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Utilization of Vertical Wave Movement for Sea Water Pumping

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Abstract:

This study aims to produce a wave pump design with a vertical motion piston, find and identify variables that significantly affect the pumping discharge (Q) and analyze and obtain the relationship between the influential variables studied with Q. This study is an experimental study in a laboratory using glass channels. equipped with a wave generator. A float type pump that moves vertically is simulated with wave height and period (Hi & T), water depth (d), piston tube diameter (D), float diameter and width (Dw & b), and pumping height (h), both to get the effect of each on the discharge (Q), as well as to find the formulation of the relationship between these parameters. For analysis of research results, dimensionless parameter relationships are used in the relationship $Q \approx \psi.h$, where ψ is a combination of influential parameters in dimensionless form, $\psi = f\ (Hi, L, W, A_1, A_2, d, b)$. The results showed that the performance of the vertical motion pump was quite satisfactory by producing a discharge Q at a certain value of h.The resulting pumping discharge (Q) is quite significant because it is influenced by Hi/L, b/L, d/L, A_1/A_2, h/Hi and $W/pgHi^3$. It has been found that the empirical equation $Q/\sqrt{gh^5} = m\ \psi$ can be used at a certain pumping height (h) to produce pumping discharge (Q).

***Keywords**:* Discharge, pumping height, wave pump, vertical motion buoy

I. INTRODUCTION

Growing concern over the threat of global climate change has led to an increased interest in research and development of renewable energy technologies.The ocean provides a vast source of potential energy resources, and as renewable energy technology develops, investment in ocean energy is likely to grow [1]. The ocean can be a strategic alternative for obtaining energy supplies, both from ocean waves as from sea currents and tides. Among these features, the power generation projects based on ocean currents are still under development [2]. There is enormous potential and interest in renewable energy generation from marine tidal currents.

Tidal currents have been recognized as a valuable resource for the sustainable generation of electrical power [3]. To date there were few research on the effect of non-linearity properties of the ocean waves on the performance of wave energy converter (WEC), which uses a series of unidirectional gear [4, 18, 21]. Generating electricity from waves is predicted to be a new source of renewable energy conversion expanding significantly, with a global potential in the range of wind and hydropower, future commercial installation of wave energy plants using point absorber technology will require clusters of tens up to several hundred devices, some types of renewable energy have been experiencing rapid evolution in recent decades, notably among the energies associated with the oceans, such as wave and current energies [5, 6, 7].

Wave power pump is one way of utilizing ocean wave energy to pump sea water to a higher place. In this way, it is hoped that the operational and maintenance costs will be smaller when compared to using an electric water pump or diesel power, because after the water pump is installed the water will flow automatically or excess water can be removed easily and maintenance costs on the pump valve and piston are relatively cheaper [8, 19, 20]. The development of research using a horizontal flap type wave pump model as a wave energy catcher with the aim of this study to determine the pumping height and maximum pumping power as well as the efficiency produced by the flap pump. The target of this research is the availability of a wave pump model that has a high efficiency value with low installation, operation and maintenance costs [9]. Wave energy has a huge potential compared to other renewable energy resources. The energy of sea wave can be converted into other form of energy like electrical energy using a Buoy wave energy converter. The converted power is collected by a Power take off device [12]. Ocean wave energy is a high energy density and renewable resource. High power conversion rate is an advantage of linear generators to be the competitive candidates for ocean wave energy extraction system [15, 16]. The supply of raw water is generally water available from several sources, which are available only on a river, lake, water wells and springs. The extraction can be done by drilling, damming water, and pumping [17].

The wave pump with the float type is expected to not only be able to raise water from a low place to a higher place but also to be able to produce a larger water discharge because of the performance capability of the piston pressure in the tube and moves vertically following the high and low waves that come. On this basis, the researcher also wishes to research and develop a wave pump structure that is effective, efficient, more economical and environmentally friendly both in terms of design, in terms of implementation and of course the materials used are very easy to obtain. This research is the use of wave energy by relying on the vertical motion of the piston and buoy and can be useful for the development of a wave pump model that is friendly to the environment, including: can be used as reference material and information in developing research related to a float type wave pump with a vertical movement; as a reference for the development of a more effective and efficient wave pump structure innovation, one of the activities that requires results in this study is the use of a float type wave pump that moves vertically which can be applied to actual conditions. The problems discussed in this study are how to produce a wave pump design with a vertical motion piston with good performance, how to identify variables that affect the discharge (Q) and pumping height (h) including the magnitude of their respective effects, how to analyze and obtain the relationship between influential variables (Q and h) with the parameters examined, how to measure the performance of the tool through the efficiency value obtained.

The objectives to be achieved in this research are: Produce a wave pump design with a vertical motion piston with good performance, find and identify variables that affect the discharge (Q) and pumping height (h).

