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The reproducibility of the al matrix composite material reinforced with b4c via hot pressing technique

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ABSTRACT

In this study; by using Alumix 13 (<200 µm) powders which are 8% Boron carbide (B_4C) (<10 µm) and 92% Aluminum (Al) alloy, the reproducibility of composite material (CM) was investigated with the hot pressing method (powder metallurgy production technology). B_4C and Al powders were mixed in the turbula device 20 min for uniform mixture. The mixture powders were cold pressed in a mould for pre-shaping by exerting 110 bar pressure. After the pressing, the mould were heated up to 595 ^{0}C and kept under 45 bar for 15 min and then left to be cooled in the atmospheric conditions. After the material production process, it has been determined that the Al matrixed B_4C reinforced metal matrixed composite material could be produced with hot pressing (HP) method.

1. Introduction

MMC materials were developed to meet lightness, high strentgh, hardness and wear resistance properties [1-3]. Aluminium is the most used material as the matrix material in the MMC materials due to its low density, easy reproducibility and better engineering property. For this reason, it is used in structure components, especially in the otomotive and aviation industry. In the Al matrixed composite materials oxides, carbides, nitrides are used as particle and fibers and whisker reinforced elements are used as form. In the Al matrixed composite materials, the most widely used reinforced elements are SiC and Al_2O_3 materials [1, 4-9]. Because of the high cost of B_4C powder its usage as the reinforcement element in the Al matrixed composite materials was limited [10, 11]. B_4C is a ceramic material with excellent hardness, extra ordinary elastic modulus, low density, high wear resistance, high melting point, high thermal conductivity and good chemical stability. In addition, it has a good future for the engineering materials [12-17]. B_4C is the third hardest material in nature after diamond and cubical bor nitride [12, 17]. Al- B_4C composite materials can be produced by casting method. However, due to the wettability problem between Al and B_4C it is difficult to produce by the liquid phase method [1, 18]. Powder metallurgy (PM) is an older processing technology than casting and melting processes. The raw material of PM particles is powder [19]. PM production technique covers the gathering of powder size particles by various technique. This production technique provides a production which does not need a secondary manufacturing technique (machining) with very close size to the last form or at the last form. PM production technique can be used in the production of composite materials by gathering the conventional material powders. Especially it is the only production technique which is used in the production of cementite carbide cutters [20]. HP is the application of temperature and pressure simultaneously to make the pressed powders stronger completely or partially [21, 22]. HP technique is a suitable method to produce the materials of higher performance and of lower sintering behavior [23]. Furthermore, it is also used in the production of materials which can not be produced by the liquid phase method. A lot of oxide and carbide ceramics (Al_2O_3, SiC, B_4C etc.) is known to be produced in the graphite moulds or in the moulds hot worked tool steels which can resist high temperatures by HP [23-25]. In the HP technique pressing process can be done by single or double movement punch [26]. In the system the bottom support plate can be constant. Force, generally, is applied by the top punch and an hydraulic system. Although the applied force is coaxial due to the friction on the mould surfaces it shows a distribution changing from the center to the sides. Depending on this, the created stress difference between the axial and radial directions forms a sliding area which causes powder surfaces spoil [27, 28]. In the HP technique pressure and sintering are done at the same time and a separate sintering is not necessary. Besides, uniform microstructured materials, high density, low cost, unoxidized ceramics are among the advantages of HP technique [29, 30]. The slowness of the production process of composite materials by HP method and the difficulty of the temperature control of the mould are the disadvantages of the method [20].

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2. Material and Method

2.1. Preparation of The Moulding System

The moulding system of the sample production was first designed on the computer aided drawing. The cross-sectional view of the single axis moving punch and moulding system which is prepared by CAD is shown in Figure1.

