DEVELOPMENT OF HYDRAULIC RAM PUMP TO DETERMINE THE PERFORMANCE AND EFFICIENCY

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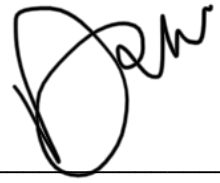
DECLARATION

I hereby declare that the work in this report is my own except for quotations, equations, summaries, and references, which have been duly acknowledgement.



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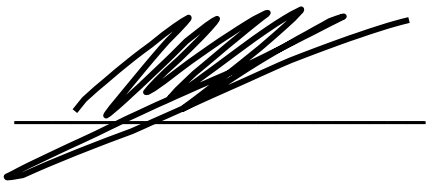

ACKNOWLEDGEMENT

Firstly, I would like to express my greatest gratitude and sincere appreciation to my supervisor, Dr. Nazrien Adrian Bin Amaludin for allowing and giving me the opportunity to work with him as well as all the guidance, valuable opinion, and constructive criticism during my Final Year Project. I am beyond grateful to have such an awesome and great advisor to assist me in accomplishing this project. All of his advice, encouragement, motivation, and recommendation really helps me to keep on track while working on this project.

I would like to acknowledge my fellow course mate of HK08 for bringing me joy and support while finishing this project. All of them are indirectly helping me in finishing this project. Last but not least, I would like to thank my family for their financial and lovely support to me. I could have not completed this project without their supports.

DANIEL WILSON SININ

1st JULY 2022

ABSTRACT

This research focuses on creating a ram pump that will enable water pumping without the use of an external energy source. The waste valve and the delivery valve are the only two moving parts in a hydraulic ram pump, which is a straightforward device. There have been numerous studies done on the ram pump in the past. In this instance, the goal was to identify the optimal set of parameters to achieve the highest level of efficiency. The project will be conducted by studying scientific literature and performing experiments. The objective of this study was to test the effects of varying the length of drive pipe combined with the variation of the size for the ram pump towards the flow rate and efficiency of hydraulic ram pump. This study was conducted by using a pipe with the length varies from 3 meters, 4 meters and 5 meters for the drive pipe and two size of pump which are in size of ½ inch and ¾ inch. The results showed that ¾ inch of pump size with the length of drive pipe be 5 meters in length showed the highest flow rate of 2.05 liters per minute with overall efficiency of 64.27%.

ABSTRAK

REKA BENTUK DAN PEMBANGUNAN PAM RAM HIDRAULIK UNTUK MENINGKATKAN PRESTASI DAN KECEKAPAN

Penyelidikan ini memberi tumpuan kepada mencipta pam ram yang akan membolehkan pengepaman air tanpa menggunakan sumber tenaga luaran. Injap buangan dan injap penghantaran adalah satu-satunya dua bahagian yang bergerak dalam pam ram hidraulik, yang merupakan peranti mudah. Terdapat banyak kajian yang dilakukan pada pam ram pada masa lalu. Dalam contoh ini, matlamatnya adalah untuk mengenal pasti set parameter optimum untuk mencapai tahap kecekapan tertinggi. Projek ini akan dijalankan dengan mengkaji kesusasteraan saintifik dan melakukan eksperimen. Objektif kajian ini adalah untuk menguji kesan perubahan panjang paip pemacu digabungkan dengan variasi saiz pam ram terhadap kadar alir dan kecekapan pam ram hidraulik. Kajian ini dijalankan dengan menggunakan paip dengan panjang berbeza dari 3 meter, 4 meter dan 5 meter untuk paip pemacu dan dua saiz pam yang bersaiz ½ inci dan ¾ inci. Keputusan menunjukkan bahawa ¾ inci saiz pam dengan panjang paip pemacu adalah 5 meter panjang menunjukkan kadar aliran tertinggi 2.05 liter seminit dengan kecekapan keseluruhan 64.27%.

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LIST OF ABBREVIATIONS

BPM **-** Beats Per Minute

HYDRAM - Hydraulic Ram Pum

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Pumps are among the oldest of the machines. They were used in ancient Egypt, China, India, Greece, and Rome. Today, pumps are the second most used kind of industrial equipment after the electric motors (Ndache mohammed, 2007). A pump is a device that moves fluids like liquids and gases. In a simple sense, a machine that is used for pumping off fluids by mechanical action. Mechanical action involving the conversion of electrical energy into hydraulic energy. There are three major groups of pumps that are classified accordingly to their method or system of moving the fluids.

