On the interaction between random waves and a freely floating body in a fully nonlinear numerical wave tank

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ABSTRACT

A fully nonlinear interaction between random waves and a freely floating body is investigated by a fully nonlinear numerical wave tank (NWT) based on boundary integral equation method (BIEM). In this model, a linear element method is adopted to solve the boundary integral equation, and subsequently the nonlinear free surface is traced by Mixed Eulerian-Lagrangian method (MEL) with a cubic spline scheme and a 4th order Runge-Kutta method. In addition, a JONSWAP random wave is generated by a feeding function based on the Stokes wave theory and the superposition principle for linear waves, and two damping zones are implemented on both ends of NWT to absorb reflected waves scattered by the floating body and to dissipate the transmitted wave energy passing over the body. The hydrodynamic forces are calculated by an acceleration potential method developed by Tanizawa (1995) and a mode-decomposition method. The results of the test of numerical wave generation show that this model is suitable for long time simulation with the reflection coefficient only about 4% for random waves. For regular wave cases, the simulated results show well agreement with linear solution and other numerical models. Finally, we found that if the results of body motions induced by regular waves are multiplied by 1/4, then their comparisons with that of random waves show a good agreement. Moreover, the results of drift force from both regular and random waves have similar trends except at the resonance region.

KEY WORDS: random waves; freely floating body; boundary integral equation method; acceleration potential method; mode-decomposition method; fully nonlinear numerical wave tank.

INTRODUCTION

Floating body is one of the most common applications for the offshore structure, for example: floating breakwaters, cage aquaculture and ship moorings etc. In the past decades, the nonlinear effect of wave-body interaction has become a popular research topic since the calculating capability of computer has made a long way. However, the studies of wave-body interaction due to random waves are still rare. Therefore, developing a numerical model to investigate this interaction problem is the main objective of this paper.

Since 1976, applications of the boundary integral equation method (BIEM) to a fully nonlinear numerical solution for inviscid water waves has become extremely successful, e.g. Longuet-Higgins and Cokelet (1976); Cointe (1990); Grilli and Svendsen (1990); Tanizawa (2000); Huang et al. (2007). This method is achieved by directly solving the Laplace equation with the fully nonlinear free surface boundary conditions. The advantages of applying the BIEM are firstly no limitation to water depth and to wave height as long as the breaking wave does not occur; secondly, it simplifies the computational matrix by reducing a two-dimensional problem to a one-dimensional problem. Recently, Boo (2002) developed a time-domain higher-order boundary element scheme to simulate the linear and nonlinear random waves and diffractions due to a structure. Zhang et al. (2006) proposed a new approach for generating random waves, and the comparison between simulated and input random wave spectra showed a well agreement.

On the other hand, the diffraction and radiation problems with a freely floating body have been studied by numerous researchers, e.g. Nojiri and Murayama (1975) performed an experimental study; Tanizawa and Minami (1998) and Koo and Kim (2004) developed a numerical model based on a boundary integral equation method to deal with these problems.

In this paper, the hydrodynamic properties are calculated by both the acceleration potential method (Tanizawa, 1995) and the mode-decomposition method (Vinje and Brevig, 1981). The simulated results under regular waves as well as random waves are presented in this article.

NUMERICAL MODEL

Governing equation

Fig. 1 is a definition sketch of a freely floating body in a numerical wave tank where the water depth h is held constant. Two numerical damping zones are deployed at both sides of the wave tank to dissipate reflected and transmitted waves. The fluid is assumed to be incompressible, inviscid and irrotational. Thus the velocity potential satisfies Laplace equation

$$\nabla^2 \phi = 0 \tag{1}$$