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Research on Time-domain Dynamic Response of Tension Leg Platform in Regular Wave

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Abstract. Move performance in six-degree-of-freedom is one of the important indexes of hydro-dynamic property of tension leg platform (TLP). This paper discusses the time domain dynamic response characteristics of a tension leg platform in the regular wave. The paper focuses on the effects of the incident wave angles (15 °, 22.5 ° and 45 °), the wave height (6m, 8m and 10m) and the wave period (10s, 12s and 14s) on the movement of tension leg platform, the top tension of the tension leg. The results show that: because of the different sensitivity of the tension leg platform to the incident wave angle, the wave height and the wave period, the motion characteristics is different.

Introduction

Tension leg platform (TLP) is a semi-compliant and semi-rigid complex nonlinear system: on the one hand, the platform buoyancy is far greater than its weight, therefore, one part of the buoyancy is to offset gravity, and the other part provides the tension of the tension leg. So the tight tension leg shows its rigidity. On the other hand, under external force, greater horizontal movement of tension leg platform appears, and TLP shows its flexible feature. The platform is anchored to the base by tension legs, providing a relatively stable and safe environment for the production.

Surge and sway performance becomes one of the important indexes of hydro-dynamic property of TLP. In the design of TLP, it must be ensured that the surge and sway motion displacement does not exceed 5% working depth. Pitch and roll motion, can make the tension of tension leg change, and provides the platform restoring force. In the meantime, the tension leg always keep parallel and tight. The natural period of pitch and rolling is usually less than 4S, the natural frequency of pitch and rolling is larger than wave frequency, and the swing angle is between -3° to 3°.The natural period of yawing motion is usually greater than 40s.If tension legs are not parallel, then the intersection is yaw rotation center; if tension legs always keep parallel, then the incentive force will decrease, resulting in the weakness of yaw movement. Heave motion of TLP is small, its natural frequency is 2 ~ 4S, and larger than wave frequency. Heave and surge motion are ready to couple.

Wang Shisheng [1] (2011) carried out the motion response analysis of a TLP with SESAM software. The results show that the platform has good movement performance and can meet the need of 1500m depth in South China Sea.Y. M. low[2] (2010) calculated recovery force of TLP with equivalent linear zed method, deduced recovery force and stiffness matrix under large displacement, analyzed time-domain and frequency-domain results. Dynamic response research of a tiny TLP was carried out by Xiaohong Chen [3] (2006) with four different methods (quasi static method, the software WAMIT, software COUPLE based on the radiation and diffraction theory, experimental measurement). The results showed that the quasi static method can only forecast dynamic response performance within wave frequency range, while COUPLE can give more accurate prediction in any frequency. Dynamic response of a triangular TLP was studied under five incident wave angles (0 °, 30 °, 45 °, 60 ° and 90 °) by Chandrasekaran [4] (2007) with Stokes wave theory, ignoring high frequency vibration and low frequency surge motion. The results showed that incident wave angle have greater influence with dynamic response, and linear motion showed a little non-linearity.

The Influence of Different Incident Wave Angle on TLP Dynamic Characteristics

The numerical model of TLP in this paper: draft is 26.6m, tension legs number is 12, pre tension is 1048 T, the axial stiffness of tendons is 35000000N/m, and water depth is 1000m. This paper discusses the effects of incident wave angle, wave height and wave period. Different calculation conditions were combined with different wave heights (H=6m, 8m, 10m), different wave periods (T=10s, 12s, 14s) and different incident wave angles (D=0°, 15°,22.5°, 30°, 45°). The conditions are marked D*H*T*, such as D0H6T10. Dynamic characteristics in six-degree-of-freedom are shown in Fig.1-Fig.2,(with same wave height, same wave period, different incident wave angle of 15 °, 22.5 °, 30 °).

