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INDUSTRIAL SMELTING TESTS AND ORGANIZATION OF PRODUCTION OF FERROSILICON ALUMINUM (FSA) IN KAZAKHSTAN

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Preliminary Note – Prethodno priopćenje

Results of the industrial tests on production development of ferrosilicon aluminum alloy are showed. The made tests on smelting of ferrosilicon aluminum in electric furnaces with 1,2, 5 and 9 MVA showed a basic possibility to receive alloy of FS55A15, FS55A20 and FS65A10 grades with using of the carbonaceous raw materials in Saryadyrsky and Ekibastuz coal fields. The optimum parameters of the smelting process of FS55A15, FS55A20 and FS65A10 alloys were defined at the Ekibastuz mini-plant and "KSP Steel" LLP. The average power consumption varied within the interval of 9,1 - 12 MWh per 1 ton of alloy depending on a smelting grade of alloy. Increase in aluminum content in alloy composition might be with the rising in ash level of carbonaceous raw materials. The smelting process is characterized with hot furnace condition and active release of alloy.

Key words: FSA, ore-thermal smelting, high-ash coals, industrial tests, Kazakhstan.

INTRODUCTION

About 30 billion tons of various types of mineral resources are annually taken from Earth's deep interior. Their considerable part is not included in the finished market products. Consumption of the mineral and energy resources leads to formation of the huge waste accumulated as dumps of overburdens, slags, ash residues, etc. More than a half of world coal resources are high-ash which might be as the cheap raw materials to receive the complex alloys.

The Kazakhstan scientists of Abishev Chemical-Metallurgical Institute are developing the new types of complex ferroalloys produced from high-ash coals (carbonaceous rocks) and dradge. In this direction till 2 000 the operations to develop technology of the receiving of complex alloys were performed [1-4].

Now Abishev Chemical-Metallurgical Institute is one of the scientific institutions in Kazakhstan which strenuously advancing the idea to involve power-generating coals in ferrous metallurgy [5-7]. Today one of the perspective methods to receive the complex alloys from the coal industry waste is a smelting technology of ferrosilicon aluminum (FSA). Its production is based on the carbothermal renewal of a mineral part of high-ash coals, carbonaceous rocks and quartzite without using of coke in open ore-thermal furnaces [8, 9]. Smelting of FSA is characterized with the continuous nonslagging process with a periodic release of alloy for each 2 - 2,5 h. Amount of oxycarbide slag with metal shots does not exceed 3 - 5% of the restored metal mass. FSA is used as a deoxidizing agent to produce the quiet and low-alloyed steel grades in converters and electric furnaces and also as a metal reducer in a metallothermy [10]. The branded and chemical composition of FSA is regulated with Technical Specification No. 14-5-233-99. In ferrous metallurgy the steel-smelting production is a key user of silicon and aluminum. In the world about 1,6 billion tons of steel are annually smelted [11]. The using of silicon and aluminum in the world metallurgical industry might be estimated within more than 5 and 1,5 million tons, respectively, in terms of pure metal. In order to receive the specified amount of silicon and aluminum a considerable volume of pure natural raw materials is used such as kaolinite, quartz, bauxite and coke, and also over 110 bln kWh of electricity.

In order to obtain traditionally the quiet and alloyed steel grades in steel-smelting processing the ferrosilicon of FS65, FS75 grades and primary or secondary aluminum with 80 – 85 % of aluminum content are applied. Thus the technologies of their receiving are power-intensive, demanding big costs to prepare raw materials for smelting. Power costs for smelting of FS75 ferrosilicon and aluminum make 8 - 10 thousand and 15 - 20 thousand kWh per 1 ton of products, respectively. As the disoxidating of a considerable part of steel is made with a mechanical mixture of ferrosilicon and aluminum, the oxidation of silicon and aluminum parts on surface of smelted steel by atmospheric oxygen can be observed. The using of silicon and aluminum as alloy would permit to reduce their losses. Transition to disoxidating of a steel part with ferrosilicon aluminum will

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permit to expand significantly raw material base of silicon and aluminum production, as huge reserves of coal in the world will be their source.

This problem motivated a search of the effective and cheap methods to receive from technogenic waste (ashes of coal, waste of coal washing and coal mining, etc.) of ferrosilicon alloys with aluminum which on structure would correspond to their mechanical mixture used for steel deoxidation.

EXPERIMENTAL PART

The beginning of continuous production of ferrosilicon aluminum in Kazakhstan was set in 1998 at the Ekibastuz mini-plant ("AIK" LLP, Ekibastuz). In the next years the additional tests on smelting of FSA of FS45A15 and FS65A20 grades were performed at various steel plants of Kazakhstan, Russia, Turkey and China.

Capacity of the Ekibastuz mini-plant is presented with three ore-thermal electric furnaces. One furnace has 1,2 MVA transformer power. Two furnaces have 5 MVA transformer power. The made tests on smelting of FSA in 1,2 MVA and 5 MVA electric furnaces showed a basic possibility to receive alloy of FS55A15 and FS55A20 grades with using of mixture of carbonaceous raw materials from Saryadyrsky and Ekibastuz coal fields.

During the tests the optimum parameters of smelting processing of FSA alloy from carbonaceous rocks of Ekibastuz and Saryadyrsky coal fields were defined. With transition to the mixed carbonaceous raw materials the operation of electric furnaces was characterized with the processing stability. Results of the chemical analysis of the received alloy demonstrated the high aluminum content more than 18 %. Parameters of the chemical composition of the smelting of ferrosilicon aluminum of FS55A20 grade are presented in Table 1.

Capacity of the ferroalloy shop of "KSP Steel" LLP (Pavlodar) is presented with three open ore-thermal furnaces, one furnace has 9 MVA transformer power, and two furnaces have 24 MVA transformer power.

Pilot tests on development of smelting of alloy of ferrosilicon aluminum began in the electric furnace with 9 MVA transformer power.

Three-phase transformer of the electric furnace has 25 steps of low-voltage side (71,3 - 128,7 V) with difference of 2,5 V between steps and the electric current intensity is 45 - 35 kA.

Within 2 days the lining drying was made with firewood. Heating was performed on a coke cushion at 1 voltage level. Amount of coke which entered in bath furnace was up to 3 tons.

Adding charge material was begun after second day of heating in small amount to cover the open arches. After 4 days of heating the release was made with using of oxygen to heat the tapping block and outlet channel. Alloy was practically absent. Release No. 2 also did not show an obvious outlet of alloy. Furnace at the first step of voltage with slow loading of charge material on height of 1 500 mm was heated during the whole night shift.

Release was made, alloy was 400 - 500 kg actively with thin jet after frequent stirred by iron bar and heating with oxygen. The furnace was not heated yet and therefore alloy temperature was low.

The cone of charge material was created around electrodes. After starting mode the alloy release was stabilized. Metal was hot. At increase in current loading over 45 kA after releases the quartzite additives (80 - 100 kg) around each phase were made. Quartzite additives decreased the current loading as the insignificant excess of a reducer was observed.

For the 9th day after turning on the furnace the 3-times release was started. At the same time the current loading was supported at the level of 38 - 42 kA at the 5th step of voltage ~ 81 V.

Charge material level on furnace top of bath furnace was increased as cones to 600 - 700 mm from top edge of bath furnace. The satisfactory gas permeability of charge material was observed by reason of the low values of coking properties of carbonaceous raw materials characteristic for the Saryadyrsky coal field.

After the using of the above-named carbonaceous raw materials, the decision was made to use the combined heap from two wagons with the chemical composition given in Table 2.

RESULTS AND DISCUSSION

In order to level the process at some carbide mode on the operating platform, two kibbles with quartzite and iron turnings were prepared.

Table 1 **Parameters of smelting of FSA of FS55A20 grade in the PKO-1.2 MVA furnace**

Release number	Content of components / % (per mass)			Mass of alloy / kg	Release number	Content of components / % (per mass)			Mass of alloy / kg
	Fe	Al	Si			Fe	Al	Si	
43	19,78	20,67	59,55	910	84	24,51	18,84	54,65	1 087
44	20,33	21,09	58,58		85	29,17	20,27	48,56	
45	23,68	18,73	57,59		86	26,26	19,85	51,89	
46	20,89	20,53	58,58		87	23,92	22,43	51,65	
67	18,95	22,48	56,57	880	104	27,42	19,84	50,74	1 076
68	20,06	22,06	55,88		105	27,13	20,13	50,74	
69	17,55	23,05	57,4		106	26,54	19,70	51,76	
70	19,50	22,34	56,16		107	28,00	18,69	51,31	

Table 2 **The chemical composition of carbonaceous raw materials / wt. %**

Number of wagons	A^c	V	W	S	SiO_2	Al_2O_3	P	CaO	MgO
Wagon 1	50,4	14,3	3,0	0,217	56,44	41,55	0,021	0,08	1,13
Wagon 2	52,4	16,5	3,7	0,190	54,30	33,80	0,018	0,07	1,19
Average	51,4	20,0	3,3	0,200	55,40	37,50	0,020	0,08	1,15

Figure 1 Ferrosilicon aluminum alloy

The analysis of the chemical composition of ferrosilicon aluminum of the first 20 releases demonstrated the content of silicon 36 – 60 % and aluminum 15 – 18 %.

