Institute of Structural Mechanics, Statics and Dynamics

TEACHING AND RESEARCH FOCUS

The chairs "Structural Mechanics" as well as "Statics and Dynamics" teach the mathematically oriented fundamentals for the mechanical design and evaluation of buildings and structures in the bachelor's degree program in Civil Engineering. In addition, in-depth, practice-oriented as well as research-oriented courses are offered, which individualize the profile of the graduates and prepare them for the wide range of tasks in civil engineering. In this context, topics of sustainable construction are increasingly addressed, which is reflected, among others, in the planning of the international master's program "Mechanics of Sustainable Materials and Structures", see Fig. 1.

This Master's program (MS2), which will be offered for the first time in winter semester 2024/25, will take place in cooperation with the Università di Trento (Italy) and the Ecole Centrale de Nantes (France). Students will thus have the opportunity to educate themselves through a continuous curriculum at three European universities. The accompanying internationalization and the focus on a socially important topic in civil engineering corresponds to the overarching goals of the TU Dortmund and the faculty. Funding applications for the international Master will be submitted in the next DFH and Erasmus Mundus call. If successful, this will allow, among other things, the payment of a monthly stipend for enrolled students. The responsible persons at TU Dortmund University (Prof. Madeo, Prof. Münch) would like to thank all involved for their versatile support during the planning and accreditation phase.

MECHANICS OF SUSTAINABLE MATERIALS AND STRUCTURES (M.SC.)

Multiple Degrees offered on a joint curriculum by

Faculty of Architecture and Civil Engineering, TU-Dortmund University (Germany)

Department of Civil, Environmental and Mechanical Engineering, University of Trento (Italy)

Department of Mechanics, Materials and Civil Engineering, Ecole Centrale de Nantes (France)

Fig. 1: Excerpt from the flyer announcing the international master's program MS2.

In cooperation with various chairs, the course "Higher Mathematics 3 for Civil Engineering" was held for the first time in winter semester 2022/23. With technical contributions from Prof. Orlowsky, Prof. Hartz, Jun. Prof. Spyridis, Prof. Madeo, Prof. Barthold and Prof. Münch, the application of mathematical methods is directly related to practical construction problems in order to address the intrinsic motivation of students for this theory-based subject. A large part of the teaching team (J. Voss, K. Peper, S. Loske and I. Münch) have participated in one or more advanced training courses in high didactics at the zhb of the TU Dortmund in the summer semester 2023 and will, among other things, further develop such theory-based subjects by activating self-work phases.

In the subject of structural analysis, the creation of digital formats to supplement lectures as "Open Educational Resources" (OER content) has been implemented since 2020. The first of two stages was completed in 2022 and firmly integrated in the subject "Fundamentals of Structural Analysis". It should be emphasized that these digital materials deliberately complement the face-to-face courses and do not completely replace them, as was necessary in the pandemic semesters. In the second stage, the creation of a digital learning environment for the subject of dynamics will now be continued until the end of 2024. We are expressly grateful for the funding of the "ALFDYN" project by the state of NRW.

In the summer semester of 2023, a total of 22 students in the bachelor's degree program in civil engineering took part in the elective course "Software in Structural Mechanics" and worked, among other things, on a module for small-scale redensification of suburban areas. The elevated position of the residential structure on only two supports keeps the underlying surface as permeable as possible. The special feature here is that vertical and horizontal loads are transferred via different structural components. This principle largely frees the two columns from transverse force and bending, which minimizes their cross-section and foundation. This final project addresses numerous points of sustainable construction and gives students the opportunity to develop their own ideas.
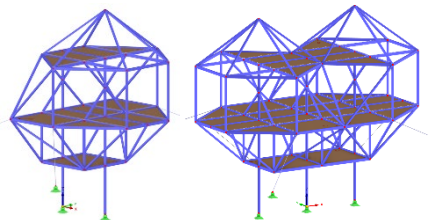

Fig. 2: Module for the redensification of suburban areas in the subject of software in structural mechanics.

In cooperation with the chair "Materials of Civil Engineering" and under the guidance of the lecturer Dr.-Ing. Daniel Algernon, a total of 17 students of the Master's program in Civil Engineering again worked in 7 teams on issues related to non-destructive structural diagnostics in the summer semester 2023, which were presented in a final colloquium on June 30, 2023, through the presentations of test instructions and posters.

