Experience of Carbonaceous Reducer Utilization in FeSi Production at Joint-Stock Company KUZNETSKIE FERROSPLAVY

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The plant produces ferrosilicon of the grades FeSi45%, FeSi65% and FeSi75%. Production characteristics are mainly determined by the quality of the reducers applied.

Requirements for the quality of carbonaceous materials in ferrosilicon production are stated in the research works [1-3]. The main requirements are:

- high reducing capability in respect of silicon dioxide;
- high specific electric resistance;
- good thermal resistance manifested itself in resistance to thermal shock when charging to the furnace top.

The main type of the reducer used at the plant, is coke bean supplied by coke-chemical and metallurgical plants. Technological rules have stated the reducer size charged to the furnace - maximum 5-20 mm .

Coke reactivity represents the constant of its gasification velocity by carbon dioxide and is taken into consideration in the practice of FeSi production to estimate its quality [4,5].

Relations between coke reactivity and indicators of melting FeSi 75% were studied in the research work [6]. As a response the following main indicators of the furnace operation were taken: specific capacity (W) and intensity of electric power use (Q). Indicators of the furnace operation with coke supplied from Kuznetsk Metallurgical Works (KMK) with minimal reactivity (0,52 $cm^3/g \cdot s$) were taken as 100%. Results of the study are shown in the figure 1. It should be noted that under conditions of one plant there is a definite relation between reactivity and efficiency of FeSi melting in the range of the reactivity 0,52-2,2 $cm^3/g \cdot s$.

It should be taken into consideration that existing methods of reactivity estimation of different fuels and carbonaceous reducers are highly various. Method of reactivity determination standartized by the sub-committee on coke at UNO, is universal while the functions performed by reducers in different processes are very diverse.

Processes of ore electrothermy connected with metal extraction from the range of hardly reducing oxides (SiO_2, MnO, Cr_2O_3, etc.) depend to less extent on the fact if reducer is a good gasificator or not [8]. Reducing capability of carbonaceous reducers is hardly yielded to systematization in view of absence of the common methods.

For its metallurgical properties coke bean is unequivalent.

* The authors express their thanks to Serov G.V. and Misin V.G. who began to introduce new carbonaceous reducers in FeSi production.

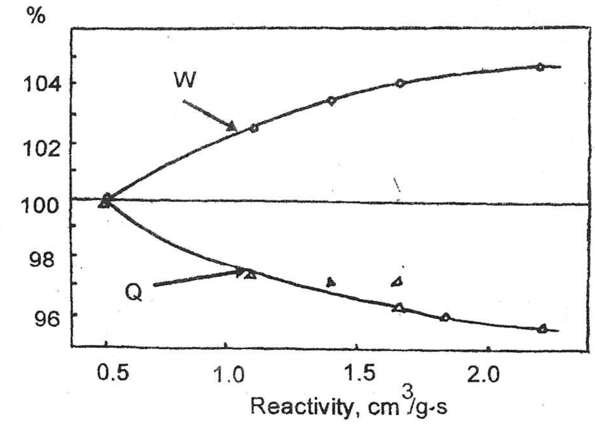

Fig.1 Influence of coke reactivity on the indicator of melting FeSi

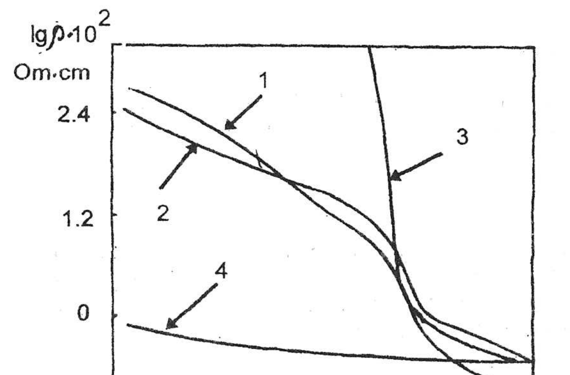

Fig.2 Specific resistance of semi-cokes and coals
1 - Leninsk-Kuznetsk semi-coke, 2 - Angarsk semi-coke, 3 - Lean coal, 4 - Coke

