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STUDY OF PHYSICAL AND CHEMICAL PROPERTIES OF COAL-WASTE FOR ALLOY FOUNDRY SILICON AND ALUMINUM

A.Kh. Nurumgaliev[1], E.L. Kreymer[2], A.R. Toleuova[3], F.Zh. Abilkanova[4], G.E. Akhmetova[5], A.A. Amenova[6], D.F. Dauletiyarov[7]
[1] Doctor of Technical Sciences, Professor, Head of the Laboratory, [2] Candidate of Technical Sciences,
[3] PhD, Engineer of the Highest Category, [4] Master of Science, Engineer of the Highest category,
[5] Master of Materials Science and Technology of New Materials, Engineer of the Highest category,
[6] PhD, Engineer of the Highest category, [7] Master Degree Student Engineer
RSE on the basis of economic control rights Karaganda State Industrial University (Temirtau), Kazakhstan

Abstract*. The article studies the physicochemical properties of coal wastes in Ekibastuz field and the mixture prepared based on them. The authors recommended charges of composition and developed technical requirements designed for smelting ferrosilicoaluminum.*
Keywords*: ferrosilicoaluminum, coal wastes, charge materials, physical and chemical properties, composition.*

The development of technical requirements for smelting complex alloy of ferrocilicate aluminum in order to intensify the process and their subsequent use as a deoxidizer in steel is made in view of physicochemical properties of the initial charge materials and batch formulation prepared on their basis [1–3].

Batch of different composition were prepared on the basis of studying of the chemical composition of the investigated charge materials and technical characteristics of carbon reductants. Technological characteristics of the studied batches were determined by laboratory tests. Based on the physical-chemical properties of the test charge and charge materials the calculated composition of the resulting of ferrocilicate aluminum requirements was determined for conducting of adjustment process of ore-smelting reduction charge in ore-smelting electric furnaces and development of appropriate specifications for ferrosilicoaluminum for its use as a deoxidizer.

1. The study of chemical composition of charge materials.

The results of chemical analyzes of the initial charge materials are given in Table 1.

According to the large discrepancies parameter $V^{г}$ of devolatilization on combustible mass, all the studied samples of coal wastes are characterized by varying degrees of coal wastes metamorphism, and with an increase of ash content in the rock, the degree of metamorphism of coal, waste is reduced. The increase of ash content in the rock is happening simultaneously with decrease of aluminum oxide and the content of silicon dioxide and iron impurities in the sol increase.

Due to the large heterogeneity of the chemical composition of coal wastes the generalization of chemical analysis was made and given in Table. 1 as well as a number of other breeds is Ekibastuz field according to their content change in these non-volatile (solid) carbon depending on the ash content of coal wastes. In view of this generalization the calculation formulas (1) and (2) recommended for use in practice were obtained:

$$C^{C}_{тв} \sim 75 - 0{,}83 \times A^{C}, \% \qquad (1)$$

$$(C_{тв})^{C}_{св} \sim 75 - 1{,}20 \times A^{C}, \% \qquad (2)$$

where:
$C^{C}_{тв}$ – the content of solid carbon in the wastes, %
$(C_{тв})^{C}_{св}$ – the content of free carbon in the solid waste,

$$(C_{тв})^{C}_{св} = C^{C}_{тв} - 0{,}37 \times A^{C}, \%$$

A^{C} – ash content of coal-waste, %;
0,37 – the amount of carbon $C_{тв,}$ necessary for the reduction of oxides of ash, kg/kg

Table 1

The chemical composition of the charge materials

№ samples	Name of samples	Technical analysis, Mass %							Mass fraction of ash and oxides quartzite%			
		W^a	A^a	V^a	A^C	V^C	$C^C_{тв}$	$V^Г$	SiO_2	Al_2O_3	$Fe_{об}$	TiO_2
1	Rock A = 59 %	0,61	58,9	13,13	59,3	13,2	27,5	32,5	57,1	35,8	2,7	1,6
2	Rock A = 54 %	0,69	54,2	14,6	54,6	14,7	30,7	32,4	67,1	25,7	2,7	1,2
3	Rock A = 80 %	0,74	79,0	13,4	79,6	13,5	7,0	65,9	55,3	20,0	6,4	1,2
4	Rock A = 90 %	1,42	91,1	6,8	92,5	6,9	0,6	91,9	71,7	24,2	1,5	1,1
5	Coak A = 13,5	0,68	13,85	1,4	13,9	1,4	84,7	1,7	54	27,8	5,6	1,5
6	Quartzite								96,1	1,2	0,13	0,07

Technical characteristics of coal-waste

Technical characteristics of carbonaceous materials are given in Table. 2.

The data of Table 2 indicate that an increase in ash content of coal wastes leads to their reactivity as determined by the interaction rate of carbon coal wastes with carbon dioxide (GOST 10089-73) increases. Metallurgical coke containing 13.9 % ash and fixed carbon 84.8 is characterized with lower reactivity.

