

Selected Research Topics of the Chair of Computational Mechanics

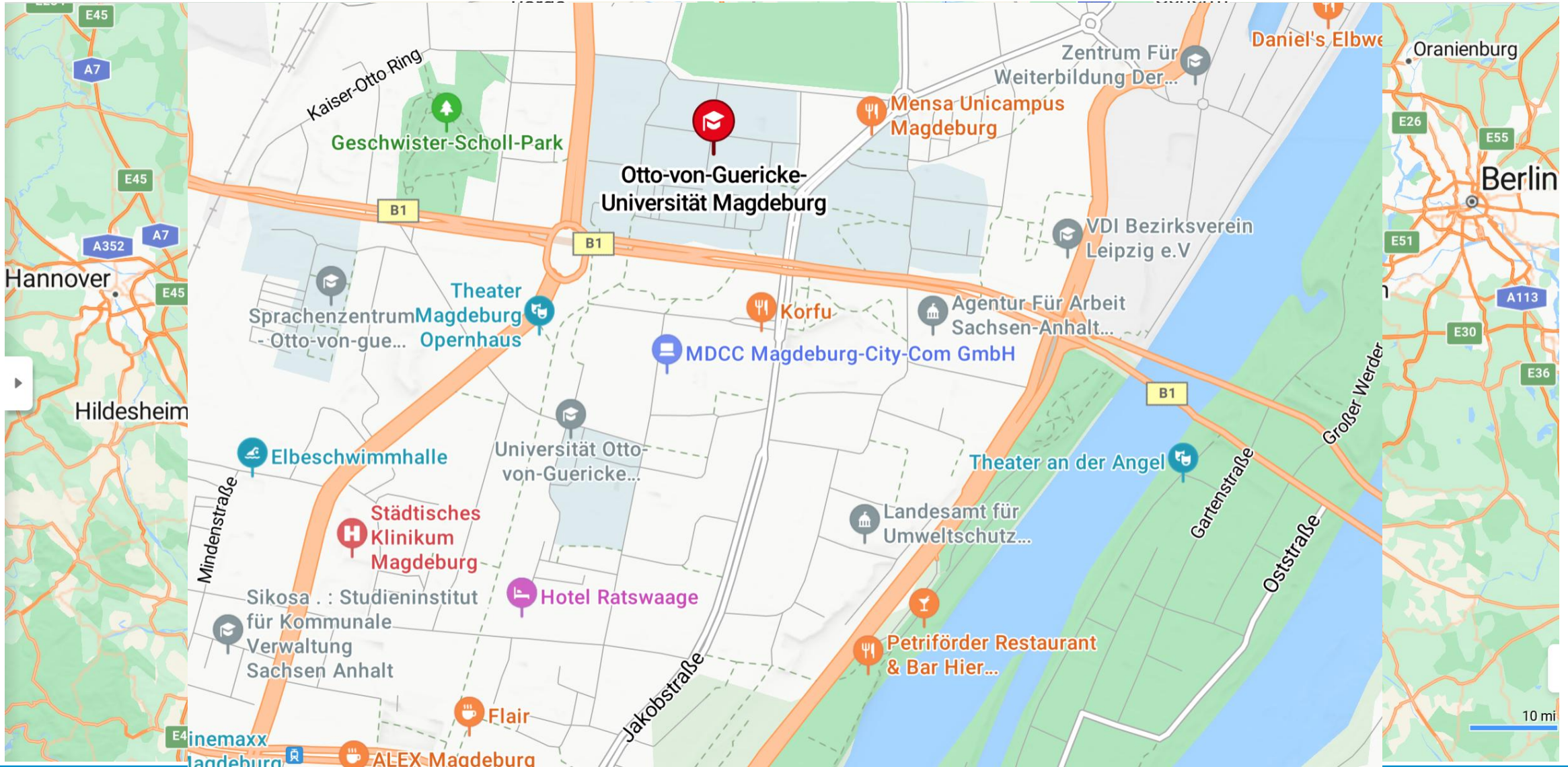
Univ.-Prof. Dr.-Ing. Daniel Juhre

Chair of Computational Mechanics

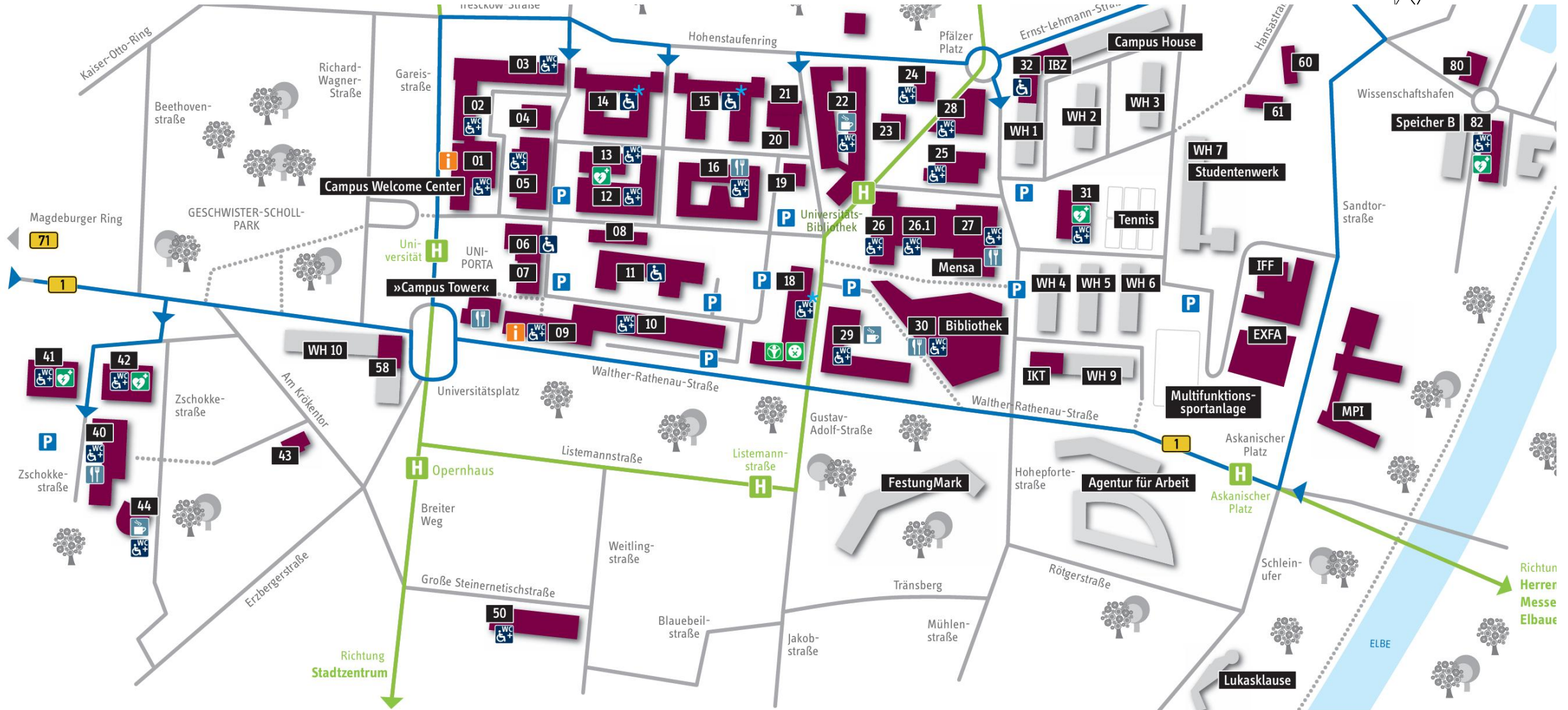
Otto von Guericke University Magdeburg



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Legende

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Facts: 13.000 students
9 Faculties
100 study programs



Tour with students on the campus:

https://www.youtube.com/watch?v=j1JLeK5I-xw&ab_channel=NikhileshDhureGermany



Chair of Computational Mechanics



Head



PostDocs

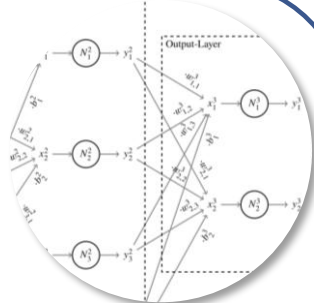
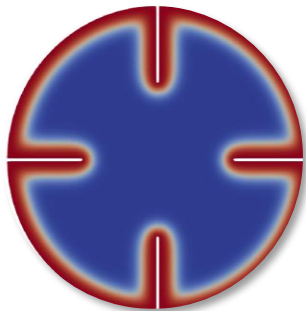
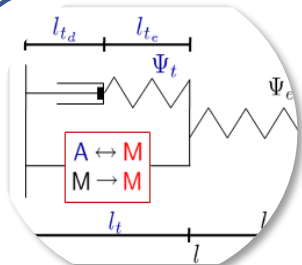


PhD students

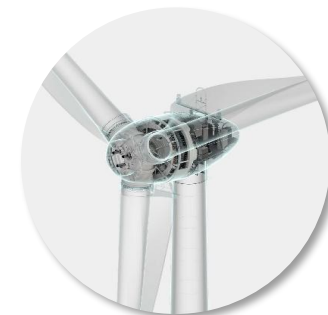
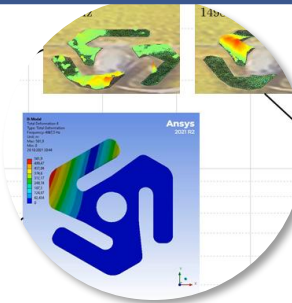
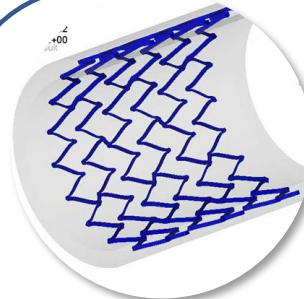
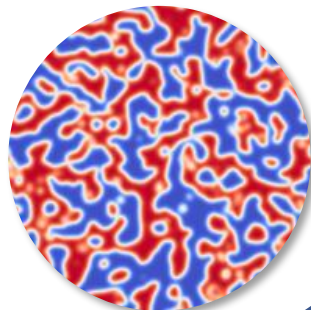
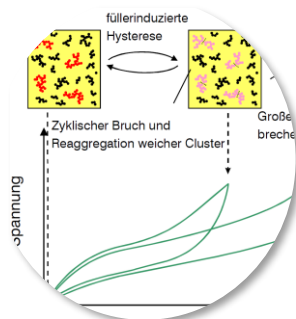
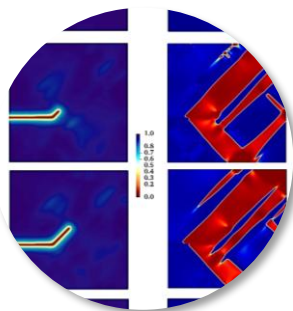


Secretary

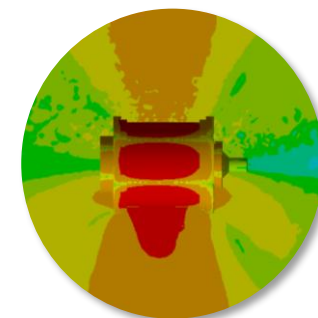
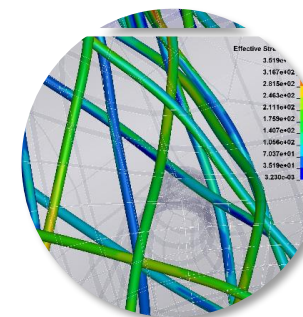
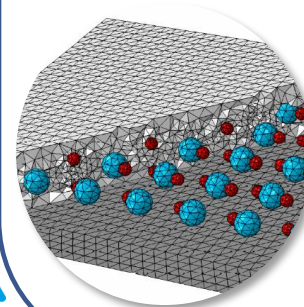




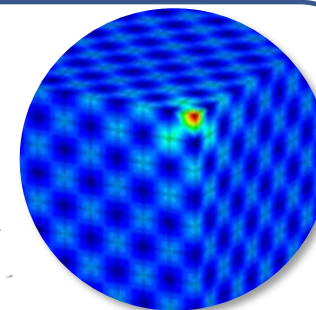
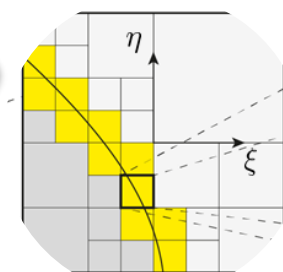
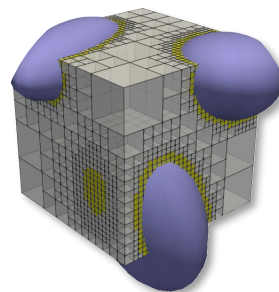
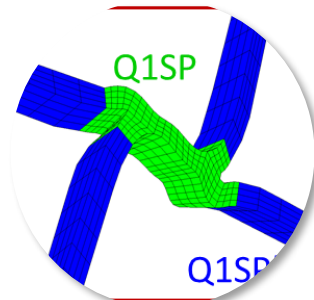
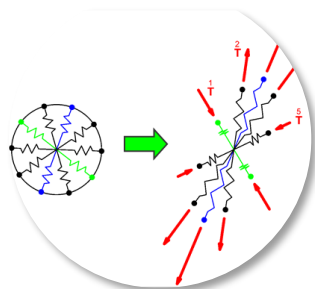
Solid Mechanics

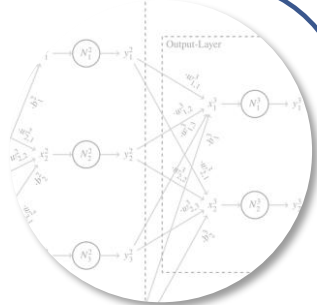
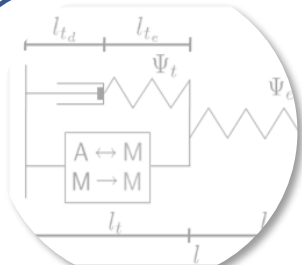


Structure Mechanics

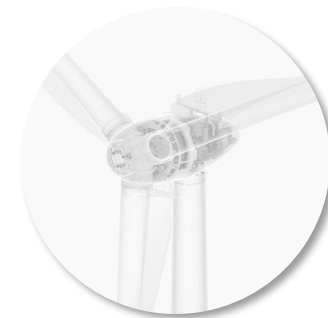
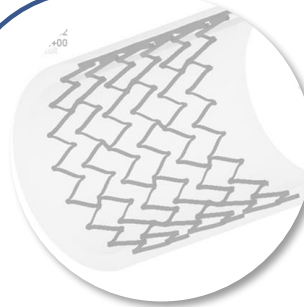
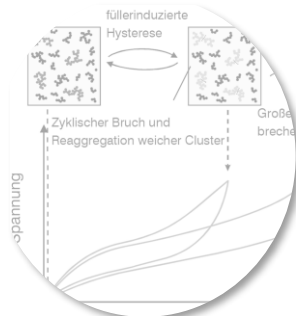
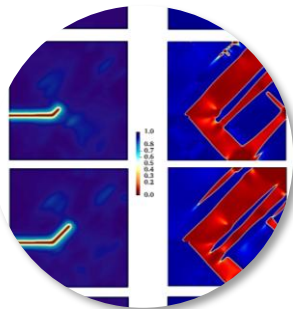


Numerical Methods

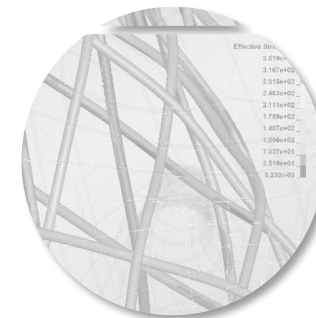
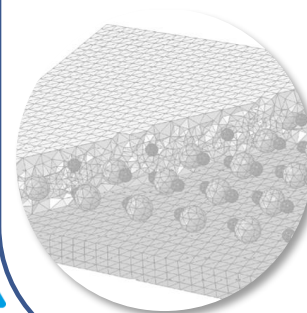




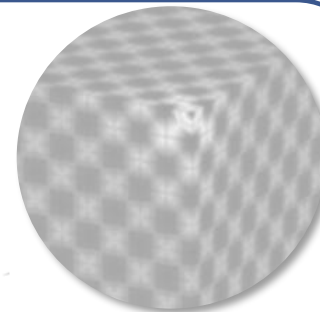
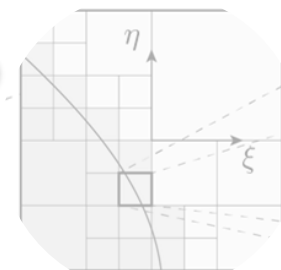
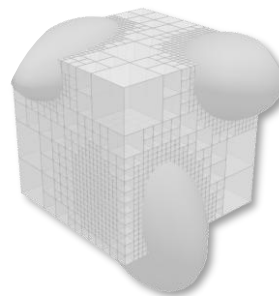
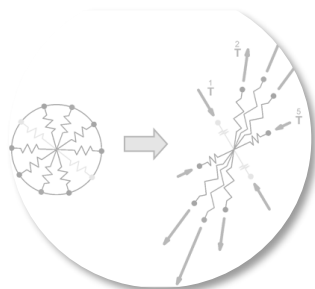
Solid Mechanics



