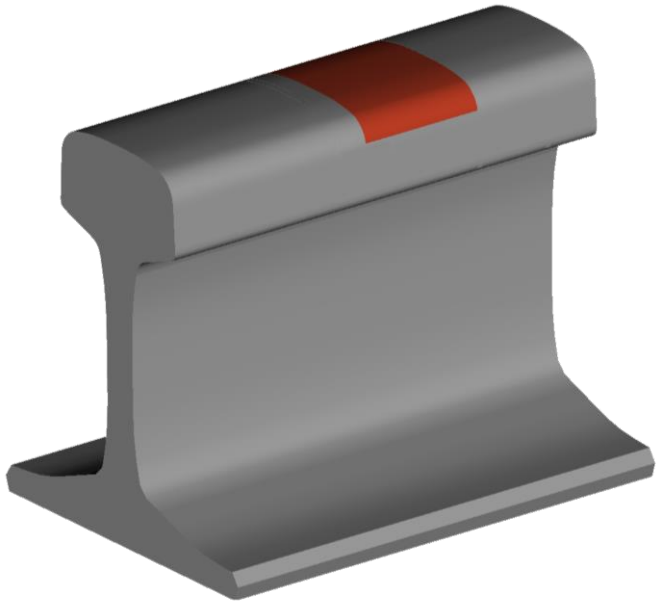
AG 60 - Rälssvetsning

Hur man kan modellera svetsning av räls numeriskt

Populärvetenskaplig presentation



Björn Andersson, Tekn lic

2022-04-28

CHALMERS
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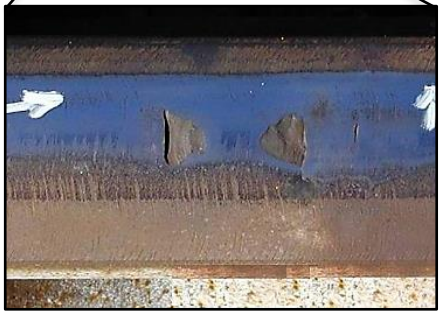
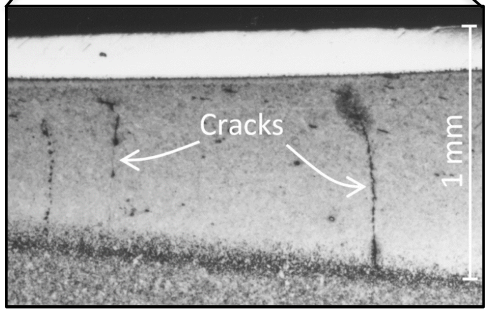
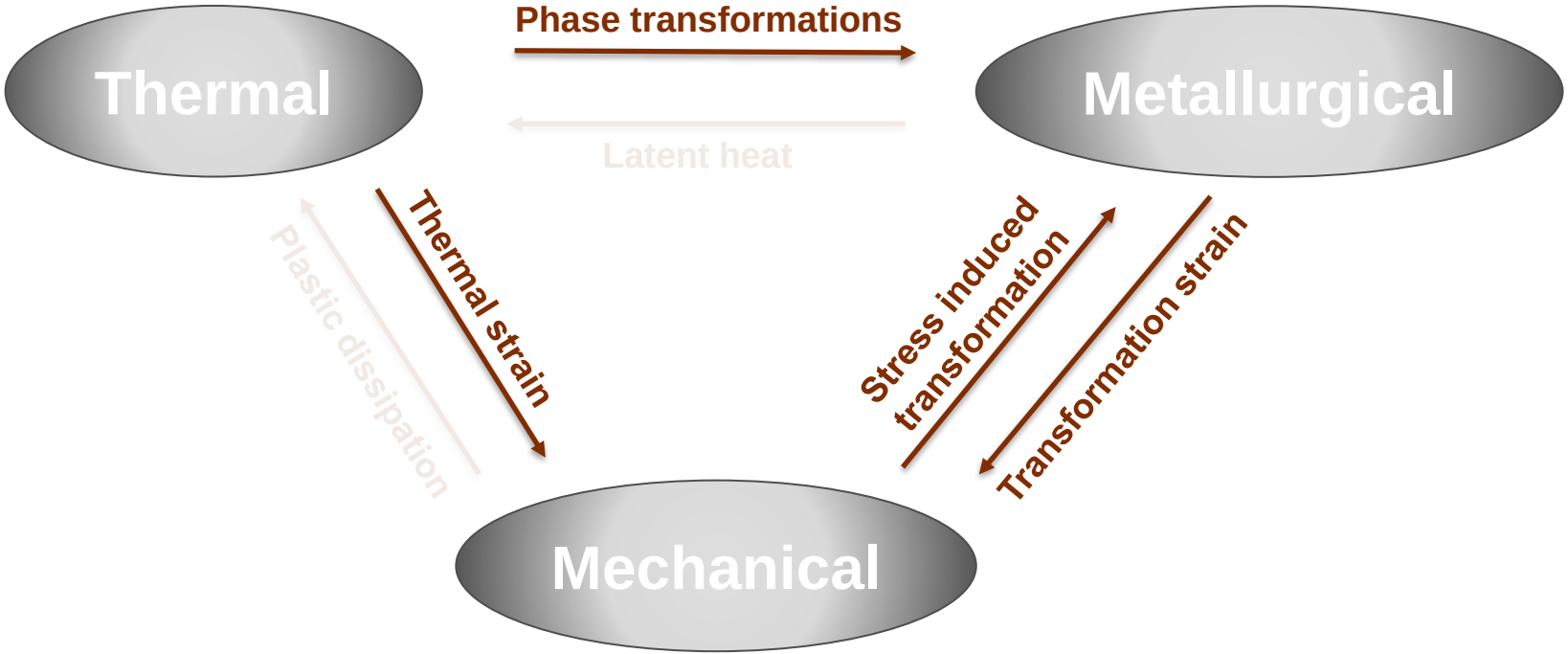
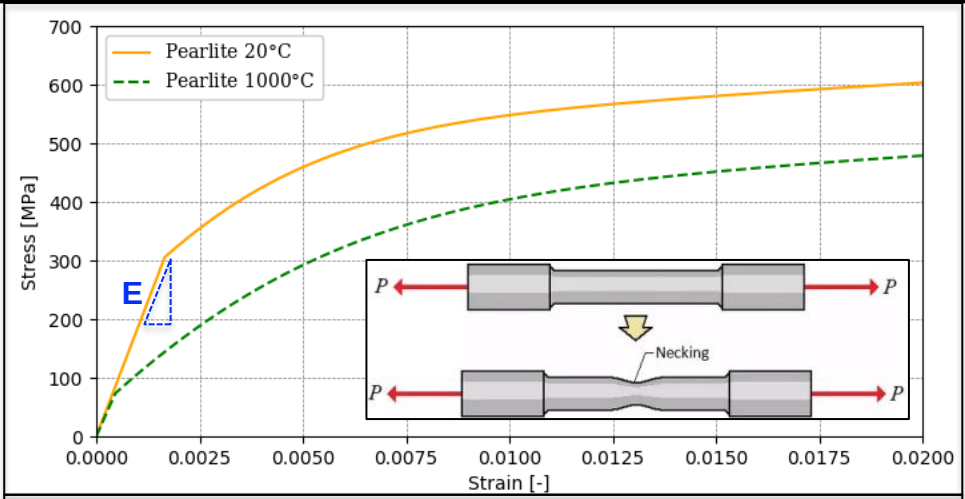
Background and motivation

