THE INFLUENCE OF STEAM TREATMENT ON MECHANICAL PROPERTIES AND ABRASIVE WEAR BEHAVIOR OF SINTERED P/M STEELS

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ABSTRACT

In this paper is a study of the influence of steam treatment on sintered P/M steels, for three different types of powder. The abrasive wear of steam-treated sintered iron is analysed by abrasion tests. The specimens were produced from atomised iron powders (Hoeganaes Corporation) with different sizes (<45, 45-63, 63-100, 100-150, >150μm). They were compacted at pressures 600MPa, sintered for 60 minutes at 1150 ºC and then subjected to continuous steam treatments at 550 ºC for 45 minutes. The abrasion tests were conducted under constant load and speed conditions. The wear properties of sintered iron were improved by steam treatment and by the addition of alloying elements. An increase in hardness was associated with an increase in wear resistance. The results reveal that the samples (P_2 and P_3) prealloyed with Cu, Ni and Mo can improve wear resistance of sintered steels.

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

1. Introduction

The growth of ferrous powder metallurgy (P/M) over the past three decades has been considerable as this technology proves to be an alternate lower cost process if compared with other metal working techniques such as machining, casting, stamping, forging, etc. The parts manufactured by powder metallurgy are broadly used, mostly in the automotive industry. The powder metallurgy parts of complex shapes are obtained and close to final form, with precise surface. Also, specific parts made by powder metallurgy processing help to save time, energy, material, labor and money [1]. Steam treatment is one of the surface treatments applied to sintered components. At first, this treatment was used as an economical way to seal the interconnected pores, sintered iron characteristic, making the component impervious to liquid and gases. This treatment is claimed to improve the superficial properties of sintered materials because the water vapor in the steam will begin to react with the iron in the part to form the oxide iron - magnetite (Fe_3O_4) [2–15].

The oxide layer formed on the sintered iron components is thicker than on the conventional wrought ferrous parts steam treated [13]. In this paper, the mechanical properties and abrasive wear behavior of steam treated sintered iron alloys are studied. The abrasion tests were conducted under constant load and speed conditions.

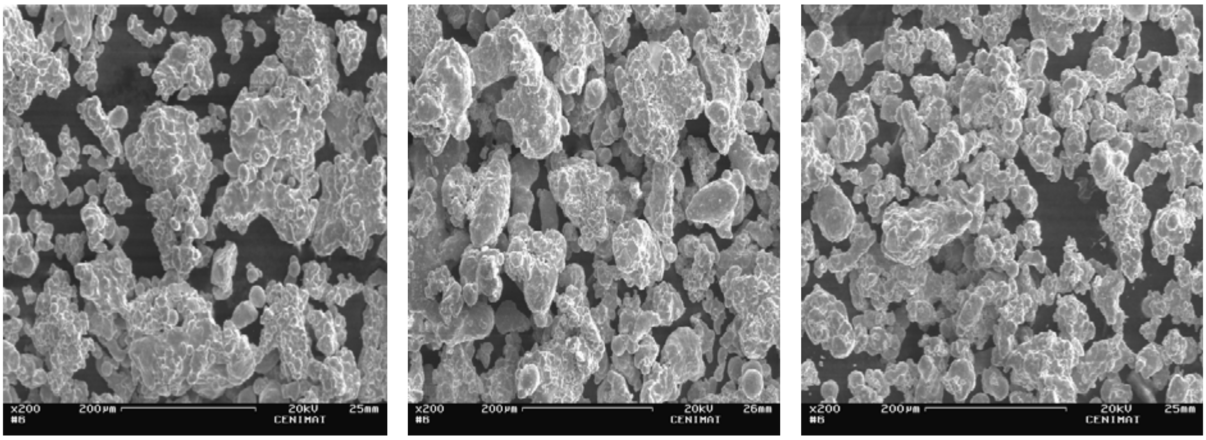
2. Experimental procedure

2.1. Materials

The specimens prepared from atomized iron powder and from pre-alloyed iron base powders were analyzed in this paper.

***Table 1**. 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	1.75	<0.01
P_3	1.50	0.50	4.00	<0.01



a b c

***Fig. 1**. SEM images of the water- atomized iron powder: a) P_1, b) P_2, c) P_3*

The chemical composition of the powder samples, pure iron and iron-based prealloyed powder with Cu, Ni and Mo is presented in Table 1, whereas Figure 1 shows SEM images of analysed powders.

To evaluate the mechanical properties, such as Vickers microhardness and abrasive wear, a die for making the samples in the form of a cylinder was produced. 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 $\phi\, 8 \times 6$ mm.

