Al/B_4C Composites with 5 And 10 wt% Reinforcement Content Prepared By Powder Metallurgy

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ABSTRACT

The preparation, physical and mechanical properties of Al/B_4C composites with 5 and 10 wt.% reinforcement content were investigated. In order to obtain the feedstock with a low powder loading, B_4C mixtures containing fine powders were investigated to obtain the optimal particle packing. The experimental results indicated that the fine containing 5 and 10 wt.% particles are able to prepare the feedstock with a good flowability. The composites fabricated by powder metallurgy have low densities and homogeneous microstructures. Additionally there is no interface reaction observed between the reinforcement and matrix by XRD analysis. The hardness of Al/B_4C composites prepared by powder metallurgy was high.

ABSTRAK

Persediaan, sifat-sifat mekanikal dan fizikal Al/komposit B_4C dengan 5 dan 10 % berat peneguhan kandungan telah disiasat. Supaya mendapatkan stok suapan dengan pemuatan serbuk rendah, campuran-campuran B_4C mengandungi serbuk halus disiasat memperoleh padatan zarah optimum. Hasil percubaan menunjukkan bahawa denda mengandungi 5 dan 10 % berat zarah-zarah mampu menyediakan stok suapan dengan satu flowability baik. Komposit dibina oleh kaji logam serbuk mempunyai densiti-densiti rendah dan microstructures homogen. Yang tambahan pula tiada tindak balas antara muka memerhatikan antara peneguhan dan matriks oleh analisis XRD. Kekerasan Al/komposit B_4C disediakan oleh kaji logam serbuk tinggi.

Keywords: *Al/B_4C composites, powder metallurgy, aluminium, boron carbide, reinforcement*

INTRODUCTION

Metal matrix composite can be fabricate by using several techniques included powder metallurgy, molten metal and spray deposition (Zhang, C. et al., 2009). For example, molten metal technique always used to manufacture aluminium composite with continuous fiber reinforcement like graphite and silicon carbide. Meanwhile, powder metallurgy method was employed to produce aluminium composites reinforce with non continuous fiber (SiC, Al_2O_3), whiskers (SiC, B_4C) and particle (SiC, Al_2O_3, B_4C). Boron carbide is non metal material that poses very useful physical and chemical properties (Sezer, A.O. and Brand, J.I., 2010).This material among excellent potential material because it known as third hardest material after diamond and boron nitride and density of 2.51g/cm^3. Boron carbide is also unique due to properties such as high shock resistance and high wear resistance. Boron carbide retains high melting point which is 2450 ºC as well as high resistance to chemical agents (Roy, T.K., Subramaniam, C. and Suri, A.K., 2006). One of the special features of boron carbide is that the ability to absorb neutron (Khakbiz, M. and Akhlagi, F., 2009) is consider high. These features allowed boron carbide applied in nuclear industry as neutron absorber materials (Chen, X.G. et al., 2009). Neutron absorption cross section for cadmium is 20 barn while boron more than 100 barn for neutron with energy 1.0 eV. Boron has naturally occurring isotope B^{10} and has a neutron capture cross section of approximately 767 barns (Celli, M., Grazzi, F. and Zoppi, M., 2006). The ability to absorb neutron is dependent on the presence of this isotope B^{10}.

Aluminium reinforced boron carbide composite gives interesting features such as high strength and high hardness. These characteristics have made this composite as a very potential material in engineering field (Yucel, O. and Tekin, A., 1996). The usage of aluminium reinforced with boron carbide composite become especially in neutron application due to its ability to absorb neutron very well. This composite is used as shielding materials to absorb free neutron caused from the reaction in the reactor nuclear and to avoid any radiation escape to the surrounding environment (Chen, X.G. et al., 2009). Fabrication of aluminium composite reinforced with boron carbide is due to several weaknesses of boron carbide when it exists as a single form where boron carbide is brittle and required extreme temperature for heat treatment due to its high melting point. By using boron carbide as the reinforcement and metal as matrix to produce metal matrix composite, the problem related to the brittleness can be solved. Until now, metal often been used is aluminium because of its characteristics that are light in weight and have the ability to wet the boron carbide at high temperature (Hulbert, D.M. et al., 2008).

