Finite Volume Micromechanics Of Heterogeneous Periodic Materials An Attractive Alternative To The Finite Element Based Homogenization Of Heterogeneous Media

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Micromechanics of Composites Springer Science & Business Media
Heterogeneous Media: Local Fields, Effective Properties, and Wave Propagation outlines new computational methods for solving volume integral equation problems in heterogeneous media. The book starts by surveying the various numerical methods of analysis of static and dynamic fields in heterogeneous media, listing their strengths and weaknesses, before moving onto an introduction of static and dynamic green functions for homogeneous media. Volume and surface integral equations for fields in heterogenous media are discussed next, followed by an overview of explicit formulas for numerical calculations of volume and surface potentials. The book then segues into Gaussian functions for discretization of volume integral equations for fields in heterogenous media, static problems for a homogeneous host medium with heterogeneous inclusions, volume integral equations for scattering problems, and concludes with a chapter outlining solutions to homogenization problems and calculations of effective properties of heterogeneous media. The book concludes with multiple appendices that feature the texts of basic programs for solving volume integral equations as written in Mathematica. Outlines cutting-edge computational methods for solving volume integral equation problems in heterogeneous media Provides applied examples of approximation and other methods being employed Demonstrates calculation of composite material properties and the constitutive laws for averaged fields within them Covers static and dynamic 2D and 3D mechanical-mathematical models for heterogeneous media

Mechanics Down Under Springer Science & Business Media
This dissertation research focuses on micromechanical modeling and simulations of two-phase heterogeneous materials exhibiting anisotropic and non-uniform microstructures with long-range spatial correlations. Completed work involves development of methodologies for realistic micromechanical analyses of materials using a combination of stereological techniques, two- and three-dimensional digital image processing, and finite element based modeling tools. The methodologies are developed via its applications to two technologically important material systems, namely, discontinuously reinforced aluminum composites containing silicon carbide particles as reinforcement, and boron modified titanium alloys containing in situ formed titanium boride whiskers. Microstructural attributes such as the shape, size, volume fraction, and spatial distribution of the reinforcement phase in these materials were incorporated in the models without any simplifying assumptions. Instrumented indentation was used to determine the constitutive properties of individual microstructural phases. Micromechanical analyses were performed using realistic 2D and 3D

models and the results were compared with experimental data. Results indicated that 2D models fail to capture the deformation behavior of these materials and 3D analyses are required for realistic simulations. The effect of clustering of silicon carbide particles and associated porosity on the mechanical response of discontinuously reinforced aluminum composites was investigated using 3D models. Parametric studies were carried out using computer simulated microstructures incorporating realistic microstructural attributes. The intrinsic merit of this research is the development and integration of the required enabling techniques and methodologies for representation, modeling, and simulations of complex geometry of microstructures in two- and three-dimensional space facilitating better understanding of the effects of microstructural geometry on the mechanical behavior of materials.

Inelasticity and Micromechanics of Metal Matrix Composites Butterworth-Heinemann

This book elucidates the most recent and highly original developments in the fields of micro- and nanomechanics and the corresponding homogenization techniques that can be reliably adopted and applied in determining the local properties, as well as the linear and nonlinear effective properties of the final architecture of these complex composite structures. Specifically, this volume, divided into three main sections—Fundamentals, Modeling, and Applications—provides recent developments in the mathematical framework of micro- and nanomechanics, including Green's function and Eshelby's inclusion problem, molecular mechanics, molecular dynamics, atomistic based continuum, multiscale modeling, and highly localized phenomena such as microcracks and plasticity. It is a compilation of the most recent efforts by a group of the world's most talented and respected researchers. Ideal for graduate students in aerospace, mechanical, civil, material science, life sciences, and biomedical engineering, researchers, practicing engineers, and consultants, the book provides a unified approach in compiling micro- and nano-scale phenomena. · Elucidates recent and highly original developments in the fields of micromechanics and nanomechanics and the corresponding homogenization techniques; · Includes several new topics that are not covered in the current literature, such as micromechanics of metamaterials, electrical conductivity of CNT and graphene nanocomposites, ferroelectrics, piezoelectric, and electromagnetic materials; · Addresses highly localized phenomena such as coupled field problems, microcracks, inelasticity, dispersion of CNTs, synthesis, characterization and a number of interesting applications; · Maximizes readers' ability to apply theories of micromechanics and nanomechanics to heterogeneous solids; · Illustrates application of micro- and nanomechanical theory to design novel composite and nanocomposite materials.

