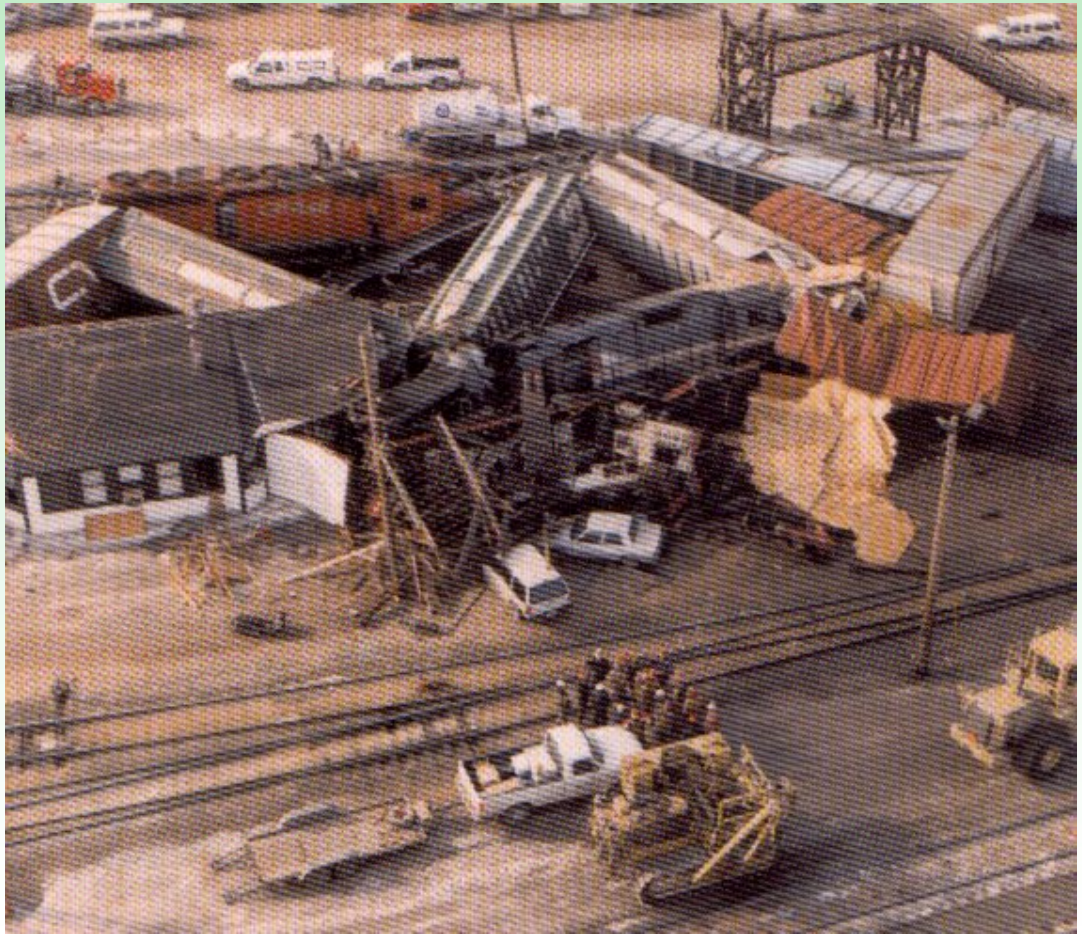
# Wheel-rail damage phenomena
# A Picture Gallery



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# Introduction

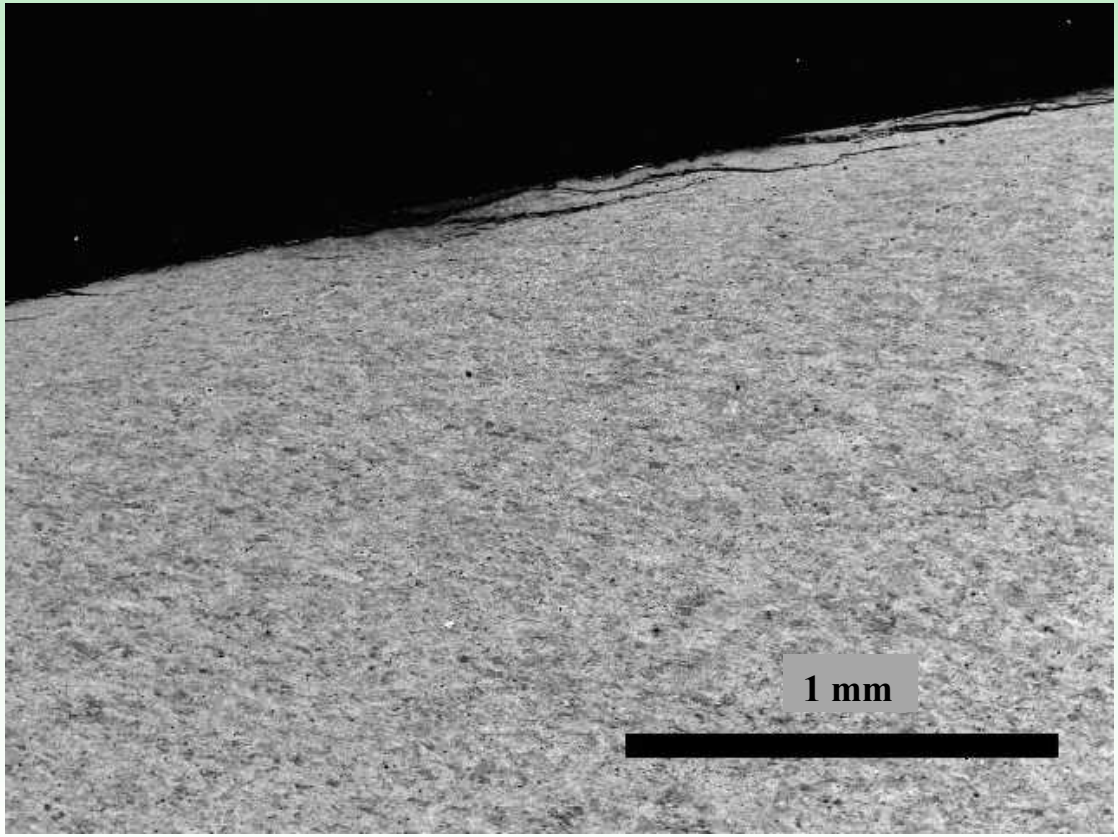
- Major reasons for deterioration and premature replacement of rail and wheels
  - wear
  - rolling contact fatigue, fatigue defects
  - plastic flow and head crushing
  - batter of joints and welds
  - corrugation
  - martensitic layers (e.g. wheel burns)

# Wear

# Abrasive Wear

# Delamination of rail steels

- Low rail 8–degree curve
  - transposed



# Adhesive Wear

# 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 | $5 \times 10^{-3} \rightarrow 5 \times 10^{-2}$ |

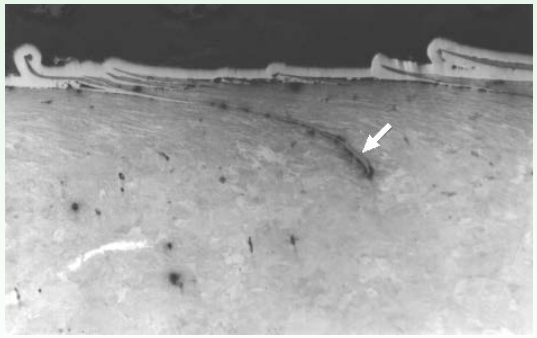
# Rolling Contact Fatigue

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**



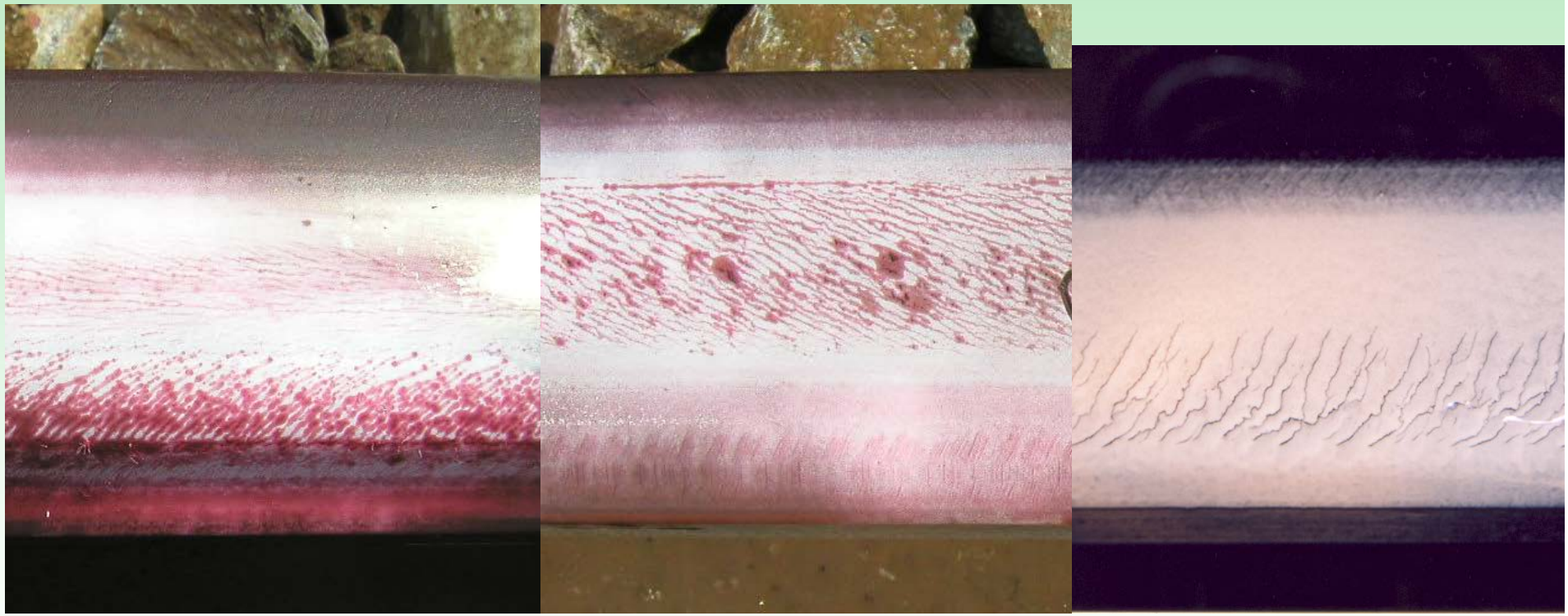
***Friction, contact stress, microstructure and hardness***

## Rail damage mechanisms

# Rolling Contact Fatigue

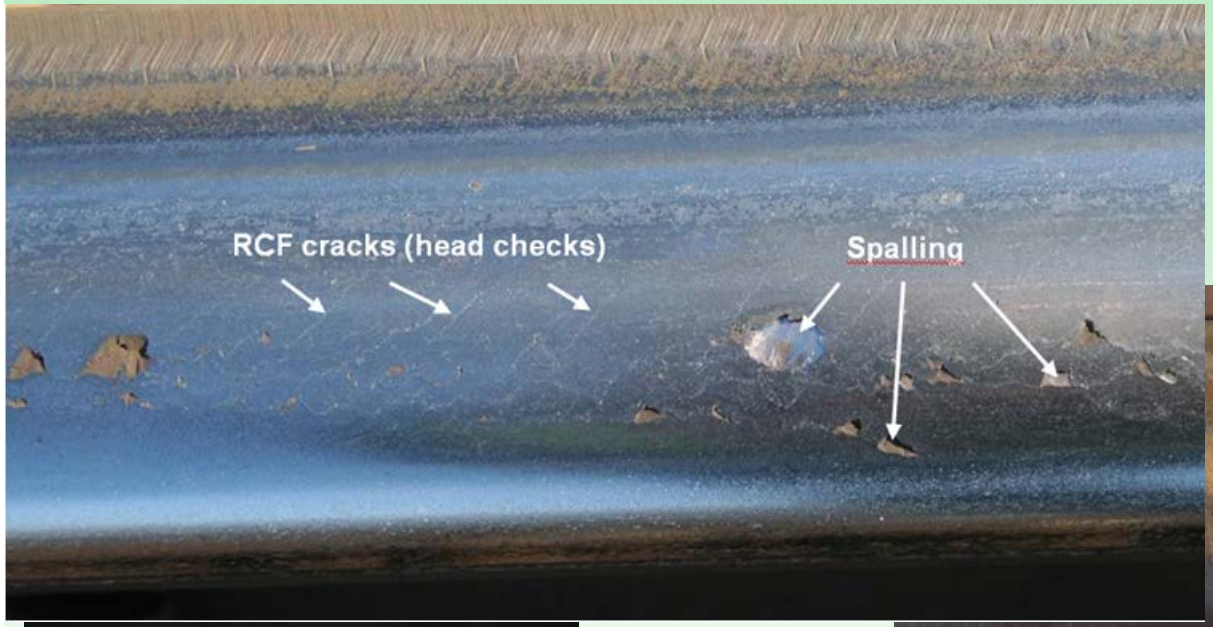
- Microscopic cracks
- Head Checks
- Shells
- Gauge Corner Collapse
  - Deep Seated Shell
- Broken Rails

