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The Effects of B_4C Amount on Hardness and Wear Behaviours of 7075-B_4C Composites Produced by Powder Metallurgy Method

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In this study, the effects of B_4C amount on hardness and wear behaviours of 7075 Al-B_4C composites produced by powder metallurgy method were investigated. Within the scope of work, different amount of B_4C (3, 6, 9%) added into gas atomized 7075 Al powders. The powders were mixed in Turbula with 67 rpm for 45 min. Then the composite powders were pre-shaped by cold pressing under 600 MPa pressure. Pre-shaped samples were sintered in atmosphere controlled furnace at 580 °C for 4 h. Scanning electron microscope, X-ray diffraction examinations and hardness measurements were carried out after standard metallographic processes. Wear tests were performed in a pin on type wear apparatus under 30 N with 1 m s^{-1} sliding speed, at six different sliding distances (500–3000 m). Results show that the hardness was increased with increasing of amount of B_4C. At the end of wear tests the lowest weight loss were found to 9% B_4C containing composites. In addition, it is determined that the weight loss increased with increasing sliding distance.

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1. Introduction

Metal matrix composites are very popular industrial materials because of their high modulus of elasticity, hardness and strength. Especially due to their excellent wear and corrosion resistance, they are widely used in automotive and aerospace industry [1–4]. Al alloys are widely used in metal matrix composite production as matrix material due to their low density and high corrosion resistance [1, 5, 6]. Among these alloys, especially the 2XXX, 6XXX, 7XXX Al alloys are preferred for their ageing properties. There are many recent studies that used 7XXX Al alloys as matrix material, which have the highest resistance among all Al alloys [1, 7–9]. In these studies, various carbides and oxides (such as SiC, Al_2O_3 B_4C, TiC, AlN, TiN, Al_4C_3) have been used as reinforcement phase [10–13]. Some recent studies used B_4C as reinforcement phase due to its low density and higher hardness compared to SiC and Al_2O_3 [10, 14, 15]. In metal matrix composite production, the reinforcement phase is done using the casting or the powder metallurgy method. In Al matrix composite production using the casting method, low wettability of the reinforcement phases and non-homogeneous distribution bring some limitations for this method [16, 17]. The powder metallurgy method, on the other hand, allows production in low temperatures with homogeneous distribution and is widely used in Al matrix composite production [18–20]. In this study, 7075 Al–B_4C composites were produced by powder metallurgy method by adding B_4C reinforcement phase at different proportions, and the effect of the reinforcement phase amount on the wear behaviour of the composites was investigated.

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2. Materials and method

In this study, the wear behaviours of B_4C reinforced *ex situ* aluminium composite materials (ACM) produced with powder metallurgy method were investigated. The powder size of the gas atomized 7075 Al alloy used in the experimental studies was 100 µm and the powder size of the B_4C used as the reinforcement phase was 20 µm. The chemical composition of the 7075 aluminium alloy was given in Table I.

TABLE I

The chemical composition of the 7075 aluminium alloy.

	Zn	Mg	Cu	Fe	Si	Zr	Cr	Mn	Al
wt%	5.48	2.58	1.568	0.549	0.403	0.0305	0.0125	0.014	bal.

The AA7075 powder was mixed in the Turbula for 45 min at 67 rpm by adding 3%, 6 % and 9% B_4C. These composite powders were then cold pressed under 600 MPa pressure and preformed green compacts with 12 mm diameter and 7 mm height were produced. These green compacts were sintered in an atmosphere controlled furnace at 580 °C for 4 h and cooled in furnace. After standard metallographic preparation, the sintered samples were etched for 15–20 s with 95 ml distilled water, 2.5 ml HNO_3, 1.5 ml HCl, 1 ml HF (Keller's) solution. Prepared samples were analysed using scanning electron microscope, energy dispersive X-ray spectroscopy (EDS) (Zeiss-Ultra/Plus FEG) and X-ray diffraction (XRD) (Rigaku D-MAX RIN-2200). For hardness measurements, the hardness of 5 different samples for each parameter were measured using a Shimadzu micro hardness device (HMV 0.5) and the mean value was calculated. The density measurements were performed according to the Archimedes principle. The wear tests were performed using a pin-on disc type standard wear device under 30 N load at 1 m s^{-1} constant sliding speed and at 6 different sliding distances (500–3000 m). Before wear tests, the surfaces of all samples were prepared with 1200 grid sandpaper and polished with 6 μm diamond solution. After each test, the sample surfaces were cleaned with acetone. Worn surfaces were examined using SEM after the wear tests were completed. The weight losses of the samples were measured using a 1/10000 precision scale.

