Preface

This book is devoted to researchers and teachers, as well as graduate students, undergraduates and bachelors in mechanical engineering, nanomechanics, nanomaterials, nanostructures and applied mathematics. It serves as a research monograph which collects the latest developments in the field of nonlinear (chaotic) dynamics of mass distributed-parameter nanomechanical structures. It can be helpful for scientists and specialists interested in a rigorous and comprehensive study of modelling nonlinear phenomena governed by PDEs. The monograph has a unique pedagogical style that is particularly suitable for independent study and self-education for many researchers and specialists who do not have time to attend classes and lectures on the subject of the monograph. In addition, the book contents stand for a good balance between Western and Eastern extensive studies of the mathematical problems of nonlinear vibrations of structural members.

The authors of the proposed book work for many years in the theoretical aspects of nonlinear dynamics of mechanical macroscale and nanoscale structures and mathematical methods for solving problems governed by nonlinear PDEs. In spite of numerous published papers, the following companion books dealing with similar problems have been recently published:

1. J. Awrejcewicz, V.A. Krysko, I.V. Papkova, A.V. Krysko, *Deterministic Chaos in One-Dimensional Continuous Systems*. World Scientific, New Jersey, 2016;
2. V.A. Krysko, J. Awrejcewicz, M.V. Zhigalov, V.F. Kirichenko, A.V. Krysko, *Mathematical Models of Higher Orders: Shells in Temperature Fields*. Springer, Switzerland, 2019.

The authors employ the accumulated experience and knowledge of the long years of their research in the proposed monograph. This book will allow readers to obtain their own new results in the field of nonlinear dynamics of continuous mass (distributed-parameter) mechanical nanostructures, based on employing the ideas contained in this monograph to design novel elements of micro/nanomechanical systems, which are challenging in development of the modern engineering world. The book material offers guidelines for the development of many sensory and executive algorithms/functions used throughout, from the largest cargo ships to the smallest handheld electronic devices and from the most advanced scientific and medical equipment to the simplest household items. This monograph is one of the first on the mechanical engineering market because the authors analyse vibrations of nanostructures based on various theories of elasticity of the higher order including the modified coupled stress theory, surface theory, nonlocal theory, gradient theory and their modifications.

The bulk of the literature on nano-objects is devoted to research in nanomechanics, nanocomposites, the theory of dislocation mechanics, etc. The issues of strength, durability and time-dependent deterioration of mechanical properties, which are the main problems for design engineers, are considered. However, majority of the dynamical problems reported in the available literature are presented for strongly order reduced systems, i.e. for the governing equations of one degree of freedom systems of the Duffing type. Moreover, there are no books on nonlinear dynamics, in particular, chaotic dynamics, for nanomechanical structures in which systems with an infinite number of degrees of freedom are studied. The issues of the "truth of chaos" are not analysed, and the scenarios of the transition from periodic to chaotic vibrations exhibited by nanomechanical systems are not satisfactorily investigated. There are also very few studies regarding dynamics of nanomechanical structures based on wavelet analysis and analysis of the largest Lyapunov exponents, while there are practically no results supported by consideration of a spectrum of Lyapunov exponents. The literature state of the art shows that there are no works devoted to the study of nanoeffects and the effect of temperature action, which play a crucial role in obtaining a reliable picture of nanostructural nonlinear dynamical systems embedded into temperature fields.

The book offers a rigorous mathematical approach and verifies numerous theory-based modelling of structural members with an emphasis on microelectromechanical structures (MEMS) and nanoelectromechanical structures (NEMS), whose nonlinear dynamics plays an important role in current research observed in applied physics and engineering.

There are no competing publications on the market for the book (except perhaps the two already mentioned), and therefore the book may have a significant impact on both theoretical- and application-oriented researchers interested in nonlinear features of nanostructural members.

The authors of this monograph are intended to fill gaps in the above-mentioned problems.

We would like to acknowledge that a part of the book material has been already published in the form of papers. We have obtained permission to reuse the mentioned material in our book.

