The Comparison of the Microstructure and Hardness of Al-B and Al-Mg-B Composites

Mohammad Reza Derakhshesh*
Young Researchers Club,
Majlesi Branch, Islamic Azad University, Isfahan, Iran
E-mail: mrderakhshesh@yahoo.com
*Corresponding author

Hossein Sina
Department of Materials Engineering,
Majlesi Branch, Islamic Azad University, Isfahan, Iran
E-mail: hoseinsina@yahoo.com

Hamid Nazemi
Young Researchers Club,
Majlesi Branch, Islamic Azad University, Isfahan, Iran
E-mail: hamidnazemy@yahoo.com

Received 15 June 2011; Revised 3 August 2011; Accepted 1 September 2011

Abstract: Aluminum base composite materials with variable properties which have been strengthened by AlB_2 particles have been widely used. In this study, composites with variable properties of Al-5%B and Al-2%Mg-2%B which are produced through centrifugal casting are investigated as far as their microstructure and hardness are concerned. The microstructure of these composite were studied by using metallography. Also the vickers microhardness test was performed on the samples. The review of the results of the microstructure showed that the volume fraction within the composite particles has continuously changed and therefore produces a non-uniform microstructure with continuously varying properties. Particle separation of AlB_2 towards the casting regions led to higher hardness in this region. The volume fraction of AlB_2 particles in the studied composites showed a strong dependence on the presence of magnesium in the composite structure.

Keywords: Al-B Composite, AlB2 Particles, Al-Mg-B Composite, Hardness, Microstructure.

Reference: M. R. Derakhshesh and H. Sina, (2011) 'The Comparison of the Microstructure and Hardness of Al-B and Al-Mg-B Composites', Majlesi Journal of Mechanical Engineering, Vol. 4/ No.4, pp. 27-31.

Biographical notes: M. R. Derakhshesh is B.Sc in Metallurgical Engineering in Islamic Azad University, Majlesi Branch, Isfahan, Iran**.** **H. Sina** is M.Sc in Metallurgical Engineering, Lecturer in Islamic Azad University, Majlesi Branch, Isfahan, Iran. **H. Nazemi** is M.Sc in Metallurgical Engineering, Lecturer in Islamic Azad University, Majlesi Branch, Isfahan, Iran.

1 INTRODUCTION

Aluminum base composites reinforced with ceramic or metal particles, due to high strength and abrasion resistance have been widely used [1]. Aluminum base composites with increasing volume fraction of particles show strength to greater wear resistance and lower friction coefficient compared with aluminum alloys without enhancing particles [2].

In Functionally Graded Composites Materials, the variable distribution of volume fraction of strengthening particles, from the interior sections to exterior sector sections, produces a non-uniform controlled microstructure with continuously variable properties [3]. Composite materials with variable properties are suitable for applications that require varied wear resistance and high toughness simultaneously [4, 5].

Al-AlB_2 composite which is a composite and includes aluminum base with variable properties is an alternative for aerospace applications. The composite has a low density but a very high resistance to abrasion. The method of centrifugal casting is one of the best methods for producing such materials. This is because under the direction of the centrifugal forces, AlB_2 heavy ceramic particles floating in the liquid metal easily move to the external surfaces through the separation phenomenon [5, 6]. Distribution of AlB_2 particles in the composite that could lead to a gradient in the chemical composition of matter can be formulated according to the differences in density of the materials [7, 8]. In Al-B alloy system, lack of boron solubility in solid and molten aluminum changes alloys enriched with aluminum into a reinforced composite with AlB_2 particles. In this composite low-density base aluminum along with high hardness of AlB_2 particles create desirable properties. AlB_2 has a density equal to 3.19 g/cm3 which is less than the molten aluminum with a density equal to 2.4 g/cm3 [9-12]. Microstructure control has been reported as to be the most important advantage of centrifugal cast method to produce the appropriate mechanical properties [13, 14].

2 PROCEDURE

In this paper, two aluminum based composites of Al-5% B and Al-2%Mg-2%B were produced by centrifugal casting method and while the distribution of particles were assessed through image analysis of these composites, their hardness was studied and compared using vickers microhardness survey method. In this study first, using precision casting, the prototype and format was made and then using centrifugal casting all required samples were made. In this study, for the centrifugal casting, a spinning frame mold with the length and diameter equal to 100mm and 80mm respectively were used. A module with a volume of 340 grams was used to transfer the molten into the cast mold. The frame mold that had been previously made was under pre warm temperature of 400˚C for a time before pouring the melt into it. The process of centrifugal casting began initially with rotational speed equal to 200rpm while pouring molten mold temperature was equal to 750˚C. Before the mold under centrifugal force stopped, it reached its maximum speed of rotation. Finally, cylinder parts to the length and diameter of 20mm and 16mm are obtained. Samples of some outer, middle and inner parts of these pieces were taken. Samples from different parts of pieces provide the possibility of fine precision in the microscopic structure investigation of different parts. After metallographic operations on samples, microstructure images were prepared using optical microscopy. Finally, vickers micro-hardness tests on samples were made by using the ASTM E384 standard.

