INVESTIGATIONS ON THE EFFECT OF FLYASH ON THE SiC REINFORCED ALUMINIUM METAL MATRIX COMPOSITES

K.A.RameshKumar[1*], Dr.K.Balamurugan[2], D.Gnanaraj[3], S.Ilangovan[4]

[1]Nandha College of Technology, Erode
[2]Institute of Road and Transport Technology, Erode
[3]Vivekanadha College of Technology for Women, Thiruchengode
[4]Amritha Vishwavidya Peedham, Coimbatore

*Author to whom correspondence should be addressed: karameshkumar1977@gmail.com

ABSTRACT

The Al-SiC composites have been prepared by using liquid sand casting technique with aluminium as the base material with 10 % SiC particulates by weight. Flyash content is varied and the abrasive wear study has been conducted on a Pin-on-Disc method. Dry sliding wear characteristics of the samples were investigated in detail. Vicker's microhardness test was carried out for the Al-SiC metal matrix composites. Scanning electron microscopic (SEM) analysis was carried out for the worn out surface to visualize the surface phenomena. The results indicate that the increase in flyash composition increases the wear resistance characteristics. The results have been discussed and are outlined in detail.

Keywords: Al-SiC composites; Metal matrix composites; frictional force; wear resistance analysis

1. INTRODUCTION

The aluminium metal matrix composites (Al-MMC's) have been conventionally used as a piston material for automobile applications. For the enhanced life of engine it is a pre-requisite that is should possess high abrasive wear resistance [1]. The addition of silicon in fine form fairly increases the wear resistance nature. The addition of particulates such as zircon, alumina, silica and silicon carbide in the aluminium matrix provides a better wear resistance nature and improves the antifriction nature. The choice of better particulate in the aluminium phase improves the stiffness, ductility and strength of Al-MMC [2,3].

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The incorporation of SiC and flyash in the aluminium magnesium alloy increases its load resistance characteristics due to dry sliding processes. The reinforcement of SiC in to the aluminium metal matrix changes the young's modululs and also favours the change in thermal expansion of the metal matrix composites. High strength metals when combined with SiC ceramics by the molten methods alters the tensile strength and indentation behaviour making it more conducive for the manufacturing processes of automobile parts [4]. The investigation of wear resistance behaviour of Al-SiC MMCs against frictional force has received much attention due to its applications in automotive applications for disc brakes. These metal matrix composites improves their wear resistance, thermal diffusivity and strength. Friction and wear resistance properties help in understanding the tribological behaviour of the Al-MMC's nature. The strengthening of aluminium alloys with a dispersion of fine ceramic composites increases their potential application for wear resistant materials which finds applications in aluminium alloy disc brake and other automobile applications [5].

Aluminium alloy reinforced with SiC particulate were tested for their wear resistance nature by dry sliding wear test using a pin on disk wear tester. The results showed that, the reinforcement of the metal matrix with SiC and TiO2 reduces the wear rate at room temperature. The sliding wear behaviour of cenosphere-filled aluminum syntactic foam (ASF) has been studied in comparison with that of 10 wt% SiC particle reinforced aluminum matrix composite (AMC) by varying sliding speeds under dry and lubricated conditions. The tribological response such as the wear rate and the coefficient of friction draw main focus and requires investigations. It was noted that the coefficient of friction, the wear rate, and the temperature rise for ASF are less than that for AMC in both dry and lubricated conditions. The craters (vis-à-vis exposed cenospheres) play an important role in the wear mechanism for ASF [6,7]

Fabrication of Al-SiC-MMC's were of different types, which includes powder metallurgy, melt quenching and mechanical alloying. Conventional techniques like casting, spraying and thixoforming have the advantages of higher porosity which can be an added advantage for the intrusion of SiC and flyash in the crystalline lattice as matrix. These aluminum matrix composites have attractive and interesting wear properties which can be enhanced through reinforcement with ceramic composites [8,9]. The widespread challenge of usage of particulate metal matrix composites for engineering applications includes uniform distribution of reinforcement of the matrix which inturn decides the quality of composite material.

