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Fundamental research on sintering technology with super deep bed achieving energy saving and reduction of emissions

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Super deep bed; sintering; technical index; energy saving; emission reduction

Abstract – In the general frame of energy saving, environment protection and the concept of circular economy, the fundamental research on the sintering technology with super deep bed, achieving energy saving and emission reduction, was carried out. At first, the characteristics of the process and exhaust emission in the sintering with super deep bed was mastered through the study of the influence of different bed depths on the sintering process. Then, considering the bed permeability and the fuel combustion, their influence on the sinter yield and quality, their potential for energy saving and emission reduction was studied. The results show that the improvement of the bed permeability and of the fuel combustibility respectively and simultaneously, leads to an improvement of the sintering technical indices, to energy saving and emission reduction in the condition of super deep bed. At 1000 mm bed depth, and taking the appropriate countermeasure, it is possible to decrease the solid fuel consumption and the emission of CO_2, SO_2, NOx by 10.08%, 11.20%, 22.62% and 25.86% respectively; and at 700 mm bed depth, it is possible to reduce the solid fuel consumption and the emission of CO_2, SO_2, NOx by 20.71%, 22.01%, 58.86% and 13.13% respectively. This research provides the theoretical and technical basis for the new technology of sintering with super deep bed, achieving energy saving and reduction of emission.

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The sintering is a major process of pollutants emission and energy consumption in the iron and steel plant [1, 2]. At present, the solid fuel consumption (coke powder and coal powder) of sintering in China is about 35 million ton of per year and the emission of SO_2 is about 1.5 million tons per year [3]. The energy consumption of sintering is about 12% of the total energy needs of the iron and steel plant, and the emissions, such as CO_2, SO_2, NOx, dust and so on, are more than half of the total [4, 5]. To realize the sustainable development, it is very necessary to develop the new sintering process achieving "energy saving and reduction of emissions".

In the theory, the effect of the sintering with deep bed, especially with super deep bed (the bed depth 1000 mm), on the energy saving and emission reduction is obvious, and mainly explained as follows: first the solid fuel consumption can be saved and the total thermal consumption can be reduced [6–8], and second the peak temperature of the bed decreases and the oxidizing degree is boosted with the decrease of the carbon addition in the bed, which results in an improvement of sinter quality and a decrease of the pollutants emission [9–11]. In recent years, the bed depth has increased to more than 700 mm, leading to some effect on the energy saving, the reduction of emissions and the production capacity [12–15], but the effect is not fully understood. Therefore, in the sintering with deep bed, especially the super deep bed, it is still necessary to further study how to improve the quality and yield, while achieving energy saving and emission reduction at the same time.

In this study, the characteristic of the process and exhaust emission in the sintering with super deep bed was investigated

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Table 1. Chemical composition and proportion of the different raw materials (wt%).

Name	TFe	FeO	SiO_2	CaO	Al_2O_3	MgO	Loss	Proportion
Blending ore	61.17	0.50	3.78	0.78	1.35	0.20	5.67	63.3
Quicklime	–	–	0.37	90.96	1.24	0.06	7.86	3.2
Limestone	–	–	1.02	53.41	0.34	0.76	43.59	3.5
Dolomite	–	–	1.49	30.57	0.48	20.07	46.21	3.4
Serpentine	–	–	38.49	1.17	0.66	38.88	12.49	1.1
Return fines	57.26	7.34	4.92	9.86	1.67	2.34	0.02	22.0
Fuel	–	–	5.93	0.23	4.20	–	C = 84.21	3.5

Table 2. Conditions of the sintering pot test.

Diameter of the sinter pot/mm	200
Mass of the bottom material/g	500
Ignition temperature/°C	1050
Succion pressure in sintering/kPa	12
basicity of the sinter (%CaO/%SiO_2)	2.0
SiO_2 content of the sinter/wt%	4.90
Al_2O_3 content of the sinter/wt%	1.65
Drum mixer specifications / (mm × mm)	500× 1200
Granulation time/min	3
Moisture level/wt%	7.5
Ignition time/min	2
Ignition depression/kPa	6

through the study of the influence of different bed depths on the sintering process. Then, considering the bed permeability and fuel combustion, the influence on the sinter quality and yield, the energy saving and the emission reduction was discussed. Finally the theoretical concept and the technology aspects of the new sintering process with super deep bed based for energy saving and emission reduction are developed.

