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Research Paper / Makale

Characterization of Borided DIN X165CrMoV12 Steel

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Abstract: In the present study, characterization properties of borides formed on DIN X165CrMoV12 steel have been investigated. Boriding was performed in a solid medium consisting of Ekabor-II powders at 1073 and 1273K for 4 h. The boride layer was characterized by optical microscopy, X-ray diffraction technique and the micro-Vickers hardness tester. X-ray diffraction analysis of boride layers on the surface of the steels revealed the existence of FexBy and CrxBy compounds. Depending on the chemical composition of substrates, the boride layer thickness on the surface of the DIN X165CrMoV12 steel was found to be 32.75 μm and 78.92 μm at 1073 and 1173K for 4 h, respectively. The hardness of the boride compounds formed on the surface of the DIN X165CrMoV12 steel ranged from 1638 to 1892 $HV_{0,1}$, whereas Vickers hardness values of the untreated steel DIN X165CrMoV12 was 432 HV0,1.

Keywords: DIN X165CrMoV12; Boriding; XRD; Micro-hardness.

Borlanmış DIN X165CrMoV12 Çeliğinin Karakterizasyonu

Özet: Bu çalışmada DIN X165CrMoV12 soğuk iş takım çeliğinin borlama işlemi sonrası karakterizasyon özellikleri incelenịştir. Borlama işlemi ticari Ekabor-II bor tozuyla kutu borlama tekniği kullanılarak 1073 ve 1273K'de 4 saat süreyle borlanmıştır. Borlama sonucunda elde edilen borür tabakaları optik mikroskop, X-Işını Difraktometresi ve mikrosertlik testleri ile karakterize edilmiştir. X-Işını Difraktometresi analizi sonucunda FexBy and CrxBy fazları elde edilmiştir. Borlama sıcaklıklarına bağlı olarak 1073K'de 32.75 μm, 1173K'de ise 78.92 μm kalınlığında borür tabaka kalınlıkları elde edilmiştir. Mikrosertlik analizi sonucunda Borlanmış DIN X165CrMoV12 çeliğinin mikrosertlik değerlerinin sıcaklığa bağlı olarak1638 to 1892 $HV_{0,1}$ arasında değiştirği tespit edilmiştir.

Anahtar kelimeler: DIN X165CrMoV12; Borlama; XRD; Mikrosertlik.

1. Introduction

Boriding is a thermochemical surface treatment that involves diffusion of boron into a substrate at elevated temperatures. Diffusion of boron into the surface of metals and alloys by means of gaseous, liquid or solid substances forms intermetallic borides [1-4].

The pack boriding of Iron alloys is very attractive because of the simplicity of the technique, the unsophisticated equipment required, and its cost-effectiveness. The boriding powder, consisting of a boriding agent, halogen activator and filler, is packed around a workpiece in a steel container and is heated up to between 700 and 1400 ^{o}C in a furnace with controlled atmosphere for 1 to 16 hours in order to form a smooth boride layer through diffusion. Once boron is deposited on the surface, the diffusion rate of boron through the matrix is controlled by the process temperature and time. In

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general, the diffusion rate of boron is higher at higher temperatures, while time is critical for the thickness and composition of the boride layer. Additionally, the chemical composition of the substrate material is another important parameter and plays a major role in boron diffusion. Therefore, there has been extensive research in recent years on the development of surface treatment processes to improve the wear resistance, corrosion and oxidation resistance of steels for high-temperature and high-pressure applications. Industrial boriding processes can be applied to a wide range of steel alloys including carbon steel, low alloy-steel, tool-steel and stainless-steel etc. [5-10].

The main objective of this study was to investigate the characterization properties of borided DIN X165CrMoV12 cold work tool steel. Structural and tribological properties were investigated using optical microscopy, XRD and microhardness tests.

