Ice Plate Deflections Generated by Point Source in a Current

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ABSTRACT

Flexural-gravity waves generated by point source in liquid under an ice sheet are considered under the assumptions of linearized theory. There is an underlying current in the liquid. It is assumed that liquid is an ideal and incompressible and its motion is potential. The ice sheet is modeled by an initially unstrained elastic, homogeneous, isotropic plate. The analysis is carried out by using Fourier and Laplace integral transforms. The solution for ice plate deflections, received in the integrated form, is analyzed numerically depending on various values of current speed, ice plate thickness, submergence depth, and basin depth. It is obtained that the flexural-gravity wave height depends on current speed for small basin depth. For large basin depth the current effect on ice plate deflections is negligible.

KEY WORDS: ice plate, flexural-gravity waves, current, incompressible liquid.

INTRODUCTION

There are many investigations devoted to interaction of waves with very large floating structure (VLFS) or an ice sheet in recent decades (Squire, 2008). It is known that the ice sheet and VLFS can be modeled as a thin elastic plate floating on liquid surface. The presence of uniform underlying current can change flexural gravity wave characteristics such as wavelength, wave height, and wave period and so on.

Bukatov (1980) studied the combined effect of current and compressive force on the generation of time dependent transient flexural gravity waves due to the presence of time harmonic normal stresses acting on the free surface using the Fourier transform method in a homogeneous fluid of constant density in finite water depth. It was observed that the basic characteristics of flexural gravity waves, generated by time harmonic pressure moving over the ice plate, depend on the velocity of current, frequency of oscillation of the stress acting on the plate surface and the magnitude of the compressive force.

Bhattacharjee and Sahoo (2007) considered the flexural gravity wave interaction with uniform currents in two dimensions in water of both finite and infinite depths. Bhattacharjee and Sahoo (2008) analyzed the generation of flexural gravity waves due to initial disturbance (initial impulse to the velocity potential, the initial surface elevation, and the initial velocity of the ice sheet) in the presence of uniform current. Using the method of the stationary phase, asymptotic results of the surface deflection are obtained for large values of the space variable (in the horizontal direction) and of time.

Mohanty et al. (2014) considered a combined effect of current and compressive force on time-dependent flexural–gravity wave motion in both cases of single and two-layer fluids in two dimensions.

Lu and Yeung (2015) considered a combined effect of current and impulsively-starting surface and submerged concentrated loads in a fluid on flexural–gravity wave motion in two and three dimensional cases. It is shown that the analytical solution, obtained by the Laplace–Fourier integral transform, consists of steady-state and transient responses. For the steady response, an explicit expression is further derived by the residue theorem, while the transient response is obtained by the stationary-phase method.

In the present paper, a combined effect of current and submerged point source on the gravity wave interaction with floating ice sheet is analyzed in time-domain under the assumption of small amplitude water wave theory. Analytical solution for ice plate deflections, obtained by the Laplace–Fourier integral transform, is analyzed numerically for various values of time, distance, current speed, and basin depth.

MATHEMATICAL FORMULATION

Let us consider an infinite homogeneous elastic ice plate floating on a surface of an ideal incompressible liquid. The plate is in the state of rest and is subjected to an impulse from a submerged point mass source at time \(t=0\). The coordinate system \(Ox'y'z'\) is arranged as follows: the \(Ox'\) axis coincides with the unperturbed ice-water interface, and the \(Oe'\) axis is directed vertically upwards. The mass impulsive source of strength \(Y_0\delta(t)\) is situated at point \((\theta, -d')\). The flow of fluid of density \(\rho_2\) is assumed to be irrotational. In addition, it is assumed that there is a uniform current flowing with speed \(U\) along the positive direction \(Ox'\) axis.