Simulation on Removal of Carbon Dioxide from Coal Power Station

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Abstract— **Removal of carbon dioxide (CO_2) from Coal Power station has been discussed and simulated using Aspen HYSYS V8.8. This research was executed in order to investigate the consumption of energy in order to remove CO_2 emitted from Coal Power Station and to improve the efficiency of CO_2 removal from Coal Power Station by using aqueous blended solvent between monodiethanolamine (MDEA) and sulfolane. From the simulation that has been executed, it can be said blended solvent of MDEA-Sulfolane is the most efficient solvent to treat CO_2 when it is compared with other single solvent such as MDEA, DGA, DIPA, TEA, MEA and DEA. This is because the result obtained from this research shows that MDEA-Sulfolane used the lowest amount of energy to treat CO_2 when it is compared with those amine solvents with flowrate of 2000x10^5kg/h. This research also shows that the most suitable amount of blended MDEA-Sulfolane and water to be used is 19%,1% and 80% respectively.**

Keywords— simulation, amine, solvent, absorption, blended

I. Introduction

Carbon dioxide (CO_2) is a colorless acidic gas which naturally occurred in our atmosphere. Excessive CO_2 release to atmosphere can cause many problems. The right amount of CO_2 is also required for the survival of all life in the world. Simulation on Carbon Dioxide removal from industries are being executed and experimented nowadays in order to overcome the greenhouse effects problem. They are so many methods of separation such as separation with sorbents/solvents, separation with membrane and separation by cryogenic distillation that are being used in industries to treat and recovery Carbon Dioxide from being released to the atmosphere in a large concentration.

The post combustion technique has been chosen because of its efficiency in capturing the CO_2 from the flue gas. However, this technology require a lot of energy to recover CO_2 and still need improvement in many aspects such as the most suitable solvent in capturing CO_2. This is because most of the existing Coal Power Station use mixture of single amine and water to treat the produced CO_2. Each of amines have their own special characteristics that can be utilized to treat CO_2 produced. As the example, monodiethanolamine (MDEA) has unlimited gas loading characteristic but the usage of this amine has the limit because of its corrosive characteristic. Therefore, it can be said each of the existing amines have their own special characteristics and limitations. Because of the limitation that possessed by each of existing amine, this research will investigate the potential of blended solvent that may overcome the limitation that possessed by each the amines and the requirement of the energy consumption of CO_2 removal from Coal Power Station.

II. METHODOLOGY

Flue gas from the Reference Power Plant North Rhine-Westphalia, German has been selected as the feed for this research. This is because the composition of CO_2 emitted from the plant is high and suitable to be as an experimental subjected to execute this research. The composition of flue gas that emitted from the plant is 23.2% CO_2, 73% N_2,)and 3.8% H_2O (Gervasi, Dubois, & Thomas, 2014)

For the selection of the absorbent, monodiethanolamine (MDEA) and sulfolane have been selected base on some specials characteristics that possessed by them. As the example the unlimited acid gas loading characteristics that owned by MDEA. By combining two types of solvents the performance of the solvent can be enhanced. The details of the amines have been discussed in details in chapter 2.

Aspen HYSYS 8.8 version has been selected in order to do the simulation of CO_2 removal from Coal Power Station. In this work, the process flow diagram (PFD) that has been selected in order to obtain the data required before will be simulated in this research.

III. RESULTS AND DISCUSSION

A. Effects blended solvent composition

The effect of blended solvent was investigated in this research. Figure 1 shows the results on the most suitable composition of water that can be used with these two solvents.

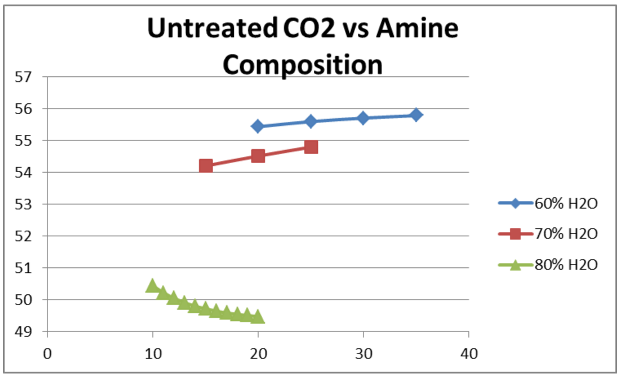

Figure 1:Comparison of composition of water

Based on figure 1, the graph figure shows the data of percentage untreated CO_2 against composition of MDEA. By analyzing the figure, 80% composition of water shows the lowest amount of untreated CO_2 compared with 70%, and 60% composition of water that shows high amount of untreated CO_2 at treated gas stream still remain. Based on the result obtained the composition of 80% water shows the highest efficient of CO_2 removal. With the high amount of composition of water along with that outstanding efficiency of CO_2 removal the cost of solvent can be cut off as we used large amount of water compared with amount ofamine.Because of that, the most suitable composition of water that can be used for CO_2 treatment of coal power station is 80% of water followed by70% and 60 % of water respectively. Therefore, composition of 80% water has been chosen for further experiment. From the further experiment, figure 2 obtained from the data collection of the further experiment that has been ran on solvent 80% and 20% mixture of water and amine respectively.

