Effect of Operational Parameters on Foam Formation in Absorption Columns

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ABSTRACT: Foaming presents a significant challenge in gas treatment plants, leading to excessive solvent loss and suboptimal product quality. Additionally, it increases operational and capital costs due to the need for foam prevention and control measures, such as reclaiming units and antifoaming agents. This study investigates foaming behavior in a monoethanolamine (MEA)-based CO_2 absorption system, focusing on the effects of liquid and gas velocities. A series of foaming experiments were conducted in an absorber to generate experimental data for model verification.
equipment.

KEY WORDS: foaming, monoethanolamine (MEA), gas treatment, liquid velocity, absorber, antifoaming agents, solvent loss.

I. INTRODUCTION

Foaming disrupts plant operations by causing issues such as excessive solvent loss, early flooding, and substandard product quality. Additionally, it raises both capital and operational expenses due to the need for foam prevention and control strategies, including installing reclaiming units or using antifoaming agents. Many gas treatment facilities that utilize alkanolamine-based absorption processes have experienced challenges related to foaming.

In 1988, excessive loss of the aqueous MEA solution (over 75% of the expected value) together with a high MEA carryover due to an onset of foaming in an absorption column caused the Longview gas plant in Texas to reduce its plant capacity for processing of natural gas from 27 to 16 MMSCFD. This resulted in an increase in expenditure of approximately $10,000 per year due to MEA loss and a reduction of $4,000,000 per year in income [1, 2].

II. SIGNIFICANCE OF THE SYSTEM

By conducting experimental studies and analyzing variables such as liquid and gas velocities, the system helps optimize operating conditions to minimize foaming and increase efficiency, ultimately reducing costs and improving product quality at gas treatment plants. The Methodology and Discussion is presented in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

III. METHODOLOGY AND DISCUSSION

Foaming experiments were carried out in an absorber to generate experimental farm data used for model verification. In the experiments, MEA was chosen as the absorption solvent due to its popularity in the gas treating industry and its potential for post-combustion carbon capture [3, 4, 5].

In addition, MEA with concentration and CO_2 loading of 5.0 kmol/m^3 and 0.40 mol/mol, respectively, was reported to induce higher foaming tendency than other alkanolamine solutions [6, 7].To eliminate the effect of mass transfer on foaming results, air was used to disperse preloaded aqueous MEA solutions. Experimental conditions are summarized in Table 1. Note that both tested gas and liquid flow rates provide liquid-to-gas (L/G) ratios ranging from 0.6 to 18.9 (kg

solution/kg air), which cover the L/G ratio range used in the CO2 capture pilot plant at the Esbjerg coal-fired power plant [8, 9].

Table 1.
Experimental conditions

Parameter	Condition
Liquid phase	
Absorption solvent	Monoethanolamine (MEA)
MEA concentration (kmol/m^3)	5.0
CO$_2$ loading (mol/mol)	0.40
Liquid velocity (m^3/m^2 h)	up to 4.6
Liquid temperature (°C)	15.3-21.6
Gas phase	
Air velocity (mm/s)	48-360
Air temperature (°C)	20.0-22.8

A series of foaming experiments, shown in Fig. 1, was carried out in a gas absorption system mainly consisting of an absorber fitted with absorber structured packing, a solution buffer tank, a solution pump, a gas filter and a gas regulator. The absorber was 0.80 m high and 0.10 m in diameter and made of acrylic plastic so as to allow visual observation of foam generated during the experiments.
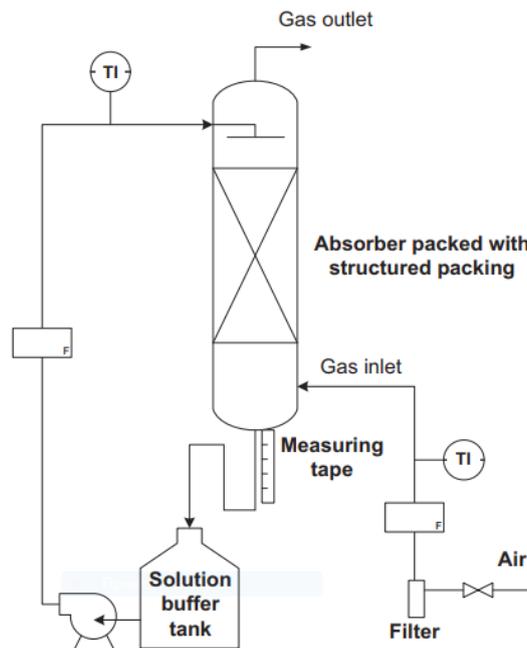
Fig. 1. Schematic diagram of the gas absorption system.

The solution buffer tank was 0.02 m^3 in volume and made of high-density polyethylene. The stainless-steel gear pump controlled by a digital dispensing drive was used to circulate the absorption solution with ±0.3% accuracy in flow rate. The liquid flow rate was regulated by a calibrated liquid flow meter with a high-resolution valve. Feed gas (air) was regulated by a pressure regulator providing a flow capacity of 15 scfm at 620 kPa and filtered by a 5-pm sintered brass element. Direct reading variable area gas flow meter with a maximum capacity of 8.0 scfm was used to measure gas flow rate. The temperatures of gas and solution were measured using a J-KEM Model 210 temperature controller and K-type thermocouples with a maximum error of ±0.4% on readings above 0°C. The foam heights were measured using a measuring tape starting from the liquid level accumulated in the outlet tubing at the bottom of the absorber.

