



EFFECT OF TiC AND B₄C ON MECHANICAL PROPERTIES OF AA7075 ALLOY FABRICATED BY POWDER METALLURGY

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ABSTRACT

In this work, aluminum metal matrix composites (AMMCs) were fabricated by using powder metallurgy. AA7075 powder is reinforced with two different ceramic particles (TiC, B₄C) with different weight fractions (2.5, 5, 7.5 and 10 wt.%). The composites were produced by powder metallurgy by preparing the powder, mixing, compacting and sintering. The particle size of unreinforced AA7075 about 100 μ m, while particle size of each TiC and B₄C about 150 μ m. The mixing process was done by planetary mixing setup rotating at 250 rpm for 2hr. by adding zinc stearate as an activator material with steel ball milling. However the mixture was compacted by hydraulic uniaxial press type (Leybold Harris No.36110) about 200 kg/cm² according to (ASTM-D 618). After compacting process, the mixture sintered at 475 °C for 2hr. by using electrical furnace with argon atmosphere.

There are many examinations and tests were carried out for the synthesized composites material (AA7075/ TiC and AA7075/ B₄C) such as examination of the microstructure, mechanical tests such as hardness and compressive strength, physical tests such as density and porosity.

The results of this work showed that improving in physical properties (theoretical density, experimental density, porosity) and mechanical properties (Rockwell hardness and Compressive strength)

KEY WORD : Composite materials, TiC, B₄C, Powder metallurgy, Physical properties, Mechanical properties.

تأثير TiC و B₄C على الخواص الميكانيكية لسبيكة الالمنيوم AA7075

المصنعة بميتالورجيا المساحيق

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الخلاصة

في هذا البحث، تم تصنيع مواد مركبة ذات اساس من الالمنيوم باستخدام ميتالورجيا المساحيق. تم تقويه مسحوق الالمنيوم AA7075 بنوعين مختلفين من الدقائق السيراميكية (TiC, B₄C) وبنسب وزنيه مختلفه 5, 7.5, 10% (2.5). تم تصنيع المادة المركبة بميتالورجيا المساحيق وذلك بتحضير المسحوق، الخلط، التدميج ثم التلييد. حجم دقائق مسحوق الالمنيوم 100 μ m، بينما حجم دقائق المساحيق المضافه TiC, B₄C بحوالي 150 μ m. تمت عمليه الخلط باستخدام جهاز خلط كوكبي يدور بسرعه 250 rpm ولمده 2 ساعه، بأضافه سترات الزنك كماده منشطه مع كرات طحن فولاذيه. بناء على ذلك أجريت عمليه كبس (تدميج) المسحوق باستخدام جهاز كبس هيدروليكي احادي الاتجاه نوع (Leybold Harris No.36110) ويضغط حوالي 200kg/cm² وبموجب المواصفه القياسيه

(ASTM-D 618). بعد عملية الكبس يتم تلييد الخليط باستخدام فرن كهربائي عند درجة حراره 475°C لمدة ساعتين في جو من الارگون .اجريت العديمن الفحوصات والاختبارات للمواد المركبه المصنعه AA7075/TiC وAA7075/B₄C مثل فحص البنيه المجهرية، اختبارات ميكانيكيه مثل الصلاده ومقاومه الانضغاط، اختبارات فيزياويه مثل الكثافه والمساميه . اظهرت نتائج البحث تحسن الخواص الفيزياويه (الكثافه النظرية، الكثافه العمليه والمساميه) وكذلك الخواص الميكانيكيه (صلاده روكويل ومقاومه الانضغاط) .

الكلمات المفتاحية: ماده المركبه، كاربيد التيتانيوم، كاربيد البورون، ميتالوجيا المساحيق، الخواص الفيزياويه ، الخواص الميكانيكيه

