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ISSN 0543-5846
METABK 62(2) 191-193 (2023)
UDC – UDK 622.785:622.62:662.74:549.1:669.011.002.61=111

STUDY OF THE OPTIMAL PARTICLE SIZE OF SINTERING SOLID FUELS

Received – Primljeno: 2022-10-22
Accepted – Prihvaćeno: 2022-12-20
Original Scientific Paper – Izvorni znanstveni rad

Carbon combustion rates can be altered with different particle sizes of solid fuel, which can directly affect the mineralization of iron ore sintering. A quantitative relationship between coke size and iron ore sintering indexes was studied using a mixture regression design method and simplex-lattice design. Also, the effects of optimal coke particle size on the cold intensity and productivity of the sinter were verified by sinter pot tests and analytical studying the sintering mineral structure. Results show that changing and optimizing the proportion of different coke sizes (<1 mm, 1 mm–3 mm, 3 mm–5 mm, >5 mm) can satisfy the need for sintering production to indexes. It has important significance to reduce solid fuel consumption and improve the yield and quality of sinter.

Key words: sintering, solid fuels, coke particle size, mineral structure, metallurgical properties

INTRODUCTION

The iron ore sintering process is complicated with both oxidation and reduction occurring simultaneously. The combustion of solid fuel supplies the main power for the process. So, understanding the reaction process of solid fuel combustion is quite important. It is the key to resolving a series of problems with sintering. Many research studies [1-2] show that the quantity of fuel, the size distribution of fuel, and the combustion properties of the fuel affect the heat distribution in the sinter bed, the thickness of the burning zone, the permeability of the sinter bed, the sintering atmosphere and so on. The particle distribution of the solid fuel becomes the main determining factor in the sintering process when the type and quantity of fuel is fixed [3-4].

To study the functionality of differently-sized particles on sintering and determine rules for sintering production, optimization studies of coke particles were carried out in Ansteel based on the raw materials found in the west plant.

EXPERIMENTAL

The iron material, solid fuel, and flux all came from the west sintering plant of Ansteel. Concentrates 1 and 2 are produced in-house, while fine ore 3 was purchased outside. This study adopts the regression design and analysis for the quantitative research of coke particles.

Coke particles were separated into four categories (<1 mm, 1 mm–3 mm, 3 mm–5 mm, >5 mm) in the experimental design. The iron partition ratio and the sintering conditions were unchanged. The addition of carbon in the mixture was the same for different tests, but the tests had different size distributions of coke particles. The design basicity of the sinter was 2,2, the design content of magnesium oxide was 2,0 %, and the total amount of carbon was 4,2 %. The level code of design and scheme are shown in Table 1.

As the coke particle size increases, the content of fixed carbon for the different coke particle sizes gradually decreases with smaller absolute difference values. In the meantime, the content of ash increases. In general, there are smaller differences in the physicochemical properties of the various coke particle sizes and did not cause many changes in the experiments [5-7]. The design scheme is 1 to 10, and the optimum principle is the base of the scheme.

The height of the sinter bed was 700 mm (the weight of the hearth layer was 2 kg, the height of the hearth layer was 20 mm) in sintering. The Ignition temperature

Table 1 **The level code of design and scheme**

Scheme	Code				Weight percent/ %			
	X_1	X_2	X_3	X_4	Z_1	Z_2	Z_3	Z_4
1	1	0	0	0	4,2	0	0	0
2	0	1	0	0	0	4,2	0	0
3	0	0	1	0	0	0	4,2	0
4	0	0	0	1	0	0	0	4,2
5	0,5	0,5	0	0	2,1	2,1	0	0
6	0,5	0	0,5	0	2,1	0	2,1	0
7	0,5	0	0	0,5	2,1	0	0	2,1
8	0	0,5	0,5	0	0	2,1	2,1	0
9	0	0,5	0	0,5	0	2,1	0	2,1
10	0	0	0,5	0,5	0	0	2,1	2,1

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was 1 025 °C and the Ignition time was 2,0 min. The value of Ignition suction and Sintering suction were 8 820 Pa and 12 000 Pa. Each step in the process follows the GB standard.

RESULTS AND DISCUSSION

Based on the conditions of the raw materials in the west plant of Ansteel, the result of each item relative to sintering is shown in Table 2.

