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RESEARCH ON THE PRODUCTION OF SINTERED POWDER 316

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ABSTRACT

The 316 austenitic stainless steel powders are typically used in applications requiring good corrosion resistance, mechanical strength at high and very low temperatures, good ductility, wear resistance, associated in some cases with adequate porosity. The paper presents some experimental research on the production of sintered 316 stainless steel powders and their characterization in terms of microstructure and wear resistance.

KEYWORDS: powder metallurgy, 316 stainless steel, abrasive wear

1. Introduction

The increasing development of the technology for obtaining parts by powder metallurgy and extend their scope of application is due to the advantages presented [1, 2, 3, 7, 8]:

- full use of raw materials compared to other manufacturing processes that use the material at a rate of 50%;
- low energy consumption;
- complex shapes parts obtained, with high accuracy and good surface quality, elimination of mechanical processing needed for other manufacturing processes;
- high reproducibility, even for complicated parts in terms of shape;
- flexibility in design and manufacturing;
- isotropic properties due to structure;
- superior mechanical properties: high hardness, up to 60-65 HRC, ultimate and impact strength, good wear resistance and elongation properties, resistance to fatigue;
- fine and controlled structure;
- new unique properties, related to pore structure and represented by the self-lubricating and filtering abilities;
- low cost of large series fabrication compared to forging, casting or cutting technologies.

The technological process of manufacturing sintered parts includes the following phases:

- obtaining powdered materials;
- making homogenous the powder or powder mixture with the desired chemical composition;
- obtaining tablets of metal powders by pressing or other means;
- presintering and sintering of powder tablets at high temperatures in a protective atmosphere;
- secondary operations: calibrating the sintered parts, machining or other finishing processes of the sintered parts, oil or easily fusible alloy impregnation of the sintered parts;
- reception and control of the sintered products.

Special attention has been paid in recent years to obtain products of high corrosion-resistant steels with ferritic or austenitic structure.

The 300 series austenitic alloys are typically used in applications requiring good corrosion resistance, mechanical strength at high or very low temperatures, good ductility, wear resistance, associated in some cases with an adequate porosity (filters) [4, 5, 6].

The 316 austenitic stainless steel powders are designed for manufacturing various parts in machine manufacturing industry (valves, gears), in the petrochemical industry (filters, test probes), the energy, food, medicine, and photographic industries.

With austenitic stainless steels, nickel along with chromium are the main alloying elements. The influence of Ni is opposed to that exercised by Cr, so that with increased Ni content there is an extension of the γ range and a narrowing until progressive disappearance of the range α and $\alpha + \gamma$.

Nickel is dissolved in Fe γ and extends the life range by acting on the lowering of temperatures below the critical transformation points.

According to specialized references [9, 10] nickel causes in stainless Cr-Ni steels two important phenomena:

*the extension of the austenitic range and increased austenite stability;

*the stabilization of phase σ (FeCr) at high temperatures and its occurrence at lower concentrations in chrome, as compared with stainless steels alloyed only with chromium.

In the case of a steel containing a major amount of Ni (8-13%), the mixed range (α + γ) occurs with a low carbon content and high temperatures (1400 °C) and the austenitic field becomes very large.

Nickel also contributes to better corrosion performance: resistance to corrosion in air, sea water and acids.

Molybdenum increases the corrosion resistance (pitting) in H_2SO_4 solutions, chloride and organic acids. This paper presents some experimental research on the production of sintered powder 316 stainless steel products and their characterization in terms of microstructure and wear resistance.

2. Experimental conditions

To obtain sintered parts, a powder of 316 austenitic stainless steel with the following chemical composition was used: 0.03%C; 17.1%Cr; 12.09%Ni; 0.51%Si; 2.5%Mo; 0.84%Mn; 0.012%S; 0.03%P; rest Fe.

Fig. 1. shows the aspect of 316 austenitic stainless steel powder.

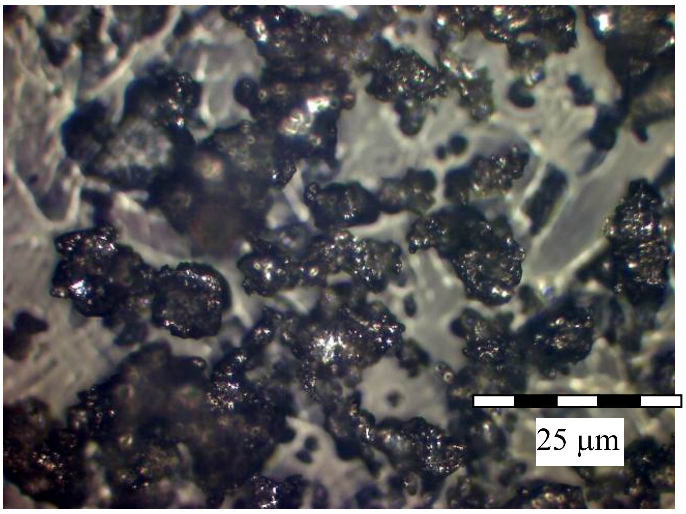


Fig. 1. *Aspect of 316 austenitic stainless steel powder*

The 316 stainless steel powder in Figure 1 has an irregular shape specific to water atomisation.

