Annual Report
2010

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1 Preface

Now is a good time to reflect on the professional achievements and social activities at the Chair of Applied Mechanics. The summer barbecues and joint support of the football team during the world cup may have provided some incentive to fulfil the demanding teaching commitments and produce the internationally recognised outputs, but it was the hard work and never-ending enthusiasm of all of the member of the Chair that made this possible. This report aims to shed light on the state of Applied Mechanics at the University of Erlangen-Nuremberg and should convince the reader of the high level of dedication and ambition exhibited by all members of the Chair.

Paul Steinmann, Kai Willner, Julia Mergheim

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Student assistants are mainly active as tutors for young students in basic and advanced lectures at the BA- and MA-level. Their indispensable contribution to high quality teaching at the Chair of Applied Mechanics is invaluable, thus financial support from the students enrollment fees as requested at Bavarian universities is gratefully acknowledged.

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Werner Winter, Matthias Karl, Paul Steinmann

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, dealt with the creation of a software tool, which is capable of analyzing experimental crack growth data. This software tool processes digital black and white pictures of a crack specimen taken during the crack growth. The output of the software is the current position of the crack tip, respectively the rate of the crack growth, with respect to the stress cycles and the crack start point.

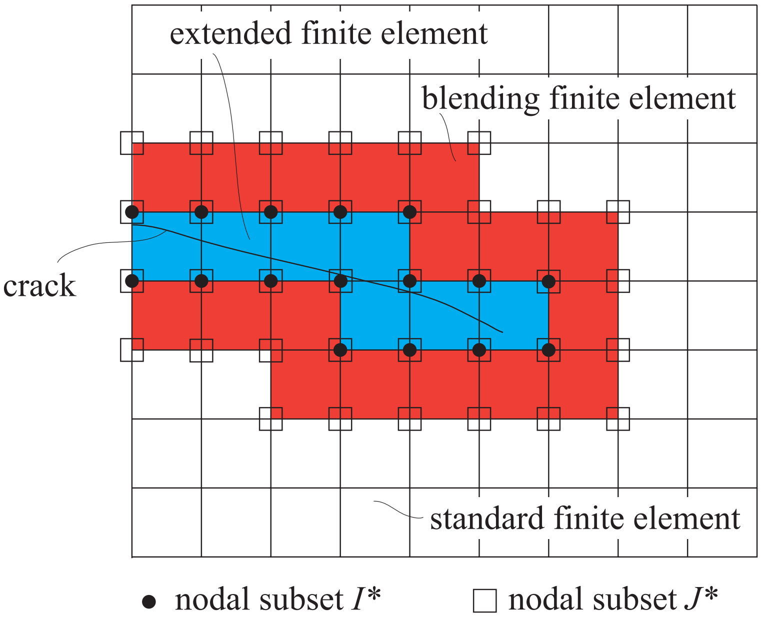

Figure 1: sketch of a partially cracked specimen using extended finite elements

The second part of this work, the numerical simulation of the crack growth, is carried out by extending the chair's own finite element program PHOENIXwith an additional element type, an extended finite element. This element is characterized by the extension of the standard FE formulation with a problem specific term (enrichment). However, the standard XFEM approach (usage of nodal subset I^*) leads to a violation of the partition of unity if only a part of the nodes of an element are enriched. This problem can be solved by introducing a ramp function $R(\mathbf{x})$ and usage of a nodal subset J^* of the global domain Ω:

$$u^h(\mathbf{x}) \;=\; \sum_{i\in I} N_i(\mathbf{x})u_i + \sum_{i\in J^*} \tilde{N}_i(\mathbf{x})\psi(\mathbf{x})R(\mathbf{x})\tilde{u}_i \quad \text{with} \quad R(\mathbf{x}) = \sum_{i\in I^*} \tilde{N}_i(\mathbf{x})$$

where $\tilde{N}$ is a shape function (which may be identical to the shape function N of the standard FE part), ψ is a problem specific function and $\tilde{u}$ are the additional degrees of freedom.

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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Modelling and Simulation of the Interaction of Process and Machine for High-Performance Surface Grinding

Aous Bouabid and Paul Steinmann

The process-machine interaction in high-speed grinding has gained in the last decade a high importance in the process and machine simulation. Although the process principles are quite elementary, there are till today many questions related to the physical effects taking place in the running process, that can not be answered in a straightforward manner. “Why does a grinding machine start for a certain spindle velocity and workpiece feed up to chatter as large as it can?” is a typical question, that can not be answered as long as the process and the machine are studied apart from each other.

On the other side, grinding offers a wide variety of options to realize functionally and visually high-end surfaces for a large range of materials. The mixture of fascination and mysteriousness, both confirmed by the same process, fructified in a number of interesting works published over the last decade. All of them aim at getting a near insight into the process physics [1,2,3].

Computer simulations enable to get a first insight into operating regions, i.e. mainly the contact surface between the grinding wheel and the workpiece being operated, that are experimentally not accessible. Did someone have already seen, what happens, if a diamond grinding grit penetrates at high velocity into a metallic surface?

Figure 1 illustrates one aspect concerning the dynamical behavior of the grinding wheel when considering and when ignoring the process-machine interaction, respectively. The response spectrum shown demonstrates, how the response of the grinding wheel due to harmonic excitations can largely differ for coupled and uncoupled simulations.

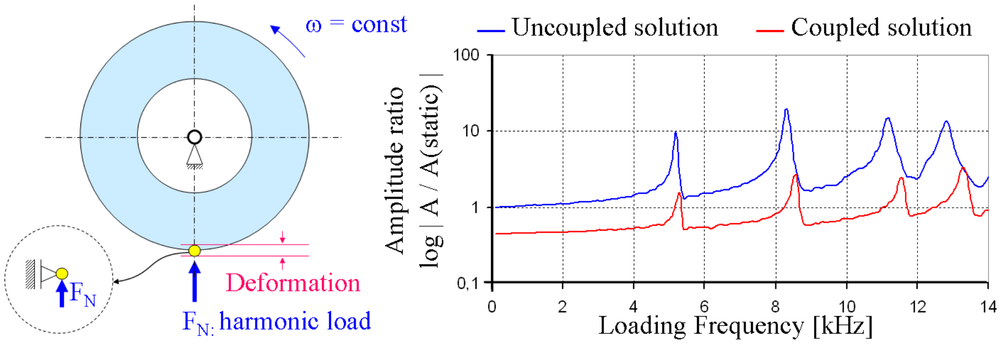

Figure 1: Influence of the process-machine interaction on the frequency spectrum of a grinding wheel.

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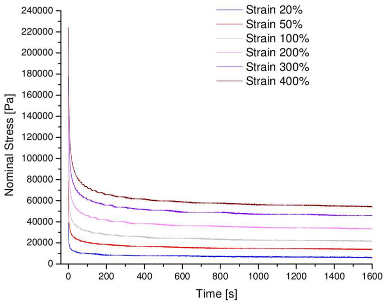
Electronic electro-active polymers under electric loading: Experiment, modelling and simulation

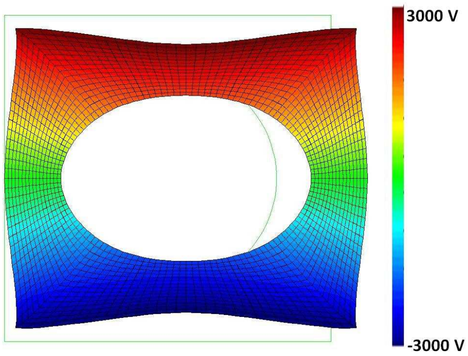
Hernán De Santis, Duc Khoi Vu, Paul Steinmann

In the last decade, electronic electroactive polymers (EEAP) have become an interesting subject of study due to its practical application in developing dielectric elastomer actuators that can work as artificial muscles. When a thin layer of an EEAP is placed between two compliant electrodes, the electrical behavior of the system is pretty simmilar to that of a capacitor and the atractive Maxwell forces between the electrodes tend to put them together, therefore squeezing the polymer and outputing motion as a result of the electrical input.

The response of the EEAP during this process is influenced by both its mechanical and its electrical properties, and it is therefore very important to study and characterize the behavior of these novel materials in order to obtain accurate parameters that can be used to carry reliable numerical simulations. For this purpose, a testing bench has been set up in the facilites of our chair and several mechanical and electro-mechanical experiments have been conducted on a standard EEAP. The data obtained from these tests is being used to validate different models that describe the mechanical behavior of the material (hyperelastic, viscoelastic) and also to calculate its electrical properties. Some progress on the simulation side has also been made but the accuracy of the results is so far restricted to uniaxial loading conditions. Widening the scope of the modeling and obtaining accurate results under general- and complex electromechanical loading conditions constitutes the main goal of this project for the future.



Relaxation curves, used to characterize the viscoelastic behavior of VHB 4910



Simulation of an actuator in 2D, showing undeformed and deformed configurations. Colors denote electric potential.

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Multiscale modelling of fiber structured materials

Sebastian Fillep and Paul Steinmann

This research focuses on the mechanical modeling and simulation of the heterogeneous composition of fiber structured material, especially taking into account the contact between the fibers. Various phenomena occurring on the macrostructure originate from physical and mechanical behaviour on the microlevel [1]. The material behaviour is strongly influenced by the material-properties of the fiber, but also by the geometrical structure. Periodically arranged fibers like woven, knitted or plaited fabrics and randomly oriented ones like fleece can be distinguished in their assembly.

In consideration of different lengthscales the problem involves, it is necessary to introduce a multi-scale approach based on the concept of a representative volume element (RVE). The macro-micro scale transition requires a method to impose the deformation gradient on the RVE by boundary conditions. The reversing scale transition, based on the HILL-MANDEL condition, requires the equality of the macroscopic average of the variation of work on the RVE and the local variation of the work on the macroscale [2]. For the micro-macro transition the averaged stresses have to be extracted by a homogenization scheme (see figure 1). From these results an effective material law can be derived.

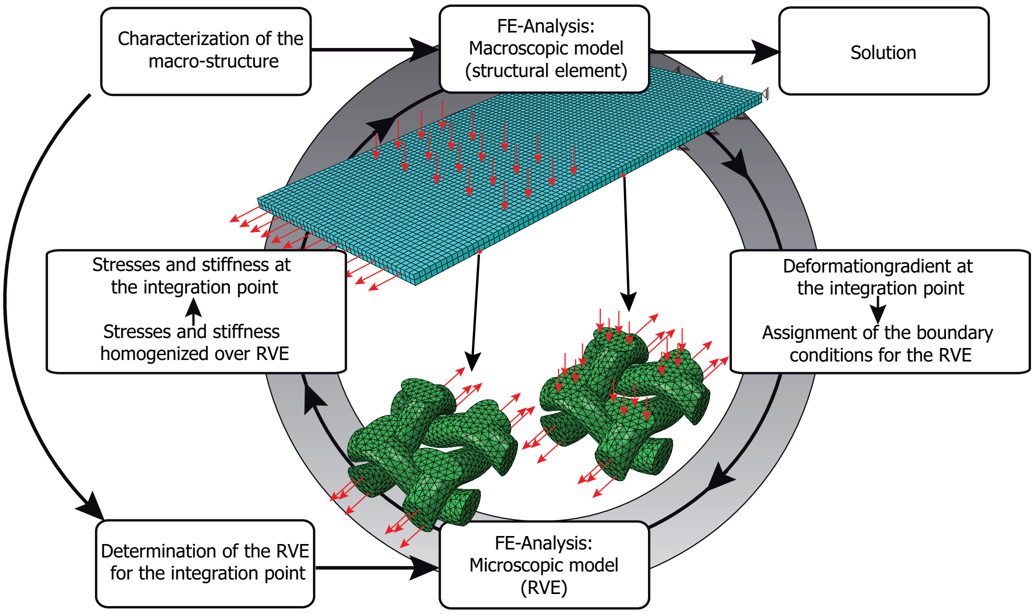

Figure 1: Multiscale methods: After the definition of a RVE microscopic boundary conditions are formulated from the macroscopic input variables. Then macroscopic output variables are calculated and a relation between macroscopic input and output variables is obtained.

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Cahn-Hilliard generalized diffusion modeling using the natural element method

Paul Fischer, Amirtham Rajagopal, Paul Steinmann

This work deals with the application of the natural element method to the Cahn-Hilliard equation. The Cahn-Hilliard equations is a nonlinear fourth order partial differential equation, describing phase separation of binary mixtures.
Numerical solutions of the Cahn-Hilliard equation requires either a two field formulation with C^0 continuous shape functions or a higher order C^1 continuous approximations to solve the fourth order equation directly. Here, C^1 NEM, based on Farin's interpolant is used for the direct treatment of the second order derivatives, occurring in the weak form of the partial differential equations. Additionally, the classical C^0 continuous Sibson interpolant is applied to a reformulation of the equation in terms of two coupled second order equations. In [1], it is demonstrated that both methods provide similar results, however the C^1 continuous version needs fewer degrees of freedom to capture the contour of the phase boundaries. This is indicated by the evolution of the surface energy Ψ^{sur}.

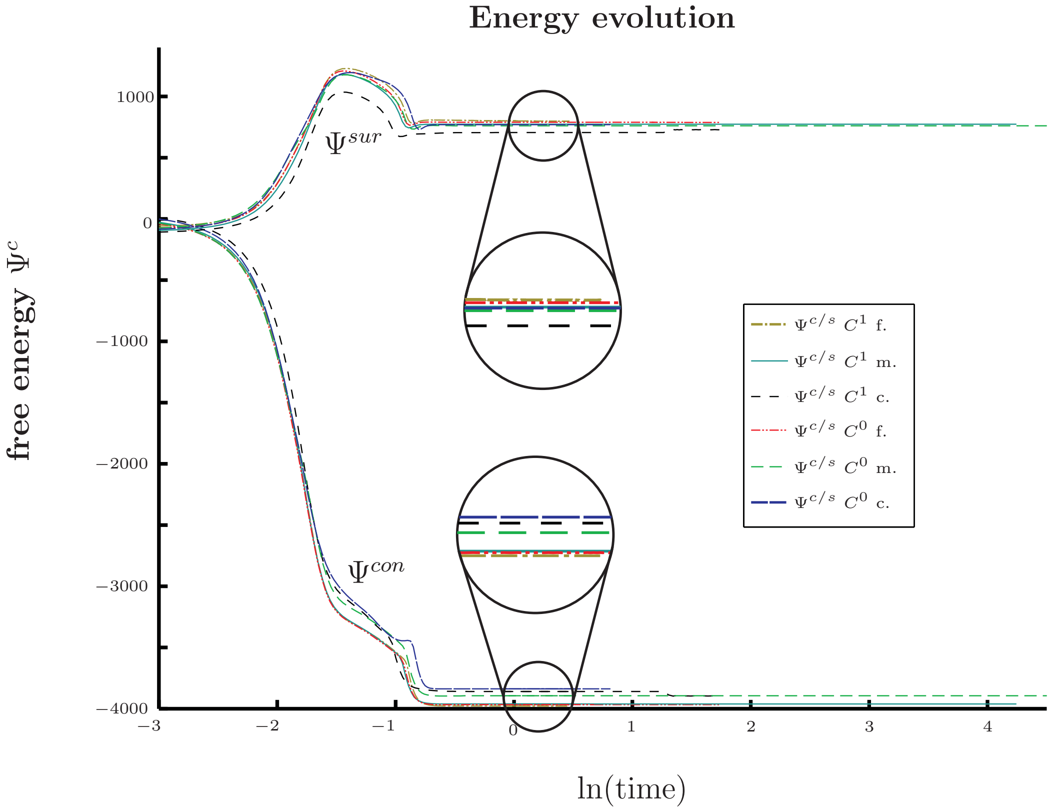

Figure 1: Energy evolution whithin the phase separation processes. Ψ^{con} denotes the configurational energy and Ψ^{sur} the surface energy. The starting point of the evolution is a quite homogeneous mixture of the two phases.

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Isogeometric Shape Optimization based on a Fictitious Energy Regularization

Jan Friederich, Paul Steinmann

In recent years, *isogeometric analysis* [1] has received considerable attention in the finite element community. In this approach, B-Splines or NURBS are used as shape functions in an isoparametric, finite-element-type discretization. Among other features like higher-order continuity and various refinement strategies, this method is able to provide exact representations of a broad class of computational domains including conic sections. Because of these properties, this discretization method seems to be especially convenient for computational shape optimization, where a smooth and CAD-like parametrization of the optimal geometry is desired. Choosing boundary control point coordinates of an isogeometric discretization as design variables, an additional design model and, hence, a costly linkage between two separate models for design and analysis can be avoided.

