

Studies on Production of High Carbon Ferromanganese in Blast Furnace with High Proportion of Sinter and Improvement in Manganese Recovery

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Abstract

In connection with the characteristics of domestic and imported Mn ores and the actual conditions of Xinyu Co., tests on HC FeMn blast furnace production with high proportion of sinter were made. Results from tests have shown the feasibility of FeMn production with high proportion of sinter up to 100% and the smooth operation with improved technical and economical indexes.

1. Introduction

China has considerable deposits of manganese ores, but most of them are lean, 90% of which has content less than 30%. In addition, they are of low strength and have high proportion of fines. The ore reserves are mainly located in Guangxi and Hunan provinces where the proportion of fines reaches over 60%. Usage of large quantities of high grade Mn ores from Australia, Gabon and South Africa will result in unacceptable production cost while low-priced ore fines from many domestic mines with Mn content of about 42% have not yet been fully utilized. Therefore, great importance should be attached to HC FeMn production in blast furnace with high proportion of sintered ore fines.

However, it seems that there have not yet been previous examples both at home and abroad regarding this problem. For example, the average proportion of sinter used in our country during the last two years is only 40.5%; the highest 66.13% being in our company (see Table 1). For this

reason, tests on high proportion of sinter have been carried out.

2. Tests on the use of high proportion of sinter

In order to study the feasibility of use of high proportion of sinter in the blast furnace production of HC FeMn, stagewise tests on different proportioning of sinter were conducted on blast furnace No. 1 in the ferroalloy plant of our company from April to December in 1996.

2.1 Purposes of the tests

2.1.1 Find the optimum proportion of Mn sinter within the range 70-100%.

2.1.2 Work out the system of operation under the condition of high proportion of sinter, overcome the conditions which are unfavorable to the smooth running of furnace and the tendency of high temperature at furnace top.

2.1.3 Improve the metallurgical performances of Mn ore sinters, select proper slag-forming system and heat system to raise recovery and other economical and technical indexes.

2.2 Test equipment and flow process

Smelting tests were carried out in a 255 m³ blast furnace. Ore sinter was supplied from two 24 m³ sintering machines. The sintering process and furnace charging are shown in Fig. 1.

Table 1 Proportion of sinter used in some domestic plants, 1994-1995

Producer	Xinyu	Saoxin	Yangquan	Bayi	Guilin	Xinyang	Langfang	Wujing	Average
Sinter %	66.13	7.82	39.16	48.67	63.13	34.45	41.16	31.19	40.50

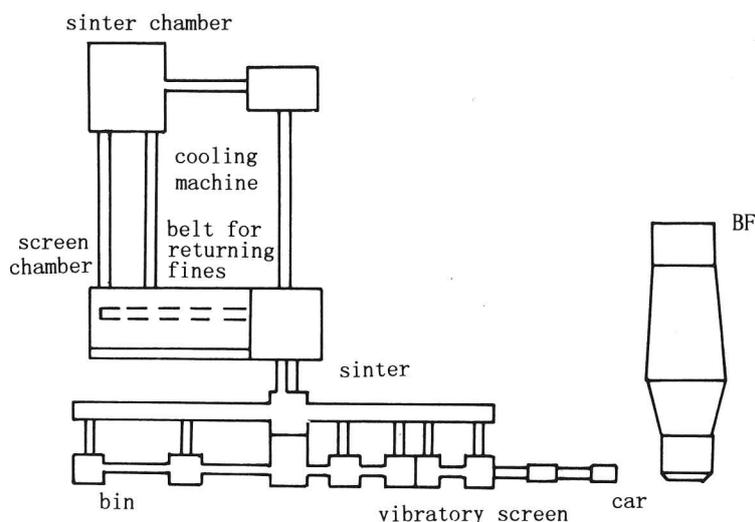


Fig. 1 Schematic diagram of process of sintering and blast furnace charging

2.3 Raw materials and fuels

The Mn ores used in the tests were cooled ore sinter and domestic natural lumpy ore. To ensure smooth running of sintering processing, sintering cup tests were done beforehand in the laboratory.

