MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

K.I. Satbayev Kazakh National Research Technical University

Mining and Metallurgical Institute named after O.A. Baikonurov

Department of Metallurgy and Mineral Processing

Dariya Mukhamedkhan

Investigation of the processes of obtaining granular cast iron

GRADUATE WORK

Specialization 5B070900 – Metallurgy

Almaty 2022

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GRADUATE WORK

on the topic: Investigation of the processes of obtaining granular cast iron

specialty 5B070900 – Metallurgy

done by D. Mukhamedkhan

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«11» 01 2022 y.

ASSIGNMENT
for the completion of the graduation work

To the student Dariya Muhamedkhan
Topic: The study of the processes of obtaining granular cast iron
Approved by the order of the Rector of the University No. 489-b until December «24», 2021 y.
Deadline for the completion of the completed work: «23» may 2022 y.
Initial data for the graduation work: Data from the SSMPA field
The list of issues to be developed in the thesis:
a) introductory part
b) the main part
c) the technological part
The list of graphic material (with the exact indication of the required drawings):
14 slides of the presentation of the work are presented
Recommended main literature: from 7 titles

THE SCHEDULE
of preparation of the thesis

Name of sections, list of issues being developed	Deadlines for submission to the scientific supervisor	Note
Introductory part	1.02.2022-30.03.2022	Khoishina
The main part	1.04.2022-30.04.2022	Khoishina
The technological part	1.05.2022-25.05.2022	Khoishina

Signatures
of consultants and the norm controller for the completed diploma project with an indication of the relevant sections of the project

Section names	**Consultants, Full name (academic degree, title)**	**Signature date**	**Signature**
The technological part of the work	G.M. Koishina Doctor of PhD, Assistant Professor	30.05.2022	Khoishina
Normal inspection	S.K. Jumankulova Doctor of PhD	30.05.2022	К. Джуманкулова

Scientific supervisor Khoishina G.M. Koishina

The task was accepted for execution by the student D. Mukhamedkhan

Date «01» 02 2022 y.

АННОТАЦИЯ

Работа включает: 27 страниц, 7 таблиц, 10 рисунков, использованных источников - 7.

Предмет исследования: концентрат ССГПО и концентрат из Абаилского железорудного месторождения.

Цель работы: Исследование получения гранулированного чугуна оптимального состава со стехиометрическим количеством углерода.

По результатам экспериментальных данных и расчётов выявлено, что содержание серы в концентрате, полученном после процесса обжига при 800°С, уменьшилось до 0,015 %. Получившиеся окатыши далее отправили на восстановительную плавку при 1300-1400 для получения жидкого чугуна. При прохождении жидкого чугуна через специальную трубу получаются чугунные гранулы размером 2-3мм.

ANNOTATION

The work includes: 27 pages, 7 tables, 10 figures, 7 sources used.

Subject of research: SSMPA concentrate and concentrate from the Sabail iron ore deposit.

The purpose of the work: To study the production of granular cast iron of optimal composition with a stoichiometric amount of carbon. According to the results of experimental data and calculations, it was revealed that the sulfur content in the concentrate obtained after the firing process at 800 ° C decreased to 0.015%. The resulting pellets were then sent for reduction melting at 1300-1400 to produce liquid cast iron. When liquid cast iron passes through a special pipe, cast iron pellets of 2-3mm in size are obtained.

АҢДАТПА

Жұмысқа мыналар кіреді: 27 бет, 7 кесте, 10 сурет, пайдаланылған көздер - 7.

Зерттеу пәні: ССТБӨБ концентраты және Сабаил темір кені кен орнынан алынған концентрат.

Жұмыстың мақсаты: көміртектің стехиометриялық мөлшері бар оңтайлы құрамдағы түйіршікті шойын алуды зерттеу.

Эксперименттік деректер мен есептеулердің нәтижелері бойынша 800°С кезінде күйдіру процесінен кейін алынған концентраттағы күкірт құрамы 0,015% - ға дейін төмендегені анықталды. Алынған түйіршіктер сұйық шойын алу үшін 1300-1400 кезінде қалпына келтіру қорытпасына жіберілді. Сұйық шойынның арнайы құбыр арқылы өтуі кезінде өлшемі 2-3 мм шойын түйіршіктері алынады.

CONTENT

INTRODUCTION

The ferrous metallurgy of Kazakhstan, including the production of cast iron, occupies a special place among other industries. The largest producers of cast iron in the republic are JSC "Arcelor Mittal Temirtau" and JSC "Sokolovsko-Sarbayskoye Mining and Processing Production Association". Main activity: extraction and processing of iron ore, limestone, dolomite; production and sale of iron ore pellets, iron ore concentrate, crushed stone, lime; organization of complex use of mineral raw materials, including the use of stale raw materials, and other activities. In recent years, the association has mined more than 42 million tons of crude ore, more than 17 million tons of iron ore concentrate and produces 9.0 million tons of iron ore pellets. All products of the mill are exported to many CIS countries and Central Asia. [1-2] The share of Kazakhstan's iron-containing products in the world market is very significant. With the trend of industrial development, the demand for cast iron and steel products will only grow. Joint Stock Company "ArcelorMittal Temirtau" is the largest enterprise of the mining and metallurgical sector of the Republic of Kazakhstan and is an integrated mining and metallurgical complex with its own coal, iron ore and energy base. ArcelorMittal Temirtau JSC consists of:

- steel department;
- coal department;
- iron ore department.

