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# Promising Technology Making Cast Details with Optimal Chemical Composition and Improved Mechanical Properties

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**ABSTRACT:** The article presents the results of studies cast parts made of white high chrome cast iron. Studied the chemical composition, mechanical properties and parameters of macro - and microstructure of white iron, local and imported. Defined hardness and microhardness of the samples before and after heat treatment, as well as abrasion tested on a work surface. It is proved that the wear resistance of components after heat treatment in a double phase recrystallization is increased twice or three times.

**KEY WORDS:** chemical composition and mechanical properties of white high chrome cast iron, hardness and microhardness of cast samples, heat treatment with a double phase recrystallization, macro - and micro-structure, performance and abrasive wear resistance of cast products.

## I. INTRODUCTION

Currently, the development of the chemical, metallurgical and engineering industries, as well as other related branches of technology, largely depends on various factors to increase the profitability of production [1]. One of the ways to increase productivity is to use optimal chemical elements to produce high-quality cast parts from high-chromium white cast iron.

In this paper, two main objects were investigated: 1-cast worn impellers from a centrifugal sand pump for the metallurgical industry (Fig. 1a); 2-cast worn tsilpebs constantly rotating inside large drums of cement production (Fig. 1b). At the same time, crack formation is visible in the macrostructure (Fig. 1c, d). Both parts are made of castings of white high-chromium cast iron in the foundry of JSC Almalyk Mining and Metallurgical Plant and LLC Dalvarzinsky Repair Plant. At the moment, the plant and the plant are operating cast parts of local and foreign production by Warman. The serviceability and wear resistance of locally manufactured cast parts of AGMK JSC and DRZ LLC are several times lower than those of imported production and are limited by the resistance to abrasive wear of cast iron ИЧХ28Н2, of which cast parts are made that work for abrasive and impact-abrasive wear. Therefore, to clarify the reasons for such a big difference, special studies were conducted of materials produced by Warman and the working parts of AGMK JSC and DRZ LLC. In addition, the chemical compositions of various cast iron melts of JSC "AGMK" and LLC "DRZ" for the period of the contract execution have been analysed. The chemical compositions of white cast iron of both industries vary within wide limits, sometimes going beyond the brand composition [2,3]. A series of swimming trunks was selected for research, which significantly differed in the content of the main chemical elements and sulphur.

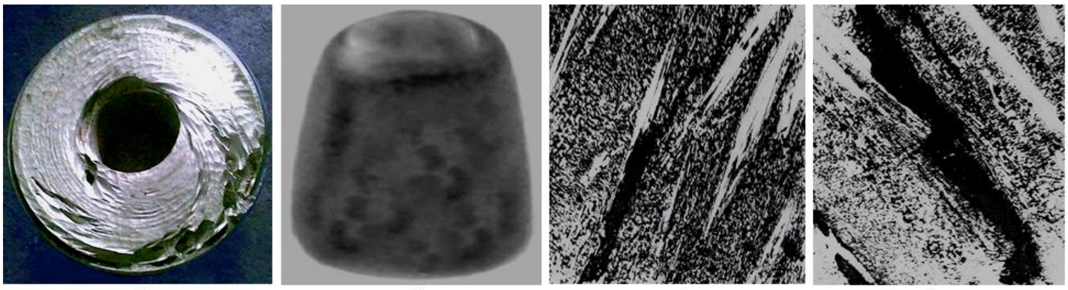

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Fig. 1. Cast worn parts and macrostructures cast from high-chromium white cast iron: a-pump impeller; b-clippers of drum mills; c, g-cracked specimens.

## II. METHODOLOGY

Special imported samples of white high-chromium cast iron, cut from a used impeller and tsilpebsa, were used as a kind of standard in terms of chemical composition, mechanical properties and structural parameters.
The aim of this work is to develop an innovative technology for the manufacture of cast parts in earthen form from high-chromium white cast iron with the optimal chemical composition, mechanical property and the necessary structural parameter, as well as increase the hardness and wear resistance of parts using optimal heat treatment conditions with double phase recrystallization [4,5 ].
Research Methodology. The optimal chemical elements that we offer for these castings were analysed in the central laboratory of the repair and mechanical plant of JSC "AGMK" and LLC "DRZ" and used to produce both cast cast iron parts of the brand X28N2.
The chemical compositions of the studied samples of white cast iron are given in Tables 1 and 2. The results obtained show that all the melts in the main elements can be attributed to the known brands of cast iron [2], but the following differences are observed:
- Smelting No. 910, 926, 939 and 1, 2, 3 has a clearly overestimated carbon content for the brand ICHCH28N2;
- the sulphur content in all smelting of AGMK JSC and DRZ LLC is many times higher than in Warman cast iron;
- the chromium content in almost all melts is less than in Warman cast iron.
Cast clippers of white chrome cast iron to relieve internal stresses, improve machinability by cutting and prepare the structure for hardening heat treatment, are subjected to softening annealing at 700-7300C for several hours, followed by cooling together with the furnace for hardness HRC = 39-46

**Table 1 The chemical composition of the studied samples of white cast iron TsRMZ JSC "AGMK"**

| Product, melting | Content of elements, mass% | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | P | S | Cr | Ni | Mo | Cu |
| Working wheel (Warman) | 2,87 | 0,317 | 1,38 | 0,031 | 0,012 | 28,31 | 0,53 | 0,049 | 0,025 |
| Impeller of AGMK JSC | 2,45 | 0,59 | 0,65 | 0,089 | 0,071 | 22,87 | 1,26 | - | - |
| Smelting No. 910 of JSC "AGMK" | 3,49 | 0,51 | 0,57 | 0,067 | 0,032 | 28,86 | 1,54 | 0,057 | 0,2 |
| Smelting No. 926 of JSC "AGMK" | 2,99 | 0,87 | 0,62 | 0,064 | 0,034 | 26,54 | 0,99 | 0,059 | 0,26 |
| Smelting No. 939 of JSC "AGMK" | 2,92 | 1,35 | 0,33 | 0,036 | 0,035 | 23,0 | 1,16 | 0,053 | 0,22 |

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**Table 2 The chemical composition of the investigated samples of white cast iron, OOO DRZ**

| Product, melting | Content of elements, mass% | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | P | S | Cr | Ni | Mo | Cu |
| Work Tsilpebs (Warman) | 2,88 | 0,318 | 1,39 | 0,032 | 0,013 | 28,30 | 0,54 | 0,050 | 0,026 |
| Workers tsilpebsy OOO "DRZ" | 2,47 | 0,61 | 0,67 | 0,091 | 0,073 | 22,84 | 1,27 | - | - |
| Smelting No. 1 LLC "DRZ" | 3,45 | 0,53 | 0,59 | 0,069 | 0,034 | 28,85 | 1,56 | 0,058 | 0,2 |
| Smelting No. 2 of LLC DRZ | 2,98 | 0,89 | 0,64 | 0,066 | 0,036 | 26,53 | 0,99 | 0,060 | 0,27 |
| Smelting No. 3 of LLC DRZ | 2,94 | 1,36 | 0,35 | 0,037 | 0,038 | 24,0 | 1,18 | 0,054 | 0,23 |

After clarifying the entire complex of the chemical composition of the samples, studies were conducted. In our experiments, samples of white high-chromium cast irons were annealed at 7000C for 2 hours, followed by cooling together with the furnace. The results of these experiments are presented in tables 3 and 4.

**Table 3 Chemical elements and hardness of white cast iron samples TsRMZ AGMK JSC**

| Product, melting | Main elements, % | | | | | ΣC, Ni, Si | Hardness HRC | | Difference in NRC |
|---|---|---|---|---|---|---|---|---|---|
| | C | Cr | Ni | Mn | Si | | before annealig | after annealig | |
| Warman impeller | 2,87 | 28,31 | 0,538 | 1,38 | 0,317 | 3,22 | 57 | 44 | 13 |
| Working wheel | 2,45 | 22,87 | 1,26 | 0,65 | 0,59 | 4,3 | 50 | 43,5 | 6,5 |
| JSC "AGMK" | 3,49 | 28,86 | 1,54 | 0,57 | 0,51 | 5,54 | 50 | 49,66 | 0,34 |
| Smelting No. 910 of JSC "AGMK" | 2,89 | 26,54 | 0,99 | 0,62 | 0,78 | 4,76 | 53,5 | 42,7 | 10,8 |
| Smelting No. 926 of JSC "AGMK" | 2,92 | 23,0 | 1,16 | 0,33 | 1,35 | 5,43 | 55 | 51 | 4 |

**Table 4 Chemical elements and hardness of white cast iron samples of DRZ LLC**

| Product, melting | Main elements, % | | | | | ΣC, Ni, Si | Hardness HRC | | Difference in NRC |
|---|---|---|---|---|---|---|---|---|---|
| | C | Cr | Ni | Mn | Si | | before annealig | after annealig | |
| Work Tsilpebs (Warman) | 2,86 | 28,30 | 0,536 | 1,39 | 0,316 | 3,21 | 56 | 45 | 11 |
| Workers tsilpebsy OOO "DRZ" | 2,47 | 22,84 | 1,27 | 0,67 | 0,61 | 4,4 | 49 | 43 | 6 |