Table 2 **Sintering test results**

Scheme	Productivity / t/(m^2.h)	Particles / %	
		40~10 mm	<5 mm
1	1,52	57,33	20,6
2	1,46	62,21	15,3
3	0,92	29,19	44,9
4	0,62	23,98	52,7
5	1,27	57,41	21,0
6	1,28	59,25	19,2
7	1,29	57,46	21,6
8	1,59	62,90	19,0
9	1,40	53,35	27,0
10	0,74	26,01	47,8

With the increasing of coarse coke size, sintering indexes decrease when using a single coke size (scheme 1 to scheme 4). Fixing the addition of less than 1 mm coke powder, the sintering indexes change irregularly with increasing coarse coke size (scheme 5 to scheme 7). When the overall coke size coarsens further, the sintering indexes continue to decrease. However, the indexes of scheme 10 are better than scheme 4.

To explain the irregular changes of indexes of sintering from scheme 5 to scheme 7, the indexes (scheme 1 and scheme 5 to scheme 7) of drum strength, productivity, fuel consumption, and yield are shown in Figure 1.

Analysis from Figure 1 shows that different coke particles sizes have varying contributions relative to the indexes of sintering. For example, the drum strength is best when the coke particle sizes are mixed between less than 1 mm and 1 mm to 3 mm. So, in contrast to other sizes, the contribution of coke particle of 1 mm to 3 mm is the largest. When the fuel consumption is the least (only in scheme 1 and scheme 5 to scheme 7), the coke particle size of 3 mm to 5 mm has the largest contribution. So, the coke particle size must be optimized to generate better indexes of sintering.

Accordig to the principle of fuel combustion and results that are generated from the test, drum strength, productivity, and other indexes of sintering worsened by when using one coke particle size. Indexes of sintering were improved in different grades when fine particles and coarse particles were mixed together. Based on the theory of optimization, there must be an optimal proportion in the different coke particle sizes. So, a single index can generate the best value. Therefore, the test can be represented by a mathematical relationship between the indexes and the coke particle size.

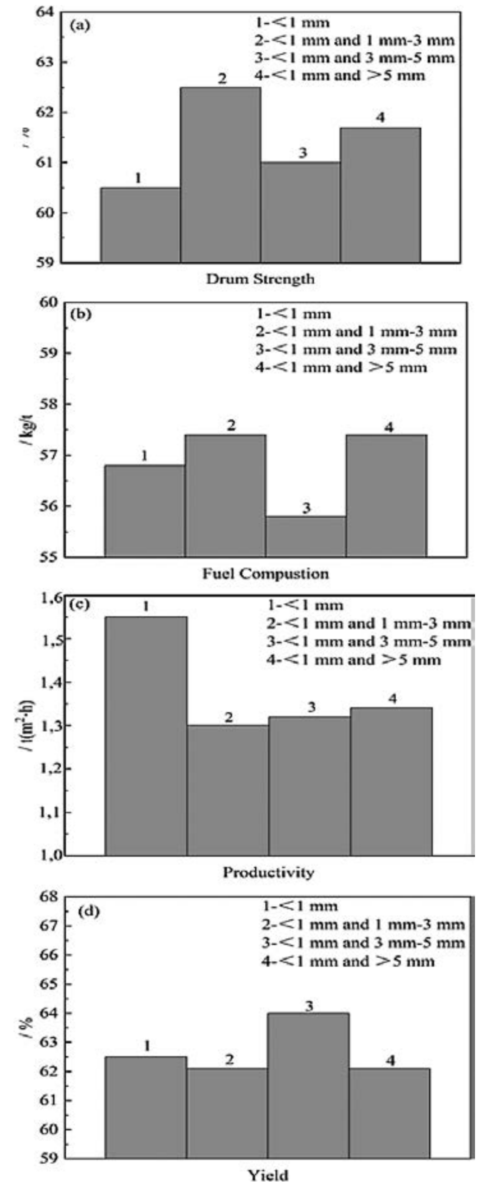

Figure 1 Contrasts in indexes for a scheme

$$Y_{(max/min)}=X_1Z_1+X_2Z_2+X_3Z_3+X_4Z_4+X_5Z_1Z_2+ +X_6Z_1Z_3+X_7Z_1Z_4+X_8Z_2Z_3+X_9Z_2Z_4+X_{10}Z_3Z_4 \quad (1)$$

Here, X_1 to X_{10} are the coefficients of the equation. Z_1 to Z_4 are shown in Table 1. If values of the sintering indexes. However, these values are determined by the results of the test.

Taking the value of the drum strength, highest productivity and entering into equation (1), equations can be shown for drum strength and the highest productivity. To verify the equation's accuracy and practicability, the step acceleration method [8] was adopted to generation the solutions of equations. Using this method, coke particle size can be optimized when the drum strength and productivity are optimized. Compared to common coke (as shown in Table 3) powder in the west plant.

