

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

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Abstract

Powder metallurgy technique utilized in samples preparing. Samples were compacted by using cold uniaxial pressing then followed by sintering process at 600 °C 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/mm² and decrease wear rate ($6.6 \times \exp(-8)$ – $4.22 \times \exp(-8)$) g/cm at time 30 min. with (0 – 20)% Al_2O_3 & B_4C . While increase apparent density (2.76 – 2.83) g/cm³, Bulk Density increase (2.71-2.82) g/cm³ 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.

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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

6063 matrix composite material that reinforced by (5,10,15&20) wt.% of Al₂O₃&B₄C 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)

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

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

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

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/cm³).

A.P: Apparent porosity (%).

W.A.: Water absorption (%).

ρ_w : Water density (g/cm³).

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 Al₂O₃, alpha-indian type, Particle size <100 μm , purity 99.5%, and B₄C Particle Size (100-125) μm 99.5% purity. Table (1) Aluminum alloy components 6063. Various weight ratios (5,10,15 & 20) wt.% of Al₂O₃&B₄C 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.



Figure (3) Wear tester

3. Results And Discussion

Figure (4) shows the relationship between the apparent density and the content of Al₂O₃&B₄C, as the apparent density increases (2.76-2.83 g / cm³) at Al₂O₃

& B₄C (0-20%). The reason for increasing the apparent density is the high density of alumina (3.95 g / cm³) while the density of B₄C is low (2.52) g / cm³ compared with the density of aluminum (2.7) g / cm³.

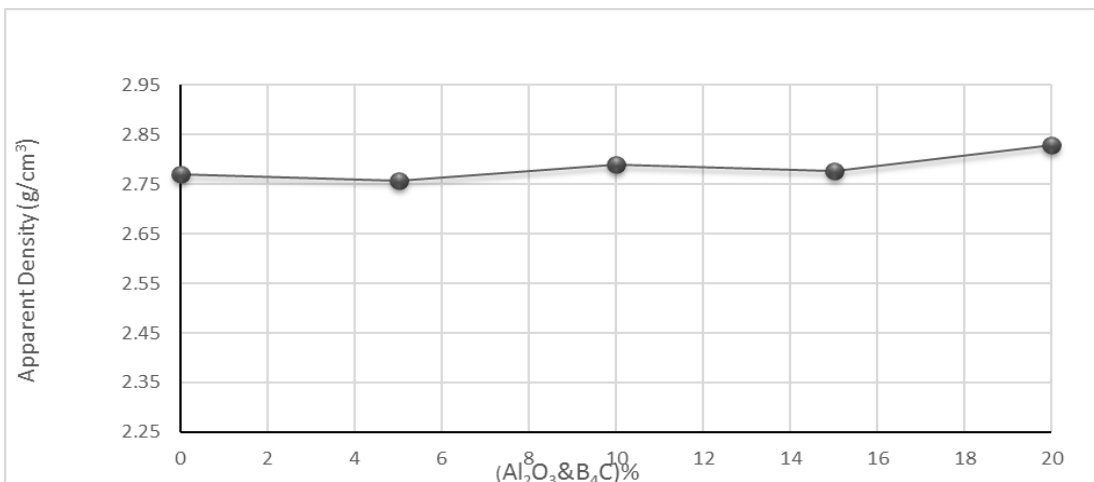


Fig.(4): Relationship between Apparent Density with Reinforcement ContentD.

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

Figure (5) shows the relationship between the Bulk density and the content of Al_2O_3 & B_4C . Bulk density

($2.71-2.82 \text{ g / cm}^3$) is increased at Al_2O_3 & B_4C (0-20%).

