

Numerical modelling of ductile damage mechanics coupled with an unconventional plasticity model

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ABSTRACT. Ductility in metals includes the material's capability to tolerate plastic deformations before partial or total degradation of its mechanical properties. Modelling this parameter is important in structure and component design because it can be used to estimate material failure under a generic multi-axial stress state. Previous work has attempted to provide accurate descriptions of the mechanical property degradation resulting from the formation, growth, and coalescence of microvoids in the medium. Experimentally, ductile damage is inherently linked with the accumulation of plastic strain; therefore, coupling damage and elastoplasticity is necessary for describing this phenomenon accurately. In this paper, we combine the approach proposed by Lemaitre with the features of an unconventional plasticity model, the extended subloading surface model, to predict material fatigue even for loading conditions below the yield stress.

KEYWORDS. Unconventional plasticity; Ductile damage; Subloading surface; Cyclic loading.



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INTRODUCTION

The degradation of material properties, which results from the initiation of cavities and microcracks induced by large plastic deformations, has been widely studied. Material failure results from microscopic material imperfections, which cause the formation and coalescence of microvoids that eventually produce cracks during deformation. Modelling this mechanism is important in many industrial processes for creating optimized reliable designs for structures and components.

There are two main models for the elastoplastic framework [1, 2]: Gurson's void growth model [3] and Lemaitre's model [4, 5], often referred as continuum damage mechanics. Gurson's model is based on void growth, where the plastic yield is inversely proportional to the amount of imperfections; as the porosity increases the material loading decreases. Further studies by Needleman and Tvergaard [6], Koppic and Needleman [7], and Ohata and Toyota [8] extended the damage evolution concept by introducing material parameters to model the acceleration of the degradation of mechanical properties. Lemaitre's theory describes damage as an internal variable and models its evolution with a dissipative potential

Numerical Modelling In Damage Mechanics

George Z Voyiadjis



Numerical Modelling In Damage Mechanics:

Numerical Modelling in Damage Mechanics Collectif, 2001 **Numerical Modelling in Damage Mechanics** Khémais Saanouni, 2003 These collected writings gather recent advances in numerical and computational aspects of damage mechanics with the intention of stimulating current research and future challenges in this field **Numerical Modelling of Failure in Advanced Composite Materials** Pedro P. Camanho, Stephen R. Hallett, 2015-08-07 Numerical Modelling of Failure in Advanced Composite Materials comprehensively examines the most recent analysis techniques for advanced composite materials Advanced composite materials are becoming increasingly important for lightweight design in aerospace wind energy and mechanical and civil engineering Essential for exploiting their potential is the ability to reliably predict their mechanical behaviour particularly the onset and propagation of failure Part One investigates numerical modeling approaches to interlaminar failure in advanced composite materials Part Two considers numerical modelling approaches to intralaminar failure Part Three presents new and emerging advanced numerical algorithms for modeling and simulation of failure Part Four closes by examining the various engineering and scientific applications of numerical modeling for analysis of failure in advanced composite materials such as prediction of impact damage failure in textile composites and fracture behavior in through thickness reinforced laminates Examines the most recent analysis models for advanced composite materials in a coherent and comprehensive manner Investigates numerical modelling approaches to interlaminar failure and intralaminar failure in advanced composite materials Reviews advanced numerical algorithms for modeling and simulation of failure Examines various engineering and scientific applications of numerical modelling for analysis of failure in advanced composite materials **Numerical Modelling of Ductile Fracture** Odd Perry Søvik, 1996 **Advances in Numerical Modeling of Adhesive Joints** Lucas Filipe Martins da Silva, Raul D. S. G. Campilho, 2011-10-15 This book deals with the most recent numerical modeling of adhesive joints Advances in damage mechanics and extended finite element method are described in the context of the Finite Element method with examples of application The book also introduces the classical continuum mechanics and fracture mechanics approach and discusses the boundary element method and the finite difference method with indication of the cases they are most adapted to At the moment there is no numerical technique that can solve any problem and the analyst needs to be aware of the limitations involved in each case **Modelling of Damage Processes in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites** Mohammad Jawaid, Mohamed Thariq Hameed Sultan, Naheed Saba, 2018-11-23 Modelling of Damage Processes in Biocomposites Fibre Reinforced Composites and Hybrid Composites focuses on the advanced characterization techniques used for the analysis of composite materials developed from natural fiber biomass synthetic fibers and a combination of these materials used as fillers and reinforcements to enhance materials performance and utilization in automotive aerospace construction and building components It will act as a detailed reference resource to encourage future research in natural fiber and hybrid composite materials an area much in demand

due to the need for more sustainable recyclable and eco friendly composites in a broad range of applications Written by leading experts in the field and covering composite materials developed from different natural fibers and their hybridization with synthetic fibers the book s chapters provide cutting edge up to date research on the characterization analysis and modelling of composite materials Contains contributions from leading experts in the field Discusses recent progress on failure analysis SHM durability life prediction and the modelling of damage in natural fiber based composite materials Covers experimental analytical and numerical analysis Provides detailed and comprehensive information on mechanical properties testing methods and modelling techniques

IUTAM Symposium on Multiscale Modelling of Damage and Fracture Processes in Composite Materials Tomasz Sadowski,2006-07-06 The IUTAM Symposium on Multiscale Modelling of Damage and Fracture Processes in Composite Materials was held in Kazimierz Dolny Poland 23-27 May 2005 The Symposium was attended by 48 persons from 15 countries During 5 day meeting 4 keynote lectures and 39 invited lectures were presented This volume constitutes the Proceedings of the IUTAM Symposium The main aim of the Symposium was to discuss the basic principles of damage growth and fracture processes in different types of composites ceramic polymer and metal matrix composites cement and bituminous composites and wood Nowadays it is widely recognized that important macroscopic properties like the macroscopic stiffness and strength are governed by processes that occur at one to several scales below the level of observation starting from nanoscale Understanding how these processes influence the reduction of stiffness and strength is essential for the analysis of existing and the design of improved composite materials The study of how these various length scales can be linked together or taken into account simultaneously is particular attractive for composite materials since they have a well defined structure at the nano micro and meso levels The well defined microstructural level can be associated with small particles or fibres while the individual laminae can be indentified at the mesoscopic level Moreover the advances in multiscale modelling of damage and fracture processes to the description of the complete constitutive behaviour in composites which do not have a very well defined microstructure e g cementitious bitumous composites and wood was analysed

Damage Mechanics of Cementitious Materials and Structures Gilles Pijaudier-Cabot,Frederic Dufour,2013-02-07 The book prepared in honor of the retirement of Professor J Mazars provides a wide overview of continuum damage modeling applied to cementitious materials It starts from micro nanoscale analyses then follows on to continuum approaches and computational issues The final part of the book presents industry based case studies The contents emphasize multiscale and coupled approaches toward the serviceability and the safety of concrete structures

Advances in Damage Mechanics: Metals and Metal Matrix Composites George Voyiadjis,2012-12-02 This book provides in a single and unified volume a clear and thorough presentation of the recent advances in continuum damage mechanics for metals and metal matrix composites Emphasis is placed on the theoretical formulation of the different constitutive models in this area but sections are added to demonstrate the applications of the theory In addition some

sections contain new material that has not appeared before in the literature The book is divided into three major parts Part I deals with the scalar formulation and is limited to the analysis of isotropic damage in materials Parts II and III deal with the tensor formulation and is applied to general states of deformation and damage The material appearing in this text is limited to plastic deformation and damage in ductile materials e g metals and metal matrix composites but excludes many of the recent advances made in creep brittle fracture and temperature effects since the authors feel that these topics require a separate volume for this presentation Furthermore the applications presented in this book are the simplest possible ones and are mainly based on the uniaxial tension test