3 RESULTS AND DISCUSSION

Microscopic microstructure alloys of Al-5% B (A and B), Al-2% Mg-2% B (C) are seen in Fig. 1. The strengthening AlB_2 particles which are within the field of aluminum base alloy of Al-5%B can be seen in the two longitudinal section (A) and lateral section (B).

As it is clear hard sediment particles Al_3Mg_2 (β) can be observed in microscopic sample of the microstructure Al-2% Mg-2% B. This is one of the sustainable phases in the system of Al-Mg alloy.

In Fig. 2, the manner of distribution of volume fraction of the strengthening particle AlB_2 in different samples have been studied. In both composites studied, the center of samples has a higher density than strengthening particles in exterior areas compared with areas inside the casting piece. This is because of the separation of the AlB_2 particles due to the application of centrifugal force. Thickness of the particle-rich region is strongly the function of rotation rate and local solidification time and the density difference between base alloy and strengthening particles.

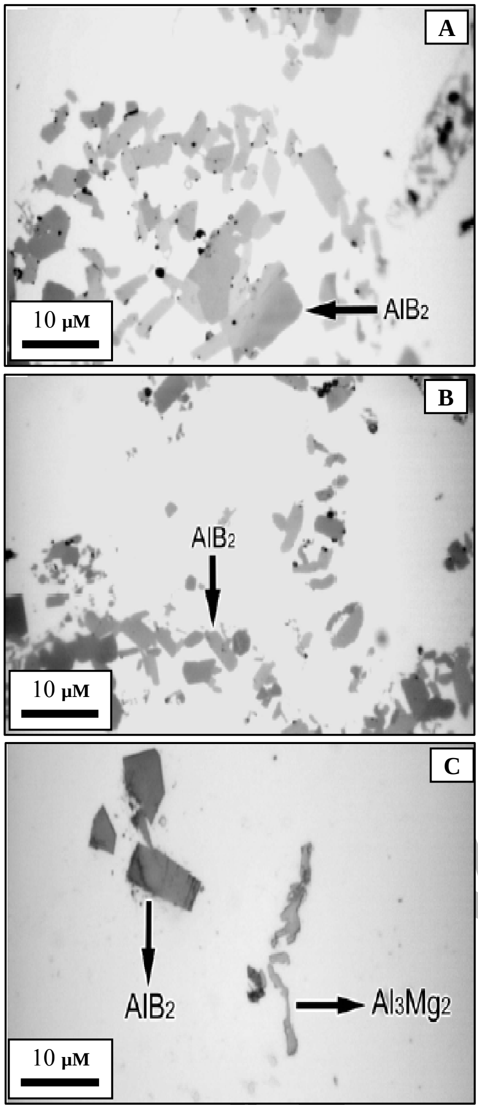

Fig. 1 Microscopic microstructure of the alloys A and B) Al-5% B, C) Al-2% Mg-2% B

On the other hand, Al-Mg-B composite shows larger values of AlB_2 particles, under the influence of separation in comparison with the Al-B composite. This can be attributed to lower density of molten Al-Mg alloy which provides more fluidity of molten than Al-Mg-B alloy. In other words, the amount of more boron in composite increased the volume fraction of AlB_2 particles and has increased viscosity of the semi-solid material. This higher viscosity prevents the motion of AlB_2 particles which in turn causes the falling of the gradient layer of these particles from the inner layer to the outer layer. Figure 3 shows the distribution of AlB_2 particles along the Al-2% Mg-2% B composite that has been casted through centrifuge by a speed of 300rpm.

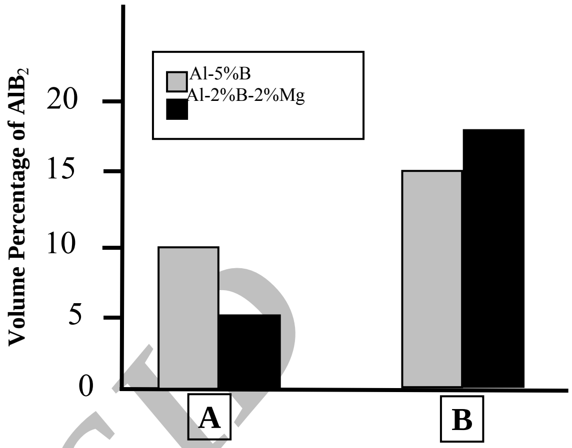

Fig. 2 Distribution of volume fraction of AlB_2 particles in the different samples, A) Outer area by the speed of 200 rpm, B) inner area by the speed of 200 rpm

AlB_2 particles separation is due to centrifugal force that acts from the center to semi-solid alloys mixture and scattered particles dispersed in it which leads to the production of gradient of the chemical composition. Here gradient is substantially scattered by the control of the density difference between the base and by the particles scattered in it. This can be described by the chemical composition gradient that has been caused by centrifugal force.

