Annual Report
2011

Chair of Applied Mechanics
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Prof. Dr.-Ing. Kai Willner
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1 Preface

It is again a good time to look back in order to reflect on the academic achievements and social activities at the Chair of Applied Mechanics. The various summer barbecues, parties and excursions may surely have served as an incentive to fulfil the quite heavy teaching commitments and produce the internationally recognised outputs, but it was of course only the hard work and amazing enthusiasm of all of the member of the Chair that made this possible. This annual report aims to highlight the modus operandi at the Chair of Applied Mechanics at the University of Erlangen-Nuremberg during 2011 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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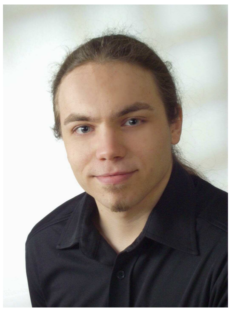
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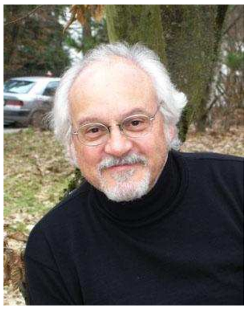
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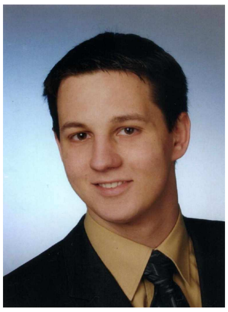
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Student assistants are mainly active as tutors for young students in basic and advanced lectures at the BA- and MA-level. Their indispensable contribution to high quality teaching at the Chair of Applied Mechanics is invaluable, thus financial support from the students enrollment fees as requested at Bavarian universities is gratefully acknowledged.

3 Scientific Reports

The following pages allow a short overview on the various ongoing research projects pursued at the Chair of Applied Mechanics during 2011. These are mainly financed by third-party funding of various (public and industrial) funding sources and are in addition supported by the core support of the university. Topicwise we have a nice mix of continuations of previous projects with projects that started afresh in 2011. Also the complementing expertise as displayed in the three professorships for continuum mechanics, structural mechanics and computational mechanics established at the Chair of Applied Mechanics is reflected by the variety of research that is performed. This spans from atomistic approaches to structural problems, from experimental investigations to computational challenges and from frictional contact to dental mechanics. Of course the research on these topics constantly produces new insights, thus the following reports can only shed a spot-light on the current state of affairs.

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. 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.

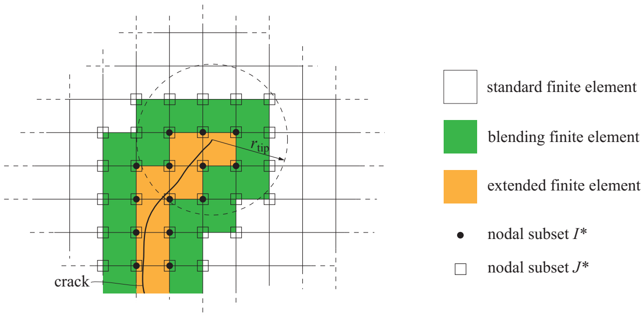

Figure 1: sketch of a partially cracked specimen using extended finite elements

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 extended finite elements. This element type 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:

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

where $\tilde{N}$ is a shape function, ψ is a problem specific function and $\tilde{u}$ are the additional degrees of freedom. Using $\psi^1(r,\theta) = \sqrt{r} \sin\frac{\theta}{2}$, $\psi^2(r,\theta) = \sqrt{r} \sin\frac{\theta}{2} \sin\theta$, $\psi^3(r,\theta) = \sqrt{r} \cos\frac{\theta}{2}$ and $\psi^4(r,\theta) = \sqrt{r} \cos\frac{\theta}{2} \sin\theta$ as enrichment functions for the nodes lying within a radius r_{tip} of the crack tip, the above given equation can be modified as follows:

$$u^h(\mathbf{x}) \quad = \quad \sum_{i \in I} N_i(\mathbf{x}) u_i + \sum_{j=1}^{4} \sum_{i \in J^*_{ct}} \tilde{N}_i(\mathbf{x}) \left[\psi^j(\mathbf{x}) - \psi^j(\mathbf{x}_i) \right] R_{ct}(\mathbf{x}) \tilde{u}_i$$

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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A coupled MD-FE simulation method accounting for interphases in nanoparticle filled thermoplastics

Denis Davydov, Paul Steinmann

This aim of this project is to extend a recently developed hybrid MD-FE simulation scheme [1,2] to describe materials dominated by polymer–solid interphases. Atomistic methods can, intrinsically, resolve the microstructure and mechanical behaviour of interphases. A coarse-grained MD domain, which contains a single nanoparticle and a sufficient amount of polymer to reproduce the bulk behaviour at the boundary, will be coupled to a FE continuum. The continuum domain will account for the interphase between the particle and polymer using a surface energy in the sense of Gibbs. Material parameters will be optimised so that the continuum model's predictions agree (in a least-squares sense) with those from the atomistic simulations.

In order to bridge the gap between particle-based models (MD) and continuum approaches, as well as to enhance the MD-FE simulation scheme, a corpuscular approach to continuum mechanics is considered [3]. Continuous mass and momentum densities, ρ and P respectively, are defined using a spatial kernel function $\omega(x)$ as follows:

$$\rho(x,\tau) \equiv \sum_{\alpha} m^{\alpha}\ \omega\left(x^{\alpha}(\tau) - x\right)$$

$$P(x,\tau) \equiv \sum_{\alpha} m^{\alpha} v(\tau)\ \omega\left(x^{\alpha}(\tau) - x\right)\ .$$

This elegant approach allows us to derive the continuum balance equations and calculate the appropriate continuum fields; in particular the stress state which can be used to benchmark the performance of the FE-MD coupling method. The approach also allows a comparison of the MD and surface-energy-enhanced FE solutions for selected benchmark problems. The methodology outlined above is applicable to polymers at non-zero temperatures.

Aside from the surface energy effects, the internal strain state may be of significant importance for polymeric materials. This will be addressed using generalised continuum theories, e.g. micromorphic theory [4].

Once the continuum model is capable of describing the atomistic simulation, different homogenisation techniques will be applied to the nanoparticle composite.

The financial support of the German Science Foundation (Deutsche Forschungs-gemeinschaft, DFG) , grant STE 544/46-1, is gratefully acknowledged.

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Towards molecular simulation of ferroelectric materials

Florian Endres, Paul Steinmann

In the past few years molecular models for the simulation of ferroelectric materials have been developed further and are able obtain accurate results for atomistic level simulations. These models such as the core-shell model calculate all different interactions in a ferroelectric crystal like, e.g., barium titanate. However, applications on systems with macroscopic length scales are limited by the complexity of such simulation models. Especially the computational intensive pre- and post- processing in order to calculate electrostatic forces, electric fields and electric potentials between charged particles are disadvantages for most calculation algorithms. The aim of this project is the development of a new algorithm to highly reduce pre- and post- processing costs. Every particle has three translatoric degrees of freedom. In order to admit easy applications of electric boundary conditions a fourth degree of freedom, which is represented by the electric potential φ of a particle, is necessary. The quasi-static balance of forces is represented by

$$\boldsymbol{f}_i^{int} = \boldsymbol{f}_i^{ext} \quad \text{with} \quad \boldsymbol{f}_i^{int} = \sum_{j \in \mathcal{N}_a} \Big[\boldsymbol{f}_{ij}(\boldsymbol{r}_i, \boldsymbol{r}_j) + q_i^{int} \boldsymbol{e}_{i(j)}(\boldsymbol{r}_i, \varphi_i, \boldsymbol{r}_j, \varphi_j) \Big] .$$

The calculation of an internal particle charge is a result of Gauss's law and the analogy to a network of capacitors

$$q_i^{int} = q_i^{ext} \quad \text{with} \quad q_i^{int} = \sum_{j \in \mathcal{N}_a} c_{ij}(\boldsymbol{r}_i, \boldsymbol{r}_j) \varphi_{ji}.$$

The electric potential difference between two particles is represented by $\varphi_{ij} = \varphi_j - \varphi_i$.

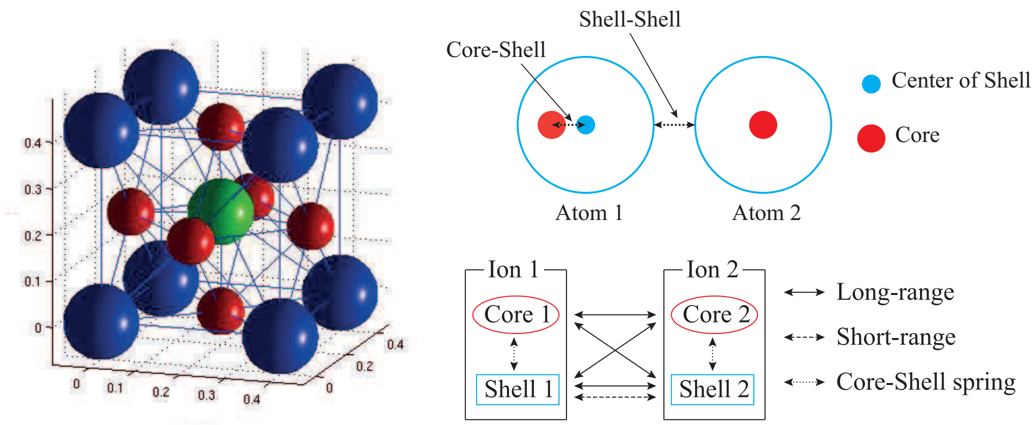

Figure 1: Barium titanate and core-shell model interactions

The results of the novel algorithm agree with classical algorithms for simple atomistic level simulations. In a next step more complex molecular systems and models like, e.g., the core-shell model will be simulated with the new algorithm. Especially polarization processes and electric boundary conditions will be discussed.

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Modeling and homogenization of technical textiles

Sebastian Fillep, Julia Mergheim, Paul Steinmann

The consideration of material behavior at different length scales is essential for understanding the sources of physical phenomena that are responsible these properties. This allows to realize the development of appropriate constitutive laws. Feasible homogenization techniques permit to construct reliable scale transitions between the connected levels. The basic method for homogenization is to cover the macroscopic constitutive behavior of the heterogeneous material by a appropriate micro scale representative volume element (RVE) [1]. By employing the RVE it is possible to create phenomenological material laws based on physical principles.
Technical textiles conform to that description of materials with a nonlinear behavior that differs from the underlying fiber material and relies on heterogeneities on the micro level (Fig. 1). The macroscopic constitutive condition is strongly influenced by the structural assembly of the fibers. The arising micro structural contact zones between the fibers result in nonlinear material behavior.
Intrinsically the macroscopic textile problem with its small thickness can be considered as shell structures. To capture the micro structural contact behavior a volumetric micro sample has to be introduced [2]. Therefore a shell specific energy averaging theorem is established that deals with work conjugate quantities which are used on both scales to describe the transitions.

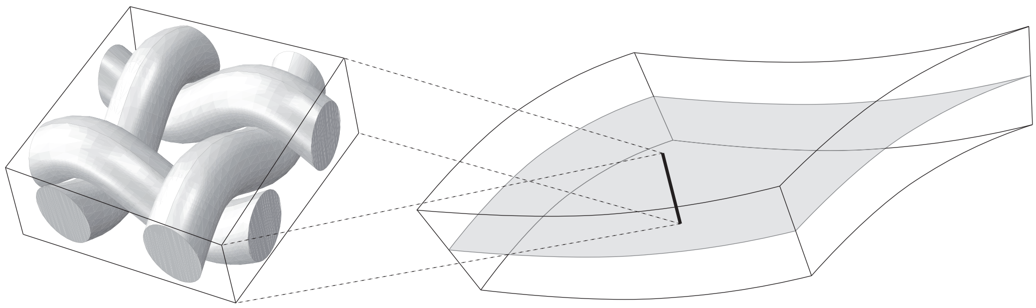

Figure 1: Identification of a volumetric RVE and connection to a macroscopic shell structure.

For these scale transitions deformation boundary conditions have to be obtained [3]. For a physically correct approximation periodic boundary conditions are chosen which need a periodical continuance of the structure. A homogenization framework is derived which connects the macroscopic shell to a microscopic continuum.

