# INFLUENCE OF ALLOYING CONDITIONS ON THE PROPERTIES OF WHITE CAST IRON

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**ABSTRACT**
The article highlights the results of studying the influence of alloying conditions on the quality of white cast iron. In the experiment, the doping conditions were carried out in various ways. Based on the conducted experiments, the results of the study were summarized.

**KEYWORDS:** Cast iron, high-chromium eutectic cast iron, carbide, inoculator, high-carbon ferrochrome, processing, low-carbon steel.

## INTRODUCTION
The effect of silicon and mishmetal additives on the structure of preeutectic chromium cast iron containing, wt. %: 2.56 C, 16.8 Cr, 1.77 Ni, 1.93 Mo. The metal was melted in a 10 kg furnace and cast iron was poured into a metal mold. The metal pieces were remelted in a 1 kg furnace in an argon medium and additionally introduced into the furnace different amounts of silicon: 1; 2 and 5 % and mishmetal: 0.1 and 0.3 %, and then poured into a steel mold, obtaining a sample size of 15-25-20 mm. It was found that silicon grinds the dendritic structure and increases the eutectic carbide fraction. The introduction of mishmetal led to a decrease in austenitic dendrites, but did not significantly affect the structure of carbides. The effect of 0.1 to 2 % Ti on the properties of preeutectic chromium cast iron containing 2.5 % C and 16 % Cr was studied. The hardness of the matrix has increased.

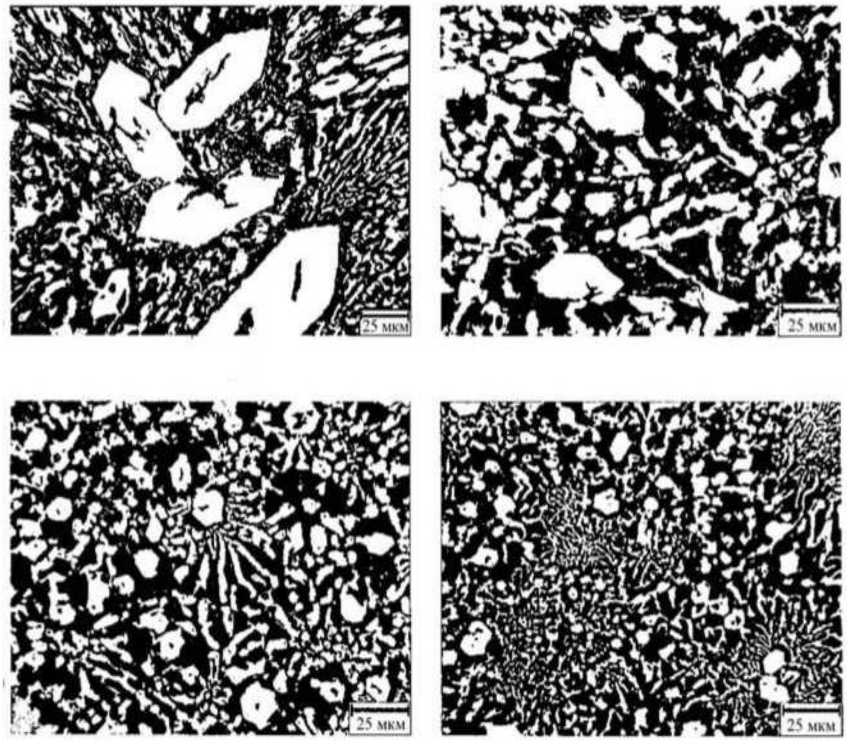
## MATERIALS AND METHODS
However, the addition of titanium practically did not change the strength of the alloy. The effect of titanium on the properties of commercial cast iron of 15 % Cr-Mo was studied in this paper. Cast iron containing, wt. %: 2.33–2.42 C; 14.93–16.89 Cr; 0.49–1.94 Si; 0.85–1.15 Mn; 0.36–0.7 Ni; ≈3 Mo was studied. In the alloy we add 0,1–0,25–0,38 % Ti. With the addition of 0.38% Ti and after 6h austenization with 1050 °C, the wear test was performed with an $Al_2O_3$ abrasive. These tests showed a 30 % increase in the abrasive resistance of cast iron. That an increase in the wear resistance of cast iron can be associated with an increase in the hardness of the metal matrix. A 30% increase in wear resistance when tested with a very hard $Al_2O_3$ abrasive is a good result, since a very hard abrasive eliminates the difference in the wear resistance of

