Research on Working Performance of an Oscillating Floater Buoy based on Sea Condition of The South China Sea

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***Abstract*—The working performance of an oscillating floater buoy under different mooring modes is studied based on the theory of ariy wave theory and potential flow theory. The heave motion response, hydrodynamic performance and power capture efficiency under different design schemes are calculated and compared. The results show that the mooring system can be ignored when design an oscillating floater buoy since it has little effect on the power capture efficiency of the device. The results also show that the buoy has less contribution to the power capture efficiency of the device, but the property of mass of floater has a great influence on the device's heave motion response, hydrodynamic performance and power capture efficiency. It provides some ideas for design of the same type of oscillating floater buoy.**

Keywords—Wave power generation, Oscillating floater buoy, Hydrodynamic power capture efficiency.

I. Introduction

The oscillating floater buoy wave energy converter is regarded as the third-generation wave energy converter. Compared with the oscillating water column technique and the overtopping wave energy converter, the oscillating float buoy wave energy converter enjoys the following advantages: .

(1)The converter contacts seawater directly, reducing the conversion series of wave energy and significantly lowering the energy losses during wave energy conversion.

(2)Since the converter is relatively small and only generates electricity based on the heave motion response, the multi-body wave energy converter can be adopted and arranged to increase the generating capacity of the system according to the actual engineering requirements and sea conditions.

(3)The principle and internal structure of the converter is comparatively simple, which makes it cheaper to manufacture and easier to maintain and repair.

The studies of wave energy converters took off earlier abroad, mainly concentrated in Japan, America and European countries [1-15]. The wave energy converters (WEC) studied in those countries are mainly one-degree-of-freedom WECs, multi-degree-of-freedom WECs, array-based multi-body WECs, etc. For one-degree-of-freedom WECs, there are two kinds: the heaving buoy WEC [1-6]and the oscillating flap WEC [7-13]. Due to their relatively simple principles of electricity generation, structural design and low manufacturing and maintenance costs, they are the most widely applied wave energy converters at present. Whereas the multi-degree-of-freedom WEC is a power generation scheme that utilizes other degrees of freedom to assist a certain degree of freedom to increase the power generation efficiency [14]. Based on the design principle of low volume and high intensity, the array-based multi-body WEC uses the energy converter of a certain degree of freedom as a generation unit, aiming to improve the generating capacity of the system through optimal placement of generation units. Typical examples include the FO3 from Norway, the WaveStar from Denmark, etc. [15]

Universities and institutions in China that have conducted extensive research on oscillating floater buoy WECs include the Ocean University of China, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Shangdong University, etc. In addition, Tsinghua University, Shanghai Jiao Tong University and Tianjin University have also initiated research in this field. So far, the 50KW Oscillating Floater Buoy WEC developed by Guangzhou Institute of Energy Conversation has been put into use in Shanwei, Guangdong. Another representative near-shore floating wave energy converter is funded and constructed in Qingdao, Shandong by the National Ocean Technology Center [18].

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In terms of domestic theoretical research, Zhe Ma and Hongda Shi et al. from the Ocean University of China reached the conclusion that the optimal shape for a buoy is a cylinder by using the parameters of a buoy's shape as variables and the Potential Flow theory. Based on CFD simulation, Yujian Sun and Daxiao Gao et al. [20] from the Ocean University of China found out that among the buoys with the same mass and the same drainage volume, cylindrical buoys have the highest wave energy absorption efficiency. Jianjun Peng and Jianhua Zhang et al. from Shandong University derived the motion response function and capture power of the energy conversion system based on the coupled buoy and pontoon model. They also investigated the effects of the buoy's mass, the floater's mass, the buoy draught line and the external damping coefficient on the energy capture width by using frequency domain analysis. On the basis of the linear theory and frequency domain analysis, Zhengshun Cheng and Jianmin Yang, et al. [22] from Shanghai Jiao Tong University elaborated on the influence of the energy output system, the shape of the floater and the frequency response function on the energy capture width of damping coefficient only considering the heave motion of the buoy.

This paper investigates the motion response, hydrodynamic performance and the wave energy capture efficiency of an oscillating floater buoy wave energy converter (PDJH17-A0234, hereinafter referred to as "the converter") operated in the South China Sea. The motion response model is simplified by solely taking the heave motion response into consideration and thus the heave response equation is confirmed. Furthermore, hypotheses are put forward according to the actual sea conditions in the South China Sea. The Airy wave theory and the Potential Flow theory are employed to calculate the motion response equation and the hydrodynamic coefficient under various schemes so as to find out the energy converter with the optimal wave energy capture efficiency.

II. GOVERNING EQUATION AND ITS SOLUTION THEORY

A. Fundamental Assumptions of the Research.

Based on the actual sea conditions in the working area of the converter (based on the annual average statistics of the South China Sea in Zhanjiang), the following hypotheses are proposed.

