Influence of the Nuclei Particle Properties on Granulability of Marra Mamba Iron Ore by High Speed Agitating Mixer

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The newly developed brand Marra Mamba ore from Australia has a comparatively high water absorptivity, and since many fine ore is contained, if it is used as a raw material of sintered ore, it will cause the fall of permeability, and the productivity fall of a product sinter by the fall of the granulability. By blending nuclei particles with this Marra Mamba ore, the granulability and the permeability have improved sharply by processing them in a high-speed agitating mixer. This that point, about 25 mass% is suitable for nuclei particle mixture ratio to a high-speed agitated material.

Moreover, the granulability was improved by using the ore containing much 1–3 mm particles. As for this, it is considered that the granulation of a middle size ore domain is accelerated, because of the consistency of the particle size composition of the material processed and pot characteristic of high-speed agitating mixer.

KEY WORDS: sintered ore; Marra Mamba; granulability; permeability; productivity; high-speed agitating mixer; nuclei particle; specific surface area; size distribution.

1. Introduction

In iron ore sintering process, the granulability of the iron ore, which is the main raw material, influences a permeability in bed greatly and it is the important factor which influences the productivity of a product sinter. In recent years, it follows on advance of the degradation of the iron ore which is represented by development of the Marra Mamba ore in West-Australia, this importance is still getting larger.

Differs from the ordinary hematite ore, Marra Mamba ore has the following features, 1) contains about 5.0–6.0 mass% of combined water, 2) water absorptivity is comparatively high and 3) containing many fine ore. When this ore is used as a raw material of sinter, a strength and a yield of sinter are decreased because of the decomposition of the combined water which is similarly seen in the case of the Australian pisolite ore. And because of the decrease of the granulability by the increase in fine ore ratio, the permeability is decreased. As a result, the phenomenon in which the productivity falls is confirmed. Therefore, in order to use Marra Mamba ore so much as sinter, it is necessary to consider the increase method of a strength and a yield of sintered ore, and also increase the permeability and the granulability.

As a granulability improvement means at the time of using a fine ore as the raw material, many methods are examined and put in practical use conventionally. However, differ from conventional fine ore, since the water absorptivity is comparatively high as mentioned above, in order for a Marra Mamba ore to secure sufficient granulability, a lot of moisture addition is required. Although the drum mixer usually used at the sintering plant is suitable for mixture and carrying out granule in a lot of material, since a granule movement will become unstable if the moisture addition ratio increases, it is difficult to add the moisture of a quantity required for granule of a Marra Mamba ore.

In this report, the high-speed agitating mixer where larger quantity of moisture addition becomes possible to the iron ore, control of the granulability and the ore bed permeability fall in the use case was tried by using a Marra Mamba ore as sintered ore material. Moreover, the combination condition of the material processed by high-speed agitating mixer by which the granulability at the time of Marra Mamba ore combination serves as the maximum were also examined collectively.

2. Granulability and Permeability Improvement Effect by High-speed Agitating

2.1. Experimental Condition

2.1.1. Influence of the High Speed Agitating Process

Granulability change of the raw material at the time of carrying out pretreatment of the Marra Mamba ore using a high-speed agitating mixer and the permeability change of the raw material were considered.

The outline of the high-speed agitating mixer used for the experiment is shown in Fig. 1. The capacity of this mixer is $3.0 \times 10^{-3} - 5.0 \times 10^{-3}$ m$^3$/ch. A rotation number of agitator is 510–2,750 rpm, and that of pan is 47–94 rpm. And below, ore W was used as Marra Mamba ore. These chemical compositions of iron ores used for this examination are shown in Table 1.

