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ASSESSMENT OF BALL VALVE CLOSING IN WATER HAMMER EVENT VIA VIDEO PROCESSING METHOD

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Abstract: *Water hammer event suddenly emerges as a result of instantly stopping or beginning the water flow through installation components and pipelines and is seen frequently in water installations. The waves emerging as a result of water hammer may lead to fractions and deformations by spreading throughout the installation. Valves and pumps are the main components of the most basic water installment schema, and are seen as the components that most frequently lead to water hammer in starting and stopping the water flow. In this study, for 3 flow velocities in a simple installment setting containing the main installment components, the event of closure of a ball valve with pneumatic actuator was examined experimentally via video processing method, and the effects of flow velocity on water hammer were investigated by visualizing the flow.*

Keywords: Water hammer, Hydraulic shock, Video processing, Ball valve, Valve closing

1. Introduction

The most used component of the installments is the valves. There are many types of valves depending on the operation systems. Furthermore, depending on the dimensions of installments, there are also different sizes of valves.

The ball valves are the vales changing the flow rate of the liquid according to the movement of the ball in those valves. Some of the main characteristics of those valves are that they can be closed and opened with a single maneuver, and that they do not create significant changes in pressure. With these valves, water hammer effect may occur when the flow is suddenly stopped. As a result of this, due to the pressure fluctuations, severe damages may occur in installment components.

The water hammer occurs as a result of the pressure changes in flow velocity of the liquid. This change occurs at the same rate and velocity with the change pressure. Suddenly stopping the liquid having high flow rate leads to dangerous pressure changes, and this may exceed beyond the operational limits of the installment components (Gürsel & Çağlar, 2014). It is necessary to sufficiently analyze this important event. Otherwise, various levels of problems may emerge (Martin, 2000). The water hammer event has typically 2 types; thermal water hammer in hot water-vapor systems and hydraulic water hammer in cold water flow systems (Wylies, 1993). When the liquid moving with its own energy crashes the closed valve, then its pressure spreads throughout the installment in wave form in order to damp the energy. The continuity of this case leads to weakening in many regions of the installment (Gürsel & Çağlar, 2014). In case of thermal water hammer, the size of surface of contact of vapor with water, the temperature differences between water and vapor, and the liquid flow velocity are the main parameters determining the blast effect (Wylies, 1993). The first study on water hammer has been carried out by Menabra (1885). In studies performed, the assessments of various flow parameters were executed. Michaud (1878), in order to ensure the controllability of water hammer event, has carried out studies on the use of air channels and safety valves. In early 19th century, Weston (1885), Carpenter (1893) and Frizell (1898) have made effort to develop the intra-pipe flow velocity changes and pressure relation. The fundamental theories of transition flow have been established by Jukowski (1898). And then, these equations have become the basis of water hammer event. Jukowsi (1898) has examined the equations, which he has obtained under different physical conditions and from various parameters, through advanced

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mathematical relations (Gibson, 1908). Kavurmacıoğlu & Karadoğan (2003) have carried out studies on designing the water hammer in pumping systems due to valve actions and electricity cuts. Padmanabhan, Kochupillai & Ganesan (2004) have developed a model for liquid structure transfer in installments by developing a finite elements formulation based on flow velocity for solving the instability problem when the valve is closed. Bakeer, Barber, Sever & Boyd (2004) have experimentally examined the general characteristics of the flow through a 6-inch smooth pipe. Ramos & Almeida (2002) have examined the effect of water hammer in order to better determine the dynamic behaviors of turbo-machines.

In this study, the emergence of water hammer in case of closing the valve at different flow rates was examined in relation with the time. At the same time, the methods were discussed for preventing the effects of water hammer or minimizing the results.

2. Methods

In test setting, the components involved in a classic water installment such as pump, various valves, connection components, pipes, and tanks were utilized. In order to monitor the pressure change via camera, various colors of food coloring were utilized, and the blue color that provided the best image was preferred, and then the experiments were executed. In order to keep the closure of valve under same conditions at each of the experiments in experiment system, the ball valve was opened closed by a pneumatic actuator.

The experiment setting consists of a pump, a pipeline ensuring the integrity of installation, the valves, storage tank (250lt water in it), the pneumatic actuator, compressor, 2 cameras, and a rotameter for measuring the flow rate. The image of experiment setting is presented in Figure 1.

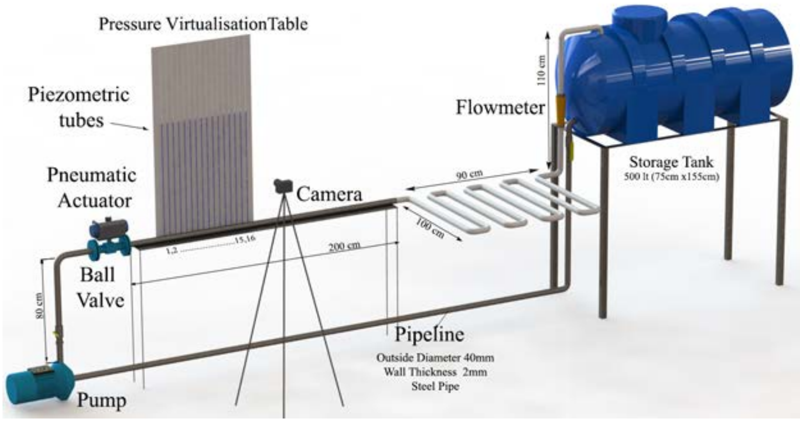

Fig. 1: Solid Model of Experiment Setting.

In order to monitor the water hammer effect throughout the experiment, various interventions were made to flow through the installment.

In this study, the closure of flanged-type ball valve through the air removal from actuator and the springs in actuator by changing the direction of solenoid valve, which directs the air to pneumatic actuator fed by compressor, emergency stop button was observed while the system was operating in actual order. During this process, the flow rates measured by the rotameter were recorded and the experiment was carried out under different flow-rate conditions.

By setting the flow rate, at which the results were obtained, the persistent flow conditions were established.

• While the video camera was recording, the valve was closed (closing time 0.66 seconds) by the closing button connected to pneumatic actuator.

• The images were translated into numeric values via an algorithm prepared in Matlab software. Video frame rate is 50 fps, in algorithm data taking ratio is 25fps/1data (two data in every second).

• The processed values were transformed into time-related graphics, and then the experiments were completed for that parameter.

3. Results and Discussions

In this study, the pressure changes due to water hammer that occurred because of the closure of a ball valve via a pneumatic actuator were examined. The data obtained from experiment setting are presented in relation to flow velocity values in Figures 2, 3 and 4.

Tab. 1: Flow rate and velocity values.

Flow Rates	Flow Velocity Values
0.3 m^3/h	***0.066 m/s***
0.5 m^3/h	***0.111 m/s***
0.7 m^3/h	***0.155 m/s***

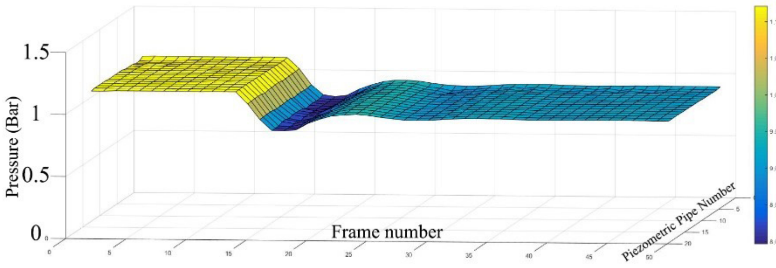

Fig. 2: Time-related pressure change for 0.066 m/s flow velocity.

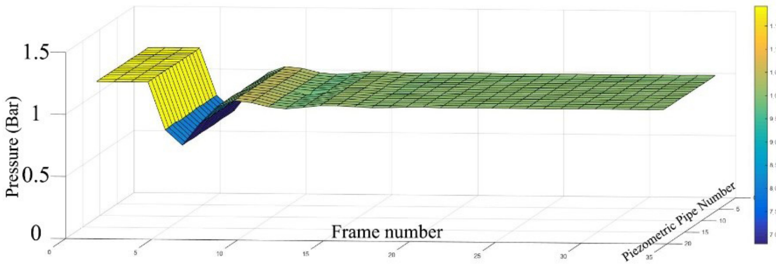

Fig. 3: Time-related pressure change for 0.155 m/s flow velocity.

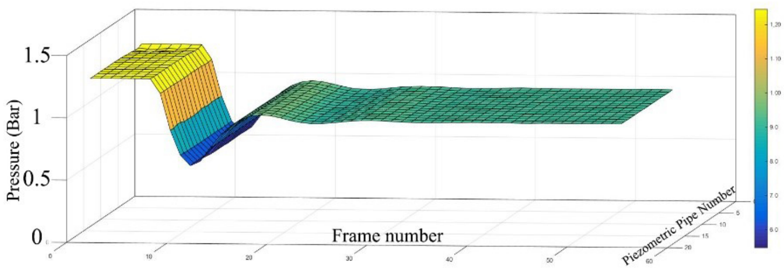

Fig. 4: Time-related pressure change for 0.111 m/s flow velocity.

Considering the results obtained as a result of experiments, it can be seen that the pressure changes occurring as a result of water hammer due to increase in flow velocity because of liquid flow rate has increased linearly. In 3D time-related graphics, the flow velocity-related changes in pressure fluctuations are clearly seen.

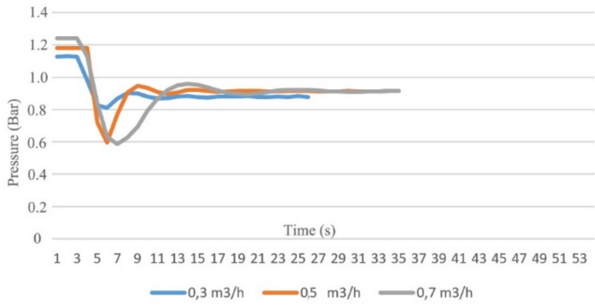

Fig. 5: Comparison of time-related pressure changes.

In Figure 5, the results obtained at 3 different flow velocities are presented in a single graphic. In this graphic, it is obviously seen that the duration of damping the pressure waves occurring due to water hammer increased in proportion to increase in flow velocity. The flow velocity's effect on occurrence of water hammer was analyzed, and the measures that can be made for decreasing the influence of water hammer are as follows:

• The water flow velocity in pipe should be decreased; the diameter of pipe should be increased for this purpose.

• Wave speed (a) should be decreased; for this purpose, PVC or polyethylene pipe should be used when possible.

• Water pressure regulator should be added into installations carrying high-pressure and the valves should be fixed via clamp (Kavurmacıoğlu & Karadoğan 2003).

The flowmeter used in this study has the accuracy tolerance of ±1%. Moreover, the data obtained from image processing method were analyzed, and it was found that the error rate in translating the images into numeric values was ±5%. Since it is not further improve the measurement differences originating from these situations in laboratory environment, they were ignored.

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