Realistic Micromechanical Modeling and Simulation of Two-phase Heterogeneous Materials Springer Science & Business Media

In this second edition several new topics of technological interest have been added. These include: coupled mechanical and nonmechanical overall properties of heterogeneous piezoelectric materials, new upper and lower bounds for these coupled properties, a systematic comparison between the average-field theory and the results obtained using multi-scale perturbation theory, an account of the uniform-field theory, improveable bounds on overall moduli of heterogeneous materials which remain finite even when isolated cavities and rigid inclusions are present, and a brief account of a fundamental duality principle in anisotropic elasticity. In addition, better explanations of a number of topics are given, more recent references are added, the Subject Index has been expanded and printing and typographical errors have been corrected. The material is organized into two parts preceded by a précis. Part 1 consists of four chapters which are organized into fourteen sections and four appendixes. It deals with materials with microdefects such as cavities, cracks, and inclusions, as well as with elastic composites. Part 2 consists of two chapters which are divided into seven sections. It provides an introduction to the theory of linear elasticity, added to make the book self-contained, since linear elasticity serves as the basis of the development of small-deformation micromechanics. Part 2 mainly contains part of the lecture notes on elasticity which the first author wrote in the late 1960's. The material is mostly standard, given for background information.

Arbitrary Lagrangian Eulerian and Fluid-Structure Interaction Springer

Micromechanics of Composites: Multipole Expansion Approach, Second Edition outlines substantial recent progress in the development of the multipole expansion method and focuses on its application to actual micromechanical problems. The book covers micromechanics topics such as conductivity and elasticity of particulate and fibrous composites, including those with imperfect and partially debonded interfaces, nanocomposites, cracked solids, and more. Complete analytical solutions and accurate numerical data are presented in a unified manner for the multiple inhomogeneity models of finite, semi-, and infinite heterogeneous solids. This new edition has been updated to include the theories and techniques of the multipole expansion method. Two entirely new chapters covering the conductivity and elasticity of composites with ellipsoidal inhomogeneities and anisotropic constituents have been added. A special emphasis is made on the heterogeneous solids with imperfect interfaces, including the nanoporous and nanocomposite materials. Gives a systematic account on the multipole expansion method, including its theoretical foundations, analytical and numerical techniques, and a new, dipole moment-based approach to the homogenization problem Contains detailed analytical and numerical analyses of a variety of micromechanical multiple inhomogeneity models, providing clear insight into the physical nature of the problems under study Provides a reliable theoretical framework for developing the full-field based micromechanical theories of a composite's strength, brittle/fatigue damage development, and other properties

