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Short-Term Nonlinear Response of Tension Leg Platform in Random Sea Waves

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ABSTRACT

Most of the existing mathematical models for analyzing the dynamic response of TLP are based on explicit or implicit assumptions that motions (translations and rotations) are small magnitude. However, when TLP works in severe adverse conditions, the *a priori* assumption on small displacements may be inadequate. In such situation, the motions should be regarded as finite magnitude. This paper will study stochastic nonlinear dynamic responses of TLP with finite displacements in random waves. The nonlinearities considered are: large amplitude motions, coupling the six degrees-of-freedom, instantaneous position, instantaneous wet surface, free surface effects and viscous drag force. The nonlinear dynamic responses are calculated by using numerical integration procedure in the time domain. After the time histories of the dynamic responses are obtained, we carry out cycle counting of the stress histories of the tethers with rain-flow counting method to get the stress range distribution.

KEY WORDS: Tension Leg Platform (TLP); large amplitude motions; finite displacement; nonlinear dynamic response; random waves; short term analysis; wave loads

INTRODUCTION

In recent years, China's petroleum industries take great interest in deep water exploration and development just as their international counterparts do. The fixed exploitation platforms fit for shallow water are not suitable to deep sea because the construction cost increase greatly with the water depth. To meet the challenge, the concept of compliant platforms favorable for deep sea is thought over. Tension leg platform (TLP) is one of the candidate platforms for deep water exploitation. TLP can move with waves other than fixed at the initial position as the jacket platform does. It consists of hull, taut tethers and foundations, which allows motions of surge, sway, and yaw in the horizontal plane and heave, pitch, and roll in the vertical plane. Therefore, the dynamic response of TLP is an important problem of offshore mechanics, and there are many researches on it. Williams and Rangappa (1994) developed an approximate semi-analytical technique to calculate hydrodynamic loads, added mass and damping coefficients for idealized TLP consisting of arrays of circular cylinder. Yilmaz, Incecik and Barltrop (2001) calculated free surface elevations for an array of four cylinders. Ahmad, Islam and Ali (1997) investigated TLP's sensitivity to dynamic effects of the wind. Chandrasekaran and Jain (2002a, b) developed a method to analyze the dynamic behavior of triangular and square TLP. Furthermore, they performed numerical studies to compare the dynamic responses of a triangular TLP with that of a square TLP. Ahmad (1996) conducted stochastic response analysis considering viscous hydrodynamic force, variable added mass and large excursion.

Up to the author's knowledge, most existing investigations on TLP virtually make *a priori* assumptions explicitly or implicitly that the translational displacements and angular displacements being kept small magnitude. Therefore, the finite motions and accordingly aroused other nonlinear factors are not taken into account (or at least not considered completely). In fact, in harsh sea state or ultimate adverse operation state, the displacements of TLP may be large quantities and should not be taken as small magnitudes. Even though the small magnitudes are kept to two or three orders, it may be deficient for such terrible situation. Very few investigations ostensibly claim to have considered arbitrary displacements. However, it may not be the fact. Zeng et al (2005, 2006) have explained the reason.

As a continuation of the research on a tethered cylinder by Zeng, Shen and Wu (2005), Zeng, Liu, Shen and Wu (2006) proposed a theoretical model for analyzing the nonlinear behavior of a TLP with finite displacement, in which multifold nonlinearities are taken into account, such as large amplitude motions, coupling of the six degrees of freedom, instantaneous position, instantaneous wet surface, free surface effects and viscous drag force. The nonlinear dynamic analysis of ISSC TLP in regular waves was performed in the time domain. It was found that large amplitude motion nonlinear responses of TLP differ from that of linear case significantly. Such analysis on nonlinear behavior in regular waves is suitable for deterministic design approach.

Sea waves are random instead of regular in nature. Therefore a study on stochastic responses of TLP in random waves is favorable for probabilistic design approach. The subject of this paper is the stochastic nonlinear responses of TLP in short-term (e.g. half hour or several hours during which the wave spectrum is invariable) sea-state. Based on the theoretical model proposed by Zeng et al (2006), the stochastic responses of TLP with 6 degrees of freedom finite displacements are evaluated in the time domain.