Impact of Stone Wear on the Rail Grinding Process and Surface Integrity Across Various Rail Grades

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Presenter: Lucas Biazon Cavalcanti

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Agenda

- **Introduction**
  - Rail grinding process;
  - Potential issues with grinding premium rails;
  - Objectives;
- **Methodology:**
  - Test setup;
  - Laboratory stone topography reproduction;
- **Results:**
  - Stone topography;
  - Grinding forces;
  - Grinding power, energy and material removal;
  - Ground surface and subsurface analysis;
- **Discussion:**
  - Laboratory and field correlation, heat partition and rail's metallurgy impact;
- **Conclusion, limitations and further directions:**

Introduction - Rail grinding process

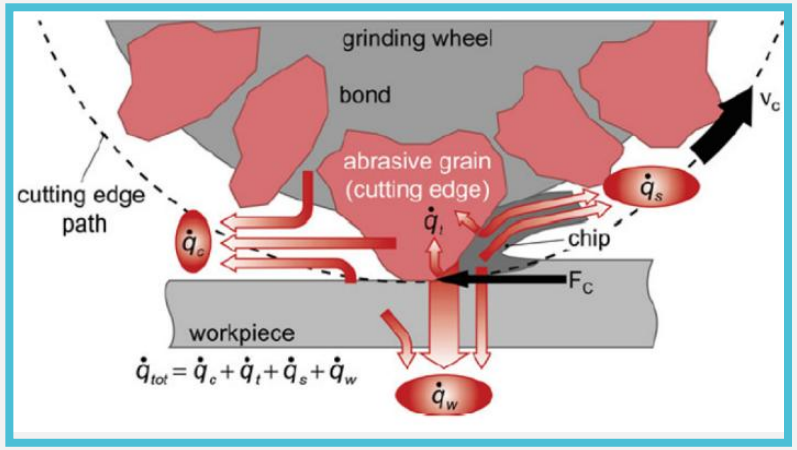
New and harder rail grades are used for better performance, but affecting maintenance

Wheel-rail interface 1
- Contact stresses
- Rolling-sliding contact

Deterioration 2
- Wear and RCF
- Corrugation

Rail grinding 3
- Profile correction
- Remove surface defects

New generated surface 4
- Surface topography
- Surface layer properties



Grinding parameters:
Power (depth of cut/normal force); Forward speed; Rotational speed; Rail head position

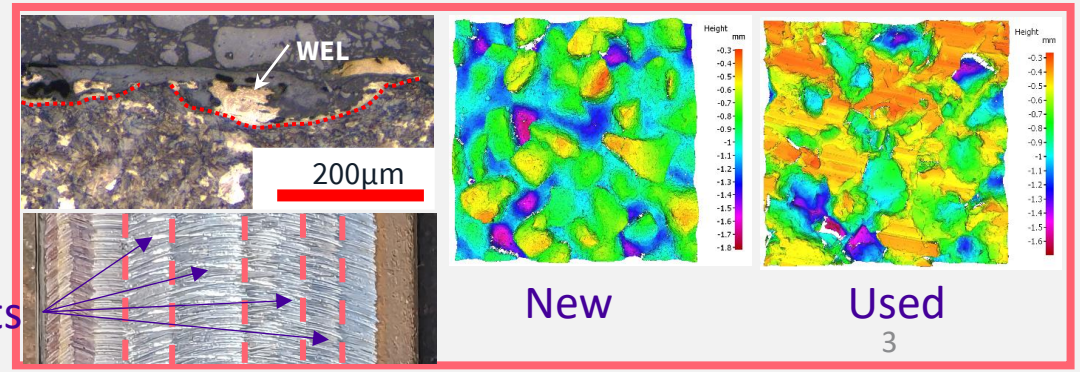
Rail properties:
Mechanical properties, metallurgical aspects

Stone properties:
Abrasive material, wheel hardness, porosity, grit size and topography

Material removal mechanism:
chip formation, forces, temperature, power, material removal

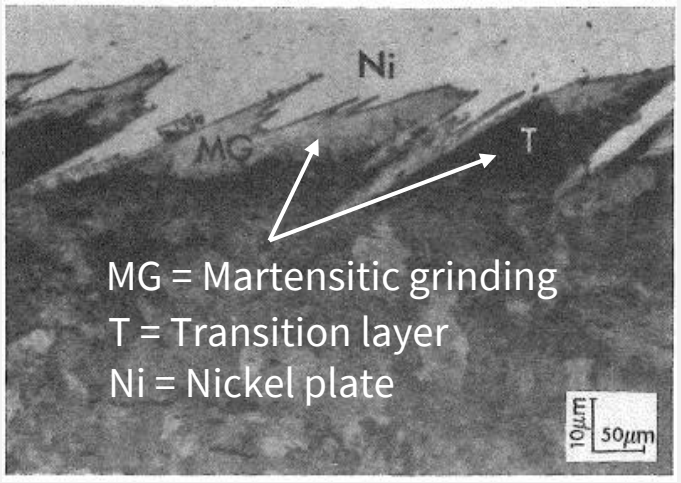
Rail surface integrity:
Surface roughness, WEL, hardness gradient, residual stresses

Stone wear:
Wear flat, grain fracture, etc.



Introduction - Potential issues with premium rails

- **Conditions:** Continuous power controlled material removal process without coolant and dressing the stones leads to excessive heat and produces WEL
- **Potential issues with premium rails:** WEL coupled with the premium rail's high wear resistance and track geometry irregularities (transverse profile, corrugation), may result in spalling defects.



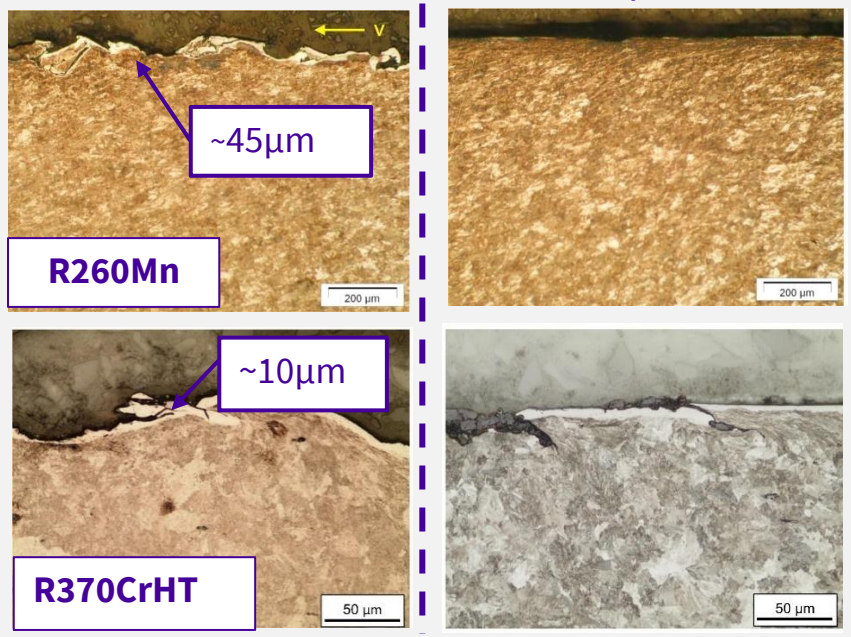
(KALOUSEK et al, 1989)

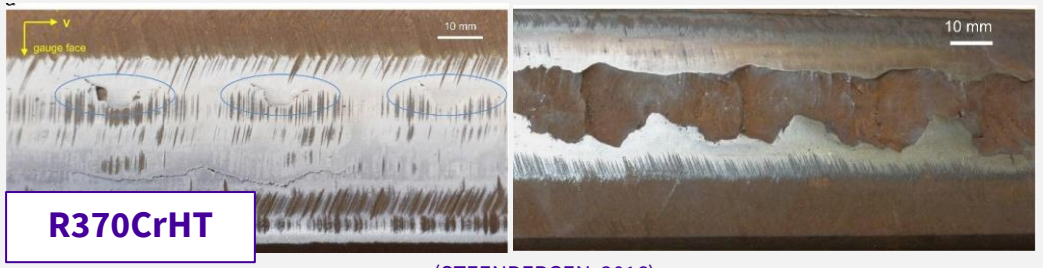
Immediately after rail grinding

After few days of operation

Standard grade
- Run-in remove WEL

Premium grade
- WEL stays in the surface during run-in





(STEENBERGEN, 2016)

Objectives and Methodology

- Evaluate the impact of **rail grades**, **depth of cut** and **stone topography** on *grinding forces, power, and material removal* while assessing rail surface integrity properties such as *surface roughness* and *grinding burn*.

Design of experiments

3x Rail grades :
A: Standard
B, C: Premium

3x Stone topographies:
Dull, Worn and Sharp

2x Depths of cut (µm):
100, 180

1x Feed speed (km/h):
2.1

1x Stone speed (rpm):
3500

Field rail grinding cases

4x Field grinding stones
1x new and 3x used

Process Monitoring

Grinding
Forces: piezoelectric (Dyno 9257B)
Power: CNC data machine recording
Material Removal: Micrometre gauge

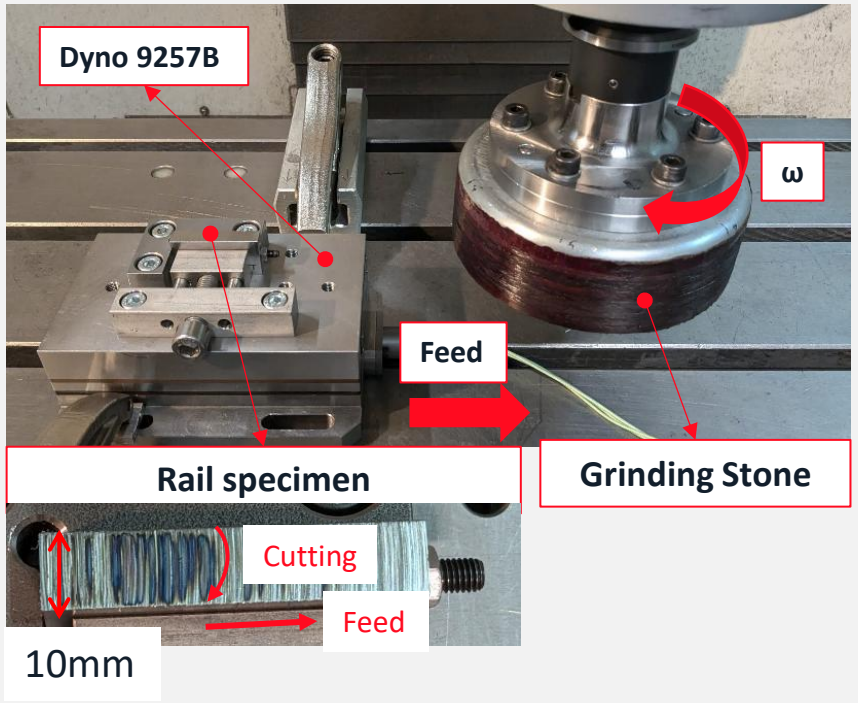
Characterisation

Rail samples
Surface Roughness: Optical 3D (Alicona InifiniteFocusSL)
Subsurface: Optical microscope

Stones
Topography: Optical 3D (Alicona InifiniteFocusSL)
Wear flat: Image segmentation (Field stones) and Optical 3D (Lab stones)

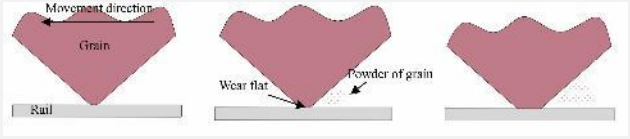
Methodology – Test setup

- **Laboratory rail grinding**
  - A vertical milling CNC machine was adapted to accommodate a grinding stone with similar composition from field
    - Max power: 28 hp
    - Max feed speed: 2.5 km/h
    - Front end and back end cutting
    - Samples dimensions: 50mm x 10mm
      - Removed from new rail head (~5mm from surface)



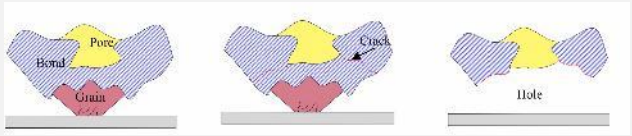
Methodology – Stone Topography Reproduction

- **Field:**
  - Natural Wear



Wear flat generation

Grain fracture



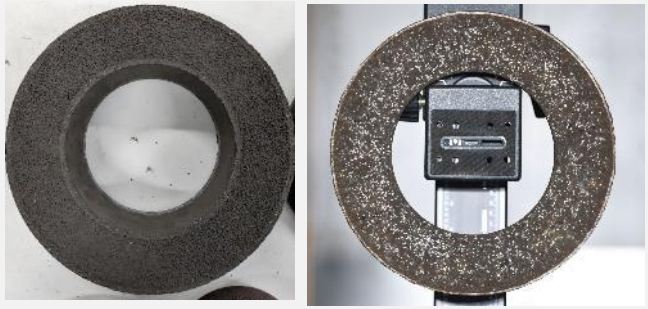
Grain pull-out

Reproduce stone's topography

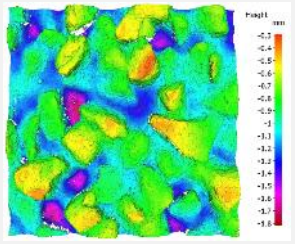
- **Laboratory:**
  - Artificial wear by dressing

