Overview

1. Brief review of **key damages** and **root causes** in relation to S&C vehicle-track interaction

2. Understanding/predicting **wheel and rail interaction** at S&C

3. Predicting **damage mechanisms** in rails and support and identifying the **key drivers**

4. Assessing the **benefit** of **crossing geometry change** and other **innovations** on the system performance
# C4R S&C Failure Catalogue

- #44 Failures catalogued in public Deliverable-13.1
- Presented at 1\textsuperscript{st} Dissemination event, Paris June 2015
Components damages in S&C

- Switch and stock rails
  - Lipping & spalling
  - Head checks
  - Squats
  - Wear

- Points
  - Additional fracture by fatigue

- Bearers
  - Fatigue cracking
  - Vertical movement and hanging
  - Lateral shift

- Slide plates
  - Poor movement (high friction)
  - Seizure
Components damages in S&C

- Transverse fatigue crack (foot or nose)
- Wear
- Plastic deformation
- Shelling & spalling
- Excessive Wear
- Fatigue cracks
- Voids & hanging
Components damages in S&C

- **Cast crossing**
  - Transverse fatigue crack (foot or nose)

- **Switch and stock rails**
  - Lipping & spalling
  - Head checks
  - Squats
  - Wear

- **Points**
  - Additional fracture by fatigue

- **Bearers**
  - Fatigue cracking
  - Vertical movement and hanging
  - Lateral shift

- **Check rails**
  - Excessive Wear

- **Crossing nose & Wing**
  - Wear
  - Plastic deformation
  - Shelling & spalling

- **Bearers**
  - Fatigue cracks
  - Voids & hanging

- **Slide plates**
  - Poor movement (high friction)
  - Seizure
Root causes

- System Design
  - vehicle-track, wheel-rail...

- Environmental
  - local and weather variations...

- Installation/set-up
  - tolerances and human factors...

- Operational
  - speed, loading, traffic mix...

- Manufacturing
  - processes & capabilities...

- Maintenance
  - frequency, mechanised/manual repairs...
2) Vehicle-track and wheel-rail interaction
Fundamental behaviour in S&C
Change in rolling radius difference (left/right) as stock rail moves outward and point of contact also
- induces a steering of the wheelset (angle of attack)
- and associated lateral steering forces (also the case on through route to a lesser extent)
- Jump (double) point contact introduces higher frequency force disturbances
Fundamental behaviour at crossing

Key driver:
- Speed (V)
- Dip angle (\(\alpha\))
- Track & wheel mass (M)
- Track Stiffness (K)

Jenkins 74 “The effect of track & vehicle parameters on W-R vertical dynamic forces”

<table>
<thead>
<tr>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1ms</td>
<td>&lt; 10~20ms</td>
</tr>
</tbody>
</table>

- \(f_{cy} \approx 500-2kHz\)
- \(f_{cy} \approx 50-120Hz\)

- Wheel and track mass
- Contact stiffness
- Rail head damage (plastic deformation, subsurface fatigue) and rail fatigue

- Wheel and track mass, rail elasticity
- Ballast support stiffness
- Rail head damage, ballast degradation, sleeper fatigue and rail fatigue
Fundamental behaviour at crossing

Through the crossing the loading is mainly vertical

- Although lateral impact load is also present: RRD $\Rightarrow$ angle of attack + lateral offset in diverging routes
- Jump (double) in point contact at entry/exit of casting geometry (smoothed in reality by manual and operational grinding)
- Vertical impact at load transfer between wing and nose (vice versa)
Fundamental behaviour at crossing

\[ \text{dip angle} = \alpha_1 + \alpha_2 \]
Fundamental behaviour at crossing

• More parameters affecting reaction forces
  – Range of wheels and crossing geometry shapes
  – Vehicle types and steering ability (PYS)
  – Axles lateral position and angle of attack
  – Track geometry and misalignment
  – Support type and conditions
  – Direction of travel (through/diverging-facing/trailing)
3) Predicting damage mechanisms and identifying key drivers
Observing & predicting damage forces

Load vectors showing high magnitude sustained load (P2) => leading to component/ballast fatigue

Load vectors showing high intensity initial impact load (P1) => leading to local rail damage

wheel-rail contact location showing intensity of loading

Vertical Force Gradient shown on contact location [kN]

