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MICROSTRUCTURAL CHARACTERISTICS OF SINTERED POWDER METALLURGY ALLOYS

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ABSTRACT

The purpose of this paper is to study the influence of processing parameters on the microstructural characteristics of sintered powder metallurgy alloys. The specimens were produced from atomised iron powders with different sizes (<45, 45-63, 63-100, 100-150, >150 μm). They were compacted at pressures of 600 MPa and sintered for 30 minutes and 120 minutes at 1150 ºC, respectively. The porosity of the sintered samples was analyzed according to their microstructural characteristics and chemical composition.

KEYWORDS: powder metallurgy, porosity, sintering, microstructure

1. Introduction

Powder metallurgy (P/M) is a metal processing technique of production of metal powders and their consolidation into components with near net shape, helping in this way to save time, energy, material, labor and money [1-3].

In conventional P/M, metal powders are mixed, compacted into molds and sintered in different atmospheres. The products obtained by powder metallurgy (P/M) are widely used, especially in the automotive industry.

One of the main problems in powder metallurgy products is the presence of porosity, but this can be viewed as a consequence of this technique. The porosity in these products can be classified into two types: open and closed porosities. In closed porosity, the pores are isolated within the material and to the external surface of the sample. In open porosity, the pores are represented as a network of pores that are connected one with another and also to the external surface of the sample.

Sometimes, porosity is deliberately produced in the component to meet certain requirements such as filters or bearings. Porosity has influence on the mechanical properties of P/M alloys [4-11].

In this paper, the microstructural characteristics of iron based powder metallurgy alloys were studied.

2. Experimental procedure

Two types of iron powders (P_1 and P_2) produced by the water atomization method in irregular shape were used. The chemical composition of the powders is given in Table 1. The powders were mixed with 1% zinc stearate. The mixed powders were uniaxially compacted in a universal mechanical testing machine at a pressure of 600 MPa to produce cylindrical specimens with the dimensions of 8× 6 mm. After pressing, the compacts were subjected to sintering. The sintering temperature was approximately 1,150 °C.

Two types of treatment cycles were used: the first, with a sintering time of 30 minutes and the second, with the sintering time of120 minutes. Following sintering, the sintered density of the alloys was measured using the geometrical method and image analysis techniques.

Table 1. *Chemical composition of analyzed powders*

Powder type	C	Cu	Ni	Mo
P_1	<0.01	0.09	0.05	0.01
P_2	<0.01	1.50	4	0.50

3. Results and discussion

3.1. Microstructure and density

In Figs. 1 and 4 are presented the optical micrographs of the specimens to analyze the pore size, morphology, and distribution. Also, in Figs. 2 and 5, a 3D view of the surface using Image Jis presented. In the sample with the lowest density, P_1, the pores appeared to be larger and more irregular than the pores in the sample with the highest density,

P_2. The higher fraction of porosity, as well as the larger, more irregular pores for sample P_1 with the lowest density are observable.

The green and sintered densities of the samples were determined from weight and dimensional measurements, which were accurate within the ±0.01 g and ±0.001 mm ranges, respectively (Table 2).

The density of a green part (ρ_g) is calculated by the following relation:

$\rho_g = (m_g / v_g)$, where, m_g is the mass of the green part and v_g is the volume of the green part.

The density of a sintered part (ρ_s) is calculated by the relation:

$\rho_s = (m_s / v_s)$ where, m_s is the mass of the sintered part and v_s is the volume of the sintered part.

3.2. Porosity measurements

Porosity is determined by a couple of processing variables such as: type and amount of alloying elements, powder size distribution, green and sintered density of compacts, temperature and sintering time [6-8].

The usual method for porosity measurement of powder metallurgy products is by density technique. The total porosity of the green compact, in volume percent, is calculated using the following equation: $P_t = 100 (1 – \rho_s/\rho_t) [\%]$ where, ρ_s, ρ_t and ρt are the sintered density and theoretical density.