According to the content of free carbon in coal wastes and temperatures melted the beginning of the ash-most preferred rock samples of coal wastes submitted by samples № 1 and 2. The sample № 5, metallurgical coke, should not apparently be recommended as a corrective additives to the batch during the melting and may be replaced by a more energetic reaction coal power plant, containing approximately 47 % ash and about 36 % of the solid carbon.

Table 2

Technical characteristics of carbon materials (the numbering of samples in accordance with Table. 1)

Sample №	Density, g / cm^3		Porosity,%	Carbon content,%		Reactivity, cm^3/h (GOST10089-73)	Temperature ^0C	
	True	Apparent		$C^C_{тв}$	$(C_{тв})^C_{св}$		softening	melting
1	2,0211	1,72	14,9	44,4	5,56	0,303	1385	1780
2	1,8985	1,64	13,62	47,72	10,50	0,536	1310	1740
3	2,4935	2,31	7,36	9,48	(-22,45)	0,713	1280	1560
4	2,5408	2,38	6,33	0,71	(-33,63)	2,49	1310	1725
5	-	-	-	93,99	79,56	0,178	1270	1550

Table 2 demonstrates that the samples of coal wastes № 3 and № 4, in spite of their high reactivity, do not have enough carbon for reducing oxides contained in the ash. Takeing into account the ensuring necessary refractoriness of charge and need to adjust the composition of the charge during melting additives quartzite and thermal coal from the maximum-content ash of coal wastes should not exceed 65–66 %, with a lack of actually contain of carbon not exceeding 15–20 % of stoichiometric amount of carbon necessary for reducing oxides of ash.

Technological characteristic of the studied charges

Technological characteristics of charges is shown in Table 3.

Table 3

Technological characteristics of studied charges

№	Composition of charges		The carbon content $C_{тв}$ in charge, % of stoichiometry	Specific Electronic resistance of charges at 1200 ^0C, Om.sm.	Degree of recovery Al Si at 2000 ^0C, 20 min, % rel.	Calculated alloy of composition		
	№ of sample according to Table 1	Sample Content, % by weight				Al	Si	Fe
1	S.1 S.6	91,3 8,7	100,2	5,37	75,3	33,6	59,7	4,8
2	S.2 S.6	79,0 21,0	96,8	2,14	78,6	19,6	75,0	3,9
3	S.2 S.5	98,0 2,0	154,6	1,70	-	-	-	-
4	S.3 S.5	78,0 22,0	101,2	10,71	59,1	34,6	51,1	12,6
5	S.3 S.5	86,5 13,5	68,2	28,8	-	-	-	-

The charges № 1 and 2, which are characterized by quartzite additives and at relative dosage carbon the charge equal to 97–100 % of the stoichiometric value of the degree of recovery of the metallic phase of the feedstock comprise 75,3–78,6 % rel. The electrical resistivity of charges of the composition at 1200^{0}C is from 2,14 up to 5, 37 Om/sm.

It should be noted that similar technological characteristics of kaolin-briquetted aluminous charges used in the Dnieper aluminum plant are:

The degree of metals recovery is of 72–73% relatively.

The electrical resistivity of the charges at 1200 ^{0}C is 20–30 Om/cm.

The Table 3 demonstrates the charge № 4 characterized by a higher-ash coal wastes with metallurgical coke additives and it has a higher electrical resistivity (10,71 Om/cm), but at the same time it has a much lower degree of metals recovery (59.1 % rel.), as compared with the charges № 1 and № 2.

The cited research results draw attention to certain tendency to increase the electrical resistivity of charges from reduction of the amount of carbon used in coal wastes and increase their ash content. The mentioned above means that in order to increase the maximum electrical resistance of charges and to improve electro modes when smelting furnaces it is necessary to strive for maximimum, to 65–66 % ash content in coal wastes, with appropriate adjustments to lack of carbon in the charge composition of steam coal additives.

The charges compositions and melted ferrosilicoaluminum

The Table 4 shows the calculated compositions of charges and the expected composition of ferrosilicoaluminum when using coal wastes as a raw material with carbon containing 55, 60 and 65 % of ash.

The initial data used for calculations in the Table 4 are:

1. The content of oxides in the composition of the ash for all coal wastes and thermal coal are the same and is, %:

30,0 Al_2O_3; 61,2 SiO_2; 4,0 Fe_2O_3; 2,0 CaO; 1,5 TiO_2; 1,2 MgO; 0,1 P.

2. Extraction of raw material components in ferrosilicoaluminum, %:

75,0 – for Al и Si; 100 – fro Fe и Ti; 40 – for Ca and 10 for Mg.

Additional income of iron impurity in ferrosilicoaluminum due to the electrode casing and scrap for taphole furnaces is 12 kg/t.

