EFFECT OF DIFFERENT VOLUMETRIC FLOWRATE USING ENERGY ANALYSIS FOR POWER TO METHANOL PRODUCTION PLANT

Izzati Auni Batra'azman, Mohd Aizad Ahmad

Faculty of Chemical Engineering, Universiti Teknologi Mara

Abstract— **Emission of carbon dioxide to the atmosphere can cause a global warming. Global warming is the increasing of the earth's atmosphere overall temperature in which it is contributed by the greenhouse gas (GHG) emission such as carbon dioxide, methane and nitrous oxide. The main contributor to the emission of the carbon dioxide into the atmosphere is the industry of power plant in which it contributed 40% of carbon dioxide emissions into the atmosphere. The term of carbon dioxide captured is used to separate carbon dioxide from the fuel gas. The configuration of technology for capture carbon dioxide is post-combustion by using an absorption method using monoethanolamine (MEA). Methanol is a main product of carbon dioxide utilization in this research in which it can be produced by capturing carbon dioxide with hydrogen gas and it can be used in many products such as fuels application. The aims of this research are to design and simulate power to methanol plant by using different volumetric flowrate and to analyse energy consumption using energy analysis by manipulating different volumetric flowrate. The method used to simulate the methanol plant by using carbon dioxide and hydrogen as a raw material is the Aspen Hysys software. The energy consumption analysis was investigated by using effect of volumetric flowrate of carbon dioxide which is 1595.5 and 49577.5 m^3/h and also hydrogen which is 158.2 and 4959.02 m^3/h. The other fixed variables are temperature which is 210^{0}C, pressure at 75.7 bar and reactor volume at 45 m^3. Three plants are simulated in the Aspen Hysys and the energy consumption duty was analysed. The total energy duty for plant 1 is 146775 kW in which it cost about RM 59,713.14 meanwhile for plant 2, the total energy duty is 3510 kW and has a cost about RM 2,003.87. Lastly, the total energy duty for plant 3 is 393789 kW in which it is cost RM 191,876.35. Therefore, it can conclude that the plant that has the lowest cost is plant 2 with the cost of RM 2,003.87 per month compared to plant 1 and 3. The reason is because of the low volumetric flowrate enters the plant in which it contributes a small amount of energy duty that only consumes 3510 kW compared to the other plants and thus, it can be stated that the lower volumetric flowrate for feed, the smaller amount of energy it will be used and thus used a low cost for the production.**

Keywords—Power plant, Post combustion, Methanol, Carbon dioxide utilization

I. INTRODUCTION

Carbon dioxide is one of the important gaseous needed in the world as much as oxygen gas. All of the plants in the world are needed carbon dioxide to make a photosynthesis process in which that process will produce oxygen gas. This process is important because humans need oxygen gas to survive and live. The emission of carbon dioxide to the atmosphere is very important to the survival of the humanity but if it is only emits into the atmosphere in the lower quantity. Excessive emission of carbon dioxide to the atmosphere will make the planet suffering a dangerous climate change. In the other word, the natural or anthropogenic emission of carbon dioxide into the atmosphere will make the temperature increase and thus create a global warming [6]. Global warming is the increasing of the earth's atmosphere overall temperature in which it is contributed by the greenhouse gas (GHG) emission. The main contributor to the greenhouse gases is carbon dioxide (CO2). Other than carbon dioxide, the other gases are water vapour (H2O), methane (CH4), nitrous oxide (N2O) and fluorinated [5].

There are several sources that contribute to the emission of the carbon dioxide into the atmosphere such as industry and agriculture which is come from the waste management, power plant, refineries and paper mills. Next, buildings also can emits carbon dioxide such as the particular residences, offices and malls and lastly, from the vehicles. Railways, aircraft and roadstead can also emit carbon dioxide into the atmosphere and causes a global warming [7]. From all of these sources, the main contributor to the emission of the carbon dioxide into the atmosphere is the industry of power plant in which 40% of carbon dioxide emissions is come from the power plant [14]. Power plant is basically used to generate the electricity from fuels. There are two types of fuels used to produce electricity in Malaysia which is natural gas and coal. From these two fuels, coal has a high tendency to emit carbon dioxide into the atmosphere from the flue gas.

