

# Horizontal Pendulum Performance Analysis with Multilevel Model Plate on Ocean Wave Electric Power Plant (PLTGL)

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**Abstract**—with the times and the industry, the energy sources such as fossil fuels dwindling. It encourages all parties to be more advanced and developed by creating solutions to renewable energy generation with the latest innovations, one of which is the sea wave power plant - pendulum system. Pontoon which uses pendulum system is one tool used to convert from ocean wave energy into electrical energy. In this study, the test conditions without using ballast onshore and off-shore testing with the ballasts. Obtained from testing the many rounds that can be generated pendulum pie plate thickness and the angle of the pontoon. To test the largest on-shore power obtained on the test using arc angle 30°, 3 mm thick, the angle of 60° power produced 0036 watts. For testing offshore in the ballasts 12 cm, 15 cm, 17.5 cm, the largest power generated at 15 cm ballasts with 0041 watts power on pie, thick, and a tilt angle equal to the on-shore testing. Number of rounds with time, the on-shore testing that produces the greatest value in the segment with an angle of 30°, a thickness of 3 mm the angle of 60° value obtained 0.938 rad / s. In the off-shore test is highest value is filled with 15 cm ballasts with 0847 rad/s.

**Keywords**—pontoon, pendulum system, test the on-shore, off-shore test, power

## I. INTRODUCTION

With population growth and increasing technological development and the resulting human increasingly dependent on fossil energy sources that can not be updated. Energy sources such as petroleum, natural gas and coal are expected to run out about the next 30 years. This causes the energy crisis in the world and make human thought to find the most energy that does not depend on fossil fuels today. In addition dwindling fossil energy and require a long time to produce this energy back, and can damage the environment due to gas emissions and other pollution caused. The use of nuclear energy requires a high cost as well as limited security issues. Hydropower generation not applicable in many places

because of the availability of water.

It is necessary to search for the source of environmental friendly energy and renewable. Solar, wind, sea, water, electromagnetic, electrostatic, thermal, vibration, and movement of the human body are all kinds of renewable energy sources [1].

In this analysis, the problem of the subject in the preparation of this study are:

- 1) What is the greatest power generated by each of the differences, thick, and the slope angle of the pontoon to the generated power?
- 2) What is the use of arc with a certain thickness to obtain the number of rounds and the most optimal time?
- 3) What is the use of ballasts, to obtain the greatest power and the number of revolutions with a specific time greatest? While the purpose of this study was to answer the question above.



Figure. 1. On-shore test

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## II. METHOD

The methodology to be used in completing this research is through modeling approaches with 1:10 scale from actual size. Then it will be tested.

TABLE 1.  
 TABLE EXPERIMENTAL RESULTS 1MM THICKNESS

No.	Pendulum Angle	Time	Total Rotation	
			Clock Wise	AntiClock Wise
1	5°	0	0	0
2	15°	0	0	0
3	30°	4,61	2	1
4	45°	7,52	2	2
5	60°	9,55	3	2

III. EXPERIMENT AND SIMULLATION RESULTS

A. Onshore Test

The test is conducted by assembling a pontoon which there is a segment with a 30 ° angle, with each - each a thickness of 1 mm, 2 mm, 3 mm. then with a buffer as shown in the picture 3.1, will be tilted at an angle 5°, 15°, 30°, 45°, 60°.

This experiment will be known from the number of revolutions during the time stops. Table 3.1 shows the experimental results on a pontoon using a pie with a certain angle.

B. Offshore Test

Testing of off-shore is a test in the water or in the pool using ballasts with a depth of 12 cm, 15 cm, 17.5 cm measured on the one part thereto, as shown in the **Figure 2**. Tests on ballasts system is almost the same as on-shore testing only place using water medium. The experimental results are shown by Table 2. It uses ballasts 12 cm, 15 cm, 17.5 cm with a thickness of 1 mm.

Pontoon filled with ballasts 12 cm, 15 cm, 17. 5 cm, then given a pendulum with a 30 ° angle with a thickness of 1mm, 2mm, 3mm. After that the new pontoon tilted with a slope of 5°, 15°, 30°, 45°, 60°

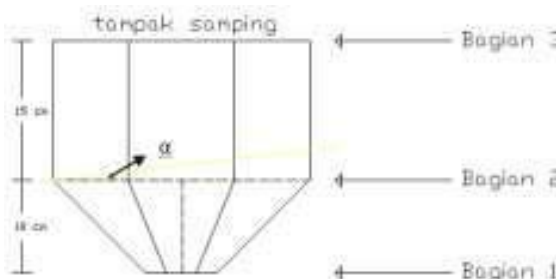


Figure 2. Pontoon with a depth of each ballast

TABLE 2.  
 THE RESULTS OF THE EXPERIMENT 1MM THICKNESS, 12 CM BALLAST

No.	Pendulum Angle	Time	Total Rotation	
			Clock Wise	AntiClock Wise
1	5°	0	0	0
2	15°	0	0	0
3	30°	4,61	1	1
4	45°	7,52	2	1
5	60°	9,55	2	2

TABLE 3.  
 THE RESULTS OF THE EXPERIMENT 1MM THICKNESS, 15 CM BALLAST

No.	Pendulum Angle	Time	Total Rotation	
			Clock Wise	AntiClock Wise
1	5°	0	0	0
2	15°	2,02	1	0
3	30°	4,24	2	1
4	45°	6,86	3	2
5	60°	8,76	3	3

TABLE 4.  
 THE RESULTS OF THE EXPERIMENT IMM THICKNESS, 17,5 CM BALLAST

No.	Pendulum Angle	Time	Total Rotation	
			Clock Wise	AntiClock Wise
1	5°	0	0	0
2	15°	2,02	1	0
3	30°	3,32	1	1
4	45°	6,03	2	1
5	60°	7,98	2	2

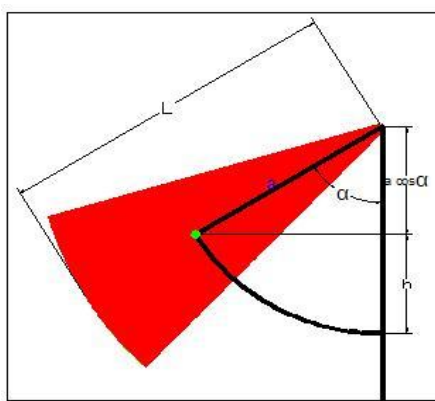


Figure 3. The scheme of the arc

In the off-shore testing will be performed calculations to determine the power generated at each arc with a certain thickness.

High-arc (L) = 11.5 cm = 0.115 m  
 Long emphasis (a) = 7246 cm = 0.07246 m  
 arc slope angle (α) = 60°  
 The density of iron (ρ) = 7800 kg / m<sup>3</sup>  
 Plate thickness = 1mm = 0.001 m  
 for heavy arc on arc angle 30 ° with 1 mm thick

with a slope of 60 °.

Wide arc = 30° / 360° x wide circle  
 = 30° / 36° x 3.14 x 0.115 x 0.115  
 = 0.00346 m<sup>2</sup>

Volume = Area x pie plate  
 = 0.00346 m<sup>2</sup> x 0.001 m  
 = 0.00000346 m<sup>3</sup>

Mass arc ρ = x Volume  
 = 7800 kg / m<sup>3</sup> m<sup>3</sup> x 0.00000346  
 = 0.027161 kg

G = 27,161

Furthermore, for torque and power

Before seeking the value, to determine a (long-emphasis) using software SolidWork. Then the value of long-gravity 0.0724 m.

The value of h = a - a cos α  
 = 0.07246 - 0.07246 cos 60  
 = 0.036 m

By using the same software, the inertia value of 274.71gcm<sup>2</sup>=0.027471gm<sup>2</sup>. The following data processing on -shore in theory and practice by using a segment with a 30 ° angle with a thickness of 1 mm with a slope of 60° arc.

Furthermore, to determine the value of the torque and power, need to know the results of the omega (ω). Value omega (ω) calculated by the following formula:

$$(\omega) = \sqrt{\frac{2mgh}{I}} \quad (1)$$

Mass arc ( m ) = 27.161 g  
 Acceleration of gravity( g ) = 9.8 m/s<sup>2</sup>  
 h ( a – a cos α ) = 0.036 m  
 Moment of Inertia ( I ) = 0,027471 gm<sup>2</sup>

$$\omega = \sqrt{\frac{2 \times 27.161 \times 9.8 \times 0.36}{0.027471}}$$

ω = 26.41 rad/s

Torque ( T ) = mg sin60 a  
 = 27,161x9,8xsin60x0,07246  
 = 27,161x9,8x0,866x0,07246  
 = 16,7 gm<sup>2</sup>/s<sup>2</sup>  
 = 16,7 x 10<sup>-3</sup> Nm

Daya = T x ω  
 = 16,7 x 10<sup>-3</sup> x 26,41  
 = 0,441 Watt

Then the results obtained by using the theory of the power of 0441 Watts.

