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Design, Fabrication and Performance Analysis of Hydraulic Ram Pump

Prashidda Kharel [a], Sunny Kumar Sah [b], Durga Tandon [c],
Khadka Prasad Timilsina [d], Prakash Giri [e]

[a, b, c, d, e] *Department of Mechanical Engineering, Pashchimanchal Campus, IOE, Tribhuvan University, Nepal*
[a] prashiddakharel@gmail.com, [b] sunnygbp1@gmail.com

Abstract
The study describes the techniques for fabrication and performance analysis of a Hydraulic Ram Pump (HRP) which is powered by water falling from a small height to lift a fraction to a higher elevation. The pump was fabricated using an inlet diameter of 25 mm whereas the outlet diameter of parts used is 18.75 mm. The size of the waste valve and spring valve was 18.75 mm and the inlet pipe length was 3 m. The mass of the impulse/waste valve used in the pump was 94 grams. Preliminary testing was done to confirm the pump's operation feasibility and different experimental data values were obtained after further testing. Testing was done by varying input and output heads to obtain different data for pump parameters. Performance curves were plotted in the graph for obtained data values to analyse the characteristics of pump parameters. The designed efficiency of the pump was initially assumed to be 50 percent and the experimental value of efficiency was calculated for each observed data. Both practical efficiencies with loss and theoretical efficiency excluding loss were calculated. The maximum value of experimental efficiency was 25 percent and the value of theoretical efficiency averaged to 46.205 percent. Obtained values of theoretical efficiency fell under the confidence interval of the t-test with a 5 percent significance level when statistical analysis of the project was done which proved the project to be efficient technically.

Keywords
Hydraulic Ram Pump, Waste Valve, Water Hammer, Unplasticized Polyvinyl Chloride, t-Test

1. Introduction

HRP is a completely automatic device that utilizes the energy contained in the flowing water to pump a part of the water to a higher elevation above that of the source or transport the water to a long distance from the source. It is a simple mechanical device and it operates continuously with no external energy source. HRP is a simple mechanism that consists of two moving components which are the impulse (waste) valve and the spring (delivery or check) valve and an air pressure chamber. It operates when the waste valves and spring valves open and close cyclically[1]. Being a country with several river sources but unimproved irrigation systems and inadequate power supply installation of Ram Pumps provide adequate domestic water supply that is scattered in rural agriculture and other household need in places where it is difficult to serve water by conventional means or other energy sources are unavailable[2].

2. Problem Statement

Hydraulic Ram Pumps utilize the flow of water to pump water to higher altitudes. Normally they are constructed using galvanized steel (GI) pipes. Unplasticized Polyvinyl Chloride (UPVC) pipes are lighter and corrosion-resistant than steel pipes. There are changes in efficiency due to frictional as well as other losses because UPVC has different characteristics than a GI pipe. The size of the waste valve also plays a vital role in the efficiency of the pump[3].

3. Research Objectives

The main objective of the research is to fabricate and conduct a performance analysis of the Hydraulic Ram Pump.

The specific objectives are:

- To fabricate and operate a UPVC Hydraulic Ram Pump model for water pumping.
- To calculate the efficiency of the model and verify it with the design (assumed) efficiency at 50 percent.
- To carry out performance analysis of pump model based on experimental data.

4. Limitations

- UPVC pipe used in fabrication has higher losses than GI pipe.
- Weight on the commercial waste valve had to be added to balance the weight for reopening.
- Pressure loss due to contraction and expansion of UPVC pipe was not considered.

5. Methodology

Initially, the Hydraulic Ram Pump was fabricated using Unplasticized Polyvinyl Chloride(UPVC) pipe according to the manual provided by UNICEF[4]. Preliminary testing was done to check if the pump worked. When the commercially available valve did not provide a successful result, the waste valve was modified. After a successful feasibility study, testing was done on the pump. Test data were obtained by varying input and output heads. From the obtained data, the volumetric efficiency of the pump as well as theoretical and experimental efficiency were calculated[5]. Finally, the obtained data were validated by statistical analysis using a t-test with 5 percent significance.

