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Study of the Influence of the Composition of Manganese Ores on the Quality of Silicomanganese

Naboko E.P., Issagulova D.A.*, Platonova E.S., Yudakova V.A., Pitirimova T.V.
Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan
*corresponding author

Abstract: Today the production of silicomanganese is in a promising direction. Silicon manganese is used to alloy steels, increasing their strength and corrosion resistance; in the production of cast iron, where it plays the role of a desulfurizer and degasser. In recent years, the demand for silicomanganese has increased significantly, which is caused by an increase in steel production in the world. In this work, the issue of using "poor" manganese ores of Kazakh origin to produce high-quality ferroalloys with reduced costs (by reducing import logistics costs) based on Kazakh enterprises was investigated.

Keywords: silicomanganese, manganese ore, raw materials, alloy, steel, cast iron, ferroalloy, mineral composition, phosphorus, chemical composition.

Introduction

The mining and metallurgical complex of the republic is one of the basic industries that plays an important role in the formation of the country's macroeconomic indicators. The development of the national economy as a whole will depend on its further development.

Currently, the goal of Kazakhstan's industrial policy is to create the most balanced industrial complex (industrial-innovative), capable of serving the domestic market with competitive products for further processing, constantly increasing export potential through highly processed products.

Ferroalloys, which until recently were a semi-product of metallurgical production, are today used not only as an alloying additive but also in the production of various products and structures. Silico-manganese is used to degas the steel, reduce the exposure of the metal alloy to sulfur and phosphorus, and provide increased strength and wear resistance to the steel. In addition, it can be used in the production of electrodes, other types of ferroalloys, casting alloys and other metal products.

Ferroalloy production is a relatively new branch of metallurgy in Kazakhstan. Until recently, it was represented by two large factories located in Aksu and Aktobe, owned by JSC Transnational Company Kazchrome. Both plants specialize in the production of such types of alloys as ferrosilicon, ferrochrome and silicomanganese.

Kazakhstan occupies one of the leading places in the ranking of producers of these types of alloys and is also one of the largest exporters. Considering ferroalloy production in the Commonwealth of Independent States countries recently, it can be noted that 25 ferroalloy plants produce about 4.8 million tons of finished products per year. A feature of the production of ferroalloys is the fourfold excess of product production over domestic consumption in metallurgical production, which explains that this production is mainly export-oriented

The Karaganda region became a center of ferroalloy production relatively recently. Today, in the industrial zone of the city of Karaganda there are two ferroalloy plants, YDD Corporation LLP and Asia FerroAlloys LLP. The enterprises produce high-quality ferrosilicon (an alloy of iron and silicon). The Asia FerroAlloys LLP company specializes in the production of silicomanganese of the MnC17 grade. Product output is aimed at meeting local and global demand for ferroalloys in the markets of Kazakhstan, Europe, Southeast Asia, North and South America. The enterprises' products meet the highest international quality requirements.

1. Research methodology

When assessing the quality of ores, the first place comes the question of the content of the main element in them, but this criterion also changes. Due to the increasing depletion of minerals, consumers are now settling for increasingly poorer minerals. When deciding on the use of a particular grade of ore in production, the technical and economic results of work on this ore should be assessed. In this case, first of all, it should be taken into account that reducing the proportion of manganese in the charge by 1%, other things being equal, reduces the furnace productivity by 2.3%. A decrease in the Cr_2O_3 content in the ore by 1% reduces the productivity of the furnace and, accordingly, increases energy consumption in the production of low-carbon ferrochrome by 4.8% and high-carbon ferrochrome by 3%. The value of ore increases by reducing the content of harmful impurities such as phosphorus, sulfur and copper [1].

The number of impurities often determines the processing technology. The volumes of Kazakhstani manganese ores mined for the production of silicomanganese make it possible to meet the needs of the growing ferroalloy production of the metallurgical industry of Kazakhstan. The main advantage of domestic manganese raw materials is its low phosphorus content, which ensures the production of low-phosphorus ferroalloys; silicomanganese with phosphorus content of less than 0.15% and ferromanganese carbon of less than 0.25%. This allows the use of raw materials without preliminary preparation - enrichment [2].

