Effect of HS Binder on Reducing the Amount of Bentonite in Oxidized Pellets

Qianqian Duan, Yongbin Yang, Rui Xu, Yingrui Dong, and Zhichen Yuan

Abstract In order to decrease the amount of bentonite in the production of oxidized pellets, the addition of HS binder is carried out in response to the problems of wasting of resources, high costing and serious pollution in the production and application of bentonite in China. In this study, the effect of the organic binder in iron ore pellets was characterized by using pelletizing, preheating and roasting experiments; the optimal ratio of HS binder to bentonite was determined. The results showed that combination of bentonite and HS binder can significantly reduce the amount of bentonite. When the ratio of bentonite of HS binder was HS binder dosage 0.2% and bentonite dosage 0.7%, the drop strength of green pellets reached 3.2 times/(0.5 m) and the amount of bentonite reduced the mass of 1.6% compared with that of without HS binder. Under the best preheated roasted conditions, the strength of the preheated ball was 436.9 N/P and the roasted ball strength achieved 2794.3 N/P, which could meet the demands.

Keywords Oxidized pellets · Bentonite · Organic binder · Preheating roasting

Introduction

Bentonite is widely used as binder in domestic oxidation pellet factories. Although the bentonite has good bonding performance, the content of Al_2O_3 and SiO_2 is high, which leads to the increase of coke ratio and the decrease of pellet grade. According to the data, the coke ratio will be reduced by 2.0–2.5% and the output will increase by about 3% for every 1% increase in the iron grade [1, 2]. Therefore, it is of great significance to increase the iron grade of pellets to reduce the iron consumption and increase the production of blast furnace. However, in China's pellet production, due to the constraints of bentonite resources and other aspects, the use of poor performance of natural calcium bentonite is very common, resulting in the actual production of bentonite dosage which is too high (about 2 ~ 3.5%) [3]. Researchers in China have

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been developing new adhesives to partially or even completely replace bentonite. When organic binders (such as peredo, carboxymethyl cellulose and organic binders GPS) [4–6] are used alone, the cost of pellets increases, and the raw pellets are liable to burst, and the preheating strength difference is difficult to meet the production requirements of soccer balls [7]. Cao [8] used composite binder to replace some bentonite, which reduced the bentonite content from 2.56% to 1.46% and improved the iron grade of pellets by 0.77%. Zhu [9] studied that adding organic compound bentonite could significantly improve the performance of raw pellets and the iron grade of pellets. When the ratio of organic compound bentonite was 1.2%, the raw pellet strength could reach 2.2% when the bentonite content was added. In this study, HS binder was used to partially replace bentonite, so as to reduce the consumption of bentonite, improve the grade of iron in finished pellets and control the cost of production of football league.

Experimental

Properties of Raw Materials

The iron-bearing raw materials used in the experiment were four kinds of iron concentrates (expressed as concentrates A, B, C and D) from the production site of A factory in Shandong Province. The four kinds of iron concentrates A, B, C and D were made into pellets according to the mixture ratio (30, 30, 30 and 10%, mass fraction). The chemical composition, static pelletizing properties and particle size composition of iron concentrate are shown in Tables 1, 2 and 3.

The data in Tables 2 and 3 show that the mixed ore has good pelletization. The chemical composition and basic physical properties of bentonite are shown in Tables 4 and 5.

HS binder is a kind of high molecular compound containing a large number of hydroxyl and carboxyl groups. The polar groups contained in it act on the surface of magnetite in the form of chemisorption. The hydrophilic group has strong hydrophilicity and acts on the surface of iron concentrate. The structure of organic chain frame is cohesive, which can improve the performance of magnetite pellets.

