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DEVELOPMENT OF CARBON FERROCHROME SMELTING TECHNOLOGY USING HIGH-ASH COAL

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This article presents the results of experimental tests using coal from the Saryadyr deposit as a reducing agent for the smelting of carbonaceous ferrochrome. Large-scale laboratory tests were carried out on the smelting of carbonaceous ferrochrome in an ore-thermal furnace with a capacity of 200 kV · A.
X-ray diffraction analysis of the obtained alloy and slag on a diffractometer was carried out. The presence of forsterite $2MgO·SiO_2$ and magnesitochromite $Cr_2Fe_{0,2}Mg_{0,8}O_4$ in the slag was revealed, as well as the FeCr compound and the absence of silicide compounds.
The optimal percentage of replacing traditional coke with coal up to 30% (by weight) has been found, which can significantly reduce the specific consumption of quartzite in the charge.

Key words: carbonaceous ferrochrome, high-ash coal, chemical composition, coal-thermal process, X-ray diffraction (XRD).

INTRODUCTION

A widespread and traditional method of obtaining carbonaceous ferrochrome is the use of metallurgical coke as a reducing agent. There are also known experiments with the use of various carbon reducing agents for the electrothermia of chromium - containing ferroalloys. Many works have shown the possibility of using semi-coals obtained from coals by different methods [1], mineral coals [2] (brown, stone, lean and fatty) with a small ash content and volatile substances.

Large ferroalloy plants in Kazakhstan cover their needs for metallurgical coke by importing from China and Russia, thereby becoming economically dependent partners. In this regard, it is relevant to use alternative carbon reducing agents, instead of expensive and scarce coke. The use of coal in Central Kazakhstan is seen as promising both in terms of reserves and technical and economic indicators. Scientists of the CMI named after Zh.Abishev are actively developing the idea of involving Kazakhstan's coals in the metallurgical redistribution. Impressive resultshave been achieved in this direction: new technologies have been developed, technological tests have been carried out in industrial conditions, experimental batches have been developed, security documents have been obtained [3-8].

Taking into account the results of laboratory smelting, technological studies of the process of obtaining carbonaceous ferrochrome using high-ash coals instead of a part of traditional coke were carried out on an enlarged laboratory arc single-phase electric furnace with a graphite conductive base with a transformer capacity of 200 kV·A. The main objective of the study was to provide partial replacement of coke with high-ash coal with a continuous stable easily adjustable slag regime.

RESEARCH METHODOLOGY

For large-scale laboratory studies, the selection and preparation of samples of chromium ore from the Aktobe deposit of the Kempirsay massif, coke, quartzite and high-ash coals were carried out to study their physico-chemical characteristics and conduct smelting with a total weight of 2 500,0 kg. The chemical compositions of all charge materials, as well as the technical compositions of coke and high-ash coal were determined. All charge materials were averaged and subjected to chemical analysis. The qualitative characteristics of the charge materials are given in Tables 1 and 2.

The calculation of the composition of charge materials for the smelting of high-carbon ferrochrome consisted in determining the ratio between the components of the charge, which ensures the production of ferrochrome of a given composition, i.e. the FH800 grade. A fluxing material, quartzite, was used to regulate the course of the process.

For various ferroalloys (ferrosilicon, silicocalcium, ferromanganese, etc.), the proportion of reducing agent fumes on the grate is from 5 to 30 %. A higher carbon monoxide of the reducing agent is observed in the slag-free processes of obtaining elements with a higher affin-

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

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 high-ash coal	-	-	96,72	0,84	0,77	0,89	0,67	-	-

Table 2 **Technical composition of carbon reducing agents**

Name of materials	A_c / %	W_c / %	V_L / %	C / %
Coal Saryadyr	42,3	2,04	17,37	38.2
Coke	15,92	2,50	0,19	81,36

Figure 1 The process of smelting a carbon ferrochrome in an ore-thermal furnace with a transformer capacity of 200 kV·A

ity for oxygen: silicon, calcium, aluminum, etc. [9-15]. Therefore, when calculating the optimal composition of the charge mixture for smelting carbonaceous ferrochrome, the excess carbon was taken at the lower limit – 5 % of the stoichiometry. In the smelting process, 4 variants of charges were used: 1 - without replacing coke, 2 - with replacing coke, equivalent to the content of solid carbon, with coal in an amount of 10 %, 3 - replacing coke with coal by 20 %, 4 - with replacing the traditional reducing agent with the studied one by 30 %.

Melting was carried out in a continuous way, with the charge being loaded in small portions as the grate shrank, with the periodic release of metal every 2 hours into cast-iron mills. The process was characterized by a hot stroke and a stable regime. Metal and slag were actively leaving the furnace, which indicates a high temperature in the crucible cavity. After each release, the metal and slag were weighed and samples were taken for chemical analysis. The process of smelting carbonaceous ferrochrome in an ore-thermal furnace with a transformer capacity of 200 kV·A is shown in Figure 1.

