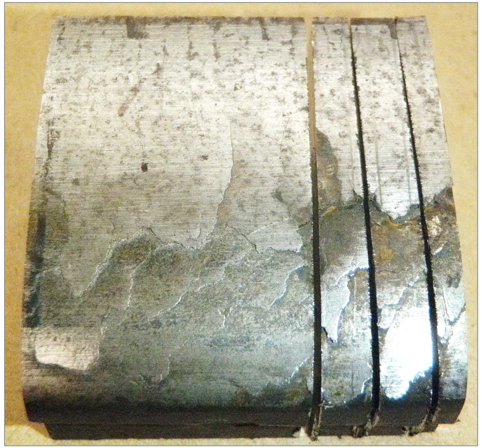
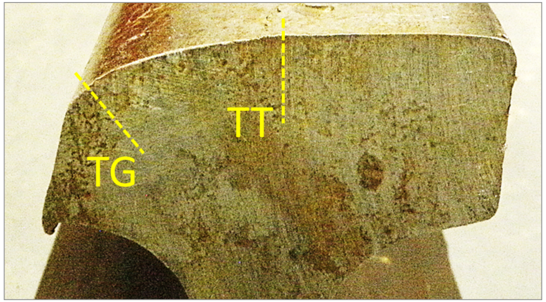
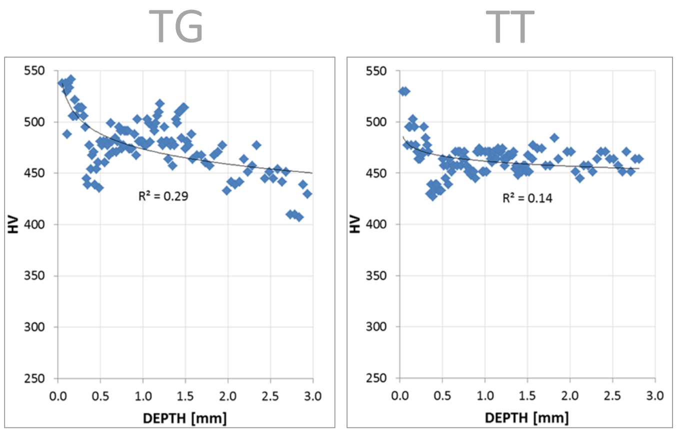
ICRI Studies on RCF and Rail Grinding





TT: Transverse Top-of-Rail (TOR)

TG: Transverse Gauge

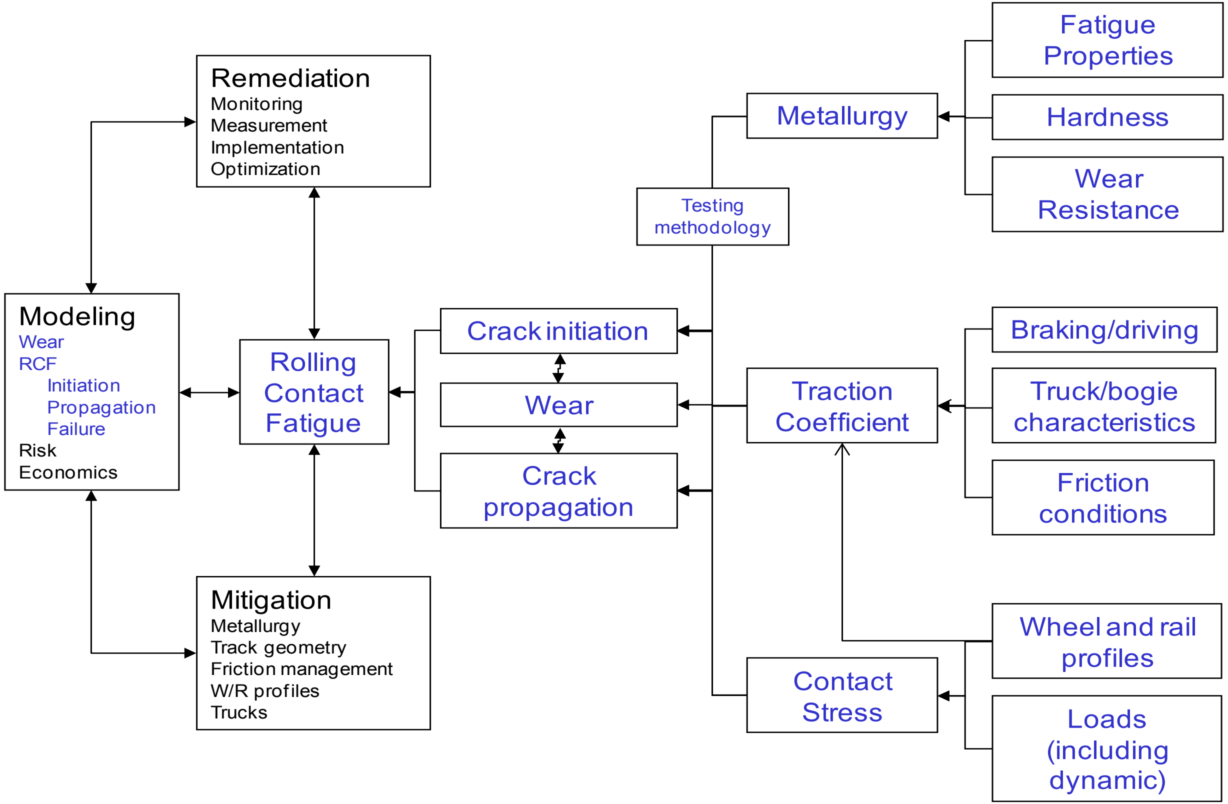


Eric Magel and Daniel Szablewski
Automotive and Surface Transportation
National Research Council of Canada

Outline

- ICRI Introduction
- 4 ongoing projects related to RCF
  - Quantifying Surface Damage
  - Performance of new rail before first grinding
  - Predictive rail grinding
  - Damage modeling

Managing Rolling Contact Fatigue



2011 – FRA workshop
Magel: RCF Review

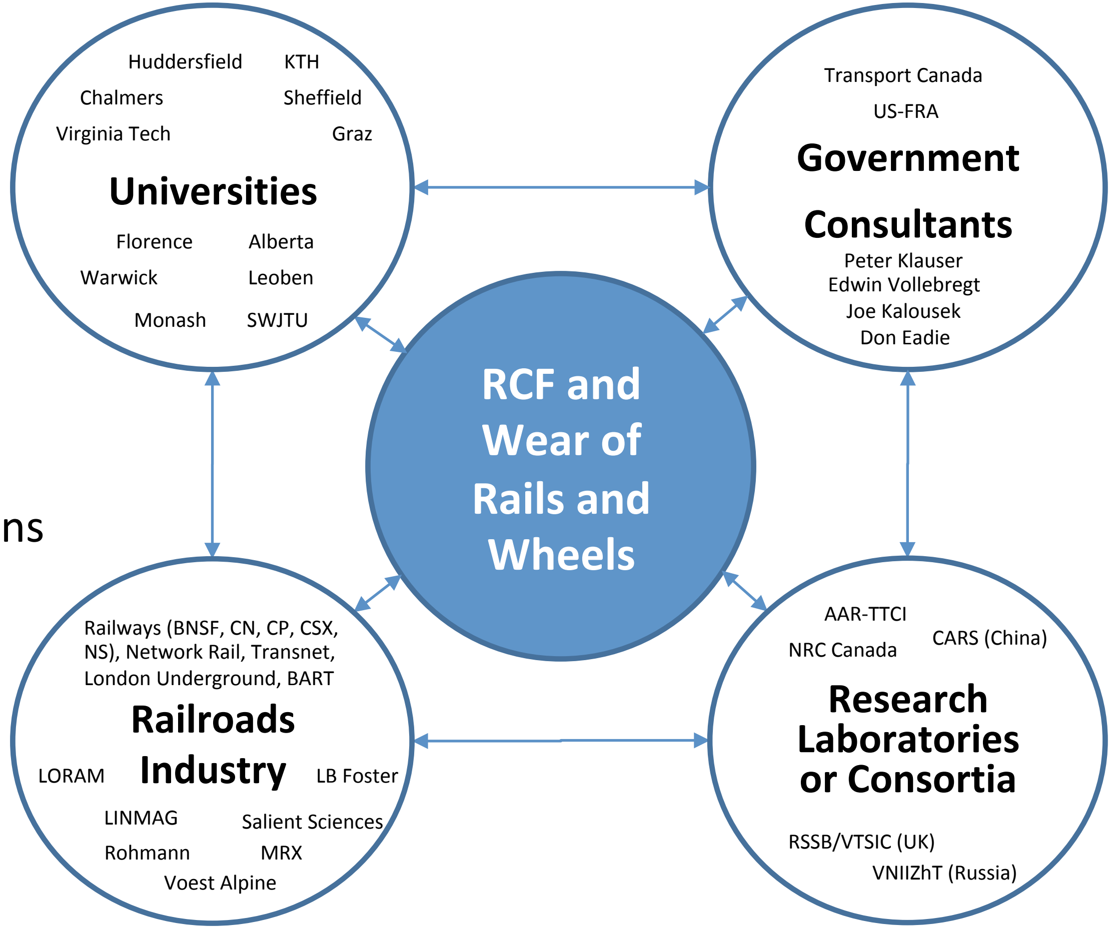
ICRI – International Collaborative Research Initiative

- Bring together interested parties to work on topics of common interest
- Leverage resources (personnel, models, data, field studies) where they can be shared
- Minimize overall costs – no "re-inventing the wheel"
- Minimize administrative overhead – informal, "open-source"

The ICRI - operating model

- Participants contribute data, expertise, models, ideas *from existing projects*
- All contributions are "in-kind"
- The ICRI IS NOT a funding body. Each participant is self-funded (obtains funding by conventional means from existing clients)
- Information shared amongst all participants
- For most: not explicitly looking for new money, but need authority to share
- "Open Source" model

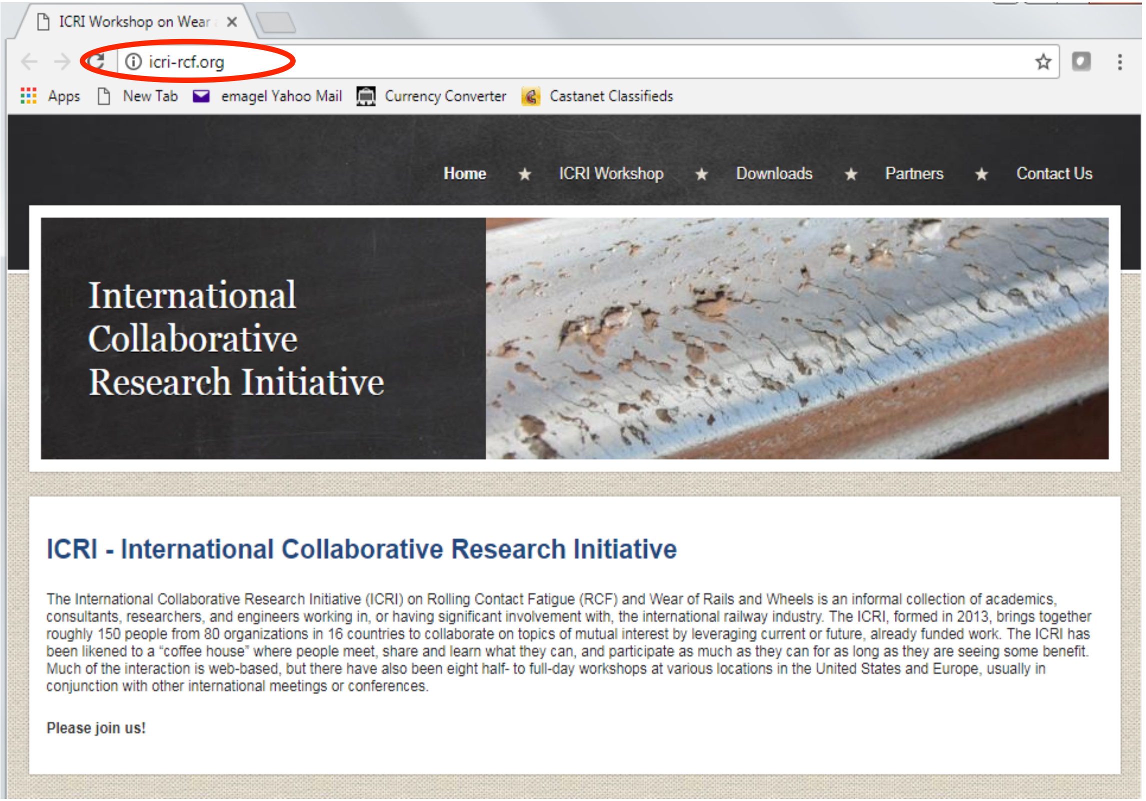
175 persons
16 countries
80 organizations



Current Projects & Leads

HEAV

ICRI Website: icri-rcf.org



Acknowledgements

U.S. Department of Transportation Federal Railroad Administration

virtual vehicle

MRX TECHNOLOGIES

Transport Canada / Transports Canada

CSX How tomorrow moves

CN

Canada NRC·CNRC

LORAM SPEED PERFORMANCE RELIABILITY

NS NORFOLK SOUTHERN

BNSF RAILWAY

UNIVERSITY OF ALBERTA

University of HUDDERSFIELD Inspiring tomorrow's professionals

eRT Rohmann GmbH

SPERRY

TTCI Transportation Technology Center, Inc.

1. Quantifying Surface Damage / Crack Modeling

Daniel Szablewski, National Research Council, Canada

RCF

Inspection Methods

- Visual surface assessment
  - Human+machine
- Non-destructive:
  - Dye penetrant
  - Magnetic particle
  - Walking stick (Rohmann, MRX, Sperry)
- Destructive:
  - Cutting
  - Milling
  - Metallography
    - LOM, SEM

Factors to Consider

- Rail type
- Position in curve
- Track curvature
- Lubrication
- Traffic:
  - Axle load
  - MGT accumulation
  - Frequency
- Maintenance practices
  - Grinding/Milling
    - Frequency
    - Amount

Outcomes to Evaluate

- RCF location:
  - TOR vs. GF
- RCF severity:
  - Mild vs. Severe
  - Depth of spalling
- RCF crack morphology:
  - Length, depth, angle to rail surface, density & distribution, amount of branching
  - Propagation in rail microstructure
    - Trans-granular vs. inter-granular
    - Assisted by inclusions (rail cleanliness)

Rail Performance in Service

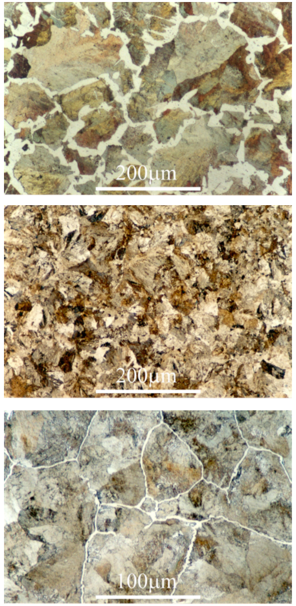
Chemistry vs. Microstructure

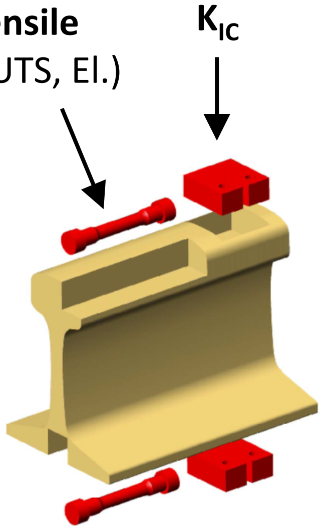
Microstructure vs. Mechanical Properties

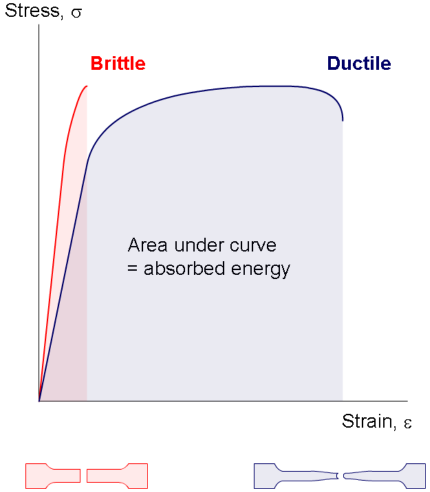
Hypoeutectoid

Eutectoid

Hypereutectoid

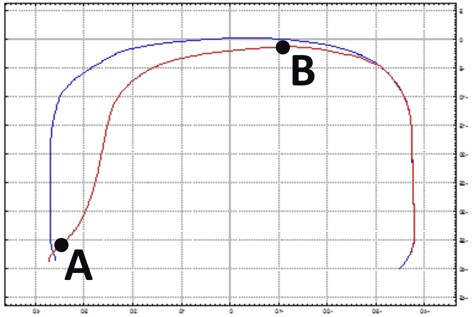


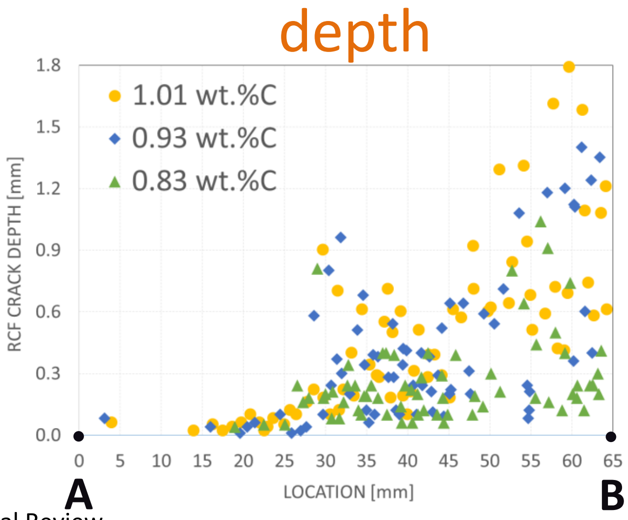


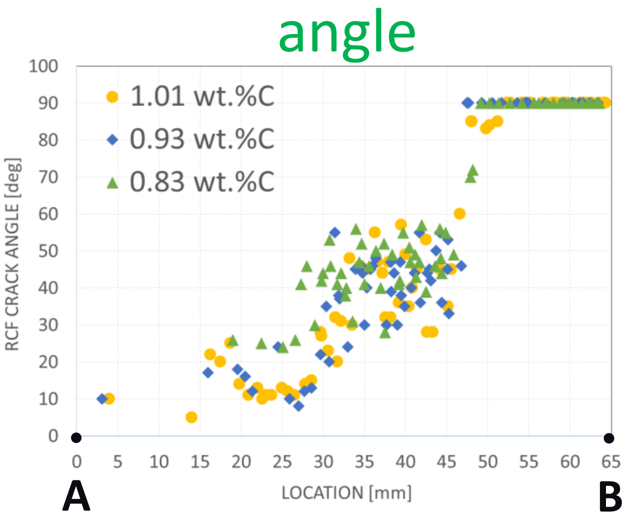


Crack Morphology

- High rail quantitative RCF assessment on a **5 degree curve**
- RCF crack depth & angle analyzed in 3 rail types with varying Carbon content

