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ACID GAS ABSORPTION STUDIES IN PACKED COLUMN

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ABSTRACT

Carbon dioxide is a major greenhouse gas that results in climatic changes. Reducing CO_2 emission for addressing the climatic change concerns is becoming increasingly important as the CO_2 concentration in the atmosphere has increased rapidly since the industrial revolution. Many mitigation methods, including CO_2 sequestration and novel CO_2 utilization, are currently under investigation. Most of these processes require CO_2 in a concentrated form. However the CO_2 from large sources such as fossil fueled power plants is mixed with nitrogen, water vapor, oxygen and other impurities. The current commercial operations for capturing CO_2 from flue gas use a chemical absorption method with Monoethanol Amine (MEA) as the sorbent. The method is expensive and energy intensive. The cost of capturing a ton of CO_2 including removing impurities and compressing CO_2 to supercritical pressure using existing MEA technology would be very high, and the power output would be significantly reduced by the energy consumption in capturing and compressing CO_2. In this work alternative solvent ammonia, is used which can overcome the disadvantages of current technology using amines such as MEA and DEA.

Keywords: carbon dioxide absorption, chemical absorption, MEA, DEA, Ammonia

INTRODUCTION

The global warming caused by increasing emission of carbon dioxide is one of the most serious environmental problems. Carbon dioxide discharged by the consumption of fossil fuel for power and heat production is said to occupy nearly 35% of the amount of discharged CO_2 all over the world. Therefore, removal of carbon dioxide from flue gases is a key measure to reduce CO_2 emission. Several technologies of CO_2 sequestration include chemical solvent absorption methods, adsorption methods, cryogenic methods, membrane separation and biological fixation, and the O_2/CO_2 combustion process. The absorption process is one of the most common industrial technologies today. Chemical solvent absorption methods are considered as a reliable method for reducing CO_2 emission from fossil fuel power plants. Among the chemical solvent absorption processes, the monoethanolamine (MEA) scrubbing is widely used in the chemical engineering process of gas purification and carbon dioxide capture. However, the cost to capture CO_2 from flue gas of power plants is very high when using MEA scrubbing. It is estimated that the energy penalty from using this method for CO_2 capture from coal-fired power plants is about 15% to 35%. Besides, the MEA process suffers the following disadvantages, such as low CO_2 loading capacity, high equipment corrosion rate, amine degradation by SO_2, NO_2, HCl and O_2 in the flue gas, and high energy consumption during absorption and regeneration.

So, the MEA process requires that the flue gas be clean, which SO_2 and NO_2 must be removed first.Some researchers found that ammonia seems to be an alternative and promising absorbent for removing CO_2 from flue gas. Aqueous ammonia is not easy to be degraded and the energy input is much lower than MEA process, and the solution does not have a corrosion problem. Three major acid gases, SO_2, NO_2 and CO_2, will be captured in the aqueous ammonia process, which is expected to reduce the total cost and complexity of emission control systems. Yeh and Bai carried out experimental investigation of ammonia and MEA capturing CO_2 in a bubble reactor. The tests showed that the NH_3 absorbent is superior to MEA absorbent in its capacity to absorb and removal of CO_2 from flue gas systems. Yeh et al, performed CO_2 absorption and regeneration with aqueous ammonia in a semi-continuous flow reactor. It is found that the regeneration energy saving for the aqueous ammonia process is approximately 62% compared with the MEA process. Diao et al, studied the mechanism and kinetics of the reaction between CO_2 and NH_3 solvent in a sieve-plate tower. Their experimental results showed that the CO_2 removal efficiency reaches its highest value at 33^0C.The main objective of this work is to analyze how the CO_2 absorption varies according to the various parameters such as gas flow rate, liquid flow rate, contact time and concentration of the solvent by using different solvents such as MEA, DEA and Ammonia.

