THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 2 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.2.01

RESEARCH ON OBTAINING SINTERED MATERIALS FROM 410 STAINLESS STEEL POWDER

Simona BOICIUC
"Dunarea de Jos" University of Galati, Romania
e-mail: simona_boiciuc@yahoo.com

ABSTRACT

Ferritic steels are used in applications that require good thermal conductivity and/or durability in operation involving heat cycles. They are easy to process due to their high ductility and have magnetic properties.

The paper presents a series of experimental research on the manufacture of sintered products obtained from 410 stainless steel powder and their characterization from the microstructural and wear resistance point of view.

KEYWORDS: powder metallurgy, 410 stainless steel, abrasive wear

1. Introduction

The development of powder metallurgy was determined by the need to obtain products with special properties.

Special attention was paid to the development of corrosion-resistant sintered steel with a ferritic structure. Due to the rich content of chromium and the presence of chromium oxides on the granules surface, a series of difficulties arise during sintering, so that in order to obtain compact and resistant materials one needs sintering temperatures higher than those for ordinary ferrous materials. In the case of simple pressing and sintering, liquid phase sintering can be applied in order to achieve high compactness. However, the high contraction during sintering leads to the need for subsequent splintering processing [1-6].

Stainless steels are used in various industrial branches due to their high resistance to corrosion in the atmosphere, water vapor, aqueous solutions of salts of organic acids and nitric acid.

The corrosion resistance of low-alloy steels is quite reduced, because the oxides formed do not provide a sufficiently compact structure to protect the alloy from chemical interaction with the corrosive environment. By increasing the chromium content to 12%, the oxidation potential of Fe-Cr alloys changes suddenly, increasing from -0.6 V to 0.2 V, thus becoming positive and ensuring the necessary structure for exploitation in corrosive environments [1-6].

The 410 ferritic stainless steels are characterized by resistance to atmospheric corrosion, sea water and resistance in a series of acids, salts, alkalis, by a high plasticity, heat stability, resistance to thermal shocks and to medium pressures, so they are used in the production of guide parts, pinions, ABS sensors, valves, components for steam and hydraulic turbines, household appliances, in the food and medical industries [1-6].

The 410 stainless steel powder is easy to process and has a corrosion resistance superior to martensitic and a lower cost price than austenitic.

In this paper, the aim is to obtain certain products from stainless steel powder 410, through specific technologies of powder metallurgy and their characterization from the point of view of microstructure and wear resistance.

2. Experimental conditions

In order to obtain the sintered products, a 410 ferritic stainless-steel powder (X12Cr13, SR EN 10088-2:1998) was used with the following chemical composition: 0.15%C; 13.5%Cr; 0.8%Si; 0.2% Mn; 0.015%S; 0.035% P; rest Fe.

The powders were cold-pressed, using the universal machine for mechanical tests. The pressures used to compact the 410 powder were 540, 628, 726, 863 MPa. The compressed samples are cylindrical in shape with dimensions of approximately 8 X 6 mm.

The sintering of compressed items from 410 powders was carried out in a laboratory furnace. The samples were placed in a ceramic cylinder, in which graphite was added. It prevents the penetration of air, thus ensuring the protective atmosphere.

Sintering was performed at a temperature of 1150 °C, for 60 minutes, and cooling was done along with the furnace.

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

The microhardness HV 0.05 determined on the sintered powder compressed items was performed on a PMT-3 micro-durimeter, with a load of 50 g.

The porosity of the compressed items was determined by the method of linear segments.

The 410 stainless steel sintered samples were subjected to wear testing on a rotating disc with sandpaper. The method consists in successively pressing, under identical conditions, the powder compressed items, 8 x 6 mm in size, on a rotating disk, covered with sandpaper with a 120 grit. A mechanism for radial movement of the sample by 0.5 mm/rot ensures spiral travel on the surface of the rotating disc. A device for applying a 6.229 N load ensures the perpendicular pressing of the test piece on the sandpaper at the pressure of 0.123 N/mm^2. At the disk speed of 25 rpm, a road length of 11.6 m was covered.

3. Experimental results

Following the microscopic analysis, carried out on the 410 ferritic stainless-steel powder and shown in Figure 1, it was found that it has an irregular shape specific to atomization in water, being suitable for mould formation and sintering in order to obtain products with high compactness.

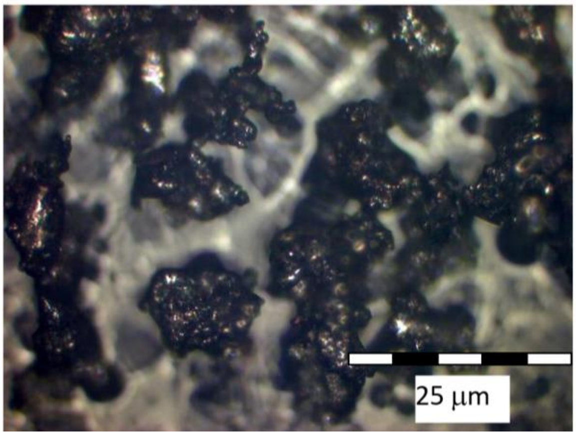

Fig. 1. *Aspect of 410 stainless steel powder*

The microstructure of the 410 ferritic stainless-steel powder, shown in Figure 2, is composed of alloyed ferrite and was highlighted by metallographic etching with 2% nital.

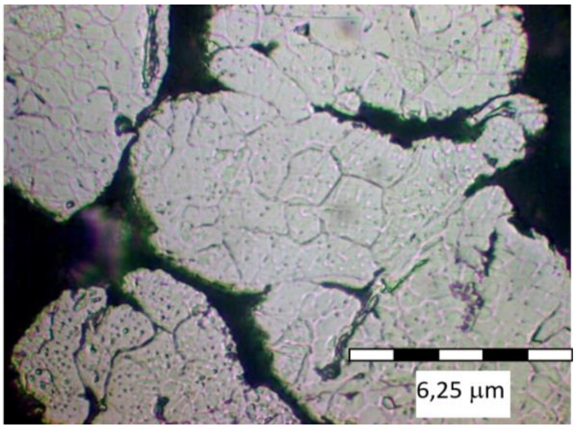

Fig. 2. *Microstructure of 410 ferritic stainless-steel powder, nital attack 2%*

The microhardness of the powder determined on the polished section of the particles under the load of 50 g was HV 0.05 = 2309.5 MPa.

Figure 3 shows the metallographic aspect of the powder compressed items, cold-formed with different pressures. It can be seen that with the increase in pressure there is a reduction in porosity and an increase in the mechanical cohesion between the particles.

The cold-pressed samples show low mechanical and physical properties due to the presence of intercommunicating pores, crystalline defects and internal stresses in the deformed particles. That is why the sintering operation is necessary.

Sintering involves a thermally activated mass transport process that leads to the strengthening of bonds between particles and/or to the modification of porosity and pore geometry and to the reduction of the free energy of the system (by reducing the free surface).

The microscopic analysis carried out on the pressed and sintered samples in an unatacked state, and presented in Figure 4, highlighted the fact that after sintering there is an increase in the mechanical resistance of the contact sections between the particles and a reduction in porosity (the pores in the material round off and the small ones disappear in the favour of the big ones). These phenomena increase in intensity with the increase of the forming pressure from 540 MPa to 863 MPa.