However, for a higher number of design variables, typical drawbacks like oscillating boundaries as known from early node-based shape optimization methods appear. To overcome this problem, we propose to use the *fictitious energy approach* [2]: a fictitious deformation $\boldsymbol{\varphi} : \Omega_0 \to \Omega$, which maps the initial/reference domain to the optimized domain, is constructed and a bound on the corresponding strain energy $\mathcal{I}(\boldsymbol{\varphi})$ is introduced as an additional constraint $\mathcal{I}(\boldsymbol{\varphi}) \leq \mathcal{I}_{max}$ in the optimization problem; alternatively, the energy can be added to the cost function as a regularization term, i.e. $\mathcal{J}_\lambda(\Omega) := \mathcal{J}(\Omega) + \lambda \mathcal{I}(\boldsymbol{\varphi})$, $\lambda > 0$. Moreover, the fictitious deformation $\boldsymbol{\varphi}$ is used for efficiently moving the dependent nodes inside of the domain in every step of the optimization process. This regularization technique implemented in isogeometric shape optimization shows good numerical results in 2d and 3d, cf. figure 1.

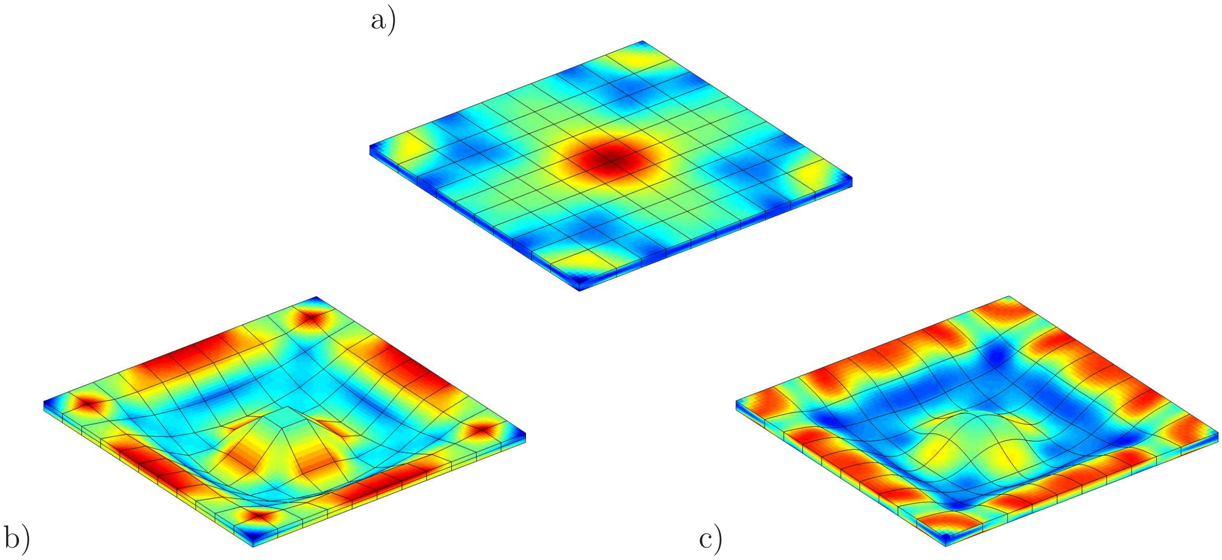

Figure 1: Plate subject to vertical loading, compliance minimization with volume constraint: Von Mises stress distribution of a) the initial shape and of the optimal shapes obtained for b) linear ($p = 1$) and c) quadratic ($p = 2$) isogeometric discretizations.

References

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Towards Form Finding For Anisotropic Materials

Sandrine Germain, Michael Scherer, Paul Steinmann

A challenge in the design of work pieces is the determination of the initial, undeformed shape such that under a given load a part will obtain the desired deformed shape. This problem is inverse to the standard (direct) elastostatic analysis in which the undeformed shape is known and the deformed unknown. In this contribution, we further extend the method originally proposed in [2] to anisotropic hyperelasticity that is based on logarithmic (Hencky) strains. The governing equation for the resulting finite element analysis is the weak form of the balance of momentum formulated in terms of the deformed configuration using the Cauchy stress tensor. The anisotropic free energy density is expressed as a quadratic function of the logarithmic strain and the fourth-order elasticity tensor, on which we applied a spectral decomposition to enable the use of different symmetry classes of anisotropic materials. The eigenvalues and eigentensors (Kelvin modes) of the elasticity tensor have been first discussed by [3] for many elastic symmetries.

As an example, we consider a Cook's membrane in 3D. The left side surface of the shape is fixed in the three directions. A load **F** is applied. We consider an anisotropic material with a cubic symmetry class. Figure 2 shows the computed undeformed shape.

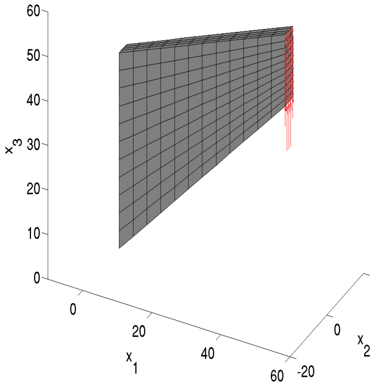

Figure 1: Deformed Cook's membrane in the final configuration.

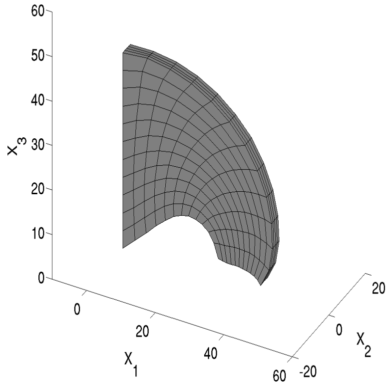

Figure 2: Undeformed Cook's membrane in the initial configuration.

This work was supported by the German Research Foundation (DFG) under the Transregional Collaborative Research Center SFB/TR73 project.

References

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Constitutive friction law for the description and optimisation of Tailored Surfaces

Franz Hauer, Kai Willner

Tribological aspects play a decisive role in metal forming processes and often have a significant influence on the tool lifetime and the quality of products. Friction between tools and workpieces is primarily caused by adhesive forces. The adhesive forces depend on the size of the real contact area, which is usually smaller than the apparent contact area. An upper limit for the friction forces is given by the real contact area times the shear strength of the softer contact partner.

The aim of this project is to predict the tribological behavior of Tailored Surfaces by means of an elastic-plastic halfspace model. The halfspace model is based on the analytical solution for surface deformations by Boussinesq and Cerruti. Elastic calculations of the real contact area and pressure distribution underestimate the size of the real contact area and give local pressures at surface peaks exceeding the hardness of the material by far. The extension to an elastic-plastic model is made to overcome these shortcomings.

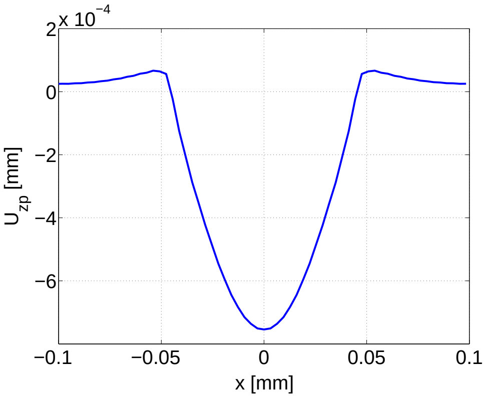

Figure 1: Plastic deformation

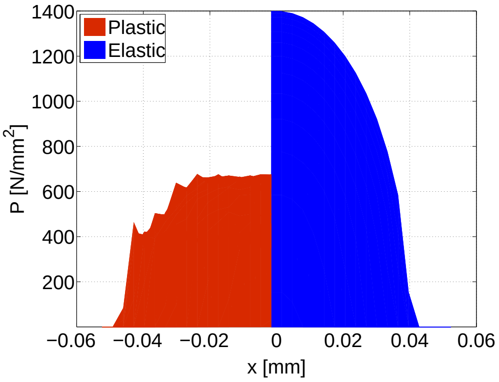

Figure 2: Pressure distribution

Figure 1 shows the plastic deformation underneath a rigid ball pressed onto a smooth surface. It can be seen that material is removed from the center of contact and accumulates at the border of the contact zone. Figure 2 shows the pressure distribution in the same load case. The maximum pressure is much lower in the plastic case, while the radius of the contact zone is increased.

The project is funded by the DFG (Deutsche Forschungsgemeinschaft) within Transregio 73.

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On Finite Strain Models for Nano-filled Glassy Polymers

Mokarram Hossain, Paul Steinmann

Polymer nanocomposites are a novel class of composite materials which demonstrate a significant improvement in strength, stiffness and thermal properties compared to homopolymers (bulk polymers). These superior properties result from the fact that nanocomposites have much larger surface area per unit volume, since one of the constituents has dimensions that range between 1 nm to 100 nm. Nano-filled, especially silica-filled amorphous glassy polymers have extensively been used in various practical application areas that cover automotive and construction industry, electronics, optical devices and medical technology. Bulk amorphous glassy polymers simultaneously exhibit rate-dependent finite elastic-plastic material behaviour. The elastic-plastic response originates from the inherent disordered micro-structure of the material that is formed by linear polymer chains. Compared to elastomers (less cross-linked polymers) or thermosets (highly cross-linked polymers), glassy polymers are generally not cross-linked by chemical bonds but their network structure is mainly formed by physical junctions, the so-called chain entanglements. This built-in micro-structure brings along the rate and temperature effects prevailing in the material behaviour.

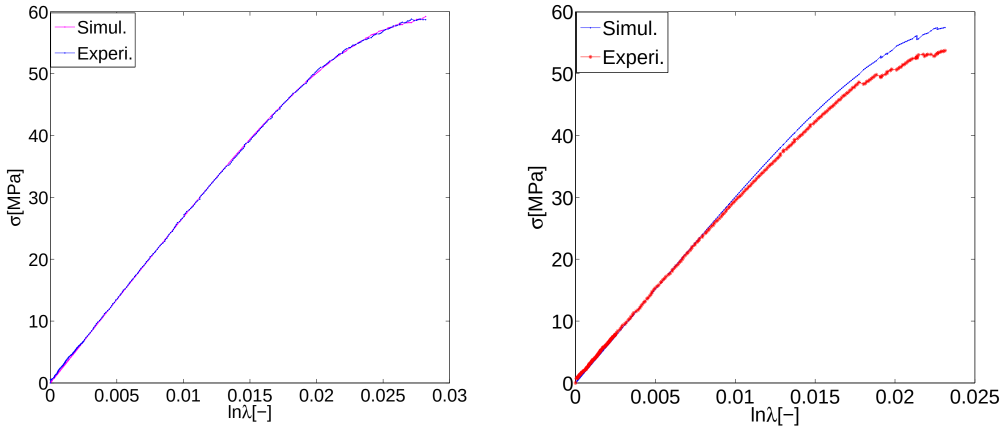

Figure 1: Comparison between simulation and experiment of silica-filled Polystyrene (PS) at room (25°C) temperature and 1%/min strain rate with two filler contents, i.e. 5.0% (left) and 0.5%, respectively [experimental data: BOSCH]

In this contribution, the constitutive model of amorphous glassy polymers proposed by Miehe et al.[1] will be extended towards modelling the nano-particle (mainly silica) influence in the amorphous glassy polymers which can be conceptualized either by changing the linear elastic energy function, or the visco-plastic evolution (flow) rule or the entropic elastic energy function or changing all two/three parts in a systematic manner or simply adapting the material parameters. The proposed modified models will be validated with experimental data, cf. Fig. 1.

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A finite element framework for continua with boundary energies

Ali Javili and Paul Steinmann

Although boundary effects can play a dominant role in material behavior, the common modelling in continuum mechanics takes exclusively the bulk into account, nevertheless, neglecting possible contributions from the boundary. Boundaries of bodies, in general, exhibit properties different from those associated with the bulk. Due to large surface to volume ratio at nanoscale, the boundary role becomes particularly important in nanomaterials behaviors, see e.g [1]. These effects could phenomenologically be modelled in terms of boundaries equipped with their own potential energies which dates back to Gibbs. Such phenomena can also be modelled in terms of surface stress of tensorial nature, see e.g. [2]. Motivated by this idea, a suitable finite element framework based on rank defcient deformation gradients is established. The elastic effects of solid surfaces, in general, have been formulated, e.g. in [3] and implemented in [4,5], for thermomechanical coupling see [6].

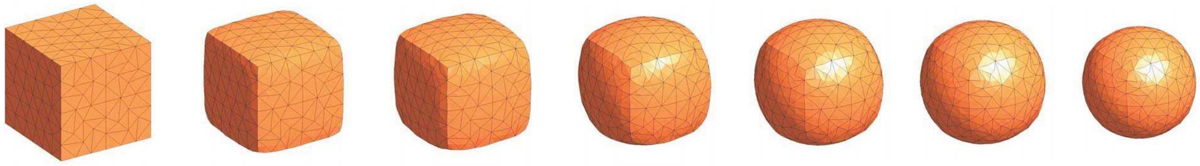

Figure 1: Transformation of a cube to sphere due to surface tension effect

For instance, we assume a constant surface tension over the surface of a body which is customary in case of fluids. In order to minimizae the energy, the cube transforms to a sphere and shrinks as illustrated in the Figure 1.

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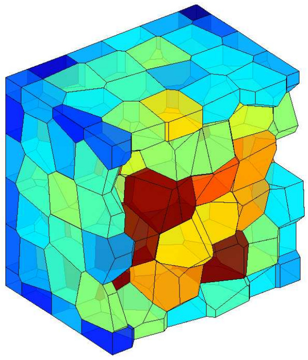
Polyhedral finite elements for nonlinear elastic continua

Markus Kraus, Paul Steinmann

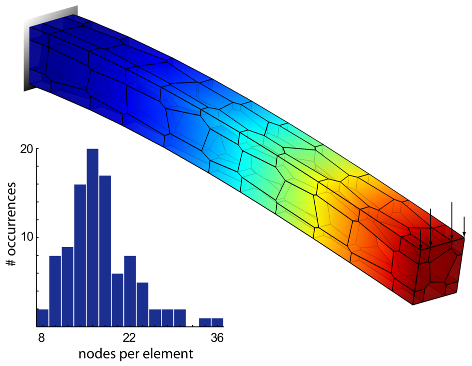
The foundation of polyhedral finite elements proposed in 2d by Sukumar [1] for granular materials are given by the well-known balance of linear momentum

$$\int_{\Omega} \delta\mathbf{E} : \mathbf{S}\, dV - \int_{\Omega} \rho\,(\mathbf{b} - \mathbf{v})\,\boldsymbol{\eta}\, dV - \int_{\Gamma_\sigma} \bar{\mathbf{t}}\bar{\boldsymbol{\eta}}\, dA \overset{!}{=} 0,$$

here in terms of the second Piola-Kirchhoff stress and the Green-Lagrange strain tensor. The difference for our arbitrary (convex) polyhedral domains Ω is the non-trivial interpolation and integration compared to standard elements. In addition to known polyhedral interpolants that cover the interpolation on simple polyhedra, a general interpolant extending Malsch's 2d approach [2] has been developed that is also capable for complex geometries and consists of evaluations of both invariant and variable geometric measures inside the polyhedra. Unfortunately, the numerical costs are very high, hence alternative interpolation strategies have been investigated. Based on a hanging node approach, simple shape functions for tetrahedra can be applied on subelements that reduce the computational cost significantly, but only the additional strain averaging around each node inside the polyhedra proposed by Gee et al. for uniform strain tetrahedra [3] also leads to good mechanical responses. Figure (a) shows a automatically generated polyhedral mesh based on voronoi cells around given scattered seed points with up to 32 element nodes, figure (b) presents a cantilever with a random mesh, element node distribution and displacement result with uniform strain polyhedral elements.



