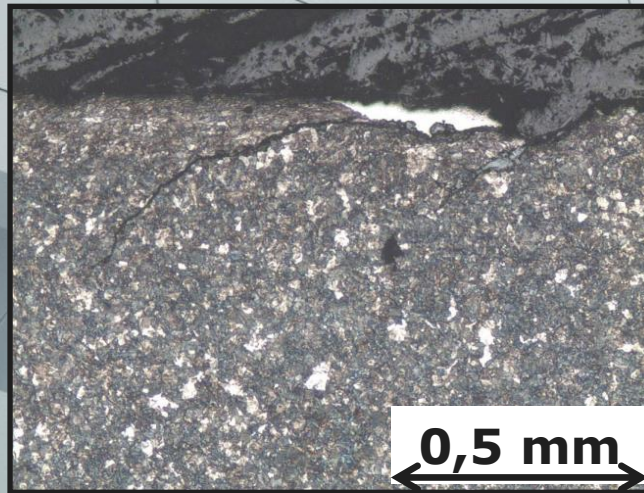


Grinding-induced Rolling Contact Fatigue in Rails

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COWI



COWI

My experience

Carsten Jørn Rasmussen

- M.Sc., IWE, Consulting rail specialist at COWI
- Rail System Manager at the Danish infrastructure manager, Banedanmark for 12 years
- Rail welding and defect specialist at the testing company, FORCE Technology for 12 years
- Specialized in:
 - Rail monitoring and maintenance
 - Rail metallurgy and welding
 - Rail strategies and regulations



Grinding-induced RCF in Rails

Presentation:

- Introduction
- RCF cracks in R350HT
- Influence of the grinding process
- Findings over 10 years



Europe



Rail network in Denmark



3500 km track

Rail network in Denmark

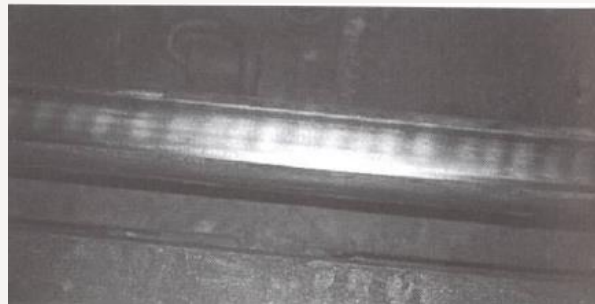
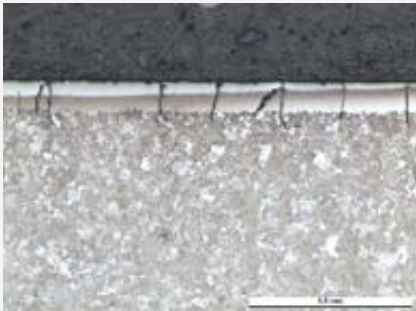
Banedanmark:

- 3500 km track
- 30 % curves
- Flat country - no mountains
- Max. 22,5 tons of axle load
- Standard rail profile: 60E2
- Standard rail grade: R260
- Standard inclination: 1:40



Grinding of rails

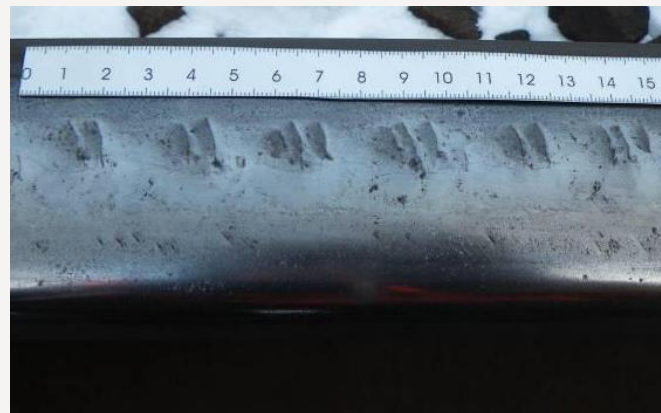
- > Speed: 5-7 km/h
- > Around 0,15 mm removal per passage
- > To reprofile and to remove/prevent RCF defects and corrugation.



RCF in R350HT rails

Case 1) Odense-Middelfart

- › Cracks found in 2010 after 72 MGT
- › Curves with R350HT rails
- › Mixed traffic – passenger/freight
- › 12 MGT per year



RCF in R350HT rails

Case 2) Single track

- › Cracks in 2011 after only 20 MGT
- › Curves with R350HT rails
- › Lint41 - light passenger train
- › 2 MGT per year



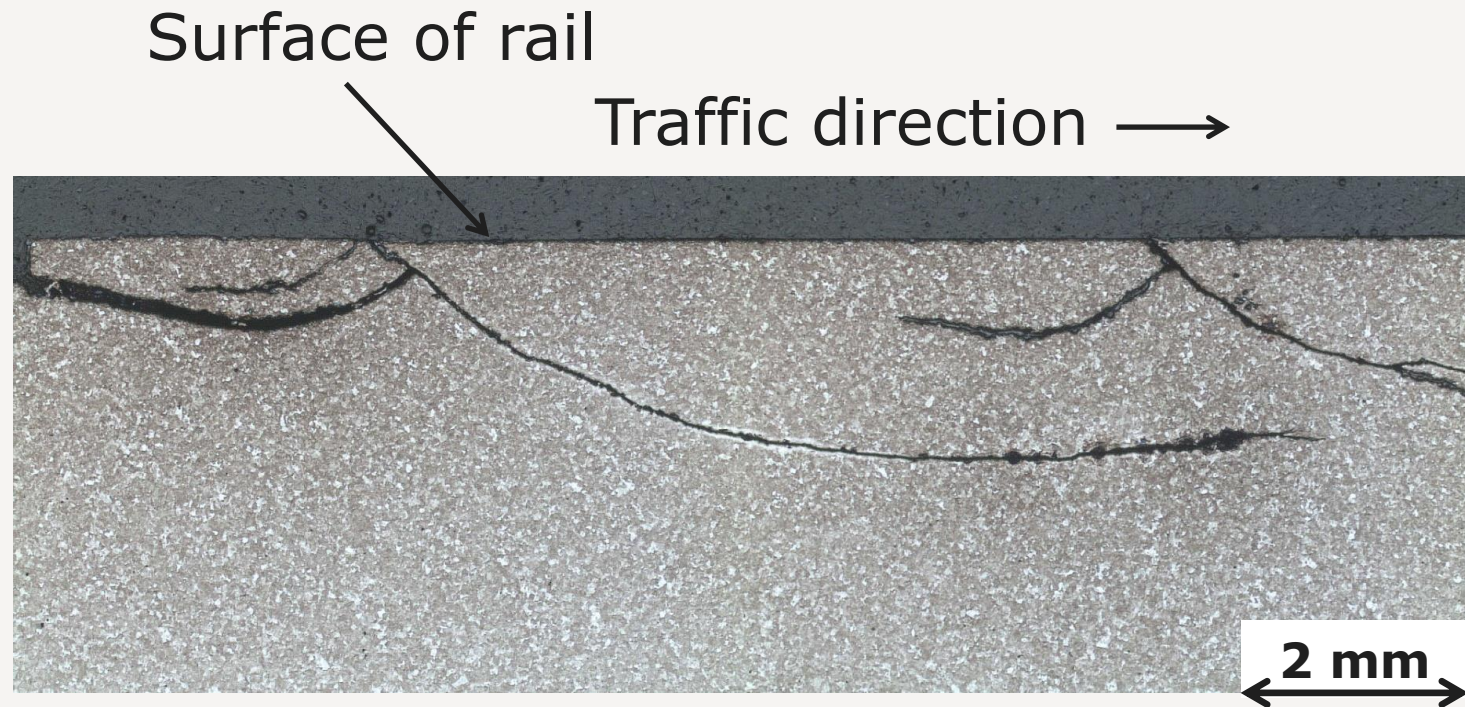
RCF in R350HT rails

Case 2) Single track



Spallation

RCF cracks in R350HT rails



Longitudinal cut in R350HT rail

RCF cracks in R350HT rails

Periodic cracks of 25-30 mm !



RCF cracks in R350HT rails

Transition weld between R350HT and R260



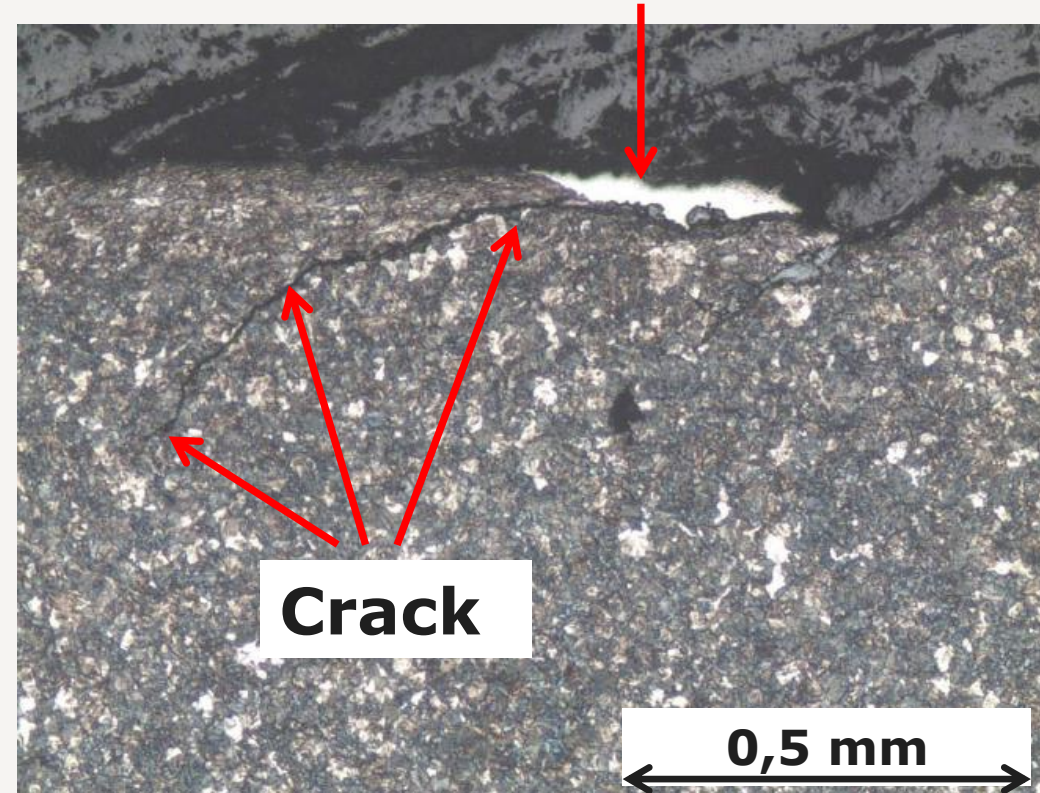
Also on straight track!

