World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:10, No:9, 2016

Wear Behaviors of B_4C and SiC Particle Reinforced AZ91 Magnesium Matrix Metal Composites

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Open Science Index, Materials and Metallurgical Engineering Vol:10, No:9, 2016 publications.waset.org/10005559.pdf

***Abstract*—**In this study, the effects of B_4C and SiC particle reinforcements on wear properties of magnesium matrix metal composites produced by pressure infiltration method were investigated. AZ91 (9%Al-1%Zn) magnesium alloy was used as a matrix. AZ91 magnesium alloy was melted under an argon atmosphere. The melt was infiltrated to the particles with an appropriate pressure. Wear tests, hardness tests were performed respectively. Microstructure characterizations were examined by light optical (LOM) and scanning electron microscope (SEM). The results showed that uniform particle distributions were achieved in both B_4C and SiC reinforced composites. Wear behaviors of magnesium matrix metal composites changed as a function of type of particles. SiC reinforced composite has better wear performance and higher hardness than B_4C reinforced composite.

***Keywords*—**Magnesium matrix composite, pressure infiltration, SEM, wear.

I. INTRODUCTION

METAL matrix composites (MMCs) reinforced particulates have a big potential to be applied in automobile and aerospace industries [1]. Among the MMCs, magnesium MMCs are more attractive due to their low density, high specific stiffness and specific strength [2]-[5]. Magnesium is the lightest material and it is ~35% lighter than aluminum [6]. Because of its low density, magnesium offers high specific mechanical properties. In addition, magnesium has some other advantages including, high dimensional stability and good machinability. With these beneficial properties, magnesium becomes a popular material to produce lighter products [7], [8]. The desired properties can be achieved by a good selection of the type of the reinforcement particles [9]. On the other hand, some properties of magnesium alloys such as fatigue and creep resistance at elevated temperatures, ductility, hardness, corrosion resistance and wear properties are lower than other metals.

The most commonly used reinforcements are SiC, B_4C, Al_2O_3 and TiC. Addition of SiC increases the strength, hardness and elastic modulus. Boron carbide (B_4C) ceramic particulate has high hardness value, fracture toughness and also low density [10]. MMCs have been produced by such techniques as casting, powder metallurgy, pressureless infiltration, pressure infiltration and spray forming. In pressure infiltration process, ceramic particles are packed in a tube or a mold then pressured melt infiltrated to form a composite that contains about 50-60 vol.% of reinforcement. Particles disperse in matrix but the dispersion is quite difficult. On the other hand, the advantage of this method is to produce a composite with high volume fraction of reinforcement so porosity level can be decrease in lower level [11].

Many research studies were carried out in order to improve wear resistance of magnesium alloys by the use of SiC and B_4C particles as reinforcement. It was reported that reinforced with silicon carbide particulates exhibit good wear behaviors during dry sliding and SiC particulate improve wear resistance of magnesium under lower loads [12]. Another study about SiC particle reinforced composites showed that increasing of SiC content up to 10 wt.% increased mechanical properties of AZ31 magnesium alloys and if the content raised above this value, agglomeration can be occurred effecting mechanical properties negatively [13]. One study reported that different volume fractions (5, 10, 15 and 20%) of B_4C particles were used as a reinforcement and wear resistance was significantly improved with the increase of this reinforcement on aluminum composites [14]. Generally, casting and powder metallurgy method was used for production of SiC and B_4C particulate reinforced composites. Also volume fractions of particulates were below 30%. In this study, pressure infiltration method was used and volume fraction of SiC and B_4C particles was 50%. Two different loads were applied for wear test and wear behaviors of B4C and SiC reinforcement were compared under these loads.

II. EXPERIMENTAL

A. Pressure infiltration

The Mg-%9Al-1%Zn alloys were produced by conventional gravity casting. AZ91 magnesium alloy placed in graphite crucible and melted at 750 °C under an argon atmosphere. The melt was infiltrated to preform containing particles with a pressure of 8 bar. B_4C and SiC particles with an average grain size of 45 μm were preformed separately with a volume rate of 50%.

