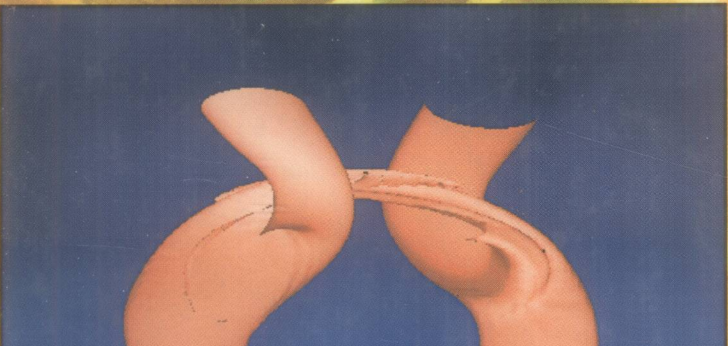
Advances in Fluid Mechanics

Nonlinear Instability Analysis

Volume II

Editor: L. Debnath



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Volume II

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Thanks are due to R. Kerr for the use of figure 14 which appears on the front cover of this book.

Nonlinear Instability Analysis
Volume II

International Series on Advances in Fluid Mechanics

Objectives

The field of fluid mechanics is rich in exceptional researchers worldwide who have advanced the science and brought a greater technical understanding of the subject to their institutions, colleagues and students.

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Preface

The mathematical theory of nonlinear instability analysis and its applications has grown considerably over the past three decades. This volume II is a collection of chapters submitted by leading applied mathematicians and scientists who have made important contributions in the area. It brings together current developments in the theory and applications of nonlinear stability theory and related topics likely to determine fruitful directions for further study and research.

In the opening chapter, Grimshaw considers models for instability in inviscid fluid flows due to a resonance between two waves. It is shown that the structure of the weakly nonlinear regime depends critically on whether the modal structure coincides, or remains distinct at the resonant point, where the phase speeds of the wave coincide. In a weakly nonlinear model for long waves, the generic model consists either of a Boussinesq equation, or of two coupled Korteweg-de Vries (KdV) equations. For the weakly nonlinear models for short waves, the generic model satisfies either a cubic nonlinear Klein-Gordon equation for the wave envelope or a pair of coupled first-order envelope equations.

Chapter 2 by Kerr deals with a new role for vorticity and singular dynamics in turbulence. Singular behavior in vorticity in the Euler equations is reviewed and how this influence turbulent statistics in the Navier–Stokes equations is described. It is shown that the self-similar structure of a singular solution of Euler equations has anisotropy described by two small length scales that is consistent with mathematical bounds on singularities of Euler equations. Experimental and numerical evidence for two dynamically significant small length scales in turbulence is discussed in some detail. New calculations are outlined that would show how turbulence can develop from near singularities and which might show directly the relationship between the structure of singularities and turbulent statistics.

In Chapter 3, Pusri, Singh and Malik present both theoretical and numerical studies of the problem of evolution of surface waves, stability and instability phenomena. They have shown that the evolution of wave envelope is governed by two-coupled partial differential equations with cubic nonlinearity. The stability analysis shows the existence of different regions of instability. They also study the long wave equation in -dimension in the presence of tangential magnetic field, periodic forcing and weak damping. The dynamical system exhibits a homoclinic saddle point leading to a criterion for the existence of chaotic motions. This is followed by the Rayleigh-Taylor instability analysis in the presence of a magnetic field and surface tension, and then the Kelvin-Helmholtz instability problem in the presence of uniform magnetic fields acting along the surface of separation of two moving superimposed fluids. It is shown that the evolution of the amplitude of the two-dimensional wave-packets is governed by a nonlinear Klein-Gordon equation. The phenomenon of nonlinear focusing arising in this instability problem is discussed. The explosive instability for the second harmonic case is investigated when the uniform speed of the fluid exceeds its critical value.

Internal wave-shear flow resonance and wave breaking in the subsurface layer are studied by Voronovich, and Shrira in Chapter 4. In the weakly nonlinear regime the dynamics is governed by a system of two coupled evolution equations, the effect of the interaction on the internal wave dominating its own nonlinearity. For the case of shallow water, the detailed study reveals that the system possesses two families of stationary solutions of both periodic and solitary wave type propagating slightly faster and slower than a linear wave mode. The fast solitary waves become locally close to the limiting form with a singularity at the crest at a certain depth specified by the initial data. The solution cannot be continued adiabatically beyond the point, and hence, invariably, wave breaking occurs. This study is of primary importance to physical oceanography as the breaking of internal waves occurring in the sublayer represents an important additional mechanism of mixing, and can considerably change traditional views of a subsurface mixed layer dynamics.

The wavelet analysis of turbulent flows: Coherent structures identification and intermittency by Camussi and Guj is presented in Chapter

5. They reviewed a number of important experimental results by the application of a novel technique for coherent structures identification in turbulent flows. Application of the wavelet transform to velocity time series obtained by pointwise measurements with single and multiprobe hot wires seems to be successful to study both homogenous and non-homogeneous turbulent flows. It is shown that this new methodology yields interesting results which seems relevant for the correct description of the role played by coherent structures in the framework of intermittency in turbulence. One of the important findings of the present study is that, even if the distributions of energy in space and scale are correlated to each other, the intermittency corrections of the scaling exponent have to be attributed more to the non Gaussian statistics of the spatial distribution of the energy fluctuations rather than to the energy cascade mechanism from large to small scales.

