THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{o}. 4 - 2022, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2022.4.17

THE INVESTIGATION ON DIMENSIONAL STABILITY IN SOME SINTERED POWDER METALLURGY ALLOYS

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ABSTRACT

The subject of this research was to study the effect of sintering time on the dimensional characteristics of some powder metallurgy (PM) materials. The powders used in this study are prealloyed iron-based powders with Cu, Ni and Mo. The powders were single pressed at 600 MPa and the disc specimens have the dimensions of 8-6 mm. The green compacts were sintering in a laboratory furnace at 1150 ºC for 60, 75 and 90 minutes and air-cooled to room temperature. The density of green and sintered specimens, the porosity and the dimensional changes were evaluated.

KEYWORDS: powder, sintering, dimensional stability

1. Introduction

Powder metallurgy (PM) has been regarded as a green manufacturing technology for producing high quality technical components. The conventional PM method (Fig. 1) entails creating a formulated mixture of metal powders, pressing the mixture into appropriate shapes, and then heating (sintering) the compacted powder at a temperature to achieve the desired density and strength [1-3]. The dimensional changes are critical in the production of PM components. An important goal is to manage the dimensional change that occurs during the sintering treatment in order to achieve the required part dimensions. The dimensional changes are influenced by both the powder properties and the process parameters. Several factors influence the dimensional changes of PM products, including particle size, alloying element addition, compaction density, sintering time and temperature [4-6]. The temperature and time sintering process have an impact on the shrinkage of the specimens.

The alloying elements have a significant influence in the chemical composition of the powders, which helps to improve the mechanical properties of sintered parts [7-9]. In theory, sintered steels and conventional steels are both affected in the same way by the alloying elements. In general, all the alloying components increase hardenability. For example, due to its relatively minor impact on compressibility, molybdenum (Mo) is one of the primary pre-alloyed elements utilized in powder metallurgy [10, 11]. Nickel (Ni), as an alloying element, raises the sintered density due to the fact that during sintering, nickel is in solid state and forms the as-called Ni-rich areas in the sintered microstructure, which provide a local ductility [12]. Copper (Cu), increases the strength and hardness when the typical amounts of copper used as an alloying element are 1.5-3 wt.%; any more can cause iron to expand [13, 14]. An investigation regarding the dimensional changes in some iron-based P/M alloys were investigated in this paper.

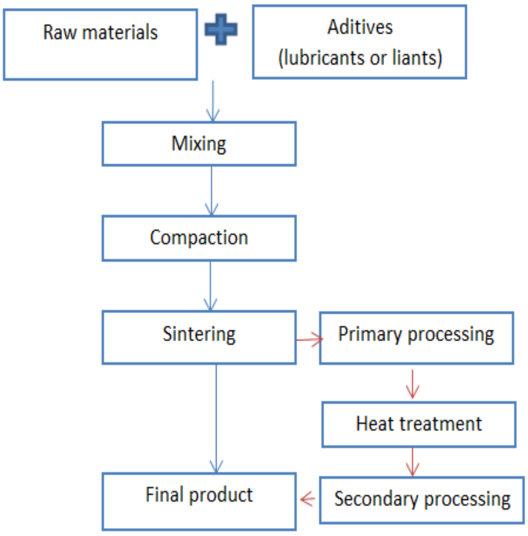

***Fig. 1.** Process flow diagram of powder metallurgy*

2. Experimental procedure

The analysed specimens in this paper were prepared from pre-alloyed iron base powders. In Table 1 is showed the chemical composition of the analysed powders and Fig. 2 provided the particle size distribution of analysed powders. The analysed powders were mixed with zinc stearate 1% as a lubricant. In the next step, the homogenous powders were cold compacted at 600 MPa in cylindrical specimens with ϕ8 x 6 mm dimensions using a uniaxial steel matrix.

***Table 1.** Chemical composition of analysed powders*

Powder type	Cu	Mo	Ni	C
P_1	1.50	0.50	1.75	<0.01
P_2	1.50	0.50	4.00	<0.01

After the compaction step, the green samples were sintered in a laboratory furnace at 1150 °C for 60, 75 and 90 minutes (Fig. 3). The density of green, sintered specimens, the porosity and the dimensional changes were evaluated. The sintered compacts' volumetric dimensional change was calculated, which were accurate to within ±0.01 g and ± 0.001 mm, respectively. All the test results were the average of three experiments.