EXPERIMENTAL WORKS

Al/B_4C composites with reinforcement of 0 wt.% , 5 wt.% and 10 wt.% of B_4C powders were fabricated by powder metallurgy. Aluminium and B_4C powders were mixed by ball milling, dried and sintered at 850°C for 2 hours. In this study, the parameters controlled were milling time of 8 and 16 hours. Hardness test was conducted to determine hardness of Al/B_4C composites with different milling time. The Rockwell machine was used to measure the hardness each of samples. Prior testing, samples were grind and polished to remove any contaminant on surface and reduce the defect. Hardness test was measured on the sample surface and four readings were taken for every sample. X-ray diffraction (XRD) was used to study phase identification and trace elements while scanning electron microscopy (SEM) was analyses microstructure of surface samples.

RESULTS AND DISCUSSION

Figure 1 shows the SEM morphology of Al/B_4C milling at 8 hours and 16 hours. In the milling of 8 hours, aluminum particle size is greater than the milling of 16 hours. This result is caused by the milling effects of aluminum particles size. In the period of milling, the aluminum particles suffer fractures or broken due to the pressure force exerted by the balls mills during the milling process. Therefore, particles breaking up and become smaller particles size at the longer milling time. It can be seen in Figure 1(b) which shows that the aluminum particles size of 16 hours milling is smaller than 8 hours of milling.

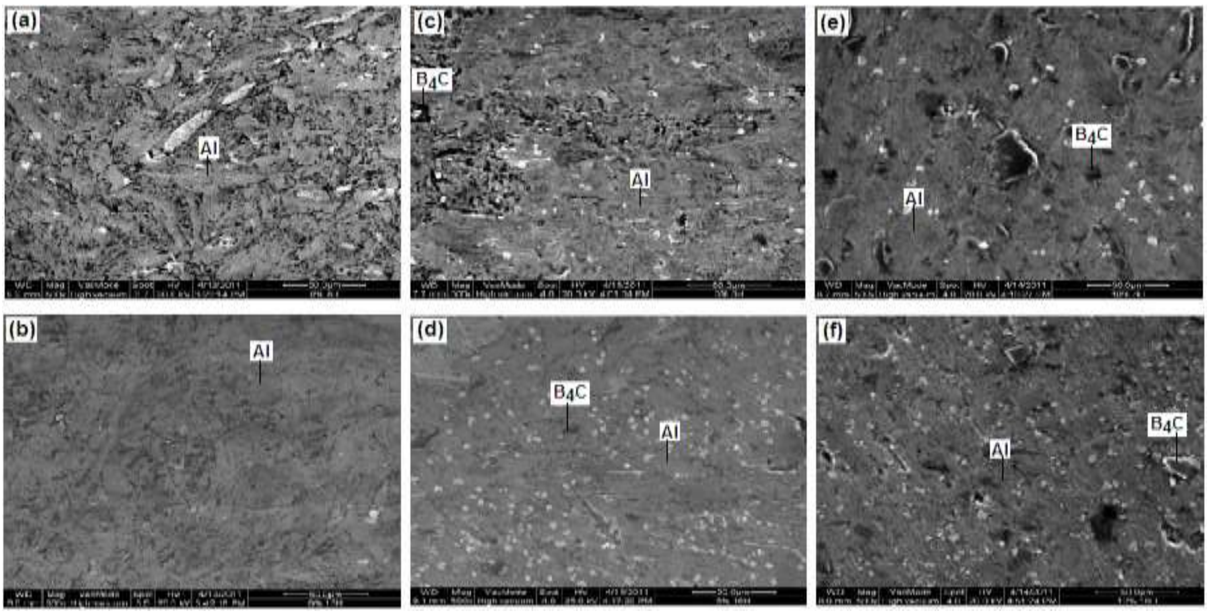

Figure 1. SEM morphology (500 x magnifications)

