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STUDY OF ABRASIVE WEAR BEHAVIOUR OF Al-Si (12%)-SiC METAL MATRIX COMPOSITE SYNTHESISED USING VORTEX METHOD

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ABSTRACT

In the present investigation, Aluminium based metal matrix composite containing up to 15% weight percentage of Silicon carbide particles are synthesized using stir-cast method. Macrostructural studies have shown near uniform distribution of SiC particulates in the longitudinal direction. Microstructure also showed uniform distribution along the cross section of the specimen. Friction and wear behavior is studied by using computerized pin on disc wear testing machine. Resistance to wear has increased with increase in silicon carbide particles. But wear has increased with increase in normal load and sliding velocity. Hardness has increased with increase in SiC particles.

Keywords: Metal matrix composite, SiC, Sliding wear, Macro and microstructure.

1. INTRODUCTION

Among the advanced materials that are developed to an increasing extent are metal matrix composites. The space industry was the first sector interested in the usage of these materials and another sector of even greater economic importance for the development of new MMCs is the automotive industry [1]. The flexibility associated with metal matrix composites (MMC'S) in tailoring their physical and mechanical properties as required by the end application have made them suitable candidate for a spectrum of applications related to automobile and aeronautical sectors [2].

The invention of novel processing techniques coupled with the ability of metal matrix composites to unify the ductility and toughness of metallic materials with the strength and modulus of ceramic materials has been instrumental in the insurgence of global research activities. The majority of MMCs are metallic matrices reinforced with high strength, high modulus and often brittle second phase in the form of fiber, particulate, whiskers embedded in a ductile metal matrix. The reinforced MMCs offer opportunities for sufficient improvement in efficiency, reliability and mechanical performance over traditional base metals. In particular, the particulate reinforced metal matrix composites are attractive because they exhibit near isotropic properties compared to continuously reinforced counterparts and are easier to process using standard metallurgical methods. Particulate reinforced MMC's provide additional advantage of being machinable and workable. The primary disadvantage of all MMC's however, is that they suffer from low ductility and inadequate fracture toughness compared to their constituent matrix material [3].

Now a day the main focus is given to Aluminium as matrix material because of its unique combination of good corrosion resistance, low electrical resistance and excellent mechanical properties. Reinforcement material in MMC's may be carbide, nitrides and oxides.

2. MATERIALS

2.1 Matrix Material

The matrix material used in the experimental investigation is an Aluminium alloy (Si-12.2%) whose chemical composition (in weight percent) is listed in Table I. This alloy has a composition very close to the Al-Si eutectic. It therefore has a low melting point (577^{o}C). Aluminium and silicon have no solid solubility below the eutectic and the microstructure solidifies as silicon particles in an aluminium matrix. Aluminium-silicon alloy in its unmodified state is extensively used in sand casting and die-casting. The molten metal has high fluidity and solidifies at constant temperature. Aluminium-silicon castings have good corrosion resistance and good weldability. The microstructure can be refined by rapid cooling to increase the strength and ductility. The SEM (Scanning electron microscope) micrograph of matrix material is shown in fig (1)

2.2 Reinforcement Material

The reinforcement material was Silicon carbide (SiC) with an average grain size of 10 microns. Silicon Carbide (SiC) is highly wear resistant and also has good mechanical properties with low density, including high temperature strength and thermal shock resistance. SiC, as a technical ceramic, is produced in two main ways. Reaction bonded SiC is made by infiltrating compacts made of mixtures of SiC and Carbon with liquid Silicon. The Silicon reacts with the Carbon forming SiC. The reaction product bonds the SiC particles. Sintered SiC is produced from pure SiC powder with non-oxide sintering aids. Conventional ceramic forming processes are used and the material is sintered in an inert atmosphere at temperatures up to 2000°C or higher. The SEM (Scanning electron microscope) micrograph of SiC used in the investigation is shown in fig (2).

3. EXPERIMENTAL PROCEDURE

3.1 Processing

The synthesis of the metal matrix composite used in the present study was carried out by using stir casting method. Al-12%Si alloy in the form of ingots were used for the trials. The cleaned metal ingots were melted to the desired super heating temperature of 800°C in graphite crucibles under a cover of flux in order to minimize the oxidation of molten metal. 3-phase electrical resistance furnace with temperature controlling device shown in fig (3) was used for melting. For each melting 3-4Kgs of alloy was used. The super heated molten metal was degassed at a temperature of 780°C. SiC particulates, preheated to around 600°C were then added to the molten metal and stirred continuously by using mechanical stirrer shown in fig (4) at 720°C. The stirring time was maintained between 5 – 8 minutes at an impeller speed of 550 rpm. During stirring, Magnesium was added in small quantities to increase the wettability of SiC particles. The dispersion of the preheated SiC particulates was achieved in accordance with the vortex method [4]. The melt with the reinforced particulates were poured into the dried, coated, cylindrical permanent metallic moulds of size 50mm diameter and 175mm height. The pouring temperature was maintained at 680°C. The melt was allowed to solidify in the moulds. For the purpose of comparison, the base alloy was cast under similar processing conditions as described. The fig (5) shows the castings made with stir-casting method.

