Effect of Drying Treatment after Granulating Sinter Raw Materials on Flame Front Speed and Sintering Yield

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For increase of sinter productivity, it is important to design sinter mixture granulation. Moisture is indispensable for granulation as a binder between raw material particles. Once granulation is completed, moisture is dispensable during sintering because moisture vaporization is an endothermic reaction. Based on the above-mentioned view, a process of drying the granules after granulation with high moisture examined for sintering productivity by use of sinter pot test.

The main results obtained are described as follows:

1) Drying in conjunction with high moisture granulation is effective to increase flame front speed with maintaining sintering yield;
2) Increasing flame front speed is due to shorten the time to evaporate moisture in the wet zone of sintering packed bed in addition to increasing permeability of sintering packed bed. This effect is also evaluated and proved based on calculation of moisture transition in and out of sintering packed bed;
3) Maintaining sintering yield is due to higher heat generation in sintering packed bed caused by higher coke combustion efficiency in addition to lower moisture concentration of sinter mixture.
4) Collapse of granules in case of drying after granulation is avoided till the critical moisture, that is defined as the one left in the mix after higher moisture granulation makes granules to keep shape easy due to higher moisture quantity on the surface of granules.

KEY WORDS: sinter; granulation; drying; moisture transition; granules; pseudo-particle; coke combustion.

1. Introduction

Sinter productivity strongly depends on sinter permeability in sinter packed bed due to increase of air flow rate in it. Furthermore, high sinter permeability is achieved by large pseudo-particle which is sinter raw materials after granulation, and high void ratio of sinter packed bed represented as Ergun Formula.

And pseudo-particle structure is core particle coated with fine particles or only small particles adhering each other, which is formed mechanically by granulator as drum type mixer.

Agglomeration is particle cohesion caused by moisture capillary force. In addition, pseudo-particle size strongly depends on raw materials particle characterization and mixing condition. The former are size distribution, adhesive force, particle surface properties, and particle shape etc.1,2) The latter are mixer specifications3,4) as mixing time, rotating speed, particle rolling length in mixer and utilizing conditions of moisture and quick lime.

In fact, charging mini-pellet,1,2) which is large particle as pseudo-particles in sinter process has a roll of increasing permeability.

First, as mixer specifications, Pre-Granulating process5–9) has developed, based on raw material properties, instead of one-line granulating method, for purpose of improving sinter quality and sinter productivity.

Pre-granulation process has the two and more granulation routes and after granulation in each route they are gathered and charged into sinter machine. This process has been applied in lots of Japanese sinter plant in various styles4–6) based on fundamental study10) as duplex mini-pellet.11,12) Recently, as controlling the bed structure technique for high permeability MEBIOS (Mosaic Embedding Iron Ore Sintering)13–15) was developed. In this method, large pseudo-particle size (5–15 mm) by use of pan-pelletizer has a role of increasing void ratio in sinter bed. When introducing the process, mixer specifications has also examined for determination of essential mechanical parameters, for example angle size and rotation speed.8)

The typical applications for utilization of granulating binder as moisture and quick lime are Technique of adding dry return fine on raw materials after granulation stage6,17)
and of Anionic polymer dispersant (APD) utilization at sinter material granulation. Philosophy of the former is promoting granulation caused by increasing moisture content at granulation stage through bypassing dry return fine. Philosophy of the latter is to approximate optimum moisture content at granulation to optimum moisture content against collapsing with drying, where the optimum value at granulation is higher than that against collapse with drying and APD has a role of decreasing optimum moisture content at granulation. And it caused by fine particle captured on coarse particle is released into moisture and acts as moisture. Both these two typical technique is based on the concept, in which moisture is necessary at granulation but not necessary at sintering.

In this study, based on the purpose which is confirming the concept, moisture at granulation and that at sintering are varied as independent parameters each other. Then, effect of these two parameters on flame front speed and product yield is examined. Specifically, before sintering through granulating and drying sinter mixture, as well as adhering and collapse coke combusting efficiency are evaluated and considered.

2. Experimental

2.1. Sinter Pot Test

Table 1 shows blending conditions. Major 5 brand of iron ore in Japan were used and blend ratio of coke fine is 4.5 mass%. Figure 1 shows granulation and drying methods. Sinter mixture was mixed for 4 min by drum type mixer (600 mm diameter and 800 mm length). Then moisture was added to sinter mixture under the determined content. After that, sinter mixture was mixed for 4 min again. In some cases, the sinter mixture was dried before sintering. For the drying method, it was spread with 30 mm thickness on a steel plate for decreasing moisture content to the determined value. Table 2 shows experimental cases. The cases were 6. In details, the cases of moisture content with 7.9 mass% at granulating were three cases of that without drying and those with drying to 6.7 mass% and 6.2 mass% wer. The cases of moisture content with 6.5 mass% at granulating were two cases of that without drying and that with drying to 5.3 mass%. The case of moisture content with 5.5 mass% at granulating was one case of that without drying. In this paper, moister after granulation and before drying and moisture after drying are called as “Moisture after granulation” and “Moisture at charging”, respectively. Pseudo-particle size was also measured both after granulation and at charging. The measuring method was mechanical sieving with several size of meshes for 15 seconds without tapping after dry treatment for 2 h under 105 degree C.

Sintering pot size was column shape with 300 mm diameter and 500 mm height and it was set on wind box with same size of diameter. After charging sinter mixture, thermo-couple was set at center position in cross section at 240 mm and 430 mm height from top surface of the sinter pot. Another thermo-couple was set in the wind box.

Surface of the sinter packed bed was sintered with LPG burner for 1 min with inducing air under the condition of −5.2 kPa at inner wind box. After igniting, the sinter packed bed was sintered with inducing air under the condition of −10.3 kPa at inner wind box. Pressure at inner wind box was controlled at constant value on opening level at the valve at duct, combining the wind box with the fan. Exhaust gas temperature was measured with the thermo-couple set at the center position in the wind box, and sintering time was defined as time from starting igniting to reaching to peak temperature. During sintering, exhaust gas was cautiously sampled and analyzed components (CO, CO₂, and O₂) after dedusting. CO and CO₂ were analyzed on infrared absorption spectrum method and O₂ was analyzed on magnetic force method by use of portable analyzer. Permeability of sinter packed bed was measured on JPU formula defined as

\[ JPU = v \cdot (\Delta h / \Delta P)^{0.6} \]

\( v \) (m/min): Superficial velocity \( \Delta h \): bed height (mm) \( \Delta P \): Pressure in the wind box (mmAq)

![Fig. 1. Method of granulation and dry treatment.](image)

### Table 1. Blending conditions of sinter mixture. (mass%)

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Brand</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron ore</td>
<td>R</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>19.1</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>21.3</td>
</tr>
<tr>
<td>Serpentine</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Limestone</td>
<td></td>
<td>12.3</td>
</tr>
<tr>
<td>Return fine</td>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td>Coke breeze (-5 mm)</td>
<td></td>
<td>4.5</td>
</tr>
</tbody>
</table>

### Table 2. Moisture conditions of raw materials. (mass%)

<table>
<thead>
<tr>
<th>after granulating</th>
<th>7.9</th>
<th>6.5</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>at charging</td>
<td>◆</td>
<td>■</td>
<td>▲</td>
</tr>
<tr>
<td>without drying</td>
<td>◆</td>
<td>6.5</td>
<td>5.5</td>
</tr>
<tr>
<td>at charging</td>
<td>◆</td>
<td>◆</td>
<td>▲</td>
</tr>
<tr>
<td>after drying</td>
<td>6.7, 6.2</td>
<td>5.3</td>
<td></td>
</tr>
</tbody>
</table>

Symbol: use in Figs. 3–6, 11, 12, 14
Here, superficial velocity was measured continuously by use of an orifice set at the duct.

