Distribution Temperature of Analysis on CH_4-CO_2 Gas Mixed in Double Pipe Heat Exchanger by Controlled Feeze Out Area Methode

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Abstract :

The research purpose to get the temperature distribution on CH_4-CO_2 gas mixture in the annulus double pipe heat exchanger and position of formation CO_2 frozen from end input the double pipe heat exchanger. Controlled freeze out area method using a heat exchanger in this research uses four steps, such as, *flushing impurities*, *start-up* equipment, the proses of freezing CO_2, sampling CH_4-CO_2 output from *double pipe heat exchanger* and *sampling* CO_2 *frost* in *double pipe heat exchanger.* CH_4-CO_2 gas mixture and carbon dioxide out from heat exchanger is analyzed by using Gas Chromatography (GC). The data get in this research is distribution temperature of CH_4-CO_2 gas mixture, wall temperature and nitrogen along the double-pipe heat exchanger in which to solve these two temperatures simultaneously using MATLAB software with Newton Rhapson and Runge Kutta order 4. The results of analysis Gas chromatography shown in CH_4 5% CO_2 with pressure of 1, 5, 10, and 20 bar most produced yield of CH_4 99% mol so that This indicates that the purification of CH_4 has been successful although there are still a small percentage of CO_2 in it.

Keywords : CO_2 *removal*, *controlled freeze out area*, *carbon dioxide* (CO_2), *cryogenic, heat exchanger*

1. Introduction

Natural gas is a mixture of hydrocarbon compounds that have a very high boiling point, so that at atmospheric pressure and room temperature that form of a gas (except C_5 +). The mixture is usually composed of methane, ethane, propane, butane, pentane, and a small amount of hexane, heptane, octane, and the heavier fraction. Natural gas components, indicating that methane is the largest component of the gas mixture. Inorganic components such as nitrogen, hydrogen sulfide, carbon dioxide is an undesirable component in the production because it can not generate heat and cause corrosion and other problems that may occur in the process **[1]**. One advantage of using natural gas compared with other sources of energy that is produced natural gas is more efficient, much more clean and very friendly environment. While in the manufacture of LNG, CO_2 gas must be removed beforehand to prevent freezing at extremely low temperatures **[2]**. Because natural gas liquefaction process is running at very low temperatures (-161^{o}C), while the freezing point of CO_2 around -78.4 ° C **[3]**.

There are several methods that can be used to eliminate the CO_2 content. Some of the latest methods being developed or have been performed testing the feasibility of a small scale (Pilot Project) and has even been used to eliminate the CO_2 content. Some methods such as amine absorption, membrane, PSA (pressure swing adsorbtion), controlled freeze zone (CFZ^{tm}), and controlled freeze out area using a heat exchanger.

The basic concept of controlled freeze out area is to remove CO_2 by utilize the phase change from gas to solid (CO_2 frost) with cryogenic in heat exchanger without an additional tool. This process does not require high-pressure such as distillation, but operate at atmospheric pressure. In addition, this method does not require a large surface area such as adsorption, because deposition of CO_2 based on direct phase change from gas to solid **[4]**. In 2009, Chang et al studied temperature distribution with the effect of composition CO_2 and pressure. Phenomenon that occurs in heat exchanger is not known when using different of CO_2 concentrations. Therefore, needed research further on temperature distribution in CH_4-CO_2 mixtures at various concentrations of CO_2 and gas mixture pressure.

2. Material and Methods

2. 1. The materials used

a. CH_4-CO_2 gas mixture (PT Samator)
b. 99% HP nitrogen gas as flushing and sampling (PT Samator)
c. 99% liquid nitrogen as start-up and freezing CO_2 process (PT. Samator)
d. 40% volume solution of ethylene glycol as an anti freeze
e. Aquades

2.2. Variables of research

a. Comparison of CO_2: CH_4 gas mixture = 5% CO_2 (mol/mol)

b. Pressure of CO_2 - CH_4 gas mixture = 1, 5, 10, and 20 bar

2. 3. Research equipments

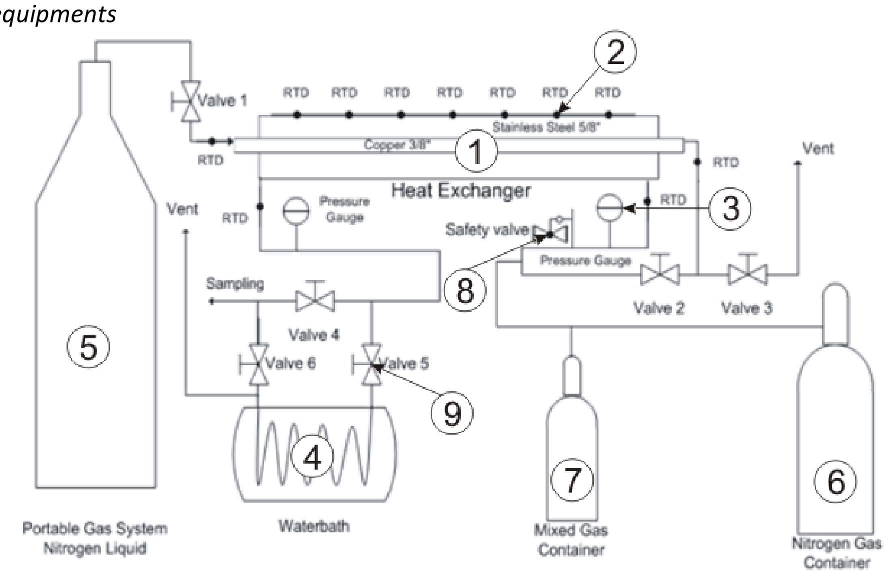


Figure 1. Tool of Temperature Distribution CO_2 frost Process

Description:
1. *Double pipe heat exchanger*
2. RTD (*Resistance Temperature Detector*)
3. *Pressure gauge*
4. *Water bath heater*
5. Tangki N_2 liquid
6. Tangki N_2 gas
7. Tangki campuran gas CH_4-CO_2
8. *Safety valve*
9. *Valve*

2. 4. Procedures of Research

Preparation of reactant

CH_4-CO_2 gas mixture with gas ratio of CO_2 to CH_4 gas mixture = 5% CO_2 (in mole ratio) that has been provided by PT. Samator.

Experiment

The procedure of this study consists of 4 stages:

Stage I : Flushing impurities
Stage I aims to eliminate impurities such as air, CO_2 and H_2O which there in the Figure 1 research equipment.

Stage II : Start-up equipment
Stage II aims to conditioning equipment to suit the current operating conditions of the study. Start-ups with streaming gas N_2 HP (High Purity) and gas N_2 liquid which contained Figure 1 research equipment.

Stage III : Freezing CO_2 Process and sampling of CH_4 gas output double pipe heat exchanger
Stage III aims to test cryogenic so get CO_2 frost which contained Figure 1 research equipment.

Stage IV : Sampling of CO_2 Frost in Double Pipe Heat Exchanger
Stage IV aims to Determine the concentration of CH_4 in the CO_2 frost which contained Figure 1 research equipment.

The above research was repeated with feed of CH_4-CO_2 gas mixture pressure at 1, 5, 10, and 20 bar with composition of different CO_2 that is equal to 5% CO_2.

3. Results And Discussions

Analysis of temperature distribution CH_4-CO_2 gas mixture in double pipe heat exchanger using controlled freeze-out area (CFO-area) method has been performed. In CFO-area technique, CH_4-CO_2 gas mixture at room temperature through the annulus and N_2 gas at cryogenic temperatures through the tube, where each flow of gas in counterflow. Then CO_2 gas in CH_4-CO_2 gas mixture freeze, based on data from distribution of temperature can know the position of formation CO_2 frost in annulus double-pipe heat exchanger. The position of formation CO_2 frost has been predicted previously from temperature of CO_2 frost based on HYSYS v7.0 which contained Table 1.

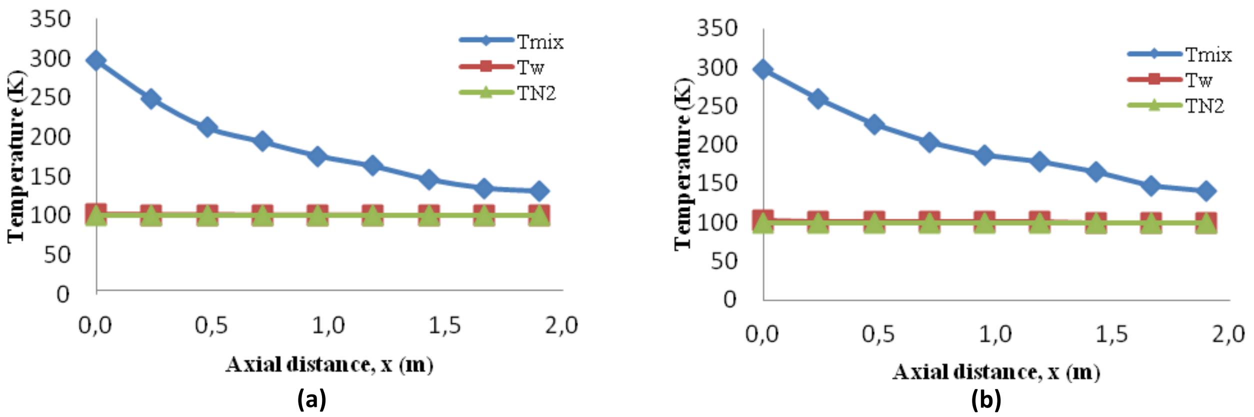
Tabel 1. Pridicted Data temperature of CO_2 frost based on HYSYS v7.**0**

Composition of CO_2	Pressure (bar)	Freezing of CO_2 Temperature (K)
5%	1	163,60
	5	178,15
	10	184,43
	20	190,32

In Table 1 show that temperature CO_2 frost will be increase at the higher of pressure and composition. It based on the ideal gas equation PV = nRT where if composition and pressure increases, temperature of CO_2 frost will increase too. In addition, CO_2 frost temperature data in Table 1 are also used as reference for prediction position of the formation CO_2 frost while experiment. In this study, get temperature CH_4-CO_2 gas mixture data along double pipe heat exchanger. From temperature gas mixture can be known temperature outer wall tube and temperature N_2 along double pipe heat exchanger. The method used to solve the equations used is Newton Rhapson and Runge Kutta order 4 simultaneously using MATLAB software.

3.1 Distribution of temperature on CH_4-CO_2 gas mixture

Of the two methods above, obtained temperature of outer wall tube double-pipe heat exchanger and temperature of gas N_2 liquid, which can be described profile temperature distribution in double-pipe heat exchanger. Temperature distribution profiles can be obtained from the change in temperature of CH_4-CO_2 gas mixture (Tmix), outer wall tube temperature (Tw), and N_2 temperature (TN_2).



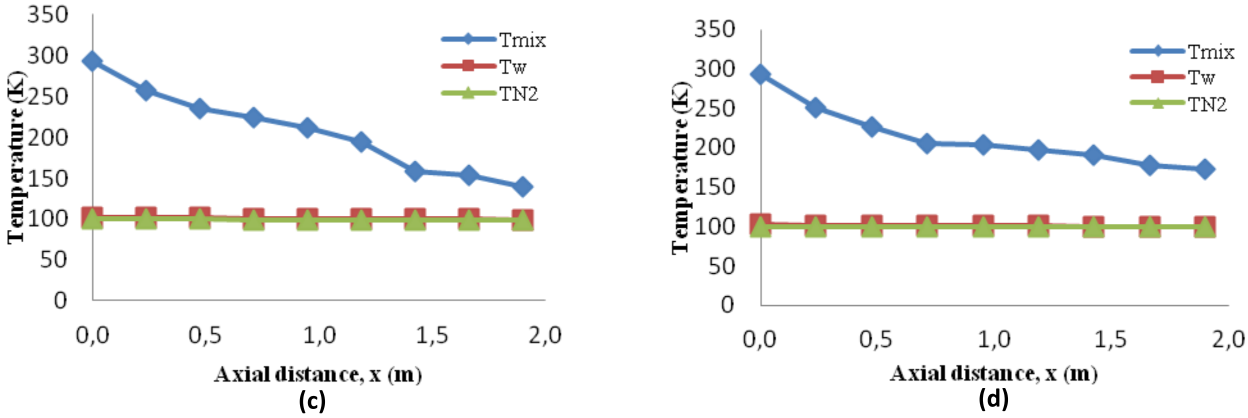


Figure 2. Temperature distribution of CH_4-CO_2 gas mixture at the composition of 5% CO_2 and various pressures: (a) 1 bar, (b) 5 bar, (c) 10 bar, and (d) 20 bar

