In2Rail

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No: 635900

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Switch & Crossings

Sustainable Mechatronics

Data telemetry

Performance improvement

Safe by design

Life Cycle Costs

Track

Rail Power Supply and Energy Management

Intelligent Mobility Management

Optimisation of Asset Management

Efficient

Radical Innovation

New technology

Adaptive control

Low noise and vibration

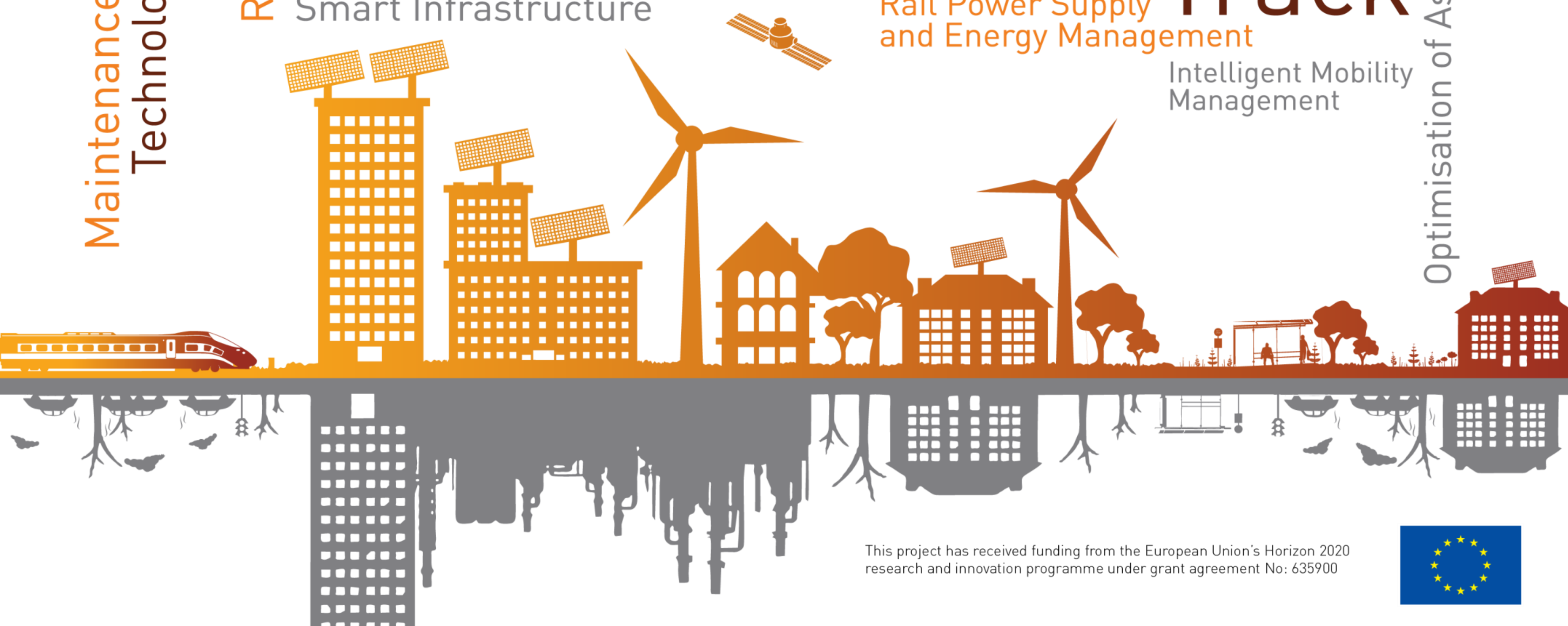
Smart Infrastructure

Maintenance Strategies

Technology transfer

Capacity

Reliability



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Track Map

- Identification of tolerances for the residual switch rail opening and switch rail height
- The crossing impact angle – an analytical study

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Identification of Tolerances for the Residual Switch Rail Opening and Switch Rail Height

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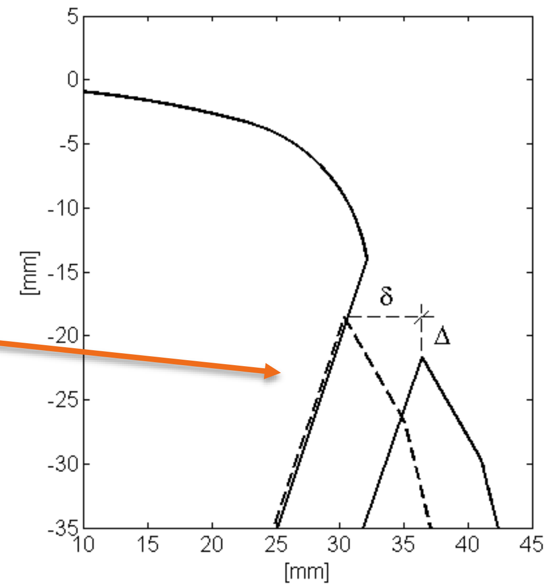
Investigated Topics

- Risk of derailment for traffic in the facing move of a switch.
- Risk of interference contact between wheel and the tip of the switch rail



...As a function of residual switch opening and switch rail height

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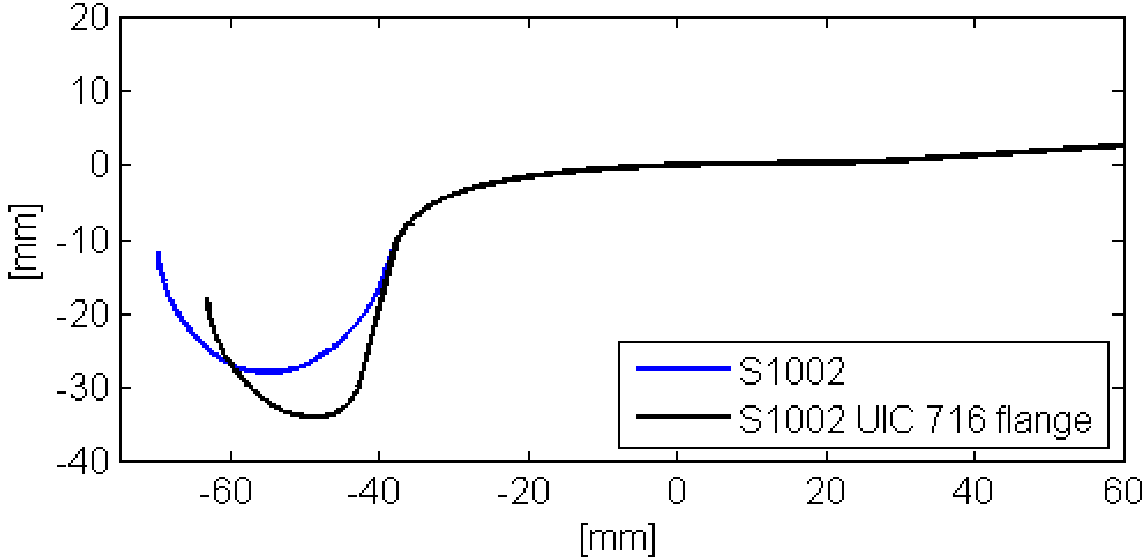
Wheel Profiles



