ABSTRACT
Dissertation for the degree of Doctor of Philosophy PhD
specialty 6D070900 - "Metallurgy"
KURMANSEITOV MURAT BAUYRZHANULY
" DEVELOPMENT OF TECHNOLOGY FOR PRODUCING CAST IRON AND THERMOCHEMICAL TRANSFORMATION OF ITS SURFACE INTO STEEL"

Assessment of the current state of a scientific or scientific-technological problem being solved. The development of ferrous metallurgy is the most important condition for the production of means of production and technical equipment for all branches of the national economy. Today, pig iron production is 3.1 million tons / year. However, the use of cast iron as a structural material is limited, since, in solid form, it is a brittle metal. Its brittleness depends on the high concentration of carbon in the content. In the world, in order to change the physical and mechanical properties of cast iron, several methods are used.

One of the main methods is decarburization of the cast iron melt by oxygen purging. The inefficiency of this approach is obvious. First, when iron is purged with oxygen, not only dissolved carbon is oxidized, but also all the useful alloying metals contained in cast iron – manganese, chromium, vanadium, and they pass as oxides to the Converter slag dumped into the dump at most metallurgical plants. Secondly, molten steel contaminated with oxide compounds is crude and requires further extra-furnace processing with high material and energy costs. Taking into account the specified costs of the technological process, the search for ways to selectively reduce the carbon concentration in cast iron is promising.

One of the solutions to the above problem is to use the reduction smelting process of iron ore outside the blast furnace process and obtain products from cast iron with an alloyed surface by activating alloying additives contained in the resulting cast iron.

Basis and background data for developing the topic. First, the difference between cast iron and steel depends on the percentage of dissolved carbon. Their boundary is 2.0 % carbon. As the carbon content increases by more than 2.0 %, the melting point of the iron-carbon mixture decreases, and when the carbon content reaches more than 4.5 %, its melting point decreases from 1500 °C to 1159 °C. In addition, the mobility of cast iron in the liquid state is increased and the possibility of obtaining precise cast parts from it is improved. As the carbon content decreases by more than 2.0 %, the iron-carbon mixture turns into steel, its melting point increases and reaches up to 1550-1600 °C. Obtaining steel parts in the form of ingots is more difficult. Therefore, the production of various steel parts is obtained by mechanical rolling or process. In this regard, obtaining parts from cast iron in the form of ingots achieves significant accuracy and ease.

Justification of the need to conduct research work. All characteristics of the iron-carbon mixture, as shown above, depend on the percentage of carbon. This is due to the mobility of the main carbon in iron. The atomic radius of carbon is half that of iron. Therefore, carbon can get into the iron crystal lattice and move in

different directions. In addition, the electronic potential of carbon is twice as high as the electronic potential of iron. When the system is heated, it, like donor, spews its electrons into metal oxides added from outside, and joins the reactions of their oxidation. Such possibilities of carbon content in cast iron were not taken into account in previous scientific studies. Increasing the strength of cast iron parts is limited to lining their surfaces with special melts.

The mobility of carbon in the solid phase and its solidification in oxidation reactions make it possible to turn the surface of cast iron parts from cast iron into a steel layer. Conducting research in this area will ensure the achievement of a high level of technical and economic results.

Information on the planned scientific and technical level of development, on patent studies and conclusions from them. Increasing the surface strength of cast iron parts is achieved by using the effect of mobile dissolved carbon in its composition without melts of precious metals. The whole base is in the ratio of iron-carbon. To strengthen the surface of cast iron products, it is sufficient to reduce the carbon concentration in it from 4.5 % to 0.5-1.0 %. A decrease in the carbon content of more than 1.0 % in the iron-carbon mixture indicates its conversion to steel. So the main question is how to reduce it. In connection with new theoretical data, it is shown that the activity of participation of carbon dissolved in the metal in oxidation reactions is significantly higher than that of free carbon. To start and conduct such a solid-phase reaction, it is enough to apply a powder of iron oxides or other metals to the surface of the cast-iron product and warm up the system to 1000-1100 °C. In this case, the metal oxide dissociates and begins to release oxygen, and the dissolved carbon begins to emit electrons in its atomic composition. While carbon produces electrons as a donor and has a +4 charge, oxygen consists of two atoms with a -2 charge, taking four electrons as an acceptor. This is how the law of attraction begins between the positive charge of carbon and the negative charge of oxygen. Mobile carbon leaves the iron crystal lattice and combines with oxygen, turning into a diatomic and triatomic gas CO, CO_2. Depending on the course of this reaction, the surface of cast iron is decarburized, that is, it turns into steel. In this direction, patent research has been conducted and it has been established that increasing the strength of the surface of cast-iron parts is carried out only by coating it with solid melts and powders of precious metals, the possibility of increasing its strength in the composition of cast-iron parts is not provided in previous works. As a result of patent research on the plan under consideration, recommendations were made for obtaining a new patent and a decision on its reliability was received from the Kazakhstan patent office.

