Experimental analysis of the wear behaviour of reinforced hybrid LM25 metal matrix nano composite

B. KUMARA GURUBARAN[*], P. GOPAL, V. DEEPAKARAVIND, T. SENTHILKUMAR
Department of Mechanical Engineering, BIT Campus, Anna University, Tiruchirappalli, Tamilnadu, India.

In this paper new concept was implemented to improve the wear and temperature resistance in addition to reinforcements such as Aluminium oxide and Silicon carbide nano particles added in the LM25 hybrid composite by using stir-casting process. The wear resistance and frictional properties of the hybrid metal-matrix nano composite were studied by performing a dry-sliding-wear test by using a pin-on-disc wear tester. The experiments were conducted at a constant sliding velocity of 1.04 m/s and sliding distance of 628 m with various loads of (10-40) N .The results showed that the reinforcement of the metal matrix with nano SiC and nano Alumina reduced the wear rate at room temperature and also indicate that increasing the wear of the test specimens with an increasing the load and sliding distance. In addition to the coefficient of friction decreased with the load and increased volume content of the reinforcement. The wear surfaces were examined with a scanning electron microscope which indicated abrasive wear mechanism due to the hard ceramic particles on the wear surface of the metal matrix nano composite of LM25 samples.

1. Introduction

The need for the light-weight and high-performance materials is increased day by day due to the increase in the application areas such as automotive, aerospace, deep-ocean, nuclear-energy-generation and structural applications, that have led to the invention of hybrid materials in the form of composites.[2–5]

Metal-matrix composite materials are finding to increase the numbers of applications in a variety of engineering fields due to their important properties. Hybrid composite materials are advanced composite materials reinforcement with the one or more substance in order to achieve a combined effect. This allows a rather high degree of freedom in the material design. [1]

The studies on the wear of hybrid composite materials are necessary for the industry. An addition of hard particles to the matrix of a composite material influences the wear properties. The hard ceramic particles such as Al_2O_3, SiC, TiC, etc., embedded in the matrices of hybrid composite materials have shown to reduce the wear loss compared to the base alloys.[6–8]

The studies indicated that the wear loss normally decreases with an increase in the hard-phase volume fraction and particle size.[9]. The studies on the wear of composite materials indicated that the wear rate of Al_2O_3 reinforced composites decreases by two fold as the particle size increases from 5 μm to 142 μm at a fixed volume fraction.[10,11] .The results from the literature reveal that commonly only a single reinforcement is incorporated into a metallic matrix, but the recent trend involves hybrid reinforcements[12–14] enhancing the properties more than a single reinforcement.

There was an investigation of the factors influencing the dry-sliding-wear behavior such as the load, the sliding speed, the reinforcement content in an aluminium/fly ash/graphite hybrid metal-matrix composite and the results reveal that the load is the most significant parameter influencing the wear rate of the hybrid composite followed by the sliding speed and the reinforcement content.[14] Asif et al.15 conducted a comparative study made between binary and hybrid composites of an aluminium alloy reinforced with silicon carbide and an aluminium alloy reinforced with silicon carbide and graphite. Both composites were manufactured using the powder-metallurgy technique. The results from the pin-on-disc wear tester showed that the wear rate of the hybrid composite was lower than that of the binary composite.

The results also indicated that the hybrid composite had an accepted level of tribological characteristics of the black and smooth worn surface. For discontinuous metal-matrix composites, stir casting is generally accepted as a promising route, currently practiced commercially. Its advantage lies in its simplicity, flexibility and applicability to a large-quantity production. It is also attractive because, in principle, it allows the conventional metal processing route to be used, hence, minimizing the final cost of the product. This liquid-metallurgy technique is the most economical of all the available metal-matrix-composite productions [16] allowing an easy fabrication. An important factor for the liquid-metallurgy technique is the solidification of the melt containing suspended dispersions under a selected condition to obtain the desired distribution of the dispersed phase in the cast matrix.

The sliding-wear behavior of a composite is found to be a function of many factors such as the volume fraction and particle size of reinforcement, the hardness and strength of the matrix alloy, applied load, environmental

temperature, etc. The investigation of the sliding-wear properties of aluminium MMCs with the reinforcements such as SiC, Al2O3, TiC, TiB2 and graphite was carried out by the researchers.[19–23]

The aim of the present investigation is to evaluate the dry-sliding metal-metal wear behavior of the LM25Metal matrix nano composites of Samples1,2&3, discontinuously reinforced with two different types of particles such as nano particles of SiC and Al_2O_3. The stir-casting method was chosen for the manufacturing of hybrid metal matrix composites.