In this study SiC was added in weight percentage of 5%, 10%, 12%, and 15% in matrix material using conventional casting method. The successful incorporation of SiC particulates in the limits exceeding 10wt% using this technique can be attributed to the enhanced wet ability of SiC particulates as a result of the preheating of SiC particulates to 800ºC prior to the addition in the superheated liquid metallic melt and addition of magnesium during stirring of metallic melt and SiC particulates mixture. Preheating of SiC particulates seems to assist in (i) removal of surface impurities (ii) free flow of particulates (iii) desorption of gases and (iv) altering of surface composition owing to the formation of thin oxide layer [5].

3.2 Macro and Microstructural characterization

Macrostructural study was conducted on the as processed and machined composite castings in order to investigate distribution of SiC particles retained in the metal matrix. Castings were plain turned on lathe to remove 5mm of material to reveal the particle distribution on macroscopic scale.

Microstructural characterization studies were conducted on unreinforced and reinforced samples. This is accomplished by using optical metallurgical microscope. The composite samples were metallographically polished prior to examination. Characterization is done in unetched conditions.

3.3 Hardness and Microhardness

Since hardness is one important property which effects wear resistance of any metal, bulk hardness measurements were carried out on the base metal and metal matrix composite specimens. Brinell hardness measurements were carried out in order to investigate the influence of particulate weight fraction on the matrix hardness.

Microhardness measurements were carried out in order to investigate the influence of SiC particle on the matrix hardness. Microhardness measurements were made on the particle and in the vicinity of the SiC particle.

3.4 Sliding Wear behavior

Abrasive wear has been defined as the displacement of material caused by hard particles or hard proturberances where these hard particles are forced against and moving along a solid surface [6]. Two body sliding wear tests were carried out by using a computerized Pin on disc wear testing machine shown in fig (6) and parameters like normal load, sliding velocity, percentage SiC were varied. A cylindrical pin of size 5mm diameter prepared from composite casting was loaded through a vertical specimen holder against horizontal rotating disc. Before testing, the flat surface of the specimens was abraded by using 2000 grit paper. The rotating disc was made of steel of diameter 50mm and hardness of 64 HRC. The principal objective of investigation was to study the effect of variation of normal load, sliding velocity and percentage SiC on wear rate.

4. RESULTS AND DISCUSSION

4.1 Hardness Measurements

The results of bulk hardness measurements conducted on the unreinfoced and reinforced materials are as shown in fig (7). The results reveal that an increase in the SiC particulates weight percentage in MMC increases the material hardness.

The results of microhardness measurements conducted on the composite samples containing 12 wt. % of SiC particles is shown in Table II. Measurements were made using 50gms load. The results indicate that hardness vary in the vicinity of SiC particulate depending on distance from interface. But the variation does not show a clear trend. Near the particle-matrix interface the hardness value is higher compared to other regions. Lack of clear trend in variation of microhardness values can be attributed to influence of neighboring particles, beneath and sides, on hardness of matrix.

4. 3 Macro and Microstructural characterization

Macrostructural studies revealed reasonable uniform distribution of SiC particles and macrosegregation of particles. Photo macrograph Fig (8) shows the distribution of SiC particles (10% weight percentage) in permanent mold cast ingot (φ60mmX 175mm). Higher concentration of SiC particles was obtained at the top and lower concentration at the bottom of the castings. Central 80% length of castings had near uniform distribution of SiC particles. A more uniform distribution of particles will be obtained by increasing the solidification rate.

Microstructural studies of MMC with 5% SiC shows that there is no void or discontinuities (see fig (9)). At some places there was clustering of SiC particulates. There is good interfacial bonding between SiC particles and Al matrix. Good interfacial bonding can be obtained by heating of SiC particulates prior to dispersion and addition of magnesium during stirring to increase wettability.

