Tribological behaviour of AA 5083/Micron and Nano SiC composites fabricated by ultrasonic assisted stir casting process

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Abstract- Metal Matrix composites (MMCs) are light weight, high-strength materials with potential application in areas such as automobile, aerospace, defence and other industries. MMCs are projected to significantly reduce the overall weight of the vehicle and aircraft while maintaining satisfactory structural strength. Micron and Nano-sized ceramic particle reinforced aluminum matrix composites fabricated using conventional stir casting technique usually present poor distribution of these particles within the matrix and high porosity. In this study, AA 5083 alloy micron and nano SiC composites have been fabricated by Ultrasonic assisted Stir casting process. Different weight % of SiC particles Micron (10 wt%) and Nano (1, 2, 3, and 4 wt%) were used for synthesis of aluminum matrix composites. Scanning electron micrographs show uniform distribution of SiC particles however with agglomeration at some places. An attempt has been made to study the influence of wear parameters like applied load, sliding speed, sliding distance and percentage of reinforcement on the dry sliding wear behaviour of aluminum matrix micron and nano SiC composites. Results revealed that at low load and smaller sliding distance composites with nano SiC show higher wear resistance; however at high load and longer sliding distance composites with micron SiC shows higher wear resistance among all composites tested. The application of ultrasonic vibration on the composite during melting not only refined the grain structure of the matrix, but also improved the distribution of nano-sized reinforcement.

Index Terms: Metal Matrix Composites, Ultrasonic Assisted Stir Casting, Agglomeration, Nanocomposites, SiC particles.

I. INTRODUCTION

The properties attainable in any alloy system are limited to a certain extent and reach a saturation limit; further improvement can be done by strengthening mechanism, controlling microstructure, alloying constituents, addition of modifiers etc. During design & research of such materials, the concept of composite materials is used which can bring together the combined advantages of the constituent materials not possible when they are employed alone [1]. Aluminium matrix composites have drawn immense interest for various applications in making aerospace and automobile components due to their high strength to weight ratio, high stiffness, lower cost, good formability and low coefficient of thermal expansion. Particulate–reinforced Aluminum matrix composites (AMCs) are of particular interest due to their ease of fabrication, lower costs, recyclability and isotropic properties. Overall strength of such particle reinforced AMCs depends on size of the particles, the inter-particle spacing, volume fraction of the particles and the nature of matrix and reinforcement interface. Bindumadhavan et. al. [2] reported that applied load is one of the major factors influencing the wear rate of the composites. Lim et. al. [3] studied the effect of load on wear rate of alloy and composites reinforced with micron SiC particles at fixed speed, percentage of SiC_p and for 30 minutes test duration. Results revealed that the wear rate of the unreinforced alloy is found to be higher than that of the composites. Hassan et. al. [4] and Kwok and Lim [5] reported that composites with SiC_p exhibits significantly higher wear resistance than the matrix alloy due to the addition of hard SiC particles which acts as a load bearing constituent. As the percentage reinforcement of SiC particles increases, the wear rate of the composite decreases. Veeresh Kumar et. al. [6] compared the tribological properties of Al6061-SiC_p (20 µm) and Al7075-Al_2O_3 (20 µm) composites with 2-6 wt. % of particulates. Results revealed that the wear resistance of the composites increases with increase in wt % of reinforcements. Hosking et. al. [7] reported that SiC_p reinforced composite is superior to Al_2O_3 reinforced one for improving the wear resistance of the alloy because of the former one have superior hardness and toughness than the later one. Sudarshan and Surappa [8] & Mahendra and Radhakrishna [9] both stated that wear mechanism is strongly dependent on the sliding distance. At any constant load for a constant period of time the wear rate increases with increase in sliding distance and wear rate of the unreinforced alloy is found to be higher than that of the composites.