Article DOI: https://doi.org/10.35219/mms.2023.2.01

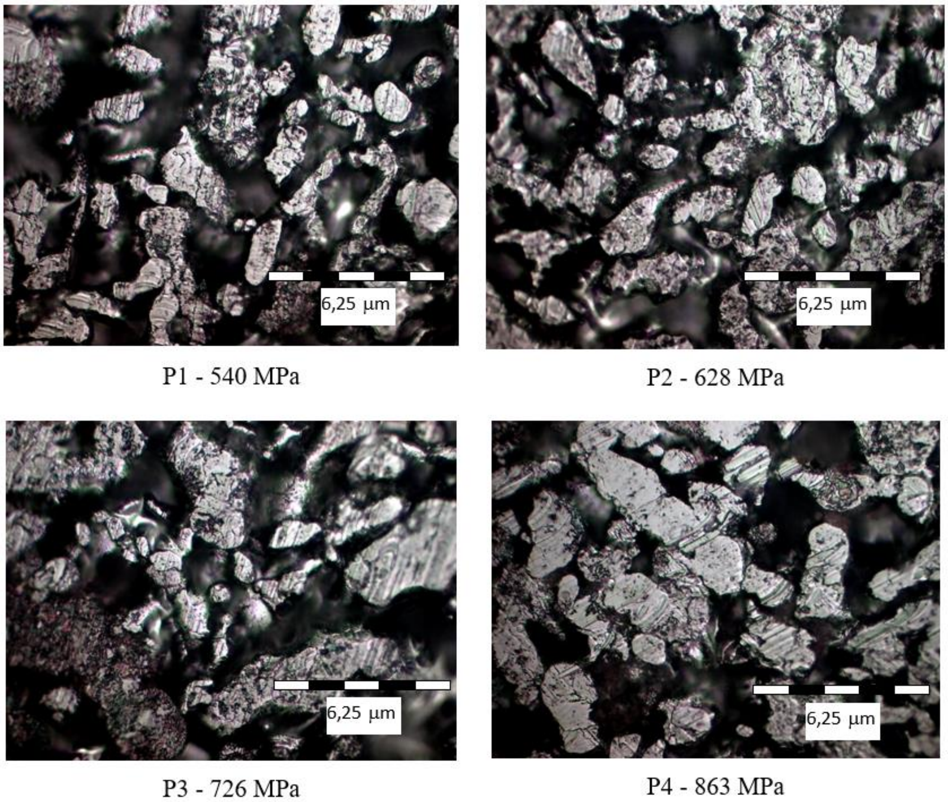

Fig. 3. *Metallographic aspect of 410 ferritic stainless-steel powder at different pressures*

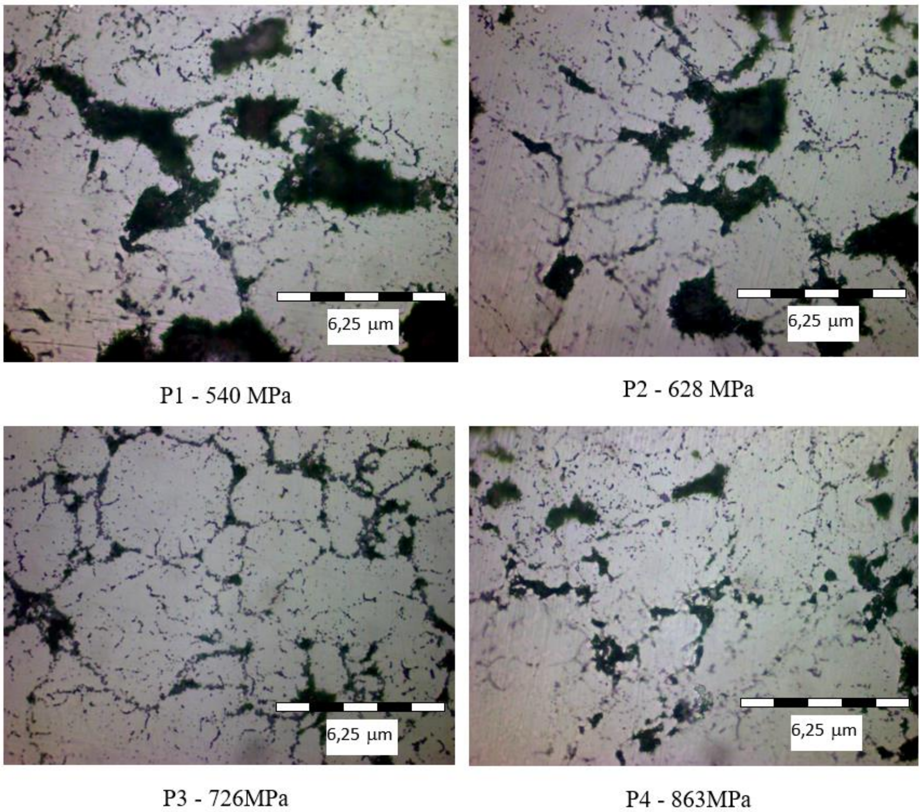

Fig. 4. *Microstructure of sintered 410 ferritic steel samples, unattacked state*

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 2 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.2.01

Analysing Figure 5, it can be seen that the structure of the 410 ferritic stainless-steel samples in the sintered state and attacked with nital 2% is formed by ferrite and carbides. The presence of carbides is due to the sintering medium used, namely graphite.

