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RESEARCH ARTICLE

COMPARISON STUDY OF HAMMERING PHENOMENON FOR HYDRAULIC SYSTEMS USING VARIOUS MATHEMATICAL APPROACHES

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ABSTRACT

In this paper, a theoretical comparison was made of the state of the current flow in the pumping networks between the two methods, the first hydraulic analysis, the most common or so-called method of properties and is used in the analysis on the time range and the second method is called the method of frequency range. For the purpose of comparison, two types of networks that suffer from the phenomenon of transitional flow or so-called water hammer were studied. The first is a simple network without extensions or fittings. This kind of network is far from reality, because real networks are usually many extensions and branches. The second network is more complex and closer to reality. The results of the analysis showed that the two methods gave identical results to the first network. However, the results were not identical in the second most complex network, where it was clearly observed that the first method felt that the water hammer phenomenon was more than the second method from reality.

KEYWORDS

Hydraulic, frequency, water hammer, hammer phenomenon

1. INTRODUCTION

The pumps have many uses and are important in engineering fields. A study, Comprehensive water distribution systems analysis handbook for engineers and planners, MWH Soft, Inc., Pasadena, Calif [1]. A study, "Pathogen intrusion into water distribution systems due to transients," Proc., ASME/JSME Joint Fluids Engineering Conf., ASME/JSME, San Francisco [2]. A study, The potential for health risks from intrusion of contaminants into the distribution system from pressure transients [3]. A study, Verification and control of low-pressure transients in distribution systems," Proc., 18th Annual ASDWA Conf., Association of State Drinking Water Administrators [4]. Maher (2009) study the numerical comparison of hammering effects in simple pipeline systems using some mathematical solutions, this study shown that the time domain method more efficient in huge pipeline systems. X. Wang (2001) study the transient in pipeline with a leak using Laplace transformer. Maher Abdul Ameer (2013) study the operation of centrifugal pumps with variable net positive suction head, this investigation clearly shown that when the net positive suction head rise, the pump being more efficient to facing transient flow. Maher (2014) study the numerical analyses of hydraulic transient in pipeline systems with varying boundary condition using Laplace transformations and Frequency domain method, this research shown that the Laplace approach more efficient with the networks with suddenly varying in discharge. Maher (2018) study the numerical analyses for characteristics curve for rotodynamic pumps using spline interpolation, the results of analysis clearly shown that the natural cubic spline interpolation is a useful technique to interpolate these types of curves to obtain the undesirable overshooting points than constrained cubic spline they are generally well behaved and less prone to oscillation or overshoot.

2. THEORETICAL ANALYSIS

2.1 Development of the classical method

Using the classical method to follow the pressure wave in the piping networks and neglecting V, P. Then we have two independent partial differential equations [7]

$$\frac{\partial V}{\partial t}+\frac{1}{\rho}\frac{\partial p}{\partial s}+g\frac{dz}{ds}+\frac{f}{2D}V|V|=0 \tag{1}$$

$$a^2\frac{\partial V}{\partial s}+\frac{1}{\rho}\frac{\partial p}{\partial t}=0 \tag{2}$$

By combined the equation (1) and (2), one possible combination is, Figure 1.

$$\lambda\left(\frac{\partial V}{\partial t}+\frac{1}{\rho}\frac{\partial p}{\partial s}+g\frac{dz}{ds}+\frac{f}{2D}V|V|\right)+\left(a^2\frac{\partial V}{\partial s}+\frac{1}{\rho}\frac{\partial p}{\partial t}\right)=0 \tag{3}$$

Regrouping terms,

$$\left(\lambda\frac{\partial V}{\partial t}+a^2\frac{\partial V}{\partial s}\right)+\left(\frac{1}{\rho}\frac{\partial p}{\partial t}+\frac{\lambda}{\rho}\frac{\partial p}{\partial s}\right)+\lambda g\frac{dz}{ds}+\frac{\lambda f}{2D}V|V|=0 \tag{4}$$