In order to decrease the rate of atmospheric carbon dioxide concentration that are increasing nowadays, researchers have discovered a technology name 'carbon capture'. The term of carbon capture is defined as the technique to capture the emission of carbon dioxide from large source such as power plant so that it will not enter the atmosphere and thus causing a global warming. There are three different configurations of techniques to capture the carbon dioxide such as post-combustion, pre-combustion and oxy-fuel combustion but for this research, the only main configuration that been investigate is the post-combustion carbon capture. The natural gas processing industry such as power plant have been developing and implementing the post combustion capture technique to capture carbon dioxide from the flue gas. The objective of the post combustion capture is to capture a pure or high concentration of carbon dioxide by modifying the combustion process [11]. Post combustion capture will use the amine solvent to absorb the carbon dioxide from the flue gas and the absorbed carbon dioxide will be compressed for transportation and storage.

The main method to capture the carbon dioxide from the flue gas is the absorption method. Chemical absorption is more preferred than the physical absorption. This is because the flue gas obtained from the power plant is operated at the low carbon dioxide partial pressure which is more preferred by the chemical absorption meanwhile the physical absorption are more preferred at high partial pressure. The solvent used in this method is the monoethanolamine (MEA) in which it has a high reaction rate and high absorption [12].

Carbon dioxide that has been captured can be utilized into many products such as urea, polymer, ready mixed concrete and also methanol. As for the ready mixed concrete, carbon dioxide can increase the strength of the concrete coming from the cement plant with the minimal impact on fresh air content or workability [9]. Other than that, carbon dioxide also can be used in the production of polymer. Carbon dioxide is used as an alternative to the organic solvent because it can consume less energy and environmental friendly [3]. The main utilization of carbon dioxide in this research is to the methanol process. There are two steps to produce methanol from carbon dioxide. The first step is by converging the hydrogenation of carbon dioxide to produce methanol. While the other step is to convert the carbon dioxide into carbon monoxide first through Reverse Water Gas Shift (RWGS) reaction and then hydrogenated it to produce methanol [14].

Energy usage always has been an important issue in almost every industrial process as they need to consider how much energy need in their plant so that they can spend less money on that production. Chemical plant such as methanol plant can used the energy to converted the sources to electricity by purchasing the demand energy from the utility company but it was very expansive and not pragmatic in the long term so another alternative that many industrial companies done is by installed an equipment with an onsite energy conversion and transmission system. Energy conversion such as combustion, electricity generation, air compression and thermal energy exchange is involve the changes in the energy forms and quantity while the energy transmission is to delivered the same amount and form to the production line. The turbine that are connected with an electrical generator will rotate when coal or natural gas are burned in the combustion chamber to generate steam and the will be converted to electricity. Other than that, electrolysis of water also used a lot of energy to break the hydrogen and oxygen bond. The hydrogen gas then will be used in the production of methanol by react with carbon dioxide gas that captured from the flue gas in the power plant [4].

Methanol production is using much energy consumption for the high productivity and selectivity. In order to consume the energy used in the methanol production, different volumetric flowrate of carbon dioxide and hydrogen are act as a parameter to analyze the energy consumption. This energy analysis study helps us to prove the efficiency of volumetric flowrate to reduce energy consumption. According to the Grazia Leonzio, low energy consumption will give a lower cost and thus have a higher selectivity and productivity [8]. In order to achieve lower energy consumption, the flowrate of the carbon doxide and hydrogen will be manipulated to 1595.5 m^3/h and 49577.5 m^3/h of carbon dioxide flowrate while flowrate of hydrogen at 158.2 m^3/h and 4959.02 m^3/h. Hence, the effect of volumetric flowrate can be investigated to know which one of the volumetric flowrate that used by which plant produce lower energy consumption and thus it can reduce the cost spending by the plant about the energy consumption.

