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STUDIES AND RESEARCH ON OBTAINING BRONZE FILTERS USING POWDER METALLURGY METHODS

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ABSTRACT

The article presents how to obtain porous bronze products using copper - based powder by powder metallurgy methods. The formation of tablets was done by free pouring the spherical powder into the mould, followed by their sintering them in the range of 780 - 925°C, with an exposure time of 30 minutes. Characterization of the tablets thus obtained was done in terms of microstructure, microhardness, porosity and permeability.

KEYWORDS: powder metallurgy, microstructure, microhardness, porosity, permeability

1. Introduction

A main feature of the powder metallurgy is the possibility that this area offers to create porous materials whose working capacity and operating areas are determined by the characteristics of the porous structure.

Modern applications of powder metallurgy include obtaining special properties parts (permanent magnets, ferrite, electrical contacts, carbon brushes) for the electrical industry, the titanium and beryllium super alloys for the aerospace and nuclear industry, developing hard alloys for metal cutting, manufacturing products of predetermined porosity (filters - 25 - 90%, ball bearings - 8 - 25%) [1].

Porosity of filters must be associated with a high permeability for the filtered environment (gas or liquid) with as high mechanical strength as possible, shock resistance and sufficient corrosion resistance. Most recommended from these points of views are metal filters rather than ceramic or organic, except for corrosion resistance. But this aspect can be remedied by using bronze, nickel, stainless steels [1].

Thus metal filters show a number of advantages:

- Higher resistance to temperature variations;
- Possibility of relatively simple production, providing defined and uniform pore size;
- Goof reproducibility of the filtration properties;
- Easy cleaning in case of clogging.

The basic properties of metal filters are open porosity (passing), pore permeability and active size.

The structural characteristic of the highly porous materials is the intercommunicating porosity, associated with a constant pore size throughout the porous space. Pore sizes range from micron to millimeter order fractions. The method chosen for obtaining porous permeable material is a function of the initial raw material characteristics and determines the porosity, pore geometry and nature of the link between them. Within porous materials there are intercommunicating, sunken and closed pores [2].

The porosity is determined by the shape of the powder particles, the powder particle size distribution, the texture of its surface as well as the processing method [2].

Porous materials obtained by powder metallurgy technology are specified when necessary special features are required such as good mechanical properties, stiffness, corrosion resistance, uniform porosity and controlled permeability. For example, the porous bronze, stainless steel or nickel alloys are frequently selected for making parts operating in high temperature and pressure environments [1-3].

Researches undertaken in this paper are focused on the development of a technology to obtain porous powders products using copper based alloys and their characterization in terms of microstructure, micro hardness and permeability.

2. Experimental conditions

Within experimental research used was of bronze powder with the following chemical composition: 11% Sn; 89% Cu. The powder has a spherical shape determined by gas horizontal atomization. The average particle size of the powder

is 400 μm. The appearance of the copper based powder is shown in Figure 1.

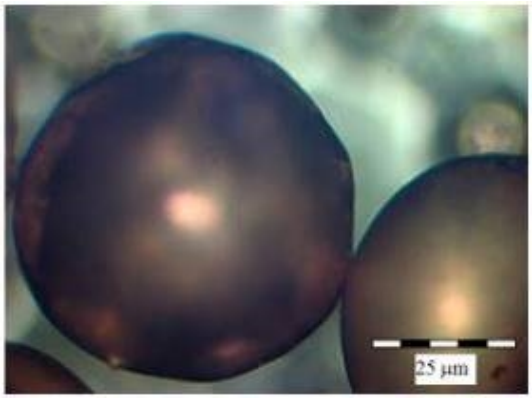


Fig. 1. *Appearance of Cu – Sn powder*

Formation of tablets was done by freely pouring the spherical powder into the mold and its slight compaction by shaking.

The mold used is made of graphite and is of cylindrical shape with the dimensions 23.9 X 9.8 X 18.5 mm.

The specific forming method chosen is specific for obtaining porous products such as filters, as it can give them various degrees of compaction regardless of the shape and size of the products and being at the same time an economical method.

Sintering of the powder tablets was made in a laboratory electrical furnace, and the regimes achieved are shown in Table 1.

Microscopic analysis of the powder and products obtained was performed using an optical microscope Neophot 2 with computerized data acquisition.

