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Effect of Boron and Nitrogen Addition on the Solidification Microstructure and Hardness of High Speed Steel Type Mill Roll

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Influence of boron and nitrogen addition as one of the alloying element on the formation of solidification structure and the improvement of hardness after thermal treatments was investigated for high-speed-steel alloys (Fe-2%C-5%Cr-5%Mo-5%V). The macrohardness of the quenched specimens gradually increases with increasing quenching temperature. Nitrogen addition helps to improve the hardness as carbon does. Boron addition is also contributed to the increasing of hardness. B-containing specimens maintained higher tempered-hardness than HSS and N-containing specimens quenched at the peak hardness. The specimen, which contains high volume fraction of residual austenite, shows the superior secondary hardening after the optimized tempering.

Keywords: *high-carbon high-speed steel, cast iron, carbide, heat treatment, martensite, solidification*

1. Introduction

For the last several decades, high-carbon high speed steel type cast alloys (HSS) which have hard carbides like MC, M_2C and M_7C_3 in the matrix have been used in cast mill rolls, because of the attractive thermal resistance and wear resistance imparted by the carbides [1,2]. However, further improvement of the durability of cast rolls under high pressure environment is still required, to decrease the replacement costs of the rolls as much as possible. It could be effective that generating hard intermetallic compounds in the matrix to improve wear resistance [3,4]. In this study, we focus on boron and nitrogen because both elements could create the hard compounds. Furthermore, boron is low cost alloying element, and some researchers have reported that boron addition can increase the hardness and improve the abrasion resistance of high chromium cast steel [5]. On the other hand, nitrogen tends to form hard compounds with Al, Cr, Nb, Ti, and V, and alloys including these elements exhibit great abrasion resistance by nitrogen addition [6].

In this study, influence of boron and nitrogen addition on the solidification microstructure, solute distribution and hardness after quenching and tempering treatments were evaluated for high-carbon high-speed steel type alloys.

2. Experimental Methods

Pure iron, carbon, Cr (99.99% purity) and ferroalloys (Fe-83%V, Fe-60%Mo) were melted in a high-frequency induction furnace at 1873K in an argon atmosphere, and cast into a permanent mold (ϕ15mm×200mm). N-containing specimen and B-containing specimens were prepared by the addition of Cr_2N and Fe-20%B, respectively. The chemical compositions of obtained as-cast specimens are listed in Table 1. The heat treatment of as-cast specimen was performed from 1123K to 1373K for 1 hour in an argon atmosphere and the subsequent quenching into an oil bath. Tempering treatment was also performed twice or three times from 673K to 873K for 1 hour, systematically. As-cast and heat-treated specimens were mirror-polished, etched using Murakami reagent and metallurgically analyzed by an optical microscope. Vickers macrohardness was measured at a load of 30kgf for 10s and evaluated with the amount of retained austenite, which has been measured by XRD (Rigaku, RINT2100) using Mo-Kα radiation.

Table 1 Chemical composition of specimens.

Specimen	Chemical compositions(mass%)						
	C	Cr	Mo	V	B	N	Fe
HSS	2.04	4.96	5.00	5.07	-	-	Bal.
0.1N	2.06	5.01	4.87	5.07	-	0.132	Bal.
0.1B	2.02	4.45	4.85	4.59	0.108	-	Bal.
0.5B	2.04	4.59	4.81	4.60	0.497	-	Bal.
1.0B	2.03	3.44	4.93	4.52	1.040	-	Bal.

3. Results and Discussion

Figure 1 shows the relation between Vickers hardness and quenching temperature. Vickers hardness increase toward the peak and then decrease with the elevation of quenching temperature in all specimens. Standard HSS specimens shows peak hardness of 900HV at 1223K. 0.1N specimen shows higher hardness than HSS from 1123K to 1223K. Microstructural analysis indicates that the formation of M_2CN carbonitride cause the increasing of carbon content and hardness of the martensite matrix in these temperatures. On the contrary, 0.1B specimen shows higher hardness from 1273K to 1373K, and that could be attributed to the lower amount of soft retained austenite.

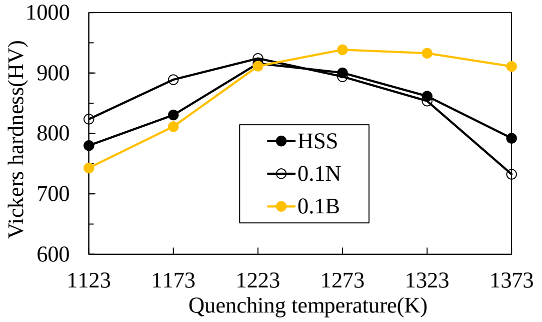

Fig. 1 Relation between Vickers hardness and quenching temperature.

In order to evaluate the influence of next tempering temperature on Vickers hardness, two quenching temperatures were selected; one was peak hardness temperature and the other was maximum temperature (1373K) in Fig. 1. The relation between hardness and tempering temperature were shown in Fig. 2. In Fig. 2(a), Hardness of HSS specimen decreases continuously. However, B-containing specimens maintained higher macrohardness than other specimens. In HSS and 0.1N specimens, the amount of solute alloying elements is not enough to produce the secondary hardening at this quenching temperature. Figure 2(b) shows relation between Vickers hardness and tempering temperature on specimens quenched at 1373K. HSS, 0.1N, and 0.1B specimens exhibit secondary hardening and 0.1B and 0.1N specimens increase 819HV at 773K and 853HV at 823K, respectively. The appropriate amount of retained austenite, carbonitride precipitation during tempering could cause the instable retained austenite and formation of martensite at quenching after tempering process.

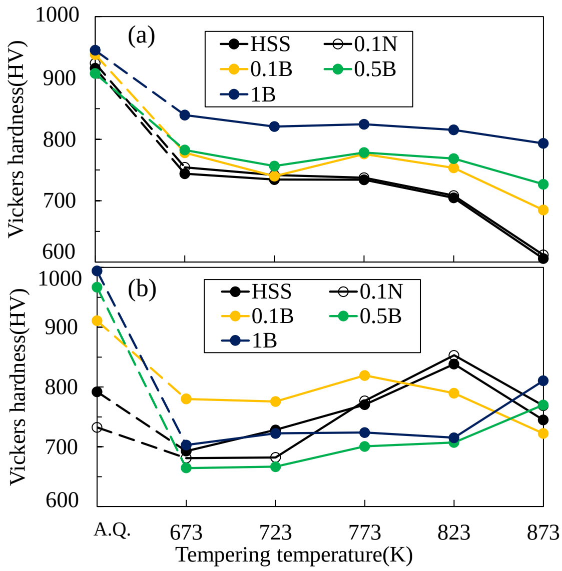

Fig. 2 Relation between Vickers hardness and tempering temperature on specimens (a) quenched at the peak hardness (b) quenched at 1373K.

4. Conclusion

The influence of boron and nitrogen addition on the solidification and hardness after heat treatments was investigated for high speed steel type cast alloys, and the following conclusions were obtained:

(1) B-containing specimens maintained higher tempered-hardness than HSS and N-containing specimens quenched at the peak hardness.

(2) Specimens tempered at 1373K exhibited secondary hardening, and N-containing specimen showed 15~30HV higher hardness than that of HSS standard specimen.

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