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CO_2 Absorption Using Potassium Carbonate as Solvent

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- The combustion of fossil fuels produces a large amounts of CO_2, one of the main greenhouse gases, which impacts global warming.
- Tackling climate change requires reducing CO_2 emissions, either through the use of alternative fuels or through the use of carbon capture technologies.
- One of the well-known CO_2 capture technologies is chemical absorption in an amine-based solvent (mono- ethanolamine (MEA), me-thyldiethanolamine (MDEA) etc.) followed by desorption.
  - Amines are widely used mainly because of their reactivity with CO_2 under mild temperature (absorber: 40-65°C; stripper: 100-120°C) and pressure (1-2bar) conditions.
  - Amines are corrosive and cause equipment problems and through their easy degradation by oxidation reaction can be potentially toxic to the environment.
  - A major drawback of amines is the high reboiler heat duty for desorption.

<u>In this study,</u>

- The absorption of CO_2 using K_2CO_3 solution is investigated, as well as its regeneration. ASPEN PLUS® software is used to evaluate the operating parameters of the CO_2 capture pilot unit.
  - K_2CO_3 is less toxic and less corrosive than amines, and is considered a particularly attractive wet chemical absorbents as it has fewer energy requirements for its regeneration.

Rate based method

- The methodology for a rate model is used.
- The rate of absorption and desorption is determined by two mechanisms,
  - mass transfer and
  - chemical reaction,
- The mass and energy balance equations determine the concentration and temperature along the column.
- The electrolyte NRTL method is chosen for computing liquid phase properties and RK equation of state is chosen for computing vapor phase properties.
- CO_2, H_2S, N_2, O_2, CO and H_2 are selected as Henry-components to which Henry's law is applied, while the activity coefficient basis is aqueous.

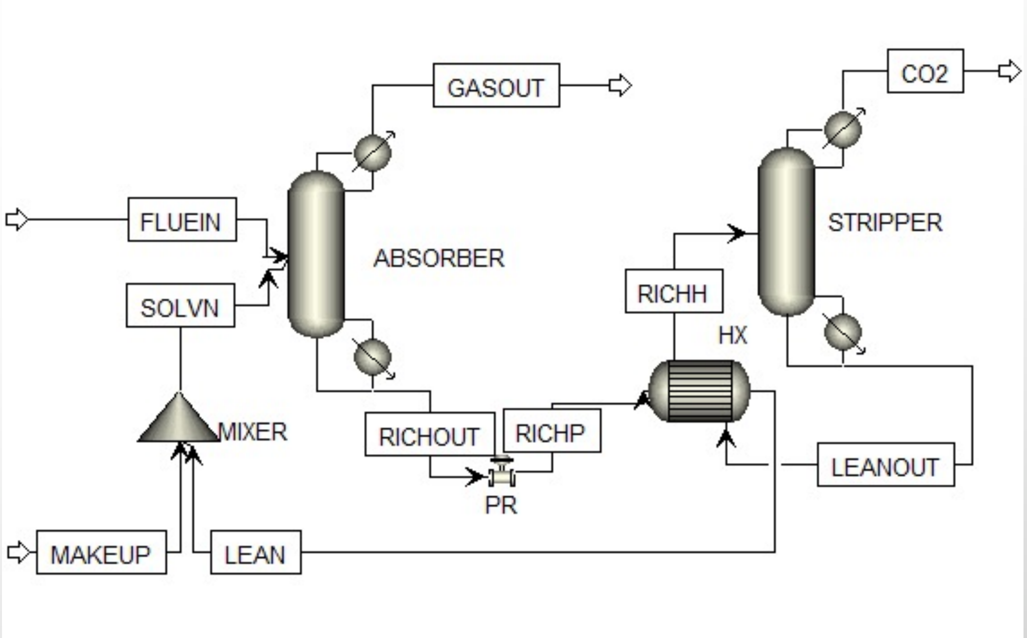
Reactions
$CO_2 + 2H_2O \leftrightarrow H_3O^+ + HCO_3^-$
$HCO_3^- + H_2O \leftrightarrow H_3O^+ + HCO_3^{-2}$
$2H_2O \leftrightarrow H_3O^+ + OH^-$
$H_2O + H_2S \leftrightarrow HS^- + H_3O^+$
$H_2O + HS^- \leftrightarrow S^{-2} + H_3O^+$
$KOH \rightarrow K^+ + OH^-$

- All the data are retrieved from Aspen Plus® databank and chemical equilibrium is assumed.
- In post-combustion capture applications, the absorber is operated close to atmospheric pressure, which is similar to input stream of flue gas.
- When CO_2 is absorbed into K_2CO_3 solvents, particularly at high concentrations of K_2CO_3, both physical reactions and chemical reactions occur.
- The summary of the reactions for the absorber and stripper specifications are shown in the table.

