Wear Characteristics of Aluminium & Al_2O_3 Metal Matrix Nano Composite

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***Abstract*---The wear characteristics of commercially pure aluminium reinforced with nano alumina particulateof metal matrix nano composite are studied. The bulk Nano composite is prepared using non-contactcavitation method .The wear properties of aluminium based nano composite are investigated with an unlubricated Multiple Tribo Tester. The sliding wear test was conducted for different loads, speed and time. The result shows that wear rate increases with increasing load and with increasing speed. The worn out surfaces of the specimens of both pure aluminium and MMNC were studied with a Field Emission Scanning Electron Microscope to determine the wear mechanism. Analysis revealsthat the MMNC has greater resistance to sliding wear compared to pure Aluminium anddominating wear types are delamination and abrasion.**

Keywords---MMNC, sliding wear, wear mechanism, delamination and abrasion.

1.INTRODUCTION

The applications of lightweight and high-performance metal matrix composites and Nano composites (MMCs, MMNCs) in aerospace, automobile, and consumer-related industries have been hindered by high costs of producing components of even minimally complex shape. Casting technologyplays the key to overcomethis problem, although several technical challenges exist. Achieving a uniform distribution of reinforcement within the matrix is a big challenge, which directly influences the properties and quality of the composite materials. Discontinuously reinforced aluminium metal matrix composites (DRAMMCs) are a class of composite materials that have desirable properties, such as low density, high specific stiffness, high specific strength, a controlled co-efficient of thermal expansion, increased fatigue resistance, and superior dimensional stability at higher temperature [1-7].

The metal matrix Nano composites (MMNCs) reinforced with Nanoceramic particulates, are showing properties like light weight and high strength. Because of these properties, MMNCs captured large area of applications. The MMNCs possess excellent mechanical and tribological propertiesand are considered as potential engineering materials for various tribological applications [8-13].Severalresearchershaveworkedon slidingwear mechanismofMMCsand MMNCs reinforcedwithceramic particulates like SiC, Al_2O_3 and have observedimprovement in wear and abrasion resistance [8-11].Further, the increased percentage of thesereinforcements contributed in increased hardness and density of the composites [11]. Wear is a common mechanism observed in machine tools and its components and is a very slow process. However, if the rate of wear on a particular machine component is high, which requires frequent repair and replacement, then it may create a wear problem. The MMNC is tested under various conditions by varying parameters like speed and load. In particular, MMNCs showhigher abrasion and wear resistance under variable conditions [10]. Further the compo cast heat-treated nano composites have been studied for abrasive wear by Rahimipour et al [14].In the present study, the Nano composite is prepared by non-contact cavitationtechnique [15-16]. The specimen is subjected to dry sliding condition using pin on wheel wear testing machine. The worn-out specimen is analyzed for nature of wear.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

The chemical composition of aluminium and alumina nano composites is shown in Table 1.

Element	Fe	Mg	Si	Al	Al_2O_3
Wt. %	1.3	0.43	0.26	96.51	1.5

Table 1: Composition of Al-Al_2O_3 (1.5 wt. %) MMNC.
The Nano composites are prepared by a non-contact ultrasonic solidification method by Padhi et al [15-16].

2.2 Methods

2.21Procedurefor Synthesis of MMNCs

The procedure for fabrication of metal matrix nano composite done by Padhi et al [15-16] is described as follows. The experimental set up isshown in Fig.1. The setup consists of an ultrasonic generator which generates ultrasonicwaves, an ultrasonic chamber and steel mould. The mould was preheated to avoid thermal cracking. The preheated mould was kept in the ultrasonic chamber and the chamber was subjected to vibration at a frequency of 35 KHz. Liquid aluminum and alumina particulate (1.5 wt. %) having average size 10 nm were simultaneously poured into the vibrating mouldfrom the mixing chamber. After thesimultaneous pouring, the heating element was immediatelybrought down above the liquid metal in order todelay thesolidification. The vibration was carried out for a period of five minutes to ensure complete mixing. The castings were obtained in both longitudinal and transverse section.

