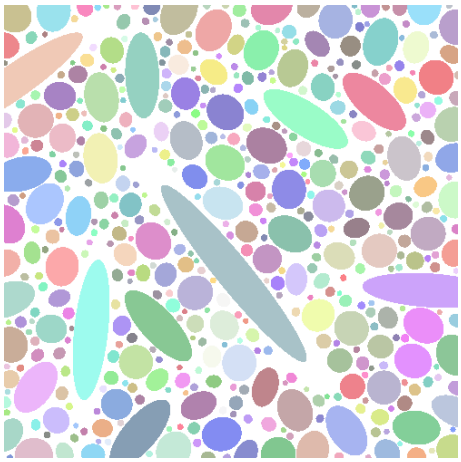
Universität Karlsruhe (TH)
Institut für Technische Mechanik

Universität Paderborn
Lehrstuhl für Technische Mechanik

21. Workshop
Composite-Forschung in der Mechanik



Bad Herrenalb

01.12.-03.12.2008

Zielsetzung des Workshops

Moderne und klassische Werkstoffe zeigen ein makroskopisches Materialverhalten, das auf komplexe Weise von deren Nano-, Mikro- und Mesostruktur abhängt.

Welche Mechanismen und Größenskalen für das makroskopische Materialverhalten relevant sind, hängt unter anderem von den betrachteten mechanischen oder physikalischen Größen und von der thermomechanischen Prozessführung ab.

Ein Verständnis des Zusammenhangs von Mikrostruktur bzw. mikromechanischen Verhalten und dem makroskopischen Werkstoffverhalten ist von grundsätzlichem Interesse für viele Fragestellungen der Werkstoffauswahl und -entwicklung sowie der Bauteildimensionierung.

Homogenisierungs- und Mehrskalenmethoden haben in den letzten Jahren beträchtliche Fortschritte auf theoretischem und numerischem Gebiet erfahren und tragen, neben experimentellen Methoden, wesentlich dazu bei, das komplexe Verhalten mikrostrukturierter Werkstoffe zu verstehen.

Ziel des Workshops ist es, aktuelle Fragestellungen im Kontext von Homogenisierungs- und Mehrskalenmethoden zur Berechnung des mechanischen Verhaltens von Compositen und anderen heterogenen Werkstoffen zu diskutieren und Gelegenheit zum Erfahrungsaustausch zu geben. Der Workshop wendet sich an Mitarbeiter von Industrieunternehmen, Forschungseinrichtungen und Universitäten.

Prof. Dr.-Ing. habil. Thomas Böhlke Prof. Dr.-Ing. habil. Rolf Mahnken

Programm Montag, 01.12.2008

Zeit	
ab 18:00	Registrierung und Welcome

Programm Dienstag, 02.12.2008

Zeit	Autoren	Titel
08.30 - 09.00	Dreyer, W.	The Storage of Hydrogen in Crystals
09.00 - 09.30	Becker, W., Sator, C.	Zum Laminatrandeffekt an kreisförmigen Laminatlöchern
09.30 - 10.00	Duderstadt, F.	Keimbildung bei Fest-Flüssig-Phasenübergängen von Galliumarsenid
10.00 - 10.45	Kaffeepause	
10.45 - 11.15	Böhm, H. J. , Pahr, D. H.	On Modeling the Behavior of Non-Periodic Inhomogeneous Volume Elements
11.15 - 11.45	Jöchen, K., Böhlke, T.	On the homogenization of mechanical properties of single-phase polycrystals
11.45 - 12.15	Le, K.C., Kochmann, D.M.	A continuum model for initiation and evolution of deformation twinning
12.15 - 13.30	Mittagessen	
13.30 - 14.00	Glüge, R., Böhlke, T., Bertram, A.	Elastic modelling of deformation twinning
14.00 - 14.30	Prakash, A., Hochrainer, T., Reisacher, E. and Riedel, H.	Comparison of twin modeling approaches in the self-consistent texture framework
14.30 - 15.00	Schneidt, A., Mahnken, R.	Simulation martensitischer Phasenumwandlung am Beispiel eines Hybridumformprozesses
15.00 - 15.30	Wilmanns, S., Mahnken, R.	Micromodelling of shape memory alloys
15.30 - 16.00	Kaffeepause	
16.00 - 16.30	Nestler, B., Selzer, M., Jainta, M., Reichardt, M.	Performance optimized algorithms for large-scale simulations of grain structures in the presence of elastic forces
16.30 - 17.00	Selzer, M., Nestler, B., Reichardt, M.	Phasenfeldsimulation mit experimentellen 3D Korngefügen aus EBSD Messdaten
17.00 - 17.30	Fritzen, F., Böhlke, T.	Boundary condition induced effects on the homogenization of heterogeneous materials: Theoretical and numerical investigations
17.30 - 18.00	Willert, U., Reuschel, A., Schmauder, S.	Simulation der mechanischen Eigenschaften von Metall/Keramik-Durchdringungsgefügen
19.00	Konferenzdinner	

Programm Mittwoch, 03.12.2008

Zeit	Autoren	Titel
08.00 - 08.30	Bussiba, A., Piat, R., Böhlke, T., Kupiec, M., Carmi, R. and Alon, I.	Assessment of damage initiation and growth in C/C composites utilizing acoustic emission technique
08.30 - 09.00	Piat, R., Böhlke, T., Dietrich, S., Gebert, J.- M. and Wanner, A.	Modeling of effective elastic properties of a uniderectional carbon/carbon composite
09.00 - 09.30	Lauterbach, S., Orifici, A.C., Thomson, R.S., Abramovich, H., Wagner, W. and Balzani, C.	Investigations of the Postbuckling Damage Criticality in Multi-Stiffened Composite Airframe Panels
09.30 - 10.00	Andrianov, I., Topol, H., Weichert, D.	Analytical study of the viscoelastic fibre-reinforced composite materials
10.00 - 10.45	Kaffeepause	
10.45 - 11.15	Lapusta, Y., Samborskaya, A.N., Beucler, T., Breton, T.	Analysis of matrix and interface cracks in laminates.
11.15 - 11.45	Mahnken, R.	Simulation of crack growth for functionally graded materials with material forces
11.45 - 12.15	Hauck, T., Schmadlak, I., Müller, W.H.	Sprödbruch fluidisch gedämpfter Beschleunigungssensoren
12.15 - 13.30	Mittagessen	
13.30 - 14.00	Kayser, T., Klusemann, B., Parvizian, F., and Svendsen, B.	Experimental investigation and modeling of microstructural development in aluminum alloys during extrusion
14.00 - 14.30	Jänicke, R., Steeb, H. and Diebels, S.	A numerical homogenisation strategy for micromorphic continua
14.30 - 15.00	Schmidt, I., Kraft, T.	Numerical Homogenisation of Metal Powder: Computation of Yieldsurfaces
15.30 - 16.00	Closing	

On Modeling the Behavior of Non-Periodic Inhomogeneous Volume Elements

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Abstract. Even though periodic homogenization is at present the most powerful and versatile method in continuum micromechanics of materials, its use of periodic volume elements brings about some restrictions in its applicability. On the one hand, it is obviously not the method of choice for studying the non-periodic inhomogeneous volume elements resulting from experimental techniques such as computed tomography, and, on the other hand, it is not suitable for handling strongly localized (as opposed to diffuse) damage. For the former type of situation, recent extensions to "windowing methods" [1, 2] have provided an approach to extracting estimates for the apparent elastic tensor, and embedding models can be used to advantage for the latter group of problems.

The two groups of models are introduced, their backgrounds, advantages and disadvantages are discussed, and some applications to studying the thermomechanical and thermal conduction behavior of inhomogeneous materials are presented.

References

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Assessment of damage initiation and growth in C/C composites utilizing Acoustic Emission technique

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Abstract. The continuation efforts in development of advanced and reliable composites require knowledge about the effects of different structural and morphological parameters (matrix and fiber properties, lay-ups, etc.) and manufacturing processes (temperature, time, environment, etc...) on the mechanical response in macro and micro scales. The difficulty in determining the effective composite based only on micromechanical models requires additional and complementary approach. Non-destructive evaluation of materials from mechanical aspect in comprehensive view has attracted considerable attention in the last decade and become an important tool in composite materials characterization. The current study adopted the Acoustic Emission (AE) technique in order to assess damage initiation and growth in C/C composites with different levels of density, during quasi-static loading in different states of stress (uniform and gradient). The dynamic nature of AE makes it a useful and powerful method for monitoring the structural integrity of critical load bearing engineering structures. As such, threshold parameters are essential in structural integrity assessment procedure. As known, in metallic materials threshold parameters in fatigue and in stress corrosion cracking, ΔK_{th} and K_{ISCC} respectively, are crucial to be determined in order to increase the performance reliability of structure in service. These parameters are being determined in various experimental methods. However, in composite materials threshold values are less familiar, if at all not experimentally, nor by definition. Here, the onset of the damage has been quantified by threshold stress and threshold stress intensity factor (σ_{th} and K_{Ith} respectively) which indicate on first AE activity to be noticed. In addition, attention has been given to the damage growth profile up to fracture in terms of cumulative AE counts.
Beyond looking for correlation between mechanical and acoustical response in macro scale, some attempts were done in micro scale in order to explore the operated micro-failure mechanisms and the fracture sequence processes using AE waveform analyses supported by optical and scanning electron microscopes characterizations. Here, Fast Fourier Transform (FFT), Short -Time Fast Fourier Transform (STFFT) and Wavelet Transformations (WT) were applied on AE signals and the results were displayed in frequency and time domains.
The experimental results show that the threshold parameters detected by AE varied with composite density with almost the same trends as flexural stress and fracture

