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Hyperactivation of Bentonite in Pelletizing Process

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Abstract

Application of hyperactivation process in palletizing iron ore, in order to decrease bentonite consumption has been investigated. Different amounts of bentonite and sodium hydroxide, as activating agents, were added to iron ore and the quality of formed pellets were determined. The results show that addition of 0.01 pct. NaOH improves the pellet quality significantly while the bentonite content remains constant at 0.7 pct. Moreover, pellet quality parameters were maintained within desired limit values while 0.02 pct NaOH and 0.4 pct bentonite were used. NaOH changes the chemistry of calcium-bentonite to sodium-bentonite that dispatches more easily in iron ore matrix. Homogeneous dispersion of bentonite in hyperactive mixtures creates uniform physical bonds between iron ore particles within pellet and results in less bentonite consumption.

Keywords: Pelletizing, Bentonite, Hyperactivation.

Introduction

Bentonite is well known as a binder additive in molding and foundry. It is also widely used in pelletizing of iron ore so that most pelletizing plants consume bentonite as the main binder . This thixotropic clay mineral that, as an additive, gives the pellets the desired properties, has low price and does not detract from its metallurgical behavior. However the amount of binder is relatively high, 0.5-1 weight percent. This high level of acid gangue not only decreases the reducibility, but also reduces the Iron units in the pellets1-3).

Bentonite consists primarily of montmorilonite clay and acts by absorbing water and filling the voids within the pellet matrix with a viscous gel. Bentonite is typically known in two different types, natural sodium bentonite, sometimes called Wyoming, and calcium bentonite, called Mediterranean4). Sodium bentonite has the highest water absorption properties and is preferred as a binder for pelletizing. However most bentonite resources have a chemistry of a combination of both sodium and calcium bentonites1-2).

Hyperactivation of bentonite for different applications; namely, foundry molding has been practiced for years4-6).When bentonite is activated by sodium carbonate or sodium hydroxide, in an ion-exchange reaction, calcium cations are replaced by sodium cations and sodium bentonite is obtained. Compared with calcium bentonite, a lower amount of sodium bentonite, may be consumed whereas the mold strength remains constant4).

Hyperactivation of bentonite in pelletizing process has rarely been reported7). In this research, hyperactivation of bentonite in pelletizing plant at Mobarakeh Steel Company (MSC) was investigated. Studies were conducted in order to decrease bentonite consumption and hence pellet gangue. Mechanism of the hyperactivation effect on the pellet properties was also investigated.

Experimental procedure

Pelletizing tests were carried out in the pilot plant of MSC. Batches of about 100 kg of iron ore concentrate, bentonite and NaOH (as activator) were mixed. The fineness of ground ore mixture was 1900 cm^2/gr. The amount of bentonite was kept at 2 levels , 0.4 and 0.7 pct and NaOH content varied from 0.0 to 0.02 pct. Chemical analysis of iron ore and bentonite is provided in Table1. NaOH was used in commercial purity (>98%).

The prepared batches were charged on a small pelletizing disk with a diameter of 0.8 meter.

The quality of green pellets was determined by measuring moisture content, dry and wet compression strength and drop number according to standards of MSC's pilot.

In order to determine the mechanism of hyperactivation and to elucidate how it changes the pellet properties, some complementary water adsorption tests were carried out on bentoite plus NaOH mixtures. Different blends of bentonite and NaOH were subjected to water for four hours and by measuring weight change, Enslin index (water

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adsorption capacity of pellet) was calculated. This is considered as an important physicochemical property of bentonote.

Results and Discussion

Pelletizing tests

The effect of both bentonite and activator agent on the quality of green pellets was studied. The effect of NaOH on the green pellets properties at a fixed amount of bentonite (0.7 pct) is shown in Figure1. As shown, additions of NaOH influence drop number and compression strength of pellet significantly. NaOH contents higher than 0.01 percent have a more significant effect on the pellet quality. Keeping in mind that at pilot scale, the minimum requirements for green pellet are a drop number of 3.0 and a dry compression strength (DCS) equal to 2 kg/Pellet. It can be concluded that at 0.7 pct bentonite, 0.01 pct NaOH may be consumed to attain desired properties. Consumption of 0.02 pct NaOH results in much higher quality measures than the acceptable values. Therefore, there will be a potential to decrease the amount of bentonite in the presence of high NaOH contents, i.e. more than 0.01 pct.

