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A Study on the Effect of SiC Reinforcement on the Surface and Tribological Behavior on Al-Metal Matrix Composites

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Abstract. Al matrix composites (Al-MMC) were reinforced with SiC and flyash particulate. The effects on the variation of SiC (5 %, 10 % and 15 %) were investigated by dry sliding method, whereas the flyash content was maintained at 14 %. Effect on the SiC on the mechanical and tribology was discussed in detail. Friction wear properties SiC reinforced was investigated. Coefficient of friction was estimated and is discussed for the various SiC compositions. Powder X-ray diffraction (XRD) was carried out to identify the homogeneous formation of the composites. Surface morphology was investigated by the use of optical microscope and scanning electron microscopic probe. Hardness of the prepared samples was subjected to Vicker's microhardness test.

Introduction:

Metal matrix composites offer tremendous applications in automobile and aerospace applications. The flexibility in the metal matrix composites in terms of physical and mechanical properties finds them as a suitable candidate for automobile applications [1,2]. Particle reinforced Al matrix composites possess higher specific heat capacity and thermal conductivity. In particular, Aluminium based metal matrix composites have received much attention due to their high strength, hardness and wear resistance properties when compared to the conventional cast iron. Silicon carbide and flyash are the most preferred reinforcement due to their stability and low cost during their fabrication [3]. Aluminium matrix composites with combined reinforcement of SiC and flyash exhibits improved tribological behavior compared to other metal matrix composites. Flyash, a waste by-product generated by combustion of coal in thermal powder plants were dispersed into cast and wrought aluminium alloys to make into aluminium-ally-flyash composites. [4]. Moreover, the inclusion of flyash in aluminium alloy casting reduces the density and increases the damping capacity [5].

The strengthening of aluminium alloys with a dispersion of SiC particulates has increased their application in wear resistance applications such as development of aluminium alloy brake discs [6]. Coefficient of friction plays a major role in designing the Al-MMC's based braking systems for which a wide range of stressing conditions needs to be followed. As there will be wear in the braking systems which is unavoidable, this needs to be reduced by means of SiC-flyash reinforced Aluminium metal matrix composites. There were reports on the wear analysis of the composites, whereas, there are less reports on the coefficient of friction analysis for various SiC compositions. Effect on SiC composition on the A356-SiC composite was reported for various SiC composition's for which the coefficient of friction remains unaltered [7, 8].

In this study, the mechanical behavior and tribological properties of aluminium-SiC-flyash metal matrix composites were investigated by varying the percentage of SiC. Also we have carried out microstructural investigations and hardness teston the surface behavior of the metal matrix composites.

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Experimental procedure

Materials and production method. The aluminium metal matrix composites were synthesized by sand casting method. Three different composites were prepared as follows: (Al-80 % : SiC – 5 %), (Al-75 % : SiC – 10 %), (Al-70 % : SiC – 15 %) and in addition (Al-85 %) with SiC – 0 % for reference purposes. The required aluminium, SiC, flyash and magnesium was melted and the samples were moulded to required shapes by using sand casting technique. In the whole process, the flyash content was maintained at 14 %, with only SiC content is varied to investigate the tribological properties.

The chemical compositions of the samples are provided in Table 1.

Sample .No.	Aluminium	SiC	Flyash	Magnesium
1	85	0	14	1
2	80	5	14	1
3	75	10	14	1
4	70	15	14	1

The flyash content used in the present investigations were obtained from Mettur thermal power plant, Tamil Nadu, India. Surface morphology of the fresh flyash was probed by SEM analysis. Fig.1 shows that the flyash particles contain both solid spheres (precipitators) and hollow spheres (cenospheres) were of uniform sizes [9]