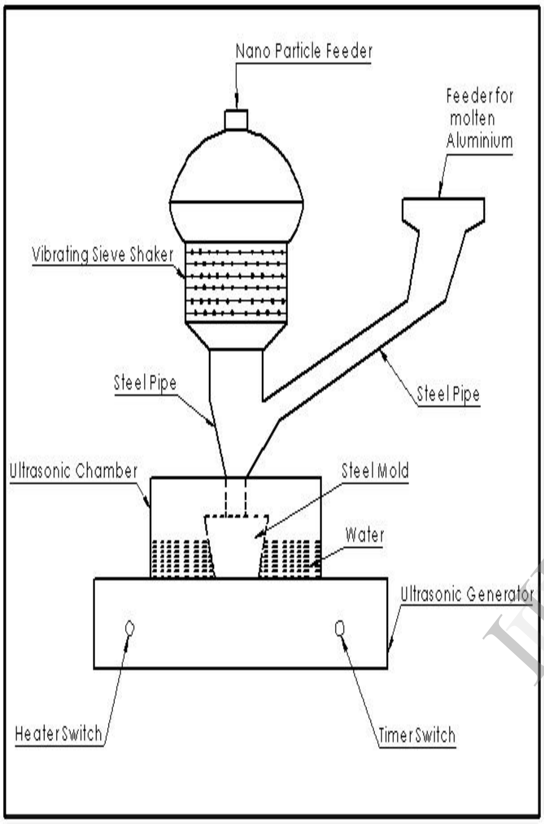

Fig 1: Experimental set up.

2.22 Procedure for Sliding Wear Studies

The experiments reported herein were carried out on a Multiple Tribo Tester (TR-5), Ducommake. In the Multiple Tribo Tester, the wheel rotates and the specimen (6.35 x 6.35 x 9 mm) is pressed against the wheel .The specimen is held by the fixture. Loads ranging from 0 to 1000 N and speeds up to 2000 rpm can be applied to press the specimen against the periphery of the 20 mm thick, 60 mm roller diameter wheel. As the specimen is held stationary and the wheel rotates, the sliding contact occurs and wear of both the specimen and the wheel takes place as the load is applied for the test duration. At present, the wear tests were conducted under different load conditions and at different speeds for a period of 30 minutes. The test conditions are as follows.

1. Constant load of 100 N, constant speed of 300 rpm and test duration of 30 minutes (1800 Seconds).

2. Constant load of 100 N, constant speed of 350 rpm and test duration of 30 minutes (1800 Seconds).

3. Constant load of 130 N, constant speed of 300 rpm and test duration of 30 minutes (1800 seconds).

3. RESULTS AND DISCUSSION

3.1 Results of Wear Studies

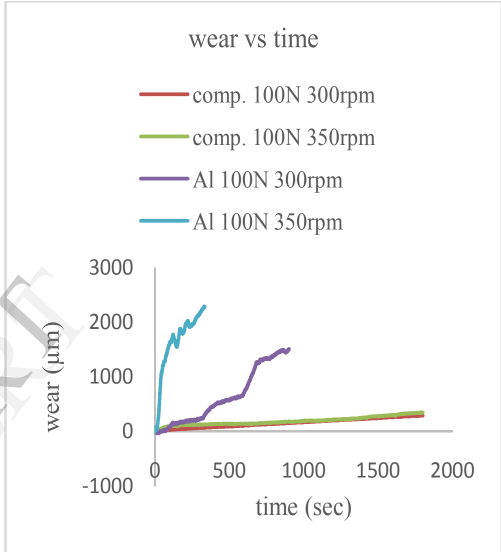

Fig. 2: Wear verses time keeping load (100 N) constantat two different speeds 300 and 350 rpm for MMNCs and pure Aluminium.

Fig 2 shows the graph between wearin (µm) verses time in seconds for pure Aluminium and MMNCs keeping load constant i.e. 100N, at two different speeds of 300 and 350 rpm. The sliding wear of commercially pure Aluminium in both the conditions shows that under 100N load and 300& 350 rpm, the wear increases w.r.t. time in both the cases. But when speed increases to 350 rpm from 300 rpm within a short span of time i.e. 200 seconds, the material gets completely worn out. Further, in case of MMNCs, in both the cases, though rpm varies from 300 to 350 rpm, no significant variation in the time occurs. Also the maximum rate of wear in case of MMNC is 300 µm which occurs after 1800 seconds whereas, in case of pure aluminium, it is 1500 µm at 900 seconds approximately. When speed increases to 350 rpm, the wear in case of pure aluminium increases to 2300 µm and the complete worn out takes place at 300 seconds.