The composition of blended amine (MDEA-Sulfolane) was manipulated in order to find out the best composition that can be used for the CO_2 removal. Based on figure 2, it has been verified the best composition of MDEA-Sulfolane mixture was 19% MDEA and 1% sulfolane. Therefore, based on the result obtained the best composition for the blended solvent of MDEA and sulfolane was 19% and 1% respectively

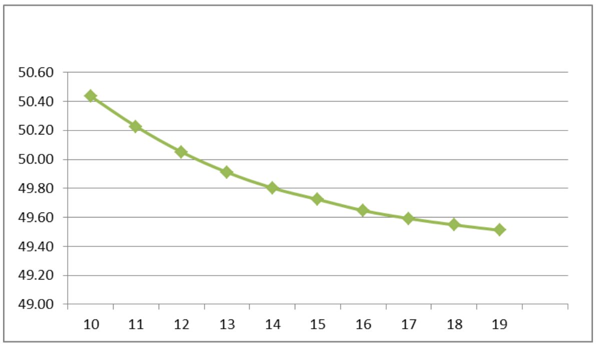

Figure 2: Percentage of untreated CO_2 at treated gas stream by using 80% and 20% of water and amine respectively

B. *Effect of flowrate on CO_2 treatment*

The effect of flowrate was investigated in this research was to obtain the most suitable flowrate that the most economical in term of energy consumption that can be used for CO_2 removal of coal power station. This objective was executed because of coal power station produced large amount of CO_2 as the product from coal burn to produce energy. This was proved as mentioned in literature review that the coal power station contribute one third of CO_2 emission in the whole world. Because of the concern to the environment that can be affected with the massive amount of CO2 produced by coal power station, the CO_2 need to be treated. In order to treat theCO_2 produced, large amount of energy need to be used because of its large capacity. Because of that, to find the most suitable flowrate was important to run the treatment plant economically.

By referring 2, the amount of flowrate was obtained until the allowed amount of CO_2 emitted to atmosphere achieved. According to regulation that has been discussed in literature review, the amount of CO_2 that can be emitted to the atmosphere was only at1100 pounds/MWh. On the other hand the amount of CO_2 produced by NRW Plant was at 333337.6 kg/h which was not can be emitted carelessly to the environment because of its effect to the environment and allowed amount that has been stated in regulation.

Table 2: Trend of solvent flowrate and treated CO2.

Flowrate(10^5), kg/h	Amount of treated gas (10^6), kg/h	CO_2 composition at treated gas, %	CO_2 flowrate at treated gas(10^6), kg/h
150	1.266	0.2193	0.27769
200	1.229	0.1971	0.24227
300	1.174	0.1612	0.18926
400	1.136	0.1338	0.15197
500	1.107	0.1125	0.12460
1000	1.036	0.0537	0.05597
2000	0.996	0.0174	0.01736
3000	0.9847	0.0072	0.007134
4000	0.9801	0.0035	0.003382
5000	0.9777	0.0018	0.001764
10000	0.9720	0.0002	0.000158
20000	0.9635	0	0

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The feed from NRW plant has been treated until zero amount of CO_2 achieved. Based on table 2, the flowrate that can cause the CO_2 treated meet the regulation requirement were starting from 150x10^5 kg/h and higher. Table 4.6 shows the extracted data of the flowrate that can be used to treat CO_2 until the regulation was obeyed.

C. *Effect of flowrate on energy consumption*

After the amount of flowrate that can cause the CO_2 emission of the flue gas from coal power station were obtained, the energy consumption of each of the flowrate were obtained in order to identify the most suitable flowrate that shows the lowest energy consumption. Table 3 shows the data obtained of the effect of solvent flowrate on CO_2 consumption.

