High Speed S&C – Design and Maintenance

Dr Sin Sin Hsu
*Head of Track Engineering, NRHS*

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What is a High Speed Turnout?

Three main parts:

Switch – Geometry, profile, components

Intermediate Part – closure rail and fixings

Crossing nose – Swing nose or fixed nose
High Speed S&C

Definition
- S&C on high speed through route and
- S&C with turnout speeds of 160km/h

What is defined as ‘High speed’?

- HS1 is 230km/h
- China is 250km/h
- TSI requires swing noses at 280km/h or above
Requirements

• Safety – must be tested with real vehicles and undergo long term running tests
• Passenger comfort – designed in-line with vehicle track interaction theories and analyses
• Minimum maintenance – wheel-rail interface modelling
• High reliability – high precision engineering for system, components and electrical equipment

High Speed Turnout on Slab Track in China
25,000km of High Speed Rail built since 2004
Technical Aspects of High Speed Turnouts in UK

- Tangential or Non-intersecting geometry
- Rail head inclined at 1 in 20 in all the turnouts
- Glued insulated joints, if any, in turnout routes only
- Swing nose crossings
- Locking device for switches and movable crossings
- Control of the opening and closing of the switch-rail and the swing nose with a switch position detector
- Electrical equipment for heating switch and swing nose crossing
Switch Rail Profiles

Vossloh Cogifer uses UIC 60D type switch rail with an asymmetrical 1:20 profile.
Positioning of High Speed S&C

These are **must**

- Straight track
- Flat or small constant gradient
- Constant support and track stiffness
- Control of settlement of earthworks
- Away from structures and bridges
- At locations with relatively easy road access

Canal Street Tunnel S&C on 3.5% gradient – started running trains this week!

Complicated scissors partly on slab and partly on ballast!
## Construction Tolerances

<table>
<thead>
<tr>
<th>Track Parameter</th>
<th>Network Rail</th>
<th>HS1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100-125mph (160-200km/h)</td>
<td>over 220 km/h</td>
</tr>
<tr>
<td>Vertical alignment (mm)</td>
<td>+10, -20</td>
<td>5, maintain to less than 10</td>
</tr>
<tr>
<td>Horizontal alignment (mm)</td>
<td>±10</td>
<td>6, maintain to less than 8</td>
</tr>
<tr>
<td>Crosslevel / cant (mm)</td>
<td>±3 (±2 for over 125mph)</td>
<td>3, maintain to less than 10</td>
</tr>
<tr>
<td>3m Twist (mm)</td>
<td>6 (1 in 500)</td>
<td>3, maintain to less than 7</td>
</tr>
<tr>
<td>Gauge (mm)</td>
<td>1435 – 40</td>
<td>1434 - 1438</td>
</tr>
<tr>
<td>Plain line</td>
<td>1435 – 38</td>
<td>For S&amp;C, 1mm maximum variation from bearer to bearer on through route</td>
</tr>
<tr>
<td>CEN60 S&amp;C</td>
<td>1435 – 37 for over 125mph</td>
<td></td>
</tr>
</tbody>
</table>
Defects in High Speed S&C

Pitting

RCF
Defects in High Speed S&C

Lipping on point rail

Ballast and ice pitting
Geometry is important for High Speed Turnouts

Traditional turnout design methods assume vehicle response is determined by kinematics, rather than vehicle dynamics.

Based mainly on three parameters:

- Maximum cant deficiency or maximum uncompensated lateral acceleration (m/s\(^2\)) \(\text{e.g. 100mm cant deficiency is } 100 \times \frac{g}{1500} = 0.66\text{m/s}^2\)
- Maximum rate of change of cant deficiency or maximum rate of acceleration change (m/s\(^3\))
- Maximum entry and exit jerk (m/s\(^3\))
  
  ✓ Jerk is calculated using an assumed vehicle length, usually the bogie spacing

  ✓ \textit{UK conventional network adopts 12.2m; France – 19m; German – 17m}
Types of Turnout Geometry

Intersecting geometry
- Shorter turnouts, larger entry angle, less comfortable
- UK vertical designs from AV to GV, NR60 mk2
- Vossloh Cogifers 1 in 9 and 1 in 12

Tangential geometry
- Better ride comfort due to smaller entry angles
- UK vertical design HV
- Vossloh Cogifers 1 in 15, 1 in 21, 1 in 26, 1 in 29, 1 in 46

Non-Intersecting geometry
- Smallest entry angles
- UK NR60 mk 1 switches
- BWG switches
What is a Clothiod?

In track alignment designs, transitions are normally used to connect straight to curves.

Versine at any point \( P = \frac{c^2 l}{8RL} \)

Local radius at point \( P = \frac{RL}{l} \)
BWG Design Philosophy

- Clothiod turnout to minimise jerk, limit lateral acceleration/ cant deficiency to less than 80mm
- Kinematic gauge optimisation to reduce switch wear
- Multiple point machines in the switch and movable crossing
- Head hardened (350HB) rail steel for cradle and points of movable crossing etc.