To meet the requirement of smelting;

Firstly, Brazilian ore fines were used to adjust Mn/Fe and P/Mn of the Mn ore sinter to ensure qualified smelted products that will meet the users' demand.

Secondly, based on the results of cup test, Mn ore sinter of good metallurgical performances were produced. In view of the fact that with the increase of basicity and MgO content of the sinter, mineral phases of MgO system tended to form, such as bustamite (3CaO. MgO. 2SiO₂), monticellite (CaO. MgO. 2SiO₂) and akermanite (2CaO. MgO. 2SiO₂), etc., the softening temperature of ore sinter rises and the range of softening and melting becomes narrow (<40°C), Mn ore sinter of high basicity and high MgO content was produced. The compositions of Mn sinter and lumpy ore are shown

in Table 2;

Table 2 Composition of Mn ore used in test

Composition %	Mn	Fe	SiO ₂	CaO	MgO	Al ₂ O ₃	P
Sinter	23.81	7.82	15.20	23.13	7.28	9.07	0.145
Domestic lumpy ore	26.97	8.56	26.51			8.46	0.169

Thirdly, the strength of ore sinter was improved and the content of fines was reduced to meet the requirement of the smooth running of the blast furnace. With the increase of basicity and MgO content of ore sinter the composition of mineral phase tends to become a complicated multi-component system which is favorable to improve the sinter strength and reduce friability. Especially after cooling and screening, the particle size will become uniform, middle size constituting 73.43%. Cold strength is evidently improved and fines are mostly screened out, percentage of fines being less than 3%. See Table 3, 4 and 5 for the relevant qualities.

Table 3 Qualities of ore sinter

Drum index	Anti-resistance index	Distribution of sizes %				
		>40mm	>25mm	>10mm	>5mm	<5mm
2.93	86.18	4.9	7.62	19.54	54.49	15.42

Table 4 Qualities of coke (%)

C	A ^B	V ^r	S	M40	M10	A ^B					
						Mn	Fe	SiO ₂	CaO	MgO	Al ₂ O ₃
0.10	3.52	51.88	2.81	0.77	31.92	83.34	15.47	1.19	0.79	75.60	8.60

Table 5 Composition of quicklime

SiO ₂	CaO	MgO
1.98	86.83	1.73

3rd stage; ore sinter 9/10, domestic lumpy ore 1/10;

4th stage; ore sinter 10/10; Reference period; ore sinter 6/10, domestic lumpy ore 4/10

2.4 Arrangement of test

Tests were done in 4 stages, proportioning of ores in each stage being respectively;

1st stage; ore sinter 7/10, domestic lumpy ore 3/10;

2nd stage; ore sinter 8/10, domestic lumpy ore 2/10;

3. Results and discussions

Results in each stage (all stages throughout 1996) are shown in Table 6;

Table 6 Main technical and economical indexes of test

Item	Reference period Jan 3-17	Experimental Period			
		Stage 1 April 6-20	Stage 2 Nov 1-15	Stage 3 Nov 17-Dec 1	Stage 4 Dec 5-19
Efficiency, t/m ³ .d	0.465	0.492	0.509	0.514	0.537
Coke rate, kg/t	2196	2145	2083	2075	2064
Ore rate, kg/t	3070	3252	3333	3345	3340
Flux rate, kg/t	1158	978	604	526	355
Mn recovery, %	79.21	79.43	80.05	80.51	81.37
Slag/alloy, kg/t	2684	2631	2484	2473	2465
Utility, t/m ³ .d	1.021	1.055	1.060	1.067	1.108
Charge grade Mn %	34.45	33.96	34.45	35.01	34.10
Temp at top, °C	429	438	447	437	452
(Al ₂ O ₃)	9.17	9.97	10.16	10.41	12.51
(CaO)	40.97	40.50	39.23	38.66	37.99
(SiO ₂)	29.86	29.97	28.31	28.74	27.97
(MgO)	8.54	9.37	9.44	10.12	12.26
(MnO)	5.42	5.34	5.19	5.14	4.92
Binary basicity	1.37	1.36	1.39	1.35	1.36
Ternary basicity	1.66	1.68	1.72	1.70	1.80

