Simulering av Reparationssvetsning

Processparametrar och Reparationskvalitet

AG60, 2024-04-16, Vossloh Nordic Switch Systems, Örebro

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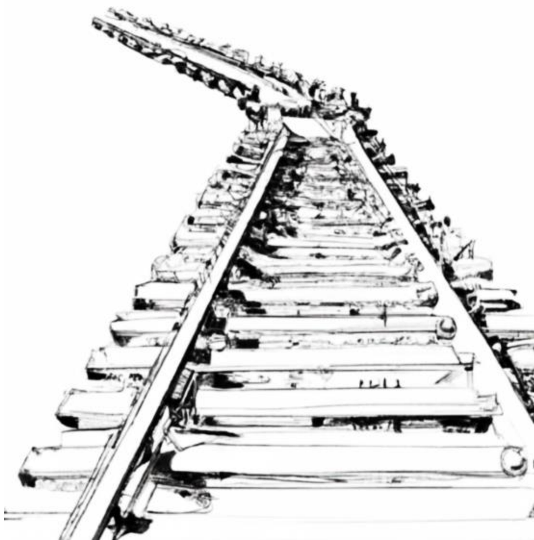

Background and motivation

Trafikverket 2022 rail defect statistics:

- 20-60% of all rail defects in weld regions
  - 60% most urgent (fix within a week)
  - 20% least urgent (wait until next inspection)
- ~ 450 defects in weld regions
- ~ 2100 defects in rail and switches

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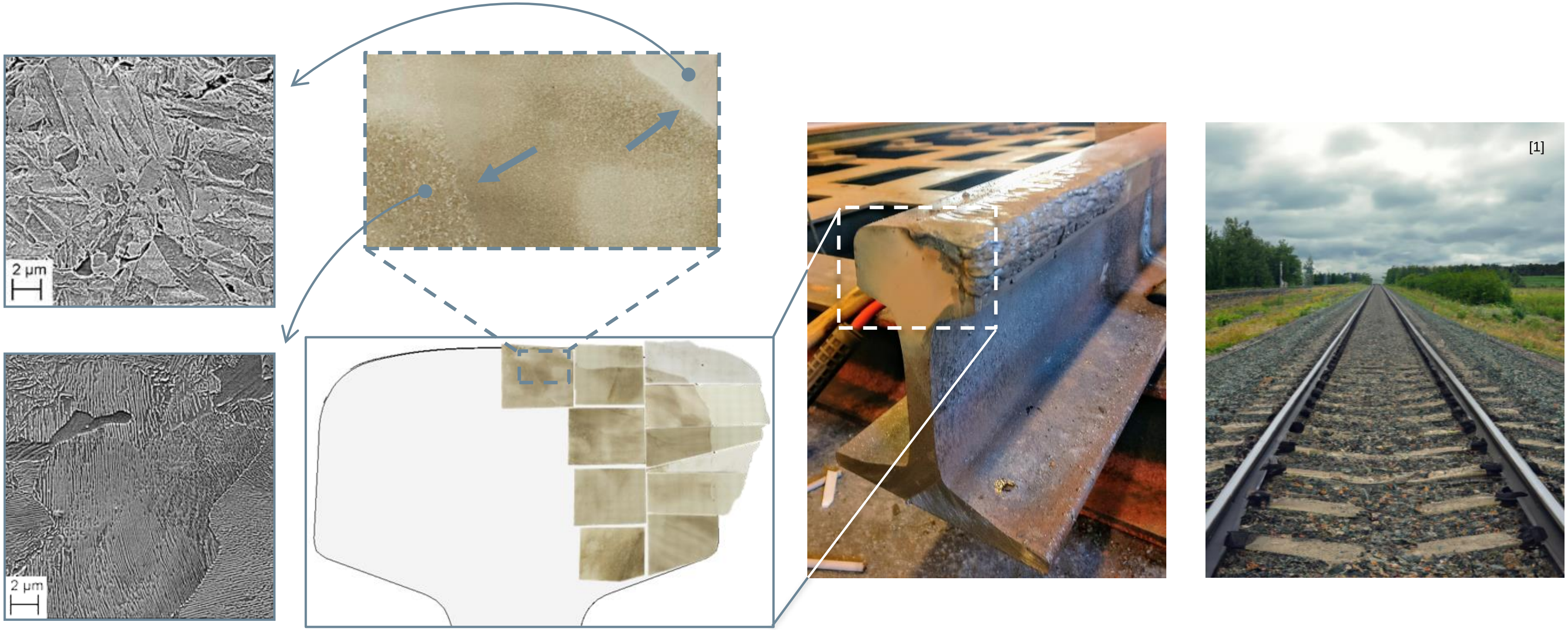
Research Overview



