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Dynamic modeling of varying flue gas input, load conditions and ramping behavior in CO_2 absorption plants for post combustion capture

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Introduction

As new large scale CO2 capture plants come into operation, there is a need to look into operational issues of these plants. It is known that power plants change load depending on demand usually knitted to subsequent adjustments on power prices, thus, the capture plants will see changing flue gas flow rates over a day. The way the capture plant is operated on an hourly basis depending on the power plant variations, sets new challenges to the design of the plant with respect to operational flexibility on cost measures. There are also issues associated with start-up and shut-down of these plants that need to be studied. Furthermore, the control structure needs to be resilient in order to handle the large disturbances on flue gas flow rates and composition. This requires a dynamic model of the capture process.

Because of the various amine formulations and vastly different operating conditions encountered in these processes, detailed experimental trials are very often not feasible with respect to the different applications. Therefore, accurate models for simulating column behavior are important in understanding these processes. In describing the transport mechanisms at the gas liquid interface, the chemical reaction taking place in the liquid-phase very often controls the absorption process. Thus, in determining the absorption effectiveness, it is important that information about the degree to which the chemical species diffuse in the solvent is available as well as information about the kinetics of the reactions involved.

Objective

The purpose of this work is to use a previously developed dynamic column model to primarily investigate transient behavior of a plant (as well as steady state) in order to understand important operational aspects of such plants. This includes varying flue gas input conditions, load changes and disturbances to lean solvent loadings, etc. The impact of any such changes will affect absorber performance as a consequence. The model will therefore help to determine those changes that adversely affect the performance of the absorption process.

Simulation model development

A rate based dynamic model of a packed column, implemented in CO2SIM, has been used for the study.[i] The simulator allows for the solution of a wide variety of problems, such as operability studies (of feed changeover and start-up operations) and column instability studies (effect of hydraulics during transient operations). The dynamic

model is programmed as a general packing model for CO2SIM and includes a user specified number of species undergoing mass transfer and is not restricted to a set number in the code design. Following implementation and verification of solution numerics, the model has been validated towards pilot plant data, which can be found elsewhere.[ii] A network solver (at this point only handling the absorber unit) ensures simple handling of any type and number of transient state changes. The general implementation methodology allows for efficient simulation of the units' transient behaviour for continuously changing input conditions or design parameters, part-load operation, varying input conditions and or ramped changes.

Preliminary results

A practical operational problem we have encountered at our pilot plant is unsteady lean loading to the absorber due to significant flashing at the heat exchanger rich side. This causes varying input lean loading to the absorber, varying flowrate as well as slightly varying temperatures. This example can be modelled by using the developed simulator with a sinusoidal function representing the varying input loading, flowrate and temperature to the absorber. The vapour flowrate out of the absorber, i.e the CO_2 capture rate is then monitored continuously over the given time intervals. All other conditions, such as input CO_2 flue gas composition are kept constant. The cyclic variations are then compared to a base-case, which is a steady state operation.

A cyclic perturbation of inlet lean loading (dotted line) with respect to time is shown in Figure 1 (left side) as well as resulting outlet rich loading (smooth line). It is interesting to see that the outlet average loading shows lower cyclic variation indicating that the large and *slow response* absorber "absorbs" some of the cyclic variations. The same can be seen monitoring the outlet CO2 gas stream. The cyclic changes occur over a time interval of 2 hours, with 20 consecutive changes in loading and input flowrate. The average CO2 outlet flow from the top of the absorber is 34.7 kg/h whereas the steady state simulation (shown in the figure as the straight line) has an averaged value of 36.52 kg/h. The reduction in loading thus increases the reactivity of the solvent leading to a favourable effect on the capture rate. This abstract includes only one example showing the many applications of this model. The final work will include a deeper analysis of such kind of transient behaviour.

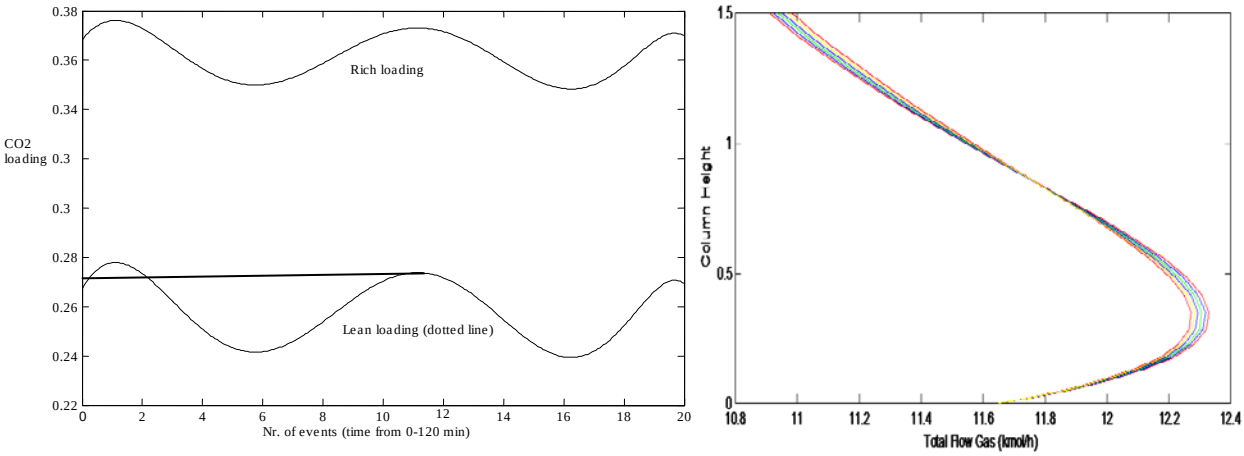

Figure1: Left side: Inlet lean CO2 loading (dotted line), Outlet rich loading (smooth line), Right side: Variations in total gas flow along the column.

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