(a) Al/0%B_4C, 8 hours (b) Al/0%B_4C, 16 hours

(c) Al/5%B_4C, 8 hours (d) Al/5% B_4C, 16 hours

(e) Al/10%B_4C, 8 hours (f) Al/10%B_4C, 16 hours

Figure 1(c) shows that the period of 8 hours of milling, B_4C found scattered among the aluminum matrix. The increase in the milling time causes a more uniform distribution of B_4C powders in aluminum matrix. It can be seen in Figure 1(d) shows a uniform distribution of B_4C powders. In the early milling process, B_4C is stick among aluminum particles. The increase in the milling time will cause cracks in the particles and the aluminum particles broke down and form a new surface with B_4C particles attached to it. Milling process that continues conducted result in uneven distribution of B_4C. Study by Sharifi et al. (2011) on aluminum reinforced with boron carbide composites found that an increase in the milling time will result in uneven distribution of B_4C on the milling time of more than 5 hours compared to 15 minutes. Figure 1(e) showing the B_4C particles spread located between the aluminum matrixes. An increasing in milling to 16 hours showed that there was a more even uniform distribution. This could be due to the occurrence of cracks and broken during the milling process causes the aluminum and B_4C particle more distribution uniform. There was also observed that the changes in the size of the B_4C particles occur due to particle fracture and breakdown during the milling process. The SEM images also indicated that the aluminum particles are beginning to experiences fractures and broken as a result of the grinding process as milling time at 8 hours. Brighter areas indicated aluminum while dark area shows the gray area are represented B_4C and other trace elements including carbon, boron and B_2O_3 as determined by XRD analysis.

The effect of B_4C reinforcement into composites on density was analysed and shown in Figure 2. It was observed that the increased in B_4C composition decreased the density of the Al/B_4C composites. Al/10%B_4C composites have lower density compared to Al/5%B_4C and Al/0%B_4C. Changes in the B_4C content causes higher amount of porosity formed in composites. The increased in amount of porosity decreases the density. Therefore, the density of Al/5%B_4C composites is higher than the density of Al/10%B_4C composites. Aluminium has higher density which is 2.70 g/cm^3 compared to boron carbide which is 2.51 g/cm^3. Combination of these two materials will produce a composite with lower density. Mohanty et al. (2008) in his study of fabrication technique and characterisation of aluminium/boron carbide composites determined that the increased in composition of boron carbide would decrease the density of the composite. The composition of composite is reinforced with 0-25% of B_4C and the density decreased from 2.52 g/cm^3 to 1.8 g/cm^3. Furthermore, the density of composite shows increasing amount of porosity with increasing percentage of boron carbide.

