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Experimental Research on Motion Response and Mooring Characteristics of Floating Platform near a Reef Island

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Abstract

In this paper, a floating platform with a tensioned mooring system near to reefs and islands in shallow water is investigated. For the reason that the simulation of motion response of the floating platform, mooring tensions and some other characteristics under real conditions seabed topography of the marine environment has essential significance for design, construction and safe operations of the floating platform. In order to investigate the motion response and mooring characteristics of the nearshore floating platform, model tests are carried out in a wave tank with real three-dimensional topography of the seabed. The damping levels and natural period in three degrees of freedom of the platform in a free state are measured by hydrostatic attenuation test; the damping levels and natural period in six degrees of freedom of the platform with mooring system are measured in the same way. The natural vibration frequency of the platform is measured by hammering test. RAOs under different wave angles of the platform in a free state are given by model tests in regular waves. Motion response, vertical accelerations and mooring cable tension of the platform with tensioned mooring system under a series of regular waves and irregular waves conditions are recorded. The effects from seabed topography, wave frequency and amplitude on motion of platform and tension distribution of the mooring system are analyzed. The experimental result shows that seabed topography near reefs and islands in shallow water affected the incident wave, making unpredictable changes to the motion response of platform and mooring tension distribution. Detailed instructions will be given in the text. This paper provides essential guiding significance for the design of nearshore floating platform and its mooring system near reefs and islands.

Key words: reefs and islands; floating platform; motion response; mooring characteristics

1 Introduction

Hundreds of meters wide shallow water are distributed near reefs and islands usually. In these area, topography is complex; evolution of wave and current are irregular and unpredictable. Complex natural environment near reefs and islands may have appreciable impact on motion response and mooring system characteristics of the offshore platforms and ships worked nearby.

In recent years, many scholars have carried out numerical simulation and model tests on the motion response of marine structures in waves, which are mainly concentrated in deep water. However, there's few study on hydrodynamic tension of structures in shallow water with complex topography.

Mansour[1] carried out numerical simulation analysis on RAOs of a new semi-submersible platform, and compared with the results of conventional semi-submersible platform. Clauss[2] calculated motion response and wave tension in time domain by using the GVA4000 semi-submersible platform as a prototype, and the numerical results of the wave induced motion are in good agreement with the experimental results. Orszaghova J[3] studied on numerical wave tank in shallow water based on Madsen and Srensen theory. Tian Chao[4] proposed reefs influence coefficient and engineering prediction methods of motion response of floating structures near reefs and islands, considering the influence of wave environment near reefs and islands by mild slope equation. Ding Jun[5] studied on the evolution of wave propagation near reefs and islands based on model test. Xiao Longfei[6] studied on the safety performance of a 160kDWT FPSO in shallow water.

Arcandra[7] studied hydrodynamic coupling problem of a floating platform and its polyester mooring lines. Zhou Sulian[8] made analysis on dynamic response of semi-submersible platform mooring system, and gave the basic design method of deep-water semi-submersible platform mooring system. Ding Jun, Cheng Xiaoming[9] studied on motion response of a semi-submersible platform with catenary mooring and tensioned mooring near reefs and islands, and proposed a new pile type mooring system. Shi Qiqi[10] studied on hydrodynamic properties of a semi-submersible platform and its catenary mooring system in 1 000 m water depth by using time domain coupled analysis method.

Motion response and mooring characteristics of a floating platform near to reefs and islands is investigated in this paper. This floating platform is equipped with tensioned mooring system. The grade of submarine topography changes dramatically, which making the surrounding environment very complex. Therefore, conducting a model test of floating platform in real submarine topography environment conditions and studing its motion response and mooring characteristics are significant for design, construction and safe operation of the floating platform.

2 Experiment Design

The model test of floating platform is operated in wave tank of Jiangsu university of science and technology.

2.1 Reefs and islands topography model

In order to simulate the real 3D topography around reefs and islands, reduced scale submarine topography model is made in the wave tank according to a measured topographic map of some area. As shown in figure 1 and figure 2.

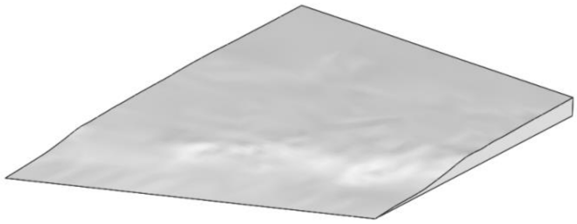


Fig.1 Topography near reefs and islands

Fig.2 Topography model

2.2 floating platform model

Reduced-scale of the floating platform is selected as 1:36.The model is shown in figure 3. Detailed parameters of the platform and the model are shown in Table 1

Table 1 Parameters of floating platform

Items	Actual	Model
Molded length (m)	100	2.78
Molded breadth (m)	25	0.69
Molded depth(m)	6	0.167
Draught (m)	2.5	0.069
Weight（t）	6229.1	0.133
Height of gravitational center (m)	3.17	0.088

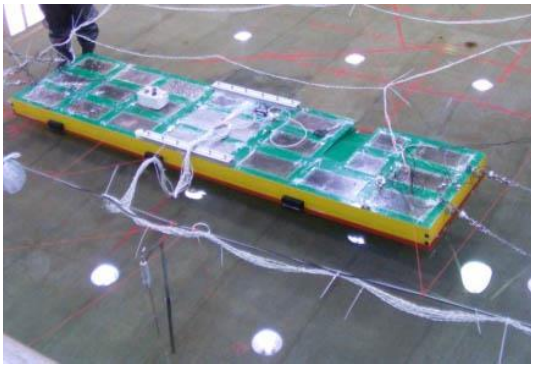


Fig.3 Scale model of floating platform

2.3 Mooring system arrangement

The floating platform is equipped with tensioned mooring system. There are 8 mooring lines totally, of each one length is 120 meters. 10 meters long studless chain is used in both ends of the line, and 100 meters long polyester cable is used in middle of it. The mooring lines are installed between the submarine caisson and anchor machine on deck. The angle between mooring line and Y axis is 10° without environmental tension.

In order to facilitate the experiment, 4 mooring lines are used for the model of floating platform. The number and arrangement of mooring system are shown in Figure 4. The pretension of each mooring line model is about 25N (21N~25N). The detailed parameters of the mooring line and the model are shown in Table 2.

Table 2 Parameters of mooring cables

Items	Actual	Model
Length of chain(m)	10.0+10.0	0.28+0.28
Diameter of chain(mm)	81	2.25
Length of polyester cable (m)	100	2.78
Diameter of polyester cable (mm)	144	4
Pretension	50-60(t)	21-25(N)

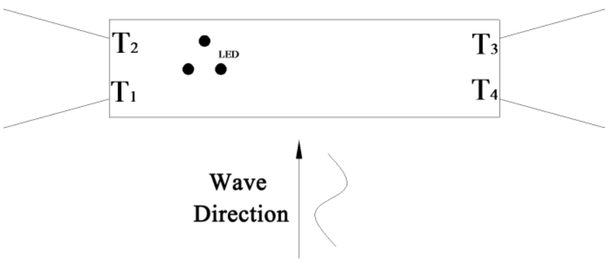


Fig.4 Mooring system arrangement

The coordinate system of the floating platform and the wave direction angle are shown in Figure 4. The direction of movement regulations are as follows.

Surge --Motion along the X axis
Sway --Motion along the Y axis
Heave --Motion along the Z axis
Roll --Rotation around the X axis
Pitch --Rotation around the Y axis
Yaw --Rotation around the Z axis

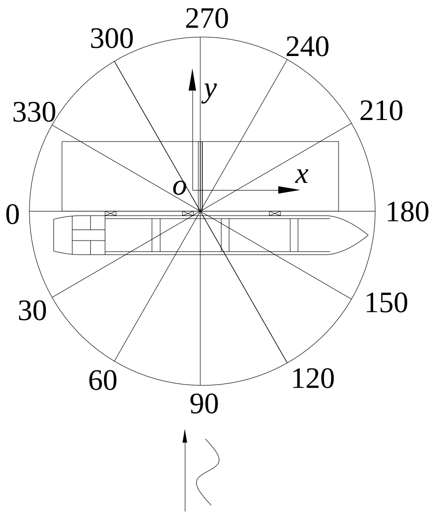


Fig.5 Coordinate system

2.4 Test conditions

6-DOF motion response of the floating platform under mooring mode in regular waves test conditions are shown in table 3. The wave direction angle is 90°.