II. MATERIALS AND METHODOLOGY

2.1 Types of Research and Data Sourcer

The type of research used is Experimental, where the conditions are created and regulated by the researcher with the aim of analyzing the relationship between the influential parameters in the study. In this study, two sources of data were used, namely: Primary data is data obtained directly from physical model simulations in the laboratory. Secondary Data i.e. data obtained from the literature and the results of existing research, both those that have been carried out in the laboratory and carried out elsewhere related to wave pump research.

2.2 Materials and tools

The model is made of a cylindrical tube which is assembled using a piston on the inside of the tube which is connected to a float on the outside of the tube, the size of the tube diameter, the height of the model, variations of the inlet and outlet holes.

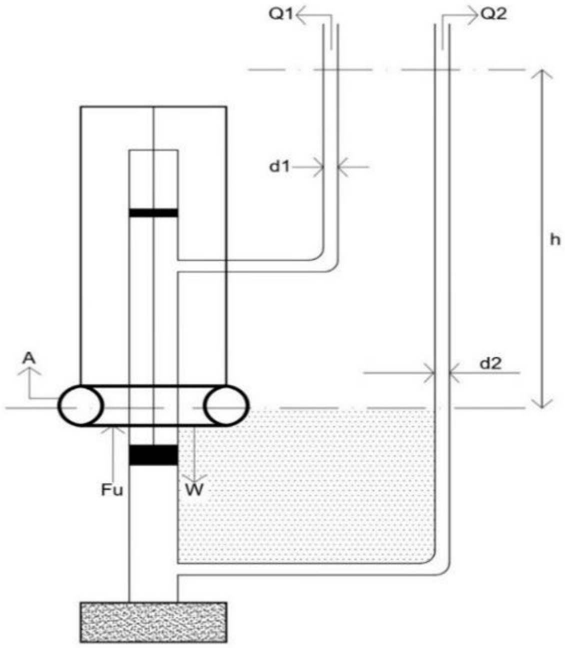

Fig 1: Model design of a float type wave pump

TABLE 1. Specific model of float type wave pump

PROPERTIES	DETAILS
CYLINDRICAL TUBE WITH CLEAR ACRYLIC MATERIAL	0.3 cm thick acrylic
TUBE DIAMETER	2.5 cm
TUBE HEIGHT	50 cm
DIAMETER OF UPPER AND LOWER INLET HOLES	2.0 cm
DIAMETER OF UPPER AND LOWER OUTLET HOLES	0.5 cm
BUOY WEIGHT	1.0 kg
RECTANGULAR BUOY SHAPE	Pipe
BUOY DIAMETER	6.0 cm
BUOY LENGTH	20 cm
FLOAT WIDTH	20 cm
PISTON MAST	Stainless steel diameter 0.5 cm
PISTON RUBBER	0.5 cm thick waterproof material
RECTANGULAR SHAPE TUBE HOLDE	10 cm thick, weighs 12 kg solid cement mix

PROBLEMS

- Ocean waves have enormous energy potential and are available continuously and free of charge, which until now have not been utilized properly.
- Aquaculture along these beaches is still dependent on irrigation using electric/diesel water pumps.
- Ocean wave energy can be used to pump seawater to higher ground on land.

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RESEARCH VARIABLE

- Dependent variable : Q
- Independent variables: Hi, L, T, d, h, D, b, W, A_1, A_2

↓

SIMULATION VARIATION

- Wave Parameters: Wave Height (Hi), Wave Length (L) and Wave Period (T)
- Model Parameters: Tube Diameter (D), Float Width (b), float weight (W), Tube area (A_1), Float area (A_2)
- Water Depth parameter (d) on the float type wave pump model, pumping height (h)

↓

HOW TO RESEARCH AND DATA ANALYSIS

- This research was conducted using physical modeling with laboratory simulations on regular waves
- Dimensional analysis and the relationship between parameters are used in dimensionless parameter relationships

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EXPECTED RESULTS

- Find and identify parameters that have a significant effect on pumping discharge (Q)
- Produces a high-performance vertical-piston wave pump design.

Fig 2: Research Framework

Based on consideration of the facilities in the laboratory, available materials and accuracy at the time of measurement, the model is made with perfect geometric concordance (non-distortion) and dynamic congruence according to Froude number conditions. The model scale in this study used a model scale of 1: 10, the complete model scale value is shown in Table 2.

TABLE 2. Research Model Scale

VARIABLE	NOTATION	SCALE VALUE
HIGH SCALE	n_H	1:10
LENGTH SCALE	n_L	1:10
WATER DEPTH SCALE	n_d	1:10
TIME SCALE (PERIOD)	n_t	1:10
WAVE PERIOD SCALE	n_T	1:10

Preparation for initial simulation on flume (without wave pump model), to obtain initial data, namely:

1. With the stroke/wave generator used in this study with the stroke number values of 6, 7, and 8, to get the wave height in front of the model (Hi), the scale of the stroke is 0 to 10 which functions to adjust the flap deviation distance to generate waves , the larger the stoke scale used, the farther the flap drift distance and the higher the resulting wave, essentially the stroke is used to vary the wave height in the channel. The measurement of the generation wave is carried out to determine the productivity of the wave height (H) and the wave period (T) produced by the wave generator based on the value of stroke, variator and channel depth (d). So that the measurements were carried out in conditions without a breakwater model. The wave generator consists of a wave generator, flap, stroke (S), and variator (V). The stroke can be varied based on the length of the flap board pusher arm.