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Adaptive h-refinement based on topological sensitivities on finite element meshes

Jan Friederich, Günter Leugering, Paul Steinmann

Improvement of finite element approximations can be achieved by – among other methods – local refinement of elements, for instance based on refinement indicators like element-wise a posteriori error estimators (h-adaptivity), or by optimal positioning of nodes while keeping the connectivity of the mesh fixed (r-adaptivity). The latter approach can be pursued by solving an optimization problem for nodal coordinates: in particular, for linear second-order elliptic problems, it can be easily shown that minimization of the total potential energy w.r.t. node positions decreases the approximation error in the energy norm, cf. [1-2] and references therein. In [2], sensitivies for this objective have been derived by means of the speed method known from shape optimization.
We propose to extend the framework of [2] towards adaptive h-refinement by deriving sensitivities for minimization of a given objective function w.r.t. topological changes within the finite element mesh. Inspired by the results of [3] on topological derivatives on graphs, we consider the insertion of new nodes (and hence edges and elements) as a continuous operation, namely by splitting nodes along edges. The sensitivity of the objective function w.r.t. the topological change can then be derived by asymptotic analysis of the linear system that arises from the Galerkin approximation on the perturbed mesh. In special cases, the same result can also be obtained by employing a well-known relation between the topological derivative and the shape derivative, i.e. by calculating certain singular limits of the sensitivities for node movement that have been derived in [2].
Finally, the absolute value of the topological sensitivity is used for the definition of an element refinement indicator. First results for Poisson's equation in dimension $d = 1$ lead to similar expressions as known from the classical residual-based refinement indicator. Numerical studies show that this new approach is indeed competitive, see Fig. 1.

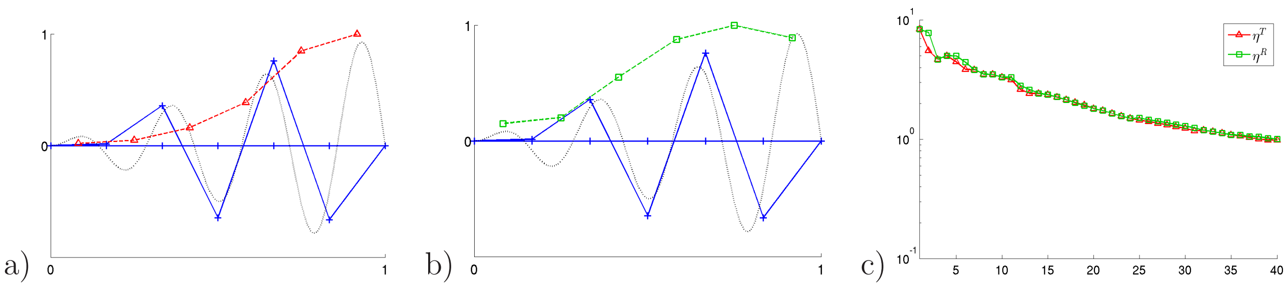

Figure 1: Numerical comparison in dimension $d = 1$ for $-u_{xx} = a\sin(bx)$, $u(0) = u(1) = 0$ on a coarse discretization: a) topological refinement indicator, b) residual-based refinement indicator. c) H^1 error history after a series of refinements.

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On inverse form finding for elastoplastic materials

Sandrine Germain, Paul Steinmann

A challenge in the design of functional parts in sheet-bulk-metal forming processes is the determination of the initial, undeformed shape such that under a given load a part will obtain the desired deformed shape. Two numerical methods might be used to solve this problem, which is inverse to the standard kinematic analysis in which the undeformed shape is known and the deformed shape unknown.

The first method deals with the formulation of an inverse mechanical problem, where the spatial (deformed) configuration and the mechanical loads are given. Hence the objective is to find the inverse deformation map that determines the (undeformed) material configuration. This formulation can be applied in elastoplasticity if the plastic strains are previously given [1].

The second method deals with shape optimization that predicts the initial shape in the sense of an inverse problem via successive iterations of the direct problem. In [2] a nodes-based shape optimization approach for anisotropic elastoplastic materials based on logarithmic strains is presented. As a novelty regarding to [2] an update of the reference configuration was added to the shape optimization formulation in [3] to avoid mesh distortions, which often occur in nodes-based optimization problems.

A simplified deep-drawing is simulated [3], where no contact between the workpiece and the tool are taken into account. Fig. 1 shows the deformed shape in the spatial configuration. Fig. 2 shows the computed undeformed shape in the material configuration. The von-Mises stresses on Fig. 1 are plotted after computing the direct mechanical problem considering the computed undeformed shape (Fig. 2) as input.

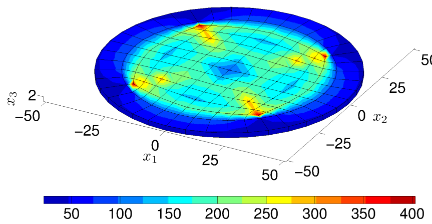

Figure 1: Simplified deep-drawing: Deformed shape in the spatial configuration with von-Mises stresses.

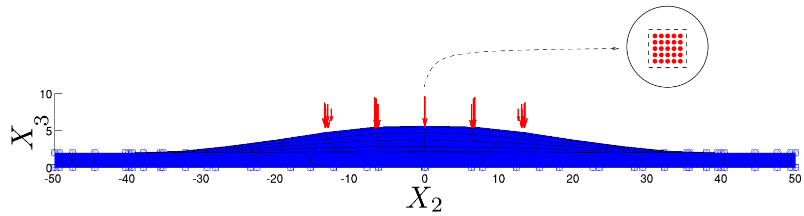

Figure 2: Simplified deep-drawing: Computed undeformed shape in the material configuration.

This work is supported by the German Research Foundation (DFG) within the Collaborative Research Centre SFB Transregio 73: "Manufacturing of Complex Functional Components with Variants by Using a New Sheet Metal Forming Process - Sheet-Bulk Metal Forming".

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Halfspace Modelling of Elastic-Plastic Contact of Rough Surfaces

Franz Hauer, Kai Willner

Friction has a significant influence on manufacturing processes. The aim of this research project is the simulation of the contact between tools and workpieces in metal forming processes and eventually the identification of a friction law based on the simulation results. Real surfaces are always rough, so that for moderate loads contact occurs only at surface roughness peaks. Thus the real contact area A_{real} is smaller than the apparent contact area A_0. Adhesive forces, which are an important contribution to friction, can only be transferred within A_{real}. Consequently A_{real} has to be determined in order to analyse the tribological behaviour of a surface. The halfspace approach is used because of its advantage in numerical effort compared to the Finite-Element-Method. The plastic deformation of roughness peaks has to be taken into account due to the fact that the local contact pressures can be very large. Therefore a plasticity algorithm is implemented into the halfspace model [1]. The pressure distribution and the displacement field on the surface are calculated with an elastic halfspace model [2]. The bulk underneath the contact is discretised into cuboids. The stresses within the cuboids due to pressure on surface segments are calculated via analytical influence functions. When the equivalent stress in a cuboid exceeds the yield strength of the material plastic strains are calculated. These plastic strains lead to residual stresses within the bulk, which are as well calculated by means of influence functions [3]. The residual stresses and the elastic stresses are superposed and the calculation of plastic strains is repeated with the superposed stresses. Plastic strains in the bulk cause a deformation of the surface, which changes the geometry and pressure distribution of the contact. Therefore the surface shape is updated with the residual surface displacements and the contact is recalculated iteratively until convergence is obtained. The figure below shows the load-area-curve for an elastic and an elastic-plastic simulation. There is no plastic deformation at low contact pressure, though at higher contact pressure there is a growth of the real contact area due to plastic deformation.

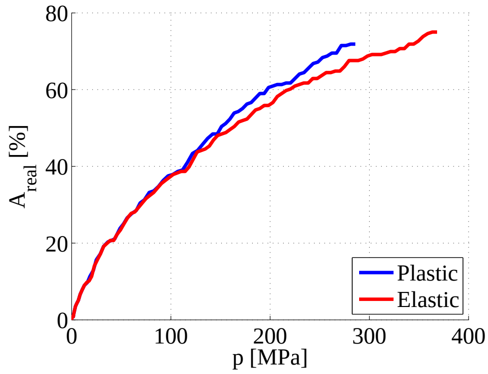

Figure 1: Load-area-curve

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VHB 4910 polymer: Experiments, modelling and validation

Mokarram Hossain, Duc Khoi Vu, Paul Steinmann

In recent years, there is a growing interest in the so-called electronic electro-active polymers (EEAPs) that exhibit electro-mechanical coupling behaviours. EEAPs have a great potential in developing artificial muscles, where actuators made of EEAPs are used. EEAP actuators are made by placing a thin film that is sandwiched between two electrodes and then exposed to a sufficiently high potential difference which creates Maxwell forces between the electrodes, i.e. a mechanical output is the resultant due to electric stimuli [1]. VHB 4910, an acrylic polymer, is an important polymeric material widely used in the fabrication of EEAP actuators. The mechanical behaviour of such acrylic elastomer is typically viscoelastic and is characterized by few standard large strain experiments, e.g. cyclic loading, single- and multi-step relaxations under force and strain control loading conditions [1,2]. The experimental data obtained in such mechanical tests are prerequisite for identifying constitutive model parameters as well as validation and simulation procedures for electromechanical coupling appearing in EEAP actuator simulation.

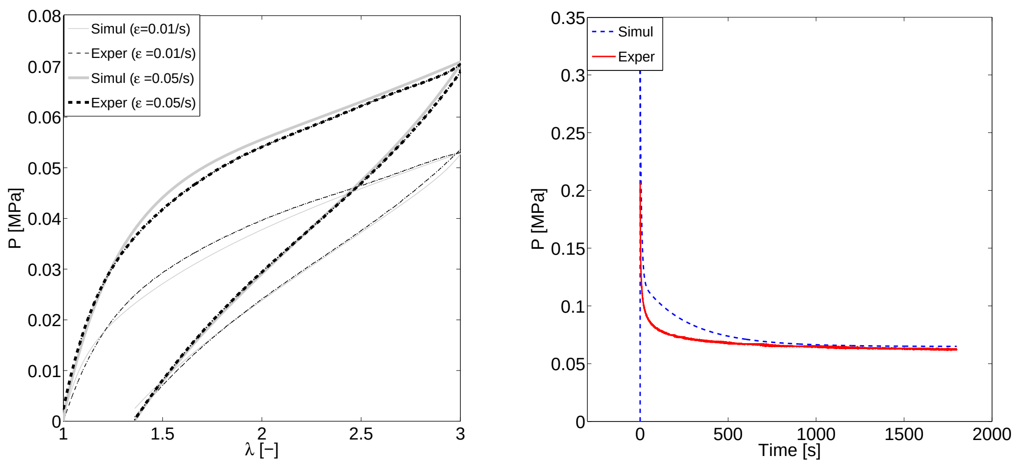

Figure 1: Cyclic tests at strain rates of 0.01/s and 0.05/s; Experimental data and fitting with the 8-chain viscoelastic model (**left**). Single-step relaxation test for validation of the model with data not used in the parameter identification (**right**)

In this contribution, the micromechanically-inspired chain models are applied to model the viscoelastic behaviours of VHB 4910; then corresponding material parameters are identified from experimental data. The micromechanically-motivated constitutive approach will be extended towards modelling the electric influence as a coupled problem where the material parameters identified by the mechanical tests will be pivotal. The proposed electro-mechanical coupled constitutive framework will be validated with experimental data.

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Thermomechanics of continua with surface energies

Ali Javili, Paul Steinmann

Although surface effects can play a dominant role in material behavior, the common modeling in continuum mechanics takes exclusively the bulk into account, nevertheless, neglecting possible contributions from the surface. Surfaces of bodies, in general, exhibit properties different from those associated with the bulk. Due to the large surface to volume ratio at the nanoscale, the surface role becomes particularly important in nanomaterials behaviors. These effects could phenomenologically be modeled in terms of surfaces equipped with their own potential energies which dates back to Gibbs. Such phenomena can also be modeled in terms of the surface elasticity theory of Gurtin-Murdoch. Motivated by this idea, the surface is equipped with its own thermodynamic life, i.e. we assume separate surface energy, entropy and the like. Afterwards the balance equations are generalized to include the surface contributions for thermomechanical continua, see [1]. Within this robust framework it is also possible to study the coupling to other fields, for instance the coupling to diffusion is studied in [2]. Equipped with the strong forms of generalized balance equations, the corresponding weak forms are derived which provide a suitable framework for finite element implementation, see [3].

