Production of Carbon Included Sinter and Evaluation of Its Reactivity in a Blast Furnace Environment

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Recently, the reduction in the amount of CO₂ emission has become an important issue. It is important to increase the reactivity of iron sources used in a blast furnace to decrease of CO₂ emission. Therefore, the carbon composite iron ore agglomerates are significant. The production experiments of a new agglomerate named CIS (Carbon Included Sinter), where green balls were granulated by a model pan pelletizer were carried out using pot tests. The reduction of produced CIS with CO–CO₂ gas mixture were examined, and were compared with that of ordinary sinter ore. Also, the softening and melting property tests of 50% CIS–50% sinter mixed layer were carried out and compared with the results using 100% sinter layer. The results are summarized as follows:

(1) A new agglomerate, which an anthracite particle was surrounded by a shell with the same components as ordinary sinter ore, was produced by sintering pot test.
(2) When CIS was reduced by CO–CO₂ gas mixture at 1 273 K, the degree of reduction achieved 80% in 120 min, even though ordinary sinter ore achieved less degree of reduction.
(3) 250 g CIS–250 g ordinary sinter ore packed bed achieved 1/3 maximum pressure drop of 500 g ordinary sinter ore packed bed in the softening-melting property test.

KEY WORDS: new agglomerate; pellet; sinter; carbon composite; CO₂; blast furnace; reduction; softening and melting property.

1. Introduction

Recently, the reduction in the amount of CO₂ emission has become an important issue. Increase of reactivity of burden is one of the important ways to reduce CO₂ emission from a blast furnace. Carbon composite iron ore agglomerates, in which the distance between iron ore and carbon is shortened so that the reduction of iron ore and the gasification of carbon occur rapidly at the same place because CO₂ produced from the reduction used for the gasification to generate CO simultaneously, have been studied and some of them are used in commercial plants. The main stream of the carbon composite iron ore agglomerate seems to be cold-bond pellets. Cement is used as a binder to increase the strength of the cold-bond pellets. However, the degradation seems easy to occur during the cold-bond pellets reduction because of its cement. Also, an increase of cold-bond pellets causes the increase of the slag in the blast furnace because pellets have cement as a binder. To solve these problems, the carbon composite iron ore hot briquettes has been studied. The powder of iron ore and that of coking coal are heated so that the coal shows plasticity, then they are mixed together and briquetted in a hot atmosphere. The carbon composite iron ore hot briquette shows high density and low porosity, so the strength is enough to be used in the blast furnace without any binder. However, coking coal is one of the main ingredients of coke, therefore an increase of carbon composite iron ore hot briquettes may causes a decrease of the blend ratio of coking coal for coke making. It means the strength of coke may decrease. In addition, the recent price of coking coal has increased drastically, so the cost of producing the carbon composite iron ore briquettes may become higher.

Therefore, the sinter ore included an anthracite particle, which is named CIS (Carbon Included Sinter), was studied. In this study, the production experiments of CIS, where green balls were agglomerated by a model pan pelletizer were carried out, using the pot tests. The reductions of produced CIS with CO–CO₂ gas mixture were examined. Also, The softening and melting property test of 50% CIS–50% sinter mixed layer was carried out and compared with the result using 100% sinter layer. In addition, the gasification test of CIS packed bed with CO₂ gas was compared with that of coal-sinter packed bed.

