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Effect of Heat Treatment on the Structure and Properties of the ChKh3 Low-Alloy Wear-Resistant Chromium Cast Iron

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Abstract—The effect of heat treatment on the microstructure, microhardness, and structural-phase state of the samples of the ChKh3 low-alloy wear-resistant chromium cast iron is studied. The metallographic analysis is performed using a Carl Zeiss Axio Observer Z1m metallographic microscope and ThixoMet PRO software. The heat treatment of the samples is carried out in a SNOL furnace equipped with a Termodat 16-E3 PID controller. After 2-h-long quenching at a temperature of 890°C, the samples are removed from the furnace and cooled in still air. After cooling to a temperature of 40–50°C, the samples are tempered at a temperature of 180–200°C for 2 h. The samples cooled after tempering have a hardness of 54–56 HRC compared to a hardness of 320–340 HB in the cast state. The results for heat treatment show that the main contribution to an increase in the hardness of the ChKh3 wear-resistant chromium cast iron is provided by a significant increase (by a factor of 2–2.5) in the hardness of the metal matrix due to solid-solution hardening and partial precipitation of fine inclusions (carbide particles). Tests of heat-treated shot blast blades made of the ChKh3 cast iron show an increase in service life by a factor of 8–11 compared to cast blades not subjected to heat treatment, and a factor of 1.5–2 compared to serial shot blast blades, made of the 510Cr2 cast iron in China.

Keywords: chromium cast iron, heat treatment, microstructure, microhardness

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INTRODUCTION

Chromium cast irons with chromium content ranging from 2 to 38 wt %, having high wear resistance, heat resistance, and corrosion resistance in aggressive environments, are widely used for the fabrication of critical parts in various branches of mechanical engineering. Working in complicated regimes that combine effects of various wear factors and aggressive environments, machine parts and components of equipment lose their performance due to natural destructive processes (friction, warping, mechanical loads, extremely high temperatures, etc.). In this case, an appropriately selected technological process of heat treatment of a part made of chromium cast iron can extend its service life.

In this regard, the development of new efficient technologies that make it possible to produce an item that meets modern quality standards and a given level of properties is a primary task of modern material science.

In modern technology, heat treatment (HT) is the most wide-spread method for improvement of the performance characteristics of most steels and cast irons. In addition, it is known that the strength of cast iron products depends on the chemical composition, crystallization conditions, and HT regimes [1]. The selection of an efficient HT method can provide a given set of technological and functional properties of the product as a whole.

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Table 1. Chemical composition of the melts of the ChKh3 chromium cast irons

Cast iron grade	C	Si	Mn	S	P	Cr
ChKh3 according to GOST	3–3.8	2.8–3.8	Up to 1	Up to 0.12	Up to 0.3	2.01–3
ChKh3 heat under study	3.2 ± 0.037	1.27 ± 0.06	0.73 ± 0.06	0.089 ± 0.0032	0.165 ± 0.0024	2.44 ± 0.11

Multiple works have been devoted to the HT of alloyed cast irons. For example, the authors of [2–5] studied the HT effect on the structure and properties of several grades of chromium cast iron and offered recommendations for the HT. The known literature data on the HT parameters have been systematized for a group of wear-resistant chromium cast irons, and the HT regimes have been specified for items working in mining and processing industries [6]. However, the problem of control of the structure and properties of cast-iron castings during the process of thermal hardening still needs to be considered in detail.

The topicality of this work is related to the need to study the process of structure formation of chromium cast irons using optimization of the HT regimes.

The purpose of the work is to identify the features of changes in the microstructure and hardness of the ChKh3 low-alloy wear-resistant chromium cast iron resulting from the HT.

MATERIALS AND METHODS

Samples of the ChKh3 low-alloy wear-resistant chromium cast iron were objects under study. Table 1 presents the chemical composition of chromium cast irons in accordance with the 7769-82 GOST (State Standard) 1 [7]. The castings were obtained by casting using gasified models. Upon completion of the solidification process, the castings were knocked out and cooled in air. Cooled castings were cleaned of burnt marks using a shot blasting machine. Metallographic template blanks with dimensions of 20 × 20 × 40 mm were cut from the finished castings using waterjet cutting methods. Then, metallographic samples were prepared, which were, first, cut from the templates on a MICROCUT-201 precision cutting machine and, then, pressed into a bakelite compound. The resulting samples were ground and polished on a DigiPrep-P automatic grinding and polishing machine and sequentially etched in Nital etchants and Berahi no. 3 etchant. The microsections were studied according to the methods of [8, 9].

Metallographic analysis was carried out using a CarlZeissAxioObserverZ1m metallographic microscope and a ThixoMetPRO software package using the methods of [10–16].

RESULTS AND DISCUSSION

Figure 1 shows the microstructure of the ChKh3 cast iron samples in the original (cast) state. It is seen that, when gray cast iron is alloyed with chromium, it acquires the structure of ledeburite and the graphitization process is completely suppressed even at a chromium content starting from 1.6 wt % [17]. The photographs of the microstructure of cast iron in the cast state fully prove this: a panoramic macrostructural image demonstrates the skeletal ledeburite eutectic. Free graphite is predictably absent. The metal matrix is represented by ferrite. The hardness of cast iron in the cast state ranges from 320 to 340 HB.

