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Modeling of Post-Combustion Carbon Capture (PCC) process of a coal-fired power-plant using the equilibrium-based governing approach and ASPEN HYSYS

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Abstract

The potential of carbon capture and storage to provide a low carbon fossil-fueled power generation sector that complements the continuously growing renewable energy sector is becoming apparent. This is aimed towards maintaining the standard percentage of carbon dioxide in the earth atmosphere. Carbon dioxide capture from exhaust gas of power plants, natural gas and refinery gas can be successfully achieved by absorption with mono-ethanol amine. This work presents the description of a CO_2 removal process of an 800MW coal fired power plant. This was done by designing a capture plant model using acid-gas thermodynamic model employing mono-ethanol amine as solvent in Aspen HYSYS to simulate 96% capture of the CO_2 in the flue gas of the coal fired power plant. The effect of absorber pressure and absorber packing height on stripper re-boiler duty are studied. Re-boiler duty is decreasing with the increase of packing height and pressure. The effect of solvent properties on CO_2 removal efficiency is also analyzed. The removal efficiency increases with solvent flow rate and absorption column height and while the absorption temperature is increasing, the efficiency of the removal process is decreasing. The optimum CO_2 removal efficiency of the plant was obtained at 5 m^3/h flue gas flow rate and the required re-boiler heat duty was calculated as 4100 KJ/Kg CO_2.

Keywords: Carbon capture; ASPEN HYSIS; Post-combustion; Global warming; CO_2 emission

1. Introduction

The major sources of energy for mechanical purpose and electricity generation purpose is obtained by the process of combustion of fossil fuels in power plants, of this fossil fuels, coal is much more carbon intensive than oil or natural gas. The flue gases of fossil fueled power plants can contain up to 8% CO_2 for a gas powered power plant and up to 20% CO_2 by molar concentration for a coal fired power plant. Yelebe and Samuel (2015) reported that roughly six billion metric tons is used yearly for electricity generation in coal fired power plants, producing eighteen (18) billion tons of carbon dioxide (CO_2) and its accounts for 40% of carbon emission. Other sources of carbon emissions include cement production, gas flaring, liquid fuels, gaseous fuels, bunker fuels, deforestation and steel production.

It has being scientifically proven that CO_2 emission from fuels has caused a change in climate and pose a risk of devastating effect in the future (Chu Steven, 2009). Vis-à-vis to the challenges posed by the emission of CO_2 into the earth atmosphere, different understudy technologies such as amine scrubbing,O_2/CO_2 recycle combustion, membrane gas absorption, photosynthetic bioreactor,CO_2 hydrate and mineral trapping are being used to mitigate the emission of carbon dioxide to the earth atmosphere (Amir, Saeeh and Ashraf, 2015). The three common technique use to mitigate the emission of carbon dioxide to the earth atmosphere from fossil fuel power plant are pre combustion CO_2 capture, where carbon is removed from the fuel-air mixture prior to combustion; Oxy-fuel combustion, where coal is combusted with oxygen instead of air with CO_2 enriched environment; and post combustion carbon capture where fossil fuel is

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combusted to produce energy and CO_2 is removed from the flue gas after combustion (Udara and Morten, 2012). This is the technique used in post combustion carbon capture plants.

Post combustion carbon capture plant based chemical absorption with aqueous amine solution is presently the mature and viable technology for the removal of CO_2 from the flue gas of fossil fueled power plants. One advantage of PCC plants is that they can easily be retrofitted into existing coal and gas power plants without significant modification. This CO_2 separation technology with MEA as solvents has been commercially deployed in chemical industries for several years, primarily for gas sweetening and therefore can be said to be well proven (Adam, Casten *et al*, 2017). The choice of mono-ethanol amine (MEA) as solvent in most post combustion carbon capture plants is because of its high absorption rate, low solvent cost and low regeneration heat requirement (Aaron and Tsouris, 2005). In the study of EEDI, the perspective of ship engine-propeller design and matching receives little attention; however, since the ship propulsion system is where the majority of CO2 emissions originate, this study used the Hughes-Proshaka method to extrapolate the results to large scale vessels in order to determine the actual resistance and effective power of such ships. The particulars were taken from several already-existing ships, but assumptions were established based on the displacements of the vessels so that the analysis of their EEDIs could be statically determined. From the investigations carried out, it can be concluded thusly (Chuku *et al.,* 2024).

In recent years, the earth surface temperature has being on the increase. The recent data published by NASA *et al* (2014) shows that earth surface temperature has been increasing by 1% over the past one hundred and thirty years (130) years. This increase in global surface temperature has been traced to the unbalance in the gases contained in the earth atmosphere. Some of these gases which include but not limited to are carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4) etc. often times, majority of these gases are released into the atmosphere from the exhaust of power plants that utilizes the process of combustion of fossil fuels. Carbon dioxide one of the product of combustion of fuel with air; a major greenhouse gas as being on the increase in the earth atmosphere due to its release via the exhaust of fossil fueled power plants. This increase in CO_2 has being proven to be one of the major contributors to global warming. Therefore, the capture of CO_2 via PCC is important to maintain the emission levels to standard. However, the application of this PCC CO_2 capture technology is limited by its high energy consumption during the regeneration process of the solvent in the stripping column of the capture plant and high capital cost as it relate to the absorber column height of the capture plant.