Recent Trends in Fracture and Damage Mechanics Geralf Hütter,Lutz Zybell,2015-09-01 This book covers a wide range of topics in fracture and damage mechanics It presents historical perspectives as well as recent innovative developments presented by peer reviewed contributions from internationally acknowledged authors The volume deals with the modeling of fracture and damage in smart materials current industrial applications of fracture mechanics and it explores advances in fracture testing methods In addition readers will discover trends in the field of local approach to fracture and approaches using analytical mechanics Scholars in the fields of materials science engineering and computational science will value this volume which is dedicated to Meinhard Kuna on the occasion of his 65th birthday in 2015 This book incorporates the proceedings of an international symposium that was organized to honor Meinhard Kuna s contributions to the field of theoretical and applied fracture and damage mechanics

Damage Mechanics in Engineering Materials Jiann-Wen Woody Ju,J.-L. Chaboche,George Voyiadjis,1998-03-04 This book contains thirty peer reviewed papers that are based on the presentations made at the symposium on Damage Mechanics in Engineering Materials on the occasion of the Joint ASME ASCE SES Mechanics Conference McNU97 held in Evanston Illinois June 28 July 2 1997 The key area of discussion was on the constitutive modeling of damage mechanics in engineering materials encompassing the following topics macromechanics micromechanical constitutive modeling experimental procedures numerical modeling inelastic behavior interfaces damage fracture failure computational methods The book is divided into six parts Study of damage mechanics Localization and damage Damage in brittle materials Damage in metals and metal matrix composites Computational aspects of damage models Damage in polymers and elastomers

Damage and Healing Mechanics of Materials George Z. Voyiadjis,Peter I. Kattan,2025-06-27 Damage and Healing Mechanics of Materials Metals and Metal Matrix Composites covers the fundamentals of damage mechanics with various damage models presented coupled with elastic and elasto plastic behavior Experimental investigations and the related data for damage in composite materials are included as are computational modeling and simulation methods for investigating damage and healing in various materials and structures Healing mechanics using both scalars and more general theory based on tensor notations are discussed as are applications of damage mechanics Undamageable materials the generalized method of cells phase field modeling cyclic plasticity concepts and more are all also covered Introduces computational methods and

numerical techniques such as finite element analysis and molecular dynamics to model and simulate damage and healing in various materials and structures Discusses the ways cracks and voids are subjected to healing mechanisms and new composites that are designed to be more resilient and resistant to damage Covers uniaxial tension in metal matrix composites damage and plasticity in metals experimental damage investigation techniques anisotropic healing and more **From Creep Damage Mechanics to Homogenization Methods** Holm Altenbach,Tetsuya Matsuda,Dai Okumura,2015-06-03 This volume presents a collection of contributions on materials modeling which were written to celebrate the 65th birthday of Prof Nobutada Ohno The book follows Prof Ohno s scientific topics starting with creep damage problems and ending with homogenization methods **Damage Mechanics and Micromechanics of Localized Fracture Phenomena in Inelastic Solids** George Z Voyiadjis,2012-01-29 This book resulted from a series of lecture notes presented in CISM Udine in July 7 11 2008 The papers inform about recent advances in continuum damage mechanics for both metals and metal matrix composites as well as the micromechanics of localization in inelastic solids Also many of the different constitutive damage models that have recently appeared in the literature and the different approaches to this topic are presented making them easily accessible to researchers and graduate students in civil engineering mechanical engineering engineering mechanics aerospace engineering and material science **Continuum Damage Mechanics** Sumio Murakami,2012-02-23 Recent developments in engineering and technology have brought about serious and enlarged demands for reliability safety and economy in wide range of fields such as aeronautics nuclear engineering civil and structural engineering automotive and production industry This in turn has caused more interest in continuum damage mechanics and its engineering applications This book aims to give a concise overview of the current state of damage mechanics and then to show the fascinating possibility of this promising branch of mechanics and to provide researchers engineers and graduate students with an intelligible and self contained textbook The book consists of two parts and an appendix Part I is concerned with the foundation of continuum damage mechanics Basic concepts of material damage and the mechanical representation of damage state of various kinds are described in Chapters 1 and 2 In Chapters 3 5 irreversible thermodynamics thermodynamic constitutive theory and its application to the modeling of the constitutive and the evolution equations of damaged materials are described as a systematic basis for the subsequent development throughout the book Part II describes the application of the fundamental theories developed in Part I to typical damage and fracture problems encountered in various fields of the current engineering Important engineering aspects of elastic plastic or ductile damage their damage mechanics modeling and their further refinement are first discussed in Chapter 6 Chapters 7 and 8 are concerned with the modeling of fatigue creep creep fatigue and their engineering application Damage mechanics modeling of complicated crack closure behavior in elastic brittle and composite materials are discussed in Chapters 9 and 10 In Chapter 11 applicability of the local approach to fracture by means of damage mechanics and finite element method and the ensuing mathematical and