Coke bean, when formed after being sized from the middle part of coke cake, less calcined and possesses high electric resistance. On

Table 1 Phisical - Chemical Properties of The Carbonaceous Reducer

Reducer	Technical analysis, (%)			Elementary analysis on combustible mass, (%)					Density, (g/cм3)		Porosity, (%)	Reactivity, (cм3/g·s)	Specific electr.resist, (Ом·cм)	Structural resistance, (%)	Thermal resistance, (%)
	A d	V daf	S d	C daf	H daf	N daf	O daf	S daf	actual	apparent					
Coke KMK	10,3	1,4	0,46	96,99	0,55	1,24	0,65	0,57	1,870	0,975	47,9	0,52	1,48	81,4	99,7
Coke ZSMK	10,8	1,7	0,6	97,1	0,59	1,20	0,42	0,73	1,858	0,993	46,6	0,98	2,52	82,4	99,3
Coke KKHZ	11,3	1,6	0,56	97,50	0,57	1,13	0,16	0,64	1,815	0,930	48,8	1,07	2,42	79,4	99,1
Semi-coke ANHK	25,2	7,7	0,70	89,70	1,63	1,53	6,23	0,91	1,780	0,729	57,5	9,55	14,77	67,0	96,6
Semi-coke LKZP	5,96	7,55	0,48	87,95	2,80	2,90	5,82	0,54	1,665	0,821	50,8	4,62	$1,5 \cdot 10^3$	69,4	93,5
Lean coal (grade TO)	8,3	10,8	0,38	90,89	3,69	2,39	2,61	0,42	1,458	1,283	12,0	1,56	$> 3,3 \cdot 10^6$	70,5	71,2
Lean coal (grade TM)	5,7	10,3	0,26	91,25	3,74	2,98	1,74	0,29	1,433	1,272	11,2	1,98	$> 3,3 \cdot 10^6$	80,4	82,3
Lean coal (grade TOM)	15,94	17,1	0,30	89,90	4,00	2,10	3,60	0,24	1,527	1,358	11,1	0,93	$> 2,2 \cdot 10^6$	78,9	92,4
Weakly caking coal (grade SS)	6,4	29,5	0,16	86,30	4,64	2,19	6,70	0,17	1,413	1,205	14,7	0,62	$> 3,3 \cdot 10^6$	71,3	94,7

the contrary, coke bean produced in blast-furnace shops at coke-sizing is more calcined and electroconductive.

Chemical composition of coke charge and method of coke quenching exert great influence on metallurgical properties of coke bean. In process of wet quenching vapor moisture-laden activation takes place, which increases coke reactivity and electric resistance. Coke of dry quenching is regularly supplied to the plant in the quantity of 10-15% from the total delivery of carbonaceous reducers. Therefore organization of industrial experiment on coke of dry quenching only was practically impossible. Operation analysis showed that with application of dry quenching coke in quantity to 50% in reducer mixture during FeSi70% and FeSi75% melting at Kuznetsk ferroalloys plant, furnace capacity decreased by 2,4% and 4,8% respectively, specific electric power use increased by 2,4-5,0% [9].

High quantity of weakly metamorphosed coals in charge increases coke electric resistance and its reactivity. Coke metallurgical properties are shown in the table 1.

Relatively stable chemical and real composition and high thermal resistance are the qualities of coke bean.

Coke bean produced at Kemerovo coke-chemical plant (KKHZ) which coke battery charge has high share of gas coals (up to 35%) and weakly caking coals (up to 25%) possesses comparatively better properties.

Experimental-operational melting's on coke with high (60%) content of gas coals in coke battery permitted to increase the furnace capacity by 5-7% and to reduce electric power use by 6-8% [10].

Requirements for coke used in blast-furnace iron castings differ from requirements for coke used by FeSi melting. In this connection the idea of coke battery specialization in production of coke for FeSi production inevitally comes to mind. Unfortunately number of circumstances prevents from realization of this often repeated idea. Considerable gain in melting indicators with application of special cokes' sorts is mainly achieved by melting ferrosilicon with high silicon content, when it is necessary to provide high concentration of capacity in reactionary zone from the one side, and effective accumulation of much silicon monoxide quantity from the other. Unfortunately, capacities for production of FeSi with high silicon content in the region are insufficient to keep running even one coke battery at capacity of 1 million tons of coke per year.