A literature data from Aasberg-Petersen, Nielsen, Dybkjær and Perregaard stated that a when the flowrate is reducing, it will minimize the investment or the cost of the production [1]. Generally, as the flowrate of feed is small, the energy used for the production also will be small. This is because when there is little raw materials enter the productions; it will use little work to convert the raw material into product inside the plant. Because of a little work is used to convert the raw material, it will used only a little energy in every equipment inside the production and causing it to have a cheaper amount of cost of production.

There are other reviews that discuss about other analysis than energy which is financial analysis in which it need to know how profitable methanol is so that it can be sell. According to Perez-Fortes and Tzimas, univariate and bivariate sensitivity analyses have been performed for the methanol process in order to know under which circumstances the methanol plant could have a positive NPV. The selected variables such as the price of Methanol and price of CO2, are varied widely in order to obtain a NPV equal to zero meanwhile the electricity price are varied within a specific interval. As a result, the price of carbon dioxide must be inversely proportional to the price of methanol that is needed to be selling so that the production will have a higher profitability and thus create NPV is equal to zero [10].

There are many researchers that already study about the methanol production from carbon dioxide captured based on the experimental lab scale but not in the large production scale and it has success 90% removal of carbon dioxide from fuel gas so a study about the design of methanol production from carbon dioxide based on the result of experimental lab scale will be investigated.

II. METHODOLOGY

A. *Methanol Plant Simulation by Aspen Hysys*

Three methanol plants is simulate in the Aspen Hysys. All of the three plants of simulation Aspen Hysys have a different parameter. Plant 1 has a manipulated variable of volumetric flowrate. Both carbon dioxide and hydrogen flowrate is manipulated at 49577.5 m^3/h and 4959.02 m^3/h respectively. Meanwhile for plant 2, the manipulated parameter is also the volumetric flowrate but it has smaller amount of flowrate compared to plant 1 and 3 which is 1595.5 m^3/h and 158.2 m^3/h for carbon dioxide flowrate and hydrogen flowrate respectively. As for plant 3, it has an additional parameter compared to plant 1. It has manipulated parameters of volumetric flowrate which is the same as plant 1 and also a higher reactor's temperature which is 280^{o}C.

B. Methanol Plant 1 (49577.5 m^3/h CO_2 and 4945.02 m^3/h of H_2)

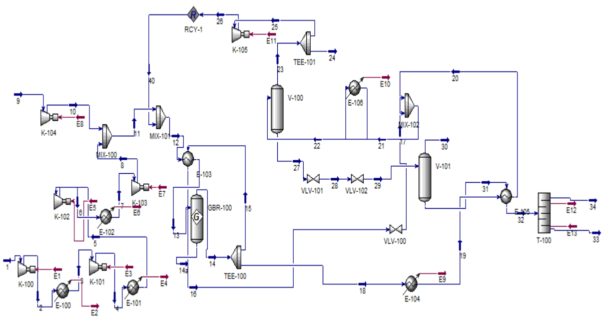

Figure 3.1: Process Flowsheet of Methanol Plant 1

Figure 3.1 shows about the process flow sheet of methanol plant 1. Carbon Dioxide is fed at mass flowrate of 49577.5 m^3/h at stream 1 with 25^{o}C of temperature and 1 bar of pressure. While hydrogen was fed at mass flowrate of 4959.02 m^3/h, 25^{o}C of temperature and 30 bar of pressure in stream 9. Carbon dioxide that is been compressed in a series of compressor then will mix at the mixer (MIX1) together with hydrogen gas at 78 bar. After that, both carbon dioxide and hydrogen will re-mix with the second mixer (MIX2) with the recycle stream. Gas that exit the MIX2 will be heated (HX4) to 210^{o}C and enter Gibb's reactor. Next, the exit gas from the reactor will enter splitter (DIV1) and it will be split into two parts. The first part where 60% of initial stream will use to heat the fresh feed (HX4) meanwhile the second part is used in the cooler and also to heat the feed of distillation column (HX5). The knock-out drum (KO1) is used to separate water and methanol which were condensed in heat exchanger (HX6) from the non-reacted gases. In order to minimize the accumulation of inert and by products in the reaction loop, the non-reacted gases (1%) will be purged [14]. Next, the residual gases are removed in the a flash tank (TKFL1) while the remaining is heated in the heat exchanger (HX5) to 80°C before sent to the distillation column (DT1) as a feed. Methanol product comes out at the top of the distillation column in 64°C and 1 bar in which it contain 69 wt-ppm of water and some non-reacted gases. In the bottom of distillation column, the water comes out at 102⁰C with 23 wt-ppm of methanol [14]