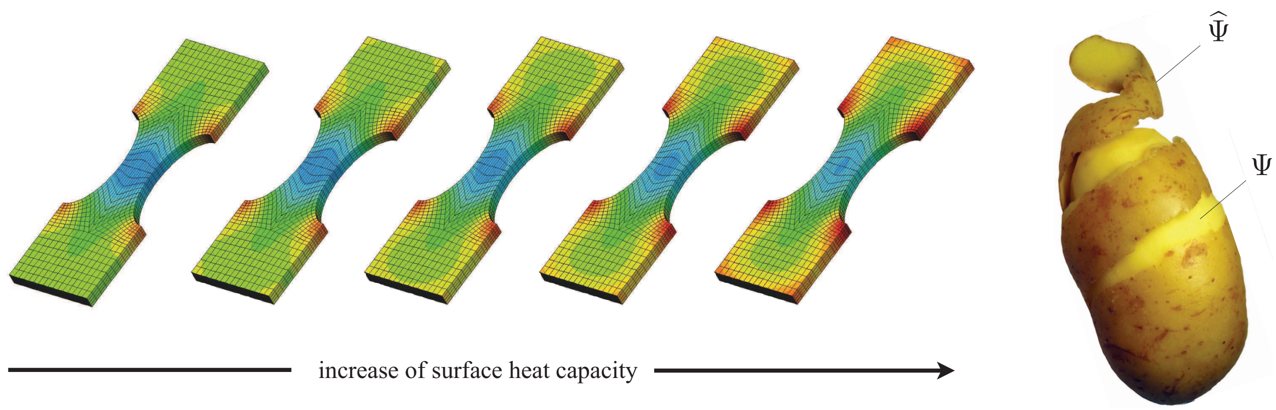

Figure 1: Temperature distribution for a strip endowed with surface energy and illustration of free energies Ψ and $\widehat{\Psi}$ assigned to the bulk and the surface, respectively.

Consider a homogeneous strip in plane strain subject to a prescribed displacement at the edges. The tensile stress cools down the specimen due to Gouph-Joule effect and the corresponding temperature profile for different values of surface heat capacity is illustrated in Figure 1.

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Investigations on the polygonal finite element method

Markus Kraus, Paul Steinmann

For polygonal finite elements, the general balance of linear momentum of elastic continua,

$$\int_{\Omega} \delta\boldsymbol{\varepsilon}(\boldsymbol{\eta}) : \boldsymbol{\sigma}(\mathbf{u})\; da - \int_{\Omega} \rho\,(\mathbf{b} - \mathbf{v}) \cdot \boldsymbol{\eta}\; da - \int_{\Gamma_\sigma} \bar{\mathbf{t}} \cdot \boldsymbol{\eta}\; ds \overset{!}{=} 0,$$

retains validity, where the trail and test functions $\mathbf{u}$ and $\boldsymbol{\eta}$ are linear combinations of the element's nodal interpolation functions ϕ^I and its nodal values.
The numerical integration can be obtained e.g. by a simple splitting of the polygonal domains into triangular subdomains with subsequent use of classical Gaussian quadrature. Otherwise, the most important key for polygonal (and polyhedral) finite elements is the avail- and reliability of the interpolation functions ϕ^I. Recently, various types of conforming polygonal interpolants applicable to both convex and concave elements were implemented and investigated with numerical examples [1,2]. A displacement patch test was performed on randomly generated meshes (see Figure 1), on which stochastical evaluations regarding several test parameter settings including the characteristic mesh length, mesh distortion and chosen interpolant were made. Besides the consistency ot the implementations, we particularly showed the robustness of the formulations against mesh distortions and higher fraction of high order polygonal elements. As application in two dimensional elasticity a plate with a circular hole was meshed by a constrained adaptive Delaunay tessellation and a uniform tension was imposed. The simulations showed that the polygonal finite elements gives accurate and robust results for both the stress and the displacement field.

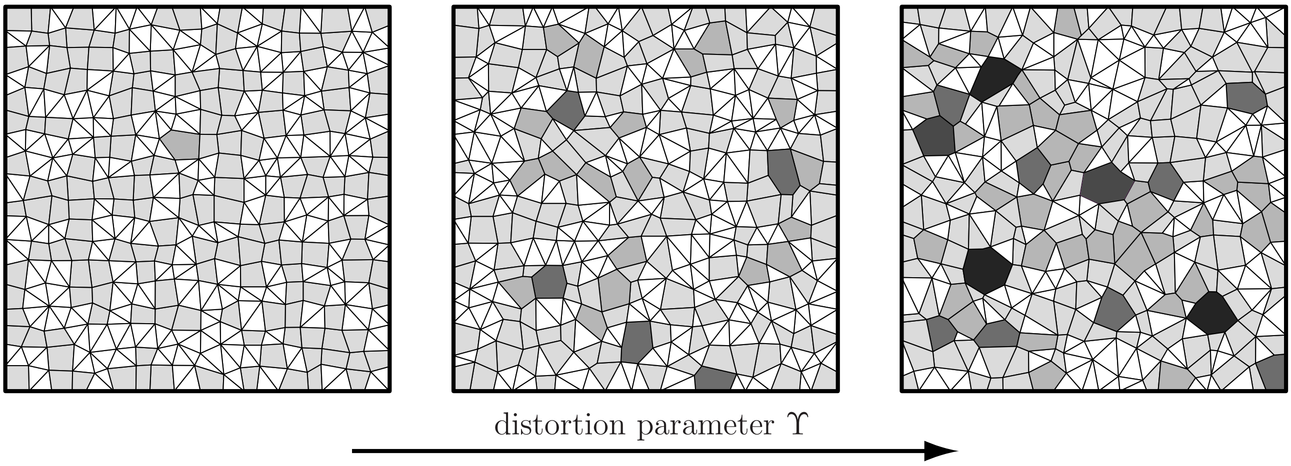

Figure 1: random polygonal element meshes created by ADT: uniformly distributed initial seed nodes are distorted (distortion parameter Υ) and then merged to polygonal elements (color indicating the node number per element)

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Analysis of the lamination stack influence onto the damping and stiffness of armature and stator active components

Vera Luchscheider, Kai Willner

For electric motors light weight construction becomes increasingly important. This leads to new problems in calculating the vibrational behavior because the unidentified influence of the lamination stack grows. For this reason the stiffness and damping parameters shall be analyzed in this project. In a first step, quasi-static tests are performed and a model of the static load-displacement behavior of the lamination stack will be developed and identified. Subsequently, the procedure will be extended to dynamic behavior.

In the first quasi-static tests the electric sheets are just stacked and an axial load is applied. Pressures of $1.5\,\mathrm{N/mm^2}$ and $3\,\mathrm{N/mm^2}$ are used, representing typical loads of the packaging process. The measured load-displacement curve shown in figure 1 exhibits strong progressive behavior and a settling can be observed. It is supposed that the settling is a result of the waviness of the sheets, which is a result of the rolling process.

In figure 2 there is the load-displacement curve, were a packaging load of $3\,\mathrm{N/mm^2}$ is applied and subsequent a triangular load of $1\,\mathrm{N/mm^2}$ is overlayed. Now the effect of the relaxation also can be observed. The coreplate varnish of the sheets, of which the mechanic characteristic is unknown, has also a big influence on the package behavior. For modeling the coreplate varnish and the contact behavior rheological models of coupled springs, dampers and frictional elements will be employed. The hysteresis can then be modelled with frictional elements. The characteristic of at least one spring is nonlinear and is correlating with the distribution of the heights of the surfaces roughness [1,2]. After building the model for the axial loading, experiments examining the tangential behavior of packaged sheets will be performed.

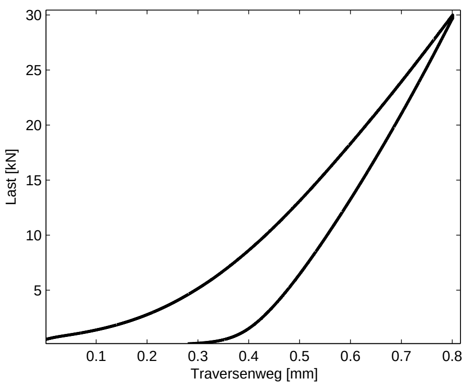

Figure 1: quasi-static cyclic load

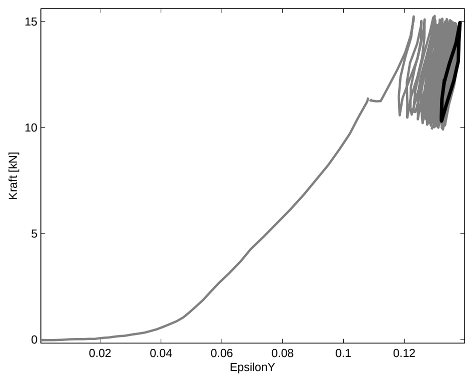

Figure 2: quasi-static load with overlayed cyclic load (black: the hysteresis of one cyclic load)

This project is a cooperation with Siemens AG.

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Non-Classical Diffusion: Theory and Computation

Andrew McBride, Paul Steinmann, Swantje Bargmann

This project concerns the anomalous diffusion of a low molecular weight solvent within a polymeric solid, coined case II diffusion (see our review [1]). The presence of the solvent causes the polymer to undergo a transition from its initial glass-like state to a rubber-like one. 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. The ability to model such behaviour is motivated by industrial applications, e.g. the production of electrical circuits.

Based on the conclusions of [1], a thermodynamically-consistent continuum model for coupled heat conduction, species diffusion, inelastic processes, and finite deformations was developed in [2]. The choice of the Helmholtz energy that specialises this general structure to capture the key features of case II diffusion was presented. This general model allows case II diffusion to be distinguished from standard coupled diffusion and deformation.

Two important aspects to consider when modelling case II diffusion are the interface and the surface of the body. The behaviour of the system at the surface exposed to the solvent is distinct from that in the bulk. Our contribution in [3] was to develop the equations governing the response of a continuum body with a surface possessing its own Helmholtz energy. Motivated by the phenomena of case II diffusion, the framework for a Helmholtz energy that accounts for finite thermo-inelasticity coupled to diffusion and mixing was also described.

Configurational mechanics describes the energetic (configurational) changes that accompany a variation of the initial configuration of a continuum. Configurational mechanics is thus ideally suited to describe the role of interfaces. In our contribution [4] we considered the coupled problem of heat conduction and species diffusion within an inelastic continuum intersected by a coherent interface undergoing finite deformations.

Limited work exists currently on a multi-scale approach for case II diffusion even though the key-processes clearly occur at the microscopic scale. This motivated our work on a framework wherein the underlying microstructure of a layer (interface) within a continuum body is described using computational micro-to-macro transitions. The framework and numerical results have recently been submitted.

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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Modeling of curing and damage in thermosetting adhesives

Julia Mergheim, Gunnar Possart, Paul Steinmann

This contribution introduces a continuum mechanical model suited to describe the emergence of stresses and a possible corresponding initiation of material degradation in adhesive layers, both during the process of curing and, of course, during subsequent loading. A previously developed small strain curing model [1] has been extended with a gradient enhanced damage formulation [2,3]. Various numerical examples demonstrate the complex interplay between curing shrinkage, stress and damage evolution and the consequences for the strength of adhesive joints.

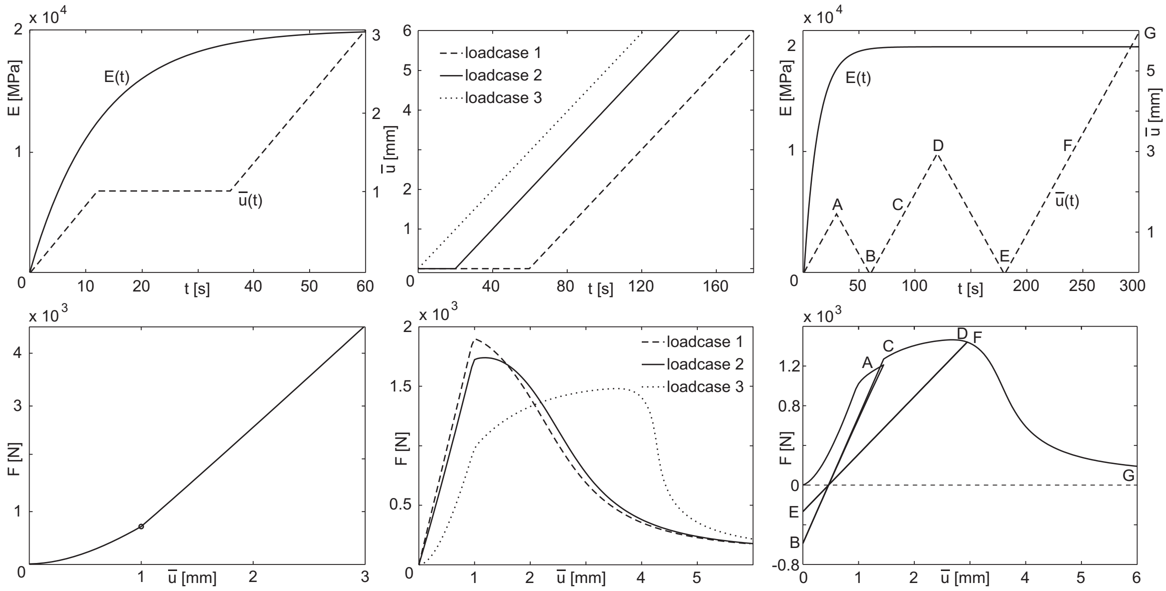

Figure 1: 1-D bar. **left:** Curing without shrinkage/damage: deformation/stiffness (top), response (bot). **center:** Curing & damage without shrinkage: deformations (top), responses (bot). **right:** Cyclic test: deformation/stiffness (top), response to loading/unloading (bot).