Table. 1. *Sintering regimes*

Sample code	Sintering temperature [°C]	Sintering time [s]	Size of powder tablets	
			Diameter [mm]	Height [mm]
P1	900 - 925	1800	3.85	6
P2	830 - 860		4.2	5.9
P3	800 - 830		4.2	5.6
P4	780 - 800		4.2	7.5

To study the influence of sintering on powders tablets, porosity of the samples was determined by the segments method.

Determination of hardness was performed using a micro hardness tester PMT 3.

Determination of the permeability of the obtained products was done using a lab plant, Fig. 2, wherein the fluid sample was air.

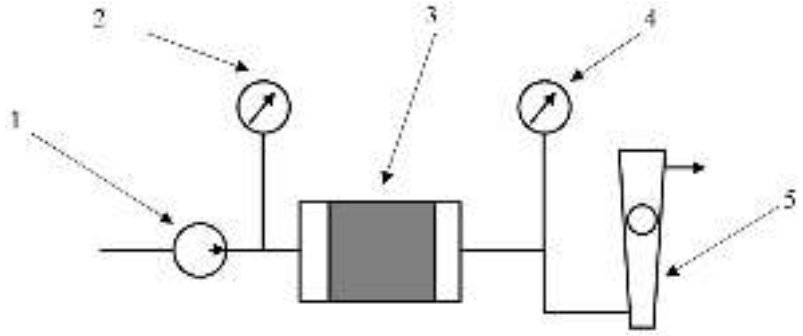


Fig. 2. *The lab plant for determination of the permeability: 1 - membrane pump; 2 - manometer 1; 3 - capsulated sample; 4 - manometer 2; 5 - flow-meter with floatable*

Permeability is the ability of a filter to be passed by a fluid when subjected to a pressure gradient. The permeability unit is 1 darcy which corresponds to the case where a fluid in laminar condition with a viscosity of 1 centipoise, has a rate of 1 cm^3/s through a cross section of 1 cm^2 of the filter under the influence of a pressure gradient of 1 at, over 1 cm thick material, (1 darcy = $0.9869 * 10^{-8}$ cm^2) [3].

The eq. used is:

$$\Phi = \frac{s \cdot \eta \cdot q}{A \cdot (p_1 - p_2)}$$

where:

Φ - permeability in darcy units;

s - material thickness, in cm;

η - test fluid viscosity, in centipoise (1 cp = 10^{-3} Pa*s);

Q - flow rate of average pressure p, in cm^3/s;

p_1 - absolute pressure immediately upstream the fluid material, in at, 1at = 10^5 Pa = 100 kPa;

p_2 - downstream absolute pressure, in at;

A - effective surface of the filter in cm^2;

3. Results and discussions

For a metallographic study, the powder was incorporated into a cyanoacrylate adhesive and metallographic ally prepared by polishing and chemical attack with ferric chloride reagent (5 g ferric chloride, hydrochloric acid 30 ml, 100 ml water) and then examined under a microscope Neophot 2 with computer image acquisition.

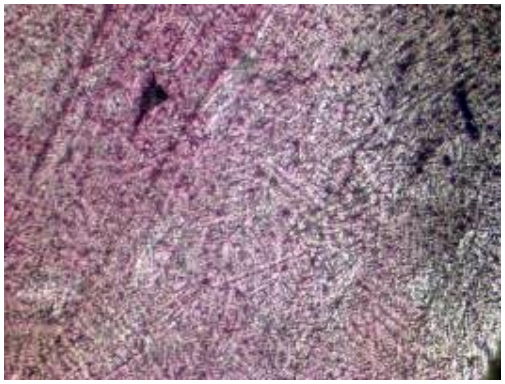


Fig. 3. *Microstructure of the Cu – Sn powder, attacked by ferric chloride reagent*

Microscopic analysis on particles embedded, polished and attacked with ferric chloride highlights their spherical shape and good compactness. It shows the microstructure of the Cu – Sn particles, resulting from the atomization process, consisting of a very fine dendritic solid solution α of Sn in copper as shown in Fig. 3.

Micro hardness determined on polished attacked section of the particles under load of 50 g was HV0.05 = 1600 MPa.

The metallographic analysis performed on powder tablets Fig. 4 suggests that the increase in temperature results in the reduction of porosity.

The sample P1 due to the high sintering temperature it was reported the presence of the liquid phase, which resulted in a stronger compaction.

At lower temperatures, corresponding to samples P3 and P4, sintering did not occur properly, which resulted in a low cohesion of the powder particles and their detachment during preparation of the samples.

