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MECHANICAL AND TRIBOLOGICAL ANALYSIS OF SIC AND FLYASH REINFORCED ALUMINIUM6063 METAL MATRIX COMPOSITES

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ABSTRACT

In the present study the mechanical properties and wear behavior of aluminium alloy 6063 reinforced with SiC particulate and further addition of fly-ash particulate fabricated by stir casting process is investigated. The results of the Brinell hardness test shows that, the hardness of the composite material are improved on increasing weight fraction of the reinforcement .The wear resistance and frictional properties of hybrid metal matrix composite are studied by performing dry sliding wear test using a pin on disk wear tester. The experiments to be conducted at a constant sliding velocity of 1.04m/s and sliding distance of 628m over a various load of 3,4,5kg for addition of particulate weight fraction of SiC 5% and increase in weight fraction by 4% ,9% & 14% fly-ash.

1. INTRODUCTION

Composite Materials in general are well established engineering materials with most of them possessing the advantages of higher specific weight and specific modulus [1,2] and also better thermal stability, fatigue properties and wear resistance [3,4] compared to many of the metals and alloys. Metal matrix composites (MMCs) are the forerunners amongst different classes of composites. Over the past two decades metal matrix composites (MMCs) have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance [5]. MMCs offer a unique balance of physical and mechanical properties. Aluminium based MMCs have received increasing attention in recent decades as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance. The stir casting method is widely used among the different processing techniques available. Stir casting usually involves prolonged liquid-reinforcement contact, which can cause substantial interface reaction [6].

Charles et al. [7] reported that the wear and hardness of aluminium alloy hybrid (Al alloy/Silicon carbide (SiC)/fly-ash) composites were enhanced on increasing the volume fraction of SiC. Basavarajappa et al. [8] revealed that the mechanical properties of aluminum alloy (Al2024) reinforced with SiC and graphite particles increased predominantly with the increase in volume fraction of reinforcement. Mahendra et al. [9] reported that the properties of Al-4.5% Cu alloy composite with fly ash as reinforcement increase with increase in the fly ash content.Sudarshan et al.[10] studied characterization of A356 Al - fly ash particle composites with fly ash particles of narrow range (53-106μm) and wide size range (0.5-400 μm) and reported that addition of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. They also concluded that composites with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range fly ash particles. Hayrettin Ahlatci et al. [11] investigated the mechanical properties of Aluminium Silicon with 60 volume % SiC composites and concluded that as amount of Si increased up to 1%, the strength of composites increased without significant loss in toughness after which the strength showed a decline with further in crease in Si content. S. Q. Wu et al. [12] studied the mechanical properties of monolithic Alluminium with 12 weight % of silicon and found that ultimate tensile strength is improved considerably by the addition of low volume fraction (3-7%) of aluminosilicate short fibres. Veereshkumar G. B., et al. [13, 14] reported that the mechanical properties of Al6061-Al2O3 and Al7075-SiC composites were found to be increased with increase in filler content in the composites and the dispersion of Al2O3 in Al6061 and SiC in Al7075 alloy confirmed enhancement of the mechanical properties. M. N. Wahab et al. [15] studied the characterization of aluminum metal matrix composites reinforced with aluminum nitride and found that hardness was 44 Hv for Al-Si matrix and increased to 89 Hv for an Al-Si composite reinforced with 5% wt.% AlN powder. M.Ramachandra and K.Radhakrishna [16] revealed that the wear resistance of the fly ash reinforced aluminium matrix composite increased with increase in flyash content, but decreases with increase in normal load, and track velocity. T. Miyajima, and Y. Iwai [17] concluded that particles reinforcement (volume fractions of SiC whiskers, 5-29%, Al2O3 fibers, 3-26% and SiC particles, 2-10%) with matrix materials Al-2024 and ADC12 aluminum alloys were the most effective in improving the wear resistance of MMC.

From the above literature review, it can be concluded that in order to study the influence of the particle size of fly ash as reinforcement on the aluminium alloy (Al6061) composite and to study its effect on mechanical and tribological properties different sizes of fly ash have been selected in the present study. Even though some of earlier investigations showed that the mechanical properties will be enhanced with increase in particle size, but a systematic study has not been carried out. Hence an attempt is made to the influence of these parameters on the various properties so as to explore it as an interesting and useful engineeringmaterial.