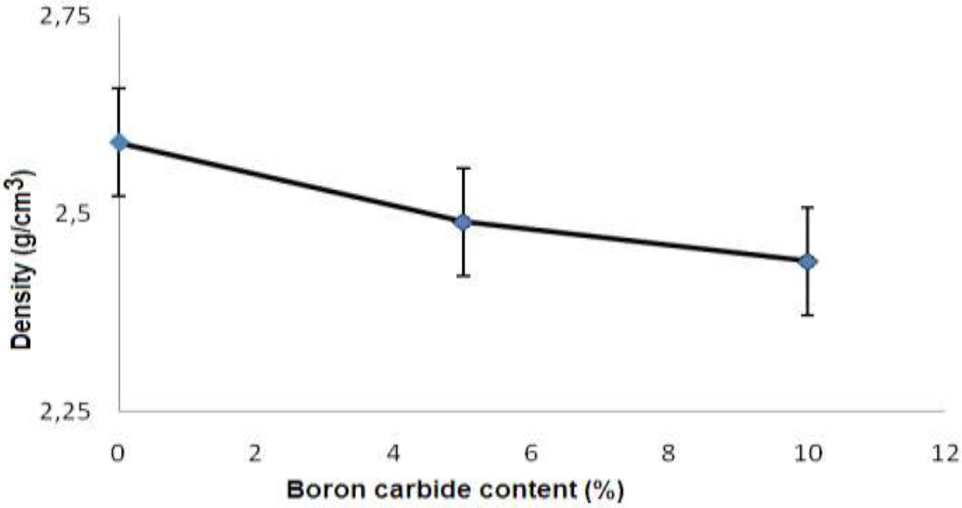

Figure 2. Effect of B_4C content on density of Al/ B_4C composites

Figure 3 shows the effect of milling time and composition on hardness of Al/B_4C composites. The increasing of hardness was observed as well as milling time increase from 8 hours to 16 hours. However, gradually increasing in hardness is slow as milling period increase. The increasing in hardness become slowly might be due to increasing in particles agglomeration. Grain boundary is one of defects that lead to increase the value of free energy of materials. Thus, in order to reduce free energy in materials, particle size should be large enough to shrink the grain boundaries. Nevertheless, increasing in grain size will lead lack of resistance and allowed dislocation to occurred which is primary enforcement mechanism as mentioned by Askeland (2006).

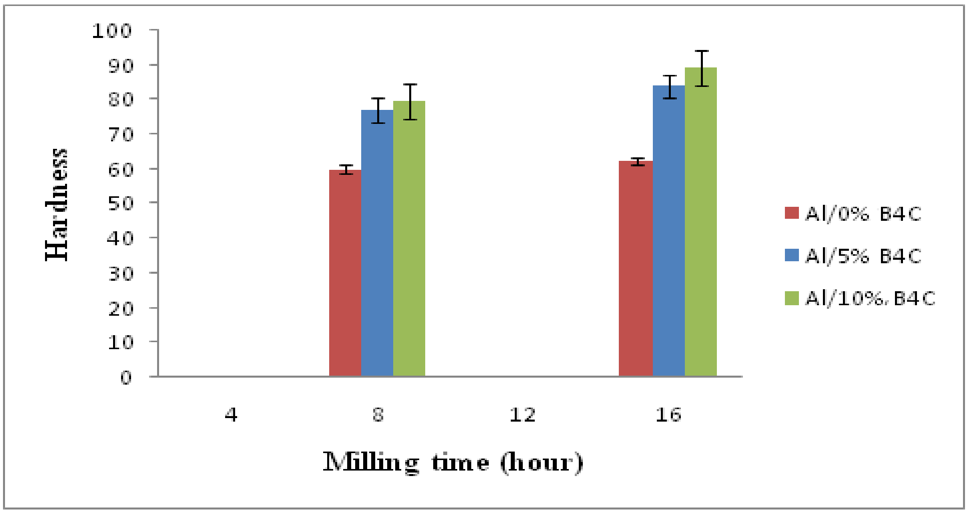

Figure 3. Hardness versus milling time of Al/B_4C composites

According to Sharifi et al. [9] who studied on effect of composite hardness with milling time between 0 to 45 hours, the composites hardness increase along with milling time. The value was increase drastically at early milling period. However, rate of hardness value decrease after 5 hours of milling process. He also found that increasing in hardness not only caused by strain of grain result from powder metallurgy process but also from uniform distribution of boron carbide nanoparticles. Meanwhile, relative hardness of Al/0%B_4C, Al/5%B_4C and Al/10%B_4C are shown in Table 1.

