Tribological properties of micro and nano SiC reinforced Aluminium metal matrix composites

K.R.Padmavathi[1]*, R. Ramakrishnan[2]

[1]Dept. of Mechanical Engg., Sathyabama University, Chennai-600 119, India.
[2]Tamilnadu Physical Education & Sports University, Chennai- 600 127, India

Abstract : Metal matrix composites (MMCs) have a prospective for improved wear resistance over the unreinforced alloy and are the most capable in achieving enhanced mechanical properties. In this research, composites of Al 6061- micro SiC (5, 10 and 15 wt.%) and Al 6061- nano SiC (0.5, 1.0 and 1.5 wt.%) were produced by stir casting technique. Hardness and wear tests were performed on the micro and nano composite specimens. The fabricated nano composites showed improvement in hardness and wear resistance over the micro composites. The microstructure of the worn out specimen was examined by scanning electron microscope. Considering all the factors, it can be concluded that aluminium based composite with 1.0% by weight nano SiC reinforcement possess better wear resistance properties as compared to micro SiC reinforced aluminium metal matrix composites.
Keywords : Metal matrix composites, Silicon carbide, Wear test, Stir casting, Hardness.

1. Introduction

Metal matrix composites have a possible for increased wear resistance over the unreinforced alloy and are the foremost promising in achieving increased mechanical properties [1]. Among different composites, metal matrix composite are promising new materials for recent engineering application having high specific strength, stiffness and their high temperature stability and widely used in aerospace and automotive industries. Aluminium is the most popular matrix for the MMC's and the aluminium alloys are quite attractive due to their low density, low cost, its capability to strengthen by precipitation, good corrosion resistance, high electrical and thermal conductivity and improved tribological properties [2,3]. The mechanical property results of micro and nano composites led in to improvement of yield strength, ultimate tensile strength, compressive strength and hardness. The fabrication process such as compocasting and the size of the reinforcement particles were the effective factors influencing on the mechanical properties [4]. Uniform dispersion of reinforcement particulates with aluminium matrix material is a greatest drawback in producing metal matrix composites. It is revealed by microscopic observation for A356 with nano SiC particulates also the highest yield strength, ultimate tensile strength and hardness are obtained [5,6].

Wear rate of SiC reinforced composite specimen reduces with the increase in reinforcement content in the dry sliding wear tests. Also wear rate decreases as the sliding speed increases up to transition speed and load due to work hardening of the surface, formation of iron-oxide and crushing of SiC particles [7]. To avoid agglomeration of nano particles during solidification process, a non-contact method, where the ultrasonic probe is not in direct contact with the liquid metal was attempted to disperse nanosized Al_2O_3 particulates in aluminium matrix and the mould was subjected to ultrasonic vibration [8]. SiC and Al2O3 are the common reinforcing materials used in aluminum matrix composites [9]. SiC is composed of tetrahedral of carbon and

silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material [10,11]. The aim of the work presented here is to investigate the possibility of combining the micro SiC (5, 10 and 15 wt.%) of 400 mesh and nano SiC (0.5, 1.0 and 1.5 wt.%) reinforcement particles of 50nm size with aluminum alloy Al 6061 to form lightweight, high performance MMC materials. Particular attention is given to characterize the wear properties of these materials.