Heat treatment of the samples was carried out in a SNOL furnace, equipped with a Termodat 16-E3 PID controller. The heating temperature for quenching was 890°C, and the exposure time was 2 h, after which the samples were removed from the furnace and cooled in

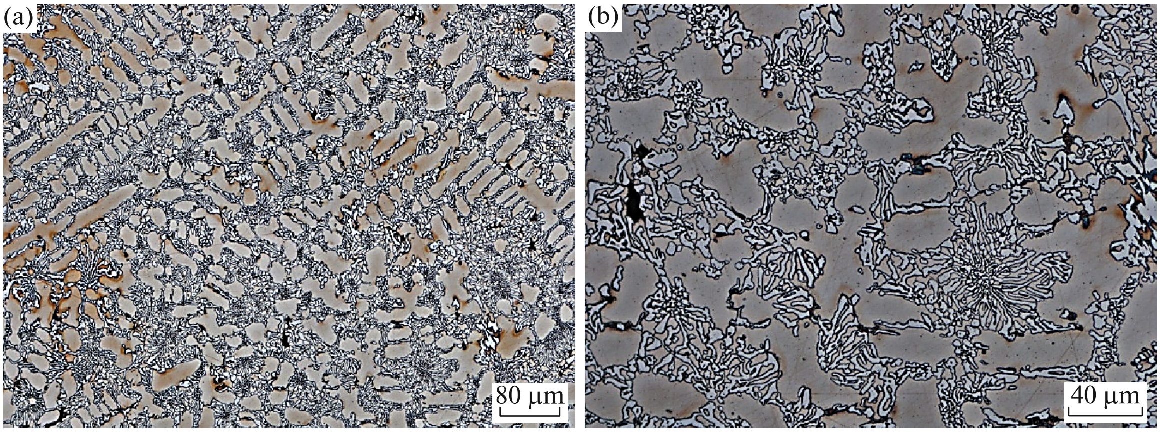

Fig. 1. Microstructure of the ChKh3 cast iron in the original (cast) state. Optical magnification: (a) ×200 and (b) ×500.

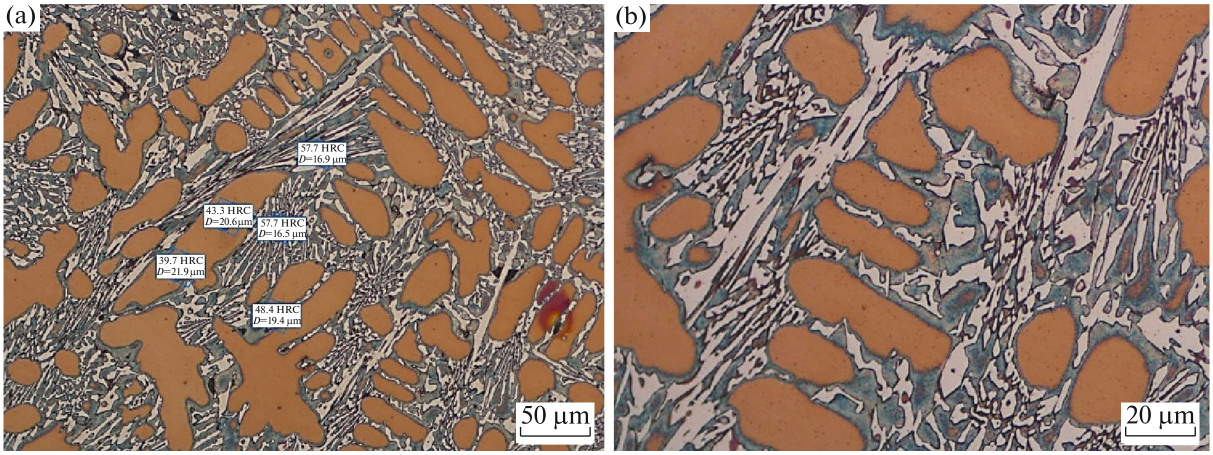

Fig. 2. Distribution of (a) microhardness and (b) microstructure of the ChKh3 cast iron in the heat-treated state. Optical magnification: (a) ×200 and (b) ×500.

still air in accordance with the recommendations of [17]. After cooling to a temperature of 40–50°C, the samples were tempered at a temperature of 180–200°C for 2 h. The samples cooled after tempering had a hardness of 54–56 HRC. Figure 2 shows the microstructures resulting from quenching of the ChKh3 cast iron. Figure 2a also presents the experimental results on the microhardness of the main phase components (skeletal eutectic and metal matrix). It is seen that the carbide skeleton of the ledeburite eutectic has a hardness of 57.7 HRC, while the hardness of the metal matrix ranges from 39.7 to 48.4 HRC. In the cast state, the hardness of the carbide skeleton was 57–58 HRC, while the hardness of the metal matrix was only 22–24 HRC. Thus, an increase in the hardness of the material as a whole after heat treatment results from a significant increase in the hardness of the metal matrix. Comparing the microstructure of cast iron in the cast and heat-treated states (Figs. 1b and 2b, respectively), we conclude that the significant strengthening of the metal matrix is related to partial dissolution of the carbide skeleton in it and subsequent thermal fixation of the solid solution under rapid cooling. This is evidenced by a characteristic halo around the carbide phase, as well as rounded finely dispersed precipitates of carbides in the metal matrix (dark dots in Fig. 2b).

CONCLUSIONS

The study has shown that, under heat treatment, the main contribution to increasing hardness of the ChKh3 wear-resistant chromium cast iron is provided by a significant (by a factor of 2–2.5) increase in the hardness of the metal matrix as a result of solid-solution hardening and partial release of fine inclusions of carbide particles in it.

The tests of heat-treated shot blasting plant blades made of the ChKh3 cast iron have shown an increase in service life by a factor of 8–11 compared to cast blades that were not subjected to heat treatment, and a factor of 1.5–2 compared to serial shot blasting plant blades made of the 510Cr2 cast iron in China.

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CONFLICT OF INTEREST

The authors declare that there is no conflicts of interest.

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