toughness. Three stages in damage evolution up to fracture were observed: Stage I, with no AE activity, Stage II, linear growth in AE counts up to an abrupt jump and Stage III with exponential increase in AE counts. Similarities in profile and threshold value were found between the cumulative AE counts vs. strain data and the crack density vs. strain predicted by micro mechanical model. Wave's analysis point out on four possible failure micro-mechanisms: multilayer cracking, breaking of fiber bundles, interfacial matrix de-bonding and micro-crack growth. The dominate fracture micro-mechanism at different levels of loading up to final fracture is also suggested and discussed.

The Storage of Hydrogen in Crystals

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Abstract. Hydrogen is the ideal synthetic fuel to convert chemical energy into electrical energy or into motive power because it is light weight, highly abundant and its oxidation product is vapour of water. There are various possibilities to store the hydrogen for later use: liquid and gaseous hydrogen can be stored in a pressure vessel, hydrogen can be adsorbed on large surface areas of solids, and finally crystal lattices of metals or other compounds can be used as the storage system, where hydrogen is dissolved either on interstitial or by substitution on regular lattice sites.

The focus of this lecture concerns the thermodynamic modelling of the loading and unloading process of a crystal with hydrogen. That process exhibits hysteretic behaviour which is related to a phase transition that likewise appears. For small partial pressure, which comes along with a small hydrogen fraction of the crystal, the hydrogen atoms form a single solid solution. Above a certain pressure, the appearance of a so called hydride phase sets in, and as long as both phases coexist, the slope of the *pressure vs. hydrogen fraction curve* becomes almost horizontal. The phase transition is controlled by two mechanical phenomena: In the crystal, the hydrogen atoms need more space as it is available by the lattice sites. Moreover, along the interface of two adjacent phases, surface stresses are induced.

The resulting model consists of a coupled system of partial differential equations and initial and boundary conditions at the internal free interfaces and at the outer boundaries. A non-convex free energy density is involved so that regularization of the system is necessary. An important topic of this lecture is a study of various different regularizations leading to different interfacial jump conditions.

Keimbildung bei Fest-Flüssig-Phasenübergängen von Galliumarsenid

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Abstract. Die Züchtung von Gallium-Arsenid-Einkristallen und deren Wärmebehandlung ist eng mit dem Auftreten von Phasenübergängen verbunden. Durch unerwünschte Phasenübergänge entstehen jedoch inhomogene Bereiche im homogenen Einkristall, so dass sich die Qualität des gezüchteten Einkristalls verschlechtert.

Das Entstehen von Inhomogenitäten geht von zufällig entstandenen kleinen Inseln aus, die Keime einer neuen Phase sind. Mit Hilfe einer Keimbildungstheorie lässt die Frage beantworten, unter welchen Bedingungen die Keime in einem bestimmten Beobachtungszeitraum so rasch anwachsen, dass sie eine kritische Größe überschreiten.

Im Vortrag werden drei verschiedene Situationen der Keimbildung in GaAs betrachtet: 1. Homogene Keimbildung von flüssigen As-reichen Präzipitaten in einer festen GaAs-Umgebung. 2. Homogene Keimbildung von festem GaAs in flüssigen GaAs. 3. Heterogene Keimbildung von festem GaAs an den Wänden des Schmelztiegels.

Das vorgestellte Modell berücksichtigt neben Oberflächenspannungen und der Zusammensetzung der Mischung auch deviatorische Spannungen im Festkörper. Im Vortrag werden Einflüsse von Temperatur, der mittleren Zusammensetzung und des äußeren Drucks auf die Keimbildungsrate diskutiert. Für heterogene Keimbildung wird außerdem der Einfluss der Geometrie von kleinsten Rissen an der Innenseite Tiegelwand auf die resultierende Keimbildungsrate dargelegt.

Boundary condition induced effects on the homogenization of heterogeneous materials: Theoretical and numerical investigations

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Abstract. Microheterogeneities of materials are omnipresent in technical applications. An example for such microheterogeneities is the crystallite orientation in polycrystals such as ceramics or metals. In technical applications two different aspects of such heterogeneous materials are of importance: (i) The concept of effective material behavior can be applied when the length scales of the heterogeneity and the part are clearly disconnected. (ii) When the length-scale on the micro- and macro-scale cannot be seperated, the concept of apparent properties can be applied. In the latter case statistical examinations are used to find confidence intervals for design parameters such as structural stiffness or compliance.

While the homogenization of linear material properties is possible using a variety of analytical or semi-analytical techniques (e.g. [1]), the non-linear material behavior cannot be estimated analytically in general. However, it can be predicted using numerical homogenization techniques. The latter often rely on either a Representative Volume Element (RVE) (i) oder a Statistical Volume Element (SVE) (ii) [2].

A problem arises from the uncertainty of the boundary conditions which replicate the observed material behavior in numerical experiments [3]. Particularly, one is interested in finding *optimal* boundary conditions allowing for the fast computation of the properties of a RVE or SVE. A systematic analysis of different boundary conditions on both, theoretical and numerical level, is presented, with the focus being put on kinematic boundary conditions. Numerical examples based on the finite element method are used to illustrate various aspects of the theoretical outcomings.

References

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Elastic modelling of deformation twinning

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Abstract. Deformation twinning is a major deformation mode encountered in many crystals. It is activated at low temperatures and high strain rates, i.e. when when crystallographic slip is hindered. It is therefore able to extend the usability of many materials, which has been successfully demonstrated with the manganese alloyed TWIP (TWinning Induced Plasticity) steels.
A twin appears mostly as lamella shaped subgrain, which has its crystal lattice mirrored to the lattice of the surrounding crystal at the lamella principal plane. Twinning has therefore a strong impact on the grain morphology and the crystallographic texture. Due to the phase-transition like behaviour, its modelling on the microscale is rather difficult. Such a modelling is nevertheless desireable, because it delivers precise predictions on the material behaviour and microstructure evolution, if used in conjunction with a numerical homogenisation technique like the RVE (Representative Volume Element) technique.
In this talk, a modelling approach based on a nonconvex elastic energy and results obtained from finite element calculations are presented. The material model consists of a pseudoelastic law for the elastic behaviour and the twinning, a plastic part for the incorporation of crystallographic glide and a regularising viscosity. It is applied to $10\bar{1}2\langle 1011\rangle$ twinning in the hcp lattice, with the material parameters adopted to magnesium.

References

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Sprödbruch fluidisch gedämpfter Beschleunigungssensoren

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Abstract. Freescale's Beschleunigungssensoren werden aufgebaut in Silizium-Oberflächenmikromechanik. Die Meßzelle besteht immer aus einer elastisch gelagerten Siliziumplatte die sich unter dem Einfluß von Beschleunigungskräften verbiegt. Die Plattendeformation wird kapazitiv mit Hilfe von Meßelektroden auf der deformierbaren Platte und dem darunter befindlichem starren Substrat bestimmt. Der gesamte Aufbau nimmt lediglich eine Fläche von etwa einem Quadratmillimeter ein. Der Spaltabstand zwischen Platte und Substrat beträgt nur wenige Mikrometer. Bei diesen Größenverhältnissen hat die fluidische Dämpfung der Luft einen starken Einfluß auf die Plattendynamik. Mit Hilfe der Fluid-Strukturkopplung wird die Bandbreite des Beschleunigungssensors in der Frequenzganganalyse gezielt beeinflußt. Andererseits verringert die Luftdämpfung Stoßkräfte bei möglichen Stoßvorgängen. Mithin vermindern richtig eingestellte Dämpfungseigenschaften das Risiko für Schä-digungen der Siliziumstrukturen.
Im Vortrag werden Berechnungsmethoden zur Lösung der Bewegungsgleichungen der Sensormeßzelle unter Berücksichtigung der fluidischen Dämpfung gezeigt. Die Gleichungen werden für den Anwendungfall eines Kraftstoßes ausgewertet. In der Siliziumplatte resultierenden mechanischen Spannungen werden berechnet, Kerbwirkungen in der Einspannungen ermittelt und zugehörige Spannungsüberhöhungen untersucht.
Wir werden die statistische Bruchmechanik zur Bewertung von Versagensrisiken anwenden. Hierfür wird die experimentelle Ermittlung der Weibullkoeffizienten für polykristallines Silizium gezeigt. Ein eigens für die Optimierung der Sensorgeometrie entwickelter Finite Element Postprozessor wird vorgestellt. Das Weibullintegrale und die daraus resultierende Bruchwahrscheinlichkeit des Siliziums in der Umgebung der Einspannstelle werden für den Fall des Kraftstoßes berechnet. Damit gelingt ein optimaler Sensorentwurf mit vorhersagbarer mechanischen Zuverlässigkeit.

A numerical homogenisation strategy for micromorphic continua

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Abstract. In this contribution, we apply a numerical homogenisation scheme for micromorphic continua [1] replacing constitutive equations on the macroscale by a microscopic boundary value problem in each material point[2].
The aim of this procedure is to describe the influence of the microtopolgy on the effective behaviour of microstructured materials such as biological tissues as well as polymer or metal foams [3]. On the one hand this approach allows for avoiding the numerically expensive calculation of a fully resolved microstructure. On the other hand there is no need to identify additional material parameters which are in general hard to interpret from the physical point of view.

References

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On the homogenization of mechanical properties of single-phase polycrystals

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Abstract. The macroscopic mechanical response of polycrystals under particular loading depends strongly on the constitutive behavior of the grains as well as their geometrical arrangement in case of anisotropic grain morphology. Micromechanical information about the considered material can be integrated in the prediction of the effective material behavior by applying micromechanical models [1]. In this presentation, we compare the predictions of the effective elastic and plastic behavior of polycrystals resulting from the application of a variational approach based on a linear comparison material [2,3] and a finite element approach in which microstructures are generated based on periodic Voronoi tesselations.

As an example, the mechanical behavior of polycrystalline microspecimens composed of face-centered cubic single crystals is evaluated concerning the influence of the grain size. Since the macroscopic material response is governed by the particular microstructural distribution of grain orientations, ensemble averaging over several hundreds of randomly generated microstructures is carried out for statistical evaluations. It is shown that both of the aforementioned methods result in similar predictions for the mean values as well as the standard deviations of Young's modulus and the initial yield stress. However, the computational effort in applying the finite element method compared to the application of the homogenization scheme based on a linear comparison material is significantly higher.

References

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Experimental investigation and modeling of microstructural development in aluminum alloys during extrusion

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Abstract. The purpose of this work is the modeling and simulation of the material behavior of aluminum alloys during extrusion processes. In particular, attention is here focused on Al-Mg-Si alloys of the 6000 series, which are characterized by providing a maximum of ductility and Al-Zn-Mg alloys of the 7000 series, which show better hardness properties but reduced ductility. During extrusion the material behavior is governed by the process of dynamic recovery, whereas static recrystallization is the dominating process during cooling.

The material properties of the produced parts strongly depend on the resulting microstructure. The microstructure developement during extrusion is influenced by several interacting microphysical phenomena such as subgrain evolution, dislocation motion and recrystallisation. Using the Electron Back Scattering Defraction (EBSD) method with experimental specimens provides the microstructure properties subgrain size and grain misorientation depending on different process conditions.

Based on the EBSD measurement data a statistical analysis on the microstructure is performed and meshes adapted to the microstructure are generated for use in the finite element simulation of microstructural development as based on material models for the aluminum alloys of interest. Examples will be given.

Analysis of matrix and interface cracks in laminates

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Abstract. Matrix cracking can be the initial stage of degradation of composite laminates under a uniaxial or biaxial loading. This damage results, due to the redistribution of stresses, in other local failures, such as further cracking, delaminations and fiber breakage which can lead to the laminate's failure. Both the matrix crack density and the delamination areas grow with increasing applied load as the corresponding stresses in the layers and at the interface achieve their ultimate values. Note that transverse cracks with and without delaminations in cross-ply laminates have been actively studied in the scientific literature, both analytically and numerically. There also exist models treating laminates with somewhat more complicated geometry, e.g. having not only 0°- and 90°-plies, but also plies oriented in other directions. In order to simplify the solution, the majority of existing analytical models for these laminates usually do not take into account the coupling between the normal and shear stress fields in the layers. The purpose of this study is an analysis of matrix and interface cracks in laminates under plane loading, accounting for the coupling between the normal and shear stresses in layers of various orientations. First, a simple analytical model for matrix cracking is discussed. After that, some FE-models are presented. The latter take into account the possibility of interface weakening or cracking (local delaminations) induced by the matrix cracks.

Investigations of the Postbuckling Damage Criticality in Multi-Stiffened Composite Airframe Panels

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Abstract. Within the COCOMAT [1] project several degradation models for the collapse analysis of composite aerospace structures were developed. Different multi-stiffener panels were manufactured of a carbon fibre-reinforced polymer (CFRP) in an intact and a pre-damaged configuration. These were experimentally tested under a compressive load for the validation of the new developed numerical tools. The analysis of the intact configuration predicted collapse due to fibre fracture in the stiffeners and the failed locations agreed with the observations from the experiment. The outcome of the simulation of the pre-damaged configuration is that no progression of the initial skin-stiffener separation occurred. However, the pre-damaged panel configuration was proposed to get observable crack growth for numerical validation of the degradation models. Thus, a parametric study is conducted. Several modifications of the initial pre-damaged regions are virtually tested. The parametric study includes length, type and location of the initial debonds and is performed to investigate the effect of skin-stiffener pre-damage on crack growth and the collapse behaviour of the panel. An analysis tool proposed by Orifici [2] and Orifici et al. [3] is applied in this work. This tool includes an approach for predicting interlaminar damage initiation and degradation models for capturing interlaminar damage growth as well as in-plane damage mechanisms. This work presents the results of the parametric study on damage criticality.

References

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A continuum model for initiation and evolution of deformation twinning

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Abstract. Within continuum dislocation theory the plastic deformation of a single crystal with one active slip system under plane-strain constrained shear is investigated. By introducing a twinning shear into the energy of the crystal, we show that in a certain range of straining the formation of deformation twins becomes energetically preferable. An energetic threshold for the onset of twinning is determined. A rough analysis qualitatively describes not only the evolving volume fractions of twins but also their number during straining. Finally, we analyze the evolution of deformation twins and of the dislocation network at non-zero dissipation. We present the corresponding stress-strain hysteresis, the evolution of the plastic distortion, the twin volume fractions and the dislocation densities.

Simulation of crack growth for functionally graded materials with material forces

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Abstract. The continuum concept of material forces is employed for fracture analysis of functionally graded materials (FGMs), such that the corresponding balance equation can be discretized with a standard Galerkin finite element procedure. A domain-type formulation is used for evaluation of a vectorial J-integral, and the accuracy is discussed for examples form the literature. Additionally, an algorithm for brittle crack growth driven by material forces is used. Here geometry changes due to crack growth are considered by combing Delaunay triangulation and local mesh densification. In three-dimensional crack simulations we investigate the influence of inhomogeneity within FGMs. Furthermore, preliminary results on the simulation of ductile crack growth are presented.

Performance optimized algorithms for large-scale simulations of grain structures in the presence of elastic forces

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Abstract. In the last few years, there has been a rapid progress in the development of phase-field simulations for microstructure formation processes [1,2]. By the attempt of incorporating more and more physical effects, the complexity of the model formulations has become computationally extremely intense. The hardware requirements for conducting large-scale simulations in reasonable time has increased in the same manner.

In applications to polycystalline materials such as grain coarsening and grain growth, it is necessary to run simulations with a large number of different order parameters representing the different grain orientations. The gain to derive statistically meaningful data from computations requires simulations in sufficiently large domains with a tremendous need of memory and computing time ressources. To treat complex systems, high-performance computing, parallelization, and optimized algorithms including adaptive mesh generators are mandatory. We discuss a numerical algorithm for dynamically adapting order parameters of local relevance. The method makes use of the fact that the number of states simultaneously present at the same place is limited to approximately six in three space dimensions. We demonstate that it is possible to radically reduce memory requirement and computing time. This technique in combination with parallel algorithms on multiprocessor machines allows the 3D simulation of an unlimited number of grain orientations keeping memory and computation time constant.

The simulation environment is applied to derive growth laws resulting from grain growth and to analyse the influence of grain size and misorientation distributions on the microstructure evolution. Experimental EBSD measurements of the misorientations are converted into simulation data for the initial domain filling. The computed grain structures are compared with experimenal results. We study the effect of the formation of anormal grain structures observed in sintering processes of ceramic materials. Furthermore, we extend the phase-field model to incorporate a formulation for elastic forces, [3]. In simulations, we investigate the evolution of strain distribution and crack propagation in grain structures.

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Modeling of effective elastic properties of a unidirectional carbon/carbon composite

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Abstract. Three-dimensional structural information obtained by X-ray computed tomography on carbon/carbon laminates is used as input for a mechanical model describing the elastic behaviour of the composite. The model is based on a homogenization procedure consisting of two sequential steps covering the fiber and matrix interaction and the pores:

1. In the first step the mechanical behavior of a pyrolytic carbon matrix with embedded unidirectional and randomly oriented fibers is approximated using the Mori-Tanaka model [1-3].
2. In a second step under the assumption of an ellipsoidal shape of the pores the stiffness reduction due to an anisotropic pore distribution is taken into account. The pore morphology, i.e., the distribution of pore size and orientation is taken from μCT microstructure studies.

The predictions of this homogenization scheme are compared with experimental data.

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Comparison of twin modeling approaches in the self-consistent texture framework

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Abstract. Over the past couple of decades, there has been an enormous interest in the new age austenitic steels, also known as TRIP (transformation induced plasticity) and TWIP (twinning induced plasticity) steels. In particular, TWIP steels find a major interest in the automobile industry due to the excellent properties that they possess: high work hardening rate, high ductility and a high tensile strength along with a high wear and corrosion resistance. The high work hardening rate is attributed to the dynamic microstructure refinement resulting from the emergence of twins, which act as obstacles to the movement of dislocations. Not much study has been done towards understanding the influence of twinning towards texture and anisotropy development in TWIP steels. In order to predict the evolution of texture and the developing anisotropy accurately, texture models must account for the enhanced twinning activity. In this work, we compare two approaches towards modeling twinning, under the self-consistent framework. The central challenge in incorporating twinning in texture models is the exponential increase in new orientations, caused by the fact that the twinned region in a grain has a markedly different orientation with respect to the untwined part of the grain. To overcome this, two main modeling approaches have been proposed. Type (a) models do not increase the number of grains defining the polycrystal. Instead, a selection of grains is completely reoriented if a certain criterion is met. Thus, the number of grains under consideration remains constant. Type (b) models divide the grain into twin and non-twin parts, thereby increasing (virtually) the number of grains in the simulation. This increase in number can however, be limited through a few assumptions. Under the framework of the VPSC model, we evaluate these two modeling approaches. The results are compared with experimental data. The type (b) model provides better results with smaller number of grains (<1000 grains) and the results of both models seem to converge with increasing number of grains.

Simulation der mechanischen Eigenschaften von Metall/Keramik-Durchdringungsgefügen

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Abstract. Um das mechanische Verhalten von Metall/Keramik-Verbundwerkstoffen mit zufällig verteilten Einschlüssen bzw. mit mit Durchdringungsgefüge zu simulieren, wird ein selbstkonsistentes Matrizitätsmodell vorgestellt. Das Matrizitätsmodell ermöglicht es, neben dem Volumenanteil den Mikrostrukturparameter "Matrixcharakter" in die Simulation des mechanischen Verhaltens von Verbundwerkstoffen einzubeziehen. Das Modell basiert auf der Erweiterung einer selbstkonsistenten Einheitszelle durch die Berücksichtigung von gegenseitiger Umschließung zweier Phasen sowie der bei der Herstellung des betreffenden Verbundwerkstoffs auftretenden Eigenspannungen. Neben dem elastischen Verhalten (E-Modul) kann mit Hilfe dieses Modells auch das Spannungs-Dehnungs-Verhalten (Fließkurve) sowie der thermische Ausdehnungskoeffizient zweiphasiger Verbundwerkstoffe ermittelt werden.

Dieses Matrizitätsmodell wird in dieser Arbeit auf Metall/Keramik-Verbundwerkstoffe mit Durchdringungsgefüge angewendet. Diese Werkstoffe bestehen aus einer keramischen Vorform (TiO_2), die mit Leichtmetallen (Al bzw. Mg) infiltriert wird.

Zur Charakterisierung des Werkstoffversagens wird ein konservatives phasenspezifisches Abbruchkriterium für die berechnete Spannungs-Dehnungs-Kurve eingeführt. Dieses Kriterium wird unter Anwendung der Normalspannungshypothese (NH) sowie der Gestaltänderungsenergiehypothese (GEH) erstellt. Über einen ständigen phasenbezogenen Abgleich zwischen vorherrschenden und kritischen Spannungswerten wird bis zur phasenspezifischen Schädigung im Verbundwerkstoffgefüge gerechnet und die Spannungs-Dehnungskurve des Verbundwerkstoffs dadurch begrenzt. Zudem wird der Einfluss von Eigenspannungen auf die Fließkurve der Verbundwerkstoffe dargestellt.

Numerical Homogenisation of Metal Powder: Computation of Yieldsurfaces

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Abstract. In the powdertechnological process, complex shaped parts are produced by compacting powder in a die and subsequent sintering of the resulting green part to obtain the final geometry and strength. Simulation of the compaction process can help to eliminate undesired part distortions due to inhomogeneous density distributions in the green part. For this, the constitutive behaviour of metal powders during compaction needs to be modelled. This contribution presents a method for the computation of yield surfaces of an assembly of elasto-plastic granules based on the finite element method. A representative volume element with a limited number of elasto-plastic granules interacting with one another through frictional contact is considered and periodic boundary conditions are used to prescribe arbitrary deformation- or loadinghistories to the aggregate. The yield surface after uniaxial compression is computed and compared to existing models [1,2,3]. The development of a significant anisotropy is demonstrated and the underlying mechanisms of inelastic deformation – plasticity and friction – are discussed.

