



Effects of high temperature and cryogenic treatment on the microstructure and abrasion resistance of a high chromium cast iron

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ABSTRACT

Effects of deep cryogenic treatment on the microstructure, hardening and abrasion resistance behaviors of 16Cr1Mo1Cu cast iron subjected to destabilization treatment were investigated. The results show that the cryogenic treatment can effectively reduce the retained austenite after destabilization heat treatment, but cannot make retained austenite transform completely. Cryogenic treatment can markedly improve bulk hardness and abrasion resistance of the high chromium cast iron. In the course of destabilization treatment and then cryogenic treatment, the amount of precipitated secondary carbide, $M_{23}C_6$, was more than that in air cooling. The additional fine secondary carbide precipitated during the cryogenics treat after destabilization heat treatment comparing with air cooling, is the main reason for the increase of the bulk hardness and wear resistance.

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1. Introduction

High chromium cast irons are commonly used for wear-resistance applications in the mining and minerals industry due to their excellent abrasion resistance (Tabrett and Sare, 1998; Pearce, 2002). In the as-cast condition, the hard alloy eutectic carbides $[(Fe,Cr)_7C_3]$ embedded in a predominant martensite matrix that always contains retained austenite resulting from heat treatment (Wang et al., 2005). For many applications, the castings are heat-treated prior to service. The destabilization heat treatment is the technique in common use (Tabrett et al., 1996; Wang et al., 2006). Nowadays, one of the most prevalent claims in low-temperature treatment is an increase in wear resistance of certain materials (Molinari et al.,

2001; Yun et al., 1998; Huang et al., 2003; Liu et al., 2008) and cryogenic treatment is an inexpensive one time permanent treatment affecting the entire section of the component unlike coatings (Mohan Lal et al., 2001). Most researchers believed that the main reason for this was the almost complete transformation from austenite into martensite plus the formation of very small carbides dispersed in the tempered martensitic structure (Yun et al., 1998). But some researcher suggested that there was always the retained austenite after cryogenics treatment after destabilization treatment in high chromium cast iron (Tabrett and Sare, 1998; Hann and Gates, 1997). Hann called the retained austenite after cryogenics treated for “stable austenite” (Hann and Gates, 1997). So it would be in the interest to research the benefits of the cryogenics treatment

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and to know the conditions at which the treatment derives maximum benefits of the cryogenics treatment.

The present work is a systematic comparative study on the microstructure, hardening and abrasion resistance behaviors of cryogenic treated high chromium cast iron samples after subjected to destabilization heat treatment, want to give an insight of the effects of the cryogenics treatment on the cast iron and to understand the cryogenic mechanism.

2. Experimental procedure

The high chromium white iron was cast from 1773 K as 80 mm diameter balls into a chilled mould. The chemical composition is given in Table 1. The ball was cut into test samples by 10 mm × 10 mm × 10 mm blocks. The test samples were subjected to destabilization treatment at serials of test temperatures. The holding time is 0.5 h for each temperature. After destabilization treatment, some of the samples were air cooled to room temperature and the others put into liquid nitrogen directly and held for 3 h.

The bulk hardness was measured using a Rockwell hardness tester with a load of 150 kg (HRC). Optical metallography and JSM-5900 LV scanning electron microscopy was performed after etching. The contents of the retained austenite and martensite were measured using XRD, with X'Pert Philip X-ray diffraction instrument that used a Cu K alpha X-ray source and a nickel filter. A continuously rotating/tilting sample holder was used to eliminate the effect of the texture. In the wear experiment using M-200 abrasion experimental tester with the 150-girt Al₂O₃, 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.

3. Results and discussion

The microstructure and XRD profile of the cast iron in the as-cast condition are illustrated in Figs. 1 and 2. Typically, the high chromium iron consists of hard eutectic carbides embedded in an austenitic matrix. Fig. 2 shows that the microstructural constituents of this cast iron are austenite, (Fe,Cr)₇C₃ [M₇C₃] and martensite. By calculation from the XRD results, the content of austenite, martensite is 77.0% and 7.2%, respectively. Using quantitative metallographic analysis, the eutectic carbide, M₇C₃ is 15.8%.

