Practical Implications of the Magic Wear Rate

Eric E. Magel

Principal Engineer

Magic Wear Rate (MWR)

- optimal balance between damage and wear
  - Optimal = fn(many variables)
  - damage = fn(many variables)
  - Wear = fn(many variables)

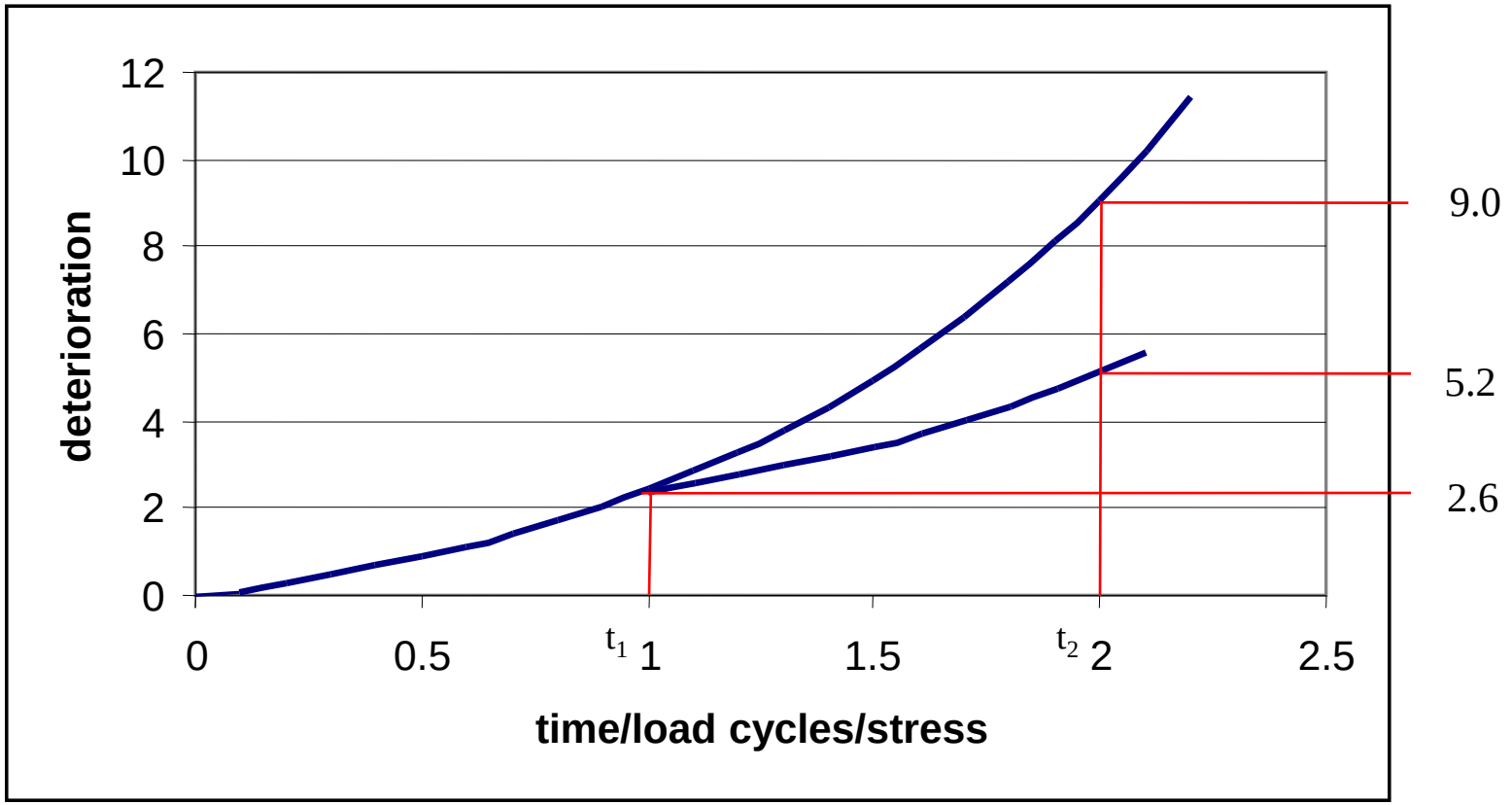
MWR = fn(many variables)

probably differs between railroads

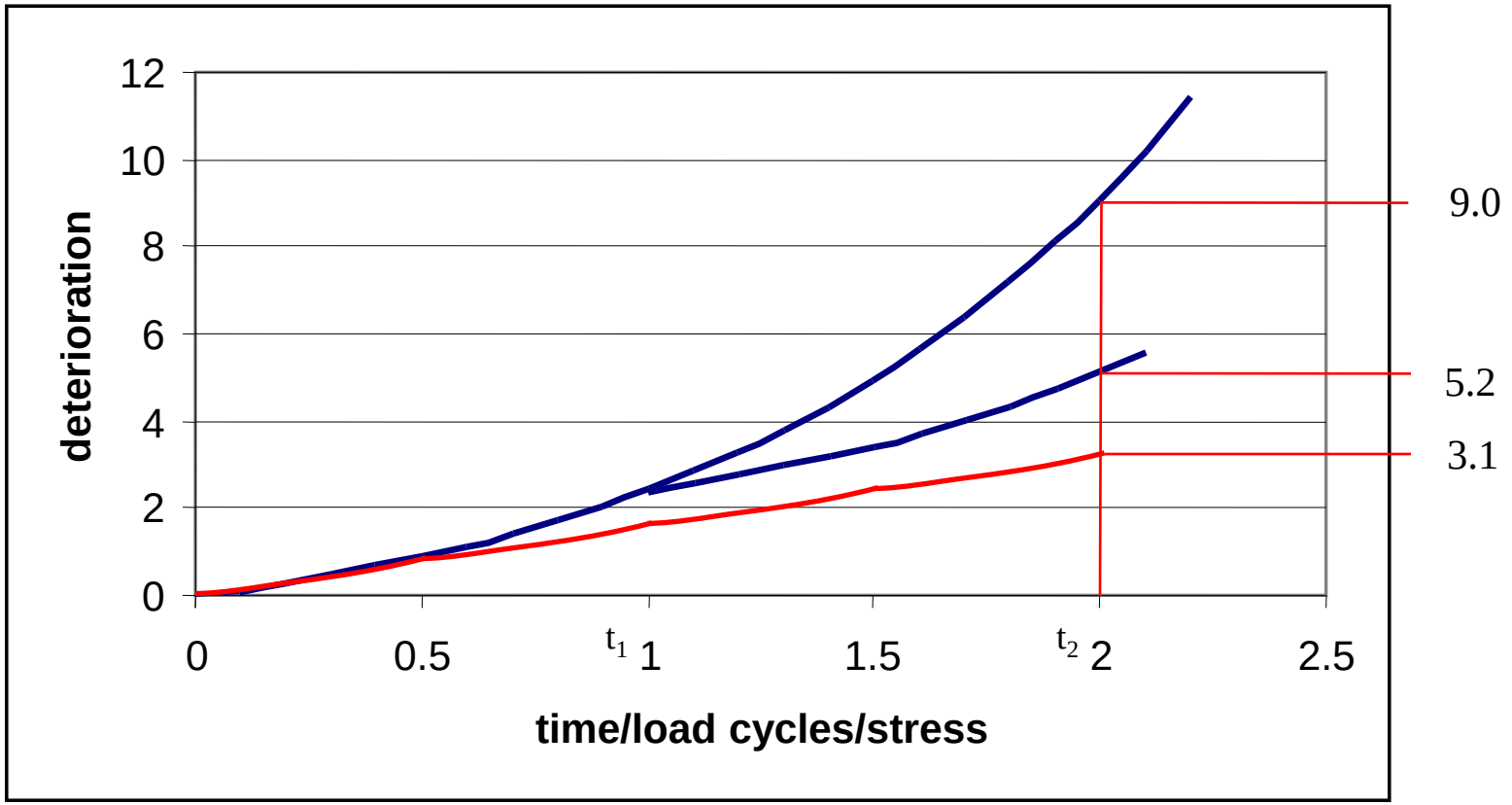
Outline

- Magic Wear Rate
- Preventive vs corrective grinding
- Wear and (RCF) Damage
- Quantifying the MWR
- Extend an invitation

