Structural Analysis and Component Strength of Energy Systems

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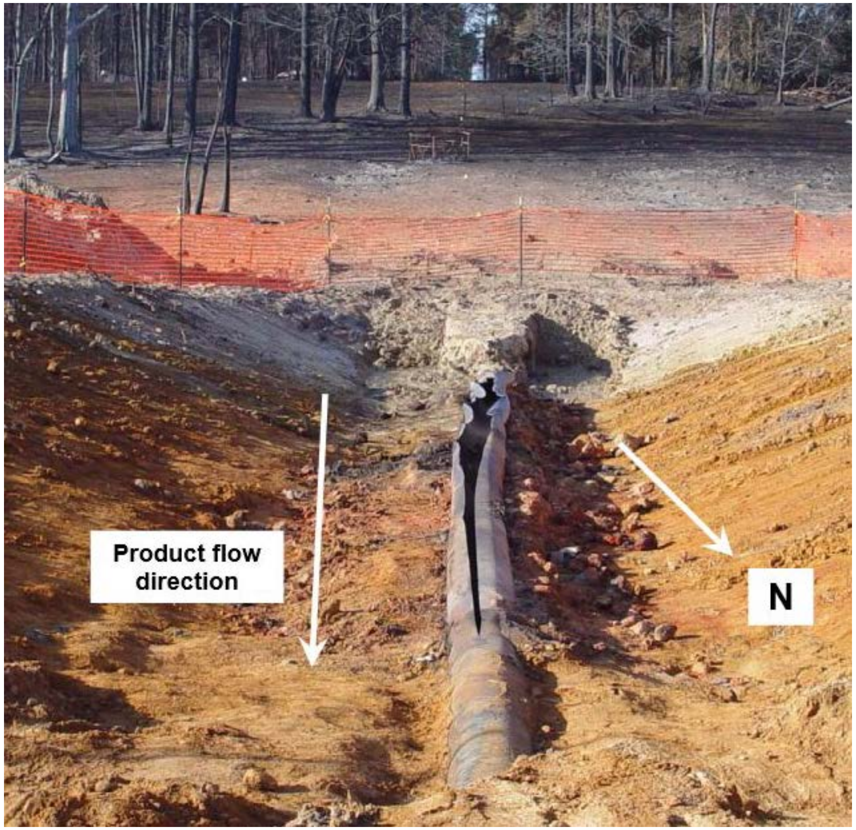
Failure scenarios of pipeline systems

Failure due to stress corrosion



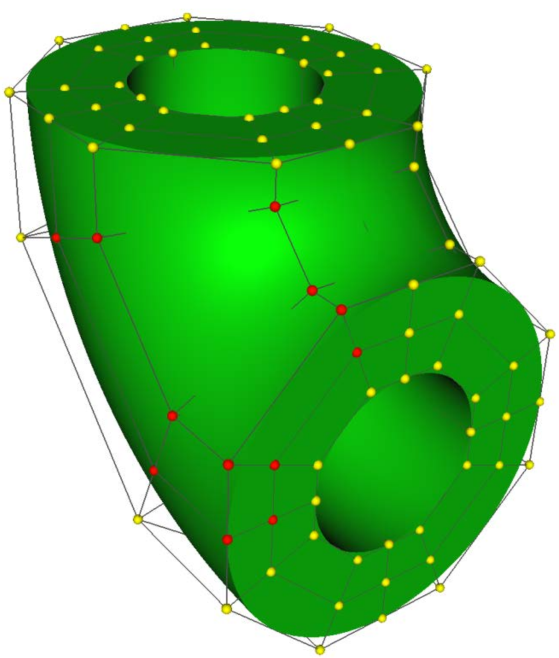
Failure due to physical damage

Source: Metropolitan Engineering, Consulting and Forensic

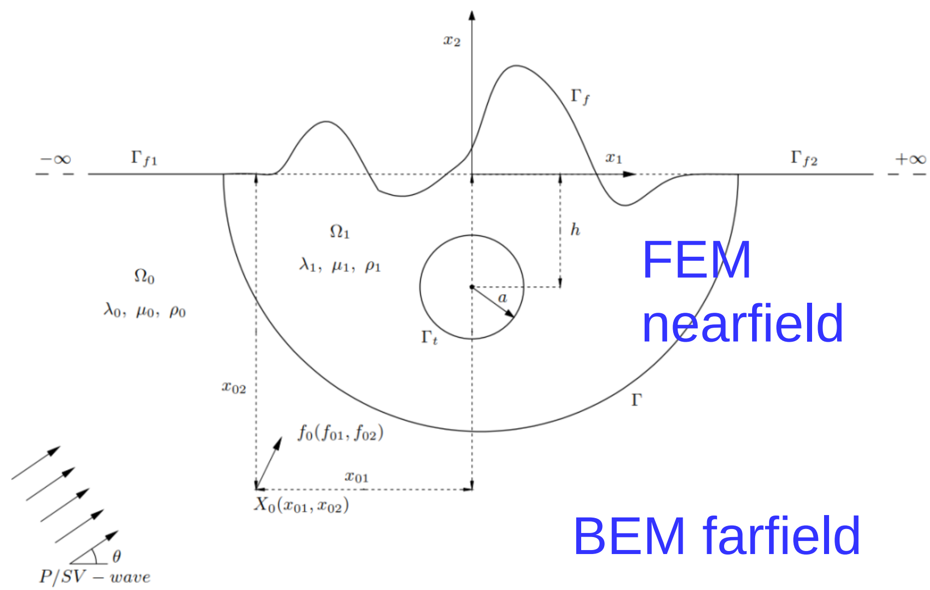
Structural Analysis:

- Geometric descrition of NG pipeline systems in 3D
  Isogeometric Finite Element formulation for multiple inconsistent patches