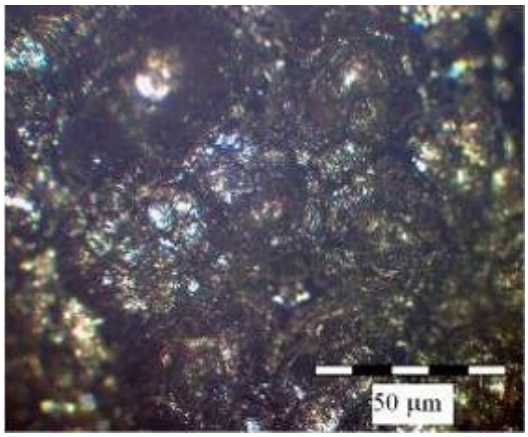
The optimum sintering regime is that corresponding to sample P2, which resulted in a proper porosity and good mechanical strength of the tablet.

Figure 5 - 8 illustrate 3D images, made with the software Image J, of the powder tablets after sintering [4-6].

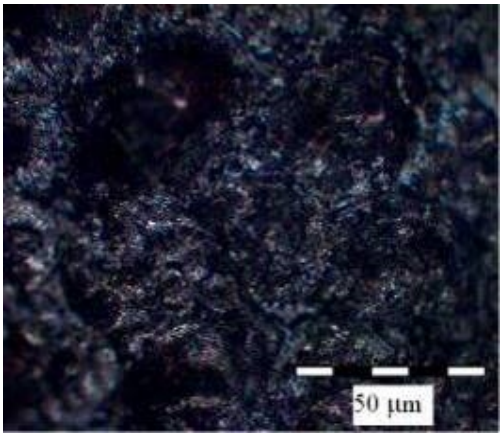
Looking at Fig. 5 - 8 it can be noticed the presence of a smoother surface of the sample P1 due to the occurrence of the liquid phase, with high toughness and low porosity.

Sample P2 has a homogeneous surface with a good bond between the powder particles.

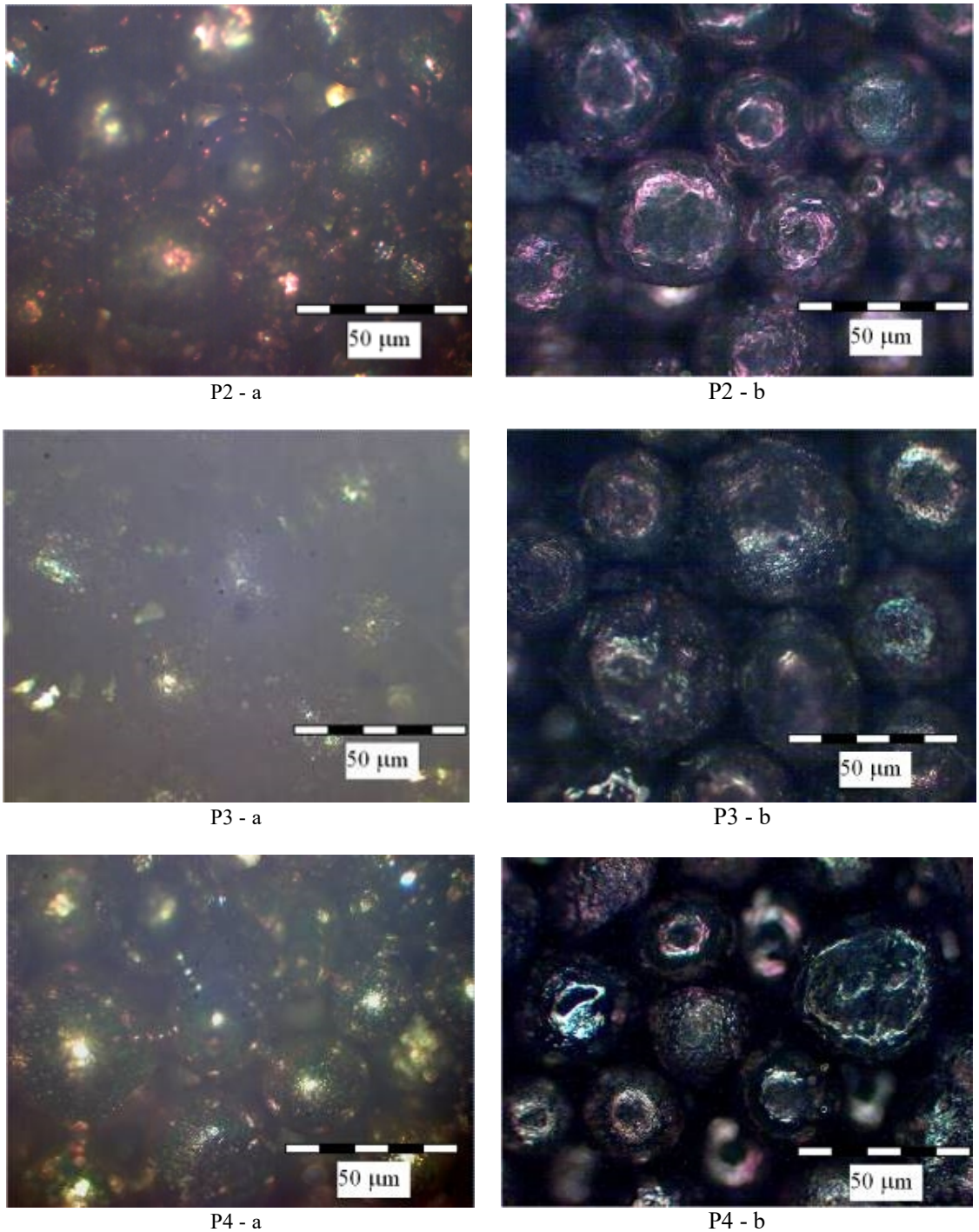
Samples P3 and P4 shows a heterogeneous surface with a weak bond between the powder particles.