1 The process characteristics of sintering with super deep bed

Sintering pot tests are carried out at different bed depths: 700 mm, 850 mm and 1000 mm. The chemical composition and the proportion of raw materials are shown in Table 1; the conditions of the sintering pot tests are shown in Table 2, and the results are shown in Table 3. The evolution of NOx, SO_2, CO_2 and O_2 content in exhaust gas during sintering are shown in Figure 1. The corresponding amounts of the different components in the flue gas, per ton sinter, are shown in Table 4, according to the different bed depths.

With the increase of the bed depth, the sinter production yield and the tumbler index gradually increased, the size distribution of the sinter gradually improved, and the solid fuel consumption significantly decreased. It indicates that the quality index of the sinter was markedly improved. However, with the increase of the bed depth, the vertical sintering speed was slowed down, and this caused a large decrease of the sintering productivity.

The general trends of the concentration-time evolution of the flue gas components is maintained when the bed depth increases; however the profiles are different for each component. Moreover, at the same sintering time, the concentration strongly depends on the bed depth (Fig. 1).

As the bed depth increases, the amount of O_2 emission increases, whereas the amounts of SO_2 and CO_2 emissions gradually decrease (Tab. 2). The main reason for these evolutions is the decrease of carbon addition whenincreasing the bed depth [16, 17]. Two advantages of the sintering with super deep bed are revealed by the variation of the flue gas characteristics. First the increase of the oxygen potential in the sintering bed, which can promote the decrease of the FeO content in the sinter and the increase of SFCA, leading to an improvement of the

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Table 3. Results of sintering pot tests with different bed depths.

Schemes	Vertical sintering speed	Production yield	Productivity	Tumbler index	Proportion of 10^{-5} mm	Solid fuel consumption	FeO	$RDI_{-3.15}$
	mm/min	%	t/(m^2.h)	%	%	kg/t	/wt%	/wt%
Bed depth 700 mm	25.59	79.12	1.705	63.33	13.34	58.29	7.36	15.2
Bed depth 850 mm	24.24	79.86	1.587	64.67	11.88	55.03	8.02	15.6
Bed depth 1000 mm	19.87	80.87	1.364	65.33	10.81	51.40	8.54	16.4

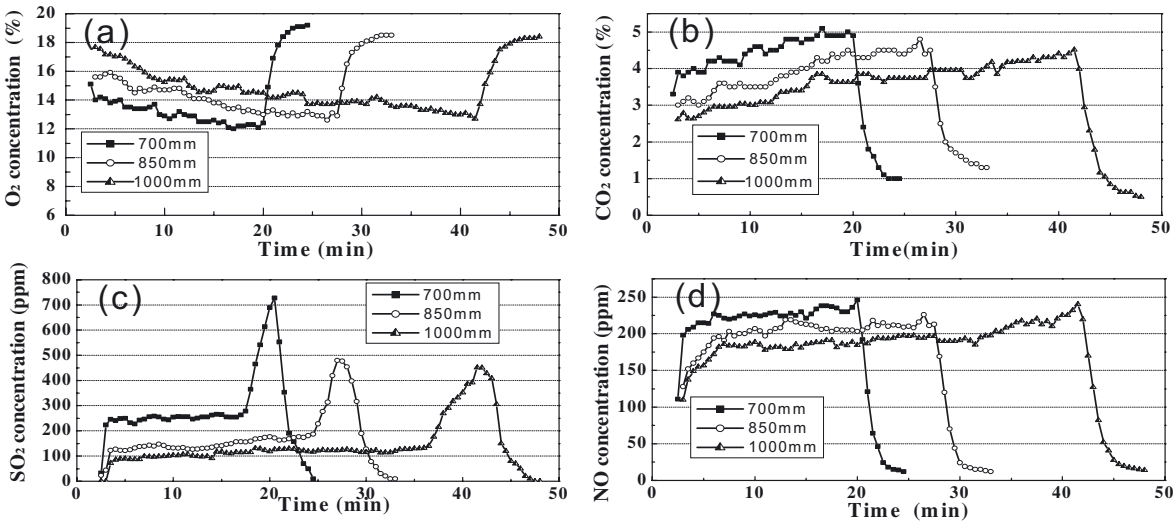


Fig. 1. Variations of the concentration of flue gas components during the sintering process.