Fig. 3: Group picture with participants of the course "Non-destructive Building Diagnostics" in the summer term 2023

In December 2022, Dr. Adam Sky, former research associate at the chair for Statics and Dynamics, successfully defended his dissertation thesis entitled: Higher Order Finite Elements for Relaxed Micromorphic Continua. The work spans a coherent arc from the fundamentals of continuum mechanics, through mathematical methods for constructing suitable polynomial spaces, to unlock the propagated novel strategy for constructing H(curl)-conforming elements. With the help of theorems on linear independence and conformality of the approaches, their sound justification succeeds. In addition, an efficient construction for Bernstein polynomials within the numerical environment is presented, which is based on the principle of dual numbers and yields their derivatives. The vector-valued finite elements programmed with it thus achieve high efficiency. Comparison with analytical solutions shows that the new construction method yields robust and high-quality approximations for H(curl) based micromorphic continua.

GAMM-JUNIOR RESEARCH GROUP

The GAMM junior research group was founded at TU Dortmund University in 2019. This is a research group which consists of the Institute of Mechanics of Mechanical Engineering, the Institute of Structural Mechanics, Statics & Dynamics of Civil Engineering and various chairs of the Department of Mathematics. The aim of the junior research group is the interdisciplinary exchange of the different PhD students in applied mathematics and mechanics. After four successful years at TU Dortmund University, many interesting lectures in the field of applied mechanics and mathematics took place this year. The year 2022 ended with a lecture by Jun.-.Prof. Dr. rer. nat. Matti Schneider on micromechanical simulations based on Fast-Fourier "A modern view of FFT-based computational methods in micromechanics" on 01.12.2022. The year 2023 started quickly with more interesting lectures on neural networks "Model-driven neural networks: From basics to applications in the calculus of variations" by Prof. Dr. Robert Martin on Jan. 19, 2023, and two lectures on Jan. 26, 2023 by Prof. Dr. Stefanie Hahmann on "Geometric Construction of Auxetic Metamaterials" and by Prof. Dr. Georges-Pierre Bonneau on "Computational Design of Laser-Cut Bending-Active Structures." On 28.02. there was a lecture by Dr.-Ing. Stephen Gerke, which dealt with the experimental side of material characterization, entitled "Biaxial testing of ductile damage in metals: New approaches and specimens". On 02.03. Dr. Hanna Bishara gave details on damage at the microscale in his presentation "Local Electrical Properties of Microstructural Defects". On 05/10, Assoc. Prof. Stephan Rudykh, Ph.D. gave his talk on "Micromechanics and Instability-driven Pattern Formations in Soft Magneto-Active Materials." In addition to these many interesting lectures, the offer of a PhD hour has also been given every semester since 2022. The purpose of this is to give interested students the opportunity to find out from staff members of various institutes who are currently working on their doctorates what the day-to-day work of a doctoral student is like and to ask general questions about the topic of doctoral studies. The second doctoral hour took place on 04.11.2022 and led to a lively exchange between doctoral students and students. In 2023, the number of members at TU Dortmund University continued to increase when the newly founded chair "Reliability Engineering" under the direction of Prof. Faes at the Faculty of Mechanical Engineering joined the junior research group. This now comprises 56 members, divided among 8 chairs. To ensure a scientific exchange of the members in a relaxed atmosphere, the junior research group also offers regular social activities. For example, a summer party organized by the junior research group took place on 07.09.2023, where the prospective PhD students could exchange ideas outside of work and a nice evening was organized. Furthermore, the members from the junior research group of the Ruhr University Bochum, as here a scientific exchange across the university is sought. This will be continued in the coming year, whereby the respective presentations of the junior research groups will also be made available to the other. To facilitate this, social activities will also be continued. Thus, excursions to a climbing hall as well as playing soccer together at the TU Dortmund will continue to be items on the list of activities.
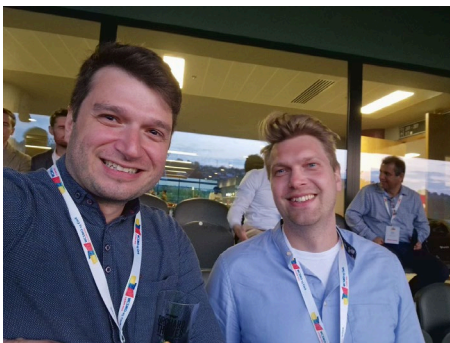