materials. Apparently, testing with a quartz-type abrasive will show a higher difference in the wear resistance of the alloy under study and the steel from which the standards are made. This assumption is made on the basis of our wear tests on quartz and corundum skins. In these tests, cast iron ИЧ290Н12М on quartz skin exceeded the standard of steel 20 by 10-11 times, and on corundum skin this superiority decreased to 2.58. The same pattern was observed when testing other wear-resistant white cast iron. For eutectic white high-chromium cast iron attracted researchers and operators with a higher (compared to eutectic cast iron) content of hard and wear-resistant carbides M7C3 . However, the use of high-chromium eutectic cast iron (ВХЗЧ) caused great difficulties due to their low mechanical properties, brittleness and high level of marriage in the manufacture of castings. It is noted that the mechanical properties of the ВХЗЧ be improved by doping and technology that provides the desired alloy structure. Modification and inoculation are widely used for grinding the structure of alloys. However, in most cases, the attempt to modify the ВХЗЧ to improve the structure of primary carbides has had little success , and the use of inoculation requires pouring at a lower temperature, which limits the use of this technology. Wear-resistant high-chromium eutectic cast iron is widely used for the manufacture of slurry pumps, equipment for mineral processing in the cement, coal industry, etc. When extracting oil-containing sands (Canada, Northern Alberta), traditionally used eutectic chromium cast iron did not provide sufficient equipment stability.
The desire to reduce large economic losses from wear of pumps that pump abrasive pulps has led to the use of non-eutectic chromium cast irons: A12 (30 % Cr, 4, 5 % C) and A217 (35% Cr, 5% C). Wear-resistant cast iron A217 had small primary carbides. Cast iron A61 is similar in chemical composition to cast iron A12, but with small primary carbides. The use of eutectic cast iron A61 and A217 with small primary carbides allowed to increase the service life of impellers of pumps and other parts by 1.7–3 times in comparison with the previously used eutectic chromium cast iron A05 and eutectic A12 with large primary carbides. The use of A217 alloy instead of A12 (with large carbides) increased the durability of the discharge sleeve from 1350 h to 3600 h. Replacing the eutectic A05 alloy with a non-eutectic A61 with fine carbides increased the durability of the impellers from 2500 h to 5500 h, i.e. 2.2 times. The methods used for grinding carbides in non-eutectic chromium cast irons are not reported in the report, which seems to be related to the economic interests of the companies that manufacture the equipment and funded this research.
The metal was smelted in a 10 kg medium-frequency induction furnace. High-carbon ferrochrome, low-carbon steel, and pig iron were used for the charge. The metal was brought to a temperature of 1580-1600 °C. After the metal was melted, it was deoxidized with pure Al (0.05-0.15 %), after which ferrotitane was added in different amounts. The molten metal was poured at 1380°C in a dry, sandy form. Sample sizes, mm: 60×60×200. Metallographic research was carried out on their surface.