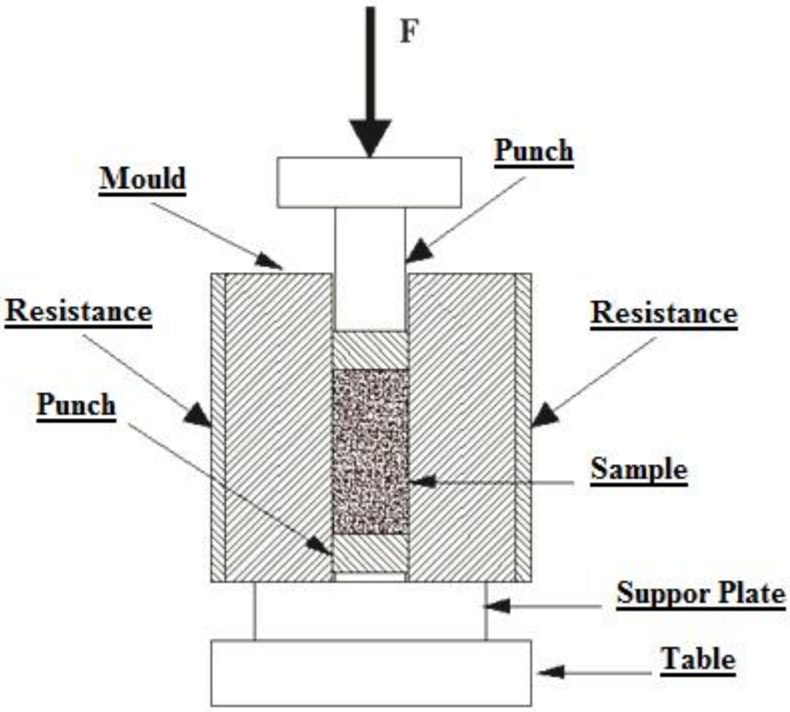


Figure 1. Cross-sectional view of single axis moving punch and moulding system.

For the better functioning of the moulding system, the mould material must be made of high temperature resistent material [31]. At the end of the detailed literature study, it was decided that the composite materials must be cold moulded and then hot pressed. For this, 1.2344 hot work tool steel must be used for the mould elements except pressure punch. Pressure punch C1050 was specified to reduce the mould cost. The chemical composition of the used 1.2344 mould steel is given in Table 1.

Table 1. 1.2344 Chemical composition of mould steel [32]

C	Si	Mn	P	S	Cr	Mo	V
0.39	1.18	0.44	0.019	0.0006	5.11	1.28	0.91

1.2344 hot work tool steel is a material of high toughness, thermal shock resistant, better wear resistance at high temperatures and high thermal conductivity. From the mould set elements borehole of mould body and inner punches will be grinded on the surface grinding machine. Because of this, borehole was manufactured with the sizes 0.5 mm smaller and inner punches 0.5 mm greater. Then, some of the mould elements were subjected to heat treatment in ASSAP KORKMAZ heat treatment company to bring their hardness to 54 HRC by 1.2344. After the hardening operation, mould hole and inner punches were grinded for proper sizing. Grinding operation is done at the very end because there is a possibility of a deviation in the sizing of the mould set elements due to the higher temperatures during heat treatment. The mould elements which were sent to heat treatment were pictured by the heat treatment company before hardening (Figure 2).

