Formation of the Ice Cover's Flexural Oscillations by Action of Surface and Internal Ship Waves — Part I. Surface Waves

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ABSTRACT

The ice cover's three-dimensional flexural deformations formed by surface and internal waves are considered when the disturbance generator is moving. The investigation is based on the linear equations of movement of the continuously stratified fluid of finite depth under the nonleaking conditions at the basin's bottom, and nonseparating oscillations of the floating ice cover. Expressions for the ice bend amplitudes are obtained by using the integral transform method. Their investigation is carried out by using the contour integration method with subsequent numerical analysis.

The first part of the paper is devoted to the investigation of the ice flexural deformations caused by surface waves in the case of an axially symmetric pressure area of constant intensity moving over the ice. An analytical solution allowing the investigation of induced disturbances at each distance of the pressure epicenter is obtained here. A quantitative analysis of dependence of spatial distribution of the ice bend amplitudes before the moving generator, in its near vicinity and in the wave afterwake, on the characteristics of both generator and ice cover, is carried out on the basis of the obtained solution. The critical values of the load displacement speed, bend profiles, and flexural strains of the ice along the pressure displacement track are compared with known experimental results.

INTRODUCTION

The mastering of the polar regions of the world ocean amplified the necessity of investigations in the domain of ice cover dynamics. In particular, the problem of response of the floating ice on the moving disturbance generators became acute. A series of studies has been devoted to solving such a problem. In this connection, the moving perturbation's generator was assumed to be a planar front, as well as a bounded pressure area of constant or variable intensity.

The first theoretical description of the dispersion relation for the surface waves in an ice-covered basin was obtained by Greenhill (1887).

Wilson (1958), Kheisin (1962), Dotsenko and Cherkessov (1977), Bates and Shapiro (1981), Bukatov (1980b), Bukatov and Mordashiov (1981), Schulkes and Sneyd (1988) considered the generation of planar flexural-gravity waves by the moving pressure of constant intensity. An analogous investigation in the case of the pressure of variable intensity was accomplished by Bukatov and Cherkessov (1969, 1977) and Bukatov (1980a,c). Duffy (1991) considered the generation of planar flexural-gravity waves by moving and vibrating load, taking into account the inertia forces caused by the load's vertical accelerations.

A theoretical study of the dependence of the deflection depth under the axially symmetric load on its displacement speed was carried out by Kheisin (1967), Nevel (1970), Kozin (1985), and Bukatov and Zharkov (1988). In particular, Kheisin (1967) and Nevel (1970) considered the deflection change caused by the transfer over the critical speed value being equal to the minimum of the phase velocity of the free flexural-gravity waves. A theoretical estimation of the influence of compressing forces on this critical speed value was given in the case of uniform ice compression

by Bukatov (1980b), Kerr (1983), Bukatov, Cherkessov and Yaroshenko (1984), and Schulkes, Hosking and Sneyd (1987); in the case of the nonuniform one, by Bukatov, Zharkov and Zav'yalov (1991).

The phase structure of the ice cover's three-dimensional flexural oscillations caused by a moving constant pressure area was investigated by Davis, Hosking and Sneyd (1985), Schulkes, Hosking and Sneyd (1987) and Bukatov, Zharkov and Zav'yalov (1991). These authors used a method of ascertainment of connection between the phase characteristics of waves and the features of the hodograph of the wave vector. Such a technique was described in a monograph (Lighthill, 1978). Similar studies of the three-dimensional ice flexural oscillations were carried out without taking into account the ice compression by Dotsenko (1976), and with consideration of the compressing forces by Bukatov, Cherkessov and Yaroshenko (1984), although investigations described in these papers were based on the stationary-phase technique. In addition, they studied the dependence of the angular zones of disturbances formed by the flexural-gravity waves, and the longitudinal and transversal zones formed by the ship-type waves, on load displacement speed and ice conditions. An asymptotic analysis of the unsteady ship waves under the ice conditions was carried out for the pressure of constant intensity by Dotsenko (1978), Bukatov and Yaroshenko (1984), and for the time-oscillating one by Bukatov and Yaroshenko (1986). The influence of the ice cover's viscosity on the bending vibrations caused by the moving load of constant intensity was estimated by Hosking, Sneyd and Waugh (1988), and Bukatov and Solomakha (1994).

The results of experimental studies of the ice bend near the load displacement track (Kobeko, Ivanov and School'man, 1946; Eyre, 1977; Beltaos, 1979; Haspel et al., 1981; Squire et al., 1985, 1987; Takizawa, 1985, 1988) are on the whole in agreement with theoretically predicted results.

However, the possibilities of the use of mentioned models to investigate the spatial distribution of the ice bend caused by surface waves are restricted. These models may be used either within subcritical range of the load displacement speed (to simulate the