The uniaxial pressing in the mold is used effectively for mass production of simple components. In Figure 2 are presented the surface of sintered and stream treated samples.

a b

***Fig. 2.** The aspect of sample surface:*
a- sintered; b- steam treated

The green samples were sintered in a laboratory furnace, in a controlled atmosphere. The sintering temperature was approximately 1.150°C and the sintering time was 60 minutes with a heating rate of 30-40°C/minutes.

All the samples were kept in the furnace for slow cooling to room temperature. Before the sintering temperature is reached, the parts were maintained during 30 minutes at 500°C to burn lubricant, respectively the zinc stearate. After cooling to room temperature the samples were steam - treated.

The steam treatment was carried out in a furnace with steam atmosphere at 550°C for 45 minutes. The steam-treated specimens were air-cooled to room temperature. It can be seen that on the surface of the samples a blue layer of iron oxide–magnetite (Fe_3O_4), typical for this process, was formed (Fig. 2).

2.2. Mechanical properties

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

2.3. Abrasion wear tests

The abrasive wear is a process of removal and the destruction of the surface tested material. It is affected by many factors such as mechanical properties and abrasive materials, microstructure, loading condition, etc. The steam-treated specimens were tested for abrasion wear test (Fig. 3).

***Fig. 3**. Worn surface after the abrasion test*

The samples were weighed using a precision balance with a sensitivity of 10^{-4} before and after each test, so it was possible to evaluate the wear mechanism undergone by the material. 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 76.5m. The samples were subjected to circular motion over the wheel on which the abrasive paper was stuck.

The abrasion wear process in which the abrasion test was carried out included the steps: fixing the abrasive paper on the wheel machine; the samples of known weight were loaded on the machine tester and then the load was applied.

The surface of the sample and the abrasive paper were always in strong contact with each other under the predetermined load, and the samples were cleaned and weighed prior to and after each test interval. After tribological tests, the worn surfaces were examined by optical microscope, in order to identify and characterize the dominant wear mechanisms.

3. Results and discussion

3.1. Microstructure

Because the steam treatment is not a treatment that can produce structural changes, all the sample structures consist of ferrite and pores filled with iron oxides and a growth porosity for sample P_1. The optical micrographs are reported in Fig. 4a) – f) and were obtained at a magnification of 400x.

