Modelling Of CO_2 Capture Using Aspen Plus For Coal Fired Power Plant

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Abstract: Many industrial power plants burn fossil fuels to get their energy while releasing flue gases to the atmosphere. Greenhouse gases are responsible for global warming and which causes severe environmental impacts. Carbon dioxide capture from the coal-fired power plant is important to maintain a better clean environment. The Post-combustion chemical absorption process is the most viable option to capture Carbon dioxide from industrial flue gases. The carbon dioxide capture model is developed and implemented in Aspen Plus process simulation software to calculate the required re-boiler energy demand. The required re-boiler energy demand is increasing when CO_2 content of the flue gas is decreasing. The re-boiler energy is calculated as 3481, 3620, 3840 kJ/kg CO_2 for the 85, 90 and 95% CO_2 removal process for flue gases from EDF CHP power plant, Krakow, Poland.

Index Terms: Flue gas emission, Chemical absorption, Post-combustion, Re-boiler duty, Aspen Plus.

1 Introduction

Due to global warming and climate change effect, there has been significantly increased in efforts to reduce the greenhouse gasses in the atmosphere to maintain a better environment. The European Union has been promised to reduce greenhouse gas emissions (GHGE) by 20-30% until 2020 compared to the levels of 1990[1]. One of the major anthropogenic greenhouse gas in the atmosphere is carbon dioxide (CO_2). Majority of the energy generative sources around the world are fossil fuel based power plants and that leads to an enormous amount of flue gas emissions. Carbon Capture and Storage (CCS) is the process of separating the CO_2 from industrial and energy source, capture it before it enters into the atmosphere, and then transport the gas to a storage location. This entire process is called post-combustion carbon capture process [2]. To overcome the drastically increasing energy demand, the consumption of coal and fossil fuel is going to increase in the future. Therefore, shifting to renewable energy sources are important in the near term future. Until that, CCS is the most viable option to continue the development process and industrial production processes. CO_2 can be captured basically in three different ways.

1. Oxy-fuel Combustion.
2. Pre Combustion CO_2 Capture.
3. Post Combustion CO_2 Capture.

Fig. 1 illustrates that the most available CO_2 capturing methods.

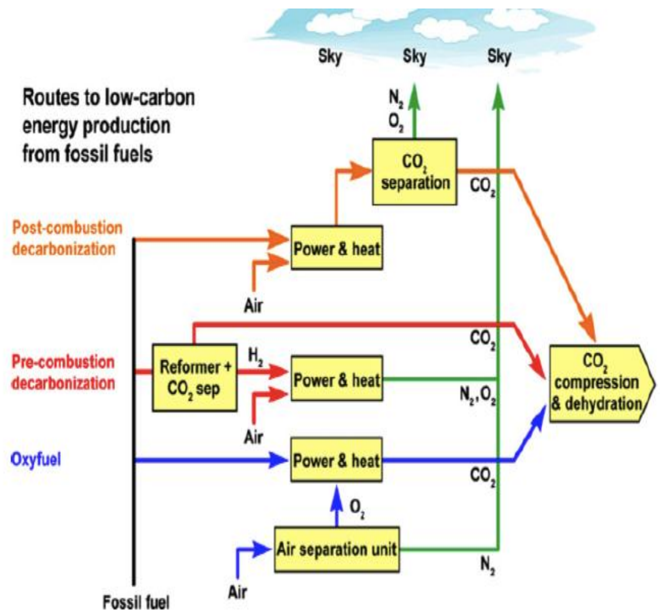

Fig. 1. *CO_2 Capture And Sequestration [3].*

Even though CCS is not a new technology, it has several issues to implement before introduction into the industrial flue gas treating processes. The main problem arises from the cost involving CO_2 capture. According to the carbon trading and cost involving with the capturing process, it is costlier to capture and transport the CO_2 compared to releasing it in the atmosphere. Chemical absorption is the most preferred and widely applicable method for the separation of CO_2. The post-combustion chemical absorption process is briefly described in the following section. In chemical absorption process, CO_2 is separated from the flue gas by a continuous scrubbing system. The flue gas stream which has reduced the temperature is sent to the absorption column. Flue gas is entering in the bottom of the absorption column while the solvent is entering at the top to counter currently react each other. The chemically bound CO_2, then separated by high-temperature steam and pure CO_2 stream is collected for compression section. The main objectives behind the project are to reduce the re-boiler energy demand in the stripping section which is caused by the high operating cost of the CCS project [4].

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2 MODEL DEVELOPMENT

The process model is developed and implemented in Aspen Plus process simulation software. In this paper, post-combustion amine absorption process of CO_2 in a coal fired power plant is modelled with Aspen Plus. Amine concentrations, CO_2 lean loadings are taken from the previous studies to implement the process to simulate the capture process with 85%, 90% and 95% removal efficiencies [2]. A simulation of a coal-fired power plant flue gas is presented. The flue gas composition is taken from the one of thermal power plants which are located in Poland [5]. The simulation software was used for odeling of the reference thermal-steam cycle model of the power unit in EDF CHP plant, Krakow, Poland. Coal is combusted at the mass flow rate of 32.5 ton/h with boiler thermal efficiency of 212.4 MW to generate the required energy. Flue gas composition is given in Table 1. All sensitivity analyses were performed in the open loop model (before SOLVENT stream is recycled back to the absorber) to identify the optimum parameters. The schematic of the process flow diagram is shown in Fig. 2.