Micromechanics of Heterogeneous Materials World Scientific Publishing Company

The book will concentrate on the application of micromechanics to the analysis of practical engineering problems. Both classical composites represented by carbon/carbon textile laminates and applications in Civil Engineering including asphalts and masonry structures will be considered. A common denominator of these considerably distinct material systems will be randomness of their internal structure. Also, owing to their complexity, all material systems will be studied on multiple scales. Since real engineering, rather than academic, problems are of the main interest, these scales will be treated independently from each other on the grounds of fully uncoupled multi-scale analysis. Attention will be limited to elastic and viscoelastic behaviour and to the linear heat transfer analysis. To achieve this, the book will address two different approaches to the homogenization of systems with random microstructures. In particular, classical averaging schemes based on the Eshelby solution of a solitary inclusion in an infinite medium represented by the Hashin-Shtrikman variational principles or by considerably simpler and more popular Mori-Tanaka method will be compared to detailed finite element simulations of a certain representative volume element (RVE) representing accommodated geometrical details of respective microstructures. These are derived by matching material statistics such as the one- and two-point probability functions of real and artificial microstructures. The latter one is termed the statistically equivalent periodic unit cell owing to the assumed periodic arrangement of reinforcements (carbon fibres, carbon fibre tows, stones or masonry bricks) in a certain matrix (carbon matrix, asphalt mastic, mortar). Other types of materials will be introduced in the form of exercises with emphases to the application of the Mori-Tanaka method in the framework of the previously mentioned uncoupled multi-scale analysis

Micromechanics and Nanosimulation of Metals and Composites CRC Press

The strength of metallic materials determines the usability and reliability of all the machines, tools and equipment around us. Yet, the question about which mechanisms control the strength and damage resistance of materials and how they can be optimised remains largely unanswered. How do real, heterogeneous ma- rials deform and fail? Why can a small modification of the microstructure increase the strength and damage resistance of materials manifold? How can the strength of heterogeneous materials be predicted? The purpose of this book is to present different experimental and computational analysis methods of micromechanics of damage and strength of materials and to demonstrate their applications to various micromechanical problems. This book summarizes at a glance some of the publications of the Computational Mechanics Group at the IMWF/MPA Stuttgart, dealing with atomistic, micro- and meso- chanical modelling and experimental analysis of strength and damage of metallic materials. In chapter 1, the micromechanisms of damage and fracture in different groups of materials are investigated experimentally, using direct observations and inverse analysis. The interaction of microstructural elements with the evolving damage is studied in these experiments. Chapter 2 presents different approaches to the - cromechanical simulation of composite materials: embedded unit cells, multiphase finite elements and multiparticle unit cells. Examples of the application of these models to the analysis of deformation and damage in different materials are given. Chapter 3 deals with the methods of numerical modelling of damage evolution and crack growth in heterogeneous materials.

IUTAM Symposium on Mechanical Behavior and Micro-Mechanics of Nanostructured Materials Springer

This book presents the most recent progress of fundamental nature made in the new developed field of micromechanics: transformation field analysis, variational bounds for nonlinear composites, higher-order gradients in micromechanical damage models, dynamics of composites, pattern based variational bounds.

Handbook of Micromechanics and Nanomechanics Springer Science & Business Media

This textbook demonstrates the application of the finite element philosophy to the solution of real-world problems and is aimed at graduate level students, but is also suitable for advanced undergraduate students. An essential part of an engineer's training is the development of the skills necessary to analyse and predict the behaviour of engineering systems under a wide range of potentially complex loading conditions. Only a small proportion of real-life problems can be solved analytically, and consequently, there arises the need to be able to use numerical methods capable of simulating real phenomena accurately. The finite element (FE) method is one such widely used numerical method. Finite Element Applications begins with demystifying the 'black box' of finite element solvers and progresses to addressing the different pillars that make up a robust finite element solution framework. These pillars include: domain creation, mesh generation and element formulations, boundary conditions, and material response considerations. Readers of this book will be equipped with the ability to develop models of real-world problems using industry-standard finite element packages.

Design and Analysis of Materials and Engineering Structures Elsevier

This book is the first to apply the Spectral Finite Element Method (SFEM) to inhomogeneous and anisotropic structures in a unified and systematic manner. Readers will gain understanding of how to formulate Spectral Finite Element; learn about wave behaviour in inhomogeneous and anisotropic media; and, be able to design some diagnostic tools for monitoring the health of a structure. Tables, figures and graphs support the theory and case studies are included.

