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ISSN 0543-5846
METABK 55(4) 581-584 (2016)
UDC – UDK 669.05.1.292.295:622.781:539.43=111

OPTIMIZATION UTILIZATION OF VANADIUM - TITANIUM IRON ORE IN SINTERING BASED ON ORTHOGONAL METHOD

Received – Primljeno: 2015-12-08
Accepted – Prihvaćeno: 2016-03-10
Original Scientific Paper – Izvorni znanstveni rad

The main aim of this work was to optimize the proportions of vanadium and titanium iron ore from diverse sources in sinter mixture. Industrial V - Ti sinter was observed firstly, then 16 groups of sinter using different proportions V - Ti ore from diverse sources, designed through orthogonal method, were prepared by sinter pot, and their performances were determined. It showed that, V - Ti sinter had complex mineral compositions, particularly perovskite ($CaO·TiO_2$). V - Ti ores from diverse sources had different impacts on V - Ti sinter properties. V - Ti sinter should be sprayed with proper $CaCl_2$ to improving the lower reduction degradation index ($RDI_{+3,\ 15}$). And the V - Ti sinter mixture with 5 % DaBan (DB), 25 % HengWei (HW), 25 % YuanTong (YT), 45 % JianLong (JL) ore was optimal.

Key word: sinter, vanadium - titanium iron ore, tumbler strength, RDI, orthogonal method

INTRODUCTION

China is the world's largest steel producer and has an increasing demand for iron ore. In recent years, with the rising in price of high - grade ordinary ore, a growing number of Chinese steel companies began to use vanadium and titanium (V - Ti) iron ore with a lower price largely. V - Ti ore has a very high comprehensive utilization value for it contains vanadium, titanium, etc [1, 2]. However, there is a larger difference between V - Ti and ordinary sinter [3 - 5] for the special mineral compositions and structure especially perovskite ($CaO·TiO_2$). Perovskite, a worthy mineral to mention, which consumes CaO sources and causes the decrease in calcium ferrite. Meanwhile, it has a higher fragility and does not have the bonding effect. So, V - Ti sinter has poor metallurgical properties. What's more, the V - Ti iron ores from diverse sources were often used as the same kind of V - Ti iron ore in sintering in most of Chinese steel companies and their differences in sinter properties were neglected, which causes the properties and smelting operation of V - Ti sinter instability in blast furnace. Thus, V - Ti iron ore from diverse sources should be used reasonably to obtain the optimal sinter properties.

In this work, industrial V - Ti sinter produced by Jianlong Iron and Steel Company (China) was observed under Leica microscope equipped firstly. Then, on the basis of industrial ore - matching scheme, 16 groups of sinter mixture using V - Ti ore from diverse sources were designed through orthogonal method, and prepared by sinter pot, meanwhile, their performances were determined.

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EXPERIMENTAL WORK

Raw materials

Industrial V - Ti sinter samples and the four vanadium - titanium ores from diverse sources DaBan (DB), HengWei (HW), YuanTong (YT), JianLong (JL), and two ordinary ores YinDu (YD), MaFeng (MF) used in this study are supplied by Chengde Jianlong Iron and Steel Group Company, China. The chemical compositions of iron ores for experimental work are listed in Table 1.

It can be seen from Table 1 that the total iron content of four V - Ti ores is higher than that of ore YD and MF especially MF, and the TiO_2 content of V - Ti ores varies from 1,45 % to 2,56 % along with the V_2O_5 content of V - Ti ores varies from 0,37 % to 0,55 %.

Therefore, it will have a significant effect on the iron grade of the sinter and the content of TiO_2 has a negative influence on the quality of the sinter to a certain extent. In addition, the content silica of four V - Ti ores is smaller than 5 % while the total iron content is larger than 63 %. Thus, they are high iron and low silica ores.