The microhardness HV 0.05 determined on the sintered powder compressed items was HV 0.05 = 6222.3 MPa, superior to the powder in its initial state.

Increasing the duration and temperature of sintering can lead to an increase in grain size with direct implications on strength and ductility.

The porosity of the samples was determined by the method of linear segments. Analysing Figure 6, it results that as the formation pressure increases, the porosity decreases. It varies between 0.35-0.24 at the edge of the compressed items and between 0.48-0.28 in their centre.

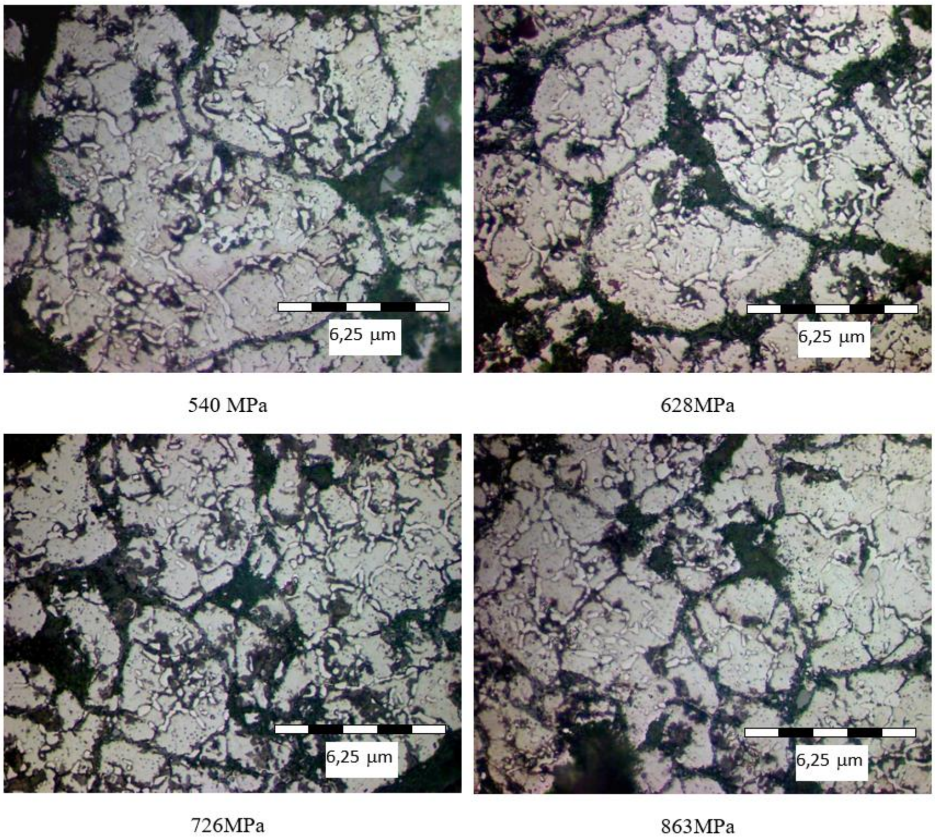

Fig. 5. *Microstructure of sintered 410 ferritic stainless-steel samples, nital attack 2%*

