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Tracks 1 and 2 : Post-Combustion Capture by Amine Scrubbing

UMONS communications for remote presentations

(ideally during the morning at Austin, the earliest possible)

Study of the post-combustion CO_2 capture applied to cement plant flue gases with high CO_2 contents

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Post-combustion CO_2 capture using amine-based chemical absorption is a mature and industrially developed technology which has been proved to be efficient but the solvent regeneration step requires a high-intensive energy consumption. An alternative solution for CO_2 capture is the post-combustion capture applied to kilns working under enriched O_2-combustion which leads to a more CO_2-concentrated flue gas compared to the conventional one and which allows further reductions on the overall energy consumption thanks to the choice of an adequate solvent and the reduction of the energy costs for the Air Separation Unit (ASU) in comparison with total oxy-fuel conditions (lower quantity of O_2 needed). This technology has been validated for the application to power plants (see ECO-SCRUB European Project) and thus, in order to evaluate its potential for the cement industry, the aim of this work is to focus on cement flue gases compositions for conventional kilns (y_{CO2} from 15 to 30%) but also for partial oxy-fuel kiln conditions (y_{CO2} up to 60%) which is clearly innovative in comparison with the available results in literature. More precisely, the present communication involves the evaluation of solvent performances at high CO_2 contents including hybrid solvents (blends between an amine based solvent and a physical component) and also the Aspen Hysys™ simulations of the absorption-regeneration process using MEA 30 wt.% in order to quantify the impact of higher CO_2 contents in the gas to treat on the solvent regeneration energy.

The lab scale experimental device used for the absorption tests (at 25°C) is a cables-bundle contactor composed by vertical yarns that allow the contact between the gas and the liquid. In order to measure the amount of CO_2 absorbed by the solvents ($G_{CO2,abs}$), the gas phase was analyzed by an Infrared gas analyzer and the liquid phase was analyzed in terms of Total and Inorganic Carbons (TC and IC), the pH of the solvents being also measured. Both continuous tests (unloaded solutions) and semi-continuous tests (recirculation of the solution leading to an increasing CO_2 loading) were performed with different solvents: primary and secondary alkanolamines (Monoethanolamine (MEA), Diethanolamine (DEA) and Methylmonoethanolamine (MMEA)), cyclical di-amines (Piperazine (PZ)) and non-cyclical tetramines (Triethylenetetramine (TETRA)). The positive activation effect on the absorption performances was also highlighted during these tests (activation with PZ 5% or TETRA 5%) and the hybrid solvents tested were composed of a physical solvent (an acetal in the present case, namely TOU - 2,5,7,10 -Tetraoxaundecane) and a chemical solvent (such as for example MEA).

It was shown that the ranking of the solvents based on their $G_{CO2,abs}$ is modified during the semi-continuous test due to the CO_2 loading. For example, even if MMEA 30% (simple and activated solutions) presented the best absorption performances without any CO_2 loading, TETRA 30% is the solvent which presented the highest $G_{CO2,abs}$ with significant CO_2 loadings. The use of a hybrid solvent such as MEA 30% + TOU 35% seems also competitive with activated solutions as it showed better absorption performances than MEA 30 wt.% or other conventional solvents. Regarding the simulation results, it was highlighted that an increase of y_{CO2} from 20% to 44% leads to a decrease of 24% of the MEA 30 wt.% regeneration energy (from 3.4 to 2.6 GJ/t_{CO2}).

Further works on this topic will include the continuation of the screening tests with different solvents and especially hybrid ones. Combined absorption-regeneration tests with a micro-pilot unit and other simulations (including the energy costs for O_2 production) will be also scheduled in order to have a more global evaluation of the solvent performances under partial oxy-fuel conditions.

Simulations of various configurations of the post-combustion CO_2 capture process applied to a cement plant flue gas: parametric study with MEA 30 wt.%

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Carbon Capture Storage and Utilization (CCSU) has gained widespread attention as an option for reducing greenhouse gas emissions from power plants but specific developments are still needed for the application to cement plants (flue gas with higher CO_2 content in comparison with power plants ones). More precisely, the post-combustion CO_2 capture process by absorption-regeneration using amine based solvents is the more mature technology for the application in the cement industry but it is still needed to reduce its costs.

The present study is focusing on the Aspen Hysys^{TM} simulation of different CO_2 capture process configurations (namely “Rich Solvent Recycle” (RSR), “Solvent Split Flow” (SSF), “Lean/Rich Vapor Compression” (L/RVC)) applied to the flue gas coming from the Norcem Brevik cement plant (Norway) where different post-combustion CO_2 capture technologies are tested and especially the absorption-regeneration process (Aker Clean Carbon technology). For each configuration a parametric study was carried out in order to identify the operating conditions ($(L/G)_{vol.}$ ratio, split fraction, flash pressure drop, etc.) minimizing the solvent regeneration energy (E_{regen}) and allowing to highlight the interest of using alternative process configurations in order to reduce the energy consumption of the process.
The simulations were carried out considering a pilot unit used during a previous European project, namely the CASTOR/CESAR one (designed to handle a flow of 5000 Nm^3/h, all the design and operating parameters being available). In a first step, these simulations were performed considering the benchmark monoethanolamine (MEA) 30 wt.% as solvent but in a second step, other solvents will be considered. The modeling was developed in Aspen Hysys^{TM} v.8.6 software using the acid gas package and the conventional “efficiency mode”. The CO_2 recovered purity was fixed at 98 mol.% and the absorption ratio was equal to 90 mol.%.

Among the different process configurations simulated with MEA 30 wt.% as solvent and considering the optimum operating parameters, it was shown that the heat pump modifications (namely LVC and RVC process modifications) give the best regeneration energy savings (around 14%) leading to E_{regen} lower than 3 GJ/t_{CO2} (namely 2.9 GJ/t_{CO2}). Regarding the two other categories, namely absorption enhancement (RSR) and the exergetic integration (SSF), smaller energy savings were measured (between 4 and 8 %) which can be justified by the fact that even with the conventional process configuration, the rich CO_2 loading of the MEA 30 wt.% was close to its equilibrium value, thus the potential for increasing this loading is very limited (which is normally the purpose of RSR configuration for example). Concerning the SSF one, the major advantage identified was linked to the decrease of the condenser cooling energy (which is also clearly decreased thanks to the LVC configuration). Finally, even if not negligible, the pumping and LVC/RVC compressor energy consumptions have an order of magnitude clearly lower than the regeneration energy.

As perspectives, other solvents will be considered for future simulations, such as piperazine (PZ) alone or used as absorption activator (aMDEA), because the energy savings linked to the use of alternative configurations strongly depend on the solvent properties. Other configurations will be also investigated such as the combination of two configurations (for example RSR and RVC). Finally, in addition to the interest in terms of OPEX, the consequence in terms of CAPEX will have to be estimated in order to be able to evaluate more precisely the global economic interest of using alternative process configurations, especially for the application to cement plant flue gases.