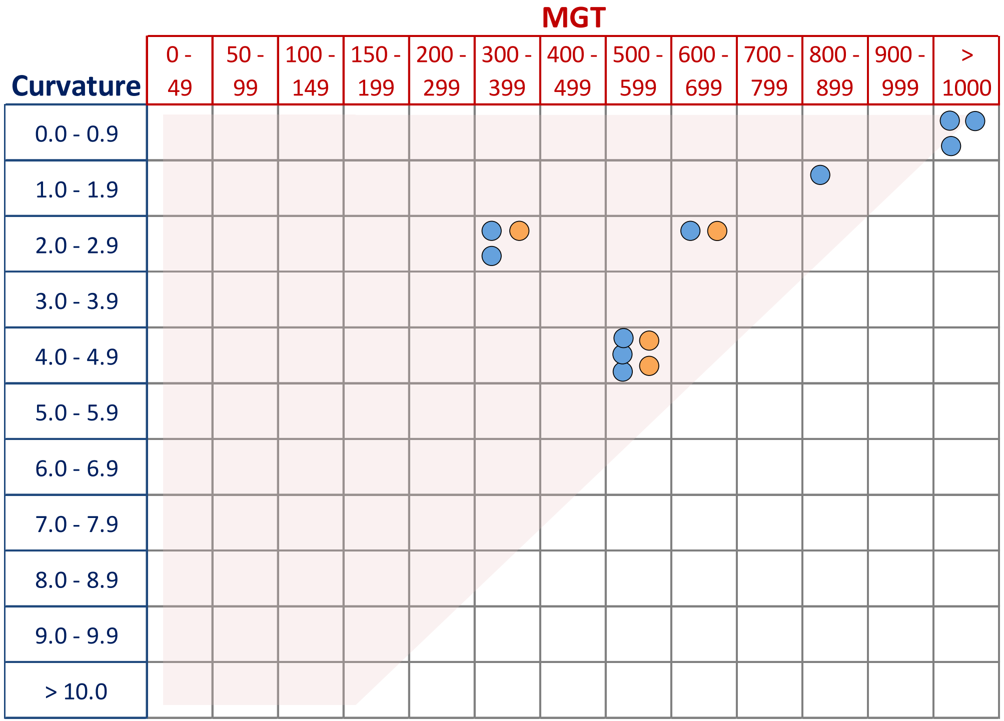






Transportation Technology Center, Inc. Reference: 2013 TTCI Annual Review

Quantifying Rail Surface Damage – RCF Matrix



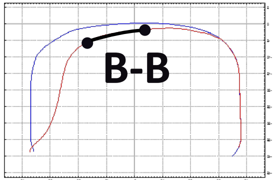
Rails Analyzed to Date:

- 90 degree cut
- 45 degree cut

Layers to Consider:

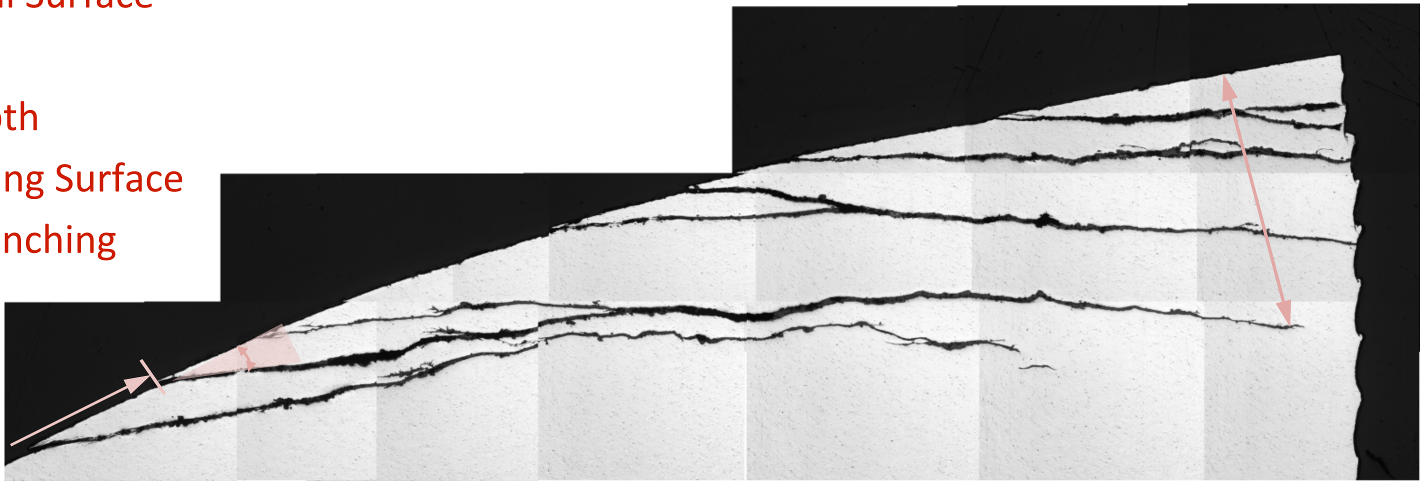
- High & Low Rails
- Rail Grade (i.e. standard, intermediate, premium)
- Track Curvature (i.e. variable radius)
- Tonnage Accumulation (i.e. variable MGT in rail life-cycle)
- Running Surface Condition (i.e. dry, lubricated, TOR friction modified)
- Traffic Type (i.e. axle load, train speed)
- Maintenance Grinding (frequency and amount)

Metallography of Crack Morphology



RCF Morphology:

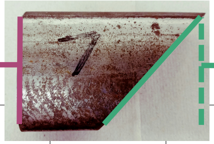
- Position on Rail Surface
- Length
- Maximum Depth
- Angle to Running Surface
- Amount of Branching



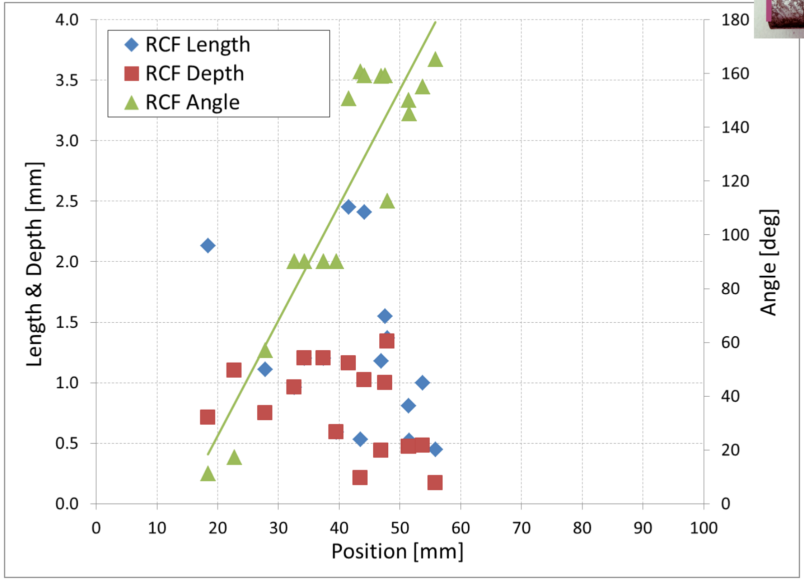
BNSF-7 rail:
2-Deg curve, high rail
1994 (most likely premium rail)

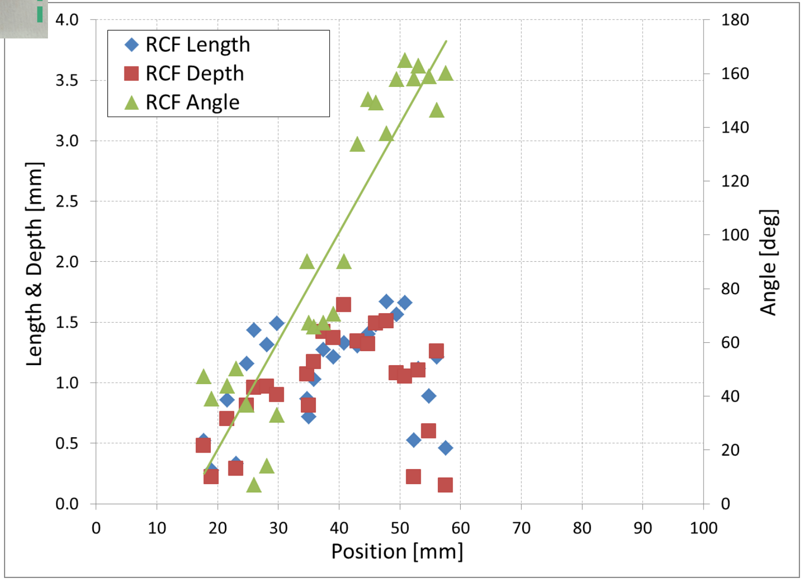
1-degree family of curves (preliminary results)