2 Experimental Method

2.1 Boriding and Characterization

The high alloy cold work tool DIN X165CrMoV12 steel essentially contained 1.72 wt.% C, 0.30 wt.% Mn, 11.45 wt.% Cr, 0.70 wt.% Mo and 0.60 wt.% W. The test specimens were cut into Ø18x10mm dimensions, ground up to 1000G and polished using diamond solution. The boriding heat treatment was carried out in a solid medium containing an Ekabor-II powder mixture placed in an electrical resistance furnace operated at the temperature of 1073K and 1173K for 4 h under atmospheric pressure. Following the completion of the boriding process, test specimens were removed from the sealed in a stainless steel container and allowed to cool down in still air. The microstructures of polished and etched cross-sections of the specimens were observed under a Nikon MA100 optical microscope. The presence of borides formed in the coating layer was confirmed by means of X-ray diffraction equipment (Shimadzu XRD 6000) using Cu Kα radiation. The hardness measurements of the boride layer on each steel and unborided steel substrate were made on the cross-sections using a Shimadzu HMV-2 Vickers indenter with a 100 g load.

3. Results And Discussion

3.1 Characterization of Boride Coatings

The cross-sections of the optical micrographs of the borided DIN X165CrMoV12 cold work tool steel at the temperature of 1073K 1173K for 4 h are shown in Figure 1. As can be seen, the borides formed on the cold work tool steel substrate have a smooth morphology due to higher alloy content. It was found that the coating/matrix interface and matrix could be significantly distinguished and the boride layer had a columnar structure. Depending on the chemical composition of substrates and boriding time, the boride layer thickness on the surface of the steel ranged from 32.75 μm and 78.92 μm. In the literature studies, the boron layer thicknesses increased with the increase of boron temperature [9-12]. It is seen in this study that the hot factor is the most effective factor increasing the boron layer.

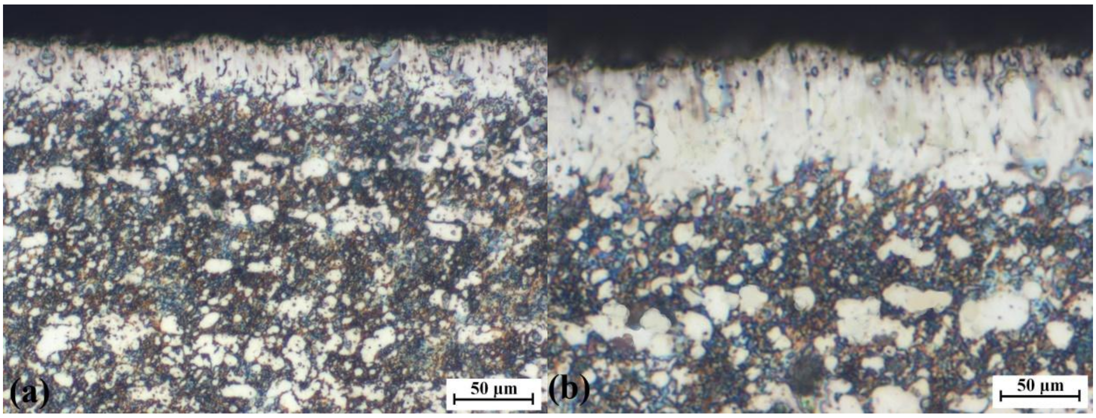

Figure 1. The cross-section of borided DIN X165CrMoV12 steel a) 1073K-4h, b) 1173K-4h

In this study, the presence of borides was identified using XRD analysis; see Fig. 2. XRD patterns show that the boride layer consists of borides such as AB and A_2B (A=Metal; Fe, Cr). XRD results showed that boride layers formed on the steel contained the FeB, Fe_2B, CrB and Cr_2B compounds, see Fig. 2. In this study chromium and iron boron phases were formed due to the high content of iron and chromium inside the steel. CrB and FeB phases become dominant with increasing boriding temperature.

