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WEAR PROPERTIES OF AL-CU-MG COMPOSITES REINFORCED WITH MGO AND MWCNT UNDER DIFFERENT LOADS

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Abstract

Wear of metals is one of the most important failure mechanisms encountered on engineering basis. Especially in places where there is friction, it is important to use engineering materials with high friction resistance. In this study, 40 nm diameter nano magnesium oxide and 1.5 micron long and 9.5 nm diameter multiple walled carbon nano tubes were added to Al-Cu-Mg alloy. 50 wt% MGO and 50 wt% MWCNT were mixed and added to the matrix material in 1wt% and the composite materials were produced by the semi-solid mixing method. The aim of this study was to investigate the major tribological aspects affecting the wear properties of Al-Cu-Mg composites reinforced with MGO/MWCNT. Composite materials were produced by semi-solid mixing method. The wear behavior of MGO/MWCNT reinforced Al-Cu-Mg alloy aluminum matrix composites (Al MMCs) was investigated. Wear properties were investigated under different loads and the shear rate and shear distance were kept constant. Abrasion tests were carried out considering the weight loss at 500 m distance under 2N and 5N load on the ball-on-disc type wear device. Al-Cu-Mg wear weight loss was reduced by approximately 49% with the addition of 50% CNT 50% MgO 1% wt.

Keyword: Composite, Abrasion, Al-Cu-Mg, Ball on disc, CNT.

1. Introduction

Aluminum hybrid composites are the most demanded composites in the field of improved light-weight materials due to their low density, high mechanical properties, high wear and corrosion properties, and low thermal expansion coefficient compared to conventional metals. Different reinforcements are added to increase the mechanical properties of the composites. Particle-reinforced aluminum matrix composites [1] have attractive properties such as high strength with high specific modulus, low coefficient of thermal expansion, high wear resistance. Particle reinforced metal matrix composites (MMCs) have become extremely important engineering materials because they combine all these properties [2, 3, 4, 5]. One of the most important reinforcement is multiwall carbon nanotubes (MWCNTs) [6, 7]. Recently, research has focused on carbon nanotubes (CNTs) and nano-sized carbonaceous materials such as nano-graphite or graphene to obtain improved, electrical, mechanical and tribological properties.

CNTs and graphene have excellent mechanical strength and, high thermal and electrical conductivity, and their participitation into metallic matrix caused to composites having higher magnetic, electrical and mechanical properties. This caused interest in the use of CNTs in metal marix composites as one of the most effective reinforcing in composites for structural engineering materials and designing of functional devices [6, 8].

Movement of a solid surface on another solid surface is essential to the operation of many mechanisms. Almost there is no mechanical method where surfaces do not move or roll without contacts. For this reason, tribology is gaining importance in a wide range of applications. In the field of surface interactions, which are the main subject of tribology, there are interests of mechanical engineers or scientists. Advances in the field of tribology have contributed to many engineering disciplines around the world. Tribology touches all aspects of modern technology, from transportation and energy production to medical engineering, food science and cosmetics, where surfaces are in contact with each other [9].

Wear occurs when surfaces move on top of each other. Generally, one or both surfaces are damaged due to loss of material. Sometimes wear is too slow to be evident, and in some cases too fast. A small amount of material or part may be damaged by abrasion, which can cause large and complex machines to fail completely and become unusable [10].

Abrasion is defined by DIN (DIN 50320-1979), as a result of the separation of small particles from the surface due to mechanical effects caused by contact of the material with another material (solid, liquid, gas) and undesirable surface deformation [11]. Based on the statement herein, it creates undesirable effects on the shapes, surface qualities and dimensions of the machine elements. These changes of machine elements over time affect the operation of the machine negatively Because contact caused by wear is directly related to wear mechanisms, conditions at the point of contact become important. The contact strength forms the wear mechanisms according to the elastic or plastic contact. The most basic and most important of the wear mechanisms can be expressed abrasive wear, adhesive wear, surface fatigue and corrosive wear. Abrasive wear occurs at a certain load with solid materials of the same hardness or harder than solid materials. A material with low hardness can cause abrasive wear due to the harder particles contained in it against a material with a high hardness [12]. Adhesive wear is a phenomenon which occurs when two metals rub together with sufficient force to cause the removal of material from the less wear-resistant surface.