In the common sintering process, the content of coke powder that is less than 3 mm must be greater than 85 %. The optimal coke particle size is quite different from the common coke particle size. Disregarding drum

Table3 Coke **particle size distribution**

Particles	<1 mm	1 mm–3 mm	3 mm–5 mm	>5 mm
Common coke size	35,38	50,01	8,18	6,43
Coke size-drum strength (max)	57,2	25,63	11,17	6,00
Coke size-productivity (max)	47,22	23,10	28,68	1,00

strength or productivity, the content of coke powder that is less than 1 mm should be increased compared to the coke particle size of the west plant, and the proportion of 1 mm to 3 mm should be reduced (the proportion of 1 mm to 3 mm is big in common coke size. The proportion of 3 mm to 5 mm should be increased and the portion greater than 5 mm should be reduced.

The mineral structure of sinter A is more rational than sinter B (as shown in Figures 2 and 3). The mineral structure of sinter A is quite uniform and primarily contains an interwoven corrosion structure. Also, it has a minority granule structure and eutectic structure. The calcium ferrite is the primary bonding phase. The morphology of calcium ferrite is needle-like, columnar, and sheet. Glass phase is quite a little. Hematite is the main mineral in the sinter. About 5 % to 7 % of hematite is regenerated hematite. Original hematite has a larger granular shape (>1 mm) and the core is quite densification. The shape of the original hematite becomes rhombohedral due to the oxidization and recrystallization. The sinter with the structure has good intensity and reduction.

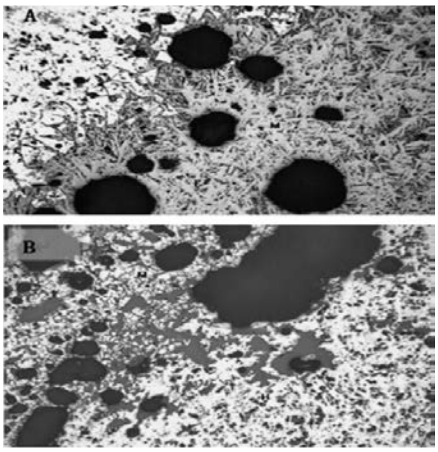

Figure 2 Mineral structure of sinter A and B (reflected light, 120 X)

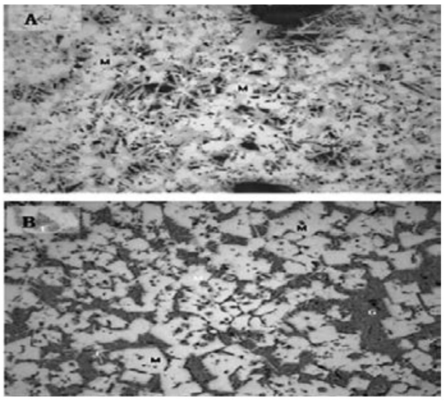

Figure 3 Mineral structure of sinter A and B (reflected light, 240 X)

Interwoven corrosion is the main structure in sinter B with some eutectic structures. Minority granule shape structures, interwoven structures, and vermicular shape structures are distributed among the magnetite crystal grain. Hematite in sinter B reduces a little. Regeneration hematite is about 4 % to 5 % in sinter. The original hematite shape has big particles and a particulate shape. The mineral structure of sinter B is not uniform. There is also considerable residual flux, especially magnesium, in the sinter. These structures have direct effects on the intensity and reduction of the sinter. So, it will decrease the quality of the sinter.

CONCLUSIONS

When the drum strength is maximized, the optimum coke particle size causes the low temperature degradation and reduction indexes to improve. At the same time, the mineral structure of the sinter becomes more rational and uniform. Aimed at the drum strength, the common coke particle size is lower in less than 1 mm (35,38 %), and higher in 1 mm to 3 mm (50,01 %). However, the proportion of 3 mm to 5 mm and greater than 5 mm approaches the particle sizes of the optimal coke particle size. Using the optimum coke particle size, the other indexes of sintering can be maximized. So, based on the particular need for yield and quality of sinter, the coke particle size can be adjusted at the crushing plant. If the coke particle size in production can be realized or approach the range of the optimal coke particle size, the energy consumption can be reduced. Last, the yield and quality of the sinter shall derive more benefits from the optimized coke particle size.

Supporting projects: none

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Note: Zhou Mingshun is the responsible translator and the corresponding author