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Modelling of Accelerated CO_2 Absorption Using an Enzyme in a Hollow Fiber Membrane Contactor

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ABSTRACT

Carbon dioxide (CO_2) is widely recognized as the main cause of climate change affecting our planet. In recent years, the concentration of CO_2 in the atmosphere has increased significantly due to the intensive combustion of fossil fuels. This study is devoted to the simulation of the 1D case of the CO_2 capture process by aqueous Potassium carbonate K_2CO_3 as chemical solvent promoted with BCa (Bovine carbonic anhydrase), using a membrane contactor in the counter current case. The system of partial differential equations resulting from the modelling were solved using MATLAB's PDEPE function. We also carried out a parametric analysis to see the impact of various parameters on the CO_2 capture process. Among these parameters, we studied the influence of solvent concentration, gas velocity and liquid velocity. The results show that 13% increase (74% to 87%) on CO_2 capture while the increase of solvent concentration from 20 to 50 (mol/m3), also for gas and liquid velocity from 0.001 to 0.05 and 0.006 to 0.05 (m/s) we have 52% and 3 % increase of CO_2 capture respectively.at final the Enzyme had an effect of average 7% of absorption of CO_2.

Keywords: Absorption, BCa, CO_2, Potassium carbonate (K_2CO_3), Hollow fibre membrane contactor (HFMC), Modeling

1 Introduction

Carbon dioxide (CO_2) is widely recognized as a major contributor to global climate change. In recent years, the concentration of CO_2 in the atmosphere has increased significantly due to the intensive combustion of fossil fuels. Rising CO_2 emissions are a major cause of catastrophic environmental change that has led to growing interest in successful CO_2 capture [1]. Over the past decades, various technologies have been used for CO_2 capture. Chemical absorption by absorbents in trays and packed columns is the traditional method [2]. However, this method has economic and operational problems. Membrane contactor absorption is a new technology with many advantages, including: Prevention of interphase dispersion, high specific surface area, and compact size of the contactor [3]. In porous membrane contactors, absorption typically occurs when CO_2 diffuses from the shell side through the membrane pores and contacts the liquid phase within the fibers. One of the intensification processes using to increase the absorption of CO_2 is using Bovine Carbonic anhydrase (BCa) is an excellent candidate for novel biocatalytic processes based on the capture and utilization of CO_2 [4].

2 Methods

In this work, the study was made by taking a volume element of the CO_2 absorption model using a membrane.
The equation of balances was:

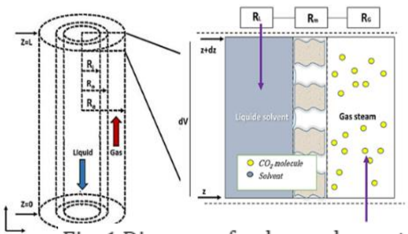

Fig. 1 Diagram of volume element

Gas phase:

$$\frac{\partial C_{CO2,g}}{\partial t} = D_{CO2,g}\frac{\partial^2 C_{CO2,g}}{\partial z^2} - V_g\frac{\partial C_{CO2,g}}{\partial z} - K_G a\left(H \times C_{CO2,g} - C_{CO2,l}\right) \quad (1)$$

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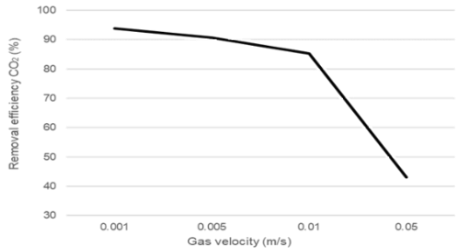
Liquid phase: (For CO_2 and K_2CO_3)

$$\frac{\partial C_{CO2,l}}{\partial t} = D_{CO2,l}\frac{\partial^2 C_{CO2,l}}{\partial z^2} - V_l\frac{\partial C_{CO2,l}}{\partial z} + K_G a\left(H \times C_{CO2,g} - C_{CO2,l}\right) - K_{K2CO3} \times C_{CO2,l} \times C_{K2CO3} \quad (2)$$

$$\frac{\partial C_{K2CO3}}{\partial t} = D_{K2CO3,l}\frac{\partial^2 C_{K2CO3}}{\partial z^2} - V_l\frac{\partial C_{K2CO3}}{\partial z} - K_{OH} \times C_{CO2,l} \times C_{K2CO3} \quad (3)$$

3 Results and Discussion

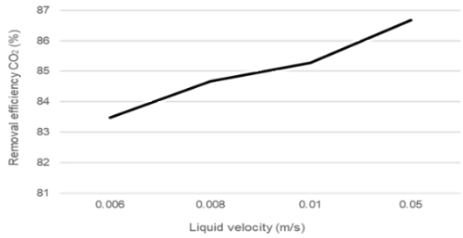
The effect of gas velocity



Concentration of K_2CO_3= 40(mol/m^3), liquid velocity =0.01(m/s),Porosity=0.4585, membrane length =0.21(m), t=100(s)

Figure: 2 Effect of gas velocity on CO_2 removal

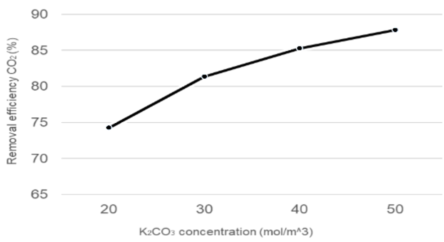
The effect of liquid velocity



Concentration of K_2CO_3= 40(mol/m^3), gas velocity =0.01(m/s),Porosity=0.4585, membrane length =0.21(m), t=100(s)

Figure.3 Effect of liquid velocity on CO_2 removal

The effect of inlet solvent concentration



Gas velocity =0.01(m/s),liquid velocity =0.01(m/s),Porosity=0.4585, membrane length =0.21(m), t=100(s)

Figure4 : Effect of loading concentration of K_2CO_3 on CO_2 removal

4 Conclusions

In a nutshell, robust and reliable mechanistic model and simulation methodology was validated and implemented to study the effects of concentration, gas velocity and liquid velocity on CO_2 capture by K_2CO_3 accelerate by BCa using membrane process to study the performance of the hollow fibre membrane contactor in terms of CO_2 removal. The CO_2 removal was increased by 52% in the range of 20–50 (mol/m3) of Concentration of flow rate, also the results show that 13% increase (74% to 87%) on CO_2 capture while the increase of solvent concentration from 20 to 50 (mol/m3), also for gas and liquid velocity from 0.001 to 0.05 and 0.006 to 0.05 (m/s) we have 52% and 3 % increase of CO_2 capture respectively. The Enzyme had an effect of average 7% of absorption of CO_2.

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