

Multiscale modeling of AA 6xxx automotive sheet production

AMAP Project 1,
presented by Thiemo Brüggemann and Christian Bollmann



Novelis

Mubea

SMS  group



RWTHAACHEN
UNIVERSITY

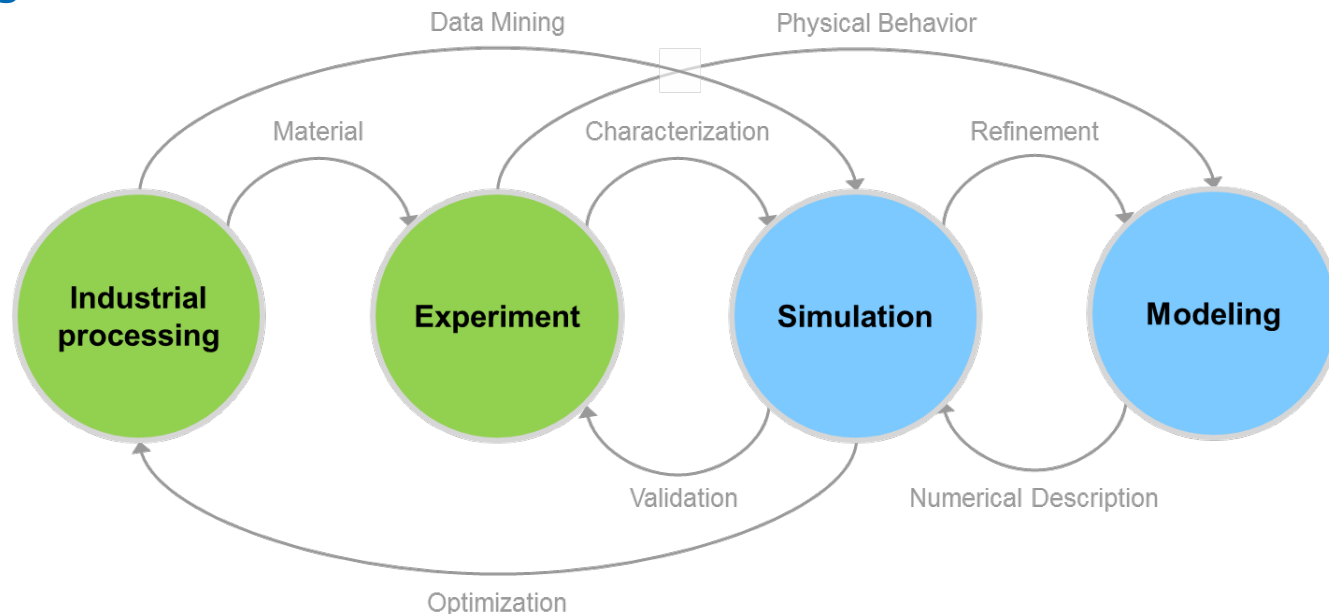
Goals

- to understand the link between process, microstructure, and properties of Al-Mg-Si sheets for optimization

Approach

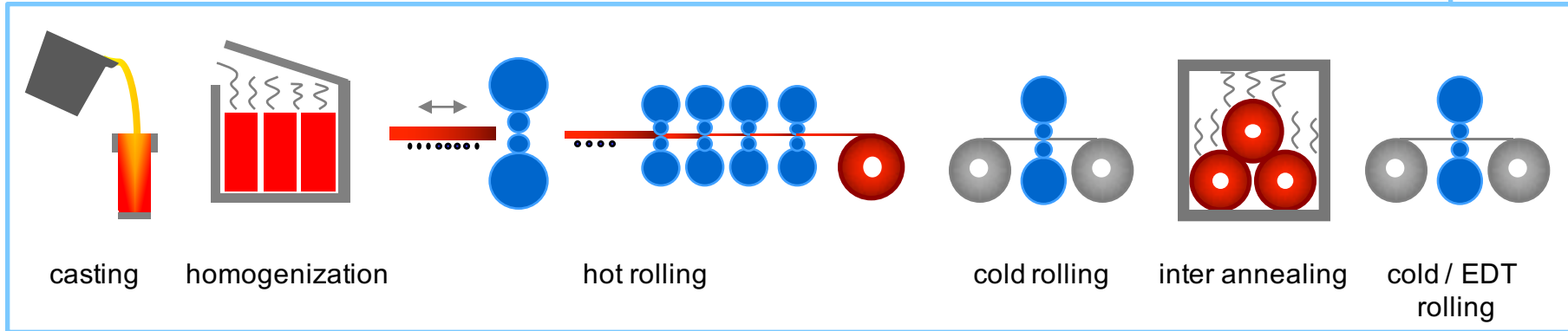
- use, build, validate and integrate models for through-process simulation

Working Fields

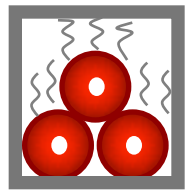


Rolling

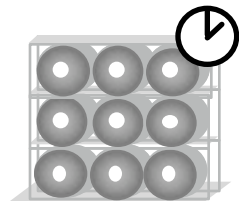
WP1



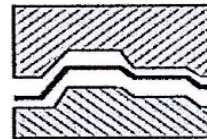
Aging and Forming



solution heat treatment



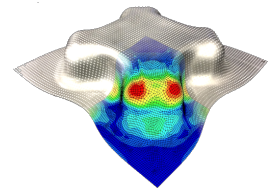
natural aging (T4)



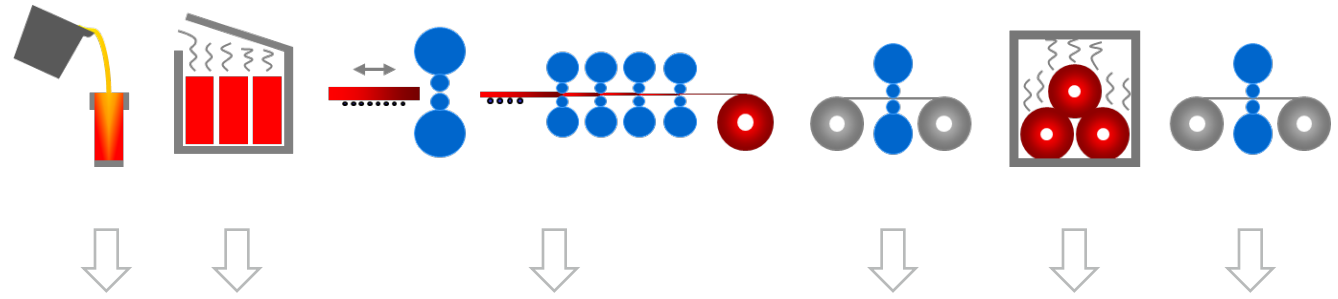
forming



artificial aging (T6)



properties



Data mining

- rolling degree
- temperatures
- speed
- force / torque

Characterization

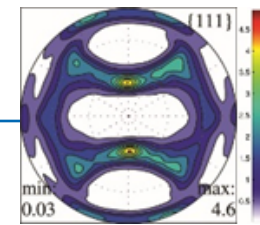
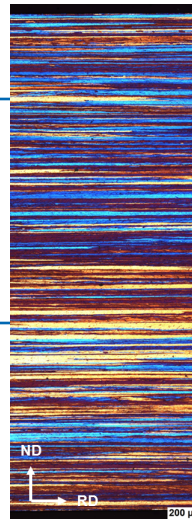
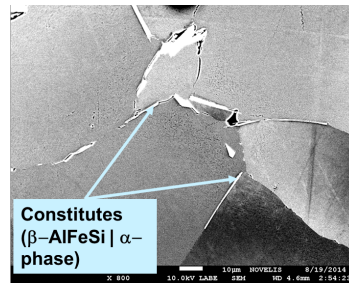
- grain size
- texture
- micro chemistry
- strength

