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# Design, Fabrication and Testing of Hydraulic Ram Pump with Water Recirculation System

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**Abstract**
This research was focused on introducing water recirculation system in hydraulic ram pump so as to reuse excessive waste water and make the pump operatable in dry seasons when the inlet flowrate is low. Necessary design parameters were determined after desk study and literature review. The currently working AIDFI pump was studied and a new pump of same size was developed so as to introduce water recirculation system. To aid the statement of increase in volumetric efficiency of the pump, 1" model pump was built along with test system and test was carried out. Then with necessary altercations, 3" mild steel pump was fabricated and tested in Jharuwarashi-Badegaun, Lalitpur. The result showed that around 1.48% increased efficiency at around 57.17% of inlet flow rate by introduction of recirculation system and similarly the result obtained at other inlet flowrates showcased the feasibility and improvement in efficiencies by the addition of recirculation system.

**Keywords**
Hydraulic Ram Pump – AIDFI – Volumetric Efficiency – Water Recirculation System – Flowrate

## 1. Introduction

Hydraulic ram pump commonly known as 'Hydram Pump' is a device which is used to deliver water to higher elevations capitalizing the energy already possessed by the water [1]. It works on the principle of water hammer effect [2]. In simple terms, it is the device that makes use of kinetic energy of the water into potential energy to lift the water to higher altitudes without any sorts of external energy [1]. In a country like Nepal, small streams and other water related resources are abundantly present. However, people are still facing the cruelty of nature, not being able to make use of those water resources. Moreover, other sources of energy as well have not been able to make any impact on the people's lives. AIDFI pump, a hydraulic ram pump can be found in use in Nepal as per the design of Alternative Indigenous Development Foundation Inc, Philippines.

## 2. Problem Statement

The overall efficiency of existing Alternative Indigenous development Foundation Inc, (AIDFI) pump is around 84% and the volumetric efficiency is around 7% at full flow condition. But when the flow-rate declines, the pump performance degrades drastically, which makes it infeasible to use in dry/winter season [3]. Besides that, the pump geometry, on its own disrupts smooth flow of water causing it to decrease energy and thus increases losses within the pump geometry.

## 3. Research Objectives

The main objectives of research was to design, fabricate and test the hydraulic ram pump with water recirculation system.

The specific objectives were:

1. To detect and analyze the existing problems on hydraulic ram pump.
2. To analyze the inlet geometry, delivery pipe opening

and waste valve system.

3. To develop and test a model of the pump.

4. To test the performance of pump at various operating conditions.

5. To study the impact of re-circulation system placing it on waste valve and analyzing its impact over pump performance.

**Limitations**

1. Due to the lack of test rig, the design and calculation of pump was entirely based on fixed available head. Hence, the effect of varying the intake head on pump performance wasn't determined in this research.

2. Although casted pump body is more favorable, due to the manufacturing difficulty welding of body components was incorporated for fabrication.

3. Although AS steel is more suitable for fabrication of waste valve, due to manufacturing difficulty, mild steel was used.

**Advantages**

1. Increase in volumetric efficiency of pump.

2. Utilization of water supposed to be wasted.

3. Increase in part flow efficiency of pump.

4. Conservation of both water and energy.

**Disadvantages**

1. Loss in overall head of water due to addition of low energy water to high energy water.

2. Possible case of circulation loss of energy within pump body due to mixing of water from different direction.

## 4. Research Methodology

1. Identification of design parameters
2. Test Model Design
3. Calibration of Model
4. Final Design
5. Fabrication
6. Experimental Setup
7. Testing
8. Analysis of results

