Separation and Purification Technology 295 (2022) 121248

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

A comprehensive review on the hydrodynamics, mass transfer and chemical absorption of CO_2 and modelling aspects of rotating packed bed

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A R T I C L E I N F O

Keywords:
CO_2 capture
Process intensification
Rotating packed bed
Hydrodynamics
Chemical absorption

A B S T R A C T

CO_2 levels are quickly rising over the world and have a significant impact on climate change. Post-combustion CO_2 capture by chemical absorption is regarded as a widely accepted as well as an efficient technology for mitigating CO_2 emissions from power plants especially fossil fuel-fired ones. Because of the kinetic limitations, high capital costs, low selectivity, and inferior energy efficiency, process intensification of equipment, material, and process development strategies are needed for carbon capture. Rotating Packed Beds (RPBs) have been identified as the most suitable equipment for enhanced post-combustion carbon capture. In the first part of the review paper, the recent developments on the process intensification of post-combustion CO_2 capture using RPBs are updated and discussed. The hydrodynamics as well as the mass transfer characteristics of RPBs are discussed first. The applicability of different correlations reported for hydrodynamic and mass transfer characteristics was analysed. In the second part, the process modelling, computational fluid dynamics(CFD) simulation of single and multiphase flows in RPBs and techno-economic analysis of CO_2 capture using RPBs are also reviewed to accelerate further research toward large-scale implementation.

1. Introduction

The global concentration of CO_2 gas, the main greenhouse gas, has increased rapidly, which results in global warming and climate change. Research communities are working on developing technologies for the efficient reduction of CO_2, and Carbon Capture and Storage (CCS) has been considered as a key strategy in this regard for decades [1]. Pre-combustion capture, post-combustion capture and oxyfuel combustion process are the three basic techniques for carbon capture. Out of the three approaches, post-combustion capture has the advantage that, without any fundamental changes, the prevailing combustion technologies can be used, and can be utilised as a retrofit option to the current power plants. Solvent-based chemical absorption offers immense potential in the post-combustion carbon capture process, in which, the CO_2 absorption process by the solvent is accomplished with the chemical reaction. Solvents like NaOH and ammonia were used earlier, but amine-based solvents such as monoethanolamine (MEA), diethanolamine (DEA) and methyl diethanolamine (MDEA) and their blends are used extensively in recent studies. The blended amines are having enhanced absorption–desorption capacity due to the benefit of different amine groups. The use of piperazine (PZ) as an absorbent and promoter in a mixed amine for CO_2 capture is also studied intensively. When employed as an additive in mixed amine solutions, PZ has been shown to considerably improve CO_2 absorption rates [2]. In addition, the trio-amine systems, i.e., binary-amine is mixed with either primary or secondary amine, have gotten more interest as an alternative CO_2 absorbent blend. Liu et al. [3] investigated MEA/MDEA/AMP (2-amino-2-methyl-1-propanol) trio-amine blends for CO_2 regeneration performance and observed that the trio-amino blends require less desorption time than the dual-amine blends, thereby reducing the heat generation cost. Nwaoha et al. [4] discovered that the blended solvent of three amines consumed less energy for solvent regeneration in comparison with the MEA-AMP-PZ system and also, showed that the absorption capacity is higher for the MEA-AMP-PZ system than that of the PZ-AMP system. Recently Hu et al. [5] reported that the trio-amine system of MEA-IDMA2P (1-Dimethylamino-2-propanol)-PZ effect mixture for CO_2 capture and found lower energy consumption. Post-combustion carbon capture using conventional packed columns requires a very large packed volume and thereby results in high capital costs. The thermal efficiency is also affected because of the substantial use of steam for solvent regeneration. Thus, process intensification can be applied for CO_2 capture for reducing capital and operating costs.

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https://doi.org/10.1016/j.seppur.2022.121248
Received 21 February 2022; Received in revised form 20 April 2022; Accepted 6 May 2022
Available online 11 May 2022