2. Experimental procedure

The Stir casting method was used to prepare micro and nano composites. The Al alloy pieces were heated in a graphite crucible. The reinforcement particulates of micro and nano SiC and magnesium (1%wt) are preheated disjointedly for 30 minutes. Magnesium is added to promote wettability. Aluminium degassing tablets are added in the powdered form to remove the bubbles formed during the process. The heated slurry was stirred at 320 rpm for 15 minutes using a two blade stainless steel impeller to ensure uniform incorporation of the reinforcement particles into the Aluminium matrix. The two blade stainless steel impeller was coated with alumina powder to avoid iron contamination of the molten Al metal. The impeller was placed just 20 mm above the bottom of the graphite crucible, and the blades of the impeller (tilted at an angle of 55°), when rotated, covered a relatively large area of the crucible base. This design prevented the SiC from settling down when the melted slurry was stirred for 5 minutes. Furthermore, stirring at an optimized speed of 320 rpm created a vortex in the melt, and this effectively enhanced the distribution of the particles. This stirring process was used to ensure the homogeneity of the melted slurry. The melt, with the micro SiC incorporated Al6061 MMC and nano SiC particles incorporated Al6061 MMC, are poured in to a mould of length 100mm and diameter 10mm as a rod. The stir casting setup is shown in figure 1.
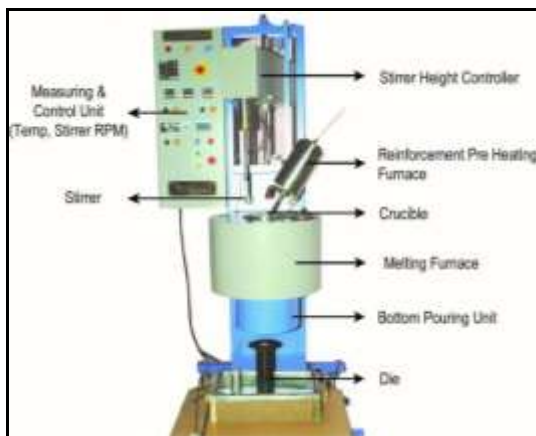

Figure1. Photograph of Stir casting setup

3. Results and discussion

The Pin on Disc tester is used for a quick and easy method of kinetic friction and sliding wear measurement. The pin on disc tester measures the friction and sliding wear properties of dry or lubricated surfaces of a variety of bulk materials and coatings [12,13]. The pin surface can be wear and friction tested. The normal load, rotational speed, and the wear track diameter are all the set by the user prior to the pin on disc test. Dry sliding wear tests were conducted using a pin-on-disc tester as per the ASTM G-99 standard. Pin specimens of diameter 8mm and length 30 mm were machined from the casted rods. A pin holder loaded the stationary pins vertically onto a rotating En-31 steel disc. A normal load of 1 kg was applied using dead weights at 600, 450 and 360 rpm for the corresponding wear tracks of 30, 40 and 50mm diameter over the steel disc. For each sliding condition, 26 minutes of run were carried out. At the end of it, the pins were carefully cleaned and weighed using a sensitive electronic balance with an accuracy of ±0.001 mg to determine the weight loss. The following table 1 shows the mass loss and wear rate for the applied load of 1 kg for Al6061- micro SiC and Al6061-nano SiC Composites and interprets that increasing the weight percentage of reinforcement particles, reduces the wear rate up to 10wt% micro SiC and 1.0 weight % of nano SiC. The variation of wear rate of Al6061- micro SiC and Al6061- nano SiC composites for a sliding distance of 1500 meters are depicted in fig.2 and the co-efficient of friction(COF) are shown in figure 3 and figure 4.

Table 1 –Mass loss of composite pins

MMCs	% wt of reinforcements with Al6061	Mass loss (gm)	Wear rate (mm3/m)
Micro SiC	5	0.00851	3.273×10^{-3}
	10	0.00670	2.580×10^{-3}
	15	0.00673	2.590×10^{-3}
Nano SiC	0.5	0.004	1.540×10^{-3}
	1	0.003	1.150×10^{-3}
	1.5	0.0035	1.350×10^{-3}