- Derailment risk: The nominal wheel profile is most critical
- Interference contact: Worn flange is most critical (UIC716 R)

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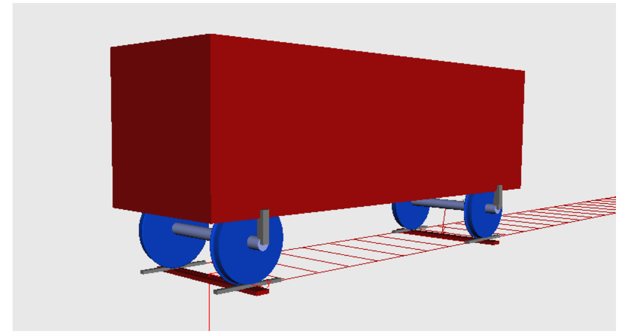
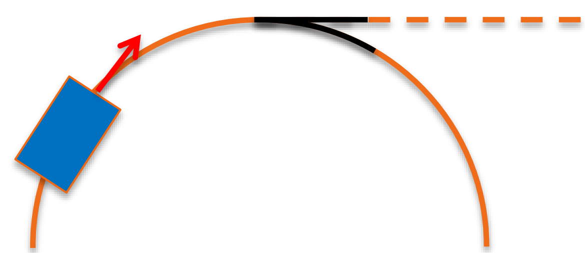
Dynamic Assessment

- Simulations in SIMPACK (Only cross-sectional wheel and rail profiles accounted for)
- Manchester Benchmarks two axle freight vehicle
- Traffic in the facing move of the diverging route in a switch with radius R=190 m. Hard flange contact conditions.
- The vehicle enters the switch via a curve
- Wheel-rail friction 0.5. Speed 40km/h
- The leading wheelset is assessed
- UIC60 based switch rails with 1:30 inclination





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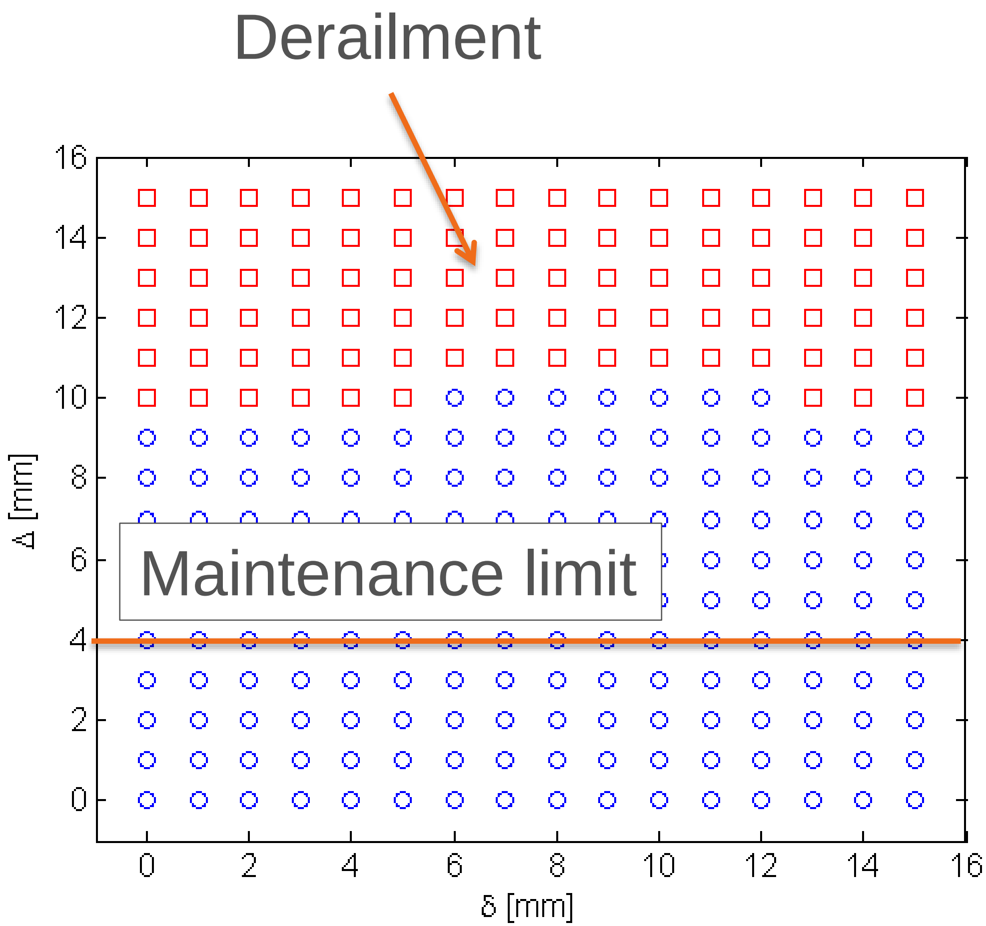
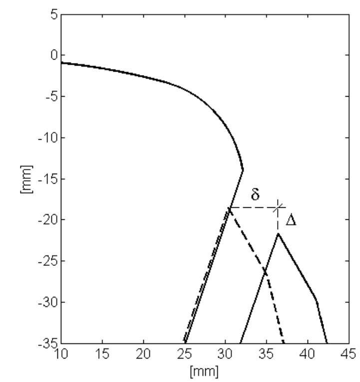
Derailment risk



Evaluation of δ - Δ grid



Changes in both δ and Δ are applied to the full length of the switch rail as this is considered to be the most conservative implementation.

