Visualization and Pressure Distribution of Gas-Liquid Flow

by Dewi Puspitasari

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Visualization and Pressure Distribution of Gas-Liquid Flow in ¾ inch Plexyglass Pipe Diameter with the Slope Orientation Upward, Horizontal and Downward

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Abstract: The existence of the flowing phase in the pipe is affecting on the continuity of fluid transport process, this is due to the interaction between the phases when the fluid mixture flowing at a certain superficial velocity. Due to the interaction between the phases then there will be a variety of flow pattern which will produce a different pressure distribution. Besides the orientation of the pipe also affects the process of interaction between the phases that occur. The flow that are changing the flow pattern can cause fluctuating of the pressure distribution. Therefore it will be studied the distribution of pressure and flow pattern inside transparent pipe (plexyglass) ¾ inch in diameter, and its influence on the orientation of the slope of pipe 10°, 5°, 0°, -5° and -10°. The research was carried out experimentally with the flow of water 10 - 20 lpm and air flow 5 - 15 lpm. The results showed that the flow pattern be produce on every slope of the pipe is a bubble, elongated bubble, plug, plug-slug transition, plug bubble, bubble slug, slug, stratified wavy and stratified with mixture interface. On the upward slope of the bubble flow patterns likely to appear more and result the highest pressure of 1690 N/m^2 on J_{mix} = 9.3 m/s, on the horizontal position bubble slug flow pattern that often appears with the highest pressure drop of 593 N/m^2 on J_{mix} = 8.23 m / s, while the downward slope of the wavy stratified flow pattern likely to appear more with the highest pressure drop of 685 N/m^2 on J_{mix} = 5.88 m / s.

Keywords: Flow pattern ; Pressure distribution; Pipe slope orientation

1. INTRODUCTION

On the industry often encountered two-phase flow, which is part of the multiphase flow. A form or phase of a substance in the two-phase flow can be divided into three : liquid, solid, and gas. Two-phase flow more encountered both in everyday life and in industrial processes, such as boilers, condensers, heat exchangers, nuclear reactors, natural gas liquefaction, and flows in the petroleum industry.

Multiphase flow is divided into several phases combinations among others the solid-liquid, liquid-gas and solid-gas. It is very important to study the flow pattern from the two-phase flow. The Flow that are changing the flow pattern can cause pressure drop fluctuating. Therefore it is necessary for us to know and identify the flow patterns that occur to predict the pressure drop relationships with the two-phase flow, on a variety of pipe slope orientation.

The result [8] showed that the fluctuation pressure differential of slug flow were very influence by the superficial velocity of the fluid. [5] describes the visualization of the air-water mixture flow in a vertical pipe that is heated. The result showed that the heat transfer coefficient of air-water flow increase with increasing air flow and water flow was represented by the superficial velocity of water.

2. LITERATURE REVIEW

A multiphase flow related to solid, liquid or gas. Multiphase flow is the mixture flow of phases such as bubble flow which shows gas (bubble) in liquid or liquid in gas or a combination of solid, liquid and gas simultaneously in the same pipe. Many engineering and scientific applications of the multiphase, such as gas-liquid flow, solid-liquid (slurry), gas-oil-water (petroleum Industry) and many others applications of the multiphase. The research about flow regime in horizontal and vertical pipe has been studied by [1] which can be seen in figure 1 and 2.

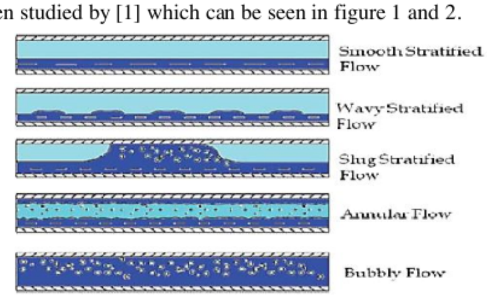

Fig.1. Flow Regime in the horizontal pipe [1]

The flow pattern consists of :

a. Bubbles flow (bubble), where the gas bubbles tend to flow at the top of the tube.

b. The flow of gas bag (plug), in which small gas bubbles combine to form gas pockets.

c. Smooth stratified flow, where the interface of the liquid-gas is very smooth, but the flow pattern like this usually does not happen. The interface is almost always wavy (stratified wavy).

d. Stratified wavy occured when gas velocity increases.

e. Liquid plug flow (slug), which are typically large amplitude waves to reach the top of the tube.

f. Flow ring (annular), is same with the vertical tube flow, but film liquid in the bottom is thicker from the top.

