Surface Characterization of Borided S220 Rebar

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Abstract

In this study, the surface characterization properties of borided S220 rebar were investigated. Rebar was borided at 870 and 920°C for 2 and 6 h by Ekabor II boron powders. Borided rebar surface properties were examined using optical microscope, XRD and microhardness tests and surface profilometry. X-ray diffraction analysis of boride layers on the surface of the rebars revealed the existence of FeB and Fe₂B compounds. Depending on the chemical composition of substrates, the boride layer thickness on the surface of the S220 rebar was found to be 64.28 µm. The hardness of the boride compounds formed on the surface of the steels ranged from 1472 to 1674 HV_{0.05}, whereas Vickers hardness values of the untreated the steels was 142 HV_{0.05}. As a result of the boronization process, the thickness of the boride layer, hardness and the surface roughness increased depending on the temperature and time.

Keywords: S220 Rebar, Boriding, Microhardness, Surface Roughness.

Borlanmış S220 İnşaat Demirinin Yüzey Karakterizasyonu

Öz

Bu çalışmada, borlanmış S220 donatıların yüzey karakterizasyon özellikleri incelenmiştir. İnşaat demiri 870 ve 920°C’de 2 ve 6 saat süreyle Ekabor II bor tozu ile borlanmıştır. Borlanmış inşaat demirinin yüzey özellikleri, optik mikroskop, XRD, mikrosertlik ve yüzey profilometrisi kullanılarak incelenmiştir. XRD analizi sonucunda inşaat demiri yüzeyindeki borür tabakalarında FeB ve Fe₂B fazları elde edilmiştir. Çeliğin kimyasal bileşimine bağlı olarak, S220 inşaat demiri yüzeyindeki borür tabakası kalınlığı 64,28 µm olarak bulunmuştur. Çeliklerin yüzeyinde oluşan borür tabakalarının sertlikleri 1472 ile 1674 HV_{0.05} arasında değişirken, herhangi bir işlem görmemiş çeliğin Vickers sertlik değeri 142 HV_{0.05}’tir. Borlama işlemi sonucunda sıcaklığa ve zamana bağlı olarak borür tabakasının kalınlığı, sertliği ve yüzey pürüzlülüğü artmıştır.

Anahtar Kelimeler: S220 Rebar, Borlama, Mikrosetlik, Yüzey Pürüzlülüğü.

1. Introduction

Rebar is a specially shaped steel that is placed in concrete in reinforced concrete structures in order to meet tensile stresses and shear problems. Iron is the most common metal in the earth's crust. Ferrous metals are obtained from iron ore and are rarely found in elemental form in nature. The metallic iron to obtain material in the ore have to be removed by chemical reduction. Iron is used to make steel, which can actually be considered a largely carbon alloy. Rebar is one of the most important materials used in construction. Ribbed iron is a type of iron that increases resistance. It has recesses and protrusions on it. In this way, it holds the concrete more tightly. Ribbed rebar contains Carbon and Manganese elements and the carbon ratio should not be over 25 percent [1].

Boriding is a thermochemical surface treatment, a diffusion process similar to carburizing and nitriding in that boron is diffused into a metal base. Like other treatments involving diffusion, the substrate to be treated must be in contact with a boronaceous substance in the form of a solid powder, paste, plasma paste, liquid, or gas and held at high temperatures (700–1200°C). Under these conditions, boron atoms diffuse from the surface into the metal lattice, forming borides with the atoms of the substrate and alloying elements, promoting the formation of the borided layer. Fluidized bed techniques can also be used for boriding. Other means to promote boride layer deposition without using thermochemical activation are plasma vapor deposition (PVD), ion implantation, and plasma spray [2,3].

The main objective of this study was to investigate of the surface characterization properties of borided S220 Rebar. Surface properties of borided rebar were investigated using optical microscopy, XRD and microhardness tests and surface profilometer.

2. Material and Method

The S220 rebar essentially contained 0.25 wt.% C, 1.20 wt.% Mn and 0.05 wt.% Si. Samples cut in Ø12x10mm dimensions by machining processes were prepared metallographically. 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 870°C and 920°C for 2 and 6h under atmospheric pressure. 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 using Cu K α radiation. The hardness measurements of the boride layer on each steel and untreated steel substrate were made on the cross-sections using a Vickers indenter with a 50 g load.

3. Results and Discussion

The cross-sections of the optical micrographs of the borided S220 rebars at the temperature of 870°C and 920°C for 2h and 6h are shown in Figure 1. As can be seen, the borides formed on the steel substrate have a smooth morphology. Depending on the chemical composition of substrates and boriding time, the boride layer thickness on the surface of the rebar ranged from 18.47 μm and 64.28 μm . Boride layer thickness, micro hardness and surface roughness of borided rebars are shown in Table 1. Boride layer thickness and surface roughness increased depending on the temperature and time.

Figure 1. The cross-section of borided S220 rebar, a) 870°C-2h, b) 870°C-6h, c) 920°C-2h, d) 920°C-6h

Table 1. Microhardness, coating layer thickness and surface roughness values of borided S220 rebar

	Layer thickness, (μm)	Microhardness ($\text{HK}_{0.025}$)	Surface roughness, Ra (μm), untreated	Surface roughness, Ra (μm), treated
870 °C - 2h	18.47 ± 1.6	1472	0.151 ± 0.01	0.208 ± 0.02
870 °C - 6h	45.82 ± 2.7	1584	0.168 ± 0.03	0.321 ± 0.07
920 °C - 2h	37.65 ± 2.1	1545	0.134 ± 0.02	0.274 ± 0.05
920 °C - 6h	64.28 ± 3.5	1674	0.179 ± 0.05	0.396 ± 0.09

XRD results showed that boride layers formed on the rebar the FeB and Fe₂B compounds, see Fig. 2. The boron rich FeB phase (containing approx. 16.23 wt.% B) is not desirable because FeB is more brittle than the iron subboride Fe₂B phase (containing approx. 8.83 wt.% B) [4]. Thus, the obtained boride layer is either single-phase (Fe₂B only) or double-phase (FeB and Fe₂B). Generally, a single-phase layer of Fe₂B boride is preferred to the double-phase layer for two main reasons: the important brittleness of the FeB phase and the large difference between the expansion coefficients of the two kinds of borides (FeB = $23 \times 10^{-6} \text{ } ^\circ\text{C}^{-1}$, Fe₂B = $7.85 \times 10^{-6} \text{ } ^\circ\text{C}^{-1}$) [5].

Figure 2. X-ray diffraction patterns of borided rebar, a) 870°C-2h, b) 870°C-6h, c) 920°C-2h, d) 920°C-6h

The hardness of the boride compounds formed on the surface of the rebars ranged from 1472 to 1674 HV_{0.05}, whereas Vickers hardness values of the untreated rebars was 142 HV_{0.05} (Figure 3). The hardness values of the boron rebars increased due to the boron phases. When the hardness of the boride layer is compared with the matrix, boride layer hardness is approximately eleven times greater than that of the matrix. The hardness values of the boron rebars increased due to the boron phases. Similar results were obtained in the literature [6-8].

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

4. Conclusions and Recommendations

The results obtained from this study are as follows. Depending on the boriding temperature and times, the thickness of borides formed on the surface of borided rebars ranges from 18.47 to 64.28 μm . In XRD analysis, FeB and Fe₂B phases were obtained on borided rebar. The surface hardness of the borided rebar was in the range of 1472 to 1674 HV_{0,05} while for the untreated the rebar substrate it was 142 HV_{0,05}. Boride layer thickness and surface roughness increased depending on the temperature and time.

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