Experimental Analysis of Water Hammer Effect

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Abstract- *Water hammer is a pressure wave that occurs when there is a sudden momentum change of a fluid within an enclosed space. This may occur in pipelines when a valve is closed suddenly or when a pump is failed suddenly. The created pressure wave and the negative wave will propagate through the pipeline. During the water hammer phenomenon, the high produced pressures can rupture the pipeline and its components, Several strategies have been developed to control the water hammer within the pipelines such as, changes of diameter, profile within the pipeline systems, reducing the wave speed, applying the optimal operational procedures and installation of control devices such as air vessels, surge tanks, air valves and pressure relief valves. A comprehensive experimental, theoretical and investigations focusing on the aspects of water hammer effect. Here the work is carried out in regard for developing a test rig for the experimental purpose which detects the rise in pressure waves with the operation of valve whether it closed suddenly or gradually.*

Keywords- Water Hammer, Pressure Waves, Test Rig, Experimental.

I. INTRODUCTION

This While it may look and sound harmless, the impact force on the valve – caused by the fluid's momentum – can create pressure spikes that may exceed ten times the working pressure of the system. These sudden stoppages of flow and the resulting increases in pressure from the shock waves can cause significant damage to the overall piping system either due to a singular event or be cumulative damage occurring over time. Ignoring water hammer can ultimately result in the catastrophic failure of your flow system. The long-term effects of water hammer can include:

- Pump and Flow System Damage-Repeated water hammer may also cause significant damage to pumps, existing valves, and instruments, lead to the catastrophic failure of gasketed joints and expansion joints, and affect the integrity of pipe walls and welded joints.
- Leaks- Water hammer can damage fittings, joints, and connections, resulting in leaks.These leaks often start slowly, gradually increasing in intensity over time. Smaller leaks may go unnoticed for quite some time, leaving surrounding equipment susceptible to damage.

II. LITERATURES SURVEY

A literature survey represents a study of previously existing material on the topic of the report. This includes (in this order) –

1. Existing theories about the topic which are accepted universally.
2. Books written on the topic, both generic and specific.
3. .Research done in the field usually in the order of oldest to latest.
4. Challenges being faced and ongoing work, if available.

Tan Wee Choon, Lim Kheng Aik, Lim Eng Aik, Teoh Thean Hin [1], In their paper they have described the condition where the water hammer effect is occurs in pipe line. Water hammer can cause the pipe to break if the pressure is high enough. The experiment will be set-up to investigate the water hammer effect in order to avoid the water hammer effect happen. The prevention of water hammer effect will be proposed and prove the prevention method is successfully reduce the water hammer effect. The prevention method using is installing the bypass pipe with non-return valve. The experiment is done by capture the vibration signal by using data acquisition device and accelerometer. The pressure signal is capture after a sudden shutoff for the valve. The signal is than analyze and convert to wave speed. The project is differentiating and compares the water hammer phenomenon with different pipe material, pipe length, inlet diameter of pipe, and pressure in pipeline. From the experiment, result shown that the lower strength material pipe, smaller inlet diameter pipe, and longer pipe will deal with lager water hammer effect. Besides, the prevention method by installing by pass pipe with non-return valve of water hammer effect is prove successfully reduce the water hammer phenomenon by 33.33% of pressure.

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Almakhles [2], In their paper they have described various conventional methods such as the method of characteristics and wave attenuation methods are available to identify water hammering problems, and the predictive control method is one of the finest and time-saving methods that can identify the anomalies in the system at an early stage such that the device can be saved from total damage and reduce energy loss. In this research, a machine learning (ML) algorithm has used for a predictive control method for the identification of water hammering problems in a pumping system with the help of simulations and experimental-based works. A linear regression algorithm has been used in this work to predict water hammering problems. The efficiency of the algorithm is almost 90% compared to other ML algorithms. Through a Vib Sensor app-based device at different pressures and flow rates, the velocity of the pumping system, a fluctuation between healthy and faulty conditions, and acceleration value at different times have been collected for experimental analysis.

Boran Zhang, Wuyi Wan and Mengshan Shi [3], In this paper they have described that Water hammer is an undesired hydraulic shock phenomenon in water supply pipe systems.A corresponding experiment is conducted to optimize the numerical model. Based on the experimental result, an additional friction function is proposed to evaluate the influence of the air content on the attenuation. The result shows that the energy dissipation of the shock waves may be underestimated in air-water mixture flow using the common steady friction. By introducing the additional friction function, the improved model can more accurately simulate the attenuation of the water hammer in the gravitational pipe with continuous air entrainment. As there are plenty of practical water supply systems running with air content, the improved Lax-Wendroff Method (LWM)is valued in accurately predicting water hammer processes especially in those conditions.

Yong-liang Zhang, Ming-Fei Miao, Ji-Ming MA [4], In this paper they have described that presents an analytical investigation of water hammer in a hydraulic pressurized pipe system with a throttled surge chamber located at the junction between a tunnel and a penstock, and a valve positioned at the downstream end of the penstock.

