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TRIBOLOGICAL CHARACTERISTICS OF AL/TiC COMPOSITES USING A BALL-CRATERING METHOD

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ABSTRACT

The aim of the research was to investigate the effect of speed, load and reinforcement on abrasion behavior of Al/TiC composites by ball-cratering abrasion tester. Al/TiC composites were prepared by a stir casting method, with Al 6061 alloy matrix and TiC reinforcement varies from 5 to 20 wt.% with steps of 5 wt.%. A ball-cratering tester was used to determine the 3-body abrasive wear behavior under a different normal load and abrasive particle loading and wear duration. Al/10% TiC composites, Al/15% TiC and Al/20% TiC composites showed excellent abrasive resistance. The higher percentage TiC content avoids plasticity behavior in the composites, which is mainly responsible to severe wear at higher load due to near brittle cracking process. Wear mechanisms were investigated by scanning electron microscopy (SEM).

KEYWORDS: Al/TiC Composites Using a Ball-Cratering Method

INTRODUCTION

Presently, high specific strength alloys and their composites used in marine, automotive, and even in aero based industries. Due to high specific strength mostly Al composites are slowly replacing many other high density materials. The ceramic particulate in the composites improve the wear properties hence they encourage the tribological applications. Many researchers have carried out work on the wear behaviors of aluminum MMCs [1-3]. Generally they have investigated on structural and tribological performance for finding potentiality in tribological applications. They focused on wear causes parameters such adhesion [4], abrasion [5] and surface fatigue [6]. Further researchers have gone into the invent of novel reinforcement novel composites, which leads further improvement of Al composites performance in wear resistance. [6-7]. But, only few researchers investigated reinforced composites for on three body abrasion wear behavior. In addition the abrasive role has not been clarified, probably also due to the strong dependence of reinforcement effects on the tribolgocial tests condition. The erosive type wear and abrasive type wear for different materials have been investigated with various process parameters [8] using different testing equipment. They are Coriolis method [8], ball-cratering tribometer [12], the gas jet erosion [10], the whirling arm apparatus [9], the ball mill [11]etc.

In this paper Al/TiC composites were fabricated using stir casting method with various percentages of TiC particles leading to different wear behavior under ball-cratering abrasive wear conditions. Further investigation was to study the developed Al/TiC composites performance of a ball cratering when presence of alumina abrasive particle and also study the influence of the ball speed and load on wear behavior.

EXPERIMENTAL STUDIES

For present investigation Al 6061 alloy was select as a matrix material due to its excellent casting property and moderate mechanical strength. The composition of matrix alloy is given in Table 1.

Table 1: Chemical Composition of Al 6061 Alloy

Mg	Fe	Cu	Si	Al
0.92	0.28	0.22	0.76	**Balance**

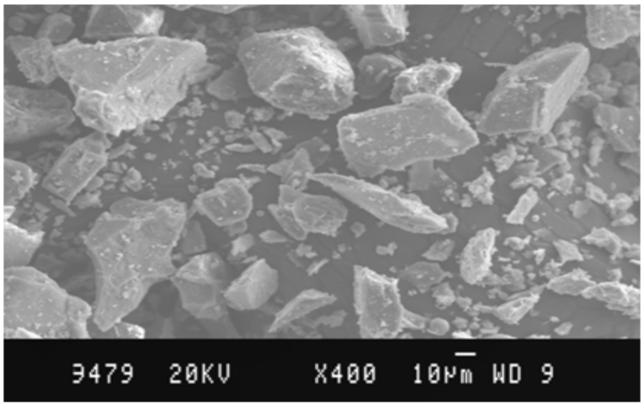

Figure 1: Al_2O_3 Abrasive Particles of 90–150 µm size

The ceramic Titanium carbide (TiC) is used as a reinforcement due to its excellent abrasion resistance with excellent hardness. All composition of Al/TiC composite specimens for ball-cratering abrasive were fabricated using stir casting technique, with composition of TiC particles in step of 5, 10, 15 and 20 % by weight. The wear samples were square plates with a dimension of 20 x 20 x 6 mm^3. The specimen surfaces polished with series of sand papers then diamond paste to obtain roughness of 0.01-0.02 µm. polished specimens cleaned with acetone to remove dust and dirt ultrasonically. Tungsten balls for using ball-cratering abrasion of hardness 860 Hv.