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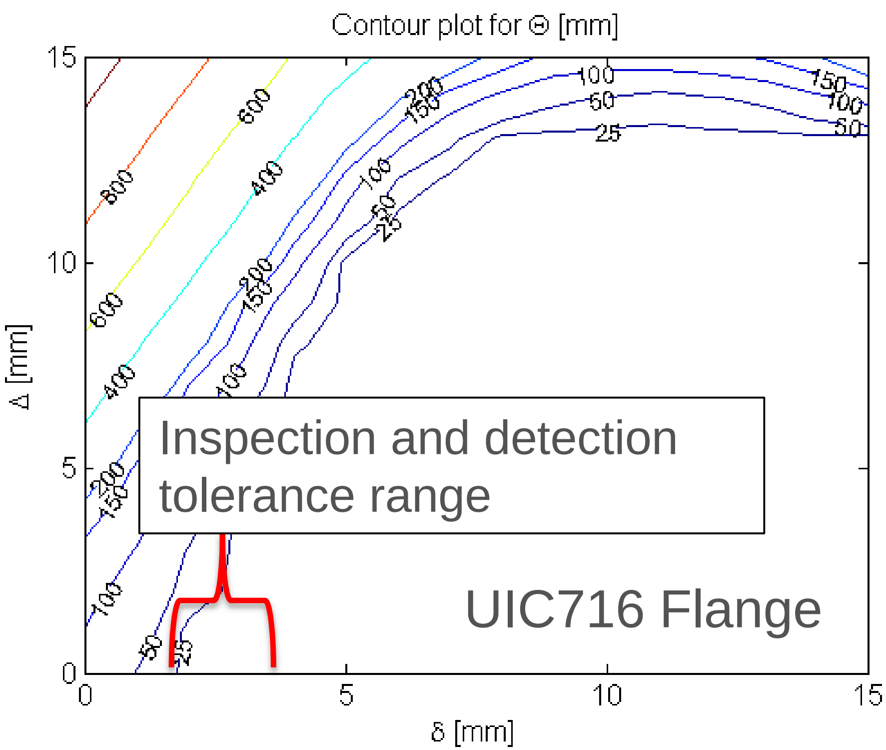
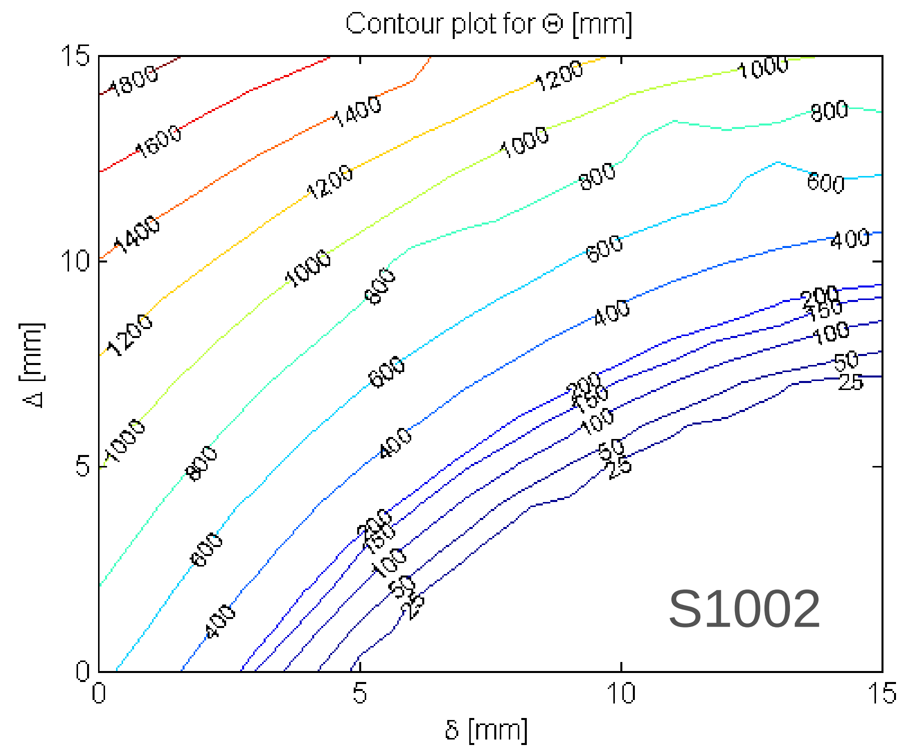
Interference contact

- Position of first wheel to switch rail contact (measured from tip of switch rail)





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Conclusions

- According to this simulation study
  - 2 or 3 mm requirement on residual switch opening reasonable to avoid interference contact between switch rail and worn wheel flanges (if the tolerance should be relaxed tougher wheel requirements are required)
  - Should be plenty of margin agains flange climb derailment in switches if current maintenance tolerances are followed
  - Result are reported in I2R D2.1

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The crossing impact angle – An analytical study

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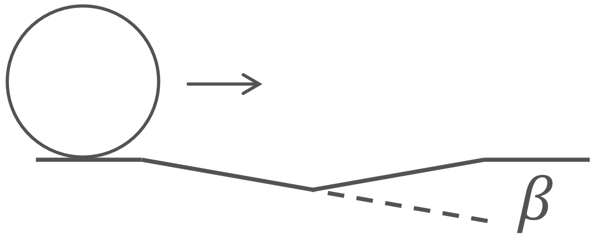
Crossing Impact Angle

- Which parameters determine the impact angle at crossings?



- Previous studies (Pålsson, 2015) have shown that $\bar{\beta} = \dfrac{\alpha\Delta}{T}$
  - α=crossing angle
  - Δ=Measure of spread in wheel profile geometries
  - T=Change in crossing nose width over the transition zone
- The relation assumes that the crossing geometry is adjusted according to the parameters

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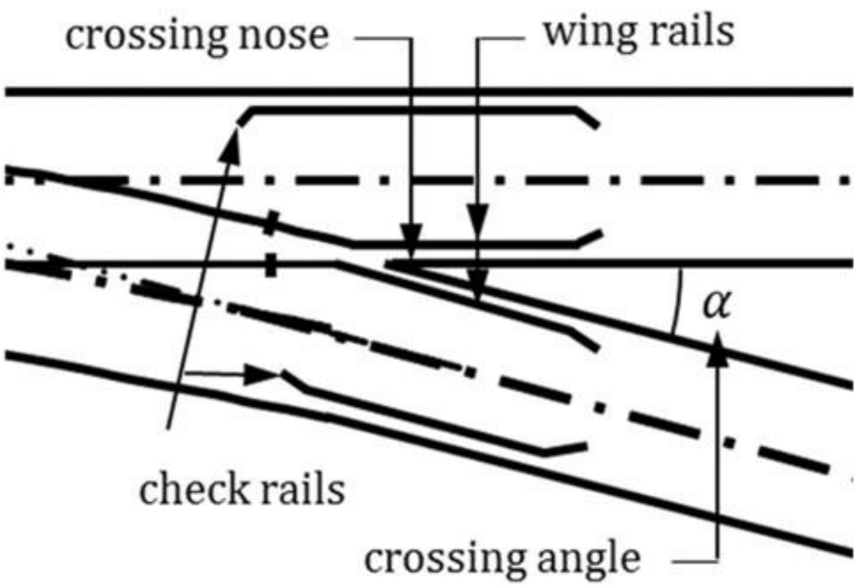
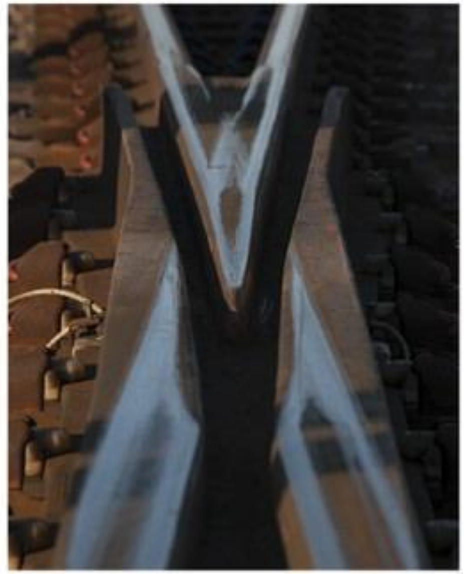
Crossing Angle