The effect of an equal volume fraction of the reinforcement and the applied load on the dry-sliding metal-metal wear behavior of the composite is investigated using a pin-on-disc wear tester. The hardness of the hybrid composite is measured to analyze the effect of the reinforcement.

The microstructure of the specimens is studied as the particle distribution and worn surfaces were examined with a scanning electron microscope.

2. Preparation of the wear samples

The LM25 metal matrix nano composite material was fabricated by using the stir casting method in addition to the different volume fractions of the reinforcement of nano SiC and nano Alumina in the metal matrix of LM25 composite were thus produced.   Every wear sample specimens were made from the master sample with the dimensions of 10mm diameter and Length of 10mm.Which as shown in Figure 1,1a and 1b

Fig. 1 shows the Wear Sample 1(A), Sample 1(B) and Sample 1(C)

Fig. 1a shows the Wear Sample 2(A), Sample 2(B) and Sample 2(C)

Fig. 1b shows the Wear Sample 3(A), Sample 3(B) and Sample 3(C)

3. Experimental procedures

The sliding experiments were conducted at room temperature with a pin-on-disc wear-testing machine (wear and friction monitor TR-201). The pins were loaded against the disc by a dead-weight loading system.

Fig. 2. Photographic view of the pin-on-disc wear-testing machine

The disc test piece was 100 mm in   diameter and 10 mm in thickness. They slide on a disc with a diameter of 50 mm. The material of the disc is hardened steel of HV698. The wear tests conducted in the Metal matrix nano   composite   specimens   of Sample1(A,B&C),Sample2(A,B&C)&Sample3(A,B&C) were carried out under dry-sliding condition at four different applied loads of 10 N, 20 N, 30 N and 40N for a total sliding distance of 628 m at a constant sliding speed of 1.04 m/s.

During the test the relative humidity and temperature of the surrounding atmosphere were about 50 % and 25 °C, respectively. The test duration was 10 min at a constant disc speed of 400 r/min for all the tests. The vertical height (displacement) of a specimen was continuously measured using a linear variable differential transformer (LVDT) with the accuracy of 1 μm during the wear test and the height loss was taken as the wear of the specimen. A photographic view of the pinion-disc wear tester used in this investigation is shown in Fig. 2.

An experimental graph showing the height loss or

wear in mg/s against the sliding time in seconds obtained with the wear testing is shown in Figure (3,4,5&6). The sliding speed and the sliding distance covered by a test specimen on the complete course of the experiment or in a particular interval of time are calculated in the following way:

Sliding speed = $\pi DN/ 60\ 000$, m/s

Sliding distance = $\pi DNT/ 60\ 000$, m/s

Where D = diameter of the wear track,

N = disc speed in r/min,

T = test duration in s.

4. Results and discussion

The study on the wear of composite materials is very important for material scientists and manufacturing engineers. Especially when hybrid composite materials are used for a particular application, their response to wear is to be analyzed. The wear rate of hybrid composite materials are different from that of metallic materials because it consists of three different phases. In the present work the wear behavior of hybrid metal-matrix composites is analyzed and presented in detail.