Table 3: The effect of solvent flowrate on CO_2 consumption

Flowrate(10^5), kg/h	Power usage, kW			
	Condenser (10^{12})	Reboiler (10^{12})	E-101 (10^4)	Total (10^{12})
150	151600	150400	38.73	302000
200	253.7	253.7	53.52	507.4
300	2498	2499	82.38	4997
400	95.25	95.29	110.9	190.54
500	38.35	38.36	138.6	76.71
1000	3.137	3.138	271	62.75
2000	2.738	2.739	533.5	54.77
3000	2.721	2.722	793.4	54.43
4000	2.722	2.722	1054	54.44
5000	2.618	2.619	1314	52.37
10000	5.923	5.923	2613	118.46
20000	7.621	7.621	5240	152.42

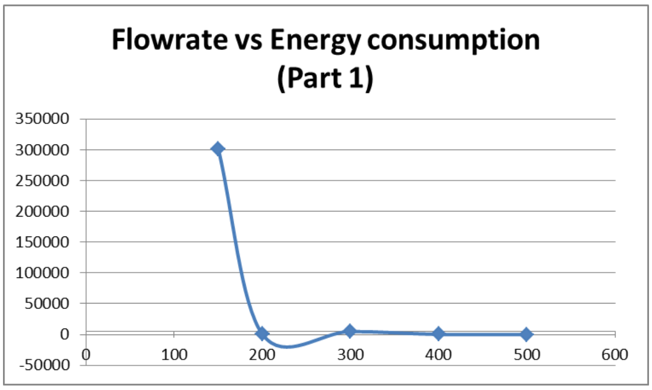

Figure 7: Graph of effect of flowrate against energy consumption (part 1) – *from amount of flowrate 150x10^5kg/h until 500x10^5kg/h*

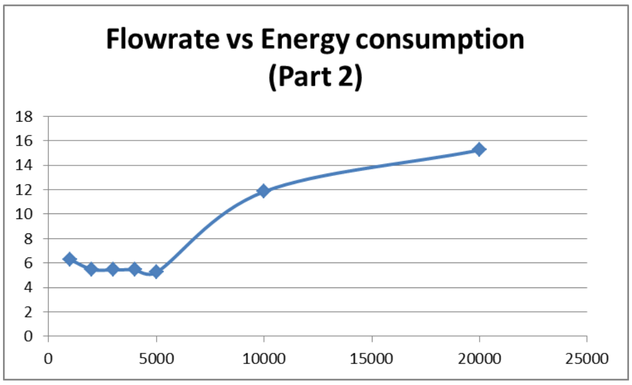

Figure 8: Graph of effect of flowrate against energy consumption (part 2) – *from amount of flowrate 1000x10^5kg/h until 20000x10^5kg/h*

Based on the figure 7 and 8 we can see the solvent of flowrate that consumed the least amount of energy were within 2000 x 10^5kg/h – 5000 x 10^5kg/h. The results shows that the amount of energy that consumed by the plant when using those flowrates are within 5-6 x 10^{12}kW which where the lowest energy consumed when compared with other flowrates. Therefore, in order to minimize the consumption of energy for CO_2 treatment of coal power plant the flowrate obtained from this research can be used

Table 4: Comparison of energy consumption of MDEA-Sulfolane with other solvent by constant the flowrate of 2000x10^5kg/h.

Amine	**Power, kW**			
	Reboiler (10^{15})	**Condenser (10^{15})**	**E-101 (10^6)**	**Total (10^{12})**
DEA	2.847	2.847	4.803	5694
DGA	307900	307900	5.059	615800000
DIPA	1.061	9.062	5.060	10123
MDEA	2.038	2.138	7.565	4176
TEA	8.350	8.349	4.207	16699
MDEA-Sulfolane	0.02738	0.02739	5.335	54.77

Table 4 shows the comparison of energy usage between MDEA-Sulfolane and other single solvent. By referring table 4.8, MDEA-Sulfolane solvent consumed only 54.77x10^{12}kW of power which was the lowest when compared with other amine solvent. The result shows that MDEA-Sulfolane used the least amount of energy usage to treat CO_2 followed by MDEA, DEA, DIPA, TEA and DGA. This positive result shows that this type of blended solvent can give positive effect towards the energy consumption of CO_2 treatment plant.

IV. Conclusion

Based on the result obtained from the simulated PFD that has been done, the blended solvent of MDEA and sulfolane show positive result as this aqueous blended solvent has the best performance with composition of 90% and 10% of water and amine respectively. This shows that this blended solvent may reduce the cost of the CO_2 treatment from coal power station as it has the best performance when the composition of water high. It can be said that this blended solvent may reduce the operation cost because the market price of amine is much higher when compared to water. Therefore, as water is being used in a high composition the cost of the solvent can be reduced. By referring to result that has been obtained, the objective to identify effect of blended solvent on CO_2 removal from Coal Power Station seems promising as the ratio of water and amine used is at the best condition in term of cost and availability. The consumption of energy of the blended solvent was investigated and with other single amine. The result shows that the blended solvent has the lowest energy consumption when compared to the solvent of monoethanolamine, diethanolamine, diglycolamine, diisopropylamine, monodiethanolamine and triethylamine with the same condition of temperature, pressure and composition. Therefore, based on the result obtained it can be said that the blended solvent of MDEA and sulfolane have high potential to reduce the amount of energy consumption CO_2 treatment from coal power station

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