Assessment of RCF Length, Depth and Angle to running surface



Transverse Cut ← → **Angle Cut Component**

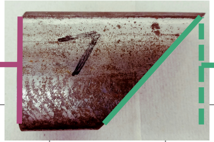




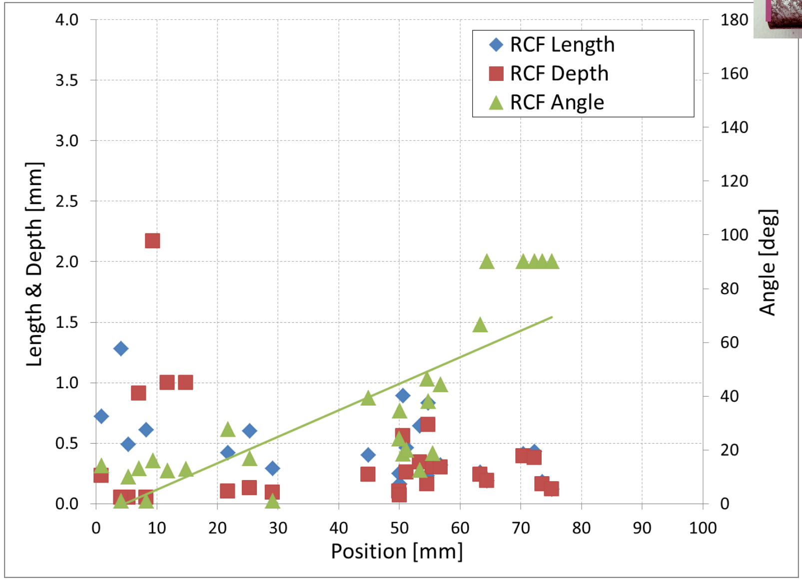
Note: Component calculation is for RCF Position and Length. RCF Depth and Angle are presented unchanged (as they remain the same in rail end-view).

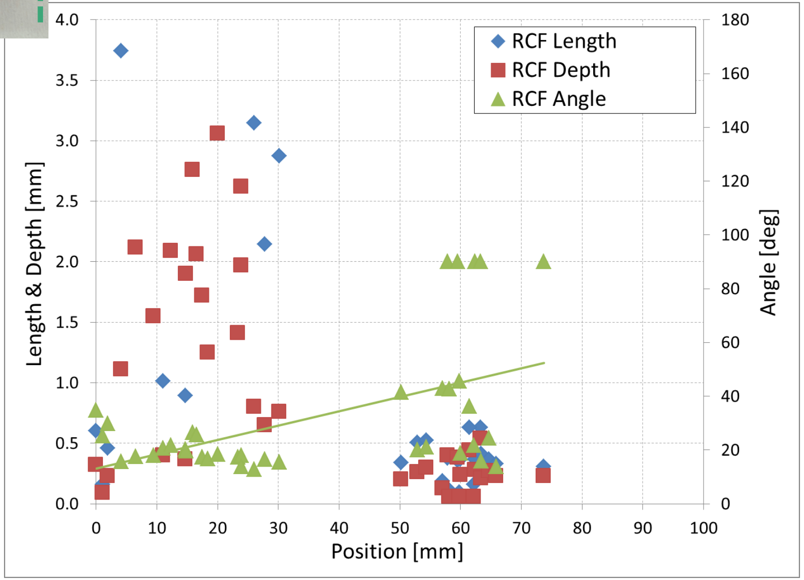
2-degree family of curves (preliminary results)

Assessment of RCF Length, Depth and Angle to running surface



Transverse Cut | **Angle Cut Component**

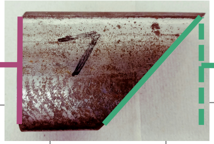




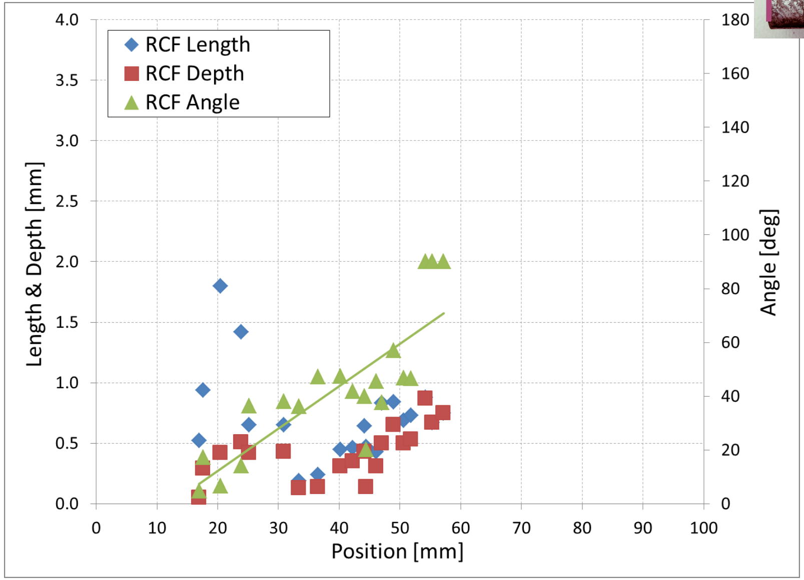
Note: Component calculation is for RCF Position and Length. RCF Depth and Angle are presented unchanged (as they remain the same in rail end-view).

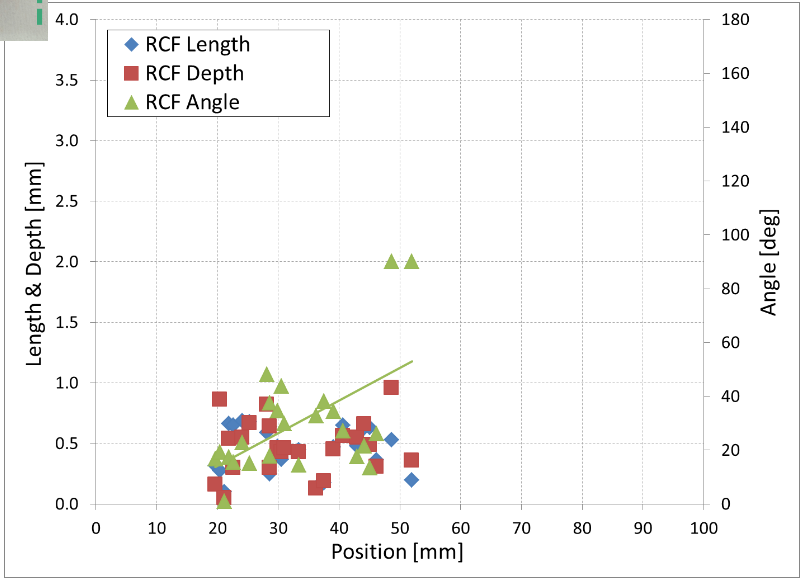
4.75-degree family of curves (preliminary results)

Assessment of RCF Length, Depth and Angle to running surface



Transverse Cut ← → **Angle Cut Component**





Note: Component calculation is for RCF Position and Length. RCF Depth and Angle are presented unchanged (as they remain the same in rail end-view).

Action Plan

- 13 rails have been analyzed to date
- Plan is to complete analysis on 25 rails by August 2018

  => more meaningful statistical analysis of results
- Plan to include low rails in future analysis
- *Leverage RCF metallography measurements to calibrate Eddy Current probe settings (i.e. more accurate crack angle to yield more accurate results)*
- Results from RCF investigation will be presented at upcoming ICRI fall conference and 2018 Contact Mechanics conference

2. Performance of New Rail *Before First Grinding*

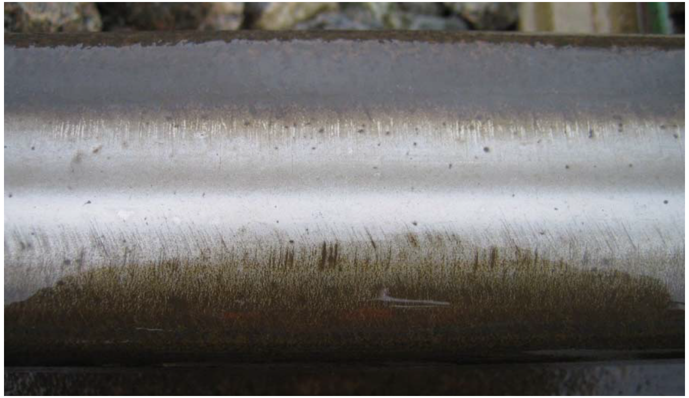
Bob Harris – LORAM (retired)
Dan Bjork – CN Railroad
Brad Kerchof - NS

Rail First Grind - Questions

- Is there a point where it is too late for a first grind? Does damage become irreparable at some point?
- What is the role of improper shape and what is the role of mill scale when determining the optimal first grind timeframe?
- Should new rail be rolled with a profile closer to high rail, low rail or tangent templates? If HR template is used are there adverse effects on low rails and/or tangent rails?
- What role does rail hardness play? How much of the work hardened layer is removed by grinding?
- What field tests can be conducted?

