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Technical paper title: Ram pump experimental rig

Student Name: Hilal AL-Jahwari
Number: 201645292
Supervisor: Dr. Matthew Stickland
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Abstract

It can be clearly seen in the agriculture area the DC pumping system used in order to lift the water from certain heights. Therefore, the cost of electricity would rise due to the huge consumption of electricity. Moreover, some of the poor villages have limited electricity which will be difficult to deliver the water to those villages. There is a system can deliver the water from a low point to higher one called the ram pump. The function of the ram pump is to deliver water from a low point to a higher one by converting the mechanical power to hydraulic energy. This paper will carry out the experimental and theoretical results of the ram pump when the supply head is 1m and the delivery head is 1.3m. Three experiments were tested with changing only in the drive pipe length. The best efficiency has been found 13.8% and a flow rate of 42.5 L/h with drive pipe length 2.4m.

Contents

Nomenclature

Notation	Descrabtion
%	Percent
DC	Direct Current
HZ	Hertz
L	Litre
m	meter
m^2	Meter square
M^3	Cubic meter
min	Minute
Pa	Pascal
PSIG	Pound per square inch gauge
s	second
v	Volt

1.0 Introduction

1.1 Background

Ram pump or hydraulic ram pump is a water pumping system powered with no external energy. The function of the ram pump is to deliver water from a low point to higher on be converting the mechanical power to hydraulic energy by using the water hammer motion to create a pressure that allows the water to be lifted to a higher point. It used for agriculture applications and it can take a place of DC water pump in order to save energy. The system of the ram pump contains three basic parts which are they check valve, waste valve and air chamber as Figure 1 shown.

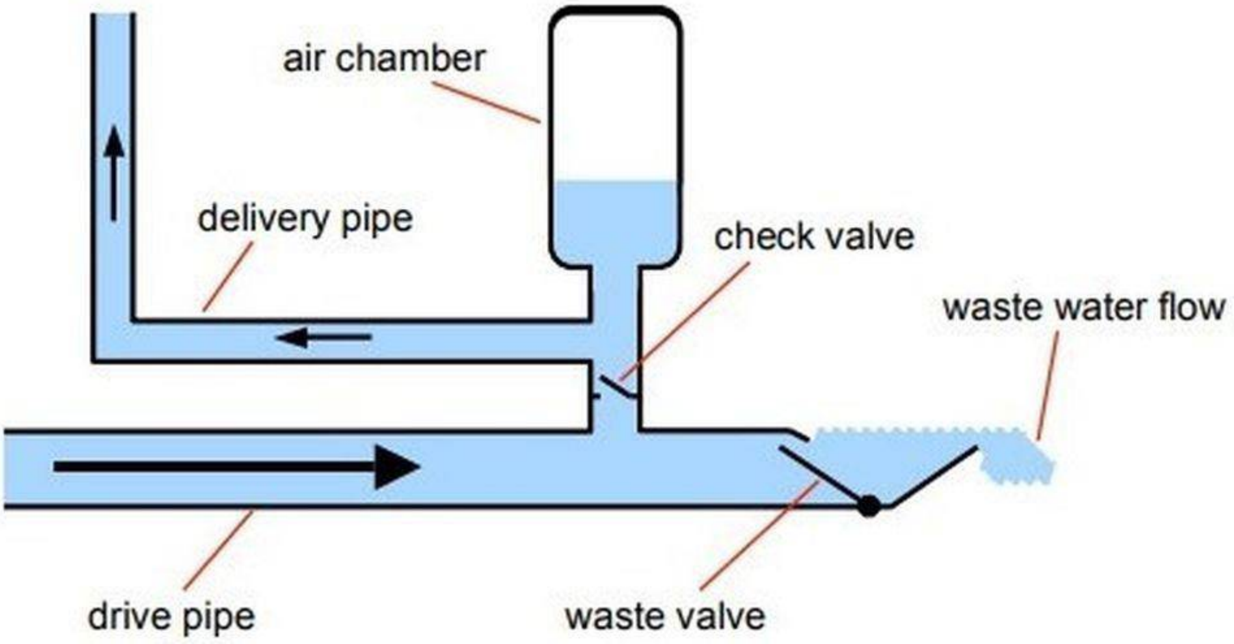

Figure 1: Ram pump's parts[1]