- Interaction effects between pipeline and soil
  Isogemeomteric FEM in nearfield plus coupling with Boundary Element in farfield



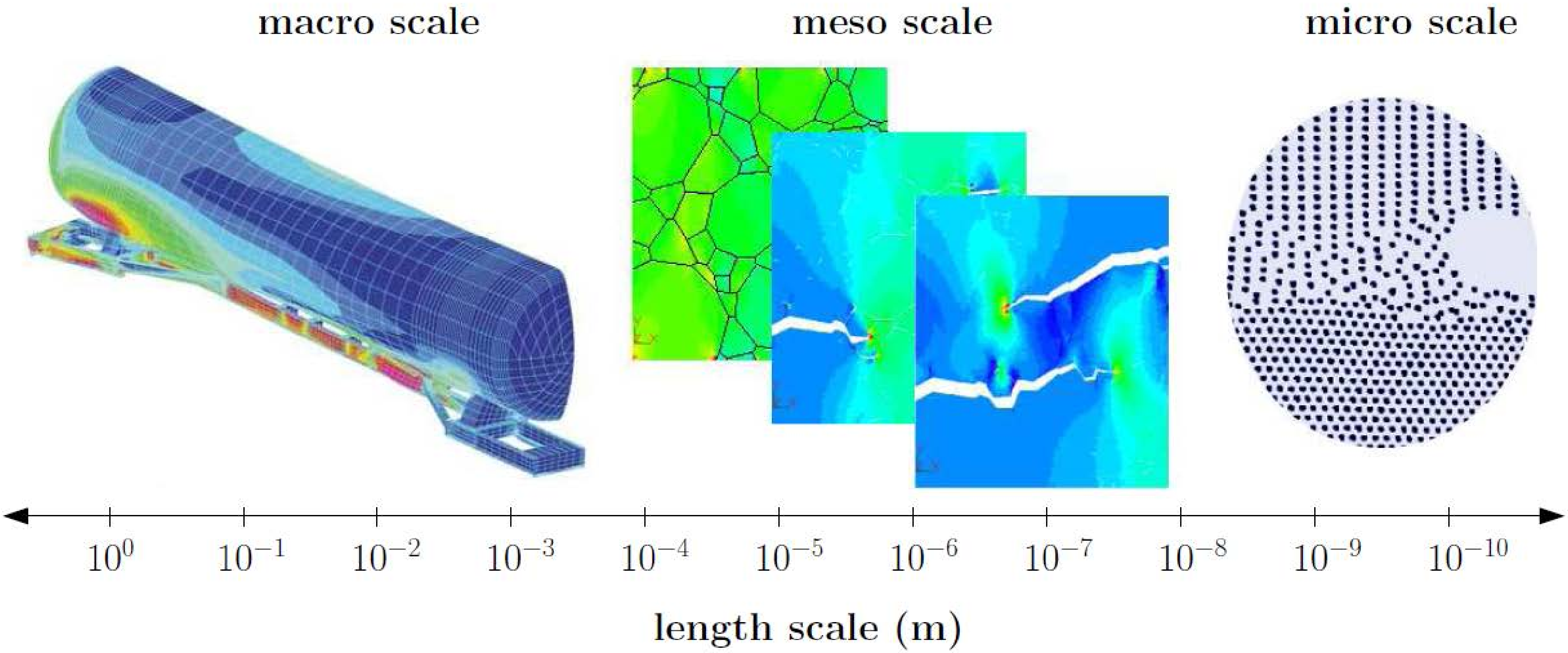
M. Schwedler, BU Weimar



M. Basnet, BU Weimar and CU Kiel

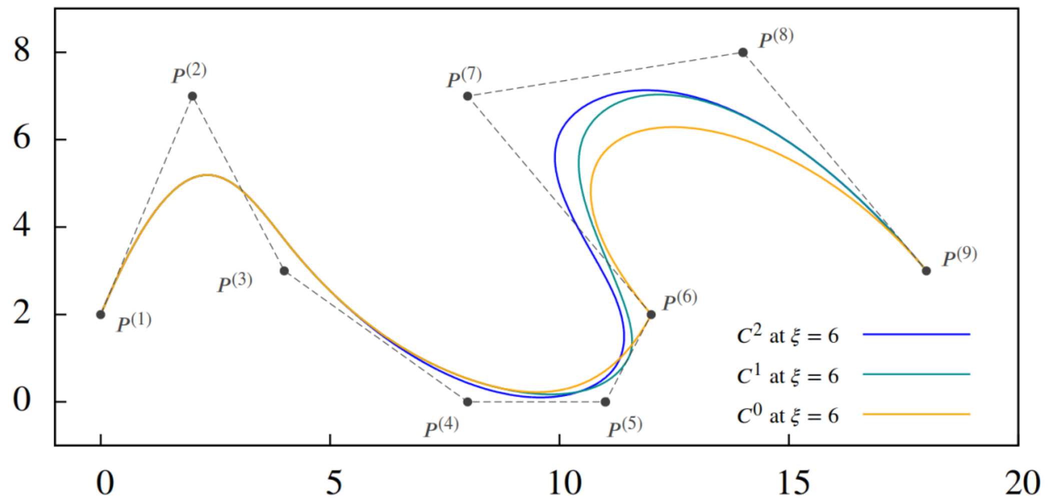
Component Strength:

High fidelity material models for ultimate limit scenarios
Hierrachical material models for damage and fracture phenomena in polycrystal materials

