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Techno-economic comparison of different configurations, including demixing solvent, for the absorption-regeneration process applied to cement plant flue gases

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Abstract

In the context of CCUS (Carbon Capture Utilization and/or Storage) implementation in different sectors like the cement industry, reducing the capture costs, especially of the post-combustion CO_2 capture process by absorption-regeneration, is still a challenge. Among the solutions already investigated for such purpose (e.g. implementation of advanced process configurations [1], integration with an exothermal CO_2 conversion process [2], etc.), the demixing solvents technology appears as a very promising option to significantly reduce the thermal energy consumption of the process without impacting too much the equipment investment [3]. Indeed, thanks to the separation of the two immiscible phases formed after the CO_2 absorption, a demixing technology allows to regenerate a lower solvent flow rate with a higher CO_2 loading in comparison with non-demixing solutions. Nevertheless, a question arises: is there any interest of combining the use of a demixing solvent process with a process configuration like L/RVC (Lean/Rich Vapor Compression)? In comparison with two reference cases (conventional MEA (monoethanolamine) 30 wt.% process and an advanced process configuration (RVC with Inter-Cooled Absorber (ICA) and Rich Solvent Splitting and Preheating (RSSP), with MDEA (methyldiethanolamine) – PZ (piperazine) 40 wt.% blend), a techno-economic study was performed for a demixing process (DEEA (diethylethanolamine) + MAPA (methyl-amino-propylamine) blend [4-5]). It is worth mentioning that even if promising demixing solvents are still under investigation, especially less volatile and degradable than DEEA+MAPA blend, such solution is a relevant demixing process reference in terms of thermal energy consumption. In addition to the demixing process including only ICA and a decanter as new equipment, the combination with a LVC or RVC was investigated in order to quantify the eventual interest of such kind of combination. The process configurations were modeled using Aspen Plus™ V12.1 software considering a reference cement plant as case study (3 000 tons of clinker per day, 250 000 m^3/h flue gas flow rate containing 20 mol.% of CO_2). In order to carry out a relevant techno-economic comparison between the different cases, the simulations were performed considering the same calculation hypotheses and the same boundaries (including flue gas cooling in a Direct Contact Cooler (DCC) and the compression of the captured CO_2).

It was pointed out that the lowest solvent regeneration energy (1.90 GJ/t_{CO2}) was obtained with the demixing process combined with a LVC (DEMIX-LVC), corresponding to a decrease of 5% in comparison with the demixing process alone (2.00 GJ/t_{CO2}), while the combination with a RVC (DEMIX-RVC) does not lead to a measurable gain. Relatively to the conventional MEA process (3.36 GJ/tCO_2), both the demixing processes and the advanced process configuration (1.97 GJ/t_{CO2}) allow to reduce the regeneration duty by more than 40% (see Fig. 2 (left)). Nevertheless, on an economical point of view, it was highlighted that the regeneration duty savings linked to the LVC addition on the demixing process does not counterbalance the equipment cost and electricity consumption increases linked to the addition of a compressor for the LVC configuration. Therefore (see Fig. 2 (right)) the demixing

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process alone leads to the lowest capture costs (57.72 €/t_{CO2}), while the advanced process configuration allows to obtain a capture cost (60.39 €/t_{CO2}) lower than the combined demixing-LVC/RVC processes. These conclusions can be partially linked to the lowest solvent flow rate going to the stripping column in the case of a demixing process, meaning that the potential for vapor generation thanks to a LVC/RVC is lower than with a non-demixing process.

Therefore, it was shown that to keep the economical advantage of a demixing process, the combination with a LVC or RVC process configuration seems not to be an option to be further investigated to obtain supplementary economic savings. The investigations of other demixing processes is still under progress in order to propose relevant alternatives to DEEA+MAPA blends.

Figures

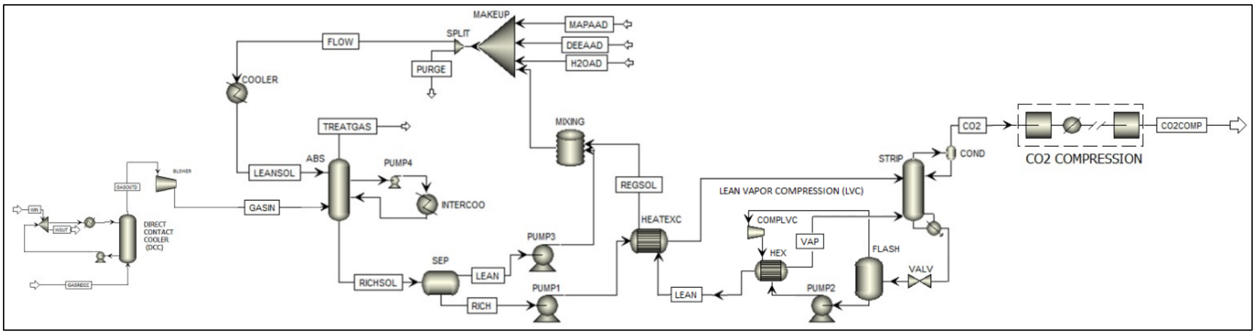

Fig. 1 Aspen Plus^{TM} flow sheet of the demixing CO_2 capture process (DEEA+MAPA as solvent) combined with Lean Vapor Compression (LVC)

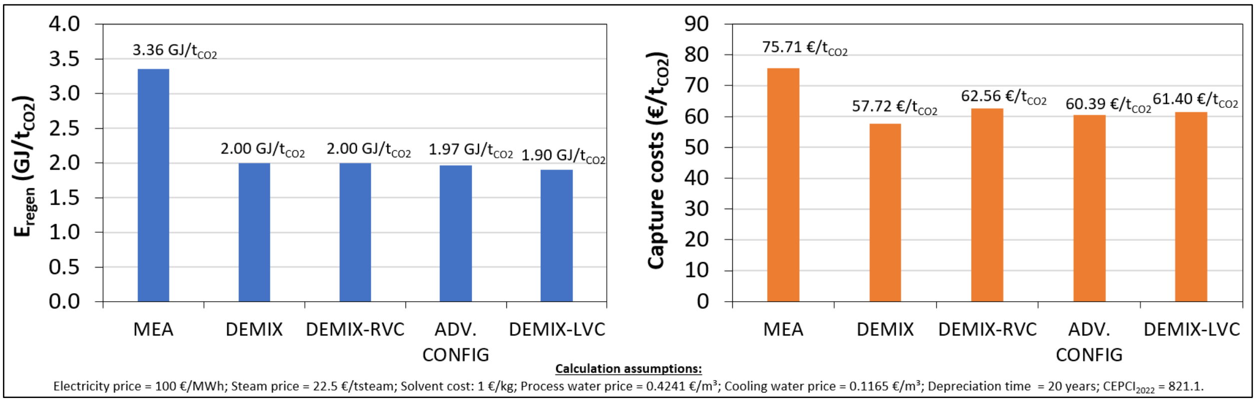

Fig. 2 Techno-economic results in terms of solvent regeneration energy (left) and total CO_2 capture costs (right)

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Keywords: Post-combustion CO_2 capture; Absorption-regeneration process ; Aspen Plus^{TM} simulation; Demixing solvent; Process configurations.

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