

Nonlinear Solution for Vibration of Vertical Elastic Plate by Initial Elevation of Free Surface[‡]

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Nonlinear numerical simulations on the interaction of waves with a vertical elastic plate are performed by a newly developed computer code based on the MEL (Mixed Eulerian Lagrangian) method. The time-dependent elastic deflection of a vertical plate is described by the mode-expansion method. An implicit boundary-condition method is developed to calculate the acceleration of the plate without evaluating the hydrodynamic force acting on it. The 4th-order Runge-Kutta scheme with uniform time step is applied for time marching in solving the coupled motions of an elastic plate and the fluid. A hybrid wave absorbing beach is installed to prevent the wave reflection from the end of the wave tank. With an initial condition that a plate is bent, illustrative results of numerical computation for the elevation of the free surface are compared with a corresponding linear analytical solution. The hydroelastic vibration of a vertical plate induced by an initial pulse-type elevation of the free surface is also simulated. Finally, the effect of the plate stiffness and the edge condition at the top of plate on hydroelastic behavior is studied systematically.

INTRODUCTION

Hydroelasticity has received considerable attention by many authors (e.g. Wu et al., 1995; Kashiwagi, 2001; Meylan, 2002; and Sturova, 2006, to name a few). A thin floating plate is one of the most well studied hydroelastic problems, because it models many physical applications, such as a VLFS (Very Large Floating Structure), to be used for various purposes and a sea ice floe; reviews of their research are provided by Kashiwagi (2000b) and Watanabe (2004) for the VLFS and Squire (2007) for the sea ice floe.

Various solution methods have been developed to solve hydroelastic problems. Endo and Yago (1999) and Kashiwagi (2001) have developed a time-stepping procedure to compute time-dependent elastic responses. Watanabe and Utsunomiya (1996) obtained the elastic response due to impulsive loading on a circular VLFS by using a FEM method. Alternatively, Meylan (2002) derived the spectral theory for a 2D time-dependent motion of a thin plate floating on shallow water. Hazard and Meylan (2007) then expanded the applicable range of the spectral theory to finite water depth. The advantage of the spectral theory is that the solution can be calculated for all time using the FFT (Fast Fourier Transform), which is based on the single frequency solution.

According to the treatment for the deflection of a thin floating plate, solution methods can also be categorized by 2 major

approaches: the mode-expansion method and the eigenfunction-expansion method. In the mode-expansion method, the plate motion is expressed with the superposition of dry natural modes. Kashiwagi (2000) reviewed the state of the art in the research on VLFS problems and reported some major works based on the mode-expansion method. Sturova and Korobkin (2005) calculated the behavior of a thin floating plate under localized periodic loading in infinitely deep fluid in linear 2D problem. On the other hand, the eigenfunction-expansion method is also employed by many authors. Meylan (2001) derived a variational equation for a thin floating plate subject to the wave forcing, which is solved with simple polynomials to express the deflection of a plate. Sahoo et al. (2001) used an eigenfunction-expansion method to analyze hydroelastic interactions of surface waves with a semi-infinite horizontal elastic plate floating on the free surface.

As mentioned above, most of the studied hydroelastic models are floating thin plates. So far, few papers deal with a model for the vertical elastic plate, even for a linear problem, although it is also a very fundamental and important hydroelastic model that needs to be investigated. Newman (1994) gave a set of orthogonal polynomials to represent the deflection of a vertical column, and an analysis is also made of the methods using orthogonal polynomials and dry natural modes. Recently, Peter and Meylan (2008) presented an analytical solution for the interaction of waves with an elastic vertical plate based on the linear potential theory. So inspired, we treat the 2D vertical elastic problem in the framework of nonlinear potential flow rather than linear potential flow. This work can be seen as a numerical extension of the paper written by Peter and Meylan (2008) to a considerably more complicated situation when the solution can no longer be approximated as a linear one.

There are some different ways for the treatment of nonlinearity in the fluid-structure interaction problem. For example, Tanizawa (1998) simulated an impact of an elastic beam onto a wave crest

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