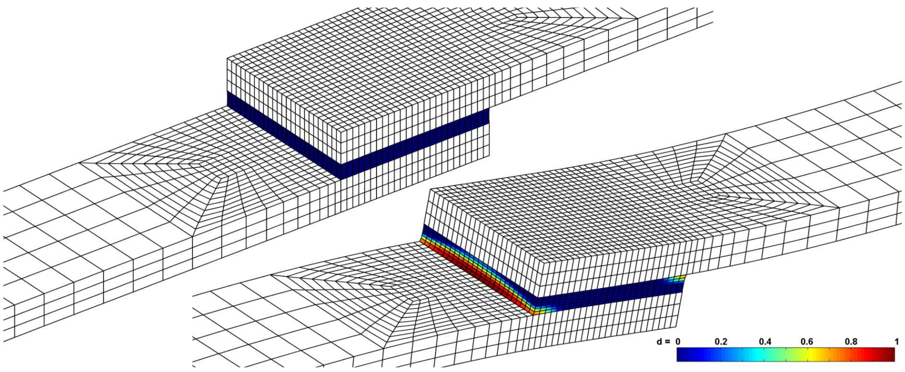

Figure 2: Single lap shear test: deformation and damage after curing with 3% shrinkage and loading

References

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

Sebastian Pfaller, Paul Steinmann

Many material properties are caused by the atomistic structure of matter which necessitates certain simulation techniques: in contrast to continuum mechanics that usually treats matter as homogeneous, particle based approaches offer a deeper insight into the material and allow to take into account effects on the level of atoms or molecules. Usually, Molecular Dynamics (MD) or Monte Carlo (MC) solution techniques are applied to model such particle systems. In our approach, 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).

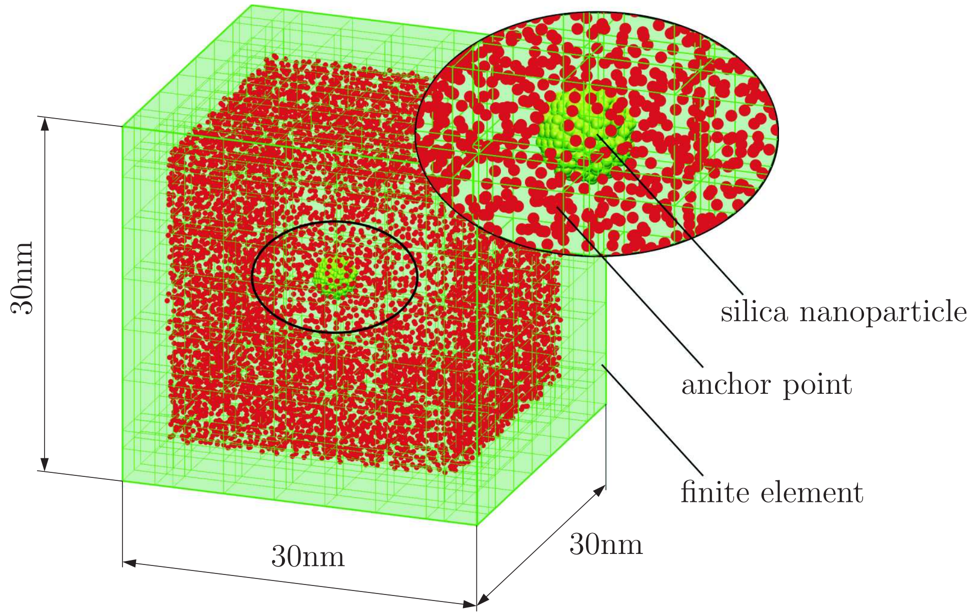

Figure 1: Coupled system consisting of a FE domain (green) and a particle domain (red), containing a nanoparticle (yellow)

Within the European project "NanoModel" and a very close cooperation with the Theoretical Physical Chemistry Group at the Darmstadt University of Technology, a coupling algorithm of FE with MD has been developed, implemented and tested. The most important application of this procedure is the simulation of polymers filled with nanoparticles, cf. Figure 1: a FE domain consisting of 729 elements is coupled to a coarse grained simulation of filled polystyrene (PS) with approx. 80,000 super atoms. Numerical results show the suitability of this method.

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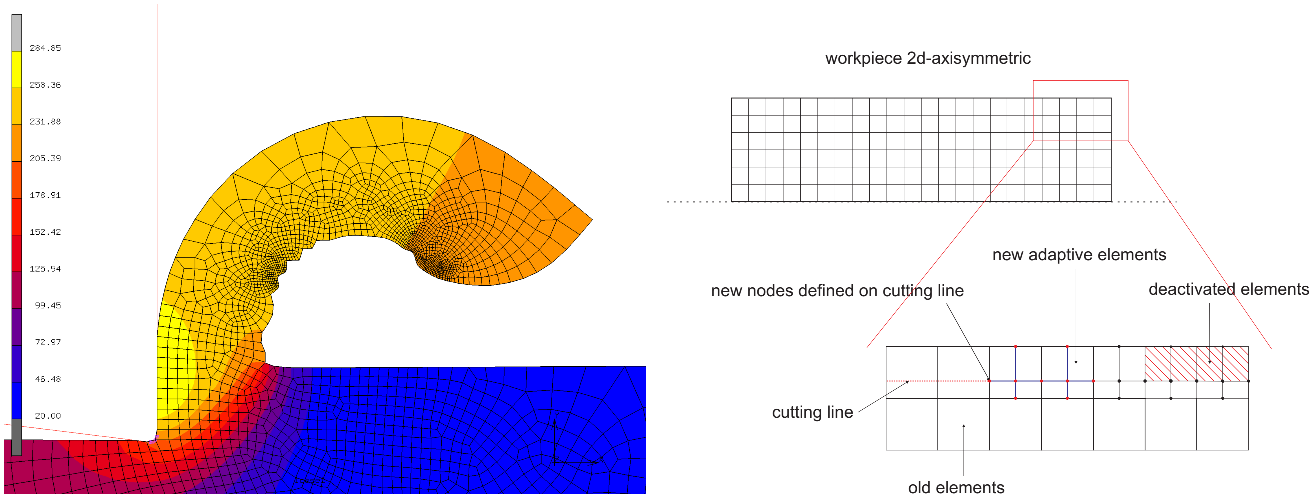
Modelling and Simulation of thermal influences in turning process

Stefan Schindler, Paul Steinmann

To optimize the turning process it is necessary to know the thermal influences and to compensate them. Especially the thermal expansion causes unwanted deviations in dimension. To solve this problem, the whole process is split into two models, a local model of the chip formation process (figure 1a) and a global model of the whole workpiece (figure 1b).
In the local model the heat generation due to inelasticity and friction is represented. The chip formation is actually a plastic deformation with large strains at high strain rates. Therefore coupled thermal-mechanical analyses under finite strain are used. To take into account strain-dependent and strain-rate-dependent hardening as well as thermal softening, the Johnson-Cook material model [1] is used. To handle the excessive deformations and strains and to permit the material separation a continuous remeshing technique is required. The output of this local model is the heat flux into the workpiece and the cutting forces.
In the global model the temperature distribution and the elastic strains are computed. Therefore the output of the local model, the heat flux and the cutting forces, are applied as boundary conditions. The material removal is realized by element deactivation. All these boundary conditions are dependent on time and position and can be controlled by the original NC-code of the turning machine. As mentioned above the thermal expansion as well as the elastic strains cause unwanted deviations. To reproduce these correctly an adaptive remeshing technique is used. In each time step the elements to be deactivated are divided into four new elements, whos newly created nodes are defined on the current cutting line. Afterwards the elements above the cutting line are deactivated and the heat flux and cutting forces are applied to the elements underneath.



(a) chip formation (b) adaptive remeshing

Figure 1: Local (a) and global (b) model of the turning process

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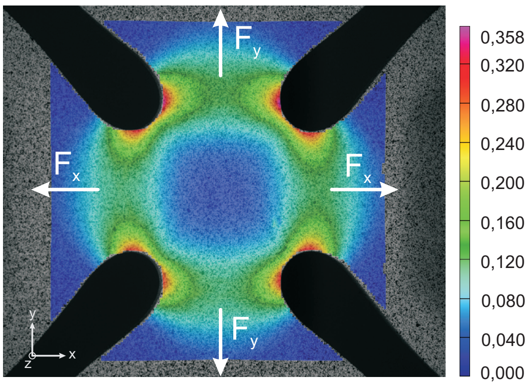
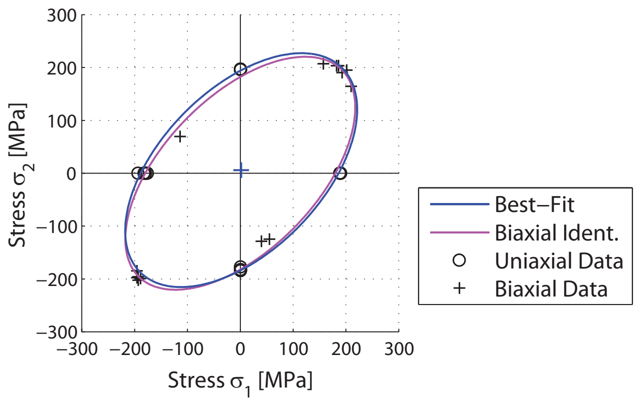
Parameter identification for sheet steel via DIC and FEMU

Stefan Schmaltz, Kai Willner

Reliable numerical simulations of complex forming processes, as deep-drawing and sheet-bulk-metal forming, are based on potent material models with proper material parameters. As multiaxial load states occur in these forming processes and as sheet metal shows anisotropic behaviour, several different experiments have to be performed to get the material parameters. To reduce the experimental costs a numerical identification procedure is set up.
Biaxial tensile experiments are performed where the displacement is recorded with a full-field measurement system. Via Digital Image Correlation (DIC) the full-field strain data is calculated at certain load levels, see Fig. 1a. As identification procedure Finite Element Model Updating (FEMU) [1] is chosen. Therefore the experimental setup is modelled in a Finite Element software tool.
The identification procedure is controlled through an optimisation algorithm. A Finite Element simulation is started with a pre-defined set of initial parameters. At a certain subset of the nodes, the optimisation points, the numerically and experimentally determined displacements are processed by the objective function. To verify the convergence of the procedure to a global minimum, a gradient-free and a gradient-based optimisation algorithm and several sets of initial parameters are taken [2].
In this case the variational parameters are the four coefficients for the plane stress Hill 1948 initial yield surface. Fig. 1b shows the numerically identified Hill 1948 yield surface compared to the Best-Fit ellipsis. The Best-Fit curve is a general ellipse equation which is fitted to the initial yield values determined through several different types of experiments.
By performing biaxial tensile tests and executing a numerical parameter identification process via FEMU very well fitting material parameters are found.



(a)



(b)

Figure 1: (a): Experimental principal strain field [-] ($F_x = 10.6\,\mathrm{kN}$; $F_y = 10.8\,\mathrm{kN}$); (b): Identified yield surface.

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Multi-scale modeling of heterogeneous materials

Ulrike Schmidt, Julia Mergheim, Paul Steinmann

The macroscopic behavior of microscopically heterogeneous material can efficiently be described by multi-scale modeling. Based on geometry, material model and parameters of the microscopic structure, a homogenized stress-strain-relation can be calculated and thus the macroscopic response. The corresponding inverse problem is finding the best fitting micro material parameters based on the measured macroscopic response. The homogenization problem is discretized with the FE^2 method. The parameter identification is formulated as a least squares problem such that the macroscopic observable gap between simulation and experiment is to be minimized. To ensure the natural restrictions of the microscopic parameters optimization constraints are added. Gradient-based methods usually yield a good convergence and thus are employed to solve the optimization. Analytical and numerical sensitivities of the objective function differ significantly [1] and therefore, a strategy to calculate the analytical sensitivities in the context of elastoplastic multi-scale modeling has been derived. Earlier results for the elastic case can be found in [2]. Since the elastoplastic behavior depends on the load history, the derivatives of the stresses with respect to the material parameters within a FE program are usually calculated recursively [3]. The microscopic displacements at the boundary depend on the macroscopic strain and therefore on the material parameters. This dependency has to be taken into account when calculating the sensitivities of the multi-scale simulation. The order of the design variables, especially for yield strength and compression modulus, differ greatly and a negative effect on the reidentification of parameters has been observed. Normalization of the design variables proved to be an easy to implement and effective remedy.