In the present work, AA 5083-SiC_p composites have been fabricated by Ultrasonic assisted stir casting. Different weight % of SiC particles Micron (10 wt. %) and Nano (1, 2, 3 and 4 wt. %) were used for synthesis of composites. SEM microstructure shows uniform distribution of SiC particles with some places agglomeration. An attempt has been made to study the influence of wear parameters like applied load, sliding speed, sliding distance and percentage of reinforcement on the dry sliding wear of micron and nano SiC metal matrix composites (MMCs).

II. EXPERIMENTAL

Selection of Material: Aluminum alloy 5083 has been selected as matrix alloy for synthesis of AMCs. The chemical compositions are shown in Table 1.

Table 1 Composition of AA 5083 Al alloy

Element	Zn	Fe	Ti	Cu	Si	Pb	Mn	Mg	Cr	Al
Percent	0.03	0.173	0.04	0.0181	0.16	0.014	0.526	5.13	0.097	Balance

Selection of Reinforcement Particles: Micron and Nano size Silicon Carbide particulates have been used as reinforcement material. SiC micron size particles with average particles size of 35 µm SiC_p (99% Pure) and SiC Nano particles of average particle size 40 nm (SiC_p-b, 99+%pure) were used.

Fabrication of Aluminum matrix-SiC_p Composites: 1400 gram Aluminum 5083 alloy has been melted in graphite crucible in electrical resistance furnaces at a temperature 760^{o}C which is above the melting point of the alloy. When the alloy reaches to a semi-pasty stage, the surface was covered with flux (Coveral-11). About 5 grams of the flux was added to the molten alloy. After complete melting, the dross is removed from the surface using a graphite-coated skimmer. The dissolved gases were removed by passing dry nitrogen grade I gas into the melt for 5 minutes. Dross is also removed by nitrogen gas bubbling, most probably by mechanical action i.e., inert gas carrying the oxides to the surfaces of the melt. After degassing, the surface was again cleaned and the temperature of the melt increased to 780^{O}C. It is worth mentioning that during degassing, the temperature of the melt is brought down to 680^{O}C. This takes care of minimum gas absorption during bubbling. Stirring the alloy melt with the help of a mechanical stirrer and add the pre-heated micron SiC particles with different wt. % in the melt. After stirring for about 10 minutes, ultrasonic treatment was given to the melt for about 5 minutes with ultrasonic probe to prevent agglomeration of fine SiC particles. Composites have been prepared with 10 wt. % of micron SiC_p particles and also with 1, 2, 3 and 4 wt% of Nano SiC_p particles through ultrasonic assisted stir casting. Figure 1 shows the Ultrasonic assisted stir casting setup for the casting of composites. After successful addition of particles, the composite melt was solidified into a mild steel die in the form of cylindrical samples (20 mm diameter and 200 mm length). Figure 2 shows the photograph of die used for casting of samples. Standard size cylindrical pins were machined for wear test from the cast cylindrical samples.

