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Tethers tension force effect in the response of a squared tension leg platform subjected to ocean waves

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Abstract. The tension leg platform (TLP) is one of the compliant structures which are generally used for deep water oil exploration. With respect to the horizontal degrees of freedom, it behaves like a floating structure moored by vertical tethers which are pretension due to the excess buoyancy of the platform, whereas with respect to the vertical degrees of freedom, it is stiff and resembles a fixed structure and is not allowed to float freely. In the current study, a numerical study for square TLP using modified Morison equation was carried out in the time domain with water particle kinematics using Airy's linear wave theory to investigate the effect of changing the tether tension force on the stiffness matrix of TLP's, the dynamic behavior of TLP's; and on the fatigue stresses in the cables. The effect was investigated for different parameters of the hydrodynamic forces such as wave periods, and wave heights. The numerical study takes into consideration the effect of coupling between various degrees of freedom. The stiffness of the TLP was derived from a combination of hydrostatic restoring forces and restoring forces due to cables. Nonlinear equation was solved using Newmark's beta integration method. Only uni-directional waves in the surge direction was considered in the analysis. It was found that for short wave periods (i.e., 10 sec.), the surge response consisted of small amplitude oscillations about a displaced position that is significantly dependent on tether tension force, wave height; whereas for longer wave periods, the surge response showed high amplitude oscillations that is significantly dependent on wave height, and that special attention should be given to tethers fatigue because of their high tensile static and dynamic stress.

Keywords: tethers tension; tension leg platforms; hydrodynamic wave forces; wave characteristic

1. Introduction

Significant part of the world oil and natural gas reserves lies beneath the sea bed. The drilling and production operation to exploit this offshore oil and gas supplies is generally done from offshore platforms. Compliant platforms are used in deep water, where the stiffness of a fixed platform decreases while its cost increases, and they are the only technical solution in very deep water (>500 m). TLP is one of compliant platforms which is basically a floating structure moored

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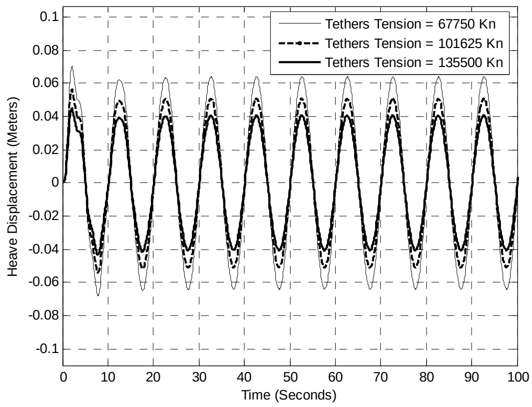

Fig. 11 Coupled Heave response of square TLP for Wave Height = 10 m and wave period = 10 sec

4.3 Pitch response

The time histories shown in Figs. 12 to 15 it is clear that the increase of tether tension decrease the amplitude of the pitch response and that effect is more obvious for small wave period. Also the pitch response is inversely proportional to the wave period and directly proportional- but to a less extent- to wave height. The pitch response appears to have a mean value of nearly zero. Moreover, the transient state takes about 20-40 seconds before the stationary state begins.

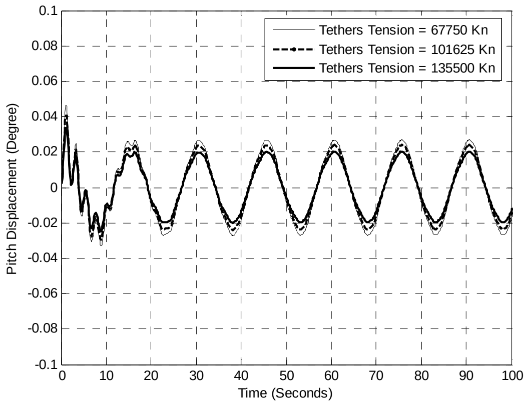

Fig. 12 Coupled Pitch response of square TLP for Wave Height = 8 m and wave period = 15 sec

