Journal of Applied Mechanics

Book Reviews

Mathematical Models in Applied Mechanics, by A. B. Tayler. Oxford University Press, New York, 1986. 280 Pages. Price: $29.95/cloth; $14.95/paper.

REVIEWED BY J. B. KELLER[1]

This very readable book is concerned primarily with the formulation of mathematical models of physical phenomena, especially in mechanics. It teaches modeling by example, using twenty-two typical problems which have arisen from industrial research. In each case it explains the physical background of the situation and then shows how to formulate a mathematical problem to model it. This is followed by some mathematical analysis of the problem, with the purpose of illustrating some important features of the solution.

All of the mathematical models involve partial differential equations. They are grouped into three chapters on hyperbolic, elliptic, and parabolic problems, respectively. These chapters are preceded by one which describes nondimensionalization, some perturbation procedures, some methods for solving ordinary differential equations, and some basic equations of fluid dynamics and elasticity. A final chapter presents asymptotic methods for nonlinear problems, such as boundary layer and ray methods. Each chapter ends with a set of exercises.

The variety of problems is great as the following selection indicates: Pantograph dynamics, coal seam exploration, flow of granular material, electrochemical painting, percolation in a sand dune, hot rolling of steel, smoke dispersion from a chimney, welding of two steel plates, spreading of an oil film, injection moulding, seismic detection.

The book can be read by anyone with some knowledge of differential equations and mechanics. It could be used as a text for a course on modeling or as a supplementary text for a course on partial differential equations. Since the presentation is lively and informal, it is a pleasure to read just to learn about a large number of interesting applications.

Solid Mechanics Research for Quantitative Non-Destructive Evaluation, edited by J. D. Achenbach and Y. Rajapakse. Martinus Nijhoff Publishers, The Netherlands, 1987. 438 Pages price: $122.00.

REVIEWED BY A. K. GAUTESEN[2]

This book contains the proceedings of the ONR Symposium on Solid Mechanics Research for Quantitative Non-Destructive Evaluation (QNDE) which was held at Northwestern University in September, 1985. Here, the state of the art in QNDE was reviewed along with the methods and techniques being investigated at the time.

With the advent of modern technology it has become possible to detect very small inhomogeneities in materials by nondestructive evaluation procedures. Since some of the detected inhomogeneities will not affect the serviceable life of the material, the need has arisen for more quantitative information about the inhomogeneity—such as location, size, shape, and orientation. This need has given birth to a more fundamental and rigorous approach called QNDE. Disciplines spanned by this approach include mechanics of solids, materials science, electrical engineering, applied physics, applied mathematics, and computer science. Although significant progress has been made, QNDE is still in its infancy and fundamental deficiencies exist in many areas. This field continues to be the focus of intense research.

This book is organized into nine chapters. In Chapter 1, R. deNale and D. E. Chimenti describe requirements in QNDE for the Navy and Air Force, respectively. In Chapter 2, H. N. G. Wadley discusses the use of acoustic emission as a QNDE technique for the study of fracture; and W. Sachse summarizes the application of quantitative acoustic emission measurements for the investigation of dynamic fracture processes and for the characterization of materials and transducers. In Chapter 3, J. D. Achenbach reviews some aspects of flaw characterization by ultrasonic scattering

[1] Professor, Mathematics Department, Stanford University, Stanford, CA 94305.

[2] Senior Mathematician and Professor of Mathematics, Dept. of Mathematics and Ames Laboratory, Iowa State University, Ames, IA 50011.

methods, and L. Adler discusses related experimental results. In Chapter 4, J. N. Yang describes the application of QNDE results to retirement-for-cause analysis; R. B. Thompson, O. Buck, and D. K. Rehbein review the present state of theoretical understanding of elastic wave interactions with partially contacting interfaces; and A. Vary advances three conceptual models for interrelating ultrasonic attention, microstructure, and fracture toughness. In Chapter 5, G. A. D. Briggs and M. G. Somekh review recent developments in acoustic microscopy of surface cracks; and B. T. Khuri-Yakub and P. A. Reinholdtsen present experimental results obtained by an acoustic microscope. In Chapter 6, Y. Bar-Cohen reviews the ultrasonic NDE of composites; and in separate articles by I. M. Daniel and S. C Wooh, and by E. G. Henneke, II, J. C. Duke and R. C. Stiffler, the characterization of damage in composite laminates is studied. In Chapter 7, R. L. Thomas, L. D. Favro, and P. K. Kuo review various techniques for making thermal wave images of defects and maps of material characteristics of opaque solids. Chapter 8 begins with a review by Y. H. Pao of the theories of acoustoelasticity and of acoustoplasticity, which is followed by three papers (by H. Fukuoka; M. Namkung, D. Utrata, J. S. Heyman, and S. G. Allison; and C. M. Sayers) on the measurement of residual stresses. The final chapter contains eight contributed papers.

This book offers a valuable collection of expository articles and is to be recommended to the reader for its excellent overview of current directions of research and latest results in the field of QNDE.