Table 3 Platform in regular waves test conditions

Actual wave height(m)	Experimental wave height(m)	Wave length
2.0	0.056	0.3，0.4，0.5，0.6，0.75，1，1.25，1.5，1.75，2，2.25，2.5，2.75，3
4.0	0.111	0.4，0.5，0.55，0.6，0.75，1，1.25，1.5，1.75，2，2.5，2.75，3

6-DOF motion response and mooring tension of the floating platform under mooring mode in irregular waves test conditions are shown in table 4. The wave direction angle is 90°.

Table 4 Platform in irregular waves test conditions

Actual period Tp(s)	Experimental period Tp(s)	Actual wave height(m)	Experimental wave height(m)
8.0	1.33	h1/3=1.25	h1/3=0.035
		h1/3=3.00	h1/3=0.083

10.0	1.67	h1/3=1.25	h1/3=0.035
		h1/3=3.00	h1/3=0.083

3 Result analysis

Motion response and mooring tension of the floating platform under mooring mode in regular and irregular waves tests are carried out.

3.1 RAOs of the floating platform in regular waves

Figure 6 shows the 6-DOF RAOs of the floating platform in regular waves when wave height H=2m/4m and wave direction angle is 90°. Longitudinal coordinate represents motion response amplitude of the platform in unit wave height, and the abscissa represents wave periods. The result shows:

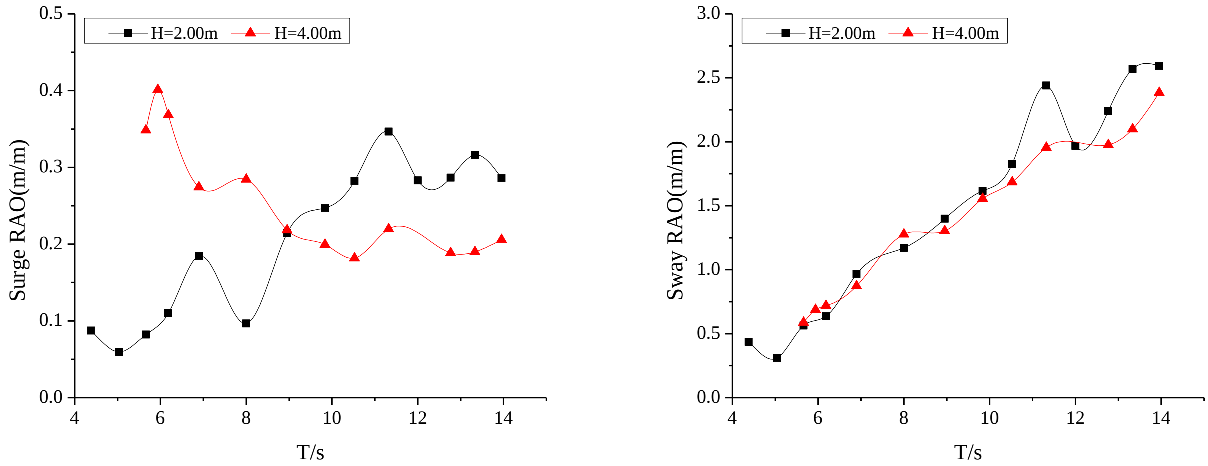
(1) There is a similar regularity that RAOs(except surge) change with wave period in different wave height, but the surge amplitude response presents an opposite change trend when wave height H=2m/4m. The platform is a symmetric structure, which means surge should not appear when the wave direction angle is 90°. However, the 3D topography changes waveform and causes small amplitude surge motion of the platform. The maximum motion response amplitude is about 0.4 and appears in the vicinity of T=6.0s. Due to an increase of wave height while wavelength is fixed, the wave steepness and energy increase, making longitudinal load on platform increase. This phenomenon will ease with increasing wavelength and lower wave steepness.

(2) Sway motion amplitude of the platform is much larger than the surge when the wave direction angle is 90°. The sway motion amplitude increases with wave period, but the increase becomes weaken, because the mooring tension will increase with the sway. The peak sway motion amplitude is about 2.5, which appears in the vicinity of 14.0s.

