Diyala Journal of Engineering Sciences Vol. 12, No. 03, September 2019, pages 29-36 ISSN 1999-8716
DOI: 10.26367/DJES/VOL.12/NO.3/5 eISSN 2616-6909

Study of the Effect of Al_2o_3&B_4c Particles Reinforcement on Some Physical and Mechanical Properties for Aluminum Alloy 6063 by Powder Metallurgy Technique

Salah Fadhil Abduljabbar
Mechanical Technology Department, Al-Dour Technical Institute, Northern Technical University
Email: salahphd@yahoo.com

Abstract

Powder metallurgy technique utilized in samples preparing. Samples were compacted by using cold uniaxial pressing then followed by sintering process at 600 ºC under inert gas. Results showed improving in (Brinell Hardness, wear resistance & compression strength) and increasing in (density, porosity & water absorption). Brinell Hardness increasing (106. – 114.7), compression strength increasing (35.1 – 40.8) N/mm^2 and decrease wear rate (6.6*exp(-8) – 4.22*exp(-8)) g/cm at time 30 min. with (0 – 20)% Al_2O_3&B_4C. While increase apparent density (2.76 – 2.83) g/cm^3, Bulk Density increase (2.71-2.82) g/cm^3 apparent porosity decrease (1.88 – 0.193) % and water absorption decrease (0.699 – 0.068) % at (0 – 20) % Al_2O_3&B_4C.

Keywords: Composite materials, Powder metallurgy, Aluminum, Physical properties, Mechanical properties.

Paper history: (Received: 3/12/2017; Accepted:14/5/2018)

1- Introduction

Because of the urgent need for modern engineering materials and sophisticated and typical mechanical and chemical properties. Accordingly, engineering materials have developed or developed some engineering materials in line with technological development. (1). The composite materials possess effective qualities and properties for use in most important modern applications such as space and transport Especially in internal combustion engines as well as marine applications and industries on a single material possessing various recipe properties suitable for use in complex applications (2)

.Powder metallurgy technology is the preparation of metal powders. These powders are extracted to obtain products in the required forms. These products are heated by sintering process to improve the bond between the particles and obtain a product with a cohesive mass (Rigid Mass). Compression machines and molds are used to obtain pressurized products at certain pressure levels, while sintering takes place at temperatures below the melting temperature of the base metal (3).

As a result of massive industrial progress, the researchers have manufactured materials with distinct quality properties such as shock resistance, corrosion resistance and low cost. These materials are called "composite materials", a mixture of two or more substances, and the other is called Reinforcement Material or Distributed Phase. The phase surrounding the base material is called the Interstitial Phase. The base materials shall be metal, ceramic or polymeric, and the reinforcement materials shall be particles, fibers, sheets or bristles. Knowing the characteristics and specifications of the base materials and the supporting materials helps us determine the type of material that can be produced and where the material is used. For example, in the aerospace industries, overlapping materials were manufactured in high temperature and low density. In the medical industries, composite materials were developed with high resistance to corrosion and cracking (4).

The aluminum-based composite materials have demonstrated advanced properties in the field of engineering materials than traditional aluminum alloys. The dependence on these composites has grown considerably in the industry as modern modulation methods have evolved and low-cost reinforcement materials have been adopted. Aluminum composite supported by ceramic materials are among the most popular and used composites, because these materials give wear resistance, hardness and high rigidity if compared with the base material. One of the most prominent applications of this type of composite are the applications of spacecraft, aeronautics, engineering and medical applications (5).

The aim of this work is studying some physical properties (density, porosity & water absorption) and some mechanical properties (Brinell Hardness, compression strength & wear resistance) of aluminum

DOI: 10.26367/DJES/VOL.12/NO.3/5 eISSN 2616-6909

6063 matrix composite material that reinforced by (5,10,15&20) wt.% of Al_2O_3&B_4C particles.

2-Theoretical Part

Equation (1) was used to determine Brinell hardness, whereas The rate of wear rate is calculated using equations (2), (3) ,(4) &(5) [8]

$$HB = \frac{2P}{\pi D[D - \sqrt{D^2 - d^2}]} \quad (1)$$

P: Force (Kg. f).

