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Foam and Antifoam Behavior of PDMS in MDEA-PZ Solution in the Presence of Different Degradation Products for CO_2 Absorption Process

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Abstract: Absorption is one of the most established techniques to capture CO_2 from natural gas and post-combustion processes. Nevertheless, the absorption process frequently suffers from various operational issues, including foaming. The main objective of the current work is to elucidate the effect of degradation product on the foaming behavior in methyldiethanolamine (MDEA) and piperazine (PZ) solution and evaluate the antifoaming performance of polydimethylsiloxane (PDMS) antifoam. The foaming behavior was investigated based on types of degradation product, temperature, and gas flow rate. The presence of glycine, heptanoic acid, hexadecane, and bicine in MDEA-PZ solution cause significant foaming. The presence of hexadecane produced the highest amount of foam, followed by heptanoic acid, glycine and lastly bicine. It was found that increasing the gas flow rate increases foaming tendency and foam stability. Furthermore, increasing temperature increases foaming tendency, but reduces foam stability. Moreover, PDMS antifoam was able to reduce foam formation in the presence of different degradation products and at various temperatures and gas flow rates. It was found that PDMS antifoam works best in the presence of hexadecane with the highest average foam height reduction of 19%. Hence, this work will demonstrate the cause of foaming and the importance of antifoam in reducing its effect.

Keywords: foaming tendency; foam stability; PDMS antifoam

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1. Introduction

The removal of acid gas from natural gas processing is an important process in which acid gases such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), mercaptans (R-SH), and carbonyl sulfide (COS) are removed [1,2]. It is generally used in petrochemical plants and refineries. Acid gas removal or gas sweetening is one of the main components in carbon capture technology which is the first key step in the carbon capture, utilization, and storage (CCUS) industry. CCUS technology is important whereby it aims to reduce the emission of CO_2 as it is released to the environment and could cause severe aftereffects such as a rise in global temperature, climate change, and negative health effects. Furthermore, the presence of CO_2 in industrial processing may cause corrosion to downstream processing equipment and pipelines, and may decrease the economic value of natural gas. The alkanolamines-based absorption process is the most common method for CO_2 and H_2S removal. Some common types of alkanolamines are monoethanolamine (MEA), diethanolamine (DEA), methyldiethanolamine (MDEA), and piperazine (PZ). Among these amines, MDEA is widely regarded as a cost-effective solvent with excellent CO_2 absorption capabilities, low corrosion rate, and low heat regeneration [3]. However, the use of amine-based solvents has its disadvantage in which degradation of amine into contaminants that can cause foaming in alkanolamine solution [4].

The formation of foam in an absorption process is one of the main problems that commonly occur in gas-treating plants. Foams are generated by the presence of various impurities that are introduced into the absorption system [5]. Some of the main impurities in the acid gas sweetening process are the presence of contaminant and degradation products such as condensed liquid hydrocarbon, suspended solids, organic acids, and heat-stable salts [6]. The presence of degradation products reduces the surface tension of the amine solution. Gas bubbles rise to the surface of the liquid solvent by buoyancy force. A thin layer of elastic film around the gas bubbles stabilizes them as the gas bubbles rise to the top of the absorption column. This process results in foaming in the absorption process [7,8]. The formation of foam is an undesirable phenomenon, as it causes flooding in the absorption column, process performance reduction, carryover of solvent to downstream facilities, incomplete regeneration of solvent, change of pressure in the column, and decrease in absorption efficiency [6,9]. Therefore, antifoam is added to the absorption system to reduce the effect of foaming. The addition of antifoam serves as a quick and an effective way to reduce foam formation as well as destroying existing foam formation [10]. Unlike mechanical methods of foam control that are complicated to use and consume a lot of electrical power, the use of antifoaming agents is simple, economical, and does not affect the continual absorption process [11]. There are three classifications of antifoams that are commonly used in acid gas removal system. These three types are non-polar antifoam, polar antifoam, and solid-based antifoams. Table 1 describes the types of antifoams in acid gas removal system. They are typically pre-added into a foaming system as either oil, hydrophobic solid compound, or a mixture of both compounds.

Table 1. Typical Types of Antifoam.

Classification	Types of Antifoams	Ref.
Non-polar Antifoam	• Mineral oils • Silicone oils	[8]
Polar Antifoam	• Fatty alcohol • Alky amides • Alky amines	[8]
	• Polypropylene glycol (PPG) • Polyalkylene glycol (PAG)	[12] [10]
Solid Antifoam	• Fumed silica	[13]
	• Treated silica • Aluminum oxide	[8]

1.1. Foaming Tendency in Amine-Based Solution

Recently, many studies on the foaming behavior in acid gas removal systems have been studied. These works are crucial to show that foaming is an issue that needs to be addressed. This will also emphasize the importance of the foam prevention method, especially with the use of chemical antifoaming agents. Some studies on foaming behavior in acid gas removal are described in Table 2.