In this research, a computer based simulation software will be used to simulate a PCC plant using the flue gas of an 800MW coal fired power plant to study the parameters that affects the operational cost as it relates to the heat duty of the re-boiler and also to determine the maximum possible CO_2 removal efficiency by simulating the parameters that affects CO_2 removal efficiency using the two acid-gas chemical solvent thermodynamic model available in the amine property insert package of ASPEN HYSYS.

The aim of this study is to use Aspen HYSYS process simulation software to simulate an amine based post combustion carbon capture plant running on 800Nm^3/h flue gas flow and with an absorption column inlet temperature of 40^{0}C. This research paper has the objectives which included to analyze the effect of changing amine circulation rate on CO_2 removal efficiency of the plant, the effect of changing absorption column height/packing height on CO_2 removal, the effect of changing absorption temperature on CO_2 removal efficiency of the plant, the effect of changing absorption pressure on stripper re-boiler heat duty and the effect of variation of absorption column packing height on the stripper re-boiler heat duty

Aspen HYSYS process simulation software is used to develop and simulate a post combustion carbon capture plant model using mono-ethanol amine as solvent. It also employs the flue gas data of an 800MW coal fired Medupi power plant and the data of the operating conditions of the component of the Medupi carbon capture plant in the process simulation aimed to attain about 95% CO_2 removal efficiency. However, this study does not consider the transportation, compression and storage of the CO_2 captured.

Therefore, from the aforementioned, this research will provide an optimization strategy of post-combustion carbon capture plant and also contribute to various researches and knowledge on simulation of PCC plant using mono-ethanol amine (MEA) as solvents.

2. Materials and methods

2.1. Materials

The material used for this study included the following:

- An Hp Laptop
- ASPEN HYSYS software version V11
- Flue gas composition data of 800MW coal-fired Medupi power plant extracted from literature [2]
- Operating condition data of the units of the post combustion carbon capture plant in consideration

Table 1 Coefficients for Calculation of Thermodynamic Equilibrium and Heat of Reaction, As Used in Equations 1 and 2

c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_g
22.53	-7904	103	-16810	-286.4	2648	381.7	8295	-257.4

2.2. Methods

2.2.1. The Equilibrium-based Governing principles and approach

In this study, acid gas available in amine property insert package is used to carry out simulation of the post combustion carbon capture plant model using mono-ethanol amine as the absorption solvent. The data to be used for the simulation include the composition of the flue gas, temperature, pressure, flow rate of the inlet stream, the operating condition of the units of the plant.

The model of the post-combustion CO_2 capture unit is intended for integration into a model of the entire power plant. Ultimately, its purpose is to study the interaction of different plant units during transient operations. In the instance of a plant-wide system analysis, a reduction in the degree of detail would be required to improve the model robustness and to allow for reasonable simulation time. In terms of accuracy of model predictions, it is worth mentioning that deviations in the absolute values of process variables have often a negligible impact on the predictions of system dynamics, which are of main interest in this type of studies. For this reason, the equilibrium-based approach assuming thermodynamic and chemical equilibrium at each column stage was adopted for the modeling of the absorber and stripper component. The implementation is based on the method described on ASPEN HYSIS process.

It is assumed that CO_2 that crosses the phase boundary reacts instantaneously with the solvent. This approach has the advantage that only the equations for the thermodynamic equilibrium, given as;

$$InP_{CO_2}^{*} = c_0 + c_1\frac{1}{T} + c_2\alpha + c_3\frac{\alpha}{T} + c_4\alpha^2 + c_5\frac{\alpha^2}{T} + c_6\alpha^3 + c_7\frac{\alpha^3}{T} + c_g\alpha^4 \quad (1)$$

and for the heat of reaction, written as;

$$\Delta hco_2 = -R(c_1 + c_3\alpha + c_5\alpha^2 + c_7\alpha^3) \quad (2)$$

must be implemented. A rather complicated implementation of the chemical reaction including several side reactions, for which actual kinetic data is very scarce, can be avoided.

The partial pressure of CO_2 is denoted by $P_{CO_2}^{*}$, α *is the* CO_2 loading of the liquid medium at the temperature T, R is the ideal gas constant, and Δhco_2 is the combined absorption and reaction enthalpy of CO_2. The coefficient c_0 and c_g are shown in table 1.

2.2.2. Modeling

Modeling is a process where a system is described by appropriate mathematical equations that are executed in a computational technique such as Aspen HYSYS in order to predict the system behavior (Iribarren & Dufour, 2019). In this study, the acid gas model available in the amine property package for flue gas treating will be employed in the simulation of the capture plant. Aspen HYSYS execute models based on user specification. Thus, the predicted results will depend on the quality of data used for input. Engineering software packages such as Aspen HYSYS enable processes to be simulated so as to determine various parameters such as mass and energy balances and economic viability of a process. It has a database composed of components for petro chemistry and other organic components.

2.2.3. Process Description

The exhaust gas from the 800MW Medupi coal fired power plant is used as the feed to the absorber. The flue gas which contains 13.3% molar CO_2 and H_2S free enters the absorber at a flow rate of 800Nm^3/hr and at a temperature of 40^{0}C.

In the chemical absorption process, the flue gas enters the absorber at the bottom while the solvent (MEA) enters at the top. The reaction starts between MEA and CO_2 while flowing through the column packing bed. An unreacted gas leaves the column at the top (Treated gas), while the rich amine discharges the column at the bottom. The rich solvent goes through the heat exchanger to increase the temperature before sending it to the stripper section. The heated rich solvent then goes to the stripper at the top (Pure CO_2). The lean amine then leaves the system at the bottom of the stripper after passing through the regeneration process and go through the heat exchanger and then to the top of the absorber. See figure 1.