D: Ball Diameter (mm).

d: Average penetration diameter (mm).

$$\sigma_D = \frac{2F}{\pi dh} \quad (2)$$

σ_D : compressive strength (MPa)

F : Force (N).

d : Sample diameter (mm)

h : Sample Thickness (mm)

$$S_D = 2\pi rnt \quad (3)$$

$$\Delta w = w_1 - w_2 \quad (4)$$

$$\text{Wear Rate} = \frac{\Delta w}{S_D}\left(\frac{gm}{cm}\right) \quad (5)$$

Δw: Weight difference before and after test (g).

w_1: Sample weight before test (g).

w_2 : Sample weight after test (g).

S_D: Slip distance (cm).

r : Radius from sample center to disc center(cm).

n: No. of disc revolution (r.p.m)

t : Test time (min.).

The density, porosity and water absorption percentage was calculated using the Archimedes base by equations (6) & (7), respectively [8]

$$B.D. = \frac{W_d}{W_s - W_i} * \rho_w \quad (6)$$

$$A.D = \left(\frac{W_d}{W_d - W_i}\right) * \rho_w \quad (7)$$

Equations (8) and (9) used to determine both apparent and water absorption percentage.

$$A.P = \frac{W_s - W_d}{W_s - W_i} * 100\% \quad (8)$$

$$W.A. = \left(\frac{W_s - W_d}{W_d}\right) * 100\% \quad (9)$$

A.D: Apparent density (g/cm^3).
A.P: Apparent porosity (%).
W.A.: Water absorption (%).
ρ_w: Water density (g/cm^3).
W_d : dry weight sample (g).
W_i: suspended weight sample (g).
W_s : saturated weight sample (g).

3- Experimental Work

The aluminum powder was used in 6063 indian particle size <63 µm and with 99.7% purity and Al_2O_3, alpha-indian type, Particle size <100 µm, purity 99.5%, and B_4C Particle Size (100-125) µm 99.5% purity. Table (1) Aluminum alloy components 6063. Various weight ratios (5,10,15 & 20) wt.% of Al_2O_3&B_4C were both equally added to 6063 aluminum alloy to form the composites as shown in Table (2). The particle size was measured by using special sieves for this purpose in the laboratory, and the purity was determined by the standards of the Central Drug House of India. The powders were mixed with a mechanical mixer for 30 minutes and then the samples were pressed using cold pressing method and in one direction in a mold made of tool steel, which was put pressure of 5 tons [6]. This was followed by sintering of the samples at a temperature of 600 ° C for 120 minutes in an inert atmosphere.

The Brinell hardness test was performed using a Chinese LARYEE (Digital Micro Hardness Tester) device fig.(1).

Fig. (1) Micro Hardness Tester

The test was conducted using the Chinese Microcomputer Controlled Electronic Universal Testing Machine fig.(2)

Fig. (2) Universal Machine Tester

The wear device fig.(3) used a pin-on-disc with a rotational speed of 500 rpm. The samples (10 * 6) mm in 30 minutes. The density, porosity and water absorption test was carried out using the Archimedes base using equations (6) & (7), respectively and holding samples for 24h in water. The samples were prepared for microscopy at the University of Technology / Production Engineering and Metallurgy Department using a particle size paper (600,800,1000,1200) and then refined with diamond paste polishing.