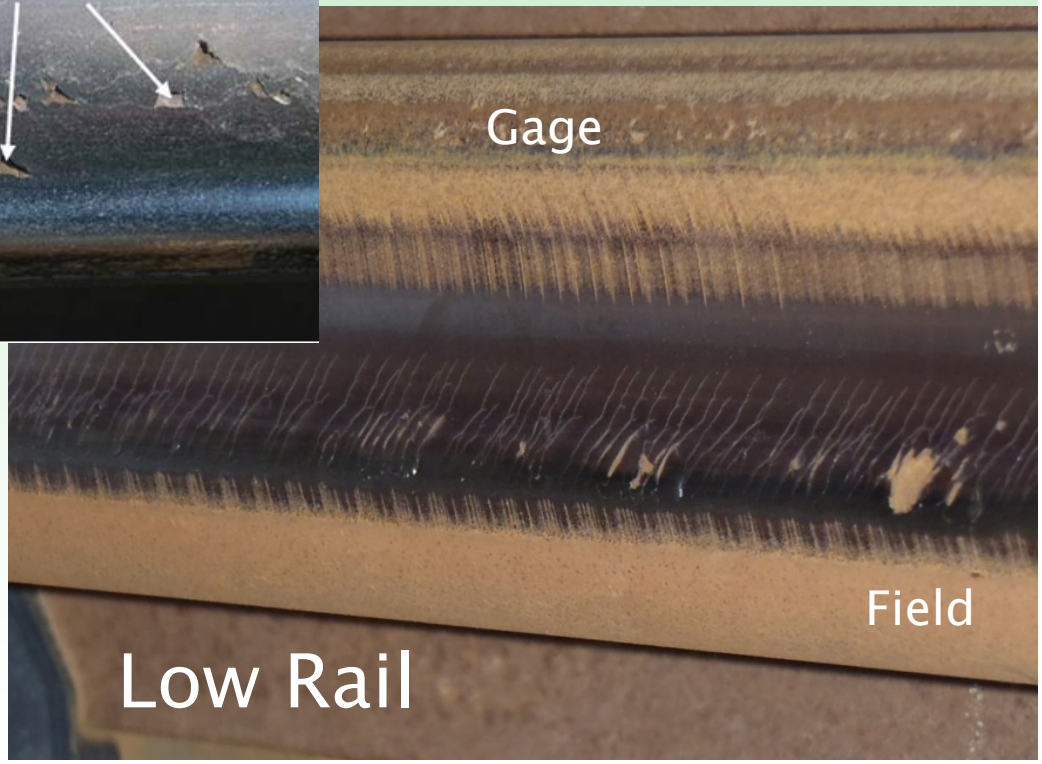
# Head Checks




2.05

# Shelling



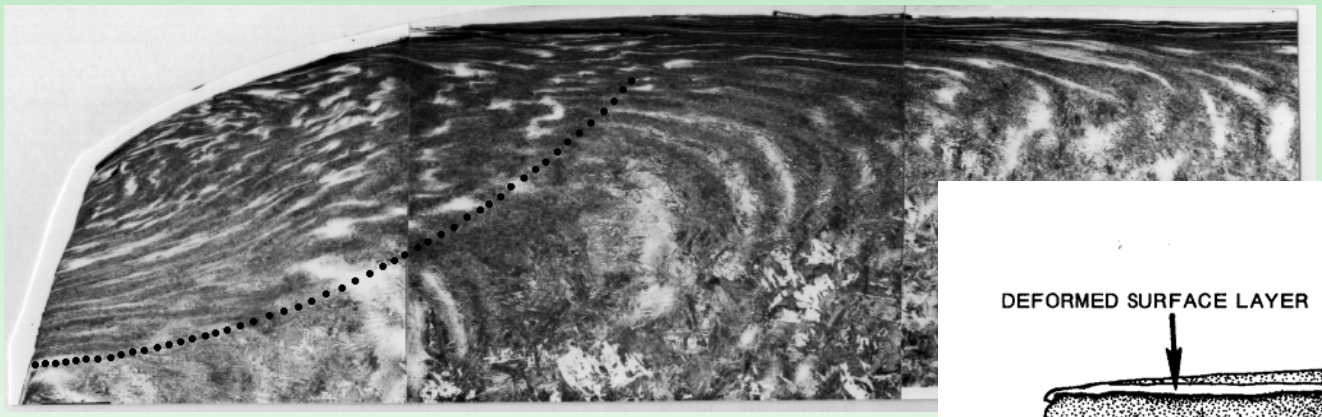



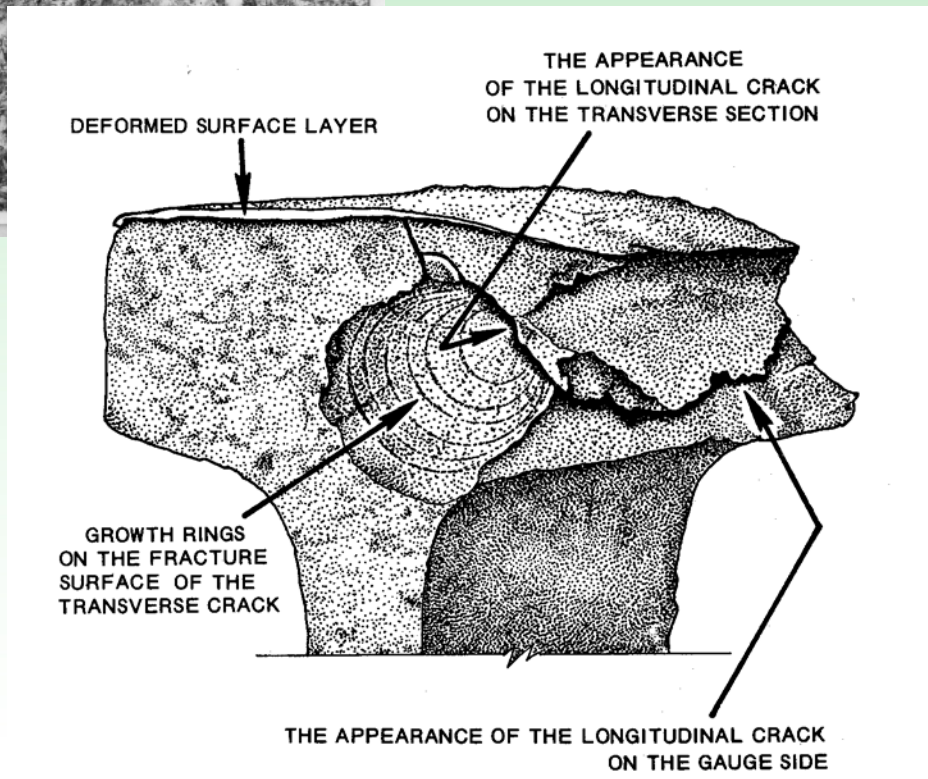
# Controlling Track Geometry Errors

- Track irregularities
- Super-elevation

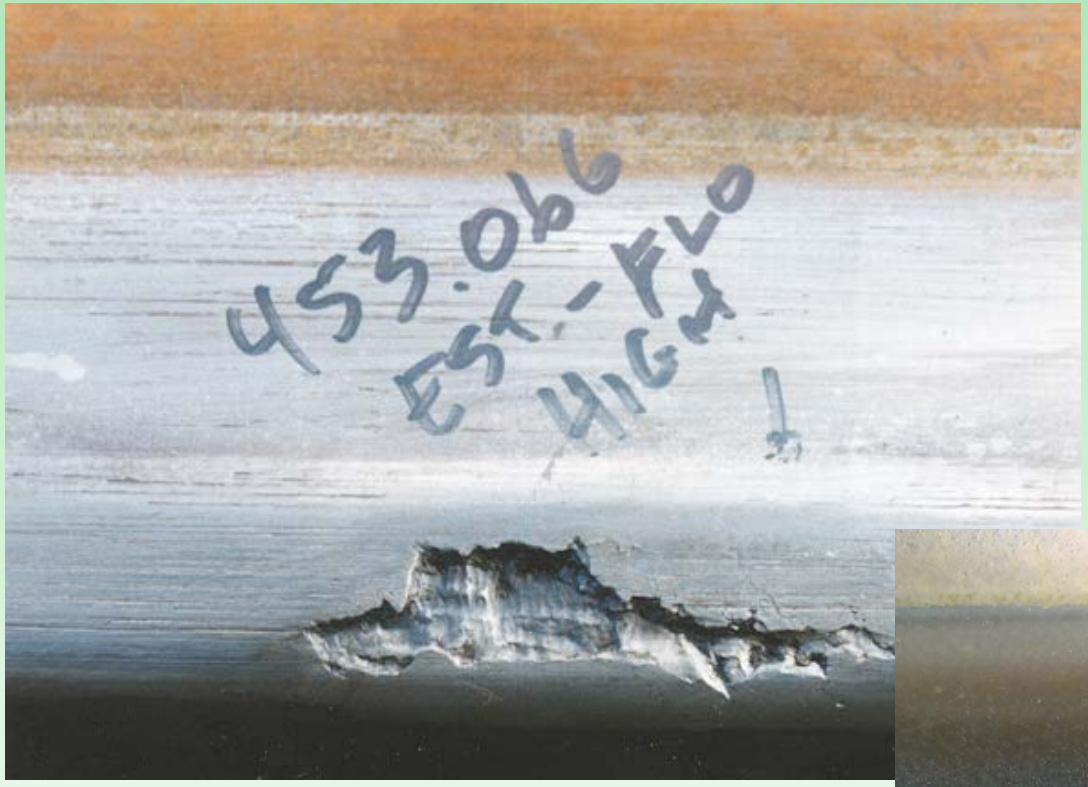

- Track Gauge
- Plate cut sleepers

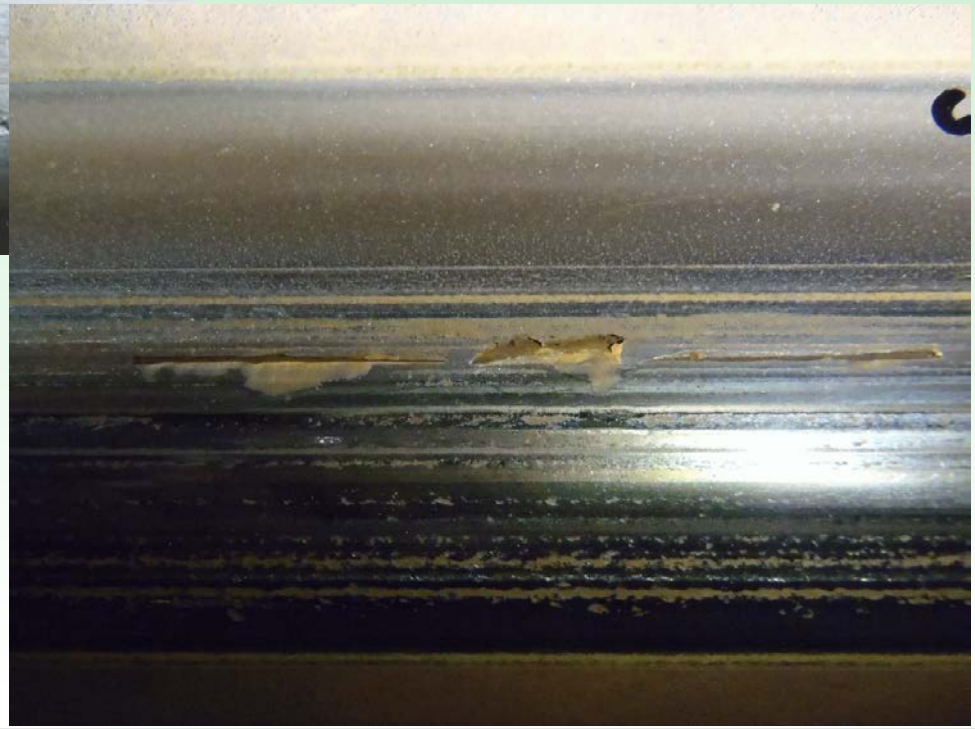