(1)In motion analysis, only the heave motion of the converter is taken into consideration. The principle of power generation of the oscillating floater buoy WEC drives the dynamo by taking advantage of the heave motion of the buoy. Therefore, this paper only focuses on the heave motion of the buoy.

(2)The viscous force on the buoy is ignored in this paper and the Potential Flow theory is applied to study the motion response of the converter. The research carried out by Lopes and Hals et al. [23,24] show that the effect of viscous forces on buoys is insignificant compared with that of wave energy, which means it exerts little influence on the generating capacity of the converter.

(3)Since the waves in the working sea area can be treated as small amplitude waves, the Airy wave theory is adopted. The annual average wave height in the South China Sea in Zhanjiang where the converter is operated is 0.6 to 1.0 meters, and the water depth in that area is 40 to 100 meters. The ratio of the wave h`he water depth is $H/d \ll 1$, which satisfies the conditions for using the Airy wave theory.

(4)Assuming that the energy output system is linear, which means the mass force, damping force and elastic force of the system are directly proportional to the acceleration, velocity and displacement of the linear converter, the force acting on the buoy can be calculated using a damping coefficient (or damping plates). This hypothesis obtains desirable calculation results at the initial or middle stage of the design.

B. The Motion Response of PDJH17-A0234

Under the influence of linear waves, the motion response of the six-degree-of-freedom converter can be written as

$$\left([M]+\left[M^*\right]\right)\ddot{y}_i+\left([C]+\left[C^*\right]\right)\dot{y}_i+\left([K]+[B]\right)y_i=[F_i] \tag{1}$$

Here, $[M]$ is the mass matric of the converter; $\left[M^*\right]$ is the supplemental mass matrix of the converter; $[C]$ represents the damping matrix of the converter; $\left[C^*\right]$ represents the supplemental damping matrix of the converter; $[K]$ is the stiffness matrix of the converter; $[B]$ is the hydrostatic restoring stiffness matrix of the converter; $[F]$ is the wave excitation force or moment matrix acting on the converter ;

The stiffness matrix of the converter system $[K]$ can be expressed as

$$
[K]=\begin{bmatrix} m & 0 & 0 & 0 & mz_c & -my_c \\ 0 & m & 0 & -mz_c & 0 & mx_c \\ 0 & 0 & m & my_c & -mx_c & 0 \\ 0 & -mz_c & my_c & I_{yy}^b+I_{zz}^b & -I_{yx}^b & -I_{zx}^b \\ mz_c & 0 & -mx_c & -I_{xy}^b & I_{xx}^b+I_{zz}^b & -I_{zy}^b \\ -my_c & mx_c & 0 & -I_{xz}^b & -I_{yz}^b & I_{yy}^b+I_{xx}^b \end{bmatrix}
$$

The hydrostatic restoring stiffness matrix of the converter $[B]$ can be expressed as

$$
[B]=\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho g A_w & \rho g I_y^A & -\rho g I_x^A & 0 \\ 0 & 0 & \rho g I_y^A & \begin{bmatrix} \rho g\left(I_{yy}^A+I_z^V\right) \\ -mgz_c \end{bmatrix} & -\rho g I_{xy}^A & \begin{bmatrix} -\rho g I_1^V \\ -mgx_c \end{bmatrix} \\ 0 & 0 & -\rho g I_x^A & -\rho g I_{yx}^A & \begin{bmatrix} \rho g\left(I_{xx}^A+I_z^V\right) \\ -mgz_c \end{bmatrix} & \begin{bmatrix} -\rho g I_y^V \\ -mgy_c \end{bmatrix} \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}
$$

where m is the mass of the converter, A_w is the waterline area of the converter, I^b is the moment of inertia of the converter on each coordinate axis, x_c 、 y_c 、 z_c are the center-of-mass coordinates. The specific values of the two matrices are only related to the structural design of the converter and can be solved by using software.

According to the Assumption(1)， if we only consider the heave response of the converter, Eq.(1)can be simplified as:

$$
(M+m_{zz})\ddot{y}_z+(C+c_{zz})\dot{y}_z+([K]+[B])y_z=[F_z] \tag{2}
$$

where m_{zz} is the heave-added mass of the converter and c_{zz} is the heave added damping coefficient of the converter， which are considered collectively as the hydrodynamic force coefficient of the converter.

