Book Reviews

Die Methode der Finiten Elemente, Band III: Einfüring in die Dynamik (in German)

John Argyris F. R. S. and Hans-Peter Mlejnek, Friedr. Vieweg and Sohn, Braunschweig/Wiesbaden, 1988, 946 pp.

Professor Argyris, having envisioned the emerging capabilities of high-speed computing machines as early as 1950, introduced the concept of finite elements into the field of modern computational mechanics. This concept has been extended to other disciplines including fluid mechanics, heat transfer, electromagnetism, and others that involve continuum and discontinuum field problems. His forty years of research experience is shared in this treatise, which is comprised of three volumes. This, indeed, is a masterpiece.

The first two volumes deal with the force and displacement methods employed in structural analysis, including nonlinear computational methods. The third volume is devoted to linear and nonlinear dynamic analyses and is the subject of this review. The volume begins with Chapter 14 and continues through Chapter 26, with half of the chapters being devoted to linear dynamics and the other half to nonlinear dynamics. The first chapter covers basic introductions to dynamics with extensive use of illustrations. The next chapter highlights the understanding of kinematics in inertial and moving coordinate systems. Subsequently, the virtual work principle is introduced to derive element mass matrices. Chapter 16 demonstrates the application of these principles to develop element mass matrices.

Chapter 17 describes, in great detail, the eigenvalue analysis methods of large-scale systems, which may include singular mass or stiffness matrices and multiple eigenvalues. This chapter also includes an interesting appendix describing the computation of orthogonal vectors with respect to a given mass matrix. Chapter 18 summarizes economical methods of eigenvalue analysis, such as modal techniques and dynamic reduction.

The response analysis of damped and undamped systems are discussed in Chapters 19 and 20. Many numerical examples are used to illustrate the characteristics of responses due to various types of excitations. The authors present statistical analyses in Chapter 21, using easy to understand mathematical notations. Important statistical definitions are tabulated for ready references. A large number of examples are also included.

Chapter 22 treats special eigenvalue solution schemes, such as the modified Jacobi and Eberlein techniques as applied to systems with nonproportional damping. In Chapter 23, the authors extend the finite-element formulation to space and time coordinates. A vivid discussion on the basic principles of direct integration methods is covered in the first few sections of this chapter. In subsequent sections, the stability and accuracy characteristics of Newmark's β-γ method and the cubic Hermitian method proposed by Argyris and his collaborators are discussed in detail.

A fascinating introduction to nonlinear dynamics is presented in Chapter 24. Nearly 150 pages are devoted to this complex topic. Aspects of nonlinear phenomena are illustrated by means of the classical Duffings' equation. Following this introduction, advanced numerical integration methods are described at length. The cubic Hermitian and Newmark's methods are again applied to solve highly nonlinear problems such as those concerned with displacement dependent forces and the large deformations of crashworthiness studies. In all these test cases, the cubic Hermitian method is seen to show excellent computational stability and robustness, even when large time steps are used. This chapter also includes an interesting example of the modeling of the dynamics of celestial bodies by finite-element methods.

The study of Chaos has always been of interest to mathematicians and physicists. However, because of the recent availability of high-speed computing machines, this study of irregular motions based on nonlinear deterministic equations has been extended to engineering sciences. Some of the dynamical systems, under particular initial conditions, exhibit strange behaviors. For example, a mass point as a nonlinear system may have more than one equilibrium position, which may be unpredictable in time. This complex phenomenon cannot be explained in simple mathematical terms. In Chapter 25, however, the authors have succeeded in describing the basic principles of chaotic motions, in as simple a language as possible, while keeping the famous quotation from Albert Einstein in mind: "Everything should be made as simple as possible, but not simpler." The first few sections review the definitions of commonly used terms such as causality, point attractor, limit cycles, Lorenz attractor, Poincaré mapping, Hénon portrait and invariant manifolds with ample amount of examples and illustrations. In subsequent sections the well-known Kolomogorov-Arnold-Moser (KAM) theory and the criteria for the existence of chaotic motions are presented with a number of color photographs depicting the fractals of chaotic motions.

