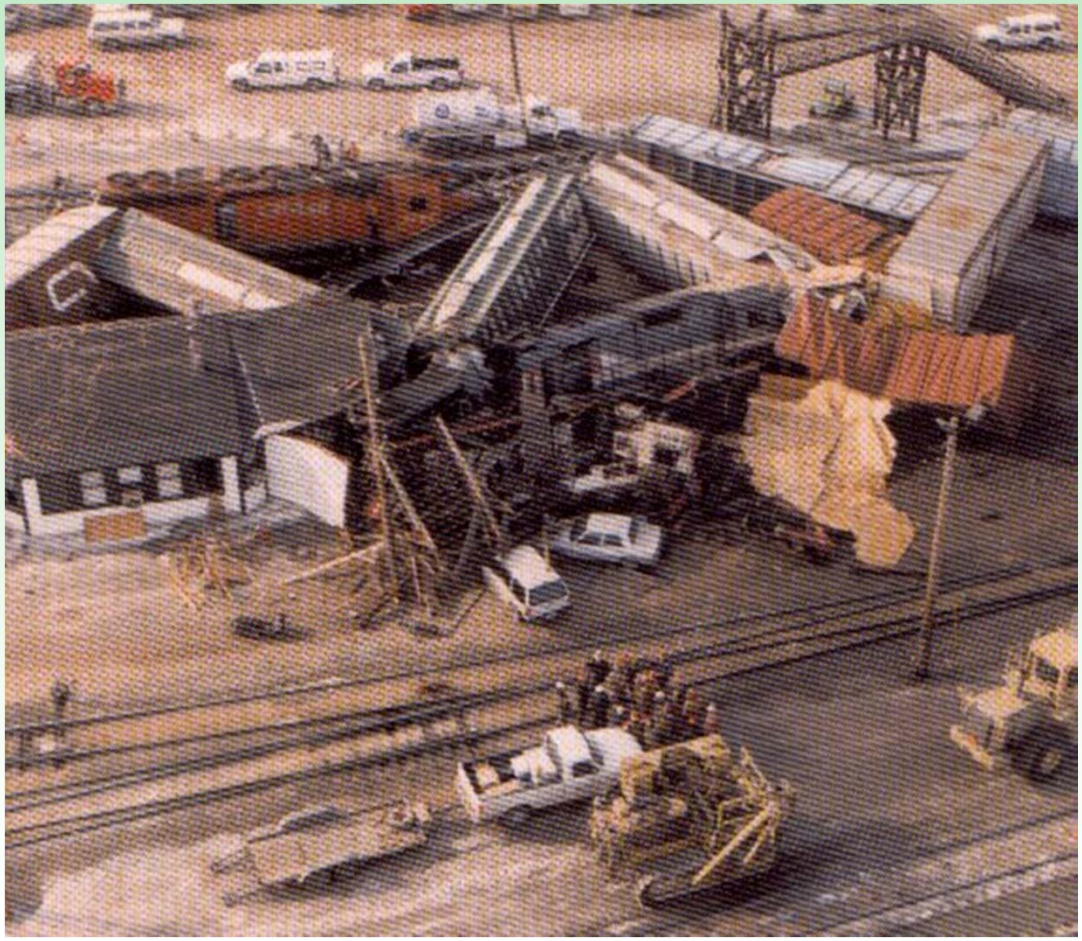
Wheel-rail damage phenomena
A Picture Gallery



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Introduction

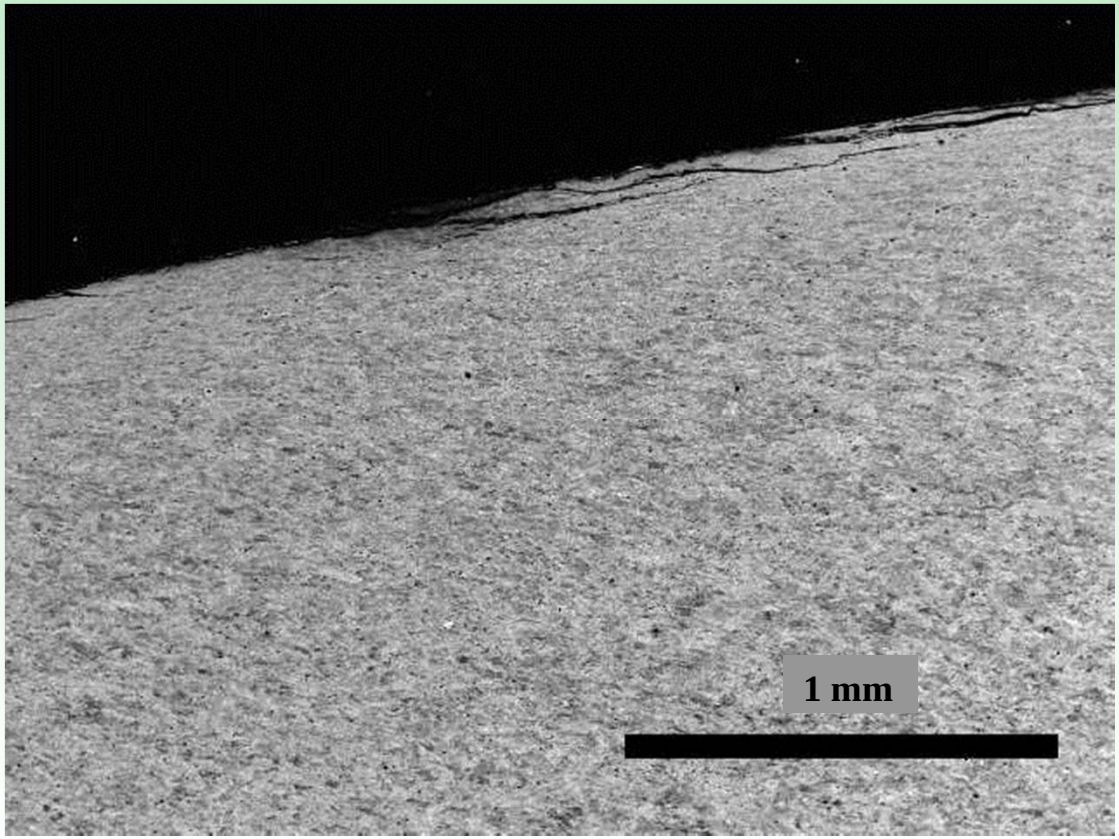
- Major reasons for deterioration and premature replacement of rail and wheels
  - wear
  - rolling contact fatigue, fatigue defects
  - plastic flow and head crushing
  - batter of joints and welds
  - corrugation
  - martensitic layers (e.g. wheel burns)

Wear

Abrasive Wear

Delamination of rail steels

- Low rail 8-degree curve
  - transposed



Adhesive Wear

Dandruff

Oxidative wear

- Reaction of surface iron with oxygen
  → Brittle oxide layer
- Relative motion separates layer from surface
- High stress, low amplitude top-of-rail/wheel-tread contact

Archard Wear Equation

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

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

Typical values for K for different types or wear		
Sliding wear (metals	mild	$10^{-6} \rightarrow 10^{-4}$
and ceramics)	severe	$10^{-4} \rightarrow 10^{-2}$
Abrasive wear	three body	$5 \times 10^{-4} \rightarrow 5 \times 10^{-3}$
(metals)	two body	$5 \times 10^{-3} \rightarrow 5 \times 10^{-2}$

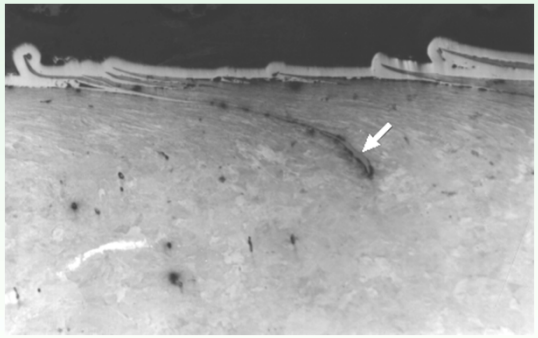
Rolling Contact Fatigue

Rail damage mechanisms

Rolling Contact Fatigue

- Rail ≈ 4 million cycles/100 MGT
- Wheel ≈ 33 million cycles/100K km
- High contact stress + friction + slip
  - plastic deformation - ratcheting
  - work/strain hardening
  - fracture

→ **Surface crack**

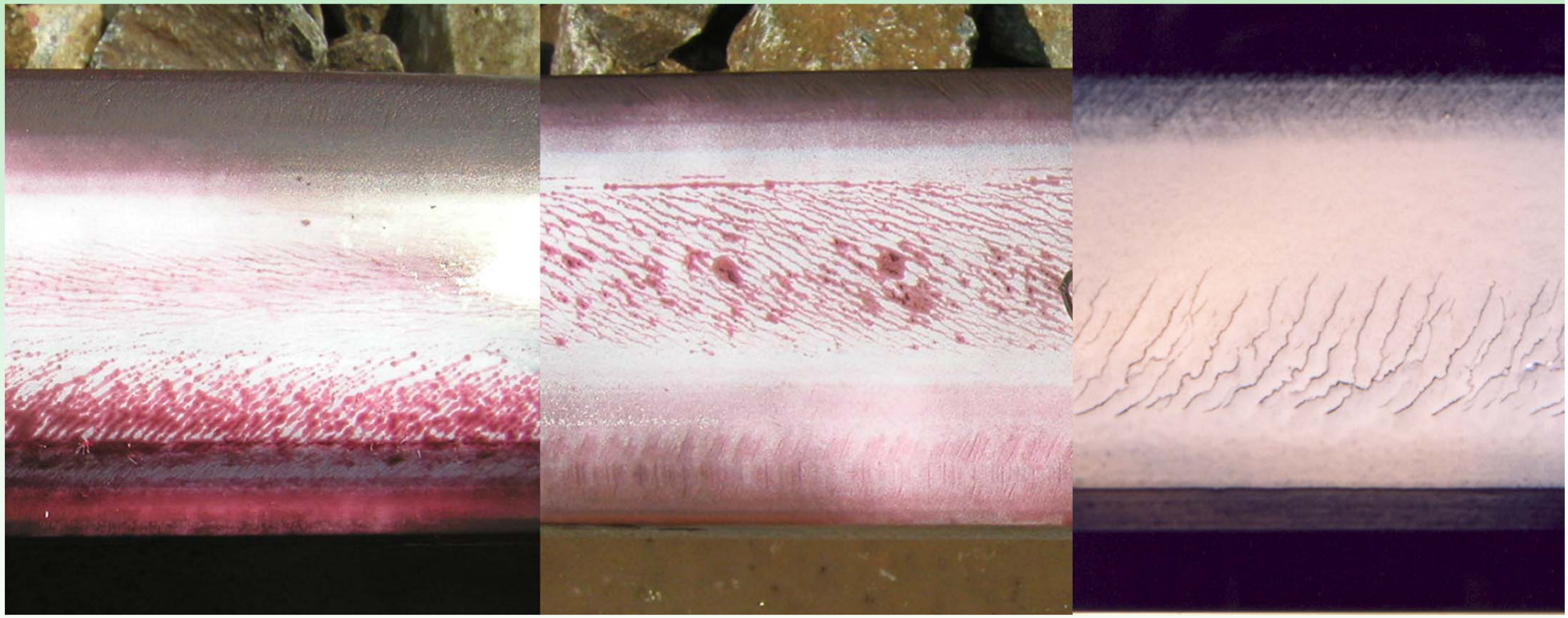


Rail damage mechanisms

Rolling Contact Fatigue

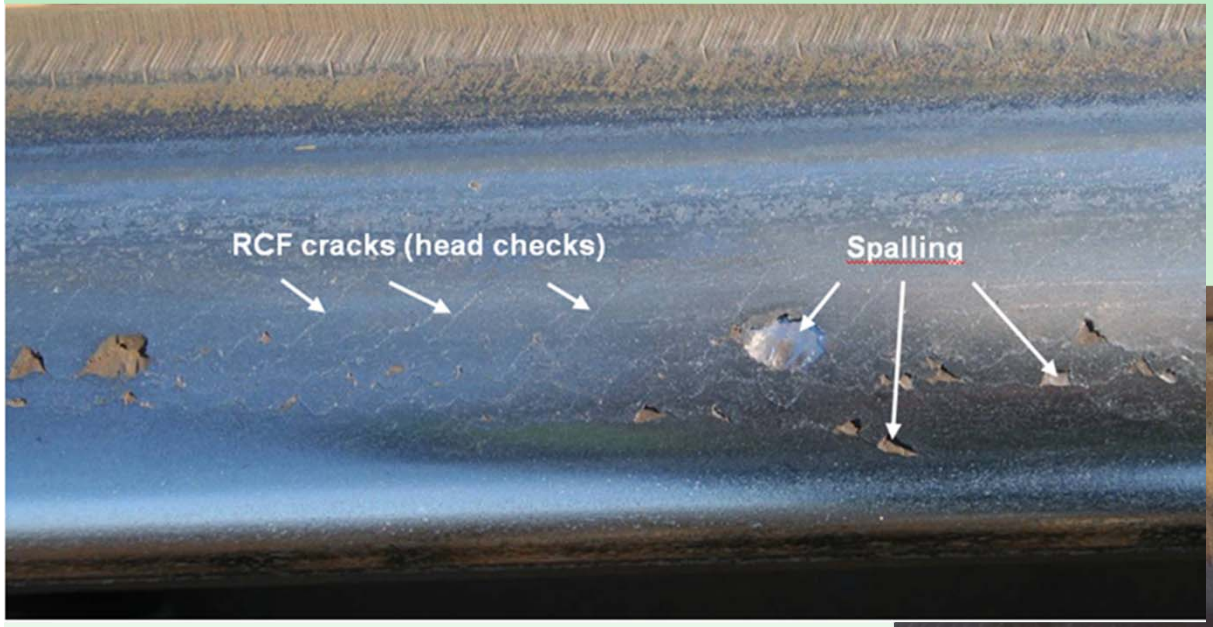
- Microscopic cracks
- Head Checks
- Shells
- Gauge Corner Collapse
  - Deep Seated Shell
- Broken Rails