DOI: 10.26367/DJES/VOL.12/NO.3/5 eISSN 2616-6909

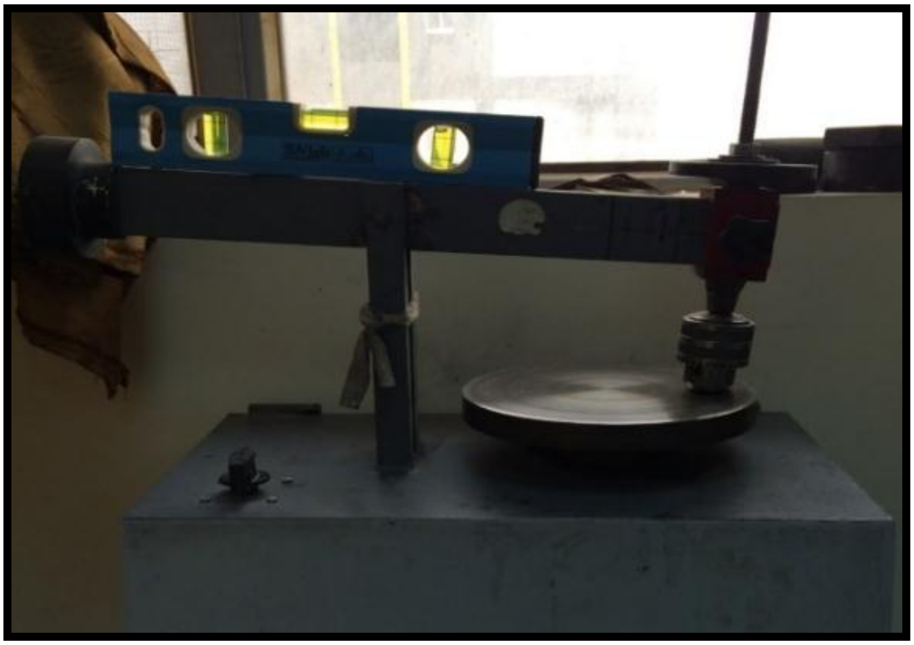

Figure (3) Wear tester

3. Results And Discussion

Figure (4) shows the relationship between the apparent density and the content of Al_2O_3&B_4C, as the apparent density increases (2.76-2.83 g / cm^3) at Al_2O_3 & B_4C (0-20%). The reason for increasing the apparent density is the high density of alumina (3.95 g / cm^3) while the density of B_4C is low (2.52) g / cm^3 compared with the density of aluminum (2.7) g / cm^3.

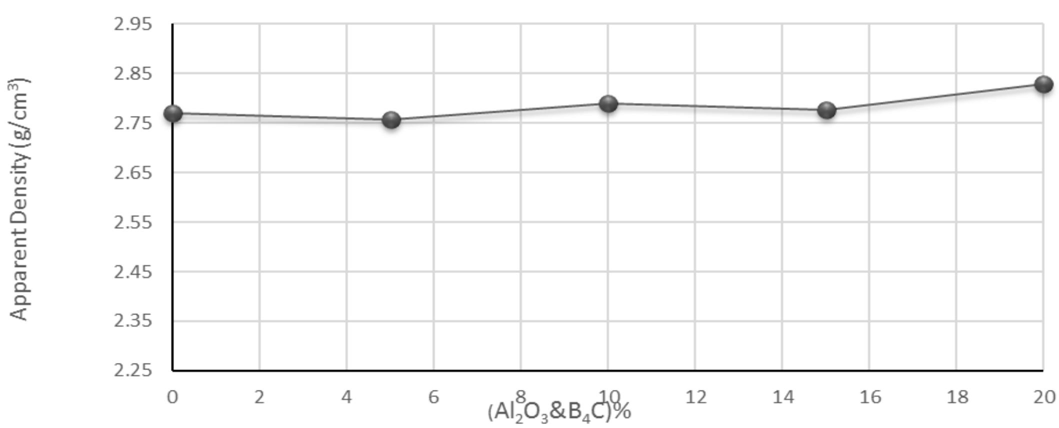

Fig.(4): Relationship between Apparent Density with Reinforcement ContentD.

Table (1): Chemical Composition for Al 6063

Matrix%	Al6063	80	85	90	95	100
Reinfo-rcement	Al2O3&B4C	20	15	10	5	0

Table (2): Weight Ratios for Al6063 Composites

Type	Al	Ti	Zn	Cr	Mg	Mn	Cu	Fe	Si
%	Rest.	0.1	0.1	0.1	0.74	0.1	0.1	0.35	0.42

Diyala Journal of Engineering Sciences Vol. 12, No. 03, September 2019, pages 29-36 ISSN 1999-8716
DOI: 10.26367/DJES/VOL.12/NO.3/5 eISSN 2616-6909

Figure (5) shows the relationship between the Bulk density and the content of Al_2O_3&B_4C. Bulk density (2.71-2.82 g / cm^3) is increased at Al_2O_3 & B_4C (0-20%).

