DETERMINATION OF POROSITY IN FLUIDIZED - BED CARBURIZED P/M COMPACTS USING AN IMAGE SOFTWARE ANALYSIS

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ABSTRACT

The aim of this research was to study the porosity in carburizing in fluidized-bed on sintered alloys produced by powder metallurgy route using an image analysis software and to compare the obtained results with the conventional method for porosity measurements. Porosity is a measure of the void fraction in a material. The total porosity is defined by the ratio of the volume of void space to the total bulk volume of the material, expressed as a percentage. Development of digital images and computer software lead to a new and suitable method to determine the porosity of powder metallurgy materials.

KEYWORDS: powder metallurgy, sintering, fluidized bed carburizing, porosity, image software

1. Introduction

Powder metallurgy (P/M) is an important alternative technology of lower cost process. The main problem of P/M products is the presence of pores due to the fact the pores act as potential crack initiation sites and can also guide and propagate cracks through the material. The conventional P/M processing can produce iron-based P/M parts with a density less than 7.1 g/cm³, so their mechanical properties are considerably less than their full density part obtained by classic metallurgy [1-3]. The properties of sintered P/M alloys can be improved by adding alloying elements [4-7]. The most commons alloying elements added in powder form are: copper, nickel, molybdenum, manganese and phosphorus. Cu increase the toughness and density by filling the pores due to melting during the sintering process (copper melts at 1083 °C) [8-11]. Nickel (Ni) increases the sintered density due to the formation of the Ni-rich areas during sintering in solid state which have a positive influence on hardness and strength by providing a local ductility [12, 13]. Molybdenum (Mo) has a good response in hardenability [14].

Another way to improve the properties of these alloys is by applying heat, thermochemical or mechanical treatments [15-22]. Fluidized bed carburizing is a thermochemical treatment that provides high heat and mass transfer.

The goal of this paper is to study the porosity in some fluidized bed carburizing sintered P/M materials by applying an image software tool and to compare the obtained results with the results obtained by the conventional method.

2. Experimental procedure

The specimens studied in this paper are represented by atomized iron powder and pre-alloyed iron base powder. The chemical composition of the powders, pure iron and iron-based pre-alloyed powder with Cu, Ni and Mo is presented in Table 1. The raw samples were mixed with 1% zinc stearate.

The green compacts, obtained at 600 MPa pressure using a single die action, were sintered in a laboratory furnace at 1150 °C for 60 minutes. The obtained disc specimens have the dimensions of ϕ 8 X 6 mm. After cooling to room temperature, the samples were subjected to fluidized bed carburizing treatment at 900 °C during 60 minutes.
3. Results and discussions

3.1. Density results

The green, sintered and carburized in fluidized bed densities of the specimens were determined using geometrical method, weight and dimensional measurements. The measurements result of the density in green state, sintered and carburized in fluidized bed, measured from by conventional technique are presented in Fig. 1.

![Fig. 1. Green density, sintered and carburized in fluidized bed density for analysed specimens](image)

3.2. Microstructure analysis

The microstructures of fluidized bed carburized samples were observed by optical microscopy (Olympus BX 51M) at 100 X are presented in Figure 2. Examination of Figure 2 shows that the optical micrographs of the carburized in fluidized bed specimen P1 has the pores larger and irregulars than pores in the sample with the highest density, P2.

3.3. Porosity measurements

In Table 2 are presented the porosity measurements of P/M products calculated using the conventional method from density technique. Another method for porosity measurements was using an image processing software tool, Image J. Image J [23] is a free and useful image analysis software tool to analyse using filters, adjustments and Threshold binary function in detection the porosity. In [24-26], Image J was applied to study porosity in sintered P/M specimens. The images acquisition was carried out for non-etched samples using a digital camera coupled to optical microscope. By extrapolation the areas with pores using the function of Thresholding, the program generates the separate image only with porosity and can calculate it in percent. The porosity measurements result of carburized in fluidized bed samples using Image J software are presented in Table 2 and Fig. 3.

<table>
<thead>
<tr>
<th>Powder type</th>
<th>Cu</th>
<th>Mo</th>
<th>Ni</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>P₁</td>
<td>0.096</td>
<td>0.008</td>
<td>0.046</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>P₂</td>
<td>1.50</td>
<td>0.50</td>
<td>1.75</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

**Table 2. The porosity of analysed alloys in carburized in fluidized bed state**
The measurements of porosity resulted from density technique are ranging from 8.91% to 9.85%. The measurements of porosity resulted by using the Image J software are ranging from 10.44% for 6.93 g/cm³ to 11.73% for 6.98 g/cm³. A correlation between higher density and a decreasing in porosity was established. The sample P2 had a lower porosity. Also, the Image J software can generate a 3D image of the surface for the carburized in fluidized bed samples presented in Fig. 4.

**Fig. 2.** Micrographs of the non-etched carburized in fluidized bed samples a) P1; b) P2

**Fig. 3.** Processed images by using the image software for porosity measurements of carburized in fluidized bed samples: a) P1; b) P2

**Fig. 4.** 3D image of the surface for the carburized in fluidized bed samples, obtained using image software: a) P1; b) P2
4. Conclusions

The measurements of porosity in fluidized bed carburized state of analysed samples, using image analysis software - Image J was correlated to the density results obtained by geometrical method.

A correlation between higher density and a decreasing in porosity was established. The sample P2 had a lower porosity.

A correlation between the experimental and software data analysis was established, the porosity measured from image analysis was higher than from density technique due to the fact that only open porosity is considered in the image analysis technique, so the closed porosity is not accounted in the image analysis. An increase in the sintered and carburizing in fluidized bed density of the samples was correlated with a lower porosity and smaller pore size.

References