POSSIBILITIES OF APPLICATION THE TITANIUM ORE INTO THE SINTERING MIXTURE

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Abstract
Titanium-bearing burdens are commonly introduced into blast furnaces to protect the hearth and, consequently, extended operating campaign life. Application of titanium ores as part of sintering mixture is one of the way for implementation of titanium into blast furnace. The objective of the present work was to appreciate possibilities for application of supplied titanium ore into the sintering blends. There was studied effect of titanium addition and granularity of titanium ore on sinter properties and technological parameters. There was also sintered mixtures on the base of sintering ore and on the base of concentrate. Each of them was added constant content of titanium ore. The basicity of monoblends was from 0.62 (without of limestone and dolomite) to 2.00. Monoblends on the base of concentrate had positive effect on total content of iron. In the case of mixtures without bases addition was observed higher temperatures in sintering bed because of endothermal effect could not be used. Laboratory analyses indicated that introduction of tested titanium ore did not have a significant influence on productivity. Increasing the titanium ore levels up to 16 % had no significant influence on sintering quality but a significant deterioration in sinter strength was recorded. Results also showed that a granularity of investigated titanium ore had no clear affect on sinter quality.

Keywords: sintering, titanium, ore, concentrate, mixture

1 Introduction

The use of appropriate amount of titanium-bearing burdens in the blast furnace (BF) was found to be an effective way to protect the hearth wall and, consequently, extended operating campaign life [1, 2]. It was well kown that the so-called "titanium bear," [3] which is a precipitate of carbide, nitride and carbonitride of titanium, may form in the BF hearth area if TiO_2 presents in the feed. Titano carbonitrides precipitate out in the cooler areas of the hearth, i.e. areas with greatest heat loss, as additional refractory [4, 5, 6]. According of the above it is necessary to control the amount of titanium-bearing burdens added to the blast furnace to effectively protect the hearth refractories while maintain a smooth operation. The main of titanium containing materials that can be used are natural titaniferous iron ores, directly added to the burden of the blast furnace, and ilmenitic sands of small particle ilmenite, incorporated into the sintering blend or directly injected through the tuyeres in the form of briquettes. Titanium magnetite is an ores with the complex mineral composition which is difficult to beneficiate, sinter and smelt [7]. Its concentrate is low-grade iron and high TiO_2. There are little data available in literature concerning the sintering of titanium-magnetite ores.

The objective of the present work was to appreciate possibilities for application of supplied titanium ore into the sintering blend.

2 Materials and Methods

2.1 Materials

The materials for laboratory experiments was supplied from innominate blast furnace plant. Chemical composition of ferriferous materials is shown in **Table 1**. Supplied materials is commonly used in a sintering process. The sintering ore granularity has been 18.68 % above 8 mm and under 0.5 mm only 1.64 %. Given titanium ore has no directly suitable for agglomeration because of its oversize granularity where fraction above 8 mm was 73.8 %, even though under 0.5 mm was just 2.79 %. There are no presented any knowledges about application of supplied titanium ore in sintering blend. A standard blast-furnace coke under 3 mm was used as fuel. Granulometry of limeston and dolomite was in the range of norm for grinding.

Table 1 Chemical composition of metalliferous materials used in study

	Sintering ore [%]	Concentrate [%]	Ti ore [%]
Fe	60.05	64.79	34.64
FeO	0.21	23.93	24.33
SiO_2	11.65	8.91	11.68
CaO	0.06	0.19	1.95
MgO	0.06	0.22	3.58
Al_2O_3	0.71	0.13	5.08
TiO_2	0.031	0.007	30.440