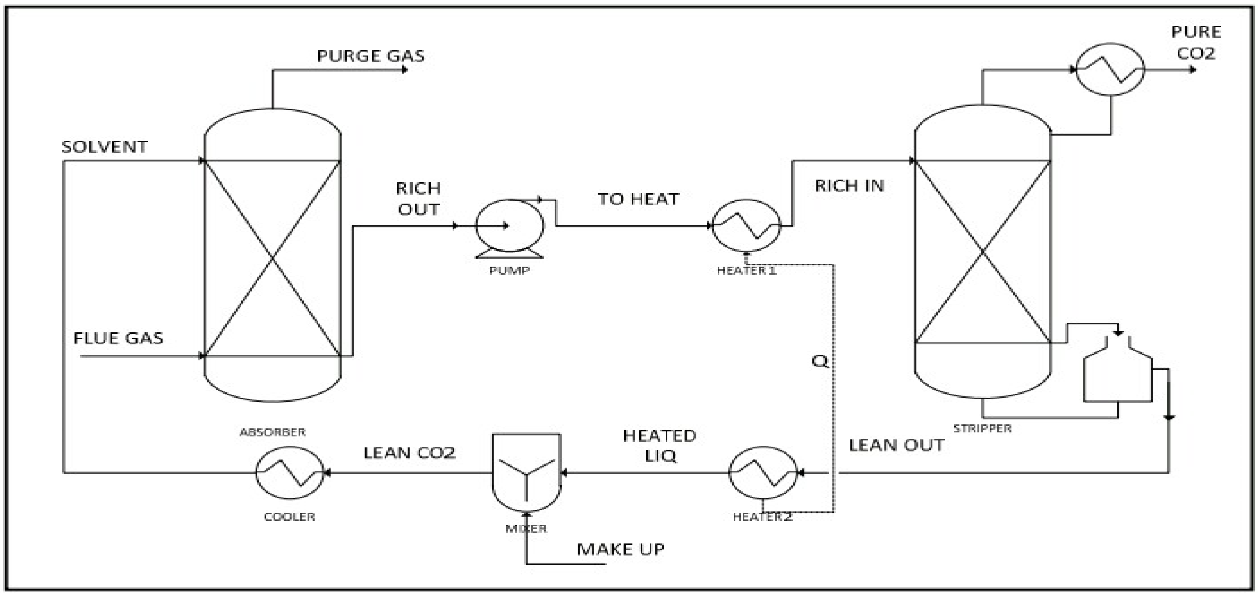

Figure 1 Typical Process Flow Sheet of a Post Combustion Carbon Capture Plant

2.2.4. Flue Gas Composition

The feed stream for this simulation is a flue gas from an 800MW coal fired power plant. The feed components and the various composition used for this simulation are presented in the Table 2.2 and Table 2.3 for the lean amine stream. The flue gas contains water (H_2O), oxygen (O_2), Carbon dioxide (CO_2), Nitrogen (N_2), methane (CH_4) and their composition are specified in Table 3.1

Table 2 Composition of the Flue Gas

Flue Gas Components	Mole/Mole Fraction
H_2O	0.074
O_2	0.054
CO_2	0.133
N_2	0.739

Table 3 Component and Composition of Lean Amine

Lean Amine Component	Mole/Mole Fraction
MEA	30%

2.2.5. Operating Conditions of the Units

The operating conditions for the flue gas and the liquid Amine are presented in the Table 2.4.

Table 4 Operating parameters

Operating parameters	Unit	Value
Lean solution temperature	^0C	40
Flue gas temperature	^0C	40
Flue gas pressure	Bar	10
Lean Amine pressure	Bar	15
Flue gas flow rate	Nm^3/hr	800
Absorption column pressure drop	Bar	0.1
Stripper pressure	Bar	1.9
Lean Amine pump pressure	Bar	1.9
Rich Amine pump pressure	Bar	1.013
Reboiler temperature	^0C	120

Table 5 Model Parameters of the Plant Components

Column Parameters	Units	Absorber	Stripper
Packing height	(m)	8.4	8.2
Column diameter	(m)	0.65	0.4
No of equilibrium stages		20	20
Packing type		IMTP 50	IMTP 50
-Void fraction		0.98	0.98
Specific surface area	m^2/m^3	102	102
Specific heat capacity	kj/kg k	460	460
Density	kg/m^3	7900	7900

(Source: Adam, 2020)

Table 6 Heat Exchanger Operating Conditions

H/E parameters	Unit	Rich/Lean Exchanger	Lean solvent cooler
Overall heat transfer coefficient	W/m^2K	1400	1500.0
Area	m^2	29.5	10.0

2.2.6. Unit Operation

The unit operation that are used for this study are shown below in Table 2.7

Table 7 Aspen Hysys Unit Operation parameters

Unit Operation	Aspen Hysys ID
Amine contactor	T-100
Scrubber	T-101

Valve	VLV-100
Heat exchanger	E-100
Flash tank	V-100
Air cooler	AC-100
Pumps	P-100
Mixer	MIX-100

2.2.7. Simulation Procedure

In this study, the two thermodynamic equilibrium models available in the amine property package have been utilized to evaluate the effect of changing the most important parameters. In most of the calculations, the percentage CO_2 removal was calculated while keeping all other parameters constant. Another calculation that was done is the calculation of the stripper re-boiler heat duty by keeping the percentage CO_2 removal constant.