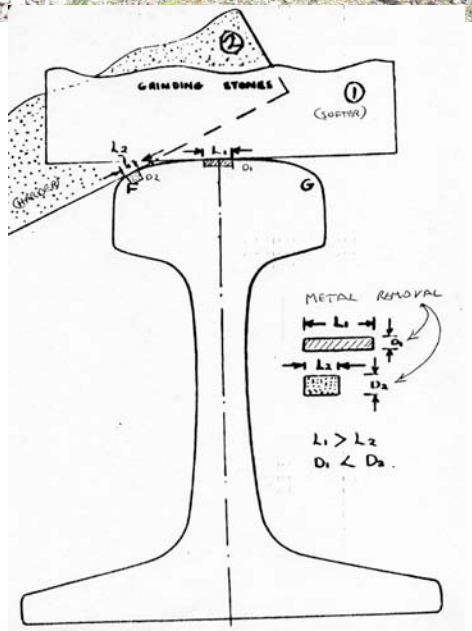
Preventive Maintenance



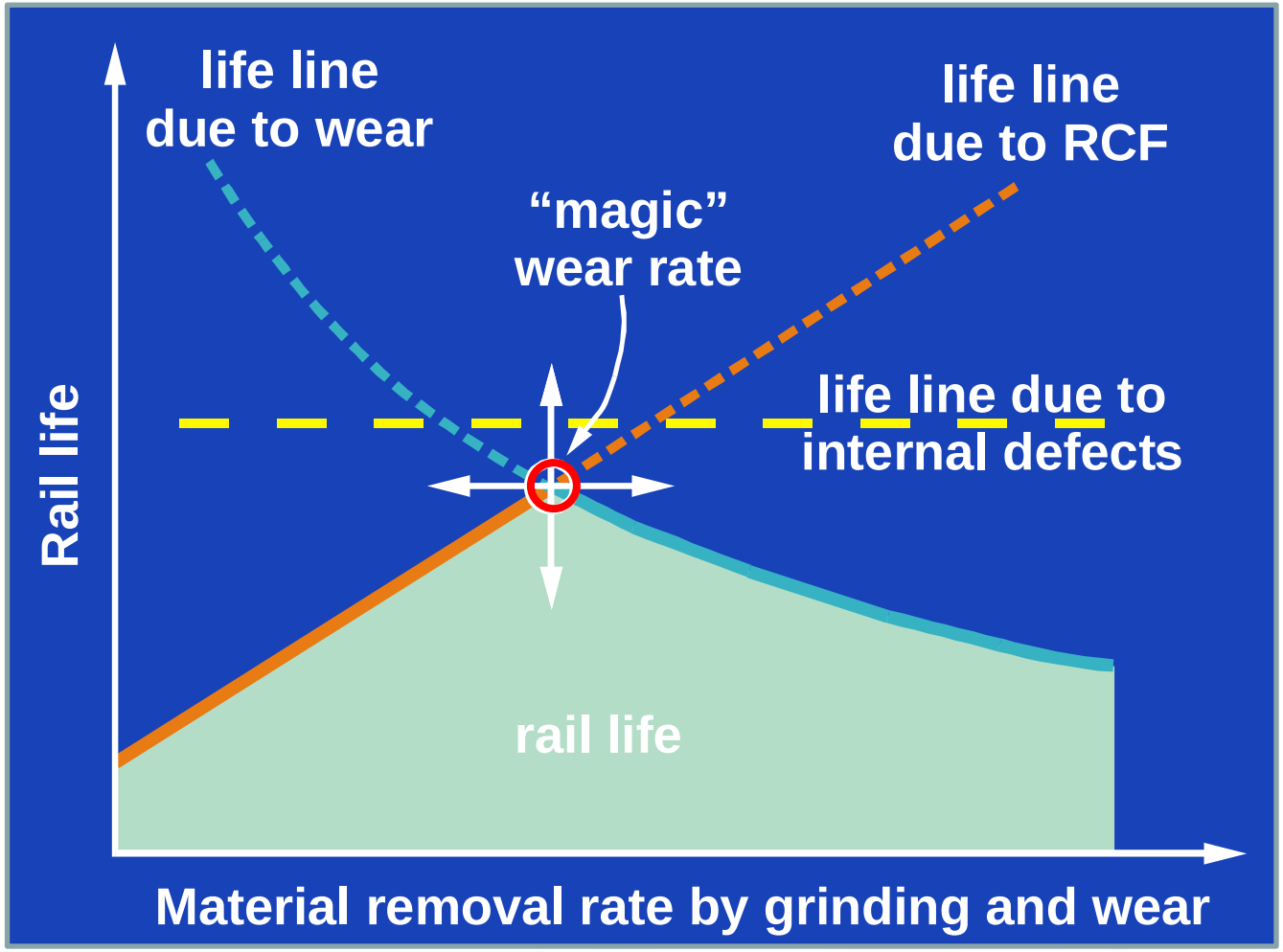
Preventive Maintenance



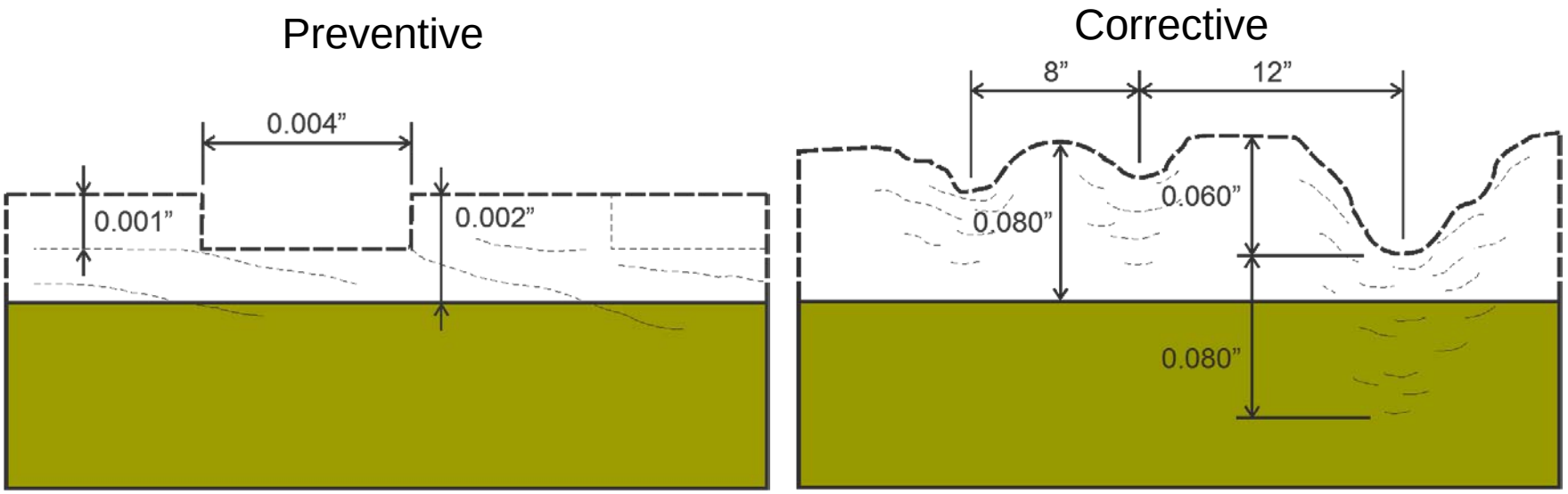
Rail grinding



The Magic Wear Rate balances wear with fatigue



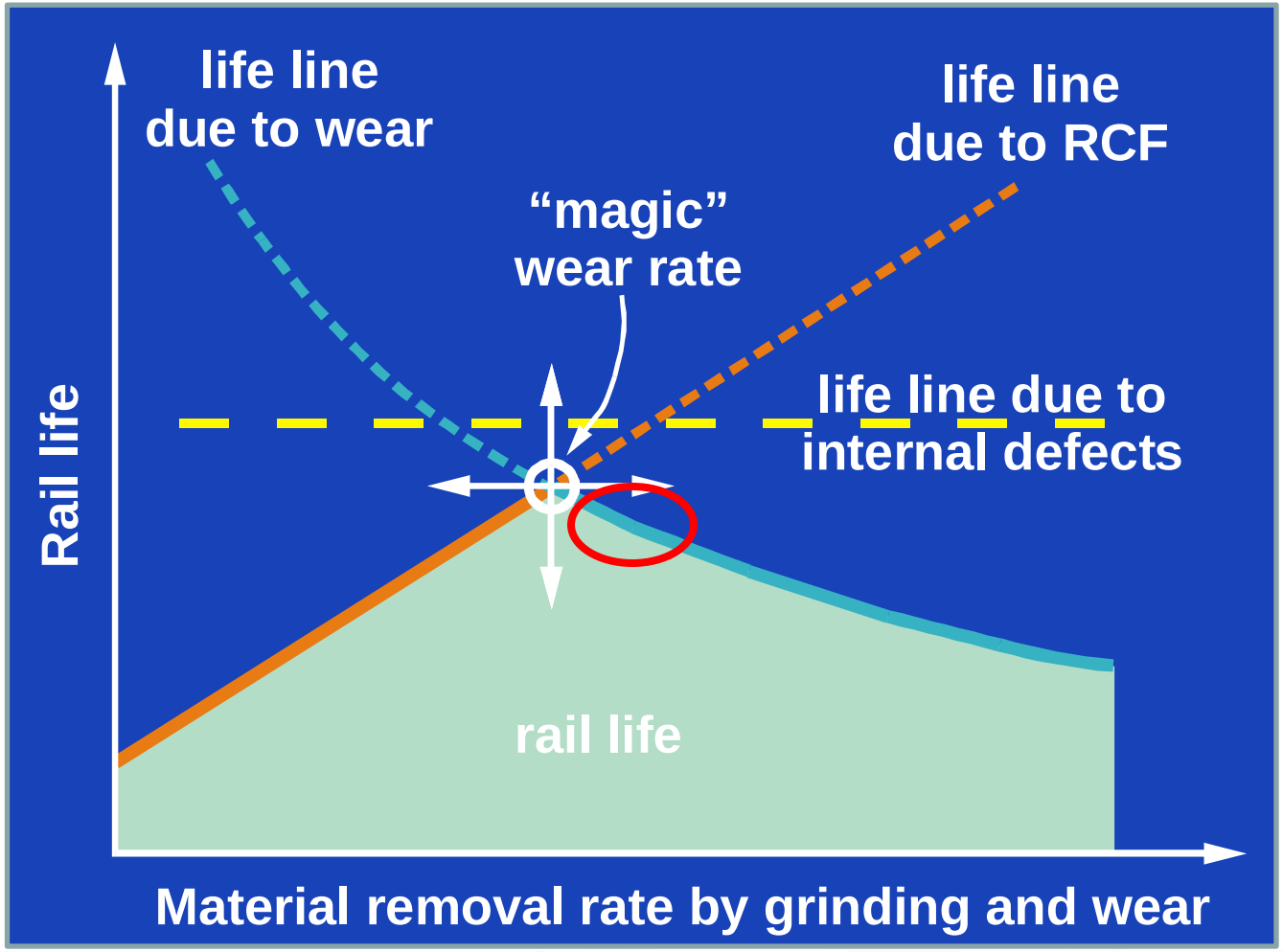
Preventive vs. Corrective



- frequent, high speed, single pass
- rail ground “on schedule” even if no visible cracking
- surface cracking mostly removed
- profile regularly maintained
- always good/safe surface condition

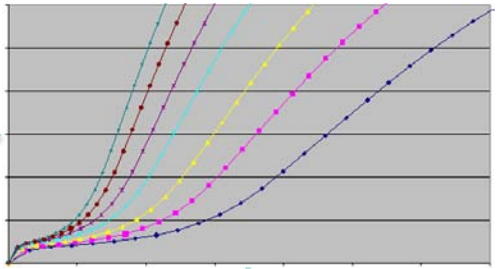
- infrequent, slow, multi-pass
- heavy damage develops, fire-fighting
- cracks rarely removed
- profiles deteriorate btw cycles
- surface cracking impedes NDT

Preventive Rail Grinding



Predictive Preventive

historical data
- past grinding effort
- defects
- costs



- curvature breakdown
- rail wear limits
- annual tonnage

optimized rail grinding cycle based on ROI analysis

grinder capabilities

Magic Wear Rate?

- Controls RCF - safely, efficiently
- Practically achievable
  - can’t have the rail grinder in all places at all different times.

Magic Wear Rate?

- Controls RCF - safely, efficiently
- Practically achievable
  - can't have the rail grinder in all places at all different times.
- The minimal value required "to do the job"
  - synergistic with other approaches (profiles, friction management, best superelevation, track geometry)
- accounts for local and seasonal variations
  - curvature, tonnage, speeds, metallurgy, risk

WEAR

Wear Mechanisms

- There exist a large variety of wear mechanisms in nature.
- Clear distinction between the individual wear modes not always possible
- Often two or three modes operating simultaneously

