

The problems of application of domestic ore raw materials in the production of ferroalloys

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Abstract. There is a difficult situation with ferroalloy production in Russia – production has a raw material import dependence in the presence of our own large, although not quite high-quality, in accordance with world standards, mineral resource base. As rule, domestic ferroalloy raw materials are of low quality: a low content of leading elements (manganese, chromium ores), a high content of phosphorus (manganese, niobium ores), sulfur (manganese ores). The paper gives examples of a complex of physicochemical studies and the development of a number of alternative technologies for the smelting of new ferroalloy compositions with Mn, Cr, Nb, W. The scientific studies together with the development of the technology have been carried out to study the effect of ferroalloys composition on consumer properties. Because of the fact that the chemical composition of the ores of most new deposits cannot ensure the production of standard ferroalloys. By help deep physicochemical and technological studies it is possible to create new processes and combinations of different types of ferroalloys from non-traditional domestic mineral raw materials. The alloys are not inferior in terms of technical and economic indicators of products obtained from rich imported ore materials.

1. Introduction

Currently, the importance of ferroalloy production is constantly growing due to increasing demands on the quality of metal and the creation of new products types with unique properties. The development of the industry is prevented by the widening gap between the need for quantity and improvement of the quality of ore raw materials and also declining reserves of high-quality ores. At present, about 40 million tons of various ferroalloys are produced in the world, in Russia ~ 2 million tons [1].

The structure of ferroalloy production in the world and in Russia is different (figure). The world structure of ferroalloy production over the past decades has not undergone significant changes. It is consistent with their global consumption. The production of manganese alloys ranks first in the world. In individual countries the consumption of ferroalloys is balanced by their exports and imports, and production depends mainly on the available mineral resource base [1–4].

The structure of ferroalloy production in the Russian Federation predetermined by the reserves of domestic raw materials. Silicon alloys are produced mainly in Russia due to the lack of restrictions in the raw material base (49.4%), then manganese (25.8%) and chromium (16.4%) ferroalloys. The remaining ferroalloys account for ~ 9% of production [5].



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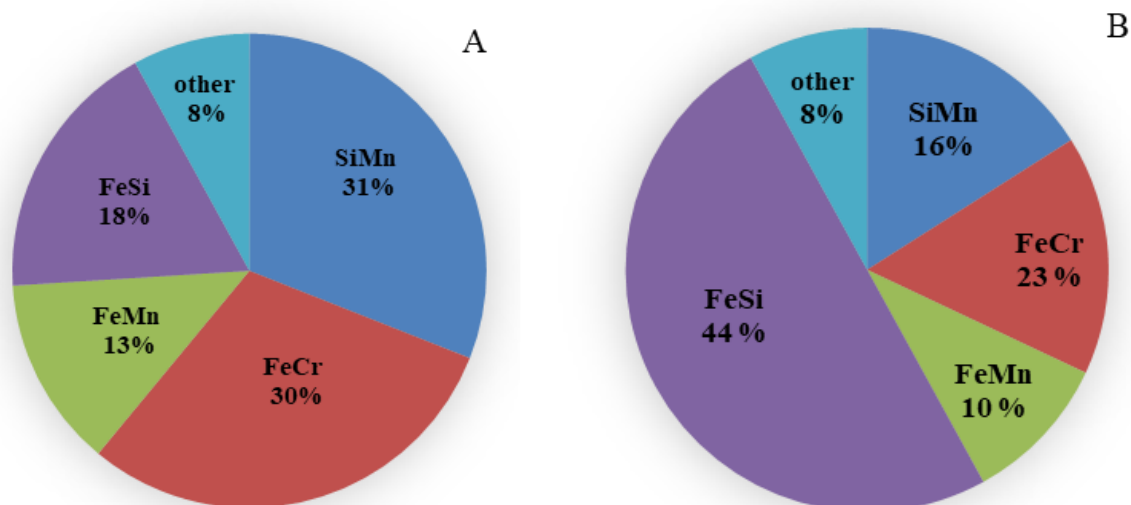


Figure. The structure of ferroalloy production in the world (A) and in Russia (B).

In addition to ferroalloys of the ‘large’ group (manganese, chromium, silicon), there are ferroalloys of the ‘small’ group, which include vanadium, niobium, molybdenum, titanium and others.

2. Results and Discussion

The main problem of ferroalloy production both in the world and in Russia is the availability of ore raw materials. A few types of alloys are produced at domestic plants from our own raw materials (ferrosilicon, vanadium alloys). The majority of ferroalloys are either imported from abroad or smelted from imported raw materials [6, 7].