The blast furnace shop smelts the front and foundry cast iron for the converter and shaped foundry shops. The blast furnace shop consists of four furnaces DP1 - 1719m3, DP2 – 2291m3, DP3 – 3200m3, DP4 - 3200m3. DP-2 is a new generation unit in terms of technical equipment, reliability and environmental impact. The reconstruction of the blast furnace was one of the largest and most expensive investment projects of ArcelorMittal Temirtau. The design capacity of the furnace is 1.3 million tons of cast iron per year. Modern blast furnace melting technologies are used to produce cast iron. The steelmaking production includes an oxygen converter shop and 3 lines of CCMB (continuous casting machine of blanks). The continuous casting machine of blanks - MNLZ-3 is designed for the production of long blanks with dimensions of 130 by 130 and 150 by 150 millimeters on the territory of the operating converter shop. The productivity of the machine is designed for 1.2 million tons of blanks per year, which will meet the needs of the rolling mill. The MNLZ-3 was fully adapted to the existing workshop. The converter shop has three oxygen converters with a capacity of 300 tons and two mixers of 2000 tons, two ladle furnace installations, 2 radial continuous casting machines, each with a capacity of 2.6 million tons of slabs per year. In the production of converter steel from phosphorous cast iron, a complex of modern methods of metal smelting is used**.** [1]

1 The current state of iron and steel production and prospects for the development of the industry

1.1 World production and consumption of cast iron and steel

Metallurgy of cast iron and steel is a whole complex of technological processes for the preparation and processing of metal–containing raw materials and the smelting of structural metals from them. Metal-containing raw materials are located in the earth's crust. Therefore, iron and steel metallurgy is primarily interested in the development and extraction of iron ore raw materials from the earth's crust. Currently, the composition of the winter crust has been determined by the content of elements and mineral formations. The Earth's crust, as it is known, contains all the elements of the periodic table of about 104 elements. However, it has already been established that only four elements in total make up 90% of the mass of the entire earth's crust. Of these, oxygen is the most common, accounting for 47.2%, silicon takes the second place with a share of 27.6%, aluminum and iron take the third and fourth places. Accordingly, with their total share of 13.9% of the earth's crust mass. Chemical contents are formed from the elements listed above in accordance with the law of acting masses. Therefore, the primary chemical compound is between oxygen and silicon with the formation of silica SiO2. 31.568% of oxygen was consumed for the formation of this chemical compound. The residual amount of oxygen 15.632% is spent on the oxidation of the remaining elements, of which aluminum is the main part, and a sufficient amount of oxygen 15.632% is spent on the oxidation of the remaining elements, of which aluminum and iron are the main part. As can be seen, all three leading elements silicon, aluminum, iron, forming chemical compounds with oxygen, are converted into oxide materials with a total mass in the earth's crust of about 90%. In addition to iron and aluminum, some metals from the iron group are also converted into oxides – these are manganese, chromium, vanadium and titanium. This will basically exhaust the oxide compounds with oxygen. In addition to oxygen, sulfur and fluorine also have an oxidizing potential, which occupy an insignificant share in the earth's crust. They also oxidize a small proportion of elements in the form of copper, lead, zinc, etc., forming sulfides and fluorides of the corresponding elements. [4-3]

Of the three leading elements listed above, aluminum and iron belong to the metallurgical ones, which, by their physico–chemical and mechanical properties, represent the basis of structural materials. Therefore, their extraction and use for the production of structural materials are of practical importance in the national economy.

The extraction of silicon from the most common raw materials is also of practical interest for the production of special silicon-containing alloys and single crystals used in engineering and in the production of solar panels. Since all these elements, which occupy the bulk of the earth's crust, are represented in oxide compounds, their extraction is associated with solving the general problem of organizing restoration processes. At the same time, it is necessary to take into account the fact that silicon, aluminum and iron oxides have different levels of strength of their chemical compounds, which will require, firstly, the choice of an appropriate reducing reagent, and different levels of thermal energy costs for their recovery. Choosing a reducing reagent should have a higher affinity for oxygen oxide than the element being reduced from the corresponding oxide. The higher the chemical bond strength of oxide compounds, the higher the temperature at which their recovery begins. As can be seen, the heating of the oxide system and the regulation of its temperature in the flow of reducing reagents and thereby the organization of reduction processes for the extraction of metals represent the general basis of metallurgy of iron and iron-like metals. Depending on the processed metal-containing cheese and the products produced, large metallurgy is carried out in the areas of production of ferroalloys, aluminum, as well as iron and steel. Of these three areas, iron metallurgy occupies a special position. Since iron forms the basis of structural materials – steels of various grades, on which mechanical engineering, instrumentation and the entire industry as a whole are based. The initial raw material resource for the production of cast iron and steel is iron ore raw materials. Therefore, the characterization and preparation of iron ore raw materials is of great practical importance. [1-7]

1.2 Brief analysis of cast iron and steel production technology in Kazakhstan

The development of ferrous metallurgy is the most important condition for the production of materials, equipment and technical equipment for all sectors of the national economy. The increase in metal output implies the development of the raw material base due to the expansion of existing capacities and the development of new iron ore mining enterprises. The open mining method, the share of which is already about 90% in iron ore production, will remain dominant in the future. Technical re-equipment of quarries with new drilling equipment, powerful excavators, dump trucks and electric locomotives with a large coupling weight will continue. [5]

1.2.1 Blast furnace production of cast iron and steel production at «Arcelor Mittal»

To date, iron ore reserves in Kazakhstan are estimated at l6.6 billion tons, which is about 8% of all world reserves, of which about 8800 million tons have been explored and prepared for operation. About 90% of iron ore is concentrated in the Torgai region of Northern Kazakhstan, the rest is located in Central Kazakhstan [2].

Several iron ore deposits with approved reserves of over 6 billion tons are exploited in the republic:

Sokolovsko–Sarbayskoye (including Kachary) with approved reserves of more than 2500 million tons; iron content — 38-43%; harmful admixture — sulfur;

Lisakovskoye (LMPP), approved reserves — more than 3000 million tons; iron content – 3438%; harmful admixture – phosphorus;

Atasuyskoye (Kentobinskoye, Karazhalskoye), approved reserves — more than 800 million tons; iron content – 48-70%; harmful admixture — sulfur;

Atansorskoye, approved reserves — more than 39 million tons; iron content — 37-57%; no harmful impurities.

Currently, Arcelor Mittal Temirtau JSC uses a charge from unfavorable iron ore raw materials characterized by a complex composition for smelting pig iron:

– pellets and SSMPA concentrates with high sulfur content and low mechanical strength;

– lisakov concentrates with high (up to 0.8%) phosphorus content and low iron content;

– Atasui non-enriched ferromanganese ores having a low iron content (less than 48.0%), an increased content of manganese and sulfur;

– Kentobin unenforced magnetite ores with a high (up to 3.5%) sulfur content.