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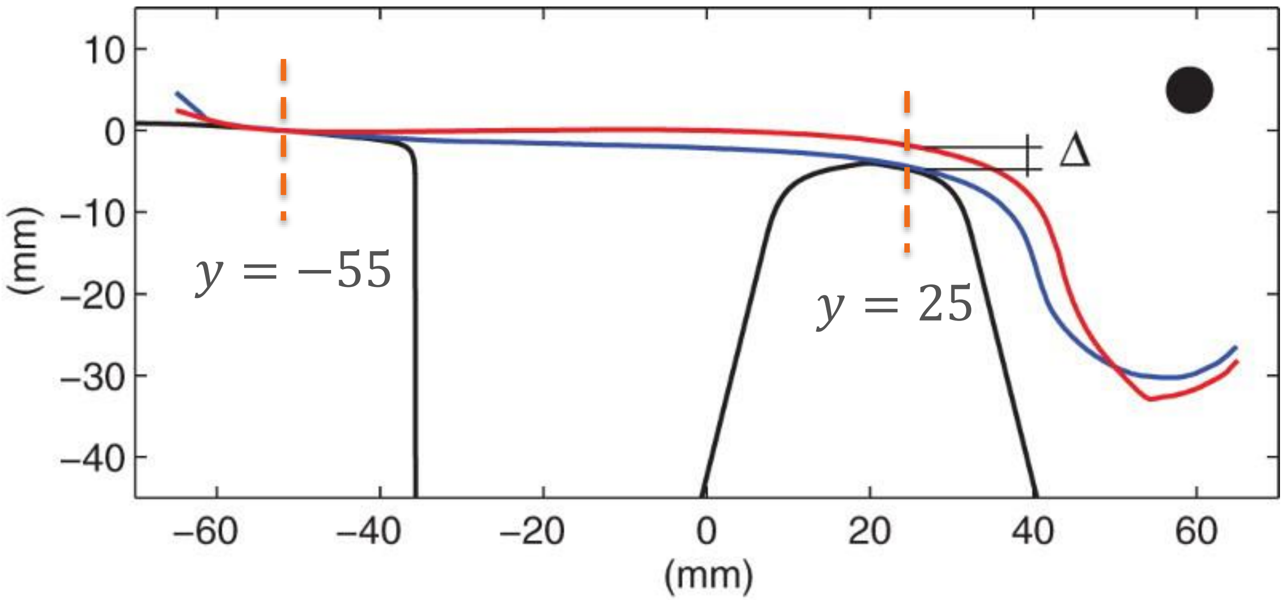
Spread in wheel profile geometry



$$\Delta_z = z_{wp}(y = -55) - z_{wp}\ (y = 25)$$

$$\Delta = \Delta_{z,max} - \Delta_{z,min}$$

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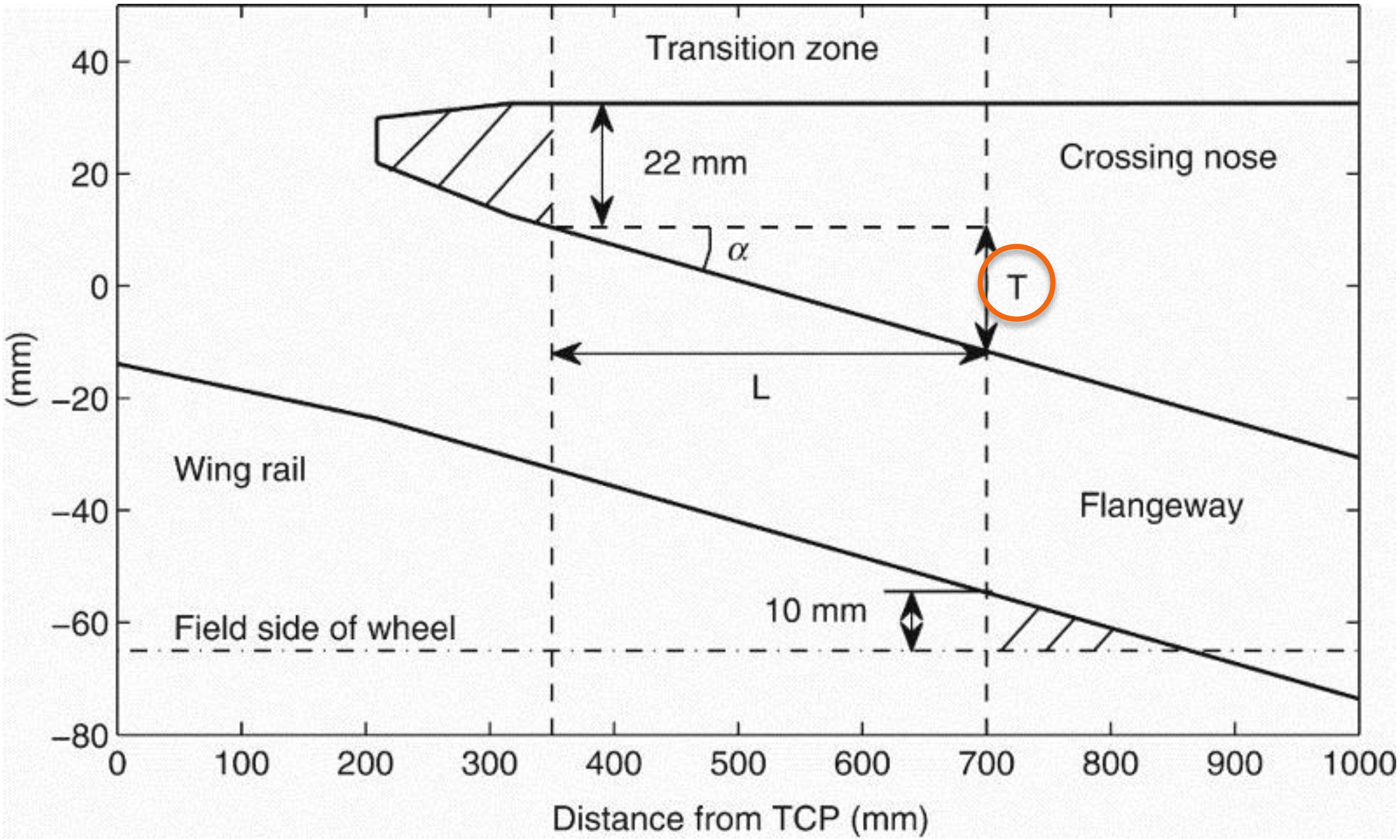
Change in crossing nose thickness



$$\alpha \approx \frac{T}{L}$$

$$T \approx \alpha L$$

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Research Question

- The $\bar{\beta} = \frac{\alpha\Delta}{T}$ relation was derived using geometrical reasoning
- Can the same or a similar relation be dervied using a more mathematical description of the wheel-crossing interaction?
- This will now be investigated using linear descriptions of contact point locations and wheel profiles

