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Research Paper / Makale

Hardness change due to carburization time and material thickness during heat treatment of SAE 8620 (21NiCrMo2) plates

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Abstract: In this study, SAE 8620 (21NiCrMo2) cementation steel was carburized in a salt bath containing 10% cyanide (Potassium Cyanide KCN). Samples with, two different sizes as 15x15x100 mm and 20x20x100 mm, were gradually heated from room temperature to the hardening temperature of 930 °C and kept at this temperature for two different holding times as six and seven hours. The temperature was gradually reduced to 860 °C and the samples were held there for 40 minutes and then quenched in the oil cooling medium. After quenching, the materials were tempered at 180 °C for two hours. The surfaces of the samples which were sanded according to microstructure examinations and polished with diamond paste were etched with 5% Nital solution. Surface hardness and microhardness of the samples were measured and then their microstructures were examined with an optical microscope. The hardness depth and effective hardness depth were 1.6 mm and 1.2 mm, respectively. It was observed that hardening up to a 0.2 mm depth was at maximum level and hardness values decreased while approaching the core. The microstructure examinations displayed that the martensitic layer was formed on the surface and this layer lost its effect as it penetrated inwards. In the cementation process, it was determined that material thickness and carburization time had an effect on material properties.

Keywords: SAE 8620 (21NiCrMo2); carburizing; heat treatment; hardness; microhardness

SAE 8620 (21NiCrMo2) plakaların ısıl işleminde karbürizasyon süresi ve malzeme kalınlığına bağlı olarak oluşan sertlik değişimi

Öz: Bu çalışmada; SAE 8620 (21NiCrMo2) sementasyon çeliğine %10 siyanür içeren (Potasyum Siyanür KCN) tuz banyosunda karbürizasyon işlemi uygulanmıştır. 15x15x100 mm ve 20x20x100 mm olarak iki farklı ölçüde kesilen numuneler oda sıcaklığından sertleştirme sıcaklığı olan 930 °C' ye kadar kademeli şekilde ısıtılmış ve bu sıcaklıkta altı ve yedi saat süreyle iki farklı tutma süresinde bekletilmiştir. Kademeli bir şekilde sıcaklık 860 °C' ye düşürülmüş ve 40 dakika bu sıcaklıkta bekletilmiş numunelere yağ soğutma ortamında su verilmiştir. Su verme sonrası malzemeler 180 °C'de iki saat süreyle temperlenmiştir. Mikroyapı incelemelerine uygun olarak zımparalanan ve elmas pasta ile parlatması yapılan numunelerin yüzeyleri %5 nital çözeltisi ile dağlanmıştır. Numunelerin yüzey sertlikleri, mikrosertlik ölçümleri yapılmış ve optik mikroskop ile mikroyapıları incelenmiştir. Malzemeler için sertlik derinliği 1,6 mm ve etkili sertlik derinliği ise 1,2 mm olarak tespit edilmiştir. 0,2 mm derinliğe kadar sertleşmenin maksimum seviyede olduğu, çekirdeğe yaklaşıldıkça sertlik değerlerinin düştüğü görülmüştür. Mikro yapı incelemelerinde yüzeyde martenzitik tabakanın oluştuğu ve içeriye doğru penetre edildikçe bu tabakanın etkisini yitirdiği gözlemlenmiştir. Sementasyon işleminde, malzeme kalınlığının ve karbürizasyon süresinin malzeme özellikleri üzerinde etkili olduğu tespit edilmiştir.

Anahtar kelimeler: SAE 8620 (21NiCrMo2); Sementasyon; ısıl işlem; sertlik; mikrosertlik

1. Introduction

As the amount of carbon in steels decreases, they can be shaped more easily by the machining method. Low carbon steels are widely used in the manufacturing industry due to their high

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formability. However, their disadvantage is that they do not give the desired hardness for use. In this case, the required process is to take advantage of their softness during production, then to harden or to incorporate the carbon required for hardening.