2.2 Methods

Sintering studies were carried out using the pilot scale sintering facility at the laboratories Department of Ferrous Metallurgy and Foundry in Košice. Methodology and conditions for blend preparation and sintering was carried out according sinter plant technology. There was prepared modelling stacks in various combination. The titanium ore was added into the blends as a diluent, of up to 16 %. An addition of titanium ore was in two grain size fractions i.e. below 0.2 mm and in the second case on granularity like sintering ores. The proportion of sintering ore and concentrate was 1:1.3, 1:0 and 0:1. The homogenization stacks was prepared by interleaving of components in several layers and consequently seasoning for few days. After this granulation process was carried out in a diameter drum and the granulated mix was then transferred into the sinter pot on constant bed high and ignited by means of direct flame burner. Underpressure was controled to constant level of 5 kPa. Sintering process was monitored continuously and recorded. A temperature profile of sinter bed (T1, T2, T3), temperature (T4) and chemical composition (O_2, CO, CO_2, SO_X, NO_X) of exhausted hot gases was monitored after an ignition immediately (**Fig.1**). When the maximum waste gas was taken, the sintering was finished. The sinter was allowed to cool in the pot and then subjected to a standard testing.

3 Results

3.1 1st series - Effect of titanium addition

The effect of increasing the level of titanium ore on sinter properties had more or less influence on sinter properties. Direct effect of titanium ore addition on TiO_2 content in mixture and sinter we can see on the **Figure 2**. There is a function of chemical composition and mutual proportion of substrates in sintering mixture. **Figure 3** shows that addition about 16 % of titanium ore into mixture decreased total content of Fe about 2.3 %. A positive effect of titanium ore addition on

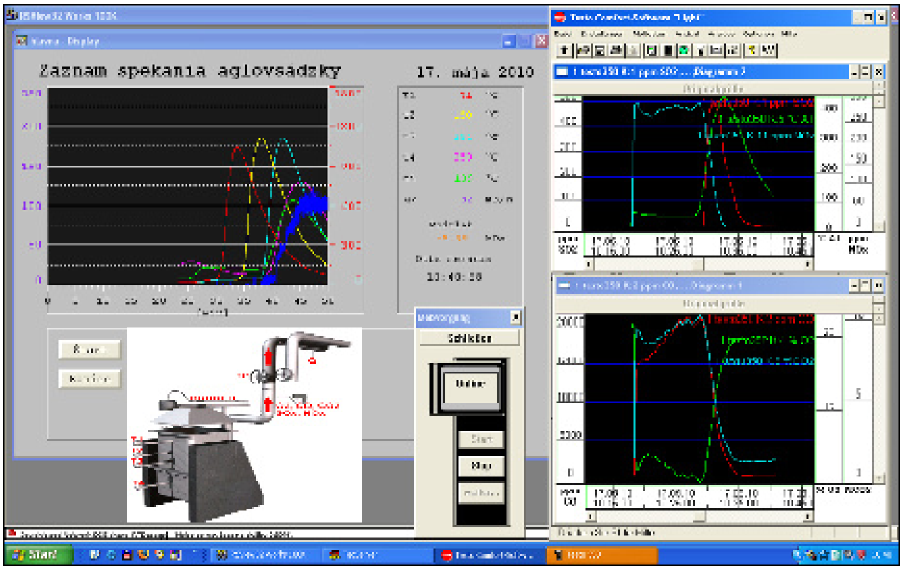

Fig.1 Monitoring of sintering process

fraction +25 mm and the mean diameter has been observed (**Figure 4**). Next picture (**Figure 5**) show negative effect of fine titanium ore on sintering production. The sintering permeability was decreased because granulation capability is worse due to concentrate coarse particle size. This caused consequently longer sintering time. **Figure 6** indicates that increasing the level of titanium ore decreasing sinter stability. An abrasion was practically similar. Chemical composition of sinters is shown in **Table 2**.

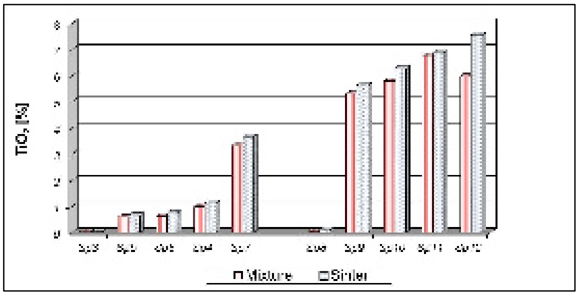

Fig.2 TiO_2 content in mixture and sinter

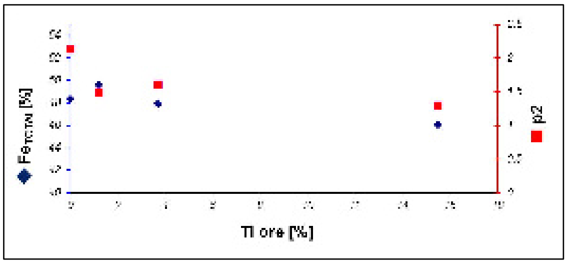

Fig.3 Effect of Ti ore on basicity and total content of Fe

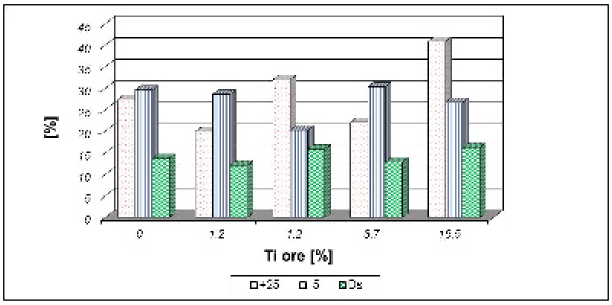

Fig.4 Granulometry of agglomerates

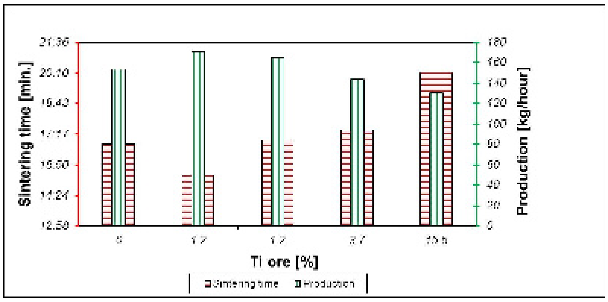

Fig.5 Effect of Ti ore on technological parameters

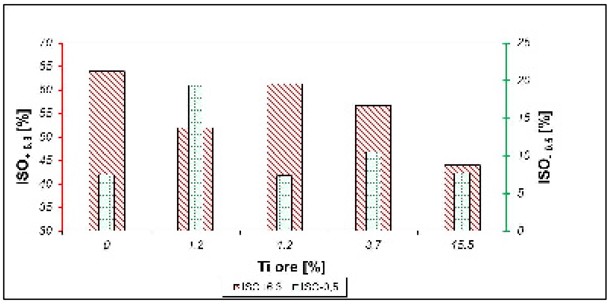

Fig.6 Effect of Ti ore on qualitative parameters

Table 2 Chemical composition of sinters

		AR:KC 1:1.3				
		SP3	**SP4**	**SP5**	**SP6**	**SP7**
Ti ore	[%]	0	3.7	1.2	1.2	15.5
chemical analysis [%]	Fe_{TOTAL}	48.37	47.92	48.92	49.65	46.08
	FeO	6.18	6.61	6.03	5.96	7.54
	Fe_2O_3	62.29	61.17	63.24	64.39	57.53
	SiO_2	9.08	10.59	10.95	10.75	11.15
	CaO	16.04	14.04	13.43	13.57	12.05
	MgO	4.87	4.43	4.05	3.59	4.01
	Al_2O_3	0.72	0.93	0.78	0.72	1.24
	TiO_2	0.037	1.130	0.674	0.754	3.670
	p_2	2.13	1.60	1.49	1.50	1.30

3.2 2nd series – Effect of granularity

Investigation in the next five laboratory tests was oriented on the effect of titanium ore addition into the blends based on one type of sinter ore and one type of concentrate eventually. Titanium ore was crushed and sieved below 8 mm at first. Sintering test Sp8 was done because of sinter below 5 mm. Undersize sinter was used in all tests. Sinter blends Sp11 and Sp12 did not contain alkaline admixtures. Methodology was similar as previous laboratory tests. Results of sintering (**Table 3**) indicated follows:

1. There are no clear effect of granularity of Ti ore on the sinter quality. Reached results of technological and qualitative parameters are in the range of the previous results (compare with Table 2).
2. We can see, that it is possible to make a titanium sinter from different blends as evidence from sintering SP9-SP12.
3. The high temperatures had been achieved in sinter bed (in the case of acid sinters SP11 and SP12), because of too much content of coke in the sinter mixture or more precisely there wasn´t done endothermal effect as in the case of basic sinters. The procceds of sintering (case SP11, SP12) was even though increased approximately about 34% (in case of mixture with sintering ore) or about 47% (in case of mixture on the base of concentrate).

