Paper sludge incineration in BFBC

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BFBC – Waste to Energy plant

Fuel:
• Primary & Secondary sludge
• De-inking sludge
• Plastics

Capacity:
• Overall CHP plant 80/200 MW
• Waste to Energy component
  ~ 20 t/h fuel  at ~ 3.5 MJ/kg
  (Design CV >4.6 MJ/kg)
### Fuel composition

<table>
<thead>
<tr>
<th></th>
<th>MIXED FUEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AS RECEIVED %</strong></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>57.1</td>
</tr>
<tr>
<td>Ash</td>
<td>12.3</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>28.0</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.03</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.06</td>
</tr>
<tr>
<td>CV, MJ/kg Net</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>DRY ASH FREE %</strong></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>48.4</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5.7</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.6</td>
</tr>
<tr>
<td>Oxygen</td>
<td>45.0</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>91.5</td>
</tr>
</tbody>
</table>
Background – Fuel Issues

- High Ash
- High moisture
- Low CV
- Non-auto thermal operation (cool bed)
  - Particle growth
  - CaCO₃ deposition
  - Distorted axial T gradient
- Natural gas support firing
- Tramp material
  - Blockage in material handling plant and excessive wear
  - Tramp metal in sludge
  - Tramp fabric/ wire in plastics
- Sand loss
- Bed loss due to T excursions
- Additional waste stream
- Thermal stresses
- Water attemperation
- Cost
- Slagging
- Builds up in bed
- Increased wear
- NOx control costs
- Bed defluidisation
- Increased wear
- Cost
- Slagging
- Builds up in bed
- Increased wear
- NOx control costs
- Bed defluidisation
Background

General FBC Issues:

• Bed Agglomeration (sintering, slagging, tramp material)
• Fouling/Deposition
• Corrosion/Erosion

Impacts:

• Bed de-fluidisation and forced outages (bed dig out)
• Boiler performance and outage frequency
• Tube leaks
Review
Impact of increasing fuel CV and bed temperature on:

• Bed Agglomeration
  - sintering due to higher bed temperature
  - sintering due to alkali metals (co-firing)

• Fouling/Deposition
  - changes to ash characteristics

• Corrosion/Erosion
  - increasing chlorine (plastics)
  - increasing alkali metals (co-firing)
Bed agglomeration

Causes: alkali silicates; low melting point compounds of Pb/Sn

Control strategies:
- Ongoing sand bed replacement
- Alternative bed materials

Brus, E., Öhman, M., Nordin, A., Skrifvars, B-J, Backman, R., 'Bed material consumption in biomass fired fluidised bed boilers due to risk of bed agglomeration – coating formation and possibilities for regeneration', IFRF Combustion Journal Article Number 200302, Jun 2003

Particle size distribution

Particle size distribution

Cumulative (%) vs. Particle size ($\mu$m)

Size fraction (%) vs. Particle size ($\mu$m)

Source: DEFRA, August 2005
Bed material

+1.4mm
-1.7mm
Bed material – particle structure

Outer part of a crushed particle

Inner part of a crushed particle

Outlet from fluidised bed burner (outer part of a crushed particle)
Bed material – particle composition

Outer part of a granulated particle (crushed)

Inner part of a crushed particle (smooth surface)
Agglomeration Indicators

\[
\frac{(Na + K)}{(2S + Cl)} > 1
\]
Alkali metals > (sulphur + chlorine)

\[
\frac{(K + Na + Si)}{(Ca + P + Mg)} > 1
\]
(Alkali metals + silica) > Calcium

## Fly ash composition

<table>
<thead>
<tr>
<th>ASH ANALYSIS</th>
<th></th>
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<tbody>
<tr>
<td>SiO₂</td>
<td>12.4</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>7.9</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.6</td>
</tr>
<tr>
<td>CaO</td>
<td>75.5</td>
</tr>
<tr>
<td>MgO</td>
<td>1.9</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.3</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.3</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.5</td>
</tr>
<tr>
<td>BaO</td>
<td>0.01</td>
</tr>
<tr>
<td>Mn₃O₄</td>
<td>0.03</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Agglomeration indices**

\[
\frac{(Na + K)}{(2S + Cl)} > 1
\]

0.6

\[
\frac{(K + Na + Si)}{(Ca + P + Mg)} > 1
\]

0.2

**Fouling & corrosion indicies**

\[
\frac{S}{Cl} < 2
\]

0.6
Bed material – impact of changing temperature

FBC Bed Ash

- Standard 1h LOI
- 48h LOI
- Non-standard LOI
- N2 atmosphere
- Dry stack gas
- Wet stack gas
- Upper bed temp.
- Lower bed temp.
- Standard LOI temp.
- Sludge LOI temp.

- Sintering

Temperature (°C):
- 730°C
- 850°C
- 550°C
- 815°C

LOI (%):
- 0
- 2
- 4
- 6
- 8
Bed material – impact of changing temperature (TGA)

CO₂ delays carbonate decomposition

CO₂ uptake at low temperatures

Source: DEFRA, August 2005
Conclusions – Fluidised Bed

• Ca forms a protective layer that prevents agglomeration

• Higher bed temperature OK

• Carbonate decomposition must be caused by combustion and/or support firing

• Carbonate levels should be small and less variable at higher T

• Higher bed temperature $\rightarrow$ more uniform axial profile – better emissions performance
Fly ash composition

<table>
<thead>
<tr>
<th>Ash analysis</th>
<th>CaO</th>
<th>Ex ash CO₂</th>
<th>LOI&lt;sub&gt;815°C&lt;/sub&gt;</th>
<th>Ex ash CaCO₃</th>
<th>Ex ash CaO</th>
<th>Ca species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52.2</td>
<td>12.0</td>
<td>11.2</td>
<td>27.2</td>
<td>36.9</td>
<td>64.1</td>
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<td></td>
<td>53.6</td>
<td>14.1</td>
<td>13.4</td>
<td>32.1</td>
<td>35.6</td>
<td>67.7</td>
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<td></td>
<td>52.4</td>
<td>13.1</td>
<td>12.5</td>
<td>29.8</td>
<td>35.7</td>
<td>65.5</td>
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<tr>
<td></td>
<td>54.5</td>
<td>12.5</td>
<td>12.3</td>
<td>28.5</td>
<td>38.6</td>
<td>67.0</td>
</tr>
</tbody>
</table>

How will this be affected by changing operating conditions?

- axial temperature profile (peak temperatures lower)
- residence times
- CO₂ re-absorption
RTD
Fly ash – changing temperature – drop tube furnace

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>Res. time (s)</th>
<th>LOI 815°C (% wt. loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>730</td>
<td>1</td>
<td>37.25</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>36.61</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>34.69</td>
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<tr>
<td>850</td>
<td>1</td>
<td>36.46</td>
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<tr>
<td></td>
<td>2</td>
<td>35.01</td>
</tr>
<tr>
<td>1000</td>
<td>1</td>
<td>25.46</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15.45</td>
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</tbody>
</table>
Fouling in FBCs – alkali metals

Fouling aggravated by alkali metals when S/Cl < 2
(Only trace levels of alkali metals and not seen to be a problem)

Conclusions - fouling and corrosion - co-firing

• Avoid fuels high in alkali metals since the bed will not absorb these – doping with sulphur would be required

• Past corrosion mostly attributed to chlorine (plastics) - increase would need corrosion trial

• Fossil fuels may aggravate fouling but calcium oxide may be sufficient to absorb the SO$_2$

• Dry, clean, woody biomass is preferred for co-firing

• Plant trials or pilot trials are advisable when changing fuel mix.