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Research Paper

EVALUATION OF TRIBOLOGICAL PROPERTIES OF A356-Al_2O_3 METAL MATRIX COMPOSITES

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MMCs are promising materials under constant development and their application in different industries is increasing. They have better mechanical and tribological properties comparing to the matrix materials. This paper presents tribological tests results of Aluminium A356 with 10% Al_2O_3 reinforcement. The reinforcement was in the shape of particles with size of 25 μ, 45 μ, 75 μ and 120 μ and the technology for producing of composite was stir casting. Dry sliding wear tests of the specimens were conducted using pin-on-disc test apparatus conforming to ASTM G99 standards with electronic data acquisition system. EN32 hardened steel disc with a hardness of 65HRC and Ra value of 2.5-3.5 μm was used as the counter surface. The wear displacement with respect to sliding distance of different test specimens at different loads were studied and analysed. The slope of the curves is higher initially, indicating running-in wear, during which, asperity contacts take place resulting in higher wear rates. Later, as the asperities get flattened, contact area increases, with reduction in wear rate, which is indicated by reduced slope of wear curves. With further increase in sliding distance, rate of wear increases, due to abrasive wear of entrapped particles between mating surfaces.

Keywords: Aluminium Matrix Composites (AMCs), A356, Al_2O_3, Dry sliding, Friction, Wear

INTRODUCTION

The use of different types of Metal Matrix Composites (MMCs) is in constant growing over the years, because they have better physical, mechanical and tribological properties comparing to matrix materials. Composite materials based on light metals like Aluminium, Magnesium and Zinc, due to their low density; find application in many industries (Surappa, 2003; Prasad and Asthana, 2004; and Hunt and Miracle, 2001). The idea that relatively small amount of reinforcement can improve characteristic of matrix material by several times is very interesting, so constant

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improvements of MMCs process technologies and possibilities for their new application are not a surprise. Better tribological properties of composite comparing to the matrix material is of great importance in all machines where parts are in contact and relatively motions. The fact is that tribological properties are the one that define possible application of material far more than their mechanical properties, since they are in better correlation with behaviour in practice. Numerous authors have investigated friction and wear properties of Aluminium Matrix Composites (AMCs) and have analysed different influences:

- The type of matrix and counter part material and their hardness,
- The type of reinforcements, its shape, dimension and volume percentage
- Testing conditions (load, speed, temperature, type of relative motion and lubrication and environment) (García-Cordovilla *et al.*, 1996; Bialo *et al.*, 2000; and Yang, 2003).

Most of these investigations were conducted on model type pin-on-disc tribometers. The aim of this paper is to present investigation on domestically produced Al based composite (Miškovic *et al.*, 2006) and to show possible directions how to improve its tribological properties, in the next phase of the project.

Abdul Samad *et al.* (2006) studied on wear and friction of Al-Al_2O_3 composites at various sliding speeds. This study addresses the dry wear behavior of Al_2O_3-6061 Aluminum particulate composite under different sliding speeds and applied load using pin on-disk tribometer at room temperature. Three grades of the submicron particle composites containing 10, 20, and 30 vol. % Al_2O_3 were tested. The results illustrate that higher load and higher concentration of Al_2O_3 particles lead to higher wear rates. For 10 and 20% Al_2O_3 concentrations, the wear rate decreases with increasing sliding speed, while it increases for 30% Al_2O_3.

Literature review indicates that the mechanical and tribological characteristics of metal matrix composites depend on wide range of material, processing and operating parameters. There is great scope for improvement with proper combination of these parameters.

MATERIALS AND METHODS

Work Material Details: The details of the material selected for present investigation are as discussed below. Aluminum (A356) based metal matrix composite with varying particle sizes particulate aluminum oxide with volume fraction of 10% are used (Table 1). α-aluminum oxide average particles sizes of 23 µm, 45 µm, 75 µm, and 120 µm has been selected for the present investigation. Wear test specimen: The wear test specimens of

Table 1: Composition of Work Material

Elements	Percentage
Al	91.1-93.3
Cu	<=0.2
Iron	<=0.2
Mg	0.25-0.45
Mn	<=0.1
Other each	<0.05
Silicon	6.5-7.5
Titanium	<=0.2
Zinc	<=0.1

28 mm length and 10 mm diameter are prepared as per the ASTM G99 standard as shown in the Figure 1.

Figure 1: Wear Testing Specimens

Dry sliding wear tests were carried out under ambient conditions (24-28 °C) using pin-on-disc wear testing machine (Figure 2). Prior to testing, the specimens were ground against a 600 grit SiC abrasive paper to make the surface flat and maintain the surface finish between 1.5 and 3 μm Ra value. Then the specimens were thoroughly cleaned with acetone and dried. The specimens were then weighed accurately using electronic balance with 0.1 mg accuracy. The counter face disc also was cleaned with acetone to remove any oil film present. The wear test was conducted at different loads, with increments of 10 N and constant velocity of 2 m/s. After every 5000 m run the specimen was removed, cleaned, dried and weighed to calculate the mass loss. The friction coefficients and wear were recorded continuously. Table 2 shows the technical specifications of wear and friction test rig.

Figure 2: Wear and Friction Test Rig

Table 2: Technical Specifications of Wear and Friction Test Rig

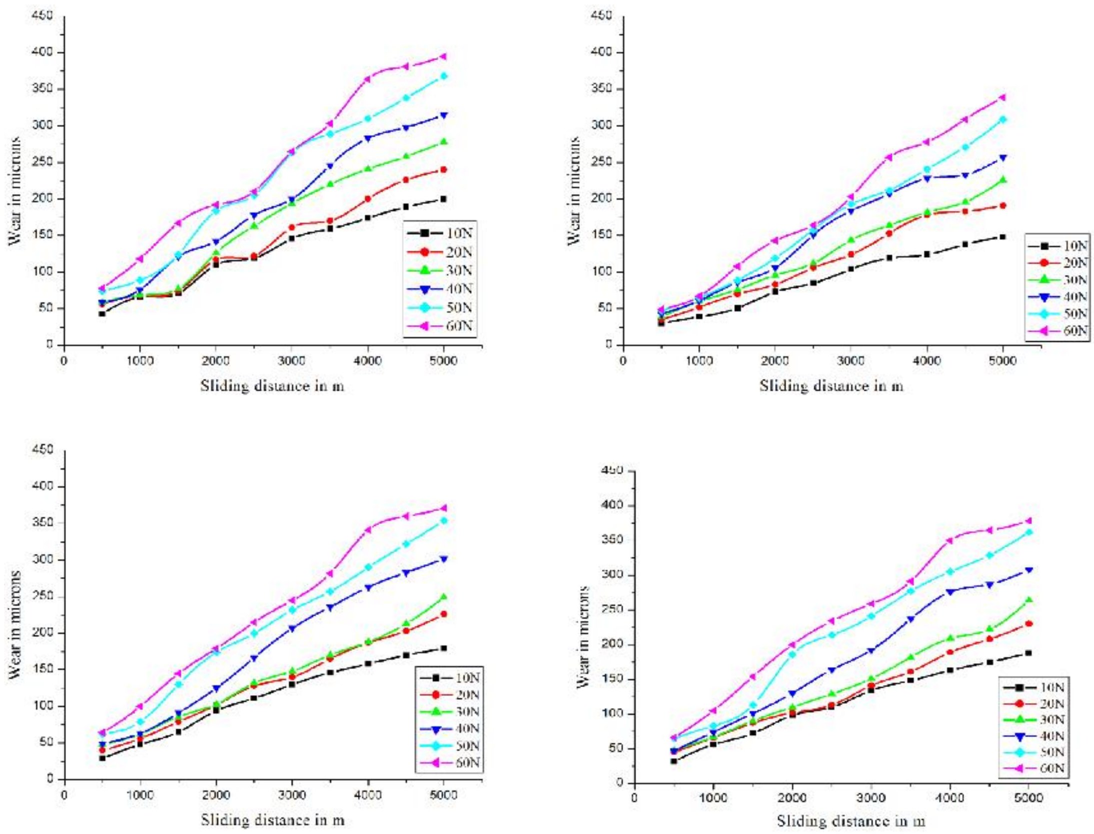
Rotational Speed	Up to 2000 rpm
Track Diameter	40 mm-118 mm
Load Range	Up to 200 N
Disc Size	Dia 120 mm × Thickness 8 mm
Pin Size	6 to 12 mm
Wear or Displacement	± 2000 microns
Frictional Force	Up to 200 N

RESULTS AND DISCUSSION

Wear V/S Sliding Distance with Varying Load

Figure 3 indicates the wear displacement with respect to sliding distance of different test specimens at different loads. In most of cases, it can be observed that the slope of the curves is higher initially, indicating running-in wear, during which, asperity contacts take place resulting in higher wear rates. Later, as the asperities get flattened, contact area increases, with reduction in wear rate, which is indicated by the reduced slope of wear curves. With further increase in sliding distance, rate of wear increases, because of the abrasive nature of wear due to the entrapped particles between the mating surfaces.