Separation is controlled by rotation speed, density and particles size, viscosity of semi-solid material, the average volume fraction of particles and local solidification time. Specifically, higher levels of boron and increasing number of AlB_2 particles increase the viscosity.

Porosity increase together with increasing AlB_2 particle can be due to apparent viscosity increase of semi-solid composite which reduces the ability of composite to exit the air stuck in the alloy. Figure 4 shows an AlB_2 particle in the Al-Mg-B composites. Analysis which has been done by electron microprobe analysis shows when there is magnesium in a composite, these Mg particles can penetrate into AlB_2 particles to replaced aluminum atoms and form the compounds containing between phases magnesium. In addition, it is believed that these compounds are harder than AlB_2. This hypothesis must be confirmed by hardness studies in a nano scale.

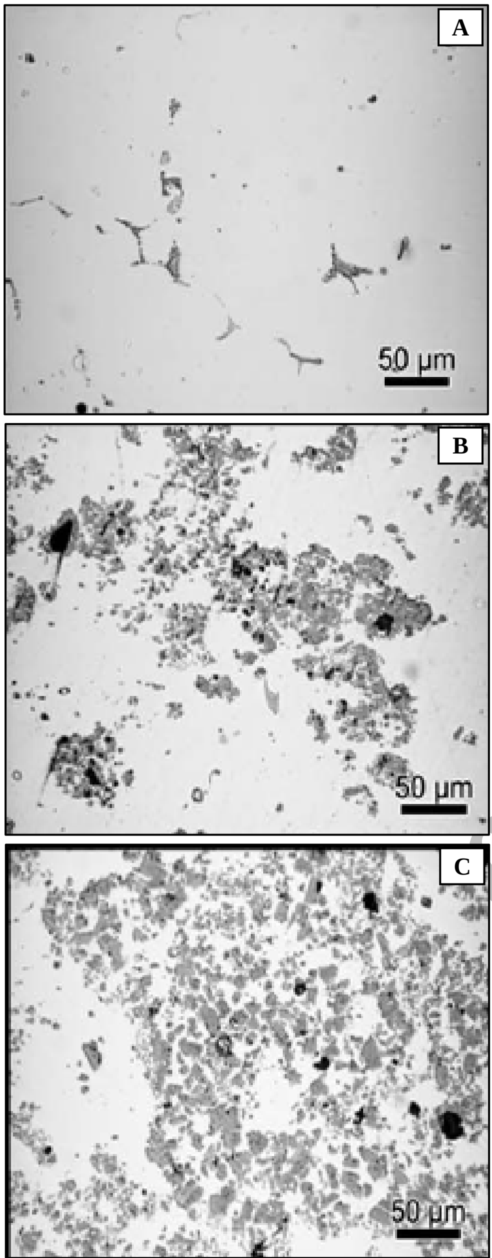

Fig. 3 Distribution of AlB_2 particles throughout the composite Al-2%Mg-2%B A) in the center of casting, B) in the distance of 10 mm, C) in the distance of 20 mm

The results obtained from the casted composites by a centrifugal manner do not show a significant change in AlB_2 particle size. The small particle sizes that are obtained in this study could be a reason for these results because the particle size has not been affected and this is because the collision rate for each particle with other particles is less for smaller particles than larger particles.

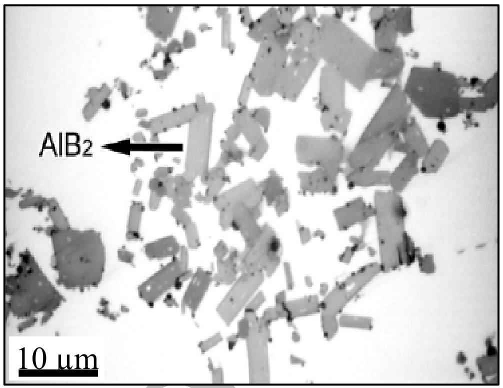

Fig. 4 Microscopic microstructure of Al-2%Mg-2%B composite

Figure 5 shows vicker's hardness differences on both sides of the aluminum base composites prepared using the method of centrifugal casting. The results show that hardness, as a function of distance, increases from the central region of the composites towards the external region of Al-2%B-2%Mg composite. The alloy Al-5%B does not show this behavior because AlB_2 gradient particles are not as significant as the composite gradients seen in Al-Mg-B.

