UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MOTION SIMULATION ANALYSIS OF PORTABLE ACCUMULATOR FOR DOMESTIC WATER SYSTEM

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) with Honours.

by

LAI WEI WEIN

B051110076

911021-14-5194

FACULTY OF MANUFACTURING ENGINEERING

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DECLARATION

I hereby, declared this report entitled "Motion Simulation Analysis of Portable Accumulator for Domestic Water System" is the results of my own research except as cited in references.

Signature : …………………………………………………………

Author's Name : …………………………………………………………

Date : ……………………………………………….......

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The member of the supervisory committee is as follow:

(Signature of Supervisor)

……………………………………

(Official Stamp of Supervisor)

ABSTRACT

Hydraulic transients are known as pressure surge or water hammer. It is caused by sudden changes of the water distribution network. The water hammer effect can cause serious consequences, ranging from pump defects to pipeline failures, bad water quality and health implications. This research focuses on the design and installation of a surge control device – portable hydraulic accumulator. A hydraulic accumulator is a device which stores potential energy in the form of fluid pressure, where the pressure will be released when required. The accumulator installed near the rapidly closing valve eliminates hydraulic transient by suppressing pressure pulsations or high pressure surges. This study will only include problems faced by domestic water users due to the hammer effect. An online questionnaire was conducted to gather data in order to understand the water hammer phenomenon in domestics in Melaka area. Finally, a 3D CAD drawing of the accumulator was generated and a Motion Simulation Analysis was conducted using the Autodesk Simulation Computational Fluid Dynamic (CFD) software. From the CFD analysis results, the accumulator design with three bladder balls was able to reduce 81.08% of the water velocity. The steel bladder balls were able to reduce the highest percentage of water velocity which was 77.55%.

ABSTRAK

Fana hidraulik dikenali sebagai lonjakan tekanan atau *water hammer*. Ia adalah disebabkan oleh perubahan mendadak dari rangkaian pengagihan air. Kesan *water hammer* boleh menyebabkan akibat yang serius, daripada kecacatan pam, kegagalan saluran paip, kualiti air yang buruk dan implikasi kesihatan. Kajian ini memberi tumpuan kepada reka bentuk dan pemasangan alat kawalan lonjakan – penumpuk hidraulik mudah alih. Penumpuk hidraulik adalah alat yang menyimpan tenaga dalam bentuk tekanan cecair, di mana tekanan akan dikeluarkan apabila diperlukan. Penumpuk dipasang berhampiran injap yg ditutup dengan cepat bagi menghapuskan fana hidraulik dengan menyekat denyutan tekanan atau lonjakan tekanan tinggi. Kajian ini hanya akan membincangkan masalah yang dihadapi oleh pengguna air domestik yang disebabkan oleh kesan *water hammer*. Soal selidik dalam talian telah dijalankan untuk mengumpul data untuk memahami fenomena *water hammer* dalam membantu rumah di kawasan Melaka. Akhir sekali, lukisan *3D CAD* penumpuk telah dihasilkan dan “Motion Simulation Analysis” telah dijalankan menggunakan perisian *Autodesk Simulation Computational Fluid Dynamic (CFD)*. Dari keputusan analisis *CFD*, reka bentuk penumpuk hidraulik dengan tiga bola pundi dapat mengurangkan halaju air sebanyak 81.08%. Bola pundi keluli dapat mengurangkan halaju air peratusan tertinggi iaitu 77.55%.

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Introduction

1.1 Background

Hydraulic transients are known as pressure surge or water hammer. It is caused by either planned or sudden changes of the water distribution network. The sudden change in the liquid velocity generates a pressure wave which can have serious effects, ranging from pump defects to pipeline failures. The hydraulic transient phenomenon may also cause bad water quality and health implications.