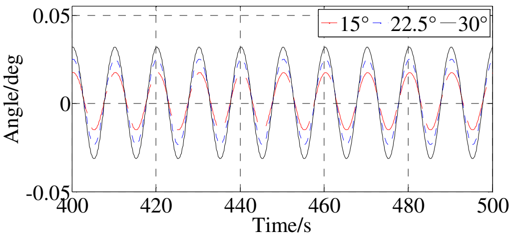

Fig. 1 Time series of rolls Under different directions

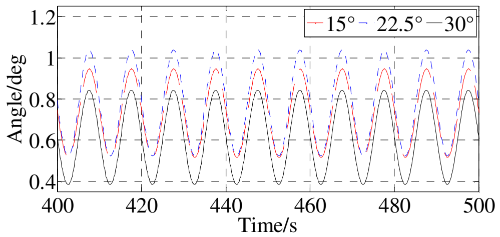

Fig. 2 Time series of yaw under different directions

The results show that: incident wave angle has less influence on heave and pitch, especially on pitch, while it has greater effect on the other four degrees of freedom of movement. With the increase of the incident wave angle, sway displacement mean decreases. With the increase of surge equilibrium position, surge displacement amplitude unchanged. Swaying mean increases gradually, showing that sway equilibrium position increases. From Fig.1, rolling mean changes slightly with the change of incident wave angle, its equilibriusm position is almost invariant.But the roll amplitude increases with the increase of incident wave angle, increasing about 16%. In summary, effects of incident wave angle on six-degree-of-freedom movement are varied, which is caused by different sensitivity of six-degree-of-freedom with incident wave direction and different stress on TLP in different direction.

Effects of Different Wave Height on Six-Degree-of-Freedom

The results of calculation condition D0H6T10, D0H8T10 and D0H10T10 are shown in Fig.3-Fig.6 (with the same 0 ° incident wave angle, the same wave period and different wave height).

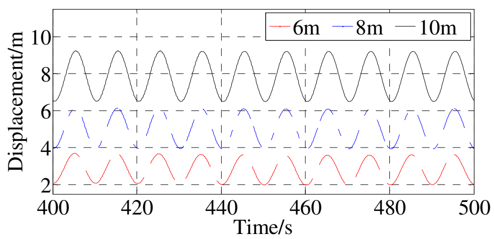

Fig.3 Time series of surge under different wave heights

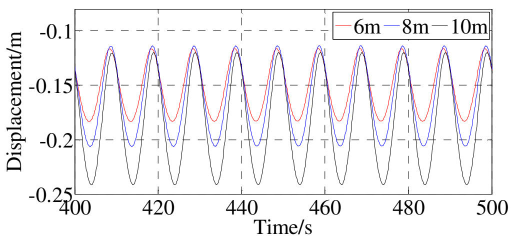

Fig. 4 Time series of heave under different wave heights

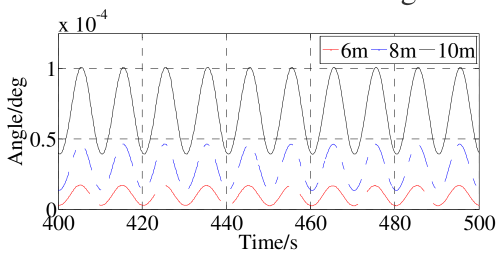

Fig. 5 Time series of roll under different wave heights

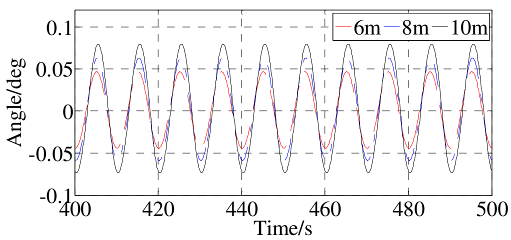

Fig. 6 Time series of pitch under different wave heights

From the results, in addition to pitch, the other three degree of freedom mean increases with the increase of wave height. As shown in Figure 3, with the increase of wave height, the growth rate of surge displacement value gradually increases, the equilibrium position value increases, the amplitude increases slightly. The equilibrium position changed from 2.8 to 5, and then changed into 8(approximate), increased about 60%. From Fig.4, with the increase of wave height, heave maximum amplitude changes little, the maximum displacement increases. Heave equilibrium position deviate from horizontal plane, and appears certain phase difference. This is due to different vertical component caused by different wave height.

As shown in Figure 5, with the increase of wave height, roll increases, the amplitude increases gradually, the growth rate of equilibrium position gradually increases too. As shown in Figure 6, under different wave height, pitch equilibrium position is almost invariable, but the amplitude increases with the increase of wave height. Under different wave height, Time series of yaw change little, here not to repeat.

To sum up, different wave height of has greatest effect on surge and roll, greater effect on pitch, minimal effect on heave. This is due to different sensitivity of different degrees of freedom on wave height.

