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Effects of Sloped Bottom and Unsteady Load Motion on Deflections of Floating Plate

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ABSTRACT

This paper studies the three-dimensional unsteady problem of the hydroelastic behavior of a floating infinite plate under the impact of waves generated by moving loads on ice plate in conditions of sloped bottom. An analytic solution of the problem is found by integral transformations and asymptotic expansions. The amplitude is analyzed for various values of bottom slope, basin depth, plate thickness, vehicle length, deceleration and acceleration coefficients.

INTRODUCTION

The topic of moving loads on floating elastic plates is of interest in a number of practical applications: floating platforms, ice fields and so on.

There are a number of papers devoted to the impingement of waves on a floating plate or the motion of a load on ice cover (see Squire, 2008 and Squire et al, 1996, and the references therein). It is known that the flexural-gravity waves occurring during the load motion reach their maximum amplitude at critical velocities. Deceleration and acceleration of load introduce special difficulties. It is interesting to analyze an effect of sloped bottom and deceleration (acceleration) of load on plate deflection to prevent possible plate breakup.

We note that the effect of the bottom topography has recently been investigated in the linear problem of the scattering of periodic surface waves by a floating elastic plate (Wang and Meylan, 2002; Sun et al, 2003; and Kyoung et al, 2005) on the assumption that the liquid flow and the plate deformation are periodic functions of time. Sturova (2008) investigated the behaviour of the plate for different actions and shapes of bottom irregularities. The ship motion over sloping bottom has been considered by Buchner (2006), Ferreira and Newman (2008). Kim et al (2010) considered the motion of floating barge and a LNG carrier in sloping bottom.

The purpose of the present study was a theoretical analysis of the effect of the plate thickness and the depth, velocity of rectilinear motion, and bottom slope on the amplitude of deflection of the plate floating on the fluid surface.

MATHEMATICAL FORMULATION

We consider an infinite elastic, originally unstressed homogeneous isotropic thin plate floating on the surface of a fluid. The load q' moves at a velocity $U(t')$ over the plate, here t' is the time. The coordinate system is located as follows: the plane $x'Oy'$ coincides with the unperturbed plate-water interface, the x' direction coincides with the direction of motion of the load, and the z' axis is directed vertically upward. It is assumed that water is an ideal incompressible fluid of density ρ_2. We assume that the motion of liquid is potential, where $\Phi'(x', y', z', t')$ is the liquid velocity potential function satisfying the Laplace equation $\Delta\Phi' = 0$. The plate has density ρ_1 and thickness h. We consider a sloping bottom $H = H(x')$, here H is the basin depth without the ice submergence depth in static equilibrium.

To obtain an analytical solution of the problem, we make the formulation dimensionless. For this, we introduce the characteristic dimension – the basin depth H_0 at the time $t' = 0$ corresponding to an initial location of load center $x' = y' = 0$ – and consider the following dimensionless variables:

$$x = x'/H_0, \quad y = y'/H_0, \quad z = z'/H_0, \quad u = U/\sqrt{gH_0} \tag{1}$$

$$t = t'\sqrt{\frac{g}{H_0}}, \quad \Phi = \frac{\Phi'}{H_0\sqrt{gH_0}}, \quad q = \frac{q'}{\rho_2 g H_0}$$

Then we assume that a basin depth has the form $H = 1 - \tanh(\gamma x)$, where $\dfrac{\gamma}{\cosh^2(\gamma x)}$ is the bottom slope, γ<<1. Note, that the bottom slope $\dfrac{\gamma}{\cosh^2(\gamma x)} \approx \gamma$ for γ<<1. We introduce new coordinates:

$$\xi = x - s(t), \quad \eta = y, \quad \zeta = z/(1 - \tanh(\gamma x)) \tag{2}$$

Here *s(t)* is dimensionless distance traveled by the vehicle. New