C. Methanol Plant 2 (1595.5 m^3/h of CO_2 and 158.2 m^3/h of H_2)

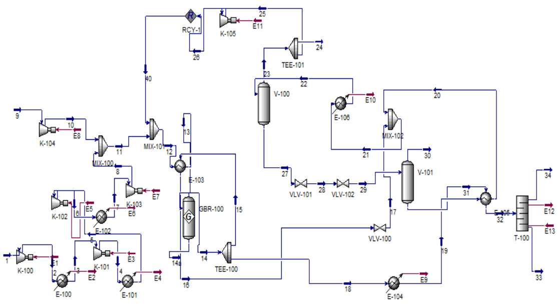

Figure 3.2: Process Flowsheet of Methanol Plant 2

Figure 3.2 shows about the process flow sheet of methanol plant 2. Carbon Dioxide is fed at mass flowrate of 1595.5 m^3/h at stream 1 with 25°C of temperature and 1 bar of pressure. While hydrogen was fed at mass flowrate of 158.2 m^3/h, 25°C of temperature and 30 bar of pressure in stream 9. Carbon dioxide that is been compressed in a series of compressor then will mix at the mixer (MIX1) together with hydrogen gas at 78 bar. After that, both carbon dioxide and hydrogen will re-mix with the second mixer (MIX2) with the recycle stream. Gas that exit the MIX2 will be heated (HX4) to 210°C and enter Gibb's reactor. Next, the exit gas from the reactor will enter splitter (DIV1) and it will be split into two parts. The first part where 60% of initial stream will use to heat the fresh feed (HX4) meanwhile the second part is used in the cooler and also to heat the feed of distillation column (HX5). The knock-out drum (KO1) is used to separate water and methanol which were condensed in heat exchanger (HX6) from the non-reacted gases. In order to minimize the accumulation of inert and by products in the reaction loop, the non-reacted gases (1%) will be purged [14]. Next, the residual gases are removed in the a flash tank (TKFL1) while the remaining is heated in the heat exchanger (HX5) to 80°C before sent to the distillation column (DT1) as a feed. Methanol product comes out at the top of the distillation column in 64°C and 1 bar in which it contain 69 wt-ppm of water and some non-reacted gases. In the bottom of distillation column, the water comes out at 102°C with 23 wt-ppm of methanol 14]

