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Nonstationary Movement of Load Along Ice Cover

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ABSTRACT

A dynamic problem on ice cover bending under moving concentrated load is presented with numerical examples. By choosing the proper function to represent the liquid motion potential, the assumed three-dimentional problem is reduced to the two-dimentional one. Equations for ice plate bending are obtained. The algorithm of a numerical solution to these equations is based on the finite element method and the method of finite differences. Two variants of the initial condition assignment are studied. The presented method offers ample score to apply the stated problem to any law of ice motion of load.

INTRODUCTION

Investigations of the stress-strain state in moving various kinds of loads along ice cover enable one to solve a number of applied ice engineering problems. Two types of such problems are, in our opinion, of considerable interest. First, there are some problems connected with studying the resonance method potentialities of ice breaking that is done by exciting the bending-gravitational waves of sufficient amplitude in this ice cover (Zhyostkaya and Kozin, 1994). Second, there are also problems of estimating the carrying capacity of ice cover used as a carrying platform.

Extensive investigations have been carried out to solve the problems under conditions of subjecting the endless solid ice cover to a stationary movement of load. A number of experimental works done in the field should be mentioned. As far back as 1929 S.A. Bernstein (1929) published some investigations concerning the definition of ultimate loads on freshwater ice. Later 1940s studies of the ice cover response to moving load resulted in defining the wave character of the ice oscillations and possibility of dangerous resonance phenomena (Zubov, 1942), the existence of the load velocity (critical, or resonance velocity) at which ice cover deflection increases dramatically (Bregman and Proskuryakov,1943). Learning ice breaking under moving load Ivanov, Kobeko and Shulman (1946) recorded for the first time ice cover deflections under some moving loads. There are also recordings of experimental data on ice oscillations under moving loads in the work by Ivanov and Peschanskii (1949). Then Lecourt and Kotras (1975) obtained experimental curves of ice deflections depending on the speed of the Arctic hovercraft (ACV) along modelled ice. Gold (1977) carried out research on ice oscillations due to moving loads. Works by Takizava (1985) and Squire, Robinson, Haskell and Moore (1985) are worth noting among the recent investigations on bending-gravitational waves arising under moving load.

Theoretical investigations of ice response to moving loads appeared rather early as well. Golushkevich contributed to the research in the field of water wave-movement effects caused by moving and impulse loads along ice on ice cover oscillations (Golushkevich, 1947). Kheisin (1967) considerably enlarged the study of the problems, further developed in the papers by Squire, Hosking, Kerr and Langhorne (1996).

The application of available solutions becomes more complicated if one has to take into consideration the actual ice conditions, like the confined water area, existence of ice hummocks, openings, cracks, etc. There is no possibility of making calculations of moving loads along a curved path by means of the solutions mentioned above either. We tried to overcome the present difficulties by a numerical solution to differential equations for ice cover oscillations with allowance made for nonstationary movement of load.

GOVERNING EQUATION

As the main mathematical functions modeling the problem, (Zhyostkaya and Kozin, 1994), the governing equation for viscoelastic ice oscillations under the moving concentrated force P is:

$$\frac{Eh^3}{12(1-\nu^2)}\left(1+\tau_f\frac{\partial}{\partial t}\right)\nabla^4 w+\rho_w g w+\rho_i h\frac{\partial^2 w}{\partial t^2}+\rho_w\left.\frac{\partial \Phi}{\partial t}\right|_{z=0} = -P\delta\big(x(t),y(t)\big) \qquad (1)$$

where $x(t)$ and $y(t)$ are the coordinates of the point of application P; Φ satisfies Laplace equation;

$$\nabla^2\Phi = 0 \qquad (2)$$

and the boundary conditions on the basin bottom and on the ice-water boundary

$$\left.\frac{\partial \Phi}{\partial z}\right|_{z=-H} = 0, \qquad (3)$$

$$\left.\frac{\partial w}{\partial t}-\frac{\partial \Phi}{\partial z}\right|_{z=0} = 0, \qquad (4)$$

where Φ = liquid movement potential, w = ice bending deflection, E = Young's modulus, ν = Poisson's ratio, h = ice cover thickness, H = basin depth, ρ_i, ρ_w = ice and water density, g = gravitational acceleration, τ_f = strain relaxation time, and δ = dirac delta function.

The coordinate x and y axes lie in the ice plate, the x-axis being directed towards the load moving, while the z-axis goes upwards. Force P directed downwards is considered positive.

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