Influence of Operational Conditions on Dust Emission from Sintering Bed

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Dust emission is an environmental concern to iron ore sintering. To suppress it by preventing dust from migrating into gas stream in the sintering bed, the effect of various operational factors was investigated and the site and cause of dust generation in sintering bed were estimated through pot tests with a dust sampler placed between the pot and the wind box. Dust emission increased with increasing coke content or decreasing moisture; suction pressure, bed height and blend ratio of Marra Mamba ore did not affect significantly. Of 750 mg/kg dust emitted from bed, about 150 mg/kg originated in the drying zone, another 150 mg/kg in the dehydration zone and the rest in the coke combustion zone. The dominant causes allowing particles to move into gas stream in the bed was estimated to be granule’s breakage in the drying/dehydration zones and extinction of adjacent particles in the combustion zone.

KEY WORDS: iron ore sintering; dust emission; pot test; coke content; moisture; bed height; suction pressure; Marra Mamba ore.
the hot exhaust around the burnthrough (Fig. 2). Tapped off the filter into a stainless steel butt, the dust was sieved and weighed. Judging from the fact that no dust penetrated to the tails of filter, the filter was able to capture all dust emitted from the sintering bed during sintering. A small amount of dust however remained stuck to the filter after tapping, which was unavoidably neglected. In this article the amount of dust was described as ‘dust ratio’ that was defined as the amount of dust collected over dry weight of sintering mixture.

Some dust samples transferred to chemical analysis for identifying their heat careers.

2.2. Variable Factors Examined in Pot Test

Table 2 shows factors and levels examined in the pot test.

The variation in blend of sintering mixture as described in Sec. 2.1 was to confirm some data suggesting Marra Mamba ore might increase dust emission.

Sintering operation often adjusts coke content and moisture of green mixture to maintain the performance optimal. Therefore, the experimental levels of coke content and moisture were varied widely.

Suction pressure and bed height were less variable in practice. But their dependency on dust emission could also provide some hints for understanding the true nature of dust emission.

Binder was expectedly a quick remedy if it could reduce granule’s breakage. The examinees in this work were quick lime (QL) and carboxyl methyl cellulose (CMC). The former was an inorganic binder of commercial use, which enhanced after-dried strength of granules. The later was an organic binder, which improved both wet and dry strengths.

Sintering reaction proceeds in the sequence of wetting (condensation of water), drying of moisture, dehydration of combined water, coke combustion, melting and solidification. To account for contribution of each reaction on the dust emission, a hot-air suction test was conducted where the sintering bed was dried out with 500°C air without ignition, and compared with normal sintering tests. The dust obtained by the hot-air suction test was regarded to generate below the dehydration zone; the dust obtained from normal sintering test contained all dust generated at every zone, hence the subtraction of the hot-air suction test’s dust from the sintering test’s dust estimated the dust generated at the combustion zone with ignoring the melting and solidification zones.

Underlines in Table 2 mean pivot conditions. An experimental series had a base run and others where irrelevant factors were set constant at the standard values. As some sets of series comprised the whole experiment, this work repeated the base run some times, which could tell the margin of experimental error.

3. Results

3.1. Size of Dust Collected Beneath the Sintering Pot

Figure 3 plots the total dust ratio of all data in this work on the axe of −0.125 mm dust ratio. They showed good correlation, which gave a basic idea on the dust emitted from bed. Namely, the dust was not fine particles that were come off granules and blown away in the gas stream, but granules with adhering fine particles on core particles that passed down through void in bed.

This article will often use the total dust ratio as a representative of result below.

3.2. Influence of Coke Content, Moisture, Suction Pressure and Bed Height on Total Dust Ratio

Figure 4 shows the result on the influence of major operatives in sintering on dust emission.

The total dust ratio increased with increasing coke content (Fig. 4(a)). Despite of the stereotype that increasing coke content would raise bed temperature to enhance not only sintering yield/sinter strength but also dust suppres-
sion, the positive dependency of coke content was new and suggested the existence of different determinant for dust emission from the bed temperature for sintering yield/sinter strength. A possible explanation for such dependency of dust on coke content was by the coke extinction after combustion that had supported the fluidized particle. More coke, more particles fluidized at combustion zone.