D. Methanol Plant 3 (280°C and 76 bar)

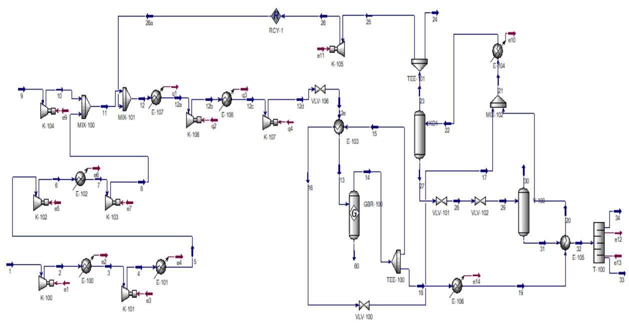

Figure 3.3: Process Flowsheet of Methanol Plant 3

Figure 3.3 shows about the process flow sheet of methanol plant 3. Carbon Dioxide is fed at mass flowrate of 49577.5 m^3/h at stream 1 with 25°C of temperature and 1 bar of pressure. While hydrogen was fed at mass flowrate of 4959.02 m^3/h, 25°C of temperature and 30 bar of pressure in stream 9. Carbon dioxide that is been compressed in a series of compressor then will mix at the mixer (MIX1) together with hydrogen gas at 78 bar. After that, both carbon dioxide and hydrogen will re-mix with the second mixer (MIX2) with the recycle streamThen, the carbon dioxide will enter cooler and compressor to adjusting temperature to 143°C and increase the pressure to 443 bar. The gas then will enter control valve to reduce the pressure to 78°C before been entering the heat exchanger (HX4) where it will be heated to 280°C and enter Gibb's reactor. Next, the exit gas from the reactor will enter splitter (DIV1) and it will be split into two parts. The first part where 60% of initial stream will use to heat the fresh feed (HX4) meanwhile the second part is used in the cooler and also to heat the feed of distillation column (HX5). The knock-out drum (KO1) is used to separate water and methanol which were condensed in heat exchanger (HX6) from the non-reacted gases. In order to minimise the accumulation of inert and by products in the reaction loop, the non-reacted gases (1%) will be purged [14]. Next, the residual gases are removed in the a flash tank (TKFL1) while the remaining is heated in the heat exchanger (HX5) to 80°C before sent to the distillation column (DT1) as a feed. Methanol product comes out at the top of the distillation column in 64°C and 1 bar in which it contain 69 wt-ppm of water and some non-reacted gases. In the bottom of distillation column, the water comes out at 102⁰C with 23 wt-ppm of methanol [14].

E. Theory and equations of Energy

1. Cooler

Cooler is a device used to transfer heat from higher temperature to the lower temperature. In other word, a cooler is will take a hot material and remove heat from it and make the materials become cooled. The equation of cooler is shown as below:-

$$Q = mc_p \Delta T$$

Where,
M = mole flowrate
Cp = heat capacity
ΔT = difference of temperature

2. Compressor

The function of compressor is to increase the pressure of the fluid. This is can be done by securing the work energy from the surroundings with the help from the rotating shaft by neglecting the kinetic and potential energy. Therefore, the energy equation for compressor:-

$$Q = mz_i RT_i \left[\frac{\left({}^{P_2}/_{P_1} \right)^{\alpha} - 1}{\alpha} \right]$$

Where,
M = mole flowrate, mol/s
Z = Z factor

R = gas constant
P = pressure in bar
T = temperature in kelvin
K = Cp/Cv
A = K-1/K

3. Heat Exchanger

To determine the heat lost to the surrounding by the heat exchanger, a parameter is needed to calculate the percentage of heat losses or gains by applying overall energy balances for hot and cold fluids. In heat exchanger, there is no shaft work, mechanical potential and kinetic energies in the energy balance equation [7]. Because heat exchanger has hot and cold fluid in and out of the systems, the real equation is [7]:-

$$Q = UA\ \Delta T_{lm}$$

Where,
UA = overall heat transfer coefficient
ΔTlm = Logarithmic mean temperature difference

4. Condenser and Reboiler

Both condenser and reboiler is a component in the distillation. Condenser is a device used to condense a material in the gas phase to the liquid phase. The gas or vapour can be condensed to form a liquid again when the liquid evaporates and this is when it needs cooling. Basically, condenser is a water-cooled to give cooling to the vapours so that it will not return to be liquid again. Meanwhile, reboiler is the opposite of condenser. Reboiler is used to generate steam to feed to a distillation tower; the steam rises up the tower contacting a downwards-flowing liquid stream.

The energy equation for condenser and reboiler is shown as below:-

Condenser:-

$$Q = m(h_f - h_g)\ x\ Reflux\ ratio$$

Where,
M = mass flowrate
h_f = enthalpy of liquid
h_g = enthalpy of gas

Reboiler:-

$$Q = (D\ x\ D_h) + (B\ x\ B_h) + Q_{condenser} - \sum(F_i\ xF_{hi})$$

Where,
D = distillate flowrate
B = bottom flowrate
F_i = feed flowrate
D_h = enthalpy of distillate
B_h = enthalpy of bottom
F_{hi} = enthalpy of feed

III. RESULTS AND DISCUSSION

A. The energy duty for cooler equipment for all three plants

Table 4.1 shows about the total energy duty for cooler in all three plants. Plant 1 has a total of 38740.10 kW energy duty while plant 2 has a total of 1243.08 kW energy duty. As for plant 3, the total energy duty is 164738 kW. The result shows that each equipment has a tiny error percent. . Percent error between the calculated energy duty and simulation Aspen Hysys's energy duty for plant 1, 2 and 3 is 0.19803 %, 0.20502 % and 0.21768 % respectively.