Table 4. Emission of the different flue gas components and increase in comparison with the emission at bed depth of 700 mm.

Component	Emission (kg/t sinter)			Increase as compared to 700 mm bed depth (%)	
	700 mm	850 mm	1000 mm	850 mm	1000 mm
O_2	838.72	1035.49	1298.37	23.46	54.80
CO_2	184.67	173.52	162.19	–6.04	–12.17
SO_2	3.16	2.34	1.68	–25.95	–46.84
NOx	0.99	1.07	1.16	8.08	17.17

reducibility of the sinter. Second, the decrease of the SO_2 and CO_2 emission is helpful to reduce the total pollutants emission in the sintering process.

However, with bed depth increasing, the NOx content in the flue gas gradually increased. The reason was that, although the carbon rate decreased with the increase of bed depth, the maximum temperature of the bed increased, the high temperature region became wider, enhancing the ability to produce NOx from N_2 and O_2 [18].

In summary, with the increase of bed depth, the oxygen potential increased, the SO_2 and CO_2 emission per ton sinter decreased. All these effects are beneficial for improving the quality of the sinter and the environmental protection in the sintering. Simultaneously the productivity greatly decreased and the NOx emission increased; it is necessary to solve these issues through better controlling the maximum temperature in the bed depth and the width of the high temperature region. However, an improvement of the bed permeability and an increase of the solid fuel combustion properties can improve the kinetics of the solid fuel burning and the heat-transfer speed in the bed.

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Therefore, it is necessary to discuss the effect of improving the bed permeability and increasing the solid fuel combustion on the productivity and the NOx emission.

2 Study of the technical countermeasures for improving the permeability of super deep bed

The improvement of the bed permeability can accelerate the fuel combustion, make narrower the width of high temperature region, increase the vertical sintering speed and decrease the NOx emission. In this work, some technical countermeasures for the improvement of the super deep bed permeability are studied, such as the assimilation of the quicklime, the use of vertical rods for loosing the sintering feed, the addition of specific diversion material in the bed and the segregation of the solid fuel.

2.1 The technical countermeasures for improving the permeability of super deep bed

(1) The assimilation of the quicklime.

The process of assimilation of the quicklime occurs as the atomization water is added to quicklime, well-mixed and reacted with quicklime, and finally as the colloid hydrated lime generated from the previous reaction is mixed with the other sintering raw materials. The hydrated lime particles can increase the maximum moisture capacity of the mixed material, and its water-holding capacity is larger than that of the iron ore and other raw materials. Then the water in the iron ore particle and on the surface is captured, and capillary forces are generated by the vicinity between the iron ore particle and the hydrated lime particle. The capillary force is helpful for the pelletizing of raw materials and can further improve the granulation efficiency of the sintering raw material. Moreover, the particles containing colloid hydrated lime shrink when heated during the drying process, which causes the nearby solid particles to come closer each other and generates molecular forces. The strength of the quasi-particles is thus increased, and the sintering bed permeability is improved.

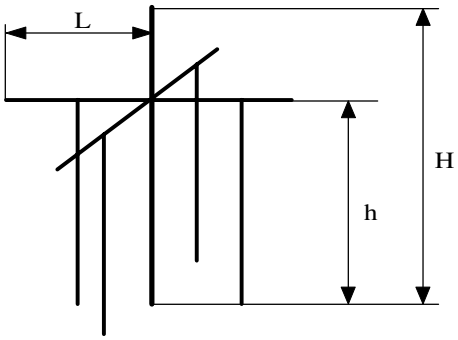


Fig. 2. Sketch of the vertical rods.

(2) The use of vertical rods for loosing sintering feed.

The use of vertical rods is a method method for loosing the charged material in the vertical direction of the sintering bed [19]. The sketch of the vertical rods is shown in Figure 2. With the increase of the bed depth, the permeability of the lower part of the bed gets worse, and the vertical rods are mainly used to improve the permeability of the middle and lower parts.

(3) The addition of diversion material in the bed.

The concept of using diversion material [20–22] is to add a weighted amount of pellets, lump ores or so on into the mix, and then to carry out the mixing and the granulation. The diversion material is evenly distributed in the bed to improve the permeability (as shown in Fig. 3). The effect of the diversion material is to increase the proportion of larger particle in the quasi particles, leading to an increase of the particle size of the mixed material, and thus to an improvement of the strength of the sintering feed. In this study, pellets in the range from 10 mm to 15 mm were used as diversion material, at a proportion of 5%.