In order to examine the possibility of lowering bentonite consumption compared with frequent values (>0.7 pct), experiments were also carried out on two different levels of bentonite, i.e. 0.4 and 0.7 pct and different amounts of NaOH as activator. The results are shown in Figure 2. In the whole range of NaOH between 0.01 to 0.02 pct, the green pellet DCS is in an acceptable range. It is seen that at 0.7 pct bentonite, samples with NaOH content higher than 0.010 pct have drop numbers more than 3.0 . When the bentonite content is reduced to 0.4 pct, NaOH content of at least 0.015 pct is required to keep the drop number above the acceptable value (3). Figure 2 proves that bentonite consumption can be reduced from present level of 0.7 pct to 0.4 with hyper activation process.

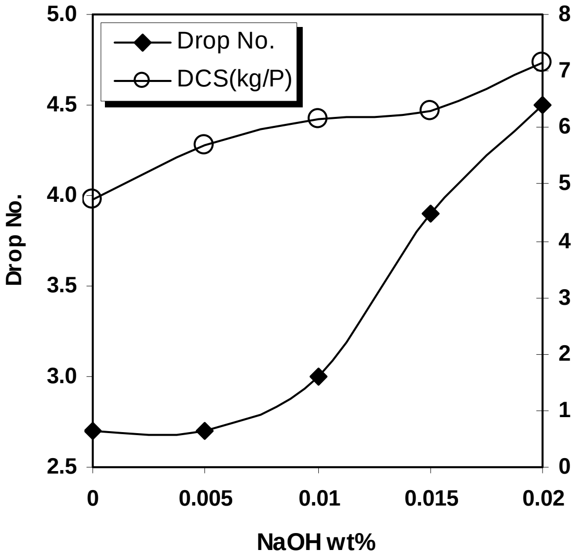

Fig. 1. Effect of activator (NaOH) content on properties of green pellet.

Table 1. Chemical analysis of iron ore and bentonite.

	Fe	SiO_2	Al_2O_3	CaO	MgO	Na_2O
Iron Ore	74.07	1.79	0.31	1.41	0.71	Trace
Bentonite	2.01	65.96	14.49	3.55	2.15	1.85

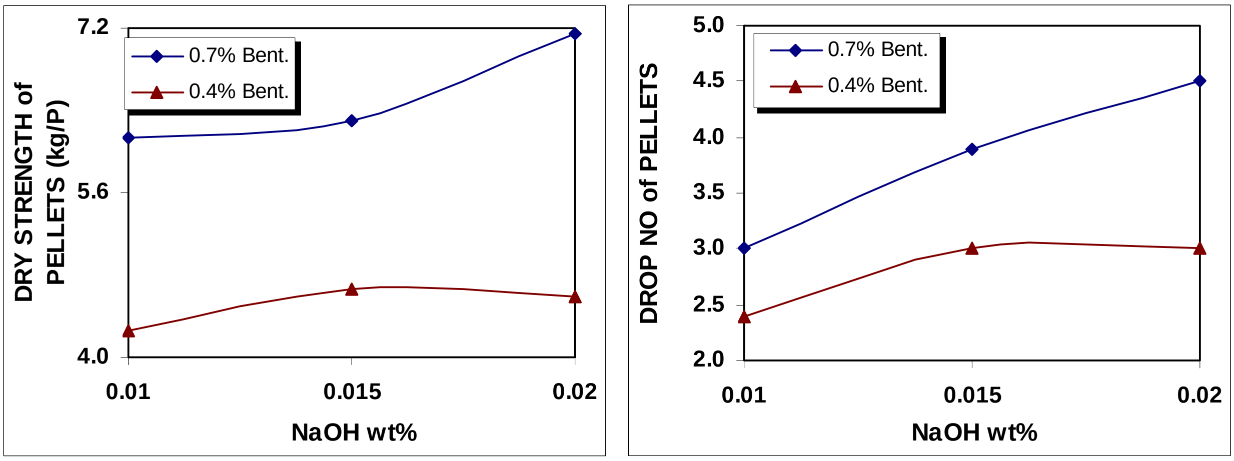

Fig. 2. Effects of bentonite and NaOH contents on green pellet quality.

