

Effect of Carbon Dioxide (CO₂) concentration in the gas feed on Carbon Dioxide Absorption Performance using Aqueous Potassium Carbonate promoted with Glycine

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Abstract. This paper presented the effect of CO₂ concentration in the gas feed to the CO₂ absorption performance using a green solvent, potassium carbonate promoted with glycine (PCGLY). Recently, the performance of this solvent (with precipitates) was hindered by its poor mass transfer performance due to the blockage in packings and piping. Therefore, this study focused to study the CO₂ absorption performance of non-precipitating potassium carbonate promoted with glycine. This green solvent contains aqueous blend of 15wt% potassium carbonate and 3 wt% glycine. The absorption performance of the solvent was obtained by demonstrated a few experimental works using a bench scale packed absorption column. The packing type was Sulzer metal gauze and the column consisted of six sampling point which located equidistance along the packing. The effect of CO₂ concentration at the gas feed was assessed in term of its CO₂ removal efficiency and concentration profile along the packing. The study shows the decreasing trend of CO₂ removal as CO₂ inlet concentration in the gas feed increases. The reason of this behavior is due to the limited reactant of liquid phase to absorb high CO₂ concentration in gas phase. The main outcome of this study demonstrated the efficient absorption which can absorb up to 79.24 % of CO₂ from natural gas using non-precipitated PCGLY.

1 INTRODUCTION

As yet, the interest to explore undeveloped natural gas resources is tempered by the risk to encounter with high non-hydrocarbon concentration which reduces the gas heating value and increases corrosion risk to the pipeline [1]. Literally, the allowable CO₂ content in natural gas in subsea gas pipeline to the onshore processing plant should be in between 1-2% or in some cases can reach at most 5% [2]. Hence, an effective system must be installed at the offshore to remove bulk CO₂ concentration directly from the gas reservoir.

Among of commercialized CO₂ separation technology, chemical absorption separation process has gain the most attention in this project as it is a mature technology that has been commonly adopted due its high efficiency and requires low cost [3-5]. Aqueous amine – based solvent is the common type of chemical solvent and has been commercialized for many decades in CO₂ removal process [6-8].

Typical amine-based solvent includes MEA, DEA, MDEA and AMP [9]. However, its high energy penalty for amine regeneration and solvent degradation are the impeding issues for large scale implementation of this technology [10]. Moreover,

aqueous amine-based solvent is corrosive to equipment and its degradation may turn into nitrosamines and nitramines which are hazardous to environment and human health [3, 11]. Therefore, the use of aqueous amine-based solvent in chemical absorption CO₂ removal system might be not suitable for offshore condition.

The development of environment friendly solvent with high solubility and less degradation rate have been the emerging research trending for an effective CO₂ capture with low environmental impact. Shaikh et al. [12] had reported the solubility of a new solvent blend known as aqueous potassium carbonate promoted with glycine (PCGLY) which is found to be comparable with conventional solvents. It possesses several advantages over amine-based solvent including less toxicity, non-degradation, and require lower regeneration energy [13]. The characteristics of PCGLY are suitable for offshore condition and provides motivation for the insight study in term of its CO₂ removal efficiency and mass transfer performance at continuous system of packed absorption system [5].

2 METHODOLOGY

2.1. Chemicals

The chemicals used in this experiment were potassium carbonate (PC) with 99.95% purity and glycine (GLY) with 99% purity. Both chemicals were bought from Avantis Supply Sdn. Bhd. Purified CO₂ were purchased from Air Product Sdn. Bhd. NG with 97% CH₄, 2% CO₂ and 1% heavier hydrocarbon was purchased from PETRONAS NGV Sdn. Bhd. All materials were used as received without further purification.

2.2 Experimental procedure

CO₂ and NG were separately heated by a heat exchanger to 343 K. This to avoid the gas hydration due to the sudden pressure drop from the gas cylinder to 0.7 MPa at the inlet of gas heat exchanger. Then, the inlet CO₂ and NG concentrations were set by a mass flow controller. CO₂ and NG were mixed by gas mixer. The mixed gas was compressed into a high-pressure vessel and flowed into an absorption packed column until the desired operating pressure was reached. Pressure of the absorption packed column was maintained by a back-pressure regulator.

CO₂ and NG mixed gas was injected from the bottom part of the column at the respective gas flow rate. The gas flow rate was controlled by a gas flow controller. Meanwhile, a well-mixed PCGLY was pumped into the top of the column. The liquid flow rate was controlled by a liquid flow controller, which was equipped with a back-pressure regulator. The pressure of the gas in high pressure gas vessel was monitored to be at least 0.1 MPa above the column pressure to ensure that the gas can flow into the column.

The absorption performance experiments were performed within 1 hour and 30 minutes until the CO₂ concentration was stable. It indicated that steady state conditions at each sampling points were reached. Then, CO₂ concentration along the sampling point was measured by using an infrared (IR) analyser.