(3) Heave motion of the platform is mainly induced by the first order force of wave. The first order wave force increases with the wavelength, so does the heave amplitude response factor of the platform. The peak response amplitude factor of heave is about 1.3 and in the vicinity of 14.0s.

(4) Pitch response amplitude factor is opposite to roll, and minimum when the wave direction angle is 90°. It increases first and then decreases, while wave period increases.The maximum value of pitch is about 1.35 and in the vicinity of the 8.0s.

(5) Yaw response amplitude increases with the wave period. Because the 3D topography has an impact on longwave, making its crest lines bend. Increase of the torque on the platform makes yaw response amplitude increase either.



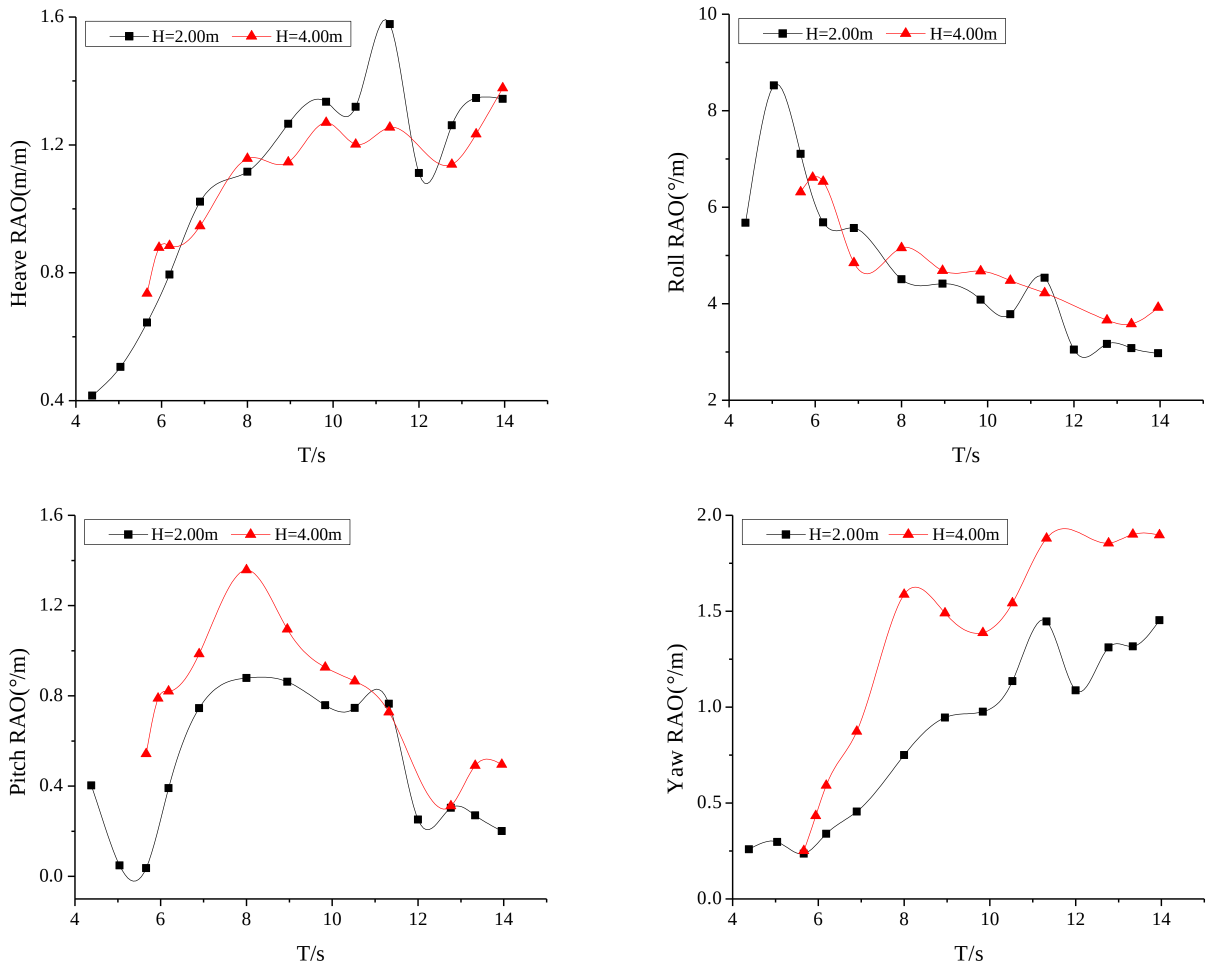
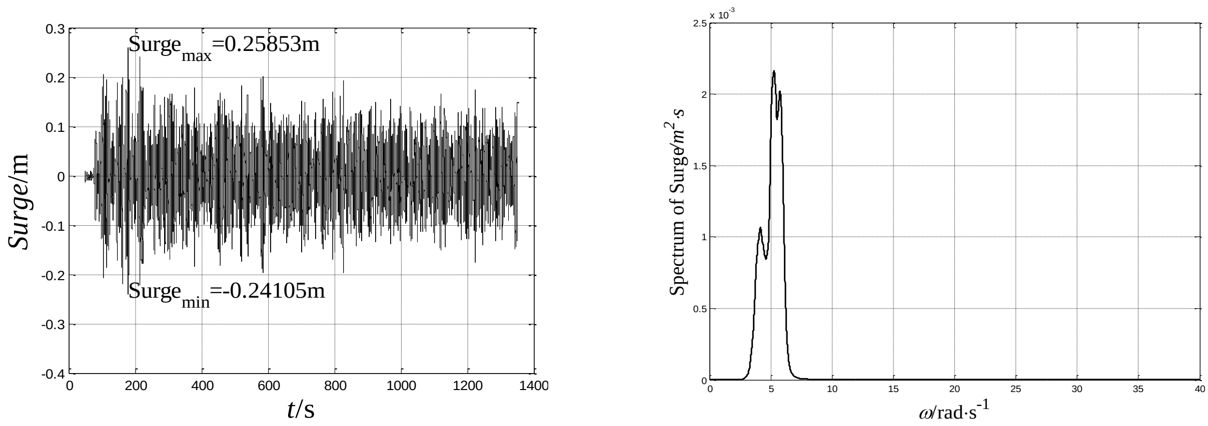


