Numerical studies of the influence of laterally deteriorated track geometry on track shift forces and RCF in freight operations

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Outline

Background

Numerical investigation tools

- Multibody simulations

Track shift force predictions based on multibody simulations

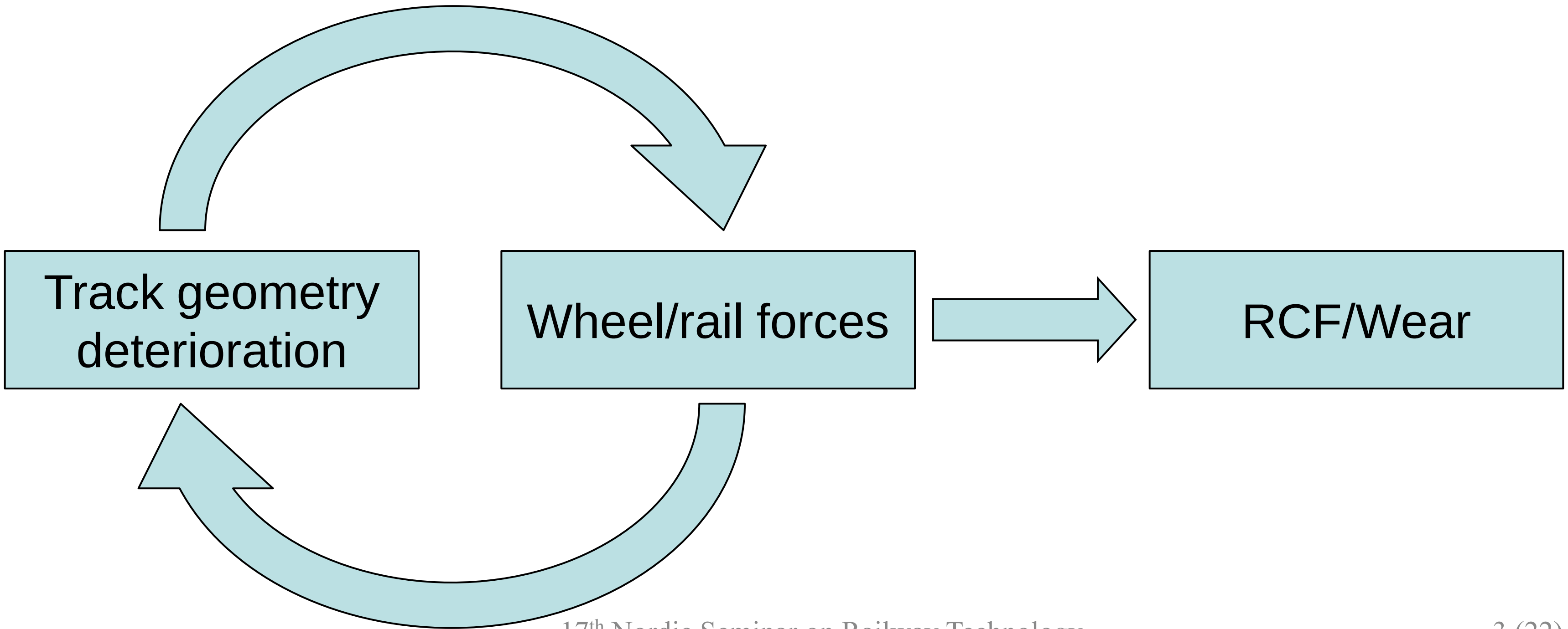
- Normal distribution of lateral track irregularities
- Normal distribution of track shift forces
- Relationship between irregularities and track shift forces

RCF predictions based on dynamic multibody simulations

- Irregularities generated from PSD
- Amplification of irregularities in wavelength spans

Background

- Optimisation of maintenance
- Development of predictive models for optimisation and maintenance actions
- Understanding and quantifying the deterioration of key components



Numerical investigation tools

Multibody simulations

- Multibody simulations performed in GENSYS
- Vehicle model originally developed and verified by T. Jendel

(T. Jendel , Dynamic analysis of a freight wagon with modified Y25 bogies, MSc thesis, Department of Vehicle Engineering, Royal Institute of Technology, Sweden, 1997)

Freight wagon with Y25-bogies

Multibody simulations (cont.)

