Adaption of Water Ram Pump for Small-Scale Irrigation

Assefa Asmare Tsegaw(✉)

Bahir Dar Institute of Technology, 6000 Bahir Dar, Ethiopia
assefaa@bdu.edu.et

Abstract. A hydraulic ram is a cyclic water pump powered by water hammer effect. The device uses to develop pressure permits a portion of water that powers pump to be elevated to a point higher than where the originally started. The ram is often useful, since it requires no outside source of power other than kinetic energy of flowing water. This paper deals with adaptation of water ram pump for small-scale irrigation. This research conducted making using of ANSYS, computational fluid dynamics. Different configurations of waste valves have been designed, checked and investigation results recorded. Investigations show that height testes effect on drive head, delivery head, pipe cross sections, design and arrangements of waste valve, flow rate and velocity. The final optimum ram pump has designed, developed and tested for small-scale irrigation and household purpose. It is observed that at a river flow rate of 9 L/min and head of 5 m, hydraulic ram pumps water at a flow rate of 0.7 L/min for 37M head. This typical test shows raising of water up to 740% with respect to height can be achievable. Moreover, this pump can extensively be utilized in rural areas where water is flowing in gorge areas for 7/24 at no expense of extra power utilized.

Keywords: Hydraulic ram · Elevation · Head · CFD · Kinetic energy · Waste valve

1 Introduction

Even though Ethiopia has plenty of water sources, the burden of fetching water for household and irrigation system is a hard work for women and children (Fig. 1) since rivers are flowing somewhat deep in valleys. Hydraulic ram pumps are one of the most historical and significant water delivery device which use power from the water flow to lift to some extent of elevation greater than the original sources of water [1–5]. They are used in rural areas where there is no electricity and other sources of supply of energy for small scale irrigations, household and other purposes. There is no need of external power to drive the pump [6–9].

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Even though the drive energy for hydraulic ram pumps is gravity, its different components and their special arrangements play significant role in lifting the water up [10–16]. A simple hydraulic ram pimp has five main components, namely, inlet pipe, check valve, waste valve, pressure chamber and delivery pipe. Inlet pipe is the pipe through which the water gets into the pump. The water then flows into the waste pipe and closes the waste valve. The water that closed the waste valve flows against the newly entering water and build up a higher pressure that exceeds the pressure on the delivery valve. This pressure differential lifts the water up to some elevations through the delivery valve [9, 17–19]. As some of the water is lifted up through the drive pipe, the remaining is also wasted through the waste valve. The check valve permits water to flow only in one direction and does not allow reverse flow.

Hydraulic ram pumps are simple in construction and have very small initial costs compared to power driven pumps. They also do not require fuel supply as they are driven by gravity only. Ram pumps are also environmentally friendly for they have zero emissions. Operating ram pumps and maintenance is also very simple as just cleaning the drive way [9, 10, 15, 20].

Water is the most essential resource for the agricultural growth in animal husbandry, irrigation and crop productions. Especially in countries like Ethiopia which mainly depends on agriculture, the increment in the supply of water will increase the growth of the sector. Water is also highly available in Ethiopia, despite of its accessibility. Most of the places where agricultural operations are made are highly mountainous. In contrast springs, rivers, and streams are found in valleys. To find water, farmers must go down, fetch some and then go back up the hill to use the water, which is very laborious. Even though, using power driven pumps is possible, the economical limitations remain as barriers because power driven pumps are expensive. Rural areas do not even have any other means of finding energy that can be manipulated to pump the water. These problems of extreme geographic and economic in-capabilities remain as threat for access of water.

Farmers in the rural areas of Ethiopia do not have access for both electricity and other means of obtaining energy. Though there are plenty of water sources, the people settle in higher place in pursue of loam lands. Thus, they are found at higher elevation compared to the rivers. Hydraulic ram pumps have a great potential of solving these problems [3].

The hydraulic ram pump gives a great benefit for growing crops cultivation and drinking water for animals. The adaption of this mechanism takes place especially for the low level of irrigation purpose to maximize the production capacity such as crops, vegetables, and animal breeding through the water lifting system.

