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Flow characteristic of horizontal-vertical upward air-water with 45° elbow

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Abstract. An experimental investigation of flow characteristics of horizontal-vertical upward with 45° elbow has been conducted in a $\frac{3}{4}$ " inner diameter pipe. The aims of this research are to determine the pattern of two-phase fluid flow (water-air) and pressure drop occurred in the flow. Data were obtained by varying flowrate of 1 – 3 lpm and volumetric proportion of gas (β) of 25-50%. The results showed that a slug/plug flow was occurred at the 45° with various characteristics. The slug/plug flow indicated more bigger as the gas volume fraction (β) bigger and those are inversely to the superficial air Reynolds (VSL). The size and the shape of the slug/plug flow were inversely with the pressure drop due to the mixing of two flow of air–water. The higher pressure drop theoretically and experimentally occurred at 216.6 Pa and 107.4 Pa respectively on gas volume fraction (β) of 25%, superficial air speed (vsG) of 0.076 m/s and superficial water speed (vsL) of 0.227 m/s.

1. Introduction

The fluid flow properties is a very interesting thing to study, both static fluid and dynamic fluid. Liquid fluid that flows through a pipe with a certain length causes energy losses in the form of pressure drop caused by major losses due to friction along the pipe wall and minor losses due to changes in the local shape of the channel in the form of bends, valves and pipe connections and also depend on large friction coefficient of the pipe. In everyday life, not only do we find a case for a single phase flow in a piping system, in fact multiphase flow often occurs (two phases, three phases, or more) [1].

Multiphase flow is the flow which phase (solid, liquid and gas) interacts with each other and each connection between the phases of its movement affects each other. While the two-phase flow is a flow consisting of two different phases, and is part of the multiphase flow. Applications of multiphase flows such as cavitation pumps and turbines, electrophotographic printers in the process of effective flow of toner to produce image quality and printing speed, steam boilers, nuclear reactor processes in nuclear power generation systems, distillation processes, oil and mining industries, medical fields for blood flow and sperm, so it would be very valuable to think about the application of multiphase flow [2].

To design and apply in the field, the use of bends is very necessary. Pipe turns have a large pressure drop value compared to straight pipes, this is because changes in geometry and trajectory result in changes in flow patterns so that a separate flow from the inner side of the pipe turns is formed. The size of the pressure drop is determined by the selection of the bend angle [3].



Kim et.al., (2008), concluded that the geometric effect of 45° bend showed a decrease in pressure increasing with increasing gas and liquid flow rates, the correlation results developed with experimental data $C = 65$ and factor $k = 0.58$ for 90° turns and $k = 0.35$ for a 45° turn it produces very good data with a difference in the average percentage of each turn $\pm 2.1\%$ and $\pm 1.3\%$ [4].

Adiwibowo (2009), variations in fluid superficial velocity from 0.3 m/s to 1.1 m/s and volumetric gas quality of 0.05 to 0.20 will produce bubble flow patterns in vertical test fields, global void fraction deviations from homogeneous models by 42% to 50% and decreases the pressure drop value occurs in various liquids superficial velocities with increasing volumetric gas quality [5]. Abdulkadir et.al., (2011), low fluid flow rates and high superficial gas velocities, burn out films occur at 45° around the bend. The effects of gravity occur significantly at high gas superficial speeds [6].

From this description and see the importance of knowledge about the flow of two phases through turns and a data base that is still lacking, it is necessary to do research on the effect of gas volume fraction and air flow discharge on pressure drop with different variations. In this study using gas fraction volume with moderate classification, variations in air and water flow discharge.

2. Research Method

This research was performed by an experimental method of direct and indirect measurement. The equipment used as shown in Figure 1. Test section (9) used a transparent acrylic pipe so that flow behavior can be observed. Water and air flow discharge were measured using flow meters (6 and 5) both flow (air-water) mixed in mixer (7). Before passing through the test section (9), a two-phase flow (air-water) passes through a horizontal pipe (8) of 200 mm. Flow measurement using a U manometer before (11) and after (12) turns (9) with an elevation pressure tap (ΔZ) 30 mm [7]. Experiments will be conducted with gas variations in the volume of fraction (β) (25 - 50)% and air discharge (QG) (1 - 3) LPM. This variation will get a water discharge (QL) through the equation [5]:

$$\beta = \frac{Q_G}{Q_G + Q_L} \quad (1)$$

Measurement of fluid properties (air-water) is adjusted to the average temperature of the research room which is 20°C..

