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Physical Model Performance of Wave Energy Converter Based on Water Mass Gravity Force under Container Shape Variation

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Abstract: ***To date there has not been an adequate information on the effects of container shape on the power take off (PTO) performance of wave energy converters (WEC) based water mass gravity force of that was developed at the Hydraulics Laboratory, University of Hasanuddin Indonesia. In this work, physical model investigations were carried out to study the influence of three different type of container shape on the PTO performance of the proposedWEC. In this experiment, cube, cylindrical and spherical plastic container shapes were employed respectively. Each container shape was operated at similar wave parameters and the captured energies were measured, analyzed and compared. The results showed that the cylindrical container produce the highest power take off, followed by cube and sphere shapes respectively. Furthermore, theability of the proposed WECto reduce the wave amplitude was shown highest recorded percentage under sphere container shape, however it produced the lowest power take off. Moreover, cube container has a moderate performance on PTO and wave height reduction capability. The result obtained can be used as reference for further research on the development of wave energy converter based on water mass gravity force as a renewable energy source.***

Keywords: wave energy, renewable energy, wave energy converter, gravity force, water mass

1. Introduction

Modern human life cannot be separated from the problem of energy, water and food. Today most of the energy needs depend on fossil fuels and nuclear (Masjono, et al., 2014).The increase of energy demand in the future will be triggered by rapid population and industrial growth. On the other hand, energy sources thatrely on fossil fuels as the dominant source of today's energy consumption has a negative impact on the environment due to carbon dioxide releases as the result of fossil fuel burning. Moreover, its reserves are also now are decreasing, while the need for energy continues to increase. U.S Energy Information Administration reports (OECD/IEA, 2015) showed that the world's energy consumption increased from 524 quadrillion Btu in 2010 to 630 quadrillion Btu in 2020 and 2040 is expected to reach 820 quadrillion Btu. Based on the report within 30 years period, the world's energy needs will increase by 56 percent(Masjono, et al., 2016).

To cope the energy demand in the future and to preserve the environmental sustainability, necessary efforts are required todevelop environmentally friendly energy sources. A variety of green energy sources that already used today include solar energy, wind, tidal, wave, geothermal, hydroelectric, biomass and firewood(BBC, 2014). Each of these alternative energy sources have advantages and disadvantages. This paper presented the investigation result of the utilization of wave power as a renewable energy source. One of the main part of WEC used in this experiment was the water container that moves up and down in harmony with the wave oscillation. The amount of captured power is strongly determined by these container. Therefore this research was carried outto investigate the most efficient container shape that able to capture wave power as source of renewable energy.

2. Methods and Materials

This study was aimed to investigate the effect of gravity weight container on power take off performance of wave energy converter based on water mass gravity.

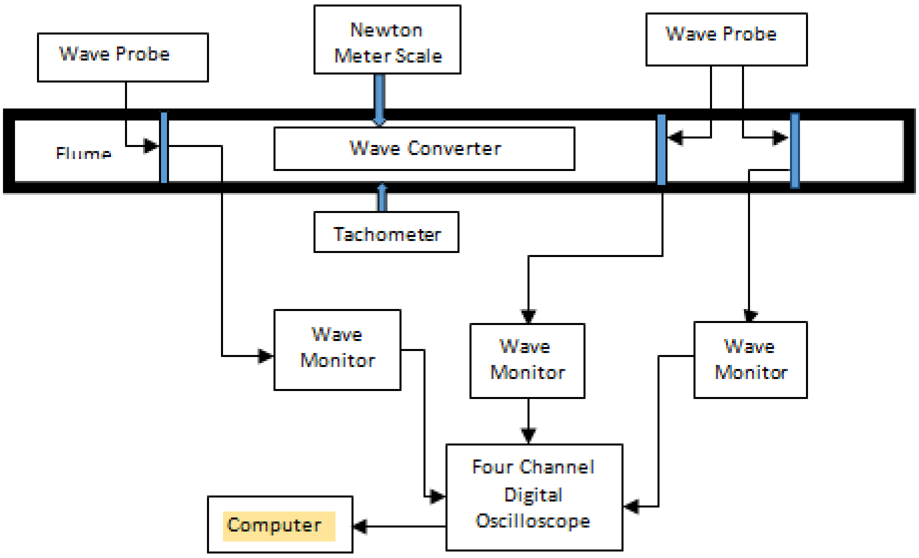

Figure 2.1: Block diagram of the experiment

The experiment was carried out from February to March 2016 at wave flume, Hydraulic Laboratory Department of Civil Engineering Hasanuddin University Indonesia. Experiment set up is described in Figure 2.1. In this study, wave height was varies from 2 cm up to 9 cm. Water depth 25 cm, wave period 1.2 second and wave length 160 cm. All these wave variableswere applied for three types of container used as a gravity weightthat were cube, cylinder and sphere shapes respectively.These gravity weight connected with one way gear drove the converter shaft to rotate in one direction. Furthermore, these rotation was multiplied by gearbox and further stabilized using flywheel.

Wave parameters as an input of the converter were measured by means of wave probe connected with wave monitor module and four channel digital oscilloscope as illustrated in Figure 2.1. The power take off performance on the converter were measured at flywheel shaft using digital tachometer and newton meter scale. Digital tachometer was used to measure the radial speed (RPM) and Newton Meter scale was measured the flywheel shaft torque. Power take off (PTO) was calculated using Equation 2.1(WEN Technology, 2002).

$$P \text{ (Watt)} = (n * \tau)/9.550 \text{ Watt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.1)$$

Where:
n = Radial speed (RPM)
τ = Torque (Nm)

Performance of each container shape was decided based on radial speed of flywheel and power take off calculation under similar wave parameters. However, this experiment was limited to regular waves due to the flaws of flume used which only able to generate regular waves. Furthermore, wave height and water depth were limited to 25 cm by flume shallow bed.

3. Results

With the physical model experiment it was easy to investigate the effect of container shape on power take off yielded by the proposed wave energy converter based on water mass gravity force.

(a) (b) (c)

Figure 3.1: Experiment set-up for three type containers

The experiment result indicated that each container produce different converted power. The experiment was initiated with cube container Figure 3.1. In this experiment, there were four pair of container used. The weight of container was 5.024 Kg, counter weight 0.328 Kg and converter gear spacing was set at 40 cm. Result obtained showed that the output power generated by the proposed wave energy converter exist even at a very low wave height. In this experiment the lowest wave height was 2 cm, the converter produce 0.65 Watt. The radial speed of flywheel shaft showed significant increase at the wave height of 3 cm. The highest radial speed was achieve at the wave height of 8.5 cm and went down slightly at 9 cm to 214.7 RPM. The measured torque was proportionally related to wave height and RPM Table 3.1 and Figure 3.1(a).

Table 3.1: Experiment result of three type of containers

Wave Height (cm)	Radial Speed (RPM)			Torque (τ) (Nm)			Calculated Power (Watt)		
	Cube	Cylinder	Sphere	Cube	Cylinder	Sphere	Cube	Cylinder	Sphere
2	12.4	62.7	0	0.5	0.8	0	0.65	5.25	0.00
2.5	33.2	77.8	0	0.75	1.2	0	2.61	9.78	0.00
3	60.4	85.9	43	1.5	2	0.75	9.49	17.99	3.38
4	81.8	114.8	74.1	2	2	1.5	17.13	24.04	11.64
5	107.3	165.8	114.9	2.5	2	2	28.09	34.72	24.06
6	143	206.5	126.1	3.7	2.5	2	55.40	54.06	26.41
7	190.4	224.5	184	4	3.5	2.5	79.75	82.28	48.17
8	204.1	267.5	221.5	4.5	3.5	3	96.17	98.04	69.58
8.5	217.8	265.1	227.9	5.5	3.5	3	125.43	97.16	71.59
9	214.7	265.2	228.5	4.5	4	3	101.17	111.08	71.78

The next experiment was cylinder container Figure 3.1 (b). In this experiment, there were four pair of container used. The weight of container was 3.6 Kg, counter weight 0.328 Kg and converter gear spacing was set at 40 cm. Result obtained showed that the output power generated by the proposed wave energy converter using cylinder container outperform the cube container. Even at a very low wave height the converter produce significant shaft radial speed. In this experiment the lowest wave height was 2 cm. However, the converter able to produce 5.25 Watt. The radial speed of flywheel shaft showed linear increment since at the wave height of 2 cm. The highest radial speed was achieve at the wave height of 9 cm recorded by digital tachometer 265.2 RPM.

The lastexperiment of was the use of spherecontainer Figure 3.1 (c). In this experiment, there were four pair of container used similar to the previous experiments. The weight of container was 3.5 Kg, counter weight 0.328 Kg and converter gear spacing was set at 40 cm. Result obtained showed that the output power generated by the proposed wave energy converter using sphere container was the lowest among three container shapes. The performance of converter at the wave height of 2 cm did not move at all. Therefore the calculated output power was zero. However at higher wave the sphere container outperform the cube container that rotate the flywheel shaft at 228.5 RPM.

In term of power the cube container produced the higher output power since its container weight was 5.25 Kg. It was heavier than the weight of cylinder and sphere containers. Therefore, the result indicated that not only the container shape that influence the power take off, however, the container weight was the most dominant variable that determine the converter power take off. Calculation result of yielded power showed that the wave height was proportionally related to the amount of converted energy. The different container weight was one of the limitation of this experiment. Therefore, the torques as shown in table 3.1 were slightly different. Moreover, radial speed was the only indicator that can be used to decide which container gave highest performance. In term of radial speed (RPM), cylinder container showed the best result. Even at wave height as low as 2 cm, the converter started to generate power Figure 3.2. That means, as long as there is a water movement, than cylinder as an interface between wave and converter could capture the wave energy.

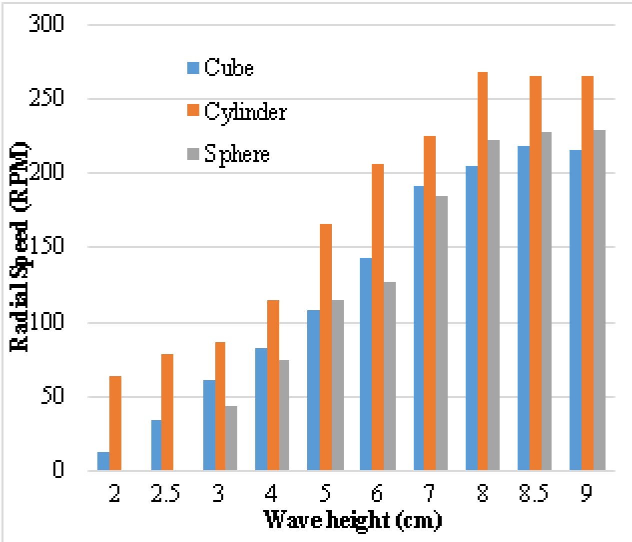

Figure 3.2: Wave height and radial speed of flywheel shaft on different container shape

4. Discussion

The main objective of this research was to find the most efficient form of container to be used in wave energy converter based on water mass gravity force that was developed at hydraulic laboratory Hasanuddin University Indonesia. Experimentresults showed that cylindrical shape container gavehigher performance in generating energy compared to the two other counterpart. However, this preliminary result valid for regular wave only due to the limitation of flume.

The experiment result indicated that shape of container gave significant effect on the performance of wave energy converter. In this experiment the performance indicator used to decide the best result was the correlation between wave height and radial speed (RPM). The calculated output power in this case was not suitable to be used to compare the performance since the container weight were different. Therefore, the measured torque (Nm) were showed different value. The experimental results show that the cylindrical shape of the container provides the highest rotational speed of 265 RPM as shown in Table 3.1.

The results obtained in this study was limited to only three types of container. Therefore, further studies is required to investigated the converter performance for the other container shape such as such as parabolic, cone, triangleetc.

Since the experiment was conducted in regular wave condition, thanfurther research need to be carried outon various forms of container on regular and non-regular waves.

When compared with the existing wave energy converters, the proposed converter shows an advantage in terms of the amount energy produced and converters dimension. Previous research such as Pelamis WEC models solely rely on buoyant force of the ocean wave(Henderson, 2006)(Andres, et al., 2015)(Blažauskas, et al., 2015). There was similar finding with single model of non-buoy wave energy converters(Amarkarthik & Sivakumar, 2016).

This research result indicated that the container shape have significant effect on the performance of the proposed wave energy converter. Theprincipal findings of this study is useful forfuture researchin the development and design of moreefficient wave energy converters.

5. Conclusion

This paper describes the influence of the container shape on the performance of wave energy converter based on water mass gravity force as a source of renewable energy. Cylinder shape container perform the best result compared with cube and a sphere shapes. In term of calculated yielded power, the cube container showed the best result due to its weight was possessed the heaviest weight. The experiment result valid for regular wave only with limited number of container shape. Therefore, further research is needed for the various types of container under regular and non-regular wave environment.

6. Acknowledgement

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