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Utilizing Tidal Energy for Low Head Hydraulic Ram Pumps: An Innovative Method for Soil Improvement Using Seawater

CHARLES ROMMEL L. TADO[1], VANESSA F. PASTOR[2], DR. VINYL H. OQUIÑO[3]
[1]*Mechanical Engineering Dept., Palompon Institute of Technology, Philippines*
[2]*Mechanical Engineering Dept., Eastern Visayas State University,Ormoc City, Philippines*
[3]*Electrical Engineering Dept., Eastern Visayas State University, Tacloban City, Philippines*

***Abstract* - In this study, we investigate the feasibility of using tidal energy to power low head hydraulic ram pumps to bring sea water to elevated agricultural lands, thereby providing a sustainable and cost-effective solution for soil conditioning. To ensure global food security, innovative approaches to agriculture are essential considering the rising demand for food production and the challenges posed by climate change. As a renewable and predictable energy source, tidal power provides a promising alternative to conventional irrigation techniques.This method not only reduces reliance on fossil fuels for irrigation, but also provides a method for soil conditioning via the addition of minerals and nutrients from sea water. Due to its ability to operate with minimal head differences and low maintenance, the low head hydraulic ram pump, which is renowned for its simplicity and efficacy, is an ideal candidate for this application.This research demonstrates the viability and efficiency of tidal energy as a power source for low head hydraulic ram pumps in agricultural contexts. Hoping to resolve the challenges of food production and soil degradation by integrating renewable energy sources and innovative irrigation techniques, paving the way for a more sustainable and resilient agricultural future.**

***Indexed Terms*- Tidal Energy, Low Head Hydraulic Ram Pump, Quinoa, Seawater, Soil Improvement**

I. INTRODUCTION

In their pursuit of renewable energy sources, scientists and engineers have long been captivated by the immense and unrealized potential of tidal energy. As the tides rise and fall, they transport a vast quantity of untapped kinetic energy.

This study seeks to determine if a tidal-powered low-head hydraulic ram pump is a viable tool for lifting seawater to an upland agricultural area as a cost-effective method of soil conditioning.By utilizing the ocean's natural rhythms, these low head hydraulic ram pumps may be able to transport sufficient seawater inland, thereby providing much-needed irrigation and aiding in the management of soil salinity. This method could not only improve the health and productivity of agricultural ecosystems, but also provide a sustainable solution to the rising demand for tap water as main source of irrigation.

In the following sections, we will delve into the mechanics of tidal energy and low head hydraulic ram pumps, exploring the operating principles and prospective benefits of these technology by answering the following questions:

1. What is the maximum head required to lift sea water to an upland area for agricultural use?
2. What is the efficiency of the mechanism that will be used in this study?
3. How many liters of seawater can be collected using this tidal power device?

II. METHODS

This study involves a review of several published journals that conducted experimental studies on the optimal design, performance, and efficiency of hydraulic ram pump systems. These journals have varied experimental focus but with common desired output, to determine the most efficient hydraulic ram pump design and the evaluate the desired discharge height using different input head and volume.

A hydraulic ram pump is a pump that employs the energy of water falling from a height to pump water to a higher outlet level. Until there is a continuous flow of cascading water, the pump will operate automatically and without additional power. Hydraulic ram pump is a straightforward pumping device that operates on renewable energy and is durable. The hydraulic ram has only two easily maintained moving elements, which are the impulse and delivery valves. A hydraulic ram relies on the unbalanced flow of water in a conduit connected to a pump from a water source. This flow is produced by situating the hydraulic ram a predetermined distance below the water source and connecting the water source to the pump via a drive conduit. Two check valves, which are the only moving elements of the pump, are utilized by the hydraulic ram (Kale 2022)[2].

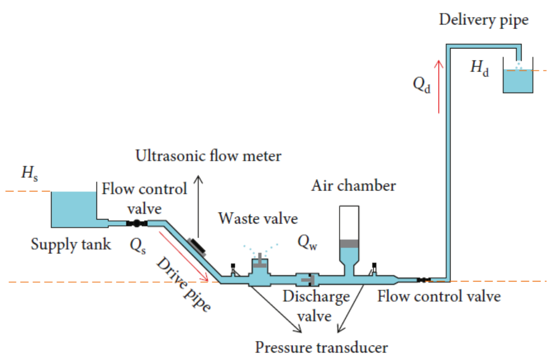

Figure 1 Schematic diagram of a Hydraulic Ram Pump

In order to determine the hydraulic ram pump's efficiency (denoted by η), we divide the value of the increased potential energy of the delivery flow by the value of the decreased potential energy of the waste flow, using the water level in the upper reservoir as a reference point. The equation is

$$\eta = \frac{qh}{QH}$$

The resistance to flow and the pressure on the wastevalve of a hydraulic ram pump should be minimized and kept as constant as feasible, respectively, duringthe design process. When thinking about logistics, setup, and final cost, it's also crucial to consider how big the equipment is and how much raw materials it uses. A smooth flow path with no jerky expansions or contractions is preferred for optimal hydraulic performance. (Guo,Xinlei 2018) [4]

These basic ideas on how a hydraulic ram pump work has been the working principle for all experiments conducted by various authors in this study.

III. RESULTS AND DISCUSSIONS

Experiments conducted by various authors on the design and efficiency of hydraulic ram pumps gave varied positive results that made this research study viable.

In the experiment conducted by Kale [2], as the Input Head (H_s)is increased, the Output Head (H_d) and Discharge Volume also increases however the required Supply Volume (Q_s) at a higher Input Head (H_s) is reduced.

Sr. no.	Input Head (Hs)	Hs in meters	Output head (Hd)	Hd in meters	Qs (L/min)	Qd (L/min)	Qw	Beats per min	Efficiency η
1	0.5ft	0.1524	5ft 1 inch	1.54	2.5	0.21	2.29	54	76.48
2	1ft	0.3048	6ft 5 inch	1.96	1.8	0.24	1.56	47	72.41
3	1.5ft	0.4572	6ft 10 inch	2.08	1.9	0.28	1.62	49	52.31

Table 1 Result table for Hydraulic ram pump model system.

In this experiment, it showed a directly proportional relationship between the input head and the output head where on the first trial, a head of 0.5ft has raised the water at an elevation of 5ft 1inch; the second trialhad an input head twice the first trial, and it significantly raised the water by 1ft and 4inches more than the first trial; the third trial had an input head of 1.5ft however it only raised the water by 5inches more than the second trial. Out of the three trials, the first had the highest efficiency but significantly reduced during the third trial. Input head is inversely proportional to the efficiency of the output head.

To compare the decrease in efficiency, the first trial was set as a base reading having a value of 76.48%. The percent decrease in efficiency during the second was 4.07% while on the third trial it reached as much as 24.17%.Assuming that the supply volume is capable of delivering a constant discharge volume of 0.28 L/min, this mechanism will be able to approximately 16.8Liters of seawater for a period of 1hour.

In the experimental study conducted by WanchaiAsvapoositkul [1], a comparative result on two different supply heads were considered (H_s = 2.0m andH_s = 2.5m) and its correlation to the increase and decrease of valve beats that will also affect the volume of wastewater generated on the system. Also, variations of the supply volume (Q_s), Discharge head (H_d), and discharge volume (Q_d) are represented on the graph shown below:

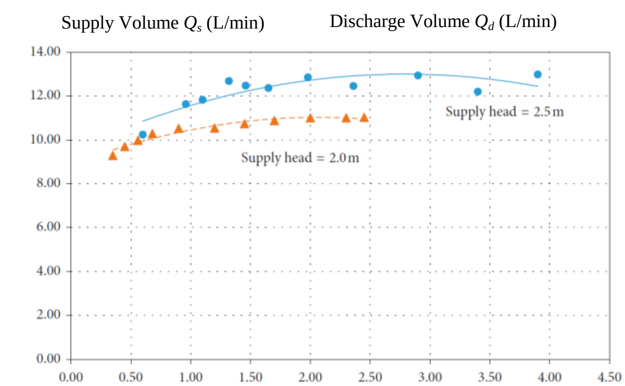

Figure 2: Supply Volume vs. Discharge Volume at different head, H_s = 2.0m and 2.5m