2. Period (T) 1.3 = 13 sec, 1.4 = 14 sec, 1.5 = 15 sec, to get Wavelength (L), every 10 cycles = 10 sec. The period is the time it takes to travel one wavelength. For example T = time/number of laps = 13 seconds/10 laps = 1.3 seconds.

3. Start a modelless waveform simulation by generating a waveform by pressing the start button on the control panel. This simulation is carried out to ensure that the wave height and period in the wave flume are in accordance with the variations determined in this study.

4. Calibrate the instrument with a simulation without a model by adjusting the stroke and variator, then run an experiment to get the wave height data (Hi) that will be used when the simulation is carried out using the model.

5. Put the test model in the middle of the wave flume.

6. Filling the water in the wave flume with variations in water depth (d) 0.25 m. 0.27 m and 0.29 m.

7. After all components are ready, wave simulation begins by generating waves in the wave flume as in procedure no. 2.

8. Measure and record the wave height in front of the model on the flume.

9. Measure the water that comes out of the upper and lower outlet holes with a time of 10 seconds for each water intake and is carried out 3 times to get the average discharge (Q).

10. Variation of pumping height (h) 0.05 m to 0.40 m.

2.4 Research Parameters

The bound parameter in this study is the discharge (Q) or relative discharge, this parameter (Q) will be influenced by several other parameters related to the wave pump. The independent parameters used in this study are; Hi, L, T, b, W, A_1, A_2, d, h, g, . with the respective functions of the independent parameters namely; Wave parameters are: wave height (Hi), wavelength (L), wave period (T) and gravity (g) . The model parameters are: the width of the float (b), the weight of the float (W), the cross-sectional area of the tube (A_1), the cross-sectional area of the float (A_2). Parameters of water depth (d), pumping height (h) and mass density of liquid (ρ). In this study, the data were analyzed with various relationships between parameters and then can be determined based on the relationship between parameters expressed in dimensionless numbers using the Langhaar method [14]. This method was chosen with the consideration that the variables that have an effect are relatively few so that this method is considered more appropriate.

Fig 3: Channel model used

Fig 4: In-channel wave pump model

2.5 Wave Power

The wave energy is captured by the oscillating board which is placed vertically with the hinge support at its base when the flap receives the wave force, causing the flap to move back and forth harmoniously. The movement of the oscillation board moves the piston arm which is installed perpendicular to the oscillation board. The movement of the piston arm back and forth causes the valve to open and close. When the valve is open, seawater enters and fills the piston tube and when the flap is reversed, the wave force is transmitted to the piston arm and pushes the piston. As a result, there will be pressure in the piston tube, which will be forwarded to the distribution pipe to pump water up to a certain height. This mechanism occurs repeatedly until the water in the tubes will be pushed and flow with a certain Q. The oscillation board is designed to be able to oscillate freely following the wave motion, so the board must be made of a material that floats. Because the wave energy captured by the device is not continuous, in the evaluation the average power parameter for one wave is reviewed [10].

$Dw = 1/8\ x\ \gamma\ x\ B\ x\ H^2\ \ x\ c\ x\ L$ ………………………………………………………..….(1)

Where Dw is the wave power, is the γ gravity of the water, B is the flume width, H^2 is the wave height, c is the wave propagation speed and L is the wavelength.

2.6 Pumping Yield

The power obtained from the pumping results is different for each height, the pumping power is formulated as follows [11]

$Dv = \gamma\ x\ h\ x\ Q$ ………………………………………………………………………...(2)

Where Dv is the power of the pumped water, is the γ gravity of the water, h is the pumping height and Q is the average discharge from the pump.

III. DATA ANALYSIS AND INTERPRETATION

3.1 Wave Height Measurement

Wave height (Hi) is the vertical distance between wave crest and wave trough when the incident wave height (Hi) is measured in front of the model. The recording used is a probe tool or commonly called a wave probe (WP) which is placed in front of the model with a distance of WP1 = 0.25L and a distance of WP2 = 0.5L, then the Hmin and Hmax wave height data are recorded by the wave oscilloscope monitor so that the results are visible. wave height data. The calibration of measurement data and recording results from the wave monitor oscilloscope device from the incident wave height (Hi) can be seen in Table 3.