INTRODUCTION

Generally there are two conventionally important techniques to produce metal matrix composites (MMCs): the primary technique is the powder metallurgy without changing in the final shape or the microstructure of the products, while the second technique is obviously using to alter the final microstructure and the shape of the products such as stir casting (S.Attar et al. 2015)(Sachin 2017). Composite materials considered an important type of advanced engineering materials. The applications of the advanced engineering materials has been increasing recently, the most important properties of advanced materials must be due to their performance, lightness, excellent mechanical and thermal properties (E.Sabau, 2009). One of an important alloy using as a matrix to obtain advanced composite materials is aluminum, while the main important reinforcements are the ceramic particulates such as SiC, B₄C, TaC, TiC and Al₂O₃ to improve the mechanical properties, thermal resistance, wear resistance and good compatibility (R.S.Rana et al. 2012). One of the most important advantages of powder metallurgy is combining at least two types of powders to produce composite material for many desired properties. The composites produced by powder metallurgy are sintered to give the tribological properties. Powder metallurgy has a great effect on the final dimensions and shapes of the products, also the powder metallurgy reveal a homogeneous distribution of the reinforced materials in the aluminum matrix where as the another fabricating techniques will fail to satisfy (Shobhit et al. 2016). There are many investigations were published in this field (C.Santosa et al. 2007) illustrated the powder metallurgy is one of the most processing method to produce particulate or short fiber reinforced composites. This technique involve cold pressing or hot pressing to fabricate metal matrix composite, this process for high melting point to avoid aggregation or brittleness as a reaction occurred to form the composite material for military applications (Whilst Jeevan et al. 2012). Studied the effect of SiC as a reinforcement material to improve the properties of aluminum matrix by manufacturing a composite material using the powder metallurgy. The results of this investigation reveal that improving the microhardness and compressive strength with increasing in a weight fraction of SiC (Cihad Nazik et al. 2016). were used gas atomization technique to fabricate composite materials by powder metallurgy with aluminum matrix AA7075 incorporated by B₄C to enhance the physical properties such as density and mechanical properties such as hardness and tensile strength. The results of SEM analysis observed that homogeneous dispersion of reinforcement B₄C in AA7075 aluminum matrix, also increasing the density and tensile strength about 40%. The aim of this investigation is to produce composite materials by powder metallurgy for aluminum matrix AA7075 embedded by TiC and B₄C respectively with different weight content. And then study the mechanical and physical properties of the processed composite.

EXPERIMENTAL PROCEDURES

Materials used

Matrix powder of AA7075 alloy was supplied by Turkey Company, produced by gas atomization with the average particle size about $75 \mu\text{m}$. While the reinforcement powders TiC and B4C powders with 99% in purity were supplied by A Johnson Matthey Company with the average particle size about $125 \mu\text{m}$. However table.1 shows the chemical composition of the matrix alloy according to ASTM B316 - 10. In this investigation powder metallurgy was used to produce the composite materials, by blending the fine powders, compacting them into a desirable shape, and then sintering the green compacts in an electrical controlled furnace. Powder metallurgy is a technique which used to produce the engineering parts by compacting and sintering metallic and or non - metallic powders.

Ball milling

In this process the desired amount of AA7075 powder was mixed with B4C powder or TiC powder with about the selected weight percentage as 2.5, 5, 7.5 and 10 wt. % and then adding zinc stearate as activator with a ball milling in a planetary mixer rotating at 100 rpm for 1 hr. After milling ball, the mixture of powders then is ready for compacting process.

Compacting process

This process is done by filling the die with the mixture of powders, and then pressed by a hydraulic press with a start loading 4 ton for 2 minutes. Through the compaction the mixture of the powders will mechanically densify to obtain the green compacts which were ready for sintering.

Sintering process

This process is done by using an electrical furnace with argon to avoid the oxidation of the powder mixture. This process is done at 580 with argon pressure about 1.5 Kg/cm^2 , sintering process was done in the furnace for 2 hrs.

EXAMINATIONS AND TESTING

Microstructural evaluation

To evaluate the microstructure of the composite materials, must be studied by using optical microscopy with magnification 250X. The specimens for this examination were cutting by lathe machine and then grinding and polishing respectively. Grinding process was carried out by using grinding machine with emery paper in grit size 500 and $1000 \mu\text{m}$, while the polishing process was done by polishing machine and suitable polishing cloth with diamond paste for 40 minute to achieve the mirror finishing surfaces of the specimen. The specimens were etched by using 1% Keller reagent for 45 seconds and then washing with distilled water. Then the specimens were examined by optical microscopy and many micrographs were taken for each specimen.

compressive strength

This test was carried out by using universal testing machine (UTM) by applying pushing forces on the composite material until the specimen is crushed. Compression test was carried out on the composite materials specimens with length to the diameter ratio 1.5. While the applied load for compression test at 1000KN and then recorded the maximum load at the failure point.

Hardness test

Hardness test was performed by using Rockwell hardness for the composite materials using B scale. The applied load for this test is about 100kg by steel ball indenter, at least four readings were recorded for each specimen and then calculated the average hardness.

Density test

This test define the change in the density of the specimens before and after sintering process. The volume and the mass of each specimen was determine by the dimensions (diameter and length) and weighing the specimen respectively. Since the specimen will shrinkage through the sintering process and occur the densification of the powders and then enhanced the physical properties. During compacting and sintering, the porosity formed and can be determined by Archimedes principles by weighing each specimen in air and then in water respectively. The density of the specimen is determined by using the following formula:

$$\rho_s = (m_a \times \rho_w) / (m_a - m_w) \quad (1)$$

Where

ρ_s : density of the specimen after sintering (g/cm^3).

m_a : weight of the specimen in air (g).

ρ_w : density of water (g/cm^3).

m_w : weight of the specimen in water (g).

While the porosity was determined by using the following formula:

$$P = 1 - \rho_s / \rho_{th} \quad (2)$$

Where

P: porosity (%).

ρ_s : density of the specimen after sintering (g/cm^3).

ρ_{th} : theoretical density (g/cm^3).

The theoretical density was determined as the following: The weight of the specimen divided by the density to define the volume of the composite.

RESULTS AND DISCUSSION

Microstructural evaluation

The photomicrographs were taken by optical microscope for the morphology of the sintered metal matrix composites. Photomicrographs showed that uniform distribution for each of TiC and B₄C, creating small amount of aggregation with small amount of TiC and B₄C contents. While increasing the weight percentage of TiC and B₄C will make the particles to disperse in aluminum matrix and create strong bonding's between the particulates reinforcement materials and the matrix as shown in Figure(1).

From the same micrographs, it can be showed that many pores defects were obtained in the composite materials as a result of compacting and sintering processes. During compacting process and with increasing the pressing loads, the particles close together as a result of densification. During sintering process, the particles will welded together as a result of creating of the necks between the particles with increasing the temperature of sintering. Figure(2) shows that the relationships between the porosity and % B₄C and TiC. Increasing % TiC and B₄C will increase the % porosity because of evaporation of zinc stearate as a result of sintering process and then causes to form porosity and voids for composite materials. This observation of microstructure is agreed with (Dinesh Kumar, Koli et al. 2013).

Effect of B₄C and TiC on the density composite material.

Each of B₄C and TiC will decrease the density during the compacting and sintering processes, because of the increasing of densification during the compacting and creating the welding between the reinforcement particles during sintering. Figure(3) shows the relationships between the density of compacted and sintered specimen. This figure shows that the density decreases with increasing in B₄C and TiC concentration; this is attributed to the decreasing of wettability with increasing the weight fractions of each TiC and B₄C. The density of Al/B₄C more than for Al/TiC because of the same reasons mentioned previously. The results of the densities agreed with (T.Varol and A.Canakci 2013).

Effect of B₄C and TiC on the hardness

The mechanical properties of composite material are extremely dependent on the characteristics of reinforcement material such as the weight fraction, size and the shape of the additive particles. Increasing the concentration of B₄C and TiC, the hardness of composite materials with B₄C higher than the hardness of composite material with TiC because of B₄C made strong bonding with aluminum particles and also B₄C prevent the dislocation and pinning them at their sites, and then increasing the hardness of the processed composite material, The results of the hardness is agreed with (B.Venkatesh and B.Harish 2015). Figure(4) shows that increasing the percentages of B₄C and TiC leads to increase Rockwell hardness.

Effect of B₄C and TiC on compressive strength of composite material.

The compressive strength is extremely dependent on the concentration of the additive particles and their properties such as the sizes and shapes. Increasing the percentage of B₄C and TiC leads to increase the mechanical properties such as yield strength, tensile strength and compressive strength. It is return to that the strong reaction between the reinforcement materials and aluminum particle as a matrix, and then increasing the dislocation density. B₄C and TiC particles obstacle the dislocation to move from one particles to another and then increase the compressive strength, this results is agreed with (Shorowordi, HA et al. 2003). Figure(5) shows that increasing the weight fraction of B₄C and TiC leads to increase compressive strength.

