VOL. 11, NO. 4, FEBRUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

CHARACTERISTICS OF TWO PHASE FLUID FLOW IN PIPE BENDS

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ABSTRACT

Fluid movement of liquid through a pipe arch supported by a drop in pressure caused by the inertia of the fluid and the secondary flow across the pipe bends. For Newtonian flow, pressure gradient near the wall area is the trigger for the secondary flow. Bend pipe has a value greater than the pressure drop due to the straight pipe geometry and track changes that have an impact on changes in the flow pattern to form separate flow resulting from the inner side of the pipe bends, this study aims to determine the pattern of two-phase fluid flow (water-air) and pressure drop that occurs at 900 curves. Research methods by varying the volumetric proportion of gas (β) of 25-50%, the air discharge (QG) of 1, 2, and 3 Liter Per Menit (LPM) and water discharge (QL) that affect fluid flow pattern and two-phase flow pressure drop in the pipe bends 900. The data obtained were carried out data processing and analysis using statistical analysis. The results obtained can be concluded that the greater the proportion of volumetric air (β) then water Reynolds number (Resl) decreases, causing friction between the large phase, due to the greater frictional force will increase the pressure drop and also cause instability water fluid (flow pattern) in turn 900. The centrifugal force caused by the 900 turn influence on the frictional forces between the phase interfaces pressed together with the emergence of a certain thickness. The smaller the water Reynolds number (Resl), the greater the thickness of the interface, the interface thickness greater then also affect the greater pressure drop.

Keywords: characteristic of fluid flow, pipe bend, two phase fluid.

INTRODUCTION

In daily life, we may find such cases on either single phase flow in a piping installation system, but also we often find multiphase flow (two phase flow, three phase flow, or more), for example the pouring water from a bottle, sea tides, condensation, pump and turbine cavitation [1]. Multiphase flow is specific terms used to differentiate such flow which contains more than one phase or components through particular classification in accordance with the different condition of the phases based on gas-solid, fluid-solid, and fluid-gas. The multiphase flow in piping installation system is imminently influenced by the interactions between the phases, geometry, and the orientation (either vertical or horizontal), flow direction (up or down) which may affect the flow pattern; this is different with the single phase flow which is only influenced by Reynolds number stated in the formula of density, viscosity, and pipe diameter [2]. Halim [3] in his research reported that the two phase flow pattern of fluids (water-air) which occurs in 90^0 curve and how it may cause turbulence on the flow, forming different flow patterns as the result of the sudden changes of the geometry. The main factor of the flow pattern formation is proportion of the air volumetric *(β),* superficial velocity of the water (V_{SL}), and superficial velocity of the air (V_{SG}) which determines whether the condition would be slip or not slip (homogeneous).

A research has been conducted by Saidj *et al* [4] about the two phase flow pattern between air and gas which flow from horizontal pipe to vertical pipe with diameter of 34 mm throw elbow 90^0 wand ratio R/D of 5. The variation of superficial velocity of the air was between 0.3 to 4 m/s while the variation of superficial velocity of the water was between 0.21 to 0.91 m/s, which resulted plug, slug, and stratified wavy flows in the horizontal pipe, while the flow pattern in the vertical pipe was slug and churn flow patterns in experimental condition, so there was a change of pattern from the upper and the bottom part of the pipe curves. On the other condition, it showed an increase on the frequency structure from horizontal pipe to vertical pipe with the length of the slug increased as well through the vertical curves.

Curves on piping installation has big pressure drop value compared with straight pipe due to the changes of geometry and line that may result flow pattern which at the end causes stratified flows; it would give the influence on the big pressure drop value. The main focus of this study was on the flow pattern as the result of geometrical changes of 90^0 curve which is caused by the extreme and sudden changes of direction two phase fluids which cause the pressure drop value is bigger than the other curve angles due to elevation which cause pressure heap [5].

When the water goes through the curve in single phase flow which causes centrifugal force with the orientation from the center of the angle to outer curves, the influence of centrifugal force affects results the limit layers to form secondary flow, which ideally, moving in two vortexes. When the curve is installed vertically, there will be centrifugal force, gravitation, and upward floating power which create complicated flow pattern like no homogeneous distribution phase, turn flow, secondary flow, and even corrosion [6].

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This research aimed at determining the pressure drop which occurs in 90^0 curve from horizontal position to vertical position as well as analyzing the flow patterns of two phase fluids (water-air) in 90^0 curvethrough computational simulation and visualization verified with the support of high-speed digital camera [7].