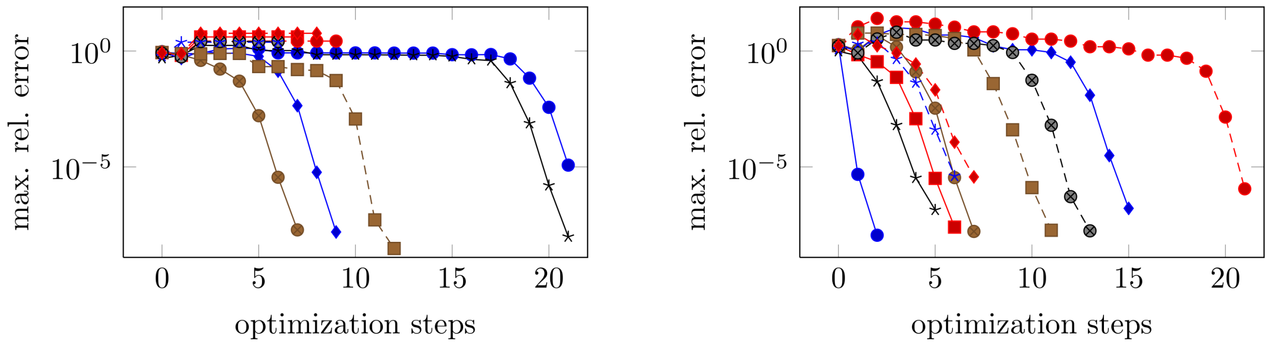

Figure 1: In an first attempt, reidentification failed for 5 out of 10 starting points (left), but succeeded for all starting points after normalization. (right)

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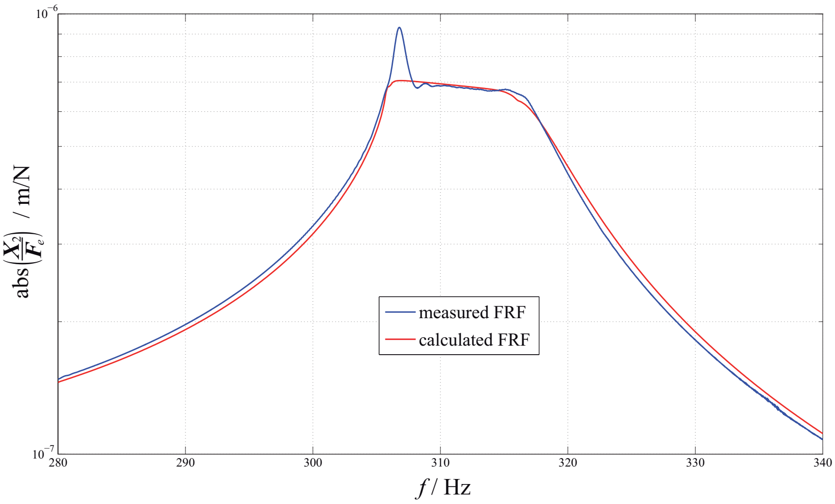
Parameter identification for nonlinear dynamical systems using Multi Harmonic Balance techniques

Dominik Süß, Kai Willner

An usual approach to investigate nonlinear systems in the frequency domain is the application of the Harmonic Balance Method (HBM), assuming that a harmonic excitation of the system leads to a harmonic response. However, for systems where the steady state response is not just harmonic but periodic or for systems which are excited periodically, this assumption does not longer lead to satisfying results. Therefore, the Multi Harmonic Balance Method (MHBM) is utilized, accounting for n_h harmonic parts.
In the framework of the MHBM, the Alternating Frequency Time Domain Method (AFT), see [1], is applied leading to an iterative solution scheme switching from frequency domain to time domain and vice versa. Therefore, a Newton-Raphson-type predictor-corrector algorithm is employed. The required partial derivatives of the nonlinear forces with respect to the response displacements can be calculated analytically in the time domain, see [2].
The MHBM/AFT is used to calculate frequency response functions (FRF) of a friction oscillator which includes a friction type nonlinearity in form of a bolted joint, which is modeled by using n elasto-slip elements in order to compute a very realistic friction behavior. Using a least squares curve fitting algorithm, the stiffness coefficient c_R as well as the friction coefficient μ of the elasto-slip elements are identified with respect to a measured FRF, containing micro slip as well as macro slip effects. For this calculation a harmonic excitation force is used.



$\tilde{F}_{e,1}$	100 N
c_R	$1.85 \cdot 10^7$ N/m
μ	0.423
n	20
n_h	11

Figure 1: Comparison of measured and calculated FRF

The good correlation between measured and calculated data can be seen in Figure 1. The biggest difference between the two curves occurs at approx. 306Hz because of an overshoot of the measured FRF due to the inertia of the shaker control. The adjacent table shows the parameters used and identified under consideration of 11 harmonics.

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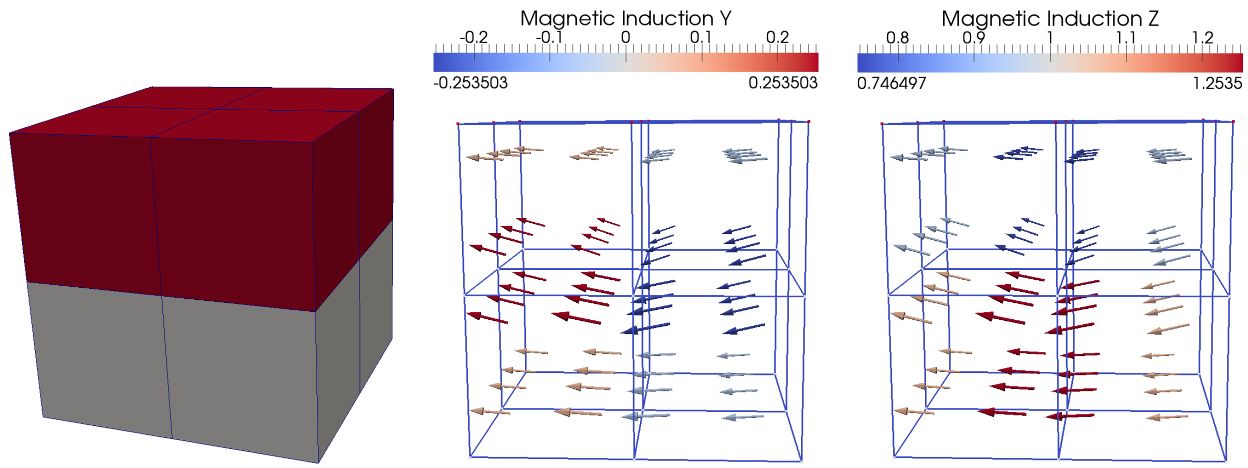
On the Modeling and Simulation of Magneto-Sensitive Elastomers

Franziska Vogel, Paul Steinmann

Magneto-sensitive elastomers are smart materials composed of a rubber-like basis matrix filled with magneto-active particles. Their ability to deform significantly, i.e. geometrically nonlinear, under the stimulation by magnetic fields makes them interesting for developing novel actuators. The overall aim of this project is the modeling and computation of the material behavior o magneto-sensitive elastomers. Thereby the physical phenomenon of jump conditions for the magnetic fields along material boundaries poses a major challenge. As demonstrated in [1], at an interface between two media the fields must satisfy

$$\boldsymbol{n} \times [\![\mathbb{h}]\!] = \hat{\mathbb{j}}^f \qquad \text{and} \qquad \boldsymbol{n} \cdot [\![\mathbb{b}]\!] = 0 \quad \text{on} \quad \partial\mathcal{B},$$

where $\boldsymbol{n}$ is the unit outer normal pointing from one material to the other and the free electric surface current density is denoted by $\hat{\mathbb{j}}^f$. Regarding the balance of linear momentum which is valid within magneto-sensitive elastomers, we follow the formulation in terms of a symmetrized total Cauchy-type stress tensor presented by Dorfmann and Ogden [2].
In order to represent the underlying physics correctly within a computational model, we choose a variational framework which allows the use of mixed finite elements with the unknown independent variables deformation map and magnetic vector potential. The solution of the mechanical problem is covered by a nodal-based finite element method, whereas the Maxwell's equations are expressed in terms of the magnetic vector potential $\mathbb{a}$ and discretized with edge-based finite elements. Their application to electromagnetics can be found, for example, in [1] or [3].



(a) Unit cube consisting of two different materials (b) Continuity in normal direction (c) Free jump of tangential direction

Figure 1: Unit cube loaded with magnetic vector potential. Plot of magnetic induction $\mathbb{b}$. Color code in (b) indicates the normal component, color code in (c) the tangential component.

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Spatial and material motion problem in nonlinear electro-elastostatics

Duc Khoi Vu, Paul Steinmann

The interaction between elastic bodies and electric fields is not a new subject of study. However, until recently the influence of the free space surrounding an electro-sensitive body on the electric and on the deformation field of the body was often of minor interest. In this work we use an energy approach to formulate the spatial and material motion problem of nonlinear electro-elastostatics. By using a stored energy density function for both the material body and the free space, the governing equations of both spatial and material motion problem are derived by considering the change of energy with respect to a change in the spatial or material configuration. In the material motion problem, besides the derivation of the governing equations, this approach reveals the formulas for the part of energy that is released from the system material body - applied forces in response to a change in the material configuration, which are particularly useful in the study of defects like crack propagation.

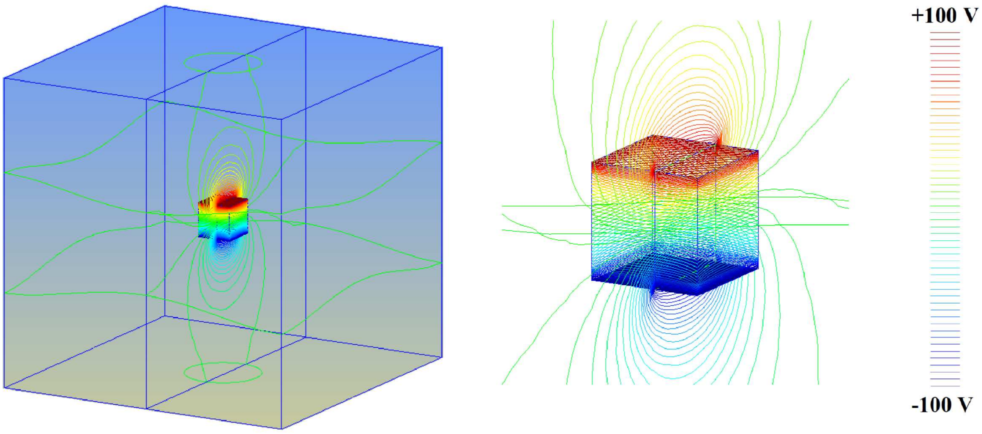


Figure 1: Electric potential inside / outside the material body (left) and close-up (right).

In solving numerically the spatial motion problem, in order to take into account the contribution of the free space, a coupled BEM - FEM approach is employed. Numerical studies using this approach show that for materials with low electric permittivity, the free space can have a huge impact on the simulated electric and deformation fields. The same observation is expected for the general case of nonlinear electro-elasticity and nonlinear electro-viscoelasticity and constitutes the direction for future works. In order to demonstrate the need of taking into account the free space, the electric field inside and outside a cube is presented in Figure 1. It is easy to observe that the electric field outside the material body is considerably strong and therefore a considerable part of the energy is stored in the free space.

References

[1] D. K. Vu, P. Steinmann. On 3-D coupled BEM - FEM simulation of nonlinear electro-elastostatics. *Comput. Methods Appl. Mech. Engrg.* **201 - 204**, pp. 82 - 90 (2012).

[2] D. K. Vu, P. Steinmann. On the spatial and material motion problems in nonlinear electro-elastostatics with consideration of free space. *Mathematics and Mechanics of Solids*, accepted (2011).

[3] D. K. Vu, P. Steinmann. Computational challenges in the simulation of nonlinear electroelasticity. *Computer Assisted Mechanics and Engineering Sciences*, submitted (2011).

