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PIN ON DISK TEST FOR ALUMINUM GRAPHENE METAL MATRIX COMPOSITES

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Abstract- Nowadays, carbon based materials such as graphite, carbon nanotubes (CNTs) and graphene have attracted much attention owing to their superior mechanical and physical properties. This study considers a laboratory test procedure for determining the wear of Aluminum Graphene Metal Matrix Composites during sliding using a pin-on-disk apparatus. For a pin specimen pure aluminum and Al–graphene nanoplatelets (GNPs) composites reinforced with up to 2 wt% prepared and tested against cast iron counter body (Hardness: 526 HV) in ambient air at room temperature. Wear properties of friction pairs of materials were given with wear rates diagrams and coefficient of friction table. Effects of graphene addition on wear properties of given material pairs were examined.

Keywords- Aluminum Graphene, Wear, Friction, Pin on disk test.

I. Introduction

The wear and friction resistances of pure aluminum (Al) are low during operation. Different attempts have been made to improve strength and wear characteristics of Al materials. Metal matrix composites (MMCs) play an important role to improve wear resistance of pure aluminum in relatively moving mechanical parts at dry sliding condition. There are various studies dealing with carbon nanotube (CNT) reinforced Al alloys, in the literature. Al-CNT composites provide lightweight, high stiffness, strength, improved wear and friction resistance, if uniform dispersion are succeeded [1,2]. So many efforts have been made to overcome agglomeration problem by using ball milling and melting processes. However, CNTs are not suitable for milling process because milling process can cause breakage [3-6]. Graphene has higher surface area than those of other carbon nanostructures hence better interface adhesion with metal matrix can be obtained [7]. It was stated that its dispersion in different kinds of matrices are easier than CNTs [8]. In recent years, most of the studies have focused on the investigation of mechanical properties of the produced Al-graphene nanoplatelets (GNPs) composites [1,3,9]. Several studies are also available in the literature to investigate wear behavior of Al-GNPs composites. However, a few studies have been reported on the estimation of the wear behavior of Al-GNPs. The estimation of wear behavior is very important in machine parts at dry sliding condition due to prediction of component lifetime and wear damage [10-12].

In this study, wear tests of the Al-GNPs composites have been performed using by pin on disk test equipment at constant wear load and distance. Test results were given by wear rate diagrams. Calculated coefficient of friction for each pairs of materials were also tabulated.

II. Materials

The powder blends of Al and GNPs at 0, 0.5, 1 and 2 wt% were mechanically alloyed (MA'd) in a planetary ball mill (Fritsch™, Pulverisette 6) at 300 rpm for 1 hour. As blended and MA'd powders were compacted in a hydraulic press (MSE™ PE-30) with 30 ton capacity to obtain cylindrical preforms with a diameter of 20 mm under an uniaxial pressure of 625 MPa. These compacts were sintered at 630 °C for 1 hour in a tube furnace (MSE™ T-1600-74-450) with a heating and cooling rate of 5 °K • min^{-1} under Ar gas flow.

III. Wear tests (Pin on disc tests)

The wear data of the produced Al-GNPs composites were collected by using pin on disk equipment shown in Figure 1. The wear tests were conducted against cast iron counter body (Hardness: 526 HV) in ambient air at room temperature. Normal load of 9.81 N was employed during the tests. Test samples of pins are shown in Figure 2. All the tests were performed at a sliding speed of 4.10^{-2} m • s^{-1} and the total sliding distance was 500 m. The wear rate K was calculated using the Equation (1):

$$K = \frac{\Delta m}{l.\rho.F} \tag{1}$$

where K is the wear rate [mm^3 • N^{-1} • mm^{-1}], Δm is the mass loss of the test samples [g] during wear test, ρ is the density of test material [g • cm^{-3}], l is the total sliding distance [m] and F is the normal force on the pin [N].

Fig. 1. Pin on disk experimental setup

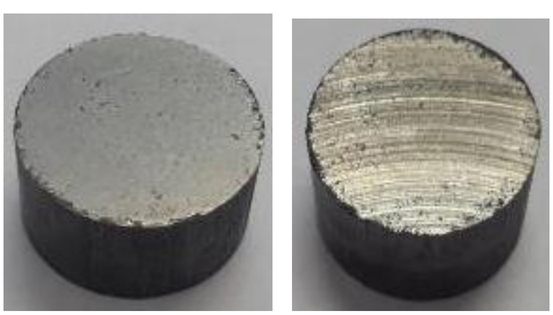


Fig. 2. Test samples of pin, before and after test.