Why RCF cracks in R350HT ?

Why RCF cracks?

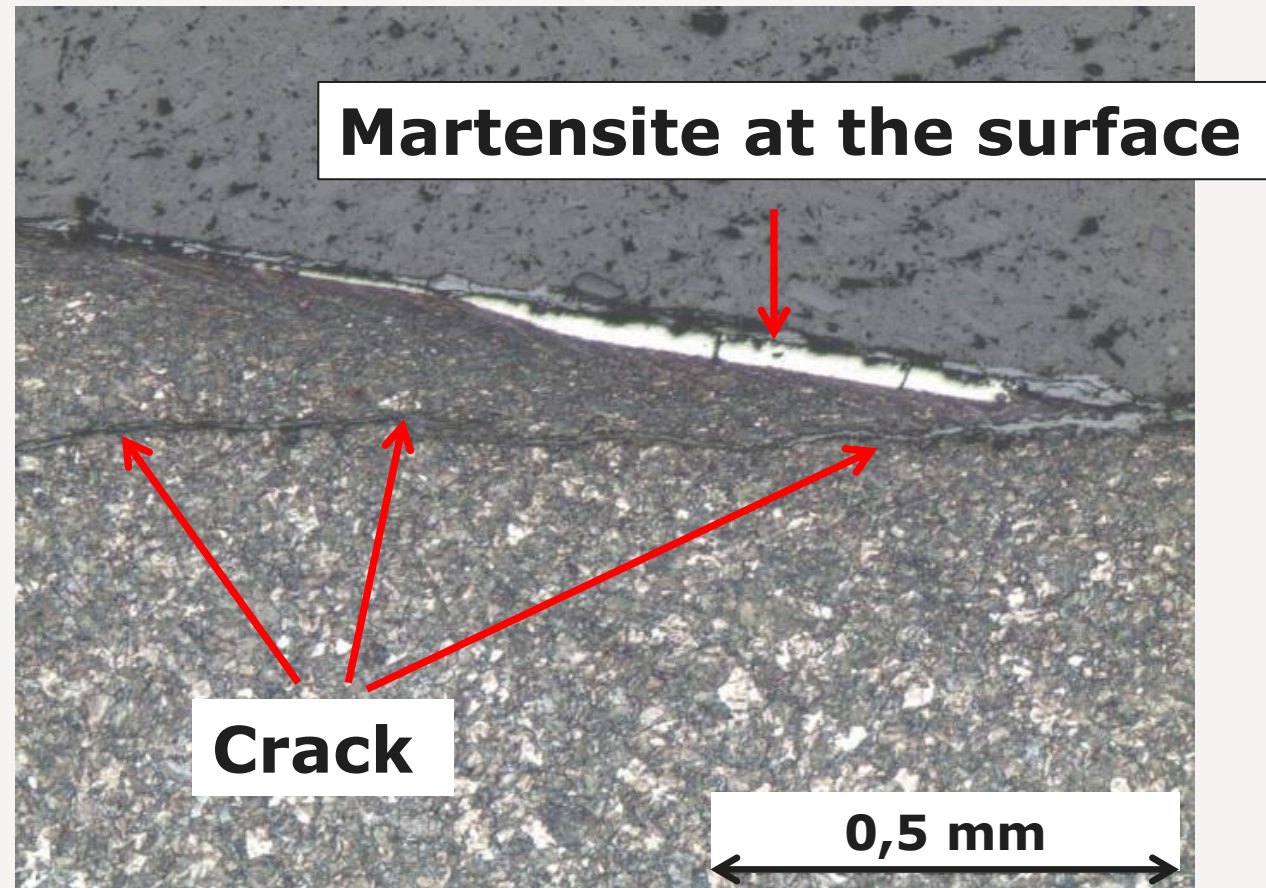
- > Cracks initiates in transition zones between pearlite and martensite.
- > Must be found and cut out in a very early stage.

Martensite at the surface



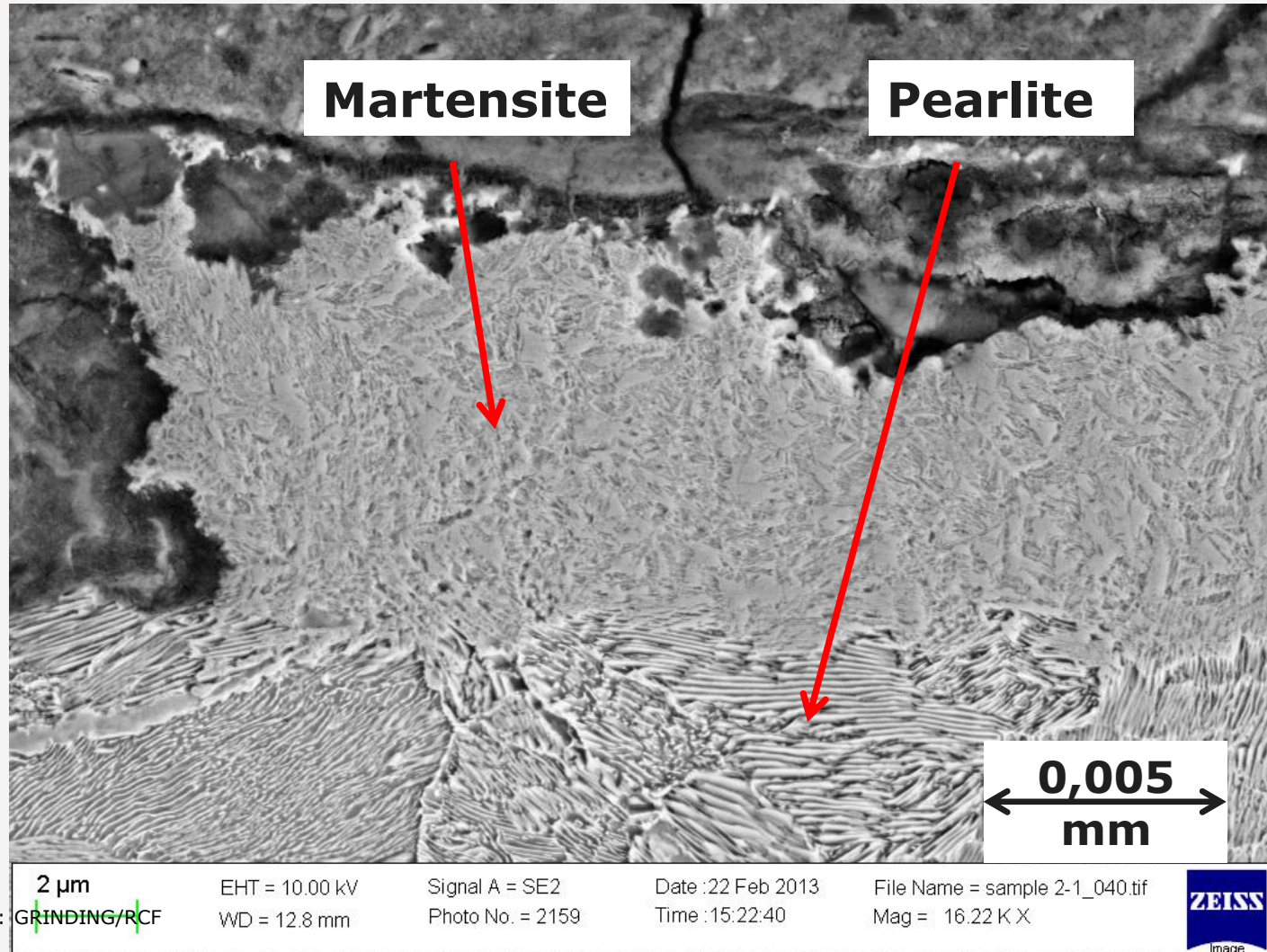
Transverse cut through a crack

Why RCF cracks?



Transverse cut through a crack

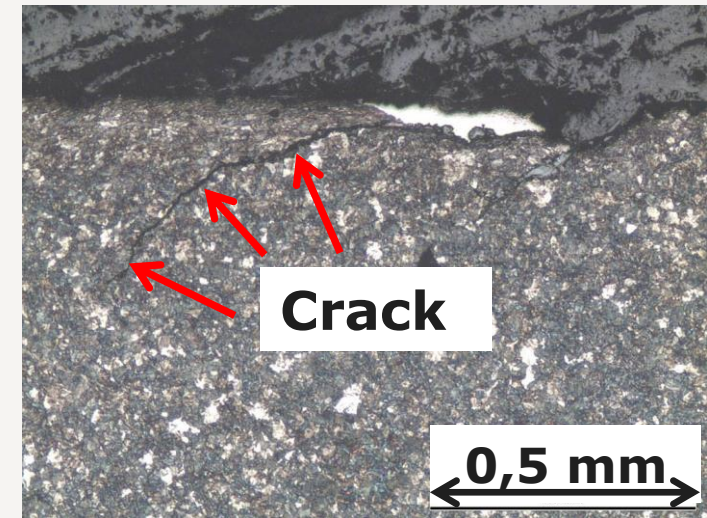
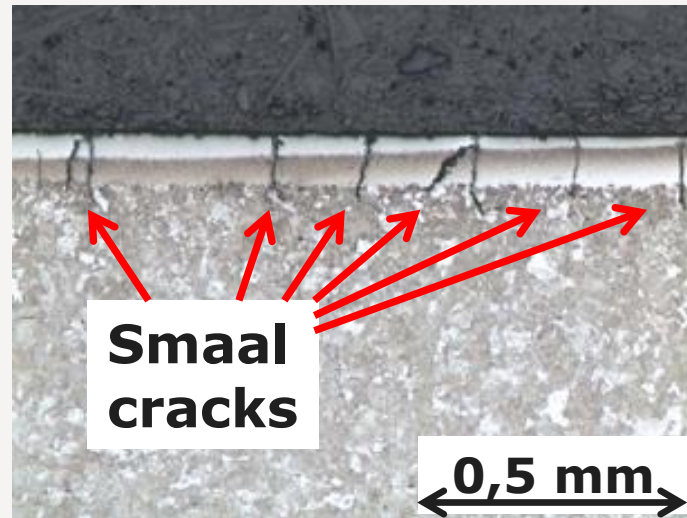
Martensitic structure



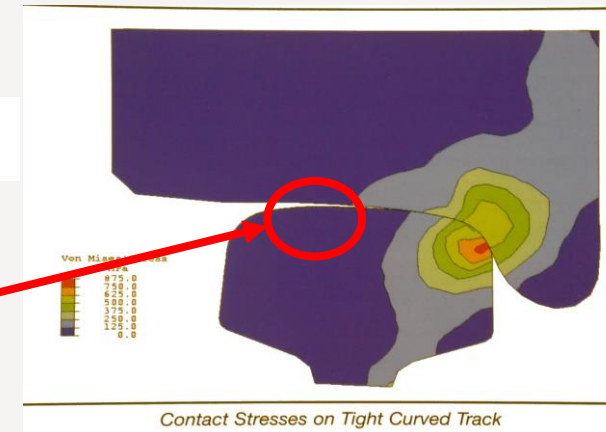
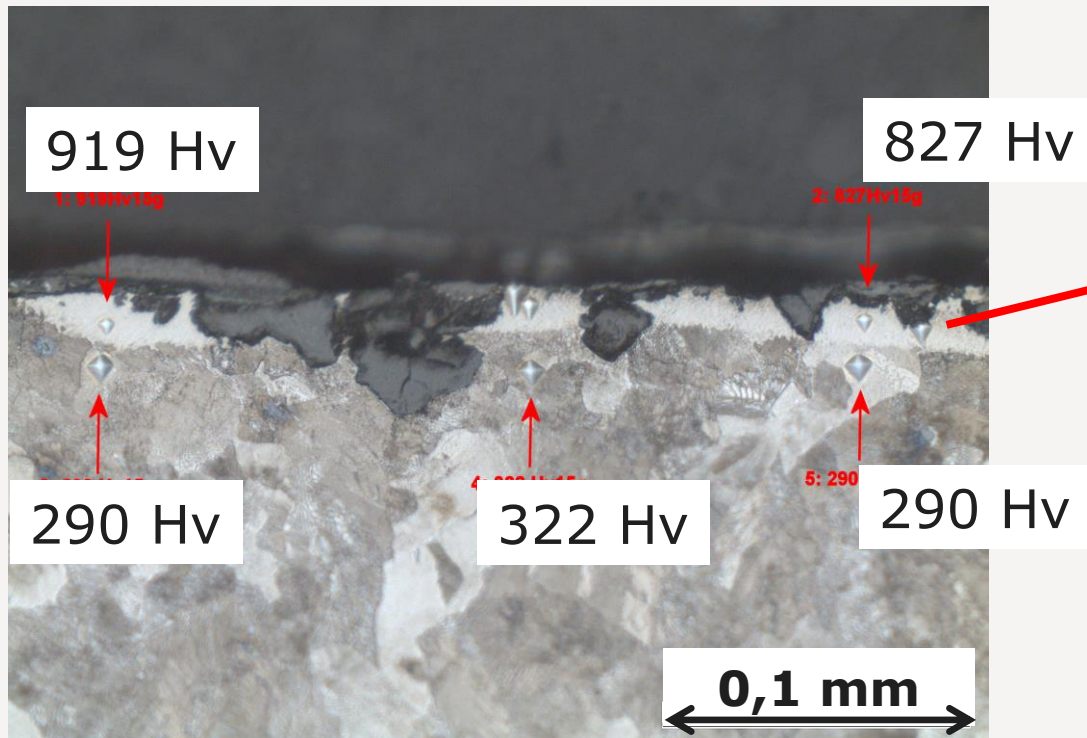
Why martensite (WEL)?

When rail temperature gets over 720 °C followed by rapid cooling.

- > Wheel/rail slip?
- > Other reasons?



By coincidence in 2011 martensite (WEL) was detected outside wheel/rail contact band in a grinded area.



First indication of grinding induced martensite in rails!

Grinded rail surface

- > Grinding stones are flat leading to facets on the rail surface after grinding
- > Sometimes periodic deeper grinding marks
- > The friction from grinding stones introduces heat into the surface of the rails.



Grinding stone



Grinded rail seen from above



Grinding train

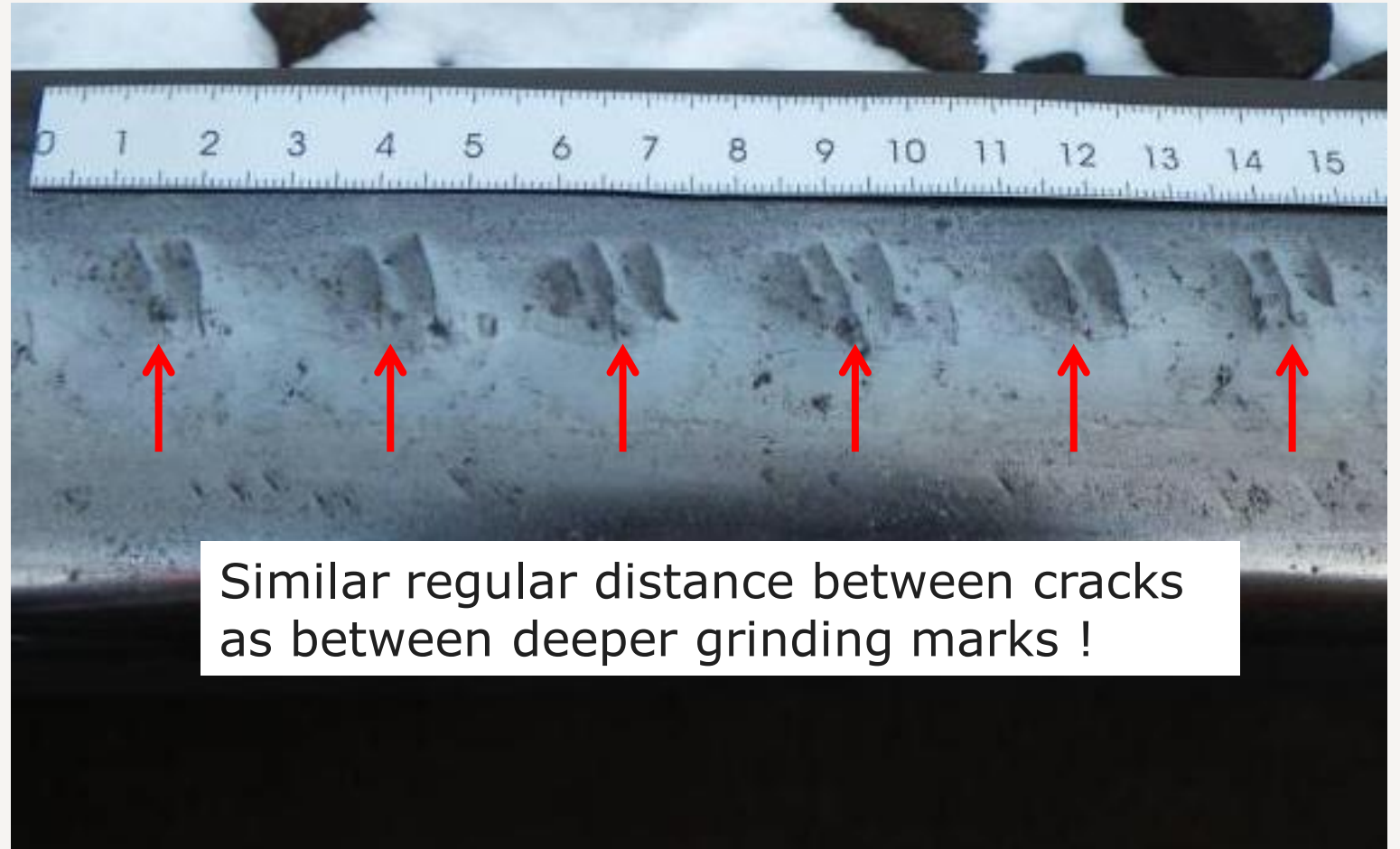
Facets and deeper marks from flat grinding stones

Grinded rail
surface seen
from above



Periodic cracks

- > Cracks with periodicity of approx. 25-35 mm.
- > Similar distance as deeper grinding marks!



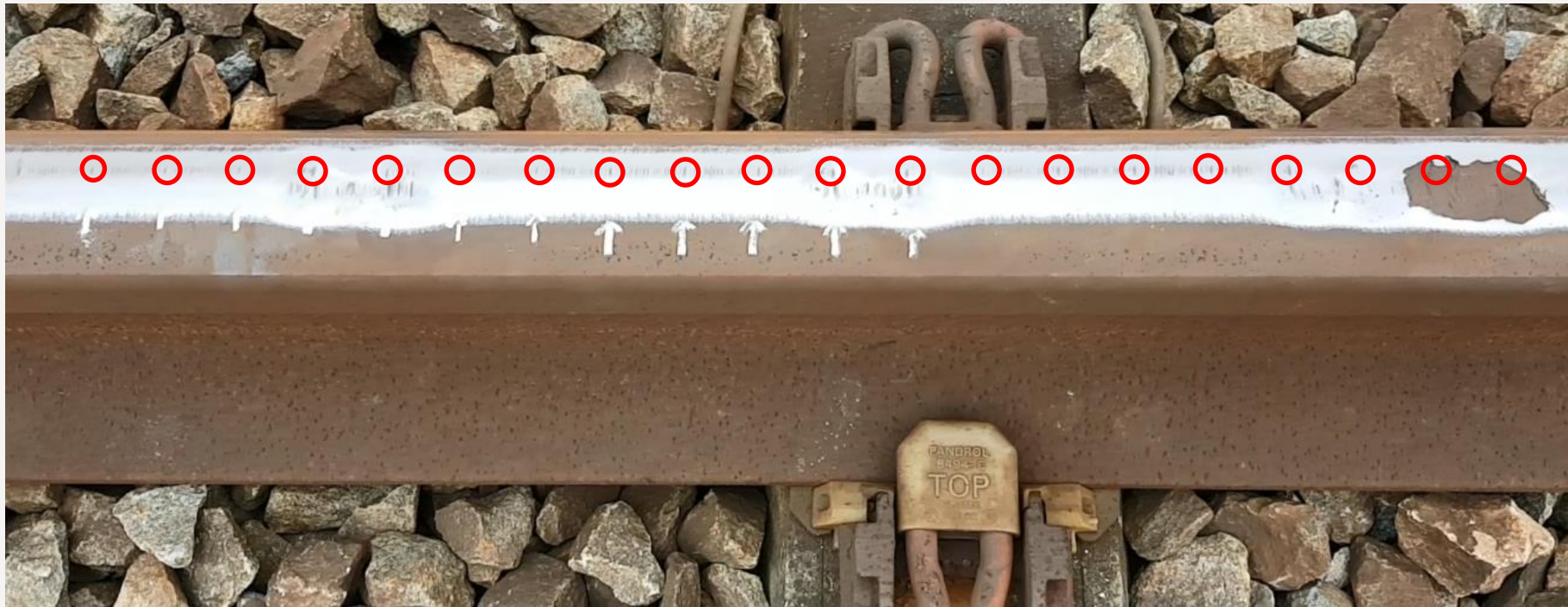
Similar periodic cracks in other countries



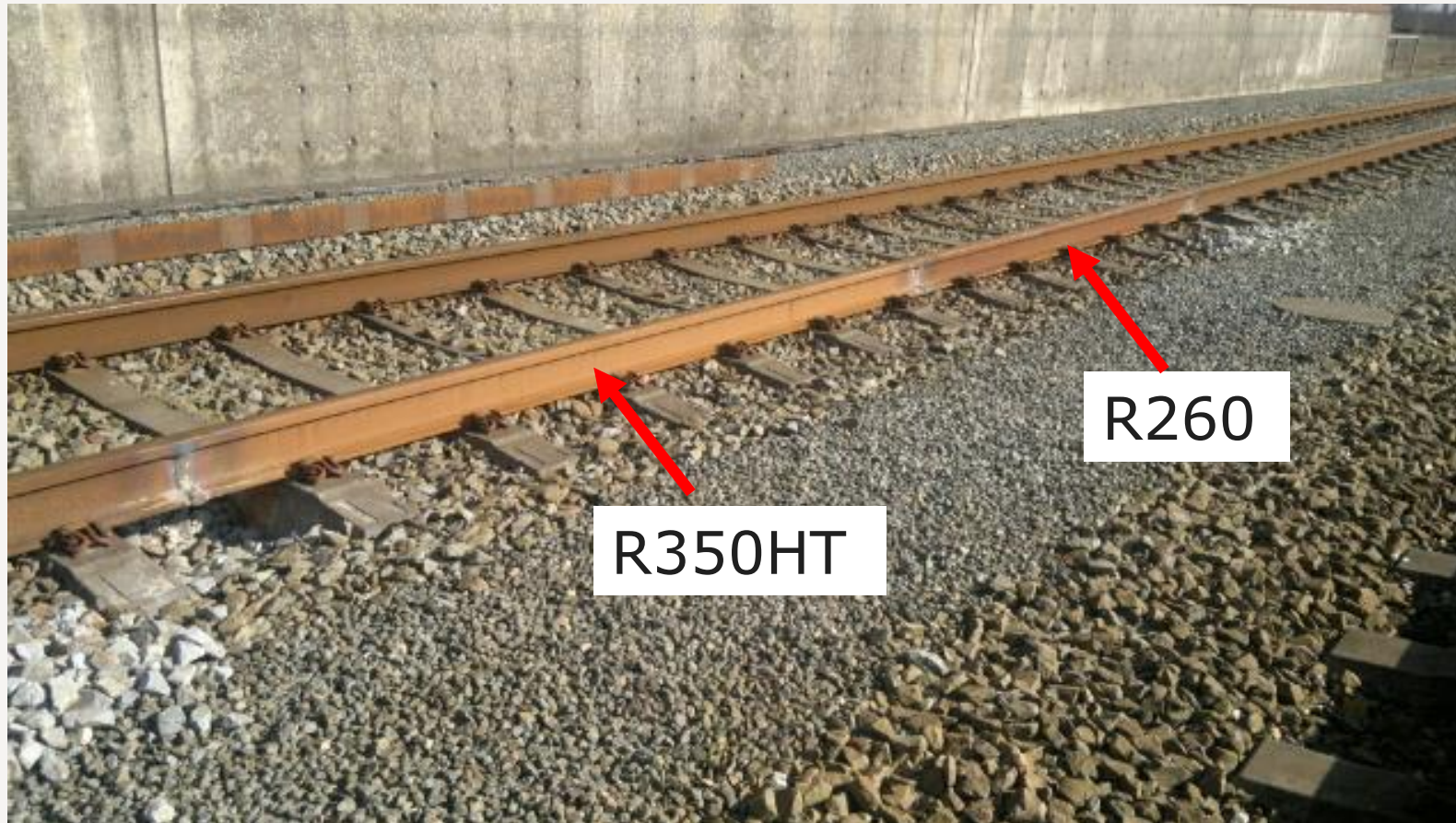


RCF cracks in R350HT rails

Initiation of RCF cracks in deeper grinding marks?



Grinding test in Padborg in 2012



Grinding test in Padborg in 2012

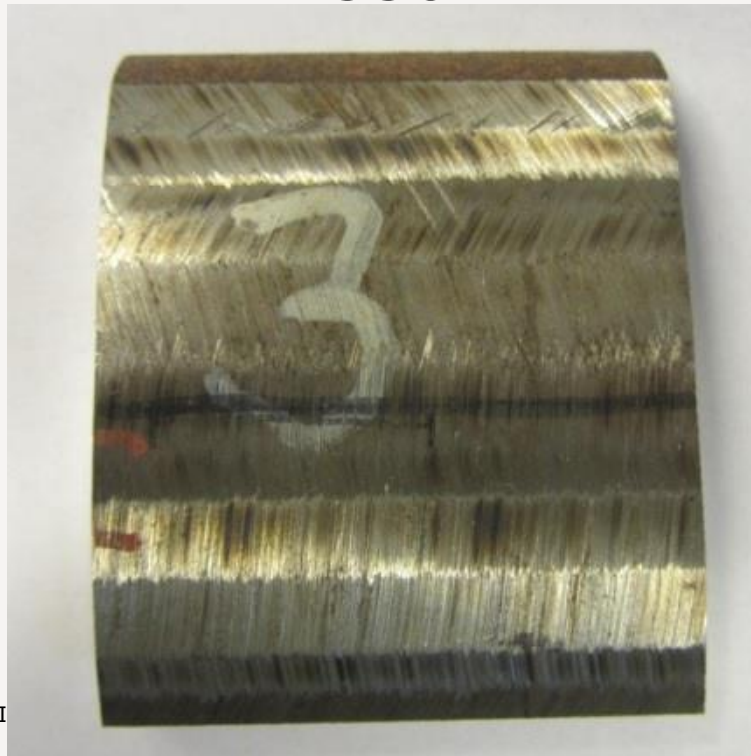
Conventional grinding of the rails in the test.



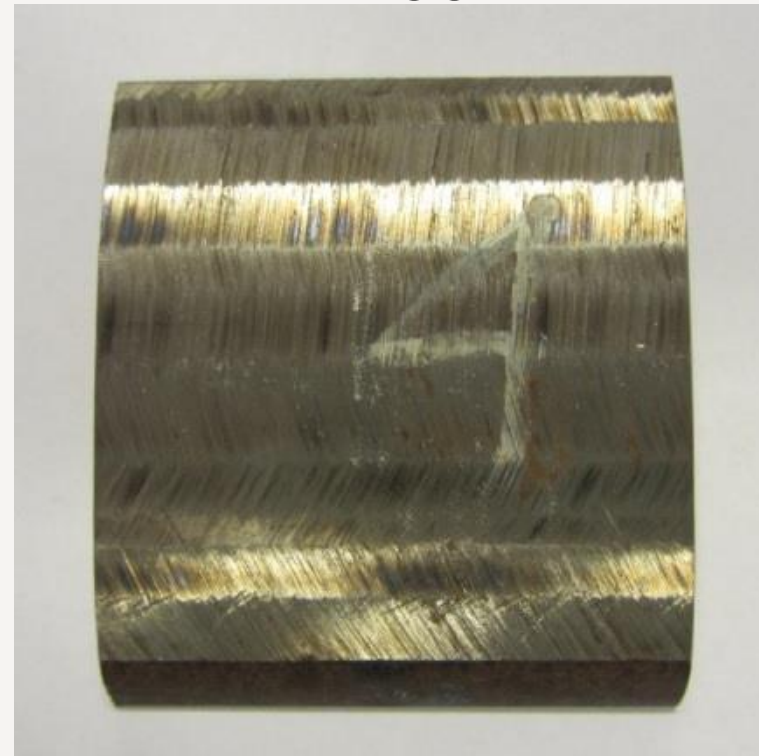
Grinding test in Padborg in 2012

Samples cut out just after grinding

R350HT



R260



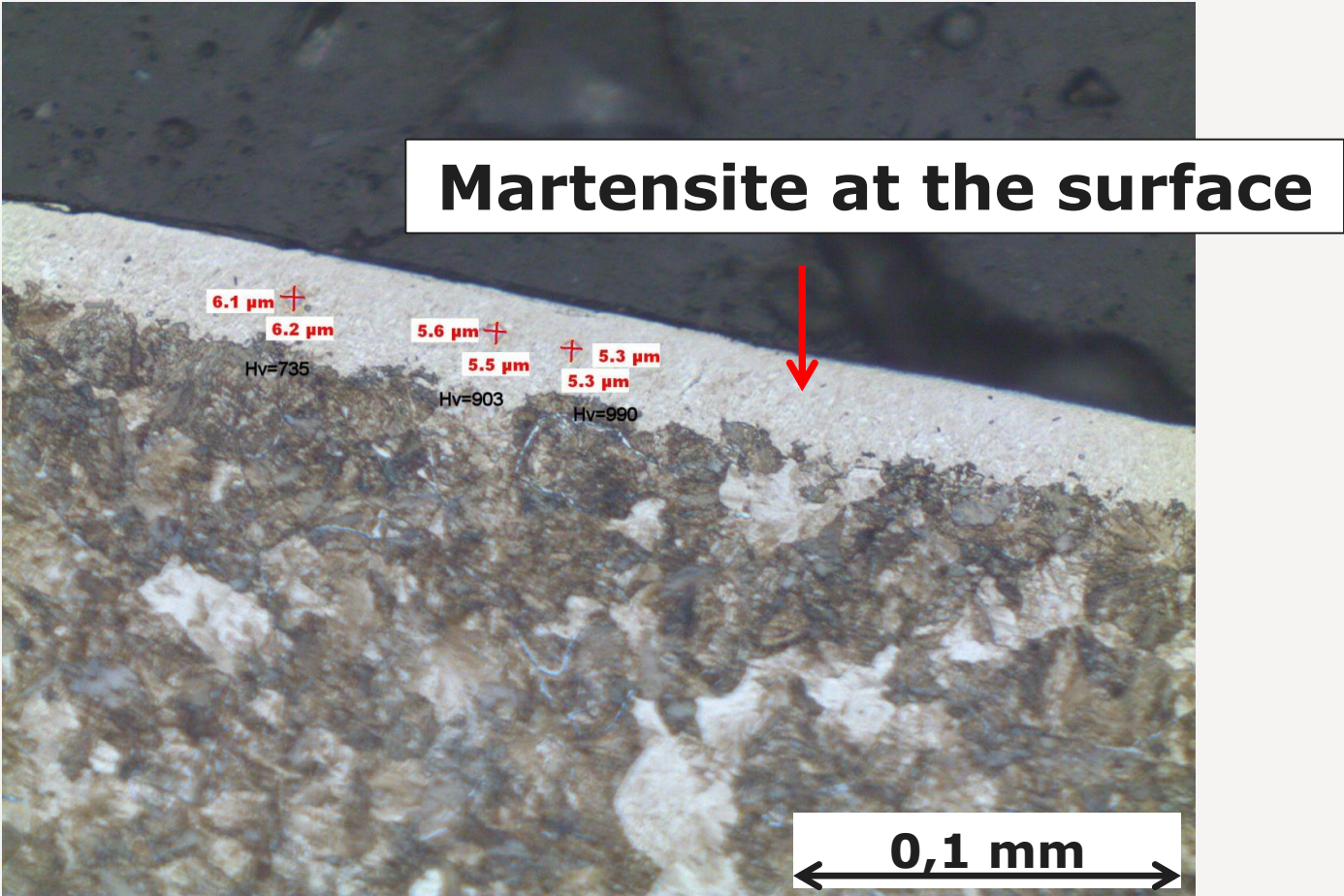
Grinding test in Padborg in 2012

Longitudinal cut in R350HT

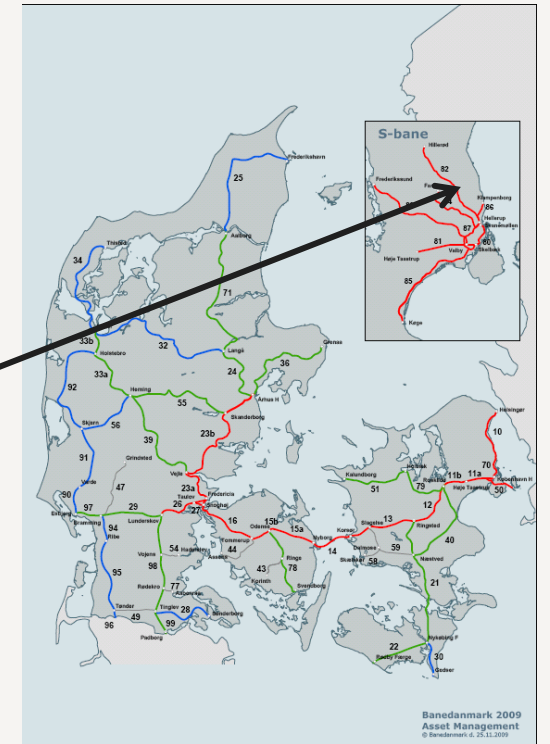
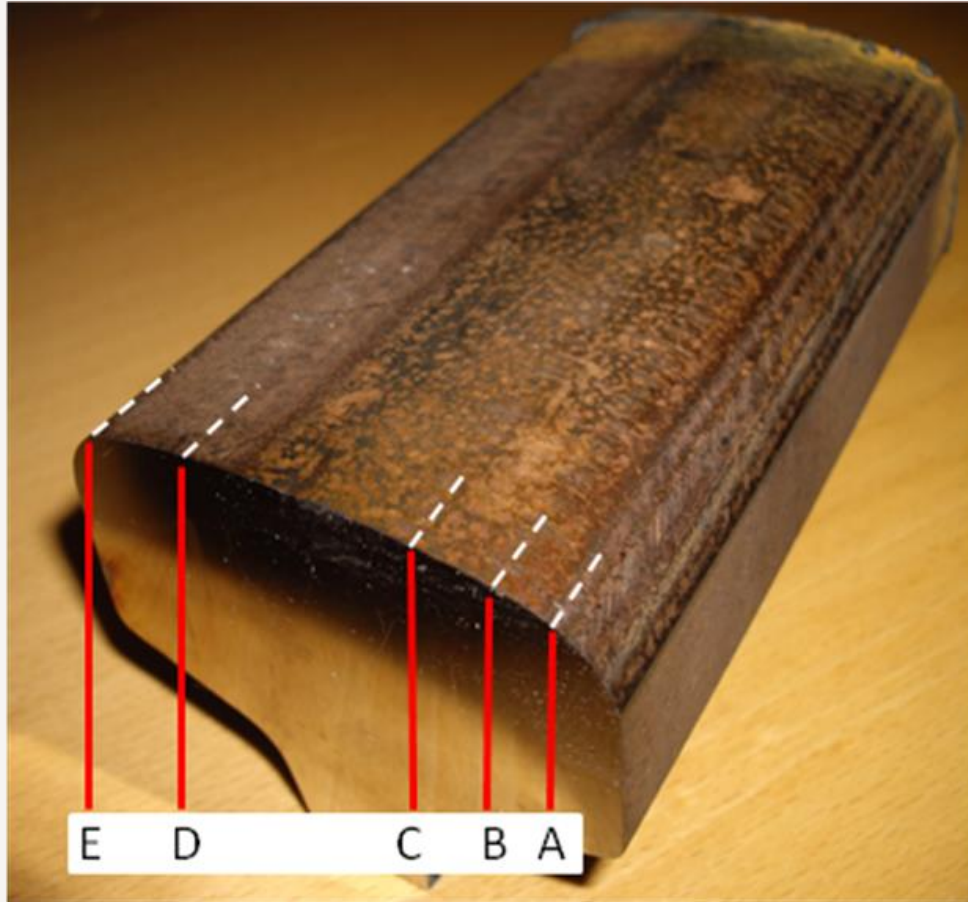


Martensite in both R350HT and R260 from the grinding process!