RESEARCH METHOD

This research was conducted at the System Planning and Engineering Studio (SPRS) and Basic Phenomena Laboratory of Mechanical Engineering Department, Faculty of Engineering, Brawijaya University through June to November 2014.

The simulation and computation for the fluid dynamics were executed with software finite element to the 90% curve testing modeling to assess the influence of the proportion of the air volumetric (β) which was gained through the following formula [2]:

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

The influence of the proportion of the air volumetric (β) was related to the flow patterns which then verified visually based on the images in 90^0 curve. The process of modeling simulations was in 90^0 curves, while meshing was as the discrete from testing component, addition of the control on the body size on meshing in 90^0 curve by inserting number 5 mm in the element size [3].

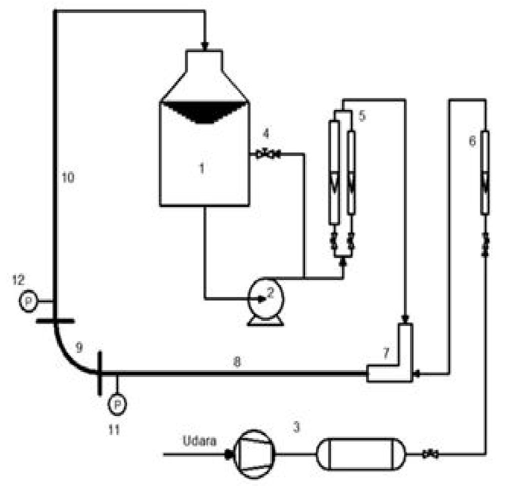

Figure-1. Installation scheme.

Figure-1 is the installation scheme of the research and the figure for testing section of 90^0 curve, when the water flows from hydraulics bench, (1) through centrifugal pipe (2) by setting the water debit in the gate valve (4) and in accordance with the perusal on the water *flow meter* (5) and calibrate it, it was assured that the water flow would move in stable. To set the air debit was by setting the wheel valve on the air *flow meter* (6). To mix both fluids which flow through mixer (7) had been assured stable, so the next step was to collect the data on the testing section of 90^0 curve (9) and observing the flow regimes which were happening from transparent horizontal pipe (8) to transparent vertical pipe (10), and noting the height level of each mercurial manometer (11) and (12) [4].

Pressure drop was calculated by using Lockhart-Martinelli's correlation consisting of acceleration, gravitation, and static pressure [9]. Pressure drop in the 900 curve was then discussed through empirical and experimental calculations so that the differences could be analyzed [3].

RESULTS AND DISCUSSIONS

The research was conducted in such condition with 20 ^{0}C temperature and 1 atm pressure. The pressure drop calculation was done empirically and experimentally, and the following are the static data which had been already known for pressure drop calculation process:

Pipe diameter (D): 2.9 x $10^{-2} m$
Width of pipe section (A) : 6.6 x $10^{-6} m^2$
Radius of 90^0curve (R) : 2 x $10^{-2} m$
Elevation pressure tap ($\Delta z_{11,12}$): 6.5 x $10^{-2} m$
Geometry ratio(R/D) : 0.7
P_{atm} : 101.325 Pa
Pipe Roughness (k) : 4.4 x $10^{-5} m$
Coefficient of losses (K) : 0.4
Mixture density: $\rho_m = (\alpha \times \rho_G) + (\alpha_L \times \rho_L)$ (2)

Restriction pressure:

$$\Delta P_{restriction} = K \times \rho_L \frac{{v_{SL}}^2}{2} + K \rho_G \frac{{v_{SG}}^2}{2} \qquad (3)$$

Friction pressure: $\Delta P_{friction} = \left[\left(\frac{dP}{dz}\right)_{friction}\right]_{\substack{Lockhart\\Martinelli}} \times \frac{\pi R}{2}$ (4)

Static pressure: $\Delta P_{static} = \rho_m \times g \times R \times \sin\theta$ (5)

Total pressure drop elbow:

$$\Delta P_{EB} = [\Delta P]_{restriction} + [\Delta P]_{friction} + [\Delta P]_{static} \qquad (6)$$

In the research focusing on two phase flow, the velocity of the flow is significantly influential on the result of the research; thus, it is really crucial to differentiate between the superficial velocity and actual velocity. Superficial velocity is related to the fluids, both water and air which flow and fill all piping line, while the actual velocity is the averaged velocity of the fluids air and water when they are flowing through piping line.