Table 4.1: Energy duty based on calculation and Aspen hysys for cooler in all three plants

Plant	Equipment	Q (kW) calculation	Q (kW) hysys	% error
1	E-100	1994.83	1995	0.00009
	E-101	2546.35	2570	0.00929
	E-102	2370.67	2387	0.00689
	E-104	13293.2	13260	0.0025
	E-106	18535.06	26200	0.41354
Total		**38740.1**	**46412**	**0.19803**
2	E-100	64.17	64.17	0.00006
	E-101	82.63	82.68	0.00058
	E-102	76.72	76.79	0.00089
	E-104	429.81	429	0.00189
	E-106	589.74	845.3	0.43334
Total		**1243.08**	**1497.94**	**0.20502**
3	E-100	2163	2164	0.00042
	E-101	2838	2840	0.00078
	E-102	2627	2629	0.00065
	E-104	33007	56650	0.7163
	E-106	37153	37130	0.000619
	E-107	27568	13780	0.500142
	E-108	59381	59400	0.00031
Total		**164738**	**174593**	**0.21769**

It can be stated that based on simulation Aspen Hysys and calculation manually for energy duty of cooler that the best plant from three plants is plant 2. Plant 2 has a smaller amount of energy which is 1243.08 kW compare to plant 1 and 3 that has 38740.10 kW and 164738 kW. This is because, plant 2 use a small volumetric flowrate which is 1595.5 m^3/h for carbon dioxide and 158.2 m^3/h for hydrogen compared to plant 1 and 3 that used 49577.5 m^3/h for carbon dioxide and 4959.02 m^3/h for hydrogen in which the volume is much larger than plant 2. A small amount of volumetric flowrate will spend a little amount of energy for the production.

B. The energy duty for compressor equipment for all three plants

Table 4.2 shows about the total energy duty for compressor in all three plants. Plant 1 has a total of 16960.46 kW energy duty while plant 2 has a total of 544.29kW energy duty. As for plant 3, the total energy duty is 135664.53 kW. The result shows that each equipment has a tiny error percent. . Percent error between the calculated energy duty and simulation Aspen Hysys's energy duty for plant 1, 2 and 3 is 0.00192 %, 0.00194% and 0.01828% respectively. It is prove that the value of energy duty from the calculation and Aspen hysys is the same with a little percent error.

Table 4.2: Energy duty based on calculation and Aspen hysys for compressor in all three plants

Plant	Equipment	Q (kW) calculation	Q (kW) hysys	% error
1	K-100	2266.69	2273	0.00278
	K-101	2562.63	2570	0.00288
	K-102	2380.98	2387	0.00253
	K-103	2362.9	2369	0.00258
	K-104	6066.29	6073	0.00111
	K-105	1320.95	1321	0.00004
Total		**16960.46**	**16993**	**0.00192**
2	K-100	72.92	73.11	0.00261
	K-101	82.44	82.68	0.00291
	K-102	76.6	76.79	0.00253
	K-103	76.01	76.2	0.00244
	K-104	193.55	193.8	0.00128
	K-105	42.76	43	0.0001
Total		**544.29**	**545**	**0.00194**
3	K-100	2434.07	2442	0.00326
	K-101	2830.15	2840	0.00348
	K-102	2619.81	2629	0.00351
	K-103	2542.29	2550	0.00303
	K-104	6614.91	6625	0.00153
	K-105	6500.6	6506	0.00083
	K-106	70249.07	70340	0.00129
	K-107	41873.64	41930	0.00135
Total		**135664.53**	**135862**	**0.01828**

As for the compressor, it can be stated that based on simulation Aspen Hysys and calculation manually for energy duty of compressor that the best plant from three plants is plant 2. Plant 2 has a small amount of energy which is 544.286 kW compare to plant 1 and 3 that has 16960.5 kW and 135665 kW respectively. This is because, plant 2 use a small volumetric flowrate which is 1595.5 m^3/h for carbon dioxide and 158.2 m^3/h for hydrogen compared to plant 1 and 3 that used 49577.5 m^3/h for carbon dioxide and 4959.02 m^3/h for hydrogen in which the volume is much larger than plant 2. A small amount of volumetric flowrate will spend a little amount of energy for the production.