Sinter cake discharged from sintering pot was dropped from 2 m height by 4 times after its weight measurement, then sieved on 5 mm mesh screen. Based on assumption at which hearth layer was not collapsed at the drop treatment, amount of sinter product was calculated on weight of sinter over 5 mm size minus the hearth weight at charging the sintering pot. Then product yield was calculated on the amount of sinter product divided by the measurement value of sinter cake.

Sinter productivity was calculated on the amount of sinter product divided by the defined sintering time and by bottom surface area of the sintering pot. Flame front speed (FFS) was calculated on sinter bed height divided by the time from starting ignition to the timing which exhaust gas temperature began to rise. It should be noted that exhaust gas temperature beginning to rise was defined as the timing of reaching 100 degree centigrade, based on the philosophy that dry zone in sinter packed bed reaches to the bottom position.

### 2.2. Evaluation of Coke Combustion Efficiency

Coke combustion efficiency was evaluated based on exhaust gas volume and its compositions (CO, CO₂, O₂).

Figure 2 shows image of inlet and outlet gas volume and compositions. Gas balance was calculated based on 4 components (CO, CO₂, O₂, and N₂), without H₂O and trace component of SOx and NOx.

Inlet gas consists of 21 vol% O₂ and 79 vol% N₂. N₂ content in outlet gas was 100 vol% minus summation of CO, CO₂ and O₂. Then ratio of inlet and outlet gas volume was determined by N₂ valance. Outlet gas volume is larger than inlet gas volume and the difference was equivalent to CO gas generated from carbonates as limestone and half volume of CO₂ gas, based on phenomena in which for the former it was generated as decomposing gas from solid carbonates without O₂ consumption and for the latter two mole CO gas consumption. As, CO gas volume was measured. Volume of CO₂ gas generation from carbonates decomposition was determined. Then CO₂ gas generation from coke combustion was determined as total CO₂ volume minus that from carbonates decomposition. Further, unburnt carbon on coke after sintering was determined from CO and CO₂ gas volume and coke blending amount with its fix carbon content. In this experiments, as exhaust gas composition was measured continuously, amount of each coke combustion state (complete combustion; C+O₂→CO₂, partial combustion; C+1/2O₂→CO, unburnt coke) was determined.

Heating value for each combustion is shown as below.

\[
\begin{align*}
C + O_2 & \rightarrow CO_2 \quad 408 \text{ kJ/mol} : \text{complete combustion} \\
C + 1/2 \cdot O_2 & \rightarrow CO \quad 125 \text{ kJ/mol} : \text{partial combustion}
\end{align*}
\]

In this paper, coke combustion state were considered shown below.

1) Coke combustion efficiency: ratio of actual heating value to possible maximum heat value where all carbon burns as complete combustion
2) Then heat generation of coke combustion was given, considering coke combustion efficiency.

Heat valance was calculated based on moisture vaporizing and carbonates decomposition in addition to coke combustion.

### 3. Results

#### 3.1. Permeability and Flame Front Speed

Figure 3 shows influence of moisture content at charging on −0.25 mm ratio of pseudo-particle size. In comparison among the cases without drying, with increase of moisture content at charging, −0.25 mm ratio of pseudo-particle size was decreased. And in comparison among the cases of equal moisture content after granulation, drying treatment after granulation made −0.25 mm ratio of pseudo-particle size increase, but in case of high moisture granulation, increase degree was small. In addition, even if moisture content at charging was equal, −0.25 mm ratio of pseudo-particle size at the case of high moisture (7.9 mass%) granulation and drying was smaller, compared with the case of low moisture (6.5 mass%) granulation. However, −0.25 mm ratio of pseudo-particle size at the case of low moisture (6.5 mass%) granulation and drying was positioned on the line combining two data, of which are the cases of low moisture (6.5 mass%) granulation and of further low mois-

![Fig. 2. Volume balance between inlet and outlet gas.](image)

![Fig. 3. Disintegration of pseudo-particle by dry treatment to granulated sinter mixture.](image)
ture (5.5 mass%) granulation. And so, the effect of drying treatment after granulation on decrease of −0.25 mm ratio of pseudo-particle size appeared at only high moisture granulation.