C. The Potential Flow Theory

According to the Potential Flow theory, when the fluid is inviscid and incompressible, the velocity of the fluid fits the Three-Dimensional Laplace Equation which can be described as

$$
\nabla^2\Phi(x,y,z,t)=0 \tag{3}
$$

The bernoullie equation in the Lagrange coordinate system can be written as

$$
\frac{p}{\rho}=-\left(gz+\frac{\partial\phi}{\partial t}+\frac{1}{2}\left|\nabla\Phi\right|^2\right)+c(t) \tag{4}
$$

The boundary conditions of the Laplace Equation are:

$$
\begin{aligned} &\frac{\partial\Phi}{\partial n}=0 && z=n \\ &\frac{\partial\Phi}{\partial z}=0 && z=\text{-}d \\ &\frac{\partial^2\Phi}{\partial t}+g\frac{\partial\Phi}{\partial z}=0 && z=0 \end{aligned} \tag{5}
$$

where $z = n$ is the surface condition of the converter; $z = -d$ is the seabed boundary condition; $z = 0$ is the free-surface condition.

For converters moving in a wave field, the effect of waves on the converter can be broken down into two aspects: the diffraction problem and the radiation problem. The diffraction problem assumes the converter is stationary. After the waves act on the converter, a stable scattering wave field is formed on the converter, which further forms a new stable wave field after superposition with the original incident wave field. As to the radiation problem, after the converter is subject to wave forces, the converter makes a small amplitude vibration in a certain mode and radiates outward a new stable wave field. Accordingly, the velocity potential of the fluid can be expressed as

$$\Phi(x,y,z,t) = \Phi^I(x,y,z,t) + \Phi^D(x,y,z,t) + \Phi^R(x,y,z,t) \tag{6}$$

where $\Phi^I(x,y,z,t)$ is the incident wave potential; $\Phi^D(x,y,z,t)$ is the diffraction potential; $\Phi^R(x,y,z,t)$ is the radiation potential.

Therefore, the hydrodynamic solution of the converter can be converted to the boundary value problem of Eq.(3)and Eq.(6).

D. The Wave Load of PDJH17-A0234

Based on what is discussed in Section 2.2, the external force exerted on the converter when it moves can be broken down into: the Froude-Krylov force caused by the incident potential and the diffraction force caused by the diffraction potential, which are collectively called excitation forces. These are the most important sources for energy absorption of the converter. The radiometric force caused by the radiation potential is measured by the supplemental mass and the supplemental radiation damping. Besides, the converter is also subject to the hydrostatic restoring force. In this paper, the details of the three waver loads aren't discussed in detail. Please refer to the paper[21] listed in the references.

The above mentioned three wave loads only take the low-order wave force into consideration. The high -order wave force will exert a certain influence on the converter in some working sea conditions, such as the slow drift motion of the coastal plane. Although the magnitude of the high-order wave force is smaller than that of the low-order wave force, it still influences the working performance of the converter in certain ways. In this paper, all the wave loads other than the first order wave energy will be classified into the high-order wave force, which are collectively referred to as the high-order drift force.

E. The Wave Energy Capture Efficiency of PDJH17-A0234

The oscillating floater buoy wave energy converter needs to go through three stages during the energy conversion process, which are the conversion from wave energy to mechanical energy (the first stage conversation), the conversion from mechanical energy to hydraulic energy (the second stage conversion) and the conversion from hydraulic energy to electrical energy (the third stage conversion). Among them, the efficiency of the first stage conversion is the most important factor in the whole design process. Within a wavelength range, the wave absorption efficiency of the converter with a width of D can be written as

$$\eta = \frac{E_O}{E_I} = \frac{4(m+m_{zz})v_z^{\,2} + \rho g A_{wp} z^2}{8D\int_0^L \int_0^{\eta(x,t)} \rho gzdxdz} \tag{7}$$

where E_O represents the effective item for the actual use after the converter absorbs the wave energy, E_I represents the total energy of waves within a wavelength range; $(m+m_{zz})v_z^{\,2}$ is the kinetic energy control items for the converter; $\rho g A_{wp} z^2$ is the potential energy control items for the converter; $\int_0^L \int_0^{\eta(x,t)} \rho gzdxdz$ is the control items of the total wave energy absorbed by the converter. The solution of $\int_0^L \int_0^{\eta(x,t)} \rho gzdxdz$ can be obtained by the Airy wave theory. According to the Airy wave theory, the surface waveform function can be expressed as

$$\eta(x,t) = \frac{H}{2}\cos(kx - wt) \tag{8}$$

where $k=\dfrac{2\pi}{L}$ is the wave number, $w=\dfrac{2\pi}{T}$ is the wave circular frequency;

The total wave energy absorbed by the converter with a width of D within a wavelength range can be derived by integrating $\int_0^L \int_0^{\eta(x,t)} \rho gzdxdz$, which can be written as

$$E_I = \frac{1}{8}\rho gLH^2 D \tag{9}$$

The first stage conversion efficiency of the converter η can be obtained by substituting the formulas into Eq. (7)