The cycle sequences of the ram pump depend on the cycle closing and opening of the waste and check valves. Water has been supplied from the water source flowing through the drive pipe going towards the waste valve. When the waste valve closes will create a high-pressure increase in the drive pipe. The air chamber will convert the high discontinuous pumped flow into a continuous flow. The check valve is required to allow the air into the ram pump to take the place of the air that was absorbed by the water as a result of the high pressure, which is mixed in the air chamber. Consequently, the air chamber will force the water flows through the delivery pipe to reach the delivery point. There are three main factors that should be considered to let the ram pump working 24/7:

- The water source (quantity of the water).
- The difference between the height of the water source and the height of the pump site (Supply head).
- The difference between the height of the pump site and delivery point (Delivery head).

The aims of this project are to design and build a ram pump that can lift the water from height 1m to 1.3m working 24/7 with no external energy, increasing the length of drive pipe to increase the efficiency of the pump and comparing the experimental results with theoretical and simulation results.

1.2 Literature review

In 2017, Hussin, Gamil, Amin, Safar, Majid, Kazim and Nasir [2] have designed and analysed three ram pumps. All of the pumps were at the same supply and delivery head. But the difference was in the air chamber and the number of pushes on the waste valve. The design with the smallest air chamber volume got the best results which are 15% efficiency and flow rate of 11.821 L/min. In addition, Shende, Ninawe and Chodhary [3] have done the analytical calculation for a ram pump by using individual head losses. They found out the performance of the flow of the ram pump is extremely affected. The flow rate of the delivery pipe was $3.92 \times \mathbf{10^{-3}}$ m^3/s with the efficiency of 26.87%.

Another experimental has been done by Mohammed [4]. The aims of the experiment were to design a ram pump which is capable of pumping the water from a depth of 2 m below the surface. The difference between the supply head and the delivery head was 1.37 m. The results illustrate the flow rate of the delivery pipe was 2.71 L/min, Power was 1.273 kW with an efficiency of 57%. W.Bryan [5], has designed two home-made ram pumps and he explained the operation of each one, and he motioned the working principle of each one. He was investigating if the change in the position of the waste valve will influence the flow in the drive pipe. When the flow rate in the drive pipe was 450 L/h the flow rate at the outlet (delivery pipe) will be 57L/h. the result was the same for both designs. Also, the ram pump will deliver 12% of the water that passes through the pump from the water source.

2.0 Method

2.1 Building the system

The pump has been built by another student from past years as figure 2 shown. The pump was not working continuously and have significant leaks on it. So improvements have been made into the pump in order to work perfectly and continuously. Moreover, a new experimental rig has built in the laboratory of the University of the Strathclyde for development and experimental porpuses, figure 3 will show the new design of the ram pump.

Figure 2: The Old ram pump.

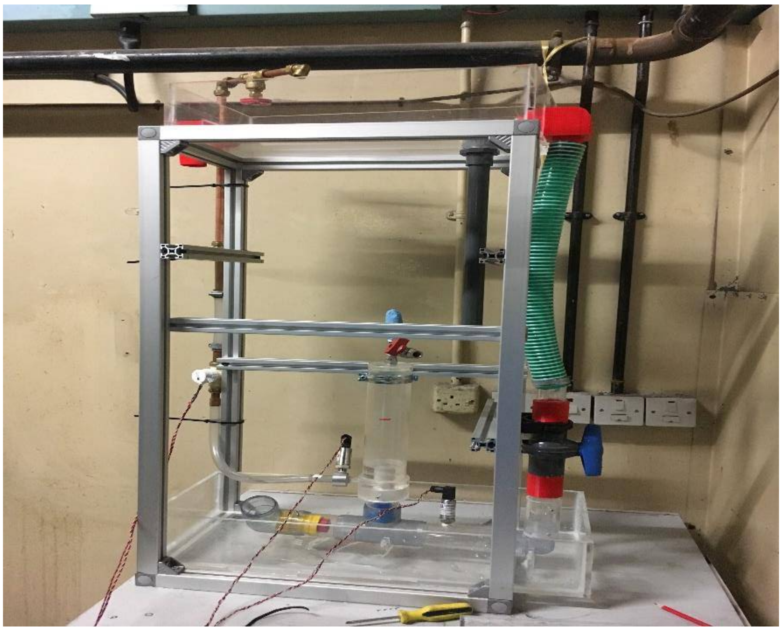

Figure 3: The new ram pump

Table 1: Specification of design components

Component name	Quantity	Description
One-way valve	2	Diameter 0.04 m valve has been made by the University (ABS plastic)
Air chamber	1	UPVC pipe, volume of 0.6397 L
Control valve	1	UPVC pipe, Diameter 0.04 m
Control valve	1	Copier pipe, Diameter 0.01 m
Tee	1	UPVC pipe, Diameter 0.04 m
Elbow 90º	2	UPVC pipe, Diameter 0.04 m
Elbow 90º	2	Copier pipe, Diameter 0.01 m
Pressure transducer	3	PX 0.0-30.0 PSIG / 99.835 mVdc
Flow Sensor	1	Max 10v/ 0.01 m
Water bed	2	0.35m x 0.3m x 0.1m
UPVC pipe	1	1m , 0.25m , 0.24m , 0.1m
UPVC pipe	1	0.3m , 0.1m
Copier pipe	1	0.77m , 0.1m

Pump improvements did not only fix the leaks or build an experimental rig, but it could also help to avoid the leaks in the future and reduced the water hammer effects on the pump. Many of the screws have been used on the valves in order to fix them into position. A clip was attached on top of the air chamber to stabilize it which will lead to obtaining accurate signals. 4 supportive saddles placed on the waterbed to hold the pump.

2.2 Set-up measurement equipment

Three pressure transducers have been placed in different locations of the pump, at the drive pipe, air chamber and delivery pipe. Those sensors are connected in electrical circuits with National Instruments Data Acquisition Module because the sensors sending a signal which is in voltage that requires translation to pressure unit. Moreover, LabView software has been used in order to read this data(Figure 4). Each pressure transducer has a separate calibration that has been provided by the manufacturer as Table 2 shows.

Table 2: Pressure Transducer calibration

	Pressure Transducers					
Location	Drive pipe		Air chamber		Delivery pip	
	Pressure PSIG	Unit data mVdc	Pressure PSIG	Unit data mVdc	Pressure PSIG	Unit data mVdc
	0.00	-o.459	0.00	0.234	0.00	-0.285
	15.00	48.629	15.00	50.096	15.00	49.662
	30.00	97.848	30.00	100.095	30.00	99.742