Theory of Plasticity, by J. Chakrabarty. McGraw-Hill Book Company, New York, 1987. 791 pages.

REVIEWED BY W. J. DRUGAN[3]

Since the pioneering work of Tresca in 1864, many talented engineers and applied mathematicians have contribuited to the theory of metal plasticity, developing an elegant framework capable of describing many nonlinear physical phenomena, and devising clever solutions to numerous technological problems. This book describes certain parts of this theory and its applications. On the topics it covers, the book is extraordinarily thorough, providing detailed analyses and discussions, and numerous references to the technical literature. It is well-written, makes generous use of figures, and reports many sets of experimental results. There is also a long list of problems at the end of each chapter. My main difficulty with the book is that, despite its substantial length (791 pages), it is too narrow in scope: many important advances of the past 25 years or so go unmentioned. Perhaps this is to be rectified by a second volume that the Preface implies is forthcoming, but the author has permitted the book's limited scope to affect the perspective presented in the present volume. For example, on Page 1, the author states "The development of anisotropy with progressive cold work and the resulting strain-hardening are too complex to be successfully incorporated in the theoretical framework. In the mathematical theory of plasticity, it is generally assumed that the material remains isotropic throughout the deformation irrespective of the degree of cold work." Another example occurs on Page 55, in a general discussion of the yield criterion concept: "In developing a mathematical theory, it is necessary to take into account a number of idealizations at the outset. Firstly, it is assumed that the conditions of loading are such that all strain rate and thermal effects can be neglected. Secondly, the Bauschinger effect and the hysteresis loop, which arise from nonuniformity on the microscope scale, are disregarded. Finally, the material is assumed to be isotropic..." These statements and others may be misleading to a graduate student or researcher attempting to learn the current status of the theory.

The book if organizaed as follows. Chapter 1 briefly describes the physical mechanisms of plastic deformation, provides a fairly detailed discussion of uniaxial stress-strain behavior, and reviews the analysis of stress and strain, including objective and nominal stress rates. Some of the discussion of stress and strain could be improved by using tensor notation or making more use of index notation. Chapter 2 is the best in the book. Although restricted to initially isotropic response of rate-independent materials, this chapter gives a clear, well-referenced, relatively concise presentation of isotropic yield criteria and stress-strain equations, with comparisons of their predictions to experimental data, isotropic and kinematic hardening, general; plastic flow rules and Drucker's postulate, Hencky's "deformation" theory and Budiansky's juistification of its use at yield surface vertices; theorems of limit analysis, and uniqueness theorems and extremum principles for small and large deformations.

The remainder of the book gives applications of the isotropic elastic-plastic theory characterized by the Mises yield condition and Prandtl-Reuss flow rule (or Tresca yield condition and associated flow rule), or its rigid-plastic simplification, assuming nonhardening response for the most part. Except for Chapter 4, which is a quite comprehensive account of the plastic analysis of beams and frames (including limit analysis of beams, frames, arches, columns, variable repeated loading, and minimum weight design), the remainder (indeed, most) of the book is largely patterned after Rodney Hill's superb *The Mathematical Theory of Plasticity* (Oxford, 1950; 1983 paperback). This contributes greatly to the book's narrowness of focus, since many new areas and perspectives within plasticity have developed in the thirty-seven years since Hill organized the then-extant body of research. Chapters 3 and 5, then, are lengthy (one is tempted to say exhaustive) collections of analytical solutions to elastic-plastic problems having simple geometries, such as problems involving bending, torsion, spherical and axial symmetry. Most of the work reported in Chapters 1–5 was done prior to 1960, although Chapter 5 does have a nine-page subsection on the finite element method. Chapter 6 lays out plane strain rigid-ideally plastic slip-line theory, the application of which to numerous problems of steady and nonsteady flow is reported in detail in Chapters 7 and 8. One of the book's greatest strengths is the completeness and clarity with which it presents and interprets the solutions of the specific problems reported in Chapters 3–5 and 7–8, together with the references provided both to the original sources and to more recent work related to these problems, such as experimental results, analyses including work-hardening, and numerical analyses.

As noted, perhaps the major drawback of the book is its omission of several important advances and areas that have developed in the past 25 years or so. To be specific, I would like to have seen included treatments of: general anisotropic elastic-plastic response, including anisotropic initial yield; modern constitutive formulations for large elastic-plastic deformations; thermodynamics of elastic-plastic materials; the micromechanical foundations of macroscopic constitutive equations; plastic flow localization; constitutive equations that account for void formation and growth, and those that exhibit non-normality; elastic-plastic wave propagation; rate-dependent plasticity; plasticity of nonmetals, such as soil, ice, etc.; and a much more expansive coverage of numerical methods for plasticity. This being understood, the book is recommended for its treatment of the topics it does cover.

[3]Associate Professor, Department of Engineering Mechanics, University of Wisconsin, Madison, WI 53706. Assoc. Mem., ASME.