Calibrating Yield Surface Models based on Full Field Crystal Plasticity Simulations

MAX-PLANCK-INSTITUT FÜR EISENFORSCHUNG

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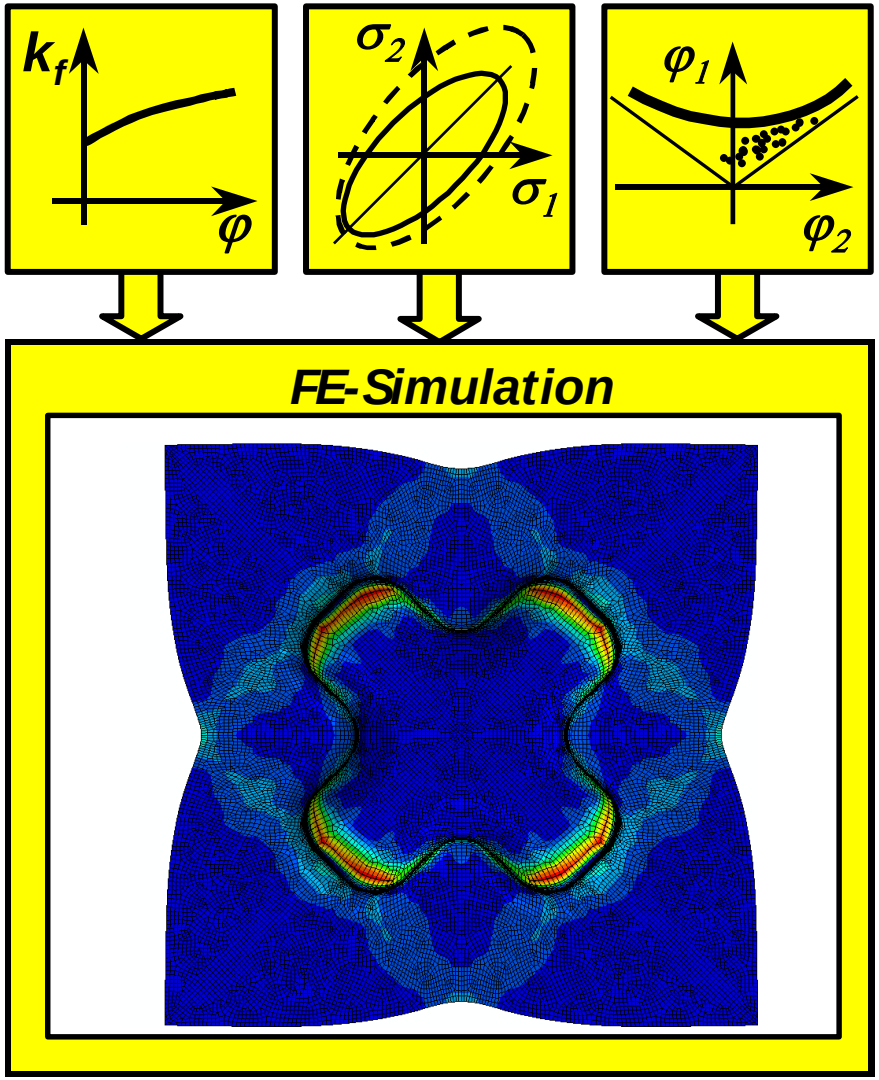
Meeting Materials
Noordwijkerhout, 10. December 2019

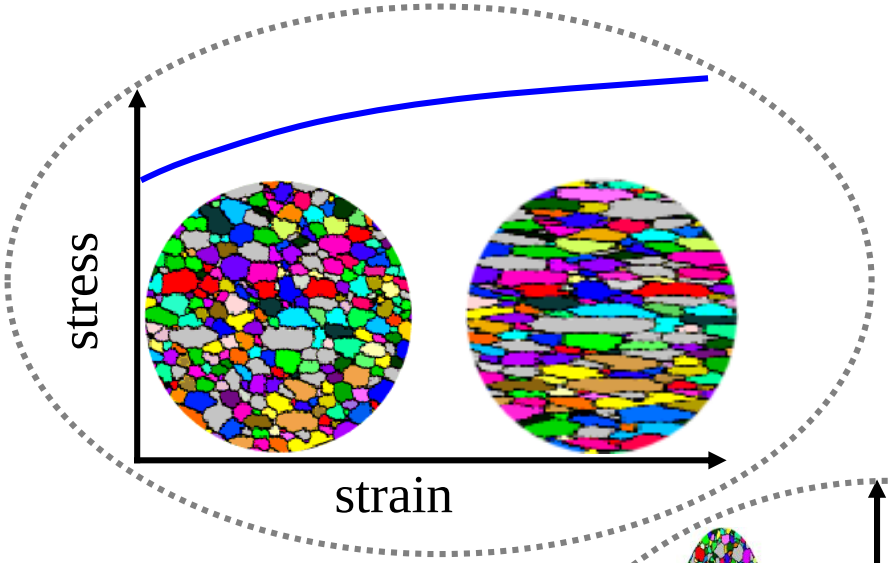
Outline

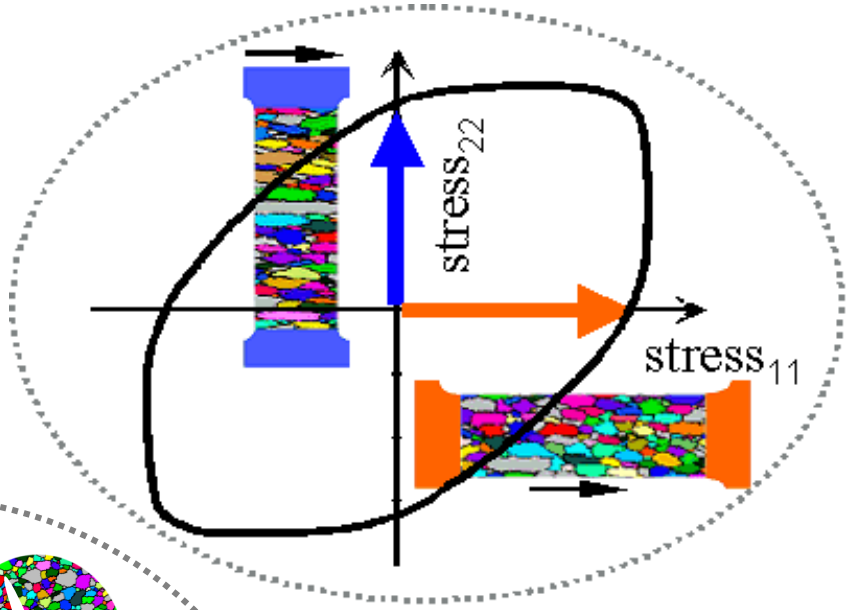
- Fundamentals
- Single Crystal Yield Surface
- Calibrating Yield Surfaces
- Application
- Outlook

