Hydrodynamic analysis of photovoltaic power generation aquaculture platform under wave action

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Abstract. The problem of energy shortage has always existed in deep-sea large-scale aquaculture platforms. A new type of wind-wave resistant photovoltaic aquaculture platform was proposed and its stability under different wave conditions was analyzed. By simplifying the structure of the platform, using the software ANSYSYS/Workbench/AQWA, the finite element model of the platform is established, and thirteen different wave heights are designed, the numerical simulation is carried out from four aspects: the force on the anchor rope, the heave motion, the pitching motion and the pitching motion. The simulation results show that the aquaculture platform has more reliable anti-wind and wave performance.

1. Introduction
The ocean has vast space and abundant resources. It is a "sea granary" for human to obtain high-quality protein source, an important guarantee for human food security, and a strategic place for the new round of global competition and development.¹⁻³ It is necessary for the sustainable development of mariculture in China to open up new space for mariculture and to develop deep-sea mariculture. How to realize the energy self-sufficiency of deep-sea aquaculture equipment is the most important problem in the development of deep-sea aquaculture.⁴⁻⁶ This paper presents a design of large-scale offshore aquaculture platform based on photovoltaic power generation and wave-resistant structure of small water surface line, which can solve the problem of energy self-supply for deep-sea large-scale aquaculture equipment.

2. Numerical Simulation Settings
The numerical simulation model of the aquaculture platform is established with CATIA as shown in Fig 1. The model is processed with the lever module of Ansys/Workbench/AQWA (Fig 1), and four moorings are added.⁷ The length of the anchor rope is 136m. In the simulation, 13 kinds of regular waves were used to test the anti-wind and wave performance of the platform.⁸⁻⁹
### Table 1 Cage model parameters

| Project name   | Parameter   |
|---------------|-------------|
| Length (m)    | 200         |
| Width (m)     | 50          |
| Height (m)    | 10          |
| Weight (t)    | 639         |
| Draft (m)     | 7           |
| HDPE pipe diameter (mm) | 800       |

### Table 2 List of relevant test program.

| Numbering | Wave height | Period |
|-----------|-------------|--------|
| 1         | 2.4m        | 10.95s |
| 2         | 4.8m        | 10.95s |
| 3         | 7.2m        | 8.87s  |
| 4         | 7.2m        | 10.95s |
| 5         | 7.2m        | 13.15s |
| 6         | 7.2m        | 15.34s |
| 7         | 7.2m        | 17.53s |
| 8         | 9.6m        | 10.95s |
| 9         | 11m         | 10.95s |
| 10        | 11m         | 13.15s |
| 11        | 11m         | 15.34s |
| 12        | 11m         | 17.53s |
| 13        | 11m         | 19.72s |

### 3. Result and discussion

The data of simulated wave heights of 7.2 m and 11 m are analyzed and plotted as Fig. 2(a). In the culture state, there is no obvious correlation between the force on the anchor rope at the side of the aquaculture platform facing the wave and the wave period. The peak values of anchor rope force at the two wave heights are obtained at T=17.53s and T=19.72s, respectively, which are 13469kN and 22765kN. Fig. 2(b) is the influence curve of wave height on the anchor rope forces at the head-wave side. The results show that the anchor rope force is positively correlated with the wave height, and increases with the wave height. The maximum anchor rope force is 10225 kN at H = 11 m.
In this experiment, the forces of the anchor rope on the back wave side of the aquaculture platform were also measured. Although the forces acting on the side anchor ropes are generally less than those on the side facing the waves, it is of great significance to investigate and understand the characteristics of the forces acting on the side anchor ropes. The relevant data of the forces acting on the side anchor rope of the back wave are arranged and plotted in Fig. 3. The results show that the force of the anchor rope on the back side of the aquaculture platform is similar to that on the head side, and the variation of the force of the anchor rope has no obvious relation with the period. The maximum force of the anchor rope is obtained when the wave height is $T = 17.53\ s$ and $T = 19.72\ s$, and the force is 6439 kN and 16721 kN respectively, similar to the wave-facing side, the anchor force on the back-wave side is positively related to the wave height and increases with the increase of the wave height. From the wave heights of 7.2 m and 11 m, the peak values of the anchor rope forces at the back side of the waves are 52.19% and 26.54% lower than those at the head side, the force of anchor rope in each period on the back wave side decreased by 34.19%~62.18% compared with that on the head wave side, and the attenuation range was 17.11%~75.92% when $H = 11\ m$. It can be seen that the larger the wave height, the greater the attenuation. The reason for this phenomenon is that, on the one hand, the wave height after the aquaculture platform attenuates in the course of wave propagation, and on the other hand, the moving trend of the aquaculture platform in the culture state is in the direction of the clockwise wave, as a result, the anchor line on the upstream side is relatively taut than that on the back side.