Structure Mechanics

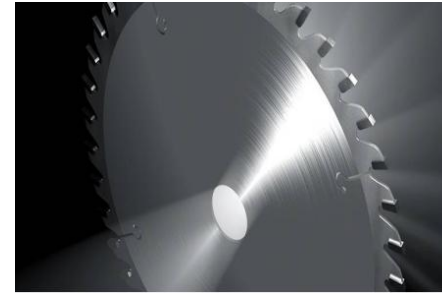


Numerical Methods

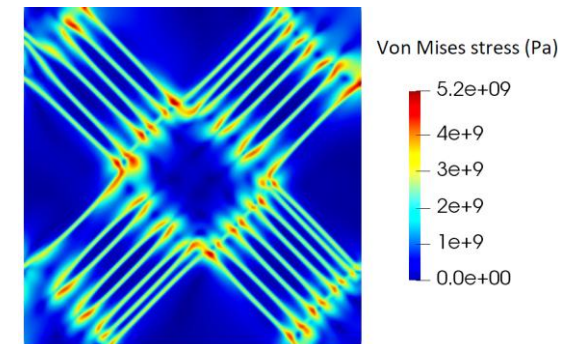
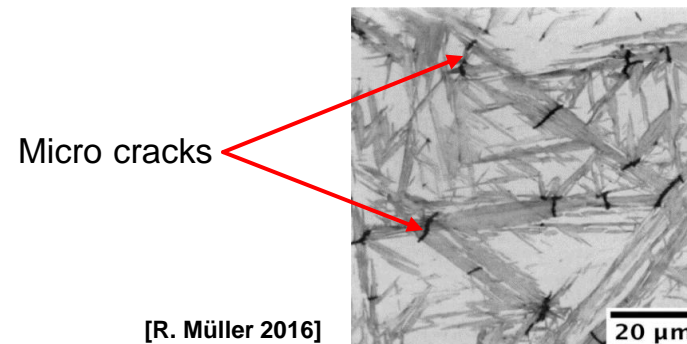


Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

- Martensitic Materials are very popular because of their hardness



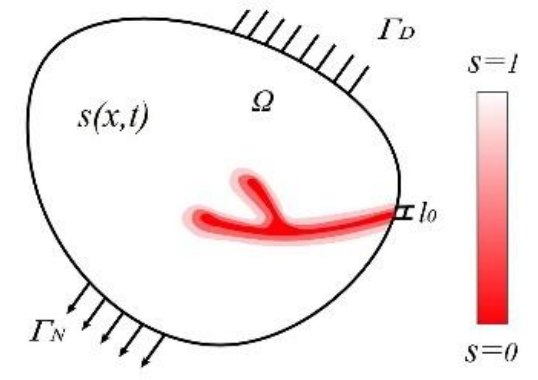
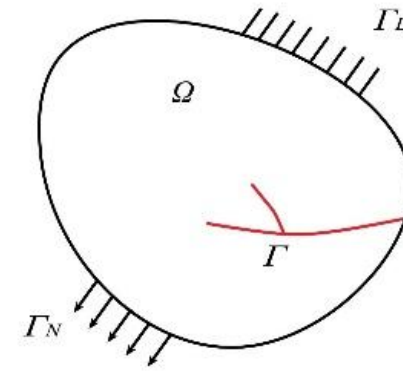
- They tend to crack due to their brittle properties
- Internal stresses due to martensitic transformation coupled to mechanical loadings significantly influence the crack nucleation and propagation



Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

Modelling of discontinuous interfaces by a continuous phase field

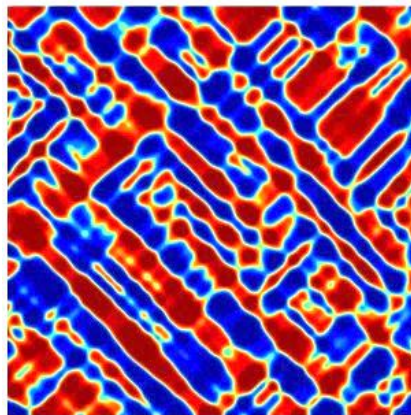
typical fields of application



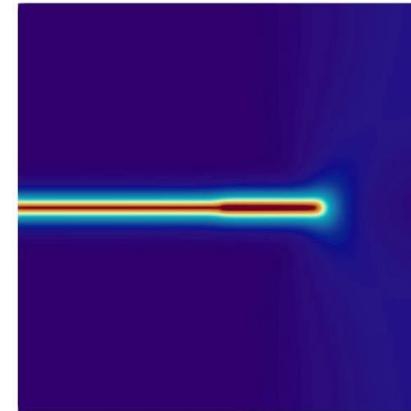
Solidification processes



Phase transformations



Crack propagation



Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

Free energy

$$\Psi_{tot} = \Psi_{el} + \Psi_{pt} + \Psi_{fr}$$

$$\Psi_{el} = (s^2 + \eta) \left(\mu(c) \mathbf{e}_{el} : \mathbf{e}_{el} + \frac{K(c)}{2} \text{tr}^+(\boldsymbol{\varepsilon}_{el})^2 \right) + \frac{K(c)}{2} \text{tr}^-(\boldsymbol{\varepsilon}_{el})^2$$

$$\Psi_{pt} = \frac{G_c}{L_c} \left(1 + \frac{A}{2}(c_1^2 + c_2^2) - \frac{B}{3}(c_1^3 + c_2^3) + \frac{C}{4}(c_1^2 + c_2^2)^2 \right) + \frac{1}{2} G_c L_c \sum_{i=1}^2 \|\nabla c_i\|^2$$

$$\Psi_{fr} = \frac{G_s}{4L_s} (1 - s)^2 + G_s L_s \|\nabla s\|^2$$

with $\boldsymbol{\varepsilon}_{el} = \boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_{pt}$ $\mathbf{e}_{el} = \mathbf{e} - \mathbf{e}_{pt}$

Basic equations

$$\text{div } \boldsymbol{\sigma} = 0 \quad \text{mit} \quad \boldsymbol{\sigma} = \frac{\partial \Psi_{tot}}{\partial \boldsymbol{\varepsilon}_{el}}, \quad \dot{c}_i = -M_c \frac{\partial \Psi_{tot}}{\partial c_i}, \quad \dot{s} = -M_s \frac{\partial \Psi_{tot}}{\partial s}$$

Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

Free energy **incl. temperature dependency**

$$\Psi_{tot} = \Psi_{el} + \Psi_{pt} + \Psi_{fr}$$

$$\Psi_{el} = (s^2 + \eta) \left(\mu(c) \mathbf{e}_{el} : \mathbf{e}_{el} + \frac{K(c)}{2} \text{tr}^+(\boldsymbol{\varepsilon}_{el})^2 \right) + \frac{K(c)}{2} \text{tr}^-(\boldsymbol{\varepsilon}_{el})^2$$

$$\Psi_{pt} = \frac{G_c}{L_c} \left(1 + \frac{A(T)}{2} (c_1^2 + c_2^2) - \frac{B(T)}{3} (c_1^3 + c_2^3) + \frac{C(T)}{4} (c_1^2 + c_2^2)^2 \right) + \frac{1}{2} G_c L_c \sum_{i=1}^2 \|\nabla c_i\|^2$$

$$\Psi_{fr} = \frac{G_s}{4L_s} (1 - s)^2 + G_s L_s \|\nabla s\|^2$$

mit $\boldsymbol{\varepsilon}_{el} = \boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_{pt} - \boldsymbol{\varepsilon}_{th}$ $\mathbf{e}_{el} = \mathbf{e} - \mathbf{e}_{pt} - \mathbf{e}_{th}$

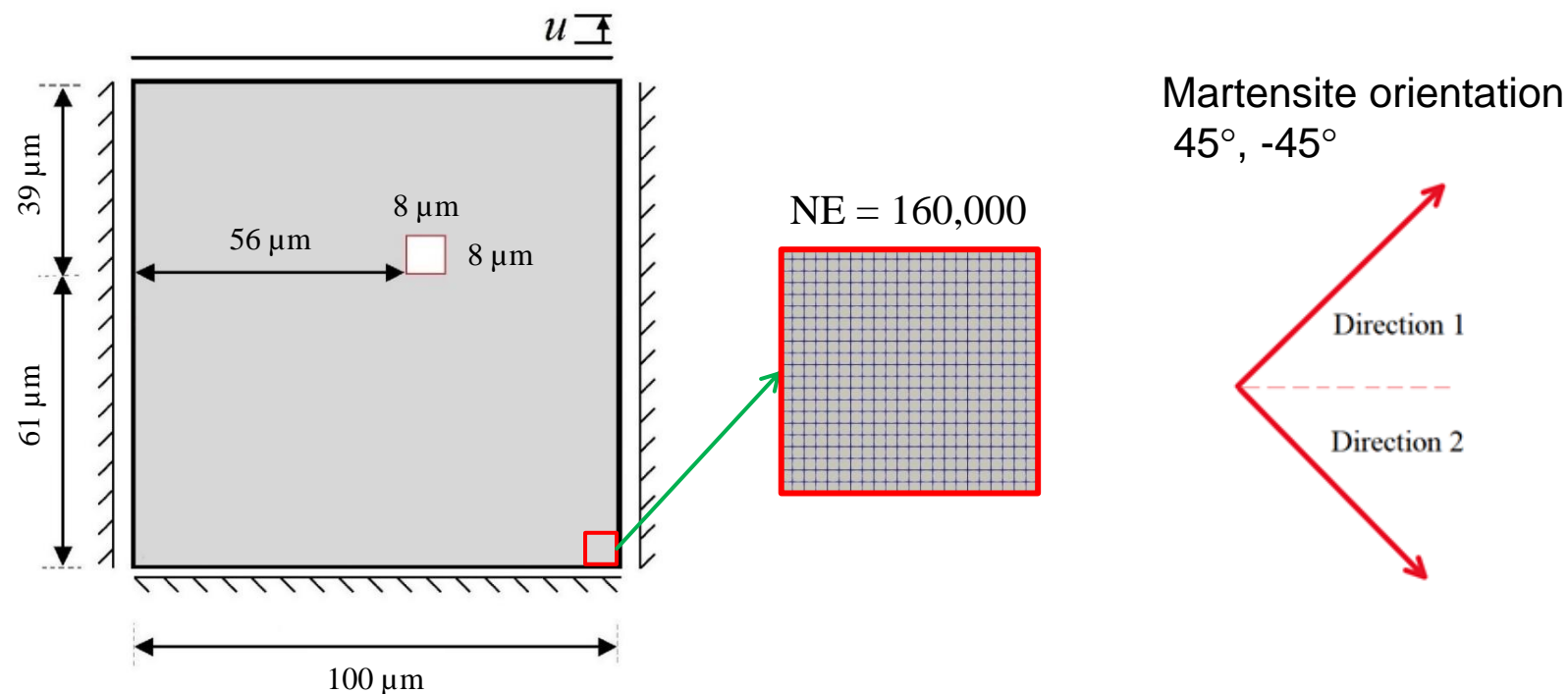
Basic equations

$$\text{div } \boldsymbol{\sigma} = 0 \quad \text{mit} \quad \boldsymbol{\sigma} = \frac{\partial \Psi_{tot}}{\partial \boldsymbol{\varepsilon}_{el}}, \quad \dot{c}_i = -M_c \frac{\partial \Psi_{tot}}{\partial c_i}, \quad \dot{s} = -M_s \frac{\partial \Psi_{tot}}{\partial s}$$

$$\rho c_d \dot{T} + \text{div } \mathbf{q} = 0 \quad \text{mit} \quad \mathbf{q} = -(s^2 + \eta) k \nabla T$$

Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

Bloc with a quadratic hole



FE-Ni Alloy

Shear modulus of A // M

Compression modulus of A // M

Length scale param. for PT // Crack

Interface density // Crack resistance

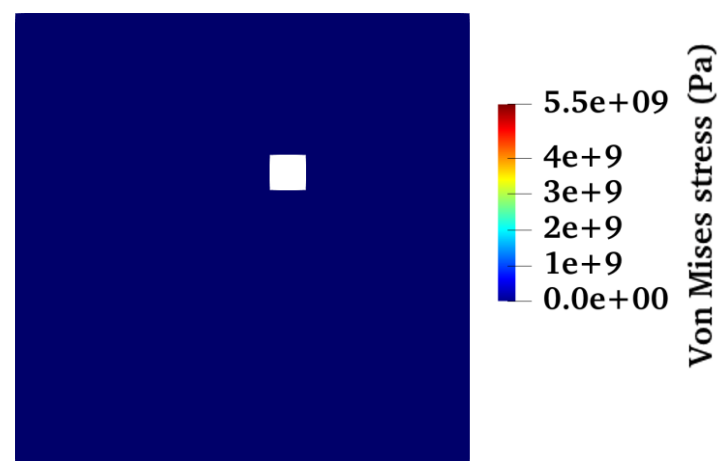
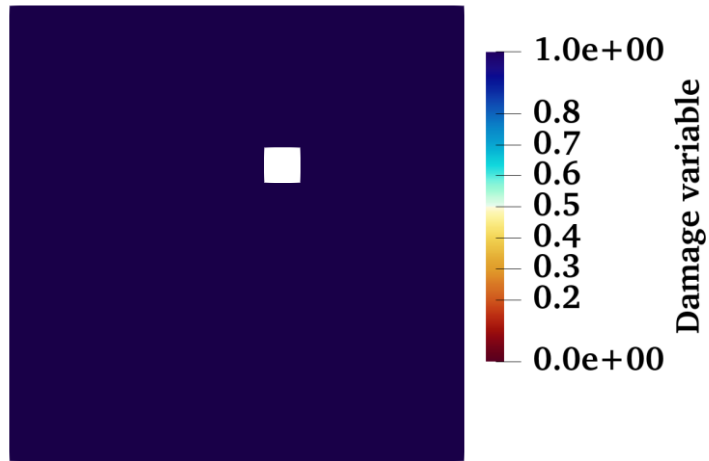
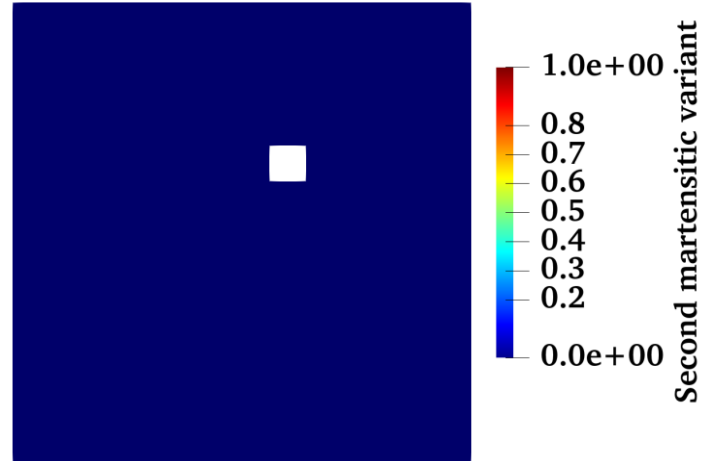
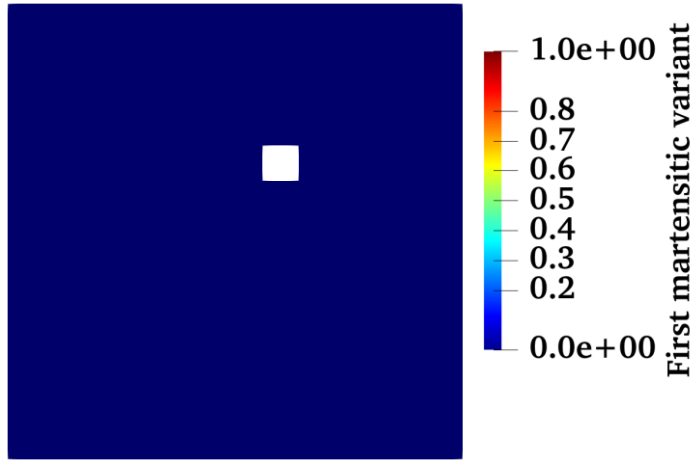
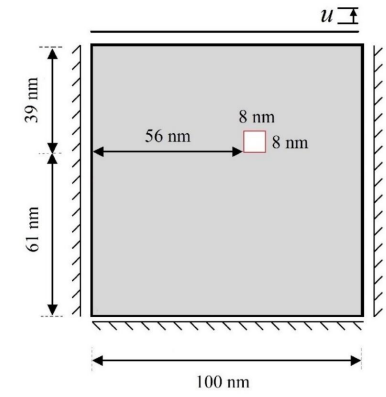
$$\mu_A = 0.28 \times 10^5 \text{ MPa} \quad // \quad \mu_M = 1.1 \mu_A$$

$$K_A = 1.027 \times 10^5 \text{ MPa} \quad // \quad K_M = 1.1 K_A$$

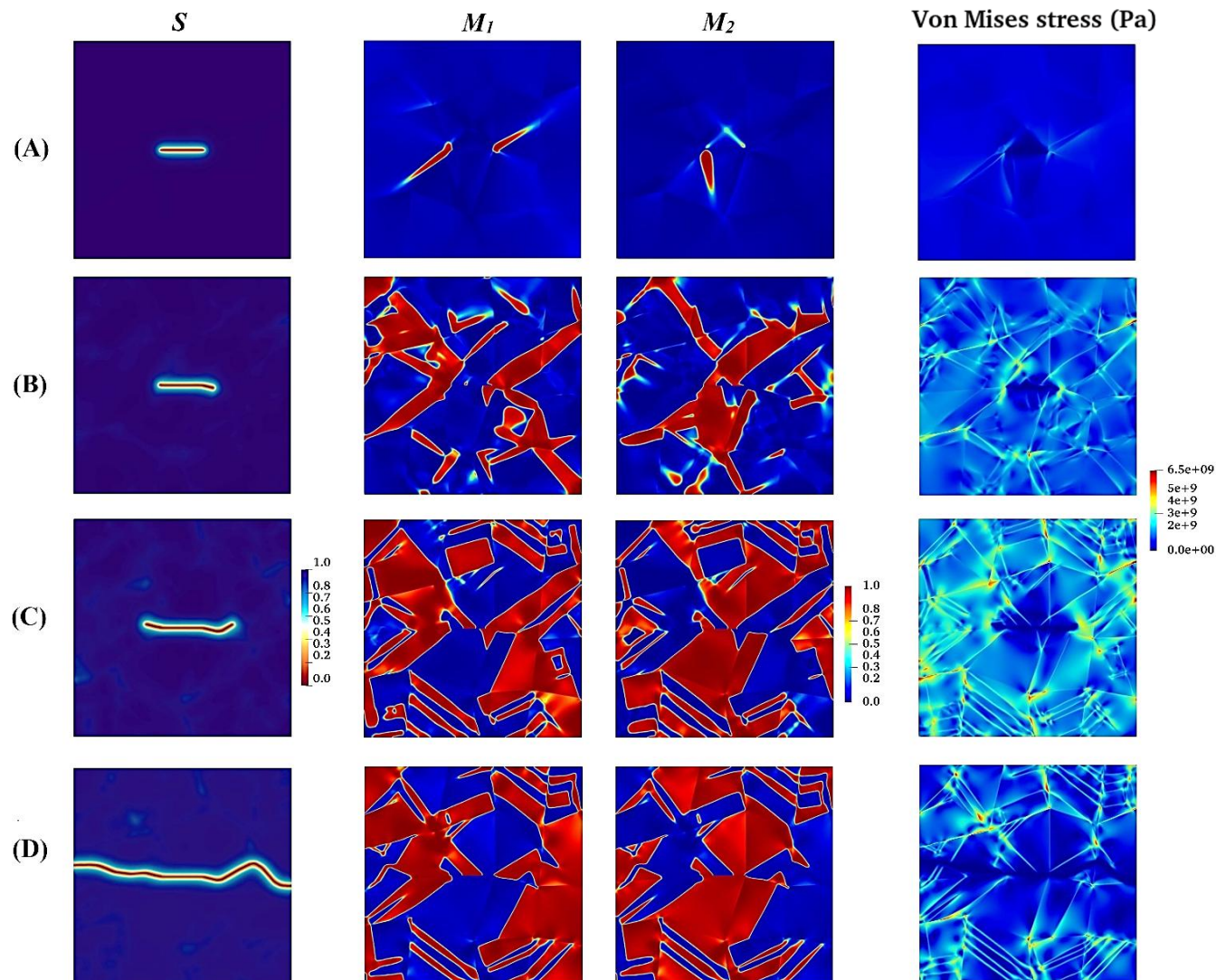
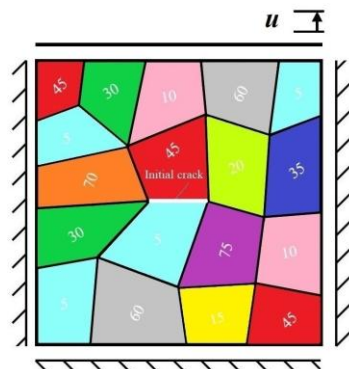
$$L_c = 2 \mu\text{m} \quad // \quad L_s = 2 \mu\text{m}$$