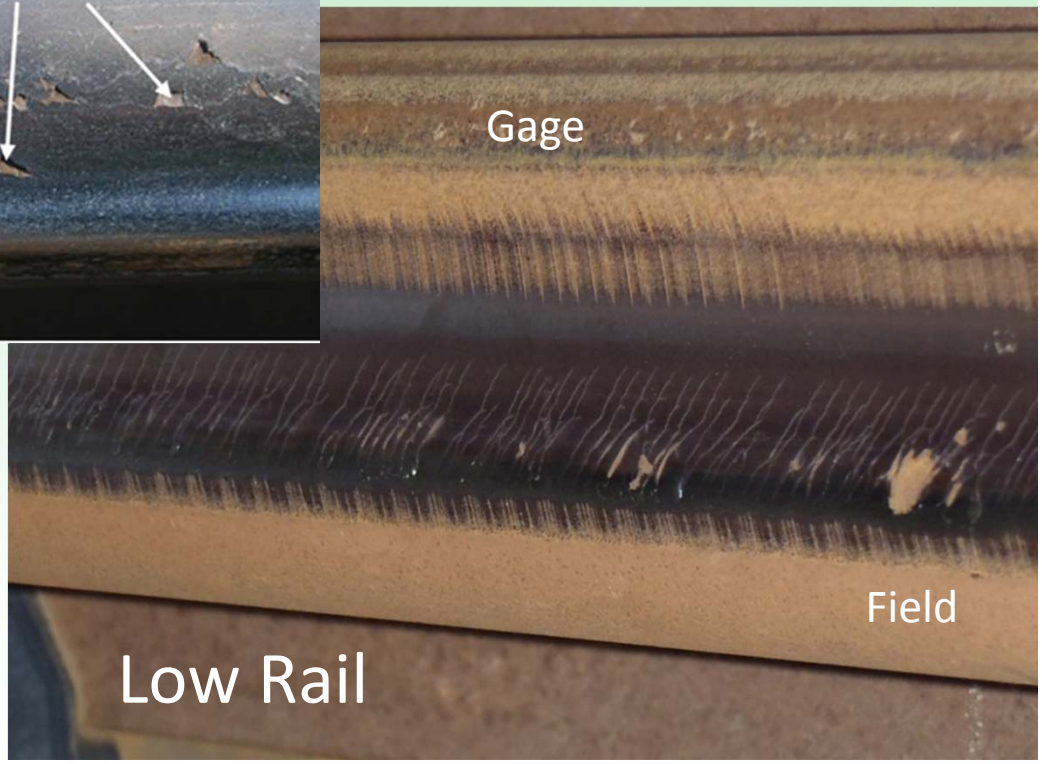
Head Checks




2.05

Shelling



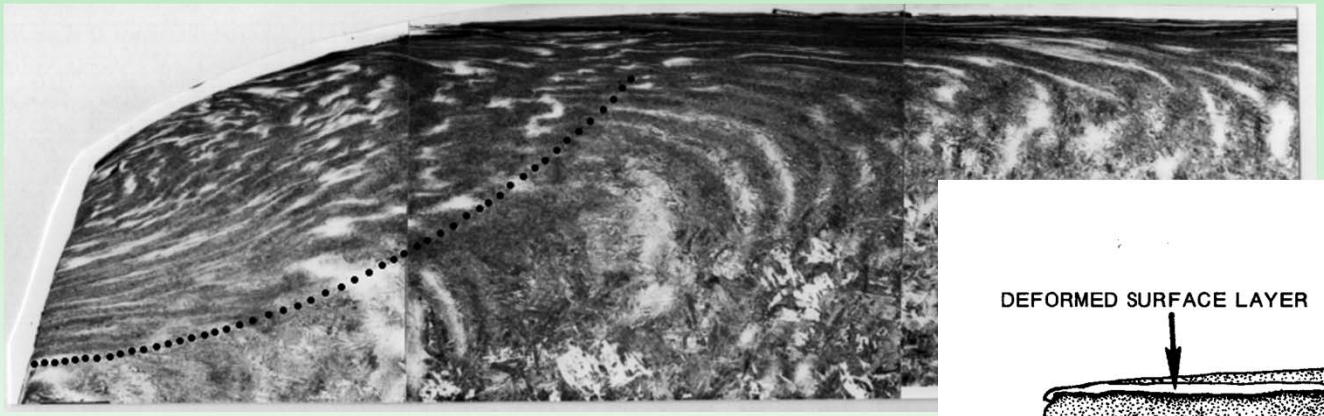


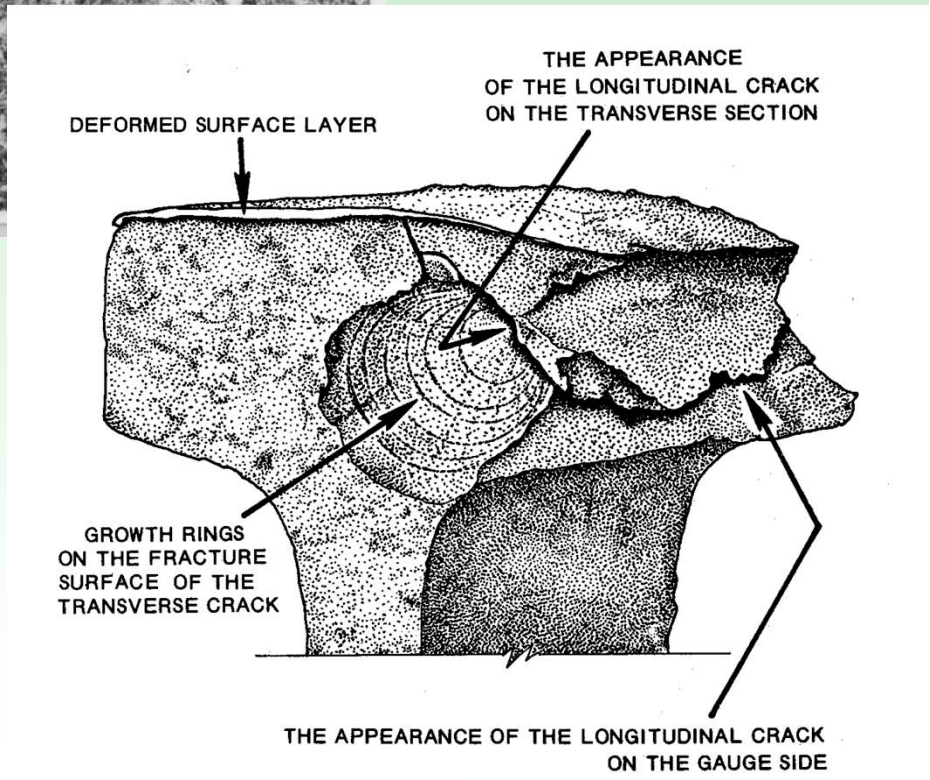
Controlling Track Geometry Errors

- Track irregularities
- Super-elevation

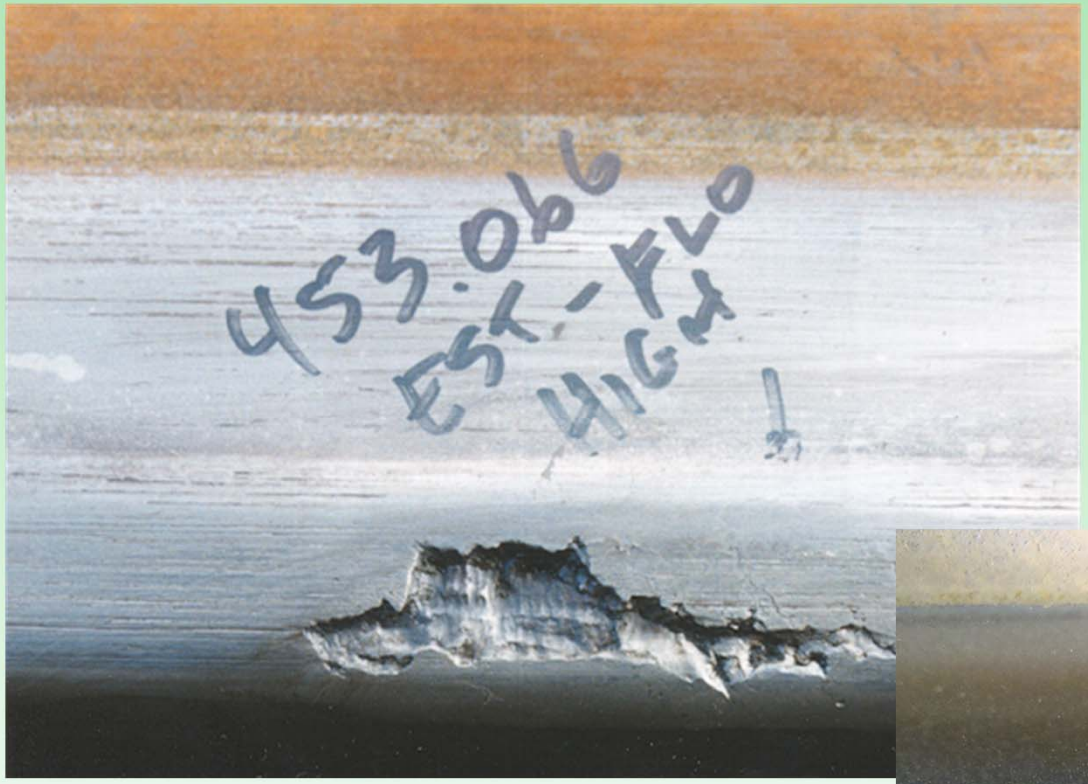
- Track Gauge
- Plate cut sleepers

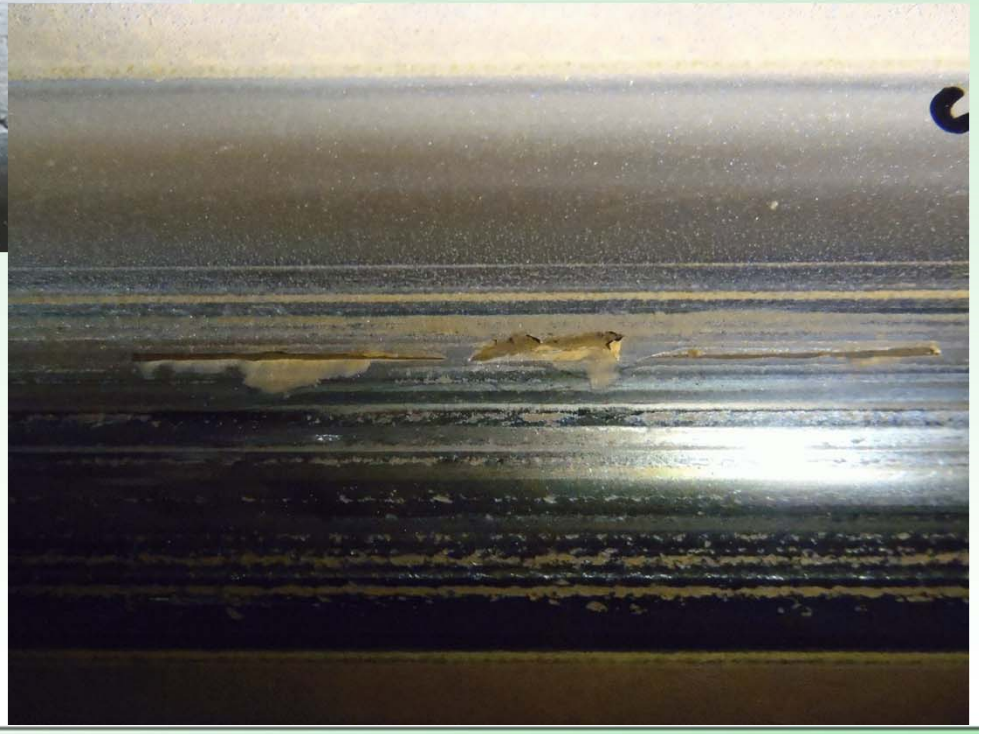
Gauge corner collapse