- Vehicle speed 100 km/h
- Nominal wheel profiles (ENS1002t32.5)
- Rail profile 50E3 with 1:30 inclination
- Static wheel load 125 kN

Freight wagon with Y25-bogies

Photo from
www.kockumsindustrier.se

Track shift forces

Track geometry

Definition of track irregularities:

- Lateral irregularities = line = mean value of lateral irregularities of left and right rail
- Vertical irregularities = longitudinal level = mean value of vertical irregularities of left and right rail

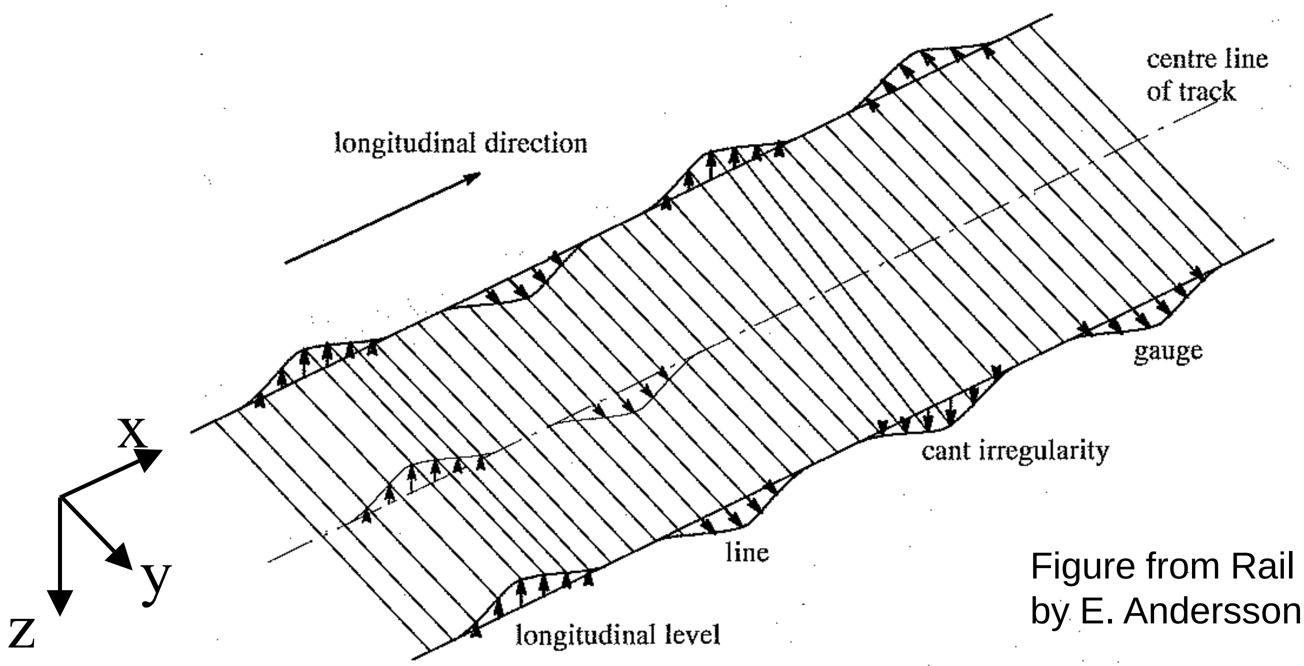
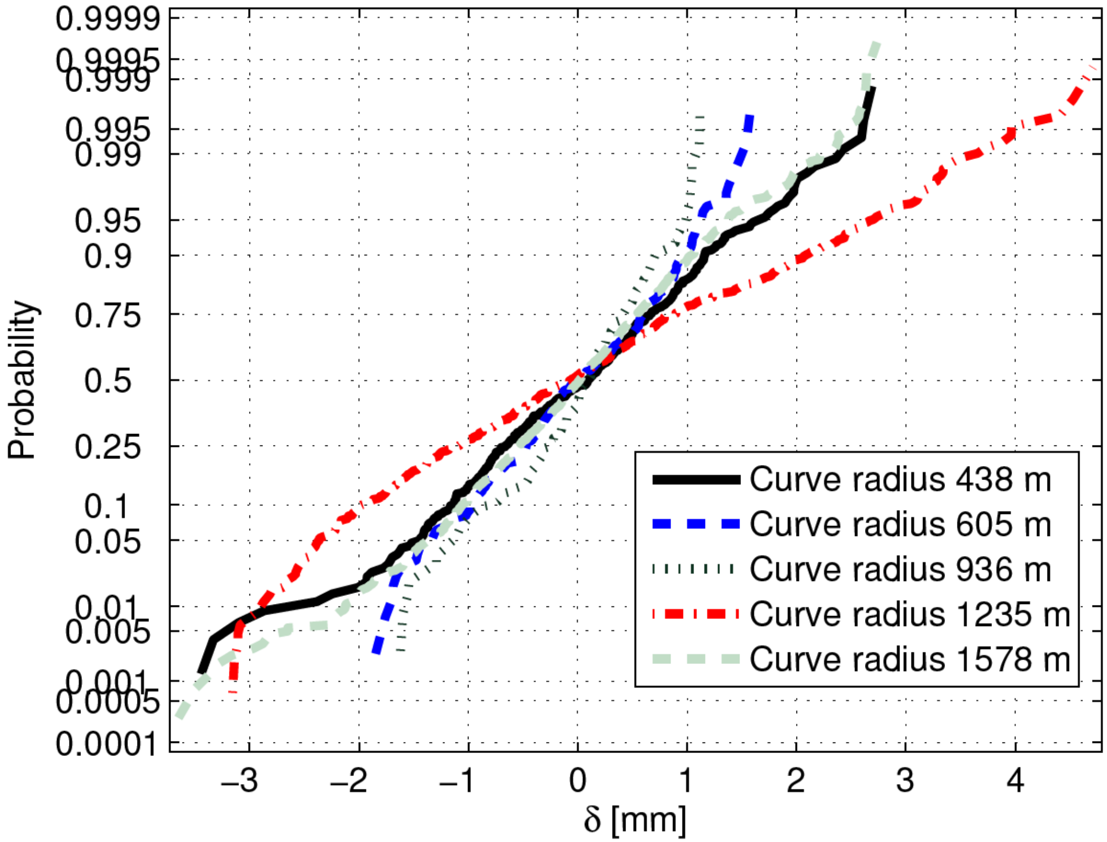