It can be seen from the table that with the increase of the proportion of sinter, various indexes have been improved. The analysis is as follows;

3.1 Effect on the operation of blast furnace

Firstly, after the increase of the proportion of ore sinter, the blast furnace was running smoothly and

no channeling occurred due to the performances of the sinter improved in strength, particle size, percentage of fines, reducibility and softening, chemical composition, slag-forming ability and permeability of gases and melts through the burden column. When the proportion was increased from 70% to 100%, the hot pressure of the furnace increased too and so did the pressure at the top of the furnace; thus the pressure difference was kept constant. Since the gas flow at the periphery weakened comparatively, large batch and other measures to enlarge the area of tuyere for blowing hot air were adopted to ensure smooth operation and increase of direct charge rate.

Secondly, although the heat consumption of evaporation of burden moisture and decomposition of flux was lowered, the heat evolved from the reduction of higher oxides of Mn was lowered also. Therefore, the temperature at the top of furnace was practically unchanged.

3.2 Effect on blast furnace efficiency

With the increase of the proportion of sinter, smelting intensity slightly increased and the FeMn output was raised due to the lowering of coke rate and the increasing of Mn recovery, resulting in the boosting of furnace efficiency. Meanwhile, tests have also shown that the Mn content of ore sinter is the key factor in determining the technical and economical indexes of smelting.

3.3 Effect on coke rate

During the 4th stage, the coke rate was 132 kg/t less than that of the reference period. The main reasons are thought to be (1) smooth running of furnace, (2) reduced coke rate, (3) reduced MnO content in slag, reduced slag volume and loss from the furnace top and improved Mn recovery, (4) lowering of heat consumption due to substantial lowering of amount of flux charged to the furnace.

4. Discussion on the relationship between high proportion of sinter and Mn recovery

The problem of Mn recovery is the core of FeMn smelting. The main objective is to attain maximum

Mn recovery and to attain it economically. As is well known, Mn loss is caused by loss in slag, loss due to the blow out from the top of furnace and mechanical loss. The first two constitute more than 80% of total loss under the conditions of lean ore and large slag volume, and hence emphasis should be placed on reducing them, the main affecting factors of which will be discussed as follows:

4.1 Relationship between slag volume and Mn recovery

Mn loss in slag can be formulated as follows:

$$P = G * (\text{MnO})\% \times 1.19$$

where P --- Mn loss in slag, kg/t;

(MnO) --- MnO content in slag, %;

G --- slag volume, kg/t;

1.19 --- constant (Mn atomic weight/MnO molecular weight)/0.65

The relationship is depicted in Fig. 2

it will be noted from Fig. 2 that with the increase of slag volume, Mn loss in slag increases, being more serious especially when (MnO) in slag is of high content. [1] After using high proportion of sinter, since the coke load improves, SiO₂ content in the ore sinter with Brazilian ore fines addition decreases and thus the amount of flux used decreases, resulting in the reduction of slag volume.

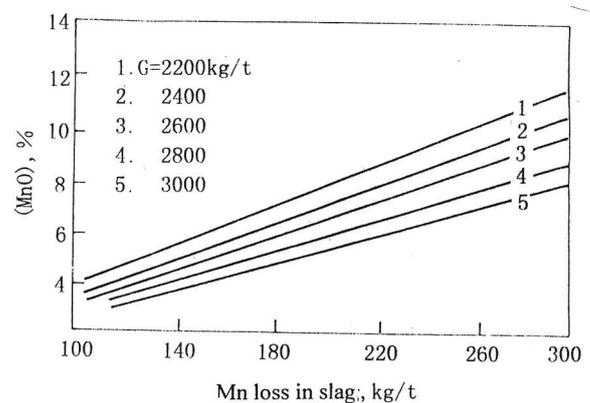


Fig 2 Relationship among slag volume G, (MnO)% in slag and Mn loss in slag
Compared with the reference period, there is a reduction of slag volume of 215 kg/t in the 4th

stage.

