INTENSIFIED POST-COMBUSTION CO_2 CAPTURE: POTENTIAL OF HOLLOW FIBER MEMBRANE CONTACTOR FOR ABSORPTION AND STRIPPING STEPS

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Post-combustion CO_2 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 CO_2, 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 CO_2 absorption process, due to their significantly higher interfacial area than that of packed columns, allowing to reduce the equipment size [2].

HFMC technology has been widely investigated for the absorption step under laboratory conditions (e.g. high reactant excess) [3]. However, despite the potential advantages of membrane contactors, very few investigations have studied implementing this technology within an industrial framework. The performance of CO_2 absorption and stripping using HFMC under industrial conditions is still unknown. To fill this lack, adiabatic multicomponent one-dimensional models have been developed to estimate the performance of both absorption and stripping steps 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 [4], [5]. The intensification potential of HFMC for both absorption and stripping steps was therefore estimated in industrial conditions.

To represent industrial conditions, the Esbjerg pilot plant has been taken as reference for both absorption and stripping operations with packed columns. The modelling of the latter led to good agreement between experimental data and model predictions. For the absorption step using HFMC, significant axial temperature variations, up to 30 °C, as well as transmembrane reversal flux of the solvent, corresponding to solvent condensation and evaporation, were predicted. Under such conditions, membrane wetting due to capillary condensation was found likely to occur, which would decrease dramatically the contactor mass-transfer performance. Provided that the membrane mass-transfer coefficient is higher than $5{\cdot}10^{-3}$ ms^{-1}, CO_2 specific absorbed fluxes from 2 to 10 $molm^{-3}s^{-1}$ could be attained, for fibre external radius varying between 400 and 100 µm, and fibre thickness between 80 and 20 µm, respectively. This corresponds roughly to volumetric contactor reduction factors comprised between 2 and 10. For the stripping step, three techniques were investigated: High-Temperature Stripping (HTS) using packed columns and high- and Low-Temperature Stripping (LTS) using HFMC. The latter has been proposed to promote HFMC implementation [6]–[8]. Compared to HTS using packed columns, simulations revealed that HTS by means of HFMC, which to our knowledge have to date not been investigated, were shown to potentially reduce the stripper volume by a factor of 10, provided that the membranes are resistant to high temperatures and wetting. Finally, LTS proved to require more energy if similar volumetric contactor reduction factors to those of HTS using HFMC are desired.

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