Experimental method

On the basis of raw materials supplied and industrial ore - matching scheme (Table 2) in Chengde Jianlong Iron and Steel Group Company, experiments adopt orthogonal method with 3 factors and 4 levels ($L_{16}(4^3)$), 3 factors were DB ore, HW ore, YT ore respectively, and 4 levels (The total V - Ti iron ore added in sinter mixture was set as 100 %, and the initial proportions of DB, HW, YT were 50 %, 5 %, 45 % respectively. In addition, the proportions of DB and YT decreased in 15 %, 10 % respectively each time while HW rose in 10 % and JL

Table 1 **Chemical compositions of iron ores /mas. %**

Items	TFe	SiO_2	CaO	MgO	Al_2O_3	TiO_2	V_2O_5
DB ore	63,04	4,55	1,86	1,38	1,50	1,92	0,44
HW ore	63,67	3,60	1,01	0,79	1,89	2,50	0,55
YT ore	63,63	3,26	1,34	1,18	1,52	2,56	0,54
JL ore	63,52	4,20	1,69	1,76	1,23	1,45	0,37
YD ore	56,06	5,57	0,06	0,15	5,63	-	-
MF ore	51,71	6,57	0,21	0,15	8,48	-	-
ZF ore	65,55	3,04	0,46	3,50	0,65	-	-

ore was used to fill the total proportion to 100 %, the experimental schemes were shown in Table 3). And the sinter moisture maintained at 7,5 ± 0,3 %, the coke content was 3,2 %, basicity was 1,90. The metallurgical properties (tumbler strength (TI) and reduction degradation index (RDI)) were determined in accordance with ISO - 3271 and ISO - 4696 respectively.

Table 2 **Industrial ore - matching scheme of sintering / mas. %**

V - Ti ore	YD ore	MF ore	ZF ore	Return fines	Waste slag	blast furnace dust
45	5	3	5	28	1,5	3

Note: Basicity=CaO/SiO_2

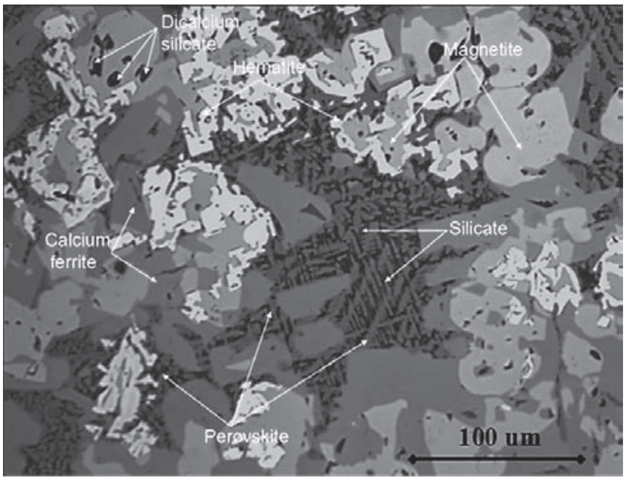
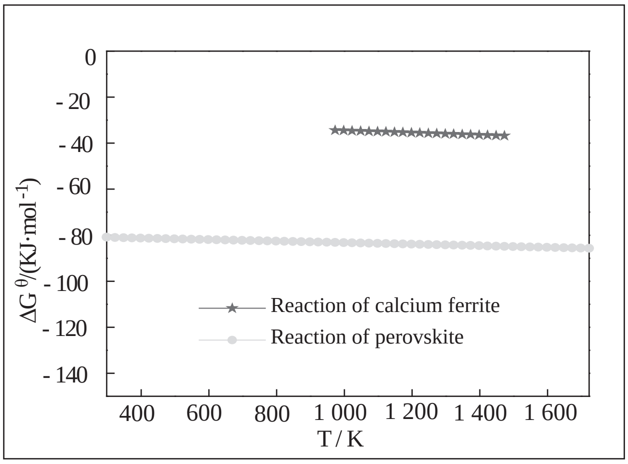


Figure 1 Optical photograph of industrial V - Ti sinter

RESULTS AND DISCUSSION

Optical microscopy analysis of Industrial V - Ti sinter

Optical microscopy photo for the mineralogical phase texture in the industrial V - Ti sinter was shown in Figure 1. The photograph showed the V - Ti sinter consisted of five key mineral phases and they were hematite, magnetite, silicate (dicalcium silicate), calcium ferrite and perovskite. And the noteworthy mineral should be pointed out for V - Ti sinter was perovskite for it just appeared in V - Ti sinter. In addition, due to Gibbs Free Energy of reaction between TiO_2 and CaO is far less than that of between CaO and Fe_2O_3, CaO prefers to react with TiO_2 to generating perovskite ($CaO·TiO_2$) (Figure 2), which consumed an additional part of basicity (CaO) and caused the decrease in liquid phase and calcium ferrite. Meanwhile, perovskite could distribute in some regions concentrated, which would weaken V - Ti sinter strength for its high fragility. Further, it dispersed in the slag phase (silicate), calcium ferrite and the iron minerals, which weakened the role of bonding phase and iron minerals and produced cracks easily when there was an external force. Thus, the V - Ti sinter with poor TI and RDI.



