Wave Energy Conversion with Floating Objects for the Coast of East Java

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Abstract: The coast of East Java has ocean waves with varying significant wave heights and wave periods. To convert wave energy into electrical energy, equipment is needed, which is a floating object. This floating object serves to convert wave energy into mechanical energy which is then converted into electrical energy. Energy conversion will be maximum if the ocean wave frequency same with natural frequency of floating objects. The natural frequency of floating objects is determined by the shape of the floating object. This study compares two floating objects, namely cylinder and cone shaped. From the results of simulations, the cylinder shape is more suitable to be applied on the south coast of East Java, while the cone shape is more suitable to be applied on the north coast of East Java.

1 INTRODUCTION

Energy produced by ocean waves is a very potential energy in the world and the most efficient when converted to electrical energy (Drew, et.al, 2009). But the implementation as a real electricity generator is still very minimum. Most are still on a laboratory scale. The energy produced by ocean waves is depended on the parameters of ocean waves, namely the significant wave height and wave period. At each location has a varying significant wave height and wave periods (Faizal, et.al, 2014). Therefore we need a wave energy conversion mechanism (Wave Energy Converter, WEC) that is suitable for wave conditions in each of these locations. Furthermore, the mechanical energy is converted into electrical energy. In general, WEC can be categorized as oscillating water columns (OWC), overtopping devices, attenuators and point absorbers (Aggidis and Taylor, 2017). The OWC structure is a column with two holes. The first hole faces the sea where a wave comes. The wave then press the water that pushes the air in the column. In the second hole, it relates to an atmosphere where an air turbine is placed to convert it into electrical energy (Ravinesh, et.al, 2016). OWC is usually installed on the shoreline. The advantage of this system is the ease of installation. Whereas the weakness is the power of the wave is not as big as offshore. The structure of overtopping devices is a water reservoir that higher position than sea level. If there is a wave, water will collect in that place. Then the water flows downward to move the turbine to convert it into electrical energy (Frigaard, 2008). The WEC attenuator is a long absorber that the incoming wave will move it perpendicular to the direction of the wave. So that each part of the attenuator moves vertically (Lopez, et.al, 2013). Point absorber is a floating object with a certain shape that is partially or completely submerged at sea level. When a wave comes, this floating object will move vertically (heave). This floating object movement will drive the generator with a certain mechanism to produce electrical energy (Faizal, et.al, 2014).

Point absorber is one of the WECs that will be developed in shape and size. By optimizing the shape and size of floating objects, floating objects will be suitable for that location, so the maximum wave energy conversion will be obtained. When the waves come, floating objects will move vertically (heave). This floating object is called a point absorber, because in this part the wave energy is absorbed by the system. This movement will excite the movement to produce mechanical energy to be converted into electrical energy, called Power Take Off (PTO). PTO will be very efficient if the movement is limited to one dimension only (Pecher, 2017). To maximize energy, a condition is needed where the natural frequency of floating objects must

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be equal to the frequency of ocean waves. Whereas the natural frequency of floating objects depends on the shape of the floating object. Therefore, to optimize the energy conversion, the structure and shape of the floating object becomes very important.

2 WAVE ENERGY ON THE COAST OF EAST JAVA

Sea wave characteristics on the southern coast of East Java (the Indonesian Ocean) and the northern coast of North Java (Java Sea) have several differences. The difference in characteristics between the two locations is related to the significant wave height (Hs) and wave period (T).

Figure 1: Wave characteristics in East Java.

From figure 1, the south coast has a significant wave height Hs = 1-2 m with a wave period T = 10-16 seconds. Whereas on the north coast has a significant wave height Hs = 0 - 1 m with a wave period T = 2 - 8 seconds (Warpindyasmoro, 2018). The energy produced by ocean waves (Goncalves, 2014; Atan, et.al, 2016) is

$$P = \frac{\rho g^2}{64\pi} H_s^2 T \quad (1)$$

Where ρ is the density of seawater (kg/m3), g is the gravitational acceleration (m/dt2), Hs is the significant wave height (meter) and T is the wave period (seconds). By using the equation (1), the potential of electrical energy on the coast of East Java can reach 232 MWh/m/year (Warpindyasmoro, 2018). Energy potential is large enough to be developed further.