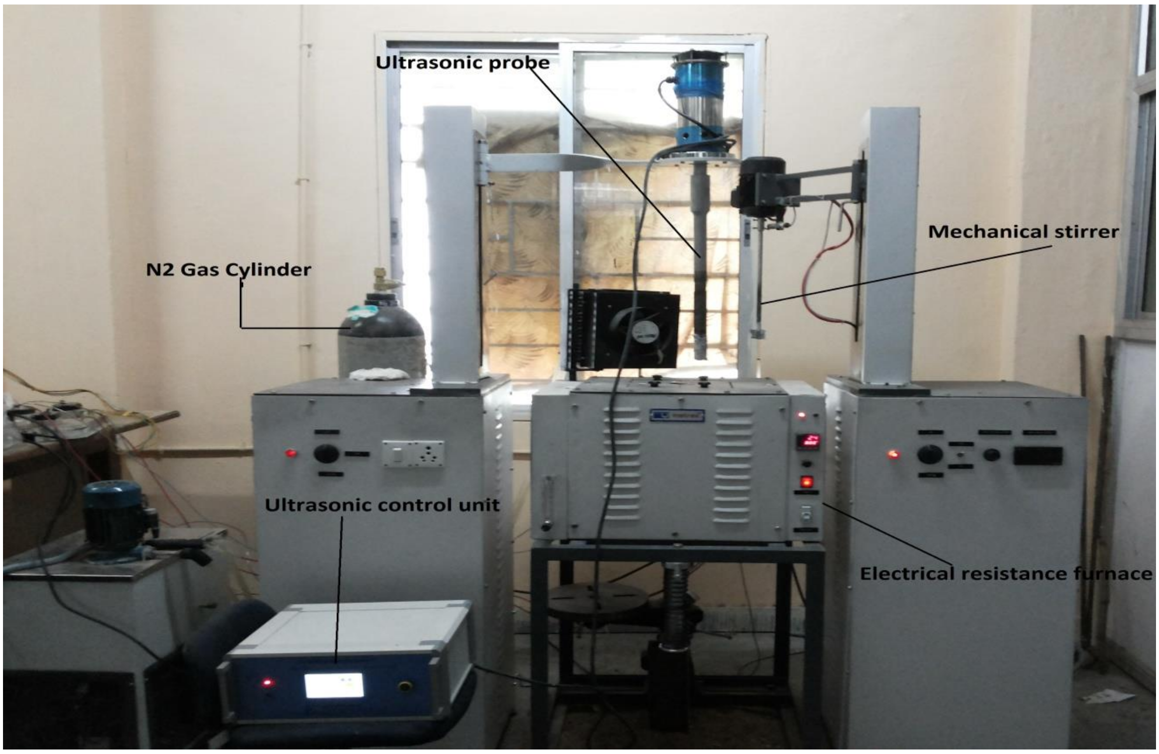

Fig. 1 Ultrasonic assisted stir casting setup

Fig.2- Die for casting of samples for wear test

III. RESULTS AND DISCUSSIONS

Effect of Sliding distance on Wear Rate: Wear mechanism is strongly dependent on the sliding distance. The Fig. 3 shows that at constant load (10 N) and for constant period of time (30 minutes) the wear rate increases with increase in sliding distance and wear rate of the unreinforced alloy is found to be higher than that of the composites. This is clearly shows from figure 3 that SiC particles improve the load bearing properties of AA 5083 alloy during sliding. As the sliding distance increases from 754 m to 1885 m the wear rate of the composite increases, which gives a direct relation between sliding distance and wear rate.

Similar trend was observed in the study of dry sliding wear behaviour of particles reinforced with Al alloys [9, 10]. Composite with nano SiC (both 3 and 4%) shows higher wear resistance than 10 % micron SiC up to the sliding distance of 1131 m. At a sliding distance above 1131 m, the wear rate of composites with nano SiC starts to increase marginally than the composites with micron SiC particles and composites with micron SiC particles exhibits low wear rate than composites with nano SiC particles at higher sliding distance and higher speed. This may be due to the breakage of particles at high sliding distance. In addition thermal softening of matrix material may take place, which further lowers the bonding effect of the nano SiC particles with that of matrix material. Due to its lower bonding strength, nano SiC particles can easily pull out from the matrix under dry sliding conditions. Similar trend was observed in the study of dry sliding wear behaviour of Al 2219/SiC, Al5083/B4C and A356/25SiCp metal matrix composites [11, 12, 13].

