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Modelling of Energy Dissipation During Transient Gaseous Cavitation

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Abstract

Hydraulic transient/ waterhammer analysis is important in the operation stage of an existing piping system for the diagnosis of malfunction problems or the causes of pipe bursts. Classical waterhammer equations cannot represent the energy dissipation phenomena after the waterhammer peak. Therefore, it is extremely important to use accurate hydraulic transient models which can incorporate additional dissipative effects in the analysis. In this study, effect of gaseous cavitation is considered for the modelling of transient flow during valve closure using a 2D approach in cylindrical coordinates. This developed model could predict the first water hammer drop and gas release. However extra damping is observed in the subsequent peaks compared to the experimental results which necessitates further investigation.

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Keywords: *Transient flow; Gaseous cavitation; Two dimensional model.*

1. Introduction

Transient flow is the intermediate stage flow between two steady state flow conditions. It generally occurs whenever the flow changes abruptly with time. The occurrence of transient flow induces large pressure forces and rapid fluid accelerations into a water distribution system. When the velocity of flow changes rapidly due to the change in operating condition of the flow controlling components, like closure of a valve, pump start up/stop etc, causes a pressure wave which travels throughout the system. The pressure wave starts to travel from the point of generation towards the other end and gets deflected back (in a closed system). This to and fro motion of the pressure

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wave continues for a long time. During the motion of the pressure wave, the performance of the whole system components gets disturbed which manifests the malfunctioning of the hydraulic equipments in a pipe network.

During transient flow when the pressure in the pipe becomes lower than the saturation pressure of flowing liquid, the dissolved gases get released which will flow along with the already present free gas. When the pressure in the flowing system drops, two mechanisms will occur. The first stage is gaseous cavitation and second is vaporous cavitation. Gaseous cavitation occurs when the pressure drops below the saturation pressure but above the vapour pressure. But, when the pressure drops to the vapour pressure of the liquid, vaporous cavitation occurs. i.e. conversion of liquid phase to vaporous phase. Because of these effects, there will be free gases in the flowing system which will reduce the transient wave speed. Sometimes the transient flow event can be extremely destructive if the magnitude and velocity of the pressure wave exceeds the capacity of system in which it takes place. This necessitates the prediction of the transient wave pressures. But the solution of recurring transient flow problems is not easy, and is generally only achievable with sophisticated software simulations.

Generally the computation for transient analysis is done on the basis of classical water hammer equations which cannot represent energy dissipation in an effective manner. i.e. discrepancy is observed between the actual and computed pressures especially when time progresses. This difference between the observed and calculated pressure may be due to energy dissipation. Therefore, in order to represent the energy dissipation during transient flow additional dissipative effects are to be incorporated.

[1] illustrates about a one-dimensional mathematical model which explains the behaviour of gas–liquid mixture transient flow. Hence, the purpose of their study is to investigate numerically the nonlinear behaviour of the transient homogeneous two-phase flow in pipes.

[2] presented a methodology which accounts non-friction energy dissipation in transient cavitating flows. The effect of gaseous cavitation on thermic exchange between gas bubbles and the surrounding liquids is described with the help of a 2D model.

[3] gives an alternate approach for modelling transient vaporous cavitation by considering the variable fluid property concept. In this study, the simulation of cavitating flow was carried out by using the continuity and momentum equation for the water vapour mixture, transport equation for the vapour phase.

[4] introduced a new discrete vapour cavity model (DVCM) to evaluate the column separation phenomena in hydraulic transients. In this study, they assumed that the calculated cavity volume in several computational pipe cross sections moves to one main cross section.

[5] discuss about the 2D model for analyzing transient cavitating pipe flow. The model considers the conservation form of continuity equation which allows simple numerical solution. 1D and 2D models are used to quantify the effect of friction in the simulation of experimental data. But the 1D model failed to reproduce the experimental results after the first peak. These studies do not consider the dissipative capacity of gas release.

Hence, the aim of this paper is to quantify the gas release as an additional dissipative effect and examine the energy dissipation in transient gaseous cavitating flow.

2. Mathematical Model

For gaseous cavitation modelling, the liquid is considered as a homogeneous two-phase air water mixture and the analysis is based on the following assumptions [2, 3]

1. Gas bubbles are distributed throughout the pipe and they are very small compared to pipe diameter;
2. Difference in pressure due to surface tension across a bubble surface can be neglected;
3. Momentum exchange between gas bubbles and surrounding liquid is negligible, so that gas bubbles and liquid have the same velocity.

2.1. Governing Equations

An important feature for gaseous cavitating flow modelling is that, it considers the flowing liquid as a homogeneous mixture of liquid and gas. For this study, modelling is carried out with an initial amount of free gas which also accounts gas release during gaseous cavitation. The current study used continuity equation in gaseous phase, mixture continuity equation and mixture momentum equation.