Mechanism of pellet quality enhancement by hyperactivation process

Studies carried out on bentonite activation has shown that the process involves an ion-exchange reaction as following:

Ca-bentonite + NaOH/Na_2CO_3 = Na-bentonite + $Ca(OH)_2/CaCO_3$

Activation of bentonite may affect bentonite properties from two aspects; firstly, changing the water adsorption capacity and so swelling of bentonite and secondly, separation of bentonite plates. To determine the mechanism of pellet quality enhancement by hyperactivation , these two different aspects of bentonite behavior were evaluated. In figure 3, drop number of pellet and water adsorption capacity of activated bentonite are plotted against the amount of NaOH in the mixture.

As shown in Figure 3, water adsorption of bentonite reaches its peak point at about 1 pct NaOH. Afterwards , it begins to fall and levels up at around 3 pct NaOH.

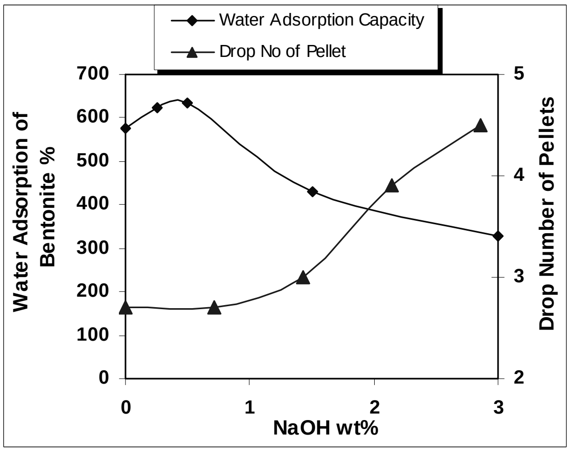

Fig. 3. Drop number of pellet and water adsorption capacity of bentonite as a function of activator content.

To describe this phenomenon, bentonite may be considered as a set of plates being held together by ionic forces. Water is absorbed around and between the plates and the distances between the plates. So water adsorption capacity depends on type of ions (cations) adsorbed to bentonite. Bentonite plates with Ca^{2+} ions, i.e. calcium bentonite tend to attract each other and agglomerate, hence little water is entrapped between plates (6). Conversely, sodium bentonite plates with Na^+ cations repel each other and disperse. Therefore, water adsorption capacity of bentonite directly depends on concentration of Na^+ cations within bentonite. This model is schematically shown in Figure 4. Even partially activated bentonite is able to adsorb a considerable amount of water between its plates compared with non-activated bentonite and higher NaOH, the more the sodium-bentonite, the higher the water adsorption. Up to a critical amount, i.e. 1 pct NaOH, the bentonite plates become completely separated so that no water can be entrapped between the plates i.e. decreasing water adsorption capacity in high levels of NaOH

Increasing water adsorption capacity of bentonite increases bentonite gel volume which is expected to improve the pellet quality. As shown in Figure 3. a reduction in water adsorption of bentonite has no adverse effect on increasing trend of drop numbers. Therefore, it can be concluded that another phenomenon (rather than water adsorption) may affect pellet quality.

As described earlier, bentonite plates repel each other when being activated. Having considered these phenomena, we expect the activated-bentonite to disperse more homogeneously in iron ore concentrate. To elucidate this phenomenon, the dispersion of activated and non-activated bentonite in the pellet was examined using SEM-EDS. In order to detect distribution of bentonite in pellet, map analysis of Si element, as a representative for bentonite, in cross section of pellet was carried out. The results are provided in Figures 5A and 5B. As it is shown, in the activated sample the Si dispersion is more homogeneous. It can be concluded that activated bentonite is more homogeneously dispersed in the pellet mixture.

Therefore the enhancement of pellet quality can be related to homogeneity of bentonite dispersion in the iron ore matrix which is due to hyperactivation. Homogeneous dispersion of bentonite creates homogeneous bentonite-iron ore bonds within pellet which promotes pellet quality.

