Calcium Looping Post Combustion CO$_2$ Capture: A promising technology for emission free cement production

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Expertise in Lime based Fluidized Bed Processes

Fluidized Bed Processes
- Calcium Looping (CaL)
- Chemical Looping (CLC)
- Oxy-fuel CFB
- Sorption enhanced reforming (SER)
- Oxy-fuel SER

Fuels
- Biomass
- Waste
- Lignite / Coal

Measurement techniques
- Sorbent Characterization (TGA)
- Online gas analysis: 
  - CO₂, CO, O₂, H₂, CH₄, SOₓ, NOₓ
- Non-condensable HC: GC
- Tar: wet chemical & online (FID)
- H₂S, HCl, NH₃: wet chemical
Calcium Looping – Post Combustion CCS

- retrofitting to existing facilities
- low CO$_2$ separation cost
- low efficiency penalty
Calcium Looping – Post Combustion CCS

General conditions

- Looping Ratio: 2 - 10
- Make-up Ratio: < 0,1 - 0,4
- Temperature
  - $T_{\text{Calciner}}$: 850 - 1000 °C
  - $T_{\text{Carbonator}}$: 600 - 700 °C
- Flue gas
  - $\text{CO}_2$: ~ 15 %
Calcium Looping – Pilot Plant (200 kW$_{th}$)

**Operation Conditions**

- Flue Gas Load: 170 - 230 kW$_{th}$
- Sorbent Looping Ratio: 3 - 13 mol$_{CaO}$/mol$_{CO_2}$
- Total Solid Inventory: 70 - 120 kg CaO/CaCO$_3$
Operational Results – Carbonator

- **Over 90% capture efficiency** achieved over a wide range of operating conditions.
Operational Results – Oxy-fuel Calcination

- Recirculation rate: 28 %
- $\gamma_{O_2,in}$, $\gamma_{O_2, in}$
- $Y_{CO_2,out, dry}$
- $\gamma_{CO_2, out, dry}$
- $\gamma_{O_2, excess}$ in vol.-%

Graphs showing concentrations over time and temperature in °C.
Operational Results – Oxy-fuel Calcination

- High inlet oxygen concentrations (> 50 vol.-%, dry) possible
- Lower recirculation rates for oxy-CaL calcination (additional CO₂ from calcination)
- Lower humidity of CaL flue gas
- Uniform isothermal conditions
Calcium Looping – Pilot Plant (200 kWₜₜ)

**Operation Conditions**
- Flue Gas Load: 170 - 230 kWₜₜ
- Sorbent Looping Ratio: 3 - 13 mol_{CaO}/mol_{CO₂}
- Total Solid Inventory: 70 - 120 kg CaO/CaCO₃

**Carbonator**
- CO₂ capture efficiency above 90 %

**Calciner**
- CO₂ outlet concentrations above 90 vol.-%, dry
- Inlet O₂ concentrations above 50 vol.-%, dry
- Excess O₂ outlet concentration below 3 vol.-%, dry
Cement Plant – Clinker Production and Properties

- clinker composition
  - CaO: 60 - 70 %
  - SiO₂: 20 - 25 %
  - Al₂O₃: 2 - 6 %
  - Fe₂O₃: 0 - 6 %

- structural change at 1400 °C (rotary kiln)
  - CaO + SiO₂ → (CaO)₃ · SiO₂ & (CaO)₂ · SiO₂

- flue gas composition
  - high CO₂ concentration ~ 30 %
Cement Plant – CaL Integration

- synergy effect between cement plant and CaL-process

General conditions

- Looping Ratio: 2 - 4
- Make-up Ratio: > 1
- Flue gas
  - \( \text{CO}_2 \): 15 - 30 %
Summary

- Calcium looping for power plant application demonstrated at pilot plant scale
  - CO₂ capture efficiency over 90 %
  - CO₂ concentrations over 90 %

- Feasibility for cement plant application will be investigated at pilot plant scale
  - Effect of high CO₂ flue gas concentration
  - Influence of make-up ratio, sorbent looping ratio
  - Optimal operation conditions
Thank you for your attention!

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Thank you for your interest!

Any Questions?

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