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ORIGINAL STUDY

Improving the Structural and Physical Yield of Aluminum by Repeated Additions of Iron Carbide

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Abstract

Aluminum suffers from low hardness and some ductility when thermal sintering which requires reinforcement with carbide or ceramic materials as Iron FeC with volumetric properties (2,4,6,8,10)%. For purpose of the pressing process after mixing the two powder together, a scanning electron microscope examination performed for the prepared samples and found that there is a surface and structural consistency between aluminum and iron carbide and the best homogeneity is at10% of carbide. Also some physical tests conducted for prepared samples and the results of the real density showed that the addition of iron carbide increases the density gradually and the highest density is 4.01 g/cm^3 at a cementing ratio of 10% and after thermal sintering at 600 °C for two hours, the real porosity was obtained and under the same conditions by 9% while the water absorption was 0.583% the mechanical properties at the same conditions was the hardness 460Hv, the diagonal compressive strength 110 MPa, the wear was 2×10^{-8} g/cm, while the results of the electron microscope cleared that the ratio 10% is the best proportion in consistency with the surface and the external composition of the pistons in the terms of the least defects and pores. Therefore the ideal conditions were the reinforcement ratio 10%FeC at thermal sintering 600 °C for two hours only.

Keywords: Powder metallurgy, Engineering materials, Porosity, Mechanical properties

1. Introduction

The method of pressing powders was distinguished from other traditional methods in that it gives suitable results for samples that can be used in cutting tools or internal combustion engines and other industrial applications, and thus the models manufactured in this way are characterized by light weight and the lack of the need for subsequent operational operations, as for other methods such as casting and partial compensation Others require mechanical operations after the sample leaves the device. And since the labor market is acute with a continuous demand for cheap work and speedy completion, it is necessary to turn to these shortcuts to work, and the availability of equipment has an effective role in increasing production [1–3]. The selection of working materials is based mainly on the convergence of mechanical and physical properties, especially density and melting degrees, in order to mix between the main components and the stiffening materials, and the powder method suffers from the appearance of weak pistons with a crystalline structure that needs strengthening, and therefore special sintering furnaces are used for the purpose of increasing the convergence of atoms and obtaining Fusion, which in turn produces an alloy with useful properties for the required work, and these furnaces are of two types, either vacuumed or in the presence of air, so whenever the atmosphere is vacuumed, it helps not to get oxidation of the presses, and this is by adding nitrogen and other reducing gases [4]. The process of manufacturing composite materials with mineral or ceramic bases takes place at relatively high temperatures [5,6]. In these conditions the problem of mechanical and chemical compatibility arises between the base material and the reinforcing phase [5]. The problem of chemical compatibility is related to chemical reactions and contact at separating surfaces [7]. This problem is often addressed

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by following a manufacturing technique that can be accomplished at relatively low temperatures (Powder technology) or by testing thermodynamically stable phases.

2. Material powders

The base material was the Aluminum (Al) with a grain size of 63 μm made by Indian company CDH with a purity of approximately 99.5% while the support material was iron carbide FeC with grain size 75 μm manufactured by the German company Fluka with a purity 99.5% while the stamping mold used was original Iron which bears high stresses with 12 mm diameter.

2.1. Experimental methods

The method of powder technology is one of the common methods through which metal or ceramic powder are formed at different pressing pressures. In the current research article aluminum metal was reinforced with iron carbide and at percentage additions (2,4,6,8,10)% all mixtures were at volumetric ratios in order to take into account density difference between the base material and the support material. A homemade electric mixer containing iron balls was used to mix the powders for a period of two hours. For the powders according to the specified proportions after the mixing was completed. The press was mediated by a press of the type (HONMAKSAN). The pressing was at a pressure of (350 MPa) and for a period of one minute. The samples resulting from the pressing, which are called presses, suffer from weakness in the crystalline structure and the internal structure, because the pressing process is to compress the granules with each other without heat, and therefore these granules need a temperature close to the melting point of the base material, for the purpose of strengthening the presses. Therefore, a Korean-origin Muffled oven was used, the pistons were placed in special lids with the addition of sand and refractory clay to prevent any oxidation, and they were placed through the oven at a temperature of (600 °C) for a period of two hours only, the temperature of the oven was gradually raised to be (10 °C/min) and after reaching the required degree, it was left for two hours, after which the oven was turned off, and the samples were left inside the oven for the next morning. The pistons coming out of the oven need to be cleaned and simple mechanical operation to be ready for the various structural and mechanical tests.

2.2. Tests used

2.2.1. Hardness test

The Vickers micro hardness was calculated using French device and according to the practical conditions in the laboratory and at room temperature, the samples were cleaned, prepared, and placed under the stitching tool, which is a quadruple diamond pyramid with an angle of 136°. The applied load was at (500 Kg) for a time of 10 s. These harnesses are in order to know the hardness more accurately, and the relationship below was used to find out the value of the micro hardness [8]:

$$HV = 1.854\,\frac{P}{d_{av}} \tag{1}$$

Where: H_V: Vickers hardness, f: shed load (N), dav: mean impact diameter.

2.2.2. Porosity test

The tests represented by the apparent porosity were carried out by following the practical standards (88_A S T M C373). The pistons are dried for an hour by using an electric oven at a (100 °C), then the model is weighed after it is removed from the oven and it is called dry weight (w_1). The samples are placed for 24 h in distilled water at room temperature, and after taking them out, only the water suspended on the surface is removed, and the samples are weighed and called the saturated weight (w_2). The sample is weighed while it is immersed in distilled water with a sensitive balance, and this is called the hanging weight (w_3). Then the apparent porosity (A.P) is calculated by using the relationship below [9,10].

$$A.P. = \frac{W_3 - W_1}{W_3 - W_2} \times 100\ \% \tag{2}$$

2.2.3. Compressive, strength test

Calculating the compressive strength value of the pistons is one of the important methods to know the strength and stiffness of the models by repeated additions, using a device manufactured in China, the pistons are placed through a special base for examination after preparing the samples and smoothing them with 2000 μm paper. After that, pressure was applied to the pistons, and the pressure was lateral until the fracture and cracking of the models occurred, and the maximum load reading was taken, and the compressive strength was calculated through the relationship below [11].

$$\sigma_D = \frac{2F}{\pi d h} \tag{3}$$

Where: σ_D: represents the compressive, strength in units of (MPa),: F represents the amount, of force applied in units of N, d: represents the diameter, of the pressed unit in (mm)., h: represents the height, of the pressed unit in (mm).

2.2.4. SEM tests

The methods of measuring the composition of the outer surface of the prepared samples varied, and the best of them was the electronic method of the scanning electron microscope. Staples are up to 1 μm, Also, the high magnification power given by those electron microscopes helps to understand the topography of the surface and thus determine the granular size and failure locations of the samples in terms of the number of cracks and pores [12].

3. Results and discussion

3.1. Effect of reinforcement content FeC on true porosity

Fig. 1 shows relationship between the true porosity and the number of additions to the FeC support material before and after thermal sintering, and we find that by increasing the addition rates, the porosity decreases until reaching the lowest value of the true porosity of 18% at a 10% support percentage before sintering. The amount of porosity becomes 9% at a 10% reinforcement ratio after thermal sintering of the pistons. The main reason for the decrease in the pores with each addition is that the support material acts as a barrier and fills the voids in the base material and improves the adhesion process between the two powders, and thus the carbides are characterized by surface bonding with the metals, thus forming a strong alloy, and the thermal sintering has a great effect on the fusion of the grains with each other and the porosity decreases more than it was before sintering, and the presence of electrostatic stress that works to close the pores [13,14].

3.2. Effect of reinforcemnt content FeC on true density

Fig. 2 shows the relationship between the volumetric ratios of iron carbide with the real value before and after the resulting sintering, through the addition of iron carbide leads to an Increasing the true density before sintering, The best density is at the reinforcement rate of 10% FeC, and its value was 3.45 g/cm^3, but after the thermal sintering process, the density increased to become 4.01 g/cm^3 at the rate of 10%. The density values with each addition before and after sintering is attributed to the high density of iron carbide, which in turn works to raise the basic density of aluminum, which is 2.7 g/cm^3. Also, cold pressing increases the real density due to the fusion between the metal and the carbide. Also, thermal sintering is a major reason for increasing the densities of the presses due to the spread of the support material through the surface of the base material [15].

