A technique for prediction of coke CSR and influence of gasification on physical strength of stamp charge coke

Presented by:
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Outline of the Presentation . . .

1. Introduction and Objective
2. Importance of Coke CSR
3. Determination of coke CSR
4. Effect of Coke CSR on Physical Strength of Coke
5. Prediction of coke CSR based on Physical Property
6. Results and Discussion
7. Conclusion
Coke in Blast Furnace

• A Thermal Role - coke furnishes the bulk of the energy and process heat required for the process.

• A Chemical Role - coke provided the necessary reduction potential in the form of carbon monoxide for the reduction process and the required carbon for carburizing the liquid hot metal.

• Physical and Mechanical Role - coke firstly carries the weight of the overlying burden, and secondly forms a highly permeable 'trickling column', ensuring ideal drainage of the molten material slag and iron while providing gas distribution in the BF.

What is CSR?

• Nippon Steel Corp developed a methodology for determination of coke hot strength in 1970's which is widely accepted.

• The methodology studies, the effects of one of the key coke reactions in the blast furnace on the strength of the coke.

• Standards for determination of CRI/CSR are:

  - ASTM D 5341
  - BIS : 4023
  - ISO : 18894
### Comparative test condition for CSR test

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>BIS- 4023:1991</th>
<th>ASTM: D5341/D5341M-17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Coke</td>
<td>(-21+19) mm</td>
<td>(-22.4+19) mm</td>
</tr>
<tr>
<td>Sample Mass</td>
<td>200 gm</td>
<td>200 gm</td>
</tr>
<tr>
<td>Test Temperature</td>
<td>1100°C ± 5°C</td>
<td>1100°C ± 5°C</td>
</tr>
<tr>
<td>Rate of Flow of CO₂</td>
<td>5 LPM</td>
<td>5 LPM</td>
</tr>
<tr>
<td>Reaction time with CO₂</td>
<td>120 Minutes</td>
<td>120 Minutes</td>
</tr>
<tr>
<td>Revolution of I drum</td>
<td>600 (30 minutes @20 RPM)</td>
<td>600 (30 minutes @20 RPM)</td>
</tr>
<tr>
<td>Screening after rotation</td>
<td>10 mm Round Hole</td>
<td>9.5 mm Square Hole</td>
</tr>
</tbody>
</table>

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Coke Strength after reaction

In a conventional method for measuring CSR and CRI, 200 gm sample of coke prepared as per the standard size range is reacted in a reaction vessel at a temperature of 1100°C in atmosphere of CO₂ at a flow of 5 LPM for 120 minutes.

The reaction that occurs during this phenomenon is

\[ \text{C} + \text{CO}_2 \rightarrow 2\text{CO} \]

The % weight loss is the measure of coke reactivity index (CRI). The reacted coke sample is then tumbled in an I-drum for 600 revolutions at 20 RPM and screened on 10 mm round screen.

Coke Sample before CSR Test (-21+19) mm
Coke Sample after reaction/gasification

49TH OPERATING COMMITTEE MEETING
COAL, COKE AND COAL CHEMICALS
Reacted Coke Sample after tumbling in l- drum (+10 mm)

Before

After

Sample size: (20 ± 1) mm
Sample size: 10 mm

A CSR value of 65 means 65 % mass is above 10 mm size after reaction
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Porosity Apparatus

\[ P = \frac{B - A}{B - C} \times 100 \]

Where,
- \( A \) is oven-dry weight;
- \( B \) is saturated surface weight;
- \( C \) is saturated submerged weight.

49TH OPERATING COMMITTEE MEETING
COAL, COKE AND COAL CHEMICALS
### Difference in Coke Porosity after CSR Test

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.4%</td>
<td>50.6%</td>
<td></td>
</tr>
</tbody>
</table>

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Why need an alternative method

1. Sample Preparation Time: 3 Hours
2. Furnace Heating- 1Hr
   Reaction time 2 Hr
   Cooling time 1 hr
3. CSR - 0.75 Hours

Total Time: 7-8 Hours

*Repeatability Limit (r) and Reproducibility Limit (R)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Repeatability Limit (r)</th>
<th>Reproducibility Limit (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRI</td>
<td>18-31</td>
<td>2.4</td>
<td>-3.69 + 0.41x^a</td>
</tr>
<tr>
<td>CSR</td>
<td>55-72</td>
<td>3.3</td>
<td>8.6</td>
</tr>
</tbody>
</table>

*where x is the average of two single between-laboratory test results.

*Data Source ASTM D5341/D5341M – 17
Coke cold compressive strength measurement

- Sample Size: ( - 21 + 19)mm.
- Quantity: 200 g (30-35 pieces)
- Drying: 1 Hr in Air oven.
- Reporting: Avg of 3 test
- Duration: 1 Hours

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Different properties of coke based on coke class

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>CL-1</td>
<td>68-70</td>
<td>68.4</td>
<td>24.2</td>
<td>252</td>
</tr>
<tr>
<td>2</td>
<td>CL-2</td>
<td>67-67.9</td>
<td>67.34</td>
<td>24.1</td>
<td>249</td>
</tr>
<tr>
<td>3</td>
<td>CL-3</td>
<td>66-66.9</td>
<td>66.4</td>
<td>24.8</td>
<td>248</td>
</tr>
<tr>
<td>4</td>
<td>CL-4</td>
<td>65-65.9</td>
<td>65.5</td>
<td>25.7</td>
<td>240</td>
</tr>
<tr>
<td>5</td>
<td>CL-5</td>
<td>64-64.9</td>
<td>64.6</td>
<td>26.6</td>
<td>229</td>
</tr>
<tr>
<td>6</td>
<td>CL-6</td>
<td>63-63.9</td>
<td>63.4</td>
<td>27.6</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>CL-7</td>
<td>62-62.9</td>
<td>62.6</td>
<td>27.8</td>
<td>184</td>
</tr>
<tr>
<td>8</td>
<td>CL-8</td>
<td>61-61.9</td>
<td>62.0</td>
<td>27.1</td>
<td>186</td>
</tr>
<tr>
<td>9</td>
<td>CL-9</td>
<td>60-60.9</td>
<td>60.1</td>
<td>30.1</td>
<td>180</td>
</tr>
</tbody>
</table>

Relation between coke CSR and coke CCS

\[ R^2 = 0.90 \]
Relation between coke CRI and coke CCS

Relation between coke CRI and coke CCS

R² = 0.83

Avg. Coke CRI

Coke CCS

Model Performance Tracker

Predicted CSR

61.6

± 3.3

Prediction performance view

Sample ID: CLT 440 / 05.02.18
CCS value: 184.6

SUBMIT
Limitations with CCS test

Factors influencing CCS test for Coke

- Sample Size
- Sample shape
- RAM Speed
- Load Cell position.
- Coke quality
- Coal Blend composition

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Conclusion

- Porosity of coke changes significantly post gasification (> 30%).

- Cold compressive strength (CCS) has a strong correlation with stamp charge coke and can be used as a measure to predict strength of coke.

- 240 cold compressive strength of coke is requisite for producing coke CSR 65-66.

- Higher the CCS, higher is the coke CSR and lowers the coke CRI.