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Research Article

Examination of corrosive wear performances of thermochemically treated cementation steels

Termokimyasal işlem uygulanmış sementasyon çeliklerinin korozif aşınma performanslarının incelenmesi

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Abstract
Rapidly developing surface development techniques in recent years positively affect mechanical properties of machinery such as fatigue and hardness, and surface properties such as wear and corrosion. In this study, the carbonitriding process was applied to low-carbon case cementation steel. After the process, their microstructures were examined with an optical microscope and scanning electron microscope. Wear tests were carried out under different loads in both dry and corrosive environments and compared with the sample without heat treatment. As a result of the carbonitriding process, up to four times an increase in hardness was observed compared to the sample that was not subjected to any thermochemical treatment. When looking at the coating thickness, it was observed that homogeneity was achieved and a thickness of 42 microns was reached. Wear performance was improved two times in the dry environment and a similar improvement was seen in the corrosive environment.

Anahtar Kelimeler
Karbonitrasyon, Sementasyon çeliği, Korozif aşınma

Öz
Son yıllarda hızla gelişen yüzey geliştirme teknikleri makina teçhizatlarının yorulma ve sertlik gibi mekanik özellikleri ile aşınma ve korozyon gibi yüzey özelliklerini pozitif yönde etkilemektedir. Bu çalışmada, düşük karbonlu sementasyon çeliğine karbonitrasyon işlemi uygulanmıştır. İşlemden sonra mikroyapıları optik mikroskop ve taramalı elektron mikroskopuyla incelenmiştir. Aşınma testleri hem kuru ortamda hem de korozif ortamda farklı yükler altında uygulanmış ve ısıl işlemsiz numuneyle kıyaslanmıştır. Karbonitrasyon işlemi neticesinde herhangi bir termokimyasal işleme tabii tutulmayan numuneye göre dört kata yakın sertlik artışı görülmüştür. Kaplama kalınlığına bakıldığında, homojenliğin sağlandığı ve 42 mikronluk kalınlığa ulaşıldığı gözlemlenmiştir. Aşınma performansı kuru ortamda iki kat geliştirilmiş ve korozif ortamda da benzer bir iyileşme görülmüştür.

Key Words
Carbonitriding, Cementation steel, Corrosive wear

Sorumlu Yazar: M. Emre Turan

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1. Introduction

Case hardening steels are low-carbon alloys which are used in the production of materials that are harder, resistant to abrasion, and have a soft and tough structure in their cores, resistant to different impact forces. These steels are generally preferred in precision gears, cam rollers, and shaft industries [1,2]. In recent years, surface development techniques positively affect the mechanical properties of equipment such as hardness, fatigue, oxidation, corrosion, wear, and friction properties. Methods such as nitriding, carburization, cementation, and boriding are used to increase the surface hardness of materials. While the surfaces of the materials are expected to be hard and wear-resistant to minimize friction, the internal structure is also expected to be soft and tough. The general purpose of using surface hardening methods is to prevent wear losses in materials [3–5]. Wear is of great economic importance as it affects material loss and the working life of the part, and accordingly its performance. It is necessary to use durable materials to prevent wear, which is the biggest cause of material losses in industrial devices. Wear losses occurring on the surface of the materials prevent the system from working efficiently. Mass loss on the surface of the materials also causes damage to machinery equipment and causes serious problems [6]. Among the surface hardening techniques, the carbonitriding process which is a modified system of gas carburizing is widely used. It includes the nitrogen and carbon atoms into the steel surface [1,7,8] The technique is most commonly used for the treatment of gears, drives, cams crankshafts, steering levers, and connecting rods [9]. The process is generally applied low carbon steels of 0.14-0.25%. The atmosphere of material treated, quenching conditions, material treated atmosphere and characteristics of materials influence the mass coefficient transfer and carbon diffusion rate [10]. The main advantage of gas-based thermochemical treatment is to control carbon and nitrogen amounts inside the thermochemical processed materials[11].. With simultaneous diffusion of nitrogen and carbon in austenite, the diffusion of carbon is accelerated and the finally wear performance and hardness can be developed by carbonitriding [12].

