THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 3 – 2013, ISSN 1453 – 083X

RESEARCHES REGARGINDG THE INFLUENCE OF STEAM OXIDATION ON SINTERED ALLOYS PROPERTIES

Mihaela MARIN, Florentina POTECAŞU, Octavian POTECAŞU
"Dunărea de Jos" University of Galaţi, 111, Domnească Street, 800201, Galaţi, Romania
email: mihaela.marin@ugal.ro

ABSTRACT

In this paper is studied the influence of steam treatment applied on sintered steels and the mechanical properties and abrasive wear behavior for two different types of powder. Steam treatment was carried out at temperature of 550° C and maintaining time of 60 minutes. It was found that the best values for Vickers microhardness and abrasive wear were recorded for sampler P_2.

KEYWORDS: powder metallurgy, sintering, steam treatment, mechanical properties, abrasive wear

1. Introduction

In the last years, there has been a growing trend in utilisation of ferrous and nonferrous alloys obtained through powder metallurgical (P/M) processing. Comparing it with conventional casting techniques, this technique offers some advantages, such as: a low processing temperature, a near-net shaping, more material utilization (>95%). The properties of a P/M component depend on the sintering cycle [1, 2].

The four basic stages of powder metallurgy are: powder manufacture, powder mixture, pressing and sintering.

Sintering is the process of compaction, consolidation by heat treatment of a compacted product [3]. During sintering, surface, intergranular and volume diffusion are the mechanisms involved in the transport of material [4]. The properties of sintered materials are determined, in the first step, by the nature of the material's characteristics for powders involved, and secondary by pressing and sintering process parameters [5].

Steam treatment is a surface treatment applied to sintered iron-based parts to reduce the interconnected pores by sealing with iron oxides [6]. Comparing it with plastic or copper impregnation, this treatment is an economic way. An increase in the hardness, wear resistance and corrosion resistance by the oxide formed was detected occur [7 – 18].

In this paper, the mechanical properties and abrasive wear behavior of steam treatment on the sintered alloys were analyzed.

2. Experimental procedure

2.1. Materials

Specimens prepared from atomized iron powder and from pre-alloyed iron base powders were analyzed in this paper. The chemical composition of the powder samples, pure iron and iron-based pre-alloyed powder with Cu, Ni and Mo is presented in Table 1. In Figure 1 is presented the size distribution of the analyzed powders.

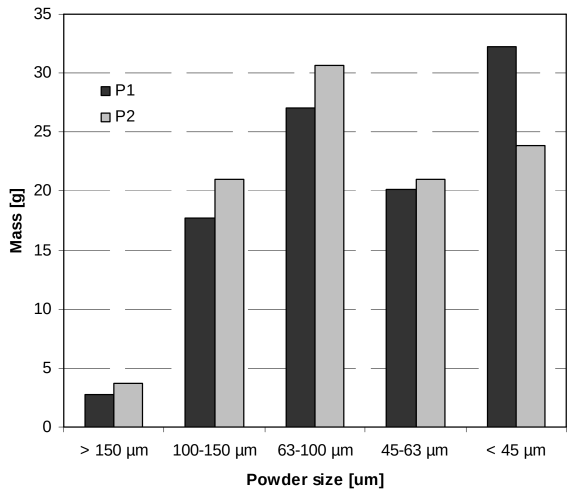

Fig. 1. *The size distribution of analyzed powders*

To evaluate the mechanical properties, a die for making the samples in the form of a cylinder was produced.

***Table 1**. The chemical composition of analyzed powders, %*

Powder type	Cu	Mo	Ni	C
P_1	0.096	0.008	0.046	<0.01
P_2	1.50	0.50	4.00	<0.01

The samples were used to evaluate the mechanical properties such as Vickers microhardness and abrasive wear. The powders were mixed with 1% zinc stearate. The samples were compressed in a universal mechanical testing machine to a pressure of 600 MPa, the dimensions of disc specimens are ϕ8 × 6 mm (Fig. 2).

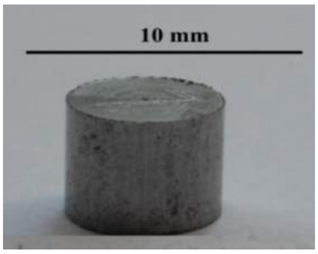

***Fig. 2.** The aspect of a sample*

The green samples were sintered in a laboratory furnace, within a controlled atmosphere. The sintering temperature was approximately 1150°C and the sintering time was 60 minutes with a heating rate of 30-40°C/min. All the samples were kept in the furnace for slow cooling to room temperature.

After cooling to room temperature the samples were steam-treated. The steam treatment temperature was approximately 550°C and the maintining time of 60 minutes. Specimens were then air-cooled at room temperature.

2.2. Abrasion wear tests

The sintered samples and those subject to steam treatment were tested for abrasion wear test. The SiC particles on the abrasive papers were the size of 80µm and the load applied was 855g. The distance traversed in each case was limited to 150 cycles, corresponding to 76.5 m. The samples were subjected to circular motion over the wheel on which the abrasive paper was stuck.

The abrasion test process included fixing the abrasive paper on the wheel, loading on the machine of the samples of known weight and then applying the load. The samples were cleaned and weighed before and after each test interval. After the tribological tests, the worn surfaces were examined by optical microscope, to identify the characteristics wear mechanisms.

2.3. Mechanical properties

The sintered and steam treated samples were analyzed according to their mechanical properties. The microhardness tests were performed by measuring Vickers microhardness, the test parameters are: the penetrator is a diamond pyramid diameter and load of 100g. The microhardness values were the average of three indentations.

3. Results and discussion

3.1. Microstructure analysis

The microstructures of sintered and steam treated samples were observed by optical microscopy (Olympus BX 50). Figures 3 and 4 show the microscopic analysis of the sintered and steam treated samples. The microstructures reveal the appearance of pores in sintered state and their filling after the steam treatment.

