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Development and Testing of Hydraulic Ram Pump (Hydram): Experiments and Simulations

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Abstract. Hydraulic ram pump (hydram) is a rather 'mature' technology as it has been used over the last two centuries with many variations in design and basic configurations have been tried. Pump motor is favoured rather than hydram to transfer the water from one point to another point because of its consistency. However, following the increasing awareness of the adverse impact of global warming and the needs of sustainable technology, interest in hydram for water supply purpose has revived. The purpose of this paper is to study the effectiveness of hydram implementation and the effect of the stroke valve design towards flow rate of water being delivered. There are three methods used in this study; (i) experimental evaluation of hydram; (ii) experimental evaluation of adjustable waste valve; and (iii) computational simulation of adjustable waste valve. The adjustable waste valve was designed, fabricated for experiment and modelled for simulation. The hydram is very good to be installed as a pump at hill because it can supply water more than high of inlet water. The different length of stroke shows different behaviour of water flow and more length of stroke, more flow rate of water at discharge pipe. Hydram has a great potential to be functioning as a simple and reliable pumping device in those hilly remote areas which are of no water supply coverage.

1. Introduction

Water provides the basis for industry, commerce, transportation, agriculture, and energy production. Although water is important in our life, the population growth, urban expansion and growing competition among users worldwide, worsen by periodic drought and possible climate change, are raising concerns over the continued availability of a stable, dependable supply of freshwater for our nation and the world, now and for the foreseeable future. In rural areas where mobilization of water is limited [1, 2]; it gives rise to supress production, poor attendance and school performance of local children, as well as health issues related to poor sanitation and impoverished home garden. Furthermore, some areas have very limited timeframe to access water that coincides with their needs for plantation. Some advancement in technology to accommodate traditional work may help in sustaining life and economy of these communities.

Hydram consists of two moving parts; the waste valve and the delivery valve which are connected to a drive pipe, a delivery pipe and an air chamber (Figure 1) [3]. Hydram works continuously due to the opening and closing cycles of the waste valve and the delivery valve. The closure of the waste valve increases pressure in the drive pipe. The air chamber is needed to ensure the water to flow continuously at adequate pressure. There are six design factors should be considered in designing a hydram [4]. These include the height in between the water source and the hydram, the height in between pump site and storage, the flow quantity, the length of pipe from water source to the pump, the volume of desired water, and the length of drain pipe.

According to Sampth et al. [5] the pressure of water increase when the length of drive pipe increases but the length of pipe can cause pressure loss. Thus, another pressure tank is installed in the middle of drive to ensure the loss of pressure is less. Diameter of the drive pipe play important role to start-up and running the hydram. According to Dumaoal et al. [6] of drive pipe, it can deliver more gallon of water per minute. Furthermore, the small diameter of pipe of pipe limit the flow of water into the pump body, such a result the water deliver from the pump is less [7]. Supply head is a height from the pump to water inlet. The higher the height of water inlet, the higher gravitational force that makes the high velocity water flow in the pipe drive pipe. According to Hamid et al. [8], the insufficient pressure in the main pumps causing a problem to start-up the pump. It is because water hammer effect cannot be happened due to water cannot push the air pressure inside the pressure chamber. High supply head also bring a problem to main pump. There is too much water flow into the pump, so that water flows out from waste valve are much more. Besides that, the turbulence happens at pump body brought a drawback to the pump because it cannot function smoothly [9].

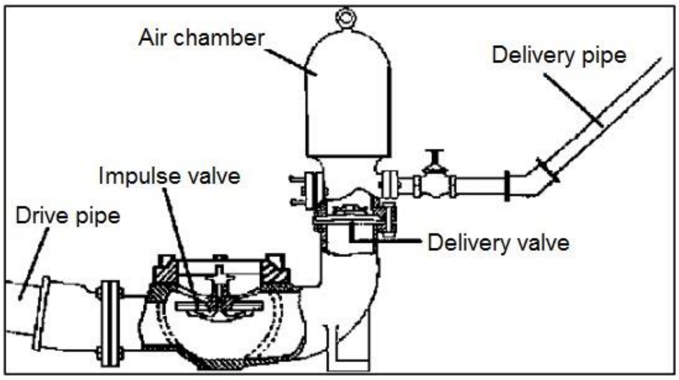

Figure 1. Hydraulic Ram Pump

According to Dumaoal et al. [6], the delivery head depend on the height of supply head. The more height of supply head, the more height of delivery head will be attained. It also supported by Nnene [10], the height of delivery head effect the flow rate enters to the pump. The high flow rate can be increase by increasing the height of supply head. Even, delivery head become higher when increasing the supply head, it needed more maintenance and become more often due to long delivery pipe [8].

