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Dry Sliding Wear Behavior of Boron-Doped AISI 1020 Steels

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In the present study, the wear properties of AISI 1020 steels produced by a casting process with different boron contents were investigated, using a pin-on-disc tribometer under dry sliding conditions. The friction coefficients of undoped AISI 1020 steel, 0.002 and 0.01 wt% boron-doped samples were 0.33, 0.27, and 0.32, respectively. The addition of boron into AISI 1020 steel led to a decrease in the friction coefficient, due to the lubricating effect of boron; X-ray diffraction showed that both Fe_2B and FeB phases are present in the boron-doped samples, both of which cause this lubrication. The wear test results also showed that the wear rate of the 0.002 wt% boron-doped AISI 1020 sample decreased compared to the undoped AISI steel, and then increased in the 0.01 wt% boron sample. Therefore, the wear resistance of AISI 1020 steel is increased with the addition of small amounts of boron. Scanning electron microscopy results indicated that the characteristic wear mechanism for the boron-doped sample surfaces was plastic deformation and mild abrasive wear; for undoped AISI 1020 steel, cracking and spalling were observed instead.

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PACS/topics: dry sliding wear, AISI 1020 steel, boron, friction

1. Introduction

Addition of small amounts of boron can increase the hardenability of low-carbon, low-alloy high-strength steels [1–6], and the hardenability of hardened and tempered steel can be enhanced by adding as little as 0.00 wt% boron [7]. Because such small quantities of boron can improve the hardenability of steel, boron addition is a desirable method for producing high strength steel products without the use of expensive materials. However, careful attention must be paid to the production process as the effect of boron on the final hardenability is quite sensitive to the form of the boron phase. It is widely accepted that solute boron segregates to austenite grain boundaries, which retards the nucleation of allotriomorphic ferrite on austenite grain boundaries and improves the hardenability [8–12]. It has also been reported that boron can easily lose its potency after precipitation [11, 13]. Excessive addition of boron leads to precipitation of borocarbides and/or boron nitrides, making such boron treatment ineffective [14]. Therefore, to control the impact of boron on the hardenability, it is essential to understand the behavior of boron with regard to the change in the form and quantity on the austenite grain boundaries, as influenced by chemical compositions and heat treatment. In this study, the wear properties of AISI 1020 steel produced by a casting process with different boron contents were investigated using a pin-on-disc tribometer under dry sliding conditions.

2. Experimental procedure

AISI 1020 steels with different boron contents (produced by casting) were cut into pieces, 10 mm in diameter and 20 mm in height, for use in the wear experiments. Prior to testing, the samples were polished using 120, 240, 400, and 600 grit SiC papers. X-ray diffraction (XRD) measurements of the samples were performed to identify the crystalline phases presence, using a Rigaku D max 2000 with Cu K_α radiation and the "Jade" software, between 2θ values of 2 and 100° with a scan speed of 2°/s.

Dry sliding tests were performed at room temperature on a pin-on-disc tribometer (TRD Engineering, Turkey), using a pin-on-disc geometry. The sample was mounted on a holder, which is driven by a motor for controlled sliding velocity and sliding distance. A high speed steel (HSS) pin was used as a counter material. Prior to wear tests, the surfaces of the test specimen and pin were cleaned with methanol. The normal loads applied on the pin were 10, 20, and 30 N with a sliding speed of 0.2 m/s, and the sliding distance was 500 m. After wear tests, wear surfaces were examined by scanning electron microscopy (SEM).

3. Results and discussion

XRD patterns of undoped and boron-doped AISI 1020 steel are shown in Fig. 1. Based on these XRD patterns, it can be seen that the Fe_2B and FeB phases were present in the boron-doped AISI 1020 steels. These phases segregate along the grain boundaries of AISI 1020 steel.

Figure 2 shows the friction coefficient curves of undoped and boron-doped AISI 1020 steels as a function of the sliding time. All three curves show an ephemeral peak during the initial period, and then experience a "run-in" stage characterized by a reduced friction coefficient. The high initial friction coefficient is generally thought to be caused by the interlocking effect between the micro-asperities distributed on the contact interface, which makes relative sliding difficult between the two counterparts [15, 16].