Wear Mechanisms

- Abrasion
- Adhesion
- Delamination
- Oxidation

Energy/work/load

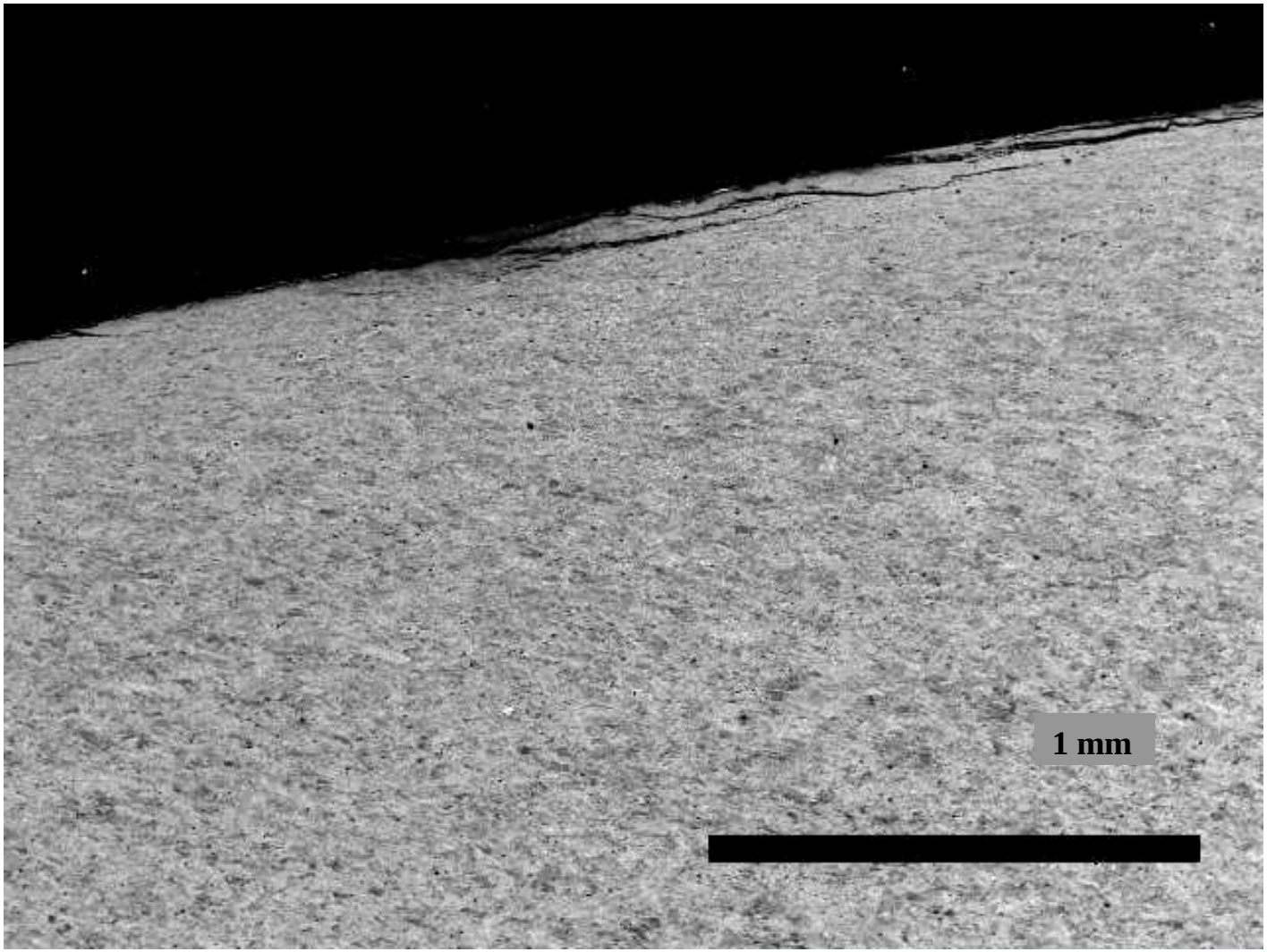
$$Q = k\frac{Wl}{H}$$

strength

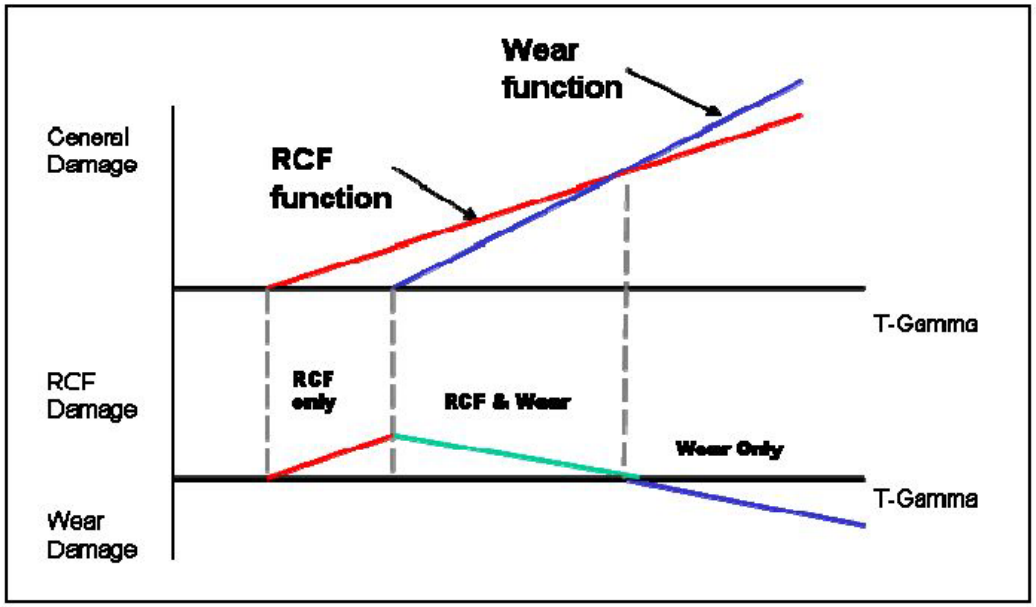
Q = volume of wear
W = normal load
l = sliding distance
H = hardness
k = wear coefficient
$1/k$ = wear resistance