In order to stabilize a probe process of alloy and carbonaceous raw materials were in addition analyzed at the Chemical-Metallurgical Institute to check the correctness of analyses by laboratory of “KSP Steel” LLP that it showed adequacy of an accepted test charge of raw materials. Results of the chemical composition of the smelted alloy in the period of heating of the electric furnace and its operating mode showed the gradual increase in content of silicon and aluminum in alloy composition.

This demonstrates the sufficiency of heat energy on temperature increase in a reactionary zone of the furnace and at the time of release.

Electric furnace output with 9 MVA power and stabilization of smelting process of the FSA alloy occurred after alloy release No. 13 (Figure 1). The alloy release was made in two casting-forms exposed in parallel on the self-propelled car. During the filling of the first casting-form, the next casting-form moved under a stream flow of smelting.

The opening of tap-hole at release was made by a steel rod with the electro-burning, and it did not cause problems. This shows on a good heating of the bath furnace and optimum balance of mixture of charge materials. Alloy at releases was well heated and flowed actively for 10 - 12 min. It also indirectly shows on optimal composition of charge material mixture and it permits to support deep electrodes in charge material mixture, thus it respectively provides high temperature in the reactionary zone. In general during the operating furnace mode, about 257 tons of the standard alloy grades (in particular FS65A10 and FS55A15) were received.

Rate of consumption of the raw and consumable materials was such as carbonaceous raw materials (A^c = 51 %) – 2 615 kg; quartzite – 900 kg; steel cuttings – 130 kg; electrode weight – 80 kg and rod steel – 80 kg.

The rate of consumption of the electric energy for FS65A10 grade made 11,5 MWh /ton. In addition the average daily capacity was 6,8 tons.

Smelting process of ferrosilicon aluminum at “KSP Steel” LLP was constantly controlled by employees of Abishev Chemical-Metallurgical Institute. In compliance with the chemical composition of carbonaceous raw materials the correction of composition of raw materials was made to receive ferrosilicon aluminum (FSA) of FS55A15 and FS55A20 grades.

The using of carbonaceous raw materials with 52 – 55 % ash-content permitted to smelt FSA alloy with aluminum over 15 % and silicon not less 50 % in alloy composition that belongs to FS55A15.

Results of the chemical analysis of ferrosilicon aluminum (FS55A15 grade) are presented in Table 3.

Also alloy contained up to 1,2 % of titan, 0,4 % of calcium and also no more 0,05 % of manganese and chrome passing into metal composition from steel cuttings.

During the using the carbonaceous raw materials containing 55,6 - 56,3 % of ashes and 20 – 21 % of volatile components, the possibility of FSA smelting (FS55A20) was observed.

During the smelting of FSA (FS55A20 grade) the average power consumption made 12 MWh per 1 ton of

Table 3 **Chemical composition of ferrosilicon aluminum (FS55A15 grade) / wt. %**

Release number	Si	Al	Fe	P	S
152	50,24	15,76	32,00	0,023	0,001
155	52,60	15,25	30,20	-	-
158	53,71	15,50	28,81	-	-
183	53,13	16,61	28,27	-	-
184	53,20	16,92	27,88	-	-
186	53,52	16,58	27,87	-	-
187	52,93	16,77	28,26	-	C - 0,10
188	57,19	15,86	24,86	0,021	0,0005

alloy. The smelting process is characterized with the hot course of furnace and active realest of alloy.

CONCLUSIONS

Thus, during the pilot tests in the electric furnaces with powers of 1,2, 5 and 9 MVA, the alloy of ferrosilicon aluminum (FS65A10, FS55A15 and FS55A20) was smelted, which depending on the technical characteristics of carbonaceous raw materials.

With increase in ash-content of carbonaceous raw materials the possibility of rising of aluminum content in alloy composition was observed.

For all period of the tests the electric furnace operated normally, except for cases of technical faults in the furnace cooling system.

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