Performance Test of Double Crossed Membrane Contactor for Simultaneous Absorption-Desorption Of CO_2 Using Diethanolamine

Yeni Rahmawati[1], Toto Iswanto[1], Muhammad Rifa'i[1]

***Abstract* – This study aimed to test the performance of polypropylene hollow fiber that were configured in the double crosses configuration as membrane contactor by combining absorption-desorption process simultaneously in one module using diethanolamine as solvent which is expected to separate CO_2 optimally by using of minimal solvents. The solvent allowed to stand in the shell module, feed gas supplied to the lumen of the first tube, and sweep gas flowed into the lumen of the second tube of membrane module. The experimental results showed that during the first three hours, the flux of absorption decreased until $2.63x10^{-5}$ mol/m^2.s and the efficiency of absorption decreased to 5.181%, whereas flux of desorption increased every hour until $6.202x10^{-5}$ mol/m^2.s during performance test, while the efficiency of desorption rose to 92.437%.**

***Index Terms* – CO_2 separation, hollow fiber membrane contactor, polypropylene, simultaneous absorption-desorption.**

INTRODUCTION

The research on membrane contactor using absorption-desorption process of CO_2 had most commonly done separately/hybrid, in which the absorption-desorption process by separate equipment requires a large enough circulation of solvent, so that when the use of expensive solvents will enhance the overall operational costs. Therefore, developed membrane contactors for absorption-desorption process of CO_2 simultaneously using a dual crosses of membrane contactor module.

The research on the crossed membrane contactor for absorption-desorption process of CO_2 simultaneously had done by Guha (1990), Kumazawa (2000), and Shimada (2006). However, these studies were still using small concentrations of CO_2 gas, which was 5-30% by volume, while the content of CO_2 gas in natural gas can reach 30-60% by volume such as in Natuna natural gas.

In this paper, the detailed study polypropylene hollow fiber that were configured in the double crosses configuration as membrane contactor by combining absorption-desorption process simultaneously in one module using DEA is reported. The concentration of CO_2 in sales gas and sweep gas out were investigated by Gas Chromatography (GC) analyzer. The flux and efficiency of absorption and desorption process of CO_2 were calculated by a formula.

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MATERIAL AND METHOD

A. Material

In the present paper, a polypropylene (PP) hollow fiber membrane contactor were used to capture CO_2 in the feed gas (40% of CO_2 balanced with N_2). Diethanolamine (DEA) 30% of mass was role as CO_2 absorber and N_2 gas, 99.95% balanced with O_2 was role as sweep gas. Those gas are from PT. Aneka Gas Industry. The PP hollow fiber membrane has specification as following:

Table 1. Specification of hollow fiber membrane module

Parameters	Value
Module inner diameter (mm)	0.35
Module outer diameter (mm)	0.5
Pore size (μm)	0.2
Membrane fiber length (mm)	83
Number of fibers	2500
Number of layer	25
Contact area gas-liquid (m^2)	21.195
Fiber Porosity	0.65

B. Experimental Apparatus and Procedures

1) Determining the Best Operating Parameters

To know the best operating parameters value of feed gas and sweep gas flow rate, so investigation of flux and efficiency of absorption and desorption were firstly determined.

The solvent, DEA 30% of mass, was pumped through the bottom of the membrane module using pump 1.6 LPM (Deng Yuan Industry co., ltd, Taiwan) until all of membrane completely submerged. Then, feed gas (mix gas 40% CO_2 balanced with N_2**)** was introduced into the system from compressed gas cylinders and its flow rate was adjusted by rotameter (Dwyer Instrument. Inc.) that was set 400-800 ml/minute according to experiment variables, so do the sweep gas.

