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Performance Analysis of Sea Wave Power Plant Oscillating Water Column System (SWPP-OWC)

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Abstract *One of the technological devices that can be used to generate electricity from ocean waves is the Oscillating Water Column (OWC) system. This system utilizes the rising and falling motion of the water in the air column to turn turbines and generate electricity. The purpose of this research is to find out the amount of electrical power generated by the prototype with a width of 0.5 m at 4 variations of the back wall slope and 3 variations of the wave height and 4 variations of the wave period. The test results on the towing tank showed that the best period is 2.4 seconds and the optimal back wall slope is 15°, where the wave height of 0.066 meters, 0.1 meters, and 0.133 meters is capable of producing electrical power of 0.25 Watt, 0.68 Watt, and 1.26 Watt respectively. This study also obtained that the greatest efficiency in the water column was 1.30% and the total efficiency of the SWPP-OWC prototype was 0.56%.*

1. Introduction

Electricity needs fulfillment by relying on fossil energy as an energy source for electricity generation can resulting in environmental pollution. Environmental pollution has become a separate problem which is increasingly shown by the depletion of the ozone layer in the atmosphere. Therefore, it is necessary to do an innovation discovering equipment that is easy to operate and environmentally friendly. One of the natural resources that can be used as an alternative source of renewable energy to generate electricity is ocean waves **[1]**.

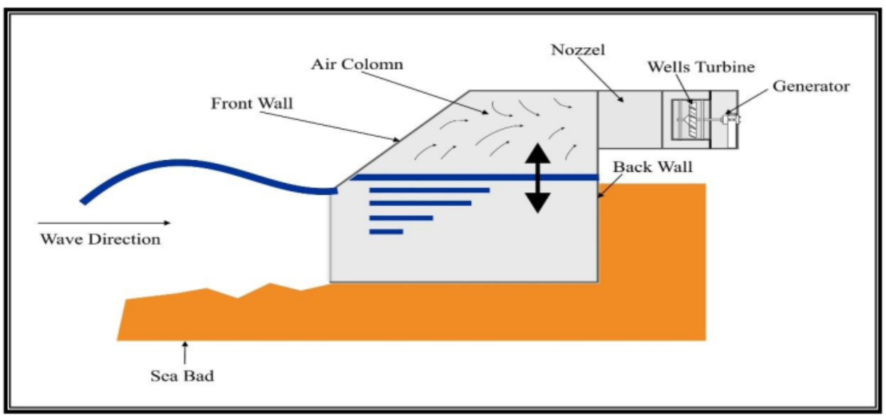

Figure 1 Schematic of OWC - Side View [2]

Of the several types of wave energy converters (WEC) the Oscillating Water Column is the most popular type of WEC **[3]**. This system generates electricity from rising and falling seawater due to sea waves entering a hollow oscillation column **[2]** (see Fig. 1). The rise and fall of seawater will result in the entry and exit of air in the top of the column and the pressure resulting from the rise and fall of seawater in the column will turn the turbine **[4]**.

Khoirul [5] in his research has made a prototype of a floating OWC system with less than optimal electrical power efficiency (around 0.2%). Furthermore, according to **Dudhdaunkar [6]**, the fixed OWC column has a 10% higher efficiency when compared to the floating OWC column.

The two results of these studies indicate that the efficiency of the Oscillating Water Column (OWC) system is still considered small, so it is necessary to make modifications to the existing OWC system. The modification made is to change the slope of the back wall of the OWC system in several variations to obtain the optimal slope tested with several variations of the wave height H and the wave period T.

According to Yizhar **[7]**, the wave height generated in the laboratory can be determined using the following equation:

$$\mathbf{Hi} = \frac{\mathbf{H_{max} + H_{min}}}{\mathbf{2}} \quad (1)$$

And the potential energy value of each wavelength is obtained by the equation **[8]**:

$$\mathbf{E_p} = \frac{1}{4}\boldsymbol{\rho wgA^2\lambda} \quad (2)$$

The potential energy of a wave that is more than one wave period has the same value as its kinetic energy. So that the wave kinetic energy **[8]** is:

$$\mathbf{E_k} = \frac{1}{4}\boldsymbol{\rho wgA^2\lambda} \quad (3)$$

Wave energy is the mechanical energy of the wave which is the total of the potential energy of the wave and the kinetic energy of the wave, so that:

$$\mathbf{E_M} = \frac{1}{2}\boldsymbol{\rho wgA^2\lambda} \quad (4)$$

Then the Power will be obtained using the equation:

$$\boldsymbol{P_w} = \frac{1}{16\pi}\, \boldsymbol{\rho wg^2h^2T} \quad (5)$$

It is assumed that the wave width = chamber area at OWC.