Unenforced ores are currently being mined by selective extraction, which may soon remove the Atasu, Atansor, Kentobe, Balbrown deposits from the active balance.

Uncompetitive iron ore concentrate of the Lisakovsky deposit (iron content – 49.2%, phosphorus — 0.7%, alumina ~ 5%) is supplied to JSC "Arcelor Mittal Temirtau" in a limited volume so far (about l,5 million tons per year). [6]

However, due to the orientation of the EPA to the Chinese and Russian markets with a sharp rise in the cost of concentrate and pellets supplied from this plant, Arcelor Mittal Temirtau JSC is forced to completely switch to the use of Lisakovsky ores. Ores from other deposits of the republic are supplied to JSC "Arcelor Mittal Temirtau" in raw form, without enrichment (only crushing is used), since there are no processing plants at the corresponding enterprises (private). The main problems of the iron ore complex of Kazakhstan are as follows:

– depletion of the prepared reserves of the main mines;

– high degree of wear of technological equipment, building structures, industrial buildings and structures;

– lack of effective iron ore processing technology that allows complex processing of raw materials;

– imperfection of the technology of enrichment of raw materials and its high energy intensity;

– insufficient investments for the development of existing and preparation of new fields and technical re-equipment.

Orken LLP is a structural (subsidiary) division of Mittal Steel Temirtau JSC, which includes Lisakovsky MPP, the Kentobe mine, and Atasuysky MPP. The prospects for the development of Orken LLP are shown in the table 1.

Table 1 – Prospects of development of Orken LLP

Company	Goal	Impact
Lisakovsky MPP	MMC dephosphorization Stage 1 MMC Dephosphorization Stage 2	An increase in Fe from 49 to 60 % A decrease in P from 0.70 to 0.20 %
	Reconstruction of GMOs with an increase in production to 4 million tons per year	Production of phosphorus-free concentrate from 0.7 million tons in 2005 to 3.0 million tons in 2007.
The Kentobe Mine	Construction of an enrichment plant with a concentrate production capacity of 1.55 million tons per year	Preservation of the iron content at the level of 55-56%. Reducing the cost of transportation
Atasuysky MPP	Commissioning of the processing factory, ore enrichment from the lower horizons	Maintaining the quality of ore in the production of 2.1 million tons per year
	Involvement in the production of off-balance sheet ores	Reducing the cost of concentrate

For the successful operation of the Orken LLP combine, it is planned to build a processing complex, including pyro– and hydrometallurgical processing of ore to produce several types of concentrate:

– for blast furnace production, with an iron content of at least 62%, not more than 0.3% phosphorus and 3% alumina;

– for steelmaking, with an iron content of more than 70% and no more than 0.15% phosphorus.

The development of the Lisakovsky deposit is carried out in an open way on small horizons, without the use of drilling and blasting operations, which ensures the lowest cost of ore.

For the development of new and further development of existing deposits of brown iron ore in Kazakhstan, it is necessary to create new, unconventional metallurgical processes that ensure the integrated use of ores with the extraction of alumina and other valuable elements.

JSC "Sokolovsko–Sarbayskoye Mining and Processing Production Association" (SSMPA). The association includes Sarbaysky, Sokolovsky, Kacharsky, Kunzhulsky and Sokolovsky operating quarries, an underground mine.

Specialization: production of iron ore concentrate, fluxed pellets, extraction of crude crushed ore, dolomite, limestone and crushed stone.

The products of JSC "SSMPA" are characterized by high quality, with an iron content of more than 66% in concentrate and over 62% in pellets.

The main consumers of the plant's products are Magnitogorsk Iron and Steel Works JSC (up to 70%) and Arcelor Mittal Temirtau JSC (30%).

With the reorientation of Russian metallurgical plants to domestic raw materials, the sale of SSMPA concentrates becomes problematic due to the difference in tariffs for

Russian and Kazakh products in Russia: for Russian plants, the railway tariff is 4.84 US dollars per 1 ton, and for Kazakh plants – 6.5 dollars, which leads to the uncompetitiveness of domestic products.

In the world market of iron ore raw materials, high requirements are imposed on the quality of iron-containing products, in particular, products containing 65-70% iron with a minimum amount of harmful impurities (silicon dioxide, sulfur and phosphorus) are recognized as competitive. Thus, at foreign processing plants, concentrates with a grain size of 0-0.044 mm, with a content of 64.00–70.50% iron, are produced from poor ores with 25-44% iron when they are enriched. Improving the quality of iron ore raw materials provides cost savings in metallurgical processing, significantly exceeding the additional costs of its enrichment.

The Abail iron ore deposit is mainly represented by hydrogetite and goethite rocks with a small admixture of siderites. The content of the useful metal – iron in the form of oxides by the mass of the deposit varies within fairly large limits, but on average amounts to 49% Fe. To use this ore for metallurgical purposes, of course, first of all, it is necessary to prepare it, enrich it and obtain an iron ore concentrate with a higher iron content.

The initial ore of the Abai deposit cannot be immediately enriched by magnetic separation, which is usually accepted for iron ores, since the goethite ore does not have magnetic properties. For the production of concentrate, the ore, after appropriate preparation, must be subjected to magnetizing firing. Since the initial ore is dense and coarse-grained with a high content of hydrate moisture, it must be successively crushed, sorted and crushed. The task of firing the prepared ore is to remove hydrate moisture, volatile and the transformation of iron oxides into magnetic states. The experience of magnetizing iron ore roasting is available at the metallurgical plants of the Urals (Russia), where siderite ores of the Bakal iron ore deposit are fired.

