Effect of Heat treatment on Dry-Sliding Wear and Corrosion Behavior of High Chromium Cast Irons

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In this study, the effects of destabilization heat treatment on the microstructure, dry-sliding wear and corrosion behavior of the 28wt.%Cr- 2.3wt.%C iron with (1,6)wt.%Mo were investigated. As-cast samples were destabilized at 1000°C for 4 h, and then air-forced cooling to room temperature. Microstructure was studied by XRD, OM and SEM. Vickers macro-hardness was tested. Dry-sliding wear resistance was tested by the pin-on-disc technique, and corrosion behavior was analyzed with the anodic polarization characteristics. It was found that the as-cast microstructure in the 28wt.%Cr-2.3wt.%C iron consisted of primary austenite dendrite and eutectic M_7C_3 carbide. The irons with molybdenum addition expressed the formation of multiple eutectic $M_7C_3/M_{23}C_6/M_6C$ carbides. The amount of M_6C carbide increased with increasing molybdenum content. The Vickers macro-hardness in the as-cast condition of the iron without molybdenum and the irons with 1 and 6wt.%Mo were 508, 529 and 567 HV30, respectively. This is due to the formation of hard M_6C carbide. After destabilization, the secondary carbide precipitated within the martensite matrix, including the M_7C_3-to-$M_{23}C_6$ transition of eutectic carbides. After destabilization, there has been an improvement in macro-hardness, dry-sliding wear and corrosion resistance.

Keywords: *High chromium cast iron, Wear, Corrosion, Carbide*

1. Introduction

High-chromium cast irons (HCCIs) are commonly used in industrial applications for high hardness, corrosion and wear resistance, such as wear parts of cement manufacturing, mining industry and slurry pumping application. The as-cast microstructures of hypoeutectic 27-30wt.%Cr and 2-3wt.%Cr irons consist of primary austenite dendrites and eutectic mixture of austenite and M_7C_3 carbides[1)]. Wear and corrosion resistance of these irons can be modified by alloying elements and heat treatments[2-3)]. For alloying elements, molybdenum is mainly added to high chromium cast irons to increase hardenability which provides a pearlite-free austenite matrix including leads to the formation of other carbides such as M_2C and M_6C. It affected the hardness increased by providing superior wear resistance[4)]. Neville et al. [5)], suggested that the corrosion resistance of the irons strongly depends on the ratio of chromium content in the M_7C_3 carbide to that in the matrix, including the primary carbide area fraction and the amount of chromium as well as other elements in the matrix.

For another method, various research efforts have been focused on destabilization heat treatment. Generally, destabilization heat treatments are carried out in the range of 900–1100 °C, for 1–6 h, carried out in the range of 900–1100 °C, for 1–6 h, followed by air quenching. The consequence microstructure contains secondary carbides within a martensite matrix together with some retained austenite[6)]. The effect of martensite matrix and secondary carbides can increase the wear and corrosion resistance due to increasing the matrix strength through dispersion strengthening, and the fine secondary carbides can increase the mechanical support of the eutectic carbides[7)].

Hence, the objective of this work is to study the effects of destabilization heat treatment on the microstructure, corrosion and wear resistance of an iron-containing 28 wt. % Cr-2.6 wt. % C with (1,6)wt.%Mo.

2. Experiment

The as-cast irons in this research had 3 composition consisting of 28wt.%Cr-2.3wt.%C (R iron), 28wt.%Cr-2.3 wt.%C-1wt.%Mo (Mo1 iron), and 28wt.%Cr-2.3wt.%C -6wt.%Mo (Mo6 iron). The as-cast irons were destabilized at 1000ºC for 4 h and then cooling to room temperature.

For microstructure investigation was studied by scanning electron microscopy (SEM). The phases identification was analyzed by X-ray diffraction technique (XRD).

Vickers macro-hardness testing was performed using 30 kgf load (HV30). Dry sliding wear resistance was achieved according to ASTMG 99 using a pin on disc wear test. It performed using with 15 N load, velocity of 160 rpm and sliding distance of 1000 meters. The worn surfaces were observed by SEM. Corrosion resistance was tested via analysis of anodic polarization characteristics with a solution containing 0.5 M H_2SO_4 acid for a voltage increase rate of 1.667 mV s^{-1} at room temperature.

3. Results

3.1 Microstructure observation

From SEM images in Figure 1, the irons in as-cast condition expressed that R iron revealed hypoeutectic microstructure consisting of primary dendritic austenite with a network of eutectic M_7C_3 carbides and eutectic austenite, as seen in Figure 1a. While, addition of molybdenum to iron illustrated the formation of multiple eutectic $M_7C_3/M_{23}C_6/M_6C$ carbides, which showed more amount according to higher molybdenum content, as seen

*1 Graduate Student, Naresuan University, Phitsanulok, 65000, Thailand in Figure 1b. It is clearly seen with the brighter contrast of eutectic M_6C and $M_{23}C_6$ in BEI mode in SEM, due to more dispersion of molybdenum, which indicated that molybdenum addition promoted multiple eutectic carbides[3)]. It corresponded to XRD analysis, which found that the R iron contained austenite, martensite and M_7C_3 carbide, while irons molybdenum addition found the presence of $M_{23}C_6$ and M_6C, together with M_7C_3. After destabilization, all iron expressed the secondary $M_{23}C_6$ carbide precipitated within the martensite matrix, as illustrated in Figure 2, which corresponds to the previous reported[6)].

