Reducing Rail RCF through Better Wheel Shapes

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Influence of Wheel Shape on Rail RCF

• Higher conicity wheel/rail combinations have greater RRD and generate greater steering forces
  – More likely to cause RCF

• We should be able to reduce RCF by reducing conicity
  – But there may be a penalty in wear damage
  – Changes to reduce damage on one curve radius may cause more damage on other curve radii

• How to reduce conicity?
  – Change rail profile
    • Grinding, can be done to different profile depending on curve radius
  – Change design wheel profile
  – Change wheelset maintenance
    • more frequent reprofiling to prevent conicity rising due to wear
\( \Delta r_1 \) as a measure of RRD

- To generate significant RRD, contact must occur between the wheel and rail on the gauge shoulder of the rail
- \( \Delta r_1 \) is the rolling radius difference 1mm before flange contact
- Wheel/rail pairs with:
  - High \( \Delta r_1 \) are prone to RCF (e.g. P8)
  - Low \( \Delta r_1 \) are prone to wear (e.g. P1)
  - Wheel profiles with low \( \Delta r_1 \) have a substantial gap or relief between flange root of the wheel and the gauge shoulder of the rail
Example from c2c

Location:
- High Rail (Left)
- East Ham Depot
- Sleeper 128

Damage Types:
- *Photo (pre-re-railing)*
  - H1 Sidewear
  - H2 Classic RCF
- *Survey (post-re-railing)*
  - H2 Classic RCF

Causes:
- H1: Class 312 leading
- H2: CL312&CL357 ldg

Plotted Examples:
- T775_EHD_312MWS9_mod
- T775_EHD_312MWS10_mod
- T775_EHD_312MWS9_holo
- T775_EHD_312MWS10_holo
- T775_EHD_357TWS1_mod
- T775_EHD_357TWS2_mod
- T775_EHD_357TWS1_worn
- T775_EHD_357TWS2_worn

Field side of rail head
Edge of observed running band (black dashed lines)

Photo, pre re-railing: mostly Class 312

Representation of observed crack location and density (black angled lines)

Gauge side of rail head

Survey, post re-railing: mostly Class 357

P1 Profile, Low PYS

P8 Profile, Moderate PYS
Example from c2c

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High Rail (Left)
East Ham Depot
Sleeper 128

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- T775_EHD_357TWS2_mod
- T775_EHD_357TWS1_worn
- T775_EHD_357TWS2_worn

Photo, pre-re-railing: mostly Class 312

- P1 Profile, Low PYS
  - Damage in wear regime (Ty>175); • no direction shown

Survey, post-re-railing: mostly Class 357

- P8 Profile, Moderate PYS
  - Location of wheel/rail contact
  - ‘Arrow’ indicating direction of force on rail, and magnitude of accumulated RCF damage
  - Different colours represent different vehicle/profile cases
  - ♦ = leading wheelset
  - □ = trailing wheelset
Example from c2c

The different types and locations of rail damage can also be shown on a ‘circle plot’.

Damage tends to form in distinct ‘clusters’ on these plots which can be associated with each damage mechanism.

- **H1**: High Rail Sidewear
- **H2**: Classic High Rail RCF
- **H3**: Plastic Flow to Gauge Side
- **H4**: Longitudinal Cracks/Spalling
- **H6**: Longitudinal Flow With Traffic
- **H7**: Longitudinal Flow Against Traffic

- **L1**: Low Rail Sidewear
- **L2**: Classic Low Rail RCF
- **L3**: Plastic Flow to Gauge Side
- **L4**: Field Side Cracks
- **L5**: Plastic Flow to Field Side
- **L6**: Longitudinal Flow With Traffic
- **L7**: Longitudinal Flow Against Traffic
The P12 Wheel Profile

- Developed by NRC Canada in 2004 for RSSB WRISA committee
- Very similar to P8, the most common wheel profile on UK passenger vehicles
- Subtle changes made to 3 areas of the profile:
$\Delta r_1$ for P12 and P8

<table>
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<tr>
<th>Wheel Profile</th>
<th>Rail Profile</th>
<th>$\Delta r_1$ (mm)</th>
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<tr>
<td>P1</td>
<td>BS113A</td>
<td>0.899</td>
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<tr>
<td>P12</td>
<td>NR-HR1</td>
<td>1.018</td>
</tr>
<tr>
<td>P8</td>
<td>NR-HR1</td>
<td>1.132</td>
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<td>P10</td>
<td>BS113A</td>
<td>1.312</td>
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</table>
• P12 wheel profiles have been applied to six train types:
  – Class 68 Diesel Locomotive
  – Class 380 EMU
  – Class 390 EMU
  – Class 395 EMU
  – Class 444 EMU
  – Class 450 EMU

• I’ll consider each application over the next few slides
UK Light (Class 68) Locomotive

- Vossloh ‘UK Light’ Mixed-Traffic Diesel Loco
- Bo-Bo, 3800hp, 80 tonnes, 100mph, disc braked
- Small fleet – 25 in service, 7 more on order
- Delivered from 2013, fitted with P12 from new
  - P12 chosen to extend wheel life and reduce track forces
  - New, small and widespread fleet unlikely to have a measurable effect on rail RCF
  - Wheel life is extended: P12 maintains lower conicity, lower RCF and wear compared to similar locos with P8 profile
  - Ride also remains excellent

