Will vortex units be the next generation of process intensification equipment for CO_2 capture?

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Highlights

- Process intensification of CO_2 capture achieved using vortex technology
- Superior mixing and mass transfer efficiency confirmed.
- Computational fluid dynamics used to optimize the design.
- CAPEX and OPEX reduction both in absorption and desorption.

1. Introduction

Process intensification (PI) plays an essential role in the new paradigm of chemical engineering [1]. Components of PI include PI equipment and PI methods, which are complementary to the development of each other. In the context of the CO_2 capture industry, the state-of-the-art technologies are characterized by high operating expenditures (OPEX) and capital expenditures (CAPEX) mainly due to significant energy requirements for solvent regeneration [OPEX] and large equipment sizes [CAPEX]. To tackle these challenges, in parallel with developing new and greener solvents (new kinetics), developing new absorption/desorption units (new equipment) is believed to be one of the most effective ways [2].

2. Methods

A methodology for the development of PI equipment is employed in this work [3], consisting of three parts: lab-scale fundamental experiments, computational fluid dynamics (CFD) simulations & optimization, and process simulations & assessment.

3. Results and discussion

A vortex unit design for CO_2 capture application has been optimized via high performance computing-based computational fluid dynamics (CFD). This methodology allowed to analyse the gas-liquid flow characteristics, contact time and total energy consumption in different vortex unit geometries. The effects of geometrical changes including reactor shape, reactor volume and gas-liquid inlet configuration are investigated. As shown in Figure 1, from a large number of CFD simulations, the best designs have been selected and manufactured, aiming for an optimal gas-liquid contact in a solvent-based CO_2 capture context.

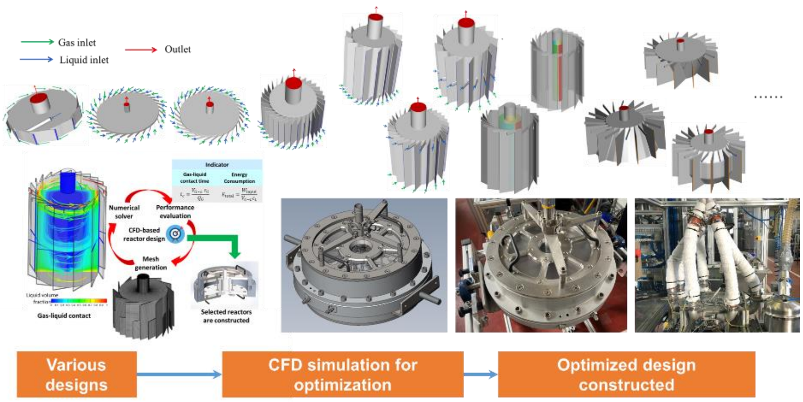

Figure 1. Design of a vortex unit for CO_2 capture based on CFD

Our previous work has confirmed that the vortex unit shows superior performance in terms of effective specific interfacial area and volumetric mass transfer coefficient, which are the transport limiting factors in CO_2 capture process [4]. For further benchmarking activities of the vortex technology for CO_2 absorption and desorption, 30 wt% MEA has been selected as the reference solvent. Figure 2 shows the key results from the most recent experiments. (i) Absorption: A CO_2 capture efficiency >80% is achieved based on 30 wt% MEA with a diluted stream of CO_2 concentration of 5%. This is associated with a processed gas flow rate of 20 Nm3/h and reactor volume of only 240 mL, which will eventually translate into significant reduction of CAPEX. (ii) Desorption: A regeneration efficiency > 70% is achieved under direct stripping, without a reboiler, with a processed rich solvent flow rate of 20kg/h and reactor volume of 75 mL. The carbon capture cost for vortex technology was then estimated as a function of the electricity cost. This cost is compared to a benchmark, conventional absorption with the Fluor process. This confirms the qualitative assumption that the sum of CAPEX and OPEX for the vortex technology is lower than for conventional approaches.

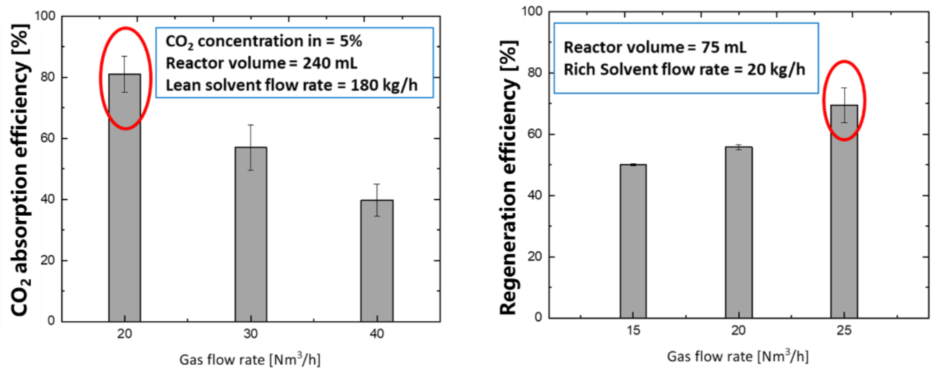

Figure 2 Absorption (a) and desorption (b) in two vortex units based on 30 wt% MEA solvent

4. Conclusions

Using 30 wt% MEA as the reference solvent, >80% absorption efficiency and >70% solvent regeneration efficiency are achieved using vortex units. This advancement results in significant reductions in both CAPEX and OPEX when applying vortex technology in CO_2 capture processes. Future work focuses on solvent assessment and energy assessment in a coupled absorption and desorption process using two vortex units.

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Keywords

CO_2 capture; vortex units; process intensification; multi-scale simulation