The more severe water hammer are caused by the quick change at the inlet and the outlet of a water system. The most common causes are valves rapidly closing or pumps suddenly going online and offline. Fluid at liquid state are highly non-compressible. When an outlet valve closes quickly, the energy in the water flow will cause the nearest valve to compress. It acts like a spring, where the energy in the water system flows in a reverse direction, sending a shockwave until it hits a barrier, such as the pipeline joint. Energy from the shockwave reflects from the barrier and returns to hit the valve again. The shockwave moves back and forth within the pipeline until friction depletes the energy.

In pipeline systems, the sudden change of liquid velocity are caused by (Igor J. Karassik, Joseph P. Messina, Paul Cooper, 2008):

1. Pump and valve activity in pipelines
2. Vapour pocket collapse in water system
3. Shockwave of water system followed by the quick rush of air out of a valve

Total surge pressure may significantly rise above the maximum allowable pressure of the system, causing serious damage to the pipelines. The water hammer effect can be reduced if the problems are identified and solved through analysis and design changes. There are three design guidelines which eases the water hammer effect (Igor J. Karassik, Joseph P. Messina, Paul Cooper, 2008):

1. Changing pipeline dimensions (profile and diameter)
2. Implementing better valve and pump activity operational methods
3. Design and fixing of surge control devices

In this project, the discussion will be made on the design and installation of a surge control device – hydraulic accumulator. A hydraulic accumulator is a device which stores potential energy in the form of fluid pressure, where the pressure will be released when required. The accumulator installed near the rapidly closing valve eliminates hydraulic transient by suppressing pressure pulsations or high pressure surges. There are three basic types of accumulator (Trinkel, 2007):

i. Weight-loaded accumulators
ii. Spring-loaded accumulators
iii. Gas-loaded accumulators

For weight-loaded accumulator, the nitrogen gas compresses from the incoming fluid and loses pressure as the fluid discharges. The accumulator does not lose pressure until the load is removed, allowing 100% of fluid used at full system pressure. For spring-loaded accumulator, a spring forces the piston against the liquid. The free-floating piston has seals to separate the fluid and gas (Trinkel, 2007). For gas-loaded accumulator, compressible gas is used in order to store the energy generated. When the system pressure decreases, the energy pumps the oil out of the accumulator.

1.2 Problem Statement

Hydraulic transients, or water hammer, is a common phenomenon when a water faucet in a house is shut rapidly. This produces a loud banging or hammering noise. The water hammer effect may cause pump failures, water system fatigue, pipe rupture and even the backflow of contaminated water. Besides that, it can cause health problems and can also lead to greater leakage and reduced reliability.

Existing accumulators are used mainly in large manufacturing plants and systems where they are used to absorb high capacity of pulsations and shocks. Such accumulators are not suitable for domestic use which have much lower volume compared to the industries.

When water hammer occurs in houses, it is most likely that the pipelines have become waterlogged. To stop the water hammer, the only way is to shut off the water supply of the entire house, drain the whole system down, shut off all the valves and turn the water back on. The conventional method to solve the water hammer problems are very time-consuming.

1.3 Objective

1. Study and identify problems faced by domestic water user.
2. Design a portable accumulator for domestic water system.
3. Conduct Motion Simulation Analysis on portable accumulator for domestic water system.

1.4 Scope

This study will only include problems faced by domestic water users caused by the water hammer effect. Other factors which cause the damage of pipelines will not be discussed. Next, the designed portable accumulator is only for domestic use as it is of a small capacity sufficient to overcome problems of domestic water systems only. Furthermore, this study will only focus on the Motion Simulation Analysis of the portable accumulator. The functioning mechanism of the accumulator will be conducted by others and will not be discussed in detail.

1.5 Significance of Research

Water hammer is highly noticeable while using appliances that require large volume of water, including toilet flushes, washing machines and dishwashers. This is because the appliances use quick-acting solenoid shutoff valves, where water stops suddenly when the valves are shut.

Accumulators are needed in water systems to absorb the surges and reduce the harmful effects of water hammer. A well-designed accumulator can reduce and eliminate the results of shock. An accumulator should be installed at or near the point of disturbance, such as the pump discharge or near the closing valve to protect the water system.

1.6 Operational Definition

1. Hydraulic transient

   Hydraulic transient are disorders in the water caused by change in state. The disorders are changes in pressure and flow of the water system which cause production of pressure wave throughout the system.

2. Water hammer

   Water hammer is the banging or thumping noise in pipelines, normally caused by pressure surge when a fluid changes direction instantaneously or is forced to stop.

3. Surge pressure

   Surge pressures are generated by the change in flow velocity in a piping system. The sudden changes in velocity are caused by pump and valve operations, collapse of vapour pocket or expulsion of air from the piping system.

4. Surge control device

   Surge control device are equipment installed to pipelines to relieve and prevent surges.

5. Domestic water system

   Domestic water systems provides consumer with sufficient clean water. Common examples are gravity storage tanks and pressurized tanks located on the top floor of the building, connected to supply pumps.

6. Hydraulic accumulator

   Hydraulic accumulators are energy storage devices that stabilizes hydraulic pressure by controlling pressure of non-compressible fluid using an external source. The external source used can be a spring, a weight load, or a compressed inert gas.

7. Portable accumulator

   A portable accumulator is a lightweight, portable unit used to stabilize hydraulic pressure.

1.7 Concluding Remarks

This chapter explains about the background of the water hammer phenomenon and problems faced by domestic water users. Accumulators are chosen as the surge control device to minimize the effect of the water hammer. In the next chapter, more theoretical details will be explained and discussed.

Chapter 2

Literature Review

2.1 Domestic Water System

According to the statistics provided by Suruhanjaya Perkhidmatan Air Negara (SPAN) as shown in Table 2.1, the domestic water consumption in Melaka is 237 litres per person per day in both year 2012 and year 2013 (Suruhanjaya Perkhidmatan Air Negara, 2014a). In year 2012, the domestic water consumption is 187 million litres per day (MLD) (51.7%) and 193 MLD (51.4%) in year 2013 (Suruhanjaya Perkhidmatan Air Negara, 2014a).

Table 2.1: Water Consumption 2012 – 2013 (Suruhanjaya Perkhidmatan Air Negara, 2014b)

State	2012					2013				
	Domestic		Non-Domestic		TOTAL	Domestic		Non-Domestic		TOTAL
	MLD	%	MLD	%	MLD	MLD	%	MLD	%	MLD
Johor	769	69.3	341	30.7	1,110	797	68.5	366	31.5	1,163
Kedah	474	74.2	165	25.8	639	487	74.8	164	25.2	651
Kelantan	130	69.2	58	30.8	188	140	69.5	62	30.5	202
Labuan	16[r]	33.8	30[r]	66.2	46	16	34.2	31	65.8	46
Melaka	187	51.7	175	48.3	362	193	51.4	182	48.6	375
N. Sembilan	247	56.3	192	43.7	439	255	54.5	213	45.5	468
Pulau Pinang	475	59.7	321	40.3	796	481	59.5	327	40.5	809
Pahang	287	57.8	209	42.2	496	299	59.3	205	40.7	504
Perak	592	73.1	217	26.9	809	607	72.6	228	27.4	835
Perlis	57	85.5	10	14.5	67	65	81.5	15	18.5	80
Sabah	305	57.6	225	42.4	529	314	59.2	216	40.8	530
Sarawak	432	56.3	336	43.7	768	446	56.4	345	43.6	790
Selangor	1,686	58.3	1,207	41.7	2,893	1,735	58.0	1,254	42.0	2,989
Terengganu	216	55.6	173	44.4	389	230	55.8	183	44.2	413
MALAYSIA	5,873	61.6	3,659	38.4	9,532	6,064	61.5	3,790	38.5	9,854

Notes:

a. For Sabah and Labuan, changes in consumption volume due to recategorization between domestic and non-domestic
b. Most of non-domestic consumption was by Petronas Methanol (Labuan) Sdn. Bhd. (34% of total Non-Domestic consumption)

Domestic water use can be divided into indoor and outdoor household water usage. Some examples of indoor uses are drinking, cooking, bathing, washing clothes and flushing toilets. Some examples of outdoor uses are washing automobiles, watering gardens and maintaining swimming pools. Water use depends on geographic location and season, mostly caused by the differences in climate. In drier regions, water withdrawal are high for irrigation and landscaping purposes. (US Environmental Protection Agency, 2008).

The domestic water supply system is important to deliver sufficient water for consumers. There are two types of water supply system, which are gravity tank and pressurized tank.

2.1.1 Domestic Water Supply – Gravity Tank

The domestic water supply with gravity tank is shown in Figure 2.1.

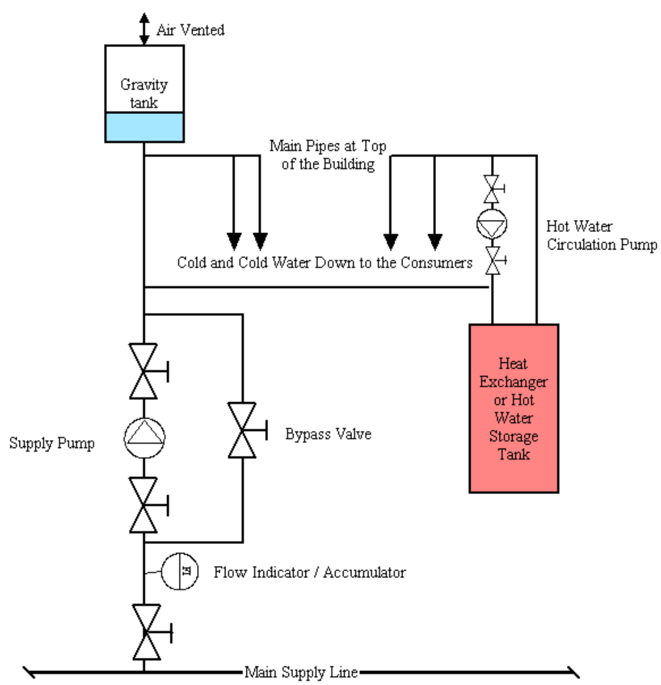

Figure 2.1: Domestic water system with gravity tank

(The Engineering Tool Box, 2013)

For the water system to function effectively, the gravity tank has to be situated more than 10 metres above the highest exit. For cases of tall buildings, pressure reducing valves are fixed at the lowest floors before installation.

The capacity of the gravity tank must be precisely designed to support the water supply system as the pipeline connections are limited. The tank starts to fill when water consumption is lower compared to pipeline capacity, and the tank is drained when water consumption is higher than the pipeline capacity.

Gravity tanks enables users to have water pressure and water supply when electricity is cut off. Water is always ready for domestic storage and fire-fighting purposes. The gravity tank consists of simple components including a tank, inlet, discharge piping, a float switch and a pump. When the water level falls, the float switch grips the pump and the tank refills (Norgaard & Nielsen, 2014).

One limitation of the gravity tank water system is the possibility of freezing during cold weather as the gravity tank on the top floor is opened. Another disadvantage is the huge size of the tank which affects the building construction. Besides that, gravity tanks require higher capital costs for set up and higher maintenance cost. In hygienic aspects, gravity tanks are used as breeding grounds for bacteria, causing health complications (Norgaard & Nielsen, 2014).

2.1.2 Domestic Water Supply – Pressurized Tank

The pressurized tank is filled with air which are able to adapt to different pressure during consumption and when the supply pump starts and stops. There are several system configurations for the pressurized tanks of different applications (Norgaard & Nielsen, 2014).

An example of domestic water supply with pressurized tank is shown in Figure 2.2.