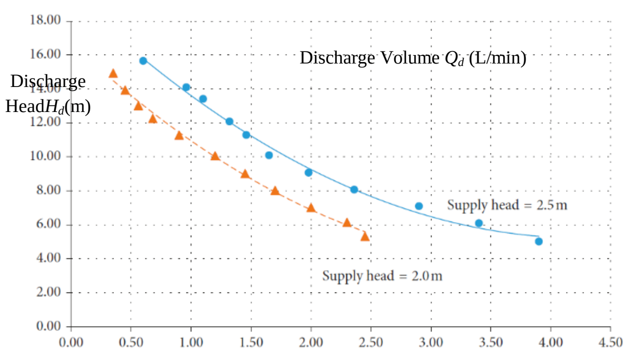

Figure 3:Discharge Head vs. Discharge Volume at different head, H_s = 2.0m and 2.5m

The graph in Figure 3 and 4 shows that an increase in supply head (H_s), will also increase the discharge head (H_d), discharge volume (Q_d) and the required supply volume (Q_s). As a result, we should anticipate a larger power addition to the water when the supply head is increased.

Figure 4 shows that for a supply head (H_s) of 2.0m approximately 15m discharge head (H_d) and discharge volume (Q_d) of 2.5 L/min can be achieved; increasing the supply head (H_s) up to 2.5m will achieve approximately 16m discharge head (H_d) at a discharge volume (Q_d) of 3.9 L/min.

Another graph shows the relationship between the efficiency of this mechanism using two different supply head values.

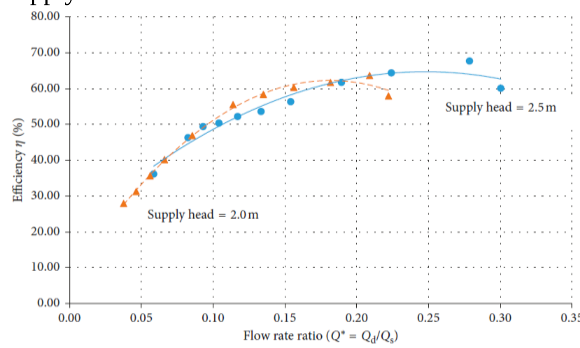

Figure 4: Efficiency vs. Flow-rate ratio at different head,
H_s = 2.0m and 2.5m

The effectiveness of the hydraulic ram pump is seen in Figure 6 for both available supply heads. According to the findings, its effectiveness reaches its highest point at around the maximum Q^* for each supply head.It is important to keep in mind that when there is a rise in the supply head, there is also a rise in the velocity and momentum of the water in the drive pipe. The findings indicate that an increase in the supply head leads to a rise in Discharge volume (Q_d), the number of waste valve beats per minute, the delivery power, and the efficiency of the pump. Because of this, we need to work toward making the supply head as big as we possibly can.

On the other hand, if the supply head is high and the drive pipe is long, the momentum of the water in the drive pipe will be extremely high, which can harm the pump. In this scenario, it is possible that the hydraulic ram pump will require a large air chamber and air volume in order to absorb the increased water hammer pressure that would be generated by the device.

The graph above showed a maximum efficiency of 65% at a supply head (H_s) of 2.0m at a flow ratio of

0.2 L/min while a maximum efficiency of 68% was achieved at a supply head (H_s) of 2.5m at a flow ratio of 0.27 L/min.

Now, to consider the practical application of this low head hydraulic ram pump in brining seawater to an upland agricultural area, the research also delved into the difference in seawater level for a certain period of the day. A Tide chart coming from PAGASA (The Philippine Atmospheric, Geophysical and Astronomical Services Administration) was used as a reference as seen on the tables below:

METRO MANILA
TIDE STATION

Manila South Harbor

HOUR	HEIGHT	HOUR	HEIGHT
0000	0.25	1200	1.19
0100	0.3	1300	1.05
0200	0.33	1400	0.83
0300	0.37	1500	0.57
0400	0.44	1600	0.31
0500	0.53	1700	0.07
0600	0.66	1800	-0.1
0700	0.81	1900	-0.19
0800	0.97	2000	-0.2
0900	1.11	2100	-0.15
1000	1.2	2200	-0.06
1100	1.24	2300	0.04

Figure 5:Metro Manila Tide Station

As shown on the Tide chart for Metro Manila and Cebu City Tide Station, an average of 1meter height difference in the seawater level can be achieved within the day. These height difference can be considered as the supply head (H_s) in this proposed application of the low head hydraulic ram pump that was considered in this research study.