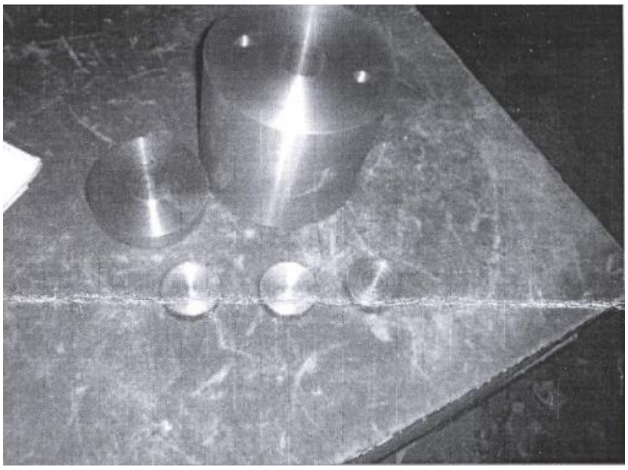
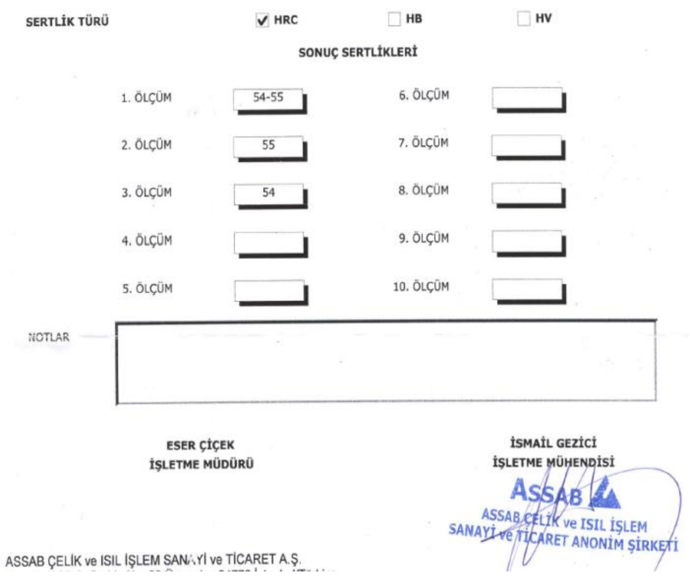


Figure 2. The mould elements which were sent to heat treatment.

The hardness values of the mould elements which were measured after hardening are shown in Figure 3.



SERTLİK TÜRÜ ✓ HRC ☐ HB ☐ HV

SONUÇ SERTLİKLERİ

1. ÖLÇÜM	54-55	6. ÖLÇÜM	
2. ÖLÇÜM	55	7. ÖLÇÜM	
3. ÖLÇÜM	54	8. ÖLÇÜM	
4. ÖLÇÜM		9. ÖLÇÜM	
5. ÖLÇÜM		10. ÖLÇÜM	

NOTLAR

ESER ÇİÇEK
İŞLETME MÜDÜRÜ

İSMAİL GEZİCİ
İŞLETME MÜHENDİSİ

ASSAB
ASSAB ÇELİK ve ISIL İŞLEM
SANAYİ ve TİCARET ANONİM ŞİRKETİ

ASSAB ÇELİK ve ISIL İŞLEM SANAYİ ve TİCARET A.Ş.

Figure 3. Hardness values of some of the mould elements after heat treatment.

Mould system elements which were grinded after heat treatment are shown in Figure 4.

Figure 4. The mould elements which were grinded after heat treatment.

In order to heat the mould system a high temperature resistant heater and when the heater reaches the desired temperature, a heat control panel (for controlling the resistance) was used. The used heat control panel is shown in Figure 5. The process temperature is 595 ^{0}C according to the % copper (Cu) ratio in the matrix element Alumix 13 (Al) powder and the resistance is in accordance with this characteristic. A thermocouple of K type was used to measure the mould temperature. The maximum temperature measurement interval of the used K type thermocouple is 1200 ^{0}C.

Figure 5. Heater resistance and heat control panel.

2.2. Mixture Powders

In the experimental study, 99% Al alloy Alumix13 (<200 µm) powder and 99% B_4C (<10 µm) powder which were supplied by ECKA GRANULES (german company) were used. The chemical composition of Alumix 13 alloy is given in Table 2. The powder mixtures in the metal matrix composite (MMC) which is to be produced were specified as 92% Al and 8% B_4C (by weight).

Table 2. Chemical composition of Alumix 13 alloy [33]

Cu	Mg	Si	Fe
4.5	0.52	0.14	0.10

2.3. Mixing Machine

For the uniform mixing of 92% Al and 8% B_4C powders which were prepared in the precision balance they were mixed in turbula (Figure 6) for about 20 minutes.