In the present study a conventional low cost sand casting method was used for producing Al-SiC-MMCs. By varying the aluminium content, dry sliding wear resistance properties were investigated in detail by varying the load simultaneously and the results were discussed in detail.

2. EXPERIMENTAL PROCEDURE

Al-SiC-flyash metal matrix composites were synthesized by classical melt technique. The required quantities of Aluminium (356 grade), SiC, flyash and magnesium was melted in a crucible and then this melt was poured in to a cast which is made of sand. The composition of the aluminium was varied as 75, 80 and 85 %. The SiC content was maintained at 10. The flyash content was varied as 14, 9 and 4 %. The magnesium content was mixed at 1 %. Homogeneous melting was done for the above mentioned compositions and then the samples were fabricated by sand casting method. The obtained samples was then mounted on the spindle of wear and friction set-up to measure the tribological behaviour. The standard samples (pins – cylindrical shape) have been prepared (Ø12mm X 40 mm) out of castings with different wt. % of aluminium is shown in Fig.1.

Powder X-ray diffraction analysis was carried out using Rigaku (fitted with CuKα1) in the range 10 – 80o. Scanning Electron Microscope was used to observed the microstructural pattern of the samples

Fig .1: Al-SiC-Flyash metal matrix samples used for standard for Wear Test

which was under investigation.MITUTOYO (MVK-H11) hardness tester was used to find the Vicker's hardness number. The Al-SiC-MMCs were subjected to wear analysis by varying loads (10 N, 20 N and 30 N) and the velocity (V = 1 m/s, 1.5 m/s and 2 m/s).

2.1. Materials and methods

Aluminium-SiC-flyash-magnesium metal matrix composites with different ratio were melted and sand casting process was applied to fabricate the required samples. The chemical compositions of the samples are provided in Table 1.

Sample .No.	Aluminium	SiC	Flyash	Magnesium
1	75	10	14	1
2	80	10	9	1
3	85	10	4	1

2.2. Microstructure of flyash-AMCs

The flyash was collected from Mettur thermal power plant, Tamil Nadu, India. Scanning electron microscopic image shown in Fig.2 reveals that the flyash particulates is of spheroidal nature [10]. These flyash particles contain both solid spheres (precipitators) and hollow spheres (cenospheres). The purchased flyash was used as they were uniform in nature.

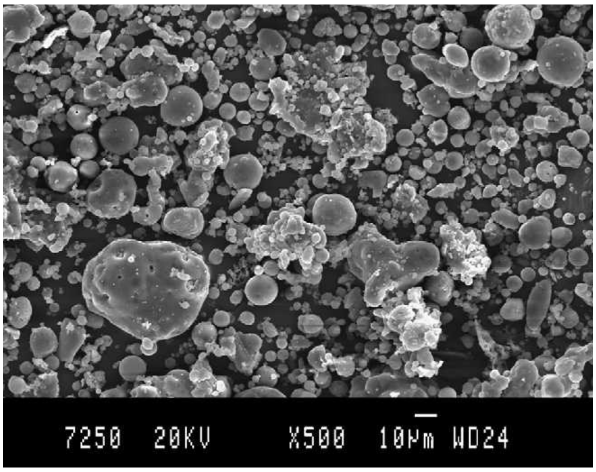

Fig.2: SEM image of flyash particulates

3. RESULTS AND DISCUSSION

3.1. Microstructure of flyash-AMCs

The scanning electron microscopic (SEM) images of the SiC and flyash reinforced Al-MMCs is shown in Fig.3(a-f). Fig.3a represents the microstructure pattern of the Al-SiC-flyash metal matrix composite (Aluminium 75 %) before the application of frictional force. Here it is clearly evident that only unreacted flyash content remains on the surface of the samples. Fig.3b represents the surface pattern of the samples after the application of frictional force