TABLE 3. Calibration of measurement data and recorded data from the wave oscilloscope monitor device at wave height come (Hi)

Depth Water (d)	Period Wave (T)	Wave Height Measurement (Hi)	Wave Height Osciloscope (Hi)	Lonh Wave (L)
0,25	1,3	0,0530	0,0521	1,8300
0,25	1,4	0,0500	0,0533	2,0000
0,25	1,5	0,0460	0,0497	2,1700
0,27	1,3	0,0528	0,0506	1,8900
0,27	1,4	0,0510	0,0492	2,0700
0,27	1,5	0,0470	0,0481	2,2000
0,29	1,3	0,0550	0,0590	2,0500
0,29	1,4	0,0615	0,0663	2,1400
0,29	1,5	0,0580	0,0610	2,2400

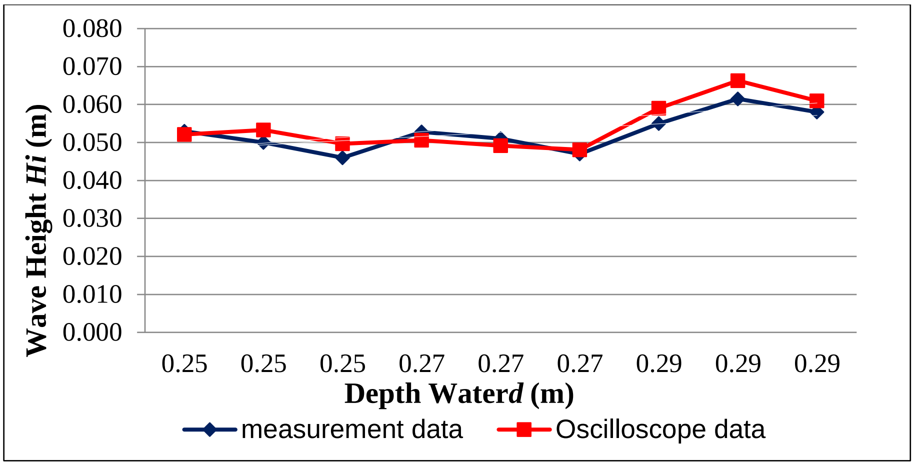

Fig 5: Measurement data and wave oscilloscope data monitor wave height (Hi) and water depth (d)

3.2 Research Discharge Measurement Analysis

The discharge measurement is carried out using a measuring cup to accommodate the water that comes out of the upper outlet (Q_1) and lower outlet (Q_2) of the wave pump model with variations of stroke 6, 7, 8 and period T = 1.3 seconds, 1.4 seconds, 1.5 seconds, taking the discharge (Q_1 and Q_2) is done with an interval of T = 10 seconds/1 time taking the discharge data (Q) with the number of taking discharge 3 times, so that the average discharge (Q_r) is obtained from each outlet hole , the results of Q_1 and Q_2 are summed to get the total discharge (Q_t).

3.3 Wave Energy Analysis

The energy of the incident wave (*E*i) consists of two types, namely the kinetic energy (*E*k) of the wave and the potential energy (*E*p) of the wave. The kinetic energy of the wave is the energy caused by the velocity of the water particles which is the resultant of the velocity of the water particles in the vertical direction (v) and the velocity of the water particles in the horizontal direction (u) due to the wave, while the potential energy of the waves is the energy produced by the mass transfer of water (m). vertical direction due to the displacement of the water level (η) due to waves. By using the incident wave height data (Hi) recorded on the wave oscilloscope monitor. To get the value of wave energy (E) is calculated using the equation [13].

$$E=1/8\,\rho g H^2 \quad \text{...}(3)$$

Where E is the wave energy, ρ is the density of the water, g is the gravity and H is the wave height. The results of the calculation of wave energy (E) in the water d = 0.25 m, d = 0.27 m and d = 0.29 m can be seen in tables 4, 5 and 6.

TABLE 4. The results of the calculation of the value of *E* at the condition d = 0.25 m

d **(m)**	***Hi*** **(m)**	***E*** **JOULE**
0,25	0,0506	3,130223
	0,0571	3,986084
	0,0588	4,226967
	0,0458	2,564514
	0,0533	3,473190
	0,0578	4,084415
	0,0456	2,542166
	0,0484	2,863947
	0,0497	3,019861

TABLE 5. The results of the calculation of the value of *E* at the condition d = 0.27 m

d **(m)**	***Hi*** **(m)**	***E*** **JOULE**
0,27	0,0521	3,318560
	0,0635	4,929713
	0,0783	7,495450
	0,0421	2,166898
	0,0492	2,959405
	0,0559	3,820303
	0,0397	1,926882
	0,0459	2,575725
	0,0481	2,828553

TABLE 6. The results of the calculation of the value of E at the condition d = 0.29 m

d **(m)**	***Hi*** **(m)**	***E*** **JOULE**
0,29	0,0590	4,255771
	0,0640	5,007652
	0,0800	7,824456
	0,0578	4,084415
	0,0663	5,374044
	0,0797	7,765883

0,0480	2,816804
0,0537	3,525516
0,0610	4,549188

A depiction of the relationship between wave energy (*E*) and incident wave height (*Hi*) is shown in Fig 6.