Figure 6. Turbula mixing machine

2.4. Press Machine

In order for the cold and hot pressing of the prepared powder mixtures in a mould, an hydraulic press machine of 55 ton pressing capacity has been used (Figure 7).

Figure 7. Hydraulic press machine

3. Production of Metal Matrixed Composite Materials

3.1 Preparation of Mould Set Main Body

In the experimental study, the mould was covered with a high temperature resistant refractory blanket to minimize the heat loss. The refractory blanket was covered with aluminium foil to prevent the opening of the blanket (Figure 8). In order to carry the mould system easily lifting eyebolt were mounted by threading the holes on the mould main body before the heat treatment.

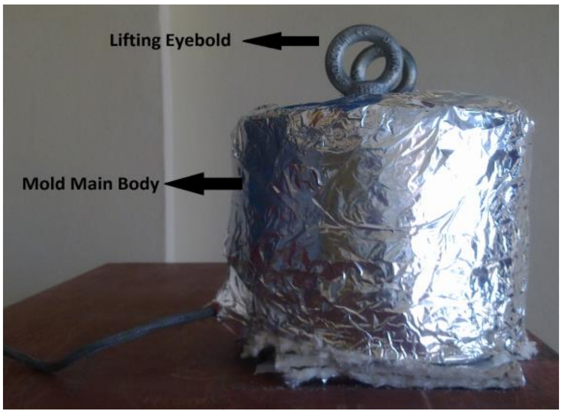


Figure 8. The mould main body covered with refractory blanket

3.2. The Production of Al Matrixed B_4C Reinforced Composite Material By The Hot Pressing Technique

Before moulding of the Al and B_4C powder mixture, the inner surface of the mould and the surfaces of inner punches were lubricated by high temperature resistant Molykote FB-180 grease oil. Lubrication was made to prevent the sticking of Al (which was melted when the mould system reached to higher temperatures) to mould surface after the cooling treatment.When the lubrication treatment is not made, taking of the Al (sticking to the mould surface) out of the mould becomes difficult and the mould surface and the produced MMC material surface are affected adversely. After lubrication of the mould inner surface, mixed powders were cold pressed for pre-shaping by applying 110 bar pressure (Figure 9) and then the applied pressure was removed. Then, when the mould temperature reached 595 ^{0}C, a pressure of 45 bar was applied to the sample for 15 minutes. This applied pressure was again removed and the mould was cooled under the atmospheric conditions. The MMC material was taken out of cooled mould system by means of the punches.

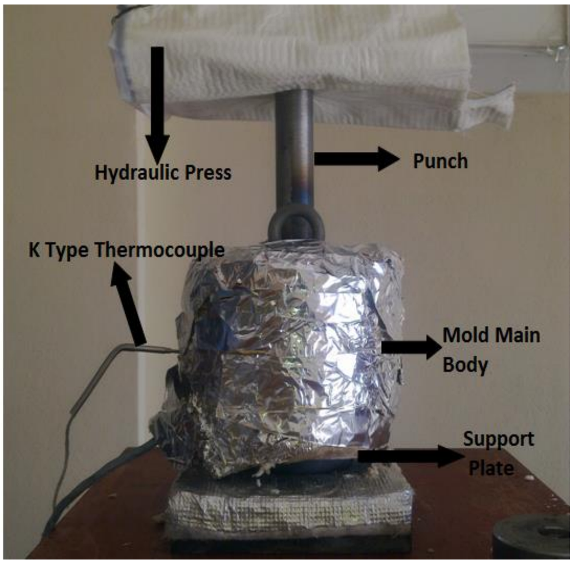


Figure 9. Production of Al matrixed B_4C reinforced composite material

A MMC material of 40 mm diameter and 100 mm length was produced by CP technique. The produced MMC sample is shown in Figure 10.

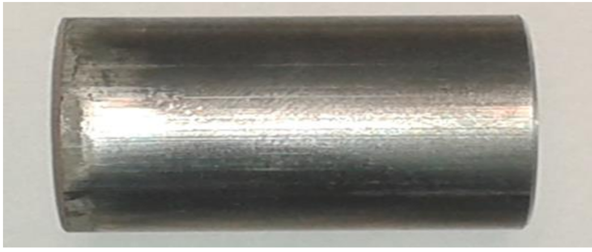


Figure 10. Al matrixed B_4C reinforced composite material

4. Conclusions

The following conclusions were obtained in the study on the reproducibility of Al/B_4C metal matrixed composite material by using hot pressing technique.

- Al matrixed B_4C reinforced composite material can be produced by using hot pressing technique,
- TM part production can be realized by pressing of the pre-mixed Al/B_4C powders under 45 bar pressure, at 595 °C temperature for 20 minutes,
- During taking the produced MMC material out of the mould, the lubricating of the mould surface creates a positive effect on the part surface,
- In the hot pressing process, the heating and the cooling time of the mould system is long, being the disadvantage of the method,
- In the hot pressing process, during the heating of the mould by the resistance (used to heat the mould system), precautions must be taken against electricity breakdowns, otherwise long term breakdowns affect the infrastructure of the material adversely and to prevent this it was decided that the place of the experimental study should be supported with a generator.

References

[1] Toptan F., Kilicarslan A., Karaaslan A., Cigdem M., Kerti I.,"Processing and Microstructural Characterisation of AA 1070 and AA 6063 Matrix B4Cp Reinforced Composites" Materials and Design 31 S87–S91, 2010.
[2] Tokaji K., "Effect of Stress Ratio on Fatigue Behaviour in SiC Particulate-Reinforced Aluminium Alloy Composite". Fatigue Fract Eng Mater Struct ; 28(6): 539–45, 2005.
[3] Lopez VH, Scoles A, Kennedy A.R., "The Thermal Stability of TiC Particles in an Al 7 wt.% Si Alloy". Mater Sci Eng;

