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Book Reviews

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Vibration of Laminated Shells and Plates

Mohamad S. Qatu, Elsevier Academic Press, Amsterdam, 2004, 409 pp., $180.00

Composites, after some reluctance on the part of designers, are finally poised to become a material of choice for aerospace, automobile, chemical, and civil engineering. Airbus's A380 and Boeing's 7E7 will both have a substantial percentage of their primary load-carrying structures made out of composites. Significant advances have been made in the past two decades toward understanding the static and dynamic behavior of composite structures (beams, plates, and shells). There is always a need for books that clearly bring out recent advances in the analysis and design of composite structures to engineers, graduate students, and researchers involved with structures made of these materials that have remarkable properties. The book under review, dealing with vibration of laminated shells and plates, is a welcome addition to the shelf of books on composite materials.

Dr. Mohamad Subhi Qatu, who works at the Ford Motor Company and who did his doctoral work under the guidance of Prof. Art Leissa, a world-renowned expert in plates and shells at Ohio State University, has divided his book into 10 chapters. It was interesting to see the word "Shell" placed before "Plates" in the title of the book. This reminded the reviewer of the book by Prof. Werner Soedel (*Vibrations of Shells and Plates*, Marcel Dekker, New York, 1993) of Purdue, who taught vibrations of shells and plates to this reviewer. It should also be mentioned at the outset that the book does not cover material on layerwise theories. That is not a huge loss as the author does provide a number of relevant references and that material is readily available in the second edition of Prof. J. N. Reddy's book *Mechanics of Laminated Composite Plates and Shells* (CRC Press, Boca Raton, FL, 2004). A reader should definitely keep a copy of both of these books at her/his side while studying Dr. Qatu's book.

Chapter 1, Introduction, gives a succinct description of the history of plates and shells, analysis of laminated plates and shells, and theory of elasticity including kinematic relations, stress-strain relations, constitutive relations for laminated materials, and Hamilton's variational principle. I wish Dr. Qatu had given more details, including an example about Hamilton's principle, especially its value in deriving boundary conditions. Fortunately, he does provide a list of references that a reader can go to for a better understanding of this very important principle. To his list, I would add a series of papers by Prof. C.D. Bailey, a recent one being "The Unifying Laws of Classical Mechanics," *Foundations of Physics*, Vol. 32, No. 1, 2002.

Chapter 2, Shell Theories, gives a brief overview of three-dimensional elasticity in curvilinear coordinates (theory of surfaces, strain-displacement and stress-strain relations, and equations of motion), reduces these equations to thick- and thin-shell theories, and provides a list of references that employ layerwise theory and also some references related to nonlinear theories. This chapter, 33 pages long, is one of the better chapters in the book. The author gives the constitutive relations for thick shells that take into account the $(1+z/R)$ terms, terms that are often simplified by other authors by assuming z/R to be negligible compared to 1. In subsequent chapters the author has given some qualitative description of the error (it could be up to 7%) that one makes when assuming z/R to be negligible compared to 1. There are some typographical errors, but overall this is a good chapter.

Chapter 3, Methods of Analysis, briefly describes various methods used in studying the vibration of shells, including experimental methods and the Rayleigh–Ritz, Galerkin, and finite element methods. The description is so brief that, at least in this reviewer's mind, the chapter does more harm than good. The methods are described as if they were being applied to a static problem. For example, see Eq. (3.2). Similarly in Eqs. (3.5) and (3.10), the term in the Lagrange equations that leads to the mass matrix, the time derivative of the partial derivative of Lagrangian with respect to a generalized velocity, is missing. Lack of this term would only confuse a reader when faced with the statement, "Note that *Kij* term includes both stiffness and mass coefficients needed in the dynamic analysis." It is never explained how one gets the stiffness and mass coefficients. To be fair, in a subsequent chapter, Chapter 4, the author changes the definition of the Lagrangian from the standard definition to $L = T_{\max} - U_{\max}$ and obtains the eigenvalue problem (stiffness and mass matrices) by finding the stationary value of this functional. It is unconventional but not incorrect. In the standard Rayleigh–Ritz method, we obtain the eigenvalue problem by minimizing the expression for ω^2, where ω is a natural frequency. Much of this confusion can be avoided by using Lagrange's equations to derive the eigenvalue problem. This chapter requires significant revision in the next edition. Until then, I suggest that a reader, before proceeding with the rest of the book, get basic background in approximate methods for dynamic problems from other sources. The classic by Hurty and Rubinstein (W. C. Hurty and M. F. Rubinstein, *Dynamics of Structures*, Prentice–Hall, 1964) readily comes to mind.