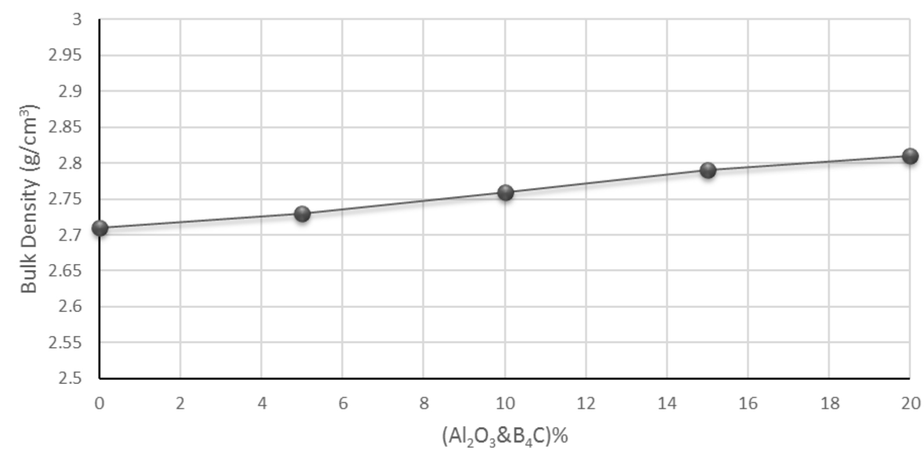

Fig. (5): Relationship between Bulk Density with Reinforcement Content

Figure (6) shows the relationship between the apparent porosity and Al_2O_3&B_4C Content, With the apparent porosity decreased (1.88-0.193)%. The reason for decreasing apparent porosity due to the increase in the amount of added particles which in turn led to increasing the density since the density behaves the opposite behavior of porosity, It is normal to decrease porosity with increasing the density, as well as giving sufficient time (2h) for the bubbles to break out of the mix before solidification.

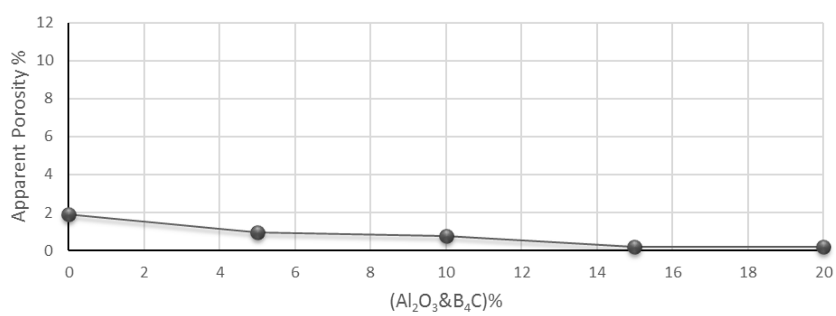

Fig. (6): Relationship between Apparent Porosity with Reinforcement Content

Figure (7) shows the relationship between water absorption capacity with Al_2O_3&B_4C Content, with less water absorption (0.699-0.0689) %. The decrease in water solubility is due to the decrease in porosity values [7].

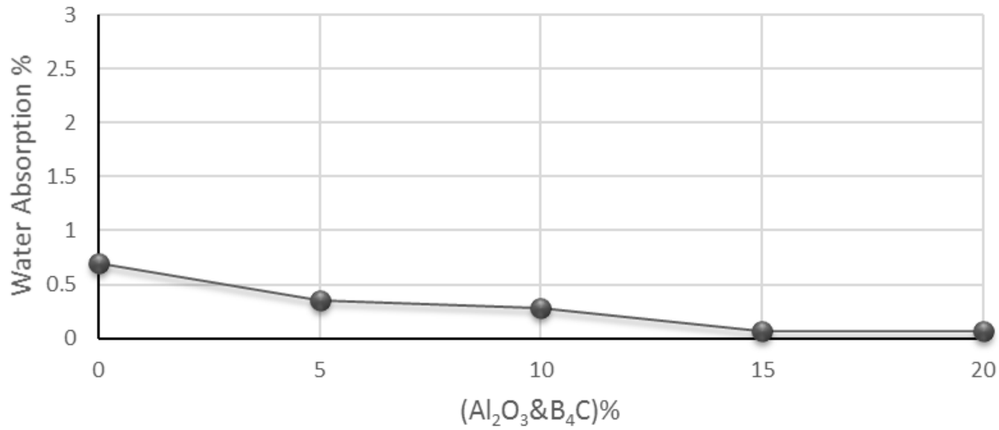

Fig. (7): Relationship between Water Absorption with Reinforcement Content

Figure (8) shows the relationship between Brinell hardness with $Al_2O_3\&B_4C$ Content, as Brinell hardness (106.5-114.7) is increased at Al_2O_3 & B_4C content (0-20).