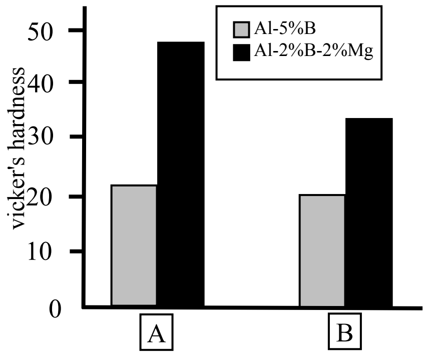

Fig. 5 The amount of the measured microhardness in different composites samples A) External part by the rotation speed of 200rpm B) internal part by the rotation speed of 200rpm

Addition of magnesium to the aluminum base has a considerable effect on the microstructure and mechanical properties compared with Al-B composites. This effect is because magnesium has high solubility in solid aluminum and the sedimentation rate is low in the above-mentioned saturated solid solution. In addition, these binary Al-Mg alloys produce a significant increase in tensile strength in comparison with the submission strength.

This justifies the significant amount of microhardness in the Al-Mg-B composite in comparison with Al-B composite.

4 CONCLUSION

1- Adding magnesium to Al-B composite, through increasing the hardness of the obtained composite substantially shows increased Vickers microhardness.

2- In the process of producing aluminum composite particles AlB_2 through centrifugal casting, due to the formation of a gradient of a chemical composition, show continuous microstructure and hardness changes in areas of internal and external pieces.

3- Volume fraction of AlB_2 particles in the composite studied, indicate a strong dependence on the presence of magnesium in the composite structure.

4- AlB_2 Particle separation towards the external areas of casting pieces through centrifuge, leads to greater hardness in these areas.

REFERENCES

[1] Gomes, J.R., Miranda, A.S., Soares D., Das, A. E., Rocha, L. A. and Crnkovic, S. J., "Tribological Characterization of Al-Si/SiCp Composites: MC's vs FGM's," Ceramic Transactions 114. 2000, pp. 579–586.

[2] Korkut, M. H., "Effect of Particulate Reinforcement on Wear Behaviour of Aluminum Matrix Composites," Materials Science and Technology 20, 2004, pp. 73-81.

[3] Paulino, G. H., and J. H. Kim, "A New Approach to Compute T-stress in Functionally Graded Materials by mea s of Interaction Integral Method," J. Engineering Fracture Mechanics 71, 2004, pp. 1907-1950.

[4] Duque, N. B., Melgarejo, Z. H. and Surez, O. M., "Functionally Graded Aluminum Matrix C omposites Produced by Centrifugal Casting," J. Materials Characterization 55, 2005, pp. 167-171.

[5] Nai, S., M. Gupta, and LIM, C., "Synthesis and Wear of Al Based, Free Standing Functionally Gradient Materials: Effects of Different Reinforcements," Material Science and Technology 20, 2004, pp. 57-67.

[6] Yucel Birol, "Production of Al-B Alloy by Heating Al/KBF4 Powder Blends," Journal of Alloys and Compounds, 481, 2009, pp. 195-198.

[7] Watanabe, Y. and Fukui, Y., "Microstructures and Mechanical Properties of Functionally Graded Material Fabricated by Centrifugal Casting Method," Metallurg. & Materials Sci 4, 2000, pp. 51-93.

[8] Barbara Previtali, Dante Pocci and Cataldo Taccardo, "Application of Traditional Investment Casting Process to Aluminum Matrix Composites," Composites: Part A, 39, 2008, pp. 1606-1617.

[9] Watanabe, Y., Yamanaka, N. and Fukui, Y., Composites Part A 29A (1998) 595.

[10] Gao, J. W. and Wang, C.Y., Mater. Sci. Eng. A292, 2000, pp. 207.

[11] Duque, N. B., Melgarejo, Z. H. and Surez, O. M., Mater. Characterization 55, 2005, pp. 167.

[12] Ogawa, T., Watanabe, Y., Sato, H., Kim, I.S. and Fukui, Y., Composites Part A, 2005, in press.

[13] Watanabe, Y., Fukui, Y., Devel, Rec., Res., Metall. Mater. Sci. 4, 2000, pp. 51.

[14] Watanabe, Y. and Fukui, Y., Aluminum Trans. 2, 2000, pp. 195.