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CFD Study of electrified gas-liquid vortex reactor for CO_2 capture

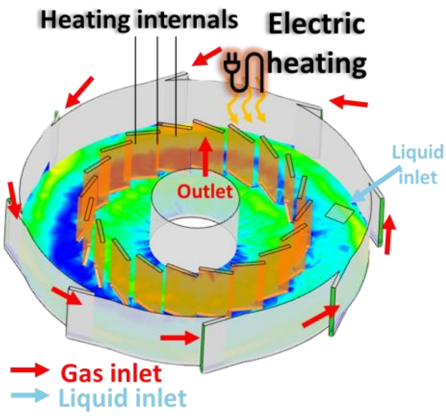
Aim

This thesis investigates the application of electrification in gas-liquid vortex reactors (GLVR) for enhancing solvent regeneration in CO_2 capture processes. The focus is on evaluating the effects of direct and indirect Joule heating on heat and mass transfer, combining experimental techniques with computational fluid dynamics (CFD) simulations.

Justification

The increasing global emphasis on reducing greenhouse gas emissions has highlighted the need for efficient and cost-effective technologies for CO_2 capture. Among various approaches, chemical absorption using amine-based solvents remains one of the most viable options for industrial-scale deployment. However, the solvent regeneration step, crucial for releasing captured CO_2, remains a major bottleneck due to its high energy demand, accounting for the largest share of operational costs[1]. Conventional methods, such as steam-based heating, face challenges like heat losses, uneven temperature distribution, and limited control over the heating process, underscoring the need for more efficient alternatives.

Electrification, specifically through Joule heating, offers a transformative solution by enabling precise, localized energy delivery with minimal losses. Joule heating[2] eliminates temperature gradients and allows for rapid thermal response, making it particularly suited for energy-intensive processes like solvent regeneration. GLVR, known for its high efficiency in heat and mass transfer, simple design, and scalability[3], presents an excellent platform for integrating Joule heating to further optimize the regeneration process. By combining electrification with the unique hydrodynamics of GLVR, it is possible to enhance interfacial renewal and improve overall process efficiency.



This project aims to evaluate the performance of the electrified GLVR for solvent regeneration using numerical simulations. A CFD model will be developed to simulate the complex interactions of heat and mass transfer under Joule heating. Experimental data will validate the model to ensure its reliability. Subsequently, the model will analyse the effects of various internal configurations within the vortex chamber to optimize energy efficiency and CO_2 desorption rates. This study offers a pathway to sustainable and scalable CO_2 capture technologies.

Program

- Make a literature study on CFD simulation methods for electrified systems.
- Gain acquaintance with the commercial CFD package ANSYS Fluent and with coding UDF.
- Develop and validate a CFD model for reactive CO_2 desorption in the electrified GLVR using experimental data
- Optimize the GLVR design and operating conditions for efficient solvent regeneration.

1. Bougie; et al. Chemical Engineering Science, 2010, 65(16), 4746-4750.
2. Selvam; et al. Nature Communications. 2024, 15(1), 5662.
3. Ouyang; et al. AIChE Journal. 2021:e17264.

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