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Bringing together materials mechanics and modelling, this book provides a complete guide to damage mechanics of composite materials for engineers.

Presents Concepts That Can Be Used in Design, Processing, Testing, and Control of Composite Materials Introduction to the Micromechanics of Composite Materials weaves together the basic concepts, mathematical fundamentals, and formulations of micromechanics into a systemic approach for understanding and modeling the effective material behavior of composite materials. As various emerging composite materials have been increasingly used in civil, mechanical, biomedical, and materials engineering, this textbook provides students with a fundamental understanding of the mechanical behavior of composite materials and prepares them for further research and development work with new composite materials. Students will understand from reading this book: The basic concepts of micromechanics such as RVE, eigenstrain, inclusions, and in homogeneities How to master the constitutive law of general composite material How to use the tensorial indicial notation to formulate the Eshelby problem Common homogenization methods The content is organized in accordance with a rigorous course. It covers micromechanics theory, the microstructure of materials, homogenization, and constitutive models of different types of composite materials, and it enables students to interpret and predict the effective mechanical properties of existing and emerging composites through microstructure-based modeling and design. As a prerequisite, students should already understand the concepts of boundary value problems in solid mechanics. Introduction to the Micromechanics of Composite Materials is suitable for senior undergraduate and graduate students.

Composite Materials Science and Engineering focuses on the structure-property relationships in composite materials. A detailed description is given of how microstructure of different fibers (such as glass, Kevlar, polyethylene, carbon, boron, silicon, carbide, alumina etc.) controls their characteristics. The important role of interface in composite materials is discussed. Up to date information about the recent advances in polymer matrix-, metal matrix-, and ceramic matrix composites is provided. Micro- and macromechanical aspects of composite materials as well as their strength, fracture, and design aspects are described in detail - always emphasizing the basic theme of how the structure controls the resultant properties. Extensive use is made of micrographs and line drawings to bring home to the reader the importance of structure-property relationships in composites. Throughout the book, examples are given from practical applications of composites in various fields. Extensive references to the literature, general bibliography, as well as practice problems are provided. The book is intended for undergraduates (senior level) and first year graduate students as well as the practicing engineer/scientist in the industry.

While currently available texts dealing with the subject of high performance composite materials touch upon a spectra of topics such as mechanical metallurgy, physical metallurgy, micromechanics and macro mechanics of such systems, it is the specific purpose of this text to examine elements of the mechanics of structural components composed of composite materials. This text is intended for use in training engineers in this new technology and rational thought processes necessary to develop a better understanding of the behavior of such material systems for use as structural components. The concepts are further exploited in terms of the structural format and development to which the book is dedicated. To this end the development progresses systematically by first introducing the notion and concepts of what these new material classes are, the fabrication processes involved and their unique features relative to conventional monolithic materials. Such introductory remarks, while far too short in texts of this type, appear necessary as a precursor for engineers to develop a better understanding for design purposes of both the threshold limits to which the properties of such systems can be pushed as well as the practical limitations on their manufacture. Following these introductory remarks, an in-depth discussion of the important differences between composites and conventional monolithic material types is discussed in terms of developing the concepts associated with directional material properties.

This textbook is written for use not only in engineering curricula of aerospace, civil and mechanical engineering, but also for materials science and applied mechanics. Furthermore, it addresses practicing engineers and researchers. No prior knowledge of composite materials and structures is required for the understanding of its content. The structure and the level of presentation is close to classical courses of "Strength of Materials" or "Theory of Beams, Plates and Shells". Yet two extensions have been included: the linear elastic material behavior of isotropic and non-isotropic structural elements, and inhomogeneous material properties in the thickness direction. The Finite Element Analysis of laminate and sandwich structures is briefly presented. Many solved examples illustrate the application of the techniques learned.