Removal of mill scale?

- Are there scientific reason for doing it?
- What would be needed for a test or evaluation
- Many transit systems require removal of mill scale prior to service
- How much material should be removed?



CN New Rail Tests

Test 1 - 4 Curves (~ 3 degree) with 3 new HR and 3 new LR

- 1 curve no grind
- 2 different grind strategies on low and high rails
- Rail was laid during fall 2016

    Data includes profiles, MRX crack measurements and photographs

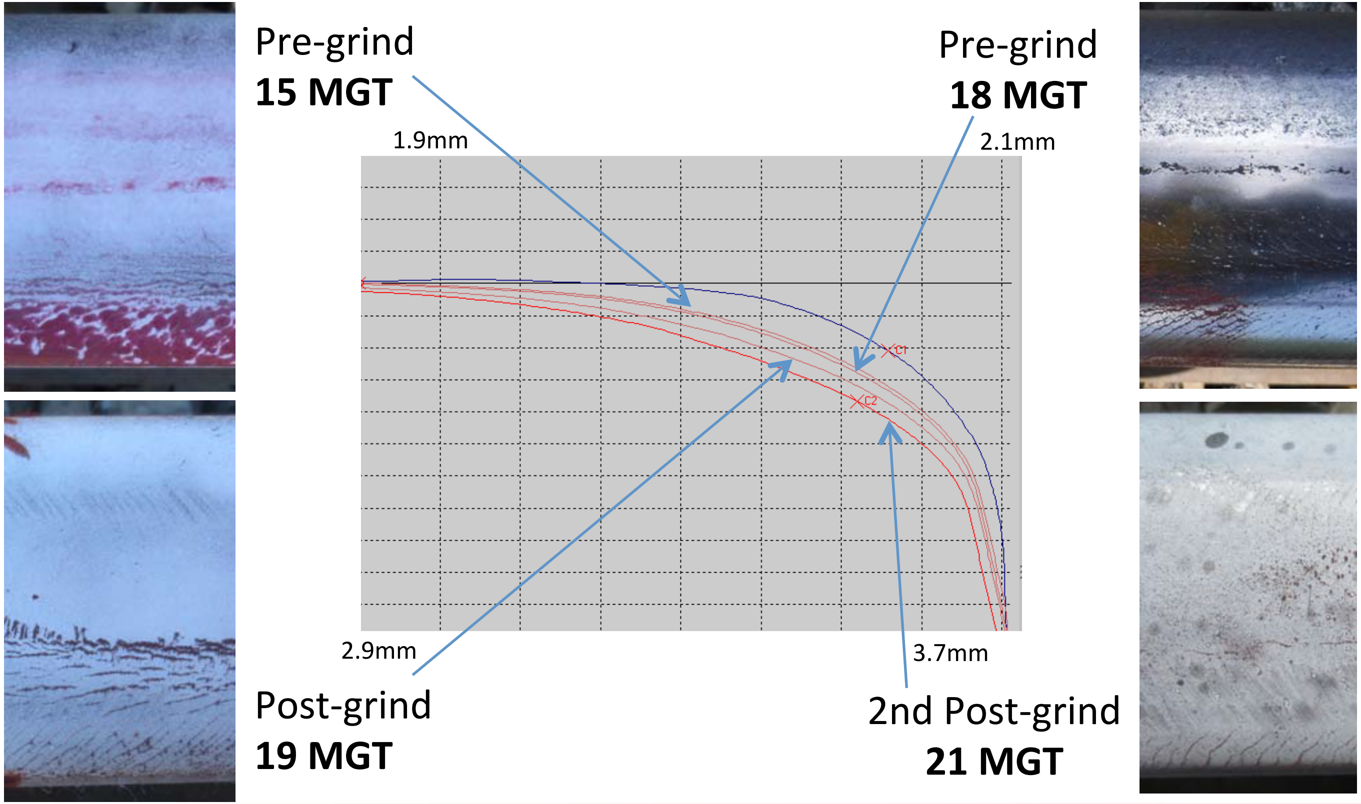
    Measured pre-grind, post-grind & 3 months post-grind

    No definitive results to date

Test 2 - High rail on a 5 degree curve with 2% grade

- Monthly traffic 3 MGT
- Ground at 18 and 21 MGT

CN New Rail Test 2



Additional Revenue Service Tests

CSX tests

As part of a larger study on RCF growth and preventive grinding 2 low rails, 2 tangent rails and 2 high rails have been replaced and are being monitored

Ground within 6 MGT of installation

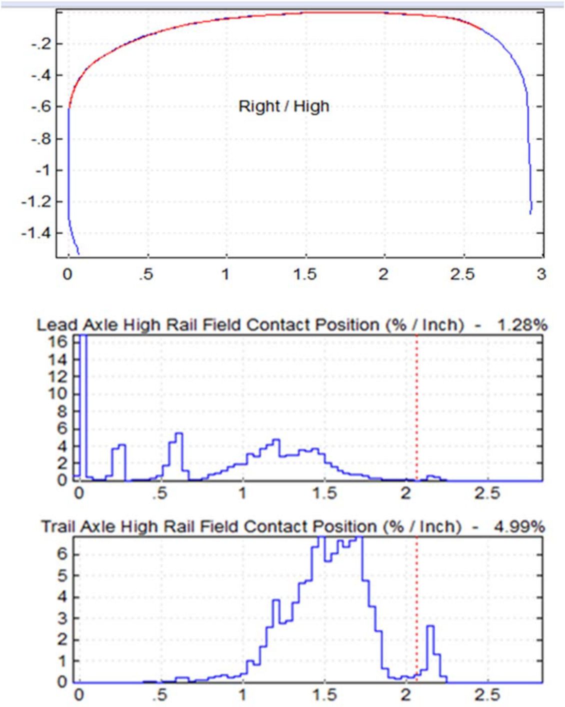
Thus far the only variables are degree of curvature

- 1 and 3 degree for the low rails
- 1 and 6.3 degree for the high rails

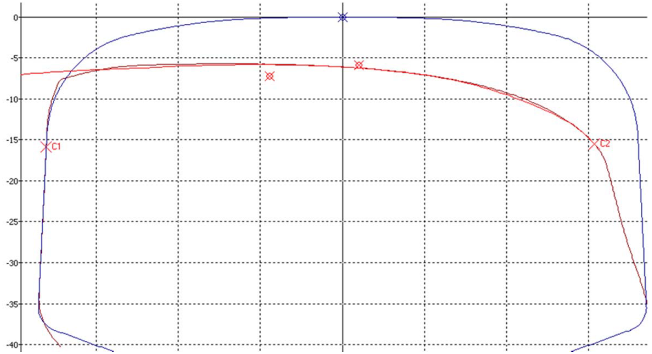
Wheel Rail Contact Interface (WRCI) as a method of evaluating wheel/rail contact?

WRCI is a wheel-rail contact prediction model developed by TTCI that uses:

- A population of wheel profiles that are representative of the railroad (for NS, WRCI includes 100 wheel sets with a variety of
- wear conditions ranging from new to 4 mm hollow-worn)
- The measured rail configurations, rail profiles, cant angles and gage
- The model results are presented as histograms showing the percentage of wheels running on each 0.05 inch of rail head width



Action Plan



- Continue with revenue service grind comparison tests on CSX and CN; determine whether a third test is needed, on NS
- Develop a rail profile based on most-desirable wheel/rail contact. Determine which template (high, low, tangent) the new rail profile should copy
- Determine work required for rail mills to change their new-rail profile
- Prepare recommendation for AREMA Committee 4

3. Optimizing the Grinding Approach

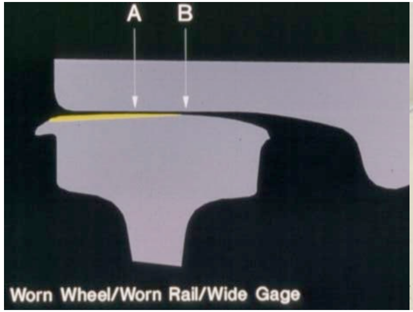
Predictive Rail Grinding

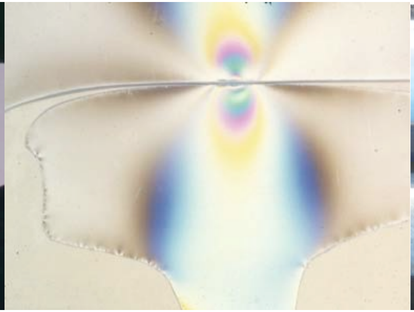
Daniel Hampton, CSX Railroad

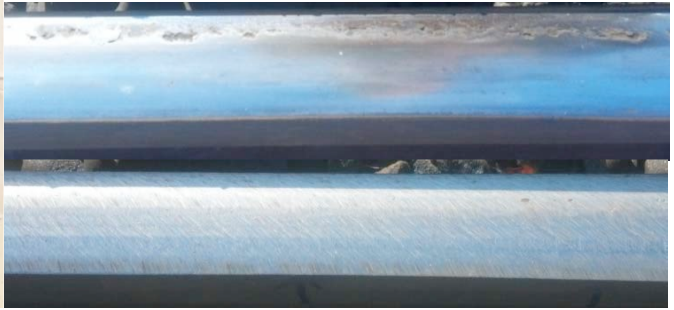
Grinding to Prevent Critical Defects

CSX – SELKIRK Subdivision
MP QG28.3 – Left Rail (H)
Track #2
Rail Service Failure – 09/17/2014