4.4 Sliding wear behavior

The fig (10) shows the results of abrasive wear. From the graph it is evident that the resistance to wear has increased with increase in SiC percentage. But wear rate has increased with increase in normal load fig (11) and sliding velocity fig (12). MMC containing 15% of SiC is used as specimens for experiments to study the effect of normal load and sliding velocity. On inspection of abraded surface under microscope revealed there is no plucking of SiC particles from matrix material. This fact suggests that a strong bond exists between reinforcement particle and matrix material. By abrasion of the composite, material can be removed in one of two ways. Firstly, the reinforcing phase can be torn or dug out of the matrix, so that the bulk wear behavior of the reinforcing phase is of little consequence to the wear resistance of the composite. Secondly, the reinforcing phase, due to its good adhesion to the matrix material and strength, is worn continuously [7]. Fig (13) shows the variation of coefficient of friction for different percentages of SiC. It is observed that the value of coefficient of friction for MMC with 5% SiC is lower compared to MMC with 15% SiC.

5.CONCLUSIONS

1) Metal matrix composite up to 15% SiC was synthesized successfully by using vortex method.
2) macro and microstructure revealed near uniform distribution of SiC particles in the center portion of the casting. But there is slight agglomeration of SiC particles on macroscopic scale. The microstructure also revealed good interfacial bond between matrix and SiC particles.
3) The hardness of MMC increased with increase in SiC content and the microhardness was high near the vicinity of SiC particle.
4) The abrasive wear resistance of MMC has increased with increase in SiC content. But wear has increased with increase in sliding velocity and normal load.

6. REFERENCES

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TABLES

Table 1: Chemical composition of Aluminium base alloy

Si	Fe	Cu	Mn	Mg	Zn	Al
12.2	0.322	0.002	0.621	0.065	0.0215	Bal

Table 2: Microhardness (VHN) of matrix material around SiC particle

Distance from SiC particle (μ)	0	10	20	30
Test1	577	483	389	421
Test2	632	554	465	355
Test3	684	590	548	453

