Fall 2023 Joint Colloquium
Materials Department & Materials Research Laboratory

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Computational Mechanics for the Modeling and Exploration of Modern Engineering Materials

This seminar presentation gives an overview of current research activities our team is engaged in, to inspire potential collaboration. The computational mechanics of coupled multiscale problems is a common theme that connects most of the modeling challenges we address, motivated by a broad range of material behaviors and technological applications. Coupling phenomena in mechanics may arise for a number of reasons—e.g., due to mutually-dependent field equations, or in the interplay of constitutive mechanism. The former is typically encountered in the context of multi-physics problems (thermo-, electro-, magneto- or chemo-mechanics) and other systems of coupled balance equations (diffusion-driven deformation, fluid-structure interaction), but also in higher-order continuum formulations (gradient-extended, micromorphic, phase-field). In terms of material responses, the behavior of many advanced engineering materials crucially depends on the coupling of mechanisms such as plasticity, damage, and solid-solid phase transformations. Another example are the unique properties of smart, active and multifunctional materials, which are enabled by multi-physical couplings (piezo-electricity or magnetism, multiferroic behavior). Moreover, both the field and constitutive equations often exhibit coupling across many length-scales.

Many of the computational tools have now reached a level of maturity in terms of predictive accuracy, numerical robustness and efficiency that allows the exploration of new materials and engineering systems in a virtual laboratory sense. Often a key goal is to establish process-structure property relations in a simulation-supported manner. To this end, hybrid algorithms that combine classical and machine learning approaches have recently shown tremendous potential. In this context, we present our scientific work over the past years dedicated to establishing fundamental frameworks for the modeling and simulation of coupled material responses, for solving coupled field problems and for scale-bridging. Some key simulation tools, such as Abaqus User Materials, User Elements, MonolithFE2 and visualization capabilities—many of which we share publicly—are also discussed. Specific application examples include functionalized ceramic filters, TRIP/TWIP steel matrix composites, 3d printing of biodegradable structures, nuclear reactor and material storage safety, thermomechanical fatigue in turbo-chargers and aero-engines as well as actuation, sensing and other engineering applications of conventional and magnetic shape memory alloys.

Bio

Dr. Kiefer currently holds the Full Professor Chair of Applied Mechanics – Solid Mechanics at the Institute of Mechanics and Fluid Dynamics of TU Bergakademie Freiberg, Germany. After completing a five-year mechanical engineering program at the Ruhr-University Bochum, Germany, he joined the Aerospace Engineering Department at Texas A&M University as a Graduate Assistant Research in 2001. There, he earned his Ph.D. degree under the guidance of Professor D. C. Lagoudas in 2006 and was honored with the Distinguished Graduate Student Award for Excellence in Doctoral Research in 2007. After returning to his native Germany, Dr. Kiefer was first employed as a Postdoctoral Research Fellow in the Civil Engineering Department at the University of Stuttgart (Prof. C. Miehe) and from 2010-2016 held the position of Juniorprofessor (Assistant Professor) for the Mechanics of Functional Materials at the Institute of Mechanics (Prof. A. Menzel) at TU Dortmund, Germany.

Dr. Kiefer's research focuses on the computational mechanics-based modeling and simulation of coupling phenomena across length-scales, with applications in a broad range of modern engineering materials. Such couplings can arise from intrinsic multi-physical constitutive interactions (thermal, electric, magnetic, chemical, mechanical), microstructural mechanisms (phase transformations, plasticity, damage), and coupled field equations (thermomechanical balance laws, Maxwell's equations, reaction-diffusion equations). Dr. Kiefer currently serves as Chair of the ASME Smart Materials, Adaptive Structures and Intelligent Systems (SMASIS) Division and was elected Fellow of the Society in 2020. He has organized more than 30 research workshops and symposia at international conferences (e.g., GAMM, WCCM, SMASIS, USNC/TAM, SES). Dr. Kiefer continues to enjoy engaging in research and teaching collaborations with colleagues from around the world.

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