PRESSURE VARIATION DUE TO SUDDEN RISE OF WATER HEAD AT WATER INLETS

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Two-phase flow is a complex subject principally because of the form in which the two fluids behave inside the pipe, known as the flow regime. The study of two-phase fluid flow is of great importance in the hydraulic situations, as pressurized flow tunnels, culverts, bends, and other similar structures. Over the past several decades, much effort has been devoted to improve analytical and computational methods for the prediction of local hydraulic conditions in gas/liquid two-phase flow. It is demonstrated both by experimental and numerical studies that trapped air and air release during rapid filling or surcharging, can cause tremendous pressure surge in the system and even cause system to fail. Hamam and McCorquodale (1982) carried out a number of experiments to investigate the formation of pressurized flow in closed conduits and concluded that severe transient pressure fluctuations of water hammer type might occur during a rapid transition from free surface to surcharged flow in closed conduits. Cardle et al. (1989) observed water hammer pressure during the transition from free-surface to pressurized flow conditions in a circular pipe. Issa and Kempf (2003) showed that when compressibility of the gas is included in the calculations, slugs generate more readily and at the right frequency. Although there are extensive previous works on the instability of water waves inside a closed conduit but, there are no exact guidelines or criteria for prediction the effects of the flow. In this paper, a new analytical/numerical model was developed and solved to investigate the rapid filling of a horizontal and inclined pipe, when the flow changes from free-surface to pressurized flow. The model based on the assumption of rigid incompressible water column and compressible air bubble, is derived to simulate the pressure fluctuations, void fraction, air/water flow rate, water velocity in a closed conduit and water depth at upper reservoir due to formation of unstable slug flow. It is a comprehensive model which can generate different hydraulic situations of instability in a closed conduit based on hydraulic approach. The boundary conditions are the system of algebraic or/and simple differential equations. The steady solution of the governing differential equations is generally performed as the initial data. The frequency of pressure fluctuation and air/water flow rate predicted by the model is in close agreement with the results of the experiments and numerical model, reffered to in the literature. In this study the rigid water column approach (Hamam and McCorquodal, 1982) was used to simulate the fully developed slug flow at water tunnels. Hence, the flow is divided into three rigid water columns with unsteady uniform velocities. Each water column was assumed to be enclosed by a fixed

control volume. Continuity and momentum equations were then derived for the water columns, the interface between columns and upstream and downstream water levels at the two reservoirs.

The finite difference method was used to solve the gained differential equations. The computer program written to solve these equations using Fortran Power Station computer programming language. Also the model is run for the variation of normalized headwater (h_l/D) versus time for different values of tank inflow (The tank is assumed to have a fixed area and, hence, the variation of h_l as shown in Fig. 1). The boundaries of this figure are the minimum inflow ($Q_i=8.5$ lit/sec) which undergoes flow to be pressurized and the water level naturally rises and passes the transitional region (from free-surface flow to pressurized) and $Q_i=0$, when there is no inflow to the reservoir. The pipe inner diameter is taken 0.1 m and its length as 10 m. Fig. 2 shows the time history of calculated pressure fluctuations using present developed model and the data calculated with the numerical model of Tarasevich (1993). Tarasevich presented a method of calculation for the two-phase flows based on the method of characteristics. It can be seen that, the predicted maximum pressure by present model is fairly close to Tarasevich. So the developed model shows to be a good tool to predict the characteristics of two-phase flows

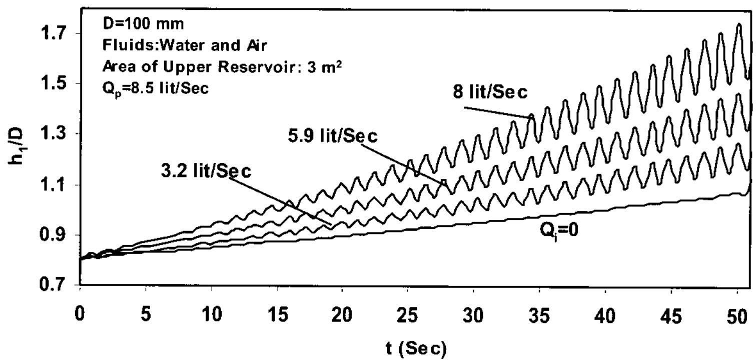

Fig. 1 Calculated headwater as functions of time and the inflow discharge to the reservoir

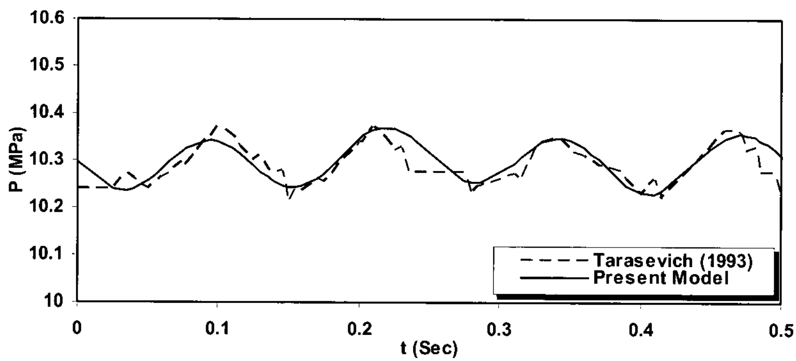

Fig. 2 The time dependency of pressure transients for fully developed slug flow regime

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