A comprehensive textbook on the mechanics and strength of materials for students of engineering throughout their undergraduate career. Assuming little or no prior knowledge, all of the topics of stress and strain analysis are covered. Mechanical properties such as tensile behavior, fatigue, creep, fracture, and impact are discussed, including the introduction of such advanced topics as finite element analysis, fracture mechanics, and composite materials. Computers and spreadsheets are used throughout to show their power as problem-solving tools.

In the last decade the author has been engaged in developing a micromechanical composite model based on the study of interacting periodic cells. In this two-phase model, the inclusion is assumed to occupy a single cell whereas the matrix material occupies several surrounding cells. A prominent feature of the mi-

micromechanical method of cells is the transition from a medium, with a periodic microstructure to an equivalent homogeneous continuum which effectively represents the composite material. Of great importance is the significant advantage of the cells model in its capability to analyze elastic as well as nonelastic constituents (e.g. viscoelastic, elastoplastic and nonlinear elastic), thus forming a unified approach in the prediction of the overall behaviour of composite material. This book deals almost exclusively with this unified theory and its various applications.

Updated and improved, *Stress Analysis of Fiber-Reinforced Composite Materials*, Hyer's work remains the definitive introduction to the use of mechanics to understand stresses in composites caused by deformations, loading, and temperature changes. In contrast to a materials science approach, Hyer emphasizes the micromechanics of stress and deformation for composite material analysis. The book provides invaluable analytic tools for students and engineers seeking to understand composite properties and failure limits. A key feature is a series of analytic problems continuing throughout the text, starting from relatively simple problems, which are built up step-by-step with accompanying calculations. The problem series uses the same material properties, so the impact of the elastic and thermal expansion properties for a single-layer of FR material on the stress, strains, elastic properties, thermal expansion and failure stress of cross-ply and angle-ply symmetric and unsymmetric laminates can be evaluated. The book shows how thermally induced stresses and strains due to curing, add to or subtract from those due to applied loads. Another important element, and one unique to this book, is an emphasis on the difference between specifying the applied loads, i.e., force and moment results, often the case in practice, versus specifying strains and curvatures and determining the subsequent stresses and force and moment results. This represents a fundamental distinction in solid mechanics.

This edition has been greatly enlarged and updated to provide both scientists and engineers with a clear and comprehensive understanding of composite materials. In describing both theoretical and practical aspects of their production, properties and usage, the book crosses the borders of many disciplines. Topics covered include: fibres, matrices, laminates and interfaces; elastic deformation, stress and strain, strength, fatigue crack propagation and creep resistance; toughness and thermal properties; fatigue and deterioration under environmental conditions; fabrication and applications. Coverage has been increased to include polymeric, metallic and ceramic matrices and reinforcement in the form of long fibres, short fibres and particles. Designed primarily as a teaching text for final-year undergraduates in materials science and engineering, this book will also interest undergraduates and postgraduates in chemistry, physics, and mechanical engineering. In addition, it will be an excellent source book for academic and technological researchers on materials.

A thorough and understandable guide to the properties and design of structural composites. It derives from the author's many years of experience of research, industrial development and teaching.

A compact presentation of the foundations, current state of the art, recent developments and research directions of all essential techniques related to the mechanics of composite materials and structures. Special emphasis is placed on classic and recently developed theories of composite laminated beams, plates and shells, micromechanics, impact and damage analysis, mechanics of textile structural composites, high strain rate testing and non-destructive testing of composite materials and structures. Topics of growing importance are addressed, such as: numerical methods and optimisation, identification and damage monitoring. The

latest results are presented on the art of modelling smart composites, optimal design with advanced materials, and industrial applications. Each section of the book is written by internationally recognised experts who have dedicated most of their research work to a particular field. Readership: Postgraduate students, researchers and engineers in the field of composites. Undergraduate students will benefit from the treatment of the foundations of the mechanics of composite materials and structures.

Composite structures and products have developed tremendously since the publication of the first edition of this work in 1986. This new edition of the now classic 1986 text has been written to educate the engineering reader in the various aspects of mechanics for using composite materials in the design and analysis of composite structures and products. Areas dealt with include manufacture, micromechanical properties, structural design, joints and bonding and a much needed introduction to composite design philosophy. Each chapter is concluded by numerous problems suitable for home assignments or examination. A solution guide is available on request from the authors.

