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Chair of Applied Mechanics
Prof. Dr.-Ing. Paul Steinmann
Prof. Dr.-Ing. Kai Willner
University of Erlangen-Nuremberg

Prof. Dr.-Ing. P. Steinmann
Prof. Dr.-Ing. K. Willner
Lehrstuhl für Technische Mechanik
Universität Erlangen-Nürnberg
Egerlandstraße 5
91058 Erlangen
Tel.: 09131 8528501
Fax.: 09131 8528503
www: http://www.ltm.uni-erlangen.de

Editor: G. Possart

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1 Preface

The present booklet reports on the activities of the Chair of Applied Mechanics at the University of Erlangen-Nuremberg demonstrating that it was developing in a very satisfactory manner during the year 2008.
This success is exclusively due to the hard work and never ending enthusiasm of all the members of the Chair of Applied Mechanics. This report is intended to shed a spotlight on the current status of affairs of Applied Mechanics at the University of Erlangen-Nuremberg and should convince the reader about the high degree of dedication and ambition of all the members of this group.

Paul Steinmann, Kai Willner

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Professor for System Dynamics:
Prof. Dr.-Ing. Kai Willner

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W. Winter


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A. Rajagopal


D.-K. Vu


V. Barth


J. Geisler


S. Germain


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A. Javili


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G. Possart


M. Scherer


J. Schmidt


P. Schmitt


F. Vogel


W. Weber


I. Welsing


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F. Sedlmeir

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Experimental and numerical analysis of crack growth and affiliated parameter optimization

Volker Barth, Paul Steinmann

This work is split into three parts. Part one, the experimental crack growth analysis, deals with the creation of a software tool, which is capable of analyzing experimental crack growth data, see figure 1. This software tool processes digital black and white pictures of a crack specimen taken during the crack growth. Using a certain way of lighting the specimen, it is possible to highlight the crack path. Knowing the timespans between the pictures one can determine the exact position of the crack tip, respectively the rate of the crack growth, with respect to the stress cycles and the crack start point. This analysis is done nearly without user interaction. The second part of this work, the numerical simulation of the crack growth, will be carried out by extending the chair's own finite element program PhoeniX. An extended finite element type will be added to the source code, thereby allowing the simulation of crack growth. In the last part of the work, the results of the numerical and the experimental analysis will be compared. A parameter optimization will be carried out with the aim of improving the numerical analysis of the crack growth.

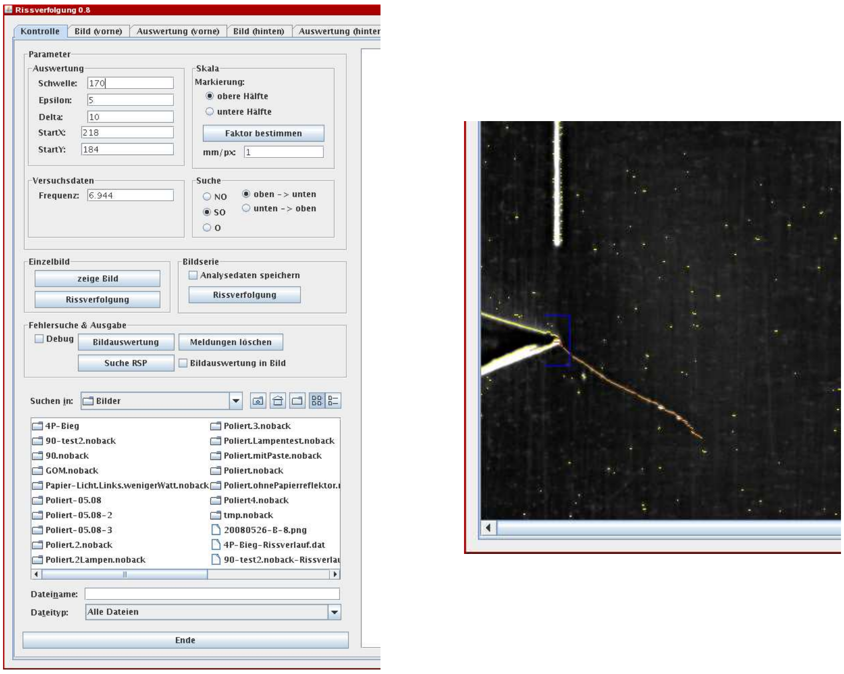

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Figure 1: screenshots of the software tool used to analyze the exerimental data.

On the left side of figure 1, one sees the control center of the software tool, providing access to several parameters influencing the quality of the analysis. On the right side of figure 1, the result of the software analysis of the experimental data of a crack specimen is displayed. One can see clearly the crack path which was found by the software.

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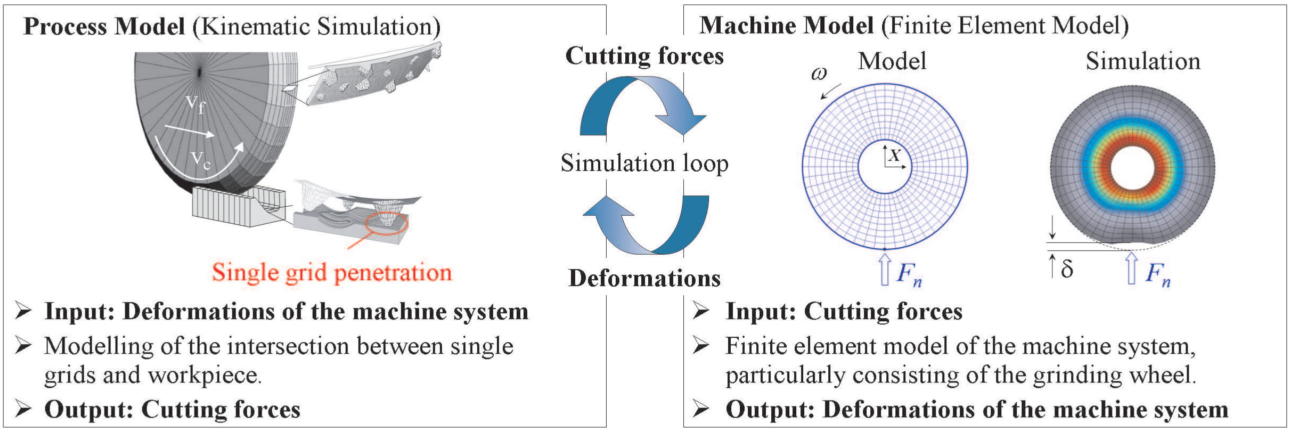
Interaction of process and machine for high-performance surface grinding

Aous Bouabid, Paul Steinmann

Due to the microscopic material cutting mechanisms during grinding, minor deformations in the machine system may significantly affect the surface of the workpiece being ground. While in the last decades several studies model the grinding process and the machine behaviour separately, new simulation approaches aim at increasing the simulation accuracy by coupling the process and machine models [1].

In [2], an integral simulation approach for high performance grinding, consisting of a process model (kinematic simulation), a machine model and a coupling model, is presented (fig 1). This approach uses the kinematic simulation to model the microscopic and macroscopic geometry of the grinding wheel, assuming first, that grinding wheel and workpiece have an ideal geometry. By simulating the intersection between the enveloping profile of the grinding wheel and the workpiece, the grinding forces can then be determined. Since the machine system has in the reality a certain compliance, the grinding forces may lead to machine deformations. Based on a finite element approach adapted for spinning structures, the deformations of the machine, in particular of the grinding wheel, due to the process forces can be simulated and fed back to the process model, in order to again determine the grinding forces, this time based on an updated geometry. This coupled simulation cycle has to be repeated, until the force or the deformation converges.

Up to now, the finite element model for the grinding wheel could be established and manually coupled to the kinematic simulation. An extensive use of the grinding wheel model to carry out reliable coupled simulations is of high interest for further considerations.



- **Input: Deformations of the machine system**
- Modelling of the intersection between single grids and workpiece.
- **Output: Cutting forces**

- **Input: Cutting forces**
- Finite element model of the machine system, particularly consisting of the grinding wheel.
- **Output: Deformations of the machine system**

Figure 1: An integral simulation approach for high-performance grinding processes.

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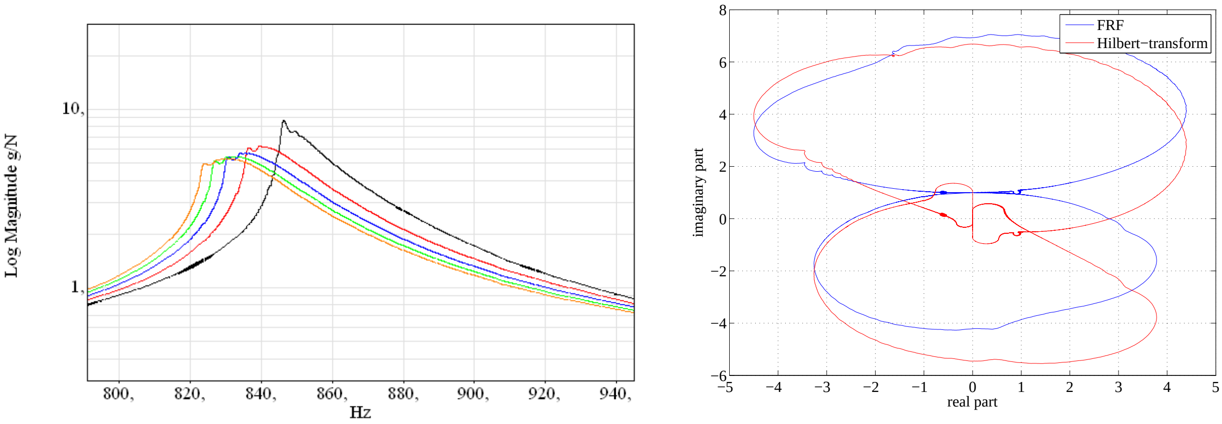
Detection of nonlinearities in jointed structures

Johannes Geisler, Kai Willner

The framework of this work is the numerical and experimental investigation of jointed structures. Here friction forces in contact interfaces play an important role especially with regard to damping effects.
In the numerical studies the Finite Elemente Method is applied using Zero Thickness Elements for the discretization of the contact interface. A classical experimental method to investigate mechanical structures is the Experimental Modal Analysis (EMA), which is strictly speaking only valid for linear behaviour. When there are nonlinear effects like the afore mentioned friction forces, the results of an EMA have to be interpreted very carefully. So the first step in an experimental analysis has to be the decision whether existing nonlinearities are weak and may be neglected or if they are too strong for meaningful results in an EMA. Therefore nonlinearities have to be detected, characterized and - if possible - quantified. There are different methods for the detection of nonlinearities, see [1] or [2], like the total harmonic distortion, testing of amplitude dependencies in frequency response functions (FRF) or the Hilbert transform.

As an example two bolted beams are excited using an electrodynamic shaker with sine sweep forcing functions. On the left side of the following figure the FRF around the second resonance frequency at different excitation levels are shown, whereas the nonlinear behaviour, i.e. the strong amplitude dependence can be seen. Different measurements have to be made with varying force amplitude. On the right hand side the Hilbert-transform is applied to a single FRF and the differences between original FRF and Hilbert-transform show the nonlinearity in the Nyquist-plot. The upper 'circle' corresponds to the first and the lower one to the second resonance. The distortion and the clockwise rotation compared to the original FRF indicate the nonlinearity due to dry friction.



