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A Study of Float Wave Energy Converter (FWEC) Model

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Abstract – *Ocean wave energy is a renewable energy that is abundant on Earth. It is a concentrated form of solar energy where differential heating on Earth generate wind which transfer their energy into open water in form of waves. In relation to atmospheric emission, wave power is less environmentally-degrading than most other form of power generation. The fluctuating wave contains potential and mechanical energy which can be converted into electrical energy. A special device needs to be developed to harness the energy which is called Float Wave Energy Converter (FWEC). The purpose of this project is to design, fabricate and test the experimental model of FWEC. The efficiency of the model will be analysed based on wave power and power generated. The model are capable to generate power for small devices with low power consumption. The power generated from designated FWEC will be depends on several parameters which is wave amplitude, diameter ratio and shape of the model. This parameter would be used to determine the best design for FWEC.*

Keywords: Float Wave Energy Converter, Wave Power, Wave Amplitude, Diameter Ratio

1.0 INTRODUCTION

There is an increase in demand of energy consumption due to the rapid change in the global development. Generally, energy exists around us in many forms which it cannot be create nor destroy but been transferred or transformed. Energy can be differentiated into two groups, renewable and non-renewable energy. Non-renewable energy, as its name, cannot be renewed such as petroleum, gases, fossil and etc. As mineral sources of energy is going to be depleted by time, various study has been made for a research of renewable energy such as hydroelectric, geothermal, biomass, wind and wave energy.

There are many research proposing the design of wave energy converter [1, 2, 3, 4] but only a few are been tested. Ocean wave consists of both potential and kinetic energy. Among all types of ocean waves, the highest energy concentration wave are generated by wind. According to the data released at the Intergovernmental Panel on Climate Change (IPCC) Scoping Conference on Renewable Energy in 2008, the theoretical reserves of wave energy worldwide are 8000 - 80,000 TWh/year [3]. Wind energy been transferred to wave energy and naturally stored in the water near the free surface. The waves created can travel thousands of kilometres

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across the ocean without losing their energy unless they oppose obstacle such as head winds. Upon reaching the coastline, wave energy intensity decreases when encountered with the seabed. The natural phenomenon such as refraction and reflection will compensate the energy dissipation near the shore, creating energy concentration area or hot spot. The fluctuating movement of wave can be used to move electric generator and create electricity. The device to transform potential and kinetic energy of wave into mechanical energy is call wave energy conversion device (WEC). There are many type of WEC but they can be categorizes as turbine and tube type. However, most of the WEC were only at research and development stage which means their application have not been commercialised yet. Examples of commercialised WEC is Pelamis where the production has entered second generation type which can generate 750kW electric power for each device.

Comparing to other resources of energy, the research and development of wave energy is at slower speed eventhough the existing theory is proven and strong. However, due to availability and amount of wave energy existed globally, the research on wave energy conversion should be brought further to its maximum potential. This research will focus on simple FWEC where the performance will be calculated based on wave amplitude, diameter ratio and shape of the device.

2.0 METHODOLOGY

The test for FWEC will be done in a room scale experiment which some of the components been fabricated to suit the variable needed. Figure 1 shows the schematic of the test equipment.

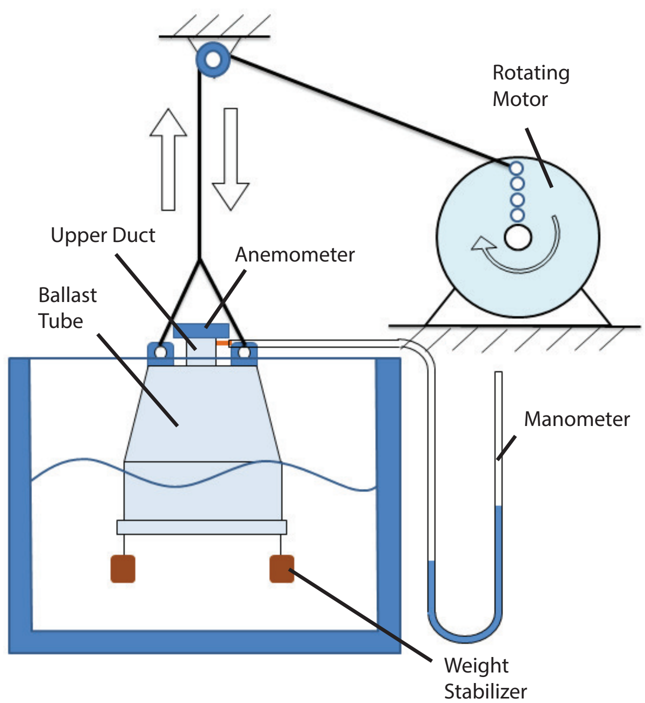

Figure 1: Schematic for the FWEC test

The efficiency coefficient of the design can be written as:

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$$\eta = \frac{P_u}{P_w} \tag{1}$$

In order to know the efficiency of the design, first thing to know is the available wave energy. The total wave energy is the sum of potential and kinetic energy. The formula for power wave energy, P_w is given as:

$$Pw{=}0.78\ w\rho g a2T2\ (W) \tag{2}$$

Where:

- w: wave width (m) *assumed equal to width of chamber
- ρ: water density (kg/$m3$)
- a = h/2 (m): wave amplitude
- ω = 2πT (rad/sec): wave frequency
- T: wave period

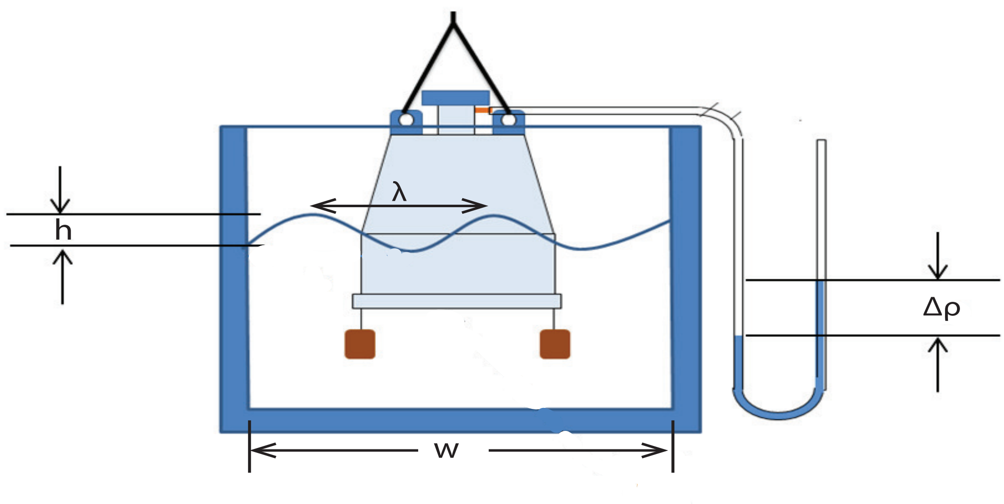

Figure 2: Diagram of unit used in the formula

Generated power at the upper duct can be calculated using equation:

$$Pu{=}\ (\Delta p{+}12\rho ava2)\ vaA\ (W) \tag{3}$$

Where

- Pu: power at the upper end of the duct (W)
- Δp: Pressure different at upper duct compare to the atmosphere (Pa)
- ρa: air density ($kg/\ m3$)
- va: air flow speed at the upper end of the duct (m/s)
- A: cross sectional area at the upper end of the duct ($m2$) $A{=}\pi D24$

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3.0 RESULTS AND DISCUSSION

The experiment for upper duct diameter ratio has been done using three different upper duct diameter which is 2cm, 3cm and 5cm. The lower duct diameter remain constant at 5cm. Since the wave amplitude is hard to control, the data gathered from wave amplitude range of 6 to 10 cm.

3.1 Result for Hemispherical Shape by Diameter Ratio

3.1.1 Airflow vs. Wave Amplitude

Figure 3 shows the graph of airflow generated on the upper duct of the experimental model under the variation of the wave amplitude for different diameter ratio of the model. From observation of the graph, the airflow is increasing with the wave amplitude.

