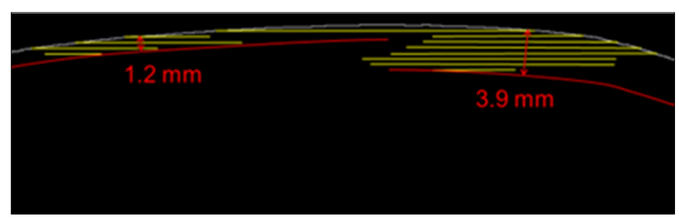
Quantifying RCF in Rails

Methods, Practice, Outcomes



Quantifying RCF – Objectives

Short Term

- Conduct review of existing rail RCF assessment methods (qualitative & quantitative):
  - In-service inspection techniques: magnetic particle, dye penetrant, eddy current
  - Metallography: light optical microscopy documenting crack morphology (length, angle, depth, branching, density)
  - RCF rating scale

Long Term

- Conduct similar assessment on wheel RCF
- Identify key stakeholders ask for their participation in project
- Determine RCF characterization framework
  - What is needed to better understand and document RCF?
- Combine existing characterization methods/indices
- Final report to group

Quantifying RCF – Objectives

Presentation Layout

- Effect of track curvature on RCF
  - GF lubrication, TOR fiction modification, wear & RCF
- Effect of rail position in curve on RCF
- Non-destructive RCF evaluation methods
- Light Optical Microscopy
  - RCF crack morphology in different rail head locations
  - RCF crack morphology vs. carbon content in rail
- RCF rating scale (two methods presented)
- RCF Atlas

