Investigation of Factors Affecting the Efficiency of Carbon Dioxide Removal in a Single Perforated Sieve Tray Column

Sarmad foad jaber, Yuosif M. Abdul wahab and Sami M. Zboon
Chemical Engineering Department/ College of engineering/Baghdad University

Abstract

An experimental work was carried out for the recovery of carbon dioxide in monoethanolamine solution (MEA) using pilot plant of perforated sieve tray column. The effect of MEA concentration, carbon dioxide ratio in the gas phase, liquid flow rate, gas flow rate and CO_2 loading in the absorption solution was investigated. The results show that the efficiency of recovery increased by increasing the concentration of MEA and better removal efficiency can be achieved by increasing the liquid flow rate and the contact time between CO_2 and the absorbent and that can be happened by decreasing the air flow rate.

Key words: sieve tray, monoethanolamine, absorption, carbon dioxide

Introduction

The major CO_2 sources are industrial byproducts which include natural gas sweetening, synthesis gas production and flue gases which include fossil fuel-fired power plants, industrial furnaces, cement plants, engine exhausts and lime kiln exhausts. [1]

Monoethanolamine (MEA) has a long history of commercial CO_2 recovery with various feeds including flue gases. Uninhibited MEA is generally limited by corrosion problems to about 15-20 wt% MEA. Furthermore,

many applications rely on the presence of hydrogen sulfide in the feed to provide a passivating layer of iron sulfide to reduce carbonic acid corrosion. This protection is absent in flue gas systems where H_2S is not present. [2]

Recently 30 wt % MEA concentration levels were made feasible by the addition of corrosion inhibitors. Jou et al (1995) obtained solubility data of CO_2 in 30 wt % MEA. Also, studies by Austgen (1989) corroborated well with the VLE data presented by Jou et al. In addition operating data for large MEA plants are reported in Kohl (1997). [2]

Aboudheir (1998) investigate the factors affecting the often requires treating in order to achieve a CO_2 cleanup target of less than 1% by volume. [5]

Sarmad (2009) find that to improve high absorption rate from gas phase to a liquid absorbent using perforated sieve absorption of CO_2 using pilot packed bed column with MEA solution and the results show that in general the absorption rate increases as the liquid flow rate increase and that was for all kind of packing materials.[3]

Fadil (2008) shows that not only the operation condition of the absorption process of CO_2 may affect the rate of recovery of the gas but even the additive materials such as surfactant (dodecyl benzene sulfuric acid sodium (DBS)) can reduces the rate of absorption of the gas.[4]

The removal of carbon dioxide from raw natural gas is an essential step for meeting cleanup targets. The majority of raw gases contains a significant amount of CO_2 and tray column it's important to reduce the flow rate of the gas mixture as possible with the operating condition of the column in order to increase the contact time between the

absorbed gas and the absorbent liquid. [6]

Many studies takes place to investigate the efficiency and operating condition of the perforated sieve tray column for absorption process, the newest one that carried out by Hemiri (2009) study the efficiency of perforated sieve tray column for absorption process using the technique of artificial neural network. [7]

The aim of this study was to investigate the capture efficiency of MEA to CO_2 in a perforated sieve tray column. A pilot scale plant was used in this study in the hope that its applicability extends to industrial scale solution systems for removing CO_2 where most of available previous studies were carried out using packed bed column.

Experimental work

The absorption of carbon dioxide takes place in a pilot plant of perforated sieve tray column that shown in figure 1.

The absorption process was conducted in a counter current mode. At steady state operation for each run the liquid with known concentration of absorbent (MEA) pass through a calibrated rotameter to control the amount of liquid flow rate that inter the absorption column from the top end of the column according to the operating condition of the run to come in to contact counter currently with the mixture of known ratio of CO_2 and air which is mixed together before enter in to inside from the bottom of the column. The outlet liquid composition was analyzed for its CO_2 loading to understand the efficiency of the process.

