THE PERFORMANCE AND EFFICIENCY RATING EVALUATION OF A HYDRAULIC RAM PUMP PROTOTYPE WITH HEIGHT VARIATIONS

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ABSTRACT

Initially, the prototype of a hydraulic ram pump was built using affordable tools and materials. Next, the experiment is divided into two stages. First, the experiment will evaluate the effect of different elevations of output pipe using three height variations (2, 3, 4 meters respectively) and two input discharge variations (7 and 8 liters/min respectively). The data collected from the experiment will yield six combinations of output discharge data which then be analyzed and discussed later in this paper. Second, the efficiency of this hydraulic ram pump will be calculated using a simple efficiency formula using the data output of the previous experiment. After that, the correlations between the height of the output pipe, input discharge, and efficiency will be concluded. Finally, the results showed that the highest efficiency (7.7%) was achieved using 8 L/min input discharge combined with 2 meters elevated output pipe. While the lowest efficiency (1.4%) was achieved using 7 L/min input discharge combined with 4 meters elevated output pipe.

Keywords**:** Hydraulic ram; hydram; hydram pump; efficiency; height variations

INTRODUCTION

The precursor of the hydraulic ram pump and the working principle behind the device has been invented since more than 2 and a half centuries ago by John Whitehurst, a scientist from Cheshire, United Kingdom. Unfortunately, the details of the device were still obscure and thus, he did not patent it.[1] Around 20 years later, the first automatic hydraulic ram pump device was invented by Joseph Michel Montgolfier, a Frenchman known as the co-inventor of the hot air balloon, in 1796.[2] His friend Matthew Boulton made out a British patent on his behalf in 1797 and then in 1816, the sons of Montgolfier obtained another British patent for an improved version of the automatic hydraulic ram pump. Since then, the hydraulic ram pump or hydram pump for short has been continuously developed and used in many applications;

e.g ., farm irrigation system, clean water source, etc.

In recent times, hydraulic rams have been less used because of their low water-lifting efficiency. Instead, the centrifugal pumps are replacing the hydram pumps, which require energy to work.[7] However, despite the declining popularity of hydraulic rams, there are still many people who want to utilize this ingenious device because of its environment-friendly, self-sufficient, and little maintenance cost.

Additionally, the idea behind a working hydram pump is actually very simple. Basically, the hydram pump consists of three vital parts, a waste valve, a delivery valve and an air chamber. These parts are then connected with pipes as shown in Figure 1.

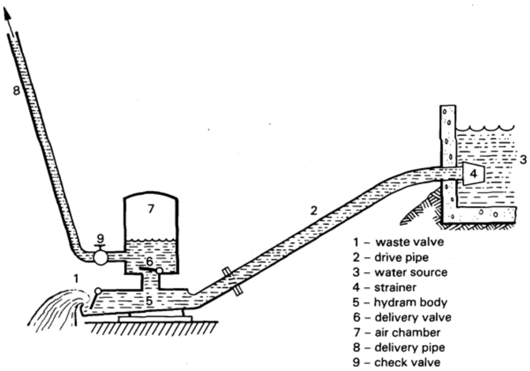


Figure 1. Schematic diagram of a hydram pump

Practically, the sequential processes of a hydram pump are intermittent because of the opening and closing activity of the waste and delivery valves.[5] There are 3 phases during these processes which happens repeatedly forever unless the water deposit ran out and/or the input/output valve is closed.

1st phase: The water flows from the source down to the hydram pump carrying along its kinetic energy and exiting at the waste valve. While at the same time pushing the waste valve to the exit hole and close it momentarily. This sudden halt movement then creates a *water hammer* effect to the whole water flow which then opens up the delivery valve. Water hammer effect is a phenomenon where the water flow is suddenly brought to rest by closing the waste valve which results in a sudden increase in pressure in the pipe.[6]

2nd phase: Once the delivery valve is pushed open to the top, the air chamber which connected to it will begin to be filled with water. At the same time, forcing the air inside the chamber to get pressurized and converting all those kinetic energy into accumulated potential energy.

3rd phase: After a short period, the accrued potential energy in the form of pressurized air inside the chamber starts to overwhelm the kinetic energy carried by the water. It pushes down the delivery valve to close it back, while at the same time delivering the water inside the air chamber through the output pipe to a determined height. At this point, the waste valve is open again and the process repeats.

Hence, because of this efficient and simple 3-phase cycles of a hydram pump, the installation of this tool is very attractive for people who live in remote areas, especially for them who happens to have their source of water several meters at a lower level than their houses and fields. If it is installed with the correct design, solid pipes and paired with resilient valves and thick air chamber, the hydram pump should last for a very long time without maintenance.

