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Calculation of material and heat balance of melting refined ferrochrome using the new complex reducing agent of aluminosilicochrome

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ABSTRACT
The article presents the results of calculating the material and thermal balances of refined ferrochrome (RFeCr) smelting using a new reducing agent. According to the results of the material balance and enlarged laboratory tests, it was found that when the traditional reducing agent silicochrome (FeSiCr48) is completely replaced with a complex alloy of aluminosilicochrome (FeAlSiCr), a metal of the following chemical composition can be obtained, %: Cr 66.8-69.1; C 0.21-0.29, Si 1.91-2.02. The composition of FeAlSiCr for silicon and chromium is the same as that of FeSiCr48, but additionally contains Al. In the process of obtaining refined ferrochrome, this aluminum passed into slag and changed its phase composition. In the $CaO-MgO-Al_2O_3-SiO_2$ system, the phase composition of the slag moved from the region of bicalcium silicate to the region of helenite, which allowed to obtain non-crumbling slags. In addition, due to the high activity of FeAlSiCr (where, $\sum = Si + Al \geq 60\%$), the basicity of the slag was maintained at the level of CaO/SiO_2 = 1.6-1.7, against to 2. Based on the results of the heat balance calculation, it was found that the use of a complex FeAlSiCr reducing agent leads to a 24% reduction in electricity consumption. The low power consumption compared to the classical technology is explained by the presence of two active elements in the FeAlSiCr, silicon and aluminum. Thus, the amount of heat introduced by exothermic reactions prevails with the heat introduced by electrical energy.
Keywords: refined ferrochrome, aluminosilicochrome , reductant, ferroalloy, material balance.

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Introduction

The production and use of a complex aluminosilicochrome alloy is a complex scientific and technical problem associated with the development of effective technological processes for their production and the rationalization of alloy compositions. Therefore, for the development of the aluminosilicochrome alloy, a scientific base was created based on the regularities of the state diagrams of the Fe-Al-Si-Cr system, and laboratory and enlarged laboratory tests were carried out in an ore-thermal furnace with a transformer power of 200 kVA to obtain the alloy itself with its further use at smelting of refined ferrochrome (RFeCr).

Considering the disadvantages (scattering of slags, an increase in the basicity and multiplicity of the slag, as well as the consumption of specific electricity to obtain 1 ton of metal) of the current technology for smelting refined ferrochrome at the Abishev Chemical and Metallurgical Institute, work was carried out to replace the traditional reductant ferrosilicochrome with a new alloy - aluminosilicochrome. The use of aluminosilicochrome as a reducing agent instead of ferrosilicochrome is due to the sufficient content of silicon and aluminum in it. The presence of chemical compounds and solid solutions of iron, silicon and aluminum in aluminosilicochrome should significantly reduce the losses of silicon and aluminum for oxidative processes when interacting with atmospheric oxygen [1-4].

In comparison with the traditional method, the developed technology for smelting refined ferrochrome has the following advantages:

- increasing the degree of extraction of chromium into metal;
- establishing the value of the basicity of the slag and, as a result, reducing the consumption of lime and reducing the frequency of slag;
- stabilization of final slags from spillage.

At the Abishev Chemical and Metallurgical Institute research was carried out on the smelting of refined ferrochrome using a complex reductant aluminosilicochrome in a refining-type electric furnace with a transformer power of 300 kVA [5].

In general, the process of smelting RFeCr using the new reducing agent was characterized by stable electrode fit. The use of aluminosilicochrome has led to the intensification of processes in the furnace. Fluctuations in the current load were noted closer to the time the alloy was tapped from the furnace, when metal accumulated in the furnace bath. The reaction zone was characterized by a high temperature (temperature of white heat, over 1200 °C).

During the campaign, 29 heats were carried out. It has been established that when using a new complex reductant aluminosilicochrome metal and slag with the following chemical compositions are obtained, %: Cr 66,8-69,1; C 0,21-0,29, Si 1,91-2,02 (metal); Cr_2O_3 4,13-7,94; SiO_2 20,37-26,41; Al_2O_3 18,24-21,97; CaO 27,87-35,8; MgO 11,95-18,26 (slag). The resulting metal in terms of the content of the main elements corresponds to the grade composition of low-carbon ferrochrome (GOST 4757 - 91, ISO 5448 - 81). Despite the relatively high percentage of carbon (0,52 %) in the composition of the new reducing agent aluminosilicochromium, its content in the final metal (RFeCr) corresponded to the permissible limits.

The use of the FeAlSiCr alloy contributed to the stabilization of the structure of self-disintegrating slags from disintegration due to the movement of their phase region from larnite to the helenite region. The samples of the obtained slags were kept in natural conditions for several months and their resistance to spillage was visually established.

In industrial furnaces, about 5,2 MW of electricity is consumed to smelt 1 ton of low-carbon ferrochrome. Given the large heat losses and structural features of the experimental 300 kVA furnace, it is impossible to achieve this figure. Therefore, in order to issue an objective assessment of the specific power consumption, appropriate calculations were carried out.

The aim of this work is to calculate the material and heat balances of refined (low-carbon) ferrochrome smelting using a complex reductant aluminosilicochrome. The tasks of calculating the material balance are to determine the consumption of a complex reductant aluminosilicochrome and to compare the results of smelting refined ferrochrome by traditional and proposed methods. Another task of the calculations is the theoretical determination and comparison of the specific consumption of electrical energy.

Calculated part

The material balance was calculated using the method of F.P. Edneral and A.F. Filippov [6].

To carry out experimental studies on the development of a technology for smelting refined ferrochrome, chromium ore of the Donskoy GOK was used, as a fluxing material - burnt lime, in which the content of calcium oxide is 75-80 %. The chemical compositions of the charge materials are shown in tables 1-3.

Table 1 – The chemical composition of chrome ore

Chrome ore, %									
Cr_2O_3	SiO_2	CaO	MgO	Al_2O_3	FeO	Fe_2O_3	S	P	other
45,09	6,44	1,30	14,29	8,99	10,42	2	0,024	0,02	3,21

Table 2 – The chemical composition of the complex alloy FeAlSiCr

FeAlSiCr (aluminum-chrome-silicon), %					
Cr	Si	Al	C	Ca+Mg	Fe
13,9	51,07	21,66	0,51	0,5	9,97

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