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Research Article

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Boriding of 34CrNiMo6 Steels

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Abstract In this study, the boriding of 34CrNiMo6 steel was carried out for the first time. For this purpose, boriding process was performed by powder pack method at 950°C for 6 h. The microstructural characterization of borided steels was characterized by optical, SEM, EDS, XRD analyses. These results showed the presence of three zones, namely borided region (boride layer), transition zone, and non-borided core. The boride layer consists of borides such as FeB, Fe2B, Cr-Fe-C compounds and has saw-tooth morphology. Basing on our experimental results, we say that the boring process was successfully carried out in 34CrNiMo6 steels.

Keywords Boriding, 34CrNiMo6 steels, boride layer, Ekabor II

Introduction

Cr-Ni-Mo steels have high strength, good ductility, and excellent corrosion resistance after thermal processes [1-3]. Thus, these steels have been used for along time in areas where excellent fatigue and wear properties are required. In literature [4-6], it has been shown that Cr-Ni-Mo steels have the microstructure of consist of ferrite, martensite, and cementite. Corresponding to this, Mohammad et al. [6] and Kumar et al. [7] showed that presence of dual phase microstructure such as ferrite-bainite and ferrite-martensite improve toughness properties. On the other hand, it has been reported that thermal process such as the tempering and quenching has a noticeable effect on the microstructure of these steels [8,9].

34CrNiMo6 steel is a typical medium-carbon, low-alloy steel, which is widely used to automotive industry due to great mechanical properties. It is clear that in order to further improve these superior properties of these steels, there is a need for heat treatments as well as alloy element effect. Regarding this issue, we think that boriding is a popular method which changes chemical composition and microstructure of steels. Although 34CrNiMo6 steel has been studied over the last decades, there is no information about microstructure and also phase properties of borided 34CrNiMo6 steels. The aim of this study is to investigate whether boriding process has taken place in 34CrNiMo6 steel and if boriding has occurred, to examine phase and microstructure properties in 34CrNiMo6 steels.

Experimental Method

The 34CrNiMo6 steel essentially contained 0.34 wt.% C, 0.40 (max) wt.% Si, 0.65 wt.% Mn, 1.50 wt.% Cr 0.23 wt.% Mo and 1.50 wt.% Ni. The boriding of the samples was achieved in a solid medium using commercial Ekabor-II powder (BorTec GmbH).The samples were packed with the boriding powders in stainless steel containers and borided in an electrical resistance furnace at at 950 ºC for 6 h under atmospheric pressure. After boriding, the containers were removed from the furnace and cooled in air. Microstructural analysis of borided steels was characterized by optical, SEM, EDS, XRD.

Results and Discussion

Microstructures of the as-received and the heat-treated (boriding) steels are shown in Fig. 1.a and b. After boriding process, three distinct regions were identified on the surface of 34CrNiMo6 steels: (i) diffusion layer (borides), (ii) transition zone and (iii) matrix (Fig. 1.b and Fig. 2). On the other hand, from these micrographs, we see that the microstructure of 34CrNiMo6 steel occurring under the diffusion layer was composed of ferrite (light matrix) and perlite phase (dark phase).In the transition zone, there is excessive grain growth and the structure is mostly ferrite and pearlite. In addition, there are a few Cr matrix carbides. The thickness of the produced boride layers was about 60µm.

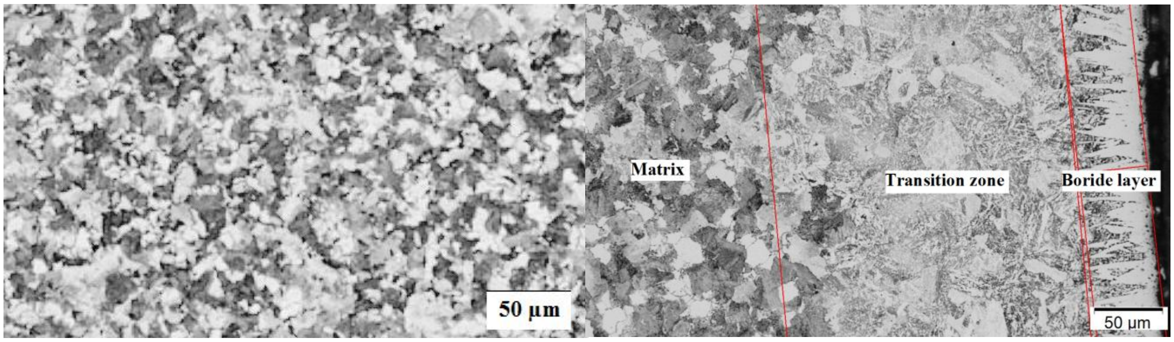


Figure 1: Optical microstructures of unborided (a) and borided 34CrNiMo6 steels at 950 ºC for 6 h (b)

Both SEM and optical micrographs shown in Fig. 1.b and Fig. 2 indicate that the sawtooth morphology consist of Fe2B (inner) and FeB(outer) phases. This morphology is a characteristics property of the boride layer and depends on alloying elements and treatment temperature [10].