The two partial differential equations replaced by two of ordinary differential equations, the new form of Eqs. (3, 4) is now

$$\frac{dV}{dt}-\frac{g}{a}\frac{dH}{dt}+\frac{f}{2D}V|V|=0 \quad \text{only when} \quad \frac{ds}{dt}=-a \tag{5}$$

$$\frac{dV}{dt}-\frac{g}{a}\frac{dH}{dt}+\frac{f}{2D}V|V|=0 \quad \text{only when} \quad \frac{ds}{dt}=-a \tag{6}$$

2.2 The Finite Difference Representation

In computer manipulations, the Eqs.(5, 6) having new forms, in finite difference form, Eq.(8) becomes

$$\frac{V_P-V_{Le}}{tp-0}+\frac{g}{a}\frac{H_P-H_{Le}}{tp-0}+\frac{f}{2D}V_{Le}|V_{Le}|=0 \tag{7}$$

And Eq.(9) becomes

$$\frac{V_P-V_{Ri}}{tp-0}-\frac{g}{a}\frac{H_P-H_{Ri}}{tp-0}+\frac{f}{2D}V_{Ri}|V_{Ri}|=0 \tag{8}$$

Accordingly, the term (t_p -0) replaced with (Δt) then the new form gives

$$C^{+}:\ (V_P - V_{Le}) + \frac{g}{a}(H_P - H_{Le}) + \frac{f\Delta t}{2D} V_{Le}|V_{Le}| = 0 \tag{9}$$

And

$$C^{-}:\ (V_P - V_{Ri}) - \frac{g}{a}(H_P - H_{Ri}) + \frac{f\Delta t}{2D} V_{Ri}|V_{Ri}| = 0 \tag{10}$$

2.3 Setting Up the Numerical Procedure

The pressure and velocity values at the end of the tube can be found by applying the available values of B.C and then rearranging the solutions to reach the formula in, fig.(2).

By developing a pair of equations to find the head and velocity on the several points. Solving Eqs.(9, 10) simultaneously to obtain

$$V_P = \frac{1}{2}\left[(V_{Le} + V_{Ri}) + \frac{g}{a}(H_{Le} - H_{Ri}) - \frac{f\Delta t}{2D}\left(V_{Le}|V_{Le}| + V_{Ri}|V_{Ri}|\right)\right] \tag{11}$$

$$H_P = \frac{1}{2}\left[\frac{a}{g}(V_{Le} - V_{Ri}) + (H_{Le} + H_{Ri}) - \frac{a}{g}\frac{f\Delta t}{2D}\left(V_{Le}|V_{Le}| - V_{Ri}|V_{Ri}|\right)\right] \tag{12}$$

2.4 Frequency range method

To study the behavior of a centrifugal pump attached to a pipe network and subjected to a sudden change in pressure leading to the phenomenon of the transitional flow or the so-called water hammer, we subject the behavior of the pump to the equations of this method to observe the wave pressure isolations [5-7].

All physical variables such as speed, discharge and pressure were expressed in a set of equations,

$$p(s,t) = \bar{p}(s) + Re\{\tilde{p}(s,\omega)e^{j\omega t}\} \tag{13}$$

$$p^T(s,t) = \bar{p}^T(s) + Re\{\tilde{p}^T(s,\omega)e^{j\omega t}\} \tag{14}$$

$$m(s,t) = \bar{m}(s) + Re\{\tilde{m}(s,\omega)e^{j\omega t}\} \tag{15}$$

2.5 Conversion Matrices

The conversion matrix for any physical quantity or for a set of elements is defined as the matrix that connects between the quantities that are exposed to changes or oscillations between the fluid entering and exiting from a particular system or within a given area. If the quantity entered is known as i = 1 and the outgoing quantity i =2, respectively, then the transfer matrix, [T], is defined as

$$\{\tilde{q}_2^n\} = [T]\{\tilde{q}_1^n\} \tag{16}$$

$$\begin{Bmatrix} \tilde{p}_2^T \\ \tilde{m}_2 \end{Bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{Bmatrix} \tilde{p}_1^T \\ \tilde{m}_1 \end{Bmatrix} \tag{17}$$

2.6 Order of the System

The first step in any analysis of the unstable transitional flow is to divide the system into compounds, the point from which two or more branches are called a point of order. Practically, we have a pump inlet and outlet. To do this, it is necessary to know the order of the system, which is the minimum of quantities or vehicles that are subject to fluctuation and which must be specified in the system points. To obtain an accurate representation of the transient flow at each point [8-10]. This number is equal to the number of first-order linear simultaneous equations that are needed to express fluid movement. In this study, it was considered that the system is exposed to the case of water hammer and is subject to analysis to know the form of pressure wave formed in the pipeline and considered that the system of the third order.