C. The energy duty for Heat Exchanger equipment for all three plants

Table 4.3 shows about the total energy duty for heat exchanger in all three plants. Plant 1 has a total of 5.47E+0 4 kW energy duty while plant 2 has a total of 1.77E+03 kW energy duty. As for plant 3, the total energy duty is 9.92E+04 kW. The result shows that each equipment has a tiny error percent. . Percent error between the calculated energy duty and simulation Aspen Hysys's energy duty for plant 1, 2 and 3 is 0.00046 %, 0.00021 % and 0.00004 % respectively. It is prove that the value of energy duty from the calculation and Aspen hysys is the same with a little percent error.

Table 4.3: Energy duty based on calculation and Aspen hysys for Heat Exchanger in all three plants

Plant	Equipment	Q (kW) calculation	Q (kW) hysys	% error
1	E-103	3.68E+04	3.68E+04	0.0006
	E-105	1.80E+04	1.80E+04	0.00018
Total		**5.47E+04**	**5.47E+04**	**0.00046**
2	E-103	1.19E+03	1.19E+03	0.00037
	E-105	5.82E+02	5.82E+02	0.00021
Total		**1.77E+03**	**1.77E+03**	**0.00021**
3	E-103	7.14E+04	7.14E+04	0.00011
	E-105	2.78E+04	2.78E+04	0.00012
Total		**9.92E+04**	**9.92E+04**	**0.00004**

As for the heat exchanger, it can be stated that based on simulation Aspen Hysys and calculation manually for energy duty of heat exchanger that the best plant from three plants is plant 2. Plant 2 has a small amount of energy which is 1.77E+03 kW compared to plant 1 and 3 that has 5.47E+0 4 kW and 9.92E+04 kW respectively. This is because, plant 2 use a small volumetric flowrate which is 1595.5 m^3/h for carbon dioxide and 158.2 m^3/h for hydrogen compared to plant 1 and 3 that used 49577.5 m^3/h for carbon dioxide and 4959.02 m^3/h for hydrogen in which the volume is much larger than plant 2. A small amount of volumetric flowrate will spend a little amount of energy for the production.

D. The energy duty for Condenser equipment for all three plants

Table 4.4 shows a value of energy duty for three plants which is plant 1, 2 and 3. The energy duty of condenser for plant 1 is -15459 kW while plant 2 has an energy duty of -521.35 kW. The value of energy duty for plant 3 is -21097 kW. The percent error for three plants shows a very small that is not more than 1%. For plant 1, the percent error is 0.002 % meanwhile for plant 2 and 3 are 0.03808 % and 0.230701 % respectively. This can stated that plant 2 has the lowest value of energy duty at 521.35 kW compared to plant 1 and 3.

Table 4.4: Energy duty based on calculation and Aspen hysys for Condenser in all three plants

Plant	Equipment	Q (kW) calculation	Q (kW) hysys	% error
1	T-100	-1.55E+04	-1.55E+04	-0.00203
2	T-100	-5.21E+02	-5.02E+02	0.03808
3	T-100	-2.11E+04	-1.62E+04	0.23070

E. The energy duty for Reboiler equipment for all three plants

Table 4.5 shows a value of energy duty for three plants which is plant 1, 2 and 3. The energy duty of reboiler for plant 1 is 13840.54 kW while plant 2 has an energy duty of 470.5303 kW. The value of energy duty for plant 3 is 5310.7 kW. The percent error for three plants shows a very small that is not more than 1%. For plant 1, the percent error is 0.00076 % meanwhile for plant 2 and 3 are 0.04852 % and 0.47285 % respectively. This can stated that plant 2 has the lowest value of energy duty at 470.5303 kW compared to plant 1 and 3

Table 4.5: Energy duty based on calculation and Aspen hysys for Reboiler in all three plants