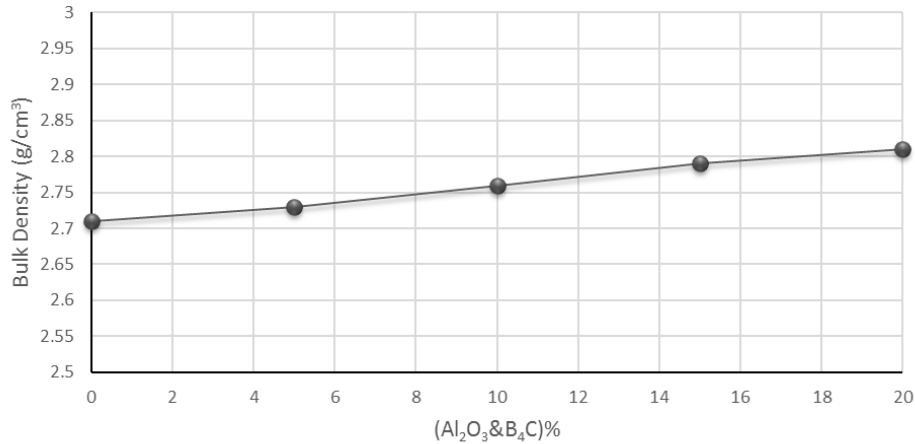


Fig. (5): Relationship between Bulk Density with Reinforcement Content

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.

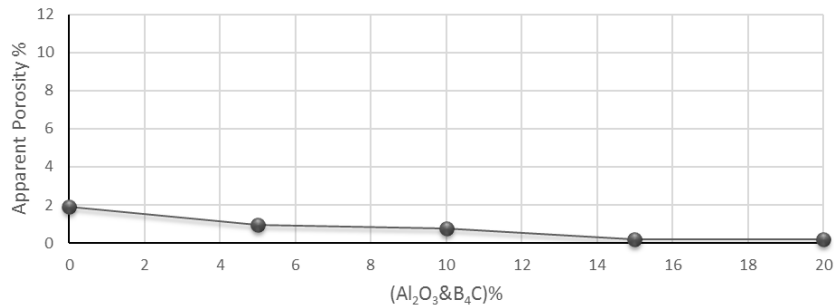


Fig. (6): Relationship between Apparent Porosity with Reinforcement Content

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⁾.

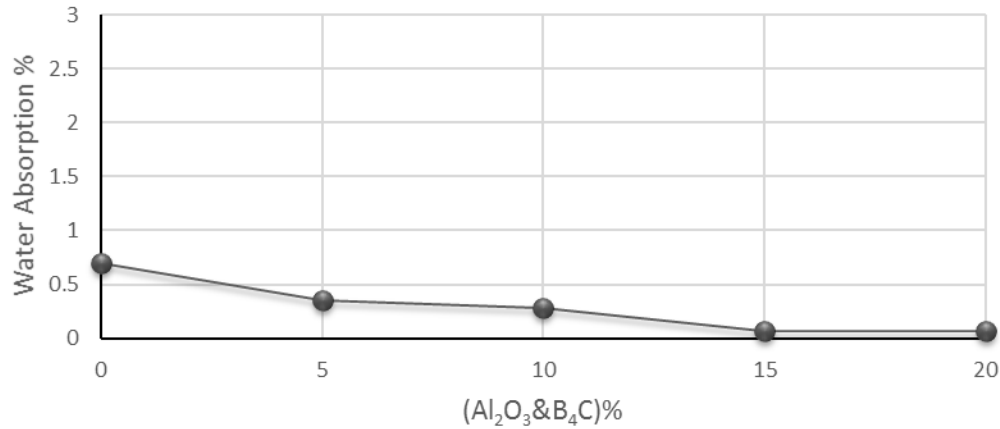


Fig. (7): Relationship between Water Absorption with Reinforcement Content

Figure (8) shows the relationship between Brinell hardness with Al₂O₃ & B₄C Content, as Brinell hardness

(106.5-114.7) is increased at Al₂O₃ & B₄C content (0-20).

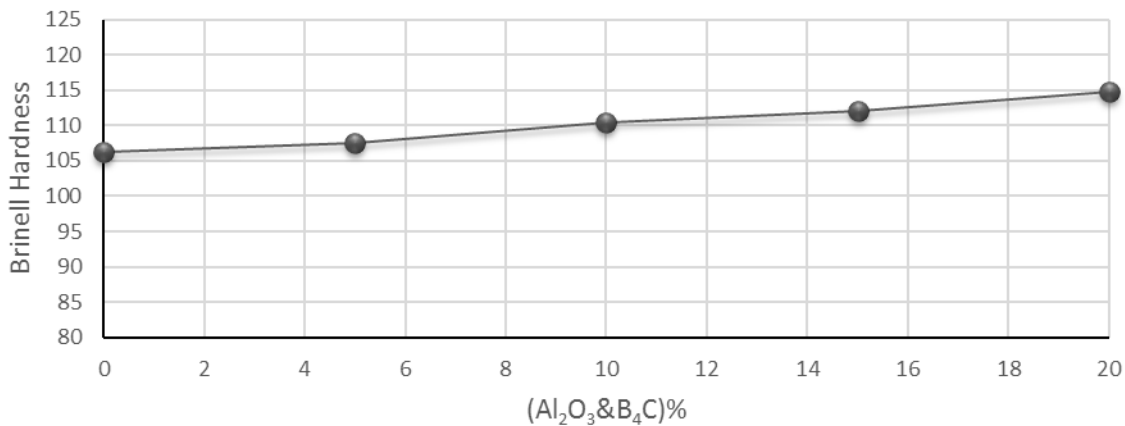


Fig. (8): Relationship between Brinell Hardness with Reinforcement Content

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

Al₂O₃ & B₄C Content. compressive strength increases (35.1-40.8) N / mm² when (0-20%) Al₂O₃ & B₄C 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 Al₂O₃ Particles, in addition to the high temperature of sintering 600 °C for 120 minutes, which lead to increase the strength of the bond between the components of Composites and Good distribution Particles for Al₂O₃ & B₄C in ground aluminum 6063 as shown in the microscopic structure (Figure 9) ⁽⁷⁾⁽⁹⁾⁽¹⁰⁾.

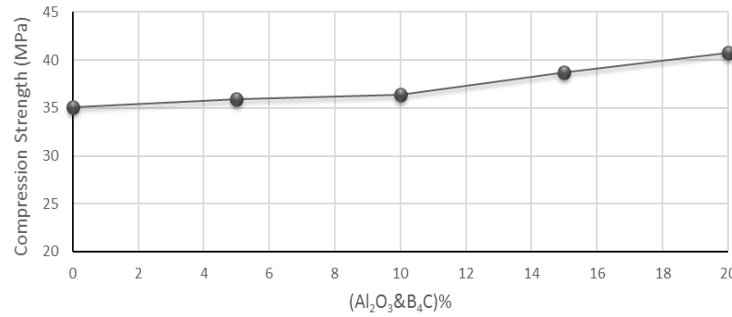


Fig. (9): Relationship between Compression Strength with Reinforcement Content

Figure (10) shows the relationship between the rate of wear rate with Al₂O₃&B₄C Content, with the mean wear rate (6.6 * exp (-8) - (4.22 * exp (-8)) g / cm at time (30) min. at (0-20) % of Al₂O₃&B₄C. The reason for the decrease in wear rate is that the 6063 aluminum

composites are more hardened when reinforced with Al₂O₃&B₄C, which in turn prevent the propagation dislocations and the difference in the thermal expansion coefficient increases the hardness by increasing Al₂O₃&B₄C Content.