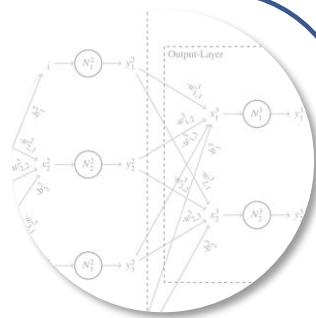
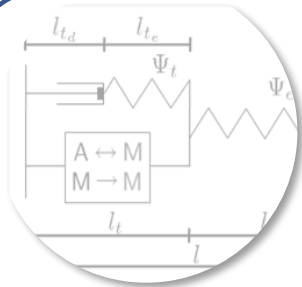
$$G_c = 0.1 \text{ J/m}^2 \quad // \quad G_s = 1.0 \text{ J/m}^2$$

Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

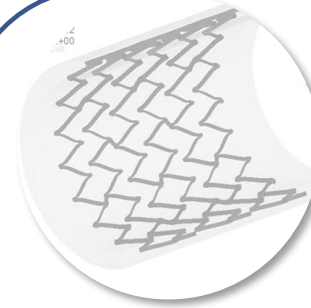
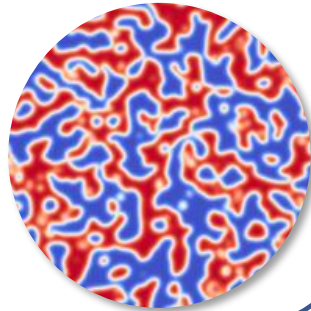
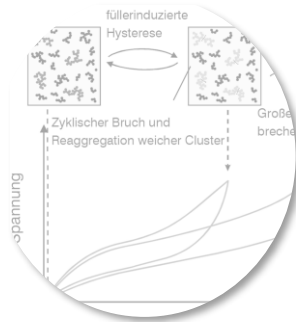
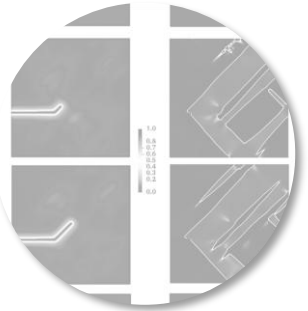


Thermomechanical Interactions between Martensitic Phase Transformation and Crack Propagation

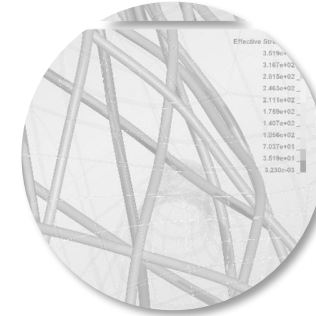
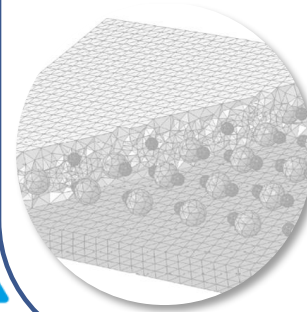




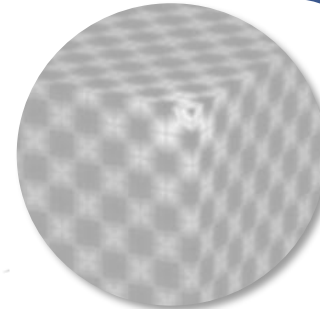
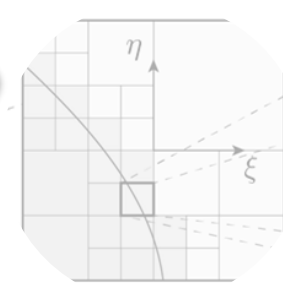
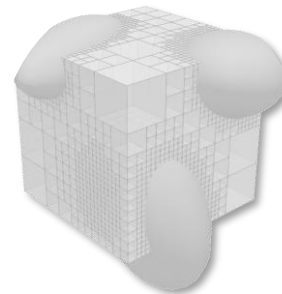
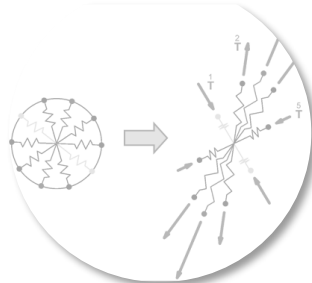
Werkstoffmechanik



Strukturmechanik



Numerische Methoden

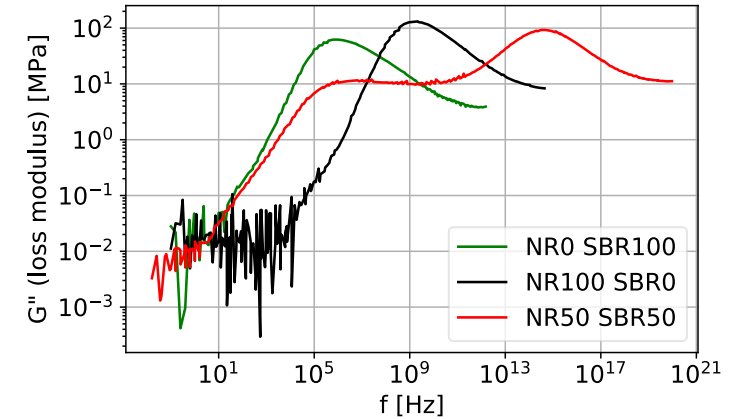
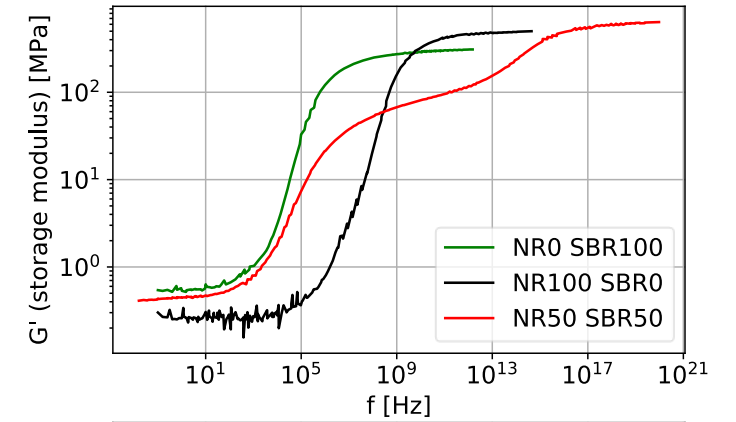
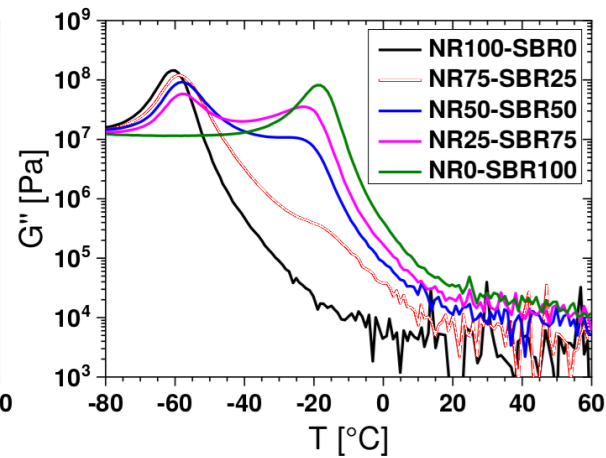
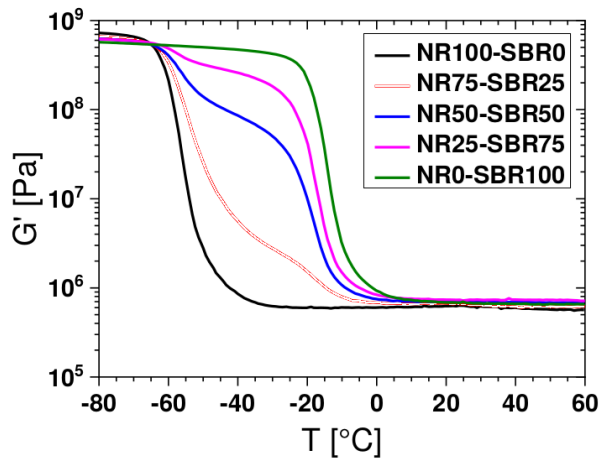


Viscoelastic Properties of Elastomer-Blends

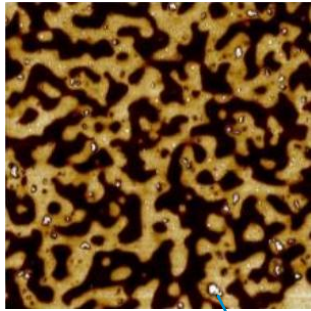


~~→~~
DMA with
f - sweep

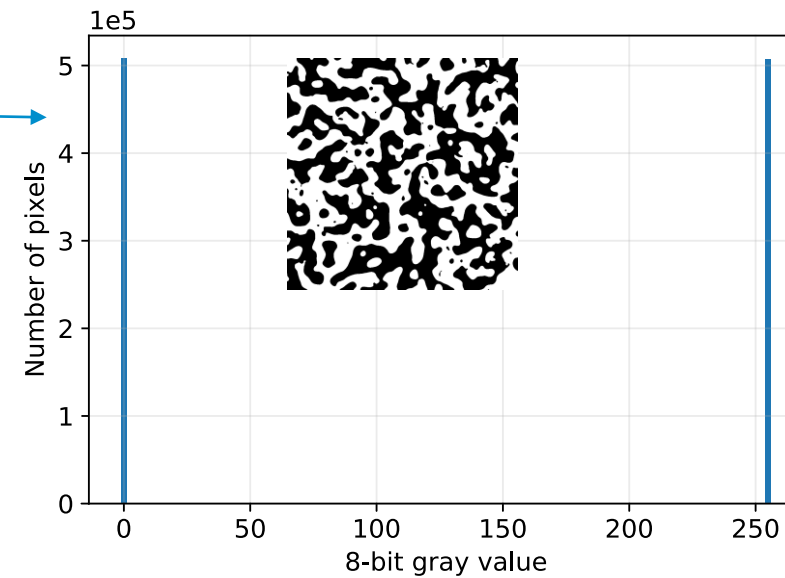
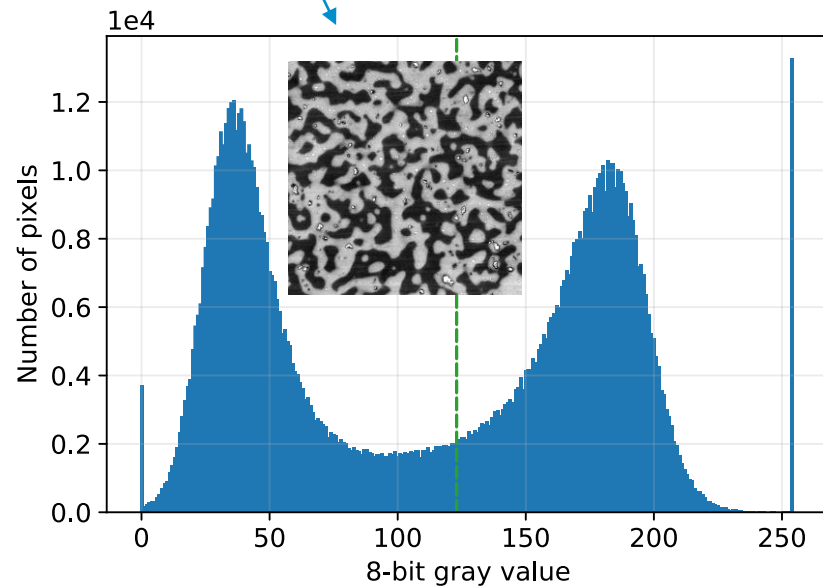
DMA with
T - sweep



Viscoelastic Properties of Elastomer-Blends



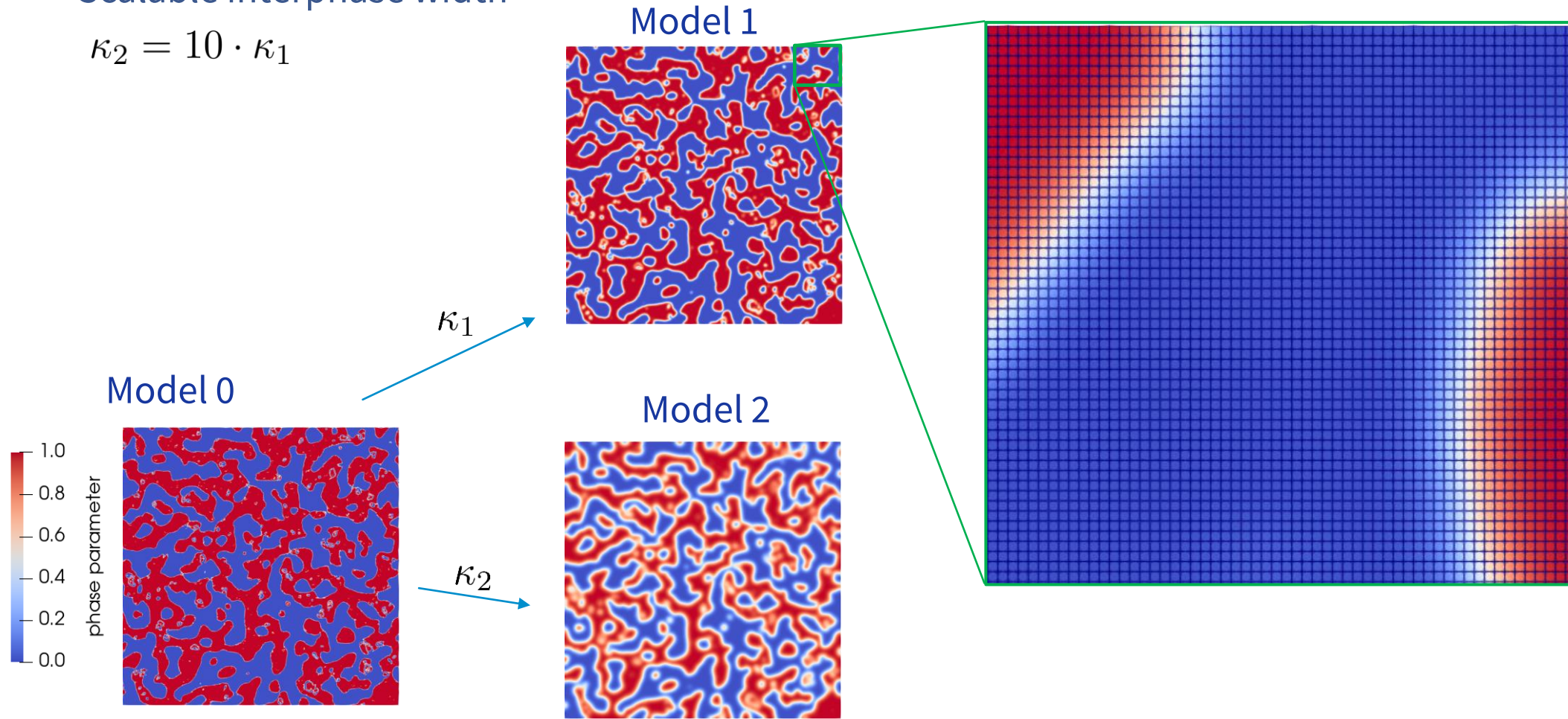
- Atomic Force Microscopy (AFM)
- Blend with NR50 and SBR50
- Idealization of the distribution of two phases
→ Leveling of 50% “Black” and 50% “White”