3. Results and discussion

The SEM images of 7075-B_4C composites produced by adding different amounts of B_4C phase are given in Fig. 1.

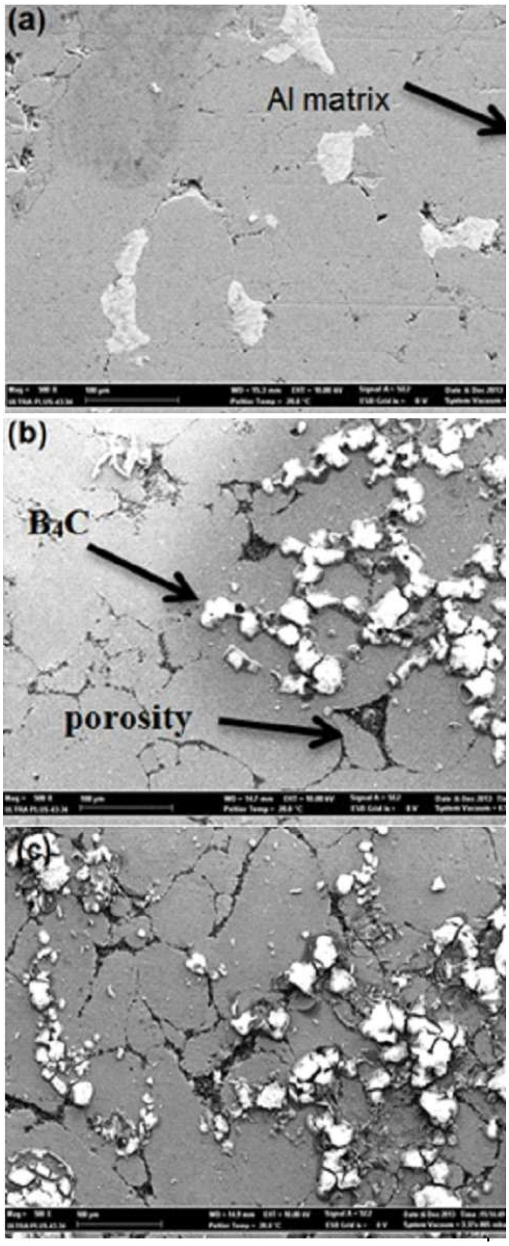

Fig. 1. The SEM images of 7075-B_4C composites produced by adding different amounts of B_4C phase (a) 3%, (b) 6%, (c) 9%.

It can be seen from the SEM images that, as the added amount of B_4C reinforcement phase in the matrix increased, a homogeneous distribution was not achieved and the particles concentrated locally in the matrix (b,c). The reason is thought to be the dimensional difference between the matrix and reinforcement phase. In addition, pores are observed in the microstructure images. These pores form in the structure as a result of powder metallurgy method used to produce composites. This situation can also be observed in density changes of the composites, which is given in Fig. 2a. Since the density of B_4C (2.50 g/cm^3) is lower than the matrix material, the density of the composites decreases as the added amount of B_4C increases.

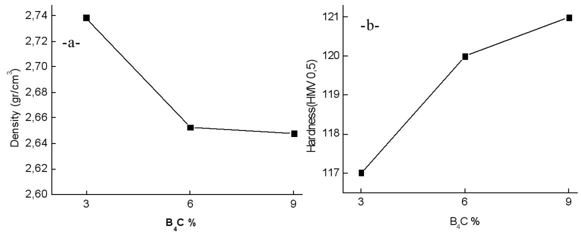

Fig. 2. The density and hardness changes of aluminium composites containing different amounts of B_4C (a) Density values, (b) Hardness values.

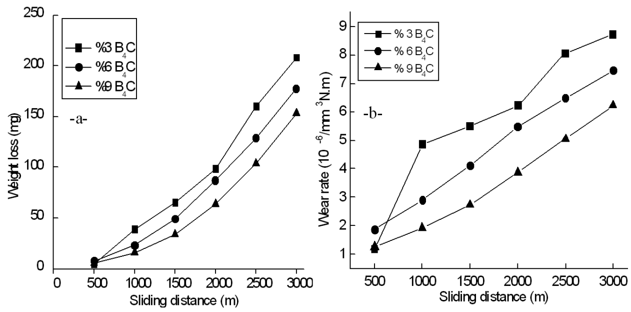

Fig. 3. The weight loss and wear rate of 7075-B_4C composites produced by adding different amounts of B_4C (a) Weight loss, (b) Wear rate.