# Gauge corner collapse



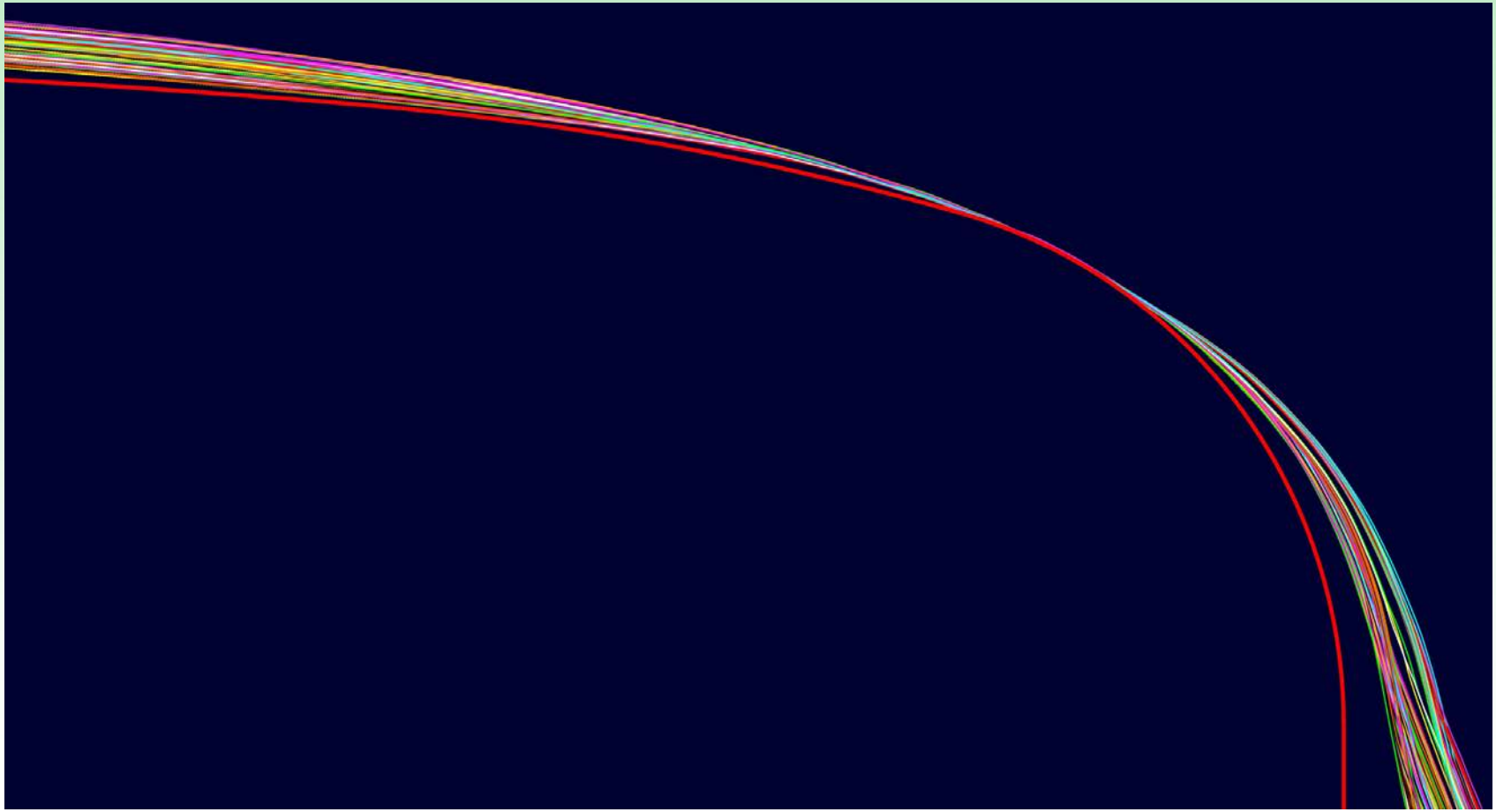


# Open Deep Seated Shells

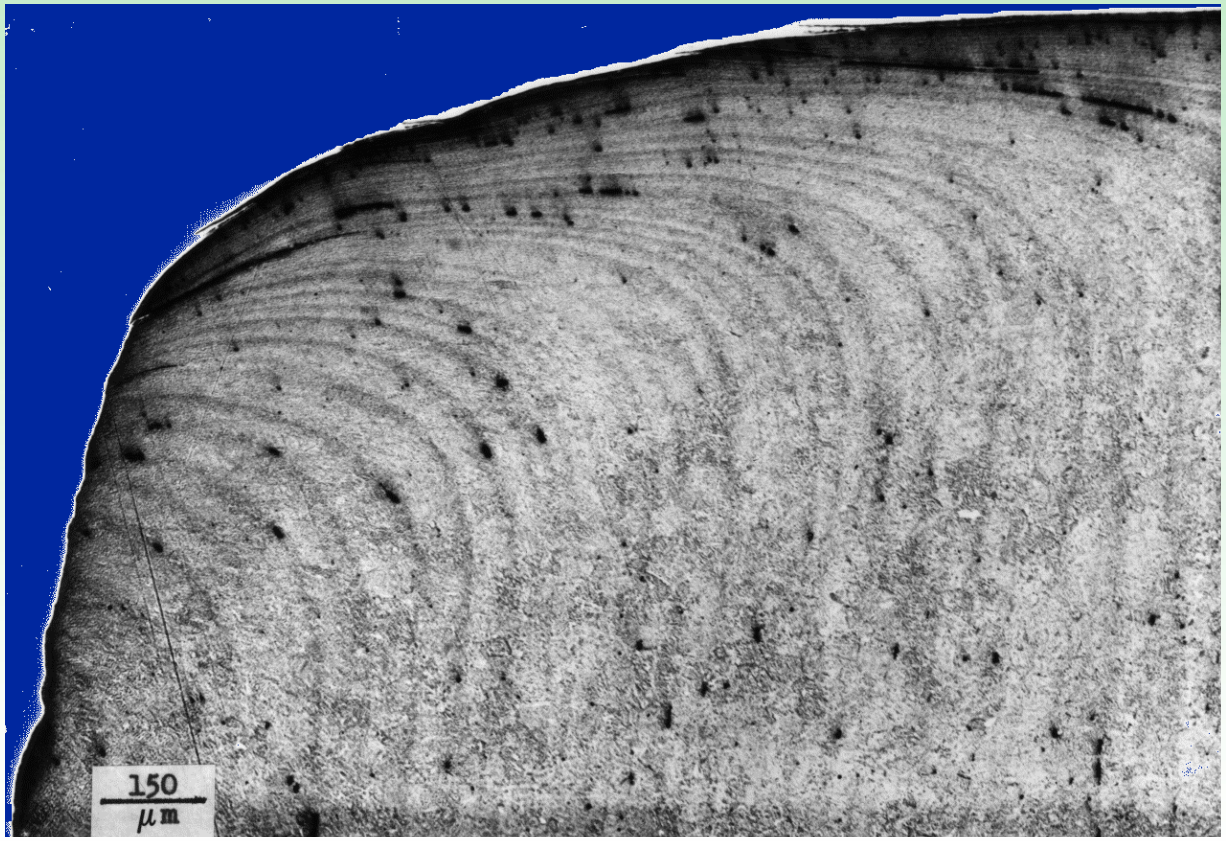

453.066
EST - FLO
HIGH



# Pummelling

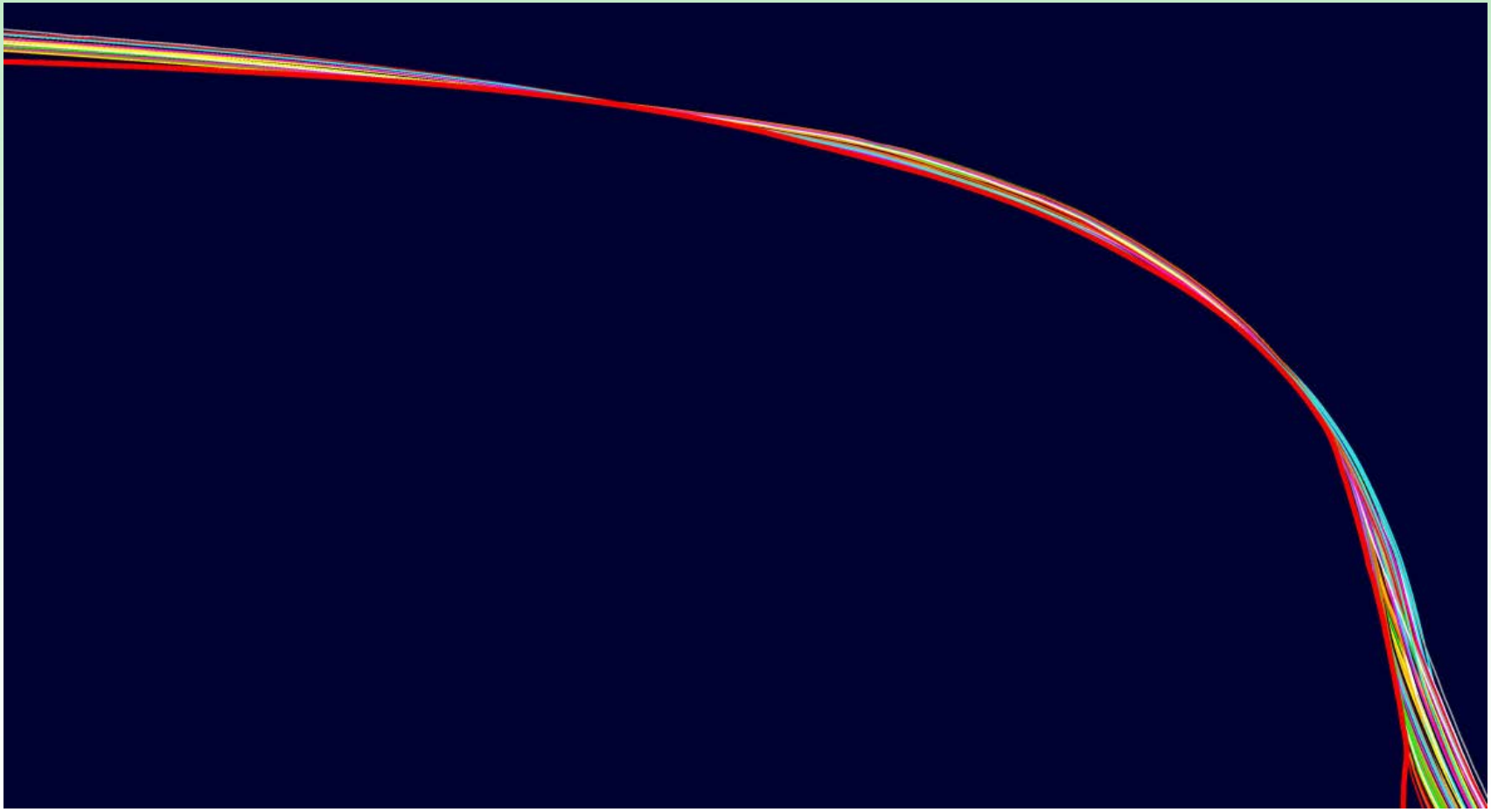


# Gauge corner relief

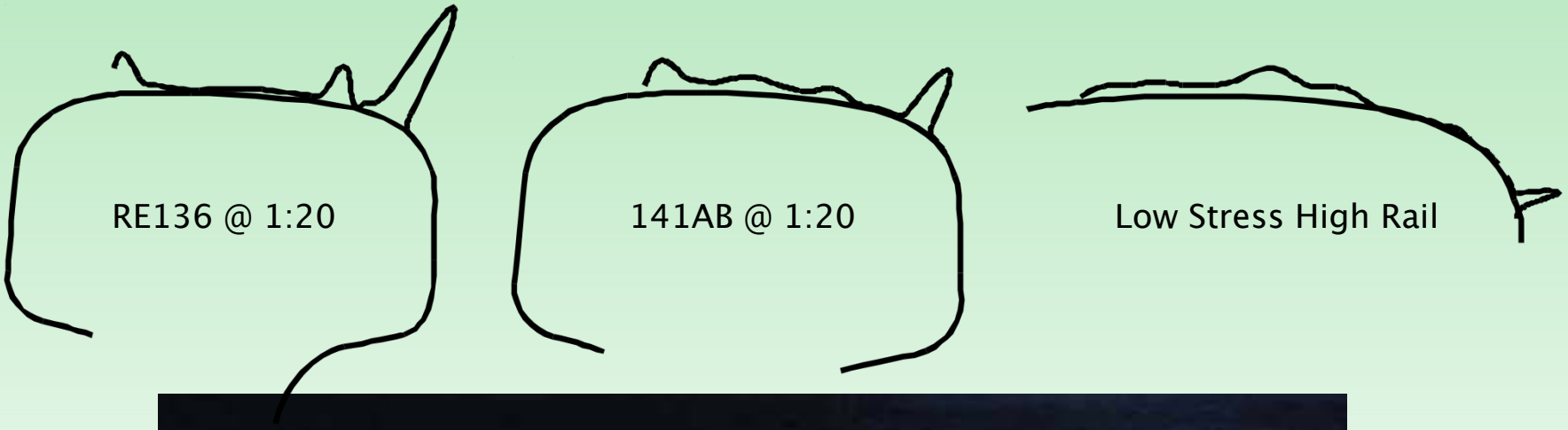


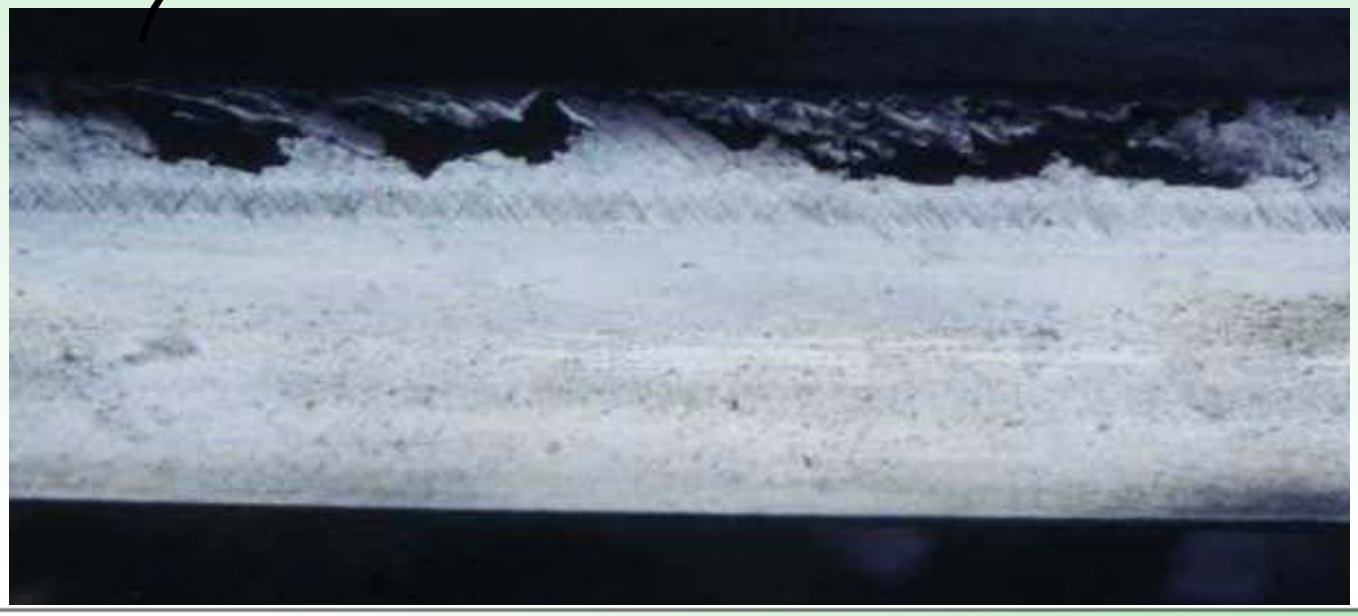

- Eliminates gauge corner collapse
- Improves Δr when combined with conformal wheel profile