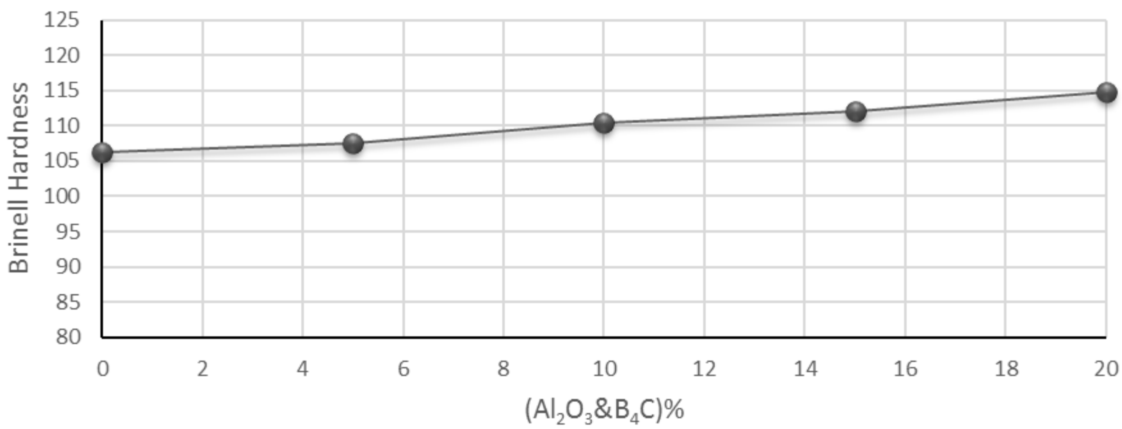

Fig. (8): Relationship between Brinell Hardness with Reinforcement Content

The hardness is increased due to the high hardness of the added particles as well as the large amount of interface surfaces formed by the addition of the reinforcing particles, In addition to increasing the resistance of the plastic deformation and increasing the internal stresses due to the difference in the coefficient of the thermal expansion between the base material and the reinforcing material, which results in many complications which lead to increasing the hardness of the layers because reinforcing particles act resist to deformation of the base material. Figure (9) shows the relationship between compressive strength with $Al_2O_3\&B_4C$ Content. compressive strength increases (35.1-40.8) N / mm^2 when (0-20%) Al_2O_3 & B_4C Content is due to increased resistance And the increase in the resistance of plastic deformation and the multitude of interstitial surfaces formed by the addition of Al_2O_3 Particles, in addition to the high temperature of sintering 600 ^oC for 120 minutes, which lead to increase the strength of the bond between the components of Composites and Good distribution Particles for $Al_2O_3\&B_4C$ in ground aluminum 6063 as shown in the microscopic structure (Figure 9) [7][9][10].

Diyala Journal of Engineering Sciences Vol. 12, No. 03, September 2019, pages 29-36 **ISSN 1999-8716**
DOI: 10.26367/DJES/VOL.12/NO.3/5 **eISSN 2616-6909**

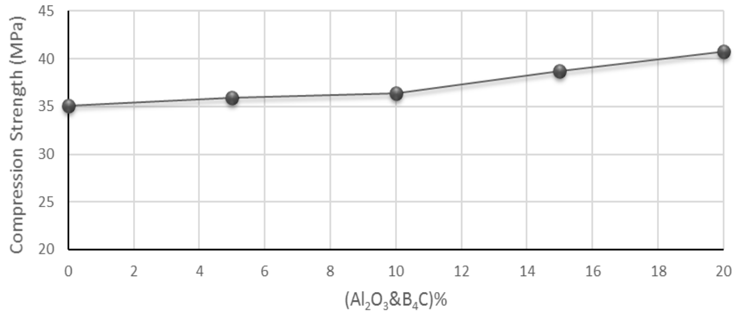

Fig. (9): Relationship between Compression Strength with Reinforcement Content

Figure (10) shows the relationship between the rate of wear rate with $Al_2O_3\&B_4C$ Content, with the mean wear rate (6.6 * exp (-8) - (4.22 * exp (-8)) g / cm at time (30) min. at (0-20) % of $Al_2O_3\&B_4C$. The reason for the decrease in wear rate is that the 6063 aluminum composites are more hardened when reinforced with $Al_2O_3\&B_4C$, which in turn prevent the propagation dislocations and the difference in the thermal expansion coefficient increases the hardness by increasing $Al_2O_3\&B_4C$ Content.