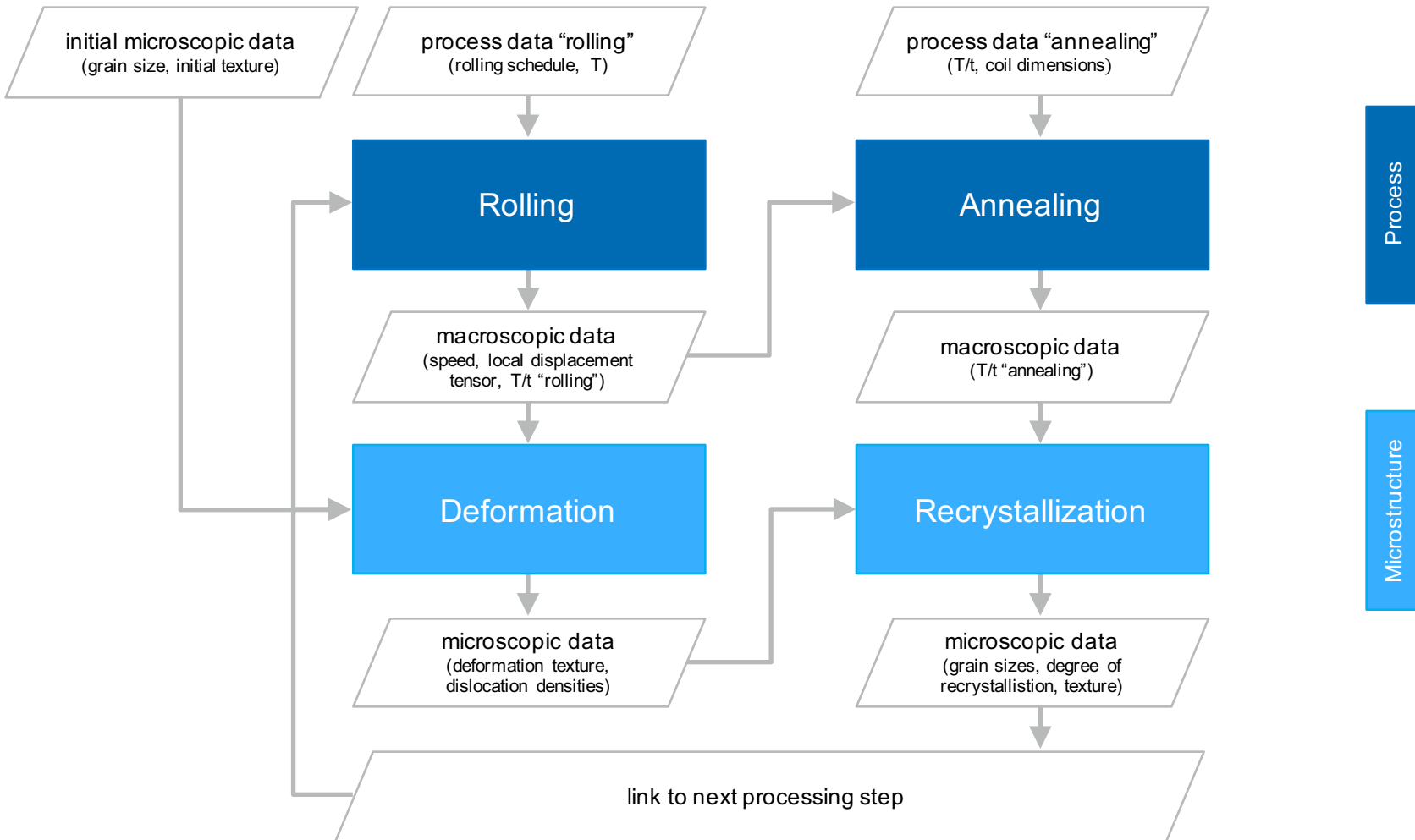
Lab processing

- homogenization trials
- recrystallization kinetics
- texture

Simulation

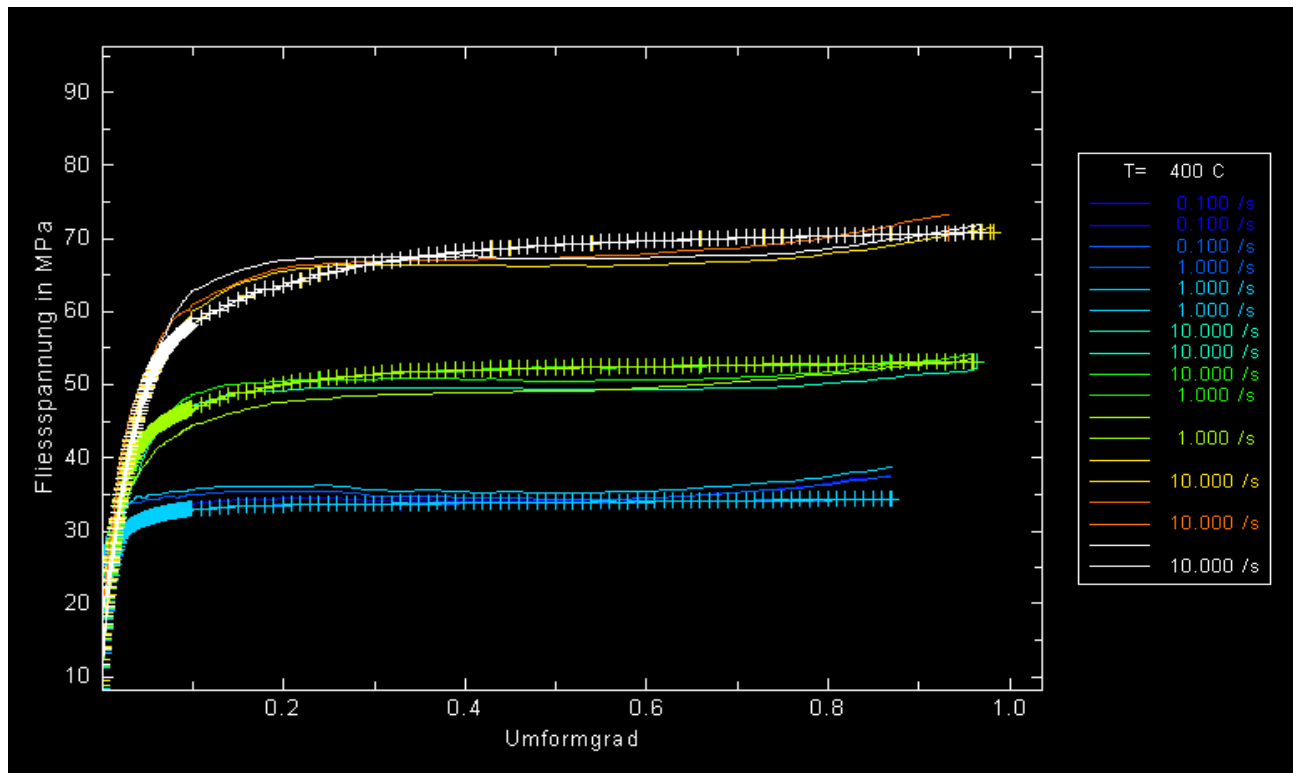
- process
- microstructure evolution

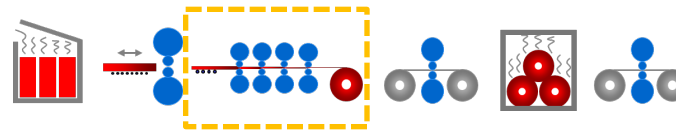




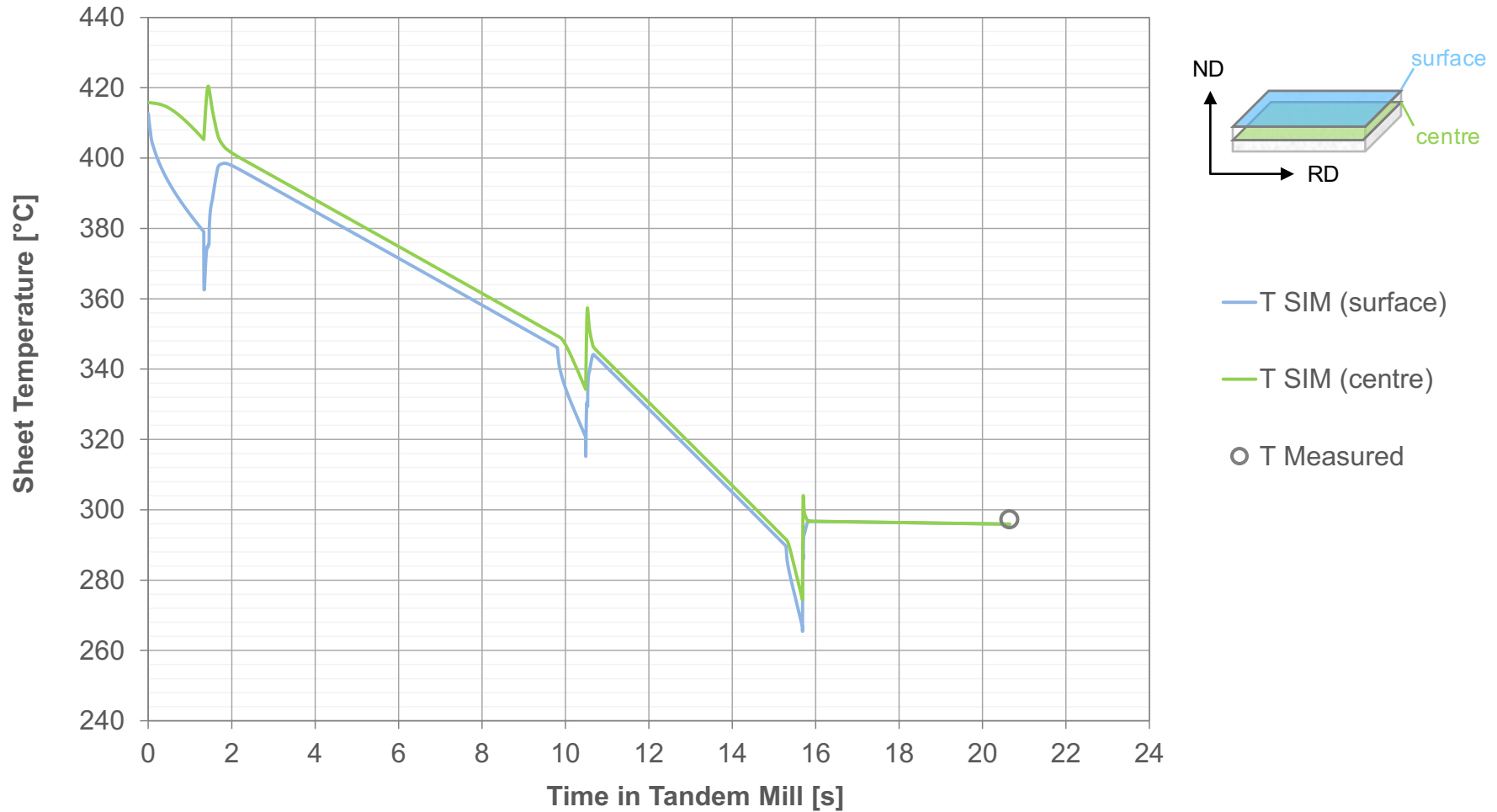
Measured and simulated compression tests

- shown: $T = 400^{\circ}\text{C}$
- various strain rates