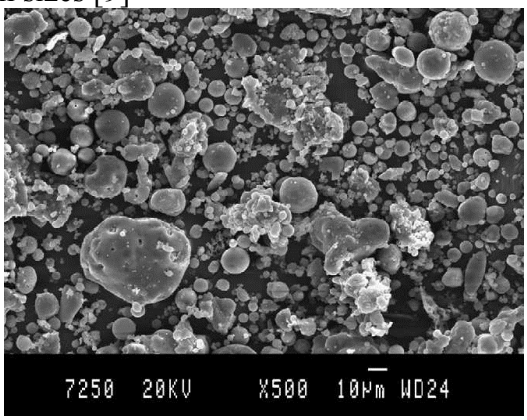


Fig.1. Surface morphology of the flyash particulates used in the present investigations

Characterization techniques. Powder X-ray diffraction analysis was carried out using Rigaku (fitted with CuKα1) in the range 10 – 80^{o}. Scanning Electron Microscope was used to observed the microstructural pattern of the samples which is under investigation.MITUTOYO (MVK-H11) hardness tester was used to find the Vicker's hardness number. Wear experiments of the Al-SiC-MMCs were carried out using pin-on-disc wear tester. It consists of a rotating disc driven by variable speed electric motor. The test specimens 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).

Results and discussion

Powder XRD analaysis. The XRD pattern of the circular disc with different SiC content is shown in below Fig.2. In all the present investigations, the flyash content was maintained at 14 %. For comparison, the samples with 0 % SiC content was also considered. The identical diffraction confirms that all Al-MMC samples without and with SiC content forms in a single metal matrix phase and that no secondary phases of SiC content alone can be found. [10,11].

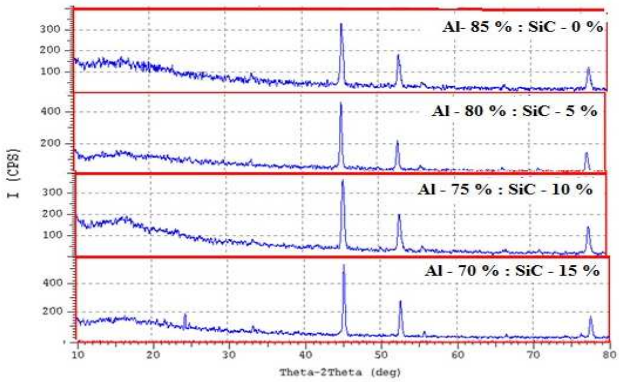


Fig.2. XRDA pattern for different SiC content (a) 0, (b) 5 (c) 10 and (c) 15 %

Microstructure of Al-SiC-flyash composites. Fig.3(a-d) shows the optical microstructure of the Al-SiC-flyash metal matrix composites. In Fig.3a, the aluminum rich content may be seen from the pattern that the surface contains dendrites pattern [11]. As the composition of SiC content is increased from 5 , 10 and 15, it shows a shortened dendrites pattern. The flyash content was maintained at 14 % in all the present investigations and also its absence on the surface clearly confirms the single phase nature of the composites formed.

Fig. 4(a-d) shows the SEM pattern of the SiC reinforced Al-MMCs. Fig.3a represents the microstructure pattern of the Al-MMC in which the the aluminium content was maintained at 85 % and flyash with 14 %. Fig.3(b-d) represents the SEM microstructure image for various SiC compositions which is varied between 5, 10 and 15 %.

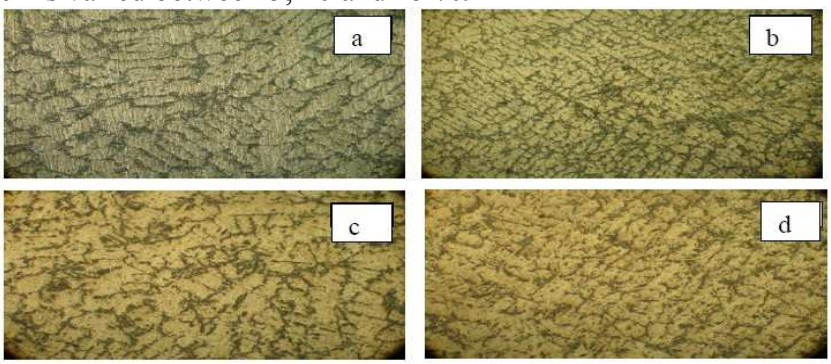


Fig. 3(a-c). Optical microscopic images of the Al-SiC-flyash for different SiC content of (a) 0 %, (b)5 %, (c)10 % and (d) `15 %