B. Microstructure and Hardness

The microstructure images of the samples were taken by LOM and SEM. Before the microstructure analysis, all the samples were mechanically ground with 120, 180, 240, 400, 600, 800, 1000, 1200, 2000 grit emery papers followed by polishing with 3 μm and 1 μm diamond paste. Samples were polished and then etched with picric acid. Then

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microstructures of samples were taken by LOM and SEM.

Brinell hardness test was performed by QNESS Q250M Hardness Test Device. 62.5 kg load was applied with 2.5 mm indenter for 15 sec. Average values of hardness were recorded.

C. Wear Test

Samples were prepared for wear tests. Contact surfaces of the samples were ground with 1200 grit emery paper. Wear tests were performed by a pin-on-disk type UTS-10 Tribometer test device. Two different loads (20 and 30 N) were used for wear tests. Wear rates, wear depth and friction coefficients of the samples were measured with a sliding speed of 0.08 m/s and a sliding distance of 500 m.

III. RESULTS AND DISCUSSION

A. Hardness Results

Hardness test results show that, AZ91+50% SiC composite has higher hardness than AZ91+50% B_4C composite. It can be concluded that, atomic bonding between magnesium matrix and SiC particle is stronger. Brinell hardness results of specimens are given in Fig. 1

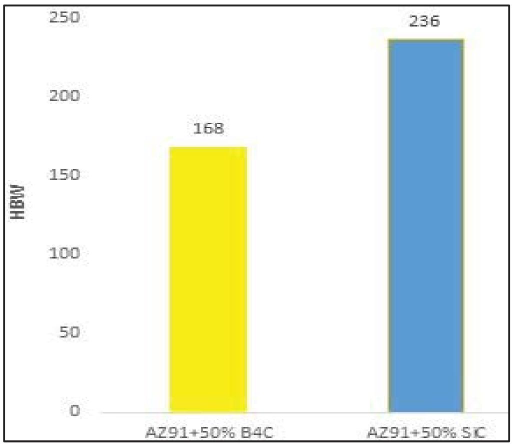


Fig. 1 Hardness values of investigated composites

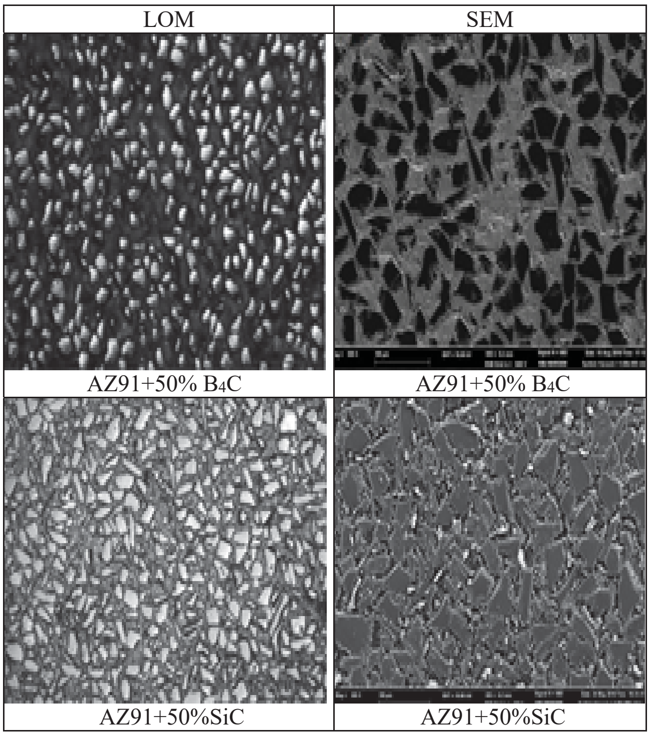
According to the hardness results, while B_4C reinforced magnesium composite has an average of 168 HBW hardness value, SiC reinforced composite has an average of 236 HBW.