**Figure 4** shows influence of dry treatment on permeability at sintering. In comparison among the cases without drying, with increase of moisture content at charging, permeability at sintering increased. And in comparison among the cases of equal moisture content after granulation, dry treatment after granulation made permeability at sintering decrease at low moisture (6.5 mass%) granulation, but made it a little change at high moisture granulation. In addition, even if moisture content at charging was equal, permeability at sintering at the case of high moisture (7.9 mass%) granulation and drying was higher, compared with the case of low moisture (6.5 mass%) granulation.

**Figure 5** shows influence of moisture and fine particle quantity on permeability at sintering, which was mean value between time at starting sintering and that at highest temperature of exhaust gas measured in the wind box. All data was positioned on one straight line, it means that permeability at sintering depended on −0.25 mm ratio of pseudo particle size and was independence of dry treatment.

**Figure 6** shows influence of permeability at sintering on flame front speed (FFS). In general, with increase of permeability at sintering, FFS increased. Especially, dry treatment after high moisture (7.9 mass%) granulation had an effect on increasing FFS and had no influence on permeability.

**Figure 7** shows effect of dry treatment on FFS in case of high moisture (7.9 mass%) granulation. FFS of upper, lower, and whole layer (0–240 mm 240–430 mm 0–430 mm) was calculated based on temperature measured in sinter packed bed at 240 and 430 mm position from upper surface of sinter packed bed. Dry treatment has a role of increasing FFS, because of moisture content decrease.

**Figure 8** shows effect of dry treatment on moisture
vaporizing and coke combustion time in comparison of the cases with and without dry treatment at high moisture (7.9 mass%) granulation. Dry treatment was effective to decrease time from temperature rising timing to reaching maximum temperature on moisture vaporizing and coke, regardless of little difference for superficial velocity.

3.2. Heat Valance and Product Yield

Figure 9 shows each ratio of coke combustion states, which are complete combustion, partial combustion and unburnt state. In three cases of high moisture (7.9 mass%) granulation, complete combustion ratio was high and unburnt ratio was low. It is considered that this high effective combustion was caused by high combustion activity, because more coke particles was exposed to flowing gas, due to lower not-granulated fine particle in sinter packed bed. Especially, in the case of drying after high moisture (7.9 mass%) granulation, unburnt ratio was zero.

Figure 10 shows coke combustion heat generation and coke combustion efficiency. In three cases of high moisture (7.9 mass%) granulation, especially, in the case of drying after high moisture granulation, coke combustion heat generation and coke combustion efficiency were high. This result was corresponding to coke combustion state shown in Fig. 9.

Table 3 shows heat generation and consumption quantity for coke combustion, moisture evaporation, and decomposition of carbonate at sinter packed bed. Heat consumption quantity for moisture evaporation was corresponding to moisture content in sinter mixture and that for decomposition of carbonate was constant due to constant blending ratio of carbonates.

<table>
<thead>
<tr>
<th>Moisture after granulating (mass%)</th>
<th>Moisture at charging (mass%)</th>
<th>Coke combustion (kJ/kg)</th>
<th>Moisture evaporation (kJ/kg)</th>
<th>Decomposition of carbonate (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.9</td>
<td>7.9</td>
<td>1.033</td>
<td>−0.188</td>
<td>−0.149</td>
</tr>
<tr>
<td>7.9</td>
<td>6.7</td>
<td>1.051</td>
<td>−0.162</td>
<td>−0.149</td>
</tr>
<tr>
<td>7.9</td>
<td>6.2</td>
<td>1.069</td>
<td>−0.149</td>
<td>−0.148</td>
</tr>
<tr>
<td>6.5</td>
<td>6.5</td>
<td>0.957</td>
<td>−0.157</td>
<td>−0.149</td>
</tr>
<tr>
<td>6.5</td>
<td>5.3</td>
<td>1.008</td>
<td>−0.126</td>
<td>−0.149</td>
</tr>
<tr>
<td>5.5</td>
<td>5.5</td>
<td>1.001</td>
<td>−0.131</td>
<td>−0.149</td>
</tr>
</tbody>
</table>