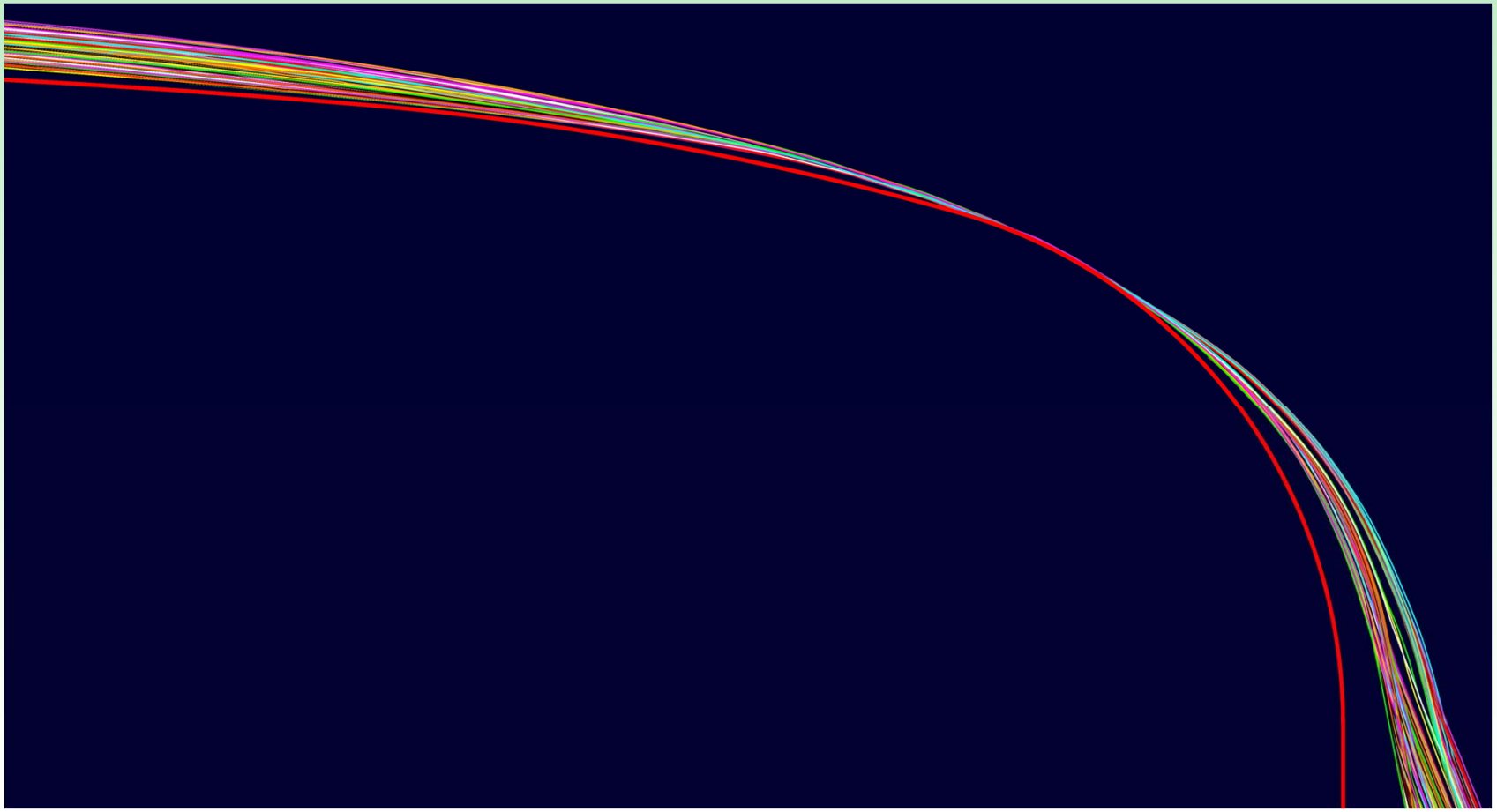


Open Deep Seated Shells

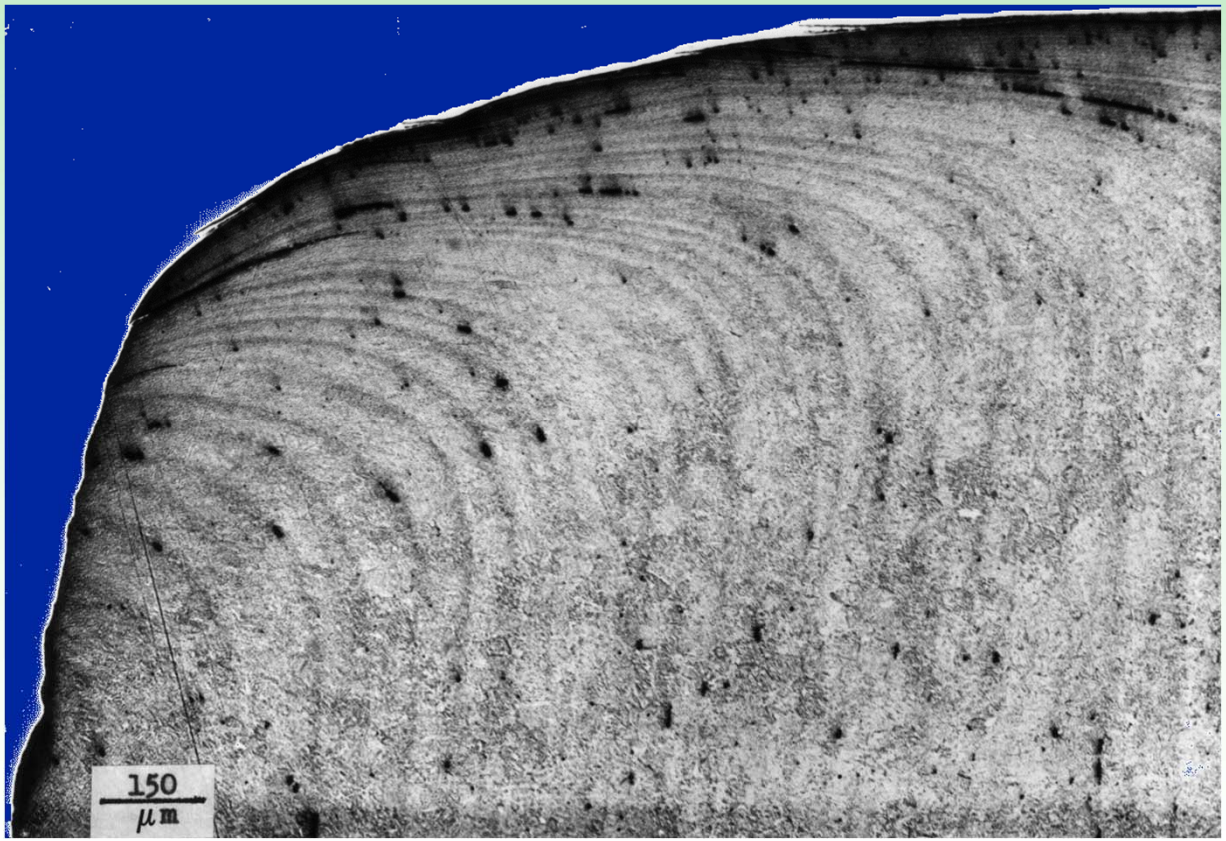

453.066
EST-FLO
HIGH



Pummelling

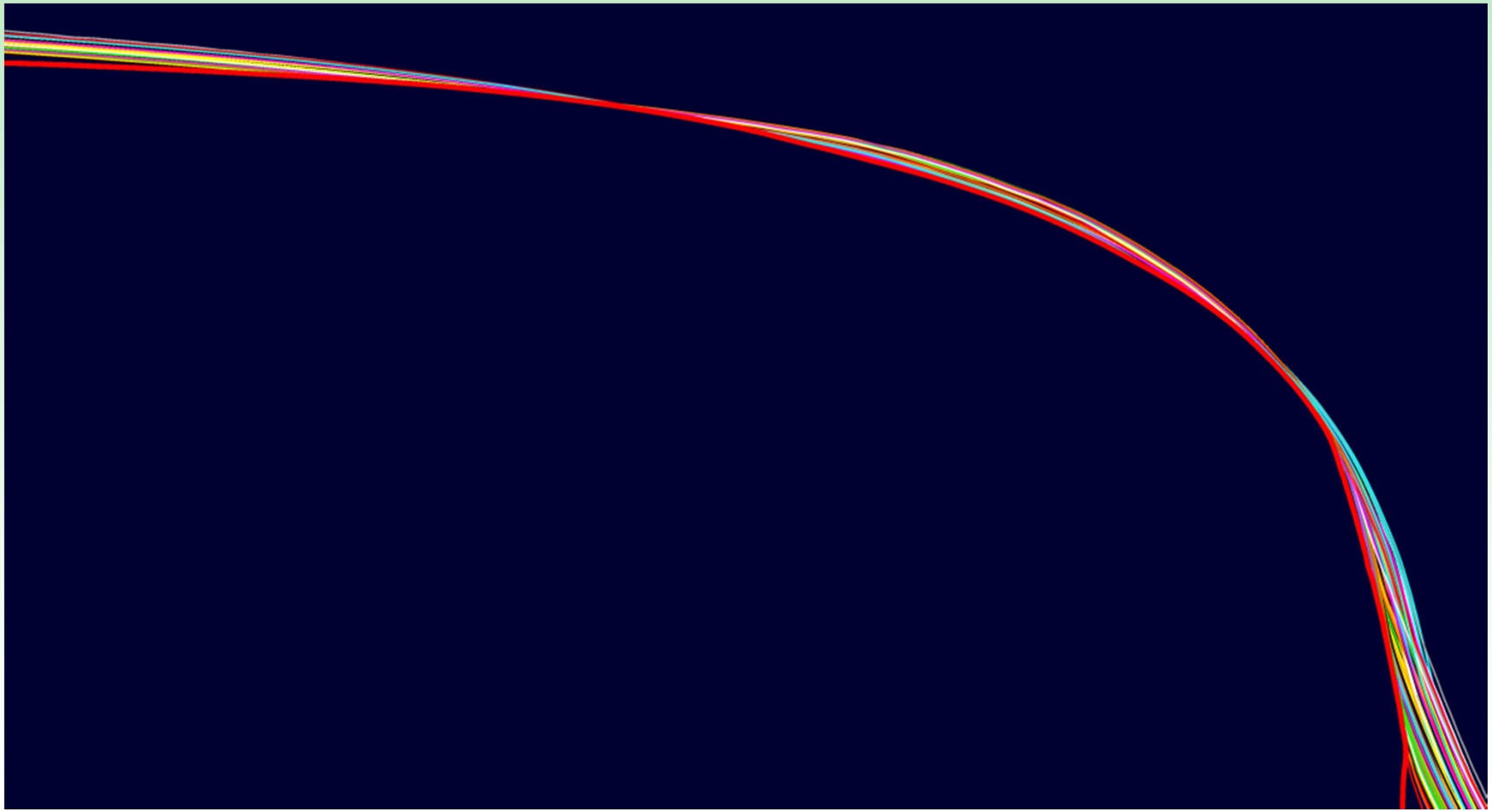


Gauge corner relief

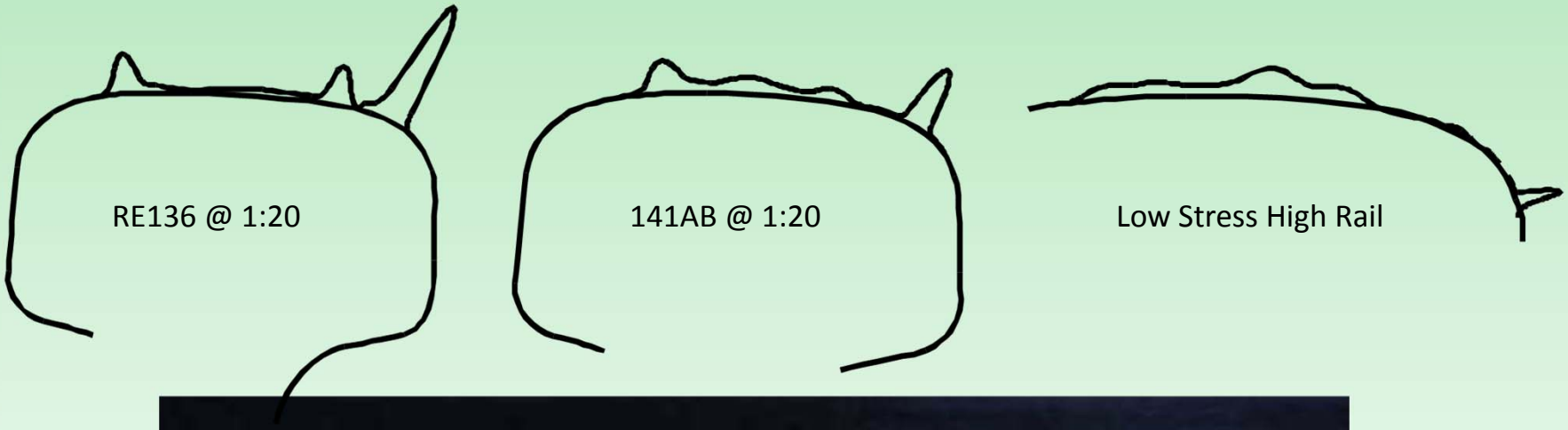


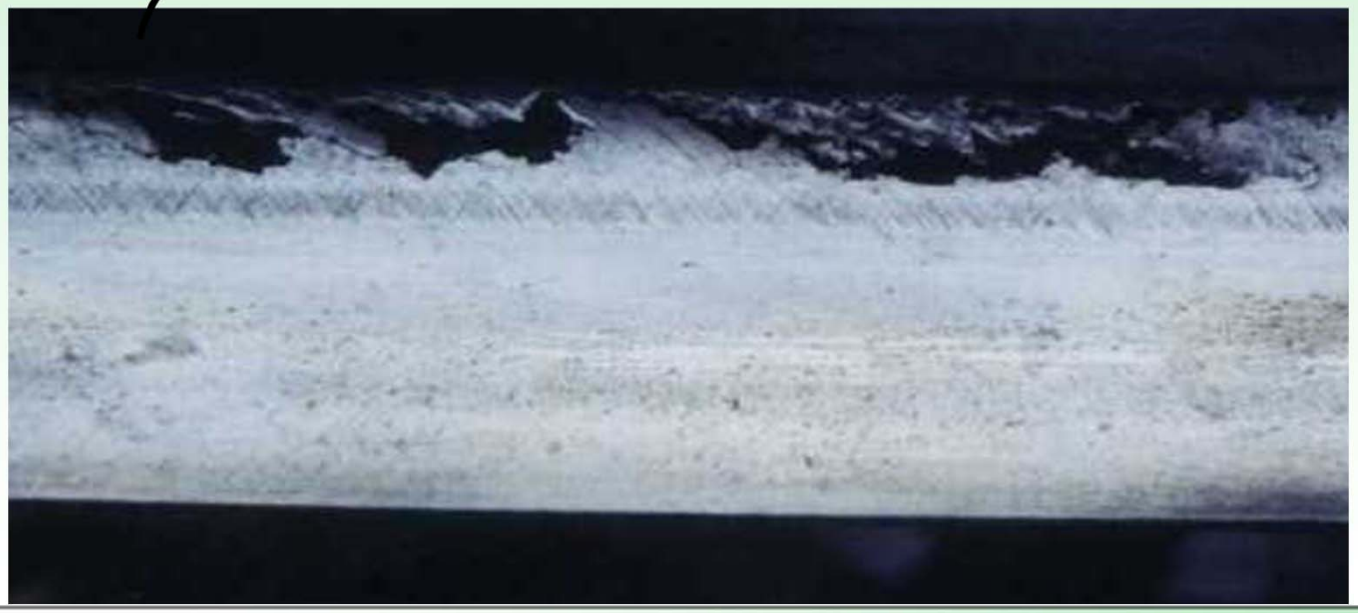
- Eliminates gauge corner collapse
- Improves Δr when combined with conformal wheel profile

2-pt conformal contact

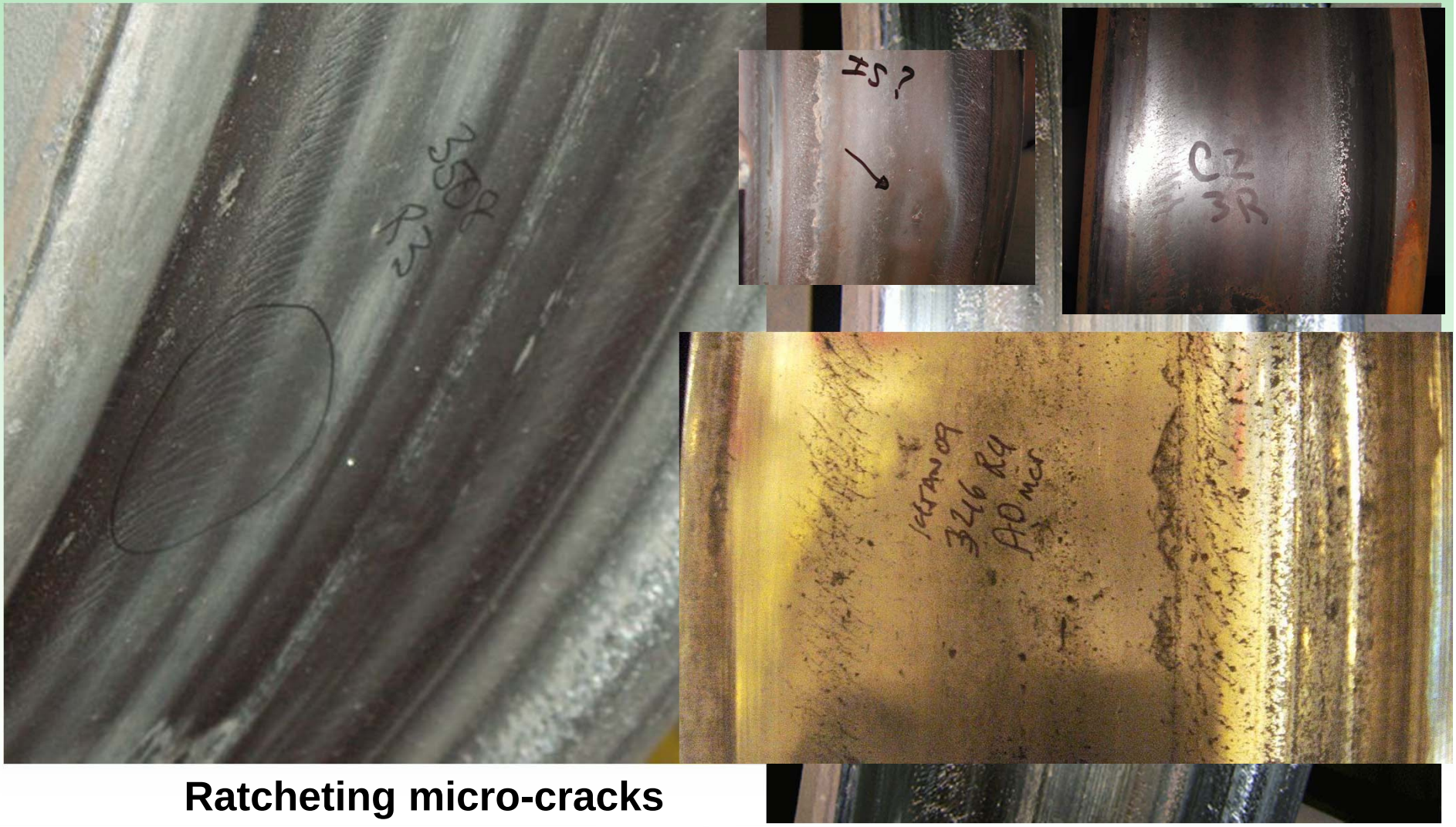


Optimizing rail profiles

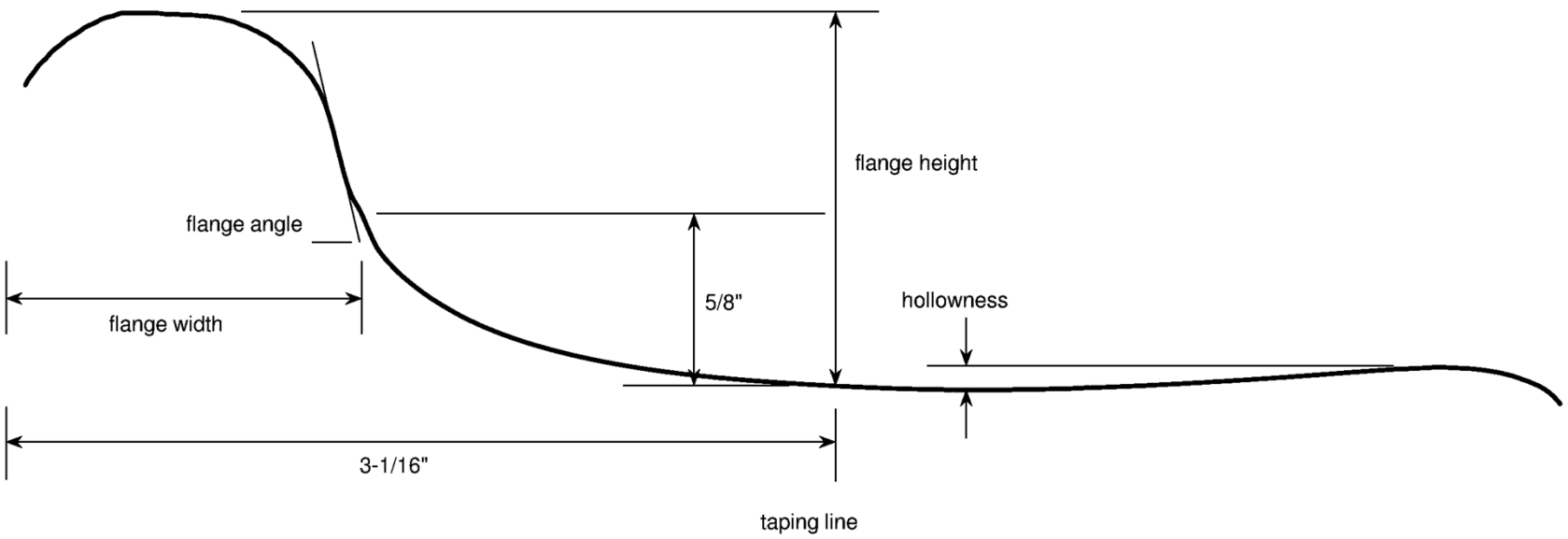




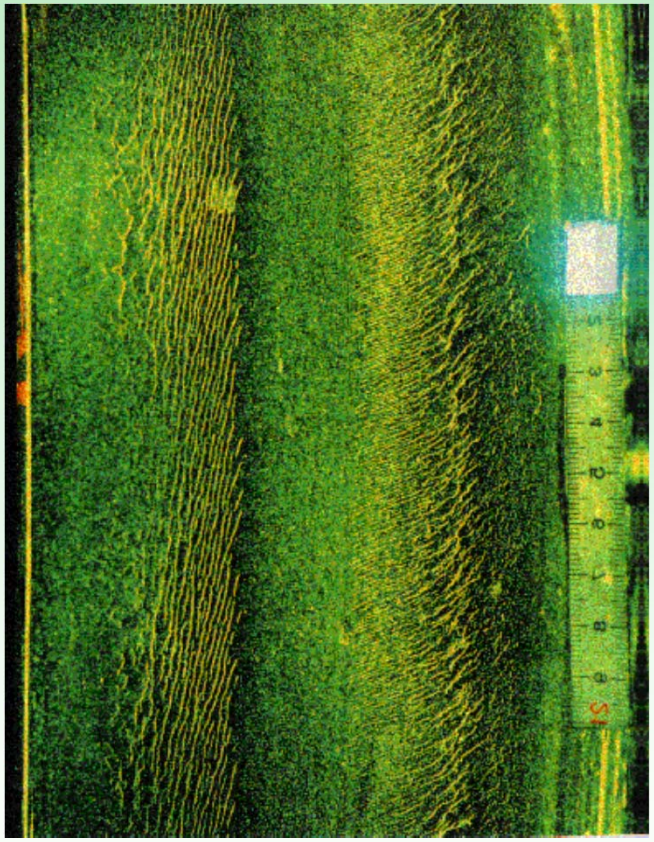
Wheel Fatigue cracking



Ratcheting micro-cracks


flange height
flange angle
5/8"
hollowness
flange width
3-1/16"
taping line

Wheel shelling from contact fatigue cracks

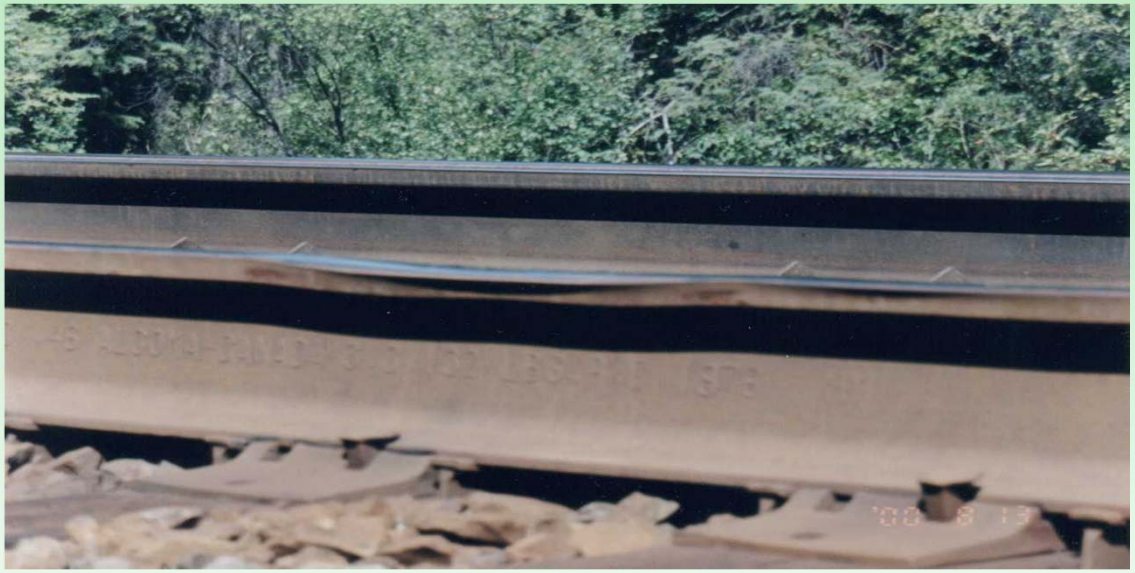


Ratcheting micro-cracks

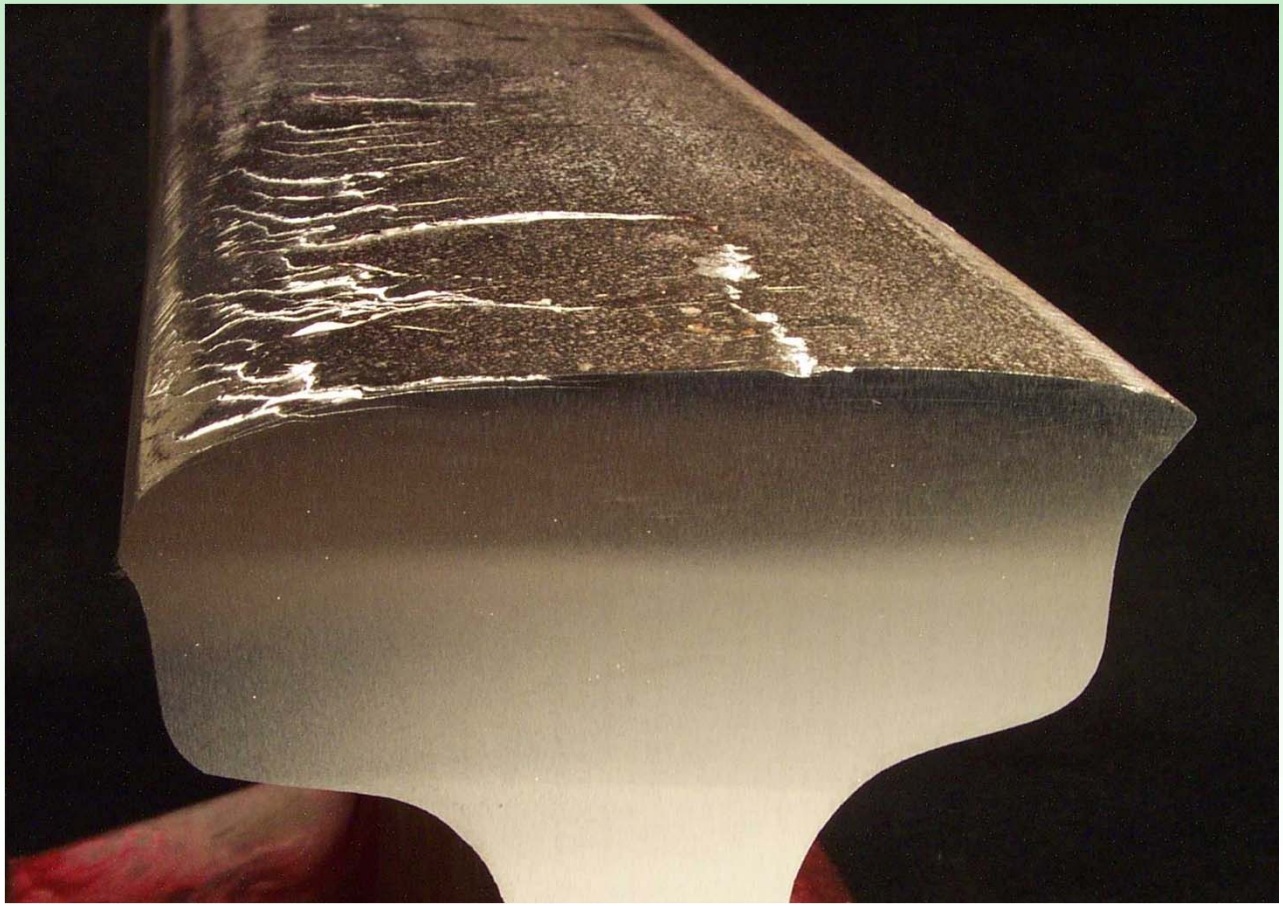
Fully shelled wheel

Plastic Flow

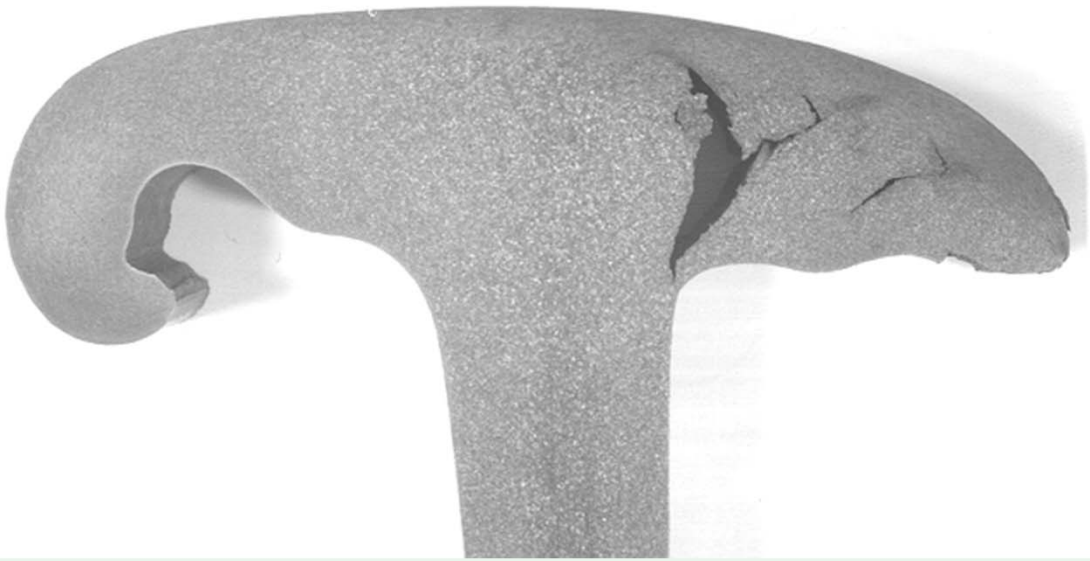
Crushed Heads

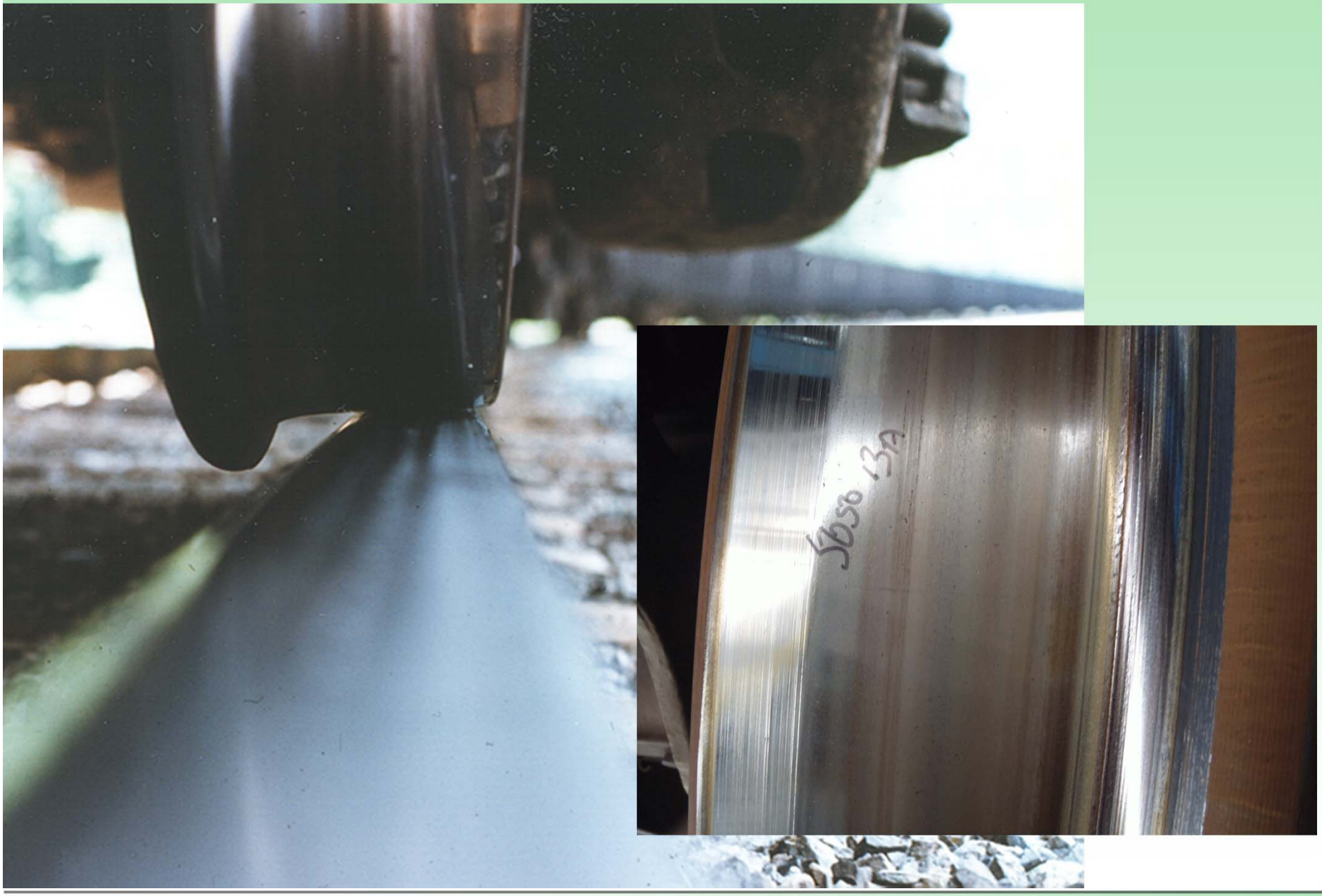


Crushed Heads (cont'd)

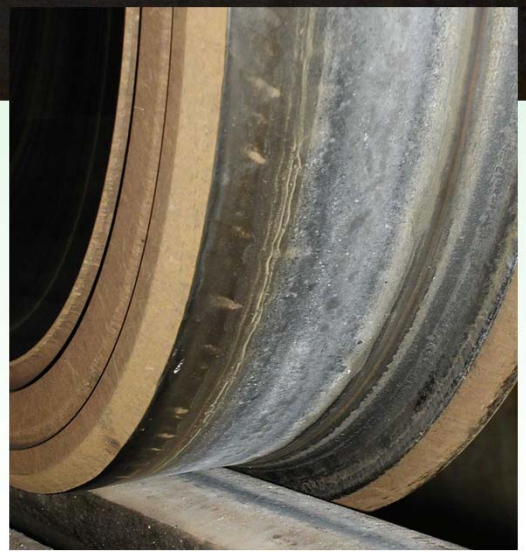


Plastic Flow (batter) - welds





Plastic Flow (transit)

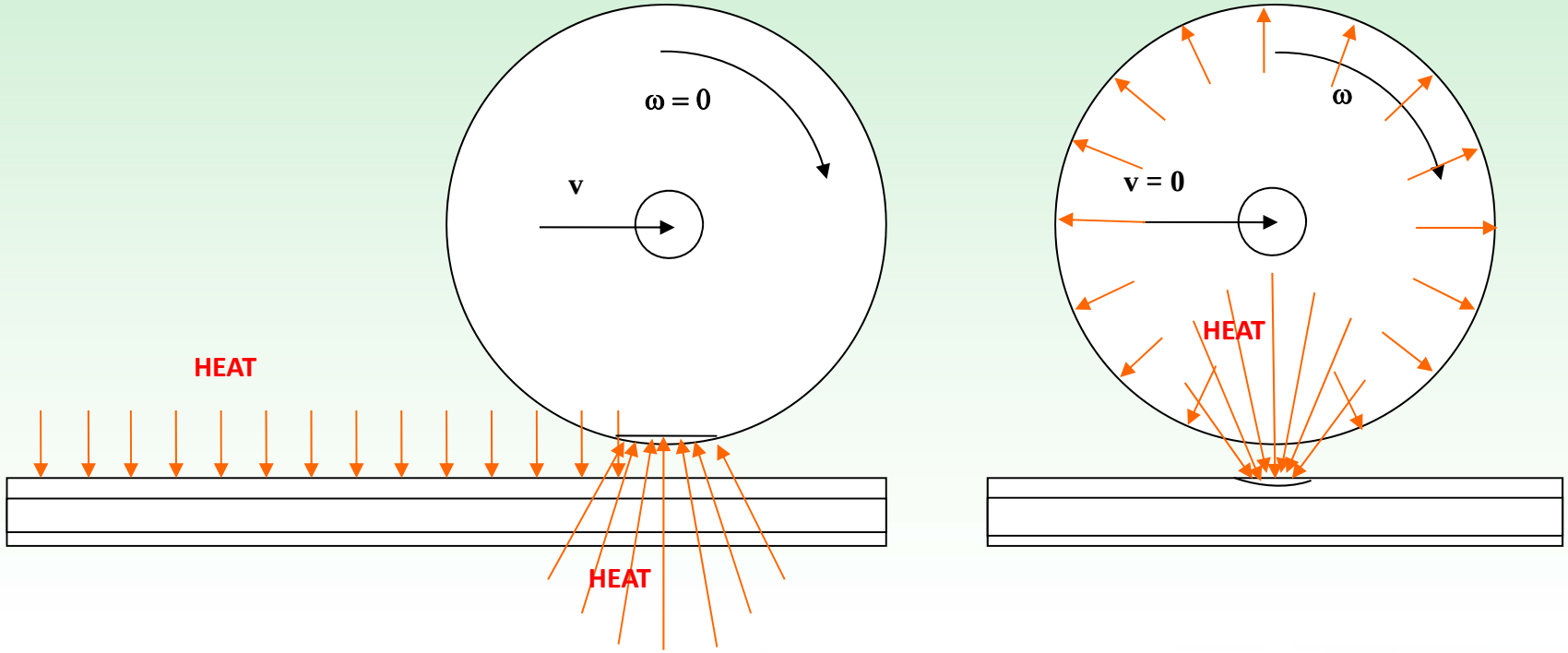


Martensite

Martensite and creepage

WHEEL FLATS
when
SLIDING / SKIDDING
(braked wheels,
negative creepage)

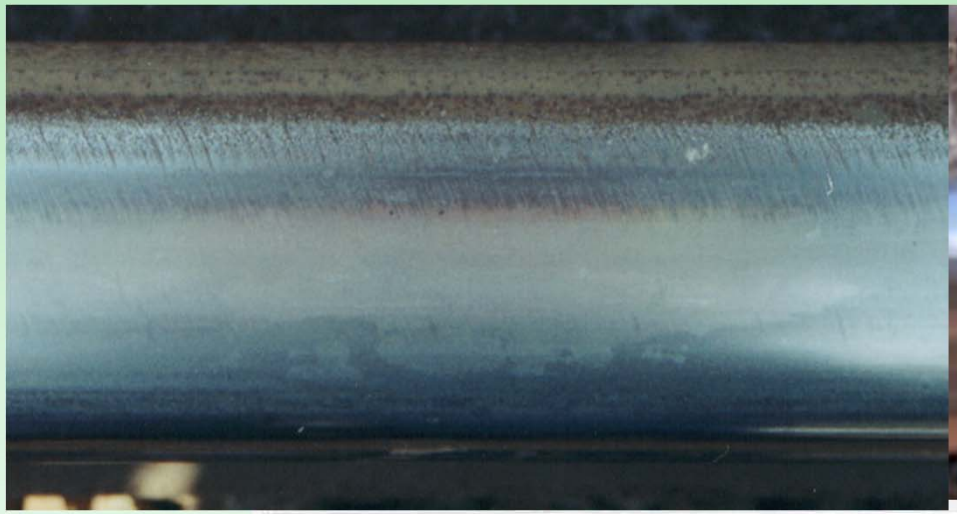
WHEEL BURNS
when
SPINNING
(powered wheels,
positive creepage)

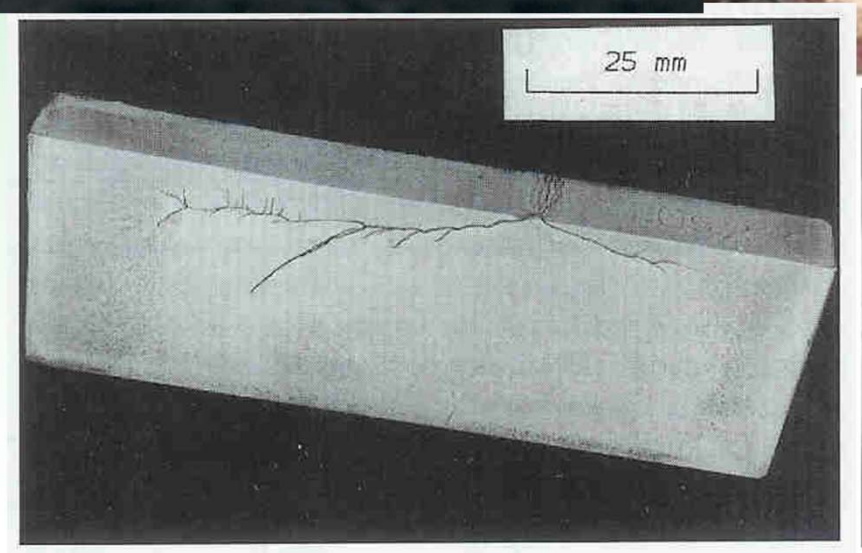


Rail Martensite

Spinning your wheels?