This study aimed to construct a small prototype of a hydram pump with correct design. It was built using easy-to-find parts, e.g., ordinary PVC pipes, a pair of valves, and a used oil drum as a water tank. This miniature hydram will then be used to simulate a real working hydram pump and to find an optimal value of water coming from the output pipe by changing the height and water discharge value.

LITERATURE REVIEW

There are quite a few compelling examples which are worth to be mentioned as some of them are real hydram pumps applied directly in real-world conditions helping the locals getting clean water or irrigating the crops. While at the same time, dealing with the efficiency and elevation problem.

One of the application examples is coming from (Intachot, Saehaeng, Max, Müller, & Spreer, 2015) who conducted a research experiment with a hydram pump in Northern Thailand region. They installed one unit of a hydraulic ram at a foothill location at Ban Ha, Samoeng District, Chiang Mai Province, and connected the device to an automatic low-pressure farm irrigation system to irrigate a small plot of coffee trees. The hydraulic ram operated fully automatic over six weeks and without maintenance, supplying the field enough quantities of water during this period at a pumping efficiency of 44%.[3]

Another application example is coming from (Asmaranto, Widhiyanuriyawan, & Anwar, 2017) who conducted a research experiment in Gunungronggo Village located about 15 KM east of Malang City, Indonesia. Topographically, this area is dominated by hills with a very steep slope and a high rate of rainfall. Thus, it has the potential of a quite large water source, and the locals named it Sumber Jenon. The availability of water discharge in Sumber Jenon is pretty massive, reaching a number around 300 liters/second. However, it is still not a guarantee to provide the locals to get clean water, although geographically the water source is close to the community area. Installations of some simple hydram pumps here have been able to help the locals to fill the reservoir directly from the water source.[4]

Moreover, there is also a study conducted on the hydraulic ram using a simulation program called ANSYS CFX. This simulated hydram pump was designed using CATIA software. Three designs were made and tested in the experimental study. Results conclude that the best design reached the target head of 3 m with 15% efficiency and flow rate of 11.82 liters/min. This study also found that higher pressure can be obtained by reducing the diameter of the pressure chamber and increasing the supply head.[5]

Finally, there is a new type of hydram pump which was invented, patented, and crafted in Madagascar. The invention is called Raseta pump, based on the name of its inventor Rasetarivelo. The quirk difference of this hydram pump over the conventional ones is that there is a spring in each of the waste and delivery valves. Additionally, the usual air chamber is replaced by a chamber with four springs.[10]

RESEARCH METHODOLOGY

This study was carried out on a mechanical engineering field laboratory located inside the University of Bangka Belitung. A hydram pump prototype was then explicitly built to obtain flow rate data using a combination of 3 (three) height variations of the output pipe (2, 3, 4 meters respectively) and 2 (two) water input discharge variations (7 and 8 liters/mins respectively).

The design can be seen in figure 2, and the fully-made hydram pump can be seen in figure 3, along with its components.

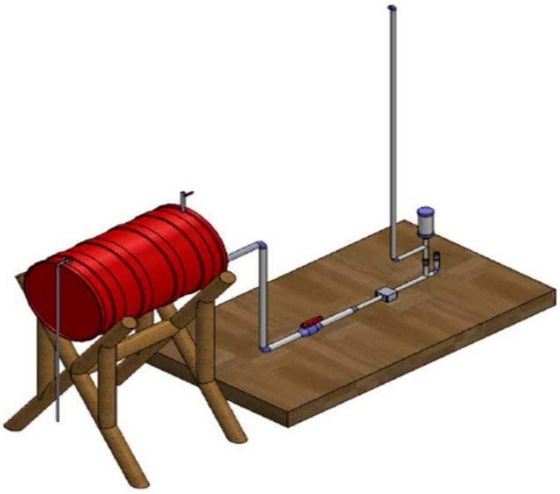


Figure 2. Hydram pump design

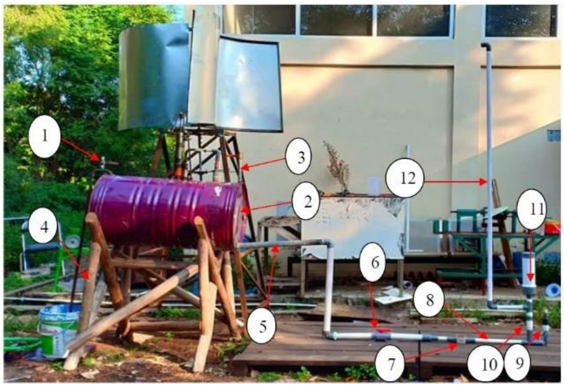


Figure 3. Fully-made hydram prototype

Components Name:

1. Water source valve (input)
2. Water source tank
3. Water source valve (output)
4. Support beam
5. Water source pipe (output)
6. Hydram valve (input)
7. Flow meter
8. Hydram pipe (input)
9. Waste valve
10. Delivery valve
11. Air chamber
12. Hydram pipe (output)

Finally, the efficiency of the hydram pump will then be calculated using a simple formula

$$\eta = \frac{Output}{Input} \times 100\%$$

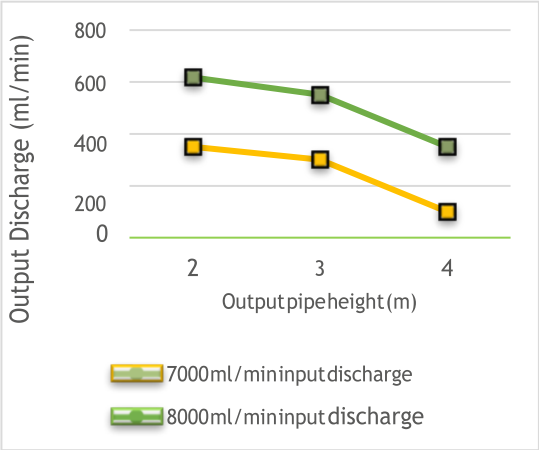
RESULTS AND DISCUSSION

There was a total of 6 combinations using the height and the input discharge variations, 7 liters/mins discharge with (2, 3, 4 meters of elevation), and 8 liters/mins discharge with (2, 3, 4 meters of elevation). Here below are the results table and graphic chart.

Table 1. Output Discharge Table

No	Input Discharge	Height	Output Discharge
1	7 L/min	2 meters	350 ml/min
	8 L/min	2 meters	617 ml/min
2	7 L/min	3 meters	300 ml/min
	8 L/min	3 meters	550 ml/min
3	7 L/min	4 meters	100 ml/min
	8 L/min	4 meters	350 ml/min

Table 2. Output Discharge Chart



As we can see at the graphic chart, the correlations between the input discharge, output pipe elevation, and output discharge are almost linear. This chart means that the higher height of the output pipe equal to the decreasing of the output discharge. While increasing the input discharge will yield a definite higher output discharge.

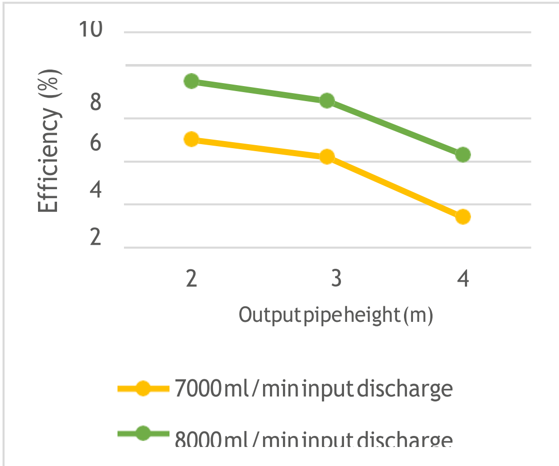
An almost similar conclusion also comes from Dhaiban (2019). His study says that there is an inverse relationship between the head and the amount of flow rate at the outlet. The hydram pump takes in water at a relatively low pressure with high flow-rate and outputs water at a higher hydraulic head with lower flow-rate.[8]

Furthermore, the efficiency calculation table and graphic chart is provided below

Table 3. Efficiency Table

No	Input Discharge	Height	Output Discharge
1	7 L/min	2 meters	5%
	8 L/min	2 meters	7.7%
	7 L/min	3 meters	4.2%
2	8 L/min	3 meters	6.8%
3	7 L/min	4 meters	1.4%
	8 L/min	4 meters	4.3%

Table 4. Efficiency Chart



If we look at the graphic chart, we can safely conclude that the efficiency of a hydram pump is diminishing the higher the output pipe. The efficiency is also directly proportional to the input discharge because the efficiency rate is rising if we increase the input value.

Another but more complex study about hydram pump efficiency has been done by (Fatahi-alkouhi, Lashkar-ara, Keramat, 2018). Their research was to determine the efficiency of the ram pump using the nonlinear regression of experimental results of specific studies. They concluded that there is a large difference between the experimental measurements and prediction of a computer program in the high delivery head. However, since the proposed equation has little difference with the experimental measurements, then the method comparison can still be used for estimation theory.[9]

CONCLUSION

The prototype of a hydraulic ram pump was assembled using components that were easy to find, and the total cost was quite cheap. The prototype was then used to execute several experiments using pre-determined data and variations.

The results showed that there is a direct relationship between the input discharge rate with height and efficiency. The higher the height of the output pipe, then both the efficiency and output discharge will drop accordingly.

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