

# *The Regularity and Local Bifurcation of Steady Periodic Water Waves*

B. BUFFONI, E. N. DANCER, J. F. TOLAND

## **Abstract**

Steady periodic water waves on infinite depth, satisfying exactly the kinematic and dynamic boundary conditions on the free surface, with or without surface tension, are given by solutions of a rather tidy nonlinear pseudo-differential operator equation for a  $2\pi$ -periodic function of a real variable. Being an Euler-Lagrange equation, this formulation has the advantage of gradient structure, but is complicated by the fact that it involves a non-local operator, namely the Hilbert transform, and is quasi-linear.

This paper is a mathematical study of the equation in question. First it is shown that its  $W^{1,2}$ -solutions are real-analytic. Then bifurcation theory for gradient operators is used to prove the existence of (non-zero) small amplitude waves near every eigenvalue (irrespective of multiplicity) of the linearised problem. Finally it is shown that when surface tension is absent there are no sub-harmonic bifurcations or turning points at the outset of the branches of Stokes waves which bifurcate from the trivial solution.

## **1. Introduction**

The periodic water-wave problem for steady irrotational free surface flows in the presence of gravity, with or without surface tension, can be formulated as a problem for a  $2\pi$ -periodic solutions  $w$  of the equation

$$\mu C w' = w + w C w' + C(w w') - \beta \left\{ \frac{w'}{\sqrt{w'^2 + (1 + C w')^2}} \right\}' + \beta C \left\{ \frac{1 + C w'}{\sqrt{w'^2 + (1 + C w')^2}} \right\}'. \quad (1.1)$$

Here  $C$  denotes the periodic Hilbert transform (also known as the conjugation operator in the theory of Fourier series [38]),  $'$  is differentiation, and



# Mathematical Introduction To The Bifurcation Of Periodic Progressive Water Waves

**Tōkyō Daigaku. Rigakubu**





## Mathematical Introduction To The Bifurcation Of Periodic Progressive Water Waves:

The Mathematical Theory Of Permanent Progressive Water-waves Hisashi Okamoto, Mayumi Shoji, 2001-09-28 This book is a self contained introduction to the theory of periodic progressive permanent waves on the surface of incompressible inviscid fluid The problem of permanent water waves has attracted a large number of physicists and mathematicians since Stokes pioneering papers appeared in 1847 and 1880 Among many aspects of the problem the authors focus on periodic progressive waves which mean waves traveling at a constant speed with no change of shape As a consequence everything about standing waves are excluded and solitary waves are studied only partly However even for this restricted problem quite a number of papers and books in physics and mathematics have appeared and more will continue to appear showing the richness of the subject In fact there remain many open questions to be answered The present book consists of two parts numerical experiments and normal form analysis of the bifurcation equations Prerequisite for reading it is an elementary knowledge of the Euler equations for incompressible inviscid fluid and of bifurcation theory Readers are also expected to know functional analysis at an elementary level Numerical experiments are reported so that any reader can re examine the results with minimal labor the methods used in this book are well known and are described as clearly as possible Thus the reader with an elementary knowledge of numerical computation will have little difficulty in the re examination

**Mathematical Reviews** ,2007 Small Divisor Problem in the Theory of Three-Dimensional Water Gravity Waves

Gérard Iooss, Pavel I. Plotnikov, 2009-06-05 The authors consider doubly periodic travelling waves at the surface of an infinitely deep perfect fluid only subjected to gravity  $g$  and resulting from the nonlinear interaction of two simply periodic travelling waves making an angle  $2\theta$  between them Denoting by  $\mu$   $gL/c^2$  the dimensionless bifurcation parameter  $L$  is the wave length along the direction of the travelling wave and  $c$  is the velocity of the wave bifurcation occurs for  $\mu \cos \theta$  For non resonant cases we first give a large family of formal three dimensional gravity travelling waves in the form of an expansion in powers of the amplitudes of two basic travelling waves Diamond waves are a particular case of such waves when they are symmetric with respect to the direction of propagation The main object of the paper is the proof of existence of such symmetric waves having the above mentioned asymptotic expansion Due to the occurrence of small divisors the main difficulty is the inversion of the linearized operator at a non trivial point for applying the Nash Moser theorem This operator is the sum of a second order differentiation along a certain direction and an integro differential operator of first order both depending periodically of coordinates It is shown that for almost all angles  $\theta$  the 3 dimensional travelling waves bifurcate for a set of good values of the bifurcation parameter having asymptotically a full measure near the bifurcation curve in the parameter plane  $\theta, \mu$  数学物理学, 1990

**Discrete and Continuous Dynamical Systems** ,2007 数学物理学  
Tōkyō Daigaku. Rigakubu, 1989 **Philosophical Transactions of the Royal Society** ,2007 数学物理学, 2000

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Proceedings of the Japan Academy Nihon Gakushuin,1988      *Physics Briefs* ,1987      **Scientific and Technical Aerospace Reports** ,1982 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database

**Meteorological and Geostrophysical Abstracts** ,1992      **A Modern Introduction to the Mathematical Theory of Water Waves** Robin Stanley Johnson,1997-10-28 This text considers classical and modern problems in linear and non linear water wave theory      **Nonlinear Water Waves with Applications to Wave-Current Interactions and Tsunamis** Adrian Constantin,2011-01-01 This overview of some of the main results and recent developments in nonlinear water waves presents fundamental aspects of the field and discusses several important topics of current research interest It contains selected information about water wave motion for which advanced mathematical study can be pursued enabling readers to derive conclusions that explain observed phenomena to the greatest extent possible The author discusses the underlying physical factors of such waves and explores the physical relevance of the mathematical results that are presented The material is an expanded version of the author s lectures delivered at the NSF CBMS Regional Research Conference in the Mathematical Sciences organized by the Mathematics Department of the University of Texas Pan American in 2010      An Introduction to the Mathematical Theories of Two-dimensional Periodic Progressive Gravity Waves Bernard LeMéhauté,Arthur Brebner,1960



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