Quality Indices for managing rail through grinding

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Background

- Rail grinding objectives
  - Correct rail profile
  - Remove surface fatigue
  - Remove rail corrugations
  - Minimize noise
- Manage?
  - Measure and monitor, quality assurance
  - Requires meaningful assessments of “good”, “adequate”, “unacceptable”

“Grind Quality Index”- GQI

±0.5 mm
± 0.2mm

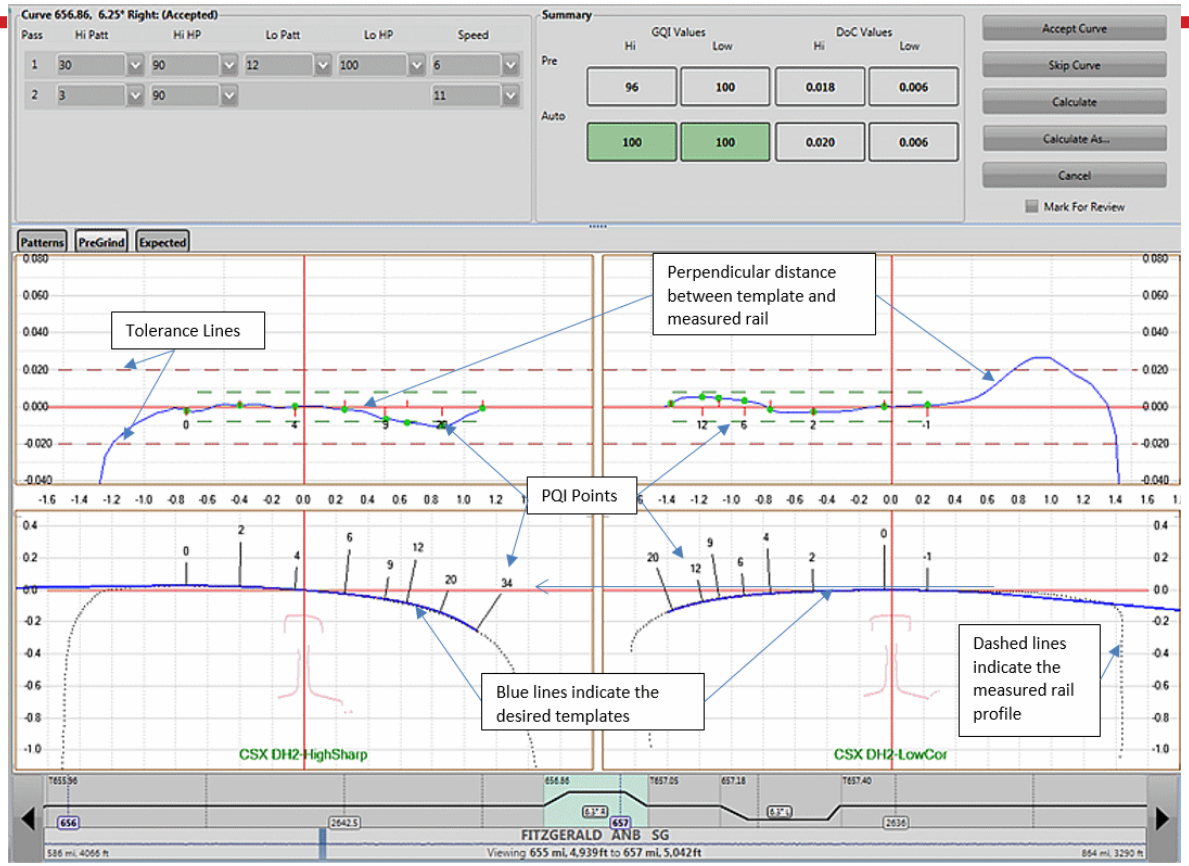
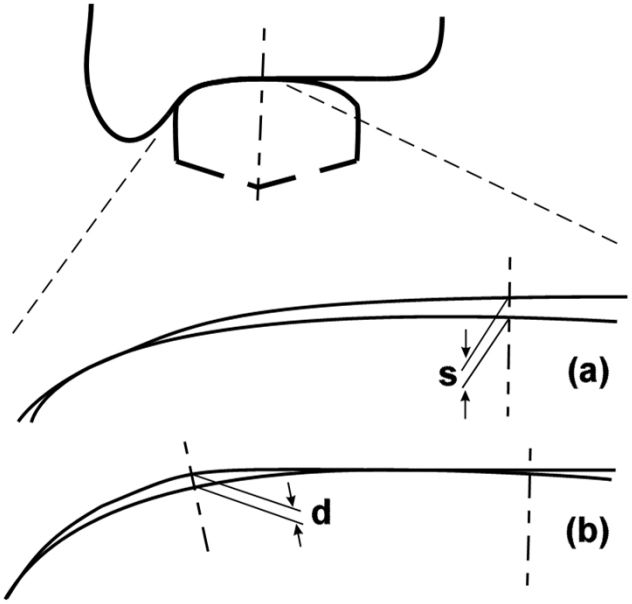


Image courtesy of LORAM MOW

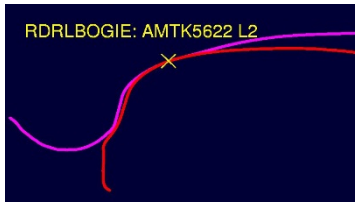
Magel, Oldknow (CM 2018)

- Effect of alignment algorithm
  - Generally small for high rails
  - Greater for tangent and low
- Average, RMS, 10^{th} or 25^{th} percentile?
- PQI of an average profile versus average of all PQI values?
- Choose to segment curve into smaller sections?
  - Example in paper: ± 10% (e.g. 75 to 86 vs avg of 80)