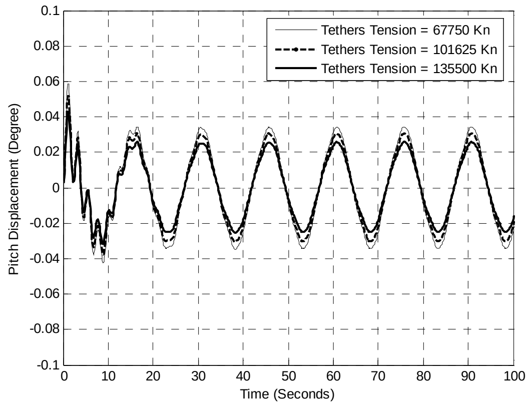

Fig. 13 Coupled Pitch response of square TLP for Wave Height = 10 m and wave period = 15 sec

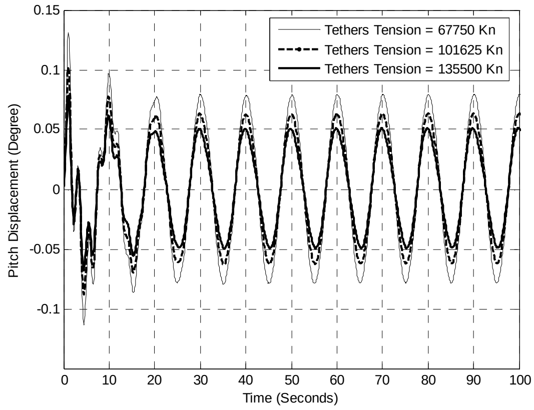

Fig. 14 Coupled Pitch response of square TLP for Wave Height = 8 m and wave period = 10 sec

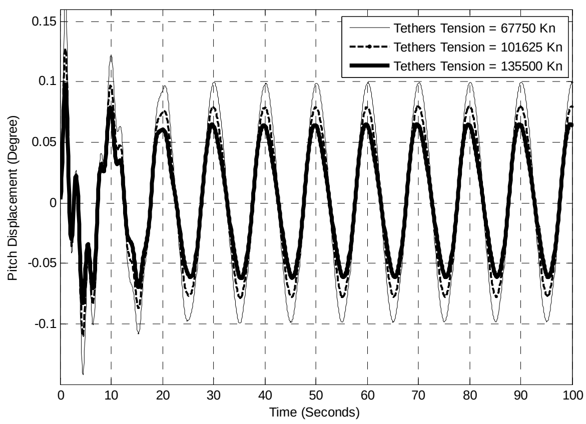

Fig. 15 Coupled Pitch response of square TLP for Wave Height = 10 m and wave period = 10 sec

4.4 Change in tether tension force

The time histories for the change in tether tension force for the square TLP are shown in Figs. 16 to 19.

It is observed that, for a specific wave period, the change in tether tension force increases as the wave height increases.

For long wave period the change of tether tension force is not affected by the initial tether tension force as the magnitude of the tension change is slightly different, however regarding the ratio of change in tension force, it increased as initial tension reduced, leading to more probability of fatigue damage.

For short wave period it can be observed that the permanent increase in tether tension force is higher for smaller initial tether tension force.

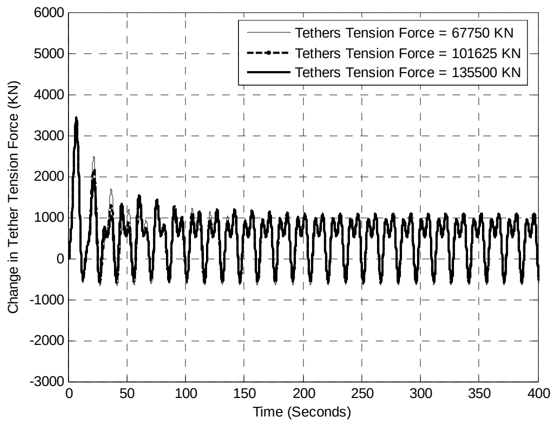

Fig. 16 Change in tether tension force of square TLP for Wave Height = 8 m and wave period = 15 sec

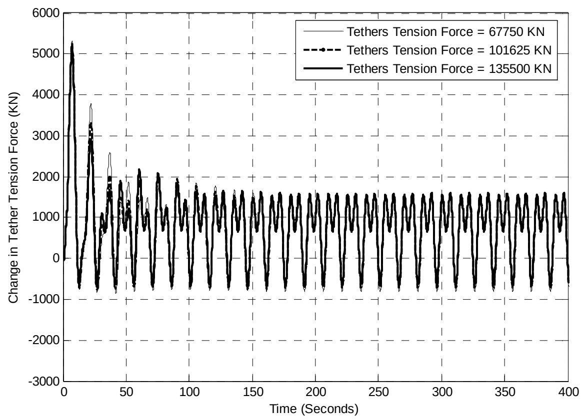

Fig. 17 Change in tether tension force of square TLP for Wave Height = 10 m and wave period = 15 sec

Also, for short wave period the initial tether tension force affect the magnitude of the tension change, the value of change of the tension force is greatly increase with the reduction of the initial tether tension force. That if we assume the same initial tension stress is introduced in the cables the smaller tether tension force will lead to a more probability of fatigue damage.