In the hardening of cementation steels with a carbon content between 0.10% and 0.20%, the cementation hardening method is widely used which improves the surface hardness and abrasion strength of materials in addition to improving the core strength and ductility [1]. Hardness and abrasion strength properties are obtained on the surface by the cementation process, while softer and tougher properties are obtained in the core by the method of carbon impregnation on the material surface [2]. The cheapest and easiest method of heat treatment of cementation steels used in the production of materials such as gears, shafts, piston pins, chain links, pulleys, discs, guide plates, bearings, rollers, measuring and control tools, cutting tools is direct hardening from cementation temperature [3]. However, this method can only be applied in a salt bath or after gas cementation [1]. By increasing the ratio of carbon and alloying elements in cementation steels, an increase in core strength can be achieved [1,4,5]. When higher core strength is desired, core hardening is required after cementation [1,2].

Similar studies on cementation steels such as, the effect of heat treatment on abrasion behavior [4], the relationship between cementation depth and fatigue properties [7,8], the effect of martensite size on tension crack in a dual-phase microstructure [9], the relationship between residual austenite amount and crack propagation and fatigue behavior were investigated [10]. In addition, the relationship between the residual austenite content of the quenching medium and tribological properties of materials [11,12], the fatigue behavior of materials at different cementation temperatures and times [13], changes in mechanical properties [14] were studied. The relationship between ion nitriding behavior [15], hardness depth and abrasion behavior [16,17], microstructure and mechanical properties before and after heat treatment [18], the effect of process parameters on material removal rate and surface roughness [19] have been also studied in detail by various research groups. The literature reviews, revealed that there are not enough studies on the effect of material thicknesses and carbonation times on material hardness and effective hardness depth.

In this study, SAE 8620 (21NiCrMo2) cementation steels 15 mm and 20 mm in thickness were cemented in a salt bath containing 10% cyanide (potassium cyanide, KCN) and then quenching was applied in oil. The aim of this study is to investigate the relationship between the hardness and microstructure properties of the materials depending on the holding time at the cementation temperature and the thickness of the material.

2. Experimental Methods

2.1. Materials

In the studies, low carbon 15x15x100 mm and 20x20x200 mm cementation steels with the material number of 1.6523 and the symbol of 21NiCrMo2 (SAE 8620) in accordance with TSE EN 10084 standard were used. Cementation steels were provided from İMS Özel Çelik (Istanbul) as certified products. The mechanical properties of the materials are given in Table 1, and the chemical composition of the materials measured by a GNR S7 branded (GNR/Italy) mass spectroscopy device is given in Table 2.

Table 1. Mechanical properties of 21NiCrMo2 steel

Type	Value
Tensile strength	530 MPa
Yield strength	385 MPa
Elastic module	190-210 GPa
Shear modulus	80 GPa
Poisson's ratio	0,27-0,30
Izod impact resistance	115 J
Hardness	149 HB
Elongation at break	% 10

Table 2. The chemical composition of 21NiCrMo2 steel used in this study

Statement	**Composition (% wt.)**							
Element	**C**	**Si**	**Mn**	**$P_{max.}$**	**$S_{max.}$**	**Ni**	**Cr**	**Mo**
Standard	0,18-0,23	0,20-0,35	0,70-0,90	0,040	0,040	0,40-0,70	0,40-0,60	0,15-0,25
Based	0,197	0,204	0,718	0,012	0,0076	0,439	0,415	0,158

2.2. Carburizing

The prepared samples were carburized according to the heat treatment cycle and processes given in Figure 1 in a salt bath containing 10% cyanide (Potassium Cyanide KCN) in Esse Isıl İşlem (Çorum). The samples were gradually heated from room temperature to the hardening temperature of 930 °C. The samples were kept at 930 °C for six and seven hours. After holding time, the temperature was gradually reduced to 860 °C. The samples were quenched in oil after keepting at this temperature for 40 minutes. Subsequently, the materials were tempered at 180 °C for two hours. The parameters used in the studies are given in Table 3.

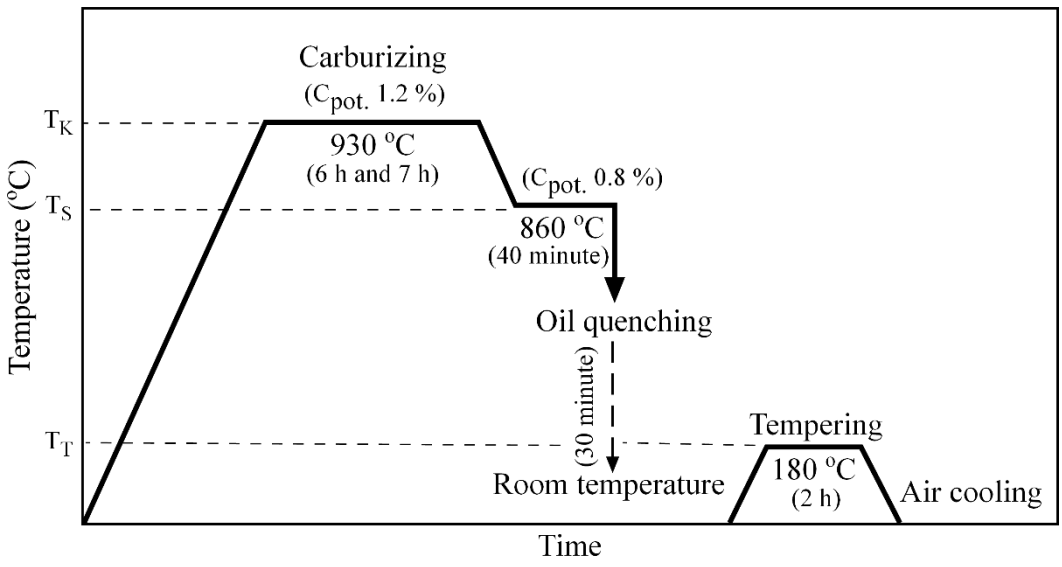

Figure 1. Schematic diagram of the heat treatment cycle

Table 3. The chemical composition of 21NiCrMo2 steel used in this study

Sample Code	Thickness (mm)	T_K (°C)	t_1 (h)	T_S (°C)	t_2 (minute)	T_K (°C)	t_3 (h)
1	15	930	6	860	40	180	2
2	20	930	6	860	40	180	2
3	15	930	7	860	40	180	2
4	20	930	7	860	40	180	2

2.2. Hardness

The hardness of the samples in HV was measured by using a MIKROSCAN branded hardness measuring device with 1 kp load and diamond pyramid tip with a point angle of 136° from the cross-sectional surface towards the center, and the effective hardness depth was tried to be determined.

2.3. Metallographic examination

For microstructure examinations, the samples were sanded up to 1200 times, polished with 3 μm and 1 μm diamond paste and their surfaces were etched with 5% Nital solution. Microstructure examinations were performed by an optical microscope.

3. Results and Discussion

It is important that the chemical composition of steel complies with the standard values for the correct application of heat treatment processes and the reliability of the results. The chemical composition (Table 1) measured by the spectrometer was found to comply with the standards. If the chemical composition is not of the desired properties, it will cause the part to lose its intended use, wear easily or deform the materials, especially in forced parts due to its high hardness [1,2]. Likewise, the difference between the surface hardness of the part and the core hardness will cause the intended heat treatment to fail and require an additional process. Naturally, these secondary processes will increase the cost of heat treatment and part production.

Graphs related to the hardness measurements are given in Figure 2. It is seen that the hardness distributions in the surface and cross-section differ depending on the thickness. Surface hardness values for a six/seven-hour holding time were measured as 832/860 HV for a 15 mm thickness and 810/840 HV for a 20 mm thickness, respectively. The images and measurement ranges of the samples after measurement are presented in Figure 3. It is expected that the material hardness will vary depending on thickness, carburization temperature and time [15]. The results, however, indicated that hardening up to a depth of 0.2 mm was at maximum level, the hardness values decreased while approaching the core and a sufficient martensite phase was formed in the structure. The hardness depth 1.6 mm and the effective hardness depth was 1.2 mm for the samples. It is known that the surface and the effective hardness depth of the part significantly depends on the amount of carbon content in the steel [2,6]. It was detected that decarburization did not occur when the material surfaces were examined, whereas hardness values decreased with the increase in thickness. Given the hardening of a solid solution such as manganese, silicon, nickel in the chemical composition and the effect of alloying elements such as chromium and molybdenum on the steel, which increases the hardness and strength, the distribution of hardness in the cross section is

expected to be different [20]. It is known that the pre-heat treatment parameters of steel, surface roughness values, heat treatment time and temperature of materials are important on the distribution of hardness in cross-section [8,15,21].

