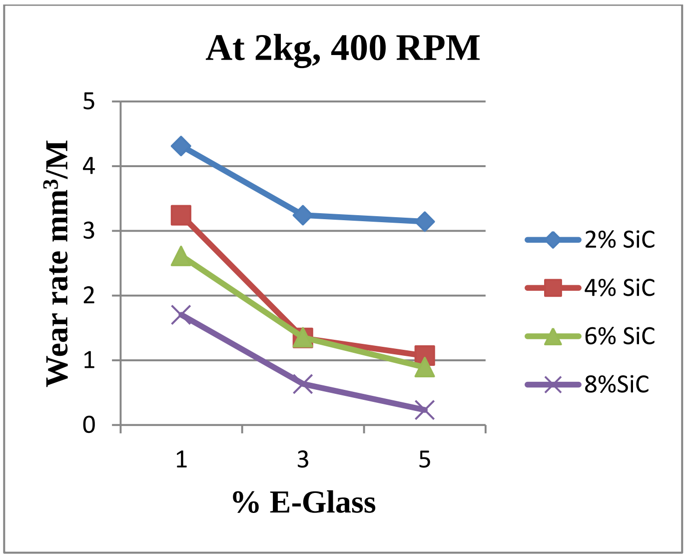

Fig. 14. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 14, the wear rate decrease as the percentage of silicon carbide and E-Glass increases from 1%, 3%, 5% in different %SiC, E-Glass reinforced Al 3003 based hybrid MMC. At 2kg load and 400rpm at a

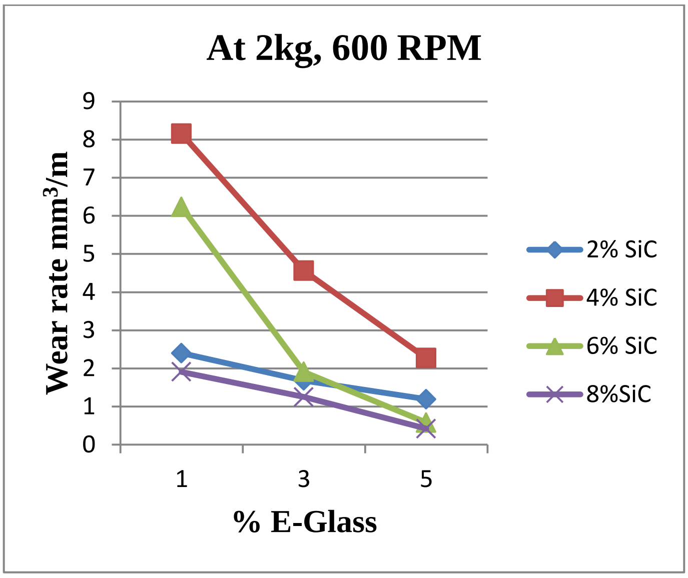

Fig. 15. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 15, the wear rate decrease as the percentage of silicon carbide and E – glass increases from 1%, 3%, 5% in different %SiC, E-Glass reinforced Al3003 based hybrid MMC. At 2kg load and 600rpm at track diameter of 120mm in pin on disc experiment, this is because of increase in the amount of reinforcements in MMC.

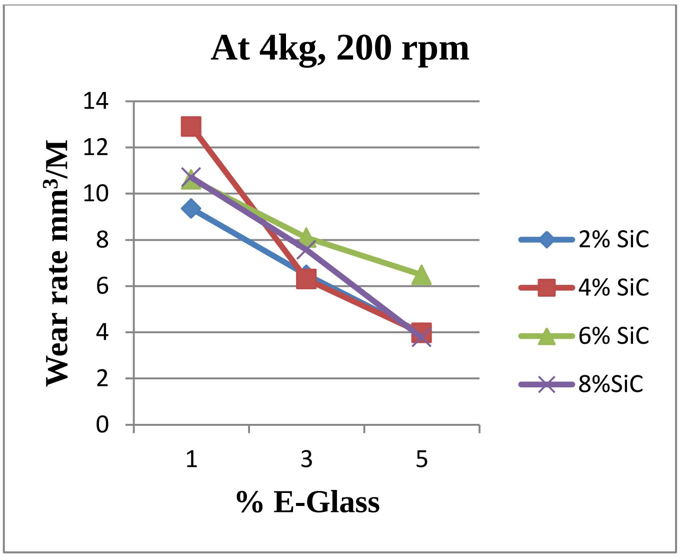

Fig. 16. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 16, the wear rate decrease as the percentage of silicon carbide and E-Glass increases from 1%, 3%, 5% in different %SiC, E-Glass reinforced Al3003 based hybrid MMC. At 4kg load and 200rpm at track diameter of 120mm in pin on disc experiment, this is because of increase in the amount of reinforcements in MMC.

