A significant effect on flow analysis & simulation study of improve design hydraulic pump

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Abstract. Hydraulic ram pump is device that can lift water to the higher position without use of external energy. Several ways have been tested to decrease the water waste rate to maximize efficiency. The purpose of this research work is to develop a new design of hydraulic pump and conduct simulation study to justify improvement of the design. Major addition on making threaded waste valve system in order to control the opening and closing of the valve. At the same time reduce time taken for creating enough momentum and hammering effect. The results revealed that with the advancement of the proposed well improve designs, the water losses at waste valve reducing about 20-30% compare to existing design across the mass flow rate of 0.10 kg/s. The min/max velocity and pressure along the pipeline also has been increase for both open and closed condition.

1. Introduction

A hydraulic ram or hydram is a pump that utilize momentum energy from a constantly falling quantity of water to pump some of it to an elevation much higher than the original level at the source. No other external energy is required as long as there is constant supply of water, the pump will remain to work continuously and automatically. This makes it a highly useful mechanism for pumping water where there is a large source of available water, such as a river, channel, dam or any other form of reservoir. Thus, the hydraulic ram pump is completely self-sustaining and green in nature. It is well known that hydraulic pump are far more environment friendly to pump water compared to conventional electrical or fossil fuel based energy pump. In addition the waste water from the hydram can easily be cycle back into the reservoir, thus effectively creating zero wastage of water. Most of the conventional pump technology are limited by the high cost maintenance and electrical usage cause it impossible to be develop in rural areas. Furthermore, these conventional system require close monitoring and need special expertise to handle it. Thus, specialized characteristics such as free energy usage, low expertise and cost of maintenance, long life span, relative pressure stability and recyclable waste have turned researchers to make use of the hydraulic pump as alternative option pump in the future. Research of hydraulic ram pump has a long history. Begin in 1797 with unsuccessful theoretical attempts to explain the hammering action by J. M. Montgolfier until the end of the 19th century, when the water hammer was first explained in detail. Over the past decade, most research in hydram has emphasized on design optimization and self-built valves for high water supply.

In an analysis of experimentation and analysis involved in the performance optimization of a hydraulic ram pump, Prasanna et al. [1] found that are multiple parameters that affect the performance of a waste valve such as shape of the valve, size of the valve, size of the bush/valve seat, length of stroke and weight of the valve, whether spring operated or weighted, and orientation of the valve. These
discovery are supported by the findings of Li J and Yang K [2] which showed that efficiency of the novel hydraulic ram pump reaches 70% by adding adjustable local resistance components in parallel in the delivery valve. With this technology, an adjustable and high-head experimental platform has been developed and experiments for the newly developed hydraulic ram pump were conducted on the platform. The adjustability and stability of the platform were verified. On the other hand, interestingly Harish Kumar [3] suggesting deeper research especially in design and manufacturing considerations to get the best design with higher efficiency. Every aspects of involved components being studied including dimensions, type of wielding preferred and material selection. Besides that, one study by E.J Schiller [4] demonstrate derivation of computerized theoretical model for hydram design, prediction of performance and surveying suitable sited. These result were contradicted by the experiments of author who considered modification of design only to improve overall hydram performance.

In particular, no investigation has been made on opening and closing condition of improve design of hydraulic pump using fluent and computational fluid dynamics (CFD). Therefore the aim of this work is to study significant effect on flow analysis and simulation study of improve design hydraulic pump. For this purpose, the opening and closing effect of valve on pump performance being investigate in order to reduce water losses at the waste valve and increase the pumping rate. To the author knowledge, no findings on CFD analysis of opening and closing condition of hydraulic pump regardless new or old design.

The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines for modelling and fabrication of more efficient hydraulic pump. Both modelling and actual fabrication can be compare and further analysis to obtain more details and improvement.

1.1. Model Designing

By using Solidwork 2017, roughly 1000 mm length and 1283 mm height hydraulic pump was designated as shown in isometric, top and bottom figure below. Total assembled of about more than 30 components.

![Figure 1. Isometric View](image1)

![Figure 2. Top View](image2)
1.1.1 Improve Design of Delivery Valve. For delivery valve design as shown in figure 4, it being created with adjustable threaded nut to enable control of waste valve opening and closing clearance dimension. Meaning this design is more dynamics because it enable time-control water volume from source to pressure chamber. Differ from existing design that just rely on valve weightage and spring loaded that were supported by Poonam et al. [5]. Next installation of spring will aid the distribution of force equally around the waste valve. Hence maintain well the clearance gap that being set based on initial requirement.

1.1.2 Improve Design of Waste Valve. Gap at the outlet being reduced to prevent big volume of water overflow. Compare with existing design that allow so much of water out just to wait enough water momentum to shut the valve close, so that hammering effect can be created as being described by Young and his co-workers [6]. Furthermore, this design also similar to delivery valve by which we can limit/control the water flow by adjustable threaded nut mechanism.
1.2 Meshing
For meshing and analysis projection, Fluent and CFD Ansys software being applied in this study as being shown by figure 6. Tetrahedrons type mesh is used for the assembly meshing method as they are easy to create automatically while the generation of other type elements is very difficult for complex shapes such as those being designated. This method supported by the finding of S.K Choundary et al. [7]. About 145977 elements and 28131 nodes successfully created for analysis preparation.

1.3 Boundary Condition

| Table 1. Boundary Condition Settings |
|-------------------------------------|
| **Velocity Inlet**                 | **Inlet Intake**                     |
|                                     | Velocity Inlet or Mass Flow Inlet    |
|                                     | Values Can Be Added For Different Head |
| **Outlet**                         | **Mass Outlet**                     |
| **Wall**                           | Rest of Parts Geometry/Boundary Condition |

2. Analysis for Existing Design
The dynamic meshing or transient analysis approach is used to treat the closing and opening of waste/delivery valve over time in the computational area. In other words, the mesh generation approach was used to treat the moving waste/delivery valve as a moving solid body in the computational domain. Valve moves upward and downward position considering open and closed condition similar to Reza Fatahi et. al findings [8]. Standard initialization was used with relative to cell zone over 1000 iterations. Figures above shown velocity vectors, pressure vectors for open and closed condition.
Figure 7. Solution Calculation Result

2.1 Result Contour at Intake Flow Rate 0.10 kg/h in Closed Condition

Figure 8. Velocity Contour in X-axis

Figure 9. Velocity Contour in Y-axis
Figure 10. Velocity Contour in Z-axis

Figure 11. Dynamic Pressure Contour

Figure 12. Static Pressure Contour
2.1.1 Mass Flow Rate for Existing Design (Closed Condition). The output generated for this simulation is 0.050 kg/s. About 50% losses created (based on the 0.100 kg/s mass flow rate input). Hence the losses created is far better than previous ram pump design conducted by Matthias Inthachot and his co-workers [9] which is between 60-70%.
2.2 Result Contour at Intake Flow Rate 0.10 kg/h in Open Condition

**Figure 15.** Velocity Contour in X-axis

**Figure 16.** Velocity Contour in Y-axis

**Figure 17.** Velocity Contour in Z-axis
Figure 18. Dynamic Pressure Contour

Figure 19. Static Pressure Contour

Figure 20. Total Pressure Contour
2.3 Mass Flow Rate for Existing Design (Open Condition)
The output generated for this simulation is 0.003kg/s. About 97% losses created (based on the 0.100 kg/s mass flow rate input). Theoretically accepted as during this process, lot of water wasted to the surroundings due to waste valve opening.

Figure 21. Mass Flow Rate Result Simulation

\[\text{Mass Flow Rate} \quad \text{(kg/s)}\]

\begin{align*}
\text{Net} & \quad -3.79566e-07 \\
\text{Outlet2} & \quad -3.79566e-07
\end{align*}

3. Discussion
The discussion of the results begin with an explanation of two conditions mainly open and closed condition. During open condition the waste valve remain open in 10mm (refer figure 22) diameter gap and water starts to flow from the source and escapes through the waste valve. The finding of velocity and pressure contour provides evidence of force flow distribution that accelerates under the effect of the supply head about mass flow of 0.10 km/h till enough velocity is attained in the drive pipe to pump water out of delivery valve. Our finding revealed that for both open and closed condition along 3 axis (X,Y and Z axis) velocity analysis as shown in figure 8, figure 9, figure 10, figure 15, figure 16 and figure 17 will generated different results and indicate area of improvement that need to be done. These result support previous research by GK Awari et al [10] into this brain area which links open and closed condition to the significant velocity effect.