(a) polyhedral mesh: color indicating number of element nodes



(b) polyhedral element mesh of cantilever with element distribution and simulation result

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Non-Classical Diffusion: Theory and Computation

Andrew McBride, Paul Steinmann and Swantje Bargmann

This project is motivated by the anomalous diffusion of a low molecular weight solvent within a polymeric solid, coined case II diffusion (see the review [1] for further details). The presence of the solvent causes the polymer to undergo a transition from its initial glass-like state to a rubber-like state. The finite time required for the molecular rearrangement of the polymer results in the solvent diffusing at a constant rate and in a manner more akin to a wave. Concurrently, the polymeric solid undergoes significant swelling as it transforms to a rubber-like state. Case II diffusion thus serves as a good example of a complex multi-physics problem. Furthermore, the ability to model such behaviour is motivated by industrial applications such as in the production of electrical circuits.

The approach adopted here to model case II diffusion is based on that proposed in the seminal work of Govindjee & Simo [2]. The wave-like nature of the solvent propagation motivates us to consider spatially adaptive finite element schemes to accurately describe the concentration front. The issue of projecting internal variable data, used to describe the inelastic response, between meshes presents a considerable challenge. The results in Figure 1 show a simulation wherein the mesh is allowed to coarsen and refine based on a simple error indicator.

The potentially significant influence of surface effects and the observation that the surface of the polymer exhibits a different, but coupled, response to the bulk motivates our current work on solids with boundary structures coupled to diffusion and deformation.

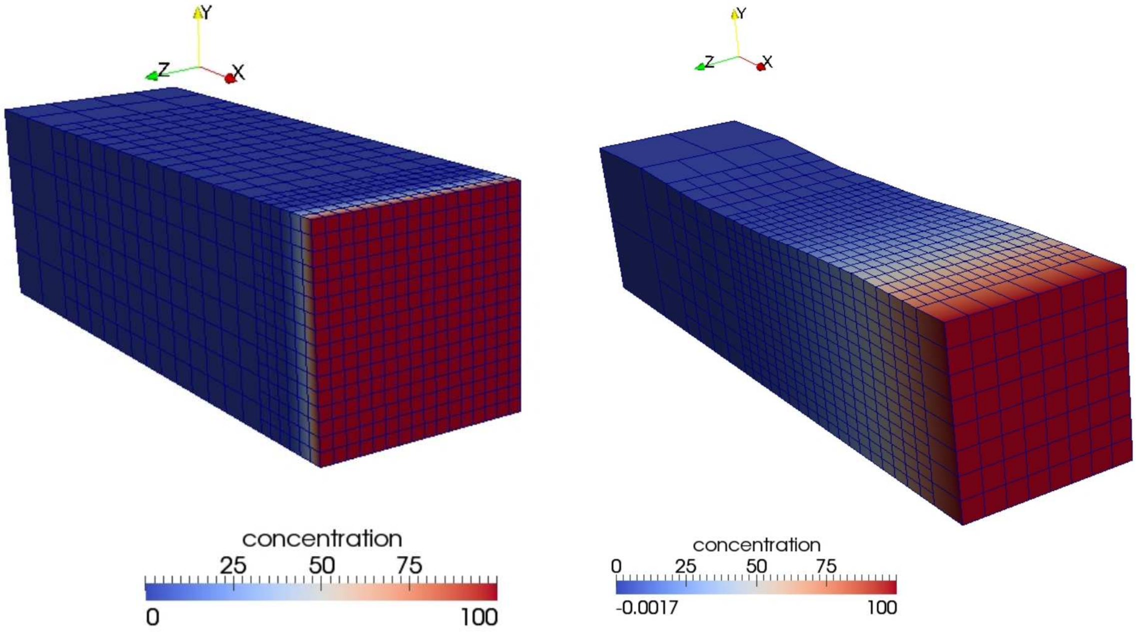

Figure 1: Coupled diffusion and deformation modelled using a spatially adaptive finite element framework

The financial support of the German Science Foundation (Deutsche Forschungsgemeinschaft, DFG), grant STE 544/39-1, is gratefully acknowledged. The first author thanks the National Research Foundation of South Africa for their support.

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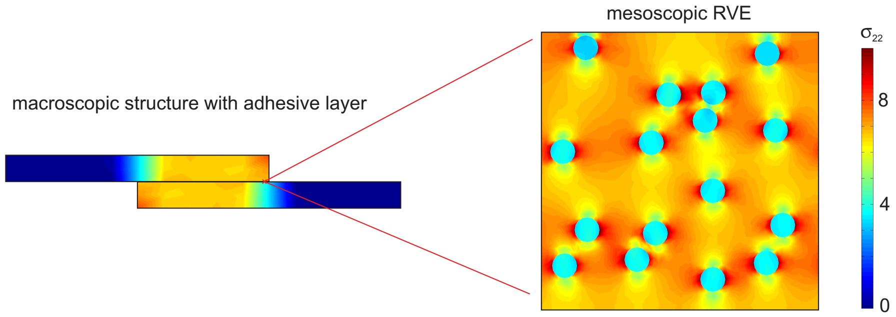
Multiscale Modelling of Particle-Reinforced Polymers During Curing

Julia Mergheim

The curing of polymers is a complex process involving the transition of a viscous fluid, i.e. the liquid monomer solution, into a viscoelastic solid. This phase transition is accompanied by increases in stiffness and viscosity as well as a volume shrinkage which may lead to residual stresses or strains. Polymeric materials are frequently enriched with different reinforcements like nanoparticles or glass fibres to enhance their properties. The resulting improvement of the stiffness or the fracture properties depends in particular on the interaction between the reinforcements and the polymeric matrix, i.e. on the strength of the bonding between particles and matrix. When the curing process proceeds the bond between matrix and particles is developed, but the concurrent shrinkage of the polymer matrix can lead to a degradation of the interfacial stiffness or even to debonding.

A multiscale framework based on computational homogenisation, i.e. on the FE^2 scheme [1] for interfaces, is developed to analyse the influence that the curing process has on the overall mechanical properties of particle-reinforced polymers. On the mesoscopic scale both the matrix material and the particles are explicitly modelled within an RVE. The curing of the polymer matrix is governed by a phenomenological hypoelastic constitutive equation which includes the temporal evolution of the stiffness and the volume shrinkage [2]. Furthermore, a cohesive law is introduced to model the interaction between matrix and particles. It governs the development of the interfacial stiffness during the curing process as well as its degradation due to the appearance of shrinkage stresses or external loading. On the macroscopic scale a structure with a layer consisting of a particle-reinforced polymer is considered. The traction-separation relation of the material layer is calculated by an interfacial homogenisation scheme from the mesoscopic response of the RVE.

In the example below the influence of the curing and shrinkage of the adhesive layer onto the mesoscopic and macroscopic stresses is demonstrated. The two substrates are bonded by an heterogeneous adhesive layer and their positions are fixed during the curing process. The adhesive layer starts curing and due to the volume shrinkage tensile stresses occur on both the meso- and the macroscale. The shrinkage stresses lead to partial debonding between particles and matrix on the mesoscale which results in a weaker interfacial stiffness during subsequent loading.



macro/meso stress distribution σ_{22} after curing

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

Sebastian Pfaller and Paul Steinmann

For numerous applications, like e.g. cracks, crazes, etc., the atomistic structure of matter has to be taken into account. Particle based methods, like for example the Molecular Dynamics (MD) method, provide a deeper insight into the processes on the level of atoms or molecules. Although it is not very difficult to set up the equations of motion for the particles, their large number for technically relevant system sizes implies problems beyond the capability of present computers: One mol, which is rather a small amount from a macroscopic point of view, contains $6.022 \cdot 10^{23}$ atoms. This problem can be attenuated by coupling particle based methods to continuum approaches, i.e. only crucial sections like crack tips or boundary layers, which require a high resolution, are modeled by particle simulations while the surrounding domains are computed by continuum based methods like the finite element method (FEM). The coupling scheme applied here is based on the "Arlequin" method as it was originated by Ben Dhia [1] and adapted to the coupling of continuum and particle approaches [2]. Within a very close cooperation with the Theoretical Physical Chemistry Group at the Darmstadt University of Technology, a concept for the coupling of FE with MD was developed, implemented and tested. As an example, a coupled system is shown in Figure 1: a FE domain consisting of 218 elements is coupled to a static particle domain represented by 7,267 so-called anchor points. These anchor points are bonded to a dynamic coarse grained simulation of polystyrene (PS), containing approximately 80,000 super atoms. First numerical experiments show the suitability of this method and deliver reasonable results.

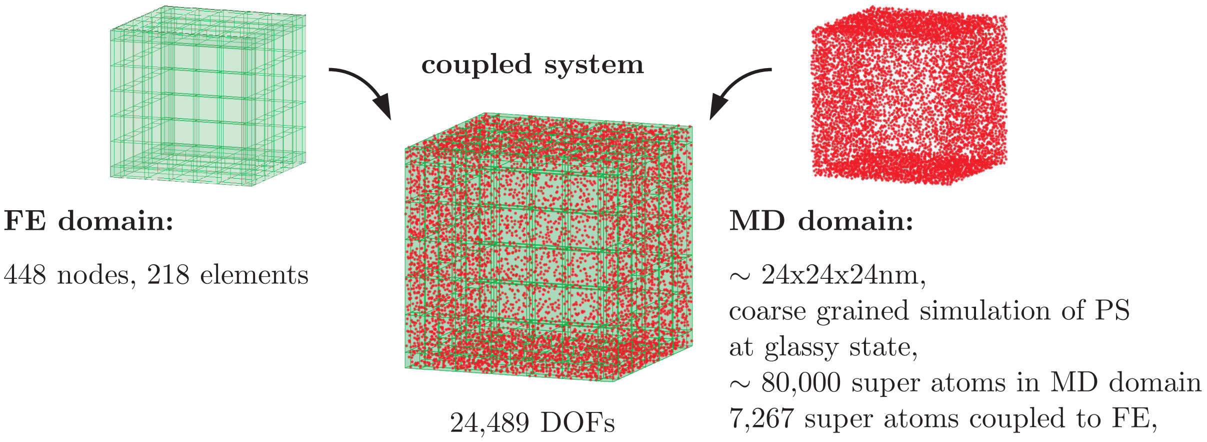

Figure 1: Coupled system consisting of a FE domain (left) and a particle domain (right); particle data is provided by Theoretical Physical Chemistry (Darmstadt University of Technology)

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Modelling and simulation of stress-dependent creep recovery compliance in PMMA-SiO$_2$ nanocomposite melts

Gunnar Possart, Mathias Etzold, Paul Steinmann

To investigate and understand the (mechanical) interplay between nanoscale filler particles and polymeric matrix materials is currently a very active field in materials research. Due to the large number of scales involved, close interdisciplinary cooperations combining very different theoretical and experimental methods are indispensable.

A joint project of Erlangen's Institute of Polymer Materials and the Chair of Applied Mechanics attempts to model and simulate the creep-relaxation behaviour of silica reinforced PMMA melts. Shear tests have shown that the recoverable compliance of such systems is, opposite to unfilled melts, highly stress dependent, cf. [1] and Fig. 1, which is an effect that is currently ascribed to the breaking of bonds between polymer chains and particle surface. Within a first step, several options for a nonlinear viscoelastic constitutive model suited to reproduce the observed creep-relaxation behaviour have been investigated [2]. Inverse identification procedures were applied to determine the governing parameters of the frequently used Carreau dashpot in terms of particle content and creep stress level, cf. Fig. 2. The measured data are reproduced with an accuracy of 10^{-5}, further investigations will aim towards the incorporation of damage models to consider stress dependent matrix-particle debonding.

$$\sigma(\dot{\alpha}) = \eta_0 \dot{\alpha} \left[1 + \left[\frac{\dot{\alpha}}{\dot{\alpha}_l} \right]^2 \right]^{-k/2}$$

stress equation of Carreau's dashpot

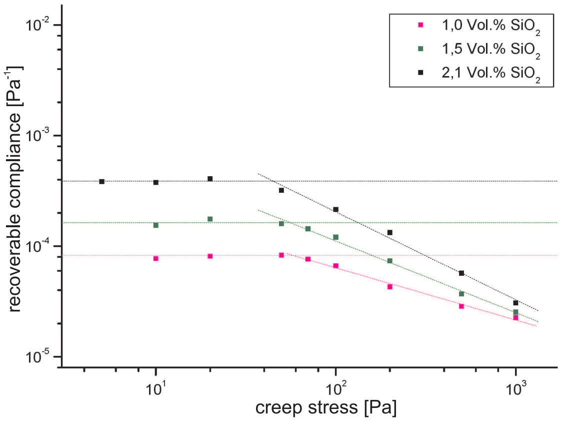

Fig. 1: stress dependent recoverable compliance

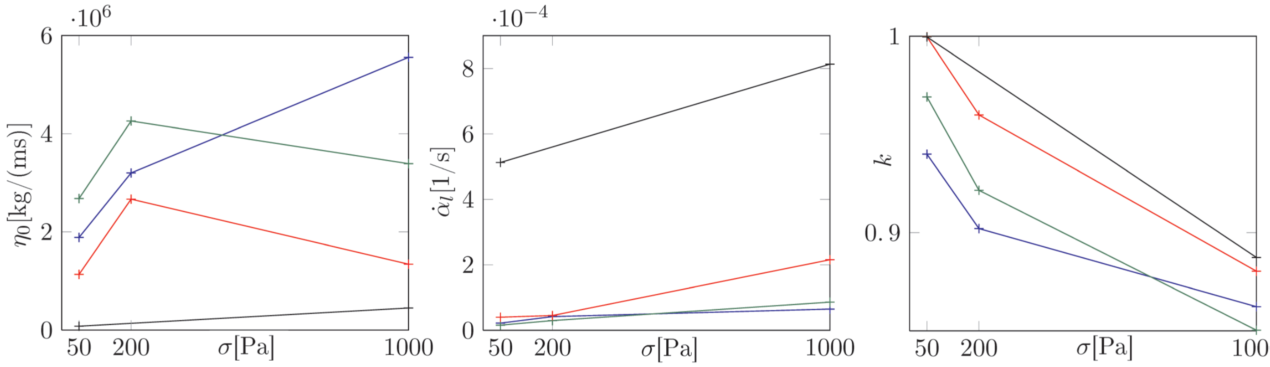

Fig. 2: Carreau parameters vs. creep stress & filler content (black/red/green/blue: 0/1.0/1.5/2.1%)

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Volume-based discretization of pressure loads

Michael Scherer and Paul Steinmann

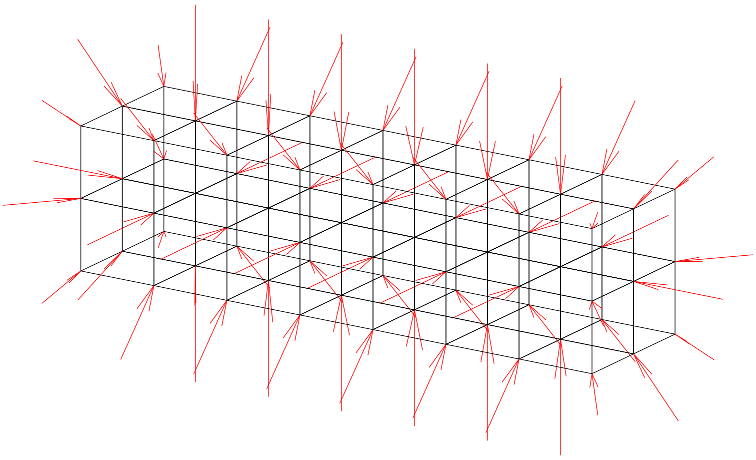

Figure 1: Nodal forces of a bar that is subjected to all-around pressure.