3.3. Effect of reinforcemnt content FeC on hardness

Fig. 3 shows the relation between each of the micro-Vickers hardness and the rates of repeated addition of FeC iron carbide before, after sintering, As we find with continuous additions of iron carbide, the hardness increases, that is, there is a direct proportion between them and before sintering, and at an addition rate of 10%, we find the hardness value is 300Hv, After thermal sintering, the

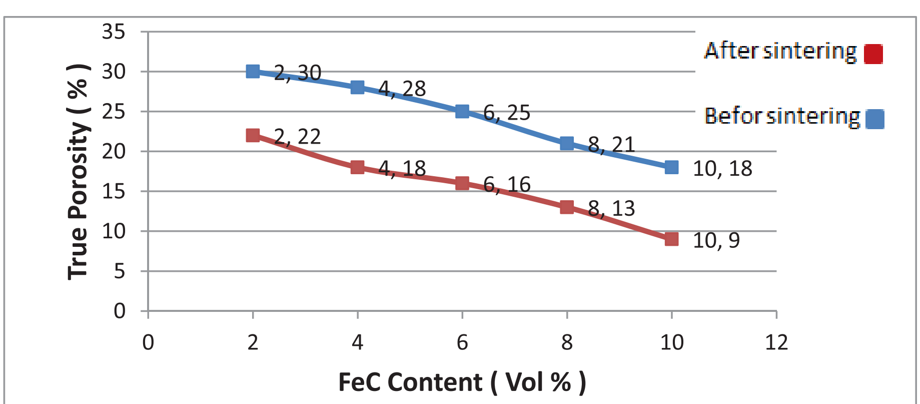

Fig. 1. The relationship between FeC and true porosity before and after sintering.

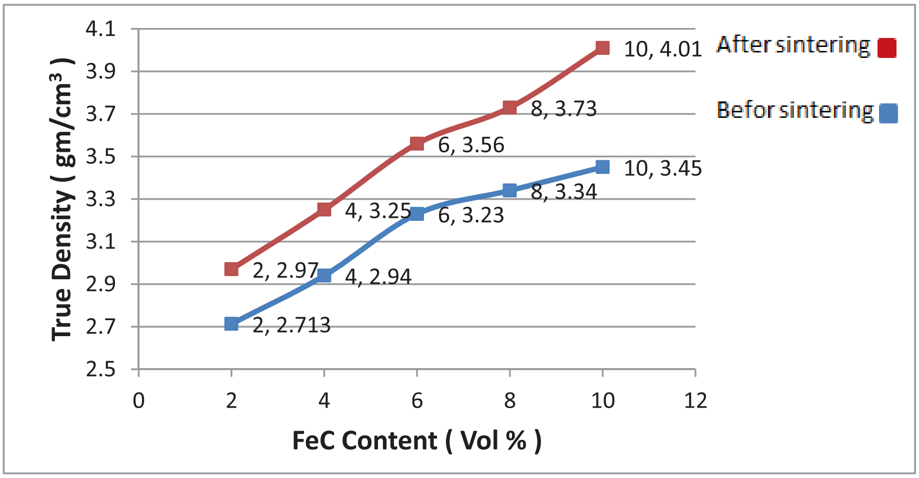

Fig. 2. The relationship between the ratio of FeC and the true Porosity before and after sintering.

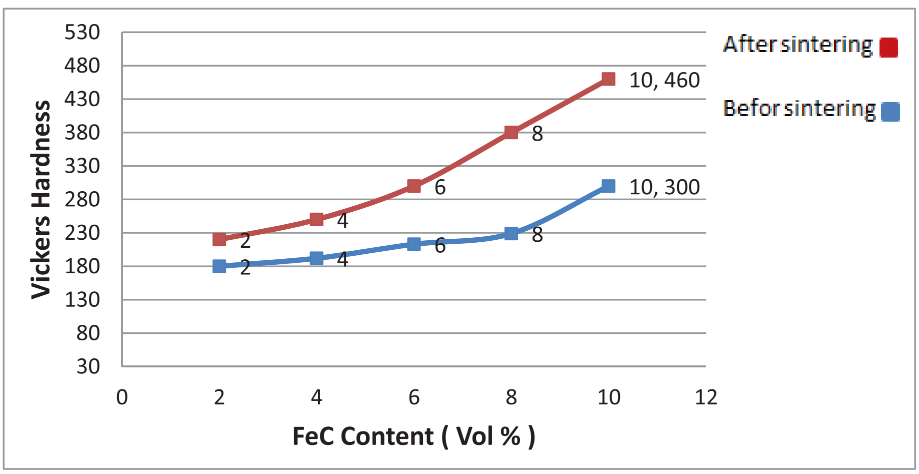

Fig. 3. The relation by the ratio of FeC and the Vickers hardness before and after sintering.

hardness value becomes 460Hv, and the best reinforcement rate is 10%. The main reason for raising the hardness value is the high qualities of iron carbide, which has high hardness and resistance, as well as, as previously mentioned, sintering has a significant effect on increasing the cohesion of atoms, in addition to increasing the resistance to the remaining internal stresses in aluminum metal due to the difference in the thermal expansion coefficient between the base material and the reinforcing particles of iron carbide [16].