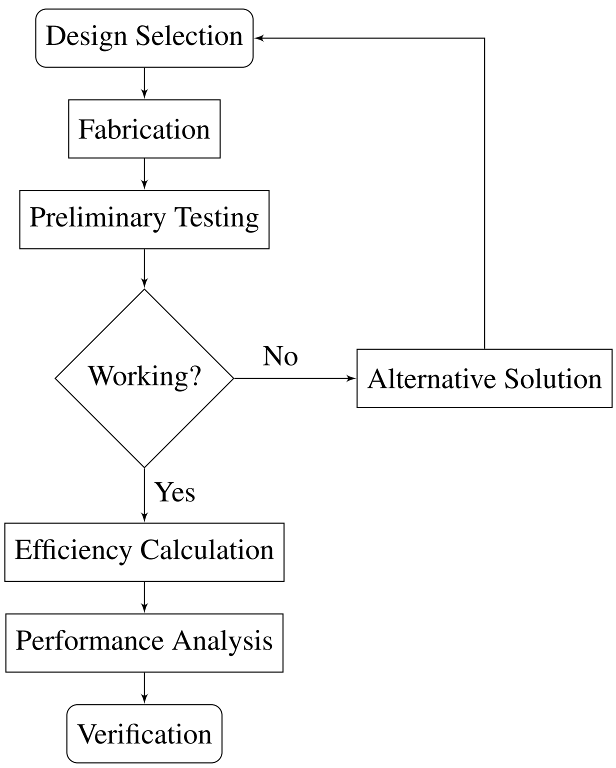

Figure 1: Methodology

6. Results and Discussions

6.1 Fabrication

A hydraulic ram pump of the following specifications was fabricated for the purpose of testing. Some design decisions were inspired by already published documents[6].

Table 1: Specification of parts

Component	Dimension (mm)	Material
Gate Valve	25-18.75	Brass
Tee Joint	25-18.75	UPVC
Union	25-18.75	UPVC
Swing Check Valve	25	Brass
Spring Check Valve	25	Brass
Tank Nipple	25	UPVC
Female Socket	25	Brass/UPVC
Male Socket	25-18.75	Brass/UPVC
Elbow	25-18.75	UPVC
Reducer	25-18.75	UPVC
PR160 Pipe	100x1200	PVC
Glue Cap	100x1200	PVC
Inlet Pipe	25x2000	UPVC
Outlet Pipe	18.75x1000	UPVC

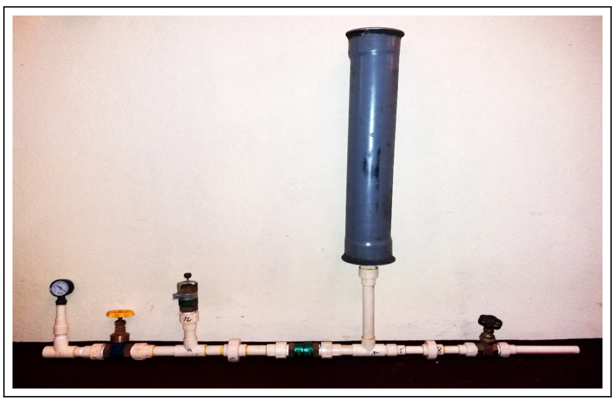

Figure 2: Fabricated hydraulic ram pump

6.2 Preliminary Testing

The conducted preliminary testing revealed that the waste valve did not have enough weight for pump operation. The required modification was done by adding weight and the final weight of the waste valve reached 94 grams.

Figure 3: Modified waste valve

6.3 Performance Analysis

The volumetric efficiency and practical pump efficiency were calculated using test data obtained after testing. The theoretical efficiency was calculated after calculating losses in the pipe and other parts and adding them to practical efficiency. Theoretical efficiency refers to overall pump efficiency without losses. Both input and output heads were varied in the test.

6.3.1 Volumetric Efficiency versus Input Head

When the output head was kept constant at 3.8m and the input head was varied, volumetric efficiency decreased with an increase in the input head because the input flow rate increased with an increase in the input head and the volume of lost water also increased together.

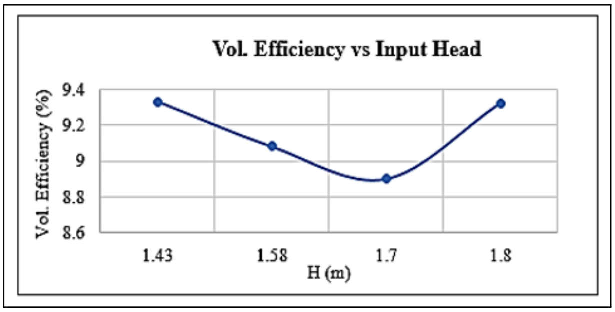

Figure 4: Volumetric efficiency vs input head

6.3.2 Pump Efficiency versus Input Head

When the delivery head was kept constant at 3.8m and the input head was increased, the curve shows that pump efficiency decreases. The pump efficiency was directly proportional to the ratio of the delivery head to the supply head. The ratio decreased when the supply head increases hence the pump efficiency.

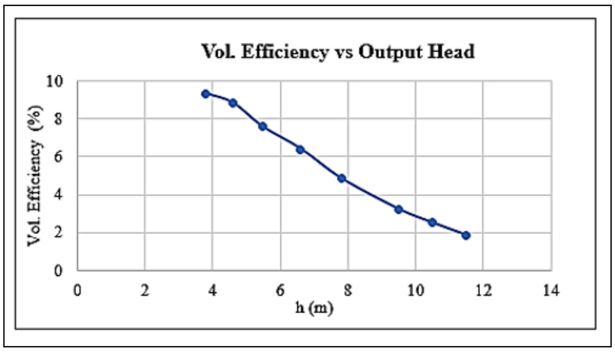

Figure 5: Volumetric efficiency vs output head

6.3.3 Practical and Theoretical Pump Efficiency versus Input Head

WWhen the delivery head was kept constant at 3.8m and the input head was increased, theoretical efficiency was somewhat offset of actual efficiency because of incurring major and minor losses were added to actual efficiency to obtain theoretical efficiency.

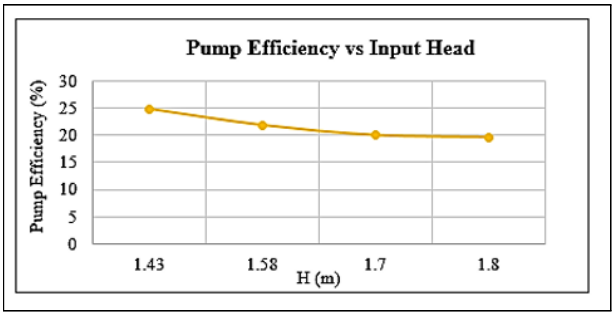

Figure 6: Pump efficiency vs input head

6.3.4 Volumetric Efficiency versus Output Head

In the graph of Volumetric Efficiency versus output head at constant input head, delivery volume decreased with an increase in output head with input volume being same as supply head was kept constant at 1.8m. Hence, the volumetric of the pump decreased with increasing delivery head. This might be due to more energy required to pump water to a higher level.