2. MATERIALS AND METHODS

2.1 Materials

The matrix material used in the present investigation was pure aluminium. Aluminium was purchased from Perfect Metal Works, Bangaluru, Karnataka, India. Silicon carbide, fly ash and magnesium were commercially available.

2.2 Specimen Preparation

Fly ash reinforced Aluminium alloy (Al6063) composites, processed by stir casting route was used in this work. The three types of stir cast composites had a reinforcement particle size of 4-25, 45-50 and 75-100 µm each. The required quantities of fly ash (4, 9 and 14 Wt. %) were taken in powder containers. Then the fly ash was heated to 450oC and maintained at that temperature for about 20 min. then weighed quantity of Al (6063) alloy was melted in a crucible at 800^{o}C which is more than 100^{o}C above liquidus temperature of the matrix alloy. The molten metal was stirred to create a vortex and the weighed quantity of preheated fly ash particles were slowly added to the molten alloy. A small amount of Mg (0.5 wt. %) was added to ensure good wettability of particles with molten metal. After mixing the melt was poured into a prepared mould for the preparation of specimen.

Table 1 shows the chemical composition of the Al (6061) and Table 2 shows the major chemical composition of the Fly ash particle.

Table 1 Chemical compositions of Al (6063) alloy (Weight Percentage)

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Al
.90	.75	.25	.22	.09	.10	.05	.04	Bal

Table 2: Chemical composition of Fly ash (Weight Percentage)

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss of Ignition
28.44	59.96	8.85	2.75	1.43

2.3 Experimental Work

The Stir casting method (also called liquid state method) is used for the hybrid composite materials fabrication, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies. In this study, the aluminium-SiC, aluminum- fly ash, aluminium-SiC-fly ash and aluminium-fly ash-SiC metal matrix hybrid composite was prepared by stir casting route (Fig. 1). For this we have chosen 100gm of commercially pure aluminum and desired amount of SiC, fly ash, SiC-fly ash mixtures in powder form. The fly ash and SiC and their mixture were preheated to 300°C for three hours to remove moisture. Pure aluminum was melted in a resistance furnace. The melt temperature was raised up to 720°C and then the melt was stirred with the help of a mild steel turbine stirrer. The stirring was maintained between 5 to 7 min at an impeller speed of 200 rpm. To increase the wettability, 1.5% of pure Mg was added with all composites. The melt temperature was maintained 700°C during addition of Mg, SiC, fly ash, SiC-fly ash mixture particles. The dispersion of fly ash and other particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metallic mold. The pouring temperature was maintained at 680ºC. The melt was then allowed to solidify in the mould (Fig. 2). The metal matrix hybrid composites that we obtained are shown in the Fig. 3.

2.4 Microstructural Characterization

The composites produced were examined by optical microscope to analyze the microstructure. A section was cut from the castings, which is first belt grinded followed by polishing with different grade of emery papers. After that they were washed and again cloth polishing of the sample was done. After etching they were examined for microstructure under optical microscope at different magnifications.

2.5 X-Ray Diffraction Analysis

The composites prepared were analyzed with the help of x-ray diffraction technique to check the presence of different compounds in the composites.

2.6 Mechanical Properties Observation

2.6.1. Density

Density of the composite specimens was obtained experimentally by the Archimedes principle. Theoretical density was calculated applying the rule of mixtures according to the weight fraction of reinforcement.

2.7. Tensile Behavior

The tensile testing was done using a computerized UTM testing machine as per the ASTM E-8 standards. The sample rate was 9.103 pts/sec and crosshead speed 5.0 mm/min. Standard specimens (Fig. 4) with 36 mm gauge length were used to evaluate ultimate tensile strength, yield strength and percent elongation. Samples used for the tensile behavior tests are shown in Fig. 5.

2.8. Hardness

Bulk hardness measurements were carried out on the base metal and composite samples by using standard Brinell hardness test machine. Brinell hardness measurements were carried out in order to investigate the influence of particulate weight fraction on the matrix hardness. Load applied was 10 kg and indenter used was square based diamond pyramid. Samples used for the hardness tests are shown in Fig. 6.