III. The Operating Mode Setting of PDJH17-A0234

A. Geometric Model and Grid Model

In this paper, the calculation is completed by using AQWA, the Marine Engineering hydrodynamics software. When using the boundary element method to calculate the motion response and the hydrodynamic performance of marine floating structures, we only need to consider the part of the structure that directly contacts the waves, which means the surface part and other minor structures can be ignored. Therefore, the paper only considers the wet surface of the converter and other parts such as the pipes and the steel frames on the buoys are neglected. Only the weight of those parts is considered during calculation. The model of the wet surface is shown in Figure 1. In Fig. 1, the left part is the model of the floater's wet surface which is blow the sea level during operation. In Fig. 1, the right part is the model of the buoy's wet surface. At the lower end of the connecting rod, the damping force of the simulated hydraulic pressure system of the damping plates is used. While working, the lower end of the buoy is below the sea level whereas the upper end of it is above the sea level. The buoy can achieve the heave motion by absorbing the weave energy at sea level. In Table I, different design schemes of buoys are shown. Changes in the buoy's mass are realized by adjusting the ballast in its interior. The buoy can adjust its weight according to different wave environments to ensure the normal operation.

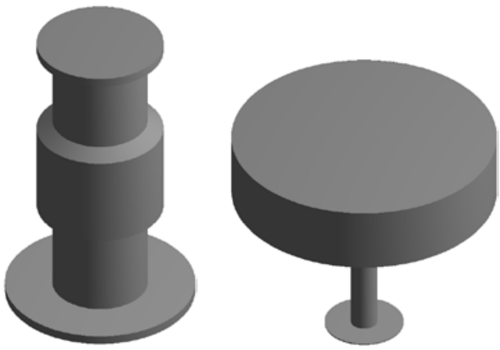

Fig. 1 Models of the Floater's and the Buoy's Wet Surface

TABLE I Design Schemes of Buoys

Scheme	The Mass of the Buoy(kg)	Height of C.G. (m)	Moment of Inertia Ixx (kg·m^2)	Moment of Inertia Iyy (kg·m^2)	Moment of Inertia Izz (kg·m^2)
LC1	16648	0.298	54610	73815	77736
LC2	19145	0.223	59415	59416	85590
LC3	21643	0.145	64218	64218	93445
LC4	24140	0.065	69017	69017	101300
LC5	26638	-0.015	73815	54610	109150

The mooring scheme employed in this paper is the suspended chain mooring, of which the anchor chain is the second-class studless chain manufactured by the Asian Star Anchor Chain Co., Ltd. Jaingsu (AsAc) with a dry weight of 27.378kg/m, tensile load of 299.90KN and fracture load of 599.80KN. In the coordinate system used in this paper, the XY plane represents the horizontal plane and the Z axis is perpendicular to the XY plane in an upward way. The parameters of the working sea conditions are selected according to the paper [25] listed in the references. The annual average wave height of the South China Sea is 0.8 meters in Zhanjiang with an average cycle of 4.2 seconds. The wavelength is calculated iteratively based on the dispersion relation. The layouts of the mooring systems are shown in Fig. 2 and Fig. 3.

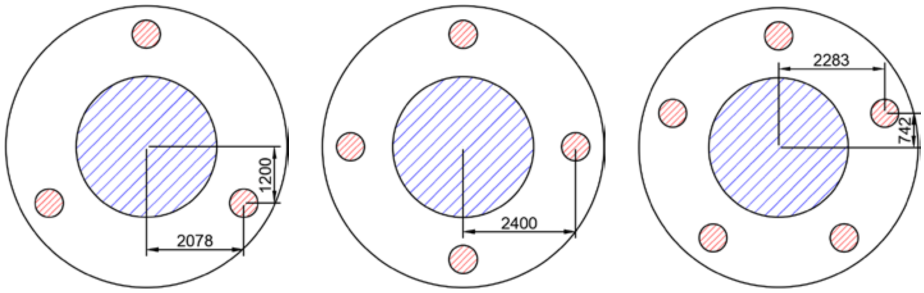

Fig. 2 The Sizing of the Mooring Point

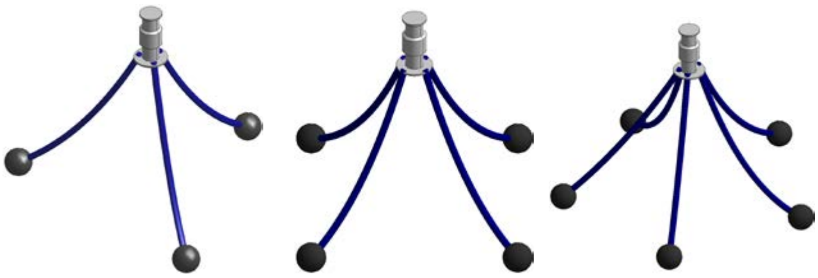

Fig 3 Three Mooring Schemes for PDJH17-A0234

IV. The Frequency Domain Analysis of PDJH17-A0234

A. The Wave Load Spectrum of the Buoy

The wave excitation force is the most important power source when the oscillating floater buoy converter is in heave motion. When the converter is in operation, the position of the floater is relatively fixed whereas the buoy is in heave motion under the influence of waves. The motion of other degrees of freedom is constrained by the mooring system. During that time, the motion frequency of the whole system is basically coupled with the wave frequency while the influence of wave loads of other kinds on the heave motion is insignificant. The frequency spectrum of the wave excitation force and the spectrum of the high order drift force are shown respectively in Fig. 4 and Fig. 5.

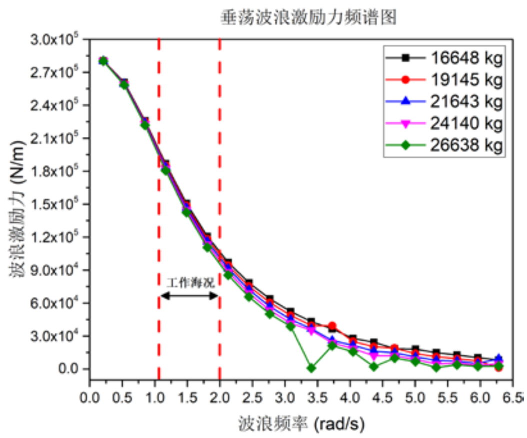

Fig 4 Spectrum of Heave Wave Excitation Force

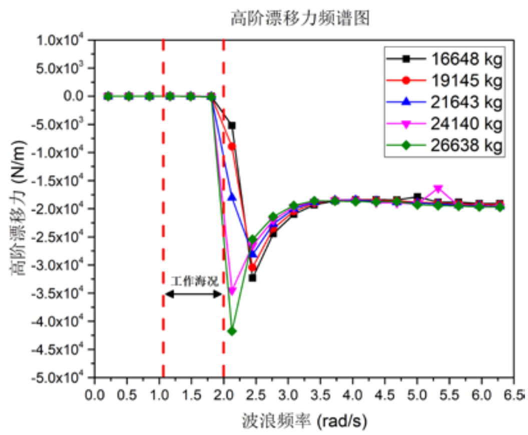

Fig 5 Spectrum of High Order Drift Force

From the wave excitation spectrum, it can be seen that the wave excitation force decreases with the increase of the wave frequency and the change of the wave excitation force in the frequency range of 0~3rad/s is very radical. In the frequency range of 0~1rad/s, although the converter can obtain the highest wave excitation force, the possibility of such wave condition is extremely low according to the statistics of the wave conditions in the South China Sea in Zhejiang. The frequency range of 1~2rad/s is the main working range of the converter. It can be seen from the Fig. 4 that within the frequency range, the order of magnitude of the wave excitation force can be kept at 105, which is the guarantee of normal working performance of the converter. Whereas when the frequency range is greater than 2rad/s, the wave excitation force of the converter drops sharply and the heave motion of the converter will be impacted, which greatly reduces its working performance. Therefore, we should try to avoid operating the converter in this frequency range.

From the high order drift force spectrum, it can be seen that the high order drift force of the converter is minimal. Even for high order drift forces of high frequency range, its order of magnitude is 104, which is negligible compared with the wave excitation force and exerts little influence on the heave motion response. Generally speaking, the converter demonstrates decent working performance within the common frequency ranges in the South China Sea.

