Available online at www.sciencedirect.com
ScienceDirect
Materials Letters 62 (2008) 1215–1218
materials letters
www.elsevier.com/locate/matlet

Microstructural variations in cast B_4C-reinforced aluminium matrix composites (AMCs)

Isil Kerti *, Fatih Toptan

Department of Metallurgical and Materials Engineering, Faculty of Chemistry & Metallurgy, Yildiz Technical University, Davutpasa Campus, Esenler, Istanbul, Turkey

Received 3 July 2007; accepted 3 August 2007
Available online 10 August 2007

Abstract

The present work introduces a cost-effective and reliable casting technique to overcome the wetting problem between B_4C and liquid aluminium metal as well as the formation of undesirable phases at the interface using K_2TiF_6 flux. For this aim, experimental work was carried out using B_4C powders with different particle sizes to reinforce commercially available aluminium using casting technique. It was shown that B_4C addition with bigger particle size resulted in better microstructure with free of agglomerated particles.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Aluminium; Boron carbide; Flux; Casting; Composites; Wetting

1. Introduction

Today searches in finding new materials superior than the conventional ones have an increasing demand. In these studies, aluminium matrix composites (AMCs) have gained great attention especially in the industries such as aviation, space and automotive [1,2]. Recently, AMCs have been used for the automobile products, such as engine piston, cylinder liner, brake disc/drum due to their light weight, high strength, high specific modulus, low co-efficient of thermal expansion and good wear resistance properties [3].

An important issue in the production of metal matrix composites (MMCs) is the chemical compatibility between the matrix and the reinforcement, particularly when using liquid metal processes [4]. Casting of MMCs is an attractive processing method since it is relatively inexpensive and offers a wide selection of materials and processing conditions [3]. But poor wetting between Al and B_4C below 1100 °C means that it is difficult to produce Al–B_4C composites by mixing particles into the liquid phase. In order to enhance the wettability of ceramics and improve their incorporation behaviour into Al melts, particles are often heat treated or coated [5].

Therefore, K_2TiF_6 flux is used in order to increase the wetting between Al and B_4C and facilitate the incorporation of B_4C particles into molten aluminium. To avoid insufficient reaction phase at the interface and to lower the processing cost, no additional processes except the traditional casting methods were used in this study.

2. Experimental procedure

Boron carbide powders of two different mesh sizes from Alfa Aesar (USA) were used in this study. The particle sizes were < 10

Table 1
Casting conditions

Specimen number	B_4C particle size (μm)	B_4C (wt.%)	Particle addition temperature (°C)	Mixing
1	<10	5	800	No
2	>20	5	800	No
3	<10	10	800	No
4	>20	10	800	No
5	<10	15	800	No
6	>20	15	800	No
7	<10	5	920	Yes
8	>20	5	920	Yes
9	<10	10	920	Yes
10	>20	10	920	Yes

* Corresponding author. Tel.: +90 212 4491695; fax: +90 212 4491554.
E-mail addresses: ckerti@yildiz.edu.tr (I. Kerti), ftoptan@yahoo.com (F. Toptan).

0167-577X/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.matlet.2007.08.015

