The Characteristic Of Two-Phase Flow Pattern On Air-Water Countercurrent Flow In Vertical Pipe

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The Characteristic of Two-Phase Flow Pattern on Air-Water Countercurrent Flow in Vertical Pipe

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Abstract. Two-phase flow is widely encountered in several engineering and industrial facilities. The purpose of this study is to investigate the characteristic of slug countercurrent flow pattern in a vertical small diameter pipe. An experimental investigation in this study has been performed toward a transparent tube of 19 mm diameter (outside diameter 22 mm, length 200 mm), water and air as the liquid and gas fluid in the vertical pipe followed by taking a picture of flow pattern in the transparent pipe using the high-speed camera. Two differential pressure sensors were set in transparent tube in order to receive slug countercurrent flow rate associated with the acquisition data as media to record data and then displayed on the screen. The two-phase flow was always preceded by the instability of flow rate and bubbles appearance. It occurred after the steady flow data acquisition rate was turned on for recording the differential pressure. The result showed that the flow pattern characteristic of two-phase flow (air-water) in the vertical pipe caused by the superficial velocity of air.

Introduction

Vertical slug flow is part of the multi-phase flow. The multi-phase flow consists of two-phase flow or more. The study of two-phase flow can be classified into some categories, i.e. phase form, streamline and channel position. Two-phase flow can be found in the steam boiler flow, condenser, heat transfer, nuclear reactor, liquefaction of natural gas, pipeline, etc. Vertical slug flow pattern in a horizontal pipeline will be different to a vertical pipeline. The difference focuses on the position of gas/steam, i.e. in the horizontal pipe, the gas tends to be on top because it's a lightweight particle. It was observed the flow visualization and pressure drops of every flow patterns in a variety of fluid and gas velocity diameter 25.3 mm, the fluid velocity was 0.14-14 m/s and the air velocity was 0.624 m/s. The result showed that the very high air rate velocity would decrease the pressure and constantly continue after reaching the random flow pattern [1].

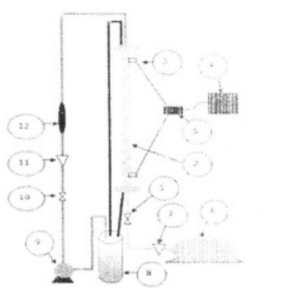
The pressure drops and flow pattern visualization were investigated. In air-water two-phase flow with a sudden magnification of a rectangular section of a vertical channel. The water discharge was 0.04-0.28 dm^3/s, and the air discharge was 6.06-0.39 dm^3/s. The visualization showed that the changes of flow pattern did not depend on the water or air discharge but the changes of cross-sectional area [2]. The characteristics of flow patterns in gas and liquid flow in the straight pipe were observed. The inner diameter of pipe was 36 mm with superficial liquid velocity of 0.5 minute/second and the pressure of 0.2 bar. The result showed that the changes of flow patterns as it approached the superficial liquid velocity with bubbles flow injector Reynolds was 49488 [3]. The effect of viscosity on the flow of gas-liquid fluid through a vertical pipe was studied. The vertical pipe had a specified i.d. of 2000 mm. The discharge of liquid flow started from 1.8 lpm – 10.5 lpm and the discharge of air began from 10 lpm – 70 lpm. It was known that change of flow pattern depended on the variant of increase of water and air discharge. In a liquid discharge constant and air discharge increase, the slug transformed to ring in a condition that the air discharge was increasing [4]. The characteristic of water flow resistance in the narrow annulus was observed. Three concentric pipes with the length of 1350 mm and the size of inlet annulus were 0.9 mm; 1.4 mm and 2.4 mm. The result mentioned that flow without heat transfer occurred in a narrow inlet causing a higher friction. The transition area of flow from laminar to turbulent occured in R_e number of 2000. The flow of heat exchange in different temperature had a little effect on pressure drop [5].