B. Spectrum of the Buoy's Hydrodynamic Coefficient

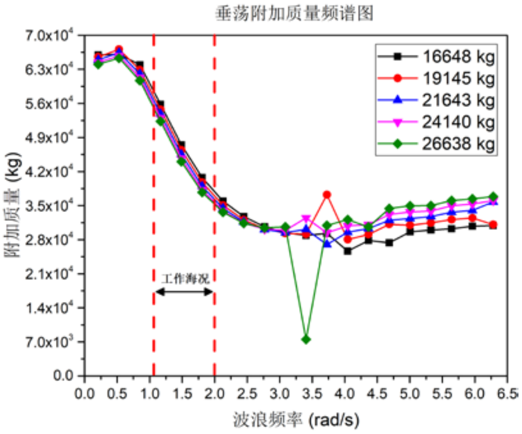

Fig 6 Spectrum of Heave-Added Mass

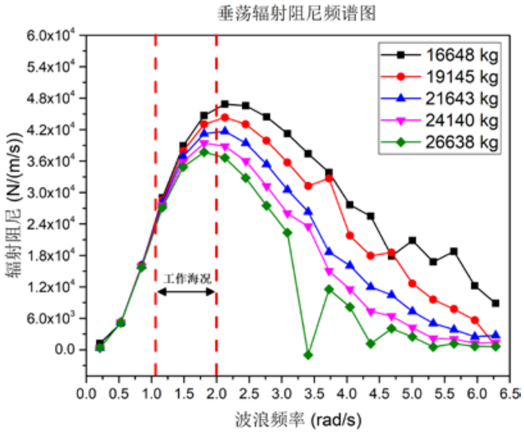

Fig 7 Spectrum of Heave Radiation Damping

The spectrum of the supplemental mass demonstrates that the supplemental mass plummets in the low frequency range at the beginning and rises in the high frequency range. In addition, the amplitude frequency range of radiation damping deviates from the sea conditions where the converter is operated. The supplemental radiation damping is mainly related to the heave velocity of the buoy. The wave energy absorbed by the buoy can be divided to the kinetic energy and the potential energy. According to the discussion in Section 2, The kinetic energy of the buoy is related to its the supplemental mass and the heave velocity. When the heave velocity is the same, the higher the supplemental mass of the buoy, the greater the kinetic energy absorbed by it. Generally speaking, the supplemental mass of the buoy in the working sea conditions can be maintained within a reasonable range compared with other frequency ranges.

C. The Spectrum of Heave RAO

The spectrum of the heave motion response is an important criterion for measuring the working performance of the converter. The spectrum of the converter's heave RAO is shown in Figure 8.

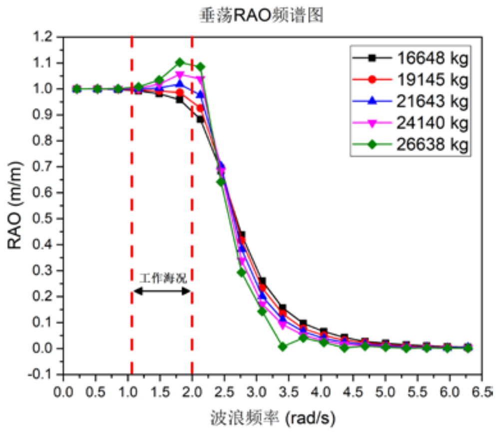

Fig 8 Spectrum of Heave RAO

From Figure 8, it can be concluded that the heave motion response of the converter is mainly concentrated in the low frequency range. When the frequency is greater than 2.2rad/s, the heave motion response decreases drastically. If the converter works in a frequency range greater than 2.2rad/s, the wave motion capture efficiency will be significantly reduced. In general, the highest heave motion response frequency of the converter occurs in the working sea conditions and also in the normal operating environment, the highest heave motion performance can be realized, which prove that the design of the buoy is relatively reasonable.

V. Time Domain Analysis of PDJH17-A0234

A. The Influence of Mooring System on the Working Performance of the Converter

Since the workflow of the oscillating floater buoy WEC is completed via the relative heave motion of the buoy and the floater, the motion amplitude of the buoy and the floater and their relative motion at the same instant are the key criteria for measuring the working performance of the converter. In this paper, a dimensionless coefficient is defined to establish a standard for comparing the masses of different buoys and the heave performance of the converter in different mooring schemes. The coefficient can be expressed as

$$C_{\text{heave}} = \frac{1}{T}\int_0^T \frac{H_i\text{-}H_0}{h}\, dt$$

where T is the sampling time; h is the height of the buoy's main cylinder; H_i is the instantaneous height of C.G. at different sampling points; H_0 is the initial height of the gravity, which is defined as the coefficient of heave amplitude. The integral of the formula is completed by the SciPy Library of Python.

The calculation results of the buoy's and the floater's heave amplitude coefficients in different schemes are shown in Figure 9.

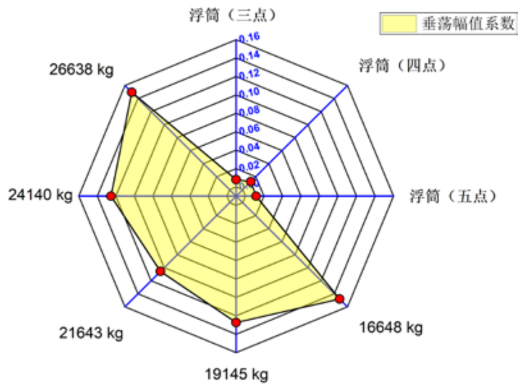

Fig 9 Contrast Diagram of Heave Amplitude Coefficients

It is shown in Figure 9 that in the working sea conditions, the heave amplitude coefficient of the buoy is minimal (mainly less than 0.01) in all of the mooring schemes, which proves that the influence of the suspended chain mooring system on the converter's working performance is insignificant. The conclusion is also supported by the research conducted by Muliawan[26] and Vicente[27] et al. Furthermore, we can see from Figure 9 that most of the heave motion of the converter is completed through the buoy. The driving force of the hydraulic system mainly comes from the heave motion. When the buoy absorbs the wave energy, the wave energy will be converted into the mechanical energy for the hydraulic system, which is then converted to electrical energy. This conclusion also illustrates how the oscillating floater buoy wave energy converter generates electricity.