Figure from Rail Vehicle Dynamics
by E. Andersson, M. Berg & S. Stichel

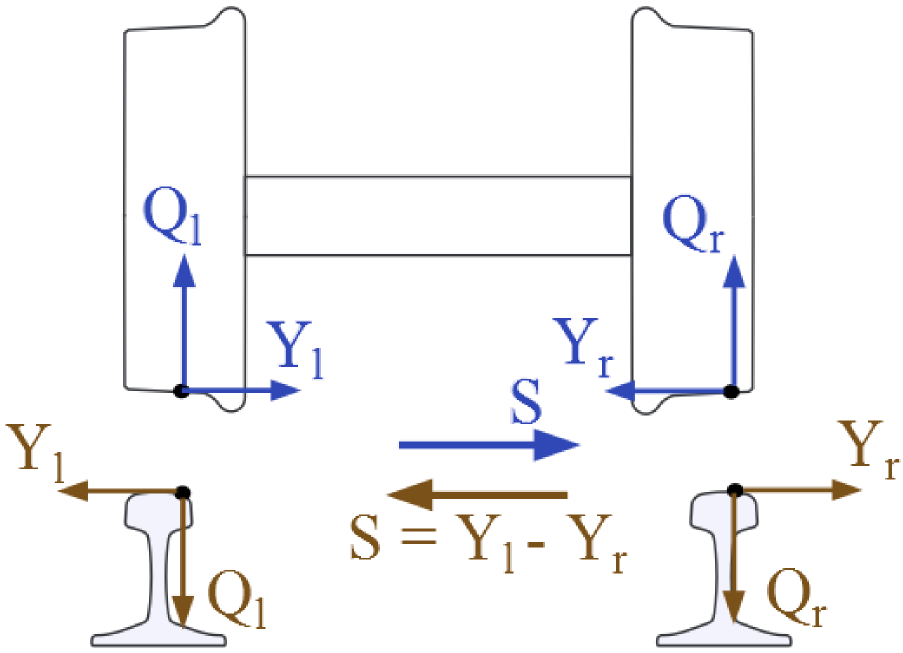
Normal distribution of irregularities

- Measured lateral (line) irregularities follow a normal distribution
- Measurements from the Iron Ore Line