The total dust ratio monotonically decreased with moisture (Fig. 4(b)). But the explanation of the behavior seemed complicated as follows. The best moisture for the present blend lied between 6.5 and 7.0 mass%. As the under-moisture brought lack of binding water between grains to decrease strength of granules in the bed, it was natural that the total dust ratio increased toward 5.5 mass% in moisture. The over-moisture at 7.5 mass% still gained the improvement in the dust ratio, which claimed another function of moisture in the bed than that for granulation.

Suction pressure, standing for heating or cooling speed in technical meaning, did not change the total dust ratio significantly (Fig. 4(c)).

Bed height did not affect the total dust ratio (Fig. 4(d)). It meant that the rate of dust generation stayed constant at any position across the sintering bed though the dust burst into the exhaust around the burnthrough. To meet the both facts apparently conflicting with each other, wet zone in sintering bed must acted as the temporary trap as Kasama et al. reported.\(^\text{10}\)

3.3. Hot-air Suction Test

Comparison of hot-air suction test with normal sintering test could tell much about the dust generation behavior in the bed. As shown the total dust ratios of both cases in Table 3, one third of the whole dust emitted during sintering generated with hot-air suction. Its meaning will be discussed later with Table 4.

Figure 5 shows two size distribution curves: The solid line is for the dust obtained by hot-air suction test, the broken line is for the virtual dust generating at combustion zone that was calculated by subtraction of hot-air suction test’s dust from normal sintering test’s. The former dust had the similar size distribution as green mixture, suggesting that the whole pieces of broken granules got fluidized into the stream after the disintegration by wetting/drying dehydration. The latter dust, the virtual dust generated during coke combustion, contained much larger amount of intermediate size sprits, suggesting that some different causes dominated the dust generation in the combustion zone.

Figure 6 shows chemistry of green mixture, the dust by hot-air suction test and the virtual dust from the combustion zone in three size sprits: under 0.125 mm, 0.5–1.0 mm, over 1.0 mm. Note that FC represents carbon originated in coke breeze excluding carbon in limestone. The data will reflect the circumstance of the dust’s birthplace and the dust’s preference on the ingredients.

Green mixture and the dust by hot-air suction test had no significant difference in CaO or FC; combined water (CW) of the dust reduced by half in every size sprit. The reduction in CW could occur by the dust generation at the dehydration zone and/or by the preferential breakage of granules consisting of low CW ores that was of low granulability.

The virtual dust from the combustion zone additionally showed FC decreases in smaller size sprits, which verified the dust’s origin. Also CaO slightly decreased in every size sprit, which could occur as some lime (stone) particles formed SFCA to stabilize in the bed.

\[\text{Table 3. Influence of Ore B, binders and hot-air suction on total dust ratio.}\]

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Ore B</th>
<th>Binder</th>
<th>Hot-air suction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (mass%)</td>
<td>6.5</td>
<td>6.5</td>
<td>7.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Total dust ratio (mg/kg/mixture)</td>
<td>750</td>
<td>810</td>
<td>753</td>
<td>600</td>
</tr>
</tbody>
</table>

\[\text{Fig. 4. Change of total dust ratio with (a) coke content, (b) moisture, (c) suction pressure and (d) bed height.}\]

\[\text{Fig. 5. Size distribution of dusts collected in comparison to that of green mixture. Distribution obtained by substituting hot-air suction test from sintering test corresponds to that generated at the combustion zone.}\]

\[\text{Fig. 6. Chemistry of green mixture and collected dusts in three size sprits: (a) CW, (b) FC and (c) CaO.}\]
3.4. Influence of Ore Type and Binders

Table 3 also shows the influence of ore type and binder addition. When Ore B was used, the dust emission increased without moisture adjustment; whereas it changed insignificantly as far as the moisture was well controlled.

Binder additions were effective to decrease the total dust ratio approximately by 100 mg/kg. The suppression effects differed insignificantly between QL and CMC.

4. Discussion

4.1. Size Difference between Dust Emitted from Bed and Dust from Stack

Khosa et al. estimated that the dust entrained in the air from stack accounted for 20% of the total dust collected beneath the grate bars of their test pot, based on the Ball’s finding that the dust was almost finer than 0.295 mm. According to our measurement the dust passed through 0.2 mm after de-dusting by EP. Such discussion might question the sense of measuring the whole dust beneath the grates.