Annual Report WIT Press

A comprehensive overview is given in this book towards a fundamental understanding of the micromechanics of the overall response and failure modes of advanced materials, such as ceramics and ceramic and other composites. These advanced materials have become the focus of systematic and extensive research in recent times. The book consists of two parts. The first part reviews solids with microdefects such as cavities, cracks, and inclusions, as well as elastic composites. To render the book self-contained, the second part focuses on the fundamentals of continuum mechanics, particularly linear elasticity which forms the basis for the development of small deformation micromechanics. In Part 1, a fundamental and general framework for quantitative, rigorous analysis of the overall response and failure modes of microstructurally heterogeneous solids is systematically developed. These expressions apply to broad classes of materials with inhomogeneities and defects. While for the most part, the general framework is set within linear elasticity, the results directly translate to heterogeneous solids with rate-dependent or rate-independent inelastic constituents. This application is specifically referred to in various chapters. The general exact correlations obtained between the overall properties and the microstructure are then used together with simple models, to develop techniques for direct quantitative evaluation of the overall response which is generally described in terms of instantaneous overall moduli or compliance. The correlations among the corresponding results for a variety of problems are examined in great detail. The bounds as well as the specific results, include new observations and original developments, as well as an in-depth account of the state of the art. Part 2 focuses on Elasticity. The section on variational methods includes some new elements which should prove useful for application to advanced modeling, as well as solutions of composites and related heterogeneous bodies. A brief modern version of elements in vector and tensor algebra is provided which is particularly tailored to provide a background for the rest of this book. The data contained in this volume as Part 1 includes new results on many basic issues in micromechanics, which will be helpful to graduate students and researchers involved with rigorous physically-based modeling of overall properties of heterogeneous solids.

Eulerian Hydrocode Analysis of Reactive Micromechanics in the Shock Initiation of Heterogeneous Energetic Material Elsevier

This book brings together some 20 chapters on state-of-the-art research in the broad field of computational plasticity with applications in civil and mechanical engineering, metal forming processes, geomechanics, nonlinear structural analysis, composites, biomechanics and multi-scale analysis of materials, among others. The chapters are written by world leaders in the different fields of computational plasticity.