Quantifying RCF – Effect of Curvature and TOR Friction Modification

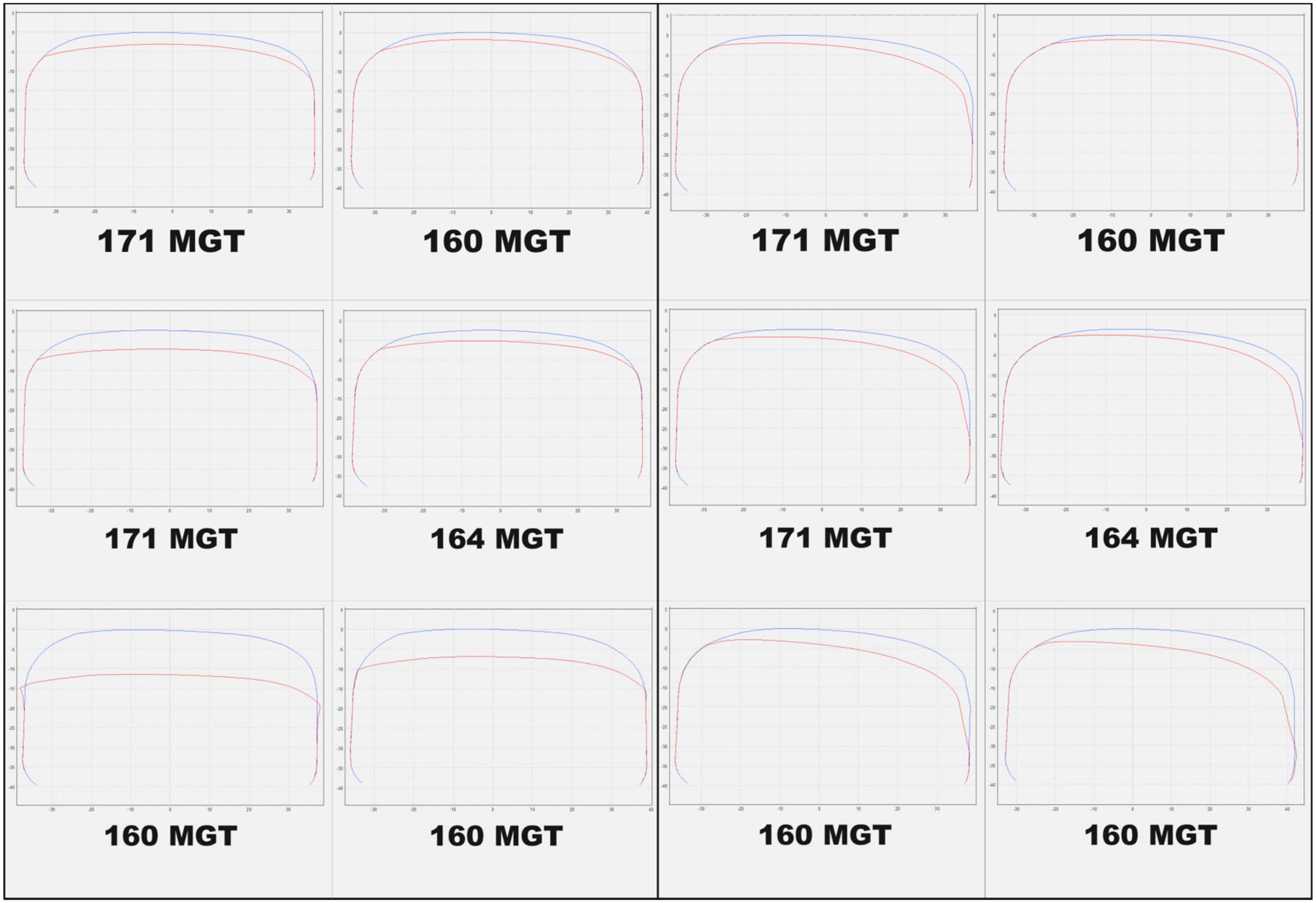
Low Rail | High Rail

TOR FC | GF Lube | GF Lube + TOR FC

3° Curves

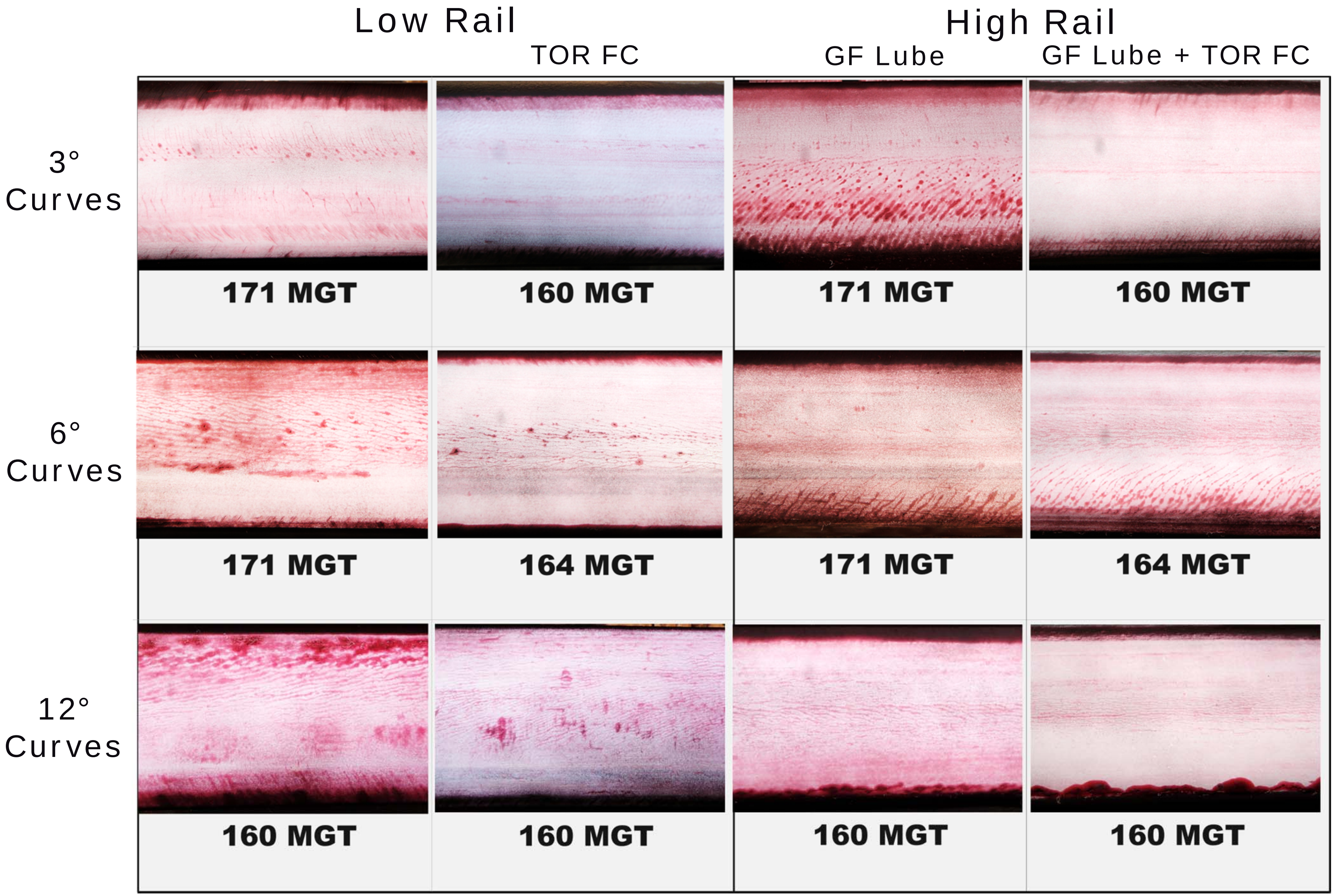
6° Curves

12° Curves



Note: Results originate from Norfolk Southern Railway heavy axle load traffic lines

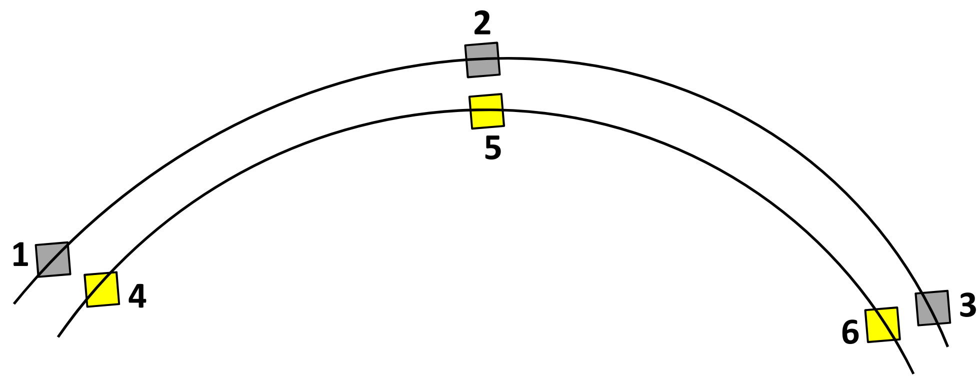
Quantifying RCF – Effect of Curvature and TOR Friction Modification



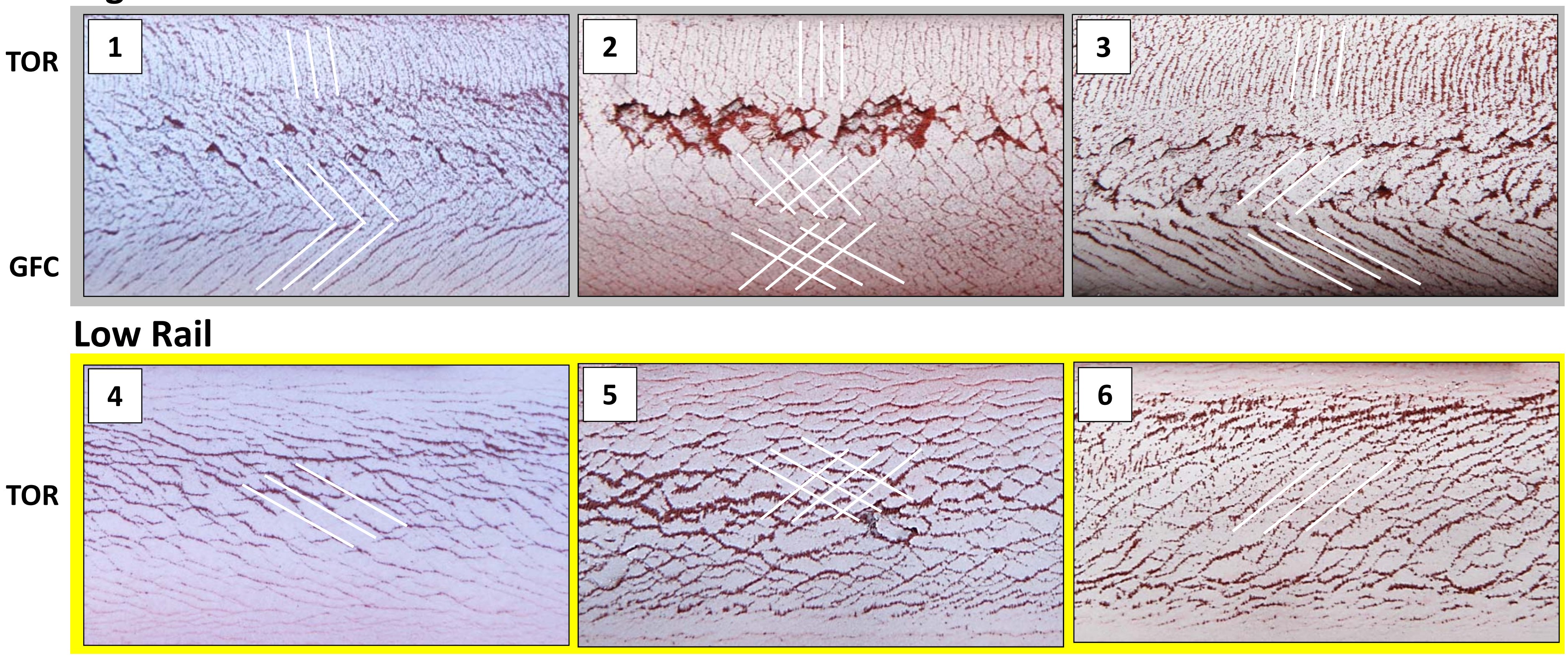
Note: Results originate from Norfolk Southern Railway heavy axle load traffic lines

