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Investigation of Dry Sliding Wear Behaviour of B_4C Particulate Reinforced Mg Matrix Composites

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Currently some composite materials and related manufacturing methods especially particle reinforced magnesium matrix composites are among important research topics because of their superior properties over monolithic metals. Mg-B_4C_p is the commonly used composite material for fabrication of light-weight functional components. Wear behaviour of particle reinforced magnesium matrix composites play critical role for potential application in industries such as automotive and aerospace. In this study, the dry sliding wear behavior of particle reinforced magnesium matrix composites manufactured by powder metallurgy with different amount of B_4C_p (3, 6, 9 wt%) addition is investigated. Wear tests are performed on a pin-on-disk configuration against SAE 1040 steel counter body under constant load and sliding speed. The wear behaviour of particle reinforced magnesium matrix composites was evaluated as a function of B_4C_p amount (wt%). After the wear test, worn surface of the samples was examined by scanning electron microscopy for pointing out the wear mechanism.

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1. Introduction

Metal matrix composites (MMCs) can be designed specially depending on the application field. MMCs are used potentially in the aircraft and automotive industries because they have high strength/density ratio and resistance to high temperatures [1]. Primary elements controlling the properties in MMCs are the production method, volume fraction of reinforcement particle, matrix alloy, and size and distribution of the reinforcement particle in matrix [2]. When compared to continuous fibre reinforced composite materials, particle reinforced MMCs (PRMMCs) come into prominence with their lower costs [3], higher wearing resistance and thermal stability properties [4]. Powder metallurgy (P/M) method that provides production closest to the net shape and tolerance has a great number of advantages for the production of PRMMCs, with a microstructure obtained in this way, it is possible to gain advanced mechanical properties [5]. Moreover, in the P/M method, for the reason that materials are produced at lower temperatures, undesired compounds come into existence in interfaces less often, and so they have higher mechanical properties. It is cheaper when compared to the other methods. With the P/M method, a homogeneous reinforcement distribution can be obtained [4]. The low elastic modulus and creep resistance of monolithic magnesium could be better by adding various reinforcements [6]. Little effort has been spent to understand the influence of B_4C particulate reinforcement on Mg based MMC's [7]. In this study, the dry sliding wear properties of Mg-B_4C_p MMCs fabricated by P/M are reported. Dry sliding wear test results illustrated a significant influence of B_4C particles addition on the wear resistance of the produced PRMMCs.

2. Experimental studies

The starting materials used in the present study consist of B_4C_p, high purity fine magnesium powders. Commercially pure magnesium (Mg) powder with 69 μm particle size was used as the matrix, while the reinforcement particle was the B_4C (69 μm). Powder mixtures with designed composition of 3, 6, 9 wt% B_4C_p were mixed for one hour at 50 rpm in the mixer and were cold pressed uniaxially at pressure of 500 MPa. The green samples were sintered at 590 °C under vacuum atmosphere for 3 h.

Hardness of the samples was measured with the Brinell hardness test method by using loads of 62.5 kg and balls of 2.5 mm diameter. Each hardness value was the average of ten measurements.

Dry sliding wear tests were carried out by using the pin-on disc testing apparatus at constant wear load of 15 N and sliding speed of 71 rpm against 1040 steel disc of hardness 180 HV. Before and following the wear test, samples were cleaned in an ultrasonic bath. In order to obtain the average wear loss (g), three samples were worn under the same experimental condition. The test was interrupted at every 500 m and the pin weight was measured after a careful cleaning process.

3. Results and discussion

Figure 1 presents the measured hardness values of the samples. The results of the hardness measurements indicate a higher value in hardness of the PRMMCs compared to unreinforced magnesium. The maximum hardness was obtained by addition of 9 wt% B_4C_p reinforcement. When it is listed from the highest to the lowest, hardness values of the samples are as follows: Mg-B_4C_p (9 wt%) $>$ Mg-B_4C_p (6 wt%) $>$ Mg-B_4C_p (3 wt%). It was detected that when the amount of the B_4C_p reinforcements in the matrix increased, Brinell hardness value of the samples also increased.