B. The Wave Energy Capture Efficiency of PDJH17-A0234

The energy captured by the buoy from waves is mainly manifested as the potential energy and kinetic energy of the buoy. The wave energy capture efficiency of the buoy can be measured by the heave displacement amplitude and the heave speed amplitude. In order to avoid the error of the primary iteration, the paper uses the time domain data calculated in a stable condition. The time domain of the sample is 1800s~3600 and the sampling frequency is 2Hz. The responses of heave displacement and heave speed of buoys with different masses are shown from Fig. 10 to Fig. 14.

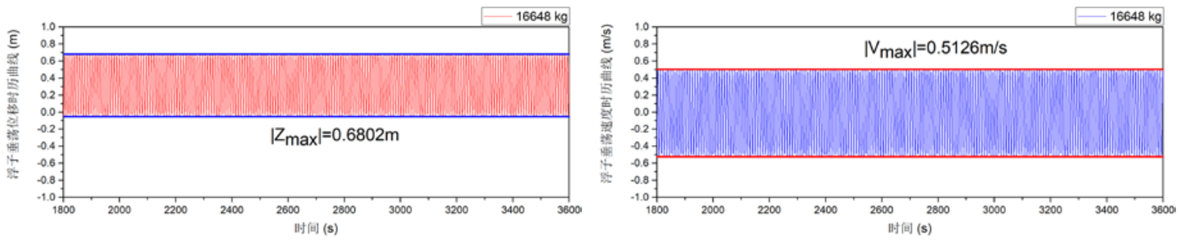

Fig 10 Response of Heave Displacement and Heave Speed of 16648kg Buoy

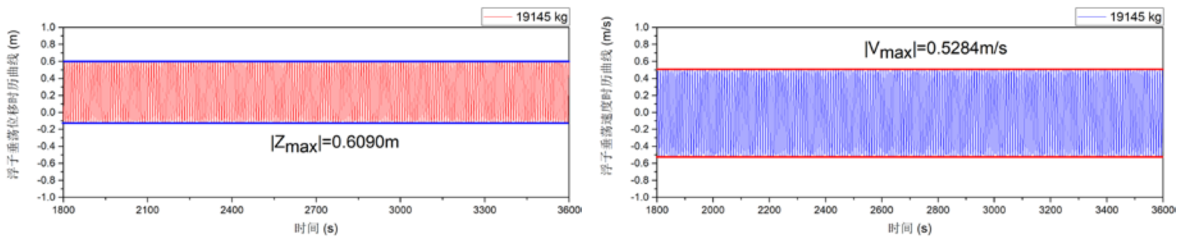

Fig 11 Response of Heave Displacement and Heave Speed of 19145kg Buoy

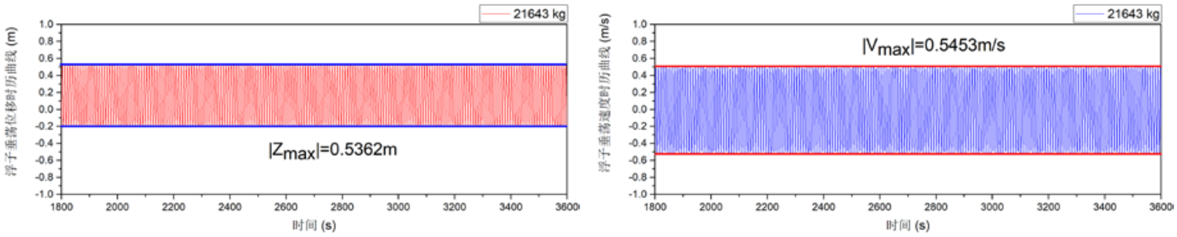

Fig 12 Response of Heave Displacement and Heave Speed of 21643kg Buoy

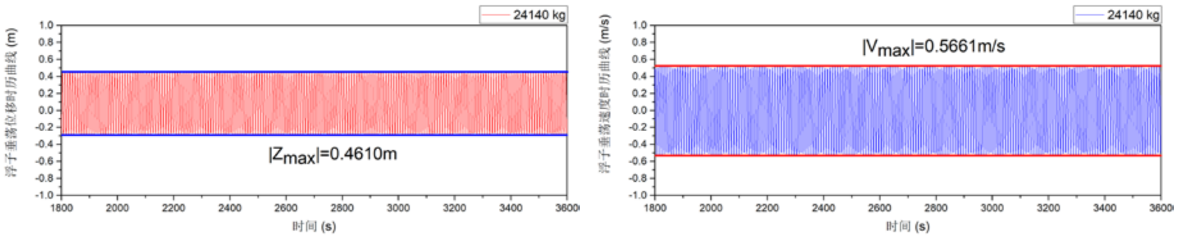

Fig 13 Response of Heave Displacement and Heave Speed of 24140kg Buoy

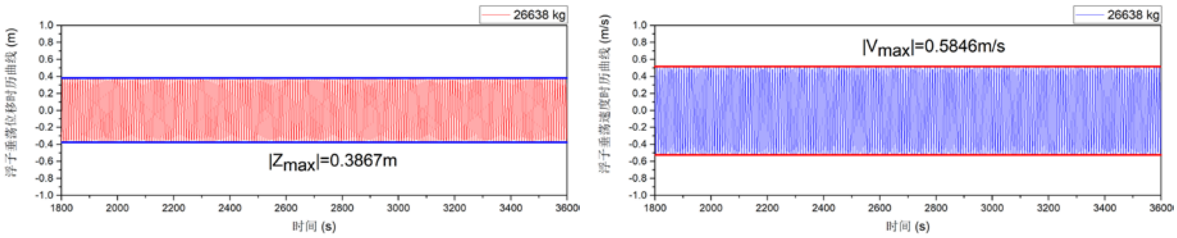

Fig 14 Response of Heave Displacement and Heave Speed of 26638kg Buoy

It is shown in Fig. 10 to Fig. 14 that when the mass of the buoy increases, the maximum heave displacement gradually decreases whereas the maximum heave speed gradually increases. That means the greater the mass of the buoy, the less the part of the energy that it converts from absorbed wave energy to its own potential energy and the greater the part of the energy it converts to its own kinetic energy. Based on the discussion in Section 2.4, the wave energy capture efficiency of the converter in a certain period of time is shown in Figure 15.

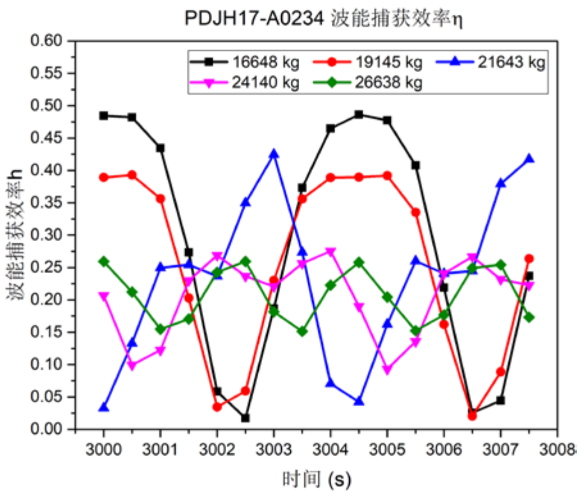

Fig 15 Wave Energy Capture Efficiency of PDJH17-A0234