IV. EXPERIMENTAL RESULTS

The experimental foam data were analyzed and presented in Fig. 2 as a function of liquid velocity and superficial gas velocity. Results show that liquid velocity has an apparent effect on foam volume, whereas superficial gas velocity has a negligible effect at a low liquid velocity and certain effect at higher liquid velocities. An increase in the liquid velocity generally increases foam volume generated at a given superficial gas velocity. This can be explained by the fact that greater liquid velocity lead to greater degrees of wetted packing area and liquid holdup. As a result, the total number of the perforations covered by the liquid solution is increased, which in turn increases foaming tendency.

The negligible effect of superficial gas velocity is evident at the low liquid velocity of 0.8 m^3/m^2 h (i.e. the foam volume does not change with superficial gas velocity).
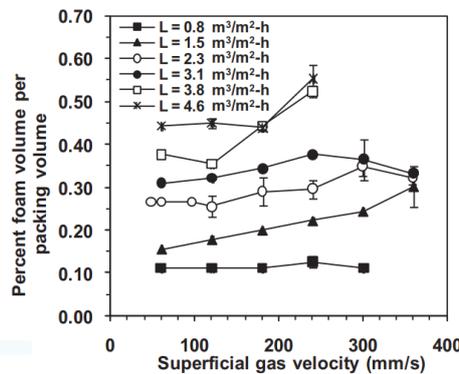

Fig. 2. Experimental percent foam volume per packing volume plotted versus the superficial gas velocity at different liquid velocities (experimental conditions: 5.0 $kmol/m^3$ MEA concentration, 0.40 mol/mol CO_2 loading, and 18.5^0C solution temperature).

This might be because the liquid hold up is too small to provide an adequate liquid layer above the perforation hole or a sufficient contacting time between a gas bubble and a liquid layer. However, at higher liquid velocities, the foam volume tends to increase with superficial gas velocity at a given liquid velocity. This is due to an increase in gas volume and in turn an increase in the number of bubbles generated above the perforation holes.

It should be noted that at 360 mm/s superficial gas velocity for 2.3 m^3/m^2 h liquid velocity and at 300 and 360 mm/s for a 3.1 m^3/m^2 h, the turbulence between gas and liquid phases at the bottom of absorber could create a slight drop in the foam volumes. The turbulence could even hinder the measurement of foam volume at the superficial gas velocity above 240 mm/s and the liquid velocity above $3.8 m^3/m^2$ h since it could obstruct and destroy down coming foam bubbles. At high gas and liquid velocities, difficulty in collecting the foam at the liquid outlet tube was unavoidable as a result of intensified turbulence.
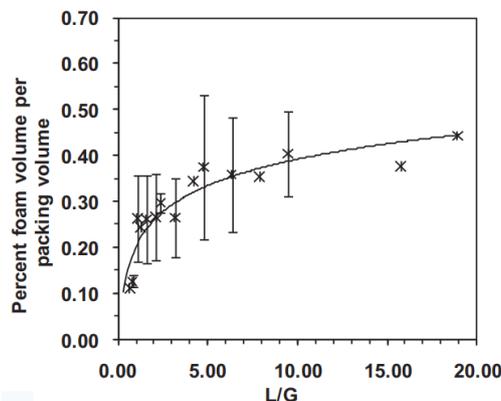

Fig. 3. (a) Experimental foam volume per packing volume plotted versus the L/G ratio (experimental conditions: 5.0 $kmol/m^3$ MEA concentration, 0.40 mol/mol CO_2 loading, and 18.5^0C solution temperature).

To combine the effects of both gas and liquid velocities on foam volume, the experimental results are also presented as a function of the ratio of liquid to gas velocity (L/G) as shown in Fig. 3. At the low L/G ratio of 0.8, the foam volume is very small due to the insufficient liquid holdup and the excessive gas velocity, which could easily breakdown the gas bubbles. As the L/G ratio is increased up to 4.8, the foam volume increases. This suggests that the effect of liquid velocity on foam volume is predominant over that of gas velocity. The effect of liquid velocity becomes much less when L/G exceeds 4.8.

V. CONCLUSION AND FUTURE WORK

The foaming experiments conducted in the absorber provided valuable insights into the influence of liquid and gas velocities on foam formation in MEA-based CO_2 absorption systems. The results indicate that liquid velocity plays a dominant role in determining foam volume, with higher liquid velocities leading to increased foaming due to greater wetted packing area and liquid holdup. In contrast, superficial gas velocity has a negligible effect at low liquid velocities, though its impact becomes more noticeable as liquid velocity increases.

Additionally, the findings highlight that at high gas and liquid velocities, turbulence can disrupt foam formation and hinder accurate measurement. The L/G ratio analysis further confirms that foam volume increases with liquid velocity until a threshold (L/G $\approx$ 4.8), beyond which the effect stabilizes. These insights contribute to a better understanding of foaming behavior in CO_2 capture processes and can aid in optimizing absorber design and operational conditions to minimize foaming-related inefficiencies.

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