3. PRACTICAL APPLICATIONS

3.1 Case study 1

The first example studied is shown in Fig. (3). The valve at the bottom of the pipeline closes abruptly to receive the transition flux and the water hammer phenomenon. the analysis resulting as shown in Figs. (5, 6).

3.2 Case study 2

In the second case studied, it consists of a more complex network than the first case and is closer to real networks, as in Figure (4). The analysis results shown in Figs. (7, 8).

4. CONCLUSION AND RECOMMENDATIONS

The study of the flow of the transition and the causes of the phenomenon of water hammer and the follow-up pressure wave in the pipeline systems is very important and is one of the priorities of the hydraulic design of the phenomenon of the effects of the shadow on the pipes and accessories and pumps connected to the network. These studies can be performed using the time-frequency method, which is based on classical pressure analysis or the so-called characteristic method. The second method, called the frequency range method, is based on the third- order transfer metrics. It was found in simple networks that the two methods give the same results, but when applied to more complex networks, the results are different for both methods.

NOMENCLATURE

A: cross-sectional area.
a: radius.
e: specific internal energy.
$e^{[F]l}$: transmission matrix.
[F]: distributed function.
δ: wall thickness of the pipe.
ρ: fluid density.
C: sonic speed.
$C\infty$: sonic speed in the fluid.
E: Young's modulus.
N: order of the system.
P: pressure.
K: bulk modulus.
q^{-n}: vector of fluctuating quantity.
S: coordinate measured along the duct.
t: time.
[T_{ij}]: transfer matrix elements.
[T]: Transfer matrix based on $\tilde{p}^T$, $\tilde{m}$.
[T^*]: transfer matrix based on $\tilde{p}$, $\tilde{m}$.
u(s,t): volumetric velocity.
gs: acceleration due to gravity.
λ: characteristic factor.
f: friction factor.
h∗: piezometric head.
Q: volume flow rate.
ω: frequency.
m: mass flow rate.
p^T: total pressure.
R_e: Reynolds number.
Z: vertical elevation.

Table 1: Pipe characteristics for case study 1.

Pipe number	Length (m)	Diameter (mm)	Darcy friction	Minor loss
1	610	914	0.012	0
2	914	762	0.013	0
3	610	610	0.014	0
4	457	457	0.015	0
5	549	457	0.015	0
6	671	762	0.014	0
7	610	914	0.013	0
8	457	610	0.014	0
9	488	457	0.012	0

Table 2: Pipe characteristics for case study 2.

Pipe number	Length (m)	Diameter (mm)	Darcy Friction	Minor losses
1	1,002.2	1.5	0.013	0
2	2,000.0	1.000	0.012	0
3	2,000.0	0.750	0.015	0
4	502.5	0.500	0.013	0
5	502.2	0.500	0.014	0
6	1,001.2	1.000	0.014	0
7	2,000.2	0.750	0.014	0

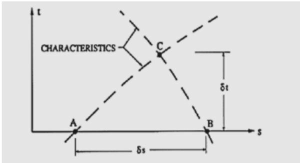

Figure 1: Method of characteristcs.

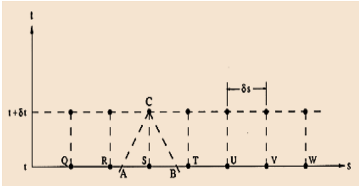

Figure 2: Numerical solution of method of characteristics.

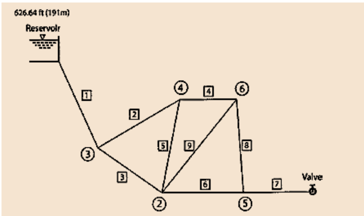

Figure 3: Simple pipeline system.