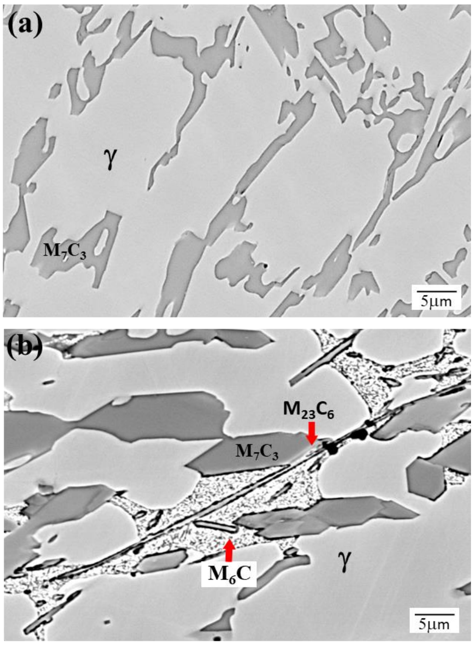

Figure 1 SEM-BEI micrographs show the microstructure in as-cast condition (a) R iron, (b) Mo6 iron.

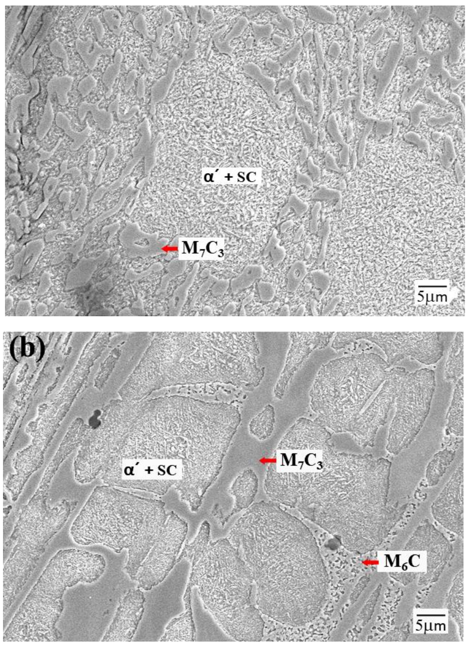

Figure 2 SEM micrographs show the microstructure after destabilization (a) R iron, (b) Mo6 iron.

3.2 Mechanical properties testing

The Vickers macro-hardness in the as-cast condition ~~in~~ of R, Mo1, and Mo6 irons were 503, 518, and 567 HV30, respectively. This is due to the formation of multiple carbides of $M_7C_3/M_{23}C_6/M_6C$. After destabilization, the macro-hardness increased up to 725, 736, and 893 HV30. It can confirm the results of the phase transformation of austenite to martensite matrix, including the precipitation of secondary $M_{23}C_6$ carbides.

From the dry sliding wear results of the irons, in the as-cast condition, it was found that the volume loss was decreased from 7.16 mm^3 in R iron to 5.03 and 3.05 mm^3 in Mo1 and Mo6 irons, respectively. It corresponded to the tendency of hardness value. This is due to the volume fraction of eutectic carbides increased and the volume fraction of the matrix reduced, which can absorb stress and force during wear tested[8)]. After destabilization, it was found that the volume loss of the R, Mo1, and Mo6 irons were 2.86, 2.14, and 1.35, respectively. This is due to the transformation of austenite matrix to a strong matrix such as martensite, including the precipitation of secondary $M_{23}C_6$ carbides. Further, the worn surface in Figure 3 shows less damage after destabilization compared to the as-cast condition.

The corrosion testing results showed that the R iron in the as-cast condition had the lowest critical current density and passive current density compared to irons with molybdenum addition. It may be due to the formation of multiple eutectic carbides, which reduced the amount of chromium in the matrix that used to form the passive film. After destabilization, there was a lower critical current density, resulting in an improvement in corrosion resistance over the as-cast condition

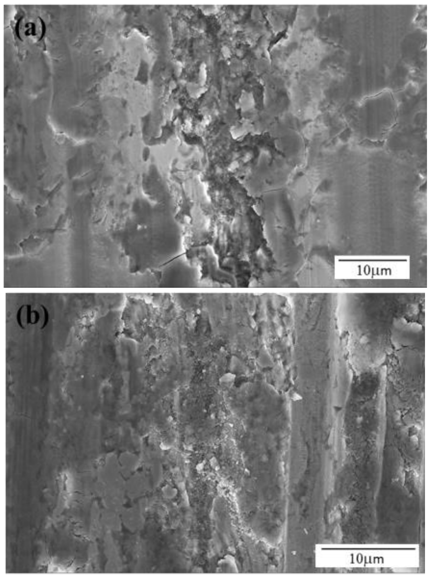

Figure 3 SEM micrographs showing the worn surface of R iron (a) as-cast condition, (b) after destabilization.

4. Conclusion

The as-cast microstructure of R iron consisted of primary austenite dendrites with eutectic M_7C_3 carbide and eutectic austenite. The irons with molybdenum addition promoted the formation of M_6C and $M_{23}C_6$. After destabilization, the transformation of austenite to martensite + secondary carbides were found in all irons. The effect of molybdenum can also increase the macro-hardness and dry-sliding wear resistance, but corrosion resistance was decreased. After destabilization, the hardness and dry-sliding wear resistance increased in the same trend, including corrosion resistance showed a slight improvement.

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