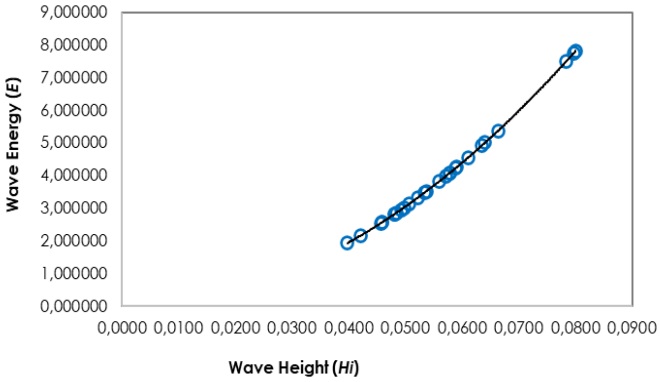

Fig 6: Relationship of parameter *E* with parameter *Hi*

In Fig 6, the relationship between wave energy (*E*) and wave height (*Hi*) is presented. The results of the wave energy calculation using equation 3 obtained the value of *E* = 1.9269 - 7.8245 and the value of Hi = 0.0397 - 0.0800, in this study the value of the parameter *E* = 2,000 resulted in the value of the parameter Hi = 0.0400 and experienced a significant increase with increasing the value of parameter *E* where the highest value of parameter *E* = 8,000 resulted in parameter value *Hi* = 0.0800.

3.4 Analysis of Research Parameter Dimensions

Dimensional analysis in this study uses the Langhaar method. This method was chosen with the consideration that the variables that have an effect are relatively few so that this method is considered more appropriate [14].

TABLE 7. Determination of the Value of the Independent Variables

VARIABLE	**Q**	**Hi**	**T**	**A_1**	**W**	**L**	**b**	**A_2**	**d**	**ρ**	**h**	**g**
M	0	0	0	0	1	0	0	0	0	1	0	0
L	3	1	0	2	0	1	1	2	1	-3	1	1
T	-1	0	1	0	0	0	0	0	0	0	0	-2
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}

Based on Table 7, the equation is obtained:

$K_5+K_{10} = 0$

$K_{10} =-15$

$3K_1+K_2+K_4+K_6+K_7+2K_8+K_9-3K_{10}+K_{11}+K_{12} = 0$

$-K_1+K_3-2K_{12} = 0$

$2K_{12} = -K_1+K_3$

$K_{12} = -0{,}5K_1+0{,}5K_3$

Eliminate K_{10} and K_{12} into K_{11}

$K_{11} = -K_1-K_2-2K_4-K_6-K_7-2K_8-K_9+3K_{10}-1K_{12}$

$= -3K_1-K_2-2K_4-K_5-K_6-K_7-2K_8-K_9-3K_5+0{,}5K_1-0{,}5K_3$

$= -2{,}5K_1-K_2-0{,}5K_3-2K_4-3K_5-K_6-K_7-2K_8-K_9$

TABLE 8. Determination of Dimensionless Number Parameters

K_i	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}
PARAMETER	**Q**	**Hi**	**T**	**A1**	**W**	**L**	**b**	**A2**	**d**	**ρ**	**h**	**g**
π_1	1	0	0	0	0	0	0	0	0	0	-2,5	-0,5
π_2	0	1	0	0	0	0	0	0	0	0	-1	0
π_3	0	0	1	0	0	0	0	0	0	0	-0,5	0,5
π_4	0	0	0	1	0	0	0	0	0	0	-2	0
π_5	0	0	0	0	1	0	0	0	0	-1	-3	0
π_6	0	0	0	0	0	1	0	0	0	0	-1	0
π_7	0	0	0	0	0	0	1	0	0	0	-1	0
π_8	0	0	0	0	0	0	0	1	0	0	-2	0
π_9	0	0	0	0	0	0	0	0	1	0	-1	0

$$\pi_1 = \frac{Q}{\sqrt{gh^5}}\,;\pi_2 = \frac{h}{Hi}\,;\pi_3 = \frac{T}{\sqrt{hg}}\,;\pi_4 = \frac{A_1}{A_2}\,;\pi_5 = \frac{W}{\rho h^3}\,; = \pi_6 = \frac{L}{h}\,;\pi_7 = \frac{b}{h}\,;\pi_8 = \frac{A_1}{A_2}\,;\pi_9 = \frac{d}{h}$$

Furthermore, from these parameters can be combined to get another dimensionless number, namely:

$$\pi_{10} = \frac{\pi_2}{\pi_6} = \frac{Hi/h}{L/h} = \frac{Hi}{h}\ x\ \frac{h}{L} = \frac{Hi}{L}\,;$$

$$\pi_{11} = \frac{\pi_7}{\pi_6} = \frac{b/h}{L/h} = \frac{b}{h}\ x\ \frac{h}{L} = \frac{b}{L}\,;$$

$$\pi_{12} = \frac{\pi_9}{\pi_6} = \frac{d/h}{L/h} = \frac{d}{h}\ x\ \frac{h}{L} = \frac{d}{L}\,;$$

$$\pi_{13} = \frac{\pi_5}{\pi_2} = \frac{W/\rho h^3}{(Hi/h)^3} = \frac{W}{\rho h^3}\ x\ \frac{h^3}{Hi^3} = \frac{W}{\rho Hi^3}$$

