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DRY SLIDING WEAR PROPERTIES OF Al(4%Cu) - SiC COMPOSITES WITHOUT AGE HARDENING

A. Kazaz[1], H. Erdem Çamurlu[2], M. Ayşe Dere[2]
Akdeniz University, Faculty of Engineering, Civil Engineering Department, 07058
Antalya, Turkey [1]
Akdeniz University, Faculty of Engineering, Mechanical Engineering Department, 07058
Antalya, Turkey [2]

erdemcamurlu@gmail.com

Abstract: *Dry sliding wear behaviour of unreinforced Al4%Cu and Al4%Cu - SiC composites was investigated. Composites containing 10-50 vol. % SiC were obtained via hot press by using Al, Cu and SiC starting powders. Wear tests were conducted by an oscillating tribometer having a 6 mm diameter alumina ball. 2 N load was employed and sliding span was 5 mm with a total test distance of 6 m. Wear tracks were examined by an optical microscope, track cross sectional areas were determined by a profilometer and wear rates were calculated. It was seen that the wear track formed on the unreinforced sample was much larger and deeper than the ones on the composite samples. Wear mechanism was suggested to be initially adhesive and then adhesive and abrasive. The wear rate of unreinforced sample was about $11x10^{-3}$ mm^3/N.m. Wear rate was seen to decrease abruptly with the addition of SiC particles into the matrix alloy. When 10 vol. % SiC was used, wear rate decreased to $1.5x10^{-3}$ mm^3/N.m. The lowest wear rate was achieved in the sample containing 30 vol. % SiC, $0.5x10^{-3}$ mm^3/N.m.*

Keywords: Dry sliding wear, SiC reinforced aluminum matrix composite, Powder metallurgy

1. Introduction

The incorporation of hard ceramic particles such as SiC, B_4C, TiB_2, Al_2O_3 has been utilized in order to enhance hardness and wear resistance of light alloys such as aluminum, etc. [1-6]. The properties such as hardness, toughness and wear resistance of the formed material, which is technologically termed as ceramic particle reinforced metal matrix composite, can be altered by varying the particulate size or content and the properties of the matrix alloy.

Particulate reinforced light metal matrix composite materials are especially suitable where weight of the part is important, due to their lightweight. These materials can be used in applications like aircraft structural and wear parts as well as in automotive industry, such as pistons, brake components, etc., with the aim of weight reduction [7]. Sliding wear resistance is important for tribological applications requiring high performance [6].

Wear resistance of aluminum matrix composites which were produced by various techniques such as stir casting, extrusion, etc. and reinforced with hard ceramic particles, have been investigated [4-7]. The common outcome of these studies, regardless of the employed production method is that, the incorporation of the hard ceramic particles enhances wear resistance, as compared to unreinforced alloy and that wear resistance generally increases with the increase in the amount of the reinforcement particles [4-6]. In these studies, in order to determine the sliding wear characteristics, a pin on disc testing apparatus is commonly utilized [4-6,8] with various loads and for various distances of wear tests. In the study of Rao et al. [4], SiC reinforced Al MMCs were produced by stir casting. It was reported that the wear resistance of the composites depends to a large extent on the matrix alloy, where AA2024 was found to possess the best wear resistance. In the study of Alpas et al. [6], SiC reinforced Al MMCs were obtained as produced commercially. Shirazi et al. obtained the SiC-Al6061 composites through hot extrusion at 500 ^oC [5]. It was seen that when SiC particles of 25-50 nm size were used, low amounts such as 1-3 wt.% of SiC was sufficient to enhance hardness and wear resistance of the Al MMCs [5].

Aluminum alloys reinforced with hard ceramic particles have the potential to be used in applications where wear resistance is required. Therefore, estimation of their sliding wear properties is of technological interest. SiC particle reinforced Al (4%Cu) metal matrix composites were produced via hot pressing method [9] and their sliding wear characteristics were determined in the present study.

2. Experimental Procedure

Composite samples, which were subjected to wear tests, were produced by hot pressing of mixed elemental aluminum (Merck), elemental copper (Alfa Aesar) and SiC (Alfa Aesar) powders at 550 ^oC for 30 min. The SiC amounts were adjusted so that the composites contained 10 – 50 vol.% SiC, with 10 vol.% increments.