The flow patterns in the vertical pipe can be seen in the figure 2.

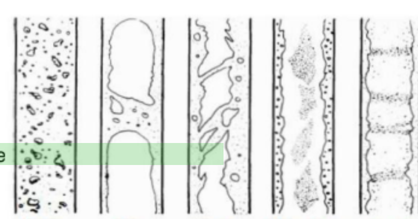

Fig.2. Flow Regime in a vertical pipe [1]

The flow pattern consists of :

a. Bubble Flow, where the vapor bubbles are estimated to have uniform size.
b. Slug Flow, gas flowing to form large bubbles (sometimes distributed small gas bubbles in the liquid)
c. Churn Flow, the oscillating movement occurs so that the liquid becomes unstable.
d. Wispy-Annular Flow, the concentration of droplets in the gas increases and merge to form wisp.
e. Annular Flow, a part of liquid phase as a film in the tube wall, and the other part in the form of droplets distributed in the gas flowing in the middle of the tube.

Hold-up of liquid (α_L) is defined as the ratio between the volume occupied by the liquid phase with overall mixture volume, whereas Hold-up for gas (α_g) is the ratio between the volume occupied by the gas phase with the overall mixture volume.

$$\alpha_L = \frac{V_L}{V_P} \quad (1)$$

$$\alpha_g = \frac{V_g}{V_P} = 1 - \alpha_L \quad (2)$$

where :
α_L = Hold up for liquid
α_g = Hold up for gas
V_L = Volume of liquid filled in pipe (m^3)
V_g = volume of gas filled in pipe (m^3)
V_P = Volume of mixture filled in pipe (m^3)

Parameter flow used in the calculation of multiphase flow is the superficial velocity which is defined as follows:

$$J = Q_{tot} / A.\alpha \quad (3)$$

where :
J = superficial velocity of the phase, m/s
Qtot = total flow rate, m^3/s
A = pipe cross-sectional area, m2
α = Phase hold up

The superficial velocity of mixture is determined by the equation :

$$J_m = J_L + J_g \quad (4)$$

The pressure distribution in multiphase flow is determined from the measured from the column manometer.

3. METHODOLOGY

The study was conducted by using the experimental set up as shown in figure 3.

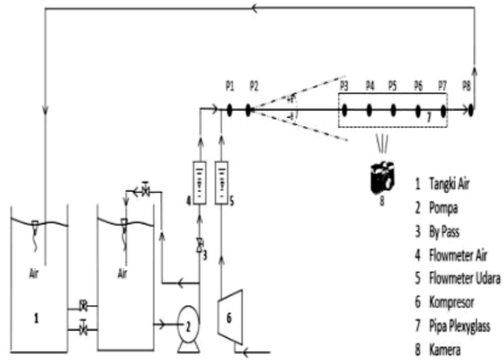

Fig.3. Schematic diagram of experimental set up

Table.1. Properties of work fluid

Work fluid	Density (kg/m^3)	Viscosity (kg/m.s)
Water	998	0.001002
Air	1.29	0.000019

4. RESULTS AND DISCUSSION

From the research results the flow pattern visualization and pressure distribution according to variation superficial velocity and orientation of pipe slope. There were nine flow pattern results as shown in figure 4 to figure 12.