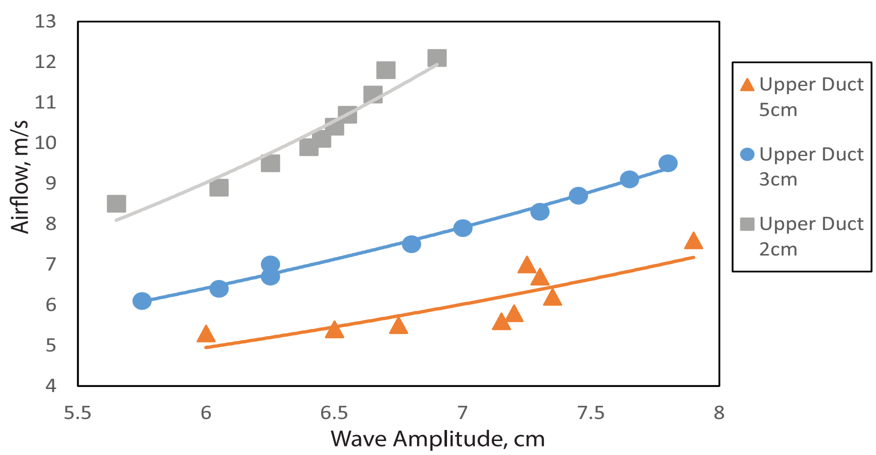

Figure 3: Airflow vs. Wave Amplitude for different diameter ratio

For the upper duct diameter of 5.0 cm, the first recorded airflow is about 5.2 m/s where the wave amplitude reading is about 5.25 cm. The value of the airflow increases almost straight until about 6.4 m/s and wave amplitude 7.4 cm and then there a slight rapid increase until final value of 8.1 m/s of airflow and amplitude about 8.3 cm. The increase rate for first part is 0.56 m/s per cm increase, then for second part the rate is 1.89 m/s per cm increase.

For upper duct diameter of 3 cm, the first point started with value of air flow of about 6.2m/s when the wave amplitude is about 5.6 cm. The values of air flow increases almost straight until the final value of about 9.5 m/s where the wave amplitude is about 7.8cm. The rate of air flow increases with wave amplitude is 1.43 m/s per cm.

The data for upper duct diameter of 2.0 cm started with the value of air flow of about 8.5m/s and the wave amplitude is about 5.7 cm. The value of air flow also increases almost straight until final value of about 12.1 m/s at wave amplitude of about 7.1cm. Increase of rate of air flow to wave amplitude is 2.57 m/s per cm.

From the observation, it is clearly that the data of upper duct diameter of 2.0 cm generate higher air flow than other set of data under the same wave amplitude. The second higher is the upper duct with diameter 3.0 cm and followed by upper duct of diameter 5.0 cm. Air flow rate depend

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on air velocity multiply by the cross sectional area. From the conservation of flow rate: $Q_1= Q_2$ & $A_iV_i= A_oV_o$ therefore, as the area of the outlet is smaller, the velocity outlet will increase.

3.1.2 Wave Power versus Wave Amplitude

Figure 4 shows the graph of wave power under the variation of wave amplitude. The data for the upper duct shows a quadratic curve which means the wave power increases with the increase of the wave amplitude. The curve of the graph is consistent with the equation of wave power where the wave power is proportional with the square of wave amplitude. The other set of data for upper duct diameter of 3 cm and 2 cm also show the same trend. The values of wave power were calculated based on the diameter of the lower part of experimental model. The value of wave power depends on the value of wave amplitude as well as the wave period and with of the experimental model.

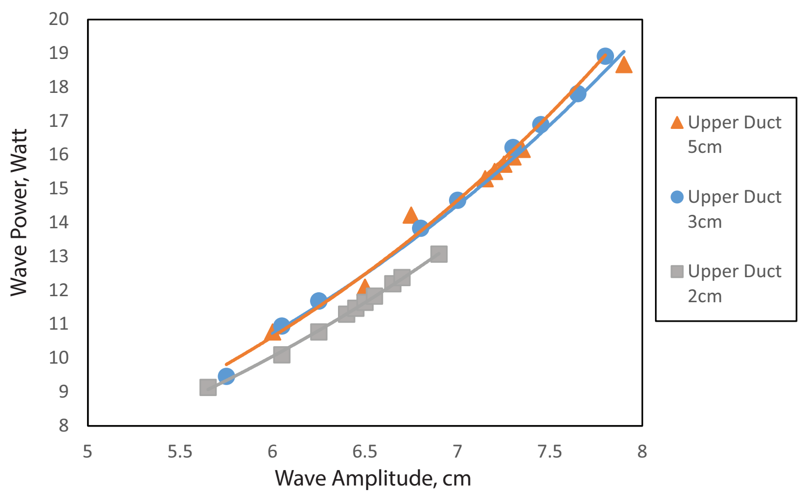

Figure 4: Wave Power versus Wave Amplitude for different diameter ratio

3.1.3 Wave Power versus Wave Amplitude

Figure 5 shows the graph of power generated at the upper duct of the experimental model with different value of air flow. All three sets of data show curves trending where the increase of air flow causes the power generated to increase also. From observation of the graph, the power generated is higher for experimental model with upper duct diameter of 5 cm, followed by upper duct diameter of 3.0 cm and 2.0 cm respectively. Based on equation, the power generated affected by air flow, cross sectional area of upper duct and pressure in the duct. The cross sectional area for upper duct with diameter 5.0 cm is the highest and that is why the power generated by experimental model mounted with 5.0 cm upper duct generated highest energy compared to other duct.