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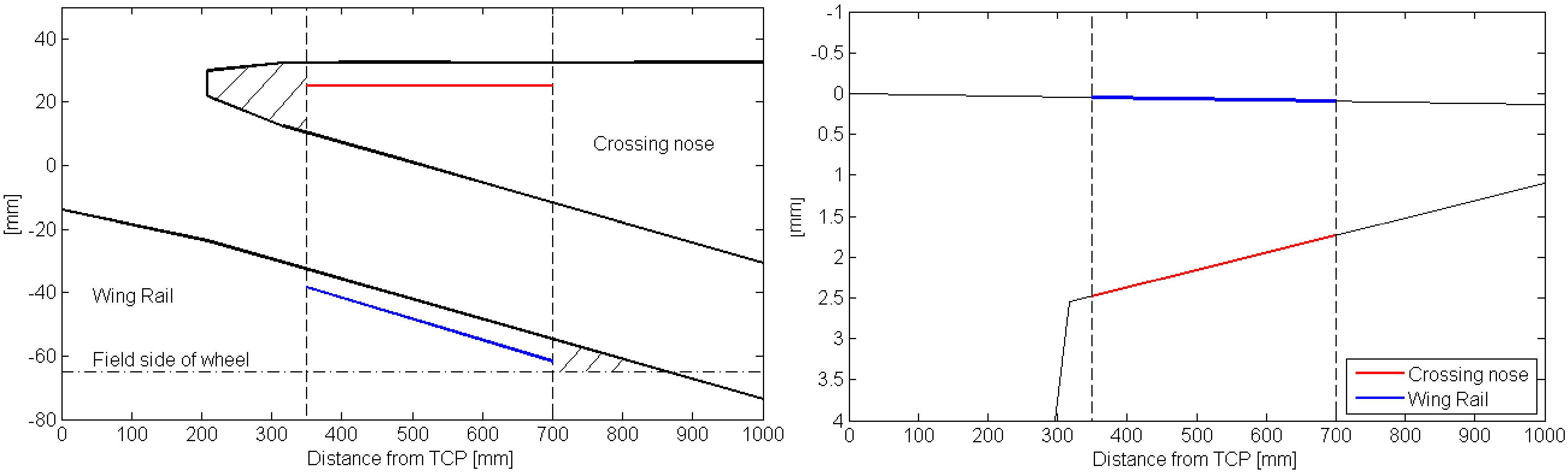
Line Contacts

Contact point trajectories



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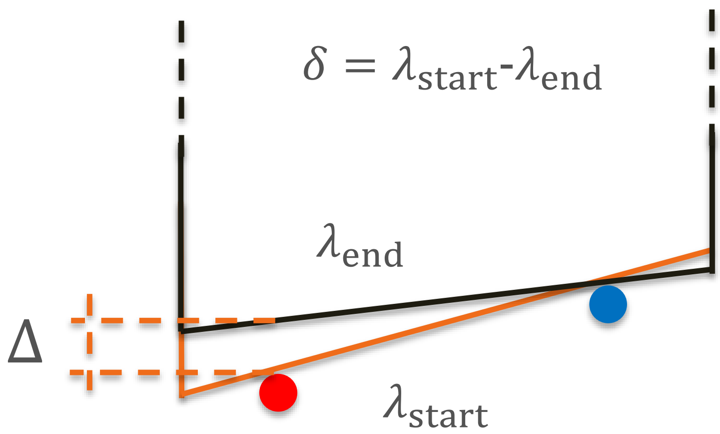
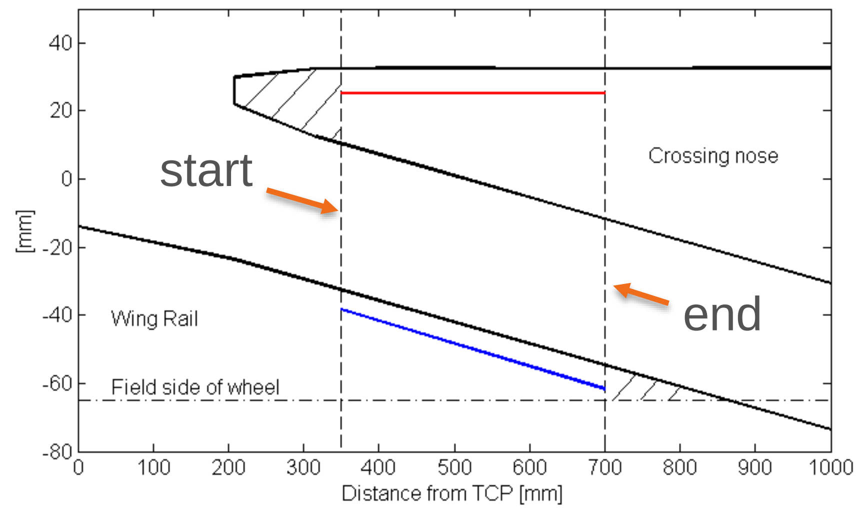
Conical wheels





The longitudinal level of crossing nose and wing rail are adjusted such that the λ_{start} and λ_{end} wheel profiles have their transition points at the beginning and end of the defined transition zone.

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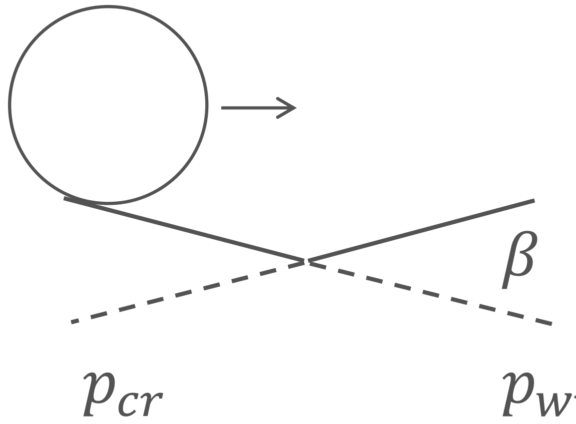
Equations



$$p_{wr} = z_{cp,wr}(x) - z_{wheel,wr}(x) = K_{wp}t + \lambda(t - m_{wr,y}) \quad \{t = \alpha x\}$$

$$p_{cr} = z_{cp,cr}(x) - z_{wheel,cr}(x) = K_{cr}t + m_{cr,z} - \lambda m_{cr,y}$$

$p_{wr} = p_{cr}$ Gives the transition point x_{trans} for a given λ

$$\beta = \frac{dp_{wr}(x_{trans})}{dx} - \frac{dp_{cr}(x_{trans})}{dx} = \cdots = \alpha(\lambda + K_{wr} + |K_{cr}|)$$

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Equations

- By specifying that
  - the λ_{start} and λ_{end} wheel profiles have their transition points at the beginning and end of the defined transition zone.
  - the average slope of the vertical wheel trajectory is equal on both wing rail and crossing nose.
- Constants K_{wr}, K_{cr} and $m_{cr,z}$ can be determined to ”tailor” a crossing for the given range of wheel profile shapes

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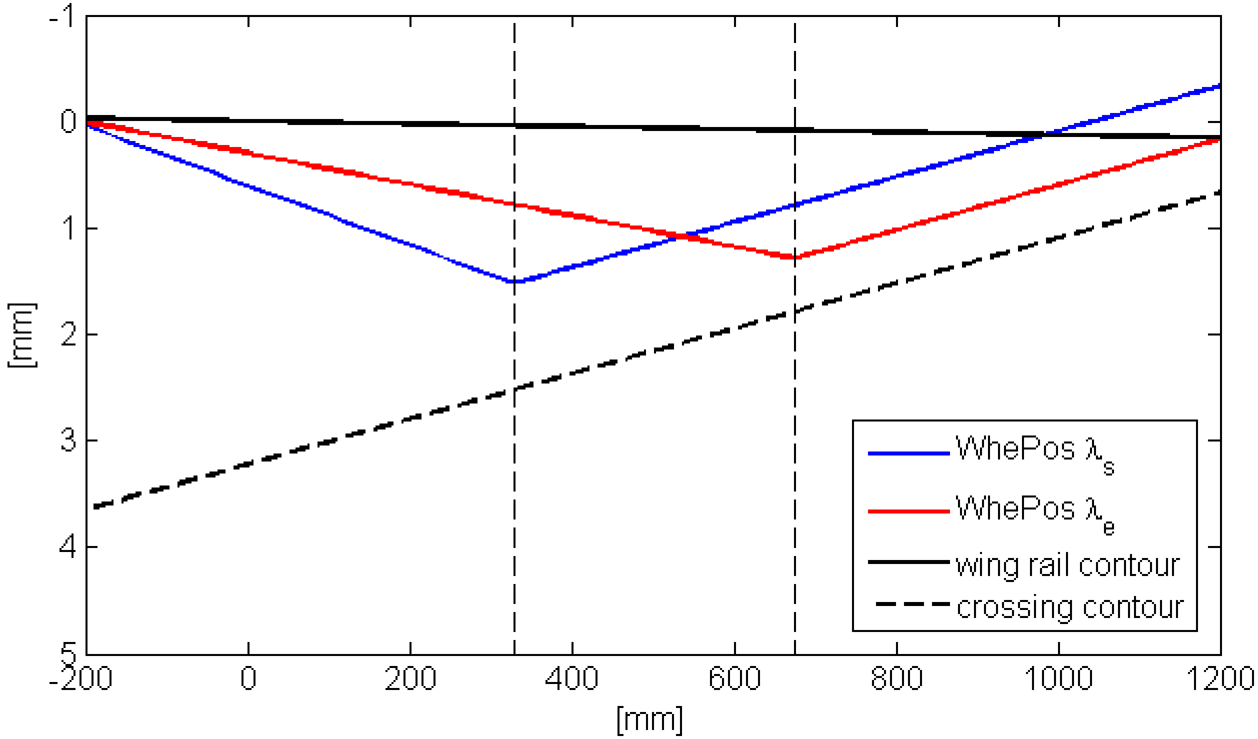
Vertical Wheel Trajectories

Using the derived equations, we can calculate the vertical wheel trajectories for the given wheel profiles



$$\lambda_s = 1:25$$
$$\lambda_e = 1:50$$

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Average Impact Angle

…And the average crossing impact angle

Geometry constant
(from line contact descriptions.)

Crossing Angle

$$\bar{\beta} = \alpha\delta\left(\frac{k}{T} + \frac{1}{2}\right)$$

Crossing nose thickness change

Range of wheel profile cone angles

Compare

$$\bar{\beta} = \frac{\Delta\alpha}{T}$$

Using representative numerical values, the difference in results between these equations is less than 10%

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Summary

- Previously derived relation for the average crossing impact angle has been verified
- It is proposed that simple analytical models could be used to guide crossing design based on the range of wheel profile shapes in traffic
- Result are reported in I2R D2.5

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The End

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Assuming that the average distance between contact points on the crossing nose and wing rail is 80 mm, the relation between δ and Δ becomes $\Delta = 80\delta$ if δ is measured in radians. Using the parameter values $\alpha=1/15$, $T=23$mm and $\Delta=3$mm, the β-value calculated from (5) becomes 8 mrad. Using the corresponding δ-value and $k=62$ (based on contact point trajectories in the Appendix), the $\bar{\beta}$-value calculated from Equation (6) becomes 8.7 mrad.

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Assessment Methods

- The risk of derailment was investigated using MBS in SIMPACK
- The risk of interference contact was assessed using SIMPACK and a kinematic study in GENSYS

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Equations

- By
  - Specifying that the λ_{start} and λ_{end} wheel profiles have their transition points at the beginning and end of the defined transition zone.
  - Specifying that the average slope of the vertical wheel trajectory is equal on both wing rail and crossing nose.
- Constants K_{wr} and K_{cr} can be solved for as

$$K_{cr} = \delta\left(\frac{m_{wr,y} - m_{cr,y} - t_s}{2T} - \frac{1}{4}\right)$$

$$K_{wr} = \frac{\delta}{2} - K_{cr} - \lambda_s$$

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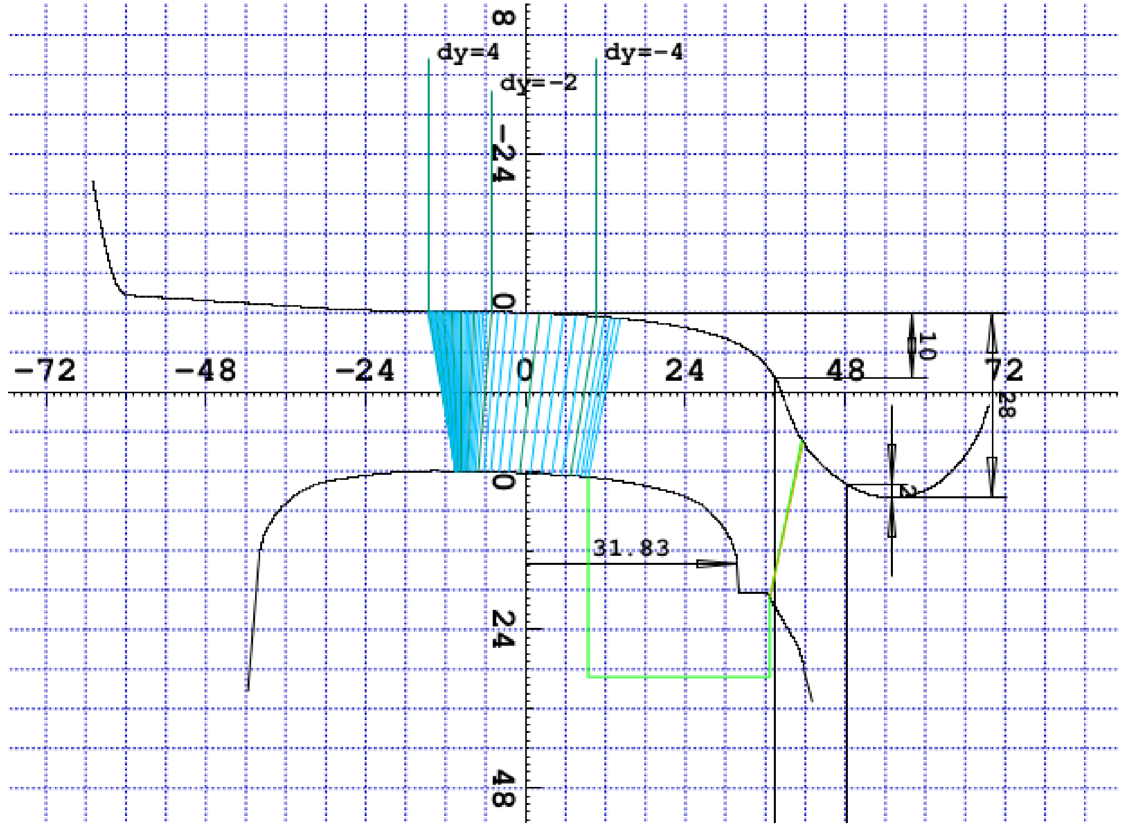
Method