Fatigue wear also known as surface fatigue is occurred a result of repeated load cycles to which materials are exposed, after a critical number of cycles, they form large pits. This can lead to the formation of sub-surface or surface cracks that will cause the surface to break with the formation of pits. This is also known as pitting. Prior to this critical point (there may be hundreds, thousands, or even millions of cycles), a negligible wear occurs that is similar to the adhesive or abrasive mechanisms, causing a gradual deterioration from the onset of wear. Therefore, the amount of material eroded by erosion is not a useful parameter. What is important here is the useful life in terms of speed or time before fatigue fracture occurs [11]. Corrosive wear occurs in an environment where the material is subjected to a corrosive effect. The most dominant corrosive medium in the air is oxygen. The chemical products of corrosion (eg oxides) form a layer on the surfaces, which tends to slow or even stop corrosion. However, if this surface disappears and the corrosive environment continues, the contact surface of the material may weaken and cause fracture. Chemical abrasion is important in many sectors such as mining, mineral processing, chemical processing [9].

Sharma et al. are considered to enhance the wear properties of the materials. They research the wear resistance of Al-6061 hybrid composites with alumina, silicon carbide and cerium oxide as reinforcement. They used the load range from 10 N to 30 N and sliding speed from 0.5 m/s to 2 m/s. They improved the wear resistance in sample containing 7.5 wt% of both alumina and silicon carbide around 38% in comparison with base metal [13]. Copper-rich and heat-treated alloy AA2017 has relatively the properties of well mechanical and abrasion [14]. Sekar and Vasanthakumar say that boron carbide can advance wear resistance, and Gr can act as solid lubricant to decrease the friction coefficient. In their work, AA2017 boron carbide + grapheme composites were produced with various wt. percentage. boron carbide and constant Gr by using stir casting processes. They claim that the hardness of AA2017 alloy was increased up to 31% [14]. Saraswat et al. carried out dry sliding friction and wear test of aluminum based composites containing 5, 7 and 9 wt.% boron carbide were at 9.8N, 19.6 N,29.4 N, 39.2N load at a constant sliding speed of 1m/s. and found that wear rate and the average friction coefficient of composites decreases with increasing weight percentage of B_4C [15]. Benal and Shivanand described the wear behavior 6061 reinforced with 9 wt.% by silicon carbide and 0, 1, 3 and 5 wt.% by E-glass fiber.

They found that the wear rates of composites reduce with enhancement in ageing durations [16]. Bastwwros found that wear resistance increases significantly with CNT content which is about 5 wt% CNT in composite and wear reduced by 78.8% compared to pure aluminum [17]. Bustamante et al. investigated and observed that the composites with higher nanotube concentration (5.0 wt%) showed a high wear resistance [18]. Alizadeh et al. declared that increasing boron carbide content advance the wear resistance by 3 times under a load of 20 N and 10 times under a load of 10 N [19].

In this study, different ceramic particle reinforcement is added to Al-Cu-Mg aluminum alloy metal matrix structure in different ceramic and carbon nanotube particle reinforcement volume ratios. In addition, test samples were produced by semi-solid mixing casting method for homogenous microstructure and less porosity. The effects of MgO and multi-walled carbon nanotube (MWCNT) particle reinforcement on the wear results of composite materials were investigated. Wear properties were investigated under different loads and the shear rate and shear distance were kept constant. Abrasion tests were carried out considering the weight loss at 500 m distance under 2N and 5N load on the ball-on-disc type wear device.

