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Sea Wave Adaptation by an Elastic Plate

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ABSTRACT

Wave propagation and damping mechanisms due to an elastic coating at the sea surface is considered. A two-way coupling model describing wave motion in a two-phase medium comprising an elastic cover on a viscous fluid that accounts for interactions between the phases is considered within the frames of the boundary layer type approximation. An asymptotic linearized model including the Navier–Stokes equations for the viscous incompressible fluid and the deformable plate motion equations for the elastic cover is analyzed for a wide range of governing parameter variations. The dispersion relationship for different Reynolds numbers shows different oscillation regimes. The structure of the fluid flow is studied in detail for two asymptotic limiting cases of high and low influence, of the elastic coating on the surface wave propagation and damping.

KEY WORDS: fluid–elastic cover; two-way coupling model; dispersion relationship; surface waves.

INTRODUCTION

Fluid-plate hydroelastic interaction problems have been of interest for a long time because of their engineering relevance. During the past decades, for instance, there has been a gradual increase in interest in the use of flexible plates or membranes as alternative effective inexpensive wave barriers in a beach zone.

In particular, the membrane is light and rapidly deployable, and thus it may be an ideal candidate as a portable temporary breakwater. Since the horizontal membrane does not directly block incoming waves, the transmitted and motion-induced waves need to be properly eliminated for the breakwater to be effective.

Siew and Hurley (1977) and McIver (1985) studied the diffraction of surface waves by a submerged horizontal rigid plate. They showed that it can reject significant amounts of incident wave energy at certain wave frequencies.

Use of a hydroelastic model for the interaction of oblique mono-chromatic incident waves with a horizontal flexible membrane was suggested by Cho and Kim (1998). It was assumed that the fluid is incompressible and inviscid, and that the wave and membrane motions are small so that linear potential theory can be used. Analytical diffraction and radiation solutions for a submerged impermeable horizontal membrane were obtained using an eigenfunction expansion method. Utilizing the computer program developed, the performance of surface-mounted or submerged horizontal membrane wave barriers was tested with various membrane tensions, lengths, and submergence depths. It was shown that an optimum combination of design parameters existed for given water depths and wave characteristics. Theoretical and numerical predictions were then compared to a series of experiments conducted in a two-dimensional wave tank. It was shown that the wave blocking performance by a horizontal flexible membrane can be reasonably predicted by the linear hydroelastic model. Finally it was concluded that a properly designed horizontal flexible membrane can be a very effective wave barrier and its optimal design can be found through a comprehensive parametric study using the theory and computer programs developed.

The elastic plate model is widely used to study the dynamic response of an ice sheet and a VLFS floating on a water surface. For example, Meylan and Squire (1993) investigated scattering of water waves by a single ice floe by invoking a variational approach employed to solve the related semi-infinite problem together with a wide-spacing approximation. The same authors (Meylan and Squire, 1994), also used Green's functions to model the response of a solitary ice floe in ocean waves precisely, for water of finite or infinite depth. The papers are just two of a vast corpus of publications concerned with ice-water interactions that is reviewed by Squire et al. (1995) and Squire (2007). Rather than reference the many papers therein, readers are referred to those works and to the plenary address by Squire being presented at this conference entitled "Synergies Between VLFS Hydroelasticity and Sea-Ice Research". In relation to "ice engineering" an important area that is neglected is that of nonlinearity; very few papers deal with large amplitude deformation. Such deformations can be produced naturally or by a vehicle moving across the ice, and, if sufficiently large, could cause the ice to break and consequent danger to the vehicle. Forbes (1986, 1988) is one study that concerns waves of arbitrary amplitude beneath an elastic sheet