Magnetizing roasting of ore is carried out in mine furnaces at a temperature of 900-1000 ° C. At the same time, natural gas or coke is used as fuel. Of no small importance is how to burn fuel. For magnetizing firing, not only a heat supply to the charge is needed, but also a certain atmosphere, i.e. the composition of the gas. Heat is spent on the decomposition of hydrates and carbonates, the transfer of decomposition products into the gas phase. In addition, the composition of the gas forming during combustion must correspond to the regenerative atmosphere. The gaseous atmosphere is determined by the ratio of the components CO_2-CO and H_2O–H_2. With the complete combustion of any fuel (coal, natural gas and fuel oil), the gaseous product consists only of CO_2 and H_2O gases, a large amount of thermal energy is released. If complete burn is carried out without excess air, then the amount of heat released is spent on heating the gas – the product of combustion and its temperature will reach more than 2000 ^{0}C. However, such overheating is not necessary for firing. Only high temperature does not ensure the conversion of non-magnetic oxides into magnetic ones. This requires a certain amount of reducing gases CO and H_2. Only these gases can interact with hematite. By taking away one oxygen atom from three hematite molecules, they convert hematite into magnetite. To implement these reactions, the ratio of the sum ($CO + H_2$) / ($CO_2 + H_2O$) must be at least 30% or 0.3. At the same time, it is necessary to regulate the temperature in the charge layer at the level of 900-950^{0}C. The establishment of such a process regime requires certain organizational and preparatory work. [4-7]

1.2.2 Characteristics of the products obtained

After melting, cast iron with a carbon content of 2.14–4.3% is obtained.

According to the content of additional components, cast iron is divided into unalloyed, low-alloyed, medium- and high-alloyed. Cast iron containing up to 3.5–4% Si, up to 1.5–2% Mn, up to 0.3% P, up to 0.2–0.25% S and up to 0.1% of elements such as Cr, Ni, Co is considered unalloyed. In low–alloyed cast iron, the content of each of the listed alloying elements usually does not exceed 1.0-1.5%, in medium-alloyed it can reach 7%, and in high-alloyed it exceeds 7-10%. Additives of hundredths and even thousandths of a percent of elements such as magnesium, nitrogen, boron, bismuth are considered alloying (micro-alloying, modification).

Gray cast iron in the fracture is dark gray, soft, well processed with tools and therefore widely used in mechanical engineering. The melting point of gray cast iron is 1100-1250 °C. The more carbon there is in cast iron, the lower the melting point. The main amount of carbon in gray cast iron is contained in the form of graphite, evenly distributed among the grains of the main alloy.

Gray cast iron, compared with white, contains more silicon and less manganese, since silicon contributes to the graphitization of carbon in cast iron, and manganese, on the contrary, causes the formation of bound carbon – cementite.

Approximate composition of gray cast iron: 3-3.6% carbon; 1.6–2.5% silicon; 0.5–1% manganese; 0.05–0.12% sulfur; 0.1–0.8% phosphorus. Sulfur is a harmful impurity in cast iron, makes it difficult to weld and reduces strength; it increases the viscosity of cast iron in the molten state and increases its casting shrinkage.

Phosphorus makes cast iron more liquid-fusible and improves its weldability, but at the same time increases brittleness and hardness. Therefore, the content of sulfur and phosphorus in cast iron should not exceed the specified limits.

Ductile iron occupies an intermediate position between cast iron and steel in terms of mechanical properties, differs from gray cast iron in greater viscosity and less brittleness. To obtain parts from ductile iron, they are cast from white cast iron, and then subjected to heat treatment, for example, prolonged annealing or "languishing" in sand at 800-850 ° C. At the same time, free carbon is released in the form of small rounded particles located in the form of isolated clusters (flakes) between iron crystals. At temperatures above 900-950 ° C, carbon passes into cementite and the part loses the properties of ductile iron. Therefore, after welding, the parts have to be subjected to a full heat treatment cycle again to obtain a ductile iron structure in the seam and near-seam zone.

Alloyed cast iron has special properties – acid resistance, high strength under shock loads, etc. Cast iron obtains these properties as a result of alloying with chromium, nickel.

Modified cast iron is obtained from gray cast iron by introducing special additives into liquid cast iron, called modifiers – silicocalcium, ferrosilicon, silicoaluminium, etc. The number of introduced modifiers does not exceed 0.1 – 0.5%, while the temperature of liquid cast iron should not be lower than 1400 ° C.

When modified, the composition of cast iron almost does not change, but graphite grains take a small-plate, slightly swirled appearance, and are located isolated from each other. From this, the structure of cast iron becomes homogeneous, dense, its strength, wear and corrosion resistance increase.

Obtaining a particular structure of cast iron in castings depends on many factors: the chemical composition of cast iron, the type of charge materials, the technology of melting and out-of-furnace metal processing, the rate of crystallization and cooling of the melt in the mold, and therefore the thickness of the casting wall, the thermophysical properties of the mold material, etc. The structure of the metal base of cast iron can also be changed by heat treatment of castings, the general patterns of influence of which are similar to those arising from the heat treatment of carbon steel, and the features are associated with concomitant changes in the metal base by graphitization processes.

Among the elements of the chemical composition C and Si determine the formation of the structure of cast iron, and with a given casting technology, the reduced size of the casting wall R_{np} characterizes its cooling rate – the ratio of the cross-sectional area of the wall to the perimeter.

Along with Si, Al is of great importance as a graphitizing element, which sometimes partially or completely replaces Si. This improves the properties of cast iron, especially ductility. The most favorable combination of strength, viscosity and ductility characteristics is achieved in aluminum cast irons with a Si content of < 1.0%.

According to the effect of small additives of other elements on the structure of cast iron and, consequently, the properties of the additive can be divided into three groups.

The first group of elements (Ni, Co, etc.) similarly Si has a graphitizing effect, contributes to the crushing of graphite secretions. At the same time, these elements stimulate the production of more dispersed pearlitic needle and martensitic structures even with relatively slow cooling.

The second group of elements (Cr, Mo, W, V, etc.), in contrast to the first, prevents graphitization with an intensity proportional to the concentration. At a content exceeding the limit of their solubility in cementite or ferrite, they form special carbides.

The third group of elements can include Ti, Zr, Ce, Ca, Mg, B, etc. These elements are characterized by high chemical activity, they are almost entirely spent on the formation of refractory carbides, sulfides, oxides, nitrides, which can serve as embryos in the process of subsequent crystallization and increase the dispersion of the metal base.