First, direct lift system which a fixed quantity of water is physically raised in a single or several containers. In order to work in water, this type of pump has an internal pipe that acts as both a piston and a pump rod. Consequently, the piston valve closes, allowing more water to enter the pump and raise the amount of water in the pump itself (Coombs A. G. et al., 1989).

Next, a displacement pump. When the piston is moved, the volume of water pumped equals the displacement of the piston. Further water is drawn through the pump known as a velocity pump when the water is driven with sufficient momentum in the absence of air.

Finally, gravity system which is when water flows downward due to gravity's impact. Water cannot, however, be moved to a position higher than the source in this system. The mechanism can only transport water to a lower level. A hydraulic ram pump can be classified in gravity system as the operation depending on the source of water situated above the pump and works by using the momentum of falling water.

1.2 Project Review

To start the development of this project, knowledge on the background of hydraulic ram pump (HYDRAM) is essential. This section will explain and discuss the background of hydraulic ram pump design which also includes the challenges in designing the hydraulic ram pump design. In addition, the background of hydraulic ram pump that has evolved over the years will also be reviewed in this section.

1.2.1 Background of Hydraulic Ram Pump (HYDRAM)

Since the gravity system cannot transferred the water to a point higher than the source. Therefore, a device called Hydraulic Ram Pump (HYDRAM) was invented over 200 years ago such that it can pump water uphill using only the water coming into it as a source of power. Even so, it is not a free energy device. The ram pump is well suited for agriculture and livestock irrigation system due to its use of gravity and environmentally friendly construction. As the hydraulic ram pump does not rely on electricity or fossil fuels, it is well suited for use as a basic component in supplying water in remote locations.

The hydraulic ram pump was first designed in 1772 by John Whiterust of Cheshire, England and originally designated as "pulsation engine". The first one was installed at Oulton, Cheshire to raise water to a heigh of 4.9 meters. In 1796, a ram pump was first documented in France. The older pulse engine was mechanized by Joseph Montgolfier after he added a few valves. In 1797, a pump similar to this one was invented in England and improved upon in 1816 (United States Department of Agriculture, 2007).

Hydraulic ram pumps have been used for irrigation in regions where electricity is not available throughout their history. The hydraulic ram pump's key advantage is its basic structure, which uses sustainable and reliable energy sources.

Hydraulic ram pumps have only two working elements and are therefore structurally simple. A driving pipe, delivery pipe, and an extra air chamber are all connected to the waste valve (or impulsive valve) and the check valve (or delivery valve), respectively. The hydraulic ram pump operates continuously because of the waste valve and delivery valve's opening and shutting cycles.

1.3 Problem Statement

One of the major concerns in hydraulic ram pump is the performance and the efficiency. Since the hydraulic ram pump operates without external forces, the output flow rate is depending on the design parameters. After an alternate cycle occurs, water hammer energy is used to pump a fraction of the entire input discharge of the supply source. The water hammer effect is created by the ram pumps, which regulate the amount of energy they need to push water in each cycle.

The flow in the drive pipe is initially at rest, with the waste valve manually opened and the delivery valve closed. The waste valve begins to close at a specific critical velocity as the flow velocity in the drive pipe continues to grow. The waste valve is quickly closed or well known as slam shut situation at one point. As this point, the water hammer phenomenon took place. Pumping now takes place as water hammer shock waves move up and down the drive pipe at the same speed as the pressure wave, and the delivery valve opens in response to each pressure pulse, pumping flow toward the storage tank (Fatahi-Alkouhi et al., 2019).

Lack of energy resources is one of the problems in hydraulic ram pump. Energy efficiency should be an important factor to be consider in the design of the HYDRAM. Since HYDRAM is mainly depending on the water hammer phenomenon to pump water. Thus, HYDRAM needs a design that will optimize the functionality of water hammer while observing the impact of the pressure wave propagation on the ram pump's components. To improve and subsequently enhance the performance of this hydraulic ram pump, an optimize version of HYDRAM that will utilizes the water hammer phenomenon is proposed.

High noise from the waste valve and consistent wear on the waste valve rubber were two other typical issues that arose in most of HYDRAM designs. A well-designed hydraulic ram pump can survive for decades because it only has two moving parts which are the check valves.

