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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**
- $$\Rightarrow$$ Jumps in contact
- $$\Rightarrow$$ Multiple point contact
- $$\Rightarrow$$ 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

![Graph of contact condition and contact stresses](image-url)
Example key output SUSTRAIL

- Axle kinematic motion
- Vertical wheel motion => dip angle
- 3-\textit{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

Vehicle speed (V)

Crossing geometry

Turnout layout

Check rail
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
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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