EXPERIMENTAL SET UP

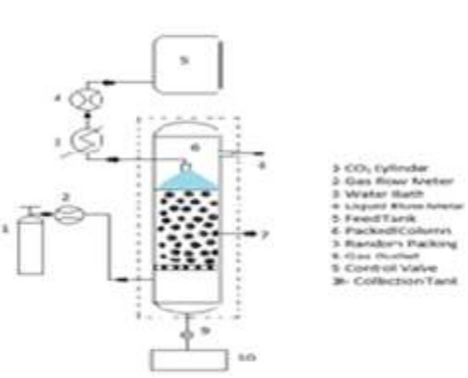

Figure 1 Experimental equipment scheme

The experimental apparatus is shown in figure1. The compressed gas and CO2 gas is passed from CO_2-cylinder through

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a flow meter and then in through the bottom of the column. Thereafter the non-absorbed gas flowed out from the top of the column. The liquid solution was placed in a feed tank and pumped upwards by pump to a head tank. The liquid solution in the head tank was held at a constant volume when steady state was achieved. A constant liquid flow entered the top of the column and was regulated by a valve. The liquid solution reacted with the incoming gas in the column and finally flowed by gravity to a product tank. From the bottom of the tank we collect samples and will analyze CO_2 absorption by using pH titration method. A pH graph method to compare and estimate CO_2 absorption in various solutions.

RESULTS AND DISCUSSION

EFFECT OF GAS FLOW RATE

Gas flow rate has an effect on the absorption performance in the packed column. Increase in the gas flow rate leads to a higher CO_2 absorption value when the ammonia concentration is high. When the ammonia concentration increases, the effect of gas flow rate on the CO_2 absorption become apparent. This phenomenon indicates that the CO_2 absorption rate is not only dependent upon the gas flow rate, it also dependent upon the concentration of solvent in the liquid. When the ammonia concentration is low, the enhancement factor would be small, which leads to higher value of resistance in the liquid phase. Thus, the resistance in the gas phase can be negligible. So, the overall mass transfer coefficient is not dependent upon the gas flow rate when the ammonia concentration is low. Whereas, the resistance in the liquid phase is decreased with increasing concentration of ammonia.

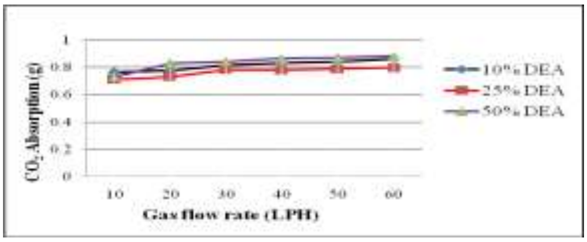

Fig.2 Effect of CO_2 absorption with solvent flow rate with DEA Solution

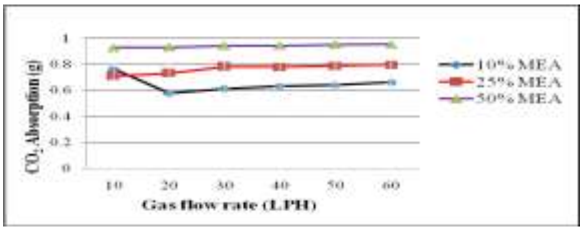

Fig.3 Effect of CO_2 absorption with solvent flow rate with MEA Solution

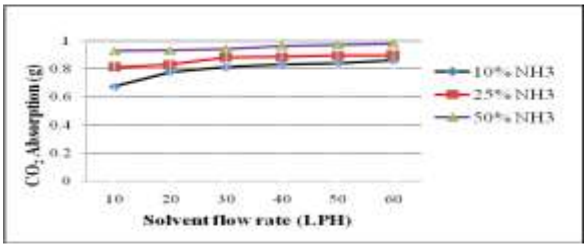

Fig.4 Effect of CO_2 absorption with solvent flow rate with NH_3 Solution

EFFECT OF LIQUID FLOW RATE

It was found from the study that an increase in the liquid flow rate results in an increase in CO_2 absorption value. With the liquid flow rate increasing, more liquid would be spread on the packing surface, and this leads to an increase in the interfacial area per unit volume. This helps the gas to absorb into the solvents at a higher rate. It was observed that, when the contact time increases the CO_2 absorption increases for MEA, DEA and NH_3. This was due to the reason that, when the time of contact between the gas and the liquid solvent increases, gas molecules get more time to diffuse into the liquid solvent. So sufficient contact time was needed for the effective absorption.