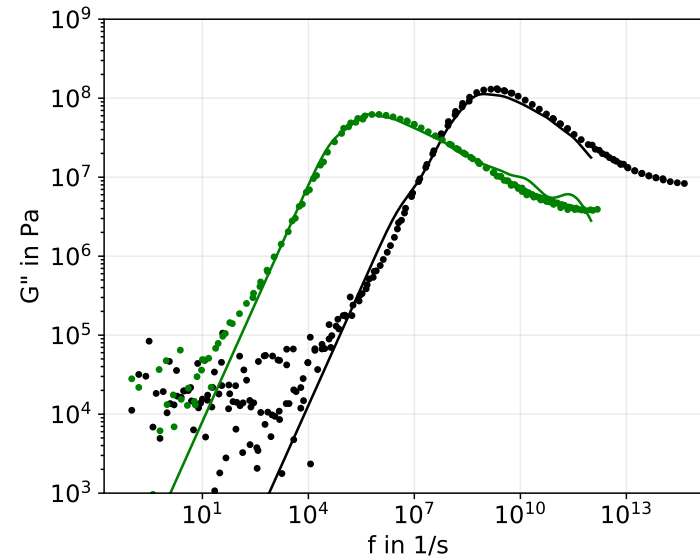
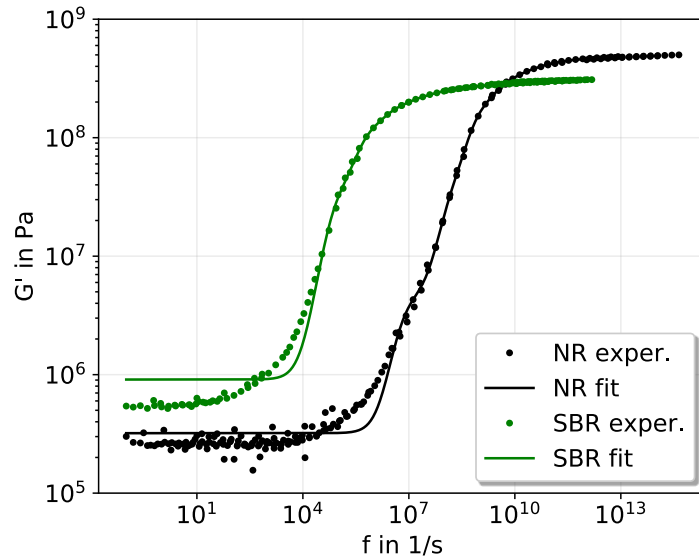
Viscoelastic Properties of Elastomer-Blends

- Phase field method to generate the diffuse interphase
- Scalable interphase width

$$\kappa_2 = 10 \cdot \kappa_1$$



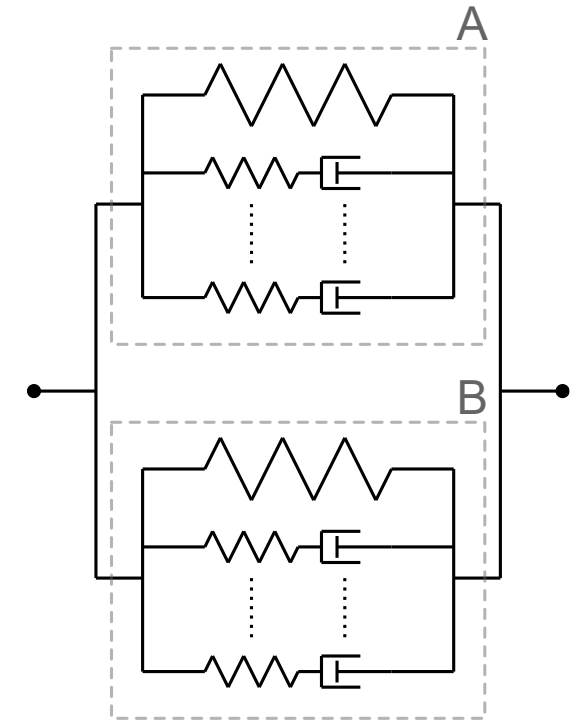
Viscoelastic Properties of Elastomer-Blends



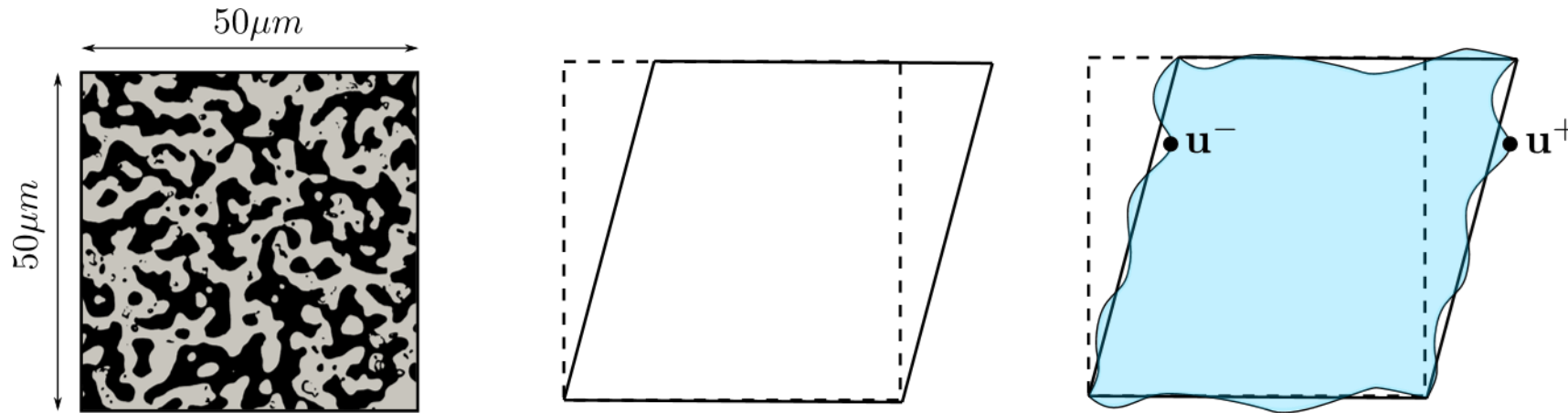
$$G' = G \left[\mu_0 + \sum_{i=1}^n \mu_i \left(\frac{\omega^2 \lambda_i^2}{1 + \omega^2 \lambda_i^2} \right) \right]$$

$$G'' = G \sum_{i=1}^n \mu_i \left(\frac{\omega \lambda_i}{1 + \omega^2 \lambda_i^2} \right)$$

- 9 sets with μ_i and λ_i for NR
- 9 sets with μ_i and λ_i für SBR



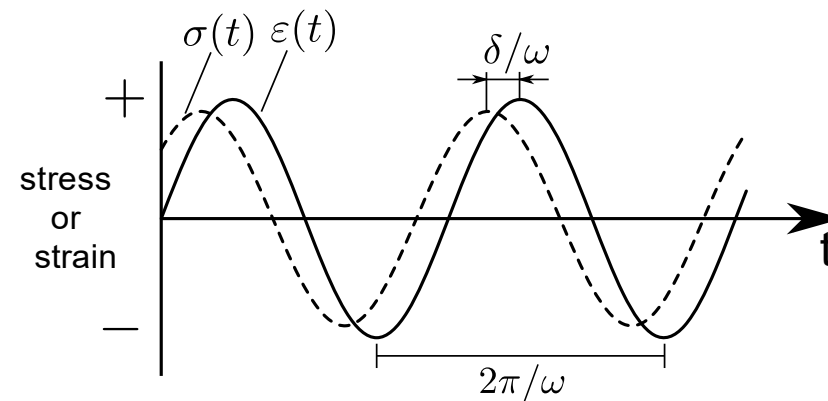
Variable	Description
λ_i	Relaxation times
μ_i	Weight factors
ω	Radial frequency
G	Shear modulus



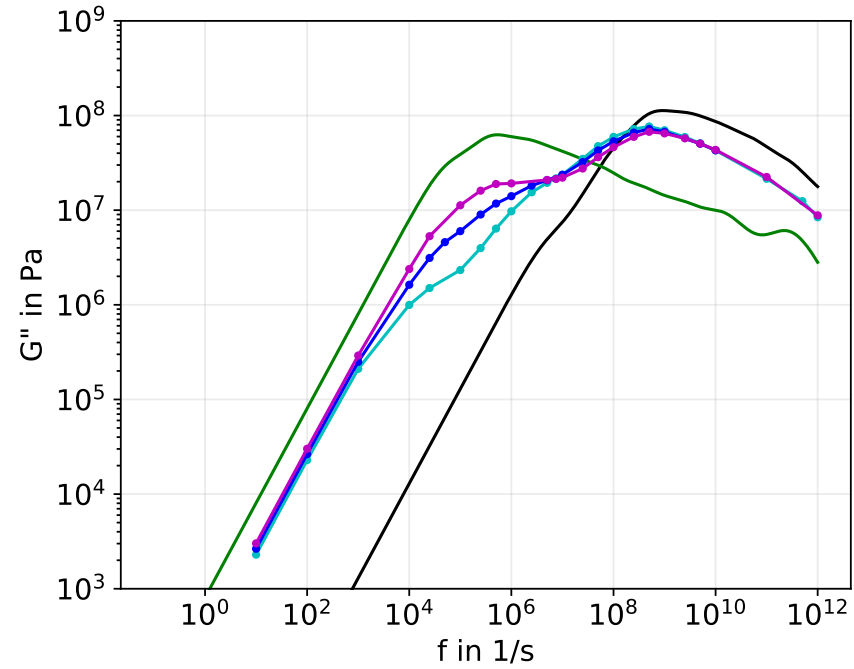
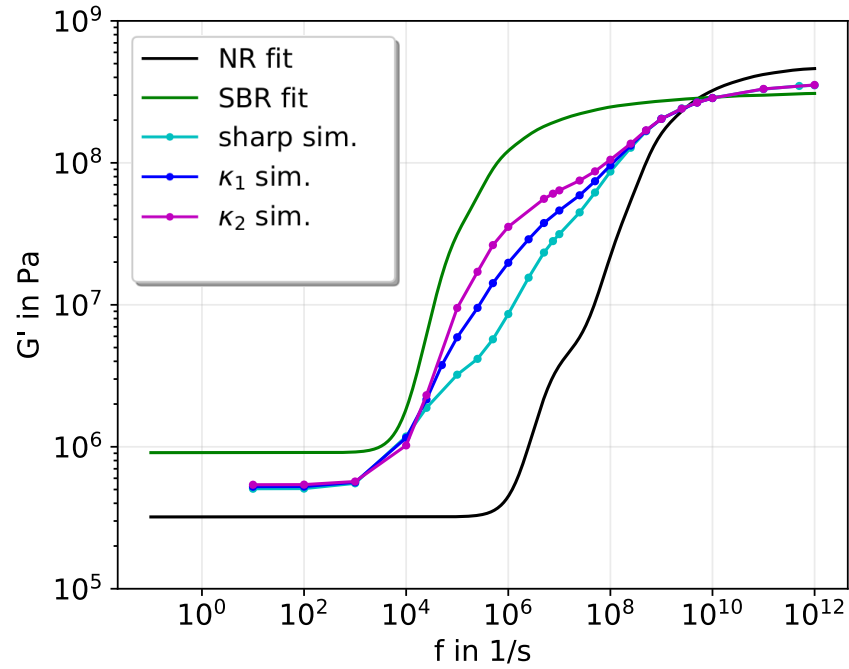
- Harmonic excitation leads to a phase shift → viscoelastic properties

$$\bar{\epsilon} = \bar{\epsilon}_0 \sin(\omega t)$$

$$\bar{\sigma} = \bar{\sigma}_0 \sin(\omega t + \delta)$$



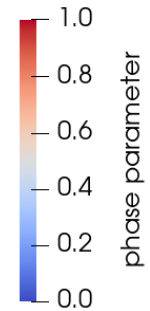
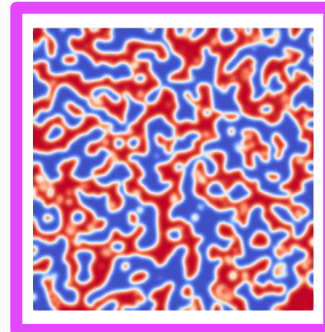
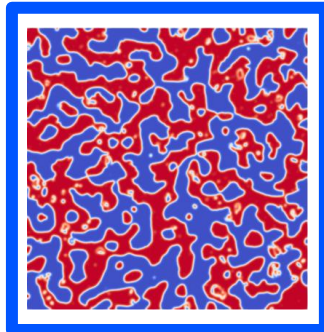
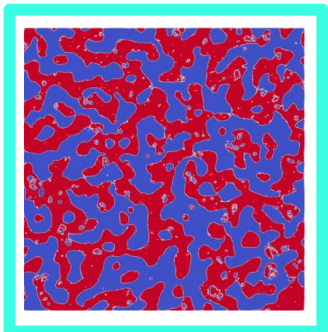
Viscoelastic Properties of Elastomer-Blends



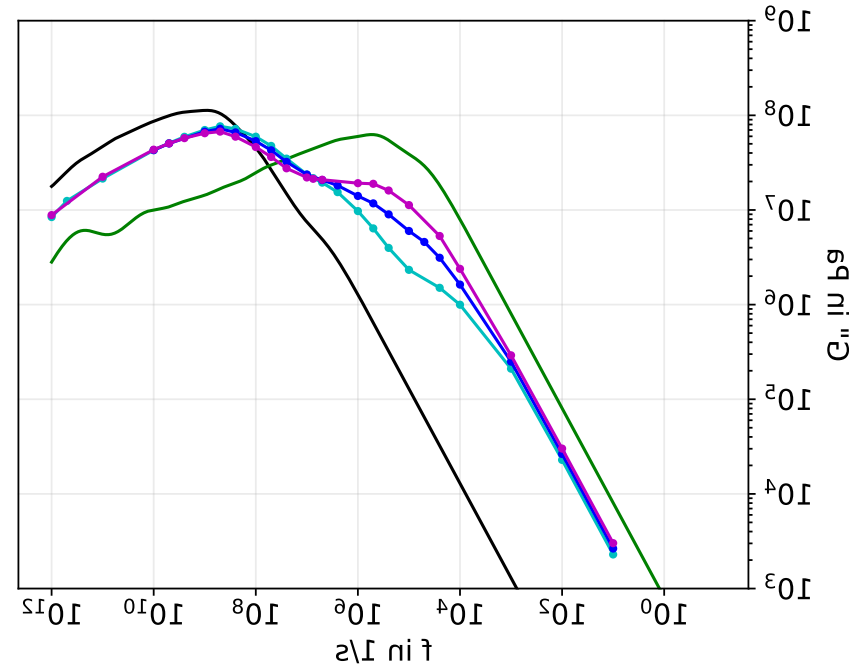
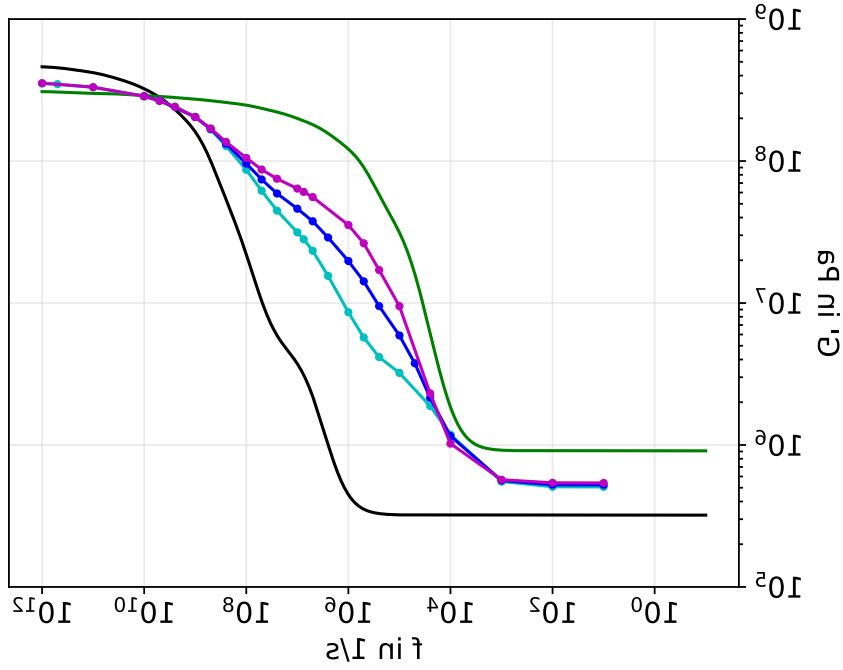
No Interphase

κ_1

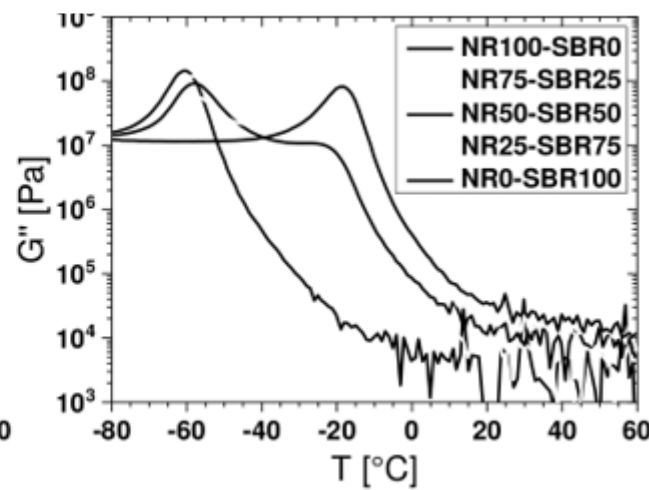
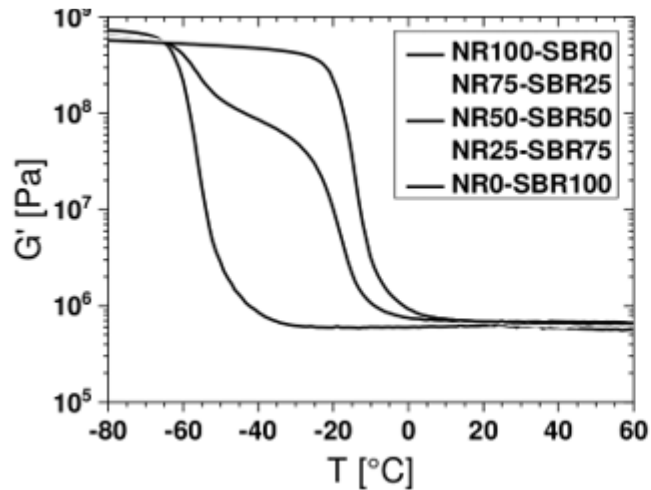
κ_2