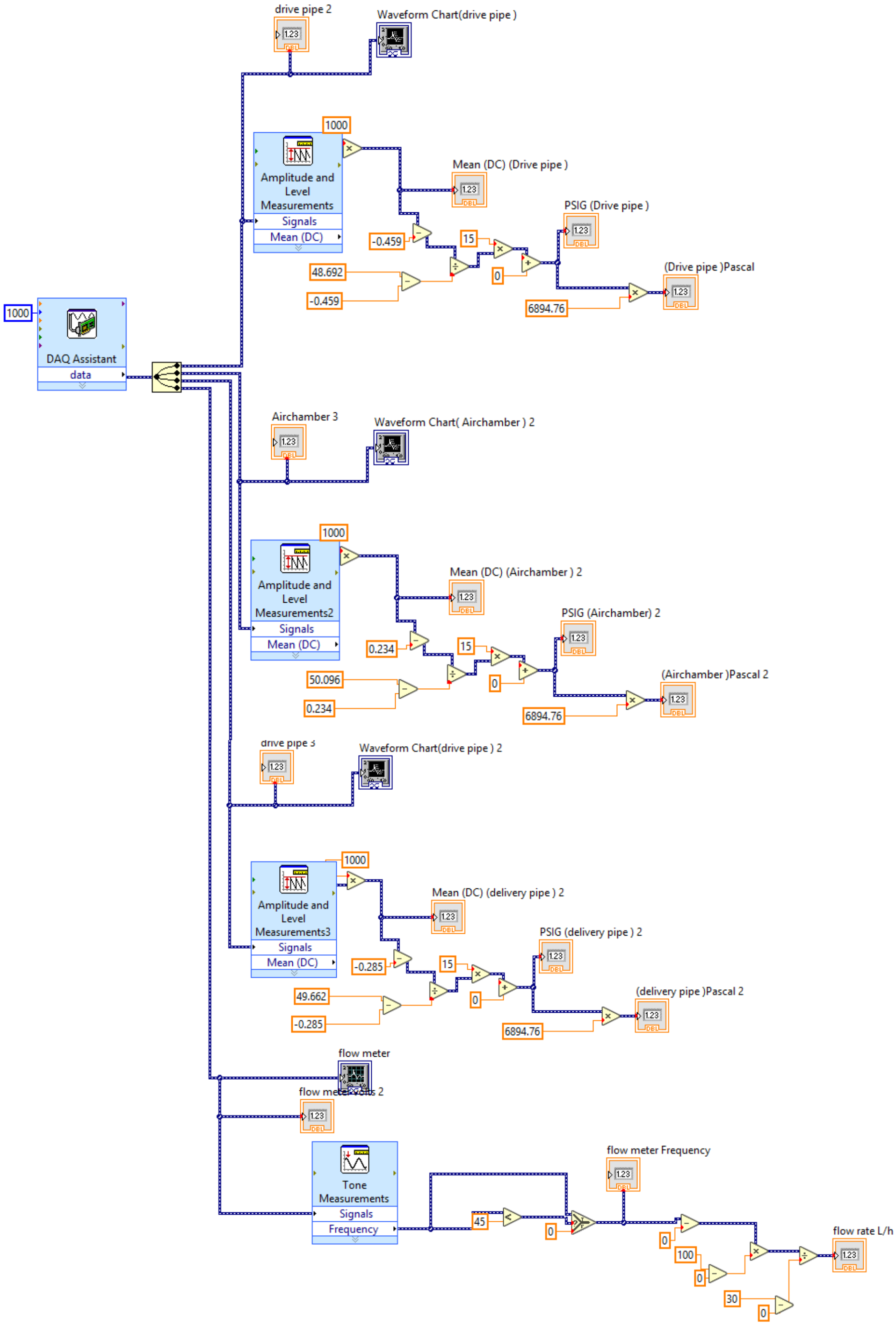

Figure 2: Program code

For the flow meter, a calibration has been done by measuring the frequency of the signal at various flow rates (Figure 5). As same as the pressure transducers, The flow meter sensor has been connected in electrical circuit with the National Instruments Data Acquisition Module to measure the frequency of the pump. The results were recorded by LabView software. Figure 6 shows the Flow rate in LabView when there is no flow rate delivered.

