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Time Domain Analysis on Hydroelastic Response of VLFS Considering Horizontal Motion

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ABSTRACT

A time domain analysis on the hydroelastic deformation of a pontoon-type very large floating structure (VLFS) is investigated considering horizontal motion effect. In our previous study on time domain analysis, the only vertical motion of VLFS has been considered in the analysis of hydroelastic responses, which is appropriate for operational condition. But in the state of survival condition, the horizontal motion coupled with the hydroelastic response would be very important to design the mooring system of VLFS. In the present study, a three-dimensional free surface flow with the fully nonlinear free surface conditions is formulated in the scope of potential flow theory. A finite element method based on the variational principle is employed both for fluid motion and structural response. Elastic response of VLFS is analyzed by Mindlin plate model. The only surge motion is considered as the horizontal motion for numerical simplicity.

KEY WORDS: Hydroelasticity; Horizontal motion; Finite element method; Nonlinear free surface; Potential theory; Time domain analysis.

INTRODUCTION

Researches and technology developments of VLFS have been carried out for various applications such as floating airport, terminal and military utilities. For the operational safety and reliability, it is of great importance to investigate the dynamic response of VLFS due to harsh environments at the sea. Recently, global warming seems to cause the disastrous weather conditions such as typhoon and hurricane occur frequently in the coastal area. Therefore the survivability of VLFS in the extreme wave condition should be investigated as one of important considerations. Such an extreme condition requires time domain analysis to investigate the dynamic response of VLFS due to strong nonlinearity occurring under such an extreme condition. Reviews on the hydroelasticity of VLFS (Watanabe et al., 2004; Kashiwagi; 1998,1999) mentioned that more studies on hydroelastic response of VLFS under highly nonlinear waves. In those extremely nonlinear wave conditions, it is important to estimate the mooring force to ensure safe mooring system. In the past decade, some approaches were proposed to estimate drift and mooring forces. Takagi(1996) have investigated mooring force and elastic deformation of a VLFS induced by tsunami waves. Liu et al.(2001) have carried model experiment in two dimensional wave tank and proposed a practical prediction of tsunami induced mooring force on a flexible floating structure. Masuda et al.(2003) have also studied hydroelastic response of floating structure under various tsunami wave conditions by both model experiment and numerical computation using 2D BEM. A practical estimation was proposed by Takagi et al.(2002) for wave drift force and moment acting on a VLFS of arbitrary geometry. Utsunomiya and Watanabe(2001) studies breakwater effect on drift force on VLFS.

In the previous researches, estimations on mooring force by tsunami wave were made based on two dimensional numerical methods such as 2D-BEM and modified Boussinesq equation. But to estimate the hydroelastic response and mooring force in various conditions, more general numerical approach which can handle three dimensional case and arbitrary body geometry would be required.

In the present study, a 3-D numerical method with fully nonlinear free surface conditions considering horizontal motion of VLFS is developed in time domain. To solve the fluid flow with fully nonlinear free surface conditions, the finite-element method based on the variational formulation is adopted. Advantages and versatilities of finite element method in time domain analysis have been already reported in Kyoung et al.(2006). A pontoon-type VLFS is modeled by Mindlin plate. For the time integration of plate equation Newmark method is adopted. The interaction between fluid flow and the motion of structure is solved by 4^{th} order predictor-corrector method until the converged solution is obtained. A VLFS with dolphin-fender mooring system is considered. To consider the horizontal motion effect of VLFS, a practical approach including radiation wave is proposed.

To validate the developed numerical method, the experimental data(Kim et al., 2006) of horizontal motion and elastic response of VLFS in regular wave are compared with the computations. As another numerical computation, the elastic responses and mooring forces on VLFS are investigated by varying the wave height of solitary wave in shallow water region.

MATHEMATICAL FORMULATIONS

The Cartesian coordinate system is employed. The origin of the coordinate is located at the center of the VLFS. The *z* axis is directed opposite to the direction of gravity and the *Oxy* plane coincides with the