## CHEMICAL COMPOSITION OF EXPERIMENTAL SAMPLES AND THE AMOUNT OF TITANIUM INTRODUCED, WT. %:

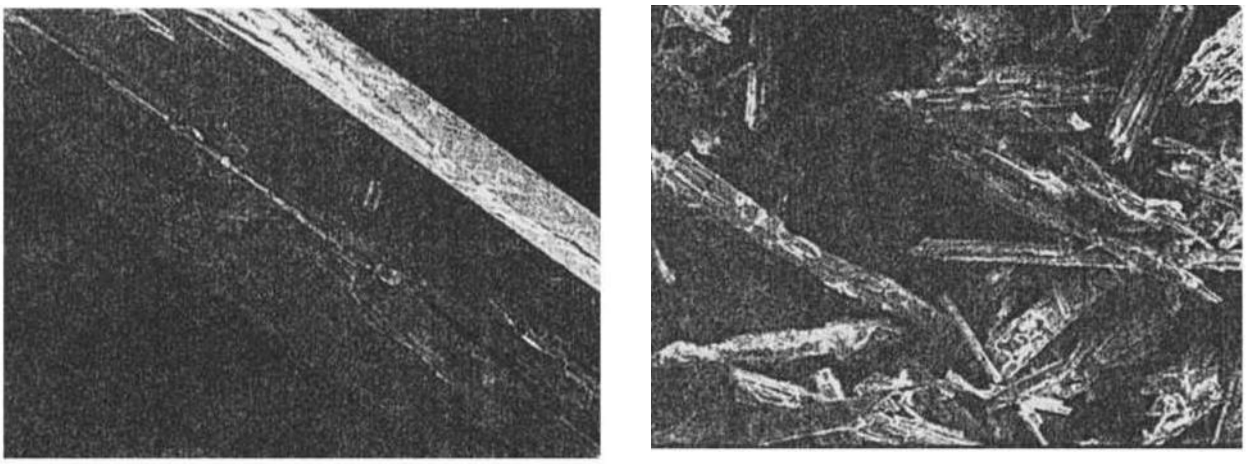
| Sample | № 1 | № 2 | № 3 | № 4 |
|---|---|---|---|---|
| C | 4,0 | 3,95 | 3,90 | 3,86 |
| Cr | 20,0 | 19,74 | 19,50 | 19,29 |
| Ti | 0 | 0,50 | 1,0 | 1,5 |

The microstructure of cast iron samples with different amounts of titanium is shown in Fig. 1 and 2. Fig. 1, a shows that the microstructure of the ВХЗЧ without the addition of titanium consists of large primary M7C3 carbides with a hexagonal shape and a typical eutectic matrix structure-2., shows a significant difference in the size of primary carbides. The morphology of primary carbides improves as the concentration of titanium in the alloy increases. It is obvious that the introduction of titanium has a great influence on the structure of primary carbides in the ВХЗЧ. The ratio of equivalent diameters of carbides decreases sharply with an increase in the content of titanium in the ВХЗЧ (Fig. 3). It was expected that titanium and carbon could dissolve in the molten metal, and a chemical reaction [Ti] + [C] = TiC between these elements is possible.




a) b)

Fig. 1. The effect of the amount of titanium in the alloy on the value of the equivalent diameter of carbides in the ВХЗЧ.



a) b)

Fig. 2. Primary carbides in the samples of ВХЗЧ without (a) and with the addition of 1.5% Ti (b), the image was obtained on SEM.

In this case, it is likely that the resulting TiC particles absorb the heat of the liquid alloy during crystallization. With the introduction of titanium in the amount of 1.5%, the size of carbides sharply decreased to 4 microns instead of 10 microns in the absence of this element in the alloy. When the size of carbides decreases, the mechanical properties of cast iron and its wear resistance increase.

