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STUDYING THE CHROME-NICKEL CAST IRON STRUCTURE AND PROPERTIES AFTER MODIFICATION ON INDUSTRIAL SAMPLES

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The paper presents the results of studying the structure and properties of chrome-nickel cast iron samples obtained under production conditions. Cast iron with a given ratio of silicon and chromium smelted in an industrial arc furnace was treated with titanium carbide followed by modification with a complex modifier containing (Scanning electron microscope). As a result of the composition adjustment and appropriate processing, a mixed structure was formed represented by an austenite-ledeburite matrix, iron, chromium and titanium carbides and a small amount of free graphite, both lamellar and spherical. This structure is characterized by higher wear resistance and impact resistance compared to Nihard-2 but at the same time it shows lower hardness.

Keywords: chrome-nickel cast iron, modification, structure, wear resistance, hardness.

INTRODUCTION

One of the trends in improving the properties of Nihard group alloys is formation of a mixed structure, i.e. a structure where carbon is present both in the carbide phase and in the form of graphite inclusions [1].

In works [2,3] it was shown that the volume and morphology of the graphite phase in Nihards is affected by the silicon content.

The silicon content must be balanced with a certain chromium content, otherwise, the process of carbon precipitation in free form begins. Cr : Si = 2,5:1 is the optimal ratio, and the content of silicon below 0,5 % is undesirable, because fluidity of cast iron decreases and the risk of casting defects increases [4]. Therefore, by reducing the ratio between silicon and chromium, it is possible to obtain some content of free graphite in the Nihard structure. In works [1, 5-7], using the Yates's planning method, it was shown that at the Cr:Si=1.4:1 ratio, graphite inclusions appear in cast iron of the Nihard class, and the volume, shape and length of the lamellae largely depend on the Cr:S ratio. Previous studies (our paper) showed that at a certain Cr:Si ratio [8,9] and with introducing titanium carbide in the amount of 0,5 – 1,0 %, a certain amount of lamellar graphite appears in the structure. After modification, part of the lamellar graphite is transformed into a spherical shape. As a result, a mixed structure is formed that is represented by an austenite-ledeburite matrix, cementite, and free graphite of various shapes. Laboratory samples showed [10] that castings obtained using that technology had higher wear resistance than castings obtained using classic Nihard-2.

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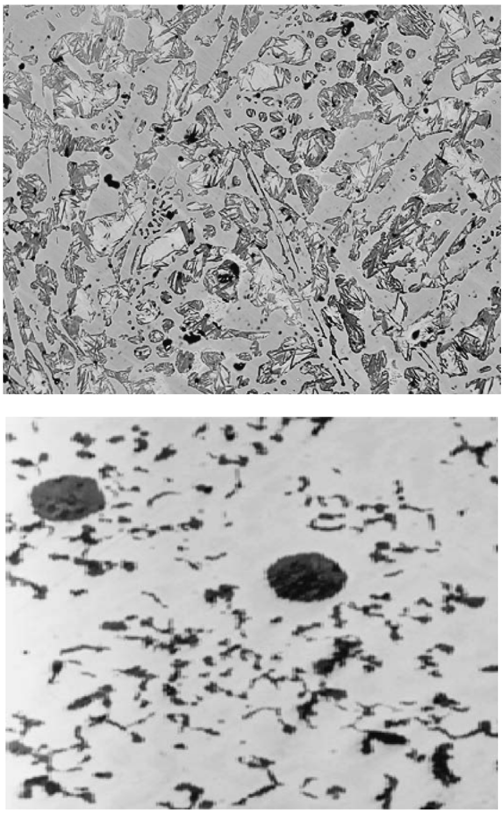
At the production site of the Parkhomenko (Limited Liability Partnership «Karaganda machine -building plant»), pilot tests of the developed technology of manufacturing replaceable parts were carried out. The alloy of the composition shown in Table 1 was used as an experimental alloy. Nihard-2 cast iron was used as a reference sample. The difference between the experimental alloy and classic Nihard-2 cast iron consists in the composition adjustment by changing the content of silicon, chromium and nickel and additional alloying with titanium carbide. Increasing the silicon content to 1,5 - 2,5 % with the chromium content of 3 - 5 % leads to formation of a certain amount of free lamellar graphite. Subsequent modification with a complex modifier (Spherolite-P) partially changes the graphite lamellar shape to spherical.

Increasing the content of nickel in comparison with the analogue provides formation of the martensitic-bainitic structure. Introducing titanium carbide into the composition of cast iron compensates for the decreasing hardness, which occurs as a result of decreasing the volume of chromium carbides. In addition, introducing titanium carbide has a beneficial effect on formation of lamellar graphite, because it contributes to the simplification of its shape and dimensions, which subsequently facilitates the process of converting lamellar graphite into spherical. Titanium carbides have a high melting point (3 140 ^{0}C) and do not melt retaining their phase identity. Due to their low density, titanium carbides float during the casting process and are evenly distributed over the casting cross section.

The presence of some molybdenum provides sufficient toughness. Since the introduced titanium carbide already contains carbon, the initial carbon content before alloying with titanium carbide should be 2,3 – 2,8.

Table 1 – **Experimental alloy composition**

Sample	Element / %							
	C	Cr	Mn	TiC	Ni	Si	P	S
1 (reference)	3,6	0,2	0,5	-	1,0	1,8	≤ 0,05	≤ 0,09
2	2,6	1,5	0,6	0,5	4,0	1,5	≤ 0,05	≤ 0,09
3	2,8	4,0	0,6	0,8	4,5	2,0	≤ 0,05	≤ 0,09
4	3,0	5,0	0,5	1,0	5,0	2,5	≤ 0,05	≤ 0,09



a)

b)

Figure 1 Structure of the experimental alloy (melting 1 at the production site of the Parkhomenko KMZ LLP), magnification x 100 (a), magnification x 300 (b)

In classic Nihard cast irons, to suppress the graphitization process, the silicon content is strictly regulated by the ratio Cr : Si = 2,5:1. Increasing the chromium content to 3,0 - 5,0 % with the silicon content of 1,5 – 2,5 % leads to the fact that the graphitization process is not completely suppressed, and some of the carbon is graphitized forming lamellar graphite.

As a result of adjusting the composition and subsequent modification, there is formed a structure consisting of an austenite-ledeburite matrix, chromium, iron and titanium carbides, lamellar and spherical graphite. It should be noted that titanium carbides are present in the structure due to introducing the titanium carbide powder. In this case, carbides are characterized by a more rounded shape than the carbides obtained in the crystallization process, which has a beneficial effect on the properties of the structure.

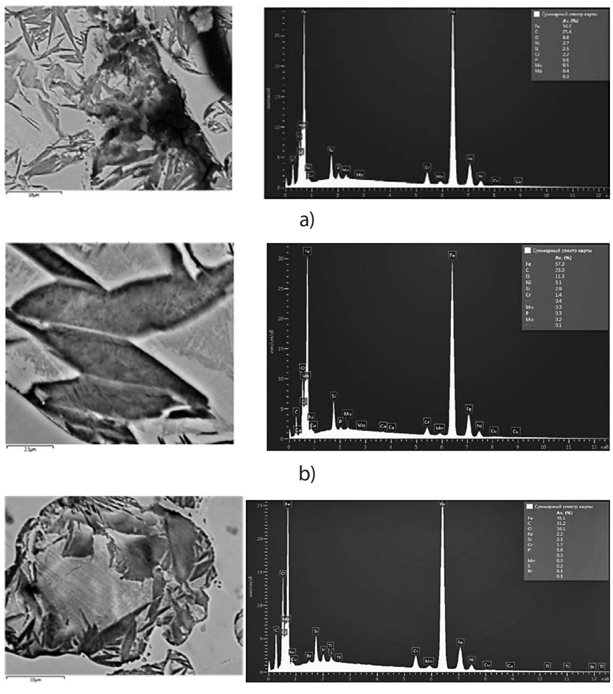
Spherical graphite is obtained by modifying lamellar graphite, which provides a final structure consistent with the Charpy principle: the simultaneous presence of hard and relatively soft components, which provides high resistance to abrasive wear.

EXPERIMENTAL STUDIES

Equipment and tools

Upon completion of melting and complete cooling, samples were made for metallographic analysis and control of properties. The results are presented in Figures 1 and 2.

The carried out studies of experimental melts samples showed in the structure the presence of free graphite of various shapes: mixed (Figures 1, 2a), lamellar (Figure 2b) and spherical (Figure 2c). It should be noted that these forms of free graphite are somewhat different from the "classical" ones and are rather vague. Nevertheless, the trend towards changing the morphology of free graphite before and after modification can be traced quite clearly.



a)

b)

c)

Figure 2 Structure and MRSA of the experimental alloy inclusions: the presence of mixed (a), lamellar (b) and spherical (c) graphite, magnification x5000

On the obtained samples, some mechanical properties were determined: hardness, wear resistance and impact strength. Wear tests were carried out on a TABER ABRASER 352G. Tungsten carbide was used as an abrasive, the test period was 10 000 cycles. Hardness was determined on a Wilson VH1156 instrument at no less than 5 points; Impact tests were carried out on an

Table 2 – **Mechanical properties of experimental samples**

Sample	Hardness / HV	Wear resistance / %	Impact strength, number of impacts before destruction
1 (reference)	658	70,2	6
2	558	87,2	9
3	587	89,0	10
4	602	88,4	9

eccentric impact driver with the striker weight of 30 kg. The results are shown in Table 2.

It is seen from Table 2 that hardness of the prototypes is reduced by 10 – 15 % but wear resistance and impact resistance are increased by on average by 20 and 30 %, respectively. Decreasing hardness is explained by the appearance of a certain amount of free graphite in the structure, however, the positive effect of its presence in the structure is manifested in increasing wear resistance and impact resistance.

CONCLUSION

Thus, it can be assumed that inclusions of free graphite play the role of "lubrication" and contribute to increasing abrasive wear. Changing the shape of free graphite from lamellar to spherical has a positive effect on impact resistance. It should be noted that only a part of lamellar graphite was transformed into a spherical shape after modification (Figure 2a). It is obvious that with a complete transformation of the graphite morphology after modification, it is possible to expect a more significant increasing of properties. Introducing titanium carbide into the composition of chrome-nickel cast iron and subsequent modification make it possible to obtain a mixed structure represented by an austenite-ledeburite matrix with a certain amount of free graphite, both lamellar and spherical. This change of the structure has a beneficial effect on wear resistance and impact resistance, although it is accompanied by some decreasing of hardness.

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Note: Responsible for the English language is Natalya Drak, Karaganda, Kazakhstan