Waste valve is a main component to the hydram to allow the water hammer effect to occur [11]. According to Mohamed [12] the waste valve needs to complete its cycle between 1.5 to 2 seconds. The output performance will be worsened if it is either too slow or too fast. The waste valve needed more weight if the cycle is too fast. According to Sheikh et al. [13], there is optimal weight used on the waste valve to control the flow at delivery pipe. If the weight used on waste valve is too high than optimal weight, the water discharged reduce significantly with increasing of weight. The optimal weight is also important to find, to ensure maximum amount of water been delivered. Both Mohamed [12] and Sheikh et al. [13] findings also supported by Diwan et al. [7] and Siswinda [11], which found out the increasing weight on waste valve would decrease the frequency. Thus, it may increase water delivered if optimal frequency is determined. The frequency of waste valve can be controlled by the managing the weight on waste valve. The current design of waste valve by Inthachot et al. [14] is made using galvanized metal which is expensive to be built for small application of hydram. According to Njhia et al. [15] the weight and stroke of the open and close valve can regulate the frequency of waste valve. The high frequency of waste valve can stop the pump function and to low the water flow out in delivery pipe is slow. Further, simulation study conducted by Harith et al. [16, 17] found that improved design of threaded waste valve have reduced water loss.

The aims of the present study are to investigate the effectiveness of hydraulic ram pump towards flow rate and delivery head at discharge pipe. To the best of our knowledge, no study reported on the different behaviour of adjustable valve and its effect towards the output pressure. Thus, this study also aims to develop adjustable waste valve to control the stroke of valve towards the different output pressure.

2. Methodology/Material

2.1 Design and Experimental Setup

The head of water supply was maintained at 1 m height with the size 52 litre of water tank. The process started with the hdyram tests in which the length of drive pipe was evaluated against the flow rate of discharge pipe. Next, the adjustable waste valve was compared to swing waste valve to see it effects towards flow rate of water at discharge pipe. Different length of stroke (5, 7, 10, 13 and 15 mm) was chosen based on the optimum flow rate with an adequate high pressure. It showed that different behaviour of water flow and the more the length of stroke, the higher the flow rate of water at discharge pipe. The hydram was more effective compared to water that was delivered using the siphon, in which it supplied water at higher volume than that of inlet water. Hydram has a great potential to be functioning as a simple and reliable pumping device in those highly remote areas which are of limited water supply.

2.1.1 The hydram test

The parameters used for the experiment were the length of drive pipe and the height of delivery head. The data collected from this experiment were flow rate of water being discharged at delivery pipe and pressure at the inlet of hydram. The data were collected using liquid flow meter and pressure gauge. Figure 3 shows the experimental setup of the hydram.

2.1.2 The valve test

The parameters used for this experiment was the length of stroke waste valve. Data collected from this experiment was the flow rate of water being discharged at discharge pipe.

2.2 Fabrication of Hydram

Figure 2 shows the design of the hydram before fabrication. The hydram used in present study was fabricated with PVC pipe and stainless steel (base to support the hydram). Various pipe sizing were used; 2", ¾", and ½" in diameter. The diameters for inlet and outlet pipe of the hydram were ¾" and ½", respectively.