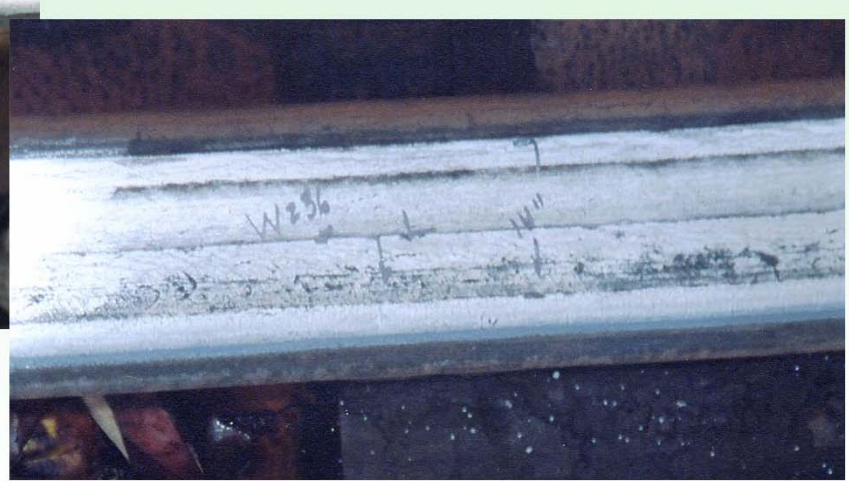
Rail Squats



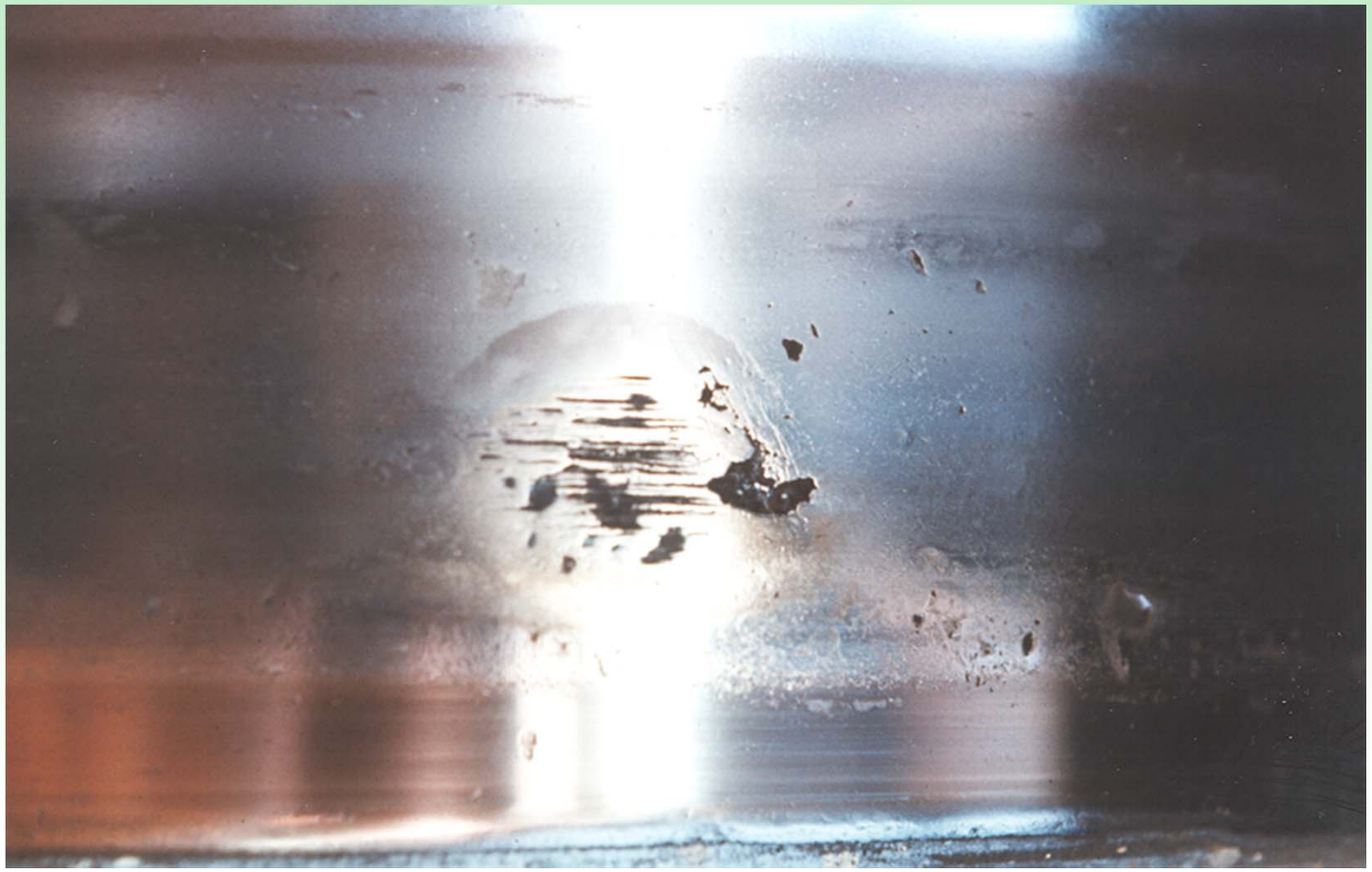


http://lievin.wiki-citoyen.fr/index.php?title=Fichier:Tramway_lyon_pierre_guevar.JPG

Slippery Conditions



Wheel Slide

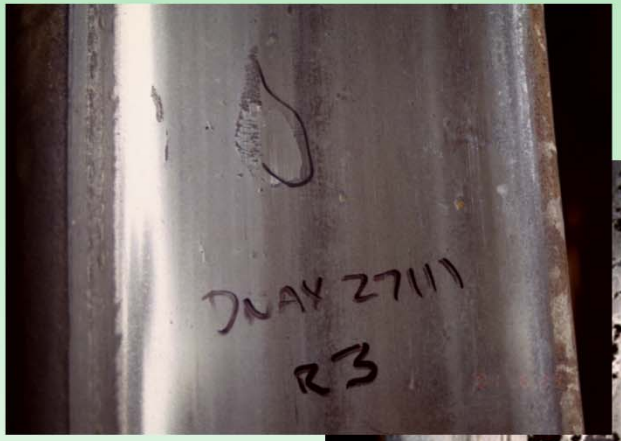


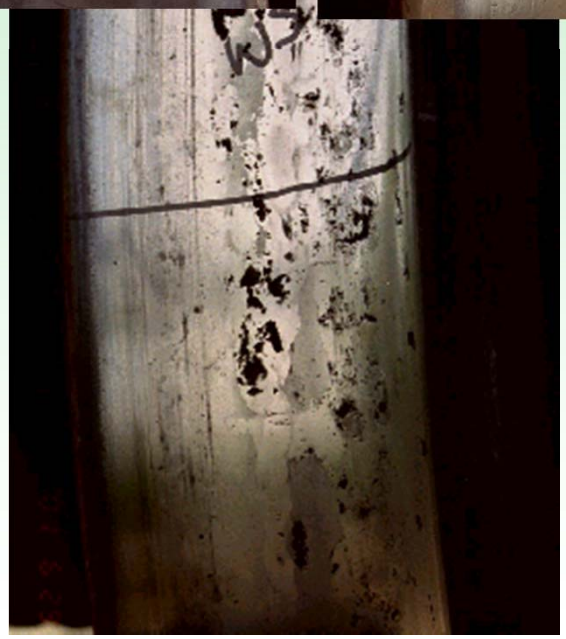
Spalling from skid flat

Partially worn skid flat containing martensite

Wheel spall with martensite material cracked and drolled out

Wheel surface damage - Martensite





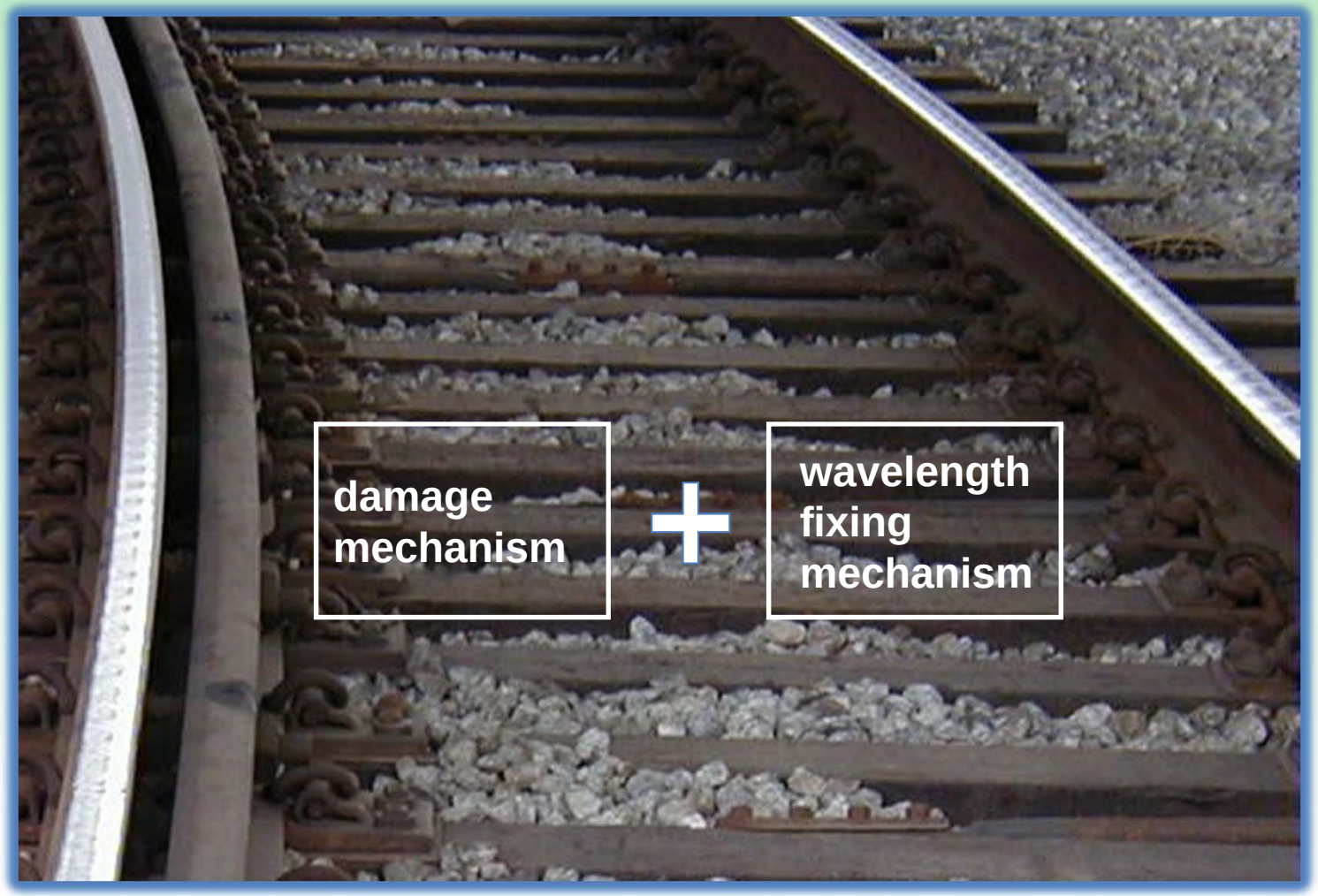
freight wheels

Wheel flats

Indentations and Martensite

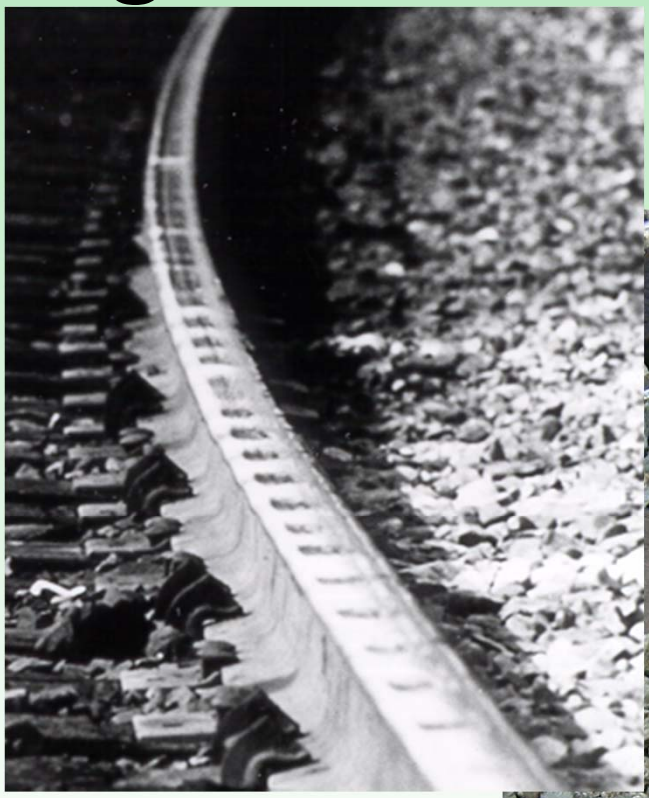
- Most of the indentations, as well as the immediate area around them, contain 100 – 350 μm (0.004 – 0.014 inch) thick surface martensite. Most of the indentations are filled with rust.

