Study of the post-combustion CO₂ capture applied to conventional and partial oxy-fuel cement plants

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Context of the study: CCU (Carbon Capture and Re-Use)

In the context of Carbon Capture Storage (CCS) or utilization (CCU), this work evaluates the application of the post-combustion CO₂ capture in cement plants using novel solvents carrying from conventional co-current contactors and for the best solvents, experimental studies were conducted at lab scale. The strategy of the study was to carry out a screening study of solvents and the best ones were selected for pilot test and then for the best solvents, a semi-continuous test was conducted in the regenerator of a pilot unit to evaluate the CO₂ capture performances. In this study, two different micro-pilot tests are presented to compare the absorption performances of the solvents in a wide range of CO₂ contents (from 20 to 60 vol%). Simulations were also conducted with Aspen Hysys™ of the application of the CO₂ capture processes in high CO₂ concentration flue gas in order to estimate the energy savings linked to the partial oxy-fuel conditions.

Experiments: Experimental devices, procedures & absorption results

Lab scale: cables-bundle contactor

Two types of tests conducted:
- Continuous tests: fresh mixing solutions (CO₂-loaded solutions at the onset of the contactor) and a gas phase continuously fed in the contactor with varying CO₂ content (30, from 10 to 60 vol.%).
- Semi-continuous tests: recirculation of 1.28 m³ of the solution fixing a CO₂ inlet content of 40 vol.% in the gas phase and allowing a progression of CO₂ loading of the solvent and following the temporal evolution of the absorption performance.

Results of the continuous absorption tests:

Comparison of the absorption performances of the solvents at different CO₂ contents into the gas phase (unloaded solutions):

Activated solutions

Activated solutions

Results of the semi-continuous absorption tests:

Comparison of the absorption performances of the solvents at different experimental times (Gₐ₁₅ = 48%):

Activated solutions

Micro-pilot scale: Absorption-regeneration micro-pilot unit

Experimental procedure: after neutralisation, the aqueous solution composed of nitroglycerin and carbon dioxide enters the absorption columns where a counter-current contact is made between this gas mixture and the absorption solution, which is achieved at atmospheric pressure. The CO₂-loaded solution at the outlet of the absorption column is then pumped ("external heat exchanger") positioned between the two columns through which the rich and lean solution flow countercurrently through the regenerator column, where by heating the solution to its boiling point (maximum heating power of 2 kW), the CO₂ is liberated from the solution, regenerating the solvent which is pumped back to the absorption columns.

Micro-pilot unit (Figure):

Operating conditions:

Results of the micro-pilot absorption tests:

For the three selected solutions, the equal flow rate of 5.11 m³/h was fixed at the beginning of the tests leading to a similar absorption efficiency (Gₐ₁₅) of around 98%.

Simulations: Aspen Hysys™ simulations of the absorption-regeneration CO₂ capture process

Aspen Hysys™ flow sheet for the conventional MEA 60% process configuration:

Flue gas compositions:

Conclusions & prospects:

Simulations results for the micro-pilot tests:

An increase in Gₐ₁₅ leads to a significant decrease of the regeneration energy consumption. For the most favourable case, it can be seen that an increase of Pₚ₂₃ from 20% to 60% decreases the regeneration energy from 3.66 to 2.48 MJ/kg CO₂.

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