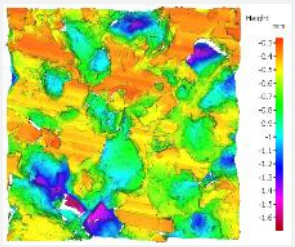
Star wheel

PVD insert



New



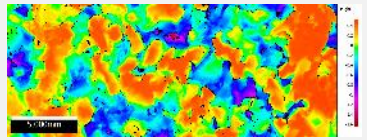


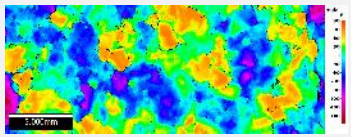
Used

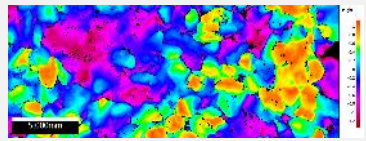
Dull

Worn

Sharp

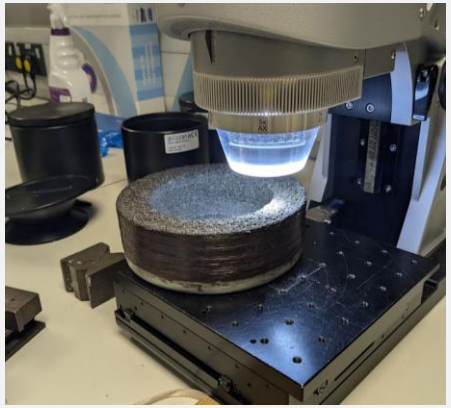


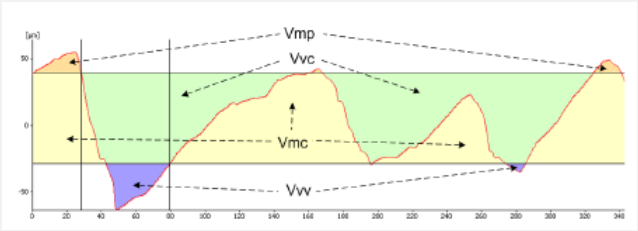


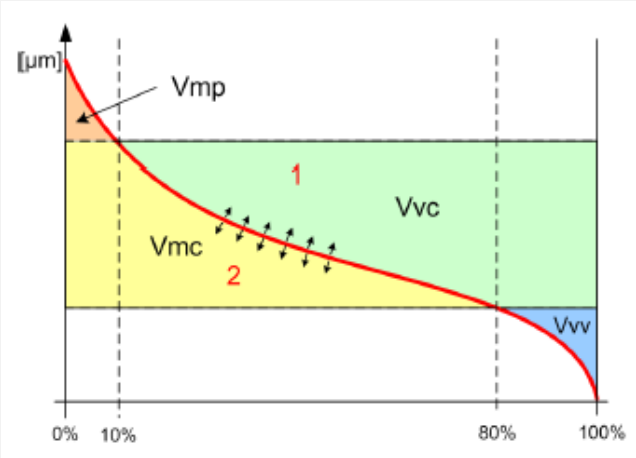


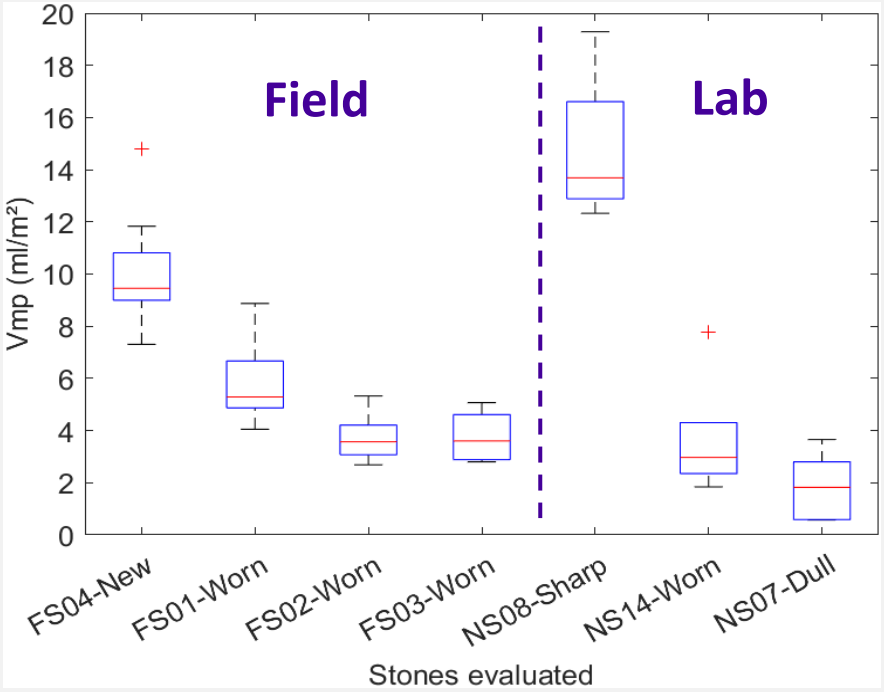
Results - Stone Characterisation

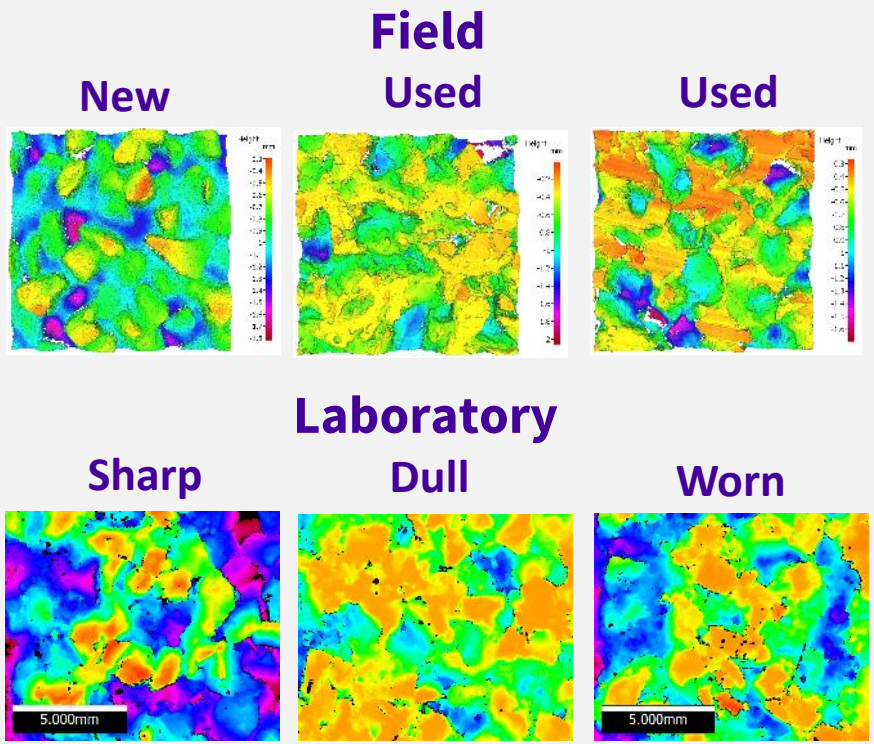
- **Stone Topography:**
  - Vmp parameter: Peak volume
  - Optical 3D device measurement based on focus variation (Alicona InfinityFocus SL)







