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Robust design optimization of mass dampers for control of tension leg platforms

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ABSTRACT

Under severe sea and wind conditions, Tension Leg Platforms may experience large response amplitudes that affect their serviceability and structural integrity. The idea of using mass dampers has been introduced for reduction of the effects of these types of dynamic loadings. For achieving larger vibration suppression, appropriate tuning of the parameters of the dampers is necessary. A robust stochastic design approach is presented in this study for this purpose. Stochastic simulation is considered for evaluation of the system's performance in the *design stage*. This way, nonlinear characteristics of the structural response and excitation are *explicitly* incorporated into their respective models. Model parameters that have some level of uncertainty are probabilistically described. In this probabilistic setting, the system reliability is adopted as the system design objective. In this framework, the complex relationship between the coupled dynamics of the platform, the stochastic excitation and the vibration of the dampers is fully addressed in the design stage.

KEY WORDS: Tension Leg Platform; mass dampers; vibration absorbers; robust design; stochastic simulation; stochastic sea model.

INTRODUCTION

Tension Leg Platforms (TLPs) (Fig. 1) are floating structures of semi-submersible type, moored by vertical tendons under initial pretension, T_o, imposed by excess buoyancy. Several TLPs have been used for oil drilling and production operations in deep waters. They can be modeled as a rigid body having six degrees of freedom, including three translations (surge, x, sway, y, and heave, z) and three rotations (roll, φ, pitch, θ, and yaw, ψ). The natural period in surge, sway and yaw are in the range 80-120 sec and well above the range of dominant waves, which typically have periods 6-18 sec. On the other hand the heave, pitch and roll periods are *typically* in the range 2-4 sec and below the period of storm waves. Thus, forces at the dominant wave frequencies do not excite the TLP at its natural frequencies. Still, higher-order nonlinear forces at the sum and difference of the wave frequencies can produce significant resonant excitations at the TLP natural frequencies because of the small amount of damping available at these frequencies (Mekha et al. 1996). Additionally, deepwater TLPs have longer periods for the heave, pitch and roll motions (up to 6 sec) which are close to the dominant periods of fatigue sea states (consisting of small amplitude but also small period waves) and thus may be excited at resonance by direct wave energy (see, for example, Spillane et al. 2007).

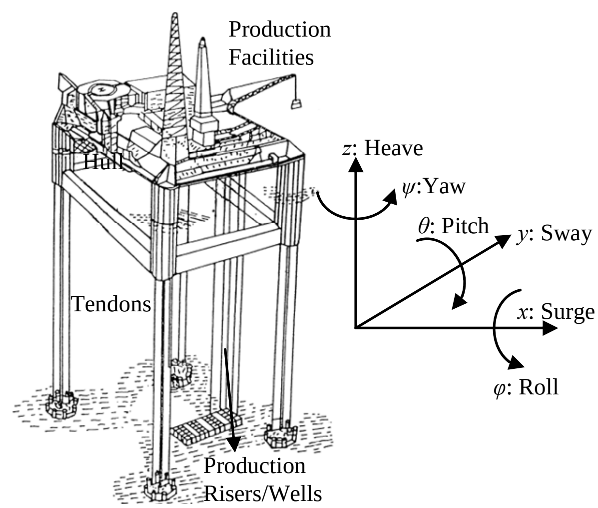

Fig.1 : Tension Leg Platform and degrees of freedom.

Passive and active control techniques have been investigated for reducing the effects of dynamic excitations on TLPs (Ahmad and Ahmad 1999; Alves and Batista 1999; Taflanidis et al. 2007). Of particular interest is the control of the coupled heave/pitch/roll motion since large displacements in the vertical direction may lead to unacceptable strain for both pre-stressed tendons and production risers. A number of researchers have investigated the idea of using mass dampers for this purpose. These dampers consist of a secondary mass attached to the TLP hull. The motion of this mass counteracts the motion of the platform, thereby providing energy dissipation. Alves and Batista (1999) suggested placing Tuned Mass Dampers (TMDs) in the columns of the TLP hull but they only consider the implications of the dampers on the heave response of the TLP. Lee et al. (2006) discussed the placement of Tuned Liquid Column Dampers (TLCDs) on the