ASPEN SIMULATION OF CO_2 ABSORPTION SYSTEM WITH VARIOUS AMINE SOLUTION

Seok Kim, Hyung-Taek Kim

Dept. of Energy Studies, Ajou University
Wonchon-dong San-5, Paldal-gu
Suwon, Korea 442-749

Introduction

The desire to alleviate the problem of global warming has resulted in the environmental concern over a reduction of greenhouse gas emissions from industrial sources. CO_2 is the major contributor to the global warming phenomena due to its abundance comparing to other greenhouse gases, as a result, it is considered to be a primary target for reduction. The gas absorption process with a chemical reaction using amine is recognized as the most cost effective and has the best proven operability record. The main purpose of this study is to minimize the amount of energy required in the desorption (commonly called regeneration) process through the simulation of various process concept of solvent absorption and to suggest the optimum operating condition to the actual CO_2 absorption experimental setup. Bench-scale, continuous CO_2 absorption reactor (capacity =5 Nm3/hr) located in the Korea Institute of Energy Research is modeled and simulated with ASPEN Plus for this purpose.

In the present research, CO_2 absorption process is simulated with commercial ASPEN Plus code and various combination of the operating parameters, such as flow rates of flue gas and amine solution, concentration of amine solution, temperature of absorption and regeneration tower, etc. Every set of operating condition of CO_2 absorption process is compared in terms of energy usage.

Methods

Carbon Dioxide Absorbents

Absorbents utilized in the CO_2 absorption technology can be classified according to their reactivity/solubility with CO_2. Widely-used absorbents in the industrial application are family of alkanolamines. Alkanolamines are usually utilized as aqueous solution in the CO_2 absorption process. Alkanolamines are divided into three classes: primary, secondary and tertiary amines according to their functional group. The classification is based on the substitute of the hydrogen on the nitrogen atom. Primary amines, which are most reactive among amine compounds, represent monoethanolamine (MEA) and diglycoamine (DEA).Initially, monoethanolamine (MEA) is used in the simulation investigation of CO_2 absorption.

The reactions of MEA and CO_2 are mainly occurred by electrochemical reaction in the aqueous solution. Typical reaction mechanism are as in the following equations.

$$2RNH_2 + CO_2 + H_2O \leftrightarrow (RNH_3)_2CO_3$$

$$(RNH_3)_2CO_3 + CO_2 + H_2O \leftrightarrow 2RNH_3HCO_3$$

$$2RNH_2 + CO_2 \leftrightarrow RNHCOONH_3R$$

Description of Absorption Process

Flue gases containing CO_2 are introduced into a direct cooler where they are cooled by a circulating stream of water. The gas is then compressed with a blower to overcome the pressure drop inside the absorber. The flue gases are flowed through the absorber in the countercurrent direction to the flow direction of absorbent solution. Inside absorber tower, the absorbent solution reacts chemically with the carbon dioxide in the flue gases. The CO_2-lean gases then enter the wash section of the absorber, where and entrained absorbent are removed and returned to the absorber. The washed gases are vented to the atmosphere. For the simulation, the CO_2 concentration in the washed gas is set to less than 1%.

The CO_2-rich solution leaves the absorber and is pumped to the lean/rich cross heat exchanger. In the cross heat exchanger, the CO_2-rich solution is heated and the CO_2-lean solution is cooled. The CO_2-rich solution is entered into regeneration tower where the absorbent amine solution is regenerated. To regenerate the solvent, the CO_2-rich solution is heated in a reboiler using low-pressure steam. Due to the heating, water and absorbent are vaporized. The water vapor and absorbent vapor leave the reboiler and enter the regenerator. The vapors move up in the condenser section of regenerator while liberating the CO_2 and heating the down-coming solution. Some vapor and CO_2 enter the wash section of the regenerator where absorbent vapor is removed. Water vapor and CO_2 enter the reflux condenser where the water vapor is condensed and the CO_2 is cooled. The condensed water is returned to the regenerator.

The CO_2-lean solution leaves the reboiler and enters the cross heat exchanger where it is cooled. The solution is then pumped and cooled further before it re-enters the absorber. The entire schematic diagram of CO_2 absorption process is illustrated in **Figure 1**.