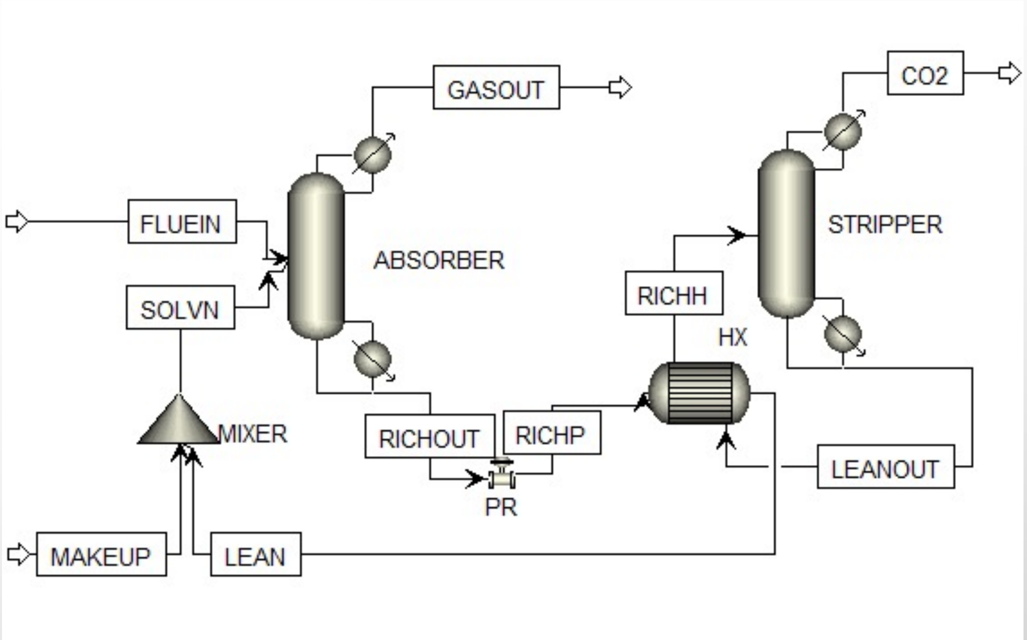
Simulation

➢ The specifications and operating conditions are presented in Table. A schematic flowsheet developed in this study is presented in Figure.

	Absorber	Stripper
Temperature (°C)	35	80, 85, 100
Pressure (bar)	1	0.3, 0.7, 1
Gas flow rate (slpm)	1	
Solvent flow rate (slpm)	0.1	
Concentration of K_2CO_3 (%v/v)	15, 20, 25	
Concentration of CO_2 (%v/v)	15	



- Two main streams were specified, the solvent stream named "SOLVN" and the flue gas stream "FLUEIN".
- The flue gas was considered to be composed of CO_2 and N_2 while other components like H_2O, O_2, and SO_2 are neglected.
- A solvent makeup stream was added to the recycled stream before entering the absorber in order to compensate for the solvent loss during the absorption and stripping process.
- The solvent was added at atmospheric pressure and at a temperature of 35°C.
- From the absorber, a gas stream containing almost no carbon dioxide is released.
- Meanwhile, the liquid stream which is rich in solvent leaves the absorber and is pressurized and heated before entering the stripper.
- From the stripper, a gaseous stream of CO_2 is produced, while the liquid solvent stream is recycled back to the absorber.