In this report, the materials which carried out dryness processing were used. The granule procedure of these raw
After feeding the material which carry out high-speed agitating into the high-speed agitating mixer, and adding moisture of 9.0 mass% (Group A in Fig. 2). Also, by an agitator of 891 rpm and a pan of 47 rpm in 45 s the process is completed. Then, the material after high-speed agitating process and its other material (Group B in Fig. 2), and a moisture ratio of 7.0 mass% is fed to a drum mixer (335 mm (Group B in Fig. 2), and a moisture ratio of 7.0 mass% is after high-speed agitating process and its other material were fed to the drum mixer and granulated for 8 min by the addition of material after processing and its other material are shown in Fig. 2. The following procedures performed the examination. After feeding the material which carry out high-speed agitating into the high-speed agitating mixer, and adding moisture of 9.0 mass% (Group A in Fig. 2). Also, by an agitator of 891 rpm and a pan of 47 rpm in 45 s the process is completed. Then, the material after high-speed agitating process and its other material (Group B in Fig. 2), and a moisture ratio of 7.0 mass% is fed to a drum mixer (335 mmφ×270 mmL, rotation number: 36 rpm), granulated for 8 min, and inserted in a sinter pot (100 mmφ×330 mmH) and fired under a fixed suction pressure condition of 3.23 kPa.

In this exam, the mixture ratio of ore W was made in two levels of 0 mass% (standard) and 20 mass% (all are for the ratio in new material). Moreover, two cases at the time of doing combination of the case of ore W simple substance and 20 mass% (ratio in new material) of ore R which is a porous ore were used as nuclei particle with a high-speed agitated material.

In addition, since the phenomenon in which adhering fine was not fully removed was checked by evaluation by the granular index (GI)*1 used conventionally in the case of ore W. Moreover, when nuclei particle is added with high-speed agitated material, the productivity has been improved greatly to a level almost equivalent to the time when high-speed agitated ore W. Moreover, when nuclei particle was added with high-speed agitated material, the productivity has been improved very large by adding a nuclei particle with a high-speed agitated material.

Materials are shown in Fig. 2. The following procedures performed the examination. After feeding the material which carry out high-speed agitating into the high-speed agitating mixer, and adding moisture of 9.0 mass% (Group A in Fig. 2). Also, by an agitator of 891 rpm and a pan of 47 rpm in 45 s the process is completed. Then, the material after high-speed agitating process and its other material (Group B in Fig. 2), and a moisture ratio of 7.0 mass% is fed to a drum mixer (335 mmφ×270 mmL, rotation number: 36 rpm), granulated for 8 min, and inserted in a sinter pot (100 mmφ×330 mmH) and fired under a fixed suction pressure condition of 3.23 kPa.

Table 1. Chemical compositions of ores.

<table>
<thead>
<tr>
<th></th>
<th>TFe</th>
<th>FeO</th>
<th>CaO</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore W</td>
<td>62.08</td>
<td>0.33</td>
<td>0.03</td>
<td>3.62</td>
<td>1.84</td>
<td>5.12</td>
</tr>
<tr>
<td>Ore H</td>
<td>61.71</td>
<td>0.28</td>
<td>0.15</td>
<td>4.90</td>
<td>3.07</td>
<td>2.85</td>
</tr>
<tr>
<td>Ore C</td>
<td>67.54</td>
<td>0.12</td>
<td>0.05</td>
<td>0.51</td>
<td>0.98</td>
<td>1.53</td>
</tr>
<tr>
<td>Ore D</td>
<td>64.29</td>
<td>0.34</td>
<td>0.04</td>
<td>5.34</td>
<td>0.98</td>
<td>1.06</td>
</tr>
<tr>
<td>Ore R</td>
<td>57.34</td>
<td>0.11</td>
<td>0.17</td>
<td>5.61</td>
<td>2.73</td>
<td>9.42</td>
</tr>
<tr>
<td>Ore E</td>
<td>59.10</td>
<td>0.03</td>
<td>0.04</td>
<td>5.00</td>
<td>1.26</td>
<td>8.62</td>
</tr>
</tbody>
</table>

Table 2 shows the mixture ratio in high-speed agitated material was carried out. Then, ore H which is an Australian dense hematite ore and ore R which is a porous ore were used as nuclei particle without adjusting particle size distribution. The mixture ratio of ore W was 20 mass%. And in case of ore R was 5–13 mass% and in the case of ore H was 5–10 mass% (all are for the ratio in new material). These mixing conditions and these granulation conditions are shown in Tables 2 and 3. Also, the high-speed agitating process condition were, addition of moisture of 9.0 mass%, agitator of 891 rpm, pan of 47 rpm, and a 45 s processing time, the material after processing and its other material were fed to the drum mixer and granulated for 8 min by the addition of moisture ratio of 7.0 mass%. After granulation, inserted in a sinter pot and fired under a fixed suction pressure condition of 3.23 kPa.