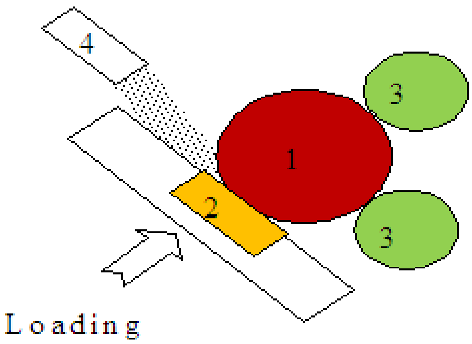

Figure 2: Ball-Cratering Tribometer Schematic Diagram
1. Tungsten Ball 2. Specimen 3. Shaft 4. Slurry

In this abrasive wear tester (ball-cratering abrasive), a tungsten balls were rotated against a composite specimen with a velocity of 0.25 ms^{-1} on the driving shaft. 10 N of normal load exerted on the ball against to composite specimen. Alumina particle (as shown in Figure. 1) slurry was introduced at the rate of 2±0.05 ml/min between the ball and specimen for 60 min as shown in Figure 2. The composite specimens were weighed at the end of the test using weighing ball of accuracy of ±0.01mg. the worn-out specimens were examined by SEM.

RESULTS AND DISCUSSIONS

Figure 3 shows typical micrographs of Al6061 alloy and Al/TiC composites presenting fairly homogeneous TiC distributions. The TiC particulate uniformly distributed in the Al matrix alloy. Figure 4-6 show that the wear loss (weight loss) against alumina abrasive generally decrease with increase in the wt% of TiC

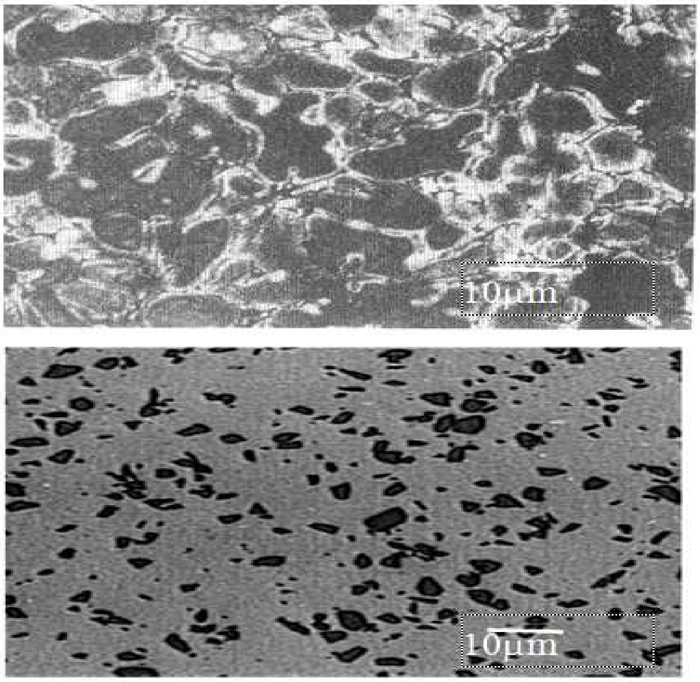

Figure 3: Microstructure of a) Etched Al and b) Unetched Al / 20% TiC Composites

Effect of Sliding Duration on Material Loss

The relationship between wt. loss and sliding duration for various normal loads and reinforcement are given in Figure 4. Abrasive wear results obtained at loads of 5N, 10N, 15N and 20N showed that the weight loss of both unreinforced and reinforced composites increase with increasing sliding duration but the curve at higher duration for higher % of composites showed almost flat due to strain hardening of mating surface and the specimen.