The most striking result to emerge from these analysis is the total, dynamics and pressure forces that further analyse the pressure illustrated in 3 different condition within the same pump (Refer figure 11, figure 12, figure 13, figure 18, figure 19 and figure 20). For instance, experiment in open condition recorded 4.42kPa and 15.15 value of dynamics and static pressure respectively. Contradict with closed condition that generated 128.00kPa and 97.8, a tremendous difference that justify the operation of alternating valve in open and close condition.
Next for a good hydram design, the valve closure must be rapid or instantaneous as being experimented by Nambiar and his friends [11]. Thus for this analysis we set 0.20 seconds for the waste valve to close (refer figure 22). 4 sets of data as shown in figure 21 were simulated to demonstrate the transient analysis for the waste and delivery valve. This ways is somewhat surprising given that other research do not consider this parameter in their analysis.

![Diagram of Outlet Gap for Waste Valve](image)

Figure 22. Outlet Gap for Waste Valve

The sudden closure creates a high pressure in the hydram and on the delivery valve that is in excess of the static delivery pressure. What is surprising is that 15.44kPa (open condition) and 115.89kPa (close condition) total pressure force were recorded, far better than Gan Shu San et al findings [12]. The waste valve is forced open again and pumping takes place till the velocity becomes zero and pumping stops as the force value drop drastically. After that, delivery valve then closes. Resulted the pressure near the waste valve is much higher than the static supply pressure and the flow is reversed towards the supply source. This action is also termed as recoil. The recoil action creates a vacuum condition in the hydram caused temporarily forcing a small amount of air to be sucked into the hydram through the air valve. The pressure on the underside of the waste valve is also reduced and together with the effect of its own weight, the waste valve opens automatically. The water in the drive pipe returns to the static supply pressure as before and the next repeating cycle begins.
Figure 23. Data for Transient Flow Analysis

Overall based on analysis, this improve design especially on the waste and delivery valve manage to reduce losses generated in order to create hammering effect by establish control mechanism in closing the waste valve. The single most striking observation to emerge from the data comparison as tabulated in Table 2 is the reducing of overall waste percentage for both open and close condition compare to previous Sakhare et al. research [13].

Table 2. Summary of Analysis Data for Both Condition

| Condition | Parameter Vectors | Min    | Max    | Mass Flow Rate | Waste Percentage % |
|-----------|-------------------|--------|--------|----------------|--------------------|
| Open      | Velocity X-axis(m/s) | 0.20   | 0.21   | 0.003kg/s       | 97%                |
|           | Velocity Y-axis(m/s) | 0.82   | 1.26   |                 |                    |
|           | Velocity Z-axis(m/s) | 0.47   | 1.27   |                 |                    |
|           | Dynamics Pressure(kPa) | 2.22x10^{-5} | 4.42  |                 |                    |
|           | Static Pressure    | 0      | 15.15  |                 |                    |
|           | Total Pressure(kPa) | 1.22   | 15.44  |                 |                    |
| Close     | Velocity X-axis    | 49.21  | 57.04  | 0.050kg/s       | 50%                |
|           | Velocity Y-axis    | 46.68  | 58.97  |                 |                    |
|           | Velocity Z-axis    | 55.14  | 89.97  |                 |                    |
|           | Dynamics Pressure(kPa) | 0.96  | 128.00 |                 |                    |
|           | Static Pressure    | 78.19  | 97.80  |                 |                    |
|           | Total Pressure(kPa) | 68.50  | 115.86 |                 |                    |

4. Conclusions
This present study was designed to determine the effect of improved design to significant effect on flow analysis and simulation study. This study set out to evaluate how effective the new design towards improving the overall pump performance. These experiment confirmed that the by adding control mechanism to the newly design component delivery and waste valve have enhance about 20% more efficiency than current design. The main finding can be summarized as follow:

I. A hydraulic ram pump create a lot of water waste at the waste and delivery valve. 90% from the incoming water will be left as waste, just 10% will be pump out to the greater heights. Additional of threaded control valve for both valve will help to control the water losses created.
II. The projection of velocity and pressure contour will help to understand of water flow profile within designated pump. These will help to analyze and discover area of improvement for better pump performance.

More information on the new design hydraulic ram in actual model would help us to establish a greater degree of accuracy on this matter. If the debate is to be moved forward, a better understanding of comparison between simulated and actual fabricated modelling need to be developed.

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