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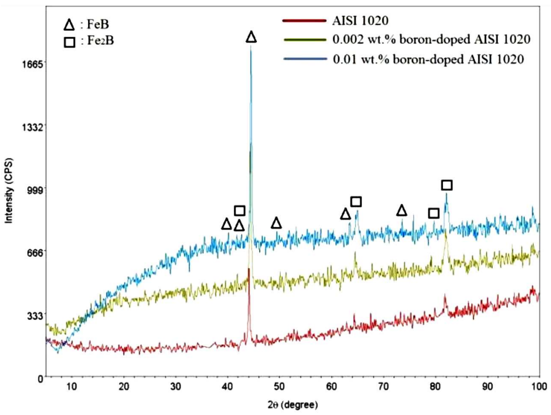

Fig. 1. XRD results of undoped and boron-doped AISI 1020 steel.

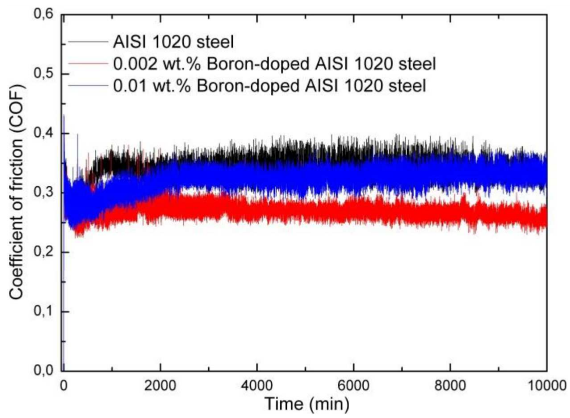

Fig. 2. The friction coefficients of undoped and boron-doped AISI 1020 samples.

The friction coefficients of undoped and boron-doped AISI 1020 samples are presented in Fig. 3. The addition of 0.002 wt% boron into AISI 1020 steel (when sliding against a HSS pin) can reduce the friction coefficient from 0.33 to 0.27, which then increases back to 0.32 in the 0.01 wt% boron-doped steel. Boron addition into AISI 1020 steel led to a decrease in friction coefficient due to the lubricant effect of boron. Boron has low solubility in iron.

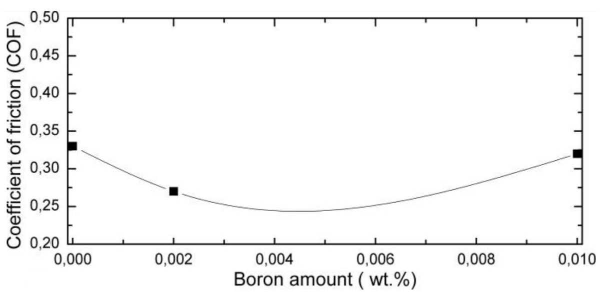

Fig. 3. The change in the coefficient friction as depending on boron amount of AISI 1020 steel.

The weight losses of undoped and boron-doped AISI 1020 steels are shown in Fig. 4. The wear rate of the 0.002 wt% boron-doped AISI 1020 sample decreased compared to the undoped AISI 1020, and then increased at 0.01 wt% boron content. The low wear rate in the sample with 0.002 wt% boron addition may be attributed to the effects of boron lubrication. When boron is added to AISI 1020 steel at a concentration of 0.01 wt%, the wear rate increases owing to the existence of the harsh borocarbides, FeB and Fe_2B phases precipitated at the grain boundaries, which promote fracturing at the surfaces.

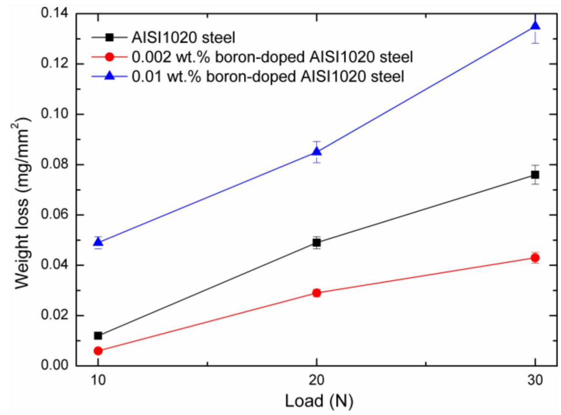

Fig. 4. Weight losses of undoped and boron-doped AISI 1020 steels.

