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Influence of Varying Inertia Coefficient and Wave Directionality on TLP Geometry

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A BSTRACT

Response behavior of TLP under hydro-dynamic loading is nonlinear due to large structural displacements and fluid-structure interaction. This study focuses on influence of two imperative parameters namely inertia coefficient and wave directionality on its geometry. Paper develops a mathematical formulation for non-linear variation of hydrodynamic inertia coefficient (C_m) along the water depth to yield optimum force on TLPs as well as influence of wave directionality on their geometric configuration while discussing the method of solution. Responses are obtained for two configuration of TLPs namely square and equivalent triangular TLP with total initial pretension same as that of square.

KEY WORDS: TLP geometry; Stokes' theory; varying inertia coefficient; wave directionality.

INTRODUCTION

Offshore TLPs are vertically moored compliant structures built for petroleum extraction in deep sea. Their compliant mechanism extends high degree of mobility to alleviate destructive loads, enabling early oil production and reduced field installation costs. Inertia forces become predominant when they are dynamically excited. Researchers (Chandrasekaran et al., 2002b) studied the complexities arising from various nonlinearities namely: i) change in tether tension; ii) buoyancy; as well as iii) hydrodynamic drag forces and discussed appropriate solution procedures. They showed that calculation of wave forces on displaced position of the platform introduces a steady offset component in structural response. Water particle kinematics based on Navier-Stokes' equation is nonlinear with respect to the transverse velocity (see for example, Drobyshevski, 2004). Therefore influence of hydrodynamic coefficients on response behavior of compliant structures like TLPs showed the importance of including first order terms while computing the wave forces. (Sabuncu and Sander, 1981); however, these variations do not influence heave response much. (see for example, Spyros 2005). Chaplin & Subbiah (1994) presented results for probability distribution of peak forces and Morison coefficients based on experimental investigation on a rigid vertical cylinder under multidirectional waves. Natvig and Vogel (1995) reported several advantages of TLPs with triangular geometry namely: i) no tether tension measurements required on day-to-day operation; ii) increased tolerances for the position of foundation; as well as iii) increased draught and heel tolerances making it more advantageous than four legged square TLPs. Triangular TLPs that are statically determinate shall not require complicated devices for installation and hence foundations can be placed with larger tolerances without affecting the tether behavior. Researches on comparative studies on TLPs with different geometry by varying inertia coefficients and wave directionality have been relatively limited in the literature. As triangular TLPs possess many potential advantages and proven viability for deep water oil exploration, the current study presents a mathematical development of nonlinear variation of inertia coefficients along the water depth for optimum force in the pontoons and examines their influence on both the square and triangular TLPs. Analysis methodology of TLPs under wave directionality is presented and their influence on dynamic response behavior of TLPs is examined.

MATHEMATICAL DEVELOPMENT

Mathematical and numerical procedures for computations of wave forces on slender members like columns and pontoons of TLPs are well-known in the literature. Burrows et al. (1992) showed that mean sea state estimates of the Keulegan-Carpenter number (K_c) in the range 2.5 to 8.5 are representatives of the conditions where inertial loading is pre-dominant. However, variation of inertia coefficient (C_m) covering higher range of K_c values along the water depth is limited to few experimental investigations. Therefore, in this study, variation of C_m along the water depth is analytically modeled and its influence on the wave force on vertical cylinder is examined.

Variation of inertia coefficient (C_m)

Variation of C_m along water depth is idealized as a two degree curve with the function values known at the extreme points namely: i) at the sea bed; as well as ii) at MSL. The inertia coefficients adequate to cover deep-sea state vary generally from 1.6 to 3.0 for $C_{m,sea\ bed}$ and 0.6 to 2.5 for $C_{m,MSL.}$ Two appropriate hydrodynamic conditions are chosen namely: i) shallow water; and ii) deep water to examine the influence