

Hardness and Microstructural Characterization of Powder Metallurgy Steel Subjected to Martempering Heat Treatment

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Abstract. Production of High Carbon Powder Metallurgy specimens, ATOMET 1001 pure iron powders produced by atomization method and 1.5% by weight graphite powder as a carbon source were mixed and then pressed in a single action press with 700 Mpa pressure. The pressed specimens were then sintered in Ar atmosphere in the atmosphere controlled furnace to produce high carbon powder metal steel with a rate of 1.5% carbon. Firstly, specimens were austenitized at 950 °C for 4 minutes and martempering heat treatment was applied in a neutral salt bath with a temperature of 350 °C - 400 °C for different periods. It was observed that the hardness decreased due to the decrease in martensitic regions in the microstructure with increasing martempering times.

Keywords: Powder Metallurgy Steel, Martempering, Bainite, Martensite.

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Powder metallurgy is a method of producing parts by blending metal powders in certain proportions, compacting metal powders at room temperature in precise molds, at pressures appropriate to the required technical values (pressing) and roasting in controlled atmospheres (sintering). After sintering, processes such as calibration, deburring, lubrication and heat treatment can be performed in order to produce parts with desired properties. [1]. Powder metallurgy production methods are completely different from other metal forming methods and are similar to ceramic part production technology. The process starts with the compression of the powders in both cases in a mold. The formed shape

is roasted and gained the necessary strength. Thus, the material with the desired properties is obtained. [2]. Sintering and tempering is applied to the specimens to make the material usable. The purpose of the applied tempering is to improve the workability of the material, to reduce the internal stresses, to improve the mechanical properties, flexibility, strength, hardness, and toughness, to change the grain size, to increase the heat and corrosion resistance, to change the electrical and magnetic properties, to change the chemical composition. The aim of this study is to observe the transformation time of martensite structure into bainite by applying martempering heat treatment

to high carbon steels produced by powder metallurgy method at different methods and temperatures and to examine the hardness and microstructure properties of the specimens produced.

In this research, 1.5 wt.% natural graphite powders were added to NC100.24 pure iron powders to obtain plain high-carbon steel powder metallurgy (PM) specimens according to ASTM G99-05. [3]. Prepared high carbon iron powder was pressed according to ASTM G99-05 standard using a hydraulicsan brand pressing device 700 MPa pressure and cylindrical specimens with a size of 10x10 mm were produced. (Fig. 1)

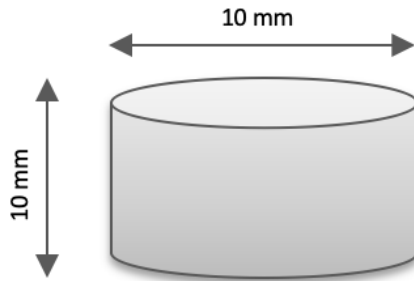


Figure 1. Specimens geometry and dimensions (mm)

After the pressing process, sintering process was carried out using Protherm furnace. The sintering process of the pressed specimens was carried out in a 6x110 cm pure alumina tube belonging to the furnace by keeping it in the homogeneous temperature zone at 1200 ° C for 20 minutes. (Fig. 2) Specimens at room temperature were placed in the determined homogeneous temperature zone. The front and back of the tube are covered with graphic caps to allow the entry and exit of Ar gas. Sintering process is done under special protective atmosphere or vacuum. 99.99% purity argon gas and sponge titanium are used as a protective atmosphere to protect the specimens against carbon depletion and oxidation.

In this research, pressing, sintering, martempering, grinding and polishing processes have been studied. Powder metallurgy was used to obtain different grain-sized specimens given its high performance. [4] Sintered specimens were placed in the homogeneous temperature zone of the furnace. The specimens, which were austenitized at 950 ° C for 4 minutes, were taken out of the furnace and kept in a neutral salt bath at 350 ° C and 400 ° C for 30, 60, 90, 180 and 360 seconds,

and martempering heat treatment was applied. The specimens taken out of the salt bath were quenched for rapid cooling. (Fig. 3)



Figure 2. Protherm Furnace and Argon Gas Tube



Figure 3. Austenitizing the specimen in a furnace

After the heat treatment, the surfaces of the specimens were sanded using different grit size sandpapers. After the sanding process, the specimens were polished. (Fig. 4)



Figure 4. Grinding Process

Results

In the microstructural analysis, cementite lamellae in the microstructure of the sintered specimen clearly seen. The part numbered 1 in the figure 5 shows the cementite area. (Fig. 5) The area numbered 2 in the figure 6 shows the pearlite structure and it is a phase composed of the combination of pearlite, cementite and ferrite phases. (Fig.6) While ferrite is a very soft phase and cementite is a very hard phase. [5]

