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STUDY ON THE PELLETIZING OF SULFATE RESIDUE WITH MAGNETITE CONCENTRATE IN GRATE-KILN SYSTEM

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Abstract

The experiment on the feasibility of pelletizing with magnetite concentrate and the wasted sulfate residue was carried out, to research the performance of pellet in grate-kiln system and simulate the grate-kiln pelletizing process in the micro-pellet roasting simulation system in laboratory, and the process experiments on preheating and roasting sections were conducted. The results show that in order to obtain pellet with good performance and the magnetite concentrate should be over 20 in mass percent, the suitable pelletizing time is about 10 min and moisture is around 12.5%. Also, according to the process parameters of drying and preheating sections obtained from experiment, it will be successful to use magnetite concentrate and the wasted sulfate residue for pelletizing, which exploits a new way for the use of sulfate residue.

Keywords: *Magnetite concentrate fines; Sulfate residue; Pelletizing; Grate-kiln.*

1. Introduction

Recently, with the rapid development of iron and steel industry, production of iron ore can not meet its demand. It is an indisputable fact that iron ore resources are in shortage. So now some waste materials containing Fe should be used / recycled, some researches had been done to produce iron oxide from waste materialssuch as slags, iron ore and mill scale [1]. As a by-product of chemical factory, sulfate residue is a kind of iron-

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containing material with hematite as its main component [2], and the iron-containing grade is about 62%. Discarding the sulfate residue not only wastes iron-containing resources but also causes enormous pollution to the environment [3]. So far, a variety of researches on the usage of sulfate residue have been carried out in China [4-9], but the results are not quite satisfactory. Grinding sulfate residue and mixing it with concentrate fines to pelletize will not only exploiting a new way of using sulfate residue but also have strategic significance in making comprehensive utilization of waste resources, solving the problem of insufficiency of resources and achieving circular economy and ecological pelletizing.

2. Experimental

2.1. Material

Concentrate fines used in this experiment are magnetite concentrate ore and sulfate residue. The main chemical composition is shown in Table 1.

2.2. Procedure

First, the sulfate residue was solarized to appropriate moisture for pelletizing. And then, it was mixed evenly and sampled to test the performance. The rest material was put into a bag for airproofing.

Each time, 4kg (dry weight) of iron-containing mixture was weighed and added in bentonite in a certain proportion. Then, they were mixed evenly on the rubber cloth and the moisture was kept nearly 2% lower than the suitable moisture of the green-pellets. The mixture was ground by stepless speed-run damp mill of Φ500×500mm, whose rolling speed is fixed at 40r/min and medium filling rate is 12%. The mixed material was added into the mill and ground for a fixed period of time. Then, the mixture together with the medium was poured out and separated using a sieve.

The green-pellets are made by the disc pelletizer, whose diameter is 1000mm, rolling speed is 2r/min and inclination angle is 45°. In order to simulate actual production condition, pelletizing process consists of the formation and growth of mother pellets, and the compaction of green-pellets. Firstly, the

Table 1. The chemical compositions of material / %

Material	TFe	FeO	SiO_2	Al_2O_3	CaO	MgO	MnO	P	S	LOI
Ore 1	58.08	25.09	10.81	3.69	0.95	0.6	0.32	0.0081	0.16	1.58
Ore 2	66.02	27.39	4.66	1.81	0.59	0.2	0.14	0.091	0.09	0.66
Xingtai sulfate residue	61.84	5.43	6.36	2.08	0.84	0.32	0.2	0.0074	0.28	1.65
Handan sulfate residue	62.41	11.55	6.2	1.66	0.5	0.3	0.041	0.0098	0.5	2.35
Shanxi sulfate residue	61.6	12.81	6.46	1.77	0.68	0.31	0.035	0.01	0.9	3.1

mixed material was added to the pelletizer together with some water to make mother pellets (2min). Then, water and materials were continuously added (each batch is 4kg), so that the mother pellets can grow up within the prescribed time. After 1 to 2min, the green-pellets were compact and were shoveled out. And the green-pellets of 10-15mm were taken as the finished ones, of which the strength and bursting temperature were examined. The rest were dried in electrically heated drier at 110°C±5°C. Then, the dried pellets are used for pipe furnace roasting experiments.

3. Magnetite proportioning experiment

In the experiment, the proportion of magnetite concentrates and sulfate residue is changed for research. There are three types of sulfate residue in the mixture (Xingtai: Handan: Shanxi = 10:7:3). And the amount of bentonite is 1.25% and the thickness of material layer is 200mm. The experimental results are shown in Table 2.