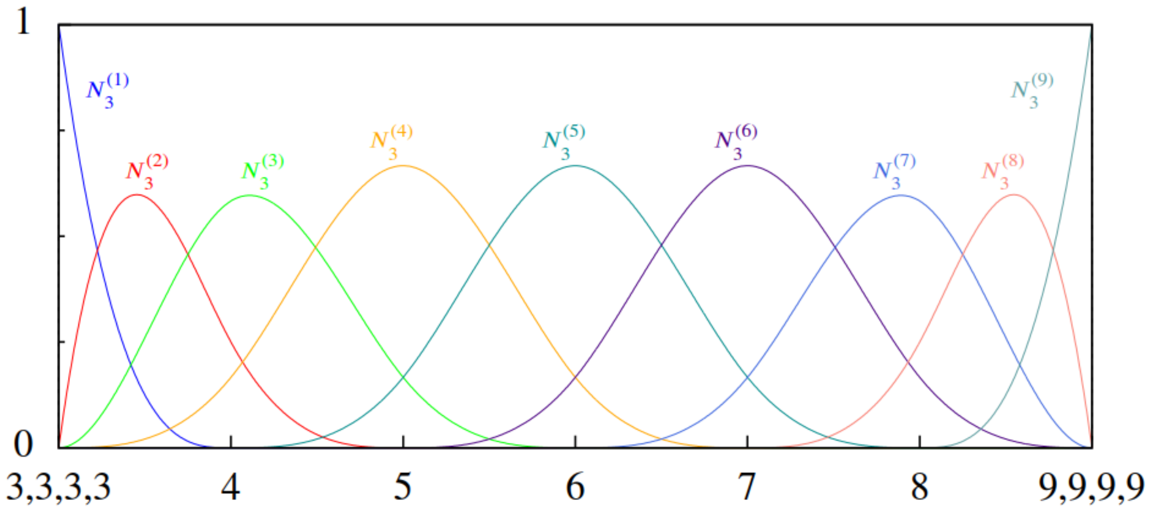


Isogeometric FEM with multiple inconsistent patches:

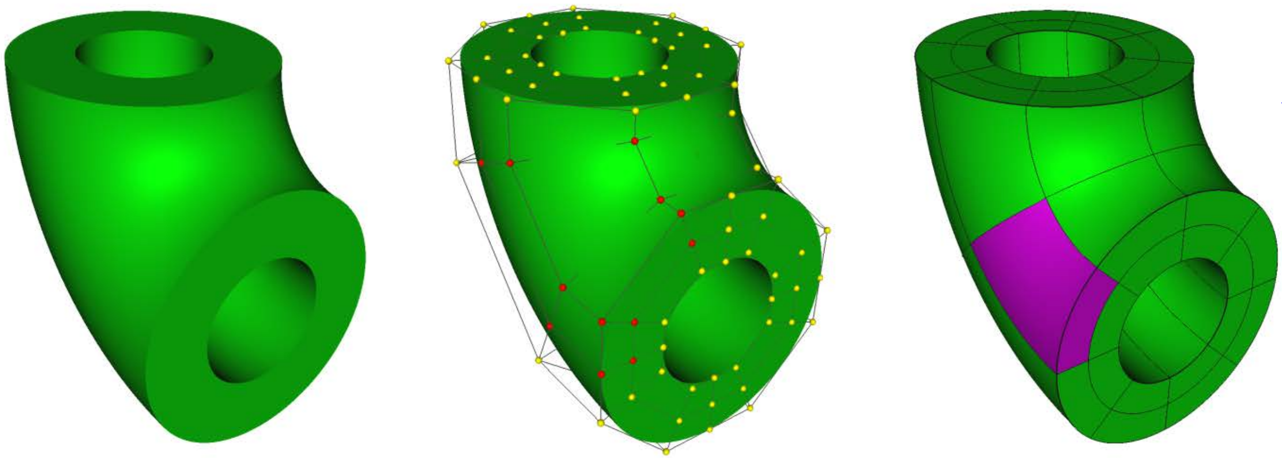
B-Spline basis,
polynomial of order 3



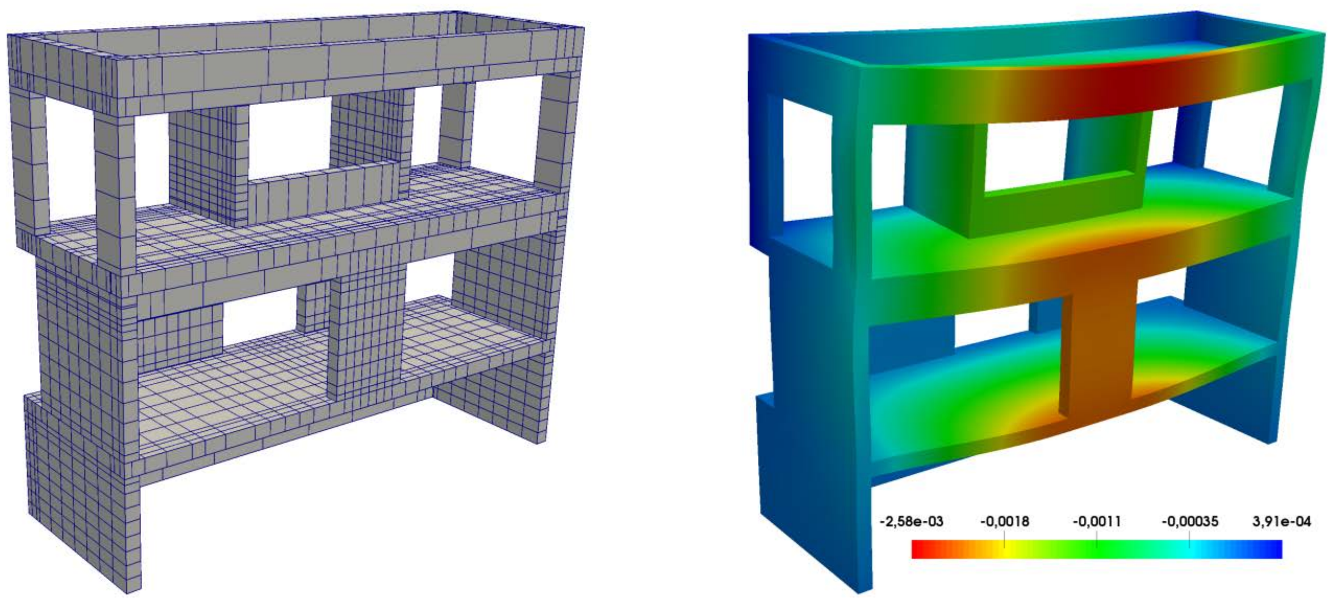
B-Spline basis, polynomial of order 3



Isogeometric FEM with multiple inconsistent patches:



Single patch



Multiple patches

M. Schwedler, BU Weimar

Isogeometric FEM with multiple inconsistent patches:

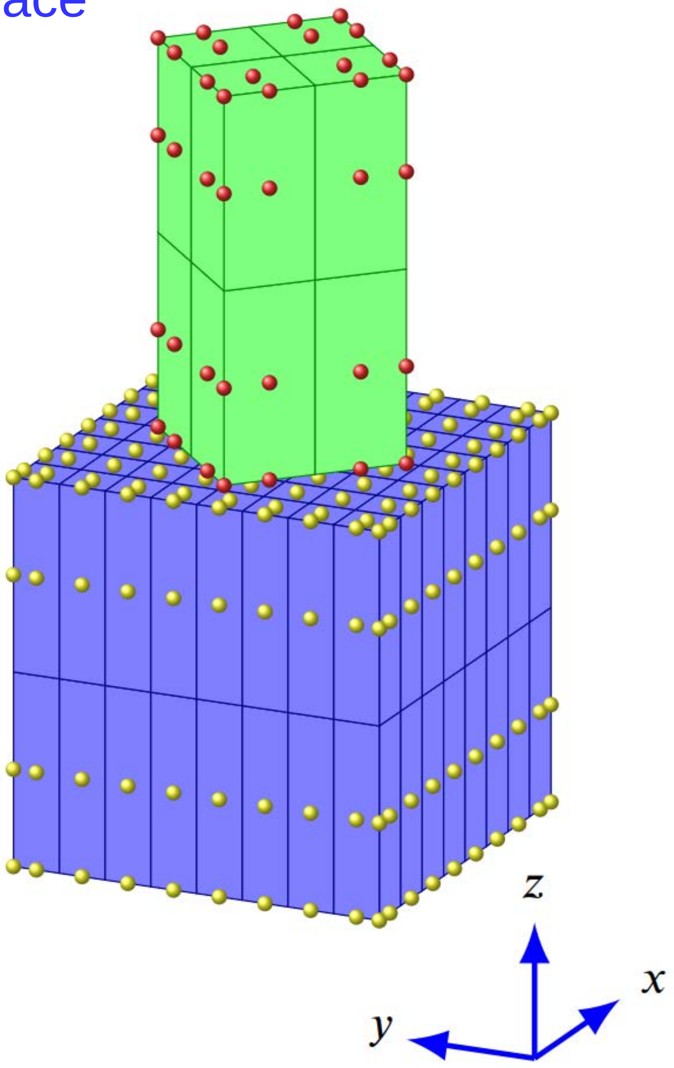
Two patchess with coupling surface

Mortar coupling

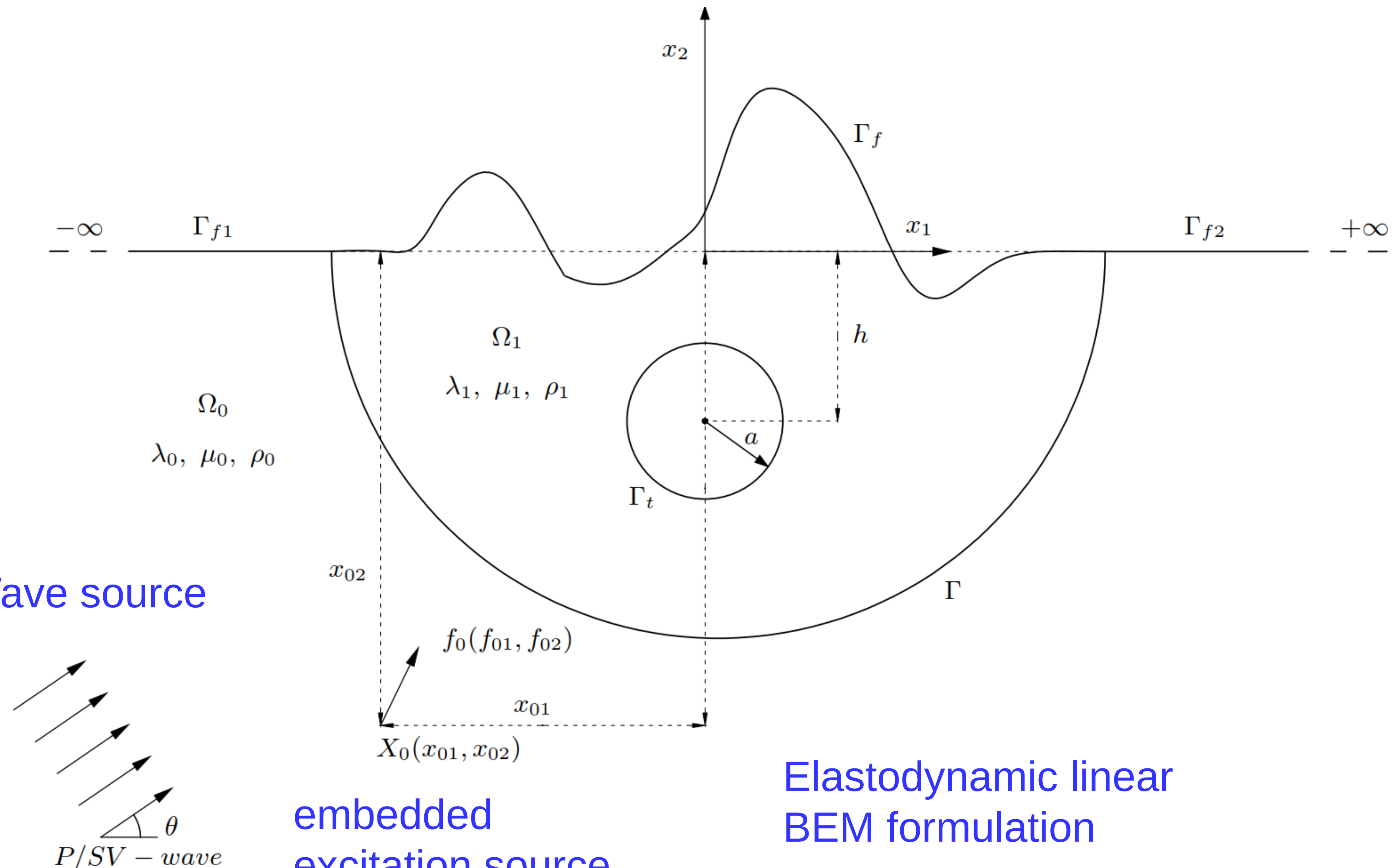
$$\int_{\Gamma_c} \delta \boldsymbol{\lambda} \left(\boldsymbol{u}^{(i)} - \boldsymbol{u}^{(j)} \right) \, \mathrm{d}\Gamma_c = 0$$