2.1.2. Influence of the Nuclei Particle Mixture Ratio

It is considered that the nuclei particle mixture ratio is very important factor on high-speed agitating process. Then, an evaluation about the influence of the nuclei particle mixture ratio in high-speed agitated material was carried out. Then, ore H which is an Australian dense hematite ore and ore R which is a porous ore were used as nuclei particle without adjusting particle size distribution. The mixture ratio of ore W was 20 mass%. And in case of ore R was 5–13 mass% and in the case of ore H was 5–10 mass% (all are for the ratio in new material). These mixing conditions and these granulation conditions are shown in Tables 2 and 3. Also, the high-speed agitating process condition were, addition of moisture of 9.0 mass%, agitator of 891 rpm, pan of 47 rpm, and a 45 s processing time, the material after processing and its other material were fed to the drum mixer and granulated for 8 min by the addition of moisture ratio of 7.0 mass%. After granulation, inserted in a sinter pot and fired under a fixed suction pressure condition of 3.23 kPa.

2.2. Experiment Result

2.2.1. Influence of the High Speed Agitating Process

Figure 3 shows −0.5 mm adhering fine ratio change of the pseudo-particle in each mixing condition. When high-speed agitating process was carried out, also in the case where nuclei particle was added with high-speed agitated material, −0.5 mm adhering fine ratio showed the increasing tendency. Moreover, the adhering fine ratio showed the tendency which becomes very large by adding a nuclei particle with a high-speed agitated material.

In addition, since the phenomenon in which adhering fine was not fully removed was checked by evaluation by the granular index (GI)*1 used conventionally in the case of the pseudo-particle which carried out high-speed agitating. In this report ‘for convenience’, drying the pseudo-particles, after that removing the non-granular particles sieved by 0.5 mm, then washed on the sieve, the rate of the removed particles of 0.5 mm or less (= −0.5 mm adhering fine ratio) is considered as the index showing the granulability of a pseudo-particle.

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Figure 4 shows the change in the permeability (JPU)*2 before ignition and Fig. 5 shows the productivity change of the sinter.

From these figures, the permeability and the productivity shows the improvement of the tendency by high-speed agitated ore W. Moreover, when nuclei particle is added with high-speed agitated material, the productivity has been improved greatly to a level almost equivalent to the time when the mixture ratio of ore W being 0 mass%.

From these results above, the granulability of a pseudo-particle and the permeability of ore bed have been improved by high-speed agitated the Marra Mamba ore, as a result the productivity is improved, and that these improvement effects become large by adding nuclei particle with

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*1 Granular index (GI) = \(\left(\frac{W_{0.25}}{W_{0.25}} - \frac{W_{0.25}}{W_{0.25}}\right)\times100\) (%)

Where, \(W_{0.25} = 0.25\) mm fine ore ratio before granulation (mass%); \(W_{0.25} = 0.25\) mm fine ore ratio after granulation (mass%).

*2 Bed permeability index (JPU) = \(F/A \times (h/1.02\times10^{-3})s^{-1}\) (−)

Where, \(F\): Gas flow rate (Nm³/min); \(A\): Suction area 7.85 \(m²\); \(h\): Bed height 0.33 (m); \(s\): Suction pressure 3 230 (Pa).
high-speed agitated material.

2.2.2. Influence of the Nuclei Particle Mixture Ratio

The relation between the nuclei particle mixture ratio \(^3\) and \(-0.5\) mm adhering fine ratio change of adding dense ore and porous ore as nuclei particle is shown in Fig. 6.

Diffsers from anticipation, even if the nuclei particle mixture ratio increased, \(-0.5\) mm adhering fine ratio hardly changed. Also, in both cases, dense ore and porous ore, a significant difference was not recognized.