Grinding test in Padborg in 2012

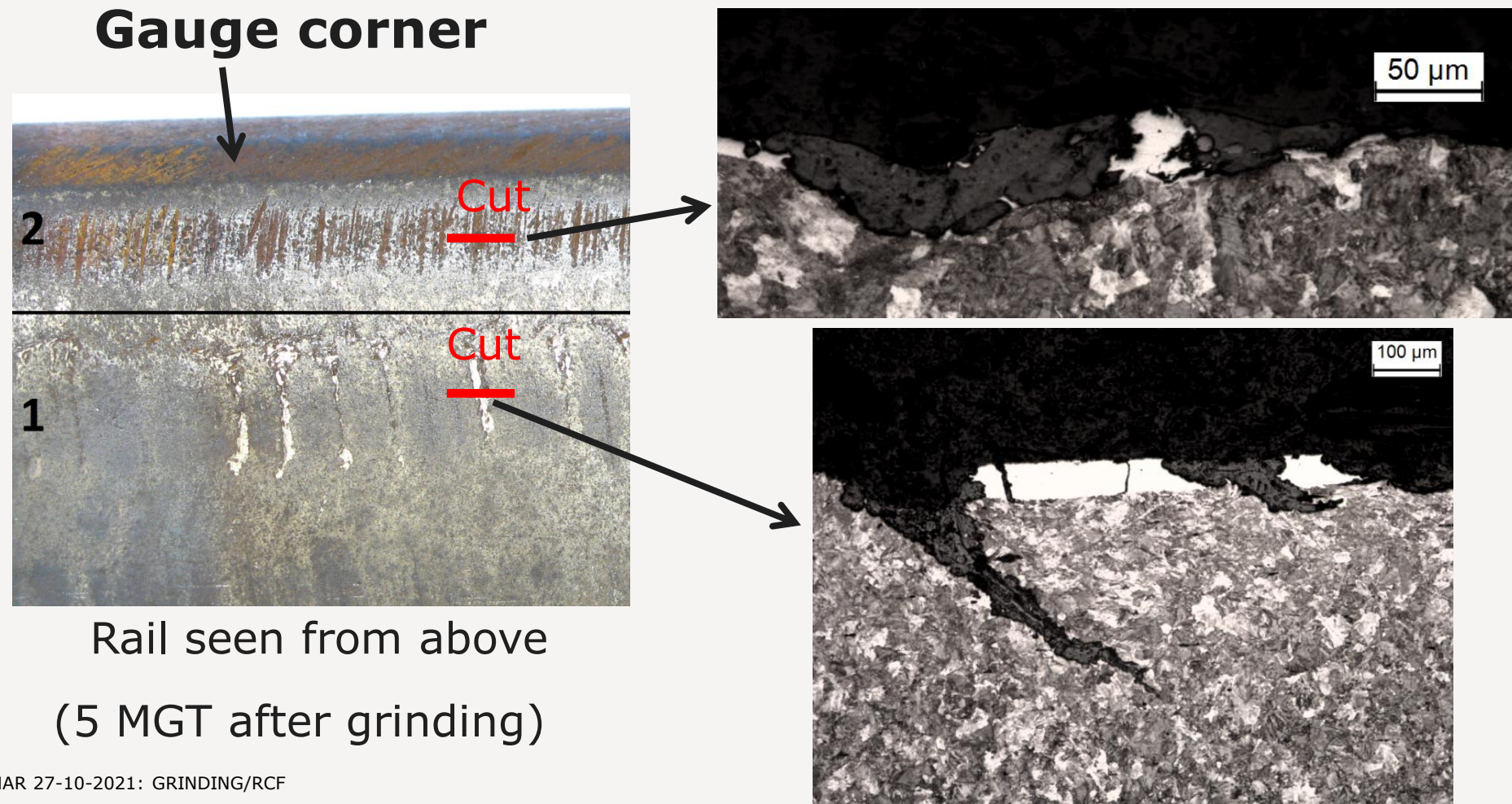


R350HT rail cut out from track in service



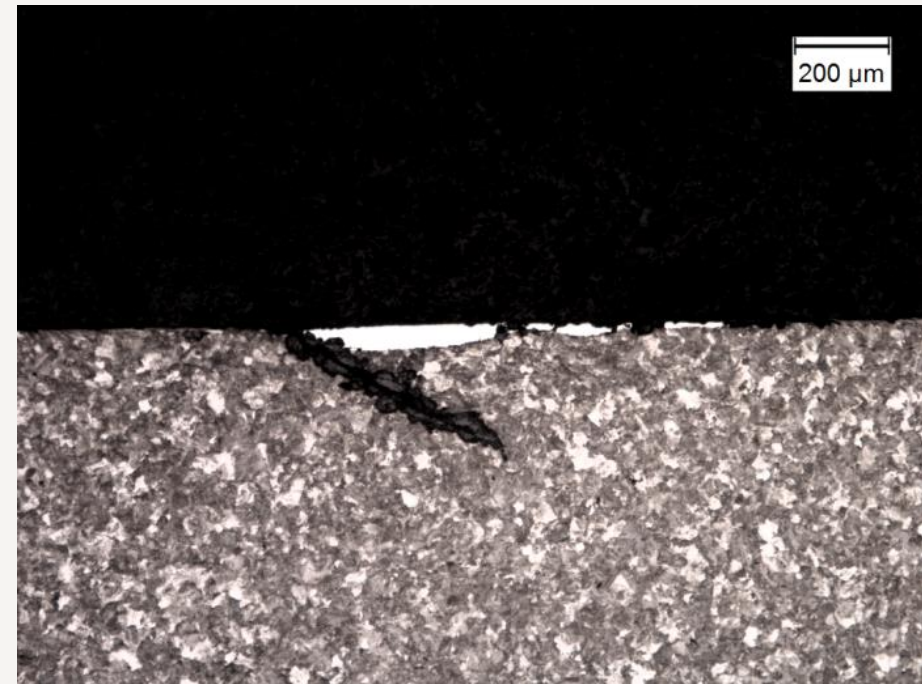
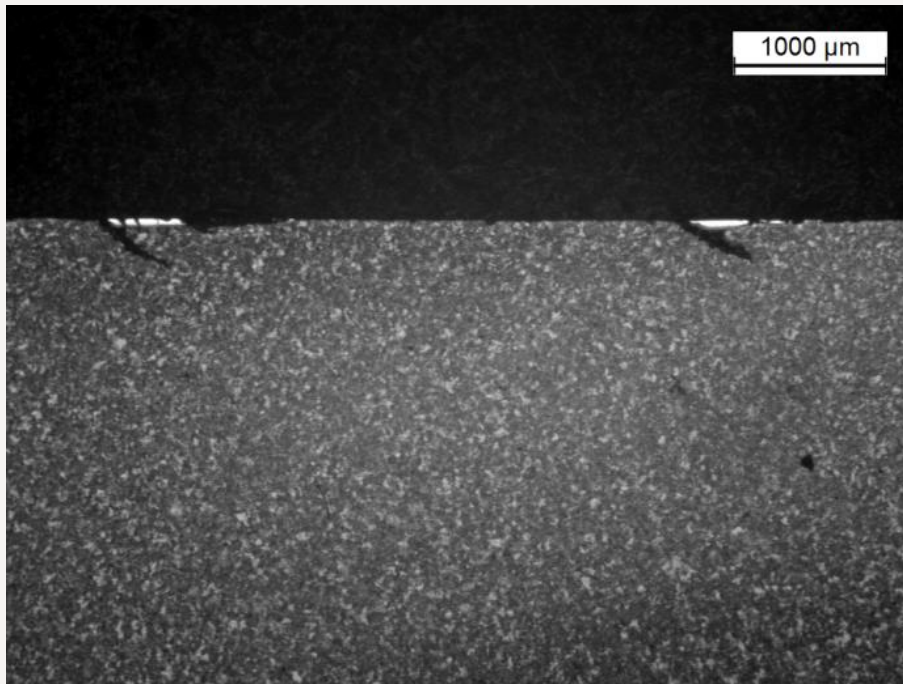
Grinded in 2010
Extracted in 2012
Total traffic: 5 MGT

R350HT rail cut out from track in service

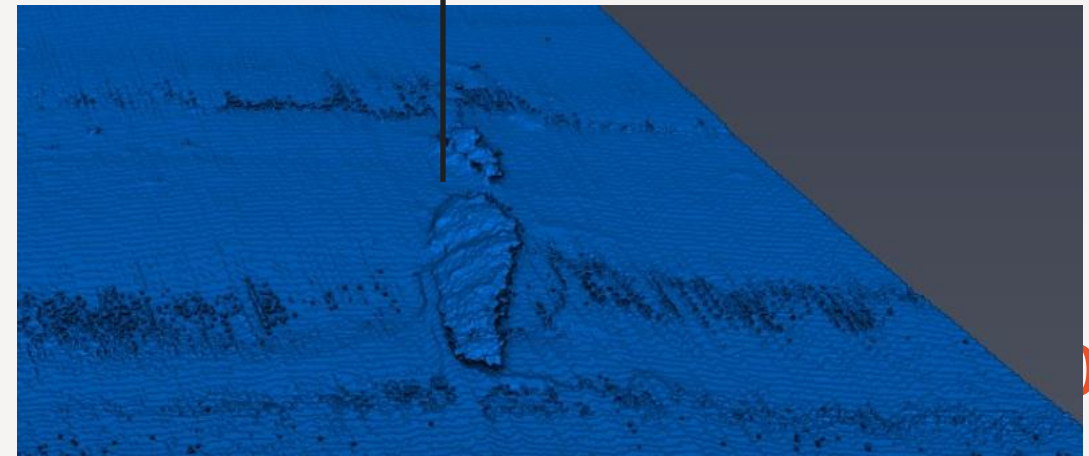
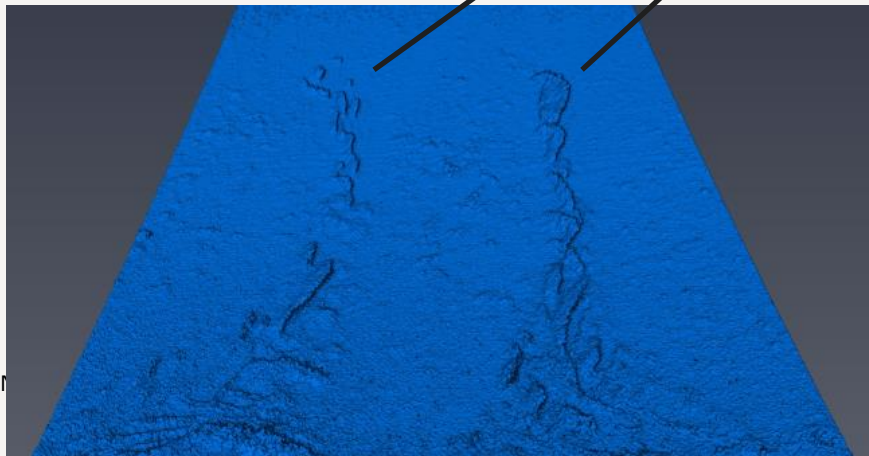
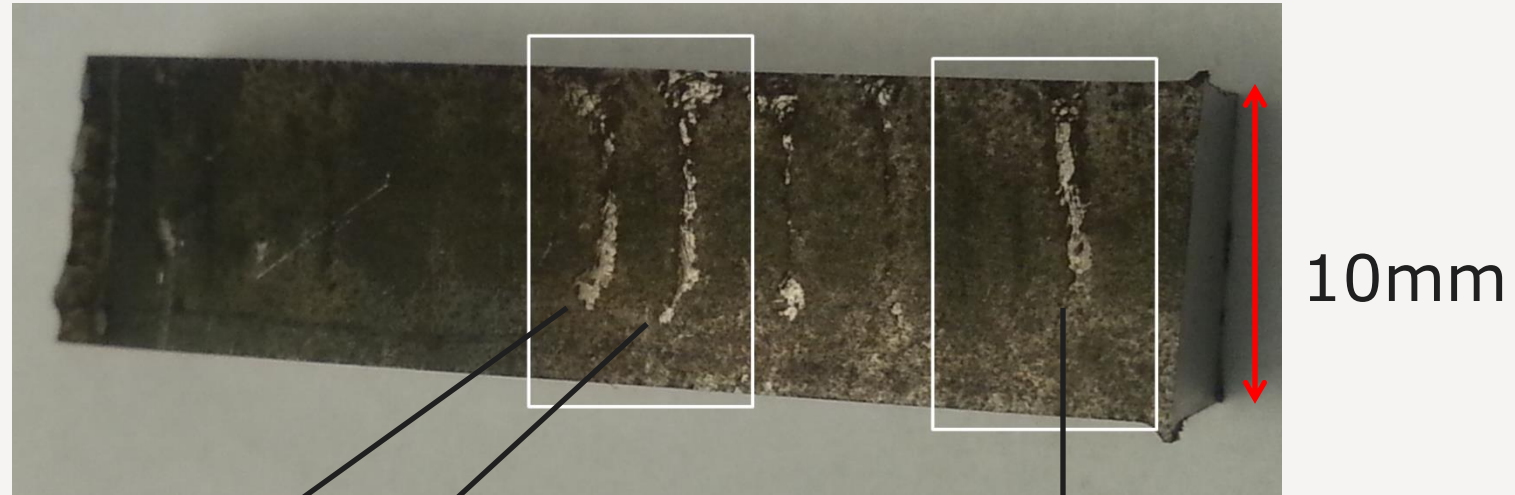