To find out the value of wind energy conversion, it can be seen by calculating the amount of power generated by isolated wind energy **[3]**, and the power from the wind can be seen from the following equation:

$$\boldsymbol{P_a} = \frac{1}{2}\boldsymbol{\rho}.\,\mathbf{A}.\,\mathbf{V^3} \quad (6)$$

So that electrical power **[9]** can be determined by the equation:

$$\mathrm{P}_{listrik} = \mathrm{V.\,I} \quad (7)$$

And the efficiency of the OWC prototype that has been made is obtained by comparing the wind power to the wave power generated in the oscillator, using the equation **[3]**

$$\boldsymbol{\eta_{ka}} = \frac{P_a}{P_w}\, \boldsymbol{x\ 100\%} \quad (8)$$

$$\boldsymbol{\eta_{total}} = \frac{P_{electricity}}{P_w}\, \boldsymbol{x\ 100\%} \quad (9)$$

2. Materials and Methods

The OCW system prototype testing was carried out at the Hydrodynamic Laboratory of the Department of Marine Engineering, Faculty of Engineering, Universitas Hasanuddin. The tested OWC system scheme is shown in Figure 2 below:

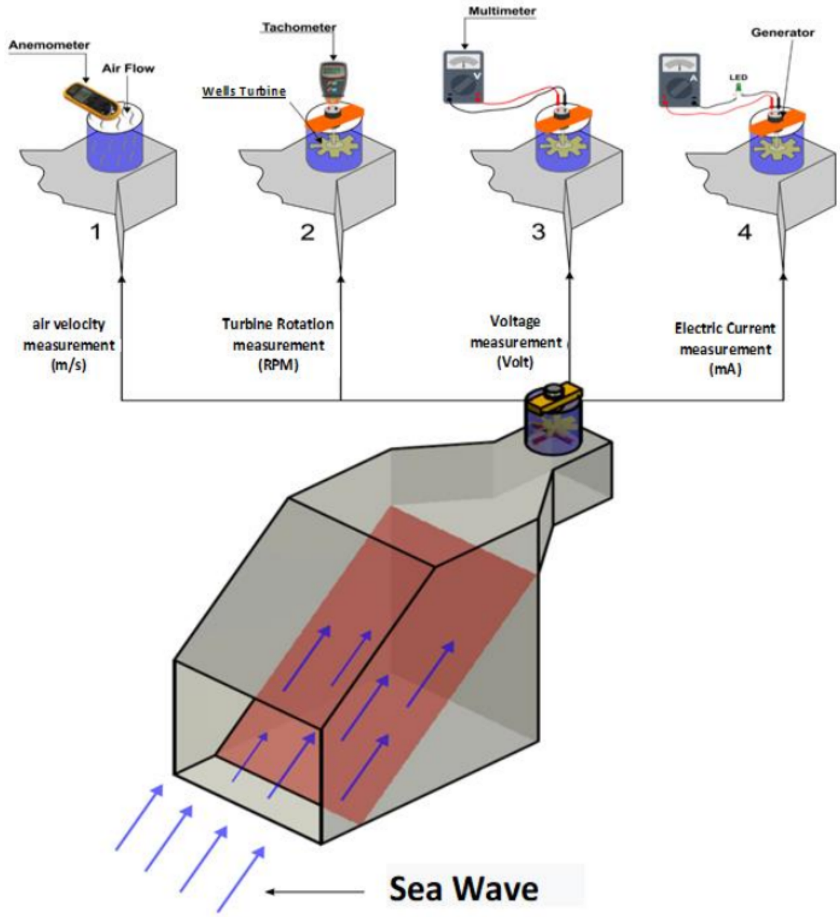

Figure 2 Variable Measurement of testing experiment

The facilities used for wave testing in the Hydrodynamics Laboratory are: 1) Wave observation pool tank, 2) Glass observer, to observe wave characteristics, 3) Wave absorbers and 4) Wave Gauges

3. Results and Discussions

In this study, there are several variations used, namely variations in wave height (H), a variation of period (T), and variations in the slope of the back wall of the OWC prototype model as can be seen in table 1.

Table 1 Data Variation

Back Wall Slope	Wave Height H (m)		Wave Period (T) s
	Field	Lab Scale	
0°	1	0.066	1.6
15°	1.5	0.1	1.8
30°	2	0.133	2
45°			2.2
			2.4

- **Air Velocity**

The rising and falling movement of water in the oscillating column causes a velocity pressure difference of air that comes out of the turbine line (orifice). Measurement of air velocity using an anemometer which is placed in the orifice channel when the turbine is not installed, this is done so that the reading of the measuring instrument is more optimal because there is no obstacle experienced by the air coming out of the orifice channel.

