Hydrodynamic Response Of Non-Uniform Flexible Structures

Abstract

This thesis focuses on addressing challenges related to the interaction between surface waves and porous, flexible barriers. It takes into account the principles of linear water wave theory and Kirchhoff's thin plate theory. The primary emphasis of this research is on the development and generalization of mathematical tools based on integral equations to tackle a specific category of physical problems involving the scattering of water waves by barriers with diverse geometrical shapes and orientation. All the problems require solving a set of integral equations out of which at least one integral has a hypersingular kernel. The primary goal of this study is to explore how different physical parameters impact the hydrodynamic characteristics of these structures.

The entire thesis is structured into five parts. **Part I** encompasses the introductory section, a concise review of relevant literature pertaining to the thesis topics, the fundamental equations of linearized water wave theory, boundary conditions on thin plates, and essential mathematical prerequisites that will be employed in the subsequent sections of the thesis. **Part II** delves into the examination of water wave interactions with porous-elastic plates, addressing two specific scenarios: the first one involves considering fluid motion under the influence of surface tension at the free surface, while the second scenario involves motion solely under the influence of gravity without surface tension. The first problem requires the use of a modified free surface Green's function accounting for a third order differential equation at the free surface of the fluid domain due to the inclusion of surface tension. On the contrary, in the second problem when no surface tension effects are considered, the boundary condition on the free surface reduces to a first order differential equation. Also, the second problem deals with an oblique plate with varying porosity while in the first problem a uniform vertical plate is considered. **Part III** is dedicated to exploring the problems associated with the scattering of surface gravity waves by elastic plates with varying thickness, both in the frequency and time domains, which requires solving a fourth-order linear differential equations with variable coefficients. The first chapter of **Part III** treats the non-uniform plate in frequency domain using two distinct mathematical techniques: perturbation method and direct integration method. On the other hand, in the second problem of this part, using a specialized plate Green's functions based on the modes of a constant thickness plate, the motion of the non-uniform plate is studied in time domain using Fourier transform. **Part IV** shifts the focus towards the interaction of water waves with a submerged multi-plate system, where at least one of the plates exhibits non-uniform flexibility. As the model incorporates multiple plates, the analysis entails solving a system of coupled integral equations, progressively increasing in complexity. The second chapter of **Part IV**, specially focuses on enhancing the wave power absorption efficiency of piezoelectric plate wave energy converters, where the expression for absorption efficiency is determined using two methods that are based on Green's integral theorem. Lastly, **Part V** encapsulates the primary findings and conclusions drawn from the research conducted in this thesis, along with a discussion of potential avenues for future research endeavors in this field.

Keywords: Water wave scattering; Linear theory; Flexible barrier; Non-uniform flexibility; Multi-plate system; Reflection coefficient; Transmission coefficient; Energy identity; Hydrodynamic force; Perturbation method; Green's integral theorem; Hypersingular integral equation; Coupled integral equations; Fourier transform.