Table 1. Hardness value for Al/0%B_4C, Al/5%B_4C and Al/10%B_4C composites

Sample	Hardness measurement				Average hardness
Al/0%B_4C	59.95	60.15	61.98	62.40	61.12
Al/5%B_4C	75.85	77.05	77.78	84.04	78.68
Al/10%B_4C	76.33	79.74	81.52	89.30	81.72

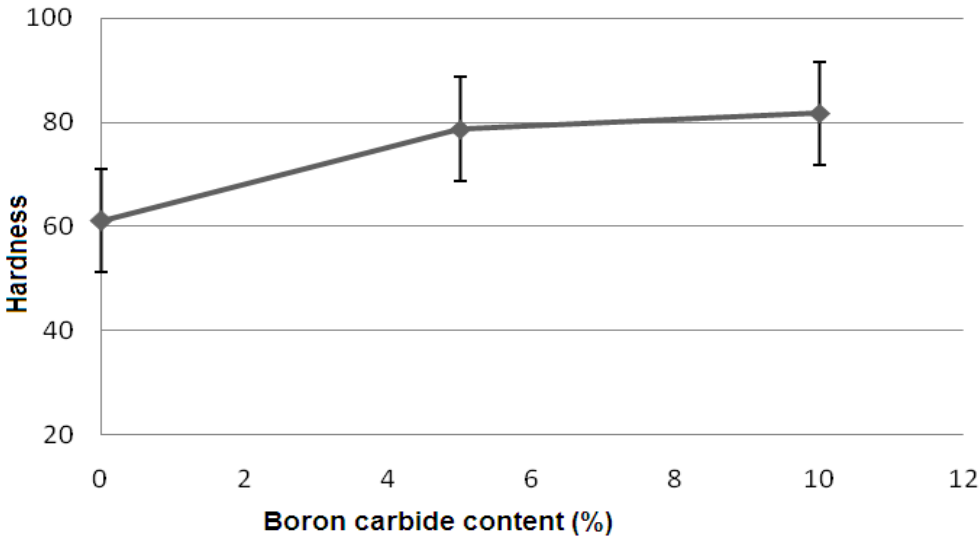

Figure 4. Hardness versus composition of boron carbide in Al/B_4C composites

The hardness of Al/10%B_4C composites is higher than Al/5%B_4C as shown in Figure 4. It was believed that the difference in boron carbide content in composites influence the hardness properties. Boron carbide is a material having a higher strength than aluminum with the reading of 2.75 Mohs compared to 9.3 Mohs. Thus, the increase in the quantity of boron carbide in the composites increases the strength of the Al/B_4C composites. Hardness for Al/5%B_4C was also higher than

Al/0%B4C. This result also supported by report from Sharifi et al. [9] which found that the hardness of the composites of aluminum reinforced with boron carbide increase with increasing the boron carbide content. The hardness reading of Al/5% B_4C is increased by almost three times more than Al/0%B4C. It was concluded that the higher percentage of boron carbide, the higher hardness of composites.

Figure 5 shows phase identification analysis using x-ray diffraction (XRD) of Al/B_4C composites at different milling periods. It was found that the crystalline of the composites is improved with an increase in the milling time from 8 to 16 hours. Crystalline of the Al/5%B_4C at milling for 16 hours is more crystalline than milling in 8 hours. It was found that the milling at 16 hours, the crystalline of the resulting composite was higher than milling at 8 hours.