$$\forall i, j \in 1 \ldots n_{sub} \quad \text{with} \quad i \neq j,$$

$$\begin{bmatrix} \boldsymbol{K}^{(i)} & 0 & \boldsymbol{m}^{(i)^T} \\ 0 & \boldsymbol{K}^{(j)} & \boldsymbol{m}^{(j)^T} \\ \boldsymbol{m}^{(i)} & \boldsymbol{m}^{(j)} & 0 \end{bmatrix} \begin{bmatrix} \tilde{\boldsymbol{q}}^{(i)} \\ \tilde{\boldsymbol{q}}^{(j)} \\ \tilde{\boldsymbol{\lambda}}^{c,(i,j)} \end{bmatrix} = \begin{bmatrix} \tilde{\boldsymbol{g}}^{(i)} \\ \tilde{\boldsymbol{g}}^{(j)} \\ \boldsymbol{0} \end{bmatrix},$$



FEM / BEM coupling



Wave source

embedded
excitation source

Elastodynamic linear
BEM formulation

FEM / BEM coupling

Complex stiffness and force mnatrix for Boundary element region

$$\hat{H}_{ij} = \int_{\Gamma_j} P^*_{lk}(X^{(i)}, \xi^{(j)}, \omega)\ |J|\ d\Gamma_j$$

$$G_{ij} = \int_{\Gamma_j} U^*_{lk}(X^{(i)}, \xi^{(j)}, \omega)\ |J|\ d\Gamma_j$$

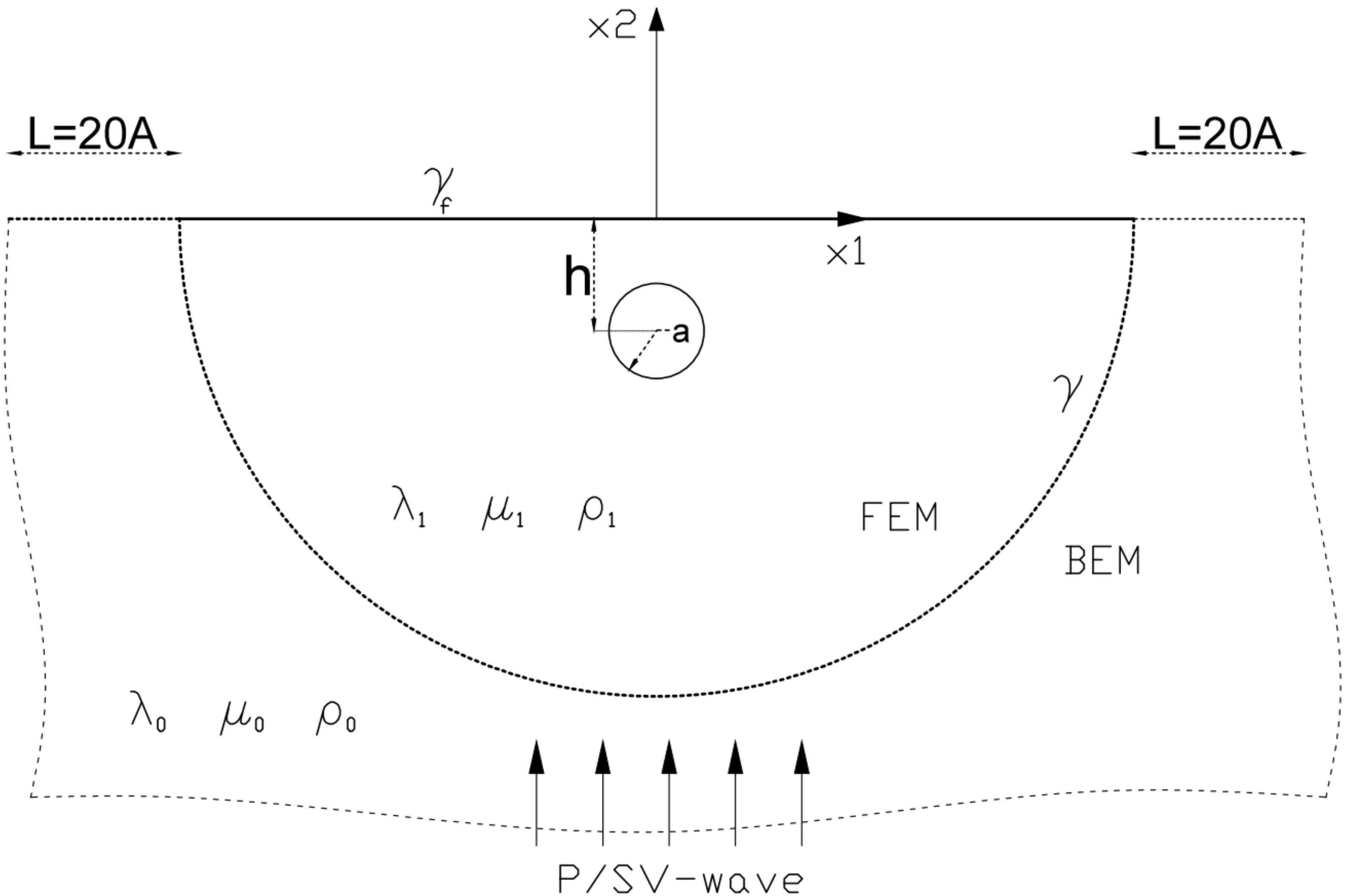
$$[K] = -\left[G_f\right]^{-1}[H]$$ Stiffness