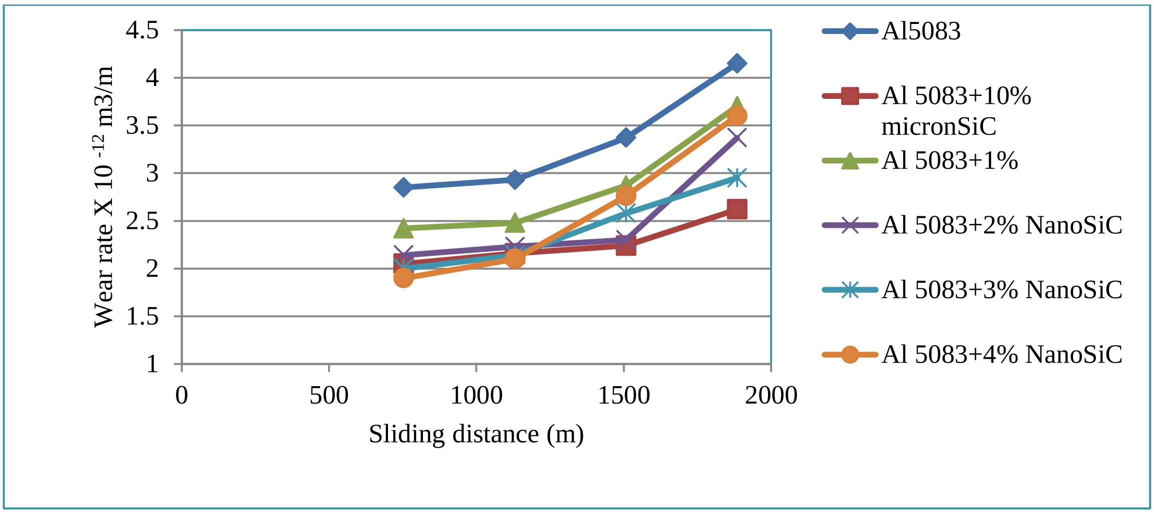

Fig. 3 Wear rate at Load 10 N and test duration 30 minutes

Effect of Applied load on Wear Rate: Applied load is also one of the major factors influencing the wear rate of the composites. The wear rate of the unreinforced alloy is found to be higher than that of the composites. This is primarily due to the fact that the hard dispersoids, present on the surface of the composites, act as protrusions, which protect the matrix from severe contact with the counter surfaces and thus resulting in less wear in composites as compared to that in the case of alloy for all loads. Figure 4 shows that at constant sliding distance (754 m), the wear rate of the composites increases with increase in load.

