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Study of the Effect of Graphite on Some Physical Properties of (Al-SiO_2) System Prepared by Powder Metallurgy Method

Ibtisam Saadan Hamidi, Niran Fadhil Abdul-Jabbar

Department of Physics, College of Education for Pure Sciences, University of Tikrit, Tikrit, Iraq

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ABSTRACT

The objective of the study is to create a composite material using powder metallurgy that is based on aluminum and reinforced with silicone oxide (SiO_2) particles, with a constant volume fraction of (7 wt.%) and variable volume fractions of graphite (Gr) particles equal to (2, 4, 6, 8, and 10 wt.%). It was investigated how introducing graphite particles affected a few physical characteristics, including porosity, water absorption capacity, and apparent and volumetric density. Samples measuring (11 mm) in diameter and (5 mm) in height were obtained by cold pressing the mixture at a pressure of (5 tons) after it had been blended for (10 min) with a mechanical mixer. After that, sintering was carried out for two hours at (600 °C). A few physical characteristics were then examined, including water absorption, porosity, and apparent and volumetric density. The results demonstrated a direct correlation between apparent and volumetric density, which decreases as the graphite volume fraction increases, and total and apparent porosity, which rises as the graphite level increases, increasing the composite's capacity to absorb water.

Keywords: Composite materials, Al-SiO_2, Powder technology, Bulk density, Porosity

Name: Ibtisam Saadan Hamidi **E-mail:** is230073pep@st.tu.edu.iq

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دراسة تأثير إضافة الجرافيت على الخواص الفيزيائية لنظام ($AL-SiO_2$) بطريقة ميتالورجيا المساحيق

ابتسام سعدان حميدي، نيران فاضل عبد الجبار

قسم الفيزياء، كلية التربية للعلوم الصرفة، جامعة تكريت، تكريت، العراق

الملخص

يهدف البحث إلى تصنيع مادة متراكبة ذات اساس من الألمنيوم ومقواه بدقائق الاكاسيد (SiO_2) بكسر حجمي ثابت يساوي (7 wt.%) وكسور حجمية متغيرة من دقائق الجرافيت (Gr) تساوي (2, 4, 6, 8, 10 wt.%)، حيث حضرت من خلال تقنية ميتالورجيا المساحيق. تم دراسة تأثير اضافة دقائق الجرافيت على بعض الخواص الفيزيائية متمثلة بـ(الكثافة الظاهرية والحجمية، المسامية، قابلية امتصاص الماء). تم مزج الخليط لمدة (10 min) باستخدام خلاط ميكانيكي، بعدها تم كبس المزيج على البارد بضغط (5 tons) طن للحصول على عينات بقطر (11 mm) وبارتفاع (5 mm) وبعدها أجري التلبيد بدرجة حرارة (600 °C) لمدة ساعتين. ثم درست بعض الخواص الفيزيائية الكثافة الظاهرية والحجمية والمسامية وامتصاص الماء. بينت النتائج أن هنالك علاقة طردية بين الكثافة الحجمية والظاهرية، إذ تنخفض بزيادة الكسر الحجمي للجرافيت على عكس كل من المسامية الكلية والظاهرية، حيث تبين أنها ترتفع بزيادة مستوى الجرافيت مؤدية إلى زيادة امتصاص الماء للمتراكب.

INTRODUCTION

Composite materials have useful qualities that make them suitable for a wide range of contemporary and fundamental uses in industry, transportation, and space, particularly in internal combustion processes [1, 2]. The solution is composite materials since it is hard to discover a single material with certain qualities and traits that can be applied in complex applications [3, 4]. Composite materials consist of two main stages: matrix and reinforcement material. The reinforcement material gives strength and rigidity to the composite material. While the matrix material bonds, reinforcement materials transfer and distribute the load, as well as protecting it from the surrounding environment[5]. The manufacturing technology (powder metallurgy) is one of the important methods to produce metal-based composite materials. It is a good and appropriate way to produce material systems with a homogeneous and tight particle distribution and includes mixing the metal powder with the ceramic reinforcement phase, for example (bristles, fibers, minutes) mixing [6, 7]. Homogeneous and well in the required controlled proportions and is usually followed by cold or hot pressing under controlled conditions to improve the bond between the particles to obtain a product with good coherent density (solid mass) [8]. There are many modern methods used in the manufacture of composite structures that depend on the composition of the structure, material performance requirements and production rates [9, 10]. Metals matrix composites (MMCs) are combined with another metal with other reinforcing materials (organic or ceramic). Important cells of MMC are used for their physical properties (bulk density, volume, porosity and water absorption. Aluminum-based composites are strengthened with ceramic materials such as oxides (Al_2O_3, ZrO_2, and SiO_2) and carbides (SiC, BuC, and TiC) as the reinforcement includes the uniform distribution of particles within the base material. These materials give good hardness and wear resistance, high toughness and hardness at low density when compared with base material [11]. Aluminum-based composite materials have proven rare and advanced properties within the industry compared to alloys, with the development of modern forming methods and the adoption of low-cost reinforcing materials. Knowing the specifications and properties of basic and supporting materials helps to determine the type of materials that are produced and where they can be applied in the medical and engineering industries,