Moreover, the elements of this group Mg, Ca, Ce and other rare earth metals (REM) are part of the ligatures for modifying cast iron in order to obtain graphite of a vermicular or spherical shape.

1.3 Features of carburization and decarburization of iron in metallurgy

Iron and carbon, as the most common elements on our planet, represent the main material resources of metallurgy. One of the priority areas of human activity for the production of cast iron and steel is based on the extraction and use of iron ore and coal. The technology of the process has reached such a level of development today that 80% of the world's production of cast iron and steel is provided under the name "Coke metallurgy".

As you know, coke metallurgy is based on the complex "Blast furnace - oxygen converter", which implements a two-stage technology.

The sustainable development of iron and steel metallurgy based on this two-stage technology worldwide and its prospects are primarily based on the efficiency of the blast furnace process.

Tinned iron ore raw materials and sorted metallurgical coke are an integral part of the charge and its main components. A very complex heat and mass transfer process in the working space of such a high unit begins with the injection of hot combined blast (HCB) through the lances along the circumference of the furnace (lower part), where incomplete combustion of coke and fuel additives occurs, the formation of an appropriate amount of hot reducing gas (HRG) with a temperature of 2000-2200 ° C. HCG, consisting of CO, H_2, N_2 with such a temperature, is a coolant and reducing agent, provides heating of the charge column, reduction of iron, melting of the metallized charge, formation of metal and slag melts and exits through the blast furnace grate with an average temperature of 200 ° C. As can be seen, the peculiarity of the blast furnace process is the high degree of use of thermal energy, reaching up to 90%. In addition, the released blast furnace gas (after cleaning) is used as a fuel for heating the blast and blowing the HCB from the bottom of the furnace. In this closed cycle, all input and output parameters of processes are fixed, controlled, and used in process control. An important role is played by coke, which is not only a generator of thermal energy and reducing gases, but also a "coke nozzle" in the high-temperature zone of the furnace and provides a counterflow of molten charge and HRG. It is in this packing that, when filtering the molten slag and metal, the processes of additional reduction of metals and, at the same time, their carburization with solid carbon of coke take place. The formation of the composition of metal melts and slag is almost completed. Therefore, blast-furnace slag, after filtering through the coke layer, is the purest in terms of the content of non-reduced metals (within no more than 1.0%) compared with slags from other metallurgical processes. The inevitable carburization of iron in such a high-performance and highly efficient unit as a blast furnace ends with the release of an iron-carbon alloy melt - cast iron with a carbon content of 4.2-4.5%. Further, the cast iron melt passes to the second stage of the technology – oxidative remelting in oxygen converters in order to decarbonize it and produce steel. As can be seen, in traditional technology, carburization and decarburization of an iron-carbon alloy in a molten state are criteria for the formation of such important and necessary industrial products as cast iron and steel. They have their own characteristics not only in the molten, but also in the solid state. Due to viscoplasticity, deformability and the acquisition of strength with appropriate processing, steel has become widely used in mechanical engineering. Cast iron has high hardness, but also brittleness, which limits its use in the production of structural metal products. At the same time, it has certain advantages – fusibility and fluidity, thanks to which the production of cast metal products and machine parts from cast iron is expanding. In addition, the mechanical characteristics of cast iron are largely determined by structural transformations of the carbon contained in its composition. To realize these possibilities and increase the structural parameters of cast iron, the technology of producing high-strength cast iron has now been developed by converting the structure of graphite (carbon) from a lamellar to a spherical state by introducing special modifying reagents. High-strength cast iron with spherical graphite has even higher yield strength and tensile strength, a sufficiently high modulus of elasticity compared to steel. The high fluidity of the cast iron melt and high strength in the solid state opens up the prospect of expanding the range of metal products from it. Technologies for producing ductile iron with good ductility and malleability have also been developed and are being developed, which are achieved due to the movement and transformation of the graphite structure in cast iron under the influence of the heating mode of the system and modifying reagents. At the same time, there is a decrease in the size of graphite structures, between which iron acquires a pearlitic structure with viscosity and plasticity. The formation of ductile iron is also facilitated by the partial removal of dissolved carbon through the outer surface of the cast iron to react with oxide components, which accelerates the formation of small graphite structures.

Such transformations of the structure of an iron-carbon alloy and its transformation into structural materials that meet the requirements of the engineering industry are primarily associated with the movement and transformations of carbon, which has a high mobility of its atoms. The radius of a carbon atom equal to 0.077 °A (angstrom) is almost a multiple of the atomic radius of iron – 0.127 °A. Therefore, it easily penetrates into the crystal lattice of iron through its interatomic distance. Penetrating into the structure of α – Fe, it forms a solution representing the ferritic phase, and dissolving in γ – Fe forms an austenitic phase. In addition, a chemical compound with iron, cementite Fe3C, is formed, in which the carbon concentration reaches up to 6.67%.

The concentration of carbon in ferrite, depending on the temperature, is set in the range of 0.025-0.10%. In austenite, as in a solid solution of carbon introduced into γ – Fe, the carbon concentration reaches 2.14% at 1147 ° C and 0.8 at 727 ° C. When the cast iron melt released from the blast furnace is cooled, solid-phase structures are formed, consisting mainly of a solution of cementite in the austenitic phase and the formation of ledeburite with an average concentration of 4.2-4.5%. As can be seen, carbon in cast iron is in the form of a solution and chemical compounds, has high mobility and activity. Therefore, in order to use it in further studies of redox processes, it is advisable to use the term "dissolved carbon" in a simplified way.

The activity of dissolved carbon in the iron-carbon alloy has shown its advantage over free carbon in coal or coke as a reducing reagent in solid-phase processes. Therefore, decarburization of cast iron can be organized not only by oxidative remelting of its melts in an oxygen converter, but also in solid-phase states, which leads to a qualitative transformation of not the melt, but finished cast iron parts.

In connection with the development of low-tonnage production of cast iron, the production of various parts, cast metal products in the national economy is expanding. At the same time, there is often a problem about the need to harden the working surface of cast-iron parts. Methods of surfacing special alloys and metal powders on the working surface are devoted to solving this problem. There is also an alternative option for hardening the surface of cast iron casting by decarburizing it in a solid-phase state.

