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The simulation buoy shape bullet of sea wave energy absorption based on diameter variations

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Abstract. The use of fossil energy on a large scale to meet energy demand will be a threat to life in the form of air pollution, global warming and threats to the availability of fossil energy. Therefore, researchers feel it is important to conduct research with the aim of studying the potential of new and renewable energy from ocean wave energy absorption using buoys by varying the absorbent diameter of the buoyancy form. This potential is a great opportunity to meet the energy demand in coastal areas and small islands in Indonesia. This study focuses on the potential to absorb buoys carried out in transitional seas with a depth of 5.0 meters, variations in buoy diameter ranging from 1.0 meters to 10.0 meters. The wave force absorbed by the buoy is calculated using the Strip Theory Method including the kinetic force caused by the movement of the buoy. The highest efficiency of buoyancy absorption efficiency was 37.17% for floating buoys with diameter of 2.5 meters and meeting frequency of 1.379 rad/sec and the lowest 36.58% for diameter of 10.0 meters and meeting frequency of 1,463 rad / sec.

1. Introduction

More than 80% world energy demand are supplied by fossil energy [1,2]. The massive used of fossil energy to meet these energy needs will be a threat to human survival. The first is a threat to the environment, namely air pollution and global warming [3,4]. The second threat is the threat of the depletion of fossil energy, the world fossil fuel reserves data for OPEC has only reserves of up to 80 years and Non-OPEC has only 20 years of reserves which is a threat to the availability of energy sources for the lives of our generation in the future [3,5]. Therefore there is a need to maximize the use of existing new and renewable energy potentials to overcome the two threats mentioned above. The potential of renewable energy such as solar energy, photovoltaic, ocean energy, hydro energy, biomass, biodiesel and geothermal energy is quite large, but its use is still minimal [6–9]. Efforts to maximize the use of renewable energy continue to be carried out, as evidenced by the existence of various studies conducted in various uses of new and renewable energy in accordance with the potential and characteristics of each regions.

Indonesia as an archipelago geographically stretches from 60 North Latitudes to 110 South Latitudes and 920 to 1420 East Longitude, which consists of large and small islands of around 17,504 islands. Three quarters of this region is the sea (5.9 million km^2), with a coastline length of 95,161 km, the second longest after Canada [10,11]. Based on Indonesia's geographical conditions, the abundant potential of marine energy to be used includes tidal energy, ocean current energy, ocean wave energy, and ocean thermal energy. Of the four ocean energy potentials, the most developed and trend by researchers is the ocean wave energy potential. Therefore researchers feel it is important to conduct research with the aim of studying the potential of new and renewable energy from ocean wave energy by varying the diameter of the absorbent buoy and the renewable energy source. In this research an assumption is built that the variation in buoyancy diameter will affect the efficiency of

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wave power absorption by bouy. Energy absorption is obtained from the theoretical power of sea wave multiplication results with buoy diameter [12].

Some countries have used ocean wave energy converter technology, such as Archimedes Waveswing (AW) 0.25 MW in Portugal 2008, CETO in Australia 2008, Pelamis 0.75 MW in Portugal 2008, Wave Dragon 11 MW in Nissum Bredning Scotland 2003, Limpet 0 , 10 - 0, 50 MW on Islay Scotland 2000, Oyster on the Orkney Coast of Scotland, PowerBuoy 0.5 MW in Atlantic City 2005, and AquaBuOY 0.25 MW Washintong US 2004 [13]. Utilization of wave energy converter technology that uses ocean wave energy above provides many advantages namely this potential is abundant, renewable, available, and environmentally friendly [10]. However, all of the wave energy converter (WEC) designs cannot be directly applied in Indonesian sea areas. This is due to differences in the characteristics of sea waves from countries that have implemented the WEC design with the characteristics of Indonesian sea waves. The characteristics of the height and frequency of Indonesia's sea waves based on estimated data of average sea wave heights, significant heights of 0.2 - 2.0 meters and average maximum height of 0.4-2.5 meters. Wave frequencies above 3 meters are only 0% -5% [14,15].

Therefore, researchers feel it is important to conduct research with the aim of studying the potential of WEC based on the characteristics of sea waves in the Indonesian Archipelago. The main component that plays the biggest role in absorbing the wave energy of the WEC is the buoy, so this research is focused on researching the optimal absorption by the bullet shape buoy. The selection of bullet buoy forms used in this study is based on previous research which states that the bullet buoy shape has the greatest efficiency among other forms [16]. The assumption used is varying the diameter of the buoy will affect the efficiency of absorption of wave power by the buoy. The reason for this assumption is that buoy absorption is a product of theoretical wave power available multiplication buoy diameters. The things observed and analyzed in this study are the processes of utilizing hydrodynamic forces arising from ocean waves. Theoretical study of the power of wave hydrodynamics has considerable challenges, where the diffraction force is relatively complex because it consists of various excitation, radiation and attenuation forces [17,18]. The hydrodynamic excitation force of ocean waves absorbed by the oscillating buoy float is obtained using the Strip Theory Method. Results The Strip Theory Method is used as input to determine the generator power output, using relevant mathematical equations.