Good correlation between the total dust ratio and 0.125 mm dust ratio shown in Fig. 3 brought the validity of measuring the total dust beneath grates for the true dust finally emitted from stack.

4.2. Estimation of Dust Generation Behavior in the Sintering Bed

Table 4 shows possible routes for dust generation. Intuitively, either the breakage of granules themselves or the extinction of adjacent particles caused granule’s fluidization. The extinction means that of coke particles after their combustion. The question was which reaction zone from wetting to solidifying were the dominant site the fluidization occurred at.

Findings so far narrowed down the possibilities. Dust generation at the wetting zone was impossible because over-moistening still had suppressing effect on it. According to the total dust ratio of 285 mg/kg by the hot-air suction test, granule breakage at the drying/dehydration zone was a possible route; moreover the drying and the dehydration zones might have fifty-fifty contribution based on half decrease in CW; whereas, the temperature was too low to extinct any support particles in those zones. Another possible route was by the coke extinction at the combustion zone. The melting zone had less possibility owing to little change in CaO of the virtual dust. The solidifying zone seemed unlikely. Thus, the total dust ratio of 465 mg/kg was concluded to be due at the combustion zone.

4.3. Influence of Marra Mamba Ore on Dust Emission

In this work, as shown in Table 3, the dust emission changed insignificantly as far as the moisture was well controlled. This suggested that the ore type was a false factor and the true one was moisture. The result coincided with the definite dependency of the total dust ratio on moisture as shown in Fig. 4(b).

Before starting commercial use of Marra Mamba ore from 2002, we were apprehensive that it might increase dust emission based on a few data obtained by trial shipment (Fig. 7). The present pot test, however, led to the opposite result. Though details were lost about test conditions for Fig. 7, insufficient moisture control might have brought such data.

4.4. Effect of Binder on Suppression of Dust Emission

Binder additions were effective to decrease the total dust ratio approximately by 100 mg/kg (Table 3) without denoting significant relative merit between QL and CMC. As discussed along Table 4, about 150 mg of the whole dust derived from the drying zone; another 150 mg from the dehydration zone; the rest from the combustion zone. Obviously, the binders were incapable of preventing either dehydration or coke combustion; their effect only reached to the drying zone. Hence, the possible dust reduction was 150 mg/kg-mixture at most. The effect of 100 mg seemed small of the whole 750 mg/kg-mixture dust ratio in base condition, but it proved reasonable.

4.5. Role of Wet Zone

According to Kasama’s measurement of dust concentration at wind boxes (WB) in Oita No. 2 sintering machine showing its typical strand-wise distribution (Fig. 8′), dust emission into exhaust started increasing at the same WB
that the gas temperature rose, and ceased before the maximum temperature appeared at the burnthrough. It confirmed Ball’s similar result and discussion that the wet zone behaved as the temporary trap for the particles fluidized at upper zones. Additionally, re-increase at the last WB probably depended on the suction from discharging area through dead plate, not through sinter bed.

If the trapping was temporary, it was insufficient to explain the suppressing effect of moisture on dust emission; otherwise, some part of trapped dust must re-stick to granules while the wet zone was drying. With these consecutive processes of trap and re-stick, the increase in moisture could decrease dust emission via widening the wet zone.

5. Conclusions

The effect of various factors on dust emission during iron ore sintering was investigated, and the site and cause of dust generation in sintering bed were estimated through pot test.

(1) Dust emission increased with increasing coke content or decreasing moisture. Suction pressure, bed height and blend ratio of Marra Mamba ore did not affect significantly.

(2) Of 750 mg/kg dust emitted from bed, about 150 mg/kg originated in the drying zone, another 150 mg/kg in the dehydration zone and the rest in the coke combustion zone. Binders, QL and CMC both suppressed dust emission by about 100 mg/kg, which almost corresponded to the dust derived from the drying zone.

(3) The dominant causes allowing particles to move into gas flow in the bed seemed granule breakage in the drying/dehydration zones and extinction of adjacent particles in the combustion zone.

REFERENCES