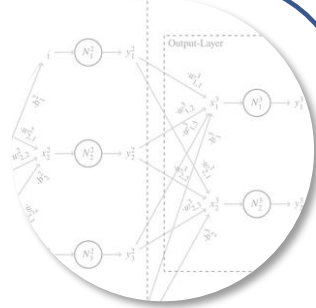
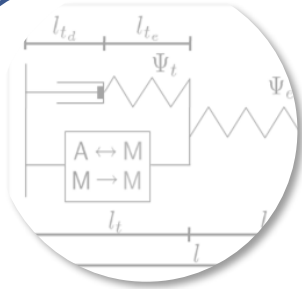


Viscoelastic Properties of Elastomer-Blends

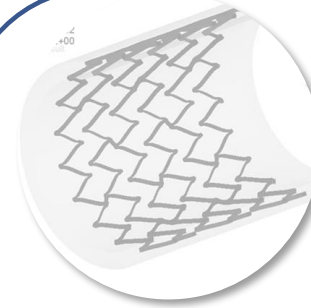
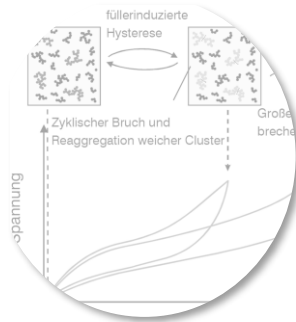
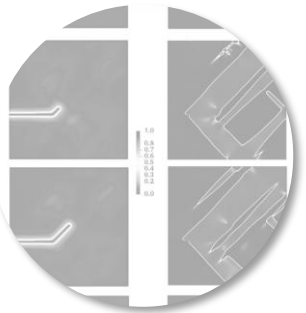


DMA with
T - sweep

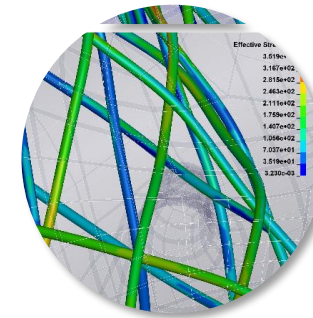
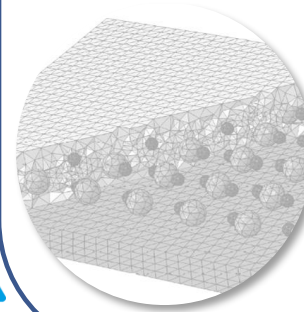




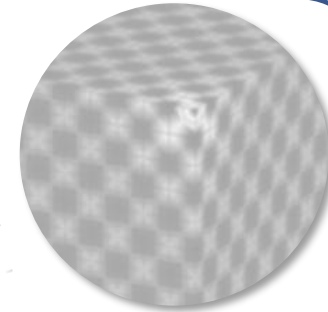
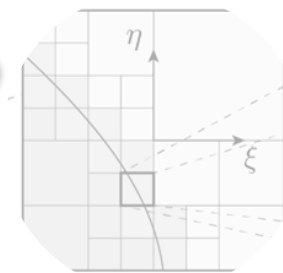
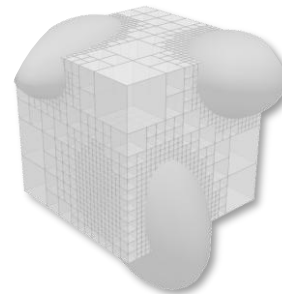
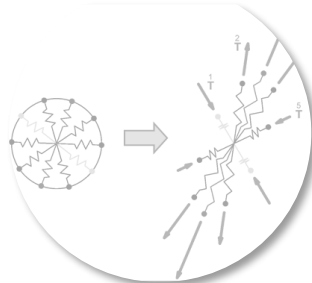
Solid Mechanics



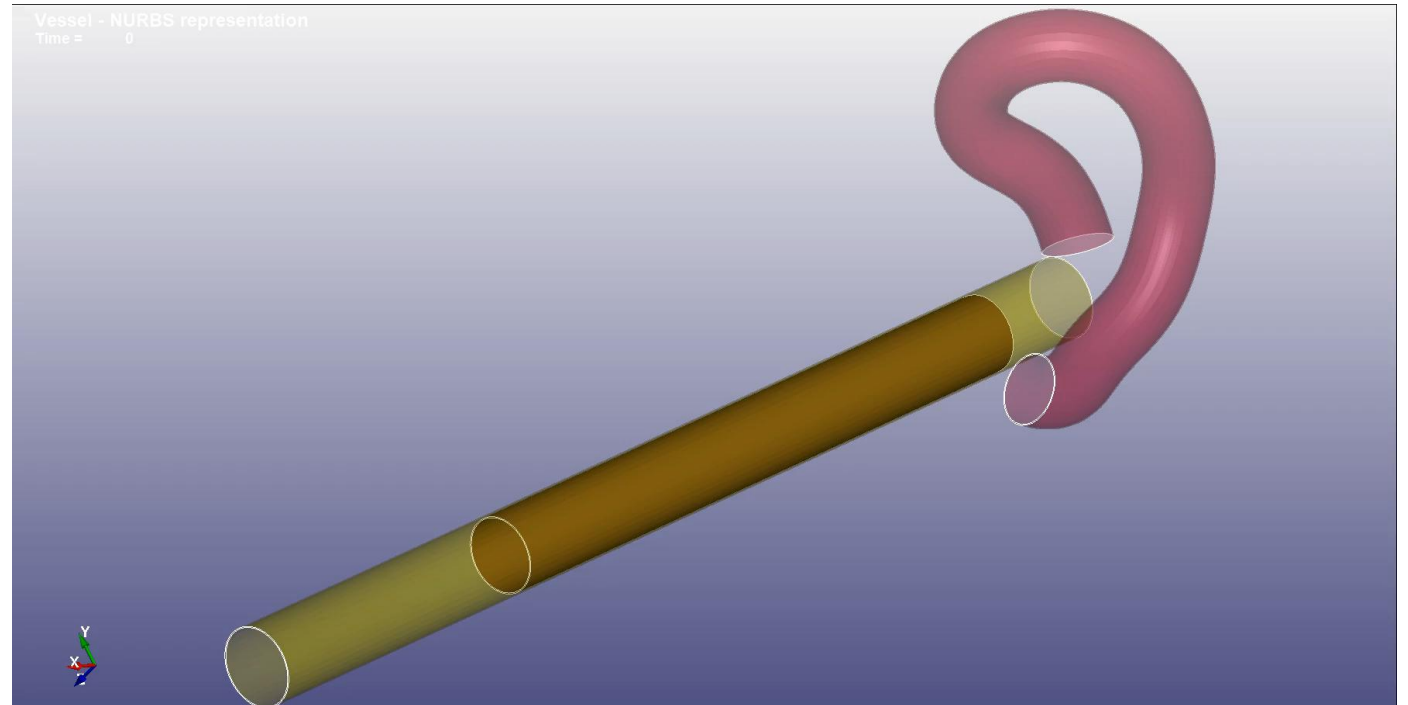
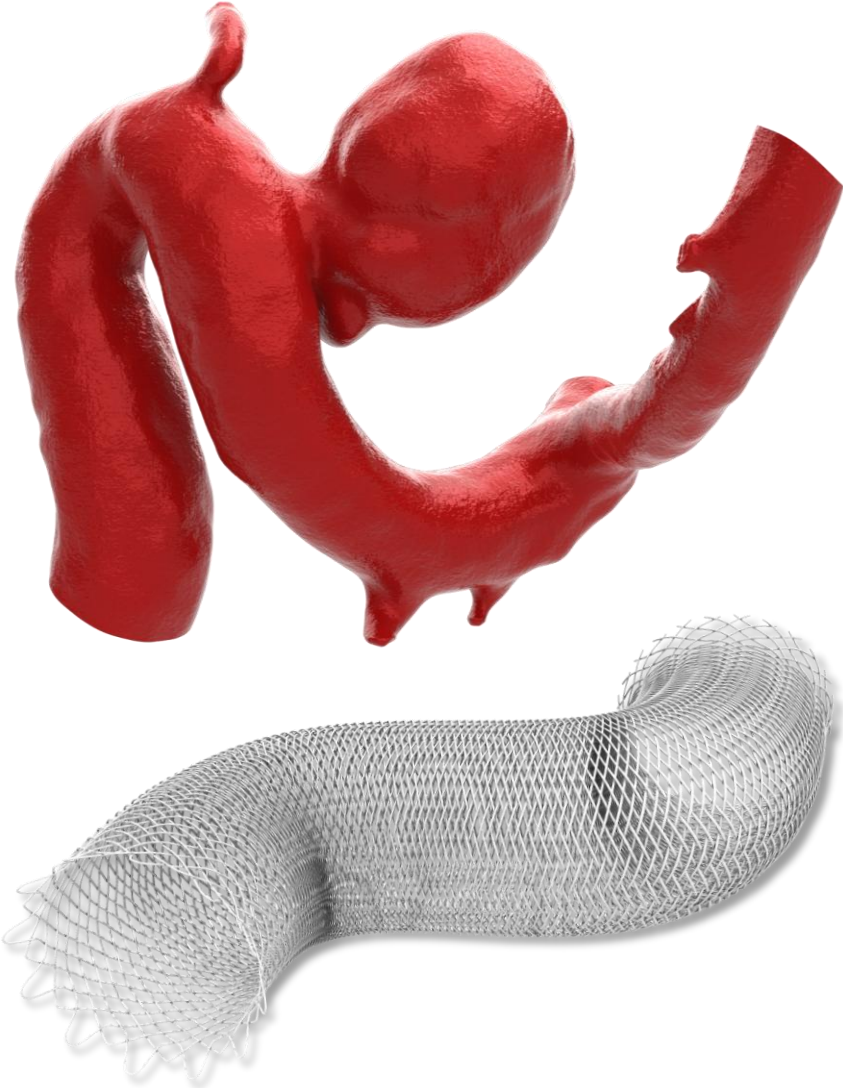
Structure Mechanics



Numerical Methods



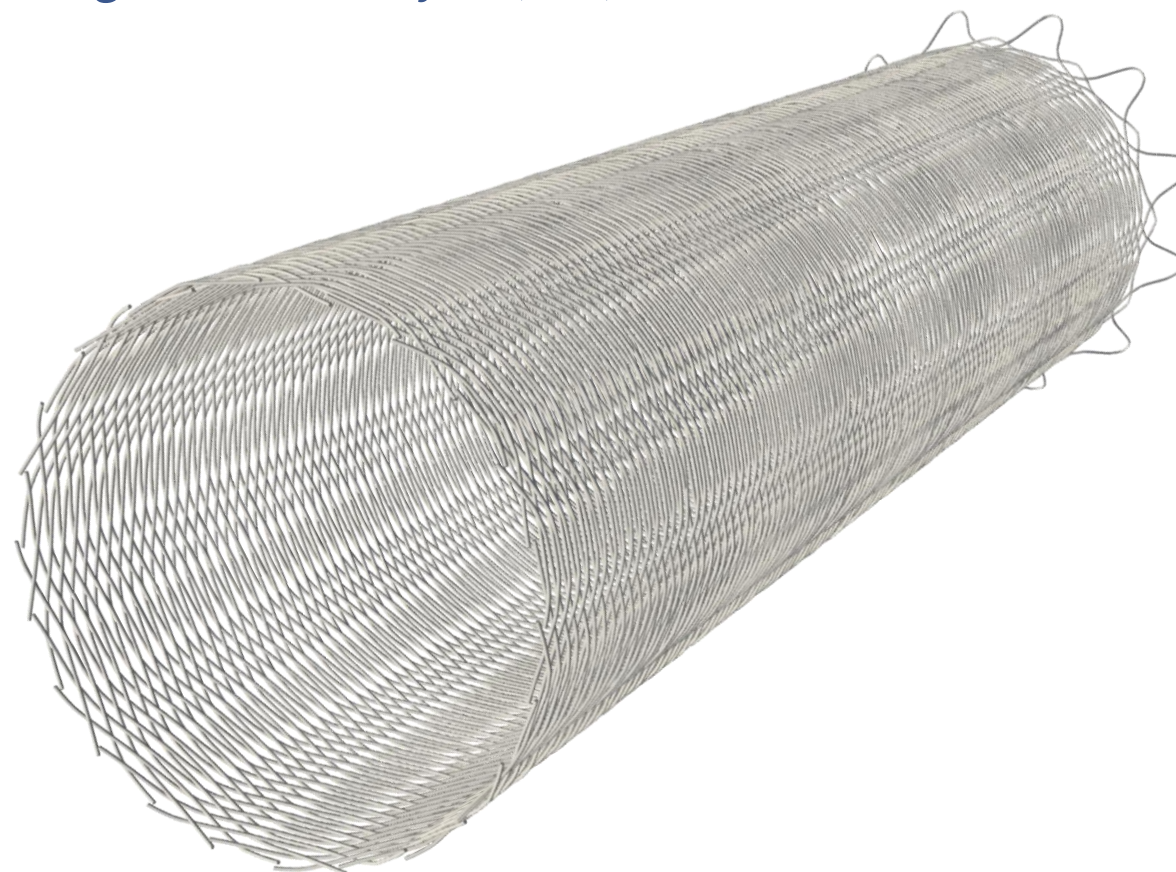
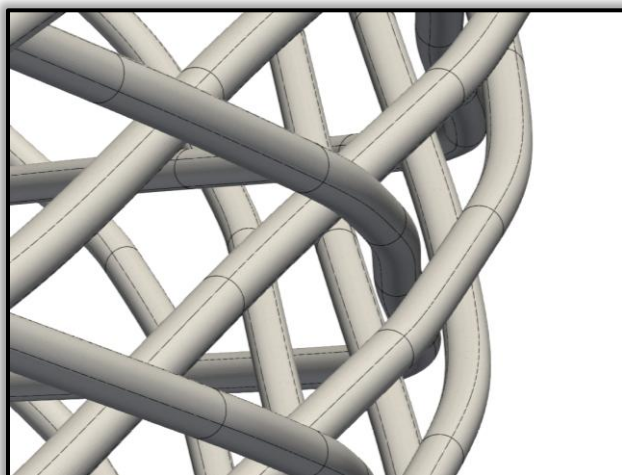
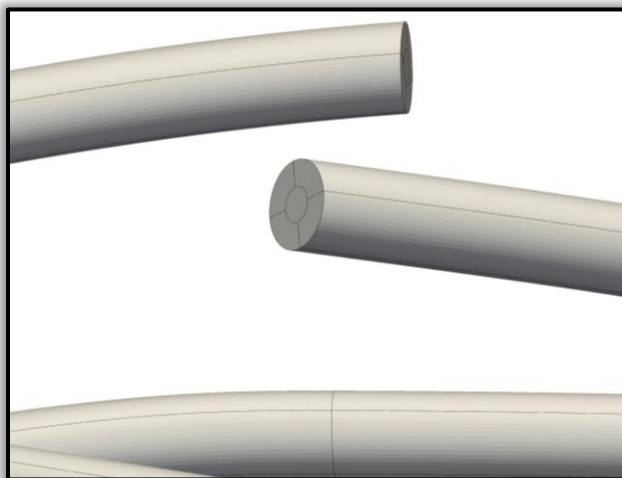
Simulation of the Placement of Flow-Diverters into Patient-Specific Blood Vessels



Bundesministerium
für Bildung
und Forschung

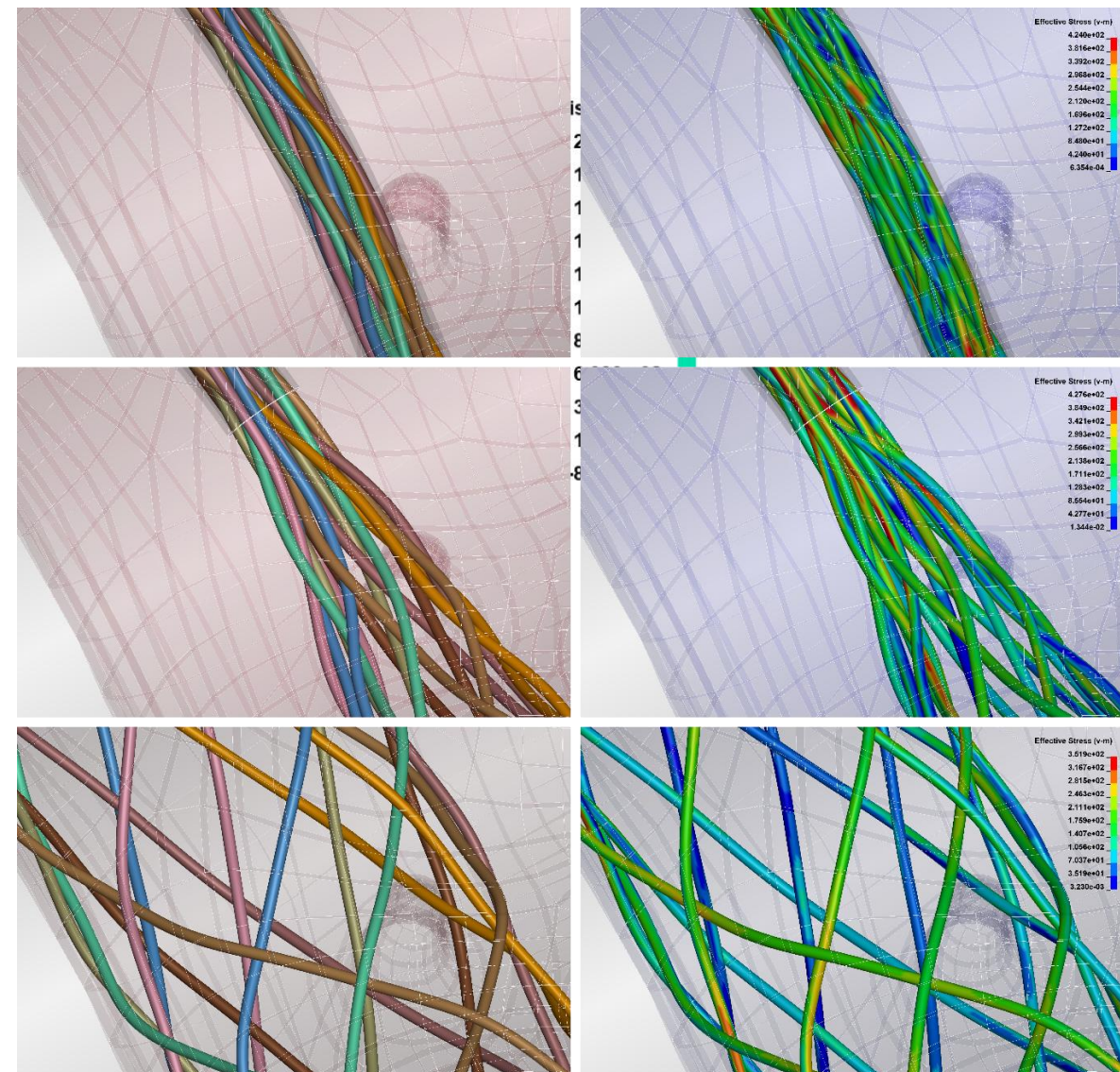
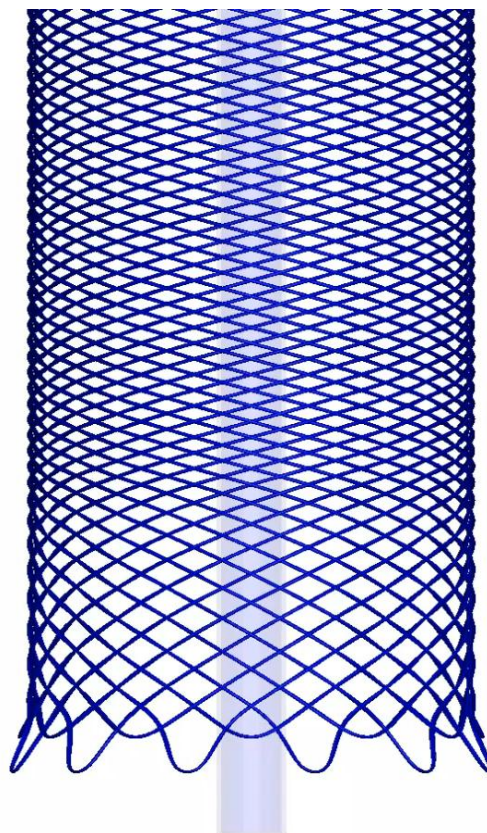
Simulation of the Placement of Flow-Diverters into Patient-Specific Blood Vessels