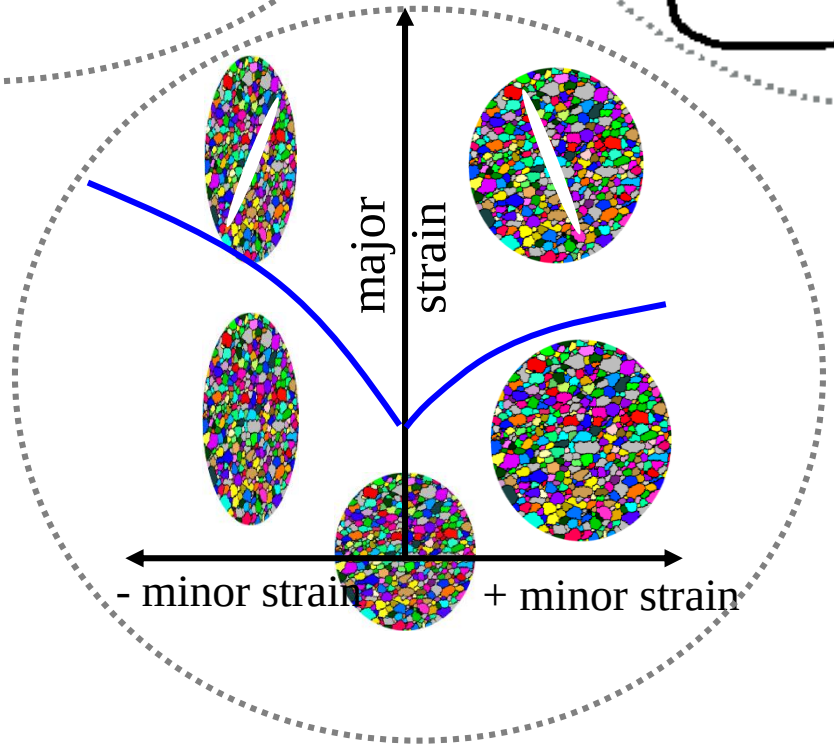
Fundamentals



Fundamentals





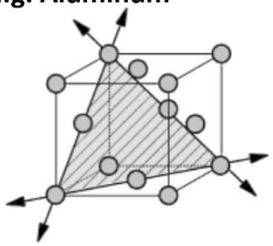


Single Crystal Yield Surface

Continuum Mechanics: $\mathbf{F} = \mathbf{F}_\mathrm{p}\mathbf{F}_\mathrm{e} \qquad \dot{\mathbf{F}}_\mathrm{p} = \mathbf{L}_\mathrm{p}\mathbf{F}_\mathrm{p}$

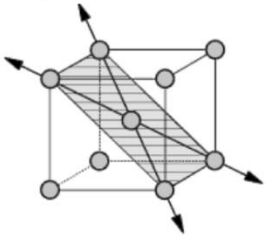
Crystal Plasticity: $$\mathbf{L}_\mathrm{p} = \sum_\alpha \dot{\gamma}^\alpha \underbrace{\left(\mathbf{s}_\mathrm{s}^\alpha \otimes \mathbf{n}_\mathrm{s}^\alpha\right)}_{=:\mathbf{P}_\mathrm{Schmid}^\alpha}$$

Face centered cubic, e.g. Aluminum



Slip systems: {111}<110>

Body centered cubic, e.g. α-Iron



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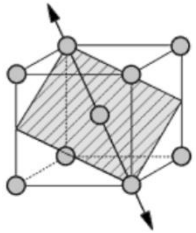

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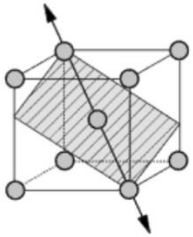
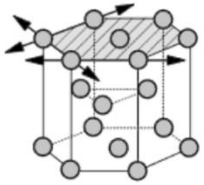
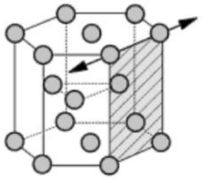


{123}<111>

Hexagonal, e.g. Magnesium



Slip systems: {0001}<1120>



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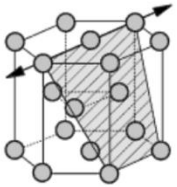


{1011}<1120>

Single Crystal Yield Surface

Slip system becomes active:

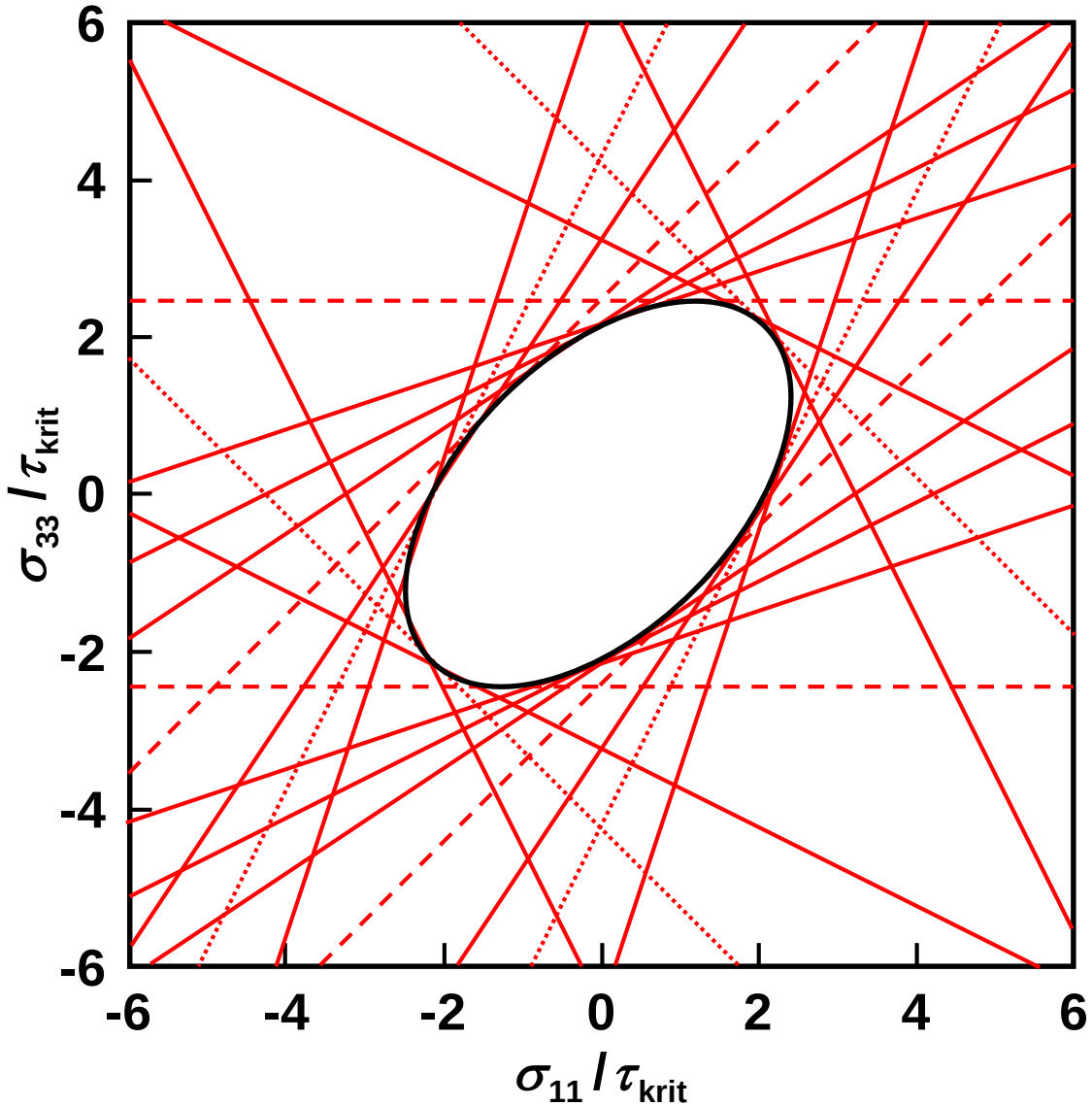
$$\tau^{\alpha} = \tau_{\text{critical}}$$

bcc crystal 48 slip systems
orientation {001}<100>

12 x {110}<111>

12 x {112}<111>

24 x {123}<111>



Calibrating Yield Surfaces

2 simple examples:

Von Mises Yield Surfcace:

$$\sigma_{\mathrm{vM}}^2 = \frac{1}{2}[(\sigma_{22}-\sigma_{33})^2+(\sigma_{33}-\sigma_{11})^2+(\sigma_{11}-\sigma_{22})^2+6(\sigma_{23}^2+\sigma_{31}^2+\sigma_{12}^2)] = \sigma_{\mathrm{y}}^2$$

Hill 48:

$$F(\sigma_{22}-\sigma_{33})^2+G(\sigma_{33}-\sigma_{11})^2+H(\sigma_{11}-\sigma_{22})^2+2L\sigma_{23}^2+2M\sigma_{31}^2+2N\sigma_{12}^2 = 1$$

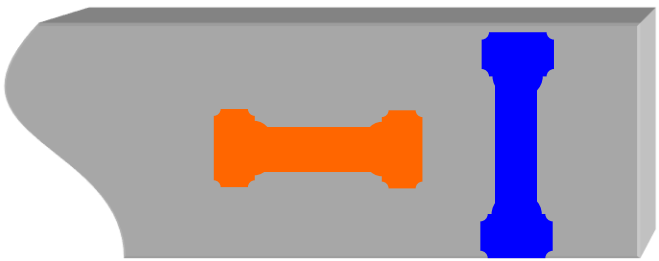
6 parameters => 6 (experimental) data points

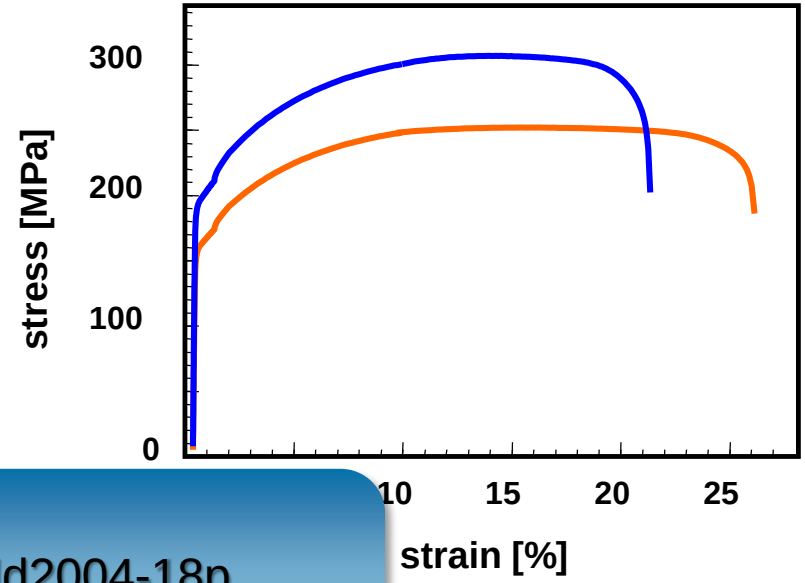
plane stress => L, M = 0 => 4 (experimental) data points

$$\sigma_1^2 + \frac{R_0(1+R_{90})}{R_{90}(1+R_0)}\sigma_2^2 - \frac{2R_0}{1+R_0}\sigma_1\sigma_2 = {\sigma_{y,1}}^2$$

Calibrating Yield Surfaces

Experimental Approach:



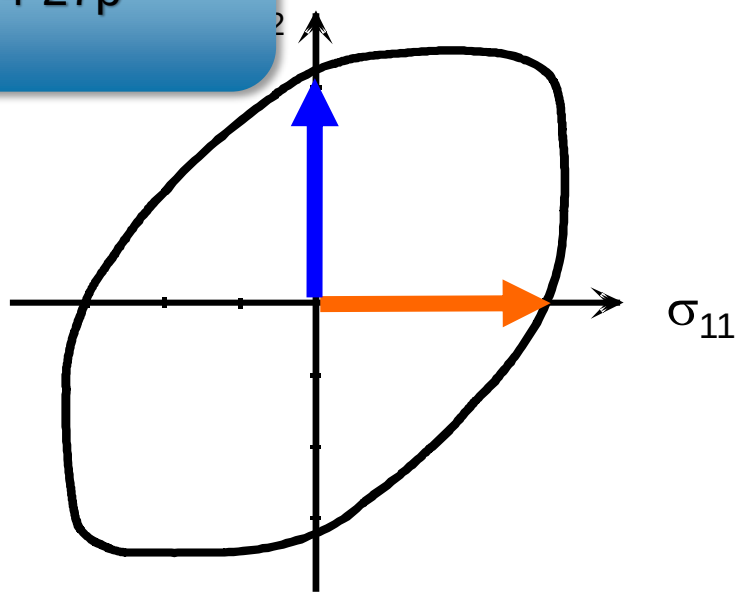


R

Barlat Yld2004-18p
Barlat Yld2004-27p

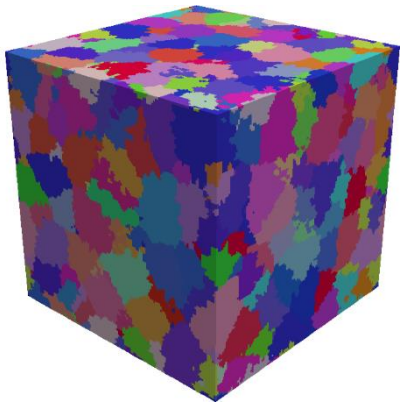
determine R-values

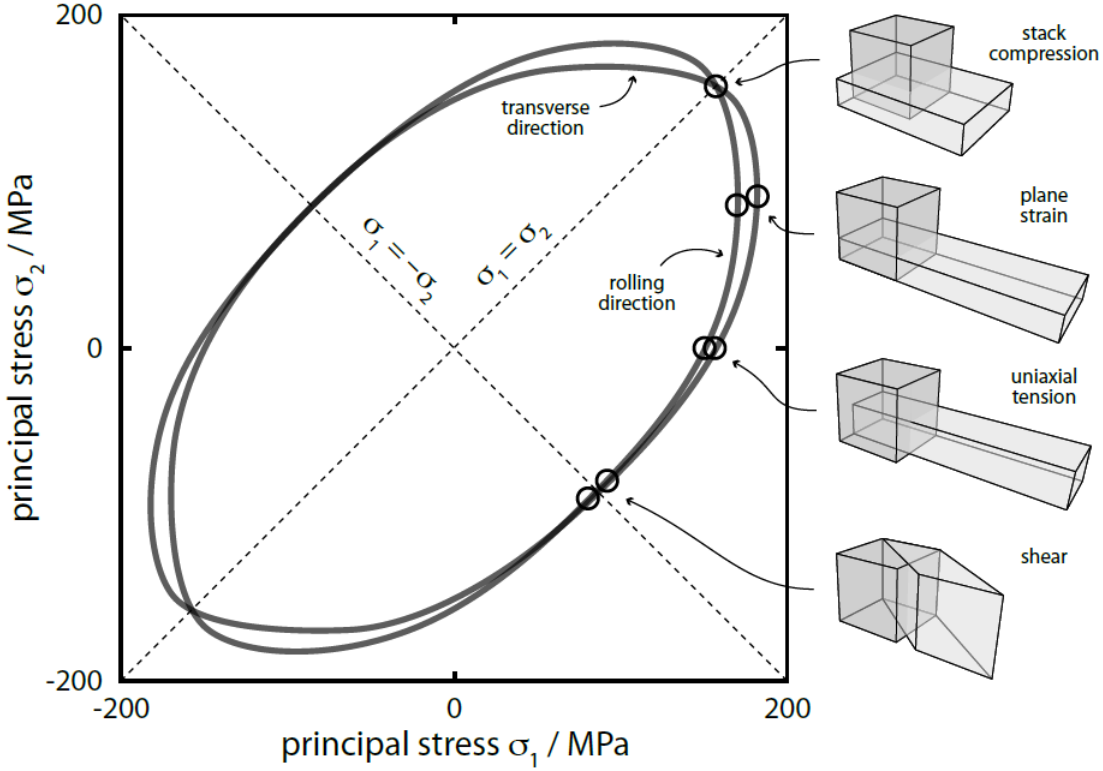
$$R = \frac{\epsilon_{\text{width}}}{\epsilon_{\text{thickness}}}$$