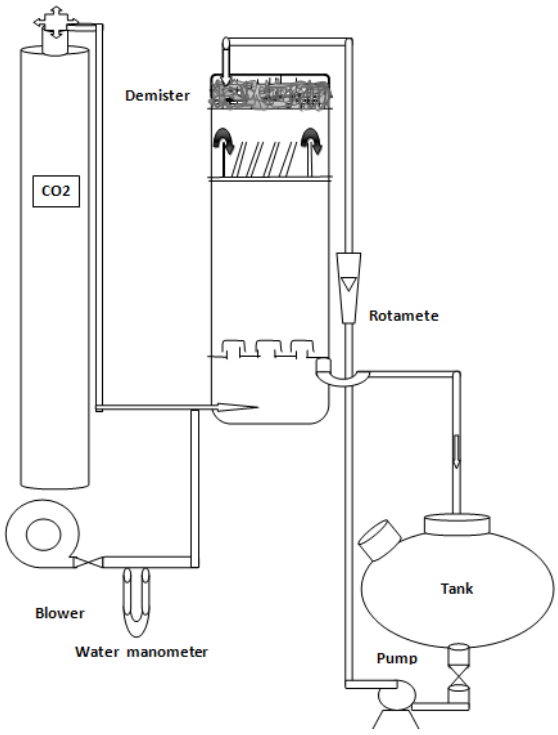

Figure (1) Schematic flow diagram of the absorption unit

Result and Discussion

Figure 2 shows that by increasing the MEA concentration, the removal efficiency will increase but that effect is not as great as might be expected. It's clear from the results that increase MEA concentration from 18 wt% to 30 wt% the CO_2 increase the removal efficiency from 62% to 69% with only 7% increasing achieved, also the increase of MEA concentration from 30wt% to 55wt% will increase the removal efficiency from 69% to 70%. that happened because of the acid-gas vapor pressure is higher over more concentrated solutions at equivalent acid gas/amine mole ratio and also when the same quantity of CO_2 is absorbed in a smaller volume of solution the heat of reaction results case a greater increase in temperature and that will increase the CO_2 vapor pressure in the solution. [8]

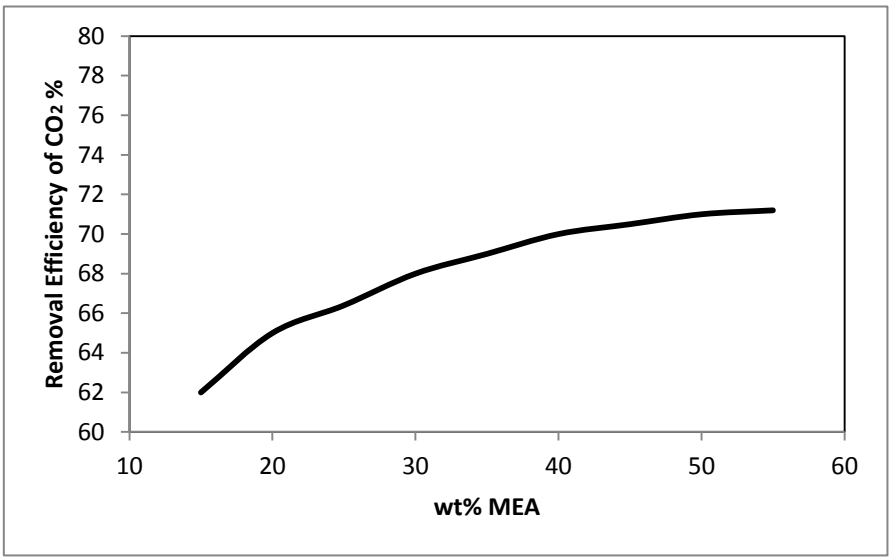

Figure (2) the effect of MEA concentration on the efficiency of CO_2 removal

Figure 3 show that when the liquid flow rate increased the absorption rate (Removal efficiency) will increase because of the higher liquid mass transfer coefficient and quantity of free mono ethanol amine (the absorbent). [3]

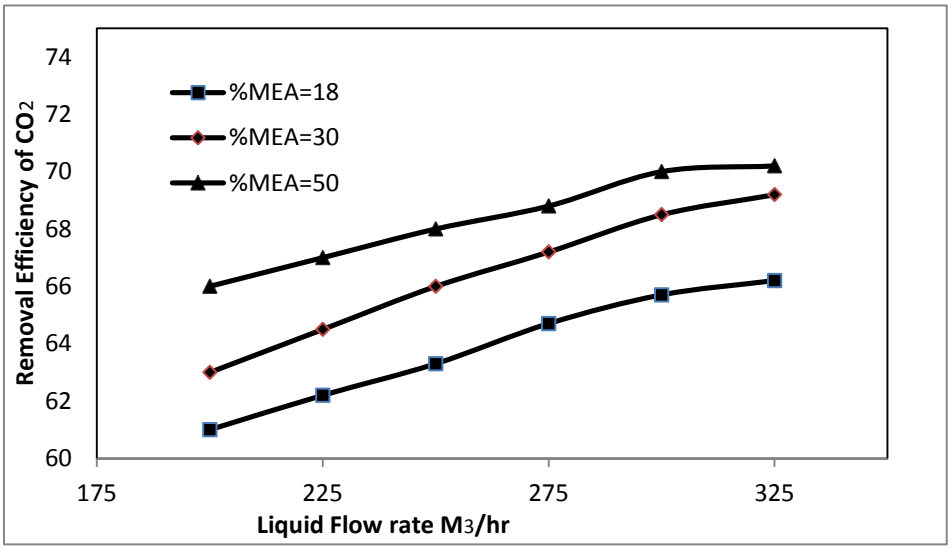

Figure (3) the effect of liquid flow rate on the removal efficiency for CO_2 at different MEA concentration

Figure 4 shows that the reduction of air flow rate will increase the absorption rate by increasing both of the amount of CO_2 to air in the gas phase and the contact time between the gas being absorbed and the absorbents liquid.