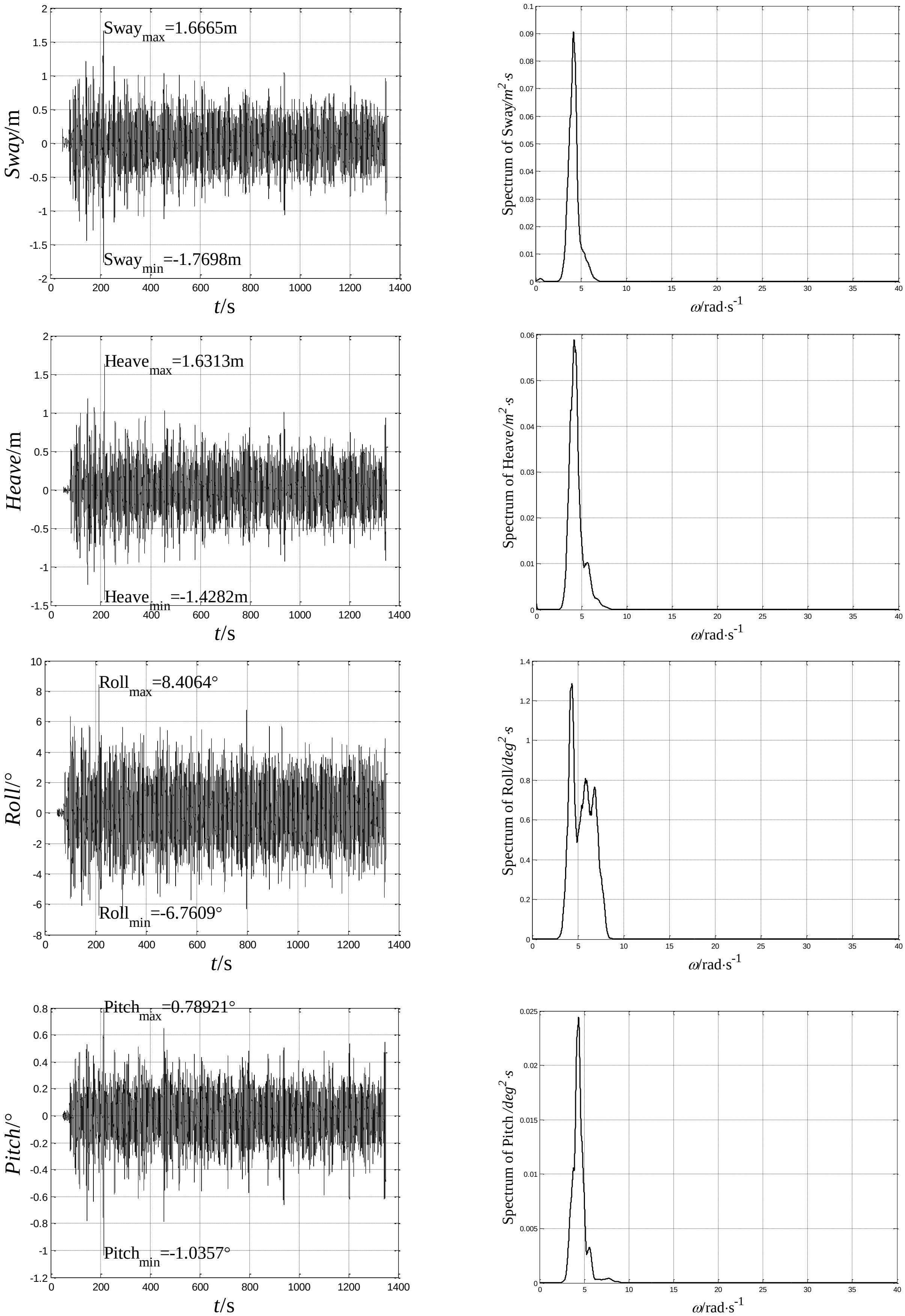
Fig.6 6-DOF RAOs of floating platform under mooring mode