FIGURES

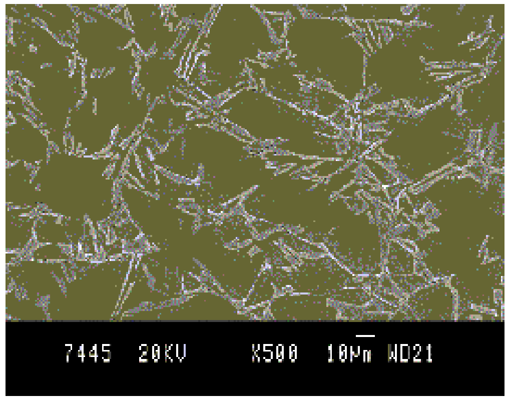

Fig (1) Micrograph of matrix material

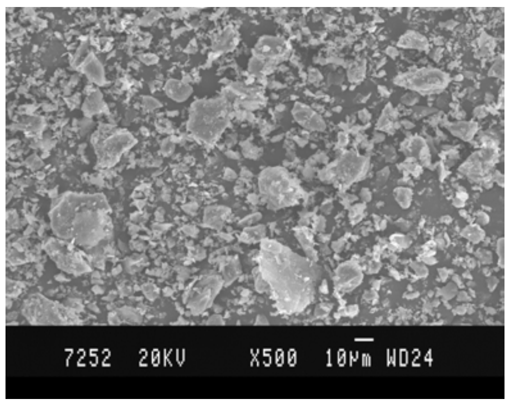

Fig (2) Micrograph of SiC

Fig (3) Electrical resistance furnace used for melting

Fig (4) Mechanical Stirring of metal-particle mixture

Fig (5) Metal matrix composite castings

Fig (6) Computerized pin on disc wear testing machine

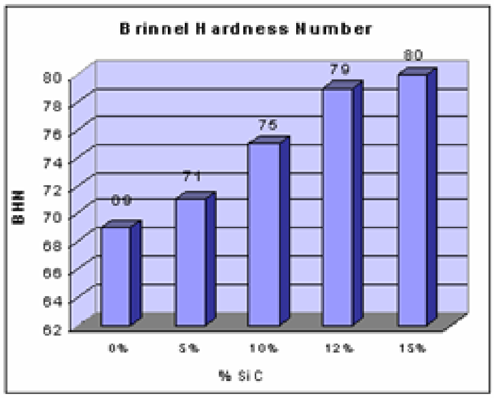

Fig (7): Variation of BHN with percentage SiC

Fig (8): Photomacrograph showing distribution of SiC