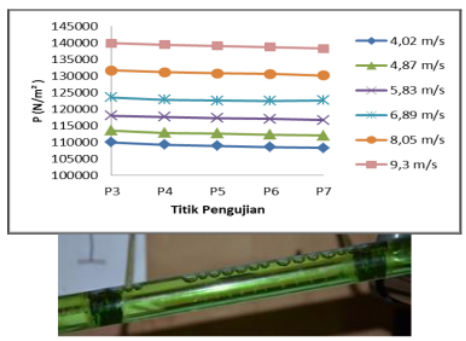

Fig.4. The pressure distribution and flow pattern Bubble on the upward slope 10°

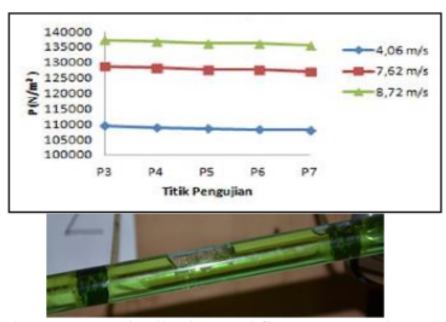

Fig.5. The pressure distribution and flow pattern Elongated Bubble on the upward slope 10°

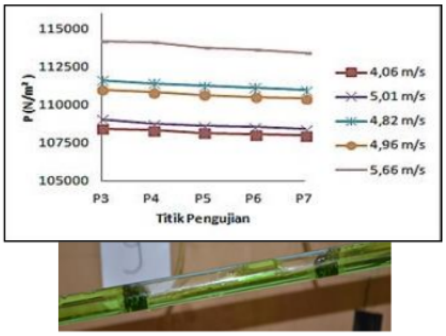

Fig.6. The pressure distribution and flow pattern Plug on the upward slope 5°

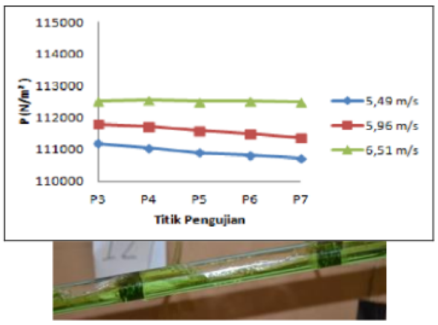

Fig.7. The pressure distribution and flow pattern Plug Slug on the upward slope 5°

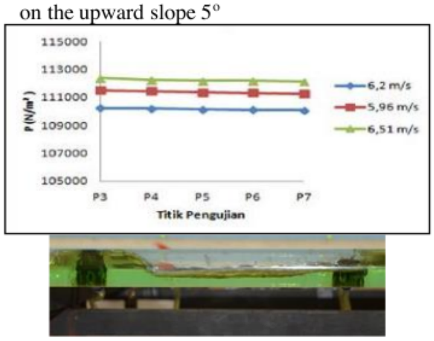

Fig.8. The pressure distribution and flow pattern Slug on the horizontal slope 0°

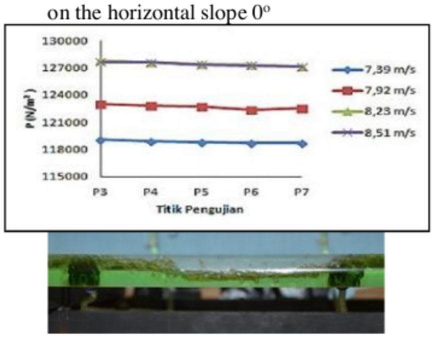

Fig.9. The pressure distribution and flow pattern Slug Bubble on the horizontal slope 0°

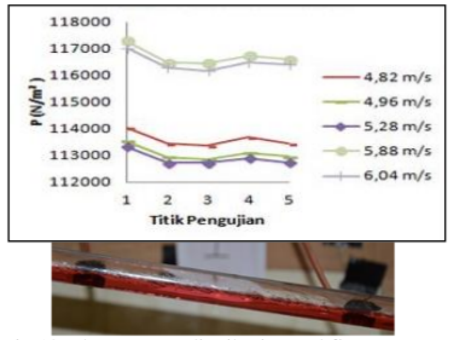

Fig.10. The pressure distribution and flow pattern Stratified Wavy on the downward slope -5°

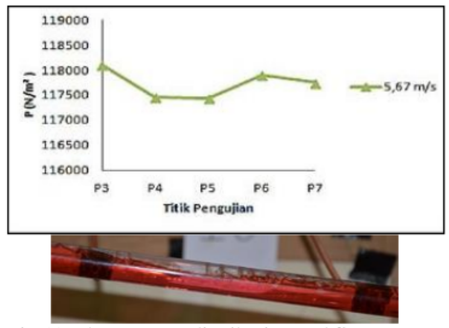

Fig.11. The pressure distribution and flow pattern Plug Bubble on the downward slope -5°