B. Microstructural Characterization

The SEM images (500X Magnification) of composite materials in Fig. 2 show that the reinforced particles (SiC and B_4C) distributed homogeneously in AZ91 matrix. However, there are partial oxidations at around the matrix because of the low corrosion resistance of magnesium based composite especially in AZ91+50% SiC composite. Generally, the size of SiC and B4C particulate are almost similar.

C. Wear Properties

The wear performances of SiC and B_4C were compared with each other. Results show that SiC has a higher wear resistance than the B_4C. Wear depth values of composites are shown in Fig. 3. As seen in Fig. 3, the depth of wear B_4C under load 20 N is 174 μm, the depth of wear B_4C under load 30 N is 652 μm, the depth of wear SiC under load 20 N is 75 μm and the depth of wear SiC under load 30 N is 165 μm.



AZ91+50% B_4C AZ91+50% B_4C

AZ91+50%SiC AZ91+50%SiC

Fig. 2 Microstructure of investigated composites

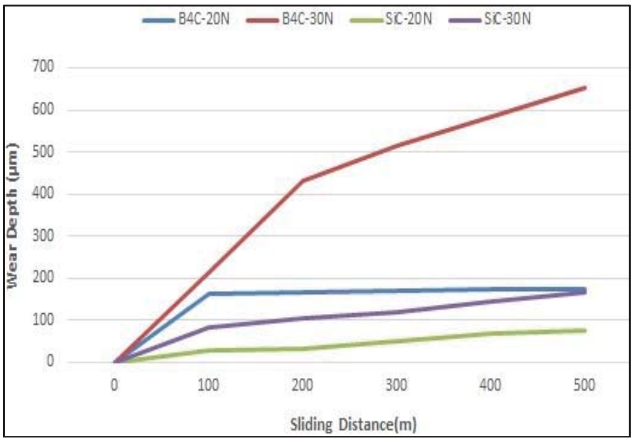


Fig. 3 Wear depth values of investigated composites

Fig. 3 revealed the wear depths of the studied composites, it can be seen in Fig. 3 that wear depths increased with increasing applied loads and AZ91+50%SiC composite showed lower wear depth than AZ91+50%B_4C.

TABLE I
WEAR RATES OF COMPOSITES

Composites	Mass Loss/Sliding Distance (g/m)	
	20N	30N
AZ91+50% B_4C(p)	$1.22x10^{-5}$	$5.92x10^{-5}$
AZ91+50%SiC(p)	$0.22x10^{-5}$	$0.6x10^{-5}$

The wear rates of composites are given in Table I. It is clearly seen that B_4C has a higher wear rate.

When the comparison about wear depths of composites is taken into account in Fig. 4, the wear performance of B_4C has dramatically reduced with increasing applied loads. While the wear depth of B_4C under load 20 N is 174 µm, the depth of wear B_4C under load 30 N is 652 µm.

In B4C reinforced composite, wear depth has increased at least four times from 20 N to 30 N. On the other hand, wear depth for AZ91+50%SiC composite wear depth has increased but not too much like AZ91+50%B_4C.

As a result of wear depth and wear rates of composites, SiC has shown better wear resistance and wear depth and wear rate increase with applied loads. B_4C reinforced composite is more effected than SiC reinforced composite with an increasing of loads. This situation is caused by bonding structure. SiC has good wettability so there is a strong bonding between matrix and reinforcement. Furthermore, hardness results support the wear performance of materials.

