Study on Wave Diffraction from a 3D Box in a Two-layer Fluid by Time-domain Approach

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ABSTRACT

The wave diffraction from a box in a two-layer fluid was studied by time-domain approach. The Rankine source is used in the upper layer to establish the boundary equation. While the Rankine source and its images are adopted in the lower fluid. Through the construction of a boundary element method; time-domain approach function by velocity potentials of upper and lower velocity potentials on the internal surface, a single set of linear equations are set up to compute the time histories of wave forces and wave profiles by using a fourth-order Runge-Kutta method. The comparison results with other numerical method demonstrate the validity of this method.

KEY WORDS: Wave diffraction; two-layer fluid; higher-order boundary element method; time-domain approach

INTRODUCTION

In the real ocean, density of sea water is changing due to the variations in temperature and salinity in the water depth direction. We usually simplify this complex situation as a two-layer fluid model in the ocean with density stratification. In this model the density of fluid above and below the interface is approximately constant. In this paper we also focus on this two-layer fluid.

The internal waves will be generated on the interface between the two fluid layers with different types such as incident solitary wave and periodic wave. For internal solitary wave the wave length is much longer than the characteristic length of structure. So the internal solitary wave forces acting on structures can be simulated only by Morison formula (Cheng et al. 2004; Song et al. 2011). For the other typical harmonic internal waves, the wave length is over a wide range. The diffraction/radiation theory should be adopted when the characteristic length of structure is relative large.

Incident harmonic waves in a two-layer fluid can propagate with two different wave numbers for a given frequency, corresponding to the surface-wave mode and internal-wave mode, respectively. For the internal wave interaction with structures, for simple structures the multipole expansion method was adopted. Linton and McIver (1995) studied the horizontal cylinders interacted with waves in two-layer fluids. Cadby and Linton (2000) extended this method to study three-dimensional scattering problem. Sturova (1999) solved the diffraction and radiation problems of a horizontal cylinder which located under the interface. Das and Mandal (2010) also used this method to study the radiation problems by a submerged sphere in a two-layer fluid with an ice-cover. You et al. (2007) calculated the radiation and diffraction of water waves by a vertically floating cylinder in a two-layer fluid of finite depth by using eigenfunction expansion method, the wave exciting forces for a floating circular cylinder due to incident waves of both surface- and internal-wave modes was presented. For the limitation of the analytical method, the numerical methods were developed also. Ten and Kashiwagi (2004) and Kashiwagi et al. (2006) derived the time-harmonic Green’s function and studied 2D radiation/diffraction problems respectively in a two-layer fluid of finite depth by a boundary integral-equation method. Yeung and Nguyen (1999) derived the Green source in a two-layer fluid of finite depth for 3D problems to use the boundary integral equation method, and then unsteady source was derived by Nguyen and Yeung (2011).

To author’s knowledge, most of the studies of the interaction between internal waves and structures are based on analytic method or three-dimensional source method. Because of the limitation of analytic method, it couldn’t be used in practical engineering. For source method the complex wave Green function in two-layer fluid should be calculated. Therefore, developing a numerical method which is easy to implement to study the wave interactions between internal waves and structures has important significance.

In this present work, a time-domain higher-order boundary element method (THOBEM) was developed for internal wave diffraction from a 3-D body located in the upper layer fluid. Integral equation in the upper and lower fluid domain are derived by applying the Green’s second identity to simple Rankine source and velocity potential in each layer respectively. By the construction of a function on the interface, a single set of linear equations are set up to compute the time histories of wave forces and wave profiles by using a fourth-order Runge-Kutta method. An artificial damping layer is adopted to dissipate the scattering waves on both free surface and interface. The internal wave force and moment on a rectangular box are calculated and compared with published numerical results which obtained by Green source method. Through the comparison, a relatively good agreement was found. Some other