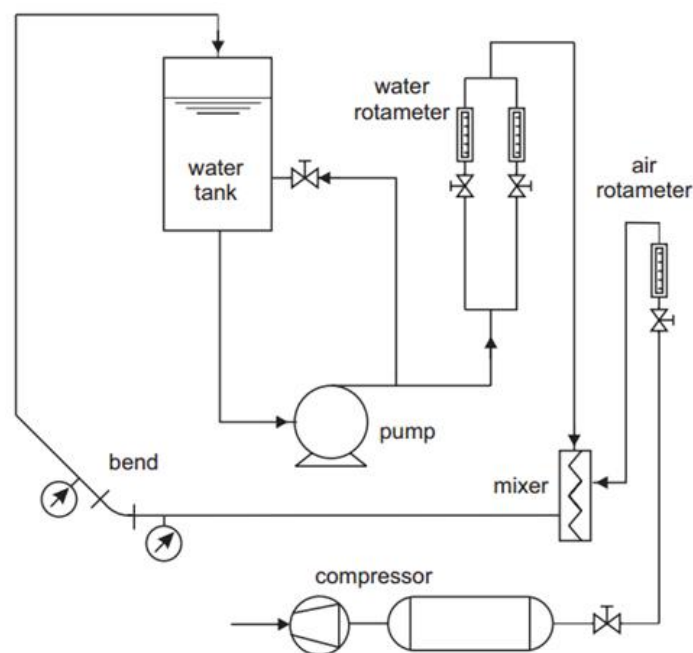


Figure 1. Instalation scheme

Figure 1 shows that the water in the reservoir (1) is circulated by the pump (2) to the installation. Setting the desired flow rate of water through a flow meter (5) uses a gate valve (4). After the water flow appears to be fully developed in the transparent horizontal pipe (8), air from the compressor (3) is injected into the mixer (7). Discharge of air flow is measured using a flow meter (6). The two-phase (air-water) flow pressure distribution before (11) and after (12) turn 45o (9) towards the upward sloping vertical pipe (10) is measured using a manometer U [8].

Retrieval of data about the phenomenon of fluid flow patterns (air-water) through turns using a high-speed Nikon D90 camera in the form of a second image format. For experimental pressure drop calculations through turns using equation [5]:

$$\Delta p_{EB} = [\Delta Z + (h_{in} - h_{out})] \times \rho_m \times g \quad (2)$$

Where :

- Δp_{EB} = pressure drop in the bend (N/m²)
- ΔZ = elevation between pressure taps (m)
- h = the results of the water level height on the manometer (m)
- ρ_m = mixture density (kg/m³)
- g = gravitational acceleration (m/s²)

For the calculation of theoretical pressure drop through bends, it is affected by pressure drop due to friction, static and retraction, that is, using equations

$$\Delta p_{EB} = [\Delta p]_f + [\Delta p]_s + [\Delta p]_r \quad (3)$$

Pressure drop friction and static two phases use Lockhart-correlation [4]: A subsection.

$$\Delta p_f = \left[\left(\frac{dp}{dx} \right)_f \right]_{\text{Lockhart Martinelli}} \times \frac{\pi R}{2} \quad (4)$$

$$\left(\frac{dp}{dx} \right)_f = \Phi_L^2 \left(\frac{dp}{dx} \right)_{SL f} = \Phi_G^2 \left(\frac{dp}{dx} \right)_{SG f} \quad (5)$$

Gradient pressure for friction using equations:

$$\left(\frac{dp}{dx} \right)_{SL f} = 2 \frac{f_{SL} \rho_L v_{SL}^2}{D} \quad (6)$$

The Lockhart-Martinelli correlation developed is :

$$\Phi_L^2 = 1 + \frac{C}{X} + \frac{1}{X^2} \quad (7)$$

Pressure drop static using equations:

$$\Delta p_s = \left[\left(\frac{dp}{dx} \right)_s \right]_{\text{Lockhart Martinelli}} \times R \times \sin \theta \quad (8)$$

Gradient pressure for static using equations:

$$\left(\frac{dp}{dx} \right)_{static} = \rho_m \times g \quad (9)$$

Pressure drop two phase restriction uses the equation:

$$\Delta p_f = \frac{k_s}{2} (\rho_L v_{sL}^2 + \rho_G v_{sG}^2) \quad (10)$$

3. Results and discussions

The research visualization results of the two-phase fluid flow pattern through the 45° bend are as follows;