3.1.4 Efficiency versus Wave Amplitude

Figure 6 shows the graph of the efficiency of the experimental model relating to wave amplitude. The graph for model with upper duct diameter of 5.0 cm show scrabble data where most of the value are far from each other. This is happened because of error while running the experiment such as human error and instrument error. The human error might be in taking the reading of parameter especially wave's high and manometer reading. The scale for measurement instrument is high which means the accuracy will be low. This combination of

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error might lead to the inaccuracy of the reading. However, a fit line was able to be drawn which shows that the efficiency increases as the wave amplitude increase.

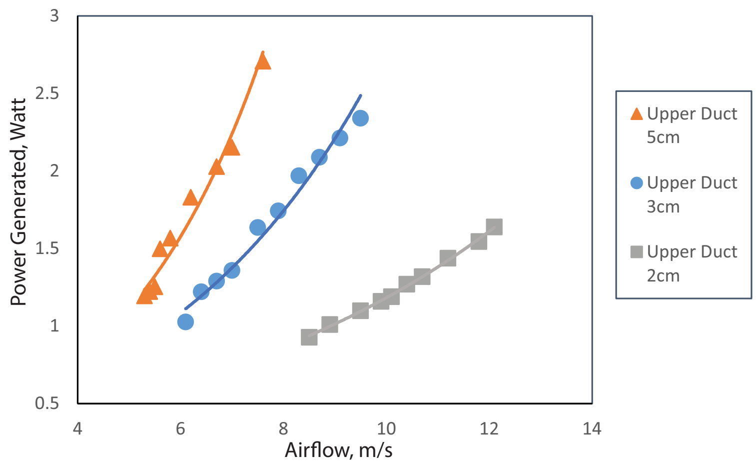

Figure 5: Power Generated vs. Air flow

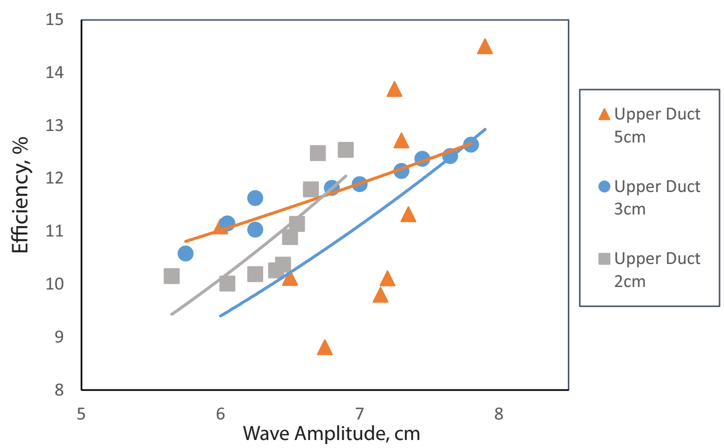

Figure 6: Efficiency versus Wave Amplitude

The data for upper duct diameter 3.0 cm and 2.0 cm also show the same trend. The value of efficiency for upper duct diameter 3.0 cm show the highest value among the three variance at the beginning, but then the efficiency of model with upper diameter 2.0 become the highest as the graph is stepper compared to the other two. The efficiency for model with upper duct diameter 5.0 shows the lowest value. The graph shown can be accepted because theoretically, the efficiency line should make almost straight line when increasing the value of the wave amplitude.

3.2 Result Comparison between Hemispherical and Conical Shape

3.2.1 Airflow vs. Wave Amplitude

Figure 7 shows graph of air flow versus wave amplitude for different shape of experimental model. The graph shows that the air flows increase linearly with the wave amplitude. From observation, the airflow of cone shape model show higher reading rather than hemispherical

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shape. The graph for cone shape shows that the starter value of air flow was is about 7.2 m/s at amplitude of about 6.4 cm. then the value of air flow increase linearly until final value of about 11.6 m/s and amplitude of about 8.4 cm. the rate of air flow per wave amplitude for cone shape is about 2.2 m/s per cm of wave amplitude.

