EXPERIMENTAL RESULTS OF PRESSURE VARIATION IN TWO-PHASE AIR-WATER FLOW IN WATER TUNNELS

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Two-phase gas-liquid flows occur in a wide variety of situations, ie; in chemical processing, power generation, water supply systems, petroleum industry and energy production facilities. In recent years, extensive work has been carried out for more reliable analysis and application of two-phase flow detection systems. Depending on the application, prediction methods for two-phase gas/liquid flow requires information about flow rates to pressure drop relationships in more detail such as; frequency of the slug flow, void fraction, pipe inclination and air concentration. Zhou et al. (1999) have investigated flow transients in a rapid filling horizontal pipe containing trapped air in sewer pipes. One of the major concerns of engineers is the pressure of two-phase flow at different stages. Rapid approximations of pressure drop can be calculated using the relation presented by Lockhart and Martinelli (1949). Pressure oscillations in a pipeline occur when the gas-phase is discontinouse, or the flow rates are changed. Since two-phase flow is an important phenomena in hydraulics conduits and little guidance is available for the engineers, no doubt that much more field and laboratory investigations are needed to increase the knowledge in this area of science. Hence, this paper is another experimental study on two-phase air-water flow. In this study, experimental investigation has been carried out to verify characteristics of pressure fluctuations inside a circular, horizontal and inclined pipeline (90mm inside diameter and 10 m long) carrying two-phase air-water flow in a controlled manner. The tests were carried out varying with time, space, water flow rate/air flow rate ratio and pipe inclination. The pressure fluctuations were measured simultaneously at different sectional and longitudinal locations using Differential Pressure Transducer (DPT). Among many parameters and forces which affect the two-phase flow, turbulent diffusivity and buoyant force are the most important. Therefore, the pressure which relates to gravity, Reynolds shear stress, interfacial forces and fluids properties being important factors Applying dimensional analysis, leads to the following relation among the dimensionless parameters

$$\frac{P_h}{h} = \xi(\bar{C}, K_f, \alpha, Fr, f, \frac{We}{Fr}\sqrt{1-S_0}) \tag{1}$$

where K_f, We, α, Re and Fr are; friction factor ($K_f = f_{TP}L/D$, L is characteristic length), Weber number, void fraction, Reynolds and Froude numbers respectively, $\beta = Q_a/Q_w$, $\bar{C} = \beta/(1+\beta)$, $P_h = P/\gamma_w$, $h = kV_w^2/2g$, $S_0 = \sin\varphi$. Using the above dimensionless parameters, the experimental tests have been carried out and analyzed based on the achieved data.

As an example, in order to show the influence of air/water flow rates and the pipe slope (0, 0.5, 1, 2, 3 and 4%) on mean pressure, Fig. 1 is presented. The figure includes all data points for different set-up conditions. It is clear that the normalized mean pressure increases with air/water rates ratio up to a certain value of about 0.85 and then, decreases with the increase of air/water rates. To investigate the effects of dimensionless parameters given in Equ. 1, the results of normalized mean pressure are plotted against each parameter.

It is shown, P_h/h has significant relations with each dimensionless parameter, developed in Equ. 1. However, in order to show the multi-variation equation between the results, the general mathematical program SPSS and the trial and error methodology were used. A number of combinations have been tried and the following relation has been obtained as the best equation for forecasting the mean pressure inside the pipe due to formation of two-phase air-water flow

$$\frac{P_h}{h} = \frac{2.489\alpha^{0.316} K_f^{0.933} f^{2.296} \overline{C}^{1.216}}{Fr_c^{1.056} (\frac{We}{Fr_c} \sqrt{1 - Sin\varphi})^{0.449}} + 1.038 \tag{2}$$

In this study, it is shown that, the air-water mixture entering the pipe during rapid filling or surcharging can cause tremendous pressure surge in the system and eventually may cause failure in system (e.g. the maximum pressure inside the pipe would reach up to 10 times of upstream hydrostatic pressure). By introducing non-dimensional mean pressure as P_h/h, it is found that; all the results can be represented by mean pressure. P_h/h increases with air/water rate ratio up to a certain value of about 0.85 and then, decreases with the increase of air/water rate. P_h/h increases with the frequency up to about 0.5 s^{-1} and then decreases by increasing the frequency. There is a peak for P_h/h at K_f=200 and also, for a constant K_f, pipe inclination increases the value of pressure. Pressure is maximum at a value for $We/Fr(1\text{-}S_0)^{0.5}$ of about 1700. Pressure is maximum at void fraction of about 0.5. Finally Equ. 2 which, includes most of the present data within ±10% bound, has been presented for obtaining pressure in an air/water two-phase flow in a pipe.

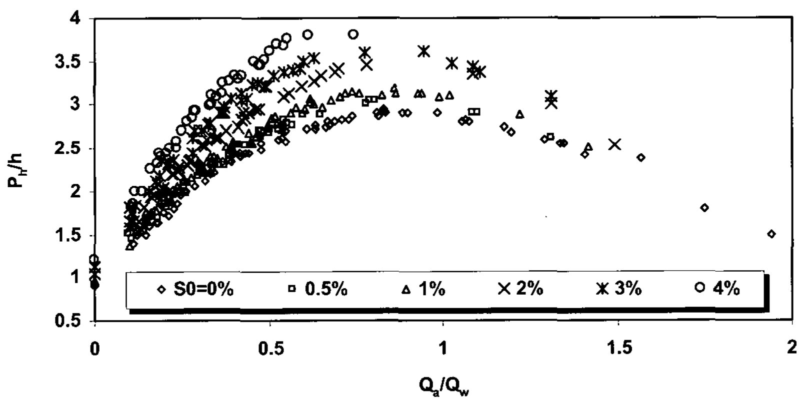

Fig. 1 Dimensionless mean pressure versus air/water flow rates ratio for different pipe inclinations

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