To objective of this paper is to enhance the hardness and wear behavior of case-hardening steels by applying a thermochemical heat treatment process. In literature, lots of surface hardening techniques were tried to develop the mechanical performance of steel groups. However, there are rare studies about the corrosive wear performance of case-hardened steel before and after thermochemical surface hardening methods.

2. Experimental Studies

Carbonitriding process was applied to low-carbon cementation steel. The chemical composition of this alloy is presented in Table 1.

Table 1. Chemical composition of 16MnCr5 steel

C	Si	Mn	P	S	Cr
0.18-0.19	0.20-0.22	1.10	0.012	0.013	0.90

For the carbonitriding process, the samples were cut into appropriate sizes and made suitable for the heat treatment. This type of thermochemical heat treatment of steel was carried out through a nitriding furnace. The process was applied to the samples in ammonia and carbon dioxide environments. In the process, nitriding was applied for 1.5 hours and carbonitriding was applied for 6 hours. 4 m^3/h NH_3 and 0.4 m^3/h CO_2 were poured into the furnace. After the process, it was removed from the oven and cooled.

Metallographic procedures were applied by grinding beginning with 120 until 2000 SiC grit paper and the surface of the materials was polished with diamond paste before carbonitriding. After the process, samples were prepared for hardness, microstructure, and wear tests. LOM and SEM were used to see the formation of the nitride layer and observe the coating thickness. Hardness was performed using the HV05 Vickers Method during 15 sec. and finally, samples were prepared for tribological tests. Wear tests were applied in both dry sliding and corrosive environments (3.5 wt.% NaCI) as Reciprocating using 5N, 10N, and 20N loads during 500 m. AISI 52100 steel balls were used for counter-face material.

3. Results and Discussion

Figure 1 illustrates the OM image of carbonitrided sample. When the thermochemical coated region is investigated, homogenous nitride layer can be observed. The coating thickness is measured an average of 40 micron. Also, there is a regular shape in this place. Furthermore, SEM image at the highest magnification is given in Figure 2. A little amount of crack formation can be occurred but there is a homogeneous and smooth layer throughout the coating area of the sample.