Fig. 1. Traditional water transporting

2 Hydraulic Ram Pump Design

A hydraulic ram pump has been design based on the input parameters such as intake flow rate, intake head, intake temperature and pressure. Technical parameters in design consideration of ram pump is shown in Fig. 2 [21]. Figure 3 shows basic components of the hydraulic ram pump.

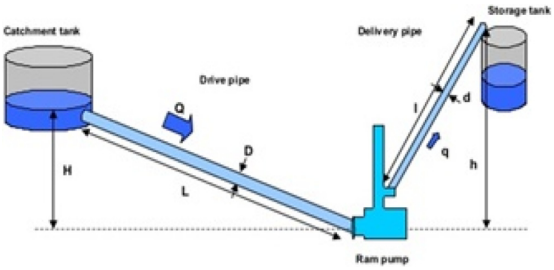


Fig. 2. Design consideration of ramp pump

$$\frac{L}{H} = 3 - 7, \quad \frac{L}{D} = 100 - 1000 \tag{1}$$

$$q = f \times \frac{H \times Q}{h} \tag{2}$$

Where:

L, Length of drive pipe
H, Supply head
h, Delivery head
D, Diameter of drive pipe
Q, Supply flow rate
f, Efficiency factor

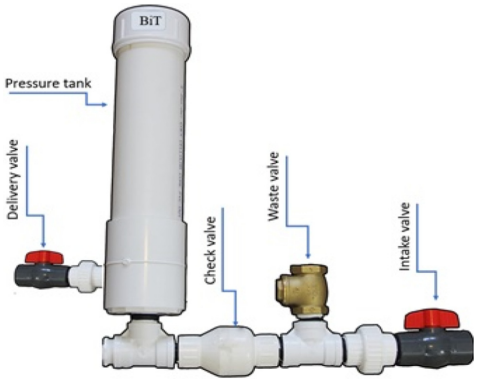


Fig. 3. Photo of manufactured hydraulic ram pump

3 Experimental Setup

Experimental setup of hydraulic ram pump testing is shown in the Fig. 4. On the left-hand side, the supply tank is placed at input heads of 4, 5 and 6 m. The input flow rate is kept constant at 9 L/min. The output flow rate and the output heads are measured in the right-hand side. The water that has been pushed up by the hydraulic ram pump is accumulated in the delivery tank placed higher than the supply tank.

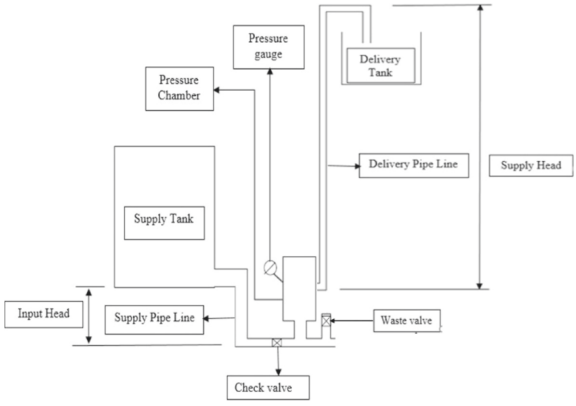
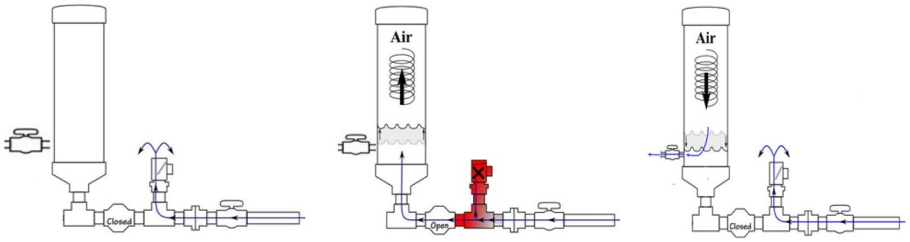


Fig. 4. Experimental setup

At first, the waste valve allows some of water to exit, subsequently it is the nonpumped water as shown in Fig. 5(a) will open due to gravity (or by help of a light spring) and water will flow down to the drive pipe source [23]. As the flow rushes, the water pressure at waste valve and the static pressure in the body of the ram pump will increase up to the resulting forces overcome the weight of the waste valve and start to close it.