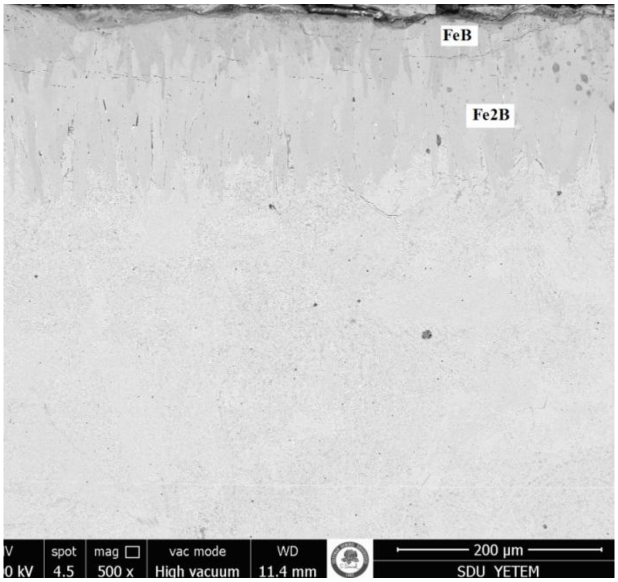


Figure 2: SEM images of borided 34CrNiMo6 steels

Figure 3 shows the x-ray diffractograms (XRD) of unborided and borided specimen at at 950 ºC for 6 h. From this Fig, the 34CrNiMo6 steel borided at 950 °C showed FeB and Cr15.58Fe7.42C6 peaks in addition to Ekabor II peaks in the boride layer.

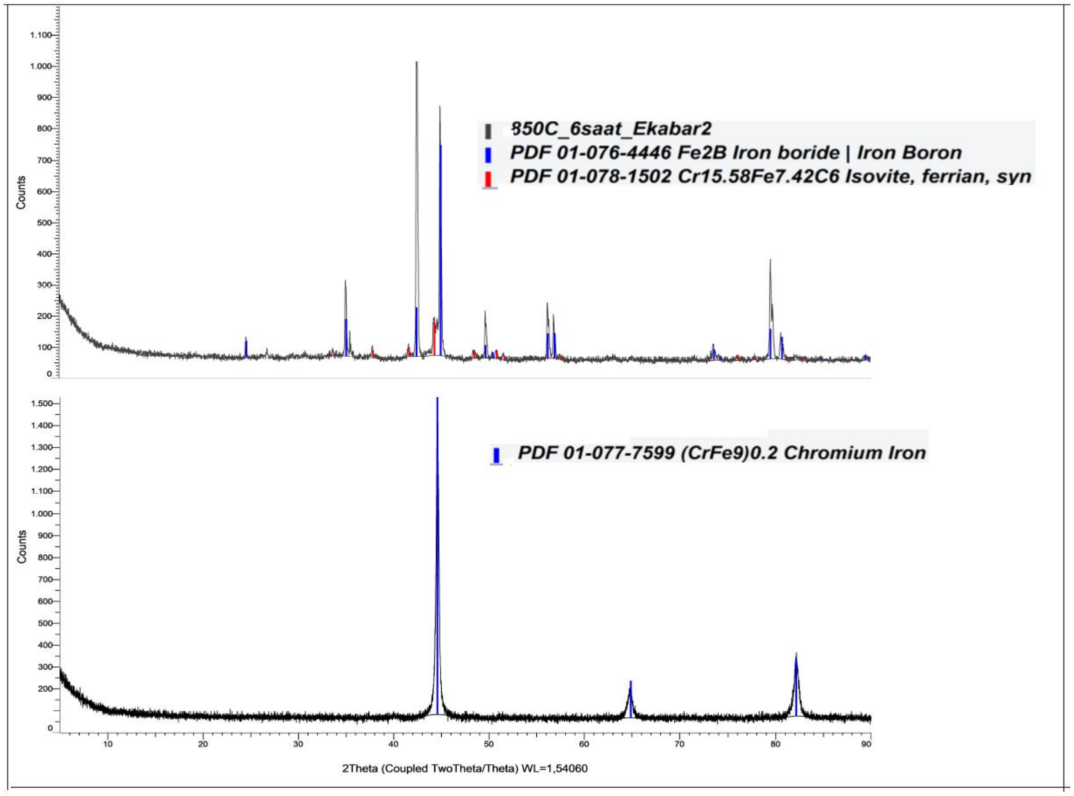
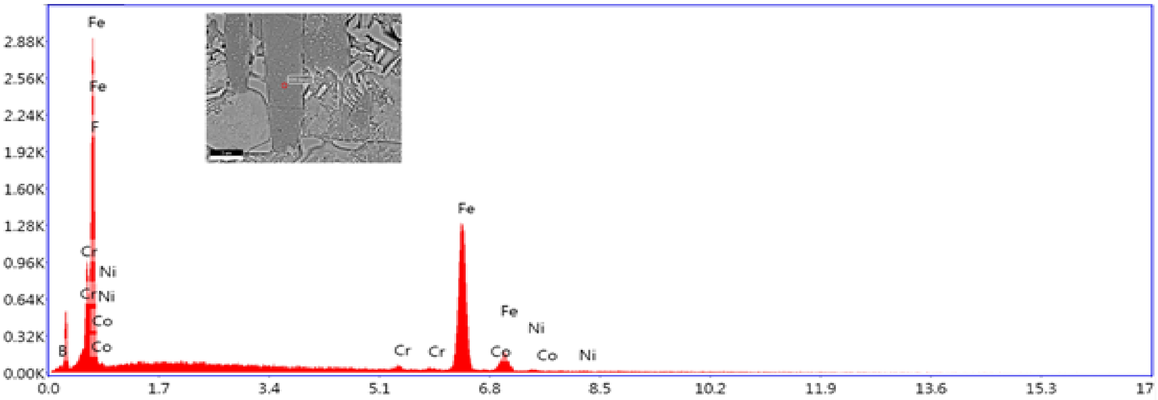
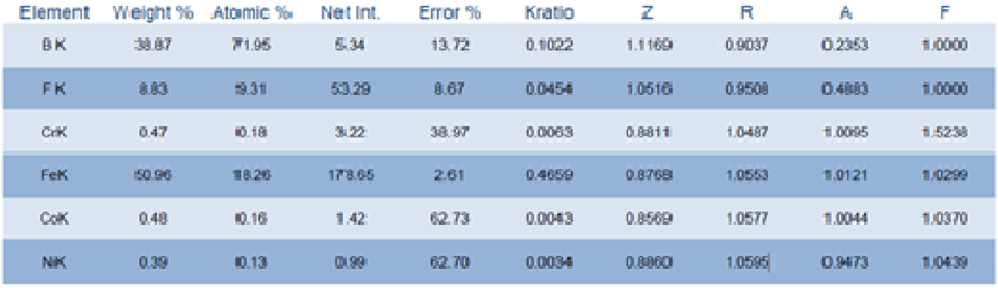


