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Designing future turnouts – where research capabilities meet industry needs

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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

<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>
S&C key components and damages

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

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
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

![Graphs showing contact condition and contact stresses](image)

- Top graph: Vertical position vs. Lateral position with a peak stress of 422 MPa.
- Bottom graph: Vertical input metric vs. Longitudinal position with a dynamic force of 110 kN.

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Example key output SUSTRAIL

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

$$z_w(x) = z_r(x, y) + r_0 - \Delta r(x, y)$$
Example key output SUSTRAIL

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

References:
Example key activities Capacity4Rail

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

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

Vehicle speed (V)

Crossing geometry

Crossing layout

Check rail

Crossing 1in^1 Lead Lengths Radii Length

<table>
<thead>
<tr>
<th>Switch</th>
<th>Natural</th>
<th>Actual</th>
<th>Lead L2 Toe to nose</th>
<th>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>
<td>245767</td>
<td>245767</td>
<td>4250</td>
<td>7366</td>
<td>584</td>
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<tr>
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<td>964</td>
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<td>18.5</td>
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<td>7000</td>
<td>24555</td>
<td>3605</td>
<td>64</td>
</tr>
</tbody>
</table>

Turnout Speed /kph

15
Example key activities Capacity4Rail

Time simulation

Leading axle
Trailing axle

Leading axle
Trailing axle

Leading axle
Trailing axle

Leading axle
Trailing axle

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

LATERAL FORCE - right rail

VERTICAL FORCE - right rail

CONTACT STRESS - right rail

- Capacity for 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
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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Acknowledgements:
Support from European Grants SCPO-GA-2011-265740 (SUSTRAIL), SCP3-GA-2013-60560 (Capacity4Rail) are gratefully acknowledged. Software used: Vi-Rail (www.vi-grade.com) and ArgeCare (argecare.com)