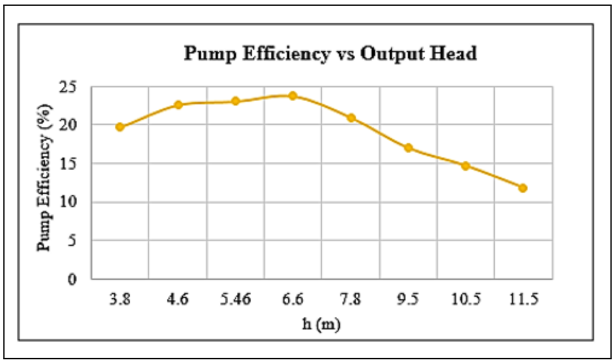

Figure 7: Pump efficiency vs output head

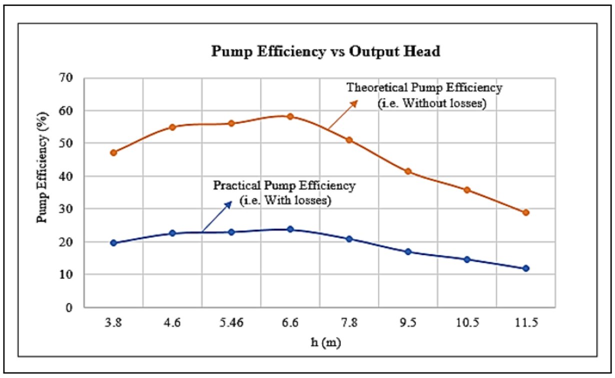

Figure 9:
Comparison between theoretical and practical (pump efficiency vs output head)

6.3.5 Pump Efficiency versus Output Head

When the input head was kept constant at 1.8m and the output head was varied, the pump efficiency first increased with an increase in delivery head reaches to a maximum value and then decreased when the output head further increases. As the output head increases energy transfer for some heads was efficient and after some value, it decreased due to extreme losses and gravity.

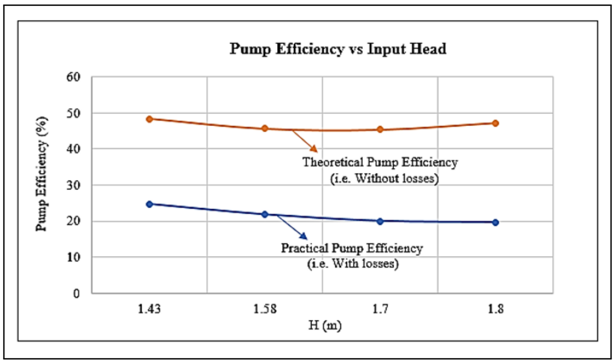

Figure 8:
Comparison between theoretical and practical (pump efficiency vs input head)

6.3.6 Practical and Theoretical Pump Efficiency versus Output Head

When the input head was kept constant at 1.8m and the output head was varied, the value of theoretical efficiency was greater than practical efficiency because no losses were considered in theoretical efficiency.

6.4 Validation

The value of theoretical efficiency calculated from the experiment was validated using a t-test of statistics with a 5 percent confidence interval[7]. With a sample size of 13 and an assumed efficiency of 50 percent[6] standard deviation of 8.32 percent was obtained among the sample. The confidence interval for the sample efficiency was found to be in-between 41.18 percent to 51.22 percent. Thus, out of the all theoretical efficiency obtained, the majority of them lie under the confidence interval region and thus are significant.

7. Conclusion

The design efficiency of the Hydraulic Ram Pump was in cohesion with assumed efficiency (50 percent). After the fabrication, operation and analysis of the Hydraulic Ram Pump, the efficiency of the pump was obtained within the acceptable range. For input pipe of dimension 25 mm and output dimension 18.75 mm, the maximum value of experimental pump efficiency was found to be 25.03 percent. After including the losses in the obtained data, the average theoretical efficiency of the pump was obtained as 46.03 percent. Statistical t-test analysis confirmed that the theoretical efficiency obtained from the experiment met the designed efficiency under the significance level of 5 percent. HRP is only 10 percent volumetric efficient while the maximum value of experimental volumetric efficiency of the pump was found to be 9.33 percent which is quite significant.