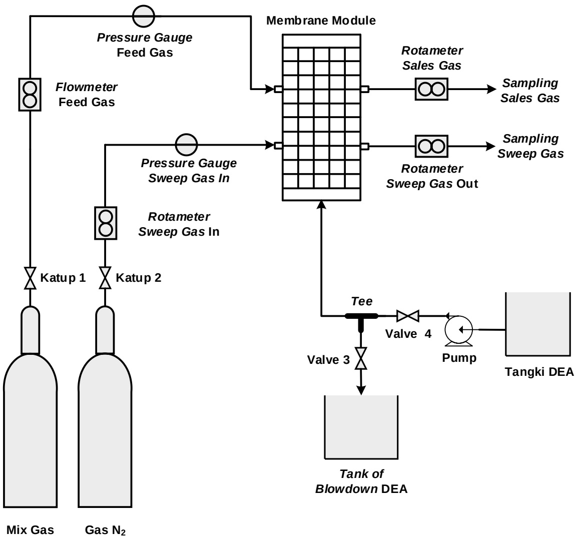

Figure 1. Schematic drawing of experimental setup

All data were collected at steady state, after at least 30 min of operating time. Steady state was indicated by constant CO_2 concentration in the outlet gas (sales and sweep gas) stream. All concentration of CO_2 had determined by GC analyzer. The value of absorption and desorption efficiency and mass transfer rate of CO_2 were calculated by equation (1) [1] and (2) [2] for absorption and equation (3) and (4) for desorption.

$$J_{CO_2(absorpsi)} = \frac{(Q_{in}\times C_{in} - Q_{out}\times C_{out}) \times 273{,}15}{0{,}0224\times T_g \times S} \quad (1)$$

$$\eta = \frac{Q_{in}\times C_{in} - Q_{out}\times C_{out}}{Q_{in}\times C_{in}} \times 100\% \quad (2)$$

$$J'_{CO_2} = \frac{(V_{out}\times K_{out}) \times 273{,}15}{0{,}0224\times T_g \times S} \quad (3)$$

$$\eta' = \frac{V_{out}\times K_{out}}{Q_{in}\times C_{in} - Q_{out}\times C_{out}} \times 100\% \quad (4)$$

From the maximum value of absorption and desorption efficiency and mass transfer rate of CO_2 in this part, flow rate 800 ml/min of mix gas and 400 ml/min of sweep gas were selected as the best of operating parameters value that will be used in long-term test performance of membrane module for 8 hours of operation time. Its procedures were almost same with procedure of determining the best operating parameter above. The differences were about their flowrate of mix and sweep gas.

RESULT

From Figure 2, it can be seen that the flux of desorption progressively increasing. This could be caused by solvents that became saturated with CO_2. The difference in CO_2 concentrations were large, the CO_2 in the solvent diffused into the sweep gas.

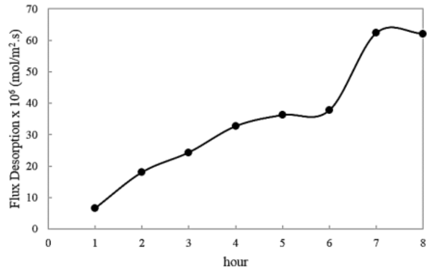

Figure 2. Flux of desorption for long-term performance of membrane contactor during 8 hours of operating time.

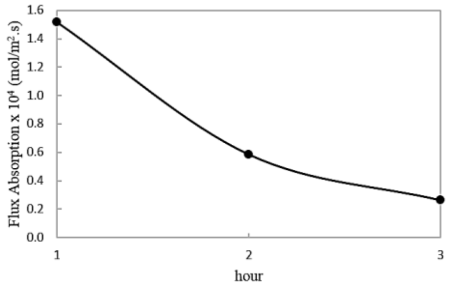

Figure 3. Flux of absorption for long-term performance of membrane contactor during 3 hours of operating time.

In the first three hours of the test performance, absorption flux progressively decreased, as shown in Figure 3. It could be caused by gas trapped in the membrane that was pushed out. CO_2 gas was trapped in the membrane indicates that the gas was not absorbed into the solvent. It could be caused by a solvent which began saturated or membrane surface that had been wet resulting membrane pores closed.

During the first three hours, the flux of absorption decreased until $2.63\text{x}10^{-5}$ mol/m^2.s and the efficiency of absorption decreased to 5.181%, whereas flux of desorption increased every hour until $6{,}202\text{x}10^{-5}$ mol/m^2.s during performance test, while the efficiency of desorption rose to 92.437%.

CONCLUSION

For overall, the membrane contactor was able to absorb and desorb CO_2 during the three-hour performance test.

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