CONCLUSIONS

- 1- Increasing the weight percentage of B₄C and TiC into Al powder leads to improve the physical properties such as density and porosity.
- 2- Increasing the weight percentage of B₄C and TiC into Al powder leads to improve the mechanical properties such as hardness and compressive strength.
- 3- Increasing the weight percentage of B₄C and TiC are distributed uniformly into Al matrix.
- 4- The increment in physical properties and mechanical properties for B₄C as reinforcement material more than for TiC.

Table 1. Chemical composition of AA7075 alloy matrix powder .

Cu	Mg	Mn	Fe	Si	Zn	Cr	Ti	Al
1.2 – 2	2.1 - 2.9	0.3	0.5	0.4	5.1 - 6.1	0.18 - 0.28	0.2	87.1 -91.4

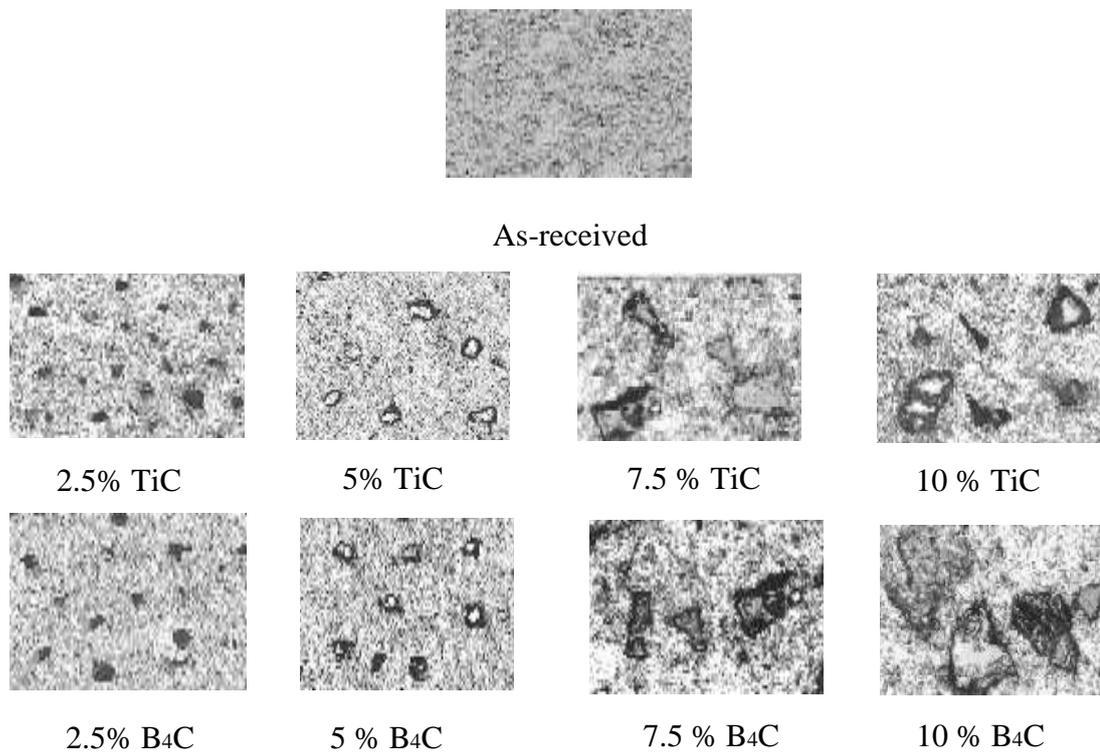


Figure.1. Photomicrographs of all the specimens for power with magnification (250 X).