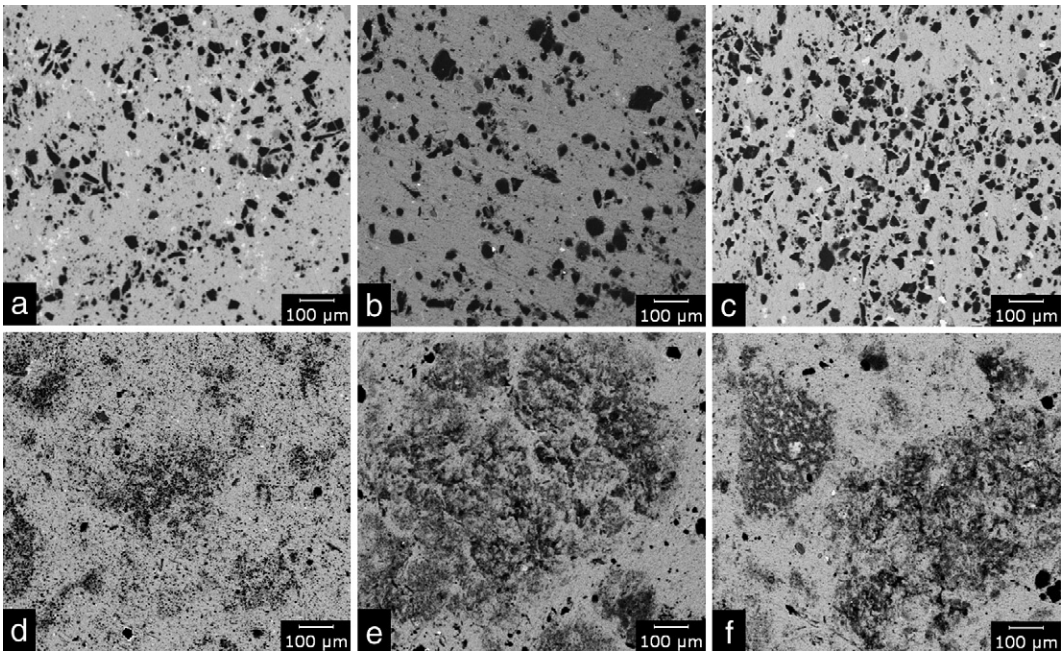


Fig. 1. SEM images of a) S6, b) S8, c) S10, d) S5, e) S7 and f) S9 indicating that homogeneous distribution of bigger B_4C particulates (a, b, c,) and agglomeration of smaller B_4C particulates (d, e, f) within the matrix.

(99+% metals basis) and >20 μm (99+% metals basis), respectively. The metal used as the matrix materials in the composite was commercially available aluminium obtained from Seydisehir Aluminyum (Turkey). In order to enhance the wettabbility of boron carbide powders and improve their incorporation behaviour into aluminium melts, potassium fluotitanate (K_2TiF_6) flux from Honeywell (USA) was used.

Different B_4C particulate reinforced AMCs were produced using 500 g of commercially available aluminium charges which were melted in a SiC crucible utilizing induction furnace for each specimen. Mixture of B_4C particles and the same amount of K_2TiF_6 flux were added into the melt in the crucible. Melt was held for 5 min at the fixed temperature. Finally the melt was poured into a metal mould.

Metallographic samples sectioned from the cast bars were prepared using the diamond grinders and suspensions. Microstructures were examined under the JEOL JSM-5600 scanning electron microscope (SEM) equipped with EDX analysis. Casting conditions are summarized in Table 1. To investigate the changes in particle incorporation to melt by using flux, particles with various sizes and ratios were employed, as shown in Table 1. For enhancing castability, process temperatures were increased in the latter processes. Manual mixing for 30 s was performed within S7 and following groups to avoid deposition of the powder mixture and increase castability.

3. Results and discussion

Fig. 1 shows the effects of B_4C particle sizes on the microstructure of the cast samples. SEM observations of the bigger particle reinforced samples (particle size >20 μm) revealed homogeneous distribution of B_4C particles in the Al matrix as shown in Fig. 1a,b,c. However, the

