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Short communication

Effects of deep cryogenic treatment on property of 3Cr13Mo1V1.5 high chromium cast iron

Hao-huai Liu [a,*], Jun Wang [a], Bao-luo Shen [a], Hong-shan Yang [a], Sheng-ji Gao [a], Si-jiu Huang [b]

[a] *Department of Metal Materials, Sichuan University, Chengdu, Sichuan 610064, China*
[b] *Sijiu Rare Earth Alloy Foundry, Shuangliu, Sichuan 610211, China*

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Abstract

Effects of deep cryogenic treatment on the microstructure, hardening behavior and abrasion resistance of 3Cr13Mo1V1.5 high chromium cast iron subjected to sub-critical treatment were investigated in this paper. The results show that deep cryogenic treatment after sub-critical treatment, the hardness and abrasion resistance of high chromium cast iron can be boosted obviously due to abundant retained austenite transforming into martensite and secondary carbides precipitation. In the course of sub-critical treatment with cryogenic treatment, the amount of precipitated secondary carbides was more than that in air cooling, and the secondary hardening peak advanced at a lower temperature. When abrasion resistance reach the maximal, there was about 20% retained austenite in microstructures. Cryogenic treatment can further reduce the austenite content but can not make retained austenite transform to martensite completely.

Keywords: High chromium cast iron; Deep cryogenic treatment; Sub-critical treatment; Martensite transformation; Abrasion resistance

1. Introduction

High chromium cast irons are based on the iron–chromium-carbon ternary system [1,2]. White iron in the compositional range of 12–30% chromium are extensively used for components that manipulate and mechanically process aggregates and raw materials [2–4,6–8]. These alloys consist of hard iron–chromium carbide in a supportive matrix and are particularly suited for abrasion resistant applications which are, for example, demanded by the coal and cement industries [4–8].

For many applications the casting are heat treated prior to service. The destabilization heat treatment and sub-critical heat treatment are techniques in common use [5,7]. The sub-critical heat treatment is usually used to further reduce the austenite content after the destabilization heat treatment or directly used to reduce retained austenite content for obtaining martensitic matrix [12,15].

There has also been interest in using cryogenic treatments to eliminate the destabilization heat treatment from the processing route for high chromium white irons. It is thought that the secondary carbide precipitation associated with the destabilization heat treatment can adversely affect the fracture toughness of white iron alloys, while the temperature gradients established during the heat treatment may produce undesirable residual stresses. Cryogenic treatments, which produce a martensitic matrix by cooling the as-cast material below the M_f temperature, may eliminate these two problems [6]. But there few references to report the effect combining deep cryogenic treatment with sub-critical treatment of high chromium irons. In this paper, we investigated the effects of deep cryogenic treatment on the microstructure, hardening behavior and abrasion resistance for high chromium cast iron subjected to sub-critical

* Corresponding author. Tel.: +86 28 66037663; fax: +86 28 85402231.
E-mail address: huaihuai99@163.com (H.-h. Liu).

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treatment by X-ray diffraction, hardness tests and abrasion tests.

2. Experimental procedure

The testing high chromium iron was cast from 1450 °C as ∅ 80 mm balls by chilled mould. The chemical composition is given in Table 1. The ball was cut into sub-critical treatment samples, cryogenic treatment samples and X-ray diffraction samples. The test samples were subjected to sub-critical treated at serials of test temperatures. The holding time is 1 h for each temperature. After sub-critical treatment, the samples were air-cooled to room temperature or put into liquid nitrogen directly and held for 3 h.