MATERIALS AND METHODS

Materials

Materials used in this work include: sensitive electric scale manufactured by a French company, homemade electric grinder, single effect manual hydraulic press, steel cylindrical mold, and programmed electric oven has a maximum temperature of (1000 °C). The materials currently used are the basic material aluminum and silicon oxide and the reinforcing material graphite. The composite materials were prepared using powder technology.

Theoretical Part

The apparent density, volume, porosity, and water absorption ratio were calculated using Archimedes' rule and applying the following relationships [14, 15]:

A.D $=(W_d \backslash W_d - W_i) * \rho_W$ ……….. (1)

B.D $= (W_d \backslash W_S - W_i) * \rho_W$ ………. (2)

A.P $=(W_S - W_d \backslash W_S - W_i) * 100\%$ ……… (3)

W.A$=(W_S - W_d) \backslash W_d * 100\%$ ………. (4)

Whereas: A.D represents bulk density, W_d Represents body weight which is dry (gm), W_i represents the weight of the body suspended (gm), ρ_W represents the density of water in (gm\cm3), B.D represents volumetric density, A.P represents porosity, and W.A represents the ability to absorb water.

Experimental Work

The samples in this study were prepared using powder metallurgy technology, which is divided into three main sections for their production:

Powder Preparation

Aluminum powder was used as a base material with (99.6 %) purity and silicon oxide powder and graphite as a hardener with (99.8 %) purity for both. Then mix each component after preparing the for example [12, 13]. The aim of the study is to improve the physical properties of composite materials when adding a weight percentage of graphite and the possibility of their industrial applications such as the manufacture of car bodies and some internal combustion engines.

weights for each component following the volumetric ratios shown in Table (1).

Table 1: Weight percentage of materials

Materials	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)	Sample 5 (%)
AI	93	91	89	87	85
SiO_2	5	5	5	5	5
Gr	2	4	6	8	10

The powders were weighed using a sensitive electric balance with high precision. Then they were mixed using a mechanical mixer for (10 min). When the mixture of several elements is placed in the container of this device, then frequencies occur in the auditory system. In this case, we add an alcoholic substance to the mixture so that the substance does not evaporate and we ensure that the mixture is obtained completely and correctly.

Powder Pressing

After obtaining a homogeneous powder for the composite materials and forming the samples in one direction in a hardened steel mold with an inner diameter (11 mm). The prepared mixture is placed inside the mold and pressed with a pressure of (5 tons) and for (3 min). Cylindrical specimens were obtained with a diameter of (11 mm) and a height of (5 mm).

Sintering Samples

The sintering process was carried out inside an electric oven with a maximum temperature of (1200 °C) and the samples were entered inside the furnace at a temperature of (600 °C) for two hours. Where the samples were covered with a quantity of sand inside a special rear container to prevent oxygen from reaching the surface of the sample, then the samples were cooled inside the oven to room temperature. The temperature of the relationship below is calculated [16]:

$T_s = (0.7\text{-}0.9)T_m$ ………. (5)

T_S is the sintering temperature (K) and T_m is the melting temperature of base metal (K). The physical properties were examined, which are both bulk density, volumetric and porosity, as well as water absorption according to the international standard ASTM. Where the samples were dried using a sensitive electric balance with an accuracy of (0.1 mg) at a temperature of (150 °C) for an hour and represent W_d. Then the weight of the samples is taken while they are suspended and immersed in distilled water for (3 hours) with a density of (1 gm/cm^3) and represents the suspended weight W_i. Then we put the samples submerged inside the water for (24 hours), then take out the samples and remove the surface water suspended by them and weigh the samples, which represent the saturated weight W_s. Bulk Density (B.D) represents the ratio between mass to the total volume of the sample (volume of water particles + volume of closed and open pores) and is calculated from equation (2). Apparent Density (A.D) represents the ratio between mass to the apparent size of the sample (volume of water particles + size of closed pores) and is calculated from relation (1).