Table 1 Chemical composition of iron concentrate w/%

Chemical composition	TFe	FeO	CaO	MgO	SiO_2	Al_2O_3
A	65.96	27.02	0.20	0.38	8.38	0.10
B	65.69	26.40	0.92	0.44	6.58	0.45
C	66.07	25.47	0.54	0.30	6.40	0.45
D	67.87	30.12	0.45	0.30	6.06	0.10
Mixed ingredients	66.10	26.68	0.54	0.37	7.01	0.31

Table 2 Static pelletizing performance of iron concentrate

Sample	Maximum molecular water/%	Maximum capillary water/%	Capillary water migration speed /mm · $(min)^{-1}$	Balling performance index	Spheroidity
A	4.81	12.59	4.68	0.62	Good
B	5.43	12.89	4.37	0.73	Good
C	3.91	13.87	4.40	0.39	Medium
D	6.55	12.97	4.55	1.02	Excellent
Mixed ingredients	4.12	12.56	4.89	0.49	Medium

Table 3 Size distribution of iron

Particle size composition		Specific surface area $/m^2 \cdot g^{-1}$
Mineral species	<0.074 mm (%)	
A	92.23	0.589
B	65.27	0.864
C	67.50	1.294
D	74.95	1.106
Mixed ingredients	75.83	0.633

Table 4 Composition analysis of bentonite w/%

SiO_2	Al_2O_3	CaO	Fe	Na_2O	MgO	LOL
51.19	12.98	8.28	4.31	2.58	2.89	11.61

Table 5 Physical properties of bentonite

Colloid index (% 3 g)	Swelling capacity (%)	Water absorption ratio (%)	Blue absorption (g/100 g)	Montmorillonite content (%)	Particle size composition <0.074 mm (%)
71.5	13.5	263.1	33.8	76.47	97.065

After preheating and roasting, the products are CO_2 and water vapor, with less residue and less pollution compared with bentonite [10]

Experimental Method

Pelletizing

Weigh 5 kg of iron-containing mixture in proportion, add a certain proportion of bentonite and HS binder, mix on the rubber cloth, and then add pre-wetting moisture to make the moisture of the mixture lower than 1% of the suitable moisture of the raw ball −2%, and then mix for the second time. The preparation of green balls is carried out on a disc pelletizer with a diameter of 1000 mm, a side height of 150 mm, a rotation speed of 25r/min (adjustable) and an inclination of 47°.

Determination of Burst Temperature of Green Ball

The decrepitation temperature of pellet was measured in a vertical tube furnace (650*1000 mm). The ball dropped repeatly from 0.5 m height to 10 mm thick steel plate, until the ball was broken. The number of tests was n, the ball drop strength was n-1. Ten balls were measured each time, and the average value was taken as the falling intensity of the balls (unit: times/0.5 m).

Preheating Roasting Experiment

The preheating roasting small-scale test was carried out in a horizontal tubular electric furnace. The electric furnace consists of an iron chromium aluminum wire resistance furnace with a furnace diameter of 50 mm and a silicon carbon tube resistance furnace. The former is used for preheating and the latter is used for roasting. Raw balls with a diameter of 10–15 mm are first dried in a drying box at a temperature of 120 °C. The raw balls are loaded into a porcelain boat during the test. Carry out preheating and roasting according to the pre-established operation system.

Results and Discussion

Study on the Preparation of Pellets with Added HS Binder

Effect of Strengthening Mixing HS-Type Binder

Figure 1 is the test results of the amount of bentonite used when the amount of HS binder is 0.2% when it is not strengthened and the amount of HS binder is 0.1% when it is strengthened and mixed. It can be seen from the figure that the addition of 0.2% HS-type binder has a significant improvement in the performance of green balls.

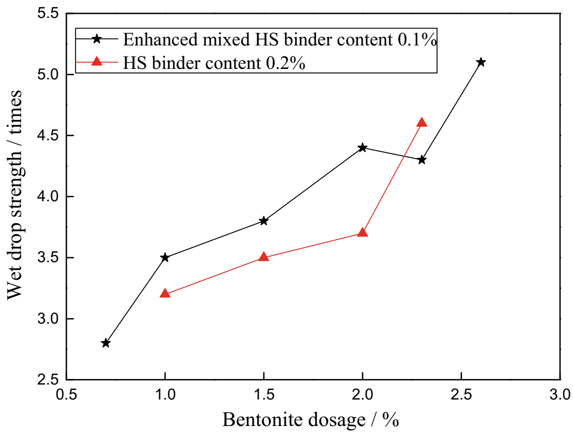

Fig. 1 Effect of enhancing mixed HS binder on bentonite dosage. (Color figure online)