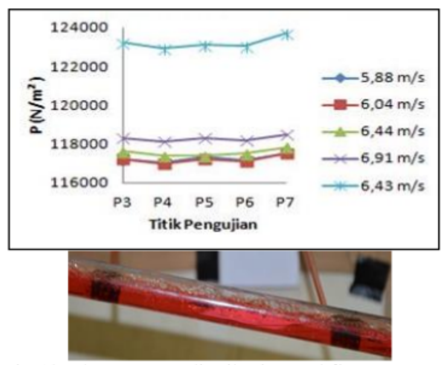

Fig.12. The pressure distribution and flow pattern Stratified-Mixture Interface on the downward slope -5°

The discussion of the research just focused on the flow patterns that often appear and higly fluctuating pressure distribution.

On the upward slope 10° flow patern form are : bubble, elongated bubble, plug, transition slug-plug, slug, and plug bubble. The lowest pressure drop for bubble flow is 887 N/m² on J_{mix} = 6.89 m/s and the highest is 1690 N/m² on J_{mix} = 4.02 m/s. For elongated bubble flow the lowest is 1462 N/m² on J_{mix} = 4.06 m/s and the highest is 1648 N/m² on J_{mix} = 8.72 m/s.

On the upward slope 5° flow pattern form are : bubble, plug, slug, transition slug-plug, plug bubble, and the slug bubble. The lowest pressure drop for plug flow is 452 N/m² on J_{mix} = 4.06 m/s and the highest is 741 N/m² on J_{mix} = 5.66 m/s. For slug flow the lowest is 39 N/m² on J_{mix} = 6.51 m/s and the highest is 454 N/m² on J_{mix} = 5.49 m/s.

On the horizontal slope 0° flow patern form are : elongated bubble, plug, slug, transition slug-plug, plug bubble and slug bubble. The lowest pressure drop for slug flow is 156 N/m² on J_{mix} = 6.2 m/s and the highest is 235 N/m² on J_{mix} = 5.96 m/s. For slug bubble flow the lowest is 353 N/m² on J_{mix} = 7.39 m/s and the highest is 593 N/m² on J_{mix} = 8.23 m/s.

On the downward slope -5° flow patern form are : stratified wavy, plug, bubble, elongated bubble, plug bubble and stratified with mixture interface. The lowest pressure drop for stratified wavy flow is 587 N/m² on J_{mix} = 4.82 m/s and the highest is 685 N/m² on J_{mix} = 5.88 m/s. For plug bubble flow there is only one flow pattern was found then the pressure distribution is 342 N/m² on J_{mix} = 5.67 m/s.

On the downward slope -10° flow patern form are : stratified wavy, plug, bubble, elongated bubble, plug, transition slug-plug, slug, and stratified with mixture interface. The lowest pressure drop for stratified with mixture interface flow is 184 N/m² on J_{mix} = 6.91 m/s and the highest is 1690 N/m² on J_{mix} = 4.02 m/s. For elongated bubble flow the lowest is 450 N/m² on J_{mix} = 6.43 m/s.

5. CONCLUTIONS

1. The flow patterns were found throughout the study for each slope are : bubble, elongated bubble, transition plug-slug, plug, slug, plug bubble, slug bubble, stratified wavy, and stratified with mixture interface.
2. The pressure drop for each flow patterns in the variation of slope is different. For upward slope 10° highest pressure drop is achieved under conditions bubble flow with a drop of pressure of 1690 N/m² and J_{mix} = 4.02 m / s. The more lower of J_{mix} the more higher of pressure drop.
3. On the upward slope of 5° highest pressure drop occurs in the Plug flow of 741 N/m² with J_{mix} = 5.66 m / s. In the horizontal position (0°) highest pressure drop occurs in slug bubble flow of 593 N/m² on J_{mix} = 8.23 m/s.
4. On the downward slope of the highest pressure drop occurs in conditions Stratified wavy flow of 685 N/m² with J_{mix} = 5.88 m / s.

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