Selection and optimization of mooring cables on floating platform for special purposes

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Abstract. This paper studied a new type of assembled marine floating platform for special purposes. The selection and optimization of mooring cables on the floating platform are studied. By using ANSYS AQWA software, the hydrodynamic model of the platform was established to calculate the time history response of the platform motion under complex water environments, such as wind, wave, current and mooring. On this basis, motion response and cable tension were calculated with different cable mooring states under the designed environmental load. Finally, the best mooring scheme to meet the cable strength requirements was proposed, which can lower the motion amplitude of the platform effectively.

1. Introduction

Offshore platform is a structure which provides producing and living facilities for drilling, oil extraction, observation, navigation, construction, etc. Traditional offshore platforms--drilling platforms, for example--include barge-type drilling platform, semi-submersible drilling platform[1], Tension-Leg Platform (TLP)[2], Spar platform[3], Floating Production Storage Offloading (FPSO), Very Large Floating Structures (VLFS) and Mobile Offshore Bases (MOB)[4]. In addition, as National Blue Ocean Strategy develops[5], a multi-purpose offshore simple floating platform, which can be used in both shallow sea and deep sea, is urgently needed for offshore operations, such as marine pasture observation, leisure fishing, offshore playground and aquaculture. This platform should meet the satisfaction of stability and resistance of wind, waves, current, corrosion and fouling, and have rooms for upper equipment.

The work studied a new type of assembled marine floating platform for special purposes (figure 1 and 2). The platform consists of standard floating modules. The upper part adopts steel structure, laid with board, while the lower uses buoys to provide buoyancy. According to the requirements of use, they can be combined into required sizes.

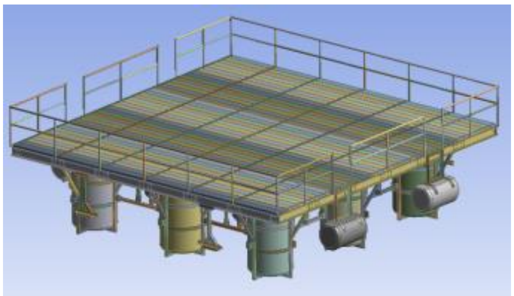

Figure 1. Axonometric drawing 1

Figure 2. Axonometric drawing 2

In order to ensure the platform with a certain degree of seakeeping, it is necessary to establish a finite element model for the new floating platform. What's more, under load impact of wind, wave, current and ice, its hydrodynamic characteristics and mooring schemes should be studied[6,7]. This paper studied the selection and optimization of mooring cables on the floating platform. By using ANSYS AQWA software, the hydrodynamic model of the platform is established to calculate time history response of platform motion under complex water environments, such as wind, wave, current and mooring. On this basis, motion responses and cable tension are calculated on different cable mooring platforms under the designed environmental loads, and then the optimization analysis on the mooring system are taken. In that way, it is expected to find the best mooring scheme to meet the cable strength requirements, lowering the motion amplitude of the platform.

When it comes to the working environment, water depth is about 20 m. It was designed in extreme water environment, with calculations of motion response and tension of mooring ropes, etc. The work chose the data of the wind, wave and current in the condition of five-grade sea state as the water environment simulation[8].

2. Cable types

In the structure of marine engineering, mooring systems are usually designed with catenaries and tension cables, catenary and tension cable mooring system.

Due to the small size of the platform in the work, as well as relatively shallow working depth, it adopted tension cable made of nylon rope or polyester rope as the mooring rope. The advantages of tension cable are listed as follows:

- Under the same water depth, tension cable is shorter than catenary, conducive to saving material.
- With greater restore stiffness, tensed nylon rope and polyester rope can provide greater restoring force, so as to reduce the motion range of the platform.
- Because of the light weight, nylon rope and polyester rope is in favor of reducing mooring gravity, which means to lower the load of the platform.
- The smaller mooring radius reduces the risk of collision with other nearby underwater facilities. Owing to larger vertical angle between the catenary and the platform, the anchor chain produces a great downward pulling force on the platform. But the tension cable mooring system can effectively solve the problem.

Among conventional synthetic fibers and natural fibers, a suitable material should be selected as the mooring cable for the platform. Polypropylene monofilament is economical and practical, widely used in the field of mooring cables. In wet state, its strength and elongation is consistent with the normal state, with characteristics of light and convenient, chemical resistance and good drainage.

Therefore, the platform in this study can adopt 8 or 12 strands of Polypropylene monofilament as the mooring cables. Both of the two kinds have similar mechanical properties. In the following analysis, we used 8 strands of Polypropylene monofilament cable.

3. Overview of hydrostatic conditions and environmental loads

AQWA software is a hydrodynamic analyzing software product by ANSYS Inc., which is mainly used in calculating hydrodynamic properties of ocean engineering. AQWA has the abilities of calculation of the first and second order wave forces and various analyses of the sea keeping quality, stability, mooring, launching, colliding, air gaps and cable dynamics.

The analyzing model of floating platform (figure 1, figure 2) is created based on the known weight, center of gravity and moment of inertia of platform. The static waterline can be calculated by AQWA software (table 1).

Table 1. Hydrostatic conditions of platform

Hydrostatic conditions	Weight (kg)	Volume of drainage (m^3)	Draught (m)	Height of the center of gravity above water plane (m)
	3480.95	3.396	0.791	0.392

Wind loads were calculated based on CCS rules <*Offshore platform classification specifications*>, with wind speed of 51.5 m/s in self-existence state.

Current loads were analyzed by unidirectional fluid-solid coupling between Fluent and Mechanical, with the current load calculated by Fluent transferring to the wet surface of Mechanical structure. The velocity of water flow used 0.85m/s, like the condition of once-in-a-decade in the South China Sea.

Ice loads were calculated in accordance with the contents of volume 2 of the CCS rules <*Rules for Classification of Sea-going Steel Ships in 2015*>, with consideration of a uniform load of 0.5 kN/m^2 on the deck, so as to account for snow, ice or other environmental loads.

4. Cable schemes

4.1. Scheme designing

Table 2 shows mooring connections, fixed point positions and cable lengths (figure 3). The section only discussed cables with different diameters (table 3), in comparison with motion response and the peak tension of the platform, using 4 kinds of mooring schemes under the same environmental loads.

Table 2. Geometric information of mooring cables

Numbers of mooring cables	Connection point positions (m)	Fixed point positions (m)	Distance between the connection points and the fixed points (m)	Cable lengths (m)
1	3,3,0.6	18,18,-20	29.57	29.5
2	3,-3,0.6	18,-18,-20	29.57	29.5
3	-3,3,0.6	-18,18,-20	29.57	29.5
4	-3,-3,0.6	-18,-18,-20	29.57	29.5

Table 3. Four kinds of new cable design schemes

Scheme	1	2	3	4	5	6
Cable type	Eight strands of Polypropylene monofilament					
Cable shape						

Density (g/cm^3)	0.91					
Elongation at break %	17~21					
Diameter (mm)	44	40	36	32	28	24
Load per meter (g/m)	880	720	590	460	355	260
Breakage force (kN)	243	201	167	132	104	79
Tension stiffness (kN/m)	1279.0	1057.9	879.0	694.7	547.4	415.8

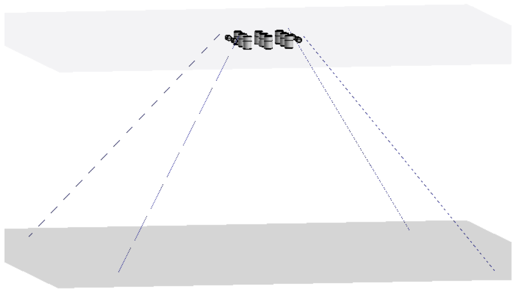

Figure 3. Mooring stat

4.2. Comparison of the results of different schemes

The response peaks of translational movement and rotational angle of the platform take the absolute value of the peak. table 4 shows the results of the different cable diameters.

Table 4. Comparison of the results of different cable diameters

Scheme	Response peak of translational movement (m)			Response peak of rotational angle (°)			Response peak of cable tension (kN)	Cable breakage tension (kN)
	U	Y	Z	Rx	Ry	Rz		
1	1.33	1.42	1.43	14.76	12.25	32.40	34.25	243
2	1.73	1.74	1.46	16.54	13.42	32.60	31.88	201
3	1.50	1.61	1.46	14.96	12.56	35.16	30.05	167
4	1.70	1.93	1.60	16.33	12.14	33.40	27.52	132
5	1.93	1.87	1.72	12.96	12.84	44.63	25.61	104
6	2.17	1.93	1.81	12.46	13.61	37.07	23.11	79

It can be seen from table 4 that when the cable diameters are between 24 and 44 mm, there are small changes in translational and rotational displacement response, as well as in the situation of cable tension response between 23.11 and 34.25 kN. Therefore, from the perspective of saving material and reducing weight, it is economical to choose 8 strands of Polypropylene monofilament cable with the diameter of 24 mm. However, because of the initial tensions between 2.5 and 3.5kN in these schemes, the subsequent analysis will change the initial tension to find the appropriate cable initial value, so that the motion amplitude and cable response tension will not too large in the platform.