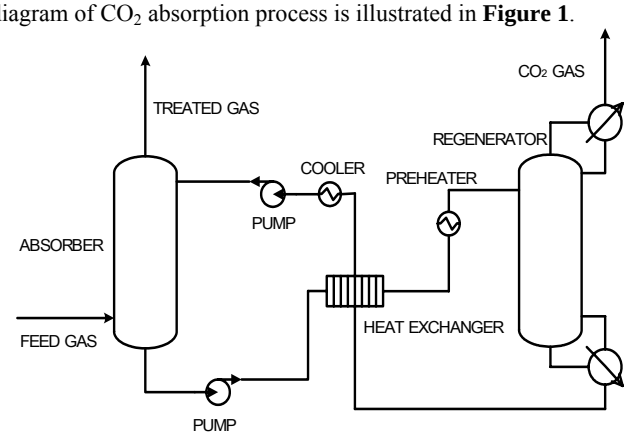

Figure 1. ASPEN Plus Block Diagram of CO_2 Absorption Process

Results and Discussion

Carbon dioxide absorption phenomena with amines is simulated with ELECNRTL method in the ASPEN PLUS. The ELECNRTL Property Method is the most versatile electrolyte property method. It can handle aqueous and mixed solvent systems.

During the simulation, The concentration of MEA solution is varied for sensitivity analysis. Concentration of MEA solution is fixed at 30 w% for the initial simulation study. Flue gas flow rate was set as 35 l/min and the composition of flue gas is CO_2=13.89%, N_2=82.56% and O_2=3.55%.Within this simulation set-up, the absorber pressure is varied from 1 to 10 atm. The results are illustrated in **Figure 2**. The increase of absorber pressure resulted in the better absorption rate up to the absorber pressure 3 atm. The absorption rate was almost saturated at about 3 atm or more.

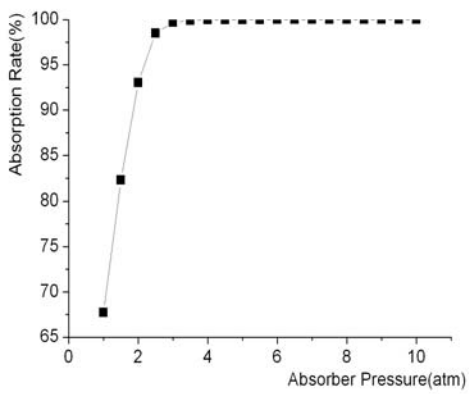

Figure 2 The effect of Absorber Pressure Variation

The effects of flue gas flow rate and MEA solution flow rate on CO_2 absorption rate are plotted all together in **Figure 3** when the concentration of MEA solution set as 30 %. As the flow rate of flue gas increased or flow rate of MEA solution decreased, the absorption rate has the decreasing tendency. The optimum condition represents when the flow rates of feed gas of 9 kg/h and MEA solution of 65 kg/h with over 97% CO_2 absorption.

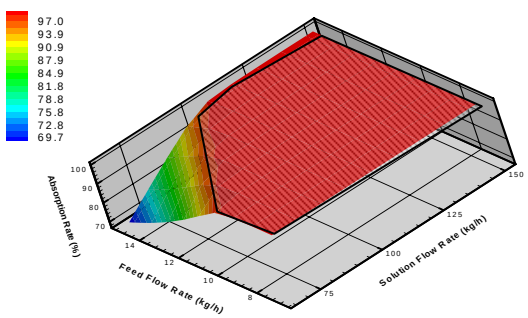

Figure 3 The effect of flue gas flow rate and MEA solution flow rate on CO_2 adsorption rate

Conclusion

The simulation using ASPEN Plus is progressed for an evaluation of optimum operating condition of the laboratory-scale continuous absorption apparatus treating 5 Nm^3/hr which is located in the Korea Institute of Energy Research.

Results of the simulation showed:

1) The increase of an absorber pressure and MEA solution flow rate causes the increase of CO_2 absorption rate and absorption rate reaches 97% at 3 atm.

2) The optimum condition represents when the flow rates of feed gas of 9 kg/h and MEA solution of 65 kg/h with over 97% CO_2 absorption.

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