CONTINUUM MECHANICS

This is a modern textbook for courses in continuum mechanics. It provides both the theoretical framework and the numerical methods required to model the behavior of continuous materials. This self-contained textbook is tailored for advanced undergraduate or first-year graduate students with numerous step-by-step derivations and worked-out examples. The author presents both the general continuum theory and the mathematics needed to apply it in practice. The derivation of constitutive models for ideal gases, fluids, solids, and biological materials and the numerical methods required to solve the resulting differential equations are also detailed. Specifically, the text presents the theory and numerical implementation for the finite difference and the finite element methods in the Matlab® programming language. It includes thirteen detailed Matlab® programs illustrating how constitutive models are used in practice.

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Continuum Mechanics

CONSTITUTIVE MODELING OF STRUCTURAL AND BIOLOGICAL MATERIALS

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To Irene, Emma, and Nina with love.

Contents

Preface

This textbook is designed to give students an understanding and appreciation of continuum-level material modeling. The mathematics and continuum framework are presented as a tool for characterizing and then predicting the response of materials. The textbook attempts to make the connection between experimental observation and model development in order to put continuum-level modeling into a practical context. This comprehensive treatment of continuum mechanics gives students an appreciation for the manner in which the continuum theory is applied in practice and for the limitations and nuances of constitutive modeling.

This book is intended as a text for both an introductory continuum mechanics course and a second course in constitutive modeling of materials. The objective of this text is to demonstrate the application of continuum mechanics to the modeling of material behavior. Specifically, the text focuses on developing, parameterizing, and numerically solving constitutive equations for various types of materials. The text is designed to aid students who lack exposure to tensor algebra, tensor calculus, and/or numerical methods. This text provides step-by-step derivations as well as solutions to example problems, allowing a student to follow the logic without being lost in the mathematics.

The first half of the textbook covers notation, mathematics, the general principles of continuum mechanics, and constitutive modeling. The second half applies these theoretical concepts to different material classes. Specifically, each application covers experimental characterization, constitutive model development, derivation of governing equations, and numerical solution of the governing equations. For each material application, the text begins with the experimental observations, which outline the behavior of the material and must be captured by the material model. Next, we formulate the continuum model for the material and present general constitutive equations. These equations often contain parameters that must be determined experimentally. Therefore, the textbook has a chapter covering the theory and application of experimental error analysis and simple curve fitting. For each material class, the continuum model is then applied to a specific application and the resulting differential equations are solved numerically. Complete descriptions of the finite difference and finite element methods are included. Numerical solutions are implemented in Matlab® and provided in the text along with flow charts illustrating the logic in the Matlab® scripts.

CONTINUUM MECHANICS. (Lecture Notes). ZdeneË‡k Martinec.Â The subject of all studies in continuum mechanics, and the domain of all physical quantities, is the material body. A material body B = {X } is a compact measurable set of an innite number of material elements X , called the material particles or material points, that can be placed in a one-to-one correspondence with triplets of real numbers. Such triplets are sometimes called the intrinsic coordinates of the particles.