RESULTS RESEARCH

The replacement of coke with coal by the amount of solid carbon up to 30 % led to a decrease in the melting point of the slag due to the increased content of SiO_2 in the slag. It should be noted that the high ash content of coal of more than 40 % and the content of more than 60 % silica in the ash can significantly reduce the specific consumption of quartzite. In the course of large-scale laboratory tests, the optimal percentage of replacing traditional coke nut with Saryadyr coal was found - 30 % is equivalent to the content of solid carbon. In this case, quartzite is completely removed from the composition of the charge.

The ratio of MgO / Al_2O_3 in the slag is 2,35 - 2,64. The concentration of phosphorus in the alloy averaged 0,026 %. In total, 1,680 kg of chrome ore, 339,24 kg of coke, 225,56 kg of coal and 69,85 kg of quartzite were consumed. 733,42 kg of ferrochrome FX 800 was smelted. The slag multiplicity was 1,08 - 1,12. The degree of chromium extraction was 85,2 %. The main indicators of the experienced company are shown in Table 3.

Table 3 **Main indicators of experimental ferrochrome FX800 smelts**

Indicators	Variants			
	1	2	3	4
Charge composition / kg:				
Chrome ore	100,0	100,0	100,0	100,0
Coke	23,35	21,03	18,6	5,4
Coal	-	9,89	19,79	29,67
Quartzite	7,77	5,05	2,33	-
Received metal / kg	183,0	168,1	177,1	205,12
Average chemical composition of the metal / %				
Cr	70,69	69,8	69,7	69,6
Fe	17,89	18,02	18,41	18,54
Si	0,74	0,87	1,03	1,079
C	8,02	7,89	7,96	7,88
P	0,028	0,021	0,027	0,029
S	0,01	0,008	0,007	0,009
Average chemical composition of slag / %				
Cr_2O_3	6,29	6,21	6,12	5,93
FeO	0,69	0,68	0,6	0,70
SiO2	35,27	35,28	36,01	36,28
CaO	1,91	1,87	1,78	1,72
Al_2O_3	15,31	15,9	16,35	17,06
MgO	40,51	40,02	39,13	39,3
P_2O_5	0,005	0,006	0,005	0,007
Slag received / kg	197,64	184,24	196,23	229,73
The multiplicity of slag	1,08	1,096	1,108	1,12

In order to determine the phase composition of the resulting alloy and slag, an X-ray diffraction analysis was performed on an Empyrean Malvern Panalytical diffractometer. The results of XRD analysis of the resulting alloy and slag are shown in Figures 2 and 3. The study showed that forsterite $2MgO·SiO_2$ and magnesi-

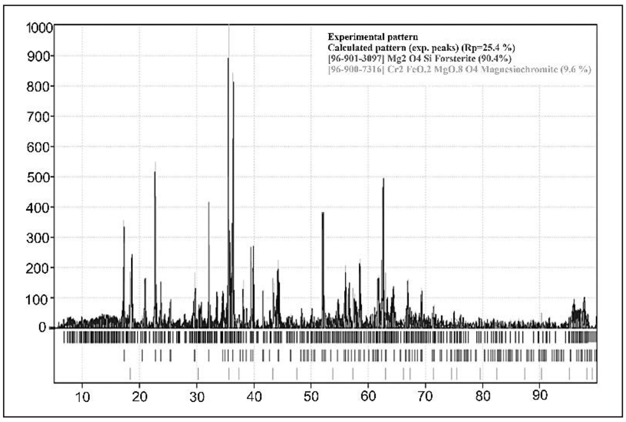

Figure 2 XRD of ferrochrome slag

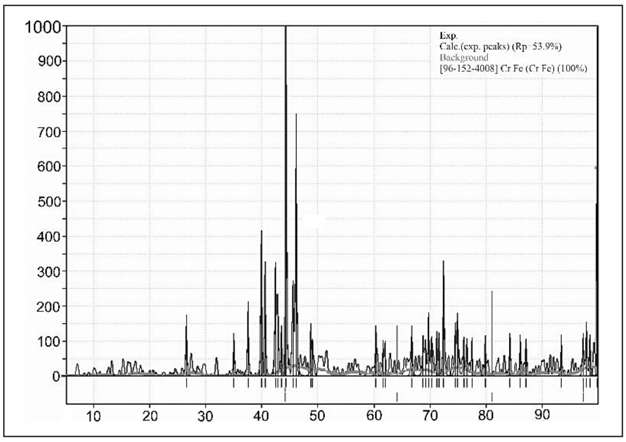

Figure 3 XRD of the alloy

ochromite $Cr_2Fe_{0,2}Mg_{0,8}O_4$ are present in the slag. A FeCr compound was found in the metal, there are no silicide compounds in the alloy, which indicates a low silicon content.

CONCLUSIONS

In a 200 kV·A ore-thermal furnace, the principal possibility of obtaining a standard grade of carbonaceous ferrochrome using high-ash coal from the Saryadyr deposit has been established. The resulting alloy in chemical composition corresponds to the FH800 brand. The use of high - ash coal gives a positive economic effect by reducing the cost of the alloy.

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Note: The responsible for England lan-guage is Gauhar Yerekeyeva, Temirtau, Kazakhstan.