$$[F] = -\left[G_f\right]^{-1}\left[F^{ff}\right]$$ Force

Condensed to interface degrees of freedom

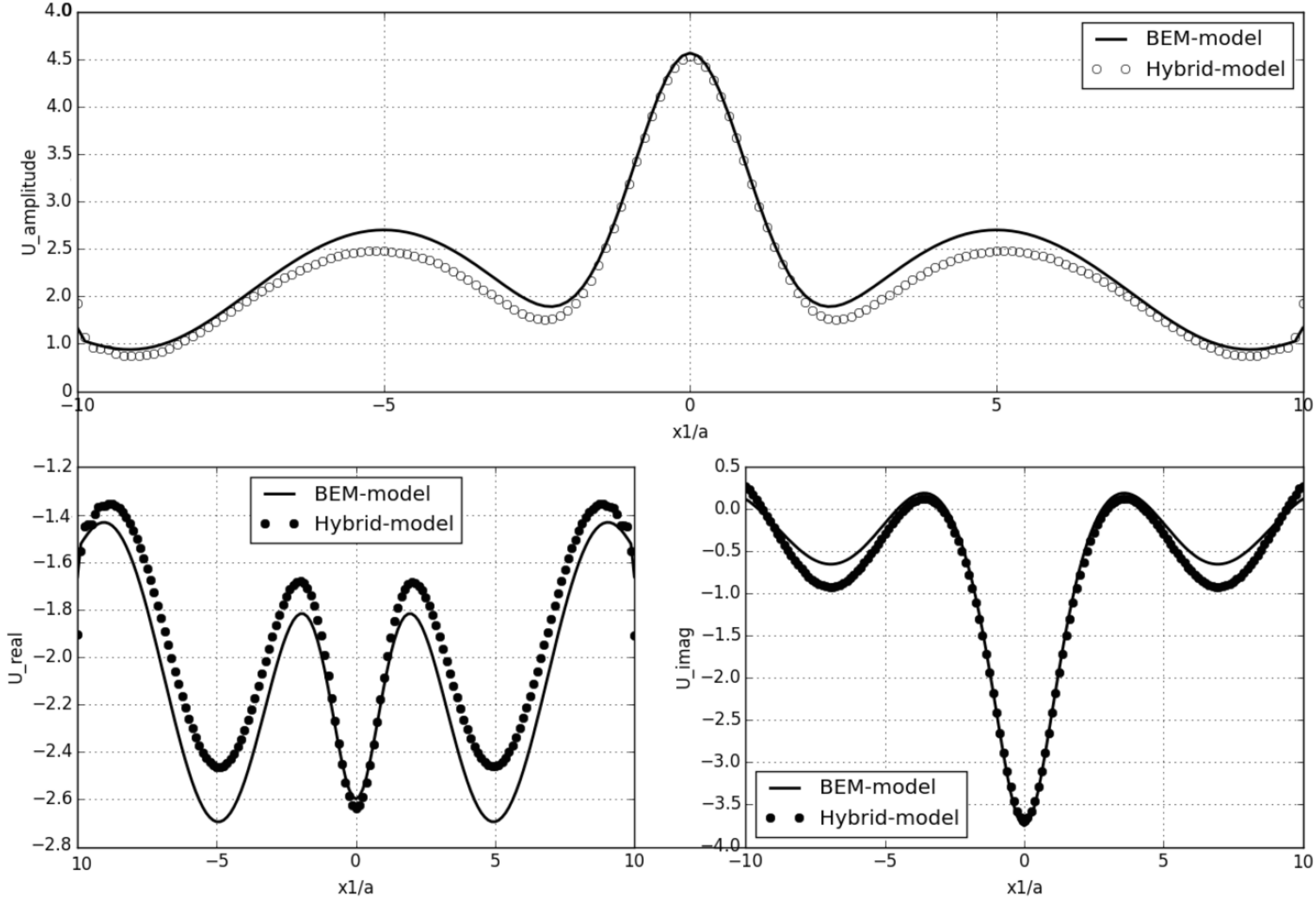
Added to the global system matrices of the FEM region

