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INFLUENCE OF ALLOYING ELEMENTS ON CORROSION RESISTANCE OF SOME IRON - BASED SINTERED P/M ALLOYS

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ABSTRACT

In this paper is described the influence of alloying elements on corrosion behavior of sintered iron parts. The compacts were sintered at 1,150 °C and the sintering time was 60 minutes. After microstructural studies, the electrochemical tests were carried out. The corrosion behavior of samples was evaluated using potentiodinamic polarization technique in 3.5% NaCl solution. Different parameters like i_{corr}, cathodic (βc) and anodic (βa) slopes derived after the extrapolation of the Tafel plots were obtained. The results reveal that the alloying elements can improve significantly corrosion resistance of iron based sintered P/M alloys.

KEYWORDS: alloying elements, powder metallurgy, sintering, corrosion resistance

1. Introduction

In Powder Metallurgy (P/M), the produced parts are of complex shapes and closed to final form, and are widely used, especially in the automotive industry [1, 2]. But the main problem of these products is the presence of the pores, which can act as potential cracks initiation, and also can propagate cracks through the material. The properties of the sintered powder metallurgy alloys can be improved by reducing the pore size [3-5], increasing the density [6, 7], by adding some alloying elements [8-17] or by additional operations [18-20]. The most common alloying elements added in the mixing powders are copper, nickel, molybdenum, manganese and phosphorus because of low cost and their ability to improve the properties of the alloys. Cu increases the density of the alloys by filling the pores due to its melting point during the sintering time (1,083 °C). Ni can also increase strength, ductility and impact properties. In the literature, Hong et al. [21] have investigated the effect of copper addition to low alloy steels on their corrosion response in sulphuric acid have found that the rate of corrosion is reduced by the addition of Cu due to higher hydrogen over potential and prevention of the active dissolution. Addition of higher percentage of alloying elements such as Cu, Ni, Cr, P, S, Si, Mn is reported to enhance the corrosion resistance of the steels in aqueous solutions. It is concluded that the addition of higher percentage of chromium could act as a passivating agent [22].

In this paper, the influence of alloying elements on corrosion resistance of iron based sintered P/M alloys is analyzed. The anti-corrosion performances of the sintered specimens in 3.5% NaCl solutions were studied.

2. Experimental procedure

The starting materials studied in this paper are represented by atomized iron powder and pre-alloyed iron base powder. The chemical composition of the powders, pure iron and iron-based prealloyed powder with Cu, Ni and Mo is presented in Table 1. The powders were blended with 1% zinc stearate and then were uniaxially compacted into specimens, using a universal mechanical testing machine at ambient temperature. After blending, the samples were compressed in a mold using uniaxial pressing and the applied pressure was 600 MPa. The disc specimens have the dimensions of $\phi 8 \times 6$ mm. After compacting, the green samples were subjected to sintering, the temperature was approximately 1,150 °C and the sintering time was 60 minutes and then air-cooled to room temperature. In order to evaluate the effect of alloying elements, the sintered specimens were subjected to corrosion resistance tests and electrochemical characterization. The corrosion behavior of the sintered specimens was investigated by potentiodymanic polarization technique. The polarization curves were obtained using a Voltalab PGP 201 Potentiostat at a scan rate of 2 mV/s. A conventional three electrode electrochemical cell consisting of the saturated calomel electrode (SCE) as the reference, the platinum plate as the counter electrode and the specimen was used as working electrode. The test area (0.5 cm^2) was obtained by embedding the specimens. After 40 minutes of exposure to an open circuit potential, the measurements were carried out. The tests were carried out in a 3.5% NaCl electrolyte solution. All electrochemical experiments were performed at room temperature.

Table 1. *Chemical composition of analyzed powders*

Powder type	Cu	Mo	Ni	C
P_1	0.10	0.01	0.05	<0.01
P_2	1.50	0.53	4.01	<0.01

The microhardness Vickers values were used to correlate the influence of alloying elements on corrosion resistance. The results show that an increase in microhardness leads to an increase of corrosion resistance.

3. Results and discussions

3.1. Microstructural characterization

The microstructural characterization was carried out using an optical microscopy (Olympus BX 50). Optical micrographs of sintered samples are presented in Figure 1 and indicates a basic ferritic structure. The copper and nickel have diffused with the iron, the copper melted and moved throughout the pore network. Mo is known as a ferrite stabilizer element and a carbide former also. In combination with Ni, the presence of Mo in this alloy has conducted to a ferritic microstructure with distributed molybdenum carbide. Also, the Mo particles are combined with diffused carbon during sintering; forming molybdenum carbide, their presence in the alloys may improve the strength. As can be seen in microstructure, the sample P_1 has the higher porosity.

3.2. *Mechanical properties*

The microhardness Vickers of the sintered specimens was investigated by using a microhardness tester. The test parameters are: the penetrator is a diamond pyramid diameter and load of 100 g. The sample P_1 has the microhardness Vickers value of 152 daN/mm^2, comparintg with sample P_2 with a value of 181 daN/mm^2.

