

Nonlinear Interaction of Second Order Stokes Waves and Two-Dimensional Submerged Moored Floating Structure

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ABSTRACT

The present paper discusses the nonlinear wave deformation due to a submerged moored floating structure, and its dynamic responses. Theory is based on the frequency-domain method using the second order perturbation and boundary integral method. Theoretical development for a fixed submerged breakwater is developed for an arbitrary shaped floating structure. Validity is demonstrated by applying to an airchamber structure, which has been studied by the authors. Nonlinear effect of initial air pressure in the airchamber on the water surface profile and motion of the structure is newly formulated with Boyle's law.

INTRODUCTION

A time-domain method (e.g., Isaacson et al., 1991), based on the second order perturbation expansion and boundary integral method, has been developed to study the nonlinear properties of the floating structure-wave interaction. Although the method is suitable to solve the nonlinear wave-structure interaction problems in irregular wave field, it requires long computational time until waves and motions of a floating structure attain a stationary state by a time-stepping procedure.

On the other hand, a frequency-domain method, which is also based on the second order perturbation expansion, is also available to predict the wave-structure nonlinear interaction problems in case of regular waves, and to investigate the fundamental nonlinear characteristics of the wave-structure interaction. The frequency-domain method can be classified in three groups, that is, the methods based on 1) Green's function (Vada, 1987; McIver et al., 1990; Palm, 1991; Kioka et al., 1993); 2) Green theorem (Yoshida et al., 1989; Iwata et al., 1992a, 1992b) and 3) potential matching method with eigenfunction expansion (Massel, 1983; Yoshida et al., 1990). These methods have been applied to a fixed submerged structure such as a submerged breakwater and a horizontal circular cylinder. Regarding the nonlinear behavior of the wave-structure interaction, Iwata et al. (1992b) investigated the nonlinear wave transformation and dynamic behaviors of a semisubmerged moored floating structure with pressurized airchamber, by expanding the method suggested by Yoshida et al. (1989b) for the floating structure. This airchamber structure can control well the wave transformation and its dynamic behaviors by adjusting the initial air depth in the airchamber. In addition, it can reduce the tensile force acting on the mooring line because the action of air between the structure and the water surface within the structure (Fig. 1) acts as a buffer (Iwata et al., 1991). According to Iwata et al. (1992b), the time-independent struc-

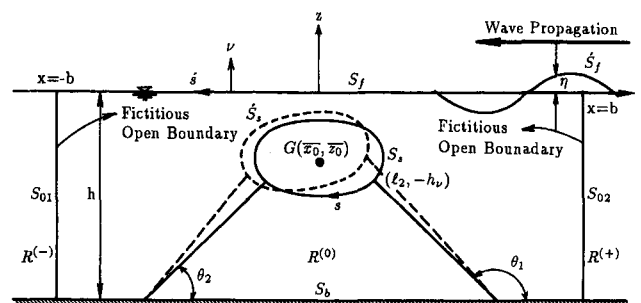


Fig. 1 Definition sketch

ture's motion and tensile force caused by the drift force cannot be ignored, and they are proportional to an increment of the first order wave reflection.

In this paper, nonlinear theory based on the frequency-domain method is newly developed to evaluate the wave deformation due to a submerged and moored floating structure with arbitrary shape, and the nonlinear dynamic responses of the structure. Theoretical formulation is made by the second order perturbation expansion and boundary integral method. Validity of the present theory is verified by comparing its results with experimental values obtained for the airchamber structure. In the application of the present theory, the second order air pressure variation in the airchamber is newly formulated by using Boyle's law, under the condition of the adiabatic process of ideal gas.

THEORETICAL FORMULATION

Boundary Condition

An arbitrary shaped floating structure is considered here in the two-dimensional wave flume of constant water depth h , as shown in Fig. 1. Fictitious open boundaries S_{01} and S_{02} at $x = \pm b$, where evanescent mode waves can be neglected, divide the fluid domain R into three regions, such as $R^{(+)}$, $R^{(-)}$ and $R^{(0)}$. The Cartesian coordinate system (x, z) is employed, in which x is measured horizontally in the direction of reflected wave propagation and z is measured vertically upward from the stillwater level. Let η_0 denote the amplitude of the first order incident wave, $k^{(1)}$ the

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KEY WORDS: Frequency-domain method, second order Stokes waves, submerged moored floating structure, nonlinear interaction, airchamber structure.