In Chapter 6, Wollkind used a particular reaction-diffusion model system relevant to the representation of chemical Turing pattern formation as a prototype problem to derive standard stability criteria for each critical point of the amplitude equations associated with rhombic and hexagonal platform weakly nonlinear analyses from first principles. Then these results are interpreted with respect to Turing instabilities and compared to those deduced for analogous model systems traditionally employed to illustrate pattern selection involving convective, morphological, and flame instabilities.

The final chapter by Debnath, Soundalgekar and Takhar deals with classical and recent developments of the Taylor-Couette flow between two rotating and concentric cylinders. Special attention is given to the mathematical formulation with perturbation equations for the Taylor-Couette stability problem with some recent work on stability analysis with graphical representations. The role of both axisymmetric and non-axisymmetric disturbances in the stability of the Taylor-Couette flow is discussed with experimental and computational results. Effects of gravity on the Taylor-Couette flow problems are included with graphical representations. Some attention is also paid to the effects of radial temperature gradient. The nonlinear Taylor instability problem is briefly described with recent references. Finally, recent developments of experimental and computational studies of the Taylor-Couette flow are presented with many new results. An updated list of references is included to stimulate new interest in future study and research on this important subject.

I wish to record my grateful thanks to the authors for their important contributions. I believe this volume brings many important recent developments in the nonlinear analysis of unstable phenomena in an accessible, but reasonably comprehensive fashion. I want the reader to share in the excitement of present day research in this rapidly growing field. I hope this volume will not only be a useful and accessible introduction to techniques and the research literature, but will also generate new leads for researchers, and attract new researchers into this vibrant and dynamic field.

Finally, I wish to sincerely thank Professor M. Rahman for his encouragement and advice at all stages in this project, as well as gratefully acknowledge the help and professionalism of the staff at WIT Press for helping this volume see the light of day.

Lokenath Debnath

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Nonlinear Instability, Chaos and Turbulence

Volumes 1 & 2

Editors:
***L. DEBNATH**, University of Central Florida, USA and **D.N. RIAHI**, University of Illinois, USA*

Volume 1
This collection of invited chapters has been written by fluid dynamicists and applied mathematicians who have made significant contributions to the areas of nonlinear flow instabilities, chaotic motion and turbulence. Containing original research, research-expository and survey articles, it provides a digest of current developments, together with open questions and unsolved problems which are likely to determine fruitful directions for future advanced study and research.
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Nonlinear Instability Analysis

Editors:
L. DEBNATH & S.R. CHOUDHURY,
University of Central Florida, USA

There have been remarkable developments in the mathematical theory of nonlinear instability problems and their applications. This volume is a collection of eight research, research-expository and survey articles written by leading applied mathematicians and scientists who have made important contributions to this rapidly growing field. It brings together several important aspects of nonlinear instability phenomena which are likely to determine fruitful directions for future advanced study and research.

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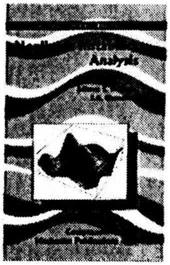

Nonlinear Water Wave Interaction

Editors:
O. MAHRENHOLTZ & M. MARKIEWICZ,
Technische Universität Hamburg – Harburg, Germany

This volume provides an important contribution to the evolution of the intriguing field of the physics of gravity waves. Recent progress in the areas of nonlinear wave-structure and wave-wave interaction is reviewed and special attention is paid to higher-order effects and their influence on the dynamic behaviour of marine and offshore structures.

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Covering both practical problems and mathematical methods, **Nonlinear Water Wave Interaction** will be invaluable to offshore engineers and naval architects. It will also be of interest to CFD scientists and applied mathematicians.

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Editor:
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Advances in Fluid Mechanics III

Editors:
***M. RAHMAN**, Dalhousie University, Canada, and **C.A. BREBBIA**, Wessex Institute of Technology, UK*

Placing emphasis on new applications and research currently in progress, this volume contains the proceedings of the Third International Conference on Advances in Fluid Mechanics. Topics covered include: Experimental versus Computational Methods; Numerical Methods in Fluid Mechanics; Boundary Element Methods for Fluids; Inverse Fluid Mechanics Problems; Fluid-Structure Interaction; Heat and Mass Transfer; Bio-Fluid Mechanics; Geophysical Fluid Dynamics; Environmental Fluid Mechanics; Hydrodynamics; Aerodynamics; River, Lake and Estuary Dynamics; Coastal Sea Modelling; Nonlinear Ocean Waves; Air-Sea Coupling Dynamics; Wave Propagation and Scattering; Non-Newtonian Fluids; and Constitutive Relationships.

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Contents

Chapter 6

Chapter 7