Circulating Fluidized Bed Scrubber (CFBS) pilot tests in 1 MW\textsubscript{th} scale

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Agenda

- Circulating Fluidized Bed Scrubber (CFBS) technology
- CFB-CFBS pilot test rig
- Tests performed
- Results
- Conclusions
Circulating Fluidized Bed Scrubber (CFBS) Technology

- Multi-pollutant control
  - Acid gases (SO₂, HCl, HF)
  - Particulate matter
  - Heavy metals
- Compact footprint
- Lower installed and O&M costs
- Low water consumption
- Wastewater treatment exemption
- Large-scale applications
- Combined with CFB boiler for maximum sorbent utilization and/or emissions performance

Absorber
- Self-cleaning CFB process minimizes maintenance
- Carbon steel design avoids expensive liners and alloys
- Multiple venturi design allows wide range of capacities
- Long gas and solid mixing time for high pollutant capture and maximum lime utilization

Fabric Filter
- Optimized pulse frequency across filter sectors allows efficient solid recirculation, dust capture and long bag life

Solid Recirculation
- Reliable non-mechanical air slide proven by years of use in the power industry

Shut Down Valve
- Fast acting shut down valve to allow purge of absorber solids during a boiler trip

Absorber Bottom
- Flue gas inlet chamber drops out large particles
Advantages of CFB-CFBS Combination

- In CFB combustion, limestone is used for in-furnace SO\(_2\) capture.
- The unreacted CaO in the fly ash can be reactivated in the CFBS, eliminating the need for external sorbent use, thus reducing the costs.

Very high limestone utilization rate can be achieved with CFBC + CFBS

\[
\begin{align*}
CaO_{(s)} + H_2O & \rightarrow Ca(OH)_{2(s)} \\
Ca(OH)_{2(s)} + SO_{2(g)} & \rightarrow CaSO_{3(s)} + H_2O_{(g)} \\
CaSO_{3(s)} + \frac{1}{2}O_2_{(g)} & \rightarrow CaSO_{4(s)}
\end{align*}
\]
CFB-CFBS Pilot Test Rig
Main Specifications

<table>
<thead>
<tr>
<th>Pilot equipment</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal capacity</strong></td>
<td>Up to 1 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>ID 0.59 m; Height 8.5 m</td>
</tr>
<tr>
<td><strong>Pressure rate</strong></td>
<td>Up to 200 mbar in the gas distributor</td>
</tr>
<tr>
<td><strong>Combustion temperature</strong></td>
<td>Up to 1000 °C</td>
</tr>
<tr>
<td><strong>Feeding systems</strong></td>
<td>Sand/limestone, solid fuels, RDF, additives</td>
</tr>
<tr>
<td><strong>Flue gas cooling</strong></td>
<td>Water cooling; five tubes in furnace and convection</td>
</tr>
<tr>
<td><strong>Flue gas cleaning (FGC)</strong></td>
<td>CFBS, fabric filter baghouse system. DSI + baghouse can be tested</td>
</tr>
<tr>
<td><strong>CFBS sorbent feeder</strong></td>
<td>Main sorbent feeder, PAC feeder</td>
</tr>
<tr>
<td><strong>Flue gas analysis</strong></td>
<td>Continuous on-line analyses: O&lt;sub&gt;2&lt;/sub&gt;, CO, SO&lt;sub&gt;2&lt;/sub&gt;, NO&lt;sub&gt;x&lt;/sub&gt;, CO&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
Water is controlled by the FG temperature
Tested between 85-125 °C
CFB-CFBS Pilot Test Rig

Pilot Configuration
**Tests Performed**

- High chlorine and heavy metal fuels: RDF and coal + RDF mixtures
- High sulfur fuel tests: coal doped with sulfur (up to ~10%-wt) and petcoke

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Fuel</th>
<th>S-content [%-wet]</th>
<th>Cl-content [%-wet]</th>
<th>Hg-content [ppmw]</th>
<th>Sorbent</th>
<th>Ca/S ratio(^1)</th>
<th>Ca/HCl ratio(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coal-RDF</td>
<td>0.6</td>
<td>0.3</td>
<td>0.45</td>
<td>CaCO(_3), Ca(OH)(_2)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>RDF</td>
<td>0.4</td>
<td>0.5</td>
<td>0.75</td>
<td>Ca(OH)(_2)</td>
<td>0.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>Coal</td>
<td>3.3</td>
<td>-</td>
<td>-</td>
<td>CaCO(_3)</td>
<td>1.5 to 2.0</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Coal</td>
<td>5.4</td>
<td>-</td>
<td>-</td>
<td>CaCO(_3)</td>
<td>1.5 to 2.2</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Coal</td>
<td>9.5</td>
<td>-</td>
<td>-</td>
<td>CaCO(_3)</td>
<td>1.5 to 2.0</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Petcoke</td>
<td>8.7</td>
<td>-</td>
<td>-</td>
<td>CaCO(_3)</td>
<td>1.5 to 1.8</td>
<td>-</td>
</tr>
</tbody>
</table>

**Notes:**
1) In CFB; limestone feeding into CFB based on fuel sulfur content
2) In CFBS; Hydrated lime feeding based on HCl content
## Results

### Multi-Pollutant Control

- Complete HCl removal
- Complete SO\textsubscript{2} removal up to 3% S, with no sorbent added to the FGC system
- High sulfur retention (up to 10% S), no sorbent added to the FGC system

<table>
<thead>
<tr>
<th>Test no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Coal-RDF</td>
<td>RDF</td>
<td>Coal (3% S)</td>
<td>Coal (5% S)</td>
<td>Coal (10% S)</td>
<td>Petcoke (9% S)</td>
</tr>
<tr>
<td>CFB sorbent</td>
<td>CaCO\textsubscript{3}</td>
<td>None</td>
<td>CaCO\textsubscript{3}</td>
<td>CaCO\textsubscript{3}</td>
<td>CaCO\textsubscript{3}</td>
<td>CaCO\textsubscript{3}</td>
</tr>
<tr>
<td>Furnace Ca/S</td>
<td>2.0</td>
<td>0.0</td>
<td>1.9 – 3.0</td>
<td>1.9 – 2.5</td>
<td>1.7 – 2.2</td>
<td>1.4 – 1.7</td>
</tr>
<tr>
<td>CFBS sorbent</td>
<td>Ca(OH)\textsubscript{2}</td>
<td>Ca(OH)\textsubscript{2}</td>
<td>Fly ash</td>
<td>Fly ash</td>
<td>Fly ash</td>
<td>Fly ash</td>
</tr>
<tr>
<td>Total SO\textsubscript{2} reduction [%]</td>
<td>99%</td>
<td>99%</td>
<td>87-100%</td>
<td>95-98%</td>
<td>83-91%</td>
<td>90-98%</td>
</tr>
<tr>
<td>HCl reduction [%]</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td>93-99%</td>
<td>91-98%</td>
<td>89-97%</td>
<td>-</td>
</tr>
</tbody>
</table>
Results

Mercury Capture: Complete Hg Removal

Measured inlet concentration (total)

<table>
<thead>
<tr>
<th>Test number</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel mix</td>
<td>Coal-RDF</td>
<td>RDF</td>
</tr>
<tr>
<td>Hg sorbent</td>
<td>PAC</td>
<td>PAC</td>
</tr>
<tr>
<td>Hg theoretical [µg/Nm³, 6% O₂ dry]</td>
<td>47</td>
<td>79</td>
</tr>
<tr>
<td>Hg at stack [µg/Nm³, 6% O₂ dry]</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>FGC capture [%]</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

PAC specification:
- Bulk density (kg/m³) approx. 550
- Total surface area (m²/g) approx. 800 (BET-method)
- Granulation D 50 (µm) 15 - 30
- Ash content (wt.%) < 10
Sumitomo FW SHI has built a CFBS pilot plant at the Technical University of Darmstadt to further refine this technology.

The pilot is built downstream a 1 MW\textsubscript{th} CFB furnace to illustrate and quantify the ultimate advantages of the CFB-CFBS combination.

Multi-pollutant control capabilities

- More than 99% SO\textsubscript{2} and HCl reduction for certain fuels, even without additives feeding to either furnace or scrubber.
- With PAC injection, Hg emissions were below detection limit, even for 100% RDF feeding.

High-sulfur coal and petcoke

- Extremely high SO\textsubscript{2} concentration in the flue gas can be reduced dramatically by reactivating the furnace fly ash inside the scrubber, without any external additive into the scrubber.

Additional tests also include other fuel mixes, such as lignite and biomass.

The final goal is to optimize the CFB-CFBS system for multipollutant emissions control with minimum limestone (and other sorbent) consumption.
Thank You!
Acknowledgement

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