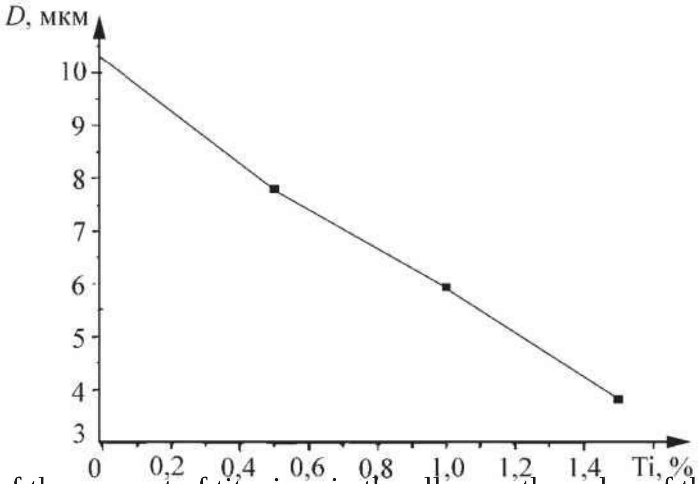



Fig. 3. The effect of the amount of titanium in the alloy on the value of the equivalent diameter of carbides in the ВХЗЧ.

The influence of modification and inoculation on the structure and viscosity of hypereutectic cast iron containing 4% C and 20% Cr was studied at higher (1380°C) casting temperatures than those used in the work.

Table1

| Sample | C | Si | Mn | Cr | P | S | Influence |
|---|---|---|---|---|---|---|---|
| A1 | 4,03 | 1,13 | 0,45 | 20,35 | 0,04 | 0,05 | - |
| A2 | 4,03 | 1,13 | 0,45 | 20,35 | 0,04 | 0,05 | Modification (M) |
| B1 | 3,93 | 1,15 | 0,58 | 19,84 | 0,03 | 0,05 | Input 2,1 % particle |
| B2 | 3,93 | 1,15 | 0,58 | 19,84 | 0,03 | 0,05 | M + И |

## RESULTS

The alloy was smelted in a medium-frequency induction 20 kg furnace. The charge consisted of pure steel scrap, pig iron, and ferrochrome containing 63 % Cr. Approximately 1.2% of the modifier was placed on the bottom of the heated bucket, mainly containing Fe, Si, Re, Al and the alloy made by the researchers (3.0-3.5 % C, 3-5 % Mn, 3-4 % Cr, 0.5–3.0% Nb, 0.2–1.8% V, 0.1–1.0% Si, 0.005–0.04 N, OST.Fe). Inoculator particles consisted of an alloy containing 0.7-1.2 % C, 0.6-1.2 % Mn, 0.4-1.2 % Si, 0.05 % P and S. These particles had a size of 0.125-0.180 mm and were uniformly introduced into the melt through the filling bowl of a vertical spigot of a liquid-glass mold. 20×20×110 mm samples were cast in a mold without a cut for impact testing. After casting, these samples were released for 2 hours at 250 °C. The melt was deoxidized with aluminum at 1550°C, after which the liquid metal was poured into a bucket, and then poured into a mold. The chemical composition of hypereutectic cast iron and methods of influence on the alloy are shown in table 1.

The results of the three impact tests

| Sample<br>a, Gj/m$^2$ | A1 | A2 | B1 | B2 |
|---|---|---|---|---|
| experience 1 | 290 | 460 | 540 | 620 |
| experience 2 | 220 | 420 | 570 | 650 |
| experience 3 | 230 | 420 | 550 | 600 |
| $a_{average}$, Gj/m$^2$ | 250 | 430 | 550 | 620 |

## CONCLUSION

This research showed that modification and insertion of inoculator particles increased the impact strength of the by a factor of 1.7–2.48. The impact of inoculators on the impact strength of the alloy was more significant than the modification – an increase in viscosity by 2.2 and 1.7 times, respectively. The combined effect of modification and inoculation gave a small (13%) increase in the viscosity of the alloy compared to inoculation alone. Apparently, the addition of inoculator particles increases the rate of crystallization and increases the number of crystallization centers. Referring to a number of works that inoculation can increase the rate of crystallization and solidification of the alloy, improving the distribution, reducing the temperature range of crystallization. Thus, the crystallization time is shortened and the solute can have a good effect on the melt.

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