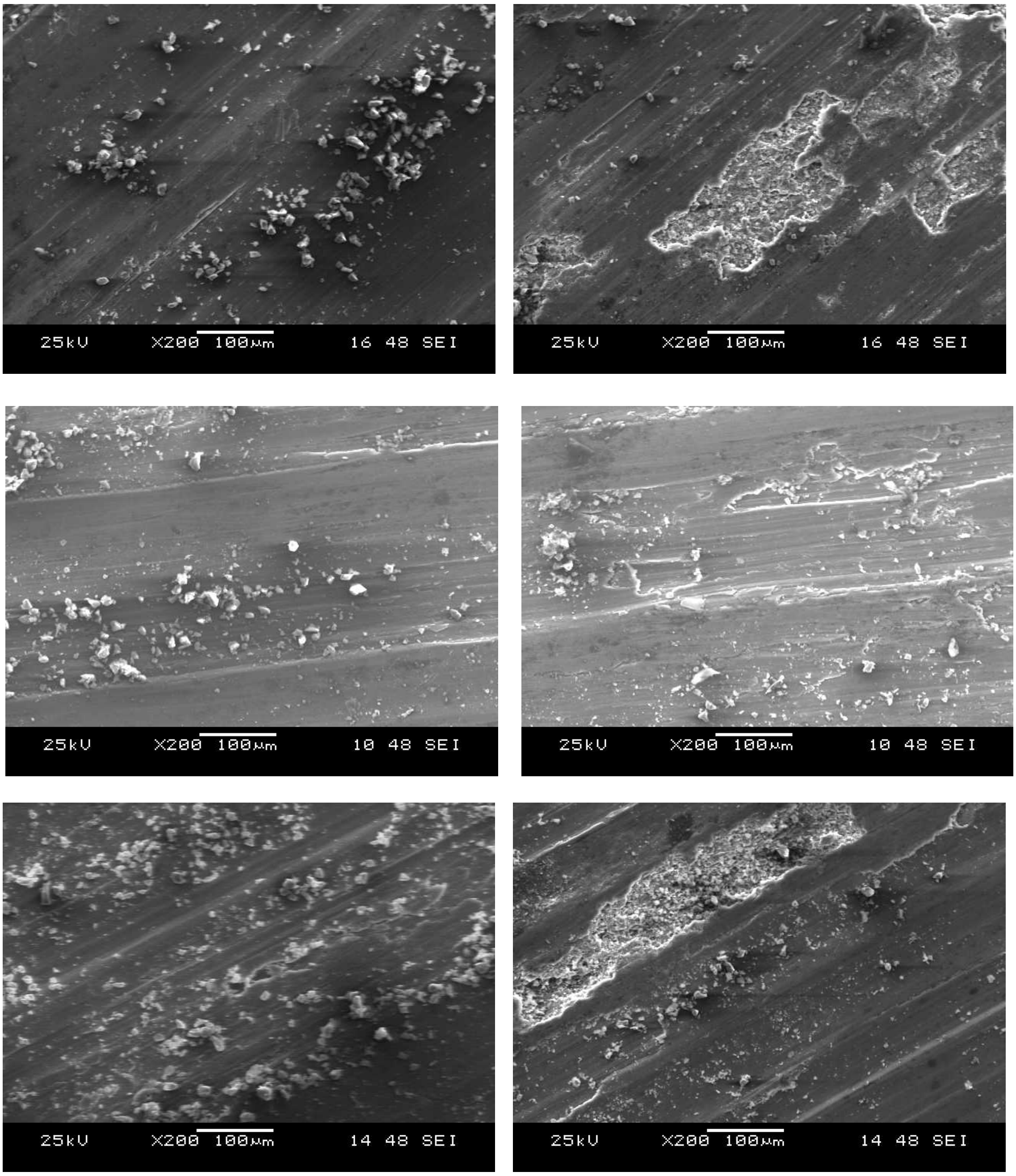

Fig. 3(a-c). SEM images of the Al-SiC-flyash-MMCs for different aluminium compositions

(at 10 N) for the velocity of the spindle at 1 m/s (191 RPM) for which the craters are created on the surface. The loss of weight increases on the surface due to the frictional force. Similarly Fig.3c represents the microstructure pattern for the aluminium content of 80 % before the application of frictional force and Fig. 3d represents the microstructure after application of the frictional force. Fig.3e represents the frictional force for the aluminium content at 85 % and Fig.3f represents the microstructure of the surface after application of the load. In all the images its clear evident that the surface remains clear with only unreacted flyash. Whereas, after application of load crests and troughs are created due to the loss of material at the surface due to frictional force [11-13]