The amount of bentonite 1.0% can reach the drop strength level when using bentonite alone 2.3%. When adding 0.2% HS-type binder on the basis of adding 2.3% bentonite, the drop strength of green ball is increased from 3.2 times/0.5 m to 4.6 times/0.5 m. Therefore, from the perspective of pelletizing effect, the HS binder has a significant effect on reducing the amount of bentonite. For the small amount of organic binder (1000 grade), it is generally difficult to fully mix into the mixture, so there is a high requirement for mixing operation, and strengthening mixing will be conducive to better play the role of organic bonding effect. In this experiment, the dosage of HS binder was reduced to 0.1% by strengthening the mixing operation, and the effect was further improved. Although the amount of HS binder decreased from 0.2% to 0.1%, the falling intensity of green pellets increased from 3.2 times/0.5 m to 3.5 times/0.5 m when the amount of bentonite was 1.0%, and it increased from 3.7 times/0.5 m to 4.4 times/0.5 m when the amount of bentonite reached 2.0%. Therefore, by strengthening the mixing operation, the effect of HS binder has been better highlighted.

Influence of HS Binder Dosage

Figure 2 shows the influence of the dosage of HS binder on the falling strength of green pellets when the dosage of bentonite is 1.5%, 1.0% and 0.7%, respectively. As can be seen from the figure, the amount of bentonite is 1.5%. With the increase of the amount of HS binder, the falling intensity of the spore shows an upward trend (0.1% of the point is abnormal fluctuation). When the dosage of HS binder is 0.2% and the dosage of bentonite is 1.5%, the requirements of raw pellet strength can be satisfied. When the amount of bentonite was 1.0%, the falling strength of the spheroidal material increased with the increase of the amount of HS binder. When 1.0% bentonite was used and 0.2% HS binder was used, the falling intensity of green pellets was 3.2 times/0.5 m, which was equivalent to 2.3% when bentonite was

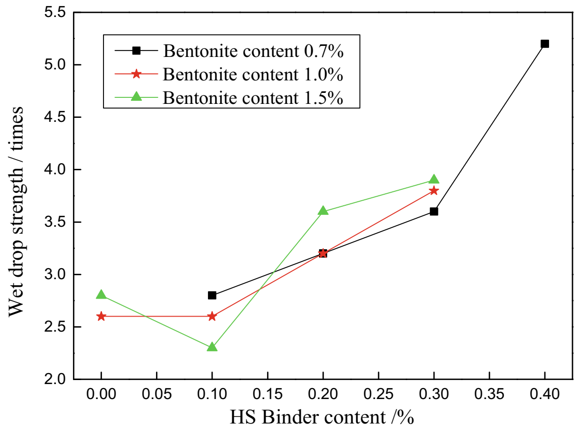

Fig. 2 Effect of HS binder dosage on the performance of green balls. (Color figure online)

used alone. In order to further understand the effect of HS binder, the experiment in this group examined the condition that the dosage of HS was 0.7%, and the falling intensity of the ball at this time was up to 8.0 times/0.5 m, which further verified the efficient effect of HS binder.

As can be seen from Fig. 2, if the bentonite dosage is reduced to 0.7%, the intensity of falling balls can still reach 3.2 times/0.5 m with the addition of 0.2%HS binder, and the effect is equivalent to the use of 2.3% bentonite alone. When addition of 0.2% HS binder, the amount of bentonite decreased from 2.3% to 0.7%. HS-type binder is a kind of high efficiency binder, which has a good application prospect in pelletizing iron concentrate.

