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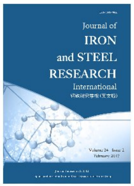

Comparison of microstructure and property of high chromium bearing steel with and without nitrogen addition

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ABSTRACT

Microstructure and property of bearing steel with and without nitrogen addition were investigated by microstructural observation and hardness measurement after different heat treatment processing. Based on the microstructural observation of both 9Cr18 steel and X90N steel, it was found that nitrogen addition could effectively reduce the amount and size of coarse carbides and also refine the original austenite grain size. Due to addition of nitrogen, more austenite phase was found in X90N steel than in 9Cr18 steel. The retained austenite of X90N steel after quenching at 1050 ℃ could be reduced from about 60% to about 7% by cold treatment at －73 ℃ and subsequent tempering, and thus finally increased the hardness up to 60 HRC after low temperature tempering and to 63 HRC after high temperature tempering. Furthermore, both the wear and corrosion resistance of X90N steel were found much more superior than those of 9Cr18 steel, which was attributed to the addition of nitrogen. It was proposed at last that nitrogen alloying into the high chromium bearing steel was a promising way not only to refine the size of both carbides and austenite, but also to achieve high hardness, high wear property and improved corrosion resistance of the stainless bearing steel.

1. Introduction

The high chromium martensitic stainless steel 9Cr18 (AISI440) is widely used for bearing manufacture of petrochemical engineering, shipping industry, and instrument process under condition of either high or low temperature, which can achieve high strength-hardness, excellent wear and corrosion resistance through quenching-tempering process. It was revealed that different types of carbides influenced the microstructure and mechanical properties of martensitic stainless steel[1-4], such as the coarse eutectic carbides (type of M_7C_3) in 9Cr18 steel, which could induce locally stress concentration point and crack initiation of contact fatigue and corrosion[5-8].

In order to refine the size of carbides in the high chromium stainless bearing steel, many works have been done and demonstrated in literatures[9-11]. It was revealed that adding nitrogen into stainless bearing steel usually resulted in a fine and homogeneous microstructure, such as the cronidur 30 steel with about 0.4 wt.% N and 0.3 wt.% C, in which no carbides with size larger than 5 μm could be found and these fine carbides and carbonitrides uniformly distributed in the matrix. Due to elimination or reduction of the coarse carbides and formation of the fine-disperse carbontrides, more excellent combination of mechanical and electrochemical properties was obtained in the nitrogen-alloyed steel than in the conventional 9Cr18 (AISI440) steel after appropriate heat treatment[12,13]. Pickering[14] reported that nitrogen addition led to carbides transformation from initial M_7C_3 to $M_2(C,N)$, and the amount of $M_2(C,N)$ precipitation increased after tempering process. Ngo et al.[15] found that the nitrogen addition increased the hardness of martensitic stainless steel due to precipitation of fine CrN phase during tempering.

In this study, the microstructural evolution and properties of the 9Cr18 (AISI440) steel with and without nitrogen addition were studied, aiming to examine the possibility of adding nitrogen into the high chromium stainless bearing steel to refine the size of carbides and improve properties such as hardness, wear property and corrosion resistance.

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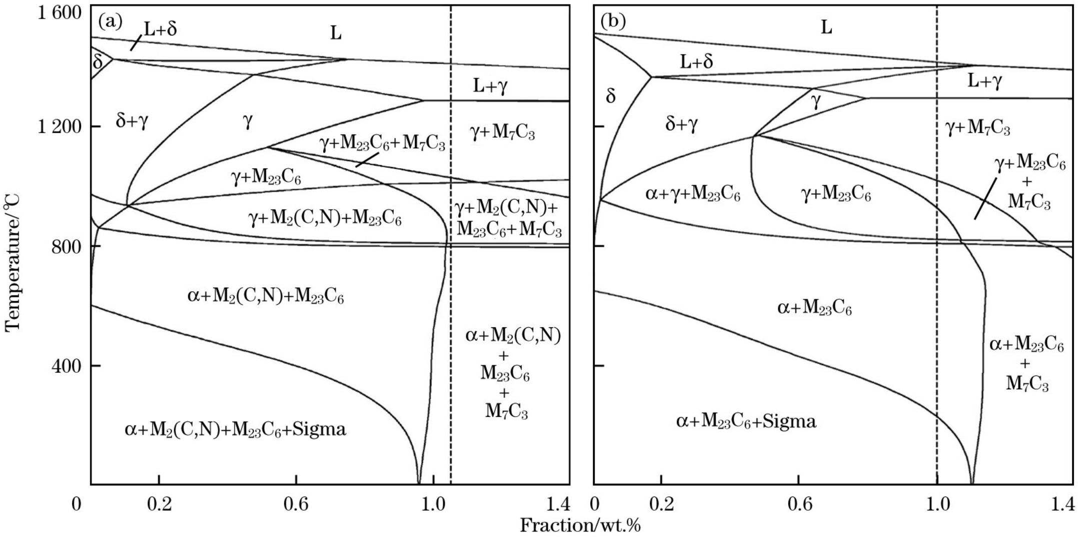
2. Experimental Procedure