2.2.8. Selection of Component List

In this simulation, the component list for the feed (flue gas) based on Table 3 was created and the component is added in the Aspen HYSYS simulation case as shown in Figure 2.

The simulation basis manager, a property view, allows for the creation of component list in the simulation which is independent of but can be associated with the individual fluid packages in the case

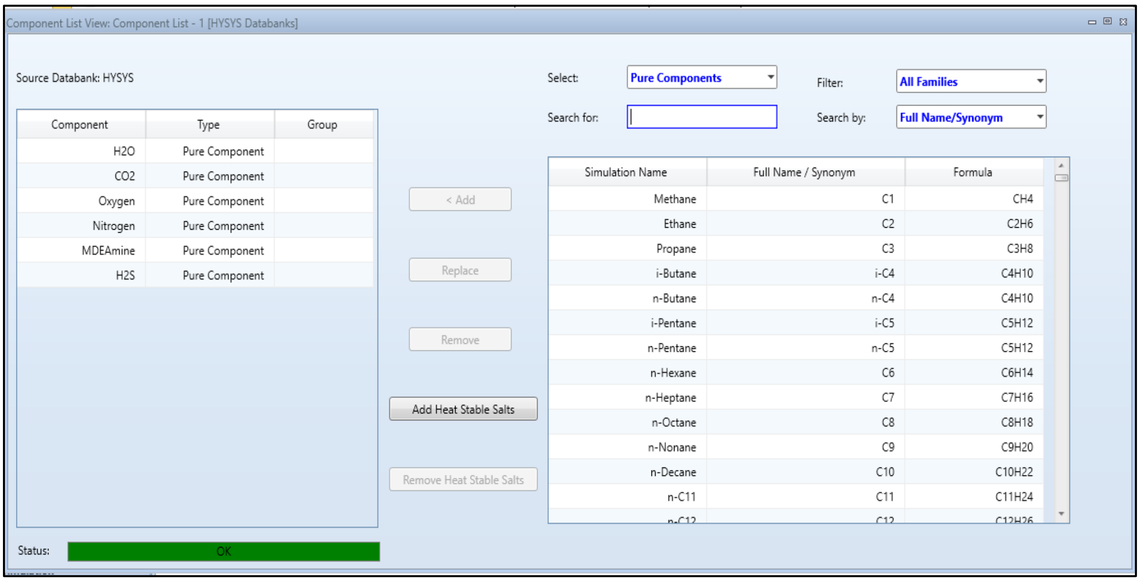

Figure 2 Basis Manager for the Selection of Component List

2.2.9. Selection of Fluid Package

The simulation basis manager also allow for the creation of thermodynamic fluid packages in the simulation case. In the simulation, the recommended 'Acid Gas-Chemical Solvent' fluid package was created and added in the simulation case as shown in Figure 2.3

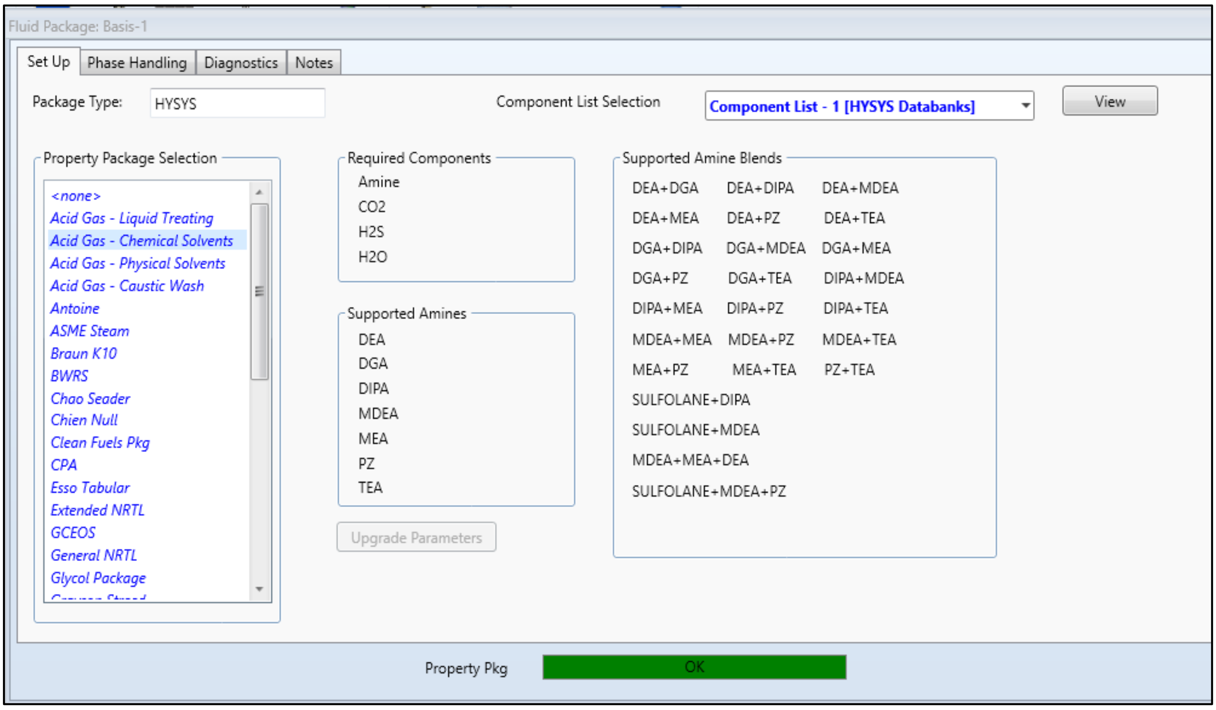

Figure 3 Simulation Basis Manager for the Selection of Thermodynamic Fluid Package