As valve opening cuts, the water pressure in the ram pump body increases quickly and bangs the waste valve closed, as shown in Fig. 5(b) [4]. The dynamic column of



(a) Phase I (Initializing waste valve) (b) Phase II (Pressurizing tank) (c) Phase III (Delivery)

Fig. 5. Working principle of ram pump [22]

liquid in the intake pipe is no longer able to exit via the waste valve, so its velocity must suddenly diminution; this continues to cause a considerable rise of pressure which forces open the valve to the air-chamber.

As pressure surpasses the static delivery head, water will be forced up the pressure chamber, as shown in Fig. 5(c) [24]. Air trapped in the pressure chamber is instantaneously compressed to a pressure beyond the delivery pressure. Eventually, the water in the output pipe arises to a standstill and the static pressure in the tank then cascades to close the supply head. The output valve will then close, when the pressure in the air chamber beats that in the casing.

When the delivery valve shuts, the reduced pressure in the ram pump body will permit the waste valve to drop below its own weight, thereby letting the cycle start all over again. Most hydrams operate at 50–110 cycles a minute [25].

4 Results and Discussions

4.1 Simulation Results

The CFD analysis was done on two cases both for the velocity and pressure. Both cases ae investigated when the check valve is closed and opened.

Case 1: when the check valve is fully opened and the waste valve is fully closed: this is the case where the water hammer, the main driving phenomenon of the pumping system, happens. When the flow of water through the waste valve encounters a sudden encounter the velocity decreases, literally approaches to zero. Simultaneously the check valve is fully opened which means a larger flow area for the water to pass through which leads to a relatively lower velocity at a given mass flow rate. But it is still higher than the velocity near the waste valve (Fig. 6).

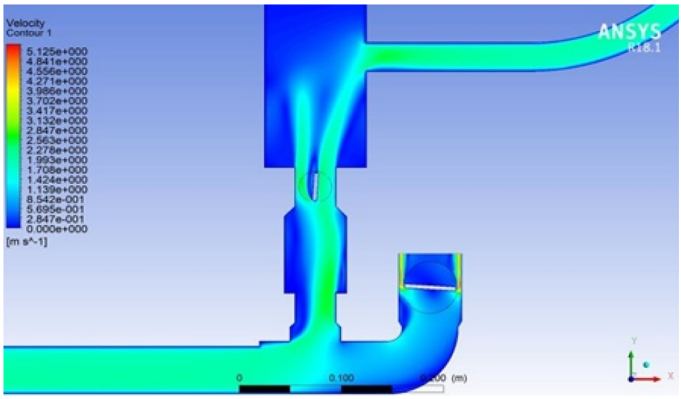


Fig. 6. Velocity contour when check valve is fully opened and waste valve is fully closed.

In this case, the pressure reaches its maximum due to the water hammers. This effect of the water hammer reaches back to check valve fully opening it to allow the fluid blocked by the waste valve to pass through the delivery valve (Fig. 7).

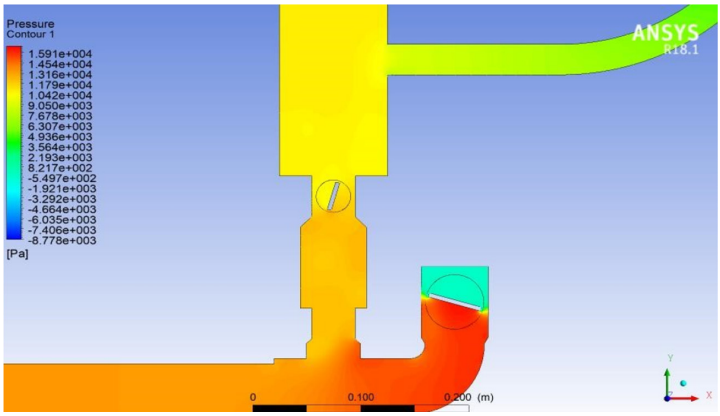


Fig. 7. Pressure contour when check valve is fully opened and waste valve is fully closed.

Case 2: when the check valve is fully closed and the waste valve is fully opened: in this case almost all the water coming through the drive pipe passes through the waste valve with almost the same velocity it enters the drive pipe except the effect of friction losses and minor head loses of elbow nature of the pipe at the end which have a cumulative effect of increasing velocity as shown below (Fig. 8).