Analytical formulas of maximum water hammer pressures at the downstream end of the tunnel and the valve were derived for a system subjected to linear and slow valve closure. The analytical results were then compared with numerical ones obtained using the method of characteristics. There is agreement between them. The formulas can be applied to estimating water hammer pressure at the valve and transmission of water hammer pressure through the surge chamber at the junction for a hydraulic pipe system with a surge chamber.

III. DESIGN OF EXPERIMENTAL SET UP

Designing of a pipe layout

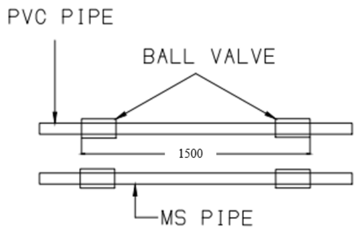

Fig. 1 Pipe Layout Design

Here are the following pipe layout specifications in fig. 1

The Length of pipe for both PVC & MS pipe we have selected 1500 mm (1.5 m). The layout is designed in such a way that the main inlet is common to both the pipes & ball valve is fitted at both pipes inlet and outlet for each pipe for better functioning of test rig.

After conducting the trial we had calculated both major loss and minor loss and together it is total loss.

Table 1:- Calculation of Losses

Specification	P.V.C pipe	M.S. pipe
Coefficient of friction	0.0015	0045
Bulk modulus	$2.3 \times 10^7\ p.s.i$	$4.7\ G.P.a$
Discharge Q	0. 25 m^3/sec	0.1667 m^3/sec
Velocity V	4.93 x 10^2	3.28 x 10^2
Major losses	4.403 x 10^3 m	5.861 x 10^3 m
Minor losses	13.661 x 10^3 m	13.661 x 10^3 m
Total losses	18.064 x 10^3 m	19.522 x 10^3 m

IV. EXPERIMENTAL TESTING & OBSERVATION.

In our project the first trial is conduct to the validation of pipe layout design whether they can sustain the vibration produced by the pressure waves by namely two conditions

i. Sudden closing valve
ii. Gradual closing valve.

Procedure to run the test rig

1. First assure for which pipe you are going to carry the current and check the valve opening and closing of it.
2. Open the valve for which we wish to the water hammer effect.
3. Start the motor.
4. Allow the flow through pipe for desired time.
5. Close the valve by sudden or gradually, depends upon the condition.

The above sequence of procedure is common for both MS and PVC Pipes.

Precautions: -

Check the pump conditions whether it works satisfactory.
If any trouble occurs

i. Go for remedial actions like priming, current, voltage leakage solution etc.
ii. Check the pipe fittings for suitable layout.

Fig. 2 Experimental Set up of Water Hammer Test Rig

Fig. 3. Readings Shown by Pressure Gauge.

V. PRESSURE RISE CALCULATIONS IN M.S. PIPE

<u>Trial 1) Gradual rise in pressure is given on 25 sec</u>

$$P = \frac{\varrho \times V \times L}{T}$$

$$= \frac{1000 \times 328.927 \times 1.5}{25}$$

$$P = 19.735 \times 10^3 \ N/mm^2$$

Actual Experimental we get the following reading through pressure gauge for 3 set of readings

∴ Actual $P = 0.3 \ kg/cm^2$

$= 0.3 \times 9.81 \times 10^4$

1. $P = 29.43 \times 10^3 \ N/mm^2$
2. $P = 0.6 \times 9.81 \times 10^4 = 58.86 \times 10^3 \ N/mm^2$
3. $P = 0.8 \times 9.81 \times 10^4 = 78.48 \times 10^3 \ N/mm^2$

<u>Trial 2) Gradual rise in pressure is given on 40 sec.</u>

$$P = \frac{\varrho \times V \times L}{T} = \frac{1000 \times 328.927 \times 1.5}{40}$$

$$P = 12.334 \times 10^3 \ N/mm^2$$

Actual Experimental we get the following reading through pressure gauge for 3 set of readings

1. $P = 0.4 \times 9.81 \times 10^4 = 39.24 \times 10^3 \ N/mm^2$
2. $P = 0.7 \times 9.81 \times 10^4 = 68.67 \times 10^3 \ N/mm^2$
3. $P = 0.9 \times 9.81 \times 10^4 = 88.29 \times 10^3 \ N/mm^2$

<u>Trial 3-Gradual rise in pressure is given on 60 sec</u>

$$P = \frac{\varrho \times V \times L}{T} = \frac{1000 \times 328.927 \times 1.5}{60}$$

$$P = 8.223 \times 10^3 \ N/mm^2$$

Actual Experimental we get the following reading through pressure gauge for 3 set of readings

1. $P = 0.6 \times 9.81 \times 10^4 = 58.86 \times 10^3 \ N/mm^2$
2. $P = 0.7 \times 9.81 \times 10^4 = 68.67 \times 10^3 \ N/mm^2$
3. $P = 0.8 \times 9.81 \times 10^4 = 78.48 \times 10^3 \ N/mm^2$