Rail Corrugation



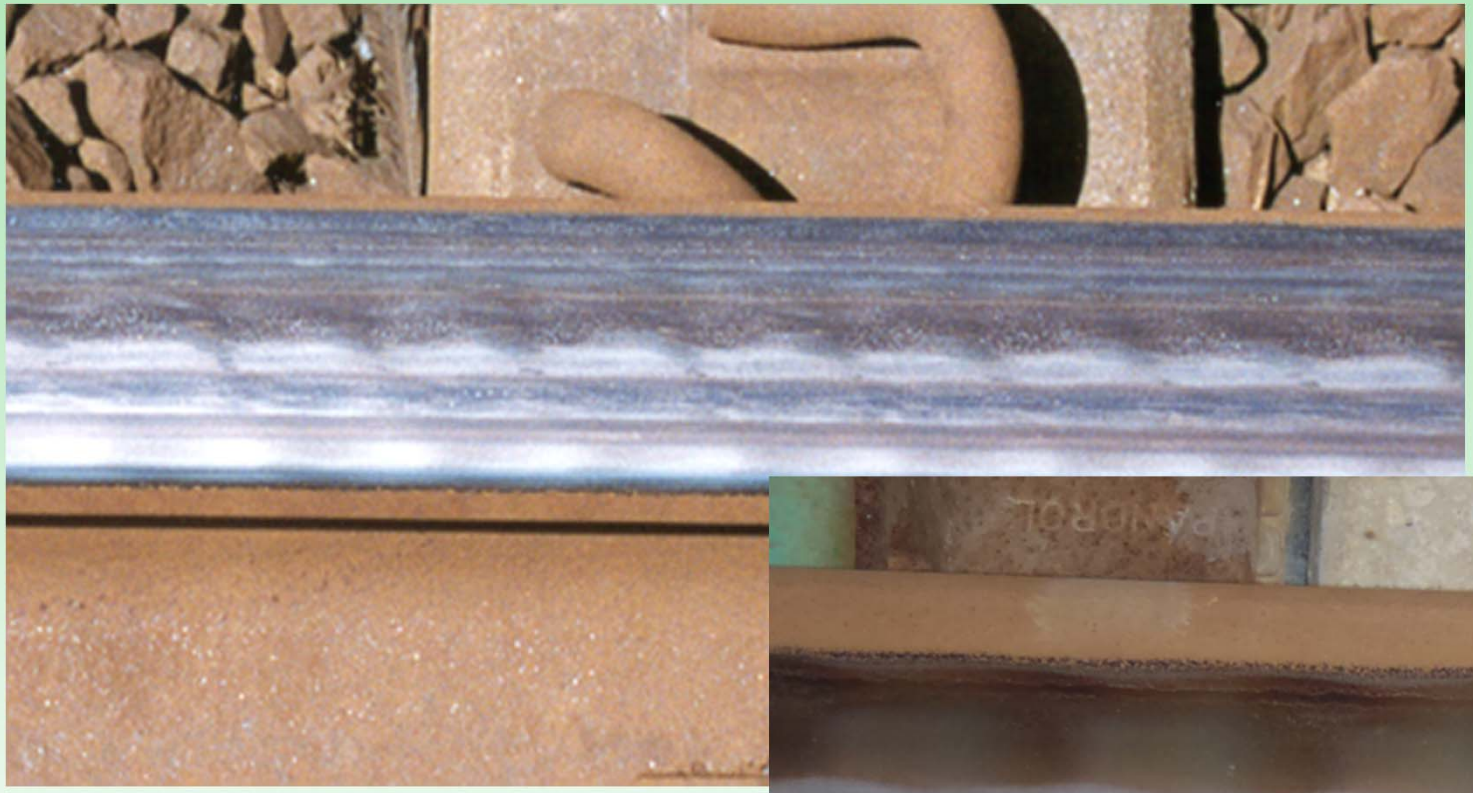
Corrugations

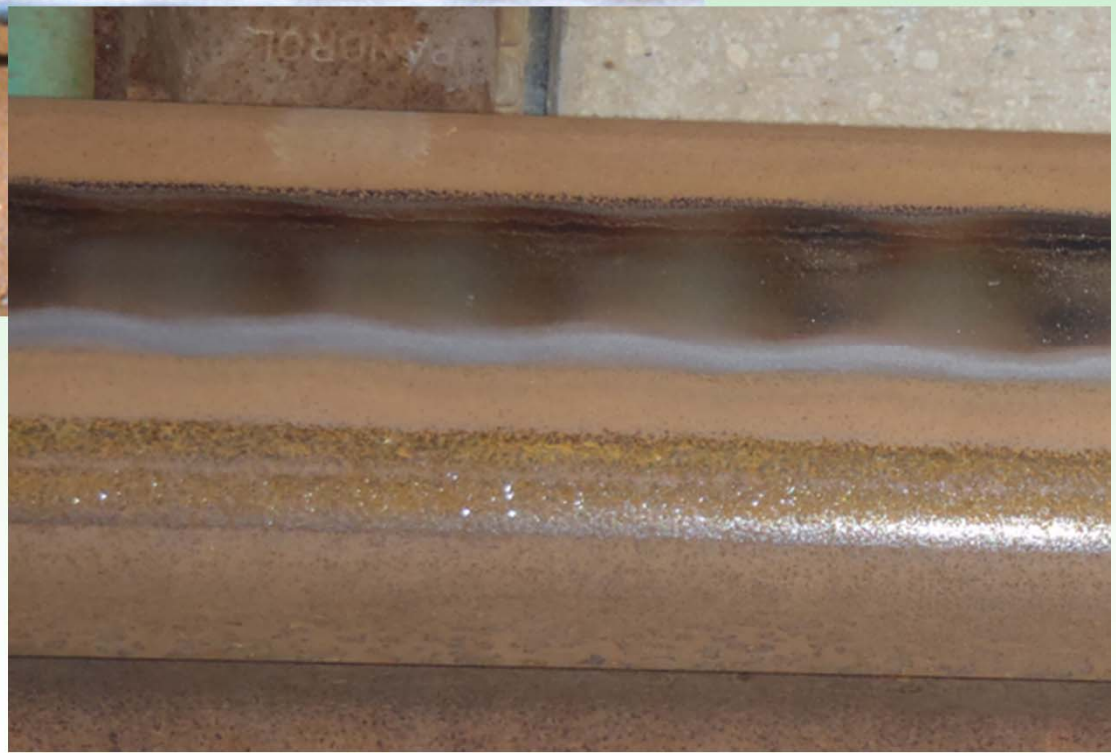
- Heavy Haul corrugation
  - High dynamic forces
    - degrades ballast
    - noise
  - Heavy unit trains
  - Consistent speed
  - Discrete irregularities
    - welds, joints, crossings
  - P2 resonance
  - Plastic flow
- RCF Corrugation
  - Same as above but damage mechanism is fatigue



Corrugations (cont'd)

- Rutting
  - differential wear from oscillatory tractions
    - Wear $\propto$ (μ x load x s)
    - wheelset torsion
    - vertical track oscillation.
  - Most common areas
    - high traction (or braking)
    - curving





Transit Corrugations

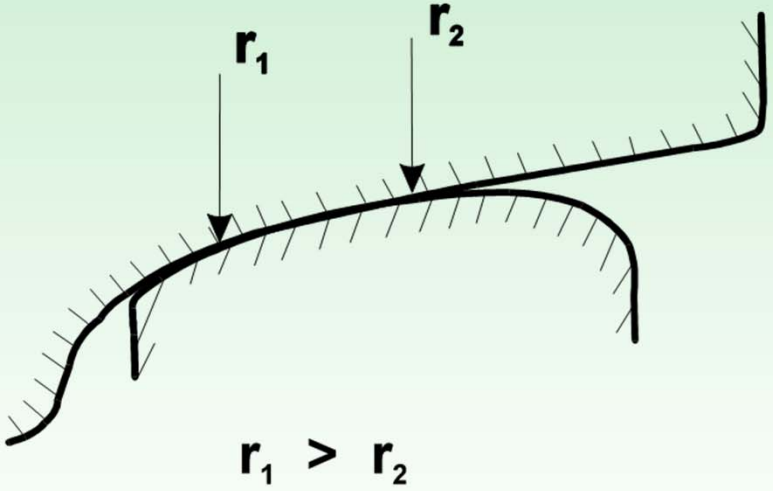
Different wavelengths, same railroad

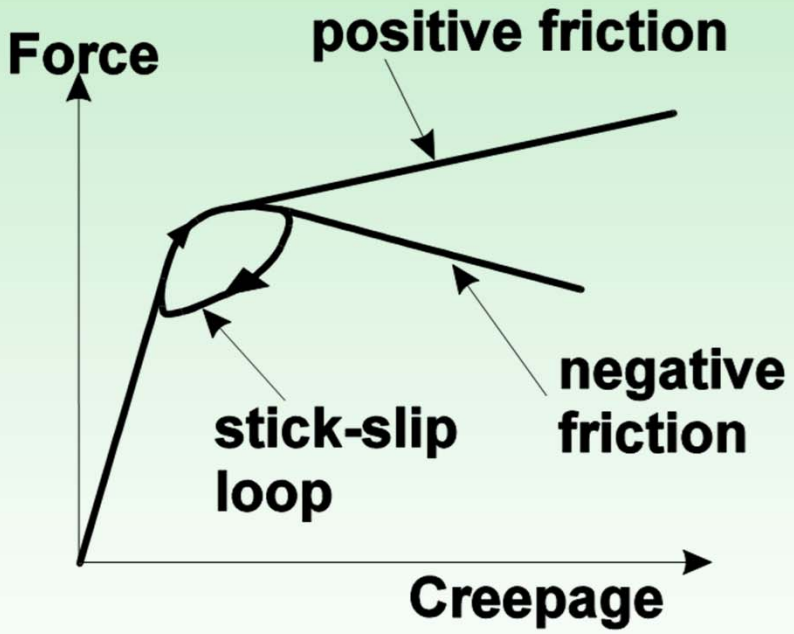
The repercussions

Wavelength fixing mechanism

- Resonance of sleeper (bending)
- Bending or lateral resonance of rail
- Monomotor bogies (connection of motor to axle)
- axle bending
- torsional resonance of wheelset
- …..

Roll-Slip Oscillation due to Spin Creepage

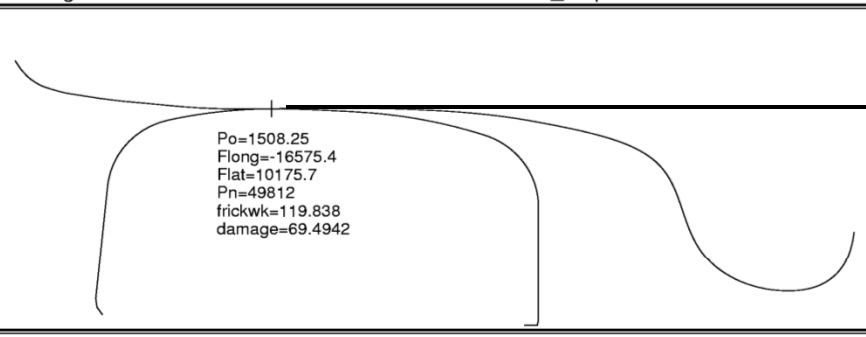




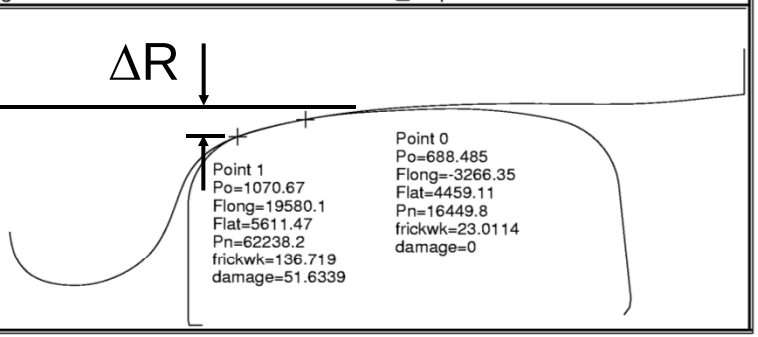
Hunting

GPummel4 NRC-CSTT Sat Mar 29 23:00:20 2003

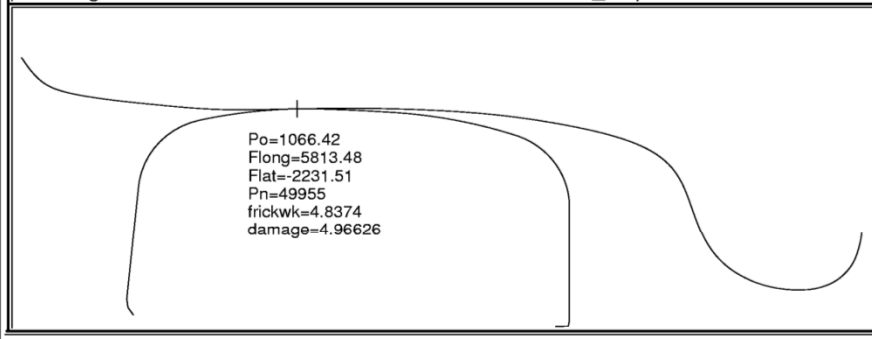
Leading Axle - Left Rail 11062001-1781.whl.tbrbs113a_20.prd