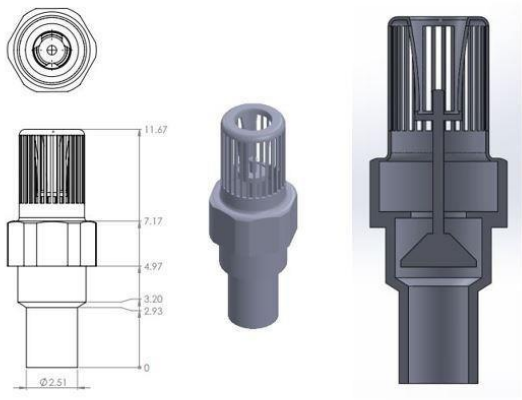

Figure 2. Adjustable waste valve

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There were two check valves used in the present study which acted as waste valve and check valve. The size of pressure tank was 2” diameter pipe with 2.5’ height in order to contain more air pressure. Figure 3 shows the final product of the hydram with swing waste valve. The figure also shows the sealing process to avoid the hydram from bursting during the operation.

The opening of the valve was 2 cm. The open and closing of the valve was done by a 2.5 cm rubber disc fixed to a 5 cm long threaded rod. The rubber disc has a cone shape to ensure the valve was tightly closed. The rod was used in the valve to support the vertical movement of valve and adjusting the stroke.

The adjustable waste valve as in Figure 4 was fabricated using ¾” PVC pipe to match with the hydram when being installed. The cap of waste valve was simply design with the net cap to ensure the water is not spill out during the opening of valve. So, the weight of water can help open the valve easily.

Figure 3. Hydram setup

Figure 4. Adjustable waste valve installed at hydram

2.3 Simulation of Hydram

Simulation of hydram was to study the behaviour of flow inside the pipe and valve as well as to determine the velocity and pressure profile for different valves design. Figure 5 shows the simulation done using COMSOL 5.3. Then, in the simulation software, the laminar flow was evaluated. The pressure for inlet pipe of model was set to 1.42 Psi. The data collected from the simulation was compared with the data from experiment. The simulation of adjustable waste valve was to study the behaviour of water flow inside the pipe and adjustable of waste valve focusing on the laminar flow inside the pipe in which the velocity and pressure at the adjustable waste valve for each stroke can be obtained. Then, the data was compared with the data from waste valve experiment

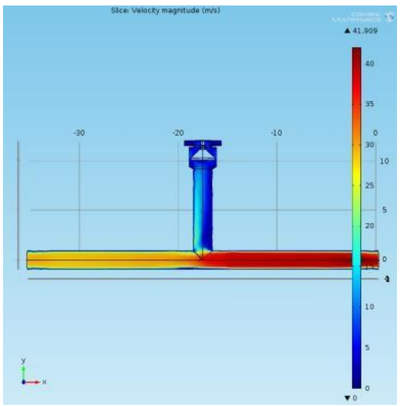

Figure 5. Flow velocity in the model

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3. Results and Discussions

The entire flow rate at discharge pipe was found to decline slightly between 1 m and 2 m for each length of the pipe (Figure 6). According to Boatwright et al. [18], it is because the water is starting to climb up more than the height of the supply water. Thus, the siphon effect that gives pressure on the water is loss. The height of supply water is 1 m. The water that flow out at discharge pipe above the 1 m is causing by water hammer effect on the hydram. The water also is affected by the gravity that causing the return flow velocity when the water is at inclined state [19]. As the gravitational effect increases, there is a reduction in the kinetic energy supply to sustain the flow rate of water at discharge pipe.

The flow rate of water at discharge pipes becomes constant from the 2 m and 3 m height of delivery head for all length of drive pipes. According to Camigniani et al. [20], in the hydram there are resonance of wave pumping. There is strong and steady flow for each of the resonance that being created by the hydram. Thus, the flow rate is at 2 m and 3 m is being constant due to the pulsating of air pressure inside the pressure tank as the waste valve opens and closes.

The most optimum length of drive pipe is 2 m. There is similar flow rate of discharge water between 1 m and 2 m drive pipe length at 1.5 m of delivery head height. Based on the observation of experiment the 2 m drive pipe vibrates more than 1 m drive pipe when the hydram operates. There is occurrence of turbulence in pulsating pipe flow [21, 22]. The pressure outlet of drive pipe 1 m and 2 m are 1.10 psi and 1.42 psi respectively. The longer the drive pipe the more pressure at its outlet because the water has built its velocity [23]. Thus, each open and close of waste valve causing more pulsating on the drive pipe 2 m than drive pipe 1 m.