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Intrinsic laws for the normal and tangential contact of rough surfaces

Daniel Goerke, Kai Willner

The aim of this research is to describe the normal and tangential contact behavior of rough surfaces. For a large class of typical surfaces measured structure functions can be approximated by a three-parameter function [1], employing the RMS-value of the roughness, a transition length x_T between fractal behavior at high wavenumbers and stationary behaviour at low wavenumbers, and the fractal dimension D in the fractal region, respectively, as intrinsic parameters to describe an isotropic rough surface.

In order to study the influence of the different parameters and to develop constitutive contact laws it is necessary to numerically generate surfaces with specified properties, see e.g. Figure 1. These generated surfaces are then used in a simulation based on elastic halfspace theory [2]. The model is extended to elasto-plastic contact by correcting the height values iteratively such that the local pressures don't exceed the hardness of the material. For the tangential contact a local Coulomb or a local Tresca contact law has to be observed.

The halfspace model of the fractal-regular surface is tested against experimental data. Normal and tangential contact tests are conducted separately in two different setups. In the normal contact test setup the pressure gap relationship is measured [3] and in the tangential contact test setup the contact behavior is determined by hysteresis curves (Figure 2). In both setups surfaces made of different materials and produced by different production processes are tested.

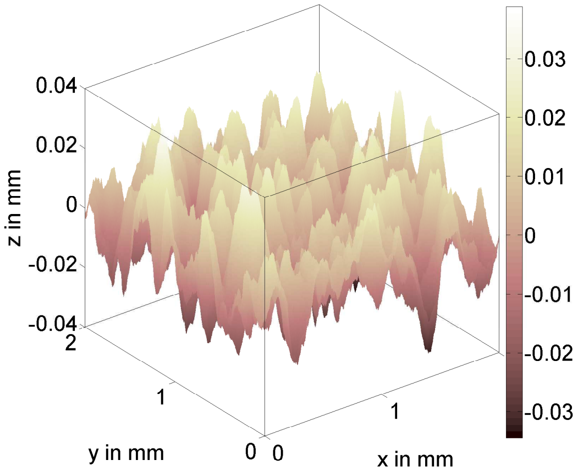

Figure 1: Generated fractal surface with following parameters: $D = 2.1$, $x_T = 0.1$ mm and RMS = 0.01 mm

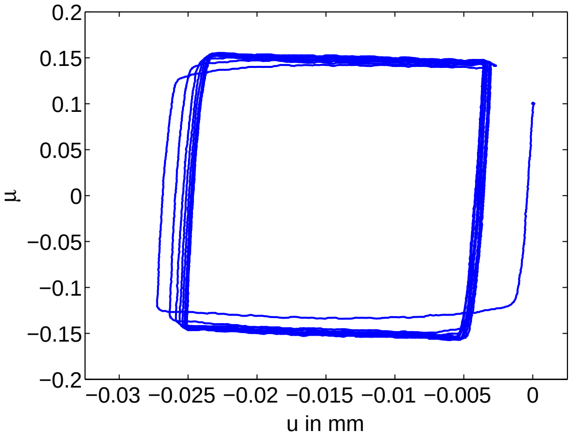

Figure 2: Measured hysteresis curves of ground, hardened steel against stainless steel under a normal load of 2 kN

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Finite strain models to simulate the curing process of polymers

Mokarram Hossain, Gunnar Possart, Paul Steinmann

Motivated by the one dimensional main equation in small strain elastic curing part, i.e., $\dot{\sigma}(t) = c(t)\dot{\varepsilon}(t)$, see [1],the large strain version can be formulated as

$$D_t \boldsymbol{S} = \mathbb{C}(t) : D_t \boldsymbol{C} \tag{1}$$

where $\mathbb{C}(t)$ replaces the stiffness factor $c(t)$ of one-dimensional case. Using Euler backward (implicit) integration scheme, the stress update can be expressed as

$$\boldsymbol{S}^{n+1} = \boldsymbol{S}^{n} + \mathbb{C}^{n+1} : \left[\boldsymbol{C}^{n+1} - \boldsymbol{C}^{n} \right]. \tag{2}$$

Note that a energy function is required to derive the modulus $\mathbb{C}(t)$. One of the main advantages of the expression (2) is that, any energy function, whether it is phenomenological or micromechanical motivated, which is used for a particular type of fully-cured rubber-like hyperelastic material model can be used to derive the stiffness modulus $\mathbb{C}(t)$. Thus, the main formulation for the finite strain curing (2) is independent from the hyperelastic energy function which is used for the fully-cured polymeric materials.

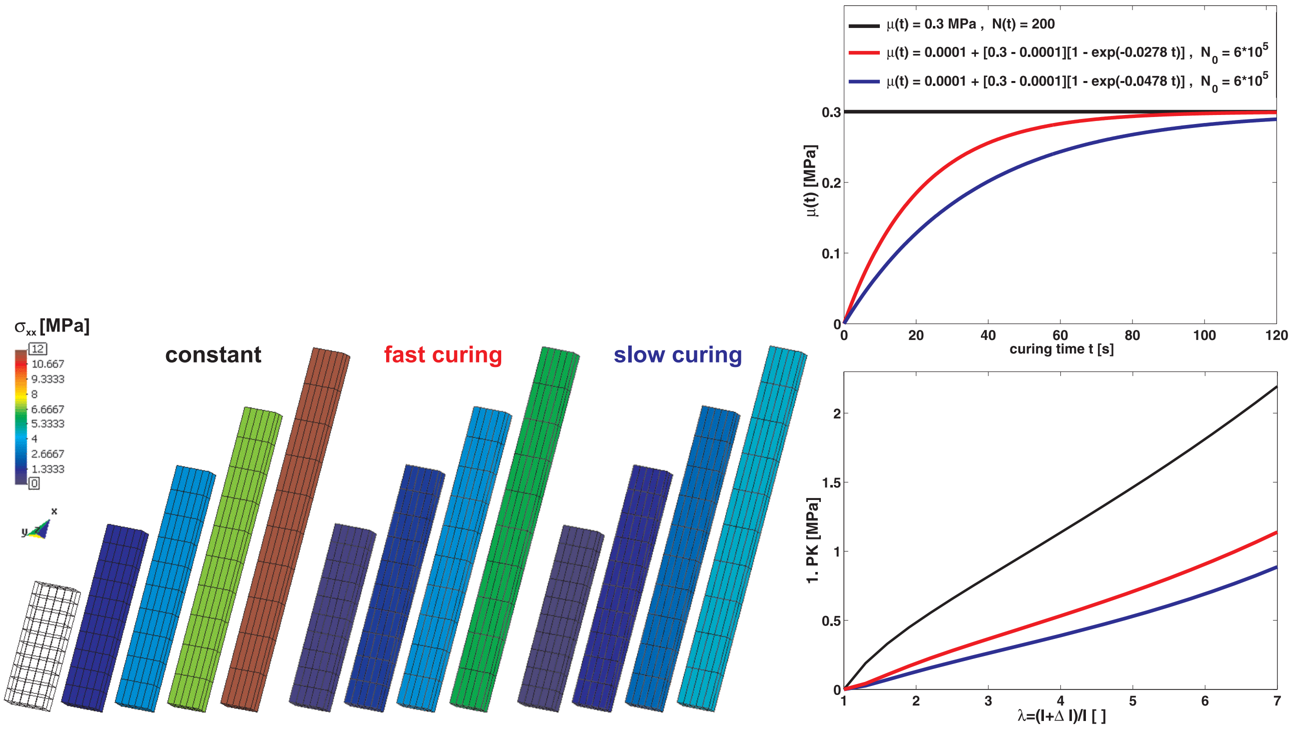

Figure 1: a) A three-dimensinal block is stretched up to 600% using three different sets of material parameters; constant material parameter (left), fast curing (middle) and slow curing (right). b) shear modulus evolution with different curing rates (top); stress-stretch relation (bottom)

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A finite element framework for continua with boundary energies

Ali Javili, Paul Steinmann

Common modeling in continuum mechanics takes exclusively the bulk into account, nevertheless, neglecting possible contributions from the boundary. However, boundary effects sometimes play a dominant role in the material behavior, the most prominent example being surface tension. Within this project boundary potentials are allowed, in general, to depend not only on the boundary deformation but also on the boundary deformation gradient. Motivated by this idea, a suitable finite element framework based on rank deficient deformation gradients is established. In essence, the total potential energy functional $I = I\,(\boldsymbol{\varphi})$ that we seek to minimize with respect to all admissible variations $\delta\boldsymbol{\varphi}$ (spatial variations at fixed material placement) reads

$$I(\boldsymbol{\varphi}) := \int_{\mathcal{B}_0} U_0(\boldsymbol{\varphi}, \boldsymbol{F}; \boldsymbol{X})\ \mathrm{d}V + \int_{\mathcal{S}_0} \mathsf{u}_0(\boldsymbol{\varphi}, \widehat{\boldsymbol{F}}; \boldsymbol{X})\ \mathrm{d}A. \tag{3}$$

Then the minimization of the total potential energy functional, $\delta I\,(\boldsymbol{\varphi}) = 0$, renders the principle of virtual work including contributions from boundary terms

$$\int_{\mathcal{B}_0} \boldsymbol{P} : \mathrm{Grad}\delta\boldsymbol{\varphi}\ \mathrm{d}V \quad + \int_{\mathcal{S}_0} \widehat{\boldsymbol{P}} : \widehat{\mathrm{Grad}}\delta\boldsymbol{\varphi}\ \mathrm{d}A = \int_{\mathcal{B}_0} \boldsymbol{b}_0 \cdot \delta\boldsymbol{\varphi}\ \mathrm{d}V + \int_{\mathcal{S}_0} \widehat{\boldsymbol{b}}_0 \cdot \delta\boldsymbol{\varphi}\ \mathrm{d}A \qquad \forall \delta\boldsymbol{\varphi}. \tag{4}$$

As an example, due to the surface tension effect, the surface of a body tends to obtain constant curvature, i.e. a cube tends to transform to a sphere. This fact is shown in Figure 1.

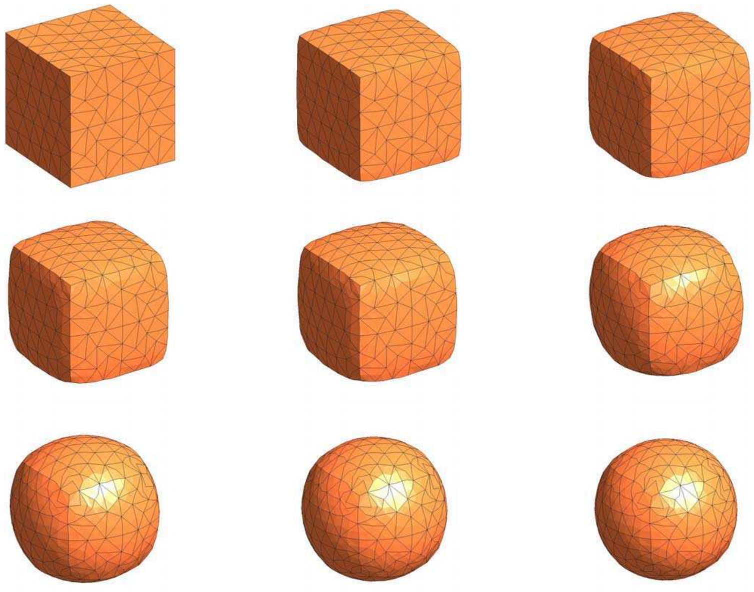

Figure 1: Transformation of a cube to sphere due to surface effects.