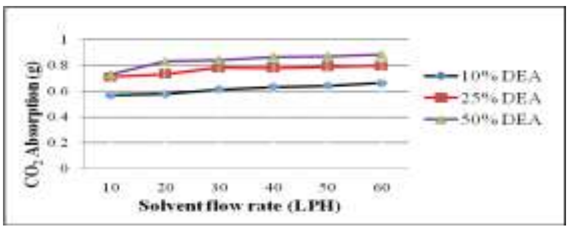

Fig.5 Effect of CO_2 absorption with solvent flow rate with DEA Solution

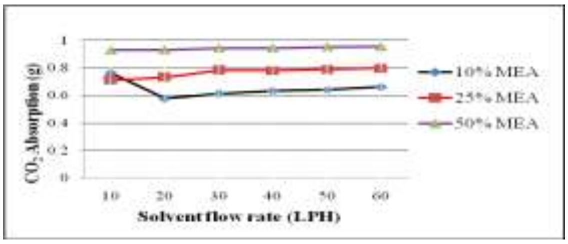

Fig.6 Effect of CO_2 absorption with solvent flow rate with DEA Solution

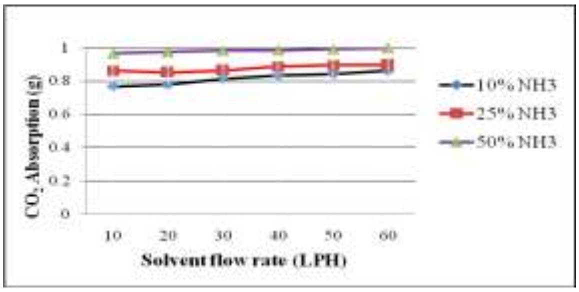

Fig.7 Effect of CO_2 absorption with solvent flow rate with NH_3 Solution

EFFECT OF CONCENTRATION

We observe that the increase in concentration of ammonia will leads to the increase in absorption. While in case of MEA and DEA, increase in concentration will leads to the decrease in absorption. This was because, the increase in concentration in case of MEA and DEA leads to the increase in viscosity of the liquid. This causes the molecular diffusion to reduce. The increasing viscosity also tends to cause a reduction in the effective interfacial area between gas and liquid in the packed column. The increase in ammonia concentration seems to show that the effect of ammonia concentration on the liquid viscosity is less than the effect of MEA and DEA.

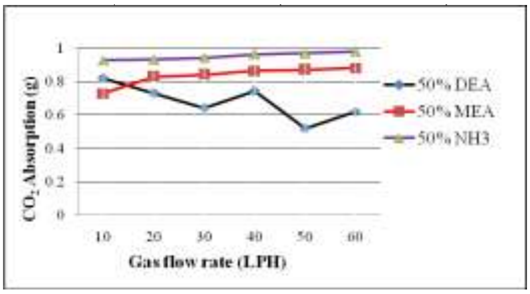

Fig.8 Effect of CO_2 absorption with different solvents at 50 % concentration

CONCLUSION

From this work ammonia seems to be an alternative and promising absorbent for removing CO_2 from flue gases. Aqueous ammonia is not easy to be degraded and the energy input is much lower than MEA and DEA process. Ammonia solution does not have the corrosion problem. While the current technology using amines (MEA and DEA) suffers many disadvantages such as low CO_2 loading capacity, high equipment corrosion rate, amine degradation by SO_2, NO_2, HCl and O_2 in the flue gas, and high energy consumption during absorption and regeneration. It is observed that as liquid flow rate increases and gas flow rate decreases maximum absorption takes place. NH_3 absorbent is superior to MEA and DEA absorbent in its capacity to absorb and remove CO_2 from gas streams. The regeneration energy required for NH_3 solvent is very less when compared to MEA and DEA, so we can save cost. The cost of ammonia is very less when compared to MEA and DEA. MEA and DEA absorb CO_2 at very low concentration while NH_3 absorbs large amount of CO_2 at high concentrations. So NH_3 solvent can be used to remove high concentrated flue gases from industry with greater efficiency. Therefore NH_3 can be used as an alternative solvent to remove CO_2 from the flue gases which can overcome the disadvantages of the currently using solvents.

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