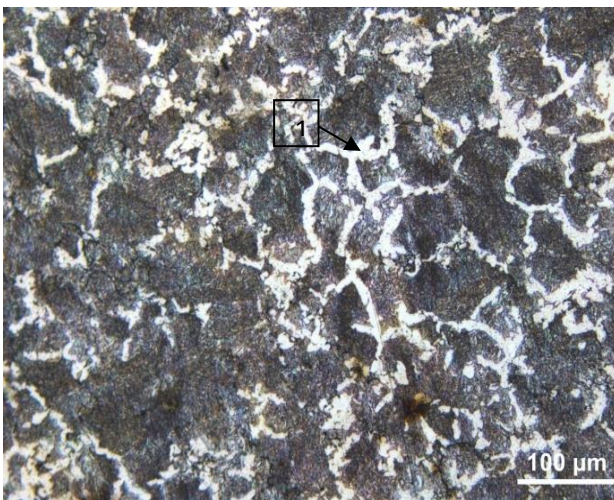


Figure 5. Microstructure of Specimen Sintered with 200X Magnification

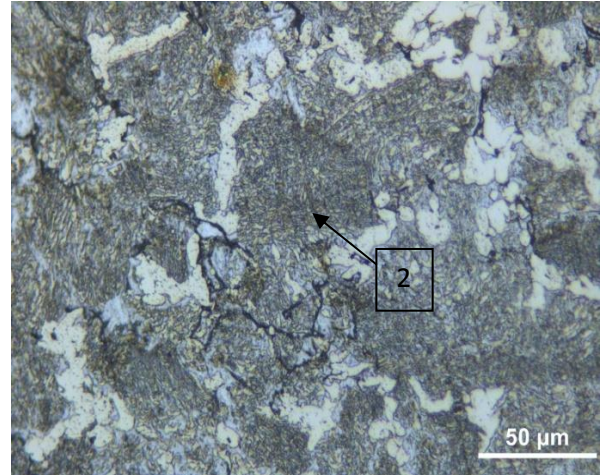


Figure 6. Microstructure of Specimen Sintered with 500X Magnification

Carbon atoms which is dissolved in austenite cannot find time for diffusion and cannot be separated from the structure when rapid cooling is performed. As a result, austenite transforms from a face-centered cubic structure to a volume-centered tetragonal structure that is supersaturated with carbon. This structure is called martensite. Figure 7 shows the microstructure of the quenched specimen and this structure is called martensite. (Fig. 7) The needle-shaped grains indicate the martensite phase, while the white areas indicate residual austenite.

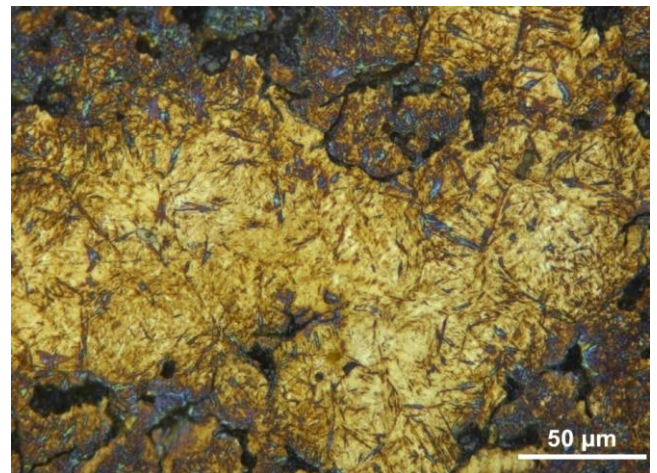
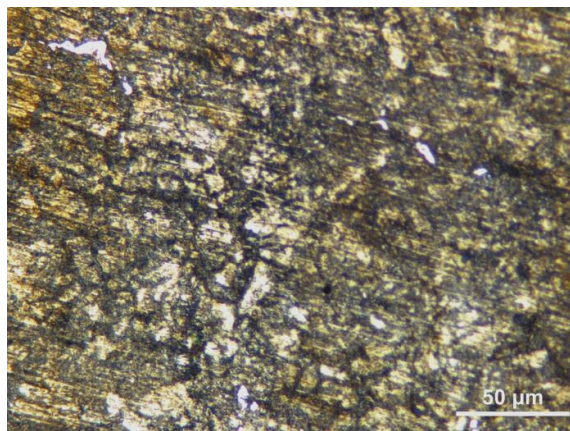
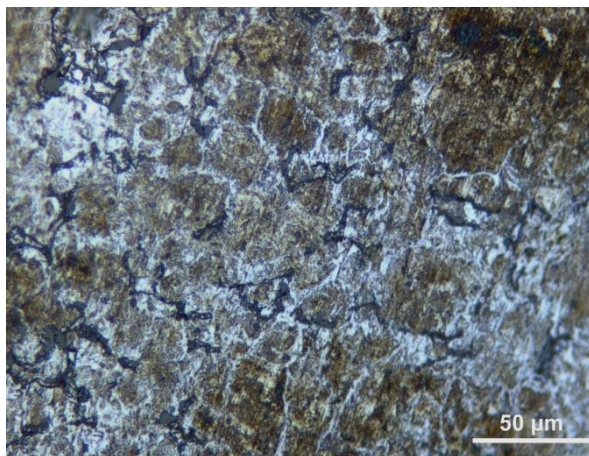