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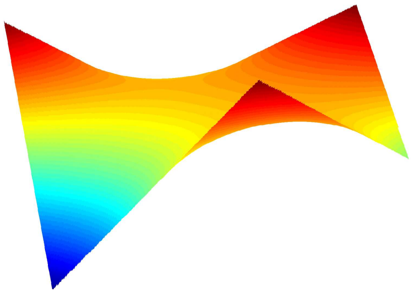
Polygonal finite elements

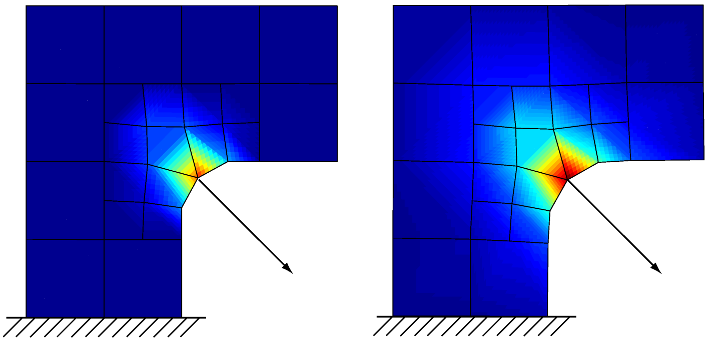
Markus Kraus, Paul Steinmann

The finite element method is a generally acknowledged and very efficient technique for the numerical solution of partial differential equations. Traditional element formulations are often limited to simple geometries, like triangles in 2d or hexahedra in 3d problems. Otherwise, polygonal and polyhedral finite elements like proposed in [1] with almost arbitrary number of straight edges and flat faces respectively provide great flexibility meshing complex structures –like in biomechanics– or modelling materials with polygonal or polyhedral grain structure. Additionally these elements can also be valuable in automatic mesh generation and adaptive mesh refinement.

The actual task in the development of these elements is to offer adequate and secure numerical results compared with regular finite elements at low computational costs. Creating polygonal finite elements may be split in two main projects: At first the unusual shape of the element domain leads compulsorily to the search for good interpolation functions of field variables. This can be realized for abritary and even convave domains using barycentric coordinates or other modified computer graphics related algorithms (figure (a)). The second – and more ambitious– part is to find an efficient and appropriate integration algorithm of the arbitrary element domain. Several approaches are considered: The decomposition of the n-sided polygonal domain in n triangles [1] exhibit the problem of locking. With the propositions in [2,3] an sophiticated result can be received (figure (b)) and has the real advantage of an unique formulation for arbitarly elements. An other approach is to use a nodal integration or to consider only the boundary of the elements and stabilize the results adequately.



(a) barycentric interpolation in hexagonal domain



(b) simulation results for locking-affected (left) and locking-free (right) polygonal elements (here used as transition elements in h-refinement)

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Coupling of particle- and finite-element-based simulations by using a bridging domain

Sebastian Pfaller, Paul Steinmann

The current research investigates and develops schemes to couple domains of different resolution in time and space, a problem frequently arising in multi-scale modelling of materials. To couple a standard finite element domain with a high resolution atomistic or molecular, i.e. particle-based domain, we consider a so-called bridging domain, e.g. Xu and Belytschko [1], Zhang, Khare, Lu and Belytschko [2] and Bauman et al. [3]. In this handshake region a total energy which is the sum of the weighted energies of both domains needs to be formulated.

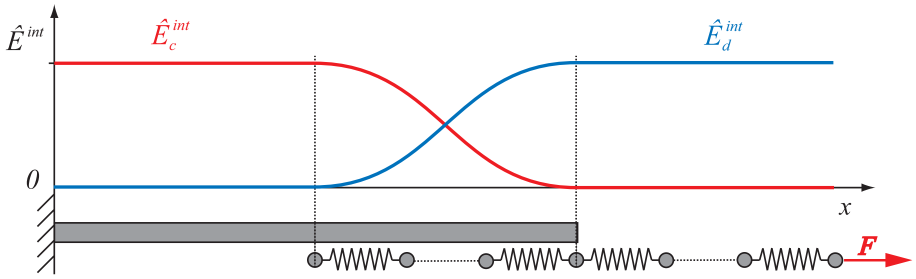

Figure 1: Coupling of a linear elastic rod (left) with a chain of particles (right), weigthed internal energies in the continuum $\hat{E}_c^{int}$ and in the particle domain $\hat{E}_d^{int}$

Furthermore, several coupling constraints can be used, see e.g. [3]. The formulation leads to an optimization problem with equality constraints that can be solved by using a Lagrange multiplier method. The constraints are required to be sufficiently strong to allow physically reasonable results on the one hand while, on the other hand, they should be formulated weak enough to avoid expensive calculations with too many Lagrange multipliers.

Interactions in the particle domain are modelled by potential functions, e.g. a harmonic potential in the simplest case or the Lennard-Jones-potential to consider also non-linear forces between atoms or molecules. More complex formulations like they occur in the modelling of larger molecules up to polymers can also be taken into account.

Depending on the format of this atomistic energy the equations become linear or non-linear and have to be solved adequately. In the non-linear case this is usually accomplished by the monolithic Newton-Raphson algorithm. The main goal is to separate the computation of finite element and atomistic domains as much as possible, amongst others to calculate the different domains on several CPUs.

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Experimental investigation of epoxy-metal-interphases

G. Possart, M. Presser, S. Passlack,
P. Steinmann, A. Brodyanski, M. Kopnarski, P. Geiss

The polymer network formation in adhesively bonded joints is susceptible to be locally influenced/disturbed by the presence of the substrate surface - especially in reactive systems like two-component epoxies. Such disturbances have been proven to possibly reach as far as some hundreds of microns into the polymer bulk, which is obviously of some relevance concerning the integral behaviour/durability of the joint. As underlying mechanisms the preferred adsorption of a particular component of the liquid adhesive, demixing, curing shrinkage or the formation of anisotropic networks near the interface due to preferential binding sites or van der Waals interactions between adjacent polymer chains have been assumed by various authors.
In a joint research project the mechanical behaviour of the interphase region is investigated by microextensometry using Scanning Electron Microscopy (SEM) as an imaging device and computational image analysis. To this end, aluminium-epoxy-compounds are marked with a regular grid by Focussed Ion Beam (FIB) technique. By tracking this grid of points during deformation within SEM inhomogeneities in the deformation field at a resolution in a range of ten microns can be captured. Such information will then be used to inversely identify possible gradients in the parameters of appropriate constitutive models - which will allow some back-reasoning on the local polymer structure.

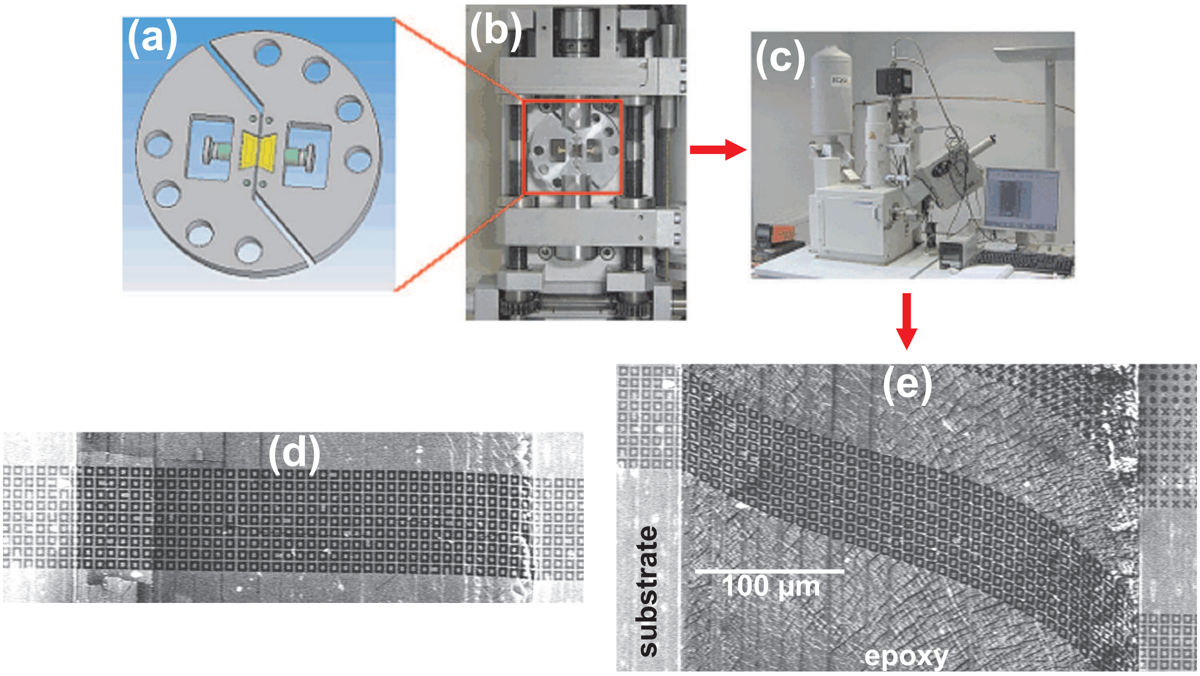

Figure 1: (a) micro-shear-specimen fixture, (b) micro tensile testing device, (c) SEM, (d) undeformed and FIB-marked shear specimen in SEM, (e) inhomogeneous deformation field during shearing

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Smooth conformal α-NEM for gradient elasticity

A. Rajagopal, M. Scherer, P. Steinmann, N. Sukumar

Strain gradient theory for continuum analysis has kinematic relations which include terms from second gradients of the deformation map. This results in balance equations that have fourth order spatial derivatives, supplemented with higher order boundary conditions. The weak formulation of fourth order operators stipulate that the basis functions must be globally C^1-continuous, very few finite elements in two dimensions meet this requirement. In this work, we have proposed a meshfree methodology for the analysis of gradient continua using a conformal α-shape based natural element method (NEM). The conformal α-NEM allows the construction of models entirely in terms of nodes and ensures quadratic precision of the interpolant over convex and non-convex boundaries. Smooth natural neighbor interpolants are achieved by a transformation of Farin's C^1-interpolant, which are obtained by embedding Sibson's natural neighbour coordinates in the Bernstein-Bézier surface representation of a cubic simplex (see Figure 1). For example an L-shaped specimen subjected to biaxial loading, as shown in Figure 2, demonstrates the length scale effect.

