How temperature and pressure mediate mass transfer in microporous and dense-skin hollow fibre membrane contactors for CO_2 absorption

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Abstract:

Hollow fibre membrane contactors (HFMC) are an emerging technology for CO_2 capture. Microporous HFMC promote high mass transfer but pore wetting can increase membrane resistance. Adding a dense polymer-film to the hollow fibre can prevent wetting, but this increases membrane resistance which can be practically prohibitive (depending on thickness and permeability). Absorbent temperature and operating pressure are factors that can improve CO_2 mass transport. While several HFMC studies sought to establish their role on mass transfer, temperature and pressure can also be expected to mitigate membrane resistance in dense-films increasing viability, while exposure to such conditions, may also increase the value of dense polymers over microporous membranes due to the improved robustness to wetting. Consequently, this study directly compares an asymmetrically structured polymethylpentene (PMP) HFMC, comprising a 1μm film to a microporous HFMC, exposed to a practically relevant range of absorbent temperatures and pressures.

Membrane resistance in microporous HFMC increased at higher operating temperatures, which was attributed to partial pore wetting via capillary condensation, due to increasing vapour pressure. However, as CO_2 diffusivity in water exponentially increased with temperature, membrane resistance did not increase above 20°C. For the dense-skin HFMC, membrane resistance decreased at higher temperatures due to the improved permeability. However, this was lower than expected due to the competitive sorption of water vapour within the polymer. Consequently, the PMP membrane mass transfer coefficient was 4.3-times lower than for microporous HFMC with partially wetted pores. Flux enhancement was proportional to pressure, independent of membrane type. However, pressure is beneficial to product purity, reducing solvent flow to regeneration, and minimising membrane area. Provided transmembrane pressure was sustained in the microporous HFMC, increased wetting was not observed with an increase in pressure. Temperature and pressure benefit CO_2 separation but thinner higher permeability films are needed to compete with microporous HFMC.

Keywords: CO_2 capture; biogas upgrading; CCS; membrane contactor optimisation; thin-film composite