R350HT rail cut out from track in service

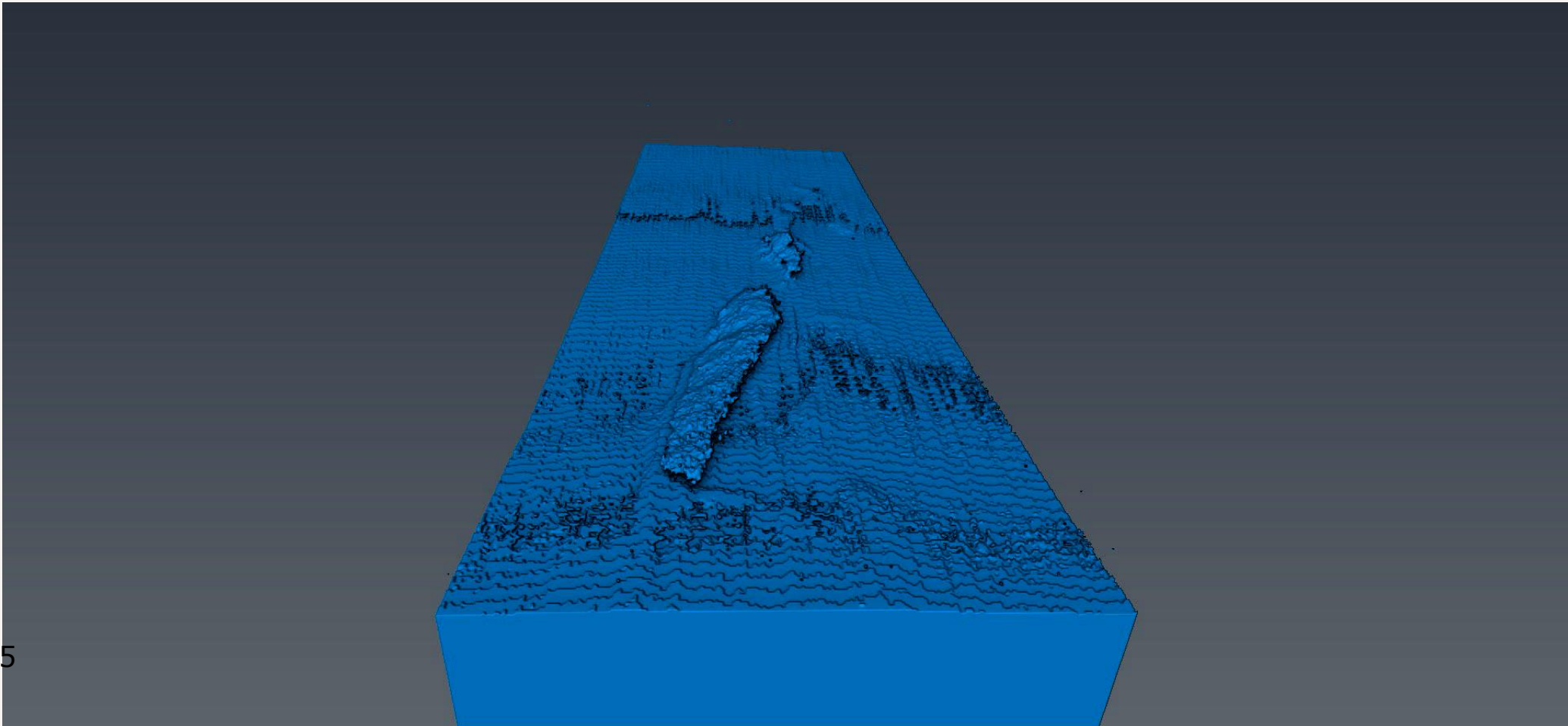
Cracks initiated at transition between martensite and pearlite in grinding marks



X-ray tomography of cracks in R350HT



3d representation of a martensite crack in R350HT

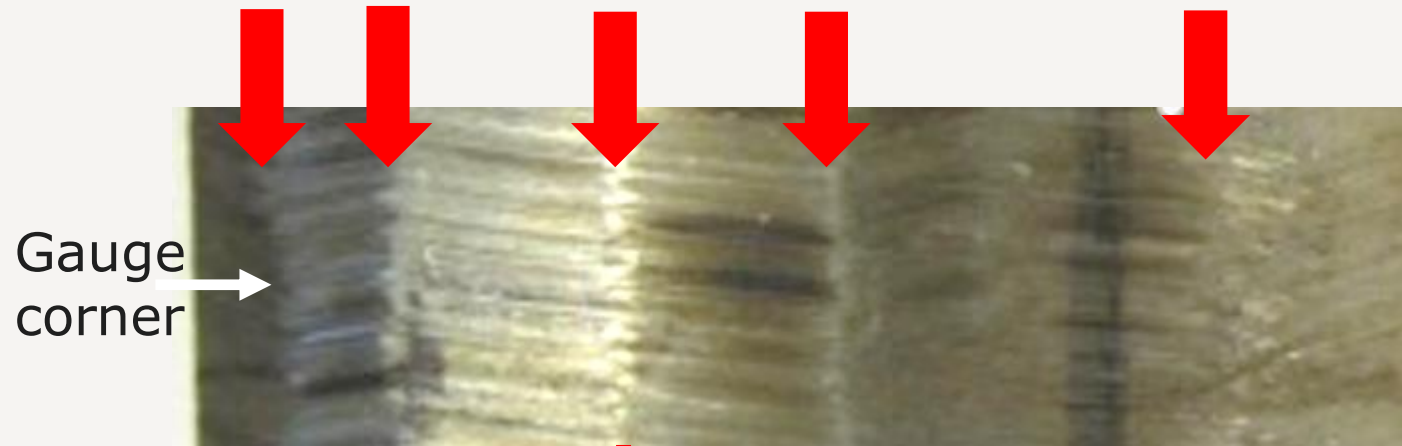


Facets from flat grinding stones

Gauge
corner →

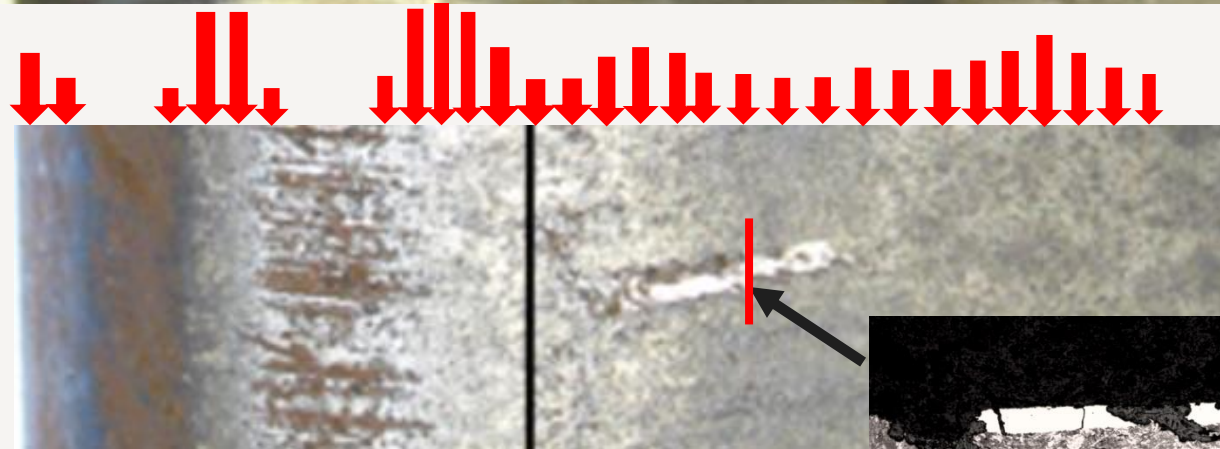


High stresses at facets just after grinding



Stresses

Just after grinding.



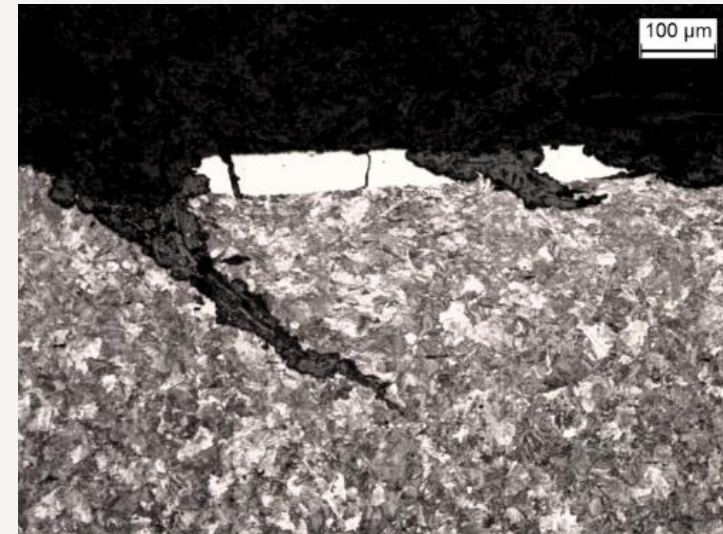
Stresses

After 5 MGT



Main factors for RCF cracks in R350HT

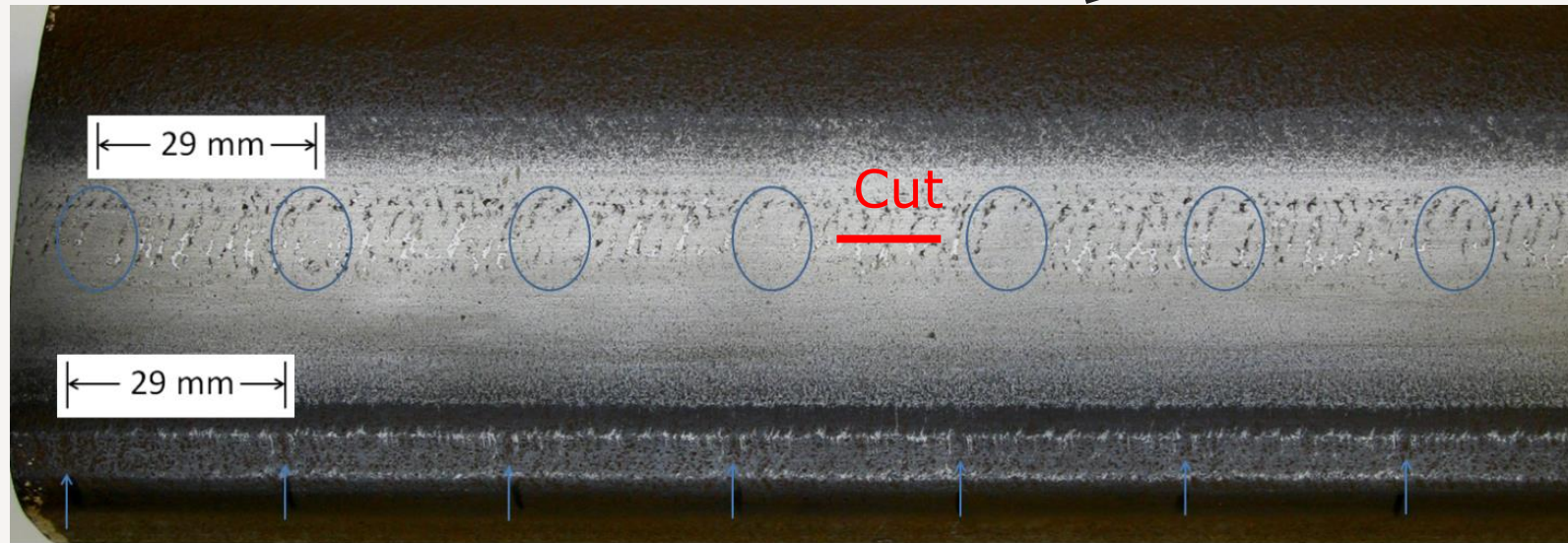
- Cracks initiates along the grinding induced hard and embrittle martensite and propagates down in the rail.
- R350HT is wear resistance –> grinded profile with facets and concentrated stresses stays for longer time.
- Shear stresses on high rail in curves



What about softer rails?
Why not similar type of cracks?