For the proposed practical application of this device in bringing seawater to upland agricultural areas, various conditions shall be taken into consideration for this to become viable. Looking at the tide

VISAYAS
TIDE STATIONS

Cebu City, Cebu

HOUR	HEIGHT	HOUR	HEIGHT
0000	0.7	1200	1.81
0100	0.75	1300	1.69
0200	0.7	1400	1.4
0300	0.59	1500	1.01
0400	0.47	1600	0.58
0500	0.41	1700	0.2
0600	0.45	1800	-0.08
0700	0.63	1900	-0.21
0800	0.92	2000	-0.18
0900	1.26	2100	-0.03
1000	1.57	2200	0.18
1100	1.77	2300	0.4

Figure 6:Visayas Tide Station

difference daily, a possible supply head of 1 meter can be obtained by locating the low head hydraulicpump on a cliff face area near the shore or on upland areas along shorelines. This is to minimize the distance of the discharge pipe from the hydraulic ram pump that would eventually create a backflow pressure limiting the discharge volume of seawater coming out from the pump. The pump shall be located in an area where the average tidal difference is more than 1 meter to guarantee its effectiveness.

Selection of crops that can be propagated in a salty environment is also considered particularly *Chenopdium quinoa Willd.* The halophytic pseudocereal crop known as Chenopodium quinoa is currently being grown in an increasing number of nations throughout the world. Because quinoa can withstand a wide variety of abiotic pressures and its seed has a higher nutritional content than that of any other major grain, it is seen as a potential crop for ensuring the continued availability of food on a worldwide scale in the future. [9]

CONCLUSION

The results of the experiment conducted by various authors showed the different elevation and discharge volume that a low head hydraulic ram pump can achieve for a certain supply volume and supply head.

In the experiment conducted by Kale [2], a maximum of 6ft and 10inches*(2.08 m)*Output Head (H_d) was reached for a supply head (H_s) of 1.5ft*(0.4572m)*. This experiment also obtained a discharge volume (Q_d) of 0.28 L/min. For a period of 1 hour, a total of 16.8 Liters of seawater can be collected from this tidal powered device.

While the efficiency of this tidal powered device reduced significantly as the supply head (H_s) was increased, the optimal performance for this specific design may be obtained by lowering the supply head or tweaking the components of the device to include adjusting the position of the waste valve and non-return valve after conducting various experiments from different iterations

In WanchaiAsvapoositkul's [1] experiment, the study was focused on the conditions of operation and performance of the rate of pumping and waste volume in the hydraulic ram pump. Experiments were carried out on a hydraulic ram pump in which each of the following aspects may be altered individually: (a) supply head (H_s); (b) air chamber pressure; and (c) waste valve beats per minute. The change of the head ratio, flow rate ratio, and pump efficiency at each condition has been analyzed, and performance curves have been determined for each combination.

It is possible to observe that the supply volume(Q_s), discharge volume(Q_d), the discharge head (H_d), and the pump efficiency increased when the supply head (H_s) is raised to a higher level. The performance curves, which used H^* and Q^* as parameters, made a better knowledge of the device's operation possible.Even if the points are slightly dispersed, it is clear that thevolume ratio (Q^*) at which the highest efficiency occurs becomes higher as the supply head rises. This is the case even when the points are somewhat dispersed. It is also obvious that increasing the supply head will result in a reduction in the amount of water lost at the waste valve (Q_w).

This study could still be further enhanced by other researchers considering the objective and the means of powering the hydraulic ram pump using only the height difference of seawater during high tide and low tide. Aside from the mechanism used in this study, propagating quinoa seeds is one of the most promising applications of this study.

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