ABSTRACT

Dissertation for the Doctor of Philosophy (Ph.D.) degree
in the specialty 8D07203 – «Metallurgy»

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Development and research of production technology of wear-resistant cast iron castings using modifiers

The thematic justification of the research. Annual friction and wear losses worldwide amount to hundreds of billions of dollars. Premature wear of machines, appliances, equipment and tools leads to enormous costs. Wear is one of the main reasons for repairs. In some cases, repair and maintenance costs approximately 3-10 times more than the cost of their manufacture for various pieces of equipment, according to various estimates.

According to some reports, currently about 5-10% of the electricity produced in the world and several million tons of alloyed cast iron and steel are spent on grinding natural raw materials, from which protection elements and working parts of equipment for grinding are made.

Most of the technologies and methods used abroad to increase the wear resistance of parts and castings (high or complex alloy alloying, thermo-mechanical processing of products, etc.) are not used in mass production due to the high cost of materials and equipment.

In this regard, the issues of improving the working properties of such relatively inexpensive, technologically advanced and most affordable materials for domestic manufacturers as low-alloy white cast iron do not lose relevance. This paper presents comparative studies on the modification of low-chromium cast iron with boron- and barium-containing additives of domestic production, as one of the most effective and affordable methods for improving the parameters of the cast alloy structure.

The goal of this research is improving the wear-resistant properties of low-alloy chromium cast iron by treating the alloy with boron- and barium-containing modifiers of domestic production.

Research objectives. To achieve this goal, it is necessary to solve the following tasks:

- to analyze the compositions and properties of modern industrial brands of wear-resistant cast iron for the production of cast parts operating under conditions of shock-abrasive wear. Choose the optimal cast iron composition and modification technology;
- perform a complete thermodynamic analysis of the smelting process and the out-of-furnace treatment of Low-Cromium Cast Iron (LCCI) with boron- and barium-containing additives to determine the characteristics of the influence of chromium, boron and barium on the phase composition and properties;
- to conduct laboratory and experimental studies on smelting and in-mold modification of LCCI with boron- and barium-containing additives, to investigate

the microstructure, hardness and impact resistance of the obtained samples. Adjust the consumption of modifying additives;

- to determine the dependence of the mechanical properties of LCCI on the degree of chromium doping and the amount of modifying additives introduced – ferroborum, ferrosilicobarium and a complex borbarium modifier (BBM). Set the optimal consumption of modifiers;

- to perform a series of pilot tests on the modification of LCCI with boron- and barium-containing additives, to investigate the operational properties of the obtained samples. To determine the type of modifier optimal for modifying effect on the structure and wear-resistant properties of cast iron;

- to develop a technological map for the production of wear-resistant cast iron castings using modifiers.

Scientific novelty. The following results were obtained for the first time:

- a mathematical description of the Fe–Fe_3C diagram has been developed, which makes it possible to automatically calculate the phase and structural composition of alloys of this system with high accuracy without using graphical methods (the rule of segments);

- theoretically justified and experimentally confirmed the existence of new phases (FeB and BaS) in low-chromium cast iron after treatment with experimental modifiers;

- the dependences of hardness, abrasion resistance and shock-dynamic impact on the chromium content and the number of introduced modifiers are established;

- the dependences between the parameters of the microstructure (dispersion, morphology and number of structural components) and the number and nature of experimental modifiers are established.

Practical effect of the research. Based on the results obtained in the dissertation:

- the optimal modifier for LCCI has been determined, which makes it possible to increase the hardness, wear resistance and service life of parts by 9-12%;

- the technology of modifier input (in-mould modification) has been developed when casting according to gasified models, which allows to significantly reduce the consumption of the modifier and the time of the technological process;

- the technology of production of wear-resistant grinding balls using modifiers has been developed, the technological map of the process has been developed and agreed upon.

Research methods. The following methods were used in this work:

- a mathematical method for determining the phase composition of cast iron based on the mathematical description of the equilibrium lines of the Fe-Fe_3C phase diagram;

- thermodynamic modeling of the alloy melting and modification process using TERRA, HSC Chemistry and ThermoCalc software;

- mathematical planning of the experiment using the Malyshev-Protodyakonov method;

- physical modeling of the processes of melting cast iron, casting and in-mold modification of castings obtained by the LGM method;

- methods of metallographic analysis of samples (optical microscopy, scanning electron microscopy, MRSA);

- methods of quantitative and qualitative analysis of the microstructure of samples using Thixomet PRO software;

- determination of the hardness of metal samples using Vickers and Rockwell methods;

- methods for determining the mechanical properties of samples (when attrition according to the "ball-disc" scheme and during cyclic shock-dynamic action).

The main provisions of the work to be defended:

- a mathematical method for determining the phase composition of cast iron based on the mathematical description of the equilibrium lines of the Fe-Fe_3C diagram;

- results of thermodynamic modeling of the process of smelting and modification of LCCI by experimental modifiers;

- results of laboratory studies on in-mould modification of LCCI with boron- and barium-containing modifiers;

- results of experimental and industrial work on smelting and modification of LCCI with boron- and barium-containing modifiers;

- results of the study of the microstructure and wear-resistant properties of samples made of modified cast iron;

- technology of production of wear-resistant cast iron castings using modifiers, including a new method of introducing a modifier in the production of castings by the LGM method.

The work was carried out at the Department of «Nanotechnology and Metallurgy» of Karaganda Technical University named after Abylkas Saginov and in the laboratory «Boron» of the Chemical and Metallurgical Institute named after Zh. Abishev.

The reliability and validity of the scientific results presented in the dissertation are confirmed:

- positive results of industrial tests in the conditions of «Karaganda Machine-building Plant named after Parkhomenko» LLP;

- high correlation of the results of theoretical and experimental studies.

Research evaluation. According to the results of the conducted research, 9 works have been published in domestic and foreign publications, including:

- 3 articles in international scientific journals («Metallurgist» (Russia) – percentile 45, «Metalurgija» (Croatia) – percentile 37, «Metals» (Switzerland) – percentile 76);

- 3 articles in scientific publications recommended by the CCSON of the Ministry of Science and Higher Education of the Republic of Kazakhstan («Proceedings of the University» No. 3 (80) (Karaganda, Kazakhstan), «Bulletin of KazNITU», No. 6 (142) (Almaty, Kazakhstan), «Proceedings of the University» No. 2 (87) (Karaganda, Kazakhstan);

- 2 articles in other domestic publications (Materials of the international scientific and practical journal «Global Science and Innovation 2019: Central

Asia» and «Technology of Materials and Mechanical Engineering» Volume 4 (2020));

- a patent for a utility model «Method of production of wear-resistant chrome cast iron» was obtained.

The main research results were presented by the author in 5 reports at international scientific and practical conferences «Integration of science, education and production - the basis for the implementation of the National Plan» (Saginaw Readings No. 12-14).

According to the results of the industrial tests , certificates were obtained:

- test certificate of the production technology of modified grinding balls (in the conditions of «QazCarbon» LLP);

- the act of industrial tests for the production of grinding balls using the developed technology of intraform modification (in the conditions of LLP «KMZ named after Parkhomenko»);

- the act of industrial testing of grinding balls (in the conditions of LLP «KMZ named after Parkhomenko»).

Structure and volume of the dissertation. This dissertation work consists of the following parts - introduction, 6 main sections, conclusion, list of sources used and 7 appendices. The dissertation is presented on 119 pages of typewritten text, contains 64 figures, 27 tables and a list of references consisting of 114 titles.