The microhardness determined on the polished section of the particles under a load of 50 g was $HV_{0.05}$=939.6 MPa.

The pressing process used was cold pressing, with universal machine for mechanical tests. The 316 powder compaction pressures used were 540, 628, 726, 863 MPa. Compact samples are cylindrical with dimensions of approximately 8x6 mm. The powder tablet sintering was carried out in an electric oven. The sintering temperature was 1150°C and the exposure time to this temperature was 60 minutes. The samples were placed in a ceramic cylinder, where graphite was added.

Graphite has an important role in the cooling stage to prevent air intake in the cylinder, thus providing protection to the atmosphere. After sintering, all samples were cooled slowly.

The main purpose of sintering is to reduce porosity. The sintering process is often accompanied by changes in the material, some of them desirable, others not so: changes occur in the mechanical strength, hardness; particle size and shape are affected; there is variation in pore shape and size, the chemical composition and crystalline structure may change too due to the appearance of the chemical reaction processes in solid phase.

The microscopic analysis of sintered samples was performed by a Neophot 2 microscope with computer data acquisition.

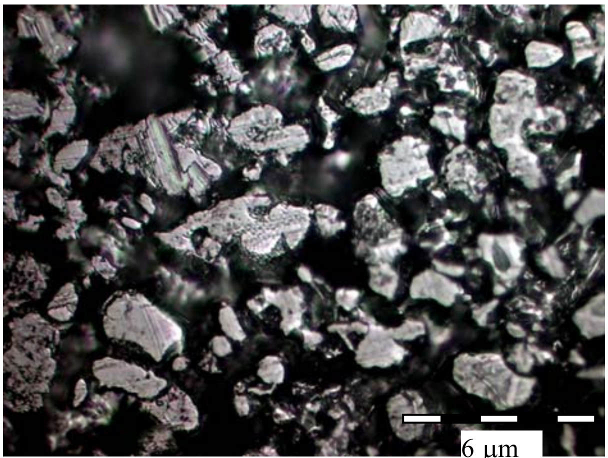
$HV_{0.1}$ microhardness determined on the sintered powder tablets was conducted on a PMT-3 microhardness meter of 100g load.

316 stainless steel sintered samples were subjected to wear test on a rotary disk with sand paper. The method consists in the successive pressing, under identical conditions, of two 8x6mm samples onto a rotating disk covered with 120 grit sand paper. A radial displacement mechanism of the specimen with 0.5 mm / rev provide spiral running on the rotating disc surface. A device for applying a load

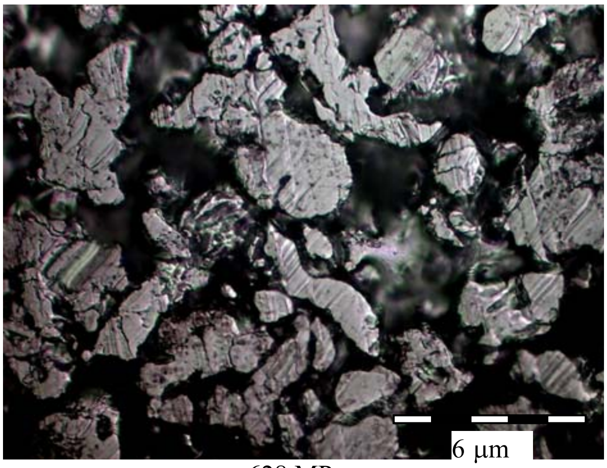
of 6.229 N provides perpendicular pressing of the specimen on the sandpaper to 0.123 N/mm^2 pressure. At a disk speed of 25 rev/min, a length of 11.6 m was run.

3. Results and discussions

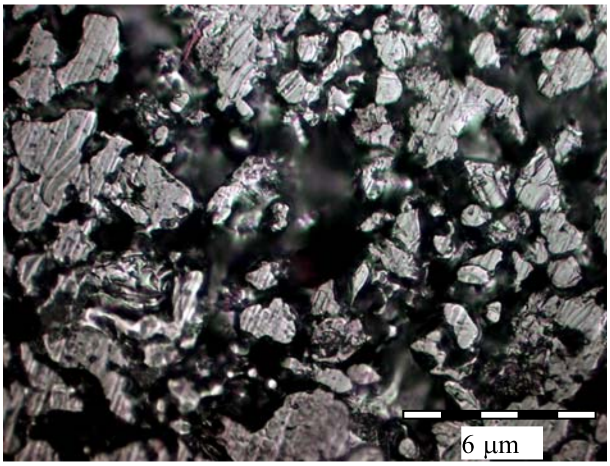
The microscopic analysis of the pressed tablets performed with a Neophot 2 microscope reveals the presence of pores and their shape (Fig.2).