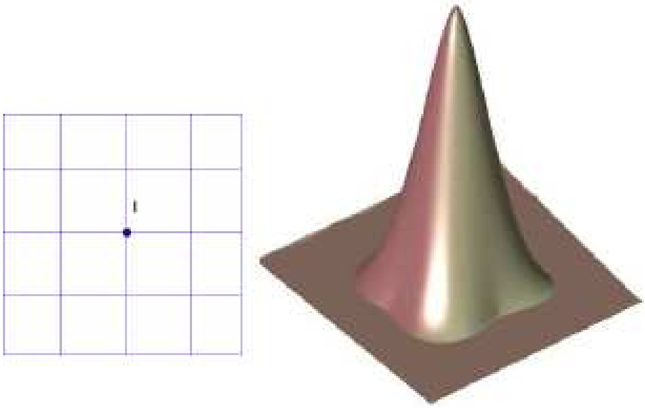

Figure 1: C^1-NEM shape function ψ_{3I-2} at node I

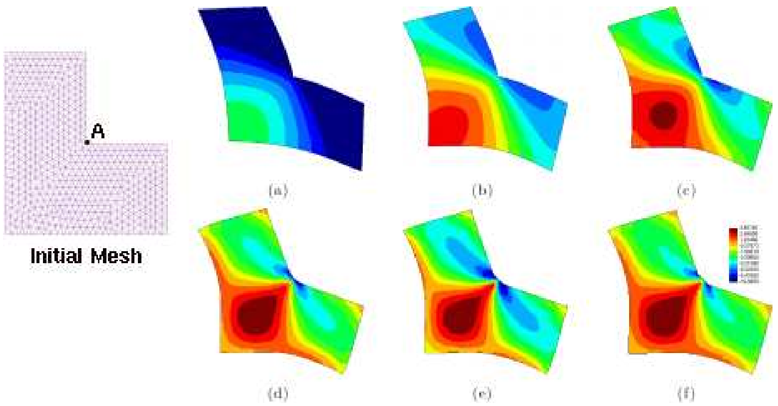

Figure 2: Plot of Cauchy type stress σ_{12} at various length scales for an L-shaped specimen subjected to biaxial loading and with point A fixed. (a) $l = L_0/2$, (b) $l = L_0/5$, (c) $l = L_0/10$, (d) $l = L_0/100$, (e) $l = L_0/\infty$, (f) $l = L_0/\infty$ with C^0-NEM

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A fictitious energy approach for isoparametric shape optimization in elasticity

Michael Scherer, Paul Steinmann

Classical shape optimization methods combine a geometry model (based on Bézier curves or surfaces, B-splines, or NURBS) with the FEM-model of a structure. The geometry model on the one hand provides the design variables and the FEM-model on the other hand is used for the computation of the state variables and sensitivities. The principal characteristic of the isoparametric shape optimization method, mainly developed in 2008, is that coordinates of boundary nodes can directly be chosen as design variables, whereas well-known problems of node based methods with maintaining a smooth and regular boundary do not occur. This is accomplished through a special regularization technique: an artificial inequality constraint based on a fictitious elastic energy controlls the deformation of the design. Gradients provided by the optimization can be interpreted as forces that deform an artificial body, where an "enforced locking" stops this process. Beside the regularization, the fictitious energy allows for the movement of interior nodes via a nonlinear version of the boundary displacement method. As a solution strategy for the shape optimization, we use a penalty-barrier algorithm.

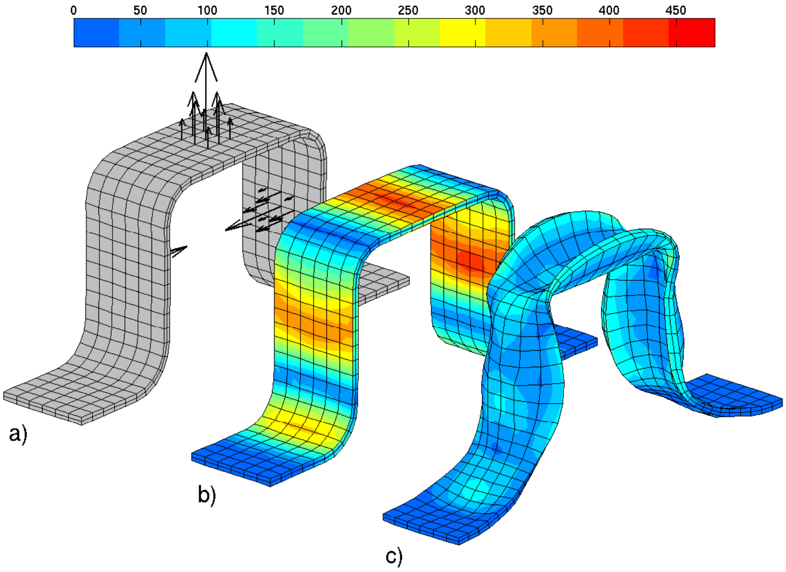

Figure 1. a) Initial design of a linear elastic sheet metal part that is clamped at the two horizontal straps and subjected to three constant surface loads. b) Von Mises stress distribution of the initial design. c) Von Mises stress distribution of the optimized design. The objective of the shape optimization is to minimize the compliance while keeping the volume constant. Following a common approach in topology optimization, the compliance is measured by the (negative) potential of the external forces. In addition to a 90% reduction of the compliance, the maximum von Mises stresses decrease since the optimization improves the equal distribution of the free energy.

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Geometric numerical integration of simple dynamical systems

Patrick R. Schmitt, Paul Steinmann

In order to study the behavior of dynamical systems one usually makes use of the theory of Hamiltonian systems and the phase-space concept. Within Hamilton's framework a dynamical system is completely described by specifying the scalar Hamiltonian function H together with Hamilton's equations of motion, i.e. $2n$ ordinary differential equations for n degrees of freedom. It is however useful to consider these equations from a geometric point of view as discussed in [1]. The (finite dimensional) configuration space of a physical system has the structure of a (smooth) manifold and is denoted by Q. The momentum phase-space of this system is just the cotangent bundle T^*Q which is equipped with a natural symplectic structure ω (a 2-form in the language of differential geometry). The Hamiltonian is a smooth map $H : T^*Q \to \mathbb{R}$ and the corresponding Hamiltonian vector field is denoted X_H and determined by $dH = \omega(X_H, .)$. Hamilton's equations are just the equations of the flow of the vector-field X_H. In order to integrate the Hamiltonian flow a class of geometry preserving integrators based on Lie-groups and -algebras is used, see [2] for details.

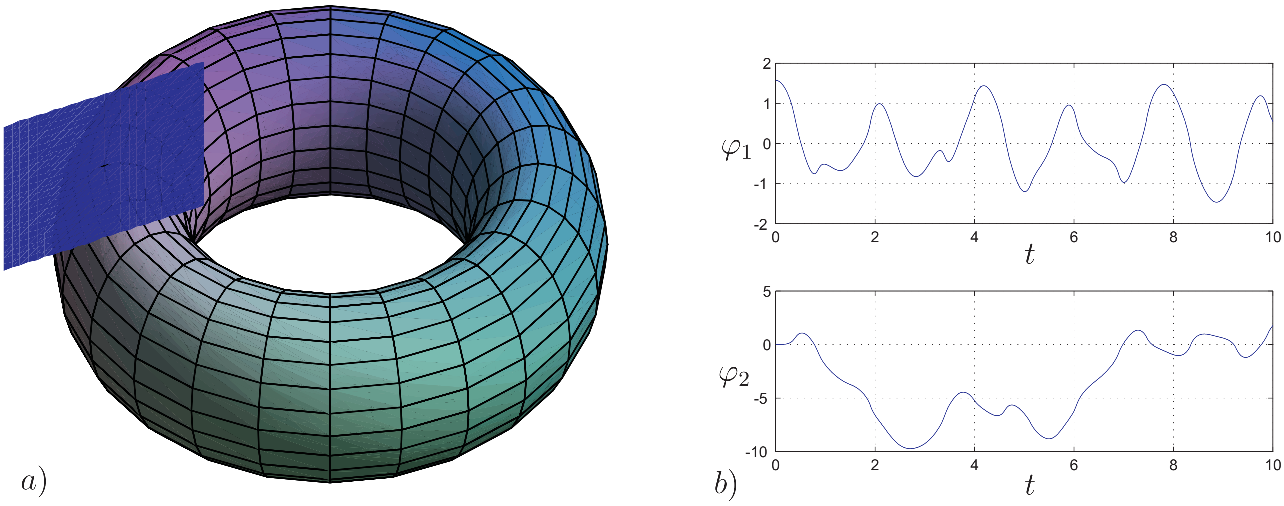

Figure 1: a) The configuration space of a planar double pendulum is the torus $T \cong S^1 \times S^1$.
b) Time evolution of the generalized coordinates φ_1, φ_2 determined by employing a structure preserving Lie-type integrator.

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On the modeling and simulation of magneto-sensitive elastomers

Franziska Vogel, Paul Steinmann

Magneto-sensitive elastomers are smart materials which are composed of a rubber-like basis matrix filled with magneto-active particles. Due to highly elastic properties of the rubber-like material, these compounds are able to deform significantly, i.e. geometrically non-linearly by the application of external magnetic fields. It is planned to realize a simulation of such materials with the help of the following modeling ideas.

For the quasi-static case the coupled equations that have to be considered in a magneto-sensitive body consist of the kinematic compatibility conditions, the mechanical equilibrium condition and the magnetic part of the Maxwell equations:

$$\nabla \times \mathbf{F} = 0, \qquad \nabla \cdot \mathbf{T} = -\mathbf{f}, \qquad \nabla \times \mathbf{H}_l = 0, \qquad \nabla \cdot \mathbf{B}_l = 0. \tag{5}$$

Here, $\mathbf{F}, \mathbf{T}, \mathbf{f}, \mathbf{H}_l$, and $\mathbf{B}_l$ denote the deformation gradient, the total nominal stress, the body force, the Lagrangian magnetic field, and the Lagrangian magnetic induction, respectively. To derive a coupled variational formulation for the magneto-elastic problem either the vector potential for the magnetic induction or the scalar potential for the magnetic field can be used as the independent magnetic variable. The choice of the primary magnetic variable depends on focusing either on the magneto-electrodynamic case or the magneto-static case. Based on these variational principles, suitable finite element discretizations of the coupled magneto-elastic problem will be developed. For this purpose, the constitutive equations in terms of the total energy function need to be formulated. An important part of the model proposed here is the use of a total energy function $\Omega(\mathbf{F}, \mathbf{B}_l)$ which depends on the deformation gradient and, e.g. the Lagrangian magnetic induction. Then it is possible to show that the total nominal stress and the Lagrangian magnetic field are given as

$$\mathbf{T} = \frac{\partial \Omega}{\partial \mathbf{F}}, \qquad \mathbf{H}_l = \frac{\partial \Omega}{\partial \mathbf{B}_l}. \tag{6}$$

The overall project aims are to model realistic and at the same time simple constitutive equations, in comparison with available experimental data, and to apply these equations to solve typical magneto-elastic benchmark problems using the finite element method.

In order to achieve this suitable boundary conditions for the coupled boundary value problem have to be defined, microstructural features have to be incorporated into the model, and simple forms of the energy function have to be proposed. Furthermore, there is need for an analysis of the constitutive equations to assure that they will lead to well-posed problems. For the finite element discretizations mixed ansatz-spaces are considered. In particular, the formulation in terms of the vector potential necessitates the use of so-called edge-elements or rather Whitney-Nedelec-expansions.

