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ISSN 0543-5846
METABK 61(2) 367-370 (2022)
UDC / UDK 536.46:661.183.2/662.613:66.094.1/546.26:621.783=111

MELTING OF HIGH-CARBON FERROCHROME USING COAL OF THE SARYADYR DEPOSIT

Received – Primljeno: 2021-09-04
Accepted – Prihvaćeno: 2021-11-20
Preliminary Note – Prethodno priopćenje

The article presents the results of large-scale laboratory tests on the smelting of high-carbon ferrochrome with the replacement of parts metallurgical coke with high-ash coal from the Saryadyr deposits. According to the test results, it can be stated that the optimal percentage of replacing metallurgical coke with high-ash Saradyr coal is 30 – 40 %. During a large-scale laboratory test, it was also established that the cost of the alloy was reduced due to the partial replacement of expensive coke and removes the fluxing component of quartzite from the charge composition, and improves the TPE of the high-carbon ferrochrome smelting process.

Keywords: chrome ore, high ash coal, reduction, carbonaceous reductant, thermal ore furnace

INTRODUCTION

The branch of production of chromium alloys is developing intensively, since they are widely used in the smelting of stainless and alloyed steel grades. Improving the quality of products is one of the most important problems of world ferrochrome producers, which leads to the search for ways to improve and reduce the cost of existing technologies for producing chromium alloys. One of the ways to solve the problem is to search for new sources of carbon-containing raw materials [1-5].

Most of the expensive coke used as a reductant in the smelting of high-carbon ferrochrome is imported from China and Russia. In this regard, for ferroalloy plants in Kazakhstan, it is necessary to look for new types of domestic reductants with a low cost and appropriate chemical composition. Another topical issue is the study and assessment of the suitability of carbon-containing materials as reducing agents.

Scientists of the Zh. Abishev Chemical-Metallurgical Institute (CMI) are developing technologies for smelting manganese, chromium and new types of complex ferroalloys, where high-ash coals are used. The Institute is actively promoting the idea of involving power-generating coals in the production of ferroalloys. Within the framework of program-targeted financing of scientific activities on the topic: «Development of technology for the use of medium- and high-ash reductants in the smelting of manganese and chromium ferroalloys», the technological mode of the process of smelting carbonaceous ferrochrome with the use of high-ash coals of the Saryadyr deposit was studied and a large-scale laboratory test was carried out to smelt high-carbon ferrochrome [6-14].

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RESEARCH METHODOLOGY

To conduct semi-industrial tests for smelting high-carbon ferrochrome, trial sampling and preparation of chrome ores, coke and high-ash coals of the Saryadyr deposit were carried out:

- fractionated chrome ore of the Kempirsay deposit in the amount of 2 000,00 kg with a particle size of 10-60 mm;
- carbonaceous reducing agents, consisting of 300,0 kg of coke and 400,0 kg of coals from the Saryadyr deposit with a total weight of ≈ 700 kg with a fraction of 10 - 40 mm.

The above-mentioned charge materials were averaged and subjected to chemical analysis. The chemical compositions of all charge materials (Table 1), as well as the technical compositions of coke and high-ash coal (Table 2) have been determined.

To carry out semi-industrial tests of the technology for smelting chromium ferroalloys, an RPZ-300 kVA ore-thermal furnace was prepared. An ore-thermal furnace with a transformer capacity of 300 kVA has two graphite electrodes with a diameter of 200 mm (Figure 1).

The furnace is single-phase, two-electrode, equipped with a 300 kVA transformer. The characteristics of the furnace transformer are shown in Table 3.

The furnace transformer has 6 steps of the secondary voltage (on the low side) from 18 to 50 V. The maximum current in the electrode is 6 000 A. The transformer on the high side is supplied with a voltage of 380 V.