Usually coke bean with fraction 13-25 mm is supplied to the ferroalloy plant by a coke-chemical plant. If coke of blast-furnace fractions is crushed to this size, its reactivity will be lower. For example, coke bean with fraction 0-25 mm from coke cake has reactivity 0,83 $cm^3/(g{\cdot}s)$ and specific electric resistance 3,82 Om·cm. At the same time coke bean with fraction 0-25 mm obtained after crushing coke with fraction 25-40 mm, has reactivity 0,57 $cm^3/(g{\cdot}s)$ and specific electric resistance 2,63 Om·cm.

Expediency of reducer utilization from weakly metamorphosed coals by melting ferrosilicon and complication of production organization of special cokes' sorts in coke furnaces stimulates involving in production coals and semi-coke – intermediate product between coal and coke, as a matter of fact. In production semi-coke supplied from Angarsk petro-chemical plant and Leninsk-Kuznetsk semi-coking plant is used. Technological scheme of semi-coke obtaining is shown in the figures 3 and 4, properties in the table 1.

Semi-coking of coal concentrate at Angarsk petro-chemical plant (ANHK) is made in the furnaces of Lurga system (two-shaft, multizone with inner heating, of continuous operation, with peri-

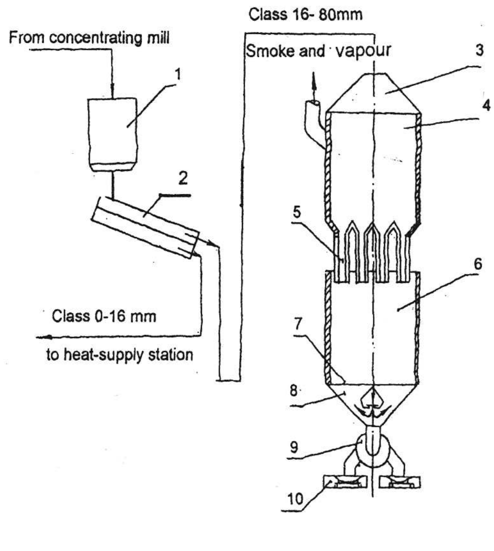

Fig.3 Technologic diagram of coal preparation and semi-coking at Angarsk petro-chemical plant. (1- receiving hopper for coal concentrate, 2- screen, 3- coal feed hopper, 4- drying chamber, 5- transfering hopper, 6- semi-coking chamber, 7- coke unloading table, 8- semi-coke unloading hopper, 9 - hudraulic coke unloader, 10 - belt conveyer

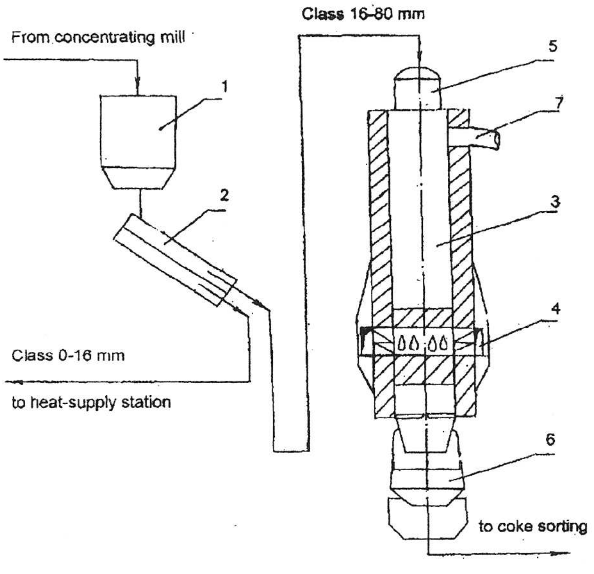

Fig. 4 Technologic diagram of coal preparation and semi-coking at Leninsk-Kuznetsk semi-coking plant. (1- receiving hopper for coal concentrate, 2- screen, 3- Pinch furnace shaft, 4- Distributing flue for heating gas, 5- feed box, 6- unloading installation, 7- Outlet pipe for distillation products and heating gas).

odic coal charging and continuous semi-coke discharging). The furnace includes 2 vertical shafts and has drying chamber and semi-coking chamber. During semi-coking coal is gradually heated by gas heat-carrier to the temperature 700-750°C . In contrast to Angarsk semi-coke, Leninsk-Kuznetsk semi-coke (Leninsk-Kuznetsk semi-coking plant – LKPZ) is produced in Pinch furnaces also operating according to the principle of inner heating, but not having drying chamber, therefore coal drying is made in the furnace shaft and for this reason much quantities of heat are consumed beside the purpose, i.e. for semi-coking. The temperature of semi-coking in Pinch furnaces is lower than in Lurga furnaces - 500-600°C.

Leninsk-Kuznetsk semi-coke was tested more than once. First campaign was conducted in 1958, the last – in 1966. Campaigns lasted from 5 to 20 days and all of these campaigns were resembling to each other. In the beginning of the campaign furnace operation was stable, with good indicators. However one couldn't manage to keep the furnace in this condition over a long period of time: gas permeability of the furnace top became worse, slag content increased, dust entrainment to the gas-cleaning rose. After that the campaign ceased.

At first sight the result seems to be surprising, in fact, according to the data of the table 1 Leninsk-Kuznetsk semi-coke exceeds coke to its physical-chemical properties by far. Properly speaking, just because of this we return to this material in spite of negative results. Some-times disruption of the furnace operation was explained by furnace top sintering due to high content of resinous fractions in comparison with semi-coke organic mass. However, at present experience of coke utilization in charge mixture puts doubt on this argument. In fact, the content of resinous fractions in the composition of organic mass is much more than in semi-coke and coke that doesn't prevent good furnace operation.

To our opinion the reason of the furnace operation disruption during campaigns is non-stability of Leninsk-Kuznetsk semi-coke proper-ties; thus volatize substances vary from 4% to 20%. In semi-coke both calcined lumps and almost not calcined coal can be found. This is explained by low (500-600°C) and changeable temperature of semi-coking process.

According to the data of the research work [11] specific electric resistance of semi-coke produced from long-flame coals decreases from 6700 to 26 Om·cm when the calcination temperature rises from 650 to 950°C. It is very difficult for personnel to accommodate their-selves to the work with materials having inconstant properties. Possibility of the furnace top disruption sharply increases. Once again we can make sure of the statement correctness given in the research work [11] that stability of ore characteristics is one of the major preconditions for the achievement of high technical-economical indicators of production.

In the course of some years at our plant Angarsk semi-coke was utilized by melting ferrosilicon of all grades. It was entered to the charge at a rate of change of 30-50% coke carbon. Content and properties of Angarsk semi-coke are more stable. Wet quenching also con-tributes to raising semi-coal quality.

Semi-coke short-coming is its higher ash content (to 30%). The results of the furnace operation is given in the table 2. In the early eighties Angarsk semi-coke was given up for utilization by melting ferrosilicon of the grades FeSi75% and FeSi65% because of the problems with FeSi production with Al content less than 1,5%.

Table 2 Indicators Of Open Furnace Operation By Meltng Ferrosilicon Grade Fesi75 With Utilization Of Different Types Of Reducers In The Charge

№	Name of indicators	Composition of the carbonaceous reducer			
		coke of KKHZ	coke + wood chips	coke + coal of the grade "SS"	coke + coal of the grade SS + wood chips
1	Share of coke bean substitution by carbonaceous reducer, (in % on the carbon)	0	13,4	26	41
2	Furnace operation, (tons per day)	36,5	45,3	49,4	51,8
3	Spec. expenditure of:				
	electric power,(kWth/basic t)	9952	9559	10095	9081
	quartzite, (t/basic t)	1,917	1,912	1,911	1,921
	coke bean, (t/basic t)	0,951	0,882	0,73	0,631
	component of reducer, (t/basic t)	-	-	0,342	0,446
	wood chips, (t/basic t)	-	0,588	-	0,459
4	Used power, (MW)	15,7	18,1	21,0	20,3

Table 3 Indicators Of Half-Closed Furnace Operation By Meltng Ferrosilicon Grade Fesi45, Fesi65 With Utilization Of Different Types Of Reducers In The Charge

№	Name of indicators	Composition of the carbonaceous reducer							
		coke of KKHZ		coke + semi-coke ANHK		coke + coal of the grade "SS"		coke + coal of the grade "TM"	
1	Share of coke bean substitution by carbonaceous re ducer, (in % on the carbon)	0	0	35	35	30	30	35	35
2	Furnace operation, (tons per day)	97,1	59,1	93,0	54,9	92,8	64,9	95,9	54,3
3	Spec. expenditure of:								
	electric power,(kWth/basic t)	5040	7803	5213	8087	5085	7380	4873	8377
	quartzite, (t/basic t)	1,017	1,517	1,022	1,470	0,998	1,466	0,961	1,699
	coke bean, (t/basic t)	0,521	0,775	0,282	0,417	0,434	0,646	0,308	0,498
	carbonac. reducer, (t/basic t)	0,521	0,775	0,304	0,458	0,214	0,285	0,197	0,339
4	Used power, (MW)	20,5	19,4	20,2	18,94	20,3	20,8	19,9	19,8

Angarsk semi-coke utilization is given in the research works [1,12] in detail.

Coals are divided into long-flame, gas, rich, weakly coking, lean coking, lean and anthracites. With growth of metamorphism degree carbon content in the combustible mass of coals increases and content of oxygen, hydrogen and volatize substances decreases. Coal proper-ties important for FeSi production are given in the table 1.

Expediency of coal utilization in FeSi production is explained by its low cost and high specific electric resistance. In the figure 2 data on specific electric resistance of different reducers [13] are given. At low temperatures (600-700°C) specific electric resistance of coals is much higher than of coke and semi-coke; at the temperature 1100-1200° C specific electric resistance of reducers are drawing together. We can come to the conclusion that coal entering to the charge positively influences on the electric resistance of the furnace top.

We tested lean and weakly caking coals in FeSi production. The results are shown in the table 2,3.

Positive results were obtained by utilization of lean coals by melting FeSi45% Substitution of coke for coal by 35% on carbon didn't deteriorate melting indicators and allowed to reduce alloy cost (table 2). Evidently, low porosity and reactivity of lean coals don't influence on the velocity of silica reduction. In fact, according to the data [14] for complete collecting SiO by melting FeSi45% in the furnace upper zone will be enough to have about 12% of free carbon. At the same time by melting FeSi75% for SiO collecting formed in the furnace low part it is necessary to consume not less than 57% carbon by charge entering. It is explained by extention of forming SiO in volume with in-crease of Si concentration in the alloy. From this point of view the more silicon content in the alloy, the higher requirement to the reducer quality. Indeed by melting FeSi75% with entering to the charge 30-40% of weakly caking coal on the carbon and 400-500 kg/g of wood chips, the furnace operation became worse (table 3).

Gas coal testing by melting FeSi75% brought to rising the temperature of outgoing gases, increase of the thermal load on the furnace equipment and as a consequence to the growth of repair standing idles.

Best results were obtained by weakly caking coal utilization, now used by melting ferrosilicon of all grades, in quantity 30% from coke quantity on the carbon.

Conclusions

By melting FeSi75% the lowest electric power expenditure (the best indicators of the furnace operation) is achieved by utilization of the coals with low degree of metamorphism. Coke quality also increases with the increase of the coal share having low degree of metamorphism in the charge for coking. In semi-coke from long-flame coals the content of volatile substances should be 10% max. Stable indicators of the furnace operation are obtained by utilization in the charge of 30% coal and 400-500 kg of wood chips per 1 ton of an alloy.

By coal utilization with high output of volatile substances in open furnaces the thermal load on the furnace equipment increases and the quantity of the furnace repair downtimes grows.

By melting FeSi45% it is permissible to use in the charge 30% lean coals without deterioration of melting indicators.

Perspective coal sort, suitable for utilization both in closed and in opened furnaces, is weakly caking coal. Entering weakly caking coals to the charge provides reduction of electric power expenditure per one ton of alloy by melting ferrosilicon of all grades.

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