Figure 3: Wear v/s Sliding Distance



Frictional Force V/S Sliding Distance with Varying Load

Test results, indicating the variation of frictional force with respect to sliding distance with varying load of different particle size of composites are shown in Figure 4. From the plots, it can be observed that friction force is relatively higher in case of composites compared to that of matrix alloy. This can be attributed to increased resistance offered by the harder worn out particles, entrapped between the mating surfaces. Also it can be observed that the composites with larger particulate reinforcement experience marginally higher frictional force compared to those with smaller particulates. This again can be attributed to penetration of the larger particulates, to a greater depth in the counter surface, resulting in friction force of the higher order.

Temperature V/S Sliding Distance with Varying Load

Figure 5 illustrates variation of temperature with respect to sliding distance of different particle size of composites. It can be observed from the plots that the temperature increases with increasing load, with increasing load contact between surface of pin and disc increases due to this temperature increases with increasing load. Marginally higher temperature can be observed in case of base alloy test specimen compared to those in case of composite specimens. Among the composite specimen, recorded values of temperature appear to

Figure 4: Frictional Force v/s Sliding Distance

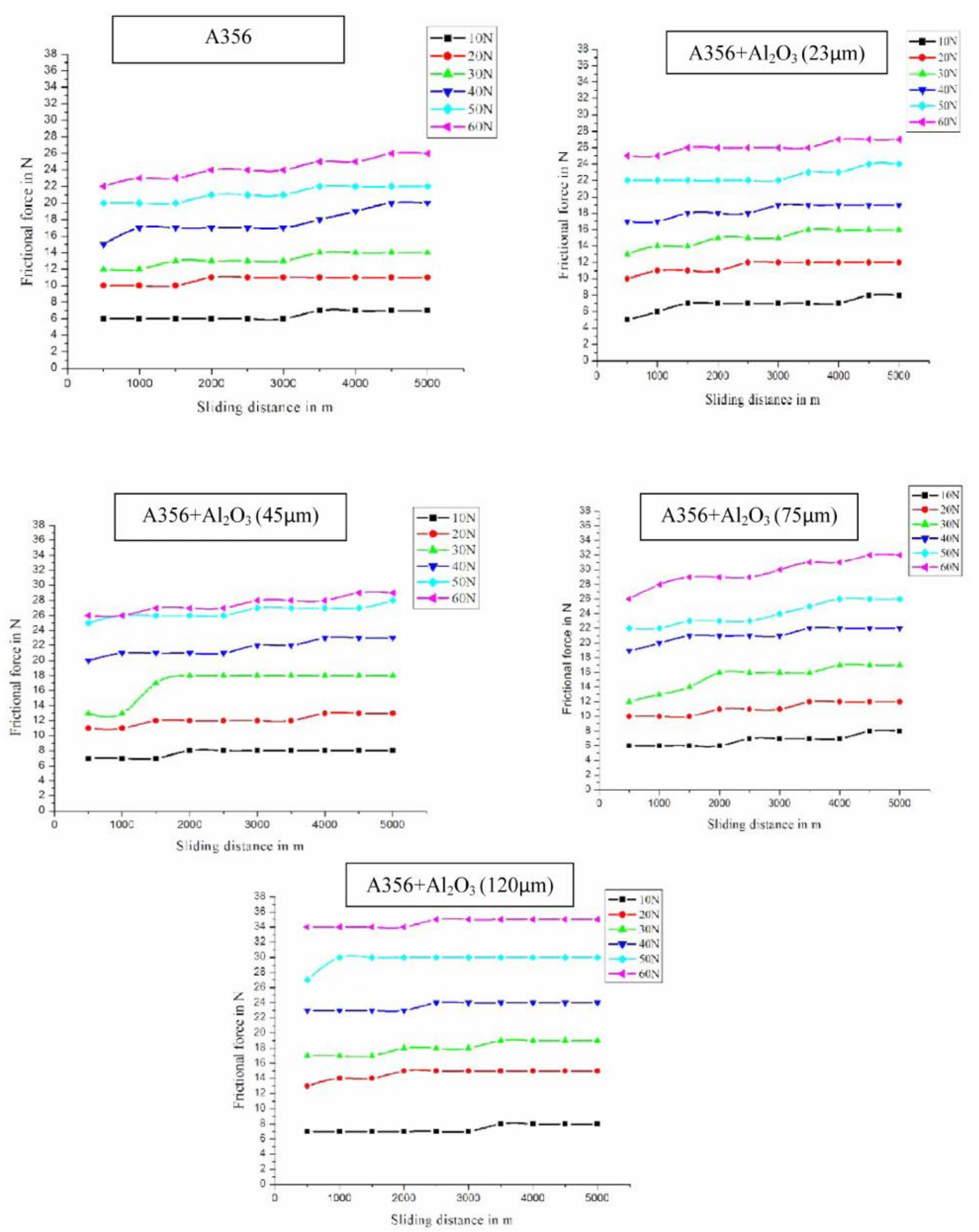
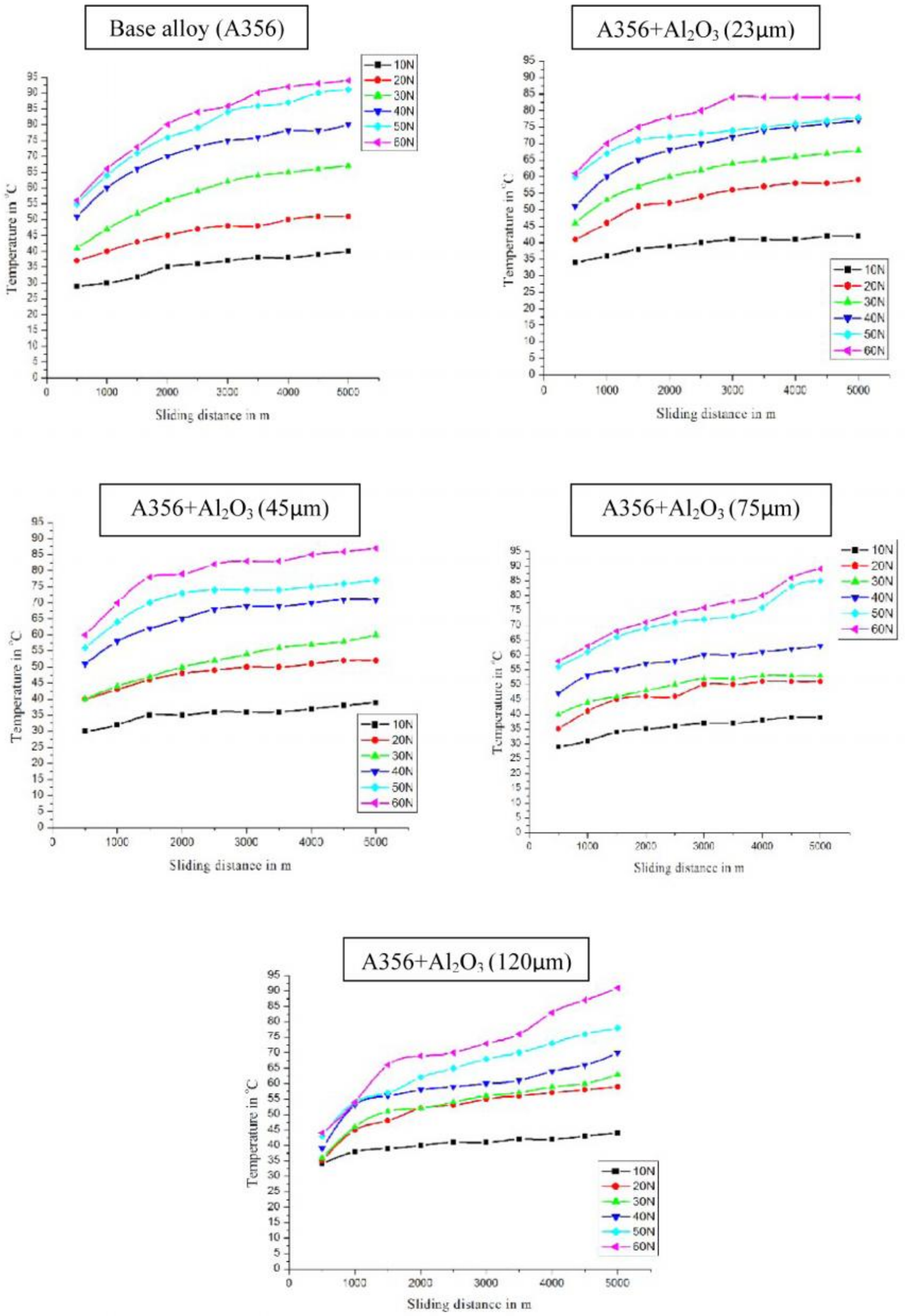


Figure 5: Temperature v/s Sliding Distance



decrease marginally with decreased particulate reinforcement size.

CONCLUSION

Experimental investigations on the evaluation of tribilogical characteristics of A356-Al_2O_3 p metal matrix composites have provided the following conclusions.

- The wear properties of the A356 alloy were considerably improved by the addition of Al_2O_3 particulates and the wear resistance of the composites was much higher than that of the unreinforced A356 aluminum alloy.
- The wear resistance of composites increased with decreasing particle size of Al_2O_3 particulates.
- From the wear test results, it can be observed that the transition from mild to severe type of wear takes place in the load range of 30-40 N.
- Frictional force is relatively higher in case of composites compared to that of matrix alloy. And also composites with larger particulate reinforcement experience marginally higher frictional force compared to those with smaller particulates.

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