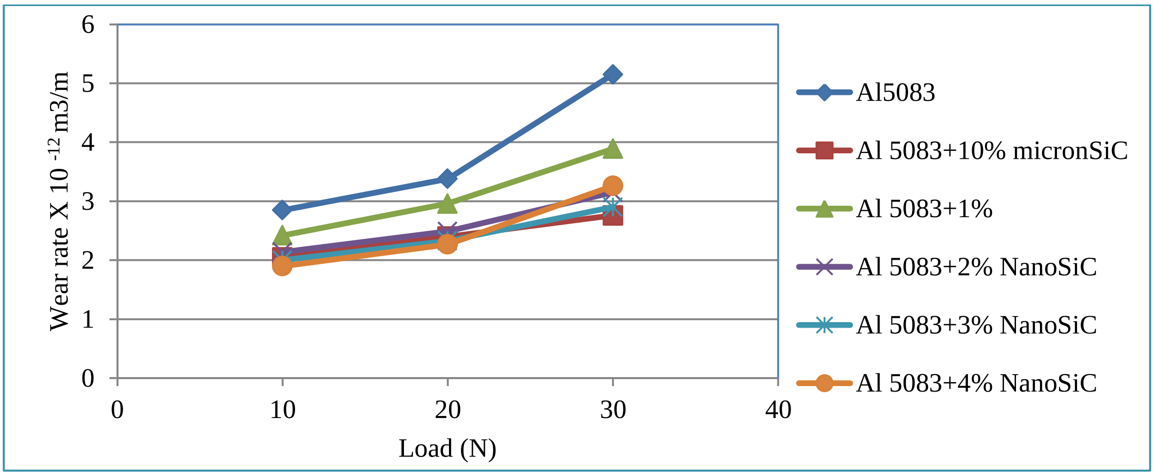

Fig.4 Wear rate at Sliding distance 754 m and test duration 30 minutes

At load 10N and 20N wear rate of Composites with 4 % nano SiC is minimum. Composites with 10 % micron SiC and composites with 3 % nano SiC have shown almost same wear rate at 10N and 20N. When there is an increase in load from 20N to 30N, the composites with 10 % micron SiC shows lower wear rate then all the nano SiC composites. From the Fig. 5, it is shown that the composites with 10 % micron SiC particles exhibits better wear resistance than all the composites with nano SiC particles at higher load, higher sliding distance and higher speed. This may be due to the fact that nano particles tend to get ploughed away from the surface of the matrix easily, thus increasing the wear. In composites with micron particles, the particles get fragmented into small pieces and continue to restrict the particle removal, thereby decreasing the wear.

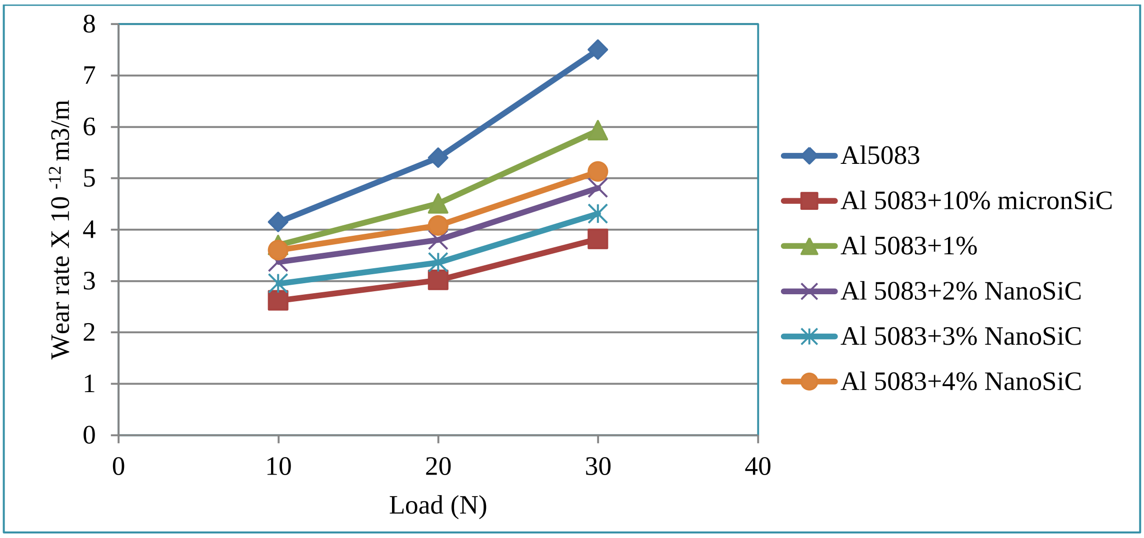

Fig.5 Wear rate at Sliding velocity 1885 m and test duration 30 minutes

The effective wear from the specimen surface is due to the combined effect of a number of factors. The increase in the applied load leads to increase in the penetration of hard asperities of the counter surface to the softer pin surface, increase in micro cracking tendency of the subsurface and also increase in the deformation and fracture of asperities of the softer surface. Beyond the critical load for each composite, the wear rate starts increasing abruptly with the applied load. The load at which wear rate increases suddenly to a very high value is termed as the transition load [14].

Effect of Reinforcement on Wear Rate: It was observed from figure 6 that the composites reinforced with micron and nano SiC exhibits significantly higher wear resistance than the matrix alloy due to the addition of hard SiC particles which acts as a load bearing constituent. As the percentage reinforcement of Nano SiC particles increases, the wear rate of the composite decreases. Increase in the addition of SiC particles restricts the deformation of the matrix material with respect to load, hence the wear rate for composites with higher percentage of SiC is low.