Sample of R200 rail from service

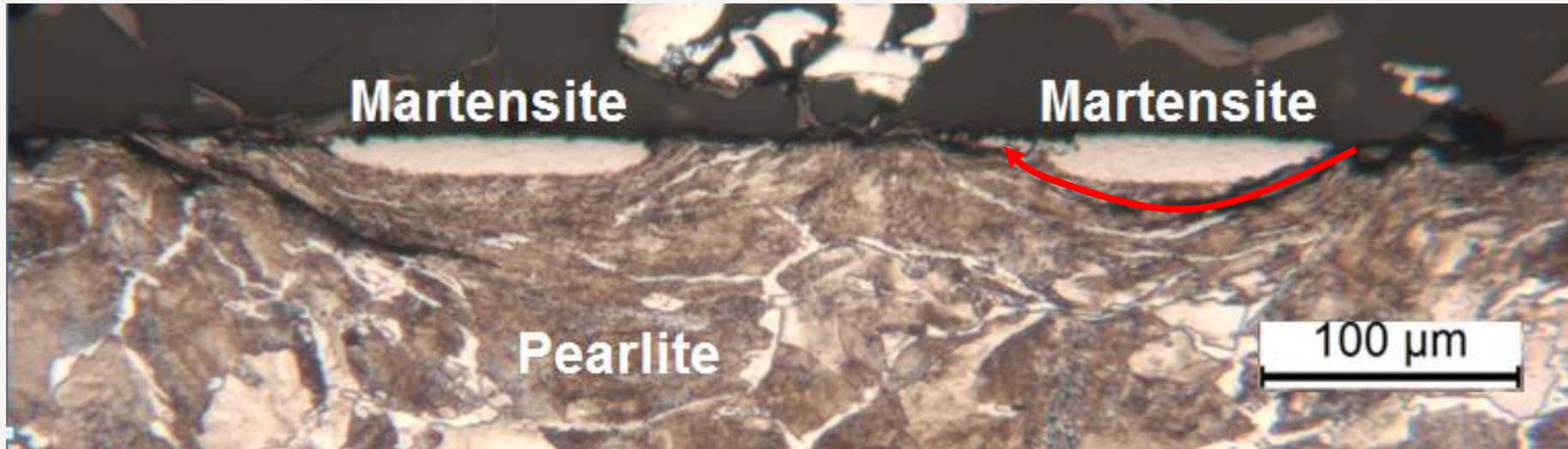
- Grinded in 2013 - extracted in 2016
- Total traffic: 2.7 MGT – **No RCF!**



Periodic bands - similar intervals as grinding marks

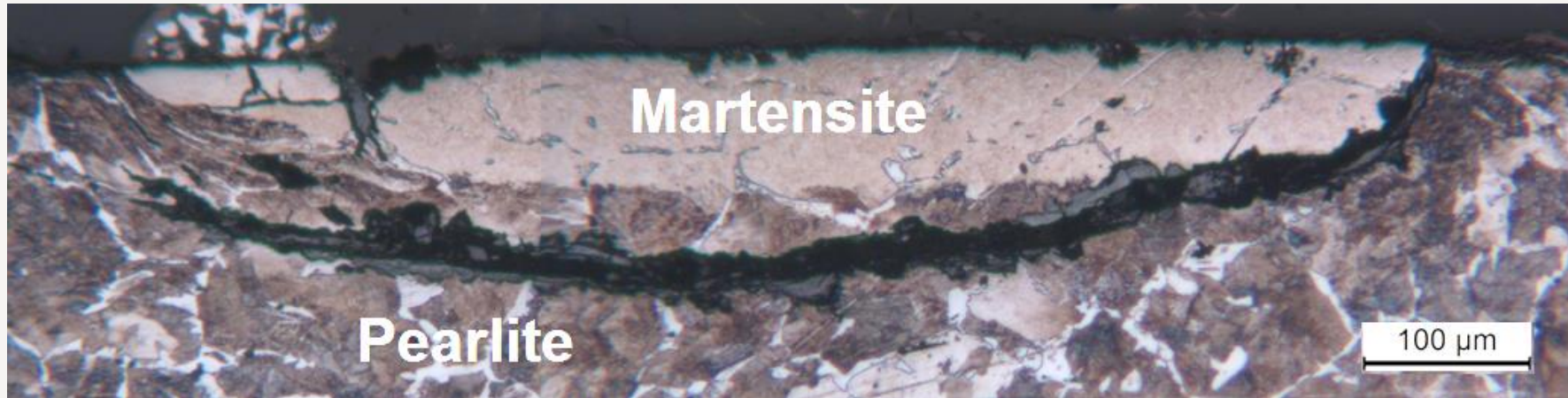


Martensite with cracks in R200



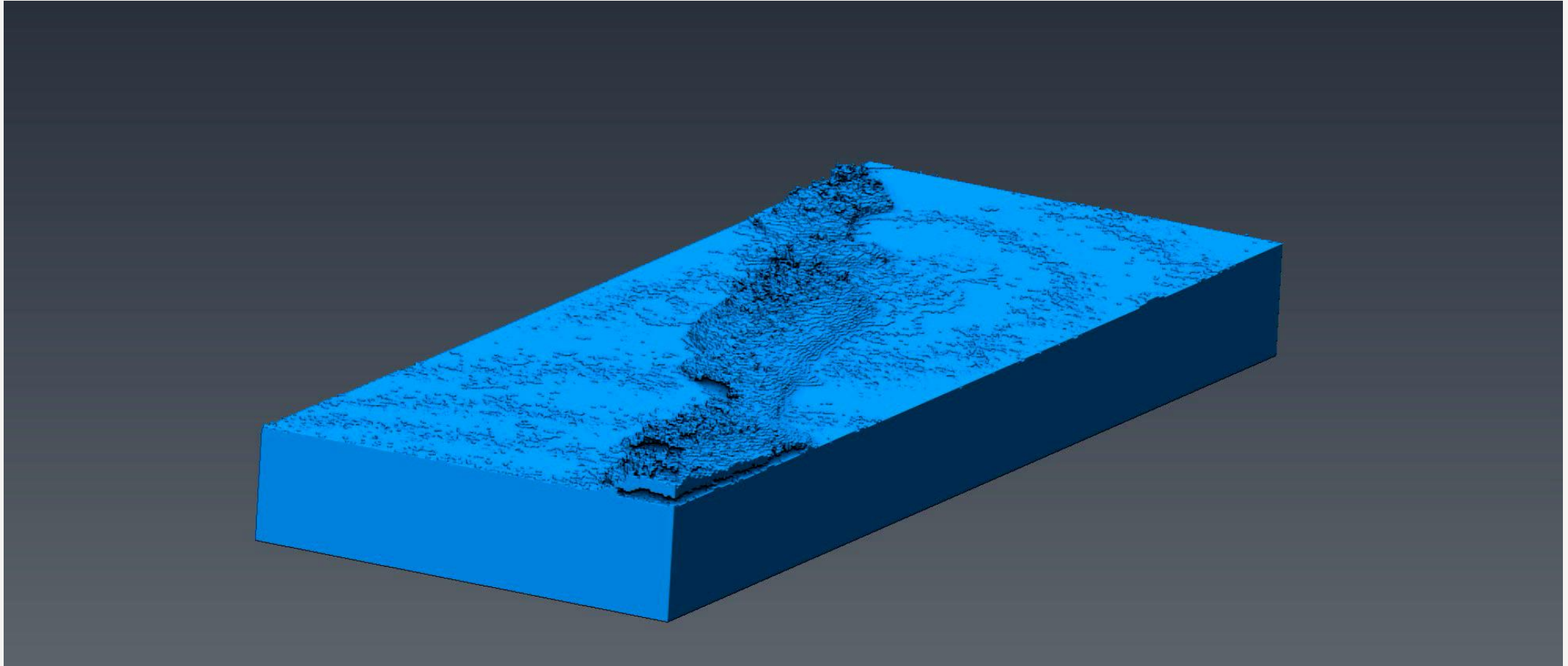
- > The martensite (≈ 1000 Hv) from grinding seems to be pressed down in the 5 times softer perlitic R200 resulting in plastic deformation under the martensite.
- > Cracks turn up with spallation to be expected.

Martensite with cracks in R200



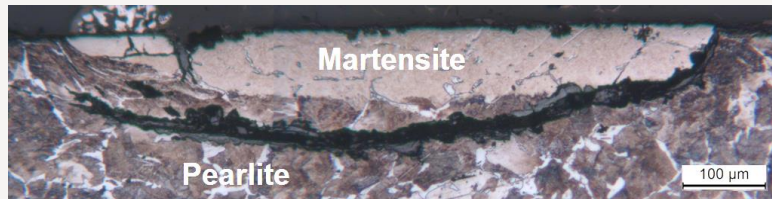
Cracks turns up - spallation to be expected

X-ray tomography of cracks in grinding mark in R200



Not RCF in R200 – why?

- Softer R200 -> Facets are worn away faster
- The martensite (≈ 1000 Hv) from grinding is pressed down in the 5 time softer perlitic R200 -> plastic deformation under the martensite.
- Initiated cracks propagates around along the zone with martensite up to the surface with spallation of the martensite -> **no RCF**.



What about R260?



Grinding induced RCF in Rails

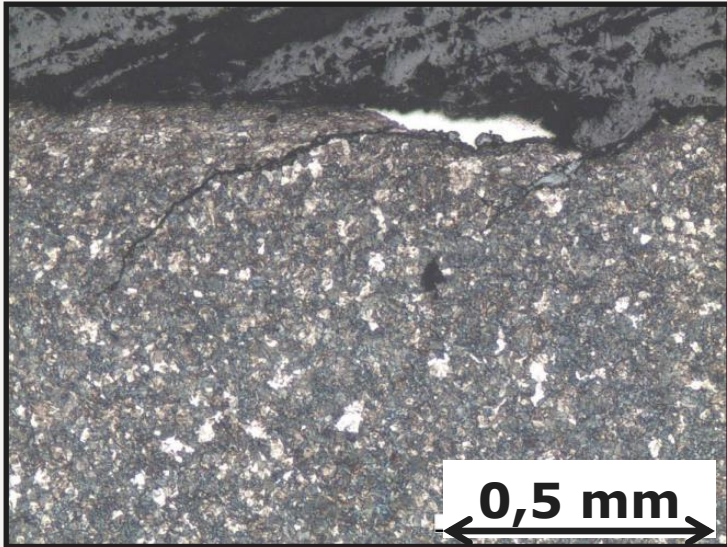
Final remarks

- This presentation shows that grinding marks in R350HT rails can lead to RCF cracks.
- An hypothesis why its not a big problem in softer rail steel like R200 is given.
- RCF cracks are influenced by a lot of different factors in very complex combinations.



Grinding-induced Rolling Contact Fatigue in Rails

Thank you for
your attention!



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