New promoted concepts for reducing energy consumption in CO$_2$ capture amine solutions

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Abstract

Mono Ethanol Amine (MEA) is a primary amine, widely used at industrial scale for gas separation. There is a great focus towards promoting the solvent to increase the efficiency of the CO$_2$ capture process and decrease the energy consumption on regenerating the solvent.

In this study, we focus on the application of amine scrubbing process for CO$_2$ capture from industrial gases containing low to a very high mole percent CO$_2$, up to 40% CO$_2$, as observed in for example biogas upgrading.

This study aims to investigate the impact of using well-engineered additives, which has an impact on the following sections of the capture process:

1. Reboilers
2. Wash sections
3. Cooling sections and heat exchangers
4. Absorber design

The studied additives pose the characteristics of changing the fluid properties to alter the process features which can provide optimal process conditions. To be more specific, the amine solvents contain a significant amount of water which consume a large amount of energy at the stripper reboiler during evaporation. In order to reduce the reboiler duty, in this study, we take the advantages of the designer-additives (VRAs) to reduce the vaporization of water and thereby reduce the need for reboiling, reduce the need for low-temperature washing, reduce the need for cooling and facilitate the heat exchanging.

The goal of this project is to benchmark the MEA process compared to MEA with various VRAs. The benchmarking will be performed using Aspen Plus.

Currently, DTU has a range of possible additives to apply. In this study, we will present the results of at least two additives possessing different characteristics in term of solvent handling and solvent formulation.

Process simulation

Aspen Plus is used as a basis for process simulation in this study. Three approaches are used in this study:

1. Equilibrium based approach
2. RADFRAC approach (Aspen Plus, Rate based model)
3. CAPCO2 (DTU rate based model)

DTU has its own in-house rate-based simulation engine called CAPCO2 which is applicable in Aspen Plus as a user model through the Aspen Customer Model interface. It is a very complex set of first-principles partial differential equations which are solved by discretization through the column height. These can predict the mass transfers by having only the most basic information of column size and solvent kinetics. The information on second-order reaction kinetics is measured by for example a wetted wall column.
Pilot data and model validation

In this paper, we will present validation the process simulation using experimental pilot measured at DTU.

Experimental studies of CO\textsubscript{2} absorption were conducted in an absorption column in a research scale pilot plant located in DTU, Denmark. The simulation results were compared with experimental data to determine which of the simulation tools generate more reasonable results. Currently, the CAPCO2 model predicts more accurate column conditions out of the three modeling cases.

Conclusion and application of the model

The modeling applied in this study contributes to the ongoing Danish funded biogas upgrading project called BioCO2. This abstract, submitted to GHGT, describes a part of this project.

The energy consumption is the most considerable issue in CO\textsubscript{2} capture by amine scrubbing. In this study, the operational parameters are optimized to find the lowest energy consumption by optimization. Studied parameters are lean CO\textsubscript{2} loading, lean temperature, inner diameter, column heights, and absorption/desorption pressure.

From this comparison, the pros and cons of VRAs in MEA aqueous solutions for CO\textsubscript{2} capture processes will be shown, and their specific changes in key performance measurements such as CO\textsubscript{2} removal percentage, temperature, and CO\textsubscript{2} concentration profile in absorber, heat exchange, wash section, and desorber energy consumption will be explained.