



REDUCTION OF GREENHOUSE GAS EMISSION DURING PRODUCT LIFE CYCLE BY REMOVING CO₂ IN BOILER INDUSTRY USING MATHEMATICAL MODELLING AND SIMULATION

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ABSTRACT

Carbon Dioxide is one of the important and major Green House Gas, It is mandatory to be removed after any combustion process (from the flue gases). In this Research work the removal rate of Carbon Dioxide (CO₂) in the flue gases coming from the combustion process of Boiler would be removed. There are common processes available for the removal/ separation of Carbon dioxide, but it takes more amount of energy. By comparing with this formerly the combustion process with the pure oxygen can be done for removal of carbon dioxide. With this the redesign of boiler is required and secondary option is chemical solvents (like monoethanolamine, diethanolamine and methyl diethanolamine etc) process can be adopted and modified in the boiler system. The later one gives the significant reduction of electricity bills. By utilizing the different special chemical solvents in the vertical column, the Mathematical model will be introduced to compare the rate of removal, further it is simulated using MATLAB and chemCAD software and by comparing the simulation results one of the best Special solvent is selected for greater energy efficiency and lowering the electricity costs.

Keywords: product life cycle, green house gas emission, emission control, boiler emission, energy efficiency.

1. INTRODUCTION

For the sustainable development, Energy problems and Green House Gas emission reduction is one of the greatest issue to protect our environment and its climate change. There are different Green house gasses which emits emission and one of the most important thing is we all know that out of all these gasses, the Carbon dioxide is the major issue. With the help of modeling and simulation, the removal of carbon dioxide can be done by using variety of aqueous solutions. Mono-ethanolamine in absorption columns for the reduction of GHG emissions. This improved mathematical model is used for analyzing and absorption rate of Carbon dioxide and using different types of solutions in this particular column, the absorption rate can be simulated with the help of software MATLAB or chemCAD software. The high pressures about 35-50 bar and low temperatures about 40-70°C are utilized.

2. EXPERIMENTAL

A different types of chemical solvents are used and studied, for e.g. MEA (monoethanolamine), DEA (diethanolamine), MDEA (methyl diethanolamine), activated MDEA (mixture MDEA - piperazine). Figure-1 below shows the system is attached with a vertical column, in which the removal of carbon dioxide is going to take place. The Absorber is of about 8 cm inner

diameter, which consists of 2 heaters and CO₂ analyzer, one pump, vertical column. CO, absorbent enters from one end of the top of the absorber through a spray nozzle to ensure best initial liquid distribution to the packing material. The nozzle of the spray, which delivers fine mists, is placed above the column at Exactly 1 Inch. In this the liquid is pre-heated electrically up to the reactor control temperature in the Stainless steel inlet line and absorber temperature is normally set about 35°C to 40°C, during CO₂ absorption. Liquid flow rate is controlled by a Micro Motion mass flow meter. All the above Flow rate datas are continuously monitored and instantly stored in a System. Simulated flue gas enters from the bottom of the absorber and the Gas flow rate is controlled by a mass flow meter controller. General Gas flow rate data are also stored in a System. The baseline gas composition is about 14% CO₂ and 80% sulfur oxides, hydrogen chloride, nitrogen oxides, and oxygen are not included in the simulated flue gas to avoid possible interferences with the test objectives for this series of experiments. These acid gases are known to cause degradation of the solvents. Coal-fuel flue gas nominally consists of 18% CO, on a dry basis when the combustion takes place with 25% excess air.

2.1. Figures and equations

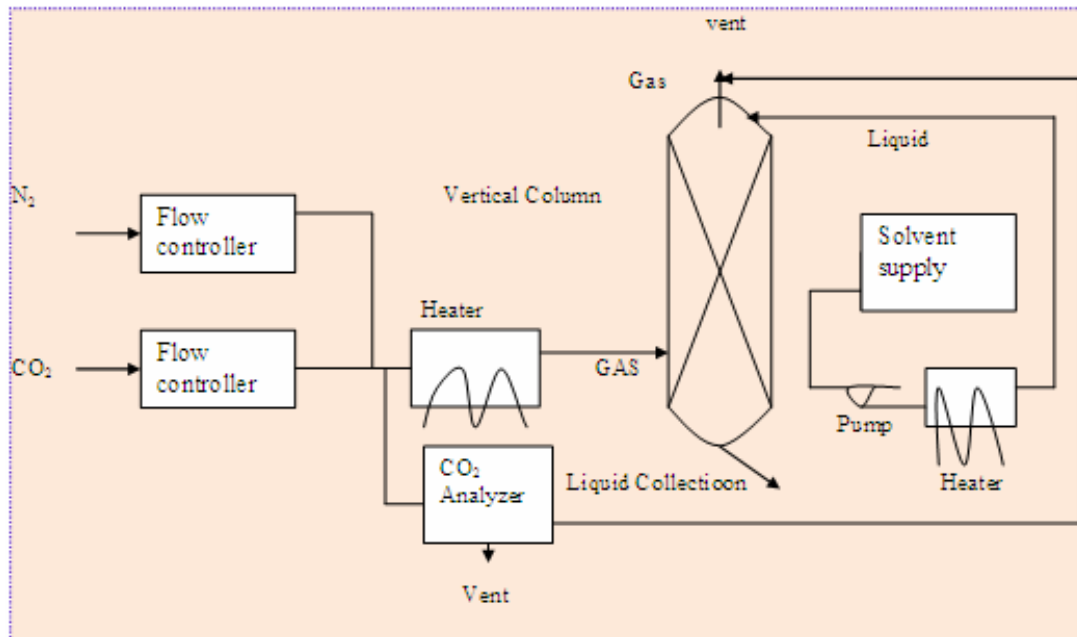


Figure-1. System with vertical column.