Thanks to Andy Martlew at DRS
Class 380 EMU

- Siemens ‘Desiro’ EMU for ScotRail
- Glasgow outer suburban services, max speed 100mph
- Fleet comprises 130 vehicles in 3 & 4 car sets
- Delivered from 2010, fitted with P12 from new
- Operate among other EMU fleets with P8 profiles
  - Some routes dominated by 380s
  - Initial wear problems apparent but have now settled down?
Class 390 EMU

- Alstom ‘Pendolino’ ICEMU for West Coast Main Line
- Max speed 125mph, tilting train (high cant deficiency)
- Fleet comprises 583 vehicles in 9 & 11 car sets
- Dominate traffic on some parts of WCML
- Delivered from 2002, P12 trialled from 2010 and rolled out fleet-wide from 2012
  - Main purpose was to reduce conicity and extend wheel reprofiling intervals
  - Very successful in achieving these goals, wheel wear and RCF also reduced

Thanks to John Williams at Alstom and Mark Burstow at Network Rail
Class 395 EMU

- Hitachi ‘Javelin’ EMU for London outer suburban trains
- Runs partly on High Speed Line (to EU standards) and partly on conventional routes
- Max speed 140mph
- Fleet of 174 vehicles in 6 car sets, delivered in 2009
- P12 successfully trialled and rolled out fleet-wide
  - Stability problems resolved
  - No increase in wheel wear
  - Reprofiling periodicity doubled
  - Dynamic behaviour through switches has improved
Class 444 and 450 EMU

• Siemens ‘Desiro’ EMUs for South West Trains
• London inner and outer suburban services, max 100mph
• Fleet of 733 vehicles, 4 & 5 car sets, delivered from 2004
• P12 trialled on selected vehicles in 2007 and 2009/10
  – Wheel & rail RCF monitored
  – Rail RCF damage findings were inconclusive
  – Wheels suffered from more RCF and wear, reducing life
  – Other influences hampered trial including wheel diameter
  – P12 not adopted: HALL Bush used instead (VTAC benefit too)

Thanks to Mark Burstow and Keith Hutchins
Challenges: Experimental Conditions

- Impossible to have consistent, robust experimental conditions on an operating railway/fleet
  - 444/450 trial influenced by wheel diameter/age
  - Mixed traffic on routes influences rail RCF
  - Lack of control experiments
  - Difficult to prevent trial sites being maintained (e.g. ground)

- Trial timescales often too short to quantify benefits

- Network Rail initiatives since Hatfield have had a bigger impact on rail RCF than the limited application of P12s
  - These crucial developments support the operational railway
  - But have made assessment of the benefit of P12s on the infrastructure almost impossible to quantify
Challenges: Experimental Conditions

Broken Rails – 1998-99 to 2015-16

Re-railing following Hatfield
Improved site welding processes
Sperry pedestrian UT equipment introduced
Train Based Grinding
Sperry train based UTU equipment
Introduced on Track Cats 1A, 1, 2
and 3

Limits and actions for dip angles introduced
Improved Rail Defect Management System - RDMS
Train based UT equipment on
Track Cats 4, 5 and 6
Lower limits and actions for dip angles
UTU Enhancements
Assess Data +

Only 10% of these are related to head defects

Thanks to Brian Whitney and Network Rail
Challenges: Quantification of Benefits

- Simulations suggest that the P12 should reduce rail RCF
  - But also indicate an increase in wear
  - There is no benefit in overall track damage cost using models such as VTISM and VTAC
  - No quantifiable evidence of a real benefit on-track either
  - Little incentive for operators to use the P12 profile

- The P12 profile has shown a benefit to wheel life
  - Improved stability and extended turning interval on fleets where conicity is critical
  - But benefits for wheel RCF and wear are unclear or inconsistent

- How to quantify benefits and incentivise use?
Quantification of Benefits: VTISM Simulation of Class 390

RCF at Tread Contact: P12 Better

P12 Better

Wear at Flange Contact: P12 Worse

Profile | Rail RCF & Wear Cost | Vertical Damage Cost
---|---|---
P8 | 0.93 | 1.07
P12 | 0.94 | 1.07

Negligible difference in track damage: P12 shows no benefit
More Frequent Wheel Reprofiling and Whole System Costing

- Wheelset Management Model used to predict effect of wheel turning policy on both wheel and track damage
- Optimum turning interval for system was different to that for the vehicles alone
- High-mileage wheels cause more RCF
- Incentivising this is not easy either!
What Have We Learnt?

• ‘Low RCF’ wheel profiles can be designed or achieved by better wheelset maintenance
• Simulations can demonstrate their RCF benefits, but there is often an increase in wear
• Track damage is influenced by too many other factors to provide clear experimental evidence of a benefit
• Other technologies (rail grinding, HALL bush) provide clearer benefits, and an impression of ‘problem solved’
• Difficult to incentivise the use of P12 wheel profiles
• Successful applications have mostly been higher-speed vehicles where conicity is a limiting factor