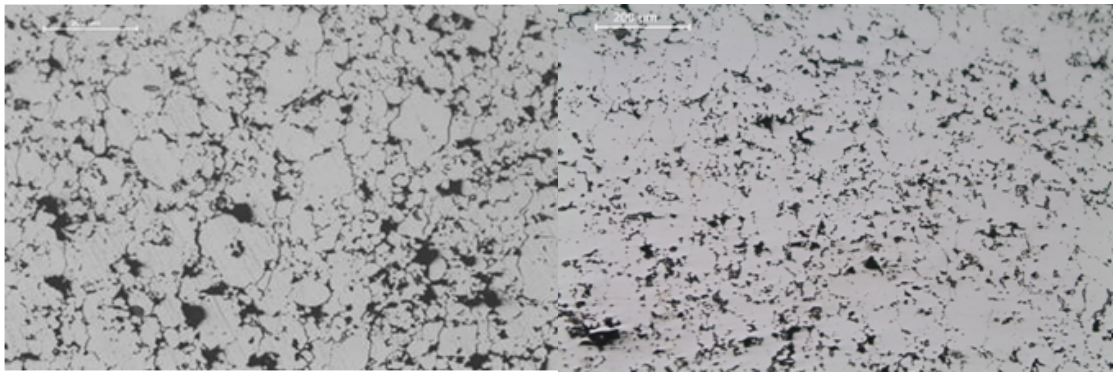
The second method for porosity measurement was using a specialized software for digital image processing, *ImageJ.* By applying filters and adjustments, the software allows the detection of the pores (black areas) and the measurement of their area as percentage.

The porosity measurements of the sintered alloys, achieved using the sintered density technique and by digital image analysis, are shown in Table 2. The porosity measured using image analysis was higher than that resulted from the use of the density technique, because only open porosity is considered in the image analysis technique, whereas closed porosity is not taken into account.

The porosity measured by image analysis software – *Image J* - is depicted in Figs. 3 and 6. Due to the prolonged time of sintering in cycle 2, the pores are smaller and the total porosity is decreasing comparing with cycle 1. Porosity decreases with increasing time.

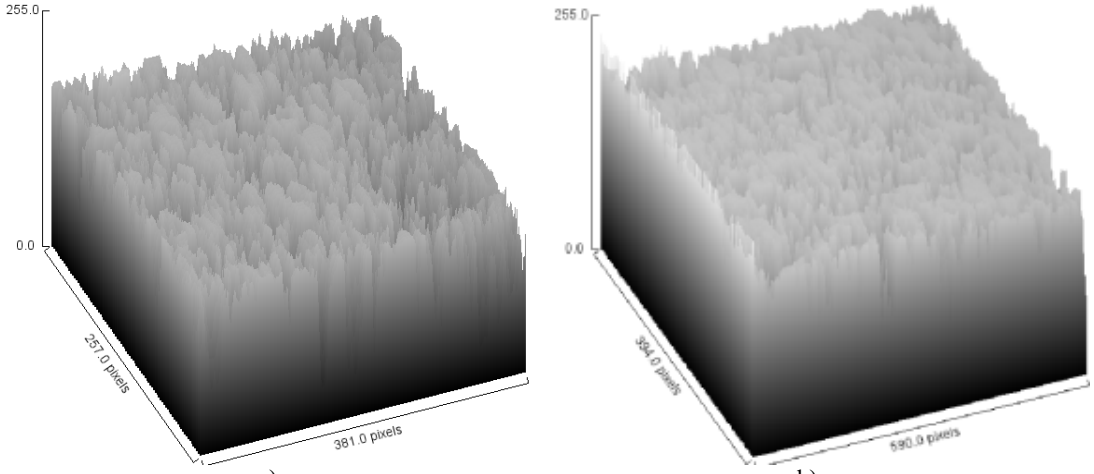
Table 2. *Green and sintered density*

Powder type	Cycle treatment	Green density, (g/cm^3) ρ_g	Sintered density, (g/cm^3) ρ_s	Porosity from sintered density (%)	Porosity from image analysis (%)
P_1	30 min.	6.91	6.93	12.05	14.14
P_2	30 min.	6.95	6.98	11.42	13.29
P_1	120 min.	6.92	7.03	10.78	13.03
P_2	120 min.	6.96	7.10	9.89	10.53



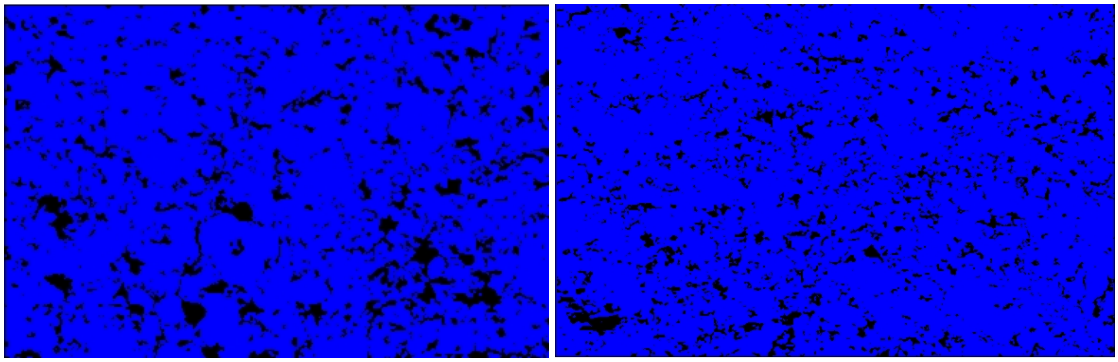
a) b)

Fig. 1. *Optical micrographs of polished surface of samples in cycle 1 of sintering (30 minutes): a) P_1; b) P_2*



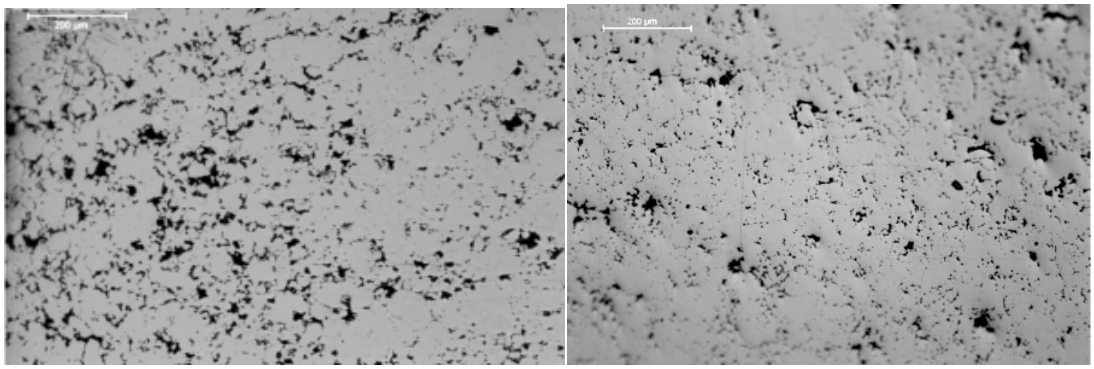
a) b)

Fig. 2. *3D image of the polished surface of samples in cycle 1, obtained using the Image J software: a) P_1; b) P_2*



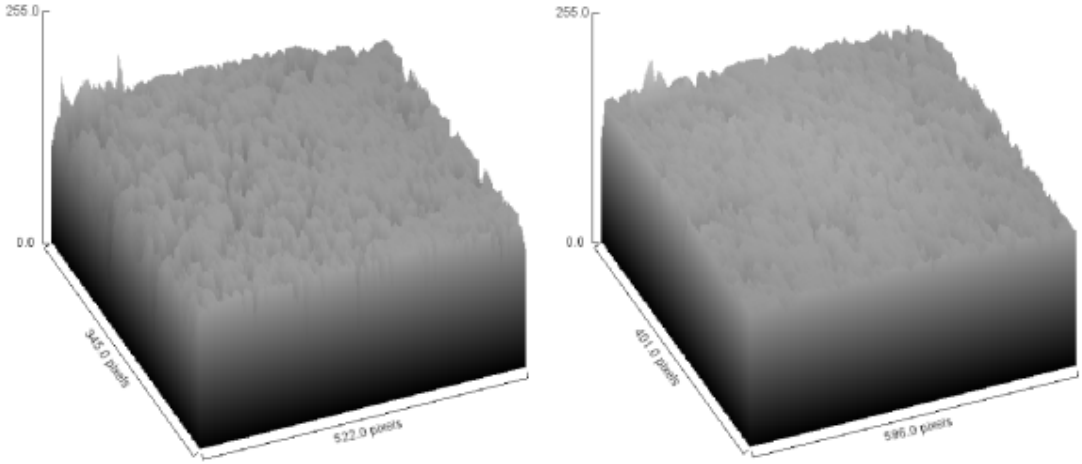
a) b)

Fig. 3. *Image analysis technique using the Image J software to detect porosity for samples in cycle 1: a) P_1; b) P_2*



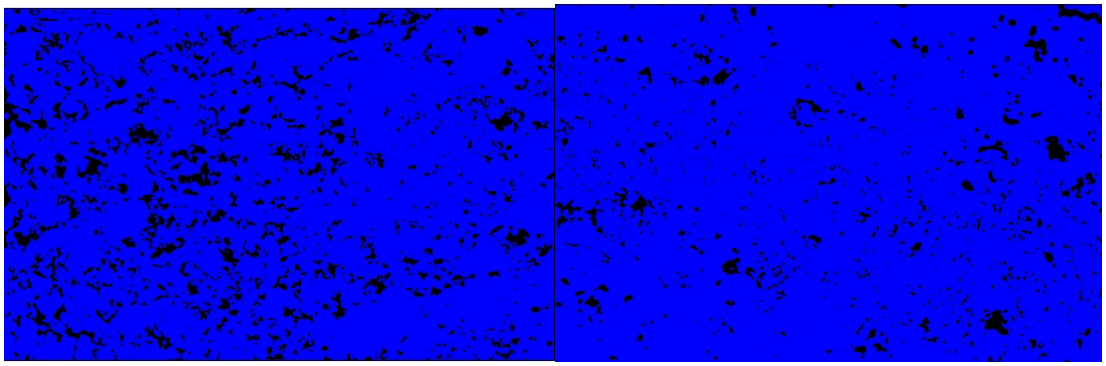
a) b)

Fig. 4. *Optical micrographs of polished surface of samples in cycle 2 of sintering (120 minutes): a) P_1; b) P_2*



a) b)

Fig. 5. *3D image of the polished surface of samples in cycle 2, obtained using the Image J software: a) P_1; b) P_2*



a) b)

Fig. 6. *Image analysis technique using the Image J software to detect porosity for samples in cycle 2: a) P_1; b) P_2*

4. Conclusions

The porosity in P/M parts is correlated to processing parameters such as green density, alloying elements, particle size distribution of the powders, sintering temperature and time.

An increase in the sintered density is correlated with a lower pore fraction, smaller pore size, and more spherical pore shape. Decreased pore size was correlated with an increase in the sintering time [12-16].

The pores in the sample with the lowest density (P_1) appeared to be much larger and more irregular than the pores in the other alloyed sample (P_2).

The porosity measured by image analysis using the *Image J* software is ranging from 10.53% for 7.10 g/cm^3 to 14.14% for 6.93 g/cm^3 in the sintered state. These values were similar to the porosity values computed from the sintered density of the alloys.

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