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SURGE CONTROL: A REVIEW

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ABSTRACT

Water hammer (hydraulic shock) is the momentary increase in pressure, which occurs in a water system when there is a sudden change of direction or velocity of the water. Water Hammer is considered one of the most important technical and economical aspects carrying out of water supply system. The purpose of this study is to compare and suggest the best option to mitigate the water hammer using Bentley's Hammer V8i. This study presents comparison of various surge control devices and detailed study of different methods used for transient analysis carried out globally to minimize the effects of transient condition in pipeline system.

Keywords -*Water Hammer, Surge Control Devices, Bentley HAMMER V8isoftware, Surge Tank, Air Valve, Pressure Reducing Valve*

I. INTRODUCTION

As water is an essential element for the survival of human beings, so transmission, distribution of water by pumping and gravity mains are essential ingredients of all water supply systems. The annual construction, operation and maintenance of these systems are important from the point of view of projects successful operation. Usually, optimizing procedures for the design of water transmission pipelines have tended to focus on the steady or nearly steady state requirements of the system [16]. Consideration of transients or surge often takes place with the tacit assumption that the cost of controlling transients represents a small portion of the overall pipeline cost. At the same time it is generally observed that pipe costs constitute a major portion of the total system expenditure. So the selection of pipe diameter, pipe material, and pipe wall thickness strongly influences the nature of the pipeline transient response. These in turn, along with other devices which may be present, usually establish the critical design conditions for the pipeline. Therefore transient considerations are often fundamental, not incidental, in determining the ultimate system cost. [16].

A water distribution system is a complex network of pipes, pumps, valves, reservoirs, and storage tanks that is used to transport water from source to consumer. It is designed and operated to consistently deliver water in sufficient quantity, of acceptable quality, at appropriate pressure, as economically as possible [4]. For many years, it was simply assumed that the quality of water that entered a distribution system was essentially equivalent to that leaving the system. Moreover, it is still often assumed that water quality models can account for the key mechanisms of transformation by considering nearly steady state considerations alone [10]. However, one challenging water quality problem is that contaminants can intrude into a pipe through a leak when induced by transient low or negative pressures. In reality, since all pipeline systems leak and since hydraulic transients occur almost continuously in distribution systems, it is not surprising that low pressure transient waves offer considerable potential to draw untreated and possibly hazardous water into a pipeline system [11].

Unfortunately, designing these critical transient protection systems is a challenging problem and a variety of strategies is commonly suggested. Protection approaches range from installing specialized devices such as surge reduction valve, surge tanks and air valve to the selection of pipe properties and the up gradation of operational procedures [6].However, the selection, installation, and operation and maintenance of these hydraulic devices strongly depend on the particular water supply system as well as on the experience/comfort of the designer and operator. Unfortunately, systematic exploration of such alternatives has been impractical in the past due to inherent computational challenges, due to the analysis burden of individual options and due to the multidimensional nature of the search space. However, improved algorithms and faster computers have been gradually changing this situation, making the optimal determination of protection devices position, size, and device characteristics a more pressing and practical problem. Many standard codes and applications are developed to calculate or simulate water hammer, including but not limited to: TREMOLO, HiTran, AFT Impulse, Surge 2000, TRACE, CATHARE, ATHLET, TRAC, FLOWMASTER and Bentley HAMMER V8*i*[16].

This study presents comparison of various surge control devices and detailed study of different methods used for transient analysis carried out globally to minimize the effects of transient condition in pipeline system.

II. SURGE PROTECTION AND SURGE CONTROL DEVICES

The purpose of surge control is to stop kinetic energy from being converted into elastic deformation energy. Water hammer caused by the start-up, or stoppage of pumps, pump run down, and opening and closing of valves in the pipeline is manifested as high pressure fluctuations and possible column separation in the system. Other possible effects are excessive reverse pump rotation and check valve slain. The undesirable water hammer effects may disturb overall operation of the system and damage components of the system, for example pipe rupture. Therefore several design approaches may be adopted to solve water hammer problems:

- Installation of surge control devices in the system. Table shows a summary of various water hammer control devices which may he installed in the system.
- Redesigns of the pipeline layout e.g. change of elevation, length or diameter of the pipeline.
- Design of a thicker pipeline or selection of a pipe material with higher strength to allow column separation in the system.
- Alteration of operational parameters e.g. reduction of velocity in the pipeline.

Economic and safety factors are decisive for the type of protection against undesirable water hammer effects. A number of alternatives should be considered before final design which may include a combination of various design approaches.

Table 1: Comparison of various surge control devices [1]

Devices	Surge tank	Air Chamber	One way Surge Tank	Pressure Relief Valve	By Pass	Air Valve
Principle of operation	Energy Accumulator	Energy Accumulator	Provides Flow	Relieves pressure	Maintains Flow, control reverse flow	Air admission and release
Pipeline system/effectiveness	Very low Head system	Long pipelines, medium to high head system	Long pipe with high joints	High head system	Low head systems, Long suction line	Long pipelines with high joints
Protection against	High pressure and column separation	High pressure and column separation	Column separation	High pressure	Column separation	Column separation
Reliability	Excellent	Good	Moderate	Poor	Poor	Poor
Auxiliary equipment/ maintenance	None	Compressor or gas bottle	Checking tank level	Regular maintenance	Inline valve	None
Restarting problem	None	Check air chamber pressure	Refilling of tank	None	Check inline valve	Remove air from pipeline
Frequency of application	Rarely	Very often	Rarely	Sometimes	Sometimes	Often
Cost	High	Very high	Moderate	Moderate	Low	Low

III. METHODS FOR TRANSIENT ANALYSIS

By certain simplifying assumptions or neglecting the non-linear terms the following methods have been developed to solve these equations:

3.1 Arithmetical Method:

This method neglects friction losses and assumes the pipeline horizontal. An account is kept of all the reflections in the system. This method is almost obsolete because it is tedious, time-consuming and approximate.

3.2Graphical Method:

This method has been developed by neglecting the non-linear terms equations. However the friction losses can be considered, if desired, by assuming ahypothetical obstruction located either at the upstream or the down-stream end of the pipe. The friction loss due to the obstruction is taken equal to that of the entire pipeline. Although more accurate solutions can be obtained by assuming a number of obstructions along the pipeline, this complicates the graphical analysis. It is time-consuming and not suited to solving networks or pipelines with complex profiles. The graphical method has the advantages that the phenomenon of water hammer can be visualized and simple systems can be easily analyzed. The disadvantages are as follows:

- Assumptions regarding friction losses are inaccurate,
- Large systems cannot be analyzed,

- Many Boundary conditions can be analyzed by trial and error.

Because of these disadvantages, this method is being replaced by numerical methods suitable for computer analysis. [17]

3.3 Design charts

It provides basic design information for simple topologies at a few specific points (valve closure, pump and pipeline with no protection, surge tank, or air chamber protection). This method has been replaced by computer programs based on the transient energy concept and backed by field and laboratory work [12].

3.4Analytical Methods:

In these methods the continuity and momentum equations are linearized by neglecting the non-linear terms of lesser importance and considering the friction losses proportional to velocity. This method gives surge pressures and velocities.

However, there are some disadvantages in using the operational mathematics, aid of the digital computer. The transformations and inverse transformations involve difficult mathematical manipulations and often result in tedious series. It has certain limitations because of necessary approximations; it is sometimes difficult to determine constants for some conditions and consequently is not flexible in application [12].

3.5 Wave-plan method

Represents initial transient disturbances as a series of pulses and tracks reflections at boundaries. Pressure waves are generated at any point in a flow system where a disturbance that results in a change in flow rate is introduced. This can include a valve that is opening or closing, a pump that is started up or shut down, a change in a reservoir pressure, or a change in an inflow or outflow for the system. Pressure and flow conditions at a component are also affected by pressure waves impinging on the component.

A valve closes and a pressure wave is generated. The wave travels toward the three pipe junction at sonic speed in the pipe. The wave is transmitted into the two connecting pipes and reflected back into the original pipe producing three new pressure waves. Each pressure wave travels at sonic speed toward the opposite end of the pipes and impinge on the elements located there. The pressure waves modify conditions at the reservoir, valve, and pump and new pressure waves are generated and travel back toward the junction.[9]

This approach to transient analysis requires the calculation of the effects of pressure waves impinging on components such as valves and pumps, junctions, surge control elements, and a calculation the effect of line friction on the magnitude of pressure waves. These pressure wave action calculations required for general applications to pipe systems.

Computer routines developed for wave action at components, junctions, surge control devices, and the effect of pipe friction have been utilized to create a general purpose computer model for pipe system transient analysis based on the wave method. The program uses the fact that pressure waves are transmitted between elements at known speeds and are modified by pipeline friction to determine the characteristics of the impinging waves at any time during the simulation. This technique may be applied to complex pipe systems the WCM and has been widely used in commercially available software for over 20 years.[9]

3.6Method of Characteristics:

It is most widely used and tested approach, with support for complex boundary conditions and friction and vaporous cavitations models. Bentley HAMMER V8*i* uses the MOC. In this method all the non-linear terms of the continuity and momentum equations are retained. The partial differential equations are converted into ordinary differential equations that are solved algebraically along lines called characteristics. These equations are then solved by a finite-difference technique. Besides the relative ease to obtain any desired accuracy, this method has the following advantages:

- Large and complex systems can be analyzed,
- It is fast because the equations derived can be easily solved on a digital computer,
- Once a programme has been written for a system, similar systems can be analyzed by changing the data cards. [19]

3.7 Laboratory Models

A scale model can be built to reproduce transients observed in a prototype (real) system, typically for forensic or steam system investigations. As a design method, this approach is limited by model scale effects and by very high costs. However, models have provided invaluable basic research data on vaporous cavitations and vortex shedding and transient friction.

