

THE EFFECT OF CRYSTALLIZER ROTATION ON THE GAS HYDRATE PERFORMANCES

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ABSTRACT

The performance of hydrate was shown by the hydrate formation rate, the hydrate stability, and the storage capacity. In the study, we investigated the hydrate performance by influencing the rotation of crystallizer that predicted to increase the agitation of the hydrate performance. The hydrate represent the bond of water molecules and gas absorbed by the water molecules. In the experiment, we used the 50% propane and 50% butane as the gas absorbed. The gas was injected in a crystallizer at 3 bar pressure, then the crystallizer was rotated by 100, 200, and 300 rpm. The results shows that the best performances of hydrate when the crystallizer was rotated at 300 rpm. The crystallizer rotation speed of 300 rpm had the highest the formation rate and the decomposition rate. The highest decomposition rate indicated the highest stability. Meanwhile, the highest hydrate storage capacity was also occurred at the rotation of 300 rpm as 2809 V / V.

Keywords: *crystallizer, rotation, gas, hydrates, performance.*

1. INTRODUCTION

Gas hydrate is one method of the distribution of natural gas which is currently still being developed by some scientists and the petroleum industries. The gas hydrate is a crystalline solid form of ice made from water and gas at a high pressure and low temperature. The water molecules having hydrogen bonds to form a frame that has a cavity. In the cavity, among the molecules are trapped the gas molecules in some various shapes and sizes [1]. There is no bond between water molecules and gas molecules. The gas molecules only rotates inside the water molecules. The gas hydrate is a mixture described as a solid solution [2]. The gas molecules inside the hydrate can be

classified as a clathrate hydrate. Clathrate is a chemical compound that its molecules were trapped in the cavity of ice crystal molecules. The gas hydrate and ice have the same structure, consist of 85 % water moles. However, it gas hydrates and ice are different in their spectroscopic implications, mechanical properties, and thermal properties.

On the hydrate formation performance, the gas consumption absorbed by the water is controlled by heat transfer. The hydrate has the unstable nature at atmospheric pressure and temperature, a few degrees below the freezing point of ice. The nature of the metastable prevent hydrate is formed at the equilibrium point. In the process of the formation of hydrates, the hydrate growth is influenced by three factors, namely the speed of crystal growth on the surface of the hydrate, mass transfer component growing crystal surface and the heat transfer from the exothermic heat [2-3].

The hydrate crystal growth process starts with gas molecules in the cluster of temporary water toward the surface of the growing crystal. It is adsorbed on the surface of the crystal. Solid crystal produces a magnetic field into the fluid, causing the hydrate crystal follows the surface. After adsorption (absorption), some water molecules apart from the hydrate and diffuses away. Hydrate diffusion on the surface enters the stage in the crystal. It is attached to the step crystals by removing the solvent molecules. Two solid surface of the step gives a style (with two interaction the surface of the reactants) in the moving hydrate. Cluster diffuses away from the area step leading to the kink (point defects in local step). The cluster has been adsorbed at kink area. In this area there are three or more solid surface so that give greater force to the hydrate molecules [3].

In the stability performance, the hydrate decomposition is an endothermic process in which there is heat from outer system causing

breaking of hydrogen bonds between water molecules to be water and gas [3].

The performance of the clathrate hydrate was investigated by Ganji et al[1], performs the formation rate, the stability, and storage capacity. In the study, for curiousing the hydrate formation rate, the surfactant solution was injected inside the methane gas molecules with stirrer rotational speed of 200 rpm. Then, to investigate the stability of methane hydrate, the hydrate has been formed allowed to stand for 10 hours at temperature 268.2 K. Meanwhile, the storage capacity of methane hydrate, after the hydrate decomposition temperature 268.2 K, it is heated at room temperature, so that the gas will release the trapped methane hydrates.

However, in this study, the formation rate, the stability, and the storage capacity of the hydrate mixture of propane and butane will be examined using pure water without using a surfactant. Because the rotation of will influence the agitation of hydrate, this study aimed to determine the effect of the crystallizer rotation towards the stability, and the storage capacity of the hydrate mixture of propane and butane. It is predicted that the rotation will increase the heat transfer and the mass transfer, so that the gas absorbed inside water molecules will be significant. Therefore, the study aims to determine the effect of the crystallizer rotation on the formation rate, stability and capacity of clathrate hydrate.

2. METHODOLOGY

The experimental devices was attached and drawn in Figure 1. This device consisted of a crystallizer with inside diameter of 4 cm, height 12 cm and a total volume of 150 cm³. The crystallizer had a valve that serves to insert and removed the gas. The electric motor and the inverter were used for adjusting the rotation speed of the crystallizer. It was used to rotate the crystallizer to mix the gas and the demineralized water resulting the hydrate. The demine water had 100 x 10⁻⁴ Ω cm resistivity. Pt type thermocouple and pressure sensor with 0:01 scale bar was used to measure temperature and pressure wass stored in the data logger.