4.3. Design of mooring initial tension

The work selected 8 strands of Polypropylene monofilament cable with the diameter of 24 mm, with one piece in each of four corners of the platform, mooring at the seabed with an angle of 45 degree. There are two steps for the initial tension design of the cable. The first design of the initial tension adopts a larger interval to quickly determine a relatively reasonable design range. The second design should be based on the results of the first step to search for more accurate variable, seeking for the optimal design.

In AQWA, through adjusting the initial cable length, we can change its tension. As for the first design, the interval of the initial cable length was defined between 27.0 and 29.5 m, with an analysis for each 0.5 m. table 5 displays the results of the initial tension schemes (The first design) for different cables.

Table 5. Comparison of the results of the initial tension schemes (The first design) for different cables

Scheme	Cable length (m)	Initial tension (kN)	Response peak of translational movement (m)			Response peak of rotational angle (°)			Response peak of cable tension (kN)
			U	Y	Z	Rx	Ry	Rz	
1	29.5	2.06	2.17	1.93	1.81	12.46	13.61	37.07	23.11
2	29.0	8.30	1.83	1.19	1.66	10.07	12.17	21.83	24.37
3	28.5	15.50	1.67	0.53	1.42	6.84	12.56	4.17	28.90
4	28.0	23.42	1.63	0.39	1.53	4.05	11.50	2.43	33.69
5	27.5	31.40	1.35	0.28	1.71	2.05	10.51	1.52	38.83
6	27.0	39.68	1.24	0.25	2.01	1.86	9.86	1.42	44.45

Table 5 shows when the cable length is reduced from 29 to 28.5m, response peak of the Rz degree of freedom decreases from 21.83 ° to 4.17 °. However, if we keep shortening the length of the cable, while increasing the tension, each degree of freedom of the platform will change little. Therefore, the optimal cable length should be around 28.5m; corresponding cable initial tension 15.50 kN; the cable tension response peak 28.90 kN, which is 36.6% breaking tension.

In the second design, the interval of the initial cable length was defined between 28.1 and 28.9 m, with an analysis for each 0.2 m. Table 6 shows the results of the initial tension schemes of the different cables (The second design).

Table 6. Comparison of the results of the initial tension schemes (The second design) for different cables

Scheme	Cable length (m)	Initial tension (kN)	Response peak of translational movement (m)			Response peak of rotational angle (°)			Response peak of cable tension (kN)
			U	Y	Z	Rx	Ry	Rz	
1	28.9	9.76	1.79	1.04	1.60	8.76	12.34	20.67	25.07
2	28.7	12.72	1.69	0.79	1.52	6.85	12.58	12.66	26.70
3	28.5	15.50	1.67	0.53	1.42	6.84	12.56	4.17	28.90
4	28.3	18.77	1.69	0.16	1.42	6.25	12.21	2.87	30.83
5	28.1	21.86	1.64	0.92	1.49	4.20	11.73	1.59	32.77

5. Conclusion

AQWA software was used to select and optimize the mooring cable of the platform. First of all, we used eight strands of polypropylene monofilament cable with the diameter of 24 mm, which was a suitable type of cable. Afterwards, the initial tension of the cable was designed in order to obtain a more reasonable mooring scheme, which can not only reduce the motion response amplitude of the platform, but also avoid large tension in the cable.

When the cable length was in the interval between 28.1 and 28.5m, which meant the initial cable tension between 15.5 and 21.86 kN, the motion response amplitude of the platform was controlled in a reasonable range. What's more, the response peak of the cable tension was 28.9 to 32.77 kN, which is about 36.6% to 41.5% the breaking tension.

Table 7. The best design scheme of mooring system

	Cable type	Diameter (mm)	Initial tension (kN)
The best design scheme of mooring system	Eight strands of polypropylene monofilament	24	15.5~21.86

The mooring scheme in table 7 was designed for the platform in this paper.

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