The chemical composition of experimental steels, which were designed and prepared in a vacuum induction furnace, is presented in Table 1. The ingots were homogenized at 900 ℃ for 1 h, then increased to 1150 ℃ by 100 ℃/s and homogenized for 1 h, forged between 850−1150 ℃ into bars with diameter of 65 mm, and finally slowly cooled to room temperature. The phase diagrams of studied steels were calculated based on Thermo-Calc software and are presented in Fig. 1, which was useful to determine heat treatment parameters. The experimental specimens cut from forged bars were processed by spheroidizing annealing and then processed as described in Table 2.

Table 1

Chemical composition of experimental steels (wt.%)

Steel	C	Cr	N	Mo	Mn	Si	P	S
X90N	1.05	16.39	0.18	0.52	0.58	0.53	0.0060	0.0048
9Cr18	1.00	17.62	—	—	0.68	0.64	0.0080	0.0050



(a) X90N; (b) 9Cr18.

Fig. 1. Diagrams of experimental steels calculated based on Thermal-Calc.

Table 2

Heat treatment parameters applied in this study

Heat treatment	T_A and t_A	T_{CT} and t_{CT}	T_{Te} and t_{Te}
1	950 ℃×30 min (OQ)	−73 ℃×2 h (AC)	180 ℃×2 h (AC), 2×500 ℃×2 h (AC)
2	1000 ℃×30 min (OQ)	−73 ℃×2 h (AC)	180 ℃×2 h (AC), 2×500 ℃×2 h (AC)
3	1050 ℃×30 min (OQ)	−73 ℃×2 h (AC)	180 ℃×2 h (AC), 2×500 ℃×2 h (AC)
4	1100 ℃×30 min (OQ)	−73 ℃×2 h (AC)	180 ℃×2 h (AC), 2×500 ℃×2 h (AC)

Note: T_A—Austenization temperature; t_A—Austenization holding time; T_{CT}—Cold treatment temperature; t_{CT}—Cold treatment time; T_{Te}—Tempering temperature; t_{Te}—Tempering time.

Microstructures and austenite fraction of specimens were examined by scanning electron microscopy (SEM) and X-ray diffractometry (XRD) using CoKα radiation. Specimens for SEM and XRD measurements were mechanically ground and polished, then etched in 2 vol. % Kalling solution (1.5 g $CuCl_2$ + 33 mL HCl + 33 mL ethanol + 33 mL H_2O) and electrolytically etched in a solution of 10 vol. % chromic acid. Retained austenite fraction was calculated based on integrated intensities of $(200)_\alpha$, $(211)_\alpha$, $(200)_\gamma$, $(220)_\gamma$ and $(311)_\gamma$ diffraction peaks[16]. Ten metallographic photos of original austenite were collected using an Olympus inverted optical microscope, and grain size of original austenite was measured by the straight line cut-off point.

The room temperature hardness was measured by using a TIME TH300 Rockwell hardness tester with 1470 N load. Five hardness points were measured to obtain the average hardness. The wear resistance specimens were prepared as cylinder with diameter of 4 mm and length of 25 mm, and processed by heat treatment-3. The wear resistance test was carried out on a ML-10 abrasive wear testing machine with 14.7 N load and 180 grit SiC water proof abrasive in a wear distance of