***TABLE 1 :** FLUE GAS COMPOSITION [5]*

Parameter	Mass fraction (wt%)
CO_2	18.66
N_2	77.52
H_2O	3.82

The electrolyte NRTL model is used to develop the process model, and equilibrium and kinetic data, as well as, relevant chemical reactions are selected from the literature [6, 7]. The information related to the absorber and stripper packing and operating parameters related to the simulation is selected from the literature and given in Table 2.

***TABLE 2:** INFORMATION RELATED TO THE ABSORBER AND STRIPPER MODELS [8].*

Specification	Parameter values	
	Absorber	Stripper
Number of stages	15	15
Operating pressure	1 bar	1.9 bar
Re-boiler	None	Kettle
Condenser	None	Partial-vapour
Packing type	Mellapak, Sulzer, Standard, 350Y	Flexipac, Koch, metal,1Y
Packing height	12m	8m
Packing diameter	6m	4m
Mass transfer coefficient method [9]	Bravo et al. (1985)	Bravo et al. (1985)
Interfacial area method [9]	Bravo et al. (1985)	Bravo et al. (1985)
Interfacial area factor	1.5	2
Heat transfer coefficient method	Chilton and Colburn	Chilton and Colburn
Holdup correlation [10]	Billet and Schultes (1993)	Billet and Schultes (1993)
Film resistance	Discrxn for liquid film and Film for vapour film	Discrxn for liquid film and Film for vapour film
Flow model	Mixed	Mixed

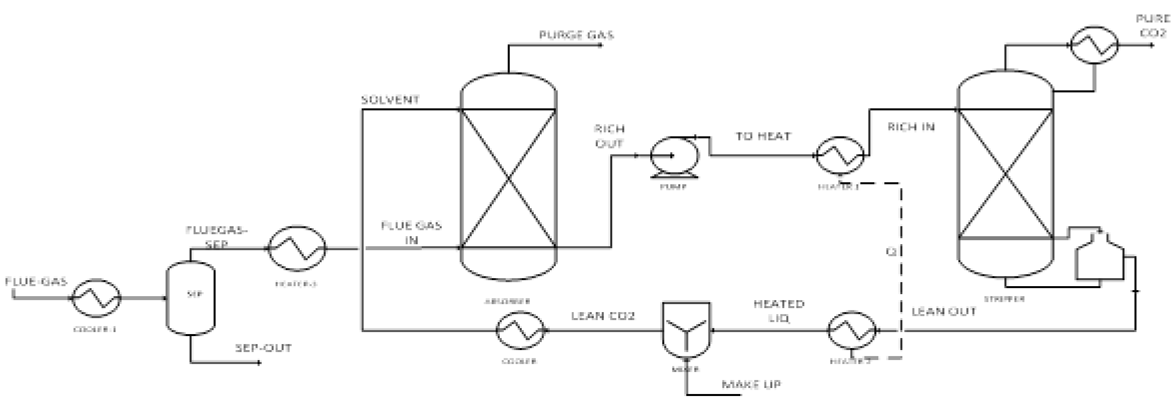

***Fig. 2.** Process flow diagram.*

Optimum solvent parameters are selected from the previous studies [11]. The monoethanolamine (MEA) is used as the solvent with 30% concentration and 0.30 lean CO_2 loading. The open loop process model is simulated with the optimum parameters and calculated the required re-boiler energy remand. Finally, the process model is converted to a closed-loop model by re-circulating SOLVENT stream back to the absorber. The required re-boiler duties are 3481, 3620, and 3840 kJ/kg CO_2 for 85%, 90%, and 95% removal efficiency models respectively. The calculated re-boiler energy duties are compared with the previous studies which have done exactly for the coal-fired power plant. According to the previous studies, simulations are performed for the flue gas from a coal-fired power plant with 13.5% of CO_2 content. The required re-boiler duties are calculated for the previous studies as 3634.2, 3736.4, 4185.5 kJ/kg CO_2 for the 85, 90 and 95% CO_2 removal process respectively [2]. Therefore, it can be easily identified that according to the CO_2 content in the flue gas, required re-boiler energy duty is changing. Moreover, higher the CO_2 percentage in the flue gas stream will lead to the reduction of re-boiler energy requirement.

6 CONCLUSION

The carbon capture model is developed and implemented in the Aspen Plus process simulation tool for flue gas from coal fired power plant. The implemented model is properly working and converging for Power plant flue gas system. Three different models were developed with 85, 90, and95% removal efficiency. The calculated re-boiler duties are 3481, 3620, 3840 kJ/kg CO_2 for the 85, 90 and 95% CO_2 removal process. It can be identified that according to the CO_2 content in the flue gas, required re-boiler energy duty is changing. The higher CO_2 percentage in the flue gas stream will directly contribute to the reduction of the re-boiler energy requirement.

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