2.2.10. Modeling Streams and Unit Operations

After selection of the component and thermodynamic fluid package, the simulation environment was then entered for installation of streams (material and energy) and the various unit operations required for the CO_2 removal process.

Material streams were installed sequentially with their operating conditions and composition. Unit operations including Absorber column, vessel separator, distillation column (stripper), heat exchanger and pump were installed and connected to the streams.

Contactor Operation: The amine contactor is simulated using an absorber (T-100) operation in HYSYS. The absorber is specified with 20 trays with top and bottom pressure of 10 bar each.

Valve Operation: Rich amine from the absorber is directed to a valve, VLV-100, where the pressure is reduced to 4.0 bar from 10.0 bar, which is close to the regenerator operating pressure.

Separator Operation: Gases, which are flashed off from rich amine, are removed using the rich amine flash tank, V-100, which is installed as a separator operation.

Heat Exchanger Operation: The rich amine is heated to 80^0C in the lean/rich exchanger, E-100, prior to entering the regenerator, where heat is applied to break the amine-acid gas bonds, thereby permitting the MEA amine to be regarded to the contactor/absorber.

Regeneration Operation: The amine regenerator is modeled as a distillation column. There are 20 trays with a re-boiler and condenser.

Mixer Operation: Water make-up is necessary, since water will be lost in the absorber and regenerator overhead streams. A mixer operation, MIX-100, make up combines the lean amine from the regenerator with a water make up. These streams mix at the same pressure.

Cooler Operation: An air cooled heat exchanger, AC-100, is used to further reduced the lean amine temperature to the operating temperature of the absorber.

Pump Operation: A pump, P-100, boosts the lean amine pressure to operating pressure of the absorber since high pressure favors CO_2 absorption.

The final streams and unit operations are modeled in Aspen HYSYS as shown in figure 4 below.

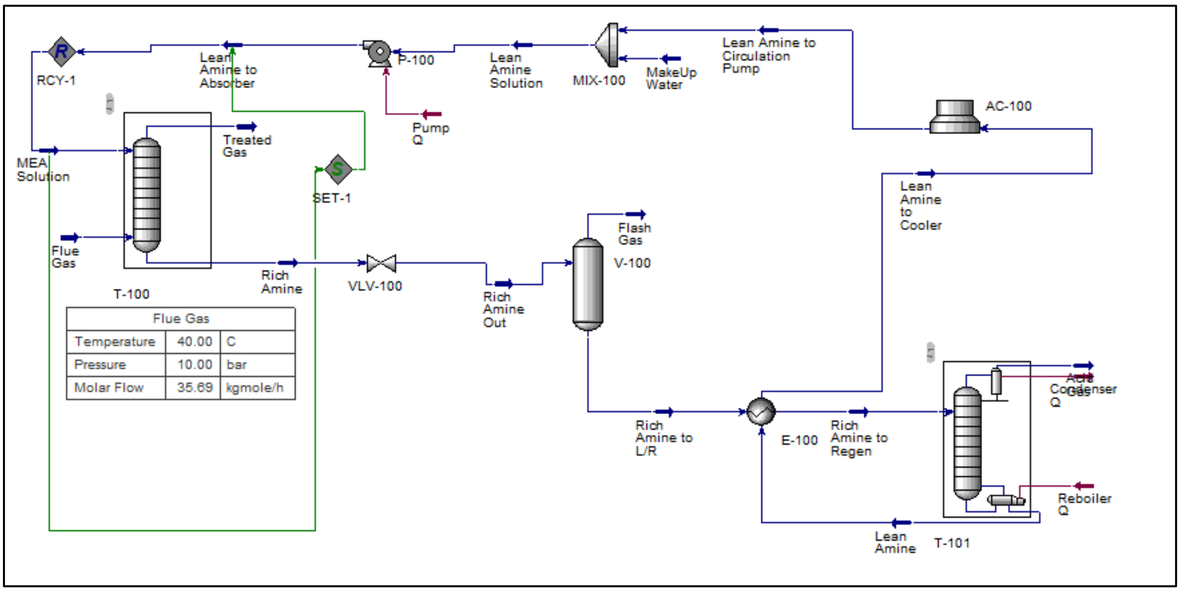

Figure 4 Process Flow Diagram of the Post Combustion Carbon Capture Plant

3. Results and discussion

The results were generated in Aspen HYSYS using the developed process flow diagram is discussed below.

3.1. Operational Parameters Held Constant

The model has been used to evaluate the effects of changing the most important process parameters. In the calculation, the CO_2 removal efficiency and the stripping heat consumption were calculated while keeping all other parameters constant.

3.2. Effect of Process Parameters on CO_2 Capture in the Post Combustion Carbon Capture Plant

The sensitivity of the capture plant to CO_2 is a function of the amine circulation rate, re-boiler temperature, absorption temperature, absorption column packing height.