kJ/kg: Heat generation value for 1 kg sinter mixture
Then it was valid in this paper that heat generation was evaluated by coke combustion, moisture evaporation as shown in Fig. 11. Heat generation was higher at high moisture granulation due to heat generation of coke combustion more than offset heat consumption of moisture evaporation. Furthermore, dry treatment after high moisture granulation had superiority both the two factors.

Figure 12 shows relation between sum of heat quantity for coke combustion and for moisture evaporation and product yield. As shown in Fig. 6, FFS was 22–23 mm/min and 24–25 mm/min in the cases without dry treatment after granulation with 7.9 mass% and 6.5 mass% moisture content and with dry treatment after granulation with dry treatment after granulation with 7.9 mass%, respectively. In comparison between these two cases with and without drying, in spite of difference value for heat generation quantity of coke combustion plus moisture evaporation, product yield was almost equal. The almost equal product yield was caused as the results of which influence of heat generation increase offset influence of FFS increase. In other words, dry treatment after high moisture granulation has no effect on product yield because both heat generation in sintering bed and sintering speed increased.

Influence of dry treatment after high moisture granulation on product yield was summarized in Fig. 13, based on results shown in Fig. 9 to 12 and table 3. From Fig. 13, dry treatment after high moisture granulation has roles of increasing heat generation in sinter packed bed due to high coke combustion efficiency and low moisture evaporation. However, product yield did not increase because FFS also increased.

Figure 14 shows two-dimensional estimation of FFS and product yield. In Fig. 14, as sinter productivity corresponds product of FFS and product yield, lines in Fig. 14 are equal for product of FFS and product yield, which means sinter productivity. The three cases of high moisture (7.9 mass%) granulation was high productivity caused by high FFS, and especially, the case of dry treatment for decreasing moisture content to 6.2 mass% after high moisture (7.9 mass%) granulation indicated the highest productivity. As shown in Fig. 15, productivity is highest in case of dry treatment to 6.2 mass% after high moisture (7.9 mass%) granulation.
Fig. 15. Improvement of sinter productivity at high moisture granulation and dry treatment.

4. Discussion

4.1. Pseudo-particle Collapse with Dry Treatment from Viewpoint of Moisture Content on Pseud-particle

As shown in Fig. 3, increase of \(-0.25\) mm pseudo-particle generation with dry treatment is little in case of high moisture granulation. So, it means that collapse of pseudo-particle depends on moisture content after granulation.

Figure 16 shows image of pseudo-particle structure at granulation and at dry treatment. Granulation makes distance between particles shorter due to liquid bridge force. At same time, moisture moves to surface of pseudo-particle and moving moisture has no concern with liquid bridge force. At high moisture granulation, pseudo-particle has enough moisture at its surface not to be collapsed with dry treatment. On the other hand, low moisture granulation restricts liquid bridge force. Then moving moisture amount to surface is not enough to maintain pseudo-particle structure with dry treatment.

Then in purpose of measuring moisture amount at surface of pseudo-particle, pseudo-particles with 3–5 mm diameter was centrifugalized. And weight difference of pseudo-particle before and after centrifugalizing was defined as moisture content after granulation. At centrifugalizing, rotating diameter, speed, and time were 500 mm, 2300 rpm, and 40 minutes. And sample was set in eight sample holders with 5 g per one holder. Here, rotating time (40 minutes) was determined on pre-test. In the pre-test, relation between rotation time and weight difference was investigated and found out saturated value. The saturation of weight difference means there are certain moisture which is impossible to be removed from pseudo-particle. It is considered that the certain moisture exists in composing particles. Conversely, removing moisture with centrifugalizing is considered to exist at surface of pseudo-particle. Measurement procedure of centrifugalizing method was based on previous study.2)