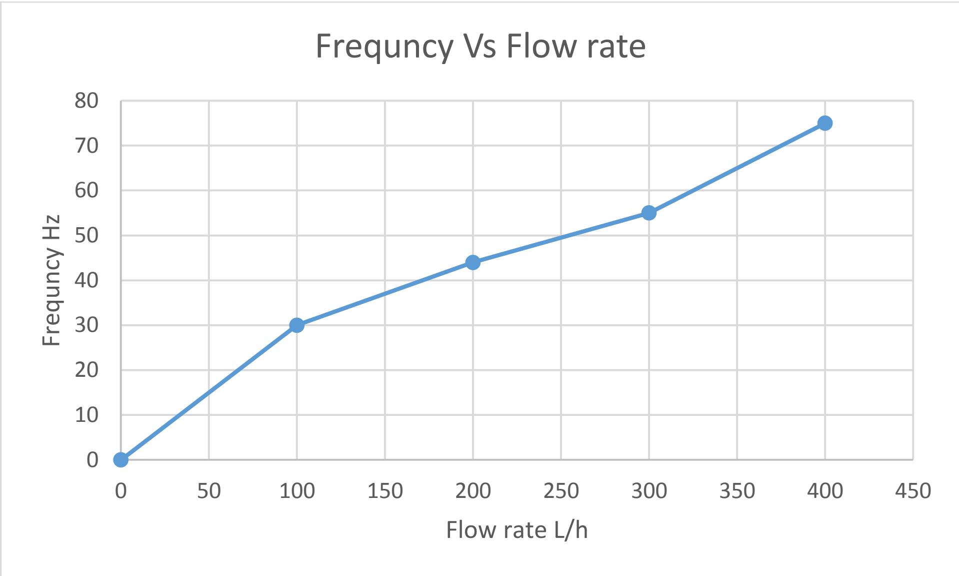

Figure 3: Flow meter calibration

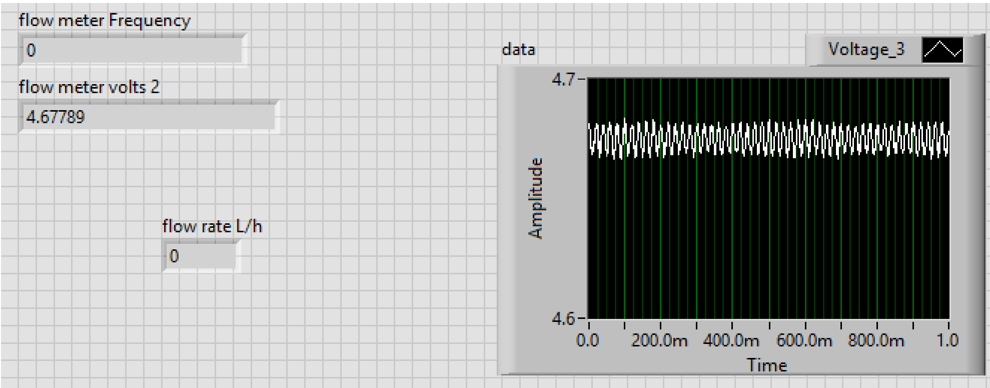

Figure 4: Flow rate Signal in LabView.

2.3 Simulation set-up

Applied flow technology impulse (AFT Impulse) software has been used in this experiment. AFT is an analysis software used to determine the pressure surge transient in the piping system.

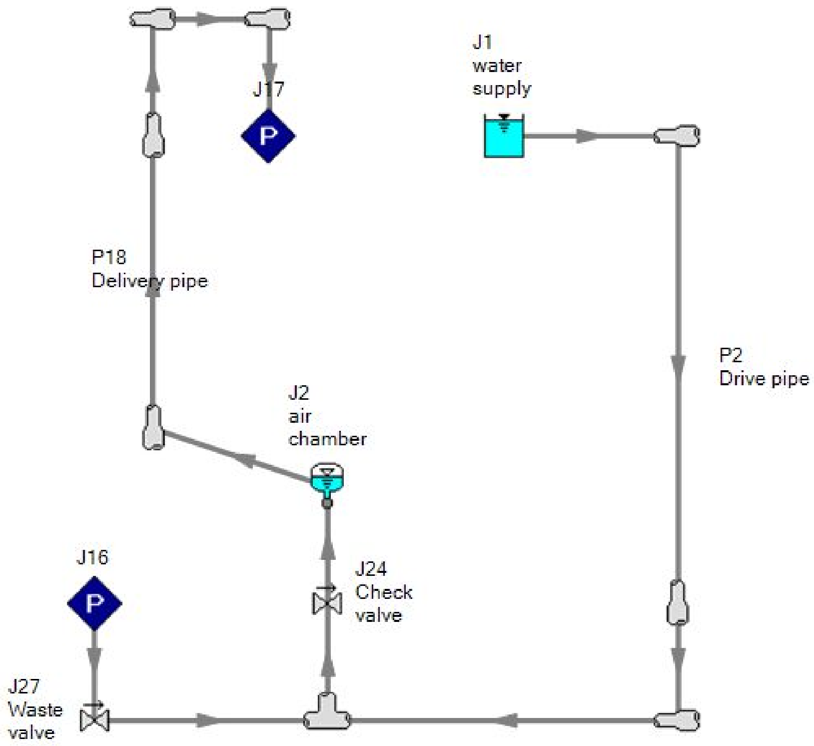

Figure 5: Ram pump model in AFT Impulse

All the parameters from table 1 used to model the ram pump In AFT. Assuming the two valves have the same parameters, with forward velocity to close the valve 0.082 m/s and flow coefficient 0.723 (6). The initial gas volume of the air chamber was set to be half the volume of the air chamber which is 0.31 L. For Polytrophic constant Υ = 1.4, assuming the system is an isentropic process. At the waste valve and the delivery point, the static pressure was set to be 0 because it is the pressure in gauge.

3.0 Results

Three experiments were conducted on the ramp pump with only a difference in the drive pipe length, with all other variables remaining constant. To increase the length of the drive pipe it was coiled around the system so that it would fit in the limited amount of space of the ram pump. As seen in figure 7. Table 3 illustrates all the parameters of the ram pump in each test. Each test was re-performed 3 times at least in order to achieve high accuracy of results.