The production of cast metal products and machine parts made of cast iron and the expansion of the possibilities of their hardening by decarburization in the solid phase state opens up the shortest path from ore to the finished metal structure, even compared to the well-known "ore-steel" path. Following this shortest path, this work is devoted to achieving the effect of transforming the structure of finished cast-iron structures.

2 Methodology and technological equipment for conducting research

The paper experimentally established the possibilities of wide interaction of carbon with metal oxides and put forward a new "adsorption–diffusion mechanism" of metal reduction. The study of the mechanism and kinetics of oxidation of iron and non-ferrous metal oxides due to dissolved carbon in the solid-phase state in order to form a layer of steel on the surface of metal structures is a rather complex and urgent problem.

2.1 Characteristics of the main components of the charge that form the basis of the initial charge for the production of cast iron

Ferrous concentrates from the local MPP deposits of SSMPA and Abail were used for the organization and conduct of research, and charcoal was used as a reducing reagent.

In a number of experimental studies, the method of interaction of dissolved carbon in an oxide system was used to carry out direct reduction of metals. Taking into account the high potential for the reduction of free and dissolved carbon, the experimental research methodology is based on the organization of processes of direct reduction of iron and non-ferrous metals in the solid-phase state.

The chemical composition of the charge components used in experimental studies is presented in Table 2.

Table 2 – Chemical composition of charge components for composite material production

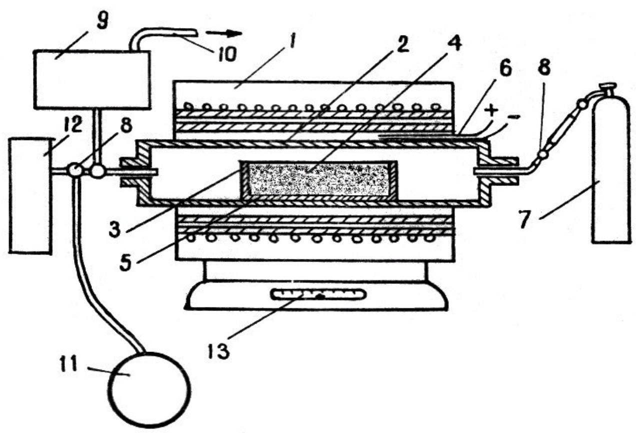
Name of the charge component	Chemical composition, %											
	Fe	FeO	MnO	V_2O_3	SiO_2	Al_2O_3	CaO	MgO	TiO_2	S	P	C
SSMPA Concentrate	62,3	18,2	0,18	0,022	4,18	1,12	1,24	0,92	0,24	0,19	0,009	–
Concentrate from the Abailsky railway deposit	66,56	8,54	2,63	–	5,82	1,24	0,72	–	–	0,02	0,05	–
Charcoal	–	–	–	–	1,56	0,82	–	–	–	0,03	–	94,0

On the basis of theoretical studies, the specificity of the kinetics of the interaction of iron and tungsten oxides with dissolved carbon, on the one hand, and on the other – the variety of temperatures at the beginning of their softening.

The methodological plan sets out the task of calculating the stoichiometric consumption of charcoal as a reducing reagent per unit mass of concentrate, taking into account the chemical composition of the specified iron concentrates, the complete reduction of iron and alloy metals and the carbonization of the metal melt in order to obtain cast iron.

2.2 Methods of conducting experimental studies

Studies of the solid-phase co-reduction of iron, manganese, chromium, silicon from oxides and the equilibrium ratio in the gas phase of CO-CO_2 depending on temperature during the reduction firing of mixtures of finely dispersed iron ore, manganese and chromite materials with a stoichiometric amount of carbon reducing agent were carried out in an electric furnace «RHTC 80 – 230/15 Controller B410» shown in Picture 1.



1 – electric resistance furnace; 2 – reaction tube; 3 – charge loading chute; 4 – a mixture of fine materials with a reducer; 5 – reaction crucible; 6 – thermocouple; 7 – argon cylinder; 8 – tee taps; 9 - gas meter; 10 – gas release; 11 – gas chamber; 12 – gas analyzer; 13 – temperature measuring device.

Picture 1 – Electric Furnace «RHTC 80 – 230/15 Controller B410»

Samples of the studied materials together with a solid reducing agent in quantities corresponding to the calculated data were placed in the form of a mixing layer in a tray. The recovery charge was prepared by thoroughly mixing a mixture of dispersed materials with a reducing agent for 6 minutes. The charge tray was inserted into a porcelain reaction tube Ø21 mm in accordance with GOST 9147-80 and together with it into an electric furnace.

The gas analyzer is designed for general gas analysis in order to determine the volume content of CO and CO_2 in a gas mixture. The gas analyzer consists of a box – case, absorption vessels, an equalizing flask, a measuring burette and three-channel taps in accordance with GOST 25336-82.

The principle of operation of the device is based on the selective absorption of unsaturated hydrocarbons, carbon monoxide by appropriate absorption solutions. In this case, the percentage of the component is determined by measuring the reduction in the volume of the analyzed gas sample during sequestration operations.

To absorb CO_2 and other acid gases, a 30-35% aqueous solution of caustic potassium (KOH) is used, which is prepared in accordance with GOST 6408-75. To absorb CO, a suspension of copper oxide (Cu_2O) is used, the preparation of which corresponds to GOST 16539-79. A 22% solution of sodium chloride (NaCl) prepared according to GOST 4233-77 or a 10% solution of sulfuric acid (H_2SO_4) corresponding to GOST 4204-77 was used as a locking liquid in the burette. The locking liquid is tinted with methyl orange (n, n'-dimethylaminoazobenzenesulfonate sodium).

The absorption analysis was carried out in a strict order, in which each subsequent reagent absorbs only one component. Gas pumping was started from a vessel filled with KOH solution, in which carbon dioxide and other acid gases are absorbed. The gas was pumped 3-4 times, and the remains of it are transferred to a burette.

