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The Production and Usage of Self-Reducing Pellets in the Blast Furnace Operation Using Pulverized Coal

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An appreciation of the reduction process was given in the chemical reserve zone of the blast furnace (900-1200 °C). It's shown, that presence of finely divided solid fuel in pellets provides the development of a complex reduction in the area and reduces the degree of direct recovery by metallization. The results of the investigation of metallurgical self-reducing pellets properties and the results of the blast furnace operation were carrying out. An appreciation of effect of usage the self-reducing pellets during blowing the apulverized coal.

Keywords: SELF-REDUCING PELLETS, PULVERIZED COAL, COMPLEX REDUCTION, CHEMICAL RESERVE ZONE OF THE BLAST FURNACE

Introduction

At the present stage of development of the iron industry, one of the priority tendency of agglomeration is getting iron ore carbonaceous materials [1, 2]. According to studies, the presence of solid fuel in the iron ore charge provides reception wustite-magnetite structure of sinter and pellets. As for development of reduction processes in a mine of blast furnace, wustite-magnetite structure can't give any advantages, because higher oxides of iron recover in the upper part of the mine [3]. One of the ways of activation the reduction process in chemical reserve zone may be the development of complex reduction [4, 5]. In usual conventional gas-recovery of carbon-free materials, its interior volumes are not involved in the reduction because of topochemical process. In the presence of solid carbon inside pellet is being reducing regeneration of reduction and direct reduction of wustite. Coal gasification reaction rate increases with temperature increase. An increase of temperature leads to an acceleration of gas-carbothermic reduction of iron. However, we must keep in mind, that the transition from recovery carbothermic to complex in a stream of CO affects on the participation of solid carbon in the process. The growth of the partial pressure of CO_2 in the interaction of carbon monoxide with iron ore charge should provide reaction $C + CO_2 = 2CO$ [5]. Participation in the gas stream of hydrogen provides faster recovery rates [6].

For the first time, the production of self-reducing carbon pellets (SRP) was achieved in the experimental plant of agglomeration Central Iron Ore Enrichment Works. Produced pellets were used for the melting of cast iron by Constantine metallurgical plant. SRP were characterized by the following quality indicators: alkalinity 0,26-0,32; content,%: Fe_{ob} 62,5-63,3; FeO 28,8-31,3; Fe_{met} 2,3; other 3,0; index for punch 73,1-80,04; abrasion 10,8; content of residual carbon 1,1. During the blast furnace operation at the DP1 Constantine MP in charge fed 20-25% SRP instead of pellets Poltava GOK. The results of blast furnace operation were compared with up to and final periods. The increase in production of pig iron was 11,1-8,7%; coke consumption decreased by 6,99-3,68%. In the future, production lot of SRP was made in the North Central Iron Ore Enrichment Works on kilning machine OK-278 (Lurgi). Good batch of pellets (21,870 tons) were meltedinto the blast furnace of Petrovsky metallurgical plant [7]. The part of good pellets in charge was from 47 to 57%. The advantage of pellets with the residual carbon compared with the oxidized (**Table 1.**) is in a higher degree of reduction and plating [8]. Good pellets contained 10,16% of iron monoxide. During the period of test pellets North Iron Ore Enrichment Works, degree of direct reduction decreased from 31 to 30,6%, that decreased the consumption of carbon on direct reduction by 7 kg/t of pig iron. DP № 2 and №6 runs on SRP for 8 days, which helped to achieve the stable mode of blast furnace.

Change of the consumption of coke in furnace № 2 was 6 kg/t of pig iron, and the furnace № 6 14 kg/t of pig iron. An alternative solution can be loading agglomerate self-reducing materials into the blast furnace. It can be as heat hardened iron-ore materials containing carbon so iron-ore materials mixed with carbon in the form of pellets or briquettes obtained by low-temperature hardening. Results of calculations using the blast furnace operation in the charge 40% of the pellets with different carbon content are shown in **Table. 2**.