2. Materials and Methods

In this study, Al-Cu-Mg (Al 2024) aluminum alloy was used as matrix material. In the composition of the matrix, Cu 4.5, Mg 1.5, Mn 0.5, Fe 0.4, Si 0.41, Zn 0.2, Ti 0.12, Cr 0.17 and the rest are aluminum. Multiple-walled carbon nanotube and nano magnesium oxide (MgO) particles were used as .

reinforcing agents. The outer diameter of the carbon nano tube is 8-10 nm, the inner diameter is 5-8 nm, the length is 1-3 µm, the actual density is 2.4 g/cm^3, the specific surface area is 240 m^2/g and the purity is > 92% and its color is black. Nano MgO is 45 nm in diameter, 99.95% purity, 3.58 g/cm^3 density, 2852 °C melting degree and specific surface area > 45 m^2/gr and chemically containing 0.023 Na, 0.0089 K and 0.016 Ca and also, it is a solid compound of white color. 50 wt% MGO and 50 wt% MWCNT were mixed and added to the matrix material in 1wt%. The temperature of the matrix was reduced to 640 ± 5 ° C, which was the semi-solid temperature, and the booster mixture was added to the matrix in the specified proportions and stirred for 10 min at 500 rpm. It was then quickly heated to 800 °C and subsequently poured into an 18x200 mm diameter mold which was heated to 250 °C. The melt was subjected to slag formation and degassing, and the atmosphere was controlled with 99.99% purity Argon gas until the casting was completed. The hardness of the produced products was measured according to international standards using Brinell hardness method.

In wear research, under dry shear conditions, abrasion tests were performed on CSM Instruments brand ball-on-disk type device at room temperature (Figure 1). In experiments; A slip speed of 0.1 m / s was used with a load of 2 N and 5 N. The sliding distance is 500 m. The aim of the abrasion tests is to investigate the abrasion behavior according to the content of metal matrix composite materials produced by mixing casting method.

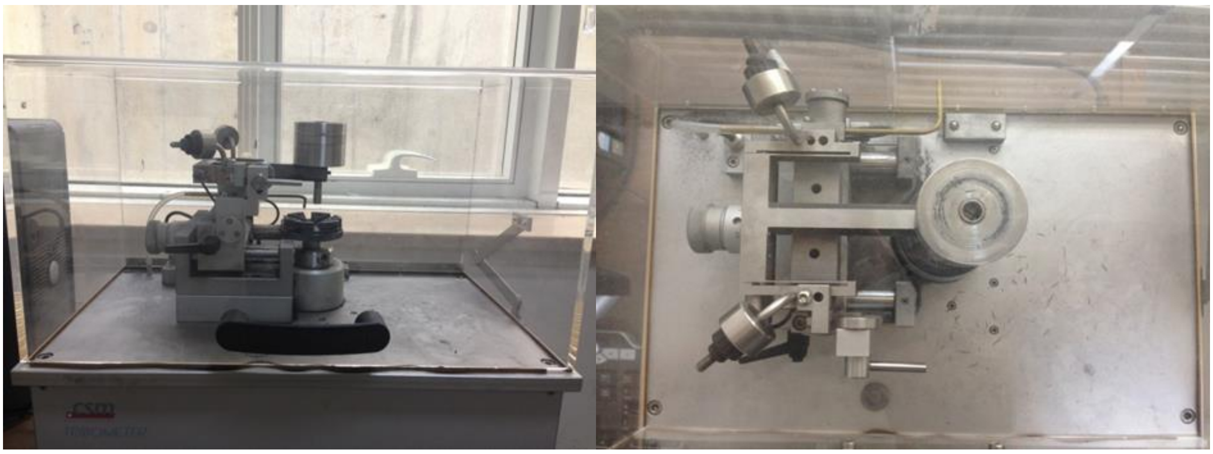

Figure 1. Ball-on-disk type Tribometer

3. Results and Discussion

Figure 2 shows wear weight loss. Al-Cu-Mg wear weight loss reduced by approximately 49% with the addition of 1% wt. of 50%wt. CNT 50% wt. MgO mixing. Figure 3 shows the wear weight loss of hybrid composites under 2 N and 5 N loads. The wear weight loss of hybrid composites showed an increase of 73% from 2 N to 5 N.

