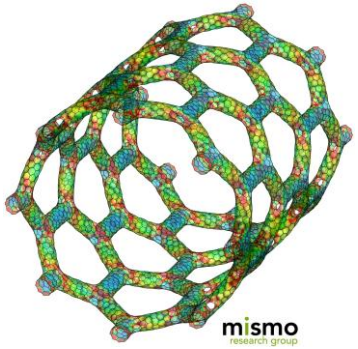
Mechanical instabilities in self-similar molecular structures of higher order

The aim of this project is to obtain basic knowledge about the causes and effects of mechanical instabilities in self-similar structures of higher order. For this purpose, we are investigating a new type of self-similar structure; our focus is on the so-called 'super' carbon- nanotube (see Figure), recently presented in the technical literature. Mechanical instabilities, e.g. the initiation and propagation of defects or the beam- and shell-like buckling, can lead to a failure of the entire structure. The interaction of such phenomena throughout several hierarchical levels will be investigated in detail. As the atomistic models usually applied on the molecular level are inefficient for structures of higher order, novel multiscale models which can exploit the self-similarity of the structures, must be developed. In the context of the numerical implementation, these models will finally be embedded in the formalism of the finite element method.



Analysis of the load carrying capacities of fiber-reinforced polymer girders

The project deals with the development of shell models for the computation of the load carrying capacities of single-span girders with box and I-shaped cross sections made of layered carbon fibre reinforced polymers. The discretization of the beams is performed with four-node shell elements which are able to predict the interlaminar stress state. Implementation of irreversible cohesive laws which allow decohesion at layer boundaries yields an effective tool to compute the load carrying behaviour under consideration of delamination growth. Accompanying stability investigations are made to detect buckling in the web or in the compressed flange. Comparisons with analytical and experimental results obtained with partner projects are made. The overall goal is to successively improve the structural behaviour of the beams.

International activities

Besides national cooperations, there exist several international activities along with researchers from: Paris (FR), Milano (IT), Zagreb (HR), Sofia (BG), Warsaw (PL), Haifa (IL), Beijing (CN), Sidney (AU), Berkeley and Santa Barbara (US), Vancouver (CA).

Funding of research and teaching

Deutsche Forschungsgemeinschaft (DFG), European Union (EU), Alexander von Humboldt Stiftung (AvH), Deutscher Akademischer Austauschdienst (DAAD), Volkswagen Stiftung, Industry.

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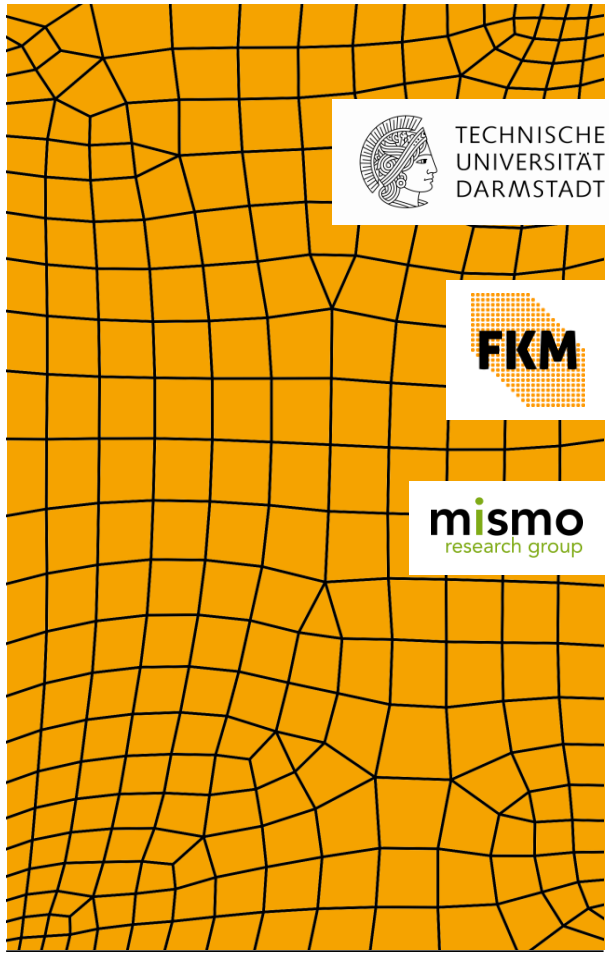


Profile

The chair of solid mechanics in the department of civil engineering and geodesy is engaged in analyses of deformation and stresses in technical structures in the framework of continuum mechanics. One focus of the activities lies in the further development of finite element methods for the solutions of mechanical problems on the macro and micro scale. The considered materials are metals and granular substances, ferroelectrics as well as modern fibre reinforced composites in lightweight structures.

