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Nonlinear Vertical Vibration of Tension Leg Platforms with Homotopy Analysis Method

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Abstract. One of the useful methods for offshore oil exploration in the deep regions is the use of tension leg platforms (TLP). The effective mass fluctuating of the structure which due to its vibration can be noted as one of the important issues about these platforms. With this description, dynamic analysis of these structures will play a significant role in their design. Differential equations of motion of such systems are nonlinear and providing a useful method for its analysis is very important. Also, the amount of added mass coefficient has a direct effect on the level of nonlinearity of partial differential equation of these systems. In this study, Homotopy analysis method has been used for closed form solution of the governing differential equation. Linear springs have been used for modeling the stiffness of this system and the effects of torsion, bending and damping of water have been ignored. In the study of obtained results, the effect of added mass coefficient has been investigated. The results show that increasing of this coefficient decreases the bottom amplitude of fluctuations and the system frequency. The obtained results from this method are in good agreement with the published results on the valid articles.

AMS subject classifications: 70G99, 70K25, 82C80

Key words: TLP, Homotopy analysis method, nonlinear vibrational equation, added mass, vertical vibration.

1 Introduction

Tension leg platform (TLP) is the newest types of restrained comparative structures. The platform is permanently moored by means of tethers or tendons grouped at each of the structure's corners. A group of tethers is called a tension leg. A schematic diagram of a

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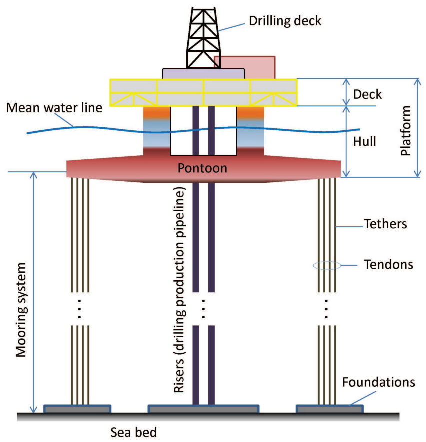

Figure 1: Schematic diagram of tension leg platform (TLP).

typical TLP is shown in Fig. 1. These platforms are connected by the stretched chains or cables to the sea floor that creates more than 15 to 25 percent of buoyancy force. Being stretched the platform, will reduced the vertical and rolling movement very much. These platforms are designed to be able to show great stiffness against the vertical loads. These types of platforms are used usually in very deep seas (approximately 300m to 1500m). As the benefits of tension leg platform can be pointed to its easy transfer during the changing of the platform location due to the completion of oilfield operations, as well as fewer installation costs.

In the last three decades, numerous attempts have been done to provide a better model in terms of costs and useful life of the platform. These platforms must be designed based on a dynamic analysis. Many studies [1–3] have been performed to understand the structural behavior of TLP and determine the effect of several parameters on dynamic response. Tabeshpour et al. [4] examined the effects of added mass by using perturbation method. In their study, many curves are presented to show free vibration response of the system that in these curves, linear solution of system is compared with the first and second order of perturbation method. They concluded that by using the first order perturbation method, the system frequency is equal to its natural frequency. Also, a conceptual discussion on the results of nonlinear dynamic analysis of TLP under arbitrary initial values had been presented by Tabeshpour [5]. Adrezin et al. [6, 7] developed a set of non-linear equations of tension leg platform for a single-tendon undergoing planar motion. The transverse and longitudinal responses of the tendon are included in the equations of motion and the Extended Hamilton's Principle is applied and the Lagrangian is fully developed. Chandrasekaran and Jain [8] studied dynamic analysis of a triangular model TLP to regular waves and considered various nonlinearities produced due to change in the tether tension and nonlinear hydrodynamic drag force. The nonlinear equation of motion is solved in the time domain using Newmark's β integration scheme and