Figure 6: The ram pump after increasing the length

Table 3: Results table

Parameter	Test 1	Test 2	Test 3
Supply head	1	1	1
Drive pipe Length	1	2.3	4.5
Delivery point head	1.3	1.3	1.3
Drive pipe voltage (V)	4.143	4.211	3.12
Drive pipe pressure (Pa)	9684.51	9971.97	7689.07
Air chamber voltage (V)	4.33768	4.32379	3.1867
Air chamber pressure (Pa)	8511.66	8502.27	6124.38
Delivery pipe voltage (V)	4.61341	4.67951	3.56093
Delivery pipe pressure (Pa)	10142.8	10279.6	7902.44
Flow meter frequency(Hz)	9.30477	12.77	0
Delivery pipe Volumatic flow rate (L/h)	31.015	42.5	0
Efficiency %	10.08	13.8	0
Fluid velocity (delivery pipe) m/s	0.1096	0.1503	0

The interpolation formula has been used to determine the pressure from voltage Table 2 and the volumetric flow rate from the frequency figure 5. In addition to that, Moreover, the efficiency **(n)** and the velocity of the fluid **(V_f)** of the ram pump are giving by :

$$n = \frac{Q_d H_d}{Q_s H_s} \times 100\% \qquad (1)$$

Where **H_d** is the delivery head, **Q_d** is the flow rate at the delivery point, **Q_S** the flow rate in the drive pipe and **H_s** the supply head.

$$v_f = \frac{Q}{A} \qquad (2)$$

Where Q is the flow rate and A is the pipe Area.

The simulation results were not carried out due to a technical error in the software. It has been used check valve as a valve type but the software did not allow the valve fully opened at the beginning of the simulation hopefully this problem will be resolved next couple week.

4.0 Discussion

According to table 3, not all the experiments produced results. Test 3 has a length of 4.5m in the drive pipe but the pump did not operate at all. The pressure was at drive pipe 7689.07 Pa which showed that the pressure in the drive pipe was not enough to operate the pump because the quantity of the water source was not enough to fill the pipe length. However, in test 1 and 2, the efficiency increased when the drive pipe length increased as well as the pressure in the drive pipe increased. This means, when the waste valve is closed, the water that flows through the drive pipe from the water source gains more momentum and speed due to the stopping of the water. As the pressure had a greater value a greater quantity of water was lifted. Also, there is a minimal difference in the air chamber between test 1 and 2. This is because the air chamber remains the same in each test. Moreover, it has been noticed that when the water level in the air chamber increased the time it took the two valves to open and close increased with no significant effects in the flow rate. Furthermore, when the water level in the air chamber reaches the top of the air chamber the pump will not deliver any water and the two valves remain working. At the delivery pipe, the pressure rises when the amount of water that delivers increase.

Rife Hydraulic Engine Manufacture Company [7] found an equation to calculated the Flow rate of the pump

$$D = 0.3 \times Q_S \times \frac{H_S}{H_d} \qquad (3)$$

The number of 0.3 is the efficiency of the home built pump. The flow rate has been obtained from test 1 is 31.015 L/h and the results from equation (3) is 92.21 L/h. It can be seen a huge gap between the two results due to the efficiency of the pump. However, by using the same equation with changing in the number of the pump efficiency to 0.1 will obtain a close number which is 30.76 L/h to the experimental result.

It can be said that 10.6% of the water has been pumped to the delivery point, this is disappointing value, nonetheless taking in the account that a 40 L out of 400 L can be delivered to a greater height than the source of water without using any electricity is an interesting point. Especially, when the rest of waste water will back to the same source.

5.0 Conclusions

The ram pump water pumping system was designed and tested. The experimental results carried out that obtained the best efficiency of the three tests was 13.8% with flow rate a 42.5 L/h which has a length of drive pipe 2.3 m. In addition to that, the theoretical calculation has been made in order to compare it with experimental results. The pump working perfectly 24/7 and it has the ability to deliver 10.6% of the water source with no external energy. It could be stated that the ram pump is a water pumping system that can be offered to places with little to no electricity, especially, those villages which have a stream or river nearby so that the flow could be utilized by the ram pump and provide water. The main problem with the ram pump is only a small amount of water can deliver. This can be solved by installing many pumps in parallel or series to significantly increase the delivered amount of water. Furthermore, the comparison between the experimental and simulation results has was not carried out in this paper due to the error of the simulation. It will be included in the final thesis.

6.0 References

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