3.4. Effect of reinforcemnt content FeC on compressive strength

Fig. 4 shows the direct proportion between the reinforcing particles of added iron carbide and the radial compressive strength before and after thermal sintering. We note that before sintering, the radial compressive strength values are of few percentages and start to increase with each addition until it reaches a maximum value of 85 MPa at 10% reinforcement, But after thermal sintering at 600 °C for two hours, the compressive strength value increases to reach a maximum of 110 MPa, with the best percentage at 10%. Thus, we find that the main reason for the increase in the compressive strength of the diameter is the high mechanical properties of the addition of iron carbide, which definitely leads to an increase in the mechanical properties of the overlays, and the compression at a pressure of 350 MPa has an effective role that led to the formation of the metal and storing stresses inside it, in other words, the occurrence of ductile formation has a wide impact on the hardness values, as the process of responding to metal powders to deformation due to applied pressure is a complex process compared to hard metals. Because of the iron

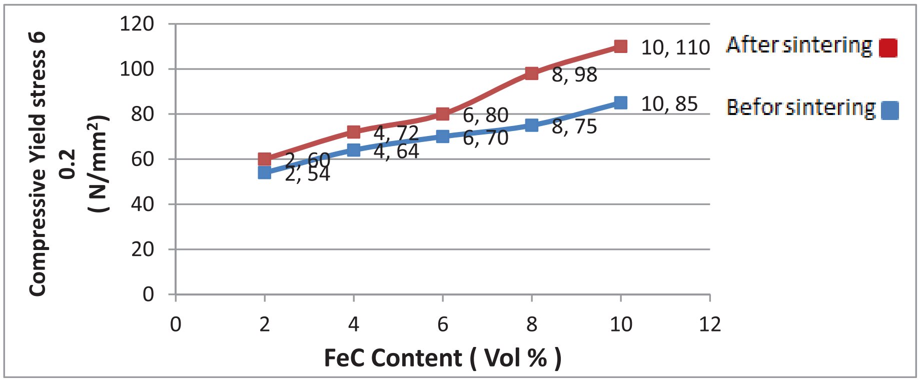

Fig. 4. The relation by the ratio of FeC and the compressive Yield stress before and after sintering.

carbide and then the formation of cohesive samples with high compressive strength, and it is possible to return to the reasons that led to increases of Matrix [17,18].

3.5. Effect of reinforcement content FeC on wear rate

Fig. 5 shows the relation between the percentage of iron carbide additions and the wear rate before, after thermal, and we find that before sintering the wear rate values are high and with the continuous addition of our support material the lowest wear value which is 4.90×10^{-8} g/cm at the best 10% addition rate. After sintering, the rate values decrease further to be 2×10^{-8} g/cm at the same 10% addition rate. The lower wear rate, when increasing the content, of reinforcing particles is due to the fact that compounds that are more stable when, iron carbide particles are added, so that the weight loss is minimal as a result of reinforcing the base with ceramic particles that impede the advancement of the stock, so the particles will generate resistance (FeC) and then generate their packing density and the difference in increasing the effect of the coefficient of thermal expansion in this process will lead to an increase in the content [19].

3.6. Scanning electron microscopy (SEM)

The Fig. 6/(a, b, c, d, e) are the scanning electron, microscope (SEM) at a depth of (50 μm), which gives the shape or the outer surface of the aluminum-based presses supported by iron carbide after thermal sintering. At the low percentages of iron carbide additions, we find a recrystallization of the powders in the presence of heat, as well as the appearance of impurities at the surface of some of the presses, and we also find that there are clear dislocations on the surface between the overlays, while at the percentages of addition, especially at 10%, the surface is very consistent and the distribution of iron carbide is greater. Consequently, it impedes the movement of the dislocation by a greater percentage, when its content is increased in the overlays. In this case, the stress must be large in order for the dislocation to pass through the

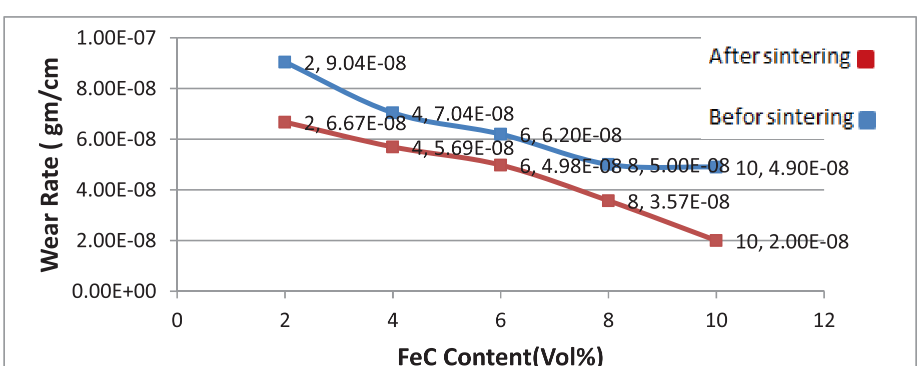

Fig. 5. The relation by the ratio of FeC and the Wear rate before and after sintering.