In the application of deep-sea aquaculture, in addition to monitoring the change of anchor rope force, it is also necessary to analyze the characteristics of the movement of the aquaculture facility in different sea conditions. The results of this study are of great value to the human activities and the behavior and living environment of fish on the platform. Aquaculture platform is a steel structure, and offshore cage is different, only need to do the whole analysis of the platform movement characteristics.

The heave motion of a platform refers to the amplitude of the motion of the platform in the direction of vertical wave motion under the action of waves in the ocean. After data analysis and collation through MATLAB drawing as shown in Fig 4, data are selected before and after the two observation points of the aquaculture platform in the maximum value.
The experimental wave heights of 7.2 m and 11 m were also used to analyze the effect of the period on the rising and sinking of the platform. From Fig. 4(a), it can be seen that the rise and sink values of the aquaculture platform both show a first decrease and then an increase with the increase of the cycle. When $H = 7.2$ m, the maximum rise and sink value of the aquaculture platform is 1.9187 m when $T = 8.87$ s, when $T = 15.34$ s, the minimum heave value is 0.3999 m; when $H = 11$ m, the maximum heave value is 4.09969 m at $t = 19.72$ s; and when $T = 15.34$ s, the minimum heave value is 0.68327 m. Fig. 4(b) is the curve of the effect of wave height on the heave value. The maximum value of heave is 2.1568 m at $H = 11$ m.

The longitudinal motion of deep-sea aquaculture platform is the motion amplitude along the direction of wave motion under the action of wave in ocean. The experimental data are analyzed and plotted as follows. The maximum values of the two observation points before and after the platform are selected.

![Fig 4. Heave movement of breeding platform](image)

![Fig 5. Swing movement of the breeding platform](image)
The experimental data of $H = 7.2$ m and $H = 11$ m are selected to study the effect of the period on the oscillation value. It is found in Fig. 5(a) that the oscillation value increases with the increase of the period. The maximum oscillation value obtained at $H = 7.2$ m is $0.05131$ m at $T = 17.53$ s, and the maximum oscillation value obtained at $H = 11$ m is $0.19526$ m. It is found from Fig. 5(b) that the longitudinal oscillation is positively correlated with the wave height and increases with the wave height. The maximum longitudinal oscillation is $0.02017$ m when $H = 11$ m.

In this simulation, the problem of the tilting angle of the platform under the action of wave is studied. The maximum clockwise and anticlockwise tilting angle of the platform under the action of wave is called the pitch of the platform. If the pitching value is too large, it will have a bad impact on the aquaculture platform and will be detrimental to the human activities on the platform and the smooth operation of the aquaculture platform. This experiment has grasped the pitch value law of the platform, so it can avoid or reduce the disaster in time.

Fig. 6(a) is the influence curve of the period change on the pitching value of the aquaculture platform when the wave height is $7.2$ m and $11$ m. As can be seen from figure, the pitching values of the aquaculture platform increased with the increase of the cycle, whether the wave height was $7.2$ cm or $11$ m. When $H = 7.2$ m, the minimum of pitching value is $0.0912$ ° when $T = 8.87$ s, the maximum of pitching value is $2.6031$ ° when $T = 17.53$ s, the minimum of pitching value is $0.0827$ ° when $H = 11$ m, the maximum of pitching value is $5.5746$ ° when $T = 19.72$ s. It is concluded that there is no obvious rule of pitch and period in the aquaculture platform, and the maximum value at $T = 1.2$ s should be related to the response transfer function of pitch motion in the aquaculture platform. Combined with the data, it was found that the pitching value of the aquaculture platform first increased and then decreased with the increase of wave height, and the maximum pitching value was $0.3605$ ° at $H = 4.8$ m.

4. Conclusion

1. The floating structure of the small water surface line of the aquaculture platform has excellent resistance to wind and waves, and its maximum pitching value is $5.57$ ° under the wave height of $11$ m.

2. The anchoring rope force on the front wave side of the aquaculture platform is $36\%$ larger than the anchor rope force on the back wave side. In the process of laying the aquaculture platform, a higher strength mooring rope should be selected.
(3) The maximum heave movement of the aquaculture platform reached 2.16 m. Attention should be paid to the draught depth in the course of laying the aquaculture platform to avoid the platform deck being immersed in water.

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