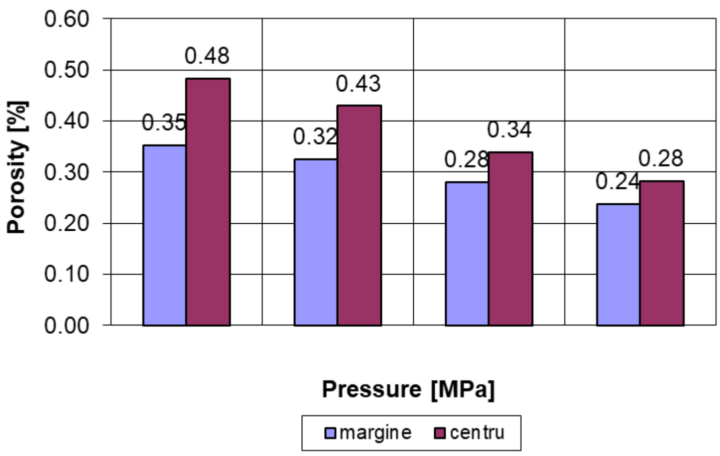

Fig. 6. *Porosity variation with formation pressure*

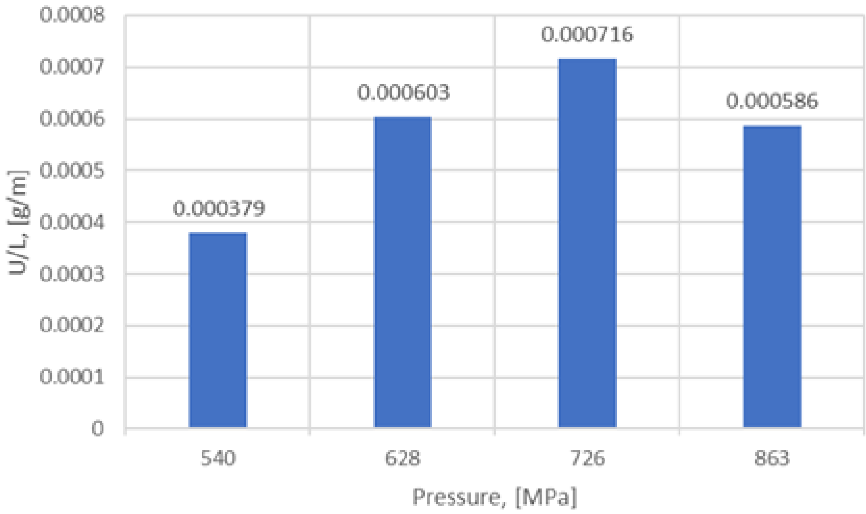

Fig. 7. *Abrasive wear behaviour of sintered powder products*

The samples thus obtained were subjected to the wear test on a rotating disk with sanding paper.

The results obtained are presented in Figure 7.

The 410 stainless steel powder is recommended to be pressed at lower pressures of about 540 MPa to ensure superior wear resistance. Pressing at low pressures causes a higher porosity which probably favours the carburization of the samples leading to an increase in wear resistance.

4. Conclusions

Obtaining products from 410 ferritic stainless-steel powders highlighted the following:

- the powder used in the experimental research has an irregular shape specific to atomization in water, with a structure made of alloyed ferrite;

- compacting the powder was achieved at pressures of 540, 628, 726, 863 MPa; it was found that when the pressure increases, the porosity of the compressed items decreases and the mechanical cohesion between the particles increases;

- sintering the powder compressed items at 1150 °C for one hour led to the reduction of their porosity and the strengthening of the bonds between the particles; the microstructure of the samples consists of ferrite and carbides;

- the microhardness HV 0.05 determined on the sintered powder compressed items was HV 0.05 = 6222.3 MPa superior to the powder in its initial state HV 0.05 = 2309.5 MPa; the increase in hardness was due to the presence of carbides; in this case, a decrease in corrosion resistance can be observed;

- as for the wear resistance on the abrasive disc, it was found that the 410 stainless steel powder is recommended to be pressed at lower pressures of about 540 MPa to ensure superior wear resistance;

- pressing at high pressures leads to higher compaction which provides poorer hardening.

References

[1]. Geru N., *Physical metallurgy (Metalurgie fizică)*, Didactic and Pedagogical Publishing House, Bucharest, 1981.

[2]. Rădulescu M., *Study of metals (Studiul Metalelor)*, Didactic and Pedagogical Publishing House, Bucharest, 1982.

[3]. Domşa A., *et al.*, *Technology of manufacturing parts from metal powders (Tehnologia fabricării pieselor din pulberi metalice)*, Technical Publishing House, Bucharest, 1966.

[4]. Palfalvi A., *Powder Metallurgy (Metalurgia Pulberilor)*, Technical Publishing House, Bucharest, 1988.

[5]. Surdeanu T., Perneş M., *Parts sintered from metal powders (Piese sinterizate din pulberi metalice)*, Technical Publishing House, Bucharest, 1984.

[6]. ***, *Stainless Steels – ASM Specialty Handbook*, 2004.