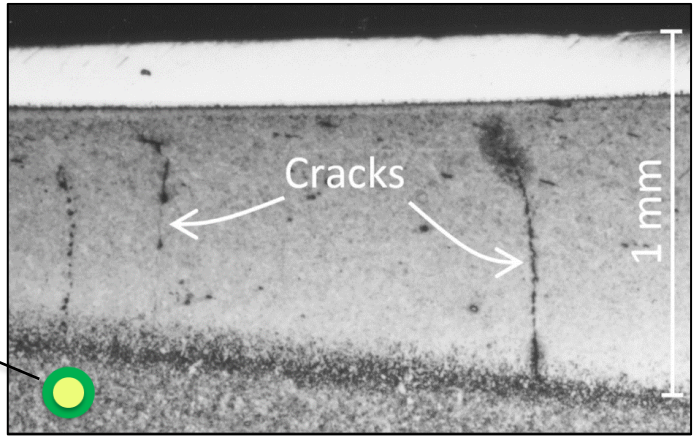
- High temperature railway processes:
  - Welding
  - Grinding
  - Train wheel braking (rail and wheel)
- What happens:
  - Phase transformations
  - Inhomogeneous material properties
- Practical consequences:
  - Residual stresses, interaction with operational loads
  - Initiation of cracks

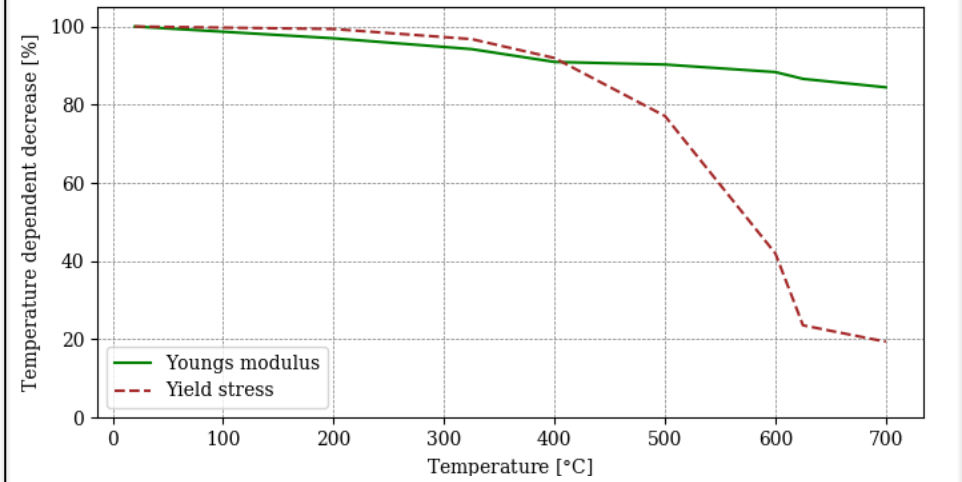


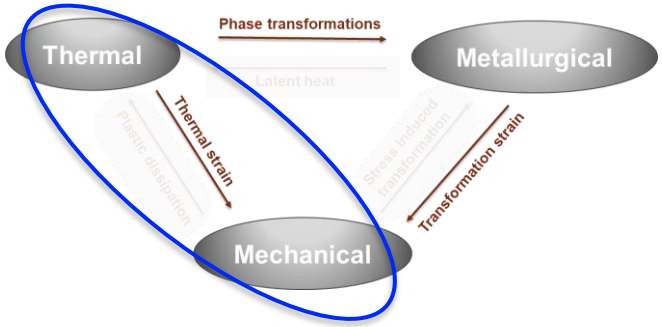



Thermal
Phase transformations
Metallurgical
Latent heat
Thermal strain
Plastic dissipation
Stress induced transformation
Transformation strain
Mechanical