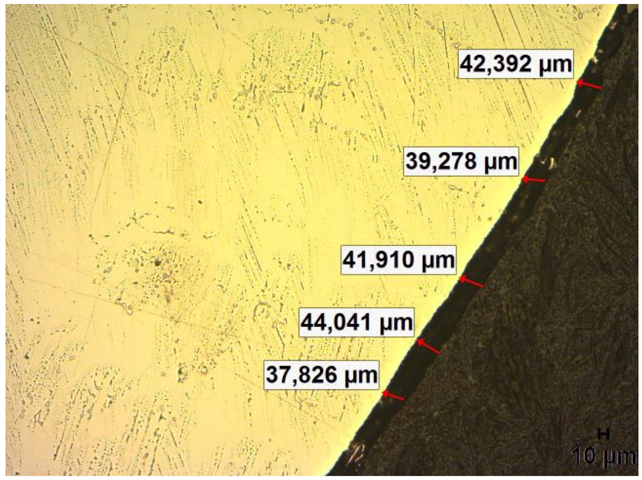


Figure 1. Optical microscope image of carbonitrided sample

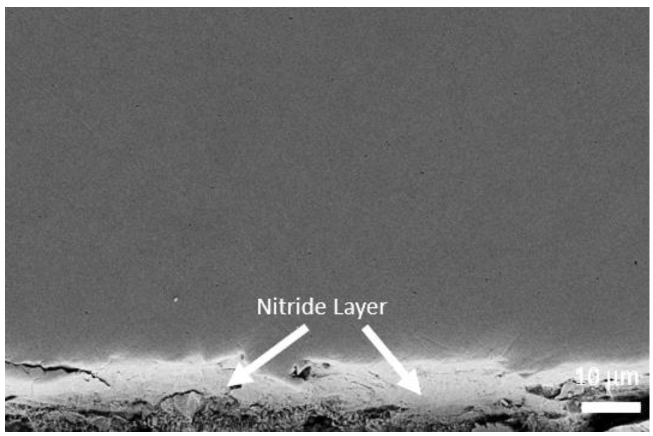


Figure 2. SEM image of carbonitrided sample

Hardness measurement results is presented in Figure 3. With the applying thermochemical heat treatment process, hard layer on the surface is an occurred. Nitrogen and carbon atoms pass on the steel as intermediate atoms and this situation leads to increase of hardness. According to the results, hardness value of steel increases up to 4 times by carbonitriding process. Vivek conducted carbonitriding process on 16MnCr5 steel and reported that carbon enrichment was obtained 0.494% in 0.45-0.50mm case depth. The hardness also reached up to 700 HV [4]. Puspitasari et. al [13] applied carbonitriding process for low carbon steel and they have observed that carbonitrided samples exhibited better performance than original sample which could be related to the presence of nitrides and carbides uniformly in the fine microstructure.

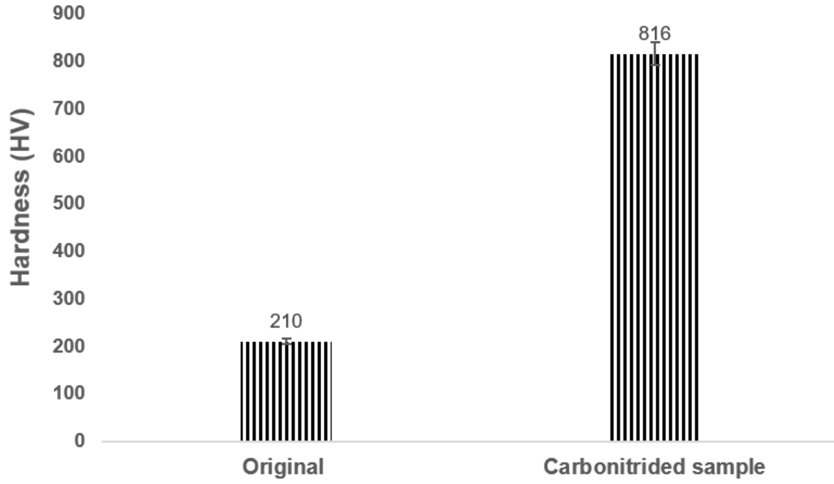


Figure 3. Hardness results of all samples

Figure 4 shows the wear rate values under three different loads of two different samples. For the calculation of wear rates, firstly wear volume loss was evaluated at the end of the sliding distance. Carbonitrided sample exhibits the better wear performance than original sample. The difference of wear rate values is more obvious especially for higher loads. For 20N applied loads, wear rate decreases nearly two times when the thermochemical heat treatment is applied. With the heat treatment process, the surface of material becomes more harder, and it prevents more wear until the coating removes from the surface. The higher hardness also lead to lower wear rate according to the Archard's principle laws.