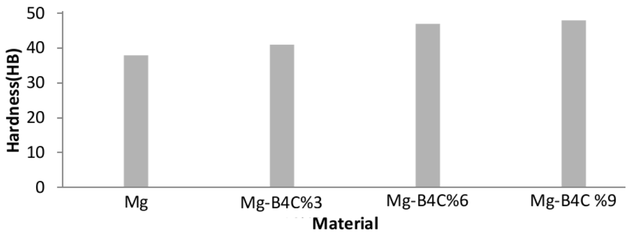

Fig. 1. Variation of average hardness for B_4C_p 3, 6, 9 wt% reinforced Mg based metal matrix composite.

The dry sliding wear test results of the composites containing 3 to 9 wt% B_4C_p and unreinforced Mg were presented as weight loss vs. sliding distance curves in Fig. 2. The total sliding distance was 3000 m for PRMMCs. The unreinforced Mg sample was damaged at the end of 1000 m sliding distance, therefore the test was finished in a sliding distance of 1000 m. Weight loss of the samples was evaluated at every 500 m sliding distance. As it is shown in Fig. 2, with the increase of the B_4C_p in the matrix, the wear loss of the samples decreased.

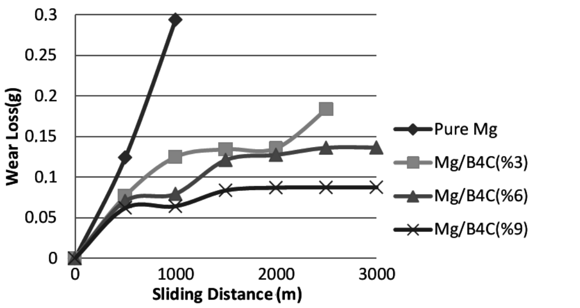

Fig. 2. Changing of weight loss versus sliding distance for all samples.

Figure 3 shows the scanning electron microscopy (SEM) images of the worn surface of samples. The worn surface of the samples reveals that abrasive and adhesion wear mechanism is less effective for the PRMMCs when compared to unreinforced Mg. Wear grooves were aligned parallel to the sliding direction on the surface (Fig. 3a–c). With the increase in the amount of reinforcement particles, wear grooves appearing on the surface of the samples gradually decrease and become shallower. B_4C particles lead to improving the wear resistance of PRMMCs as shown in Fig. 2. It is evident from Fig. 3d that Mg-B_4C_p (9 wt%) has no significant wear evidence under the applied load of 15 N for the sliding distance of 3000 m. The mild wear regime is more stable and long for the PRMMCs when compared to the unreinforced Mg. Consequently, the addition of B_4C_p increased the service life against the wear. Among the PRMMCs, 9 wt% PRMMC has the longest mild wear regime for 3000 m sliding distance as it is shown in Fig. 2.

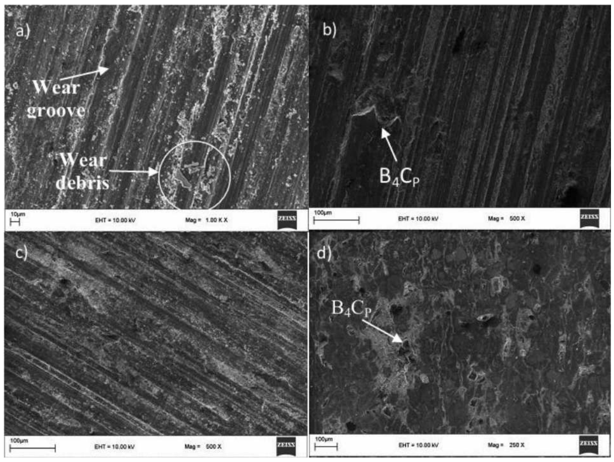

Fig. 3. SEM image of worn surfaces under 15 N load: (a) unreinforced Mg, (b) Mg-B_4C_p (3 wt%) (c) Mg-B_4C_p (6 wt%), and (d) Mg-B_4C_p (9 wt%).

4. Conclusions

In the current study, Mg-B_4C_p MMCs were fabricated by P/M process. By the addition of B_4C_p into the Mg matrix, the hardness of PRMMCs was found to be higher when compared to unreinforced Mg. It was detected that the wear loss of the samples increased with increase in sliding distance. The wear test results illustrated a significant effect of the B_4C_p on decrease of the wear loss of the samples (specially for the 9 wt% Mg-B_4C_p MMCs). B_4C_p additions also decreased the abrasive and adhesive wear traces on the sample surface, their width and depth decreased. No significant and extra plastic deformation was observed except defined abrasive and adhesive wear tracks on the worn surface of the samples (unreinforced Mg, 3 and 6 wt% B_4C_p).

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