PRODUCTION OF SPECIAL KINDS OF CARBONACEOUS REDUCING AGENTS FOR FERROALLOY SMELTING

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ABSTRACT

Developed are new special kinds of carbonaceous reducing agents for production of ferroalloys and method of their production by means of coking of thermally treated and specially selected charge mixtures. Preliminary thermal treatment allows to obtain lump reducing agent in conventional laminar coking furnaces from low-sintering mixtures; coking of thermally treated initial charges is performed at accelerated periods of coking. Obtained according to such technology at Yasinovskiy coking plant products exceed coke nut in their metallurgical properties, first of all in specific electrical resistance and chemical reactivity. Whereby at the same time tasks of coal scoping studies for coke and by-product process, effective loading of the existing coke-oven plant stock and performance indicators improvement of the ferroalloys furnaces are being solved.

Study of new kinds of reducing agents, conducted in industrial ore thermal electric furnaces with capacity of 27-81 MVA of Nikopol and Stakhanov ferroalloys works confirmed their effectiveness during production of ferroalloys of mass assortment. During melting of ferrosilicon manganese with use of special reducing agent manganese raw materials, coke and quartzite consumption decreased respectively on 1,1; 16,6 and 4,4 kg per standard ton of alloy, and electrical energy consumption – on 41,9 kWh per standard ton in comparison with use of traditional reducing agents; furnace capacity increases by 1,2%. During production of 75% ferrosilicium consumption of quartzite and reducing agents, expressed as carbon decreases respectively on 0,4% and 10,6%, and electrical energy consumption – on 375 kWh per standard ton (5,2%) in comparison with use of traditional reducing agents; furnace capacity increases by 6,6%.

Under laboratory conditions technologies of obtaining and metallurgical properties of the so called "ore coke" with entering into the charge for coking of dust from gas treatment of ferroalloy furnaces, oxidic and carbonate concentrates were studied; advantages of experimental kinds of ore coke in comparison with traditional coke nut were illustrated.

INTRODUCTION

Quality of carbonaceous reducing agents has a significant importance for ferroalloy smelting in ore thermal electrical furnaces, determining to a large extent the completeness and kinetics of extraction of leading components from ore materials into the alloy, structure of the furnace body, charge materials descent and as a consequence main energetic characteristics of the ferroalloy redistribution [1]. Oven coke of the fraction 5-25 mm, so called coke nut, which is the by-product of laminar coking in horizontal coking plants of the charges meant for blast furnace coke production is the main traditional kind of carbonaceous reducing agents used for production of mass electroferroalloys. Yield of coke nut is up to 3% of the gross volume of production of blast furnace coke of coarse fraction (over 25 mm), e.g. coke nut is in fact waste from production of blast furnace coke and does not completely meet the specific requirements of ferroalloys production in ore smelting electrofurnace.

It is commonly known that general requirements to the quality of oven coke include such parameters as content of solid (non-volatile) carbon, ashes, volatile substance, working moisture and sulphur; chemical composition of ashes; physical and mechanical properties (crush strength and abrasion resistance), chemical reactivity of the reducing agent in relation to metal oxides. For reducing agents, used during melting of electroferroalloys such parameter as electrical resistance is of great importance, since it is electrical resistance of coke what determines this parameter value for ferroalloy charges on the whole, especially in higher layers of the furnace tank.

Efforts of ferroalloy technologists are aimed at maximum increase of electrical resistance of the charge during melting of the alloys by means of continuous process is explained by necessity of decreasing of fraction of current of the charge conductivity and increase fraction of current going through the electric arc – high-temperature thermal source [2].

It is worth noting that the wish in the recent time to obtain high quality, in the first place according to structural behavior, coke for blast-furnace smelting from expensive charges (this means that coke nut at the same time also) comes into collision with the requirements of the ferroalloy industry, envisaging the use of reducing agent, mainly, with high chemical reactivity and increased specific electrical resistance. Taking into account of the specifics of performing a ferroalloy melting in low-shaft furnaces, dissimilar in this respect with high-shaft blast furnaces, in such a case a certain relaxation in the requirements to the strength, ash content etc is acceptable – in exchange for satisfaction of specific requirements to electrotechnical characteristics, with reasonable at the same time cost of the reducing agent by means of using for coking inexpensive and abundant kinds of coals in the coking charge [3].

In other words, useful is the organization of targeted production of such high-reactive reducing agent which on one hand would allow to load free or old capacities for production of furnace coke, what will influence economy of the coke and by-product process in a good way. On the other hand, by means of using cheap and less deficient raw material base and targeted improvement of quality of coke, improving effectiveness of the ferroalloy industry it would become possible to decrease the costs of the latter. Targeted production of special reducing agents for ferroalloys, in its turn, may also facilitate widening of applicability of released volumes of low reactivity coke – coke nut in blast-furnace process, as it is widely used in several foreign iron and steel enterprises.