2.3 Evaluation of CO₂ removal efficiency

CO₂ removal efficiency was calculated as in (1) [14]:

$$\text{CO}_2 \text{ removal efficiency} = \frac{y_b - y_a}{y_b} \quad (1)$$

Where, y_b (mol/mol) is the CO₂ mole fraction at the inlet of the column and y_a (mol/mol) is the CO₂ mole fraction at the last stage of packing.

3 Results and discussions

The study on the effect of inlet CO₂ concentration on CO₂ removal efficiency is important as it will provide a basis prior CO₂ sweetening process for CO₂-rich gas. Therefore, a set of experiments were conducted over 15 – 30 mol. % of CO₂ in NG with 4.04 MPa of operational pressures, 0.20 l/min of liquid flow rates, 1.50 kg/h of gas flow rate and 333 K of liquid inlet temperature.

3.1. CO₂ concentration profile along the packed absorption column

Figure 1 shows the CO₂ concentration profile across the height of the column at operational pressure range between 15 to 30 mol%. It is observed that lower CO₂ removal was acquired as the CO₂ concentration in NG increases. This behaviour may be caused by an increase of total CO₂ mole flow rate in gas phase which resultantly decrease of L/G molar ratio. As L/G molar ratio decrease, there would be less contact between the liquid and gas phase in the column [15]. In turn, more CO₂ reduction can be observed.

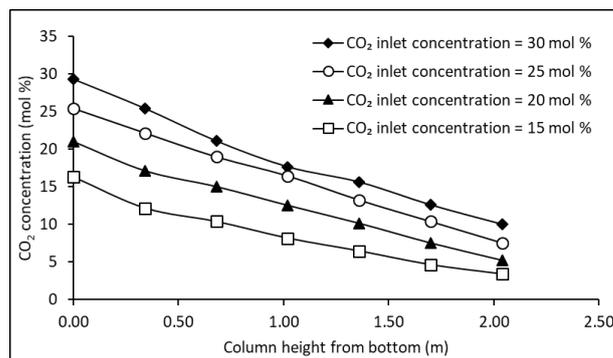


Figure 1: CO₂ concentration profile at various CO₂ concentration in the feed

3.1. Effect of CO₂ concentration in the gas feed on CO₂ removal efficiency

The effect of CO₂ concentration in the gas feed on CO₂ removal efficiency is presented as Figure 2.

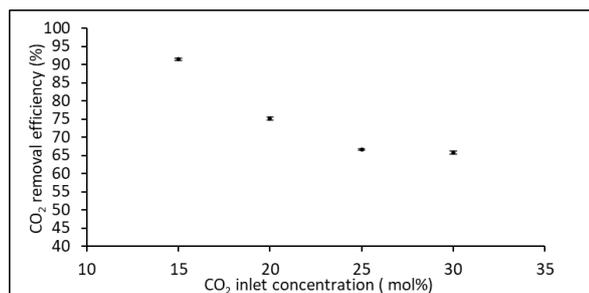


Figure 2: CO₂ removal efficiency over various CO₂ concentrations in the gas feed

As presented in Figure 2, CO₂ removal efficiency decrease from 79.24 to 65.79 % to as the CO₂ concentration in the gas feed was increased from 15 mol% to 30 mol%. At constant operational pressure, an increase of CO₂ inlet concentration would result to higher CO₂ partial pressure which would allow more CO₂ molecules to travel from gas bulk to the gas-liquid interface CO₂ concentration at the interphase [16]. This would enhance the mole fraction driving force for separation [17]. However, for this case, the effect of CO₂ concentration on the increase of CO₂ partial pressure is not significant. With operating pressure of 4.04 MPa, an increase of CO₂ inlet from 15 to 30 mol %, would only slightly increase CO₂ partial pressure by 1.2 MPa. Therefore, the main reason of this behaviour is due to the limited reactant of liquid phase to absorb high CO₂ concentration in gas phase. The results are correspond as reported by Hairul et al. [15].

4 Conclusion

The effect of operating parameter specifically of CO₂ concentration in the gas feed on CO₂ absorption was studied using a bench scale packed absorption column at 4.0 MPa with 0.2 lpm of liquid flow rates, 1.5 kg/h gas flow rate and 333K solvent temperature. CO₂ removal efficiency was studied at steady state where the system in equilibrium condition. The study shows the decreasing trend of CO₂ removal from 79.24 to 65.79 % as CO₂ concentration in the feed increases. The reason of this behavior is due to the limited reactant of liquid phase to absorb high CO₂ concentration in gas phase. The main outcome of this study demonstrated the efficient absorption which can absorb up to 79.24 % of CO₂ from natural gas using non-precipitating potassium carbonate promoted with glycine

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