Figure 3: X-ray diffraction patterns of untreated and borided 34CrNiMo6 steels





Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
B K	38.87	71.95	5.34	13.72	0.1022	1.1169	0.9037	0.2353	1.0000
F K	8.83	9.31	53.29	8.67	0.0454	1.0516	0.9508	0.4883	1.0000
CrK	0.47	0.18	3.22	38.97	0.0063	0.8811	1.0487	1.0095	1.5238
FeK	50.96	18.26	178.65	2.61	0.4659	0.8768	1.0553	1.0121	1.0299
CoK	0.48	0.16	1.42	62.73	0.0043	0.8569	1.0577	1.0044	1.0370
NiK	0.39	0.13	0.99	62.70	0.0034	0.8860	1.0595	0.9473	1.0439

Figure 4: Energy-dispersive spectroscopic (EDS) analysis of the borided 34CrNiMo6 steels borided at 950 ^{o}C for 6h EDS analysis is done in boride layer region as indicated figure.

On the other hand, EDS analysis is done in the cross-sectional region in the boride layer of borided 34CrNiMo6 steel. EDS results shown in Fig. 4 indicate the presence of Cr, C, and Fe elements with a boron. This confirms that boriding has occurred in the boride layer with hard boride phases (FeB and Fe2B) and Cr-C-Fe phases.

To summary, these results show that the boriding process for 34CrNiMo6 steels has been carried out successful. Thus, these steels can be used in a very wide range as a result of the improvements in the mechanical properties that will occur with boriding.

Conclusion

In this study, the 34CrNiMo6 steel was borided with powder pack method. Some of the conclusions can be drawn as follows.

- Three different regions in the direction from the surface into the depth of the borided34CrNiMo6 steels, namely, (i) boride layer containing boride phases, (ii) a transition zone, and (iii) a matrix not affected by boron diffusion.
- Boride layer was composed of ferrite and perlite structure.
- Boride types formed on the surface of the steel have a saw tooth morphology.
- The multiphase boride coatings was constituted by the FeB, Fe2B and Ce-Fe-C phases.

Acknowledgments

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