(4) The segregation of the solid fuel.

The segregation of the fuel is a charging method in which the proportion of carbon in the upper part of the sintering bed is higher than in the lower part. The segregation of the solid fuel can reduce the width of the combustion zone in the lower part of the sintering bed and improve the permeability of that

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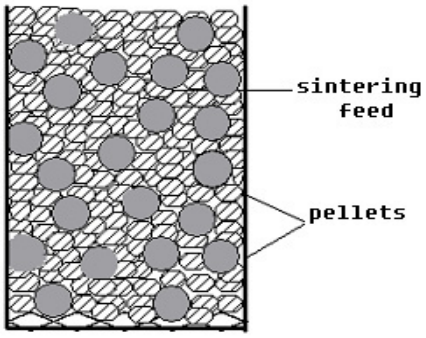


Fig. 3. Distribution of sintering feed with interior inlay of the diversion material.

part. It is an effective measure to make the best use of the heat accumulation in sintering with super deep bed. In this study, the sintering raw materials with different solid fuel proportions were granulated separately, and the sintering feed with less fuel was charged in the lower part of the sintering pot, while the sintering feed with more solid fuel was charged in the upper part.

2.2 The effect of the technical countermeasures on the improvement of the bed permeability

In this study, the effect of the technical countermeasures for improving the bed permeability was investigated through the measurement of the gas flow rate in the sintering process. The average gas flow rate measured for the different technical countermeasures is shown in Figure 4.

The permeability index is proportional to the gas flow rate in the sintering bed: so the higher the average gas flow rate, the better the permeability. The different technical countermeasures are effective for improving the permeability.

2.3 The effect of the different technical countermeasures on the sintering technical indices, on the energy saving and on the reduction of emissions

The results of sintering pot tests and the emissions in the exhaust gas are shown in Table 5. for the different technical countermeasures to improve the permeability.

Regarding the sintering technical indices, the technical countermeasures for improving the permeability lead to increase the tumbler strength, reduce the solid fuel consumption, increase the sinter production yield and the vertical sintering speed, which results in a significant increase of the sintering production capacity. In the 2 cases of implementation of the improved assimilation of quicklime or the segregation of fuel, the sintering production capacity at 1000 mm bed depth can even exceed the production capacity obtained at 850 mm bed depth.

Regarding the energy and emission issues, the investigated countermeasures lead to an increase of the oxygen potential, and a decrease of the CO_2 and SO_2 emission, but the extents of reduction are both small. This can be explained by the increase of the sintering production yield in conjunction with the slight reduction of the solid fuel consumption. The NOx emission strongly decreases, especially with the implementation of the improved quicklime assimilation and the fuel segregation; it is reduced down to the level of NOx emission at 700 mm bed depth. This results from the fact that these countermeasures lead to a better permeability, a decrease of the maximum temperature in the sintering bed, and a narrowing of the width of the high temperature region.

In summary, the improvement of the sintering bed permeability, especially through better assimilation of the quicklime and segregation of the solid fuel, can not only bring about an improvement of the sinter yield and quality, but can also have a positive impact on the energy saving and the reduction of emissions.

3 Study on the countermeasure for the improvement of solid fuel combustion in sintering

Beside the improvement of the permeability in the sintering bed, the enhancement of the solid fuel combustion can as well produce an increase of the sintering speed and a decrease of the width of the high temperature region. In this work, different countermeasures for improving the combustion proper-

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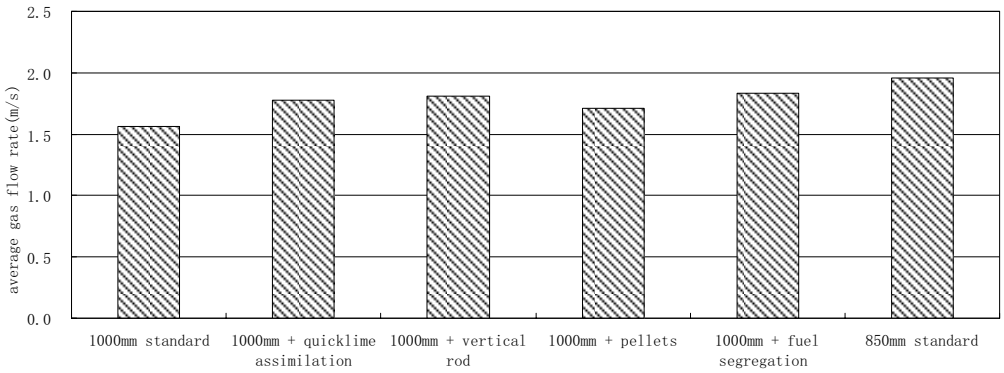


Fig. 4. Average gas flow rate measured for the different technical countermeasures.