[1] Dall·E2 generated rail image

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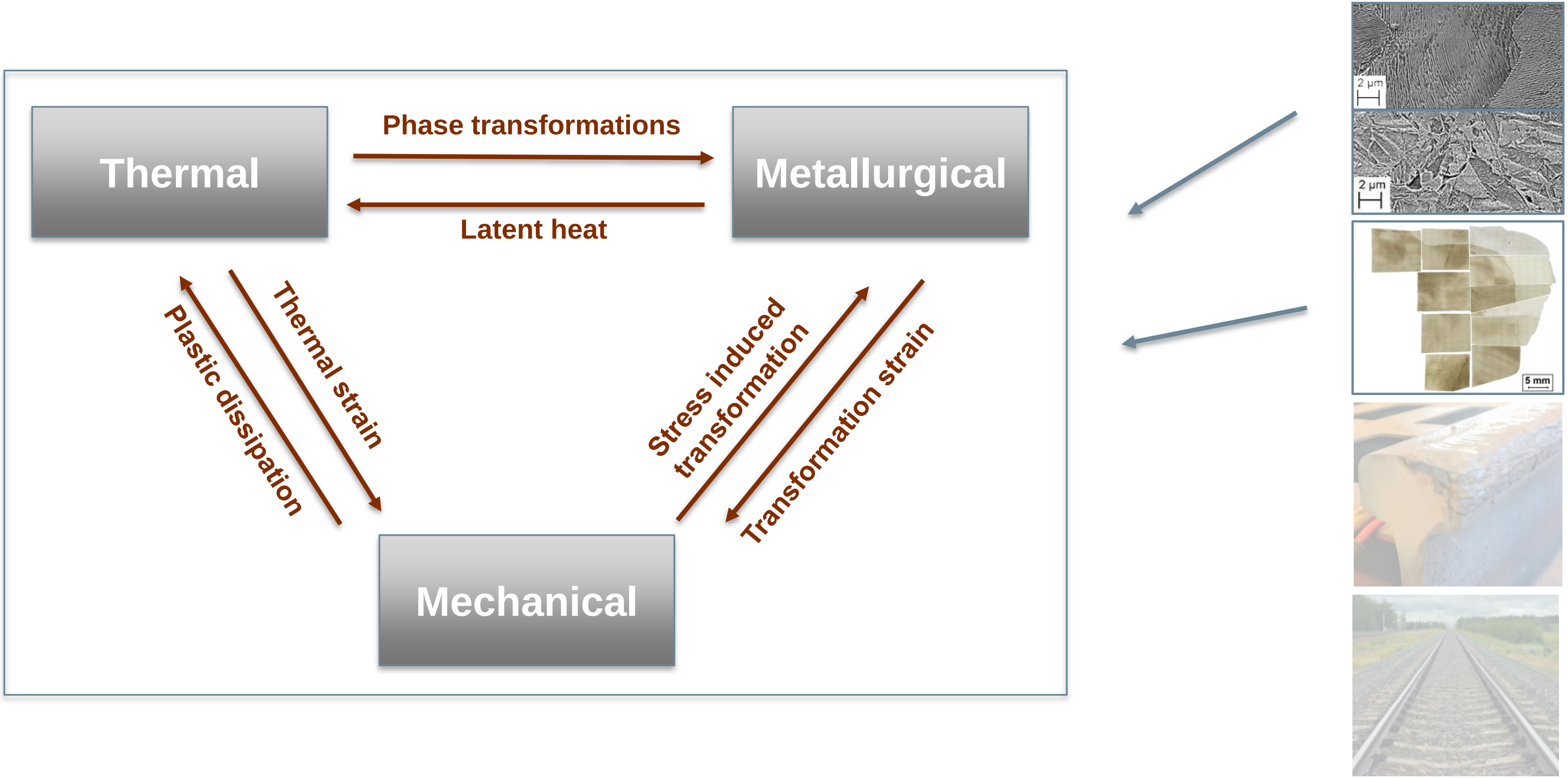
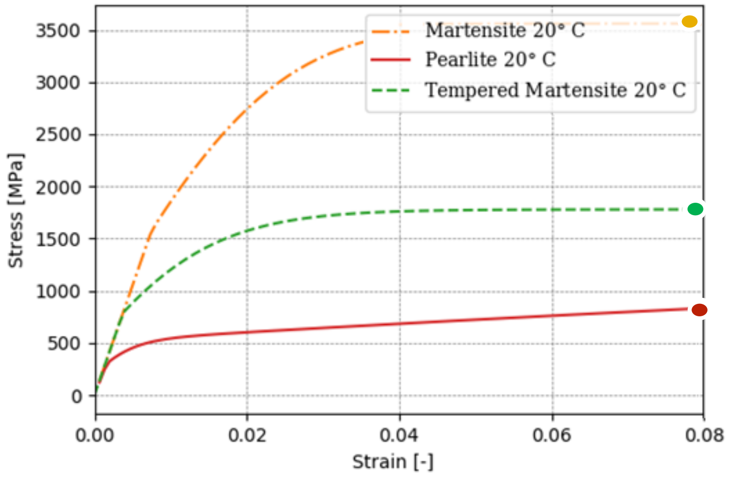
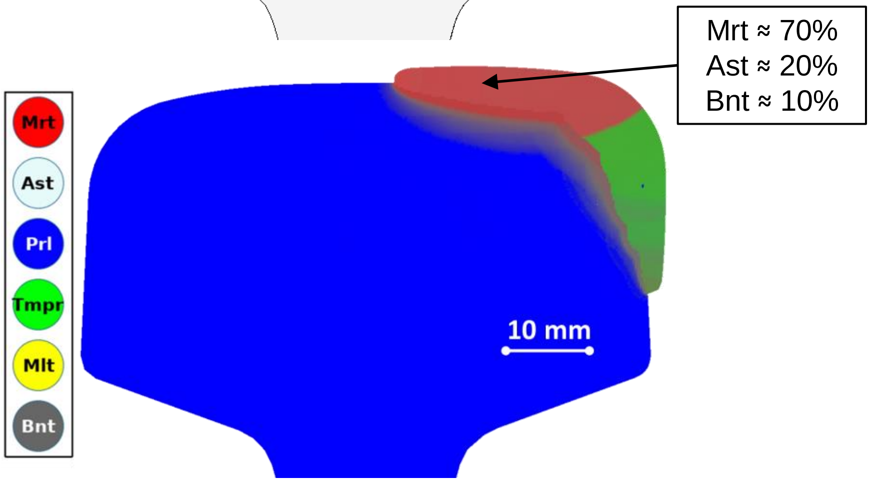
Constitutive model



