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Effects of Free Surface Fluctuation on Total Wave Force on Structures

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ABSTRACT

This study is concerned with the effect of free surface fluctuation on total wave force on the columns of a rigid platform. The waves are treated as long-crested with narrow-band spectrum and the wave forces are computed using Morison's formula. The mean and the standard deviation of the total wave force are obtained. The results show that free surface fluctuation is an important factor to be considered if the structure under consideration is in shallow water. While the spacing between the columns does not affect the mean value, it does affect the standard deviation of the total wave force in a significant way.

INTRODUCTION

Consider a point such as P in Fig. 1, fixed in space at the still water level. In the presence of a wave train, due to fluctuation of the surface, the point may be immersed at time $t^* = t_1$, but out of the water at time $t^* = t_2$. Thus, the wave-induced fluid particle velocities, accelerations (kinematics), pressure (dynamics) and force at the point only assume nonzero values intermittently. For example, consider a long-crested unidirectional linear monochromatic wave train in water of finite depth h^*. The surface displacement is given by:

$$\eta^*(x,t^*)=a^*\cos\chi^* \tag{1}$$

where a^* is wave amplitude,

$$\chi^*=k_o x-\omega_o t^*+\phi \tag{2}$$

ϕ is phase angle, ω_o is wave frequency, and k_o is wave number related to ω_o by the dispersive relation:

$$\omega_o^2=gk_o\tanh\alpha_o \tag{3}$$

g is gravitational acceleration, and $\alpha_o = k_o h^*$ is local water-depth parameter. The horizontal fluid particle velocity is given by:

$$u^*(x,s^*,t^*)=\frac{gk_o}{\omega_o}Z^*(k_o s^*)\eta^*(x,t^*) \tag{4}$$

$$Z^*(k_o s^*)=\frac{\cosh k_o s^*}{\cosh\alpha_o} \tag{5}$$

where s^* is vertical coordinate considered positive upward with origin at seabed. At point P, $u^*(x,s^* = h^*,t^*)$ is a continuous function of time t^*. However, in time intervals when $\eta^*(x,t^*)<0$, the point P is out of the water and there can be no fluid particle velocity at the point. Hence, the horizontal particle velocity as a function of time is actually discontinuous.

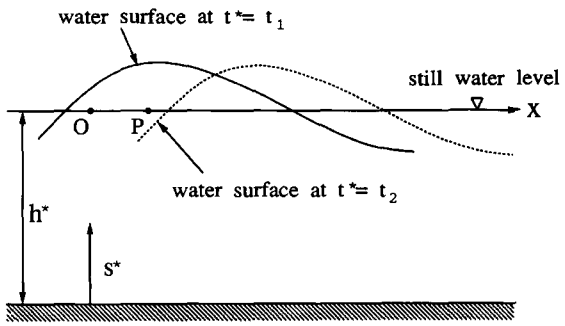

Fig. 1 Sketch of water surface

The effect of free surface fluctuation on statistical properties of the kinematics and dynamics of a random wave field was first studied by Tung (1975a, 1976, 1977), Pajouhi (1975), Pajouhi and Tung (1975), Satyanarayana and Elango (1983), and on those of wave forces on small bodies by Tung (1975b), and by Pajouhi (1975) for linear Gaussian waves. Later, the investigation was extended to nonlinear wave motions (Anastasiou, 1982; Tung and Huang, 1984, 1985). Recently, there has been renewed interest in the subject. Thus, the effect of free surface fluctuation on statistical properties of wave forces on small bodies was studied by Isaacson (1991), Isaacson and Baldwin (1991a,b) and Isaacson and Subbiah (1991).

In all the aforementioned studies of wave forces, attention has been focused on forces on elements of a rigid vertical cylinder using Morison's formula for evaluation of wave forces. It was shown that free surface fluctuation has profound influence on wave forces at points above and below in the vicinity of the still water level. For a structure modeled as a vertical cylinder extending from the seabed to above the still water level, the relevant design force would be the integral of all the element wave forces from the sea bottom to the surface of the water. The effect of free surface fluctuation on the total wave force on such a structure was recently studied by Tung (1995).

In many cases, a structure may not be adequately modeled by a stick structure. For example, the distance between the columns of a platform may be comparable to the characteristic wave length. In that case, the sum of the integrated wave forces on the columns on the platform will depend on the spacing between the columns. It is natural to inquire whether or not the free surface fluctuation phenomenon would have any effect on the statistical properties of

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KEY WORDS: Random waves, wave forces, Morison's formula, rigid vertical columns, free surface fluctuation.