Fig. 4: Participation at WCSMO 15 in Cork, Irland

Fig. 5: Participation at ASME International Conference on MSNDC in Boston, USA

Fig. 6: Annual meeting of the GACM in Vienna, Austria
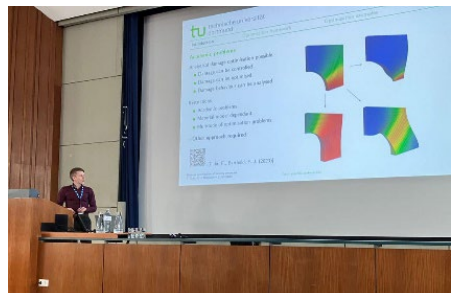

Fig. 7: Participation in the GAMM annual meeting, Dresden, Germany

Current research results around the topics of sensitivity analysis and structural optimization in the context of dynamic processes, thin-walled laminate structures or damage in forming processes, were presented at numerous international conferences. In May 2023, members of the Chair of Structural Mechanics attended the annual meeting of the Society for Applied Mathematics and Mechanics (GAMM) in Dresden, as well as the World Conference on Structural and Multidisciplinary Optimization (WCSMO) in Cork, Ireland.

The 19th ASME International Conference on Multibody Systems, Nonlinear Dynamics, and Control (MSNDC) was held in Boston, USA, from August 20-23, 2023. This symposium was devoted to the latest developments

in the theoretical, computational, and applied aspects of performance optimization and cost reduction of complex dynamic systems. Such systems can cover various disciplines and phenomena as they occur in the automotive, aerospace, micromechanical, industrial, and consumer markets.

This was followed in September 2023 by participation in the annual meeting of the German Association for Computational Mechanics (GACM) in Vienna, Austria.

PUBLICATIONS

Liedmann, J., Gerzen, N., Barthold, F.-J.: Gradient-based determination of principal design influences on composite structures. Proc. Appl. Math. Mech., 23: e202300177, 2023 https://doi.org/10.1002/pamm.202300177

Guhr, F. and Barthold, F.: Geometric and material sensitivities for elasto-plasticity including non-local damage regularisation. Proc. Appl. Math. Mech., 23: e202200233, 2023 https://doi.org/10.1002/pamm.202200233

Guhr, F., Barthold, FJ. Variational sensitivity analysis and shape optimisation applied to a non-local, ductile damage model. *Comput Mech,* 2023 https://doi.org/10.1007/s00466-023-02377-w

Guhr, F., Gitschel, R., Barthold, F.-J., & Tekkaya, A. E.: Numerical optimisation of damage in extrusion processes. Proceedings in Applied Mathematics and Mechanics, 00, e202300199. 2023 https://doi.org/10.1002/pamm.202300199

Ghasemi, S. A., Liedmann J., Barthold, F.-J.: Geometrical design modes of dynamic structures. Proceedings in Applied Mathematics and Mechanics. 2023 https://doi.org/10.1002/pamm.202300196

Sky, A., Polindara, C., Muench, I., Birk, C.: A flexible sparse matrix data format and parallel algorithms for the assembly of finite element matrices on shared memory systems. Parallel Computing, in press, available online since 22.07.2023, https://doi.org/10.1016/j.parco.2023.103039

Sky, A., Muench, I., Neff, P.: A quadratic element for the relaxed micromorphic model. Proc. Appl. Math. Mech., 22(1), 1-7, 2022. https://doi.org/10.1002/pamm.202200086

Loske, S., Muench, I.: Experiments and Modelling of the Load Capacity of Green Wood. Proc. Appl. Math. Mech., 22(1), 1-6, 2022. https://doi.org/10.1002/pamm.202200290

Wulf, J. B., Muench, I.: Growth of green wood based on a phase field model. Proc. Appl. Math. Mech., 22(1), 1-6, 2022. https://doi.org/10.1002/pamm.202200067

Sky, A., Neunteufel, M., Muench, I., Schöberl, J., Neff, P.: Primal and mixed finite element formulations for the relaxed micromorphic model. Computer Methods in Applied Mechanics and Engineering 399, 115298, 2022. https://doi.org/10.1016/j.cma.2022.115298

Sky, A., Muench, I., Neff, P.: On [H1]3x3, [H(curl)]3 and H(sym Curl) finite elements for matrix-valued Curl problems. Journal of Engineering Mathematics 136(5), 2022. https://doi.org/10.1007/s10665-022-10238-3

Zeller, M., Münch, I.: Befestigung von Bauwerken in Bäumen mit Baumanker und doppelter Umreifung. Bautechnik 99(S1), 13-22, 2022. https://doi.org/10.1002/bate.202100078

Voss, J., Rizzi, G., Demetriou, P., Neff, P., & Madeo, A. (2023). Remarks on wave propagation in an acoustic metamaterial modeled as a relaxed micromorphic continuum. PAMM, 23(1), e202200182. https://doi.org/10.1002/pamm.202200182

Ghiba, I. D., Rizzi, G., Madeo, A., & Neff, P. (2023). Cosserat micropolar elasticity: classical Eringen vs. dislocation form. Journal of Mechanics of Materials and Structures, 18(1), 93-123. https://doi.org/10.2140/jomms.2023.18.93

Voss, J., Rizzi, G., Neff, P., & Madeo, A. (2022). Modeling a labyrinthine acoustic metamaterial through an inertia-augmented relaxed micromorphic approach. Mathematics and Mechanics of Solids. https://doi.org/10.1177/10812865221137286

Rizzi, G., Neff, P., & Madeo, A. (2022). Metamaterial shields for inner protection and outer tuning through a relaxed micromorphic approach. Philosophical Transactions of the Royal Society A, 380(2231). https://doi.org/10.1098/rsta.2021.0400

Demore, F., Rizzi, G., Collet, M., Neff, P., & Madeo, A. (2022). Unfolding engineering metamaterials design: Relaxed micromorphic modeling of large-scale acoustic meta-structures. Journal of the Mechanics and Physics of Solids, 168. https://doi.org/10.1016/j.jmps.2022.104995

Rizzi, G., Tallarico, D., Neff, P., & Madeo, A. (2022). Towards the conception of complex engineering metastructures: relaxed-micromorphic modelling of low-frequency mechanical diodes/high-frequency screens. Wave Motion, 113. https://doi.org/10.1016/j.wavemoti.2022.102920

SUBMITTED PUBLICATIONS

Sky, A., Muench, I.: Polytopal templates for the formulation of semi-continuous vectorial finite elements of arbitrary order. Submitted to International Journal for Numerical Methods in Engineering, NME-Oct-22-0797

Muench, I., Loske, S.: A deterministic model combining NDT to estimate permissible bending loads on trees. Accepted for publication in ce papers: The online collection for conference papers in civil engineering. cepa.202300046

Algernon, D., Muench, I.: Machine Learning Applications for Nondestructive Testing of Concrete Structures. Accepted for publication in ce papers: The online collection for conference papers in civil engineering. cepa.202200137.

Sky, A., Muench, I., Rizzi, G., Neff, P.: Higher order Bernstein-Bézier and Nédélec finite elements for the relaxed micromorphic model. Accepted for publication in: Journal of Computational and Applied Mathematics, ELSCAM-D-23-00021

Rizzi, G., d'Agostino, M. V., Voss, J., Bernardini, D., Neff, P., & Madeo, A. (2023). From frequency-dependent models to frequency-independent enriched continua for mechanical metamaterials. arXiv preprint arXiv:2309.09219.

Demetriou, P., Rizzi, G., & Madeo, A. (2023). Reduced relaxed micromorphic modeling of harmonically loaded metamaterial plates: investigating boundary effects in finite-size structures. arXiv preprint arXiv:2303.17378.

Perez Ramirez, L. A., Rizzi, G., & Madeo, A. (2023). Multi-element metamaterial's design through the relaxed micromorphic model. In Sixty Shades of Generalized Continua: Dedicated to the 60th Birthday of Prof. Victor A. Eremeyev (pp. 579-600). Cham: Springer International Publishing.

THESES

Pinkernell, Nepomuk: Bauzustände und Vorspannung in Fachwerkbögen am Beispiel der Müngstener Brücke, Bachelorarbeit

Klaus, Julian: Tragsysteme und Parameterstudien zur effizienten Planung von Kleinwindkraftanlagen, MasterarH

Kampschulte, Robin: Stabilitätsuntersuchungen und Parameterstudien für schlanke Stützen mit Abspannung durch Seile, Masterarbeit

Schlößer, René Marc: Bemessung des Tragwerks einer Jurte nach Eurocode, Bachelorarbeit

Schaube, Katharina: Entwicklung und Kalibrierung eines Messgerätes zur Seilspannungsmessung von Tragseilen im Baumhausbau, Bachelorarbeit

Harmann, Malte: Modellierung und Analyse von Gitterträgern als Traversen zur Verifikation von Belastungstabellen, Bachelorarbeit

PRESENTATIONS

Liedmann, J., Gerzen, N., Barthold, F-J.: Gradient-based determination of principal design influences on composite structures. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Liedmann, J., Gerzen, N., Barthold, F-J.: Design exploration of layered composite shells. WCSMO 15, 05.06-09.06.2023, Cork, Irland