Pumping through the KOH solution was repeated 2-3 times. If the volume of gas does not change after repeated pumping, the absorption of the amount of acid gases is considered complete; if the volume of gas continues to decrease, pumping is repeated until the volume is constant. The gas remaining after carbon dioxide absorption was pumped through a vessel with a suspension of Cu_2O in sulfuric acid. After a series of pumping, the gas is transferred to the burette. The gas absorbed by the suspension is mistaken for carbon monoxide. The gas from the burette is sent through a system of tees to a gas meter, according to which the volume of the released gas is recorded. The nozzle on the removable lid is connected to argon for flushing the reaction chamber.

The serial connection of measuring equipment – a thermocouple with a millivoltmeter, a gas storage device, a gas analyzer, and a counter for the amount of gas released made it possible to control all the current parameters of the solid-phase reduction of metals, similar to the operation of high-precision thermal analyzers of the "Seteram" type (France), only without automated computer control. Our methodology contained an important advantage – if milligrams of samples were loaded into Seteram, then 20-40 grams of samples were loaded into the cell of our installation at a time. If we take into account the dependence of a significant error of the experiment on the mass of the initial sample, then in our case, a multiple increase in its mass minimizes possible measurement errors.

The condition and quality of solid and liquid products obtained as a result of experimental studies was carried out by careful analysis on modern high-precision devices: the desktop optical emission spectrometer SPECTROLAB JrCCD and the electron microscope JSM 5910 (for a detailed description of the installations, see subsection 4.1 of this dissertation). The mass of the initial samples and carbon-containing materials was determined on Shimadzu ELB 1200 electronic scales in accordance with GOST 24104-88. Certified methods and devices of the spectrometric method of analysis in accordance with GOST 18895-97 were used to determine the chemical and mineralogical compositions.

2.3 Instruments and technological equipment used for laboratory research

Used laboratory installations and equipment. Laboratory installations and measuring instruments were used in experimental studies. The complex of laboratory installations and devices is shown in Picture 1.

For the production of crushed charge and powder components. To obtain the crushed materials, a laboratory electro–vibration Crusher was used (Picture 2.2). The charge components were crushed separately to a fraction of ~0.074 mm.

2.1

2.2

2.3

2.4

2.1– bunkers for charge components; 2.2 – electric crusher; 2.3 – bunkers for charge components; 2.4 – granulator.

Picture 2 – Complex of laboratory installations and devices for charge preparation

Production of cast metal products from cast iron and its thermochemical treatment. The resulting gray cast iron is injected into a sealed experimental cell made of a quartz tube with a diameter of 30 mm. The cell is installed on a tubular electric furnace

"RHTC 80 – 230/15 Controller B410", shown in Picture 3. As the system heats up, starting from a temperature of 800 ° C, a solid–phase reduction product, gas, begins to be released. The yield and composition of the gas mixture consisting of CO_2 and CO are monitored in gas meters and gas analysis devices. The process was carried out in a neutral atmosphere (argon purge).

Picture 3 – «RHTC 80 – 230/15 Controller B410» tubular electric furnace

3 Experimental studies

3.1 Preparation of raw materials and their characteristics

Ferrous concentrates from the local MPP deposits of SSMPA and Abail were used for the organization and conduct of research, and charcoal was used as a reducing reagent.

The chemical composition of the charge components used in experimental studies is presented in Table 3.

Table 3 – Chemical composition of charge components for composite material production

Name of the charge component	Chemical composition, %											
	Fe	FeO	MnO	V_2O_3	SiO_2	Al_2O_3	CaO	MgO	TiO_2	S	P	C
SSMPA Concentrate	66,6	18,5	0,25	0,022	3,79	0,95	0,87	0,46	0,24	0,32	0,018	–
Concentrate from the Abailsky railway deposit	66,56	8,54	2,63	–	5,82	1,24	0,72	–	–	0,02	0,05	–
Charcoal	–	–	–	–	1,56	0,82	–	–	–	0,03	–	94,0
Flux (limestone)	0,64	–	–	–	–	–	54	–	–	–	–	

3.2 Direct production of cast iron pellets from iron ore concentrates by reduction melting

As can be seen from the table 3, the phosphorus content in the concentrates corresponds to the norm, and the sulfur content in the ferrous concentrate SSMPA is very high. In order to reduce it, the concentrate was sent to the process of oxidative annealing. The sulfur content in the concentrate obtained from the annealing process decreased to 0.015%.

Table 4 – Composition of the burnt concentrate

Name of the charge component	Chemical composition, %										
	Fe	FeO	MnO	V_2O_3	SiO_2	Al_2O_3	CaO	MgO	TiO_2	S	P
SSMPA Concentrate	67,03	1,8	0,17	0,022	3,35	0,90	0,95	0,88	0,24	0,015	0,009

To conduct laboratory experiments, we used a tubular electric furnace "RHTC 80 – 230/15 Controller B410", a special quartz experimental tube, a crusher, electronic scales and gas analysis devices.

In an oil designed to produce cast iron, the components of the charge are mixed and a pellet is obtained using a granulator. The same pellet is further melted in a melting furnace on a special refractory installation. During the experiment, the reduction processes mentioned above proceeded completely and cast iron and slag were melted at 1300 – 1400 °C.

After taking the unit out of the furnace, separating the formed slag, passing the remaining pure cast iron through a specially prepared pipe, we received cast iron pellets. Granules of 2-3 mm of the resulting cast iron alloy are shown below in Picture 4, and its chemical composition is presented in Table 4.

Picture 4 – The resulting cast iron pellet

Table 5 – Chemical composition of granules of the obtained cast iron alloy

№	Chemical composition, %						
	Fe	C	Mn	Si	V	S	P
№1 sample	95,09	4,15	0,17	0,53	0,020	0,035	0,010
№2 sample	95,01	4,20	0,16	0,56	0,021	0,038	0,015
№3 sample	92,75	4,40	2,12	0,67	–	0,025	0,040

The raw materials for producing coal from organic waste are agricultural waste: straw, sawdust, cotton.

The initial organic residues were first dried and then crushed. The crushed materials were manufactured and pressed separately according to the diameter of the quartz tube and the pressed samples were weighed on electronic scales, placed in a sealed quartz tube and injected into a tubular electric furnace. When the temperature reached 400 °C, the release of a gas consisting of H_2O and CO_2 was first observed. At a temperature of 500 ° C, the composition of the gas changed, mainly combustible gases CH_4, H_2 were released.