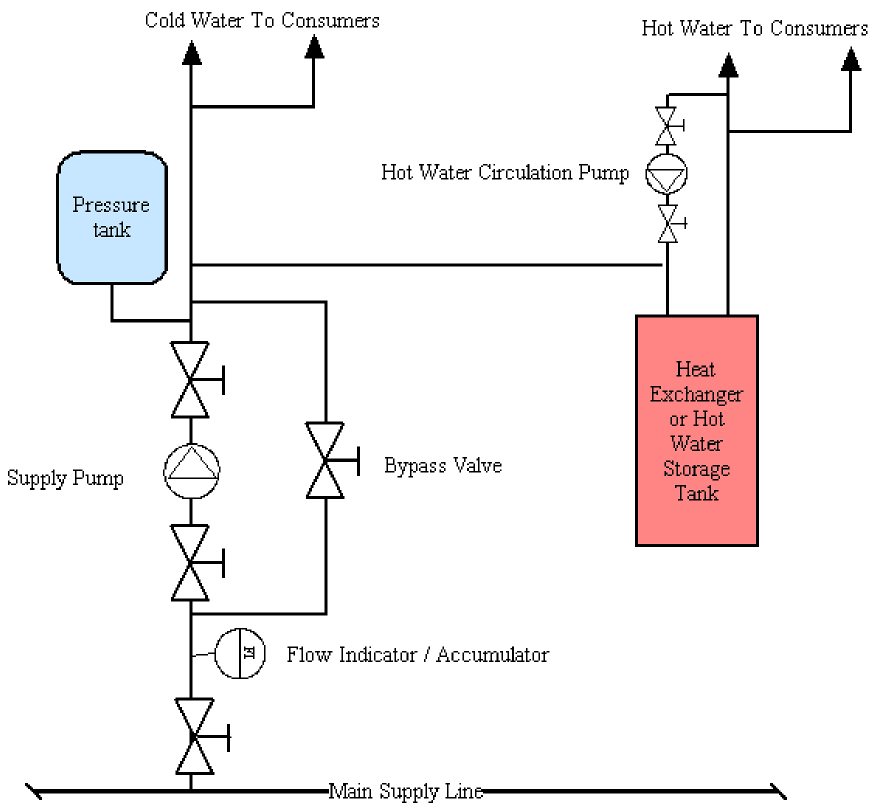

Figure 2.2: Domestic water supply with pressurized tank

(The Engineering Tool Box, 2013)

The different types of system configurations are (Norgaard & Nielsen, 2014):

1. Single booster system.

   A water supply tank is placed near the pump mechanism and filled with water. This allows the capacity to maintain low even during high demand, which ensures stable pressure even during peak flow conditions. The tank is full even during low consumption periods which always allows constant water supply.

2. Zone-divided system.

   The water supply system is divided into multiple zones. This enables suitable water pressure on all floors without installing pressure relief valves. Using this method, the minimum pressure on the highest floor and maximum pressure on the lowest floor can be controlled.

3. Roof tanks.
   This ensures both sufficient water pressure and water supply even during power deficiency. However, pressure reduction valves is required on each floor to prevent high pressures at taps.

4. Series-connected system.
   This system enables efficient power use because water is only pumped to areas where it is needed. In this system, it is important to have total control. When users on the upper floors draws water, the booster system must be able to deliver water from the lowest floor of the building.

2.2 Pipelines Materials and Properties

A good pipeline installation depends on the satisfaction on performance and life requirements. Performance is the assessment of the pipe capacity and efficiency, while life is the total operating hours before it has to be replaced to maintain its performance (Igor J. Karassik, Joseph P. Messina, Paul Cooper, 2008).

The beginning performance is the responsibility of manufacturer and is intrinsic in the design. Life is a measure of resistance construction material to corrosion, wear and factors that could affect the pipeline performance during its service. The durability of a piping system depends on the condition of the components and the plumber's skills. No piping system can operate properly if the materials or components used are in bad condition (Watson et al., 2006). Hence, it is important to select suitable construction materials to increase reliability and improve the life of the pipelines.