Creation of such targeted production on the basis of coking of watery low-sintering charges is limited by their low sintering limit and low degree of fineness of such coke column, what facilitates the rise of its hindered discharge and “sinking” during discharge from the coke-oven plants. Studies have found that in order to overcome this up to 30% participation of scarce strongly coking coal of rank Zh is needed.

At OJSC Yasinovskiy coking plant where there is equipment and technologies for preliminary thermal treatment of the charge examinations were conducted and possibility of obtaining special kinds of coke for production of ferroalloys from low-sintering high volatile coal of low metamorphism stage was ascertained (charge 1 in the table 1). Whereby increase in productivity of the coke-oven plant in comparison with watery charge may be higher by 50% and more and loading during discharge of the coke column from the furnace meet the regulatory values.

Composition and quality of coal charges, thermally treated in the experimental industrial installation with capacity of 60 tons/hour, as well as quality of high-reactive coke, obtained from coke-oven plant №3 at OJSC Yasinovskiy coking plant are given in table1.

As is clear from the data given in table 1, coking method for thermally treated and specially selected charge mixtures allows to obtain lump fuel in traditional laminar coking furnaces from low-sintering mixtures; coking of thermally treated initial charges is performed by accelerated coking periods.

During performance of these tests industrial batches of special coke were obtained; they were later tested at Nikopol (NZF) and Stakhanov (SZF) ferroalloy works.

Table 1: Composition and quality of coal charges, quality of high-reactive coke produced by Yasinovskiy coking plant

Kind of charge	Grade composition, %			Charge properties, %					Coke quality				
	G	Zh	$G_{industrial\ product}$	A^d	S^d_t	V^{daf}	Y mm	RI	A^d	S^d_t	M25	CRI	Q_{high}
1	85,0	10,0	5,0	8,1	0,8	40,0	11,5	-	11,4	1,0	74,0	63,5	-
2	80	-	20,0	10,6	0,73	36,1	10,0	-	15,9	0,99	60,0	65,3	7710

Technical analysis of special coke tested at Nikopol ferroalloy works, was as follows: water content – 10,9%, ashes – 11,4%, content of the fraction +25 mm – 5,7%, content of the fraction 10-0 mm – 16,4%. Test coke was used for melting of ferrosilicon manganese of the rank MnS17 in the round sealed furnace RKG-75 MVA № 8 NZF (table 2).

Meltings were performed according to the normal technology as a continuous process with furnace throat covered with the charge and regular melting products discharge. Despite the fugacity of the test campaign lower for about 150-200 mm interference of electrodes into the charge was recorded, what is the evidence of a higher producibility of test coke. During the tests the test portion of coke in the furnace charge was reduced from 360 – 370 kg to 320 – 330 kg.

Table 2: Key figures of melting of ferrosilicon manganese of the rank MnC17 in the furnace № 8 at NZF with use of coke nut from Yasinovskiy coking plant

Indicator name	Melting variants	
	Reference (17-20.09.06)	Test (13-16.09.06)
1	2	3
Specific raw materials consumption, kg/standard ton		
Agglomerate of the rank V2	1372	1572
Agglomerate of the rank V2P	269,7	-
Imported ore (Ghana)	25,7	94,3
Total Mn raw material (48% Mn)	1667,4	1666,3
Usual coke	440,9	-
Test coke	-	424,3
Quartzite	393,9	389,5
Pellets	37,4	29,9
Manganese raw materials	247,7	244,5
Wastes	367,4	188,3
Screenings	60	62,3
Specific energy consumption, kW·h/s.t.	4331,4	4289,5
Extraction of manganese into the alloy,%	86,6	87,3
Manganese content in the slag,%	12,3	11,5

Utilization of test coke did not cause any deviations in electrical and gas conditions of the melting of ferrosilicon manganese. At the same time consumption of manganese raw material, coke and quartzite decreased respectively on 1,1; 16,6 and 4,4 kg per standard ton of the alloy, and electrical energy consumption - on 41,9 kWh per standard ton in comparison with use of traditional reducing agent – coke nut. Furnace capacity during performance of the test meltings increased by 1,2%.

At Stakhanov ferroalloys works average rates of the quality of the experimental batch of special coke were as follows:

	Test special coke	Standard coke nut
ash content, %	10,7-11,4	11,4
moisture, %	14,7-15,7	16,4
volatile, %	2,0	1,5
solid carbon, %	85,6-86,3	85,5
sulphur, %	1,0	1,6

Test meltings of ferrosilicium FS 65 were performed simultaneously in two furnaces №№ 1,2 SZF, having common proportioning unit. Ore thermal furnaces №№ 1,2 of the type RKZ-16,5 – round, closed, with rotating tank; during reconstruction in the 70-th capacity of the furnaces was increased up to 27-27,6 MVA.

Meltings were performed as continuous process with discharge of ferrosilicium into the lined ladles and further casting on conveyor mold machines. During test meltings no deviations from normal parameters were observed, as well as any changes in the quality of the produced alloy.