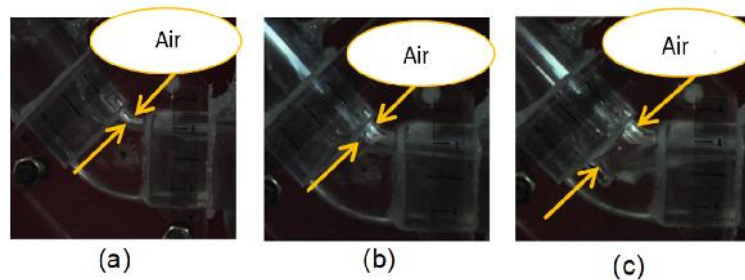


Figure 2. Flow pattern at gas superficial velocity (v_{sG}) 0.025 m/s
(a) $\beta = 25\%$ (b) $\beta = 35\%$ (c) $\beta = 45\%$

Figure 2 shows that the flow pattern that occurs is a slug / plug flow. With increasing gas volume the fraction (β) shape and size of the flow pattern that occurs is getting bigger. It is inversely proportional to the smaller superficial water (v_{sL}) speed.

Figure 3 shows the size of the slug / plug flow at a greater bend. It is directly proportional to the superficial air (v_{sG}) and gas volume fraction (β).

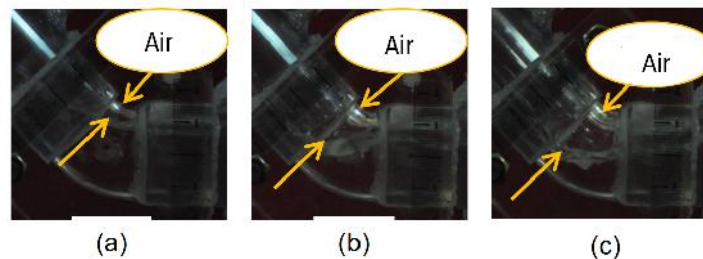


Figure 3. Flow pattern at gas superficial velocity (v_{sG}) 0.076 m/s
(a) $\beta = 25\%$ (b) $\beta = 35\%$ (c) $\beta = 45\%$

The visualization results of figures 2 and 3 are the same as the research conducted by Khairul Muhajir [9] found that the greater the air discharge added, the larger the size and shape of the flow pattern.

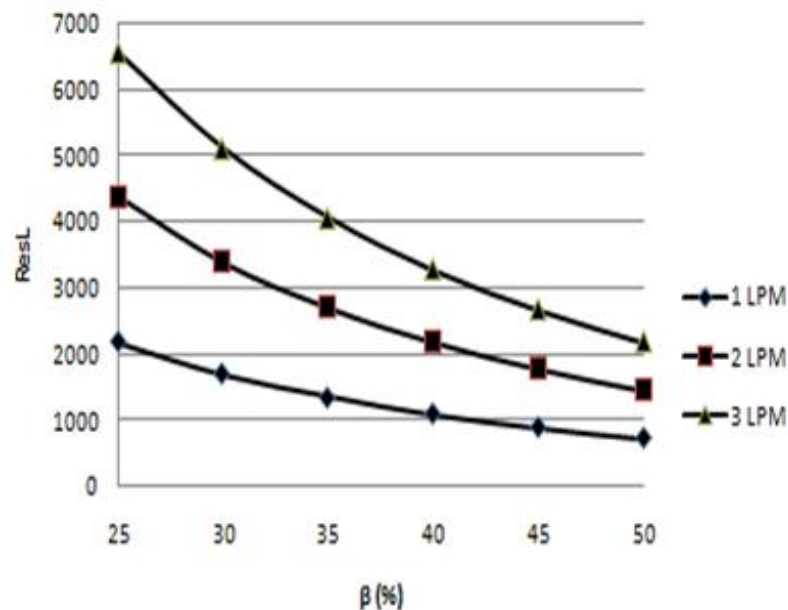


Figure 4. Correlation graph of the Reynolds number and gas volume fraction (β)

Figure 4 shows that the superficial liquid Reynolds number ($ResL$) is inversely proportional to the gas volume fraction (β) of each gas flow discharge (QG). the greater the gas volume fraction (β) in the two-phase fluid flow (air-water), the smaller the superficial liquid Reynolds number ($ResL$). If the gas discharge (QG) increases, the superficial liquid Reynolds number ($ResL$) will also increase. Adiwibowo [10] found that the greater the superficial liquid Reynolds number ($ResL$), the lower the gas quality volumetric (β).