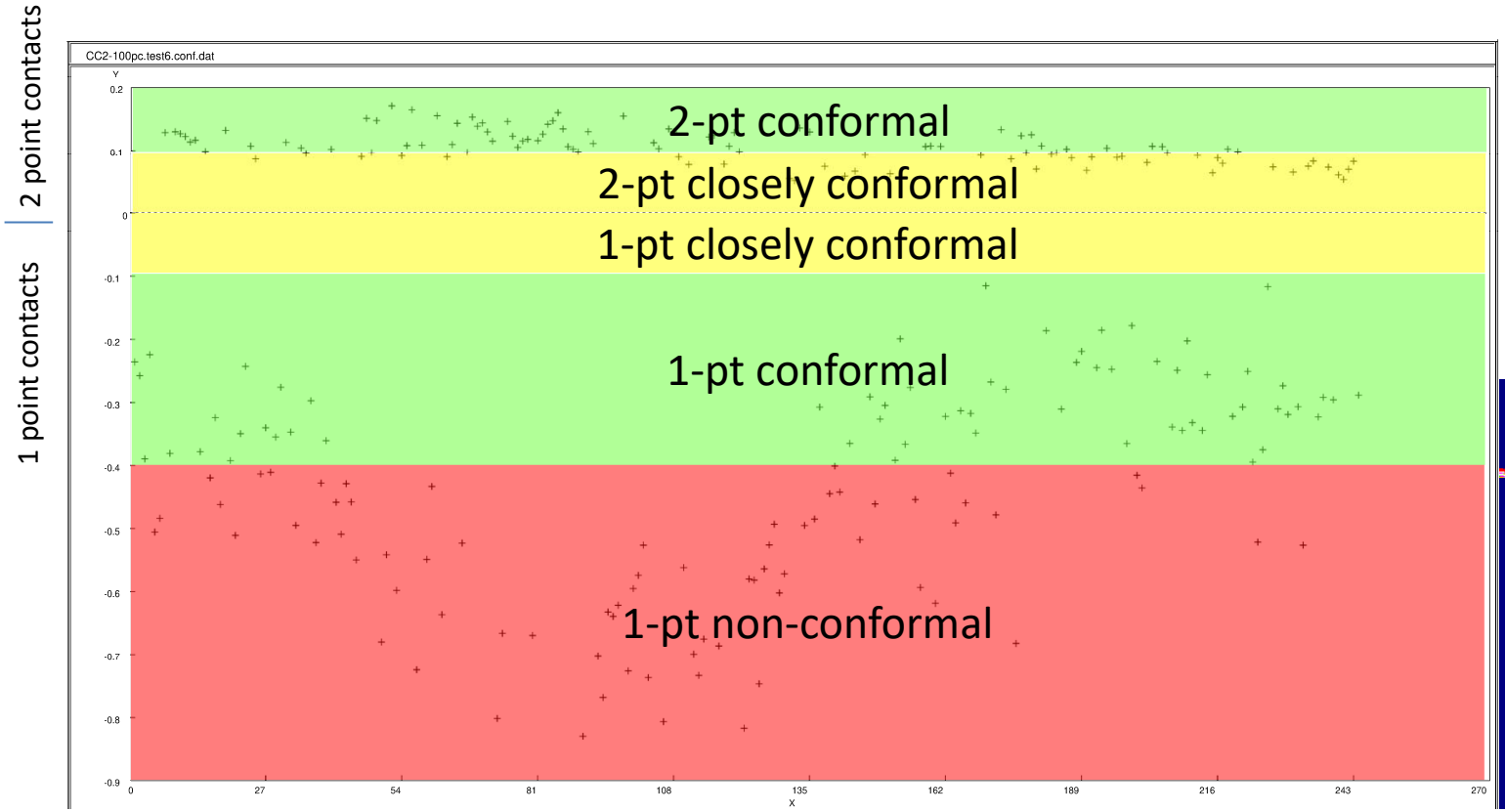
Conformality



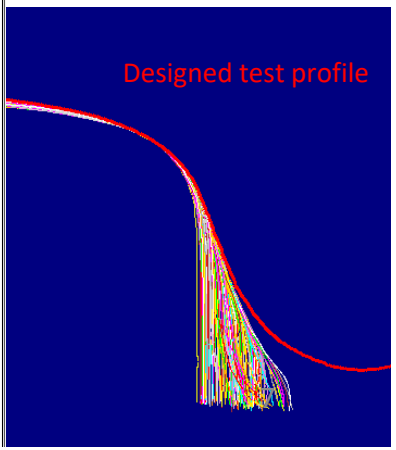
- Closely Conformal
  0.1 mm (0.004”) or less
- Conformal
  0.1 mm to 0.4 mm
  (0.004” to 0.016”)
- Non-Conformal
  0.4 mm (0.016”) or larger

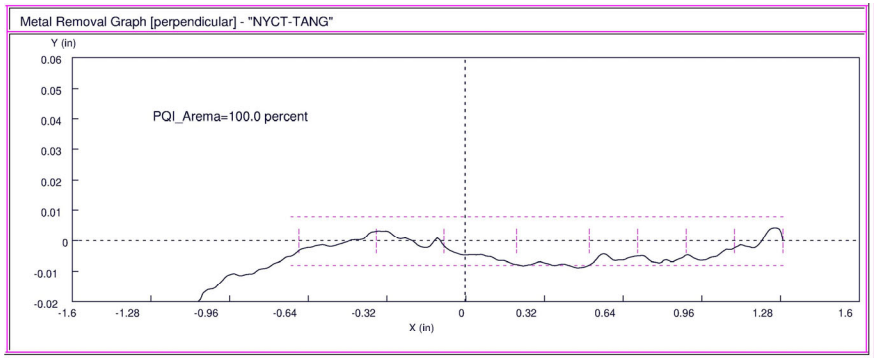


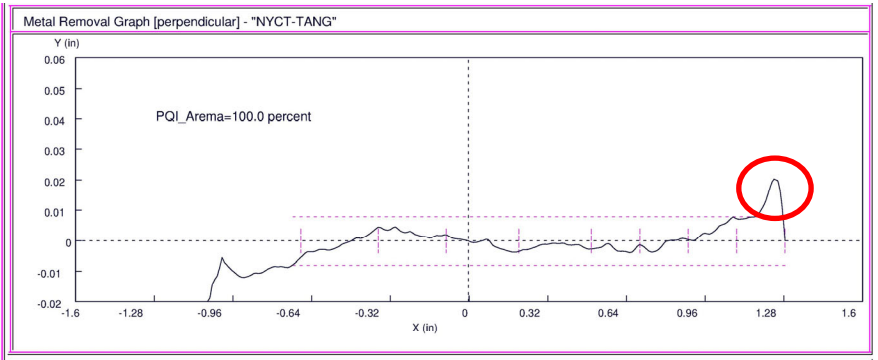
100% GQI gives a range of conformality values



and hence a range of contact conditions




Metal Removal Graph [perpendicular] - "NYCT-TANG"
Y (in)
PQI_Arema=100.0 percent
X (in)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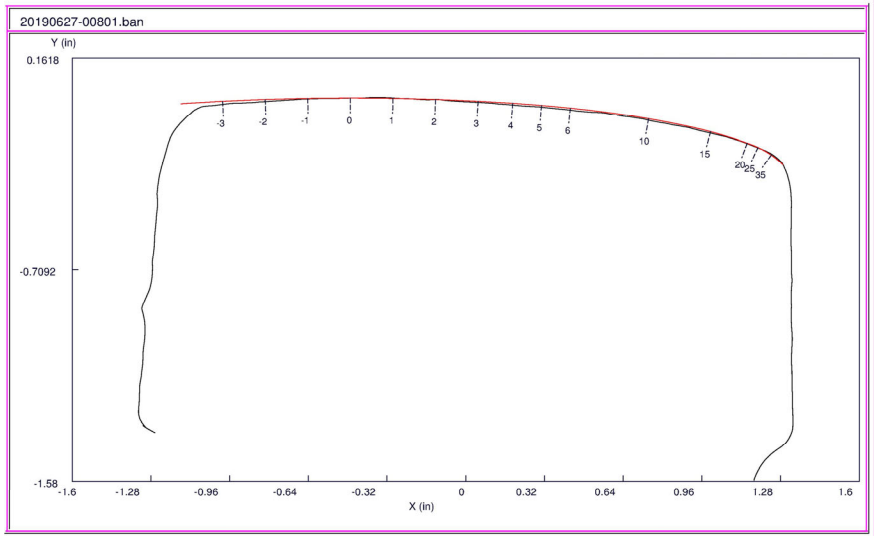
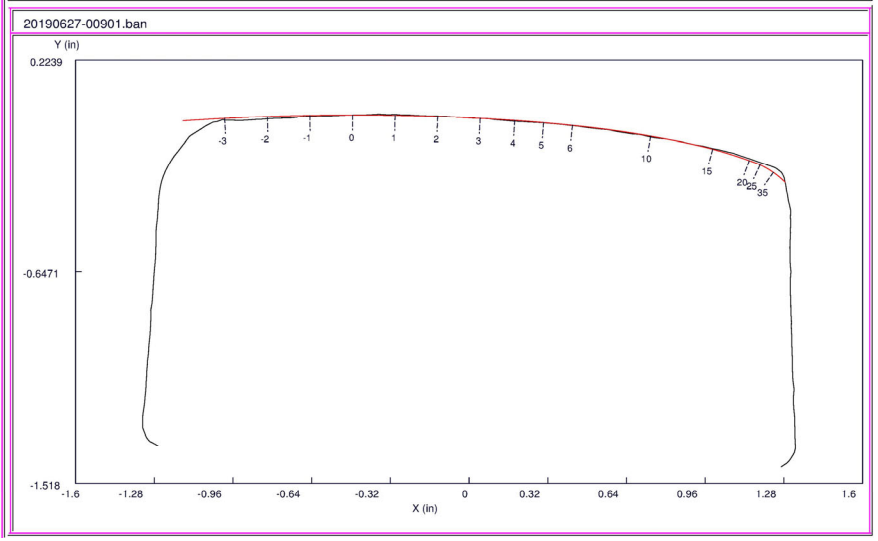
Y (in)
PQI_Arema=100.0 percent
X (in)

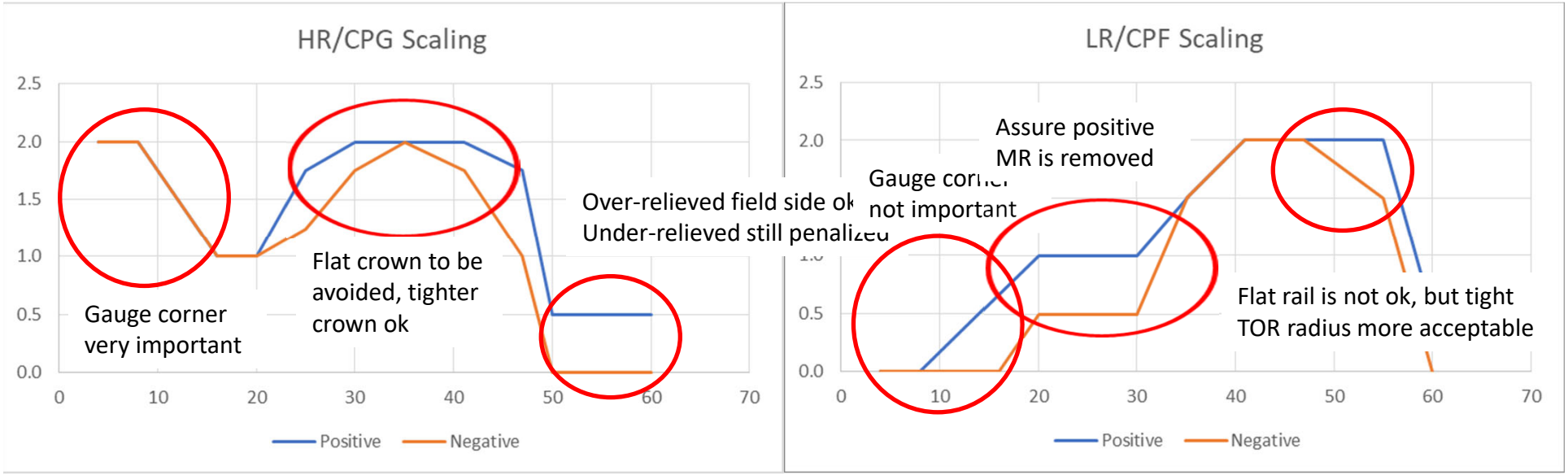

20190627-00801.ban
Y (in)
X (in)


20190627-00901.ban
Y (in)
X (in)

Profile deviation index

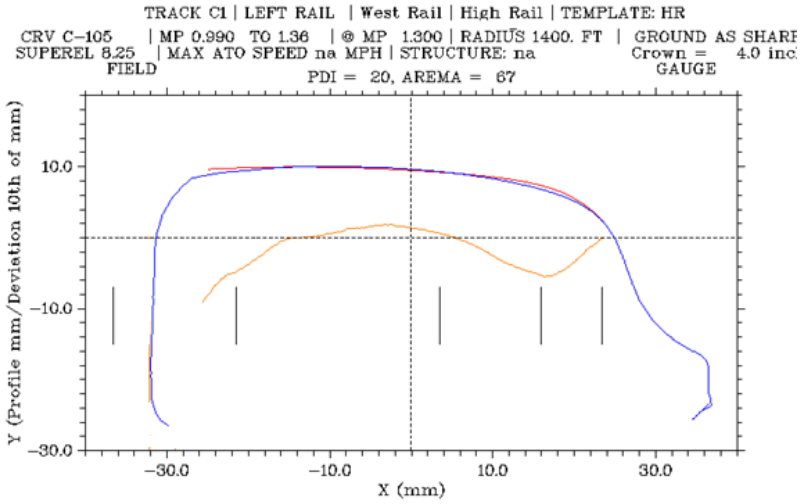
- What is most important to contact mechanist?
  - Functional performance of the shape
    - Conformality (especially for a high rail)
    - Contact band radius
    - Avoidance of stress raisers (e.g. strong facets)
    - Max deviation in critical areas
- What is most important to rail grinding manager?
  - Position of running band (not known during grinding)
  - Running band radius (can be measured)
  - Area difference
    - Metal removal required to get “perfectly” to shape
    - Metal removal required to get “close enough” to shape
  - Not worrying about deviations in areas that don’t matter

Profile Deviation – weighting functions



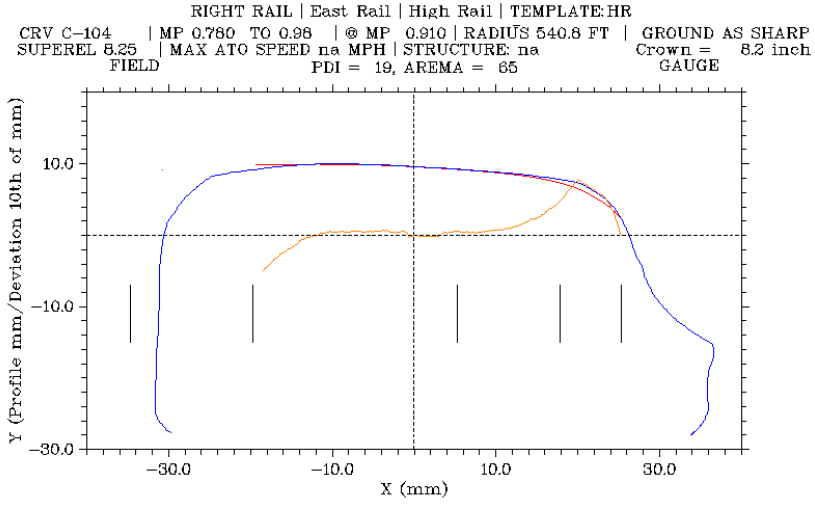
PDI Examples – High Rails

PDI=20 / AREMA=67



Over-Relieved High Rail

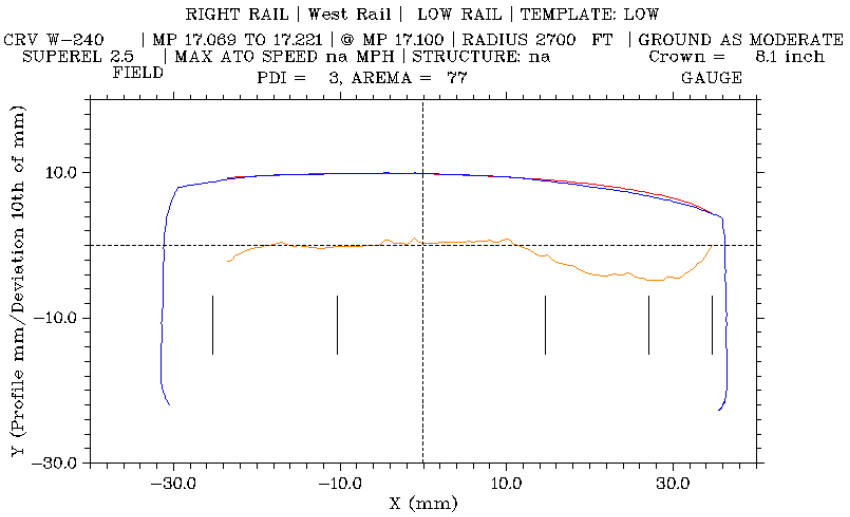
PDI=19 / AREMA=65



Under-Relieved High Rail

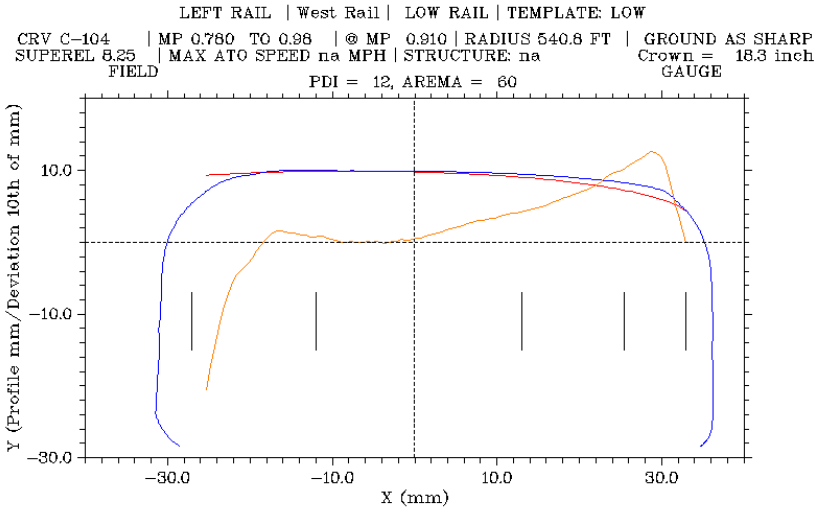
PDI Examples – Low Rails

PDI=3 / AREMA=77



Over-Relieved Low Rail

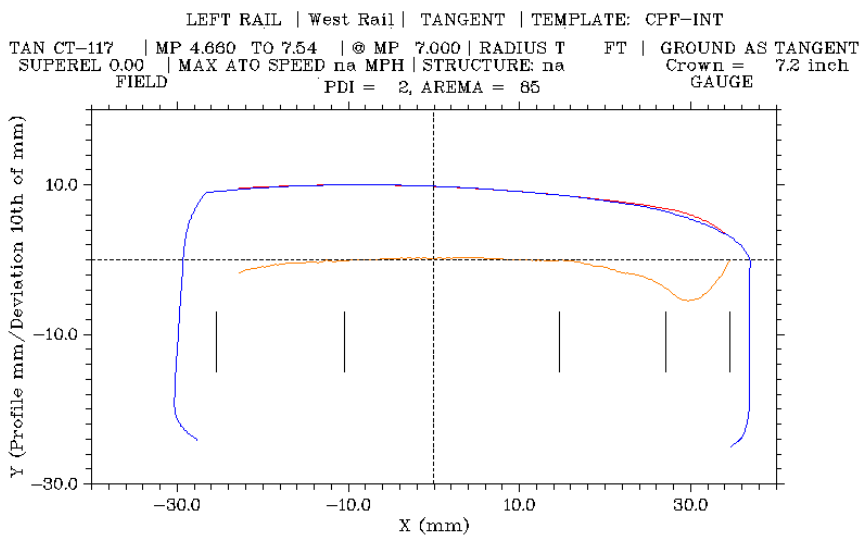
PDI=12 / AREMA=60



Under-Relieved Low Rail

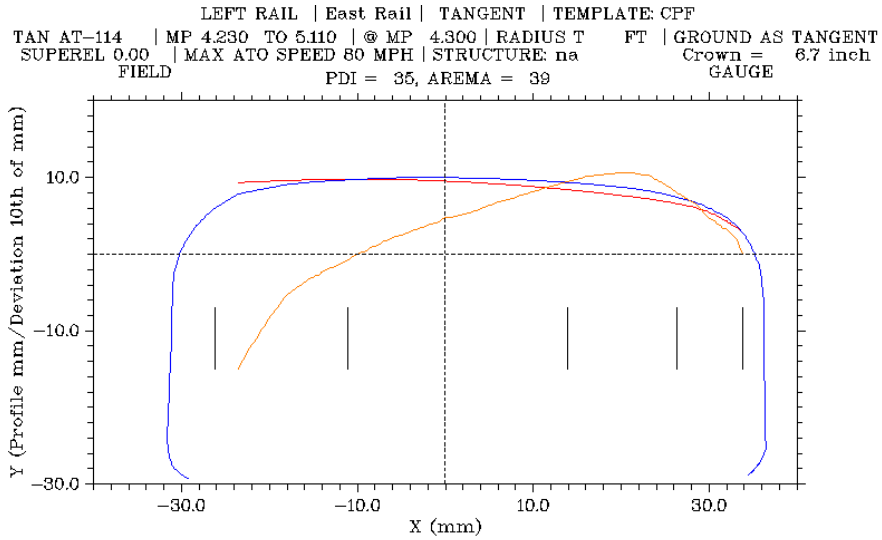
PDI Examples – Tangent Rail

PDI=2 / AREMA=85



Low PDI value

PDI=35 / AREMA=39



High PDI value

PDI – future work

- What levels of profile deviation are “acceptable”?
- Can PDI be related to meaningful consequences – e.g. amount of grinding required, impact on forces or damage?
  - If so, then are there economically justifiable PDI targets/thresholds?

  => ICRI project on “profile scoring”
- How best to score a segment of track? Is using an average profile sufficient?

Equivalent Grinding Quality Index (EGI)

RCF Quantification - Towards Rail Grinding Best Practices for Australian Heavy Haul Rail

November 2013

Conference: World Congress on Railway Research · At: Sydney, Australia

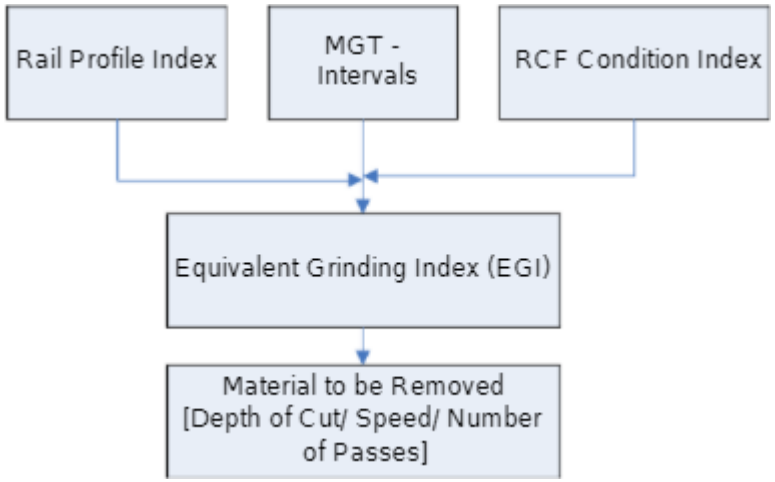
Authors:

Dhamodharan Raman

Rajkumar Devadoss

Gopinath Chattopadhyay
Federation University Australia

Dwayne Nielsen



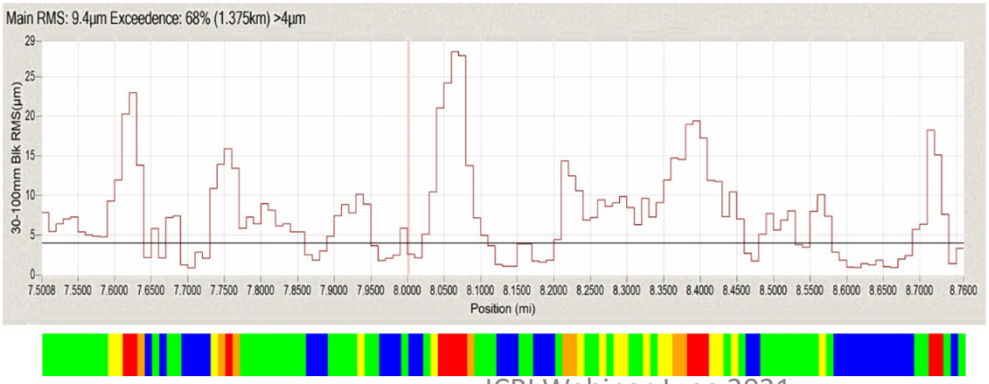
Outline

- Profile Deviation (PDI)
- Surface Damage (SDI)
- Rail Corrugation (RCI)
- Noise, vibration?

Combined Index

Rail Corrugation Index (RCI)

Corrugation Analysis Trolley (CAT)
RailMeasurement LTD
https://www.railway-technology.com/contractors/track/rml/attachment/rml1/

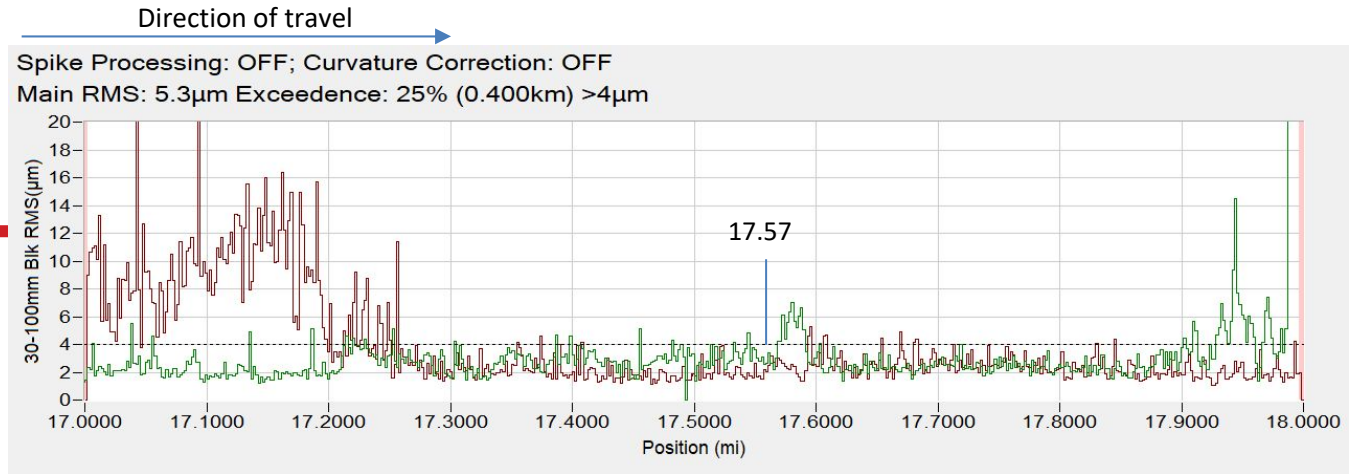


RMS (µm)

- <4 “1”
- <8 “2”
- <12 “3”
- <16 “4”
- > 16 “5”

Corrugation RCI

L1 MP18.0 East
Pre: 29AUG18
Ground: 14-20OCT18
Post: 03NOV18



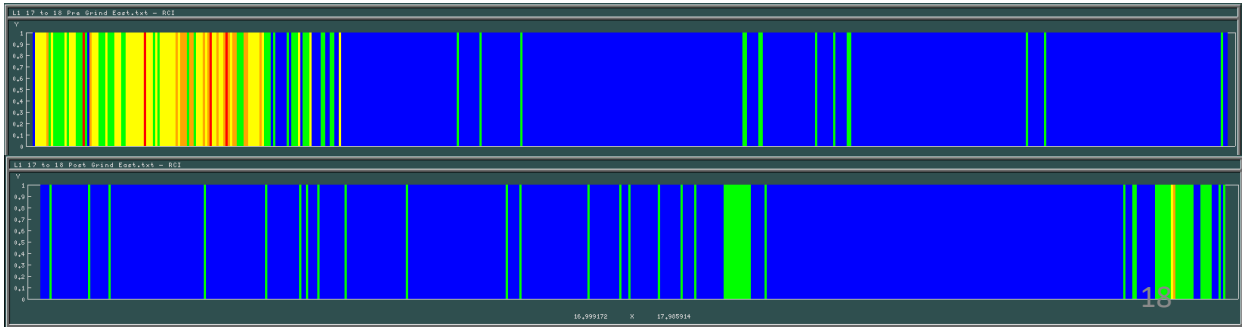
Low Rail
10 passes
1.8 degree left

High Rail
9 passes
2 degree right

7 passes
tangent

Pre-grind

Post-grind



RCI ARMapp Visualization

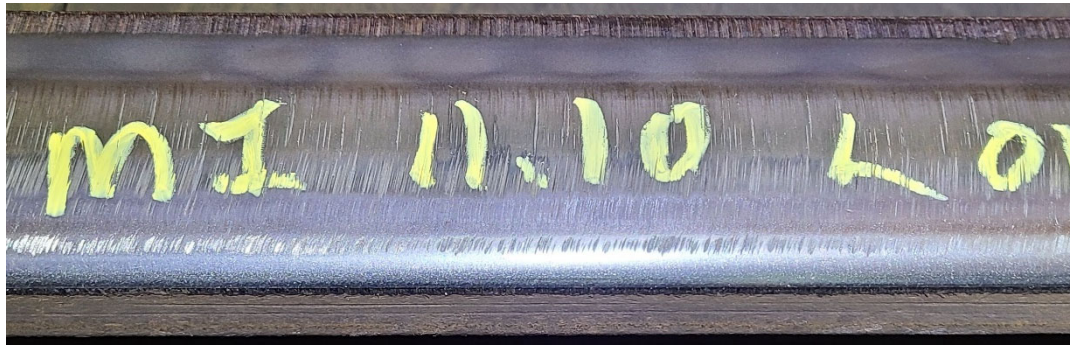
Pre-grind

Post-grind

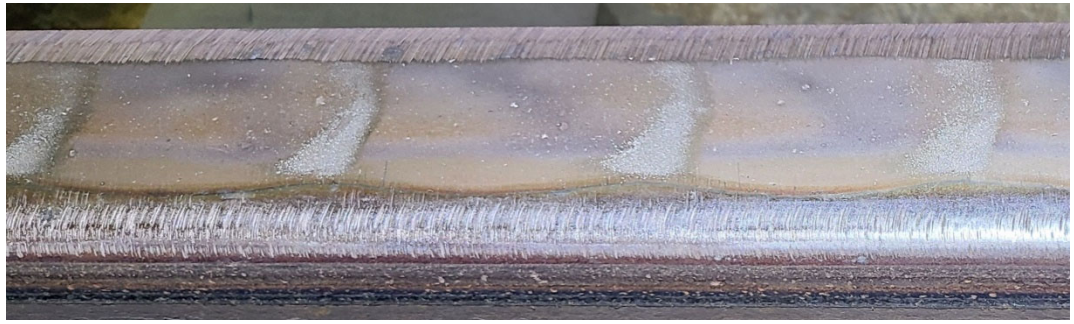
Change as a result of grinding

RCI refinement

- Current color scheme/thresholds arbitrary
- Need to associate corrugation levels with
  - Noise
  - Vibration
  - Past experience



RCI – 3.86



RCI – 31.4

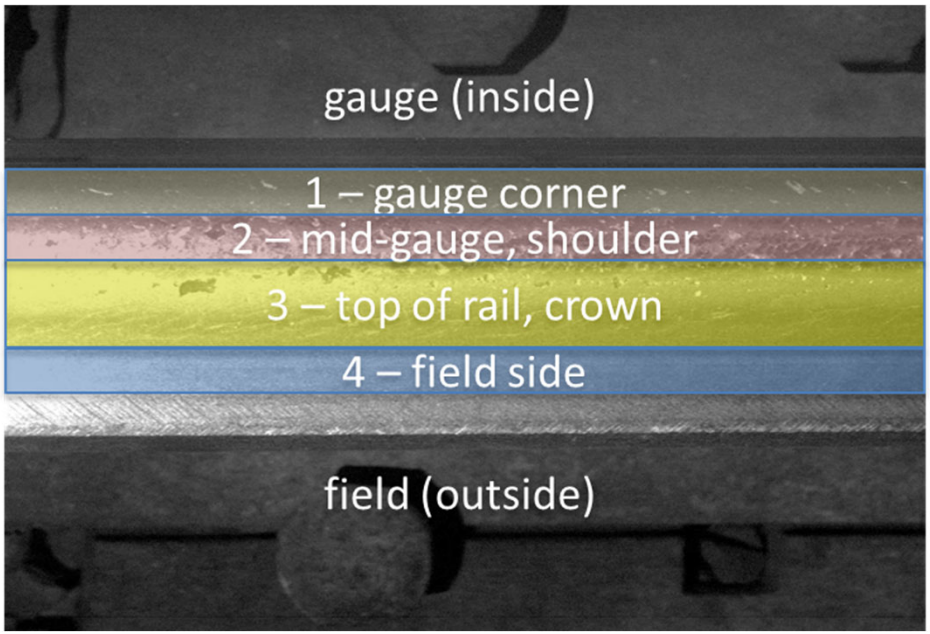
RCI – 68.37

Other related work

University of Manitoba - focusing on RCI

- Rail corrugation is a direct contributor to vibration and noise
- Working with field data to compare versus accelerometers and noise.
- What are the costs of each at various levels?

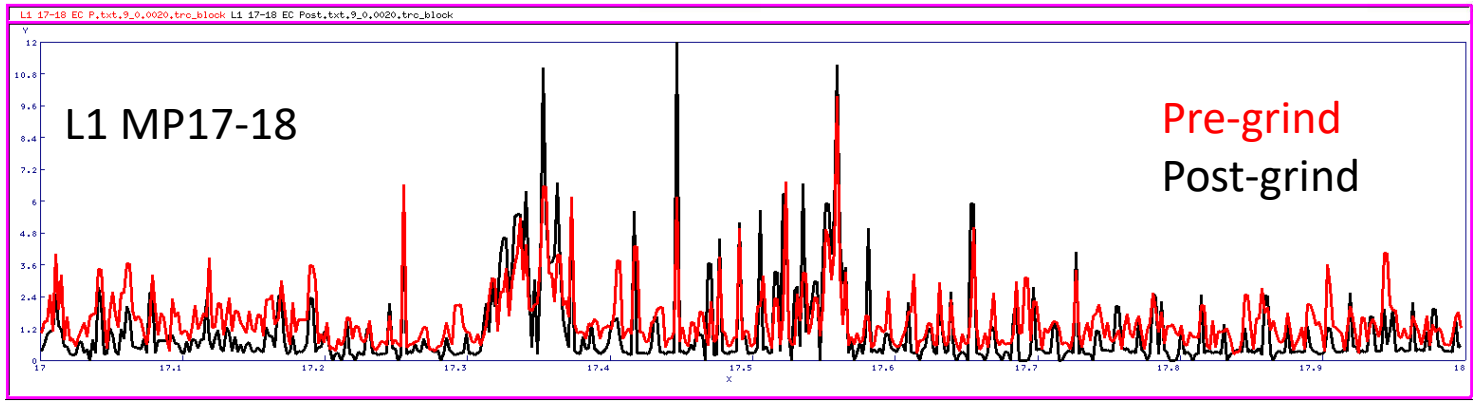
Surface Damage Index (SDI)
Visual - approach

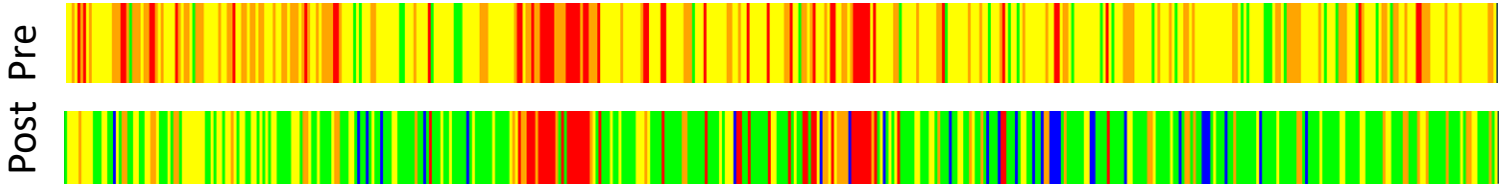


KLDLABS MEASUREMENT TECHNOLOGIES
U.S. Department of Transportation Federal Railroad Administration
LORAM SPEED. PERFORMANCE. RELIABILITY.
ARM ADVANCED RAIL MANAGEMENT CANADA INC. SERVING THE INDUSTRY SINCE 1990

0	**None**
1	Barely perceptible, but clearly regular pattern. Unable to feel with a finger nail. Depth < 0.5 mm → Preventive grinding
2	Clear, well-defined, distinct individual cracks – but no pitting. Might detect with finger nail. Depth < 1.0 mm → Maintenance grind
3	Strong, regular cracks, consistent spacing. Easily snags skin or cloth Depth < 2.0 mm → alternate maintenance and corrective grinding
4	Clear cracking, pits up to 4 mm diameter. Depth: 1.0 - 2.5 mm → Corrective grinding
5	Pitting greater than 4 mm < 10 mm. “Heavy”, well defined gauge corner cracks Depth: < 3.5 mm → Heavy corrective, or Preventive gradual grinding
6	Shelling/spalling: regular pitting, > 10 mm diameter Depth: 3-5 mm, nearly impossible to catch up on cracks → regular heavy corrective grinding
7	Shelling/spalling: any defect > 16 mm diameter or > 20 mm length Depth > 5 mm Interferes with UT detection so is unsafe. Requires very aggressive grinding and then ultrasonic inspection to verify it is safe to leave in track, or else replacement.

Rail Surface damage - SDI





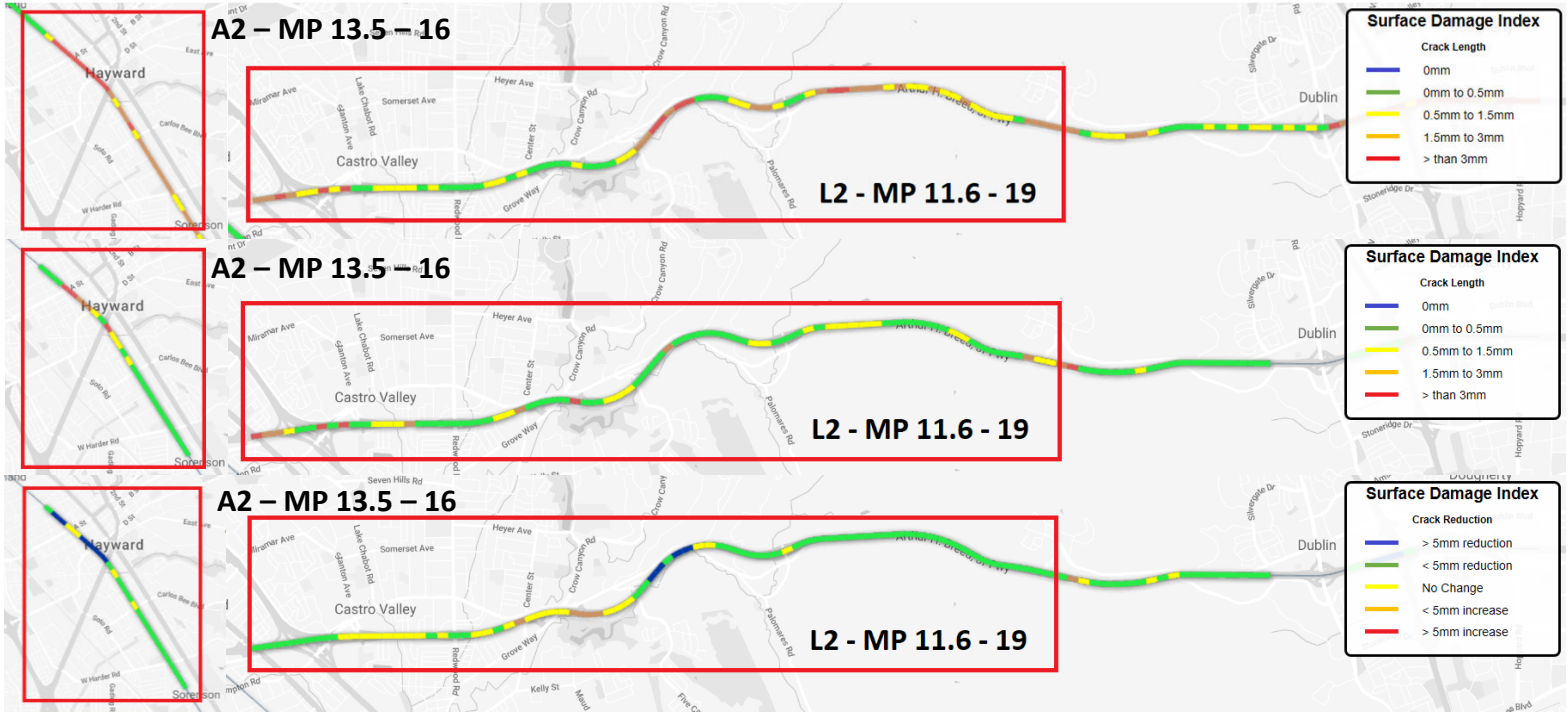
	No cracking	“1”
	<0.5 mm	“2”
	<1.5 mm	“3”
	<3.0 mm	“4”
	> 3.0 mm	“5”

SDI ARMapp Visualization

Pre-grind

Post-grind

Change as a result of grinding



SDI work ongoing

- Working directly with RAW data (0.5mm intervals)
  - Automatic removal of welds
  - Various block sizing
- Is crack density an important parameter?
- What segment lengths should be considered?

Equivalent Grinding Index (EGI)

- Meaningful combination of PQI, SQI, and CQI
- Example: using simple weighting coefficients

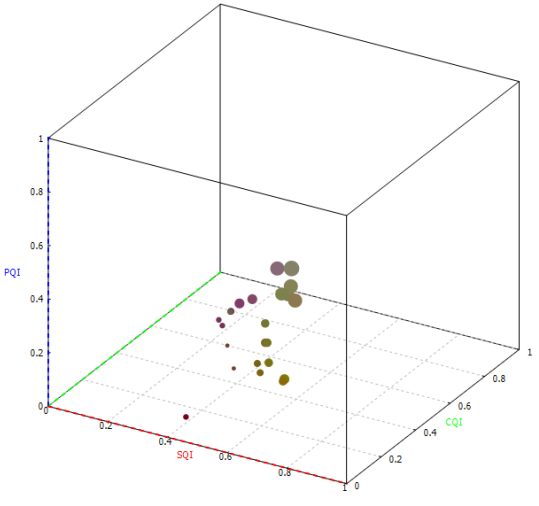
$$EGI = \frac{W_{PQI} \cdot PQI + W_{SQI} \cdot SQI + W_{CQI} \cdot CQI}{W_{PQI} + W_{SQI} + W_{CQI}}$$

- Or as a scaled vector

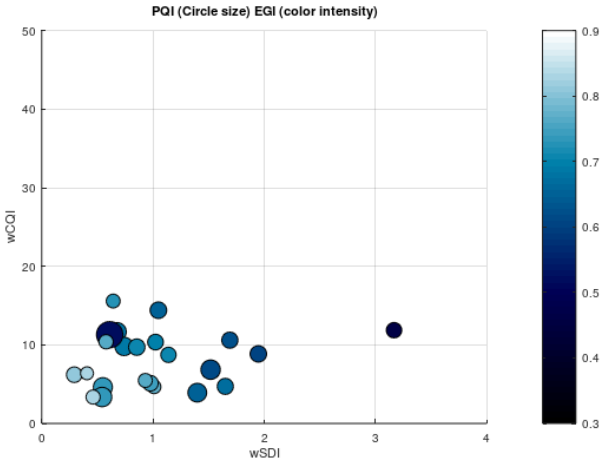
$$\overrightarrow{EGI} = \frac{W_{PQI} \cdot PQI \cdot \hat{\imath} + W_{SQI} \cdot SQI \cdot \hat{\jmath} + W_{CQI} \cdot CQI \cdot \hat{k}}{\left[{W_{PQI}}^2 + {W_{SQI}}^2 + {W_{CQI}}^2\right]^{\frac{1}{2}}}$$

Magel/Oldknow 2018

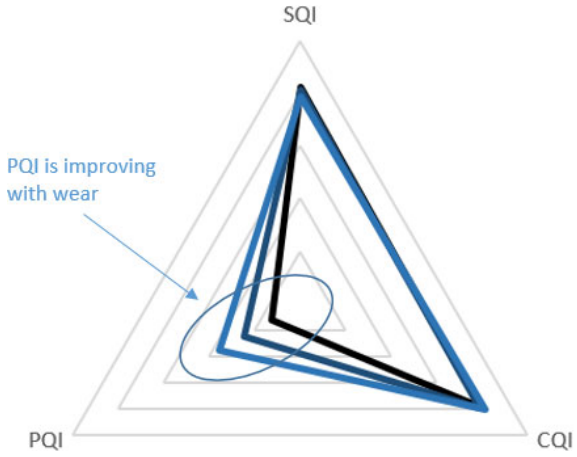
Combined Index - visualizations



3D scatter plot

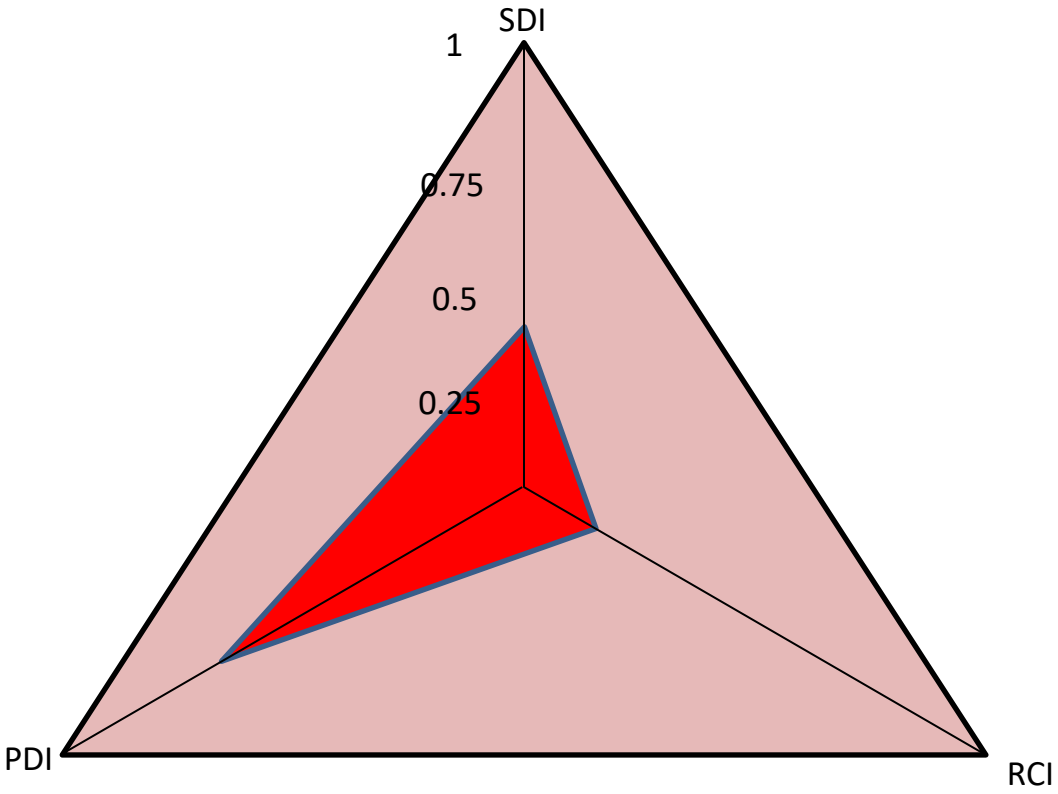


2D color intensity plot

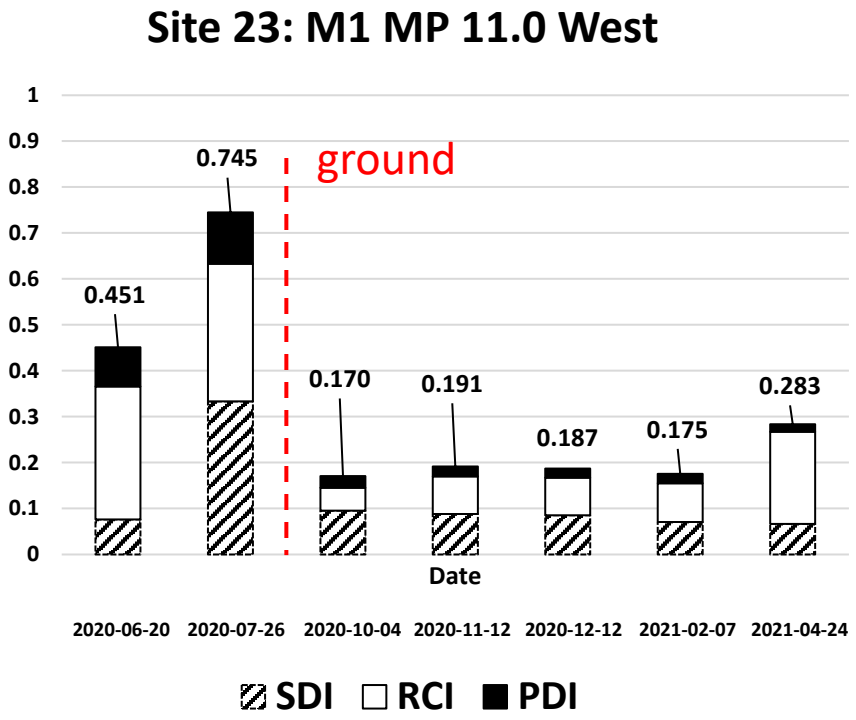


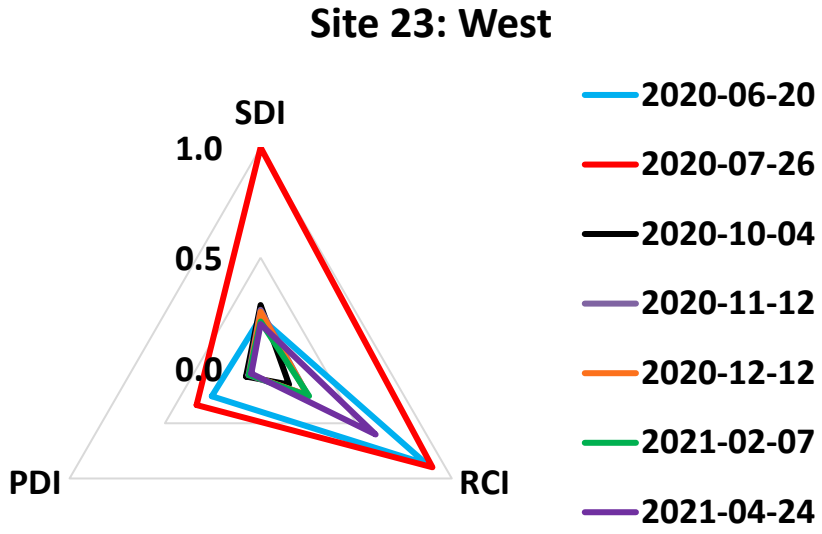
Radar plot

Evaluating the combined index



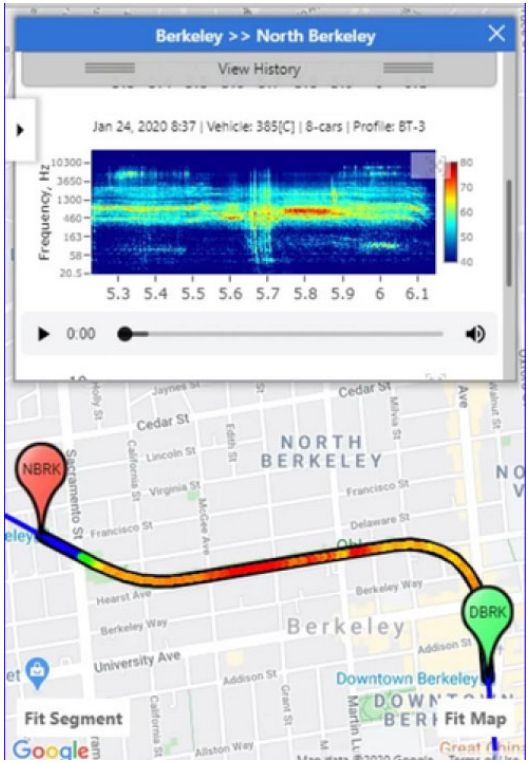
Site 23: M1 MP 11.0 West





Noise Quality Index

- Challenges
  - Most often done inside the vehicle
  - Changes with environmental conditions / seasons



Vibration Index (VBI)

- Axle box (or rail) mounted accelerometers
- Monitor surface quality of wheel/rail interface
- Focus on vertical vibrations
- Can be displayed the same as noise
- NOT effectively measured with ride quality systems which capture acceleration on the truck or car body

Conclusions

- New Technologies -> improved opportunities for meaningful quality indices
- PQI/GQI is mature
  - Provides practical measures for rail grinding
  - Gives little practical insight into suitability for performance

    => PDI has been developed
- SDI – improving technology, manage risk
- RCI – especially important for passenger rail, measurable and manageable
- EQI – to balance tradeoffs, mapping and reporting

Summary (where are we going from here?)

- PDI: refinement to weighting
- SDI: exploring crack density, comparing visual with index, changes with rail grinding
- RCI: ongoing project with University of Manitoba
- Noise and Vibration indices being considered

Collaboration?

- Looking for strong, aligned correlated sets of CAT + (external)Noise + Accelerations
- Weighting functions for PDI?
- Atlas of eddy current+surface cracking images
- Atlas of CAT + corrugation images

Acknowledgements:
A big thank you to Ben Magel and Teever Handal for their significant and ongoing contributions to this work.

Thank You.

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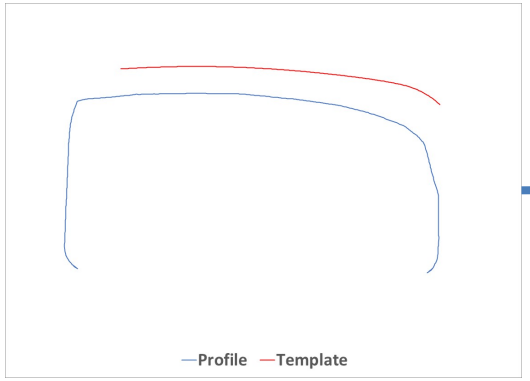
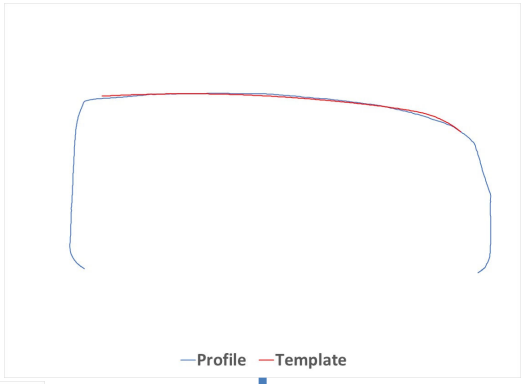
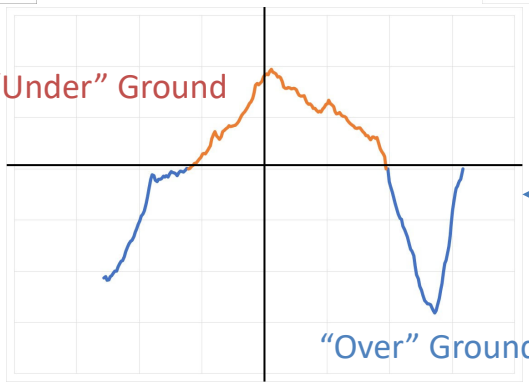
Step 1



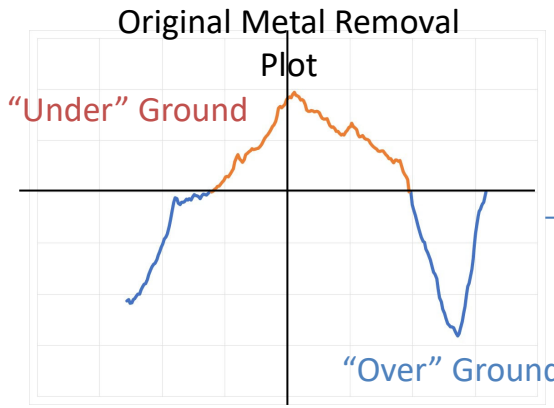
Align Profile and Template



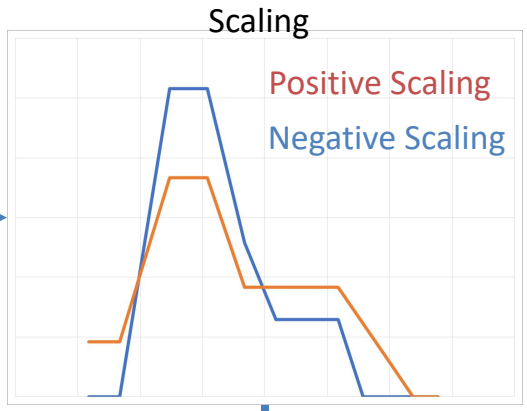
Calculate Perpendicular Distance Between Shapes



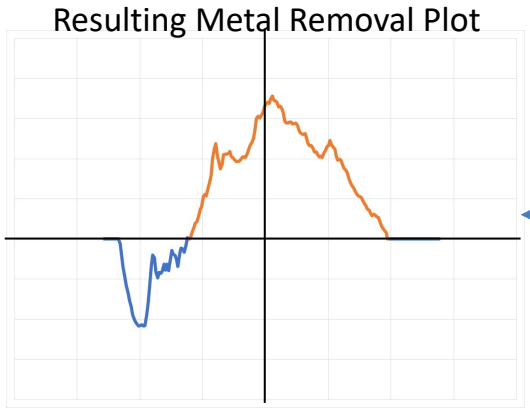
Step 2



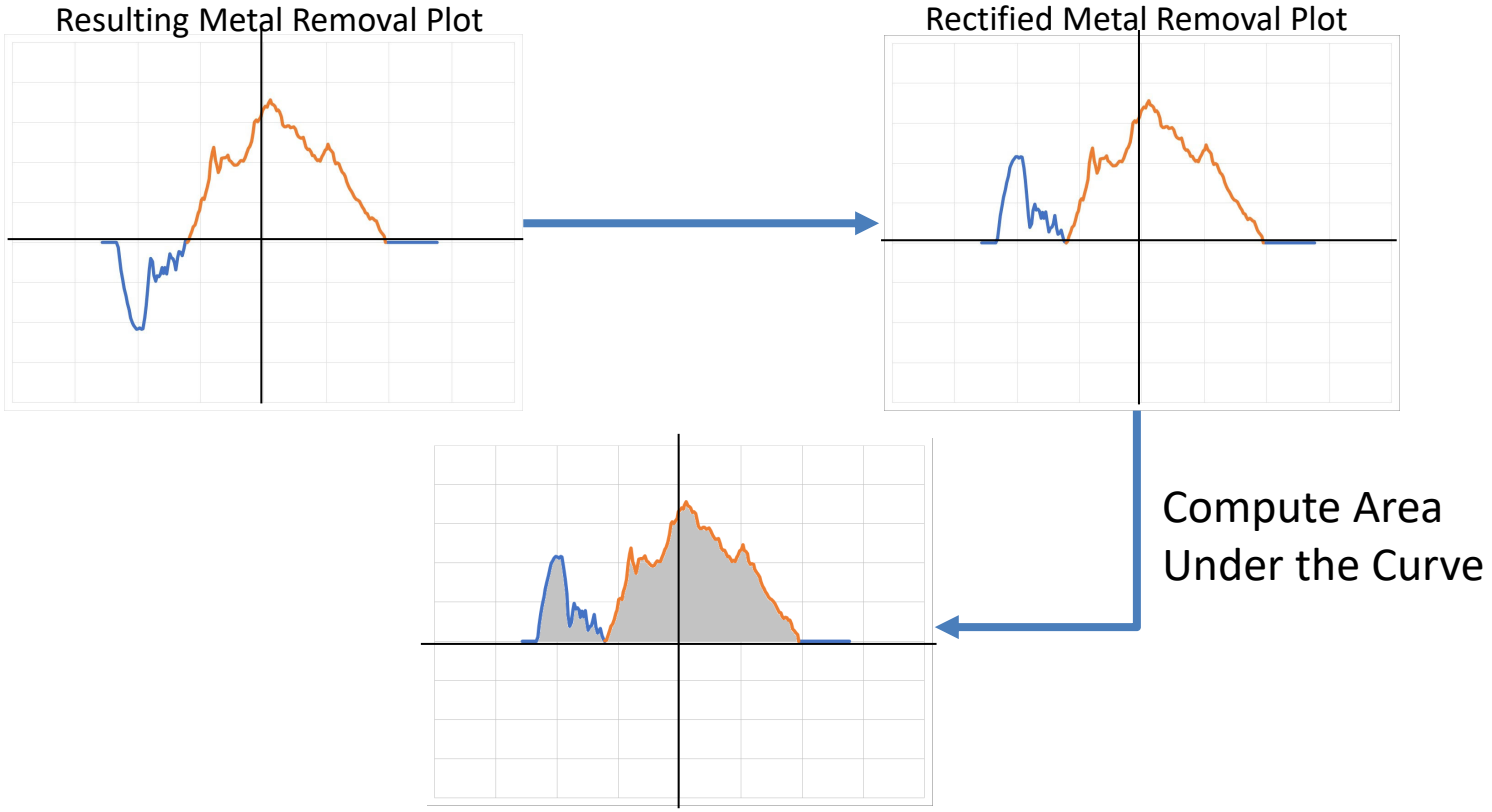
Apply Scaling Function to Metal Removal Curve



Scaling Curve is Normalized to Unit Area to Decouple the Scaling Dependency on Rail System and Template



Step 3


Resulting Metal Removal Plot
Rectified Metal Removal Plot
Compute Area
Under the Curve

Step 4

- To compute PDI, normalize the area under the rectified metal removal curve by the horizontal length of the metal removal curve