KnE Materials Science
TECHNOGEN-2019
IV Congress “Fundamental research and applied developing of recycling and utilization processes of technogenic formations”
Volume 2020

Conference Paper

The Waste of the Ferroalloy Production in Russia

Vladimir Ivanovich Zhuchkov[1], Leopold Igorevich Leontiev[2], Alexandr Vladimirovich Sychev[1], Veniamin Yakovlevich Dashevsky[3], and Oleg Vadimovich Zayakin[1]

[1]Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences, 101, Amundsen street, Ekaterinburg, Russia
[2]Presidium of RAS, Moscow, Russia
[3]Baikov Institute of Metallurgy and Materials Science, RAS, Moscow, Russia

Abstract

Ferroalloys are used to change the composition and properties of ferrous and non-ferrous metals. Therefore, the volume of ferroalloy smelting corresponds to the amount of steel and other alloys produced. Currently world steel production is approximately 1630 million tons, and about 40 million tons of various ferroalloys are produced (2.5%). The structure of ferroalloy production in different countries mainly depends not on the needs of industrial enterprises, but on ore reserves. Excessive amounts of ferroalloys produced are exported, and the missing alloys are imported. In Russia silicon alloys that have no restrictions in the raw material base (44%) are the most produced, then manganese (25%) and chromium (23%) ferroalloys. The remaining ferroalloys account for 8% of production. About half of the manganese ferroalloys needed for consumption are bought abroad, and half are produced in the Russian Federation from foreign raw materials (Kazakhstan, South Africa, Gabon). The Russian Federation provides itself with chromium ferroalloys completely, and sells ~ 80%, and for their production mainly imported raw materials (~ 65%) from Kazakhstan are used.

Keywords: ferroalloy, ferrochrome, slags, production of ferroalloy.

Corresponding Author:
Alexandr Vladimirovich Sychev
ntm2000@mail.ru

Published: 31 December 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the TECHNOGEN-2019 Conference Committee.

The global structure of ferroalloy production is closely related to their global consumption and over the past decades has not undergone significant changes (Fig.) [1, 2].

Manganese ferroalloys account for the largest production volumes of ~ 44% (31% silicomanganese and 13% ferromanganese), chromium ferroalloys 30%, silicon 18% (the group of ”large” ferroalloys) and 8% of all others (the group of ”small” ferroalloys).

In Russia silicon alloys that have no restrictions in the raw material base (44%) are most produced, then manganese (25%) and chromium (23%) ferroalloys.The remaining ferroalloys account for 8% of production. About half of the manganese ferroalloys needed for consumption are bought abroad, and half are produced in the Russian Federation from foreign raw materials (Kazakhstan, South Africa, Gabon). The Russian

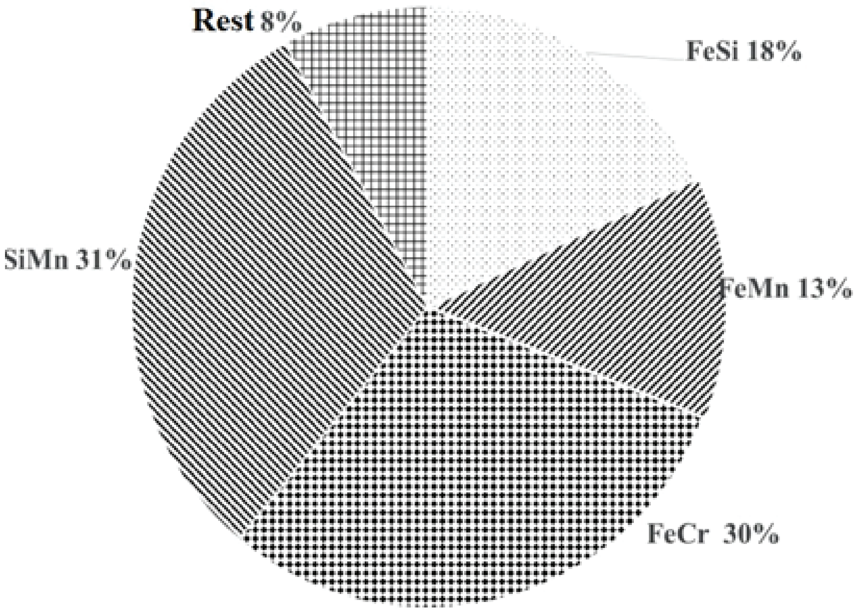

Figure 1: The global structure of ferroalloy production

Federation provides itself with chromium ferroalloys completely, and sells ~ 80%, and for their production mainly imported raw materials (~ 65%) from Kazakhstan are used.