Fig. 1 Stir casting unit

Fig. 2 Samples in the mould

Fig. 3 Samples

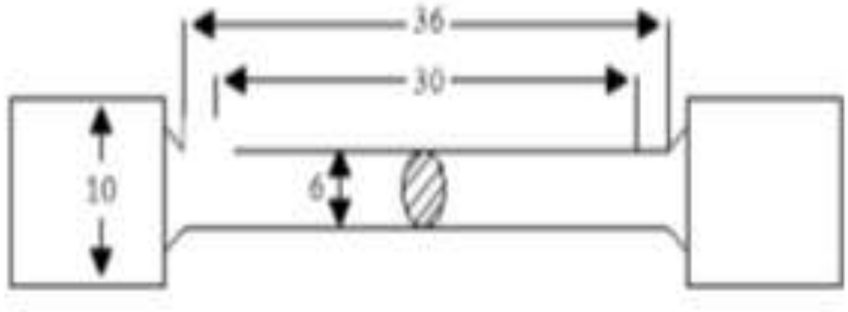

Fig. 4. Standard tensile specimen

Fig.4 Samples for the hardness tests

Fig. 5. Samples for the tensile tests

3. MECHANICAL CHARACTERISTICS

Some of these characteristics are

3.1 Tensile Strength

The reinforcing phase in the metal matrix composites bears a significant fraction of stress, as it is generally much stiffer than the matrix. Microplasticity in MMCs that takes place at fairly low stress has been attributed to stress concentrations in the matrix at the poles of the reinforcement and/or at sharp corners of the reinforcing particles (Corbin and Wilkinson, 1994). The increase in volume fraction of reinforcing particles initially decreases the microyielding stress due to increase in number of stress concentration points (Chawla, 2006). Mechanical behavior of Al-SiC and Al-fly ash particles were already reported (Hashim et al ., 1999; Quin et al ., 1999; Kok, 2005; Doel et al ., 1993; Pathak et al ., 2006; Sudarshan and Surappa, 2008).

The graph of the experimental tensile strength of the composites according to the SiC, fly ash and their mixtures. Results show that the tensile strength of composites is higher than that obtained for the unreinforced Al. Tensile strength of unreinforced Al is 236 N/mm 2 and this value increases to 265 N/mm 2 for Al/(5%SiC), 263 N/mm 2 for Al/(9%fly ash) and 293 N/mm 2 for Al/(5%SiC+9%fly ash) composite, which is about 57% improvement over that of the unreinforced Al matrix.

3.2 Hardness

The graph of the experimental hardness of the composites according to the SiC, fly ash and their mixtures is shown in Fig. 21 . As seen from the Fig. 21 , an increasing trend of hardness was observed with increase in weight fraction of SiC, fly ash and their mixtures. It is observed that the maximum hardness is observed at Al/(10%SiC+10%fly ash), which might leads to the deformation when subjected to strain. Incorporation of fly ash particles with this significantly improves the hardness and also the deformation of the Al matrix. It is observed that the fact that the combination of SiC with fly ash particles possess higher hardness than the aluminium.

Thus, it can be concluded that the mechanical properties such as density, tensile strength, yield strength and hardness of the composites increases by increasing SiC, fly ash and their mixtures. Contradictory, elongation of the hybrid metal matrix composite is very much decreased as that of the unreinforced aluminium. Addition of magnesium improves the wettability between the reinforcement particles and enhances the mechanical properties of the composites by solid solution strengthening. In addition, mechanical stirring in the semi solid state enhances the uniform distribution between them**.**

3.3 Fatigue test

To carry out a fatigue test a specimen is prepared with ASTM standard dimensions and tested using rotating bending machine with predetermined value of loads by considering 0.5UTS,0.7UTS and

0.9UTS [7] and for which required stress level and cycles up to failure were documented which is used in plotting S-N curve