# 2-pt conformal contact



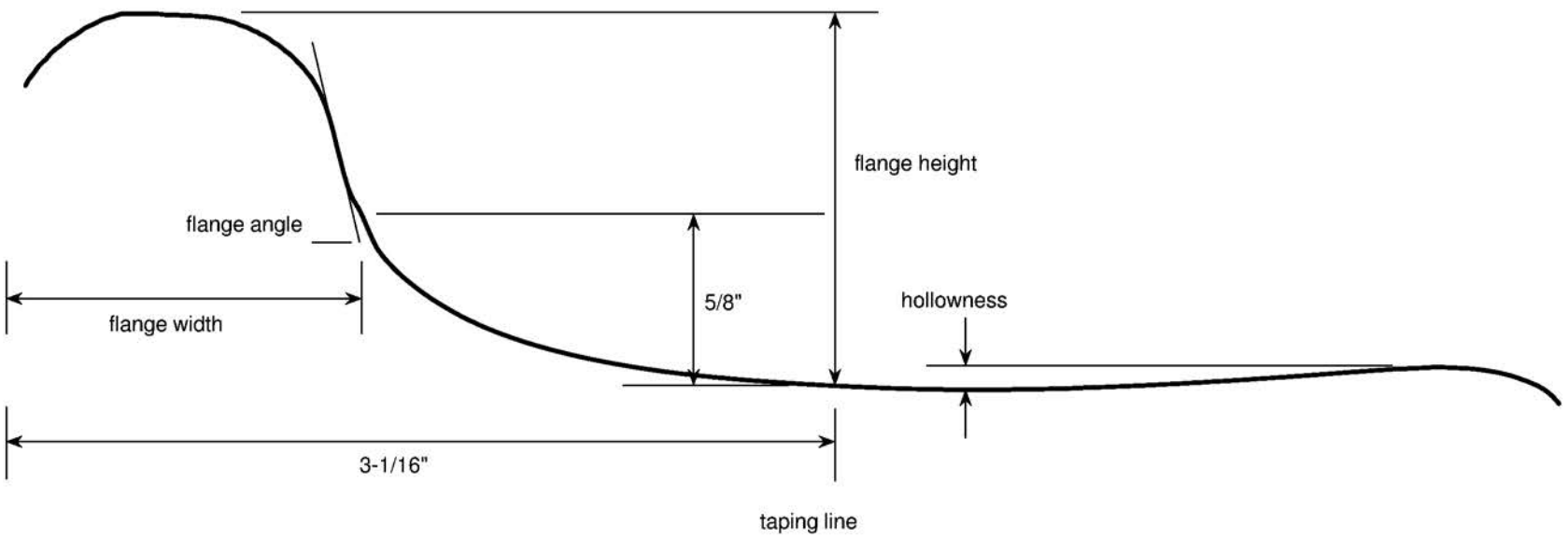
# Optimizing rail profiles



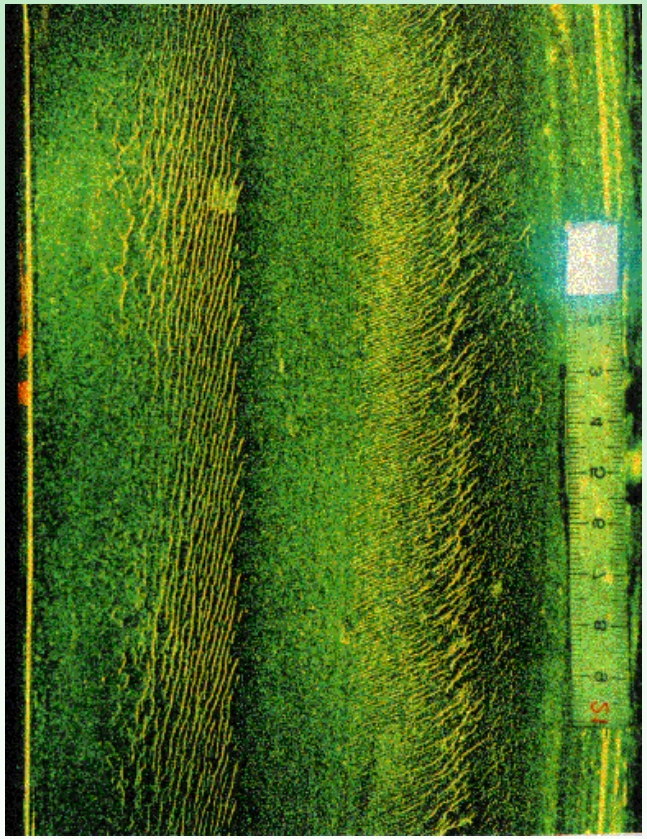



# Wheel Fatigue cracking

Ratcheting micro-cracks


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

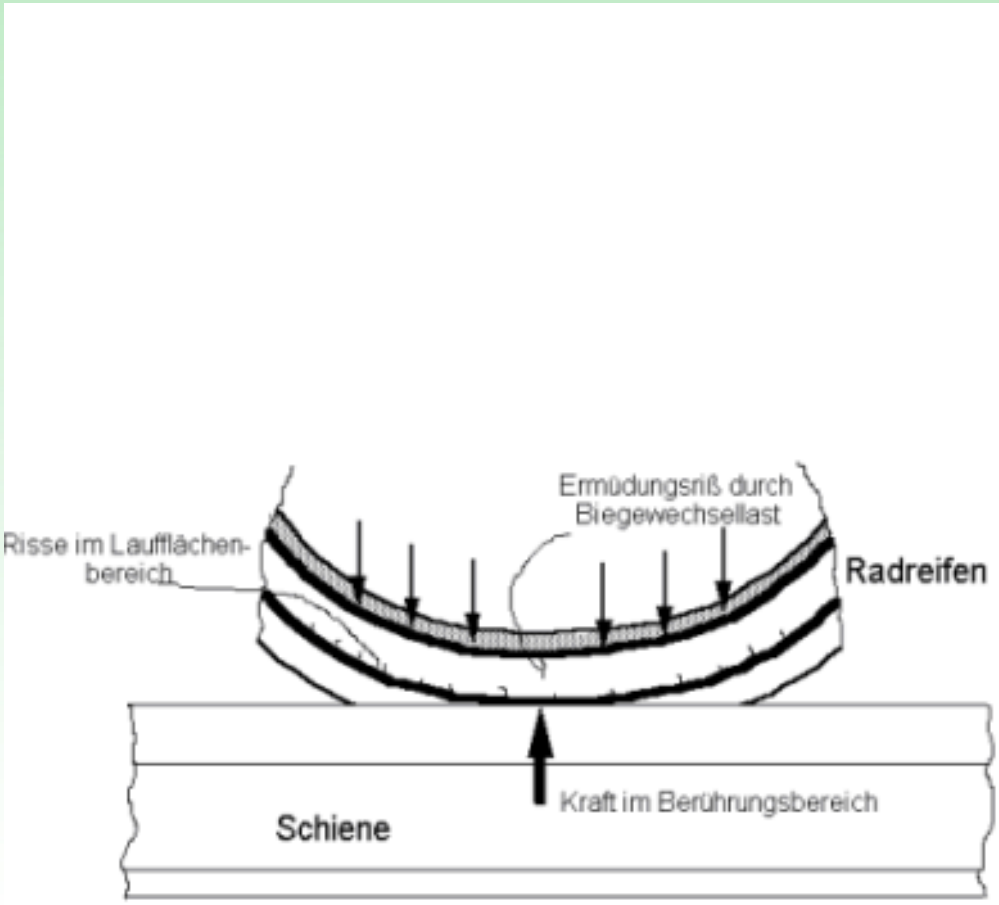
# Wheel shelling from contact fatigue cracks