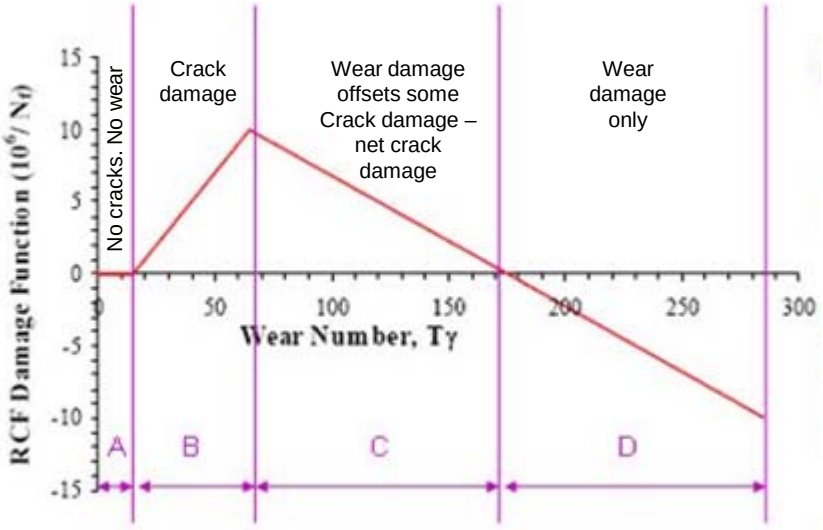
k: 10^{-6} to $5x10^{-2}$

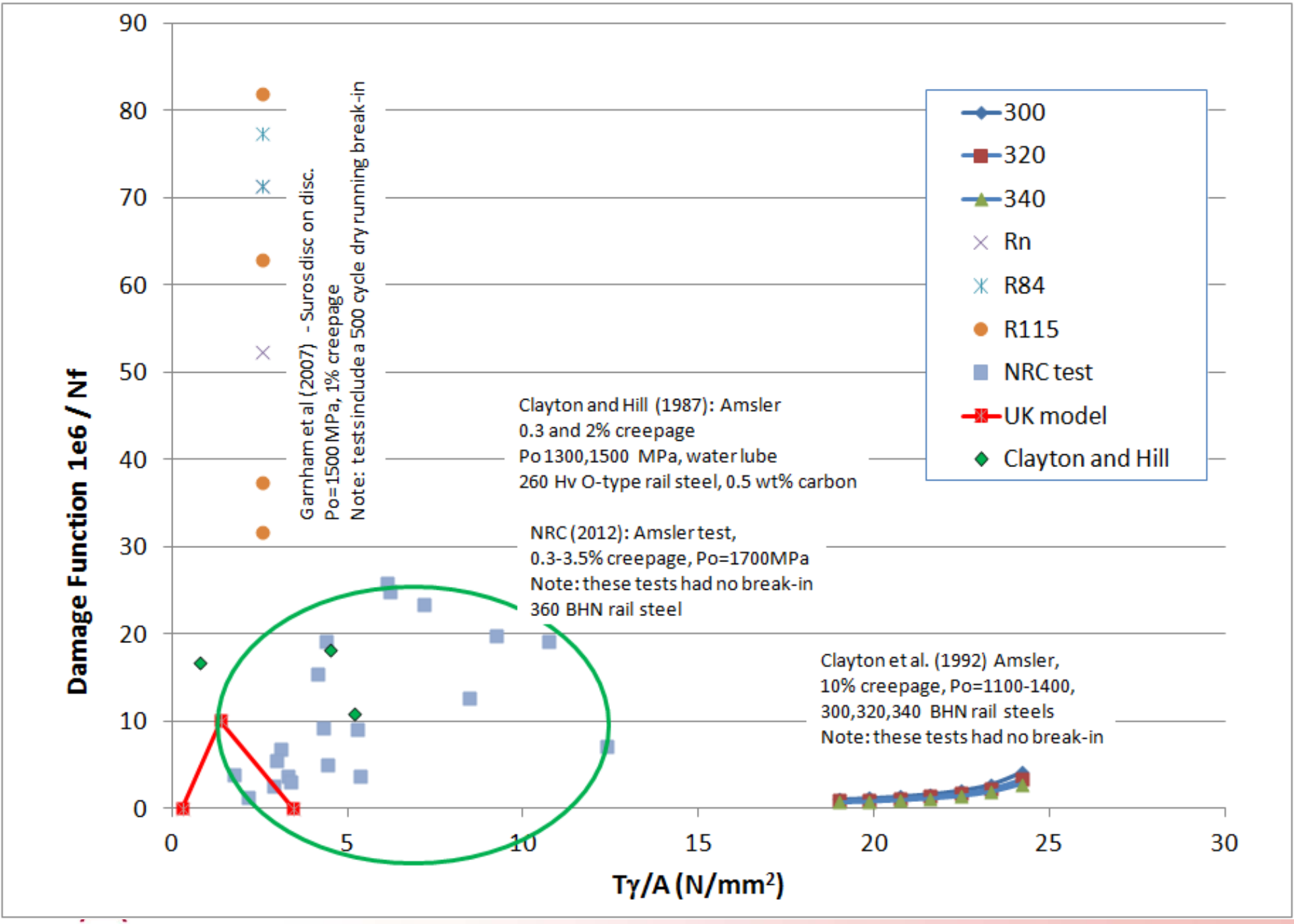
Delamination of rail steels



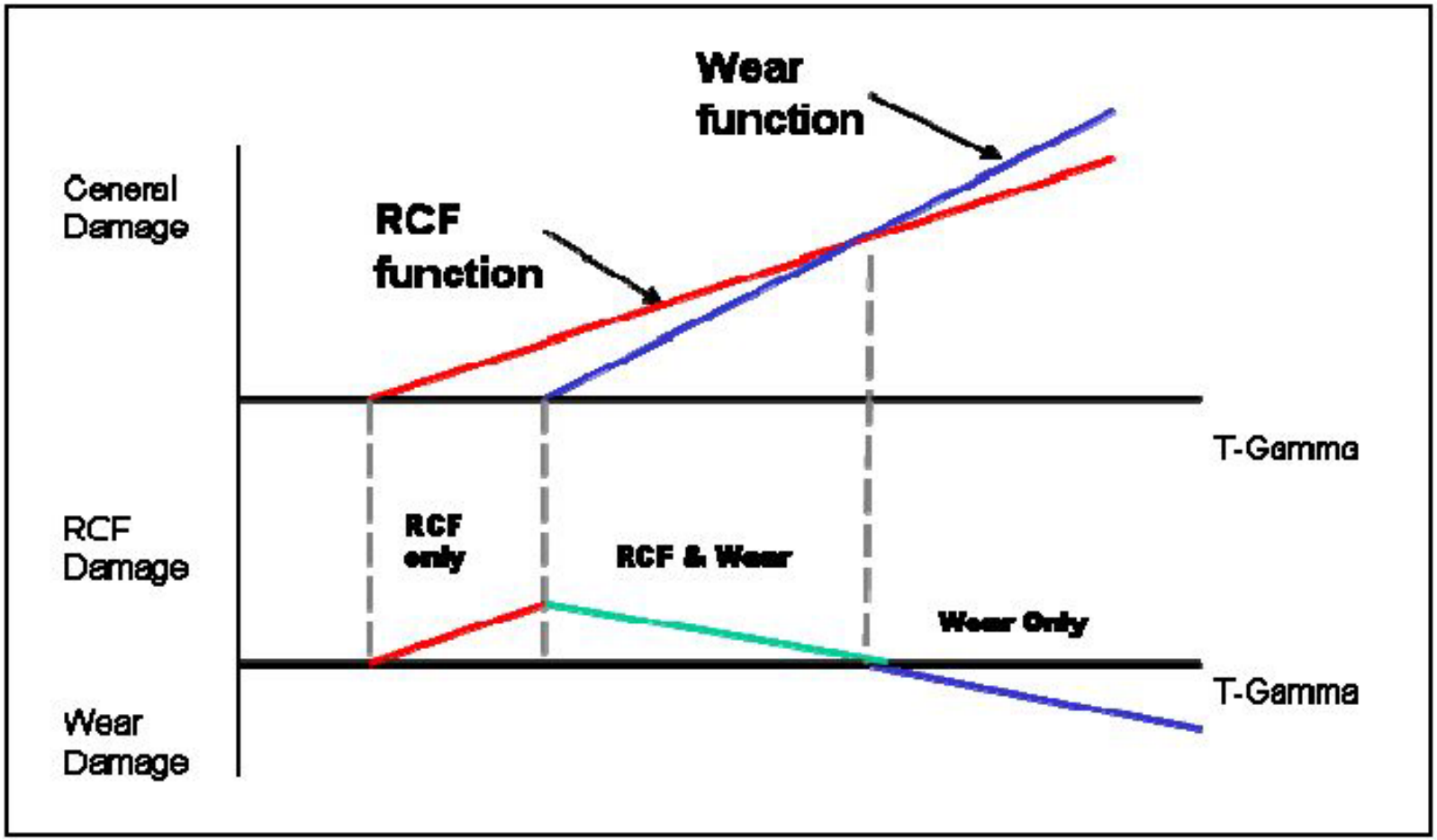
Surface Damage model



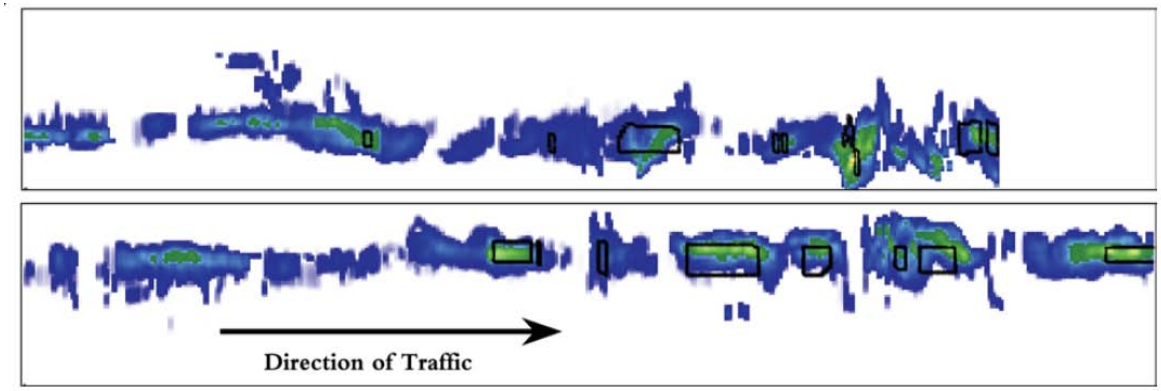


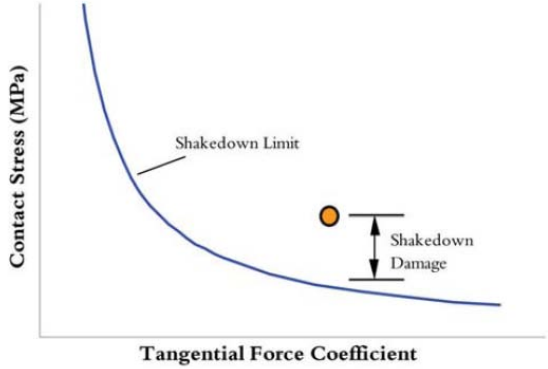

Damage Function 1e6 / Nf
Tγ/A (N/mm²)
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
300
320
340
Rn
R84
R115
NRC test
UK model
Clayton and Hill
Garnham et al (2007) - Suros disc on disc.