The dimensionless numbers used in this study are π_2, π_4, π_{10}, π_{11}, π_{12}, and π_{13} that is : $\frac{h}{Hi}$; $\frac{A_1}{A_2}$; $\frac{Hi}{L}$; $\frac{b}{L}$; $\frac{d}{L}$; and $\frac{W}{\rho Hi^3}$

Mathematically the high coefficient of pumping with the resulting discharge in this study is a function of the following parameters:

$$Q/\sqrt{gh^5} = f\left[\frac{A_1}{A_2}\,;\frac{Hi}{L}\,;\frac{b}{L}\,;\frac{d}{L}\,;\frac{h}{Hi}\,;\frac{W}{\rho Hi^3}\right]$$

Where $Q/\sqrt{gh^5}$ is the relative pumping discharge, A_1/A_2 is the relative tube cross-sectional dimension, Hi/L is the relative steepness of the wave, b/L is the relative float width, d/L is the relative depth, h/Hi is the relative pumping height and $W/\rho Hi^3$ is the relative float weight.

3.4.1 Effect of relative tube cross-sectional dimensions (A_1/A_2) on relative pumping discharge ($Q/\sqrt{gh^5}$)

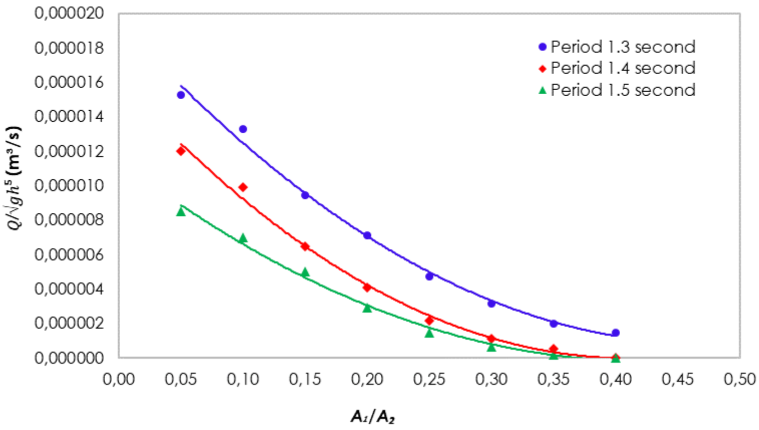

Fig 7: Relationship of A_1/A_2 with $Q/\sqrt{gh^5}$

From Fig 7, it is shown the relationship of the relative tube cross-sectional dimensions A_1/A_2 with the relative pumping discharge $Q/\sqrt{gh^5}$, in the 1.3 second period the flow rate = $1x10^{-6}$ – $1.5x10^{-5}$ m^3/second, the 1.4 second discharge period generated = $1x10^{-6}$ – $1.2x10^{-5}$ m^3/second and a period of 1.5 seconds the resulting discharge = $1x10^{-6}$ – $9x10^{-6}$ m^3/second at water depth (d) 0.25 m, 0.27 m and 0.29 m. parameter A_1/A_2 has a significant effect on the parameter $Q/\sqrt{gh^5}$, the higher the pumping, the smaller the resulting discharge.

3.4.2 Effect of relative wave steepness (Hi/L) on relative pumping discharge ($Q/\sqrt{gh^5}$)

Fig 8 shows the relationship of the relative steepness of the Hi/L wave with the relative pumping discharge $Q/\sqrt{gh^5}$, in a period of 1.3 seconds it produces a discharge = $1x10^{-6}$ – $1.7x10^{-5}$ m^3/second, a period of 1.4 seconds the discharge is generated = $1x10^{-6}$ – $1.3x10^{-5}$ m^3/second and a period of 1.5 seconds the resulting discharge = $1x10^{-6}$ – $9x10^{-6}$ m^3/second at water depths (d) 0.25 m, 0.27 m and 0.29 m, the Hi/L parameter has a significant effect on the $Q/\sqrt{gh^5}$ parameter, the higher the pumping, the smaller the resulting discharge.