In the formation of hydrates, the crystallizer was cleaned, then 50 cm³ the demine water was infused into it. Afterwards, it

was made in a vacuum condition. The gas mixtures was incorporated into the crystallizer until the pressure was 0.3 MPa at the temperature 300 K. The crystallizer put in a cooling bath until the system reached the equilibrium state. After it, the temperature of the cooling bath was set according to the hydrate formation temperature (274 K) and the crystallizer rotation was set at 300 rpm. The data of temperature, pressure and time for hydrate formation was recorded for 10 hours. The amount of gas consumed during the formation of hydrates was shown in Equation 1.

$$n = PV/ZRT \quad (1)$$

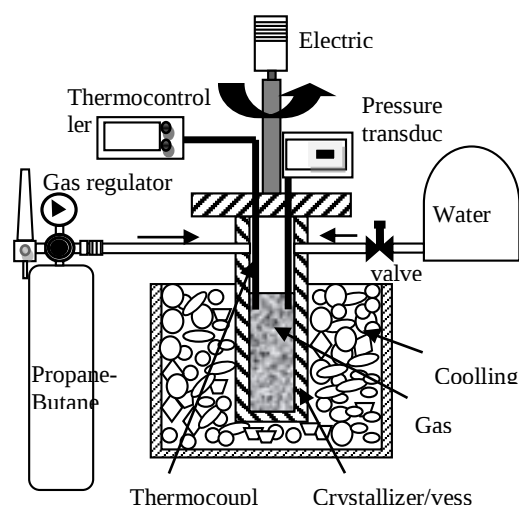


Figure 1. Experimental apparatus

P is the gas pressure, V is the gas volume, and T is the gas temperature. R was replaced by the gas constant and Z represents the compressibility factor of Peng Robinson state equation.

The Hydrate stability, the test was carried out after the formation of hydrate. The cooling bath temperature was declined to 268 K. The system was allowed to stand for 5 hours. Then, the gas valve was opened to exhaust gas into water and gas again. The gas was allowed during 5 hours to find out the decomposition of hydrate at temperature 268 K. The pressure and time data were recorded and the decomposed gas was calculated by using Equation 1.

After the stability hydrate investigation, the hydrate was tolerable to reach at room temperature, so that the hydrate could decompose completely and remove the trapped propane and butane in the cavity of the water

molecules. It will be understand the capacity storage of hydrate. The total storage capacity based on the amount of hydrates maximum pressure in the crystallizer. The trapped propane and butane was calculated in the real gas volume compared to the STP gas volume.

3. RESULTS AND DISSCUSION

3.1. The hydrate formation rate

The hydrate formation was occurred when the temperature of the system has reached the equilibrium temperature of hydrate at 274 K can be seen in Fig. 2. The hydrate formation was marked without pressure decreasing and the temperature changes. At the decreasing of temperature from 300 K to 274 K, the hydrate had still not formed yet due to the metastable state indicating a decreasing of pressure and temperature. The period was called the induction period because it was occurred the hydrate nucleation. In the results, the highest pressure drop occurs at the hydrate with crystallizer rotation of 300 rpm while the lowest pressure drop occurs at 100 rpm.

In Fig. 3, the highest hydrate formation rate was at a speed of 300 rpm due to the greater speed of rotation, the larger contact area. It is also confirmed by Fig. 4 in which the highest consumed gas, absorbed by the water molecules, was occurred at rotation 300 rpm. The contact area between the gas molecules and the water molecules was to be larger, and then the gas can be penetrated to the water molecules significantly.

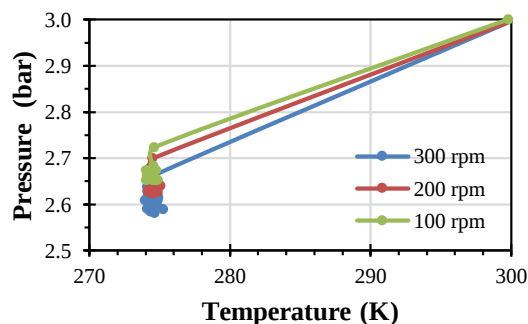


Figure 2. The pressure and temperature of hydrate formation

Besides, the heat transfer from the crystallizer (system) to the environment (the cooling bath) also will be greater because there is a significant temperature differences between the system and the environment.

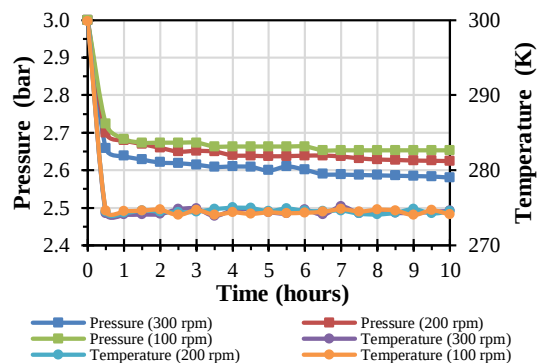


Figure 3. The pressure and temperature of hydrate formation rate in elapsed time

3.2. The hydrate stability

The hydrate stability performance can be determined in Fig. 5. The highest pressure was reached at 0.06 bar at 100 rpm. However, the pressure at 300 rpm was lower than the pressure at 100 rpm. The pressure of the stability hydrate only showed 0.03 bar at 300 rpm and 268 K. If the hydrate was decomposed more easily, so it is said that hydrate has low stability. Conversely, if the hydrate difficult to break down, the hydrate has higher the stability. The highest stability was shown by the hydrate mixture of propane and butane at the crystallizer rotation of 300 rpm