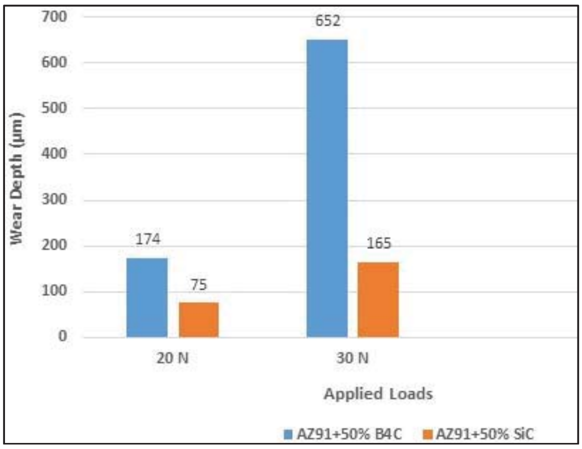


Fig. 4 The comparison of wear depth between composites (at the end of 500 m)

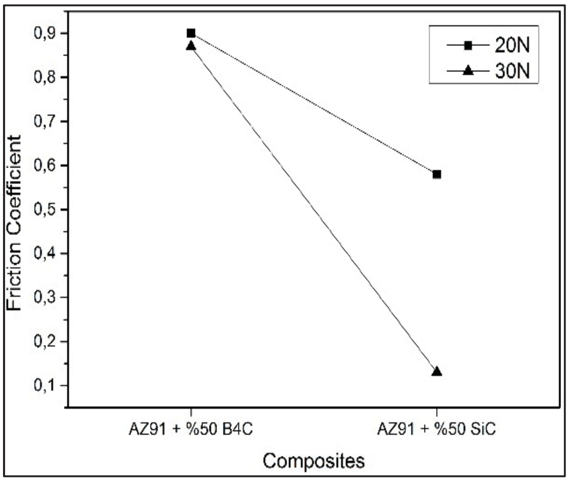


Fig. 5 Friction coefficient of samples

It can be clearly seen in Fig. 5 that friction coefficients of the studied alloys decreased as the applied load increased from 20 N to 30 N. AZ91+50%SiC composite showed lower friction than AZ91+50%B_4C coefficients for both applied loads.

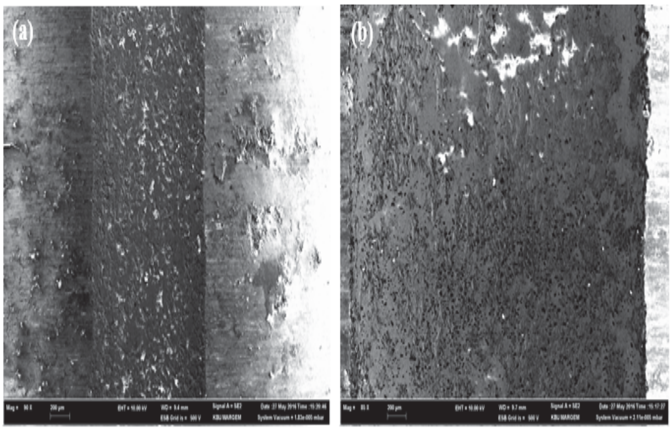


Fig. 6 SEM micrographs of the worn surfaces of (a) SiC90X (b) B_4C 90X

In Figs. 6 (a), (b), worn surfaces of AZ91+50%B_4C and AZ91+50%SiC composites were presented. The main wear mechanisms were found to be abrasion and oxidization in both composites. It can be deduced in Fig. 6 that SiC particles were bonded to the matrix more strongly than B_4C particles and this is associated with the wear test results since AZ91+%50SiC composite showed better wear resistance as shown in Table I.

IV. CONCLUSION

1. SiC and B_4C particles distributed homogeneously in the AZ91 magnesium matrix.
2. AZ91+50%SiC composite showed better wear resistance than AZ91+50%B_4C.
3. AZ91+50%B_4C composite showed the lowest wear resistance under load 30N.
4. Abrasion and partially oxide formation can be seen in the worn surfaces of the both composites.
5. AZ91+50%SiC composite has higher hardness value than AZ91+50%B_4C composite. This result supports the wear performance of investigated composites.

ACKNOWLEDGMENT

This work is supported by the Scientific Research Projects of Karabuk University in Turkey (grant no.KBU-BAP-16/1-YD-120). However, the microstructure and mechanical tests were carried out at Karabuk Iron and Steel Institute.

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