Constitutive mechanical model





- Chaboche plasticity model
- Non-linear isotropic and kinematic hardening
- Volume changes, transformation strains
- Transformation induced plasticity (TRIP)
- Melting and re-melting virgin material state
- Multi-phase homogenization

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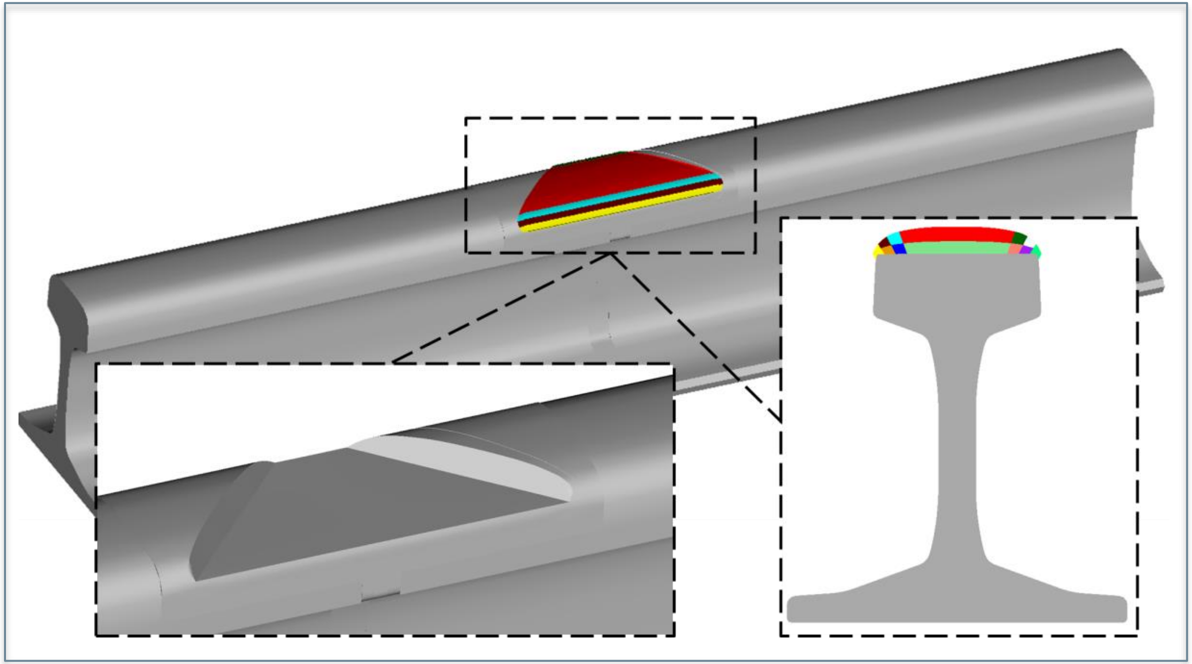
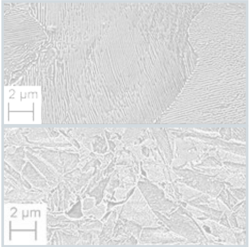
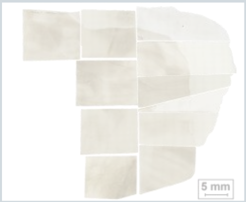
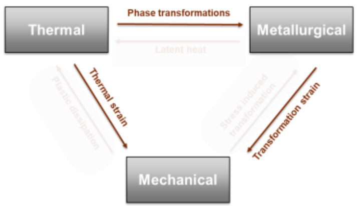
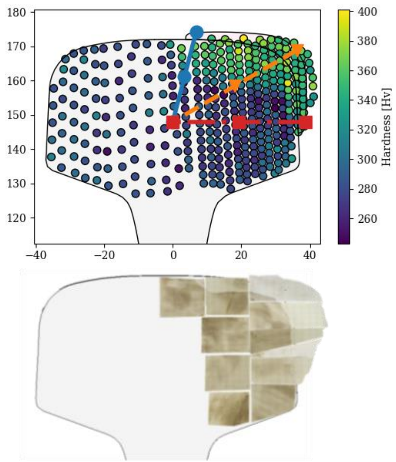