Plant	Equipment	Q (kW) calculation	Q (kW) hysys	% error
1	T-100	13840.54	13830.00	0.00076
2	T-100	470.53	447.70	0.04852
3	T-100	15310.66	8071.00	0.47285

F. The Rate cost energy for all equipment

According to the Tenaga National Berhad (TNB) Malaysia, the industrial tariff for the next kWh (201 kWh onwards) per month is 44.01 sen/kWh or RM 0.4401/kWh [13]. Table 4.6 shows a total cost of energy for all three plants calculated from the industrial tariff from Tenaga Nastional berhad. It shows that plant 2 have a lower cost which is RM 2,003.87 compared to plant 1 and 3 that cost about RM 59,713.14 and RM 191,876.35 respectively. The reason why plant 2 has the lowest cost than both plant 1 and 3 is because of the volumetric flowrate. In plant 2, the volumetric flowrate for carbon dioxide and hydrogen is 1595.5 m^3/h and 158.2 m^3/h which is much lower than volumetric flowrate of carbon dioxide and hydrogen in plant 1 and 3 which is 49577.5 m^3/h and 4959.02 m^3/h respectively. It can be concluded that the lower volumetric flowrate for feed, the smaller amount of energy it will be used and thus used a low cost for the production.

Table 4.6: Table 4.11: Rate cost energy for all three plants

Equipment	Rate cost for all three plants (RM)		
	Plant 1	Plant 2	Plant 3
Cooler	12132.61	547.08	72500.98
Compresser	7464.297484	239.5401029	59705.95746
Heat exchanger	24093.1629	780.7168555	43646.34417
Condenser	9284.849848	229.4479688	9284.849848
Reboiler	6738.219755	207.0803753	6738.219755
Total	**RM59,713.14**	**RM2,003.87**	**RM191,876.35**

IV. Conclusion

Excessive amount of carbon dioxide into the atmosphere will create a global warming and solutions are needed to be done to prevent these global warming accelerates quickly and causes a lot of harm to the people and non-living things in the world. One of the solutions is by creating a methanol plant that using carbon dioxide as a raw material. Carbon dioxide that emitted to the atmosphere from the power plant will be captured to produce methanol which is one of the valuable gas used in many production. Methanol plant can be simulated to reduce the amount of carbon dioxide in the atmosphere. Therefore, in this thesis, three simulation methanol plants has successfully been simulate to produce methanol and it has been determined which one of the three plants has a smaller amount of energy used for production by using energy analysis.

To analyse the energy consumption used for all three plants, a parameter is studies in this research which is the effect of volumetric flowrate. This parameter is influence the energy consumption. Basically, energy consumption used will be decrease as the volumetric flowrate is decreasing. According to Aasberg-Petersen, Nielsen, Dybkjær and Perregaard, reducing the flowrate can minimize the cost of the plant because of the reducing amount of energy used by the production [1].

Based on the rate cost energy for all equipment in Table 4.6, the plant that has the lowest cost is plant 2 with RM 2.003.87 per month compared to plant 1 and 3. The reason is because of the low volumetric flowrate enters the plant in which it contributes a small amount of energy duty that only consumes 3510 kW compared to the other plants. The second lower cost plant is plant 1 because of the higher volumetric flowrate compared to plant 2. Meanwhile plant 3 is the most expensive because it is not only has higher volumetric flowrate but also high temperature thus causing it used more energy than the other two plants. Therefore, it can be conclude that the most saving cost for methanol production plant is plant 2 that has a lower volumetric flowrate of carbon dioxide and hydrogen compared to the plant that used high value of volumetric flowrate which is plant 1 and 3 and thus, it can be stated that the lower volumetric flowrate for feed, the smaller amount of energy it will be used and can spend a low cost for the production.

There are several recommendations from this study that can be used in the future research such as by adding more different parameters to analyse the energy consumption using energy analysis. This is to ensure more accurate conclusion can be achieve to know which is the most suitable parameter to reduce the energy and thus minimizing the cost consumption by the production and also can use other different fluid package other than NRTL-RK model to know what the other fluid package can affect the energy and cost consumption.

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