Table 4 shows weight difference in case that moisture content after granulation were 7.9 mass%, 6.5 mass% and 5.5 mass%. Results for weight difference were 2.9 mass%, 1.2 mass% and 0.3 mass% respectively. Dry treatment to 5.3 mass% moisture content after low moisture granulation (6.5 mass%) means all moisture at surface of pseudo-particle was evaporated with dry treatment, because weight difference with centrifugalizing was 1.2 mass% and it was equal to that with dry treatment (6.5–5.3 mass%). Then it is considered that combination between composing particles in pseudo-particle were removed each other with dry treatment. Reversely, dry treatment to 6.2 mass% moisture content after high moisture granulation (7.9 mass%) means moisture at surface of pseudo-particle still remained with dry treatment, because weight difference with centrifugalizing was 2.9 mass% and it was larger than to that with dry treatment (7.9–6.2 mass%). Then it is considered that most of combination between composing particles in pseudo-particle were maintained with dry treatment.

4.2. Effect of Dry Treatment on Permeability in Sinter Packed Bed from Viewpoint of Moisture Condensation

As shown in Fig. 3, increase of \(-0.25\) mm ratio of pseudo-particle size with dry treatment after high moisture granulation is little. In other words, pseudo-particle size distribution is almost equal but moisture content is different. As shown in Fig. 8, decreasing moisture content and equal pseudo-size distribution is effective to decrease dry and combusting time in sintering bed. Here, the time is defined between starting rising temperature and top temperature measured by use of thermos-couple inserted in at center of sinter packed bed. So, moisture evaporating time is calculated and considered as below.

Figure 17 shows concept of moisture evaporation in sinter packed bed. Sinter packed bed consists of moisture condense zone, drying zone, combustion zone and cooling zone in viewpoint of moisture evaporation and coke combustion. Moisture varying rate in moisture condense zone, drying zone, combustion zone and cooling zone in viewpoint of moisture evaporation and coke combustion. Moisture varying rate in moisture condense zone depends on both input from drying zone and output to exhaust gas. The former is product of 3 factors (1), (2), (3)).
1) Dry front speed
2) Bulk density of sinter packed bed
3) Moisture content in sinter mixture at moisture condense zone

Here, dry front speed is corresponding to FFS. Calculating unit is a foursquare 1 cm on one side, being orthogonal to vertical direction of sinter packed bed. Initial value of moisture content at moisture condense zone is moisture content at charging.

The latter is product of factors (4) and 5))
4) Saturated vapor steam bulk density at gas temperature
5) Superficial velocity through sinter packed

Then moisture content variation, which corresponds moisture condensing phenomenon, is able to be calculated as difference from former and latter amount.

In addition, temperature in moisture condensed zone increases due to moisture condensation.

For calculating temperature, several assumptions are necessary as shown below.
1) FFS and surficial velocity are experimental values.
2) Initial value of both solid and gas temperature at moisture condense zone is 15 degree C. In addition, temperature was influenced by only heat generation from moisture condensation.
3) Solid and gas temperature at moisture condense zone is always equal.
4) In accordance with assumption 3), generating heat from moisture condensation per 1 min supply solid in sinter packed bed and gas flowing through the bed.
5) Temperature and moisture contents at moisture condense zone are always constant. In other words, temperature and moisture content gradient are 0 for vertical direction of the bed.

**Figure 18** shows moving moisture amount from dry zone to moisture condense zone and from moisture condense zone to exhaust gas, in case of high moisture (7.9 mass%) granulation with and without dry treatment. In these cases, moisture content at charging are 6.2 mass% and 7.9 mass% respectively.