3.2. Powder XRD analysis.

Powder X-ray diffraction analysis was performed for the samples of different aluminium compositions Viz., 75, 80 and 85 % for which the pattern is shown in Fig.4. In all the compositions, the SiC content was mainatained at 10 %. It shows that the 100 % peak at 45o corresponds to the aluminium matrix. The peak at 17o is due to the instrument broadening. These samples show no secondary phases emphasizing that all the composites formed is single phase in nature. This is more evident from the scanning electron microscope image which indicated that the surface of the sintered sample showed no traces of SiC content [14].

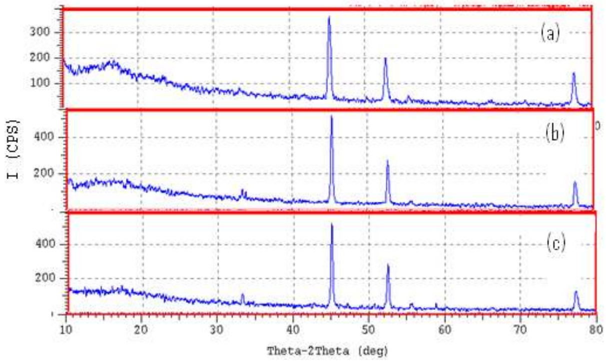

Fig.4: XRDA pattern for different Al weight % compositions (a) 75 % (b) 80 and (c) 85 %

3.3. Microhardness Measurements.

Vicker's microhardness measurement was carried out for the SiC-flyash reinforced aluminium metal matrix composites to test its mechanical strength. Several indentations were made on the surface at different points and the average hardness number (Hv) with respect to the aluminium composition is shown in Fig. 5.

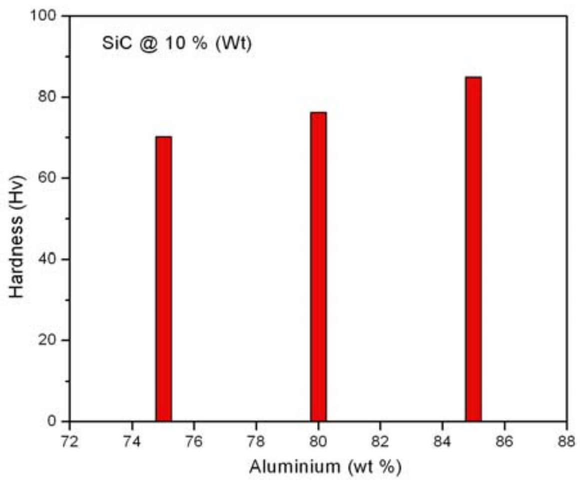

Fig.5: Hardness number (Hv) Vs aluminium composition

From the figure, it can be clearly concluded that as the aluminium content is increased, the hardness number increases. When the aluminium content is increased from from 75 to 85 %, (thus by keeping the SiC content constant at 10 wt %), the hardness increases from 70 to 90. As the aluminium content is increased, the flyash content is decreased from 14 % to 4 %. The increase in hardness may be explained on the basis of difference in thermal expansion coefficients of aluminium and flyash. Due to this difference, strain is induced during solidification. As the strain increases, the dislocation occurs and flyash particles offer resistance to the propagation of cracks during tensile loading [15,16].

3.3.Tribological behaviour

3.1.1. Friction behaviour

Frictional behaviour was investigated for various aluminium compositions by varying the frictional force (10 N, 20 N and 30 N) applied and also the velocity of sample at which it rotates (V = 1 m/s, 1.5 m/s and 2 m/s). From Fig. 6 it can be seen that as the load increases the coefficient of friction increases causing loss of the materials from the surface. This was confirmed through the SEM results which showed the worn out behaviour due to the application of load. Also, as the velocity is increased, the coefficient of friction increases which can be seen from the below figure [17].

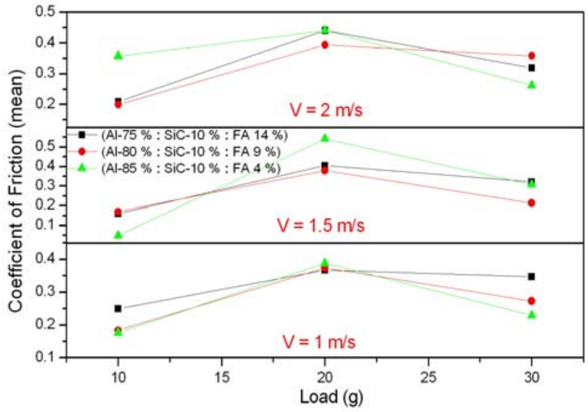

Fig. 6: Load Vs Coefficient of friction for different aluminium compositions

Coefficient of friction was determined by varying the velocity of rotation by maintaining the load at 10 N for various aluminium compositions. The experimental trial was repeated by increasing the load to 20 N and 30 N for which the coefficient of friction is shown in Figure 7.

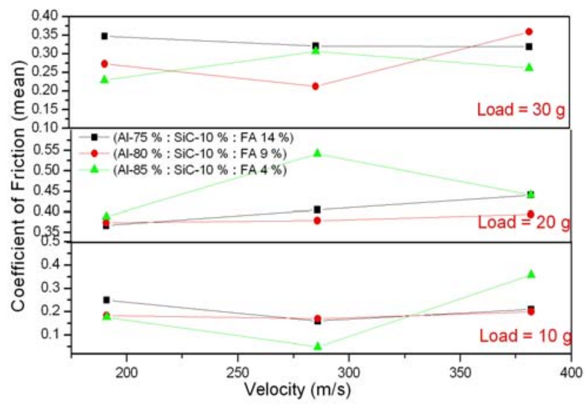

Fig. 7: Velocity Vs Coefficient of friction for different aluminium compositions

Fig.8 shows the wear rate measured by varying the frictional force (10 N, 20 N and 30 N) while increasing the velocity of sample simultaneously from V = 1 m/s to 2 m/s. As the load was increased, wear rate increases which may be accounted for the loss of sample on the surface. This loss increases as the aluminium content increases.

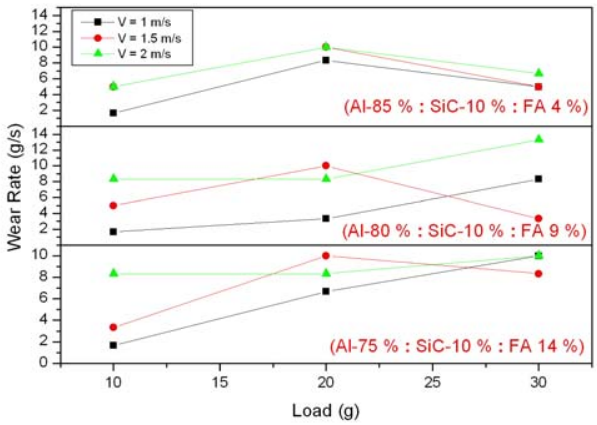

Fig. 8: Wear rate Vs Load at different velocities of the spindle for different aluminium compositions

3.1.1. Wear rate behaviour

Tribological properties of coefficient of friction and wear rate were compared with the increase in aluminium content. The frictional force was increased from 10 N to 30 N by keeping the velocity of the spindly at 1 m/s as shown in Figure 9. When the velocity is increased to 1.5 m/s, similar measurements was carried out by varying the load from 10 N to 30 N as shown in Fig. 10. Now the velocity is increased to 2 m/s and the same set of load was applied for different aluminium content as shown in Fig.11.

