Development of a Moving Bed Pilot Plant for Thermochemical Energy Storage with CaO/ Ca(OH)$_2$

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Thermochemical energy storage
Thermochemical Energy Storage
Limestone is a promising storage material

- Environmental friendly and nontoxic
- Production in industrial scale
- Cheap raw material (50€ per ton)
- Additional chemical potential with the reaction with water vapor
Thermochemical Energy Storage

Reaction system CaO/ Ca(OH)$_2$

charging step - endothermal

$\text{CaO}_\text{(s)} + \text{H}_2\text{O}_\text{(g)} \rightleftharpoons \text{Ca(OH)}_2\text{(s)} + \Delta H$

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Thermochemical Energy Storage
Reaction system CaO/ Ca(OH)$_2$

- Very high energy density – 1330 kJ/kg
- Chemically stored energy is free of losses
- Temperature range 400-700°C

=> Cheap storage capacity cost – 12,5 €ct./kWh
Material properties - CaO/ Ca(OH)$_2$

**Chemical properties:**
- Fast reaction kinetics
- Cycle stability

**Thermophysical properties:**
- Fine powder ($d_{50} \sim 5 \mu m$)
- Low permeability
- Low thermal conductivity ($0.1 - 0.4$ W/mK)

=> Complex reactor/heat exchanger design
Reactor operation

- Indirectly heated fixed bed

- Demonstration of 8kW thermal power

- Capacity of 10kWh (25 kg of Material)

- Charging and discharging at different temperatures through adjustment of vapor partial pressure

=> Upscaling is possible but economically not reasonable

Schmidt et al. (2014) Experimental results of a 10 kW high temperature thermochemical storage reactor based on calcium hydroxide; Applied Thermal Engineering

M. Linder et al. Thermochemical energy storage in kW-scale based on CaO/ Ca(OH)$_2$. Energy Procedia, 42, 888-897, 2014
Detachment of power and capacity

- Coating of Ca(OH)$_2$ by addition of nano particles
- Increased distance between particles

=> enhanced flowability
=> gravity assisted moving bed seems possible

Roßkopf et al. Improving powder bed properties for thermochemical storage by adding nanoparticles; Energy Conversion and Management 2014
Assessment of reactor geometries
Final design of moving bed reactor

Ca(OH)$_2$ / CaO
Conveyance of material to reactor inlet

- Container: 550 l
- Load cells
- Rotary valve
- Screw conveyor with heating jacket
- Pressure lock
- Reactor
Conveyance of reacted material from reactor outlet

- Screw conveyor
- Pressure lock
- Rotary valve
Overall pilot plant design
Heat extraction of moving particles

![Graph showing temperature and weight over time for different points in a moving bed pilot plant.](image)

- **Temperature** [°C]
- **Weight** [kg]
- **Time** [min]

- TR_25
- TR_28
- TR_31
- TR_33
- T_air_inlet
- T_air_outlet

Material inlet

- TR_25
- TR_28
- TR_31
- TR_34
- T_air_inlet
- T_air_outlet
Current challenge…
Moving bed under reaction conditions
Summary

- Ca(OH)$_2$ offers low cost storage capacity
- Fixed bed is working but upscaling is economically not viable
- Material improvements focused on flowability of fine powder
- Commissioning in first experiments on 10 kW/100 kWh realized
- Extracted sensible heat from the moving particles
- Performed dehydration reaction

Current work:

=> Optimization of plant operation
=> Operation at different charging and discharging temperatures
=> Possibility to utilize sensible heat