From Table 2, it can be seen that increasing the amount of magnetite can slightly enhance the compressive strength of preheated pellets. As the amount of magnetite is increased, the tumbler strength is decreased gradually, which indicates that the increase in the amount of magnetite helps to reduce the powder produced during the transportation of preheated pellets. If the sulfate residue is used alone, the tumbler strength is very poor. With the amount of magnetite increasing from 0 to 50%, the number of cracks begins to increase. However, when the amount of magnetite is increased to 90%, the number of cracks decreases. The increasing amount and the decreasing compressive strength of finished pellets indicate that sulfate residue is easier to consolidation than magnetite concentrates in the process of roasting. In addition, when the amount of magnetite is increased to 90%, because of the low bursting temperature of green pellets, the minor bursting in drying process occurs and causes more preheated powder. In conclusion, the amount of magnetite should be more than 20%. And the proportion of magnetite concentrate is fixed to 34% according to the actual amount of sulfate residue in the production.

Table 2. The relationship between the magnetite concentrate proportion and pellet performance

magnetite amount / %	Quality of preheated pellets				Quality of finished pellets		
	compressive strength / ($N \cdot a^{-1}$)	tumbler strength / %	cracking rate / %	powder volume / kg	compressive strength / ($N \cdot a^{-1}$)	tumbler strength / %	abrasion resistance index /%
0	537	9.44	2	0.04	4421	98.01	1.05
20	585	4.52	4	0.026	4238	98	1.9
34	552	2.12	14	0.02	3517	98	1.87
50	602	1.64	20	0.021	3049	98.67	0.97
90	619	1.7	9	0.312	2663	98	1.1

4. Process parameters determination

Of the experimental material, the iron concentrate, Handan sulfate residue, Shanxi sulfate residue, and bentonite account for 34%, 23%, 10%, and 1.5%, respectively.

4.1. Effect of pelletizing time on the green pellets quality

The effect of pelletizing time on the quality of green pellets is shown in Figure 1.

From figure 1, it can be seen that the falling intensity of green pellets increases gradually with the time extending, and the compressive strength slightly rises as well. After 12min, the compressive strength even goes down a little. Therefore, the appropriate time for pelletizing is 10-12min.

4.2. Effect of moisture on the quality of green pellets

The effect of moisture on the green pellets quality is shown in Figure 2.

As seen in figure 2, with the moisture increasing from 10.6% to 12.5%, the change of falling intensity is not obvious, but compressive strength increases. Considering that there is scraper board in site, the

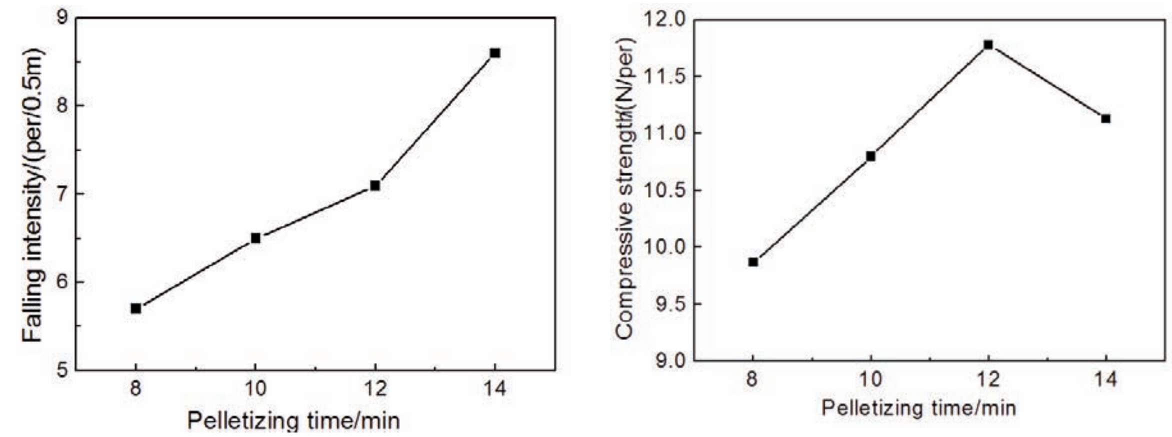

Fig. 1. The effect of pelletizing time on the quality of green pellets

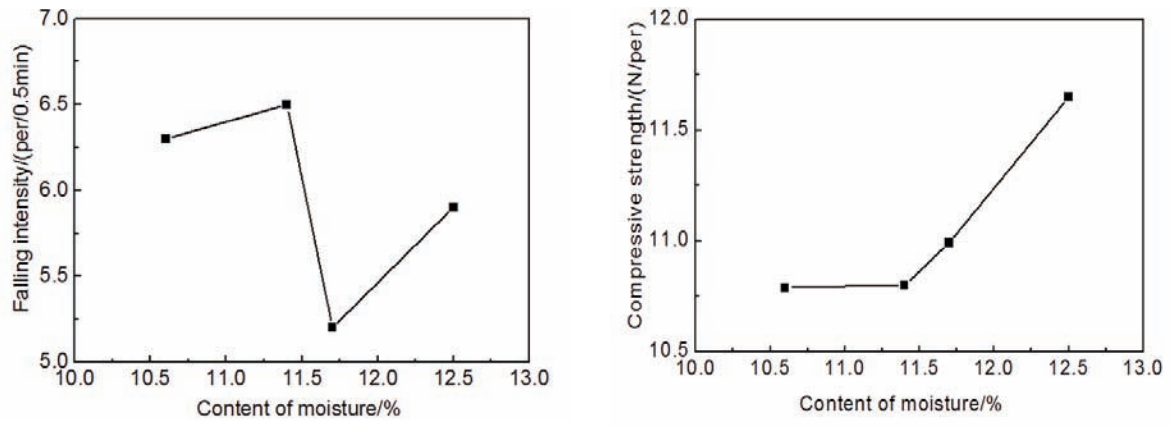

Fig.e 2. The effect of moisture on the green pellets quality moisture can be higher than that in the laboratory. Therefore, the moisture of green pellets in site should be kept at about 12.5%.

4.3. Parameters determination for preheating process

Preheating on the grate-kiln can not only raise the temperature and intensity of pellets, but also oxidize some sulphur and magnetite, to avoid layered structure formation in the kiln. The effect of the parameters during preheating process on the intensity of preheated and finished pellets is investigated, and the results are shown in Table 3.

From Table 3, it can be found that the preheating temperature has a significant effect on the compressive strength of preheated pellets. With the preheating temperature rising, the strength also increases. When the temperature reaches 850°C, the tumbler strength is low but the material contains high content of sulphur and FeO. When the temperature goes up to 890°C, there is almost no change of drum strength, sulphur and FeO content. When the suction speed increases, the compressive strength rises as well. But there is little difference for the wind speed of 2.4m/s and 2.7m/s, so the suction speed has little effect on tumbler strength and sulphur content. The preheating time also has little effect on the quality of preheated pellets. When the time used increases from 6min to 8min, there is little change of compressive strength, tumbler strength and sulfate content. For the sulfur content, it is approximately 0.33% for green pellet, and it goes down to 0.03%-0.05% after preheating, which indicates that desulfurization occurs in the preheating section with a high extent.

The effect of preheating parameters on the finished pellets is shown in Table 4.

From Table 4, it indicates that when the roasting temperature reaches 1220°C and

Table 3. The effect of preheating parameters on the preheated pellets

Temperature / ℃	wind speed / ($m \cdot s^{-1}$)	Time / min	compressive strength / ($N \cdot a^{-1}$)	tumbler strength / %	S / %	FeO / %
850	2.7	8	649	4.62	0.092	1.03
890			770	1.58	0.034	0.89
920			914	1.58	0.048	0.75
950			943	2.24	0.034	0.81
980			1093	2.44	0.044	0.93
950	2.1	8	653	1.9	0.03	1.22
	2.4		967	1.2	0.03	0.9
	2.7		943	2.24	0.034	0.81
950	2.7	4	871	1.8	0.033	1.17
		6	1001	2.4	0.049	0.98
		8	943	2.24	0.034	0.81

Table 4. The effect of preheating parameters on the finished pellets

Temperature / ℃	wind speed / ($m \cdot s^{-1}$)	Time / min	compressive strength / ($N \cdot a^{-1}$)				tumbler strength / %	abrasion resistance index / %
			kiln head	Kiln center	kiln end	mixture		
850	2.7	8	4483	3826	2523	4038	98.33	0.87
890			4169	4106	3675	4597	98.67	0.97
920			4878	4923	3566	5061	98.83	0.77
950			5129	4789	3293	5260	98.7	2.1
980			4014	3845	2813	4041	98.33	1.3
950	2.1	8	4414	3520	2915	3830	98.5	0.67
	2.4		4586	4270	3207	4372	98.66	1.43
	2.7		5129	4789	3293	5260	98.7	2.1
950	2.7	4	3452	2853	2296	3328	98.5	1.57
		6	4130	3546	2880	3660	98.33	1.33
		8	5129	4789	3293	5260	98.7	2.1

roasting time is 10min, the compressive strength, tumbler index and abrasion resistance index of finished pellets are all in good condition regardless of the preheating condition. With the preheating temperature increasing from 850°C to 890°C, the compressive strength of finished pellets increases significantly. When the temperature is between 890°C～950°C, the compressive strength has a little change. But with the temperature going up to 980°C, the compressive strength decreases. As the suction speed and time of preheating increase, the compressive strength of finished pellets is enhanced.