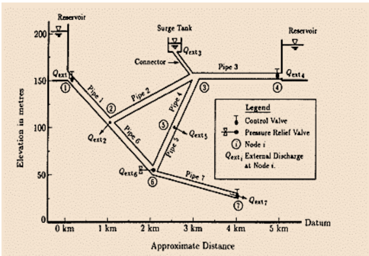

Figure 4: Network with more apparatus.

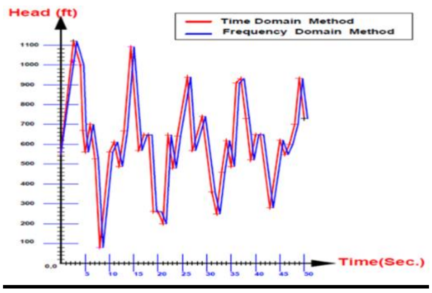

Figure 5: Comparison of results of time domain and frequency domain methods, for case 1, at Junction 4.

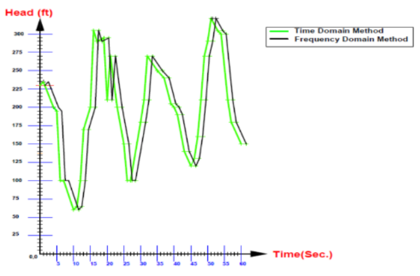

Figure 6: Comparison of results of time domain and frequency domain methods, for case 1, upstream of valve.

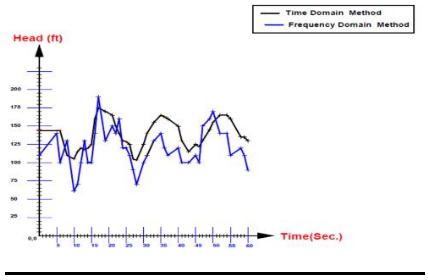

Figure 7: Comparison of results of time domain and frequency domain methods, for case 2, at junction 2.

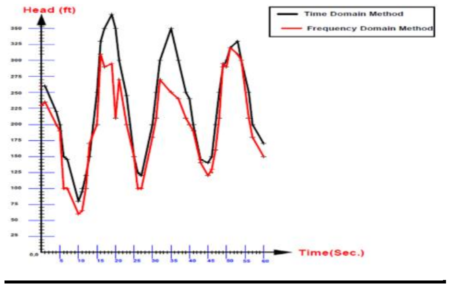

Figure 8: Comparison of results of time domain and frequency domain methods, for case 2, upstream of valve at node 7.

REFERENCES

[1] Boulos, P.F., Lansey, K.E., Karney, B.W. 2004. Comprehensive water distribution systems analysis handbook for engineers and planners, MWH Soft, Inc., Pasadena, California.

[2] Funk, J.E. 1999. Pathogen intrusion into water distribution systems due to transients, Proc., ASME/JSME Joint Fluids Engineering Conf., ASME/JSME, San Francisco.

[3] Le Chevallier, M.W. 2003. The potential for health risks from intrusion of contaminants into the distribution system from pressure transients, J. Water, Health, (1), 3–14.

[4] Friedman, M.C. 2003. Verification and control of low-pressure transients in distribution systems, Proc., 18th Annual ASDWA Conf., Association of State Drinking Water Administrators, Boston.

[5] Karim, M.R., Abbas Zadegan, M., Le Chevallier, M.W. 2003. Potential for pathogen intrusion during pressure transients, J. Am. Water Works Assoc., 95(5),134–146.

[6] Karney, B.W., McInnis, D. 1990. Transient analysis of water distribution systems, J. Am. Water Works Assoc., (7), 62–70.

[7] Wood, D.J., Funk, J.E. 1996. Surge reference manual: Computer analysis of transient flow in pipe networks, University of Kentucky, Lexington, KY.

[8] Bruce, E.L., Roland, W.J., Gary, Z.W. 2000. Hydraulic of Pipeline Systems.

[9] Christopher, E.B. 1994. California Institute of Technology, Pasadena, California.

[10] Streeter, V.L., Wylie, E.B. 1967. Hydraulic transients. McGraw-Hill.