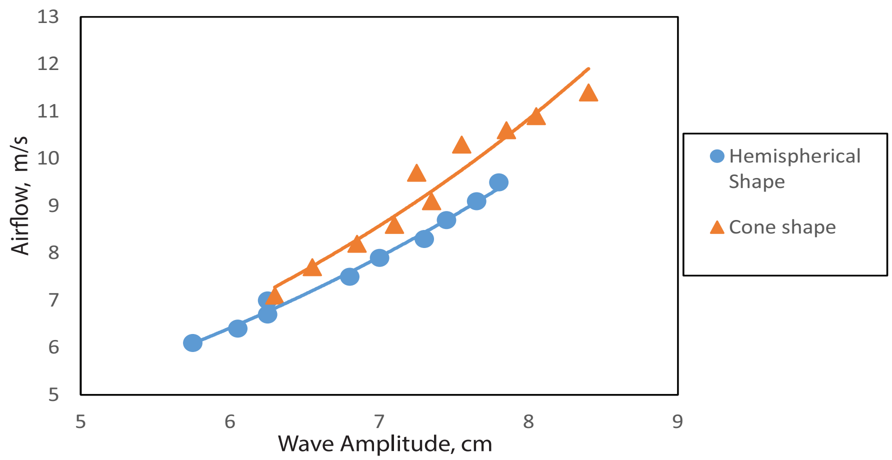

Figure 7: Airflow versus Wave Amplitude

For cylindrical shape, the graph shows a lower value where it the value of air flow is 6.9 m/s at same amplitude of starter point for cone shape which is 6.4 cm. At amplitude of about 7.9 cm, the airflow is 9.3 m/s. the rate of air flow per wave amplitude is 1.6 m/s per cm of wave amplitude.

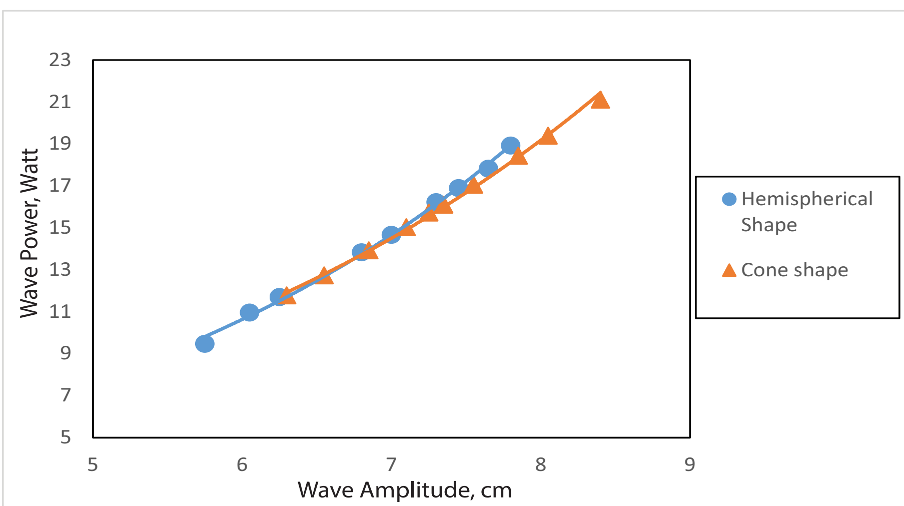

Figure 8: Wave Power versus Wave Amplitude

3.2.2 Wave power versus Wave Amplitude

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Figure 8 shows the graph of wave power corresponding to variation of wave amplitudes. Both data give a curved shaped graph which means the power increase as the wave of amplitude increasing. The curve showed by the graph is in agreement with the equation of wave power where wave power is proportional with wave amplitude at power of two. At first, the graph shows that at same wave amplitude of about 6.3 cm, the wave power of cone shaped model generate larger power until wave amplitude about 7.0 cm, the wave power generated by hemisphere shaped model is higher. However, both data are almost the same since the cross sectional area for both model are the same.

3.2.3 Power Generated versus Air flow

Figure 9 shows the graph of power generated at the upper duct under influence of air flow. From observation of the graph, the power generated by the experimental model with hemispherical shape shows higher reading than the cone shape. Power generated depends on pressure and cross sectional area. Both of the shape has same cross sectional area but the pressure in hemispherical shape is higher, that is why the power generated is higher.