Table 3 Chosen results of sintering SP8-SP12

Technological parameters			**AR:KC 1:1.3**	**AR:KC 0:1**		**AR:KC 1:0**	
			SP8	**SP9**	**SP12**	**SP10**	**SP11**
Ti ore		[%]	0	16.9	17.1	16.9	16.9
bulk density		[kg.m^{-3}]	1826.17	1782.23	1896.97	1762.70	1967.77
sintering period		[min.]	17:10	17:11	28:41	18:30	28:20
sintering rate		[mm.min^{-1}]	18.19	17.98	12.17	17.28	12.26
size	+25	[%]	31.85	18.62	53.98	20.80	36.71
	10 – 25	[%]	32.02	28.55	16.81	29.46	22.14
	5 – 10	[%]	14.38	21.45	13.42	17.33	15.86
	-5	[%]	21.75	31.38	15.78	32.41	25.29
D_S		[mm]	15.98	12.51	19.19	12.99	15.79
strenght $ISO_{+6,3}$		[%]	58.67	33.10	49.33	41.67	51.68
abrasion $ISO_{-0,5}$		[%]	10.00	6.90	8.33	6.94	8.05
chemical analysis [%]		Fe	50.49	45.13	54.17	41.33	50.88
		FeO	7.90	9.05	20.41	5.17	8.48
		Fe_2O_3	63.44	54.50	54.84	53.37	63.36
		SiO_2	10.12	8.62	9.63	12.02	10.65
		CaO	12.26	14.91	3.48	13.38	5.56
		MgO	3.76	5.13	1.29	4.94	2.12
		Al_2O_3	0.73	1.39	1.39	1.65	1.69
		TiO_2	0.100	5.620	7.55	6.280	6.880

4 Discussion

A direct effect of titanium ore addition on TiO_2 content in mixture and sinter is evident. The titanium content of the sinters produced can be very high, generally in the range of 12%. Our agglomerates has content of TiO_2 from 0.04 to 6.88%. The results confirm general agreement that increasing the level of titanium in the sinter mix reduced productivity [8-12] lowered sinter strength [l3, 14]. Forasmuch as the reducibility of sinters was not determined, we can only predict affirmation of autors [10, 12, 14], that increasing the level of titanium in the sinter mix deteriorated sinter reducibility. The content of FeO in laboratory sinters was from 5 to 9 % approximately excepting of sinter SP12 where content of FeO was about 21%. The increase of FeO in sinter with increased titanium ore addition could come about because part of the added titanomagnetite had not oxidised during sintering. High content of FeO in SP12 was because of high content of FeO in mixture (23.93% in concentrate, 24.33% in titanium ore), higher sintering temperatures of bed (absence of limestone and dolomite in mixture) and since the magnetite oxidation reaction is exothermic. Granulometry analyse the sinters, in case of fine Ti ore addition (SP4-SP7), shows positive effect of increasing the level of titanium ore on fraction +25 mm and in consequence of this the mean diameter was increased. It was caused because of generally the sintering process with fine-grained materials takes place more intensively than that with the coarse-grained ones. The fine-grained sinter mix reveals a larger surface, a greater proportion of fused particles encounters with heating up to the sintering temperature, the ionic mobility increases, the constant forces are weakening and, before achieving the melting point, the particles loss their properties belonging to solid maters and start to have the properties of liquid medium. Thus, when feeding the coarse-grained sinter mix both the specific surface and the number of contact points falls. Increase in contact area as well as a larger amount of the s.-c. liquid phase in sinter temperature, ignition temperature and by a higher fuel consumption as well. According to the below-mentioned an increased fuel consumption is not always a suitable way how to improve the sinter quality. Then, the strength of ready sinter will depend above all upon the amount of movable ions which, in the further stage, represent the nucleus of the s.-c. slag bond between the individual grains. The using of coarse-grained Ti ore in sinter mix did no significant differences in technological and quality parameters in compare with using of fine-grained Ti ore addition but increasing of undersize sinter (SP9, SP10 vs.SP7) was observed.