The demand for manganese ferroalloys from the Russian steelmakers is ~ 650 thousand tons, which is met by imported ferro and silicomanganese. The rest is smelted from foreign raw materials (South Africa, Kazakhstan, Gabon). The volume of the consumption increased from 516 thousand tons in 2002 to 1276 thousand tons in 2018. Manganese ore mining was stopped in 2014. Now all supplies of manganese raw materials are carried out by import. Previously manganese ores deliveries were from Ukraine, but now it is ceased. Imports from Kazakhstan increased to 670 thousand tons/year, but then decreased to 128 thousand tons in 2018. New import flows of manganese concentrate from the Republic of South Africa (up to 843 thousand tons/year) and Gabon (up to 338 thousand tons/year) [8].

At the same time, we have about 290 million tons in categories A + B + C1 + C2 of manganese ores reserves. The estimated resources are more than 1 billion tons.

The largest manganese ore deposit in Russia is Usinskoye (Kemerovo Region), Porozhinskoye (Krasnoyarsk Territory), Parnokskoye (Komi Republic), Severouralskoye (Sverdlovsk Region). In the Republic of Sakha, rich (40–50% Mn) sulfide manganese ores have been discovered. The domestic manganese ores are mainly poor and high phosphorous. However, the numerous laboratory and industrial studies indicate the possibility of their wide use for obtaining different types of ferroalloys [7].

Russia fully provides itself with chromium ferroalloys in contrast with manganese alloys. The chromium ferroalloys are obtained mainly from foreign raw materials. Domestic ores are used in limited quantities (about 35%). The extraction of chromite ore in the Russian Federation is at the level of 400 thousand tons/year with the content of Cr₂O₃ in concentrate 37–39%. Balance reserves (A + B + C1 + C2) amount to 51.2 million tons, forecast resources – more than 540 million tons [9]. Ore mining is currently carried out at the deposits of Saranovskoye (Ural, Perm region) and Central (Polar Ural, chromite-bearing array Rai-Iz of the Yamalo-Nenets Autonomous Okrug).

Russian imports of chromium concentrates in different years range from 640 to 1110 thousand tons/year. The main part (94%) is supplied from Kazakhstan.

Domestic chromium ores are poorer than imported ores (38–39% Cr₂O₃ versus > 45% Cr₂O₃). Though the minerals are cheaper and can be used in larger amounts. The ores from different deposits have different chemical, phase, and particle size distribution. They require an individual technological approach when using them [6].

The production of ferroalloys of the ‘small’ group is also characterized by the presence of its own ore raw materials. The production volumes of ferroalloys (with Nb, Mo, W, etc.) do not satisfy own needs [9, 10].

According to G A Mashkovtseva [9], a large of niobium deposits explored in the Irkutsk Region (Beloziminskoye, Bolshetagninskoye, Zashikhinskoye, etc.), in the Chita region–Katuginskoye, in the Krasnoyarsk Territory – Tatarskoye, Chuktugonskoye and etc. All deposits differ from each other in material composition, which includes pyrochlore, apatite, monazite, vermiculite and other minerals.

A number of molybdenum deposits have been explored. In the Republic of Buryatia, this is Orekitkan and Malo-Oinogorsk, in the Chita region is Bugdain, and in the Kurgan region is Koklanovskoye and others.

Almost all of these deposits are not being developed. In respect to ferroalloy production, Russia has ‘a paradoxical situation: the raw material dependence of production on imports in the presence of its own large, although not quite high quality, in accordance with world standards, mineral and raw material base’ [10].

In addition to organizational and financial, one of the main reasons for this situation is the well-established conservative approach to smelting ferroalloys with using the same type of ore raw materials and obtaining standard grade products.

As a rule, domestic ferroalloy raw materials are of low quality. It has a low content of leading elements (manganese, chromium ores), a high content of phosphorus (manganese, niobium ores), sulfur (chromium, manganese ores). This requires a complex of physicochemical studies and the creation of a number of new alternative technologies.

The scientific studies together with the development of the technology have been carried out to study the effect of ferroalloys composition on consumer properties. Because of the fact that the chemical composition of the ores of most new deposits cannot ensure the production of standard ferroalloys.

It is necessary to conduct the scientific research together with the development of the technology to study the effect of ferroalloys composition on consumer properties. Because of the fact that the chemical composition of the ores of most new deposits cannot ensure the production of standard ferroalloys.

Based on the studies of the metallurgical characteristics of poor chromium ore materials, the physicochemical properties of the alloys obtained from them, and industrial scientific research [11–13], four main directions are formulated:

1. Selective reduction of ore components with separation into a metal intermediate with a low chromium content (~ 20%) and an oxide product with a high Cr₂O₃ content. The metal intermediate is suitable for the smelting of corrosion-resistant steel grades. The oxide is suitable for the smelting of high-grade grades of ferrochrome.

