# Performance Testing of a Hydraulic Ram Pumping (Hydram)

PHYOE MIN THAN[1], CHO CHO KHAING[2], AYE MYA THANDAR[3]
*1 Department of Mechanical Engineering, Technological University (Hmawbi), Myanmar*
*2, 3 Department of Mechanical Engineering, Technological University (Magway)*

***Abstract- The hydraulic ram is a mechanical water pump that suitable used for agriculture purpose. It can be a good substitute for DC water pump in agriculture use. The hydraulic ram water pumping system has ability to pump water using gravitational energy or the kinetic energy through flowing source of water. This project aims to develop the water ram pump in order to meet the desired delivery head up to 3 meter height with less operation cost. The design head of 9 m and flow rate of 1.693 $m^3/s$. The results from this study show that the less diameter of pressure chamber and higher supply head will create higher pressure.***

***Indexed Terms- Hydraulic ram, Design, Pump, Flow Rate, Head.***

## I. INTRODUCTION

The concept of hydraulic ram pump (HRP) was developed 200 years ago. In a HRP, no external powers are required to drive water. Water is pumped from a particular head at a high flow rate and comes out with a higher head but at a lesser flow rate because of the water hammer effect. The system consists of a drive pipe, waste valve, discharge valve, air (pressure) chamber, and delivery pipe (Figure 1). The only moving parts of the system are the waste valve and the discharge valve which operate from the fluid dynamic actions of the pumping cycle [1].HRP is one of the simplest and the most environmentally friendly devices for domestic or agricultural use [2, 3]. There are a lot of people in a lot of countries that build and use this kind of pump. Details of these are given by Watt [4, 5], Schiller [6], Browne [7], andInthachot et al. [8].

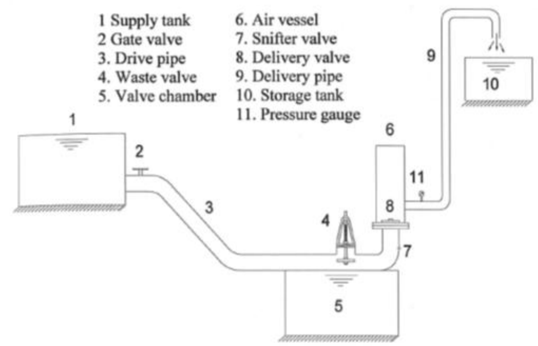


Fig.1. The Main Component of Hydraulic Ram Pump

There are a number of studies which have been done to improve the design of HRPs by experimental, theoretical, and numerical approaches. A short description of the function and history of HRPs can be found in Basfeld and Miiller [9]. Experimental and theoretical investigations on HRPs were done by Lansford and Dugan [10] to determinethe rate of pumping and wasting for any conditions of operation. The dominant factor controlling the functioning of the HRP is the velocity in the drive pipe necessary to cause the waste valve to start closing, and its value is fixed by the waste valve setting. They also reported that the maximum efficiency varied little with various adjustments of the waste valve, except perhaps for extremely high values of velocity in the drive pipe, at which the efficiency was somewhat lower. Details of the HRP working cycle are also described.

## II. LITERATURE REVIEW

In 2007, Shuaibu [5] has designed and fabricated hydraulic ram pump that capable to lift the water to reach 2 m of head pump from depth of 2 m below the surface without any external energy required. The supply head was 1.5m and delivery head was 2.87m. The result shows the volume flow rate of the derived pipe and the power was $4.5238\times10\text{-}5m2/s$ and 1.273 kW respectively. The efficiency of this water ram is about 57.3%. The author found that the total cost for the design and fabrication of hydraulic ram pump is cheaper than the current pumps.

In addition, the other authors [6] have investigated hydraulic rams with self-built valves with two size of pressure chamber for high water supply. The aim of this investigation was to construct a reliable and low-cost ram. An efficiency of 44% was achieved for the performance of the hydraulic ram. However, there was no significant difference in in term of system efficiency for the design with the large (3.6*l*) and medium size (2.3*l*) pressure chamber (33.1% and 32.6%, respectively).

Besides, the result from the previous study shows that the pressure of the output increases as the drive pipe length increases. The drive pipe length of 2 meter the discharge at the outlet is maximum compared to the other two cases .this design also produces a power of 0.73 kW and the efficiency of 59.5% [4].