Calibrating Yield Surfaces

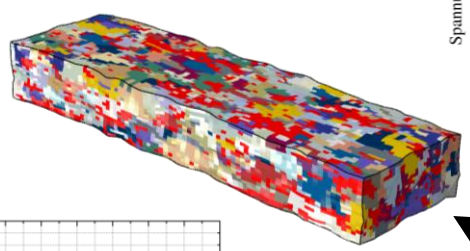
Computational Approach:

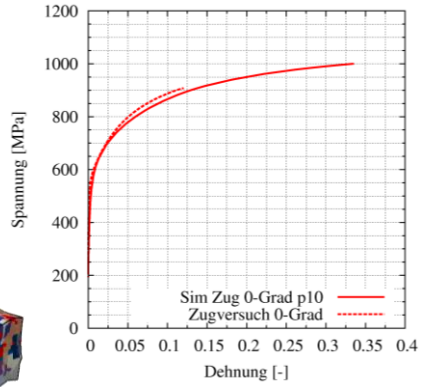




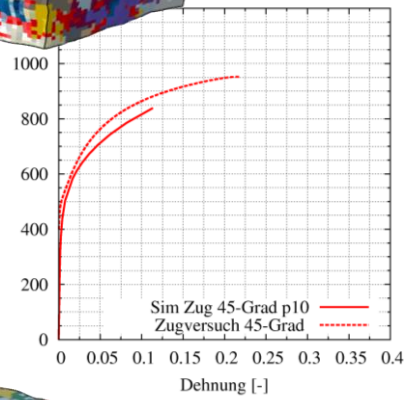
Calibrating Yield Surfaces

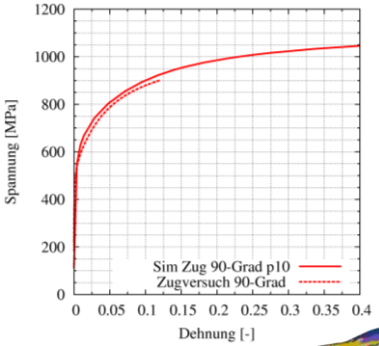
Tension 0° (RD)



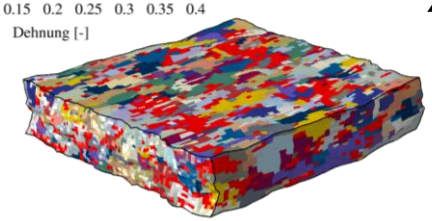


Tension 45°

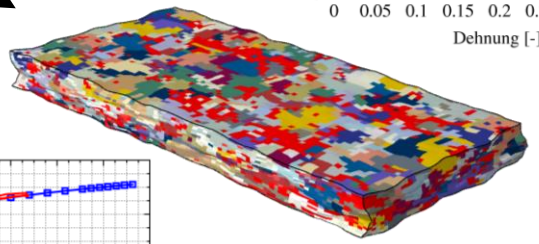




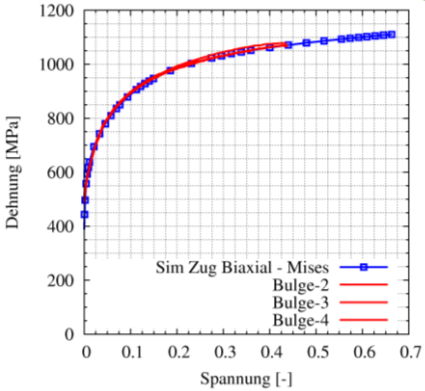
RVE from annealed DP



Tension 90° (Querrichtung)



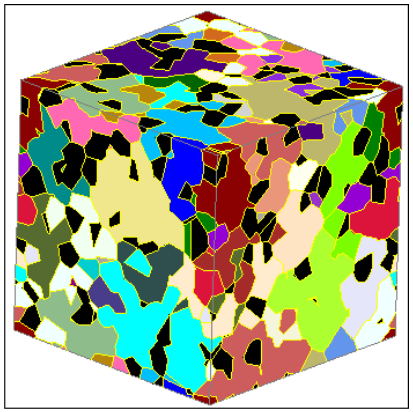
Tension biaxial

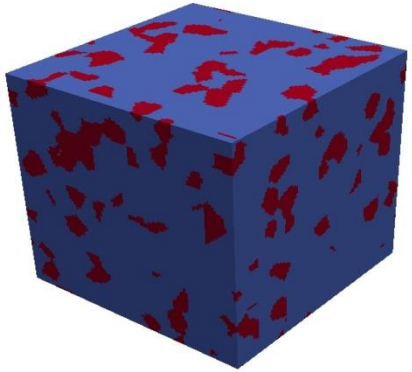


DP steel 3D artificial mocrostructure

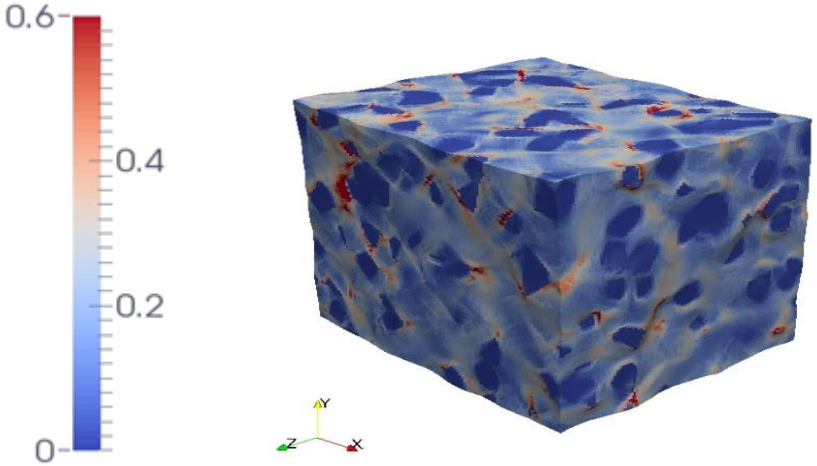
Crystal plasticity simulation of Dual Phase, 23% uni-axial deformation