Hardness values of the composites were determined by using a Brinell hardness tester (HB10). Wear tests of the composites were conducted with an oscillating (reciprocally sliding) tribometer (Tribotechnic) according to DIN 50324 Standard (Testing Of Friction And Wear Model Test For Sliding Friction Of Solids (Ball-On-Disc System)). A 6 mm diameter alumina ball was used for wearing the composites under 2 N load. The span length was 5 mm and 6 m of total test distance was employed for each specimen. The test was stopped after 2 m and 1 m intervals and the profile of the wear track was determined by using a profilometer (rugosimeter, (Taylor Hobson, Surtronik 25)). The area of the wear track cross section was multiplied by the span length (5 mm) in order to calculate the wear track volume. Wear rate (mm^3/N.m) was calculated via dividing the wear track volume by the applied load (2 N) and test distance.

3. Results and Discussion

Wear tracks formed on the unreinforced alloy and on the SiC particle containing composites are presented in Fig. 1. These tracks were formed as a result of the repeated sliding contact of alumina ball, which was used as the counter body. Detached flakes of wear debris were seen around the wear tracks of all the specimens, especially at the ends of the tracks. It can be seen that when no reinforcement SiC particles were used the wear track was quite large, about 960 microns. Wear track width was seen to decrease with the increase in the amount of SiC particles in the Al4%Cu matrix. There was an abrupt decrease when 10 vol. % SiC was added into the matrix. In the composite containing 50 vol. % SiC, wear track width was about 330 microns.

In the wear track of the unreinforced Al4%Cu matrix alloy (Fig. 1a), continuous grooves were seen to form along the sliding direction. Unreinforced matrix had the lowest hardness and highest ductility, among the studied samples [9]. There are patches of smeared particles inside the wear track of this sample. Due to the repeated stress under the alumina ball, work hardening occurs on the aluminum surface and this results in the detachment of the debris. The ductile wear debris, torn and detached from the surface of the sample, may have stuck or attached back into the wear track

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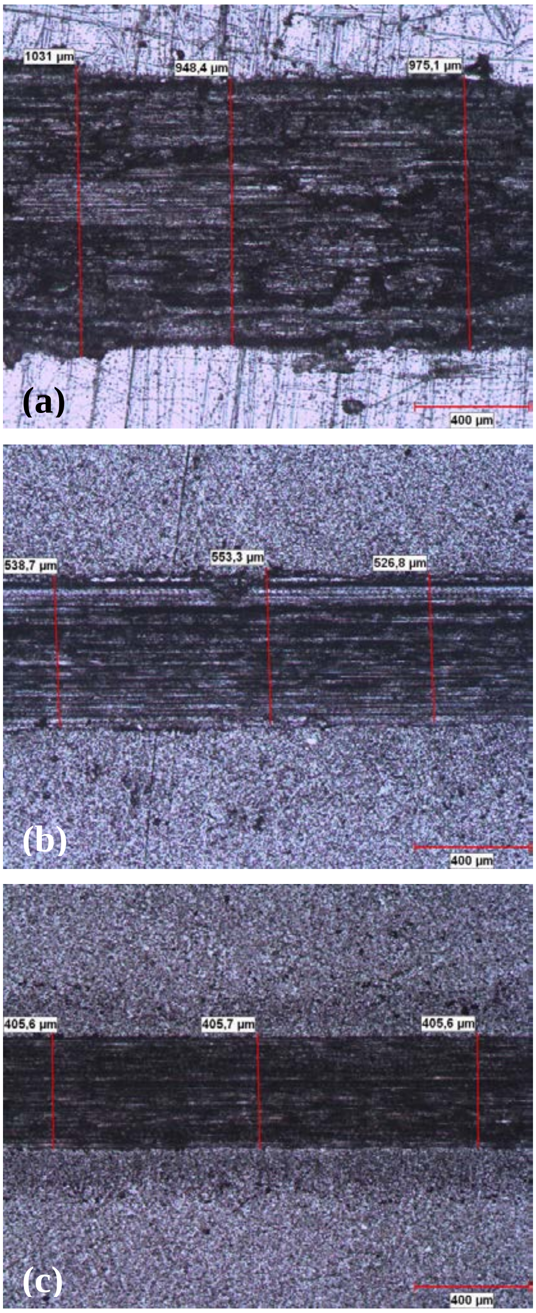
and formed patches of smeared debris inside the track. It is expected that initially adhesive wear mechanism is dominant and later abrasive wear mechanism takes place. Initial sticking of the aluminum matrix and alumina ball results in the initial adhesive wear. The aluminum particles attached on the surface of the alumina ball is expected to cause abrasive wear on the work hardened aluminum surface. This takes place by the tearing of the aluminum along the sliding direction.