2D Example



x2
L=20A
L=20A
γ_f
x1
h
a
γ
λ_1 μ_1 ρ_1
FEM
BEM
λ_0 μ_0 ρ_0
P/SV-wave

2D Example



U_amplitude
x1/a
BEM-model
Hybrid-model
U_real
x1/a
BEM-model
Hybrid-model
U_imag
x1/a
BEM-model
Hybrid-model

Quasicontinuum-model on nanoscale
apply unit deformations – determine reaction forces

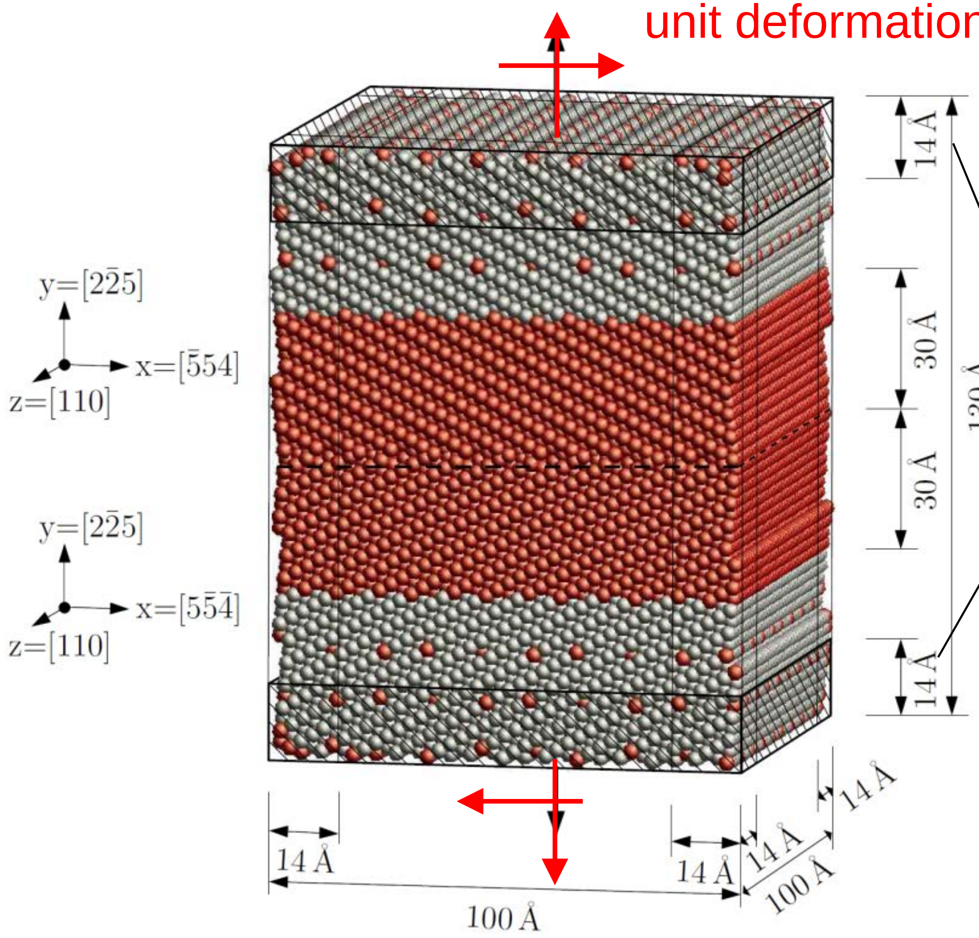
atomistic unit cell in the vicinity of grain boundary with approx. 80 000 atoms

