Session 2: “Optimising opposite demands”
Designing future turnouts - where research capabilities meet industry needs

Speaker: Dr Y. Bezin (IRR Head of Research, Huddersfield, UK)
Content

• Background
  – Key WRI issues at Switches & Crossings

• Key areas of research
  – EU projects landscape

• How to address key challenges
  – Research tools and validation aspects
  – ‘Conflicting requirements’ for optimisation

• Collaboration
  – Challenges and opportunities
Background

**Complexity**
- Large # of parts
- Wide range of possible layout configuration
- Moving parts & exposed mechanisms
- Mechanical interfaces
- Weak structural components

**Non-linearities**
- Rail cross sections (bearing surface)
- Structural stiffness (rail bending stiffness, bearers length & ballast support)
- Rail inclination
- Track curvature
- Cant deficiency
### S&C key components and damages

#### Switch Panel

<table>
<thead>
<tr>
<th>Component</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast manganese Casting</td>
<td>transverse fatigue crack (foot or nose)</td>
</tr>
<tr>
<td>Crossing nose</td>
<td>wear, plastic deformation, shelling and spalling</td>
</tr>
<tr>
<td>Wing rail</td>
<td>wear, plastic deformation, shelling and spalling</td>
</tr>
<tr>
<td>bearers</td>
<td>fatigue cracking, voids</td>
</tr>
<tr>
<td>switch rails</td>
<td>lipping, head checks, squats, wear</td>
</tr>
<tr>
<td>points</td>
<td>all the above + fracture by fatigue</td>
</tr>
<tr>
<td>stock rails</td>
<td>lipping, head checks, squats, wear, spalling</td>
</tr>
<tr>
<td>slide plates</td>
<td>poor movement (high friction) and ceisure</td>
</tr>
<tr>
<td>bearers</td>
<td>fatigue cracking, voids</td>
</tr>
</tbody>
</table>

#### Crossing Panel

<table>
<thead>
<tr>
<th>Component</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel</td>
<td></td>
</tr>
<tr>
<td>S&amp;C key components and damages</td>
<td></td>
</tr>
</tbody>
</table>
S&C key components and damages

- **Spalling of stock rail**
- **Subsurface initiated fatigue**
- **Lipping of switch/stock rails**

Reference: Capacity4Rail, D131 “Operational failures modes of S&Cs”
S&C key components and damages

Plastic deformation of wing rails

Spalling of crossings

Spalling & plastic deformation of crossing nose

Reference: Capacity4Rail, D131 “Operational failures modes of S&Cs”
Root causes – dynamic WR Interaction

Poor compliance of W-R geometries

- **Harsh interface**
- **Variable rails shapes**
- => Jumps in contact
- => Multiple point contact
- => High normal & surface/subsurface shear stresses

Poor maintenance + support

- **Cyclic top/alignment**
- **Voided/hanging bearers**
- **Uneven L/R loading**
- **Differential settlement**
Root causes – dynamic WR Interaction

Poor compliance of W-R geometries

- High rail/sleeper accelerations
- Ballast void and settlement
- Increased Dynamic Forces
- High normal & shear stresses
- Rail wear, fatigue & deformation

Poor maintenance + support

Casting/nose fatigue cracking
Root causes – Influential factors

- **Design** (system level => vehicle-track…)
- **Environmental** (incl. extreme weather)
- **Installation/set-up** (human factor, tolerances…)
- **Maintenance** (mechanised/manual…)
- **Manufacturing** (processes/tolerances/…)
- **Operational** (speed, loading regime, traffic mix, tonnages…)

Reference: D131 Operational failure modes of SCs
Key areas of research & development

Eslöv-Sweden test site:
- Kinematic Gauge Optimisation
- Resilient stiffness

Haste-German test site:
- Crossing nose shape (e.g. MaKüDe)
- Material (built-up)

Simulation software:
- Benchmarking
- KGO optimisation
- Support stiffness variation

Simulation of:
- Derailment analysis
- Switch rail shape optimisation
- Impact of wheel shape
- Under sleeper pads
- Innovative structures

Material
- Higher steel grades

Concept evaluation:
- New switch concepts
- New drive and lock devices

Towards demonstration of key innovations

FP6
Innotrack

FP7
Sustrail
Rivas
DRail
Capacity4Rail

H2020
In2Rail…
…Shift2Rail
Available simulation technology

- **Vehicle multibody system dynamics**
  - Prediction of vehicle behaviour and WRI forces
- **Vehicle-track interaction dynamics**
  - Prediction of WRI forces based on simplified or detailed track response
- **Wheel-rail contact conditions**
  - WRI forces and contact conditions (normal and tangential)
- **Wear/damage prediction & summation**
  - Based on any of the above
Contact condition and contact stresses

![Graph showing vertical position and lateral position](image)

