(Obtaining and) maintaining the optimized wheel/rail interface

Eric E. Magel

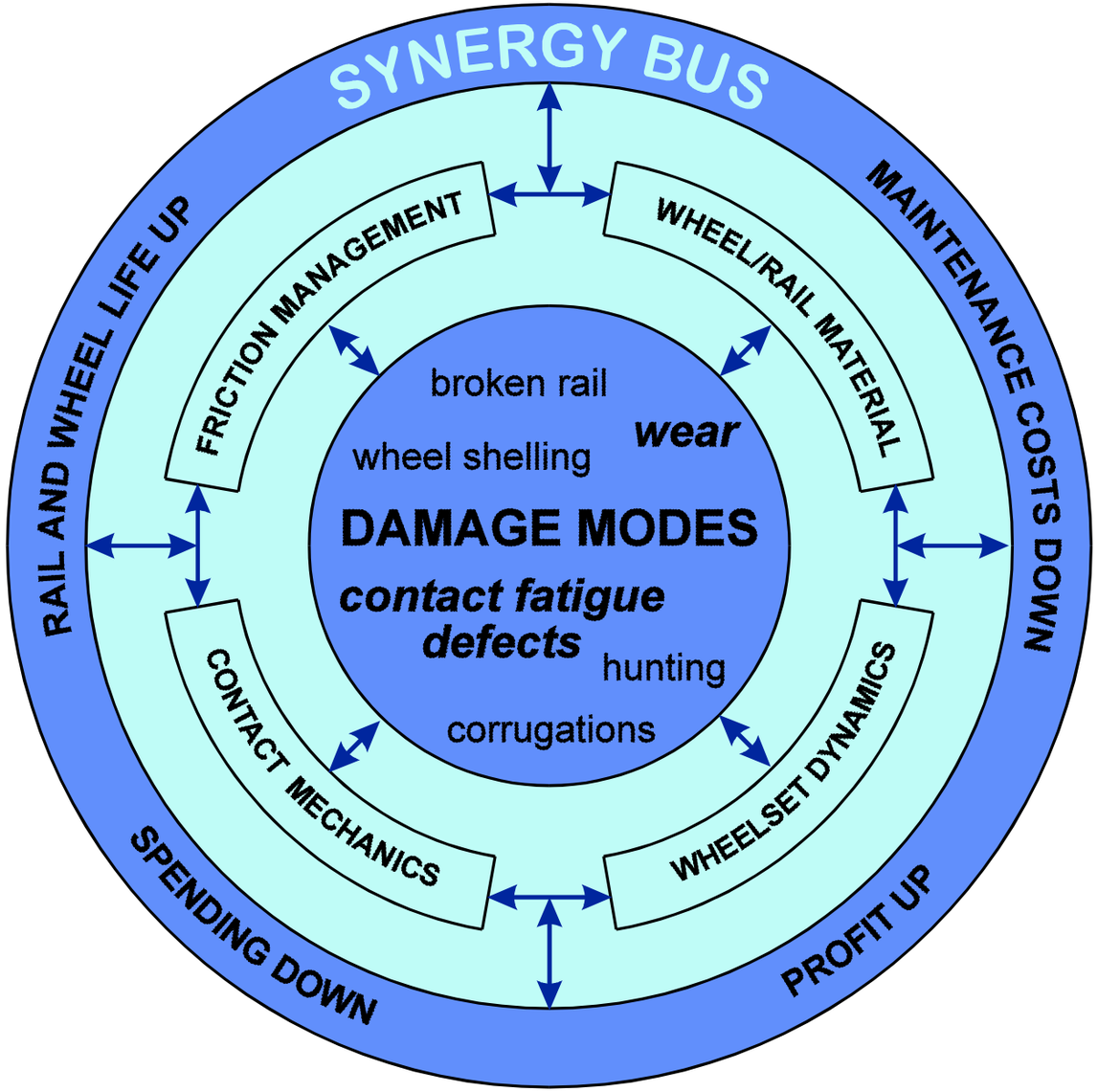
Principal Engineer, NRC Canada

OWRI

1. Contact Mechanics
2. Friction Management

   Wheel/rail Material

   Wheelset Dynamics



Examples

- Adopting a new wheel profile
- New rail or vehicle procurement
- Implementing a rail grinding program
- Improving lubrication
- Adopting (TOR) friction management
- Noise or vibration abatement

Once you have the optimized wheel/rail profile designs, friction management etc. how do you implement it?

YOU MUST PLAN, MONITOR AND VALIDATE

Planning

- What is the driving concern/motivation?
  - Examples: Wheel and/or rail wear, wheel-rail noise, broken rails
- Set Goals – what does success look like?

Employ or acquire proper tools

- Determine baseline, establish key performance indicators

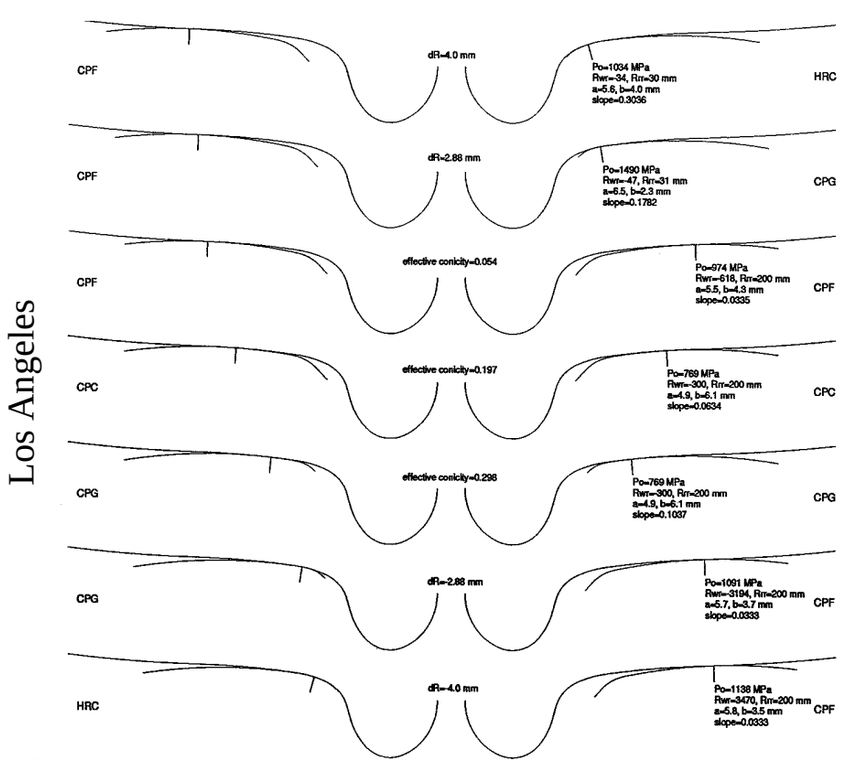
Outline

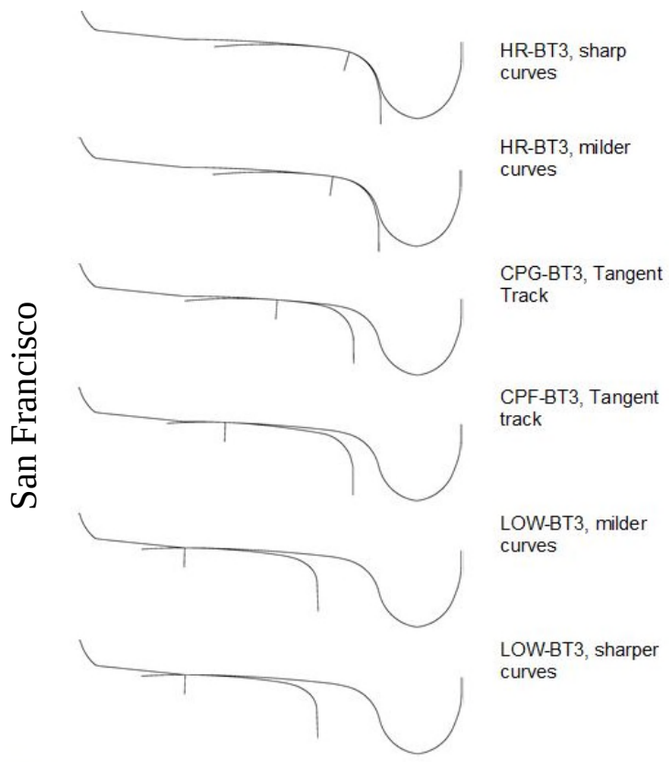
1. Rail and wheel profiles
2. Rail and wheel surface condition
3. Treating rails and wheels
4. Friction
5. Vehicle performance
6. Track Performance

1. RAIL AND WHEEL PROFILES

Rail profiles

- Some railroads have a single shape, others have multiple rail profiles



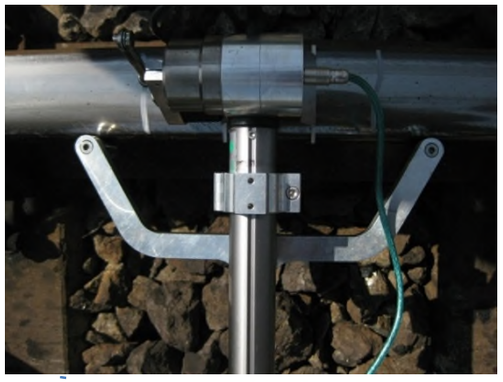


Managing rail profiles

- Choose/Install rail that is close to initial shape
  - E.g. 8” vs 10”, the JK124 story
- Vary gauge of track instead of two tangent rail profiles?

- Pre-grind survey
  - Profiles: Optical rail measurement, MiniProf, BAR gauge

Measuring rail profiles



https://www.nextsense-worldwide.com/en/industries/railway/rail-cross-profile-measurement.html

MiniProf™

ftp://ftp.greenwood.dk/miniprof/pdf/MiniProf-BT-brochure-2015.pdf

Profile Quality Index

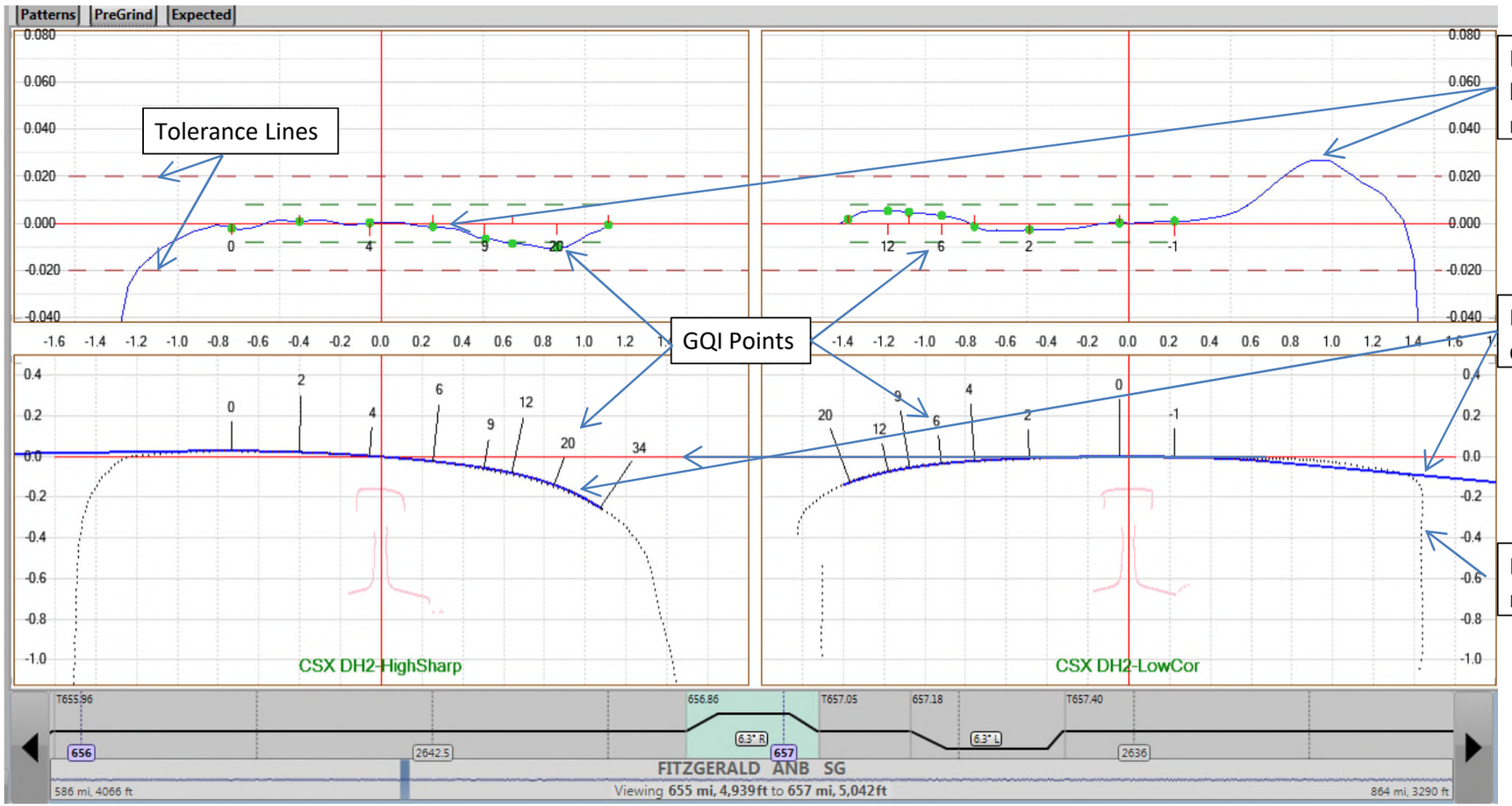


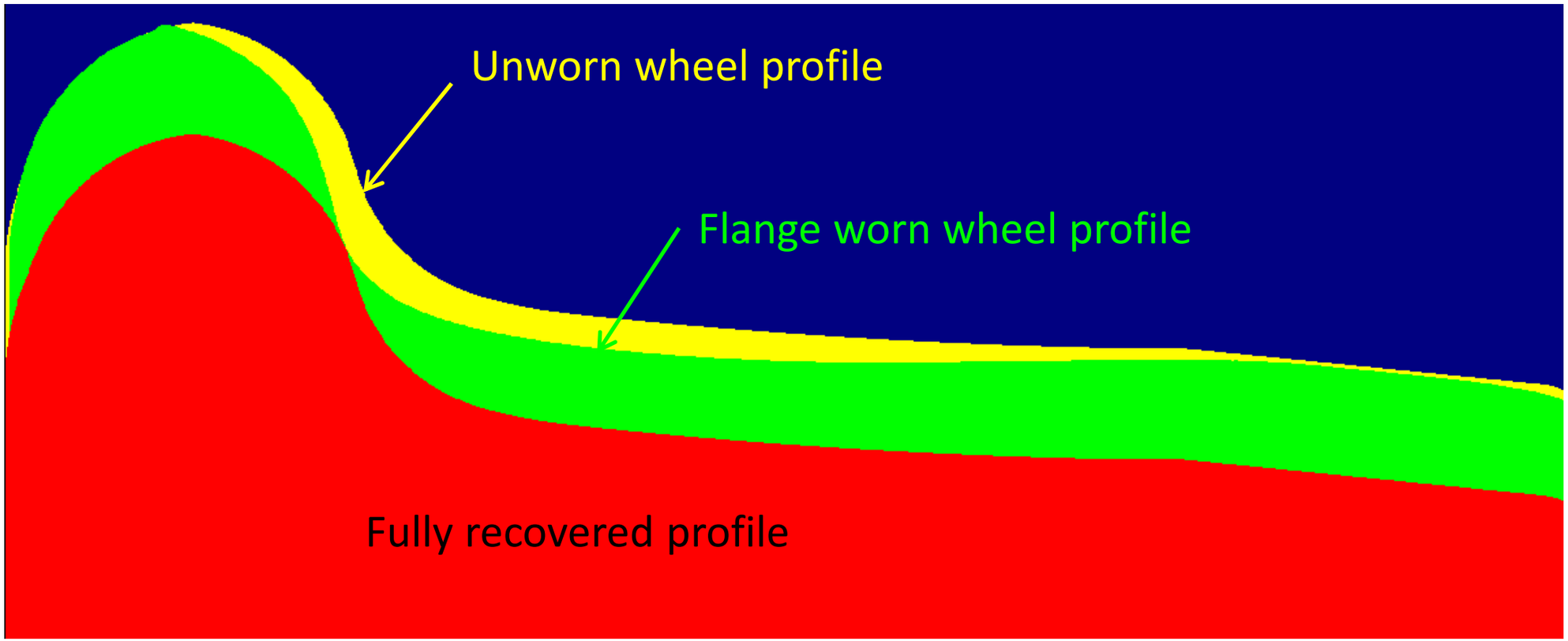
Image courtesy of LORAM Maintenance of Way, Inc.

Maintaining Wheels

Wear Limits

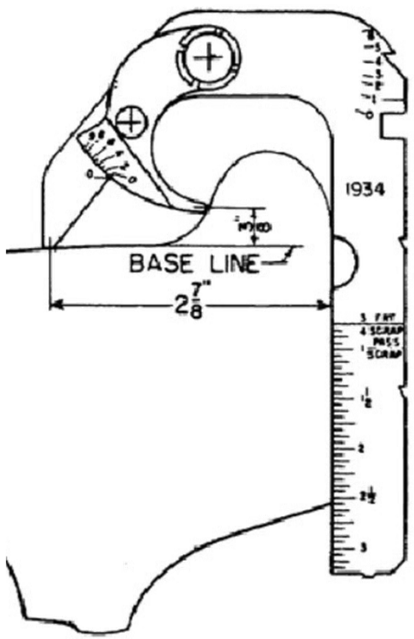
- Flange height or width, hollowing
- Thin rim
- Wheel(set) diameter mismatch
- Ride quality

Worn Wheels


Unworn wheel profile
Flange worn wheel profile
Fully recovered profile

Wheel Profile Measurement

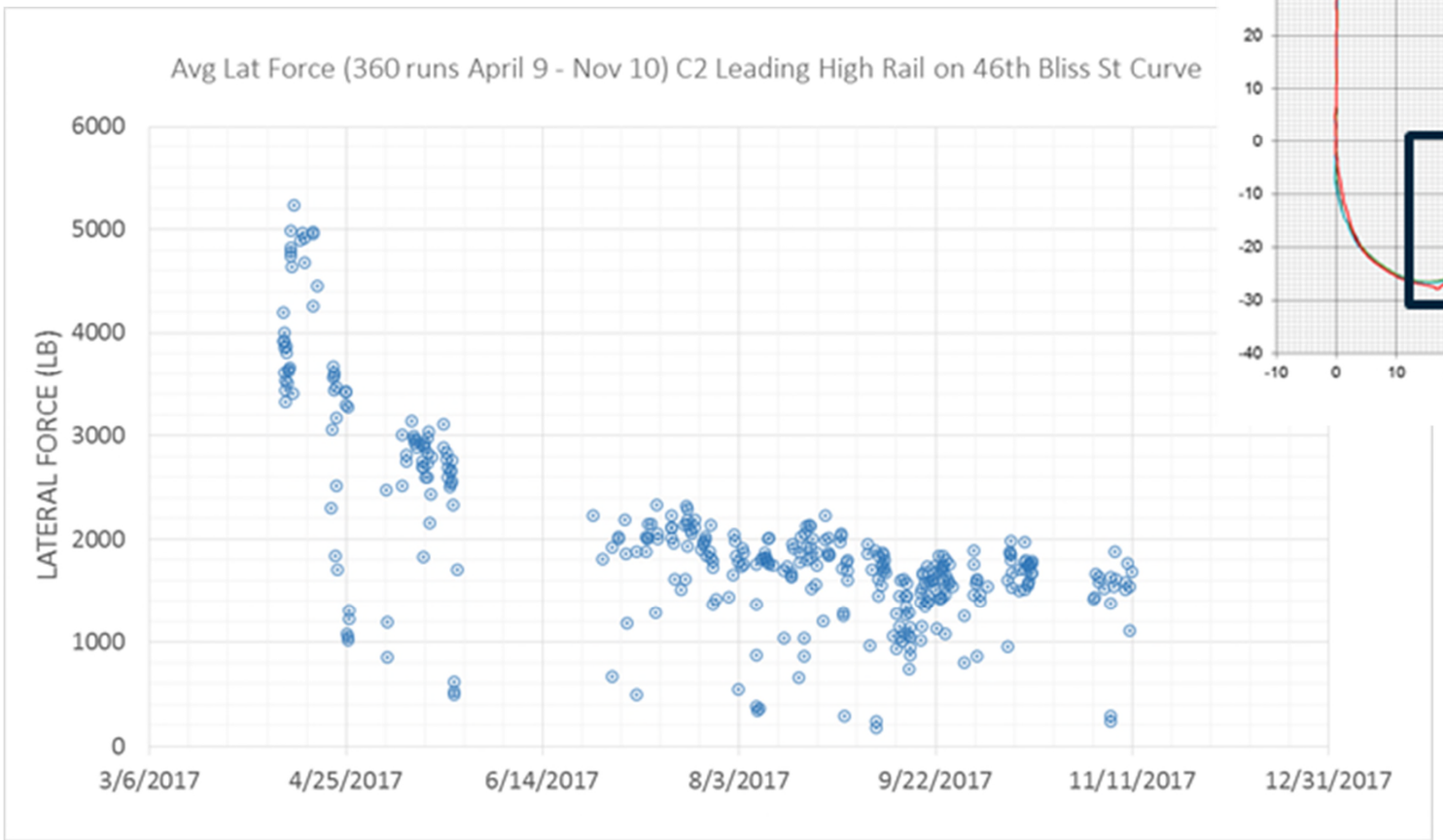
Hand gauges, digital instruments

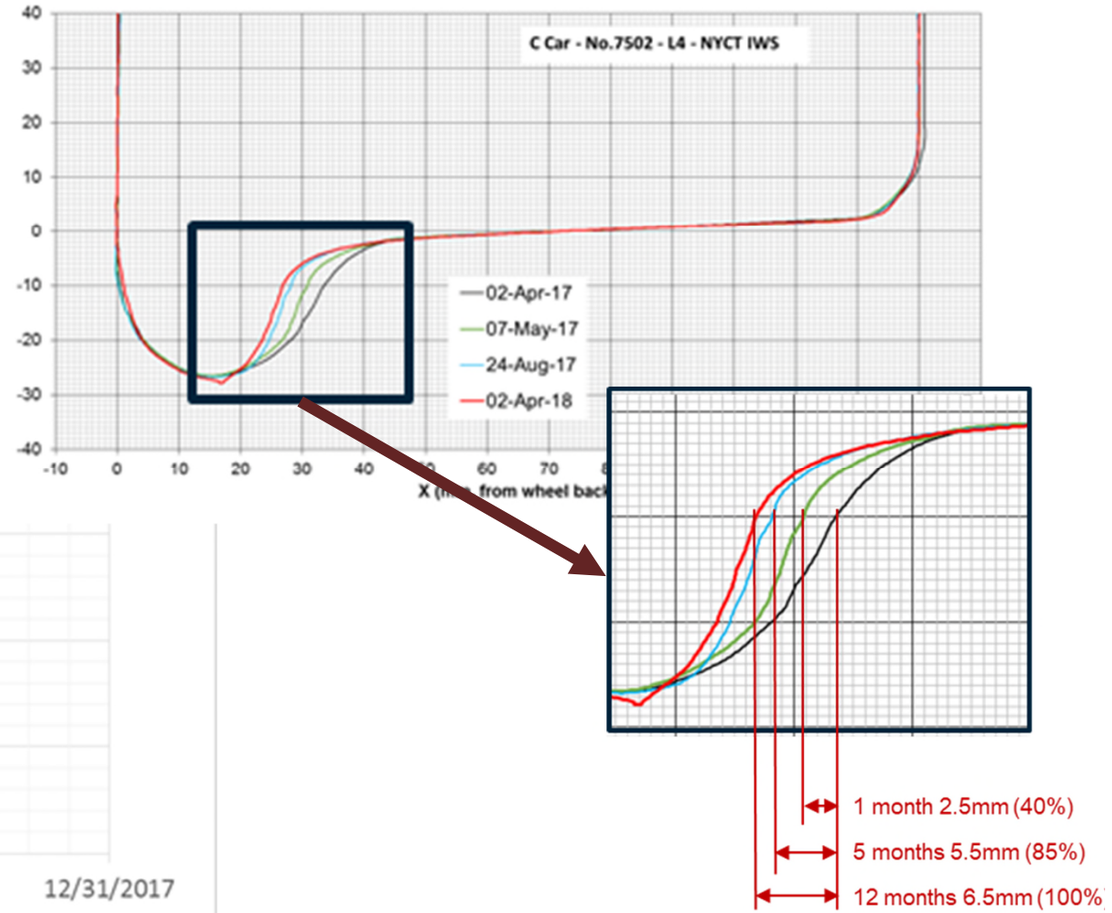


ftp://ftp.greenwood.dk/miniprof/pdf/MiniProf-Wheel.pdf

KLDLABS
MEASUREMENT TECHNOLOGIES

Trending the Effect of Wheel Wear





2. RAIL AND WHEEL SURFACE CONDITION

Managing rail surface condition

- Rolling Contact Fatigue (RCF): Visual, mag particle, dye penetrant, electromagnetic
- Corrugation: Visual, Straight edge, CAT (corrugation analysis trolley), accelerometers etc.
- Noise

Magnetic particle

Electromagnetic Walking Sticks

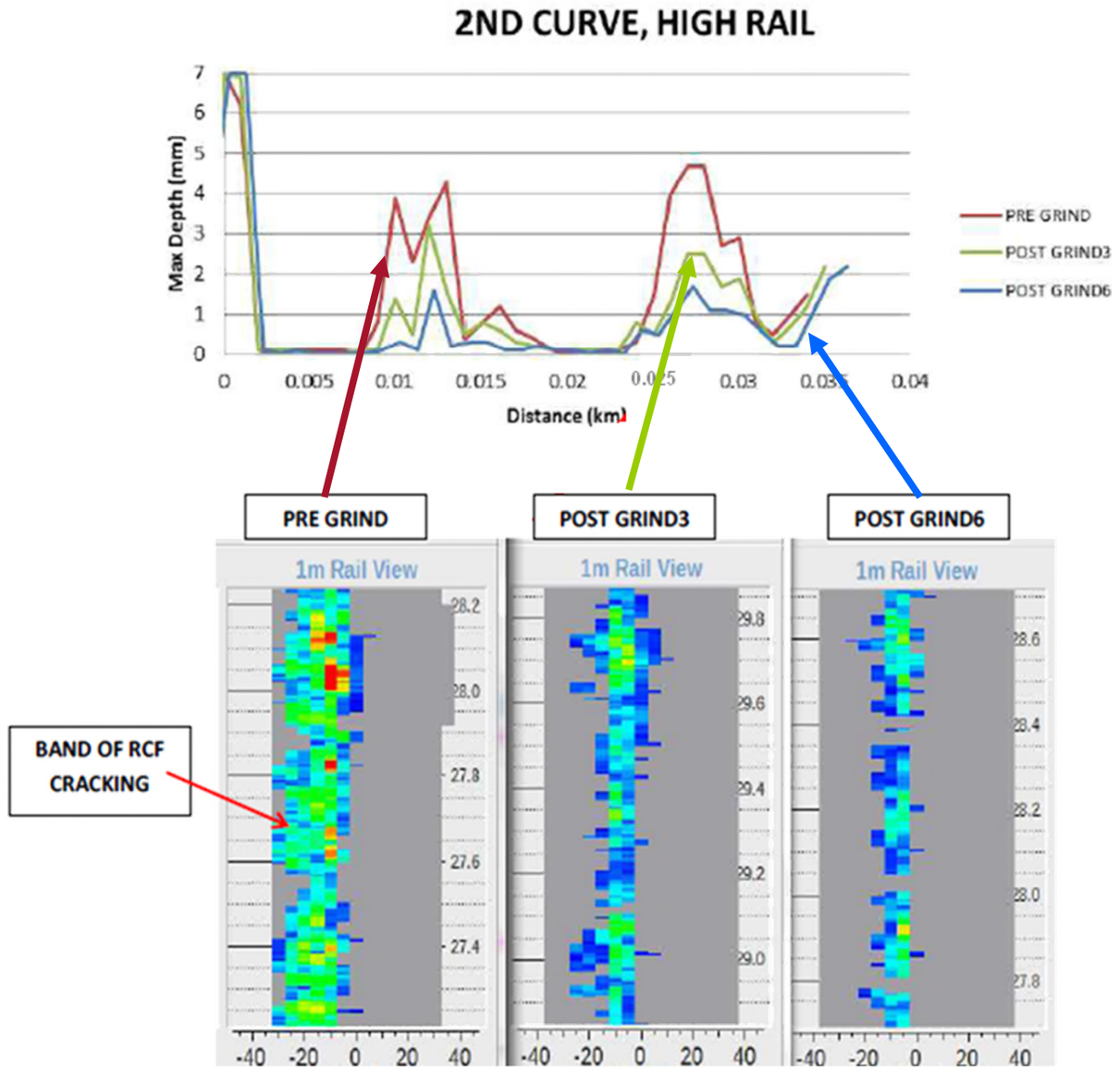
Rohmann Draisine
(eddy current)

Sperry walking stick
(eddy current

NEWT Lizard
(ACFM)

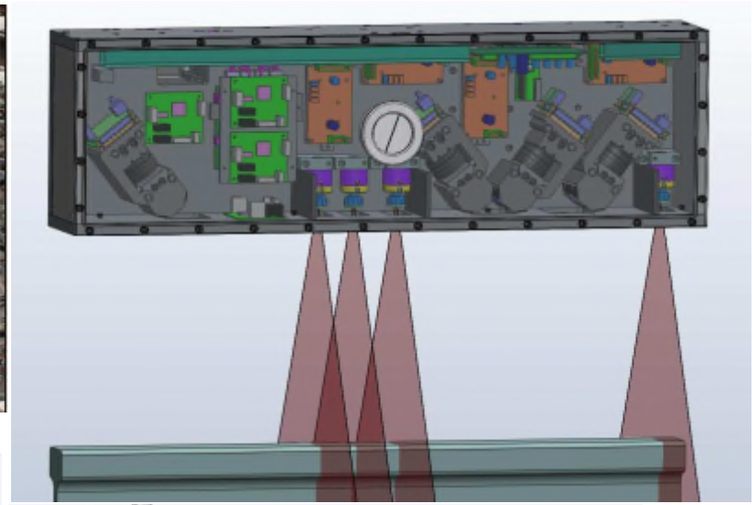
MRX RSCM
(magnetic flux)

Surface Condition Assessment (MRX)



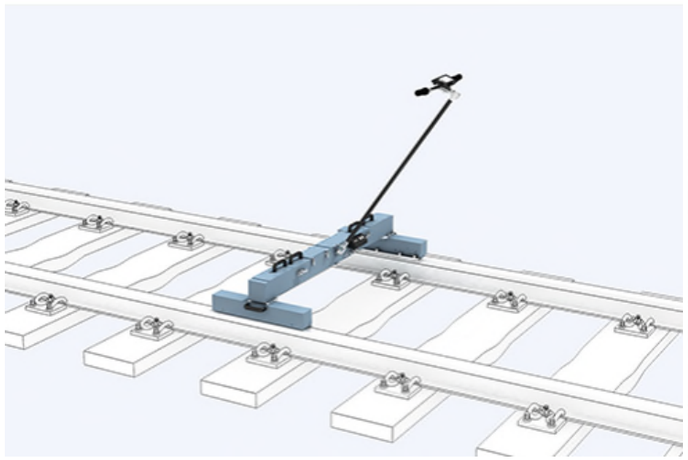
Corrugation measuring approaches

Corrugation Analysis Trolley



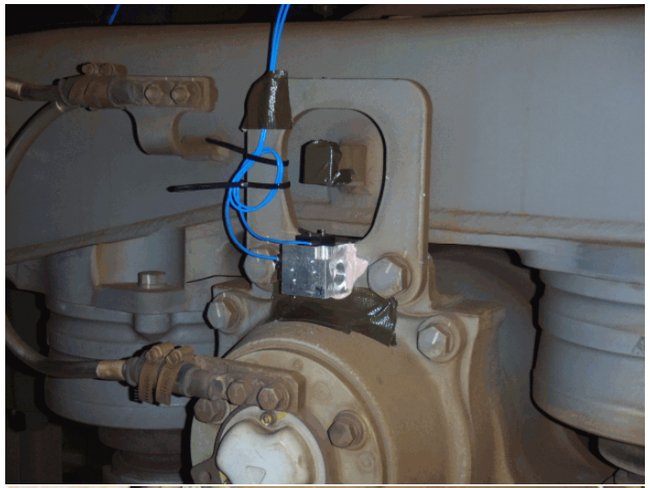
Technogamma RCMS
“3-point versine system”

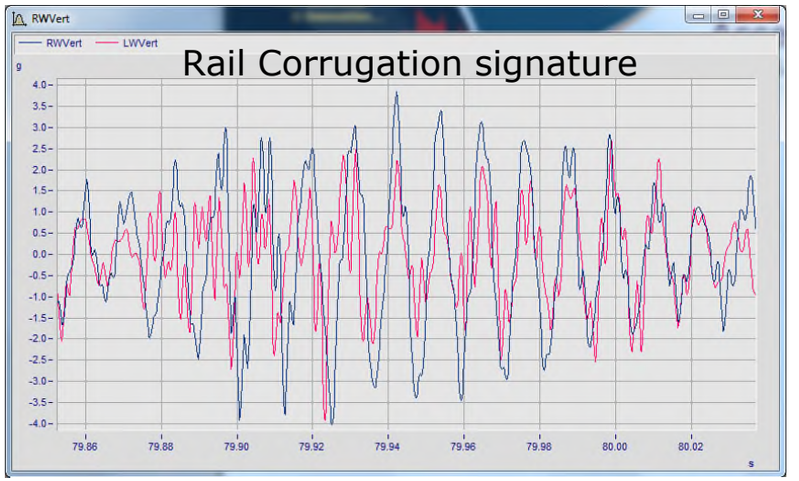
Mermec: Technoline
Uses eddy current displacement transducers

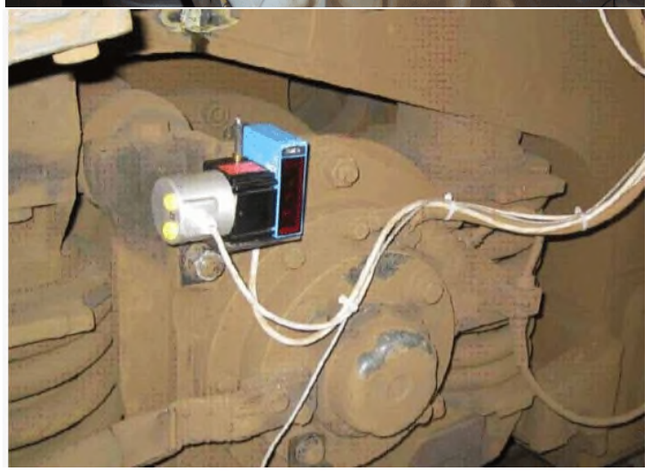


Wheelset displacement or axlebox accelerometers

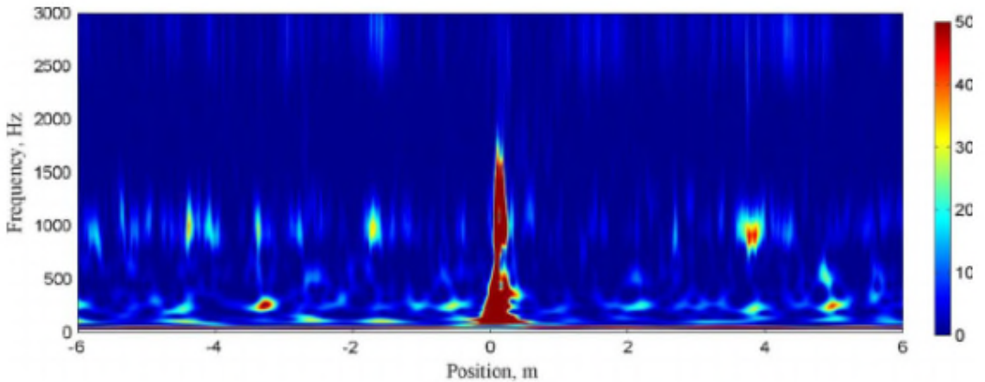
Accelerometer Based Systems







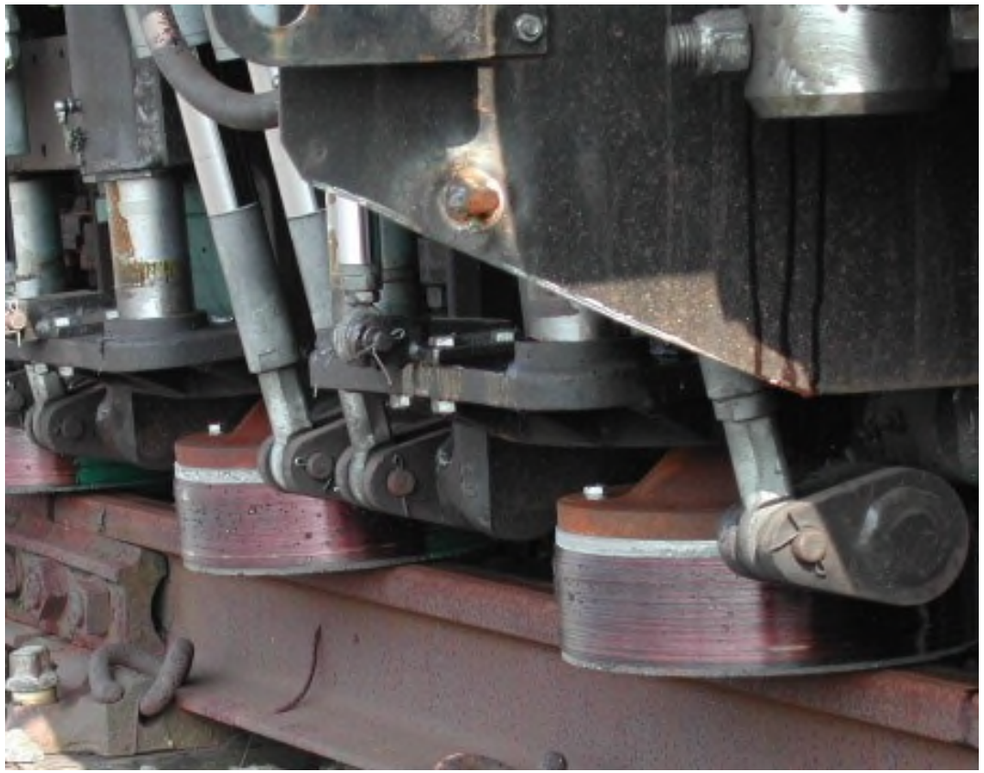
https://www.tudelft.nl/kennisvalorisatie/investeren-in-kennis/octrooien/selectie-van-tu-delft-patent-portfolio/detection-method-for-squats/



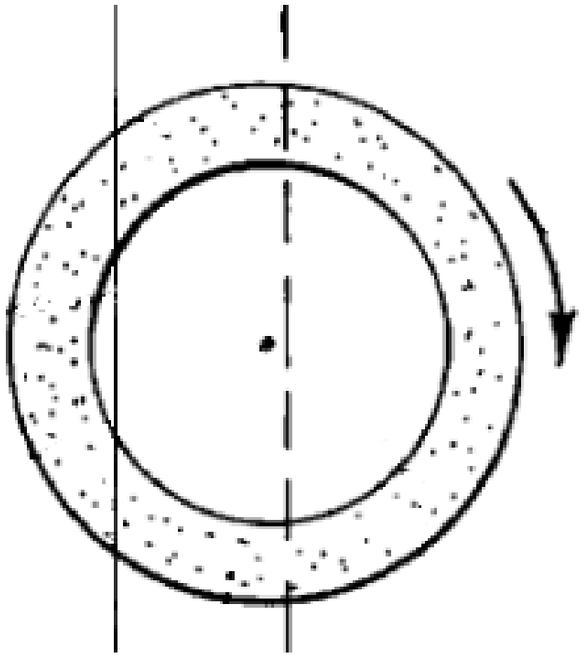
https://www.researchgate.net/publication/265085881_Automatic_Detection_of_Squats_in_Railway_Infrastructure/figures

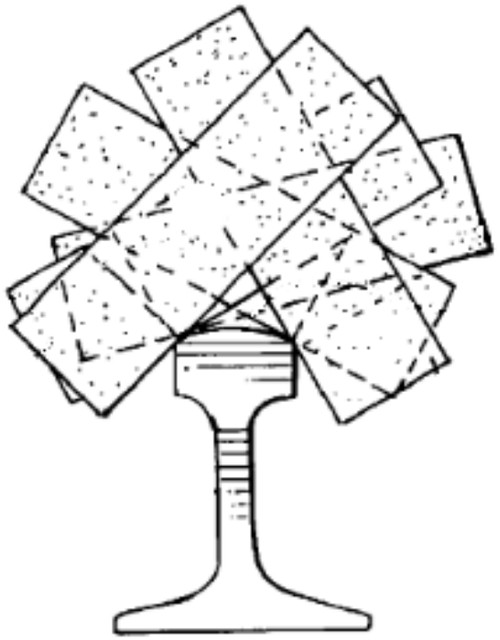
3. TREATING DAMAGED WHEELS AND RAILS

Vertical Spindle Grinding



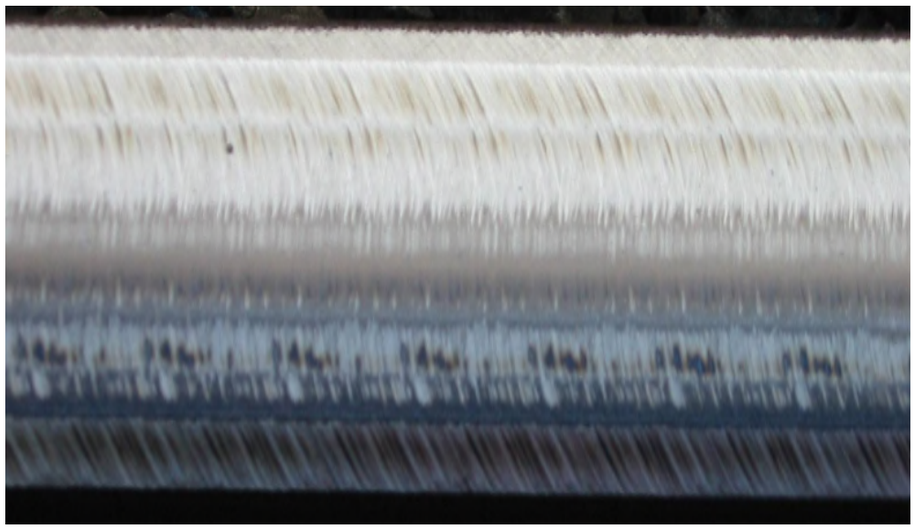
Type 2 rail grinding





Surface Finish to Avoid

Grinding stone chatter
(pressure control)



High grinding pressure causing large grinding facets.
Blueing from low grinding pressure.

Rail Milling Technology

- Non-abrasive rotary cutting process
  - Chips cut out of surface
  - Heat transfer into chips and tool
- Different machine types and sizes available
- Widely used in Europe, Asia and Australia
- Applied chiefly for corrective maintenance

Rail grinding strategy

Corrective (e.g. >60 MGT)

- Less frequent
- More metal removed each cycle
- Less track covered
- Rail profiles deteriorate
- Surface damage often significant

Preventive (e.g. 20 MGT)

- More frequent
- Less metal removed each cycle
- Covers the system quicker, maybe several times / year
- Rail maintained so always in good shape

Preventive Gradual (e.g. 20 MGT)

- More passes than preventive to catch up on poor rail
- Almost same interval and cycles as preventive
- Rail shape improved quickly to reduce stress, then catch up on damage

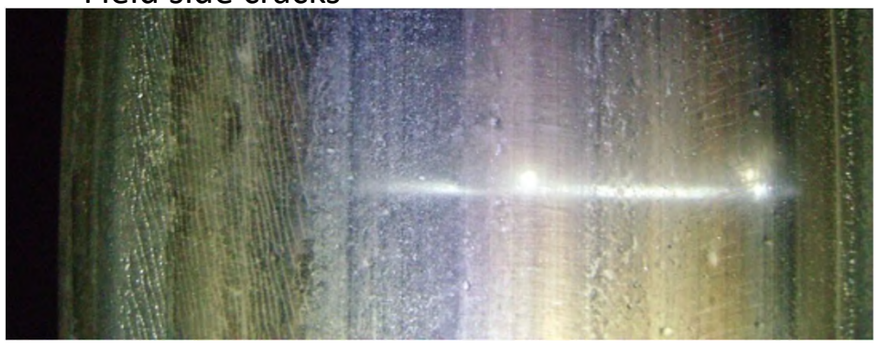
Maintaining Wheels

- Surface condition
  - Rolling contact fatigue (cracking, shelling)
  - thermal cracking
  - out of round and polygonization
  - wheel flats

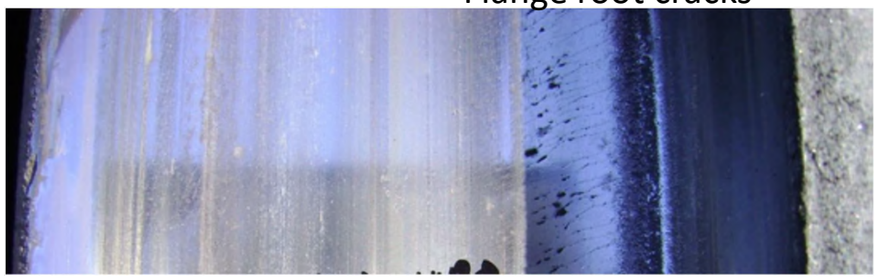
Wheel Surface Condition

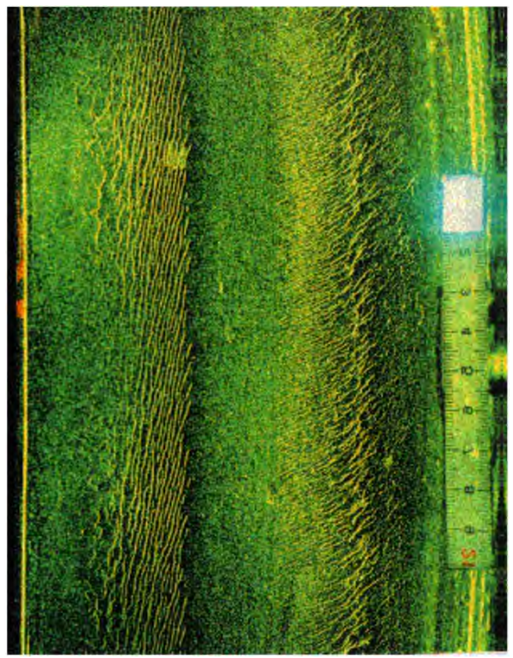
Visual, eddy current

Field side cracks



Flange root cracks



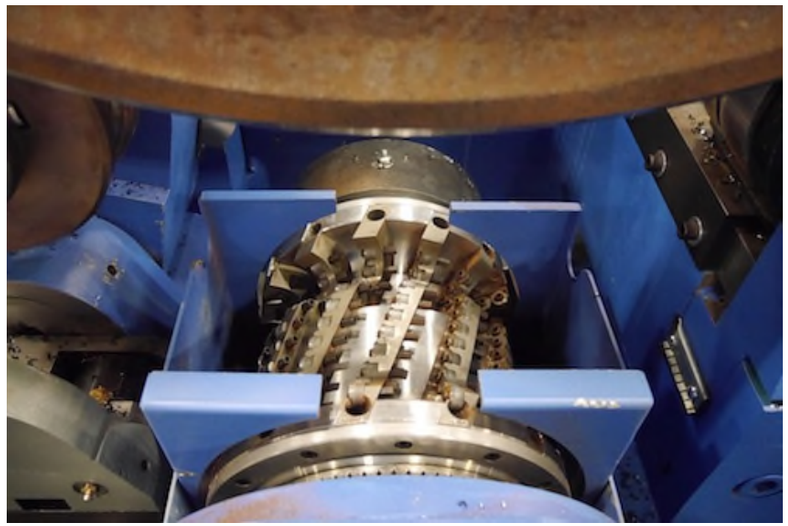


Magnetic fluorescent particle inspection

https://www.railwaygazette.com/news/single-view/view/wheel-surface-crack-measurement-device-could-offer-25-cost-savings.html

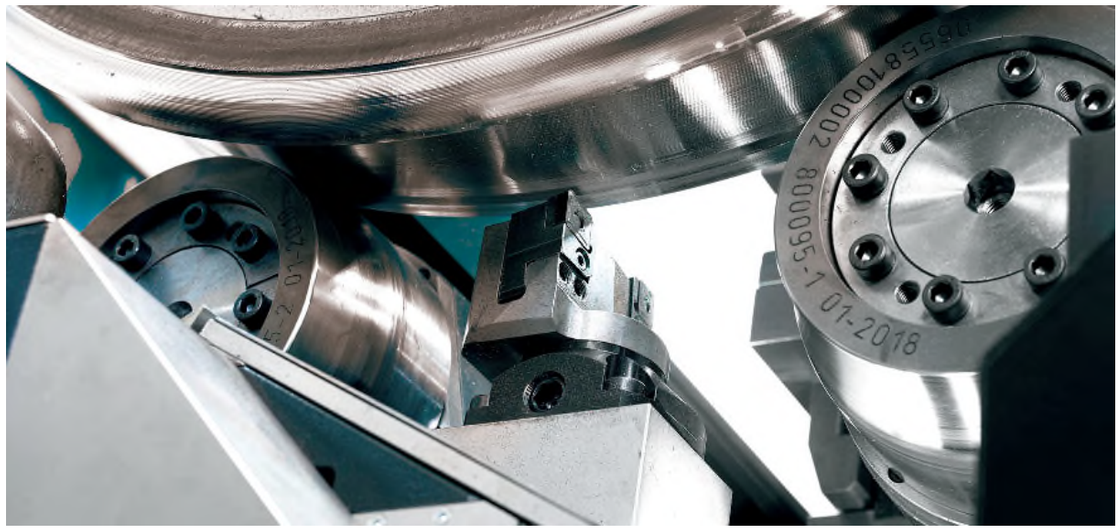
Wheel retruing machines

Milling Machine



https://smtgroup.com/en/railway-wheel-shop-equipment/underfloor-technology/underfloor-wheel-truing-machine-stanray

Lathe



https://railways.danobatgroup.com/en/underfloor-wheel-lathe

Wheel retruing machines

Milling Machine

- Cutter head ≡ 1 profile
- Multiple blades with carbide inserts
- Large cuts possible, faster
- Relatively rough surface
- Requires less experienced operators

Lathe

- Template or Programmable
- Single point cutting tool
- Lighter cuts, more tooling
- Fine surface possible
- More experience required

Regular inspection and good record keeping

… maintainers who kept detailed wheel condition and maintenance records, and actively managed and optimised their maintenance practices, achieved significantly better wheel life than those who did not.

RSSB summary report T963: Improving wheelset life by better understanding the causes of wheel damage, July 2019

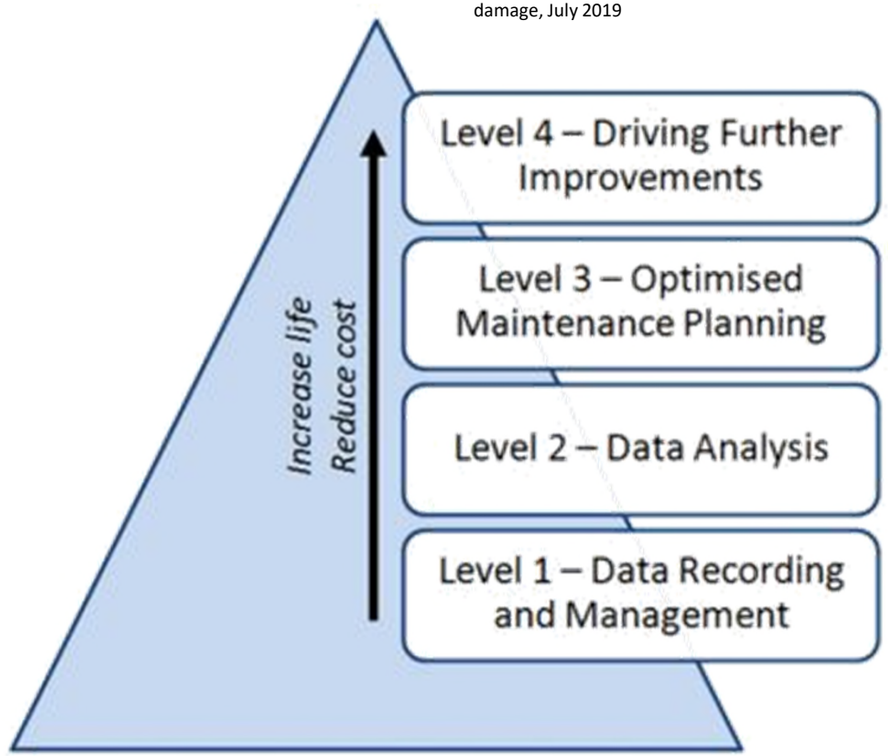


Figure 3 - Management and optimisation of wheelset life

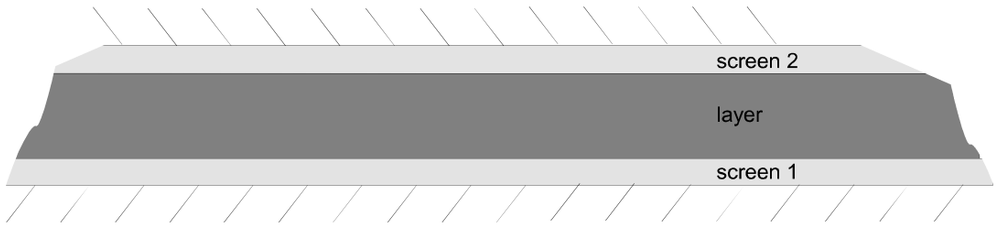
4. FRICTION

Friction

- "Is the resistance to motion which is experienced whenever one solid body slides over another"
  - The resistive force is parallel to the direction of motion
  - Concepts of "static" and "dynamic" friction coefficients
    - more generally: traction force varies with creepage
- Friction depends on the strength of the surfaces (or interface) in compression and shear
- We can modify friction by controlling the shear strength of the interfacial layer

Third-body velocity accommodation mechanism

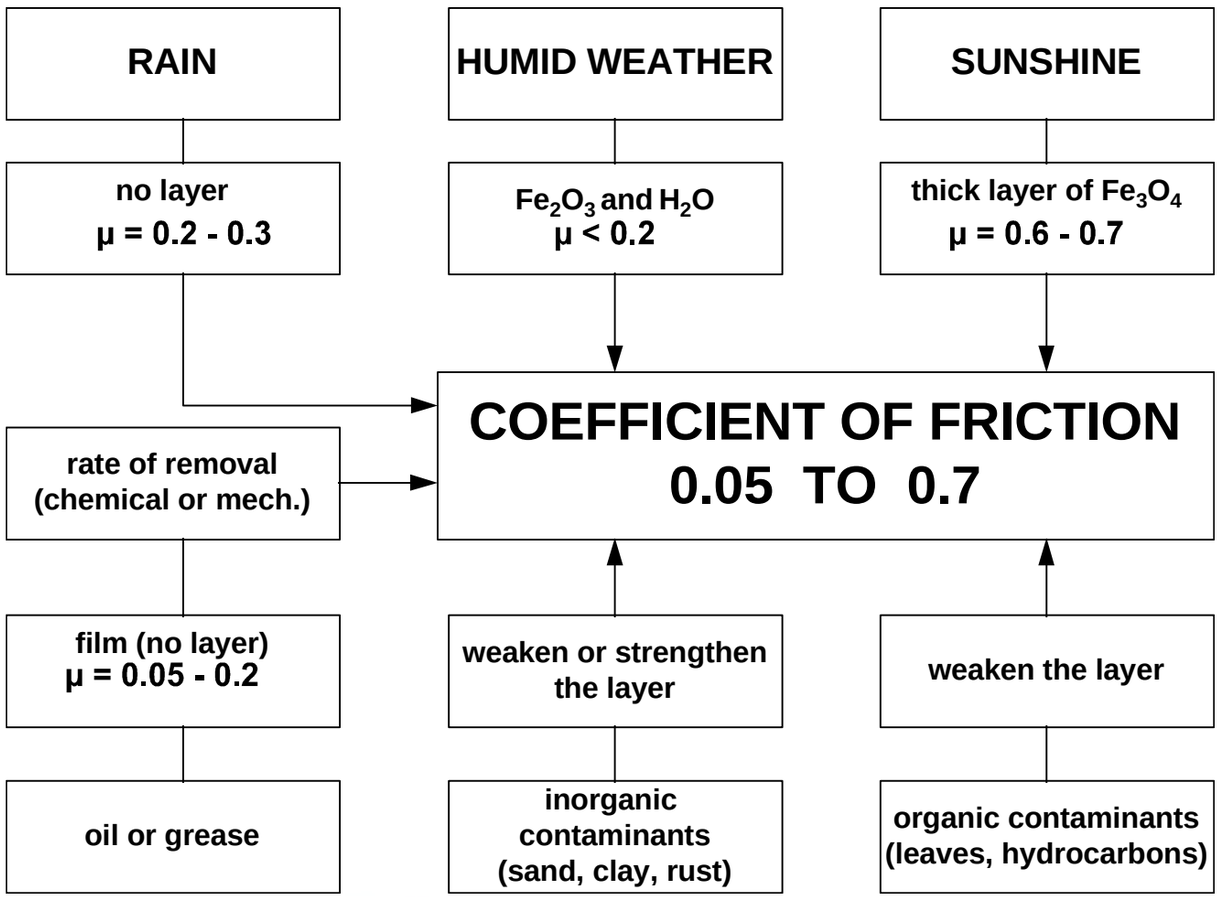
(After Godet)



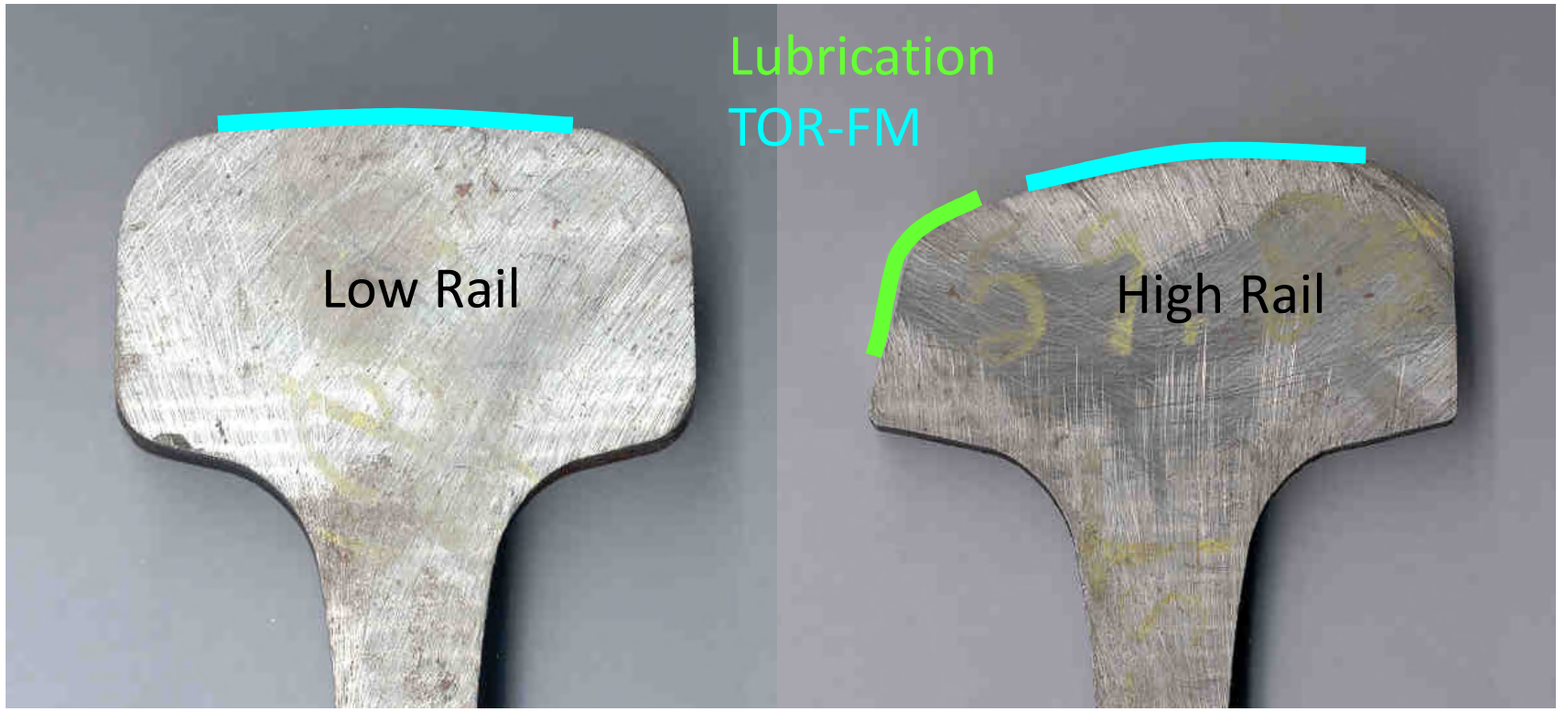
- 3 modes
  - elastic deformation
  - shearing
  - rolling
- 5 sites
  - body 1
  - screen 1
  - layer (third body)
  - screen 2
  - body 2

3 x 5 = 15 possible velocity accommodation mechanisms

COF – TOR contact

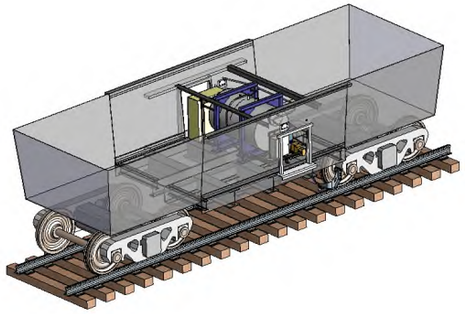


Controlling W/R Friction
2 zones of concern



Systems for Managing Friction

- Wayside
  - Mechanical and electric
  - Dispenser bars
- Vehicle borne
  - Solid sticks
  - Spray systems
  - Locomotive dispensing
  - Revenue car



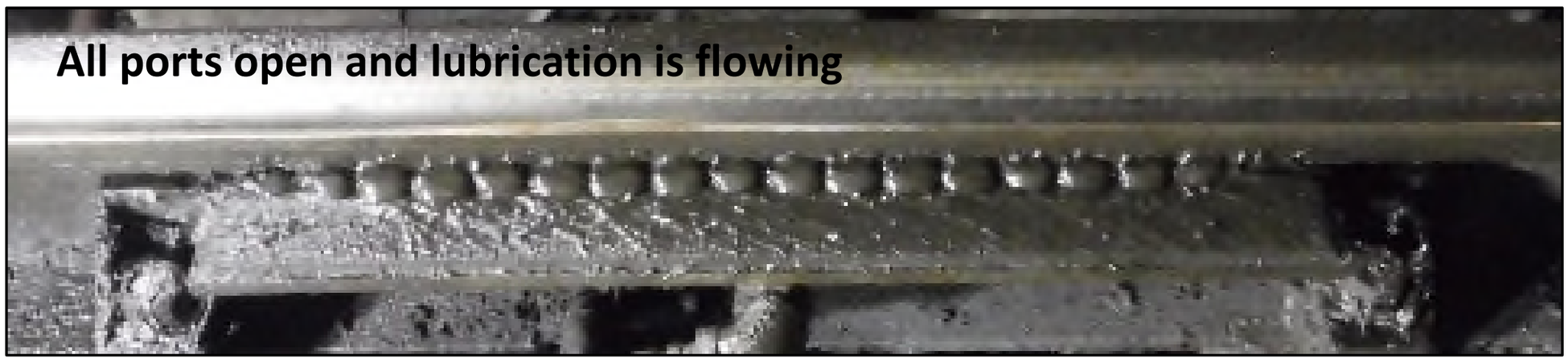
From https://www.lbfoster.com/en/market-segments/rail-technologies/solutions/friction-management/technical-support

http://evolution.skf.com/wheel-flange-lubrication-for-railway-systems-3/

Lubrication

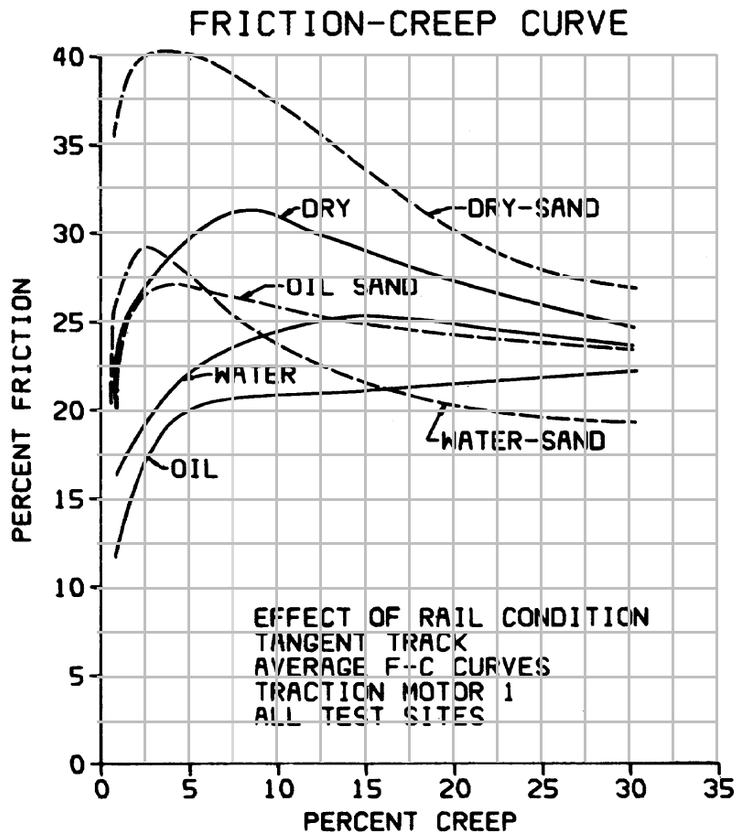
- Wayside Lubricators: criteria for a successful wayside implementation
  - Placement on track (tangent ahead of curve)
  - Bar designs (length, #ports), positive displacement pumps, minimize cavitation (e.g. stir paddles), remote monitoring
  - Selection of grease : summer versus winter
  - Dealing with difficult areas, e.g. embedded track

Lubrication

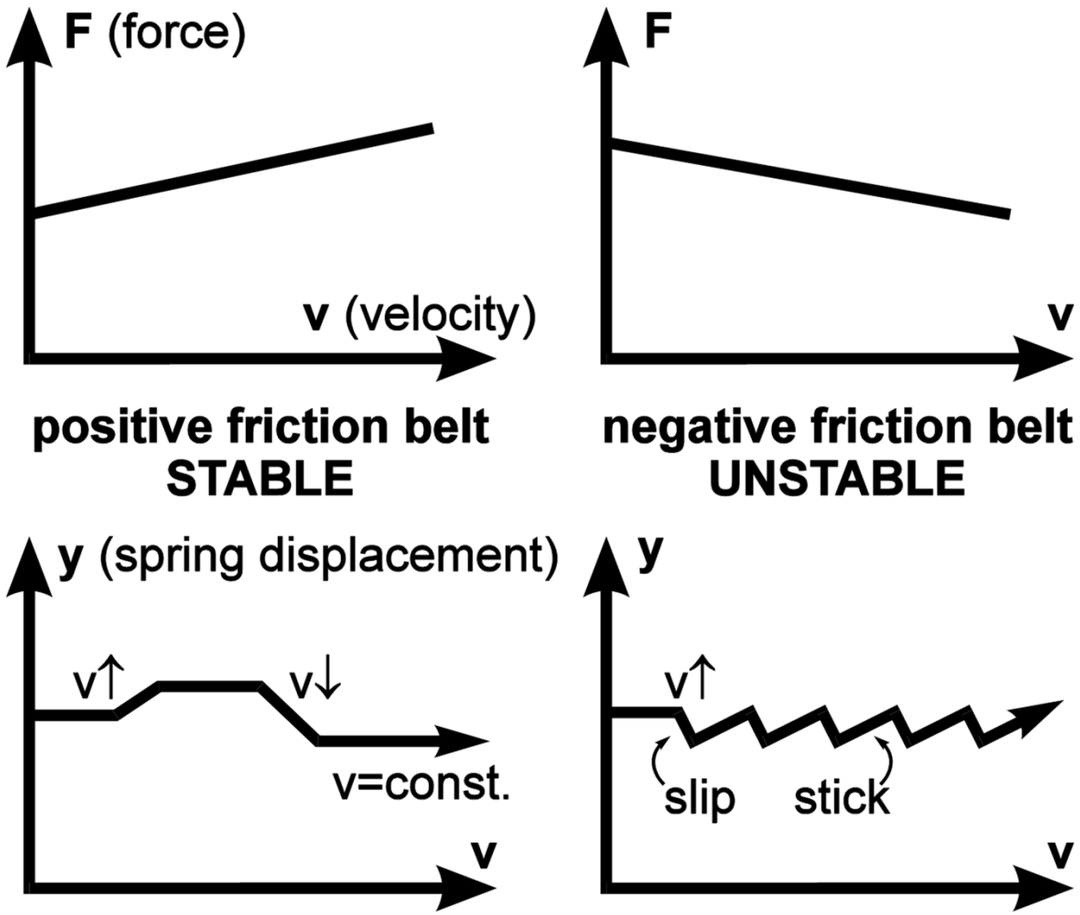


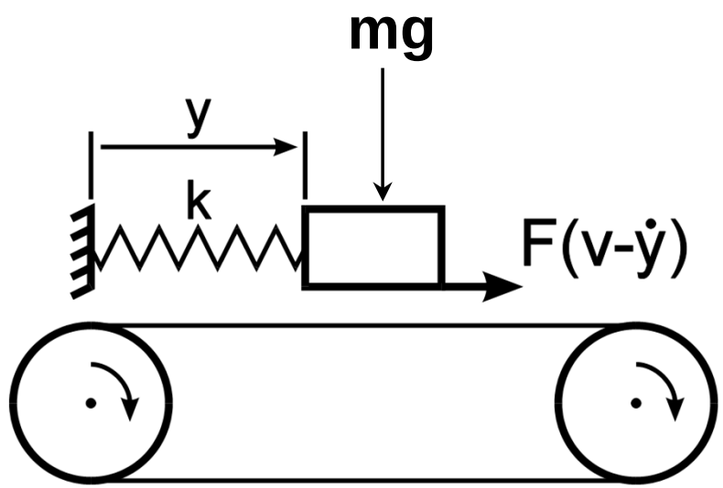
Wheel/rail traction-creepage curve

Field Tests
(Logston & Itami 1980)



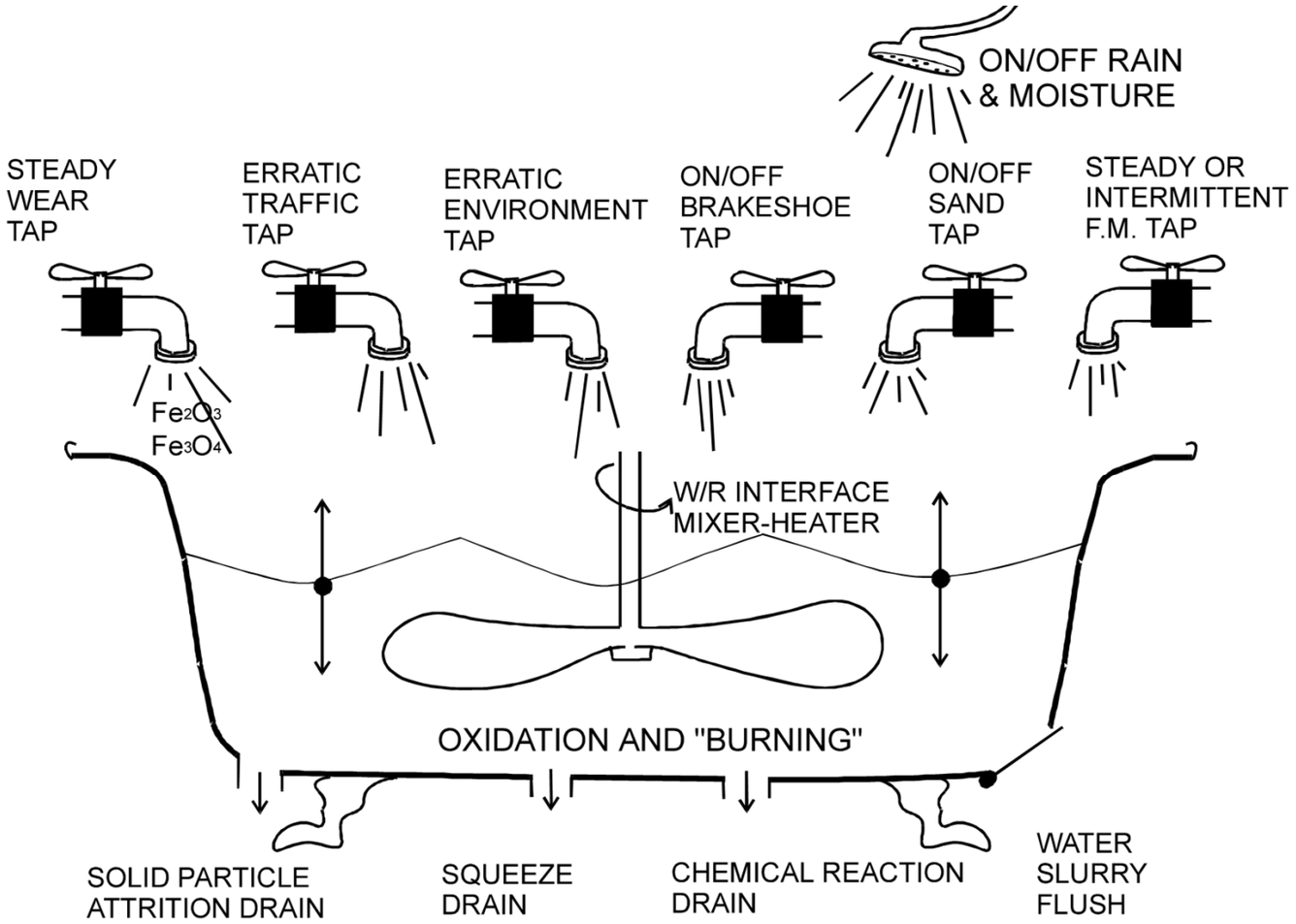
Stick-Slip - The prony brake





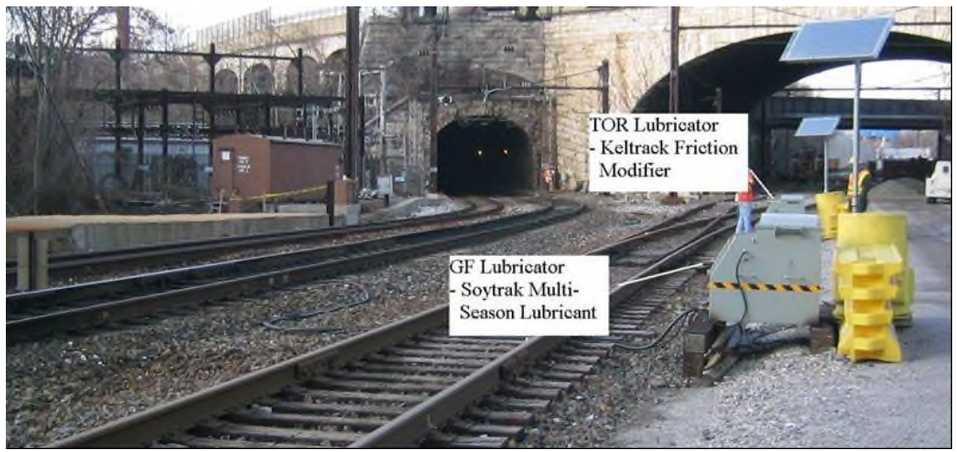
Bathtub model of wheel/rail interfacial layer

Inputs and outputs govern composition of layer and coefficient of friction on top of the rail

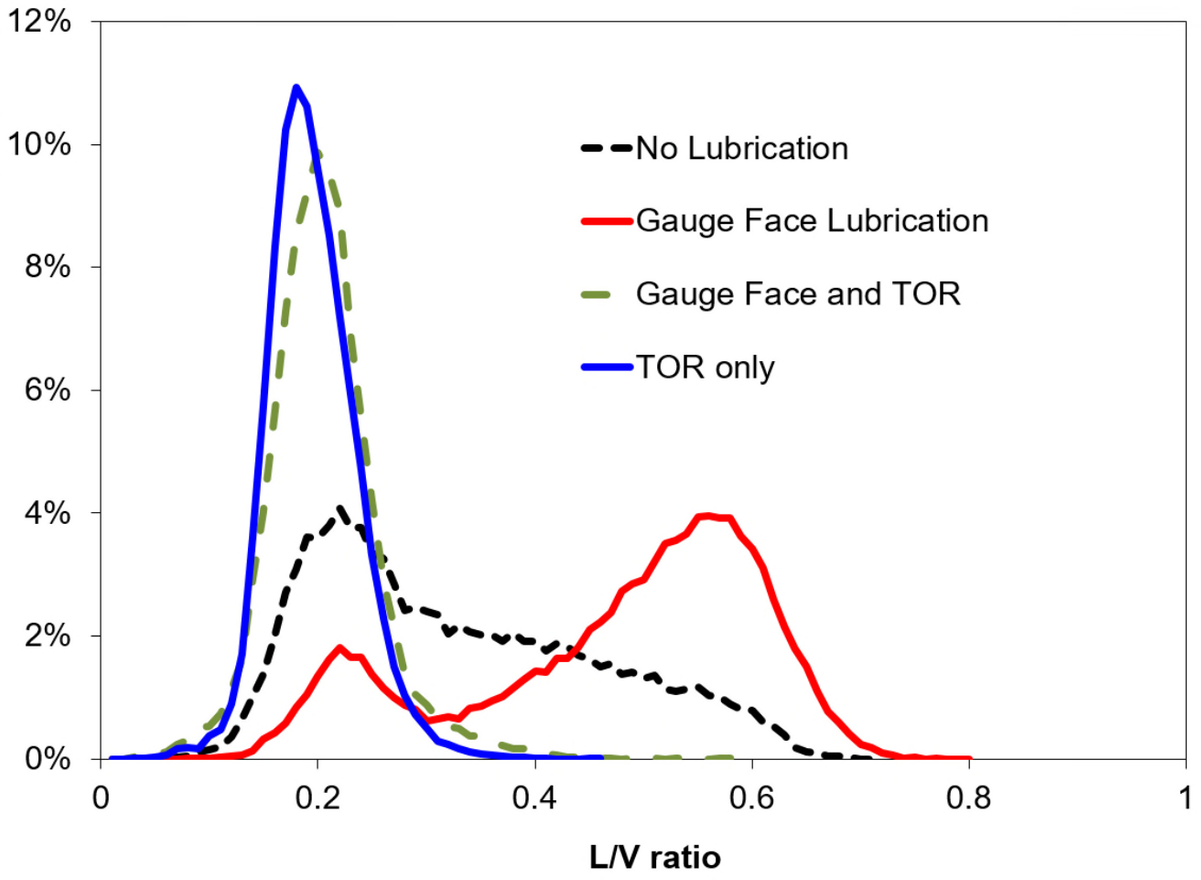


Friction Measurement

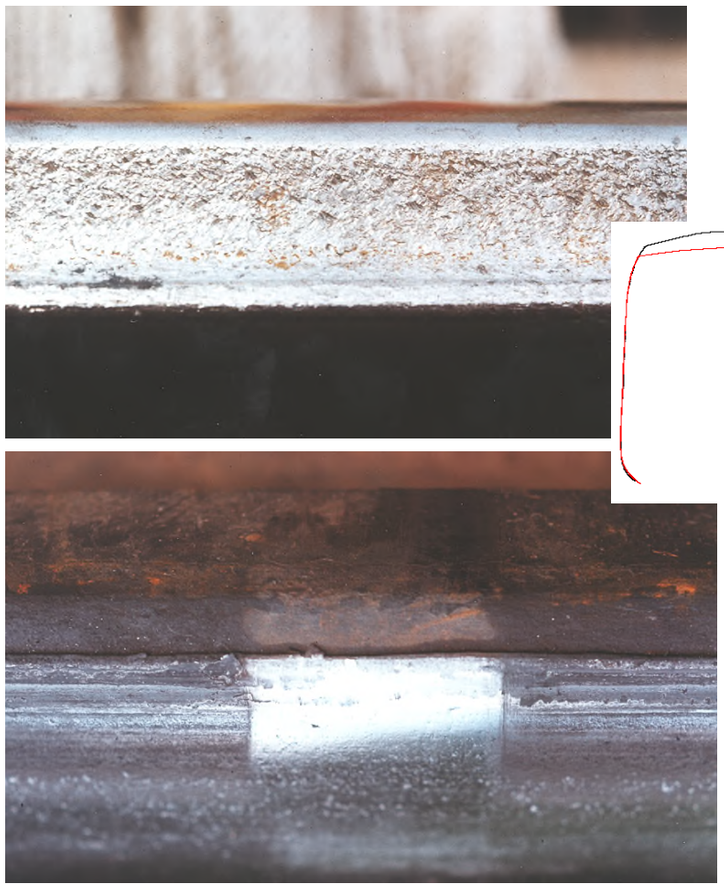
Effectiveness of Friction Management



From P. Sroba et al, Testing of Rail Friction Management on the 377.2 Baltimore Curve, NRC report #54-A62209-T11-2-AUG05



The rail tells the story



Friction Management: Conclusions

- For W/R, friction is controlled by the characteristics of the interfacial layer
- Negative friction $\rightarrow$ stick-slip
- Bathtub model - friction control must overcome all the “natural” taps and drains in a system.

5. VEHICLE PERFORMANCE

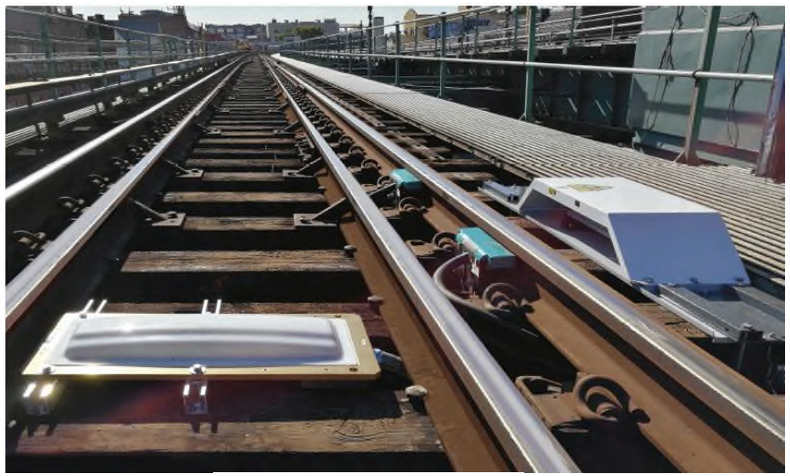
Trucks/vehicle performance

- TPD – truck performance detector
- WILD – wheel impact load detector
- TBOGI – Bogie Condition Monitor
- WheelScan – wheel profile (and others) measurement

Wayside Technologies

WILD/Hunting truck detector

TBOGIE



L/V

6. TRACK PERFORMANCE

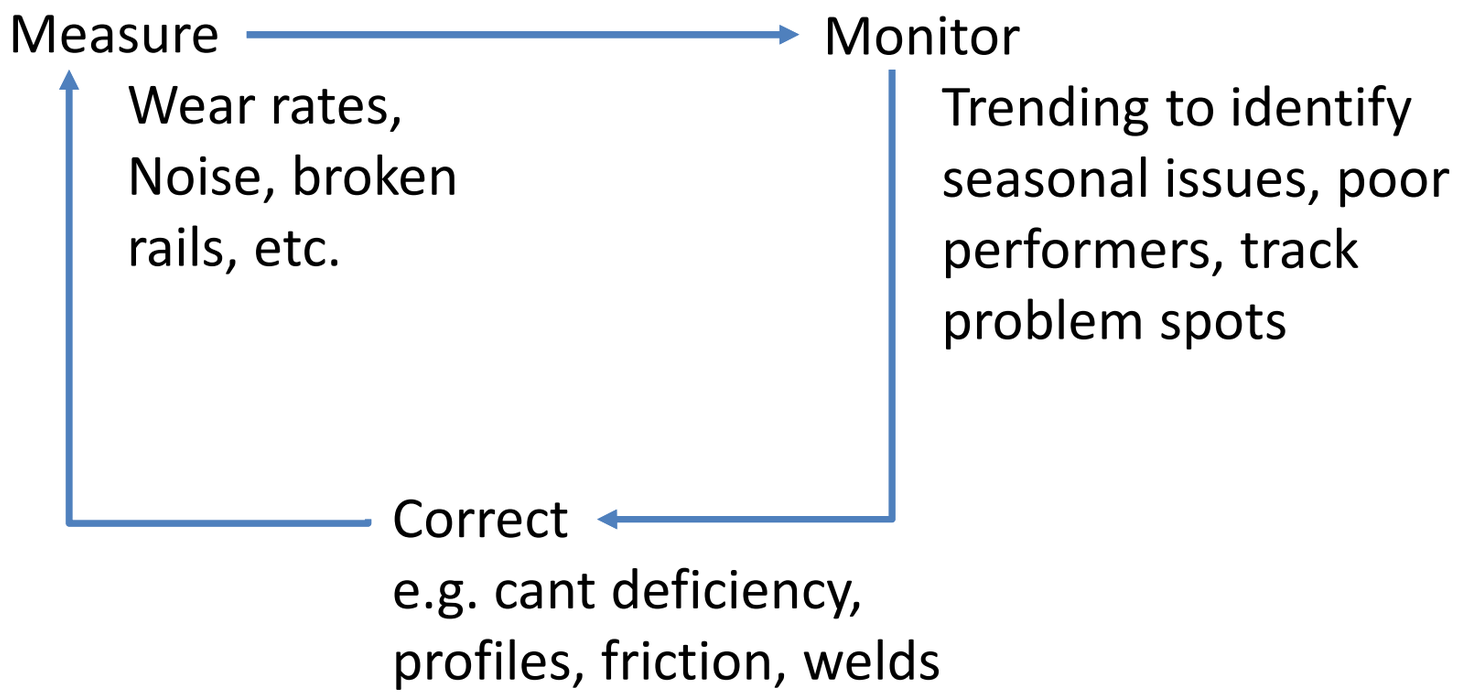
Monitoring Track Performance

- Amtrak ARMS – Automated Remote Monitoring System
- ENSCO VTI (Vehicle-track interaction)
- RMetrix – Ride Performance Assessment System
- Instrumented Wheelsets

Obtaining optimal wheel/rail performance

- Identify inadequacies in current system
  - What is driving the change? The performance problem.
  - Profiles, friction management, materials, vehicles
- Set goals
- Baseline performance
  - E.g. wheel/rail wear, noise levels, ride quality
  - Need the right tools
- Transition Strategies – e.g. profiles, grinding

Maintaining wheel/rail performance



Acknowledgements

- Colleagues within NRC
  - Rob Caldwell, Daniel Szablewski, Yan Liu
- Many colleagues within the rail industry
  - LORAM, LB Foster, Linsinger, ARM, Rohman, KLD, WID, …

Thank You

Eric E. Magel

Principal Engineer, NRC Canada

Eric.Magel@nrc-cnrc.gc.ca