unit deformations

quasicontinuum method

full atomistic resolution

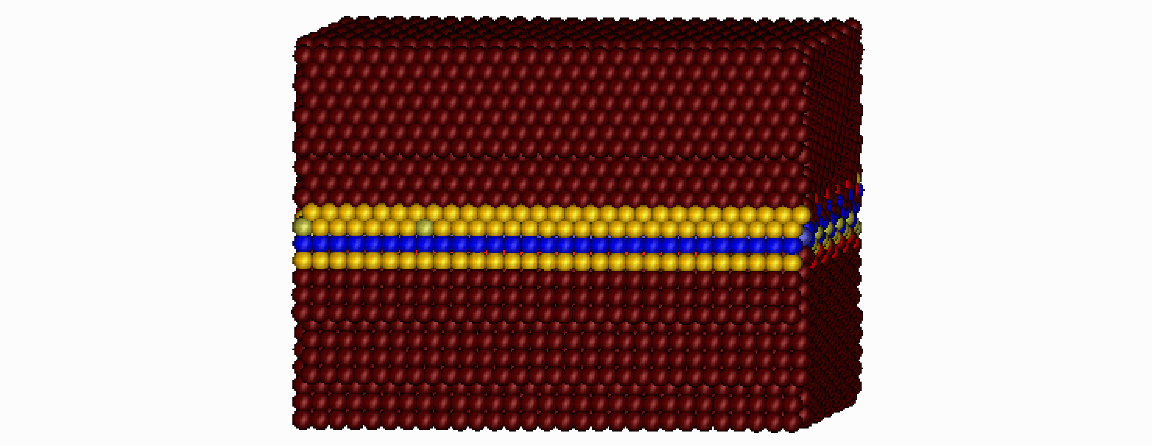
quasicontinuum method

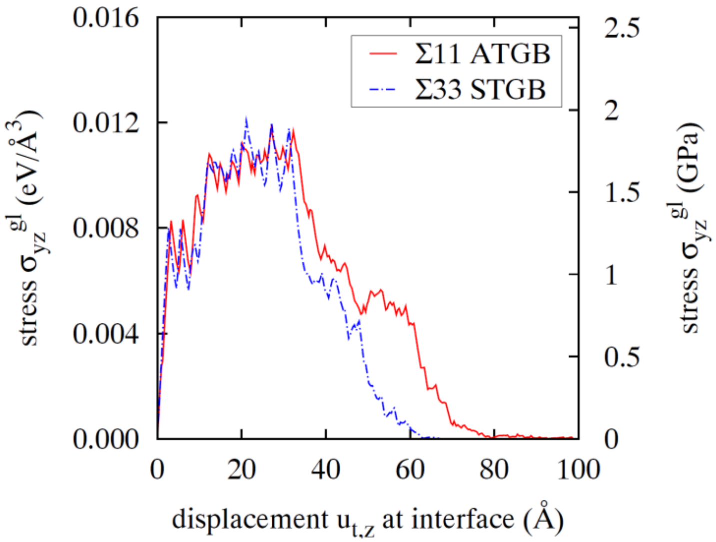


boundary layers

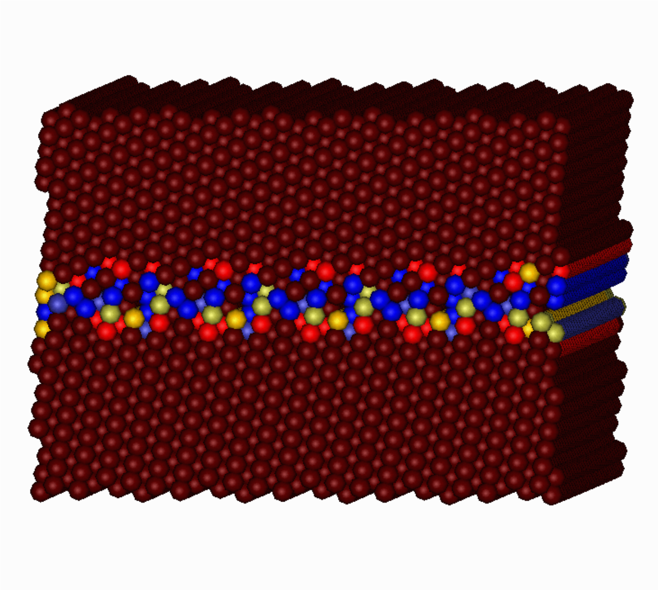
Evolution of potential energy in atomic lattice – shear deformation z-axis

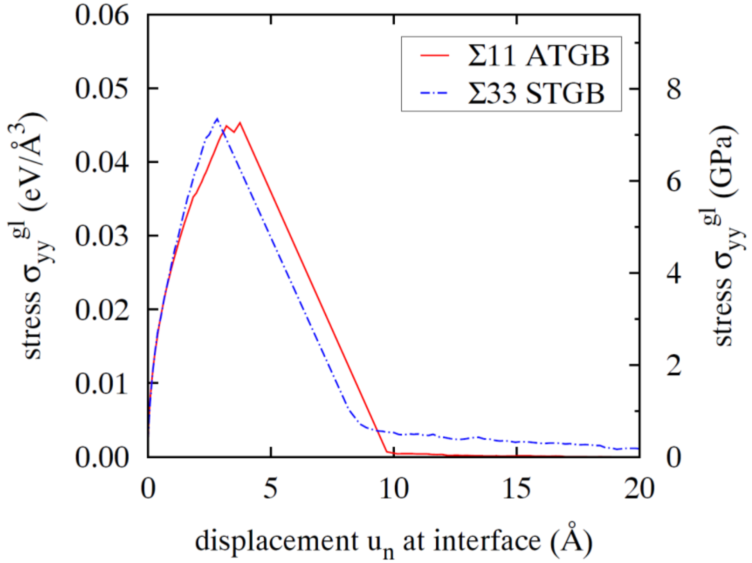
shear deformation in z-direction





normal deformation in y-direction



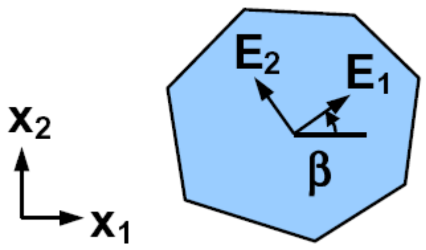


material models for mesoscale grain model

single crystals

orthotropic material behavior:

- linear elastic
- elastic-plastic (Hill)

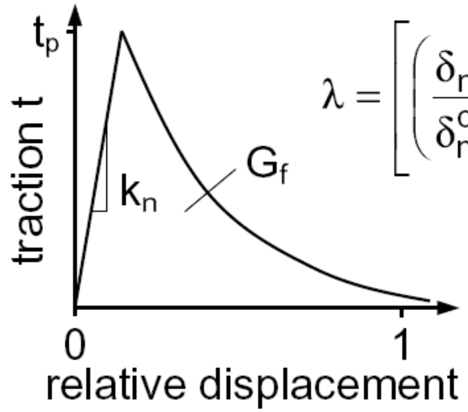


statistical distribution of:

- crystal orientation $0 \leq \beta \leq \pi$
- material properties $E_1, E_2, G_{12}, \sigma_{yield}$ (normal distribution)

interfaces

coupled cohesive zone model *(according to Tvergaard)*



$$\lambda = \left[\left(\frac{\delta_n}{\delta_n^c} \right)^2 + \left(\frac{\delta_t}{\delta_t^c} \right)^2 \right]^{1/2}$$

peak strength depending on missorientation $\Delta\beta$ between neighboring crystals:

$$\Delta\beta = \beta_1 - \beta_2$$

$$t_p(\Delta\beta) = t_p^{avg} + \Delta t_p \cos(4\Delta\beta)$$

phenomenological approach

grain model on mesoscale: tensile load in y-direction