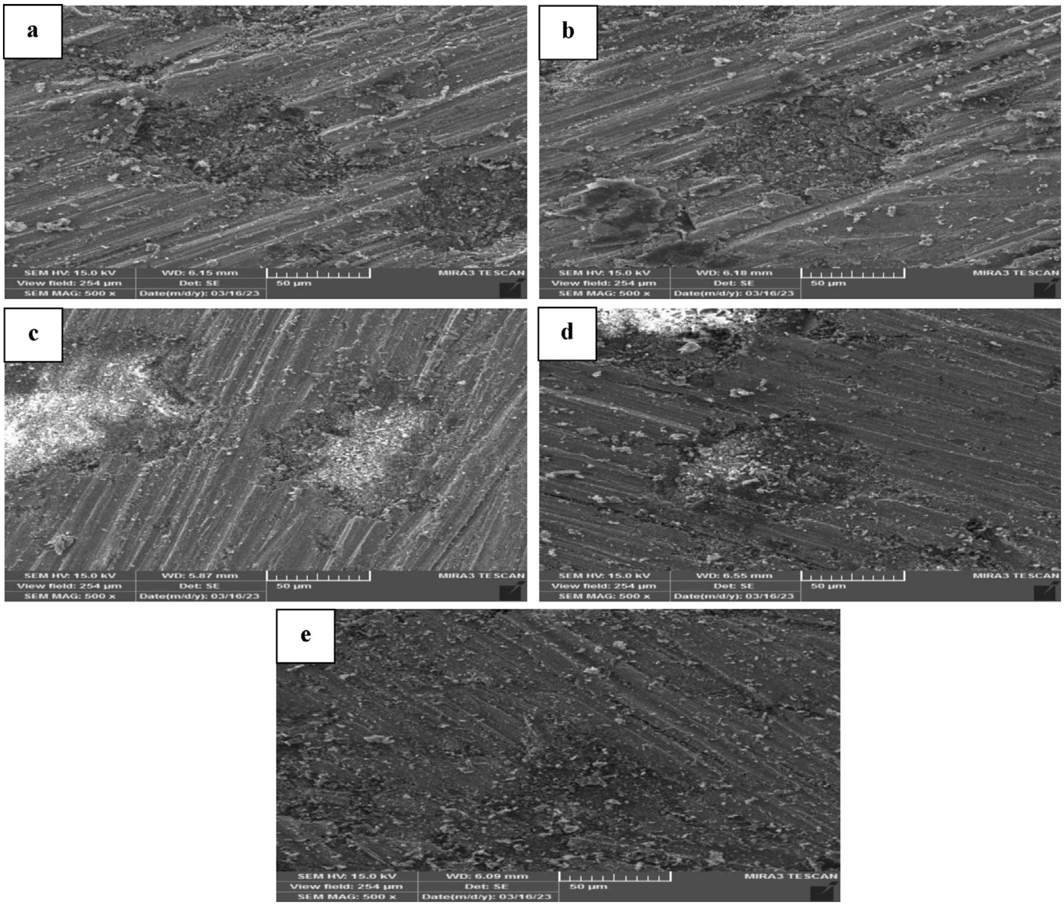

Fig. 6. Scanning Electron Microscope images of the (Al–%FeC) after sintering with different reinforcement ratios are as follows (a-2%, b-4%, c-6%, d-8%, e–10%).

granules, and thus requires, an increase in the applied load, and this means an increase in the hardness values [20–22].

4. Conclusion

The structural and mechanical properties of aluminum can be improved by adding carbide or ceramic materials, as the important conclusion in the current article is the possibility of improving these properties by adding iron carbide FeC, obtained by scanning electron microscope test on a homogeneous and consistent surface with a few dislocations and pores at the rate of 10%, while the rest of the tests showed encouraging results when multiple additions of iron carbide where it was found and at standard conditions with the best mixing ratio of 10%, and thermal sintering of 600 °C the hardness was 460Hv, true density 4.01 g/cm^3, true porosity 9%, radial compressive strength 110 MPa, minimum wear rate value 2×10^{-8} g/cm.

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