Hence it is concluded that the wear properties of composite issignificantly increased compared to pure aluminium.

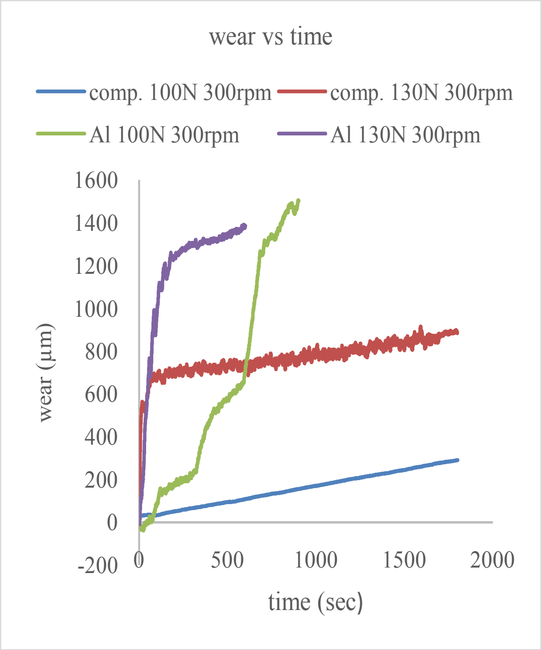

Fig. 3: Wear verses time keeping speed constant (300 rpm) at two different loads 100 and 130 N for pure Al and composites.

The fig. 3 shows the wear verses time keeping speed constant at 100 N and 130 N load. It is observed that wear of MMNCs increases gradually and linearly as time increases upto 1800 seconds. But when load increases from 100N to 130 N, wear increases to600µmsuddenly and then nearly constant upto 1800 seconds. In case of pure aluminium, the wear increases to 1200 µm at 200 sec during 130 N load and when load comes to 100 N the wear increases to 1400µm at 850 sec. This happensdue tostrengthening mechanism due to nano particlesembedded in the Al matrix uniformly.

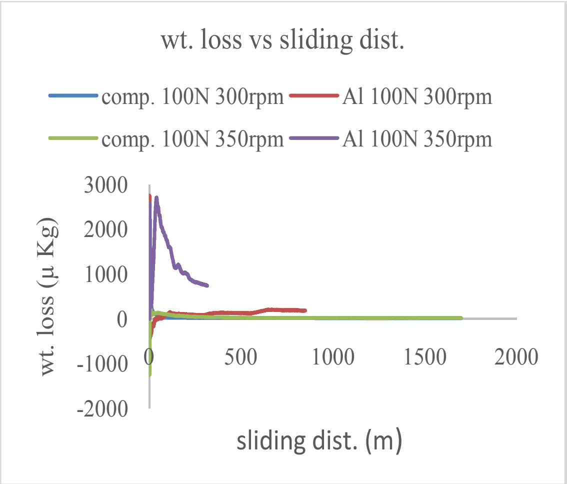

Fig. 4: Weight loss verses sliding distance at constant load (100 N) at two different speeds 300 and 350 rpm for pure Al and MMNC.

Fig. 4 shows weight loss verses sliding distance keeping load constant at two different speeds. Weight loss for MMNCs at 100N is nearly zero at 300 and 350 rpm though there is a little difference which is not so significant where as in case of pure aluminium, when rpm varies from 300 rpm to 350 rpm, weight loss of material varies significantly as shown . Initially the material is sticking to the wheel which indicates negative.