The hardness changes of 7075-B_4C composites produced using the powder metallurgy method is given in Fig. 2b. The hardness measurement results were 117 HV, 120 HV, and 121 HV for the composites produced by adding 3%, 6% and 9% B_4C respectively which means a slight increase of the hardness by the increasing amount of B_4C. The composite with 9% B_4C has the highest hardness value for our study. The wear behaviours of 7075-B_4C composites produced by adding different amounts of B_4C can be concluded from the weight loss and wear rate given in Fig. 3a and b.

Examining the weight loss and wear rate obtained as a result of wear tests, it is seen that the weight loss decreased as the amount of reinforcement phase (B_4C) increased. The highest weight loss was observed in the composites produced by adding 3% B_4C. Comparing these results with the hardness values given in Fig. 2 indicates the relationship more clearly. As the hardness of the composites increases, the weight loss measured from wear tests decreases. It was also observed that the weight loss increases by the sliding distance. The wear rates and the weight loss results from the study matches to each other. The results obtained in some earlier studies support the results obtained in this study as well [13, 21]. The SEM images of worn surfaces of 7075-B_4C composites produced by adding different amounts of B_4C after wear tests are given in Fig. 4.

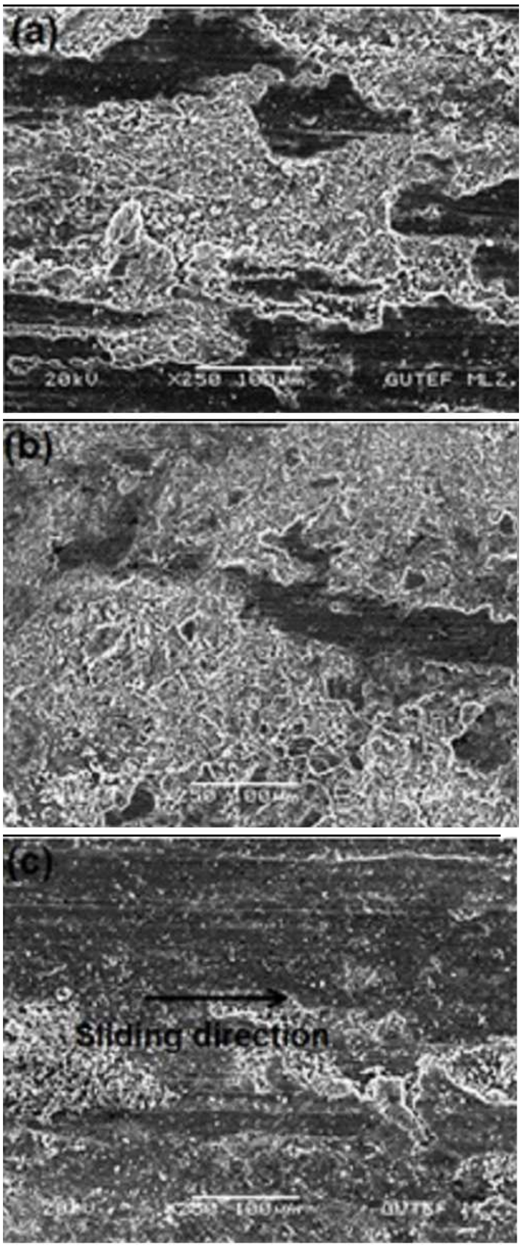

Fig. 4. The SEM images of worn surfaces of 7075-B_4C composites produced by adding different amounts of B_4C (3% (a), 6% (b), 9% (c)).

The sliding direction of the composites can clearly be seen from the worn surface of SEM images. SEM images show that the predominant wear mechanism is the adhesive wear mechanism, but there is also abrasive wear mechanism on the worn surface (due to damages occurring on the wear surfaces such as scratches and tears). In addition, it is also understood that oxidation occurred on the sample surfaces due to temperature increase during friction. The results are supported by some earlier studies as well [12, 20].

4. Conclusion

In this study, the wear behaviours of 7075 Al-B_4C composites produced by adding different amounts of B_4C reinforcement phase were investigated. Following conclusions are obtained from the study:

- In 7075 Al-B_4C composites produced by adding different amounts of B_4C (wt%), increasing amount of B_4C decreased the density and increased the hardness slightly.
- Microstructure examinations revealed that the reinforcement phase did not show a homogeneous distribution and concentrated on certain areas.
- XRD examinations showed the formation of B_4C phase in the structure.
- Examining the wear behaviours of the composite, an improvement in wear strength is observed as the B_4C proportion (wt%) increased.
- Examining the worn surfaces, it is seen that adhesive wear mechanism was predominant in the structure.

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