University of Stuttgart

Institute of Combustion and Power Plant Technology

Prof. Dr. techn. G. Scheffknecht

University of Stuttgart

Calcium looping for CO_2 capture in cement plants — pilot scale test

Matthias Hornberger*, Reinhold Spörl, Günter Scheffknecht

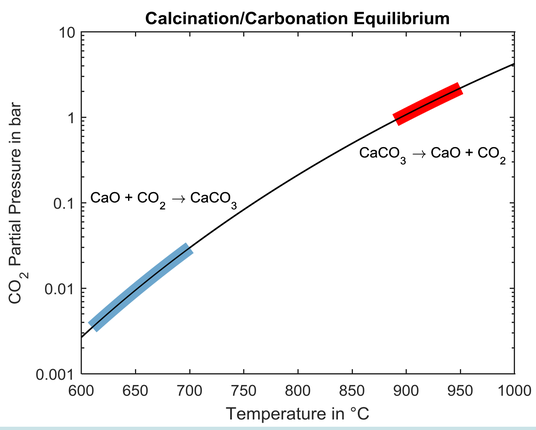
Introduction

- Cement industry is responsible for approx. 5 % of global anthropogenic CO_2 emissions
- CCS/CCU technologies shall reduce CO_2 emissions to mitigate climate change
- Calcium looping is a promising post combustion CCS technology for cement industry

Calcium Looping

- Calcium looping is based on the cyclic calcination and carbonation of $CaCO_3$
- Oxy-fuel calcination leads to CO_2-rich exhaust stream ready for sequestration or utilization
- Supply of high quality energy suitable for efficient power generation or heat integration
- Low CO_2 avoiding costs due to energy integration
- Spent calcium looping sorbent can be (re)utilized in the cement process reducing its original CO_2 flue gas concentration

Calcium Looping Operation Conditions

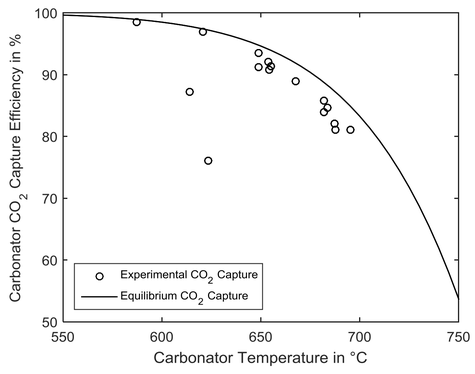


- Oxy-fuel calcination of $CaCO_3$ requires temperatures around 900 °C
- Compromise between reaction kinetics and equilibrium partial pressure leads to carbonation temperature around 650 °C
- Efficient recuperation of required heat due to high temperature level
- High specific amount of fresh sorbent due to utilization in cement production

Results

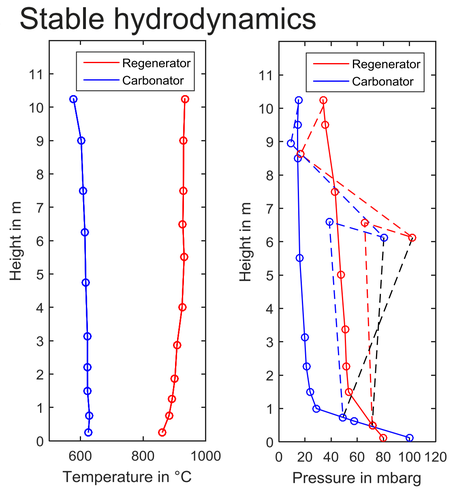
CO_2 capture performance

- CO_2 capture rates above 90 % for carbonator temperature below 650 °C and sufficient space time / looping ratio
- CO_2 capture rates near equilibrium capture rates achieved