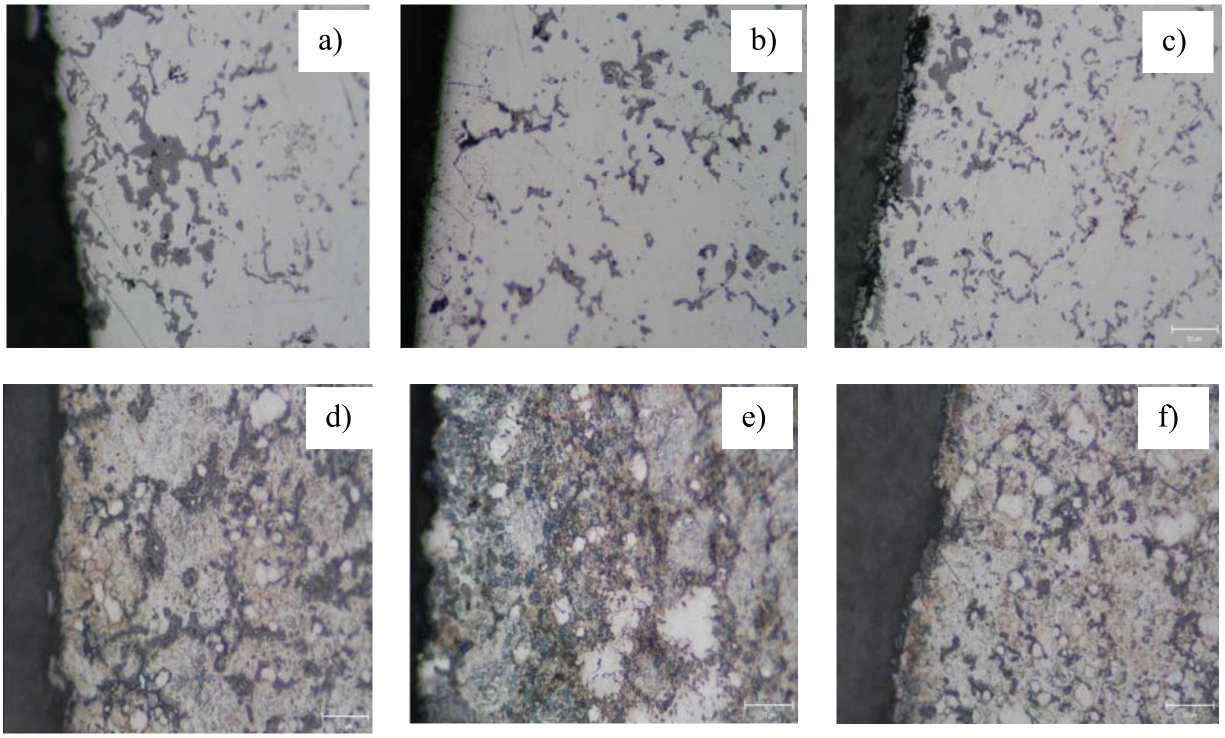


Fig. 4. *Optical photomicrographs of steam-treated samples for 45 minutes unetched: a) P_1, b)P_2, c) P_3 and etched with 2% Nital: d) P_1; e) P_2, f) P_3*

Table 2 shows the values of Vickers microhardness of the studied steam-treated samples, when powder type P_1 (pure iron) was used as a reference.

Table 2. *Vickers microhardness of the steam treated samples*

Powder type	Microhardness [µHV100]	Difference [%]
P_1	221	0.00
P_2	243	9.954
P_3	245	10.859

It is found that all three samples have a difference of approximately 10% in Vickers microhardness values.

3.2. Tribological tests

The worn surfaces of the steam treated samples after abrasion tests were examined with an optical microscope the typical aspects of the abraded surfaces are presented in Fig. 5. The depth and width of wear grooves of steam-treated samples P_1 are greater compared to steam-treated samples with higher microhardness values P_2 and P_3. The wear tracks are in the same direction and the pores are areas that have propagated the wear grooves.

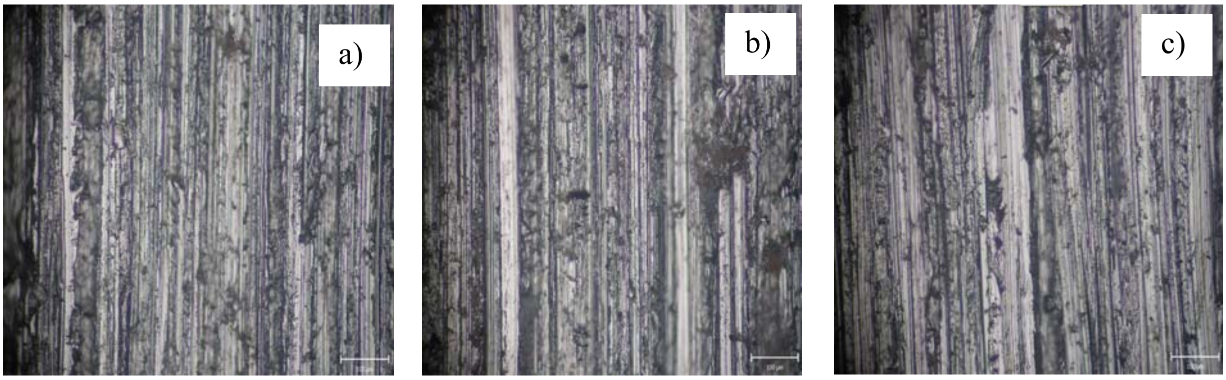


Fig. 5. *Optical photomicrographs of worn surfaces for steam treated samples (x200): a) P_1, b) P_2, c) P_3*

The wear rate was measured as the weight loss and is expressed in Table 3; the sample P_3 provided the greatest weight loss.

Table 3. *Mass loss of steam-treated samples tested to abrasion test*

Powder type	**Initial mass**	**Final mass**	**Mass loss**
	[g]		
P_1	2.271	1.882	0.389
P_2	2.285	1.922	0.363
P_3	2.286	1.935	0.351

4. Conclusions

According to the experimental results in this study, the following conclusions may be discussed:

■ As generally observed, composition plays a significant role in the resistance to abrasive wear of PM steels. In this regard, the best behavior was observed for the more hardenable steam-treated samples with higher Ni and Mo content, respectively P_3.

■ Based on microhardness measurements, the samples P_2 and P_3 show higher values compared to P_1 (the reference) because of the formation of homogeneous phase according to the largest diffusion in solid solution by the elements used in the preparation of samples, respectively Cu, Ni and Mo.

■ The steam-treated sample P_1 presents a greater depth and width of wear grooves; consequently, there is a possibility that it offers less resistance.

■ The steam-treated samples P_2 and P_3 present a much smaller wear groove width that can ensure good resistance.

■ The weight loss is smaller for the steam-treated samples P_2 and P_3.

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