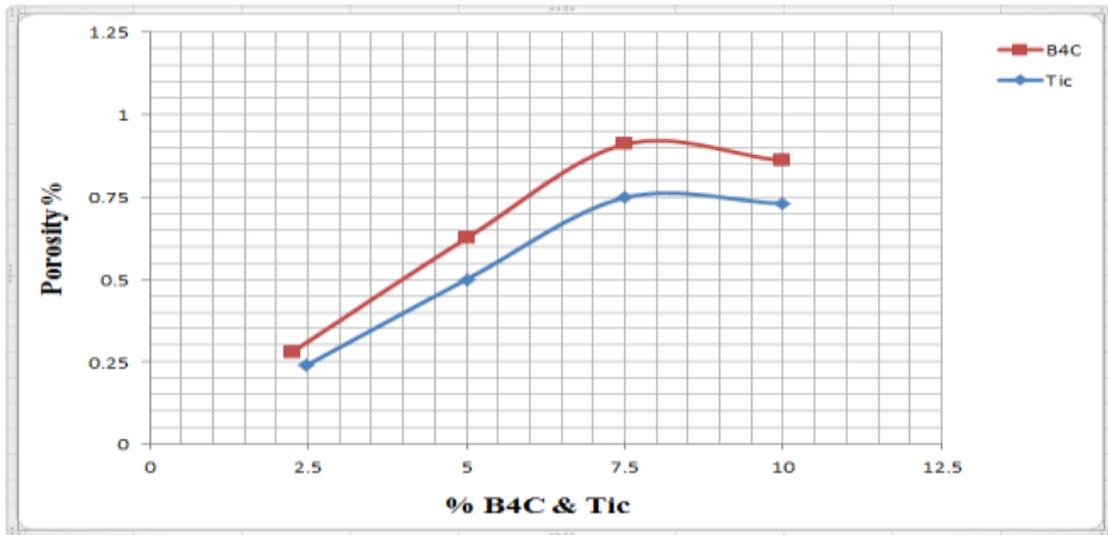


Figure .2. Relationships between % Porosity and % B₄C & TiC.

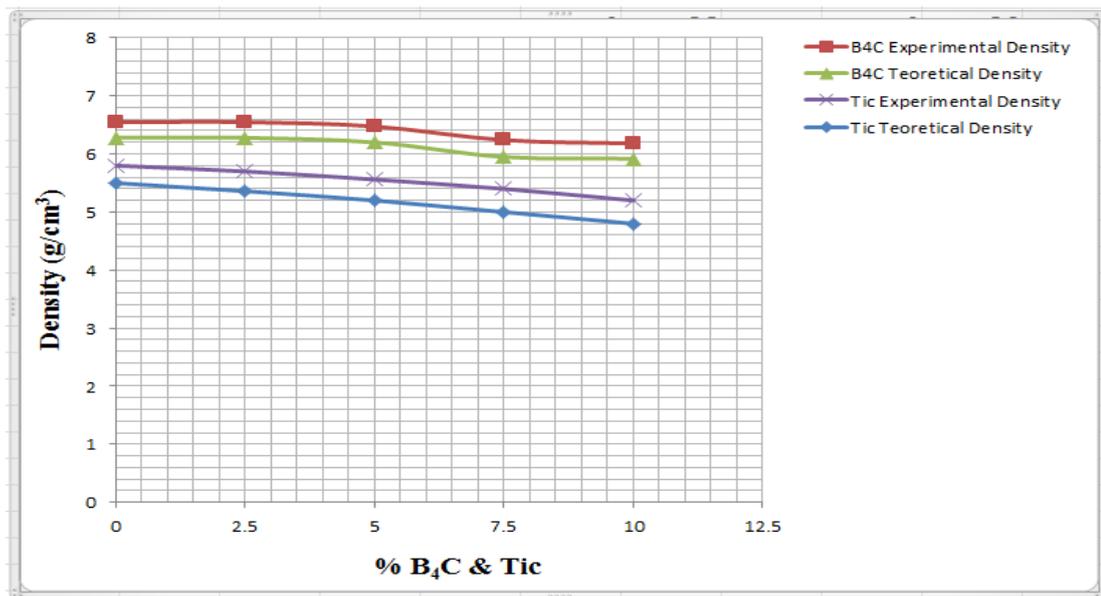


Figure .3. Relationships between Density and % B₄C & TiC.