The common method to discretize pressure loads in a finite element analysis is based on a surface discretization. We propose a new volume-based discretization method. The basis of the method is the C^0-continuous finite element approximation of a pressure field

$$p^h(\boldsymbol{x}) = \sum_{i=1}^{n_n} p^{(i)} N^{(i)}(\boldsymbol{x}), \tag{1}$$

where n_n is the number of nodes of a finite element mesh, $p^{(i)}$ are nodal pressure values, and $N^{(i)}$ denote the finite element shape functions. If a surface-based discretization were used, the computation of the nodal pressure forces of the pressure field would be based on

$$\boldsymbol{f}^{surf,(i)} = \mathop{\mathsf{A}}_{e=1}^{n_{el}} \int_{\partial\mathcal{B}^e \bigcap \partial\mathcal{B}^h} -p^h\, N^{(i)} \boldsymbol{n}^e \mathrm{d}a, \tag{2}$$

where $\mathcal{B}^h$ is the finite element approximation of the domain occupied by a mechanical body and $\boldsymbol{n}^e$ denotes the outward unit normal to the element boundary $\partial\mathcal{B}^e$. The proposed volume-based description of the nodal pressure forces is equivalent to Eq. (2) and reads

$$\boldsymbol{f}^{vol,(i)} = \mathop{\mathsf{A}}_{e=1}^{n_{el}} \int_{\mathcal{B}^e} -\nabla_x(p^h\, N^{(i)})\mathrm{d}v = \mathop{\mathsf{A}}_{e=1}^{n_{el}} \int_{\mathcal{B}^e} -\nabla_x p^h\, N^{(i)} - p^h\, \nabla_x N^{(i)} \mathrm{d}v. \tag{3}$$

A consequence of the fact that $\boldsymbol{f}^{vol,(i)} = \boldsymbol{f}^{surf,(i)}$ is that nodal forces $\boldsymbol{f}^{vol,(i)}$ that are associated with interior nodes vanish completely. Moreover, nodal pressure values $p^{(i)}$ that are associated with interior nodes can be chosen arbitrarily since they do not influence the pressure on the boundary $\partial\mathcal{B}^h$. Figure 1 shows the nodal forces of a bar that is subjected to the constant, all-round pressure field $p = 10\,\mathrm{N/mm^2}$. Note that, although $p^{(i)} = 10\,\mathrm{N/mm^2}$ for $i = 1, \ldots, n_n$, the nodal pressure forces associated with interior nodes are approximately of the order of magnitude of 10^{-13}. An advantage of the new method is that it does not require an additional surface discretization; a disadvantage is that it is not able to exactly reproduce a jump of the pressure since p^h is C^0-continuous.

Parameter optimization in the context of finite elasto-plasticity

Stefan Schmaltz, Kai Willner

The overall goal of this work is the formulation, implementation and experimental/ computational identification of an anisotropic elasto-plastic constitutive model at large strains. As material for the characterization DC04 a deep-drawing steel representatively for sheet-bulk metal forming processes is chosen.
To be able to simulate the behavior of this sheet steel the material has to be characterized first. Therefore several experiments as uni- and biaxial tension and compression tests were performed. Anisotropic material parameters at large deformations were measured [1] resulting in the need of a constitutive law being able to model the real behavior.
Elasto-plasticity at finite deformations commonly is modeled via a multiplicative decomposition of the deformation gradient. However, the embedding of anisotropic material characteristics is challenging. Therefore an alternative approach is chosen.
By converting the calculation into the logarithmic strain space an additive formulation results: $\boldsymbol{E}^e = \boldsymbol{E} - \boldsymbol{E}^p = \frac{1}{2}\ln(\boldsymbol{C}) - \frac{1}{2}\ln(\boldsymbol{C}^p)$.
In this interpretation analogies to small strain plasticity exist and the implementation of anisotropic behavior simplifies [2].
Having defined a constitutive law, the required parameters have to be identified. This is done by taking a gradient-free optimization routine using the least-square method to minimize the difference between experiment and simulation.

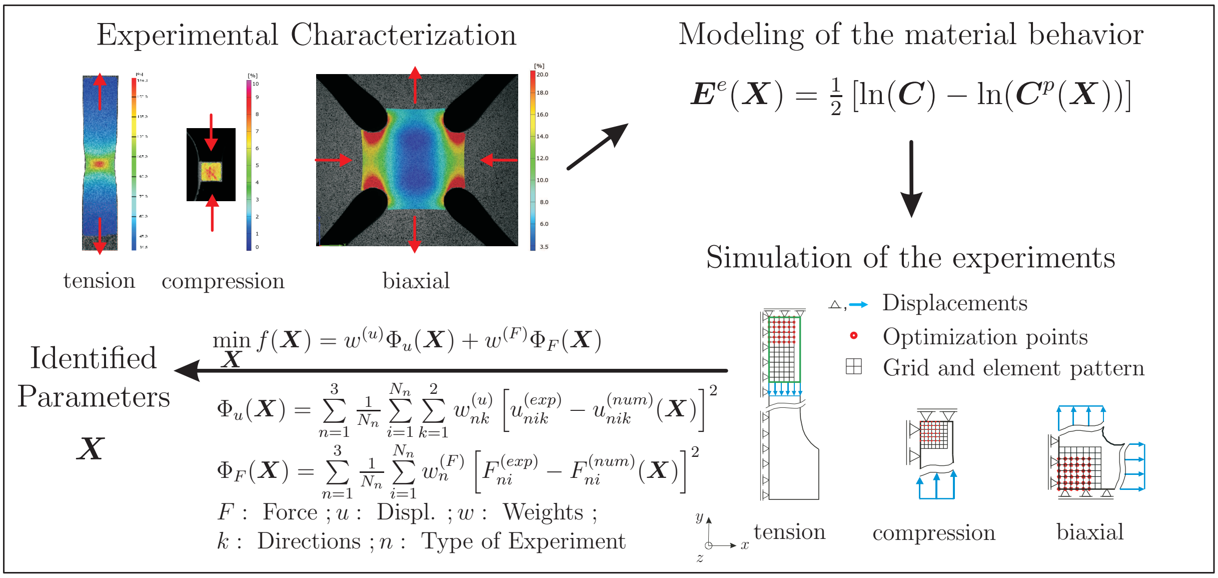

Figure 1: Complete process of the performed parameter identification

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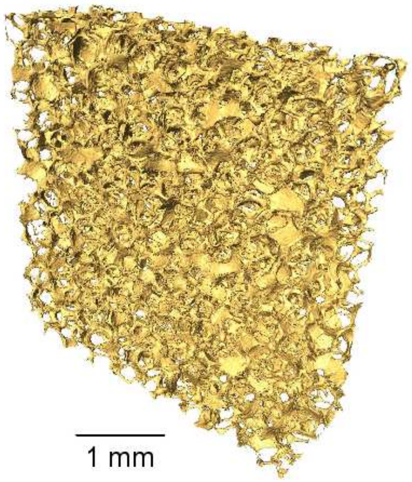
Multi-scale modelling of heterogeneous materials

Ulrike Schmidt, Paul Steinmann

The modelling of materials with heterogeneity at a smaller scale is investigated in project E-8 of the cluster 'Engineering of Advanced Materials'. The material behaviour is modelled at the scale where the heterogeneity is observable (micro). These simulations are the basis for a constitutive relation at the scale of the component (macro), which is derived by means of computational homogenization.

Regarding the implementation of the computational homogenization scheme, improvements in computational time were achieved by restructuring the program code and rewriting parts of it in the programming language C++. Some modifications had to be made in order to use the built-in parallel for-loop of MATLAB for the program to be run in parallel.

Modelling of ceramic foam in cooperation with Prof. Greil and Dr. Fey was pursued further. Finding a representative volume element is the key for a good model and proved to be more difficult than initially thought. Several sample FE meshes, provided by Dr. Fey, have been investigated. The calculated homogenized material parameters still vary depending on which sample of the same foam is under observation. Therefore, sample meshes describing a larger part of the microstructure have to be developed and then simulated. Since the ceramic foams under investigation have a highly random microstructure, the smallest representative volume element is expected to be rather large. The right compromise between resolution and computational time has yet to be made.



ceramic foam,
courtesy of Dr. Fey

Investigating the thermomechanical computational homogenization, the availability of material parameters and their validation was getting more attention. Since not too much about this topic can be found in literature, further research concerning parameter identification over multiple scales was carried out within the project. A gradient-based optimization algorithm is used to identify the parameters. Therefore, new structures were added to the program in order to allow for parameter identification over two scales for linear elasticity in the small strain setting. The new feature was first tested for artificial data. The influence of optimization algorithms, reference material parameters and loading scenarios was investigated. This research resulted in the publication [1].

The next goal in this research direction is to extend the concept of multiscale parameter identification to inelastic material behaviour. To this end, inelastic material laws are implemented in the FE^2 framework. For the direct problem, von Mises plasticity models with (non-)linear isotropic and kinematic hardening have been implemented.

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Mechanical integrators for simulation of contact in elastic multibody systems

Patrick R. Schmitt, Paul Steinmann

In simulations of frictional contact problems in dynamics one often encounters the problem of collision partners having a non-convex shape. The mathematical tools necessary to deal with this kind of contact geometry are provided by the field of non-smooth optimization, namely the concepts of normal and tangential cones and also proximal point methods. These enable us to formulate the contact laws and switching rules between different contact states via normal cone inclusions as set-valued contact/force laws. Using proximal point techniques one obtains non-linear equations that can be solved iteratively see e.g. [1].
As a simple example consider the setup depicted in Fig. 1. Two identical groups of rigid disks are initially at rest and subjected to gravity loading, where the group of blue disks has a slightly lower potential energy corresponding to its position (offset of 0.005 units with respect to the red group). The non-convex basin depicted in black is a collection of rigid bars with infinite mass and moment of inertia.

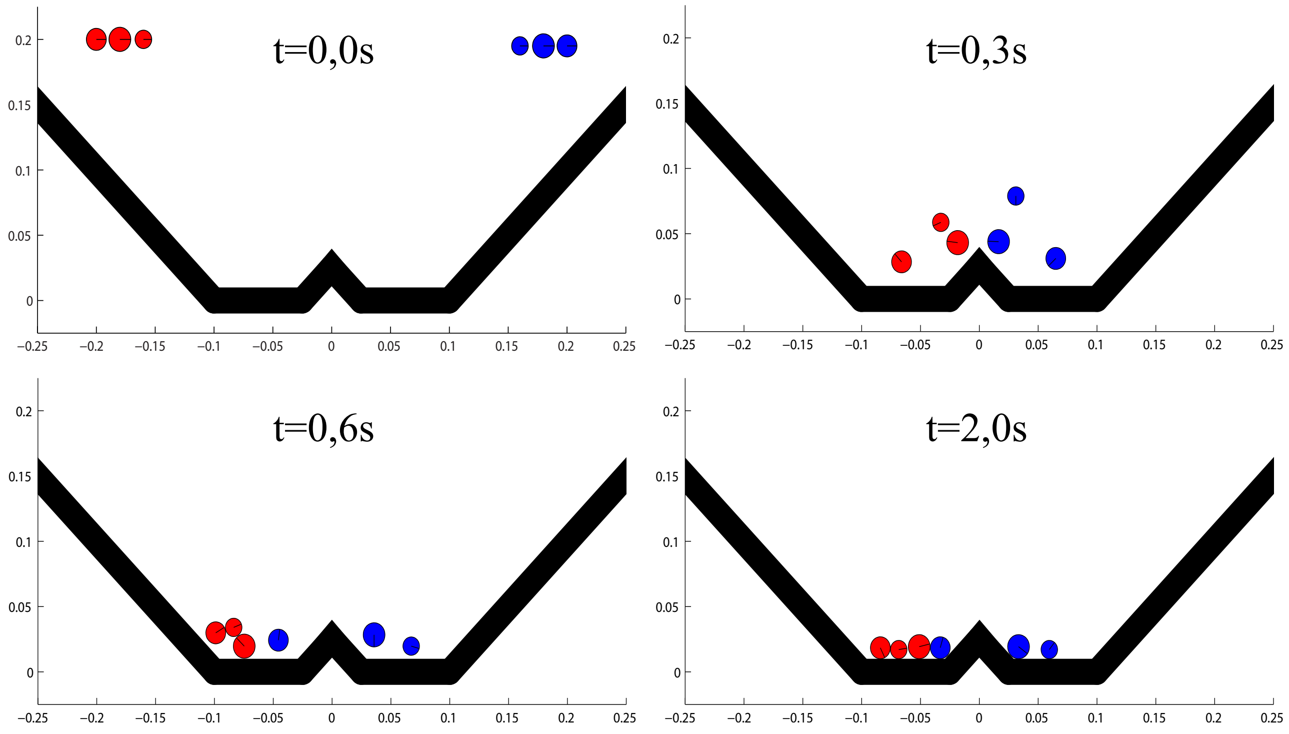

Figure 1: An (almost) symmetrical configuration of rigid disks initially at rest is subjected to gravity loading. The non-convex basin (black) is fixed in space and modelled as a collection of rigid bars with (numerically) infinite mass and moment of inertia. The simulation is performed with a fixed time-step of width $h = 0.001s$ and taking into account separate frictional contact laws for the disk/basin and disk/disk interactions.

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Modelling of jointed structures in the frequency domain

Dominik Süß, Kai Willner

This contribution deals with numerical and experimental investigations of jointed structures. Therefore it is important to investigate nonlinear friction forces in contact interfaces especially with respect to stiffness and damping properties.

In numerical studies, Zero Thickness Elements are applied for the discretization of contact interfaces in the framework of the Finite Element Method. During the investigation of the dynamic behaviour of a structure - especially for harmonic excitations - often only the steady state is of interest. In the linear case, a direct computation of the steady state in the frequency domain is possible, whereas for problems with contact interfaces, the system of equations is nonlinear. Therefore it cannot be transformed directly into the frequency domain. To solve this problem, the Harmonic Balance Method is utilized, which leads to the calculation of equivalent damping and stiffness matrices. Finally, the system is solved for the stationary answer of the structure, [1], [2].

As an example, a system consisting of two bolted beams is considered. In the following figure magnitudes of calculated and measured frequency response functions $|H|$ are shown for harmonic excitation of the structure around its first four resonance frequencies. A good agreement between measurement and computation using the Harmonic Balance Method can be observed.

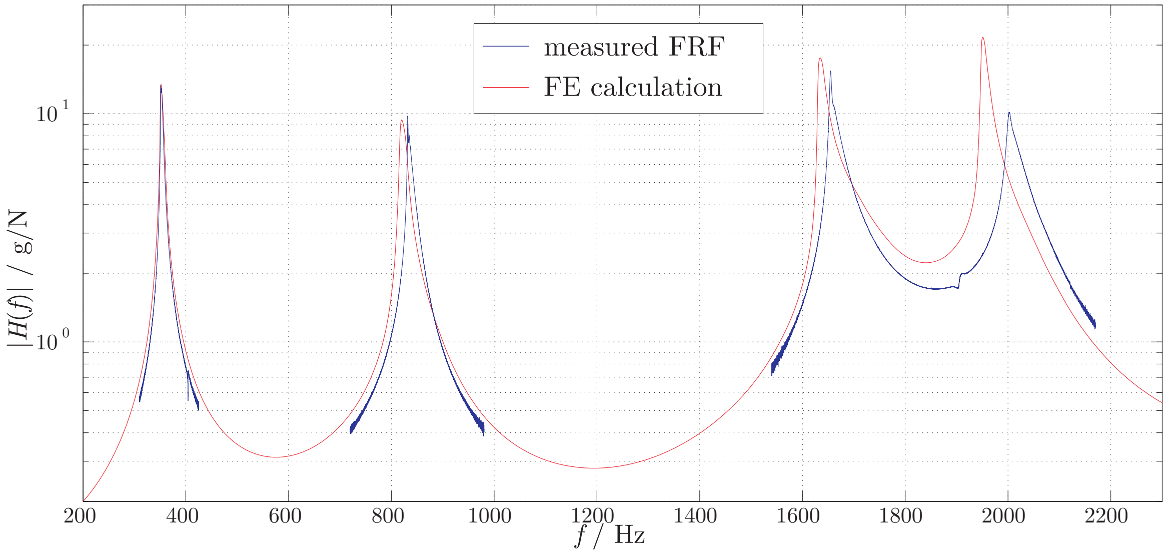

Figure 1: Measured and calculated FRF of a bolted double beam including the first four resonance frequencies

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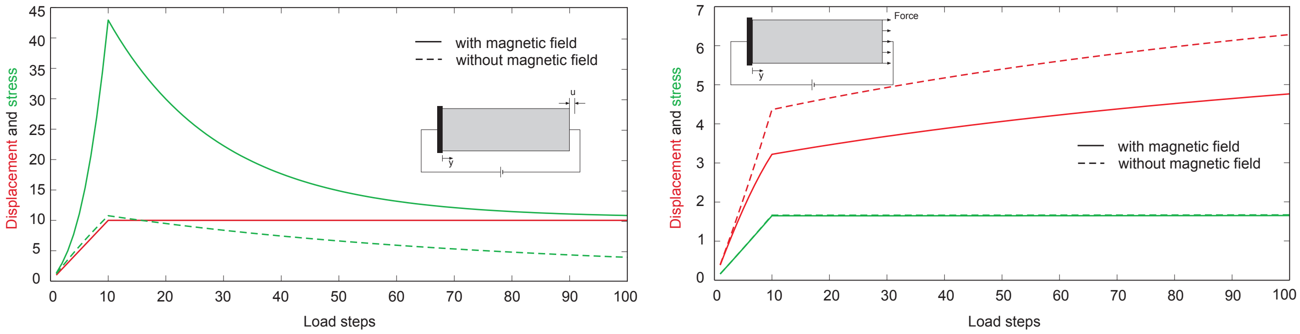
On the Modeling and Simulation of Magneto-Sensitive Elastomers

Franziska Vogel and Paul Steinmann

In this contribution, the numerical modeling of magneto-viscoelastic material is considered. For doing so, the magneto-mechanical problem formulated in terms of a symmetric stress tensor [1] is extended to a viscoelastic material model. For the incorporation of viscosity, the logarithmic strain space formulation is utilized which mimics the small strain setting [2]. Therefore a rheological model for viscosity from the geometrically linear theory can be used. Numerical examples for a typical uniaxial tensile test show the capability of the method to demonstrate typical relaxation and creep behavior and the influence of the action of the magnetic field.