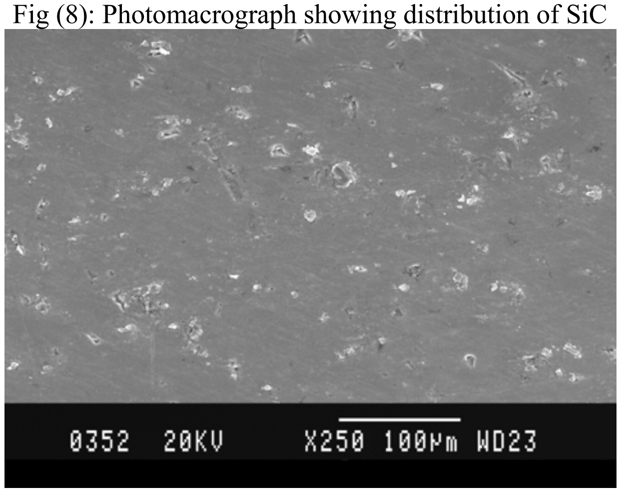

Fig (9) Microstructure of MMC containing 5% SiC

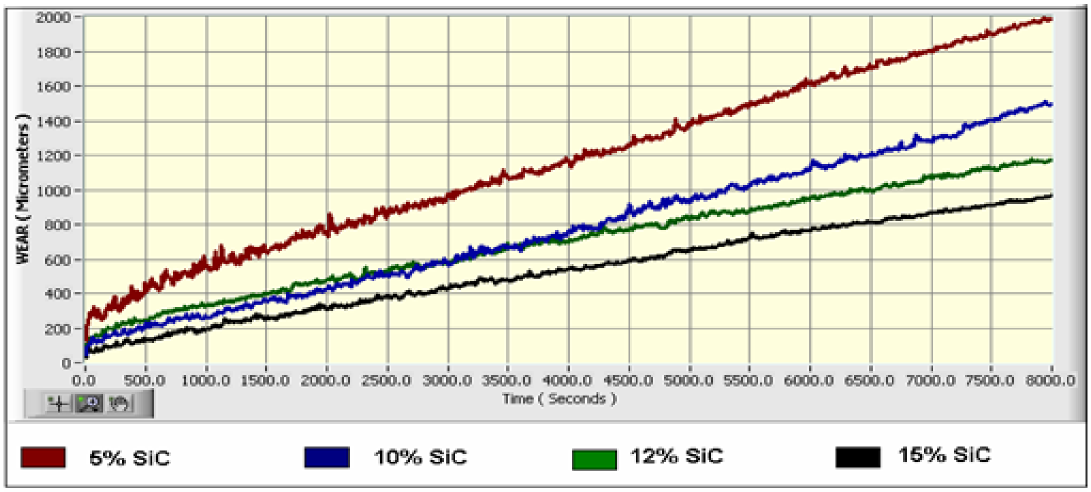

Fig (10):Variation of abrasive wear with different percentages of SiC

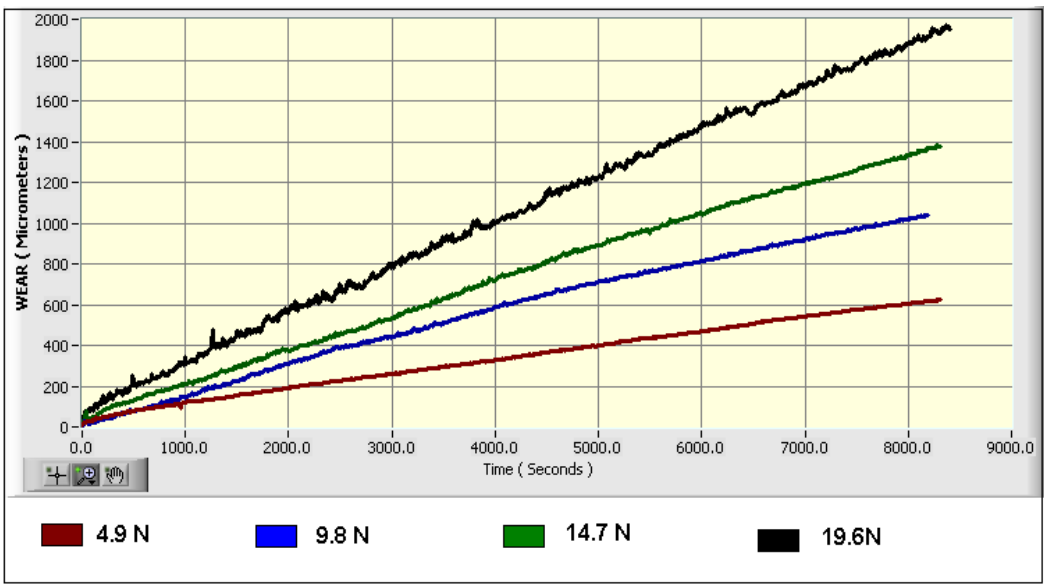

Fig (11): Varition of abrasive wear with variation in normal load

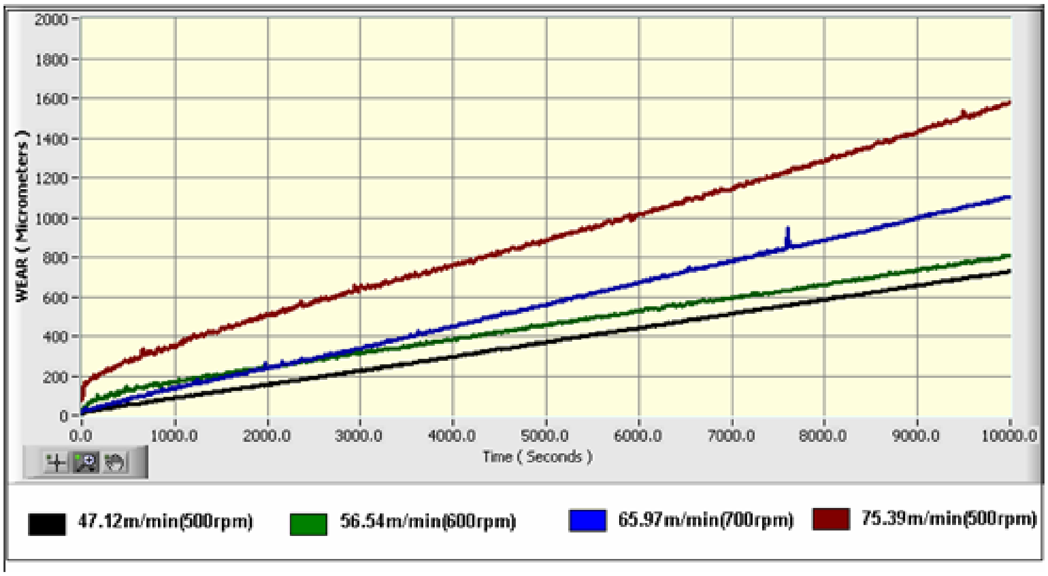

Fig (12): Variation of abrasive wear with variation in sliding velocity

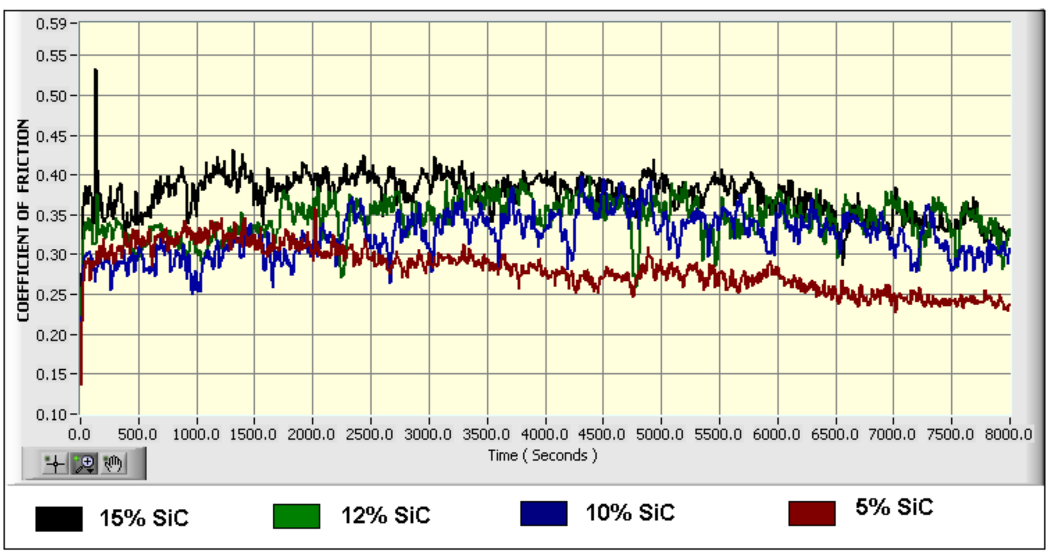

Fig (13): Variation of coefficient of friction with percentage flyash