Having discussed linear and nonlinear dynamic phenomena, the authors conclude this volume with the study of aeroelasticity in Chapter 26, a phenomena that is an interaction of aerodynamic, elastic, and inertial forces. The stability of a system is judged by the balance of energy in a cycle of oscillation, and can be classified broadly as static or dynamic in nature. The authors highlight various types of instabilities with a reference to the aeroelastic triangle used by Prof. Collar. In the first few sections an excellent introduction to the characteristics of steady and unsteady flows and the work done by the air loads is presented. Subsequently, classical two-dimensional aeroelastic problems, such as divergence, aileron effectiveness, aileron reversal speed, and flutter are presented. Linear and nonlinear panel flutter solution methods in supersonic flow, and the application of finite-element methods to determine unsteady air loads are also outlined. The reader will find some interesting discussions on nonlinear characteristics of stall flutter, both in bending and torsion modes.

Following the introduction to flutter mechanisms, practical flutter solution methods such as V-g method and the CT method of Wittmeyer are described. In the next section, the authors introduce some advanced topics in active flutter suppression and optimum design with some examples.

Finally, the authors conclude this chapter with some valuable outlines on computational fluid dynamics (CFD) by finite-element methods (FEM). In published articles, the authors have demonstrated the feasibility of applying finite-element methods for determining transient aerodynamic loads for applications in flutter analyses. They employ the Navier-Stokes equations for incompressible and compressible fluid media including hypersonic flow regimes. It appears from these discussions that CFD analysis by the FEM may have distinct advantages over other methods.

Each chapter in this book contains extensive literature references, lucid mathematical developments, and intriguing examples. The reader will appreciate the authors' efforts in maintaining systematic definitions, symbols, and notations for easy reading. This book will serve the engineering community as a valuable reference text. Therefore, the reviewer not only recommends the addition of this book (in three volumes) to every engineering library, but also as a personal copy for every practicing engineer, researcher, and student.

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Hypersonic and High Temperature Gas Dynamics

J. D. Anderson Jr., McGraw-Hill, NY 1989, 680 pp., $49.95.

Recent vehicle concepts involving high Mach-number cruise and aero-assisted orbital transfer are driving renewed interest in hypersonics, an area that had not attracted much attention since the end of the 1960s. Several texts/monographs on hypersonic flow and high-temperature gasdynamics were published before 1966,[1-7] but the present book by John D. Anderson Jr. is the first basic text to become available since then. The text was designed, as the Preface indicates, to be a *self-contained teaching instrument* for a new generation of engineers and scientists interested in learning the fundamentals of hypersonic flows and high-temperature gasdynamics, as well as certain "modern perspectives" gained from space-shuttle program developments. Thus, the work is intended to make up for this 20-year hiatus, while at the same time furnishing the needed fundamentals on the subject matter. A basic knowledge of fluid mechanics and compressible flow at the undergraduate level is assumed for the readers. The book was to play two roles: (1) a textbook to be used by senior undergraduate and first-year graduate students, and (2) a viable, working tool for engineers and program managers on jobs related to hypersonics. Of these ends, the first was achieved admirably well and the second may also be considered successful, with more specific qualifications given below.

Several textbooks written earlier by Anderson[8-11] have enjoyed great popularity among students in aerospace engineering for their lively presentation and clear exposition, and this one should not be an exception. The numerous AIAA-sponsored workshops on hypersonic flows organized and led by the author also proved to be successful. The book in fact represents a physically more attractive, compact form of his workshop lecture notes. The content falls into three distinct parts: 1) Inviscid Hypersonic Flow, 2) Viscous Hypersonic Flow, and 3) High-Temperature Gasdynamics. With the expressed goals of the book, issues on the flow physics and fluid mechanic modeling and related theoretical works, as well as some of the important advances in computation methods, cannot be critically addressed at the same level achieved by Hayes and Probstein's scholarly monograph.[1,7] However, the materials presented obviously offer a wider and more up-to-date coverage in a user-friendly format, serving well the goals set for a "modern education in hypersonics and high-temperature gasdynamics."

Much of the fundamental aspects in Parts I and II are identifiable with the more elementary treatises and equations for the classical theory[1-3,5,7] and gasdynamics,[4,6] which are interspersed with examples of computations and their comparison with flight measurements. The latter were generated partly from the author's own research in the past, but mostly from research and development in support of the space-shuttle program, unavailable two decades earlier. Although the level of sophistication in numerical methods has been kept low, to be consistent