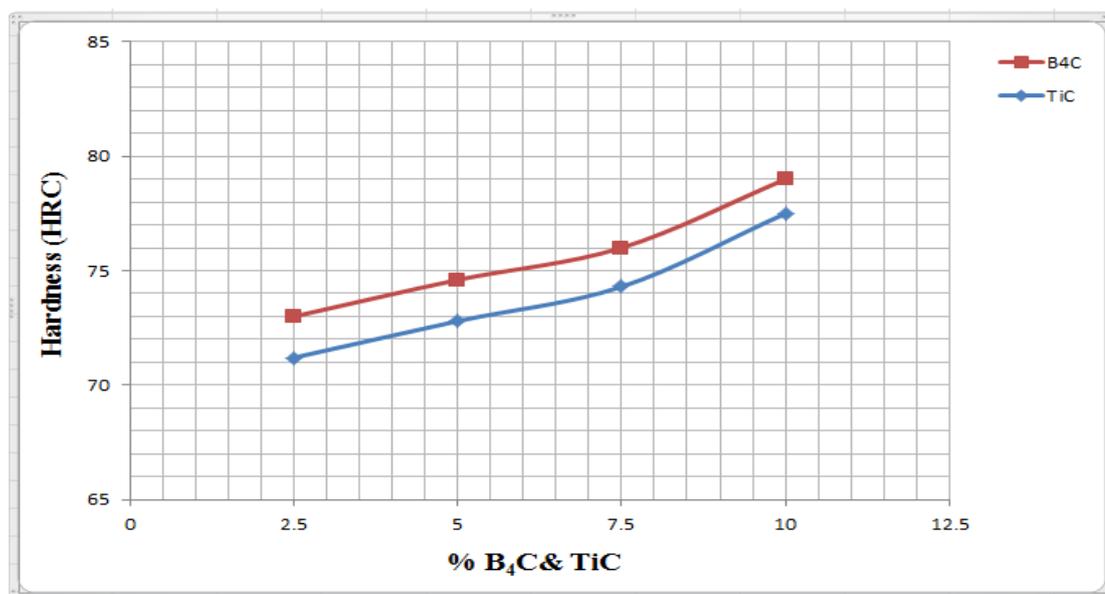


Figure .4. Relationships between Hardness and % B₄C & TiC.

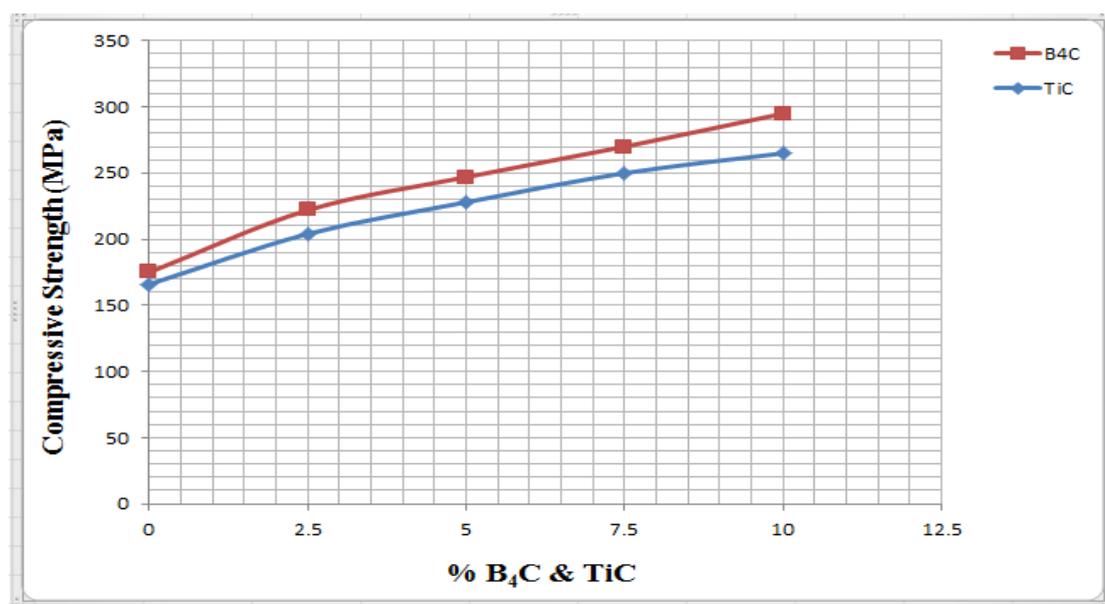


Figure .5. Relationships between Compressive Strength and % B₄C & TiC.

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