Preface

The initiation of this book started with the discussions in the ASME 2010 and 2009 Congress in the track of Dynamics Systems and Control, Optimal Approaches in Nonlinear Dynamics and Acoustics, which were organized by the editors. Since the 1980s, many new nonlinear approaches and techniques have been developed and the research on nonlinear science and dynamics have brought new insights in our dealing with nonlinear and complex systems in nature, engineering, and society. Although more and more such approaches and techniques have been brought into research and engineering practices, linearization and simplification are still the dominating approaches existing in physics and engineering. Strictly and precisely speaking, our nature is nonlinear. All the phenomena in nature and all the responses of physics and engineering systems are nonlinear. Linearization means simplification, and it damages the original natural or characteristics of the systems and may lead to inaccuracy, misunderstanding, or even incorrect conclusions in comprehending the physics and engineering systems we are trying to manage. Hooke's law including the generalized Hooke's law, for example, is linear and it composes the foundation of linear elasticity and dominates numerous solutions of physical systems and mechanical designs. However, no material is perfectly linear. Although most plain carbon steels are considered as materials obey Hooke's law in engineering practice, for instance, it is a common knowledge to the material scientists these materials are nonlinear and the constitutive relations of the materials are close to a nonlinear polynomial of third or fifth order. Any single material used in the real world can actually be a nonlinear and complex system, not only due to its material or structure nonlinearity but also due to the inhomogeneousness and anisotropy of the materials, let alone the associated complex external loading and large deformation which may occur in many engineering cases. With the explosively growing body of knowledge and discoveries in nonlinear science, obviously, we are entering an era that nonlinearity and complexity must be taken into consideration in coping with physical and engineering systems in real world.

Another challenge facing the scientists and engineers in our time is the generation of the solutions and characterization of the nonlinear systems modeled from the physical systems in reality. It would be greatly beneficial in accurately evaluating the behavior of nonlinear systems and revealing the actual nature of the systems, with utilization of the existing mathematical tools and analytical means, if the analytical solutions of nonlinear systems could be pursued. Due to the nonlinearity and complexity of the nonlinear systems, unfortunately, it is very difficult or impossible to derive the analytical or closed-loop solutions for the systems. In solving or simulating the nonlinear systems, one may have to rely on approximate or numerical methods, which may only provide approximate results for the systems while errors are unavoidable during the processes of generating the approximate results. Approximation and inaccuracy are the inescapable shadows following the current research and engineering practices involving nonlinearity or nonlinear systems.

In the role of the editors as well as the chapter contributors of this book, we have tried to present a collection of chapters showing the theoretically and practically sound nonlinear approaches and their engineering applications in various areas, hoping that this book may provide useful tools and comprehensible examples of solving, modeling, and simulating the nonlinear systems existing in the real world. The carefully selected chapters contained in the present book reflect recent advances in nonlinear approaches and their engineering applications. The book intends to feature in particular the fundamental concepts and approaches of nonlinear science and their applications in engineering and physics fields. It is anticipated that this book may help to promote the development of nonlinear science and nonlinear dynamics in engineering, as well as to stimulate research and applications of nonlinear science and nonlinear dynamics in physics and engineering practices. It is also expected that the book will further enhance the comprehension of nonlinear science and stimulate interactions among scientists and engineers who are interested in nonlinear science and who find that nonlinearity and complexity of systems play an important role in their respective fields.

With the theme of the book, nonlinear approaches and engineering applications, the book covers interdisciplinary studies on theories and methods of nonlinear science and their applications in complex systems such as those in nonlinear dynamics, nanotechnology, fluid dynamics, aerospace structure engineering, mechatronics engineering, control engineering, ocean engineering, offshore structure engineering, mechanical engineering, human body dynamics, and material science. Examples include innovative methodology of diagnosing nonlinear characteristics; approach of modeling squeeze-film phenomena in $MEMS$; nonlinear modeling of microbeams; new and explicit equations of motion for general nonlinear constrained mechanical systems; study on nonlinear dynamic behaviors of a Fermi oscillator with two periodic excitations; development of active surface control (ASC) architecture for deployable mesh reflectors to be used for satellite communications; nonlinear finite elements approach for modeling nano- and macroscale beam-like materials and structures; approach of modeling a submerged rigid body supported by slack moorings; study on linear and nonlinear viscoelastic materials in terms of constitutive equations, stress relaxation, and strain rate dependency; investigation on the nonlinear hysteresis effect in electromechanical brakes; energy conservative design and nonlinear control of a hopping robot; study on nonlinear and complex flow around a cylinder; vibration of truncated conical shells; image-based pose estimation of quadrotor unmanned aerial vehicle (UAV); and nonlinear modeling of head-neck complex system.