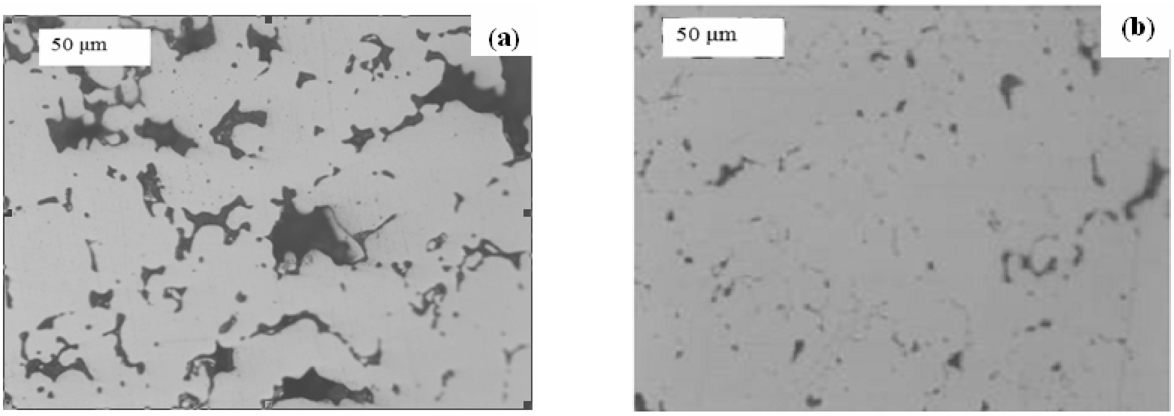

***Fig. 3**. Microstructures of sintered samples: a) P_1, b) P_2*

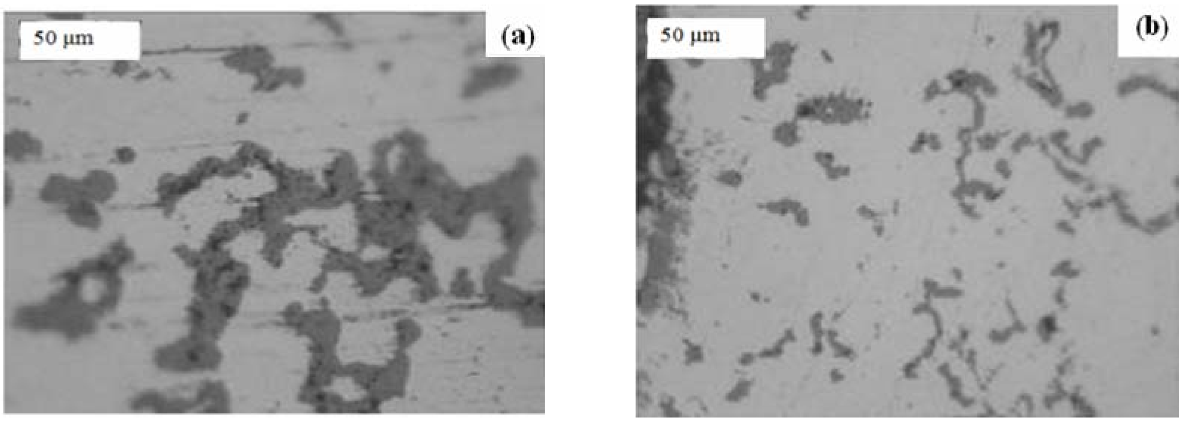

Fig. 4. *Microstructures of steam treated samples: a) P_1, b) P_2*

It appears that the iron oxide formed during steam treatment seals the pores at the surface and inside to sintered samples. It was found that the sample of non-alloy powder P_1 presents the best reaction to steam, meaning that its lower density provides a higher pore filling compared to sample P_2, which is more compact.

3.2. Microhardness values

Figure 5 shows Vickers microhardness values for sintered and steam treated samples.

The microhardness values were the average of three indentations.

It is found that steam treated samples have a difference of aproximatively 30% in values of Vickers microhardness compared to sintered samples.

This difference results from the high hardness of the induced magnetic iron oxide (Fe_3O_4). An increase in hardness was associated with an increase in wear resistance.

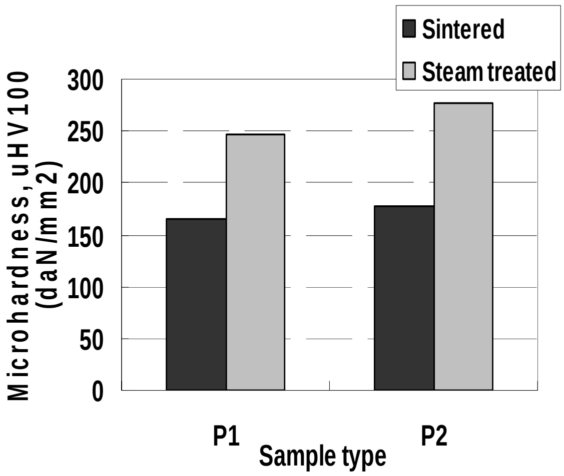

Fig. 5. *Vickers microhardness values for sintered and steam treated samples*

3.3. Tribological tests

The worn surfaces of sintered and steam treated samples after abrasion tests were examined in optical microscope, the typical aspects of abraded surfaces are represented in figures 6 and 7.

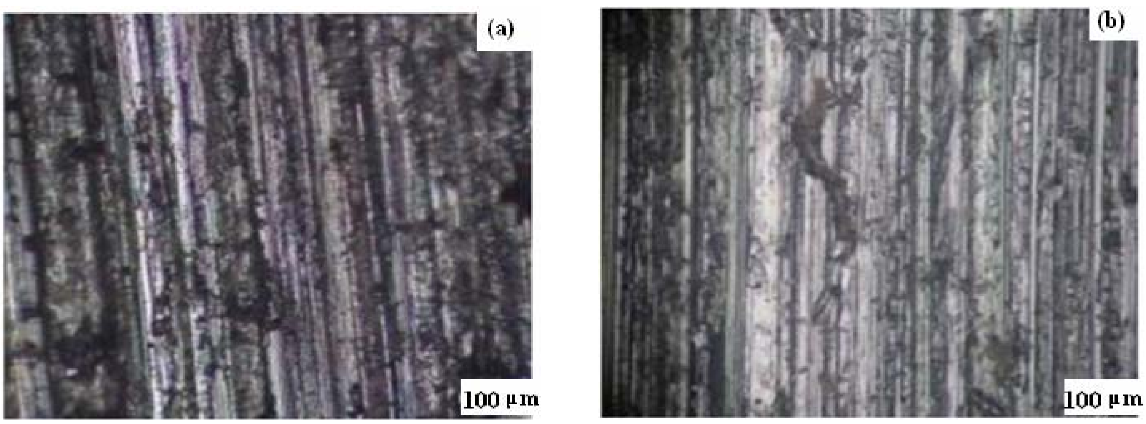

Fig. 6. *Optical photomacrographs of worn surfaces for sintered samples: a) P_1, b) P_2*

THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 3 – 2013, ISSN 1453 – 083X

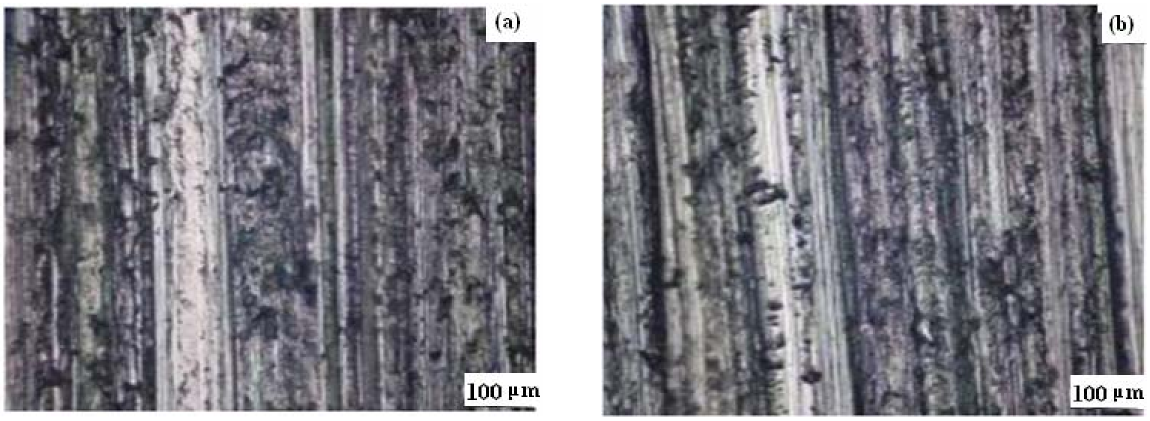

Fig. 7. *Optical photomacrographs of worn surfaces for steam treated samples: a) P_1, b) P_2*

The microscopic analysis of sintered samples subjected to abrasive wear shows that the wear traces are more pronounced for sample P_1.

This observation is confirmed by the wear loss of the sintered samples. The presence of pores increases the stress concentration around the pores and acts as wear generation and material deformation areas. The wear resistance for steam treated samples results from the high hardness of the induced magnetic iron oxide (Fe_3O_4). Also, the oxide layer produced by the steam oxidation is able to perform a lubricating action between the sliding surfaces. For the worn steam treated samples, the depth and width of wear grooves for sample P_1 are greater as compared to those of the samples P_2.

3.4. Wear loss

The wear rates were calculated from the difference in mass of the specimens before and after the tests. The samples were weighed using a precision balance with a sensitivity of 10^{-4} before and after each test (Fig. 8), so it was possible to evaluate the wear undergone by the material, the sample P_1 provided the greatest weight loss, in sintered and steam treated state.

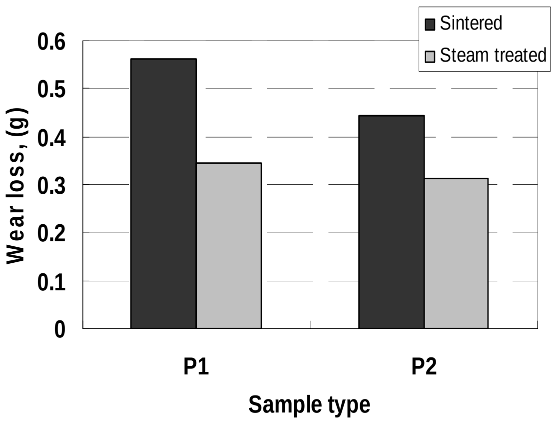

Fig. 8*. Mass loss of the sintered and steam treated samples tested to the abrasion test*

4. Conclusions

The following conclusions can be obtained from this research:

- The microscopic analysis reveals the steam treatment effect on sintered samples by pore filling of iron oxides, mainly the magnetite oxide.