Kazakhstan occupies one of the leading positions among the Commonwealth of Independent States countries in terms of manganese ore reserves. Today, about 100 manganese deposits are known on the territory of the Republic, 19 of them are included in the country's balance sheet. Manganese ores in Kazakhstan are classified into three main groups:

Zhezdy -Ulutau, Atasu and Ushkatyn. Manganese ores of the first group are characterized by low manganese content (15 - 17%) and high silica content (40 - 49%). Deposits of manganese ores of the Atasu group: Western Karazhal, Ushkatyn I, Ushkatyn III, Tur, Zhomart, Kamys, Bogach, Zhaksy, Akzhar-Sarytuma and other manganese deposits are concentrated almost exclusively in Central Kazakhstan.

In the process of work, studies were carried out on the influence of the composition of manganese ores on the quality of the resulting ferroalloy. Two deposits were considered: with a low mass fraction of the leading element content and with a high one. These are the Zhezdy deposit and the Akzhar-Sarytum deposit, respectively.

Manganese ores with a leading element content of 22.5 - 38% are mined in the Akzhar-Sarytuma deposit (Table 1), located on the border of the Karaganda and Zhambyl regions. Manganese ores are concentrated in the northern part of the deposit. Ore deposits are confined to the very bottom of the section and are usually represented by interlaying of red-colored conglomerates, gravesites, sandstones and peroxide ores. Mineral composition of the ores: braunite, psilomelane, pyrolusite. The greatest thickness of the ore-bearing horizon (up to 50 m) was noted at the Akzhar-Sarytuma deposit. In other places, it usually does not exceed 10 m.

Table 1. Chemical composition of manganese ore from the Akzhar-Sarytuma deposit

Mn	Fe	SiO_2	MgO	Al_2O_3	CaO	P
38,7%	3,2%	23,5%	-	-	3,4%	0,002%

Zhezdy ores (Table 2) with an average manganese content of 17% are characterized by a low phosphorus content and a high silica content. Ores fall into the category of dense, hard and refractory ores. Concentrates containing more than 45% manganese can only be obtained by fine grinding (up to 0.15 mm) and using complex enrichment schemes. Also, these ores contain tenths of a percent of lead, hundredths of copper and titanium, thousandths of cobalt, molybdenum, and thallium. Barium is present (average 2.36% BaO). This deposit of manganese ores has approved reserves of about seven million tons, which are in reserve.

Table 2. Chemical composition of manganese ore from the Zhezdy deposit

Mn	Fe	SiO_2	MgO	Al_2O_3	CaO	P
16,6%	4,75%	46,5%	0,6	10,2	2,51%	0,022%

The main iron-containing component of the charge when melting silicon alloys is carbon steel fragments. The use of scrap ferrous metals is permitted only when melting alloys intended for use in iron foundries. This is due to the fact that phosphorus (>1.2%) contained in scrap ferrous metals is almost completely converted into an alloy. The use of scrap ferrous alloys or scrap contaminated with impurities of non-ferrous metals is not permitted. An exception, however, is the use of chromium steel scrap for the production of alloys containing chromium, etc. The use of long and tangled iron shavings, which impede portion feeding, as well as scrap contaminated with a large amount of oil and oxidized iron scrap, is not allowed. The use of highly oxidized scrap increases the consumption of energy and reducing agents, and scrap containing iron oxide hydrides also increases the hydrogen content of the alloy [3].

Repeated attempts to use iron ore or scrap iron instead of shavings in the restoration process were unsuccessful. In this case, to reduce iron oxide, it is necessary to increase the carbon content in the charge by approximately 20 kg per 100 kg of ore, which negates the expected improvement in the electrical resistance of the charge or the depth of the electrode. In addition, even good- quality ore contains 13 kg of slag-forming impurities per 100 kg, which leads to the conclusion that it is inappropriate to use ore (or iron ingots) in the reduction process for the production of ferroalloys [4].