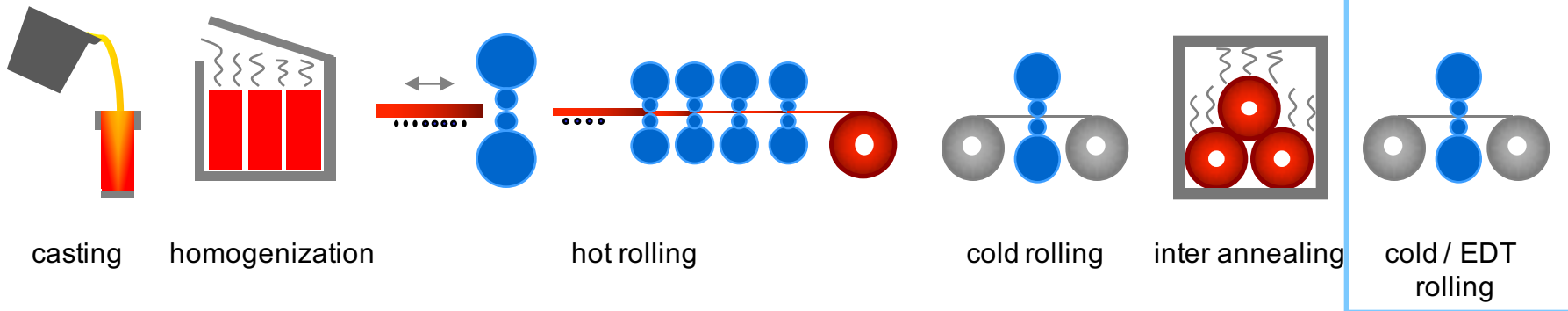




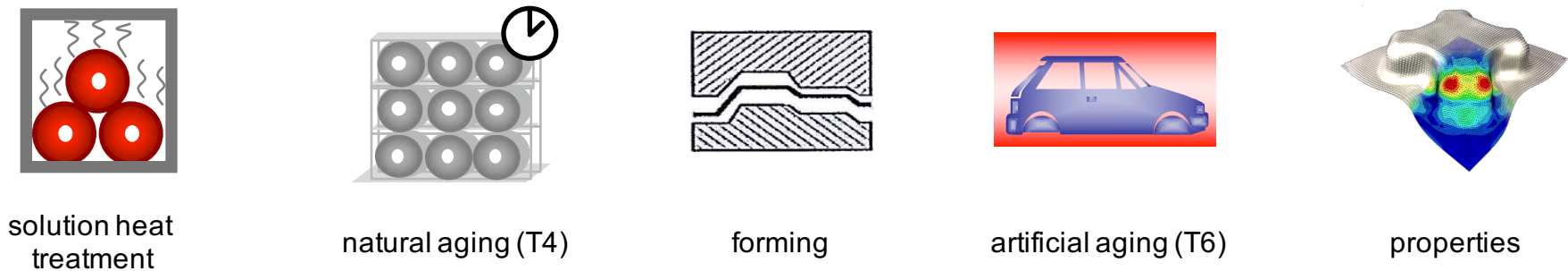
Temperature Evolution during Hot Rolling (Tandem Mill)



■ Rolling



■ Aging and Forming

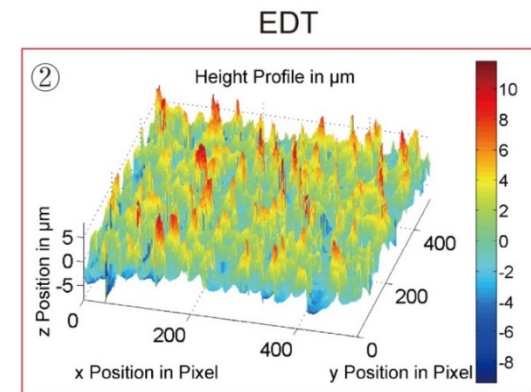
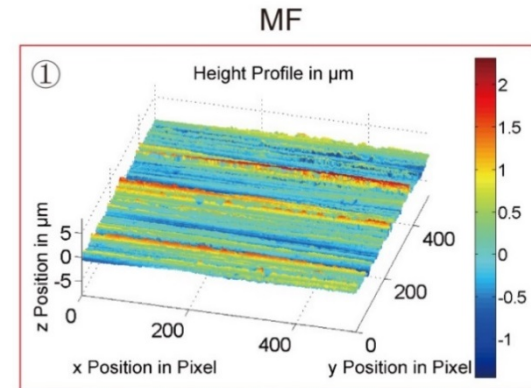


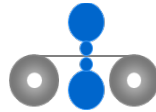
Purpose

- Surface transfer
 - Understanding transfer mechanisms
 - Prediction of final surface parameters

