University of Southern Queensland

Steady and Unsteady Free Surface Flow Past a Two-Dimensional Stern

A thesis submitted in fulfilment of

Doctor of Philosophy

Osama Nasser Ogilat

B.Sc., M.Sci.

2013

Abstract

The research examines an influence of a platform shape on free surface waves generated behind a semi-infinite two-dimensional platform moving with a constant speed on a water surface of a finite depth h. The fluid is assumed to be inviscid, incompressible and irrotational; the surface tension effect is neglected. The aim of the research is to find analytically and numerically such platform shape which minimizes generated waves and reduces wave drug exerting on a moving platform when the Froude number is relatively small, $F < 1$. It is shown that for certain platform shapes, generated waves can be minimised or even eliminated, at least, within the framework of a linearized theory.

Linearized hydrodynamic equations for a fluid of finite depth are solved analytically by means of the Fourier transform and Wiener–Hopf technique, as well as numerically with the help of boundary integral technique. A weakly nonlinear solution is also obtained for shallow-water approximation within the framework of the forced Korteweg–de Vries (KdV) equation.

The problem is investigated for steady motion of a platform having a different stern shape. Then the analysis is performed for unsteady motion of a platform having a flat shape. The linearized problem for a water of finite depth is solved by means of the Laplace transform and Wiener–Hopf technique. The linear problem is formulated by assuming that at the initial instant of time the free surface is slightly perturbed due to the platform submerging onto the depth $d \ll h$ beneath the free surface. It is shown that the unsteady solution approaches the steady state solution as $t \to \infty$. The dependence of maximum wave perturbation on the fluid depth is found numerically.

In the last Chapter 6 the analysis is extended to steady motion of a flat platform at the interface between two fluids of different density. It is assumed that the lower layer has a finite depth h, whereas the upper layer is infinite. Results obtained for internal waves on the sharp density interface depend on the density ratio $a = \rho_1/\rho_2$ and in the limit $a \to 0$ they coincide with the results obtained for surface waves.

The results of this research can help in understanding of the physics of wave generation past a bluff body (e.g., wide blunt ships) and shed some light on solving an engineering problem of ship building of an optimal shape.

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher educational institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Candidate: Osama Nasser Ogilat

Signed: ____________________

Date: ____________________

ENDORESMENT

Principal supervisor: Associate Professor Yury Stepanyants

Signed: ____________________

Date: ____________________

Acknowledgements

My first and foremost thanks to ALLAH for the opportunities that He has given to me throughout my life, especially those that have brought me to the position of finishing this thesis.

I would like to express my thankfulness and gratitude to my principle supervisor Professor Yury Stepanyants for his invaluable assistance, support, patience and guidance during the period of my research. My special thanks are addressed to my associate supervisor Dr Dmitry Strunin for his advice, support and constructive feedback. Deepest gratitude is also due to Professor Ian Turner, Dr Scott McCue and Professor John Belward without their knowledge and assistance this study would not have been successful. Warmest thanks to Dr Ben Binder for his contribution to our joint paper published in Physics of Fluids. I would like to thank all postgraduate students and staff of the Department of Mathematics and Computing of USQ for providing a very good scientific environment for mathematical research.

I am indebted to the most important person in my live, my mother "Gazeah", for her incredible support, love and patience through my many years in education. My special thanks to my wonderful brothers, Khaled, Amjad, Ahmad and Moa'ath and sisters, Manal, Tharwah, Khawlah, Hend, Wisam and Ebtsam who always wished my success. I am also thankful to my sisters-in-law and brothers-in-law who always supported me. I should not forget my relatives (uncles and cousins), as well as friends.

This thesis is dedicated to my mother; and to the soul of my father (ALLAH bless upon him), that I wish he is alive to see what I have achieved and to share my happiness for completing this Theses, who encouraged and directed me for education and provided me with safe financial living before and after he passed away.

Keywords

Boundary integral technique, Wiener–Hopf technique, weakly nonlinear theory, free surface flow, steady flow, unsteady flow, Fourier transform, Laplace transform, conformal mapping, Korteweg–de Vries (KdV) equation.

List of Publications

O. Ogilat, S. W. McCue, I. W. Turner, J. A. Belward, and B. J. Binder. Minimising wave drag for free surface flow past a two-dimensional stern. *Physics of Fluids*, 2011, v. 23, p. 072101.

O. Ogilat, Y. Stepanyants. Transient free surface flow past a two-dimensional flat stern. (*Accepted in Physics of Fluids journal*).

O. Ogilat, Y. Stepanyants. Minimising internal wave generation past steadily moving flat platform in two-layer fluid of finite depth. (*To be submitted to the journal Physics of Fluids*).

Contents

List of Figures

List of Tables