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A Direct Method Versus a Mode-Expansion Method for Calculating Hydroelastic Response of a VLFS in Waves

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ABSTRACT

A direct method for calculating hydroelastic responses of a very large floating structure (VLFS) is investigated with two different numerical schemes. The direct method means solving the integral equation for the pressure distribution beneath a structure simultaneously with the vibration equation of a freely-floating plate. In the first numerical scheme, the pressure is represented using bi-cubic B-spline functions and the structural deflection is represented by an expansion in the dry eigenmodes for bending of a uniform beam with free ends. This scheme can be shown by an appropriate transformation to be exactly the same as the mode-expansion method. The second numerical scheme adopts bi-cubic B-spline functions for representing both the pressure and the structural deflection, which is simpler and easier in coding the method. A numerical convergence test for local deflections shows that the results from the two different schemes are practically the same, and those results are in good agreement with experimental measurements. Not only the structural deflection but also the wave profile around a VLFS is computed, and the effects of hydroelastic motions on reflected and transmitted waves are discussed.

KEY WORDS: Very large floating structure, Hydroelastic responses, Direct method, Mode-expansion method, B-spline function

INTRODUCTION

Very large floating structures (VLFS) are recently considered for various purposes, such as airports, storage or manufacturing facilities, habitation, and so on. The configuration considered as an airport in Japan is of barge type, and its size is of order of 5 km long, 1 km wide, and a few meters in depth. Therefore the flexural rigidity of this type of structure is relatively small and thus hydroelastic responses are more important than the rigid-body motions. Several methods for calculating hydroelastic responses have been proposed; those are categorized roughly into the mode-expansion method (e.g. Maeda et al. (1995), Takaki et al. (1996), Kashiwagi et al. (1997), Nagata et al. (1997), and Ohmatsu (1997)) and the direct (FEM-BEM combined) solution method (e.g. Yago et al. (1996) and Yasuzawa et al. (1996)).

In the mode-expansion method, the structural deflection is represented generally by a superposition of so-called dry eigenmodes. The amplitude of each mode is determined by solving the vibration equation of a thin plate, with the added mass and damping force corresponding to specified mode shapes computed in advance. One problem in this method is that an analytical solution of the dry eigenmode, satisfying the free-end boundary conditions along the periphery of a structure, is not known. Takaki et al. (1996) obtained dry eigenmodes numerically by use of FEM. However, as shown by Newman (1994) in the analysis of a uniform beam, the structural deflection can also be represented by an orthogonal system of mathematical functions, although the convergence rate with increasing the number of modes is a little slow compared to a more conventional method using the dry eigenmodes for bending of a uniform beam with free ends (hereafter referred to as the free-free beam modes). In fact, recently, Ohmatsu (1997) and Kashiwagi (1998) confirmed for VLFS problems that a simple product of one-dimensional free-free beam modes can be used to represent the elastic deflection and appropriate free-end boundary conditions can be satisfied subsequently in the process of partial integrations in solving the vibration equation with a Galerkin scheme.

If we are not concerned with the contribution of each eigenmode but concerned with the structural deflection as a whole, the direct solution method is more lucid than the mode-expansion method. However, the direct method is generally time consuming, because the vibration equation must be solved simultaneously with the integral equation for the pressure distribution beneath a structure. In most papers based on the direct method, the vibration equation has been solved using a commercial software of FEM, and the pressure at nodal points used in FEM analyses has been determined by means of BEM; that is, the FEM has been used as a 'black box'. Therefore, the relation between the direct method and the mode-expansion method seems not clear from a viewpoint of numerical calculation scheme.

In this paper, a new direct method is studied, without relying on a commercial software of FEM, and the relation with the mode-expansion method of Kashiwagi (1998) is investigated analytically and numerically. After the mathematical formulation,