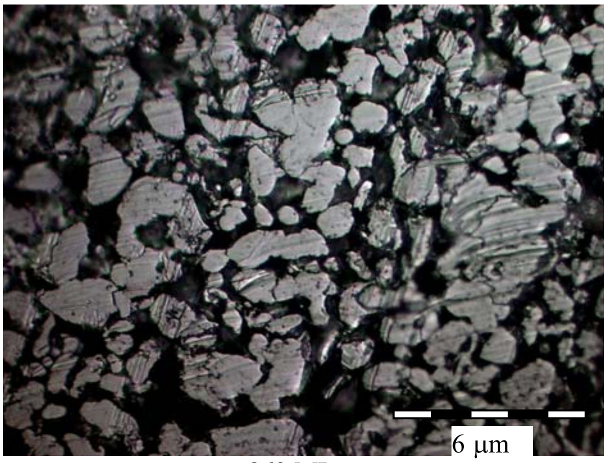
540 MPa



628 MPa

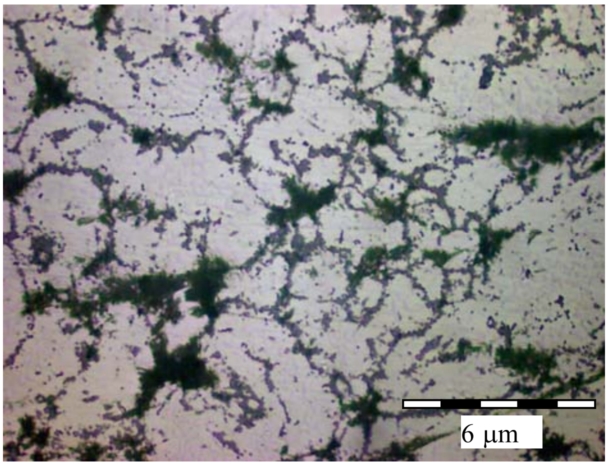


726 MPa

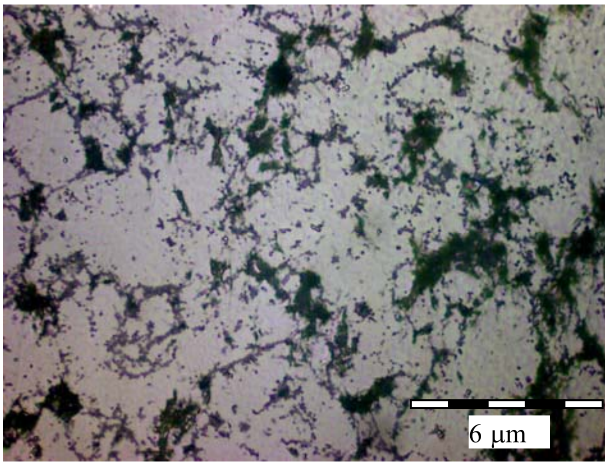


863 MPa

Fig. 2. *Microstructure of 316 stainless steel at different pressures*



540 MPa



628 MPa

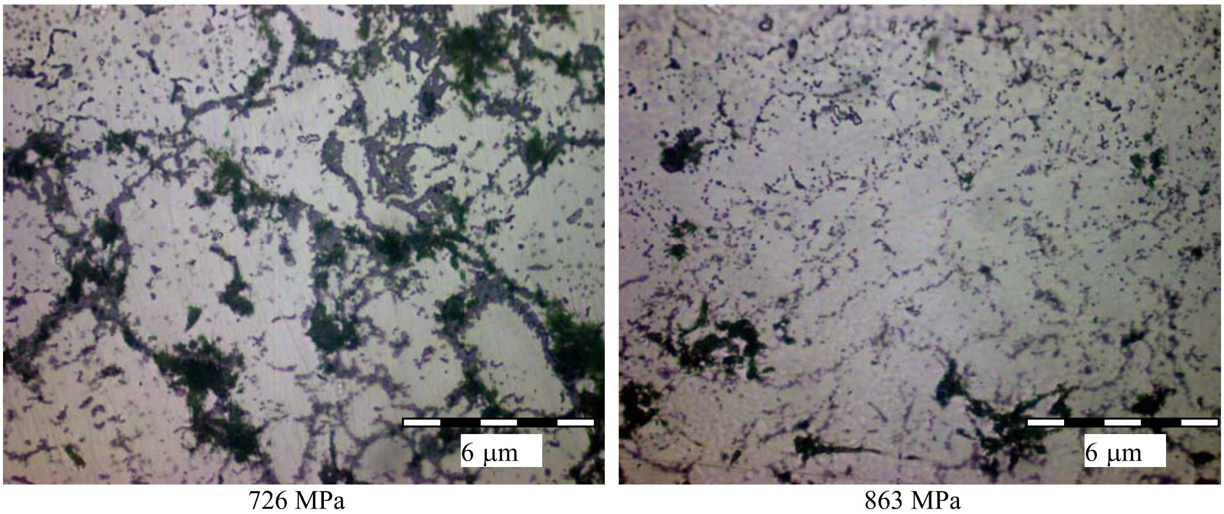


***Fig. 3.** Microstructure of 316 stainless steel samples, attack-free*

Fig. 2 shows that porosity decreases with increasing pressure. The microscopic analysis performed on the sintered samples with a Neophot 2 microscope is illustrated in Fig. 3.