The particle size is also one of the factor which influences wear. At low speed and low load the wear resistance of composites with nano SiC particle is higher than the composites with micron SiC particles due to higher hardness of Nano SiC composites. But at higher load and high speed composites with micron SiC shows better wear resistance than composites with nano SiC particles. This may be due to the fact that the probability for the Nano SiC particles pulling out from the matrix is higher as the interfacial strength between the particle-matrix becomes weak due to smaller contact area. In composites with Micron SiC particles the interfacial strength is high due to large surface bonding which avoids particle pull out and the matrix holds the particle strongly until the particles break down into small particles.

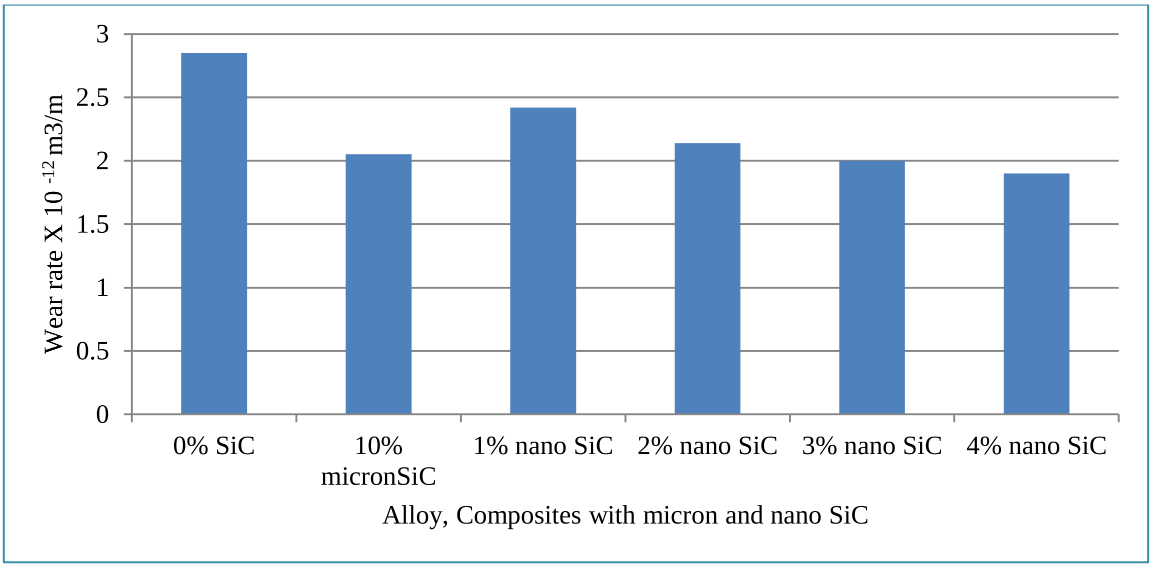

Fig.6Variation of wear rate of alloy and composites at a Load 10N and sliding distance 754 m and test duration of 30 minutes

IV. CONCLUSIONS

(1) Aluminium matrix micron 10 wt. % and nano (1, 2, 3 and 4 wt. %) SiC_p composites have been successfully fabricated by ultrasonic assisted stir casting process.

(2) Wear rate of Al-SiC_p composites increases with increase in sliding distance. This indicates that fracturing tendency of the surface is more predominant than strain hardening of the surface during sliding wear tests.

(3) Wear rate of the unreinforced alloy is found to be higher than that of the composites. As the sliding distance increases from 754 m to 1885 m the wear rate of the composite also increases with sliding distance which gives a direct relation between sliding distance and wear rate.

(4) The wear rate of Al-SiC_p composites with micron particles exhibits better wear resistance than composites with nano particles at higher load (30 N) and higher sliding distance (1885 m).

(5) The particle size is also one of the factor which influences wear. At low speed and low load the wear résistance of composites with nano SiC particle is higher than the composites with micron SiC particles due to higher hardness of Nano SiC composites.

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