Rail Grinding – Benefits





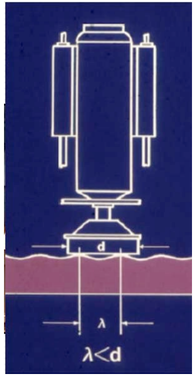


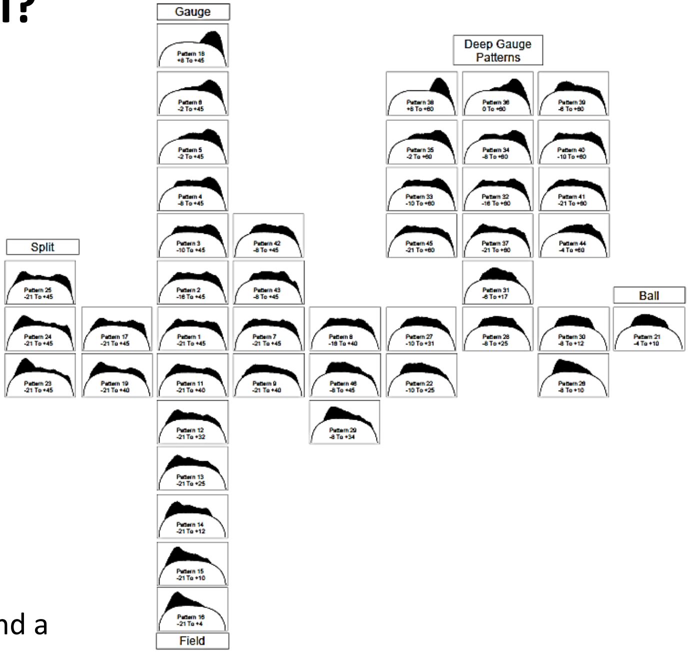
Why Grind?	Profile Correction	Surface Conditions
Benefits:	**Optimize Point of Contact** • Less rail wear • Less rail fatigue • Prolonged rail life • Less fuel consumption • Reduced vertical loads • Less vibration • Improved curving of wheel sets	**Minimize Operating Risks** • Allows ultrasonic testing to see internal defects • Reduces vertical and lateral forces • Reduces track surfacing cycles (CAT) • Reduces rail fatigue defects (TD & SD) • Reduces rail service failures • Minimizes derailments

Rail Grinding – Current State

How to obtain the desired metal removal?

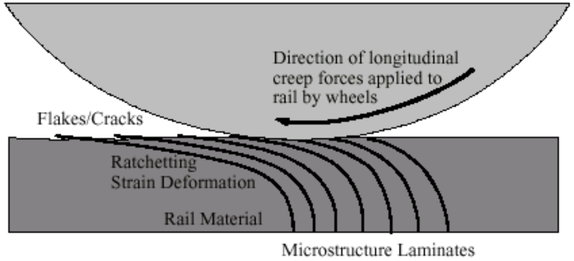
- Grind pattern selection
- Speed and downward pressure
- Number of passes*

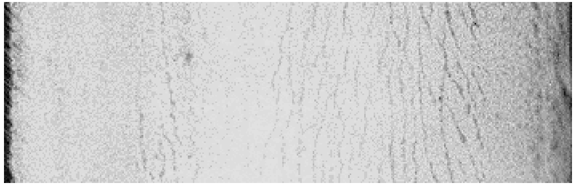


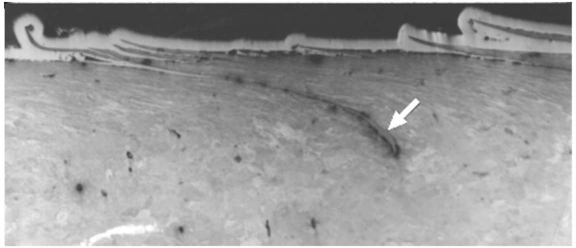


*RIV can only call a minimum speed of 6 mph to avoid bluing the rail, and a maximum of 5 passes. Additional passes must be called by the grinding superintendent.

Rail Grinding – Insufficient RCF removal

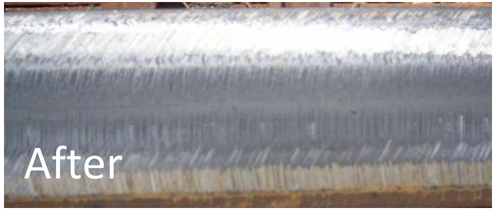






Removal of incipient RCF cracks

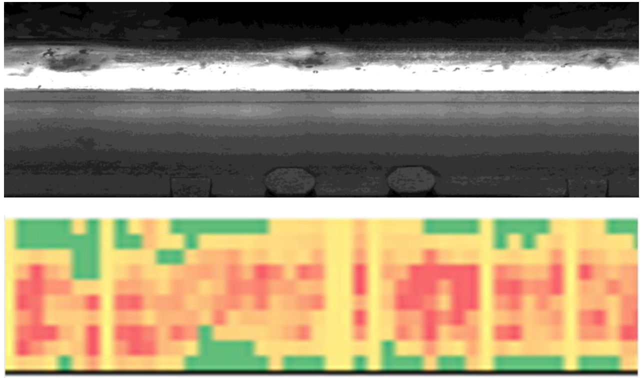
- Shallow RCF is removed



- Deeper cracks remain…

Rail Grinding – New Way Forward

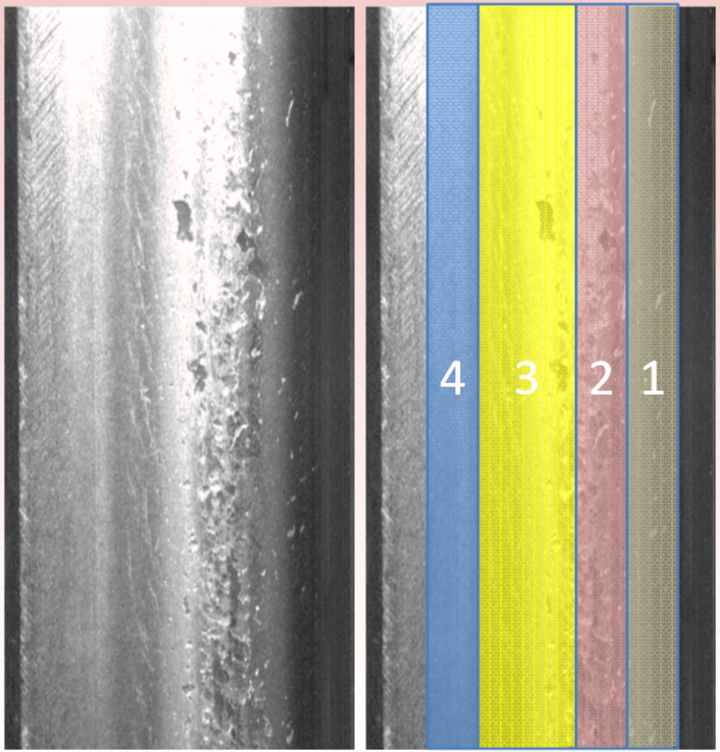
- **Goal: Develop condition based *Predictive Grinding* program**
  - Enables suppliers to use a standard scoring system industry wide
  - Determine how many MGT it takes to go from score to score
  - Determine when and what action is needed based on the surface condition score