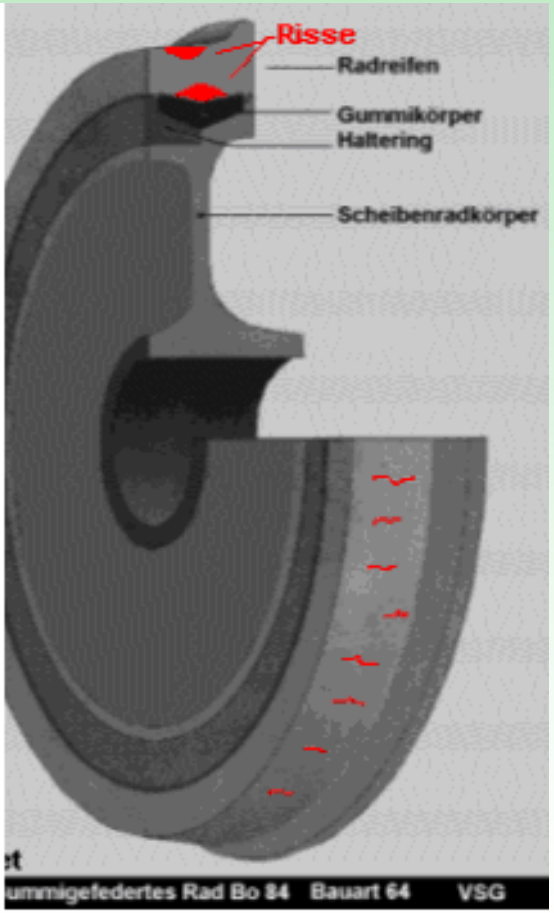


Ratcheting micro-cracks

Fully shelled wheel

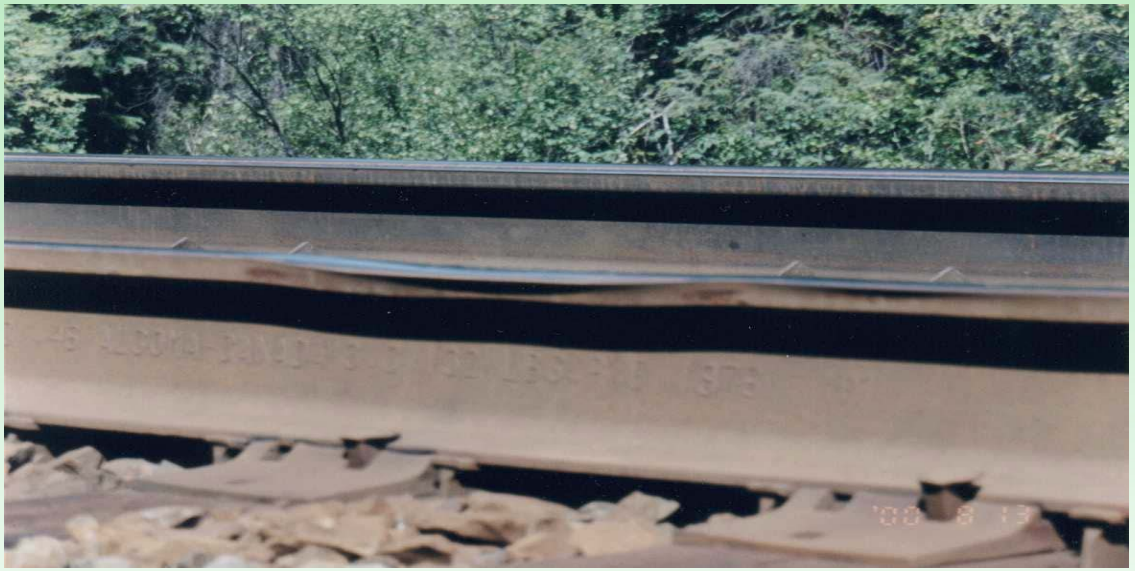
# Thermal Cracking



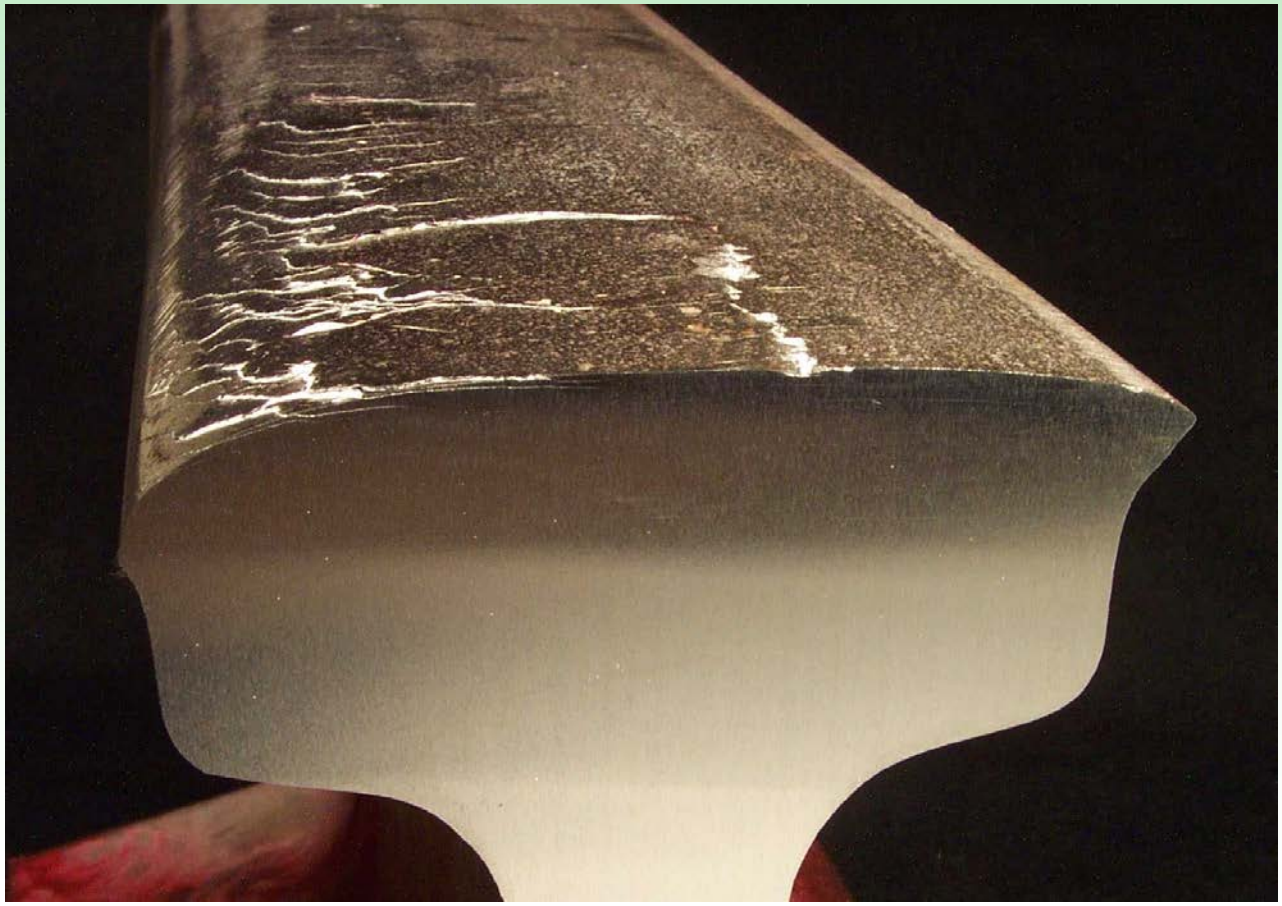



# Plastic Flow

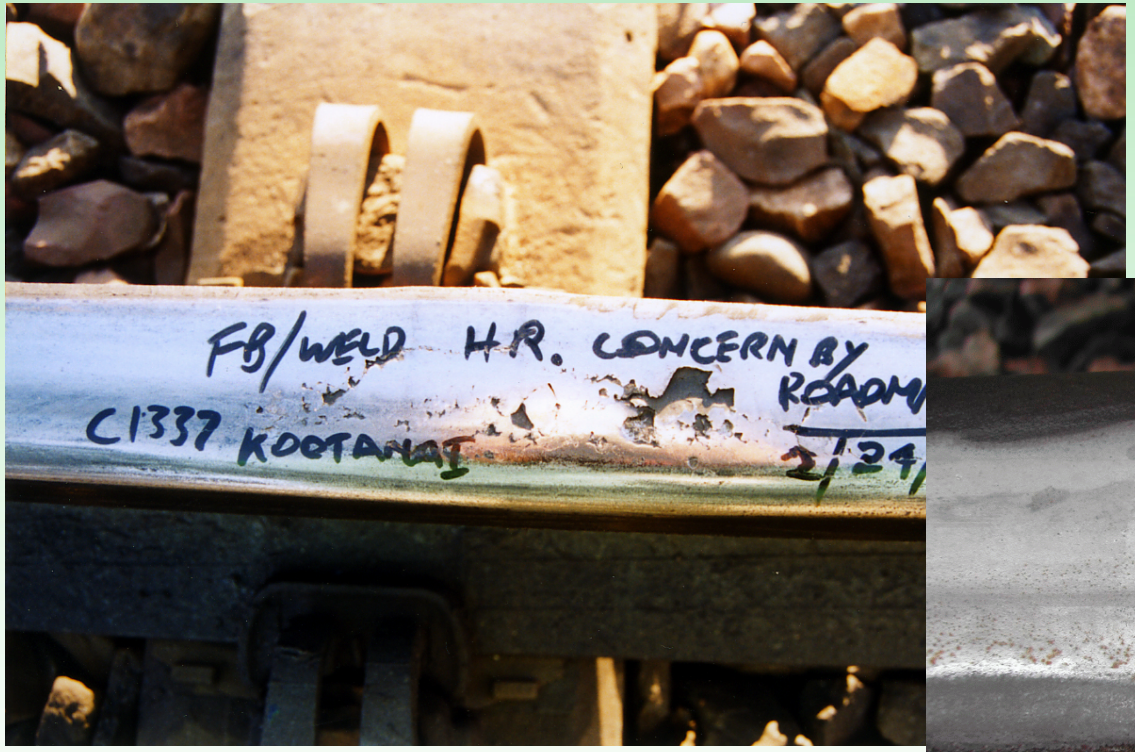
# Crushed Heads

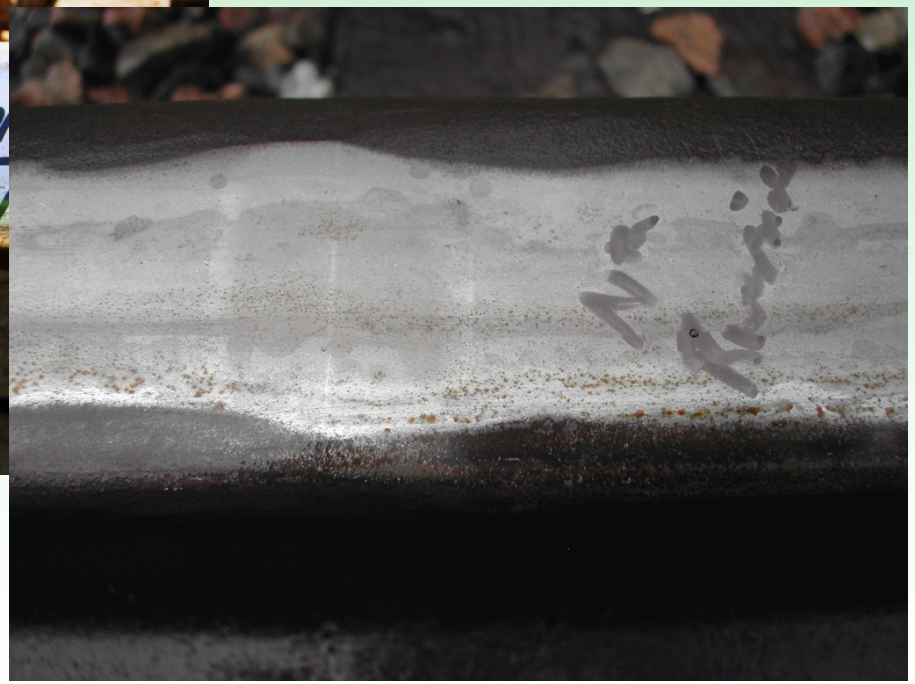


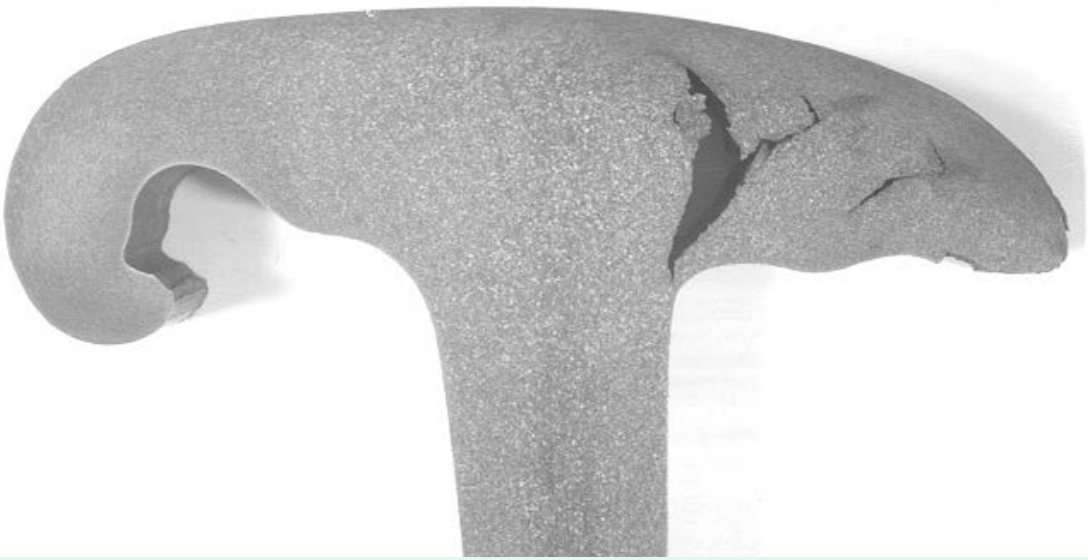
# Crushed Heads (cont'd)



# Plastic Flow – welds

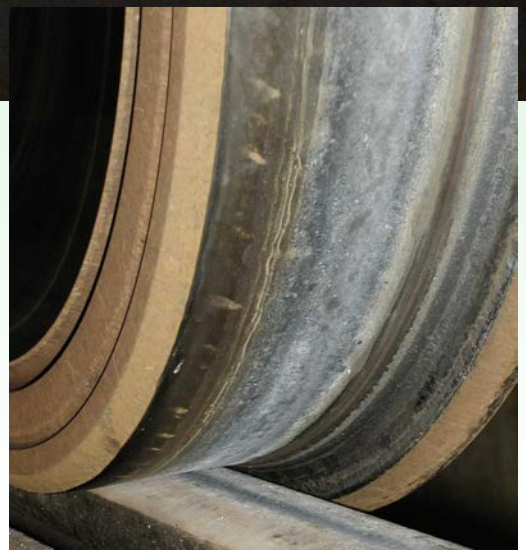





5050 13A

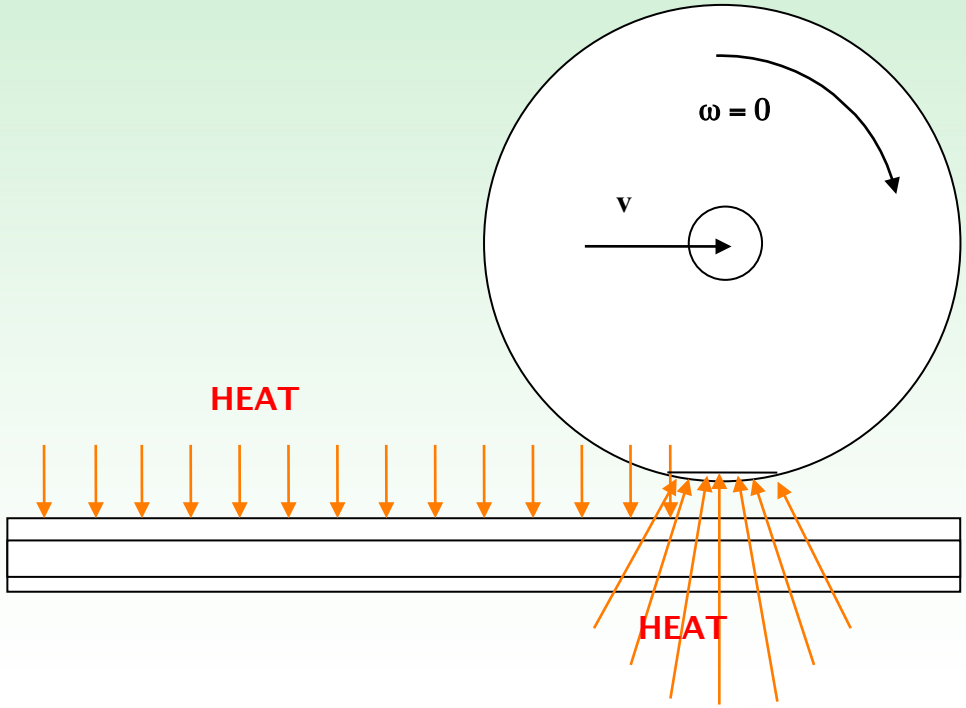
# Plastic Flow (transit)



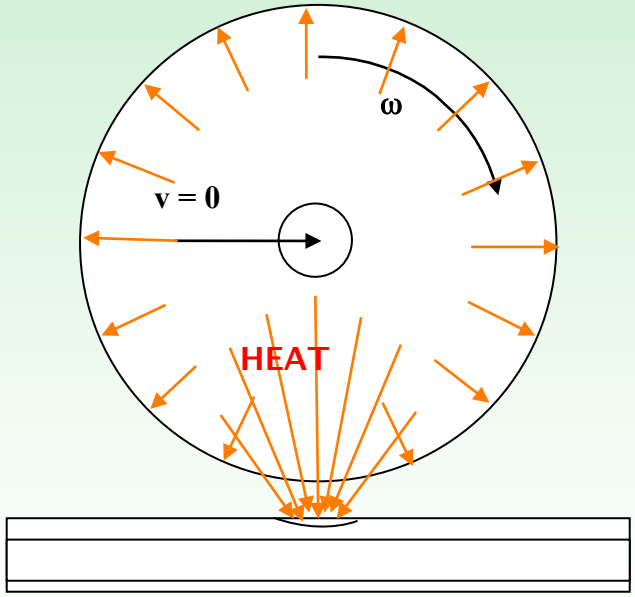
# Martensite

# Martensite and creepage

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



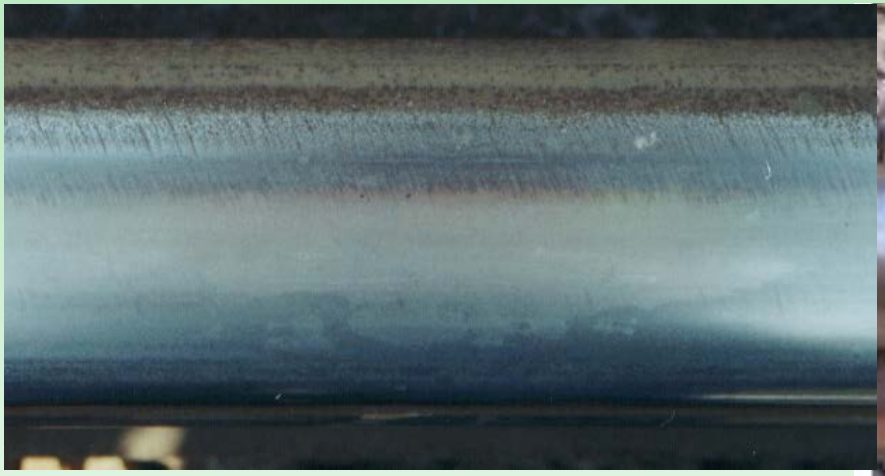

**WHEEL BURNS**
**when**
**SPINNING**
**(powered wheels,**
**positive creepage)**

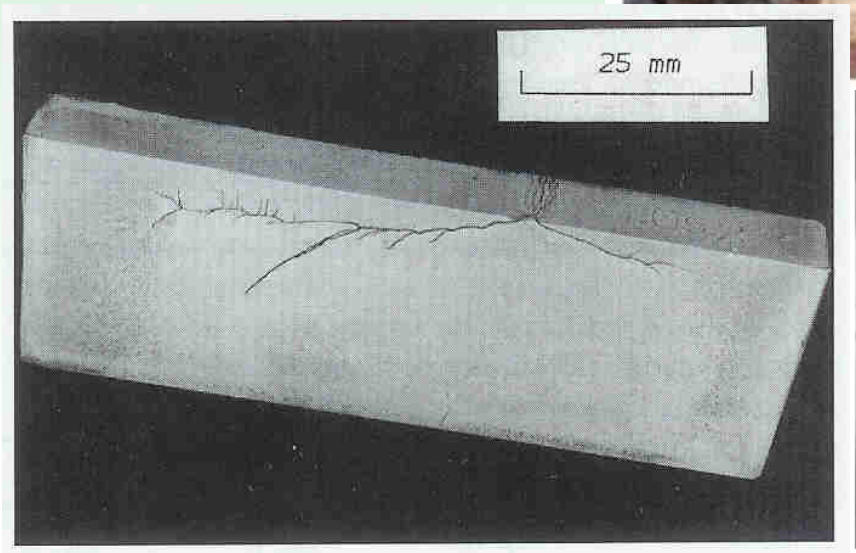


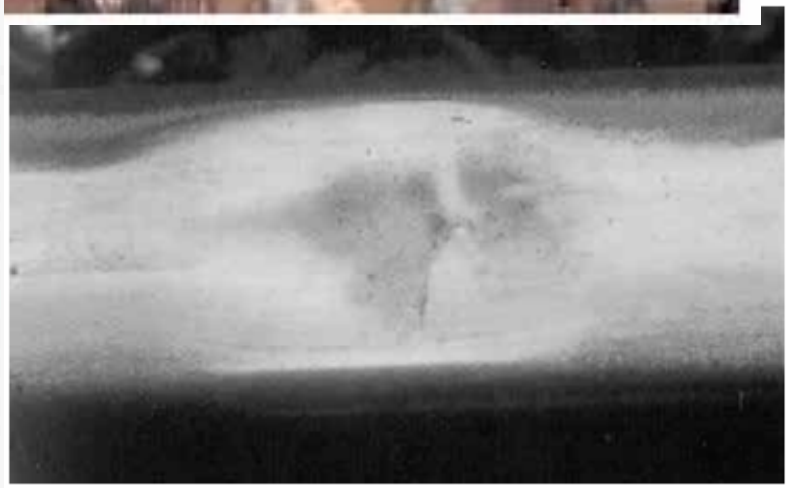
# Rail Martensite

# Spinning your wheels?

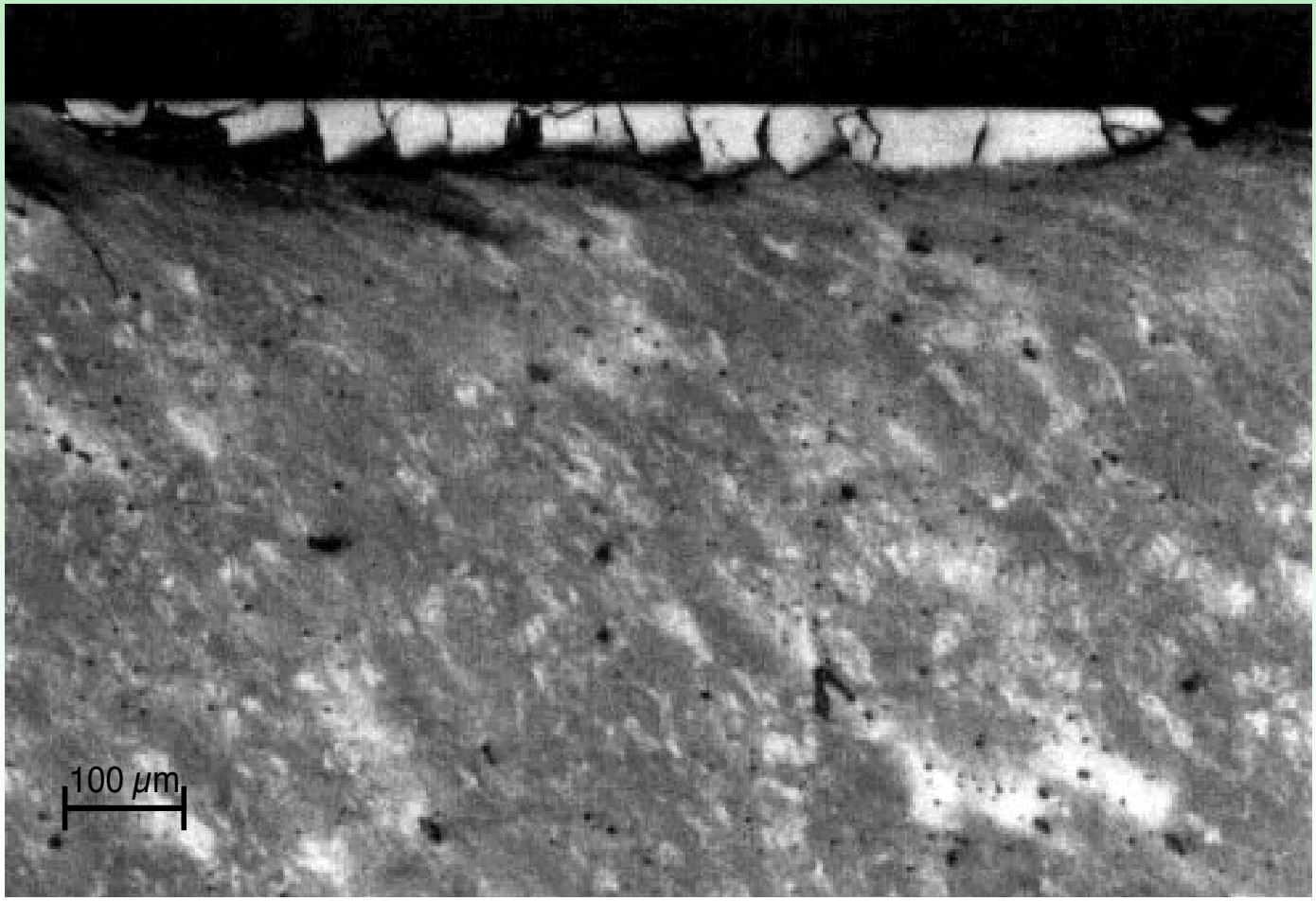
# Rail Squats





# White etching layer

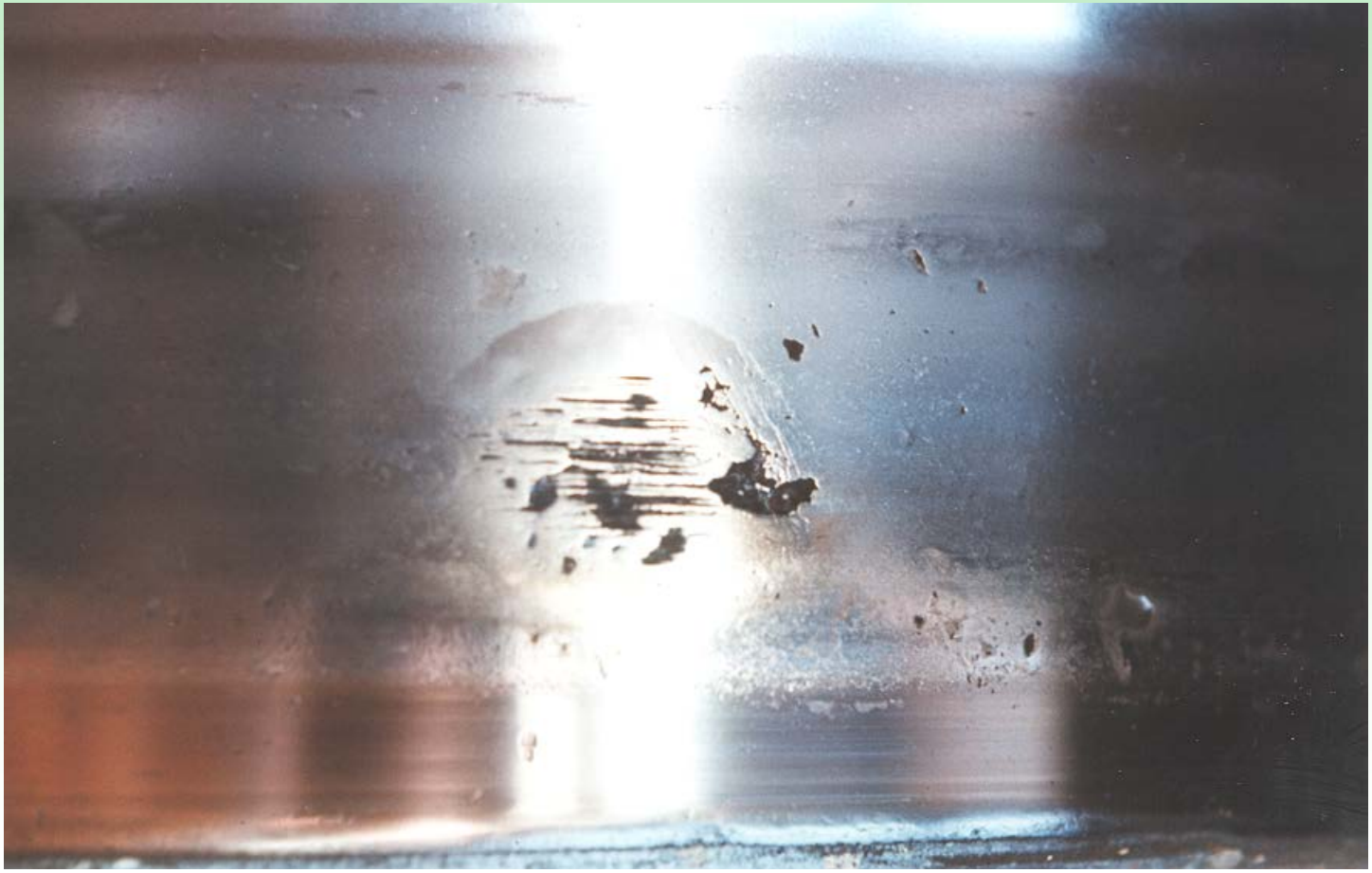


# Failure at a thin weld repair


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

# Slippery Conditions

# Wheel Slide

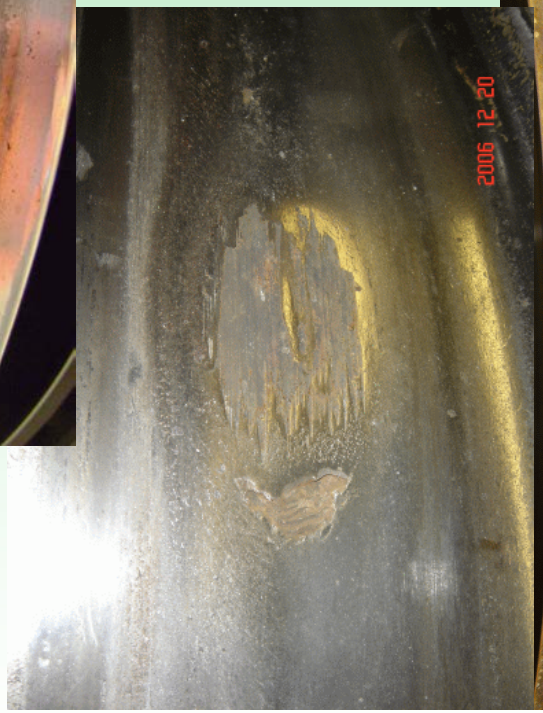


# Spalling from skid flat

Partially worn skid flat containing martensite

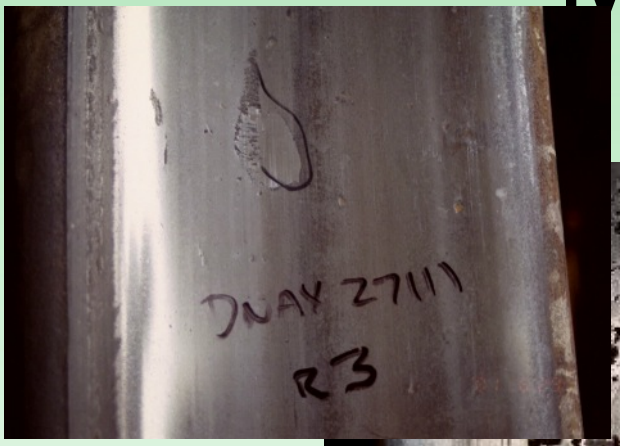
Wheel spall with martensite material cracked and drolled out

# Wheel flats

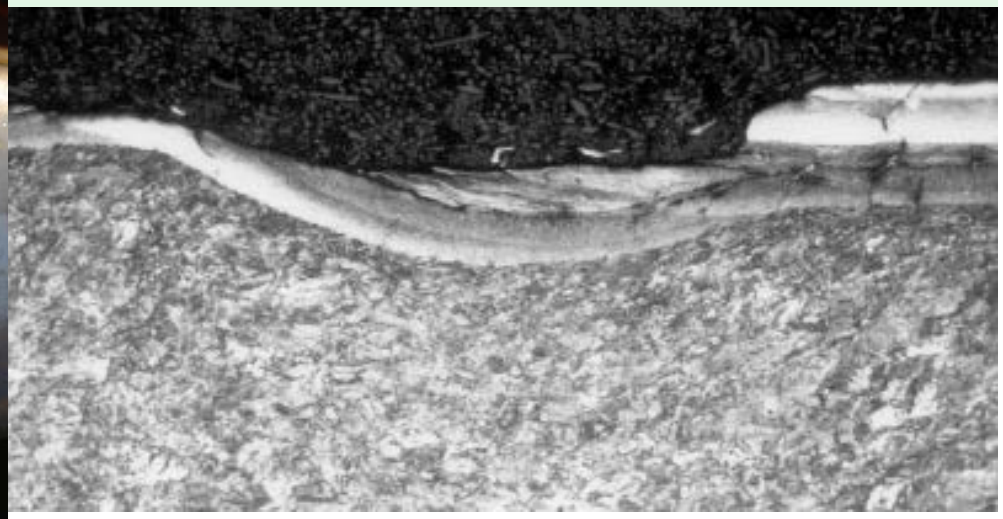

# Wheel surface damage – Martensite

freight wheels



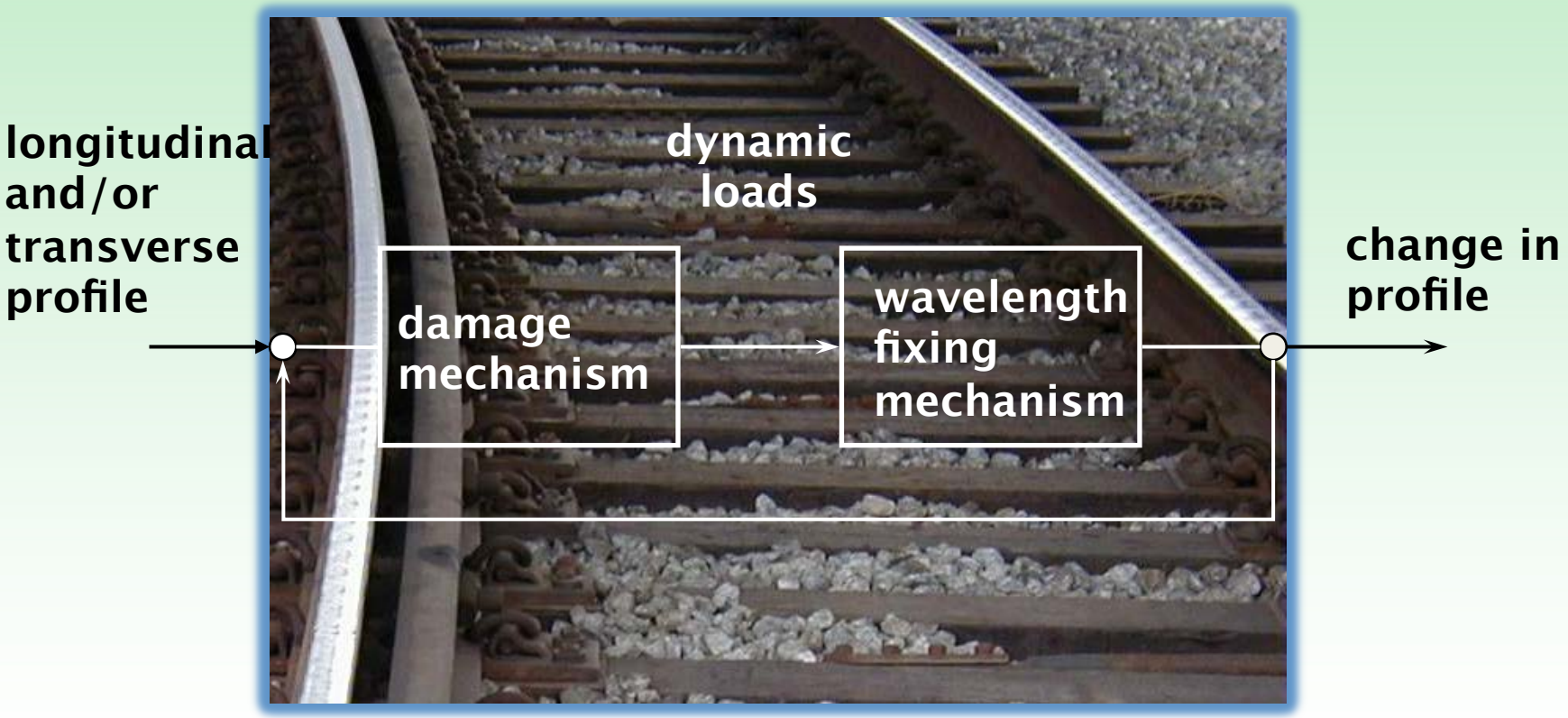

# Indentations and Martensite

- 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

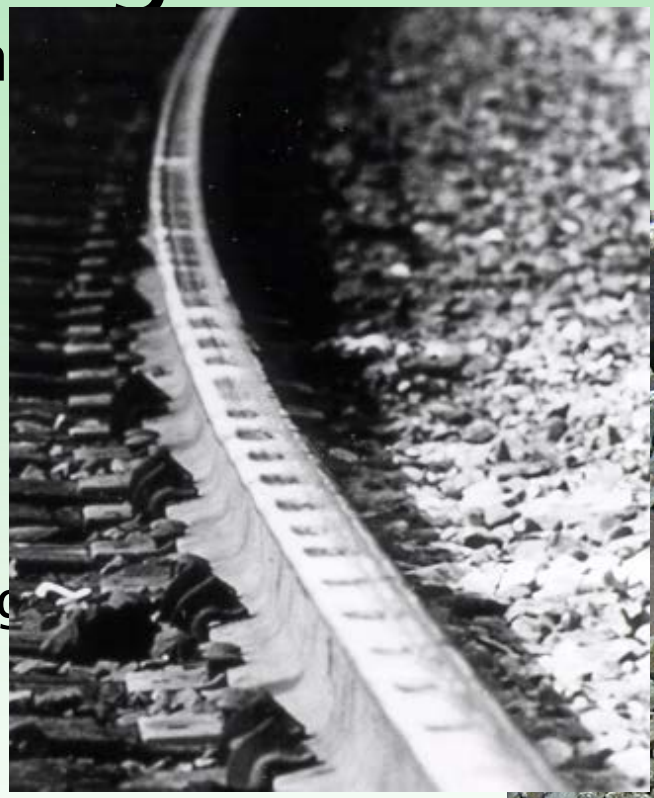
# Rail Corrugation

# Components of a General Corrugation Mechanism



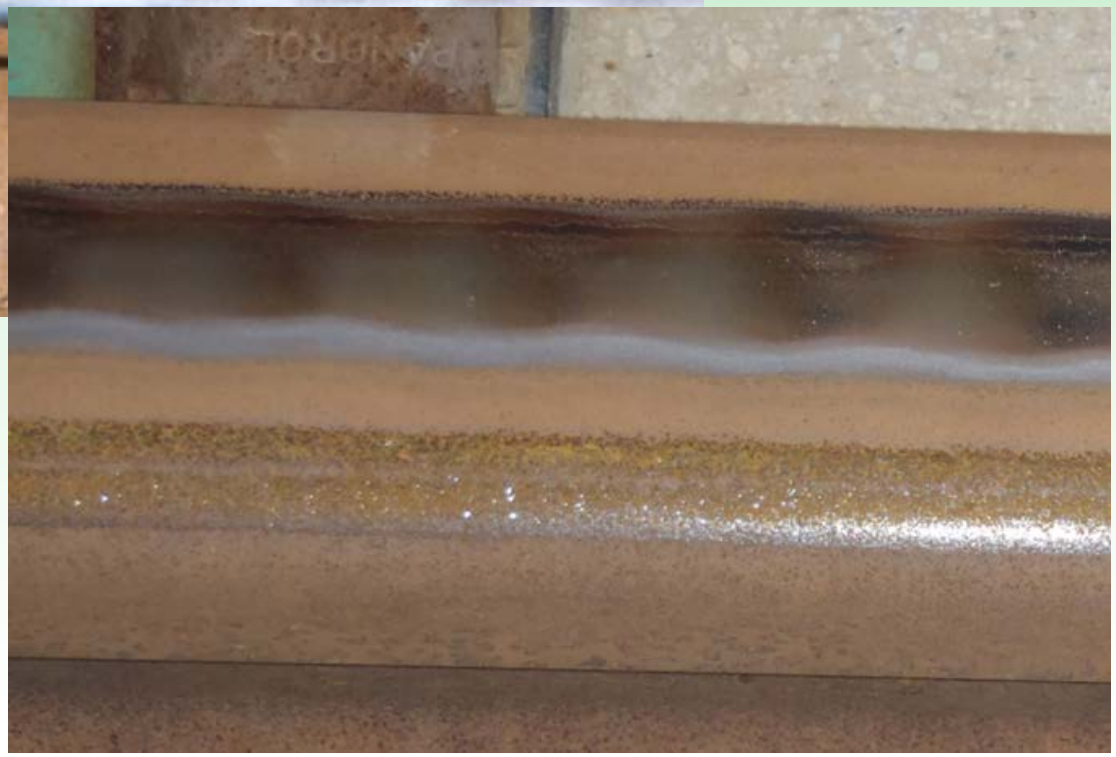
# Corrugations

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



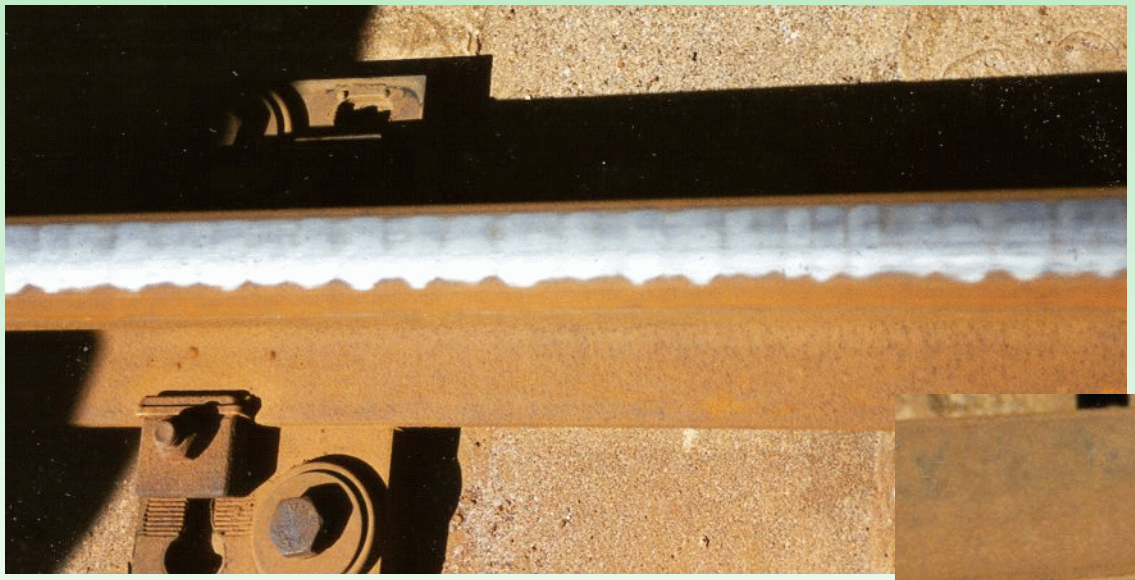
# Corrugations (cont'd)

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



# Transit Corrugations

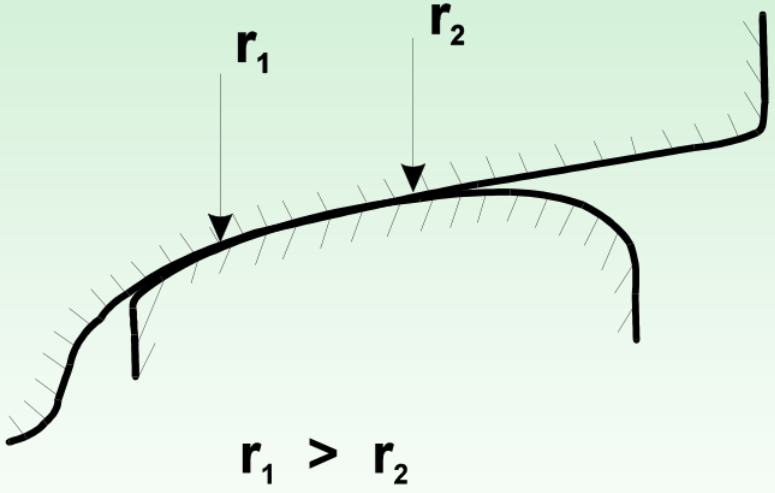
# Different wavelengths, same railroad

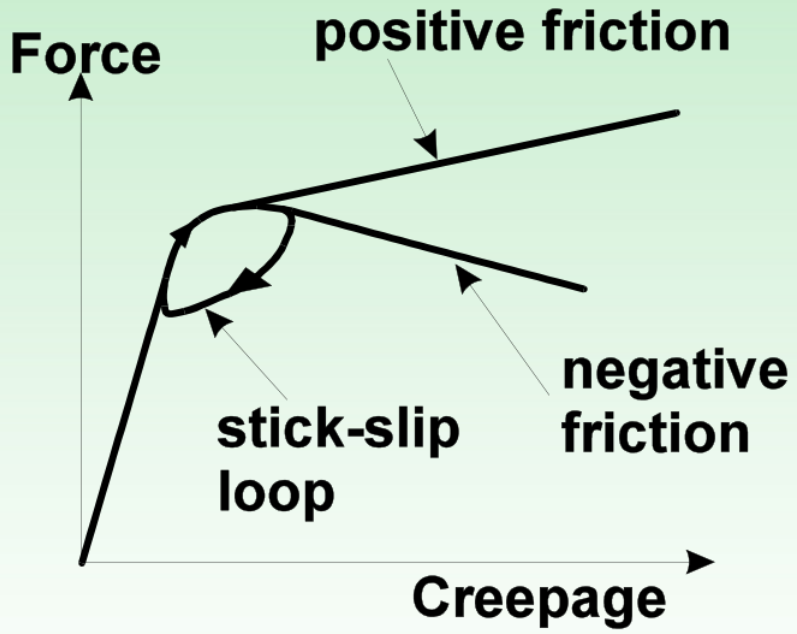


# Wavelength fixing mechanism

- 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

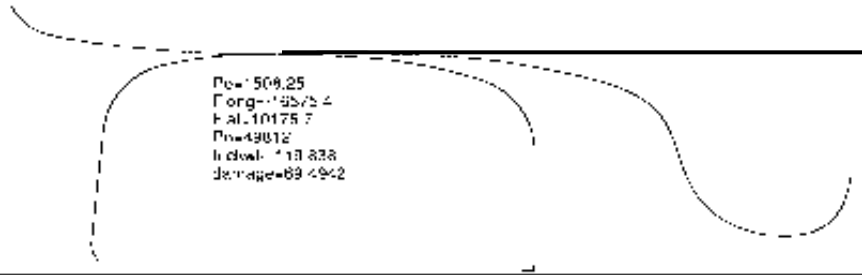


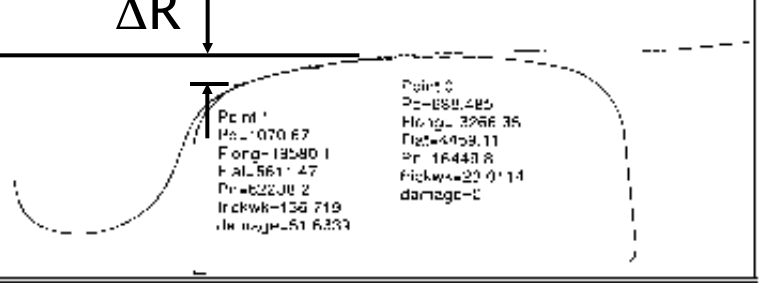
# Hunting

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

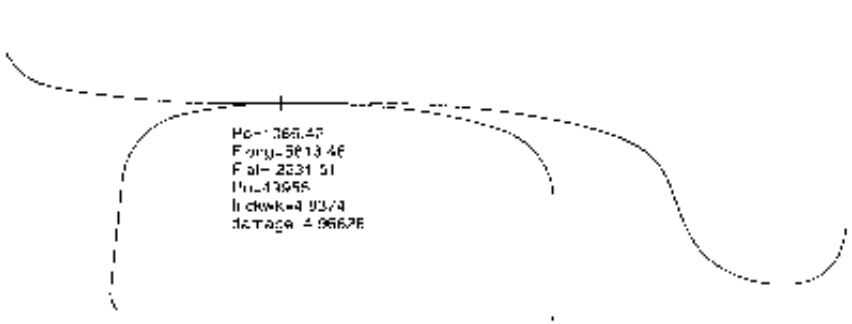
Leading Axle - Left Rail 11062001-1781.whl.tbrbs113a 20.prd