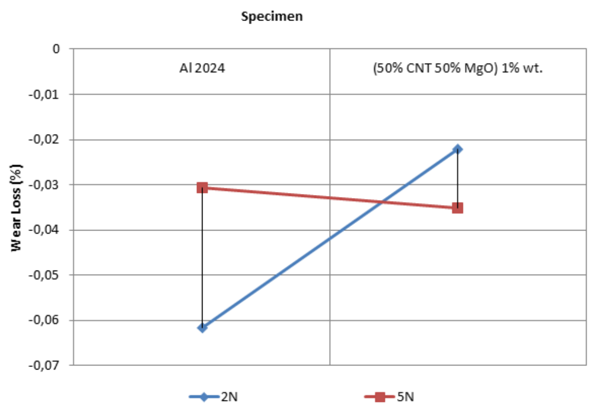

Figure 2. % wear weight loss

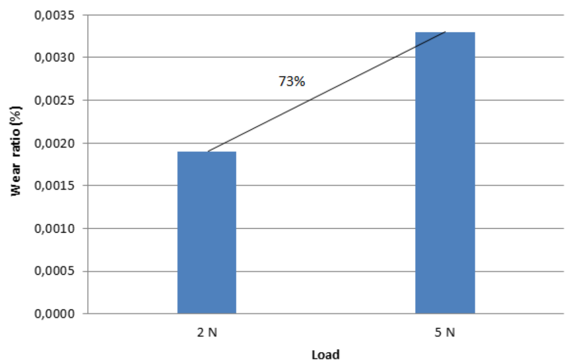

Figure 3. The wear weight loss of hybrid composites

Under dry shear conditions, at room temperature, wear tests were carried out at a distance of 0.1 m/s with a load of 2 N and 5 N and a shear rate of 500 m. The weight loss results obtained from abrasion tests are shown in Table 1.

Table 1. Wear test results

Material	Load (N)	Wear Loss (g)
Al-Cu-Mg	2 N	0,0039
%50 CNT %50 MgO 1wt.%		0,0019
Al-Cu-Mg	5 N	0,0018
%50 CNT %50 MgO 1wt.%		0,0033

When Table 1 is examined, it is seen that the weight loss decreases under load of 2N but this effect is not seen under 5N. Load of 2N, weight loss is reduced by hybrid effect. This decrease shows that the abrasion behavior of the material increases with the hybrid effect [20]. Under 5N load, the weight loss increases from the matrix material to the hybrid composite. This is not an expected situation and reduces the wear characteristics. This is thought to be caused by a decrease in the hardness of the material and / or an increase in the porosity content. Similar studies examining weight loss after abrasion testing are included in the literature and wear behavior can be examined through weight loss. In these studies, the effects of nanoparticle particle supplements on wear behavior were investigated [21]. In the present study, particle reinforcement added wear behavior negatively [22]. Composite materials provide an increase in hardness and other properties due to their reinforcing materials with higher hardness properties compared to matrix materials [23]. It is not concluded that this hardness can improve the abrasion properties. Figure 4 shows SEM images of the wear surfaces of matrix material and composite materials under various loads.

The worn surfaces provide clues to the wear mechanisms during dry sliding against the loads. The worn surface of matrix alloys was subjected to severe plastic deformation. The large wear debris formation resulted in inferior wear resistance of matrix material. As obvious from Fig. 4(a-b), the extent of plastic deformation on worn surface of these composites is much lower than that of unreinforced matrix. The formation of delamination on wear surfaces can be attributed to the difference platelets [24]. The hard MgO particles within the composite disk could be abraded the pin. It can be said that the overall features observed on the worn surface exhibit abrasion, adhesion, and their mixing and the formation.

Conclusions

In this study, abrasion behavior of Al-Cu-Mg matrix hybrid composites produced by mixing casting methodical is investigated. Al-based cast composites with various reinforcements and their wear properties are summarized. The effect of various process parameters on the nature, size, morphology and wear characteristics of the reinforcing particles are discussed in detail. Most of these composites show excellent mechanical and abrasion properties with an increase in reinforcement content. Nano MgO and multiple-walled CNT were used as reinforcing materials, which were mixed at 50% by weight and added to the metal matrix at 1% by weight. The abrasion behavior of the composites shows a linear appearance.