In Figure 2, show that temperature of outer wall tube approaches temperature of N_2 because the tube has a thin thickness so that it has a small thermal resistance. In the Figure shows that the temperature of N_2 lower than temperature of outer wall tube. This happens because the part of the outer tube wall related to the temperature of CH_4-CO_2 gas mixture which has higher temperature than temperature of gas N_2 liquid. With the same composition at lower pressure so the positions formation of CO_2 frost farther from the end of entrance CH_4-CO_2 gas mixture and temperature of CO_2 frost the lowest. In Table 1, with a higher composition of CO_2 and increasing pressure resulted temperature the formation of CO_2 frost will be higher and the position formation of CO_2 frost closer to the end of the entrance of CH_4-CO_2 gas mixture. This is consistent with the ideal gas equation $PV = nRT$, where the composition and pressure is proportional to the temperature of CO_2 frost.

3.2. Determination the position formation of CO_2 frost

Freezing point is the axial location where the partial pressure of CO_2 equal to saturation pressure (sublimation) on the wall, because the wall temperature is always lower than the average temperature of the gas mixture (Chang et al, 2009). The position of CO_2 frost each variable on CO_2 compositions and pressures different. CO_2 reach that is the point of sublimation will change into a solid so that the composition of CO_2 in the gas phase would decrease as a result of solidification, and pure solid fraction only consists of CO_2 ice or CO_2 frost without the presence of CH_4 in that solid composition.

Table 2. Temperature data of CH_4-CO_2 gas mixture along the double-pipe heat exchanger

x (m)	5% CO_2			
	1 bar	**5 bar**	**10 bar**	**20 bar**
0.00	298	298	293	294
0.24	249	260	251	258
0.47	212	227	227	236
0.71	194	204	205	224
0.95	**176**	187	203	211
1.19	**163**	**179**	197	**195**
1.43	146	**165**	**190**	**159**
1.66	135	148	**177**	153
1.90	131	140	172	139

Table 2 can be used as a reference in prediction temperature and position CO_2 frost based on temperature of CH_4-CO_2 gas mixture in Table 2. This prediction is seen when the temperature of CH_4-CO_2 gas mixture is lower than or equal to the temperature of CO_2 frost. Thus, the position of CO_2 frost could occur in each part along double-pipe heat exchanger provided that temperature of CH_4-CO_2 gas mixture has reached the temperature of CO_2 frost based on thermodynamics data in Table 1.

4. Conclusion

Based on the results and discussion, it can be concluded:

1. The measurements results of temperature of CH_4-CO_2 gas mixture along annulus double pipe heat exchanger can be used as a prediction of the position formation CO_2 frost.
2. With composition and pressure of the higher will be cause temperature in the formation CO_2 frost higher so that the position formation CO_2 frost is getting closer to the end of entrance CH_4-CO_2 gas mixture.

Acknowledgments

Authors are aware of the report will not be completed without the assistance of various parties. Therefore, on this occasion the authors wish to thank both our parents, our brothers, Mr. Professor. Dr. Ir. Tri Widjaja, M.Eng. as Chairman of the Department of Chemical Engineering, Dr.Ir. Kuswandi, DEA as the secretary of the Department of Chemical Engineering-ITS FTI, setiyo Gunawan, ST., PhD. as coordinator of the Final Project and Thesis Department of Chemical Engineering-ITS FTI, Mr. Dr. Ir. Sumarno, M.Eng, as Supervisor and Head of Materials Technology Laboratory, for their guidance and advice given, Lecturer guardians, Mr. and Mrs. teaching experience, crew polymer friends, friends of 2008, and all those who helped in Full Paper do this.

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