Quantifying RCF – Effect of Rail Position in Curve

- Same premium rail type
- Heavy Axle Load
- Bi-directional traffic
- Consistent train speed
- Approx. 300MGT



High Rail



Note: Results originate from information presented at 2013 TTCI Annual Review

Quantifying RCF – Non-Destructive Evaluation Methods

Three Electro-Magnetic Based Techniques were Evaluated by NRC Under the FRA Program:

- **Eddy Current** – electricity running through a coil generates magnetic fields in the adjacent conductive material that are disturbed by discontinuities.
- **Magnetic Flux Leakage** – the component is magnetized and the leakage of flux at discontinuities is detected with sensors near the surface.
- **ACFM** – a uniform electric current is induced into the component and the resulting magnetic fields are disturbed by surface breaking cracks that are detected by sensors above the surface.

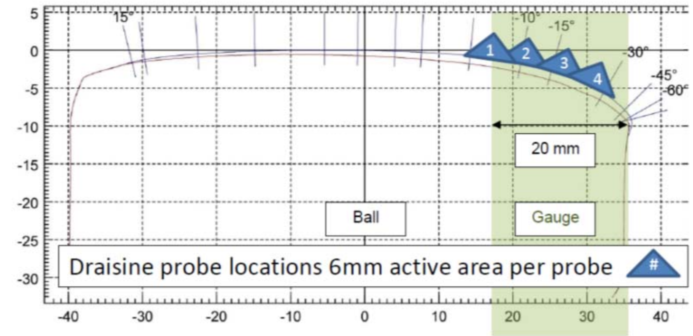
MRX RSCM (magnetic flux leakage)

Rohmann Drasine trolley (eddy current)

Sperry Surface Crack Detection + Walking Stick

Quantifying RCF – Rohmann Eddy Current Technology

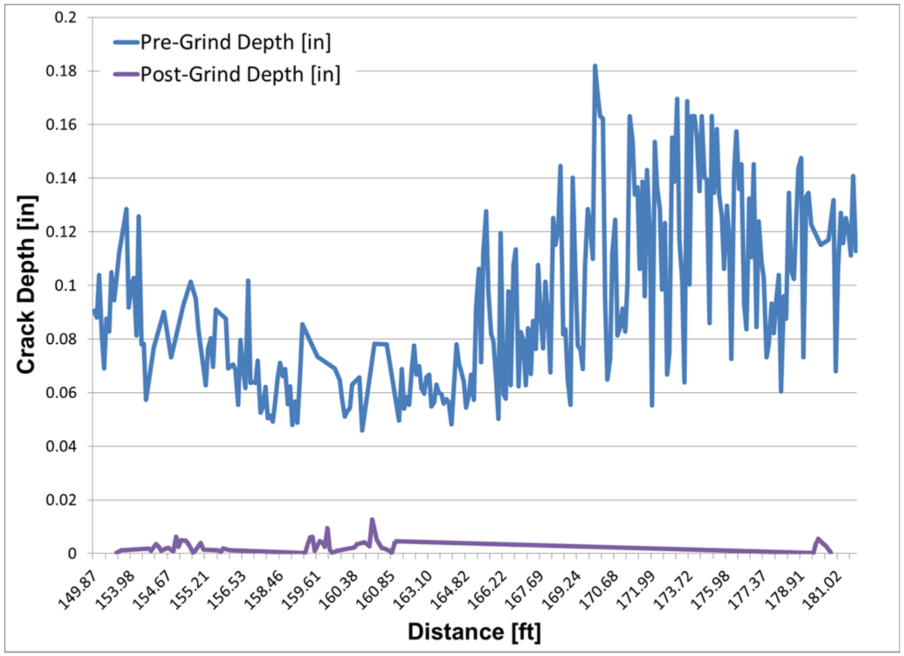
- Provides RCF crack depth vs. rail distance travelled
- Either a ‘walking’ unit with 4 eddy current probes
  - Staggered design, each probe covers a portion of the rail head
- Or a hy-rail unit with as many as 6 probes per rail, with running speed up to 40mph
- Voltage output is converted to crack length, which combined with crack angle yields crack depth



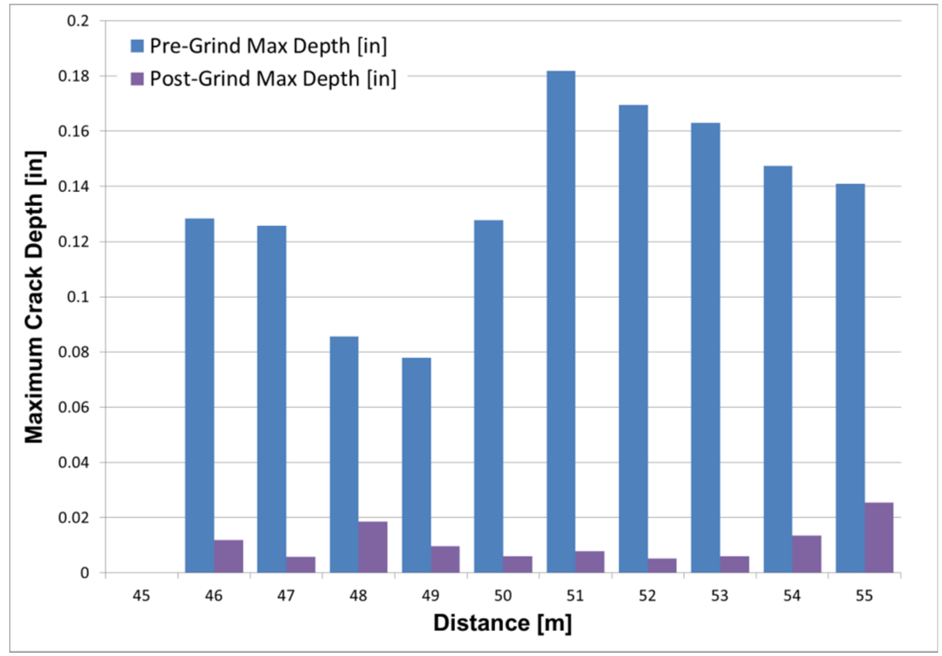
Quantifying RCF – Rohmann Eddy Current Technology

- Information is used to make grinding decisions
- Pre- and post-grind crack measurements shown

Instantaneous Crack Depth



Max Crack Depth per Section

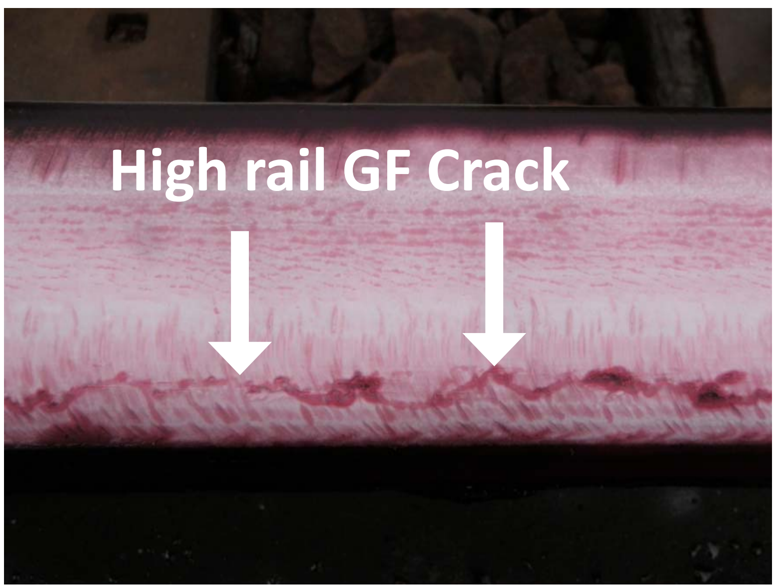


Typical Pre-Grind High Rail RCF

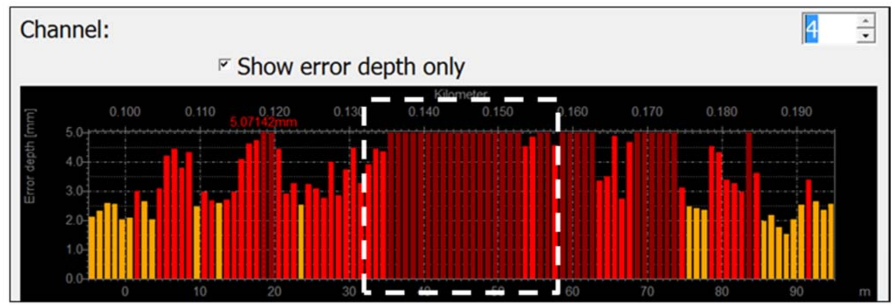
Note: Results originate from information presented at 2013 TTCI Annual Review

Quantifying RCF – Rohmann Eddy Current Technology

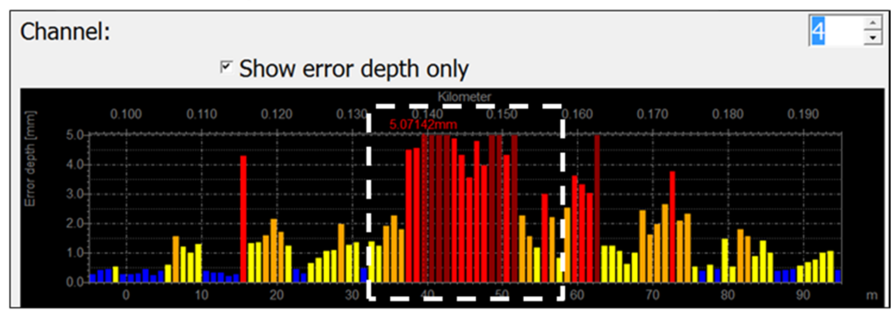
- Draisine® can also be used to detect defects in track
- Gage corner shear crack
  - Pre-grind measurements showed depth >5mm
  - Approximately 3mm of railhead was taken off in grinding
  - Post-grind measurements still indicated depth >5mm
- Rail was taken out of service



Pre-grind measurement



Post-grind measurement

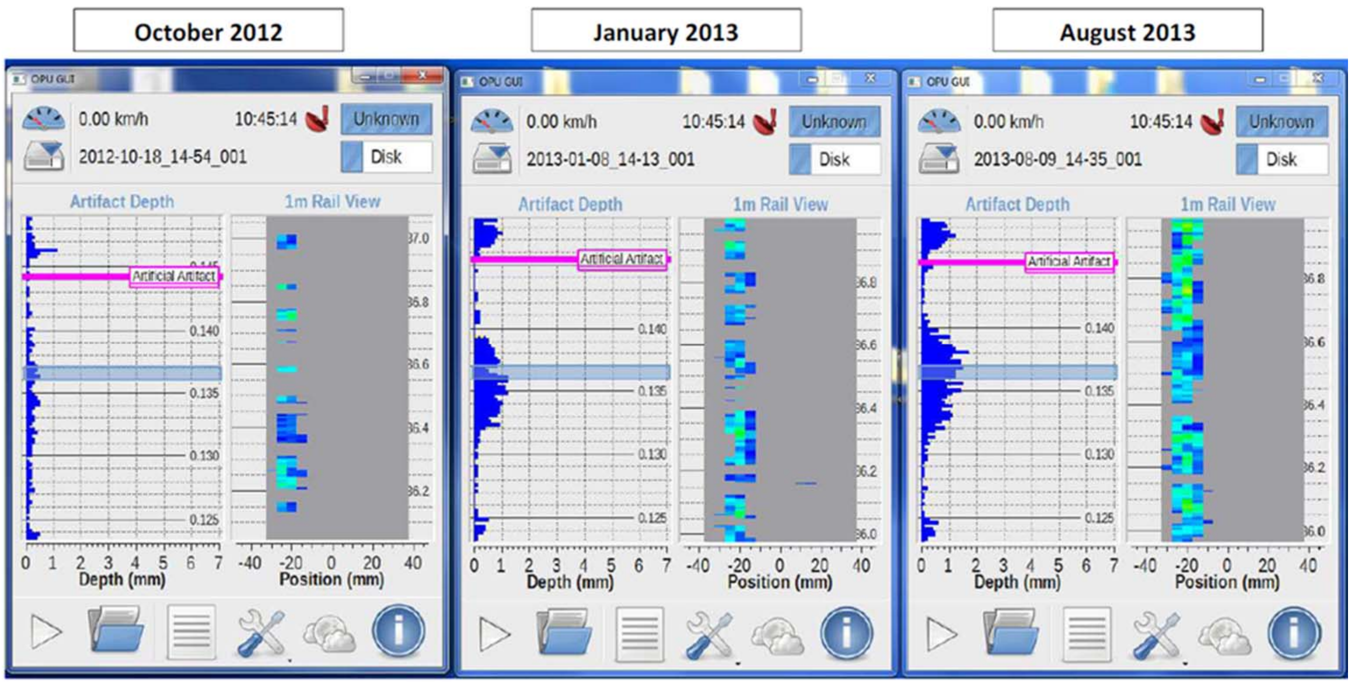


Defective Zone in Rail

Note: Results originate from Norfolk Southern Railway heavy axle load traffic lines