2. Modeling of the absorber float

2.1. Absorbent Floating Buoy

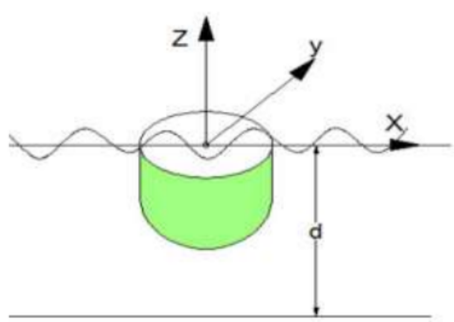

Figure 1. Schematic of floating buoy coordinates

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The right hand coordinate system is used to define fluid action on the float. Cartesian coordinate system x, y, z) is assigned to the body. The positive x-direction leads to the bow, positive z-direction is directed upward, and the z = 0 (or xy plane) field coincides with the calm surface of the water

2.2. Mass-Spring-Damper Buoy System

To simplify the problem in the analysis of the floating buoy behavior as shown in Figure 1, it can be assumed that the oscillating behavior of the mechanical motion is the same so that it can be modeled as the spring behavior in Figure 2.

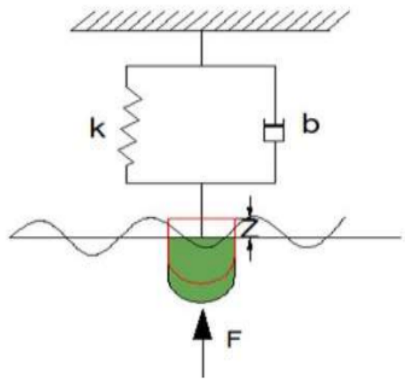

Figure 2. Spring-damped oscillating motion

3. Mathematical equation

3.1. Wave velocity

Wave Velocity be calculated based on category of grouping, deep sea, transition sea or shallow sea. The area of research carried out is limited to the transitional sea so that the equation can be written [19].

Individual Wave Velocity

$$C = \frac{L}{T} = \frac{\omega}{k}, L = \frac{2\pi}{k}, T = \frac{2\pi}{\omega} \quad \text{......................(1)}$$

Individual Wave Velocity

$$C_g = C.n \quad \text{...(2)}$$

The value of n can be calculated using the equation:

$$n = \frac{1}{2}\left(1 + \frac{2kh}{\cosh(2kh)}\right) \quad \text{................................(3)}$$

3.2. Water Depth Condition

Wave propagation speed Velocity can be calculated based on grouping categories, deep sea, transitional sea or shallow sea. The area of research carried out is limited to transitional seas so that the equation can be written [19].

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Wave Individual Velocity :

$$C = \frac{L}{T} = \frac{\omega}{k},\ L = \frac{2\pi}{k}\ ,\ T = \frac{2\pi}{\omega} \qquad (4)$$

Wave Goup Velocity

$$C_g = C.n \qquad (5)$$

The value of n can be calculated using the equation :

$$n = \frac{1}{2}\left(1 + \frac{2kh}{\cosh(2kh)}\right) \qquad (6)$$

3.3. Buoy Motion

To simplify the case, the movement of the buoy is only observed from the rise and fall of the water by the excitation of the surface movement of the water waves. Approaches to equations that are buoys can be written:

$$Z_t = Z \times \sin(\omega t + \varepsilon)\ [\text{m}] \qquad (7)$$

The movement of the buoy can be solved by using a second-order differential equation, such as the forced spring motion, mass system and dampers. The buoyancy response force is calculated based on Newton's law. The forces involved as in Figure 2 above, consist of an external harmonic force acting on the system $(F\cos(\omega t))$, add mass force $(a\ddot{z})$, damping force $(b\dot{z})$ and recovery force (cz). So the equation can be formulated in a mathematical equation as follows:

$$a\ddot{z} + b\dot{z} + cz = F\cos(\omega t) \qquad (8)$$

where: a, b, c are add mass mass, attenuation, and recovery constellation; F is a coercive function at frequency ω

Based on the equation (5) response force of the buoy harmonic motion, the magnitude of the heave (z direction direction) can be found by changing equation:

$$z = \frac{F}{\sqrt{(c - a\omega^2)^2 + b^2\omega^2}} \times \cos(\omega t) \qquad (9)$$

3.4. Drag Force

On floating objects moving oscillations will experience drag depending on the speed opposite to the movement of the buoy. Inhibition force, the addition of drag force (Fdrag) due to the effect of sea water viscosity. The magnitude of the Fdrag for an oscillating cylinder in a wave, can be calculated using the Morison Equation [20].

$$F_{drag} = \frac{1}{2}\rho U^2 C_D.D \qquad (10)$$

Where Cd drag coefficient, U vertical water particle velocity (m/s), D cylinder diameter (m), ρ volum of bullet buoy (m).

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3.5. Force Froude-Krilov section

Floating objects experience a force called the Froude-Krilov section style whose magnitude can be calculated using the equation:

$$f_3 = \rho \xi g b e^{ikx} - e^{-kds} \left[\frac{N}{m}\right] \text{......................(11)}$$

Where b is the total width of the buoy (m) that is in contact with the surface of the water.

The magnitude of the excitation force experienced by floating buoys depends on the distance of the heave vertical movement and the magnitude of the excitation force per unit length (8) as the equation below [12]:

$$F_e = f_3 . z . \sin(\omega t + \alpha) \; [N] \text{.........................(12)}$$

3.6. Wave Energy

The energy that can be produced by each wave unit correlates with the wave height associated with the equation [19]:

$$\bar{E} = \frac{E}{L} = \frac{\rho g H^2}{8} \;\; [\mathrm{J/m^2}] \text{..............................(13)}$$

here is where: $\rho \left[\frac{kg}{m^3}\right]$, $g \left[\frac{m}{s^2}\right]$, H [m] density, gravity acceleration, and significant wave height

3.7. Wave Power

The power of each unit of the wave per unit length can be calculated by using the product of the multiplication of the average wave energy with the wave group velocity as shown in the following equation [20]:

$$P_\omega = \bar{E} x C_g \;\; [Kw/m] \text{...............................(14)}$$

3.7.1. Wave Power Absorbtion by Bouy Float. Wave power can be absorbed by buoys, calculated using the following equation [12]:

$$P = P_\omega x d \;\; [Kw] \text{......................................(15)}$$

Where d [m] is a horizontal extension of the buoy that is passed by the sea wave.

3.7.2. Actual Wave Power absorbtion. Absorption of ocean waves by floating buoys is an excitation representation of power in the form of lift and absorption of power in the form of radiation needed to move up and down the floating buoy, so the equation can be written as [20]:

$$P_a = \frac{1}{2} x |F_e| |\dot{z}| . cos\varphi \text{..............................(16)}$$

3.8. Efficiency of Power Conversion

The efficiency of power conversion by a buoy can be calculated by comparing equation (13) with equation (12) such as [12]:

$$\eta_a = \frac{P_a}{P} x 100\% \text{..(17)}$$

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4. Parameter design

4.1. Simulation buoy design

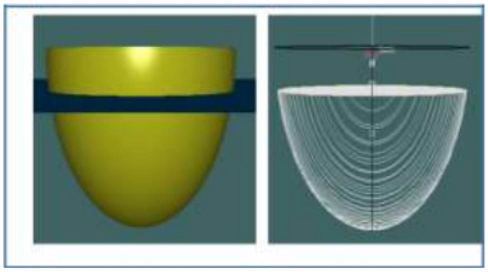

Figure 3. Shape of Simulation buoy

4.2. Diameter size variations

Table 1. Diameter size variations

Diameter	Unit
1	m
1.5	m
2	m
2.5	m
3	m
3.5	m
4	m
5	m
6	m
8	m
10	m

4.3. Setting Simulation Parameters

Table 2. Setting Simulation Parameters

Parameter	Quantity	Unit
Modal period	9.988	s
Characteristic wave height	1.000	m
Spectrum type	Jonswap	-
Wave heading	3.142	rad

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5. Simulation results and discussion

