Parametric Studies of Tension Leg Platform with Large Amplitude Motions

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ABSTRACT

Tension leg platform (TLP) is an important kind of working station for deep water exploration and development in ocean, whose dynamic responses deserve a serious thought. It is shown that for severe sea state, the effects of nonlinearities induced by large displacements of TLP may be noteworthy, and then employment of small displacements model should be restrained. In such situation, large amplitude motion model may be an appropriate alternative. The numerical experiments are performed to study the differences of dynamic responses between the two models. It is shown that for most cases, differences between results of the two models are significant. The variances of the differences vs. the wave period are the most remarkable, and that of the differences vs. wave heading angle are also apparent.

KEY WORDS: Tension leg platform (TLP); large amplitude motions; nonlinear dynamic response; wave loads; numerical simulation.

INTRODUCTION

As well known, ocean is an attractive region for mankind to exploit oil and natural gas resources, and the most promising areas include lots of deep water blocks. Tension leg platform (TLP) is a typical kind of compliant offshore working station, which has become a competitive alternative for deep water exploration and development all over the world. Similarly, it is selected by petroleum industries in China as a candidate for offshore oil exploitation to meet the rapidly growing domestic demand.

TLP can move with 6 degrees of freedom, which are surge, sway and yaw in the horizontal plane and heave, roll and pitch in the vertical plane. 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. Ahmad (1996) conducted stochastic response analysis considering viscous hydrodynamic force, variable added mass and large excitation. Ahmad, Islam and Ali (1997) investigated TLP’s sensitivity to dynamic effects of the wind. Yilmaz, Incecik and Barltrop (2001) calculated free surface elevations for an array of four cylinders. Chandrasekaran and Jain (2002a, b) developed a method to analyze the dynamic behavior of triangular and square TLP; and they performed numerical studies to compare the dynamic responses of a triangular TLP with that of a square TLP.

To the best of the author’s knowledge, the existing investigations on TLP mostly adopt the small displacements assumption explicitly or implicitly, which treat the translational displacements and angular displacements as small magnitude. In this sense, we call such method as linear model. Therefore, the nonlinear effects induced by large displacements are omitted. In fact, in severe sea state, or extreme adverse state, the displacements of TLP may be distinctly large and should not be taken for small quantities. There are very few investigations ostensibly claim to have considered arbitrary displacements. However, it may not be the fact. Zeng et al (2006) have explained the reason.

Zeng, Liu, Shen and Wu (2006) developed a theoretical model for analyzing the nonlinear behavior of a TLP with large amplitude motions, in which multifold nonlinearities are taken into account, such as nonlinear restoring forces, 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 nonlinear responses of TLP considering effects induced by large amplitude motions differ from that of the linear model significantly. By contrary to the small displacements linear model, we call this large displacements method as nonlinear model.

This paper is a continuation of the paper by Zeng et al (2006). Herein we investigate the variance trend of dynamic responses differences between the linear and nonlinear model as the wave conditions vary, by using the method developed in that paper (Zeng et al (2006)). The motivation of this paper is to study quantificationally whether the linear model may be appropriate to a certain extent even severe sea state is considered. The wave height, wave period and wave heading angle are the main variable parameters concerned. The numerical calculations are performed for a typical TLP (ISSC TLP) consisting of four columns and four pontoons.

The major assumptions we adopt are listed as followings

i) The amplitude of motions of TLP may be large, not confined to small quantities.

ii) The component cylinders of hull are assumed sufficient slender, and then the wave diffraction effects have been neglected. (For