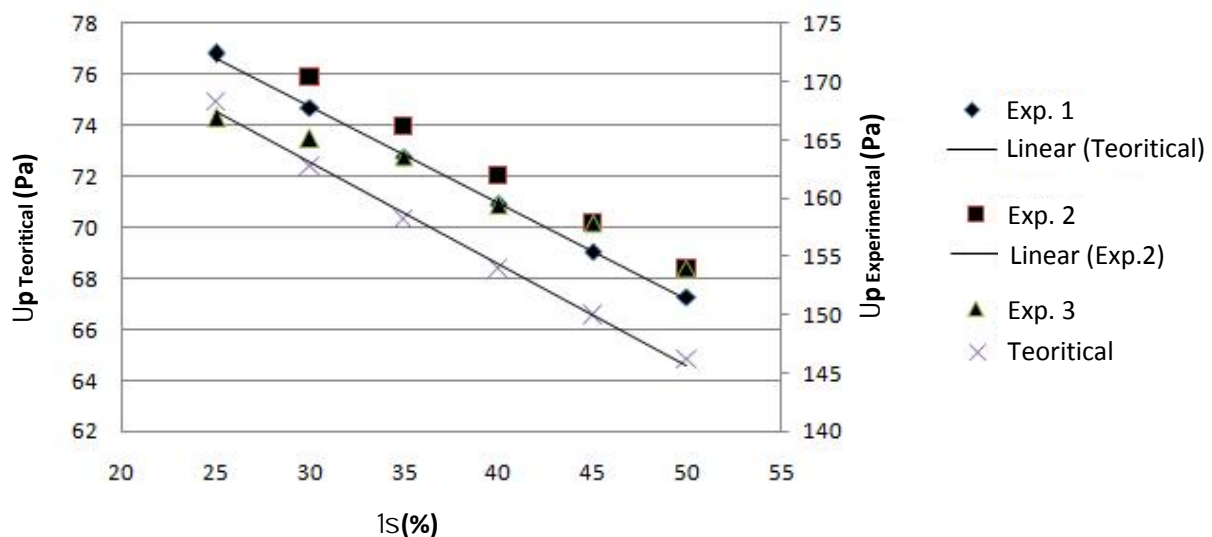


Figure 5. Correlation graph of gas volume fraction (β) to pressure drop (Δp) at 1 LPM air.

Figure 5 shows that the pressure drop (Δp) decreases with increasing gas volume fraction (β) both experimentally and theoretically. Wiryanta [2] found that the pressure drop that occurs will tend to decrease with increasing gas quality volumetric (β). The decrease in pressure drop is very stable, because the Reynolds number of the two phases has not changed (remains in a laminar condition) so

that influential parameters such as friction factors increase with decreasing superficial liquid Reynolds numbers (Re_{SL}) and correlation selection for mixing the two fixed phases as long as there is no change in flow from laminar to turbulent and vice versa.

Figures 6 and 7 show that the pressure drop value falls both theoretically and experimentally every increase in gas volume fraction (β). Kim [4] concluded that the geometric effect of 45° bend showed a decrease in pressure with increasing gas and fluid flow rate. Figure 6 with gas volume fraction (β) 35% to 40%, the pressure drop value theoretically and experimentally dropped significantly compared to before, stable again after gas fraction (β) volume 40%. This is due to the superficial liquid Reynolds number (Re_{SL}) which changes from turbulent to laminar so that the friction factor drops dramatically. In addition, the parameters selection for this event changes so that the pressure drop gas multiplier (ϕ_G) drops. For figure 7 the gas volume fraction (β) is 45% to 50%.