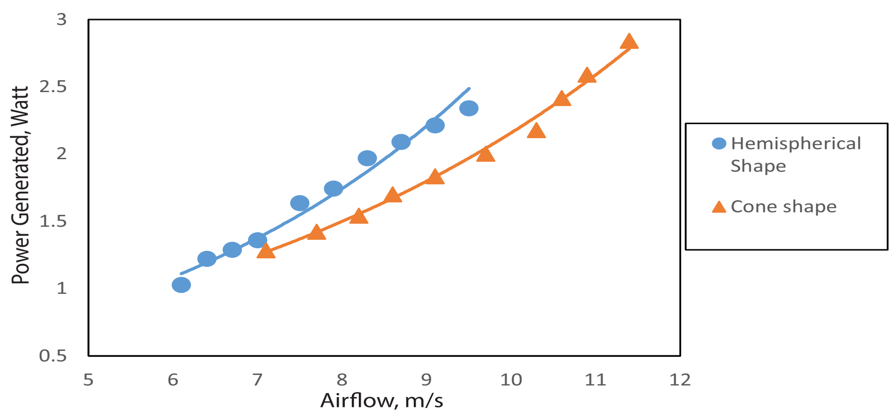

Figure 9: Power Generated versus Air Flow

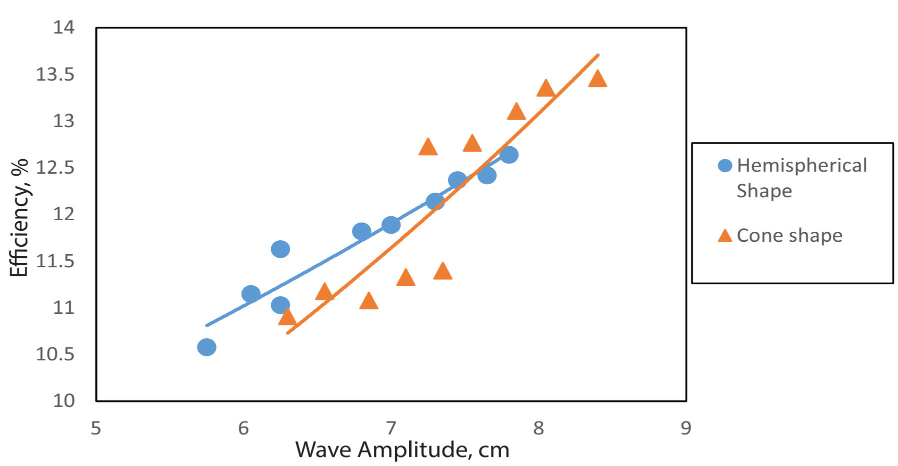

Figure 9: Power Generated versus Air Flow

3.2.4 Efficiency versus Wave Amplitude

Figure 10 shows the graph of efficiency versus wave amplitude for different shape of model. The graph shows that the efficiency of the hemispherical shape of model is higher than the efficiency for the conical shape until the wave amplitudes reaches the value of about 7.5 cm. At this amplitude, both shape of model give efficiency of about 12.4 %. The fit line for the conical shape is steeper than hemispherical shape, thus after amplitude of 7.5 cm, the efficiency of the conical shape is better than the hemispherical shape.

4.0 CONCLUSSION

Based on the result and discussion of previous chapter, the experimental models were able to generate data under various stated condition. Although there are some error and problems encountered in finishing the experiment, the data gained were enough to give a basic characteristic for a good and efficient float wave energy converter (FWEC).

The variation of diameter ratio shows that the efficiency increases as the diameter ratio decreases. The hemispherical shaped experimental model mounted with smaller diameter of upper duct gives higher efficiency than bigger upper duct. Figure 6 proves that the smaller diameter of duct give higher efficiency where for diameter 2cm, the efficiency is higher than diameter 3cm followed by the lowest efficiency where diameter is 5cm. The model for the experiment are smaller than real life model, therefore it is expected to get small value for power generated by the model.

For the variation of shape, the conical shape shows higher efficiency compared with the hemispherical shape. This is because the conical shape can reduce the resistance when the air is compressed, however the efficiency of the hemispherical shape model is also give high efficiency compared to conical but started at 7.5 cm of wave amplitude, it become smaller than conical shape model. As a conclusion, the FWEC construction needs to have conical shape and small diameter ratio to gain good efficiency.

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