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Investigation of Characterization of Borided AISI D3 Steel

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Abstract
In the present study, characterization properties of borides formed on AISI D3 steel have been investigated. 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 FeB, Fe2B, CrB and Cr2B compounds. Depending on the chemical composition of substrates and boriding time, the boride layer thickness on the surface of the steel ranged from 32.15 µm and 73.68 µm. The hardness of the boride compounds formed on the surface of the steels ranged from 1692 to 1874 HV0,1, whereas Vickers hardness values of the untreated the steels was 584 HV0,1.
Keywords: AISI D3, Boriding, XRD, Hardness

INTRODUCTION

As a thermos chemical process used for surface hardening boriding or boronizing entails heating a material to between 700-1000°C for 1 to 12 hours using a boronaceous solid powder, paste, liquid or gaseous medium. The powder-pack boriding, which is one of the thermochemical methods, is tech-nologically simpler and more economic in comparison with other boriding processes. The morphology of the boride layers is influenced by the presence of alloying elements in the matrix. Sawtooth- shaped layers are obtained in low-alloys steels whereas in high-alloy steels, the interfaces tend to be flat. Borided steel components display excellent performance in several tribological applications in mechanical engineering and automotive industries. Borided steels exhibit high hardness, high wear resistance, and improved oxidation and corrosion resistance [1-3].

The hardness achieved is many times higher than any other surface hardening process. The combination of high hardness and low coefficient of friction enhance wear, abrasion and surface fatigue properties. Other benefits associated with boriding are retention of hardness at elevated temperature, corrosion resistance in acidic environment, reduction in use of lubricants and a reduced tendency to cold weld. The borided steel surfaces with a high hardness have outstanding wear and corrosion resistance. Therefore, boriding are common thermochemical surface treatments applied to improve the surface properties of machine parts [5-7].

The wear behavior of borided steels has been evaluated by a number of investigators [7-10]. However, there is no information about the friction and wear behaviors of borided AISI D3 steel. The main objective of this study was to investigate the friction and wear behaviors of borided AISI D3 steel. Structural and tribological properties were investigated using optical microscopy, XRD, SEM, EDS, microhardness tests and a ball-on-disc tribotester.

MATERIALS AND METHODS

Boriding and characterization

The AISI D3 steel contained 1.76 wt.% C, 12.80 wt.% Cr, 0.50 wt.% Mn and 0.35 wt.% Si. The test specimens were cut into Ø28x10mm 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 1123 K and 1223 K for 6 h under atmospheric pressure. The microstructures of polished and etched cross-sections of the specimens were observed under a Nikon MA200 optical microscope. The presence of borides formed in the coating layer was confirmed by means of X-ray diffraction equipment (Rigaku Geigerflex) using Cu Kα radiation. The hardness measurements of the boride layer on each steel and untreated steel substrate were made on the cross-sections using a digital microhardness tester fitted with a Vickers indenter under loads of 100 g.

RESULTS AND DISCUSSION

Characterization of boride coatings

The cross-section of the optical micrographs of the borided AISI D3 steel at the temperature of 1123 K and 1223 K for 6 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 32.15 µm and 73.68 µm.

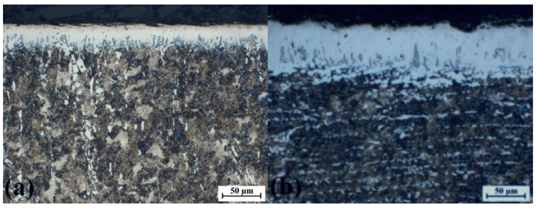

Fig. 1. The cross-section of borided AISI D3 steel
a) 1123K-6h, b) 1223K-6h

In this study, the presences of borides were identified using XRD analysis in Figs. 2a and 2b. XRD patterns show that the boride layer consists of borides such as AB and A2B (A=Metal; Fe, Cr). XRD results showed that boride layers formed on the AISI D3 5120 steel contained the FeB, Fe2B, CrB and Cr2B phases, in Fig. 2a,b.