The main of the total ferroalloys volume (~ 90%) is produced in ore heat-treating furnaces of a mine type by the carbothermic method (manganese, chromium, and siliceous ferroalloys). Waste generation in ferroalloy production occurs mainly in the form of slag, dust and sludge from gas purification, as well as in the form of "ferroalloy gas". The volume of formation of these products depends on the applied charge materials and production technology.

The main waste products are slags, the amount and composition of which depends on the production technology used [3].

Since practically no slags and dusts are formed at the ferroalloy enterprises, their volumes were calculated based on the known values of the melted ferroalloys, the slag rate and the specific amount of dust and sludge per ton of alloy.

In the literature and review materials there is a discrepancy in the number of ferroalloys produced in the Russian Federation. The article [4] indicates that the volume of all types of ferroalloys in Russia is ~ 1.1 million tons, and the publication [5] reports that more than 1.73 million tons. The authors adopted volumes according to the latest data [5]. In the production of high-carbon ferromanganese and silicomanganese by the carbothermic method, the slag ratio depending on the composition of the gangue ore and its manganese content is 1.2–1.6 and 1.1–1.3, respectively [1, 6]. The ratio of slag in the smelting of high-carbon ferrochrome and silicochrome (in a single-stage method) varies from 0.9 to 1.1; upon receipt of silicon alloys (ferrosilicon) is, depending on the alloy grade, 0.05–0.1 (0.1 adopted) [6].

After crystallization and cooling, the slags of the production of ferroalloys by the carbothermic method do not crumble and remain in lumpy form, without requiring additional stabilization measures [3]. Estimation of the volume of dust and sludge from gas cleaning can be done on the basis of dust generation in ferroalloy production. The amount of dust and sludge in the production of ferromanganese in blast furnaces is about 10 and 100 kg / t of alloy, respectively. Dust formation during the production of high-carbon ferrochrome in electric ore-thermal furnace is about 50–150 kg / t, and silicon alloys (depending on the composition) are in the range of 60–150 kg / t [3].

The volume of slag, dust, and sludge formed during the production of ferroalloys is quite large — about 1.2 million tons/year only for the group of “large” ferroalloys (tab.).

Table 1: Annual production of slag, dust and sludge

Alloys	Volume of ferroalloys, th. tonnes	Slag		Dust		Sludge	
		Ratio (avg.)	Mass, th. tonnes	Output, kg/ t	Mass, th. tonnes	Output, kg/ t	Volume, th. tonnes
Silicomanganese	291	1.2	349	10	2.9	100	29.1
Ferromanganese	167	1.4	233	10	1.7	10	16.7
Chrome alloys	436	1.0	436	150	65.0	-	-
Silicon alloys	839	0.1	84	120	10.1	-	-
All	1733		1102		79.7		45.8

* Data for the group of ”large” ferroalloys, comprising ~ 90% of production

The chemical and granulometric compositions of these wastes are diverse and depend on the type of ferroalloys. Ferrosilicon slag contains 15–25% metal inclusions, about 32% SiO_2, 18% CaO, and 16% Al_2O_3. Gas treatment dust consists of 85–98% amorphous SiO_2. In slags of carbon ferrochrome is,%: 4–5 Cr_2O_3; 40–48 MgO; 40–45 SiO2; 15-18 Al_2O; in dusts of gas purification 20–40% Cr_2O_3. High-carbon ferromanganese slags contain a significant amount of manganese oxides (15–18% MnO), 35–42% CaO, 32–36% SiO_2, 16–25% MnO, 30–35% CaO, 18–25% in dust and gas purification sludges SiO_2. Ferrosilicon manganese slag is also rich in manganese (15–17% MnO) and also contains 48–50% SiO_2 and 17–18% CaO.

There are fewer problems with slag collection and storage. To capture dust and sludge requires the construction of expensive gas treatment systems. The organization of work with finely dispersed material is more difficult compared to lumpy slags. One of the problems of dust collection in the exhaust gases from furnaces is a significant difference in the designs of ferroalloy furnaces, which in their design are open, half-closed, closed and tight. For the most efficient dust collection and elimination of dilution of ferroalloy gas with air, it is advisable to use closed and tight furnaces [3].

Dusts from the production of ferro- and silicomanganese, containing a significant amount of manganese and having a size of 1–40 μm, are rationally used after pelletizing as an additive to the ore part of the charge.

The dust captured in gas treatment plants from the production of high-carbon ferrochrome is dispersive and, like the slags of high-carbon ferrochrome, have high refractoriness. They can be used in the manufacture of lining materials [7].