Table 5. Results of the countermeasures for the improvement of the sintering bed permeability.

Schemes	Vertical sintering speed	Production yield	Productivity	Tumbler index	Proportion of 10^{-5} mm	Solid fuel consumption	FeO	O_2 emission	CO_2 emission	SO_2 emission	NOx emission
	mm/min	%	t/(m^2.h)	%	%	kg/t	/wt%	kg/t	kg/t	kg/t	kg/t
Bed depth 700 mm	25.59	79.12	1.705	63.33	20.28	58.29	7.36	838.72	184.67	3.16	0.99
Bed depth 850 mm	24.24	79.86	1.587	64.67	19.12	55.03	8.02	1035.49	173.52	2.34	1.07
Bed depth 1000 mm	19.87	80.87	1.364	65.33	18.64	51.40	8.54	1298.37	162.19	1.68	1.16
1000 mm with the quicklime assimilation	21.89	82.51	1.543	68.00	15.98	50.31	8.04	1325.75	156.80	1.53	1.02
1000 mm with the vertical rod	21.34	81.54	1.482	66.00	18.72	50.98	8.21	1310.27	159.89	1.62	1.08
1000 mm with pellets	21.13	81.91	1.469	67.34	15.49	50.52	8.12	1316.28	158.45	1.60	1.12
1000 mm with fuel segregation	22.79	82.74	1.593	67.34	15.64	50.09	7.95	1327.42	156.38	1.53	0.98

ties of the solid fuel were studied, namely the optimization of the solid fuel grain size distribution and the divided addition of solid fuel.

3.1 The countermeasures for the improvement of solid fuel combustion in sintering

(1) The optimization of solid fuel grain size distribution.

Solid fuels with different grain size distributions exhibit different combustion properties. The combustion behaviour of solid fuel was measured for different grain size distributions, and the fuel with the best behaviour was selected and used in the sintering with super deep bed. Accordingly the fuel combustion rate increases and some problems can be avoided, such as the widening of the high temperature region and the worsening of the heat transfer.

(2) The divided addition of solid fuel.

The divided addition of solid fuel is one of the new sintering techniques. The principle is as follows: a first mixing and granulation of raw materials is carried out with only a part of the solid fuel; the solid fuel taken out at the beginning is added again after the first granulation to complete a second mixing; the surface of the sintering feed becomes

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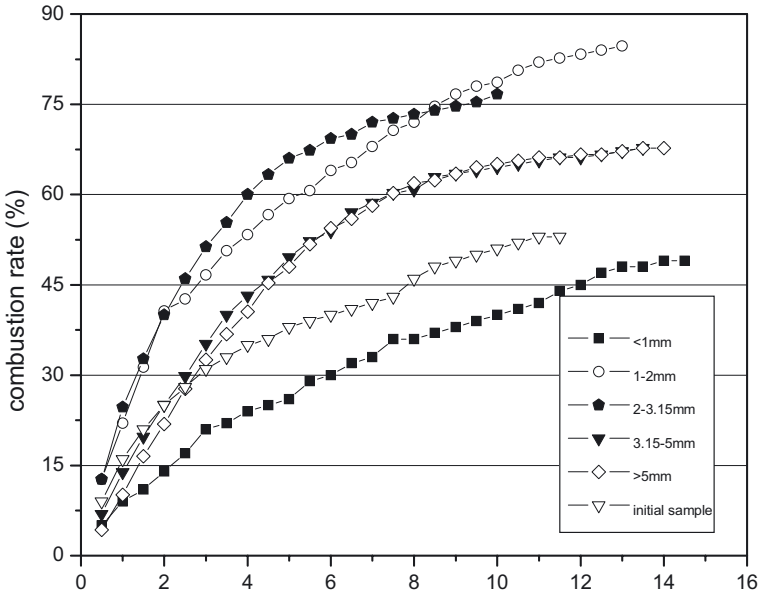


Fig. 5. Combustion rate of coke powder with different grain size.

thus wrapped with the solid fuel, prior to sintering. It results that the contact between the fuel and air is improved during sintering, which is helpful to improve the combustion of the solid fuel. Consequently the width of the high temperature region decreases and the fuel consumption is reduced. In this study, the proportion of solid fuel subjected to divided addition was 70%.