Experimental Calculation

Pressure drop in curve:

VOL. 11, NO. 4, FEBRUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

$$\Delta P_{elbow} = [\Delta z_{11,12} + (h_{11} - h_{12})] \times \rho_m \times g \left(N/_{m^2}\right) \quad (7)$$

Information:

$\Delta z_{11,12}$ = pressure taps elevation (m)

h = height level of mercurial manometer (m)

The empirical and experimental relation between proportion of the air volumetric (β) and pressure drop in 90^0 curve is as follows:

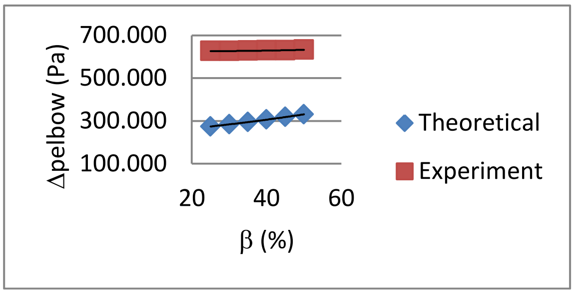

Figure-2. Graphic for Relation between Proportion of the air volumetric (β) and Pressure Drop on Re_{SG} 48.918.

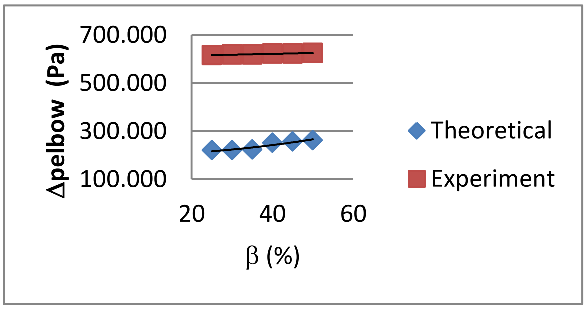

Figure 3. Graphic for Relation between Proportion of the air volumetric (β) and Pressure Drop on Re_{SG} 97.836.

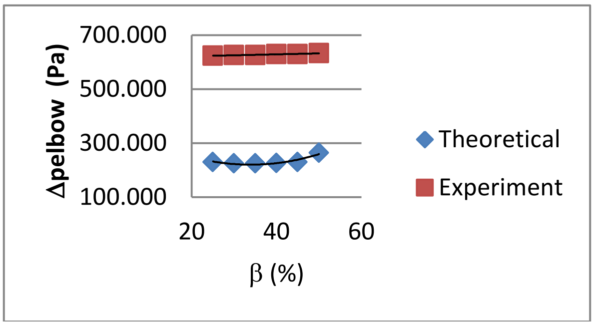

Figure 4. Graphic for Relation between Proportion of the air volumetric (β) and Pressure Drop on Re_{SG} 146.754.

The results of experiments of pressure drop are presented in Figures 2, 3, and 4 which show that the results of the calculations on the pressure drop, both empirically and experimentally, in 90^0 curve tend to show decreased lines, in which the results of experimental calculation were bigger than the result of empirical calculation. This is because the empirical calculation does not consider other conditional factors in laboratory in relation to the experimental research; the decrease of pressure drop is related to the mixture density(ρ_m). Mixture density number (ρ_m) is related to the fractions of each phase, namely gas void fraction (α) and liquid hold-up (α_L) [7]. As the air density (ρ_G) which is significantly smaller than water density(ρ_L), then the multiplier factor from liquid fraction has significant role compared with air fraction. Thus, the bigger proportion of the air volumetric (β), then gas void fraction (α) is bigger while liquid hold-up (α_L) will decrease. Those fraction numbers were obtained through calculations based on factors of Lockhart-Martinelli (X), where the factors of Lockhart-Martinelli are the comparison of frictional pressure gradient of water phase with frictional pressure gradient of air phase of which frictional pressure gradient of each phase is affected by Reynolds numbers [2] and [10].

Analysis of Flow Pattern as the result of KDF and Visualization in 90^0curve

The result of research through simulations and experiments provided descriptions that the bigger volumetric proportion of the air (β), the curve will be dominated with air on particular outer radius in 90^0 curve and this is also influenced by the gravitation which is getting bigger. The phenomena which occurs in 90^0 curve when the proportion of the air volumetric (β) is low, the air will fill part of the volume in the curve and the position is on the upper part which is caused by the lighter density of the air. If the volumetric proportion of the air (β) is bigger, however, it will fill more space in the 90^0 curve [3].