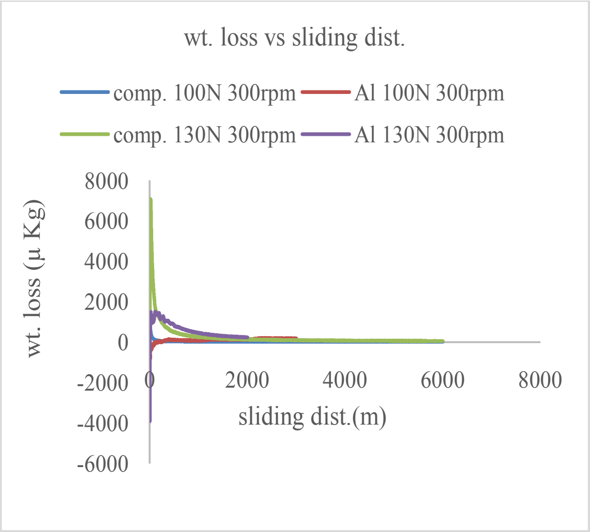

Fig. 5: Weight loss verses sliding distance keeping speed constant (300 rpm) at two different loads 100 and 130 N for pure Al and MMNC.

Fig. 5 shows weight loss verses sliding distance keeping speed constant at two different loads. Weight loss for MMNCs at 300 rpm is nearly zero at100N and 130N rpm though there is a little difference which is not so significant where as in case of pure aluminium when load varies from 100N to 130N, weight loss of material varies significantly as shown. Initially the material is sticking to the wheel which indicates negative.

4. MICRO STRUCTURAL CHARACTERIZATION AND EVALUATIONS OF WORN OUT SAMPLES

The microstructure of worn out samples were studied under FESEM. The FESEM images are

shown in the Fig. 6 (a-f).

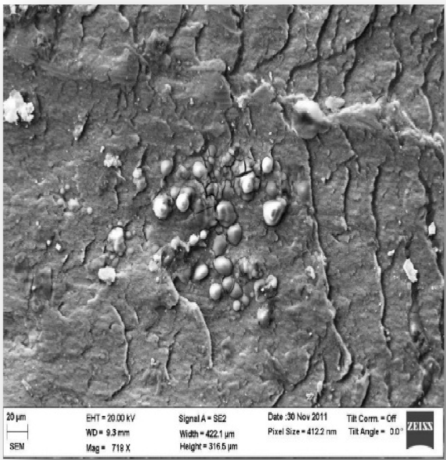

Fig. 6(a) Microstructure of pure Al at 100N and 300 rpm

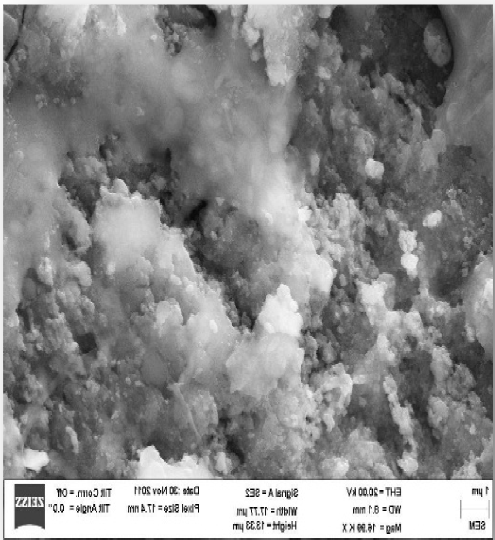

Fig.6 (b)MicrostructureofMMNC at 100N and 350 rpm

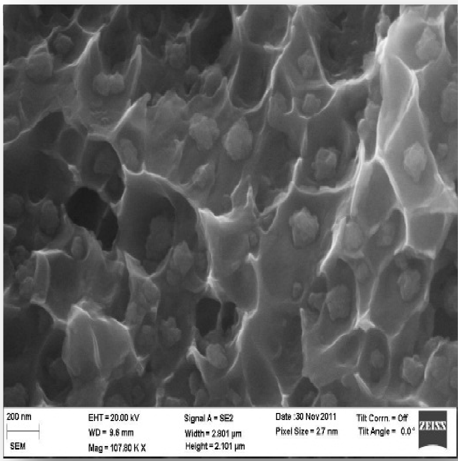

Fig. 6(c) Microstructure of pure Al at 100N and 350 rpm

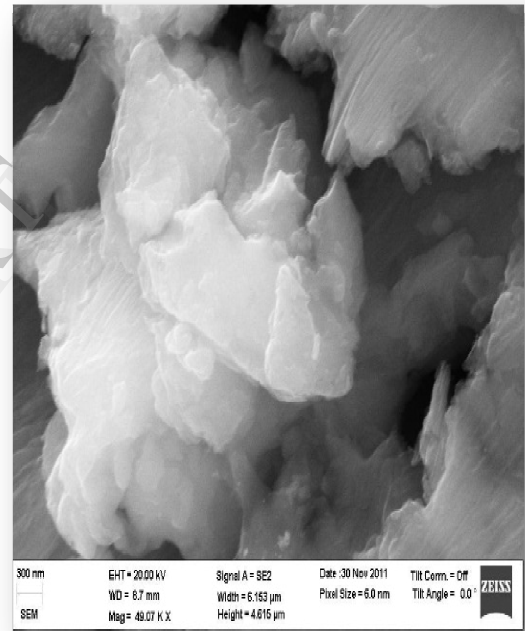

Fig. 6(d) Microstructure of MMNC at 100N and 300 rpm

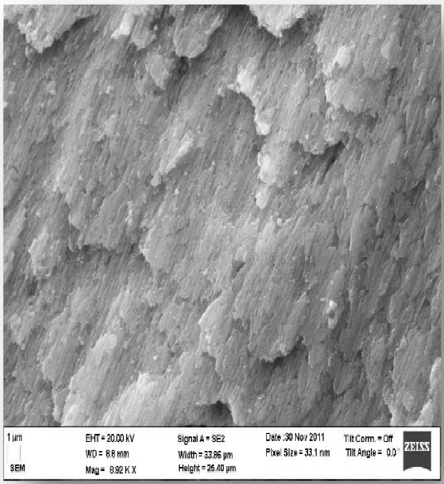

Fig. 6(e) Microstructure of pure Al
at 130 N and 300 rpm

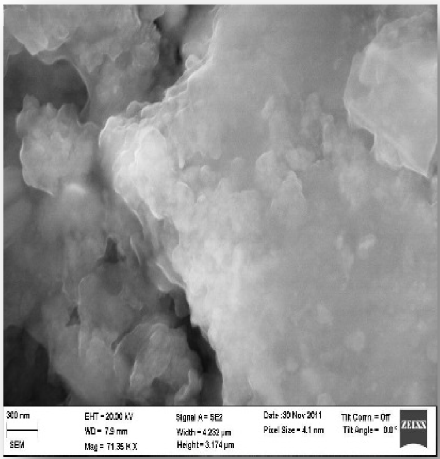

Fig. 6(f) Microstructure of MMNC

at 130 N and 300 rpm

Figure 6(a) and 6(b) show the FESEM photographs of worn out samples of pure Aluminium and composites respectively. From fig 6(a), it is observed a wavy or nodular surface due to heat generation and localized welding.

The more worn out takes place because of the sticky surfaces whereas from figure 6(b), the morphology of worn out microstructure is nearly smooth because of which wear rate is almost negligible keeping wear constant. Figure 6(c) and 6(d) shows the FESEM microstructure of worn out samples at 100N load and 350 rpm of pure aluminium and composite respectively. Figure 6(c) shows an irregular honey comb structure because of ploughing action whereas figure 6(d) has smooth microstructure showing worn out surface uniform. But, here, if we compare FESEM of 6(b) with this, wear rate in this case is more. Similarly when load increases to 130 N, the FESEM Figure 6(e) and 6(f) show the severe wear rate in case of pure aluminium compared to composite.

This happens due to strengthening mechanism of the nano particles embedded in the matrix. Since particles are very small and when embedded in the matrix, no projections are coming out of the surfaces. Hence, no ploughing action takes place thus keeping uniform wear rate.

5. CONCLUSION

This paper studies the wear characteristics of pure Al and Al-Al_2O_3Nano composite. The MMNC is prepared using liquid metallurgy route. The standard specimen prepared is subjected to dry sliding wear tests. Wear decreases as the rolling distance increases. Wearrate increases with the increase in load and speed.This is because of the strengthening mechanism due to the uniform dispersion of Al_2O_3 nano particles. The nano particles areembedded with the aluminium matrix which strengthens the composites. Further this is light in weightwhich shows encouraging results in comparison to pure aluminium for weight loss,wear resistance, wear rate etc. More tests are required to study all the parameters varying the load, speed, time, as well as weight percentage of reinforcements.

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