4.1 Effects of the various loads and sliding distance on the wear rate of the Samples1, 2 and 3

1. Wear rate of LM25 reinforced Metal Matrix Nano composites of Samples (S1, S2&S3) were measured by applying various loads such as :a) 10N, b) 20N, c) 30N, d) 40 N at the constant sliding velocity of 0.6m/s at the end of the maximum sliding distance time taken at (2000s).From the figure 3 wear test results showed that reducing the wear rate of LM25 MMNC samples due to increasing the addition of nano alumina and nano silicon carbide in hybrid LM25 composite. As a result suggested that the Sample 3 has found to be lower wear rate compared to other samples 1 and 2
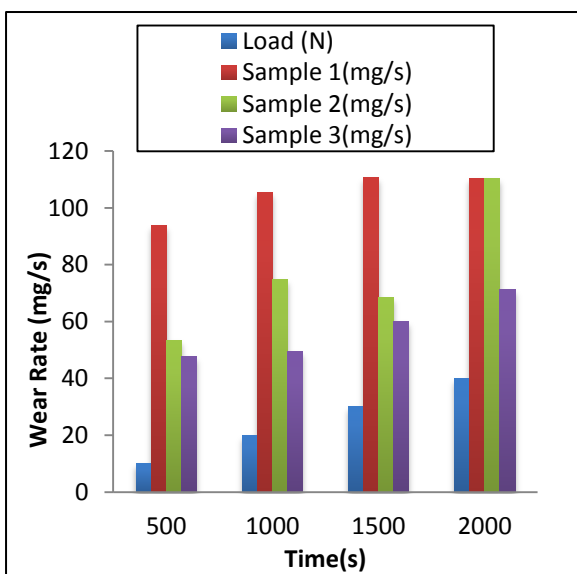
Fig. 3Wear rates of LM25 MMNC Samples at Constant Sliding Velocity at 0.6m/s
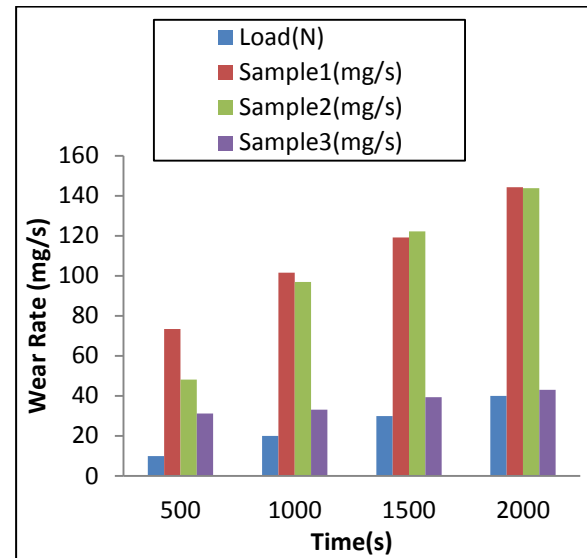
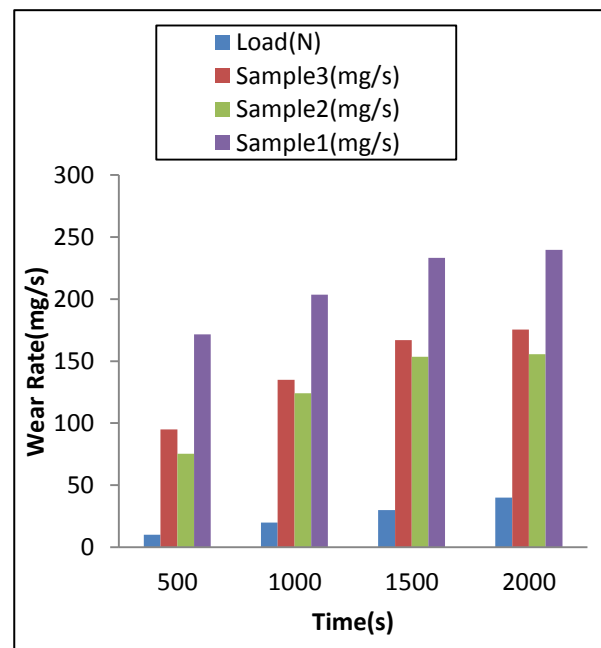*Fig. 4 Wear rates of LM25 MMNC Samples at Constant Sliding Velocity at 0.9m/s*

Fig. 5 Wear rates of LM25 MMNC Samples at Constant Sliding Velocity at 1.2m/s

2. Wear rate of LM25 reinforced Metal Matrix Nano composites of Samples (S1, S2&S3) were measured by applying various loads such as :a) 10N, b) 20N, c) 30N, d) 40 N at the constant sliding velocity of 0.9m/s at the end of the maximum sliding distance time taken at (2000s).From the figure 4 wear test results showed that reducing the wear rate of LM25 MMNC samples due to increasing the addition of nano alumina and nano silicon carbide in hybrid LM25 composite. As a result suggested that the Sample 3 has found to be lower wear rate compared to other samples 1 and 2.

3. Wear rate of LM25 reinforced Metal Matrix Nano composites of Samples (S1, S2&S3) were measured by applying various loads such as :a) 10N, b) 20N, c) 30N, d) 40 N at the constant sliding velocity of 1.2m/s at the end of the maximum sliding distance time taken at (2000s).From the figure 5wear test results showed that reducing the wear rate of LM25 MMNC samples to increasing the addition of nano alumina and nano silicon carbide in hybrid LM25 composite. As a result suggested that the Sample 3 has found to be lower wear rate compared to other samples 1 and 2.