The relation between the nuclei particle mixture ratio and the permeability is shown in Fig. 7. Unlike the variation of \(-0.5\) mm adhering fine ratio, with the increase in nuclei particle mixture ratio in high-speed agitated material, the permeability went up and showed that the tendency be-

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\(^3\) Nuclei particle mixture ratio \(= W_{en} / (W_{en} + W_{mn})\)

Where, \(W_{en}\): Nuclei particle mixture ratio in high-speed agitated material (mass%); \(W_{mn}\): Ore W mixture ratio in high-speed agitated material (mass%).
comes almost fixed when the mixture ratio was over 0.25. Also, when dense ore was added as nuclei particle, the tendency for the permeability becomes higher than the case of porous ore was shown.

According to results above, although change was not recognized in the adhesion characteristic of fine powder, the permeability improves and by using dense ore as nuclei particle showed that the improvement effect becomes large by making nuclei particle mixture ratio in high-speed agitated material more than approximately 0.25.

### 3. The Influence of the Nuclei Particle Characteristics

**Effect by High-speed Agitating Process on the Granulability Improvement**

As mentioned above, as that granulability at the time of Marra Mamba ore mixture and the permeability are greatly improved by high-speed agitating processing material by carrying out fixed quantity mixture of nuclei particle, also in case of mixing nuclei particle, it turns out it is effective in case of the dense ore. It is considered that this phenomenon originates in the interaction of fine Marra Mamba ore and nuclei particle. Especially, ore surface structures which is thought that the adhesion characteristic of fine ore to nuclei particle is affected and the particle size distribution of nuclei particle in high-speed agitated material are carried out is a factor that has a strong influence on granulability. Then, the influence of the characteristics of nuclei particle on the granulability is examined.

### 3.1. Experimental Conditions

#### 3.1.1. Influence of a Specific Surface Area of Nuclei Particle

The ore added as nuclei particle was changed, and the influence of the specific surface area of nuclei particle was evaluated. These mixing conditions of raw materials and these granulation conditions are shown in Table 2 and Table 4. In this experiment, five kinds of ores with which specific surface areas differ were used as nuclei particle. The amount of mixture was 15 mass% of ore W to 5 mass% of nuclei particle (ratio in new material) supposing it was fixed. The particle size of nuclei particles at this time were 3–5 mm particle and non-adjusted. A specific surface area measured by the adsorbing method which 3–5 mm particle is the subject, and made into the representative value of each ore.

As for these granulation conditions in the high-speed agitating process and the drum mixer are the same conditions as in Chap. 2.

#### 3.1.2. Influence of the Particle Size Distribution of Nuclei Particle

The particle size distribution of nuclei particle is a very important factor when attaining rationalization of high-speed agitating processing conditions. So, for the purpose of the explication of the particle size distribution condition required of nuclei particle, for 15 mass% of ore W and 5 mass% of ore H (ratio in new material) which its particle size distribution is changed artificially and added, then the high-speed agitating process was performed. The mixing conditions of raw materials are shown in Table 2. And these particle size distribution conditions of nuclei particle are shown in Table 4. These granulation conditions in the high-speed agitating process and the drum mixer are the same conditions as in Chap. 2.

### 3.2. Experiment Result

#### 3.2.1. Influence of a Specific Surface Area of Nuclei Particle

The change of -0.5 mm adhering fine ratio when changing the specific surface area of nuclei particle is shown in Fig. 8. When the particle size of nuclei particle was 3–5 mm, with increase of the specific surface area of nuclei particle, adhering fine ratio increased linearly.
On the other hand, when the particle size of nuclei particle had not been adjusted, when the surface area of nuclei particle became entirely large, not much change of 0.5 mm adhering fine ratio was carried out, and has a maximum value near 5.0–6.0 m²/g.