3.8Field Tests

Field tests can provide key modeling parameters such as the pressure-wave speed or pump inertia. Advanced flow and pressure sensors equipped with high-speed data loggers make it possible to capture fast transients, down to 5 milliseconds. Methods such as inverse transient calibration and leak detection use such data. Like all tests, however, data are obtained at a finite number of locations and generalizing the findings requires assumptions, with uncertainties spread across the system. At best, tests provide local data and a feel for the system wide response. At worst, tests can lead to physically doubtful conclusions limited by the scope of the test program[12].

Neither laboratory models nor field testing can substitute for the careful and correct application of a proven hydraulic transient computer model, such as Bentley HAMMER V8*i*.The extended-period simulation (EPS) capability of models such as WaterCAD or WaterGEMS does not consider momentum, and is therefore incapable of analyzing hydraulic transients. Such simulations are sufficient to analyze hydraulic systems that undergo velocity and pressure changes slowly enough that inertial forces are insignificant. If a system undergoes large changes in velocity and pressure in short time periods, then transient analysis is required.

IV. BENTLEY'S HAMMER V8I SOFTWARE

Hammer is a powerful application which helps designers to analyze waves of translation in the pipeline and complicated pumping systems. Bentley HAMMER V8*i* is based on technology originally created by Environmental Hydraulics Group (GENIVAR). Bentley Systems and GENIVAR have forged a long-term collaboration to support and improve Bentley HAMMER V8*i*. Hydraulic translations in a period ranging from a few seconds to a few minutes may damage the system or cause application failures. The name Hammer is taken from loud noise of impact which may be heard when waves of translation occur. The software helps engineers achieve appropriate designs and develop economic surge control systems for pipeline and pumping systems [16].In order to analyze unsteady waves in water conveyance systems, we use elastic properties of pipelines and the fluid in our calculations. Such features are closely associated with pressure variation and pressure wave propagation velocity. Hammer Software uses the Method of Characteristic to solve non-linear differential equations. Then, boundary conditions should be specified.

In order to solve momentum and continuity equations, the software presumes a combination of following conditions:

- The fluid is homogeneous.
- Elasticity of pipeline and fluid follows a linear pattern.
- The flow is uni-dimensional and fluid is incompressible [6].

4.1 Capabilities of Hammer Software

The software uses an advanced graphic interface through which a pipeline system, storage facilities, pumps and wave control facilities may be easily and rapidly designed. The software is equipped with flexible tables and predefined libraries which allow for quick copy of model's parameters. The user may import data and results associated with other models to the application. This method not only saves times but also reduces likelihood of mistakes which may occur while copying date to the software. Using Hammer software, the user may analyze waves of translation:

- Reduce the risk of damages associated with water hammer, and consequently increase safety and reduce failure rate.
- Reduce wearing and tearing effects of water hammer in pumping and pipeline systems, and increase lifetime of the infrastructure.
- Reduce the risk of water pollution in the case of pressures less than an atmosphere where there is the risk of underground water suction and transfer of pollution to pipeline system.
- Reduce the frequency and severity of translational pressure shocks (translational pressures and forces may cause loose junctions, growth of cracks, increasing leakage).
- Therefore, water industry's risk management plan should address hydraulic translations and wave protections needs [23].

V. CONCLUSION

It has been recognized for many years that long pipelines of large diameter may experience severe transient loading. Increasingly transmission function is being integrated in water supply system [8].

The review presents a comparison based on the various researches and study findings and these are as follow:

- Piping vibration can be an annoying problem, which can consume unnecessary maintenance activity and can affect pumping system performance and endurance. A transient control system is required to control the energy and thus minimizes transient pressure from the shock waves [20].
- Pumping stations using surge tanks and pressure reducing valve for transient control is dynamically safe but not economical than those using air valves for control.
- Complete protection of the pipeline system may require combination of more than one device (surge tank, air valves, Surge control valves, pressure regulating valves, soft starting and soft stopping) to completely overcome transient pressures.
- It is very important, during design phase, to determine where potential hydraulic transient problems may exist and means might be taken to control them from reviewing the plan and profile of the pipeline system as well as the operating scheme. It is necessary to avoid knees, high spots, and steep gradients near the pump [20].

Here are some guide lines suggested at primary level for the water pipeline system

- If possible, avoid rapid changes of flows in pipeline systems by utilizing suitable valve closure time or increasing the inertia of pumps.
- The flow can be diverted into or drawn from closed vessels.
- It may be possible to limit the pressure in certain circumstances by use of air inlets, relief valve.

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