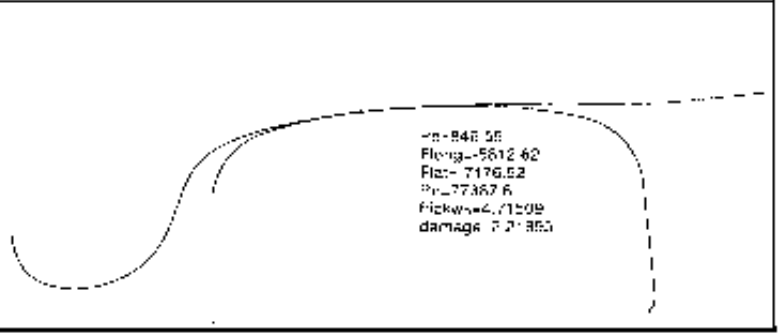
Leading Axle - Right Rail 11062001-1771.whl.tbrbs113a 20.prd




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 |
| al. force : | -6738.45 |
| moment : | -24465.6 |

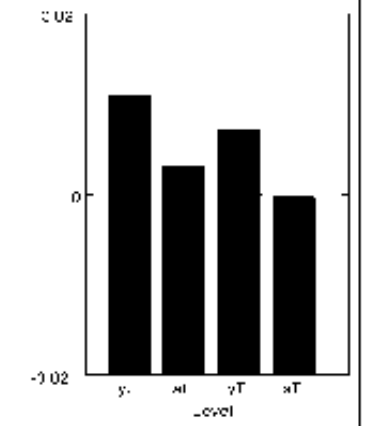
**Suspension forces**

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

**Input parameters**

| | |
|---|---|
| suspension type : | 0 |
| L wheel load R : | 78502.5 |
| L wheel load L : | 49930.3 |
| T wheel load R : | 78502.5 |
| T wheel load L : | 49930.3 |
| car speed | 136.0 |
| cant deficiency : | 6.27 |
| total side load | 26372.2 |
| track curvature | 700.0 |
| track gage | 1.4435 |
| roll right top | 0.5 |
| roll right gage | 0.5 |
| roll left top | 0.5 |
| roll left gage | 0.5 |

**Position**




**Trailing axle**

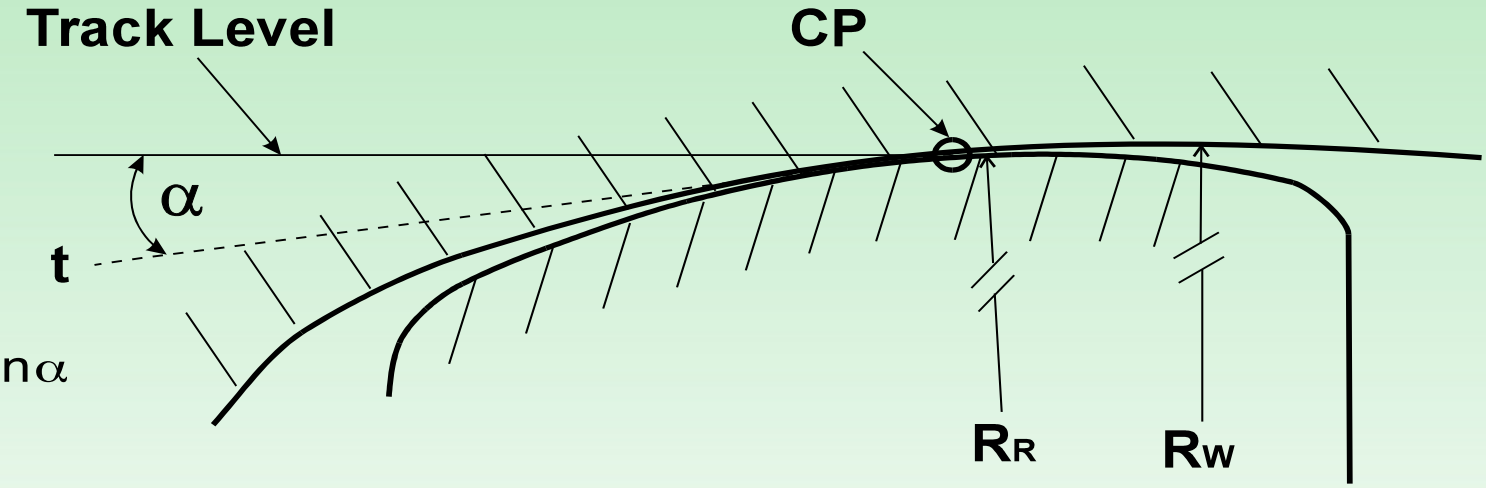
| | |
|---|---|
| y lat : | 0.0072563 |
| aoa : | 0.000210423 |
| al. force : | -19608.5 |
| moment : | 8774.35 |

**Summary**

| | |
|---|---|
| net lateral : | 25.1805 |
| net moment : | 0.057[illegible]173 |
| balance err : | 0 |
| total err : | 25.1805 |

E.E.Mage

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

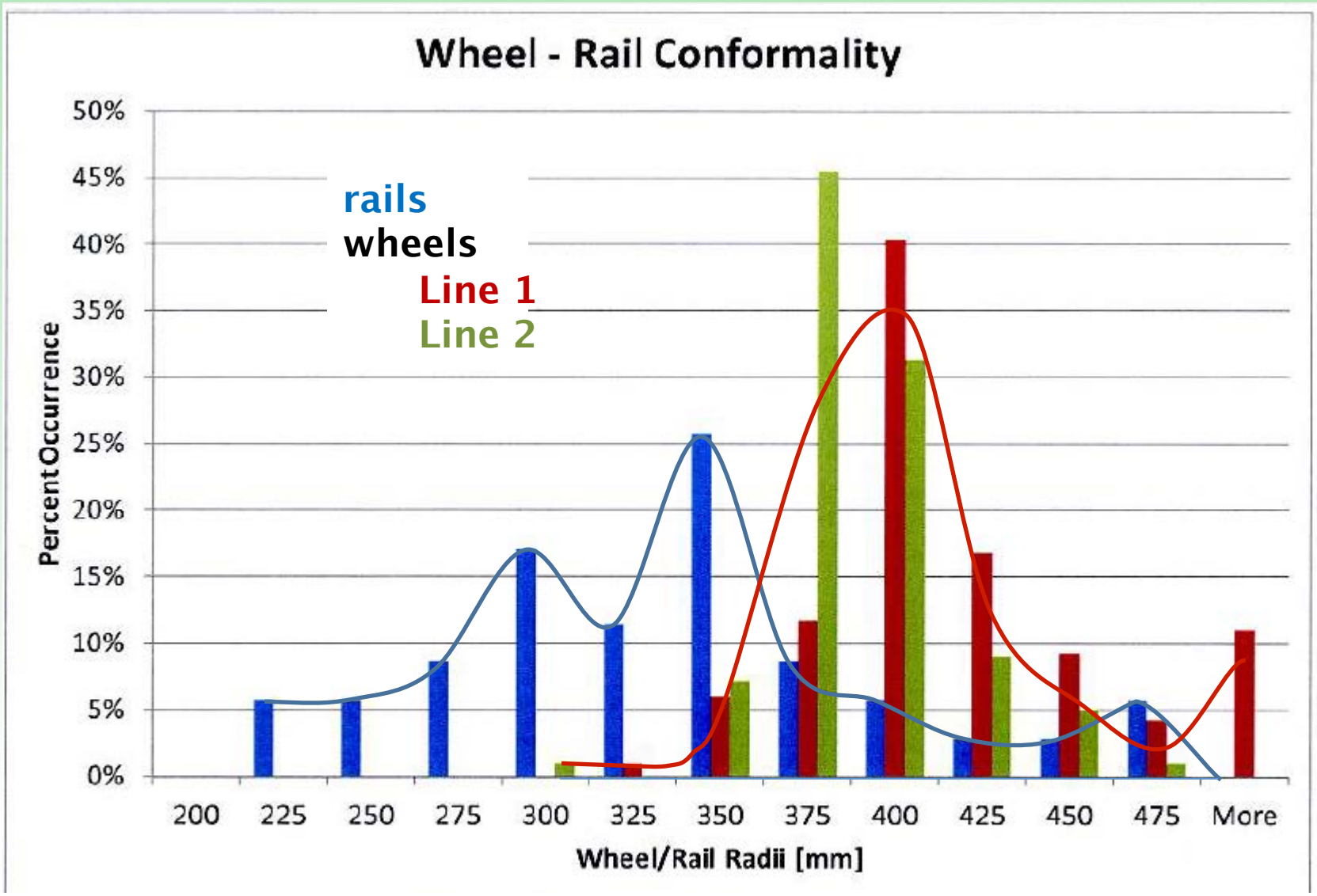



$$\lambda = \frac{R_W}{R_W - R_R} \sin\alpha$$

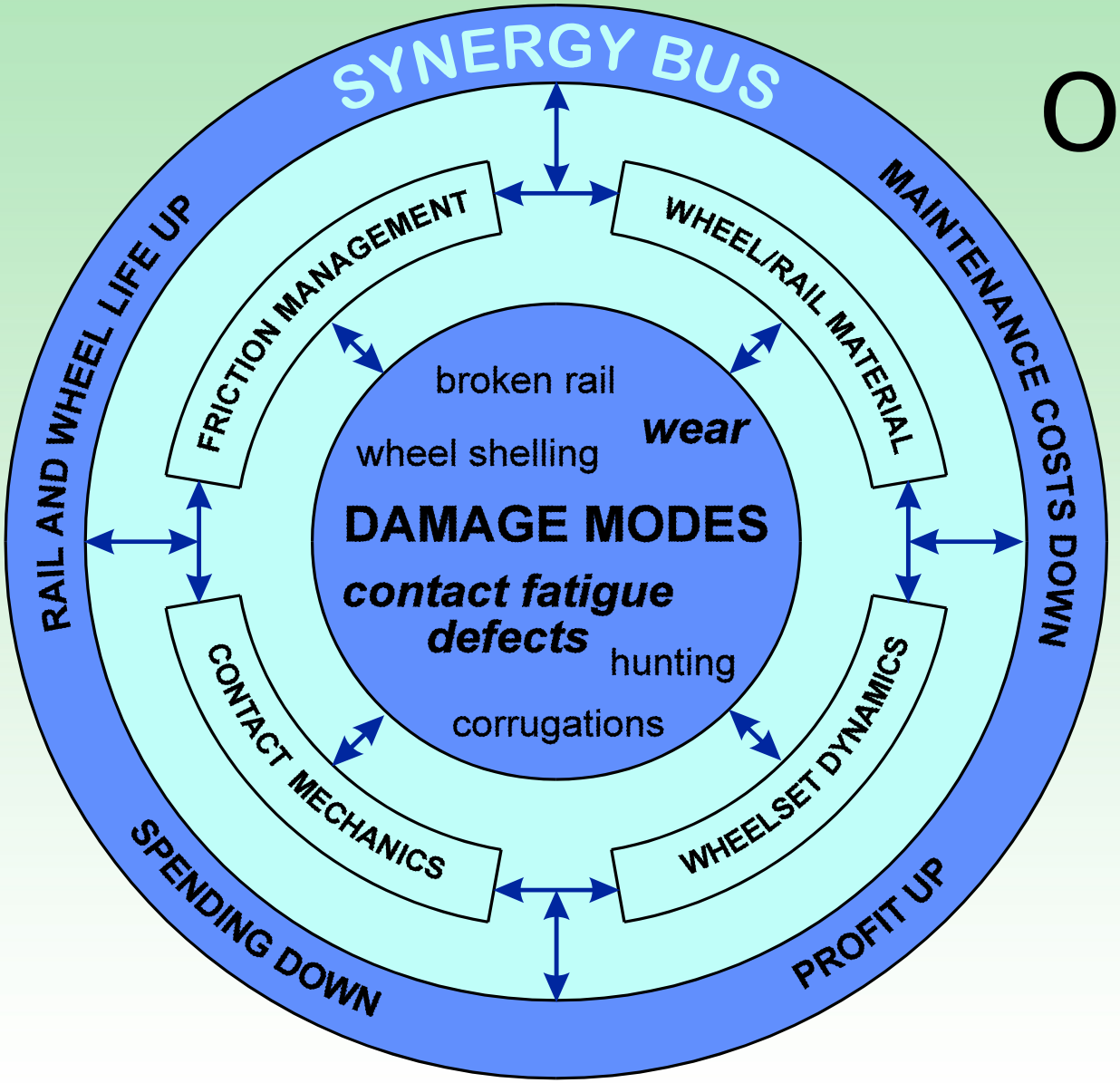
3 piece NA truck hunts at ≈ 60 MPH and λ > 0.4:

- 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]

# OWRI


SYNERGY BUS
RAIL AND WHEEL LIFE UP
MAINTENANCE COSTS DOWN
SPENDING DOWN
PROFIT UP
FRICTION MANAGEMENT
WHEEL/RAIL MATERIAL
CONTACT MECHANICS
WHEELSET DYNAMICS
broken rail
wear
wheel shelling
DAMAGE MODES
contact fatigue
defects
hunting
corrugations

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