Pearlite 20°C
Pearlite 1000°C
Stress [MPa]
Strain [-]
E
P
P
Necking
P
P


Cracks
1 mm


Temperature dependent decrease [%]
Youngs modulus
Yield stress
Temperature [°C]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Phase transformations
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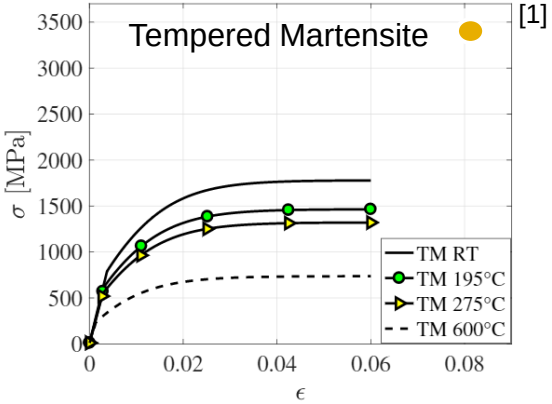
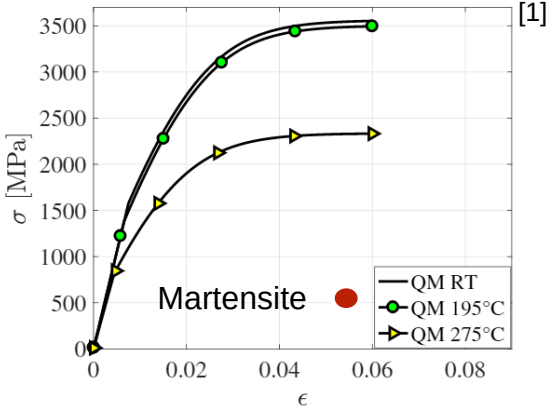
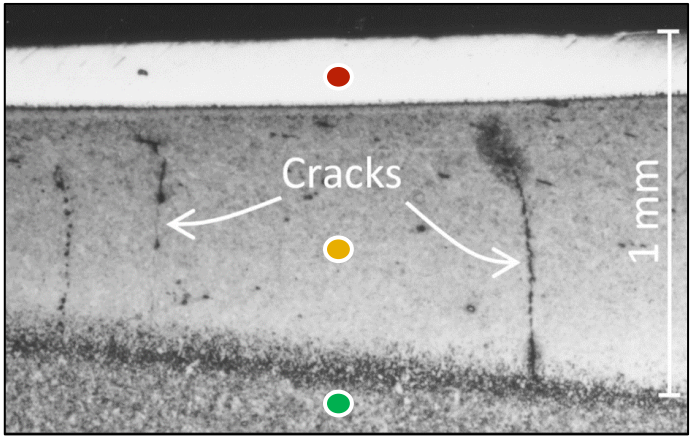
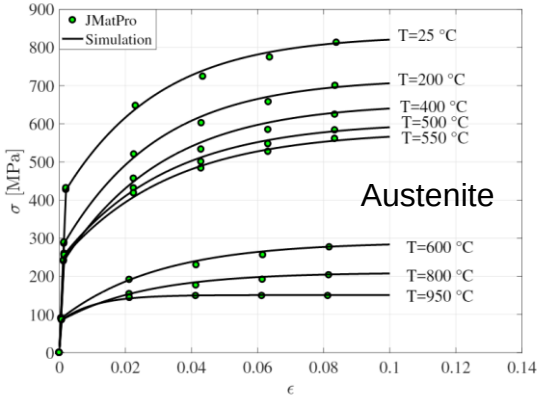
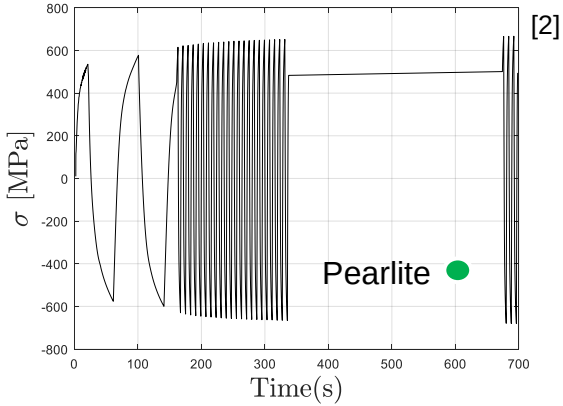
Mechanical

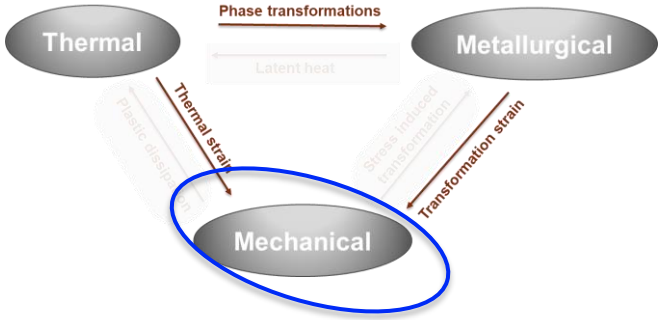




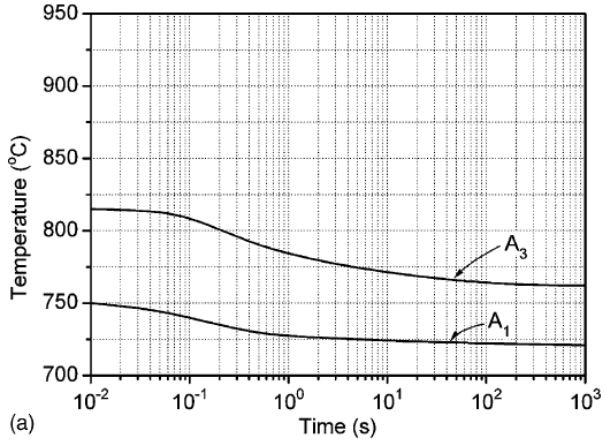


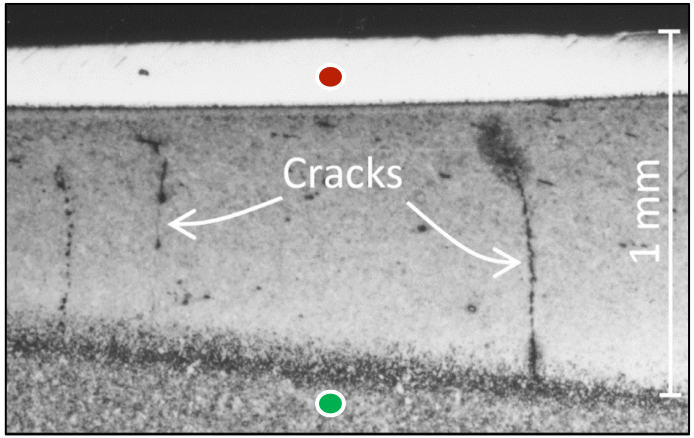


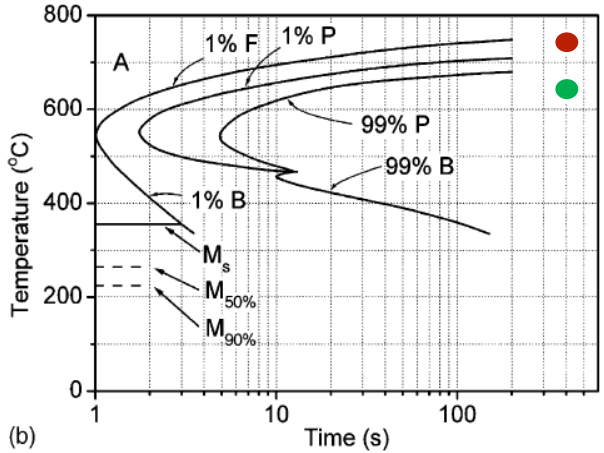


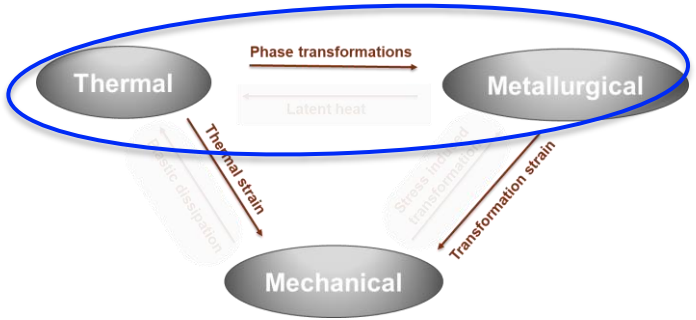


[1] Cvetkovski et al. 2013
[2] Esmaeili et al 2017

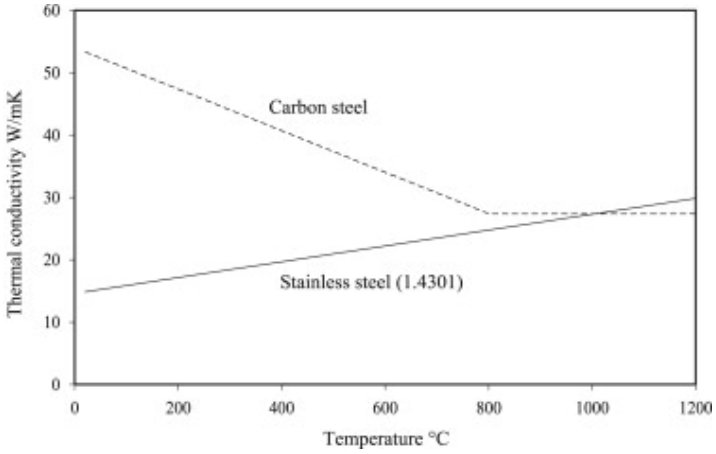


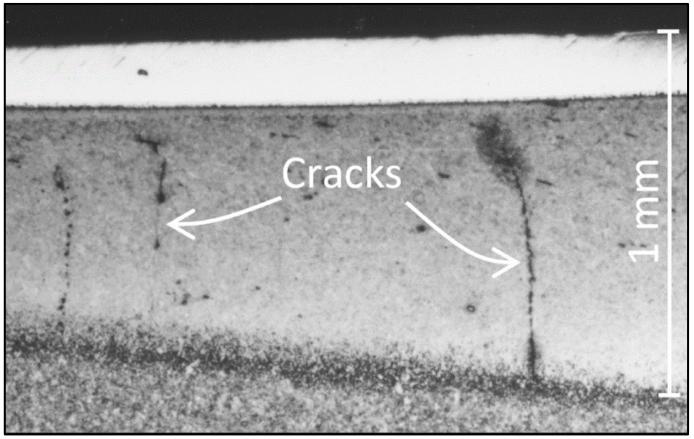


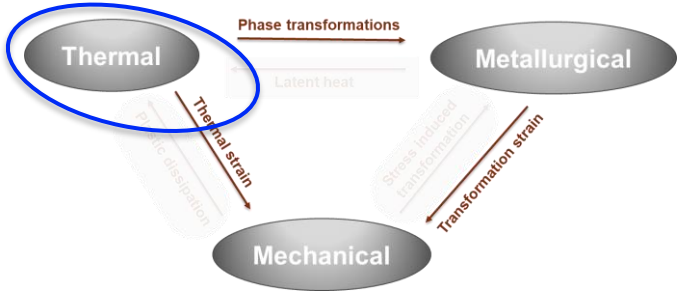




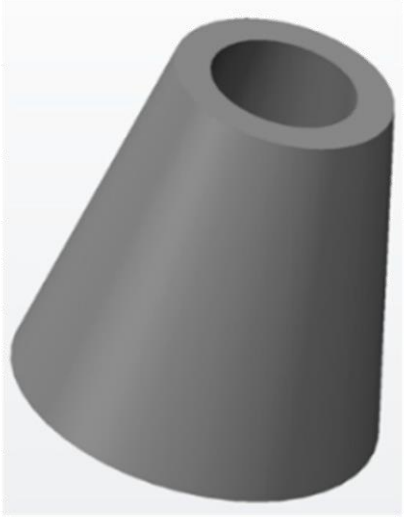
IT diagram cooling.

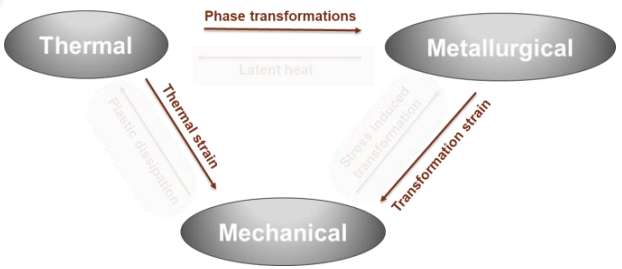

Thermal conductivity W/mK
Temperature °C
Carbon steel
Stainless steel (1.4301)
0
10
20
30
40
50
60
0
200
400
600
800
1000
1200

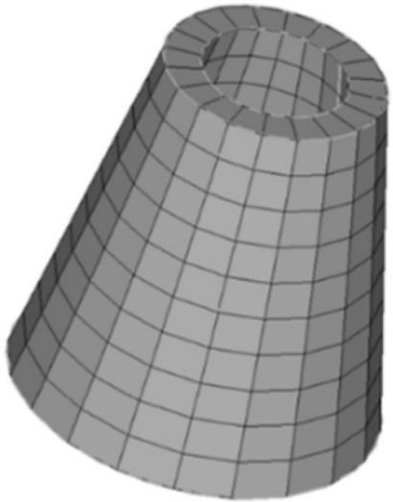

Cracks
1 mm


Thermal
Metallurgical
Mechanical
Phase transformations
Latent heat
Thermal strain
Transformation strain
Stress induced transformation

“Real component”

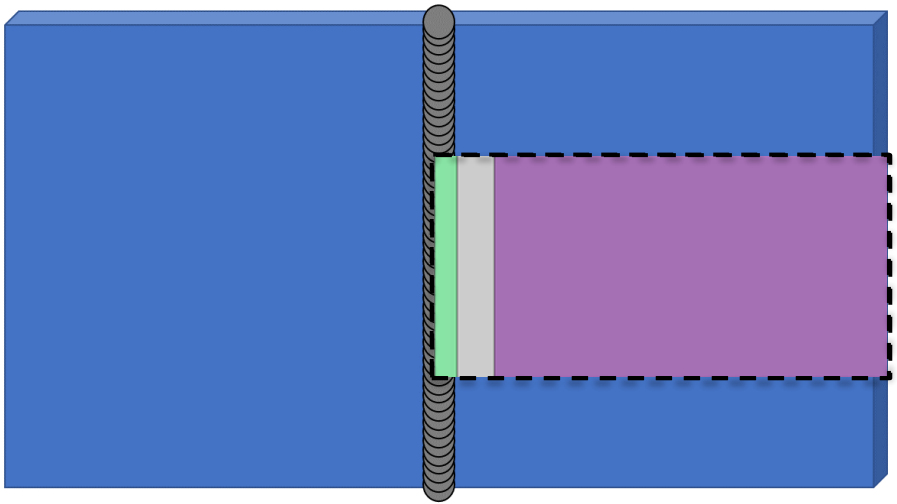


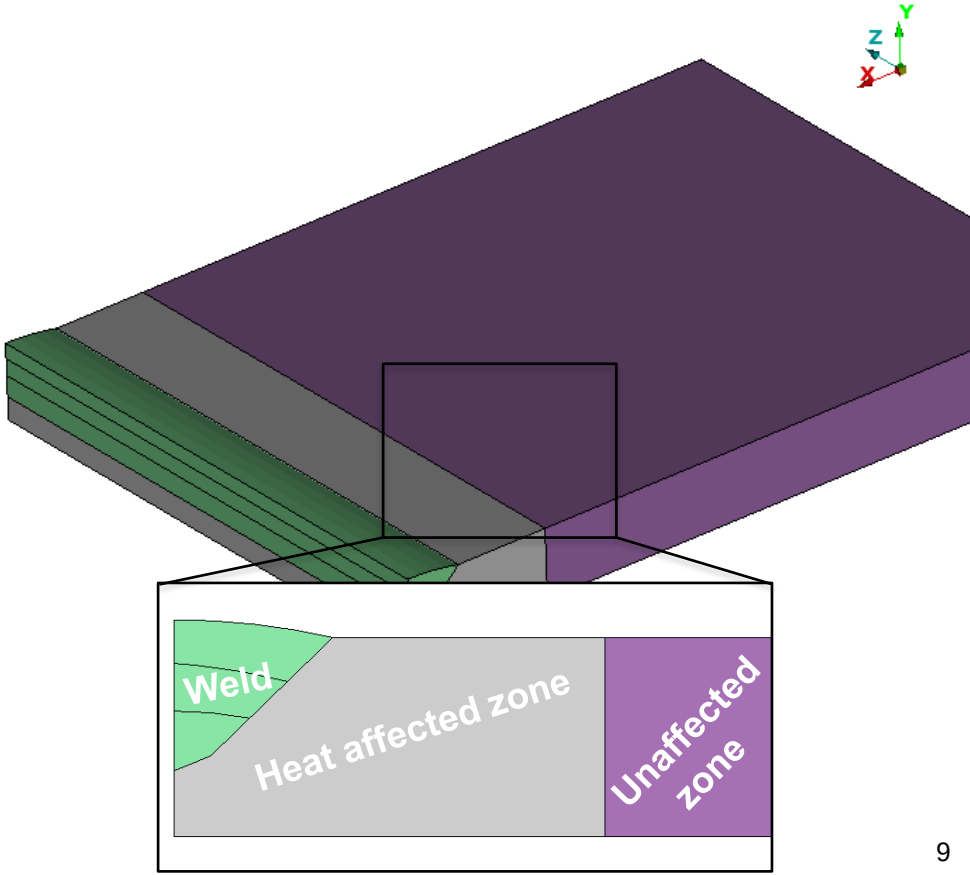


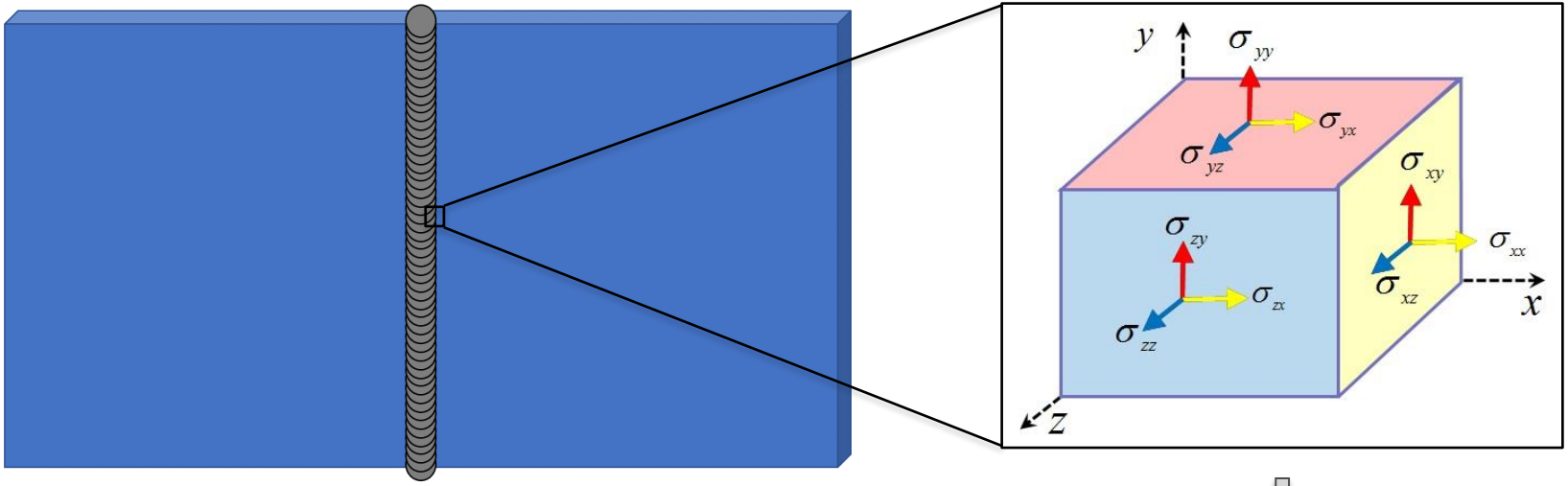


FEM – Finite Element Method

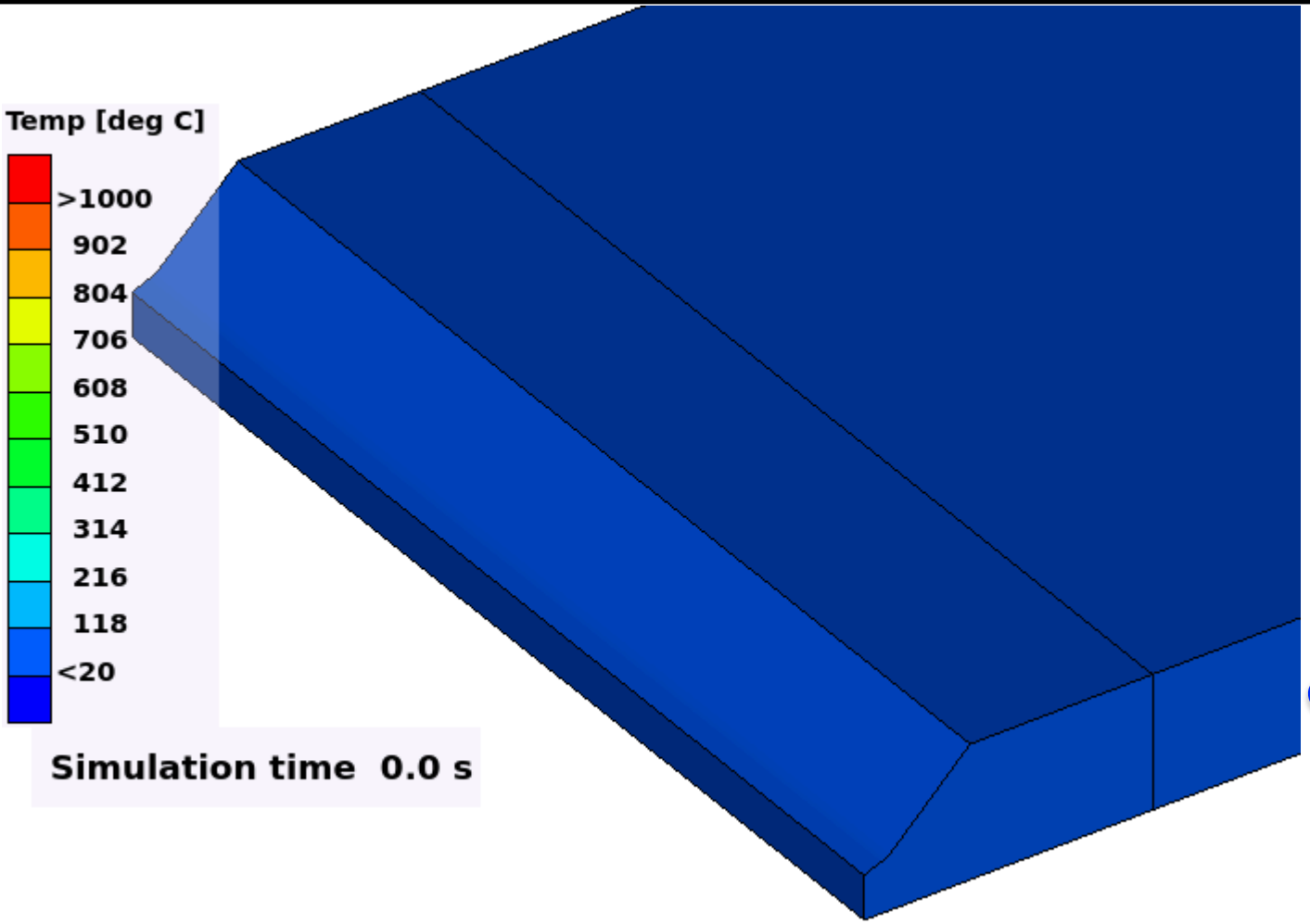
- Approximative solution
- Divide the body into elements
- Assume simple variation within the element
- Output quality from quality of:
  - Applied loads
  - Material model
  - Boundary conditions
  - Geometry approximation
  - Number of elements
- Replaces/compliments testing
- Design process aid




Y
Z
X
Weld
Heat affected zone
Unaffected zone



$$\sigma_e = f(\sigma_{xx}, \sigma_{yy}, \sigma_{zz}, \sigma_{xy}, \sigma_{xz}, \sigma_{yz})$$

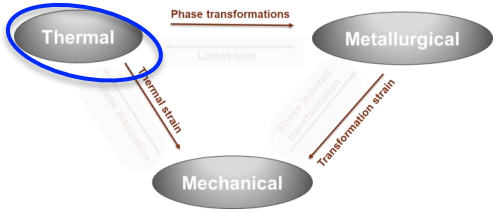


Temperature field

Moving heat source

Continuous addition of filament elements

FEM framework setup, parameter calibration needed

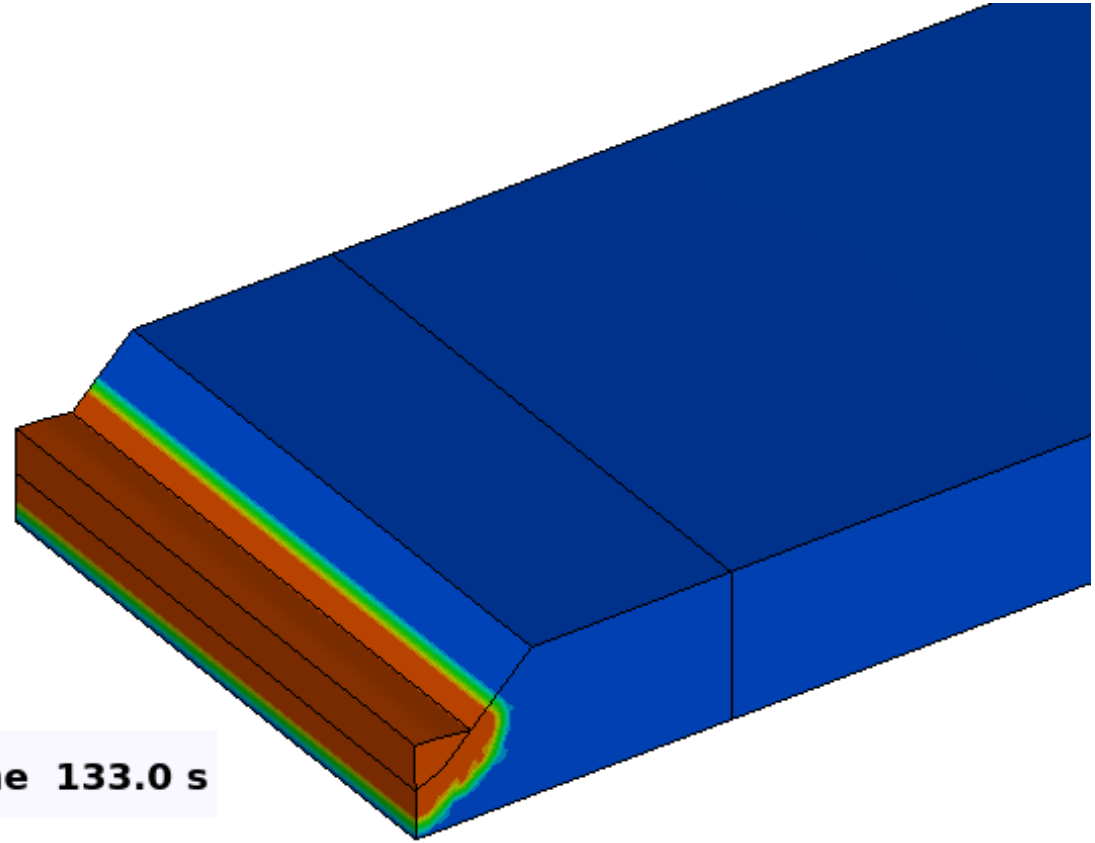


Phase field

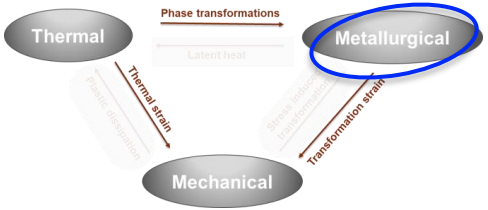
Moving heat source

Continuous addition of filament elements

Rapid cooling
→ Martensite formation

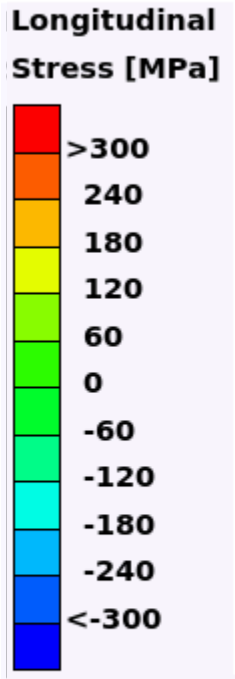


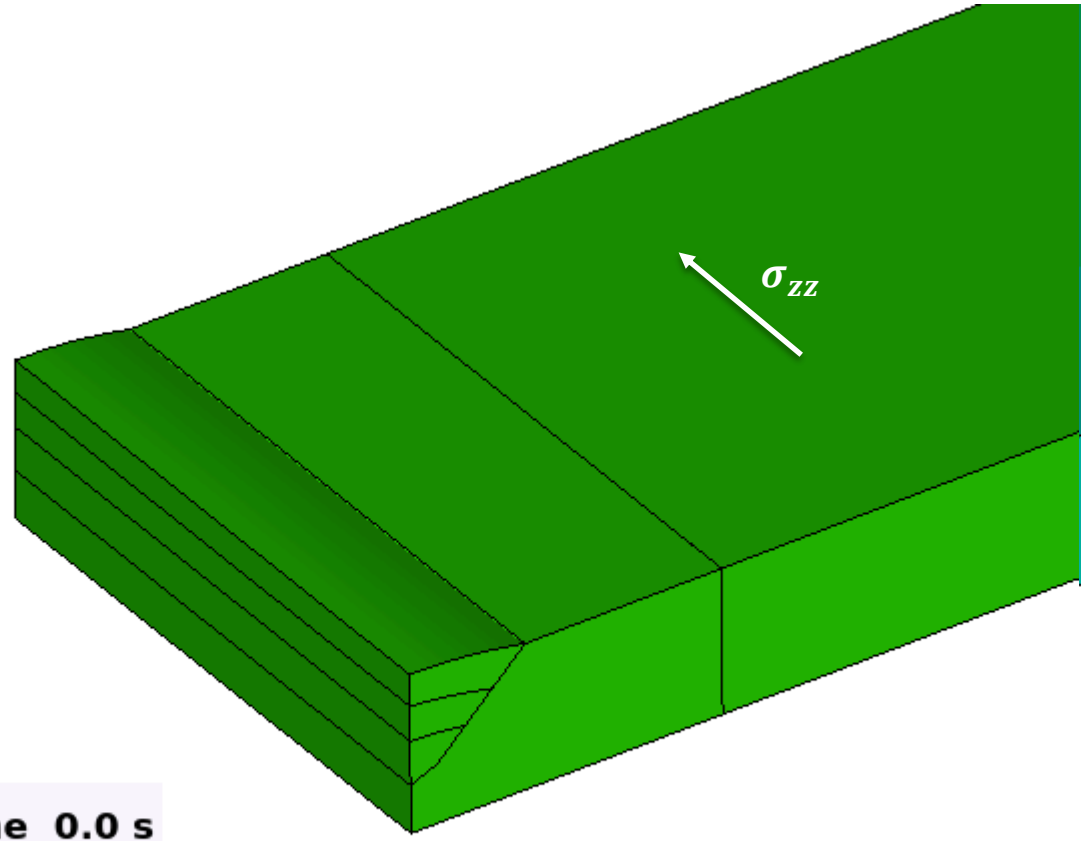
Simulation time 133.0 s



Residual stress field

Longitudinal stress

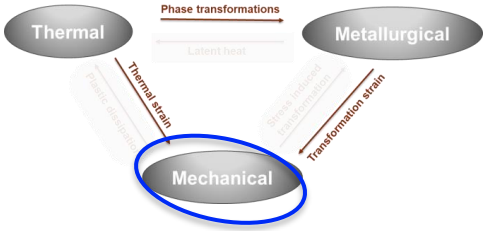


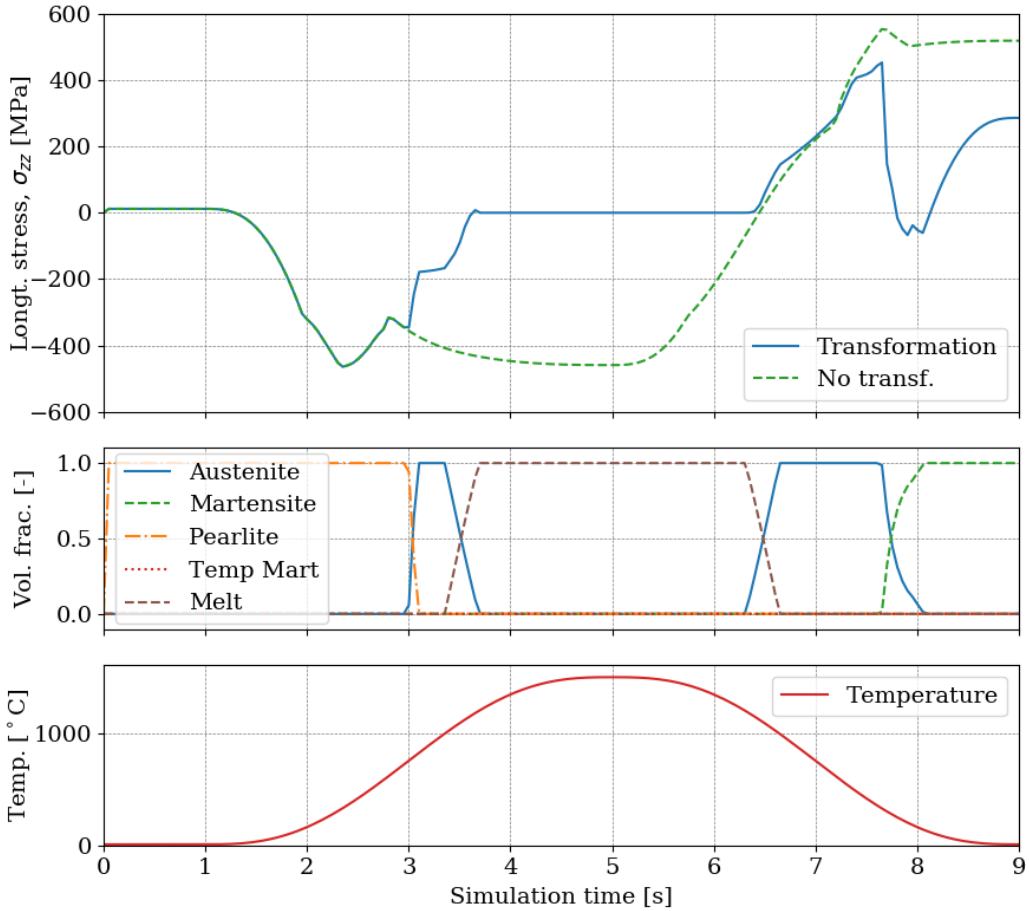


Simulation time 0.0 s

Basis for process parameter optimization together with phase evolution.

Optimization goal: Avoid both tensile stresses in certain regions and martensite formation

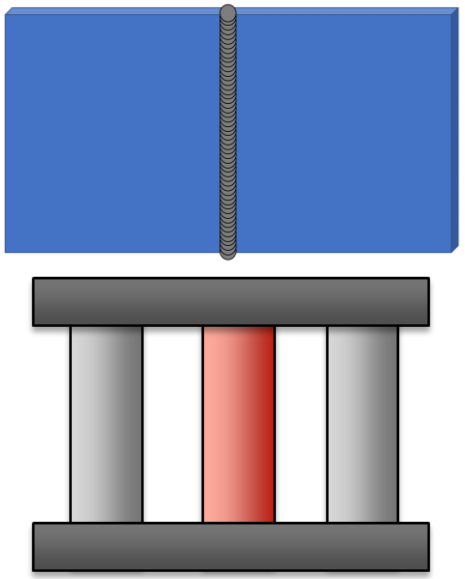