Generally speaking, when the mass of the buoy increases, the wave energy capture efficiency gradually decreases. But in actual operation, buoys with minimum mass standards can't be adopted because the working frequency of most oscillating floater buoy WECs is close to the resonance frequency of the system itself. Normally, ribs are added to the inside of the buoy or the steel plates are used to divide the buoy into different cabins to ensure its structural strengths and meet the ballast requirements of the working sea area. Therefore, buoys of the most desirable masses may not be realized. In practical engineering applications, we should select the scheme which can both guarantee the working performance and structural strength.

VI. CONCLUSION

Based on the sea conditions of the South China Sea in Zhanjiang, this paper calculates the motion response, hydrodynamic performance and wave energy capture efficiency of PDJH17-A0234, an oscillating floater buoy wave energy converter. The following conclusions are drawn:

(1)The influence of the suspended chain mooring system on the wave energy capture efficiency of PDJH17-A0234 is insignificant, which means that n practical engineering applications, the effect of mooring system on wave energy capture efficiency can be ignored.

(2)The high-order wave force of the buoy has little influence on the heave motion response of PDJH17-A0234, while the low order wave force (linear term) has great influence on the converter. Basically, the linear wave theory can satisfy the requirements for the engineering calculation of the converter at the initial and middle stage of the design.

(3)As the floater is below the sea level and the wave energy attenuates exponentially in depth, the working performance of PDJH17-A0234 is entirely dependent on the buoy. Because the buoy absorbs most of the wave energy, focus should be placed on the buoy in the structural design.

(4)The wave energy conversion efficiency of PDJH17-A0234 is decided by the mass and the hydrodynamic performance of the buoy. On the whole, under the same sea conditions, the buoy with lower mass has better working performance. In practical engineering applications, the mass of the buoy should be determined based on the actual situation of the working sea area.

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