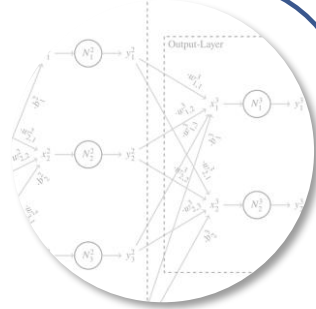
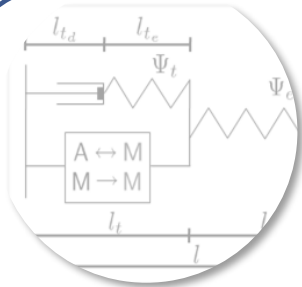
→ Use of Isogeometric Analysis (IGA)



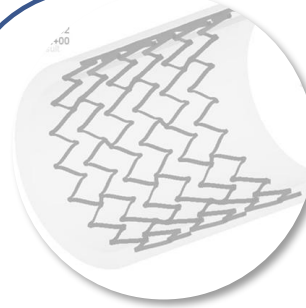
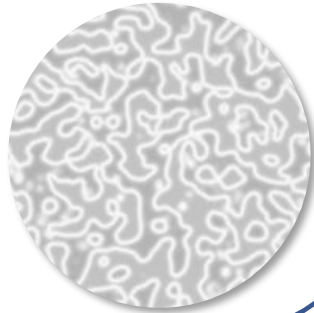
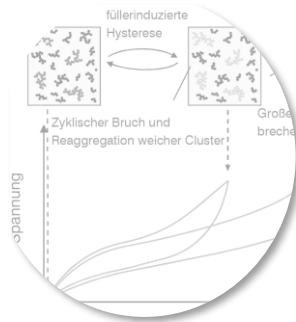
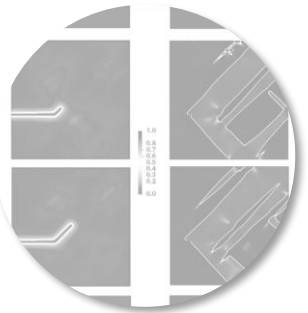
Simulation of the Placement of Flow-Diverters into Patient-Specific Blood Vessels

Vessel - NURBS representation
Time = 0.0099991
Contours of Z-displacement
min=-0.00808821, at node# 424965
max=0.21998, at node# 100971

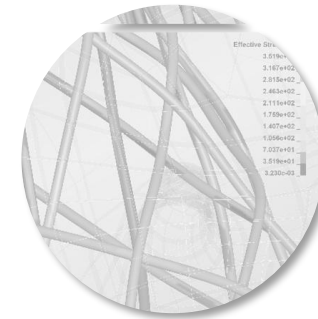
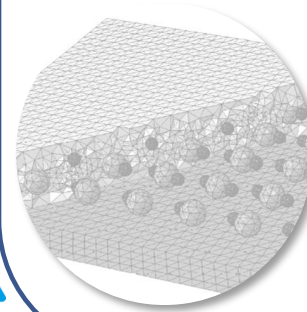




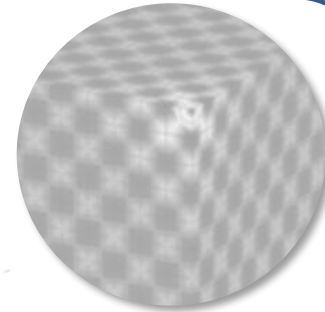
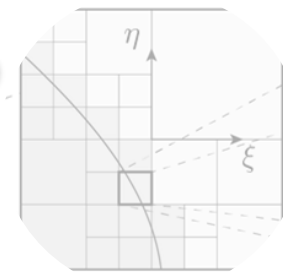
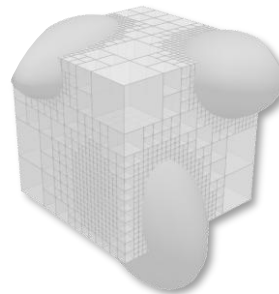
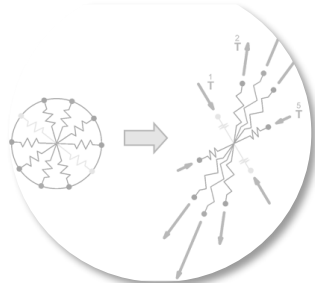
Solid Mechanics



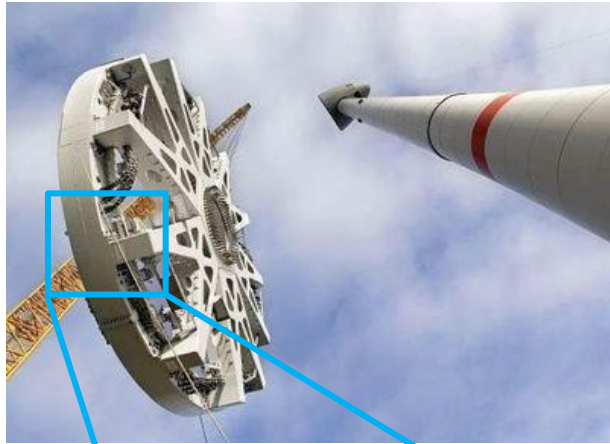
Structure Mechanics



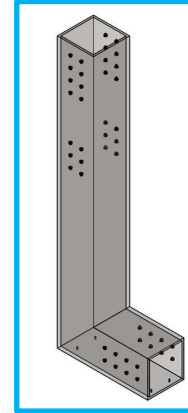
Numerical Methods



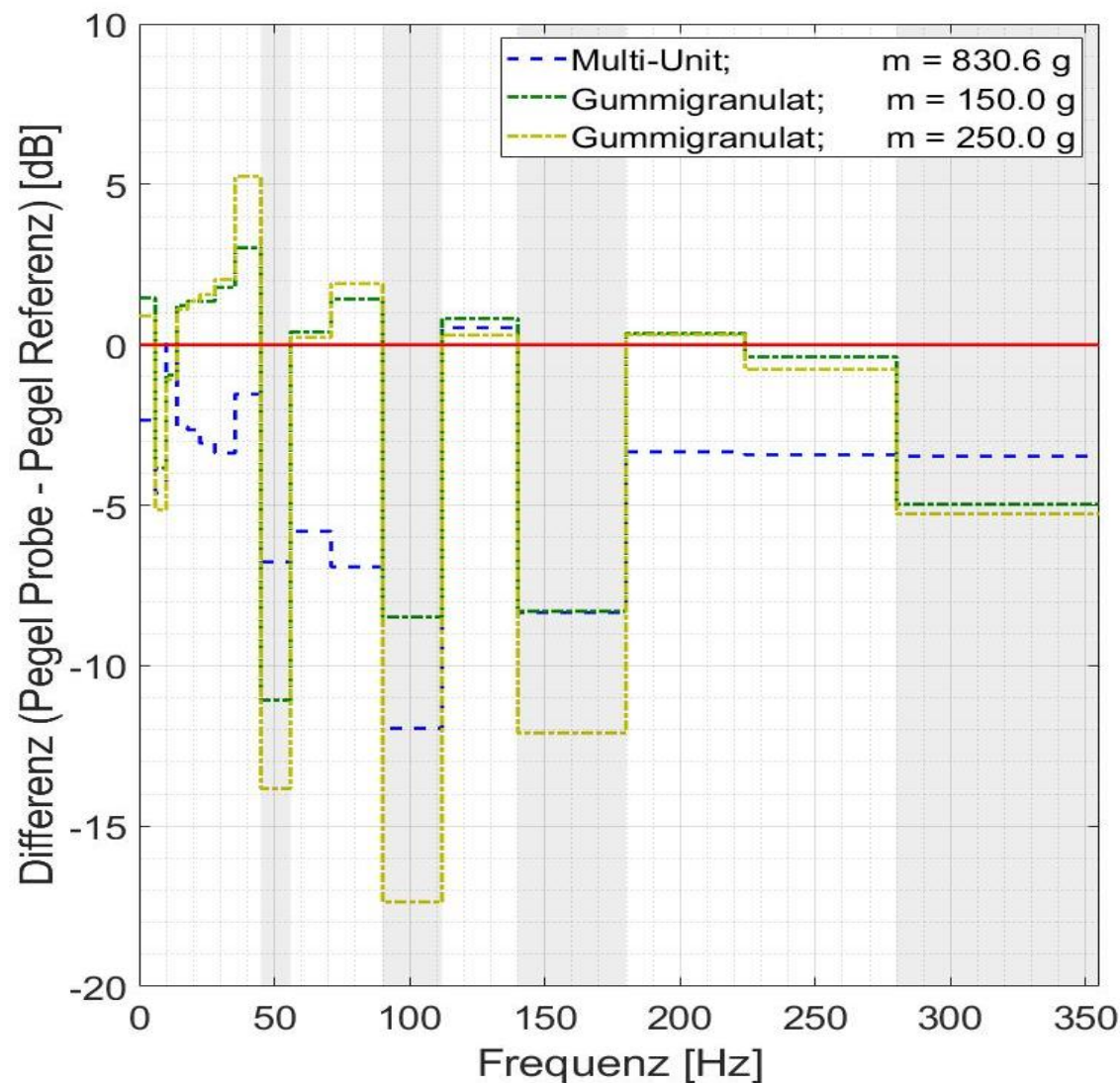
Innovative Concepts for Vibration and Sound Reduction in Wind Turbines



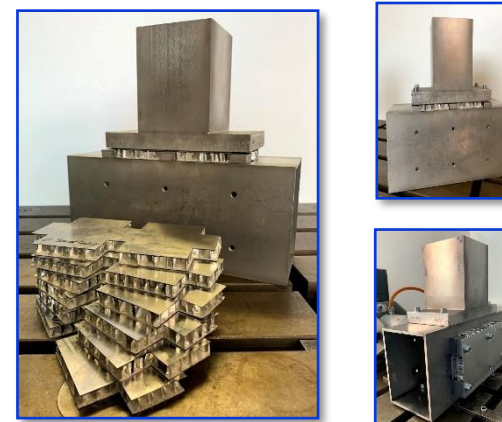
Bundesministerium
für Bildung
und Forschung



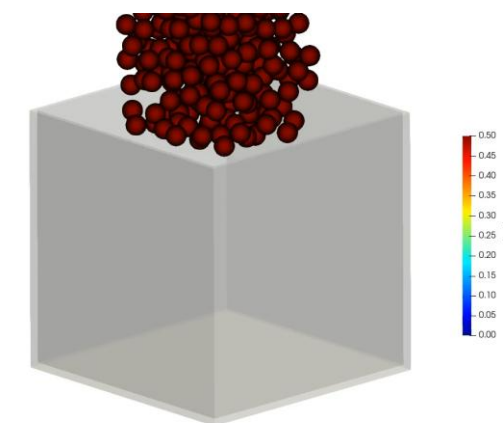
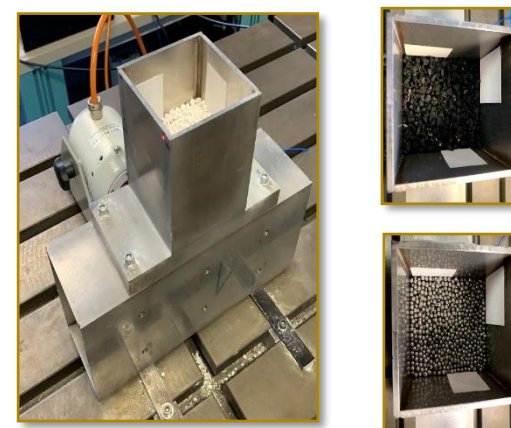
Innovative Concepts for Vibration and Sound Reduction in Wind Turbines