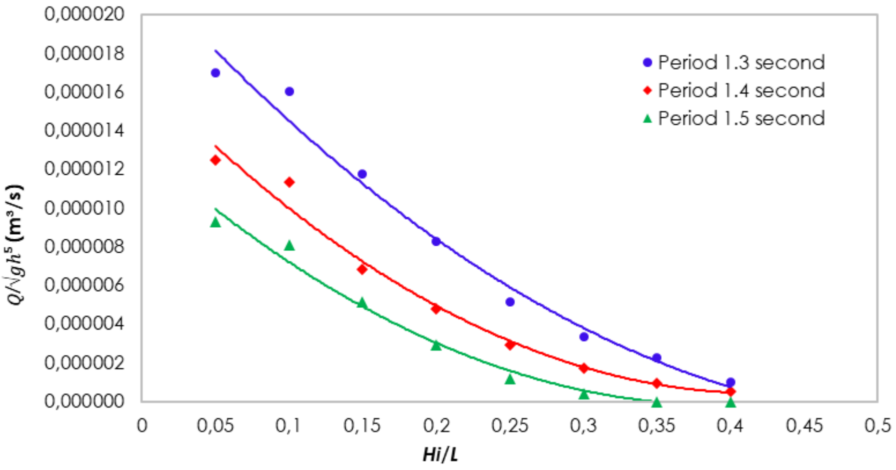

Fig 8: Relationship of *Hi/L* with $Q/\sqrt{gh^5}$

3.4.3 Effect of relative buoy width (W/L) on relative pumping discharge ($Q/\sqrt{gh^5}$)

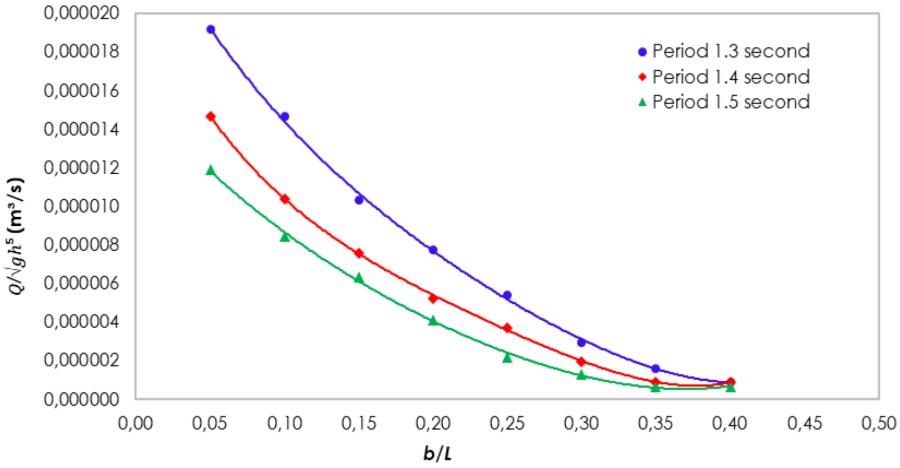

Fig 9: Relationship of *b/L* with $Q/\sqrt{gh^5}$

From Fig 9 shows the relationship of the relative buoy width b/L with the relative pumping discharge $Q/\sqrt{gh^5}$, in a period of 1.3 seconds it produces a discharge = $1x10^{-6}$ – $1.9x10^{-5}$ m^3/second, a period of 1.4 seconds the discharge is generated = $1x10^{-6}$ –$1.5x10^{-5}$ m^3/second and a period of 1.5 seconds the resulting discharge = $1x10^{-6}$ – $1.2x10^{-5}$ m^3/second at water depth (d) 0.25 m, 0.27 m and 0.29 m, the b/L parameter has a significant effect on the $Q/\sqrt{gh^5}$ parameter, the higher the pumping, the smaller the resulting discharge.

3.4.4 Effect of relative depth (d/L) on relative pumping discharge ($Q/\sqrt{gh^5}$)

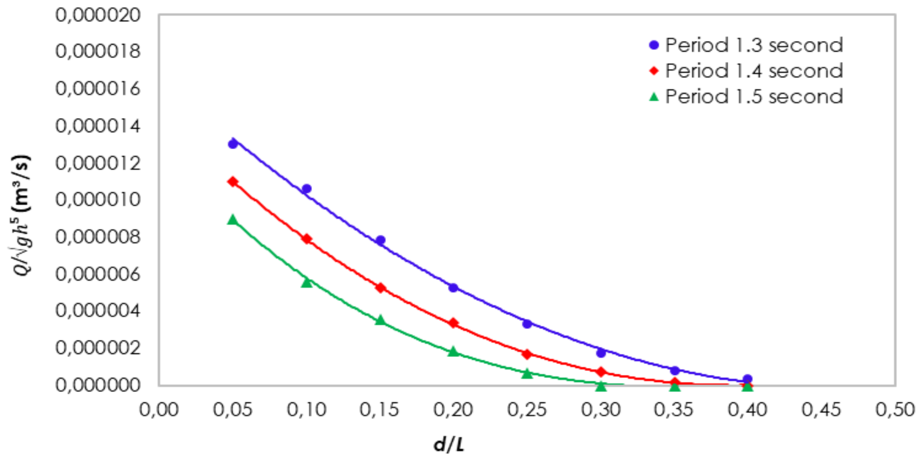

Fig 10: Relationship of d/L with $Q/\sqrt{gh^5}$

Fig 10 shows the relationship of the relative depth d/L with the relative pumping flow rate $Q/\sqrt{gh^5}$, in the 1.3 second period the resulting discharge = 1x10^{-6} – 1.3x10^{-5} m^3/second, the resulting 1.4 second discharge period = 1x10^{-6} – 1.1x10^{-5} m^3/second and a period of 1.5 seconds the resulting discharge = 1x10^{-6} – 9x10^{-6} m^3/second at water depths (d) 0.25 m, 0.27 m and 0.29 m, the d/L parameter has a significant effect on the $Q/\sqrt{gh^5}$ parameter, the higher the pumping, the smaller the resulting discharge.