This multiauthor volume provides a useful summary of current knowledge on the application of fracture mechanics to composite materials. It has been written to fill the gap between the literature on fundamental principles of fracture mechanics and the special publications on the fracture properties of conventional materials, such as metals, polymers and ceramics. The data are represented in the form of about 420 figures (including diagrams, schematics and photographs) and 80 tables. The author index covers more than 500 references, and the subject index more than 1000 key words.

Principles of Composite Material Mechanics covers a unique blend of classical and contemporary mechanics of composites technologies. It presents analytical approaches ranging from the elementary mechanics of materials to more advanced elasticity and finite element numerical methods, discusses novel materials such as nanocomposites and hybrid multiscale composites, and examines the hygrothermal, viscoelastic, and dynamic behavior of composites. This fully revised and expanded Fourth Edition of the popular bestseller reflects the current state of the art, fresh insight gleaned from the author's ongoing composites research, and pedagogical improvements based on feedback from students, colleagues, and the author's own course notes. New to the Fourth Edition New worked-out examples and homework problems are added in most chapters, bringing the grand total to 95 worked-out examples (a 19% increase) and 212 homework problems (a 12% increase) Worked-out example problems and homework problems are now integrated within the chapters, making it clear to which section each example problem and homework problem relates Answers to selected homework problems are featured in the back of the book *Principles of Composite Material Mechanics, Fourth Edition* provides a solid foundation upon which students can begin work in composite materials science and engineering. A complete solutions manual is included with qualifying course adoption.

This book is an attempt to present an integrated and unified approach to the analysis of FRP composite materials which have a wide range of applications in various engineering structures-offshore, maritime, aerospace and civil engineering; machine components; chemical engineering applications, and so on.

In 1997, Dr. Kaw introduced the first edition of *Mechanics of Composite Materials*, receiving high praise for its comprehensive scope and detailed examples. He also introduced the groundbreaking PROMAL software, a valuable tool for designing and analyzing structures made of composite materials. Updated and expanded to reflect recent advances in the field, this Second Edition

retains all of the features -- logical, streamlined organization; thorough coverage; and self-contained treatment -- that made the first edition a bestseller. The book begins with a question-and-answer style introduction to composite materials, including fresh material on new applications. The remainder of the book discusses macromechanical analysis of both individual lamina and laminate materials; micromechanical analysis of lamina including elasticity based models; failure, analysis, and design of laminates; and symmetrical and nonsymmetrical beams (new chapter). New examples and derivations are included in the chapters on micromechanical and macromechanical analysis of lamina, and the design chapter contains two new examples: design of a pressure vessel and design of a drive shaft. The author also adds key terms and a summary to each chapter. The most current PROMAL software is available via the author's often-updated Web site, along with new multiple-choice questions. With superior tools and complete coverage, *Mechanics of Composite Materials, Second Edition* makes it easier than ever to integrate composite materials into your designs with confidence. For instructions on downloading the associated PROMAL software, please visit <http://www.autarkaw.com/books/composite/promaldownload.html>.

"Engineering Mechanics of Composite Materials, Second Edition, is ideal for advanced undergraduate and introductory graduate courses on composite materials in materials science and mechanical engineering."--BOOK JACKET.

This volume focuses on quasilinear elliptic differential equations of degenerate type, evolution variational inequalities, and multidimensional hysteresis. It serves both as a survey of results in the field, and as an introductory text for non-specialists interested in related problems.