SSCs have deep cracking in center bands

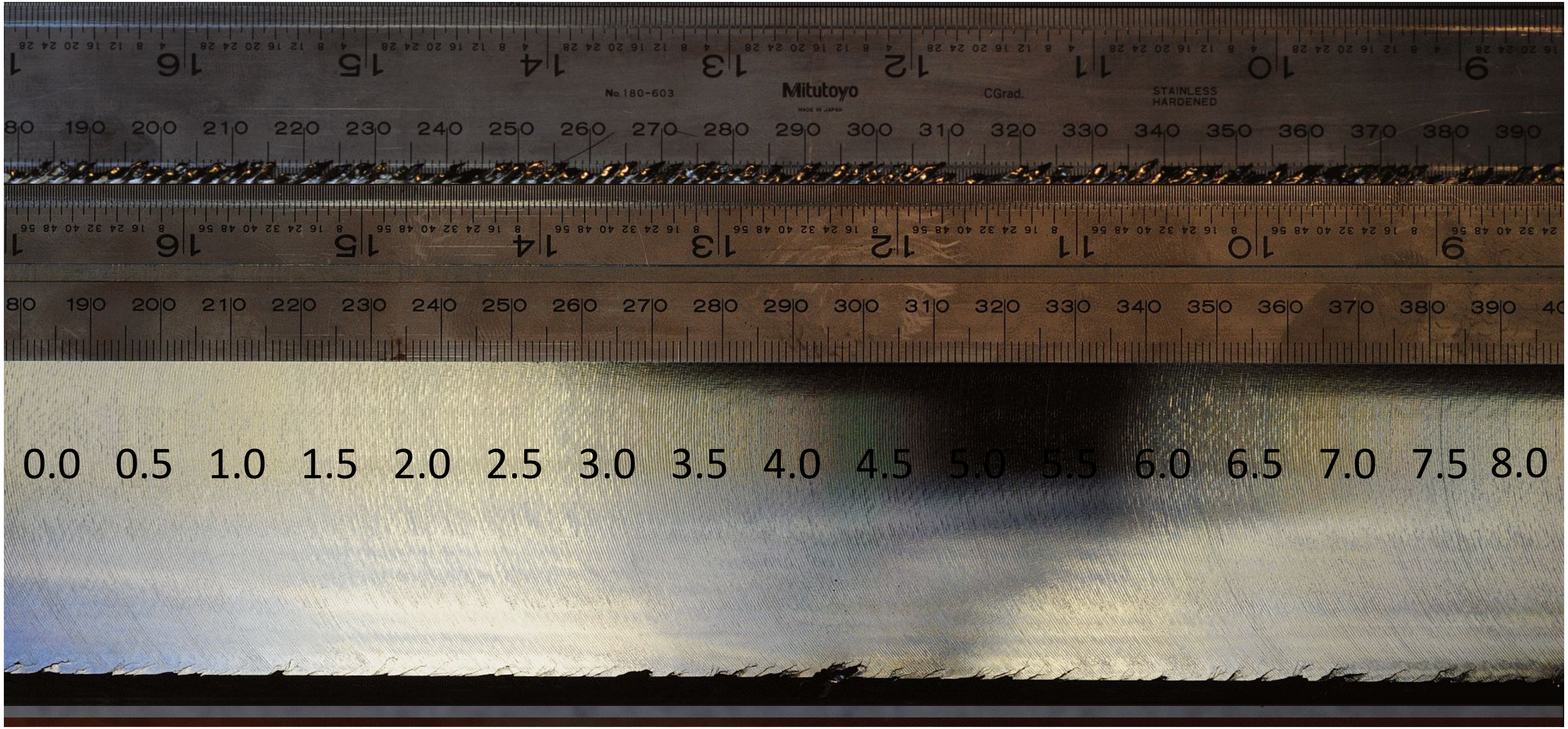
Rail Grinding - needs

0	None
1	Barely perceptible, but clearly regular pattern (preventive grinding < 0.5mm)
2	Clear, well-defined, distinct individual cracks – but no pitting > 1.5mm (maintenance, depth < 1.0 mm)
3	Clear cracking, pits up to 4 mm diameter (corrective grinding 1.5-2.5 mm deep)
4	Pitting greater than 4mm < 10 mm (preventive gradual, up to 3.5 mm deep), or “heavy” cracks with clear lifting of metal or separation of crack faces
5	Isolated pitting/shelling/spalling > 10, diameter (up to 5 mm deep)
6	Shelling/spalling: regular pitting, >10mm diameter (near impossible to catch up on)
7	Shelling/spalling: any defect > 16 mm diameter, >20mm length



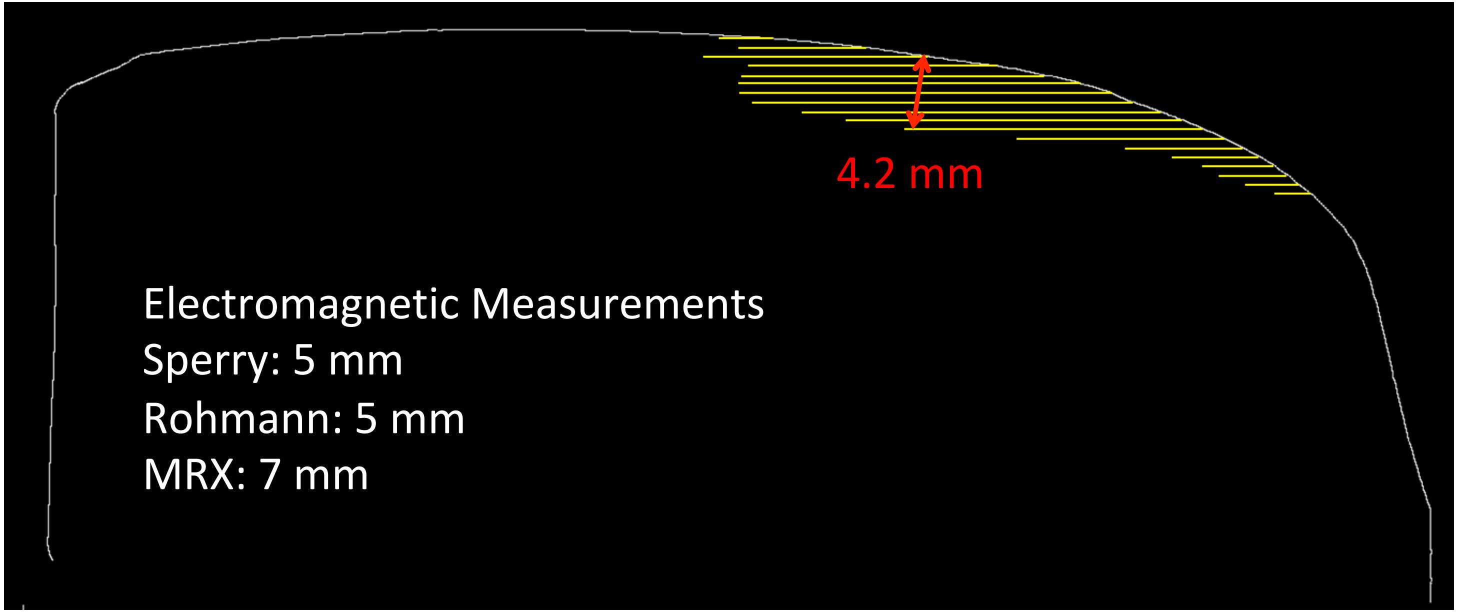
Note: Machine Vision System was developed with KLD Laboratories

Quantifying Rail Surface Damage: Rail Milling



0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0

QuantifyRailSurfaceDamage: Milling

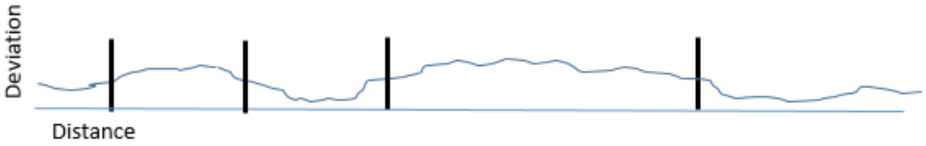


Rail from BNSF line

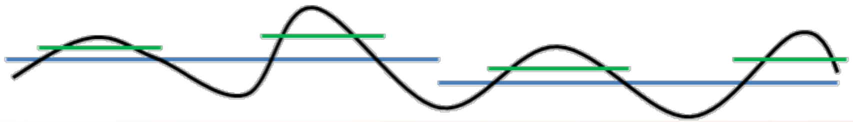
Atlas of Rail Surface Fatigue: Draft FRA report

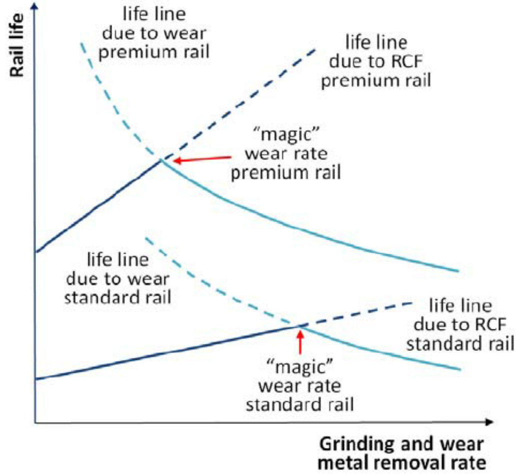
Benefits: Closer to Optimal Rail Life

- Dynamic Track Segmentation – creates segments based on similar demand after inspection



- Complementary Grind Plans – Allow detailed work on shorter segments to meet demand variation and maximize equipment productivity