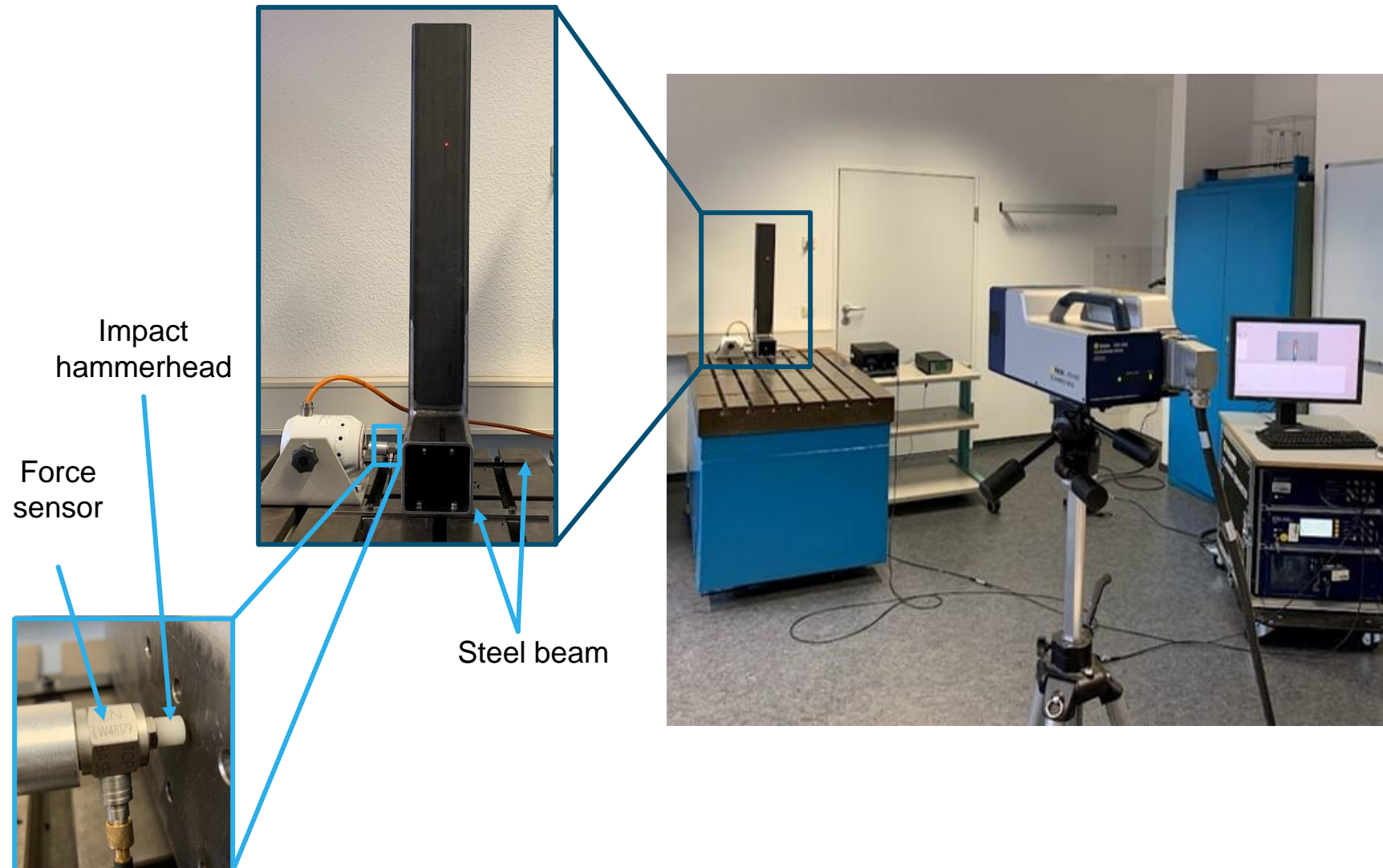
1. Damping plate concept



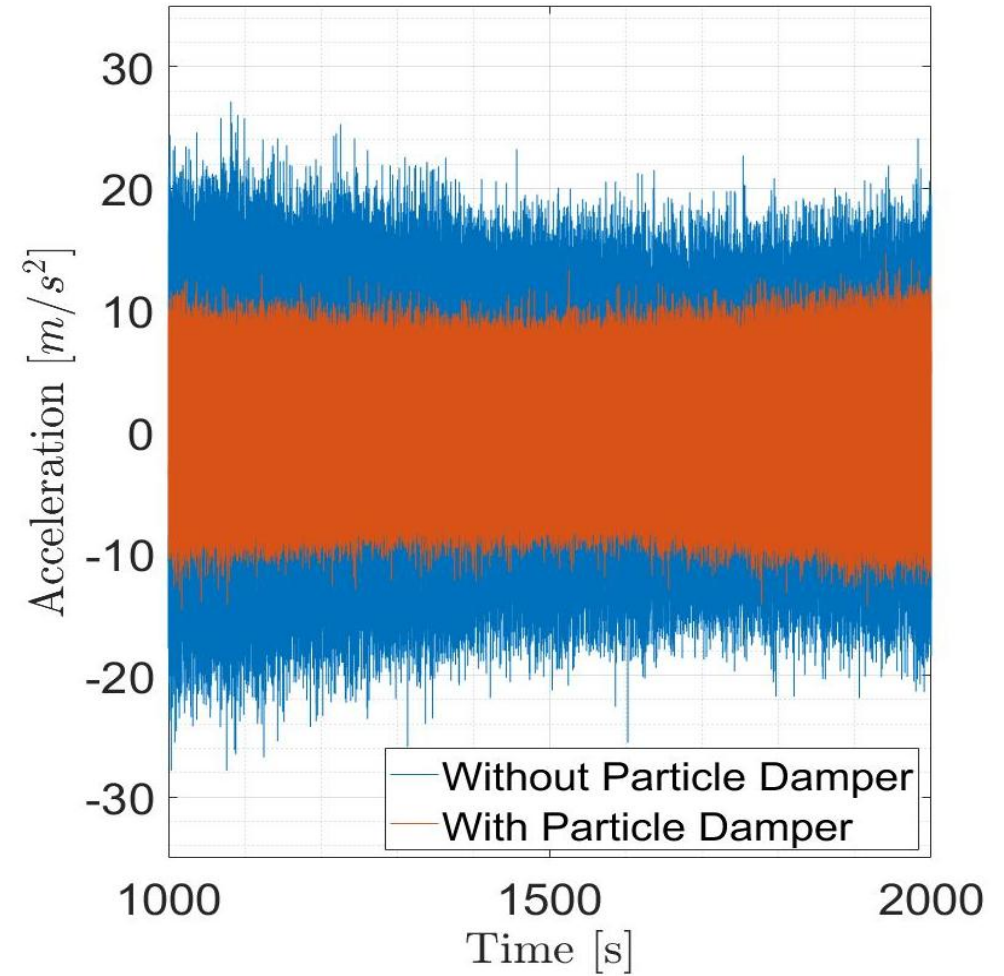
2. Cavity concept



Innovative Concepts for Vibration and Sound Reduction in Wind Turbines

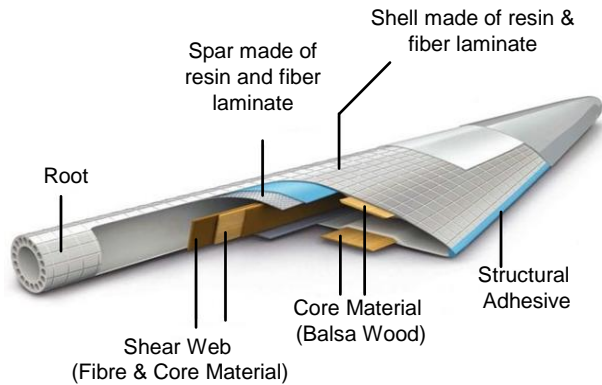


Innovative Concepts for Vibration and Sound Reduction in Wind Turbines



Innovative Concepts for Vibration and Sound Reduction in Wind Turbines

Structure of a rotor blade with sandwich core

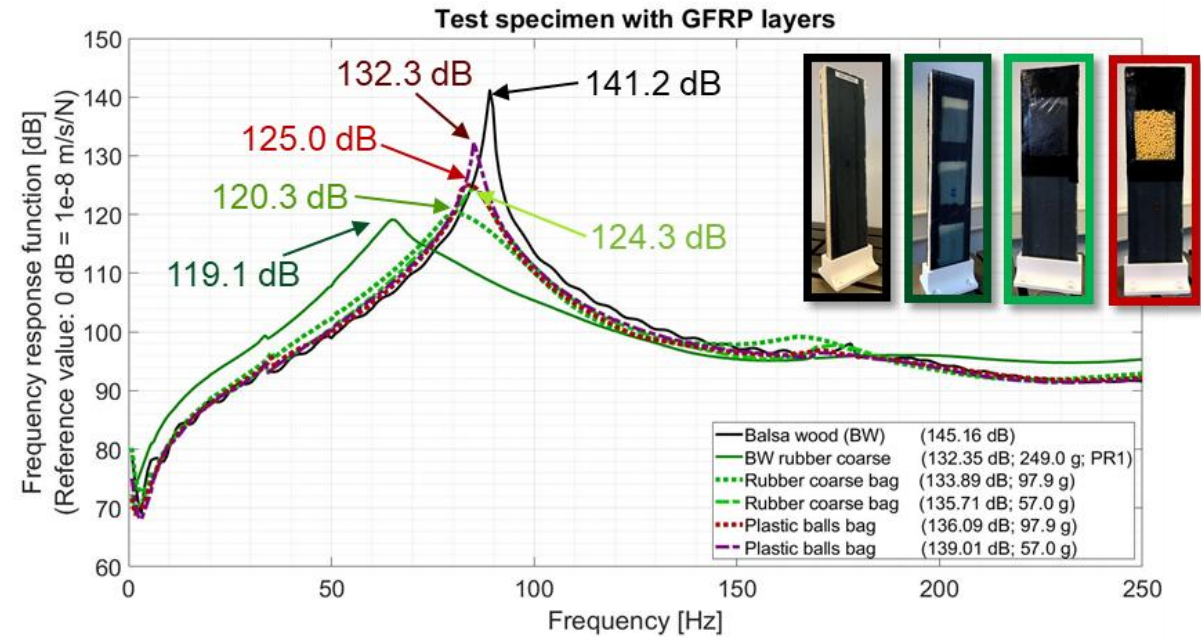
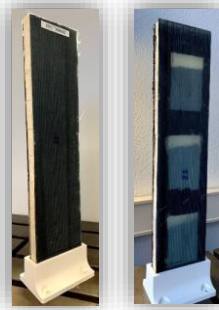


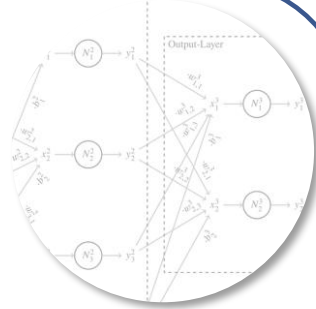
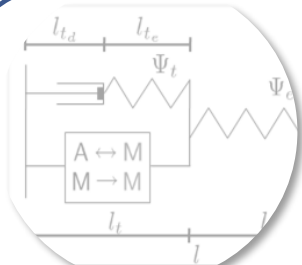
Implementation strategies

1.Strategy: Substituting the original sandwich core by a honeycomb shaped structure.

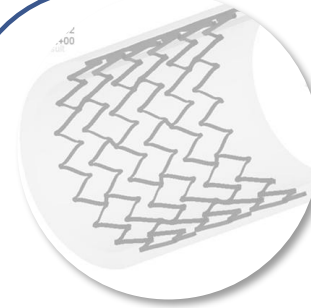
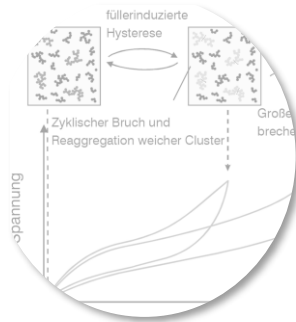
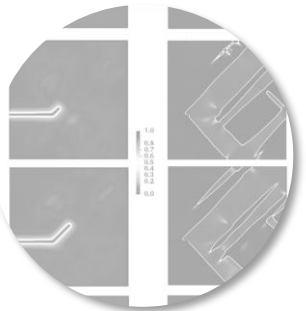
2.Strategy: Modifying the original sandwich core.

3.Strategy: Attaching an external cavity at the rotor blade.

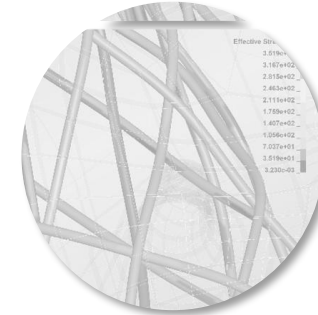
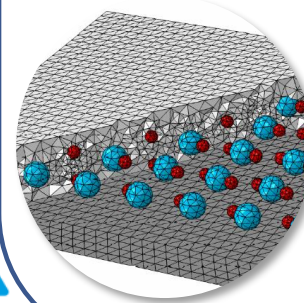




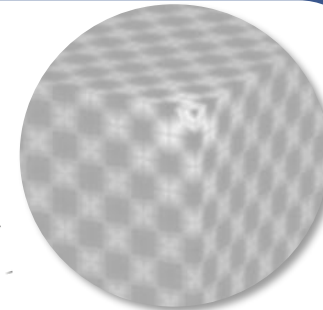
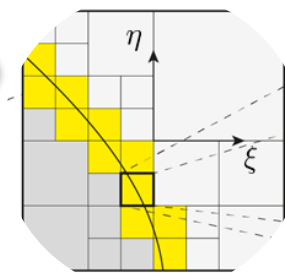
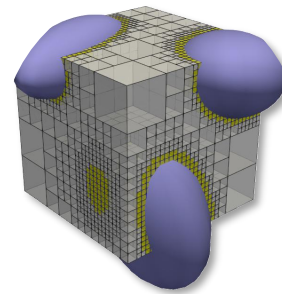
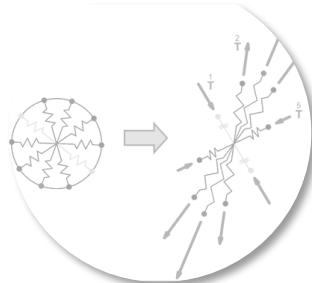
Solid Mechanics



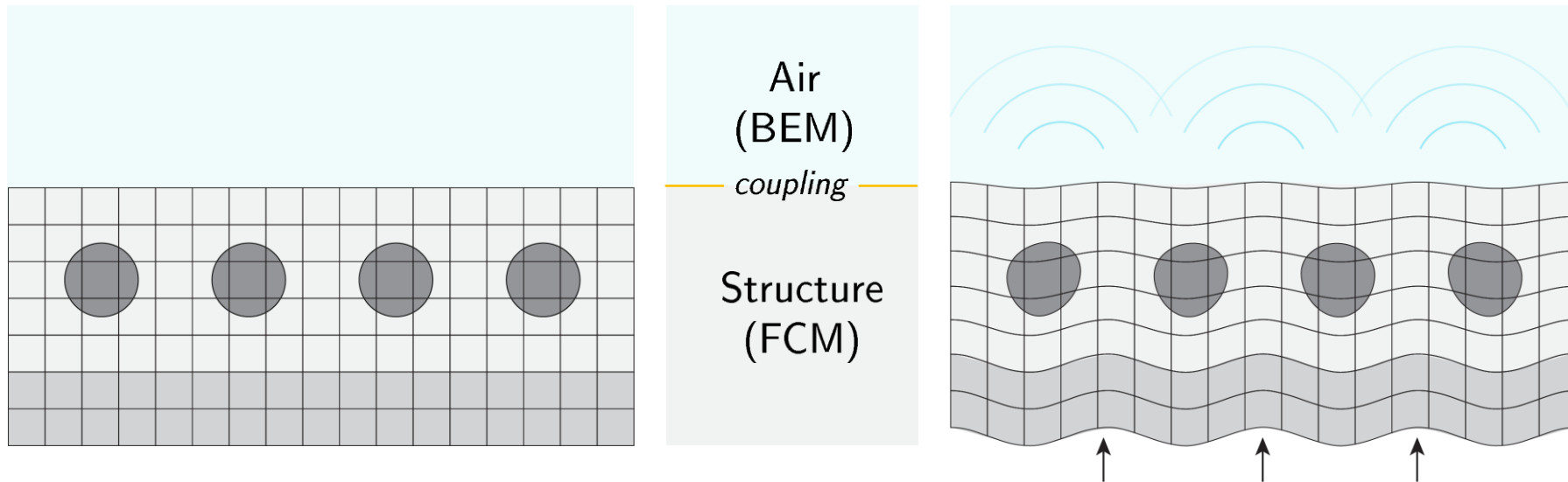
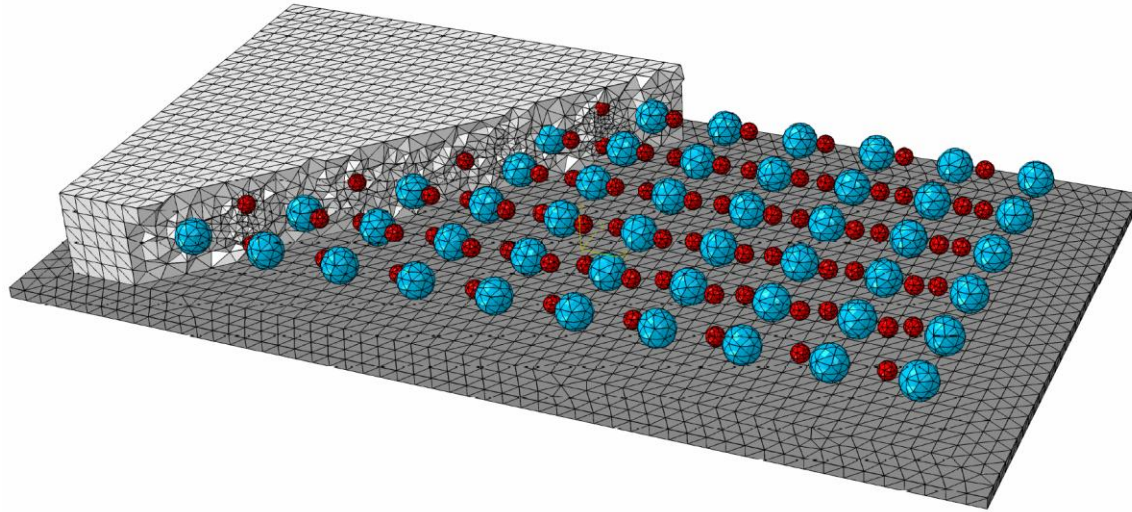
Structure Mechanics



Numerical Methods

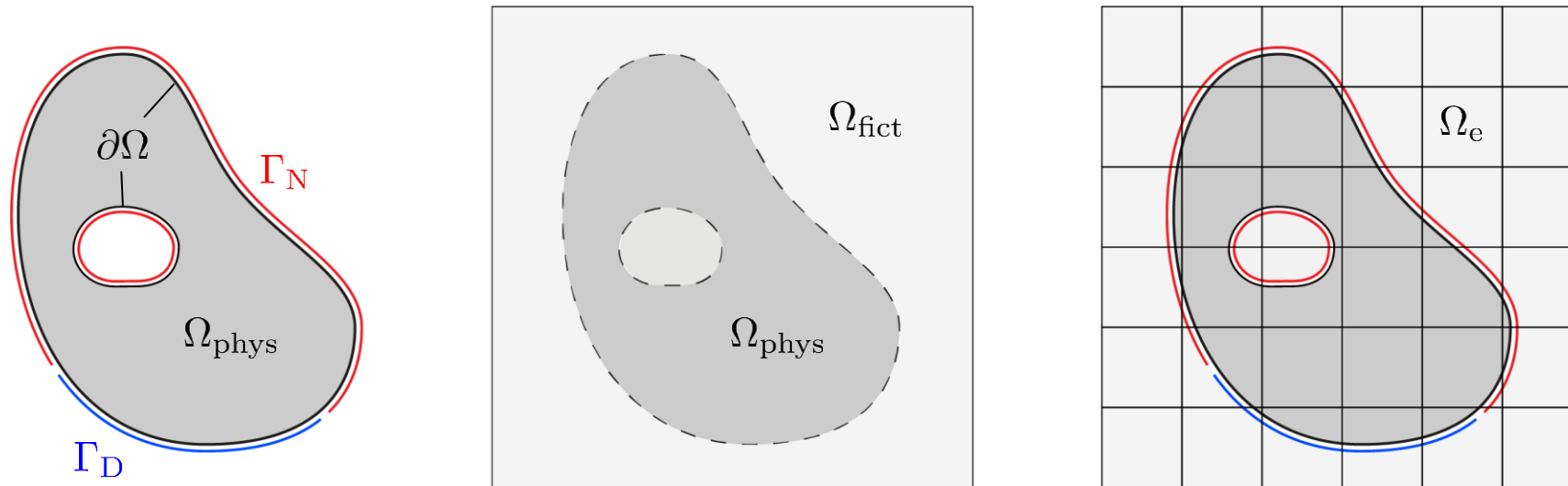


Numerical Investigation of Acoustic Metamaterials



- **Main idea:** Combination of fictive decomposition methods with the p -FEM concept

[Parvizian et al. (2007)]