For the numerical simulation a plate is clamped on the left end and free to deform on the right end. It is loaded with positive magnetic scalar potential on the fixed end and negative magnetic scalar potential on the other side. Additionally, either displacement or stress is prescribed along the free end in longitudinal direction. The whole system is loaded in ten time steps. Then the magnetic potential and displacement or force, respectively, are kept constant for 90 further time steps.

In both cases, displacement and stress in longitudinal direction increase during the phase of loading. In the first example (Fig. 1a), the prescribed displacement is kept constant after the loading. Due to this boundary condition, the displacement is independent of the application of an magnetic field. The stress decreases exponentially during the time of relaxation and the maximal value is higher for the experiment with magnetic field than without due to the effects of magnetostriction. The plate tends to contract which is prohibited by the prescribed displacement. This material behavior results in higher stresses within the material. For the case of creep (Fig. 1b), the plate elongates during the phase of constant stress. Again because of magnetostriction, the displacement is less with applied magnetic loading than without.



(a) Relaxation for constant displacement

(b) Creep for constant stresses

Figure 1: Uniaxial tensile test for clamped plate under potential loading: plot of non-dimensionalized displacement and stress with and without magnetic loading

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A 3-D coupled BEM-FEM simulation of electro-elastostatics at large strain

Duc Khoi Vu and Paul Steinmann

The coupling between the boundary element method and the finite element method is used here in this work to simulate the deformation of a body subjected to electric stimulations. Under the application of electrical forces, the behavior of an elastic body is determined by, among other material properties, the density of the polarization of the body's materials. When the polarization is strong, like in the case of piezoelectric materials, the influence of the free space surrounding the body is weak and can be conveniently ignored. In the case where this polarization is weak, numerical simulations showed that the influence of the free space surrounding the body should be taken into account. In this work, finite elements are used to model the nonlinear electro-elastic body in which both geometrical nonlinearity and electro-mechanical nonlinearity are taken into account. Besides, boundary elements are used to model the surrounding space and account for the large deformation of the boundary of the body.

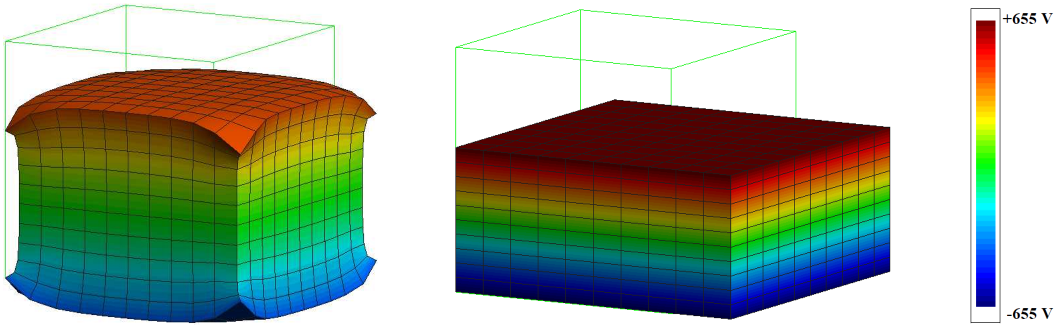

Figure 1: Distribution of electric potential (V) in deformed configuration using coupled BEM-FEM (left) and FEM (right)

As numerical example we consider a cube of dimensions $60\mu\text{m} \times 60\mu\text{m} \times 60\mu\text{m}$. The electric potential difference between the lower and upper surface of the cube is increased until instability happens. In our simulation, 1000 linear hexagonal 8 node elements are used to model the cube. On the boundary of the cube, the outer space is modeled by 600 linear quadrangular 4 node boundary elements. The simulation results obtained by using both boundary and finite elements (coupled BEM-FEM) and by using only finite elements (FEM) are presented to demonstrate the necessity of the coupled BEM-FEM.

References

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to be published

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A 2-D coupled BEM-FEM simulation of electro-elastostatics at large strain.
Comput. Methods Appl. Mech. Engrg., Vol. 199 (17-20), pp. 1124-1133

[3] D.K. Vu, P. Steinmann, G. Possart, [2007]
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Int. J. Num. Meth. Engrg., Vol. 70, pp. 685-704

On the modeling of magnetic field-induced strains in magnetic shape memory alloys

Jiong Wang and Paul Steinmann

Magnetic shape memory alloys (MSMAs) are a group of fascinating materials, which can undergo a significant and reversible nonlinear deformation driven by the external magnetic field. Compared with the conventional actuator materials and shape memory alloys, MSMAs offer the possibility of both large actuation strains (5-10%) and high response frequency (on the order of 1 kHz). The unique property makes MSMAs suitable for a wide range of applications. It is now understood that there are two underlying mechanisms responsible for obtaining the large magnetic field-induced strains in MSMAs (cf. Fig. 1): i) magnetic field-induced martensite variants reorientation and ii) magnetic field-induced phase transformation. A number of MSMAs have been reported in the literature. Among them, NiMnGa alloy is the most known and widely explored.

In this project, several constitutive models will be proposed to study the magneto-thermodynamic responses of MSMAs. For quasi-static magnetoelastic deformation problems, the governing equation system have been well formulated in nonlinear magnetoelasticity theory [1], which is composed of the field equations

$$\mathrm{div}\mathbf{B} = 0, \quad \mathrm{curl}\mathbf{H} = \mathbf{0}, \quad \mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M}), \quad \mathrm{div}\boldsymbol{\sigma}_{tot} = \mathbf{0},$$

and the boundary conditions (or the connection conditions across a surface of discontinuity)

$$\mathbf{n} \cdot [\mathbf{B}] = 0, \quad \mathbf{n} \times [\mathbf{H}] = \mathbf{0}, \quad \mathbf{n} \cdot [\boldsymbol{\sigma}_{tot}] = 0 \;\; \text{or} \;\; \boldsymbol{\sigma}_{tot} \cdot \mathbf{n} = \boldsymbol{\Gamma}.$$

To complete the formulation of the magnetomechanical boundary value problem, several constitutive relations (especially, a specific constitutive form for the free energy Φ) need to be further specified. This boundary value problem will be tackled through suitable analytical and computational methods. It is expected that the models proposed here can be used to understand and simulate some representative experimental results [2].

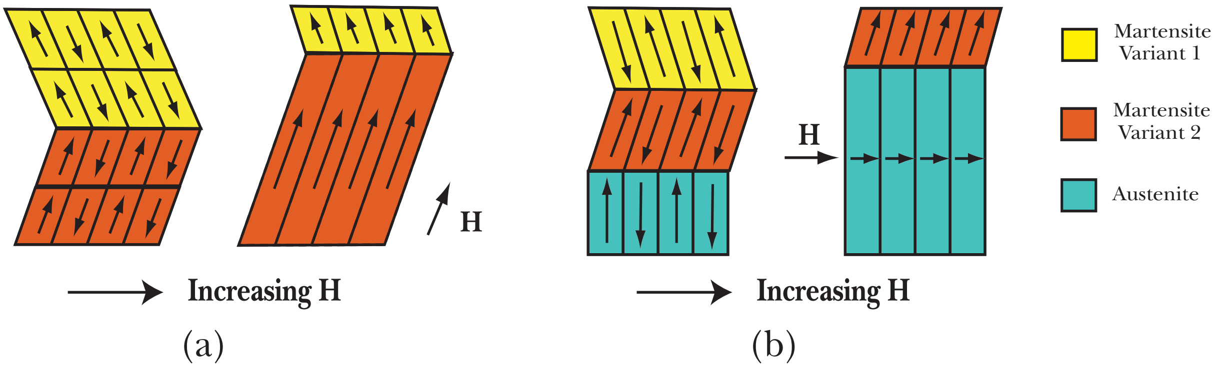

Figure 1: Magnetic field-induced martensite reorientation (a) and phase transformation (b) in MSMAs.

References

[1] A. Dorfmann, R.W. Ogden, Nonlinear magnetoelastic deformations, *Q.J1 Mech. Appl. Math.* **57**, pp. 599-622, (2004)

[2] H.e. Karaca, I. Karaman, B. Basaran, Y.I. Chumlyakov, H.J. Maier, Magnetic field and stress induced martensite reorientation in NiMnGa ferromagnetic shape memory alloy single crystals, *Acta Materialia* **54**, pp. 233-245, (2006)

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. In addition the crack surface contact is considered [5]. In order to reduce the numerical complexity of the stress analysis, fast methods are applied [1,4]. The fracture mechanical parameters are extrapolated accurately 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 in order to define the new crack front relative to the current one. In the present context the cyclic equivalent SIF is calculated by the criterion of the maximum energy release rate [2]. By the evaluation of a crack propagation rate formulation the local crack extension is obtained. 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 [3].

Due to the nonlinear nature of crack growth an analysis of the predicted crack propagation in terms of an error estimation is required. In order to minimize the linearization error an implicit time integration method in terms of a predictor-corrector scheme is applied [3]. In case of crack surface contact non-proportional mixed mode conditions have to be taken into account. Here, the challenges of changing kink angles during a load cycle and the transition of shear mode to tensile mode crack growth have to be solved [5,6].

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[1] K. Kolk, W. Weber, G. Kuhn, Investigation of 3D crack propagation problems via fast BEM formulations, *Computational Mechanics* 37 (2005) 32-40

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[4] W. Weber, K. Kolk, G. Kuhn, Acceleration of 3D crack propagation simulation by the utilization of fast BEM-techniques, *Engineering Analysis with Boundary Elements* 33 (2009) 1005-1015

[5] W. Weber, K. Willner, G. Kuhn, Numerical analysis of the influence of crack surface roughness on the crack path, *Engineering Fracture Mechanics* 77 (2010) 1708-1720

[6] W. Weber, K. Kolk, K. Willner, G. Kuhn, On the solution of the 3D crack surface contact problem using the boundary element method, *Key Engineering Materials* 454 (2011) 11-29

Parameters of implant stability measurements: a comparative finite element analysis

Werner Winter, Stefan Möhrle, Matthias Karl

It has been argued that stability both at placement and during function is an important criterion for the success of dental implants. Bone loss can be observed, too (see Fig. 1). Determination of primary implant stability has also been used as an indicator for future osseointegration.

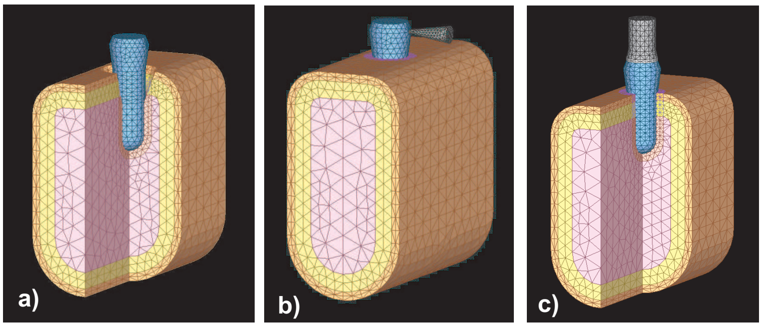


Figure 1: FE-model for a dental implant with bone loss (a) and FE-models for Periotest® (b) and the Osstell® system (c)

The need for a clinically effective noninvasive technique for monitoring implant stability has led to the development of two major diagnostic tools. Whereas the Periotest® device (see Fig. 1b) determines the damping capacity of a tooth or an implant (Periotest® value, PTV), the Osstell® system (see Fig. 1c) is based on resonance frequency analysis (Implant stability quotient, ISQ). The purpose of this Finite Element Analysis was to simulate the influence of the parameters implant length, bone quality (cortical thickness and damping factor) bone loss and quality of transducer fixation on resonance frequency (RFA) and damping capacity measurements. Measurements were simulated at four stages of osseointegration. The results of this investigation are published in [1]. In summery, although both measuring devices react similarly when different parameters of implant stability are changed, good correlation between PTV and ISQ can only be derived when measurement values of implants without bone loss are being considered (see Fig. 2).

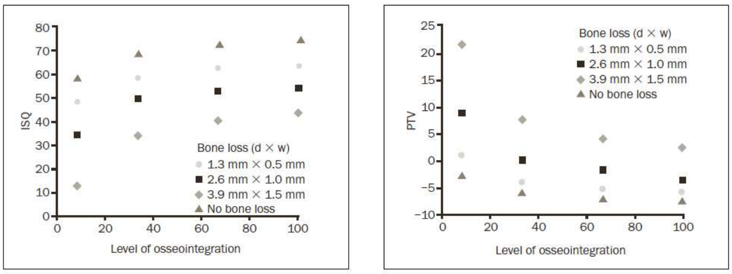


Figure 2: Implant stability expressed in ISQs and PTVs varying the level of osseointegration and bone loss [1]

References

[1] W. Winter, S. Möhrle, S. Holst, M. Karl (2010). Parameters of implant stability measurements based on resonance frequency and damping capacity - a comparative finite element analysis. *The International Journal of Oral and Maxillofacial Implants* **25**, pp. 532-539.

Quality of alveolar bone: Structure dependant material properties and a design of a novel measurement technique

Werner Winter, Thomas Krafft, Matthias Karl, Paul Steinmann

The purpose of this investigation was to describe the mechanical behavior of cortical and trabecular bone in view of bone structure, bone density and stiffness which can be used as a basis for determining bone quality by measuring elastic properties of bone (see Fig. 1) and to design a novel device for the determination of bone quality following implant site preparation.

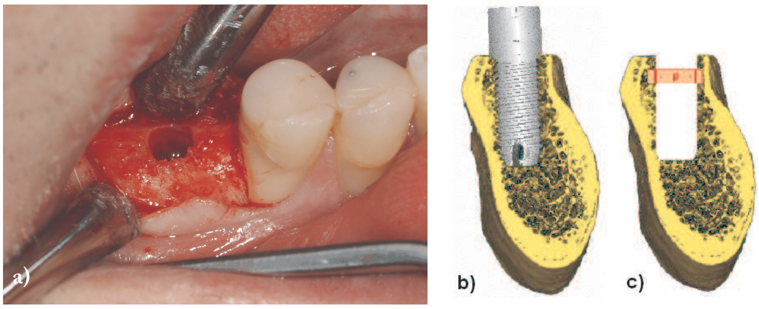


Figure 1: Clinical situation during dental implant surgery (a), implant situated in the jaw (b), measurement device (schematical) (c)

In view of elastic mechanical behavior trabecular bone is a cellular material and cortical bone a material with pores. Thus, we can use the results of cellular material in general as shown in [1]. In Fig. 2 the results of numerical simulation of the material stiffness (Young's modulus) is plotted against the relative density. The regions of trabecular and cortical bone behavior are also shown.

