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Membrane stripping technology for CO_2 desorption from CO_2-rich absorbents with low energy consumption

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Abstract

CO_2 membrane stripping is a novel method for CO_2 desorption at low temperature (around 348K) for amine-based CO_2 capture, which has the potential to reduce regeneration energy requirement. In this work, we investigated CO_2 membrane stripping with two different commercial hollow fiber membranes, polypropylene (PP) and Polyvinylidene fluoride (PVDF). CO_2 membrane stripping in PVDF membrane showed a faster CO_2 desorption rate than in PP membrane, but PP membrane presented a better stability on long-term running. Energy consumption for CO_2 membrane stripping with 20 wt% MEA solvent was evaluated. Compared with conventional thermal regeneration, 28% energy can be saved if regeneration pressure of CO_2 membrane stripping operated at 20 kPa.

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Keywords: CO2; Membrane stripping; Absorbent; Desorption; Energy consumption;

1. Introduction

Fossil fuel combustion in power generation and industrial sectors is considered as the largest stationary source of CO_2 emission, which accounts for 60% of global CO_2 emission [1,2]. At present, solvent based post-combustion capture (PCC) technology, which typically separates CO_2 from flue gas in packing columns, is believed to be one of the most mature technologies [3,4]. Nevertheless, the main challenge for this technology is its energy-intensive stripper for rich-solvent regeneration. Significant amounts of heat for rich-solvent regeneration are required, with reducing the power plant efficiency by as much as 30% [5]. Therefore, it has been proposed to develop novel

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regeneration technology with lower energy consumption in recent years.

Hollow fiber membrane contactors were proposed as a promising separation unit than conventional packed columns for CO_2 separation [6,7]. Therefore, membrane stripping technology, which has the potential to reduce energy requirement of CO_2 separation, is a novel method for CO_2 desorption [8-11]. In this process, CO_2 is desorbed in a hollow fiber membrane contactor instead of packed column. The regeneration temperature, which is usually around 353K, is much lower than conventional thermal regeneration temperature. Kosaraju et al. [8] firstly demonstrated the feasibility of CO_2 membrane stripping using commercial PP membrane contactors by long term running for 55 days. Fang et al. [12] further studied CO_2 membrane stripping comprehensively with using monoethanolamine (MEA) as absorbent. Besides MEA absorbent, Wang et. al. [13,14] screened the different amine-based absorbent for CO_2 membrane stripping process.

In this work, we studied the CO_2 membrane stripping with two different commercial hollow fiber membranes, polypropylene (PP) and Polyvinylidene fluoride (PVDF). The effects of membrane materials on CO_2 membrane stripping performance were compared by investigating their regeneration efficiencies, CO_2 desorption rates and long-term stabilities. In addition, to evaluate the advantages of membrane stripping technology, energy consumption for CO_2 membrane stripping with 20 wt% MEA solvent was estimated.

2. Experimental

2.1. Materials

The MEA absorbent (purity > 99%) we used in this work were provided by Sinopharm Company. The pure CO_2 gas (purity > 99.9%), provided by Hangzhou Jingong Gas Co., Ltd., was used to prepare the CO_2 loaded solvent by introducing to the fresh solvent in a bubbling reactor. The CO_2-loading of solutions can be determined by the standard method described in our previous work [12].

The hydrophobic micro-porous polypropylene (PP) and Polyvinylidene fluoride (PVDF) hollow fiber membrane modules were provided by the Zheda Kaihua Membrane Technology Co., Ltd. and Tianjin Fengke Membrane Technology Co., Ltd., respectively. The detail specification of the membrane modules is listed in Table 1. It should be noted that for PP membrane, we used two identical membrane modules by connecting each other in series.

Table 1 Specifications of PP and PVDF hollow fibers and membrane module

Parameters	Unit	PVDF	PP
Fiber I.D.	μm	700	344
Fiber O.D.	μm	1000	424
Thickness of membrane wall	μm	150	40
Porosity	/	85%	45%
Average micropore size	μm	0.16	0.1
Active length of module	cm	40	26×2
Module O.D./I.D.	cm	2.5/2.2	2.4/2
NO. of fibers	/	130	500
Contact area	m^2	0.068 m^2	0.14×2 m^2

2.2. Apparatus and procedure

The experimental setup of CO_2-rich solution by using membrane stripping technology is shown in Fig. 1. The prepared CO_2–rich solution was added into the rich-solvent tank, and then heated to desired temperature before membrane module. After pre-heating, CO_2 rich solution was continuously pumped into the tube side of the hollow fiber membrane contactor by a peristaltic pump. Liquid flow rate was controlled by adjusting the rotation speed of the peristaltic pump, the liquid phase temperatures and pressures are both metered in inlet and outlet of membrane module. Low-temperature water steam coming from the steam generator flowed through the shell side of the