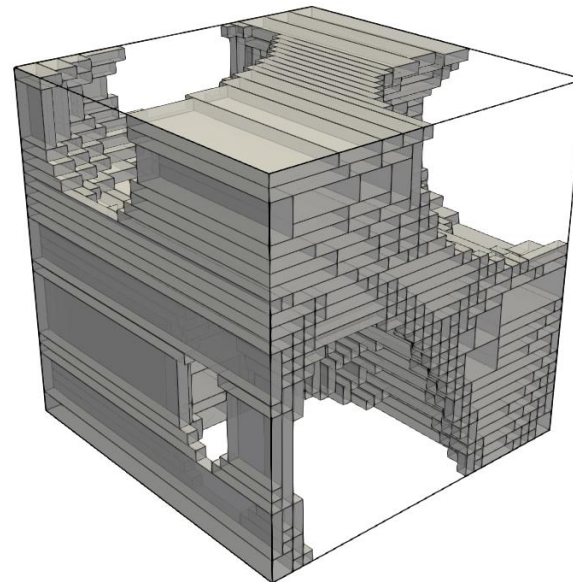
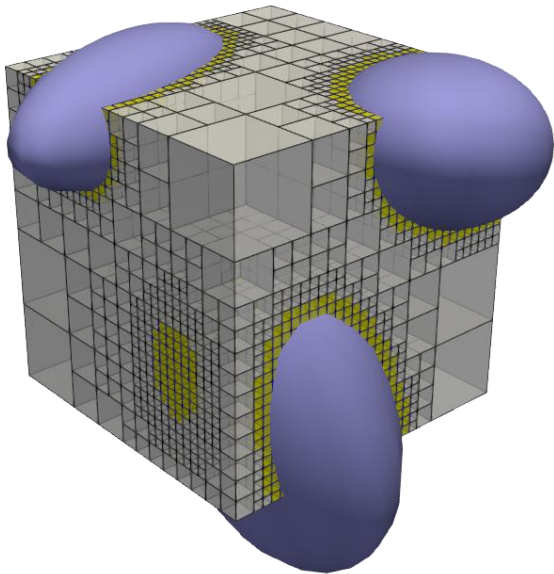
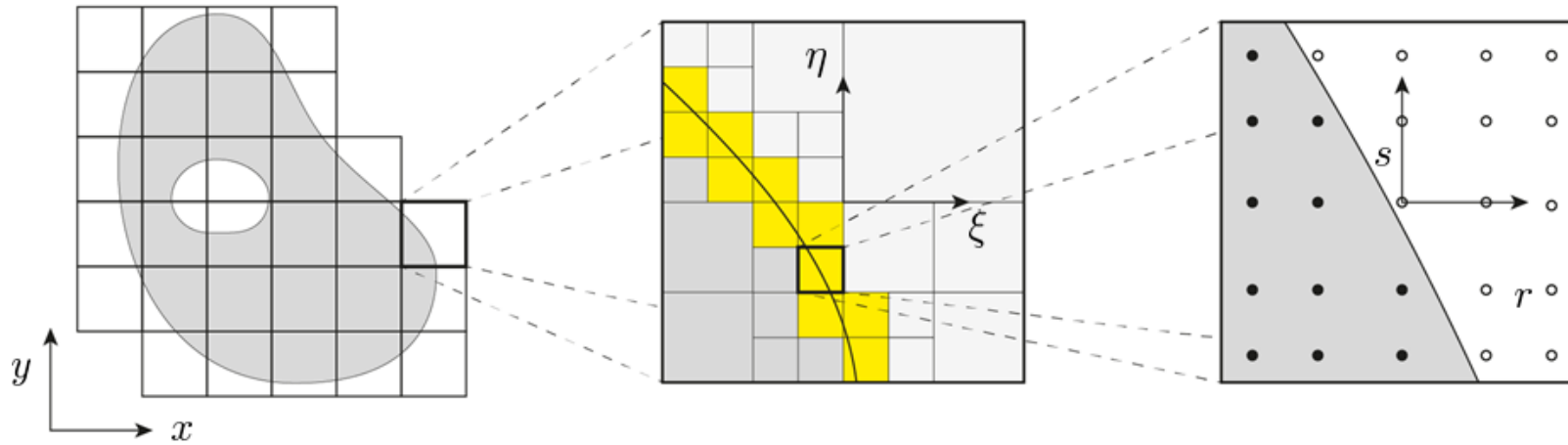
- Weak form of the balance equation:

$$\int_{\Omega_e} \alpha \rho \ddot{u}^T \mathbf{v} \, dx + \int_{\Omega_e} (\mathbf{L}u)^T \alpha \mathbf{C} \mathbf{L}v \, dx = \int_{\Omega_e} \mathbf{v}^T \alpha \mathbf{b} \, dx + \int_{\Gamma_N} \mathbf{v}^T \hat{\mathbf{t}} \, dx$$

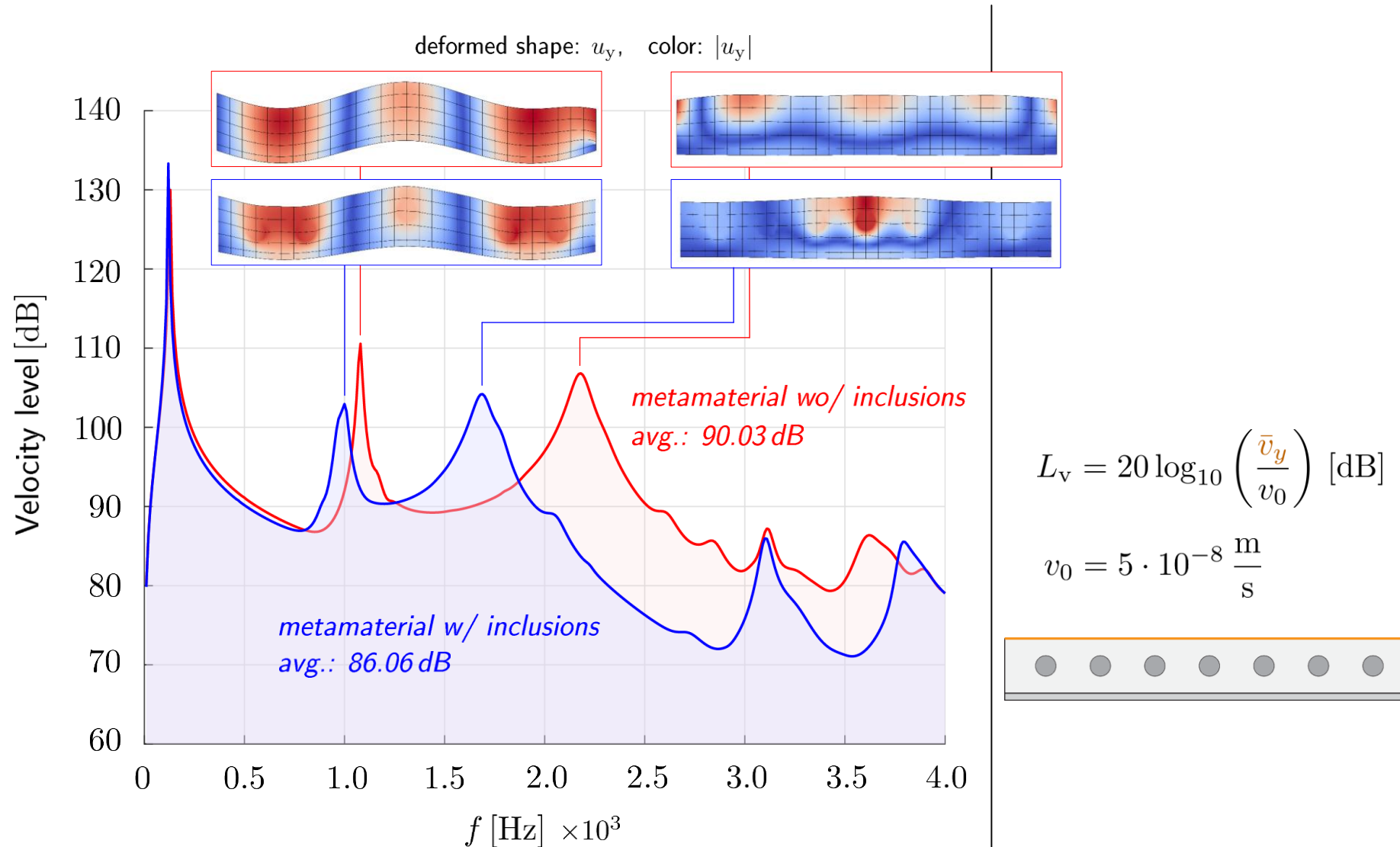
- Indicator function

$$\alpha = \begin{cases} 1, & \forall \mathbf{x} \in \Omega_{\text{phys}} \\ 0, & \forall \mathbf{x} \in \Omega_{\text{fict}} \end{cases}$$

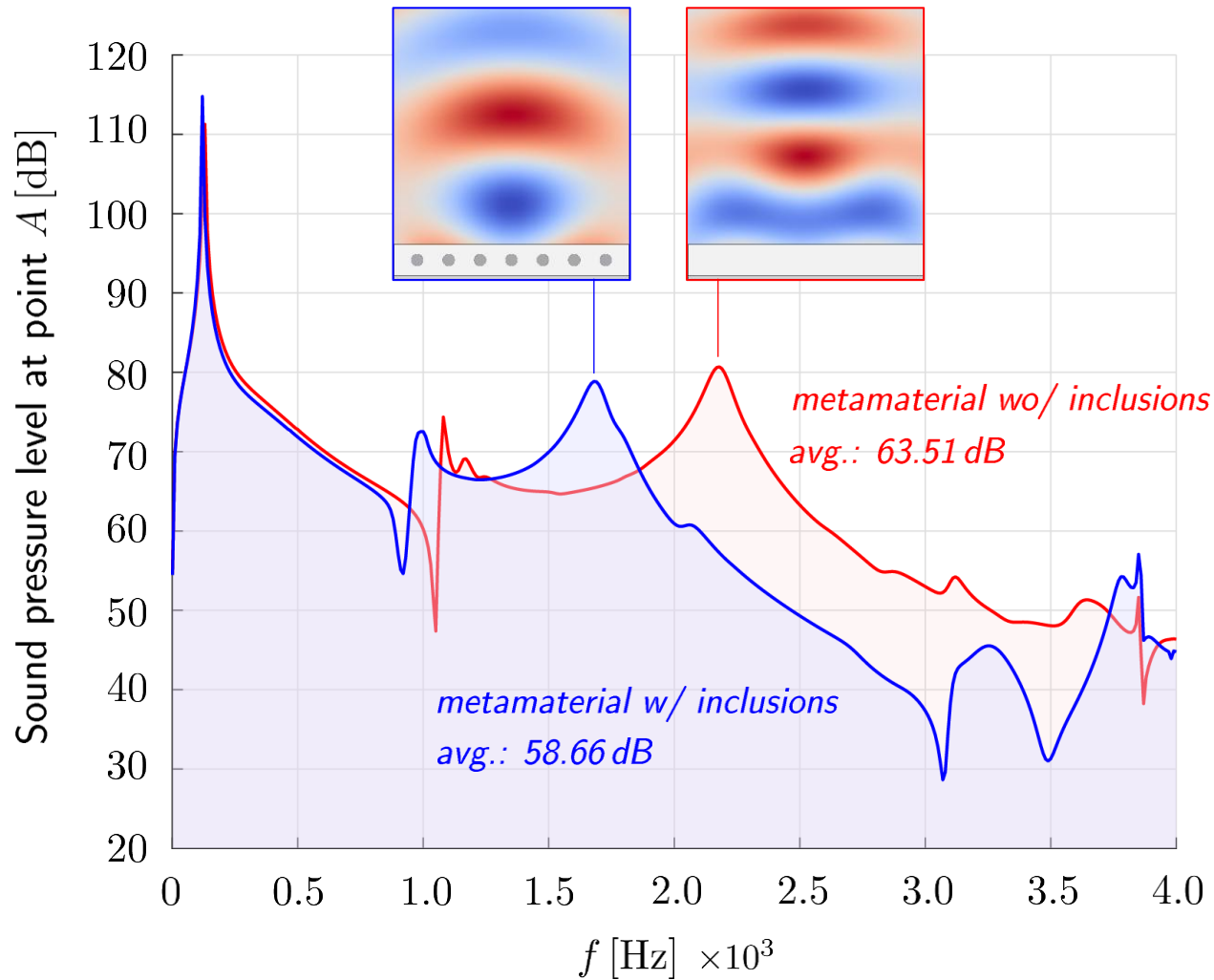
Numerische Untersuchung von akustischen Metamaterialien



Numerische Untersuchung von akustischen Metamaterialien



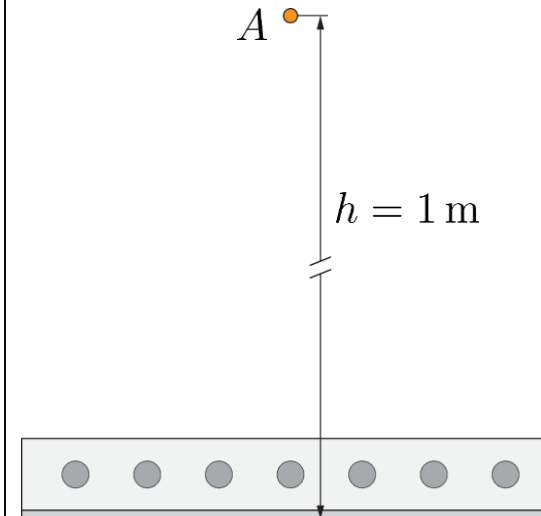
Numerische Untersuchung von akustischen Metamaterialien

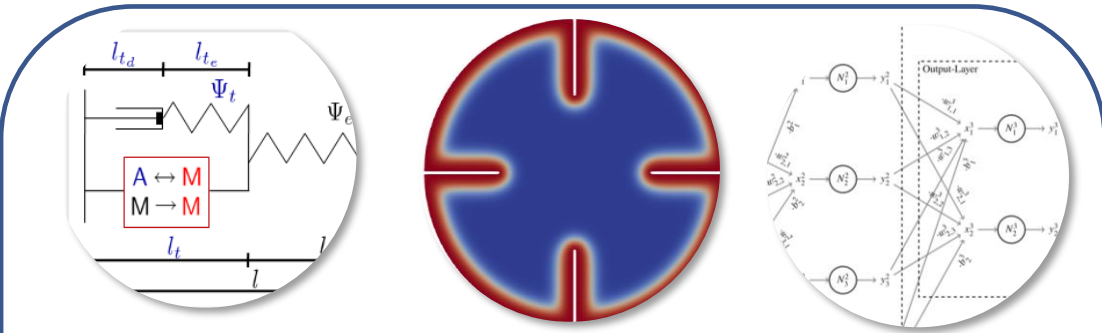


$$p^* = \sqrt{\frac{1}{2} p \cdot \bar{p}}$$

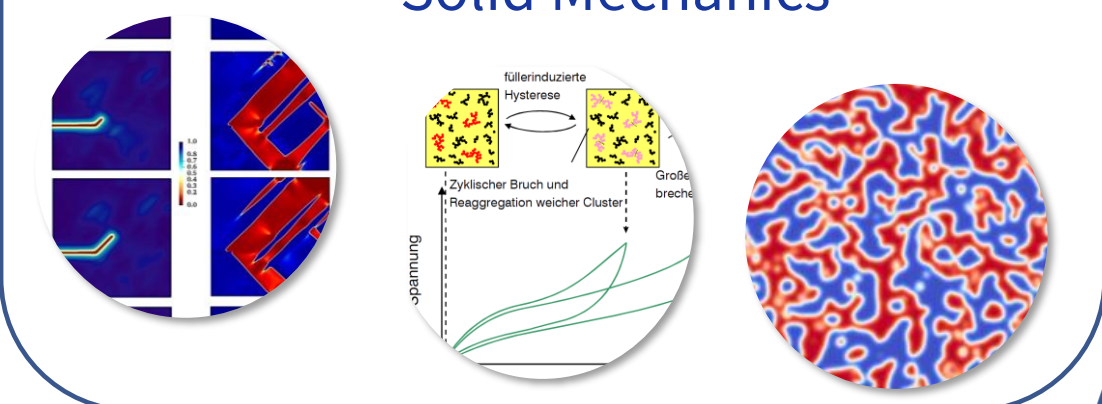
$$L_p = 20 \log_{10} \left(\frac{p^*}{p_0} \right) \text{ [dB]}$$

$$p_0 = 2 \cdot 10^{-5} \text{ Pa}$$

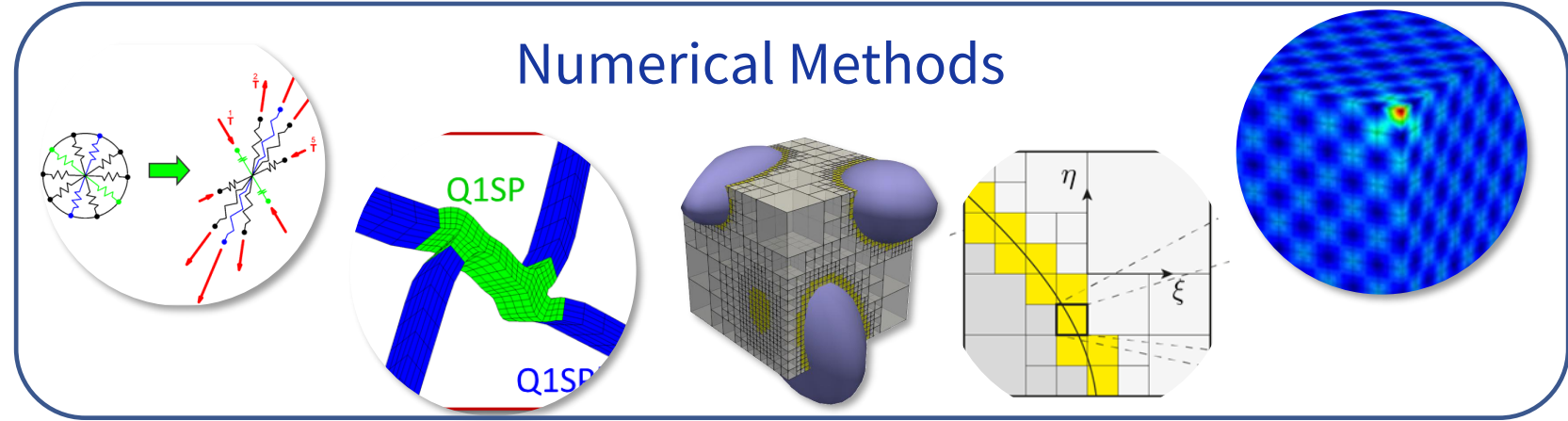




Solid Mechanics



Structure Mechanics



Numerical Methods

Selected Research Topics of the Chair of Computational Mechanics

Univ.-Prof. Dr.-Ing. Daniel Juhre

Chair of Computational Mechanics

Otto von Guericke University Magdeburg