It was shown that the novelty of scientific and technical work set in the plan, its level is much higher than in other well-known works.

Metrological support. Experimental studies are provided with standard equipment: a 75 T – DR vibration crusher and Shimadzu ELB 1200 electronic scales for measuring the mass of components and a RHTC 80 – 230/15 Controller B410 tube furnace with heating of the system.

The chemical composition, microstructure, and mechanical properties of cast iron and steel were studied in the next modern period using widely used equipment:

the JXA - 8230 electron microscope (JEOL) and the X-ray powder diffraction microscope (XRD, Rigaku TTRAXIII), the Neophot 32 optical microscope, and the pam 30-g x-ray analytical microprobe.

Relevance. The most widespread in practice is the production of direct parts and finished products from cast iron by casting a special model. The most common technology is its implementation in order to increase the surface strength of the resulting cast iron products and parts by coating it with precious metal melts. To improve the strength, the use of special features of physical and chemical processes occurring in the inner layer of cast iron has not yet begun. The study and implementation of such technology is an urgent problem. The research works included in the project are designed to find solutions to these problems.

The novelty of the topic is the development of technology for obtaining cast iron metal products and thermochemical transformation of its surface into steel. The smelting of cast iron and the production of cast metal products from it are affordable and low-cost, compared to the production of steel and steel structures. The results of the experimental studies obtained in this work can be used in the organization of metal products and structures using cast iron and open up the prospect of developing small and medium-sized businesses.

Scientific novelty of research:

– this paper presents interesting results of thermodynamic calculations of reactions of dissolved carbon in cast iron with various dispersed powders of metal oxides-MoO_3, WO_3, and V_2O_5. the mechanism of interaction of components in a heterogeneous carbon – metal oxide system is described in sufficient detail;

– new kinetic regularities of solid-phase reactions between carbon dissolved in cast iron and dispersed metal oxides are established;

– the results obtained prove the fundamental possibility of obtaining high-quality structural products from cast iron products using solid-phase reactions between dissolved carbon and a layer of dispersed metal oxides on the surface of finished metal products;

– kinetic parameters of solid-phase reactions between dissolved carbon in a metal and a dispersed oxide layer opens up new technologies for obtaining metal products with their subsequent transformation into a composite product by thermochemical treatment of their surfaces.

Connection of work with other research works. The dissertation work performed in the framework of the state grants of the Fund of science of RK on the project: «Development of scientific foundations for the continuous process of reducing melting of concentrates and secondary materials to produce structural steel» ((No. 700.F06/2, 2006-2008), funded by the Ministry of education and science of the Republic of Kazakhstan under the program «Development of scientific foundations and technologies for creating new promising materials for various functional purposes» under the priority «Grant funding for scientific research».

The purpose is to study the features and mechanism of solid-phase reduction of dissolved carbon in cast iron and dispersed metal oxide powders and to develop a technology to obtain a structural good, that is, aimed at a continuous casting method.

The object is the microstructure of the iron-carbon system based on cast iron products and plates.

The subject is the production of cast iron plates, their surface treatment, metal oxide powders and a sealed laboratory cell, in which the surface of cast iron plates is warmed by a layer of metal oxide powder and solid-phase metal reduction with carbon dissolved in cast iron is organized on the contact surface, thereby decarburizing and converting the surface layer into steel with a carbon content of less than 1.0 %.