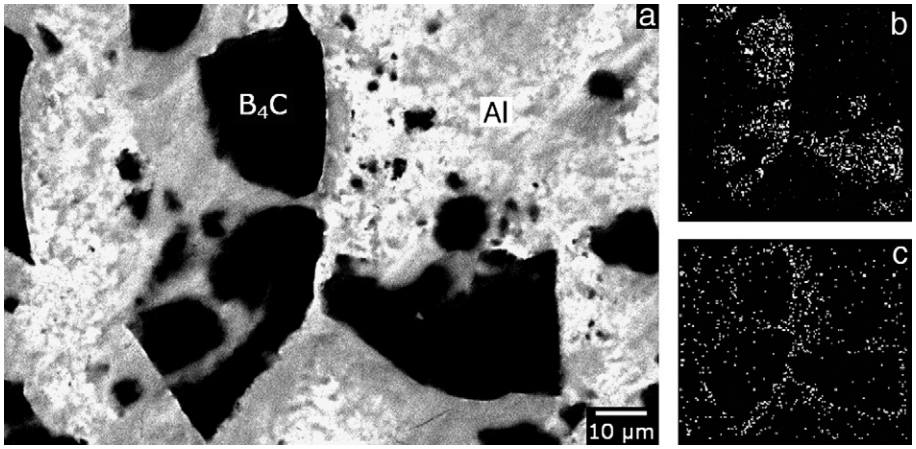


Fig. 2. a) SEM micrograph of the B_4C particles in the S4 and b, c) matching elemental maps for B and Ti, respectively.

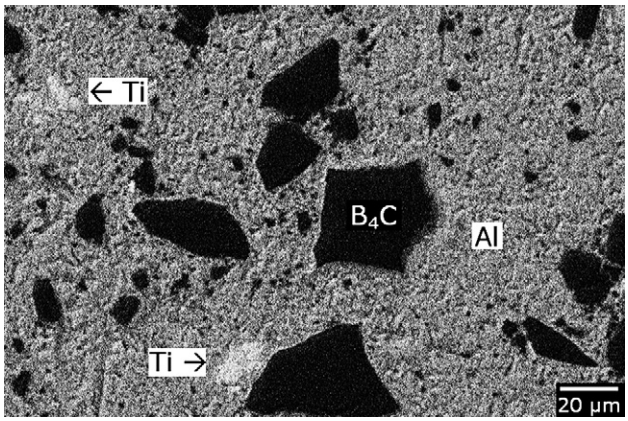


Fig. 3. SEM micrograph of the S6 shows the presence of Ti compounds within the matrix.

particles were agglomerated in some areas within the specimens which contain relatively smaller particles (particle size <10 μm) (Fig. 1d,e,f).

Further SEM examinations of S4 showed that the B_4C particles were surrounded by Ti compounds relatively weakly compared to the latter castings (Fig. 2). SEM evaluation of S6 revealed that Ti compounds did not exist at the interfaces and they became agglomerated in some areas as shown in Fig. 3. Agglomeration of Ti compounds was also shown on S2 and S4 but in those specimens, Ti compounds also exist at the interfaces.

The reaction layer that occurs with the reaction of B_4C with Ti, contains Ti compounds. Since these reaction products increase the metallic character to their bonding, they increase the opportunity for particle incorporation [5].

It has been reported that Ti/B_4C ratio should be equal to 0.07, at least, to get 100% yield [5]. In the present work, it has been calculated that, 50 wt.% of flux (K_2TiF_6) passes to melt. Therefore, the amount of flux which caused Ti/B_4C: 0.1 was employed, and it was equal to wt.% B_4C. Castings which had Ti/B_4C ratio less than 0.1 did not give desired results. But, it has also been reported that, if higher volume fractions or smaller particle sizes are to be added, increased levels of Ti in the flux are needed [5]. It has been observed that the amount of Ti in the flux, that was chosen as the same amount of B_4C, was not enough to cover all of the particles with a reaction layer in the case of higher particle ratios (i.e. 15 wt.%) or smaller particle sizes (<10 μm). It was concluded from our study that, in the case of higher particle ratios (i.e. 15 wt.%) of bigger particle sizes (>20 μm), the holding time was not enough to cover all of the particles with a reaction layer because of the agglomerated Ti compounds within the matrix as shown in Fig. 3.

In the non-mixing castings, it was seen that some of powder mixture deposited in the crucible and castability of the melt was decreased. To increase castability, the particle addition temperature of S7 increased (Table 1). And also, since the particles have continued to deposit, the melt was mixed manually for 30 s and 15 wt.% particle ratios could not worked in the next castings. However, the desirable results could not be taken for S7 and S9 depending on the lower Ti amount in the flux that was not enough for that small particles of B_4C. The desirable interface compositions could be taken for S8 and S10 that were processed at the same conditions with S7 and S9. Fig. 4 shows the SEM micrograph and the matching elemental maps for B and Ti of S10. Visible Ti-based coating layers around B_4C particles have been observed as shown in Fig. 4c and these layers were determined to be thicker than the images shown in Fig. 2c.