2. Experimental
2.1. Sintering Pot Test

Table 1 shows the chemical assay of raw materials. Also, Table 2 shows the blend of CIS green ball. Otomo examined the chemical composition of the sinter layer of the carbon composite iron ore pellet and resulted that it should be CaO/Fe₂O₃=0.1 and C/S=1.8. Therefore, the blend of the green ball imitated it. At this time, pellet feed ore M, 97.5 mass% of its grain size was –0.25 mm, was used for iron source of the sinter layer. The quick lime was used for...
the binder. Also the limestone, which was crushed to –1 mm, and the silica sand were added for basicity adjustment. These were mixed by a high-speed agitating type mixer. The model pan pelletizer, where the diameter was 580 mm and rim height was 98 mm, was used for granulation. The granulation procedures were as follows. At first, 0.1 dry-kg of 3–8 mm anthracite particles were put into the rolling pan then water was added in by using a washing bottle until the surfaces of the coal got wet. In addition, the coal slipped in the pan at that time. Next, a small amount of the raw material mixed by a high-speed agitating type mixer was added by a hand scoop. When the raw material began to stick around the coal particles, they began to roll without slipping, and all of the raw material stuck around the coal particles. The granulation was continued until 1.9 dry-kg of raw material was added while alternately repeating the raw material supplement and the moisture addition. In addition, none of the granulated green balls was discharged during granulation. At the end of the raw material addition, 0.06 dry-kg of –1 mm anthracite powder were added into the rolling pan to coat the green balls. The purpose of this anthracite powder was that when the anthracite powder burned, surface of green balls sintered faster and became hard so that the air or CO₂ diffusion into them would be blocked. The granulation time for coating was about 30 s. After that, all of the green pellets were collected. It took about 30 min for this granulation sequence. It was repeated 10 times for one sintering pot test.

Table 3 shows the blend of the sintering pot test. The ratio of each raw material was modeled on that of commercial sinter mixture used in Kashima Steel Works. The raw materials, except the green balls, was mixed 2 min then granulated 4 min after moisture addition with a drum type mixer. Figure 1 shows the schematic view of the sintering pot test. As shown in Fig. 1, CIS producing pot tests were carried out using two layer sintering method. The heat transfers from the top of the sinter mixture layer to the hearth layer. As a result, the heat would accumulate enough for sintering CIS green balls well. 20 dry-kg of green balls were charged onto the hearth layer then the sinter mixture was charged by hand and made a 480 mm depth layer by cutting the top off it. In addition, the final weight of the sinter mixture in the pot was about 36 dry-kg. The test using only the sinter mixture was for comparison. At sintering, the top of the sinter mixture was ignited 1 min under a suction pressure of 4.9 kPa by a LPG burner. After that sintering took place under a suction pressure of 9.8 kPa. The temperatures of the central part of the packed bed at the 113 mm and 238 mm from the hearth layer, inside of the CIS balls layer and above of it, and that of exhaust gas were measured during sintering. When the exhaust gas temperature rose to a maximum and 3 min passed, the suction was stopped in order to stop the sintering immediately. Then, the sintering pot with the sinter cake was lifted 2 m and turned upside down so that the cake could be dropped to the ground and crushed. After cooling at air temperature, spherical samples of CIS, those with no cracks and separated from other bunched ones, were collected because the influence of the sample shape on reactivity would be omitted. Those pot tests for making CIS took place 6 times to produce sufficient amounts.

### Table 1. Chemical assay of raw ingredients (mass%).

<table>
<thead>
<tr>
<th>Brand</th>
<th>Fe</th>
<th>SiO₂</th>
<th>CaO</th>
<th>Al₂O₃</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellet feed ore M</td>
<td>68</td>
<td>1.0</td>
<td>0.1</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Sinter feed ore R</td>
<td>57</td>
<td>5.5</td>
<td>0.0</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Sinter feed ore Y</td>
<td>59</td>
<td>5.2</td>
<td>0.0</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Sinter feed ore P</td>
<td>54</td>
<td>3.1</td>
<td>0.0</td>
<td>1.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Sinter feed ore C</td>
<td>67</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Serpentine</td>
<td>5.8</td>
<td>39.2</td>
<td>1.8</td>
<td>1.3</td>
<td>37.2</td>
</tr>
<tr>
<td>Dolomite</td>
<td>1.0</td>
<td>0.4</td>
<td>35.6</td>
<td>0.1</td>
<td>17.6</td>
</tr>
<tr>
<td>BF dust</td>
<td>41</td>
<td>4.7</td>
<td>3.3</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Silica sand</td>
<td></td>
<td>97.4</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td>—</td>
<td>0.19</td>
<td>55.20</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Quick lime</td>
<td>0.24</td>
<td>97.34</td>
<td>0.22</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>Return fine</td>
<td>59</td>
<td>4.4</td>
<td>8.5</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td>F.C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V.M.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthracite</td>
<td>81.9</td>
<td>7.1</td>
<td>11.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. The blending condition of CIS green pellets.

<table>
<thead>
<tr>
<th>Pellet feed ore M</th>
<th>Silica sand (-1mm)</th>
<th>Limestone</th>
<th>Quick lime (1-3mm)</th>
<th>Anthracite particle (3-8mm)</th>
<th>C concentration in a green ball (1-1mm)</th>
<th>Powder coal (out number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>78.9</td>
<td>3.3</td>
<td>9.9</td>
<td>2.4</td>
<td>5.6</td>
<td>4.6</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 3. Blending conditions for the sintering pot test.
were reduced at the same condition. The chemical composition of sinter ore A was shown in Table 4. In addition, CIS, which was the same diameter as sinter A, was lighter than sinter A because CIS contained a coal particle.

2.3. Gasification Test
The schematic view of experimental apparatus is shown in Fig. 3. In order to define the amount of gasification, a packed bed of 500 g CIS, which were 10–15 mm in diameter, was set in the stainless tube which an inner diameter of 68 mm. The tube was put into an electronic furnace kept at 1 273 K, and 5 NL/min CO2–15 NL/min N2 gas mixture was introduced into it simultaneously. The temperature of the packed bed and the CO and CO2 concentration of the exhaust gas were measured. In addition, a packed bed of 502 g of 10–15 mm sinter ore B and 19.5 g of 3–8 mm anthracite particles mixture were gasified at the same condition. The weight of the sinter ore B in the packed bed was decided to be the same mass of the reducible oxygen, defined by their chemical assay, as in the packed bed of CIS. Also, the weight of anthracite particles were decided that the weight of carbon in them were the same as that in the packed bed of CIS.

2.4. Softening and Melting Property Test
The experimental conditions for investigating sinter properties by softening-melting down apparatus and the schematic view of the packed bed was shown in Fig. 4.

3. Experimental Results
3.1. Results of Sintering Pot Tests
Figure 5 shows the cross sectional view of CIS green ball and size distribution after drying at 3 78 K for more than 2 h of green balls. The green balls, where the diameters were over 8 mm, were about 50 mass%. There were coal particles inside the green balls, where the diameters were over 4 mm, which were chosen randomly. Therefore, all of the green balls larger than 4 mm in diameter were defined to have coal particles inside them. However, there were some –4 mm grains. Especially –0.25 mm grains were about 22 mass%. When the green balls were granulated,
3–5 mm coals were used. Also, the green balls, where the diameter were under 4 mm, were not observed at that time. Hence, –4 mm grains were likely fragments from the broken green balls during screening. In fact, most of –0.25 mm grains were coal powder that coated the green balls.

Figure 6 shows the comparison of the permeability before ignition between the sintering pot test of CIS production with that of ordinary sinter making. The permeability of the CIS containing layer was higher than that of ordinary sinter mixture layer. It is believed that CIS green ball layer on the hearth layer was packed loser, so that the permeability of the whole layer increased. The trends of temperatures in the packed bed and exhaust gas during the sintering pot test of CIS production and that of ordinary sinter making are shown in Fig. 7. The temperatures of CIS production rose and descended slower than those of ordinary sinter making. Also, the highest temperatures at 113 mm from the hearth layer became lower when CIS were produced though CIS were coated by powder coals in order to raise the temperature around them. On the other hand, exhaust gas flow rate of CIS production was lower than that of ordinary sinter making since the suction pressure was the same as 9.8 kPa. The transition of gas components of CIS production was similar to that of ordinary sinter making from after ignition to 10 min. After that CO concentration of CIS production became lower than that of ordinary sinter making. Also, CO concentration of CIS production dropped once, then rose again at 18 min though that of ordinary sinter making was kept almost constant.

After sintering, spherical samples of CIS, those had no cracks and separated from other bunched ones, were collected. 120 dry-kg of green pellets were used for pot tests. Most of them melted or sintered each other so they could not be separated. About 4.2 dry-kg of spherical and separated CIS were collected. The chemical assay of CIS is shown in Table 5. The carbon content was changed for each diameter. The thicknesses of sinter shell were over 5 mm in CIS where the diameters were over 15 mm. Therefore, the carbon content of their green balls would be lower than those green balls of CIS where the diameters were 10–15 mm. On the other hand, the thicknesses of sinter shell were under 5 mm in CIS where the diameters were under 10 mm. Hence, the coal particles might be consumed easier than others.

3.2. Results of Reduction Tests

Figure 8 shows the comparison of reduction curves between CIS and sinter ore A. Since CIS was lighter than sinter A, the reduction speed of CIS was faster than that of sinter A. However, CIS reached 80% reduction degree within about 130 min. This length was almost half that of sinter A reached 80% reduction degree. This means that the reduction speed of CIS still seemed faster than that of sinter A.

The cross sectional views of CIS before and after reduction are shown in Fig. 9. The coal particles remained in all samples. Also, there was a gap between the sinter shell and coal particle in every sample as Otomo reported.39 The shrinkage of the raw material layer during sintering might have caused the forming of the gap. As the reduction progressed, production of metal from the outside to the inside of CIS was observed. The reduction interfaces were not clear at every period. According to the cross sections, it was believed that coal inside CIS was not consumed by gasifica-

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Table 5. Chemical assay and collected weights of CIS produced by sintering pot tests.

<table>
<thead>
<tr>
<th>Dia.</th>
<th>TFe</th>
<th>MLFe</th>
<th>FeO</th>
<th>T.C</th>
<th>SiO₂</th>
<th>CaO</th>
<th>Al₂O₃</th>
<th>MgO</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>58.3</td>
<td>0.3</td>
<td>10.7</td>
<td>2.0</td>
<td>5.35</td>
<td>8.57</td>
<td>1.12</td>
<td>0.16</td>
<td>0.33</td>
</tr>
<tr>
<td>15-10</td>
<td>58.1</td>
<td>0.1</td>
<td>6.3</td>
<td>3.1</td>
<td>4.97</td>
<td>7.84</td>
<td>1.20</td>
<td>0.15</td>
<td>2.78</td>
</tr>
<tr>
<td>&lt;10</td>
<td>59.4</td>
<td>0.1</td>
<td>4.4</td>
<td>1.7</td>
<td>4.52</td>
<td>7.74</td>
<td>1.12</td>
<td>0.13</td>
<td>1.05</td>
</tr>
</tbody>
</table>
tion or direct reduction because the metal could not be observed on the inner part of sinter shell near the coal particle.

### 3.3. Results of Gasification Tests

CO/(CO+CO₂) calculated from observed exhaust gas concentration were plotted on the Fe–C–O equilibrium diagram shown in Fig. 10. When 5 NL/min CO₂–15 NL/min N₂ gas mixture was introduced to the packed bed of 502 g sinter ore B–19.5 g anthracites, CO gas began to be observed in the exhaust gas when the temperature rose over 573 K. On the other hand, CO gas was not observed when CO₂–N₂ gas mixture was introduced to the packed bed of 500 g CSI. The packed bed was kept for 30 min in CO₂–N₂ gas mixture flow at 1363 K, but CO gas was still not observed. Therefore, 13 NL/min CO–4.1 NL/min CO₂–10.9 NL/min N₂ gas mixture, CO/(CO+CO₂)=0.76, was introduced instead of 5 NL/min CO₂–15 NL/min N₂ gas mixture. This flow rate was decided that CO/(CO+CO₂) were the same as that of the reduction tests mentioned previous section and CO₂ flow rate was nearly equal to 5 NL/min. As shown in Fig. 10, exhaust gas CO/(CO+CO₂) became 0.73, the same as the equilibrium gas concentration of Wüstite–Fe. 1 hour later, the packed bed was cooled to room temperature in N₂ atmosphere. The weights and chemical assay of CIS, before and after the experiment, are listed in Table 6. The weight loss of CIS was caused by reduction and gasification. Therefore, the weight loss by the removal oxygen from the iron oxide was calculated using the chemical assay, then it is defined that the difference between the weight loss of CIS and that by the removal oxygen was caused by the gasification. The calculated transition of the weights of the oxides and metals in CIS, before and after the experiments, is shown in Fig. 11. It was calculated that 45.5 g was lost by reduction and 1 g by gasification.

### 3.4. Results of Softening–Melting Property Tests

Figure 12 shows temperature, shrinkage ratio and pressure drop of packed bed of 250 g of CIS and 250 g of sinter B. Those of 500 g of sinter B packed bed are also shown in Fig. 12. The pressure drop of CIS–sinter B packed bed was slightly higher that of sinter B packed bed under 1650 K. However, the increase of pressure drop of CIS–sinter B packed bed was slower than that of sinter B packed bed. The maximum pressure drop of CIS–sinter B packed bed achieved 1/3 of sinter B packed bed. The shrinkage of CIS–sinter B packed bed was larger than that of sinter B packed bed under 1800 K. The transitions of CO and CO₂ during tests are shown in Fig. 13. CO concentration of ex-

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#### Table 6. Chemical assay and weights of CIS–sinter ore B packed bed before and after gasification test.

<table>
<thead>
<tr>
<th></th>
<th>T.Fe (mass%)</th>
<th>M.Fe (mass%)</th>
<th>FeO (mass%)</th>
<th>SiO₂ (mass%)</th>
<th>CaO (mass%)</th>
<th>Al₂O₃ (mass%)</th>
<th>MgO (mass%)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before gasification</td>
<td>58.1</td>
<td>0.1</td>
<td>63</td>
<td>4.97</td>
<td>7.84</td>
<td>1.20</td>
<td>0.15</td>
<td>500.0</td>
</tr>
<tr>
<td>After gasification</td>
<td>65.9</td>
<td>6.2</td>
<td>75.7</td>
<td>5.45</td>
<td>9.02</td>
<td>1.05</td>
<td>0.10</td>
<td>453.5</td>
</tr>
</tbody>
</table>

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Fig. 9. The cross sectional views of CIS before and after reduction.

Fig. 10. Relationship between temperatures of the packed bed of 500 g CIS and that of 502 g sinter ore B–19.5 g anthracites with their exhaust gas concentrations.

Fig. 11. Transition of the weights of the oxides and metal in CIS before and after experiments.

Fig. 12. Comparison of temperatures, shrinkage ratios and pressure drops of 250 g CIS–250 g sinter B packed bed with 500 g sinter B packed bed.
haust gas of CIS–sinter B packed bed was 0.5 vol% higher than that of sinter B packed bed under 1473 K, when 3.3 vol% CO$_2$ was introduced. Then the temperature was over 1473 K and the introduced CO$_2$ was stopped, the difference of CO$_2$ concentration between CIS–sinter B packed bed and sinter B packed bed became gradually smaller. On the other hand, CO$_2$ concentration of exhaust gas of CIS–sinter B packed bed was slightly higher than that of sinter B before the temperature reached 1373 K. Then they almost became the same. When the temperature rose over 1473 K and the introduced CO$_2$ was stopped, the decrease of CO$_2$ concentration of exhaust gas of CIS–sinter B packed bed was slightly faster than that of sinter B packed bed.

4. Discussions

4.1. Production of CIS

Since the CIS green balls were coated by coal powder to raise the temperature of CIS green balls layer, the temperature at 113 mm from the hearth layer became lower than that of ordinary sinter making. Also, the transitions of temperatures at 113 mm from the hearth layer and that of exhaust gas became slower than those of ordinary sinter making. It is believed that the combustion of coal was controlled by the diffusion of oxygen in CIS green balls layer. The gas flow rate of CIS production test was slower than that of ordinary sinter making, so the diffusion of oxygen in CIS was slower, too. This situation might make combustion speed to decrease and the sintering time to be extended. This means that large particles, which are CIS green balls, would disappear, and the softened wüstite or metal might stick to the coal so that the direct reduction and/or carburizing might affect the easiness to melt CIS–sinter B packed bed. When CIS began to soften, the gap between the sinter shell and coal particle would disappear, and the softened wüstite or metal might stick to the coal so that the direct reduction and/or carburizing would occur rapidly. Also, carbon of CIS might affect the melt of sinter ore around CIS. Therefore, CIS–sinter B packed bed shrunk earlier and the pressure drop became smaller. This means that CIS could increase the permeability of the blast furnace such as unfired carbon composite agglomerates or coke mixed charging operation.

