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Indirect Boundary Element Method applied to fluid–solid interfaces

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ABSTRACT

In this paper scattering of elastic waves in fluid–solid interfaces is investigated. We use the Indirect Boundary Element Method to study this wave propagation phenomenon in 2D models. Three models are analyzed: a first one with an interface between two half-spaces, one fluid on the top part and the other solid in the bottom; a second model including a fluid half-space above a layered solid; and finally, a third model with a fluid layer bounded by two solid half-spaces. The source, represented by Hankel's function of the second kind, is always applied in the fluid. This indirect formulation can give to the analyst a deep physical insight on the generated diffracted waves because it is closer to the physical reality and can be regarded as a realization of Huygens' principle. In any event, mathematically it is fully equivalent to the classical Somigliana's representation theorem. In order to gauge accuracy we test our method by comparing with an analytical solution known as Discrete Wave Number. A near interface pulse generates scattered waves that can be registered by receivers located in the fluid and it is possible to infer wave velocities of solids. Results are presented in both time and frequency domain, where several aspects related to the different wave types that emerge from this kind of problems are pointed out.

1. Introduction

Fluid–solid interfaces have been extensively studied in many areas of physics due to the complexity of the interface waves that can propagate through them. For instance, valuable contributions to study the dynamic behavior of an oceanic layer overlaying an elastic solid using analytical method can be seen in the pioneering works of Biot [1] and Ewing et al. [2], where special attention was given to the interaction between the Stoneley and Rayleigh waves. Some other applications have been focused to understand the behavior of interface waves being applied to ocean bottom too [3,4]. In this way, in Carcione and Helle [5] physics related with wave propagation in a variety of seabed mechanical properties, ranging from soft sediments to crustal rocks, was studied. Theoretical analysis to show the emergence of Rayleigh waves in an oceanic ambient due to deep earthquakes was shown for instance in [6,7].

Attenuation and dispersion of elastic waves were also investigated in multilayered schemes [8–12] and the inverse problem consisting in the determination of the mechanical properties of a layered medium in contact with a fluid by measuring the variation of the pressure in the fluid was reported by Zein et al. [13].

Several studies applied to porous media have shown the enormous influence of porosity in wave propagation, especially when the medium is partially saturated, the dynamic pressure of the overlaying fluid may be significantly affected [14–18]. The effect of fractures in the attenuation and dispersion in interface waves were studied in [11,19–22], where interface wave velocity or fracture parameters were pointed out. Green functions for homogeneous three-dimensional layered acoustic and elastic formations, such as an elastic solid layer bounded by one or two acoustic fluid media subjected to spatially sinusoidal harmonic loads, were developed in [23,24], which can also be used in numerical solutions. Moreover, numerical modeling to study complex geological fluid–solid structures/interfaces is required.

Several numerical methods such as Finite Element and Finite Difference Methods have been used to model fluid–solid interfaces (see for instance Zienkiewicz and Bettess [25] and Thomas et al. [26], respectively). Moreover, Spectral Element and Pseudospectral Methods have shown to be accurate tools for modeling more realistic problems. For instance, an algorithm based on Fourier and Chebyshev differential operators and two grid models were

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