The pressure throughout the whole pumping system varies with pipe area and against velocity. The respective angular positions of both the valves and corresponding pressure variation is related as follows.

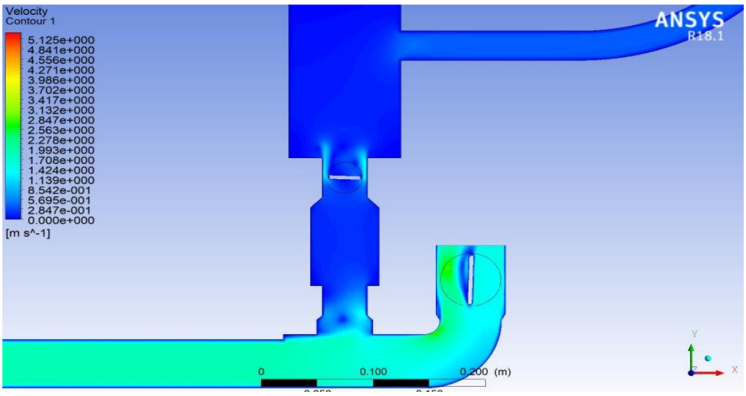


Fig. 8. Velocity contour when check valve is fully closed and waste valve is fully opened

Since there no obstacle applied to the flow of water through the waste valve, which literally means no water hammer, the pressure throughout the pumping system is almost uniform. The whole water is directly exhausted through the waste valve (Fig. 9).

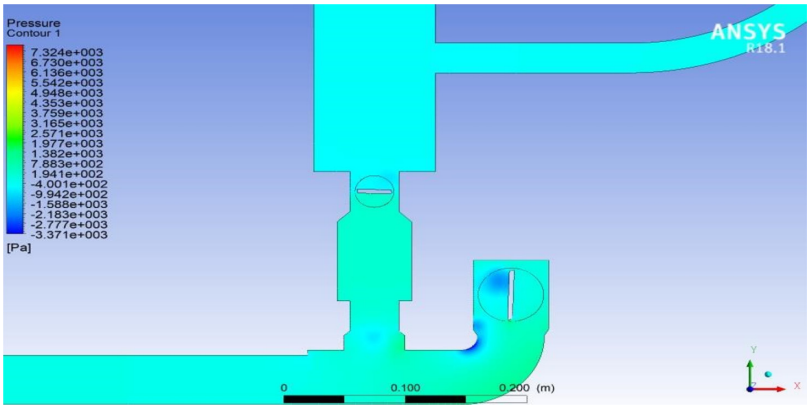


Fig. 9. Pressure contour when check valve is fully closed and waste valve is fully opened.

4.2 Test Results

As shown in Table 1, three successive tests have been made. On each of them, by varying the intake head, the output flow rate and the delivery head have been recorded.

For the same input flow rate of 9 L/min, by varying the input head, different results have been found. As the input head decreases, the output flow rate, the delivery head and the efficiency have also increased. The main reason is the potential energy that is gained by the increase in head.

Table 1. Test results

Test	Input flow rate (L/min)	Input head (m)	Output flow rate (L/min)	Delivery head (m)	Efficiency (%)
1	9	4	0.6	25	40.32
2	9	5	0.7	37	57.20
3	9	6	0.75	45	60.5

5 Conclusions

Using the proper methods of designing, all components have been designed. Based on the design, using locally available materials the pressure chamber and its cups are manufactured. The remaining components such as gate valves, waste valves, union and nipples are purchased based on their corresponding specifications. From a vertical fall of 4 m and 5 m height and at an input flow rate of 9 L/min, it delivers minimum amount of water of 0.6 L/min and 0.7 L/min to a vertical lift of 25 m and 37 m. At 6 m head of input, with the same input flow rate, the 0.75 L/min and 45 m of output flow rate and delivery head are obtained. These test results infer that, as the input head increases, the delivery head also increases. The relation between the input head and the efficiency and the output flow rate are also similarly direct proportional. Hydraulic ram can assist farmers and other users by neglecting operating costs for their farms and livestock. It can be easily adapted by small scale farms be-cause of its low installation cost, neglecting its operating cost, and free from maintaining costs.

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