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Simulation martensitischer Phasenumwandlung am Beispiel eines Hybridumformprozesses

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Abstract. Bei dem Hybridumformprozess in[1] zur Einstellung gradierter Strukturen werden Kalt- und Warmumformung kombiniert. Dabei ist die gleichzeitige Umformung erwärmter und nicht erwärmter Bereiche eine verfahrensspezifische Besonderheit im Prozess. Durch die Einstellung eines vordefinierten Temperaturprofils werden Werkstücke mit gradierten und somit flexiblen Werkstoffeigenschaften erreicht. Aufgrund der simultan auftretenden kalten und erwärmten Bereiche während des Hybridumformprozesses herrschen in dem Bauteil verschiedene Gefügezustände vor. Es treten sowohl weiche perlitische und ferritische als auch harte martensitische und bainitische Gefügen auf. Der Schwerpunkt unserer Arbeit liegt auf der Austenit-Martensit Umwandlung. Für die Simulation wird ein makroskopisch viskoplastisches Materialmodell unter Berücksichtigung der Umwandlungsplastizität (TRIP) [2,3] und der gro"se Deformation präsentiert. Die numerische Implementierung erfolgt für eine UMAT/Abaqus-Subroutine. Die Simulation des Hybridumformprozesses erfolgt mittels mechanischen und thermischen Kontaktes zwischen Werkzeug und Werkstück.

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Phasenfeldsimulation mit experimentellen Korngefügen aus EBSD Messdaten in 3D

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Abstract. In den letzten Jahren gab es große Fortschritte in der Phasenfeldmodellierung von Microstrukturen. In den Phasenfeldmodellen wurden immer mehr physikalische Effekte berücksichtigt. Die betrachteten Systeme werden daher immer komplexer. Die Rechenzeit für große Simulationsgebiete ist entsprechend hoch. Dies macht sich auch in der benötigten Rechnerhardware bemerkbar.

In diesem Vortrag soll gezeigt werden, wie mit Electron BackScattert Diffration (EBSD) gewonnene Messdaten, mit Hilfe der Phasenfeldmethode und einem modifizierten Algorithmus simuliert werden können. Mit diesem neuen Ansatz können nahezu beliebig viele Körner simuliert werden und die Systeme sind nur noch durch die Gebietsgröße in der Rechenzeit beschränkt.

Analytical study of the viscoelastic fibre-reinforced composite materials

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Abstract. In this paper, an analytical technique for the calculation of properties of plane composites with viscoelastic matrix and elastic fibrous inclusions is proposed. The study is based on the analogy (correspondence principle) between linear elastic and viscoelastic moduli (and creep compliances) of heterogeneous structured materials of identical geometry. In particular, the solution for the elastic effective properties of such material can be reinterpreted as a viscoelastic solution in the transform domain by replacing the elastic properties by the Laplace transforms of the corresponding viscoelastic properties. Then the researched viscoelastic solution is the inverse Laplace transform.

The Laplace transform inverse can be treated as solution of Fredholm integral equation of the 1st kind, so, this is the ill-posed problem. FEM analysis of the structure is difficult, because it may provide unstable numerical calculations. That is why the analytical solutions are useful not only in the engineering practice, but also in evaluating test results calculated by FEM.

First of all we determine the asymptotic behaviour of the Laplace transforms of the searched function (SF) for $t \to \infty$ and $t \to 0$. These asymptotics however do not give the complete representation of the behavior of the solution at any arbitrary time: It is necessary to obtain the values of the SF also for intermediate values of t. Therefore, we replace the SF by asymptotically equivalent functions (AEF), which are continuous functions with asymptotic behaviour coinciding with the known asymptotic behaviour of the SF for $t \to \infty$ and $t \to 0$.

The comparison of the obtained approximate analytical solution with numerical results, obtained by Gaver algorithm, shows good accuracy of proposed approach [1].

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Micromodelling of shape memory alloys

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Abstract. Extended experimental tests for shape memory alloys exhibit different behaviours for different loading types, such as tension, compression and shear. These observations, labelled here briefly as asymmetric effects, are reported in the literature e.g. in [1]. The paper is concerned with modelling of these effects in the framework of microscopic behaviour [2] and [3]. The microscopic phase transformation of the grains depends on the microscopic, orientation dependent, yield stress [3]. In NiTi material the phase transformation of a grain and the development of different martensitic variants, depend on the global stress and the local orientation. Thus we have different material behaviour, such as asymmetry, for polycrystalline, textured or single crystal NiTi. These observations will be investigated.

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