4.2 Effects of the various sliding speeds on the wear rate of the Samples S1, S2 and S3

The below figure 6 graph exhibits initially the three regions representing the running-in and steady-state periods. During the running-in period the wear rate increases very rapidly with the increasing sliding distance.
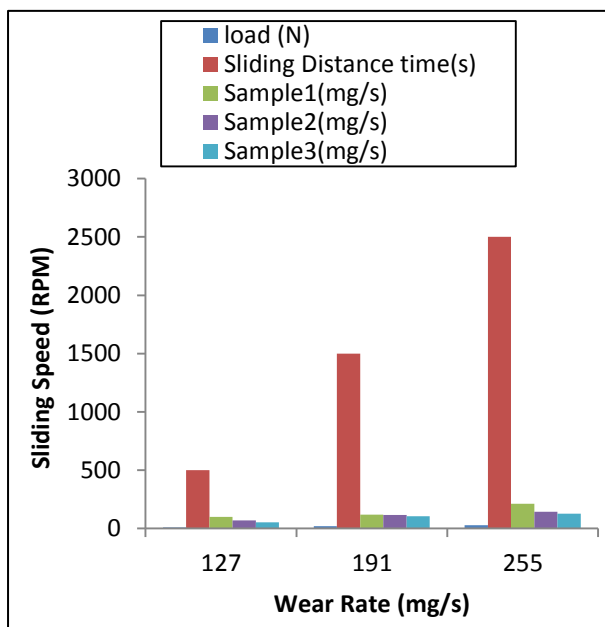
Fig. 6 Wear rates of LM25 MMNC Samples at Various Sliding Speeds

During the steady-state period, the wear progressed at a slower rate and linearly with the increasing sliding distance at the various sliding speed, which as shown in the figure6. As a result suggested that Sample 3 has found to be lower wear rate comparing to other samples 1 and 2.

4.3 Micro structural studies

The wear tracks observed on the surfaces of the hybrid metal matrix nano composite LM25 materials. These SEM micrographs were taken at a scale range of 5 μm. From the below Figure(7, 8 and 9) clearly indicated how the wear takes place on the top surfaces of the hybrid metal matrix nano composite of Sample(1,2&3).The below Figs. (7,8&9) showed that the wear pattern of Sample 3 more stronger than among the other two Sample(1&2).An

increase in the reinforcement reduces the wear and the surface observed was smooth, Which as shown in the below Figs. (7,8&9).
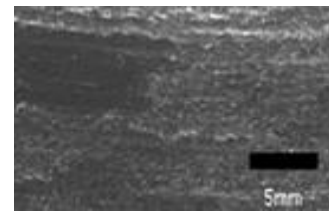
Fig. 7 SEM photographs of the wear tracks of Sample 1at 50μm scale range

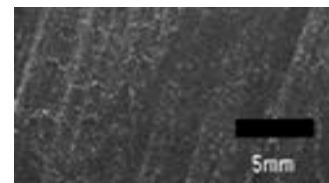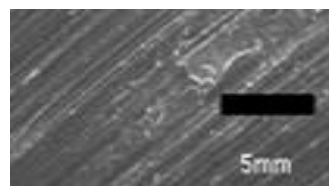*Fig. 8 SEM photographs of the wear tracks of Sample 2 at 50μm scale range*

Fig. 9 SEM photographs of the wear tracks of Sample 3 at 50μm scale range

5. Conclusion

The analysis of the effect of the nano silicon carbide and nano alumina reinforcement on the wear behavior of the LM25-alloy hybrid composite led to the following conclusions:

• As the load was increased, a change from a mild to a severe wear takes place much faster on the LM25 MMNC of Sample1 compared to other two Samples(2 and3). The wear rate decreased with the increasing volume content of the reinforcement.

• The coefficient of friction decreased with an increase in the particle reinforcement and load (for the fixed-sized nano Silicon Carbide and nano Alumina particulates).The coefficient of friction and the wear rate of a Sample 3 was lower, when compared with the metal matrix nano composites of Samples 1&2

• The result of the scanning electron microscope showed that a Sample 1 has a much rougher surface as the other two samples (2and3).This indicated that due to the abrasive-wear mechanism hard ceramic particles embedded in the surface of the metal matrix nano composite of LM25 alloy of Sample1, Sample2and Sample3.

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*Corresponding author: guru17381@gmail.com