UDC 669.162.266 Science

Production and Usage of Self-Reducing Pellets in Blast Furnace Using Coal Fuel

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An estimation of the reduction process was given in the chemical reserve zone of the blast furnace. It is shown that the presence of finely ground solid fuel in pellets provides the development of complex reduction in this zone and reduces the level of direct reduction due to metalizing. The results of the investigation of metallurgical properties of self-reducing pellets and the results of blast furnace smelting are given. The estimation of usage effectiveness of self-reducing pellets during pulverized coal fuel injection is provided

Keywords: SELF-REDUCING PELLETS, PULVERIZED COAL FUEL, COMPLEX REDUCTION, CHEMICALLY RESERVED ZONE OF BLAST FURNACE

At the present stage of ferrous metallurgy development one of the priority trend of pelletizing is to obtain iron ore carbonaceous materials [1, 2].

According to the research data the presence of the solid fuel in iron ore charge provides production of wustite-magnetite structure of agglomerate and pellets. From the point of view of reduction processes development in the blast furnace shaft wustite-magnetite structure have no advantage, since higher iron oxides reduce in the upper part of the shaft [3]. One of the ways of activation of reduction process in chemically reserved zone can be a development of complex reduction [4, 5]. With usual gas recovery of carbon-free materials their internal volumes are not involved in the reduction reaction due to the topochemical nature of the process. The regeneration of reducing agent inside the pellet and direct reduction of wustite takes place with the presence of solid carbon inside the pellet.

The speed of coal gasification reaction increases with increase of temperature. An increase of temperature leads to an acceleration of the gas-carbothermic reduction of iron. However, one should remember that the shift from carbothermic reduction to the complex reduction in the CO flow affects the participation of solid carbon in the process. The increase of the partial pressure of CO2 as a result of the interaction of carbon monoxide with iron ore charge should serve for the benefit of the reaction: $C + CO_2 = 2CO$ [5]. Participation of hydrogen in the gas stream provides higher reduction speed [6].

First production of self-reducing carbon pellets was carried out on a pilot pelletizing plant of the Central Mining and Processing Plant. The pellets produced were used for smelting of cast iron on the Konstantinovka Iron and Steel Works. Self-reducing carbon pellets had the following features: basicity 0.26–0.32; content in %: $Fe_{processed}$ 62.5–63.3; FeO 28.8–31.3; Fe_{met} 2.3; fines content 3.0; impact index 73.1–80.04; abrasion index 10.8; carbon residue content 1.1. Carrying out blast furnace smelting at blast furnace ДП-1 of Konstantinovka Iron and Steel Works the pellets of Poltava Mining and Processing Works were substituted by 20–25% of the self-reducing carbon pellets. The results of the blast furnace smelting were compared to the periods before and after the experiment. The increase of production of pig iron comprised 11.1–8.7%; coke consumption decreased by 6.99–3.68%. Then the commercial batch of self-reducing pellets was produced at Severny Ore-Mining and Processing Works on the kiln OK-278 (Lurgi). The pilot batch of pellets in the amount of 21,870 tonnes was smelted in the blast furnace of Dnipropetrovs'k Metallurgical Works named after Petrovsky [7]. The amount of pilot pellets in the charge comprised the range from 47 to 57%.

The advantage of pellets with a residual carbon as compared to oxidized ones (see Table 1) is the higher degree of reduction and metalling [8]. The pilot pellets contained 10.16% of iron monoxide. During the period of usage of pilot pellets of Severny Ore-Mining and Processing Works the degree of direct reduction decreased from 31 to 30.6%, which decreased the rate of carbon consumption for the direct reduction for 7 kg/t of pig iron. Blast furnace No.2 and No.6 operated with self-reducing pellets for 8 days, which has resulted in a steady mode of blast furnace smelting.

Table 1. Metallurgical properties of self-reducing pellets

According to GOST	Chemical composition, % Fe	59.22	59.27	62.64	59.48
19575-84	FeO	1.60	1.20	39.67	10.16
	C	-	-	1.13	0.76
	S	0.045	-	0.118	-
	CaO basicity: SiO_2	0.65	0.63	0.52	0.54
	Compression resistance, kg/pellet		217	182	118
	Wearability, %	10.8	10.8	17.6	23.5
	Impact, %	81.8	79.4	69.5	43.0
	Porosity, %	30.48	-	38.01	-
	Abrasiveness, %	4.4	4.9	10.3	13.3
	Reduction rate, %	38.74	39.57	32.83	53.06
	Metalling rate, %	15.61	16.34	19.81	35.76
According to GOST	Layer shrinkage, %	29.5	31.0	51.5	41.0
21707-76	Drop of pressure, Pa	52	50	804	240
	Sinter output, %	36.5	38.5	51.6	43.6
	Reduction rate, %	66.92	69.17	67.14	74.73
	Metalling rate, %	52.01	55.29	60.65	65.51
High-temperature	Temperature of liquid phase filtration start, °C	1330	1330	1370	1385
	Temperature of maximal filtration, °C	1530	1530	1480	1460
	FeO content in early slag, %	48.6	48.6	29.9	35.6

The reduction of the shown coke consumption in furnace No. 2 comprised 6 kg/t of pig iron, and in furnace No.6 there was a reduction of 14 kg/t of pig iron. The charge of agglomerated self-reducing materials into blast furnace can be the alternative solution. These may be both thermally treated iron materials containing carbon and iron materials mixed with carbon in the form of pellets or briquettes produced by low temperature treating. Results of calculations of blast furnace smelting properties with 40% of pellets with different carbon content in the charge are shown in Table 2.

As seen from the data shown in Table 2, the content of carbon should be at the rate of 1.6 – 1.9 % to ensure the overall degree of charge metalling at the rate of 5 – 6% with 40% of pellets content in the charge. It can be achieved under the present production conditions.

Coke substitution coefficient calculated as a relation of coke saving amount to a quantity of carbon in pellets is also of definite interest. As seen from the table 2, the given coefficient for the conditions taken in the calculation is 1.42. The second series of calculation was performed in order to make comparative estimation the efficiency of carbon reduction in the pellets. It was made using the same input data, but taking into account pulverized coal fuel injection at a rate from 50 to 200 kg/t of pig iron. Charge metalling degree in all variants remained equal to zero. The results obtained show that the carbon in the pellets contributes to the metalling degree in the temperature range of 900–1200 °C, thereby reducing the coke carbon consumption for direct reduction reaction.

Conclusions

A theoretical and experimental verification of the effectiveness of iron oxides complex reduction in the reserved zone of blast furnace is given. This effect is realized by injection of self-reducing pellets into the charge, which contain carbon in their composition. Carbon taken in the amount of 1.6-1.9% provides 6% of charge metalling degree. The estimation of effectiveness of self-reducing pellets usage according to the results of blast furnace smelting and analytical study when using pulverized coal in the blast furnaces is given.

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* Published in Russian

Received 31 October, 2012

Table 2. The main results of calculating of blast furnace smelting properties with 40% of pellets with various carbon content in the charge

Parameters and properties	Measurement unit	Base	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Carbon content in the pellets	%	0.0	0.3	0.6	1.0	1.3	1.6	1.9
Pellets metalling rate	%	0.0	2.5	5.0	7.5	10.0	12.5	15
Charge metalling rate	%	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Carbon input with pellets	kg\t of pig iron	0.0	2.19	4.38	6.57	8.77	10.96	13.15
Coke consumption	kg\t of pig iron	668.1	665.0	661.9	658.8	655.7	652.6	649.4
Coke substitution coefficient	kg of coke/kg of C_{rev}	-	1.42	1.42	1.42	1.42	1.42	1.42
Total consumption of fuel carbon	Kg of C/t of pig iron	570.1	567.5	564.8	562.2	559.5	556.9	554.2
Coke consumption for direct reduction	kg\t of pig iron	112.5	111.5	110.5	109.4	108.4	107.4	106.4
Amount of C burnt at tuyere	kg\t of pig iron	414.4	412.8	411.2	409.6	407.9	406.3	404.7
Rated consumption of blast	m^3/t of pig iron	1713.4	1706.7	1700.0	1693.2	1686.5	1679.8	1673.0
Components of dry top gas CO_2	%	14.0	13.9	13.8	13.7	13.6	13.5	13.4
CO	%	27.3	27.4	27.4	27.5	27.6	27.6	27.7
H_2	%	2.6	2.6	2.6	2.6	2.6	2.6	2.7
N_2	%	53.1	56.1	56.1	56.2	56.2	56.2	56.2
*) not including carbon injected with the pellets								

Производство и использование самовосстанавливающихся окатышей в доменной плавке с применением пылеугольного топлива

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Приведена оценка восстановительного процесса в химически резервной зоне доменной печи. Показано, что присутствие тонкоизмельченного твердого топлива в окатышах обеспечивает развитие комплексного восстановления в этой зоне и снижает степень прямого восстановления за счет металлизации. Приведены результаты исследования металлургических свойств самовосстанавливающихся окатышей, результаты доменных плавок. Дана оценка эффективности использования самовосстанавливающихся окатышей при вдувании пылеугольного топлива.