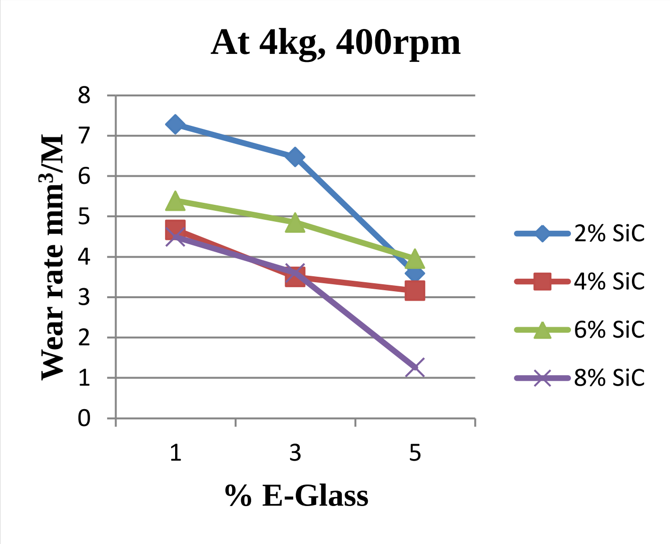

Fig. 17. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 17, the wear rate decrease as the percentage of silicon carbide and E-Glass increases from 1%, 3%, 5% in different %SiC, E-Glass reinforced Al 3003 based hybrid MMC. At 4kg load and 400rpm at track diameter of 120mm in pin on disc experiment as shown as Fig. 11.

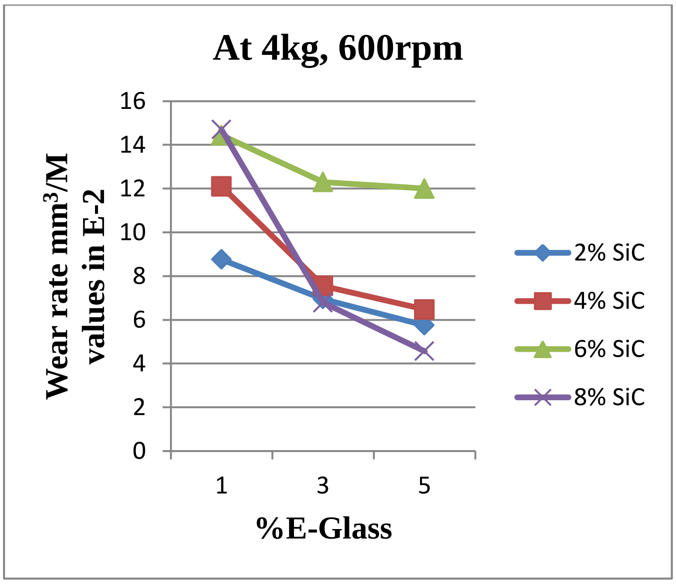

Fig. 18. Wear rate vs. various wt.% of E-Glass

As shown in Fig. 18, the wear rate decrease as the percentage of silicon carbide and E-Glass increases from 1%, 3%, 5% in different %SiC, E-Glass reinforced Al 3003 based hybrid MMC at 4kg load and 600rpm at track diameter of 120mm in pin on disc experiment.

It is observed from the Fig. that the wear rate of the composites reduced with the increase in reinforcement content. The reduction in wear rate is as much as 30 to 40% as content of the SiC (2 to 8%) and E-glass fibers (1 to 5%) varied. The improvement in wear resistance of the composites at low loads is attributed due to the presence of reinforcement, which form a thin film at the contact surface between the composite and the counter face.

The significant improvement in the wear resistance of the composites in the present case may also be due to the type of the reinforcement used. As reported by various researchers, the type of the reinforcement is also a very important contributor to the wear behaviour of the hybrid composites

V. CONCLUSION

- From the experiments conducted to study the effect on adding various volume fraction of E-Glass and silicon carbide with Al 3003 for the wear properties. The following conclusion can be drawn. Composite material of Al 3003 reinforced with E-Glass fiber and silicon carbide was successfully casted.
- Wear rate increased with the increase in speed and load for every combination of the composite. However with silicon carbide being the main reinforcement with addition of silicon carbide wear rate has reduced marginally. Addition of E-Glass also to some extent decreased the wear rate but silicon carbide plays a major role in reducing the wear rate as silicon carbide is a ceramic material.
- With increase in silicon carbide wear rate has decreased and is clear from the results that as the percentage of E-Glass increases in the composite the wear rate decreases, which is a good sign for production of low cost material.
- The best wear resistant combination is at 7% of E-Glass and 1% of silicon carbide as consideration.
- Hence, it can be concluded that properties like wear is improved and hence silicon carbide should be implemented extensively in the commercial production of composites in industries as its use for the production of composites can turn industrial waste into industrial wealth. This also solves the problem of storage of silicon carbide as well as brings down the production cost giving an economical and eco-friendly solution.

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