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Numerical Analysis of Floating-Body Motions in Finite Depth

Taeyoung Kim and Yonghwan Kim
Dept. of Naval Architecture and Ocean Engineering, Seoul National University
Seoul, Korea

ABSTRACT

This study aims the investigation of depth effects in the motion response of floating structures. To this end, a Rankine panel method adopting higher-order B-spline basis function is applied in time domain. The topology of sea bottom is assumed to be either constant or varied. Taking the advantage of the Rankine panel method, any bottom topology near floating structures can be considered by distributing the solution panels on the bottom surface. The numerical analysis includes the radiation, diffraction problems and floating motion responses for typical hull forms, e. g. LNG carrier and barge. The result is compared with other numerical solution for validation purpose. The motion RAOs are observed for different water depth and varying bottom topology.

KEY WORDS: Finite-depth effects; offshore structures; Time-domain analysis; Rankine panel method; Sloping bottom

INTRODUCTION

Recently moving inland facilities into coastal area is seriously considered. In coastal area, water waves and floating-body motion have different property by restricted water depth. Therefore considering bottom effect is important to predict the motion responses of such coastal platforms.

The motion responses of floating bodies in constant depth have been considered as one of classical problems in marine hydrodynamics, and several methods have been introduced. For instant, strip method has been utilized by Tuck (1970), Tasis et al. (1978), Andersen (1979), Perunovic and Jensen (2003). This method is still used nowadays for practical purpose, however it has limitation as a two-dimensional theory. To complement such limitation, Kim (1999) introduced a new unified theory for the finite-depth effect, showing much improved accuracy. Nowadays, three dimensional panel method programs such as WAMIT (Lee, 1995), which contains solution procedure for constant depth, are available.

In recent, many research focus on the floating body motion over a actual coastal seabed. Sloping bottom is a simple but realistic description of nearshore area. Kyoung et al. (2005), Belibassakis and Athanassoulis (2009) solved elastic body response over various sloped bathymetry. For an offshore structure, Teigen (2005) has showed motion responses of floating barge over constant and sloped bottom. Ship motion over sloping bottom has been considered by Buchner (2006), Ferreira and Newman (2008) and Hauteclocque et al. (2009). To solve the ship motion, they have used panel method and have treated sloped bottom as extra body. However, this second-body approach is not a complete formulation in diffraction and radiation problems. As they already mentioned, strong wave diffraction forbids an accurate motion analysis.

In this study, to observe bottom effects, floating-body motions in constant depth and in sloping bottom are simulated in time domain by using a Rankine panel method. The present method applies a B-spline basis function for physical parameters, e.g. velocity potential and wave elevation. In this paper, the free surface boundary conditions are limited to linear regime. The computational models are a floating barge and a LNG carrier. Hydrodynamic coefficients, wave excitations and motions responses are compared in different constant water depths, and all the results show good agreement with the results of unified theory. In the sloping-bottom problem, it is shown that motion responses show similar tendency with the result of constant water depth, particularly the water depth in the midship. The present numerical method can be applied in arbitrary bottom topology, and so a more thorough study is expected in near future.

In this study, in order to simulate more accurate wave propagation in varying bottom, the concept of numerical wave tank is applied. Two different methods are used for wave generation. At first, following Boo et al. (1994), the solution of linear incident wave is fed at inflow boundary. Numerical damping zone is also utilized for wave absorption and generation. In the second trial, free surface boundary condition is modified by including incident wave component, adopting the idea of Ferrent (1998).

BACKGROUND

Even bottom problem (Constant water depth)

Let's consider a freely-floating body under 6-DOF motion in the presence of incident waves, as shown in Fig. 1. From Newton's second law, the linear equation of motion can be written as Eq. 1. Here, $\{\xi\}$ means the displacement vector of 6-DOF ship motion. $[M]$ is a mass matrix and $[C]$ is a restoring coefficients matrix. In