Fig. 3 it shows that porosity decreases with increasing pressure. The microstructure of the sintered samples under electrolyte attack with 50% HNO_3 solution is presented in Fig. 4.

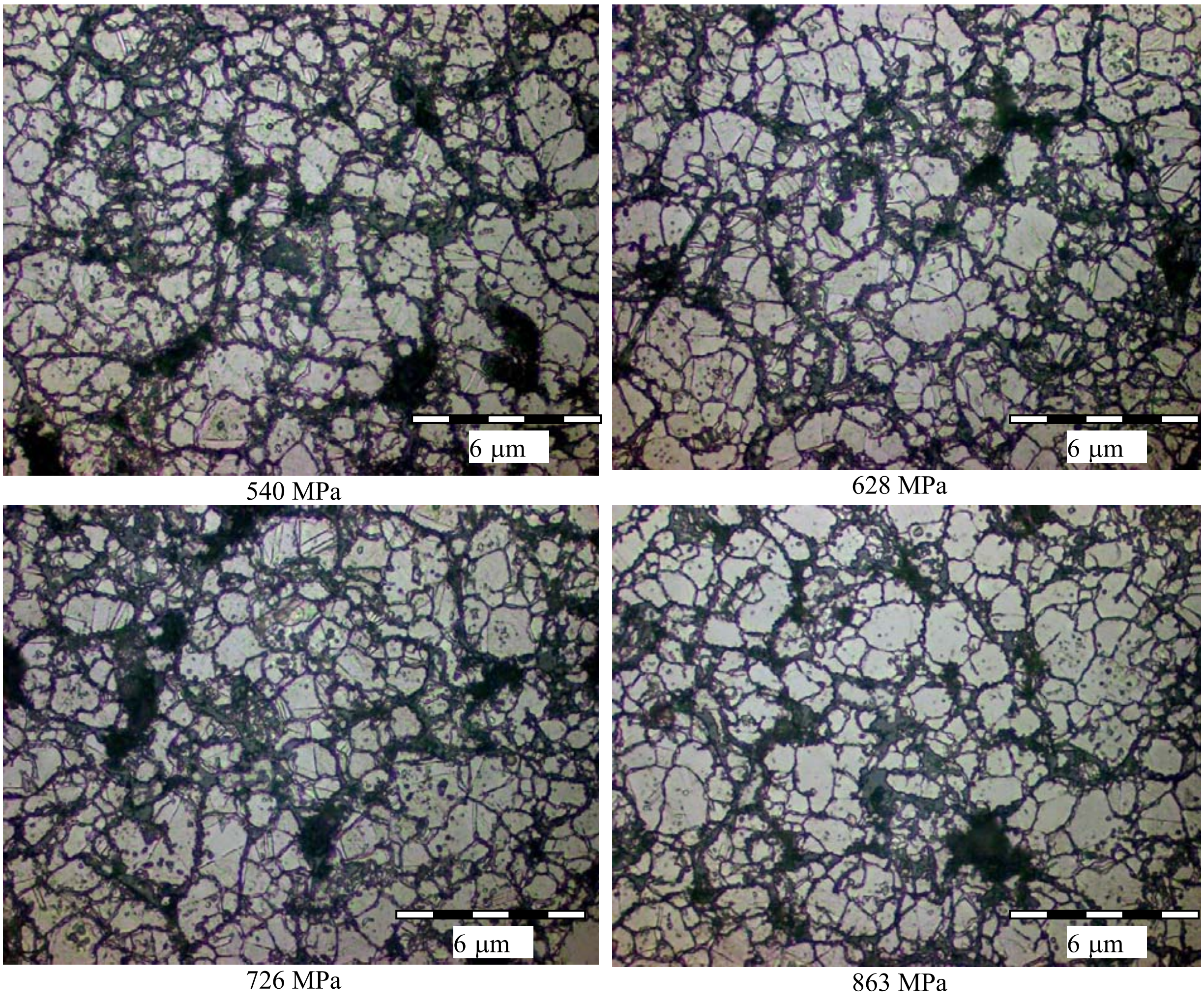


***Fig. 4.** Microstructure of sintered 316 stainless steel, electrolyte attack, solution 50% HNO_3*

From Fig. 4 shows the microstructure of the samples consists of austenite. The $HV_{0.1}$ microhardness determined on samples of sintered powder was $HV_{0.1}$= 3120.2 MPa, Fig. 5. The 316 stainless steel sintered samples were subjected to wear test on rotary disk with sand paper.