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Vol. 7, Issue 5 , May 2020

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|---|---|---|---|---|---|---|---|---|---|
| Smelting No. 1 LLC "DRZ" | 3,45 | 28,85 | 1,56 | 0,59 | 0,53 | 5,55 | 49 | 48,65 | 0,35 |
| Smelting No. 2 of LLC DRZ | 2,98 | 26,53 | 0,99 | 0,64 | 0,79 | 4,77 | 54,5 | 43,6 | 10,9 |
| Smelting No. 3 of LLC DRZ | 2,92 | 23,0 | 1,16 | 0,33 | 1,35 | 5,43 | 55 | 49 | 6 |

In the presented tables it is seen that after annealing at 700 ° C, hardness within the range of HRC = 39-46 is not achieved in all melts.

Experimental research. As we know, in high-chromium cast iron containing about 30% Cr, the γ-region expands with increasing carbon content and the amount of ferrite in the base structure decreases. However, the γ region expands nickel, and silicon impedes the diffusion of carbon and the decomposition of solid solutions. Therefore, it was found that the total content of elements should be about 4.5% (C, Ni, Si).

In the high-chromium white cast iron of the IChKh28N2 (Kh28N2) brand, it is generally impractical to exceed a carbon content of more than 3%, because hypereutectic cast iron with large primary carbides is obtained. These large carbide crystals crack already in the process of manufacturing a thin section, crumble under the influence of stresses, and contribute to the formation of macro - and micro cracks (see fig. 1c, d).

Microstructural analysis showed that the kink had a pronounced columnar character, when the iron crystals along the long primary axis are perpendicular to the wheel blade, i.e. crystal growth during the solidification of cast iron went mainly in the direction of relatively rapid cooling. Therefore, thin sections were prepared for research both across the long axis of the crystals and along them. Microstructural analysis was studied on a MBS-9 metallographic microscope.

Research results and discussion. The research results showed that the condition of the surfaces of imported cast iron samples on rubbing surfaces had thin grooves of exposure to abrasive particles. Occasionally, individual deep scratches occurred. On the friction surface of samples of locally produced white cast iron there are a lot of deep scratches of “plowing” of abrasive particles. In addition, areas of brittle chipping in the form of pits are clearly visible, on the longitudinal section of the specimen of JSC “AGMK” and LLC “DRZ” there are even more areas of brittle chipping. On a longitudinal specimen on the friction surface, not only deep plowing grooves are observed, but also very strong chipping along the fibre along the long axis of carbides. This is due to the presence of a large amount of sulphides in white cast iron of AGMK JSC and DRZ LLC, which was proved by our experimental studies. This suggests that in the chemical composition of white cast iron, sulphur is five times more than imported.

Metallographic microstructural analysis was performed on a German Neofot-21 microscope and a Russian MIM-8M microscope. For the etching of thin sections, a reagent of the following composition was used: 1. Ferric chloride - 1.25 g; 2. Picric acid - 2.5 g; 3. Hydrochloric acid - 1 ml; 4. Ethyl alcohol - 45 ml. Metallographic analysis determined the type of structure, the size of carbide particles and the structural components of white cast irons. Studies have shown that the considered white high-chromium cast iron of local production by TsRMZ of AGMK JSC and DRZ LLC has a composition close to eutectic on a transverse section with small carbide particles, the sizes of which vary within 8.6-51 μm (Fig. 2a) . A tendency to brittle chipping during the preparation of a micro section was found. On longitudinal sections, the tendency to brittle chipping manifests itself strongly (Fig. 2b). At high magnifications, it is found that spalling occurs along the alloy matrix, where there are a lot of sulphides (Fig. 2c). The spalling of sulphide particles (grey light), as it were, forms a weakened zone along the iron - carbide phase boundaries (Fig. 2d). This microstructure of high-chromium white cast iron is also clearly visible on the transverse section (Fig. 2e, f) [6].