2. The rational additional charging of poor domestic chromium ores to rich imported ones to production of standard grades of ferrochrome.

3. Obtaining new alloys including commercial high-carbon ferrochrome with a low content of chromium, carbon and with a high content of silicon and also complex ferroalloys.

4. Obtaining foundry ferro- and silicochrome and their use in the smelting of refinery ferrochrome.

The directions allow to put into operation a number of known, but not used (or poorly used) previously deposits of poor chromium ores.

All presented directions have been investigated and, to varying degrees, brought to industrial testing and implementation.

It is necessary to know their service characteristics to obtain and use new ferroalloys. Changing and improving the characteristics of the alloys should be based on the study of their properties that affect the degree of assimilation of the leading components of the alloys.

Studies of the physicochemical characteristics of chromium ferroalloys and the development of rational compositions of their compositions were carried out.

The data obtained showed that ferrochrome with a high content of silicon and a low chromium content, as well as complex alloys with manganese can be obtained from poor domestic raw materials. They are characterized by more favorable physicochemical properties compared to traditional high-percent (~ 65% Cr) ferrochrome grade FeCr850 from the point of view of their application for steel processing. Laboratory experiments have shown that an increase in the silicon content in high-carbon ferrochrome to 10% leads to an increase in the degree of absorption of chromium in steel by 11%. In addition, standard ferrochrome contains less than 1% silicon and is used only for alloying steel with chromium. The proposed alloys can contain up to 10% Si and are used not only for alloying, but also for partial deoxidation of steel.

The prospects for using poor Russian manganese ore raw materials are largely associated with the study of the possibility of successful use of ferro- and silicomanganese with a low manganese content (40–55%) and the development of methods to reducing phosphorus in manganese ferroalloys. Mixing of poor manganese ore to rich ore also requires a founded scientific approach to choosing the optimal ratio of these two components of the raw material, taking into account the composition of the formed melt (basicity, viscosity, distribution coefficient of manganese), phosphorus content in the alloy, etc.

Significant economic interest is the increase in output in Russia for domestic use and for the export of tungsten products. In one form or another, tungsten is widely used in metallurgy and machine building, the electric, oil and chemical industries in pure form, alloy steel, hard alloys, etc. Tungsten is a material that is profitable for sale, the price of ferro-tungsten (65–75% W) is 15.000–35.000 USD/t [14]. Increasing the output of tungsten-containing products in the presence of significant reserves of raw materials (3rd place in the world) is an important state task [2, 8, 9].

Currently according to [9], the State Balance of Russia takes into account 52 primary and 40 placer accumulation deposits of tungsten. Inferred resources (WO_3) are estimated at 2.234 thousand tons, production in 2017 amounted to 3.500 tons. 929 tons of WO_3 were obtained from industrial waste. In 2017, the export of tungsten concentrates amounted to ~ 2000 tons, the import is 1470 tons.

Development of the Lermontovskoye (Kabardino-Balkaria), Holtoson (Buryatia), Bon-Gorkhonskoye (Transbaikalia) deposits is continue. Explored new deposits Agylkinskoye and Mikhailovskoye, in Yakutia, as well as a number of reserves in the Western Baikal region, Eastern Sayan and in the north of the Irkutsk region. It should be noted that in many domestic ores there is a high tungsten content (above 1% WO_3). The enrichment of tungsten-containing ores is carried out mainly by gravity methods. This does not provide a stable quality of concentrates. The problem of cleaning concentrates from non-ferrous metal impurities such as copper, arsenic, lead, tin, bismuth, antimony, which are not removed by gravity enrichment, is extremely acute [15].

The concentrates obtained as a result of enrichment have significant fluctuations in the tungsten content and impurities due to the different composition of ores of different deposits and the methods of their enrichment. This creates difficulties in the development of technology for their processing into commercial products (metal tungsten, ferro-tungsten, etc.) Nevertheless, there is large arsenal of melting techniques. This including furnace and ladle melting; carbo-, silico- and aluminothermy reduction processes, pyroselecting and refining methods. This allows to developing and producing tungsten products of the required composition using rational technology.

3. Conclusion

Thus, we and other researchers have shown that it is realistically possible to create new processes and combinations of different types of ferroalloys from non-traditional domestic ore raw materials based on deep physicochemical and technological studies that are not inferior in terms of their technical and economic indicators of products obtained from imported materials. To successfully solve the problem

of providing the ferroalloy industry with domestic ore raw materials, it is necessary to combine the research of geologists, enrichment and metallurgists, creating integrated teams and government projects under the leadership of the Russian Academy of Sciences and the Ministry of Natural Resources of the Russian Federation.

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