Only this item will raise Mn recovery by around 1.5%.

4.2 Relationship between slag composition and (MnO)

4.2.1 Relationship between binary basicity and (MnO)

Slag basicity will improve the reducing condition of manganese silicate by displacement of MnO from silicate by CaO so as to increase the concentration of free MnO in slag which is favorable to the reduction of MnO. With the increase of slag basicity, MnO content in slag gradually decreases. (See fig. 3). However, a too high slag basicity will result in poor slag flowability and will worsen the furnace condition. At the same time, slag volume will greatly increase and correspondingly Mn loss will increase. The suitable slag basicity should be 1.4-1.5 under the condition of high-sinter production.

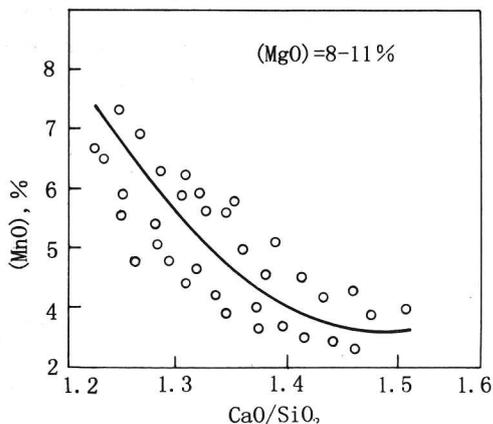


Fig 3 Relationship between binary basicity and (MnO)

4.2.2 Effect of MgO on (MnO)

Increasing the MgO content in slag will not only improve the flowability of slag of high basicity, but also improve further the reducing condition of MnO. At the same time, increasing the MgO content will also raise the temperature of slag and correspondingly improve the kinetic condition of the reduction of MnO. (MnO) decreases with the

increase of MgO. (See Fig. 4)

Of course, the MgO content is also not the higher the better. A too high MgO content will require high heat consumption to keep the slag at a high temperature in order to ensure the flowability of slag, and this will be uneconomical. Tests have shown that a MgO content of 8-11% would be suitable.

4.2.3 Effect of Al2O3 on MnO

Under the condition of same basicity, MnO content will gradually decrease with the increase of Al2O3. Especially in the case of high-MgO slag where the hearth temperature is relatively high, increase of Al2O3 content is favorable to the lowering of (MnO) in slag. In this test, Al2O3 content of around 13% in slag would be suitable.

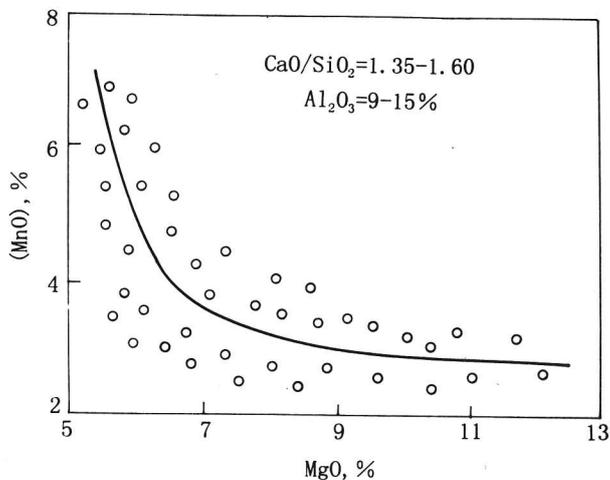


Fig 4 Relationship between MgO and MnO in slag

4.2.4 Selection of a suitable slag composition

Summming up the above said, a suitable slag composition during the production with high proportion of ore sinter should be:

Binary basicity R_2	1.4-1.5
MgO	8%-11%
Al ₂ O ₃	around 13%
MnO	4-6%

4.3 Relationship between Si content in alloy and MnO content in slag

Si content in alloy is an important factor reflecting the temperature of hearth. Adequate high temperature of hearth is an important condition for the reduction of MnO. Relationship between Si content in alloy and MnO content in slag is shown in Fig. 5. When Si content is < 0.5, MnO content increases sharply; when Si content exceeds 1.2%, the curve will become flattening. Therefore, under the present operating condition, control of Si content in alloy at 0.8-1.2% is suitable.

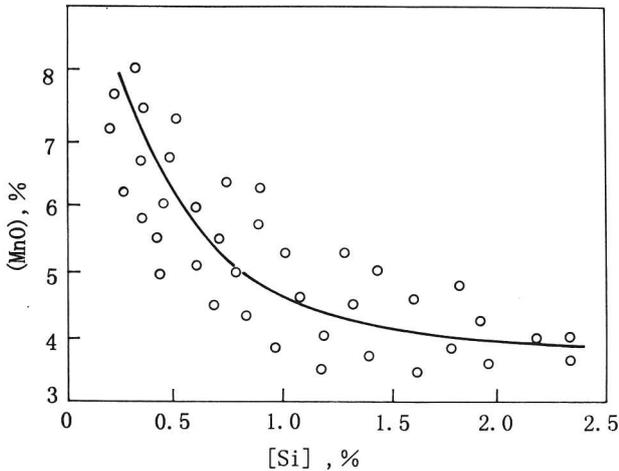


Fig 5 Relationship between Si content in alloy and MnO content in slag

4. 4 Relationship between loss from furnace top and Mn recovery

High coke rate, high volume of gas generated and high temperature at the top of furnace result in high flow of gas and considerable dust emission. With the addition of volatilization of Mn in furnace, Mn loss from furnace top constitutes about 6-20% of the total Mn charged into furnace and thus affecting Mn recovery seriously. From calculation, it is found that Mn recovery will decrease by about 1.6% when dust/alloy ratio increases by 100 kg/t. The rise of coke load in high-sinter production will result in a stable temperature and a rising pressure at furnace top, suitable Si content in alloy and smooth running of furnace. Dust/alloy ratio is 79kg/t less than that during the reference period.

In short, use of high proportion of sinter in FeMn production is favorable to the improvement of Mn recovery.

5. Conclusion

5.1 Upper limit of 100% of ore sinter can be used in FeMn blast furnace production. Furnace operation is smooth; improvement of technical and economical indexes is obvious. Ore fines from home and abroad as well as domestic lean Mn ores can be fully utilized. Application of this feasible technological process should be the direction of the further development of FeMn blast furnace in our country.

5.2 Tests have shown that the use of high proportion of Mn ore sinter is favorable to the improvement of Mn recovery resulted from the following factors: good physico-chemical properties of high slag basicity and high MgO ore sinter, reduced amount of quicklime used, smooth and stable running of furnace, reduced loss from blow out at furnace top, improved performances of slag and reduced MnO content in slag.

5.3 Upgrading the quality of ore sinter and controlling MgO content of ore sinter at a suitable level are the key factors in the further improvement of technical and economical indexes of smelting, quality of products and Mn recovery.

5.4 FeMn production with high proportion of sinter has relatively high comprehensive value. On the one hand, good results have been obtained with respect to boosting of production, saving of coke and increase of Mn recovery. On the other hand, production of various grades of FeMn is possible with high sinter proportion through rational proportioning of imported ore fines and domestic ore fines, opening up a new route for the maximum use of resources of ore fines from home and abroad.

Reference

《 Smelting of Ferroalloys in Blast Furnace 》, Wu Wanshan, Jiangxi Science and Technology Press, Dec. 1993