IV. Results and discussion

Test results were recorded by a computer as friction force versus time graphics and shown in Figure 3.

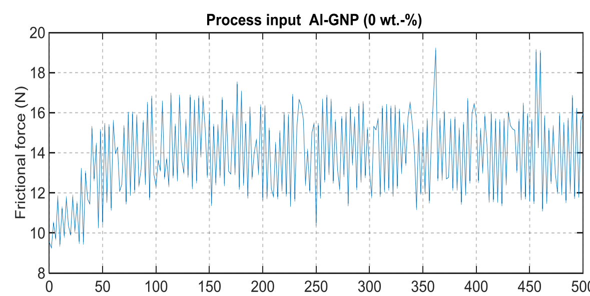
The coefficient of friction (COF) μ was calculated using Equation (2) and listed in Table 1.

$$F = \mu \bullet F_s \tag{2}$$

Table 1. Wear losses and COFs of tested materials.

Material	Graphene Addition (wt-%)	Wear loss (g)	COF (μ)
Aluminum-GNPs Metal Matrix	0	0,000104	1,5
	0,5	0,000202	1,3
	1	0,000165	1,1
	2	0,000485	1,5

Figure 3 shows the friction forces and Figure 4 shows wear rates of the Al-GNPs composites with different weight percentages of GNPs. It should be noted that upon the addition 1 wt% GNPs the frictional force and the coefficient of friction (COF) decreased significantly compared to that of the pure Al. Whereas the GNPs content was increased to 2 wt%, the COF was observed to increase significantly to reach the value of 1.5.



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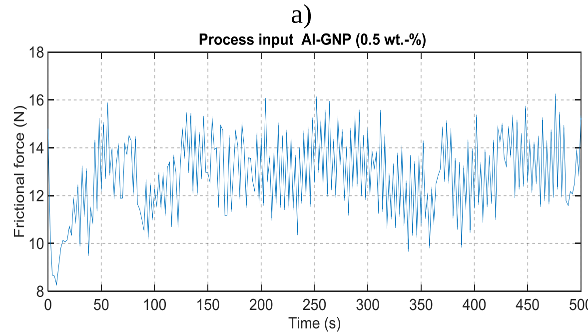

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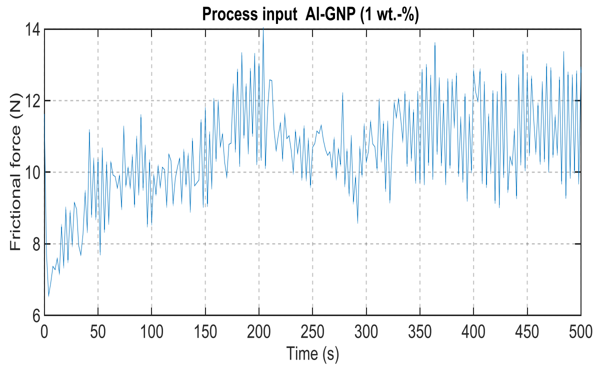

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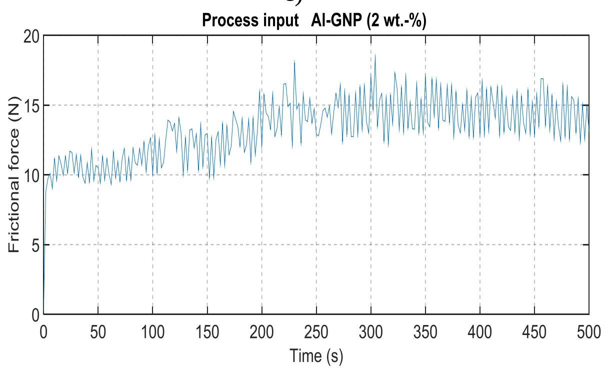