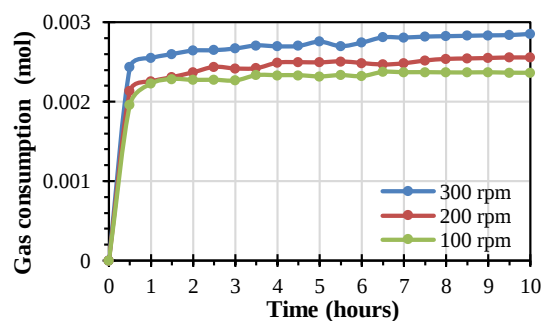


Figure 4. The consumed gas by water molecules at the hydrate formation

The hydrate stability is influenced by two factors. Firstly, the hydrate has a layer of ice around the hydrate crystals which hamper the further decomposition. Next, the decomposition of the crystallizer occurs in a closed system. The decomposed propane and butane will create an increasing of the crystallizer pressure. The increasing one will inhibit the rate of hydrate decomposition.

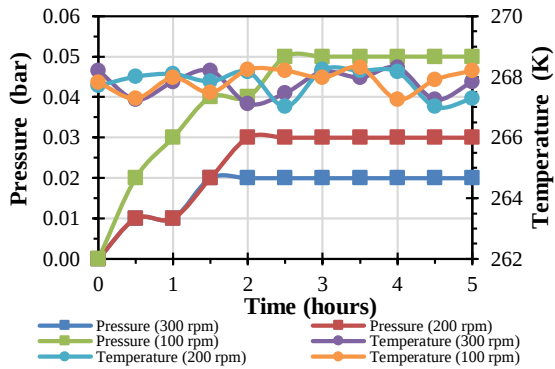


Figure 5. The hydrate pressure and temperature at the hydrate stability

Fig. 6 determined the decomposed gas at the hydrate stability. It was explained as larger the crystallizer rotation, as higher the consumed gas at the hydrate formation, as fewer the release gas at the hydrate stability. It is due to the fact that the gas can penetrate to the water molecules gas deeply at the higher rotation. Therefore, it is difficult to release

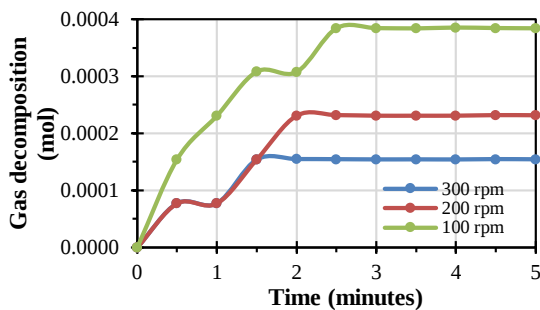


Figure 6. The gas release to decompose at the hydrate stability

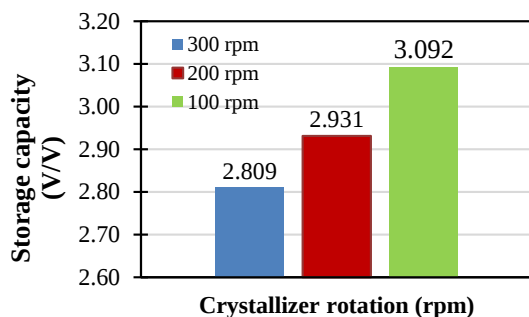


Figure 7. The storage capacity of hydrate at some crystallizer rotations

3.3. The hydrate storage capacity

The hydrate storage capacity of propane and butane is defined by a ratio between the gas volume within the crystallizer and the gas volume at STP. The result was showed by Fig.

7 that the highest storage capacity was 2809 V/V at the crystallizer rotational speed of 300 rpm. Meanwhile, the lowest storage capacity amounting to 3.092 bar at 100 rpm crystallizer rotational speed.

The highest storage capacity was occurred when the crystallizer rotation speed was high. It is because the higher the hydrates formation rate, the stronger the penetration of propane and butane mixture inside the water molecules. Even though the rotation of 100 rpm has cavities among the water molecules wider than the hydrate with the rotation speed of 300 rpm, it had the lowest the storage capacity. It has a reason in the low crystallizer rotation; the hydrate has a low gas consumption showed by the slowest the hydrate formation rate. It makes that the hydrate enclose the low storage capacity

4. CONCLUSION

The research have been investigated the performance of the clathrate hydrate consist of the hydrate formation rate, the hydrate stability, and the hydrate storage capacity influenced by the effect of the crystallizer rotation. The results show that the rotation of 300 rpm has the highest formation rate, the most stable hydrate, and the biggest storage capacity. It is due to fact that the larger contact area to make the gas penetrates the hydrates easier, the covering ice around the hydrate and the increasing the crystallizer pressure to make the hydrate more stable, and also the stronger penetration gas inside the hydrate made the higher storage capacity

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