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Material and spatial motion problems in nonlinear electro- and magneto-elastostatics

Duc Khoi Vu and Paul Steinmann

The concept of configurational forces in nonlinear electro- and magneto-elastostatics is revisited in this work, where the balance equations of linear momentum (or the balance equations of linear momentum of the spatial motion problem, as they are called in the parlance of configurational mechanics) and the corresponding boundary conditions are transformed into some appropriate forms (material motion form) and in an appropriate continuum mechanical setting (the material setting). Material and spatial motion problems in nonlinear electro- and magneto-elastostatics are considered without the assumption that mechanical loads can be derived explicitly from some potential. The corresponding variational formulations and governing equations are derived by a virtual work approach and have very similar forms. The balance equations of linear momentum and boundary conditions of material and spatial motion problems can be represented by:

$$\begin{tikzcd}
\left\{\begin{array}{r} \nabla_{\boldsymbol{X}} \cdot \boldsymbol{P}^* + \boldsymbol{b}_0 = \boldsymbol{0} \quad \text{in } \mathcal{B}_0 \\ \boldsymbol{P}^* \cdot \boldsymbol{N} = \boldsymbol{t}_0^* \quad \text{on } \partial\mathcal{B}_0 \end{array}\right. \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & \left\{\begin{array}{r} \nabla_{\boldsymbol{x}} \cdot \boldsymbol{\sigma}^* + \boldsymbol{b}_t = \boldsymbol{0} \quad \text{in } \mathcal{B}_t \\ \boldsymbol{\sigma}^* \cdot \boldsymbol{n} = \boldsymbol{t}_t^* \quad \text{on } \partial\mathcal{B}_t \end{array}\right. \arrow[d, leftrightarrow] \\
\left\{\begin{array}{l} \nabla_{\boldsymbol{X}} \cdot \boldsymbol{\Sigma}^* + \boldsymbol{B}_0^* = \boldsymbol{0} \quad \text{in } \mathcal{B}_0 \\ \boldsymbol{\Sigma}^* \cdot \boldsymbol{N} = \boldsymbol{T}_0^{d*} - \boldsymbol{f}^{-t} \cdot \boldsymbol{t}_0^* \quad \text{on } \partial\mathcal{B}_0 \end{array}\right. \arrow[r, leftrightarrow] & \left\{\begin{array}{l} \nabla_{\boldsymbol{x}} \cdot \boldsymbol{p}^* + \boldsymbol{B}_t^* = \boldsymbol{0} \quad \text{in } \mathcal{B}_t \\ \boldsymbol{p}^* \cdot \boldsymbol{n} = \boldsymbol{T}_t^{d*} - \boldsymbol{f}^{-t} \cdot \boldsymbol{t}_t^* \quad \text{on } \partial\mathcal{B}_t \end{array}\right.
\end{tikzcd}$$

where $(\bullet)^*$ stands for the corresponding quantity in nonlinear elastostatics, nonlinear electro-elastostatics and magneto-elastostatics. Due to their similarity, the three problems of elastostatics, electro-elastostatics and magneto-elastostatics can be treated in a similar way. Further studies are needed in order to extend the current result to more general boundary conditions for the electric and magnetic fields.

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Simulation of 3D fatigue crack propagation

Wilhelm Weber, Paul Steinmann, Günther Kuhn

To prevent accidents due to fatigue crack growth, 3D fatigue crack propagation in terms of linear elastic fracture mechanics is simulated. Since the nature of crack growth is nonlinear an incremental procedure has to be applied. Special attention is focused on the continuous change of the stress field within the incremental procedure. In each increment three steps have to be performed: **a)** a complete stress analysis including the calculation of the stress intensity factors (SIFs) and T-stresses, **b)** the evaluation of the 3D crack growth criterion to determine the new crack front and **c)** the update of the numerical model.

The 3D dual boundary element method is applied for the computation of the stress field. This method is especially suitable for stress concentration problems and the update of the discretization. The fracture mechanical parameters are accurately extrapolated from the stress field by a regression analysis optimized by the minimization of the standard deviation.

The crack deflection and the crack extension for every point along the crack front have to be determined to define the new crack front relative to the current one. The maximum tangential stress criterion has been established for the calculation of the kink angle. It is extended by the utilization of the T-stresses in order to consider the curvature of the crack path.

In the present context the cyclic equivalent SIF ΔK_{eq} is determined by the criterion of the maximum energy release rate. By the evaluation of a crack propagation rate formulation the local crack extension $\Delta a(P)$ is predicted in a linear way.

Since the fact of a changing stress field between the initial and the new crack front is not included in the predictor step, corrector steps are required. Within the next incremental loop the cyclic equivalent SIFs for all points of the new crack front are additionally known. By using this knowledge, the stress field between these two crack fronts is approximated and a more accurate number of load cycles ΔN_{acc} is recalculated, which differs from the prescribed number ΔN_{lc}. Therefore, the new crack front is corrected in such a way that the accurate number of load cycles ΔN_{acc} converges to the prescribed one [1].

To demonstrate the benefit of the presented predictor-corrector scheme a 4-point bending specimen of the transparent material PMMA with a complex initial crack front is chosen.

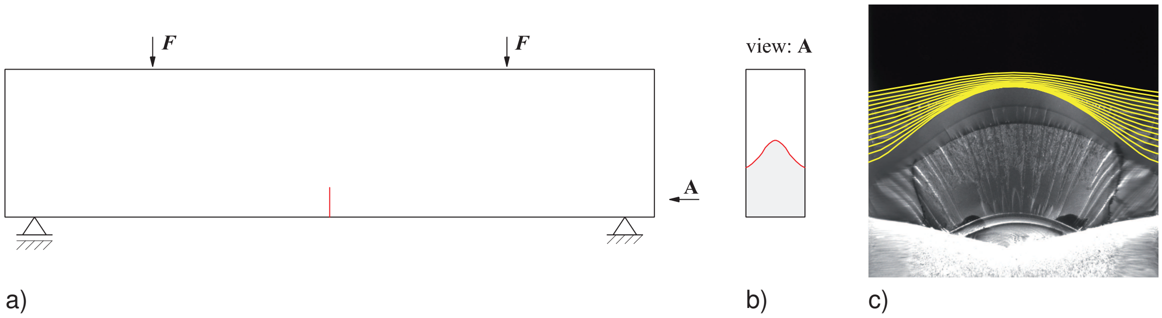

Figure 1: four point bending specimen with complex initial crack

Overall, a good agreement between the numerical obtained crack fronts and the experimental results can be observed.

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Simulation of jaw bone loading due to vertical and horizontal misfit

Werner Winter, Matthias Karl, Siegfried Heckmann

It is generally assumed that passively fitting superstructures are a prerequisite for long-lasting implant success. In an in-vitro study [1] the strain development of three-unit implant fixed partial dentures (FPDs) was evaluated at the bone surrounding the implant and on the superstructure using a strain gauge technique (see Fig. 1a). Different groups of three-unit FPDs representing the commonly used techniques of bridge fabrication were investigated in order to quantify the influence of impression technique, mode of fabrication and retention mechanism on superstructure fit. Two ITI implants (Straumann, Waldenburg, Switzerland) were anchored in a measurement model according to a real-life patient situation, and strain gauges were fixed mesially and distally adjacent to the implants and on the bridge pontics (see Fig. 1a). The developing strains were recorded during cement setting and screw fixation. About half of the measured strains were found to be due to impression taking and model fabrication, whereas the remaining were related to laboratory inaccuracies. The two impression techniques used did not reveal any significant differences in terms of precision. Both modes of fixation, i.e. cement and screw retention, provoked equally high strain levels. For analysing bone loading different FE-models were generated to simulate the stress state in the bone surrounded area. Besides simple models (see Fig. 1b and Fig. 1c) for simulation the data (STL) of a scanned three unit FDP was used (see Fig. 1d). The FE-models are able to show the bone loading due to different vertical and/or horizontal misfit produced by impression taking and model fabrication [2].

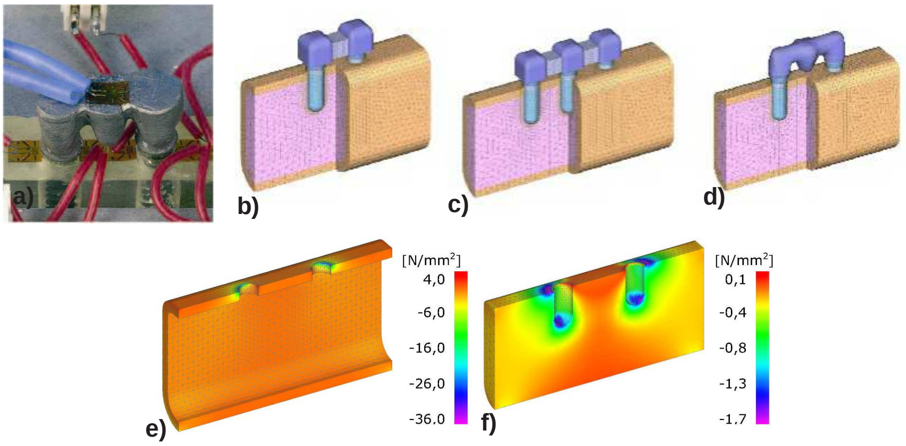

Figure 1: a) Measurement model with strain gauges. b) Three unit FDP. c) Five unit FDP. d) Three unit FDP generated from STL-data. e) Princial stress in upper layer (cortical bone). f) Principal stress in trabecular bone.

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Numerical and experimental investigation of multi-functional lightweight structures for absorption of energy

Jürgen Schmidt, Werner Winter, Günther Kuhn

During the last years a lot of activities have taken place in the European Union in order to improve pedestrian protection. Since cellular materials (foams) have an excellent characteristic to dissipate energy they will be used in composite structures as passive safety elements. For validation of experimental results and numerical calculations a three point bending device is dynamically loaded. Composite beams with steel face sheets and aluminium foams as cores are regarded and loaded with an impact velocity of $0.1m/s < v_0 < 10m/s$ (see Fig. 1a and 1b). The loading device including the measurement equipment is depicted in Fig. 1c. The aim of this study is to find possible mechanisms of deformation and dissipation of energy during systematic identification. In the numerical simulation an elastic-plastic material model with large plastic volume change was developed to simulate plastic dissipation due to different foam densities. By the application of multicriteria optimization methods optimal lightweight structures can be found.

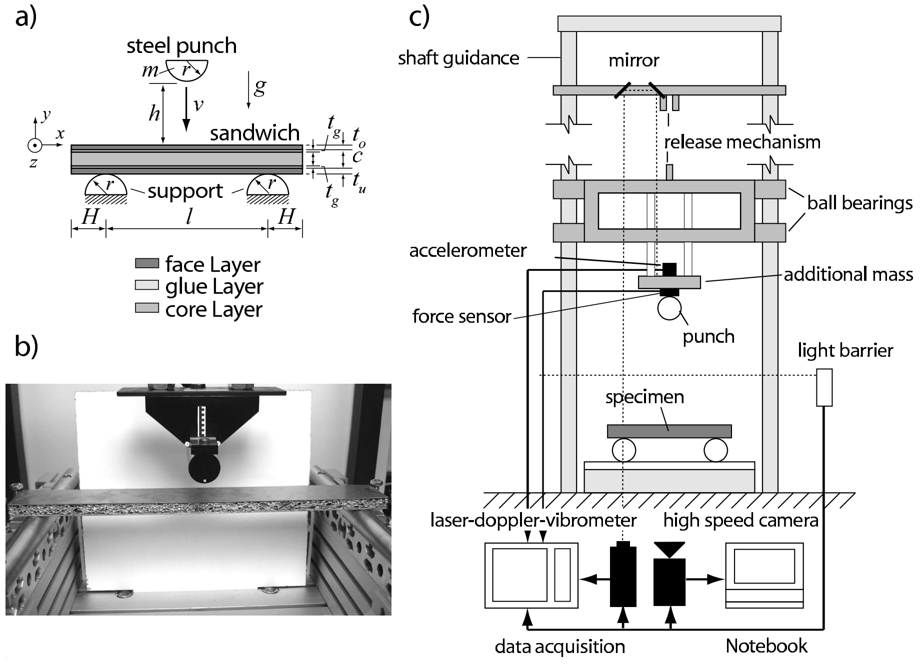

Figure 1: a) Sandwich structure with steel faces and foam core. b) Real sandwich beam. c) Experimental device with measurement equipment.

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4 Activities in 2008

4.1 Lectures

- Statik und Grundlagen der Elastostatik
- Statik, Elastostatik und Festigkeitslehre - Teil 2
- Statik und Festigkeitslehre
- Technische Mechanik III
- Technische Mechanik IV
- Kontinuumsmechanik I
- Kontinuumsmechanik II
- Maschinendynamik I
- Maschinendynamik II
- Einführung in die Schädigungsmechanik
- Mechanik der Materialverbunde
- Bruchmechanik
- Finite Elemente
- Finite Elemente in der Plastomechanik
- Finite Elemente Praktikum
- Höhere Festigkeitslehre
- Hauptseminar
- Seminar über Fragen der Mechanik

4.2 Student research projects theses

- L. Gebhard, *Experimentelle Modalanalyse linearer und nichtlinearer Systeme.*
- M. Fang, *Untersuchungen zum Hertz'schen Kontakt transversal-isotroper Körper.*
- S. Fillep, *Behandlung stationärer Temperaturfelder bei der Beanspruchungsanalyse mit der Randelementmethode.*
- M. Kaluza, *Betriebsfeste, prüf- und anforderungsgerechte Auslegung von Schweißkonstruktionen mit der Finite-Elemente-Methode.*
- S. Landeck, *Behandlung schwach und stark singulärer Volumenintegrale zur elastoplastischen Spannungsberechnung mit der Randelementmethode.*
- T. Mederer, *Untersuchung verschiedener Gurthöhenversteller-Mechanismen bei Straffung des Sicherheitsgurts.*
- S. Möhrle, *Generierung von 3D-FE-Vernetzungen für Brücken und Zahnimplantate im Kiefer.*
- J. Müller, *Simulation der Abkühlbedingungen zur Vorhersage der mechanischen Eigenschaften von Mikrospritzgussteilen.*
- S. Schmaltz, *Implementierung des reibbehafteten 3D Risskontaktes unter Verwendung der Dualen Diskontinuitäten Methode in das Programmsystem Betsy.*
- H.-B. Schmidt, *Simulation of Contact Problems in Solid Mechanics.*
- T. Sop Njindam, *FE-Modell eines Mikroschlupfprüfstandes.*
- P. Spies, *Untersuchung harmonisch erregter Schwingungssysteme.*
- J. Trost, *Adaptive Erweiterung des Randelementebereichs bei FEM/BEM gekoppelten Rissfortschrittssimulationen.*
- I. Tsoupis, *Generierung von FE-Modellen aus Oberflächendaten im STL-Format.*

4.3 Diploma theses

- M. Bär, *Konzeption und Umsetzung eines echtzeitfähigen Fahrzeugmodells.*
- S. Bergherr, *Numerische Untersuchung von Sandwichstrukturen mit unterschiedlichem Kernaufbau.*
- T. Droik, *Konstruktion und Berechnung einer Aufladeeinheit zur Wirkungsgradsteigerung eines Brennstoffzellenantriebs.*
- S. Krug, *Entwicklung und Bewertung alternativer Roboterkinematiken für die Patientenbehandlung in der Medizintechnik.*
- M. Lang, *Kopplung zwischen Prozess- und Produktsimulation bei Wärmebehandlungsproblemen.*
- C. Leidecker, *Strukturanalyse von Faser-Kunststoff-Bauteilen und Verbundkonstruktionen mit der Methode der finiten Elemente.*
- T. Mederer, *Charakterisierung und Bewertung von Verzögerungspulsen im Frontal-Crash.*
- S. Möhrle, *Numerische Untersuchung zur Stabilität von Zahnimplantaten.*
- L. Otter, *Untersuchung eines dynamischen Gesamtmodells für den Prozess des spitzenlosen Außenrundeinstechschleifens.*
- S. Pfaller, *Identifikation des Steifigkeits- und Dämpfungsverhaltens eines Schwingungsdämpfers.*
- S. Sulzer, *Entwicklung eines Simulationsprogramms zur Berechnung elektrischer Felder.*
- A. Uzunovic, *Verzerrungslokalisierung in 3D-FE-Modellen aus Polyederzellen mit statisch verteilten Störungen.*
- M. Werner, *FE-Berechnung und bruchmechanische Bewertung eines Umformteils.*

4.4 Dissertations (finished in 2008)

- Bastian Helldörfer, *Ein randelementbasiertes 3D-Rissfortschrittsmodell für Finite Element Systeme.*

Dissertation at LTM of University of Kaiserslautern, supervised by P. Steinmann:

- Swantje Bargmann, *Theory and numerics of non-classical thermo-hyperelasticity.*
- Britta Hirschberger, *A treatise on micromorphic continua. Theory, homogenization, computation.*
- Rouven Mohr, *Consistent time-integration of finite elasto-plasto-dynamics.*
- Johannes Utzinger, *Analysis and Computation of Solid Interfaces on the Meso Scale.*

4.5 Seminar über Fragen der Mechanik

11.04.08 Shashank Gupta,
Department of Civil Engineering, Structural Mechanics Division, K.U. Leuven, Belgium
A numerical model for ground-borne vibration from underground railways

23.04.08 Christian Linder
Departement of Civil & Environmental Engineering, University of California, Berkeley
Modeling of Dynamic Fracture using Finite Elements with Embedded Strong Discontinuities

05.05.08 Leopold Škerget
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Computational techniques for heat transfer in fluids and solids

05.05.08 Leopold Škerget
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Fundamentals of the Boundary Element Method

05.05.08 Leopold Škerget
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Approximation techniques for a diffusion and convection partial differential equation

05.05.08 Stefan Uhlar
Chair of Computational Mechanics, Institute for Mechanics and Control, Department of Mechanical Engineering, University of Siegen
Mechanical time-integrators for hybrid multibody systems

06.05.08 Matjaž Hriberšek
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Application of Boundary Element Method for heat transfer in fluids and solids

06.05.08 Matjaž Hriberšek
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Fast solution techniques in Boundary Element method for linear and non-linear problems

07.05.08 Leopold Škerget
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Time dependent problems in compressible fluid flow by the Boundary Element Method

07.05.08 Matjaž Hriberšek
Faculty of Mechanical Engineering, University of Maribor, Slovenia
Selected computed problems of heat and fluid flow

18.07.08 Tsuyoshi Koyama
Institute of Mechanical Systems, ETH Zürich
Computing interior eigenvalues of a generalized complex-symmetric pencil arising from the modeling of resonant MEMS systems

01.12.08 Sigrid Leyendecker
Institut für Mathematik, Biocomputing Group, FU Berlin
Discrete mechanics and optimal control of multibody dynamics

08.12.08 Igor A. Guz
Centre for Micro- and Nanomechanics, University of Aberdeen
3-D modelling of materials with pronounced internal micro- and nano-heterogeneities

4.6 IUTAM Symposium
Progress in the Theory and Numerics of Configurational Mechanics

Date	20.-24.10.2008
Venue	Unicum in Erlangen
Homepage	www.configmech.uni-erlangen.de
Scientific Committee	
Chair	Steinmann, P.
Members	Epstein, M.
	Govindjee, S.
	Kalpakides, V.
	Kienzler, R.
	Maugin, G. A.
	Ortiz, O.
	Podio-Guidugli, P.
	Shilhavy, M.
IUTAM Repr.	Freund, B.

Configurational mechanics promises high potential in various areas of theoretical and numerical mechanics. Typical applications range from new perspectives in material modelling, optimization of structures at various length scales to impacts in numerical methods like, e.g., mesh adaption or ALE-methods. Moreover, configurational mechanics often offers new and deep insights and interpretations of a variety of aspects related to defect mechanics. Conceptually speaking common (deformational) continuum mechanics, which gives rise to the familiar notion of (spatial) forces, considers the response to variations of spatial placements of 'physical particle' with respect to the ambient space, whereas configurational mechanics, which gives rise to the notion of configurational (material) forces, is concerned with the response to variations of material placements of 'physical particle' with respect to the ambient material. Well-known examples of configurational forces are driving forces on defects like the Peach-Koehler force, the J-Integral in fracture mechanics, energy release and the like. The consideration of configurational forces goes back to the works by Eshelby who investigated forces on defects, therefore this area of continuum mechanics is sometimes also denoted as Eshelbian mechanics. The Symposium was intended to cover recent progress in theoretical and numerical developments related to configurational mechanics.

Participants

Agiasofitou, E.
Bargmann, S.
Barthold, F. J.
Berezovski, A.
Braun, M.
Cleja-Tigoiu, S.
Danescu, A.
Denzer, R.
DiCarlo, A.
Ebbing, V.
Eremyev, V. A.
Fischer, F.
Francfort, G.
Ganghoffer, J. F.
Gross, D.
Hackl, K.
Herrmann, H.
Irschik, H.
Kalpakides, V.
Kienzler, R.
Kolednik, V.
Larsson, F.
Larsson, R.
Lazar, M.
Magoariec, H.
Mahnken, R.
Mariano, P. M.
Markenscoff, X.
Materna, D.
Maugin, G. A.
Menzel, A.
Morgner, C.
Mosler, J.
Müller, R.
Podio-Guidugli, P.
Randrüüt, M.
Ricker, S.
Runesson, K.
Scherer, M.
Schütte, H.
Steinmann, P.
Svendsen, B.
Tillberg, J.
Trimarco, C.
Vainchtein, A.
Verron, E.

Topics
Based on the notion of configurational forces, the theoretical and numerical study of the capability of a variety of defects, like, e.g.

- cracks
- dislocations
- inclusions
- precipitates
- phase boundaries
- interfaces

to move relative to the ambient material is an active branch of research in continuum mechanics and continuum physics. Thereby, typical topics of interest in theoretical and numerical continuum mechanics and continuum physics are, e.g.

- driving forces on defects
- kinetics of defects
- morphology changes
- energy-momentum tensors
- conservation laws
- path integrals
- energy release rates
- uality of direct and inverse motion
- 4-dimensional formalisms.

4.7 Ultimate Load Contest - The Student Event

Taking place at July 16th and December 17th the Ultimate Load Contest again attracted several participating groups consisting of students of all engineering disciplines. The object of this contest is an optimization problem in applied mechanics: built out of hard masonite, an engineering structure is loaded until it collapses. The structure is supported at three points and should have a weight of not more than 2 kg. Nearly 200 spectators were thrilled by the events and the diversity of its ideas. As a reward for the efforts, presents were handed over to all participants.
Being an exciting supplement to an engineering students curriculum, the Ultimate Load Contest deepens and enhances the theoretical part of education in Applied Mechanics by giving it a demonstrative dimension. Increasing numbers of spectators and participants are encouraging the Chair for Applied Mechanics to intensify the work on this highlight.

5 Talks

1. J. Geisler, K. Willner. Investigations on Joint Interfaces Using Zero Thickness Finite Elements. 8th World Congress on Computational Mechanics, Venice, Italy, 03.07.2008.
2. D. Goerke, K. Willner. Measured and Simulated Contact Stiffness of Dry Metallic Joints. 8th World Congress on Computational Mechanics, Venice, Italy, 03.07.2008.
3. A. Javili, P. Steinmann. A Finite Element Framework for Continua with Boundary Potentials. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
4. B. Helldörfer, W. Weber, G. Kuhn. Ein adaptives, randelementbasiertes Abaqus-Modul zur Simulation von 3D-Ermüdungsrissausbreitung. Deutschsprachige Abaqus-Benutzerkonferenz, Bad Homburg, Germany, 22.-23.09.2008.
5. B. Helldörfer, P. Steinmann, G. Kuhn. Crack propagation simulations by a combined FE/BE approach with an automatic BE domain extension. 8th World Congress on Computational Mechanics, Venice, Italy, 30.06.-04.07.2008.
6. B. Helldörfer. Ein randelementbasiertes, adaptives 3D-Rissfortschrittsmodul für Finite Elemente Systeme. TU Darmstadt, Fachgebiet Festkörpermechanik, Seminar Elastomechanik, Darmstadt, 23.06.2008.
7. M. Hossain, G. Possart, P. Steinmann. Towards modeling the curing processes of thermosets. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
8. G. Possart, M. Hossain, P. Steinmann. On modelling and simulation of the curing of thermosets and elastomers. Euromech Colloquium 502, Dresden, Germany, 08.-10.09.2008.
9. G. Possart, P. Steinmann, M. Presser, P. Geiss, S. Passlack, A. Brodyanski, M. Kopnarski. On the characterisation and modelling of epoxy-based polymer-metal interphases. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
10. A. Rajagopal, P. Steinmann. Towards the Analysis of Materials with Strain Gradient Effects Using α-Natural Element Method. Second GAMM Seminar on Multiscale Material Modelling, University of Stuttgart,Germany, 11.-12.07.2008.
11. M. Scherer, R. Denzer, P. Steinmann. On constraint based regularization techniques in configurational r-adaptivity and shape optimization. IUTAM Symposium on Progress in the Theory and Numerics of Configurational Mechanics, Erlangen, Germany, 20.-24.10.2008.
12. M. Scherer, P. Steinmann. On energy-based r-adaptivity in hyperelastostatics. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
13. H. Schmidt, A. P. S. Selvadurai, K. Willner. Separation at a Precompressed Frictionless Interface due to Asymmetric Localized Loads. 8th World Congress on Computational Mechanics, Venice, Italy, 02.07.2008.
14. P. Steinmann. Aktuelle Herausforderungen und Chancen in der Technischen Mechanik. Antrittsvorlesung, Erlangen, Germany, 11.01.08.
15. P. Steinmann. Material Interfaces with Microstructure: A Multiscale Modelling Approach. EAM Minisymposium on Multiscale Modelling and Simulation, Erlangen, Germany, 21.4.2008
16. P. Steinmann. On the Configurational Mechanics of Kinematically Constrained Bodies. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.

17. P. Steinmann. Perspectives in the Theory and Numerics of Configurational Mechanics. Seminar Series Dep. Mech. Aero. Engrg. at Peking University, Beijing, China, 09.10.2008.
18. P. Steinmann, E. Kuhl, H. A. Meier. On the Multiscale Computation of Confined Granular Media. ECCOMAS Multidisciplinary Jubilee Symposium, Wien, Österreich, 18.-20.2.2008.
19. P. Steinmann, H. A. Meier, E. Kuhl. Computational Multiscale Granular Media. IWCMM18, Beijing, China, 07.-09.10.2008.
20. P. Steinmann, H. A. Meier, E. Kuhl. Multiscale Computational Granular Media. IUTAM Symposium on Variational Concepts with Applications to the Mechanics of Materials, Bochum, Germany, 22.-26.09.2008.
21. P. Steinmann, J. Utzinger, A. Menzel. Modelling and Computation of Grain Boundary Fatigue in Piezoelectric Mesostructures. 4th Workshop Direct and Inverse Problems in Piezoelectricity, Pommersfelden, Germany, 29.09.-01.10.2008.
22. D.K. Vu, P. Steinmann. An approach to the material motion problem in nonlinear electro-elastostatics and application. Conference on Computational Solid Mechanics CSM2008, Ho Chi Minh City, Vietnam, 27.-30.11.2008.
23. D.K. Vu, P. Steinmann. Material force method: theoretical and numerical aspects in nonlinear electro-elastostatics. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
24. W. Weber, P. Steinmann, G. Kuhn. Precise simulation of 3D fatigue crack growth. 8th World Congress on Computational Mechanics, Venice, Italy, 30.06.2008-04.07.2008.
25. W. Weber, P. Steinmann, G. Kuhn. Assessment on the structural integrity based on 3D crack growth simulations. 22th International Congress of Theoretical and Applied Mechanics (ICTAM 2008), Adelaide, Australien, 24.08.2008-29.08.2008.
26. W. Weber, P. Steinmann, G. Kuhn. Simulation der 3D Ermüdungsrissausbreitung. Kolloquium über Werkstoffmodellierung, MPA/IMWF Stuttgart, 13.11.2008.
27. K. Willner. Constitutive Contact Laws in Structural Dynamics. Advances in Contact Mechanics, Delft, The Netherlands, 22.-24.09.2008.
28. K. Willner, D. Goerke. Investigations of the influence of geometrical irregularities and roughness on the normal contact stiffness of joints. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
29. K. Willner, J. Geisler. Nonlinear Dynamics of Structures with Joints. 79th GAMM Annual Conference, Bremen, Germany, 31.03.-04.04.2008.
30. W. Winter. Influence of bone geometry to bending and shear strength of osteoporotic bone. 16th Congress European Society of Biomechanics, Lucerne, Switzerland, 06.-09.07.2008.
31. W. Winter. Simulation inelastischer Verzerrungen im trabekulären Knochen. 10. Internationale Biomechanik- und Biomaterial-Tage, München, Deutschland, 11.-12.07.2008.

6 Contributions to Journals in 2008

1. J.C. Aurich, D. Biermann, H. Blum, C. Brecher, C. Carstensen, B. Denkena, F. Klocke, M. Kröger, P. Steinmann, K. Weinert. Modelling and Simulation of Process - Machine Interaction in Grinding. Accepted for publication in Production Engineering - Research and Development, DOI 10.1007/s11740-008-0137-x, 2008.
2. S. Bargmann, R. Denzer, P. Steinmann. Material Forces in Non-Classical Thermo-Hyperelasticity. J. Thermal Stresses, accepted.
3. S. Bargmann, R. Greve, P. Steinmann. Simulation of Cryovolcanism on Saturn's Moon Enceladus with the Green-Naghdi Theory of Thermoelasticity. Bulletin of Glaciological Research, accepted.
4. S. Bargmann, P. Steinmann. An Incremental Variational Formulation of Dissipative and Non-Dissipative Coupled Thermoelasticity for Solids. Heat and Mass Transfer, accepted.
5. S. Bargmann, P. Steinmann. Modelling and Simulation of First and Second Sound in Solids. Int. J. Solids Structures, accepted.
6. S. Bargmann, P. Steinmann, P. M. Jordan. On the Propagation of Second-Sound in Linear and Nonlinear Media: Results from Green–Naghdi Theory. Physics Letters A, Vol. 372, pp. 4418-4424, 2008.
7. A. Bouabid, P. Steinmann, P. Herzenstiel, J. C. Aurich. An ALE-based Finite Element Formulation for a Spinning Wheel with Transient Loading. Submitted to Journal for Sound and Vibration, 2008.
8. A. Constantiniu, P. Steinmann, T. Bobach, G. Farin, G. Umlauf. The Adaptive Delaunay Tessellation: A Neighborhood Covering Meshing Technique. Comp. Mech., Vol. 42, pp. 655-670, 2008.
9. D. Goerke, K. Willner. Experimental setup for normal contact stiffness measurement of technical surfaces with geometrical irregularities. Experimental Techniques, accepted.
10. D. Goerke, K. Willner. Normal Contact of Fractal Surfaces - Experimental and Numerical Investigations. Wear, Vol. 264 (7-8), pp. 589-598, 2008.
11. B. Helldörfer, G. Kuhn. A BE based finite element for crack propagation processes. submitted.
12. C. B. Hirschberger, S. Ricker, N. Sukumar, P. Steinmann. Multiscale Modelling of Heterogeneous Material Layers. Eng. Fracture Mech., accepted.
13. C. B. Hirschberger, P. Steinmann. Classification of Concepts in Thermodynamically Consistent Generalised Plasticity. J. Eng. Mech., accepted.
14. C. B. Hirschberger, N. Sukumar, P. Steinmann. Computational Homogenisation of Material Layers with Micromorphic Mesostructure. Phil. Mag., accepted.
15. M. Hossain, G. Possart, P. Steinmann. A small-strain model to simulate the curing of thermosets. Accepted for publication in Computational Mechanics, 2008.
16. M. Hossain, G. Possart, P. Steinmann. Finite strain models to simulate the curing process of polymers-I: Elasticity. In preparation.
17. M. Hossain, G. Possart, P. Steinmann. Hyperelastic finite strain models for rubber-like materials: Consistent tangent operators and comparative study. In preparation.