Figure 2. Wear rate of micro SiC reinforced composite

It is observed from the fig.2, fig.3 and fig.4 that the amounts of reinforcement in Al6061 alloy have influence on the wear behavior of Al6061-micro SiC and Al6061- nano SiC composite materials. The figures clearly indicate that the wear rate and co-efficient of friction are reduced by increasing the weight percentage of micro SiC up to 10wt% & nano SiC up to 1.0wt% and drastically increased by increasing the micro and nano SiC reinforcement particles. This is due to the fact that adding more amounts of reinforcement particulates to the matrix material makes it as brittle and hence its wear rate is increased.
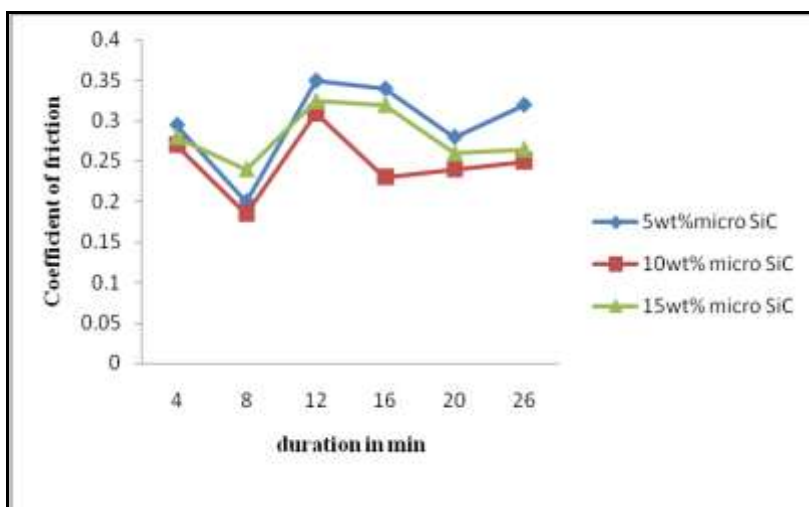

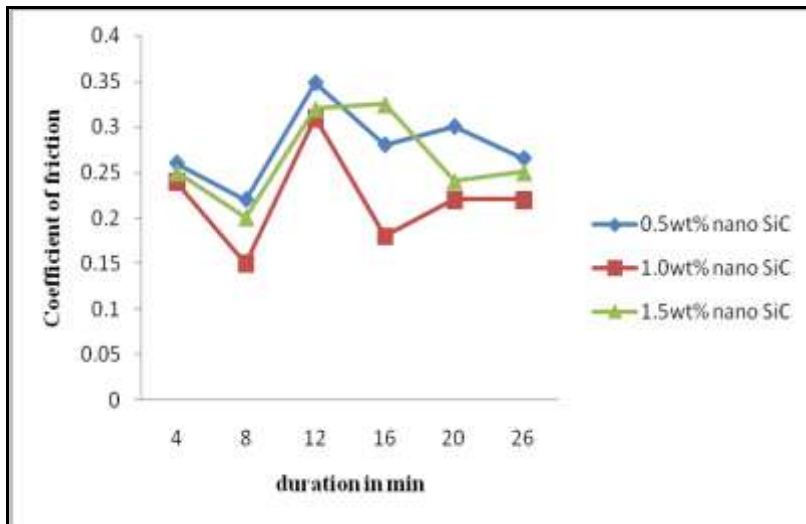**Figure 3. Coefficient of friction of micro SiC reinforced composite**

Figure 4. Coefficient of friction of nano SiC reinforced composite

4. Hardness Testing

The hardness values are taken at four different places and average hardness values of the Al6061-micro SiC and Al6061- nano SiC composites are calculated. The Vicker's hardness (HV) values are plotted in graph for various weight percentages of Al6061-micro SiC and Al6061- nano SiC reinforcement composites and are indicated in Figure5. and it indicates that the addition of micro and nano SiC increases the hardness of the composite material. The improved hardness by increasing the weight percentage of micro and nano SiC particles mainly results from the presence of extremely harder micro and nano SiC particles in Al6061 matrix material.
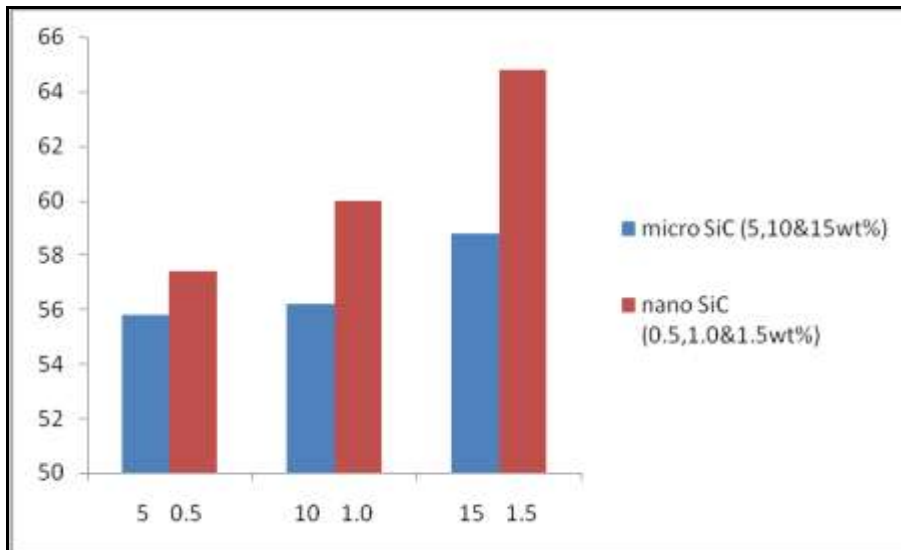