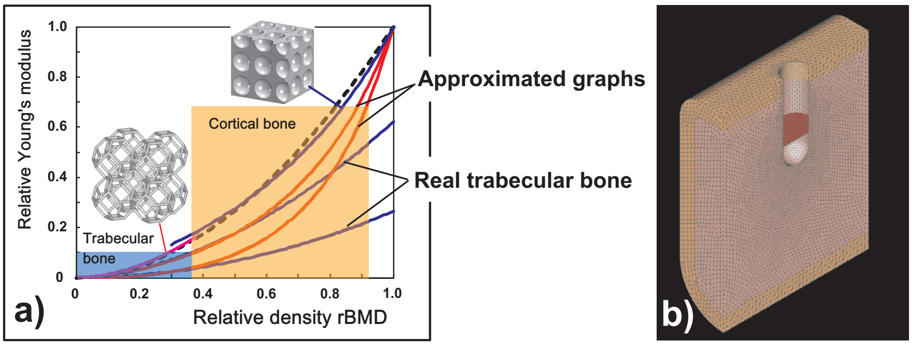


Figure 2: Normalized Young's modulus against relative density (a), FE-model for testing the novel measurement technique (b)

References

[1] S. Ströhla, Numerische und experimentelle Untersuchung des elastisch-plastischen Materialverhaltens von Metallschäumen. *Dissertation, Fortschritt-Berichte VDI, Reihe 8, Mechanik/Bruchmechanik, VDI GmbH - Düsseldorf 2006.*

[2] W. Winter, T. Krafft, P. Steinmann, M. Karl, Quality of Alveolar Bone - Structure Dependant Material Properties and Design of a Noval Measurement Technique. *Journal of the Mechanical Behavior of Biomedical Materials*, (accepted)

Bone loading due to different misfit types in implant-supported fixed dental prostheses: A 3D-Finite Element Analysis based on experimental results

Werner Winter, Stefan Möhrle, Matthias Karl

Clinical methods for the evaluation of implant framework fit in implant-supported fixed dental prostheses have been shown not to be able to provide objective results (see Fig. 1a).

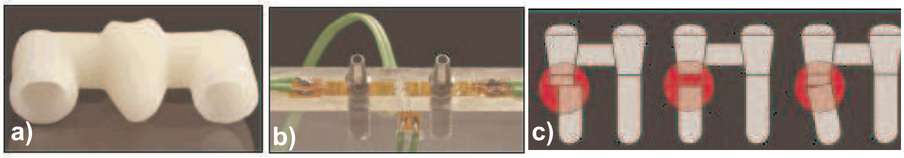


Figure 1: Implant-supported fixed dental prostheses (a), dental implants for experimental studies (b) and misfits (c)

3-D finite element models (Fig. 2) were designed for the simulation of experimentally determined strain values of three-unit fixed dental prostheses supported by two implants (Fig. 1b). Horizontal, vertical and rotational misfits between implant and restoration were used to create the predetermined strain levels (Fig. 1c). Misfit magnitudes and resulting bone loading as von Mises equivalent stress were recorded for the different misfit types. Bone loading in the cortical area around both implants ranged from 50 to 90 MPa for horizontal and vertical misfits. In the trabecular bone, loading magnitudes of 2 to 5 MPa were found. For the rotational misfit, bone loading up to 20 MPa in the cortical layer and 1 MPa in the cervical part of the trabecular bone occurred at that implant where the misfit had been introduced. Whereas by horizontal and vertical misfits the bone around implant have similar loading in the case of rotational misfit only the bone area of the implant with the misfit is stressed, approximately.

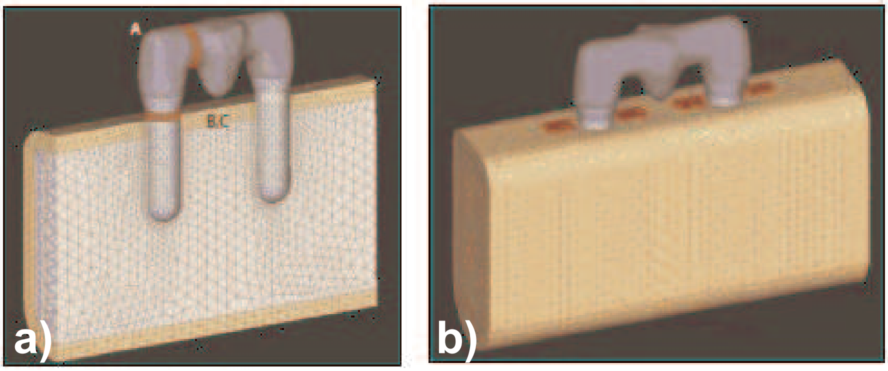


Figure 2: FE-Model for simulation of bone loading by misfits: open jaw FE-model with zones for generation of the misfits (a), FE-Model with numerical strain gauges (b)

Minimum rotational misfits between implant abutment and restoration, which can not be detected clinically, may lead to substantial bone loading [1].

References

[1] W. Winter, S. Möhrle, S. Holst, M. Karl (2010)
Bone loading due to different misfit types in implant-supported fixed dental prostheses: A 3D-Finite Element Analysis based on experimental results. *The International Journal of Oral and Maxillofacial Implants* **25**, pp. 947-952.

Effect of geometric parameters on Finite Element Analysis of bone loading caused by non-passively fitting implant-supported dental restorations

Werner Winter, Matthias Karl, Paul Steinmann

Finite element analysis (FEA) has been frequently applied for studying the loading situation of dental implants and bone as resulting from the fixation of non-passively fitting restorations. The goal of this investigation was to demonstrate the effect of geometric model parameters and mesh size on FEA results.

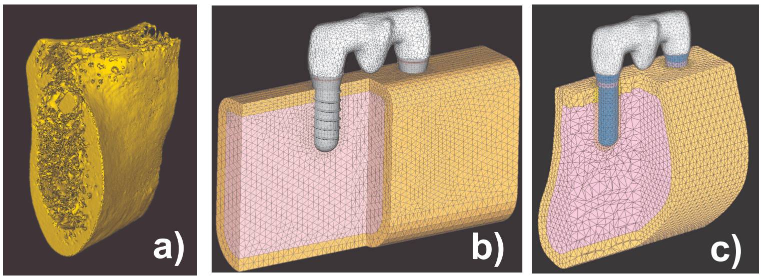


Figure 1: CT of a real jaw (a), free form FE-model and implant with thread (b) FE-model with geometry of CT scan (c)

3D-FE-models representing a three-unit fixed dental prosthesis (FDP) supported by two terminal implants were constructed. The models differed in terms of mesh size, geometry of bone, implants and restoration which were either created by joining virtual free-form objects or by utilizing optical scans of existing components (see Fig. 1). Applying thermal changes in volume of specific elements in the area of the FDP pontic, a horizontal misfit between implants and restoration was introduced and the resulting loading situation of the bone around the implants was recorded as von Mises equivalent stress. Modelling implant threads did have a remarkable effect on the stress situation as well as different span lengths of the restorations modelled. All other parameters only led to small variations in maximum loading magnitudes. Simplistic FEA models based on virtual free-form objects with limited level of mesh refinement seem to allow for a basic evaluation of peri-implant bone loading resulting from the fixation of misfitting superstructures.

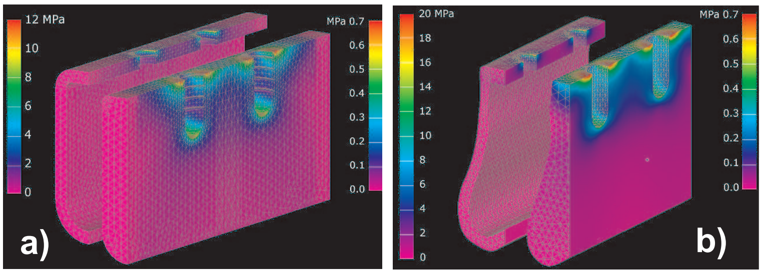


Figure 2: FE-Results (von Mises stress): Free form FE-Model and implant with thread (a), CT scan FE-model (b)

References

[1] W. Winter, P. Steinmann, S. Holst, M. Karl (2010)
Effect of geometric parameters on Finite Element Analysis of bone loading caused by non-passively fitting implant-supported dental restorations. *Quintessence International*, (submitted)

4 Activities in 2010

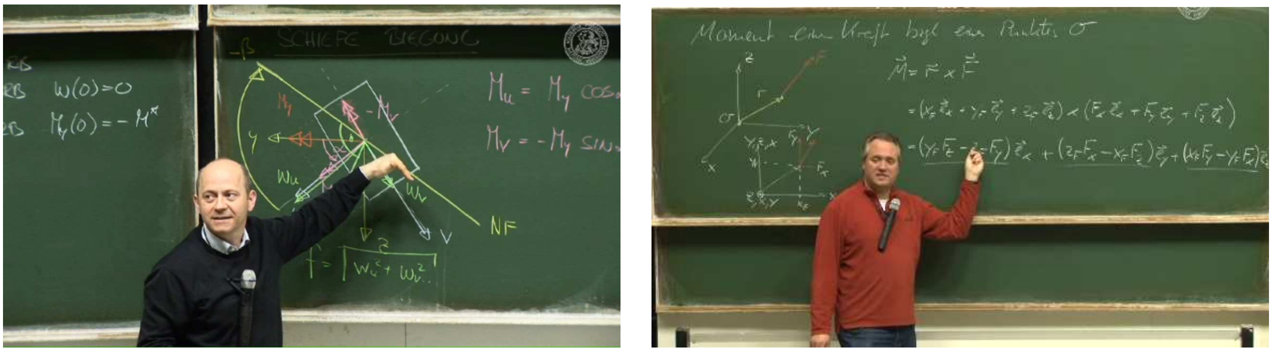
4.1 Teaching

- Statik (MB)
  (video recording `www.video.uni-erlangen.de/cgi-bin/index.pl/Course/15`)
- Elastostatik und Festigkeitslehre (MB)
  (video recording `www.video.uni-erlangen.de/cgi-bin/index.pl/Course/21`)
- Statik und Festigkeitslehre (CBI, ET, IP, LSE, ME, MT, WING, WW)
  (video recording `www.video.uni-erlangen.de/cgi-bin/index.pl/Course/59`)
- Dynamik starrer Körper (MB, ME, WING)
  (video recording `www.video.uni-erlangen.de/cgi-bin/index.pl/Course/51`)
- Lineare Kontinuumsmechanik (MB, ME, WING)
  (video recording `www.video.uni-erlangen.de/cgi-bin/index.pl/Course/53`)
- Nichtlineare Kontinuumsmechanik (MB, ME)
- Technische Schwingungslehre (MB, ME, WING)
- Mehrkörperdynamik (MB, ME)
- Methode der Finiten Elemente (MB, ME, WING)
- Einführung in die Schädigungsmechanik (MB)
- Materialmodellierung und -simulation (CE, MB)
- Mechanik der Materialverbunde (MB)
- Bruchmechanik (MB)
- Finite Elemente in der Plastomechanik (MB)
- Introduction to the Finite Element Method (CE)
- Nichtlineare Finite Elemente (CE, MB)
- Finite Elemente Praktikum (MB, ME)
- Höhere Festigkeitslehre (MB)
- Computational Dynamics (CE)
- Hauptseminar (MB, ME)
- Seminar über Fragen der Mechanik
- Number of exams - 2123

4.2 Video recording

(mk) Since the winter term 2009/2010, LTM lectures have been recorded and published in cooperation with the *Multimedia Center* (`www.mmz.rrze.uni-erlangen.de`) of the *Regional Computing Center Erlangen (RRZE)*. The videos are available world-wide and can be used by our students to repeat the lectures and to prepare for the exams. Finally, a scene from *Statics* became part of the German version of Apple's iPad commercial "iPad is electric" (`www.apple.com/de/ipad/gallery/ads.html`, released in November).

We gratefully acknowledge the financial support by student fees for this project.



scenes from the lectures; left: *Elastostatics and Strength of Material*
right: *Statics and Strength of Material*

technical data:

- cameras: 1x Sony HVR-Z5E, 1x Sony HVR-Z1E
- formats: 320x180 m4v video, 640x360 m4v video, mp3 audio

available accesses:

- iTunes U (`www.apple.com/education/itunes-u`)
- university's video homepage (`www.video.uni-erlangen.de`)

available lectures:

- Statics
- Elastostatics and Strength of Material
- Dynamics
- Linear Continuum Mechanics
- Statics and Strength of Material

4.3 Industrial contributions to lectures

05.02.2010	Dr.-Ing. Lars Küble, TRW Automotive *Anwendungen der Mehrkörperdynamik in der industriellen Praxis - Auslegung von Insassenschutzsystemen*

4.4 Dissertation theses

- Geisler, Johannes.
  Numerische und experimentell Untersuchungen zum dynamischen Verhalten von Strukturen mit Fügestellen.
  Schriftenreihe Technische Mechanik, Band 1, 2010

- Hossain, Mokarram.
  Modelling and Computation of Polymer Curing.
  Schriftenreihe Technische Mechanik, Band 2, 2010

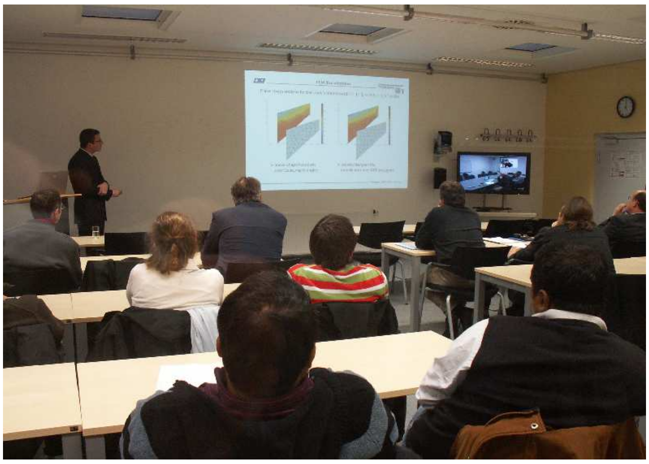
- Görke, Daniel.
  Experimentelle und numerische Untersuchung des Normal- und Tangentialkontaktverhaltens rauer metallischer Oberflächen.
  Schriftenreihe Technische Mechanik, Band 3, 2010

- Constantiniu, Alexandru
  A Hybrid Nodal-Element-Based Discretization Method.
  Schriftenreihe Technische Mechanik, Band 4, 2010

- Weber, Wilhelm.
  Entwicklung eines randelementbasierten Programmsystems zur bruchmechanischen Bewertung rissbehafteter Strukturen. VDI Fortschritt-Berichte, Reihe 18 (328), 2010.

4.5 E-Doctor Defence

(mk) Also supported by the *Multimedia Center*, the first e-doctorate has been passed at Erlangen. With the agreement of the deanery, the final talk and oral examination for Alexandru Constantiniu took place at the eStudio on 28th of January. The candidate, three members of the examination board and the audience in Erlangen were joined with a remote examinator at the University of California Davis via video conferencing. The whole examination has been passed successfully without any disconnections or other technical difficulties.