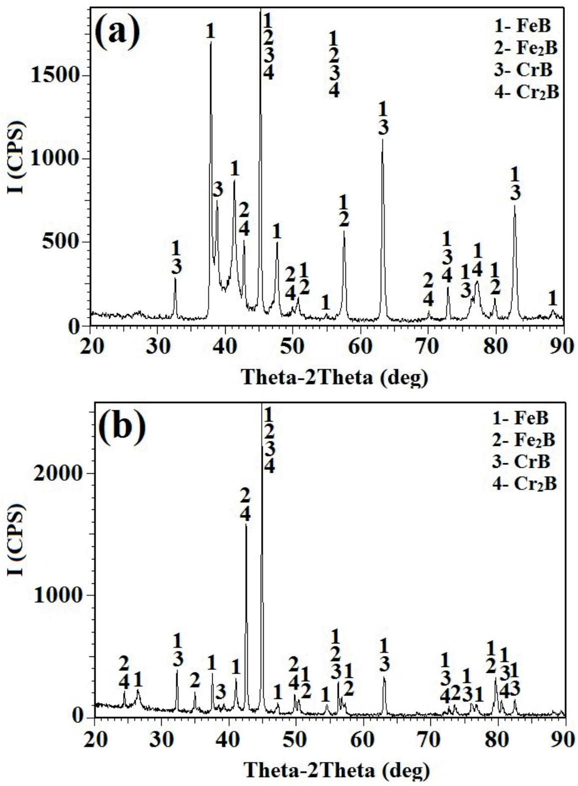

Fig. 2. X-ray diffraction patterns of borided AISI D3 steel a) 1123K-6h, b) 1223K-6h

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. Micro-hardness of the boride layers was measured at 9 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.

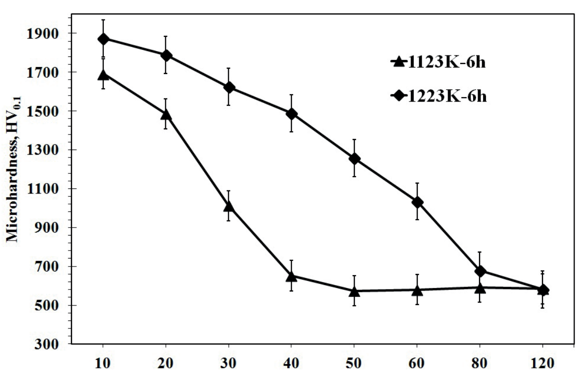

Fig. 3. The variation of hardness depth in the borided AISI D3 steel.

The hardness of the boride layer formed on the AISI D3 steel varied between 1692 and 1874 HV0,1. On the other hand, Vickers hardness values were 584 HV0,1 for the untreated AISI D3 steel. When the hardness of the boride layer is compared with the matrix, boride layer hardness is approximately three times greater than that of the matrix.

CONCLUSION

In this study, wear behavior and some of the mechanical properties of borides on the surface of borided AISI D3 steel was investigated. Some of the conclusions can be drawn as follows.

- The boride layer thickness on the surface of the AISI H10 steel was obtained, depending on the chemical composition of substrates, 32.15-73.68 μm.
- The multiphase boride coatings that were thermo chemically grown on the AISI H10 steel were constituted by the FeB, Fe2B, CrB and Cr2B phases.
- The surface hardness of the borided steel was in the range of 1692-1874 HV0,1, while for the untreated the steel substrate it was 584 HV0,1.
- The lowest wear rate was obtained in the steel borided at 1223K for 6 hours while the highest wear rate was obtained in the unborided steel.
- The wear rate of the borided steel was found to be approximately five times lower the wear rate of the unborided steel.

REFERENCES

[1] A. Milinović, D. Krumes, R. Marković, An investigation of boride layers growth kinetics on carbon steels, Tehnički vjesnik 19, 1(2012), pp. 27-31.

[2] I. Gunes, A. Dalar, Effect of Sliding Speed on Friction and Wear Behavior of Borided Gear Steels, *J. Balk. Tribol. Assoc.* 19, (2013), pp. 325-331.

[3] [1] A. G. Von Matuschka, Boronizing. Heyden and Son Inc., Philadelphia, 1980.

[4] B. Selcuk, R. Ipek, M. B. Karamis, A Study on Friction and Wear Behaviour of Carburized, Carbonitrided and Borided AISI 1020 and 5115 Steels. J Mater Process Technol, 141, (2003), pp. 189-196.

[5] I. Gunes, Wear Behaviour of Plasma Paste Boronized of AISI 8620 Steel with Borax and B2O3 Paste Mixtures, J Mater Sci Technol, 29, (2013), pp. 662-668.

[6] A. K. Sinha, "Boriding (Boronizing)," ASM handbook, J. Heat. Treat. No. 4, 437-447 [OH, USA], (1991)

[7] M. Keddam, S.M. Chentouf, A Diffusion Model for Describing the Bilayer Growth (FeB/Fe2B) During the Iron Powder-Pack Boriding, Appl. Surf. Sci. 252, (2005), 393-399.

[8] M. Keddam, Simulation of the Growth Kinetics of the (FeB/Fe_2B) Bilayer Obtained on a Borided Stainless Steel, Applied Surface Science 257, (2011), pp. 2004-2010.

[9] N. Ucar, O. B. Aytar, A. Calik, Temperature Behaviour of the Boride Layer of a Low-Carbon Microalloyed Steel, *Materials and Technology*, 46, (2012), pp. 621-625.

[10] I. Gunes,Investigation of Tribological Properties and Characterization of Borided AISI 420 and AISI 5120 Steels, *Trans. Indian Inst. Met.* (2013), pp.359-365.

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