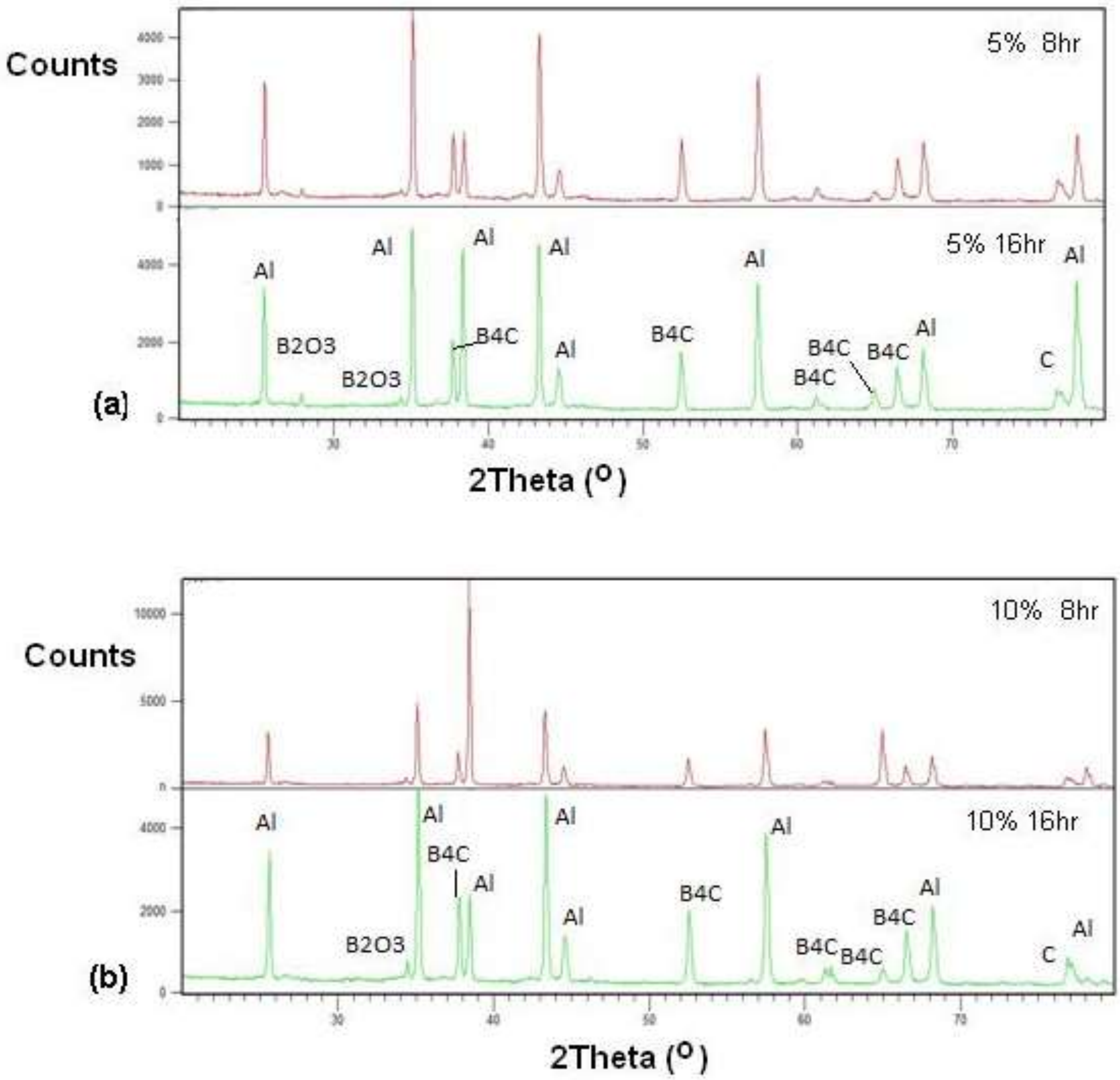

Figure 5. XRD spectrum shows the intensity (counts) versus angle 2θ for (a) Al/5%B_4C (b) Al/10%B_4C during milling 8 hours and 16 hours.

This result indicated that the grain size is more finely milled powder when milling time increased from 8 hours to 16 hours.

CONCLUSION

Aluminium reinforced with 5% and 10% boron carbide composites were successfully prepared by powder metallurgy technique. The results indicated that density increases with increasing milling time from 8 h to 16 h. The hardness of Al/B_4C composites was increased with the increasing amount of boron carbide in the composites. The hardness of Al/10%B_4C and Al/5% B_4C composites was 81.72 and 78.68 respectively. The XRD analysis shows that the crystalline composite becomes better as the milling time is longer. It also shows that a uniform distribution achieved when Al/B_4C composites is milled up to 16 hours as proven from SEM morphology. It was believed that the mechanical and physical properties of Al/B_4C composites were good and therefore this composite has a potential to be used as neutron shielding materials.

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