VI. PRESSURE RISE IN P.V.C PIPE

<u>Trial 1) Gradual rise in pressure is given on 40 sec</u>

$$P = \frac{\varrho \times V \times L}{T}$$

$$P = \frac{1000 \times 493.381 \times 1.5}{25}$$

$$P = 29.60 \times 10^3 \ N/mm^2$$

∴ Actual $P = 0.9 \ kg/cm^2$

1. $P = 0.9 \times 9.81 \times 10^4 = 88.29 \times 10^3 \ N/mm^2$
2. $P = 0.8 \times 9.81 \times 10^4 = 78.48 \times 10^3 \ N/mm^2$

3. $P = 1.0 \times 9.81 \times 10^4 = 98.00 \times 10^3\ N/mm^2$

Trial 2) Gradual rise in pressure is given on 40 sec

$$P = \frac{\varrho \times V \times L}{T}$$

$$P = \frac{1000 \times 493.381 \times 1.5}{40}$$

$$P = 18.501 \times 10^3\ N/mm^2$$

∴ Actual $P = 2.1\ \ kg/cm^2$

1. $P = 2.1 \times 9.81 \times 10^4 = 206.0 \times 10^3\ N/mm^2$
2. $P = 2.2 \times 9.81 \times 10^4 = 215.8 \times 10^3\ N/mm^2$
3. $P = 2.3 \times 9.81 \times 10^4 = 225.6 \times 10^3\ N/mm^2$

Trial 3) Gradual rise in pressure is given on 60 sec

$$P = \frac{\varrho \times V \times L}{T}$$

$$P = \frac{1000 \times 493.381 \times 1.5}{60}$$

$$P = 12.33 \times 10^3\ N/mm^2$$

∴ Actual $P = 2.9\ \ kg/cm^2$

$$P = 2.9 \times 9.81 \times 10^4$$

1. $P = 284.4 \times 10^3\ N/mm^2$
2. $P = 3.0 \times 9.81 \times 10^4 = 294.3 \times 10^3\ N/mm^2$
3. $P = 2.8 \times 9.81 \times 10^4 = 274.6 \times 10^3\ N/mm^2$

VII. CONCLUSION

From the experimental analysis it is very difficult to predict the behavior of pressure waves which leads in huge hammering effect. The theoretical pressure rise found very less than the experimental values of pressure rise. For comparison of this we have plotted the graph of our experimental reading.

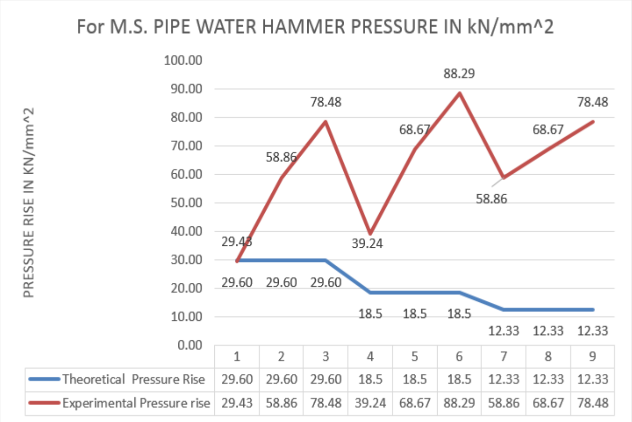

Fig. 4. Graph of M.S. pipe showing comparative variation in pressure rise

The above graph 4 shows the pressure waves variation in increasing mode for M.S. pipe. As the closure time increases the theoretical values of pressure rise decreases, but experimental values go on increasing.

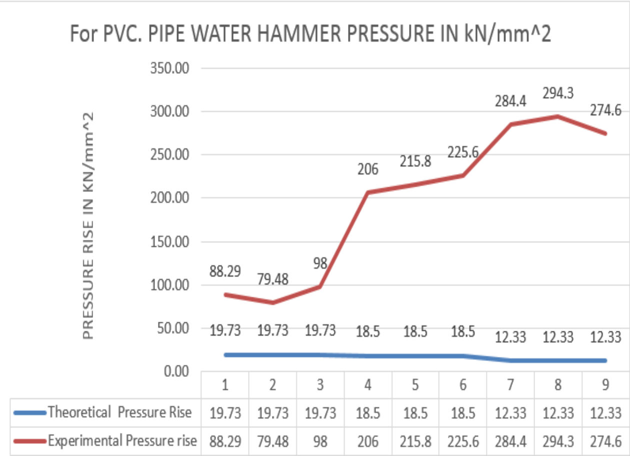

Fig. 5. Graph of P. V. C.. pipe showing comparative variation in pressure rise

The above graph 5 shows the pressure waves variation in increasing mode for PVC pipe. As the closure time increases the theoretical values of pressure rise decreases, but experimental values go on increasing.

Comparing both the M.S. & PVC pipes it is concluded that the water hammer effect is more in PVC pipe as compared to mild steel pipes. Hence for larger distribution the M.S. pipe is more suitable than PVC pipe. For domestic water distribution purpose one can use the PVC pipe but with proper valve arrangement. Hence, we have achieved the satisfactory function of our test rig. Hence, we concluded one can go by suitable design & fabrication of laboratory development project.

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