This book is concerned with the topical problems of mechanics of advanced composite materials whose mechanical properties are controlled by high-strength and high-stiffness continuous fibers embedded in polymeric, metal, or ceramic matrix. Although the idea of combining two or more components to produce materials with controlled properties has been known and used from time immemorial, modern composites were only developed several decades ago and have now found intensive application in different fields of engineering, particularly in aerospace structures for which high strength-to-weight and stiffness-to-weight ratios are required. There already exist numerous publications that cover anisotropic elasticity, mechanics of composite materials, design, analysis, fabrication, and application of composite structures but the difference between this book and the existing ones is that this is of a more specific nature. It covers specific features of material behaviour such as nonlinear elasticity, plasticity, creep, and structural nonlinearity and discusses in detail the problems of material micro- and macro-mechanics that are only slightly touched in existing books, e.g. stress diffusion in a unidirectional material with broken fibers, physical and statistical aspects of fiber strength, coupling effects in anisotropic and laminated materials, etc. The authors are designers of composite structures who were involved in practically all the main Soviet and then Russian projects in composite technology, and the permission of the Russian Composite Center - Central Institute of Special Machinery (CRISM) to use in this book the pictures of structures developed and fabricated in CRISM as part of the joint research and design project is much appreciated. *Mechanics and Analysis of Composite Materials* consists of eight chapters progressively covering all structural levels of composite materials from their components through elementary plies and layers to laminates.

This book presents a broad exposition of analytical and numerical methods for modeling composite materials, laminates, polycrys-

tals and other heterogeneous solids, with emphasis on connections between material properties and responses on several length scales, ranging from the nano and microscales to the macroscale. Many new results and methods developed by the author are incorporated into the rich fabric of the subject, which has developed from the work of many researchers over the last 50 years. Among the new results, the book offers an extensive analysis of internal and interface stresses caused by eigenstrains, such as thermal, transformation and inelastic strains in the constituents, which often exceed those caused by mechanical loads, and of inelastic behavior of metal matrix composites. Fiber prestress in laminates, and modeling of functionally graded materials are also analyzed. Furthermore, this book outlines several key subjects on modeling the properties of composites reinforced by particles of various shapes, aligned fibers, symmetric laminated plates and metal matrix composites. This volume is intended for advanced undergraduate and graduate students, researchers and engineers interested and involved in analysis and design of composite structures.

The book aims at giving an overview of current methods in engineering mechanics of FRP components and structures as well as hybrid components and structures. Main emphasis is on basic micro and macro mechanics of laminates. Long as well as short fibre composites are studied, and criteria for different kinds of rupture are treated. Micromechanical considerations for material characterization and mechanisms of static ductile and brittle rupture are studied, as well as FRP structures under thermal and dynamic loading programs. Optimum design and manufacture situations are described as well. The book makes designers familiar with the opportunities and limitations of modern high quality fibre composites. Practical engineering applications of the described analytical and numerical methods are also presented.

This book balances introduction to the basic concepts of the mechanical behavior of composite materials and laminated composite structures. It covers topics from micromechanics and macromechanics to lamination theory and plate bending, buckling, and vibration, clarifying the physical significance of composite materials. In addition to the materials covered in the first edition, this book includes more theory-experiment comparisons and updated information on the design of composite materials.

An increase in the use of composite materials in areas of engineering has led to a greater demand for engineers versed in the design of structures made from such materials. This book offers students and engineers tools for designing practical composite structures. Among the topics of interest to the designer are stress-strain relationships for a wide range of anisotropic materials; bending, buckling, and vibration of plates; bending, torsion, buckling, and vibration of solid as well as thin walled beams; shells; hygrothermal stresses and strains; finite element formulation; and failure criteria. More than 300 illustrations, 50 fully worked problems, and material properties data sets are included. Some knowledge of composites, differential equations, and matrix algebra is helpful but not necessary, as the book is self-contained. Graduate students, researchers, and practitioners will value it for both theory and application.