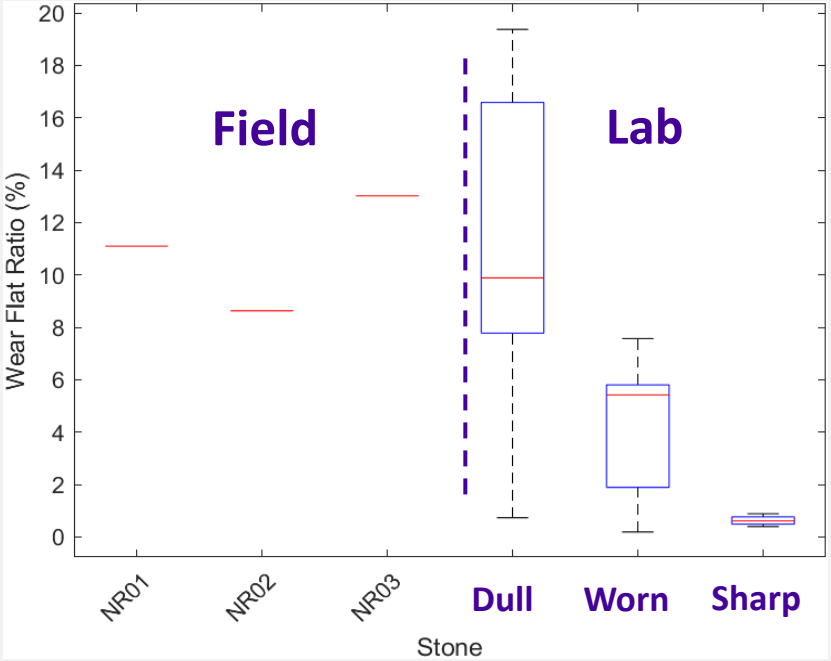




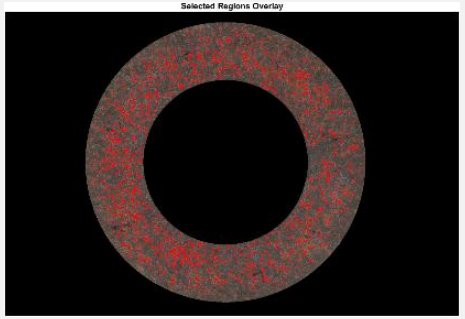
Results - Stone Characterisation

- **Stone Topography:**
  - Field: Long distance photography with image segmentation based on the reflective flat spots
  - Lab: Optical 3D device measurement based on the contour area at a given depth

Wear Flat (%)

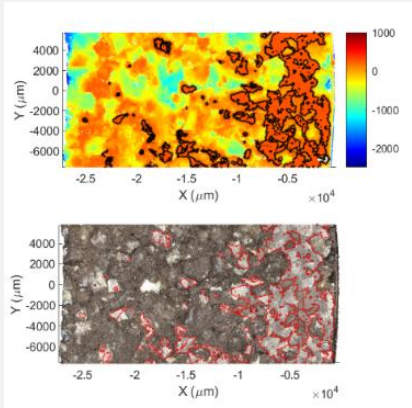


Field

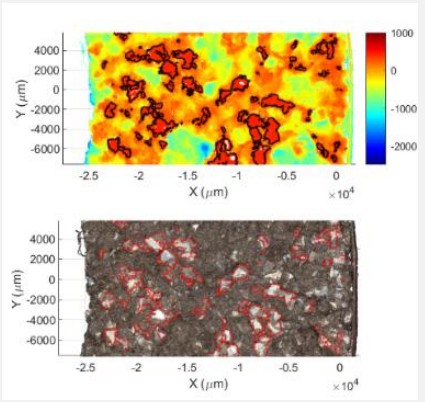


Laboratory

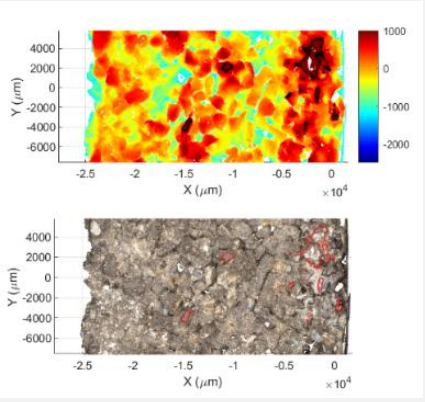
Dull



Worn

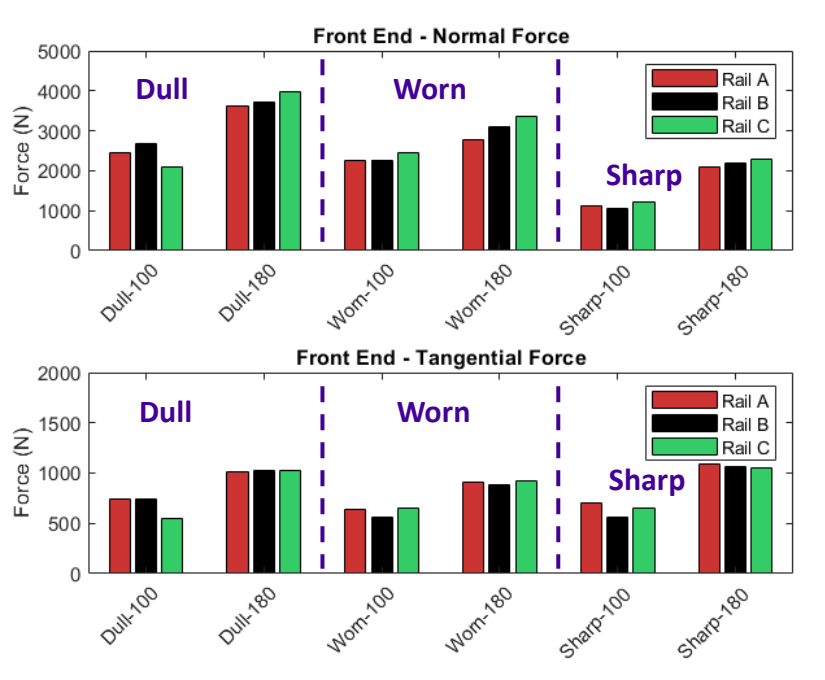


Sharp

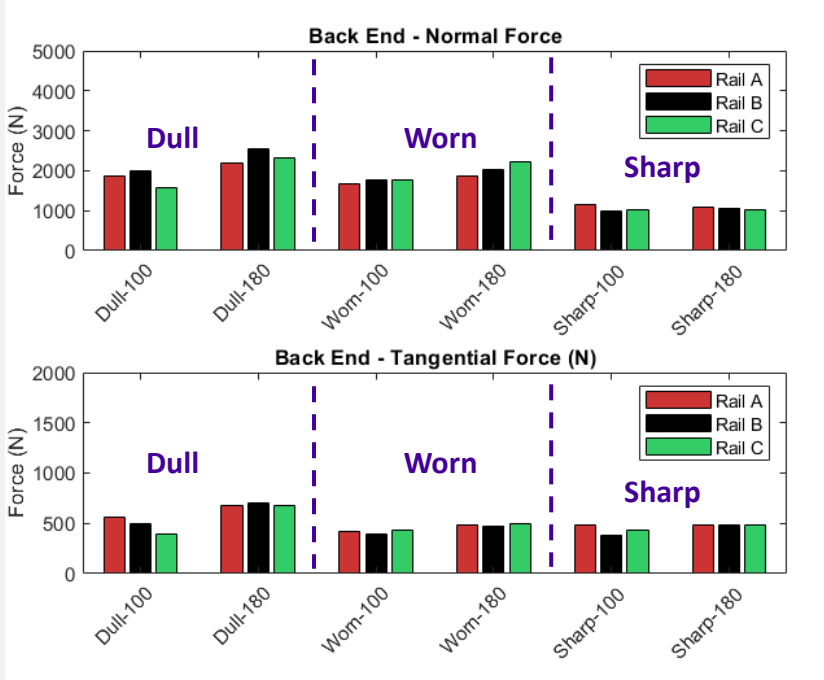


Results – Maximum Grinding Forces

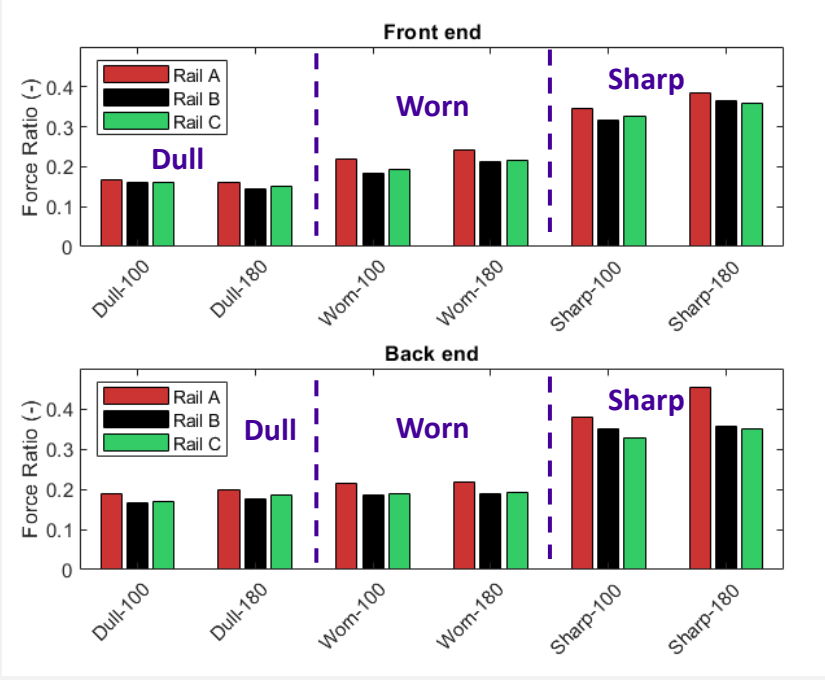
Front end - Normal and Tangential

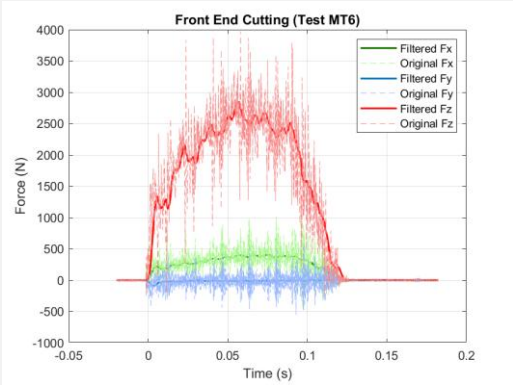


Back end - Normal and Tangential



Force Ratio



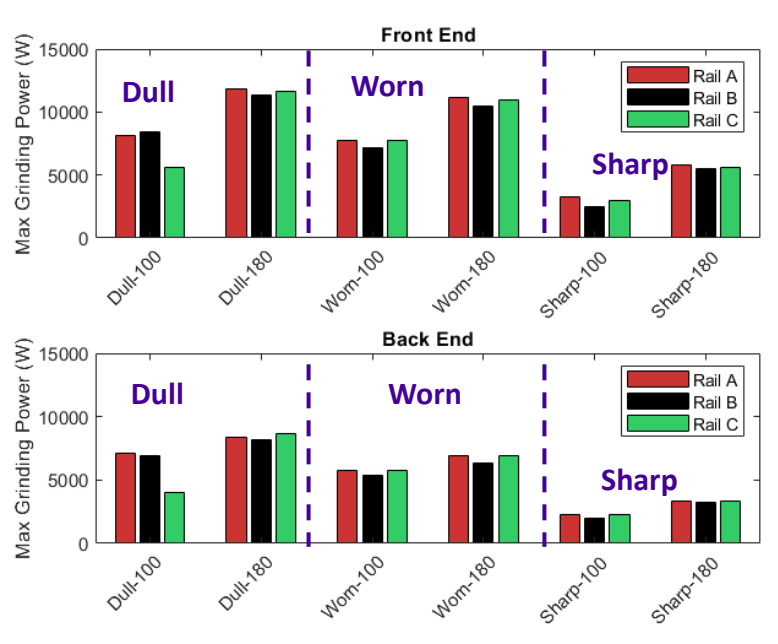


Force measurement data

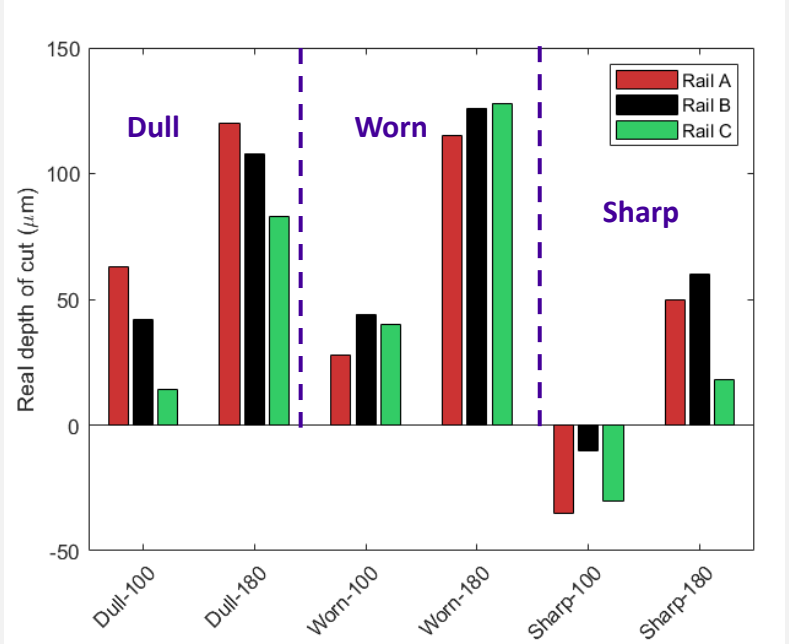
- Front end generated higher forces than back end
- Higher normal forces due to stone dullness and higher depth of cut but not clear diferences between rail grades
- Tangential forces increases with depth of cut
- Force ratio increases with stone sharpness