Po=1500 MPa, 1% creepage
Note: tests include a 500 cycle dry running break-in
Clayton and Hill (1987): Amsler
0.3 and 2% creepage
Po 1300,1500 MPa, water lube
260 Hv O-type rail steel, 0.5 wt% carbon
NRC (2012): Amsler test,
0.3-3.5% creepage, Po=1700MPa
Note: these tests had no break-in
360 BHN rail steel
Clayton et al. (1992) Amsler,
10% creepage, Po=1100-1400,
300,320,340 BHN rail steels
Note: these tests had no break-in

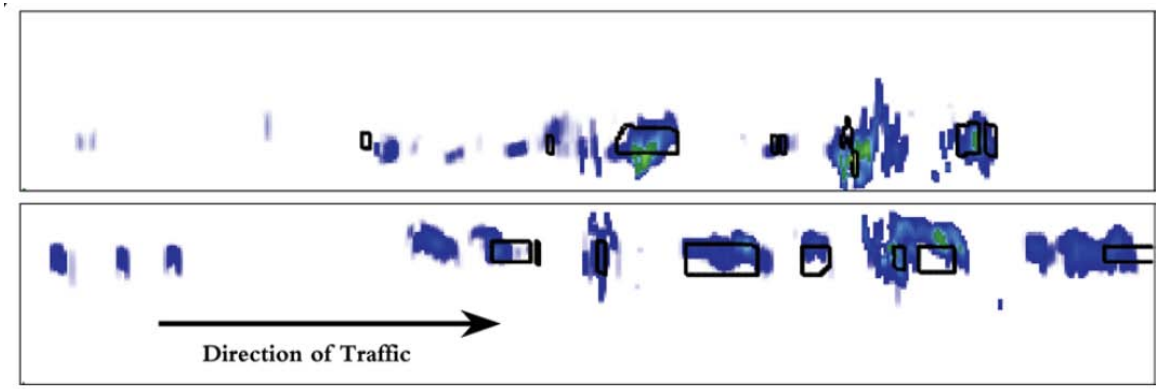
Surface Damage Model?

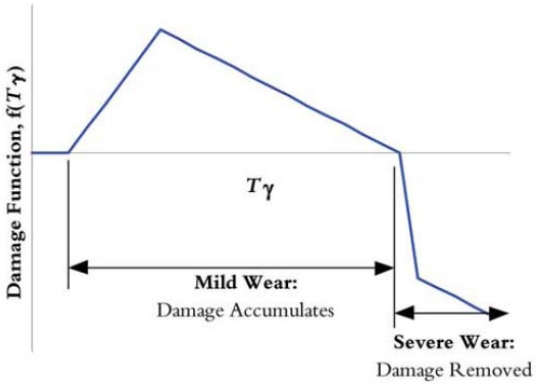


Crack initiation model



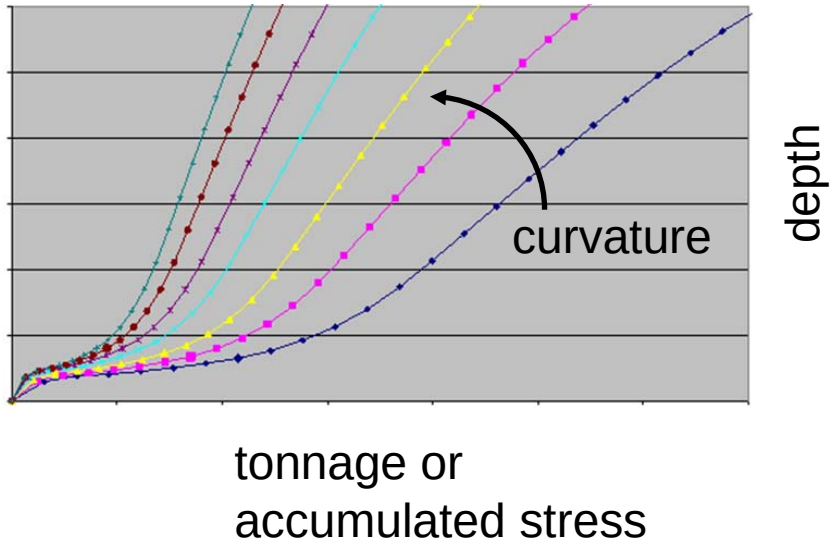




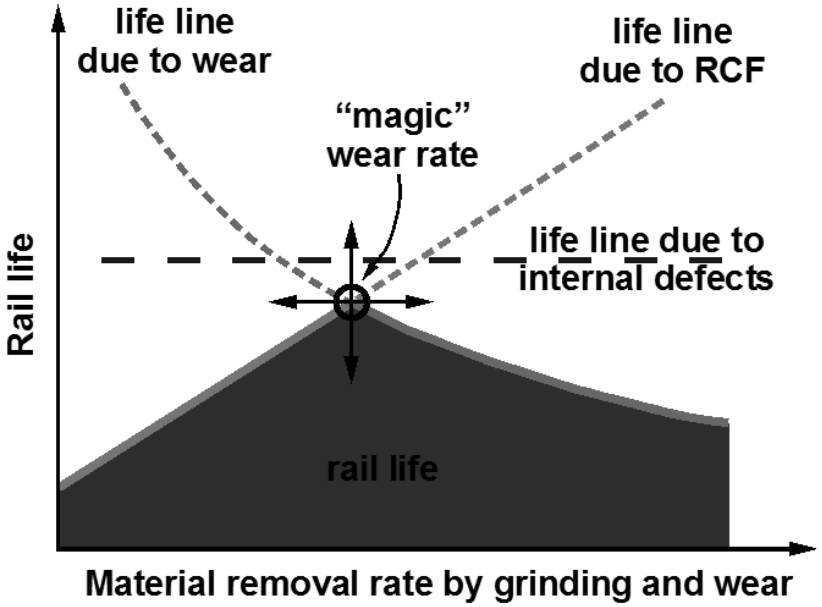


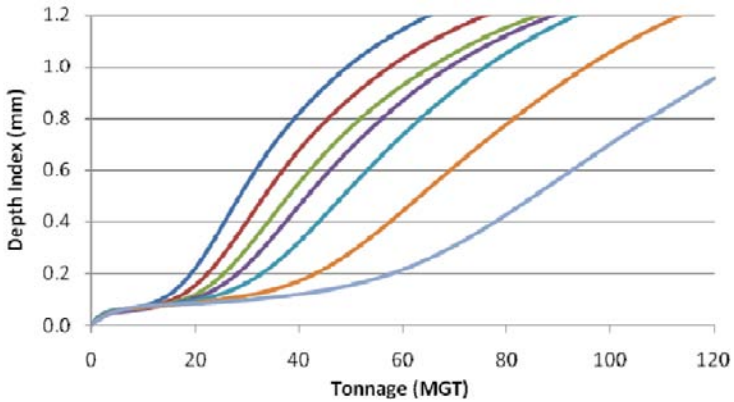
A family of crack growth curves

- probably for different
  - rail steels
  - territories
  - traffic types (e.g. passenger, transit, freight)
  - friction regimes



Quantifying the Magic Wear Rate





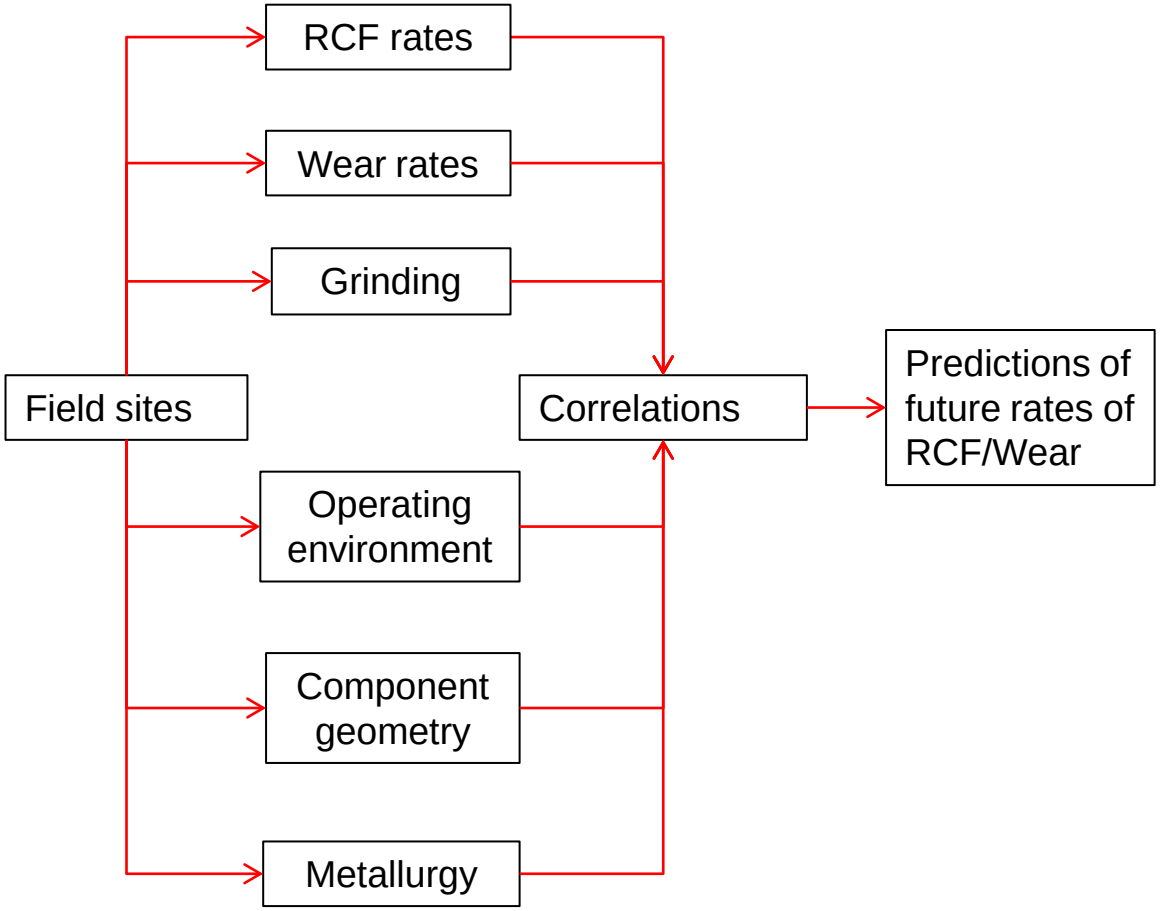
A project to be undertaken within the

International Collaborative Research Program on RCF and Wear of rails and wheels

Active Participants so far

- A. Bevan (Huddersfield, UK)
- R. Frohling (Transnet, South Africa)
- R. Harris (LORAM, USA)
- M. Hiensch (AEA, Netherlands)
- E. Magel (NRC, Canada)
- K. Sawley (Interfleet, UK)
- J. Tunna (FRA, USA)
- D. Welsby (Monash, Australia)