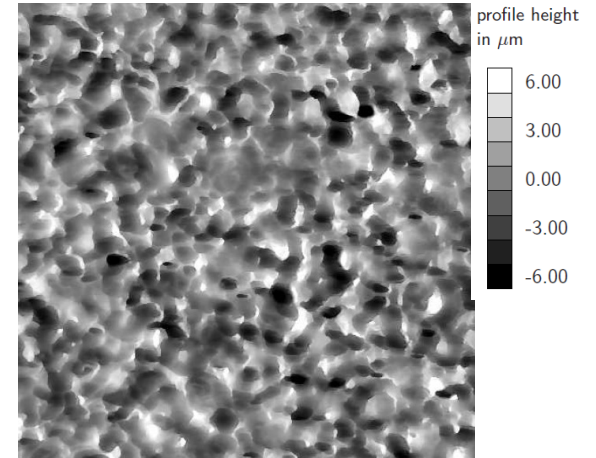
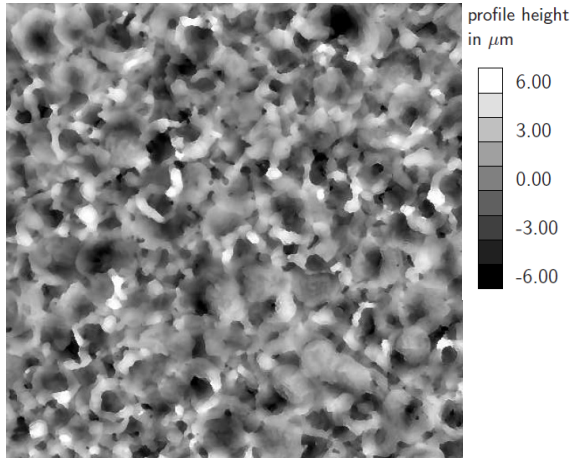
Approach

- Lab rolling tests
 - Industrial EDT-surfaces
 - Model surfaces
- Simulation of surface transfer
 - Model surfaces
 - Sections of industrial EDT-surfaces

