Preface

In practical applications that range from outer space to the deep oceans, engineering structures such as aircraft, rockets, automobiles, turbines, architectures, vessels, and submarines often work in complex environments and can be subjected to various dynamic loads, which can lead to the vibratory behaviors of the structures. In all these applications, the engineering structures may fail and collapse because of material fatigue resulting from vibrations. Many calamitous incidents have shown the destructive nature of vibrations. For instance, the main span of the famous Tacoma Narrows Bridge suffered severe forced resonance and collapsed in 1940 due to the fact that the wind provided an external periodic frequency that matched one of the natural structural frequencies of the bridge. Furthermore, noise generated by vibrations always causes annoyance, discomfort, and loss of efficiency to human beings. Therefore, it is of particular importance to understand the structural vibrations and reduce them through proper design to ensure a reliable, safe, and lasting structural performance. An important step in the vibration design of an engineering structure is the evaluation of its vibration modal characteristics, such as natural frequencies and mode shapes. This modal information plays a key role in the design and vibration suppression of the structure when subjected to dynamics excitations. In engineering applications, a variety of possible boundary restraining cases may be encountered for a structure. In recent decades, the ability of predicting the vibration characteristics of structures with general boundary conditions is of prime interest to engineers and designers and is the mutual concern of researchers in this field as well.

Beams, plates, and shells are basic structural elements of most engineering structures and machines. A thorough understanding of their vibration characteristics is of great significance for engineers to predict the vibrations of the whole structures and design suitable structures with low vibration and noise radiation characteristics. There exists many books, papers, and research reports on the vibration analysis of beams, plates, and shells. In 1969, Prof. A.W. Leissa published the excellent monograph *Vibration of Plates*, in which theoretical and experimental results of approximately 500 research papers and reports were presented. And in 1973, he organized and summarized approximately 1,000 references in the field of shell vibrations and published another famous monograph entitled *Vibration of Shells*. New survey shows that the literature on the vibrations of beams, plates, and shells has expanded rapidly since then. Based on the Google Scholar search tool, the numbers of article related to the following keywords from 1973 up to 2014 are: 315,000 items for "vibration & beam," 416,000 items for "vibration & plates," and 101,000 items for "vibration & shell." This clearly reveals the importance of the vibration analysis of beams, plates, and shells.

Undeniably, significant advances in the vibration analysis of beams, plates, and shells have been achieved over the past four decades. Many accurate and efficient computational methods have also been developed, such as the Ritz method, differential quadrature method (DQM), Galerkin method, wave propagation approach, multiquadric radial basis function method (MRBFM), meshless method, finite element method (FEM), discrete singular convolution approach (DSC), etc. Furthermore, a large variety of classical and modern theories have been proposed by researchers, such as the classical structure theories (CSTs), the first-order shear deformation theories (FSDTs), and the higher order shear deformation theories (HSDTs).

However, after the review of the literature in this subject, it appears that most of the books deal with a technique that is only suitable for a particular type of classical boundary conditions (i.e., simply supported supports, clamped boundaries, free edges, shear-diaphragm restrains and their combinations), which typically requires constant modifications of the solution procedures and corresponding computation codes to adapt to different boundary cases. This will result in very tedious calculations and be easily inundated with various boundary conditions in practical applications since the boundary conditions of a beam, plate, or shell may not always be classical in nature, a variety of possible boundary restraining cases, including classical boundary conditions, elastic restraints, and their combinations may be encountered. In addition, with the development of new industries and modern processes, laminated beams, plates, and shells composed of composite laminas are extensively used in many fields of modern engineering practices such as space vehicles, civil constructions, and deep-sea engineering equipments to satisfy special functional requirements due to their outstanding bending rigidity, high strength-weight and stiffness-weight ratios, excellent vibration characteristics, and good fatigue properties. The vibration results of laminated beams, plates, and shells are far from complete. It is necessary and of great significance to develop a unified, efficient, and accurate method which is capable of universally dealing with laminated beams, plates, and shells with general boundary conditions. Furthermore, a systematic, comprehensive, and up-to-date monograph which contains vibration results of isotropic and laminated beams, plates, and shells with various lamination schemes and general boundary conditions would be highly desirable and useful for the senior undergraduate and postgraduate students, teachers, engineers, and individual researchers in this field.

In view of these apparent voids, the present monograph presents an endeavor to complement the vibration analysis of laminated beams, plates, and shells. The title, *Structural Vibration: A Uniform Accurate Solution for Laminated Beams, Plates and Shells with General Boundary Conditions*, illustrates the main aim of this book, namely:

(1) To develop an accurate semi-analytical method which is capable of dealing with the vibrations of laminated beams, plates, and shells with arbitrary lamination schemes and general boundary conditions including classical boundaries, elastic supports and their combinations, aiming to provide a unified and reasonable accurate alternative to other analytical and numerical techniques.
(2) To provide a summary of known results of laminated beams, plates, and shells with various lamination schemes and general boundary conditions, which may serve as benchmark solutions for the future research in this field.

The book is organized into eight chapters. Fundamental equations of laminated shells in the framework of classical shell theory and shear deformation shell theory are derived in detail, including the kinematic relations, stress–strain relations and stress resultants, energy functions, governing equations, and boundary conditions. The corresponding fundamental equations of laminated beams and plates are specialized from the shell ones. Following the fundamental equations, a unified modified Fourier series method is developed. Then both strong and weak form solution procedures are realized and established by combining the fundamental equations and the modified Fourier series method. Finally, numerous vibration results are presented for isotropic, orthotropic, and laminated beams, plates, and shells with various geometry and material parameters, different lamination schemes and different boundary conditions including the classical boundaries, elastic ones, and their combinations. Summarizing, the work is arranged as follows:

The theories of linear vibration of laminated beams, plates, and shells are well established. In this regard, Chap. 1 introduces the fundamental equations of laminated beams, plates, and shells in the framework of classical shell theory and the first-order shear deformation shell theory without proofs.

Chapter 2 presents a modified Fourier series method which is capable of dealing with vibrations of laminated beams, plates, and shells with general boundary conditions. In the modified Fourier series method, each displacement of a laminated beam, plate, or shell, regardless of boundary conditions, is invariantly expressed as a new form of trigonometric series expansions in which several supplementary terms are introduced to ensure and accelerate the convergence of the series expansion. Then one can seek the solutions either in strong form solution procedure or the weak form one. These two solution procedures are fully illustrated in this chapter.

Chapters 3–8 deal with laminated beams, plates, and cylindrical, conical, spherical and shallow shells, respectively. In each chapter, corresponding fundamental equations in the framework of classical and shear deformation theories for the general dynamic analysis are developed first, which can be useful for potential readers. Following the fundamental equations, numerous free vibration results are presented for various configurations including different boundary conditions, laminated sequences, and geometry and material properties.

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