Objectives of the research, their place in scientific-research work consists of the following steps:

– analysis of modern state of the problem relating to the theme of the thesis namely the technology of mass production of cast iron and out of the blast furnace ironmaking on small businesses;

– development of methods of theoretical and experimental research;

– preparation of laboratory heating furnaces and control and measuring equipment for operation;

– preparation of iron ore oxide materials and reducing reagents in the form of solid carbon;

– preparation and preparation of the ore-coal mixture in the specified mass ratios for smelting iron ingots from it;

– carrying out experimental work on metallization and melting of ore-bearing pellet, obtaining samples of cast iron plates;

– surface treatment of cast iron plates for an organization of its thermochemical processing;

– organization of thermochemical surface treatment of cast iron plates;

– determination of the regularity of changes in the microstructure of the surface layer of cast iron plates depending on the heating temperature and holding time;

– investigation of the mechanism of metal recovery from the cover metal oxide layer with dissolved cast iron carbon;

– analysis of changes in the concentration of dissolved carbon in the thickness of the treated surface of cast iron plates;

– analysis of the microstructure of the original cast iron plates and their decarburized surface layer and assessment of the quality of the transformed surface layer;

– conversion of cast iron plates into a bimetallic plate product of increased strength;

– generalization of research results on the possibility of decarburization of cast iron and cast iron metal products in the solid state and publication of scientific papers;

All these tasks have found their solutions and places in the research work performed.

The methodological basis of the study is based on the non-straw production of cast iron, cast iron plate metal products and the use of carbon dissolved in cast iron for the thermochemical transformation of their microstructure by applying metal oxide powders to the surface and heating the system within 1000-1100 °C, in which the metal is directly reduced from the metal oxide powder layer by dissolved carbon. The methodology further includes the determination of the microstructure of the decarburized surface layer of plates and its thickness using modern standard measuring devices.

The provisions submitted for protection consist of the following research results:

– organization of non-straw production of pig iron without the use of coke on the basis of obtaining dispersed ore-coal mixtures with adjustable mass ratios and preparation of ore-coal pellets from them for reduction smelting of pig iron;

– casting of cast iron and obtaining samples of cast iron metal products on the example of metal plates;

– decarburization of the surface layers of cast iron plates by coating them with metal oxide powder and organizing direct reduction of metal from powders with dissolved carbon;

– thermochemical transformation of the surface layers of cast iron plates and production of bimetallic plates consisting of a steel (outer) layer and a cast iron (inner) layer;

– increasing the strength and viscosity properties of cast iron metal products on the example of cast iron plates due to solid-phase decarburization of their surface layers;

– mechanism of solid-phase decarburization of the surface layer of cast iron plates;

– assessment of technical, economic and environmental indicators of solid-phase decarburization of surface layers of cast iron metal products and strengthening of their strength and other quality indicators.

Practical significance of the dissertation. The practice of the existing technology for converting cast iron into steel is based solely on decarburizing the metal in the molten state. Hardening of cast-iron metal products is based on melting their working surfaces with expensive strong alloys. The developed technology for thermochemical transformation of the working surfaces of cast iron metal products eliminates the need for energy costs for melting and expensive strengthening ferroalloys, which leads to a multiple reduction in economic production costs. Solid-phase decarburization of finished cast iron metal products can be implemented in practice easily and without significant costs. For example, cast iron pipes are widely used in practice, but they are brittle and breakable. Decarburization of their outer surface according to the proposed technology leads to the formation of a steel outer layer, thereby eliminating the brittleness and fragility of pipes, and the inner surface of pipes remains in a cast-iron state and provides their anti-corrosion property, i.e. in practice, a double strength effect is achieved.

Approbation of the work. Based on the results of the dissertation, 9 publications were published, including:

– one article in journals included in the Scopus database (Steel in Translation (United Kingdom));

– four articles in the editions recommended by Committee for control in education sphere and science MES RK;

The main provisions and results of the work were presented at international conferences:

– VII Eurasian scientific and practical conference «Strength of heterogeneous structures of the earth». MISiS, 2016, pp. 75-76.;

– Satpayev readings on the topic: «scientific heritage of Shakhmardan yesenov» April 12, 2017, P. 379-382, Almaty, Kazakhstan;

– International scientific and practical conference «Integration of science, education and production-the basis for the implementation of the national Plan» (Saginovsky readings No. 10), Karaganda, June 14-15, 2018;

– International Conference on Research Challenges to multidisciplinary innovation: Conference Proceedings, October 30th, 2018, USA, Morrisville: SPO «Professional science», Lulu Inc., 2018, 99 p.

Structure and scope of the dissertation. The dissertation consists of an introduction, 7 chapters, conclusion and appendices. The work is presented on 110 pages of typewritten text, contains 21 tables and 35 figures. The list of sources used includes 95 names.