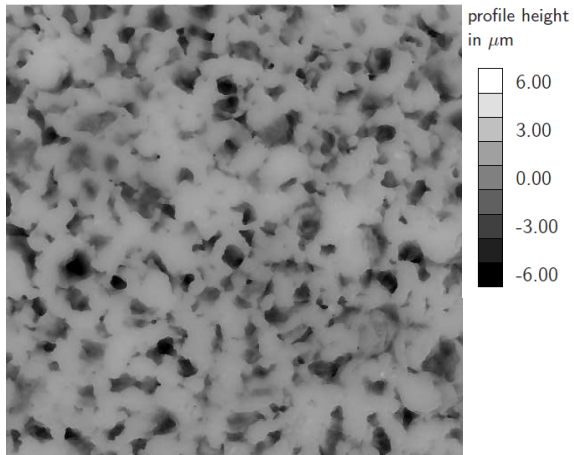




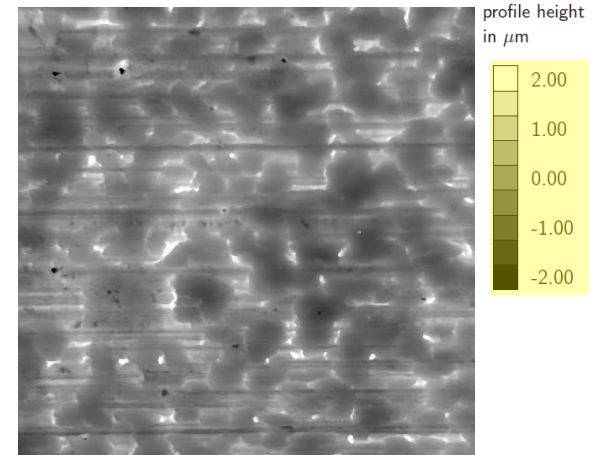
Fresh

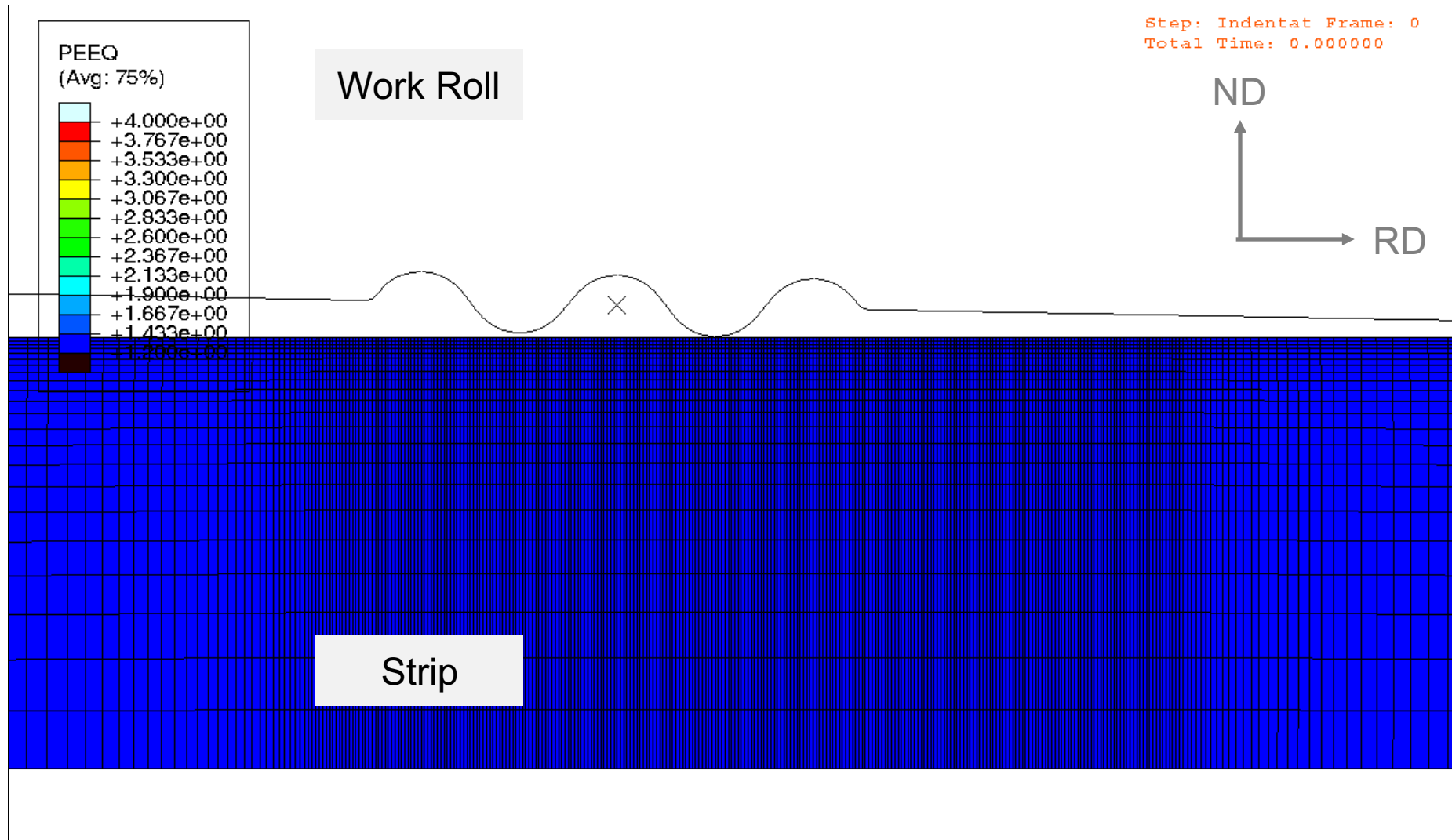


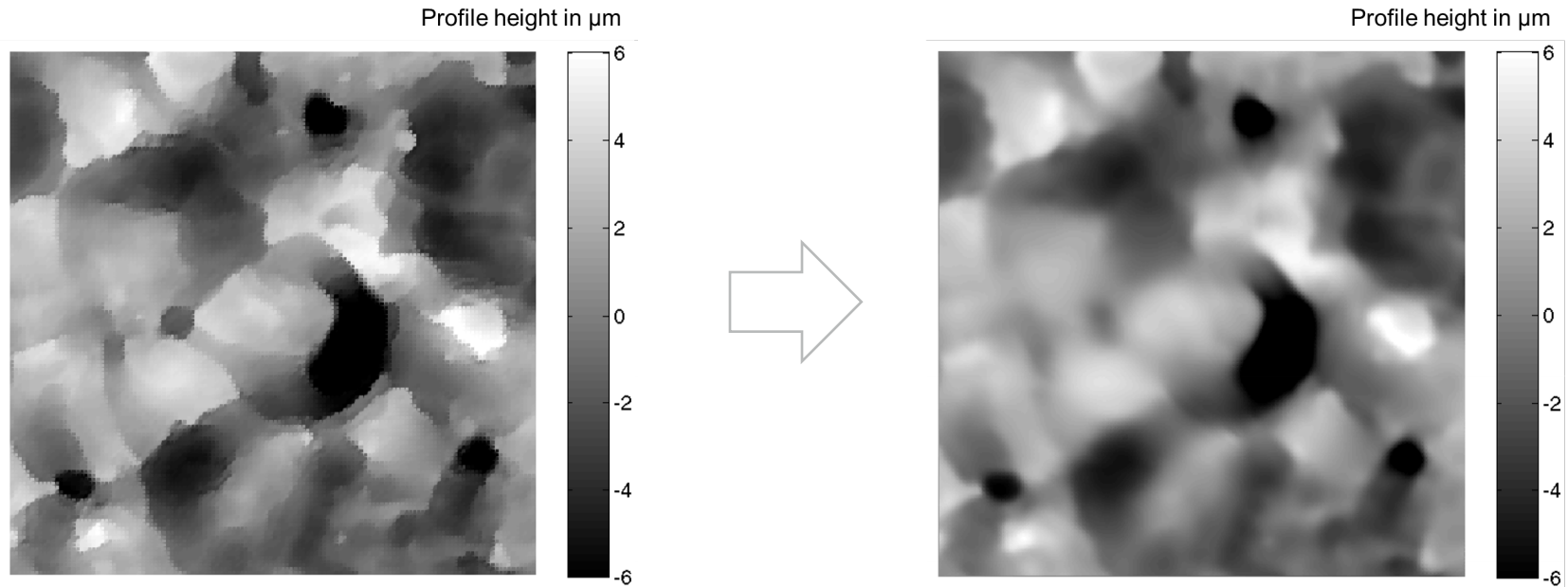
Worn



RD
→





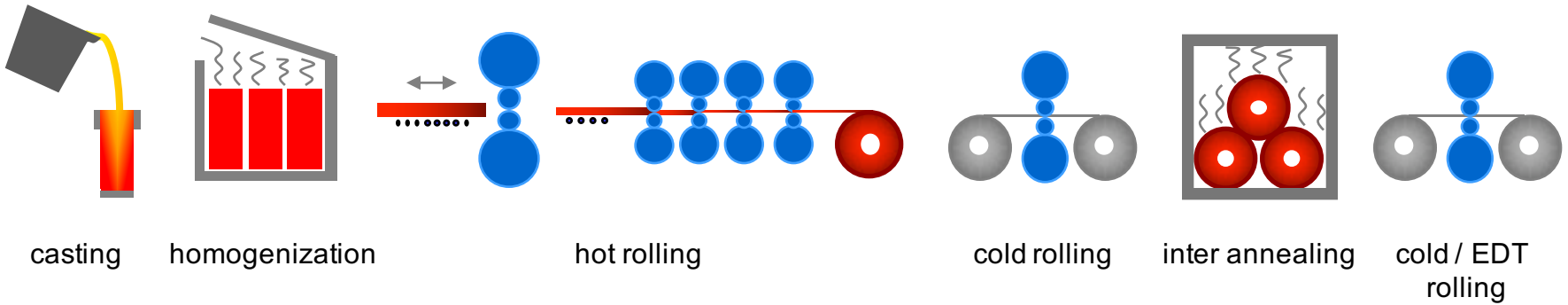


measured surface

model surface

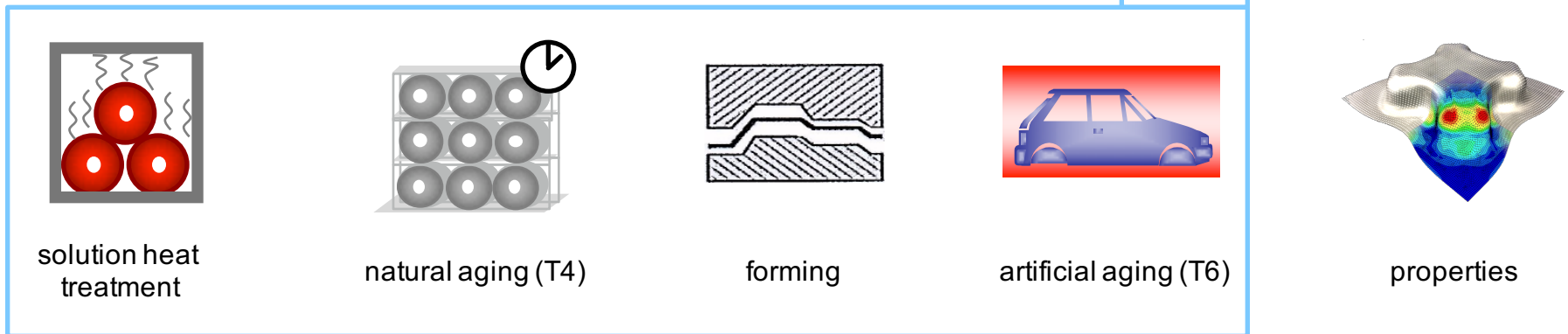
RD
→

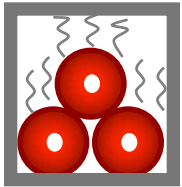
■ Rolling



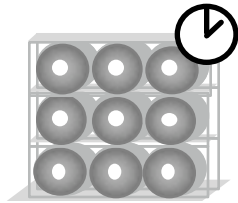
■ Aging and Forming

WP3

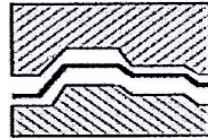




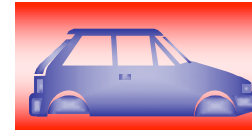
solution heat
treatment



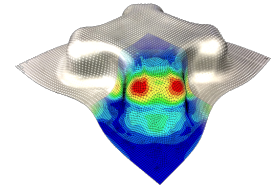
natural aging (T4)



forming



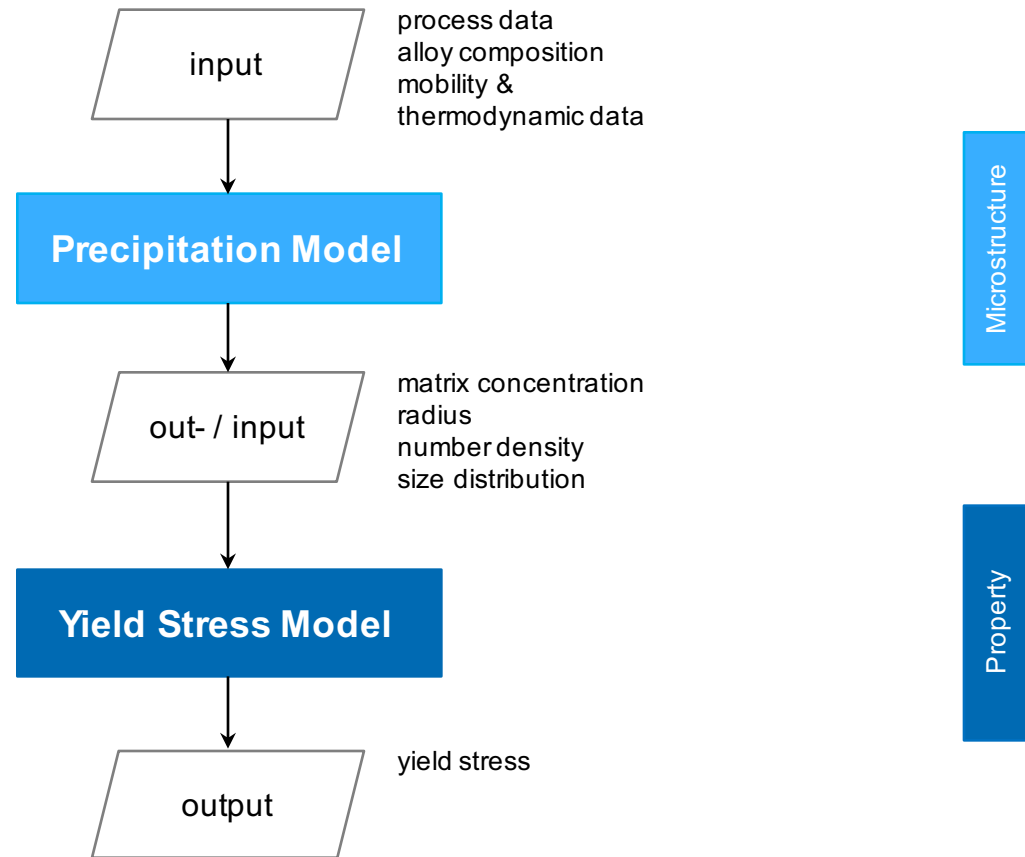
artificial aging (T6)



properties

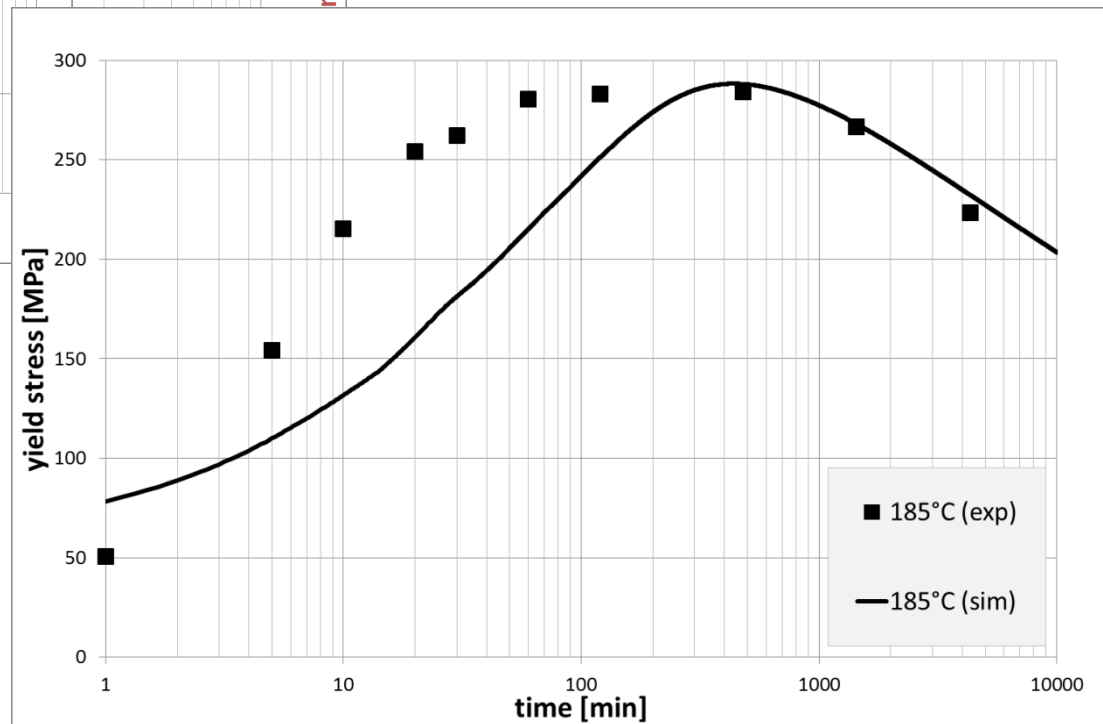
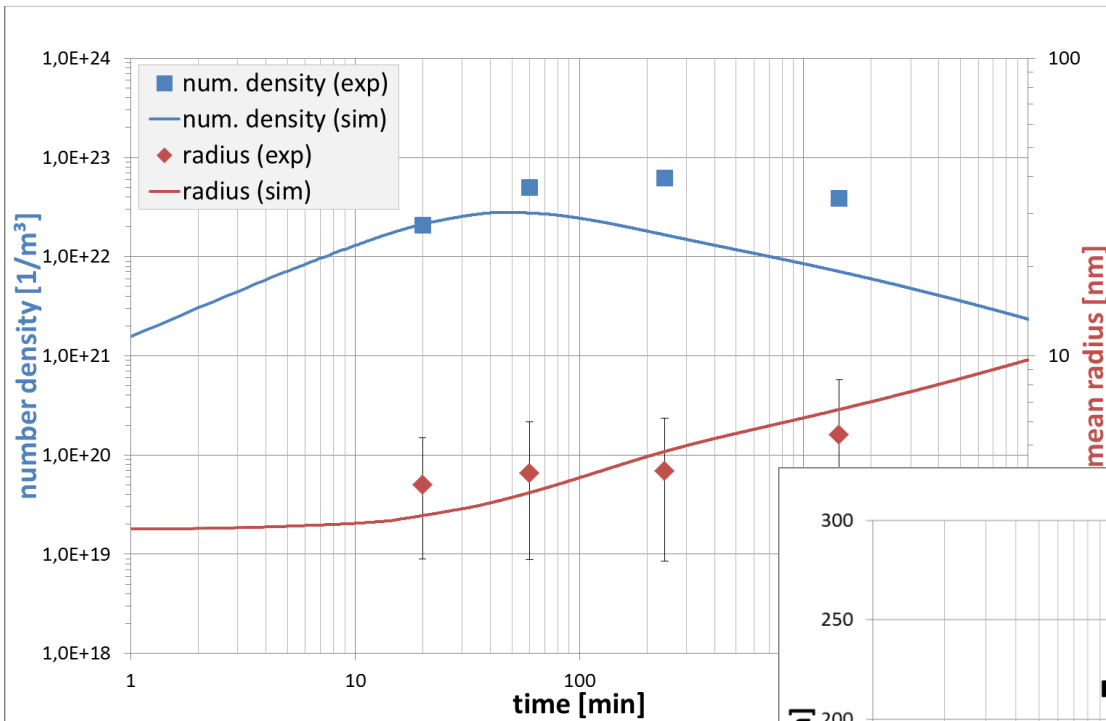


- i. Influence of **natural aging (NA)** on Age Hardening Behaviour (AHB)
- ii. Influence of **pre-bake (PB)** on AHB
- iii. Influence of **aging temperature** on AHB
- iv. Influence of **strain** on AHB



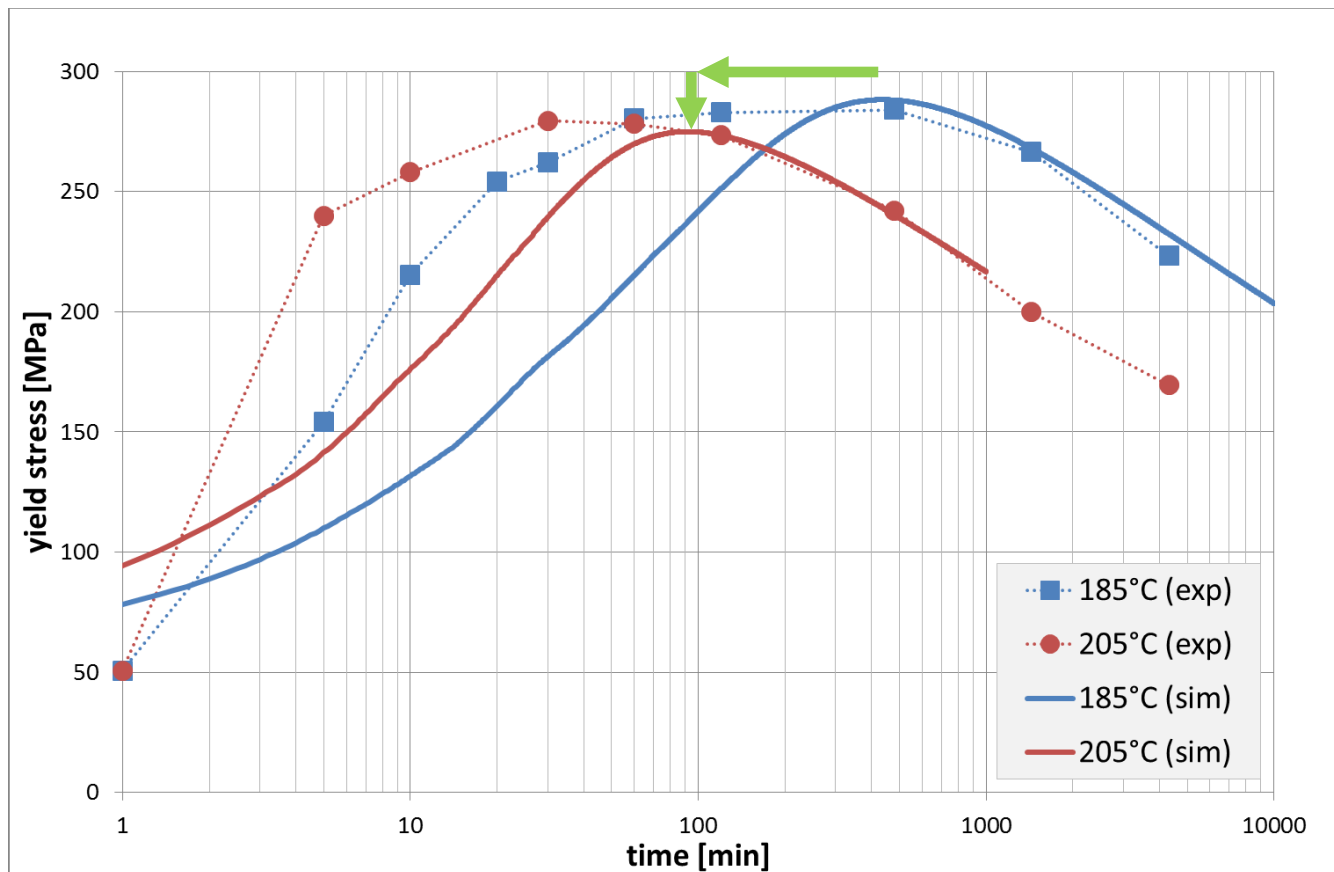
Model validation

- Model vs. TEM & tensile testing
- T = 185°C

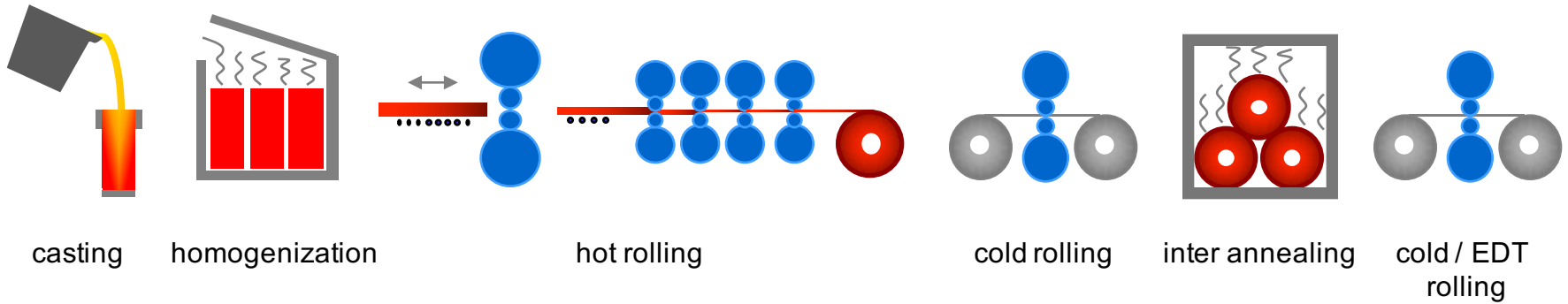


Influence of temperature on yield strength

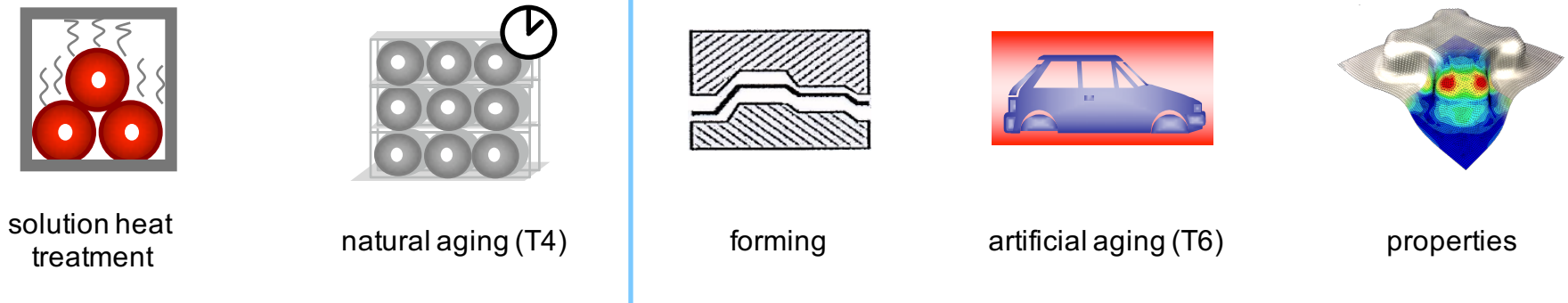
- Model vs. Tensile Test
- $T = 185^{\circ}\text{C}$ vs. 205°C



■ Rolling

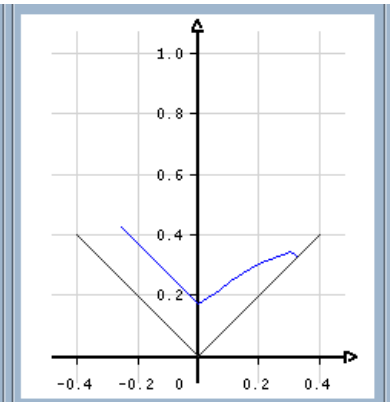
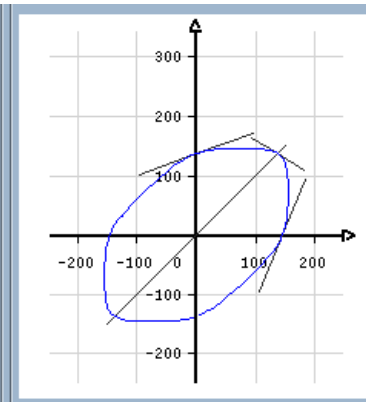
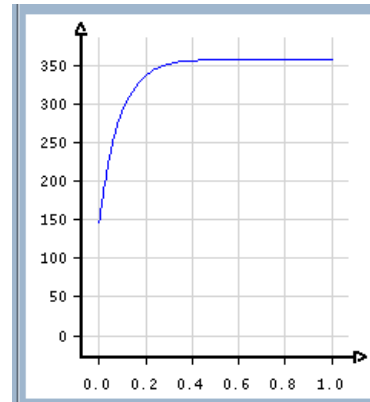
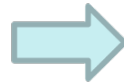
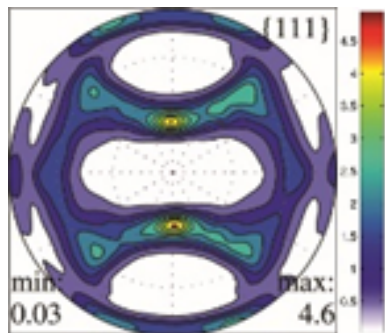


■ Aging and Forming



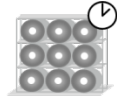
Purpose

- Prediction of input data for a forming simulation, i.e. hardening curve, yield surface and forming limit curve (FLC), based on microstructural information
 - Improvement of forming simulations by using “real” microstructure data, in particular texture information

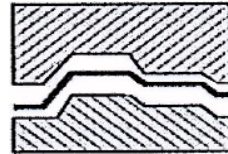




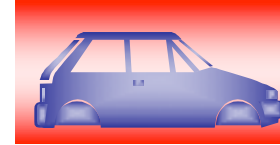
solution heat treatment



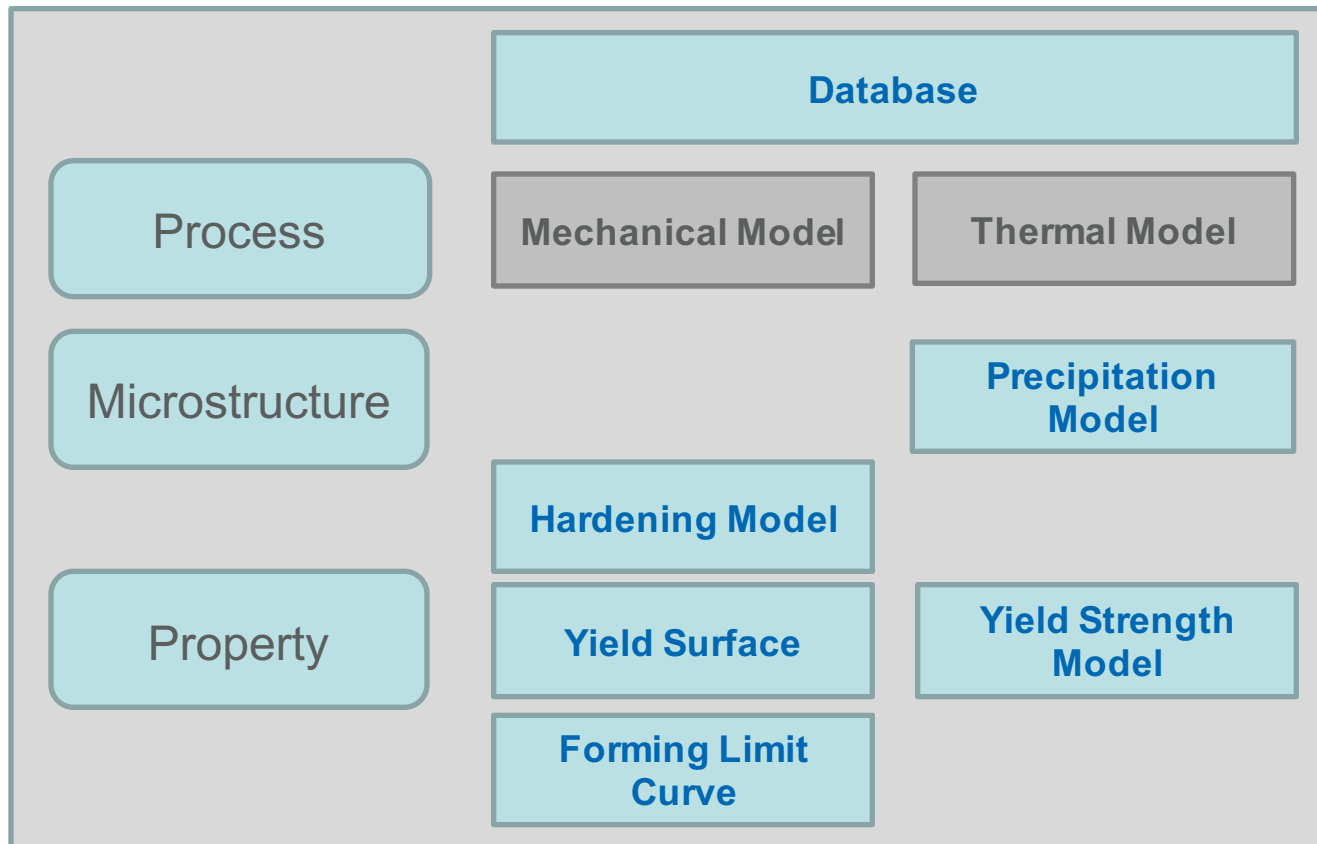
natural aging (T4)



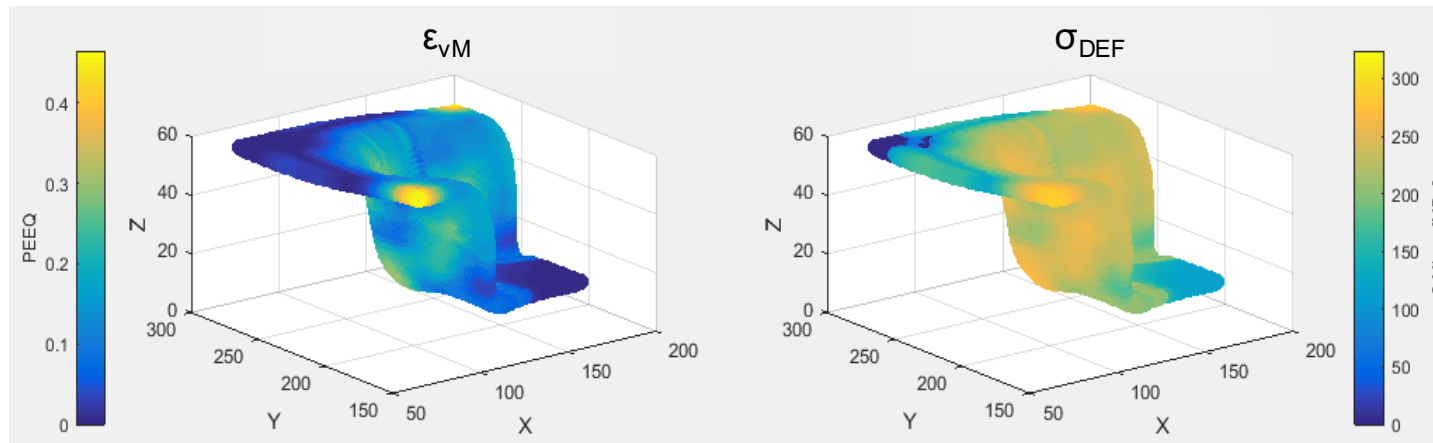
forming



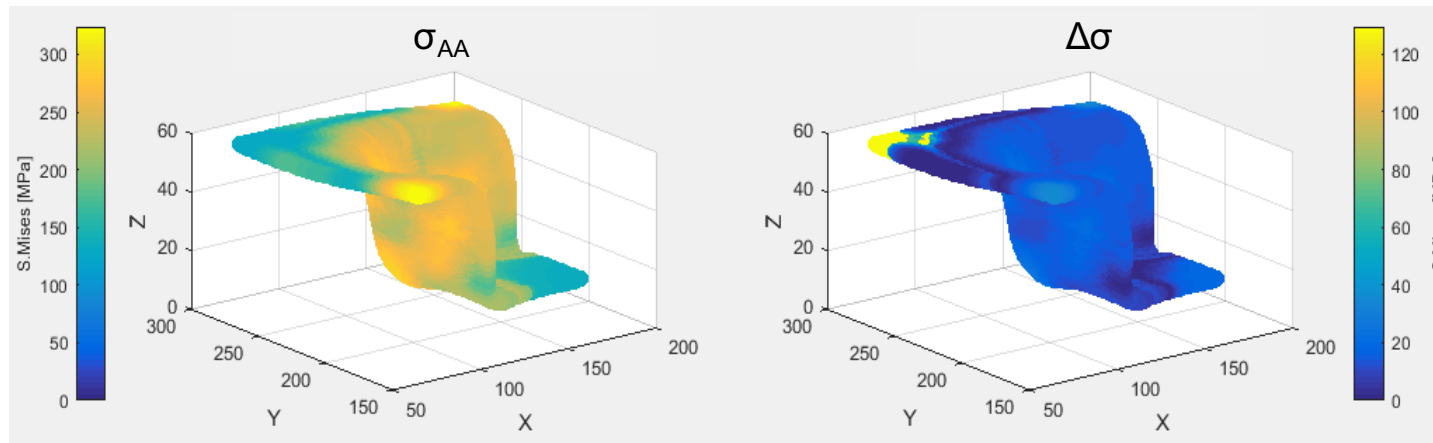
artificial aging (T6)



after forming



after artificial aging



Benefits generated via this project within AMAP

- improved tracing of microstructure development along the process chains to predict final properties
- better understanding of influences of processing on in-service properties
- models integrated for
 - surface transfer during skin pass rolling
 - precipitation during artificial aging
 - yield surface & failure prediction based on microstructure
- physics based creation of „material cards“ for customers

Name	Purpose	existing or new
ROSERoll	simulation of rolling	e
ROSEAnneal	simulation of annealing / coil cooling	e
3IVM+	simulation of work hardening	e
ClaNG	simulation of microchemistry	e
GIA	simulation of deformation texture	e
CORe	simulation of recrystallization	e
ABAQUS	simulation of EDT-rolling – 2D FEM macro model	e
EDT-Meso	simulation of EDT-surface transfer – 3D FEM meso model	n
KiNG	simulation of precipitation of metastable phases	n
WH	simulation of work hardening with precipitates	n
Local Hardening	simulation of hardening with influence of local pre-strain	n
VPSC	simulation of deformation texture / input anisotropic yield criterion	e
Yield Locus	simulation of anisotropic yield surface	n
MK	simulation of FLD	n

Thank You!