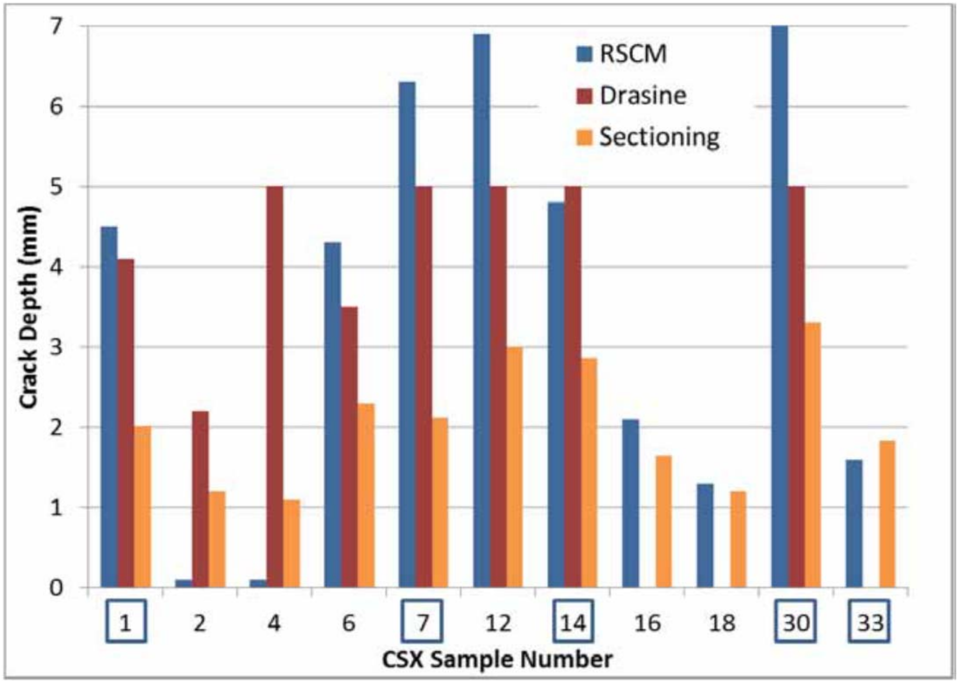
Quantifying RCF – MRX Magnetic Flux Leakage Technology

- Technology is also available in a hy-rail RSCM unit
- Ongoing testing at CSX Fitzgerald and Jessup sites in Georgia
- Progress of damage as measured with the MRX RSCM
    - Depth and extent of cracking is seen clearly to grow with time



Quantifying RCF – Comparison of RCF measurements

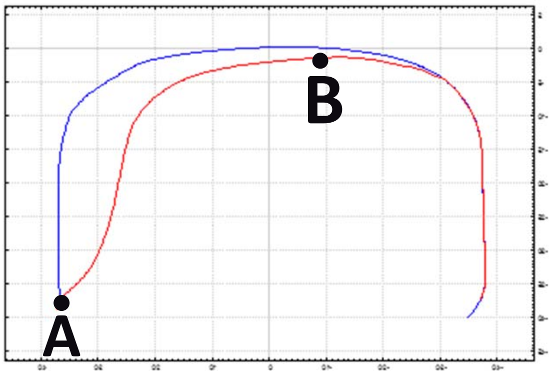
- Non-destructive vs. destructive evaluation
- Both MRX and Rohmann systems appear to overestimate the actual crack depth
  - Work needs to be conducted to explain why that is

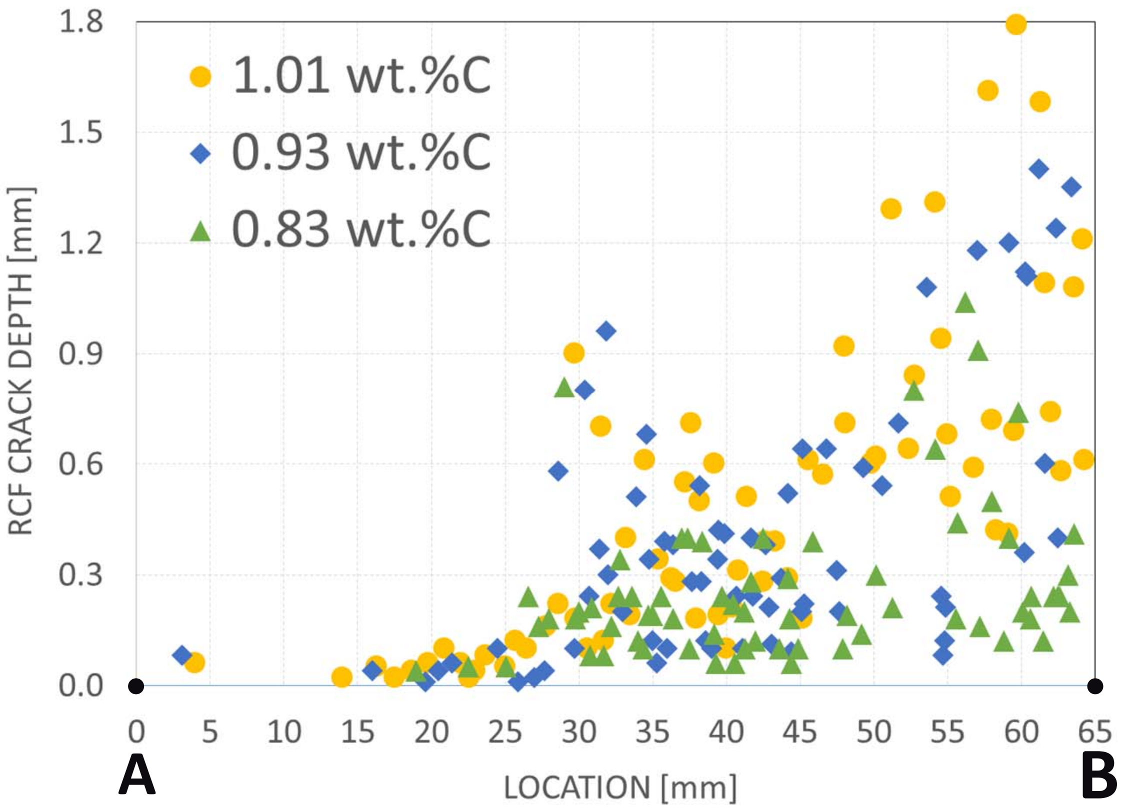


Comparison of crack depth measurements obtained with the MRX and Rohmann systems with those obtained through destructive sectioning and milling. The milled samples (which should be the most reliable) are highlighted with the blue box

Quantifying RCF – Metallography of Crack Morphology

- High rail quantitative RCF assessment was done on the GF running surface between points A and B
- RCF crack depth was analyzed in three rail types with varying Carbon content
- Distribution shown below:

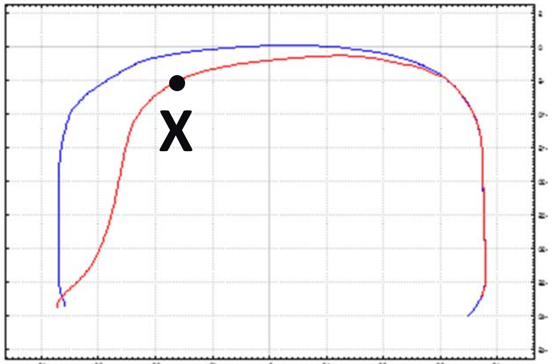




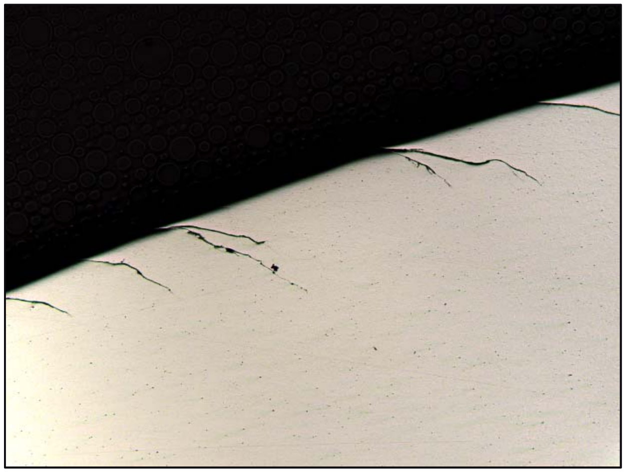
Note: Results originate from information presented at 2013 TTCI Annual Review

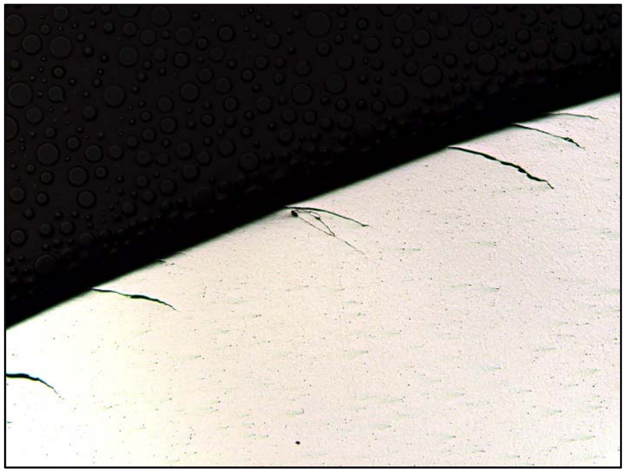
Quantifying RCF – Metallography of Crack Morphology

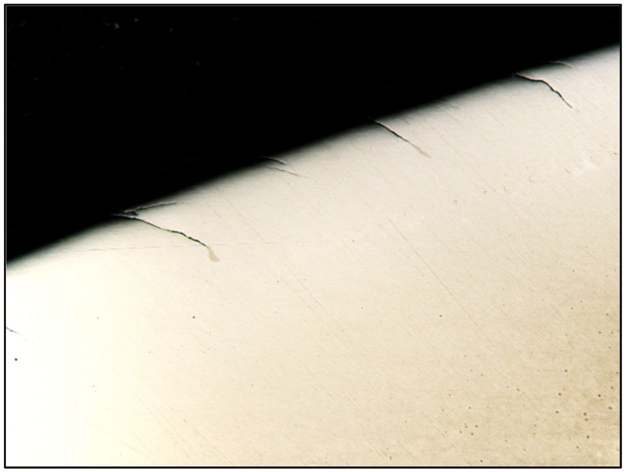
- Typical micrographs at location X in each rail type



Premium Rail 1 (1.01wt.% C)	Premium Rail 2 (0.93wt.% C)	Premium Rail 3 (0.83wt.% C)



