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Comparison of different solvents and configurations for the Post Combustion CO_2 capture applied to cement plant flue gases

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Abstract

In the context of reducing the energy consumption of the post-combustion CO_2 capture process by absorption-regeneration using amine(s)-based solvents, and complementary to the development of new solvents (e.g. demixing solvents, non-aqueous solvents, etc.) and equipment (e.g. advanced packings, new gas-liquid contactors, etc.), implementing alternative process configurations is an efficient way to reduce the CO_2 capture costs through the decrease of the solvent regeneration energy. Moreover, even if several studies have already considered other process configurations in order to reduce the CO_2 capture costs, most of the time only monoethanolamine (MEA) 30 wt.% as solvent was considered, the configurations were not necessarily combined with an inter-cooled absorber (ICA) and the flue gases considered were representative of power plants (flue gas CO_2 content (y_{CO2}) in the range 5-15 vol.%).

Based on these statements, and as the absorption-regeneration process using amine(s)-based solvents is the most mature post-combustion CO_2 capture technology for the application in the cement industry, the present work focused on the Aspen Hysys^{TM} simulations of different CO_2 capture process configurations combined with ICA, namely "Lean Vapor Compression" (LVC) and "Rich Vapor Compression" (RVC) (see illustration on Fig. 1), considering a flue gas representative of this industry ($y_{CO2,in}$ equal to 20 vol.%). The investigations were performed for four different solvents: two simple solvents (namely MEA 30 wt.% and piperazine (PZ) 40 wt.%) and two activated blends (namely methyldiethanolamine (MDEA) and diethanolamine (DEA) blended with PZ). For each solvent and configuration, a parametric study was carried out in order to identify the operating conditions (e.g. liquid to gas flow rates volumetric ratio) 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 impact of implementing intercooling in the absorber was more specifically investigated. The modeling was developed in Aspen Hysys^{TM} v.10.0 software using the acid gas package, considering a CO_2 recovered purity fixed at 98 mol.% and an absorption ratio of 90 mol.%. The design and dimensioning of the CO_2 capture installation considered was based on CASTOR/CESAR European Project one for comparison purposes with previous works. The results analysis was based on E_{regen}, but also on other energy consumptions (e.g. compression electrical consumptions for LVC/RVC configurations), on equivalent work and on operating costs (using Aspen Economics^{TM} module in Aspen Hysys^{TM}).

In addition to the comparisons of solvents and configurations, the results sensitivity linked to the choice of the calculation mode ("Efficiency" or "Advanced Modelling"), and of the mass transfer and interfacial area calculation methods (e.g. Onda and Bravo-Fair) was also investigated in order to properly evaluate the impact of some user choices on the simulation results.

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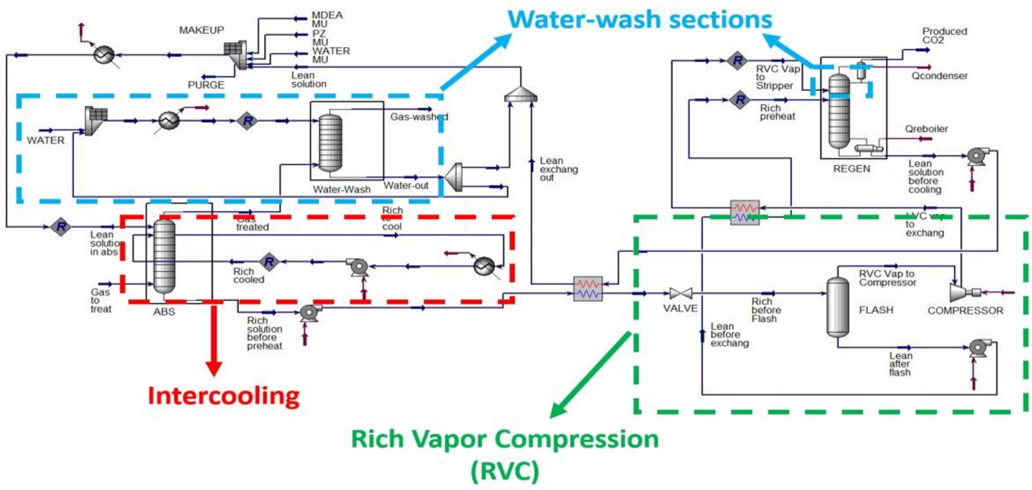

Fig. 1. Illustration of the RVC process configuration combined with ICA and water-wash sections for MDEA+PZ

Considering the operating parameters minimizing E_{regen}, the RVC (heat pump-type modification) process configuration combined with ICA lead to the highest energy savings with both MDEA+PZ and DEA+PZ solvents (see Fig. 2). More precisely, in such cases, E_{regen} was decreased to around 2.2 GJ/t_{CO2} corresponding to 35% energy savings in comparison with the base case (MEA 30 wt.% as solvent with conventional CO_2 capture process configuration). Focusing more specifically on the effect of adding intercooling to both conventional and alternative configurations, it can be seen on Fig. 2 that in all cases, ICA implementation lead to a decrease of the solvent regeneration energy. Furthermore, it was also pointed out that in comparison with available literature (application to power plant flue gases), the higher CO_2 content in the cement plant flue gases tends to lower E_{regen} values and also to higher regeneration energy savings thanks to the implementation of an advanced CO_2 capture process (alternative process configuration and activated-solutions as solvents).

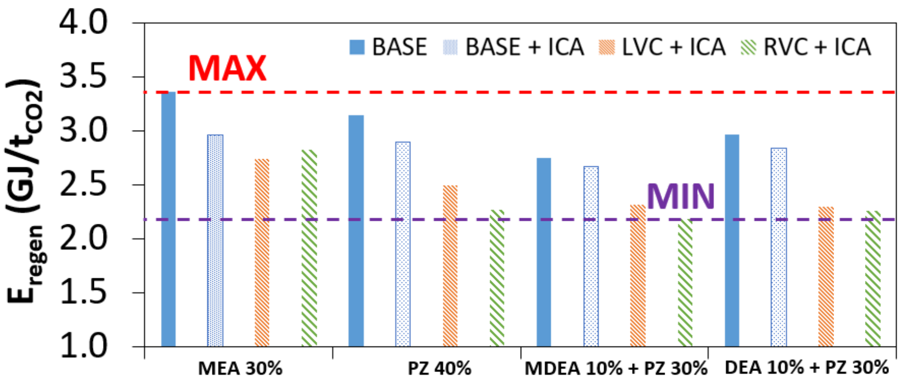

Fig. 2. Summary of the simulation results for different process configurations and solvents

Concerning the simulation results considering different mass transfer and interfacial area calculation methods, for example comparing Onda and Bravo-Fair methods for the mass transfer calculation, it was shown that even if not negligible (up to 5% relative difference in terms of E_{regen} depending on the method), the impact of the choice of these methods was quite similar in all cases and thus that would not significantly change the results comparison in terms of configurations and solvents (only the absolute value of E_{regen} could be slightly different).

Keywords: Process configurations; Aspen Hysys[TM] simulations; Cement plant flue gases