A356:316–25, 2003.
[4] Lee K.B, Ahn JP, Kwon H., "Characteristics of AA 6061/BN Composite Fabricated By Pressureless in Fltration Technique". Metall Mater Trans A; 32A(4): 1007–18, 2001
[5] Kerti I, Toptan F., "Microstructural Variations in Cast B4C-Reinforced Aluminium Matrix Composites (AMCs)". Mater Lett; 62,1215–8, 2008.
[6] Ipek R., "Adhesive Wear Behaviour of B4C and SiC Reinforced 4147 Al Matrix Composites (Al/B4C–Al/SiC)". J Mater Proc Technol;162–163,71–5, 2005.
[7] Bedir F., "Characteristic Properties of Al–Cu–SiCp and Al–Cu–B4Cp Composites Produced By Hot Pressing Method Under Nitrogen Atmosphere". Mater Design; 28,1238–44, 2007.
[8] Kalkanli A, Yılmaz S., "Synthesis and Characterization of Aluminum Alloy 7075 Reinforced With Silicon Carbide Particulates". Mater Design; 29.775–80, 2008.
[9] Kerti I., "Production of TiC Reinforced-Aluminum Composites With The Addition Of Elemental Carbon". Mater Lett 2005; 59: 3795–800, 2005.
[10] Khan K. B, Kutty TRG, Surappa M.K., "Hot Hardness and Indentation Creep Study on Al–5% Mg Alloy matrix–B4C Particle Reinforced Composites". Mater Sci Eng A; 427,76–82, 2006.
[11] Zhang H, Ramesh KT, Chin ESC., "High Strain Rate Response Of Aluminium 6092/B4C Composites". Mater Sci Eng A; 384, 26–34, 2004.
[12] Sun J., Liu C., Wang R., "Low pressure hot pressing Of B4C Matrix Ceramic Composites Improved By Al2O3 and TiC Additives". Mater. Sci. Eng., A 519: 27-31, 2009.
[13] Yamada, S., Hirao, K., Yamauchi, Y., et al., "High Strength B4C–TiB2 Composites Fabricated By Reaction Hot-Pressing". Journal Of The European Ceramic Society 23 (7) 1123–1130, 2003.
[14] Lee, S.B., Kang, S., "Low-Temperature Processing of B4C–Al Composites Via Infiltration Technique". Materials Chemistry and Physics 67. 249–255, 2001.
[15] Yamada, S., Hirao K., Yamauchi, Y., Kanzaki S., "B4C–CrB2 Composites With Improved Mechanical Properties", Journal of The European Ceramic Society 23, 561–565, 2003.
[16] Tdriolle,S.,Thevenot,F., Aizenstein, M., Dariel M.P., Frumin, N., Frage, N., "Boroncarbide – Copper Infiltrated Cermets". Journal Of Solid State Chemistry 177. 400–406, 2004.
[17] Deng, J., Zhou, J., Feng, Y., Ding, Z., "Microstructure and Mechanical Properties Of Hot-Pressed B4C/(W,Ti)C Ceramic Composites". Ceramics International 28. 425–430, 2002.
[18] Kennedy A. R., Brampton B., "There Active Wetting and Incorporation of B4C particles Into Molten Aluminium". Scripta Mater; 44: 1077–82, 2001.
[19] Angelo C. P., Subramanian R., "Powder Metallurgy: Science, Technology and Aplications". ISBN-978-81-203-3281-2, 2008.
[20] Ekici E., "Alüminyum Esaslı Karma Takviyeli Kompozitlerin Farklı Takviye Elemanı Tipleriyle Üretilmesi, Mekanik Özellikleri ve Frezede İşlenebilirliğinin İncelenmesi". Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, 27-55. Ankara 2012.
[21] Hydrogen Program Plan, FY 1993-FY, U.S. Department Of Energy, 1998.
[22] Kingery, D.W., Bowen, K.H., Uhlmann, R.D., "Introduction to Ceramis". 2nd Ed., John Wiley&Sons, New York 1976.
[23] Upadhyaya G. S., "Powder Metallurgy Technology". Published By Cambridge International Science Publishing, 2002.
[24] Hydrogen Program Plan., FY 1993-FY 1997, U.S. Department Of Energy, 1998.
[25] Kingery D.W., Bowen K. H., "Uhlmann, Introduction to Ceramics". 2nd Ed., John Wiley&Sons, New York 1976..
[26] Köksal, F., "Al-Cu-SiC ve Al-Cu-B4C Kompozitlerin Sıcak Presleme Yöntemi ile Üretimi ve Aşınma Özelliklerinin Araştırılması". Yüksek Lisans Tezi, Makine Mühendisliği Anabilim Dalı, Isparta, 118s, 2004.
[27] Öğünç, H., "Sıcak Presleme ile Sinterlenmiş α-SiC Matriksli B4C Kompozitlerinin Özelliklerinin İncelenmesi". Yüksek Lisans Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul 2006.
[28] Cura, M.E., "Sıcak Preslenmiş WC-Co/B4C Kompozitlerinin Mekanik, Manyetik ve Mikro Yapısal İncelenmesi". Yüksek Lisans Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul 2002.
[29] Somunkıran, İ., Balın, A., "Sıcak Presleme Tekniğiyle Üretilen Co Esaslı Co-Cr-Mo Toz Alaşımında Presleme Sıcaklığının Mikroyapı Üzerine Etkisi". 6th International Advanced Technologies Symposium (IATS'11), Elazığ 2011.
[30] Kaya, G., "Mechanical Properties of PM Al-SiC Compozites Produced By Conventional Hot Pressing Method". Ortadoğu Teknik Üniversitesi, Y.Lisans Tezi, Ankara, 81s, 1999.
[31] Ay İ.,Okoldan G., "Sıcak İş Takım Çeliklerine Uygulanan Isıl İşlemler ve Bir Uygulama". UlusalEO8, 1997.
[32] Assab, 2013. http://www.assab.com.tr/turkish/1152_TRK_HTML.htm
[33] Ecka,2011. http://www.ecka- granules.com/en/products/aluminum-and-aluminum-alloys/