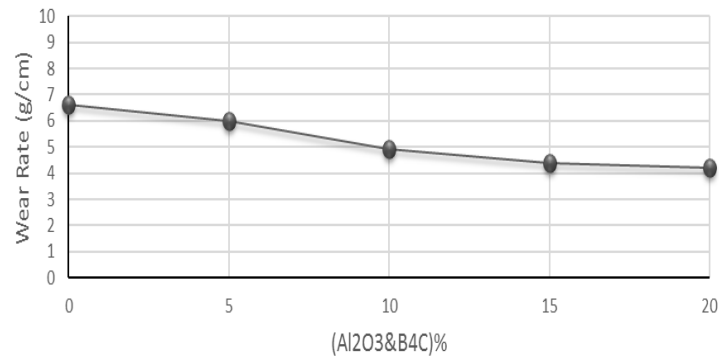


Fig. (10): Relationship between Wear Rate with Reinforcement Content

Figure (11) shows the abandoned images of the 6063Al₂O₃-B₄C aluminum composites and shows the relatively homogeneous distribution of Al₂O₃&B₄C

in the 6063 aluminum. The particle size of B₄C is bigger and recognized from Al₂O₃ particles as mentioned in experimental work.

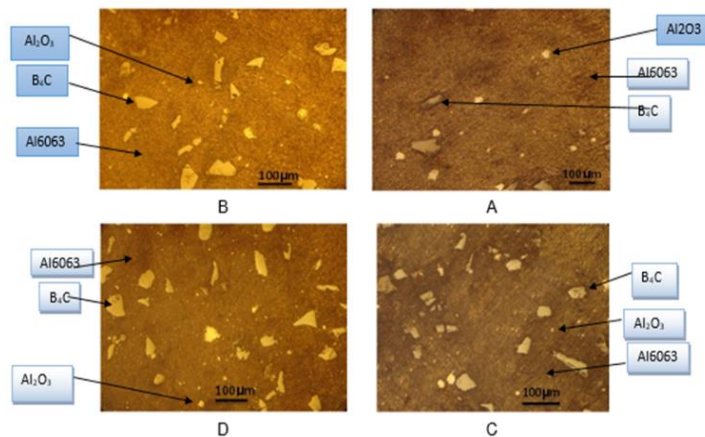


Fig. (11): Microstructure for Samples

A- Al6063+2.5%Al₂O₃+2.5%B₄C, B- Al6063+5%Al₂O₃+5%B₄C, C- Al6063+7.5%Al₂O₃+7.5%B₄C, D- Al6063+10%Al₂O₃+10%B₄C

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 .

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

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

وازدادت مقاومة الانضغاط القطرية N/mm^2 (40.8 – 35.1) بينما انخفض معدل البلى g/cm $(6.6 \cdot \exp(-8) - 4.22 \cdot \exp(-8))$ عند زمن 30 دقيقة عند محتوى (0 – 20) % Al_2O_3 & B_4C بينما تزداد الكثافة الظاهرية g/cm^3 (2.76 – 2.83) وتزداد الكثافة الحجمية g/cm^3 (2.71-2.82) اما المسامية الظاهرية فتتخفض % (0.193 – 1.88) وتتنخفض قابلية امتصاص الماء (0.699) % (0 – 20) عند محتوى Al_2O_3 & B_4C .

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

الخلاصة

هدف البحث الحالي الى دراسة بعض الخواص الفيزيائية (الكثافة، المسامية، قابلية امتصاص الماء) وبعض الخواص الميكانيكية (صلادة برينل، مقاومة الانضغاط، مقاومة البلى) لمترابك الألمنيوم 6063 المقوى بنسب وزنية من دقائق الألومينا وكاربيد البورون (20 & 15, 10, 5) wt.% باتباع تقانة ميتالورجيا المساحيق. تم خلط العينات ثم كبست كبس باودر وباتجاه واحد وبعد ذلك تم تلييد العينات بدرجة حرارة $600^\circ C$ تحت ضخ غاز خامل.

النتائج أظهرت تحسن في قيم (صلادة برينل، مقاومة البلى ومقاومة الانضغاط القطرية). حيث ازدادت صلادة برينل (114.7 – 106).