Thermochemical Energy Storage Employing Fluidized Bed Technology: Experimental Investigations with CaO/Ca(OH)$_2$ on a 21kWh Reactor

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Agenda

- **Introduction:** Thermochemical Energy Storage Systems
- **Preliminary Experiments:** Fluidisation Test Rig, Lab Scale Reactor, TGA
- **Motivation & Open Questions:** Heat Transfer and Particle Stability
- **The Fluidized Bed Reactor FluBEStoR:** Setup and Experimental Procedure
- **Experimental Data**
Thermochemical Energy Storage (TES)

Background & Potential

- First experimental investigations by Samms & Evans in 1967
- Water-based gas-solid-reactions advantageous
  \[ \text{e.g. } \text{CaO(s)} + \text{H}_2\text{O(g)} \leftrightarrow \text{Ca(OH)}_2(s) + 104 \text{ kJ/mol} \]
- Advantages:
  - Cheap storage material
  - No losses over time
  - High energy density
- Status Quo: Fixed bed and moving bed reactors [1]
- Advantages of fluidized bed reactors for TES:
  - Improved mass- and heat transfer
  - Superior mixing properties
  - Simple scalability & compact design
  - Continuous operation allows decoupling of reactor volume and capacity

Illustration of the principle of thermochemical energy storage
Preliminary Experiments

Fluidization test rig with heat transfer probe
- Cylindrical columns (glass) with ID of 140 mm
- Dehumidified Nitrogen at ambient temperature as fluidization agent
- Overall perimeter heat transfer probe (OP-HTP), cp. [4,5]

Lab-scale fixed bed reactor
- Nitrogen and steam supply (direct evaporator)
- Radial flow trough porous material container
- Approx. 300 ml of storage material
- Temperature and pressure measurement

TGA unit
- Investigation of reaction kinetics
- Characterization and improvement of materials
Motivation & Open Questions

Heat-Transfer and Particle Stability in the Fluidized Bed

<table>
<thead>
<tr>
<th>Heat Transfer</th>
<th>Cycle Stability</th>
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<td>• Has been identified as limiting factor for overall process [6]</td>
<td>• Cycle stability so far not or hardly proven in literature</td>
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<tr>
<td>• Successful measurements in fluidized bed cold model (ambient conditions)</td>
<td>• Comminution processes in the process through three aspects:</td>
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<td></td>
<td>• Induced by chemical reaction</td>
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<td>• Induced by thermal stress</td>
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<td>• Mechanical forces in fluidized bed</td>
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Combination

• Small quantity of fine materials leads to improvement of heat transfer temperature (higher collision factor → lower contact time)

• Too high a proportion of fine materials results in deterioration of heat transfer temperature (defluidisation)

Conclusion

• Definition of optimum operating point with specific fine fraction

• Particle stability for long term/high cycle experiments

• Estimation of heat transfer coefficients under operating conditions

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FluBEStoR

- Mounting plate with insulation ring
- Reactor torso
  - Temperature measurements
  - Gasinlet, gasbox and gas distributor plate
  - Flange for supplying bulk material
- Reactor-head
  - Sintered metal filter cartridges
  - Gas outlet
  - Suction lance for solid sampling
  - Flange for material input in continuous operation mode
- Cooling coil (4,4 kW)
- Radiation furnace
  - 14 kW top
  - 40 kW bottom
Exemplary FluBES-toR-Experiment

- “In-house” Calcination of CaCO₃ at around 650°C in pure nitrogen → stable CaO
- One “Cycle” consists of complete hydration and dehydration
- Conversion close to chemical equilibrium is “gentle”
- Reaction itself is limited by heat input and -output
- Material analytics: Particle size analysis, TGA/ignition loss, scanning electron microscopy, BET, particle- & bulk density
Experimental Data

20.5-cycle experiment on lab scale reactor

- Temperature in °C
- Superficial velocity in cm/s, absolute pressure in bar
- Time in hh:mm
Thank you for your attention!

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References


For additional literature on reactor see: