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Hydrodynamic Responses of Heaving Motion on One Body and Two Body Point Absorber Devices with Different Wave Condition in Malaysia

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ABSTRACT

Wave energy harvesters are still not as mature as other types of renewable energy harvesting devices, particularly when it comes to commercialization, mass production, and grid integration, even though ocean waves around the world are known to contain high and dense quantities of energy. However, recent studies and optimizations suggested that the point absorber wave energy harvester may be a viable option. This paper provides a comprehensive comparison hydrodynamic damping analysis of the heaving motion on one body and two body point absorber wave energy harvesters by using Computational Fluid Dynamic (CFD) software. A simulation run was proposed for the analysis performance of damping of the point absorber devices to low wave height (0.7m -2.5m) and period (0.9s-2.2s). There are two types of point absorbers: one-body point absorber and two body point absorber. Both point absorber body are examined by simulation in terms of its heaving dynamic motion frequency in calm, medium and strong wave condition. This analysis highlights the extensive research being done to bring point absorbers closer to technical maturity, paving the way for commercialization and mass production for low wave characteristics. The results showed two body point absorber Response Amplitude Operator (RAO) is improved to absorbed low wave height compared to one body by RAO efficiency 17% and device efficiency 25%. The two-body point absorber performed better in all wave condition.

1. Introduction

Renewable energy is defined by the International Renewable Energy Agency (IRENA) as energy extracted from nature that can be replenished indefinitely [1]. Renewable energy is energy generated from natural resources that does not emit carbon dioxide (CO_2) into the atmosphere and does not require the use of fuel to generate electricity. Renewable resources include natural sources such as waves, tidal currents, wind, and sunlight. Using these sources reduces the world's reliance on oil and gas while also reducing greenhouse gas emissions from electricity production and consumption. The

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most advanced forms of ocean energy are ocean wave and tidal current energy, which are predicted to contribute significantly to global warming [2].

Wave energy is a clean and renewable energy that is reliable, realistic, sustainable, and economical which can replace all current fuel sources used by the people of this planet. Among the different forms of renewable energy, wave energy has a range of benefits, including the density is higher than that of other renewable energy sources such as solar and wind energy [3]. It was claimed that the intensity is about 2–3 kW/m^2 for wave energy, 0.4–0.6 kW/m^2 for wind energy and 0.1–0.2 kW/m^2 for solar energy [4]. Wave energy resources are enormous, when compared to the electricity consumption as seen in a study by Qiao *et al.,* [5]. CO_2 emissions associated with wave energy generation have been claimed to be very low when compared to those associated with non-renewable energy generation, smaller than those associated with solar energy generation, and rather comparable to those associated with wind energy generation [6]. Wave conditions can be well predicted ahead of the time. The predicted incoming waves can be used for operational planning [7]. Wave energy converters (WECs) can generate power up to 90% of the time, while wind and solar energy converters can generate power only up to 30% of the time [8].

To date, there have been over 1000 Wave Energy Converter (WEC) design patents filed around the world. There are about 200 different WEC devices in various stages of production and testing at the moment [9]. However, the device's efficiency and performance in low-sea-state conditions remains low. Most current developments are based on extracting wave energy from European seas, where wave height and period are much larger than in Malaysian seas. The wave energy industry in Malaysia is currently in its infancy, with just a few units. Most of the figures on show are still in the early stages of growth, with some undergoing feasibility studies. Early theoretical experiments on a heaving point absorber converter showed that the device's oscillation frequency should match the frequency of the incident waves in order for it to be an effective absorber [10].

Malaysia is a tropical region, and the weather changes drastically as the monsoon season progresses. The Malaysian government has set an ambitious plan of increasing the percentage of renewable energy (RE) in the country's energy mix. Malaysia currently generates about 2% of its electricity from renewable sources, relatives to the total generation mix, and aims to achieve a 20% penetration rate by 2025 [11]. The current energy mix for Malaysia power generation is mainly provided by natural gas and coal.

Based on Yaakob *et al.,* [12] and Kamranzad and Lin [13], the South China Sea has a huge potential for wave power. The Figure 1 below shows that site location situated under Malaysia's Exclusive Economic Zone (EEZ) in the South China Sea. In this research, the location selected is Terengganu. Based on Yaakob *et al.,* [12], this location has the potential of wave energy resources. In general, the preliminary assessment indicates that Malaysia has an average energy resource for intermediate waves.

Fig. 1. Selected area along the coast of East Peninsular Malaysia and East Malaysia

In this research, the simulation analysis using CFD software for comparison in between one body and two body point absorber in heaving motion with three wave condition were carried to analyze the outstanding to perform better in low wave characteristics.

2. Methodology

To address the research questions and achieve the research goal, the methodology chapter must include four main stages. The first step involved determining the most optimal point absorber to Malaysian wave condition. The virtual modelling of point absorber one body and two body are sketched using Computer-Aided Design (CAD) known as Autodesk Inventor. The one body point absorber has been discussed by Amiri *et al.,* [14] and is shown in Figure 2. The two body wave energy converter numerical model has been discussed by Kim *et al.,* [15] and is shown in Figure 3. The fluid problem assessment of existing point absorber device was carried out using CFD software. The boundary condition for one body is shown in Figure 4 and two body shown in Figure 5. This chapter deals with the CFD modelling of the one and two body WEC form wave energy conversion system, with a concentration on the capacity of a computer to absorb energy. The creation of a CFD model includes model design, meshing, and wave generation. The wave communicates with the model that free float above the water. The outcome would display the motion of one body buoy and two body buoy heaving motion WEC after running the simulation. The results of the assessment are presented in three different wave condition. *Wave condition 1, 2 and 3* represent calm wave, medium wave, and strong wave, respectively. The wave condition was selected according to the probability of occurrence.

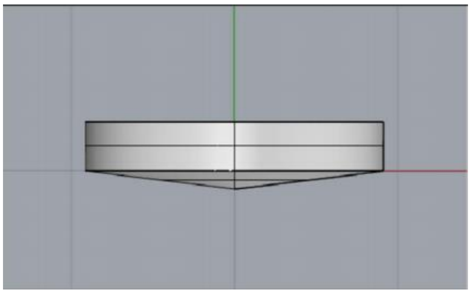

Fig. 2. One body point absorber [11]

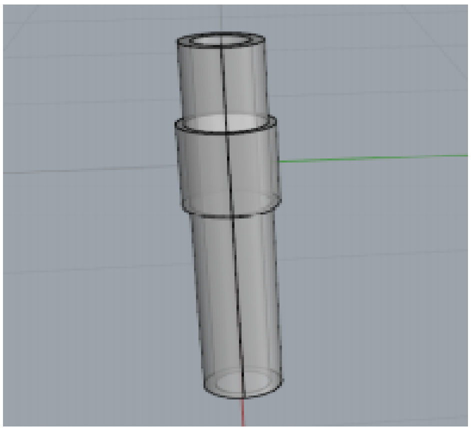

Fig. 3. Two body point absorber [12]

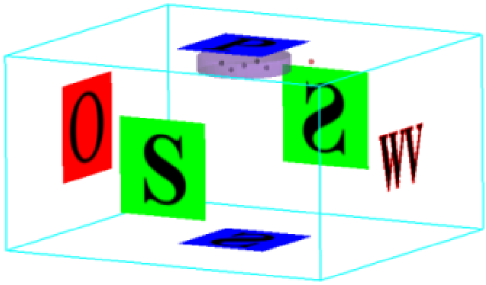

Fig. 4. Boundary condition setup for one body point absorber

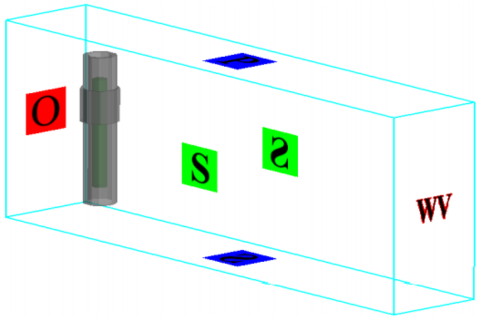

Fig. 5. Boundary condition setup for two body point absorber

3. Results and Discussion

3.1 Grid Independence Study

The grid independence study is suitable for reducing or minimizing the impact on computational performance of the number of grid sizes. The effects are influenced by the number of elements in the tank. For all individual geometry, which is routine, it is often a good practice to obey this. The mesh scale starts with larger elements to smaller elements. The fine line is that larger elements give the poor results, but smaller elements cause computation too long that the results are not at all collected. The reduction in the size of finite elements leads to more elements, leading to more nodes in the model in turn.55. To choose an optimum mesh number, the Grid-Independence Study was designed. In the next simulation, which is to determine the motion of the model, which is z-coordinate, the ideal mesh number can then be used. To prove that the solution varies nothing between coarse mesh and fine mesh.

3.2 RAO Response

The results of RAO from CFD simulation software for all wave condition is shown in Table 1. The oscillation of the device takes into account after five cycles of the wave because at this point the devices are starting to absorb the wave.

Table 1
RAO (m) efficiency

RAO (m)			
Point Absorber	Wave condition 1	Wave Condition 2	Wave condition 3
One Body	0.01	0.04	0.05
Two Body	0.04	0.08	0.3

3.2.1 Wave condition 1 (Hs 0.02m Tp 0.9s)

Figure 6 shows the heaving motion for one body and two body point absorber in a calm wave. The two-body responded to the wave frequency better by 0.03 m difference compared to one body point absorber. The heaving motion on one body seemed consistently heaving by 0.01 m whilst the two body constantly 0.04 m.

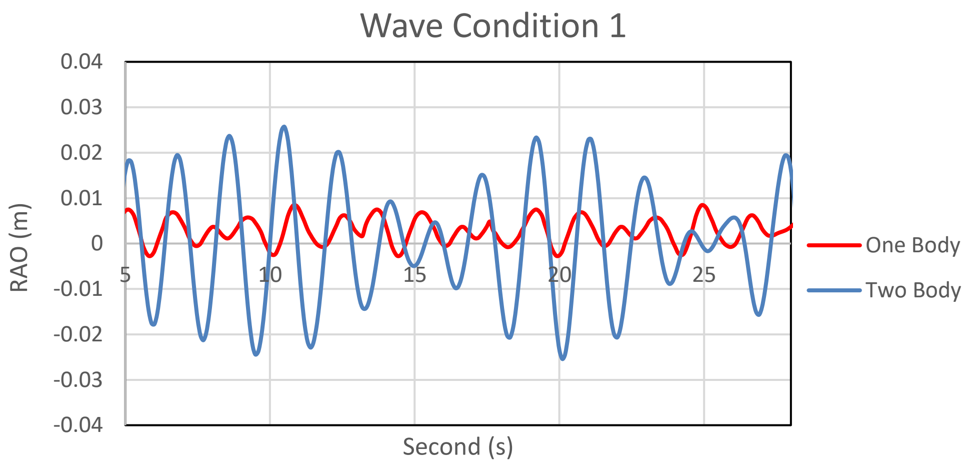

Fig. 6. Heave motion for Terengganu, wave condition 1

3.2.2 Wave condition 2 (Hs 0.05m Tp 1.4s)

As for the wave condition 2 in a medium wave (Figure 7), the two body again responded approximately 0.08 m of the heaving motion compared to one body which only 0.04 m. Two body showed again good responsive to the wave frequency.

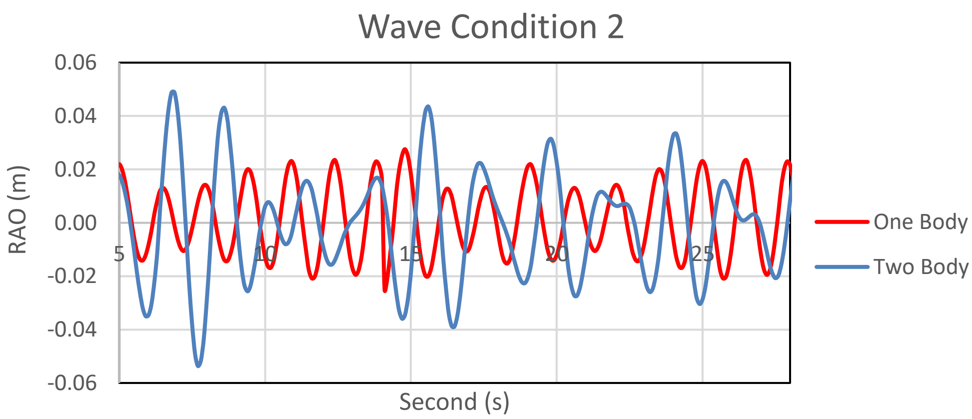

Fig. 7. Heave motion for Terengganu, wave condition 2

3.2.3 Wave condition 3 (Hs 0.08m Tp 1.7s)

In a strong wave condition, two body showed promising response to the wave which shows 0.3 m stroke of the point absorber compared to 0.05 m for one body see Figure 8. It showed that two body response higher stroke in strong wave and absorbed frequency response to the wave frequency. The floating device reacted better in this sea state which show higher RAO response compared to wave condition 1 and 2.

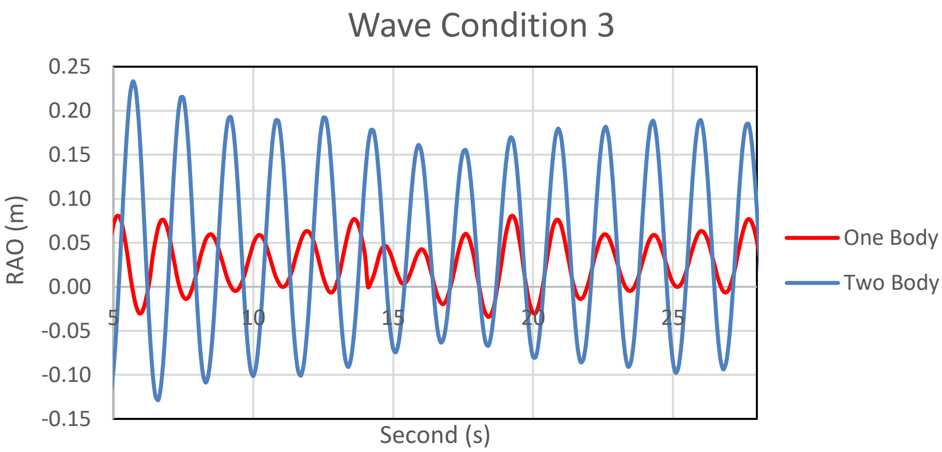

Fig. 8. Heave motion for Terengganu, wave condition 3

3.5 Power

It has been discovered that when the system is tuned to the incoming wave swell, the device produces the most power. The device's natural frequency is set to match the incoming wave frequency during this tuning. To determine natural frequency, decay tests were performed. The device was pulled in still water to full displacement and then released while the time history of the device is recorded. For the model, this section displayed the power estimated by calculation. The float type moved up and down with the change in mass above it. As a wave crest approaches, the water mass increases above the float, thus pushing it down. The forces acting on the float may be modeled via newton equation. The equation below shows the calculation estimate the power generated in this research. Eq. (1) shows the mass of water acting on the float device. The power transferred equation is shown in Eq. (2). It is simply multiplied by the velocity of the float, where the velocity is the stroke length divided by the half of the wave period.

$$F_{water} = (\rho_{water} H A_{float}) g \quad (1)$$

$$P_{generated} = F_{water}(2L_{stroke} / T) \quad (2)$$

Figure 9 shows the power estimation for one body and two body point absorber with all three conditions. From the overall results, two body shows highest result than one body by 6 Mw difference. The highest potential is two body point absorber wave condition 3 with estimated power produce is 4.22 Mw follows by wave condition 2 with 2.34 Mw at condition 2 and lastly at wave condition 1 total estimated power produce is 0.58Mw. The one body point absorber also promising to produce electricity with total average of 0.48 Mw for all wave condition.

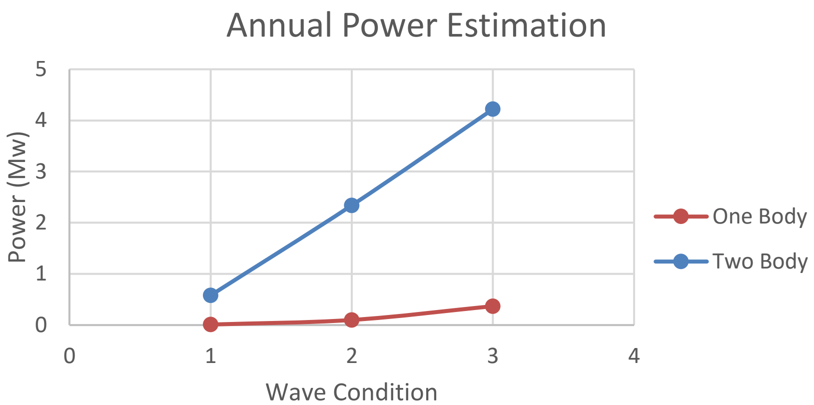

Fig. 9. Annual power estimation

4. Conclusion

The effects of some influential factors, including the incident wave height, frequency on the maximum heave displacement were quantitatively investigated. This research aimed to distinguish one body and two body wave energy converter devices for low wave height in Malaysia wave condition. Based on the result and discussion above, it can be concluded that two body wave energy converters can produce electricity for small-scale waves condition in Malaysia. Terengganu.

The RAO respond efficiency between one and two body point absorber is 17%. In this case, two body WEC can generate the power for Terengganu zone. It shows that even at low wave height and low sea state, the devices are capable to produce energy and will give benefit to the rural areas island to have electricity rather than using generator as to power up their homes thus reduce the amount of CO_2 to the atmosphere.

Living being will prosper from wave energy because it is globally available in sufficient quantity to power all human energy consumption and needs in the foreseeable future. The project can reduce environmental impact beginning with the first commercial production model and grow toward a global shift in human energy use. This research balances many elements between people, prosperity and the planet. Our will and intention are not to use any more of the additional land resources and to provide an emissions free energy source.

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