Furthermore, Balgude [7] presented the techniques and guidelines in designing a hydraulic ram pump. There are three essential factors need to considers in order to determine the quantity delivered by the hydraulic pump. These factors could be represented in the distance between the heights of the water source to the ram pump level, the distance between the desired place height and the ram pumpand the volume of water source which are the basic factors of hydraulic ram pump. The current pumping system is powered by household electricity (AC water pump) and the cost will be increased due to the higher electricity consumption. In some cases in the agricultural field, the water needs to be supplied at different height of trees and different places that are far from the water source. Besides, the existing DC water pump only can pump the water to 1.5 m height. Therefore, a water ram pumping system is proposed to deliver the water at height higher than 1.5 m.

## III. WORKING PRINCIPLE OF THE HYDRAULIC RAM PUMP

Hydraulic Ram Pump has a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases. These are acceleration, delivery and recoil.

Initially, water start flow through the drive pipe and And escapes out the impulse valve as shown in Fig 2.a. As the water accelerates its pressure overcomes the weight of the impulse valve, causing it to close suddenly as shown in Fig.2.b. The water pressure suddenly stopped causes a very high pressure called water hammer.

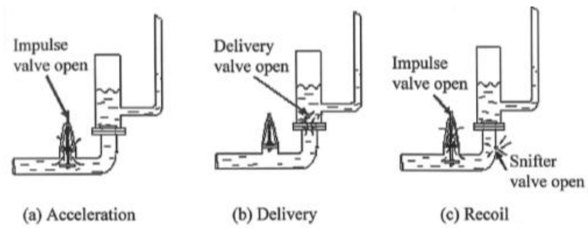


Fig.2. Operation of the Hydraulic Ram Pump

Some of the water is forced through the delivery valve into the air chamber, compressing the air until the water pressure is deleted. The compressed air acts like a spring which closes the delivery valve and forces the water up the delivery pipe as shown in Fig 2.c. When the delivery valve closes suddenly, it creates a pressure surge going up the drive pipe which takes the pressure off the impulse valve, allowing it to fall open due to its own weight as shown in Fig.2.c. The water again flows out the impulse valve as the cycle repeats itself. When the water enters the air chamber a bit of water is wasted through the air valve but on the closing of the delivery valve a bit of air enters through the air valve due to the partial vacuum that is created by the water rebounding up the drive pipe.

## IV. PUMP PERFORMANCE

A HRP is shown in Figure 1. The pump utilizes the energy from a supply head, $H_s$ with a large quantity of water, $Q_s$ to a delivery head, $H_d$ which is higher than the supply head with a small quantity of water, $Q_d$ by rapid closure of the waste valve. The operation is continuous with no other external input and the flow is intermittent. ) e power used to drive the pump is

$$\mathrm{Pow_s} = \rho g Q_s H_s$$

The power added to the fluid is

$$\mathrm{Pow_d} = \rho g Q_d H_d$$

The efficiency of the pump is defined as

$$\eta = \frac{Pow_d}{Pow_s} = \frac{\rho g Q_d H_d}{\rho g Q_s H_s} = \frac{Q_d H_d}{Q_s H_s} = Q^* H^*$$

Where $H^*$= head ratio= $H_d/H_s$ and

$Q^*$ = flow rate ratio = $\frac{Q_d}{Q_s} \approx 1 - \frac{Q_w}{Q_s}$

The flow-rate ratio is high by reducing water loss at the waste valve ($Q_w$), and the head ratio is high by increasing the momentum of the water flow in the supply pipe. For this purpose, the effect of waste valve opening and closing on pump performance is investigated in order to reduce water loss at the waste valve and increase the pumping pressure.