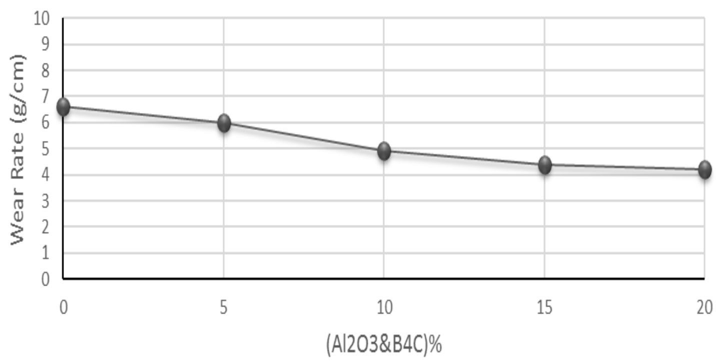

Fig. (10): Relationship between Wear Rate with Reinforcement Content

Figure (11) shows the abandoned images of the 6063Al_Al_2O_3-B_4C aluminum composites and shows the relatively homogeneous distribution of $Al_2O_3\&B_4C$ in the 6063 aluminum. The particle size of B_4C is bigger and recognized from Al_2O_3 particles as mentioned in experimental work.

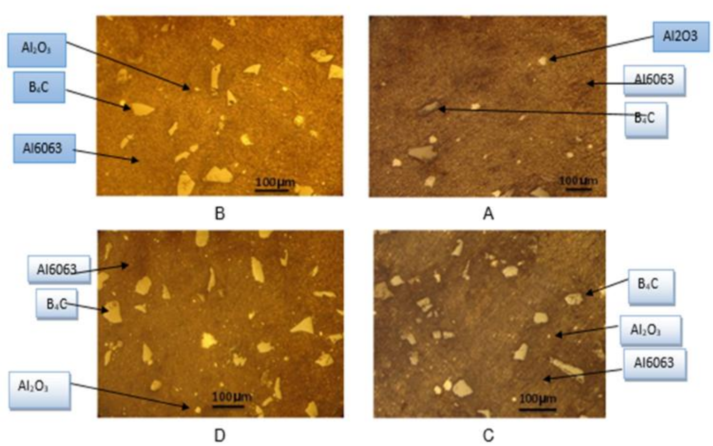

Fig. (11): Microstructure for Samples

A- Al6063+2.5%Al_2O_3+2.5%B_4C, B- Al6063+5%Al_2O_3+5%B_4C, C- Al6063+7.5%Al_2O_3+7.5B_4C, D- Al6063+10%Al_2O_3+10%B_4C

4. Conclusions

1. Increase in the values of the apparent density and the Bulk density and decrease in the values of Apparent porosity and water absorption with increased content of Al_2O_3&B_4C.
2. An increase in the values of Brinell hardness and compressive strength with increased Al_2O_3&B_4C content.
3. Reduction in the rate of wear rate with increased content of Al_2O_3&B_4C.

5. References

[1] محمد عبد اللطيف أحمد " تحضير مواد متراكبة من خردة الألمنيوم ذو النقاوة التجارية وتدعيمها بدقائق أكاسيد الحديد Fe3O4 & Fe2O3 " مجلة ديالى للعلوم الهندسية، المجلد 10 ، العدد4 71-59 (2017)

[2] Mikell P. Groover " Fundamentals of Modern Manufacturing Materials , Processes , and Systems " 4th Edition , Copyright © John Wiley & Sons, 2010.Mikell P. Groover " Fundamentals of Modern Manufacturing Materials , Processes , and Systems " 4th Edition , Copyright © John Wiley & Sons, 2010.