P1 - a



P1 - b



P2 - a P2 - b

P3 - a P3 - b

P4 - a P4 - b

Fig. 4. *Imagine of powder tablets to different temperatures: a - bright field, b - dark field*

Decrease of temperature prevents the formation of contact-bridges between particles, which leads to low cohesion and poor strength of the powder tablets.

The microscopic analysis performed on the sintered samples with the microscope Neophot 2 revealed the existing porosity and their microstructure.

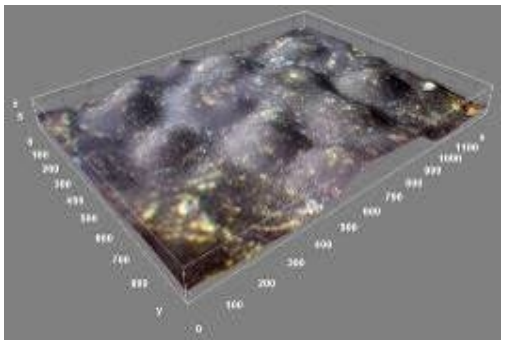


Fig. 5. *3D image of sample P1 surface after sintering*

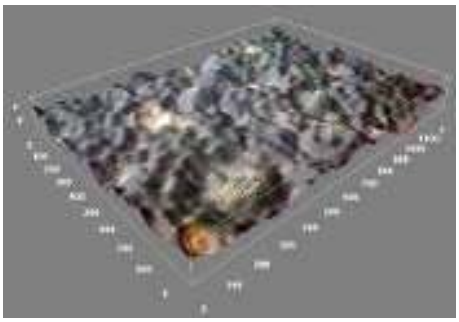


Fig. 6. *3D image of sample P2 surface after sintering*

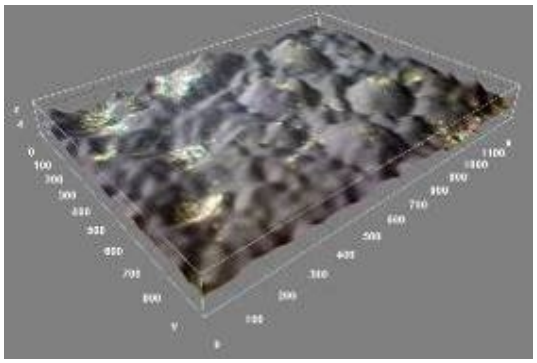


Fig. 7. *3D image of sample P3 surface after sintering*

