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Wave Response Analysis of VLFS with an Attached Submerged Plate

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ABSTRACT

This paper presents a wave response analysis of an elastic floating plate, of which a submerged horizontal plate is attached at the fore-end. The whole model is analyzed rigorously within the framework of the linear potential theory and the linear elasticity. The eigenfunction expansion matching method is employed to solve the hydrodynamic problem. The analytical results are compared with the experimental results. The agreement between the analytical results based on the linear potential theory and the experiment has been shown to be satisfactory, showing the significant effect of the submerged plate.

INTRODUCTION

For a mat-like VLFS (Very Large Floating Structure), the depth of the structure relative to its horizontal dimensions (width and length) is very small. Thus, the wave-induced responses' elastic modes of vibration in the vertical direction predominate, rather than the motions as a rigid body. It is also observed that the amplitude of the vertical deflection at the edges of the VLFS is larger than that at the inner part of the VLFS, as is shown by experiment and analysis (see e.g. Wu et al., 1995; Takagi et al., 1998).

In order to reduce such an undesirable magnification of the deflections at the edges of the VLFS, a device has been developed where a submerged horizontal plate is attached at the fore-end of the VLFS. Experimental studies have confirmed that such a device may reduce the vertical deflections of VLFS not only at their edges, but also in the inner part (Ohta et al., 1998).

In an earlier study (Utsunomiya et al., 2000), an attempt was made to reproduce the experimental results by analysis, where the radiation effect of the submerged horizontal plate is considered within the framework of the linear potential theory. In the analysis, the added mass and the radiation damping of a heaving submerged plate alone are analyzed in the open sea, and then their effects are reflected to the VLFS as an attached complex-valued mass at the fore-end. The comparison of the analytical results with the experiment has shown that such a simplified model can reproduce the reduction effect only qualitatively.

This study thus aims to construct a more precise model to reproduce the experimental results for a VLFS with an attached submerged horizontal plate. The background of the analysis is again the linear potential theory with no viscous effect. However, in this paper the model is analyzed as precisely as possible within the framework of the linear potential theory. First, we formulate diffraction and radiation potentials using the eigenfunction expansion matching method. In the analysis of the potentials, the configuration of the submerged horizontal plate is rigorously considered. The equations of motion of the elastic floating plate modeling the VLFS deflection are then formulated in the generalized modal coordinates. Finally, the solutions of the analytical results are compared with the experimental results.

FORMULATION

Basic Assumptions

Fig. 1 shows the configuration and the coordinate system for the analysis. The analyzed model corresponds to the 2-dimensional sectional model where the fluid and the structural motions in the y direction are assumed to be constant. We consider a zero-draft plate floating in the constant depth sea of H. The length of the plate is $2b$, the mass m, and the bending rigidity EI. The horizontal plate of the length $2a$ is attached at the fore-end of the floating plate at the submerged depth of d.

Assuming irrotational motions of the perfect fluid, we formulate the boundary value problem for the velocity potential $\Phi(x, z, t)$. Considering the steady state motions of the harmonically excited system at the circular frequency ω, the following expressions can be made:

$$\Phi(x, z, t) = \mathrm{Re}[(\phi_D(x, z) + \phi_R(x, z))e^{-i\omega t}] \tag{1}$$

$$W(x, t) = \mathrm{Re}[w(x)e^{-i\omega t}] \tag{2}$$

where $\phi_D(x, z)$ is the diffraction potential, and $\phi_R(x, z)$ the radiation potential; $W(x, t)$ is the vertical deflection of the floating plate, and $w(x)$ is the complex amplitude.

Radiation Potentials

First, the radiation potentials are derived as follows. In order to account for the elastic deformation of the plate, the mode method (see e.g. Newman, 1994; Wu et al., 1995) is employed. As expressed in Eq. 3, the deflection of the plate $w(x)$ is represented by a superposition of arbitrarily chosen modal functions $f_l(x)$ $(l = 1, \ldots, N)$, including both rigid body motions and elastic deformations with the modal amplitudes ζ_l. The total radiation potential $\phi_R(x, z)$ is then decomposed, using the same

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