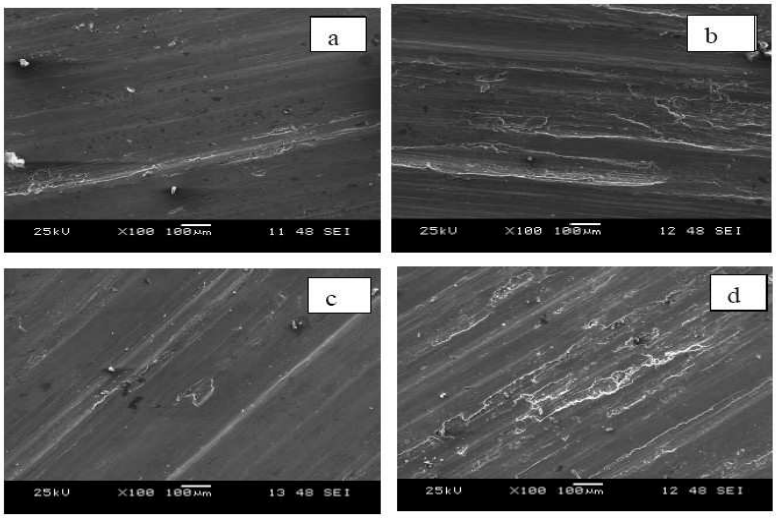


Fig. 4(a-d). SEM images of the Al-SiC-flyash for different SiC content of (a) 0 %, (b)5 %, (c)10 % and (d) `15 %

In all the images its clear evident that the surface remains clear with only worn out pieces due to application of the load appears on the surface. This is due to the loss of material on the surface due

to the application of frictional force [12,13]. 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.

Tribological behavior. Test results corresponding to the normal load and coefficient of friction was obtained as a function of SiC content. Tribological properties of coefficient of friction and wear rate were compared with the increase in SiC composition. The wear rate and coefficient of friction for various aluminium compositions shown in the below Fig.5 represents that coefficient of friction increases for the increase in frictional force. As the SiC content is increased to 15 %, the frictional force increases. When the load is increased from 10 N to 30 N (by keeping the velocity constant at 191 RPM), shows a increased behavior of coefficient of friction.

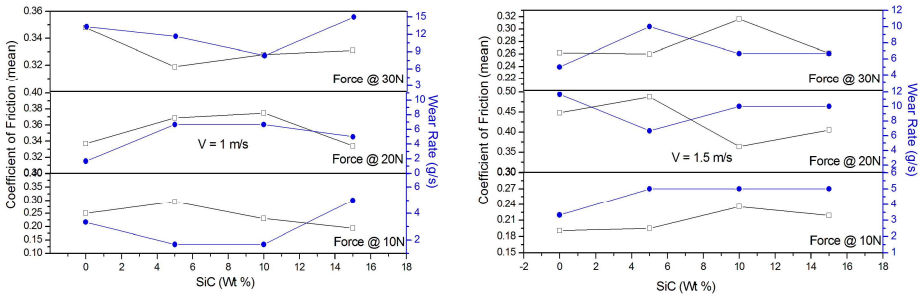


Fig. 5, 6. Coefficient of friction, Wear rate Vs SiC content at different loads (by keeping the velocity constant at 1 m/s, 1.5 m/s)

The increase in load decreases the coefficient of friction when the velocity is increased to 1.5 m/s. For the SiC content increase, the wear rate is slightly higher when the SiC content is increased to 5 %. But when the SiC content is increased to 15 %, this leads to a decrease in wear rate, thus establishing that the SiC composition with 15 % would be suited for automotive applications.