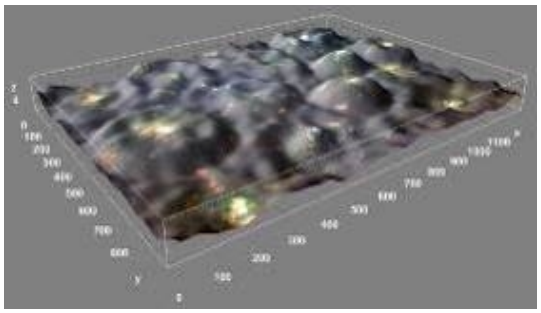
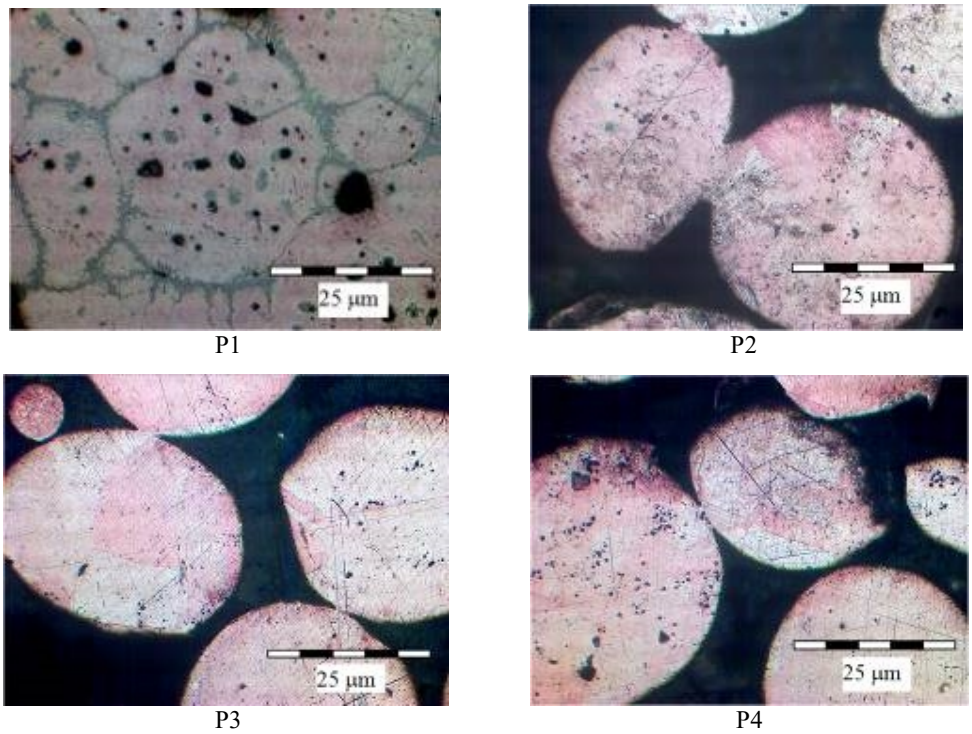


Fig. 8. *3D image of sample P4 surface after sintering*



P1 P2

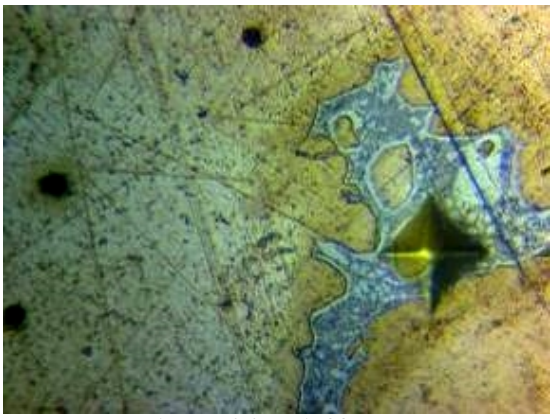
P3 P4

Fig. 9. *Microstructure of sintering samples, attacked by ferric chloride reagent*

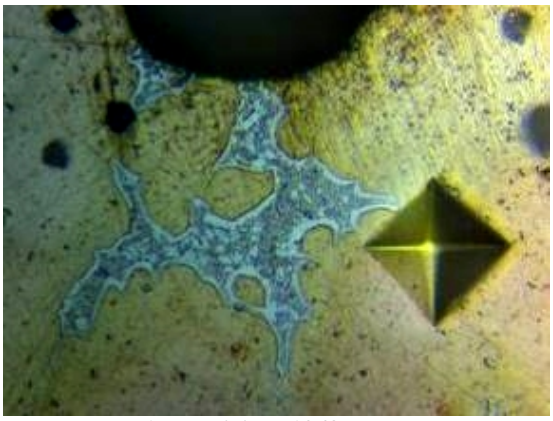
From Fig. 9 it is noted that sample P1 on which the sintering was carried out within the temperature range 900 – 925 °C, the structure consists of a solid solution α (HV 0.05 = 1060 MPa) and a mechanical mixture of the eutectoid phase composed of α and δ phases. The presence of eutectoid micro hardness of 1528 MPa increased the micro hardness in the immediate area consisting of solid solution α, this reaching HV 0.05 = 1368 MPa. These issues are highlighted in Fig. 10.