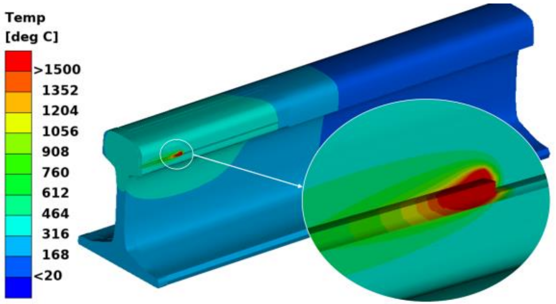


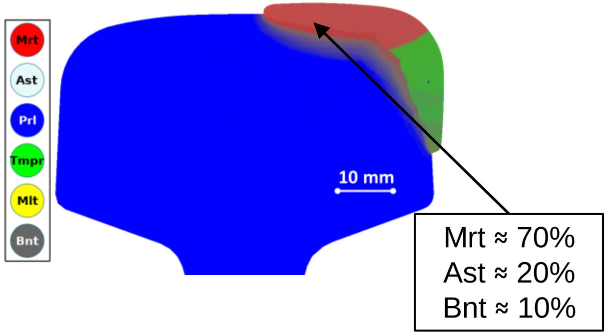


Heat source model tuning







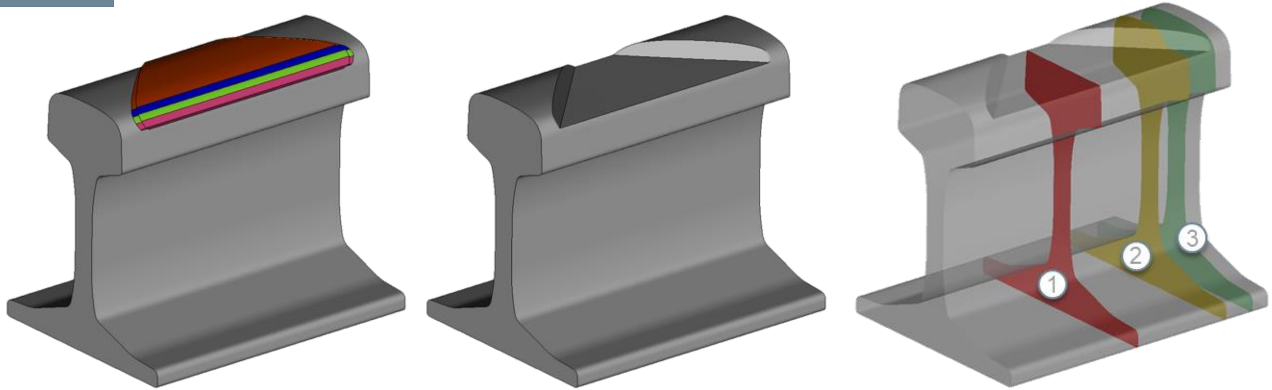


- Temperature field governs simulation outcome
- Repair weld experiment at Trafikverksskolan Ängelholm, Process parameters:
  - Preheat & reheat
  - Power & traversing speed
  - Filler material & repair geometry
- Measurements at Chalmers:
  - Cross section hardness measurements
  - Image microscopy

FE simulation – Heat source tuning:

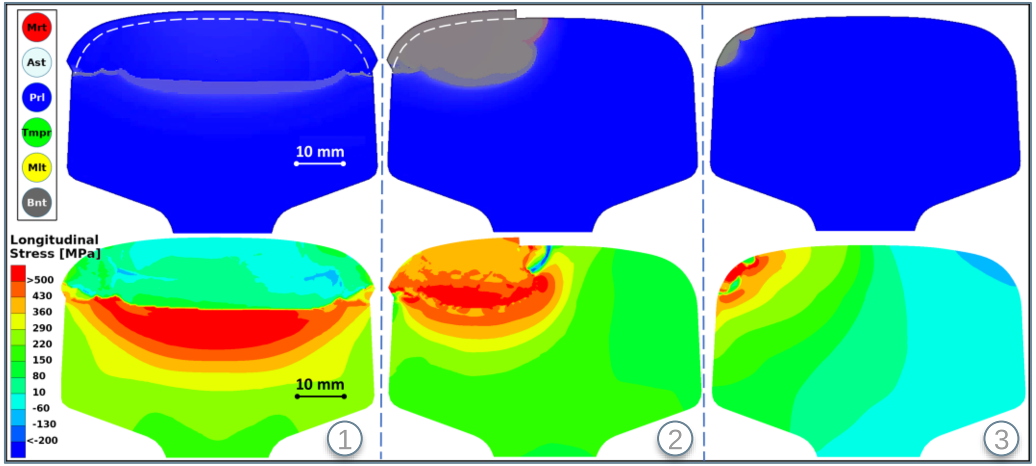
- FE-model setup
- Spatial heat source parameters
- Cut off temperature

Repair welding simulation



Railhead repair welding procedure:

- Following Swedish regulations
- 10 mm deep cut-out
- 45° chamfered cutouts
- Longitudinal support ridge weld passes
- Zig-zag weld passes between ridges
- 350°C preheat (and reheat)



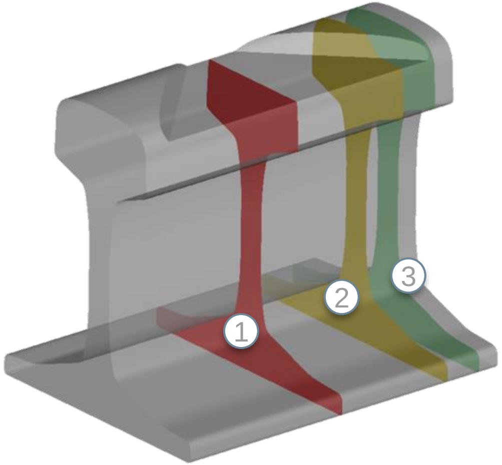
Weld simulation:

- Heat transfer: 3D model
- Mechanical: Multiple 2D cross sections

Simulation outcome:

- Critical regions, material phases, stresses

Repair welding simulation



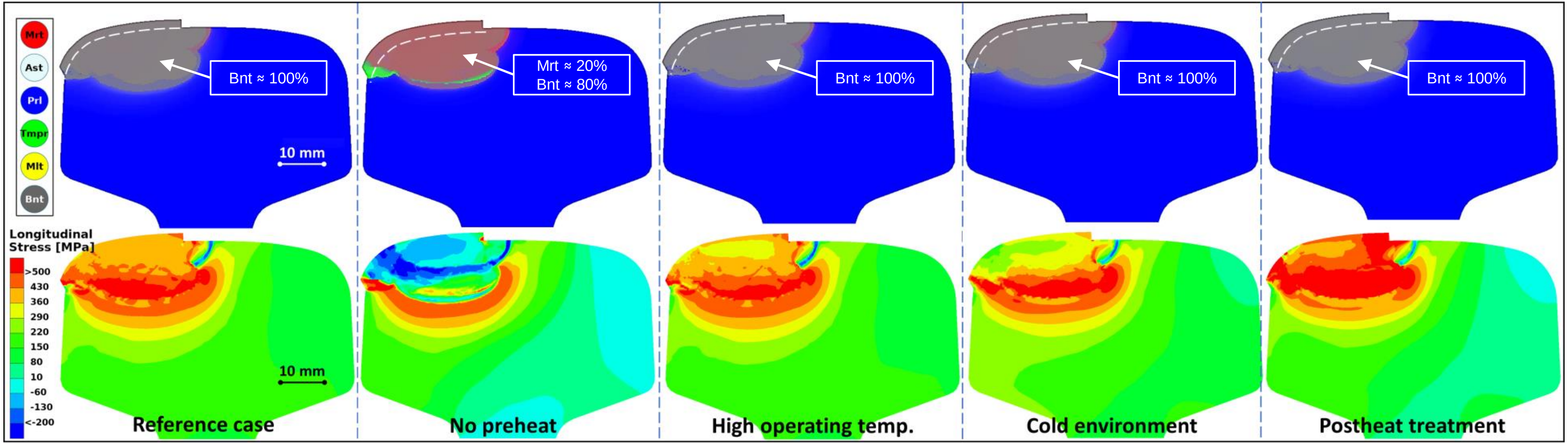
Railhead repair welding process parameter study