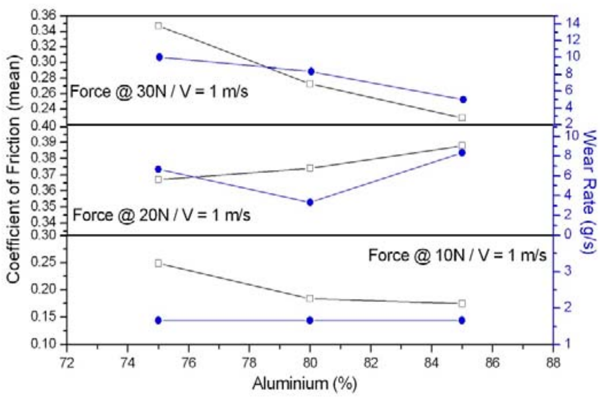

Fig. 9: Coefficient of friction, Wear rate Vs aluminium content at different loads (by keeping the velocity constant at 1 m/s)

The wear rate and coefficient of friction for various aluminium compositions shown in the above figures illustrates the fact that increase in the coefficient of friction is governed by the increase in frictional force which inturn increases the wear rare. When the load is increased from 10 N to 30 N (by keeping the velocity constant at 191 RPM), the coefficient of friction decreases when compared to the velocity increased to 2 m/s (382 RPM). From the microstructure, it can also be observed that the loss of material is due to high friction between Al-SiC-MMC and rotating disc. When the velocity is increased, the weight loss on the surface gets converted in to grooves which is reflected from the SEM pattern which shows patches of loss of material. This loss is reflected in the above figures 9, 10 and 11. [18-20]

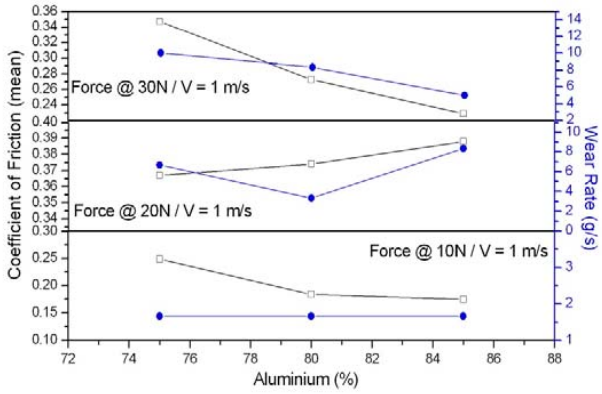

Fig. 10: Coefficient of friction, Wear rate Vs aluminium content at different loads (by keeping the velocity constant at 1.5 m/s)

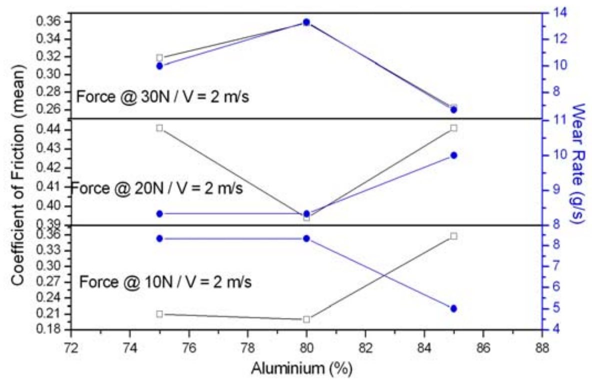

Fig. 11: Coefficient of friction, Wear rate Vs aluminium content at different loads (by keeping the velocity constant at 2 m/s)

4. CONCLUSIONS

1. Silicon carbide (SiC) and flyash reinforced aluminium metal matrix composites (Al-SiC-flyash MMC) were prepared with different aluminium content.
2. Microhardness measurements shows an increasing trend of hardness when the composition percentage of aluminium increases from 75 to 85 %.
3. When the applied load was increased, the coefficient of friction also increases which in turn increases the wear ratio. When the aluminium content

is increased from from 75 to 85 %, (thus by keeping the SiC content constant at 10 wt %), the hardness increases from 70 to 90.

4. Frictional behaviour (10 N, 20 N and 30 N) for various aluminium compositions at various velocity (V = 1 m/s, 1.5 m/s and 2 m/s) illustrates the fact that as the load increases the coefficient of friction increases leading to material loss from the surface.

5. The micromechanism of wear against the frictional force creates latent wear tracks along with fragmented SiC particulates in which fine cracks are observed.

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