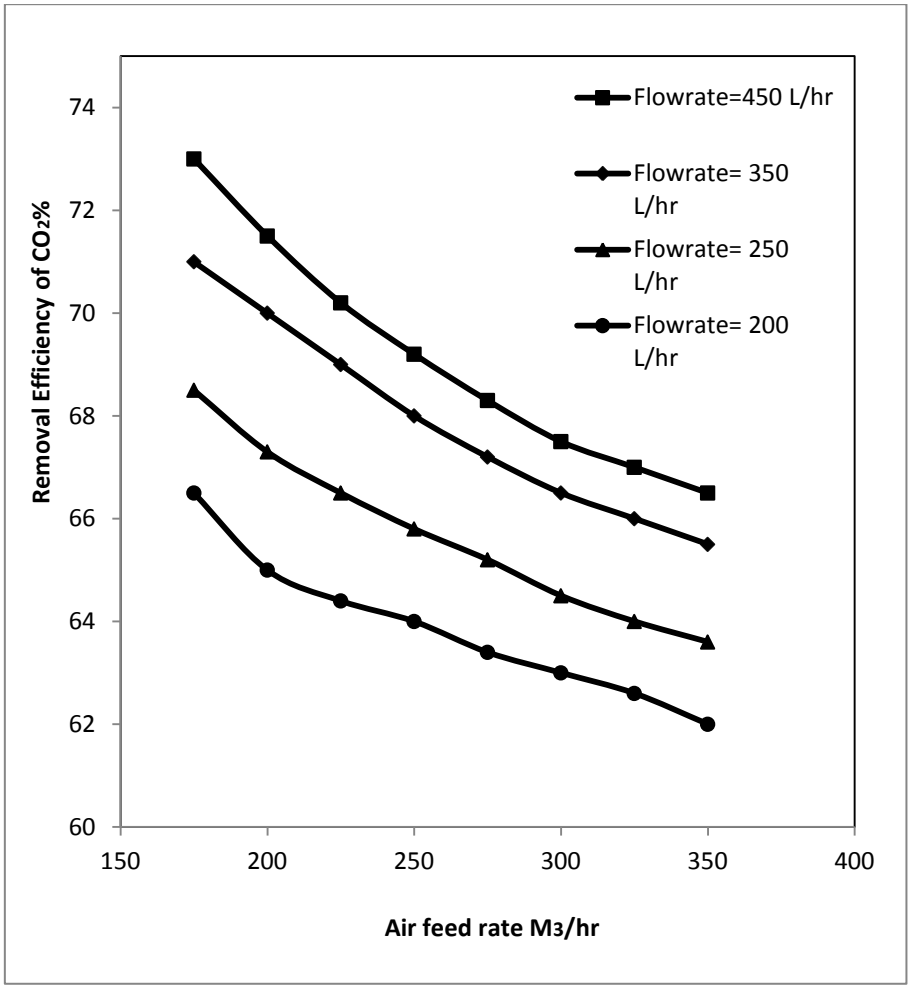

Figure (4) the effect of the air feed rate on the removal efficiency of CO_2

Figure 5 show that the increases of concentration of carbon dioxide in the liquid feed will decrease the removal efficiency of CO_2. If high removal efficiency is required the liquid flow rate or the amine concentration should be increased. [9]