Note: $CaO+TiO_2 = CaO·TiO_2$, ΔG_1=-19100-0,8T;
$CaO+Fe_2O_3=CaO·Fe_2O_3$, ΔG_2=-1700-1,15T

Figure 2 Thermodynamics of the reactions of calcium ferrite and perovskite

Orthogonal experiments results analysis by range method

TI and $RDI_{+3,15}$ of 16 groups of V - Ti sinter and the results of range analysis are shown in Table 3 and Figure 3.

Table 3 **TI and $RDI_{+3,15}$ of V - Ti sinter analysis by range method / mas. %**

Items		I	II	III	JL	TI	$RDI_{+3,15}$
		DB	HW	YT			
No.1		A(50)	A (5)	A(45)	0	59,79	40,76
No.2		A(50)	B(15)	B(35)	0	60,77	47,19
No.3		A(50)	C(25)	C(25)	0	61,57	40,33
No.4		A(50)	D(35)	D(15)	0	59,51	44,14
No.5		B(35)	A (5)	B(35)	25	59,51	41,85
No.6		B(35)	B(15)	A(45)	5	61,56	45,78
No.7		B(35)	C(25)	D(15)	25	61,57	42,48
No.8		B(35)	D(35)	C(25)	5	61,69	40,17
No.9		C(20)	A (5)	C(25)	50	61,15	44,23
No.10		C(20)	B(15)	D(15)	50	58,16	50,92
No.11		C(20)	C(25)	A(45)	10	59,32	40,14
No.12		C(20)	D(35)	B(35)	10	60,17	40,60
No.13		D(5)	A (5)	D(15)	75	62,44	48,16
No.14		D(5)	B(15)	C(25)	55	60,67	44,01
No.15		D(5)	C(25)	B(35)	35	62,77	33,06
No.16		D(5)	D(35)	A(45)	15	62,15	30,68
TI	Mean A	60,41	60,72	60,71	R(I)>R(II)>R(III) The optimal was I D(5),IIC(25),IIIC(25), JL(45)		
	Mean B	61,08	60,29	60,82			

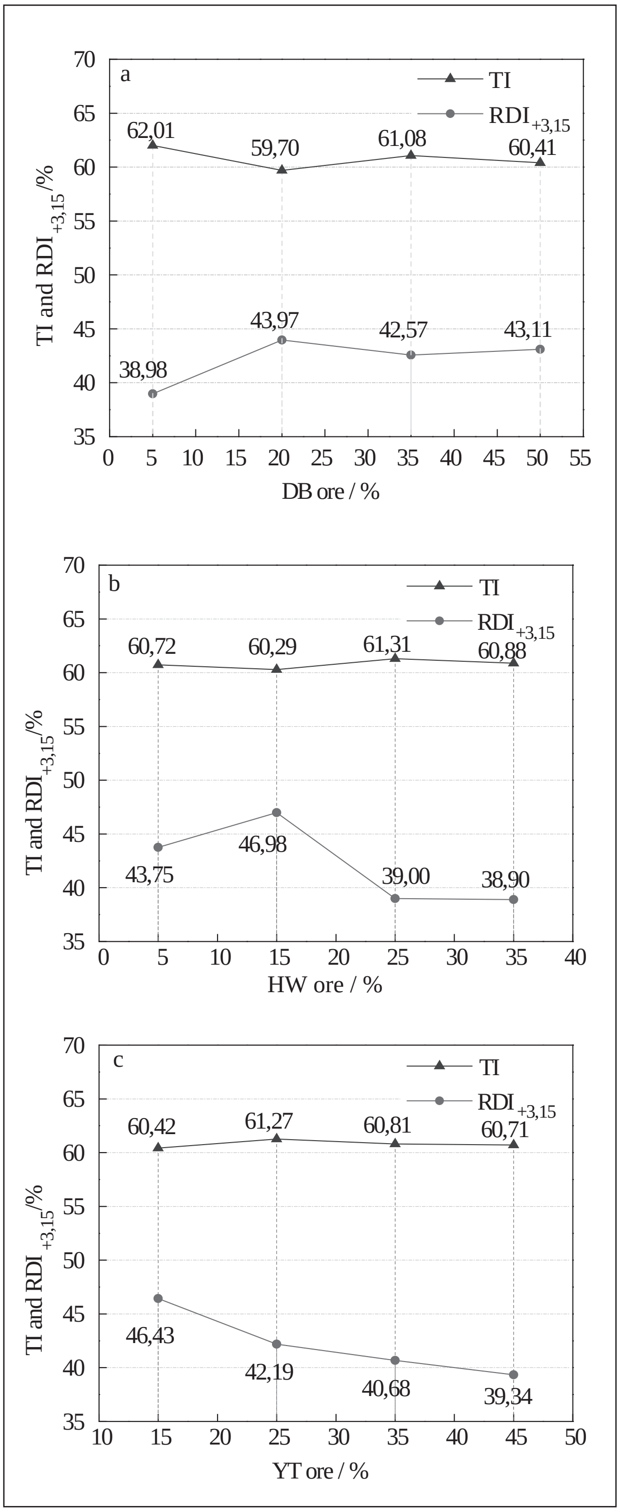


Figure 3 Influence of DB(a),HW(b),YT(c) proportions on TI and $RDI_{+3,15}$ of V - Ti sinter

From the experimental results and range analysis shown in Table 3 and Figure 3, the sequence of effect on TI from high to low was DB ore, HW ore and YT ore for R(I) = 2,31 > R(II) = 1,02 > R(III) = 0,85. In addition, when the proportion of DB ore was 5 %, the mean value of TI got a max value 62,01 % (Figure 3 a) and when the proportion of HW ore was 25 %, the mean vale of TI got a max value 61,31 % (Figure 3 b), and when the proportion of YT ore was 25 %, the mean vale of TI got the max value 61,27 % (Figure 3 c). Therefore, the optimal proportion scheme was 5 % DB, 25 % HW, 25 % YT, and 45 % JL ore in the view of TI.

Similarly to the effect of TI, the sequence of effect on $RDI_{+3,15}$ from high to low was HW ore, YT ore and DB ore for R(II)=8,08 > R(III)=7,09 > R(I)=4,99. In addition, when the proportion of DB ore was 20 %, the mean vale of $RDI_{+3,15}$ got a max value 43,97 % (Figure 3 a) and when the proportion of HW ore was 15 %, the mean vale of $RDI_{+3,15}$ got a max value 46,98 % (Figure 3 b), and when the proportion of YT ore was 15 %, the mean value of $RDI_{+3,15}$ got a max value 46,43 % (Figure 3 c). Therefore, the optimal proportion scheme was 20 % DB, 15 % HW, 15 % YT, and 50 % JL ore in the view of $RDI_{+3,15}$. However, there was still a huge gap between V - Ti sinter and the requirements in $RDI_{+3,15}$ for $RDI_{+3,15}$ of sinter must be higher than 70 % before smelted in blast furnace. Thus, V - Ti sinter should be sprayed with $CaCl_2$ to improve $RDI_{+3,15}$ to meet the requirements, and the effect of DB, HW, YT proportions on $RDI_{+3,15}$ of V - Ti sinter could be neglected.

CONCLUSIONS

1 The properties of V - Ti sinters using V - Ti iron ore from diverse sources with different proportions are different, and V - Ti iron ores from diverse sources must not be used as the same kind of V - Ti iron ore in sintering.
2 The minerals in V - Ti sinter are complex especially perovskite ($CaO·TiO_2$), which make the poor metallurgical properties particular $RDI_{+3,15}$, and $CaCl_2$ are needed to be sprayed to improve $RDI_{+3,15}$ to meet the requirements in a blast furnace.
3 20 % DB, 15 % HW, 15 % YT, and 50 % JL ore is the optimal proportion scheme in the view of $RDI_{+3,15}$. Though, 5 % DB, 25 % HW, 25 % YT, and 45 % JL ore is the optimal proportion scheme in the view of comprehensive properties.

ACKNOWLEDGMENTS

Authors are grateful to the National High Technology Research and Development Program of China (863 Program) (No. 2012AA062302 and 2012AA062304), Program of the National Natural Science Foundation of China (No. 51090384 and 51174051), and The major international cooperation of Ministry of science and technology of China (No. 2012DFR60210) for support of this research.

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Note: Mi Zhou is responsible for English language, Shenyang, China