Associated with the chair is the Emmy Noether Research Group “mismo“, under the guidance of Dr.-Ing. Jens Wackerfuß. The main focus of this group is placed on numerical methods to simulate the mechanical behaviour of molecular structures.

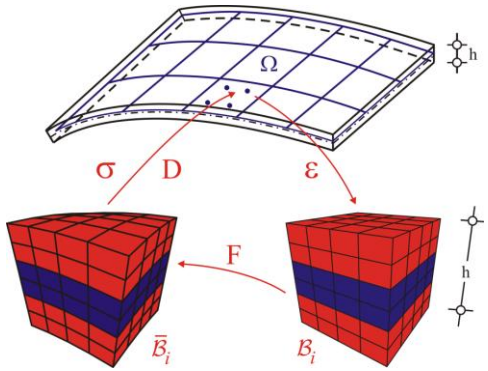
Teaching

The bachelor courses Engineering Mechanics I-III are addressed to students of the departments of civil engineering and geodesy, mathematics and applied mechanics. The master courses are suited for engineering students, mathematics and mechanics students. These are finite element methods I and II (FEM I, II), stability of structures (FEM III), intensive course FEM-simulation with ABAQUS and micro mechanics. Additionally, students can take seminars and theses.

Selected research projects

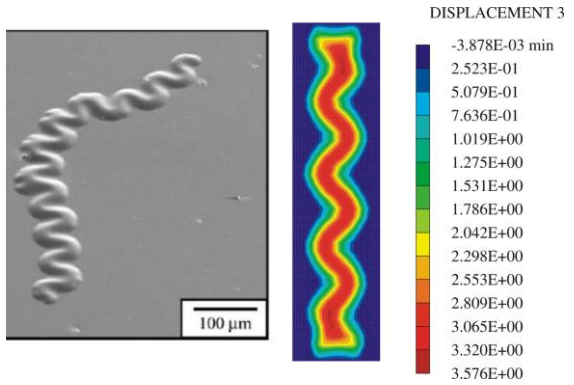
Coupled multiscale simulation of composite materials and structures

Complex structural and material behaviour as prevailing in composites is often not captured sufficiently by phenomenological models. Therefore, coupled multiscale finite element procedures (FE^2) are formulated. On the macroscale, finite elements are utilised, where in each Gauss point a micro-model with a representative volume element (RVE) is invoked. For shell and beam simulations, the RVE ranges through the full shell thickness or the full beam cross-section, respectively. Coupling of the scales is accomplished by means of homogenisation. Using rather elementary material models on the microscale, complex structural and material behaviour can be captured. In the figure below, a shell model with the corresponding RVE and the transferred coupling data is shown as an example.



Finite element models for the analysis of thin film delaminations

Thin solid films deposited over substrates are presently used in diverse technological applications. These are for instance, wear-resistant coatings in metal-cutting tools or diffusion barriers between silicon substrates and metallic conductive layers. In the project, buckling-driven delamination mechanisms are investigated, whereby a portion of the film buckles away from the substrate, thereby forming a blister. For this purpose, finite interface elements which allow description of quasi-static delamination growth are developed. By means of the computed results it is expected to understand the complicated mechanical process in order to make arrangements for the sustainment of the systems.



In the above figure, the “telephone cable” delamination of a thin film on a substrate is shown.

Micromechanics of metal ceramic composites

For high-tech applications, new composite materials with optimal properties must be designed. Metal ceramic composites (MCCs) consist of an interpenetrating network of a brittle ceramic phase and a ductile metal phase with very different thermal and mechanical phase properties. To understand the overall deformation and failure behaviour, a detailed analysis of the micro mechanisms is necessary. This is done by semi-analytical and numerical methods which are able to reflect the microstructure including the damage state of the material. In the figure below, an X-ray scan of the MCC metal phase and a detail of the FE model is shown.