Composite materials find diverse applications in areas including aerospace, automotive, architecture, energy, marine and military. This comprehensive textbook discusses three important aspects including manufacturing, mechanics and dynamic mechanical analysis of composites. The textbook comprehensively presents fundamental concepts of composites, manufacturing techniques and advanced topics including as advances in composite materials in various fields, viscoelastic behavior of composites, toughness of composites and Nano mechanics of composites in a single

volume. Topics such as polymer matrix composites, metal matrix composites, ceramic matrix composites, micromechanical behavior of a lamina, micromechanics and nanomechanics are discussed in detail. Aimed at senior undergraduate and graduate students for a course on composite materials in the fields of mechanical engineering, automobile engineering and electronics engineering, this book: Discusses mechanics and manufacturing techniques of composite materials in a single volume. Explains viscoelastic behavior of composites in a comprehensive manner. Covers fatigue, creep and effect of thermal stresses on composites. Discusses concepts including bending, buckling and vibration of laminated plates in detail. Explains dynamic mechanical analysis (DMA) of composites.

The use of composite materials has grown exponentially in the last decades and has affected many engineering fields due to their enhanced mechanical properties and improved features with respect to conventional materials. For instance, they are employed in civil engineering (seismic isolators, long-span bridges, vaults), mechanical engineering (turbines, machine components), aerospace and naval engineering (fuselages, boat hulls and sails), automotive engineering (car bodies, tires), and biomechanical engineering (prostheses). Nevertheless, the greater use of composites requires a rapid progress in gaining the needed knowledge to design and manufacture composite structures. Thus, researchers and designers devote their own efforts to develop new analysis techniques, design methodologies, manufacturing procedures, micromechanics approaches, theoretical models, and numerical methods. For these purpose, it is extremely easy to find many recent journal papers, books, and technical notes, focused on the mechanics of composites. In particular, several studies are presented to take advantage of their superior features by varying some typical structural parameters (such as geometry, fiber orientations, volume fraction, structural stiffness, weight, lamination scheme). Therefore, this Conference aims to collect contributions from every part of the globe that can increase the knowledge of composite materials and their applications, by engaging researches and professional engineers and designers from different sectors. The same aims and scopes have been reached by the previous editions of Mechanics of Composites International Conferences (MECHCOMP), which occurred in 2014 at Stony Brook University (USA) and in 2016 at University of Porto (Portugal).

This is a book for people who love mechanics of composite materials and MATLAB. We will use the popular computer package MATLAB as a matrix calculator for doing the numerical calculations needed in mechanics of composite materials. In particular, the steps of the mechanical calculations will be emphasized in this book. The reader will not find ready-made MATLAB programs for use as black boxes. Instead step-by-step solutions of composite material mechanics problems are examined in detail using MATLAB. All the problems in the book assume linear elastic behavior in structural mechanics. The emphasis is not on mass computations or programming, but rather on learning the composite material mechanics computations and understanding of the underlying concepts. The basic aspects of the mechanics of fiber-reinforced composite materials are covered in this book. This includes lamina analysis in both the local and global coordinate systems, laminate analysis, and failure theories of a lamina.

The field of composite materials is rapidly expanding with increasing applications in aircraft, automobiles, leisure and biomedical products, and infrastructure. Composite materials have unique qualities of high strength and stiffness, are light weight, and can be designed to suit the intended application. This up-to-date introductory textbook on the mechanics of structural composite materials is aimed at both undergraduate and beginning graduate stu-

dents and also at the newcomer to the field of composites. The material presented has been drawn from extensive course notes developed by both authors over many years. Beginning with basic concepts, definitions, and an overview of the current status of composites technology, the reader is taken through the theory and experimental results of research with many types of composite materials. The authors emphasize computational procedures and include flow charts for computations. The design methodology and optimization process for composite structures are described and illustrated with specific examples. One extensive chapter is devoted to experimental characterization and testing, including the latest test methods and ASTM standards. A wide variety of instructional sample problems and solutions are included. Engineering Mechanics of Composite Materials is an essential teaching tool and a self-study reference in composite materials.

This book compiles techniques used to analyze composite structural elements ranging from beams through plates to stiffened shells. The content is suitable for graduate-level students with a basic background in mechanics of composite materials. Moreover, this book will be placed in an active spot on the bookshelves of composite structures designers as well as researchers.

The newly expanded and revised edition of Fiber-Reinforced Composites: Materials, Manufacturing, and Design presents the most up-to-date resource available on state-of-the-art composite materials. This book is unique in that it not only offers a current analysis of mechanics and properties, but also examines the latest advances in test metho

Composite Materials, Volume 2: Mechanics of Composite Materials deals with the prediction of the deformation behavior and strength of composite materials. The book discusses the basic concepts in micromechanics, definition of effective moduli, and the influence of the number of fibers through-the-thickness within a single composite layer on the effective properties. The text also describes the exact moduli of anisotropic laminates; the elastic behavior of composites; and the viscoelastic behavior and analysis of composite materials. The elastoplastic behavior of composites, and the application of statistical theories for the determination of thermal, electrical, and magnetic properties of heterogeneous materials are also considered. The book further tackles the finite deformations of ideal fiber-reinforced composites; wave propagation and vibrations in directionally reinforced composites; and the phenomenological anisotropic failure criterion. The text also looks into the photoelastic investigation of composites. Civil engineers, mechanical engineers, aerospace engineers, and people involved in the study of non-metallic materials will find the book invaluable.

Composite materials have been representing most significant breakthroughs in various industrial applications, particularly in aerospace structures, during the past thirty five years. The primary goal of Advanced Mechanics of Composite Materials is the combined presentation of advanced mechanics, manufacturing technology, and analysis of composite materials. This approach lets the engineer take into account the essential mechanical properties of the material itself and special features of practical implementation, including manufacturing technology, experimental results, and design characteristics. Giving complete coverage of the topic: from basics and fundamentals to the advanced analysis including practical design and engineering applications. At the same time including a detailed and comprehensive coverage of the contemporary theoretical models at the micro- and macro-levels of material structure, practical methods and approaches, experimental results, and optimisation of composite material properties and component performance. The authors present the

results of more than 30 year practical experience in the field of design and analysis of composite materials and structures. * Eight chapters progressively covering all structural levels of composite materials from their components through elementary plies and layers to laminates * Detailed presentation of advanced mechanics of composite materials * Emphasis on nonlinear material models (elasticity, plasticity, creep) and structural nonlinearity

Computational Mechanics of Composite Materials lays stress on the advantages of combining theoretical advancements in applied mathematics and mechanics with the probabilistic approach to experimental data in meeting the practical needs of engineers. Features: Programs for the probabilistic homogenisation of composite structures with finite numbers of components allow composites to be treated as homogeneous materials with simpler behaviours. Treatment of defects in the interfaces within heterogeneous materials and those arising in composite objects as a whole by stochastic modelling. New models for the reliability of composite structures. Novel numerical algorithms for effective Monte-Carlo simulation. Computational Mechanics of Composite Materials will be of interest to academic and practising civil, mechanical, electronic and aerospace engineers, to materials scientists and to applied mathematicians requiring accurate and usable models of the behaviour of composite materials.

A comprehensive account of the basic theory of the mechanical behavior of heterogeneous media, this volume assembles, interprets, and interrelates contributions to the field of composite materials from theoretical research, laboratory developments, and product applications. The text focuses on the continuum mechanics aspects of behavior; specifically, it invokes idealized geometric models of the heterogeneous system to obtain theoretical predictions of macroscopic properties in terms of the properties of individual constituent materials. The wide range of subjects encompasses macroscopic stiffness properties, failure characterization, and wave propagation. Much of the book presumes a familiarity with the theory of linear elasticity; but it also takes into consideration behavior characterized by viscoelasticity and inviscid plasticity theories and problems involving nonlinear kinematics. Because of the close relationship between mechanical and thermal effects, the text also examines macroscopic, thermal properties of heterogeneous media. Although the primary emphasis centers on the development of theory, this volume also pays critical attention to the practical assessment of results and applications. Comparisons between different approaches and with reliable experimental data appear at main junctures. Suitable as a graduate-level text, Mechanics of Composite Materials is also a valuable reference for professionals.