- Operating temperatures
  - Preheat
  - Postheat
  - Environmental conditions
- Repair geometry
  - Cutout depth
  - Cutout shape
  - Cutout length
- Filler material

Case	Temperature limits [°C]			
	Rail	Preheat	Reheat	Postheat
Ref.	20	350	300	*none*
1	20	*none*	*none*	*none*
2	20	450	400	*none*
3	-15	350	300	*none*
4	20	350	300	350

Case	Geometry variations [mm]		Filler
	Cut out depth	Cut out length	material
Ref	10	35 / 175	Weartrode
5	5	35 / 175	Weartrode
6	10	100 (*no chamfers*)	Weartrode
7	10	135 / 275	Weartrode
8	10	35 / 175	R260

Repair welding simulation



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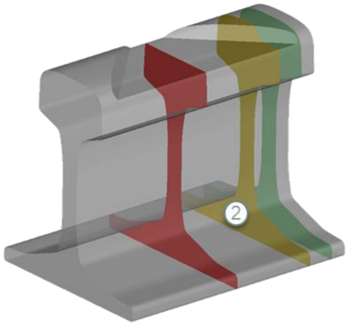
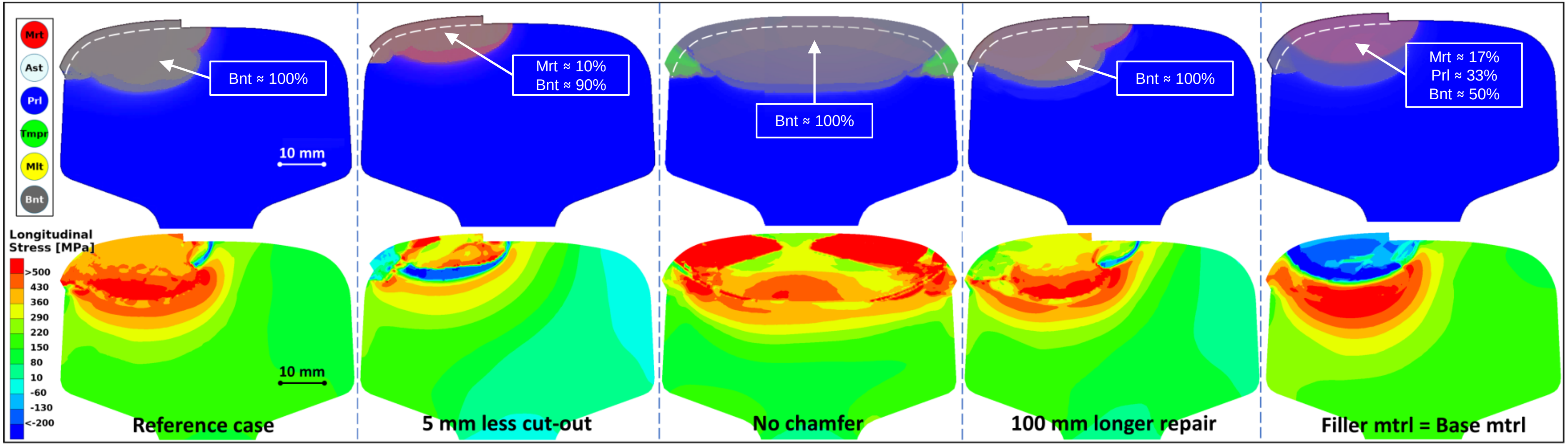


Repair welding simulation



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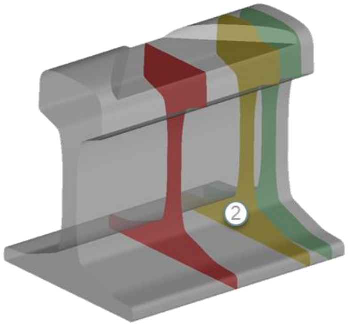
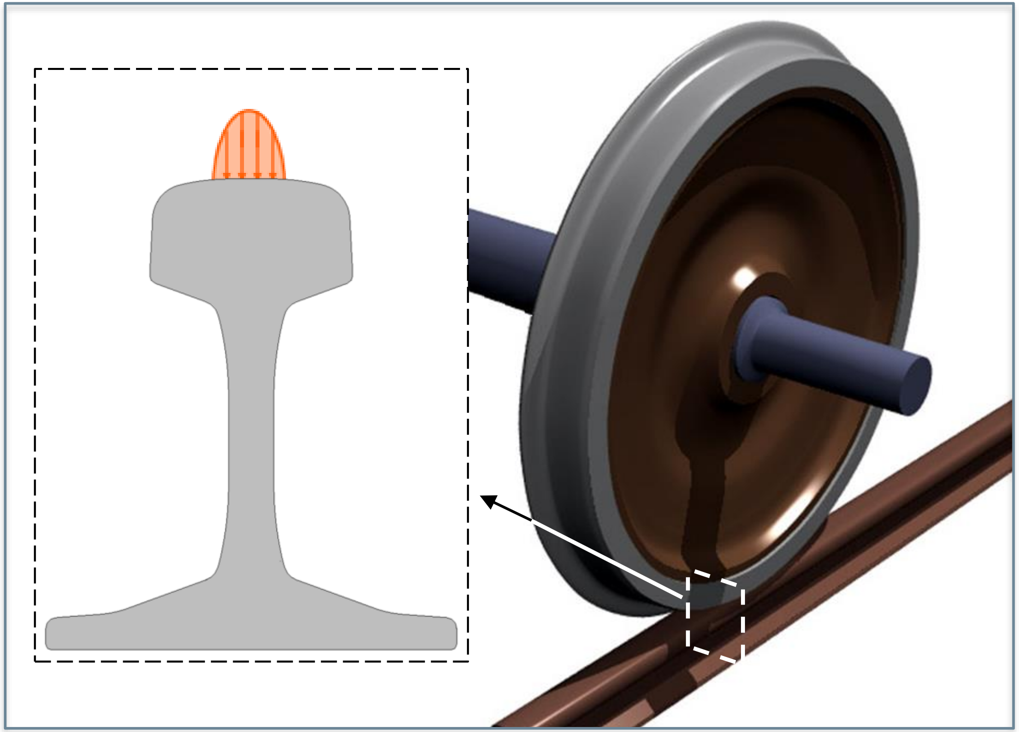
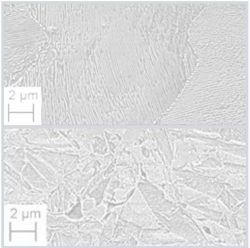
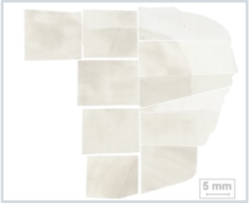





2 µm
2 µm


5 mm

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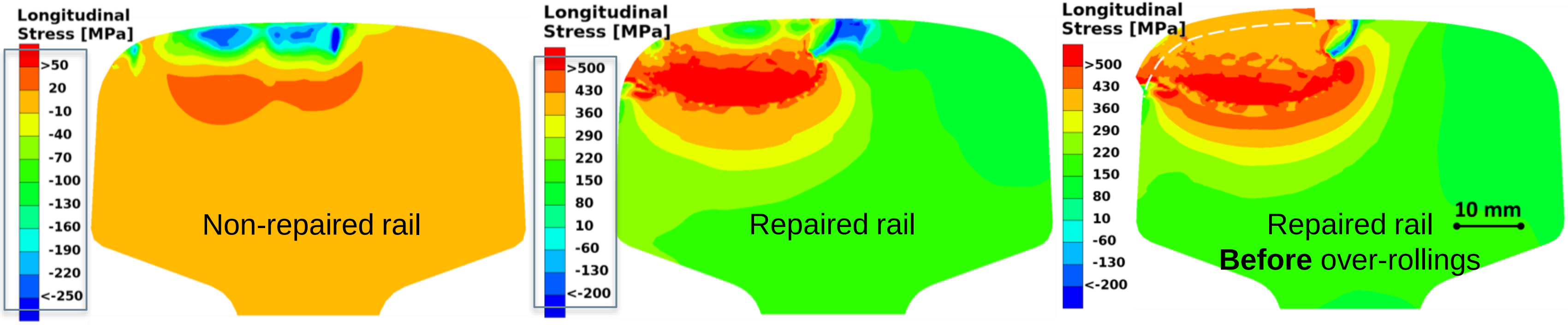
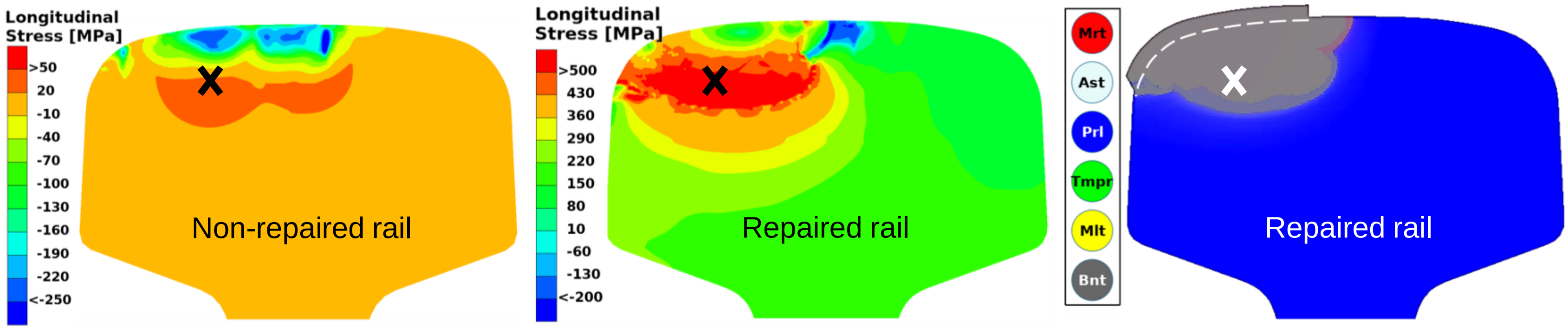
Repair welding and over-rolling simulation



Post repair weld operational condition fatigue evaluation

- Load 20 trains on Swedish western main line (Nyckelsjön-Sparreholmen), 90% Passenger (X2000, X40), 10% Freight
- Load repeated 4 times: **2000 over-rollings**
- Operational load: **Compressive at surface**
Tension beneath surface
- **Residual stress** weld + over-rollings

Repair welding and over-rolling simulation



Post repair weld operational condition fatigue evaluation

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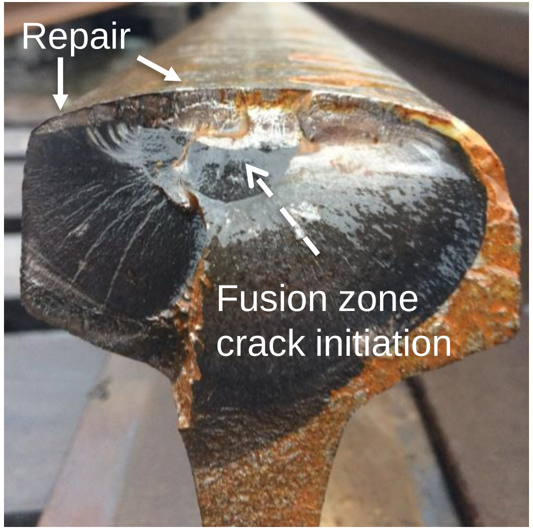
- Load repeated 4 times: **2000 over-rollings**
- Operational load: **Compressive at surface**
  Tension beneath surface
- **Residual stress** weld + over-rollings
- **Critical point** at fusion zone
- Fatigue evaluation (crack initiation) using Dang Van method
- Max Dang Van stress increase at highlight **X** (factor of ~3)
- **Correlation field failure investigations**



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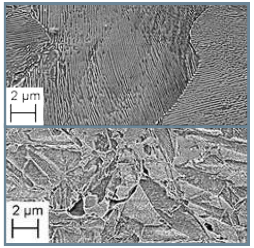
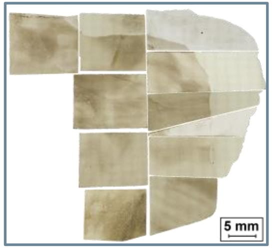
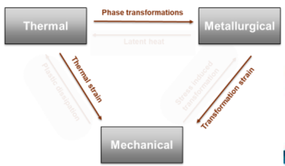
Summary

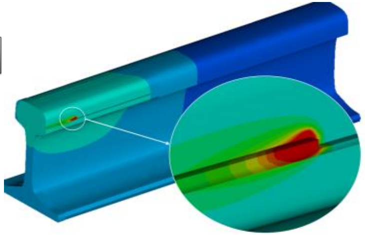
Railhead repair welding affects both microstructure and residual stress, proper process include:

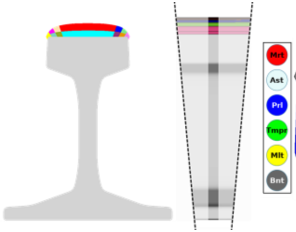
- Final **zig-zag weld passes** generate more heat than preheating, making the process robust.
- To enhance rail performance, **align short edge of railhead** cutout towards the gauge side of the rail.
- Simulations confirm the **interface zone as critical**, affected by material phases and operational stresses.
- **Chamfered cutouts mitigate tensile stresses** in repaired rail sections effectively.
- **Shallow repairs** cool faster, thereby increasing the risk **martensite**-induced fatigue cracks.
- Slow phase transformations in **ESAB OK Weartrode 3 reduce unfavorable material phases**.
- **Tensile residual stresses redistribute** significantly more **at surface** than at depth.

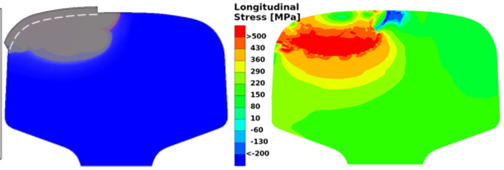












Thank you for listening!

Simulering av Reparationssvetsning
Processparametrar och Reparationskvalitet

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