Development of new burden for blast furnace operation with low carbon consumption

Kenichi Higuchi
Nippon Steel & Sumitomo Metal

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Outline

RCA, Reactive Coke Agglomerate

1. Purpose and background
2. Laboratory tests
   1) Influence of carbon content of burden
   2) Estimation of reaction beginning temperature
3. Plant trial of RCA
4. Commercialization of RCA
5. Conclusion
Two possible approaches to reduce carbon consumption of blast furnace.

- A to B; Increasing shaft efficiency. → Limitation
- B to C; Lowering the temperature of thermal reserve zone (Fe/FeO equilibrium).

Temperature of thermal reserve zone is controlled namely by gasification rate of carbon.

New agglomerates both with high reducibility and with high gasification of carbon have been designed.

Fig. Explanation of approach for decreasing carbon consumption of blast furnace by using RIST diagram*.

Principle of designing new burden

Development of new burden for blast furnace operation with low carbon consumption

- Close arrangement of coke and iron oxide results in high reactivity
- Decrease of temperature of thermal reserve zone
- Low carbon consumption of blast furnace

Conventional layer structure → Half thickness → Homogeneously mixed → Small coke mixed → New burden

- Decrease of distance between coke and ores
- Increase of contacting surface area

RCA
Reactive Coke Agglomerate

C + CO₂ = 2CO
FeO + CO = Fe + CO₂

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2. Laboratory tests

Influence of carbon content of burden

✓ Cement-bonded, carbon composite agglomerate (CCA), containing different carbon content (T.C =0 ~ 23%) were manufactured.

✓ Manufacturing condition of CCA’s is, Cement 10%, curing time 2 days in 50°C, 12 days in room temperature.

Fig. Test procedure of reduction test under load.
Result of laboratory test

CCA had higher reduction degree than fired pellet.
High carbon content of CCA resulted in higher reduction degree. 90% of reduction degree was attained by CCA with carbon content above 10%.
Further high carbon content of CCA resulted in higher reduction degree of mixed sinter due to higher reduction gas potential formed by carbon in CCA.

Fig. Influence of carbon content of CCA on reduction degree of materials at 1100°C.

Carbon composite agglomerate containing high carbon content, C=20% → RCA, Reactive Coke Agglomerate
Microstructure of CCA’s after reaction

Fig. Microstructures of CCA’s after reaction up to 1100°C. White: Metal (M), pale gray: Wustite (W), dark gray: residual carbonaceous materials (C), black: void

- Many small white particles, representing metal, were observed in CCA with high carbon content (see CCA 2, 3, 4).
- CCA 4 contained residual carbonaceous materials. Less metal formation would lead to loss of strength after reaction.
Plant trials of manufacturing and using in blast furnace were performed at Oita works in 2007.

RCA was manufactured in dust treatment factory equipped by pan-pelletizer and cured for 2 weeks in yard-piling.

Quality and quantity of RCA were enough as blast furnace burden.

Table. Result of RCA production.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Total production</td>
<td></td>
<td>21000</td>
</tr>
<tr>
<td>Crushing strength (average)</td>
<td></td>
<td>114.8</td>
</tr>
<tr>
<td>Crushing strength (minimum)</td>
<td></td>
<td>100.2</td>
</tr>
<tr>
<td>Total carbon</td>
<td>%</td>
<td>21.3</td>
</tr>
<tr>
<td>Total Fe</td>
<td>%</td>
<td>36.6</td>
</tr>
<tr>
<td>Mean size</td>
<td>mm</td>
<td>13.6</td>
</tr>
</tbody>
</table>
Table. Comparison of basic properties of plant manufactured RCA with those of other conventional burden materials.

<table>
<thead>
<tr>
<th></th>
<th>RCA</th>
<th>Fired Pellet A</th>
<th>Fired Pellet B</th>
<th>Lump ore A</th>
<th>Lump ore B</th>
<th>Sinter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS (mm)</td>
<td>13.6</td>
<td>14.3</td>
<td>14.0</td>
<td>23.2</td>
<td>23.3</td>
<td>21.1</td>
</tr>
<tr>
<td>TI (+10mm%)</td>
<td>97.4 (99.4)</td>
<td>94.1</td>
<td>95.6</td>
<td>87.4</td>
<td>82.5</td>
<td>70.2</td>
</tr>
<tr>
<td>AI (-0.5mm%)</td>
<td>2.0 (0.1)</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>JIS-RI (%)</td>
<td>97.6</td>
<td>73.3</td>
<td>71.2</td>
<td>43.9</td>
<td>70.3</td>
<td>63.0</td>
</tr>
<tr>
<td>RDI (%)</td>
<td>2.7</td>
<td>6.7</td>
<td>6.6</td>
<td>8.6</td>
<td>41.2</td>
<td>35.7</td>
</tr>
</tbody>
</table>

Basic properties of RCA were enough as blast furnace burden and comparable with those of other conventional burden materials.

*(evaluated in wet state)*
Using ratio of RCA was increased in stepwise up to 54 kg/tHM.

As RCA using ratio was increased, gas utilization was improved. Solution loss carbon was decreased accordingly.

Raw value of reducing agent rate (CR+PCR) was deceased by 25 kg/tHM.
Result of plant trial; Oita No.2 BF

Temperature of thermal reserve zone was lowered.

Fig. Changes in temperature profile with using RCA measured by vertical probe during test.
Changes in input carbon of blast furnace

Fig. Relationship between consumption of RCA and corrected input carbon* .

* calculated by heat and mass balance based on the Rist model.

✓ Input carbon was decreased with using RCA in a linear fashion.
✓ It was estimated that corrected input carbon was decreased by 0.36 kgC / tHM if we input 1 kgC / tHM from RCA.

<table>
<thead>
<tr>
<th>Decrease of temperature of thermal reserve zone (℃)</th>
<th>83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease of input carbon (kgC/tHM)</td>
<td>4.0</td>
</tr>
<tr>
<td>( kgC/tHM／▲10℃TRZ)</td>
<td>0.5</td>
</tr>
<tr>
<td>(kgC/tHM／ + 1 kgC /tHM)</td>
<td>0.36</td>
</tr>
</tbody>
</table>
5. Conclusion

1) RCA, Reactive Coke Agglomerate, containing 20% carbon has been developed as a new burden for blast furnace. Beside its high reactivity, RCA promotes reduction of mixed sinter.

2) Reaction beginning temperature of carbon in RCA was lower than that of conventional coke and along the theoretical lower limit. Thus, RCA is effective burden to lower the temperature of thermal reserve zone.

3) Facility of manufacturing RCA has been installed at Oita works in 2011. Since then, smooth production of RCA has been established. RCA has contributed low RAR, low input carbon, operation of blast furnace at Oita works.