The microstructure was characterized by optical microscope. The contents of the retained austenite were measured using X'Pert Philip X-Ray diffraction instrument. The results are given as the proportion of austenite in the matrix. The retained austenite content takes the mean value of the computing results based on different crystal face to eliminate the effect of the columnar structure, which has been shown to affect the results. The bulk hardness was measured using Rockwell hardness meter with a load of 150 kg. In the wear experiment using M-200 abrasion experimental tester with the 150-girt Al_2O_3, the load is 50 N and the rotational speed of the sample is 200 rpm. The losing weight of the sample was measured by TG328A photoelectric balance and the abrasive resistance was evaluated using the mean value of the tests. Comparing as-cast condition the relative wear ratio β is defined by the following:

$$\beta = \frac{\text{Mass loss of as-cast sample}}{\text{Mass loss of heat treated sample}}. \quad (1)$$

3. Results and discussions

3.1. As-cast microstructure

The microstructure of high chromium cast iron in the as-cast condition is illustrated in Fig. 1. Typically, high chromium iron consists of hard eutectic (Fe, Cr)7C3 carbides embedded in an austenitic matrix. X-ray diffraction of the sample (Fig. 2) shows that the microstructure of high chromium cast iron consists of austenite, M7C3 and martensite. The content of (Cr, Fe)7C3 carbides, austenite and martensite are 20.5%, 57.6% and 21.9%, respectively. By calculation based on X-ray diffraction, the lattice constant of austenite and martensite, respectively, is 0.3682 and 0.2884 nm. Both of them are bigger than the normal lattice constant of austenite (0.3585 nm) and ferrite (0.2866 nm). It indicates that the austenite and martensite both are being super-saturation state for the higher content of C, Cr and other alloying elements from nonequilibrium solidification. The crystal grains of austenite and eutectic carbides (Fe, Cr)7C3 seem smaller in the microstructure (Fig. 1) due to the element vanadium addicted to the alloy which makes the matrix structure in thinner sections. But the vanadium and molybdenum carbides are too few to be found in the XRD profile (Fig. 2).

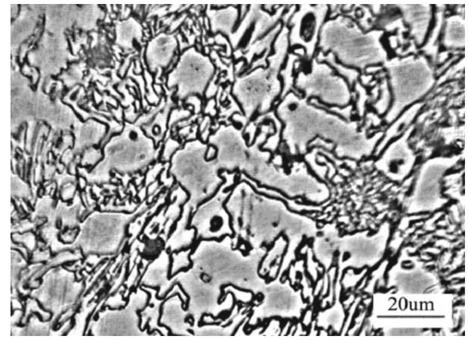

Fig. 1. The microstructure of the alloy in as-cast condition.

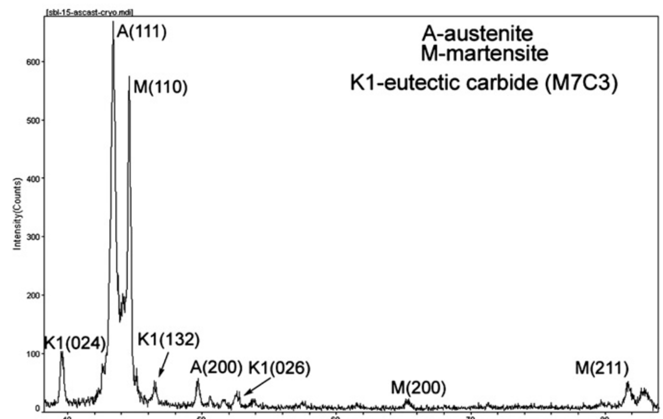

Fig. 2. The XRD profile of the alloy in as-cast condition.

3.2. Microstructure in cryogenic treatment

3.2.1. Effect of cryogenic treatment on matrix

Fig. 3 shows the micrographs alloy after sub-critical treatment with cryogenic or air cooling. As shown in it, there precipitates some secondary carbides during heat treatment, the etched secondary carbides appear dark in microstructure. Secondary carbides precipitate from random austenite grains and do not nucleate and grow on the eutectic carbide.

Table 1
Chemical composition of the high chromium cast iron (mass%)

Element	C	Si	Mn	Cr	Mo	V
Mass%	2.82	1.24	2.80	13.34	0.70	1.5