Figure 5. Vickers hardness values of micro and nano composites

5. SEM analysis of the worn surface of the Specimen

Scanning electron microscopy (SEM) of Al6061 - 10 wt% of micro SiC and Al6061 – 1.0 wt% of nano SiC was taken after the wear testing of all the specimens and are depicted in the figure 6.a. and figure 6.b. SEM of specimens has taken at a magnification range of 100µm. It is evident from that all specimens have suffered significant damage of its surface in the form of craters, grooves, debris. Most of the grooves are parallel to the sliding direction and it is evident from the worn pins [14,15]. Such features are characteristics of abrasion, in which hard asperities of the En-31 steel disc counter face, or hard reinforced particles in between the contacting surfaces, plough or cut into the pin, causing wear by the removal of small fragments of material.
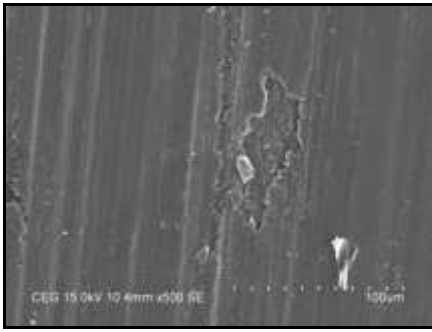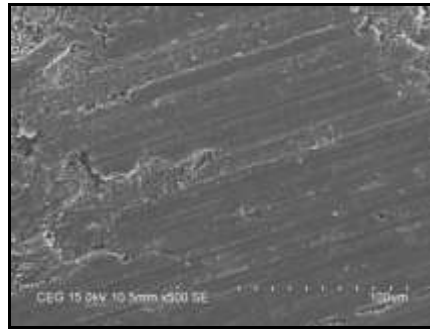
Figure 6.a. Al6061 - 10 wt% of micro SiC   **Figure 6.b. Al6061 – 1.0 wt% of nano SiC**

6. Conclusion

In the present work, wear test, hardness and microstructural studies were conducted on the cast -micro SiC and Al6061- nano SiC metal matrix composite (MMC). Based on the present experimental work the following conclusions can be drawn:

1. The stir casting method is found to be suitable for fabricating Al6061-micro SiC and Al6061- nano SiC metal matrix composites.
2. Al6061- nano SiC exhibit less wear rate and co-efficient of friction as compared with Al6061-micro SiC metal matrix composites.
3. Al6061-10% micro SiC as well as Al6061-1.0% - nano SiC composites have low wear rate compared with other reinforcement weight percentages.
4. The hardness values of Al6061 – nano SiC composites are higher than that of Al6061 – micro SiC composites.
5. SEM micrographs of the worn surfaces of the specimens have discovered the formation of craters along with the presence of grooves parallel to the slippy direction that is that the results of abrasion by laborious asperities of the steel counter face, or laborious bolstered particles in between the contacting surfaces cutting into the pin.

From this investigation it should be suggested that the Al6061 - nanoSiC composite is the most suitable choice considering the parameters like wear resistance, co-efficient of friction, hardness and microstructure among the investigated cases.

7. References

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