microstructure input

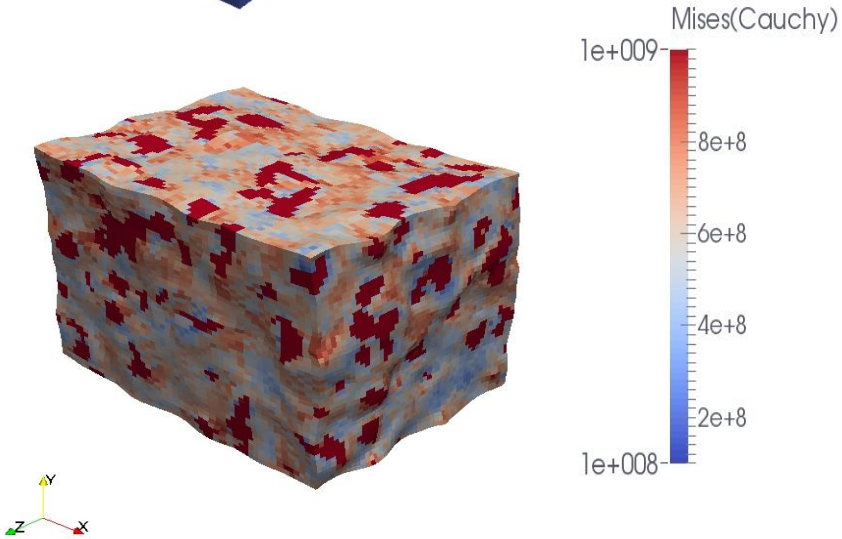




Fourier grid



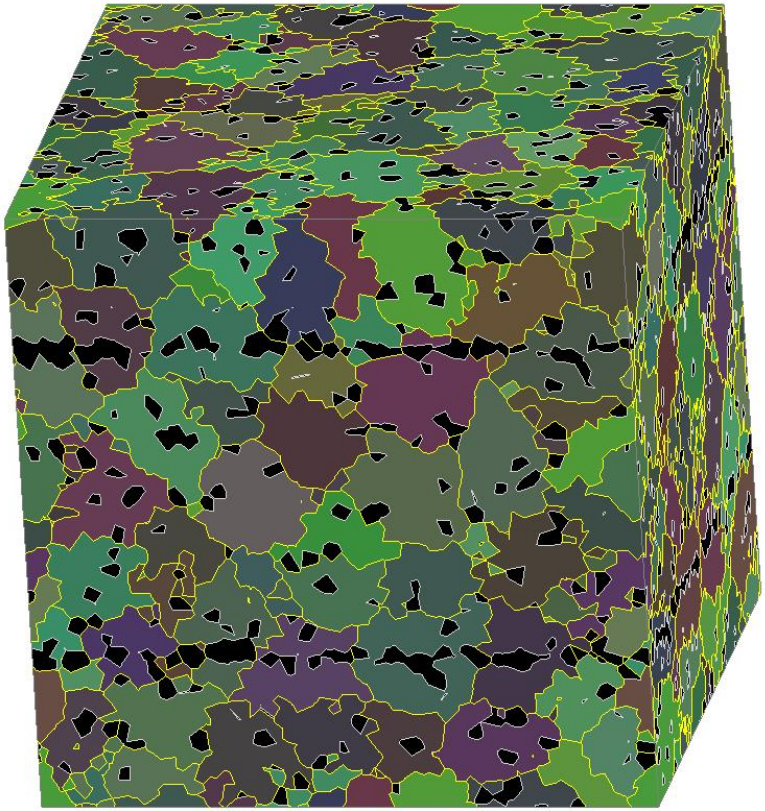
Strain distribution

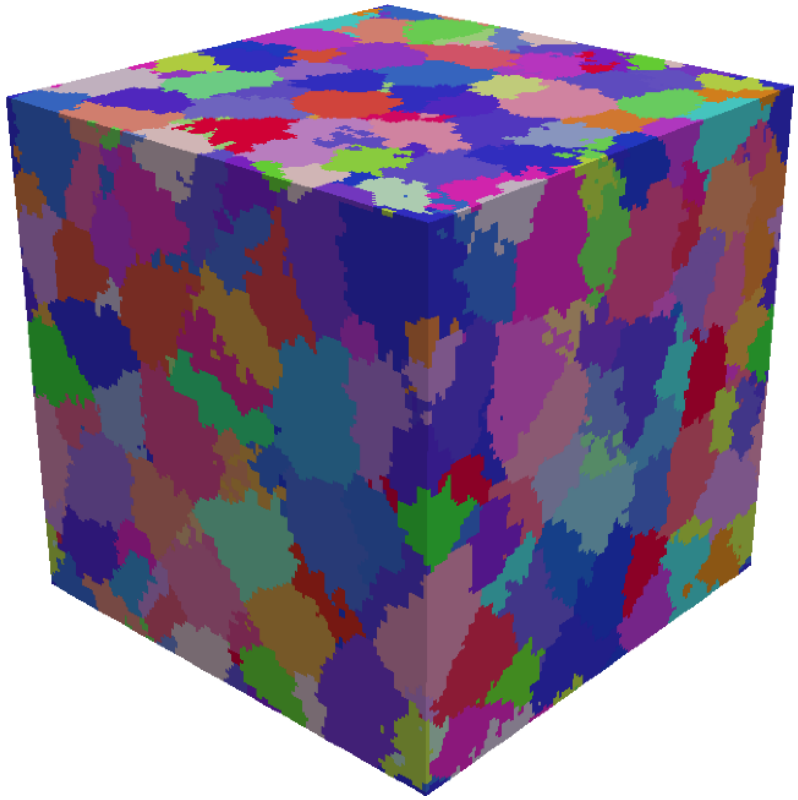


Stress distribution

Calibrating Yield Surfaces

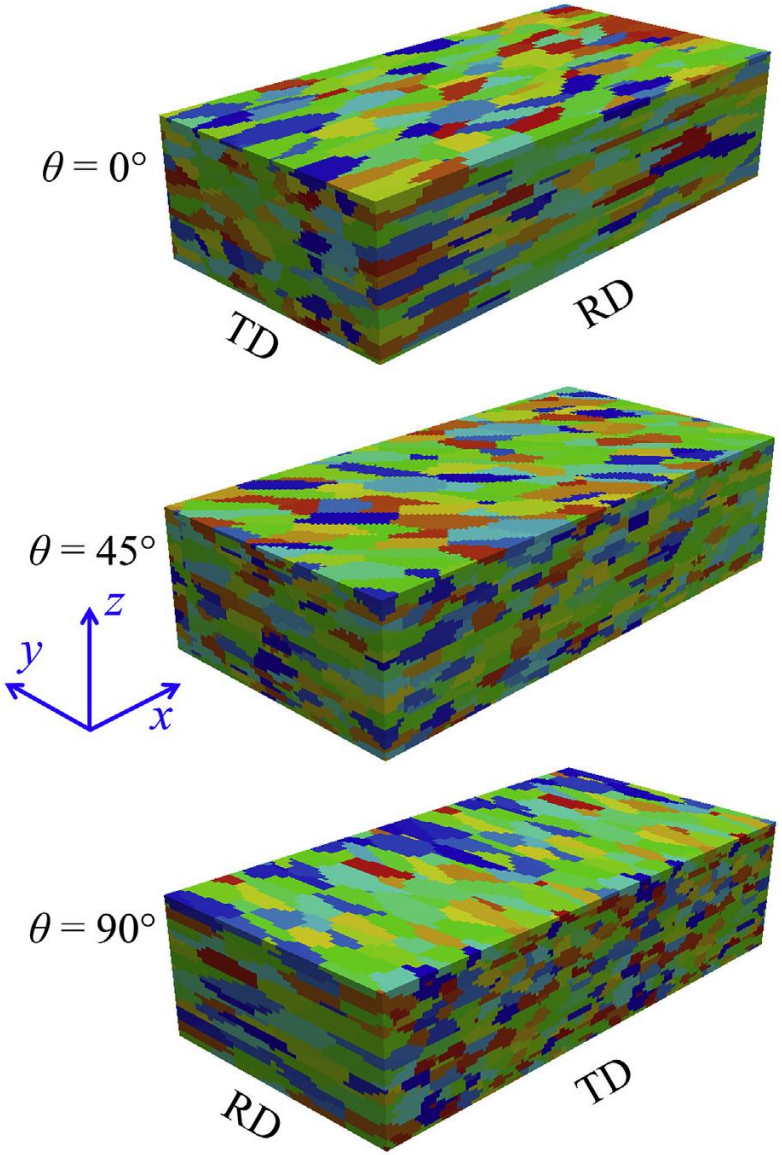
Discretization

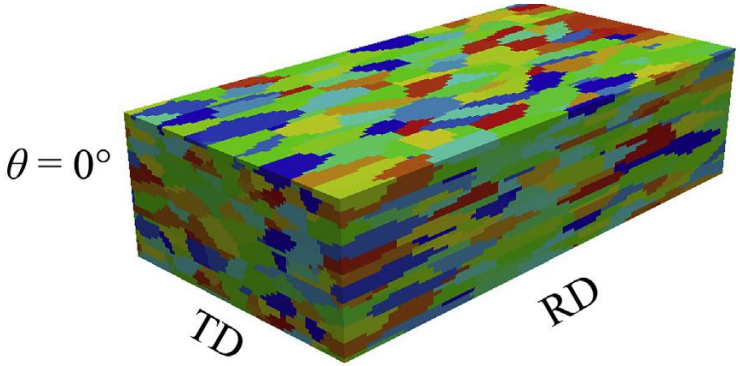




128x128x128

Calibrating Yield Surfaces





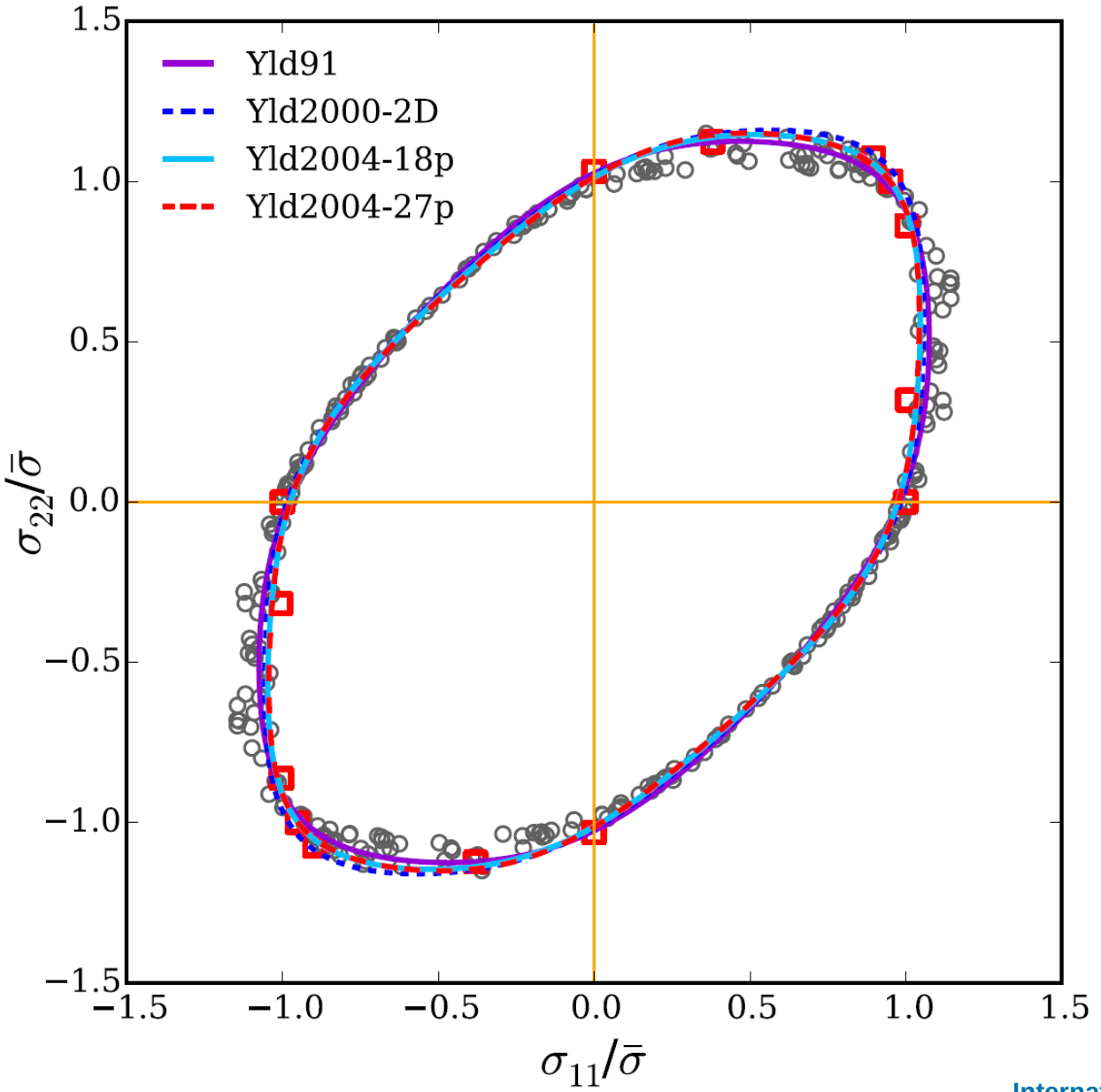
+