Figure 1 Ore-thermal furnace RPZ-300 kVA

Table 1 **Chemical composition of materials for smelting ferrochrome / %**

Material	Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	CaO	Fe_2O_3	S	P
Chrome ore	50,15	10,82	7,38	7,28	19,41	0,78	3,44	0,018	0,01
Coke ash	-	-	48,9	20,17	-	3,37	-	0,088	0,006
Ash of Saryadyr coal	-	-	63,6	34,0	0,03	0,04	2,0	0,19	0,005

Table 2 **Technical composition of reducing agents / %**

Reducing agent	A_c / %	W_c / %	V_L / %	C / %
Saryadyr coal	42,3	2,04	17,37	38,2
Coke	15,92	2,50	0,19	81,36

Table 3 **Characteristics of a 300-kVA furnace transformer**

Step number	Power / kVA	Primary voltage / V	Primary current / A	Secondary voltage / V	Secondary current / A
1	108	380	284	18	6 000
2	144	- / -	379	24	- / -
3	192	- / -	505	32	- / -
4	228	- / -	600	38	- / -
5	264	- / -	695	44	- / -
6	300	- / -	789	50	- / -

The voltage steps are switched from the high side in automatic and manual modes. The working current in the electrode is regulated according to the ammeter from the high side with a limit of up to 500 A. The lining of the wall part of the bath of the furnace for smelting chromium alloys was made of fireclay bricks. The height of the hearth of the furnace is 300 mm; it is coked up by 200 mm with an electrode mass that conducts an electric current [9, 14-15].

The furnace design is rectangular, 1 850 mm long, 1 450 mm wide, 1 000 mm high. The furnace bath depth is 500 mm. The lining of the furnace is made of refractory fireclay bricks 300 mm thick. The hearth of the furnace consists of a 300 mm lining layer and a 200 mm thick electrode mass. The internal dimensions of the furnace were as follows: length - 1 250 mm, width - 850 mm. The arrangement of the electrodes relative to the furnace body is asymmetric: the distance from the electrodes to the taphole was 250 mm, and to the rear wall of the furnace - 400 mm. The distance between the electrodes was 250 mm. The temperature in the reaction zone is provided by an arc discharge between graphite electrodes with a diameter of 200 mm. The electric furnace was heated for 12 hours on a coke bed as a conductor of electric current and preservation of the hearth. Electric mode of high-carbon ferrochrome melting on RPZ-300 kVA furnace: secondary voltage 32 V, current strength 500-600 A (on the primary winding), which corresponds to the 3rd and 4th stages of the transformer. Smelting was carried out in a continuous manner with a closed top, with charging the charge in small portions as the top shrinks. The tapping of metal and slag was carried out through the taphole 4 times per shift into cast iron molds. The taphole was opened with an iron rod or electric burner. The metal and slag of each discharge were weighed, after which samples were taken for chemical analysis.

During the semi-industrial tests, such indicators of melting were monitored as the behavior of the top, the presence of holes, the discharge of the charge, the stability of the current load, the landing of the electrode, the temperature of the metal and slag at the outlet, the productivity of the furnace, the chemical composition of the metal, the weight of an individual melt, and the slag ratio. Based on the results of the chemical analysis of the smelting products, the composition of the charge was adjusted and the degree of extraction of chromium was calculated.

RESULTS RESEARCH

A mixture of coke and Saryadyr coal was used as a reducing agent. Coal was used to smelt high-carbon ferrochrome in order to replace part of the expensive coke and improve the gas permeability of the charge.

Two large-scale laboratory tests were carried out to smelt high-carbon ferrochrome with different ratios of reducing agents: 1 - with the replacement of coke with Saryadyr coal in the amount of 30%, taking into account the content of solid carbon in coal and in coke, 2 - with replacing coke with Saryadyr coal in the amount of 40 %, taking into account the content of solid carbon in the charge.