Micromechanics Springer Nature
Here is an accurate and timely account of micromechanics, which spans materials science, mechanical engineering, applied mathematics, technical physics, geophysics, and biology. The book features rigorous and unified theoretical methods of applied mathematics and statistical physics in the material science of microheterogeneous media. Uniquely, it offers a useful demonstration of the systematic and fundamental research of the microstructure of the wide class of heterogeneous materials of natural and synthetic nature.
Micromechanics and Inhomogeneity Trans Tech Publication
The 22nd International Congress of Theoretical and Applied Mechanics (ICTAM) of the International Union of Theoretical and Applied Mechanics was hosted by the Australasian mechanics community in the city of Adelaide during the last week of August 2008. Over 1200 delegates met to discuss the latest development in the fields of theoretical and applied mechanics. This volume records the events of the congress and contains selected papers from the sectional lectures and invited lectures presented at the congresses six mini-symposia.
Annual Report, 1989 Springer Science & Business Media
This volume contains the proceedings of the IUTAM Symposium on Mechanical Behavior and Micro-mechanics of Nanostructured Materials, held in Beijing on June 27-30, 2005. The proceedings consist of approximately 30 presentations. Nano-scale, micro-scale, theoretical, experimental and numerical aspects of the subjects are covered. A wide scope of research and progress are displayed. This is the first work in print on this particular subject.
Applied Rve Reconstruction and Homogenization of Heterogeneous Materials Springer Science & Business Media
With composites under increasing use in industry to replace traditional materials in components and structures, the modeling of composite performance, damage and failure has never been more important. Micromechanics of Composite Materials: A Generalized Multiscale Analysis Approach brings together comprehensive background information on the multiscale nature of the composite, constituent material behaviour, damage models and key techniques for multiscale modelling, as well as presenting the findings and methods, developed over a lifetime's research, of three leading experts in the field. The unified approach presented in the book for conducting multiscale analysis and design of conventional and smart composite materials is also applicable for structures with complete linear and nonlinear material behavior, with numerous applications provided to illustrate use. Modeling composite behaviour is a key challenge in research and industry; when done efficiently and reliably it can save money, decrease time to market with new innovations and prevent component failure. This book provides the tools and knowledge from leading micromechanics research, allowing researchers and senior engineers within academia and industry with to improve results and streamline development workflows. Brings together for the first time the findings of a lifetime's research in micromechanics by recognized leaders in the field Provides a comprehensive overview of all micromechanics formulations in use today and a unified approach that works for the multiscale analysis and design of multi-phased composite materials, considering both small strain and large strain formulations Combines otherwise disparate theory, code and techniques in a step-by-step manner for efficient and reliable modeling of composites
Heterogeneous Media Springer
In this, its second corrected printing, Zohdi and Wriggers' illuminating text presents a comprehensive introduction to the subject. The authors include in their scope basic homogenization theory, microstructural optimization and multifield analysis of heterogeneous materials. This volume is ideal for researchers and engineers, and can be used in a first-year course for graduate students with an interest in the computational micromechanical analysis of new materials.
Advances in Computational Plasticity Springer Science & Business Media
In mining and mineral processing, compressive loading is often encountered during the comminution of ore bearing minerals and in the wear resistant materials used in the comminution circuit. A common thread joining many of the materials that are primarily used under compressive loading is the presence of a high modulus reinforcement, either fiber or particulate, embedded within a lower modulus matrix phase (i.e., a brittle heterogeneous material). Many of these heterogeneous materials are designed or manufactured such that an imperfect interface (i.e., an interface that provides less than complete coherency between the reinforcing phase and the matrix) exists between the reinforcing phase and the matrix (e.g., tough fiber-reinforced ceramics). To date, most research has focused on the response of these heterogeneous materials with imperfect interfaces to tensile loading; however, little is known about their response to compressive loading. The principal objective of this investigation is to develop a better understanding of the micromechanical behavior of these complex materials under compressive loading. Analytical solutions are reviewed and compared with finite element models for the simulation of heterogeneous materials with imperfect interfaces under compressive loading. This comparison shows that a nonlinear numerical approach (finite element method) is necessary to fully simulate the behavior of these materials. To validate the nonlinear model, laser moire experiments were conducted on a model heterogeneous material loaded under uniaxial and biaxial compression. In-plane displacements were measured and found to be in fundamental agreement with the nonlinear finite element model. Subsequently, finite element simulations were developed for a variety of heterogeneous materials with imperfect interfaces. Results show that deleterious tensile stress concentrations are primarily influenced by three factors: (i) the nature of the imperfect interface, (ii) the moduli mismatch between the reinforcement and matrix, and (iii) the volume fraction of the reinforcement. Finally, crack initiation experiments in laboratory models of a heterogeneous material with a frictional imperfect interface were conducted to substantiate the prior work using nonlinear finite element models. Experimental results correlate well with the numerically-predicted micromechanical behavior of a model heterogeneous system under uniaxial compressive loading.
Heterogeneous Media North-Holland
Atomistic and Continuum Modeling of Nanocrystalline Materials develops a complete and rigorous state-of-the-art analysis of the modeling of the mechanical behavior of nanocrystalline (NC) materials. Among other key topics, the material focuses on the novel techniques used to predict the behavior of nanocrystalline materials. Particular attention is given to recent theoretical and computational frameworks combining atomistic and continuum approaches. Also, the most relevant deformation mechanisms governing the response of nanocrystalline materials are addressed and discussed in correlation with available experimental data.
Finite Volume Direct Averaging Micromechanics of Heterogeneous Media Springer Science & Business Media
As multi-phase metal/alloy systems and polymer, ceramic, or metal matrix composite materials are increasingly being used in industry, the science and technology for these heterogeneous materials has advanced rapidly. By extending analytical and numerical models, engineers can analyze failure characteristics of the materials before they are integrat

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