- Vertical position [m] vs. Lateral position [m]
  - \( r_{\text{MAX}} \approx 4200 \, \text{MPa} \)

- Graph showing Vertical input motion [mm] vs. Longitudinal position [m]
  - \( Q_g = 110kN \)

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Example key output SUSTRAIL

- Axle kinematic motion
- Vertical wheel motion => dip angle
- 3-\textit{dof} wheel-track MBS model
- Dynamic $F_{vertical}$ prediction => P2 force

\begin{equation}
    z_w(x) = z_r(x, y) + r_0 - \Delta r(x, y)
\end{equation}
Example key output SUSTRAIL

- Parametric study: 800+ wheel pairs
  - Prediction of dip angle and P2 force levels

References:
BEZIN, Y., COLEMAN, I., GROSSONI, I., NEVES, S., HYDE, P., BRUNI, S., ALFI, S., RANTATALO, M., JÓNSSON, J., ASLAM, M., LAMBERT, R., BEAGLES, A., FLETCHER, D. & LEWIS, R. 2015. **D4.4 Optimised switches and crossings systems, SUSTRAIL, 265740 FP7.**

Example key activities Capacity4Rail

Freight vehicle model – non-linear dry friction Y-series bogies

Vehicle speed (V)

Crossing geometry

Turnout layout

Check rail

<table>
<thead>
<tr>
<th>Switch</th>
<th>Natural</th>
<th>Actual</th>
<th>Lead L2 Toe to nose</th>
<th>Lead L2 Nose across a 1970 interval</th>
<th>Toe to toe</th>
<th>Planing radius</th>
<th>Switch radius</th>
<th>Turnout radius</th>
<th>Length of Plannin g P</th>
<th>Length of transition</th>
<th>Length of straight to nose</th>
<th>Turnout Speed /kph</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
<td>9.25</td>
<td>10.75</td>
<td>25448</td>
<td>5360</td>
<td>56256</td>
<td>287251</td>
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<tr>
<td>DV</td>
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<td>13</td>
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<tr>
<td>EV</td>
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Turnout Speed /kph

<table>
<thead>
<tr>
<th>AV</th>
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<th>10</th>
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<th>CV</th>
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<td>48</td>
<td>56</td>
<td>64</td>
<td>80</td>
<td>80</td>
<td>97</td>
</tr>
</tbody>
</table>

IP of natural angle

Nose of actual crossing

Planing radius

Switch radius

Turnout radius

Transition

Str

1432

16N

1.2
Example key activities Capacity4Rail

Time simulation

Prediction of contact condition using multi-Hertzian non-elliptical contact

- LATERAL FORCE - right rail
- VERTICAL FORCE - right rail
- CONTACT STRESS - right rail
Example key activities Capacity4Rail

Damage indices prediction along crossing panel:
- Equivalent Hertzian pressure,
- Fi-surf,
- Fi-sub,
- $T_\gamma$ damage (RCF/wear)

Visualisation of contact conditions and damage level:
- Position and size of contact patch(es),
- Colour coded damage level,
- Creep vectors,
Key conflicting requirements

- **Engineering design vs cost**
  - Highly engineered material specification (at what cost?)
  - Resilient track construction (at what cost)?
  - Standardisation versus customisation?

- **Through vs diverging route**
  - Traffic mix consideration in design vs generic design!
  - Trade-off in rail shapes and layout geometry optimisation

- **Facing vs trailing move**
  - Trade-off in rail shape and layout geometry optimisation

- **Wear vs RCF**
  - Competing phenomena
Validation Challenges

• Validation of rail damage prediction
  – Based on specific site observation + stochastic data collection
  – Fast and reliable data collection (vehicle inspection vehicles?)

• Material characterisation data and experiments
  – Twin disc rigs for:
    • Wide range of traction and normal pressure
    • Full scale where possible…
    • Replicating S&C ‘harsh’ conditions (high curvature)
    • Replicating S&C materials (cast Mn, EDH, hardened steel e.g. 350HT)
  – Plastic deformation
  – Residual strains in highly stressed contained material

• Full scale testing for close to reality WRI conditions…
Validation Challenges

Centre for Innovation in Rail, University of Huddersfield
Few words of conclusion

- Key damage mechanisms in S&C relate to wheel-rail interface => *heavily strained interface!*
- Key areas of collaborative research are *geometry/shape optimisation* and *improved support stiffness* (upgrade to ballasted & novel track forms)
- Available simulation techniques enable *predicting key damages* (location, intensity and accumulation)
- exchange of *data* and *testing resources* is key to validation as a first step towards innovation selection and evaluation
- This is a system - consider both sides of the interface!
- Successful innovations depend on *exchange, collaboration, openness*, as well as *individual/corporate motivation to achieve a common goal*
Thank you for your attention.

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