rotate orientations

or

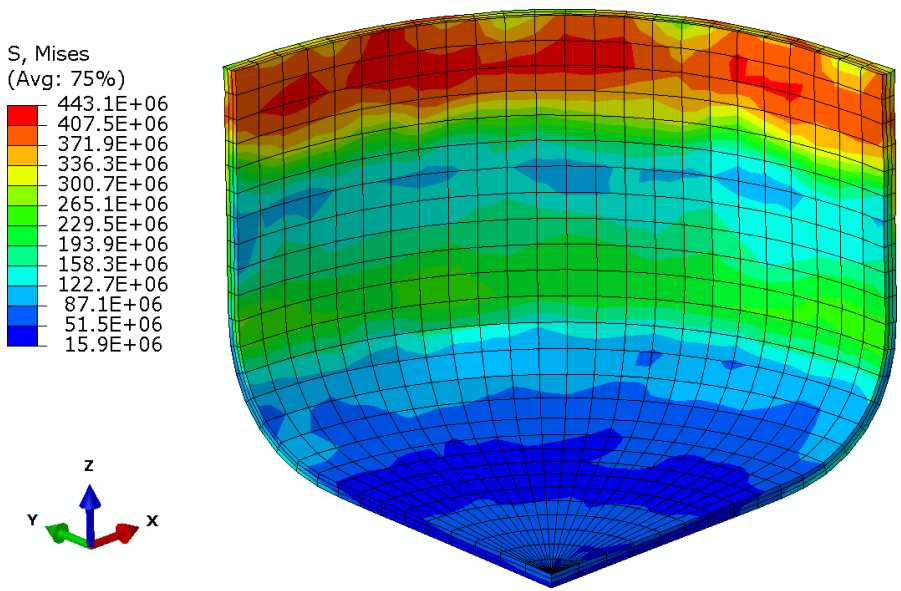
rotate loading

Calibrating Yield Surfaces

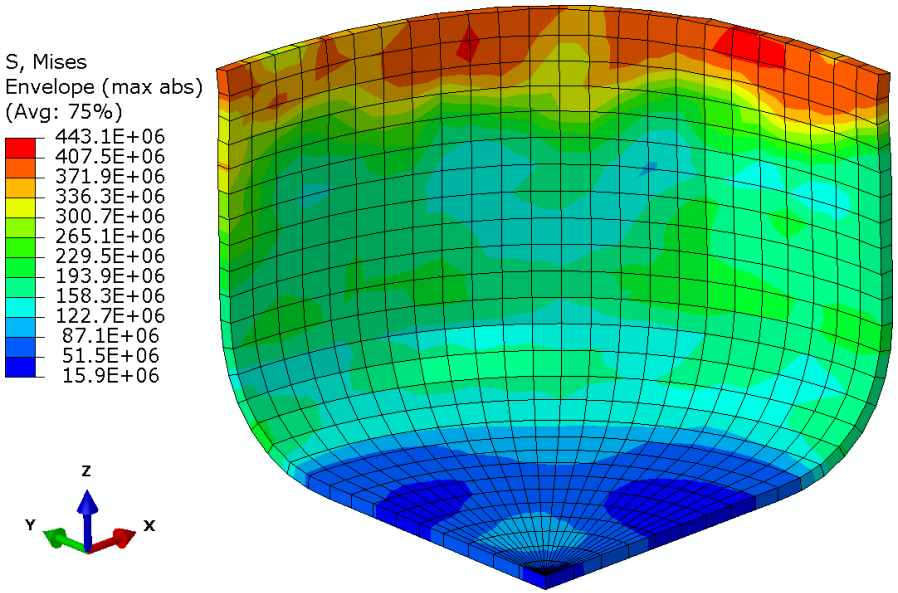


H. Zhang , M. Diehl, F. Roters, D. Raabe:
International Journal of Plasticity 80 (2016) 111-138

Cup drawing simulation

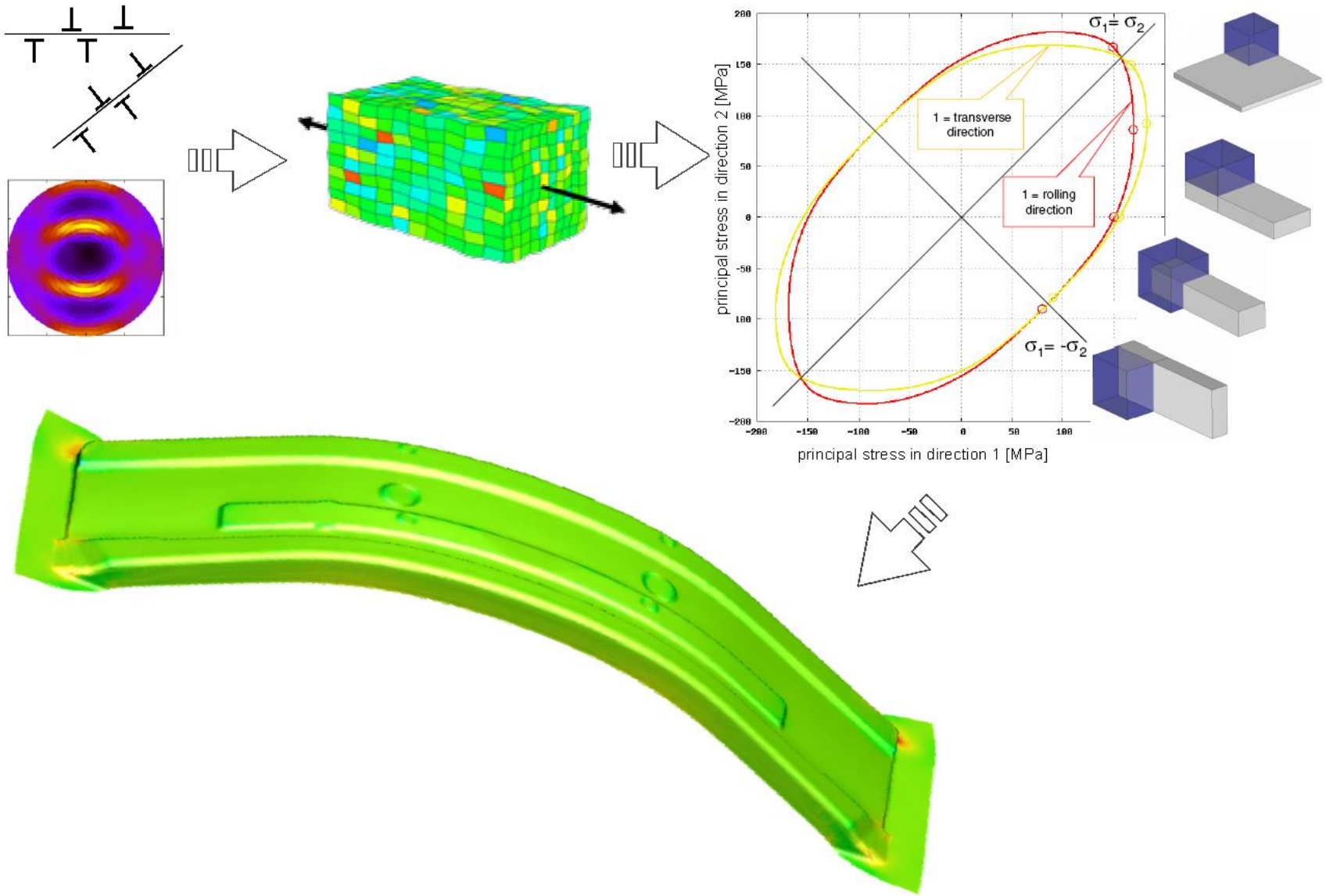


simulation with 3D Yld2004-18p

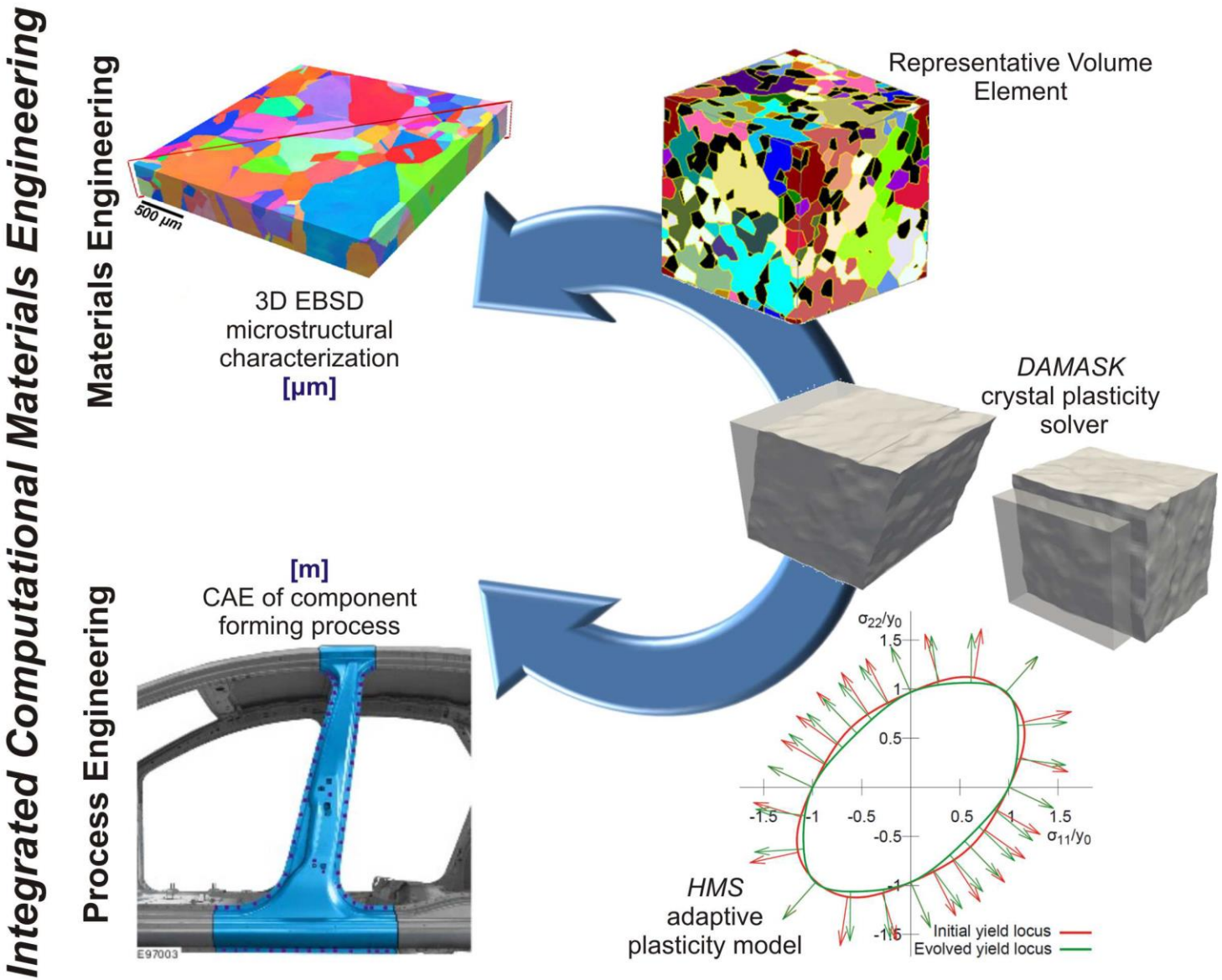


simulation with plane stress Yld2004-18p