Characteristic differences between waves on the north coast (Java Sea) and the south coast (Indonesian Ocean), especially related to wave periods, to optimize the energy produced, floating objects are needed as Wave Energy Converter (WEC) which has the maximum Response Amplitude Operator (RAO) according to the wave period at each wave location at the sea.

3 POINT ABSORBER MODELLING

One WEC that can be directly connected with a generator is a point absorber. Parameters that need to be considered when designing a point absorber are shape, length, volume, mass, draft, center of weight, buoyant force and moment of inertia (Nielsen, et.al, 2014). Modelling of absorber points can be seen in Figure 2.

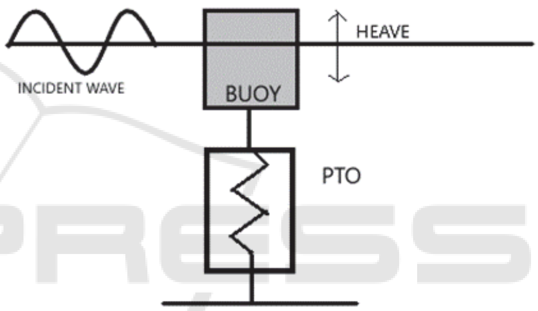

Figure 2: Point absorber modelling.

The movement of the point absorber is limited to moving only in the z axis, so that the equation of motion from the point absorber according to Newton's Law (Pecher, 2017) is:

$$m\frac{d^2z}{dt^2} = F_{ex} + F_{rad} + F_{res} + F_{damp} + F_{tun} \quad (2)$$

Where m is the mass of floating objects, (d^2 z)/(dt^2) is the acceleration of floating objects in the direction of the z axis, Fex is exciting force, Frad is radiation force, Fres is a hydrostatic restoring force, Fdamp is the external damping force , Ftun the buoy tuning force to phase-control. Because the point absorber model uses the mass-spring-damper model, the natural frequency of the floating object is

$$\omega_n = \sqrt{\frac{k}{m+m_a(\omega)+m_{sup}}} \quad (3)$$

where k is the hydrostatic restoring coefficient, m is mass of the buoy, ma (ω) is added mass and msup is supplementary mass. Because the context for waves is a period, natural period parameter will be used which is the opposite of the natural frequency. The development of point absorber has been done to obtain the largest PTO (Falnes and Hals, 2012; Shadman, 2018).

4 RESULTS AND DISCUSSION

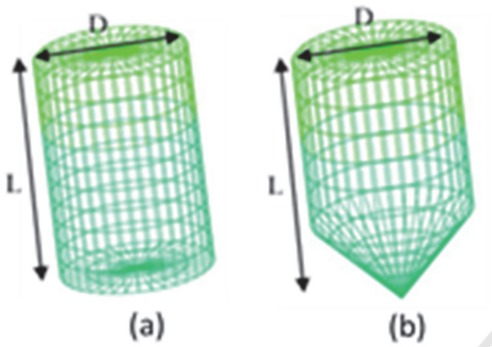

Figure 3: Model of point absorber: (a) cylinder, (b) cone.

In this study two point absorber models were made, namely cylindrical and cone shaped like Figure 3. The size of each model is L = 1.5 D, where D is the diameter. The diameter of the model varied, D = 6, 9, 12, 15 and 18 m. Figure 4 shows the comparison of RAO between cylinders and cones for D = 18 m with a 4 m draft. It appears that the maximum RAO on the cylinder occurs at a greater period than the maximum RAO at the cone.

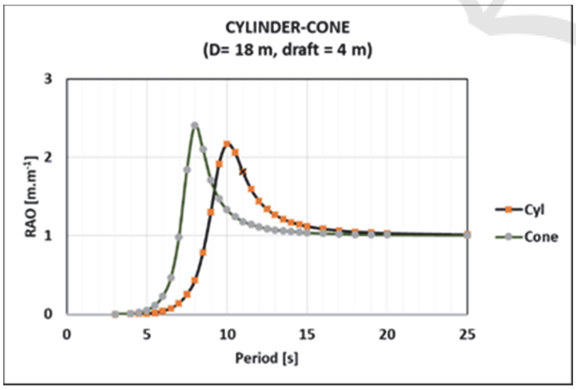

Figure 4: Comparison of maximum RAO in cylinders and cones.

To find out the relationship between the diameter of the floating object and the wave period that produces the maximum RAO, the diameter of the floating object is simulated for diameter 6, 9, 12, 15 and 18 m. For cylindrical floating objects can be seen in Figure 5.

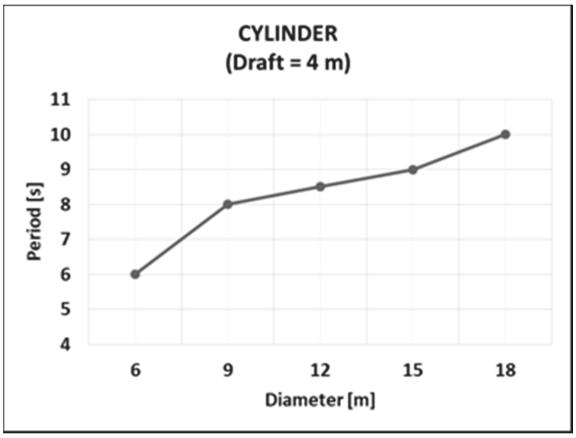

Figure 5: Relationship between diameter and period to produce maximum RAO for cylinder shape.

From Figure 5, it appears that the greater the maximum floating diameter of the RAO object will occur at the higher wave period. For maximum diameter (D) 6-18 m, RAO occurs in the wave period (T) 6-10 seconds. To produce maximum RAO in a wave period of more than 10 seconds can be done by increasing the diameter of the floating object. For locations that produce waves with a wave period of 10-16 seconds, such as on the southern coast of the Java Sea (Indonesian Ocean) can use cylindrical floating objects as point absorber for WEC to produce maximum mechanical energy.

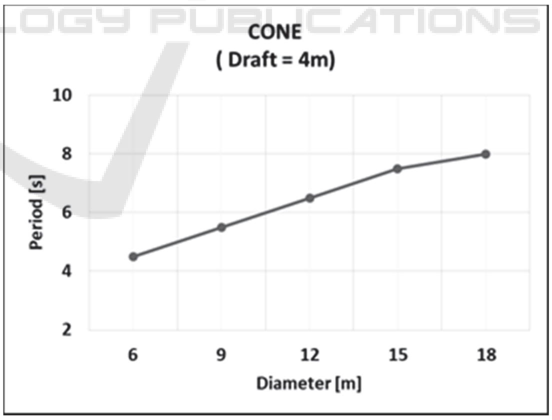

Figure 6: Relationship between diameter and period to produce maximum RAO for cone shape.

Meanwhile for conical floating objects, as shown in Figure 6, the maximum RAO with a diameter (D) of 6-18 m occurs in the period of wave (T) 4-8 seconds. By reducing the diameter, the maximum RAO will be obtained in a period smaller than 4 seconds. Thus the conical floating object can be used as a point absorber in the WEC to be applied in locations with small wave periods (2-8 seconds) such as on the north coast of East Java (Java Sea).

5 CONCLUSION

An overview of the cylindrical and cone shaped point absorber has been carried out. Point absorber with cylindrical floating objects produces maximum RAO over a larger period than cone-shaped floating objects. To produce the maximum RAO, the greater the maximum RAO floating diameter will occur in the larger period. Point absorber with cylindrical floating objects 6 - 18 m in diameter can produce maximum RAO in the wave period of 6 - 10 seconds. By enlarging the diameter, this shape is more suitable for locations with higher wave periods such as on the southern coast of East Java (Indonesian Ocean). While the cone-shaped point absorber can produce maximum RAO in the 4 - 8 second wave period. By reducing the diameter of floating objects, this shape is more suitable to be applied on the north coast of East Java (Java Sea).

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