## 5. Design Summary

| Parameters | Formula | Value |
|---|---|---|
| Pressure at inlet(P) [4] | $\rho \times g \times H$ | 0.5821 atm |
| Pressure due to water hammer effect($P_h$) [4] | $\rho \times V \times C$ | 54.74 atm |
| Backward pressure($P_b$) [5] | $\rho \times g \times h$ | 8.35 atm |
| Uplifting pressure ($\Delta P$) [5] | $P_h$-$P_b$ | 46.39 atm |
| Drag force($F_d$) [5] | Cd*A*$\rho$*(V$\wedge$2)/2g | 8.95N |
| Force that accelerates the fluid(F) [5] | $\rho$*A*L*dv/dt | 28.728 N |
| Power of pump [5] | $\rho$*$Q_d$*g*h | 280.93W |
| Required thickness of pump body [6] | (b-a)/2 | 5.36 mm |

## 6. Model Analysis

Using the locally available materials, models of proposed pump was built and tested to analyze the performance of pump in part flow condition with and without recirculation pump [7]. The pump was constructed with the concept of kinematic similarity and geometric similarity [4].

The result of model analysis can be described by the chart below:

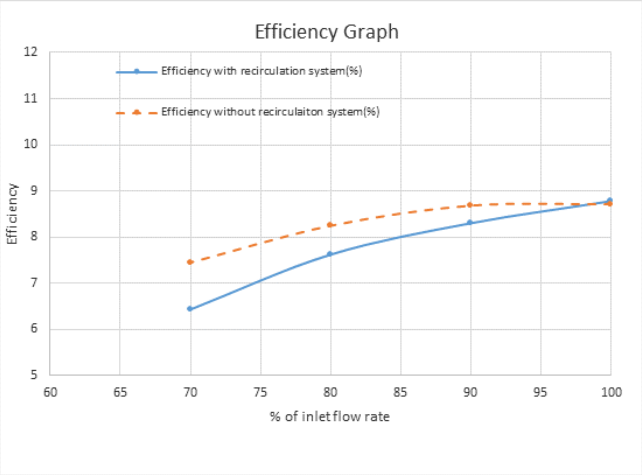
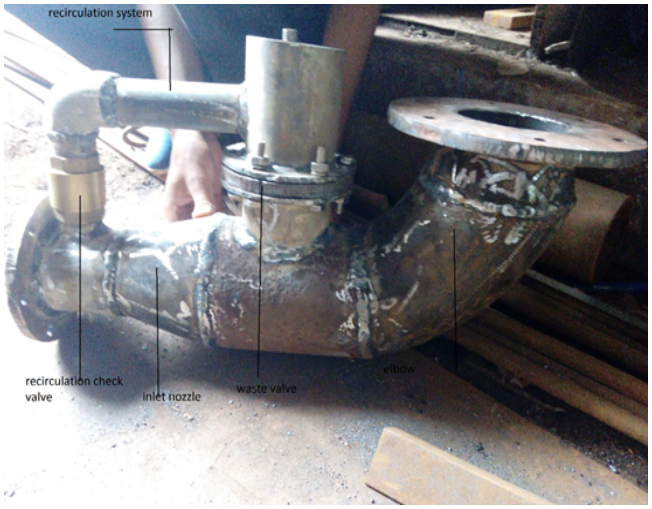



**Figure 1:** Efficiency and flow rate graphs

The above graphs shows the nature of pump performance (output flow rate and efficiency) with the variation of inlet flow rate.

Analyzing the above graph, at full flow rate, both types of pump shows similar performance. As the flow rate decreases, the performance of both pump decreases. However the pump without recirculation system seems to show better performance (both efficiency and delivery flow rate) as the inlet flow rate decreases in comparison with pump without recirculation system.




## 7. Testing

For testing of the system, setup at Jharuwarashi-Badegaun was considered having following site parameters and assumptions.

1. Drive head (H): 6m
2. Delivery head (h): 44m
3. Drive length (L): 30m
4. Delivery length (l): 154m
5. Intake diameter (D): 3 inch
6. Outlet diameter (d): 1 inch

The inlet was measured by volume method where cross sectional area of fore bay tank was measured and corresponding time to change definite depth of water was measured by stopwatch.

Maximum inlet flowrate was measured = 4.18 lps

## 8. Result analysis

For result analysis, various data were collected from test site.