Level of the Book

This book aims at engineers, scientists, researchers, engineering and physics students of undergraduate and graduate levels, together with the interested individuals in engineering, physics, and mathematics. This chapter-book focuses on application of the nonlinear approaches representing a wide spectrum of disciplines of engineering and science. Throughout the book, great emphases are placed on engineering applications, physical meaning of the nonlinear systems, and methodologies of the approaches in analyzing and solving for the systems. Topics that have been selected are of high interest in engineering and physics. An attempt has been made to expose the engineers and researchers to a broad range of practical topics and approaches.

The topics contained in the present book are of specific interest to engineers who are seeking expertise in nonlinear analysis, mathematical modeling of complex systems, optimization of nonlinear systems, nonclassical engineering problems, and future of engineering.

The primary audience of this book is the researchers, graduate students and engineers in mechanical engineering, engineering mechanics, civil engineering, aerospace engineering, ocean engineering, mathematics, and science disciplines. In particular, the book can be used as a textbook for the graduate students as well as senior undergraduate students to enhance their knowledge by taking a graduate or advanced undergraduate course in the areas of nonlinear science, dynamics and vibration of continuous system, structure dynamics, and engineering applications of nonlinear science. It can also be utilized as a guide to the readers' fulfillment in practices. The covered topics are also of interest to engineers who are seeking to expand their expertise in these areas.

Organization of the Book

The main structure of the book consists of 15 chapters. Each of the chapters covers an independent topic along the line of nonlinear approach and engineering applications of nonlinear science. The main concepts in nonlinear science and engineering applications are explained fully with necessary derivatives in details. The book and each of the chapters are intended to be organized as essentially self-contained. All necessary concepts, proofs, mathematical background, solutions, methodologies, and references are supplied except for some fundamental knowledge well-known in the general fields of engineering and physics. The readers may therefore gain the main concepts of each chapter with as less as possible the need to refer to the concepts of the other chapters. Readers may hence start to read one or more chapters of the book for their own interests.

Method of Presentation

The scope of each chapter is clearly outlined and the governing equations are derived with an adequate explanation of the procedures. The covered topics are logically and completely presented without unnecessary overemphasis. The topics are presented in a book form rather than in the style of a handbook. Tables, charts, equations, and references are used in abundance. Proofs and derivations are emphasized in such a way that they can be straightforwardly followed by the readers with fundamental knowledge of engineering science and university physics. The physical model and final results provided in the chapters are accompanied with necessary illustrations and interpretations. Specific information that is required in carrying out the detailed theoretical concepts and modelling processes has been stressed.

Prerequisites

The present book is primarily intended for researchers, engineers, and graduate students, so the assumption is that the readers are familiar with the fundamentals of dynamics, calculus, and differential equations associated with dynamics in engineering and physics, as well as a basic knowledge of linear algebra and numerical methods. The presented topics are given in a way to establish as conceptual framework that enables the readers to pursue further advances in the field. Although the governing equations and modelling methodologies will be derived with adequate explanations of the procedures, it is assumed that the readers have a working knowledge of dynamics, university mathematics, and physics together with theory of linear elasticity.

Acknowledgments

This book is made available under the close and effective collaborations of all the enthusiastic chapter contributors who have the expertise and experience in various disciplines of nonlinear science and engineering applications. They deserve sincere gratitude for the motivation of creating such book, encouragement in completing the book, scientific and professional attitude in constructing each of the chapters of the book, and the continuous efforts toward improving the quality of the book. Without the collaboration and consistent efforts of the chapter contributors, the completion

of this book would have been impossible. What we have at the end is a book that we have every reason to be proud of.

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