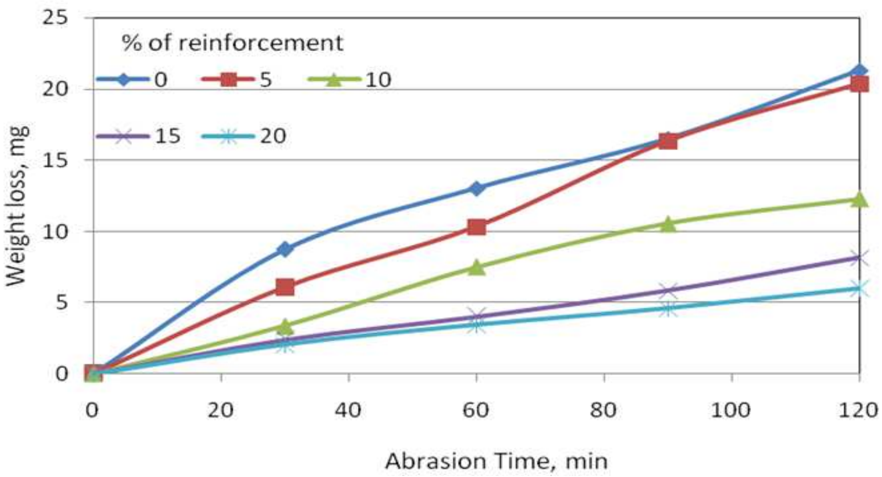

Figure 4: Average Wear Rate as a Function Wear Duration for Al/TiC Composites Abraded by Alumina Slurry for Different Size of Particles

When the sliding distance was increased, the weight loss in the specimen gradually increased. There is large difference in mass loss between the unreinforced and reinforced composites. Since, frequent fracture of the secondary TiC in the composites was found it appears that the severity of the testing condition might be the main reason for reducing wear. Generally the Al alloy is in ductile in nature hence there is retardation of crack could be seen. The addition of TiC makes matrix brittle in nature which leads more prone to stress concentration around the particles and it promotes crack propagation. But due to higher hardness of the TiC particle it acts as a barrier to crack propagation hence it also reduces the wear rate [13].

Effect of Normal Load on Material Loss

The Figure 5 shows the abrasive wear rate of the Al/TiC when tested against alumina abrasive particles, is drawn as a function of wear load. The material loss increases linearly with increasing wear load. The same trend was seen for all composition of Al/TiC composites. The graphs showed that the slope of the lines depend on the TiC content. At higher load interface between matrix and reinforcement produce a binding effect, the plastic deformation in the debris of matrix alloy give the protection to the reinforcement particle [14]. During abrasion the metal exposes to active oxygen and formed aluminum oxide and it also protect the matrix alloy. The higher percentage of TiC provide good resistance to matrix materials.

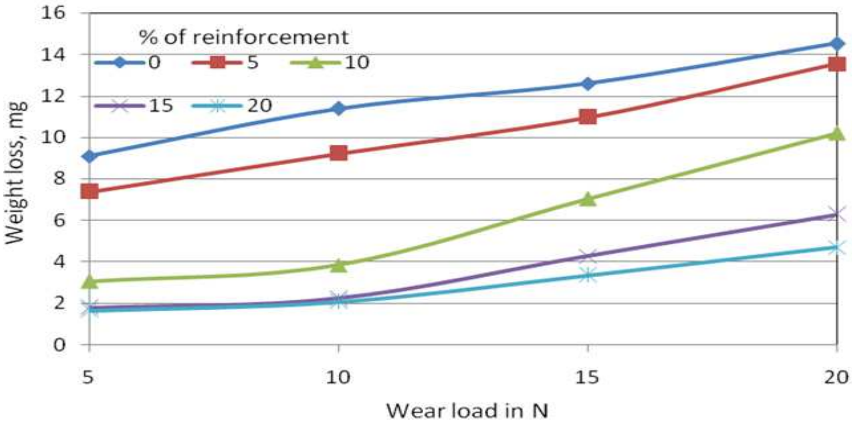

Figure 5: Variation of Mass Loss with Normal Load for Al/TiC Composites Abraded by Alumina Slurry for Different Sliding Time Min

Effect of Reinforcement on Wear Loss

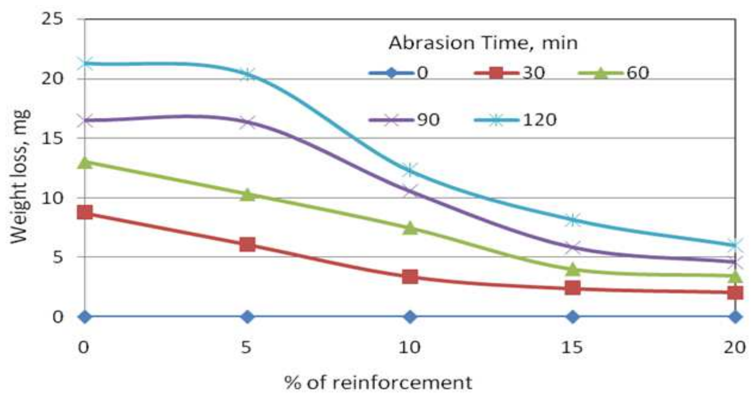

Figure 6: Variation of Mass Loss with % of Reinforcement for Al/TiB_2 Composites Abraded by Alumina Slurry for Different Sliding Duration