4. RESULT AND DISCUSSION

Al-SiC-flyash composite is casted and test for which results are

SL NO	Material	P/D^2	Diameter of indenter	Load (kg)	Diameter of intention (mm)	Surface area of intentation (mm^2)	Brinell hardness (kg/mm^2)
1	Al6063+5%Sic+4% fly ash	5	10	500	2.5	4.9873	100.2546
2	Al6063+5%Sic+9% fly ash	5	10	500	2.4	4.5914	108.8992
3	Al6063+5%Sic+14% fly ash	5	10	500	2.3	4.2113	118.7282

CALCULATION

Surface area of intentation

1) Area = $\pi \times D/2 \times (D - \sqrt{D^2 - d^2})\ mm^2$
   $A1 = \pi \times 10/2 \times (10 - \sqrt{10^2 - 2.5^2})$
   $A1 = 4.9873\ mm^2$
2) $A2 = \pi \times 10/2 \times (10 - \sqrt{10^2 - 2.4^2})$
   $A2 = 4.5914\ mm^2$
3) $A3 = \pi \times 10/2 \times (10 - \sqrt{10^2 - 2.3^2})$
   $A_3 = 4.2113\ mm^2$

Brinell hardness

1) P/A = Load/Area Kg/mm^2
   $P/A1 = 500/4.9873$
   $P/A1 = 100.2546\ Kg/mm^2$
2) $P/A2 = 500/4.5914$
   $P/A2 = 108.8992 Kg/mm^2$
3) $P/A3 = 500/4.2113$
   $P/A3 = 118.7282\ Kg/mm^2$

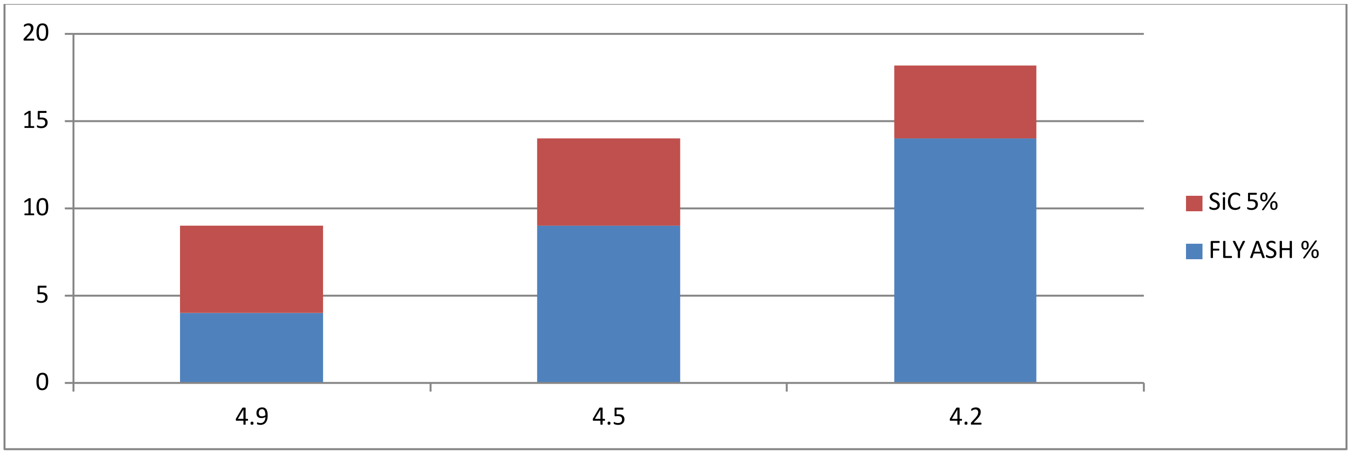

Fig 1. Hardness test graph

From results it is observed that Hardness strength of composite has enchanced and At 4%,9%, and 14% fly ash it is maximum when compared with Al6063 table and figur 1 shows the result. fatigue strength of the composite with 5% SiC and 14s% fly ash reinforcement is having good fatigue performance compared to the monolithic AL6063 alloy.

5. CONCLUSIONS

The stir casting method used to prepare the composites could produce uniform distribution of the reinforced fly ash particles. The Tensile Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The enhancement in the mechanical properties can be well attributed to the high dislocation density. However, for composites with more than 14% weight fraction of fly ash particles, the tensile strength was seen to be decreasing.

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