

### Teaching and research focus

The chairs of Mechanics, Statics and Dynamics describe a natural temporal line in the training of theory-based subjects in the study of civil engineering. This line is reflected in the revised sequence of compulsory and elective subjects in 2019, which was established last year. The now close proximity of the staff as well as numerous joint activities have strengthened the team spirit between the groups, which in retrospect was helpful in the existence of everyday life but also in the special situation created by Covid-19. Without suspecting it, the chairs already decided in November 2019 to plan a joint winter seminar with the chairs of Prof. Carolin Birk (University of Duisburg Essen) and Prof. Sven Klinkel (RWTH Aachen University), one of the topics of which was the digitalisation of teaching. It further became apparent during our stay in a self-catering house in Winterberg (Sauerland) that our international cast of kitchen teams fueled culinary enjoyment and warmed many a dish from the inside, while outside, in the wake of hurricane Sabine, a blanket of snow settled over the low mountain range and it became completely quiet around us. No one would have believed at the time that such a silence could descend on the campus.



Participants in the winter seminar for teaching and research from the chairs of mechanics and statics and dynamics at RWTH Aachen University, University of Duisburg Essen and TU Dortmund University, 10-13.02.2020, Winterberg

The second seminar and the general meeting of the "GAMM Student Chapter at TU Dortmund University" also took place on 19 November 2019 with numerous participants. This association aims to promote interdisciplinary cooperation in applied mathematics and mechanics between master's students and doctoral students at TU Dortmund University. All staff members of the Chair of Statics and Dynamics joined the group and Prof. Münch gave a lecture on "Stress field analysis for higher order continuum theories".

The general meeting of the GAMM (Society for Applied Mathematics and Mechanics) from 15-19 March 2020, which was regularly used by both chairs as a platform for scientific exchange, had to be cancelled as one of the first conferences due to the Corona crisis. Shortly afterwards, the conference "Baustatik-Baupraxis", which addresses interesting areas of mechanics, statics and dynamics from the practical field of activity, was also cancelled.



GAMM Student Gruppe der TU Dortmund

Computer-aided calculation with extensive and complex software is increasingly determining the job profile of civil engineers. In order to prepare students for this, the two chairs consider a strategy that combines theoretical basic knowledge with the exploration of such software products to be useful. This is offered, for example, through the elective subject "Software in Structural Mechanics" or "Engineering with ANSYS" in both the Bachelor's and Master's degree programmes. Some lecture units are enriched by joint webinars with training staff from the software companies in order to get to know the latest functions first-hand. The students usually receive time-limited software licences for the complete programme, which paved the way for digital teaching in the summer semester.



**b m** baumechanik  
**sd** statik dynamik

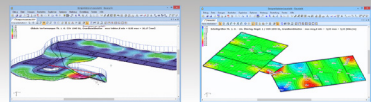
Veranstaltungsreihe  
**Software in der Strukturmechanik**

**am 24.04.2020**

10:00-16:00 Uhr

Online-Webinar

Zugangsdaten über den Moodle-Arbeitsraum BMSD KoSo



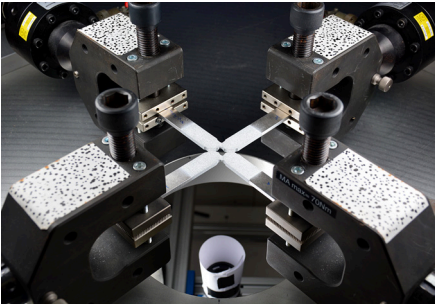
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Announcement of a webinar in the digital summer semester in cooperation with a commercial provider of structural analysis software

The specialisation "Numerical Mechanics" also includes elective subjects such as "Structural Optimisation" and "Nonlinear Material Mechanics", which prepare students for demanding but quite common tasks. Above all, the combination of these subjects provides the basis for student research projects and theses at a high scientific level. For example, the inverse determination of material parameters of a complex damage model based on biaxial tests of an aluminium alloy was the topic of a final thesis. In cooperation with the chair of Prof. Brüning (UniBW Munich), tests were carried out whose measurement data were evaluated with the help of digital image correlation (DIC) and compared with the simulation results.



