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Experimental study of a hybrid solvent MEA-Methanol for post-combustion CO_2 absorption in an absorber packed with three different packing: Sulzer BX500, Mellapale Y500, Pall rings 16 × 16

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ABSTRACT

Effects of different operating conditions on the CO_2 capture and mass transfer performance of the absorption of CO_2 into a hybrid solvent MEA-Methanol were studied in a pilot-plant absorber packed with three different packing consist of Sulzer BX500, Mellapale Y500 and Pall rings 16 × 16. The results showed that the structured packing had an obvious advantage in the mass transfer performance. And Sulzer BX500 was better than Mellapale Y500 for it had a more uniform gas–liquid distribution on the packing surface. In addition, CO_2 lean loading, lean solvent temperature, lean solvent flow rate and flue gas flow rate all had great effects on the absorption performance of the MEA-Methanol absorption system.

1. Introduction

The use of post-combustion carbon dioxide (CO_2) capture from fuel-fired power plants using reactive amine solvents is the most popular technology for reducing CO_2 emissions [1,2]. However, the main drawback of amine solvents is that they require very high regeneration heat duty, which accounts for about 70% of overall operating cost [3,4]. So it is essential to find new efficient solvents, which are considered to have fast reaction kinetics, high absorption capacity and low regeneration energy to secure the economic feasibility of chemical absorption processes [5].

Recently, hybrid solvents which replace water with organic solvents have attracted more attention for it has a higher solubility of CO_2 even at a low CO_2 partial pressure, a faster absorption rate and a lower regeneration temperature [6]. And It was conformed that the hybrid solvent MEA-Methanol showed a better performance over aqueous MEA solvent for it had a faster absorption rate and a lower regeneration energy heat duty to strip the same amount of CO_2 [7]. But to use the MEA-Methanol CO_2 capture system in industry, studies should be done to get the most appropriate packing and the optimum operating parameters.

Fu et al. [7] have studied the mass transfer and heat transfer of MEA-Methanol solvents in a double-layer glass packed column with internal diameter of 28.0 mm and total height of 1.70 m. The column was packed with 21 elements of Sulzer DX-type packing (made of 316L stainless steel and with 900 m^2/m^3 surface area per elements) to 1.25 m packed height. However, their study just studied the effects of different operating parameters on the absorption performance of MEA-Methanol under one kind of packing, but to use it in industrial CO_2 capture pilot plant, the appropriate absorber packing and appropriate absorption parameters should be obtained.

In this work, the effects of lean CO_2 loading, lean solvent temperature, lean solvent flow rate and flue gas flow rate on the absorption performance of MEA-Methanol were studied in a packing column packed with Sulzer BX500, Mellapale Y500 and Pall rings 16 × 16. The experimental data achieved in this work were presented and discussed in this paper.

2. Experimental section

2.1. Details of chemicals

CO_2 and N_2 gases with mole fractions of 0.999 and 0.999 were supplied by Shanghai Shenkai gas company. Analytical grade MEA (purity >99.9%) and methanol (purity >99%) were all used

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as purchased without further purification. The aqueous solution was prepared using distilled water.

2.2. Equipment and experimental procedure

The CO_2 absorption experiments studied in this work were carried out in a packed absorber with internal diameter of 150 DN and total height of 3 m. The absorber consists of two packing beds (packed with Mellapale packing 500Y, Sulzer 500BX and Pall rings 16 × 16) to 2 m packed height. In the middle of the columns liquid re-distributors were placed to eliminate the wall effects. Along the absorber, five gas measurement points and three temperature measurement points were installed to obtain the gas phase concentration profiles and the system temperature profiles.

Figs. 1 and 2 give the detailed flow diagram and the photo of the absorption experimental setup. The gas flow rates of N_2 and CO_2 gases were controlled by mass flow controllers before remixed and the flue gas was then passed through the by-pass tube and tested by the flue gas analyzer to maintain the CO_2 concentration of 15%. The lean solvent which was maintained at the desired temperature by water was fed into the top of the absorber by a constant liquid-flow pump to chemically reacts with the solvent. When the reaction achieves a steady-state condition, the gas concentration profile, absorber temperature profile, liquid samples outlet the absorber were collected to study the absorption performance. To verify the accuracy of the absorption experiment, a mass balance error was calculated for each run and all of the mass balance errors obtained in this work were under 10%.

Fig. 2. Photo of CO_2 capture facility in the lab of East China University of Science and Technology.

2.3. Mass transfer coefficient ($k_G a_v$)

Mass transfer occurs when a component A in a gas phase transfers across a gas–liquid interface into a liquid phase. The mass flux of component A (N_A) at a steady state can be represented in terms of gas-side mass transfer coefficient (k_G), total pressure (P), and gas phase driving forces ($y_A - y_{A,i}$):

$$N_A = k_G P(y_A - y_{A,i}) \tag{1}$$

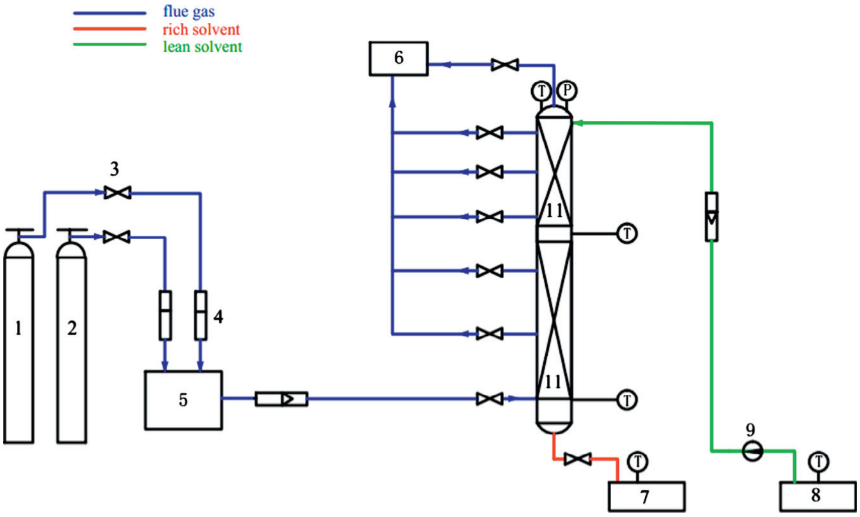
The mass flux can also be expressed in terms of the overall mass transfer coefficient (k_G) and equilibrium mole fraction of component A in gas phase (y_A^*) as follows:

$$N_A = k_G P(y_A - y_A^*) \tag{2}$$

Then, k_G can be expressed as follows:

$$k_G = N_A/[P(y_A - y_A^*)] \tag{3}$$

In a gas absorption apparatus such as a packed column, it is more useful to represent rates of absorption in terms of volumetric overall mass transfer coefficients, represented by the term $k_G a_v$,



1. CO_2 cylinder 2. N_2 cylinder 3. Valve 4. Mass flow controller 5. Gas-mixing system

6. Flue gas analyzer 7. Rich solvent tank 8. Lean solvent tank 9. Liquid pump

Fig. 1. Schematic diagram of experimental setup for CO_2 absorption.