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Investigation of Retained Austenite to Martensite Phase Transformation on Wear Behavior of White Cast Irons

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1- Introduction

In recent years, wear resistant steels have been generally replaced by wear resistant white cast irons in many applications such as: mining industry, grinding balls, liners, mill rolls, train shaft etc. A good wear-resistant white cast iron not only should have high abrasion resistance performance, but also must have sufficient stiffness to prevent sudden failure. According to ASTM A532 standard condition, wear resistant white cast irons are classified into pearlitic white cast irons, various Ni-Hards and high chromium irons. The microstructure of pearlitic white cast irons contain a mixture of continuous M_3C eutectic carbide and pearlite which result in low toughness and low wear resistance in such applications. By adding a significant amount of alloying elements such as nickel and chromium, wear-resistant white cast irons are developed in four groups called Ni-Hards 1, 2, 3 and 4. Generally, depending on the type and amount of alloying elements, casting conditions and cooling process, various kinds of multiphase microstructures including a mixture of continuous M_3C eutectic carbide, secondary carbide particles, pearlite, bainite, martensite and retained austenite are formed in wear-resistant white cast irons, which lead to completely different wear resistance behavior. Among these microphases, retained austenite is an unstable microphase at room temperature that causes wide range of changes in the wear properties of white cast irons. The aim of this paper is to study the effect of retained austenite on abrasion behavior of a low alloyed wear-resistant white cast iron with a mixture of carbide and retained austenitic microstructure.

2- Experimental

The molten samples of proposed low alloy and traditional white cast irons are prepared in an induction furnace with the capacity of 100 kg at 1450 °C; after final preparation, the chemical analysis of the molten metal was obtained using an ARL quantometer device. Table 1 shows the chemical composition of investigated white cast irons.

In order to study the wear behavior of the white cast irons, the wear tests were done by using pin on disk method under loads of 80, 100, 120 and 140N. The wear-resistant disks are made of heat treated 100Cr6 steel with 62HRC, thickness of 10mm and 70mm diameter. Abrasion test samples are prepared in cylindrical pins with: 50mm height and 5mm diameter, which are provided by wire cut from cast Y-shaped blocks.

Metallographic samples were prepared with wire cut from Y-shaped cast blocks. After polishing, the etching was carried out based on the chemical solutions given in Table 2. Optical and scanning electron micrographs were taken by Olympus PMG3 and MV2300CAM-SCAN, respectively.

3- Results and Discussion

Fig. 1 shows typical light micrographs of white cast irons in casting condition. According to metallographic image presented in Fig. 1(a), the microstructure of conventional white cast iron includes ledburite (small pearlite islands in white continuous eutectic M_3C carbide matrix) and large islands of pearlite (brown color phase) which is revealed by 2% Nital etching solution. For revealing the multi-phase microstructure of alloyed white cast iron with more contrasting resolution, a double stage etching method was used based on the Glyceregia and Marble chemical solutions. It can be observed that the microstructure of alloyed white cast iron includes a mixture of small scattered martensite islands (gray phase) with retained austenite (brown phase) and continuous eutectic M_3C white colored carbide matrix (Fig. 1(b)). These results show that a good contrasting resolution has been developed between the microphases of martensite, retained austenite and eutectic M_3C carbide in the alloyed white cast iron.

Fig. 2 compares weight loss versus loading force for both conventional and alloyed white cast irons at different wear test loads. In the samples of conventional white cast iron by increasing the loads from 80 to 100N and then 120 to 140N, the weight loss of samples has been increased. Alloyed white cast iron also shows this wear behavior, but the amount of weight loss compared to conventional white cast iron has been decreased by increasing the loads.

Table 1 Chemical composition of investigated white cast irons

Type of white cast iron	Fe	C	Si	Mn	P	S	Cr	Ni	Mo	Cu
conventional white cast iron	balance	3.26	0.61	0.52	0.012	0.022	0.89	0.053	0.055	0.054
alloyed white cast iron	balance	3.33	0.54	1.15	0.031	0.026	4.43	2.38	0.19	0.56

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Table 2 Chemical composition of etching solutions used in this study

Etching reagents	chemical composition
2% nital	2 ml nitric acid, 98 ml ethanol
Glyceregia	9 ml glyceregia, 6 ml hydrochloric acid, 3 ml nitric acid
Marble	4g copper sulfate, 16 ml hydrochloric acid, 38 ml distilled water