EffectsFFECTS of Six Degrees of Freedom on Different Wave Period

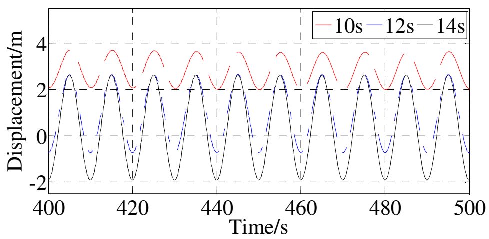

Fig. 7Time series of surge under different wave periods

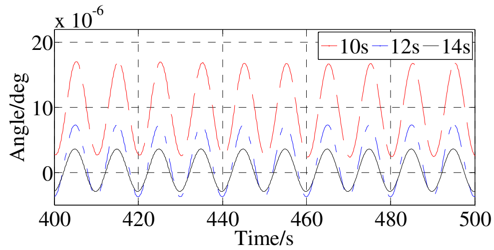

Fig. 8 Time series of roll under different wave periods

The results of condition D0H6T10, D0H6T12 and D0H6T14 are shown below, and they have the same 0° incident wave degree, the same 6m wave height and different wave period. The results show that, with the increase of the wave period, then heave, roll and pitch decreases gradually. Among these, surge and roll have more variation. From Fig.7, the surge mean of 10s period is greater than that of 12s and 14s. Surge maximums of 12s and 14s change little, but their minimum is different.

Surge equilibrium position decreases with the increase of wave period. As Fig.8 shows, the minimums of roll under 12s and 14s have little difference, but the roll maximum under 12s is greater than that under 14s. With different wave period, the variation trend of heave and pitch is very similar and phase difference both appears in their time series. In summary, under different wave period, the forces on platform vary, equilibrium position is almost invariant, time series change little, and the sensitivity of six-degree-of-freedom is different.

Effects of Pre Tension on Tension Leg Top With Different Wave Parameters

The general layout of TLP is shown in figure 9. Pre tension on tension leg top T1 under different incident wave direction, wave height and wave period is shown in figure 10~12. The results show that, incident wave direction has little effect on pre tension on tension leg top T1. The variation trend of pre tension on tension leg T1 under different incident wave direction is similar with that of heave, just reflecting the relationship of heave and top tension. As Fig.10 shows, with the increase of wave height, the pre tension on the top of tension leg T1 increases gradually. And in different wave height, top tension change has certain phase difference. In general, different incident wave angle, wave height and the wave period has little effect on the top tension. The tension legs are symmetrically arranged, therefore only the top tension of T1, T2, T3, T4, T5and T6 are analyzed. Comparing Fig.11 and Fig.12, it has been found that the mean and amplitude of tension of T1, T2, T3 is greater than that of tension leg T4, T5, T6; it is because of that T1, T2, and T3 are in front of T4, T5, and T6. The stress of the former is greater than that of the latter, and the latter tension legs lags behind the former tension legs on tension variation.

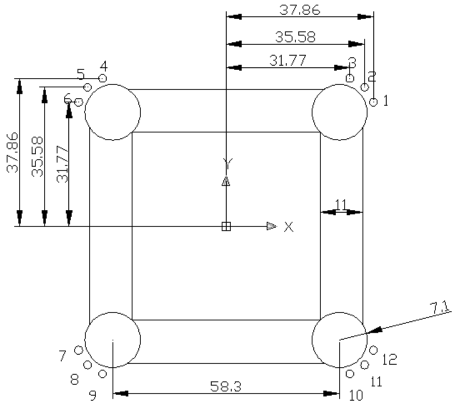

Fig. 9 Configuration of TLP

With numbered tendons

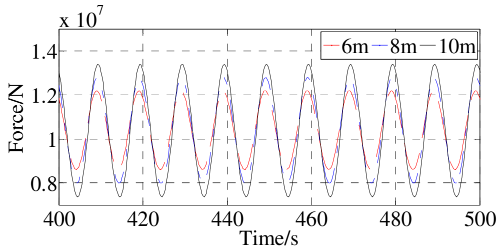

Fig. 10 Top tension of T1

under different wave heights

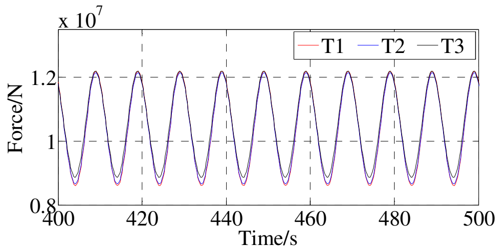

Fig. 11 Top tension of T1, T2 and T3

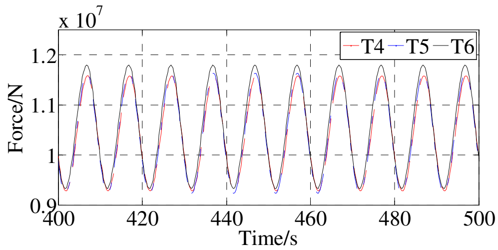

Fig. 12 Top tension of T4, T5 and T6

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