Dust production of silicon ferroalloys is a valuable product - silica fume, which can be used in the production of high-quality concrete for high-rise construction and hydraulic structures [8].

Slags from the production of various ferroalloys differ in their chemical and particle size distribution, have diverse technological characteristics and are used in many industrial fields [6]. Ferroalloy slag contains the kings of the finished alloy and unreduced oxides of the main elements of the alloys. In addition, they have strength, abrasion, and fire resistance [8].

Currently, the processing and using of ferroalloy waste is carried out as follows [6, 9, 10]. Slags of manganese ferroalloys process with crushing, granulation of liquid slags, separation of metal particles from it, and processing for slag products. Slag from smelting of silicomanganese is used mainly for processing on crushed stone after crushing or granulation. The slag sand formed during crushing (fraction 0–5 mm), containing up to 20% of the kings of the alloy, is used to obtain agglomerate. Slag of high-carbon ferromanganese and metallic manganese are used for direct alloying of steel. Fine fractions of these slags may be subjected to separation (pneumatic separation and water precipitation methods).

Slag of carbon ferrochrome is highly durable and is used in the form of crushed stone in road construction. These slags are subjected to primary crushing up to 120 mm followed by magnetic separation, and then recrushing up to 70 mm and screening with dispersion into fractions. Slags of low- and low-carbon ferrochrome when cooled, they crumble into powder with a particle size <0.1 mm, in which there are metal beads. Slag powder is used for liming acidic soils, the manufacture of self-hardening building materials and household chemicals. Self-decaying slags are first cleaned of the metal component. For separation, an air separator and magnetic separators of weak and strong fields are used.

Ferrosilicon slag contains from 40 to 60% of metal kings and scrap of ladle residues, as well as up to 15% of silicon carbide. The processing of such slags consists of crushing to fractions <0.1 mm and sieving. Extraction of metal in metal concentrate is 75%. The bulk of the slag is reused in the production cycle.

To improve the situation on the formation and use of ferroalloy production wastes in the Russian Federation, it is necessary to organize:

- maximum capture and collection of industrial waste (dust, slag and sludge);

- obtaining reliable information about the complex of their physico-chemical characteristics

(chemical and fractional composition, humidity, etc.);

- determination of a rational way of involving each technogenic material in production.

Funding

This work was carried out according to the state assignment for IMET UB RAS by the Program of Fundamental Research of State Academies and according to the project of the Russian Foundation for Basic Research No. 18-29-24027.

References

[1] Zhuchkov, V. I., *et al*. (2007). *Technology of Manganese Ferroalloys. Part 1. High carbon ferromanganese*. Yekaterinburg: Ural Branch of the Russian Academy of Sciences.

[2] Zhuchkov, V. I., Leontiev, L. I. and Dashevsky, V. Y. (2018, October-November). The State and Development of Metallurgy of Ferroalloys in Russia. Presented at *Proceedings of Prospects for the Development of Metallurgy and Mechanical Engineering using Completed Fundamental Research and R&D:* FERROALLOYS, *Yekaterinburg, Russia*. Yekaterinburg: Alpha Print.

[3] Zhdanov, A. V., *et al*. (2014). Ferroalloy Waste Management. *Steel,* issue 3, pp. 92–98.

[4] Boyarko, G. Y. and Khatkov, V. Y. (2018). Commodity Flows of Ferroalloys in Russia. *Ferrous metals*, issue 3, pp. 60–63.

[5] Analytical group "MetalResearch LLC". The market of ferroalloys in 2017–2018: production in Russia. *Metal Research.* Retrieved January 14, 2019 from http://www.metalresearch.ru/ferroalloys_market_2017--2018.html.

[6] Smooth, V. A., *et al*. (2004) *Design and Equipment of Electric Steelmaking and Ferroalloy Workshops*. Dnepropetrovsk: System Technologies.

[7] Kashcheev, I. D., *et al*. (2012, June). The Main Characteristics of Slag and Dust Generated in the Production of Ferrochrome. Presented at *Proceedings*

of Fundamentals of Technology processing and recycling of industrial waste, *Yekaterinburg, Russia*. Yekaterinburg: LLC “UIPC”.

[8] Snitko, Y. P. (2000). *Production of Ferrosilicon*. Novokuznetsk: Kuznetsk ferroalloys.

[9] Shevchenko, V. F. (2013). *Ferroalloy Production: Factories, Workshops, Electric Furnaces*. Kharkov: Around the Color.

[10] Mysik, V. F. and Zhdanov, A. V. (2014). *Design and Equipment of Electroferroalloy Workshops*. Yekaterinburg: UrFU.