Conference Paper

Promising Directions of the Application for Poor Raw Materials of the Ferroalloy Production

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Abstract

The mineral base state for Russian manganese and chromium ores does not allow our country in the foreseeable future to achieve complete self-sufficiency and to abandon imported raw materials. But the problem can be significantly mitigated due to the partial involvement in the operation of the proven ore reserves with relatively low quality. Based on the performed research, four main directions are formulated that would make it possible to put into operation a number of previously known but out-of-use (or poorly used) deposits of poor mineral raw materials for the ferroalloy production: (1) selective reduction of ore components divided into metal semi-products with a low main component content suitable for the smelting of the alloyed steel grades and an oxide product with a high content of Mn or Cr oxides suitable for the smelting of the high-grade ferroalloy grades; (2) rational additional charging of poor domestic ores to beneficiate imported ones to obtain standard grades of ferroalloys; (3) smelting of new alloys, including marketable high-carbon ferromanganese and ferrochrome with reduced main component content, high silicon content, and complex ferroalloys containing, in addition to the main, other elements necessary for the composition of a number of steel grades (silicon, manganese, titanium, etc.); and (4) production of limited grades of ferro-, silico-manganese, and chromium and their application in smelting of the ferroalloys refined grades.

Keywords: metallurgy, ferroalloys, mineral resource base, poor ores

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1. Introduction

The development of the Russian Federation economy requires an increase in metal production, an improvement of its quality, and increase in the range of metal products. The state of steelmaking as the main consumer of ferroalloys determines the development trends for the ferroalloy sub–industry of the ferrous metallurgy. The constant change in the dynamics and structure of steel production affects the nature of production and consumption of ferroalloys. Despite periodic fluctuations in world production, the

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general trend of increasing the steel volume and ferroalloy production is preserved. At the same time, global reserves of rich minerals are steadily depleted. From year to year, the gap between the growing need of metallurgists in ferroalloys and the decreasing reserves of rich ores will only grow. In this regard, in modern conditions, ferroalloys are forced to simultaneously solve two tasks: an increase in the volume and quality of the produced ferroalloys and the use of low–quality and dradge raw materials. The main amount of produced ferroalloys (over 90%) is accounted for the so–called "large–tonnage" manganese, chromium and silicon alloys [1]. In modern conditions in our country, there is an extremely difficult situation with the provision of manganese and chrome production with its own high–quality ore raw materials.

The mineral and raw material base of manganese ores in Russia is quite large: the balance (explored and preliminary estimated) reserves of manganese ores are about 230 million tons, and the forecast resources are more than 1 billion tons [2]. At the same time, the quality of Russian manganese ores is low: most of the explored reserves are carbonate ores, which are rebellious ores and have elevated phosphorus content. The average manganese content is 20%. Most of Russia's deposits are small. The production of manganese ores on the territory of our country is carried out sporadically and does not exceed 66 thousand tons per year (8% of consumption) [3]. Manganese ferroalloys obtained in the Russian Federation are mainly smelted from foreign raw materials (Kazakhstan, South Africa, etc.).

In the volume of global reserves for chromium–ore raw materials, the share of rich ores accounts for no more than 33% [4]. The balance reserves of chromium ores in the Russian Federation are $\sim$ 51 million tons, and the forecast resources are $\sim$ 540 million tons, but the vast majority of ores from the exploited deposits are poor [5]. According to [3], Russian import of high–quality chromium concentrates amounts to 640–1110 thousand tons per year (up to 70% of national consumption), the main share of which is from Kazakhstan supplies.

The state of the mineral resource base for manganese and chromium ores does not allow Russia in the foreseeable future to achieve full self–sufficiency and to refuse the import. But the problem can be significantly mitigated due to the partial involvement in the operation of proven ore reserves with relatively low quality. The overwhelming majority of deposits for domestic manganese and chrome ores are not suitable for the production of traditional grades of ferroalloys according to previously existing technological schemes.

It is known that the richer the ore (manganese, chromium, iron, etc.), the lower consumption of electricity, coke, the higher the productivity of the aggregates and the better the technical and economic indicators of the smelting during processing compared to the use of poor ores. At the same time, the cost of ferroalloy products largely depends on the price of ore materials. Depending on the type of produced ferroalloy, ore raw materials make up to 40–60% (for expensive alloys up to 97%) of its total prime cost, therefore the low price of poor ore materials can cover higher production costs compared to using rich raw materials. When switching to low–grade ores, the chemical and phase composition of the initial raw materials changes, and consequently the conditions of the reduction processes also change, which leads to a change in the composition and properties of the smelting products, both oxide and metal. A new composition of slag and metal with new physicochemical characteristics is formed. To solve the problems of involvement for poor ore raw materials in the production process, an integrated approach has been developed that contains the study of the metallurgical characteristics for the initial charge materials, the physicochemical characteristics of the reduction processes, intermediate and final slag melts and ferroalloys with the development of their rational compositions, as well as including industrial studies of technological features for the production of alloys from poor and untraditional raw materials with the introduction of the proposed solutions in the existing industrial conditions [6].

