Reducing Rail RCF through Better Wheel Shapes

ICRI Conference, Vancouver, 2016
Paul Molyneux-Berry
University of Huddersfield Institute of Railway Research
In partnership with the Rail Safety and Standards Board
Contents

• Influence of Wheel Shape on Rail RCF
• The P12 Wheel Profile (aka WRISA2)
• Trials and Implementation
• Challenges
• What Have We Learnt?
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 Idg

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

Photo, pre re-railing: mostly Class 312
- Field side of rail head
- Edge of observed running band (black dashed lines)
- 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

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

Damage Types:
*Photo (pre-rerailing)*
H1 Sidewear
H2 Classic RCF

*Survey (post-rerailing)*
H2 Classic RCF

Causes:
H1: Class 312 leading
H2: Class 312 & Class 357 leading

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

*Photo, pre re-railing: mostly Class 312*

P1 Profile,
Low PYS

Damage in wear regime
($T_\gamma > 175$); • 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
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.
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:
  - P12 has slightly steeper flange
  - P12 has Anti-RCF relief
  - P12 has Smoother reverse slope
For P12 and P8, the table shows the rolling radius difference ($\Delta r_1$) for different wheel and rail profiles:

<table>
<thead>
<tr>
<th>Wheel Profile</th>
<th>Rail Profile</th>
<th>$\Delta r_1$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>BS113A</td>
<td>0.899</td>
</tr>
<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>
</tr>
<tr>
<td>P10</td>
<td>BS113A</td>
<td>1.312</td>
</tr>
<tr>
<td>P12</td>
<td>CEN60E2</td>
<td>1.52</td>
</tr>
<tr>
<td>P12</td>
<td>BS113A</td>
<td>1.885</td>
</tr>
<tr>
<td>P12</td>
<td>CEN60E1</td>
<td>1.89</td>
</tr>
<tr>
<td>P8</td>
<td>CEN60E2</td>
<td>2.29</td>
</tr>
<tr>
<td>P8</td>
<td>CEN60E1</td>
<td>2.543</td>
</tr>
<tr>
<td>P8</td>
<td>BS113A</td>
<td>2.667</td>
</tr>
</tbody>
</table>

Increasing RCF: Tread Contact

Increasing Wear: Flange Contact

Legend:
- Blue: Class 158
- Red: Class 185
- Green: Mark 3 Coach
- Yellow: Mark 4 Coach
Trials and Implementation

• 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

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

<table>
<thead>
<tr>
<th>Profile</th>
<th>Rail RCF &amp; Wear Cost</th>
<th>Vertical Damage Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>P8</td>
<td>0.93</td>
<td>1.07</td>
</tr>
<tr>
<td>P12</td>
<td>0.94</td>
<td>1.07</td>
</tr>
</tbody>
</table>

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