After the gas was released, the quartz tube was cooled, and the weight of the extracted coal samples was measured on an electronic scale and sent for chemical analysis. The resulting charcoal is shown in Picture 5.

Picture 5 – The resulting charcoal sample.

Table 6 – Average composition of charcoal

Product Name	Experiment number					
	1	2	3	4	5	6
Carbon (C), %	96,1	97,6	97,6	95,1	95,6	96,0
Ash (C), %	3,9	3,4	3,4	4,9	4,4	4,0

Based on the results obtained, it was found that the resulting charcoal is of high quality and can be used as a reducing reagent in metallurgical processes.

3.3 General characteristics and chemical composition of the obtained granules

The microstructure of the cast-iron plate obtained by melting cast-iron granules obtained by the above method is shown below in Picture 6, and its chemical composition is presented in Table 5.

Picture 6 – Microstructure of the primary cast iron section

CONCLUSION

The purpose of this work was to study the production of granular cast iron. The subject of the study were SSMPA and Abail concentrates. It was proposed to use metallized pellets as the main material.

The technology involves the production of pellets from iron ore concentrates with a stoichiometric amount of carbon (charcoal) in a molasses bundle. Analyses were carried out to determine the required amount of charcoal. The pellets were dried at a temperature of 400 ° C and metallization at 1200 ° C. Metallization reached 0.59-0.74. This metallization was enough to melt alloy steel at a temperature of 1400 ° C.

As a result, the goal was studied, experimental studies were conducted.

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Протокол

о проверке на наличие неавторизованных заимствований (плагиата)

Автор: Мұхамедхан Дария

Соавтор (если имеется):

Тип работы: Дипломная работа

Название работы: Research of processes for obtaining granular cast iron

Научный руководитель: Гүлзада Қойшина

Коэффициент Подобия 1: 1.8

Коэффициент Подобия 2: 0.5

Микропробелы: 0

Знаки из здругих алфавитов: 1

Интервалы: 0

Белые Знаки: 0

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Дата 1-06-2022

Заведующий кафедрой МиОМ
Бөрменшиков М.Б

Протокол

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Название
Research of processes for obtaining granular cast iron

Автор
Мұхамедхан Дәрия

Научный руководитель
Гүлзада Қойшина

Подразделение
Г_М_И

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ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
Источник: Paperity			
1	Computational Analysis of The Performance of Shaft Furnaces with Partial Replacement of The Burden with Self-Reducing Pellets Containing Biomass Elisa Pinto da Rocha, Rayla de Souza Caldas, José Adilson de Castro, Leonardo Silva;	28 (2)	0.37 %
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1	**https://drytkin.wixsite.com/musaganievduman/post/2013-kazakhmys-kazakhstan**	**34 (1)**	**0.45 %**
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3	http://www.spsl.nsc.ru/FullText/konfe/NonFerrousMetals-2017.pdf	12 (1)	0.16 %
4	https://www.ictt.by/rus/exh/plan/view.php?proid=a083910c08e2a1a3825ecca9053b2b&lng=eng	11 (1)	0.15 %

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Список принятых фрагментов (нет принятых фрагментов)

ПОРЯДКОВЫЙ НОМЕР	СОДЕРЖАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN
SATBAYEV UNIVERSITY

REVIEW
of the thesis

Mukhamedkhan Dariya Ersinbekkyzy
(Full name of the student)

«5B070900 – Metallurgy»
(the cipher and the name of the specialty)

On the topic: Investigation of the processes of obtaining granular cast iron

Done:
a) graphic part on the sheets 14
b) explanatory note on the pages 30

NOTES TO THE WORK

The thesis submitted for review consists of the following chapters: abstract in Kazakh, Russian and English; management; literary review; experimental research; conclusion.

The paper provides a literary review of modern methods of producing cast iron and steel in the world and Kazakhstan. The theory and practice of direct production of cast iron are considered. Kinetic dependences are obtained on the basis of experimental studies. A method of applying pellets from iron ore concentrates is shown. The optimal technological parameters of the process of metallization of pellets with the production of cast iron have been established.

Question on the thesis: What is the behavior of impurity metals in the production of cast iron?

Job evaluation

The thesis was completed completely in accordance with the requirements and deserves a rating of "excellent, 95%". I believe that Mukhamedkhan Dariya Ersinbekkyzy deserves a bachelor's degree in the specialty "5B070900 – Metallurgy".

Reviewer
Reviewer,
Doctor of PhD, SR at the Laboratory
of Rare Metals RSE «NC CPMR RK»
(position, academic degree, title)
_______________ Maldybayev G.K.
(sign)
«_______________ 2022 y.

Ф КазНИТУ 706-17. Рецензия

МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РЕСПУБЛИКИ КАЗАХСТАН
СӘТБАЕВ УНИВЕРСИТЕТІ

ОТЗЫВ

НАУЧНОГО РУКОВОДИТЕЛЯ

На дипломную работу
(наименование вида работы)
Мұхамедхан Дәрия Ерсінбекқызы
(Ф.И.О. обучающегося)
5В070900-Металургия.
(шифр и наименование специальности)

Тема: «Исследование процессов получения гранулированого чугуна»

Выполнена в полном объёме в соответствии с утверждённым графиком. Студентка последовательно выполняла разделы диссертации: 1) обзор состояния проблемы; 2) методики исследования; 3) экспериментальные исследования при непосредственной консультации с руководителем. Мұхамедхан Дәрия Ерсінбекқызы получила уверенную научную подготовку для продолжения самостоятельных научных исследований в данном направлении.

Дипломная работа «Исследование процессов получения гранулированого чугуна» завершена новыми научно-технологическими результатами, ее автор Мұхамедхан Д.Е. заслуживает высокую оценку и присуждения академической степени бакалавра по специальности 5В070900-Металургия.

Научный руководитель,
доктор PhD, ассистент профессор кафедры
(должность, уч. степень, звание)
Gkoishina Койшина Г.М.
«01» июня 2022 г.