

Nonlinear Mechanics of Shells and Plates in Composite, Soft and Biological Materials

This book guides the reader into nonlinear modelling of shell structures in applications where advanced composite and complex biological materials must be described with great accuracy. To achieve this goal, Marco Amabili guides the readers through nonlinear shell theories, nonlinear vibrations, buckling, composite and functionally graded materials, hyperelasticity, viscoelasticity, nonlinear damping, rubber and soft biological materials. Advanced nonlinear shell theories, not available in any other book, are fully derived in a simple notation and are ready to be implemented in numerical codes. A blend of the most advanced theory and experimental results is the book's other unique feature. It is a must-read for graduate students and researchers in applied mathematics and engineering, especially those interested in mechanics, aeronautics, civil structures, materials, bioengineering and solid matter at different scales.

Marco Amabili is Canada Research Chair Professor of Mechanical Engineering at McGill University. He is the author of more than 440 research publications (over 200 journal papers) and the book *Nonlinear Vibrations and Stability of Shells and Plates* (Cambridge University Press, 2008). He is Contributing Editor of the *International Journal of Non-linear Mechanics*, Associate Editor of the *Journal of Fluids and Structures*, *Journal of Vibration and Acoustics*, and several other journals. His research areas include vibrations of shell structures, nonlinear vibrations, fluid–structure interaction, dynamics and stability of shells and plates, cardiovascular biomechanics, viscoelasticity and nonlinear damping, and the vibration monitoring of structures and buildings.

To my parents, Vito and Antonietta

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McGill University



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Preface

The present book is intended for (1) graduate students in engineering, (2) researchers working on vibrations, shell mechanics and biomechanics and (3) engineers working on aircraft, spacecraft, cars and bioengineering. This book contains both theoretical and practical methods that could be of interest for a variety of readers. Expert researchers will find the most recent progress in nonlinear mechanics and dynamics of shells and plates, including advanced problems with nonlinear materials. Professionals will find many practical concepts, diagrams and numerical results, useful for the design of shells and plates made of traditional, advanced soft and biological materials. They will be able to understand complex phenomena such as dynamic instability, bifurcations and chaos without needing an extensive mathematical background. Graduate students will find (1) a complete text on the nonlinear mechanics of shells and plates, collecting almost all the available theories in a simple form; (2) an introduction to nonlinear dynamics and an extensive treatment of composite, functionally graded, hyperelastic and viscoelastic materials and (3) the state of art on nonlinear vibrations and the stability of shells and plates.

My interest in vibrations of shells and plates started with my master's thesis, more than 25 years ago. However, the turning of my research toward nonlinear vibrations is due to the lucky meeting of two friends: Michael P. Paidoussis and Francesco Pellicano. The three of us have worked together as a team since 1997 and for several years on challenging problems of nonlinear vibrations and the stability of circular cylindrical shells with fluid-structure interaction.

Several other eminent researchers worked with me on nonlinear vibration of shells and plates (in chronological order): Alexander Vakakis, Arun K. Misra, Kostas Karazis, Eugeni Grinevitch, Rinaldo Garziera, Abijit Sarkar, Cyril Touzé, Olivier Thomas, Roger Ohayon, Yuri Mikhlin, Konstantin Avramov, Yevgeniy Kurilov, Lidia Kurpa, Galina Pilgun, Angelo Negri, Michele Pellegrini, Silvia Carra, Korosh Khorshidi, Sirwan Farhadi, Farbod Alijani, Ivan Breslavsky, Rosaire Mongrain, Raymond Cartier, J.N. Reddy, Vincenzo D'Alessandro, Giovanni Ferrari, Eleonora Tubaldi, Farhang Daneshmand, Prabakaran Balasubramanian, Miguel Gutierrez Rivera, Joachim Delannoy, Stanislas Le Guisquet, Elvio Bonisoli, Zenon del Prado, Eelco Jansen, Antonio Zippo, Lorenzo Piccagli, Francesco Giovanniello, Margherita Capriotti, Goffredo Arena, Matteo Scapolan, Peter Steeneken and Dejan Davidovikj. My thanks go to all of them.

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A memory goes to my friend Yaroslav Bisaga, who is no longer with us, to my grandparents Antenore, Liva, Cesare, Alba and Gigetta (Zia-Nonna), to my late uncle Pino Cereghini who greatly appreciated my previous book, to Tina, and to the great encouragement of my parents Vito and Antonietta, to whom this book is dedicated.