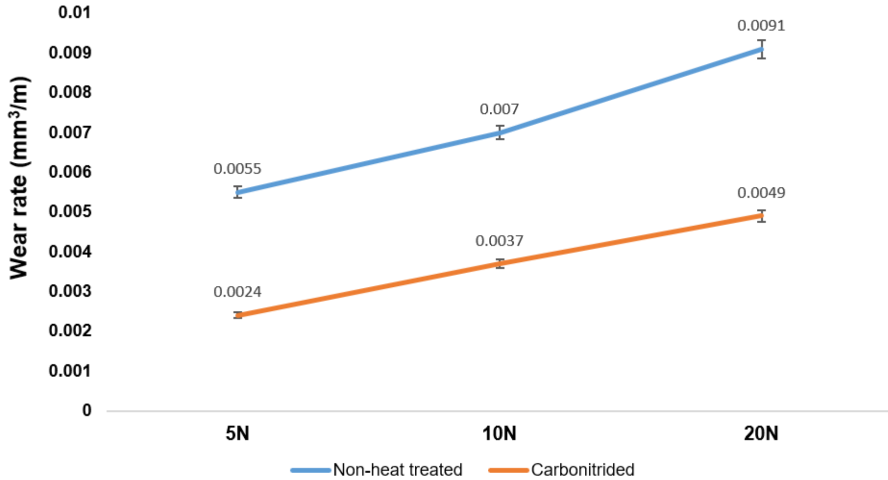
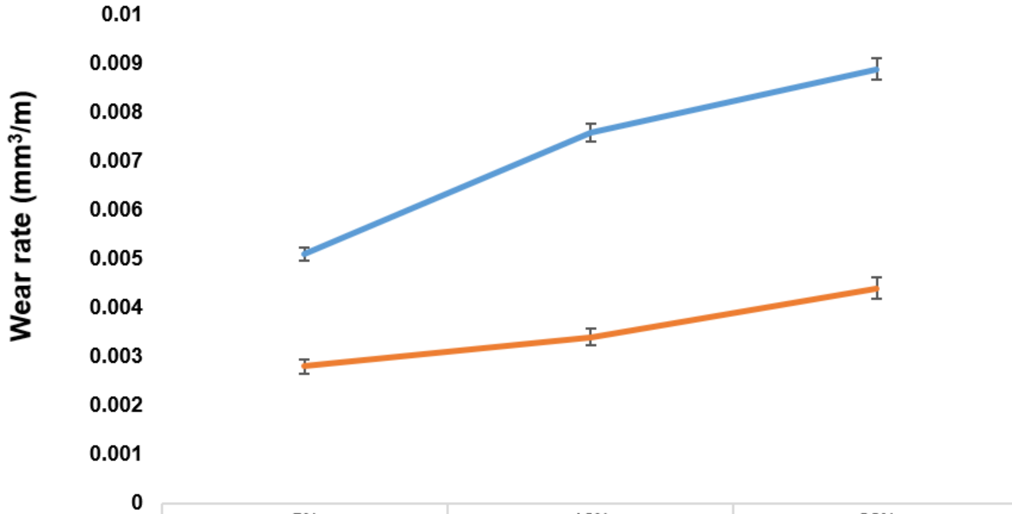


Figure 4. Wear rates of specimens (Dry sliding conditions)

Corrosive wear performance was calculated and presented in Figure 5. Similar situation is observed with dry sliding conditions. Once the applied load increases from 5N to 20N, wear rate begins to increase. Reciprocating higher loads leads to more remove the materials at the surface. According to the figure, slightly lower wear rate values were observed compared to the dry environment. The reason for this is that the material does not have the opportunity to corrode in the short distance like 500 meters and the wear has decreased slightly as the corrosive solution reduces the friction on the surface. The hard thermochemical coating on the surface again ensured that fewer pieces of the material broke off and reduced the wear. As the applied load increases, the coating thickness on the surface is removed in a shorter time, which causes more wear. Khrisna et.al [14] reported that wear performance of materials can be developed by carbonitriding thermochemical process under loads for shorter intervals of time.



	5N	10N	20N
Non-heat treated	0.0051	0.0076	0.0089
Carbonitrided	0.0028	0.0034	0.0044

Figure 5. Wear rates of specimens (In 3.5 wt.% NaCI solution)

4. Conclusions

In this study, cementation steel was used and carbonitriding process was applied successfully. Following results were obtained.

- According to the microstructural analysis, the homogeneity of the nitride layer was observed.
- As a result of thermochemical heat treatment, significantly improvements were achieved in hardness.
- Coating thickness reached up to 42 microns for the heat-treated sample.
- Wear performance of original performance was developed under all applied loads by carbonitriding process in dry sliding and corrosive environments.

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