- The wear properties of sintered iron were significantly improved by a steam treatment of 60 minutes and by the addition of copper and molybdenum. The wear resistance for steam treated samples results from the high hardness of the induced magnetic iron oxide (Fe_3O_4).

- Abrasive wear surfaces for two types of powders present deeper traces in unalloyed samples and finer trace in samples alloyed P_2, as subsequently wear tests give results in conformity with these aspects of the surface.

- Sample P_1 presents a depth and width of wear grooves greater, thus there is a possibility of less resistance offered.

- Sample P_2 presents a much smaller wear groove width that can ensure a good resistance.

References

[1]. G.B. Jang, M.D. Hur, S.S. Kang - *A study on the development of a substitution process by powder metallurgy in automobile parts*, J Mater Process Technol (2000): 110–5.

[2]. V. B. Akimenko, I. A. Gulyaev, O. Yu. Kalashnikova, M. A. Sekachev - *The Prospects for Russian Iron Powder*, Central Scientific-Research Institute of Ferrous Metallurgy, Vol. 37, No. 5, p. 472–476, (2007).

[3]. K.S. Narasimhan - *Sintering of powder mixtures and the growth of ferrous powder metallurgy*. Mater Chem Phys (2001); 67:56–65.

[4]. Hadrian Djohari, JorgeI Martínez-Herrera, Jeffrey J.Derby - *Transport mechanisms and densification during sintering: I. Viscous flow versus vacancy diffusion*, Department of Chemical Engineering and Materials Science, MN55455-0132.

[5]. C. Anayarana C, E. Ivanov, V.V. Boldyrev - *The science and technology of mechanical alloying*. Mater Sci Eng A, 304–306:151–8, (2001).

[6]. P. Beiss - *Steam treatment of sintered iron and steel parts*, Powder Metallurgy, Vol 34, No3, p. 173–177; (1991).

[7]. P. Franklin, B.L. Davies - *The effects of steam oxidation on porosity in sintered iron*, Powder Metallurgy, Volume 20, pages 11–16, (2001).

[8]. K. Razavizadeh, B. L. Davies - *The effects of steam treatment on the wear resistance of sintered iron and Fe-Cu alloys*, Wear, Volume 69, Issue 3, pages 355-367, (1981).

[9]. J.D.B. De Mello, I. M. Hutchings - *Effect of processing parameters on the surface durability of steam-oxidized sintered iron,* Wear, Volume 250, Issues 1-12, pages 435-448, (2001).

[10]. J.D.B. de Mello, R. Binder, A.N. Klein, I.M. Hutchings - *Effect of compaction pressure and powder grade on microstructure and hardness of steam oxidized sintered iron*, Powder Metallurgy, Volume 44, Number , pages 53–61, (2001).

[11]. G. Straffelini, D. Trabucco, A. Molinari - *Oxidative wear of heat-treated steels*, Wear, Volume 250, Issues 1-12, p. 485-491, (2001).

[12]. K. Razavizadeh, B.L. Davies - *Combined Effects of Steam Treatment and Age Hardening on Mechanical Properties of Sintered Fe-Cu Alloys*, Powder Metallurgy, Volume 25, p. 11–16, (1982).

[13]. A. Molinari, G. Straffelini - *Surface Durability of Steam Treated Sintered Iron Alloys*, Wear, Volume 181-183, p 334–338, (1995).

[14]. A. Molinari, G. Straffelini - *Surface durability of steam treated sintered iron alloys*, Wear, Volumes 181-183, p. 334-341, (1995).

[15]. S.L. Feldbauer - *Steam Treating; Enhancing the Surface Properties of Metal Components*; Aabbott Furnace Company; (2003).

[16]. A. Molinari, G. Straffelini - *Tribological Steam Treated Ferrous Parts*, Int. J. Powder Metallurgy, Volume 33, p. 55–62, (1997).

[17]. G. Strafelini, A. Molinari - *Dry sliding behaviour of steam treated sintered iron alloys*, Wear, Volume 159 , Issue 1, p. 127-134; (1992)

[18]. W. M. da Silva, R. Binder, J.D.B. de Mello - *Abrasive wear of steam-treated sintered iron*, Wear, Volume 258, Issues 1-4, p. 166-177, (2005).