In order to increase the reactivity of iron source used in a blast furnace, production experiments of CIS (Carbon Included Sinter), where green balls were agglomerated by a model pan pelletizer, were carried out, using pot tests. The reduction of produced CIS with CO–CO$_2$ gas mixture and

4.2. Usage of coating coal in Blast Furnace

Unfired carbon composite iron ore agglomerates such as cold-bond pellets or CCB achieve the increase of reduction rate because of its composed carbon. Also, coke mixed charging operation to the blast furnace makes the reduction agent rate lower. As shown in Fig. 10, CO gas was observed when sinter ore B–anthracites packed bed was heated over 573 K in CO$_2$–N$_2$ atmosphere. It is believed that reduction and gasification are activated because iron oxide and carbon are placed closely.

On the other hand, the reduction speed of CIS was faster than sinter ore A, however it was observed that a coal particle in CIS remained during and after reduction. Also, consumption of coal calculated from the chemical assay and weight of CIS, before and after reaction, was only 1 g since the weight loss of oxide was 45.5 g. Therefore, the anthracite particle in CIS would almost be kept during reduction. The sinter shell had a porous structure, but the inside of it seemed to have a solid structure shown in Fig. 9. Therefore, it is believed that CO$_2$ could not diffuse into the coal. This property may originate the blend of CIS green ball that purpose is prevention of the anthracite consumption during sintering. It is concluded that the faster reduction speed of CIS was affected by this porous structure.

Incidently, the CIS–sinter B packed bed shrunk earlier than sinter B packed bed shown in Fig. 12. Also, the pressure drop of CIS–sinter ore B was much smaller than that of sinter B packed bed. This means that CIS–sinter B packed bed melted easier than sinter B packed bed. Nakano reported the similar phenomena that 50% sinter ore–50% non-spherical carbon composite agglomerate packed bed archived the remarkable decrease of pressure drop during softening melting property test. The consumption of coal by direct reduction and/or carburizing might affect the easiness to melt CIS–sinter B packed bed. When CIS began to soften, the gap between the sinter shell and coal particle would disappear, and the softened wüstite or metal might stick to the coal so that the direct reduction and/or carburizing would occur rapidly. Also, carbon of CIS might affect the melt of sinter ore around CIS. Therefore, CIS–sinter B packed bed shrunk earlier and the pressure drop became smaller. This means that CIS could increase the permeability of the blast furnace such as unfired carbon composite agglomerates or coke mixed charging operation.

5. Conclusions

In order to increase the reactivity of iron source used in a blast furnace, production experiments of CIS (Carbon Included Sinter), where green balls were agglomerated by a model pan pelletizer, were carried out, using pot tests. The reduction of produced CIS with CO–CO$_2$ gas mixture and
gasification test with CO$_2$–N$_2$ gas mixture were examined. Also the softening and melting property tests of 50% CIS–50% sinter mixed layer were carried out and compared with the results of using 100% sinter layer. The results are summarized as follows:

1) A new agglomerate, which an anthracite particle was surrounded by a shell with the same components as ordinary sinter ore, was produced by sintering pot test.

2) When CIS was reduced by CO–CO$_2$ gas mixture at 1273 K, the degree of reduction achieved 80% in 120 min, even though ordinary sinter ore achieved less degree of reduction. The porous structure of sinter layer of CIS might cause the faster reduction rate.

3) 250 g CIS–250 g ordinary sinter ore packed bed achieved 1/3 maximum pressure drop of 500 g ordinary sinter ore packed bed in the softening-melting property test. The anthracite included CIS might affect not only CIS melting but also sinter ore melting.

REFERENCES

3) T. Otomo: Private Communication.