Results – Maximum Power, Total Energy and Material Removal

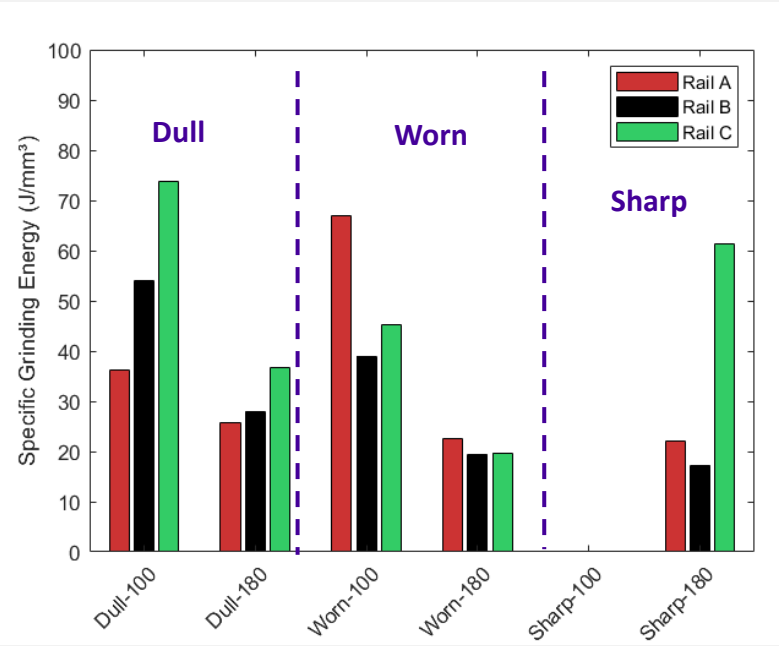
Max Grinding Power

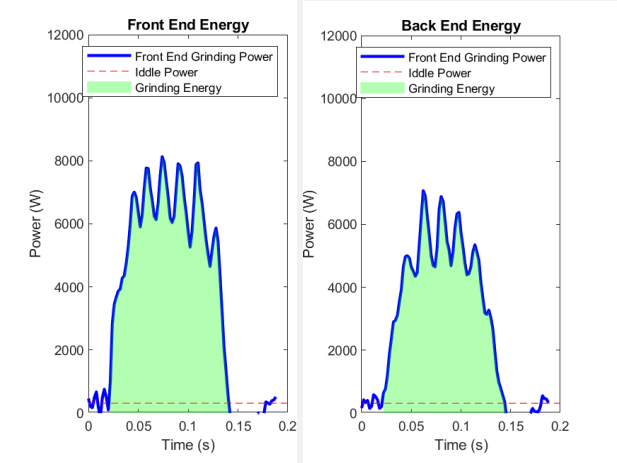


Real depth of cut



Specific Grinding Energy



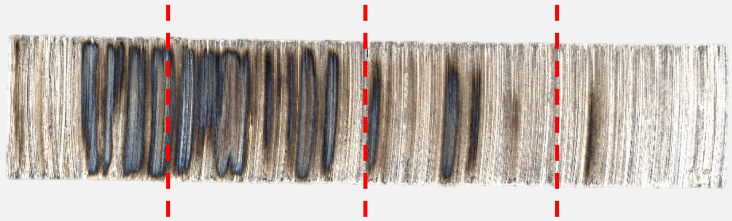


Grinding power data

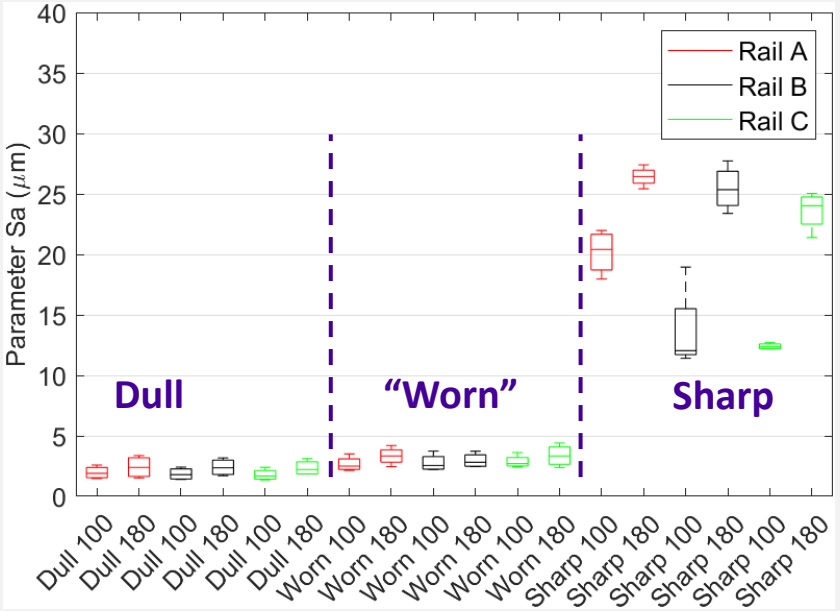
- Increasing power requirement with depth of cut, but reduced required power consumed with sharp stones
- No clear differences of power consumption between grades
- Less material was removed for harder grades with dull stones and worn stones, while scattered results from sharp stones
- Clear trend of efficiency between grades for dull stones and scattered results for worn and sharp

Results - Surface Roughness

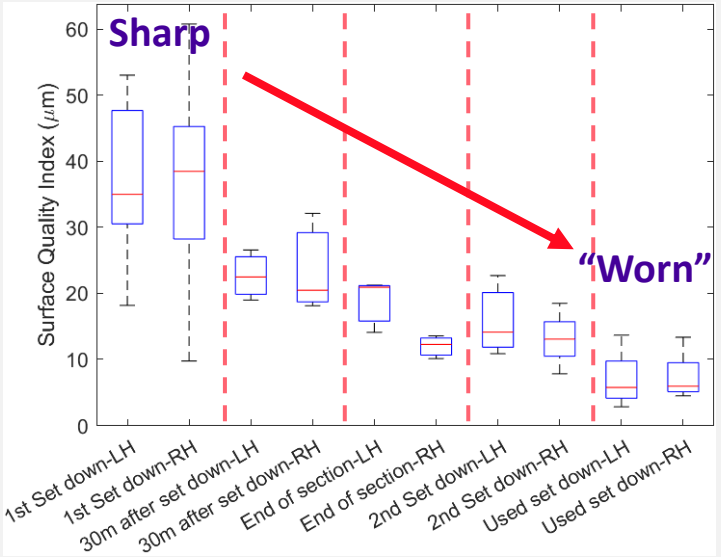
Laboratory Rail Grinding Tests

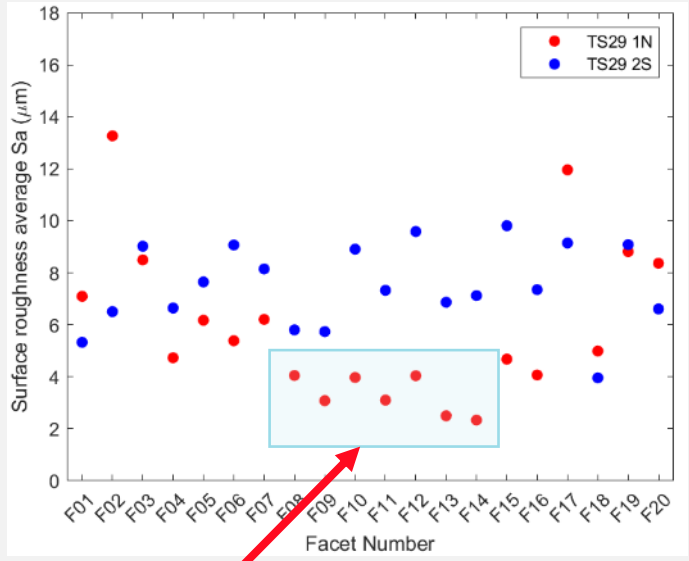


4x measurement areas
12.5mm x 9mm = 112.5mm²



Field Rail Grinding

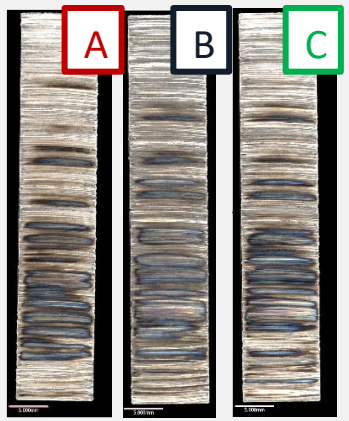




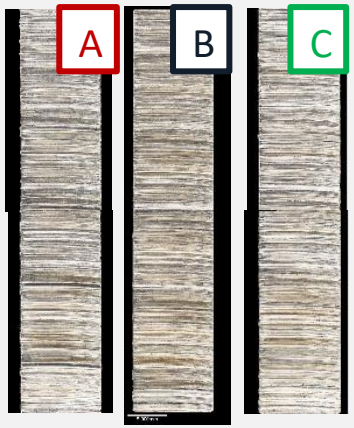
Rail crown ~10mm facet

Results – Subsurface (WEL)

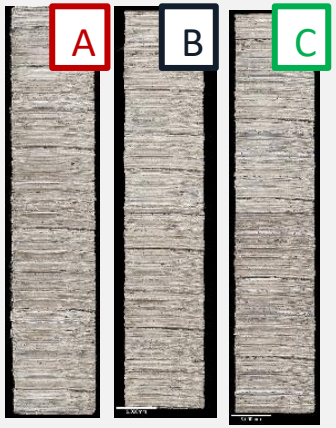
Stone: **Dull**
Depth of cut: **180µm**

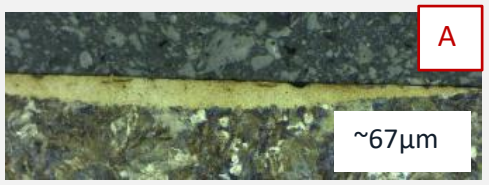


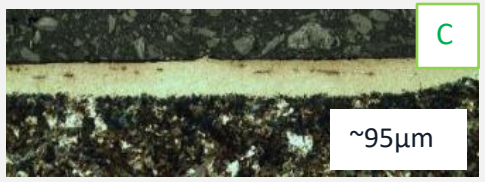
Stone: **Worn**
Depth of cut: **180µm**

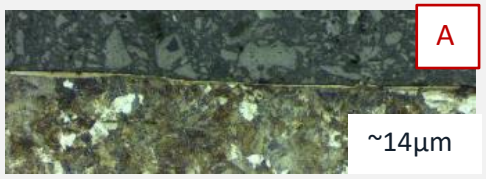


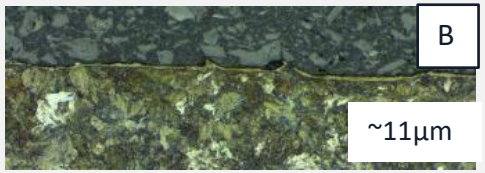
Stone: **Sharp**
Depth of cut: **180µm**