3.2 The effect of the technical countermeasures for improving the solid fuel combustion

(1) Effect of grain size distribution on solid fuel combustion.

The solid fuel (coke powder) was screened and separated according to the following size ranges: >5 mm, 3.15–5 mm, 2–3.15 mm, 1–2 mm and <1 mm. A representative sample (50 g), of each size range, was treated in a high temperature heating furnace. The sample was heated under N_2 up to 800 °C, and the initial weight was recorded; from 800 °C, the sample was reacted with air (flow rate 10l/min) and the weight loss was recorded every half minute. The combustion rate is calculated as the ratio between the weight loss and the initial weight. The results of the combustion rate measurements are shown in Figure 5.

The weight loss of the coke powders with grain size 1–2 mm and 2–3.15 mm is rapid, indicating a high combustion kinetics of those coke powders; the combustion efficiency is relatively high, and the combustion behaviour is good. The weight loss of the coke powder with grain size >1 mm is slow, and its combustion behaviour is poor. The weight loss of coke powder without screening (initial sample) is relatively slow, reflecting a relatively poor combustion behaviour. Therefore, to improve the combustion of the solid fuel during sintering, the coke powder with grain size 1–3.5 mm should be used.

(2) The combustion behaviour of solid fuel with and without divided addition of fuel.

To study the effect of solid fuel divided addition, samples made of 90% iron ore powder 10% coke powder, were prepared according to 2 modes: in the mode without divided addition the iron ore powder and the coke powder are mixed and granulated; in the mode with divided addition, the solid fuel is added after the granulation of the iron ore powder. The samples (weight 100 g) were treated in a high temperature heating furnace. The sample was heated under N_2 up to 800°, and the initial weight was recorded; from 800 °C, the sample was reacted with air (flow rate 10l/min) and the weight loss was

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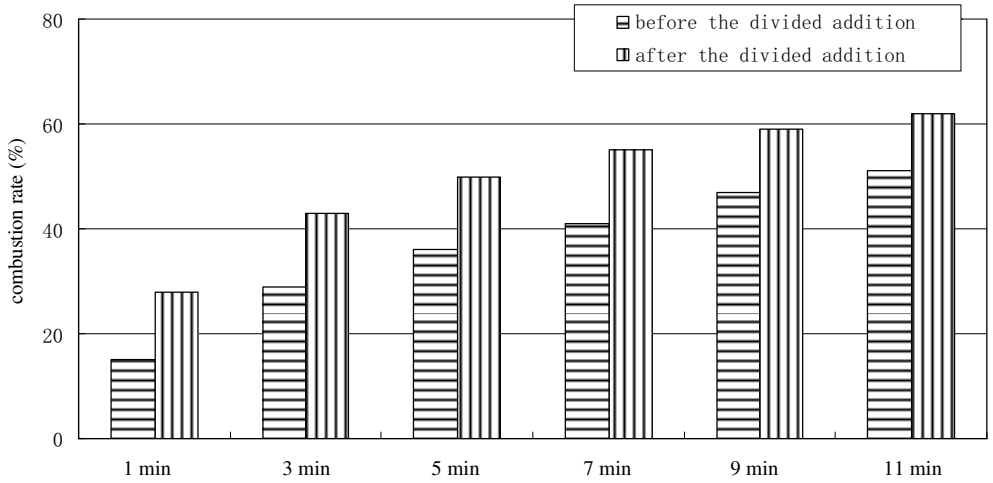


Fig. 6. Fuel combustion speed before and after the divided addition.

recorded every half minute. The combustion rate is calculated as the ratio between the weight loss and the initial weight.

The results of the combustion rate measurements with and without divided addition are shown in Figure 6.