After comprehensively considering the effect of preheating parameters on preheating and finished pellets, the suitable temperature of grate-kiln is fixed to 890-950°C, wind speed is 2.4-2.7m/s and the preheating time is about 6min.

4.4. Parameters determination for roasting process

The experimental parameters of roasting were systematically investigated to study the roasting characteristics of pellets with sulfate residue as the main raw materials.

In the experiment, the preheated pellets were put into the simulating rotary kiln with loading equipment and treated according to the roasting procedure. There are 3 sections in the experiment. They are temperature rising, high-temperature thermostat and soaking. Finally, the material is discharged by using professional device and the pellets were cooled naturally.

The effect of roasting parameters on the finished pellets is shown in Table 5.

From Table 5, it reveals that better results are acquired under all experimental conditions. The finished pellets with low

Table 5. The effect of roasting parameters on the finished pellets

Temperature / ℃	Time / min	compressive strength /(N·a^{-1})				tumbler strength / %	abrasion resistance index / %	S / %
		kiln head	Kiln center	kiln end	mixture			
1160	10	2724	2303	1600	2301	96.66	1.53	0.034
1190		5015	4432	3519	4637	98	0.77	0.032
1220		5129	4789	3293	5260	98.7	2.1	0.028
1250		4758	4619	3543	4263	97.83	1.8	0.023
1220	8	4579	3741	3052	4523	97.83	1.8	0.032
	10	5129	4789	3293	5260	98.7	2.1	0.028
	12	5693	5082	4517	6256	98.66	0.4	0.025

sulphur content have excellent quality. With the roasting temperature rises from 1160°C to 1220°C, the compressive strength of finished pellets increases from 2301N to 5360N. With the temperature going up to 1250°C, the compressive strength decreases a little. So the proper roasting temperature is 1190-1220°C. Besides, with the increase of roasting time, the compressive strength increased as well. However, considering the actual production, 10min or so is enough. In summary, satisfactory results are obtained for pellets with sulfate residue as main material. And the proper temperature is 1190～1220°C and time is around 10min.

5. Metallurgical performances of pellets

The physical properties is shown in Table 6. The metallurgical performances of pellets are given in Table 7 and Table 8.

It can be seen from Table 6 that the pellets have excellent physical properties. And as can be seen in Table 7 and Table 8, RI of pellets is 63.74%, which almost meet the

Table 6. The physical performance of finished pellets

Preheated pellets		Finished pellets		
compressive strength / (N·a^{-1})	tumbler strength / %	compressive strength / (N·a^{-1})	tumbler strength / %	abrasion resistance index / %
552	2.12	3517	98	1.87

Table 7. The metallurgical performance of finished pellets

RDI /%			RI /%	RSI /%
>6.3	>3.15	<0.5		
88.53	91.07	6.62	63.74	7

Table 8. The fusibility of finished pellets /℃

TS	TM	TD	T_D-T_S	T_D-T_M
1110	1154	1204	44	50

requirement of Grade 1 pellets (RI ≥65%). The RDI of pellets is very good. It is more than 85%. The RSI is 7.0%, which also meets the requirement of Grade 1 pellets(RSI ＜14%). The softening temperature is high while the dropping temperature is slightly low. And the intervals of softening and melting are narrow. In general, the metallurgical properties of pellets are excellent.

6. Conclusion

Based on the above experiments, the following conclusions are drawn:

(1) The sulfate residue is loose and porous. The compressive strength of green pellets is quite low if the sulfate residue is used to pelletize directly. The appropriate technological parameters are as follows: the amount of magnetite should be above 20%; the time for pelletizing is 10min; the moisture of green pellets should be around 12.5%. Under these conditions, the falling intensity of green pellet is more than 3 times, the compressive strength is above 10N and the temperature is close to 600°C.

(2) The appropriate technological parameters of grat-kiln are as follows: in the preheating section, the time for temperature rising is 6-8min; the constant temperature is 890-950°C, the wind velocity is 2.4-2.7m/s and time is 6min. In the roasting section: time for temperature rising is 12min; the constant temperature is 1190-1220°C and the time is 10min; time for soaking is 5min.

(3) The metallurgical properties of pellets: the RI of pellets is 63.74%. The $RDI_{+3.15mm}$ of pellets is better and is more than 85%. The RSI is 7.0%, which also meets the requirement of Grade 1 pellets. The softening temperature is high while the dropping temperature is slightly low. And the intervals of softening and melting are narrow.

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