Preheating and Roasting of HS Binder Pellets

Although the binder is used for the purpose of pelletizing, it will inevitably change or interact with iron concentrate under high temperature conditions, so it is very important to study its influence on the preheating and roasting performance of pellets. The reaction between bentonite and iron ore will promote the interfacial action and the formation of appropriate liquid phase, which can promote the consolidation of pellets in the process of preheating and roasting. The addition of organic binder will affect the preheating and roasting performance of pellets. On the one hand, its decomposition and volatilization at high temperature may produce a certain reducing atmosphere, which may affect the oxidation and consolidation of pellets. In addition, the decrease of bentonite content weakens the promoting effect of pellets on the consolidation. Therefore, the use of organic binder must be combined with the preheating effect of a comprehensive test.

For this reason, the pellets with HS binder were preheated and roasted, and the application effect and prospect were comprehensively examined. Figure 3 shows pellets prepared with HS binder 0.2% + 0.7% bentonite after intensified mixing. The

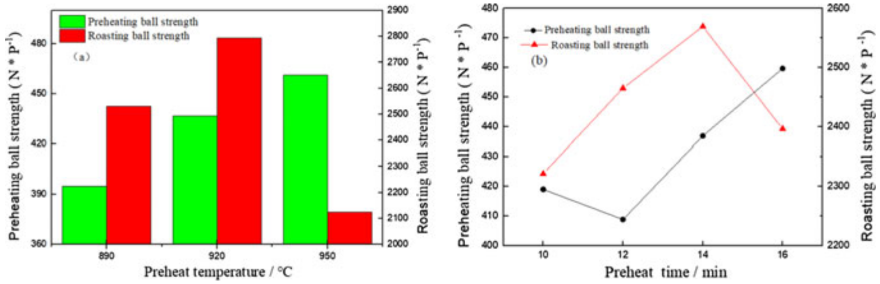

Fig. 3 Effect of preheating conditions on preheating and roasting of pellets. (Color figure online)

corresponding strength index can be obtained by changing the preheating and roasting conditions. Figure 3a shows the result of preheated pellets roasting at preheating temperature, and clearly shows that temperature had significant effect on the strength of preheated ball, strength is greater than 400 N/P. With the extension of preheating temperature continue, the ball strength still can continue to improve, fixed roasting conditions, when the preheating temperature of 920 °C, the roasting strength is exceed than 2500 N/P. Figure 3b is the test result of preheating time on pellets preheating and roasting.

The effect of preheating time on improving the strength of pellets is weak, because the crystallization rate and consolidation degree of Fe_2O_3 grains in the preheating stage are mainly affected by the preheating temperature. Except for the abnormal fluctuation at the time of preheating for 12 min, the rest are above 2500 N/P, which can meet the strength requirements of pellet products. In combination with the field practice, the preheating temperature is 920 °C and the preheating time is 14 min. The FeO in the pellet is fully oxidized, and more Fe_2O_3 microcrystals are generated. Therefore, the pellet that meets the industrial needs can be obtained.

Figure 4 is the experimental result of the effect of roasting conditions on the roasting strength of pellets. It can be seen from the figure that in the high-temperature roasting process of the composite pellets of 0.2% HS binder and 0.7% bentonite,

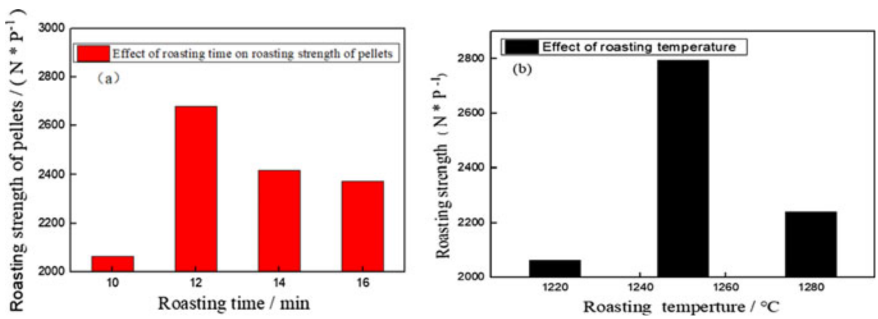

Fig. 4 Effect of roasting conditions on roasting strength of pellets. (Color figure online)