Evaluating the MWR – a field approach



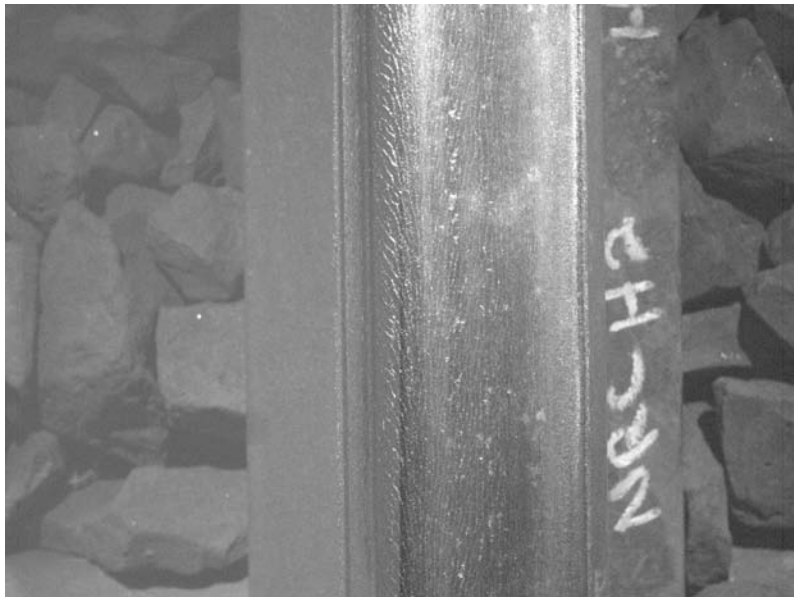
Success: the development of robust correlations of surface damage with operating parameters that enable usable predictions or trends in support of optimized rail grinding and inspection practices, assessment of metallurgy, friction management etc.

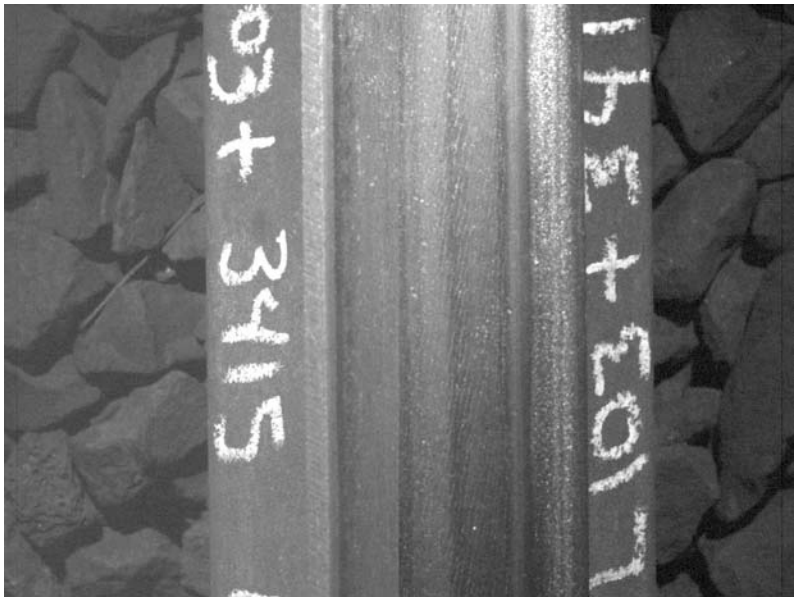
These correlations provide field evidence for development of more scientific explanations.

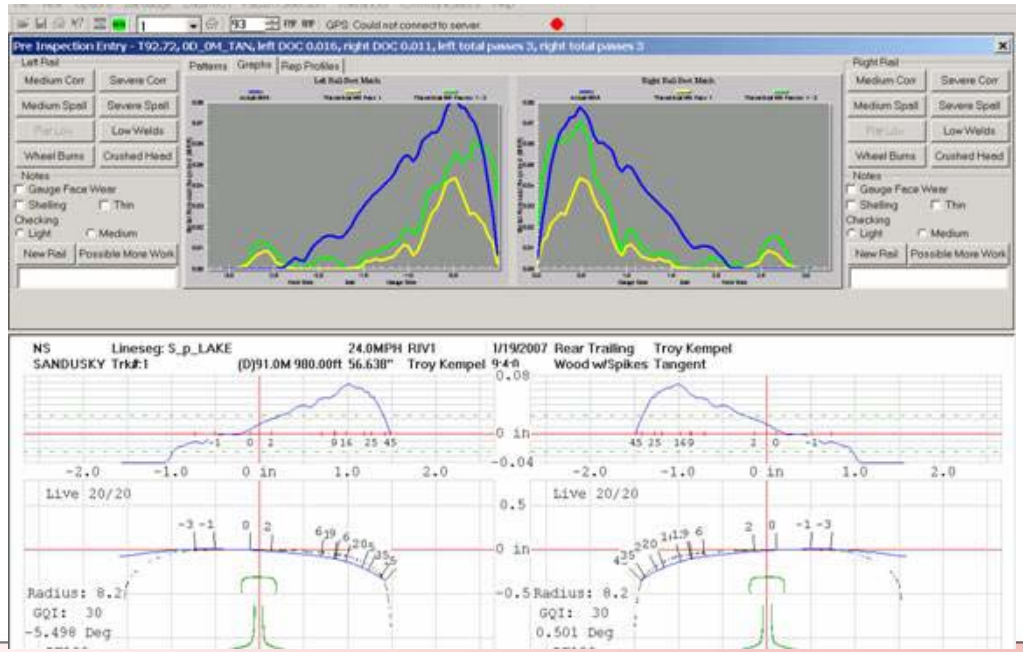
LORAM/NRC/CP (FRA)

The Loram Rail Inspection Vehicle

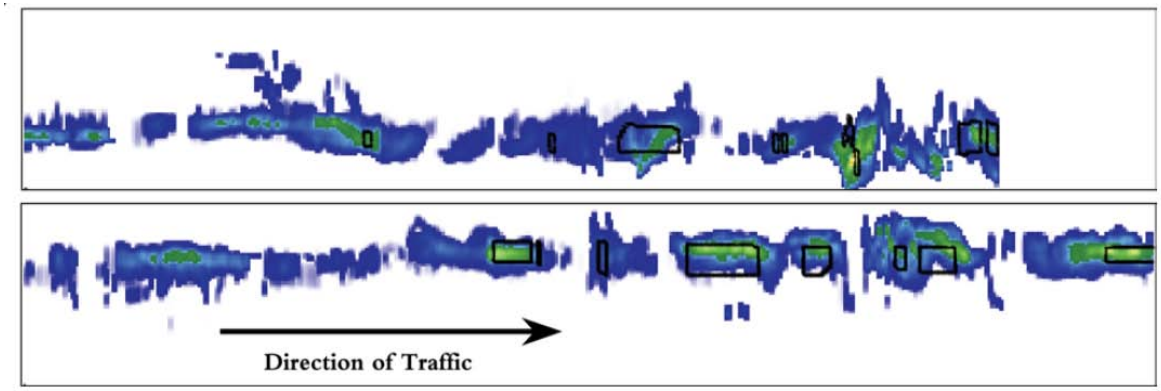
The Loram Rail Inspection Vehicle (RIV) is equipped with a track profile measurement and reporting package to track quality assurance and planning needs. This package is a proven system in use in North America and Australia, and consists of several integrated components including state-of-the art optical transverse profile measurement systems, proprietary position locator system based on differential global positioning system (DGPS), proprietary profile analysis, grind quality control software, and proprietary data viewing and reporting software.