For the sample P2 sintered in the range of 830 – 860 °C the structure consists of macled solid solution α. It is found contact-bridges between powder particles which resulted in a high mechanical strength.

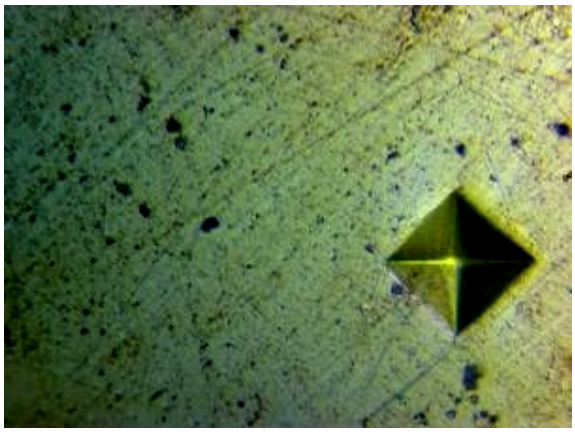
As the sintering temperature decreases, the formation of contact-bridges between the powder particles is reduced which results in reduced resistance of the powder tablets. Tablets structure is no longer altered consisting of macled solid solution α.



P1 - HV 0.05 = 1528 MPa



P1 - HV 0.05 = 1368 MPa



P4 - HV 0.05 = 1028 MPa

Fig. 10. *Determining powder tablets micro hardness*

It can be seen that for sample P1, the presence of eutectoid determines hardening of the powder tablets while for P2, P3, P4 tablets, hardness values are relatively close, respectively HV 0.05 = 1031 MPa, 1020 MPa, 1028 MPa.

Regarding the powder tablets porosity from the measurements made the following values were obtained: P_{p2} = 44.4%, P_{p3} = 50%, P_{p4} = 49.2%.

With sample P1 due to the occurrence of the liquid phase porosity was more reduced, in the range 5-10%.

Permeability of powder tablets determined with a laboratory facility and using air as test fluid showed the following values: Φ_{p1} = 5.55 darcy, Φ_{p2} = 42 darcy, Φ_{p3} = 48 darcy, Φ_{p4}= 54.86 darcy.

It was thus found that, except for sample P1 where the high sintering temperature resulted in the

formation of the liquid phase and thus the porosity was more reduced, all other samples showed a high porosity (greater than 25%), specific to filters and an adequate permeability of these products.

4. Conclusions

Obtaining porous sintered products revealed the following:

- ❖ tablet formation was achieved by free pouring of the spherical powder into the mold and its slight compaction by shaking it;
- ❖ powder tablets sintering was performed in the range 780 - 925 °C, exposure time 30 minutes; it was found that the increase in temperature leads to the reduction of porosity and increased compactness;
- ❖ Decrease of temperature prevents the formation of contact-bridges between particles, which leads to low cohesion and poor strength of the powder tablets;
- ❖ tablets powder microstructure consists of macled solid solution α of tin in copper;
- ❖ with sample P1 sintered in the range 900 - 925 °C it was found, in addition to the solid solution α, the presence of a mechanical mixture eutectoid phases consisting of α and δ which determined the hardening of the powder tablets;
- ❖ micro hardness HV 0.05 determined on the powder sintered tablets was within the range 1020 to 1060 MPa;
- ❖ 3D analysis of the tablets obtained, carried out by Image J software, highlights their surface appearance; it was found that the surface inhomogeneity increases with decreasing sintering temperature; this was due to the decreased cohesion between particles;
- ❖ porosity of powder tablets studied using the segments method showed the following values: P_{p2} = 44.4%, P_{p3} = 50%, P_{p4} = 49.2%; with sample P1, due to the occurrence of the liquid phase, porosity was more reduced in the range 5-10%;
- ❖ powder tablets permeability determined by a laboratory facility and using air as test fluid showed the following values: Φ_{p1} = 5.55darcy, Φ_{p2} = 42 darcy, Φ_{p3} = 48 darcy, Φ_{p4} = 54.86 darcy.

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