3.2.1. Effect of Amine Circulation Rate on CO_2 Removal

Figure 5 shows the result of the simulation of the effect of the solvent flow rate on the CO_2 removal efficiency. This entails the simulation of the model to study the effect of the variation of the solvent circulation rate on CO_2 removal efficiency. The efficiency of the CO_2 removal is strongly dependent on the solvent circulation rate and is directly proportional to it. The effect of increased circulation rate is that the removal grade increases. This is also demonstrated in the work of Udara *et al* (2012). The removal efficiency approaches a constant value between 4.5m^3/h to 5m^3/h.

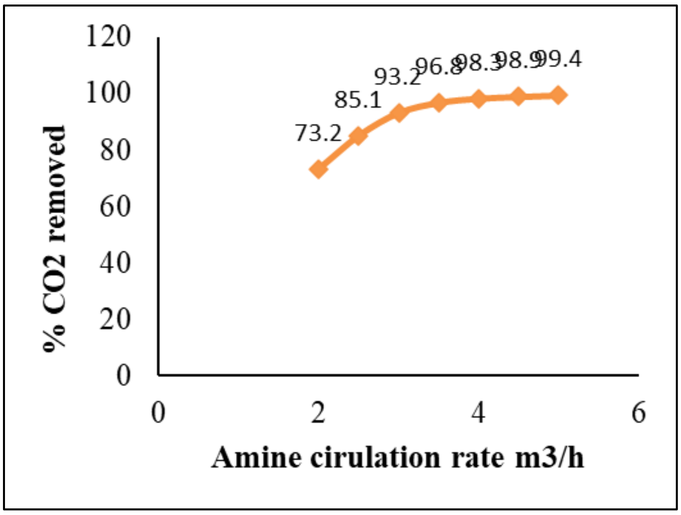

Figure 5 Effect of Amine Circulation Rate on CO_2 Removal

3.2.2. Effect of Absorption Temperature

Figure 6 shows the result of the simulation of solvent absorption temperature on the CO_2 efficiency of the plant. An increase in gas and solvent inlet temperature at a constant stage efficiency is examined; this is to study its effect on CO_2 removal efficiency of the plant. The absorption temperature is proportional to CO_2 removal. At 10^{o}C, the CO_2 removal was 99%. However, with increase in the absorption temperature, the removal efficiency continuously decreased. This was also demonstrated in the work of Colin *et al* (2014).

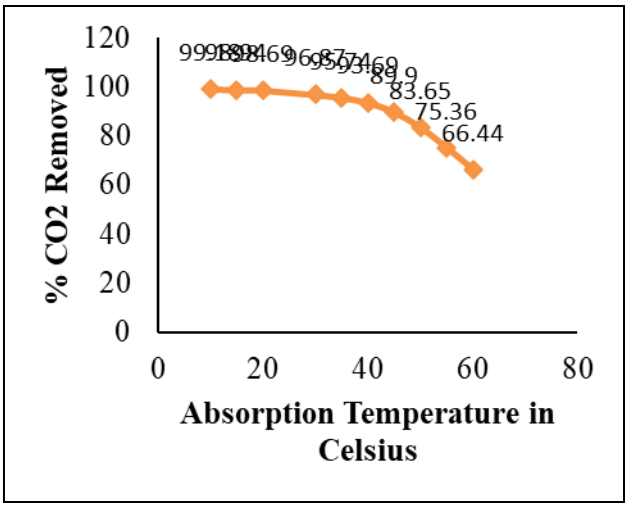

Figure 6 Effect of Absorption Temperature

3.2.3. Absorption Column Height

Figure 7 shows the result of the simulation of absorber column height on CO_2 the removal efficiency of the plant. The absorption column height is proportional to the percentage CO_2 removal efficiency, an increase in the absorption column height leads to an increase in the removal efficiency. The CO_2 removal efficiency increases from 87% at 5m to 95% at 40m.

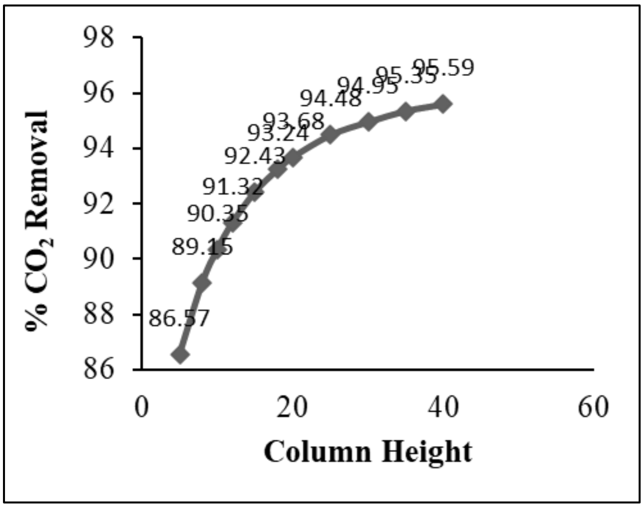

Figure 7 Effect of Absorption Column Height on CO_2 Removal

3.3. Effect of Process Parameters on Stripper Re-Boiler Heat Duty

The parameters that affect the sensitivity of the re-boiler heat duty are the absorption column height and absorption pressure. The effect of absorber pressure and absorber packing height on the stripper re-boiler duty is studied to optimize the energy requirement of the plant.