[3] رولا عبد الخضر عباس " دراسة التأثير الحراري على الخواص الميكانيكية لمتراكب هجيني " ، مجلة جامعة النهرين ، المجلد 10 ، (1) حزيران ،2007).23-11)

[4] د. محمد سعيد وحيد ، سدير موفق مجيد، "دراسة معدلات التأكل لمكبوسات الالمنيوم المدعمة بمادة كاربيد السيليكون"، مجلة (الهندسة والتكنلوجيا، المجلد 28، العدد 18، 2010) 834-846.

[5] Mohd Abdul Qadirkhan, M. Arif Siddiqui, "Fabrication and Testing of Al-Cu-B_4C Composite by Mechanical Alloying" International Journal of Innovative Research in Science, Engineering and Technology IJIRSET, DOL, Vol. 4, Issue 9, (2015) 8362-8368.

[6] Ali H. Haleem, N. Zuheir and Newal M. Dawood, " Preparing and Studying Some Mechanical Properties of Aluminum Matrix Composite Materials Reinforced by Al2O3 particles", journal of Babylon University/Engineering sciences, No. 1, Vol. 20, 2012. 30-38.

[7] كمال مصطفى حسين،"دراسة تأثيرتغير نسبة الإضافة ونسبة الارتفاع الى القطرH/Dعلى بعض الخصائص الميتالورجية والميكانيكية للمتراكب (Cu-Si)والمنتج بتقانة ميتالورجيا المساحيق"، رسالة ماجستير، جامعة تكريت 2015.

[8] Raja T. and Sahu O.P.," Effects on Microstructure and Hardness of Al-B4C Metal Matrix Composite Fabricated through Powder Metallurgy" International Journal of Mechanical Engineering /© Global Science Research Journals Vol. 1 (1),. (2014). 1-5.

[9] Amir A, Gholam-Hossein M. , "characterization of Al7075-b4c composite fabricated by powder compaction techniques under different densification rates", 10th International conference on Composite Science and Technology ICCST/10 A.L. Araújo, J.R. Correia, C.M. Mota Soares, et al. (Editors)© IDMEC 2015. 1-11.

دراسة تأثير دقائق الالومينا وكاربيد البورون على بعض الخواص الفيزيائية والميكانيكية لسبيكة الالمنيوم 6063 باتباع تقانة ميتالورجيا المساحيق

د. صلاح فاضل عبد الجبار

مدرس، قسم التقنيات الميكانيكية، المعهد التقني/ الدور، الجامعة التقنية الشمالية

الخلاصة

هدف البحث الحالي الى دراسة بعض الخواص الفيزيائية (الكثافة، المسامية، قابلية امتصاص الماء) وبعض الخواص الميكانيكية (صلادة برينل، مقاومة الانضغاط، مقاومة البلى) لمتراكب الالمنيوم 6063 المقوى بنسب وزنية من دقائق الالومينا وكاربيد البورون (5,10,15&20) wt.% باتباع تقانة ميتالورجيا المساحيق. تم خلط العينات ثم كبست كبس باودر وباتجاه واحد وبعد ذلك تم تلبيد العينات بدرجة حرارة 600 ºC تحت ضغ غاز خامل.

النتائج أظهرت تحسن في قيم (صلادة برينل، مقاومة البلى ومقاومة الانضغاط القطرية). حيث ازدادت صلادة برينل (114.7 – .106) وازدادت مقاومة الانضغاط القطرية N/mm^2 (40.8 – 35.1) بينما انخفض معدل البلى g/cm ((6.6*exp(-8) – 4.22*exp(-8)) عند زمن 30 دقيقة عند محتوى (0 – 20)% Al2O3&B4Cبينما تزداد الكثافة الظاهرية g/cm^3 (2.76 – 2.83) وتزداد الكثافة الحجمية g/cm^3 (2.71-2.82) اما المسامية الظاهرية فتنخفض % (0.193 – 1.88) وتنخفض قابلية امتصاص الماء (0.699 – 0.068) % عند محتوى (0 – 20) % Al2O3&B4C.

الكلمات الدلالية: - المواد المتراكبة، ميتالورجيا المساحيق، الالمنيوم، الخواص الفيزيائية، الخواص الميكانيكية.