The average wear rate of the Al/TiC composite specimens plot against the percentage of reinforcement as shown in Figure. 6 and under different loads. The abrasive wear loss of the Al/TiC composite specimens main responsible for reduction of wear rate. These graphs show that with an increase TiC weight fraction the wear rate of the specimen drastically reduced compared with base alloy with various loading conditions. The unreinforced matrix alloy worn-out much more rapidly than the reinforced composite materials. The hard reinforcing TiC particles resist the micro cutting action of abrasives effectively [15].

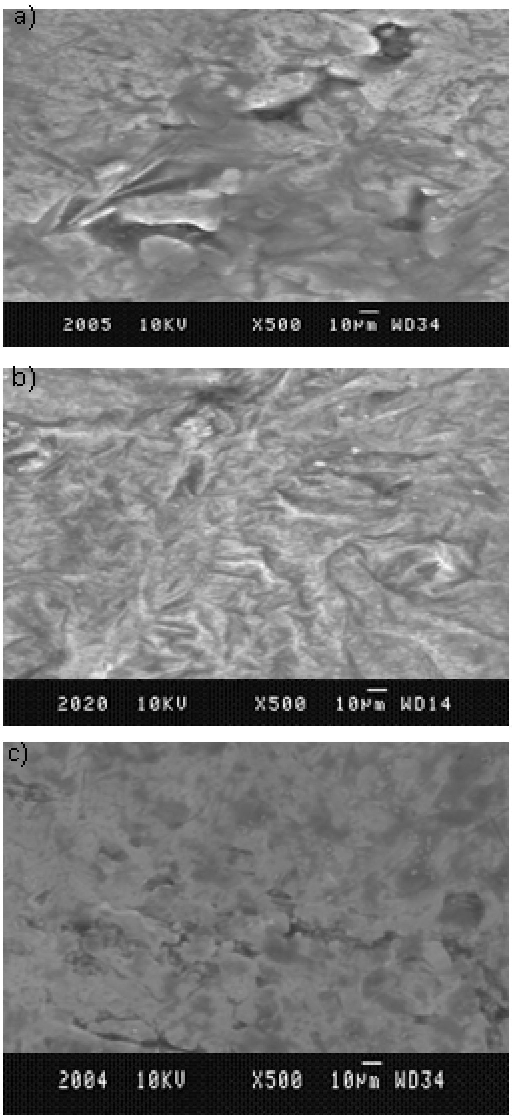

Figure 7: Worn-Out Surface Ball-Crater Morphology of (a) Al 6061 Alloy, (b) Al/5 % Tic and (c) 20% Tic Samples Abraded by the Aluminum Slurry

WORN-OUT SURFACE STUDIES

Worn-out surface of Al 6061 alloy (Figure 7a), Al/5% TiC composites (Figure 7b) and Al/20% TiC composites (Figure 7c) were examined by SEM. The two types of worn-out surface morphology generated are shown in Figure 7. Three body roller wear are seen on the tungsten ball surface. A typical three-body rolling wear is visible on the steel surface when a ball was used. In matrix alloy and lower percentage composites showed the grooves, they are short and random. The higher reinforcement i.e. 20% showed smoother surface than unre in for cement and 5% reinforcement.

CONCLUSIONS

- The ball-cratering test can discriminate between the wear resistance of materials with similar properties.
- Addition of TiC reinforcement improves the wear resistance of the composites.
- The wear loss increases linearly with applied load irrespective of the reinforcement.
- The wear resistance increases linearly with increase in TiC content
- The wear loss increase with increasing sliding distances
- Worn-out surface of matrix and composites produced by abrasive alumina particulate indents and the microstructure phases were not distinguishable.

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