3.2 6-DOF motion response of the floating platform in irregular waves

Influenced by the topography, the waveform evolve from sine wave into trochoidal wave in the process of propagation.

Spectrum bandwidth and spectral peaks of the platform's location are different from the ones in deep water areas. Therefore, the platform motion response spectrum under wave excitation does not meet Rayleigh distribution any more. Its band width increases, while the main peak is reduced; the response spectrum energy moves to high-frequency, and several second peaks appear. Figure 7 shows 6-DOF motion response durations and spectrums of floating platform while H1/3=1.25m, Tp=8.0s.




Sway/m
Swaymax=1.6665m
Swaymin=-1.7698m
t/s
Spectrum of Sway/m2·s
ω/rad·s-1
Heave/m
Heavemax=1.6313m
Heavemin=-1.4282m
t/s
Spectrum of Heave/m2·s
ω/rad·s-1
Roll/°
Rollmax=8.4064°
Rollmin=-6.7609°
t/s
Spectrum of Roll/deg2·s
ω/rad·s-1
Pitch/°
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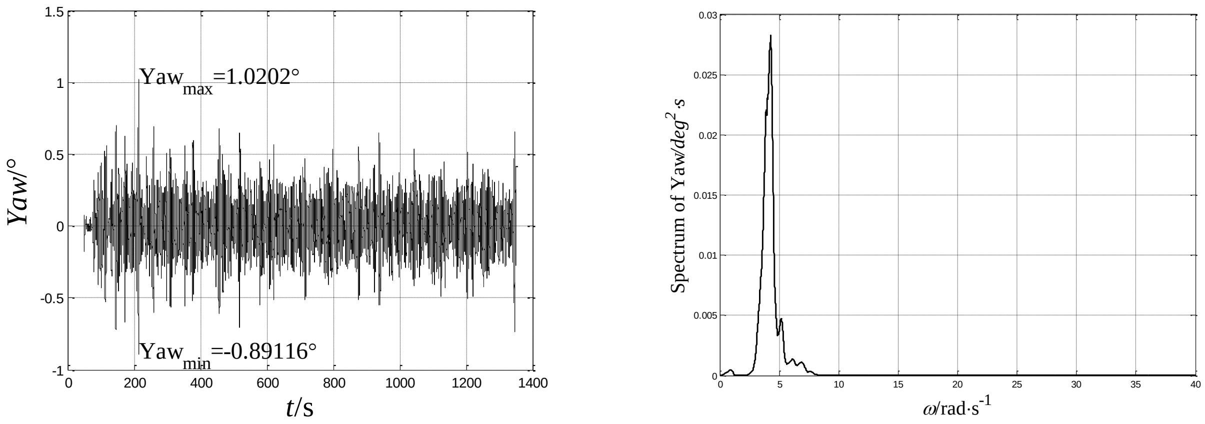