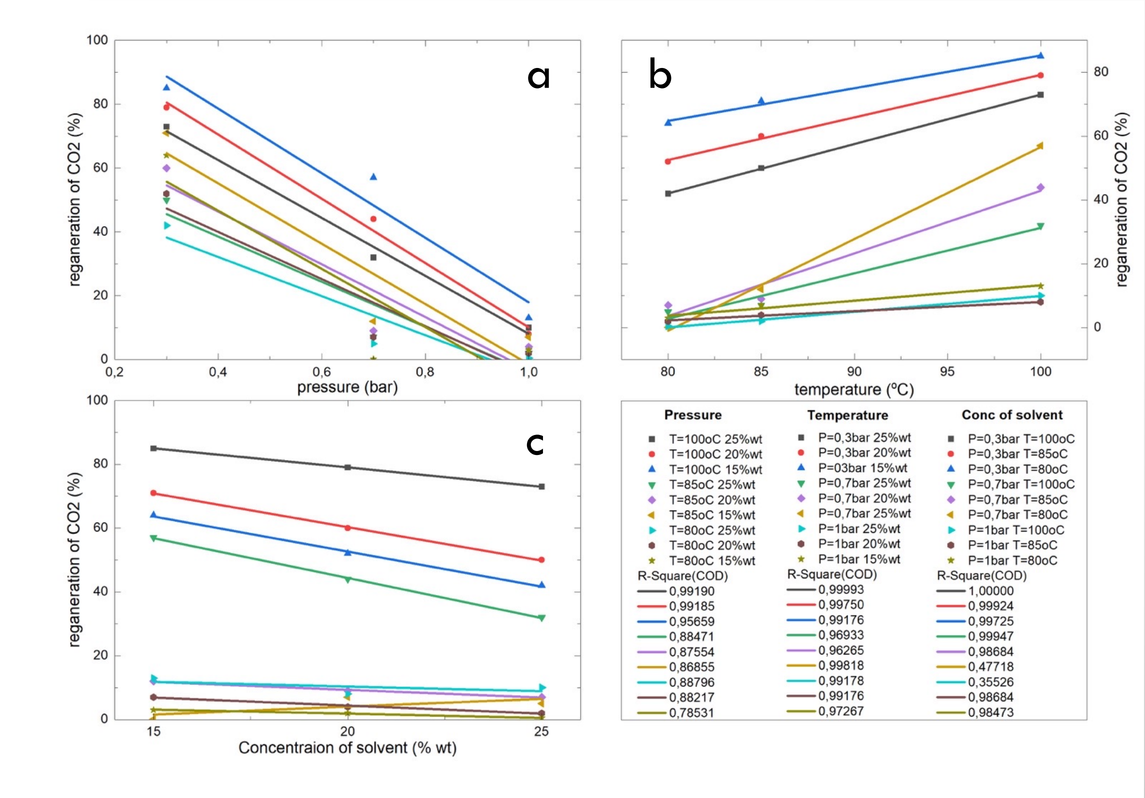


- An analysis of variance (ANOVA) was performed with independent parameters:
  - stripper temperature;
  - stripper pressure and
  - concentration of solvent.
- The results of the ANOVA analysis are presented in Tables.
- All 27 cases were simulated based on the Aspen Plus flow sheet for two responses:
  - absorption of CO_2 efficiency and
  - regeneration of CO_2 efficiency.
- The CO_2 absorption efficiency for all cases exceeded 99.8%

	Sum of Squares	Mean Square	F Value	P Value
Stripper pressure	1,69017	0,84508	101,3366	7,9357E-12
Stripper temperature	0,31846	0,15923	2,03963	1,55624E-5
Error	0,18347	0,00834		

	Sum of Squares	Mean Square	F Value	P Value
Solvent concentration	2,14728E-6	1,07364E-6	20,07851	7,50939E-6
Error	1,28333E-6	5,34721E-8		

- The simulation results for CO_2 recovery efficiency are shown in Figure.
- The increase in potassium carbonate solvent has a subtle decrease in absorption of CO_2.
  - This is inconsistent with the parametric analysis of K_2CO_3 concentration carried out by Ayittey.
  - This differentiation is due to the small variation in CO_2 absorption values.
- The regeneration CO_2 showed a large variation of values depending on the stripper operating conditions. Figure 2a shows that reducing the pressure of stripper significantly increases CO_2 recovery with a fine linear correlation (R^2>0.785).
- Greater regeneration of CO_2 is observed when the stripper temperature is higher, as confirmed in Figure 2b.
- There is a perfect linear correlation of stripper temperature with regeneration of CO_2 (R^2>0.963).
- The concentration of potassium carbonate in the liquid absorber is not expected to affect the regeneration of carbon dioxide (Figure 2c).



- An analysis of variance (ANOVA) was conducted to estimate the influence of parameters on the absorption of carbon dioxide and the CO_2 regeneration.
- Stripper pressure and stripper temperature were chosen as independent variables, as they were suggested to influence CO_2 recovery.
- The results of two-way ANOVA analysis were evaluated for CO_2 recovery as the p-value and F-factor.
- The statistically significant parameters for the regeneration of CO_2 are the stripper pressure and the temperature of the stripper, with a p value lower to the level of 0.05.
- A one-way ANOVA analysis showed that the concentration of K_2CO_3 is statistically significant for the ab-sorption of carbon dioxide.

- An eco-friendly carbon dioxide capture process is studied in this research using ASPEN PLUS® software.
- The capture and recovery of CO_2 were simulated in an absorption and a desorption column, using potassium carbonate.
- The parameters examined were the concentration of K_2CO_3 and the temperature and pressure of the stripper.
- Stripper pressure and stripper temperature influence the regeneration of CO_2, as shown in the analysis of variance (ANOVA).

THANK YOU

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