2009

Analytic solutions for linear waves propagating in an ocean with variable bottom topography and their applications in renewable wave energy

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A Thesis submitted for the degree of Doctor of Philosophy

School of Mathematics and Applied Statistic

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August 2009

Declaration

In accordance with the regulations of the University of Wollongong, I hereby state that the work described herein is my original work, except where due references are made, and has not been submitted for a degree at any other universities or institutions.

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August 2009

Abstract

Studies about ocean waves have been evolving over a period of time. Recently, there has been renewed interest in problems of refraction, diffraction and radiation of ocean waves around structures. In this thesis, the analytic solutions for linear waves propagating in an ocean with variable bottom topography and their applications in renewable wave energy are presented. In the first part, we present an analytic solution to the shallow water wave equation for long waves propagating over a circular hump. As a useful tool in coastal engineering, the solution may be used to study the refraction of long waves around a circular hump. It may also be used as a validation tool for any numerical model developed for coastal wave refraction. To validate the new analytic solution, we have compared our new analytical solution with a numerical solution obtained by using the finite difference method. The agreement between these two solutions is excellent. By using the analytic solution, the effect of the hump dimensions on wave refraction over the circular hump are examined.

In the second part of this thesis, based on the mild-slope equation derived by Smith and Sprinks [1] and the extended refraction-diffraction equation developed by Massel [2], we have constructed a two-layer mild-slope equation for interfacial waves propagating on the interface of a two-layer ocean model. First, we follow Smith and Sprinks's [1] approach to derive the mild-slope equation for the propagation of interfacial waves, with the higher-order terms proportional to the bottom slope and bottom curvature all being neglected. We then derived the extended version of the mild-slope equation with the higher-order terms included. While we were able to solve the first equation

analytically, we presented a numerical solution for the second equation. As a part of the verification process, both solutions were compared with each other and also with the single-layer mild-slope equation when the density of the upper layer goes to zero. We then used the new solution to study the effect of the hump dimensions on the refraction of the interfacial waves over a circular hump.

Finally, in the final section of this thesis, we have used what we have developed before to construct the two-layer mild-slope equation with free surface on top. By utilizing this equation, we then derived an analytic solution for long waves propagating over a circular hump with a hollow circular cylinder floating in the free surface. In order to validate our new analytic solution, we have compared our problem with Mac Camy and Fuchs [3] solution, because our solution has reduced to their solution when the lower water depth, h_2, goes to zero. We have also compared our solution with the flat bottom case in order to further verified our solution. Finally, by using the new solution, both diffraction and refraction effects from the hollow cylinder and hump dimensions are examined and discussed.

Acknowledgements

I would like to express profound gratitude to my supervisor, Prof. Song-Ping Zhu, for his invaluable support, encouragement, supervision and useful suggestions throughout this research work. His moral support and continuous guidance enabled me to complete my work successfully.

I would also like to thank all staff and fellow friends in School of Mathematics and Applied Statistics, especially Carolyn Silveri for helping me in Latex, Dr. Xiao-ping Lu for her help when I get some trouble in my calculations and Jean-Roch for his help in my programming.

Special thanks must go to my lovely husband, Mr. Fathy Kameel Mohd Fadzil for his encouragement and patience, my dear parent, Mr. Harun Mat and Mrs. Zaini Rasdi, and all my family members for their love and support throughout my life.

My indebtedness must be expressed to the financial support from Universiti Malaysia Terengganu, which allow me to pursue a Ph.D at The University of Wollongong.

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