- Gensys KPF



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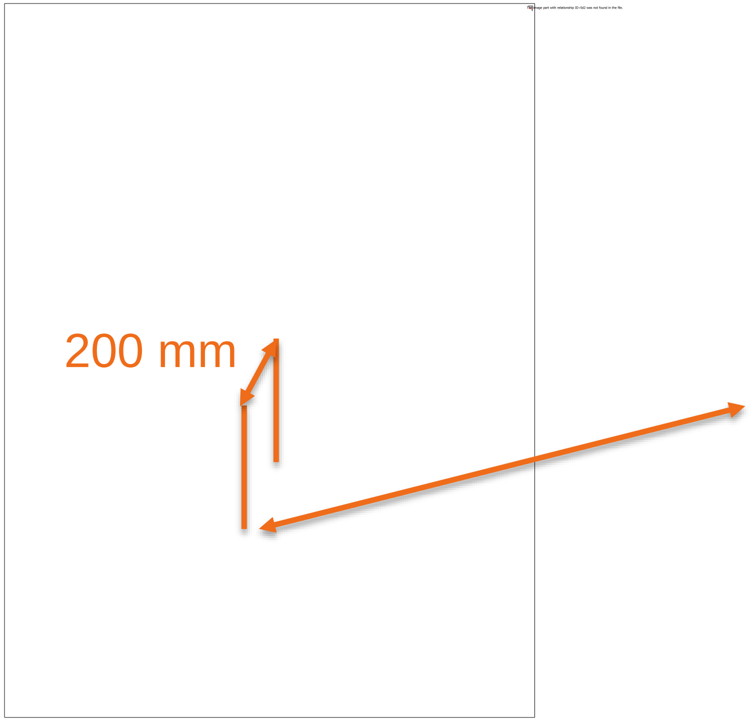
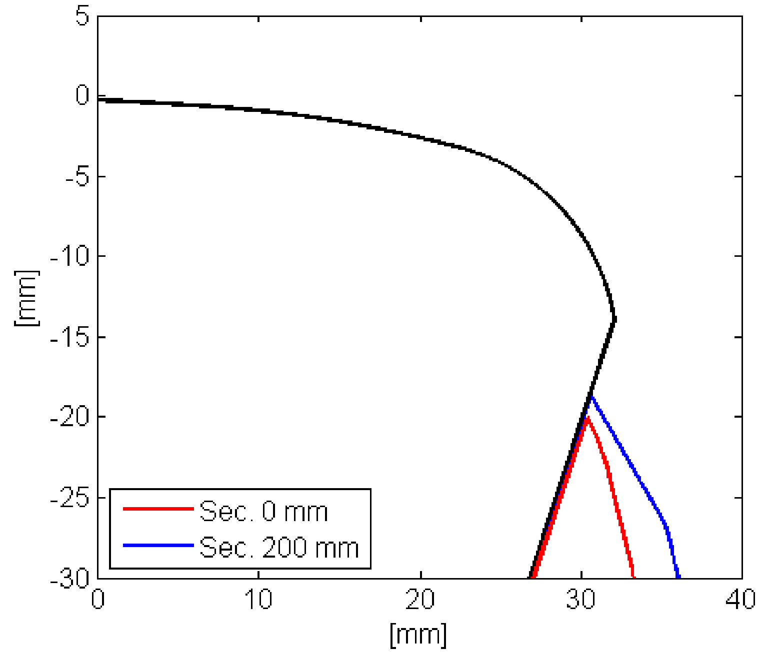
Sections of Interest





Sections from TRV drawing 9-511401

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Results

S1002

Wheel profiles in contact

Delta [mm]	1	2	3	4	5	6	7
Sect 0, Inc. 0	0	0	0	0	0	1	1
Sect 0, Inc. 1:30	0	0	0	0	0	1	1
Sect 200, Inc. 0	0	0	0	0	1	1	1
Sect 200, Inc. 1:30	0	0	0	1	1	1	1

WP Sample (120 profiles)

Delta [mm]	1	2	3	4	5	6	7
Sect 0, Inc. 0	0	0	0	0	82/120	119/120	120/120
Sect 0, Inc. 1:30	0	0	0	27/120	107/120	120/120	120/120
Sect 200, Inc. 0	0	0	24/120	104/120	120/120	120/120	120/120
Sect 200, Inc. 1:30	0	0	69/120	119/120	120/120	120/120	120/120

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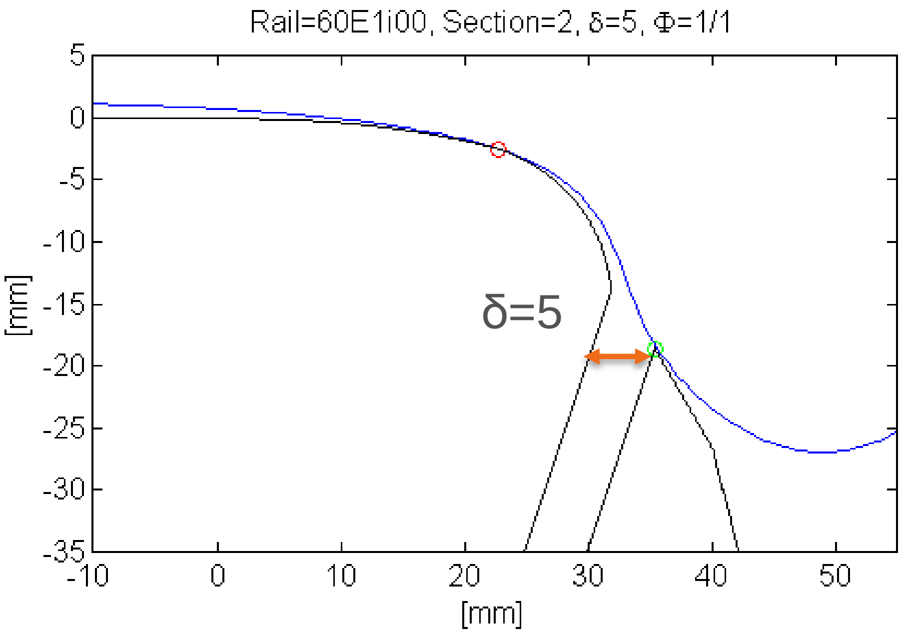
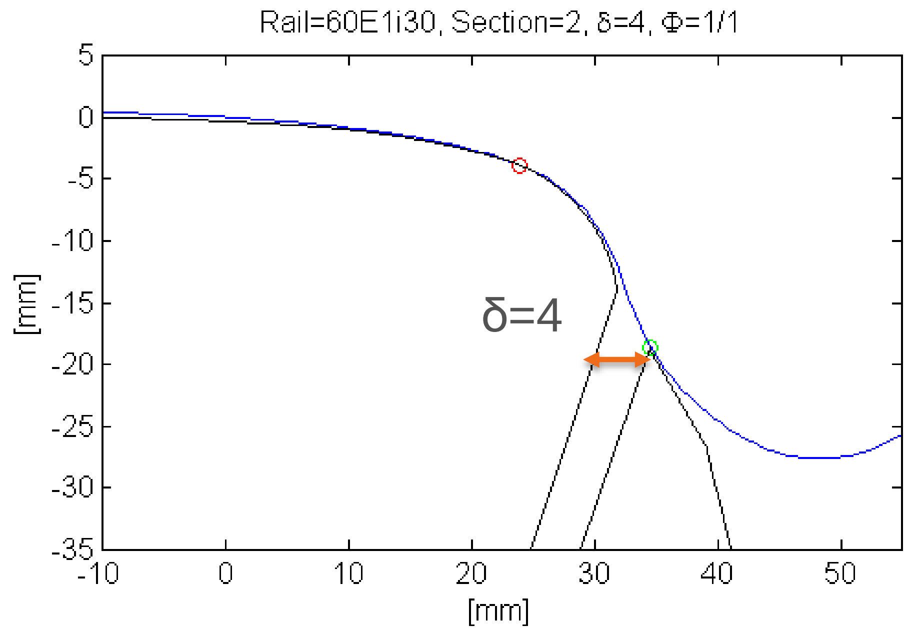
Results S1002