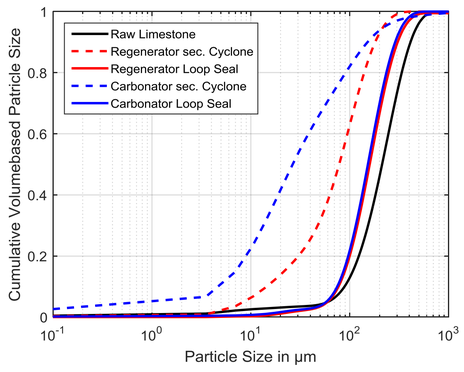
Temperature and hydrodynamic profiles

- Isothermal temperature profiles
- Stable hydrodynamics



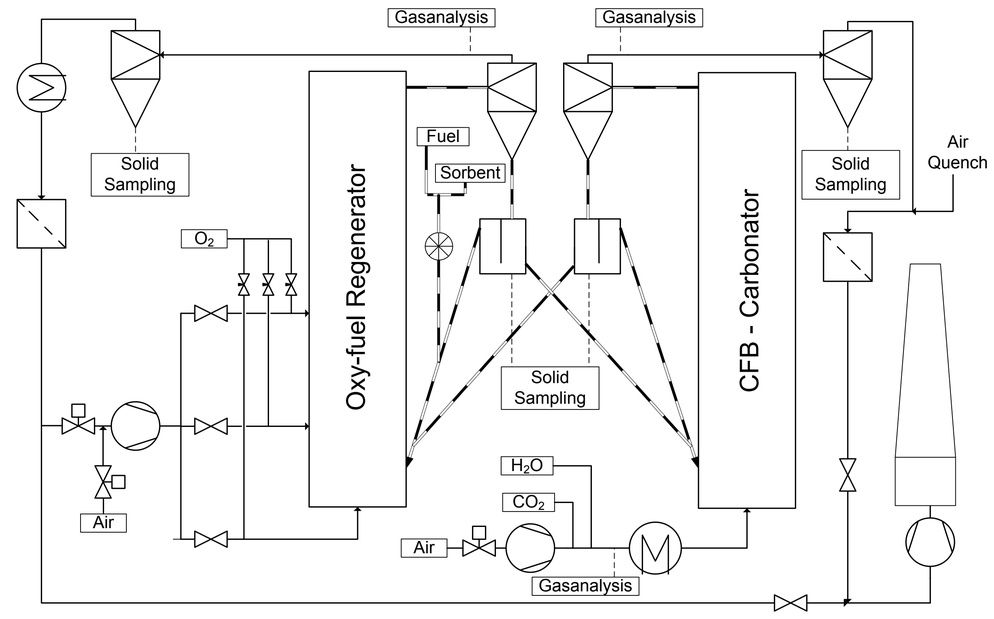
Particle size

- Reduced particle size due to attrition



Experimental Setup

CFB-CFB configuration of 200 kW_{th} pilot plant (IFK, University of Stuttgart)



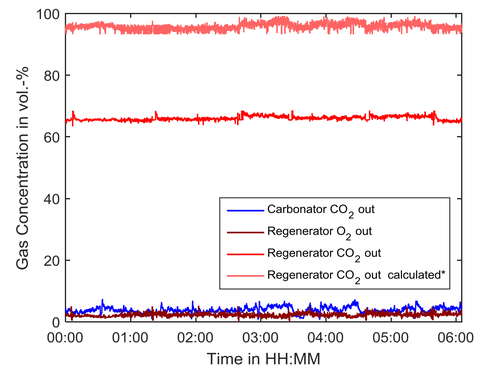
- Refractory lined interconnected circulating fluidized bed reactors (h = 10 m, d_i = 20 cm)
- Oxy-fuel calcination with recycled flue gas (wet)
- Synthetic flue gas mixture (CO_2, H_2O, air) is fed to the carbonator
- Transfer flow controlled by cone valves
- Online gas measurement: CO_2, CO, NO, NO_2, SO_2, H_2, H_2O

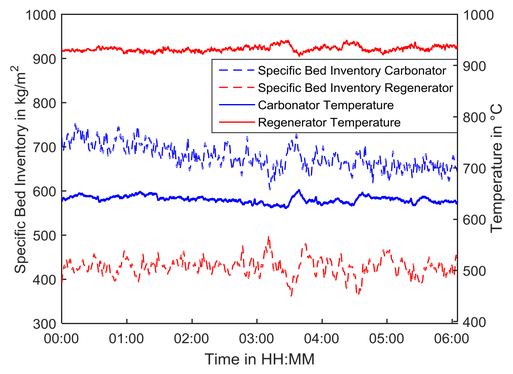
Experimental Conditions

- Calcination temperature: T_{Calc} = 890 … 930 °C
- Carbonation temperature: T_{Carb} = 600 … 700 °C
- Space time: N_{Ca} / $\dot{N}_{CO2}$ = 1.2 … 2 h
- Makeup Ratio: $\dot{N}_{Ca,0}$ / $\dot{N}_{CO2}$ = 0.5 … 0.8
- Looping Ratio: $\dot{N}_{Ca}$ / $\dot{N}_{CO2}$ = 7 … 19
- At least 1 h of steady state operation for each experimental point
- Sorbent analysis by TGA as well as major and trace elementary analysis
- CO_2 flue gas concentration 15 % - assuming cement plants raw meal is completely calcined in calcium looping

Process Demonstration

6 h extract of stable operation during 120 h experimental campaign





*) calculated assuming measurement ports are purged with recycled flue gas and exhaust gas is dried

Summary and Discussion

- Investigation of calcium looping process highly integrated into a cement plant resulting in CO_2 flue gas concentration of 15 % and high makeup ratios
- Stable operation was achived, yielding high CO_2 capture rates (> 90 % over wide parameter range)
- Uniform reaction condition in calciner and carbonator due to isothermal reactor temperature
- High CO_2 concentration in regenerator exhaust stream

Outlook

- Investigation of lower integrated calcium looping options resulting in
  - CO_2 concentrations up to 35 %
  - lower makeup ratios
- Measurement of impurities (N_2O, NO_x, etc.) in regenerator relevant for CO_2 compression

Acknowledgements

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 641185.

Disclaimer: The European Commission support for the production of this publication does not constitute endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein

Contact: M.Sc. Matthias Hornberger matthias.hornberger@ifk.uni-stuttgart.de Tel.: +49 (0) 711 685 67801 University of Stuttgart, Germany