Table 1. Metallurgical properties of the self-reducing pellets

Type of pellets test	Characteristics	Pellets			
		Oxidized		Self-reducing	
		Sinter pot	Industry	Sinter pot	Industry
ISO 19575-84	Chemical composition, %: Fe	59,22	59,27	62,64	59,48
	FeO	1,60	1,20	39,67	10,16
	C	–	–	1,13	0,76
	S	0,045	–	0,118	–
	Alkalinity CaO: SiO_2	0,65	0,63	0,52	0,54
	Resistance to compression,		217	182	118
	Abrasiveness, %	10,8	10,8	17,6	23,5
	Punch, %	81,8	79,4	69,5	43,0
	Porosity,%	30,48	–	38,01	–
	Abrasiveness, %	4,4	4,9	10,3	13,3
	Degree of reducton, %	38,74	39,57	32,83	53,06
	Degree of plating, %	15,61	16,34	19,81	35,76
ISO 21707-76 21707-76	Shrink age of lay, %	29,5	31,0	51,5	41,0
	Pressure difference, Pa	52	50	804	240
	Out of sinter, %	36,5	38,5	51,6	43,6
	Degree of reduction, %	66,92	69,17	67,14	74,73
	Degree of plating, %	52,01	55,29	60,65	65,51
High-temperature	The temperature of start of filtration the liquid phases, °C	1330	1330	1370	1385
	The temperature of max filtration, °C	1530	1530	1480	1460
	Content of FeO in primary slag, %	48,6	48,6	29,9	35,6

Table 2. The main results of calculations using the blast furnace operation in the charge 40% of the pellets with different carbon content

Parameters and characteristics	Unit of measurement	Base	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6
Carbon content in pellets	%	0,0	0,3	0,6	1,0	1,3	1,6	1,9
Degree of pellets panting	%	0,0	2,5	5,0	7,5	10,0	12,5	15
Degree of charge panting	%	0,0	1,0	2,0	3,0	4,0	5,0	6,0
Input of carbon with pellets	kg / tof 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
Factor of coke change	kg of coke / kg C_{left}	-	1,42	1,42	1,42	1,42	1,42	1,42
Total consumption of carbon fuels*)	kg C / t of pig iron	570,1	567,5	564,8	562,2	559,5	556,9	554,2
Consumption of carbon on direct reduction	kg / t of pig iron	112,5	111,5	110,5	109,4	108,4	107,4	106,4
Combustion of carbon in tuyere	kg/t of pig iron	414,4	412,8	411,2	409,6	407,9	406,3	404,7
Estimated blow consumption	m^3/t of pig iron	1713,4	1706,7	1700,0	1693,2	1686,5	1679,8	1673,0
Composition 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

*) without carbon, carring in pellets

According to the **Table 2** for providing of total degree of panting of the charge at level 5-6% with the share of pellets in the charge of 40%, content of carbon should be at level 1.6-1.9%, which is achievable in a real production environment.

We should also notice the factor of coke change. It's estimated as a ratio of savings economy of coke to amount of carbon pellets. As shown in **Table 2**, this factor, adopted in the calculation, is 1,42. For the purpose of comparative evaluation of the efficiency of reducing carbon in the pellets, it was carried out the second series of calculations, using the same data, but with the blowing into the hearth of blast furnace pulverized coal with the consumption from 50 to 200 kg/t of pig iron. Degree of panting of the charge in all cases remained at zero. The results obtained, show that the carbon in the pellets increases the degree of panting in the temperature range 900-1200 °C, thus reducing the consumption of carbon coke, going to the direct reduction.

Conclusions

Theoretical and experimental evaluation of the efficiency of complex reduction of the iron oxides in the reserve zone of blast furnace are shown in this article. This effect is realized by entering into the charge of self-reducing pellets containing carbon in its composition, which is in the amount of 1.6-1.9% provides degree of panting of the charge of 6%. The efficiency estimation of usage of self-reducing peletsdue to results of blast furnace operations and analytical study of usage of pulverized coal in blast furnaces.

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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.