3.1 Effect of drive pipe length towards flow rate of discharge water

From the observation of this experiment (Figure 6), although the 5 mm and 7 mm stroke valve gave low flow rate of discharge water but it maintained the flow for 1 m to 2 m delivery head height. The open and close of the valve is very fast when the length of stroke is short. According to Njihia et al. [15], the pressure inside the pressure tank is being developed by opening and closing of the waste valve. Thus, the water discharged by the pipe can be constant for each delivery of head height.

The 10 mm stroke valve showed a drop of flow rate of water discharge from 1 m to 2 m. Each length of stroke has a different size of gap to water flow out from the valve [20]. The 10 mm stroke valve was observed to give unstable open and close of the valve. The huge changing of pressure inside the pipe makes the water inside pipe turbulence. Thus, it caused low volume of water to pass through the check valve.

The optimum length of stroke valve is 13 mm. The flow rate of discharge water is slightly decreased due to the loss of the siphon effect. The water is also affected by the gravity that causing the return flow velocity when the water is at inclined state [19]. As the gravitational effect is increased, there is a reduction in the kinetic energy supply to sustain the flow rate of water at discharge pipe.

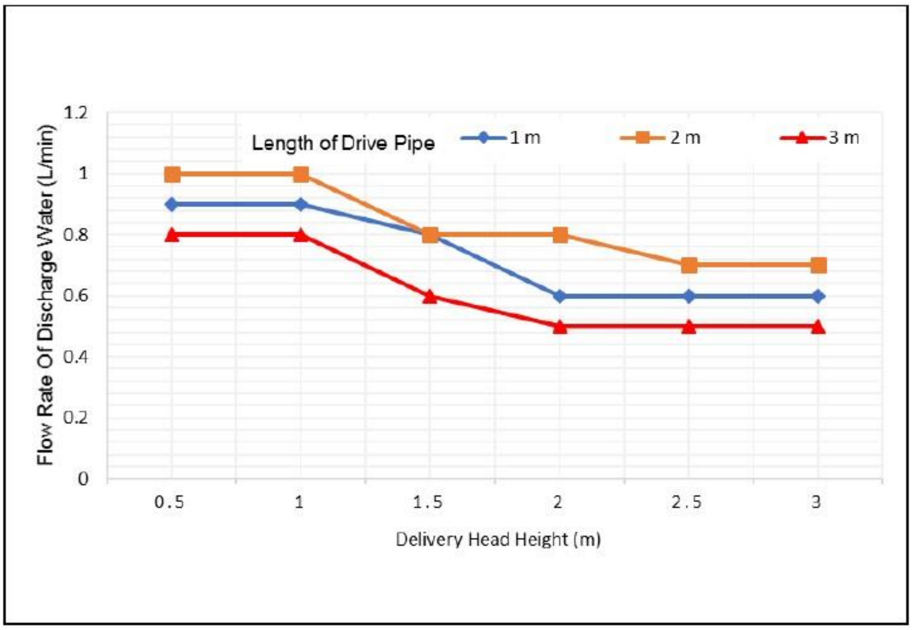

Figure 6. Effect of drive pipe length towards flow rate of discharge water

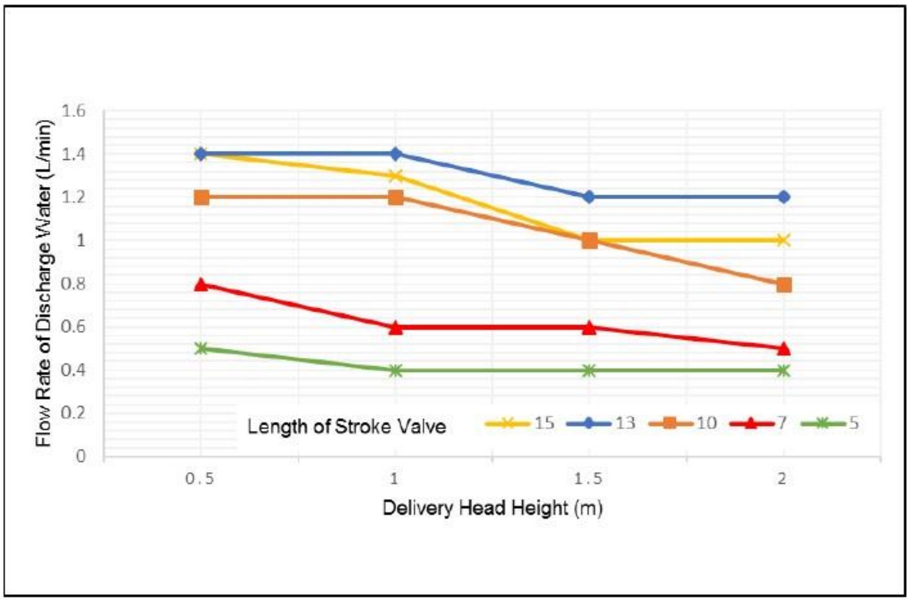

Figure 7. Comparison of swing waste valve and adjustable waste valve.

Figure 8. Comparison of swing waste valve and adjustable waste valve

Swing waste valve showed low flow rate of discharge water than adjustable waste valve (Figure 8). Thus may due to the different weight of sealing cap for both valves. The swing waste valve used brass sealing cap while adjustable waste valve used rubber cap that is lighter than that of brass. According to Mohamed [12], Sheikh et al. [13] and Girgio et al. [24], the added mass on the cap of valve can reduce the kinetic energy of water. Thus, the cap of valve is slightly hard to close when it weighs more.

Next, both valves used different type of materials, which have different of surface roughness. According to Shockling et al. [25], the general behaviour of turbulent pipe flow is in the presence of surface roughness. The index of roughness of swing waste valve and adjustable waste valve is 0.002 and 0.0015. As the roughness of valve increase, the flow of water inside the valve becomes transitionally rough. So, the water does not flow out smoothly from the valve.

The entire simulation inlet has been set up to 1.42 psi which equivalent to the pressure at inlet hydram for 2 m length of drive pipe from the experiment. 5 mm adjustable waste valve showed a high velocity of water flow passing through the cap and valve opening (Figure 9). The pressure of water was focussing on the side of cap and at the opening of waste valve (Figure 10). This can be used to explain why the 5 mm length of stroke valve is open and close very fast. According to Polenta et al. [23], the small area of water flow can increase the velocity of water and pressure. High velocity of water on top of the valve allows the high pressure on top of valve which contributes to the valve cap opens and closes very fast. The 13 mm adjustable waste valve is the optimum length of the stroke. Based on the Figure 3, there is low velocity of water at the top of valve cap. The pressure was mostly focus at the bottom of valve cap (Figure 10). According to the Jang et al. [26], the small size gap caused the turbulent of the flow. Thus, the turbulence from the small size gap between cap and valve wall at the bottom make the turbulence under the cap. The smooth flow of water above the cap put additional weight to valve cap to make the valve open. The high pressure on the bottom of cap pushes the valve to close. Both situation, help the valve to open and close at the optimal level.

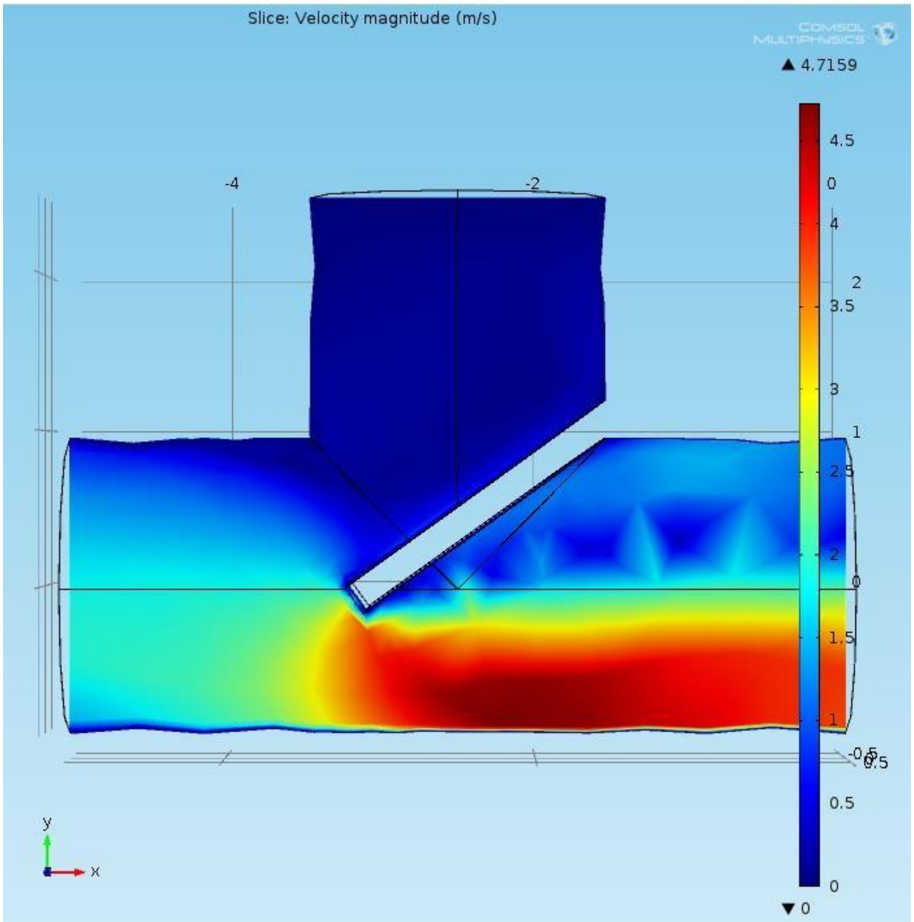

Figure 9. Velocity of water for 5 mm adjustable waste valve

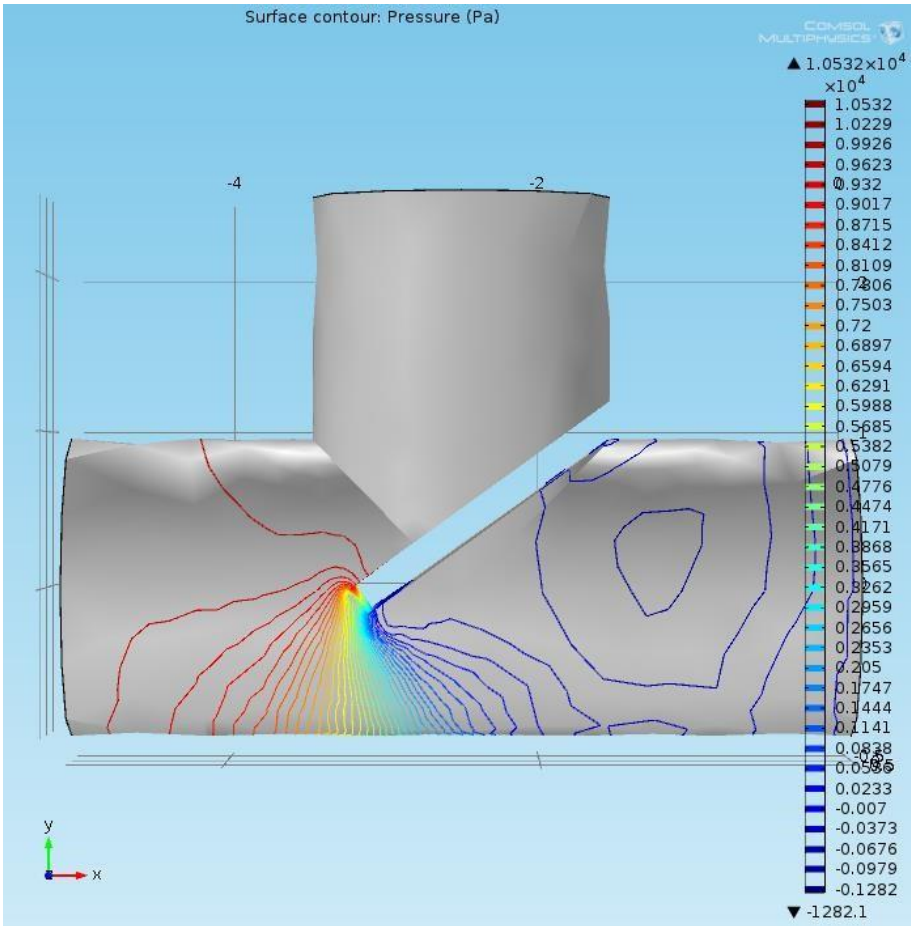

Figure 10. Pressure on the surface for 5 mm adjustable waste valve

4. Conclusion

In conclusion, the implementation of hydram as a pump system for high hill water supply is relevant. It can supply the water above the height of inlet water. It is also environmental friendly and needed minimal cost of fabrication and maintenance. The adjustable waste valves also give huge advantage to the hydram, where it can increase the flow rate of water at discharge pipe. Most of existing hydram are using a swing waste valve which its stroke cannot be controlled. The adjustable waste valve provides variety of stroke length. The most optimum length of stroke valve is 13 mm which it can discharge 1.2 L/min of water at high 2 m. The hydram can be installed in remote area to supply water in between different altitude at constant flow rate.

5. References

[1] Herlambang A and Wahjono H D 2018 *Jurnal Air Indonesia* **2**
[2] Pratowo B 2018 Universitas Bandar Lampung Indonesia
[3] Mondol S S 2017 Department of Mechanical Engineering Heritage Institute of Technology
[4] Pathak A, Pawar M, Deo A, Khune S and Mehroliya S 2016 *International Journal for Innovative Research in Science and Technology* **2** 290
[5] Sampath S, Shetty S, Pendanathu A M and Javaid W 2015 7
[6] Sr A F D, Urbano F A and Pareja B P Ilocos Agriculture Resources Research and Development Consortium Ilocos Norte, Philippines
[7] Diwan P, Patel A and Sahu L 2016 *Int. J. Curr. Eng. Sci. Res.* **3** 5

IOP Conf. Series: Materials Science and Engineering **440** (2018) 012032 doi:10.1088/1757-899X/440/1/012032

[8] Hamid Z A, Zain M Z M, Hung F C, Halim M F, Bidin W N W, Chatta I H and Omar N A 2016 *Malaysian Construction Research Journal* **19** 57
[9] Shende P B, Ninawe A and Choudhary S 2015 *International Journal for Innovative Research in Science and Technology* **2** 109
[10] Nnene O, Okoye I and Agunwamba J 2009
[11] Siwinda D E 2011 University of Malawi
[12] Dauda M T 2010 Bachelor of Engineering School of Engineering and Engineering Technology Federal University of Technology Minna, Nigeria
[13] Sheikh S, Handa C and Ninawe A 2013 *International Journal of Mechanical Engineering and Robotics Research* **2** 170
[14] Inthachot M, Saehaeng S, Max J F, Müller J and Spreer W 2015 *Agric. Agric. Sci. Procedia* **5** 107
[15] Njihia R, Maranga S and Mwai M 2015 in *Proceedings of Sustainable Research and Innovation Conference* 6
[16] Harith M, Bakar R, Ramasamy D and Quanjin M 2017 in *IOP Conf. Ser. Mater. Sci.*
[17] Harith M, Bakar R, Ramasamy D, Kardigama K and Quanjin M 2018 in *IOP Conf. Ser. Mater. Sci.*
[18] Boatwright A, Hughes S and Barry J 2015 *Sci. Rep* **5** 16790
[19] Chan C L and Chen C 2010 *J. Fluid Mech.* **647** 91
[20] Carmigniani R A, Benoit M, Violeau D and Gharib M 2017 *J. Fluid Mech.* **811** 1
[21] Xu D, Warnecke S, Song B, Ma X and Hof B 2017 *J. Fluid Mech.* **831** 418.
[22] Tuzi R and Blondeaux P 2008 *J. Fluid Mech.* **599** 51
[23] Polenta V, Garvey S, Chronopoulos D, Long A and Morvan H 2015 *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering* **9** 278
[24] Giorgio-Serchi F and Weymouth G 2016 *J. Fluid Mech.* **798**
[25] Shockling M, Allen J and Smits A 2006 *J. Fluid Mech.* **564** 267
[26] Jang S J, Sung H J and Krogstad P-Å 2011 *J. Fluid Mech.* **687** 376

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