The replacement of coke with coal by the amount of solid carbon up to 30-40 % led to a decrease in the melting point of the slags due to the increased SiO_2 content in the slag. It should be noted that the high ash content of coal over 40% and the content in the ash over 60% of silica make it possible to remove quartzite from the composition of the charge.

In the bath of an ore-thermal furnace during the smelting of high-carbon ferrochrome, an ore layer is formed (a mixture of slag and partially melted pieces of ore) and favorable conditions are created at the border with the metal to limit the reduction of silicon and saturation of the metal with carbon.

The reduction of silicon, aluminum and other impurities mainly occurs in the lower part of the furnace top with the formation of suboxides, liquid and gaseous products. Suboxides are retained and re-reduced in the zone of electric arcs, and gaseous products are also retained in this zone with the formation of carbides or condensation in the liquid alloy.

Stabilization of the metal composition and process is achieved with a certain excess of carbon in the charge.

The composition of the charge mixtures (heads) are shown in Table 4. The duration of the tests was 3 days, with the release of the alloy every 2 hours. During the testing period, no disruptions in the technological process were observed, proceeding without any special deviations, as in the traditional technology for obtaining high-carbon ferrochrome. The furnace top was operated in a stable electrical mode and was accompanied by a uniform release of gases. The landing of the electrode is firm and deep. No negative influence on the general course of the process was observed during the application of the new reducing agent. The replacement of coke with coal in terms of the amount of solid carbon from 30 % to 40 % led to a decrease in the melting point of the slags due to the increased SiO_2 content in the slag. The process was accompanied by a high transition of the main elements of the charge into metal.

With an increase in the percentage of coal in the reducing mixture in the metal, there is a slight decrease in the chromium content by 0,5 %. The use of coal in the charge is justified, first of all, in order to replace expensive coke, and at the same time to reduce the fusibility of the charge, which is an important factor for improving the technical and economic indicators (TEI) of the process. In the course of testing the technology for smelting high-carbon ferrochrome on the RPZ-300 kVA furnace, the possibility of replacing coke with coal from the Saryadyr deposit from 30 % to 40 % in terms of solid carbon was shown. In general, the results confirm the possibility of obtaining ferrochrome FKh800 in accordance with GOST 4757-91. The average chemical composition of the resulting alloy and slag is presented in Table 5.

Table 4 **Composition of charge mixtures**

Charge composition / kg	Options	
	1	2
Chrome ore	100	100
Coke	15,4	12,3
Coal	29,67	39,55

Table 5 **Average chemical composition of the resulting alloy and slag / %**

Option	Metal						
	Cr	Fe	Si	C	S	P	
1	69,6	18,54	1,079	7,88	0,009	0,029	
2	69,1	18,88	1,12	7,78	0,03	0,012	
	Slag						
1	Cr_2O_3	FeO	SiO_2	CaO	Al_2O_3	MgO	P_2O_5
2	5,93	0,70	35,28	1,72	17,06	39,3	0,007

CONCLUSIONS

Based on the results of the analysis of semi-industrial tests, the optimal percentage of replacing traditional coke nut with Saryadyr coal was determined from 30 % to 40 %. The MgO/Al_2O_3 ratio in the slag is 2,35 - 2,64. A total of 1 890 kg of chrome ore, 381,64 kg of coal, 253,76 kg of coke were consumed. 825,1 kg of FKh800 ferrochrome were smelted. Slag multiplicity was 1,12 - 1,15. The chromium recovery was 88,4 %. Average chemical composition of the alloy / %: Cr – 69,39; Fe – 18,69; Si – 1,12; C 7,82; P – 0,025 and S – 0,011.

The use of high-ash reducing agents for smelting high-carbon ferrochrome in industrial conditions reduces the cost of the alloy due to partial replacement of expensive coke and removes the fluxing component of quartzite from the charge composition, and improves the TEI of the high-carbon ferrochrome smelting process.

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Note: The responsible for England language is Gauhar Yerekeyeva, Temirtau, Kazakhstan.