4.6 Diploma theses

- M. Amann, *Ermittlung der Betriebsgrenzen für eine Dampfturbinenendstufe durch eine gekoppelte Strömungs-Festigkeits-Berechnung*
- S. Fillep, *Homogenisierung von Materialien mit Faserstruktur in ABAQUS*
- P. Heinl, *Analyse und Optimierung des Sensor- und Regelungskonzepts eines Überlagerungslenksystems*
- M. Heckel, *Dynamische Echtzeitschätzung von kinematischen Kenngrößen eines PKW-Fahrwerks*
- M. Hekrenz, *Kopplung von teilchen- und Finite-Elemente-basierten Berechnungsmethoden mit Berücksichtigung der Dynamik*
- K. Kaluza, *Ermüdungsnachweise thermozyklisch beanspruchter Schweißverbindungen*
- C. Müller, *Aktive Fahrwerksregelung zur Reduktion der Querbeschleunigung*
- S. Schindler, *Modellierung und Simulation der Aushärtung von Polymeren mit MSC.MARC*
- P. Spies, *Anwendung von Optimierungsverfahren zur Parameteridentifikation von MKS-Modellen am Beispiel elektrisch angetriebener Maschinenachsen*
- D. Süß, *Experimentelle und numerische Analyse von Strukturdämpfung durch Reibung*

4.7 Master theses

- M. Fang, *Bewertung der Flanschberechnung auf Basis der Finite-Elemente-Methode im Kontext verfügbarer analytischer Ansätze unter besonderer Berücksichtigung von transienten Temperaturfeldern*

4.8 Bachelor theses

- F. Flick, *Mechanische Modelle für die Kraftübertragung an Zähnen und Implantaten*
- M. Fechter, *Kopplung von FEM mit teilchenbasierten Berechnungsmethoden*
- P. Jänicke, *Simulation der Beanspruchung einer Zahnwurzel im Zahnhalteapparat*
- F. Liebst, *Beanspruchungsoptimierte Auslegung einer Antriebswelle aus einem Faser-Verbund-Material*
- J. Popp, *Parameterstudie über den Einfluss der Randbedingungen auf die mit FEM berechnete Lagerschildsteifigkeit bezüglich der Rotordynamik*
- B. Rank, *Simulationsmodule für inelastisches Materialverhalten*
- B. Söhngen *Numerisches Simulationsmodell für den Röhrenknochen bei elastisch-plastischer Biegung mit Schädigung*

4.9 Student research projects theses

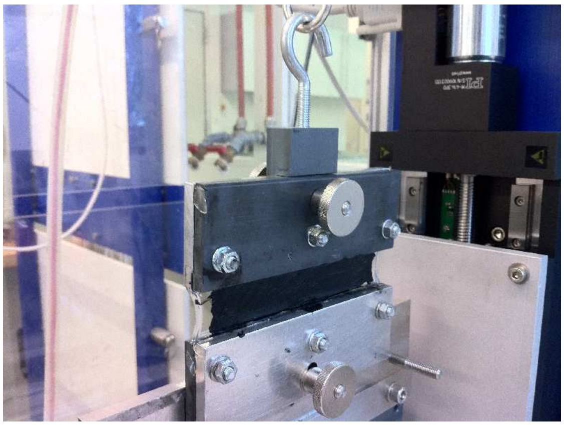
- F. Endres, *Untersuchung einer knotenbasierten Finite-Elemente-Formulierung*
- M. Etzold, *Modellierung und Simulation von Kriech- Erholungsversuchen an PMMA-SiO2 Nanokompositschmelzen*
- F. Helldörfer, *Numerische Simulation des Verhaltens von Bauteilen aus Kunststoff unter mehrachsiger Beanspruchung*
- V. Luchscheider, *Dreidimensionale Kopplung von FEM mit teilchenbasierten Methoden*
- J. Miehling, *Finite Elemente Untersuchungen des Normalkontaktes rauer Oberflächen*
- M. Reißner, *Untersuchung der Kopplung der Finiten Elemente Methode mit teilchenbasierten Berechnungsverfahren unter Verwendung von Matlab*
- C. Schaffelhofer, *Werkstoffmechanische Analyse des Femurhalses*
- S. Schindler, *Konstruktion und Auslegung eines Reibschlussversuchs mittels Finite-Elemente-Methode*
- M. Semel, *Zweidimensionale Kopplung von FEM mit teilchenbasierten Methoden*

4.10 Laboratory new equipment

As has been stated in the scientific reports, electronic electro-active polymers (EEAPs) have recently got significant attention inside the field of materials science, mainly due to their practical application in the development of dielectric elastomer actuators (DEAs) that behave as artificial muscles and can be used in a wide variety of areas, including robotics and aerospace engineering. For this reason, efforts in accurately characterizing these novel materials through experimental tests have grown significantly through the last decade, with the aim always set into reaching a mathematical model that accurately describes the behavior of the EEAP and that consequently leads to the opportunity of performing reliable numerical simulations.

Taking into account the fact that actuation of EEAPs requires the application of very high voltages (in the order of 5 KV), we have designed a suitable testing bench that has been set up in the facilities of the LTM. The core of the setup consists in an L-shaped platform mounted on a linear stage and a load cell. EEAP specimens are clamped and attached to the platform on the bottom, and through a hook to the load cell on the top (a). The platform then moves downwards, stretching the specimen and "pulling" from the load cell, which measures the load continuously. A LabView program has been written to control both the speed and displacement of the load cell from a computer. With all these data available, recording stress-strain curves is straighforward.

The core of the testing bench is enclosed in a stiff cage with plastic walls, that allows the safe application of high voltage during the tests. For that purpose, a voltage supplier was installed next to the cage and connectors are introduced through tiny holes on the plastic walls. If voltage is applied, all walls of the cage remain safely closed. The high voltage output can be set on/off from the supplier itself, and also remotely from the LabView program.

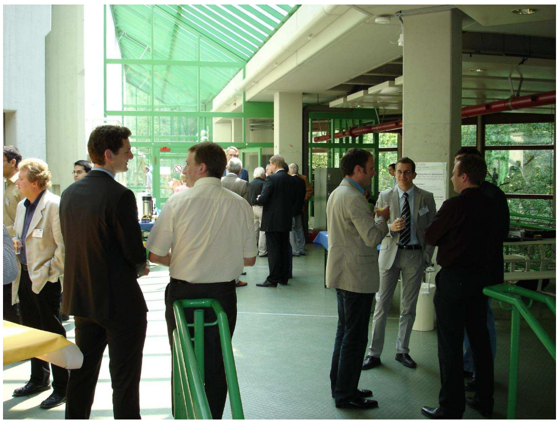


(a) Core of the testing bench

(b) Computer, voltage supplier and stiff cage

4.11 39. Bayerisch Tirolerisches Mechanik Kolloquium

Date	26.06.2010
Venue	Physikum in Erlangen
Homepage	`www.ltm.uni-erlangen.de/BTMK/btmk.htm`
Organisation	
Organizers	Prof. Dr.-Ing. Paul Steinmann Prof. Dr.-Ing. Kai Willner
Members	Prof. Dr.-Ing. Antonio Delgado (LSTM) Prof. Dr. Günther Leugering (AM2) Dr.-Ing. Sigrid Leyendecker (CDC, TU Kaiserslautern)



The 39th Bavarian-Tyrolean mechanical colloquium continues the 19-year tradition of the academic institutes for mechanics in Bavaria and Tyrol on the exchange of knowledge in theoretical and applied mechanics. The colloquia started in 1991 and have taken place twice a year at the different participating universities.

The main idea of these colloquia is the presentation of the research field of each institute to the interested academic and industrial auditorium. Therefore, the colloquium provides a forum for presentation and discussion of new ideas regarding computational mechanics, material modeling, theoretical aspects and experiments.

The 39th colloquium gave a general overview of the mechanical activities at the university of Erlangen-Nuremberg organized by the chair of Applied Mechanics. From the field of fluid mechanics the challenge of fluid-structure interaction was presented. Moreover, human finger motions and the dynamical behavior of joints were discussed. Special attention was on the shape optimization of parts as well as of fibers in fiber reinforced composites with respect to the fracture mechanical behavior. Last but not least, computational homogenization via FE^2-simulation was presented.

A further highlight of the colloquium was the visit of the transmission electron microscope Titan^3 of the Cluster of Excellence "Engineering of Advanced Materials" including a demonstration of the microscope.

Talks

- Manuel Münsch (LSTM)
  Fluid-Struktur-Interaktion in turbulenten Strömungen

- Ramona Maas (CDC)
  Über diskrete Mechanik und Optimalsteuerung menschlicher Fingerbewegungen
- Dominik Süß (LTM)
  Untersuchungen zum dynamischen Kontaktverhalten von Fügestellen
- Michael Scherer (LTM)
  Regularisierung von Formoptimierungsproblemen mit Hilfe einer fiktiven Energiezwangsbedingung
- Marina Prechtel (AM2)
  Simulation von Rissausbreitung und Optimierung spröder Verbundwerkstoffe
- Ulrike Schmidt (LTM)
  Parameteridentifikation über mehrere Skalen

4.12 Girls' Day

As every year, aiming to interest young girls in engineering and natural sciences, the Girls' Day (22.04.2010) provided an insight into science and education at the University of Erlangen-Nuremberg. The Chair of Applied Mechanics offered the opportunity to perform interesting experiments in the field of solid mechanics ranging from photoelasticity to finite elements.

4.13 Pupil Information Day

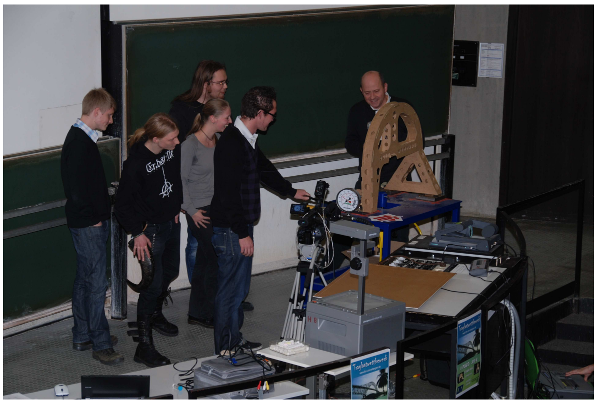
On June 24th the Faculty of Engineering opened its doors for pupils from high schools, which are interested in inside information about studying engineering sciences, natural sciences and computer sciences. The Chair of Applied Mechanics shared in this event and presented an experimental setup for the determination of strains using a contact-free measurement method. This tensile test was performed with one of the chair's fatigue testing machines. Furthermore Prof. Steinmann gave some insight in current research areas at the chair as well as in the course of studies of mechanical engineering.

4.14 Practical Course: Girls' & Engineering / Youth & Engineering

From Monday 6th till Friday 10th of September 2010, the practical course "Girls' & Engineering 2010" (Mädchen & Technik Praktikum 2010) took place at the University of Erlangen-Nuremberg and several non-university research institutes for the 12th time since 1999. This event offers interested high school girls to do some work experience at the university to get some insight in engineering disciplines and to learn more about technics. This year, for the first time, a second practical course "Youth & Engineering 2010" (Jugend & Technik Praktikum 2010) was established, which allows high school boys at the age of 14 until 19, to participate in this special practical training. The chair's experiment, titled 'Stress Analysis of Components', was well received among the youth. This encourages us to participate also next time in this event, which will be taking place in September 2011.

4.15 Ultimate Load Contest - The Student Event

Aiming at attracting the attention of students to chanllenging problems in simulation and design of machinary and construction works, the fourth successful Ultimate Load Contest organized by the Chair of Applied Mechanics took place on the 15th December 2010 in Erlangen. Participated in the event were 20 groups of competing students of all engineering disciplines and nearly 200 spectators. The object of this contest is an optimization problem in applied mechanics: built out of hard masonite and commercial glue, 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. 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.





4.16 Seminar for Mechanics

19.01.2010	Prof. Roger Bustamante, Department of Mechanical Engineering, Universidad de Chile, Santiago, Chile *A variational formulation for a magneto sensitive body interacting with a rigid semi-infinite body, and some restrictions for the total energy function*
25.01.2010	Dipl.-Ing. Fabian Wein, Lehrstuhl für Angewandte Mathematik III / Lehrstuhl für Sensorik, FAU Erlangen-Nürnberg *Introduction to Topology Optimization by the SIMP Method*
01.02.2010	Prof. Ray Ogden, Department of Mathematics University of Glasgow Scotland, UK *Non-smooth solutions in the nonlinear elasticity of fibre-reinforced solids*
15.02.2010	Prof. Anja Schlömerkemper, Department Mathematik, FAU Erlangen *Stress-induced phase transformations in shape-memory polycrystals*
02.03.2010	Dr. Enrico Riccardi, Chair of Theoretical Physical Chemistry, TU Darmstadt *Introduction to Molecular Dynamics simulations*
07.06.2010	Prof. Miroslav Grmela, Ecole Polytechnique de Montreal *Contact geometry in multi-scale equilibrium and nonequilibrium thermodynamics*
23.06.2010	Prof. Tikam Chand Gupta, Department of Mechanical Engineering, Malviya National Institute of Technology, Jaipur, India *Modified Shooting Method: Quasi-periodic Response, Instability and Chaos Analysis of a Non-linear Flexible Rotor Ball Bearing System*
16.11.2010	Dr. Frank Wendler, Karlsruhe University of Applied Sciences, IMP & IZBS & KIT, Germany *A phase-field model for twin boundary motion in magnetic shape memory alloys*
14.12.2010	Dipl. -Ing. Sebastian Fillep, Chair of Applied Mechanics, FAU Erlangen, Germany *Microscale modelling and homogenization of fiber structured materials*
21.12.2010	PhD Jiong Wang, Chair of Applied Mechanics, FAU Erlangen, Germany *An analytical study on stress-induced phase transitions in a slender SMA layer*

4.17 Editorial activities

4.17.1 GAMM-Mitteilungen

The GAMM-Mitteilungen (GAMM-Proceedings) are published by Wiley-VCH Verlag, Berlin twice a year (`www.onlinelibrary.wiley.com`).
They are edited by Prof. P. Steinmann

- Volume 33 2010 Issue 1

  Mathematical and engineering approaches to multi-field problems

  Guest-editor

  S. Reese, Aachen

- Volume 33 2010 Issue 2

  PDE-constrained optimization

  Guest-editors

  M. Hinze, Hamburg

  V. Schulz, Trier

4.17.2 Advisory/Editorial Board Memberships

Prof. P. Steinmann

- **Archive of Applied Mechanics**
- **Archives of Mechanics**
- **Computational Mechanics**
- **Computer Methods in Applied Mechanics and Engineering**
- **Computers and Concrete**
- **Computers, Materials and Continua**
- **International Journal of Numerical Methods in Engineering**
- **International Journal of Solids and Structures**
- **International Journal of Structural Changes in Solids**

4.18 Social events

4.18.1 Student summer party

(mk) This year's student summer party took place on 28th of June all around the chair building. Our students were spoiled with franconian bratwurst, steaks, and many more – cooked and fried by chair members. The party was complemented by a fine collection of (mainly local) beers.

some impressions of the student summer party

The summer party is our way to thank all students for their committed work at the chair during the whole year. Altogether, 70 students wrote a thesis, participated in the seminar, or helped for plenty of tutorials for our lectures. Thanks for all this.

4.18.2 Soccer World Cup 2010

The Soccer World Cup in South Africa, the German national team played against Serbia on 18th of June at the Nelson Mandela Bay Stadium in Port Elizabeth. Unfortunately, the game took place during our working hours on Friday afternoon. As solution we arranged a joint (and a little bit extended) lunch break at the Chair's seminar room.

Left: chair members (almost enthusiastic) watching Serbia vs. Germany, right: contest award ceremony: Ulrike Schmidt (organizer) together with the winners Jan Friedrich, Franziska Vogel, Dieter Pausewang and Wilhelm Weber (from left)

Although, we did our very best to support our team by marvelous patriotic make up and team jerseys, Germany lost both: the match 0-1 by a goal by Jovanovic and its best striker, Miroslav Klose by a red card – but as we know this had no big impact on the overall result: German became third and Klose the second best world cup striker ever.
Besides watching the matches, the chair's pools game also helped for the daily procrastination and was therefore very popular. Overall 17 chair members tried to bet the match results with very different degree of success.
Finally, Jan Friederich earned the most points, followed by Wilhelm Weber and Dieter Pausewang. At the additional bet on the world champion, Jan and Wilhelm once again got it right, but also Franziska Vogel betted on Spain as world champion.

4.18.3 Visit of the Bergkirchweih

(us) The staff members visited the Bergkirchweih on Tuesday, the 25th of May. This year we had a reservation at the Erichkeller together with the staff of the student service center. The weather was in our favor, although some protective measures against the sun had to be taken, e.g. sunscreen or sunshade. The variety of foods and beverages offered at the fair nowadays is overwhelming. Gastronomic specialities from all over, but also especially from Franconia can be bought. So everyone could find foods and beverages after his or her taste for lunch. The band "Appendix" played folk music, actors from the theatre of Erlangen performed a short dramatic interlude advertising a satirical show about the FIFA world cup. In the evening "Appendix" played pop and rock cover hits, inspiring the audience to dance and have a great time partying. The visit was a great success in cultivating the colleagueship at the chair.

well-attended Erichkeller

enjoying the food ...

Appendix playing folk music

... the drinks and the music!