Now the velocity is increased to 2 m/s and same set of load was applied for different SiC content is shown in Fig.7. The frictional force was increased from 10 N to 30 N by keeping the velocity of the spindly at 382 m/s. The coefficient of frictional for various SiC content obtained various (10 N, 20 N and 30 N) applied and the velocity of sample at which it rotates (V = 1 m/s, 1.5 m/s and 2 m/s) shows a similar trend. In Fig.5, 6 and 7, it can be seen that as the load increases the coefficient of friction increases due to which there will be loss of the materials from the surface. This was earlier proved from the SEM results which showed the worn out behavior 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 [14].

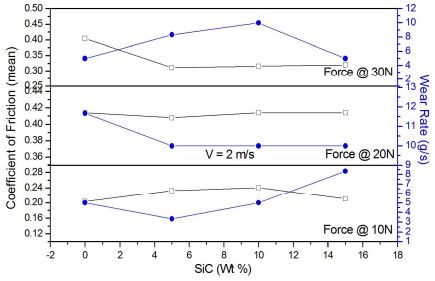


Fig. 7. Coefficient of friction, Wear rate Vs SiC content at different loads (by keeping the velocity constant at 2 m/s)

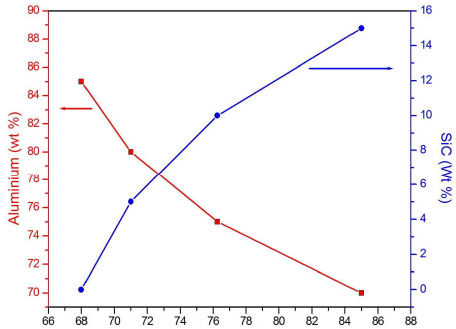


Fig.8. Hardness number (Hv) Vs aluminium composition

The difference in coefficient of friction of these Al-SiC-MMC's are small in magnitude and their values decreases when there is an increase in load and velocity. Due to this there is a higher reinforcement of volume fraction which could well be explained by the wear mechanism. During

the initial stages, the disc has to overcome the roughness of the machine. Whereas, as the velocity and the load is increased leads to the loss of materials on the surface. In some cases, these two stages cannot be distinguishable in nature. [15]

Microhardness Measurements. Vicker's microhardness measurement was carried out for the Al-SiC-flyash metal matrix composites. The average hardness number (Hv) with respect to the aluminium and SiC composition is shown in Fig. 8.

From the figure, it can be clearly concluded that as the SiC content is increased, the hardness number increases. When the SiC content is increased from from 0 to 15 %, (thus by keeping the flyash content constant at 14 wt %), the hardness increases from 70 to 88. The increase in hardness may be explained on the basis of difference in thermal expansion coefficients of aluminium, SiC and flyash. Due to this difference, strains are created during solidification. The dislocation thus created during SiC addition favours [16,17].

Conclusions

Friction and wear behavior of Al-SiC-flyash reinforced aluminium metal matrix composites (Al-SiC-flyash MMC) were investigated in detail. The effect of SiC on the coefficient of friction and wear rate was analyzed in detail by varying the load and velocity of the spindle. X-ray diffraction measurement reveals the single phase nature of Al-SiC-flyash and thus no secondary phases of SiC or flyash were found. Wear debris was investigated by scanning electron microscopic anlaysis. Microhardness measurements shows a increased trend of hardness number when the composition percentage of SiC content was increased from 0 to 15 %. Tribological results showed that the coefficient of friction is increased when the load is increased from 10 to 30 N and also when the velocity is increased, it shows a increased wear rate behavior. The increase in coefficient of friction and wear rate could be due to the higher number of reinforced particles contributes to the increase in surface area which is in contact while application of load and sliding speed.

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