0 50 100 150 200 250 300
Observing & predicting w-r interaction

Rapid change of contact in leg ends; multi point contact; high pressure

x-dimension not to scale
Observing & predicting w-r interaction

High pressure wing edge; v. high pressure nose; repeated impact load
Squats marks corresponding to peak P1 pressure and overall high pressure deformed profiles over P2 action zone
Observing & predicting w-r interaction

High pressure combined with high wear index on nose
High pressure combined with high wear index on nose
Observing & predicting w-r interaction

RCF initiation on crossing vee
4) Assessing the benefits of innovations
Assessment of new crossing geometry

Comparative study of 4 different UK crossing designs in use: CEN56 vertical and inclined, NR60 existing and improved

Machining operation from solid block, reproducing real production operations
Assessment of new crossing geometry

P1 vs load transfer position  - CEN56fc
Assessment of new crossing geometry

P1 vs load transfer position - NR60
Assessment of new crossing geometry

### FACING average P1 forces

<table>
<thead>
<tr>
<th>Speed</th>
<th>FC56</th>
<th>NR60mk2</th>
<th>new v1</th>
</tr>
</thead>
<tbody>
<tr>
<td>40kmh</td>
<td>0%</td>
<td>-17%</td>
<td>-12%</td>
</tr>
<tr>
<td>80kmh</td>
<td>0%</td>
<td>-23%</td>
<td>-17%</td>
</tr>
<tr>
<td>120kmh</td>
<td>0%</td>
<td>-36%</td>
<td>-21%</td>
</tr>
<tr>
<td>Average</td>
<td>0%</td>
<td>-28%</td>
<td>-18%</td>
</tr>
<tr>
<td>SD</td>
<td>0%</td>
<td>-38%</td>
<td>-39%</td>
</tr>
<tr>
<td>μ+3σ</td>
<td>0%</td>
<td>-33%</td>
<td>-29%</td>
</tr>
</tbody>
</table>

### TRAILING average P1 forces

<table>
<thead>
<tr>
<th>Speed</th>
<th>FC56</th>
<th>NR60mk2</th>
<th>new v1</th>
</tr>
</thead>
<tbody>
<tr>
<td>40kmh</td>
<td>0%</td>
<td>-10%</td>
<td>-13%</td>
</tr>
<tr>
<td>80kmh</td>
<td>0%</td>
<td>-19%</td>
<td>-21%</td>
</tr>
<tr>
<td>120kmh</td>
<td>0%</td>
<td>-19%</td>
<td>-19%</td>
</tr>
<tr>
<td>Average</td>
<td>0%</td>
<td>-17%</td>
<td>-19%</td>
</tr>
<tr>
<td>SD</td>
<td>0%</td>
<td>-8%</td>
<td>-36%</td>
</tr>
<tr>
<td>μ+3σ</td>
<td>0%</td>
<td>-12%</td>
<td>-29%</td>
</tr>
</tbody>
</table>
Opportunities for innovation

- **Geometry**
  - Smooth changes (avoid contact jumps) and more conformal shapes
  - Ensure compliance with a wide range of representative wheels shapes
  - Minimise dip angle (geometrical calculation)

- **Support**
  - Use of USP, shorter sleeper spacing, resilient baseplate systems
  - Hybrid tracks > slab track

- **Materials**
  - Better resisting material for nose, wing, switches

- **Monitoring**
  - Profile geometry measurement (at regular time intervals)
  - Geometry monitoring (alignment in switch panel)
  - Vibration analysis (finding and eliminating high damage instances)
    - Track-side
    - On-board vehicles
      - Instrumented wheelset (not high frequencies enough)
      - Axle box accelerations (need to be tuned for HF + data collection) and need to know positions of S&C
Conclusions

- S&C attract disproportionate amount of damage and costs
- Careful wheel-rail geometry interaction can significantly improve system performance from design through to continuous monitoring for sustained performance
- Support discontinuity should be ‘bridged’ using more resilient layers (baseplate on resilient pad) and better load distribution within the superstructure and support layers
- High impact load instances can be monitored and ruled out, this requires both track side and vehicle based instrumentations and intelligence
- Numerical simulation together with site observation/measurement can offer a unique view of the system interaction
- Finally, simple rules and algorithm can be derived from studies as presented here for a more direct industrial applications
Thank you for your kind attention

Bezin Yann
Head of Research
Institute of Railway Research
University of Huddersfield
y.bezin@hud.ac.uk

Acknowledgements: