“Continuous Carbonate Looping Tests in a 1 MWth Pilot Plant”

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5\textsuperscript{th} High Temperature Solid Looping Network Meeting

Venue: Cambridge
Outline

- Carbonate looping process
- 1 MW\textsubscript{th} pilot plant for carbonate and chemical looping investigations
- 1 MW\textsubscript{th} carbonate looping pilot plant
- Results of continuous CO\textsubscript{2} capture tests in 1 MW\textsubscript{th} pilot plant
- Conclusions
Carbonate Looping Process

- Low energy penalty (~3 % points without CO₂ compression)
- Applicable as retrofit
- Increased total power output (repowering)
- High CO₂ capture efficiencies
- Cheap and widely available sorbent
- Low CO₂ avoidance costs
WaiGaoQiao Coal Fired Power Plant 2 x 980 MWe
Carbonate looping plant

- Increase of electrical capacity of the power plant by ~50%.
- ~6% points efficiency drop (incl. CO₂ compression), ~87% CO₂ capture
- CO₂ avoidance costs ~20 €/tonCO₂
Carbonate looping unit for one flue gas cleaning train (of in total two parallel trains) for post-combustion CO₂ capture of 1052 MWₑl hard coal fired plant.

Source: TU Darmstadt
EST Pilot Plant at Campus TU Darmstadt
EST Pilot Plant

1 MW\textsubscript{th} pilot plant for carbonate investigations

<table>
<thead>
<tr>
<th></th>
<th>CFB 600</th>
<th>CFB 400</th>
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<tbody>
<tr>
<td>Inner diameter of CFB</td>
<td>600 mm</td>
<td>400 m</td>
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<tr>
<td>Outer diameter of CFB (refractory lined)</td>
<td>1.3 m</td>
<td>1.0 m</td>
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<tr>
<td>Height of CFB</td>
<td>8.66 m</td>
<td>11.35 m</td>
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<tr>
<td>Carbonate looping</td>
<td>Carbonator</td>
<td>Calciner</td>
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Hot Commissioning, Aug 2010
CFB 600 Carbonator /Air Reactor

CFB 600 Riser
Start up Burner
Nozzle Grid Deassembly
Hot Commissioning, Aug 2010
CFB600, Operation of Start-up Burner
Experimental Setup of Pilot Plant

[Diagram showing the experimental setup with various components including:
- Fluidised bed Carbonator at 650 °C
- Calciner at 900 °C
- Heat exchanger
- Primary air fan
- Synthetic flue gas
- Decarbonised flue gas
- Oxygen enriched air
- Carbonate looping]

[Flow measurement symbols: ○, Flow control symbols: Fl]
Operational experience at EST:

- > 2000 h of fluidised bed operation in coupled mode
  - Sep 2010: alternating CO\textsubscript{2} capture and regeneration tests in one reactor
  - July 2011: CO\textsubscript{2} capture in carbonator, calciner propane-fired
  - Jan 2012: CO\textsubscript{2} capture in carbonator, calciner propane-fired
  - Feb 2012: CO\textsubscript{2} capture in carbonator, calciner coal-fired

Campaigns:

- Continuous CO\textsubscript{2} capture in carbonator
- Carbonator fluidised by a synthetic flue gas
- Calciner propane-fired (campaign propane)
- Calciner coal-fired (campaign coal)
- More than 300 h of CO\textsubscript{2} capture operation
Results of 20 hours of CO$_2$ capture (calciner coal-fired)

- Max. CO$_2$ absorption carbonator: 88 %
- Max. total capture efficiency: 93 %
Further Work Carbonate Looping

- Test with flue gas from 1 MW\textsubscript{th} coal-fired combustion chamber
- Influence of circulating solid flow and make-up flow on CO\textsubscript{2} capture efficiency
- Optimisation of operating conditions
- Investigations of process improvements
Acknowledgements

COORETEC Project “LISA” - Limestone based Absorption of CO₂
Indirectly heated carbonate looping process

- Design and erection of 300 kW_\text{th} indirectly heated carbonate looping test rig
Conclusions

- more than 2000 h of coupled CFB mode operation under hot conditions
- Continuous CO$_2$ capture tests in 1 MW$_{th}$ carbonate looping pilot plant
- More than 300 h of CO$_2$ capture operation within different campaigns
- Presented campaigns with stable operation
  - Calciner coal-fired
- High CO$_2$ capture efficiencies
  - $>80 \%$ CO$_2$ absorption in carbonator
  - $>90 \%$ total CO$_2$ capture (carbonator + oxyfuel-fired calciner)
- Strong dependence of CO$_2$ absorption in carbonator on temperature
- Successful commissioning of chemical looping pilot plant
Thank you for your attention!