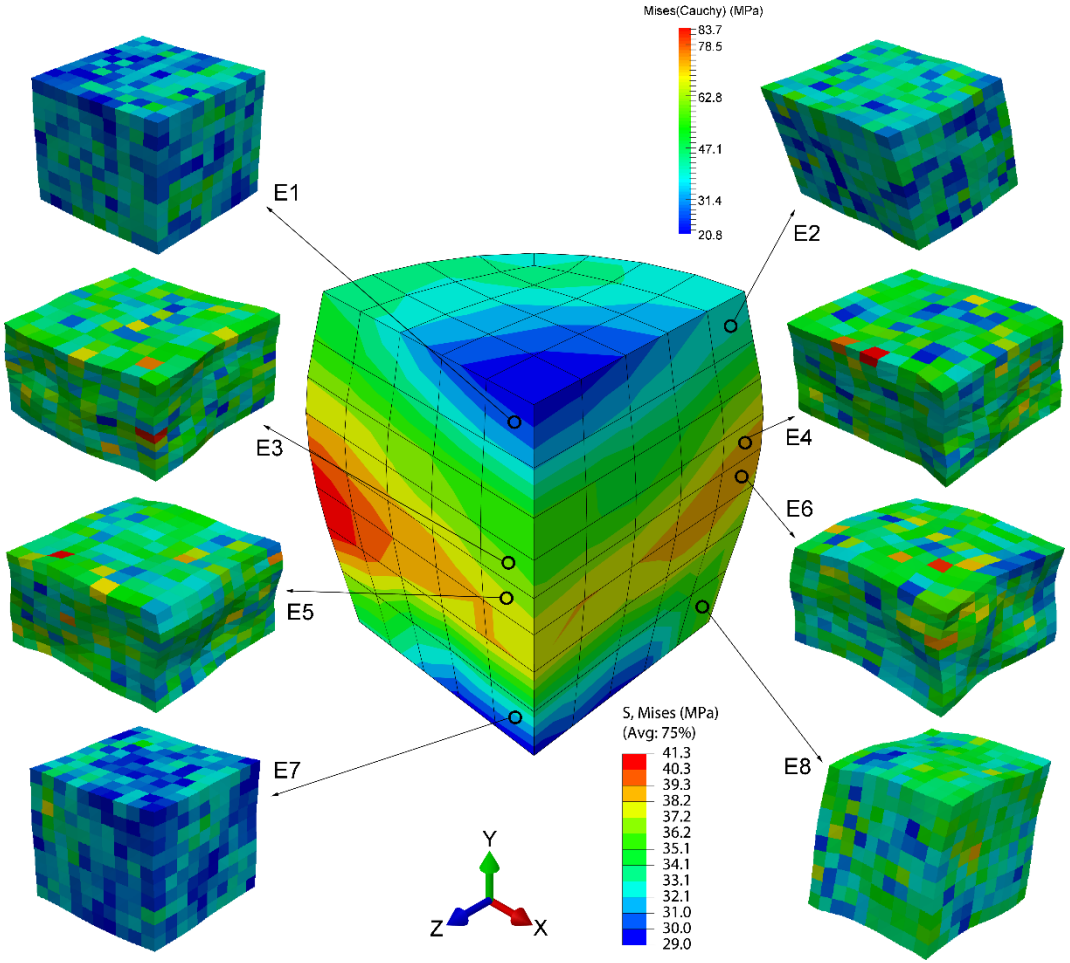
Application



M. Kraska, M. Doig, D. Tikhomirov, D. Raabe, F. Roters: Computational Material Science 46 (2009) 383-392


Integrated Computational Materials Engineering
Materials Engineering
Process Engineering
500 µm
3D EBSD
microstructural
characterization
[µm]
Representative Volume
Element
DAMASK
crystal plasticity
solver
[m]
CAE of component
forming process
E97003
HMS
adaptive
plasticity model
σ22/y0
σ11/y0
1.5
1
0.5
-0.5
-1
-1.5
Initial yield locus
Evolved yield locus

Outlook


Mises(Cauchy) (MPa)
83.7
78.5
62.8
47.1
31.4
20.8
E1
E2
E3
E4
E5
E6
E7
E8
S, Mises (MPa)
(Avg: 75%)
41.3
40.3
39.3
38.2
37.2
36.2
35.1
34.1
33.1
32.1
31.0
30.0
29.0
Y
Z
X

Thanks for your attention!

Questions?

Research Fund for Coal & Steel

100 YEARS 1917–2017

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