REFRUCTORIES FOR COKE OVEN WALL - OPERATOR'S PERSPECTIVE

K. ANDREEV, M. v. WIJNGAARDEN, P. PUT, V. TADAION, O. OERLEMANS

Ceramics Research Centre, Tata Steel Europe, IJmuiden, The Netherlands
### Coke Plant 2 – Tata Steel IJmuiden

<table>
<thead>
<tr>
<th>Design</th>
<th>Carl Still</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>800 kton/year</td>
</tr>
<tr>
<td>Total number of batteries</td>
<td>4</td>
</tr>
<tr>
<td>Total number of ovens</td>
<td>108</td>
</tr>
<tr>
<td>Oven dimensions (h l w)</td>
<td>6.5 x 15.2 x 0.42 m</td>
</tr>
<tr>
<td>Volume</td>
<td>29.5 m³</td>
</tr>
<tr>
<td>Type of under-firing</td>
<td>Half divided gas gun</td>
</tr>
<tr>
<td>Machine lay out</td>
<td>2x Pusher, 2x charger, quench car.</td>
</tr>
</tbody>
</table>

1972: First push

1972-1983: No maintenance of refractories

1983-present: Refractories maintenance activities (e.g. ceramic welding)

Since 2002: Project to replace the oven walls
Wall replacement project

Regular monitoring nominates walls to be replaced (too expensive to repair)

Mainly three walls at a time

Conventional silica bricks and modular cast blocks (MCB)

- First MCB wall commissioned in 2008

Silica bricks

Fused silica MCB blocks
Scope of the presentation

**Key refractories related aspects** of the project to replace the walls:
- specifications;
- quality control procedures;
- specific properties of bricks and mortar.

For silica bricks and MCB:
- quartz content;
- amorphous to crystalline;
- mechanical cyclic fatigue degradation.

To illustrate the policy of the sustaining and developing of the in-house knowledge of refractory materials pursued at Tata Steel IJmuiden.
### Alternative wall materials – Tata specs

<table>
<thead>
<tr>
<th>Component</th>
<th>Brick</th>
<th>MCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Al}_2\text{O}_3 )</td>
<td>(%</td>
<td>Max. 1 3</td>
</tr>
<tr>
<td>( \text{SiO}_2 )</td>
<td>(%</td>
<td>Min. 95 95</td>
</tr>
<tr>
<td>( \text{CaO} )</td>
<td>(%</td>
<td>Max. 3 3</td>
</tr>
<tr>
<td>( \text{Fe}_2\text{O}_3 )</td>
<td>(%</td>
<td>Max. 1 1</td>
</tr>
<tr>
<td>Measured by XRD:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystalline Components</td>
<td>(%)</td>
<td>Max. - 10</td>
</tr>
<tr>
<td>Residual quartz</td>
<td>(%)</td>
<td>Max. 1 -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density</td>
<td>( \text{kg/m}^3 )</td>
<td>1800</td>
<td>1800</td>
</tr>
<tr>
<td>True Density</td>
<td>( \text{kg/m}^3 )</td>
<td>2340</td>
<td>2100</td>
</tr>
<tr>
<td>Apparent Porosity</td>
<td>(%)</td>
<td>Avg.&lt; 22 18</td>
<td></td>
</tr>
<tr>
<td>Cold Crushing Strength</td>
<td>( \text{N/mm}^2 )</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Permanent Linear Change</td>
<td>( % )</td>
<td>Avg.&lt; 0,2 -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( % )</td>
<td>Avg.&gt; -0,2 -</td>
<td></td>
</tr>
<tr>
<td>Thermal expansion at 1300°C</td>
<td>( % )</td>
<td>Min. - 0</td>
<td></td>
</tr>
<tr>
<td>- load 0.02 N/mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- load 0.20 N/mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal expansion,</td>
<td>( % )</td>
<td>Min. - 0</td>
<td></td>
</tr>
<tr>
<td>growth at 1300°C,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>between 0 and 300 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see below)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creep</td>
<td>( % )</td>
<td>Max. 0,2 0,2</td>
<td></td>
</tr>
</tbody>
</table>

**Specification:**
- Ambitious
- Feasible
- Controllable
- Defines all critical parameters
Silica brick - *not off-the-shelf products*:
Different and difficult shapes – various degree of challenge for production
Some 250 formats (10-1500 bricks per format)
Properties variation is possible within one format and between different formats

**In a QC batch:**
- 50% simple format bricks and 50% complex format bricks
- Several bricks per format
### Round robin – residual quartz content

**Recorded and fitted X-ray pattern along with phase proportions**

<table>
<thead>
<tr>
<th>Lab</th>
<th>Tata Steel Method</th>
<th>Lab I Peak surface</th>
<th>Lab II Peak surface</th>
<th>Lab III Peak surface</th>
<th>Supplier I Peak surface</th>
<th>Supplier II Peak surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample I</td>
<td>3.3+/−0.5 Rietveld</td>
<td>3.0−4.0</td>
<td>2.8</td>
<td>2.2</td>
<td>3.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Sample II</td>
<td>0.3+/−0.5</td>
<td>&lt;1.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Silicon** 10.23%
**Cristobalite low** 36.50%
**Triljmite_low_C1** 26.46%
**Triljmite_low_F1** 26.53%
**Quartz** 0.29%
MCB – alternative products and suppliers

Spec.: Thermal strain @ 1300°C > 0%
Crystallization of MCB material – XRD tests

**XRD after heat treatment at 1400 °C**

**MCB walls will be crystalline within the first several weeks of service.**

*High temperature XRD 4 °C/min and holding at 1250 °C for 5 h*
Thermo-mechanical properties

At 1000 °C: Brick MCB

Brick

Dynamic Young's modulus, GPa

Temperature, °C
Cyclic loading – gradual degradation

In 30-40 years the walls will experience some 10000-15000 major process cycles
Cyclic fatigue - results

\[ \varepsilon_{\text{crit}} \leq \Delta T \times \alpha = \varepsilon \]

- MCB: less brittle failure
- MCB: can sustain higher strain loads and is expected to degrade less intensively.
Silica mortar – temperature effects

- The compressibility varies with temperature.
- In compression mortar is stiffer than the bracing system.
- Cohesion between the mortar and the brick develops only at high temperatures.
Conclusions

**Selected properties** of the silica mortar, conventional silica bricks and fused silica materials important for successful construction and utilisation of the coke plant **have been discussed.**

Due to complex geometry and specific material properties the coke oven wall refractories are **not off the shelf commodity material.** Rigorous pre-order process involving the examination of the materials and developing solid cooperation foundation with the supplier is needed.

In the process of selection and sourcing of the best Value in Use refractory solution a key role is played by the **dedicated in-house refractories knowledge and testing facility** used for the quality control and the investigation of materials.
Silica mortar – joint thickness effects

For mortar joints of variable thickness the compaction can differ by some 0.3-0.5 mm per joint.