Study of the influence of the composition of manganese ores from different deposits on the quality of silicomanganese. From the production data of the enterprise, 2500 kg of manganese raw materials, 810 kg of metallurgical coke, 340 kg of quartzite, and 500 kg of sinter are consumed according to approved standards for one ton of the finished product of the MnS 17 grade (according to state standard 4756-91) and 80 kg of coal concentrate. Based on this, for laboratory tests to smelt 150 g of alloy, the same components were used in the following ratio: 375 g of manganese raw materials, 121.5 g of metallurgical coke, 51 g of quartzite, 74 g of manganese agglomerate and 12 g of coal concentrate. However, with different quality of raw materials, the amount of one or another component can change for the necessary chemical reactions to occur. We compiled two charge mixtures (Table 3).

Table 3. Composition of the charge mixture in the smelting of silicomanganese using ores from different deposits (research)

Raw material component	Alloy No. 1, g Zhezdy ore	Alloy No. 2, g Akzhar-Sarytum ore
Manganese ore	375	346
Quartzite	51	51
Coal coke	113,2	113,2
Coal concentrate	14,6	13,5
Iron filings	3,75	4,5
Manganese agglomerate	81,4	74

Based on Table 3 and subsequent analysis of the research data obtained, we consider it possible to recommend the following compositions of the charge mixture for production conditions (Table 4, Fig.1).

Table 4. Composition of the charge mixture in the smelting of silicomanganese using ores from different deposits (research)

Raw material component	Alloy No. 1, g Zhezdy ore	Alloy No. 2, g Akzhar-Sarytum ore
Manganese ore	2500	2307
Quartzite	340	340
Coal coke	755	755
Coal concentrate	97	90
Iron filings	25	30
Manganese agglomerate	550	500

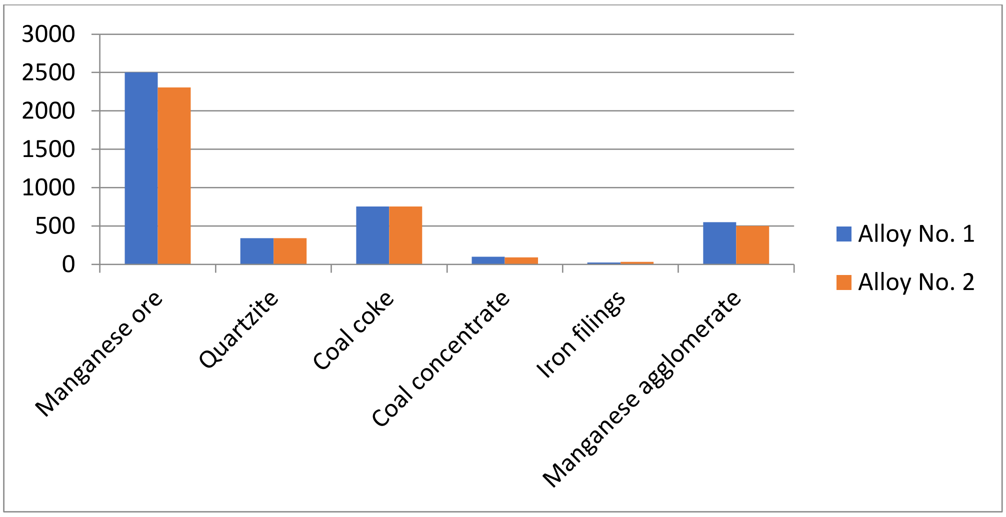

Fig. 1. – Composition of the charge mixture when smelting silicomanganese using ores from different deposits

2. Results and discussion

When comparing two alloys obtained in laboratory conditions, silicomanganese using Zhezdy manganese ore (Figure 2) showed the following:

- uneven particle size or the presence of large lumps;
- grey or black color (usually high-quality silicomanganese has a lighter color), which indicates a low-quality product.

Part of the separated alloy is necessary for chemical analysis. Quantitative and qualitative analysis was carried out by two methods: express analysis using a spectrometer, and chemical analysis for the manganese content in the alloy was used to confirm the accuracy of the results.

When conducting chemical analyses of this alloy (Table 5), a high content of impurities such as iron, sulfur and phosphorus is noted. This will affect the working properties of the alloy and the quality of steel alloying in further production.