Longitudinal stress component at one point in the weld

Is the result reasonable?

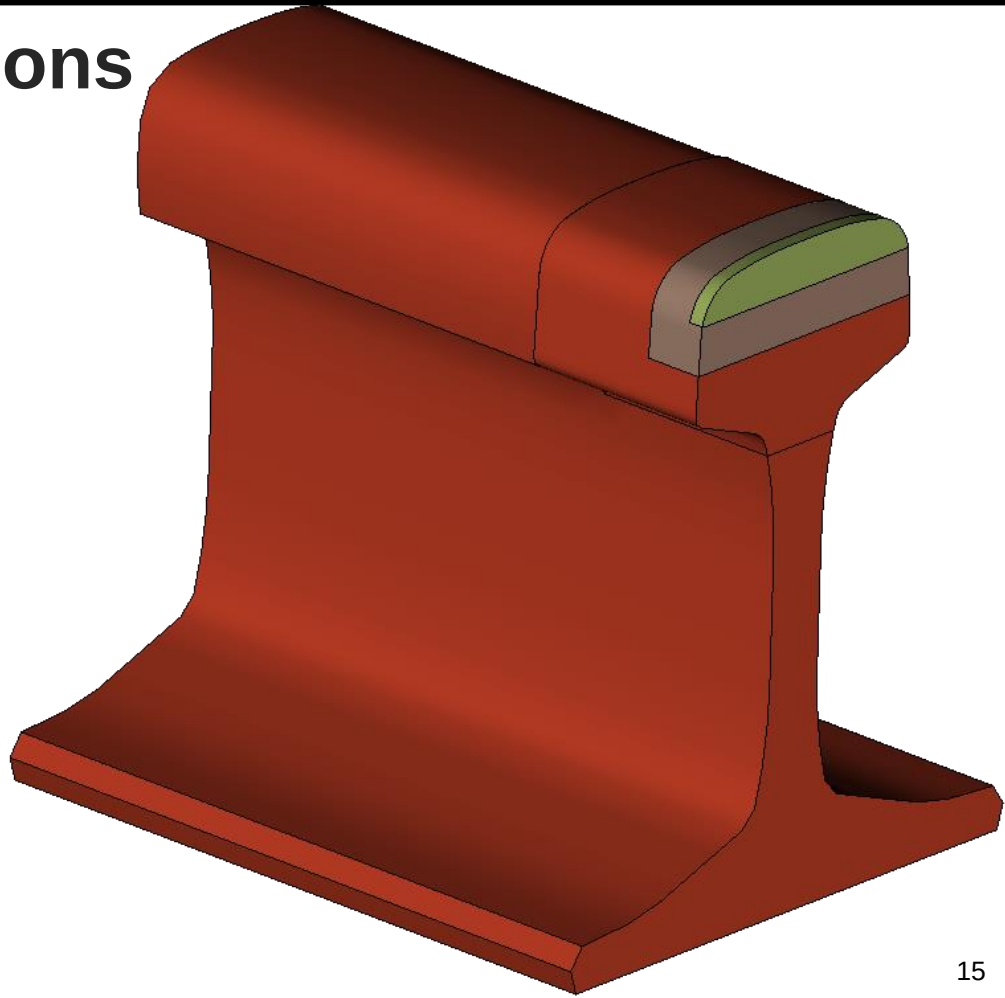
Three bar experiment



Summary and conclusions

- Thermo-mechanical-metallurgical model:
  - Phase / microstructure evolution
  - Homogenization of phase mechanical behavior
  - Transformation induced plasticity (TRIP)
  - Effect of phase transformation
- Advanced model for welding

- Future Work
  - Full scale simulation of repair welding process
  - Optimize process parameters and controlled pre-heating and operation temperature:
    - Avoid martensite formation
    - Avoid unfavorable residual stresses



Thank you

Hur man kan modellera svetsning av räls numeriskt

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CHARMEC Project MU37 – Numerical simulations of welding and other high temperature operations

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