The measurement of vacuum fraction was examined in liquid-gas two-phase flow in the pipe with a specified i.d. of 50 mm and length of 2000 mm. The superficial gas velocity was 0.0067-0.1217 m/s, and superficial liquid velocity was 0.0616-0.80772 m/s. It was obtained that if the constant fluid flow was higher than the superficial gas velocity, then the vacuum fraction would be more significant and vice versa [6]. A measurement method, which is a combination of the multiwave UVP method and WMT, has been applied to the measurement of bubbly two-phase flow in vertical pipe. Regarding the measurements of counter-current bubbly flow of air water in the vertical pipe, measured data showed that the effect of initial flow conditions, e.g. bubble size, on the pattern of cross-sectional void fraction distribution was confirmed; measured data of instantaneous profiles of void fraction and velocity can contribute to the assessment and development of numerical simulation of two-phase flow [7].

The flow patterns of air–water, two-phase flows have been investigated experimentally in a vertical mini pipe was investigated [8]. The flow regimes were observed by a high speed video recorder in pipes with diameters of 2, 3 and 4 mm and length 27, 31 and 25 cm, respectively. The comprehensive visualization of air–water, two-phase flow in a vertical mini pipe has been performed to realize the physics of such a two-phase flow. On the other hand, the counter-current flow pattern transition and pressure drop are modeled. Emphasis is placed on the understanding of the transition mechanisms from a mechanistic point of view. Some of the results are supported by data (from the literature), others are somewhat tentative suggesting future experimental verification is needed [9]. Meanwhile, Research on the countercurrent Air-Water Flow in Two Vertical Channels was also conducted [10].

In obtaining the characteristic of slug pattern, the analysis of flow can be done by using specific visualization method, i.e. Digital Image Processing. Thus, the method implemented was based on a comprehensive analysis of image combined with some steps of collecting data, e.g. layer thickness, liquid film and characteristic of slug gases velocity. One of the superiorities of this method is the ability to analyze slug gas with good accuracy in broad scale and without disturbing the flow. It can be concluded that this study is limited in term of countercurrent two-phase flow, especially the slug flow pattern.

Experimental Method. The scheme of research installation can be seen in figure 1. The equipments were water tank, pipes, air flow meter, water flow meter, data acquisition and compressor as gas supply system. The test section was equiped of tranparent pipe with D_i of 19 mm, D_o of 22 mm and length of 200 mm. The research was conducted by combining the water and air that flow became churn (countercurrent two-phase flow) in the vertical pipeline.



Note:

1. Valve of compressor
2. Transparent pipe
3. Sensor of Pressure
4. Computer
5. Acquisition data
6. Compressor
7. Flowmeter of air
8. Reservoir of water
9. Pump
10. Valve of pump
11. Flowmeter of water
12. Flow water conditioner

Fig. 1. Scheme of research installation

Result and Discussion

Based on the result of experiment and data analysis of water J_L and air J_G countercurrent of two-phase flow in vertical pipe, the calculation for flow pattern in vertical pipeline was obtained. The experiment started from the liquid velocity of J_L 1.67 x 10^{-3} m/s up to 8.33 x 10^{-3} m/s and the air velocity started from J_G 8,33 x 10^{-3} m/s up to 1,67 x 10^{-3} m/s. From these five variations observed, four variations namely bubble flow, slug flow, swarm of bubble flow and wispy annular were obtained.

Table 1 Variation J_G 8,33 x 10^{-3} m/s to the J_L 1,67 x 10^{-3} m/s

J_L (m/s)	J_G (m/s)
1,67 x 10^{-3}	8,33 x 10^{-3}
3,34 x 10^{-3}	6,67 x 10^{-3}
5 x 10^{-3}	5 x 10^{-3}
6,67 x 10^{-3}	3,67 x 10^{-3}
8, 33x 10^{-3}	1,67 x 10^{-3}

The following figure 2 shows the visualization pattern of the flow of vertical pipe in the opposite direction and the graphic of the correlation of ΔP with the time (millisecond) on each trial variation. At the first trial, the water was flowed with the velocity of (J_L) 1,67 x10^{-3} m/s, and the air was flowed with the speed of (J_G) 8,33 x 10^{-3} m/s. The trial of this flow formed slug flow pattern and water mist ring flow pattern on the pipe's side as the following Fig. 2. (a) and (b). The second trial, water was flowed with the velocity of (J_L) 3,33 x 10^{-3} m/s and the air was flowed with velocity of (J_G) 6,67 x 10^{-3} m/s. The trial of second flow formed a slug pattern. It happened because in the middle of the pipe there was a bubble like a bullet containing air. The water flow's position surrounds the slug flow as shown in fig.3 (a) and (b).

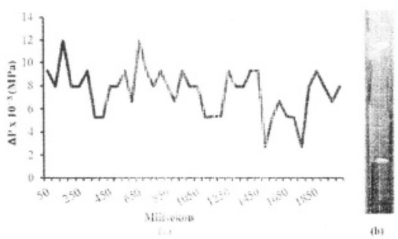


Fig. 2. **a)** The relation between **ΔP** (MPa) with time (milisecond) from (J_L) 1,67 x 10^{-3} m/s and (J_G) 8,33 x 10^{-3} m/s. **b)** The Visualization of ring flow pattern.

Fig. 3. **a)** The Relation of **ΔP** (MPa) with time (milisecond) on (J_L) 3,33 x 10^{-3} m/s dan (J_G) 6,67 x 10^{-3} m/s. **b)** Vizualization of the slug pattern.

The third trial, water was flowed with the velocity of (J_L) 5 x 10^{-3} m/s and the air was flowed with the velocity of (J_G) 5 x 10^{-3} m/s. The trial of third flow still formed small bubbles and slug flow because in the air phase there were small bubbles which flow so these bubbles become slug flow as shown in Fig.4. (a) and (b).

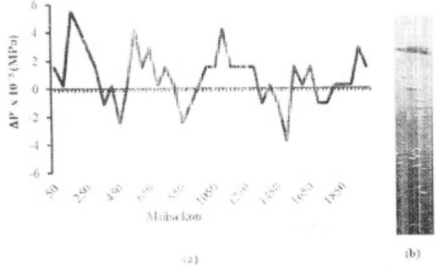


Fig.4. **a)** The relation of ΔP (MPa) with time (milisecond) (J_L) 5 x 10^{-3} m/s dan (J_G) 5 x 10^{-3} m/s. **b)** Visualization of the little bubble flow pattern and slug flow pattern.

The fourth trial, water was flowed with the velocity of (J_L) 6,67 x 10^{-3} m/s and air was flowed with the velocity of (J_G) 3,33 x 10^{-3} m/s. This fourth trial still formed small bubbles flow resulting in bubble blobs caused by the fusing of one bubble with another as shown in fig. 5. (a) and (b). The last, water was flowed with the speed (J_L) 8,33 x 10^{-3} m/s and air was flowed with the speed of (J_G) 1,67 x 10^{-3} m/s. This fifth trial formed big bubble flow which was caused by the water flow which was bigger as shown in fig. 6. (a) and (b).

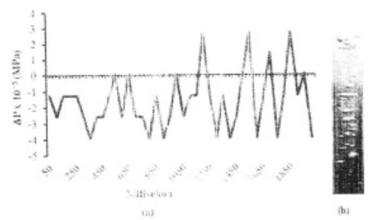


Fig. 5. **a)** The correlation between ΔP (MPa) with time (milisecond) (J_L) 6,67 x 10^{-3} m/s dan (J_G) 3,33 x 10^{-3} m/s. **b)** Bubbles flow pattern visualization, big bubble.

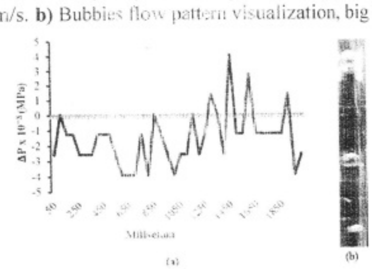


Fig. 6. **a)** The correlation between ΔP (MPa) with time (milisecond) (J_L) 8,33 x 10^{-3} m/s dan (J_G) 1,67 x 10^{-3} m/s. **b)** Bubble flow pattern visualization.

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