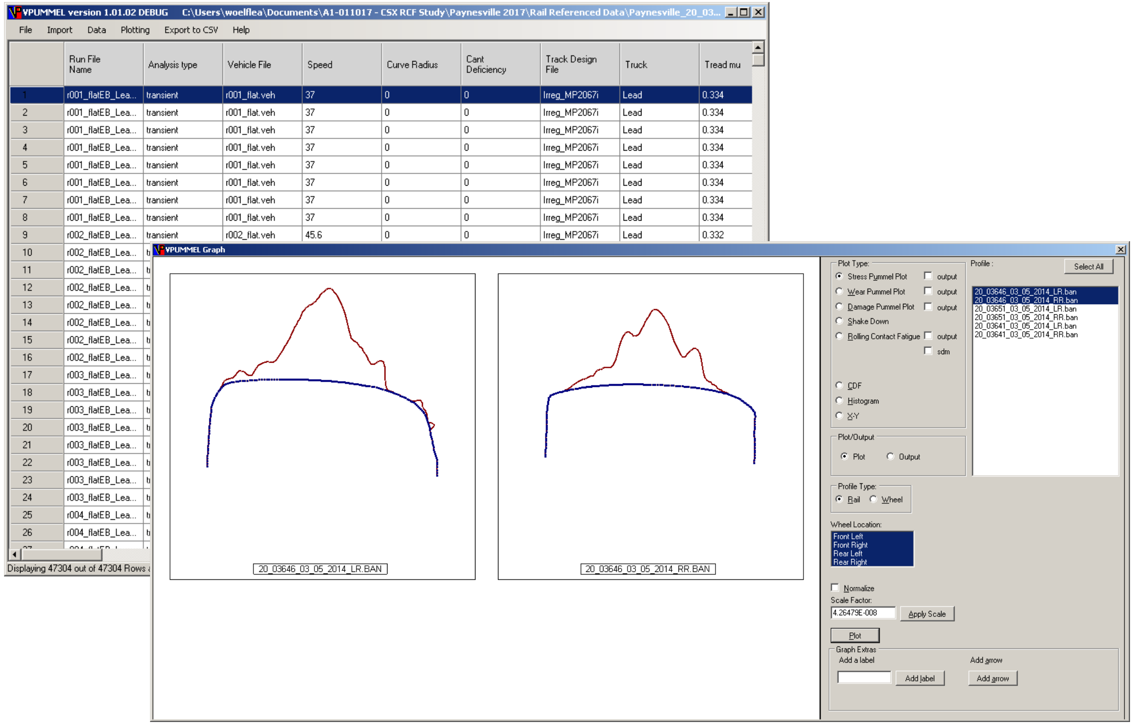


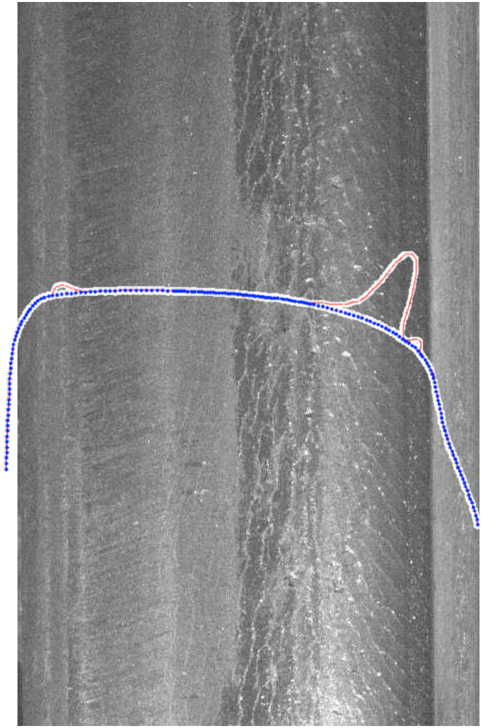
Different locations have different demands / Magic Wear Rates (optimal balance of grind without overgrinding)

4. Damage Modeling in Rails

Alexandre Woelfle and Wei Huang – National Research Council, Canada
Klaus Six – Virtual Vehicle (Austria)

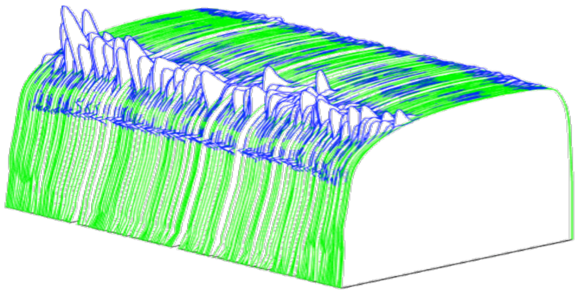
Damage Modeling - Pummeling



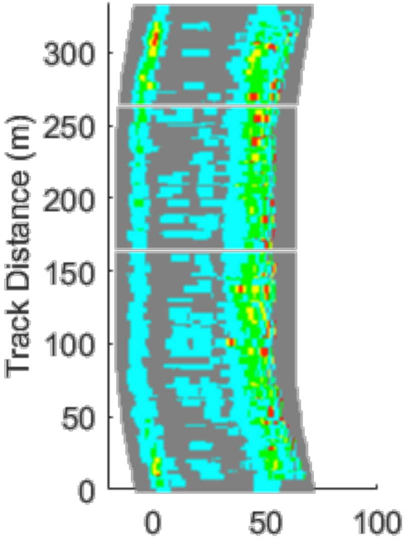


Damage Modeling – Plotting RCF

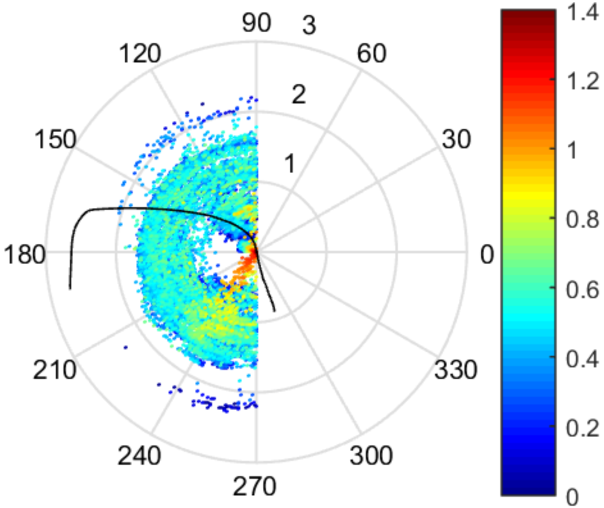
3D Envelope



Heat Map



Polar Plot

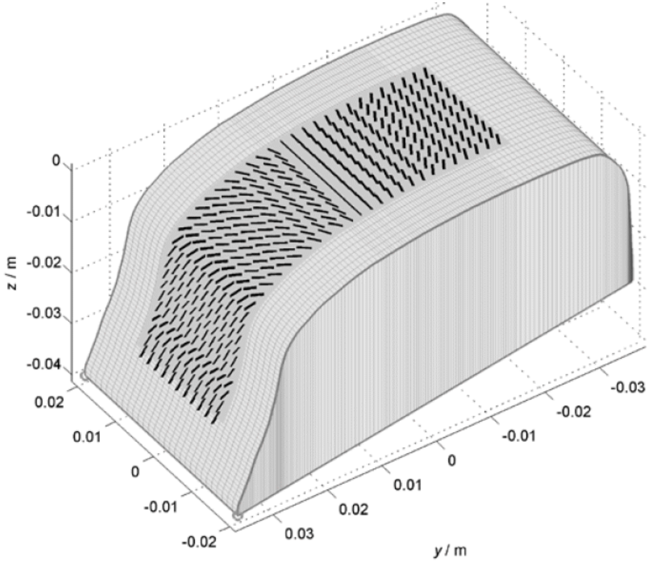


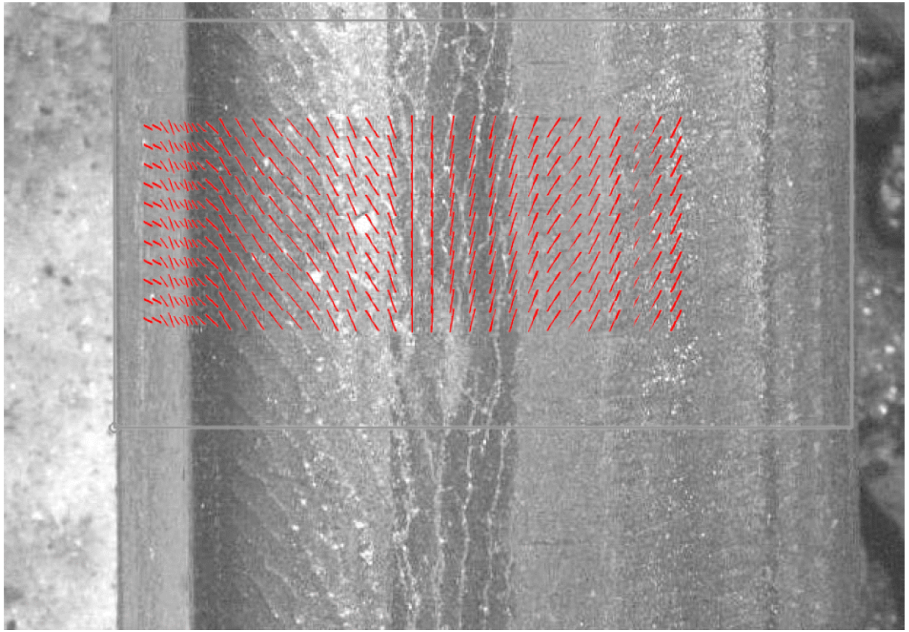
c.f. P. Molyneux Berry
Hudderfield Universtiy

Wedge Model

"Wedge" model: Surface deformation pattern, Pos 20_4116

high rail





Conclusions

- ICRI is working in several areas to improve understanding and maintenance of RCF
- More support is needed
  - Rail samples
  - Metallurgical sectioning
  - Leadership

Next ICRI Workshop

- Delft, Holland
- September 23, 2018
- Adjacent to CM2018 conference
  - www.cm2018.org

Thank You

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