Next calculate the power by using calculation practicum.  
 omega (ω) = Σ rotation / time  
 = 5/9.55  
 = 0.5234 rad/s

So, Torque ( T ) = **mg sin60 a**  
 = 27.161 x 9.8 x sin 60 x 0.0726  
 = 27.161 x 9.8 x 0.866 x 0.0726  
 = 16.7 gm<sup>2</sup>/s<sup>2</sup>  
 = 16.7 x 10<sup>-3</sup> Nm

TABLE 5.  
 THE CALCULATION FORMULA

Angle Arc	Thick ness	Mass (Kg)	Volume (m <sup>3</sup> )	I (Kgm <sup>2</sup> )	h (m)				
					5	15	30	45	60
	1	0,027	0,0000034	0,000034					
30°	2	0,054	0,0000069	0,000067	0,000290	0,002534	0,0097016	0,021213	0,0362
	3	0,081	0,0000104	0,000101					

Power = T x ω  
 = 16.7 x 10<sup>-3</sup> x 0.5234  
 = 8.74 x 10<sup>-3</sup> Watt

Results southwest practices is 8.74 x 10<sup>-3</sup> Watt.

In accordance with the above formula, the obtained

Furthermore, after the above table to calculate the value of omega, torque, power. Calculations can be done on each test.

Data from the table above will be analyzed using next graph. For data on-shore will be analyzed with a difference theory with practical work and the influence of thickness on each plate of the power generated, and the number of revolutions of the pendulum with a stop at a certain slopes.

VI. ANALYSIS AND DISCUSSION

A. Offshore Test

Here's one example, Data Analysis shown in the

analysis of the on-shore testing theoretical and practical calculations.

In this graph shows that the theoretical value is greater than the lab. 30 ° angle thick one, with slope of 5° is 0004 watts, the power generated by the lab 0 watts. Then at the angle of 15° theoretically generated power 0035 watt in lab 0 watts. At the angle of 300 power theoretically produced 0132 watts of power generated in the lab 0006 watts. The tilt angle of 45 ° is theoretically generated power 0277 watt, 0007 watt in the lab. At the angle of the theoretical power of 600 watts in a practicum 0443 0009 watts.

In theory and practice produce nearly the same graph, where the greater the tilt angle, the greater the power generated. Likewise happens in each arc that has a certain thickness, the shape of the graph obtained relatively the same,

Then in graph theory and practicum one example on the graph below, the arc angle 30 ° with a thickness of 1 mm.

TABLE 6.  
 THE CALCULATION ARC 30° 1MM THICK

Angle Arc	ω Theory (rad/s)	ω Practice (rad/s)	T Theory (Nm)	T Practice (Nm)	Power Theory (Watt)	Power Practice (Watt)
5	2.313	0	0.002	0.002	0.004	0
15	6.920	0	0.005	0.005	0.035	0
30	13.717	0.487	0.010	0.010	0.132	0.005
45	20.280	0.444	0.014	0.014	0.277	0.006
60	26.496	0.480	0.017	0.017	0.443	0.008

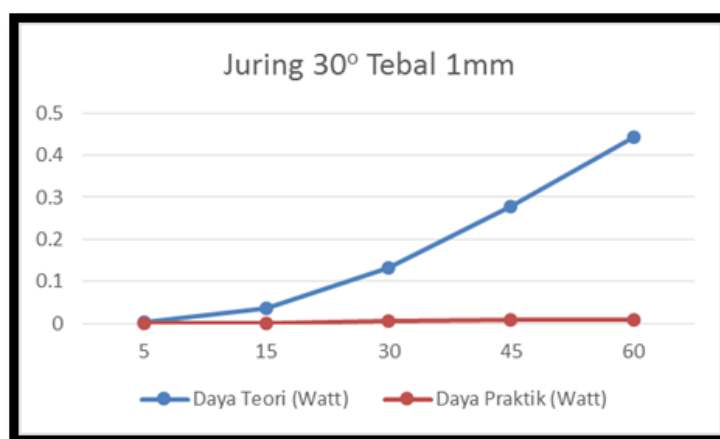


Figure. 4. Ratio of power in theory with practical results in the power arc with a 30 ° angle 1 mm thick