1.3.1 Challenges

In the process of completing this project, there are various challenges that are faced throughout the process. One of the challenges is that hydraulic ram pump existed over 200 years ago. Throughout the decades, there are countless number of research had been done to improve the performance and efficiency of this device. Therefore, to develop or to find another parameter to be studied and improved for this project is quite challenging as most problem has been sorted out by previous researcher. In addition to various parameters that need to be considered in designing the hydraulic ram pump, the lack of knowledge in these parameters is also one of the challenging tasks. Focusing on optimizing the water hammer phenomenon also required a deeper understanding as multiple variables involve in this particular topic.

1.4 Project Aim

The aim of this research is to design and develop a hydraulic ram pump (HYDRAM). Implementing new studied parameters to improve the performance of HYDRAM and prolong the lifetime of the device. The aim of this project can be achieved through the following objectives.

1.4.1 Objectives

The objective of this project is to design and develop a hydraulic ram pump to enhance the performance and efficiency. The project objective can be accomplished through the following efforts:

a) To design a prototype with different size of pipeline system that includes both check valves as well as the pipe fitting to analyze the effect of water hammer.

b) To test and analyze the effect of varying the length of drive pipe in order to increase the output pressure as well as the delivery flowrate.

1.4.2 Scope of Work

This project will develop two different prototypes having different size of the pipeline system that includes the change in size for both waste valve and delivery valve where the slam shut occurs as well as the pipe fitting used in the prototype. Moreover, this project will be using 2 bar pressure gages to examine the change in pressure due to the effect of water hammer. Next, for the length of the drive pipe, variation of three different length will be used to observe the change in flow velocity.

Different types of material are also possibly will be used in this project as to determine the effect of material in the flow rate output. In the meantime, different type of material might help to reduce the noise produce by the waste valve as sound absorption varies through different material. Proposed material are PVC pipe and steel pipe. On the other hand, a clear section of pipe might be installed to witness the water movement once the pressure spiked by the phenomenon of water hammer.

1.5 Report Outline

This project focuses on hydraulic ram pump. The output flow rate of this device is depending on the pressure inside of the pump. Enhancing the performance of HYDRAM and prolong the lifetime of this device will require a great knowledge from the previous research.

Chapter 1 discusses the overview of the whole project to give readers vision on what this project is intended for. This chapter will provide the background of the hydraulic ram pump and its architecture. The problem statement and challenges faced are also presented. Other than that, this chapter alco contain the aim and objectives of this project, including scope of work to visualize the overall project.

Chapter 2 of this report reviews the HYDRAM design and previous research done by researchers. The history and available design of hydraulic ram pump are also reviewed in this chapter. The working principle and the main topic for this report which is water hammer phenomenon is also reviewed.

Chapter 3 described the methodology used in this project. Starting with the outline of the overall flowchart that took place in the making of this project. Next, the conceptual design in hand-sketched drawing is presented before the experimental setup is explained in detail in this chapter.

Chapter 4 will display the prototype and simulation of hydraulic ram pump HYDRAM as well as their performance. The prototype design will be explained together with the studied parameters of this research. The improvement in performance and efficiency of this HYDRAM are also observed and discussed.

Chapter 5 is the conclusion for the overall project. This chapter will present the overview of the progress as well as the effort done in this project. Findings and contributions of this project will also be included in this chapter. In addition to the current effort, this chapter will provide future goals of this project which explain future planning of project development.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Literature Review

Water is generally a very basic necessity for all human life as well as for all life. With regards to piped water, the percentage of piped water in rural areas of peninsular Malaysia increased from 42% to 96% in 2020. However, Sabah and Sarawak lagged behind with only 62% in 2020 (Karunakaran et al., 2021). Among the factors that contribute to the lower coverage of piped water in Sabah and Sarawak are due to the undulating topography that makes cost providing infrastructure are very expensive. In addition, the sparsely dispersed rural population of the two states makes it uneconomical to run water pipes over large areas to reach remote, dispersed villages.

To overcome the structural problems mentioned above, this research project comes in handy as the functionality of the hydraulic ram pump is fairly reliable as the sustainable supply system alternative to supply water to uphill rural areas. This research project also hopes to reach out to those rural communities which have been left out in the development efforts.

Ram pumps are considered ancient legend technology because they have been utilized all throughout the world for the last two centuries, long before electricity and internal combustion engines were invented. Multiple variations to design and basic configuration have been tried on the hydraulic ram pump. Other than promoting awareness for sustainable technology, HYDRAM is great potential as one of the simplest pumping devices in hilly remote areas which are no water supply coverage especially in Sabah and Sarawak. This hydraulic ram pump can be firmly built by anyone as the system will have the same basic components despite the variation of shapes and sizes.

In this chapter, the design of hydraulic ram pump, including the working principle are reviewed. This chapter also reviews other design parameter to improve the efficiency of HYDRAM based on previous researched that has been done. Since the availability of hydraulic ram pump is from 200 years ago, there are multiple parameters on the design that have been studied before yet makes it challenging to explore new parameters on the design of HYDRAM to increase its performance and efficiency. In a nutshell, the knowledge in this field is primary and essential in order to complete this project.

2.2 Review of Hydraulic Ram Pump System

In this section, the general design of hydraulic ram pump is explained. To get into more detail, the working principle will also be reviewed. Since the HYDRAM are made up of several components and two moving parts, it is compulsory to review each component to understand how it works.

2.2.1 General Design of Hydraulic Ram Pump

The available design and mechanisms of a ram pump is very simple with only two moving parts and an air chamber to smoothen out those sharp spikes in pressure due to water hammer phenomenon.

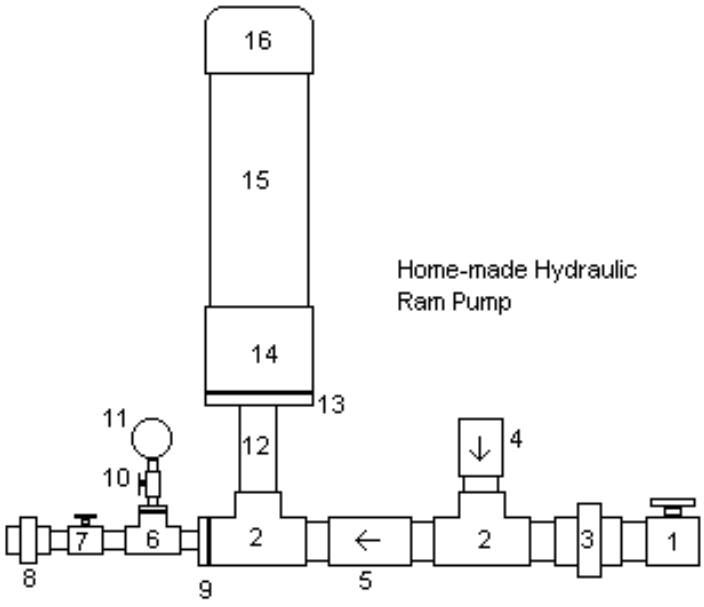

Figure 2.1 : Available design of HYDRAM

Source : (Smith & Service, 2017)

Table 2.1: Material Description for the Hydraulic Ram Pump

Item Number	Description	Item Number	Description
1	Globe valve (inlet)	9	Bushing
2	Circular Tee	10	Pipe cock gate valve
3	Union Fitting	11	100 Psi Pressure gauge
4	Swing Check Valve	12	Nipple
5	Spring Check Valve	13	Bushing
6	Circular Tee	14	Coupling
7	Globe Valve (outlet)	15	PVC Pipe (Air Chamber)
8	Union (to delivery pipe)	16	PVC glue cap

Source : (Smith & Service, 2017)

This is a fairly simple design that only requires basic plumbing fittings to be assembled. The air chamber functions as a well's pressure tank, buffering shock waves and maintaining a constant output pressure with compressible air caught in the tank.

For the pump to work properly, the fittings for numbers 1 – 4 in figure 2.1 must be the same size as the driving pipe. The drive pipe's supply spring check valve and nipple (item number: 12) should also be the same. Even if they are lowered to the same size as the delivery pipe, the pump should still work.

The globe valve, item 11 in table 1 is used to turn on or off the pump, as well as to turn off the water flow if the pump must be fixed or maintained. While the pump is starting, the globe valve for item number seven is turned off, then gradually opened to allow water to flow after the pump has started.

Item number 10 what is the name of the pipe The cock is optional, but it is required since it can be used to switch stop the flow and safeguard the pressure gauge from failure due to repetitive pulses over time.

2.2.2 Water Hammer Phenomenon

Generally, most liquids are incompressible or hardly compressible, which implies the volume of the liquid does not change regardless of how much pressure is applied. This can be useful for instance in hydraulic cylinder. However, the lack of spring force or 'springiness' can also lead to catastrophic failure of pipe systems.