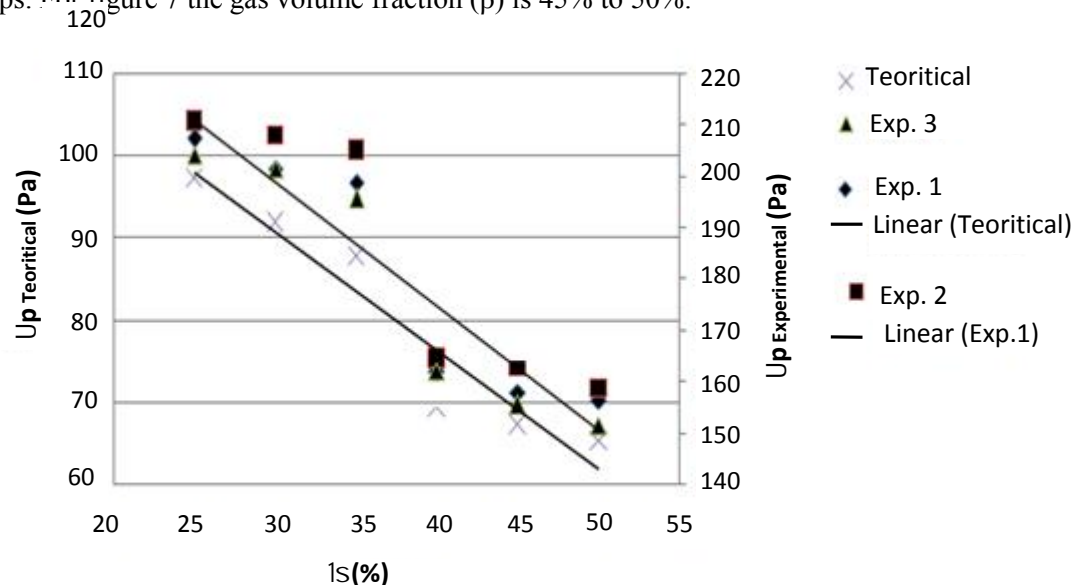


Figure 6. Correlation graph of gas volume fraction (β) to pressure drop (Δp) at 2 LPM air

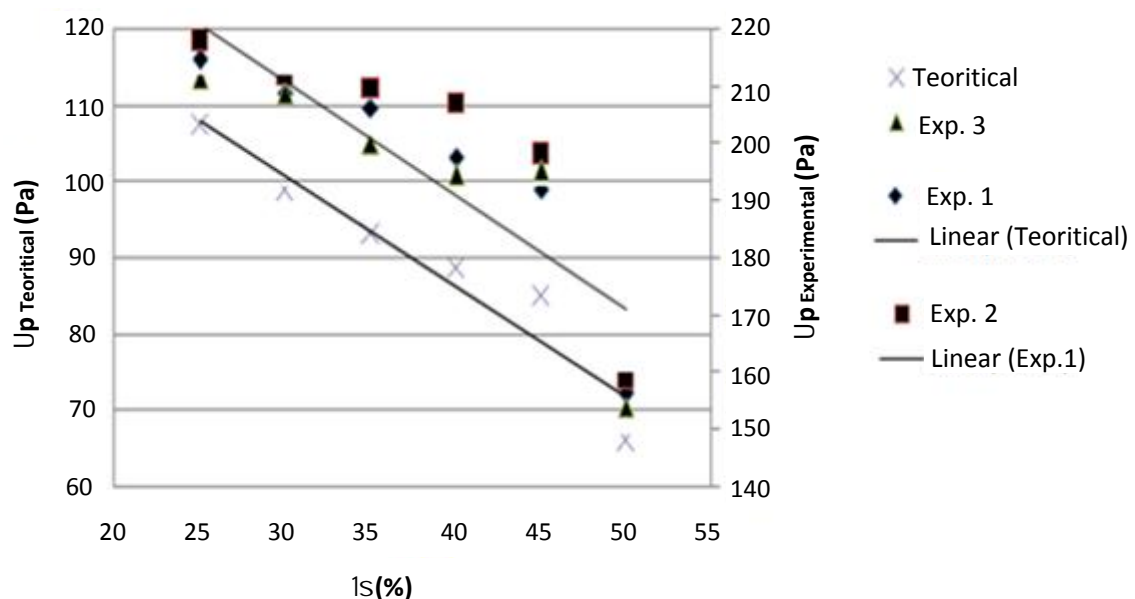


Figure 7. Correlation graph of gas volume fraction (β) to pressure drop (Δp) at 3 LPM of air

Overall the correlation graph of pressure drop (Δp) to the superficial liquid Reynolds number (Re_L) shows that there is a difference in pressure drop experimental and theoretical. Because theoretical calculations do not pay attention to the effects that occur directly in the field. Wiryanta [2] concluded that the experimental pressure drop tends to be greater than the theoretical pressure drop. Changes in superficial liquid Reynolds (Re_L) numbers from turbulent to laminar have decreased significantly both experimentally and theoretically.

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