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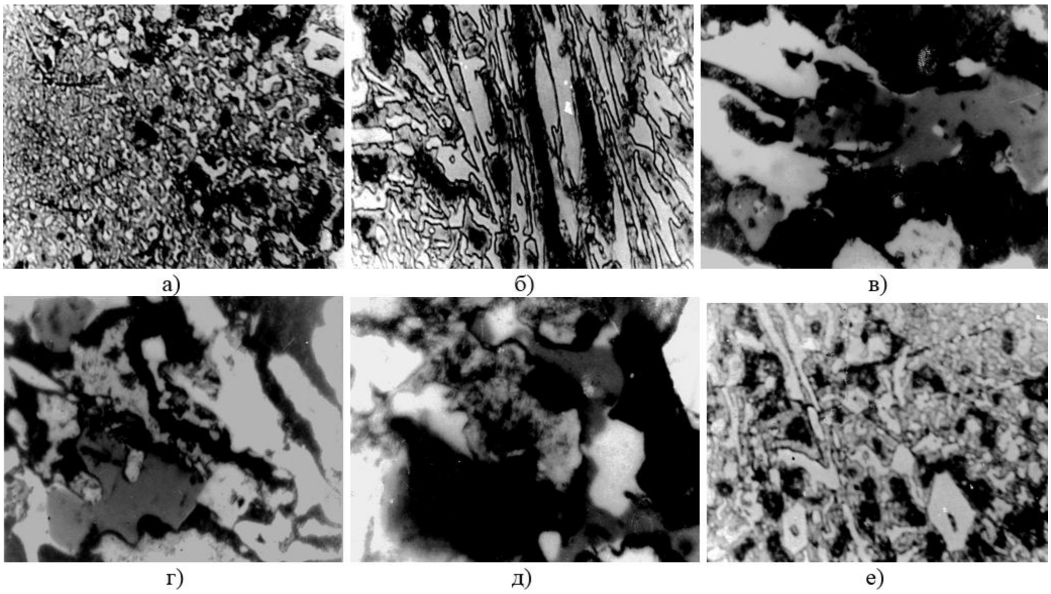

**Fig. 2.** Cross section with small carbide particles (a) and longitudinal section with brittle chipping (b) X300 and microstructure of sulfides (c); spalling of sulphide particles and the formation of a weakened zone at the phase boundaries (d) of X1700 and the microstructure of sulphide particles of phases (e) and iron carbide (e). X1700

Heat treatment aims to change the structure and properties of white cast iron in the desired direction. Therefore, heat treatment should always provide the necessary structure and properties [7]. Fig. 3 shows the heat-treated finished impellers (Fig. 3a), balls and drum cylinders (Fig. 3b, c) and the microstructure of small carbide (Fig. 3d), which increases the hardness and wear resistance of these parts. The hardness of the hardened samples and parts of high-chromium white cast iron is HRC58-63, and the mileage and working capacity reaches 2000-2500 hours.

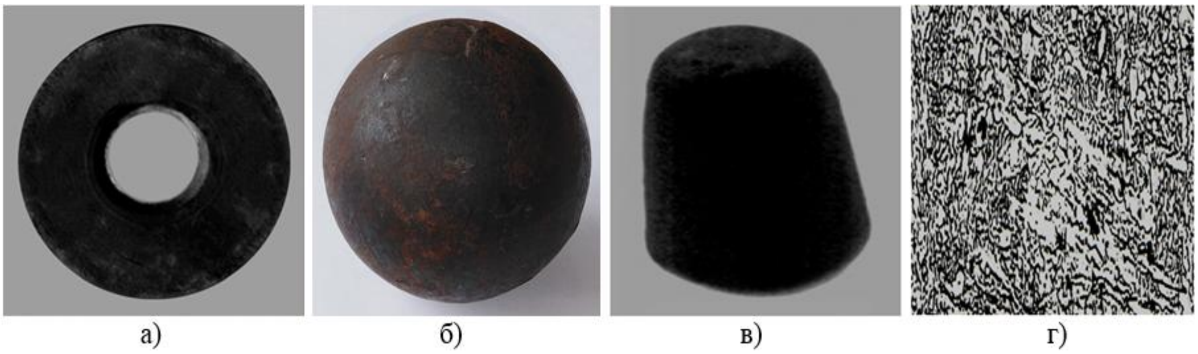

**Fig. 3. Finished cast parts cast from high-chromium white cast iron: a-pump impeller; b-ball drum; b-clippers of the drum; g-microstructure of fine carbide white cast iron. X500**

Findings. In conclusion, it should be noted that all experimental samples and cast parts were subjected to optimal heat treatment with double phase recrystallization of 925-11500C followed by tempering [2]. Heat treatment was carried out in order to increase the hardness and wear resistance of cast parts by two or more times. In addition, the hardness and micro hardness of the samples were determined, abrasion tests were performed before and after heat treatment, and phase X-ray diffraction analysis was studied to determine the phase composition and level of defect of the crystal structure of the matrix and the density of white cast iron dislocation. After the entire cycle of optimal heat treatment, the wear resistance and durability of cast impellers, balls and tsilpebs of drum mills [8] increase 2-3 times higher than serial parts. This innovative technology has been introduced into the production of JSC Metallmexqurilish with an economic effect.

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