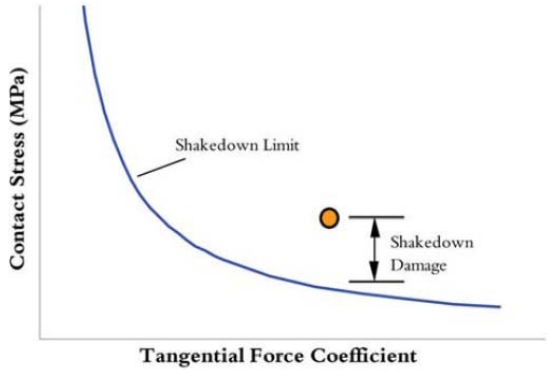


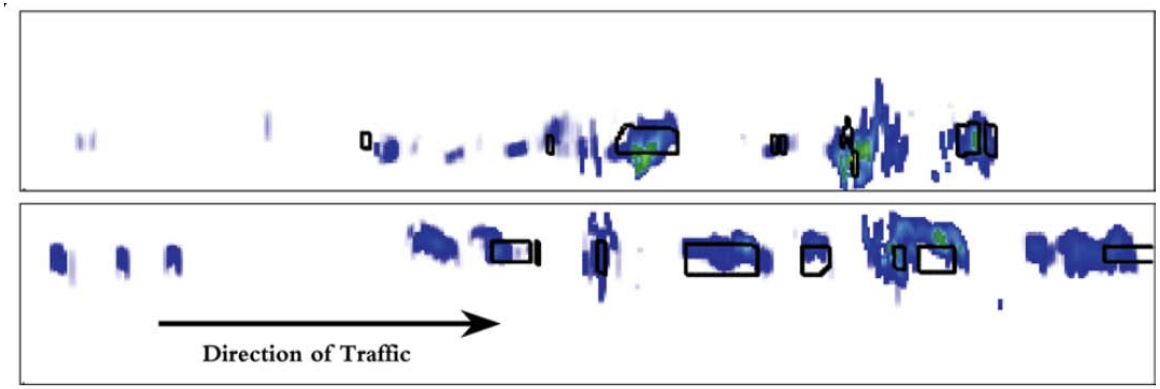


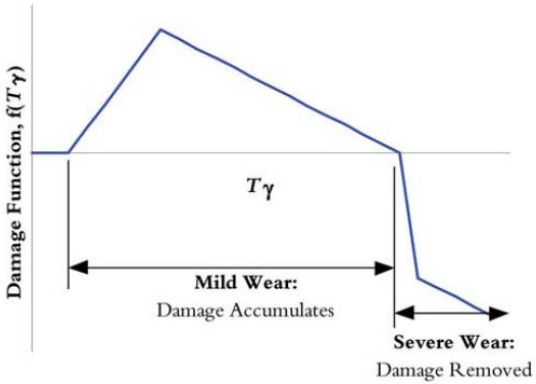

Pre Inspection Entry - 192.72, OD_0M_TAN, left DOC 0.016, right DOC 0.011, left total passes 3, right total passes 3
Left Rail
Right Rail
Medium Corr
Severe Corr
Medium Spall
Severe Spall
Low Welds
Wheel Burns
Crushed Head
Notes
Gauge Face Wear
Shelling
Thin
Checking
Light
Medium
New Rail
Possible More Work
NS SANDUSKY Trk#:1
Lineseg: S_p_LAKE
24.0MPH RIVI
Troy Kempel
Rear Trailing
Wood w/Spikes
Tangent
Live 20/20
Radius: 8.2
GQI: 30
-5.498 Deg
0.501 Deg

Crack initiation model









Other needs

- Material properties (e.g. at high strain rates)
- Damage models
- Friction characterization
- An optimization process

Definition of “Optimal”

- Safest?
- Highest performance?
  - ride quality, noise, vibration
- Lowest cost?
  - cost of rail replacement
  - cost of rail grinding, tamping, etc.
  - inspection costs
  - head wear limits

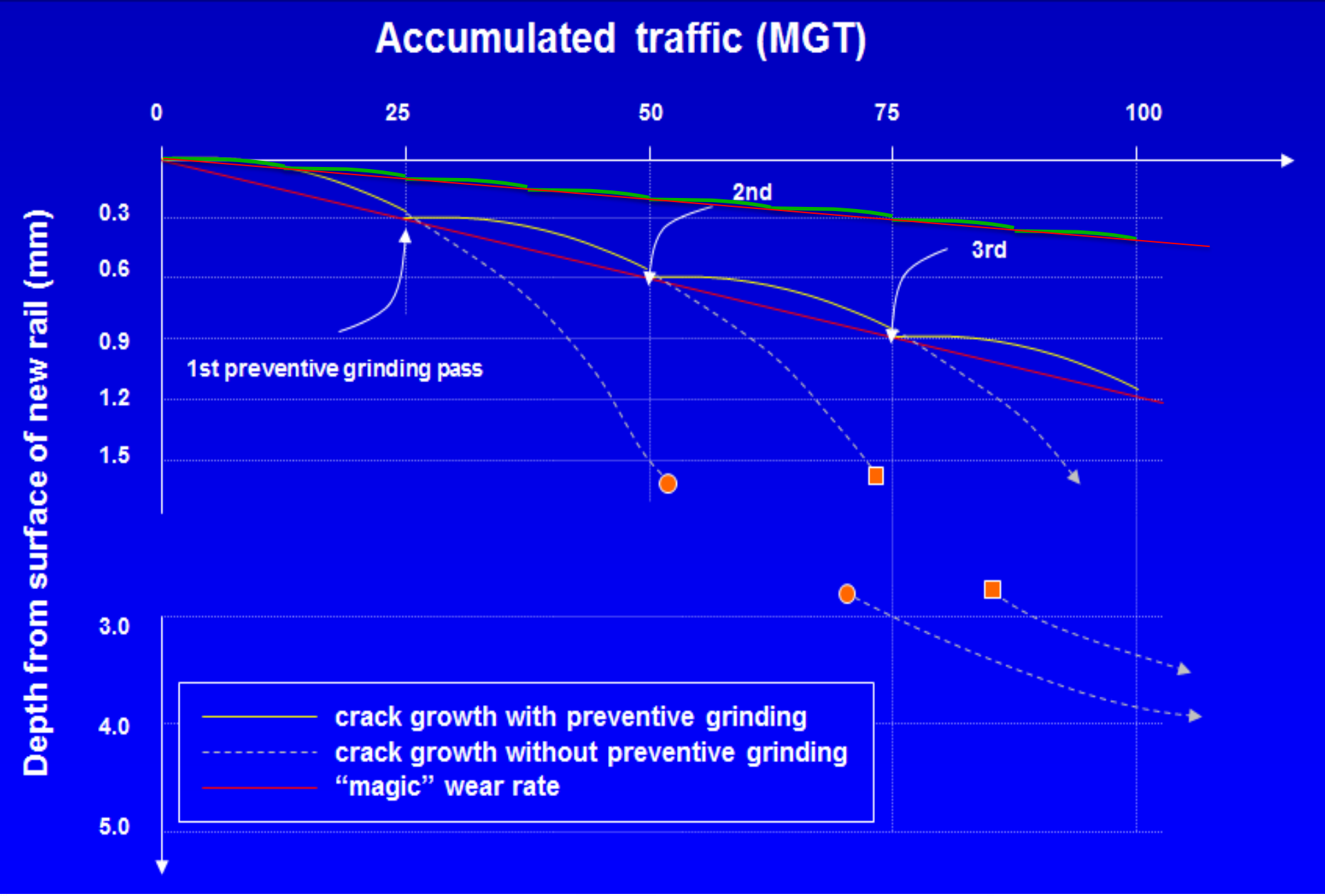
ICRP Workshop

- Thursday May 9th
- 16:30-19:00
- Laguardia room

Practical Implications

- MWR is highly variable
  - RCF / Wear / def'n Optimal

- Need to know the railroad intimately if you hope to capitalize on the Magic Wear Rate
  - Otherwise
    - grind all curves groups the same
    - tend to overgrind to be conservative


Accumulated traffic (MGT)
0
25
50
75
100
2nd
3rd
1st preventive grinding pass
Depth from surface of new rail (mm)
0.3
0.6
0.9
1.2
1.5
3.0
4.0
5.0
crack growth with preventive grinding
crack growth without preventive grinding
"magic" wear rate