The continuous wear grooves on the wear tracks of the composite samples (Fig. 1b-d) were seen to become thinner with the increase in the amount of SiC particles. In addition, patches of smeared ductile particles were not present and inside of the wear tracks were smoother.



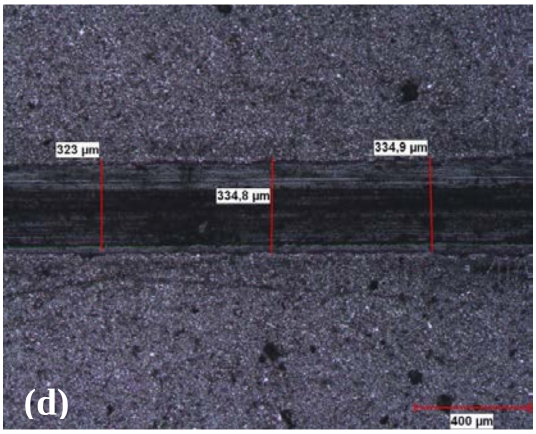


Fig. 1 Optical micrographs of the wear tracks on the (a) unreinforced Al4%Cu matrix alloy, (b) 10, (c) 30, (d) 50 vol. % SiC containing composites.

Wear track width alone is not sufficient to quantify the wear amount or rate, since for that, depth of the wear track is also necessary. Therefore, wear track profiles were determined by using a profilometer. Wear track profiles of unreinforced sample and of composite containing 40% SiC are presented in Fig. 2. It can be seen that the inner surface of the wear track of unreinforced sample is not smooth, but contains grooves. The presence of the re-attached soft wear debris on the inner surface of the wear track renders the wear track surface irregular and rough. The maximum depth of this wear track was about 40 microns, with a width of about 1 mm. The width of the track is consistent with the measurements made on optical micrographs (Fig.1a). Cross sectional area of the wear track was about 20000 square microns. Volumes of the wear tracks were calculated via multiplying the cross sectional area by the length of the wear track (5 mm).

The wear track width of the composite containing 40 % SiC was about 0.4 mm and the maximum depth was about 6 microns. Cross sectional area of the wear track was about 1600 square microns. It can be seen that the presence of SiC particles in aluminum matrix reduces wear and increases wear resistance.

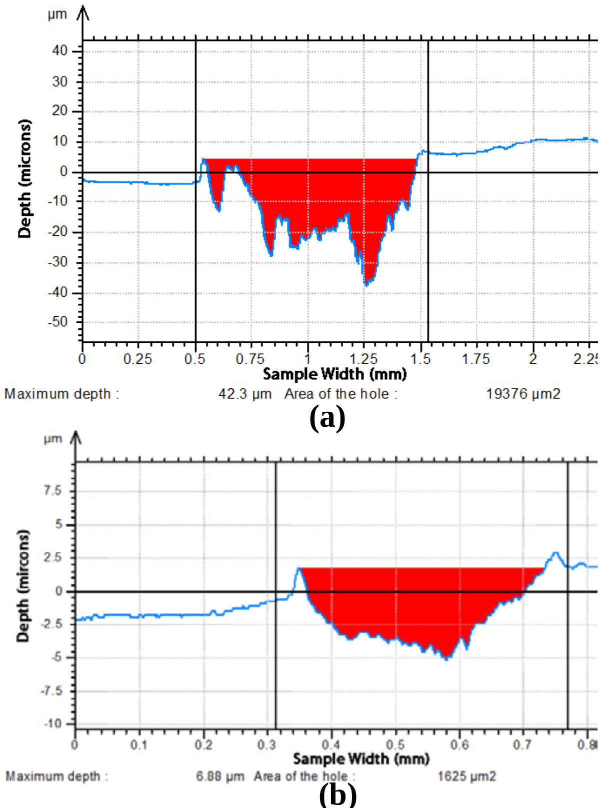


Fig. 2 Wear track profile formed on (a) unreinforced sample and on (b) 40 % SiC containing composite. (note the change in the scales)