Guhr, F., Barthold, F-J.: Numerical Optimisation of Damage in Forming Processes. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Guhr, F., Barthold, F-J.: Geometric and material sensitivity analysis for regularisedductile damaging materials. WCSMO 15, 05.06-09.06.2023, Cork, Irland

Guhr, F., Barthold, F-J.: Damage optimisation in forming processes using Abaqus as FE solver. GACM, 10.-13.09.2023, Wien, Österreich

Ghasemi, S. A., Liedmann, J., Barthold, F.-J.: Geometrical design modes of dynamic structures. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Ghasemi, S. A., Liedmann, J., Barthold, F.-J.: PCA of shape sensitivity for dynamic structures. WCSMO 15, 05.06-09.06.2023, Cork, Irland

Ghasemi, S. A., Liedmann, J., Barthold, F.-J.: Shape Modes of Dynamic Structures. ASME, 20.-23.08.2023, Boston, USA

Ghasemi, S. A., Liedmann, J., Barthold, F.-J.: Shape Modes of Dynamic Structures. GACM, 10.-13.09.2023, Wien, Österreich

Muench, I., Loske, S.: A deterministic model combining NDT to estimate permissible bending loads on trees. Eurostruct Conference 2023, 25.-29.09.2023, BOKU, Wien, Österreich.

Wulf, J., Muench, I.: Residual stresses in green wood based on a phase field model. 5th International Conference on Bio-Based Building Materials, 21.-23.6.2023, Wien, Österreich.

Loske, S., Muench, I., Spyridis, P., Zeller, M.: A minimal invasive anchoring technique for the foundation of technical structures in trees. 5th International Conference on Bio-Based Building Materials, 21.-23.6.2023, Wien, Österreich.

Rizzi, G., Voss, J., Hermann, S., Collet, M., Neff, P., Madeo, A.: Modeling large-scale acoustic meta-structures through the reduced relaxed micromorphic model. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Erel-Demore, F., Rizzi, S., Collet, M., Neff, P., Madeo, A.: Unfolding engineering metamaterials design: relaxed micromorphic modeling of large-scale acoustic meta-structures.. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Perez Ramirez, L. A., Rizzi, G., Voss, J., Madeo, A.: Multi-metamaterial structures via the reduced relaxed micromorphic model. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Demetriou, P., Voss, J., Rizzi, G., Madeo, A.: Modeling wave propagation in a finite-size metamaterial through a reduced relaxed micromorphic model. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

Voss, J., Martin, R. J., Neff, P.: Truesdell's empirical inequalities and the coaxiality of stress and stretch. GAMM Jahrestagung, 31.05.-02.06.2023, Dresden

EMPLOYEES

Chairs
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Prof. Dr.-Ing. I. Münch

Secretary
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M. Sc. Fabian Guhr
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Dr. Svenja Hermann
Dr. Felix Erel-Demore
Dr. Gianluca Rizzi
Dr. Max Jendrik Voss
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Nina Kerwien
Sophie Katharina Schliefer
Niklas Eisenblätter
Lucas Funken
Christian Michael Müller
Justus Förster
Niclas Knoop

COURSES

WINTERSEMESTER 2022/23
Stereostatik
Grundlagen der Statik und Dynamik
Lineare Elastizitätstheorie
Lineare Finite Elemente Methode
Computerorientierte höhere Mechanik
Nichtlineare Finite Elemente Methode
Engineering with ANSYS
Sondergebiete der Strukturoptimierung

SUMMERSEMESTER 2023
Elastostatik
Computerorientierte Statik und Dynamik
Software in der Strukturmechanik (WPF)
Nichtlineare Materialmechanik
Strukturoptimierung (WPF)
Zerstörungsfreie Bauwerksdiagnostik (WPF)

RESEARCH PROJECTS

ERC Consolidator Grant - Meta-Lego (101001759): Learning to play LEGO with metamaterials!

Kombinierte Form- und Querschnittsoptimierung von Faserverbundstrukturen basierend auf der Singulärwertzerlegung der Empfindlichkeiten (DFG)

SFB/Transregio 188 „Schädigungskontrollierte Umformprozesse", TP C05: „Sensitivität und Optimierung" (DFG)

Adaptive Lernumgebung im Fach Dynamik als OER - Alfdyn (Förderlinie „OER-Content.nrw" zur Produktion von digitalen Lehr- und Lernangeboten für das Landesportal DH-NRW)