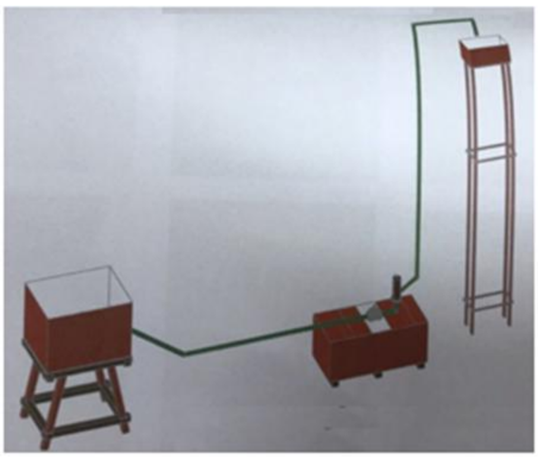

Fig. Hydraulic Ram Pump 3-D using AUTO CAD

In this research, the hydraulic ram pump is constructed and experiments are conducted on 55, 60, 70 and 75 beat per minute. The performance testing of this hydram is made behind the main building of the MTU and their test result are shown by the following Table and Figure.

Table 1.Summary of Experimental Hydram Performance with Constant Head and Variable of Number of Beat per Minute (Stroke Length=0.0381)

| No. | H (meter) | h (meter) | $Q_d$ ($m^3$/sec) $\times 10^{-3}$ | $Q_p$ ($m^3$/sec) $\times 10^{-4}$ | No. of Beat per min | Eff. (%) |
|---|---|---|---|---|---|---|
| 1 | 1.524 | 9.144 | 2.57 | 1.693 | 55 | 46 |
| 2 | 1.524 | 9.144 | 2.439 | 1.788 | 60 | 51 |
| 3 | 1.524 | 9.144 | 2.358 | 1.896 | 65 | 57 |
| 4 | 1.524 | 9.144 | 2.135 | 1.96 | 70 | 64 |
| 5 | 1.524 | 9.144 | 2.12 | 1.859 | 75 | 61 |

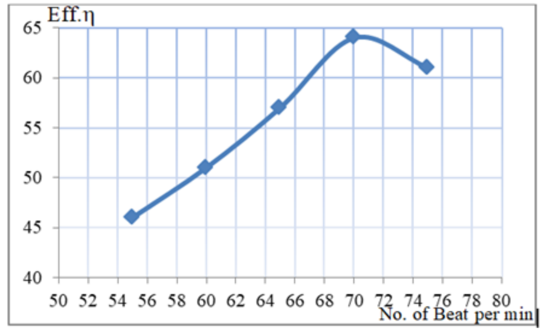


Fig.3. Efficiency and Number of Beat per Minute Relationship Curve

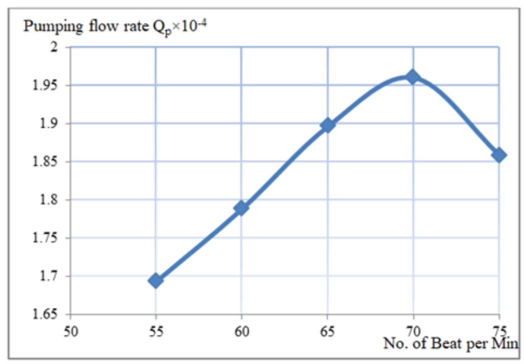


Fig.4. Pumping Flow Rate and Number of Beat per Minute Relationship Curve

In Fig. 3 and 4 show the pumping rate and efficiency curve in the graphical form. Every hydram occur the maximum pumping rate between the beat 65 and 75 per minute. If the beat per minute is fewer than 65, the beat of the valve will be stronger, so, the waste water is more and the pumping flow rate is less. When the number of beat per minute is higher than 75, the beat of the valve is weaker, Moreover, the waste water and pumping rate is less. From experimental test result, the maximum pumping rate occurs at the regular beat of the valve 70 per minute.

Table 2. Experimental Hydram Performance with Gallon per Day and Variable of Number of Beat per Minute (Stroke Length=0.0381)

| No. | H (meter) | h (meter) | $Q_d$ ($m^3$/sec) $\times 10^{-3}$ | $Q_p$ ($m^3$/sec) $\times 10^{-4}$ | No. of Beat per min | Gallon per day |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1.524 | 9.144 | 2.57 | 1.693 | 55 | 1543 |
| 2 | 1.524 | 9.144 | 2.439 | 1.788 | 60 | 1630 |
| 3 | 1.524 | 9.144 | 2.358 | 1.896 | 65 | 1694 |
| 4 | 1.524 | 9.144 | 2.135 | 1.96 | 70 | 1800 |
| 5 | 1.524 | 9.144 | 2.12 | 1.859 | 75 | 1728 |

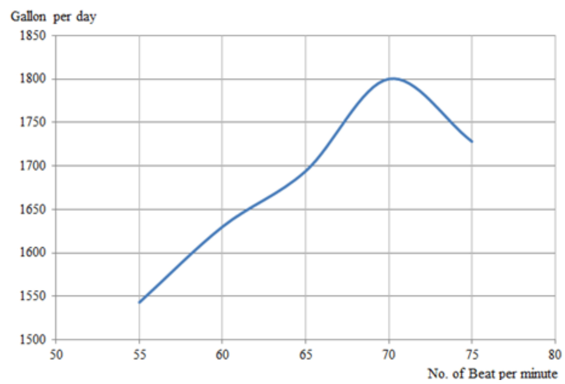


Fig.5. Gallon per Day and Number of Beat per Minute Relationship Curve

Table 3. Theoretical Performance with Constant Head and Variable of Number of Beat per Minute (Take Length =0.0381)

| No. | H (meter) | h (meter) | $Q_d$ ($m^3$/sec) $\times 10^{-3}$ | $Q_p$ ($m^3$/sec) $\times 10^{-4}$ | No. of Beat per min | Eff. (%) |
|---|---|---|---|---|---|---|
| 1 | 1.524 | 9.144 | 2.57 | 1.693 | 55 | 38 |
| 2 | 1.524 | 9.144 | 2.439 | 1.788 | 60 | 42 |
| 3 | 1.524 | 9.144 | 2.358 | 1.896 | 65 | 46 |
| 4 | 1.524 | 9.144 | 2.135 | 1.96 | 70 | 50 |
| 5 | 1.524 | 9.144 | 2.12 | 1.859 | 75 | 53 |

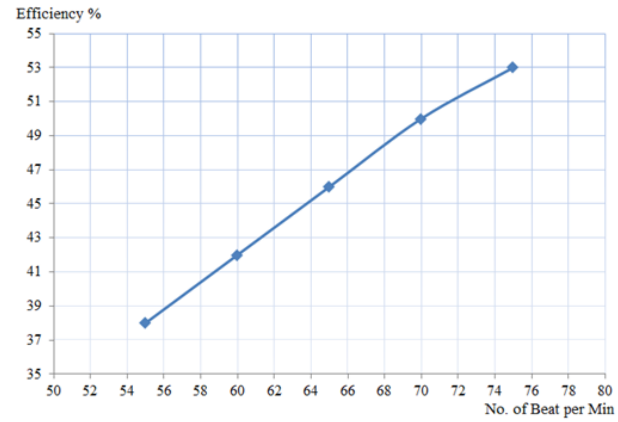


Fig.6. Efficiency and Number of Beat per Minute Relationship Curve

In a hydraulic ram pump, the momentum produced by a flow of water from a low supply head and used to pump a small part of the flow to a higher head above the waste vale opening. The rapid opening and closing of the waste and delivery valve create pressure surge which are superimposed on the major effects of steady pressure difference and kinetic energy of the flow in the drive pipe. The pressure fluctuations create compression waves which are superimposed on the velocity changes in the drive pipe. Considering all these effects would lead to a very complex analysis. Theoretical models that predict the hydram performance accurately are therefore lengthy and complex which reduces their usefulness to practical designers and users of hydram. The approximate analysis presented in this paper is based on the average effects of the supply head, atmospheric pressure, delivery head and frictional forces. Only the main effects of the hydram action are considered and the model derived is simple to understand and use. The major waterhammer effects are considered together with the friction head losses. The details of recoil and effects of elasticity of valve materials neglected.

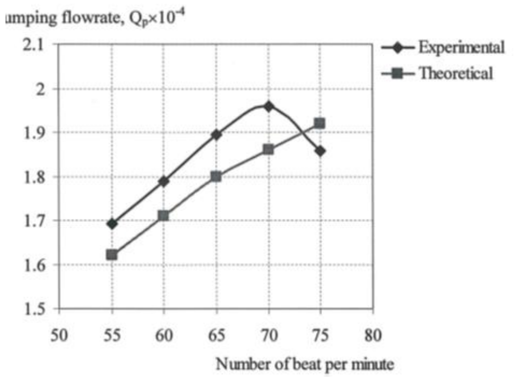


Fig.7. Theoretical and Experimental Efficiency and Number of Beat per Minute Curve

In Fig.7. Shows the comparison between calculated and experimental efficiency for the variable of number of beat per minute between 55 and 75. Experimental test graph shows the maximum peak point at 70 beat per minute and then the graph slightly decrease. In theoretical graph, it can be seen that the trend occurs slightly increase. According to the graph, the experiment results are higher than the calculated results.

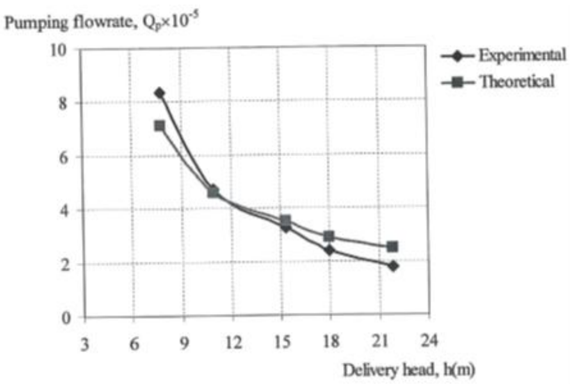


Fig. 8. Theoretical and Experimental Pumping Rates of the Dr. Slack Hydram

In Fig. 8. Shows the comparison between theoretical and experimental pumping rates of the Dr. Slack Hydram. In this graph, experimental pumping rate is higher than the theoretical for low head. And then, experimental is lower than the theoretical for high head. It is similar in this research hydram.

V. PERFORMANCE TESTING BY MATLAB PROGRAM

The following figures show the result curve of the curve of the pumping flow rate and efficiency by using the using the variable of drive pipe diameter, length and delivery head by Matlab program. According to the figures, the higher the drive pipe diameter and length within the limit, the higher the pumping flow rate and efficiency. When the drive pipe length falls outside the limited both performance and stability are impaired. Ram pumps with very long drive pipes will operate satisfactorily in many situations but are inefficient and unnecessarily expensive.

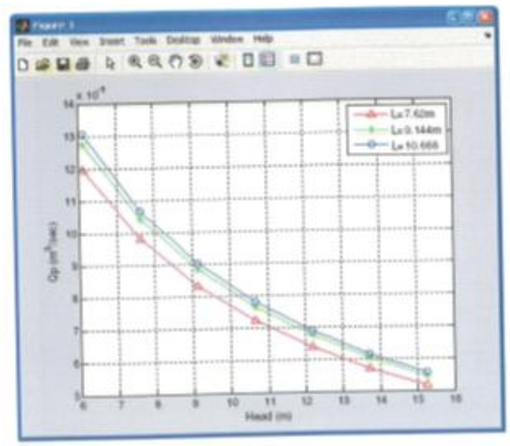

Fig.9. Pumping Flow Rate Curve for Variable of Delivery Head with the Diameter of 0.0508 m

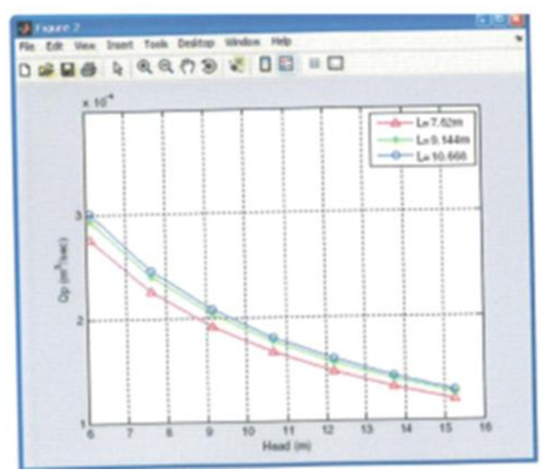

Fig.10. Pumping Flow Rate Curve for Variable of Delivery Head with the Diameter of 0.0762 m

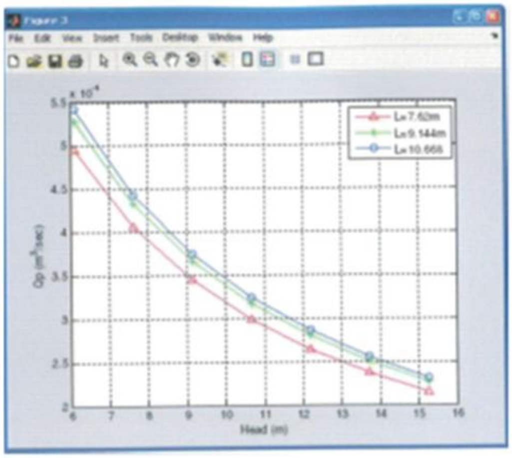


Fig.11. Pumping Flow Rate Curve for Variable of Delivery Head with the Diameter of 0.1016 m

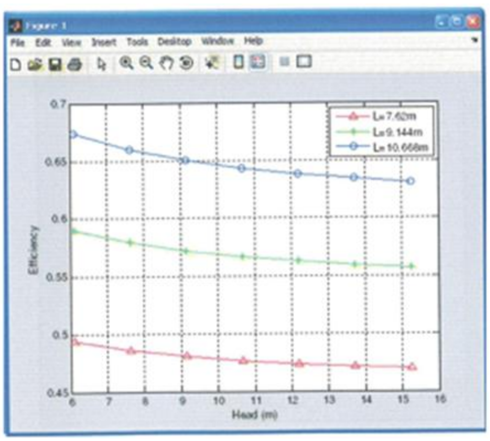


Fig.12. Efficiency Curve for Variable of Delivery Head with the Diameter of 0.0508 m

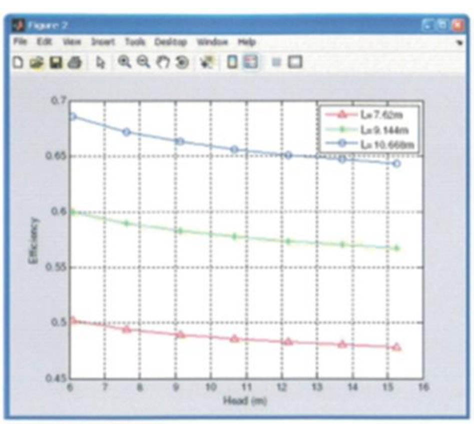


Fig.13. Efficiency Curve for Variable of Delivery Head with the Diameter of 0.0762 m

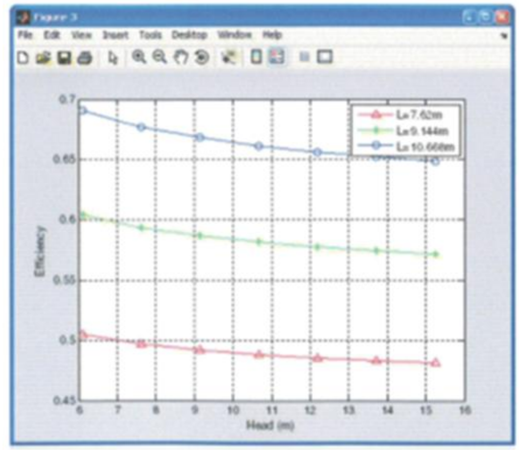


Fig.14. Efficiency Curve for Variable of Delivery Head with the Diameter of 0.1016 m

## VI. CONCLUSION

In this paper, the delivery head for hydraulic ram pump is 9.11 mm to study the performance testing under 1.524 m head and the main parts of hydram its principal operations have been discussed. Some parameters are assumed to calculate the design of 9.144m (delivery head). Impulse valve and delivery valve diameter are 0.0762 m. The drive pipe and delivery pipe diameter are 0.0762 m and 0.0381 m.

In this research paper, number of beat is taken 70 and stroke length is taken 0.0381 m in order to obtain maximum pumping range. The hydram was designed 1.524 m (drive head) with supply flow rate 0.0026 m3/sec to pump water to the 9.144 m (delivery head). The dimensions of the air vessel are diameter 0.1524 m and length 0.4318 m.

The mechanism of a hydram and its simple mechanical design and maintenance requirements make it a unique water pumping machine potentially suitable for small scale water supply schemes in developing countries. Only a spring balance, stop watch and a calibrated cylinder or pail are sufficient to determine factors for the design of a simple efficient hydraulic ram pump.

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