Figure 6, shows that, with divided addition of solid fuel, the combustion speed is high, and the combustion behaviour is good. The reason is that without divided addition, some solid fuel is wrapped with a thin iron ore powder layer, which hinders the fuel combustion. In the case of divided addition of fuel, the surface of the sintering feed is wrapped with the solid fuel, and the contact between the fuel and air is improved during sintering, which is helpful for improving the combustion of the solid fuel.

3.3 The effect of the different technical countermeasures on the sintering technical indices, on the energy saving and emission reduction

The results of sintering pot tests and the emissions in the exhaust gas are shown in Table 6 in the different sintering conditions corresponding to the technical countermeasures for improvement of fuel combustion behaviour.

The use of fuel with improved combustion properties leads to an increase of the sintering speed, a reduction of the width of the combustion zone, a decrease of the temperature of the sintering gas and an improvement of the the over-melting in the lower part of the bed This can not only increase the yield and quality, but also enhance the energy saving and reduce the emission. The emissions of CO_2, SO_2 and NOx strongly decrease.

The divided addition of fuel has a strong positive impact on the yield, the quality the energy saving and the reduction of emissions. The extent of the effects is higher for the divided fuel addition than for the improvement of the fuel combustion properties.

In conclusion, the improvement of the fuel combustion properties and the divided addition of fuel are efficient means for improving the sintering technical indices and enhancing energy saving and reduction of emission.

4 The new sintering technology with super deep bed involving improved bed permeability and fuel combustion properties

The impact of improved bed permeability and fuel combustion properties on the sintering technical indices, energy saving and emission reduction were studied in the above work. However, in the condition of super deep bed, the combined effect of both parameters needs to be further studied. This new technology of sintering with super deep bed implementing the technical means for

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Table 6. Results of the countermeasures for the improvement of fuel combustion.

Schemes	Vertical sintering speed	Production yield	Productivity	Tumbler index 10^{-5} mm	Proportion of	Solid fuel consumption	FeO	O_2 emission	CO_2 emission	SO_2 emission	NOx emission
	mm/min	%	t/(m^2.h)	%	%	kg/t	/wt%	kg/t	kg/t	kg/t	kg/t
Bed depth 1000 mm	19.87	80.87	1.364	65.33	18.64	51.40	8.54	1298.37	162.19	1.68	1.16
1000 mm with fuel with improved combustion properties	21.37	83.18	1.521	66.67	16.34	48.52	7.88	1374.37	151.34	1.38	0.96
1000 mm with fuel divided addition	22.32	82.18	1.559	66.67	17.68	47.33	7.75	1408.02	148.42	1.35	0.93

Table 7. Results of the countermeasures for improving the bed permeability and the fuel combustion properties.

Schemes	Vertical sintering speed	Production yield	Productivity	Tumbler index	Proportion of 10^{-5} mm	Solid fuel consumption	FeO	O_2 emission	CO_2 emission	SO_2 emission	NOxx emission
	mm/min	%	t/(m^2.h)	%	%	kg/t	/wt%	kg/t	kg/t	kg/t	kg/t
Bed depth 1000 mm	19.87	80.87	1.364	65.33	18.64	51.40	8.54	1298.37	162.19	1.68	1.16
1000 mm with quicklime assimilation and high combustion fuel	22.87	83.24	1.628	68.67	15.49	48.34	7.78	1378.77	150.15	1.38	0.90
1000 mm with quicklime assimilation and fuel divided addition	22.76	82.96	1.607	68.00	15.78	46.89	7.69	1422.56	146.14	1.32	0.90
1000 mm with quicklime assimilation, high combustion fuel and fuel divided addition	23.79	83.36	1.708	68.67	14.92	46.22	7.58	1434.74	144.03	1.30	0.86

improving the bed permeability and the fuel combustion properties was investigated by sinter pot tests; the results are shown in Table 7.

From Table 7, the schemes involving the means for improving the bed permeability and the fuel combustion properties lead to an increase of the vertical sintering speed, of the sinter yield and productivity, an improvement of the sinter strength (tumbler index) and size distribution, a reduction of the solid fuel consumption and a strong decrease of the emission of CO_2, SO_2 and NOx. All these effects are helpful to increase the yield and quality in the sintering process with super deep bed, and to enhance the energy saving and reduction of emissions. The effects of each single countermeasure are additive; the best results are obtained when the three countermeasures are simultaneously implemented, namely the improved quicklime assimilation, the solid fuel with high combustion properties and the divided addition of fuel.