Chapter 4, Curved Beams, provides governing equations and some sample boundary conditions for curved laminated beams. I found the author's use of the Hamilton principle in deriving the governing equations very different from the one we all are used to. For example, in Eqs. (4.18) and (4.36), the author for some inexplicable reason removes the integral over the time and simply takes the variation of the Lagrangian. It is not clear what happens to this variation. Is it equated to zero? If so, then why? What happens to the variation of velocity terms in Eq. (4.18)? Without the integration by parts over the time domain, how does one go from variation of velocity to that of displacement and obtain the terms containing accelerations? It is to be hoped that the next edition will have these questions answered. On the positive side, the author provides exact results for simply supported laminated curved thin beams along with some results using the Ritz method.

Chapters 5, Plates, 6, Shallow Shells, 7, Cylindrical Shells, and 8, Conical Shells, are substantial chapters and together constitute the core of the book. Chapter 5, nearly 70 pages long, first describes the fundamental equations of the plates as derived from the general equations for the shells by letting the two principal curvatures go to zero. The equations are kept in the fundamental form so that the same equations, using appropriate fundamental or Lame's parameters, can represent plates of all shapes, rectangular, circular, elliptic, trapezoidal, etc. Governing equations are given for both thin and thick plates. Next, results using Levy's approach are obtained for cross-ply plates and antisymmetrically laminated plates that have two opposite edges simply supported. For plates with more general boundary conditions, the Ritz (Rayleigh–Ritz) approach is used. The trial functions are expressed in terms of simple algebraic polynomials, leaving the author faced with the problem of numerical ill-conditioning. This is to be expected. As the order of the simple algebraic polynomials is increased, these polynomials, because of finite precision of available computers, become, computationally speaking, linearly dependent. This is explained by Fletcher (C. A. J. Fletcher, *Computational Galerkin Methods*, Springer-Verlag, 1984). Use of very high precision in computations and orthogonal polynomials are often recommended to overcome this problem of ill-conditioning. Some results are also given for triangular and trapezoidal plates. Finally, the governing equations for circular plates are given, but without any results.

Chapter 6 (72 pages) is very similar to Chapter 5, and it focuses on shallow shells that have rectangular, trapezoidal, triangular, and circular planforms. Shells with some pretwist, used to represent turbine blades, are also studied. Most of the results are obtained using the Ritz method and, as are the results given in other chapters, are essentially taken from the author's publications. Some finite element results for a spherical cap are also provided. In all of these chapters (5–8), the convergence is studied in some detail and many figures showing relevant mode shapes are shown. Also presented in all of these chapters is the effect of ply sequence on the natural frequencies for some sample shells. That should be of interest to researchers involved with using the Rayleigh–Ritz method to solve vibration problems in laminated plates and shells.

Chapter 7, which is 50 pages long, presents the basic theory for thin and thick cylindrical shells, including the governing equations and energy functionals. Both circular (including barrels) and noncircular cross sections are considered. Chapter 8, Conical Shells, a brief 20-page chapter, provides the basic theory and some results for conical shells. Chapter 9, Spherical Shells, a seven-page chapter, provides the governing equations and some free vibration results for spherical shells. Chapter 10, Complicating Effects, a six-page chapter, points to some recent literature on thermal loading, stiffening of a shell due to rotation, imperfect shells, piezoelectric shells, shells embedded in or filled with elastic or fluid media, and other complexities such as Pasternak foundations, variable thickness, and dynamic instability. The book also contains a large number of references related to vibration of composite plates and shells and a subject index. An authors' index would have been helpful.

In summary, the increasing use of composites in aerospace and other related industries has led to a great demand for books on various aspects of analysis and design of composite structures. Chapters 2 and 5–8 of this book fulfill some of that need. However, the high price of this book makes it unaffordable to many researchers, and the lack of examples (both solved and unsolved), along with the book's emphasis on only the Rayleigh–Ritz method, hampers its adoption as a text. Finally, I hope that the next edition will see substantially revisions of Chapters 3, 9, and 10, correct spellings of Ambartsumyan, and Goldenveizer, and this reviewer's name corrected to Kapania, R. K., from Kapania, P. K.

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