The results, as average of three determinations, are presented in Table 1. Analyzing Table 1 and Fig. 6 one can say that the 316 stainless steel powder is recommended to be pressed at pressures higher than about 863 MPa to ensure superior resistance to wear. Pressing at low pressure leads to a lower compaction which results in lower wear resistance. The sample porosity was determined by the linear segments method. Porosity variation *vs.* formation pressure is presented in Fig. 7. It can be seen that with increased pressure porosity is reduced both in the middle of the samples and at their edge.

Wear variation *vs.* average porosity is presented in Fig. 8. It can be seen that with decreasing porosity the wear resistance increases. In Figs. 9–12, 3D images are presented made with an Image J software, of the 316 powder sample areas obtained from the abrasive wear test.

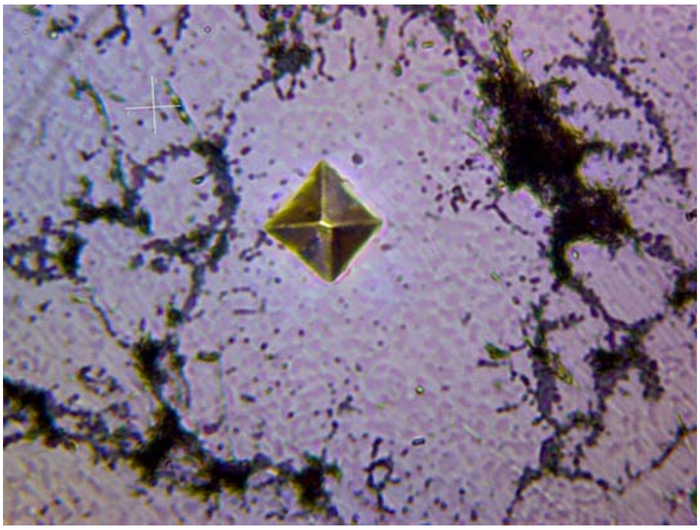


Fig. 5. *Determining microhardness of 316 stainless steel samples*

Table 1. *Abrasive wear behavior of sintered powder products*

Pressure	**Mass wear**	**Length run**	**Wear/ length run**
[MPa]	[g]	[m]	[g/m]
540	0.0141	11.6	0.001224
628	0.0122	11.6	0.001052
726	0.0117	11.6	0.001009
863	0.0113	11.6	0.000974