5 Talks

1. P. Fischer, J. Mergheim, P. Steinmann. Direct Evaluation of Nonlinear Gradient Elasticity in 2D with C1 Continuous Discretization Methods. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
2. P. Fischer, A. Rajagopal, E. Kuhl, P. Steinmann. Cahn-Hilliard generalized diffusion modeling using the natural element method. First German-French-Russian Symposium on Generalized Continua, Lutherstadt Wittenberg, Germany, 09.- 11.08.2010.
3. S. Germain, M. Scherer, P. Steinmann. On Inverse Form Finding for Anisotropic Materials. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
4. S. Germain, P. Steinmann. Towards form finding for anisotropic materials. IV European Conference on Computational Mechanics, Paris, France, 17.05.2010
5. M. Gerstner, P. R. Schmitt, P. Steinmann. Die Entwicklung der Analytischen Mechanik von Euler, Lagrange und Hamilton anhand von Beispielen. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
6. F. Hauer, K. Willner. Elastic-plastic contact simulation using halfspace theory. IV European Conference on Computational Mechanics, Paris, France, 18.05.2010
7. F. Hauer, K. Willner. Normal contact simulation of non-Gaussian fractal surfaces. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
8. A. Javili, P. Steinmann. Computational Mechanics of Solids with Boundary Energies. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
9. A. Javili, P. Steinmann. Computational Mechanics of Solids with Boundary Energies. IV European Conference on Computational Mechanics, Paris, France, 20.05.2010
10. M. Karl, W. Winter, F. Graef, M.G. Wichmann, T. Krafft. Determination of alveolar bone quality during dental implant surgery by means of compressive testing. 6th World Congress of Biomechanics, Singapur, 01. - 06.08.2010.
11. M. Kraus, P. Steinmann. Polyhedral Finite Element Formulations for 3d Elastic Continua. 9th World Congress on Computational Mechanics, Sydney, Australia, 19.07.2010
12. J. Mergheim. Crack propagation with the variational multiscale method. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
13. J. Mergheim. A variational multiscale approach to the simulation of crack propagation. 2nd German Japanese Workshop on Computational Mechanics, Yokohama, Japan, 28.-29.03.2010
14. J. Mergheim. Multiscale simulation of the curing of particle-filled polymers. 5th Multiscale Materials Modelling, Freiburg, Germany, 04.-08.10.2010

15. J. Mergheim. Simulations in Continuum Mechanics, Tutorial. EAM-Symposium, Kloster Banz, Bad Staffelstein, Germany, 16.-19.11.2010.

16. S. Pfaller, P. Steinmann. Coupling particle based and Finite Element simulations using bridging domain methods. IV European Conference on Computational Mechanics, France, Paris, 17.-21.05.2010

17. S. Pfaller, P. Steinmann. Towards Multiscale Modeling of Polymers. 9th World Congress on Computational Mechanics, Sydney, Australia, 19.-23.07.2010

18. M. Scherer, P. Steinmann. Towards node-based shape optimization: a fictitious energy constraint. 4th European Conference on Computational Mechanics, Paris, Frankreich, 16.05.-21.05.2010.

19. M. Scherer, P. Steinmann. Regularisierung von Formoptimierungsproblemen mittels einer fiktiven Energienebenbedingung. 39. Bayerisch-Tirolerisches Mechanik Kolloquium, Erlangen, Deutschland, 26.06.2010.

20. U. Schmidt, J. Mergheim, P. Steinmann. Multiscale Modeling and Parameter Identification. IV European Conference on Computational Mechanics, Paris, France, 20.05.2010

21. U. Schmidt, J. Mergheim, P. Steinmann. Parameteridentifikation über mehrere Skalen. 39. Bayerisch Tirolerisches Mechanik Kolloquium, Erlangen, Germany, 26.06.2010

22. P. Steinmann, W. Winter. Comparing the Lightweight Potential of Different Structure and Material Concepts: Performance Parameters Dependent on Geometry, Materials and Load Case. EAM-Winterschool, Kirchberg, Austria, 22.03.2010

23. P. Steinmann. Recent Progress in the Modelling and Computation of Electro-Active Polymers. IV European Conference on Computational Mechanics, Paris, France, 16-21.05.2010

24. P. Steinmann, S. Ricker, J. Mergheim. Multiscale Computation of Defect-Driving Forces in Failure Mechanics. MUSIC Seminar, Hannover, Germany, 03.06.2010

25. P. Steinmann, A. Javili. Computational Thermomechanics with Boundary Structures.. IUTAM Symposium on Surface Effects in the Mechanics of Nanomaterials and Heterostructures, Beijing, China, 08.-12.08.2010

26. P. Steinmann, G. Possart, M. Hossain. Recent Advances in Modelling and Simulation of Curing Polymer Adhesives. 37th SolMech Conference Warschau, Polen, 06.-10.09.2010

27. D. Süß, J. Geisler, K. Willner. Investigation of dynamic contact phenomena in jointed structures. IV European Conference on Computational Mechanics, Paris, France, 17.-21.05.2010

28. D. Süß, J. Geisler, K. Willner. Investigation of dynamic contact phenomena in jointed structures. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010

29. D. Süß, J. Geisler, K. Willner. Untersuchungen zum dynamischen Kontaktverhalten von Fügestellen. 39. Bayerisch Tirolerisches Mechanik Kolloquium, Erlangen, Germany, 26.06.2010

30. F. Vogel, P. Steinmann. S. Göktepe, E. Kuhl. Application of a Viscoelastic Material Model in Electro-Mechanics. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
31. F. Vogel, P. Steinmann. S. Göktepe, E. Kuhl. Exploring the Nature of Viscous Electro-Active Material. 9th World Congress on Computational Mechanics, Sydney, Australia, 19.-23.07.2010
32. F. Vogel, P. Steinmann. S. Göktepe, E. Kuhl. Theory and Numerics of Viscous Electro-Active Material. IV European Conference on Computational Mechanics, Paris, France, 17.-21.05.2010
33. D.K. Vu, P. Steinmann. Electronic Electro-Active Polymers: Observation, Modellig and Simulation Department of Sensor Technology, FAU Erlangen, Germany, 09.06.2010,
34. D.K. Vu, P. Steinmann Nonlinear electro-elastostatics:theoretical and numerical aspects. 81th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Karlsruhe, Germany, 22.-26.03.2010
35. D.K. Vu, P. Steinmann Nonlinear electro-elastostatics: numerical simulation. Institute of Mechanics, Department of Mechanical Engineering, TU Dortmund, Germany, 14.01.2010
36. K. Willner. Kontaktmechanik – Von Kontakt rauer Oberflächen zur Finite-Element-Diskretisierung. Mechanik-Kolloquium der Universität Siegen, 19.01.2010
37. K. Willner. Kontaktmechanik – Von Kontakt rauer Oberflächen zur Finite-Element-Diskretisierung. Mechanik-Seminar der Universität Karlsruhe, 01.07.2010
38. W. Winter, P. Steinmann, M.G. Wichmann, T. Krafft, M. Karl. Quality of alveolar bone - Structure dependant material properties and design of a novel measurement technique. *6th World Congress of Biomechanics, Singapur*, 01.- 06.08.2010.
39. W. Winter. Angewandte Mechanik in der Zahnheilkunde- Einführung: Was ist Biomechanik? Seminar Zahnklinik 2 der FAU Erlangen-Nürnberg, Lehrstuhl für zahnärztliche Prothetik, 24.07.2010.
40. W. Winter. Angewandte Mechanik in der Zahnheilkunde- Kraftübertragung am Implantat. Seminar Zahnklinik 2 der FAU Erlangen-Nürnberg, Lehrstuhl für zahnärztliche Prothetik., 24.07.2010.
41. W. Winter. Angewandte Mechanik in der Zahnheilkunde- Experimentelle Spannungsermittlung. Seminar Zahnklinik 2 der FAU Erlangen-Nürnberg, Lehrstuhl für zahnärztliche Prothetik, 24.07.2010.

6 Contributions to Journals

1. H.-H. Dai, J. Wang. Instabilities induced by phase fronts coalescence during the phase transitions in a thin SMA layer: mechanism and analytical descriptions. International Journal of Engineering Science, accepted [2010]
2. P. Fischer, J. Mergheim, P. Steinmann. On the C^1 continuous discretization of nonlinear gradient elasticity: a comparison of NEM and FEM based on Bernstein-Bézier patches. International Journal for Numerical Methods in Engineering, Vol. 82(10), pp. 1282-1307, [2010]
3. P. Fischer, M. Klassen, J. Mergheim, P. Steinmann, R. Müller. Isogeometric Analysis of 2D Gradient Elasticity. Computational Mechanics, DOI: 10.1007/s00466-010-0543-8, published online [2010]
4. S. Germain, M. Scherer, P. Steinmann. On Inverse Form Finding for Anisotropic Hyperelasticity in Logarithmic Strain Space. Int. J. of Structural Changes in Solids - Mechanics and Applications Vol. 2 (2), November, pp. 1-16, [2010]
5. M. Hossain, G. Possart, P. Steinmann. A Finite Strain Framework for the Simulation of Polymer Curing. Part II: Viscoelasticity and shrinkage. Computational Mechanics, Vol. 46, pp. 363-375, [2010]
6. A. Javili, P. Steinmann. A finite element framework for continua with boundary energies. Part II: The three-dimensional case.. Comput. Methods Appl. Mech. Engrg., Vol. 199, pp. 755-765, [2010]
7. A. Javili, P. Steinmann. On thermomechanical solids with boundary structures. Int. J. Solids Structures, Vol. 47(24), pp. 3245-3253, [2010]
8. A. Javili, P. Steinmann. A Finite Element Framework for Continua with Boundary Energies. Part III: The Thermomechanical Case Comp. Meth. Appl. Mech. Engnrg., accepted [2010]
9. N. Konchakova, F. Balle, R. Müller, D. Eifler, P. Steinmann. Finite element analysis of an inelastic interface in ultrasonic welded metal/fibre-reinforced polymer joints. Computational Materials Science, DOI: 10.1016/j.commatsci.2010.07.024, published online [2010]
10. M. Prechtel, A. Hartmaier, R. Janisch, P. Leiva Ronda, G. Leugering, P. Steinmann, M. Stingl. Simulation of fracture in heterogeneous elastic materials with cohesive zone models Int. J. Fract., DOI: 10.1007/s10704-010-9552-z, published online [2010]
11. A. Rajagopal, P. Fischer, E. Kuhl, P. Steinmann. Natural element analysis of the Cahn-Hilliard phase-field model. Computational Mechanics, Vol. 46, pp. 471-493, [2010]
12. B.D. Reddy & A.T. McBride. Introduction to finite element analysis and recent developments. Chapter 1. In (A. Patnaik and R.D. Anandjiwala, editors), Modeling and Simulation in Fibrous Materials: Techniques and Applications, Nova Science Publishers, New York, in press [2010]
13. S. Ricker, J. Mergheim, P. Steinmann, R. Müller. A Comparison of Different Approaches in the Multi-Scale Computation of Configurational Forces. Int. J. Fract., DOI: 10.1007/s10704-010-9525-2, published online [2010]

14. M. Scherer, R. Denzer, P. Steinmann. A fictitious energy approach for shape optimization. Int. J. Numer. Meth. Engng, Vol. 82, pp. 269-302, [2010].
15. U. Schmidt, J. Mergheim, P. Steinmann. Multi-Scale Parameter Identification. Int. J. Multisc. Comp. Eng., accepted [2010].
16. P. Steinmann, S. Ricker, E.C. Aifantis. Deformational and Configurational Mechanics of Unconstrained and Cauchy-Born Constrained Atomistic Systems: Implications to Gradient Continua. Archive Applied Mechanics, accepted [2010]
17. J. Wang, H.-H. Dai Phase transitions induced by extension in a slender SMA cylinder: analytical solutions for the hysteresis loop based on a quasi-3D continuum model. International Journal of Plasticity Vol. 26, pp. 467-487, [2010]
18. W. Weber, K. Willner, G. Kuhn. Numerical analysis of the influence of crack surface roughness on the crack path. Engineering Fracture Mechanics, Vol. 77 (11), pp. 1708-1720, [2010]
19. W. Weber, K. Kolk, K. Willner, G. Kuhn. On the solution of the 3D crack surface contact problem using the boundary element method. Key Engineering Materials, in preparation Vol. 454 , pp. 11-29, [2011]
20. K. Willner. Constitutive Contact Laws in Structural Dynamics. CMES Computer Modelling in Engineering and Sciences 48 (2009) pp. 303–336.
21. W. Winter, T. Krafft, P. Steinmann, M. Karl, Quality of Alveolar Bone - Structure Dependant Material Properties and Design of a Noval Measurement Technique. Journal of the Mechanical Behavior of Biomedical Materials, accepted [2010]

Submitted Papers in 2010

1. S. Bargmann, A.T. McBride & P. Steinmann, [2010]
   Models of Solvent Penetration in Glassy Polymers With an Emphasis on Case II Diffusion. A Comparative Review
2. C. Brecher, B. Denkena, K. Großmann, P. Steinmann, A. Bouabid, D. Heinisch, R. Hermes, M. Löser, [2010]
   Identification of weak spots in the metrological investigation of dynamic machine behaviour.
3. A.T. McBride, K.E.W. Penzhorn & B.D. Reddy, [2010]
   Consistency and convergence of SPH derivative approximations.
4. S. Pfaller, G. Possart, P. Steinmann, M. Rahimi, F. Müller–Plathe & M. C. Böhm, [2010]
   A comparison of staggered solution schemes for coupled particle-continuum systems modeled with the Arlequin method
5. M. Prechtel, G. Leugering, P. Steinmann & M. Stingl, [2010]
   Towards optimization of crack resistance of composite materials by adjusting of fiber shapes
6. M. Rahimi, H.A. Karimi-Varzaneh, M.C. Böhm1, F. Müller-Plathe, S. Pfaller, G. Possart & P. Steinmann, [2010]
   Nonperiodic stochastic boundary conditions for molecular dynamics simulations of materials embedded into a continuum mechanics domain

7. P. Steinmann P, [2010]
   Geometrically Nonlinear Gravito-Elasticity: Hyperelastostatics Coupled to Newtonian Gravitation
8. W. Winter, P. Steinmann, S. Holst & M. Karl, [2010]
   Effect of Geometric Parameters on Finite Element Analysis of Bone Loading Caused by Non-Passively Fitting Implant-Supported Dental Restorations

7 Contributions to Proceedings

1. S. Bartle, A.T. McBride and B.D. Reddy. Shell finite elements, with applications in biomechanics. In: *Proceedings of 7th South African Conference on Computational and Applied Mechanics*, (peer reviewed, University of Pretoria, Pretoria, South Africa, 10.-13.01.), 2010.

2. P. Fischer, J. Mergheim, P. Steinmann. Direct Evaluation of Nonlinear Gradient Elasticity in 2D with C1 Continuous Discretization Methods. In:*Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 10, pp. 559-560, DOI: 10.1002/pamm.201010272, published online, 2010.

3. P. Fischer, A. Rajagopal, E. Kuhl, P. Steinmann. Cahn-Hilliard generalized diffusion modelling using the natural element method. In:*Mechanics of Generalized Continua: Proceedings of the Wittenberg conference* (peer reviewed), First German-French-Russian Symposium on Generalized Continua, Lutherstadt Wittenberg, 09.-11.08., accepted. 2010.

4. P. Fischer, J. Mergheim, P. Steinmann. $C1$ continuous discretization of gradient elasticity. In *Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 9, pp. 435-436, DOI: 10.1002/pamm.200910190, published online, 2010.

5. P. Fischer, J. Mergheim, P. Steinmann. $C1$ elements for gradient elasticity. In *Mechanics of Generalized Continua: One Hundred Years After the Cosserats* (peer reviewed), Chapter 29, pp. 279-287, 2010

6. S. Germain, M. Scherer, P. Steinmann. On Inverse Form Finding For Anisotropic Materials. In:*Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 10, pp. 159-160, DOI: 10.1002/pamm.201010072, published online, 2010.

7. F. Hauer, K. Willner. Normal Contact Simulation of Non-Gaussian Fractal Surfaces. In *Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 10, pp. 411-412, DOI: 10.1002/pamm.201010198, published online, 2010.

8. A. Javili, P. Steinmann. A finite element framework for continnua with boundary potentials. In *Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 9, pp. 227-228, DOI: 10.1002/pamm.200910187, published online, 2010

9. M. Klassen, R. Müller, J. Mergheim, P. Fischer, P. Steinmann. Analysis and Application of the Rational B-Spline Finite Element Method in 2D. In:*Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 10, pp. 561-562, DOI: 10.1002/pamm.201010273, published online, 2010.

10. M. Kraus, P. Steinmann. Polygonal finite element formulations for 2d linear-elastic FE problems. In *Proceedings in Applied Mathematics and Mechanics (PAMM)*, Vol. 9, pp. 245-246, DOI: 10.1002/pamm.200910096, published online, 2010.

11. K. Mattias, W. Winter, F. Graef, M. Wichmann, T. Krafft. Determination of alveolar bone quality during dental implant surgery by means of compressive testing. In *IFMBE Proceedings 31* (6th World Congress of Biomechanics., Singapore, 01.-06.09.2010). Berlin, Heidelberg, New York : Springer, 2010, pp. 946-949, 2010

12. H. L. Morrissey, A. T. McBride, H. C. Bowles, B. D. Reddy. The modelling of natural fibre-reinforced composites using a multiscale methodology. In: *Proceedings of 7th South African Conference on Computational and Applied Mechanics*, (peer reviewed, University of Pretoria, Pretoria, South Africa, 10.-13.01.), 2010.

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