numerical problems are briefly discussed A proper understanding of the subject matter requires knowledge of tensor algebra and tensor calculus At the end of this book therefore the foundations of tensor analysis are presented in the Appendix especially for readers with insufficient mathematical background but with keen interest in this exciting field of mechanics

Modeling Damage, Fatigue and Failure of Composite Materials Ramesh Talreja, Janis Varna, 2023-09-23 Modeling Damage Fatigue and Failure of Composite Materials Second Edition provides the latest research in the field of composite materials an area that has attracted a wealth of research with significant interest in the areas of damage fatigue and failure The book is fully updated and is a comprehensive source of physics based models for the analysis of progressive and critical failure phenomena in composite materials It focuses on materials modeling while also reviewing treatments for analyzing failure in composite structures Sections review damage development in composite materials such as generic damage and damage accumulation in textile composites and under multiaxial loading Part Two focuses on the modeling of failure mechanisms in composite materials with attention given to fiber matrix cracking and debonding compression failure and delamination fracture Final sections examine the modeling of damage and materials response in composite materials including micro level and multi scale approaches the failure analysis of composite materials and joints and the applications of predictive failure models Provides a comprehensive source of physics based models for the analysis of progressive and critical failure phenomena in composite materials Assesses failure and life prediction in composite materials Discusses the applications of predictive failure models such as computational approaches to failure analysis Covers further developments in computational analyses and experimental techniques along with new applications in aerospace automotive and energy wind turbine blades fields Covers delamination and thermoplastic based composites

Nonlinear Analyses of Laminated Plates and Shells with Damage Yi-Ming Fu, 2013 The contents of this book are related to composite mechanics nonlinear plate and shell mechanics damage mechanics elasto plastic mechanics visco elastic mechanics piezoelectric elastic mechanics and nonlinear dynamics which embody the combination and integration among solid mechanics material science and nonlinear science

Damage Mechanics D. Krajcinovic, 1996-04-22 This book provides the first truly comprehensive study of damage mechanics All concepts are carefully identified and defined in micro and macroscopic scales In terms of the methods and observation scales the main part of the book is divided into three chapters These chapters consider the stochastic models applied to atomistic scale micromechanical models for arbitrary concentrations of defects on microscopic scale and continuum models on the macroscopic scale It is intended for people who are doing or planning to do research in the mechanics and material science aspects of brittle deformation of solids with heterogeneous microstructure

Engineering Damage Mechanics Jean Lemaitre, Rodrigue Desmorat, 2006-01-16 Engineering Damage Mechanics is deliberately oriented toward applications of Continuum Damage Mechanics to failures of mechanical and civil engineering components in ductile creep fatigue and brittle conditions depending upon the thermomechanical loading and the materials

metals and alloys polymers elastomers composites concretes Nevertheless to help engineers researchers beginners or not the first two chapters are devoted to the main concepts of damage mechanics and to the associated computational tools

State of the Art and Future Trends in Material Modeling Holm Altenbach, Andreas Öchsner, 2019-10-23 This special anniversary book celebrates the success of this Springer book series highlighting materials modeling as the key to developing new engineering products and applications In this 100th volume of Advanced Structured Materials international experts showcase the current state of the art and future trends in materials modeling which is essential in order to fulfill the demanding requirements of next generation engineering tasks

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