3.3.1. Effect of Absorption Column Height on Stripper Re-Boiler Heat Duty

Fig 8 presents the result of the simulation of the absorption column height on the re-boiler heat duty. The absorption column height was varied by varying the number of equilibrium stages and Mumphree efficiency of each stage. The effect of variation of equilibrium stages on stripper re-boiler heat duty was examined. Unlike the effect of the absorption column height on CO_2 removal, an increase in the absorption column height leads to a decrease in the stripper re-boiler heat.

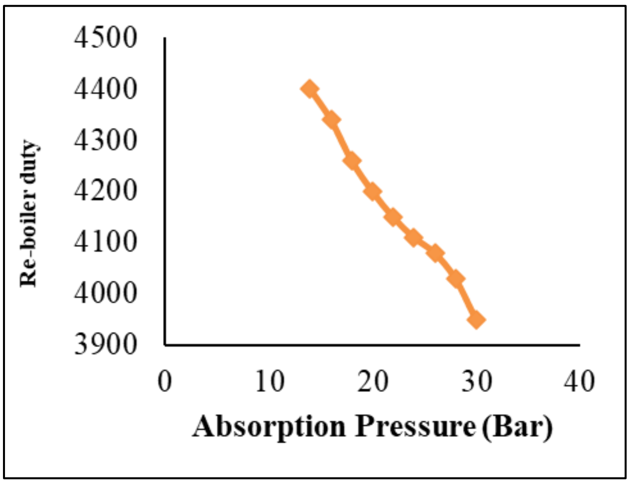

Figure 8 Effect of Absorption Packing Height on Re-Boiler Duty

3.3.2. Effect of Absorption Pressure on Stripper Re-Boiler Heat Duty

Fig 9 shows the result of the simulation of the absorption pressure on re-boiler heat duty of the plant. The absorber pressure is proportional to the re-boiler heat duty, with the increase of the absorber pressure, re-boiler duty is decreased. The re-boiler heat duty reduced from 4160KJ/Kg CO_2 at 5bar to 4080 KJ/Kg CO_2 which is reasonable with the value Kothandaraman *et al* (2010).

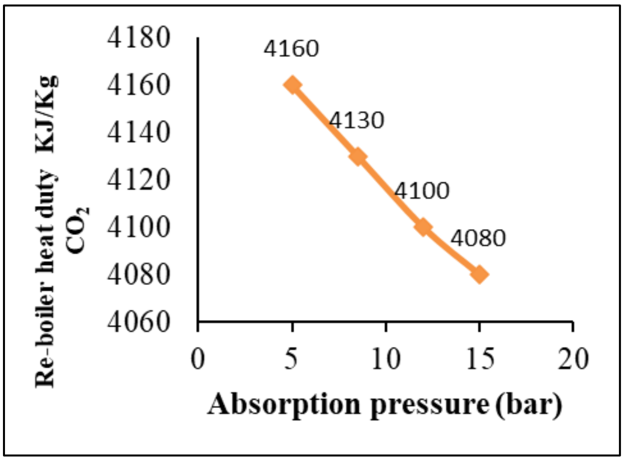

Figure 9 Effect of Absorption Pressure on Stripper Re-Boiler Heat Duty3.4 Overall Material Stream Properties for the CO_2 Removal Process Flow Model

The properties of material streams both the inlet and outlet streams were all computed by Aspen HYSYS after the simulation process. The results are present in Table 8.

Table 8 Overall Material Stream Properties for the Process Flow Model Generated in HYSYS

Material streams						
		MEA solution	**Flue gas**	**Treated gas**	**Rich amine**	**Acid gas**
Unit Operations		Absorber	Absorber	Absorber	Absorber	Valve
Vapour fraction		0.0000	0.9334	1.000	0.000	1.000
Temperature	C	40.000	40.000	40.100	59.430	39.990
Pressure	Bar	10.000	10.000	10.000	10.000	2.800
Molar flow	Kgmole/h	93.760	35.690	28.750	100.700	4.565
Mass flow	Kg/h	4092.000	1057	816.3	4333	197.700
Liquid volume flow	M^3/h	4.000	1.818	1.534	4.284	0.2401
Heat flow	Kcal/h	-7.392e+006	-6.206e+005	-3.484e+004	-7.978e+006	-4.242e005
		Lean amine	Rich amine out	Flash gas	Rich amine to L/R	Rich amine to Regen
Unit Operations		Lean MEA to H/E	Valve to Flash Gas Tank	Flash Gas Tank	Flash Gas Tank Outlet to H/E	H/E to Regenerator
Vapor fraction		0.000	0.0002	1.000	0.000	0.0328
Temperature	C	115.000	59.51	59.510	59.510	80.000
Pressure	Bar	3.000	4.000	4.000	4.000	3.200
Molar flow	Kgmole/h	96.110	100.700	1.867e-002	100.7	100.7
Mass flow	Kg/h	4134	4333	0.6683	4332	4332
Liquid volume flow	M^3/h	4.043	4.284	9.790e-004	4.283	4.283

Heat flow	Kcal/h	-7.318e+006	-7.978e+006	-896.9	-7.977e+006	-7.868e+006
		Lean amine to cooler	Lean amine to circulation pump	Lean amine to absorber	Lean amine solution	makeup water
Unit Operations Desc.		H/E to Air Cooler	Air Cooler to Mixer	Pump to Absorber	Mixer to Pump	Mixer
Vapor fraction		0.000	0.000	0.000	0.000	0.000
Temperature	C	81.910	39.98	40.000	39.87	25.000
Pressure	Bar	2.400	2.000	10.000	2.000	2.000
Molar flow	Kgmole/h	96.110	96.110	93.760	93.76	-2.356
Mass flow	Kg/h	4134.000	4134.000	4092	4092	-42.440
Liquid volume flow	M^3/h	4.043	4.043	4.000	4.000	-4.252ee-002
Heat flow	Kcal/h	-7.426e+006	-7.554e+0.006	-7.392e+006	-7.393e+006	-1.608e+005

3.4. Overall Composition of Components in the Process Flow Model

The compositions of the components in the streams were all computed by Aspen HYSYS after the simulation process. Liquid amine (MEA) removes excess acid gas (CO_2) by the counter-current washing of the flue gas in the absorption tower. From Table 9, we see that the composition of CO_2 in the flue gas reduces from 0.1330 to about 0.0045(i.e. a 97% decrease) in the lean amine stream. This new composition of the acidic gas is within the acceptable limit.

Table 9 Overall Compositions of Components in the Streams of the Process Flow Model

Compositions					
	MEA Solution	Flue Gas	Treated Gas	Rich Amine	Acid Gas
Unit Operations	Absorber	Absorber	Absorber	Absorber	Valve
Comp Mole Frac (H_20)	0.7433	0.0740	0.0056	0.7167	0.0271
Comp Mole Frac (CO_2)	0.0045	0.1330	0.0104	0.0484	0.9724
Comp Mole Frac (Oxygen)	0.0000	0.0540	0.0670	0.0000	0.0001
Comp Mole Frac (Nitrogen)	0.0000	0.7390	0.9170	0.0001	0.0004
Comp Mole Frac (MEA)	0.2522	0.0000	0.000	0.2348	0.0000
Comp Mole Frac (H_2S)	0.000	0.000	0.0000	0.0000	0.0000
	Lean Amine	Rich Amine Out	Flash Gas	Rich Amine to L/R	Rich amine to Regen
Unit Operations	Lean MEA to H/E	Valve to Flash Gas Tank	Flash Gas Tank	Flash Gas Tank Outlet to H/E	H/E to Regenerator
Comp Mole Frac (H_20)	0.7496	0.7167	0.0319	0.7168	0.7168
Comp Mole Frac (CO_2)	0.0044	0.0484	0.4938	0.0483	0.0483

Comp Mole Frac (Oxygen)	0.0000	0.0000	0.0484	0.0000	0.0000
Comp Mole Frac (Nitrogen)	0.0000	0.0001	0.4259	0.0000	0.0000
Comp Mole Frac (MEA)	0.2460	0.2348	0.0000	0.2349	0.2349
Comp Mole Frac (H_2S)	0.0000	0.0000	0.0000	0.0000	0.0000
	Lean Amine to Cooler	Lean Amine to Circulation Pump	Lean Amine to Absorber	Lean Amine Solution	MakeUP Water
Unit Operations Desc.	H/E to Air Cooler	Air Cooler to Mixer	Pump to Absorber	Mixer to Pump	Mixer
Comp Mole Frac (H_20)	0.7496	0.7496	0.7433	0.7433	1.0000
Comp Mole Frac (CO_2)	0.0044	0.0044	0.0045	0.0045	0.0000
Comp Mole Frac (Oxygen)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (Nitrogen)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (MEA)	0.2460	0.2460	0.2522	0.2522	0.0000
Comp Mole Frac (H_2S)	0.0000	0.0000	0.0000	0.0000	0.0000

3.5. Energy Requirement

Table 10: gives the energy requirement in the condenser, re-boiler and pump for the process flow model.

Table 10 Energy Streams

Energy Streams				
		Condenser Q	Re-boiler Q	Pump Q
Heat flow	Kcah/h	7998	1.343e+005	994.4

4. Conclusion

In this research, acid gas thermodynamic fluid package capable of amine calculation was employed in the simulation of CO_2 removal process model developed for the simulation of CO_2 removal using MEA as solvent. The CO_2 removal model developed in Aspen HYSYS is useful for evaluating the effects of process parameters such as changing amine circulation rate, absorption column height, absorption temperature and pressure. The developed model in Aspen HYSYS for the coal fired power plant functions properly. Results from the overall composition of components in the streams of the developed process flow model shows a significant reduction of about 96% CO_2 removed from the flue gas. The optimum CO_2 removal efficiency of the plant was obtained at 5m3/hr flue gas flow rate. The required re-boiler duty is 4100 KJ/Kg CO_2. The heat flow as obtained from HYSYS shows that the re-boiler requires highest for operation with heat flow of 1.3 x 10^5 Kcal/hr while the pump requires the least with heat flow of 994.4 Kcal/hr.

Recommendations

Based on the results from this research and knowledge gather vis-à-vis the simulation of post combustion carbon capture plant, the following recommendation can be made to improve the course of this research :

Future design of the process flow model can be made to allow for the combination of two different models in which one will be for the power plant and another for the CO_2 removal. This can be useful for total energy optimization and total cost optimization.

The design of the process flow diagram can also include the addition of CO_2 storage tank and CO_2 compression plant.

Further study can also be done to study the effect and the interaction of CO_2 compression plant and CO_2 capture plant in relation to energy requirement.

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