Biaxial test of an aluminium sample at the University of the Federal Armed Forces in Munich

A new addition to the elective courses offered by the chairs is the subject "Tree Engineering", which was offered for the first time in the summer semester 2020. Mr. Dipl. Des. Martin Zeller received the faculty's teaching assignment for this and gave an introductory lecture on the course content at TU Dortmund University on 15 January 2020. Unfortunately, this was the only attendance event for him. However, Mr Zeller resolutely countered the Corona crisis and thus appeared in front of the camera more often. This was gratefully received by numerous course participants and 48 seminar papers were produced, which are now being compiled in a seminar volume. At the end of the course, the excursion originally planned for May to different botanical trial fields in Kamen and Olfen could still be carried out. In these plants, the ability of different tree species to combine tree organism and building element is investigated and demonstrated. On the initiative of Mr. Zeller, a cooperation with the city of Kamen has now been established, which allows us to scientifically evaluate the experiments and further design the experimental field. Future courses on "Tree Engineering" as well as research activities will benefit from this.



Martin Zeller under the "Growing Footbridge" in the botanical trial field in Kamen



Young red oaks grow together with each other and with the bearing points of the footbridge to support it

With the support of the NRW Forestry Training Centre, a number of almost 70-year-old copper beeches (*Fagus Sylvatica*) were freshly taken from the forest in Arnsberg for the first time at the beginning of June and examined within two days at the Institute for Building Research. Among other things, the shafts could be loaded as a full cross-section in compression and bending tests until they broke.

The load-bearing behaviour of the fresh, water-saturated shaft differs significantly from that of technically dried wood, which is important for the load-bearing capacity of vital trees.

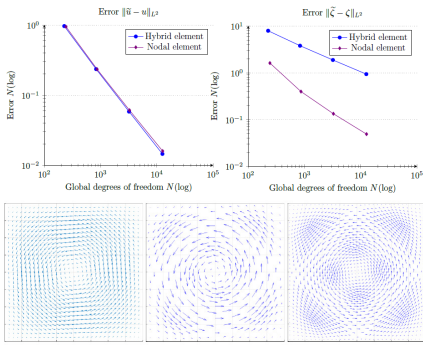


Bending test on the freshly cut shaft of a copper beech at the Institute for Building Research

Further research focuses of the two chairs can be found in the area of numerical methods, refined beam theories, sensitivity analysis and structural optimisation within the framework of nonlinear elasticity theory, metal plasticity and in the simulation of cracks in components with the Extended Finite Element Method (XFEM). The focus is on one's own approach to effective derivation as well as numerical implementation. This also includes sensitivity analyses with parameter variation, the extension of this consideration to history-dependent materials and the consideration of damage in manufacturing. The central role of sensitivity analysis is further investigated in the context of multi-scale problems. Associated optimisation problems are characterised by the fact that the objective functions, constraints and design variables are defined on both the micro-scale (material structure) and the macro-scale (structural framework). High Performance Computing (HPC) plays an essential role for the efficient implementation of developed algorithms in computer programs. In this context, programmes were developed in such a way that the performance of the computing nodes of the university's internal Linux HPC cluster (LiDO) can be exploited in the context of parallel numerics.

In cooperation with Prof. Patrizio Neff (University of Duisburg Essen) and Prof. Joachim Schöberl (Vienna University of Technology), the simulation of micromorphic continua with the Nédélec approach is investigated. By combination with

Lagrangian approach functions, a hybrid approach space is obtained, which allows both the gradient of the displacement field and the rotation of the microfield.



Comparison of convergence (top) between FEM in standard formulation and FEM with hybrid approach space with rotation present (bottom) in microdistortion field

Since September 2020, the "Open Education Resources" project "Digital Learning Environment in Structural Engineering as a Holistic Concept" has been funded and worked on in cooperation with RWTH Aachen University, the University of Duisburg Essen, TH Cologne and FH Aachen University of Applied Sciences. The funding line aims to make the benefits of freely accessible teaching and learning opportunities recognisable and tangible for teachers and students. This includes, for example, the coordination of learning objectives and a uniform nomenclature. Furthermore, a wide range of digital learning formats with the same learning objective will be created, so that students can choose the format that suits them best. The project will be accompanied by subject didactics and evaluated across the university. The first experiences from this project can be incorporated into digital teaching at TU Dortmund University as early as the winter semester 20/21.