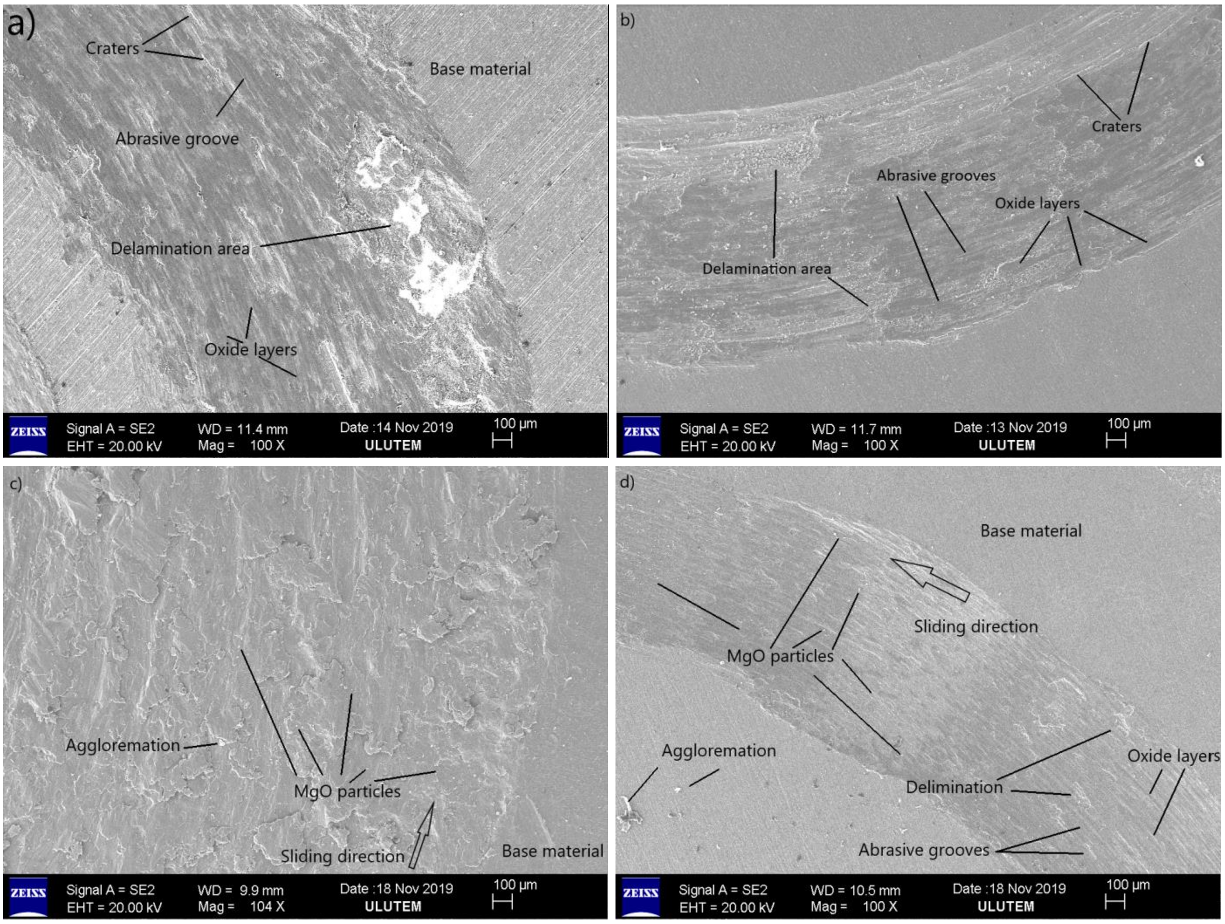

Figure 4 SEM micrographs of wear surface of Al-Cu-Mg a) 2N b) 5N and composites a) 2N b) 5N

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