S1002, 60E1i00



S1002, 60E1i30

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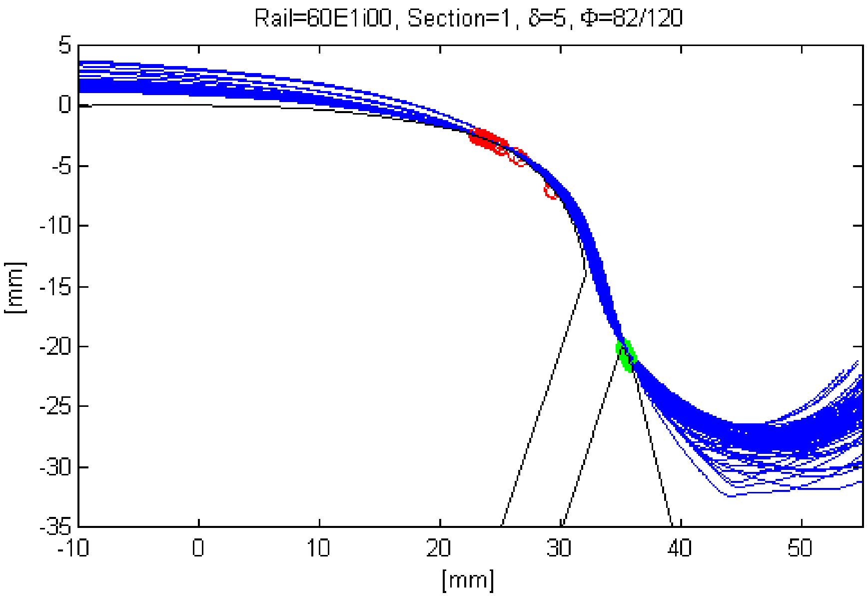
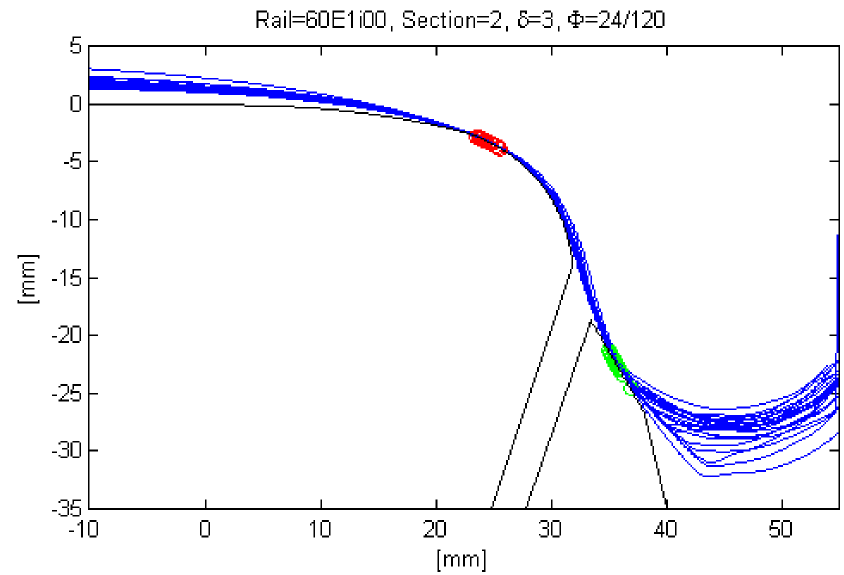
Examples Measured WP:s



Pos 0



Pos 200

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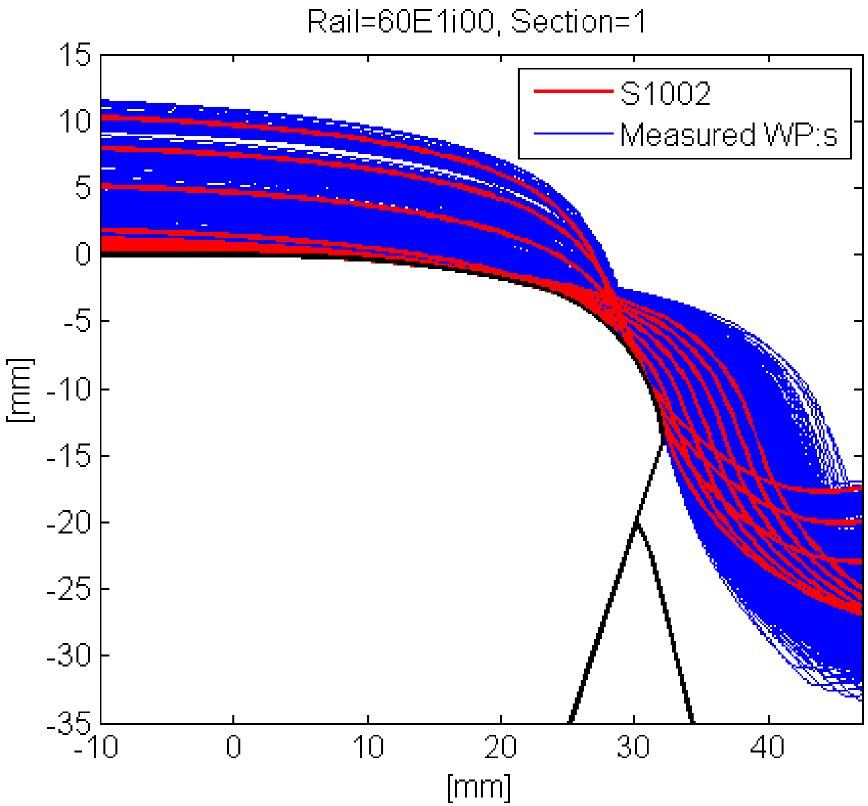
S1002 vs. Measured Profiles



Worn wheel profiles are worse compared to the nominal due to higher flange and smaller flange angle

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