3.4.5 Effect of relative pumping height (h/Hi) on relative pumping discharge ($Q/\sqrt{gh^5}$)

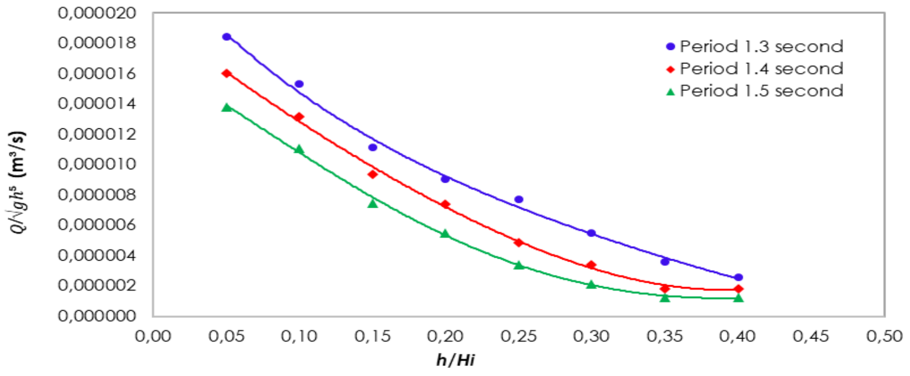

Fig 11: Relationship of *h/Hi* with $Q/\sqrt{gh^5}$

Fig 11 shows the relationship of relative pumping height h/Hi with relative pumping discharge $Q/\sqrt{gh^5}$, in a period of 1.3 seconds the resulting discharge = 3x10^{-6} – 1.8x10^{-5} m^3/second, a period of 1.4 seconds the resulting discharge = 2x10^{-6} – 1.6x10^{-5} m^3/second and the resulting 1.5 second discharge period = 1x10^{-6} – 1.4x10^{-5} m^3/second at water depths (d) 0.25 m, 0.27 m and 0.29 m , the h/Hi parameter has a significant effect on the $Q/\sqrt{gh^5}$ parameter, the higher the pumping, the smaller the resulting discharge.

3.4.6 Effect of relative buoy weight ($W/\rho Hi^3$) on relative pumping discharge ($Q/\sqrt{gh^5}$)

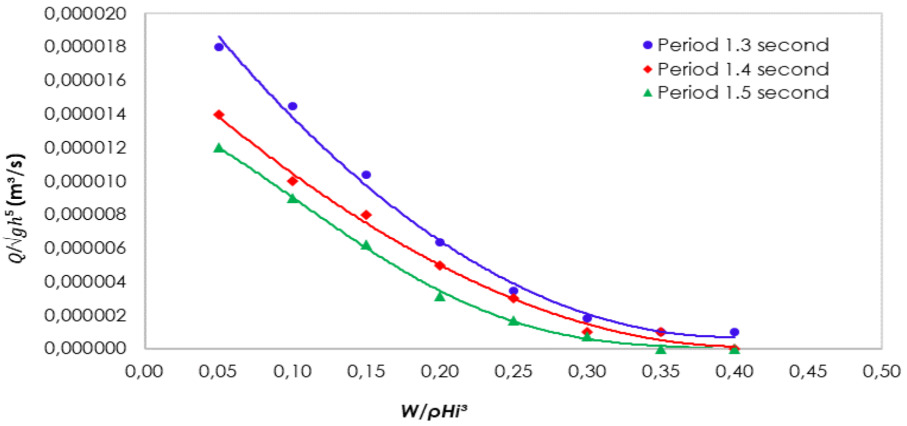

Fig12: Relationship of $W/\rho Hi^3$ with $Q/\sqrt{gh^5}$

Fig 12 shows the relationship between the relative weight of the float W/ρHi3 with the relative pumping flow rate $Q/\sqrt{gh^5}$, in a period of 1.3 seconds it produces a discharge = $1x10^{-6} – 1.8x10^{-5}$ m^3/second, a period of 1.4 seconds the resulting discharge = $1x10^{-6} – 1.4x10^{-5}$ m^3/second and a period of 1.5 seconds the resulting discharge = $1x10^{-6} – 1.2x10^{-5}$ m^3/second with water depths (d) 0.25 m, 0.27 m and 0, 29 m, the parameter W/ρHi3 has a significant effect on the parameter $Q/\sqrt{gh^5}$, the higher the pumping, the smaller the resulting discharge.

IV. CONCLUSION

`From this research, several conclusions were drawn, namely: Produce a design model of a float type wave pump that moves vertically with good performance and produces a discharge by utilizing wave energy to be used to pump water to the mainland until it reaches a maximum height with more benefits, without fuel and environmentally friendly . Obtain parameters that are very influential on the wave pump model with the Langhaar method.

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