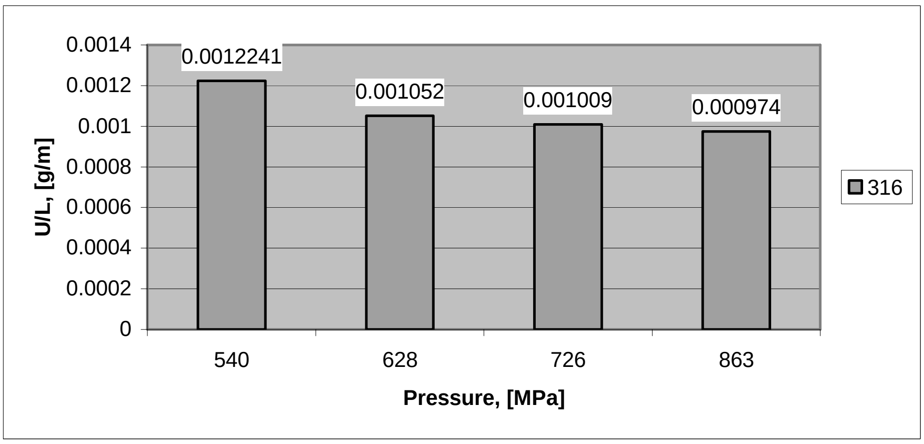


Fig. 6. *Abrasive wear behavior of sintered powder products*

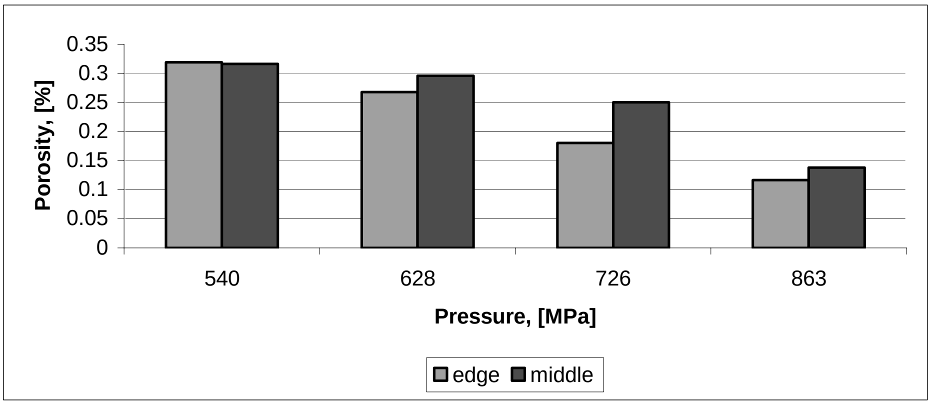


Fig. 7. *Porosity variation with formation pressure*

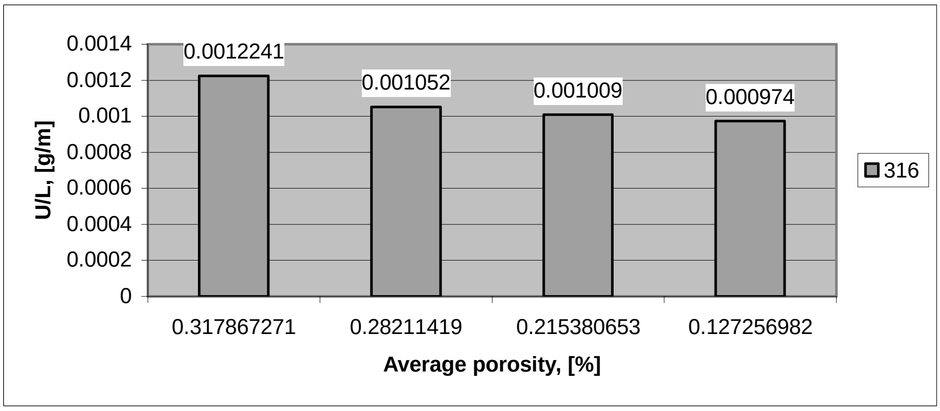


Fig .8. *Wear variation vs. average porosity*

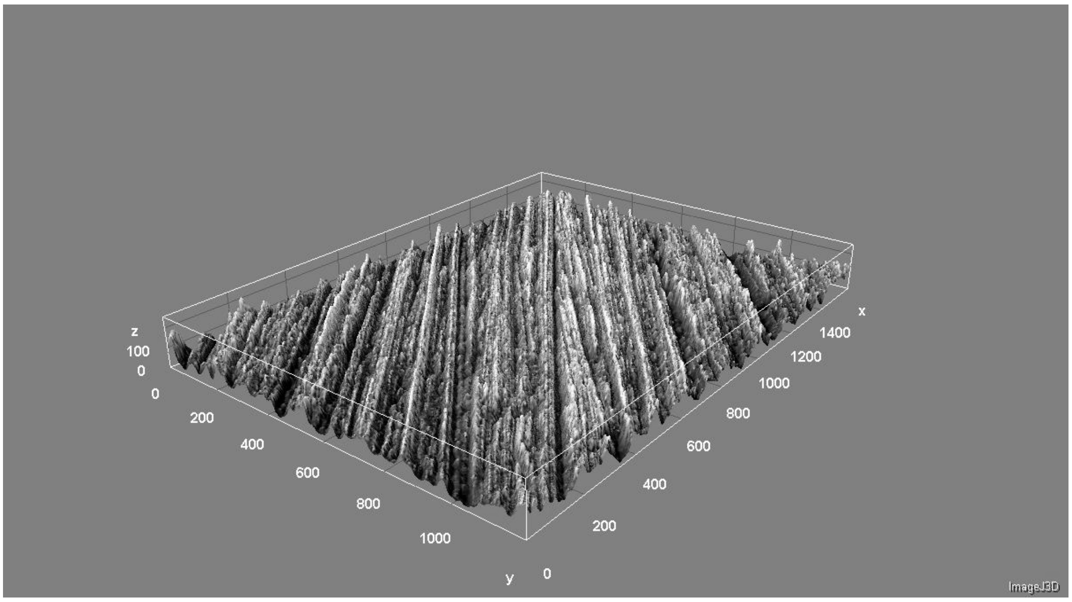


Fig. 9. *3D image of the sample surface pressed with 540 MP subjected to abrasive wear*

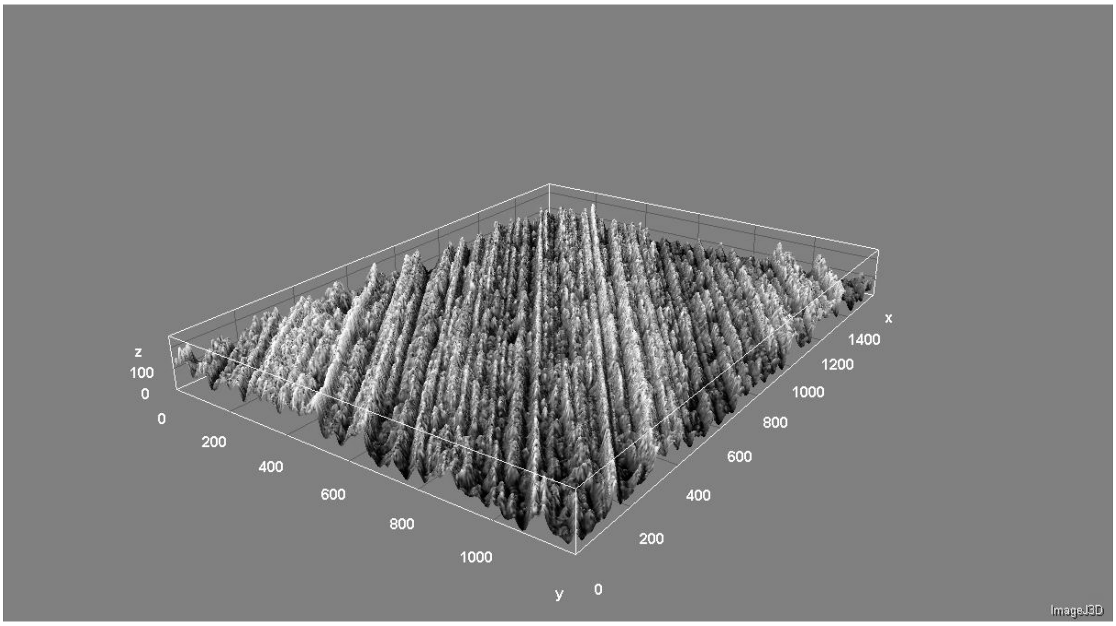


Fig. 10. *3D image of the sample surface pressed with 628 MPa subjected to abrasive wear*

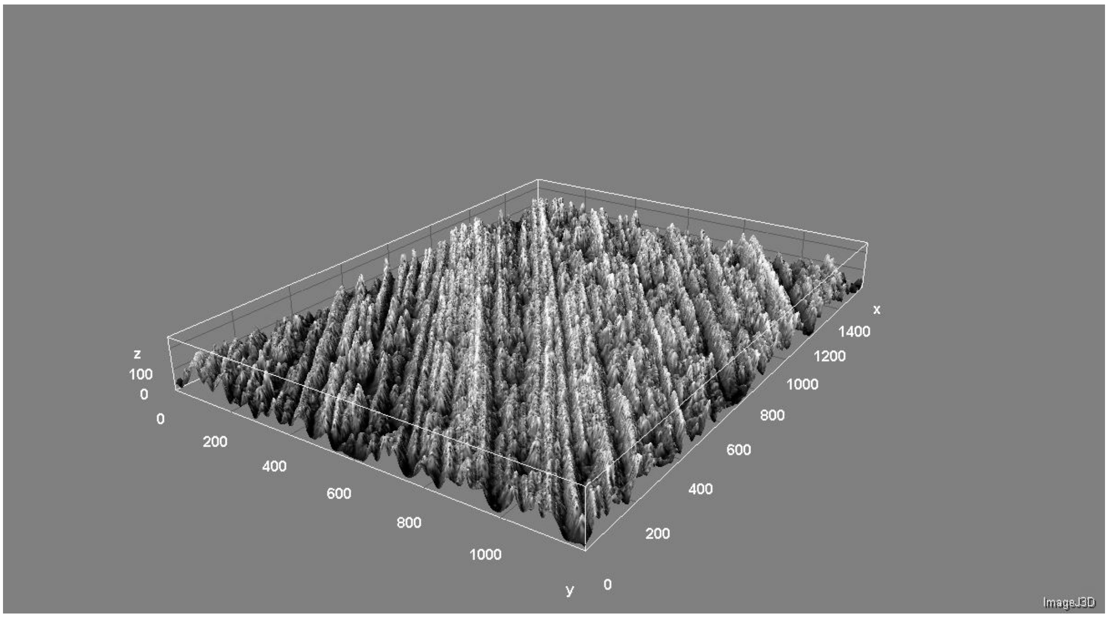


Fig. 11. *3D image of the sample surface pressed with 726 MPa subjected to abrasive wear*

Analyzing the previous images one can notice a good wear behavior of the samples pressed at higher pressures.