Processing service of the plant registered that after entering of special coke into the charge composition of higher chemical reactivity, furnaces during test period were operating more stably, interference of electrodes in the charge improved, electrode slipping slightly increased, gas releases from charge hoppers at the electrodes decreased. Alloy and slag were coming out from the furnaces simultaneously without any difficulties with operation of furnace wells.

Key indicators of the furnaces operation during test and reference periods are given in the table 3.

From the above given data it is clear that during operation of the electric furnaces with use of special coke nut in comparison with operation on run-of-the-mine coke performance indicators of the furnaces improved: specific consumption of electrical energy decreased on 375 kWh/ton or on 5,11%; capacity of the furnaces increased by 4,5 tons/day or by 6,6%; specific quartzite consumption decreased on 0,4% and specific consumption of reducing agents expressed as solid carbon on 1,06%. Electrodes slipping increased slightly (by 7,5%), what is the evidence of increase of charge resistance (due to higher specific electrical resistance of coke nut), increase of the length of the electrodes covered with charge and stabilization of technological furnace movement.

Thus, industrial tests confirmed the reasonability of use of special kinds of carbonaceous reducing agents during production of ferroalloys of the most mass assortment – ferrosilicon manganese and ferrosilicium – in the ore thermal electrical furnaces with capacity of 27-81 MVA.

Under laboratory conditions test batches of ore coke were acquired with entering of low-metamorphized coal from the mine Zarechnaya, concentrates of coals of the rank Zh from preparation plants Samsonovskaya and Krasnolimanskaya and 5-15% ore materials – dust from gas leaning from melting of manganese alloys, Nikopol oxidic concentrates of the grade 1, 2 and carbonate concentrates into the composition of the coking charge.

It is found that with adding of manganese ore materials into the coal charge bulk coke yield significantly increases. At the same time strength indices of the obtained coking products M_{25}, and especially M_{10} significantly worsen with rise of quantity of manganese ore material added to the charge, especially dust and carbonate concentrate. Entering of oxidic concentrates in the quantity of

10% into the composition of the coking charge is not accompanied by noticeable worsening of strength properties of coke.

Table 3: Key figures of melting of ferrosilicium of the rank FS65 in the furnaces №№ 1, 2 at SZF with use of coke nut from Yasinovskiy coking plant

Indicator name	Reference variant (conventional coke), 01-29.01.2007	Test variant (special coke) 30.01-16.02.2007
Operation time: - nominal, days - hot-idle, % - actual, days	 52,5 0,6 52,21	 26,0 0,14 25,86
Production, reference tons FS 65	3578,8	1881,14
Average silicium content, %	66,3	66,5
Real power, kW	20960	21146
Capacity, tons/nom. day	68,2	72,7
Discharge intensity, tons/ton: - quartzite - sorted coke nut - special coke nut - gas coal - steel chip - ferrosilicium scrap - limestone	 1,517 0,609 - 0,148 0,34 0,058 0,014	 1,511 - 0,620 0,116 0,343 0,048 0,015
Total of reducing agent expressed as solid carbon, tons/ton	0,5829	0,5567
Electric energy consumption, kW.h /ton	7338	6963
Extraction of silicium into the alloy, %	92,1	92,5
Average specific electrode slipping, mm/1000 kW.h	0,451	0,485

In optimum performance of coking test batches of ore coke were acquired with content of ore materials in the quantity of 10% in the coking charge for study of metallurgical properties. It is found that chemical reactivity of the test coke rises sharply in proportion to the increase of quantity of manganese ore material added to the charge; maximum rise of the chemical reactivity was recorded during use of dust from dry gas cleaning. For coke from the charges comprised with participation of 15% of manganese ore materials of different kinds maximum value of chemical reactivity amounted to 1,78 – 2,62 $cm^3/g \cdot s$, what is almost two times more than for reference coke.

It is shown that in the zone of low and moderate temperatures (up to 1000°C) all kinds of test raw material and charges for melting ferrosilicon manganese on their basis have higher values of specific electrical resistance (SER) in comparison with conventional coke nut. By further temperature rise difference in values of SER is leveled and then in proportion to the development of reduction processes and formation of the metal phase, SER of ore coke is slightly lower than for coke of reference composition.

Tests for melting of ferrosilicon manganese with use of specimens of ore coke of different compositions were performed in the laboratory resistance furnace, upon that a standard ferrosilicon manganese was obtained from all variants content of manganese 71,5 – 72,2 %, silicium 17,9 – 18,3% and phosphor 0,39 – 0,40%. Extraction of manganese into the alloy with the use of ore coke was somewhat higher (increase by 0,5 – 1,6%) in comparison with use of conventional coke what is connected to higher chemical reactivity of test kinds of reducing agents.

Performed researched and tests give grounds for opening a question of industrial production of special kinds of carbonaceous reducing agents for ferroalloy industry as the target product and not as coke by-product.

At present in conditions of Yasinovskiy coking plant reconstruction of the charge thermal treatment department and preparation to organization of production of new effective kinds of carbonaceous reducing agents for melting of ferroalloys on an industrial scale are being completed.

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