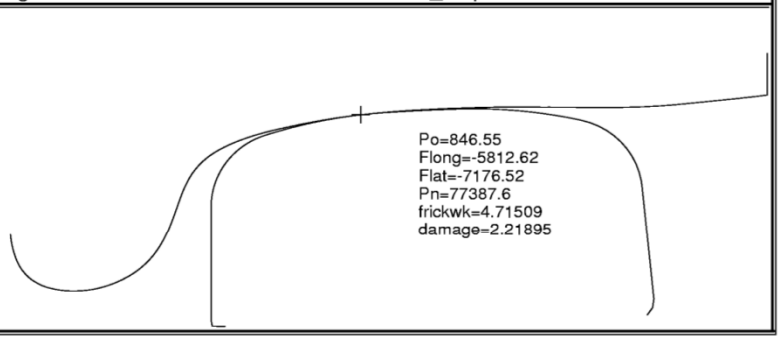
Leading Axle - Right Rail 11062001-1771.whl.tbrbs113a_20.prd



Trailing Axle - Left Rail 11062001-1801.whl.tbrbs113a_20.prd



Trailing Axle - Right Rail 11062001-1791.whl.tbrbs113a_20.prd



Leading axle

y_lat :	0.0109905
aoa :	0.00327325
lat. force :	-6738.45
moment :	-24465.6

Suspension forces

S[0] :	0
S[1] :	0
S[2] :	0
S[3] :	0

Trailing axle

y_lat :	0.0072563
aoa :	-0.000210423
lat. force :	-19608.5
moment :	8774.35

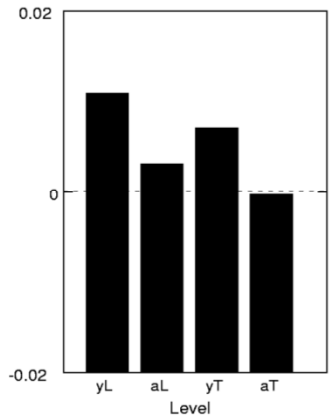
Summary

net_lateral :	25.1805
net_moment :	-0.0571173
balance_err :	0
total_err :	25.1806

Input parameters

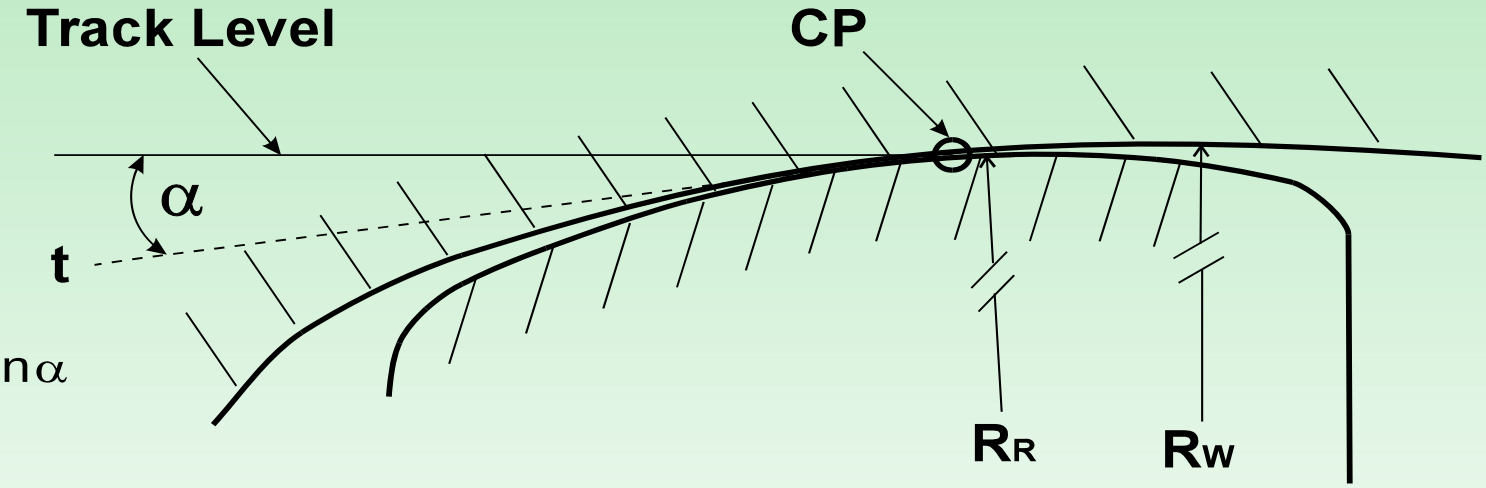
suspension_type :	0
Lwheel load R :	76832.5
Lwheel load L :	49900.3
Twheel load R :	76832.5
Twheel load L :	49900.3
car speed :	136.0
cant deficiency :	6.27
total sideload :	26372.2
track curvature :	700.0
track gage :	1.4415
mu_right_top :	0.5
mu_right_gage :	0.5
mu_left_top :	0.5
mu_left_gage :	0.5

Position



E.E.Magel

Effective (λ) Conicity (in tangent track) Governs Hunting

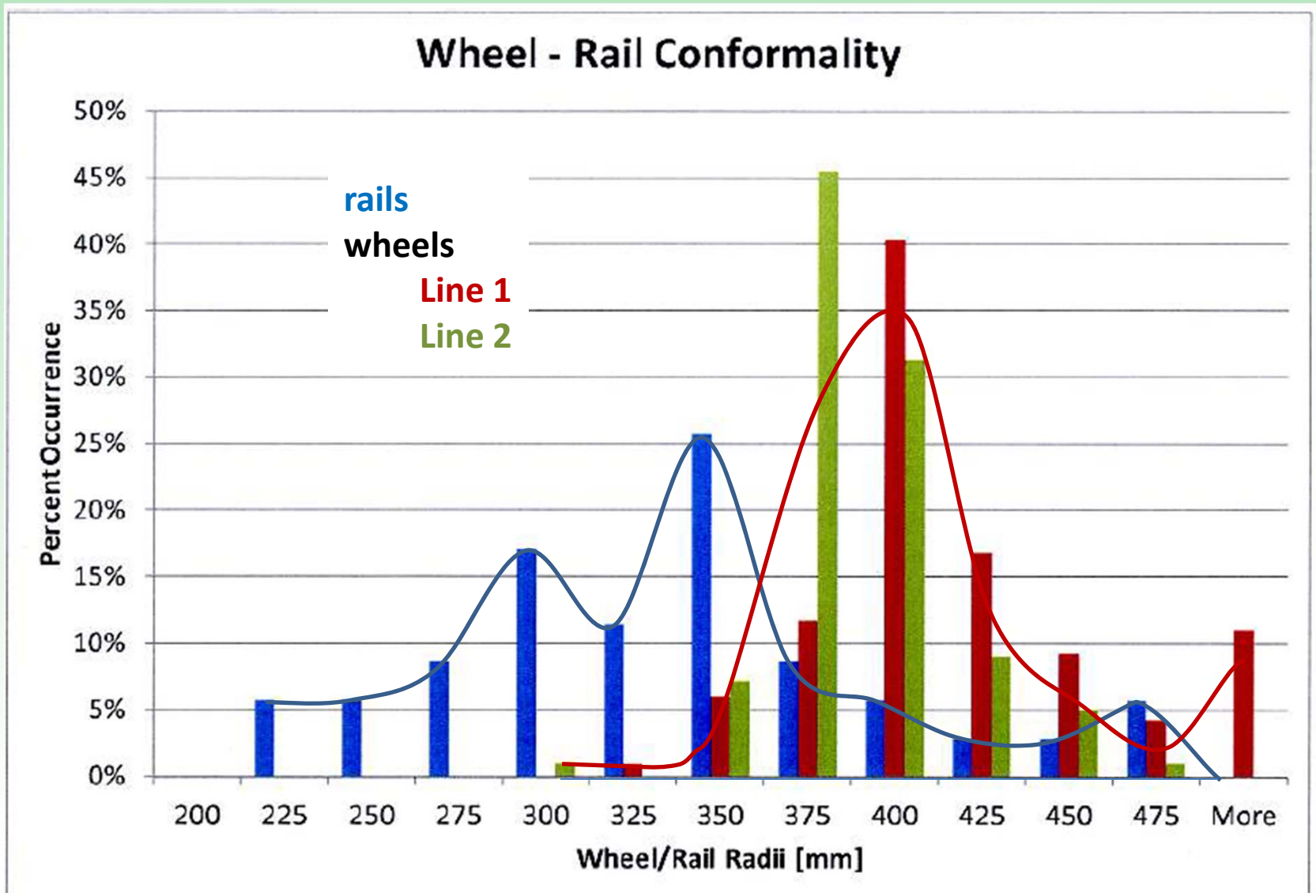


$$\lambda = \frac{R_W}{R_W - R_R} \sin\alpha$$

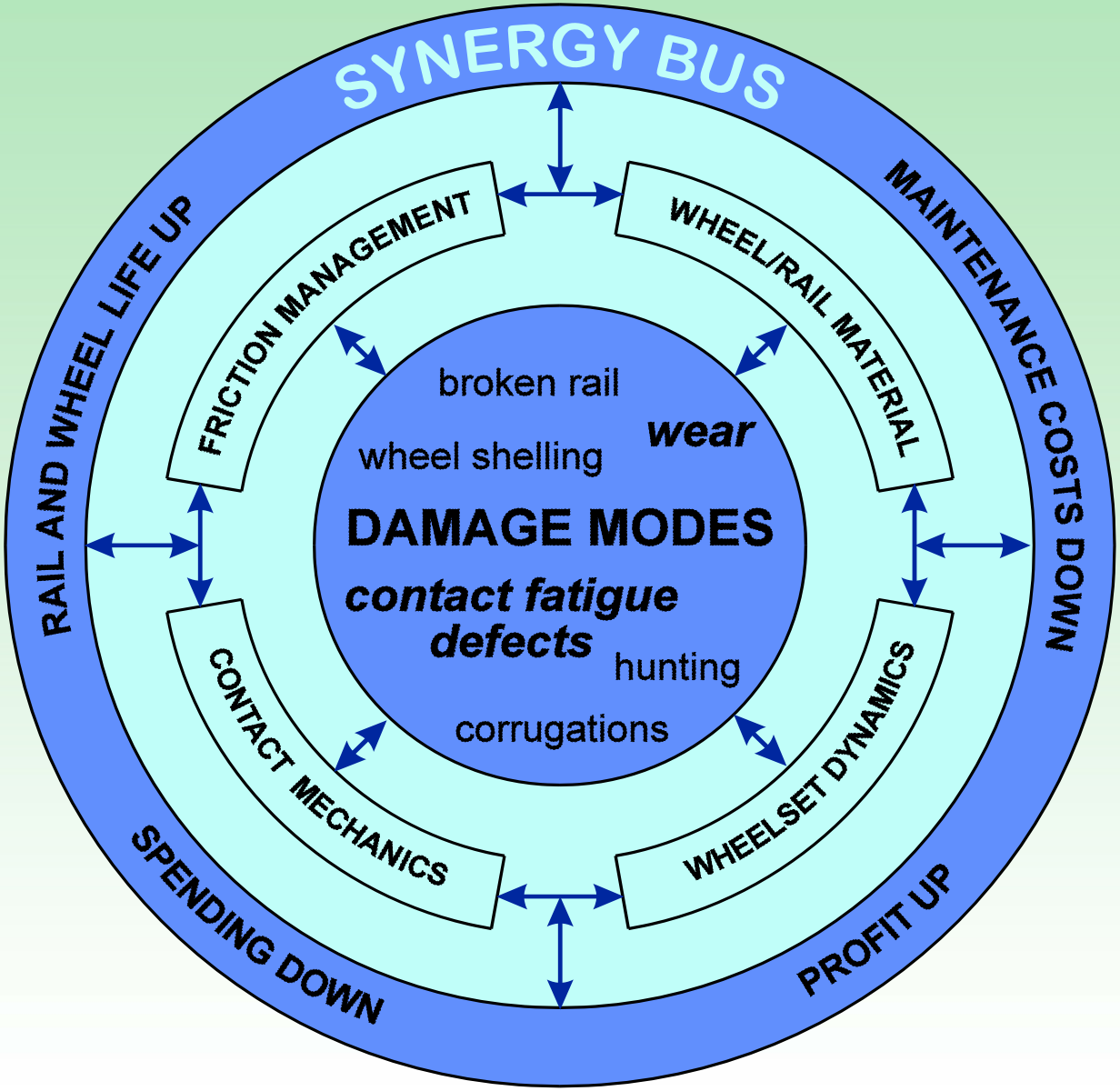
3 piece NA truck hunts at ≈ 60 MPH and λ > 0.4:

- Non-ground tangent track (TT)
- Tight gauge (profile to profile) TT

Interoperability in UK requires λ < 0.35


Wheel - Rail Conformality
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percent Occurrence
rails
wheels
Line 1
Line 2
200
225
250
275
300
325
350
375
400
425
450
475
More
Wheel/Rail Radii [mm]

Optimizing the wheel/rail interface



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- Peter Sroba
- Robert Caldwell
- Mike Roney

Please contact

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