Figure 7. Microstructure of the Quenched Specimen

For specimens kept in salt bath for 60 seconds, the cooling time is longer than those with 30 seconds. It is thought that the ferrite and cementite phases formed martensitic structure in the specimen kept in a salt bath with a temperature of 350 ° C for 60 seconds. It is thought that the structure is not exactly martensite in the salt bath with a temperature of 400 ° C, and there is less martensite than the specimen in the salt bath with a temperature of 350 ° C. (Fig. 8)



(a)



(b)

Figure 8. Optical microstructures of specimens pressed at different salt bath temperatures for 60 seconds (a)350°C, (b)400°C.

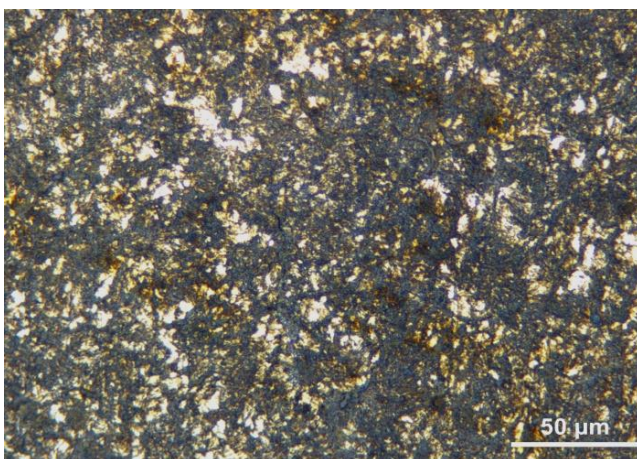


Figure 9. Optical microstructures of specimens salt bath temperatures 350°C for 360 seconds

The microstructure of the specimens kept at 350 ° C for 360 seconds is given in Figure 9. Based on the hardness values, residual austenites can be considered to be present in the structure. Increasing

the cooling time prevents the formation of martensite in the structure and the formation of bainite occurs. Considering the microstructure of the specimen, it is assumed that the cementite and ferrite phases turn into bainite and the martensite transformation decreases, and it is thought that the bainitic phase is dominant in the structure. (Fig. 9)

It can be concluded that the bainitic structure formed in the specimen kept at 400 ° C for 360 seconds is more than the specimen kept at 350 ° C for 360 seconds.

In addition, considering the hardness values, it is known that the bainite phase is softer than the martensite phase, and it can be thought that the specimen kept in a salt bath at 400 ° C for 360 seconds almost completely transformed into a bainitic structure. (Fig. 10)

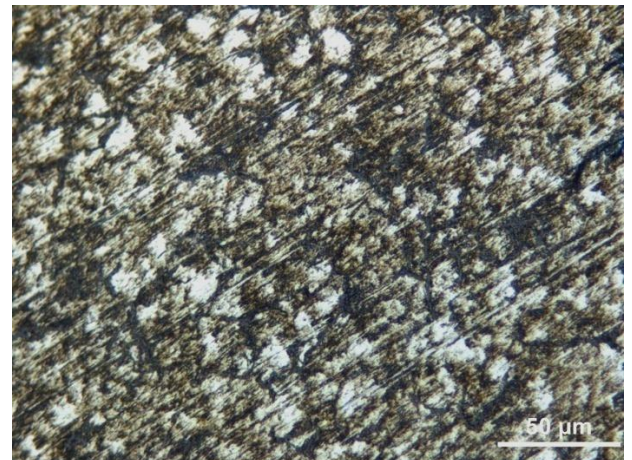


Figure 10. Optical microstructures of specimens salt bath temperatures 400°C for 360 seconds

Table 1. Brinell Hardness Values of Specimens

Martempering Times (Second)	Martempering Temperatures	
	350°C	400°C
30	376	440
60	402	320
90	386	317
180	366	316
360	360	285

It is found that the bainitic structure formed in the specimen kept at 400 ° C for 360 seconds is more than the specimen kept at 350 ° C for 360 seconds. Furthermore, it can be thought that the specimen kept in a salt bath at 400 ° C for 360 seconds almost

completely transformed into a bainitic structure due to bainite phase being softer phase than martensite. (Table 1.)

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