The Time-dependent Hydroelastic Response of Vertical Elastic Plate in Two Dimensions

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ABSTRACT
The time-dependent solution of the two-dimensional linear water-wave problem is presented, in which a semi-infinite fluid region is bounded on one side by a vertical elastic plate. Utilizing the mode-expansion method for the elastic deformation of structure, an analytical solution of the problem is constructed by decomposing the hydroelastic problem into three parts. Numerical experiments show that the validity of the present method by comparing it with other time domain methods.

KEY WORDS: Time-dependent; hydroelasticity; Fourier (or Laplace) transform; vertical elastic plate; mode-expansion method.

INTRODUCTION
Hydroelasticity is the study of the interaction between fluids and elastic structures. One of the earliest work on this subject is a book written by Bishop and Price (1979). In the present paper, we concern the time-dependent hydroelastic problem of a vertical elastic plate, which is motivated by trying to understand both the motion of wave forced by the vertical elastic plate and how the vibration of the vertical elastic plate is affected by the presence of the fluid. It is worth to pay attention that the wave forcing of a vertical elastic plate can be used to model a wide range of marine structures; for example seawalls, LNG tanks, and breakwaters. For this reason, the hydroelastic response of a vertical elastic plate is investigated in this paper.

The time-dependent problem for elastic bodies has attracted a great deal of attention from many researchers. Approaches to the time-dependent hydroelastic problem can mainly be categorized into three species. The first is based on a memory effect kernel and is known as the Cummins (1962) method. The second is based on a time-dependent Green function. Because of the difficulty to calculate the time-dependent Green function and solve the integral equation, the Cummins method is more popular than the time-dependent Green function method. But the Cummins method can not express the transient process and require the frequency-domain solution. Recently, an alternative solution method to the time-dependent problem, which is known as the generalized eigenfuntion method, has been proposed by Hazard and Lenoir (1993), Meylan and Sturova (2009), and Meylan (2014). The generalized eigenfuntion is rather more general than the Cummins method because it can be used to both calculate the solution of floating bodies as well as fixed bodies. Furthermore, the Fourier (or Laplace) transform method also play a important role in the time-dependent problem of elastic bodies.

The hydroelastic problem of a vertical elastic plate, which forms the right-hand boundary of a semi-infinite two-dimensional fluid domain, has not been well studied, even for frequency solution. Nevertheless, a large amount of work on the hydroelastic problem of a floating elastic plate has been made so far. Comprehensive reviews may be found in these review articles (Kashiwagi, 2000; Watanabe et al, 2004), which are mainly focused on Very Large Floating Structures, and (Squire et al, 2007), which is focused primarily on sea ice floes. Recently, the time-dependent water-wave problem for a vertical elastic plate has been highly regarded by several authors. An analytical solution of the interaction between a vertical rigid wall fixed to springs and free-surface fluids is presented by Korobkin et al (2009). Peter and Meylan (2010) developed a novel method for the time-dependent water-wave problem of a vertical elastic plate by using so called general spectral approach. Furthermore, a fully nonlinear coupled scheme is proposed by He and Kashiwagi (2010, 2012), in which the mixed Eulerian Lagrangian method is used for the free-surface fluid and the finite element method is used for a vertical elastic plate. We refer to this method as FEM-BEM method.

In the present paper, a analytical solution method for the linear wave forcing of a two-dimensional vertical elastic plate in the water of constant depth will be presented. The structure of the paper is as follows. Firstly, we present the govern equation in time domain for a vertical elastic plate, which is the right-hand boundary of a semi-infinite two-dimensional fluid domain. Secondly, utilizing the mode-expansion method for the elastic deformation of vertical plate, we give the frequency solution and propose a solution method for time domain, which is based on dividing the boundary-value problem (BVP) of water-wave scattering into three parts. By solving the three BVPs, we obtain the analytical solution of the velocity potential and the water-wave surface elevation. Moreover, the classical fourth-order Runge-Kutta method was applied to solve the coupled equation of fluid-plate motions. Thirdly, we give the relationship between the present method and the Cummins method. In the last, numerical experiments are given to confirm the validity of the present method, and conclusions are closely followed.

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