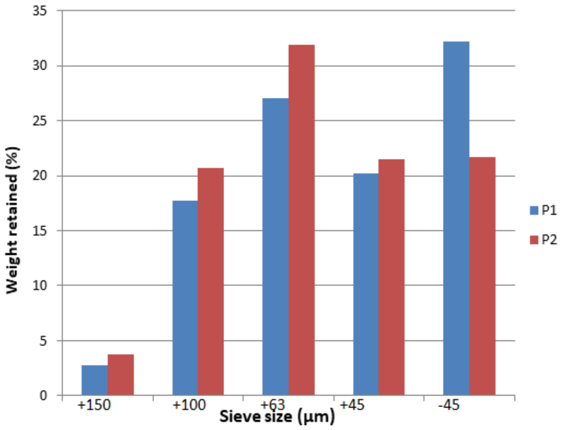

***Fig. 2.** Particle size distribution of analyzed powders*

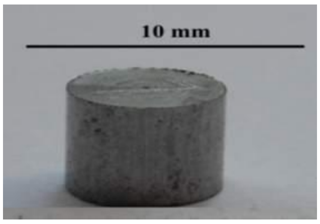

***Fig. 3.** The aspect of sintered sample*

3. Results and discussions

The density and dimensional changes of compacted, green, and sintered specimens were calculated. Table 2 displays the green and sintered density and represents the average values for each set of three samples.

A micrometre with a digital display was used to measure the dimensions of the pressed and sintered samples. The total porosity is defined as the percentage ratio of void spaces to total bulk volume of the material. The conventional method from density technique was used to calculate porosity.

The total porosity of the compact, in volume percent, is calculated using the following equation:

$$P_t = 100\ (1 - \rho_s/\rho_t)\ [\%] \qquad (1)$$

where ρ_s, ρ_t and ρ_t are the sintered density and theoretical density. In Table 3 are detailed the porosity values of the sintered specimens. The processing parameters such as: powder particle size distribution, alloying elements, green density, sintering temperature and time have influence in the porosity of P/M parts [15, 16].

The dimensional change (ΔLDGs) in % for sintered specimens were calculated using the following relation:

$$\Delta LDGs = [(L_S - L_P) / L_P] \times 100\ \% \qquad (2)$$

where: LS is the length of sintered sample and LP is the length of pressed sample, in mm.

The dimensional change analysis (Table 4) shows that the sample P_2 has a smaller dimensional change from die size than P_1. The powder type is the major contributor to the final dimensional change values in this case.

It is critical in powder metallurgy that the dimensional changes of structural parts during sintering be as small as possible. Copper alone can cause dimensional growth when is added to iron, whereas nickel alone can cause contraction [17]. Green density and compaction also have a strong influence. The green densities of two powders mixture compositions are found to be highly related to the applied pressure during compaction, the green density rapidly increasing as the compaction pressure increases.

Table 2. *Green and sintered density of analysed alloys*

Powder type	**Green density, (g/cm^3), ρg**	**Sintered density, (g/cm^3), ρs**		
	pressed at 600 MPa	**sintered at 1150 °C and 60 minutes**	**sintered at 1150 °C and 75 minutes**	**sintered at 1150 ° C and 90 minutes**
P_1	6.72	6.91	7.03	7.08
P_2	6.80	6.98	7.07	7.11

Table 3. *The total porosity of analysed alloys*

State	**Powder type**	**Porosity, (%)**
Sintered state (at 1150 °C and 60 minutes)	P_1	12.31
	P_2	12.11
Sintered state (at 1150 °C and 75 minutes)	P_1	11.76
	P_2	11.43
Sintered state (at 1150 °C and 90 minutes)	P_1	10.95
	P_2	10.31

Table 4. *The dimensional change analysis*

State	**Powder type**	**Dimensional change in sintered state (%)**
sintered (at 1150 °C and 60 minutes)	P_1	-0.06
	P_2	-0.05
sintered (at 1150 °C and 75 minutes)	P_1	-0.06
	P_2	-0.04
sintered (at 1150 °C and 90 minutes)	P_1	-0.04
	P_2	-0.02

4. Conclusions

- When manufacturing PM parts, dimensional accuracy is crucial, especially for parts with near-net shapes;

- Densities in sintered state are ranging from 6.91 to 7.08 g/cm^3 for sample P_1 and 6.98 to 7.11 g/cm^3 for sample P_2. A good compression behavior is observed for samples P_2;

- Sintering does not completely eliminate porosity; rather, it changes it. In comparison to sample P_1, sample P_2 had lower porosity for all sintering times of 60, 75 and 90 minutes;

- The porosity is decreasing with increasing sintering time. The samples with the lower porosity are in the sintered state with a high sintering time of 90 minute and 4% Ni, of 10.31% for P_2 and 10.95% for P_1;

- The shrinkage of the specimen is affected by parameters such as sintering time, but the sintering temperature has a greater influence.

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