On the modelling of stress- and magnetic field-induced variant reorientation in magnetic shape memory alloys

Jiong Wang, Paul Steinmann

In this project, a constitutive model is proposed to study the mechanical and magnetic responses of a magnetic shape memory alloy (MSMA) sample subject to the external force and magnetic field. A variational approach is adopted and the total energy formulation of the magneto-mechanical system is proposed in the following form:

$$\begin{aligned}\mathcal{G}(\mathbf{x},\Psi,\xi,\alpha,\theta;\mathbf{X}) = &\int_{\Omega_r}\rho_r\phi(\mathbb{F},\xi)dV + \int_{\Omega_r}\rho_r[\xi f^\alpha(\alpha)+(1-\xi)(K_u\sin^2\theta+f^\alpha(\frac{1}{2}))]dV\\ &-\int_{\Omega_r}\mu_0\rho_r\bar{\mathbf{M}}\cdot\mathbf{H}dV-\int_{\mathbb{R}^2}\frac{\mu_0}{2}J\mathbf{H}_d\cdot\mathbf{H}_d dV\pm\int_{\Omega_r}\int_{\xi_0(\mathbf{X})}^{\xi(\mathbf{X})}\rho_r\mathcal{D}^\pm(\tau)d\tau dV \\ &-\int_{\partial\Omega_r}\mathbf{t}_A\cdot\mathbf{x}dA.\end{aligned}\tag{1}$$

It can be seen that $\mathcal{G}$ depends on the spatial placement $\mathbf{x}$, the scalar magnetic potential Ψ and three internal variables ξ, α and θ relating to the magnetization $\bar{\mathbf{M}}$. By considering the variations of $\mathcal{G}$ with respect to the independent variables, one obtain the governing PDE system for the current model, which is composed of the magnetic field equations, the mechanical equilibrium equations and some evolution laws for the internal variables.

In our previous work, a homogeneous deformation process was studied to model the experimental measured field-strain, field-magnetization and stress-strain curves. Besides that, by considering the mechanical part of the governing system and using the coupled series-asymptotic expansion method, we derived some analytical results, which can provide a comprehensive description on the stress-induced variant reorientation process in a slender MSMA sample (cf. Fig. 1).

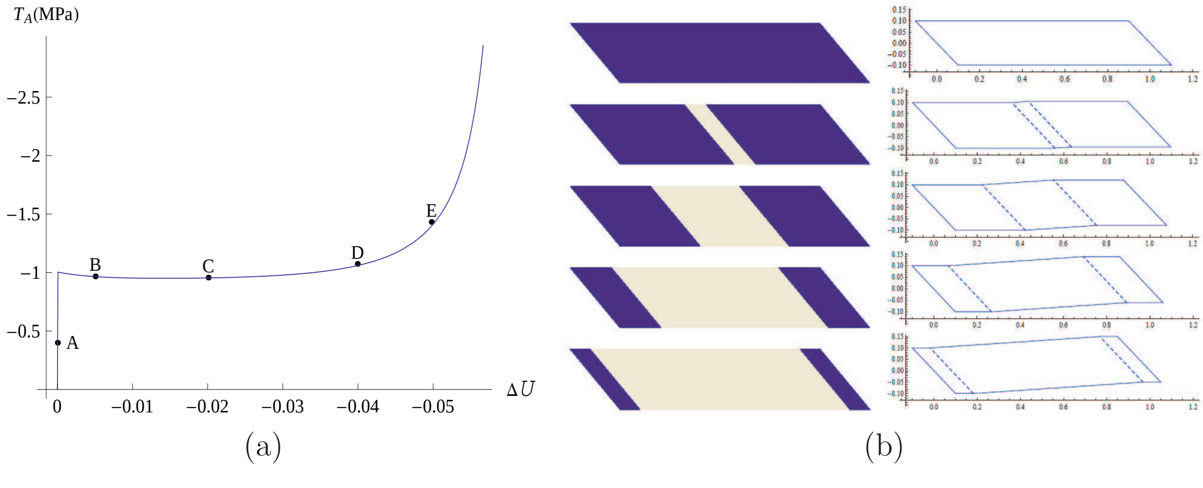


Figure 1: (a) The modeled engineering stress-strain curve; (b) The variant distributions and the current configurations of the MSMA sample corresponding to the points *A*-*E*.

In our future work, the fully coupled governing PDE system will be solved by using the nonlinear finite element method. We hope to provide a quantitative prediction on the magneto-mechanical responses of the MSMA sample. The variations of the surface morpology of the sample during the variant reorientation process will also be simulated.

Bone adaption induced by non-passively fitting implant superstructures: A FEA based on in vivo strain measurements

Werner Winter, Thomas D. Taylor, Matthias Karl

Misfit stress resulting from non-passively fitting implant superstructures may induce bone adaptation thereby reducing the magnitude of static implant loading.
In a previous investigation, repeated in vivo strain measurement, were conducted on an implant-supported bar to evaluate changes in misfit magnitude resulting from adaptational processes (see Fig. 1). Both maximum and minimum strain values were simulated using a 3D-FE-model as shown in Fig. 1c. Additionally, different stages of osseointegration were modelled by altering the elastic modulus of bone immediately surrounding the implants.

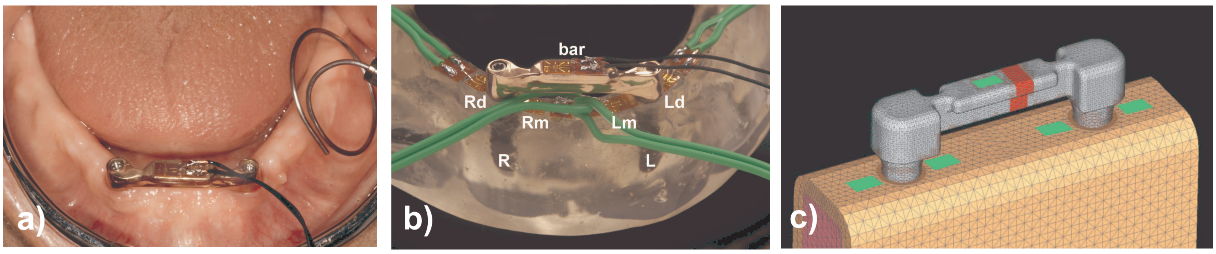


Figure 1: In vivo strain measurement of the screw-retained overdenture bar using a strain gauge (a); In vitro resin model of the patient situation with strain gauges (b), Misfit determination model showing the position of numerical strain gauges (c). Thermal changes in the volume of the red elements within the bar were used to introduce horizontal misfits between the the bar and the implants.

To simulate the maximum strain value, a horizontal misfit of $83.3\mu m$ had to be introduced whereas the minimum strain value could be simulated by a horizontal misfit of $71.5\mu m$. The difference between maximum and minimum horizontal misfit was $12\mu m$ leading to a reduction in maximum stress levels of 15MPa in cortical bone and 0.7MPa in trabecular bone. Progressing osseointegration affected the stress situation of the supporting implants. In Fig. 1c the 3D-FE model is shown with numerical strain gauges.
This finite element analysis showed that bone adaptation induced by non-passively fitting implant superstructures may lead to implant site displacement in the range of several μm. Although these changes in implant positions are minimal, substantial reductions in stress magnitude of both, restorations and bone are achieved. Furthermore, connecting non-passively fitting superstructures to implants in the early phases of osseointegration may reduce the amount of static loading occurring at the implant bone interface.

References

[1] W. Winter, T.D. Taylor, M. Karl (2011). Bone adaption induced by non-passively fitting implant superstructures: A Finite Element Analysis based on in vivo strain measurements. *The International Journal of Oral and Maxillofacial Implants* , (in press).

Effect of model parameters on finite element analysis of micromotions in implant dentistry

Werner Winter, Daniel Klein, Paul Steinmann, Matthias Karl

Micromotion may be defined as a phenomenon which occurs at the interface of different components belonging to one mechanical system leading to a displacement of a component relative to another one. In implant dentistry, micromovement of components may occur at two interfaces, the implant-abutment connection and the bone-implant interface. Micromotion at the bone-implant interface may occur when a non-osseointegrated implant is loaded such as in an immediate loading situation. Occlusal forces here may lead to a displacement of the implant relative to the bony implant socket. It is generally accepted that such micromovement occurring during the healing phase may lead to fibrous encapsulation of the implant if a threshold displacement of $50-150\mu m$ is surpassed. In an experimental study micromotion can be related to bone remodelling (see Fig. 1).

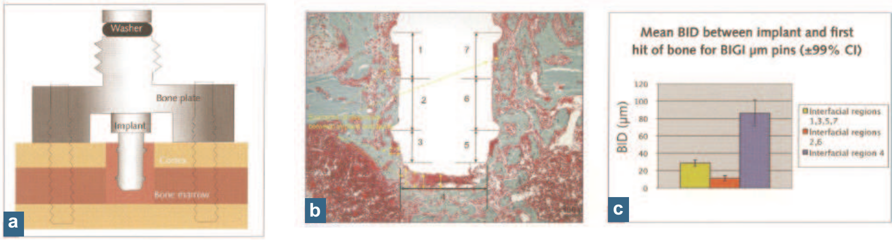


Figure 1: Experimental device for testing micromotion in mice tibia (a), undecalcified section (Golden stain) from a pin implant subject to micromotion (b), Mean BID in region having different strain histories (c). (Reproduced from [1])

The purpose of this finite element analysis was to study the effect of macroscopic implant-related parameters (direction of loading, implant geometry) and modelling parameters (stage of osseointegration, friction) on FE simulations of implant micromotions. A 3D-FE model as shown in Fig. 2a was used and some results are shown in Fig. 2b.

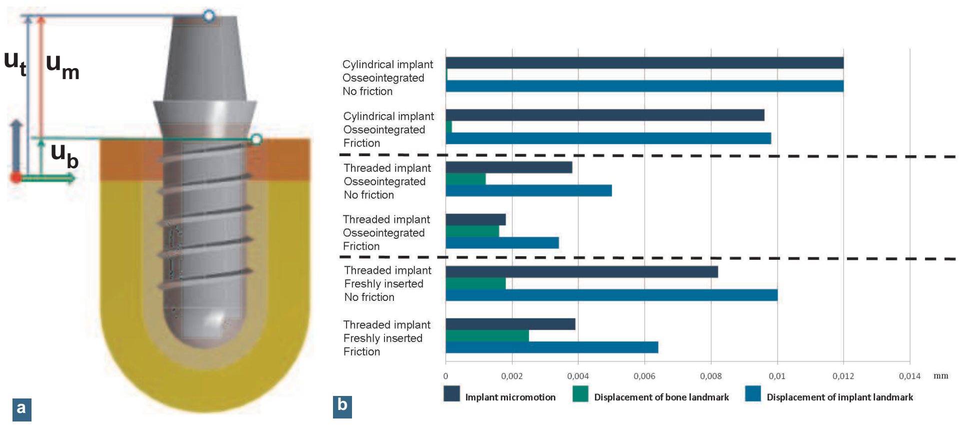


Figure 2: FE-model for numerical simulation of micromotion at a single implant (a), results of the simulations (b).

References

[1] J.B. Brunski, J.A. Currey, J.A. Helms, P. Leucht, A. Nanci, R. Wazen. The healing bone-implant interface: Role of micromotion and related strain levels in tissue. In: *A. Jokstad (ed.). Osseointegration and Dental Implants. Ames, IA: Wiley-Blackwell, 119-128, (2009)*

Monotonic and fatigue behavior of cellular composites

Sergej Diel*, **Otto Huber***, **Paul Steinmann, Werner Winter**
(*Kompetenzzentrum Leichtbau, Hochschule Landshut (LLK))

Cellular composites are a relatively new class of syntactic foams. In contrast to conventional syntactic foams, cellular composites are made with cellular place holders instead of hollow microspheres. Cellular composites offer good specific mechanical properties and are used in lightweight structures, e.g., as cores in sandwich panels or as supporting cores in crashboxes. The internal structure of a cellular composite is shown in Fig. 1a.
The monotonic and fatigue compressive behavior of a cellular composite made from epoxy resin reinforced with glass foam granules is investigated in [1]. The experimental setup is shown in Fig. 1b. The density of the cellular composite varies between $0.65 g/cm^3$ and $0.82 g/cm^3$, depending on the size of granules used. The measured Young's moduli are between $2.7 GPa$ and $4.0 GPa$. The compressive strength is between $14.6 MPa$ and $32.1 MPa$. The measured isotropic linear elastic constants are in good agreement with results obtained from analytical and numerical homogenization methods.

