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Random Wave Force on Horizontal Members

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ABSTRACT

This paper deals with wave force on a horizontal structural member located near still-water level. The waves are treated as unidirectional long-crested deep-water zero-mean Gaussian random waves of arbitrary bandwidth propagating perpendicular to the axis of the member. The forces considered are the slamming, drag, inertial and buoyancy forces. The effect of intermittent submergence of the member in water due to fluctuation of the wave surface is also considered. The statistical properties obtained are the mean value, mean square value and spectrum of wave force.

INTRODUCTION

Many offshore structures are of the steel jacket type with horizontal members located some distance above still-water level, as shown in Fig. 1. These members experience no direct wave action unless the wave crest reaches them. For structures built 20 to 30 years ago, more often than not these members were designed without due consideration given to direct wave action. Due to subsidence, however, the gap between still-water level and level of the member may be reduced. Furthermore, as more and more wave data become available, statistics shows that original wave heights may have been underestimated. Thus, the American Petroleum Institute has required owners of all existing offshore structures of the type mentioned to submit evidence that these horizontal members remain safe under wave loading.

Wave force on a horizontal member is usually considered to consist of three parts. At the instant of contact by waves from below, the member experiences a slamming force. As water level continues to rise, the member is subjected to a Morison-type wave force. In addition, there exists a buoyancy force. Determination of both the slamming force and the Morison force is not without difficulties. For the slamming force, the difficulty is primarily due to the fact that the slamming force coefficient is sensitive to possible movement of slender and flexible members. For the Morison force, the difficulty stems from the lack of symmetry of the vortices shed, and hence the determination of the values of drag and inertia force coefficients, unlike in the case of wave force on vertical members (Chaplin, 1991).

Based on the work of Sarpkaya (1978), Kaplan (1974) and some others, for prescribed values of force coefficients, Isaacson and Subbiah (1990) set out to examine some statistical properties of vertical fluid force on horizontal members located in the splash zone. They considered waves as long-crested, stationary, linear Gaussian, nonbreaking and narrow-banded, propagating perpendicular to the axis of a rigid horizontal member of uniform circular cross-section. The vertical fluid force consisted of three components. The slamming force, F_s per unit length of the member, at the instant of wave impact, is:

$$F_S = K_S w^2 \tag{1}$$

where $K_S = \rho D C_S/2$, ρ is the mass density of water, D is diameter of the cylinder, C_S is a slamming coefficient and w is the vertical fluid particle velocity evaluated at the position of the member at the time of impact calculated using the linear wave theory.

When the member is submerged, fluid force is given by the Morison equation. Thus, per unit length of the member, the vertical force is:

$$F_M = K_d w|w| + K_m \dot{w} \tag{2}$$

where $K_d = \rho D C_d/2$, $K_m = \rho(\pi D^2/4)C_m$, $\dot{w}$ is the vertical fluid particle acceleration, evaluated at the location of the axis of the member, overdot denotes differentiation with respect to time, and C_d and C_m are respectively empirical drag and inertia coefficients.

In addition, the buoyancy force, F_b, per unit length of the mem-

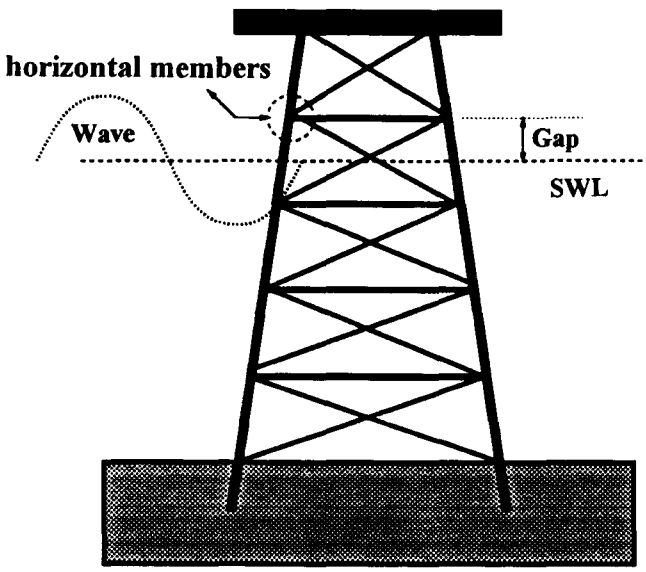

Fig. 1 A jacket-type drilling platform

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KEY WORDS: Random waves, slamming force, drag and inertial force, buoyancy force, horizontal members, intermittent submergence, mean, mean square, spectrum.