As it is shown in the Table 4, when the ash content in coal wastes is 60–65 % and the content of aluminum oxide in the composition of the ash is equal to 30 %, the estimated content of aluminum in melted ferrosilicoaluminum is about 28 %. To ensure the required ferrosilicoaluminum containing from 25 to 35 % Al, the content of coal wastes in the ash must be at least 28 % Al_2O_3 (lower limit) and up to 36–38 % Al_2O_3 (upper limit).

Reduction of-ash content in coal wastes up to 55% and below results in a substantial increase rate quartzite in melting of ferrocilicate aluminum up to 790 kg/t or more. The calculated content of aluminum in the alloy, thus, is to be reduced up to 20–25 %.

Table 4

The calculated charges composition and ferrosilicoaluminum (FSA) obtained through the use of Ekibastuz field coal wastes

Indicators	The ash content of the coal wastes:					
	A^C = 55 %		A^C = 60 %		A^C = 65 %	
1. The calculated charges compositions and the expected costs of raw materials	%	kg/t	%	kg/t	%	kg/t
-coal wastes	81,3	3430	92,9	3890	66,8	2825
- quartz	18,7	790	7,1	300	5,9	250
-energy coal	-	-	-	-	27,3	1155
∑	100	4220	100	4180	100	4230
2. Calculated composition of FSA,	%		%		%	
- aluminum	22,8		27,9		28,4	
- silica	67,0		60,1		59,4	
- iron	7,0		7,2		8,3	
- titanium	1,7		2,1		2,2	
- calcium	1,1		1,3		1,4	
- magnesium	0,1		0,2		0,2	

Conclusion

1. Physico-chemical properties of coal wastes in Ekibastuz field and the charges prepared based on them are studied. The research has shown:

- reactivity of coal wasted determined by the interaction rate of carbon wastes with carbon dioxide CO_2 (according to GOST 10089-73), increases from 0,303 up to 2,49 cm^3/g.c. with increasing ash content in the wastes from 60 to 90 %;

Likewise, with increasing ash content coal-wastes increases yield of volatile on combustible mass, indicating the changes in the degree of metamorphism of coal ash wastes with different ash content;

- due to the very low reactivity of metallurgical coke, which is amounted to 0,178 cm^3 / g.c., to compensate the lack of carbon in charge of high ash content in coal wastes it is recommended to use thermal coal in power stations instead of coke, with ash content of 47 % and containing up to 36 % of fixed carbon;

- The degree of metals recovery from charges using coal wastes with ash content of 60–65 % is about 73–78 %, which is 3–5 % abs. higher than for industrial charges used for the smelting-actuated silicoaluminum;

- electrical resistivity of charges using coal wastes is much lower than for charges of industrial composition, so electric modes of operation in smelting furnaces of coal wastes should be adjusted based on the results of the research;

- due to the large heterogeneity of coal wastes a rapid assessment of the average content of fixed carbon is recommended, depending on their average ash content, according to the formula:

$$C_{нл} \sim 75 - 0{,}83 \times A^{C}, \%$$

where A^{C} is the average ash content of coal wastes,%;

- To ensure the conditions for obtaining of ferrosilicoaluminum containing 25–35 % of aluminum, aluminum oxide content in the composition of ash content in coal wastes must be at least 28 % (lower limit) and 37 % (upper limit) with an average ash content in coal wastes from 60 to 65 %.

2. On the basis of the results of the exploration the recommended charges composition for experienced heats and developed technical requirements for smelted ferrosilicoaluminum for its use as a deoxidizer are suggested.

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ИЗУЧЕНИЕ ФИЗИКО-ХИМИЧЕСКИХ СВОЙСТВ УГЛЕОТХОДОВ С ЦЕЛЬЮ ВЫПЛАВКИ СПЛАВОВ КРЕМНИЯ И АЛЮМИНИЯ

А.Х. Нурумгалиев[1], Э.Л. Креймер[2], А.Р. Толеуова[3], Ф. Ж. Абилканова[4], Г.Е. Ахметова[5], А.А. Аменова[6], Д.Ф. Даулетияров[7]

[1] доктор технических наук, профессор, руководитель лаборатории, [2] кандидат технических наук,
[3] PhD, инженер высшей категории, [4] магистр естественных наук, инженер высшей категории,
[5] магистр материаловедения и технологии новых материалов, инженер высшей категории,
[6] PhD, инженер высшей категории, [7] магистрант

РГП на ПХВ Карагандинскии государственный, индустриальный университет (Темиртау), Казахстан

Аннотация. *Изучены физико-химические свойства углеотходов Экибастузского месторождения и шихт, приготовленных на их основе. Рекомендованы расчетные составы шихт и разработаны технические требования для выплавки ферросиликоалюминия.*

Ключевые слова: *ферросиликоалюминий, углеотходы, шихтовые материалы, физико-химические свойства, состав.*