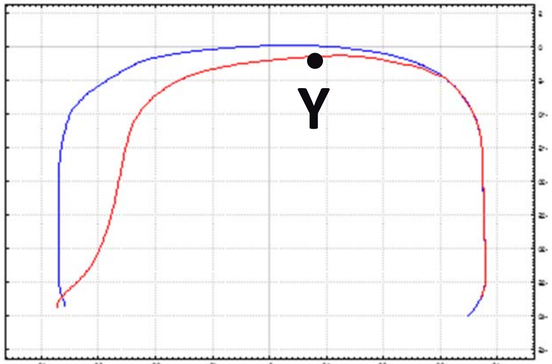




Note: Results originate from information presented at 2013 TTCI Annual Review

Quantifying RCF – Metallography of Crack Morphology

- Typical micrographs at location Y in each rail type



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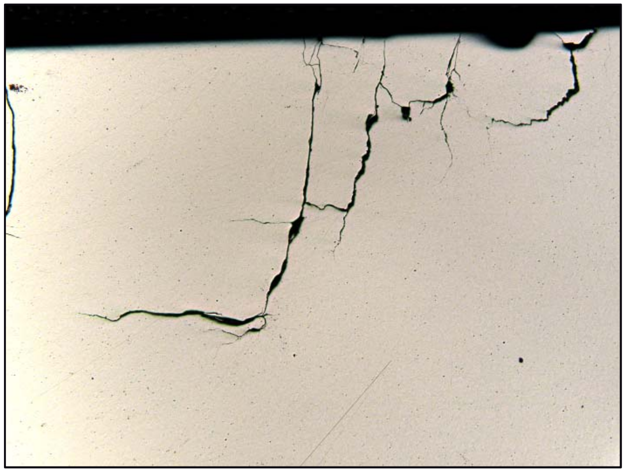
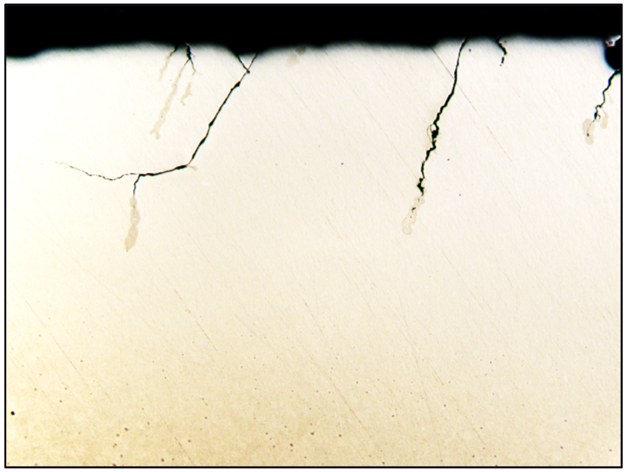
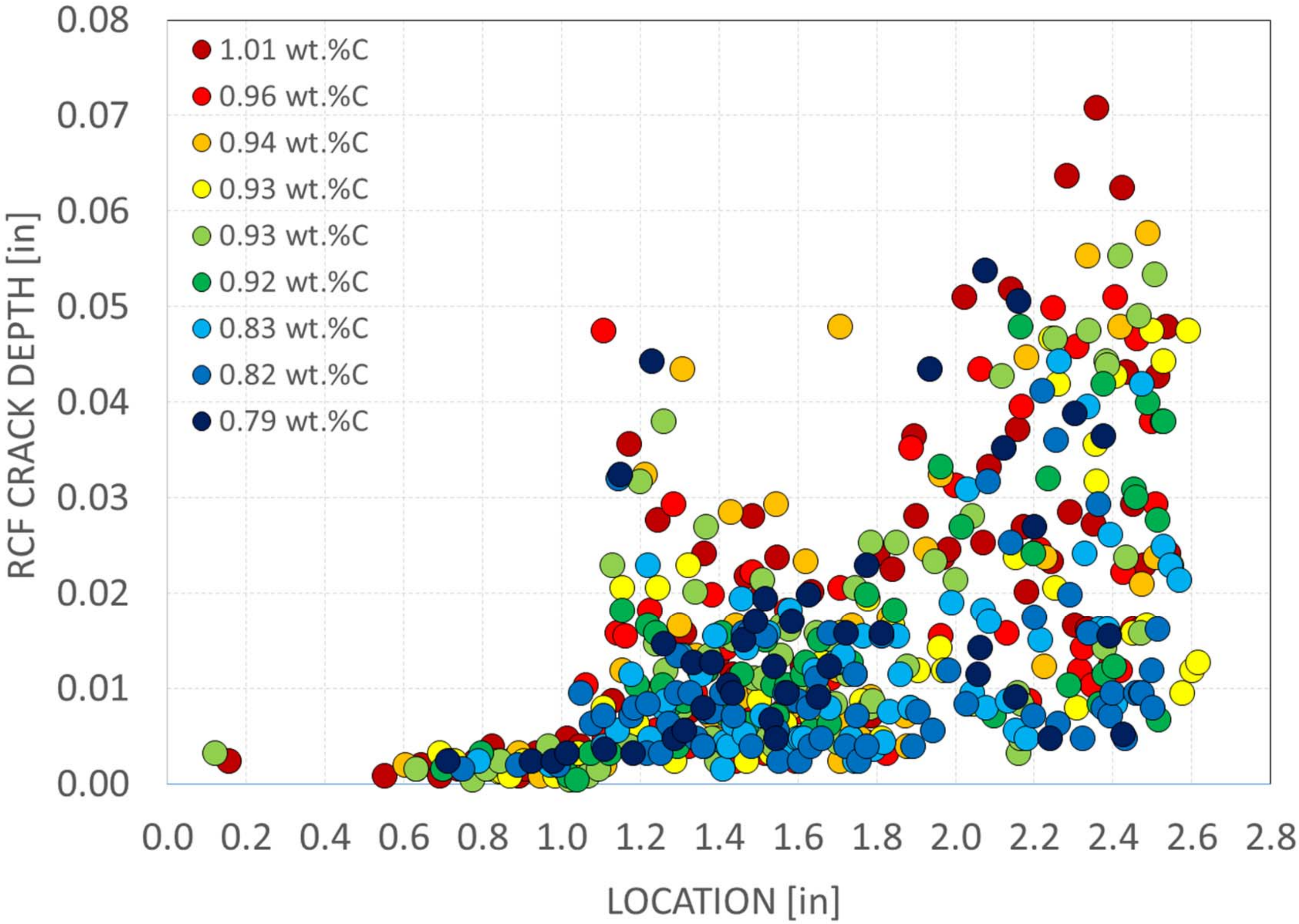




Note: Results originate from information presented at 2013 TTCI Annual Review

Quantifying RCF – Metallography of Crack Morphology

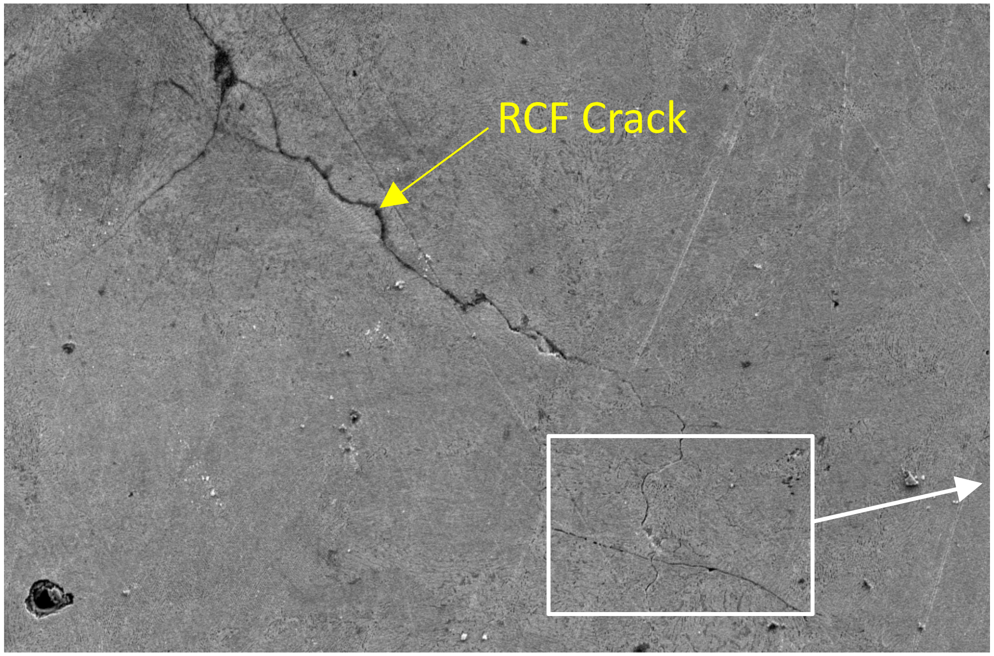
- Similar analysis being done on other rail types

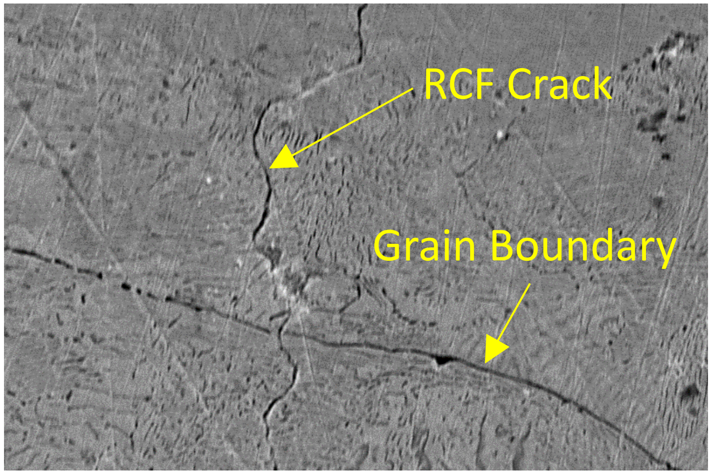


Note: Results originate from information presented at 2013 TTCI Annual Review

Quantifying RCF – Metallography of Crack Morphology

- Consideration of crack depth as a function of rail steel is the first step
- Other crack features should be analyzed as well:
  - Length
  - Angle
  - Branching
  - Density
- In addition, crack path in the microstructure should be considered as well (inter-granular vs. trans-granular cracking)