The data from the average air velocity measurement generated by the OWC prototype can be seen in Figure 3 below,

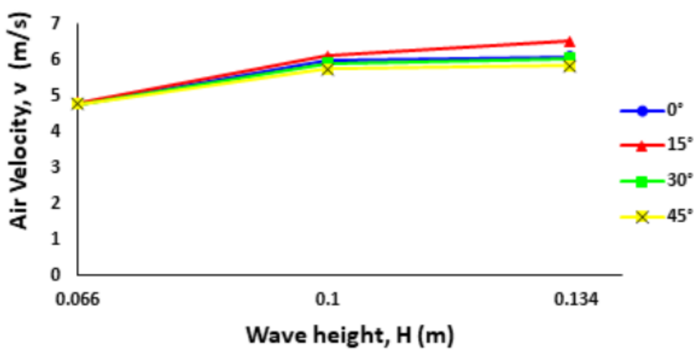

Figure 3 Air Velocity vs Wave Height Variation

Figure 3 shows the amount of air velocity against variations in wave height and rear wall slope. The highest air velocity value is obtained at the variation of the back wall slope of 15 ° wave height 0.133 with a value of 6.51 m/s and the lowest air velocity occurs at a wave height 0.066 with a value of 4.76 m/s. The changes in air velocity that occur at each variation in wave height are affected by the rising and falling motion of the water in the oscillation column.

- **Turbine Rotation**

The air turbine used is the Wells turbine since it can rotate in one direction even though the air is working in the opposite direction, with a diameter of 12 cm and the number of turbine blades is 8 **[4]**. To measure the turbine rotation, a tachometer gauge is used.

Data from the average measurement of turbine rotation speed can be seen in Figure 4 below

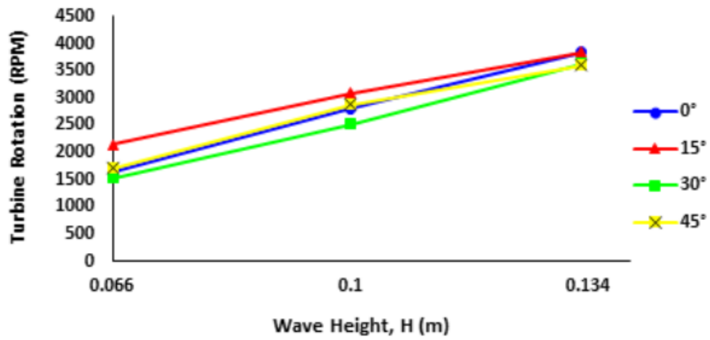

Figure 4 Turbine Rotation vs Wave Height

Figure 4 above shows the magnitude of the turbine rotation speed with respect to variations in wave height and back wall slope. The largest turbine rotation speed value is obtained at a wave height of 0.133, back wall slope of 15° with a value of 3850.08 rpm and the smallest rotation speed occurs at a wave height of 0.066, the slope of 30° with a value of 1525.32 rpm. From the graph, it can be seen that the greater the wave height, the faster the turbine rotation is produced. However, the slope of the back wall also affects the turbine rotation where at a slope of 15° the turbine rotation is greater than the other rear wall slopes, this is due to the air velocity on this slope is greater than others so that a greater rotation is obtained.

- **Electric Voltage**

The turbine rotation which is connected to a 12 V DC motor produces an electric voltage. To measure the electric voltage generated by a DC motor, a multimeter is used by attaching positive and negative cables to the DC motor terminals.

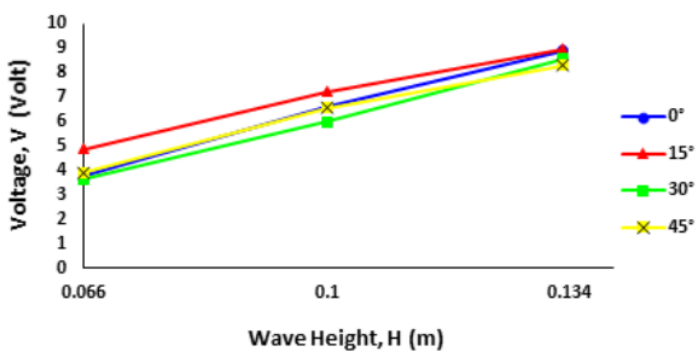

Figure 5 Electric Voltage vs Wave Height

Figure 5 shows the value of the electric voltage to variations in wave height and rear wall slope. The largest voltage value is obtained at a wave height of 0.133, the slope of the back wall is 15° with a value of 8.95 volts and the smallest voltage occurs at a wave height of 0.066, the slope of the rear wall is 30° with a value of 3.66 volts. The change in the electric voltage generated at each of these variations in wave height is affected by the rotation of the turbine, where if the rotation is greater, the greater voltage is generated, and vice versa if the turbine rotation is low, the resulting voltage is low.