2.2. Mathematical model for CO₂ absorption

The Mathematical model equations consist of both PDE (Partial Differential Equations) and algebraic equations along with the Heat and Mass conservation equations.

$$\frac{\partial C_A}{\partial t} = -v_L \cdot \frac{\partial C_A}{\partial z} - k \cdot C_A \cdot C_B + E \cdot k_G \cdot a_u \cdot (C_{AG} - H_{CO_2} \cdot C_A)$$

Where

CA, CB, CAG are the concentration of dissolved gas A / reactant B / A in gas (kmol/m³)

L = Axial velocity of liquid film (m/s)

k = reaction rate constant (m³/mol×s)

E = Enhancement factor

kG = Partial transfer coefficient (m/s)

au = Specific area (m²/m³)

HCO₂ = Carbon dioxide Henry's constant

$$\frac{\partial C_B}{\partial t} = -v_L \cdot \frac{\partial C_B}{\partial z} - 2 \cdot k \cdot C_A \cdot C_B$$

$$\frac{\partial T_L}{\partial t} = -v_L \cdot \frac{\partial T_L}{\partial z} - \frac{\Delta_R H \cdot k \cdot C_A \cdot C_B}{\rho_{sol} \cdot c_{p_{sol}}} + \frac{h \cdot a_u}{\rho_{sol} \cdot c_{p_{sol}}} \cdot (T_G - T_L)$$

The ratio of T_L/T_G = liquid/gas phase temperature in Kelvin.

Specific heat (h) of the solution (Joules per mol*K);

Transfer coefficient in gas phase (J/s·m²·K).

The Heat Transfer Coefficient values completely depend on the thermal properties like density of gas, diffusivity, heat capacity and thermal conductivity. In the secondary process the mass balance equations for gas phase is initiated by the consuming carbon dioxide.

All the mathematical modeling equations which are in the form of PDE (Partial differential equations) are converted into Ordinary Differential Equations with the help of discretization process. This model had solved with the help of MATLAB software for finding how the rate of carbon dioxide the elements are being separated into number of regions, the absorption of Carbon dioxide transforms along with the concentration which decreases in the aqueous solution.

3. MODEL SIMULATION RESULTS

The Mathematical model and its simulation of Carbon dioxide absorption and reduction in a aqueous mono-ethanolamine solution shows how the evolutions, in time and space, of temperature, and concentration in the liquid and gas phase along the absorption column. The variation of reactants is shown by the below graph between concentration vs. column height.

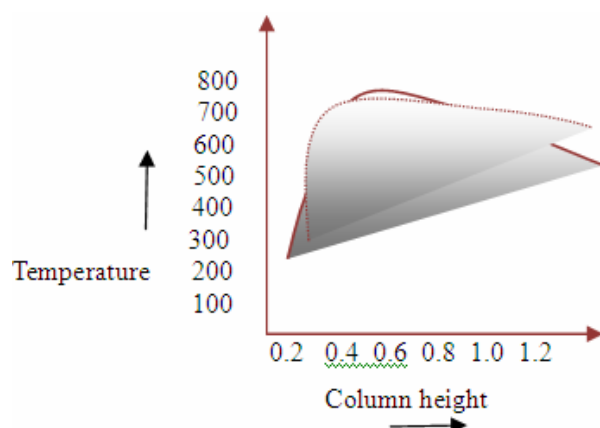


Figure-2. Column ht vs Temp.

The efficiency of the Mathematical developed model is formalized by correlating between the simulation

results with data collected and from the simulation of carbon dioxide absorption process.

By using ChemCAD software, for the similar operating conditions. The Mathematical model which is developed is similar to the kinetic model (solved in MATLAB) and ChemCAD model data Similar to the above for predicting actual gas-absorption performance of absorption column shown in the Figure-1.

4. CONCLUSIONS

The Mathematical model is generated for analyzing the Carbon dioxide absorption in the absorption column. Simulation of CO₂ gas - liquid absorption processes in mono-ethanolamine and other solvents will be done using Matlab and ChemCAD software. After generating of simulation results process, the energy consumptions like power, heating and cooling are to be determined.

Level of offering	Area of saving	Energy saving	CO ₂ reduction in Mt per Year
Providing vertical column and for different solvents	Power	4-8 %	50 - 70 Metric ton per Year

Further the design of vertical column can be changed for different chemical solvents and results can be simulated after discretization of the partial differential equations models.

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