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Wear rates were calculated by using the volume of the wear tracks. Wear rates of the unreinforced matrix alloy and of the composites are presented in Fig. 3. These wear tests were conducted for 6 m sliding distance. The wear rates indicate the worn material volume per unit load and per unit sliding length. The wear rate of unreinforced sample was about $11x10^{-3}$ mm^3/N.m. Wear rate was seen to decrease abruptly with the addition of SiC particles into the matrix alloy. When 10 vol. % SiC was used, wear rate decreased to $1.5x10^{-3}$ mm^3/N.m. Lowest wear rate was achieved in the sample containing 30 vol. % SiC, $0.5x10^{-3}$ mm^3/N.m.

The increase in the wear resistance may be attributed to the following factors. First of all, the presence of SiC particles hardens the matrix and constraints the plastic deformation of the matrix alloy. This makes the penetration of the alumina ball more difficult. Secondly, the SiC particles on the surface of the sample, reduces the contact of aluminum matrix with the alumina ball. This is expected to decrease the effect of adhesive wear mechanism.

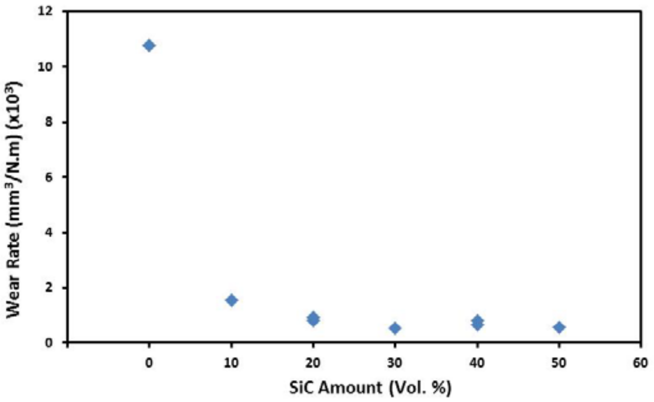

Fig. 3 *Wear rates of the unreinforced matrix alloy and of the composites obtained in the wear tests conducted for 6 m.*

Wear rates of the unreinforced sample and of the composites are presented in Fig. 4 as a function of the sliding distance. It was seen that the wear rate decreases with increasing test distance, in the unreinforced sample. This indicates that the wear volume per unit sliding distance decreases as the test continues. Similar trend was observed in most of the composite samples. This can be attributed to the fact that the contact area of the sample and the alumina ball increases as wear progresses and this results in a decrease in the stress induced by the alumina ball on the aluminum plate. The high standard deviation in the wear rates of the unreinforced sample arises from the irregular structure of and presence of smeared patches in the wear tracks formed in this sample.

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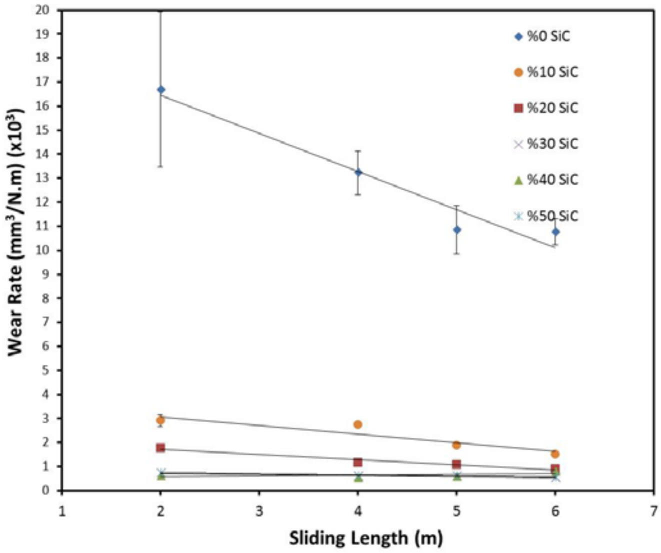

Fig. 4 *Wear rates of the unreinforced sample and of the composites, as a function of sliding distance.*

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