Fig.7 Six-DOF motion response durations and spectrums of floating platform ($H_{1/3}$=1.25m, T_p=8.0s)

3.3 Mooring tension of the floating platform in irregular waves

The tension on mooring lines of the platform in irregular waves is given in Figure 8 and Figure 9; the horizontal coordinate represents wave spectrum peak period, and the longitudinal coordinate represents the peak tension on mooring lines. The unit is tf.

It can be seen that when the spectral peak periods are same (the characteristic wavelength are same), mooring tension increase with the significant wave height. when the significant wave heights are same, mooring tension increase with the spectral peak period.

1# and 4# mooring lines are located in the deep water area, 2# and 3# mooring lines are located in the shallow water area. The tension on 1# and 4# (1# is greater than 4#) mooring lines are generally greater than 2# and 3# mooring lines, except in special conditions, such as when wave height $H_{1/3}$=1.25m, spectral peak period T_p=8.0s. When wave height $H_{1/3}$=3.0m, the peak tension of the mooring line is about 360tf, which appears in the vicinity of T_p=10s; when wave height $H_{1/3}$=1.25m, the peak tension of the mooring line is about 180tf, which appears in the vicinity of T_p=10s, either.

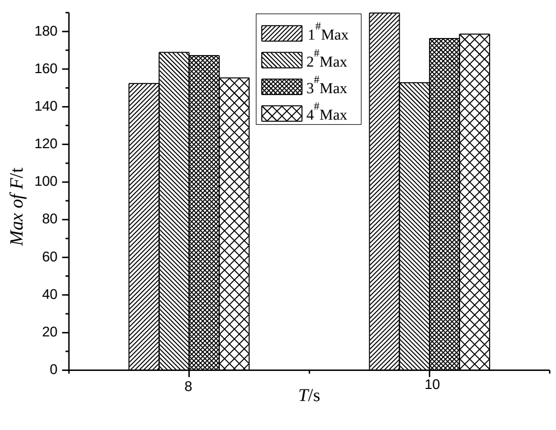

Fig.8 Peak mooring tension（$H_{1/3}$=1.25m, T_p=8.0/10.0s）

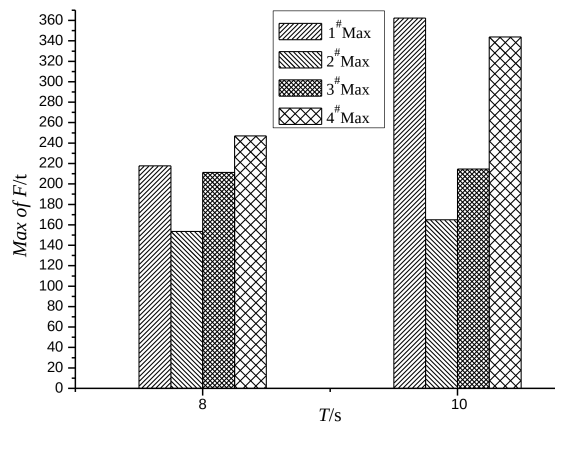

Fig.9 Peak mooring tension（$H_{1/3}$=3.00m, T_p=8.0/10.0s）

4 Conclusion

Through a model test in wave tank, motion response and mooring characteristics of a floating platform near to reefs and islands is investigated. The result shows:

(1) 3D topography near reefs and islands affects the incident waveform and direction, inducing multi DOF movements of the platform, such as surge and pitch. The wave-induced platform motion response spectrum under does not meet Rayleigh distribution any more. Its band width increases, while the main peak is reduced; the response spectrum energy moves to

high-frequency.

(2) The tension on mooring lines at wavefront side is generally larger than that at the other side, but the tension distribution of mooring line is uneven due to the influence of topography near reefs and islands.

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