5.1. Simulation Results

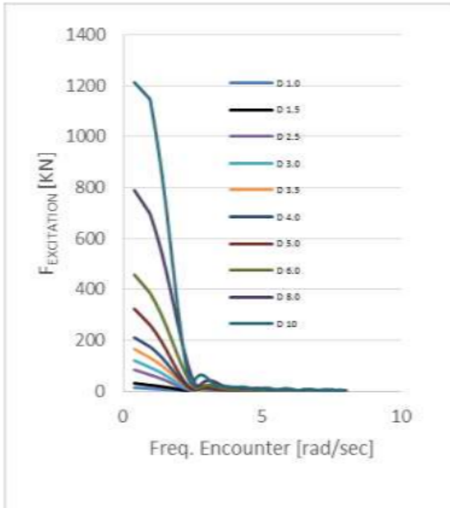

Figure 4. Force of wave excitation based on diameter variations

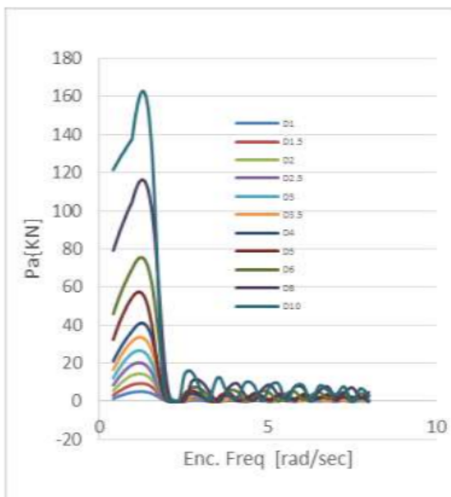

Figure 5. Actual power absorbed by buoys from wave power potential

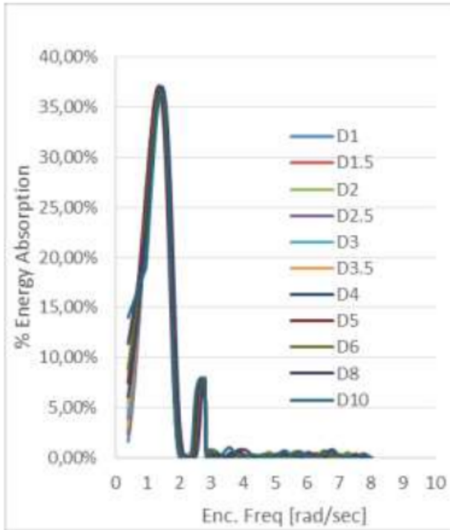

Figure 6. Absorbent absorption efficiency based on diameter variations

5.2. Validation of Results

This paper aims to examine the application of ocean wave energy by floating buoys based on variations in diameter, simulation data compared with experimental results in terms of the results of previous studies [14,16,18] to verify simulation results and calculations using mathematical equations. The buoys used in this simulation are buoys with a diameter of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 8.0, and 10 meters. Excitation force is calculated for each diameter of the test buoy. Simulation testing is carried out on regular waves with a wave height of 1 meter with transitional sea conditions. The simulation results obtained from images 3,4,5 and 6 obtained a good suitability of trend charts with experimental results

5.3. Absorption Power and Efficiency

In the calculation and analysis, the hydrodynamic parameters are obtained using Strip Theory Method. After calculations and simulations using relevant equations results are obtained as shown in Figures 3, 4 and 5. The diameter has an influence on the absorption force of the excitation force. On picture. 3 the excitation forces that can be absorbed from each float vary by diameter. The ability to absorb the excitation style of float floats directly in diameter. The magnitude of the diameter influences the absorption force of the excitation force because by extension the magnitude of the diameter will directly affect the width of the cross section of the float in contact with water (equation 9). Similarly, the ability of buoys to absorb power from wave power as shown in Figure 4 also has direct headlines with a diameter.

The diameter has an influence on the efficiency of weathering absorption. In addition, the diameter of the float also affects the radiation attenuation coefficient, b (ω) and the Fexc (ω) excitation force. Fexc and b (ω) are also directly proportional to the diameter of the buoy which will provide a drag to the heave rotating force like the results seen in Figure 5. From the variation in diameter observed, the diameter obtained gives optimal efficiency.

6. Conclusion

This research was conducted by varying the buoy diameter from 1.0 to 10 meters for determine the effect of the buoy diameter on the absorption efficiency of power in a regular wave with a height of 1 meter in the transition ocean area within 5 meters. Simulation results obtained from figures 3,4 and 5 obtained a good trend graph suitability with experimental results. Based on the research results obtained as shown in Figures 3, 4 and 5, some conclusions can be drawn:

1. The diameter and draft style of the float affect absorption. With increasing diameter, power absorption increases and is inversely proportional to the draft buoy force. For example, buoys with a 10 m diameter are absorbed 162.79 KN to 822% more than power is absorbed from buoys with a diameter of 3 m.
2. Based on the results of the efficiency obtained, the 2.5-meter diameter gives the maximum efficiency of 11 diameter variations observed at 37.17% and the smallest at 10-meter diameter buoys
3. Bullets buoys with diameter of 2.5 m can be considered in further research for use in absorbing wave energy converter around the Indonesian island area characters height wave seas

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