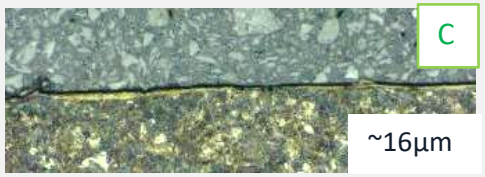


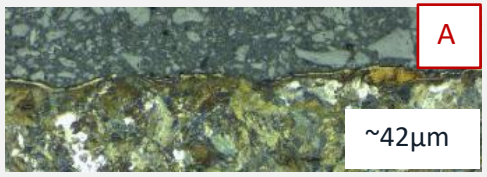


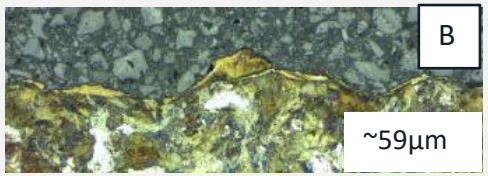


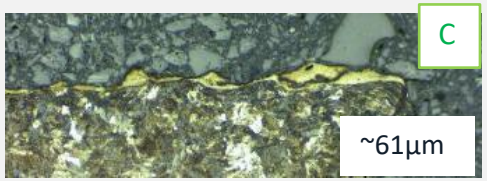


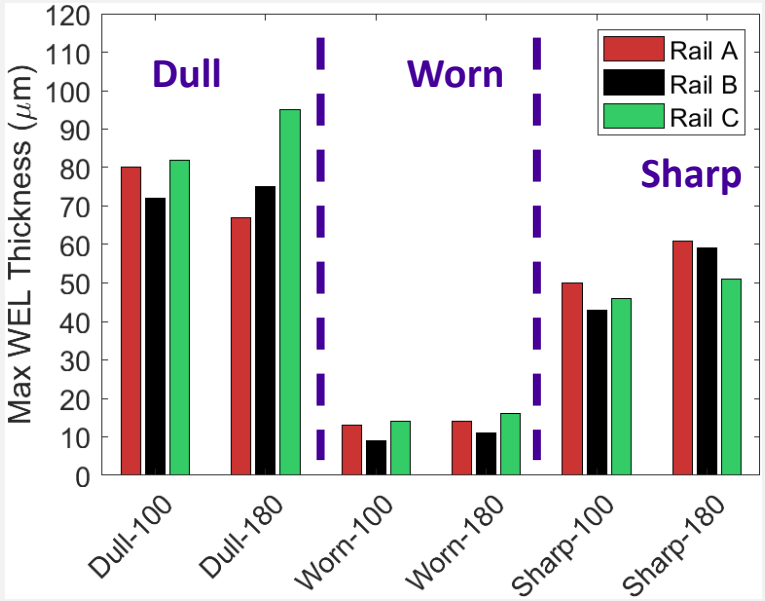


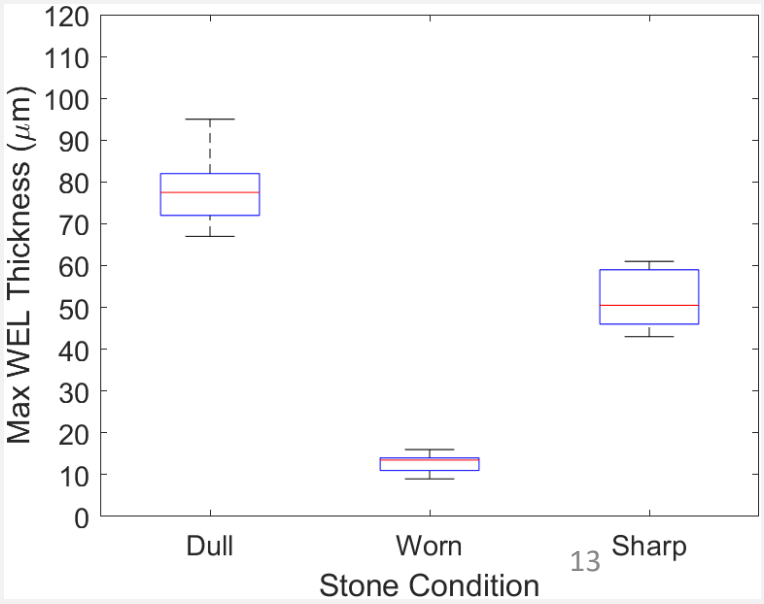








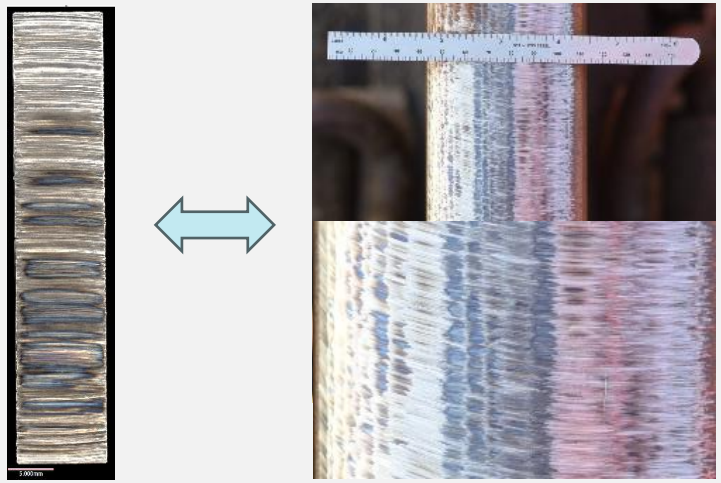


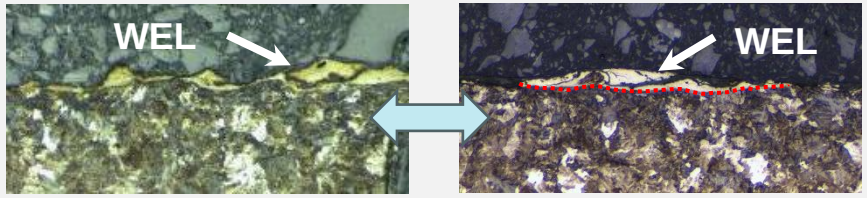


Discussion

- **Field and laboratory correlation**
  - Laboratory reproduced similar field events

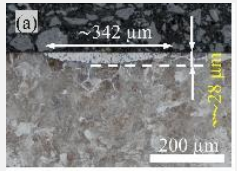
Laboratory **Field**



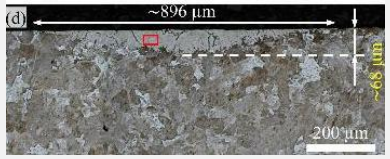


- **Rail Grade Aspects**
  - Suscetability of WEL formation with different heat inputs

Standard Grade

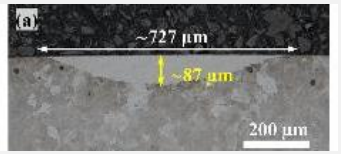


342 x 28 µm
22.5 J/mm

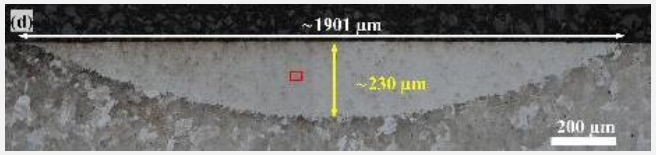


896 x 68 µm
77 J/mm

Premium Grade



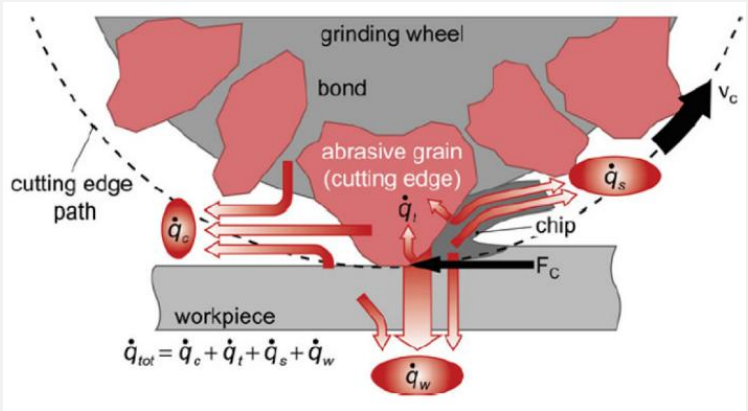
727 x 87 µm
22.5 J/mm



1901 x 230 µm
77 J/mm

(NGUYEN et al, 2022)

- **Stone Aspects**
  - Topography is affecting how much heat is generated and how much goes into raik (heat partition)



Conclusions, limitations and further directions

Conclusions:

- Field rail grinding revealed rapid changes in grinding stone topography from sharp to dull during use.
- Laboratory samples exhibited characteristics consistent with field trials.
- Stone topography had a greater influence on surface integrity properties (e.g., surface roughness, WEL thickness) than rail grade or depth of cut.
- Laboratory experiments identified optimal topography (e.g., peak volume and wear flat ratio) for achieving low surface roughness and thinner WEL.

Limitations:

- Laboratory experiments cannot replicate field train speeds or grinding stone sizes.
- Controlling method differs between field (power percentage) and laboratory (depth of cut)
- Stone topography differs between field (natural wear) and laboratory (artificial wear).

Further Directions:

- Assess hardness gradient in tested samples.
- Include other morphology parameters in the WEL quantification
- Analyse field grinding stones at varying stages of wear and consumption.
- Measure grinding temperature to estimate heat partition.
- Scale up test samples to replicate rail grinding patterns
- Test rails with different loading history
- Perform Wear and RCF tests on ground sample

Thank you for your attention.

Impact of Stone Wear on the Rail Grinding Process and Surface Integrity Across Various Rail Grades

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