RESULTS AND DISCUSSION

Bulk and Volumetric Density

To understand the general performance of composites, it is necessary to study the physical properties which are based on the microstructure and their homogeneity, the shape and size of the strengthening particles, as well as the distribution of the particles through the base material. Figure (1) shows the relationship between bulk and volumetric density and graphite content ratios, as it is clear from the figure that increasing graphite ratios leads to a decrease in bulk density as it decreases from (3.06 gm\cm^3) at the graphite content (0.02 %) and to (2.71 gm\cm^3) at the graphite content of (0.1 %). While the volumetric density decreases from (2.97 gm\cm^3) to the graphite content ratio of (0.02 %), the reason for the decrease in the values of both bulk and volumetric density due to the increase in graphite content is that the low density of graphite of (2.089 gm\cm^3) compared to the density of composite materials. We also find that the increase in graphite ratios caused aggregations and agglomerations of its particles, causing the collection of closed and open pores, causing graphite particles to hinder the process of condensation and volumetric contraction during the sintering process. This is consistent with the researcher [17].

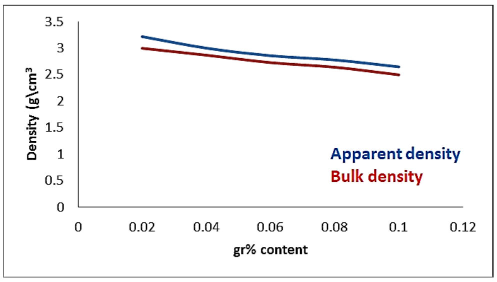

Fig. 1: Relationship between bulk density and volumetric with graphite ratios

Porosity

Figure (2) shows the relationship between porosity and graphite content ratios, and we note from the curves there is a clear increase in the porosity ratio with the increase in graphite ratios, we find that it increases from (5.32 %) to (14.43 %) with an increase in graphite ratios (0.02 - 0.1) and this is due to the increase in graphite content ratios hinder partial fusion and hinder the isolation of particles during sintering, so the pores remain in their places and the difficulty of breaking them down, so they increase with the increase in graphite ratios. We find that the porosity behavior is completely opposite to the bulk density behavior when graphite content ratios increase [18].

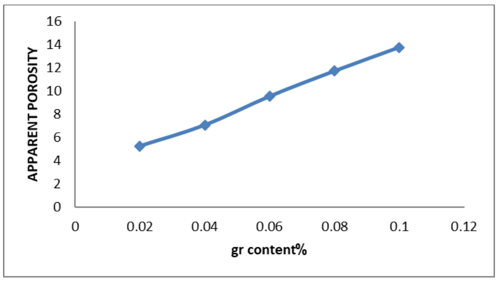

Fig. 2: Relationship between porosity ratios and graphite content ratios

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Water Absorption

Figure (3) shows the relationship between water absorption and graphite ratios and we note the proportionality in increasing absorbability with increasing graphite ratios, which is a logical relationship because increasing porosity means increasing the percentage of water absorption (the influence of water through composite materials). This finding is consistent with the reference[19].

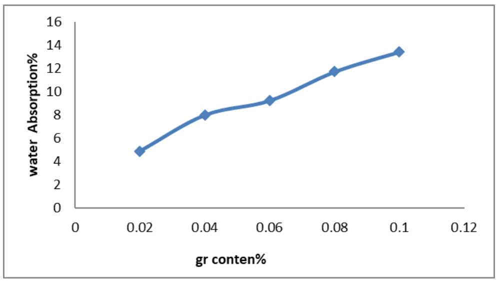

Fig. 3: Relationship between water absorption and graphite content ratios

CONCLUSIONS

By observing the results of the research and studying the properties of the prepared samples we find that increasing the graphite Al-SiO_2 content improves the physical properties. Both bulk density and volumetric density decrease with increasing graphite content ratio. We also find Increase porosity with increasing graphite content. Increase the percentages of water absorption by increasing the percentage of strengthening the graphite content.

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Author contribution: Authors contributed equally in the study.

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