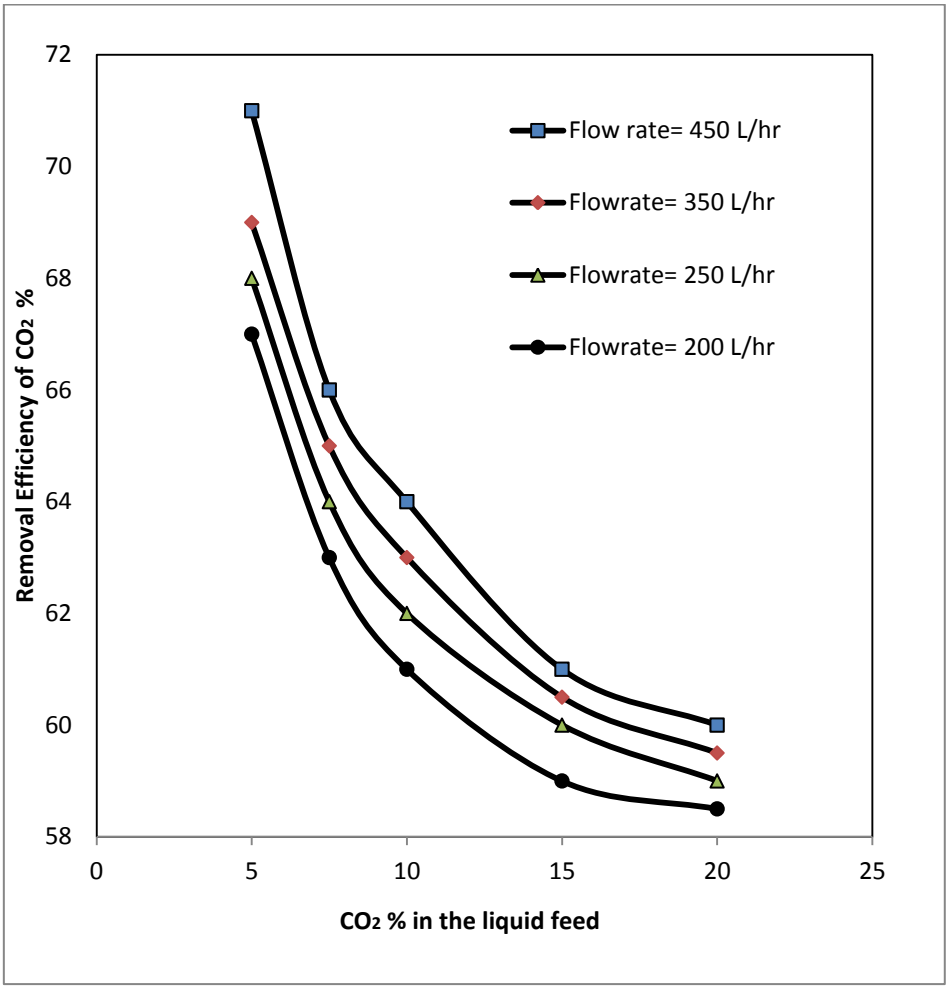

Figure (5) the effect of CO_2% in the liquid feed on the removal efficiency of CO_2

Figure 6 shows that when the loading of CO_2 in the liquid phase reduced from 0.35 to 0.15 (molCO_2/mol MEA), while keeping all other conditions approximately the same;

CO_2 removal efficiency will increase from 57 to 67%. This increase is due to the availability of more free absorbent for the reaction with the absorbed CO_2 in the gas phase. And that explain the important of the stripping unit after the absorption unit to separate free CO_2 and as a result the regeneration the MEA. [9]

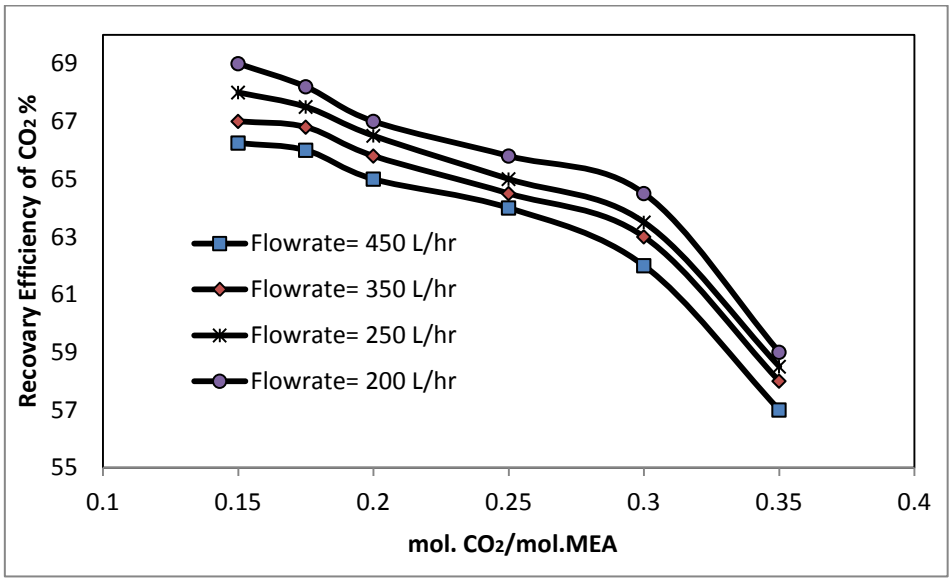

Figure (6) the effect of the ratio of (CO_2 /MEA) in the Liquid feed on the removal efficiency of CO_2

Conclusion

1. The highest removal efficiency of CO_2 from mixture of CO_2 and air could be achieved by increasing the liquid flow rate with high MEA concentration.

2. Reducing the air flow rate as possible according to the operating condition will increase the removal efficiency of CO_2.

3. The absorption ability of MEA increase as its concentration in the liquid phase increase but not linearly as much as might be expected. that explain the important of the stripping unit after the absorption unit to separate free CO_2 and as a result the regeneration the MEA.

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