In the case of the papers: J. Awrejcewicz, A. V. Krysko, N. P. Erofeev, V. Dobriyan, M. A. Barulina, V. A. Krysko, "Quantyfying chaos by various computational methods. Part 1: Simple systems", *Entropy*, 20(3), 2018, 175 and J. Awrejcewicz, A. V. Krysko, N. P. Erofeev, V. Dobriyan, M. A. Barulina, V. A. Krysko, "Quantyfying chaos by various computational methods. Part 2: Vibrations of the Bernoulli-Euler beam subjected to periodic and colored noise",

Entropy, 20(3), 2018, 170, the permission is not required, since they were published under full open access (Chaps. 3 and 5).

The same holds for the paper J. Awrejcewicz, V. A. Krysko, S. Pavlov, M. V. Zhigalov, L. A. Kalutsky, A. V. Krysko, "Thermoelastic vibrations of a Timoshenko microbeam based on the modified couple stress theory", *Nonlinear Dynamics*, 2020, 99, 919–943, material of which has been used in Chap. 8.

Chapter 4 is based on the paper V. A. Krysko, J. Awrejcewicz, I. V. Papkova, O. A. Saltykova, A. V. Krysko, "On reliability of chaotic dynamics of two Euler-Bernoulli beams with a small clearance", *International Journal of Non-Linear Mechanics*, 104, 2018, 8–18 (licence 4858731296328).

Chapter 6 is based on the papers: A. V. Krysko, J. Awrejcewicz, M. V. Zhigalov, S. P. Pavlov, V. A. Krysko, "Nonlinear behaviour of different flexible size-dependent beams models based on the modified couple stress theory. Part 1. Governing equations and static analysis of flexible beams", *International Journal of Non-Linear Mechanics*, 93, 2017, 96–105 (licence 4858731357453) and A. V. Krysko, J. Awrejcewicz, M. V. Zhigalov, S. P. Pavlov, V. A. Krysko, "Nonlinear behaviour of different flexible size-dependent beams models based on the modified couple stress theory. Part 2. Chaotic dynamics of flexible beams", *International Journal of Non-Linear Mechanics*, 93, 2017, 106–121 (licence 4858731418376).

Chapter 7 is based on the papers: J. Awrejcewicz, A. V. Krysko, S. P. Pavlov, M. V. Zhigalov, V. A. Krysko, "Chaotic dynamics of size-dependent Timoshenko beams with functionally graded properties along their thickness", *Mechanical Systems and Signal Processing*, 93, 2017, 415–430 (licence 4865190257673), J. Awrejcewicz, A. V. Krysko, S. P. Pavlov, M. V. Zhigalov, V. A. Krysko, "Stability of the size-dependent and functionally graded curvilinear Timoshenko beams", *Journal of Computational and Nonlinear Dynamics*, 12(4), 2017, 041018 (licence 1047522-1), A. V. Krysko, J. Awrejcewicz, I. E. Kutepov, V. A. Krysko, "Stability of curvilinear Euler-Bernoulli beams in temperature fields", *International Journal of Non-Linear Mechanics*, 94, 2017, 207–215 (licence 4858620136357) and A. V. Krysko, J. Awrejcewicz, S. P. Pavlov, M. V. Zhigalov, V. A. Krysko, "Mathematical model of a three-layer micro- and nanobeams based on the hypotheses of the Grigolyuk-Chulkov and the modified couple stress theory", *International Journal of Solids and Structures*, 117, 2017, 39–50 (licence 4858611485608).

Chapter 9 is based on the papers: A. V. Krysko, J. Awrejcewicz, S. P. Pavlov, K. S. Bodyagina, V. A. Krysko, "Topological optimization of thermoelastic composites with maximized stiffness and heat transfer", *Composites Part B*, 2019, 158, 319–327 (licence 4860611503624) and A. V. Krysko, J. Awrejcewicz, S. P. Pavlov, K. S. Bodyagina, M. V. Zhigalov, V.A. Krysko, "Non-linear dynamics of size-dependent Euler-Bernoulli beams with topologically optimized microstructure and subjected to temperature field", *International Journal of Non-Linear Mechanics*, 104, 2018, 75–86 (licence 4858620075449).

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Lodz, Poland — Jan Awrejcewicz
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Saratov, Russia — Maxim V. Zhigalov
Saratov, Russia — Vadim A. Krysko

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