AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Public Works Department

Simplified Approach for Water Hammer Analysis

A Thesis Submitted in Partial Fulfillment for the Requirements of the Degree of Masters of Science in Civil Engineering

(Public Works – Sanitary Engineering)

Prepared By

Shaimaa Said Abdou Aly
B.Sc. of Civil Engineering
(Public Works) Ain Shams University, 2007

Supervised By

Prof. Dr. Mohamed Hassan Abdel Razik
Professor of Sanitary Engineering
Public Works Department
Faculty of Engineering
Ain Shams University

Dr. Mohamed Aly Fergala
Associate Professor of Sanitary Engineering
Public Works Department
Faculty of Engineering
Ain Shams University

Dr. Sherien Aly Elagroudy
Associate Professor of Sanitary Engineering
Public Works Department
Faculty of Engineering
Ain Shams University

Cairo – 2014

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Approval sheet

Simplified Approach for Water Hammer Analysis

By

Shaimaa Said Abdou Aly
B.Sc. Civil Engineering, Ain Shams University, 2007

This thesis for M.Sc. degree had been approved by:

Name Signature

Prof. Dr. Mohamed El Sayed Basiouny
Prof. of Sanitary and Environmental Engineering
Faculty of Engineering, Benha University

Prof. Dr. Fekry Halim Ghobrial
Prof. of Sanitary and Environmental Engineering
Faculty of Engineering, Ain Shams University

Prof. Dr. Mohamed Hassan Abdel Razik
Prof. of Sanitary and Environmental Engineering
Faculty of Engineering, Ain Shams University

Dr. Sherin Ali El-Agroudy
Prof. Associate of Sanitary and Environmental Engineering
Faculty of Engineering, Ain Shams University

Date / / 2014

DEDICATION

I wish to dedicate this work to who suffered to educate, prepare, build capacity and help myself to be as I am,

TO

MY FATHER & MY MOTHER

Also thanks to

MY SISTERS & MY BROTHERS
For their encouragement and support to complete this work

STATEMENT

This dissertation is submitted to Ain Shams University, Faculty of Engineering for the degree of M.Sc. in Civil Engineering. The work included in this thesis was carried out by the author in the department of Public Works, Faculty of Engineering, Ain Shams University from 2009 to 2014.

No part of the thesis has been submitted for a degree or qualification at any other university or institution. The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Date / / 2014

Signature

Shaimaa Said Abdou Aly

ACKNOWLEDGMENT

First of all, thanks are due to Allah to whom any success in life is attributed.

The candidate is deeply gratefully to my supervisors **Prof. Dr. Mohamed Hassan Abdel Razik, Dr. Mohamed Aly Fergala** and **Dr. Sherein Aly El-Agroudy** Professors of Sanitary & Environmental Engineering, Faculty of Engineering, Ain Shams University, for their guidance, faithful supervision, helpful suggestions, great support, cooperation and help in thesis.

I would like to thank my parents, family, friends and course mates for their support and encouragement. Special thanks to my dear mother for her support, kindness and help, my dear father, dear siblings and relatives for all the love, all the support and all the kindness.

ABSTRACT

Name: Shaimaa Said Abdou Aly
Title: Simplified Approach for Water Hammer Analysis
Institute: Faculty of Engineering, Ain Shams University
Specialty: Public Works, Sanitary& Enviromental Engineering

This thesis aims to provide a practical and simplified approach for the analysis of water hammer phenomenon, develop the pressure transient envelops produced due to water hammer, asses the need for protection, and determine the size of protection device.

To conduct this study, a typical water supply system consisting of a pump and long transmission pipeline delivering to a terminal reservoir is proposed. About 500 runs are simulated on Bentley Hammer software to cover wide variation of physical and hydraulic parameters.

The results of simulation are used to develop a model for the pressure envelops along the pipeline profile and another model for sizing of the protection device needed to reduce the impact of water hammer.

Keywords: Transient Pressures, Water Hammer, Surge Protection Devices, Simplified Approach.

Supervisors:
Prof. Dr. Mohamed Hassan Abdel Razik
Dr. Mohamed Aly Fergala
Dr. Sherien Aly Elagroudy

Faculty of Engineering

Summary for M.Sc. Thesis Prepared by

Eng. Shaimaa Said Abdou Aly

Titled

"Simplified Approach for Water Hammer Analysis "

Supervised by

Prof. Dr. Mohamed Hassan Abd ElRazik
Associate Prof. Mohamed Aly Fergala
Associate Prof. Sherien Aly Elagroudy

Water hammer is considered a catastrophic phenomenon which has a high impact on water supply system and network performance .

Water hammer analysis is very complex in handling the complicated equations or the determination of the required surge vessel for protection . This thesis aims to provide a simplified and practical approach for the analysis of Water Hammer phenomenon in order to assess the need for protection against this phenomenon, and estimate the volume of surge vessel.

To conduct this study, about 500 simulation runs have been applied on Bentley HAMMER computer software, to a water supply system covering a wide range of physical and hydraulic parameters as follows.

Parameters	Range
Diameter (D) (mm)	300, 600, 900 and 1200
Velocity (V) (m/s)	0.5, 1.0, 1.5, 2.0 and 2.5
Wave Speed(a) (m/s)	300, 600, 900,1200 and 1500
Demand and Pump Head (H)	Depend on the velocity and diameter
Pipe length (L) (m)	Longer than 4 x wave travel length

The research conclusions were:

1. The direct relationship known as Joukowsky´s equation is valid to approximately estimate the pressure drop at the pump.

$$\Delta H_1 = \pm \frac{a}{g} \Delta V$$

2. A new empirical formula is developed to calculate the maximum and minimum pressure envelops along the pipeline and to assess the need for protection.

$$\Delta H = \Delta H_1 \left[1 + \left(\frac{X}{L}\right)\right]^{0.35}$$

3. A new empirical model is developed to size the surge vessel.

$$V = 0.4 D^5 H^{1.75}$$

After comparing the results of the simplified equations with those calculated by Bentley Hammer, it is proved that the proposed approach can be applied with ease and efficiency.

Table of Contents

List of Figures

List of Tables

List of Acronyms

AWWA	American Water Works Association
a	Wave Speed
f	Darcy-Weisbach Friction Factor
g	Acceleration due to Gravity
H	Piezometric Head
MoC	Methods of Characteristics
I	Rotational Moment of Inertia
K	Bulk Modulus of Elasticity of the Liquid
N	Rotational Speed of Pump

CHAPTER 1
INTRODUCTION

1.1 Introduction

Hydraulic transients in closed conduits have been a subject of both theoretical study and intense practical for more than one hundred years. ***(Ghidaoui et al, 2005)***

Transient flow is the transition from one steady state to another steady state in a fluid flow system. It occurs in all fluids, confined and unconfined and transition is caused by a disturbance to the flow. ***(Parmakian, 1963)***

A water hammer is the rapid change in flow momentum in closed conduits causing elastic waves (pressure waves) that travel both upstream and downstream from the point of origin. The rapid change of the velocity converts the kinetic energy carried by the fluid into strain energy in the pipe walls causing a pulse wave of abnormal pressure to travel from the disturbance into pipe system. ***(Karney et al, 2005)***

The pressure in the conduit behind these propagation waves is very rapidly increased or decreased with a velocity equal to the speed of sound in the fluid. The propagating pressure waves create both positive - and negative pressure higher or lower than the normal pressure any water system is designed to work in the normal condition.

Pump power failure is one of the most important causes of transient flow in water supply system which create negative pressure in several location that decrease the water supply performance.