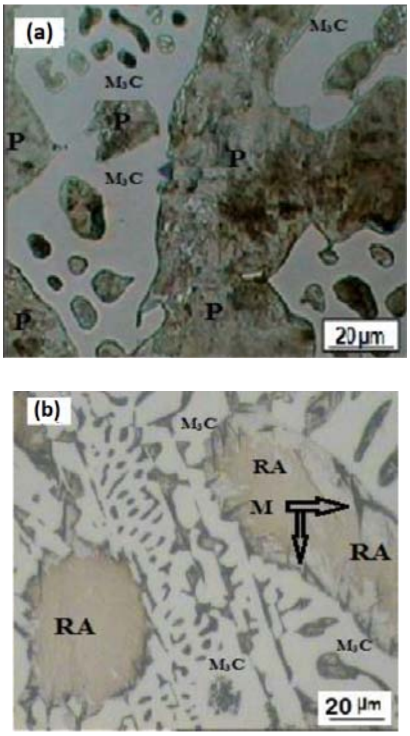

Fig. 1 Optical metallographs of (a) conventional white cast iron (2% nital); and (b) alloyed white cast iron (Glyceregia - Marble). Eutectic carbides, pearlite, martensite and retained austenite are represented by M_3C, P, M and RA symbols, respectively

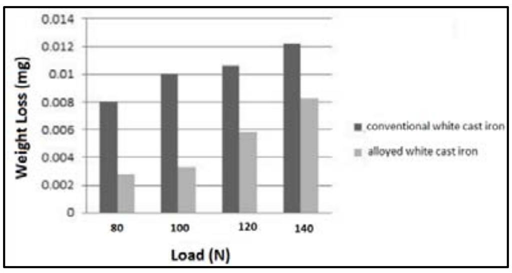

Fig. 2 Comparison of weight loss versus loads of wear test for conventional white cast iron with alloyed white cast iron

Fig. 3 shows typical scanning electron microscopy (SEM) images of alloyed white cast iron samples after wear tests at different loads. After 100N load, the amount of retained austenite transformed to martensite in sub layers of wear surface samples is negligible (Fig. 3(a)), but by increasing loads from 100 to 140N, the amount of retained austenite transformed to martensite was increased in a way that at the load of 140N (Fig. 3(b)) almost all of retained austenite was transformed to martensite in areas around the wear test surfaces.

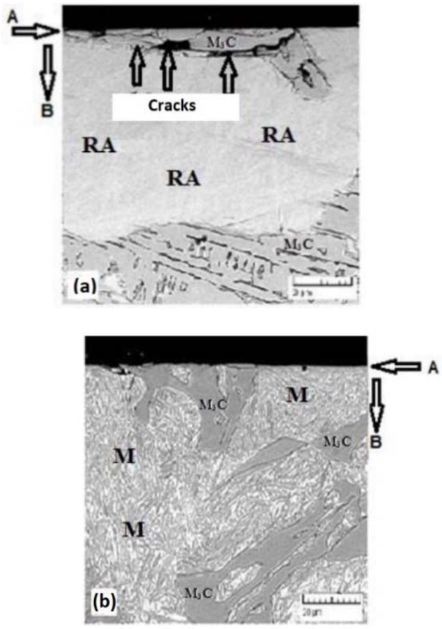

Fig. 3 SEM images from the cross section perpendicular to the wear test surfaces of alloyed white cast iron samples showing the microstructural changes by stresses and mechanical forces at loads (a) 100N, and (b) 140N. Directions of A and B were represented to the parallel and perpendicular direction to the wear test surfaces, respectively. Eutectic carbides, martensite and retained austenite are shown by M_3C, M and RA symbols, respectively

4- Conclusions

In this study, the effect of retained austenite to martensitic phase transformation on the wear behavior of alloyed white cast iron with carbide-austenite microstructure has been studied in comparison to that of conventional white cast iron consisting of pearlite-carbide microstructure. The results showed that the wear resistance of alloyed white cast iron with carbide-austenite microstructure is higher than that of conventional white cast iron consisting of pearlite-carbide microstructure. The higher wear resistance of alloyed white cast iron is because of phase transformation of retained austenite to martensite as well as higher work hardening response of retained austenite due to stresses and mechanical forces developed during wear tests.