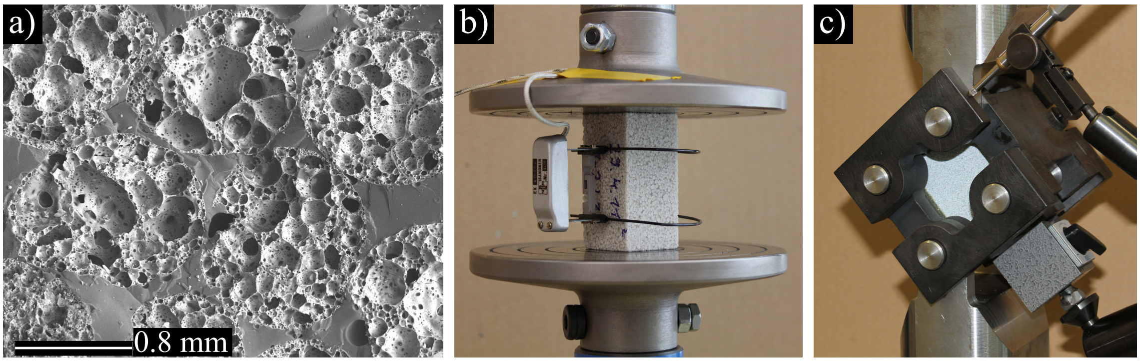


Figure 1: SEM image of the internal structure of a cellular composite (a), experimental setup of compression test (b), experimental setup of shear test (c)

The fatigue behavior is determined in cyclic tests at different frequencies and in static tests. It is shown that the fatigue life of cellular composite depends mainly on the time the specimen is subjected to loading, as shown for glass in [2]. The effect of the applied frequency is of minor significance. The reason for the damage of cellular composite under monotonic and fatigue loading is due to the formation of cracks and damage bands in glass foam granules. The mechanical behavior under pure shear loading will be investigated using a new shear test fixture which is based on a shear web construction, see Fig. 1c [3].

References

[1] S. Diel, O. Huber, H. Saage, P. Steinmann, W. Winter (2011). Mechanical behavior of a cellular composite under monotonic and fatigue compression loading, submitted for publication

[2] R. J. Charles (1958). Static fatigue of glass. Journal of Applied Physics **29**, pp. 1549-1553

[3] S. Diel, O. Huber (2011). Entwicklung und Evaluierung einer Schubversuchsvorrichtung auf Basis einer Schubfeldkonstruktion fr statische und zyklische Beanspruchungen. In: O. Huber, M. Bicker (ed.) 5. Landshuter Leichtbau-Colloquium, pp. 57-69

4 Activities

4.1 Teaching

- Statik (MB)
- Elastostatik und Festigkeitslehre (MB)
- Statik und Festigkeitslehre (CBI, ET, IP, LSE, ME, MT, WING, WW)
- Lineare Kontinuumsmechanik (MB, ME, WING)
- Nichtlineare Kontinuumsmechanik (MB, ME)
- Technische Schwingungslehre (MB, ME, WING)
- Numerische und experimentelle Modalanalyse (MB)
- Methode der Finiten Elemente (MB, ME, WING)
- Einführung in die Schädigungsmechanik (MB)
- Materialmodellierung und -simulation (CE, MB)
- Mechanik der Materialverbunde (MB)
- Einführung in die 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)
- Computational Dynamics (CE)
- Hauptseminar Technische Mechanik (MB, ME)
- Seminar über Fragen der Mechanik
- Strukturoptimierung in der virtuellen Produktentwicklung (MB, ME)
- Number of exams - 1748

4.2 Dissertation theses

- M. Scherer
  Regularizing Constraints for Mesh and Shape Optimization Probems
  Schriftenreihe Technische Mechanik, Band 5, 2011
- P. Fischer
  C1 Continous Methods in Computational Gradient Elasticity
  Schriftenreihe Technische Mechanik, Band 6, 2011

4.3 Diploma theses

- F. Endres,
  Molekularstatische Methoden zur Simulation von Ferroelektrika

- T. Leitz,
  Ein numerisches Verfahren zur Berechnung des elastohydrodynamischen Kontakts rauer Oberflächen

4.4 Bachelor theses

- C. Bartsch,
  Numerische Untersuchung eines Reibschwingers mit verschiedenen Reibgesetzen

- P. Jänicke,
  Simulation des Beanspruchungszustandes einer Zahnwurzel im Zahnhalteapparat

- T. Langer,
  Theorie und Konstruktion eines Vorlesungsexperiments zur elastischen Stabilität von Stäben

4.5 Student research projects theses

- T. Leitz,
  Lösung der zweidimensionalen Reynoldsgleichung mithilfe der Methode der Finiten Elemente

- J. Rehwald,
  Mikromechanische Modellierung und Simulation heterogener Interfaces

- S. Riehl,
  Implementierung iterativer Gleichungslöser in einem Halbraum-Kontaktsimulationsprogramm

- S. Scheeff,
  Experimentelle Untersuchung eines Reibschwingers

- D. Pöschel,
  Spannungen und Formänderungen in einer Scheibe mit heterogenen Materialeigenschaften

- A. Janeba,
  Konstruktion eines mechanischen Duffingschwingers

4.6 Seminar for Mechanics

22.02.2011 Walter Fischer,
Siemens AG, Corporate Research and Technologies, Erlangen, Germany
Phase Transitions in Thermosetting Resin Systems

04.04.2011 Jean-Paul Pelteret,
CERECAM, University of Cape Town
Computational Model of Tissue in the Human Upper Airway

05.04.2011 Dr. Louis Komzsik,
Chief Numerical Analyst of Siemens Industry Division, PLMS in California
Introduction to industrial rotor dynamics

19.04.2011 Vera Luchscheider,
LTM, FAU Erlangen-Nürnberg
Bruchmechanische Ermittlung der Ausfallwahrscheinlichkeit von Wälzlagerbauteilen mit Einschlüssen

20.06.2011 Prof. Matjaž Hriberšek,
University of Maribor, Slovenia
Numerical modeling of dilute suspension flows of magnetic particles by the Subdomain Boundary Element Method

28.06.2011 Dr. Holger Lang,
ITWM Kaiserslautern, Germany
Geometrisch exakte Cosseratsche Balken für die Mehrkörpersimulation

29.06.2011 Dr. Thorsten Schindler,
INRIA Grenoble, France
Nichtglatte MKS in industrieller Anwendung und theoretischer Analyse

05.07.2011 Jürgen Metzger,
TRW Automotive, Alfdorf, Germany
Characterization and Evaluation of Frontal Crash Pulses for USNCAP 2011

06.07.2011 Bülent Yagimli,
UniBW München, Germany
Experimentelle Untersuchungen und Erstellung eines Materialmodells zur Beschreibung von Aushärtevorgängen

12.07.2011 Dr. Holger Böse,
ISC Würzburg, Germany
Smart Materials zur gezielten Beeinflussung mechanischer Systeme

05.10.2011 Dr. Indresan Govender,
University of Cape Town
Flow modeling in tumbling mills

4.7 Editorial activities

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 34 2011 Issue 1

  Mathematical problems in solid mechanics

  Guest-editors

  P. Neff, Duisburg-Essen
  H.-D. Alber, Darmstadt

- Volume 34 2011 Issue 2

  History of Mechanics

  Guest-editors

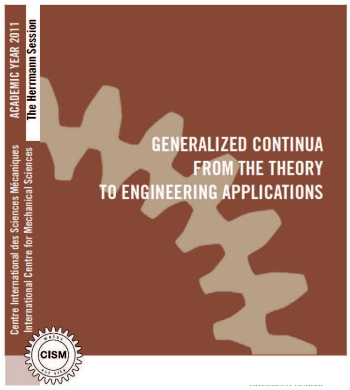
  E. Stein, Hannover
  O. Mahrenholtz, Hamburg

Advisory/Editorial Board Memberships of 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

4.8 CISM-Courses

Paul Steinmann delivered six lectures on:
Aspects of Differential Geometry and Generalized Continuum Mechanics. An Attempt.
at the CISM-Course:
Generalized Continua. From the Theory to Engineering Applications
The CISM-Course took place in Udine, Italy during 19th to 23rd September, 2011. Other lectures (in alphabetical order) were: Holm Altenbach, Rene de Borst, Victor Eremeyev, Samuel Forest, and Gerard Maugin.



Members of the chair, who attended to CISM-Courses:

- Denis Davydov
  Generalized Continua - From the Theory to Engineering Applications
  (September 19 - 23, 2011)
- Ali Javili
  Experimental and Theoretical Multiscale Analysis of Materials and Structures
  (July 04 - 08, 2011)
- Andrew McBride
  Experimental and Theoretical Multiscale Analysis of Materials and Structures
  (July 04 - 08, 2011)
  Generalized Continua - From the Theory to Engineering Applications
  (September 19 - 23, 2011)

4.9 ERC - Advanced Grant

The following article can be found on
`http://blogs.fau.de/techfak/2011/11/14/news-erc-research-grant-holder-at-the-tf`

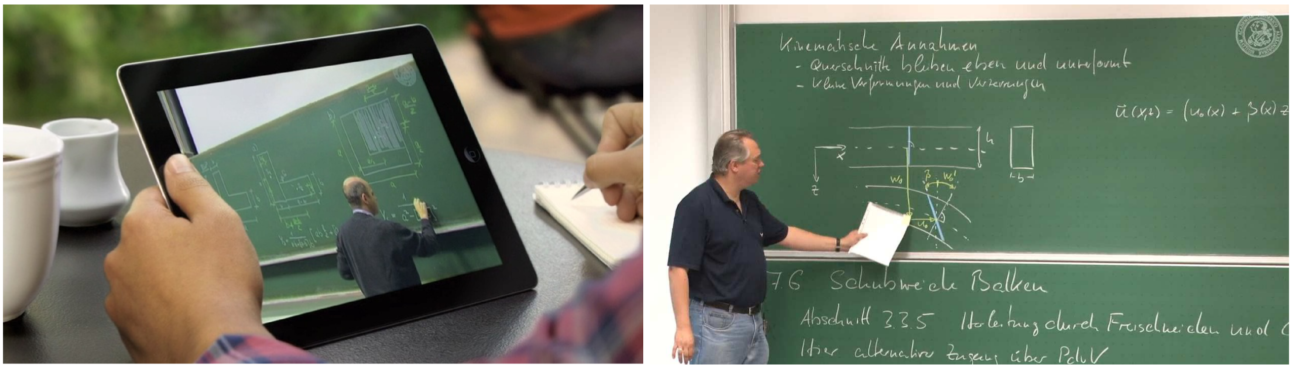
'With a prestigious award and funding amounting to €2.5m, Prof. Dr. Paul Steinmann from the Institute of Applied Mechanics (LTM) at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) has reason to be pleased. Steinmann belongs to the small group of prominent research scientists who, over the next five years, will receive an Advanced Grant from the European Research Council. Advanced Grants awarded by the ERC are reserved exclusively for groundbreaking research projects deemed of excellence.

Professor Paul Steinmann and his team will research magneto-sensitive elastomers - a new category of intelligent materials which are comprised of a rubber-like substrate, charged with magnetic particles. For the rapid and, above all, targeted deformation of these materials a weak magnetic field is sufficient. It is precisely this characteristic that makes magneto-sensitive elastomers so interesting for numerous practical applications including industrial process measurement and control, whereby elastomers convert electronic signals into movement - much the same as muscles do.

Over the next five years, Professor Paul Steinmann and his team will research the connection between the production process, the subsequent microstructure and the properties of magneto-sensitive elastomers by means of experiments, models and simulations. The research team ultimately hopes to better exploit the promising potential afforded by these new materials for future technological applications.'