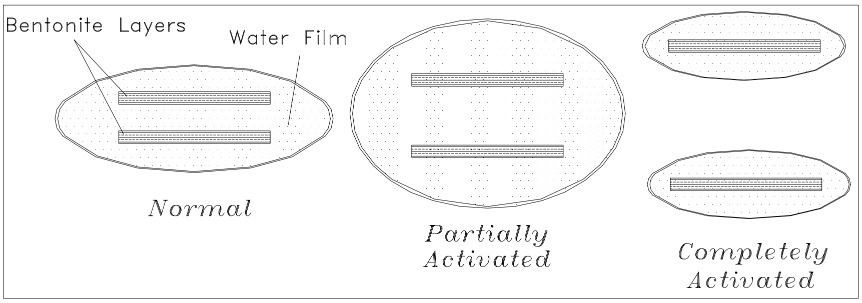

Fig. 4. Schematic representation of effect of activation on bentonite structure(6).

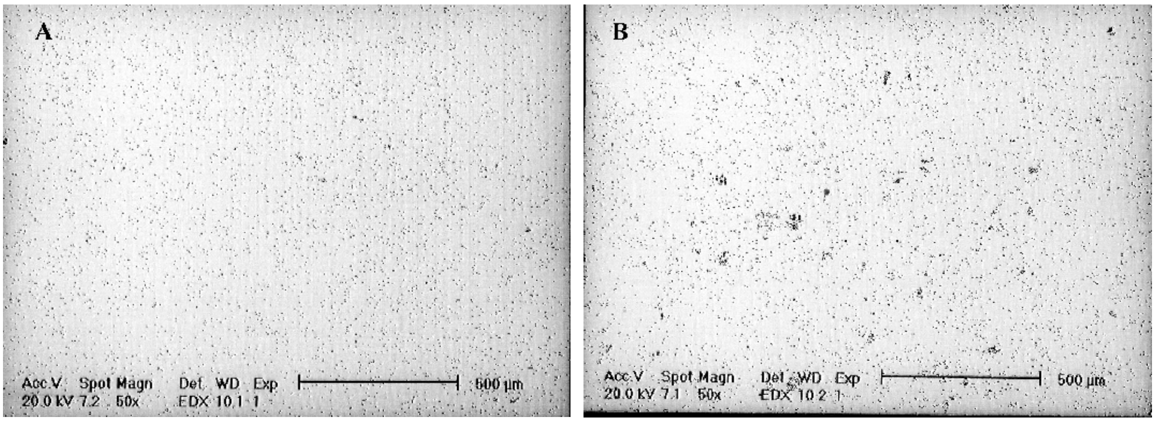

Fig. 5. The Si dispersion in cross section of activated (A) and non-activated (B) pellets

Advantages of Hyperactivation in Pelletizing Process

As described earlier, by applying hyperactivation process, bentonite consumption can be decreased by 0.3 pct while 0.015 pct NaOH is added to charge. Based on local prices, an economical analysis shows that with the new blend (0.4% bentonite, 0.015% NaOH) compared with the present blend in MSC (0.7% Bentonite), reduction in raw materials costs of US$ 0.15 /ton, ellet can be obtained.

Reducing the bentonite consumption by 0.3 pct increases total iron of fired pellets about 0.25 pct. Such an increment in iron content leads to a higher total iron unit processed in ironmaking plant i.e. higher productivity.

Homogeneous dispersion of bentonite in pellet due to hyperactivation results in a higher pellet and DRI quality. Produced green pellets are more uniform in shape and size so that lower fine formation and higher productivity are expected. Uniformity of pellet shape and size improves the efficiency of indurating machine from the point of view of heat and mass transfer.

Lower gangue in hyperactivated pellets increases the reducibility of pellet, and the metallization degree of such a pellet is higher. The reported data from the industrial practice in MSC shows an increase in DRI metallization up to 1.5 pct, when the bentonite consumption is reduced to 0.4 pct due to hyperactivation.

Consumption of low-gangue, highly metallized DRI in electric arc furnace (EAF) brings many advantages, mainly, lower energy consumption and higher productivity.

Conclusion

1. Hyperactivation of bentonite with NaOH can be done in pelletizing process in order to decrease bentonite consumption around 40 percent
2. Water adsorption of bentonite is a function of its chemistry. Hyperactivation of bentonite with NaOH changes this property of bentonite.
3. The mechanism of bentonite quality promotion by hyperactivation process is better dispersion of bentonite in pellet matrix
4. Decreasing of bentonite consumption due to hyperactivation process brings about significant advantages including lower production costs and improved quality and productivity of processed materials

Aknowledgments

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