If all the water in the pipelines of a city or a house were added up, it takes up a significant amount of space. As a result, all that water has momentum as it moves through a pipe. For example, if a valve was abruptly closed, the movement will come to a halt, and all the momentum will have nowhere to go because it is not compressible. Instead of being absorbed, the quick change in velocity causes a pressure spike that travels through the pipe as a shockwave. Water hammer is the term for this.

A shift in momentum can cause a surge in pressure in large diameter pipelines that can be hundreds of kilometers long, rupturing the pipe or causing

significant damage to other portions of the system. A bomb is another phrase for when a large pressure spike ruptures in a sealed container. Water hammer can be just as dangerous as a bomb.

Water hammer, contrary to popular belief, is a common issue for engineers. Nonetheless, there is a method to put this generally unfavorable impact to good use, particularly in the hydraulic ram pump.

In the HYDRAM, water goes into the pump and out of the waste valve as soon as it opens. The running water, however, finally causes the waste valve to slam shut as it builds up speed. The water in the pump came to a stop, transforming kinetic energy into pressure. This is where the phenomenon of water hammer took place in the hydraulic ram pump as the pressure spike opens the second check valve which is the delivery valve and forces water entering the pump into the delivery pipe. Each time the valve slams shut, the process repeats itself, pumping the water and wasting the rest.

2.3 Working Principle

Since HYDRAM is not depending on fuel or electricity, the energy required to lift the water to a higher elevation comes from gravity, which causes the water to slide downhill. That is why hydraulic ram pump is very convenient to use at hilly areas with an abundant source of water. The working principle of a hydraulic ram pump can be divided into three phases.

The first phase is when the water from the source flows into the ram pump through the inlet pipe. Initially, the waste valve and the delivery valve are closed. The waste valve must be manually opened by simply giving the valve a poke using a finger. Once the waste valve is open, water enters and passes in the direction of the non-return valve which also known as check valve that is closed. Hence, water comes out from the waste valve as indicate by the blue arrow shown in figure below.

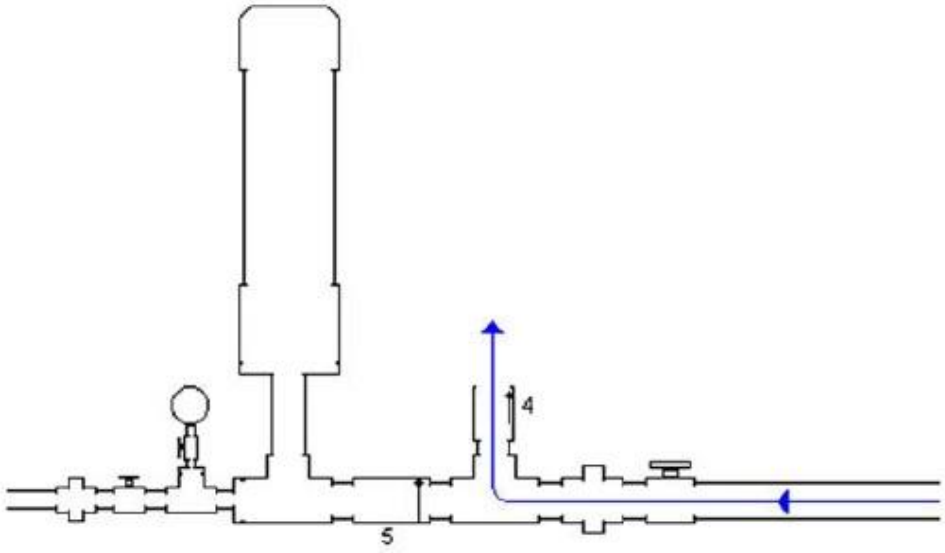

Figure 2.2 : Phase one of working principle for HYDRAM

Source : (Smith & Service, 2017)

Phase two starts once the water flowing slam shut the waste valve, creating water hammer phenomenon. The high-pressure spike indicated by the red arrow in the figure below forces some water in the blue arrow to ether through the check valve into the air chamber. Air is present in the air chamber and the water pressure causing the compression of air increase. The diaphragm placed inside the air chambers starting to move downwards due to the arising of water pressure inside the air chamber. Implying that water is incompressible fluid, therefore it starts to find a way to move out of the chamber.