18. P. Jäger, P. Steinmann, E. Kuhl. A Novel Numerical Framework for the Three-Dimensional Modeling of Brittle Fracture. submitted to ASME J. Applied Mechanics.
19. P. Jäger, P. Steinmann, E. Kuhl. Modelling Three-Dimensional Crack Propagation. A Comparison of Crack Path Tracking Strategies. Int. J. Num. Meth. Eng., accepted.
20. P. Jäger, P. Steinmann, E. Kuhl. On Local Tracking Algorithms for the Simulation of Three-Dimensional Discontinuities. Comp. Mech., Vol. 42, pp. 395-406, 2008.
21. A. Javili, P. Steinmann. A finite element framework for continua with boundary energies. Part I: The two-dimensional case. Submitted for publication, 2008.
22. A. Javili, P. Steinmann. A finite element framework for continua with boundary energies. Part II: The three-dimensional case. In preparation.
23. M. Karl, M.G. Wichmann,W. Winter, F. Graef, T.D. Taylor, S.M. Heckmann. Influence of Fixation Mode and Superstructure Span upon Strain Development of Implant Fixed Partial Dentures. Journal of Prosthodontics, Vol. 17, pp. 3-8, 2008.
24. M. Karl, S.M. Heckmann, W. Winter, S. Holst. Different Biomechanical Measurement Techniques Applied in Dentistry. Implantologia, Parodontologia, Osteologia (in Ukrainian, Abstract in English), Vol. 2, pp. 88-94, 2008.
25. S. Leyendecker, P. Betsch, P. Steinmann. The Discrete Null Space Method for the Energy Consistent Integration of Constrained Mechanical Systems. Part III: Flexible Multibody Dynamics. Multibody System Dynamics, Vol. 19, pp. 45-72, 2008.
26. H. A. Meier, E. Kuhl, P. Steinmann. A Note on the Generation of Periodic Granular Microstructures based on Grain Size Distributions. Int. J. Num. Anal. Meth. Geomech., Vol. 32, pp. 509-522, 2008.
27. H. A. Meier, M. Schlemmer, C. Wagner, A. Kerren, H. Hagen, E. Kuhl, P. Steinmann. Visualization of Particle Interactions in Granular Media. IEEE Trans. Vis. Comp. Graph., Vol. 14, pp. 1-16, 2008.
28. H. A. Meier, P. Steinmann, E. Kuhl. Towards Multiscale Computation of Confined Granular Media. Contact Forces, Stresses and Tangent Operators. Tech. Mech., Vol. 28, pp. 32-42, 2008.
29. R. Mohr, A. Menzel, P. Steinmann. Consistent Galerkin-Based Time-Stepping Schemes for Geometrically Nonlinear Elasto-Plastodynamics. Comp. Meth. Appl. Mech. Engr., accepted.
30. R. Mohr, A. Menzel, P. Steinmann. Galerkin-Based Mechanical Integrators for Finite Elastodynamics Formulated in Principal Stretches - Pitfalls and Remedies. Comp. Meth. Appl. Mech. Engr., 2008, DOI 10.1016/j.cma.2008.05.011
31. A. Papastavrou, P. Steinmann. On the Deformational and Configurational Setting of Two-Phase Solid/Fluid Mixtures: Dissipative versus Non-Dissipative Formulations. submitted to J. Mech. Phys. Solids.
32. S. Passlack, A. Brodyanski, W. Bock, M. Kopnarski, M. Presser, P.L. Geiss, G. Possart, P. Steinmann. Chemical and structural characterisation of DGEBA-based expocies by Time of Flight Secondary Ion Mass Spectroscopy (ToF-SIMS) as a preliminary to polymer interphase characterisation. Submitted to Analytical and Bioanalytical Chemistry, 2008.
33. U. Pfaff, G. Bednarek, B. Kleuter, P. Steinmann. Parameter Identification for Transmission Housings. FE Analysis of a Diecast Aluminium Alloy. ATZ, Vol. 110, 03/2008.

34. G. Possart, M. Presser, S. Passlack, P. Geiss, M. Kopnarski, A. Brodyanski, P. Steinmann. Micro-macro characterisation of DGEBA-based epoxies as a preliminary to polymer interphase modelling. Accepted for publication in Int. J. Adh. & Adh. 2008, http://dx.doi.org/10.1016/j.ijadhadh.2008.10.001

35. A. Rajagopal, M. Scherer, P. Steinmann, N. Sukumar. Smooth conformal α-NEM for gradient elasticity. Submitted.

36. K. Runesson, F. Larsson, P. Steinmann. On Energetic Changes due to Configurational Motion of Standard Continua. Int. J. Solids Structures, accepted.

37. M. Scherer, R. Denzer, P. Steinmann. A fictitious energy approach for isoparametric shape optimization in elasticity. In preparation.

38. M. Staat, D.K. Vu. Limit analysis of flaws in pressurized pipes and cylindrical vessels. Part II: Circumferential defects. Eng. Fract. Mech., submitted.

39. P. Steinmann. On Boundary Potential Energies in Deformational and Configurational Mechanics. J. Mech. Phys. Solids, Vol. 56, pp. 772-800, 2008.

40. P. Steinmann, M. Scherer, R. Denzer. Secret and Joy of Configurational Mechanics: From Foundations in Continuum Mechanics to Applications in Computational Mechanics. ZAMM, accepted.

41. T.N. Tran, M. Staat, R. Kreissig, D.K. Vu. Upper bound limit and shakedown analysis of thin shells using the exact Ilyushin yield surface. Computers and Structures, Vol. 86 (17-18), pp. 1683-1695, 2008.

42. J. Utzinger, M. Floeck, M. Bos, A. Menzel, E. Kuhl, K. Friedrich, A. Schlarb, R. Renz, P. Steinmann. Computational Modelling of Thermal Impact Welded PEEK/Steel Single Lab Tensile Specimen. Comp. Mat. Sci., Vol. 41, pp. 287-296, 2008.

43. J. Utzinger, A. Menzel, P. Steinmann, A. Benallal. Aspects of Bifurcation in an Isotropic Elastic Continuum with Orthotropic Inelastic Interface. Eur. J. Mech./A, Vol. 27, pp. 532-547, 2008.

44. J. Utzinger, P. Steinmann, A. Menzel. Computational Modelling of Microcracking Effects in Polycrystalline Piezoelectric Ceramics. GAMM-Mitt., accepted.

45. J. Utzinger, P. Steinmann, A. Menzel. On the Simulation of Cohesive Fatigue Effects in Grain Boundaries of a Piezoelectric Mesostructure. Int. J. Solids Structures, Vol. 45, pp. 4687-4708, 2008.

46. D.K. Vu, P. Steinmann. Material and spatial motion problems in nonlinear electro- and magneto-elastostatics. Mathematics and Mechanics of Solids, accepted.

47. W. Weber, P. Steinmann, G. Kuhn. Precise 3D crack growth simulations. Int. J. Frac., Vol. 149(2), pp. 175-192, DOI 10.1007/s10704-008-9241-3, 2008.

48. K. Willner. Fully Coupled Frictional Contact Using Elastic Halfspace Theory. Journal of Tribology, Vol. 130 (3), art. no. 031405, 2008.

49. K. Willner. Influence of Surface Parameters on the Elastoplastic Contact Behavior of Fractal-regular Surfaces. Journal of Tribology, Vol. 130 (2), art. no. 024502, 2008.

50. W. Winter. Simulation inelastischer Verzerrungen im trabekulären Knochen. Biomaterialien, Vol. 9 (1/2), p. 73, 2008.

7 Contributions to Proceedings in 2008

1. A. Brodyanski, P. Geiss, M. Kopnarski, S. Passlack, G. Possart, M. Presser, P. Steinmann. Investigation of the epoxy-metal-interphase by micro-extensometry. In *Proceedings of Euradh 2008*, Oxford. http://www.iom3.org/feature/investigation-epoxy-metal-interphase-micro-extensometry.
2. A. Brodyanski, P. Geiss, M. Kopnarski, S. Passlack, G. Possart, M. Presser, P. Steinmann. Investigation of the epoxy-metal-interphase by micro-extensometry. (Award Winning) Poster Presentation at Euradh 2008, Oxford.
3. J. Geisler, K. Willner. Investigations on joint interfaces using zero thickness finite elements. In *Proceedings of 8th. World Congress on Computational Mechanics (WCCM8)*, Venice, Italy, 2008.
4. D. Goerke, K. Willner. Measured and Simulated Contact Stiffness of Dry, Metallic Joints. Extended Abstract in *Proceedings of the 8th. World Congress on Computational Mechanics*, Venice, Italy, 2008, CD-ROM.
5. D. Goerke, K. Willner. Investigations of the influence of geometrical irregularities and roughness on the normal contact stiffness of joints. Submitted to *PAMM 2008 - Proceedings of the 79th GAMM Annual Conference*, Bremen, Germany, 2008.
6. P. Herzenstiel, A. Bouabid, P. Steinmann, J.C. Aurich. Experimental Investigation and Computational Simulation of Process-Machine Interactions during High-Performance Surface Grinding. In *Proceedings of 1st International Conference on Process-Machine Interaction*, PZH Hannover, 267-278, 2008.
7. B. Helldörfer, W. Weber, G. Kuhn. Ein adaptives, randelementbasiertes Abaqus-Modul zur Simulation von 3D-Ermüdungsrissausbreitung. In *Tagungsband zur 20th Deutschsprachigen Abaqus-Benutzerkonferenz in Bad Homburg*, 2008.
8. M. Hossain, R. Denzer, P. Steinmann. On the phenomenological and micro-mechanical models in finite elasticity and viscoelasticity for rubber-like materials. In *Proceedings in Applied Mathematics and Mechanics*, PAMM 2008.
9. M. Hossain, G. Possart, P. Steinmann. Towards modeling the curing processes of thermosets. In *Proceedings in Applied Mathematics and Mechanics*, PAMM 2009.
10. M. Scherer, R. Denzer, P. Steinmann. On constraint-based regularization techniques in configurational r-adaptivity and shape optimization, in preparation. In *Proceedings of the IUTAM Symposium on Progress in the Theory and Numerics of Configurational Mechanics*, Erlangen, Germany, 20.-24.10.2008.
11. P. R. Schmitt, P. Steinmann. Geometric numerical integration of simple dynamical systems. In *Proceedings of the Second Annual Workshop of DFG's International Research Training Group 'Visualization of Large and Unstructured Data Sets - Applications in Geospatial Planning, Modeling, and Engineering'*, September 2007, accepted for publication.
12. T.N. Tran, P.T. Pham, D.K. Vu, M. Staat. Reliability analysis of inelastic shell structures under variable loads. In *Limit States of Materials and Structures: Direct Methods.* Eds.: D. Weichert, A. Ponter, Springer Berlin 2009, pp. 135-156.
13. W. Weber, P. Steinmann, G. Kuhn. Assessment on the structural integrity based on 3D crack growth simulations. In *CD-ROM Proceedings of the 22th International Congress of Theoretical and Applied Mechanics (ICTAM 2008)*, ISBN 978-0-9805142-1-6, Adelaide, Australien, 2008. http://ictam2008.adelaide.edu.au.

14. W. Weber, P. Steinmann, G. Kuhn. Precise simulation of 3D fatigue crack growth. In *Proceedings of the 8th World Congress on Computational Mechanics (WCCM8)*, Venedig, Italien, 2008. http://www.iacm-eccomascongress2008.org/frontal/default.asp.

15. W. Winter. Bone strength in pure bending: Bearing of geometric and material properties. In *Proceedings of the 2nd Conference on Applied Biomechanics*, Regensburg, Germany, 2008. IOS Press, Amsterdam, Netherlands 2008, pp. 230-237.

16. W. Winter. Influence of bone geometry to bending and shear strength of osteoporotic bone. In *Proceedings of the 16th Congress European Society of Biomechanics*, Lucerne, Switzerland, 2008.