After that, moisture amount from moisture condense zone to exhaust gas rapidly increases. That corresponds increase of saturated steam pressure due to increasing temperature in the zone caused by moisture condensation. During this rapid increase, moisture amount from dry zone to moisture condense zone increase a little. That means increasing evaporation from moisture condense zone due to increasing moisture content in the zone. Finally, moisture amount from dry zone to moisture condense zone become equal to that from moisture condense zone to exhaust gas. In this condition, moisture condensation does not occur, and the zone is equivalent state. As physical phenomenon, All evaporating moisture at dry zone goes through moisture condense zone and goes out in sinter exhaust gas. After reaching equivalent state, evaporating amount at dry zone is 0.42 g/min and 0.37 g/min for the two case, in which are those without and with dry treatment before charging sinter mixture after high moisture (7.9 mass%) granulation respectively.

**Figure 19** shows trend of moisture content in moisture condense zone in case of high moisture (7.9 mass%) granulation with and without dry treatment. In these cases, moisture content at moisture condense zone shown in Fig. 19 also decreases. Here the ratio is 0.80 (=7.9/9.8). Both ratio is less than 1, but most important result is that the latter is smaller than the former. Here the ratio is 0.91 (=0.80/0.88). That has a role of decreasing moisture evaporating time, which results in FFS increase. And decreasing moisture evaporating time is independent parameter to permeability in sinter packed bed. Then effect of decreasing moisture evaporating time on FFS is consist with FFS was high in case with dry treatment compared to case without dry treatment in spite of equal permeability shown in Fig. 6. In details, in case of high moisture (7.9 mass%) granulation, dry treatment was effective to increase
FS by 6% from 23.5 to 25.0 mm/min shown in Fig. 7, despite permeability at sintering was equal shown in Fig. 4. As mentioned before, ratio of evaporating decreasing ratio to moisture content in moisture condense zone decreasing ratio is 0.91. Inverse number of it is 1.10 and has physical meaning of FFS increasing ratio under equal permeability at sintering. This inverse number means FFS increasing by 10%, which almost match the experimental value (6%).

Based on result and discussion described upper, Effect of dry treatment after granulating sinter mixture on FFS is summarized in Fig. 20.

As shown in Fig. 3, dry treatment after granulation affects increase of −0.25 mm ratio of pseudo-particle. However, the influence is little in case of high moisture granulation. This restriction is due to high moisture amount at surface of pseudo-particle. Then moisture remains after dry treatment.

In addition, as shown in Figs. 4–6, in case of high moisture granulation dry treatment was effective to increase FFS and to maintain permeability at sintering. Despite of increasing −0.25 mm particle ratio, permeability at sintering is able to maintain. It is considered difference of moisture content at moisture condense zone is larger than that at charging as shown in Fig. 19. Moreover, it is also considered FFS increasing corresponds decreasing time from starting moisture evaporation to coke combustion due to decreasing moisture content at moisture condense zone.

**5. Conclusion**

For purpose of moisture content design in sinter mixture, in this paper, effect of moisture content after granulation and at charging into sinter machine on flame front speed (FFS) and product yield was examined. Results are summarized as below.

1. In high moisture granulation, dry treatment after granulation is effective for increasing FFS and maintaining product yield.

2. FFS increase described in (1) is caused by increasing permeability due to high moisture granulation and by drying speed of sinter packed bed at sintering due to low moisture content at charging.

3. FFS increase described in (1) does not affect decrease of product yield. Product yield maintains due to decrease of evaporating amount and increase of coke combustion efficiency with dry treatment.

4. Pseudo-particle collapse with dry treatment is restricted in case that moisture decrease amount with centrifuging is larger than moisture decrease amount with dry treatment. As high moisture granulation make moisture amount at surface of pseudo-particle large, pseudo-particle hardly collapses.

5. From calculation of moisture movement to lower part in sinter packed bed in case of high moisture (7.9 mass%) granulation, dry treatment to decreasing containing moisture content to 6.2 mass% has a role of decreasing moisture content in moisture condensation zone from 9.8 to 7.9 mass%. Then ratio is 0.80 (=7.9/9.8) and it is smaller than ratio of evaporation moisture speed (0.80=0.37/0.42).

That’s why dry treatment is effective to increase drying speed of sinter packed bed at sintering described in (2).

**REFERENCES**