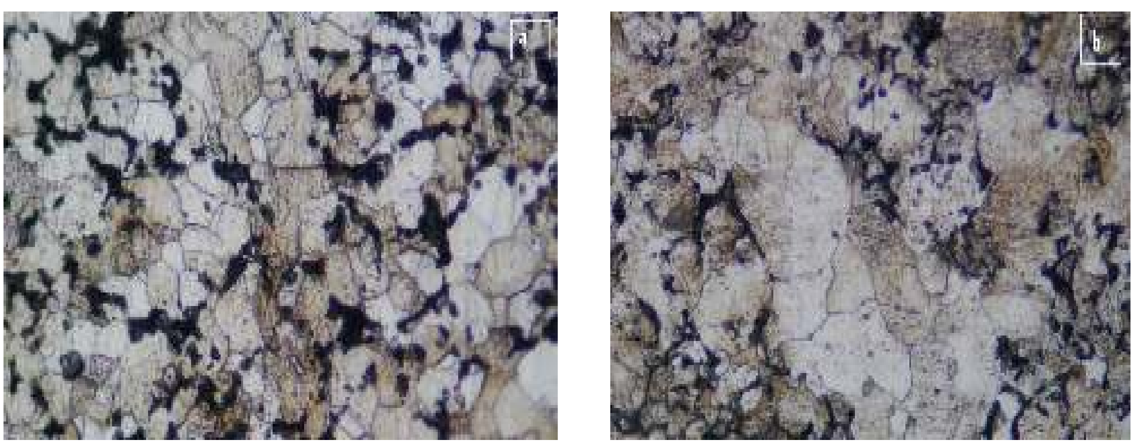

Fig. 1. *Image of the microstructure of sintered samples, 2% Nital etched, 200x: a) P_1, b) P_2*

3.3. Corrosion test results

The corrosion resistance of the sintered samples was evaluated by electrochemical measurements in 100 mL of unstirred 3.5% NaCl solution. The corrosion potential and the corrosion current density were obtained through Tafel approximation. Figure 2 shows the potentiondynamic polarization curves in 3.5% NaCl solution for sintered specimens (Tafel plots) and it can be seen that the corrosion potential of sample P_2 is higher than the unalloyed P_1 sample.

This is attributed to the alloying elements, 4% Ni, 1.5% Cu and 0.5% Mo and less porosity. Comparing polarization curves of the sintered samples, the results show that corrosion resistance is enhanced by the alloying elements. The least corrosion resistant result was subjected to series P_1, which has the highest porosity.

The potentiodynamic polarization parameters like corrosion current (i_{corr}), anodic and cathodic slopes (β_a and β_c) and corrosion rate (ν_{corr}) were calculated from Tafel plots and are presented in Table 2. The electrochemical parameters obtained by Tafel extrapolation method shoed that the prealloyed sample P_2 with Cu, Ni and Mo had an improved in corrosion resistance compared to unalloyed sample P_1.

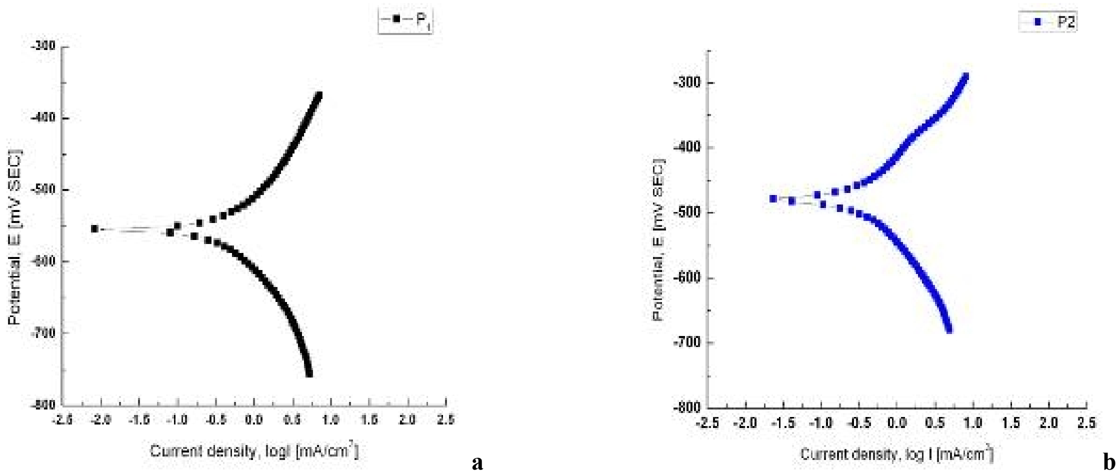

Fig. 2. *Potentiodymanic polarization curves in 3.5% NaCl*

Table 2. *Different electrochemical parameters obtained by Tafel extrapolation method*

Sample	β_a, (mV dec $^{-1}$)	β_c, (mV dec $^{-1}$)	i_{corr}, mA/cm^2	Corrosion rate (mm year $^{-1}$)
P_1	220.1	-248.4	0.98	10.49
P_2	142.5	171.4	0.45	6.31

4. Conclusions

The results reveal that the corrosion resistance in P/M parts is correlated to processing parameters such as alloying elements, porosity and mechanical properties. The prealloyed sample P_2 with Cu, Ni and Mo can improve corrosion resistance of sintered steels.

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