4. Conclusions

The production of 316 austenitic stainless steel powders revealed the following:

* the powder used in the experimental research has an irregular shape specific to water atomisation, suitable for conventional compaction in mold and sintering at a theoretically higher density;

* the pressures used for 316 powder compaction were 540, 628, 726, 863 MPa;

* it was found that increased pressure leads to reduction in tablet porosity;

* sintering of powder tablets at 1150°C, for one hour has reduced their porosity;

*samples microstructure consists of austenite;

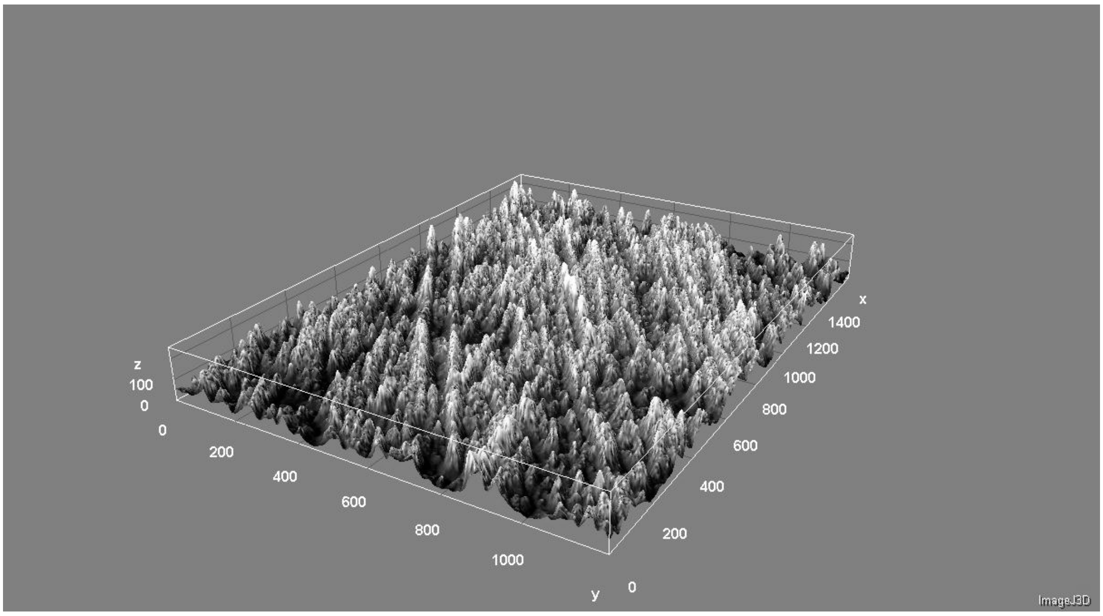


Fig. 12. *3D image of sample surface pressed with 863 MPa subjected to abrasive wear*

* $HV_{0,1}$ microhardness determined on sintered powder tablets was HV 0.1 = 3120,2 MPa, higher than the initial state powder;

* as regards the abrasive disk wear resistance it was found that 316 stainless steel powder is recommended to be pressed at pressures higher than about 863 MPa to ensure superior resistance to wear.

* pressing at low pressure leads to a lower compaction resulting in decreased wear resistance.

References

[1]. H. N. Ch'ng, J. Pan - *Modelling microstructural evolution of porous polycrystalline materials and a numerical study of anisotropic sintering*, J. Comput. Phys. 204, 430–461, Journal of Computational Physics, Volume 204, Issue 2, 20, (2005).

[2]. D. Bernard, D. Gendron, J. M. Heintz, S. Bordere, J. Etourneau, *First direct 3D visualisation of microstructural evolutions during sintering through X-ray computed microtomography,* Acta Materialia 53, (2005).

[3]. Y. V. Levinsky - *The Behavior of Closed Pores at the Final Stage of Sintering*, ISSN 1067-8212, Russian Journal of Non-Ferrous Metals, Vol. 50, No. 3, pp. 298–316. © Allerton Press, Inc., (2009).

[4]. Deleanu L., Ciortan S. - *Evaluating Tribological Damages by 3D profilometry,* EHD Lubrication and Traction, May 6-8, 2010 VAREHD 15, Suceava, Romania, http://www.varehd.usv.ro/, ISSN 1844-8917, pp. 163-169, (2010).

[5]. E. Drugescu, O. Potecaşu, F. Potecaşu, M. Marin, V. Mereuta, L. Deleanu - *Mechanical properties, abrasive wear behavior and surface quality evaluation of new sintered iron alloys*, Rotrib, Universitatea Tehnică „Gh. Asachi", Iaşi, Tomul LVII (LXI), Fasc. 1, (2011).

[6]. Deleanu L., Cantaragiu A., Ciortan S. - *Surface Quality evaluated by 3D Functional Parameters,* Proceedings of 10th Intern. Conf. "Research and Development in Mechanical Industry", RaDMI 16-19 September, Donji Milanovac, Serbia, pp. 311-318, (2010).

[7]. Palfalvi -*Metalurgia Pulberilor,* Editura Tehnică, Bucureşti, (1988).

[8]. T. Surdeanu, M. Perneş - *Piese sinterizate din pulberi metalice,* Editura Tehnică, Bucureşti, (1984).

[9]. Marshall D. - *Austenitic Stainless Steels. Microstructure and mechanical properties*, (1984).

[10]. *** - ASM Specialty Handbook, Stainless Steels, (2004).