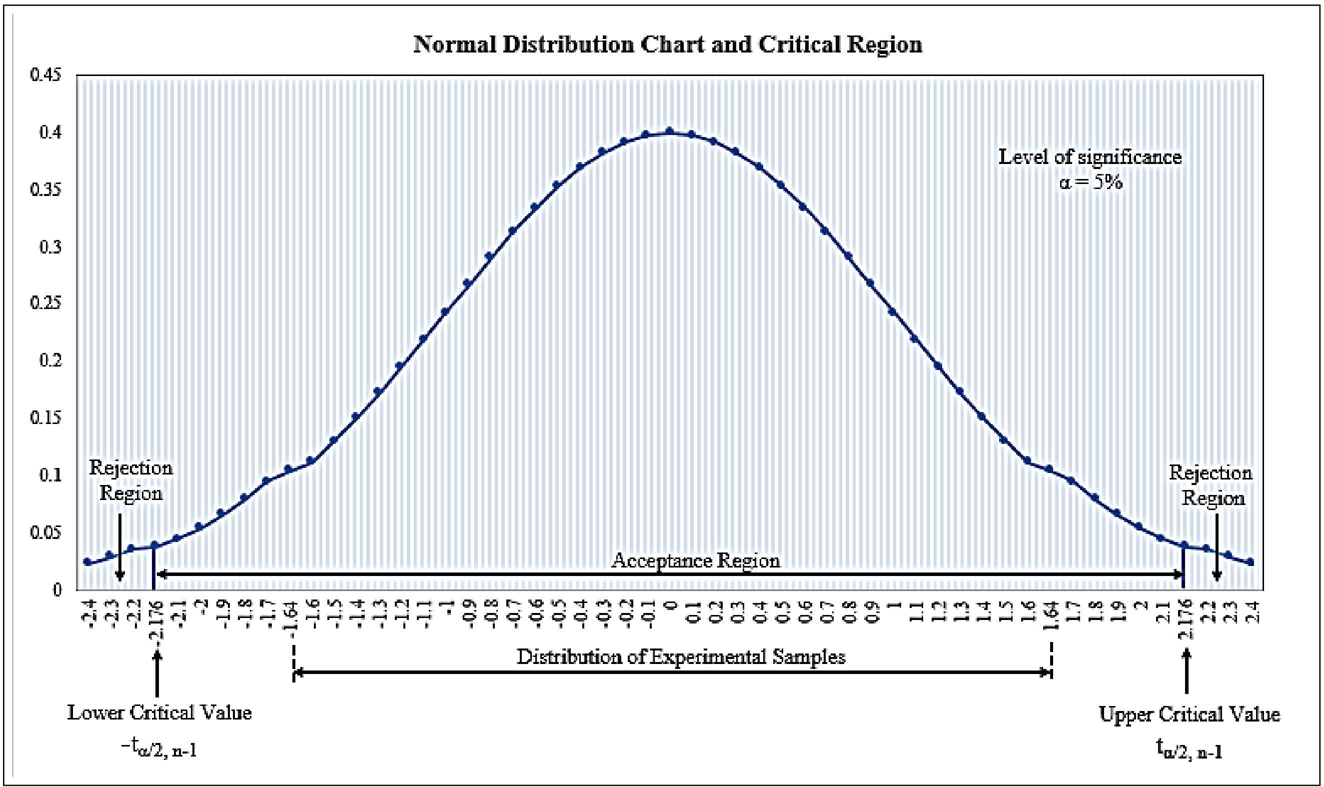

Figure 10:
Normal distribution curve showing distribution region of experimental samples

Recommendations

- The gradient of delivery and drive pipe should be gradual instead of a 90-degree turn to remove elbow loss. Also, the length of the drive pipe helps to increase the life of the pump by reducing pulse count per minute.

- The weight of the impulse valve should be taken so as it provides maximum efficiency. The material used in the impulse valve should be very strong because it is acted upon by cyclic impact force throughout its life.

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