### 3.2.2. Influence of the Particle Size Distribution of Nuclei Particle

The relation between 1–3 mm ratio in a nuclei particle and the adhering fine ratio is shown in Fig. 9. With the increase in 1–3 mm ratio, the adhering fine ratio increased and became the maximum at about 40 mass%. Even when 1–3 mm ratio increased more than that, the adhering fine ratio showed the tendency to fall a little or hardly changes. As for Fig. 10, it shows the relation between 3–5 mm ratio in a nuclei particle and the adhering fine ratio. With the increase in 3–5 mm ratio, the adhering fine ratio fell and became the minimum at about 40 mass%. When 3–5 mm ratio was increased furthermore, the adhering fine ratio showed that the tendency turned around and increased a little. Fig. 11 shows the relation between 5–10 mm ratio in a nuclei particle and the adhering fine ratio. This figure
shows clearly that the relation was not accepted between 5–10 mm ratio and adhering fine ratio.

4. Discussion

Although $0.5\,\text{mm}$ adhering fine ratio was increasing in connection with specific surface area of nuclei particle increasing when the particle size of the nuclei particle was fixed as Sec. 3.2 showed, in case the particle size of the nuclei particle has not been adjusted, a contradictory result was obtained when a relation between specific surface area and the adhering fine ratio could not be verified. This is considered as a suggestion that the influence of the particle size distribution of nuclei particle is larger than that of the surface structure of nuclei particle added with high-speed agitated material. It is also considered that the cause is that the tendency for the relations between the specific surface area of nuclei particle, the granulability, and the permeability, differ was shown in Figs. 6 and 8.

Next, when attention is focused on the influence of the particle size distribution of nuclei particle, as it is shown in Figs. 9–11 the adhering fine ratio of 1–3 mm and 3–5 mm nuclei particle, a mutual relation was confirmed in the granulability of the pseudo-particle. Figure 12 shows the change of the particle size distribution before and after the processing when high-speed agitated material is carried out. This figure shows that by high-speed agitating process, a particle between 1 and 3 mm increase tremendously, on the other hand a particle of more than 5 mm decrease tremendously. Since high-speed agitating mixer has stronger shearing power which is given to the materials processed, compared with drum mixer etc., it is thought that granule substance are hard to turn to large particles.\textsuperscript{13,14} It is led to believe that because of consistency between the particle size composition of the material processed and the equipment characteristic of such high-speed agitating mixers, the strong correlation between nuclei particles of 1–3 mm and the granulability of the pseudo-particles has been verified.

According to the results shown in Sec. 2.2, when the nuclei particle mixture ratio increased, it is thought that it is because the particle size distribution of the high speed agitated material, especially the change in the 1–3 mm particles and the $0.5\,\text{mm}$ adhering fine ratio, $0.5\,\text{mm}$ adhering fine ratio hardly changes even with the increase of the nuclei particle mixture ratio. On the other hand, although the adhering fine ratio is not changing, the reason of the improvement of the permeability is that by the effect of the adhering fine ratio of fine ore smaller than 0.5 mm or by the strong agitating of a high-speed agitating mixer, although it is possible that the pseudo-particle of the pellet made of only $0.5\,\text{mm}$ fine powder could increase, it is still no confirmed yet.

5. Conclusion

Using high-speed agitating mixer, The result of trying to control of the fall of granulability and the permeability when using Marra Mamba ore as sintered ore, The following facts became clear.

(1) By mixing the Marra mamba ore in nuclei particle and high-speed agitated it, the granulability of the pseudo-particle, the permeability and the productivity is improved tremendously.

(2) With the increase of the nuclei particle mixture ratio to Marra Mamba ore, the permeability improves and the nuclei particle mixture ratio in high speed agitated material becomes fixed from 0.25 and up.

(3) When the size distribution of nuclei particle is the same, the granulability of the pseudo-particle improves with the increase in the specific surface area of nuclei particle.

(4) The granulability of the pseudo-particle improves by mixing an ore with many 1–3 mm content rates as nuclei particle. As for this, the granulability of a middle size domain is accelerated, it is thought that it is for the consisten-
cy of the particle size distribution of the material processed and pot characteristic of high-speed agitating mixer.

(5) As the characteristic of the nuclei particle mixed in high speed agitated material, the particle size distribution causes more effect than the surface represented with specific surface area.

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