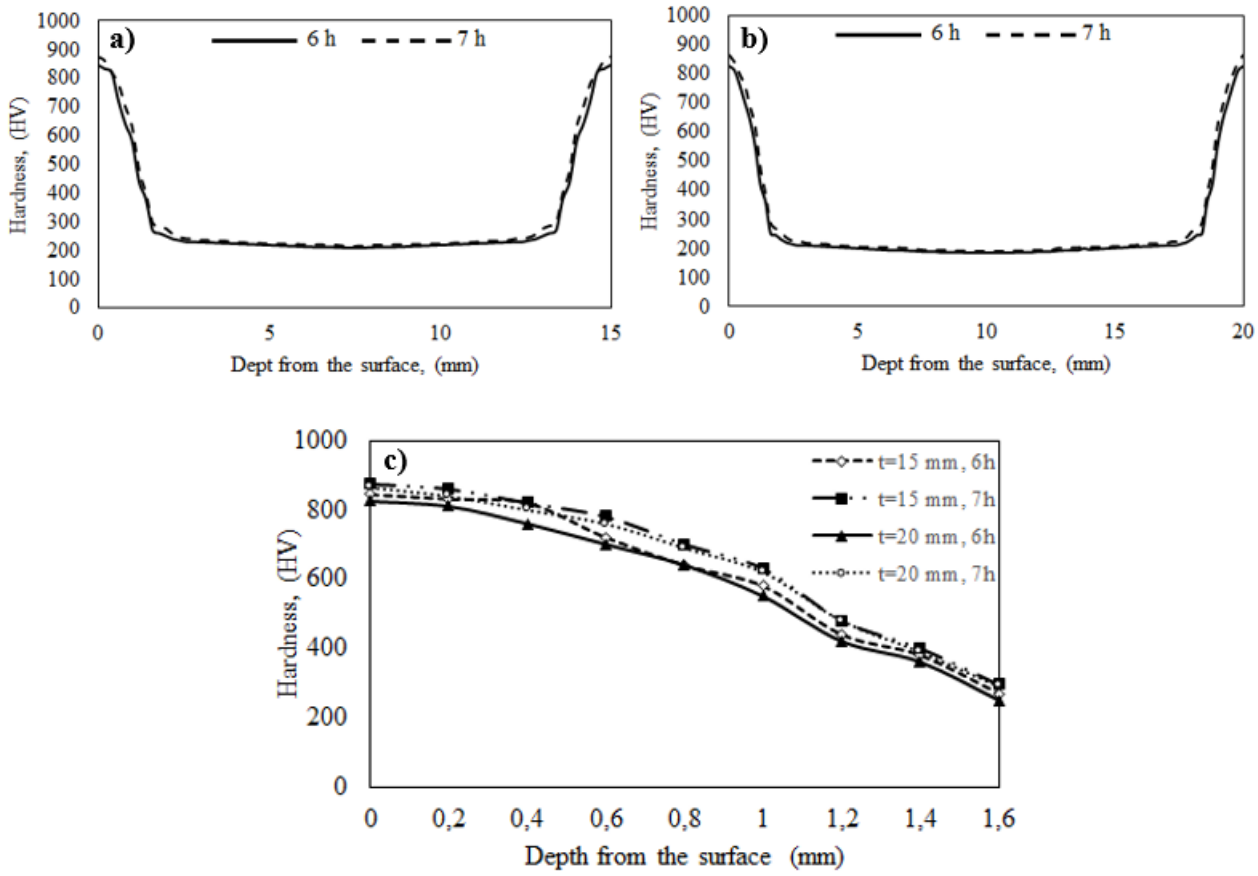

Figure 2. Hardness of samples, a) Thickness 15 mm, b) Thickness 20 mm, c) Effective hardness

Figure 3 and Figure 4 show the images of the microstructure examinations. In the microstructure examinations, the formation of-the martensitic layer the surface, which and this layer lost its effect as it penetrated inwards, is clearly seen It is known that the diffusion rate decreases while moving away from the surface as the surface has a harder structure [7,13].