Because of removal from the interface during polishing, the very thin reaction layer that formed around the B_4C particles was not so clear in the SEM images. Therefore EDS analysis could not be taken because of the thin structure of the reaction layer.

4. Conclusions

From this study the followings can be concluded:

- It is possible to produce Al–B_4C composites with homogenous microstructure using K_2TiF_6 flux by casting method.
- For desired results, the amount of flux should be at least equal to the amount of B_4C particles, and it should be increased in the case of using particles which have higher particle ratios (i.e. 15 wt.%) or smaller particle sizes (<10 μm). It has been concluded that, the case of higher particle ratios (i.e. 15 wt.%) and bigger particle sizes (>20 μm), the holding time was not enough to cover all of the particles with a reaction layer because of the agglomerated Ti compounds within the matrix.
- Addition of B_4C particles with bigger particle size (>20 μm) results in more homogeneous composite microstructure compared to the composite samples containing smaller particle size of B_4C (<10 μm) due to agglomeration.

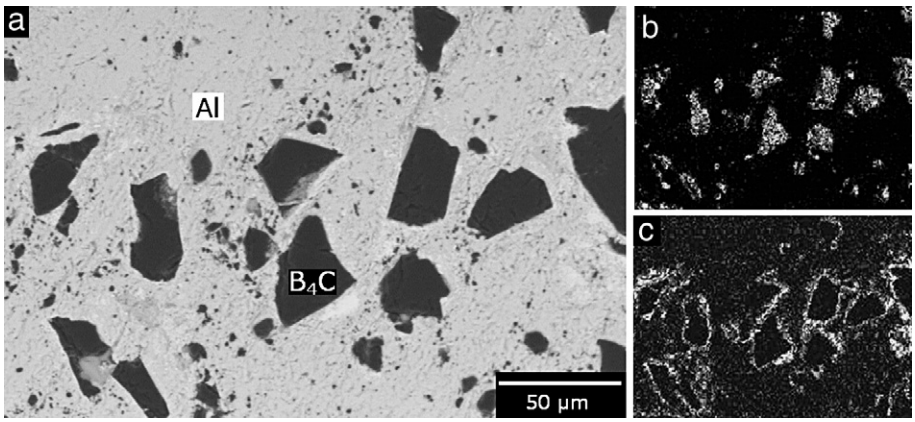


Fig. 4. a) SEM micrograph of the B_4C particles in the S10 and b, c) matching elemental maps for B and Ti, respectively.

Acknowledgements

The authors would like to thank YTU Research Foundation for financial support and ASSAN Aluminium for the provision of SEM facilities.

References

[1] I. Tsunemichi, M. JianFu, D. Shangli, S. Ichinori, S. Naobumi, L. Gilles, High strain rate superplasticity of TiC particulate reinforced 2014 aluminum alloy composites, Materials Science and Engineering A 364 (2004) 281–286.

[2] I. Kerti, Production of TiC reinforced-aluminum composites with the addition of elemental carbon, Materials Letters 59 (2005) 3795–3800.

[3] K.M. Shorowordi, T. Laoui, A.S.M.A. Haseeb, J.P. Celis, L. Froyen, Microstructure and interface characteristics of B_4C, SiC and Al_2O_3 reinforced Al matrix composites: a comparative study, Journal of Materials Processing Technology 142 (2003) 738–743.

[4] M. Kouzelli, C.S. Marchi, A. Mortensen, Effect of reaction on the tensile behavior of infiltrated boron carbide-aluminum composites, Materials Science and Engineering A 00 (2002) 1–10.

[5] A.R. Kennedy, B. Brampton, The reactive wetting and incorporation of B_4C particles into molten aluminium, Scripta Materialia 44 (2001) 1077–1082.