PREFACE

Waves and wave–body interactions have been a research focus for many years and studied by a large number of researchers. Due to the compexity of problems of this kind, a lot of research work has been based on linear or other simplified theories such as second order perturbation methods, in which higher order terms may be ignored and boundary conditions satisfied at the initial position of the free and body surfaces. These analyses are valid only when the assumed conditions, such as small or moderate steepness of waves and/or small or moderate motion of bodies, are met. Beyond these conditions, fully nonlinear theory is necessary, in which all nonlinear terms are considered and boundary conditions are imposed on the instantaneous water and body surfaces. Two types of fully nonlinear models, i.e., the NS model (governed by the Navier–Stokes and the continuity equations) and the FNPT model (fully nonlinear potential theory model), may be employed. The latter is relatively simpler and needs relatively less computational resources than the former but cannot take into account viscosity. However, the FNPT model is normally considered to be sufficient if post-breaking of waves does not occur and wave forces rather than the viscous forces are of the main concern.

Unlike simplified theories, which are often amenable to analytical solution, approaches based on the fully nonlinear theories (NS model or FNPT model) rely heavily on numerical modeling. Many numerical methods have been developed over the past decades. These include the Finite Difference Method (FDM), Finite Volume Method (FVM), Finite Element Method (FEM), Boundary (Integral) Element Method (BEM) and Spectral Methods, all of which are mesh-based. More recently, meshless (or meshfree) methods have been proposed. These include the Smoothed Particle Hydrodynamics (SPH) method, Moving Particle Semi-implicit (MPS) method, Constrained Interpolation Profile (CIP) method, Method of Fundamental Solutions (MFS) and Meshless Local Petrov–Galerkin (MLPG) Method. Numerous solution techniques have been developed for the different mathematical models and formulations. Some of these have been devised for fully nonlinear potential theory, some are based on the higher order Boussinesq equations; some deal with the Navier–Stokes equations, some are suitable for single-fluid flow whilst others can cope with two or multiple fluids; some adopt a Lagrangian formulation; some are built on the familiar Eulerian formulation of mesh-based methods whilst others use a mixed Lagrangian–Eulerian formulation or Arbitrary Lagrangian–Eulerian (ALE) formulation.

There are many situations where a fully nonlinear model has to be applied. Typical examples are overturning waves, broken waves, waves generated by landslides, freak waves, solitary waves, tsunamis, violent sloshing waves, interaction of extreme waves with beaches, interaction of steep waves with fixed structures or with freely-responding floating structures.

This book comprises of 18 chapters, reviewing the pioneering work of the authors and their research teams over the past decades on modeling nonlinear waves. Altogether, they cover all numerical methods and all of the typical applications mentioned above. Chapters 1–6 present a review of research based on nonlinear potential theory implementing spectral methods, BEM and FEM, respectively with applications to nonbreaking freak waves, overturning waves, waves generated by landslides, interactions between steep waves and floating structures, and so on. Chapters 7 and 8 review the work on the higher order Boussinesq equations and simulation of various waves. Chapter 9 is also based on potential theory but adopts the meshless MFS method. Chapters 10 and 11 offer a review of numerical modeling based on the NS model using the FVM but adopting different techniques for meshing, for interface modeling and for velocity–pressure coupling. Chapters 12–15 present the development of various meshless methods (CIP, MPS, SPH, MLPG) based on the NS Model and their applications to steep or broken waves. When broken waves are involved, modeling turbulence becomes vital. Chapters 16 and 17 reflect research efforts on this aspect with the former chapter focusing on large eddy simulation and the latter discussing a range of turbulent models. Finally, Chapter 18 presents studies of freak (or rogue) waves and their interactions with structures.

Every chapter of this book has been reviewed by up to three anonymous referees. I would like to express my sincere thanks to those who have made contributions in the review process.

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