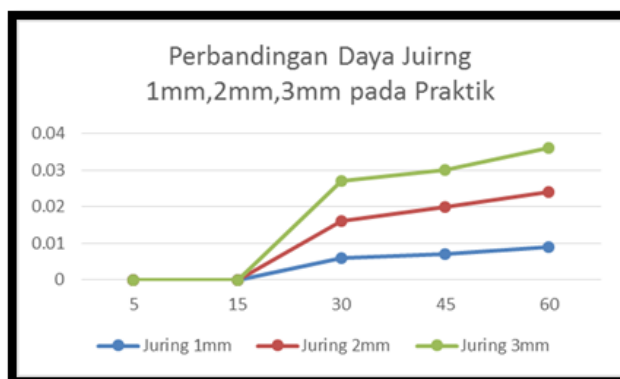


Figure. 5. comparison of the lab on top of the angle of 30° thickness of 1 mm, 2 mm, 3 mm

From here it can be seen that the theoretical and practical work together to increase in the angle of the greater power even though the difference between practical and theoretical approximately less than 20%. This is because the error readings, and bearings that are used during the test was also very influential.

#### B. Onshore Test

Analysis of On-shore in the lab, the arc with the 300, 1mm thick, 2 mm, 3 mm.

In this lab arc with 1mm thick, the angle of 300, has a value of omega most big that 0.651 rad / s in which the number of rotation 3 times the time it takes 4.61 s. With a thickness of 2 mm, tilt angle 300 memiliki omega greatest value is 0.839 rad / s in which the number of revolutions produced 4 times within 4.77 s. In the arc with a thickness of 3 mm, the angle of 300, has a value of omega 0.938 rad / s. Then the most lucrative time rotation compared with the largest is the arc at an angle of 600, at an angle of 300 with a thickness of 3 mm number of rounds produced 5 times and the time it took 5:33 s, 0.938 rad / s

In the graph above shows that omega generated not depending on the thickness and the angle of inclination, this is because at trial the greater the angle of this case could lead to a pendulum that works more quickly stopped because of the influence of the waves.

### V. CONCLUSION

Based on the discussion in the previous chapter, can be summarized as follows:

1. Calculations using the theory was found that the greater the weight of the pendulum or the pendulum angle and the thickness of the power generated will be even greater.
2. In the On-shore testing arc angle of 300, the largest power produced at a thickness of 3 mm at an angle of 600, the generated power 0.036 watt.
3. Value omega (rad / s), the largest in the arc angle of 300, with a thickness of 1 mm, 2 mm, 3 mm. The greatest value at the angle of 300, with a thickness of 3 mm, number of revolutions produced 5 times with a time of 5:33 s, omega values obtained 0.938 rad / s.
4. Off-shore testing with the ballasts 12 cm on the arc angle of 300, the largest power produced at a thickness of 3 mm at an angle of 600, the generated power 0.037 watt.
5. Off-shore testing with the ballasts 12 cm, the value of omega (rad / s), the largest in the arc angle of 300, with a thickness of 1 mm, 2 mm, 3 mm. The greatest

value at the angle of 600, with a thickness of 3 mm, number of revolutions produced seven times at 9:53 s, omega values obtained 0.735 rad / s.

6. Off-shore testing with the ballasts 15 cm on the arc angle of 300, the largest power produced at a thickness of 3 mm at an angle of 600, the generated power 0.041 watt.
7. Off-shore testing with the ballasts 15 cm, the value of omega (rad/s), the largest in the arc angle of 300, with a thickness of 1 mm, 2 mm, 3 mm. The greatest value at the angle of 450, with a thickness of 2 mm, the number of revolutions produced six times with a time of 7:08 s, omega values obtained 0.847 rad/s.
8. Testing Off- shore with ballasts 17.5 cm on the arc angle of 300, the largest power produced at a thickness of 3 mm at an angle of 600, the generated power 0.032 watt.
9. Testing Off- shore with ballasts 17.5 cm, the value of omega (rad/s), the largest in the arc angle of 300, with a thickness of 1 mm, 2 mm, 3 mm. The greatest value at the angle of 300, with a thickness of 2 mm, the number of revolutions produced three times with a time of 3:54 s, omega values obtained 0.847 rad/s.

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