Table 5. Chemical composition of silicomanganese using Zhezdy ore, %

Mn	Si	C	P	S
57,2	23,6	3,7	0,7	0,02

Silicomanganese, obtained using ore from the Akzhar-Sarytuma deposit (Figure 3.19) as manganese raw material, is lighter in appearance than the previous one, granular material with a metallic luster. Its chemical composition (Table 6) is similar to the composition of silicomanganese according to state standard 4756-91 grade MnS17, smelted at the enterprise.

Table 6. Chemical composition of silicomanganese using Akzhar-Sarytum ore

Mn	Si	C	P	S
65,4	16,7	2,5	0,3	0,02

Based on the results of the studies, it is clear that the quality of the alloy decreases when using manganese ore with a low content of the main component. The lower quality of the alloy also leads to a lower price when exporting products but at a lower cost. However, under current conditions, the selection of the necessary raw materials is becoming more complicated. Thus, we can talk about the use of “poor” manganese ores of the Zhezdy deposit only taking into account the possible improvement of existing raw materials by adding ore from “rich” deposits, for example, the Chiatura deposit (Georgia) with a total Mn content of 42%. This ore is currently used at Asia FerroAlloys LLP.

Studying the influence of the composition of manganese ores on the quality of silicomanganese is an important task for optimizing the process of its production and increasing production efficiency. Research has shown that the quality of silicomanganese depends on many parameters: the content of manganese, silicon, phosphorus and sulfur, as well as grain size and degree of oxidation. Also, as practice shows, ores with a high silicon content and low manganese content can lead to the formation of “plugs” in furnaces, which complicates the firing process and can reduce the quality of the product [5].

In addition, the influence of phosphorus and sulfur content on the quality of silicomanganese is also significant, since they can introduce undesirable impurities into the product. Therefore, it is necessary to conduct careful chemical analysis of manganese ores before using them for the production of silicomanganese. Thus, studying the influence of the composition of manganese ores on the quality of silicomanganese is important for optimizing the production process and increasing production efficiency. This leads to improved product quality and reduced production costs.

Conclusion

Studying the influence of the composition of manganese ores on the quality of silicomanganese is an important issue for optimizing the production process and increasing production efficiency. Silico-manganese is produced by mixing the ore with coke and silicon, then firing the mixture in a high-temperature furnace to extract the necessary elements from the raw materials. In addition, phosphorus and sulfur content also have a significant impact on the quality of silicomanganese as they create undesirable impurities in the product. Therefore, before using manganese ore in the production of silicomanganese, a thorough chemical analysis and determination of the parameters of the influence of one or another component of the ore material on the quality of the resulting ferroalloy is necessary. To determine the factors influencing the quality of silicomanganese, the chemical composition of manganese ores from the Zhezdy and Akzhar-Sarytum deposits was studied. As a result, it was determined that the quality of the resulting ferroalloys depends on:

- from the content of manganese, silicon and harmful impurities (phosphorus and sulfur);
- on grain size;
- on the degree of oxidation.

Having studied the influence of the chemical composition of manganese ores on the quality of ferroalloys, it should be noted that when using manganese ore from the Zhezdy deposit with total manganese of 16.6%, the resulting quality and grade do not meet the requirements of the state standard.

Research results have shown that the quality of the alloy decreases when using manganese ores with a low content of main components. The low quality of the alloy also makes it cheaper to export, but this reduces the cost of the alloy. However, the current situation makes it difficult to select the necessary raw materials, so it is possible to improve the existing Kazakhstani raw materials by adding ore from rich deposits.

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Information of the authors

Naboko Elena Petrovna, candidate of technical sciences, Abylkas Saginov Karaganda Technical University
e-mail: lena_nep@mail.ru

Issagulova Diana Aristotelevna, doctor of PhD, Abylkas Saginov Karaganda Technical University
e-mail: isagulovada@mail.ru

Platonova Elena Sergeevna, master of technical sciences, Abylkas Saginov Karaganda Technical University
e-mail: danilina1969@list.ru

Yudakova Valeriya Alexandrovna, master of technical sciences, Abylkas Saginov Karaganda Technical University
e-mail: lera-mlp@mail.ru

Pitirimova Tatyana Vladimirovna, master of philology, Abylkas Saginov Karaganda Technical University
e-mail: 26061984@mail.ru