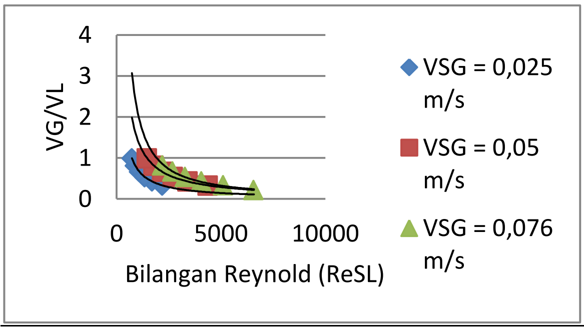

Figure-5. Graphic of the relation between Reynolds number of water (Re_{SL}) and the slip ratio of fluid $\left(^{v_G}/_{v_L}\right)$.

Figure-5 showed that on the superficial velocity of air (v_{SG}) of 0.025 m/s with the decrease of Reynold number of water (Re_{SL}), then slip ratio $\left(^{v_G}/_{v_L}\right)$ will increase in stable. On the superficial velocity of air (v_{SG}) of 0.050 $^m/_s$and 0.076 m/s, however, the turbulent flow changes into laminar flow in water which causes the slip ratio number decreases. This condition may influence on

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the flow patternwhich causes the appearance of tide in bottom of horizontal pipe and influences on the decrease of the pressure drop, which was bigger than before. The phenomena are caused by the centrifugal and gravitation forces which press each other [6] and [12].

Based on the comparison of proportion of the air volumetric (β) with geometry of 90^0 curves$\left(R/_D\right)$, the centrifugal force occurs and it affects the air phase to press the water phase in the outer wall of pipe and after the 90^0 curve. When the proportion of the air volumetric (β) is low, then the centrifugal force is decreased as well due to low the superficial velocity of air (v_{sg}) so the air trapped in the pipe is small but still affected by the gravitation. As the proportion of the air volumetric (β) increases, the velocity of the air will increase so the volume of the water will be decreased affecting the gravitation, which is getting bigger. Centrifugal force is closely related to the curve geometry due to the twin eddy so it affects the flow pattern slug in the 90^0 curve [11], if the curve geometry is bigger, the centrifugal force will decrease [11].

The cause of the turbulence which is identified by the proportion of the air volumetric (β) is due to the changes of the flow velocity of both fluids, in which the velocity of fluid air increase while the fluid water decrease so when the fluids pass through the 900 curve, there is a turbulence as the result of bug centrifugal force from horizontal to vertical and the influence of gravitation on the fluid water is getting bigger. For the flow pattern phenomena, water has significant role because the density of water has bigger mass compared with the air so the influence of the gravitation occurs on the water [3] and [6]. The direction of the centrifugal and gravitation forces has significant role in the formation of the flow pattern phenomena in 90^0 curve, which is in the form of bubble in the bottom of horizontal pipe when it is about to pass through the 90^0 curve; it is because the gravitation has influence on the return force which interacts with the velocity of the fluids from horizontal direction [12].

The decrease of pressure drop is also influenced by the slip ratio$\left(^{v_G}/_{v_L}\right)$, it can be seen that the slip ratio $\left(^{v_G}/_{v_L}\right)$ continuously as the pressure drop keeps decreasing, then in certain circumstances the slip ratio $\left(^{v_G}/_{v_L}\right)$ decreases, followed by the decrease in pressure drop compared with the previous point. This condition is also presented in the image results of the experiments which started the tide in the bottom of a horizontal pipe; the phenomenon is due to the lifting force ability of small fluid water, which is caused by the influence of big gravitation and big centrifugal force as well [4], [6] and [12].

CONCLUSIONS

Based on the research discussion, there are some conclusions as follows:

1. Flow pattern in 90^0curve is flow pattern slug.
2. There is relationship between flow pattern and pressure drop, which is the bigger the proportion of the air volumetric (β), the smaller of the Reynolds number for water (Re_{SL}) so that may allow the air to fill 900 curve, at the end the pressure drop will decrease. The decrease of pressure drop is affected by fraction of each phase which is directly related to the mixture density (ρ_m).
3. The bigger the proportion of the air volumetric (β) is also to cause instable fluid water and affect the flow pattern in 90^0 curve. The instability is caused by the pressure return in 90^0 curve.
4. Centrifugal force and gravitation force in 90^0 curve are to give influence on the friction force between the phases which press each other as the appearance of interface with particular thickness.

SUGGESTIONS

From the result of the research, there should be further research and development in relation to 90^0 curve phenomena, namely:

1. There should be other parameters like gravitation and centrifugal force which have influence on the twin eddy in 90^0 curves.
2. It is advisable to assess further study in such condition with higher velocity.

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