4.10 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)* already since the winter term 2009/2010. Due to the financial support by student fee - that we gratefully acknowledge, the technical equipment was upgraded, the video recording was continued and the lecture on the finite element method was added. The videos are available world-wide and can be used by our students to repeat the lectures and to prepare for the exams. Once again, a scene from *Statics* became part of the German version of Apple's iPad2 commercial "Now" (`www.apple.com/de/ipad/videos/#video-now`).



scenes from the iPad2 commercial (©Apple) and the lecture *Finite Element Methods*

technical data:

- cameras: 1x Sony HVR-Z5E, 1x Sony HVR-Z1E, Sony DSR 370 PK-2
- formats: 320x180 m4v video, 640x360 m4v video, 1280 x 720 m4v video *(new)*, mp3 audio

available accesses:

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

available lectures:

- Statics *(new lecture content)*
- Elastostatics and Strength of Material
- Dynamics
- Linear Continuum Mechanics
- Statics and Strength of Material *(new edition)*
- Finite Element Methods *(new)*

available special events:

- Best of Ultimate Load Contest 2009
- Best of Ultimate Load Contest 2010 *(new)*
- Best of Ultimate Load Contest 2011 *(to appear)*

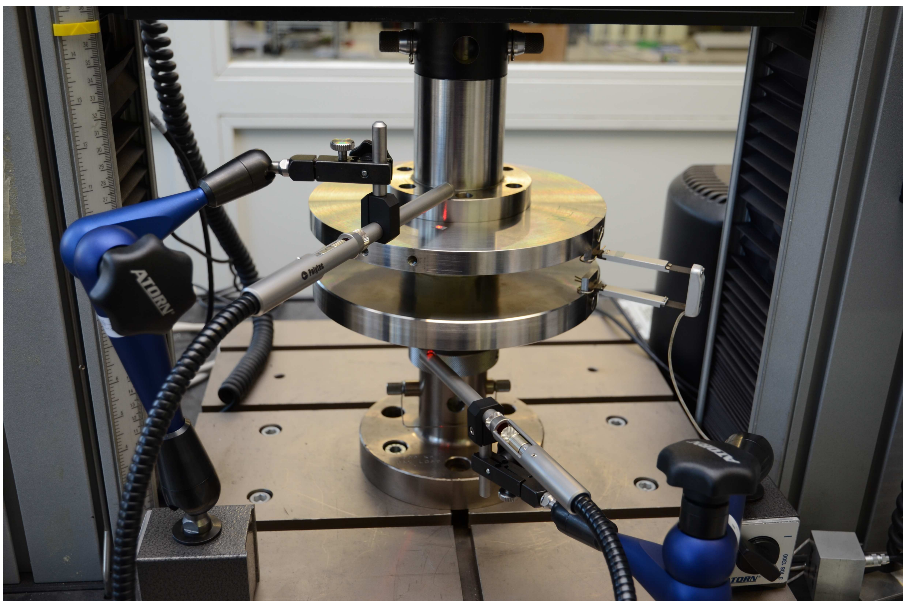
4.11 Laboratory new equipment

(ds) This year there was invested money in modernizing our vibrational testing equipment and in creating a new test facility. Here is a list of what was bought throughout the year:

- Acceleration sensors:
  - 4 x PCB-M352C65 (uniaxial)
  - 3 x PCB-352A01 (triaxial)
  - 1 x PCB-352A13 (triaxial)
- Modular signal conditioner PCB-441A38 with four times PCB-442B104 (16 channels)
- Rapid control prototyping controller board dSPACE-DS1103
- Modal shaker system TIRA-5220-M
- Closed loop shaker control and data acquisition front end M+P-VibPilot
- Differential Laser-Doppler-Vibrometer Polytec-OFV-552-3 with controller Polytec-OFV-5000

some new acceleration sensors

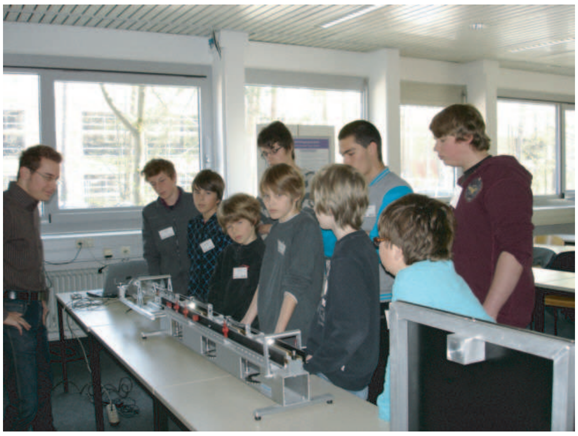
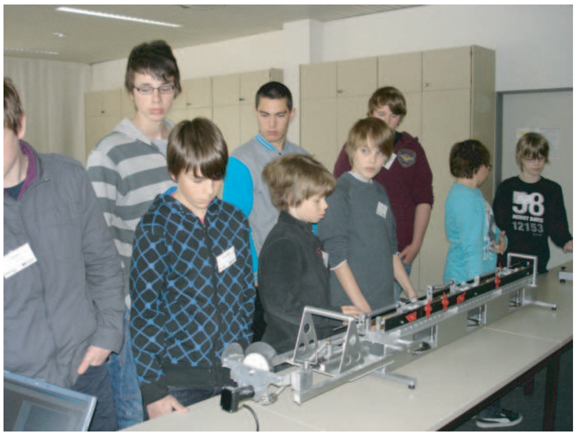
closed loop shaker control VibPilot



measuring relative displacements using the differential Laser-Doppler-Vibrometer Polytec-OFV-552-3

4.12 Girls' Day and Boys' Day

(dp, fv) On Girls' Day (14.04.2011), universities, organizations and companies opened their doors to awaken young girls' interest in engineering, science and trade. This annual event, which was originally designed for girls to provide them with information about non-typical professions for women, is accompanied since 2010 by the corresponding event for boys. From 5th grade on, the students are encouraged to gain an insight into daily life and education at the University Erlangen-Nuremberg. The Chair of Applied Mechanics contributes to this event with descriptive experiments in the field of dynamics. The students are introduced to the basic principles of free and forced vibrations as well as phenomena like resonance, anti-resonance and resonance catastrophe.

4.13 Practical Course: Girls & Engineering / Youth & Engineering

(dp, fv) Forming a long tradition since 1999, the practical course "Girls and Engineering" was held in September during the last week of the Bavarian school summer break. Since 2010, the corresponding course "Youth and Engineering", open for both genders, takes place in parallel. Within these events, students from 8th through 12th grade have the opportunity to learn about engineering and physics from an applied point of view. The students conduct several experiments, which are offered by the departements of the School of Engineering University Erlangen-Nuremberg and the Fraunhofer Institutes located in Erlangen, in order to gain some insight in the diversity of engineering disciplines and to learn more about applied sciences.

At the Chair of Applied Mechanics, we developed an experiment "Stress Analysis of a Crane Hook" which covers all basic steps in investigating a hook's behavior under loading until failure. The students receive an impression of the stress distribution within the loaded hook with the help of an optical stress analysis. Afterwards they try to extract the material constants of the hook's "unknown" material. With this information, the students perform a finite element analysis in order to reproduce the stress distribution from the optical experiment, to locate the maximal stress and to foresay the maximal possible loading. To verify the results of the numerical simulation, the course concludes with the most popular part among the students: the final destruction of the hook through a tensile test. We are happy, that our experiment was well received by the students and as a result of this good reception we are looking forward to participate also in the next year's event, which will be hosted in September 2012.

4.14 Long Night of Science

(dp, fv) Already for the fifth time since 2003, the "Long Night of Science" (Lange Nacht der Wissenschaften) took place on October 22nd, 2011 at numerous institutions spread through the metroplitan region of Nuremberg, Erlangen, and Fuerth. Between 6 p.m. and 1 a.m., an interested audience had the chance to inform itself at universities, non-university research institutes, companies and other institutions about current trends in research and development. Like recent years, the Chair of Applied Mechanics also participated in this event and opened its doors on Saturday evening to present research results in the areas of experimental stress analysis, system dynamics and cellular materials. Due to the very positive resonance to our program and the extremely large attendance at our chair, we are encouraged to participate as well in the next "Long Night of Science", which will take place in October 2013.

4.15 Ultimate Load Contest

(dkv) Aiming at attracting the attention of students to challenging 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 8th December 2011 in Erlangen. Participated in the event were 11 groups of competing students of all engineering disciplines and nearly 100 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 no 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 First Aider Training

(mk) Because of the pleasant growth of our chair, the university's administration slightly forced us to increase the number of first aiders. Thus, three members had two fantastic February days of first aid training with "ferocious" ambulance driver's (life) stories, passionate exercises, but also some useful hints and insights.

Four members are our current first aider: Dieter, who is actually the only one, who ever needed first aid, Franz, who can't stand the sight of blood, Sebastian F., whose office is the most remote to the dangerous spots, and Markus, who will soon leave the chair.

5 Social events

5.1 Visit of the Bergkirchweih

(us) The date of the Bergkirchweih depends on the date of Pentecost and therefore was rather late this year. The chairs traditional visit took place on Tuesday, the 14th of June. With this year's reservation at the Erichkeller we were seated in the Hinterhaus, together with the Chair of Applied Dynamics and the Study Service Center. As always, the fair provided us with lots of food, beverages and joy rides. A rain shower briefly interrupted the otherwise mostly sunny day. Plastic sheets were provided to protect guests, food and beer, against the rain. The band "Appendix" played mostly german songs in the afternoon, but delivered more english hits in the evening. The visit was a great success in cultivating the colleagueship within the chair and beyond.

5.2 Student summer party

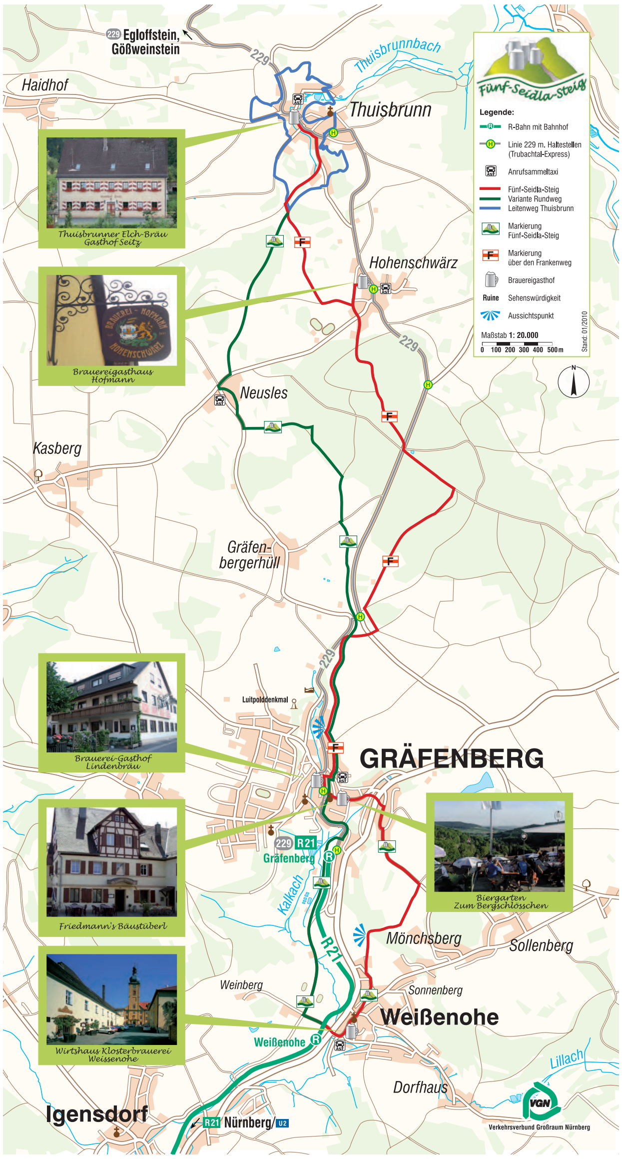
(mk) This year's student summer party took place on 28th of June all around the chair building. Our students were spoiled with franconian bratwurst, steaks, and many more – cooked and fried by chair members. The party was complemented by a fine collection of local beers. Finally, also the liquid, long ripened assets of the last resort were needed (and cleared) to perfect the felicitous party.

The summer party is our way to thank all students for their committed work at the chair during the whole year. Altogether, over 90 students wrote a thesis, participated in the seminar, or helped for plenty of tutorials for our lectures. Thanks for all this.

some impressions of the student summer party

5.3 Outing to the ‘Fünf-Seidla-Steig’

(fv) A long lasting tradition at the LTM, of which had been lost sight for some years, was re-established this year. Thanks to our colleague Ulrike Schmidt, who organized the outing to the Franconian Switzerland, we hiked along the ‘Fünf-Seidla-Steig’, or ‘Five-Pint-Trail’. Along this trail, five different breweries are located which invite for a refreshing stop after an exhausting walk. Starting in Weißenohe, we made our way to Gräfenberg, Hohenschwärz and back. Although we decided to spent this day in nature at the end of July, pouring rain was our constant companion. Therefore, we used the different stops at the breweries’ restaurants not only to try their freshly brewed beer, but also to dry our clothes and heat up with a hot coffee and a large piece of cake. Those who kept up all day and returned to Gräfenberg in the late afternoon were at last rewarded with a sunny view over the hills in the direction of Nuremberg. For the interested reader we refer to [1] for further information.



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