Constantly rising prices for raw materials and energy, tougher competition conditions in the domestic and foreign markets pose to metallurgists the task of continuously searching for ways to improve the technical and economic indicators of traditional metallurgical technologies and the development of new technological solutions, which by their characteristics are located at a higher level of scientific and technical progress. Difficulties with the enrichment of the majority of poor ores and the associated increase in the cost of products (including due to losses and the need for subsequent lumping) justify the established approach, according to which, the most rational way of using poor manganese and chromium ores is to obtain ferroalloys from them or their concentrates, suitable for steel processing or for further conversion. On the basis of the conducted studies for the metallurgical characteristics of poor ore materials, the physicochemical properties of alloys obtained from them [7] and industrial research works [8, 9], four main directions were formulated that allow to put into operation a number of previously known but out of use (or poorly used) earlier deposits of poor mineral raw materials for ferroalloy production:

1. Selective reduction of ore components divided into metal semi–products with a low main component content in most cases suitable for the smelting of the alloyed steel grades and an oxide product with a high content of Mn or Cr oxides suitable for the smelting of the high–grade ferroalloy grades.

2. Rational additional charging of poor domestic ores to rich imported ones to obtain standard grades of ferroalloys.

3. Smelting of new alloys, including marketable high–carbon ferromanganese and ferrochrome with reduced main component content, high silicon content, and complex ferroalloys containing, in addition to the main, other elements necessary for the composition for a number of steel grades (silicon, manganese, titanium, etc.).

4. Production of conversion grades of ferro–, silico– manganese and chromium and their application in the smelting of the ferroalloys refined grades.

The above directions have been investigated and, in varying degrees, brought to industrial testing and implementation.

The selective reduction method of components for high–phosphorus manganese ore was used at the enterprises of the Soviet Union to remove phosphorus with obtaining low–phosphorous slag as the main product. In modern conditions, during the processing of poor mineral raw materials, it is possible to use this method with a more complete reduction of iron and the production of conversion slags with a high content of manganese oxides (40–60%). In the laboratory and enlarged laboratory conditions, selective, preliminary reduction for the elements of poor chromium ores has been studied. It is known that the preliminary reduction and heating of ore materials can save 15–20% of electricity and increase the productivity of ore–reducing furnaces. The performed thermogravimetric experiments showed that rational characteristics for the solid phase selective reduction of iron and partially chromium (5–15%) from chromium ore materials with the release of a metallic phase containing $\sim$ 20% Cr are achieved at a temperature of 1300–1350°C, the duration of the solid–phase reduction is $\sim$ 30 min. This forms an oxide product with a high content of Cr_2O_3(more than 45%), suitable for the smelting of high–grade ferrochromium (65–75% Cr).

Additional charging of poor domestic manganese and chromium ores to enrich imported ones and the production of standard grades ferroalloys find application in modern conditions in the domestic ferroalloy enterprises. We have studied for the first time on an industrial scale the features of the technology for obtaining standard grades of ferroalloys with a gradual transition from 100% of the rich imported ore to 100% of poor domestic raw materials. Revealed the dependencies of technical and economic indicators for the production of ferroalloys on the content of poor ore materials in the charge composition, allowing the calculation of a rational amount of poor raw materials [10].

Of considerable interest is the possibility of using 100% of poor raw materials to produce new alloys, including commercial high–carbon ferromanganese and ferrochromium with a reduced content of main elements and complex ferroalloys. Under laboratory conditions, it is shown a general possibility for obtaining complex alloys of the Fe–Cr–Mn–Si system (35–40% Cr; 15–25% Mn; 8–15% Si) from poor chromium and poor manganese ores of the domestic deposits. The study of reduction kinetics and thermodynamic calculations showed that the joint reduction of chromium and manganese ores creates favorable conditions for the reduction processes due to the dissolution of the main alloy components in iron and the interaction of empty rocks for chromium and manganese ores. A sufficiently high speed and completeness of the reduction process for the components mixture for the smelting of the complex chrome–manganese alloy is achieved at 1600–1650°C. The degree of Cr extraction in the metal is increased by 3% compared to the production of standard grades of chromium alloys. On an industrial scale, the principal possibility and feasibility of processing for poor chromium ores with the production of ferrochrome that has a high silicon content (4–6% Si) and a low content of chromium (50–55% Cr) is shown. The technology has been introduced into production [11]. The resulting low–grade ferrochrome has been successfully used in steel production.

At the Russian enterprises there is an experience of obtaining conversion grades of ferro–, silico– manganese and chromium and their use during the smelting of the refined ferroalloys grades. At JSC CHEMK, to obtain conversion grades of ferrochrome, the poor chromic ores of many small deposits of the Chelyabinsk Region and the Ray–Iz deposit were involved in the production cycle [12]. Together with JSC "Serov Ferroalloy Plant", we developed the composition of the charge to produce ferrochrome with high silicon content from poor high–alumina ores [13]. Further use of such ferrochrome during the smelting of ferrosilicochrome can significantly improve the technical and economic indicators for the production of conversion ferrosilicochrome. The obtained ferroalloy fully complies with the requirements of ISO 5449–80 for the brand FeCrSi48 and is successfully used to produce low–carbon ferrochrome FeCr60C05 brand [14].

Thus, the state of the mineral and raw materials base for manganese and chromium ores in Russia does not allow our country in the foreseeable future to achieve complete self–sufficiency and abandon imported raw materials. But the problem can be significantly mitigated due to the involvement in the operation of a part of proven ore reserves of relatively low quality. Four promising areas of metallurgical processing for poor mineral raw materials of the ferroalloy production have been formulated with the production of both standard grades and new types of ferroalloys, which have successfully passed laboratory, industrial tests and have already been partially introduced into production. As a result of the development of the presented directions, the possibility and expediency of widespread use of poor ores during the production of ferroalloys with high technical and economic indicators have been experimentally shown.

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