So, we can state that different tethers of the TLP are likely to be subjected to significantly different magnitudes of stress fluctuation. Thus, probabilities of fatigue damage could be different in various tethers and special attention should be given to tethers because of their high tensile static and dynamic stress.

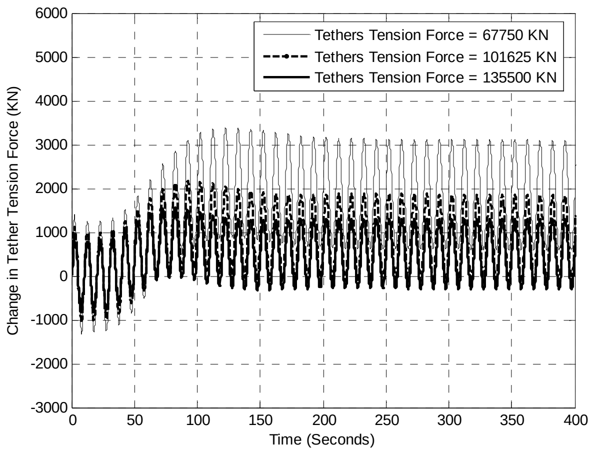

Fig. 18 Change in tether tension force of square TLP for Wave Height = 8 m and wave period = 10 sec

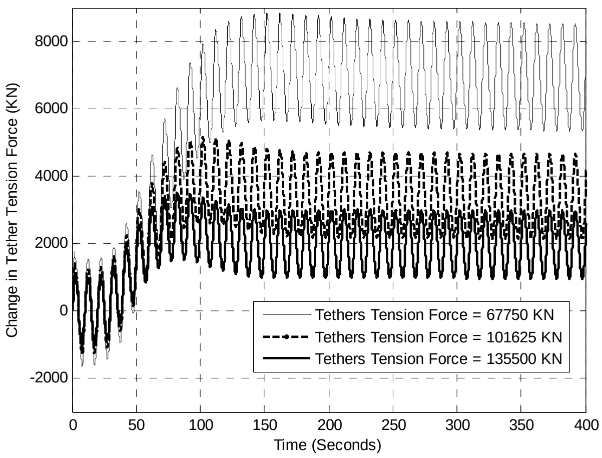

Fig. 19 Change in tether tension force of square TLP for Wave Height = 10 m and wave period = 10 sec

5. Conclusions

The present study investigates the effect of change of tension force in the tethers on the dynamic response of a square TLP under hydrodynamic forces in the surge direction considering all degrees of freedom of the system. A numerical dynamic model for the TLP was written where Morison's equation with water particle kinematics using Airy's linear wave theory was used. Results for the time histories for the affected degrees of freedom have been presented. Based on the results shown in this paper, the following conclusions can be drawn:

1) The natural periods of the surge, sway and yaw motions were in the range of (120 to 170) depending on the tension in tethers, however these periods are higher than typical wave spectral peaks (8 to 15) which precludes resonance with the wave diffraction forces.
2) The natural time period of TLP is inversely proportional to the tether tension force
3) The surge displaced position decreased as tether tension force increase whiles the amplitude is slightly affected.
4) Wave height affects the surge response oscillations. It increases both the amplitude for long wave period, and the displaced position distance for short wave period
5) The heave response is inversely proportional to the tether tension force.
6) The Pitch response is inversely proportional to the tether tension force and that effect is more obvious for small wave period.
7) Different magnitudes of stress fluctuations leading to different probabilities of fatigue damage can occur.
8) The magnitude of stress changes depends on the tether tension force, and wave period and wave height
9) For long wave period the change in tension force is not affected by tether tension value, but increase as a ratio with reduction in tension force.
10) For short wave period the change in tension force is increases in both magnitude and a ratio with the reduction of initial tether tension force leading to more probability of fatigue damage.

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