Fig. 3 shows the micrographs of cryogenically treated and non-treated sample after destabilization treatment at 1000 °C for 0.5 h. As shown in them, there precipitates some secondary carbides during heat treatment, the etched secondary carbides appear dark in microstructure. The secondary carbides are distributed more homogeneously in the cryogenic treated sample than in the non-cryogenically treated one. And after the cryogenics treated, the proportion of martensite in the matrix appears to increase. By calculated from XRD results, the amounts of retained austenite in cryogenically treated and

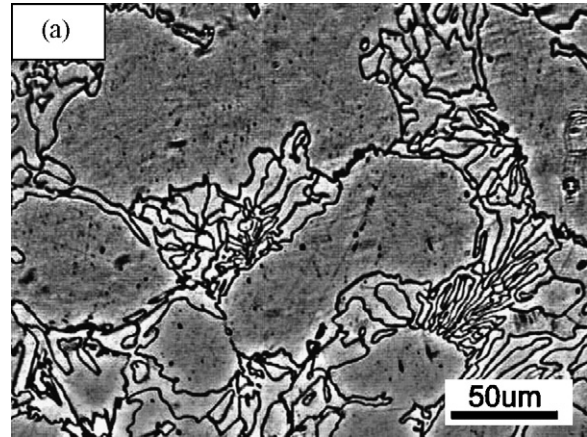


Fig. 1 – The microstructure of the as-cast high chromium cast irons.

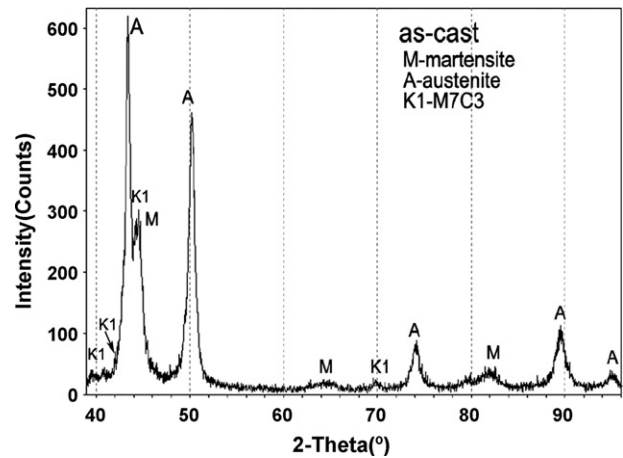


Fig. 2 – The XRD pattern of the as-cast high chromium cast iron.

non-treated are change into 18.99% and 9.93%, respectively. The netted eutectic carbide is unchanged after heat treatment.

The XRD profiles of two different states are shown in Fig. 4. Comparing with the XRD in as-cast condition (Fig. 2), it illustrates that the content of martensite increase markedly while that of retained austenite lessened greatly. Under the as-cast state, there is so little secondary carbide, M₂₃C₆, in microstructure that cannot be clear shown. Both of cryogenic treatment and air cooling after destabilization treatment, the secondary carbides, M₂₃C₆, are increasing. Additionally, as shown in Fig. 4, the content of M₂₃C₆ in cryogenic treatment is greatly more than that of in air cooling. This is because the martensite becomes more supersaturated under cryo-temperature due to the solid solubility of alloy elements and carbon in martensite lessened after destabilization treatment. This increases the lattice distortion and thermodynamic instability of the martensite, both of which drive carbon and alloying atoms to segregate. Because of this, the secondary carbide precipitation occurs with higher activation energy, thus leading to a higher nucleation rate and, in turn, to finer dimensions and a more homogenous distribution (Molinari et al., 2001; Yun et al., 1998). Therefore, the amount of precipitated fine

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

Element	C	Si	Mn	S	P	Cr	Cu	Mo
Mass%	2.77	0.7	1.90	0.063	0.05	16.38	0.9	1.08

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