Quantifying RCF – Rating Scale

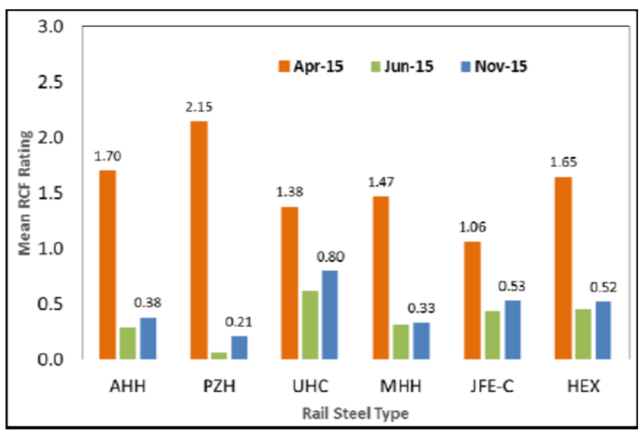
- One method applied utilizes visual rating of RCF cracks
  - Qualitative and subjective (user dependent)

Mild
Scale 1

Heavy
Scale 2

Severe
Scale 3

  - Rating done on 6 premium rail types in 1000ft curve
  - 350MGT pre-grind rating on April 15th, grinding in May, post-grind rating on June 15th
  - RCF reduced but not removed

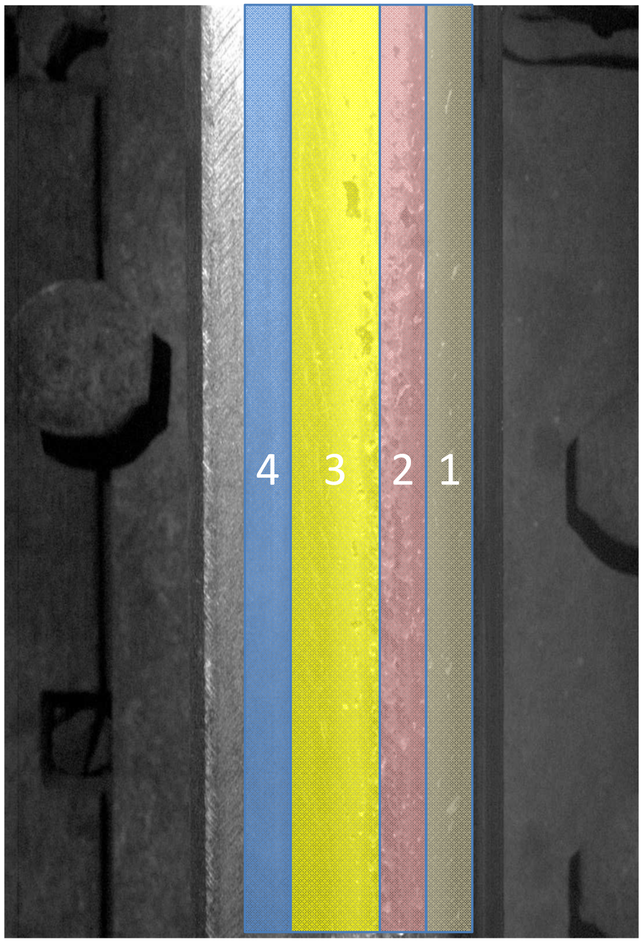


Note: Results originate from information presented at 2016 TTCI Annual Review

Quantifying RCF – Rating Scale

- Another method utilizes a Machine Vision System to rate the crack surface appearance
  - Not user dependent (more objective)

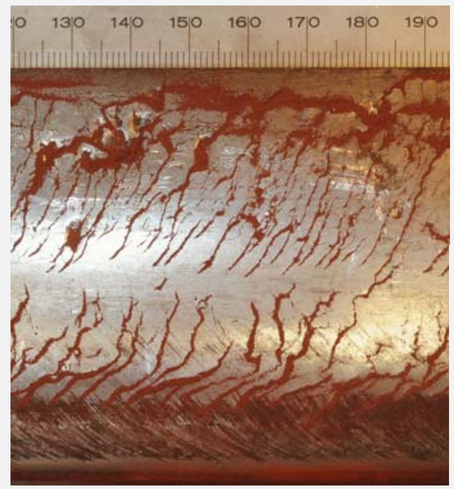
0	None
1	Barely perceptible, but clearly regular pattern (preventive grinding < 0.5mm)
2	Clear, well-defined, distinct individual cracks – but no pitting > 1.5mm (maintenance, depth < 1.0 mm)
3	Clear cracking, pits up to 4 mm diameter (corrective grinding 1.5-2.5 mm deep)
4	Pitting greater than 4mm < 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 (busted, near impossible to catch up on)
7	Shelling/spalling: any defect > 16 mm diameter, >20mm length



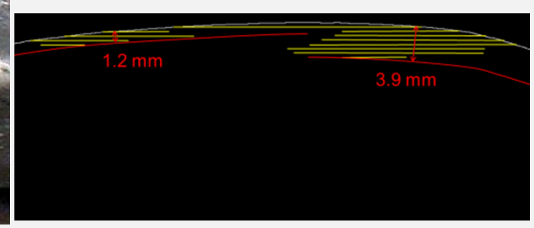
Note: Machine Vision System was developed with KLD Laboratories

Quantifying RCF – Atlas

High Low Tangent **S&C** Metallurgy: **136RE VT**	Railroad: **BNSF** Subdivision: **Staples** MP: **200.69** Curvature: **2 degree** Lubricated: Yes **No**	Date: Removed from track **November 2014** Sample: **C8**



Cross-Section



Surface Crack Length	approx. 25 mm
Start/End Position	approx. 5 - 55 mm
Surface Angle (to Longitudinal Direction)	approx. 70 degrees
Crack Depth (Milling)	3.9 mm
Spacing Avg. = approx. 2 mm	
Comment: SSC – through crossing	

Quantifying RCF – Current Understanding

Summary

- RCF is a complex problem with a multitude of contributing factors
- Some factors affecting RCF:
  - Track curvature, rail position in curve, rail type, lubrication, traffic, others
  - Different inspection methods yield different results
    - Qualitative methods are user dependent (subjective)
    - Quantitative methods are more objective
    - Eddy current method assumes crack angle to calculate depth
    - Rail milling to assess depth of RCF damage remains the most accurate method to measure amount of RCF in railhead
    - Rail microstructural analysis is important to map out crack morphology as a function of position on the railhead
    - Results need to be documented in the RCF Atlas

Quantifying RCF – Current Understanding

RCF

Inspection Methods

- Visual surface assessment
- 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
    - Tonnage accumulation
    - Frequency
- Maintenance practices
    - Grinding
        - Frequency
        - Amount

Outcomes to Evaluate

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

Quantifying RCF – Future Work

Next Steps

- Need additional rails and resources to progress the work
  - Rails with RCF from a range of curves, traffic conditions
  - Non-destructive and destructive inspection methods to evaluate the rails:
    - Milling
    - Metallography
- Feed RCF data into the Atlas
- Need help with a similar RCF analysis approach on the wheel side
  - Damaged wheel donations
  - Develop RCF rating scheme

Next update mid-2017

Work continues…
Participation welcome

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