### List of compulsory and elective courses

#### Winter Semester 2019/20

Stereostatik  
 Grundlagen der Statik und Dynamik  
 Lineare Elastizitätstheorie  
 Lineare Finite Elemente Methode  
 Computerorientierte höhere Mechanik  
 Nichtlineare Finite Elemente Methode  
 Sondergebiete der Strukturoptimierung

#### Summer Semester 2020

Elastostatik  
 Computerorientierte Statik und Dynamik  
 Software in der Strukturmechanik  
 Engineering with Ansys  
 Tree Engineering  
 Nichtlineare Materialmechanik  
 Strukturoptimierung

### Publications

Molinari, A., Witte, R., Neelisetty, K. K., Gorji, S., Kübel, C., Münch, I., Wöhler, F., Hahn, L., Hengsbach, S., Bade, K., Hahn, H., Kruk, R.: Configurable Resistive Response in BaTiO<sub>3</sub> Ferroelectric Memristors via Electron Beam Radiation. *Advanced Materials* 32 (2020).

Münch, I., Wagner, W., Naumann, J.: Isogeometrische Analyse zur Evolution von Verbundsystemen mit der Phasenfeldmethode,

in: Bischoff, M., von Scheven, M., Oesterle, B. (eds.) *Berichte der Fachtagung Baustatik - Baupraxis* 14 (2020).

Muench, I., Klassen, M., Wagner, W.: Topology Optimization with Isogeometric Analysis and Phase Field Modeling. *Proc. Appl. Math. Mech.* 19 (2019).

Klassen, M., Muench, I., Klinkel, S.: Phase field modeling with IGA and FEM: Error surveillance in the transition zone. *Proc. Appl. Math. Mech.* 19, (2019).

Keller, A., Muench, I., Wagner, W.: Comprehensive optimization of frame structures. *Proc. Appl. Math. Mech.* 19, (2019).

Liedmann, J., Barthold, F.-J.: Shape Optimization of the X0-specimen; theory, numerical simulation and experimental verification. *Comp. Mech.*, (2020).

Liedmann, J., Barthold, F.-J.: Variational sensitivity analysis of elastoplastic structures applied to optimal shape of specimens. *Struct. Multidisc. Optim.*, (2020).

Liedmann, J., Barthold, F.-J.: Sensitivity analysis of elastoplastic structures and application to optimal specimen design. *Proc. Appl. Math. Mech.* 19, (2019).

Guhr, F., Sprave, L., Barthold, F.-J., Menzel, A.: Computational shape optimisation for a gradient-enhanced continuum damage model. *Comp. Mech.* 65, (2020).

Guhr, F., Barthold, F.-J., Meya, R., Tekkaya, E.: Load Optimisation for Air Bending in the Context of Damage Reduction, *Proc. Appl. Math. Mech.* 19, (2019).

Wohlgemuth, F., Barthold, F.-J.: Controlling Physical Properties on Interfaces Using Parametrised Level Set Methods and Extended Finite Element Method, *Proc. Appl. Math. Mech.* 19, (2019).

Loske S., F., Barthold, F.-J.: Free Material Optimization of Multilayer Composite Materials, *Proc. Appl. Math. Mech.* 19, (2019).

Waschinsky, N., Barthold, F.-J., Menzel, A.: Optimisation of Diffusion Driven Degradation Processes. *Proc. Appl. Math. Mech.* 19, (2019).

### Fields of research

Continuum mechanics  
 Numerical methods and FEM formulations  
 Structural optimisation (topology, shape and material optimisation)  
 Inverse problems  
 Variational sensitivity analysis  
 Control of damage in forming processes  
 Analysis and optimisation of multi-scale problems  
 Micromorphic continua  
 Phase field simulation  
 Tree Engineering

### Research projects

Combined shape and cross-section optimisation of fibre composite structures based on singular value decomposition of the sensitivities (DFG)

SFB/Transregio 188 "Damage Controlled Forming Processes", TP C05: "Sensitivity and Optimisation" (DFG)

Digital learning environment in structural engineering as a holistic concept (funding line "OER-Content.nrw" for the production of digital teaching and learning offers for the state portal DH-NRW)

Tree Engineering (funding line "Holz-Wissen" to improve the state of knowledge about hardwoods and softwoods as materials in construction)

#### **List of employees**

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Markus Behlau  
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M. Sc. Fabian Guhr  
M. Sc. Jan Liedmann  
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M. Sc. Felix Wohlgemuth  
M.Eng. Adam Chejanovsky  
M.Sc. Simon Loske  
B.Sc. Lydia Puttkamer  
M.Sc. Navina Waschinsky  
M.Sc. Jan Bernd Wulf  
Dipl.Des. Martin Zeller

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Dominik Schwarzenberg  
Markus Waldecker