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Second-order perturbation added mass fluctuation on vertical vibration of tension leg platforms

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Abstract

Total motion in waves can be considered as a superposition of the motion of the body in still water and the forces on the restrained body. In this study the effect of added mass fluctuation on vertical vibration of tension leg platforms (TLP) in the case of vibration in still water for both free and forced vibration subjected to axial load at the top of the leg is presented. This effect is more important when the amplitude of vibration is large. Also this is important in fatigue life study of tethers. The structural model used here is very simple. Perturbation method is used to formulate and solve the problem. First- and second-order perturbations are used to solve the free and forced vibrations, respectively.

Keywords: Added mass fluctuation; Wave; TLP; Heave vibration; Perturbation method

1. Introduction

Tension leg platforms (TLPs) are well-known structures for oil exploitation in deep water and are becoming increasingly popular for oil drilling at very deep water sites. Fig. 1 shows different components of the TLP made up of vertical and horizontal elements on the upper structure and vertical tendons connecting the structure to a foundation on the seabed. These structures consist of semi-submersible platforms with sufficient buoyancy to develop the required tension in the tethers. The TLP is a moored floating structure whose

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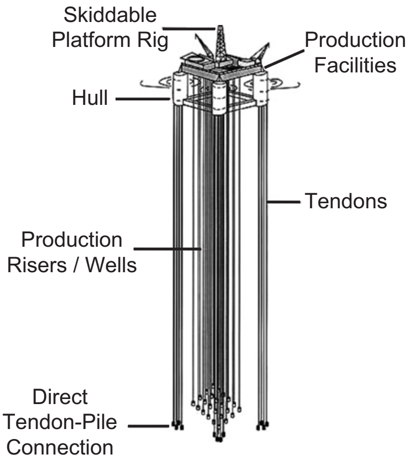

Fig. 1. TLP configuration and components [16].

buoyancy is more than its weight. The mooring system of TLP consists of a number of tensioned tethers connected to the columns at the top and anchored to the seabed at the bottom. These tethers are vulnerable to failure due to fatigue produced by fluctuation of tension. Many studies have been carried out to understand the structural behavior of TLP and determine the effect of several parameters on dynamic response and average life time of the structure [1–6]. The tether system is a critical and basic component of the TLP. The most important point in the design of TLP is the pretension of the legs. The pretension causes that the platform behaves like a stiff structure with respect to the vertical degrees of freedom (heave, pitch and roll), whereas with respect to the horizontal degrees of freedom (surge, sway and yaw) it behaves as a floating structure. Therefore the periods of the vertical degrees of freedom are lower than the others. Among the various degrees of freedom, vertical motion (heave) is very important because of the direct effect on the stress fluctuation that leads to fatigue and fracture. Therefore the conceptual studies to understand the dynamic vertical response of TLP, can be useful for designers.

Another important problem is investigating the effects of radiation and scattering on the hull and tendon responses. An analytical solution for surge motion of TLP was proposed and demonstrated [7], in which the surge motion of a platform with pre-tensioned tethers was calculated. In that study, however, the elasticity of tethers was only implied and the motion of tethers was also simplified as on-line rigid-body motion proportional to the top platform. Thus, both the material property and the mechanical behavior for the tether incorporated in the TLP system were ignored. When this simplification was applied, no matter what the material used was or what the dimension of tethers was, the dynamic response of the platform would remain the same in terms of the vibration mode, periods and the vibration amplitude. An important point in that study was linearization of the surge motion. But it is obvious that the structural behavior in the surge motion is highly nonlinear because of large deformation of TLP in the surge motion degree of freedom (geometric nonlinearity) and nonlinear drag forces of Morison equation. Therefore the obtained solution is not true for the actual engineering application. For heave degree of freedom the structural behavior is linear, because there is no geometric nonlinearity in the