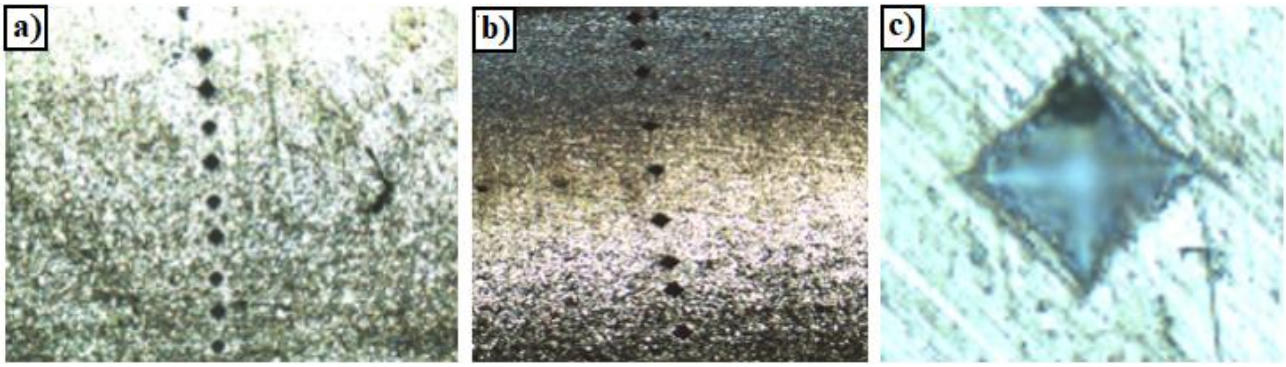

Figure 3. Optical microstructures, a) t=15 mm, b) t=20 mm c) measuring point

The microstructure images of the samples kept in the salt bath for six hours, exhibited perlite particles besides the flat martensite shapes. Asi et al. (2009) reported similar results in their study [13]. On the other hand, discontinuities and a bainitic structure were observed in the microstructure images of the samples kept in the salt bath for seven hours. As the carburization time increased, the

structure remained coarse towards the core and the perlitic structure turned into a bainitic structure. It is expected that fine grain steels after direct hardening will produce grain roughening at the usual cementation temperatures and achieve optimal core properties [1,3].

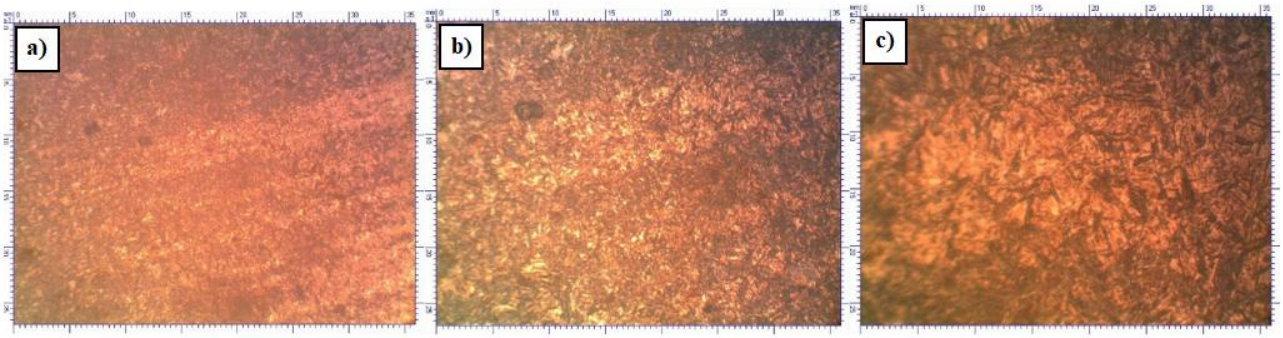

Figure 4. Optical microstructures, t=20 mm, a) x100 b) x200 c) x400

4. Conclusions

In this study, the relationship between the hardness and microstructure properties of the materials depending on the carburization time and material thickness was investigated experimentally. The following main conclusions can be drawn from this study:

1. The samples were hardened in accordance with the process and absorbed carbon from the steel surface to a certain depth during carburization. A relationship between hardness/effective hardness depth and material thickness and carburization time was shown.

2. It was determined that the hardness value decreased from the surface to the core, a thin layer of martensite was formed in the outer shell of the materials and this layer thickness progressed towards the inner surface with increasing holding time in the salt bath.

3. It was observed that the microstructure differs depending on the material thickness and carburization time. The amount of carbon dissolved in the structure increases as the carburization time increases and it reaches a hypereutectoid value.

4. After quenching, the martensite phase was transformed into a circular form with the tempering process. It is thought that this new form will provide a significant advantage in terms of the service life of parts and improve the mechanical properties.

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