5 Conclusions

Laboratory testes shown that investigated Ti ore can be used into a sintering blends for various rates of ores and concentrates. Given titanium ore has no directly suitable for agglomeration because of high content of fraction above 8mm. According to this Ti ore must be grinded on usable fraction. On the other side beating degree is closely associated with cost of energy or if you like with economy of process. A direct effect of titanium ore addition on TiO_2 content in mixture and sinter is evident. Laboratory analyses indicated that the addition of titanium ore did not have a significant influence on productivity. The addition of up to 16% titanium ore had negative affect on the total content of Fe in sinter. Increasing the titanium ore levels up to 16 % had no significant influence on sintering quality but a significant deterioration in sinter strength was recorded. The content of FeO in laboratory sinters was from 6 to 7.5 % approximately. The increase in sinter FeO with increased titanium ore addition could come about because part of the added titanomagnetite had not oxidised during sintering. Sieve analysis the sinters shows positive effect of increasing the level of titanium ore on fraction +25 mm and in consequence of this the mean diameter was increased. It was caused because of generally the sintering process with fine-grained materials takes place more intensively than that with the coarse-grained ones.

Considering to limited content of titanium in pig iron (cca 0.25-0.3%Ti) and slag (1-2.5% TiO_2) it is possible use a sinter with TiO_2 content about 3-4%.

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References

[1] T. Inada, A. Kasai, K. Nakano, S. Komatsu, A. Ogawa: ISIJ International, Vol. 49 (2009), No. 4, p. 470–478.
[2] G. T. Da Rocha, G. M. De Araujo Filho, M. B. Cardoso: Development of a High Ti-content Sinter, Metalurgia ABM, Vol. 41, 1985, No. 326, p.25-28.
[3] K. Narita, M. Maekawa, T. Onoye, Y. Satoh, M. Miyamoto: Transactions of the Iron Steel Institute of Japan, Vol. 17, 1977, p. 459-468.
[4] S. Sridhar, A.W. Cramb: Metallurgical and materials transactions B, Vol. 31B, 2000, p. 406-410.
[5] W Wang: Iron & Steel, Vol. 23, 1988, No.2, p. 9-14.
[6] Y. Li, R.J. Fruehan: Metallurgical and materials transactions B, Vol. 32B, 2001, p. 1203-1205.
[7] A. Łedzki et al.: Hutnik, Vol.7, 2007, p. 344-347.
[8] R. Budzik et al.: Hutnik, Vol. 55, 1988, No. 5, p. 146-149.
[9] G. Zhang, O. Ostrovski: International Journal of Mineral Processing, Vol. 64, 2002, No. 4, p. 201-218.
[10] R. Benesch, A. Łędzki, R. Kopeć, R. Stachura: Thermochimica Acta, Vol.152, 1989, No.2, p. 433-446.
[11] R. Benesch, M. Wyderkoand, A. Ledzki: Hutnicke Listy, Vol. 42, 1987, No. 8, p. 533-536.
[12] R. Budzik: Metalurgija, Vol. 42, 2003, No. 1, p. 41-45.
[13] R. Budzik: Metalurgija, Vol. 46, 2007, No. 2, p. 145-147.
[14] R. Benesch, M. Wyderko-Delekta, A. Ledzki: Hutnik, Vol. 56, 1989, No. 5, p. 170-174.
[15] Y. Li, Y. Li, R. J. Fruehan: ISIJ International, Vol. 41, 2001, No. 12, p. 1417–1422.