when the roasting temperature increases, the physical and chemical reactions inside the pellets will be accelerated, the particle diffusion will be accelerated, the pores in the pellets will be reduced, and the Fe_2O_3 microcrystals inside the pellets will be recrystallized and polycrystalline, making the pellets more dense and stronger. The best calcination temperature is 1250 °C, in which the pellet is oxidized completely. If the calcination temperature is too high, silicate liquid phase will appear in the inner lattice of the pellet. The decrease of Fe_3O_4 content and porosity in the pellet will significantly reduce the strength of the pellet. However, at high temperature, part of Fe_2O_3 is decomposed into Fe_3O_4 and FeO. Fe_3O_4 will react with SiO_2 in the pellets in a liquid phase, forming a liquid phase bond and reducing the pellet strength. Therefore, the optimal roasting time in this experiment is 12 min.

Comparison of the Properties of HS Binder and Bentonite Pellets

The above research shows that under the optimized test conditions, the HS binder from a factory in Shandong is mixed with bentonite to achieve the purpose of reducing the amount of bentonite. In this study, the properties of the oxidized pellets obtained by the four binders were comprehensively compared, as shown in Table 6. Four kinds of pellets were obtained under the same preheating and roasting system: The preheating temperature was 920 °C, the preheating time was 14 min, the roasting temperature was 1250 °C, and the roasting time was 12 min.

(1) As the amount of bentonite increases, the green ball drop strength gradually increases. When the amount of bentonite is 0.7–2.3%, the green ball drop strength increases from 2.1 times/0.5 m to 3.2 times/0.5 m. When the amount of bentonite continues to increase above 2.3%, the green ball drop strength will be greatly improved. When the amount of bentonite reaches more than 2.3%, the green ball falling strength meets the qualified index.
(2) When adding 0.4% HS-type binder, without adding bentonite, the strength of the preheated ball (284 N/P) is lower than the strength requirement of the preheated ball, and roasted ball is only slightly below the furnace to the strength of the

Table 6 Comparison of quality of pellets with four binders

HS content %	Bentonite content %	The green ball falls [times/0.5 m]	Compressive strength/N	Preheating compressive strength/N	Roasting compressive strength/N
	0.7	2.1	10.3	403.1	2906.3
	2.3	3.2	26.2	586.9	3704.4
0.4	/	4.0	12.5	284.0	2412.0
0.2	0.7	3.2	12.2	436.9	2794.3

pellets. Therefore, HS binder cannot be used alone or can completely replace bentonite.

(3) Under the condition of intensified mixing, after reducing the amount of bentonite to 0.7%, adding 0.2% HS-type binder can still achieve the green ball drop strength of 3.2 times/0.5 m. The pellet strength is about 2500 N/P. The main reason for the decrease in preheating roasting performance is the decrease in the amount of bentonite which weakens the promotion of pellet consolidation. Therefore, the pellet strength of this combination is close to the critical level required by the index. We thought the main reason of strength changing was brought by low dosage of bentonite, which weaken the promoting function of the pellets roasting consolidation.

Conclusions

(1) In order to meet the requirements of pelletizing, the amount of bentonite shall be more than 2.3% when bentonite is used alone as binder in the structure of the raw material. HS binder can meet the requirements of pelletizing and obtain good pelletizing performance when used alone.

(2) The combination of HS type binder and bentonite can significantly reduce the amount of bentonite. Adding type binder 0.2% can reduce the amount from 2.3% to 1.5%. Combined with the intensified mixing measures, the amount of bentonite can be further significantly reduced to a maximum of 0.7%, the pellet performance and the preheating and roasting performance can meet the production requirements, and the amount of bentonite can be reduced as much as 1.6% compared with the amount of bentonite without addition.

(3) For the structure of raw materials in this experiment, the binder combination of 0.2%HS + 0.7% bentonite can just meet the requirements of pelletizing performance and preheating and roasting performance, but the spare space is very small, which is close to the critical state.

The results showed that the combination of 0.2% HS binder and no less than 0.7% bentonite could meet the needs of pelletizing and pellet preheating and roasting and was feasible in industry and could effectively reduce the amount of bentonite

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