**Stripping of CO₂ in post-combustion capture with chemical solvents: intensification potential of hollow fibre membrane contactors**

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Post-combustion CO₂ capture (PCC) is an important strategy in mitigating greenhouse effect. The robustness of packed columns makes it the standard technology for the gas-liquid absorption of CO₂, using aqueous amine solutions as liquid absorbents. Even though it is not the best performing chemical solvent, monoethanolamine (MEA) at 30% wt. is currently considered as the benchmark solvent for PCC [1]. However, the treatment of large quantities of flue gases requires itself equipment of a large size. Hollow fibre membrane contactors (HFMC) are considered as one of the most promising strategies for intensified CO₂ absorption process, due to their significantly higher interfacial area than that of packed columns, allowing to reduce the equipment size [2].

To date, most investigations of HFMC for PCC have focused on the absorption section of the process [3] and the number of studies dedicated to the stripping of CO₂ using HFMC is very limited. CO₂ stripping is industrially performed using sweep gas generated by a partial evaporation of the liquid absorbent at high temperature (e.g. 120°C), as illustrated in Figure 1a. HFMC technology is difficult to implement as choices for suitable membrane materials that can withstand high temperatures are limited. To our knowledge, its application using HFMC has not been addressed in the literature. Alternatively and in order to promote HFMC technology, low temperature stripping based on applying vacuum to the gas phase, as illustrated in Figure 1b, has been proposed [4]–[6].

Even if significant challenges exist from material point of view (resistant to high temperature, to chemical attack and wetting), is this technology capable of intensifying high temperature stripping? In addition, are the intensification potentials of high and low temperature stripping comparable? To answer these questions, adiabatic multicomponent one-dimensional models have been developed to estimate the performance of the stripping step for both high and low temperature stripping techniques using HFMC and packed columns. The modelling of both technologies is based on coupled mass and heat transfer balances. Indeed, this is standard in packed columns modelling, however, neglecting the thermal effects appears to be common in HFMC modelling [7], [8].

The two stripping techniques were therefore compared against the conventional CO₂ stripping process using packed columns. The comparison was performed by calculating the intensification factor, defined as the ratio between the volumes of packed column and HFMC required to satisfy CO₂ absorption specifications (i.e. to desorb the same amount of CO₂ absorbed). Furthermore, since the operating conditions are different between low and high temperature stripping, both techniques were compared with respect to the equivalent work. The latter corresponds to the electric work that would be obtained by the steam that is used to supply the thermal energy, plus the electric work of compressor/vacuum and pumping.

The Esbjerg pilot plant has been taken as reference for the operation with packed columns. The modelling of the latter led to good agreement between experimental data and model predictions, as
illustrated in Figure 2a and 2b. Figure 3 shows the equivalent work as function of the intensification factor for both high and low temperature stripping techniques. HFMC implementation for high temperature stripping is a promising technology as intensification factors of nearly 10 might be achieved, provided that membranes can resist high temperatures and are equally resistant to wetting. Membrane wetting, simulated by increasing membrane mass-transfer resistance in one order of magnitude (not shown in Figure 3), removes the intensification potential of HFMC. Low temperature stripping requires more energy if similar intensification factors to those of high temperature stripping using HFMC are desired.

It is worth noting that these results are based on the performance of a given packed column, i.e. IMPT-50 packing. Advancements in packed bed technology are also expected, thus the intensification potentials identified here may be affected.

![Figure 1 Schematic representation of the process of CO₂ capture by chemical solvents using HFMC for the stripping step. a) High temperature stripping technique, b) Low temperature stripping technique.](image1)

![Figure 2 Validation of the stripping section simulation of the Esbjerg pilot plant. Solid and dotted lines: model predictions. Dots: experimental data. a) Temperature profile of the stripper for the Run 1A, b) parity plot of regeneration factor for the CASTOR campaign](image2)
Figure 3 Equivalent work of low and high temperature stripping as function of intensification factor for different vacuum pressures.

Equivalent membrane mass-transfer coefficient of $10^{-3}$ m/s

References