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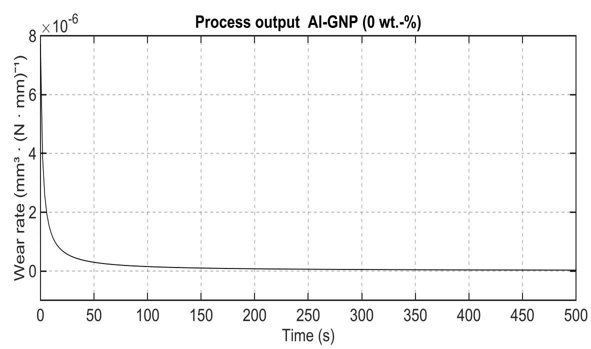
Fig. 3. Recorded frictional forces: a) pure aluminum, b) 0,5 wt-% GNPs, c) 1 wt-% GNPs, d) 2 wt-% GNPs



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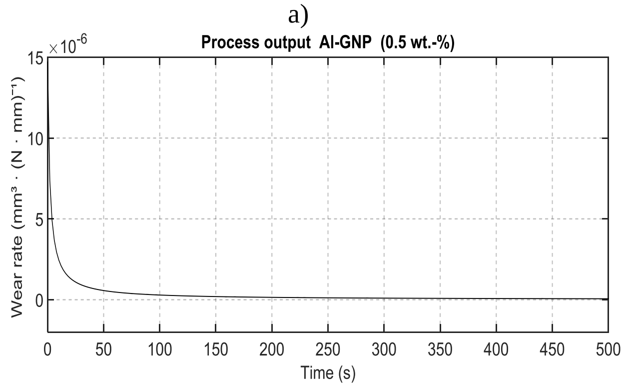

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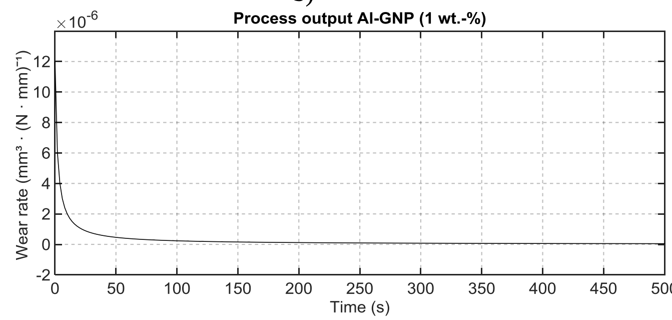

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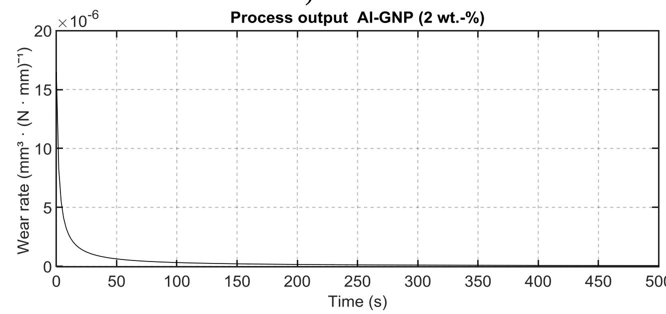

d)

Fig. 4. Calculated wear rates: a) pure aluminum, b) 0,5 wt-% GNPs, c) 1 wt-% GNPs, d) 2 wt-% GNPs

V. Conclusions

Aluminum matrix composites reinforced with 0.5, 1 and 2 wt-% GNPs were prepared by cold compaction and sintering techniques. Friction and wear behaviors of the composites with constant load and sliding speed were determined using pin on disk test setup. The following remarks can be obtained in the present study:

1. COFs of composites at 0.5 and 1 wt-% were decreased to 1.3 and 1.1, respectively from 1.5 for pure aluminum. However, at 2wt-% graphene reinforcement COF reached to the maximum value of 1.5. This may indicate that uniform dispersion was not obtained at 2 wt-%.
2. Wear losses of the pure Aluminum is lower than the all other composites. The lowest value of the material losses is observed in the 1 wt-% within Al-GNP composites.

Nomenclature

CNT	Carbon nano tube
COF	Coefficient of friction
GNP	Graphene nano platelet
MMC	Metal matrix composite
ρ	Density [g • cm^{-3}]

Δm	Mass loss of the test sample [g]
F	Normal force (Load) [N]
F_s	Friction force [N]
K	Wear rate [$mm^3 \bullet N^{-1} \bullet mm^{-1}$]
L	Sliding distance [m]
μ	Coefficient of friction [-]

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