*Pictures courtesy from Voestalpine presentations*
BWG Germany 200km/h turnout
Toe to last long bearer 190m

BWG installed at Germany, Sweden, Italy, Spain, USA, Taiwan, Netherlands, South Korea, China etc.
Vossloh Cogifors Design Philosophy

• Tangential, double radius
• Cant deficiency of up to 100mm for up to 160km/h; 85mm for above 160km/h
• Manganese cast steel cradle, normal grade point and splice rail
Vossloh Cogifer, 230km/h turnout

1 in 65, toe to nose of 152m

_Cogifer installed at France, UK, Belgium, Spain, Italy, Sweden, Turkey, Korea, China, etc._
Comparison of Design Geometries for 160km/h Turnouts

<table>
<thead>
<tr>
<th>Switch design</th>
<th>Switch Radius (m)</th>
<th>Turnout Radius (m)</th>
<th>Angle (1 in…)</th>
<th>Nominal Length (m)</th>
<th>Comment</th>
<th>POE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR60H</td>
<td>2797 D = 108mm</td>
<td>3313 D = 92mm</td>
<td>33.5</td>
<td>93.289?</td>
<td>Non-intersecting</td>
<td>Hydrive</td>
</tr>
<tr>
<td>Vossloh Cogifer</td>
<td>3550 D = 85mm</td>
<td>3550 D = 85mm</td>
<td>46</td>
<td>143.292</td>
<td>Tangential</td>
<td>MCEM91, 4kN</td>
</tr>
<tr>
<td>BWG</td>
<td>Transition from 10000m D &lt; 80mm</td>
<td>4000m D &lt; 80mm</td>
<td>39</td>
<td>141.114</td>
<td>Non-intersecting</td>
<td>Hydrostar</td>
</tr>
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</table>

*NR60H ride comfort issues reported at Searchlight Lane at Norton Bridge…*

*Are lower cant deficiency and the shallower curve radii good for vehicle ride comfort?*
BWG Crossover Geometry – 160km/h turnout

Jerk- and acceleration diagram
single crossover
V in branch 160 kph
Vossloh Cogifer Crossover Geometry – 160km/h turnout
Effect of Assumed Bogie Spacing on Change of Cant Deficiency
So what does this geometry analysis tell us?

Different methods and input parameters will give different answers.

What is the real answer?

How does the train behave?

NR60 switch wear issue
To examine ride quality – minimise discomfort through turnout

To confirm compatibility of rail profiles and geometry with wheel profiles

- wheel/rail forces, and
- predicted rail wear rates

While the resulting optimal geometries are often vehicle specific, some generalizations can be made.
Case Study – Vertical CEN60 G Switch

Ride Comfort Analysis (Lateral Acceleration and Jerk)
Comparison of new design geometry G33 with existing designs

<table>
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<tr>
<th>Switch Designation</th>
<th>Design Type</th>
<th>Crossing Angle (1 in ~)</th>
<th>Planing Radius (m)</th>
<th>Switch Radius (m)</th>
<th>Entry Angle 1 in ~</th>
<th>Max Speed (mph)</th>
<th>Two Levelling</th>
<th>Transition Length (m)</th>
<th>Max Cant Deficiency (mm)</th>
<th>CD Transition Rate (mm/s)</th>
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<tr>
<td>GV</td>
<td>Secant</td>
<td>28</td>
<td>1826.29</td>
<td>1650.38</td>
<td>349.8</td>
<td>70</td>
<td>Max 22mm</td>
<td>19.640</td>
<td>90.9</td>
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<td>28</td>
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<td>Max 34mm</td>
<td>21.000</td>
<td>94.6</td>
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<tr>
<td>NR60 G</td>
<td>Cothoidal</td>
<td>33.5</td>
<td>-</td>
<td>1582.36</td>
<td>747</td>
<td>75</td>
<td>-</td>
<td>39.555</td>
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Switch Geometries

![Graph showing switch geometries with various curves and distances, including GV, G33, NR60G, and a switch toe with facing traffic.](image-url)
NR60G resulted in the worst lateral acceleration above the trailing bogie centre 25m into the switch.
Proposed new geometry G33 resulted in the worst lateral acceleration at the switch toe.
Vehicle Resonance Modes

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<th>Mode</th>
<th>Generic Air-Sprung Vehicle (Laden)</th>
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<tr>
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<td>Frequency (Hz)</td>
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<tr>
<td>Body Lower Sway</td>
<td>0.52</td>
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<tr>
<td>Body Bounce</td>
<td>0.96</td>
</tr>
<tr>
<td>Body Yaw</td>
<td>0.71</td>
</tr>
<tr>
<td>Body Upper Sway</td>
<td>1.58</td>
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<tr>
<td>Body Pitch</td>
<td>1.15</td>
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Back to the Drawing Board

Geometry was further refined resulting in the design, GS4, by extending the transition length and removing the two levelling.

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Trailing Direction – Lateral Acceleration

*Ride comfort is much improved with the modified design*
Conclusions

• Higher speeds lead to higher dynamic forces and vibrations on the infrastructure.
• High speed S&C designs in particular need to be able to accommodate these higher dynamic forces whilst providing a good level of passenger comfort.
• Geometry design is important for high speed turnouts.
• Different supplier design philosophies lead to slightly different turnout geometries.
• However, vehicle dynamics modelling is vital for optimising turnout designs in terms of not only passenger comfort but also wheel-rail interface performance and system reliability.
Ebbsfleet RT60 Switch with MCEM91