Ore processing in fluidized bed technologies

Outotec
Overview

- Fundamentals in fluidized bed technology.
- Outotec’s experience in fluidized bed technologies.
- CFB/FB applications for iron containing ores.
- CFB applications for alumina calcination.
- Technology and project development.
Fluidized bed systems - fundamentals

- In a fluidized bed particles are held suspended by the upward.
- Increasing gas velocities will create different flow regimes.
- The highest slip velocity is reached in CFB, leading to high mass & heat transfer rates.
- Outotec has applied CFB, FB, AFB and FR for treatment of different fine ores.
Circulating fluidized bed advantages

- High mass & heat transfer
  Uniform temperature, low energy consumption.
- Direct processing of fines
  Minimum fines losses and accretions.
- High productivity
  Minimum plant downtime & low specific investment costs.
- No heavy rotating equipment
  Easy and flexible control, low operation & maintenance costs.
- Easy and exact control of temperature and retention time.
- Direct combustion of natural gas in the CFB furnace.
Outotec’s experience in fluidized bed technologies
## CFB applications

<table>
<thead>
<tr>
<th>Number of Plants</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial</strong></td>
<td></td>
</tr>
<tr>
<td>Calcining of alumina</td>
<td>52</td>
</tr>
<tr>
<td>Calcining of limestone, clay etc.</td>
<td>4</td>
</tr>
<tr>
<td>Roasting of gold ores</td>
<td>7</td>
</tr>
<tr>
<td>Power plants</td>
<td>82</td>
</tr>
<tr>
<td>Adsorption of wastes / desulphurization</td>
<td>16</td>
</tr>
<tr>
<td>Fluorine adsorption (electrolysis)</td>
<td>10</td>
</tr>
<tr>
<td>Circored</td>
<td>1</td>
</tr>
<tr>
<td>Circoheat</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>173</td>
</tr>
</tbody>
</table>

- Rio Tinto Alcan Gove 3 CFB calciners.
- HBI Circored plant Trinidad. Capacity 0.5 million t/a
## CFB applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Number of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi industrial / pilot</td>
<td>6</td>
</tr>
<tr>
<td>Circodust</td>
<td>1</td>
</tr>
<tr>
<td>Elred</td>
<td>1</td>
</tr>
<tr>
<td>Circofer</td>
<td>1</td>
</tr>
<tr>
<td>AlF3 synthesis</td>
<td>1</td>
</tr>
<tr>
<td>Pyrohydrolysis</td>
<td>1</td>
</tr>
<tr>
<td>Decomposition and recycling of salts</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>6</strong></td>
</tr>
<tr>
<td><strong>Total CFB references</strong></td>
<td><strong>179</strong></td>
</tr>
</tbody>
</table>

Outotec's fluidized bed applications
CFB applications – iron ore processing

- Outotec has built CFB plants for preheating, roasting and hydrogen based reduction of iron ores.

- In the case of iron ore preheating & calcination, the target is to remove LOI and to preheat the ore for downstream processes (e.g. direct reduction or smelting reduction).

- For ilmenite roasting the target is to change magnetic properties of the ore to allow the removal of chromite by magnetic separation.
CFB applications – iron ore processing

• One Circored plant for direct reduction of iron ore was built, using hydrogen as reductant: Circored plant Trinidad 1996.

• Two ilmenite roasters were built by Outotec: Exxaro 2001, Empangeni South Africa; and Moma Sands 2005 Mozambique.

• Two iron ore preheaters were built by Outotec: preheater for Circored plant Trinidad 1996 and preheater for HIsmelt Australia 2002.
Circored is the only hydrogen based direct reduction process for iron ores available in the market.

Hydrogen is used as reductant, which is normally supplied from steam-methane reforming plant.

Up to 95% metallization degree can be achieve using two reduction stages (CFB/FB).

Final product could be HBI or DRI as feed to other processes (e.g. EAF steelmaking, BF ironmaking).
CFB/FB applications – DRI/HBI production

Circored plant Trinidad. 0.5 Million t/a HBI plant.
CFB applications – iron ore preheating

Circoheat® iron ore preheater for HLsmelt

Circoheat® / Kwinana

Design capacity: 170 t/h Ore
Preheating temperature: 850° C

Operated at 90 – 150 t/h, 750° C
CFB applications – iron ore preheating

Circoheat® iron ore preheater
CFB applications – ilmenite roasting

Moma Sands 2005 – Mozambique, South Africa

- Capacity of roaster: 1200 tpd roasted ilmenite
- Roasting under reducing conditions at 800°C temperature.
- Ilmenite: 57 % TiO₂, 27 % Fe
- Circulating fluidized bed for optimal process control (temperature and retention time).
- External hot gas generator for substoichiometric combustion of diesel fuel oil.
- Reactor dimensions: ⌀ 3 m, 21 m high.
CFB applications – ilmenite roasting

- Capacity of roaster: 1000 tpd roasted ilmenite.
- Start-up: 1999.
- Roasting under oxidizing conditions to be able to decrease the chromite content by magnetic separation before smelting.
- Ilmenite: 49 % TiO2, 37 % Fe.
- Circulating fluidized bed with internal combustion of Sasol gas.
- Reactor dimensions: \(\Phi 1.9\) m, 12 m high.

Exxaro 2001 – Empangeni, South Africa
CFB applications – ilmenite roasting

Exxaro ilmenite roaster process flowsheet
CFB applications: alumina calcination

- Calciners built: 52

- Calciners upgraded: 11

- Total CFB Capacity: >36 MTPY (40 % of world production)

- Under construction: 2 CFBs
CFB Applications: alumina calcination
Outotec
Technology and project development
Technology development

R&D Way of work
Iterative interplay between process design & test work

• **Process design**
  - Process flowsheets, mass and energy balances of processes, operating points, sensitivity analyses.
  - Plant design: equipment dimensioning and functionality.

*Test work* (lab scale, batch, continuous, pilot scale):
  - For plant design, scale-up and process guarantees.
  - For production of material to be tested further.
## Scale up experience

<table>
<thead>
<tr>
<th>Process</th>
<th>Pilot plant size</th>
<th>Commercial plant size</th>
<th>Factor (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina calcining 1966</td>
<td>125 mm Ø 5 kg/h</td>
<td>1.0 m Ø 1 t/h</td>
<td>1:200</td>
</tr>
<tr>
<td>Alumina calcining 1970</td>
<td>1,000 mm Ø 1,000 kg/h</td>
<td>3.6 m Ø 20 t/h</td>
<td>1:20</td>
</tr>
<tr>
<td>Coal combustion 1982</td>
<td>360 mm Ø 20 kg/h</td>
<td>5 m Ø 21 t/h</td>
<td>1:1,000</td>
</tr>
<tr>
<td>Gold ore roasting 1990</td>
<td>200 mm Ø 22 kg/h</td>
<td>3.8 m Ø 83 t/h</td>
<td>1:4,000</td>
</tr>
<tr>
<td>Circored 1999</td>
<td>200 mm Ø 18 kg/h</td>
<td>5.0 m Ø 63 t/h</td>
<td>1:3,500</td>
</tr>
</tbody>
</table>
Project development time frame and costs

Phase I
- Bench scale tests
  - 50mm FB; 80mm FB
  - CAPEX & OPEX +/- 30 - 40%
- Mineralogy

Phase II
- Experimental
  - 200 mm CFB pilot plant for process validation
- Basic engineering
  - Flowsheet
  - Process control
  - Proprietary equipment design
- Increasing accuracy of CAPEX & OPEX estimates

Execution (months)
- Phase I: 3 months
- Phase II: 9 months

Relative process development costs (%)
- Phase I: 100%
- Phase II: 100% (Engineering, Procurement, Construction, Operation)
Conclusions

• Outotec’s CFB technology presents several advantages for thermal treatment of different fine ores.

• The direct combustion of natural gas in the CFB furnace results in an efficient method for fine ore heating, minimizing fuel consumption.

• The use of hydrogen for DRI & HBI production has been demonstrated, and combined with EAF could represent an alternative route for steel production.

• Outotec has a vast experience accumulated for more than 50 years in different fluidized bed applications.
Thank you