

Chapter 3

Modeling of Fluid Interaction Produced by Water Hammer

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ABSTRACT

This paper compares the computational performance of two numerical methods for two models of Transient Flow. One model was defined by method of the Eulerian based expressed in a method of characteristics “MOC”, finite difference form. The other model was defined by method of Regression. Each method was encoded into an existing hydraulic simulation model. Results indicated that the accuracy of the methods was comparable but that the “MOC” was more computationally efficient for analysis of large water transmission line. Practical investigations in this article have shown mainly this tendency.

INTRODUCTION

Water hammer as a fluid dynamics phenomenon is an important case study for designer engineers. The majority of transients in water and wastewater systems are the result of changes at system boundaries. It happens typically at the upstream and downstream ends of the system or at local high points (Asli, Nagiyev & Haghi, 2009). Consequently, the results of the present work can reduce the risk of water system damage or failure. The study of

hydraulic transients is generally considered to have begun with the works of (Joukowski, 1898) and (Allievi, 1902). The historical development of this subject makes for good reading. A number of pioneers have made breakthrough contributions to the field, including Angus and (Parmakian, 1963) and (Wood & Jones, 1973) who popularized and refined the graphical calculation method. (Wylie & Streeter, 1993) combined the method of characteristics with computer modeling. The field of fluid transients is still rapidly evolving

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worldwide by (Brunone, Karney, Mecarelli, & Ferrante, 2000; Koelle, Luvizotto, & Andrade, 1995; Fillion & Karney, 2002; Hamam & Mc-Corquodale, 1982; Savic & Walters, 1995; Walski & Lutes, 1994; Wu & Simpson, 2002). Various methods have been developed to solve transient flow in pipes. These ranges have been formed from approximate equations to numerical solutions of the non-linear Navier–Stokes equations. Hydraulic transient flow is also known as unsteady fluid flow. During a transient analysis, the fluid and system boundaries can be either elastic or inelastic: (1) elastic theory describes the unsteady flow of a compressible liquid in an elastic system (e.g., where pipes can expand and contract); (2) rigid-column theory, describes unsteady flow of an incompressible liquid in a rigid system. It is only applicable to slower transient phenomena. Both branches of transient theory stem from the same governing equations. The continuity equation and the momentum equation are needed to determine V (velocity) and P (surge pressure) in a one-dimensional flow system. Solving these two equations produces a theoretical result that usually corresponds quite closely to actual system measurements. It will be valid based on the validity of the data and assumptions which used for building the numerical model. Transient analysis results that are not comparable with actual system measurements are generally caused by inappropriate system data (especially boundary conditions) and inappropriate assumptions. Among the approaches proposed to solve the single-phase (pure liquid) water hammer equations are the Method of Characteristics (MOC), Finite Differences (FD), Wave Characteristic Method (WCM), Finite Elements (FE), and Finite Volume (FV). One difficulty that commonly arises relates to the selection of an appropriate level of time step to use for the analysis. The obvious trade-off is between computational speed and accuracy. In general, the smaller the time step, the longer the run time but the greater the numerical accuracy (Leon, 2007).

METHOD

Compared to a steady state, fluid friction increases during hydraulic transient events because rapid changes in transient pressure and flow, increases turbulent shear. The MOC model can track the effect of fluid accelerations to estimate the attenuation of transient energy more closely than would be possible. It operates with quasi-steady or steady-state friction. Computational effort increases significantly if transient friction must be calculated for each time step. This procedure can be resulted in long model-calculation times for large systems with hundreds of pipes or more. Typically, transient friction has little or no effect on the initial low and high pressures. The steady-state friction method yields conservative estimates of the extreme high and low pressures that usually govern the selection of pipe class and surge-protection equipment. However, if cyclic loading is an important design consideration, the unsteady friction method can yield less conservative estimates of recurring and decaying extremes. In the present work, this method has provided a suitable way for detecting, analyzing, and recording transient flow (down to 5 milliseconds). Transient flow has been solved for the pipeline in the range of approximate equations. These approximate equations have been solved by numerical solutions of the non-linear Navier–Stokes equations by method of characteristics “MOC”. Experiences have been ensured for the reliable water transmission for the Rasht city main pipeline in north of Iran (research pilot).

THEORETICAL BACKGROUND

Balancing the energy across two points in the system yields the energy or Bernoulli equation for steady-state flow. The components of the energy equation can be combined to express two useful quantities, the hydraulic grade and the energy grade:

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