Inlet flow rate versus overall efficiency of the pump with and without recirculation system attached at various flow rates is depicted in figure below. Here, at full inlet flow rate the overall efficiency of both pump

seems to be similar. As the inlet flow rate decreases the overall efficiency of both pump decreases. However, the pump with recirculation system clearly shows better performance in overall efficiency as compared to pump without recirculation system.

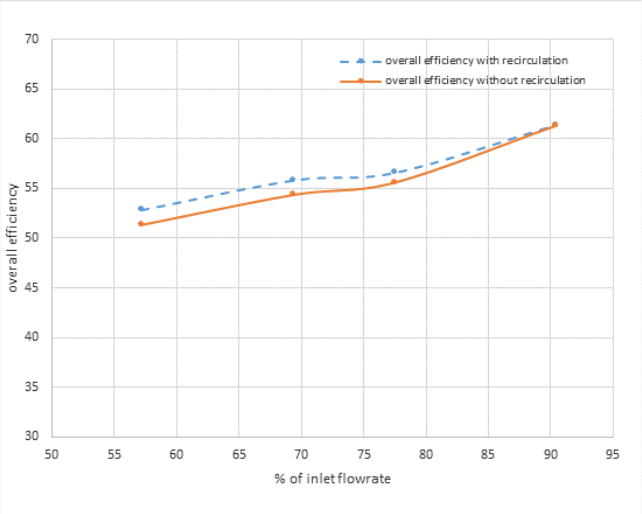



**Figure 2:** Overall efficiency versus inlet flowrate graph

Variations in delivery flow-rates with percentages of part flow rates at with and without recirculation systems is shown comparatively in figure below. Here also, at full inlet flow rate the delivery of both pump is similar. However at low inlet flow rate the pump with recirculation system has higher delivery as compared to pump without recirculation.

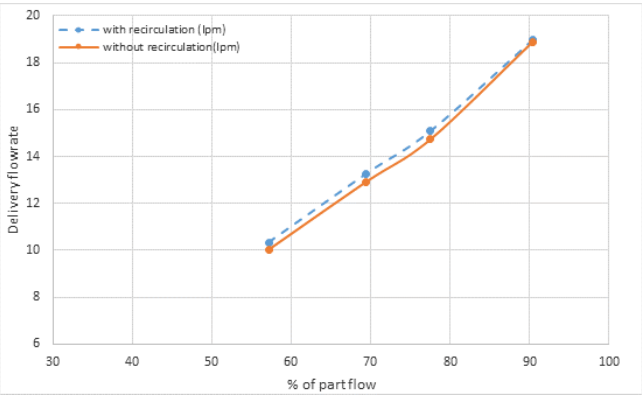



**Figure 3:** Delivery flowrate versus inlet flowrate graph

## 9. Conclusion

The testing of the pump was done at part flow conditions at 90.44%, 77.54%, 69.37% and 57.17% flow rates. The overall efficiencies when calculated at different flow rates of 227lpm, 194lpm, 174lpm, 138lpm was found to be 61.38% and 61.13%, 56.58% and 55.62%, 55.80% and 54.41%, 52.82% and 51.34% respectively at with and without recirculation conditions while the volumetric efficiency for with and without recirculation conditions for above given part flow rates were 8.367% and 8.335%, 7.76% and 7.585%, 7.61% and 7.42%, 7.20% and 7.01% respectively. These data when compared alongside pump with and without recirculation has a difference of 14256 ltr/month, 12528 ltr/month,14688 ltr/month and 3456 ltr/month respectively for given part flow rates, which indeed is a significant achievement as AIDFI pump even struggles to properly operate under these flow conditions.

## 10. Recommendations

1. Areas such as pump body length, pump geometry, inclusion of different nozzles, waste valves and its various types can be studied to improve pump performance.
2. If approaches concerning conical pump body geometry is undertaken, then it may result in significant improvement in pump performance.
3. The valves if made up of stainless steel (SS A313), with proper size and weight could result optimal performance and greater service life.

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