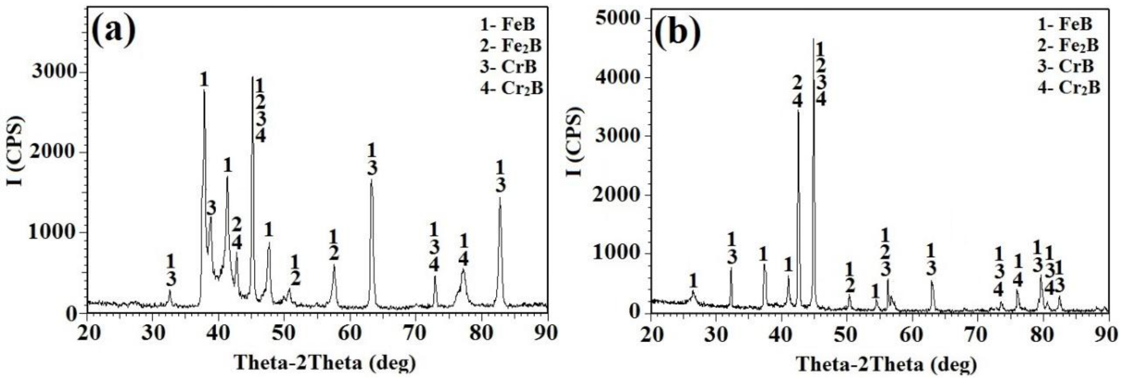

Figure 2. X-ray diffraction patterns of borided DIN X165CrMoV12 steel a) 1073K-4h, b) 1173K-4h

Micro-hardness measurements were carried out from the surface to the interior along a line in order to see the variations in the boride layer hardness, transition zone and matrix, respectively. The micro-hardness of the boride layers was measured at 8 different locations at the same distance from the surface and the average value was taken as the hardness. Micro-hardness measurements were carried out on the cross-sections from the surface to the interior along a line; see Figure 3.

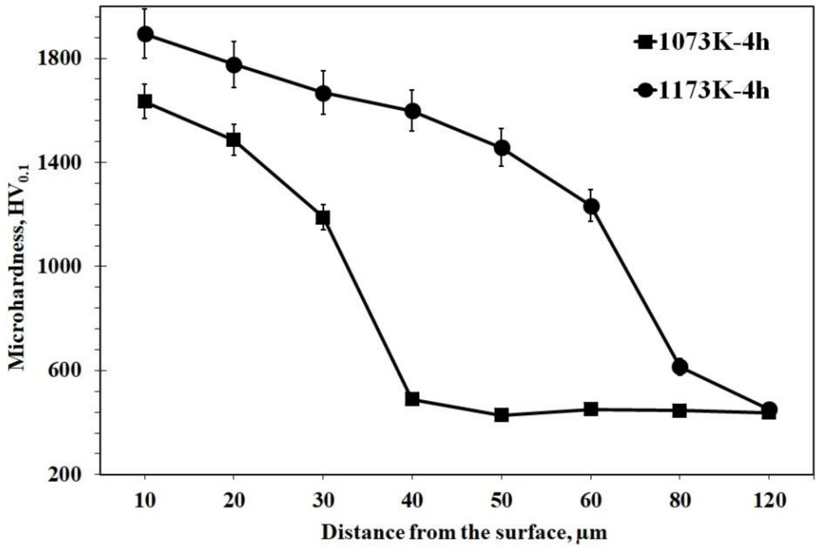

Figure 3. The variation of hardness depth in the borided DIN X165CrMoV12 steel.

The hardness of the boride compounds formed on the surface of the steels ranged from 1638 to 1892 $HV_{0,1}$, whereas Vickers hardness values of the untreated the steels was 432 $HV_{0,1}$. When the hardness of the boride layer is compared with the matrix, boride layer hardness is approximately four times greater than that of the matrix. The hardness values of the boron steels increased due to the boron phases. Similar results were obtained in the literature[13-15].

4 Conclusions

In this study, wear behavior and some of the mechanical properties of borides on the surface of borided DIN X165CrMoV12 cold work tool steel were investigated. Some of the conclusions can be drawn as follows.

- Boride types formed on the surface of the DIN X165CrMoV12 steel have a smooth morphology.
- The boride layer thickness on the surface of the DIN X165CrMoV12 steel was obtained, depending on the chemical composition of substrates, 32.75-78.92 µm.
- The multiphase boride coatings that were thermo chemically grown on the cold work tool steel were constituted by the FeB, Fe_2B, CrB andCr_2B phases.
- The surface hardness of the borided steel was in the range of 1638-1892 $HV_{0,1}$ while for the untreated the steel substrate it was 432 $HV_{0,01}$.

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