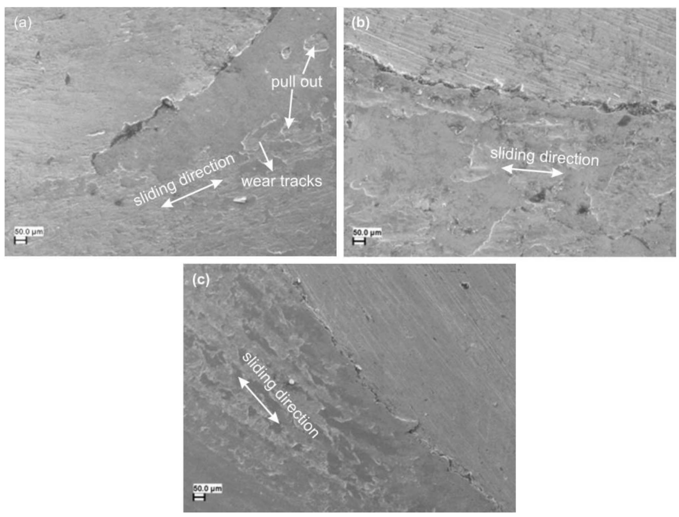

Fig. 5. Wear surface of AISI 1020 samples SEM images of (a) undoped, (b) 0.002, and (c) 0.01 wt% boron-doped AISI 1020 steel.

Figure 5 shows SEM images of the worn surfaces of disc samples after sliding against HSS pins. These images indicate that the characteristic wear mechanisms for the boron-doped sample surfaces were plastic deformation and mild abrasive wear; for undoped AISI 1020 steel, cracking and spalling were observed. Some microcracks also developed on the track surface, and there is evidence of spalling in the areas where cracks are present (Fig. 5a–c).

4. Conclusions

The wear properties of AISI 1020 steels produced by a casting process with different boron contents were investigated using a pin-on-disc tribometer and dry sliding conditions. The addition of very low levels of boron increased the wear resistance of AISI 1020 steels. Boron reduced the friction coefficient and wear rate of AISI 1020 steel due to the lubricating effect provided by boron. Boron doping also led to observed wear mechanisms of plastic deformation and mild abrasive wear after wear testing with HSS pins.

References

[1] C.R. Simcoe, A.R. Elaea, G.K. Manning, *Trans. AIME* **206**, 984 (1956).

[2] B.M. Kapadia, R.M. Brown, W.J. Murphy, *Trans. AIME* **242**, 1689 (1968).

[3] M. Ueno, T. Inoue, *Trans. Iron Steel Inst. Jpn.* **13**, 210 (1973).

[4] G.F. Melloy, P.R. Slimon, P.P. Podgursky, *Metall. Trans.* **4**, 2279 (1973).

[5] Ph. Maitrepierre, J. Rofes-Vernis, D. Thivellier, in: *Boron in Steel*, Eds. S.K. Banerjii, J.E. Morral, *AIME*, Warrendale (PA) 1979, p. 1.

[6] D.J. Mun, E.J. Shin, Y.W. Choi, J.S. Lee, Y.M. Koo, *Mater. Sci. Eng. A* **545**, 214 (2012).

[7] H.Z. Cui, W.Q. Chen, *J. Iron Steel Res. Int.* **19**, 22 (2012).

[8] M. Ueno, T. Inoue, *Trans. ISIJ* **13**, 210 (1973).

[9] J.E. Morral, T.B. Cameron, *Metall. Trans. A* **8**, 1817 (1977).

[10] J. Morral, T. Cameron, in: *Boron in Steel*, Eds. S.K. Banerjii, J.E. Morral, *AIME*, Warrendale (PA) 1979, p. 19.

[11] G. Shigesato, T. Fujishiro, T. Hara, *Mater. Sci. Eng. A* **556**, 358 (2012).

[12] E. Kanca, O. Eyercioğlu, I.H. Karahan, A. Günen, K. Göv, *Acta Phys. Pol. A* **130**, 370 (2016).

[13] P. Maitrepierre, D. Thivellier, R. Tricot, *Metall. Mater. Trans. A* **6**, 287 (1975).

[14] İ.H. Karahan, F. Tiltil, *Acta Phys. Pol. A* **130**, 282 (2016).

[15] B. Shen, F. Sun, *Chin. J. Mech. Eng.* **22**, 658 (2009).

[16] X. Wang, L. Wang, B. Shen, F. Sun, *Chin. J. Mech. Eng.* **28**, 155 (2015).