- **Electric Power**

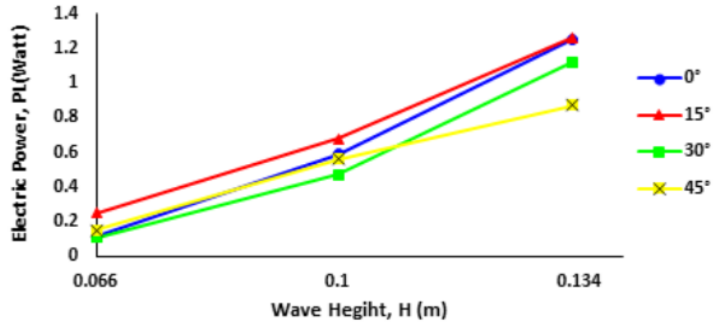

Figure 6 Electric Power vs Wave Height

Figure 6 shows the amount of electric power to the variation in wave height and the rear wall slope of the prototype, which can be seen from the overall variation of the back wall, the most optimal slope of 15° produces electrical power at each wave height. A wave height of 0.066 can produce electric power of 0.25 Watt, a wave height of 0.1, the electric power generated is 0.68 Watt, and at a wave height of 0.133, the electric power generated is 1.26 Watt. From the graph above it can be concluded that the greater the wave height, the greater the electrical power that can be generated by the Sea Wave Power Plant OWC System (SWPP-OWC).

- **Efficiency**

The results of the analysis of the calculation of wave power, air power and electric power can be used to calculate the efficiency of the OWC prototype using equations 8 and 9.

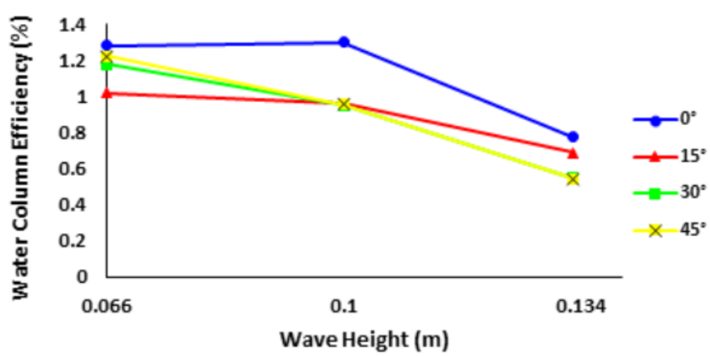

Figure 7 Water Column Efficiency vs Wave Height

Figure 7 shows the value of the water column efficiency against the variation in wave height and back wall slope of the prototype, where the largest water column efficiency is obtained at 0.1 wave height variation, 0° slope with a value of 1.30%.

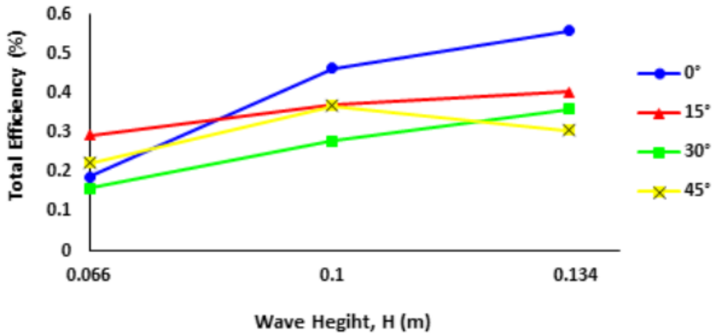

Figure 8 Total Efficiency vs Wave Height

Figure 8 shows the total efficiency value for the variation in wave height and the back wall slope of the prototype, where the largest total efficiency is obtained at 0.133 wave height variation, a slope of 0° with a value of 0.56%.

4. Conclusions

From the results of calculations and analysis, it can be concluded that: the greater the wave height, the greater the air velocity produced by the OWC prototype, and lead to the greater the electric power generated. For 4 variations of the back wall slope, the optimal value in this study is 15 °, and at a wave height of 0.133, the electric power generated is 1.26 Watt. The greatest efficiency for the water column is 1.30% and the total efficiency of the SWPP-OWC prototype is 0.56 %.

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