The sintering results for different bed depths, with and without countermeasures are compared in Table 8.

In comparison with the case of 700 mm bed depth, the scheme with 1000 mm bed depth and implementation of all 3 countermeasures shows an improvement of the sintering technical indices, an energy saving and a reduction of the emissions. The productivity increases by 0.18%; the sintering yield and the sinter tumbler index increase respectively by 5.36% and 8.84%. Besides, the solid fuel consumption is reduced by 20.71%, and the emissions of CO_2, SO_2 and NOx respectively by 22.01%, 58.86% and 13.13%. At 1000 mm bed depth, the sintering production capacity reaches the same level than at 700 mm bed depth, but in addition with a strong reduction of the NOx emission.

At 1000 mm bed depth, implementing the three countermeasures has a strong beneficial impact on the yield, the sinter quality, the energy saving and the emissions. The sintering productivity increases by 25.22%,

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Table 8. Results of sintering according to the different schemes.

Schemes	Production yield	Productivity	Tumbler index	Solid fuel consumption	CO_2 emission	SO_2 emission	NOx emission
	%	t/(m^2.h)	%	kg/t	kg/t	kg/t	kg/t
Bed depth 700 mm	79.12	1.705	63.33	58.29	184.67	3.16	0.99
Bed depth 850 mm	79.86	1.587	64.67	55.03	173.52	2.34	1.07
Bed depth 1000mm	80.87	1.364	65.33	51.40	162.19	1.68	1.16
1000 mm with quicklime assimilation, high combustion fuel and fuel divided addition	83.36	1.708	68.67	46.22	144.03	1.30	0.86
Compared with 700 mm bed depth/%	5.36	0.18	8.44	–20.71	–22.01	–58.86	–13.13
Compared with 850 mm bed depth/%	4.38	7.62	6.19	–16.01	–17.00	–44.44	–19.63
Compared with 1000 mm bed depth/%	3.08	25.22	5.12	–10.08	–11.20	–22.62	–25.86

the sinter yield and tumbler index respectively by 3.08% and 5.12%; the solid fuel consumption is reduced by 10.08%, and the emissions of CO_2, SO_2 and NOx are decreased by 11.20%, 22.62% and 25.86%.

In conclusion, in the condition of the super deep bed, the countermeasures for improving the bed permeability and for increasing the fuel combustion properties are effective, not only to produce a high quality sinter, but also to achieve large energy saving and reduction of emissions. The best results are obtained when the countermeasures are implemented together.

5 Conclusions

(1) With the increase of the bed depth, the oxygen potential increases, the SO_2 and CO_2 emission per ton iron ore are reduced, and these effects are helpful to improve the sinter quality and protect the environment in the sintering. However, the sintering productivity greatly decreases and the NOx emissions increase; these issues can be solved through control of the maximum temperature in the bed and of the width of the high temperature region.

(2) Countermeasures, such as enhancing the quicklime assimilation, using vertical rods for loosing the sintering feed, charging diversion material in the bed or achieving solid fuel segregation at charging are effective for improving the bed permeability, decreasing the maximum temperature in the bed and narrowing the width of the high temperature region. All of these countermeasures can not only increase the yield and quality indices, but also enhance the energy saving and reduce the emissions; especially the enhancement of quicklime assimilation and the segregated charging of solid fuel are the most obvious.

(3) With the use of fuel with improved combustion properties and the divided addition of solid fuel, the combustion rate of the solid fuel and the vertical sintering speed increase, and the width of the combustion zone gets narrower. These countermeasures are helpful to increase the sintering technical indices, enhance the energy saving and reduce the emissions. The divided addition of fuel is the most effective countermeasure.

(4) At 1000 mm deep depth, implementing both countermeasures for improving bed permeability and solid fuel combustion properties results in an improvement of the sintering technical indices the energy saving and the emissions. Compared to the case with 1000 mm bed depth without countermeasures, the fuel consumption and the emission of CO_2, SO_2 and NOx are respectively decreased by 10.08%,

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11.20%, 22.62% and 25.86%. Compared to the case with 700 mm bed depth, the fuel consumption and the emission of CO_2, SO_2 and NOx are respectively decreased by 20.71%, 22.01%, 58.86% and 13.13%. Under these conditions, it becomes possible not only to produce the sinter with high quality and high yield, but also to achieve a large effect on the energy saving and the reduction of emissions.

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