Track shift forces

- Defined as $S = Y_l - Y_r$, where Y_l and Y_r are the lateral wheel loads
- Evaluated as 2 meter moving average (S_{2m})
- Presented track shift forces from the leading axle in the first bogie



View from behind

Track shift forces

Right hand curve with radius 438 m

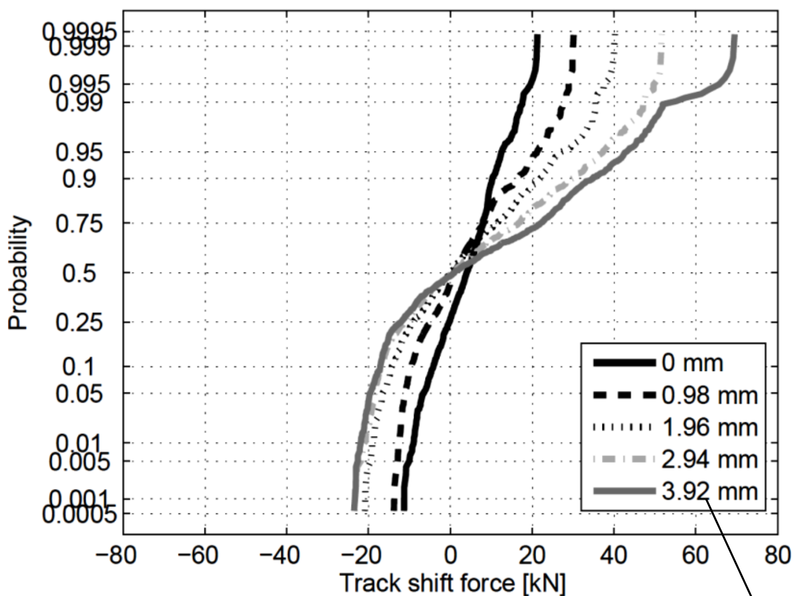
Speed 80 km/h

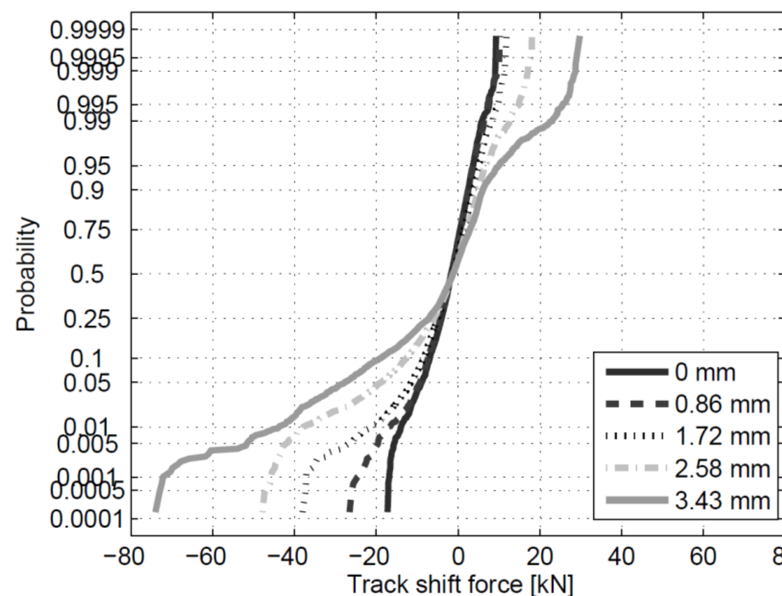
Cant deficiency 83 mm

Left hand curve with radius of 1578 m

Speed 100 km/h

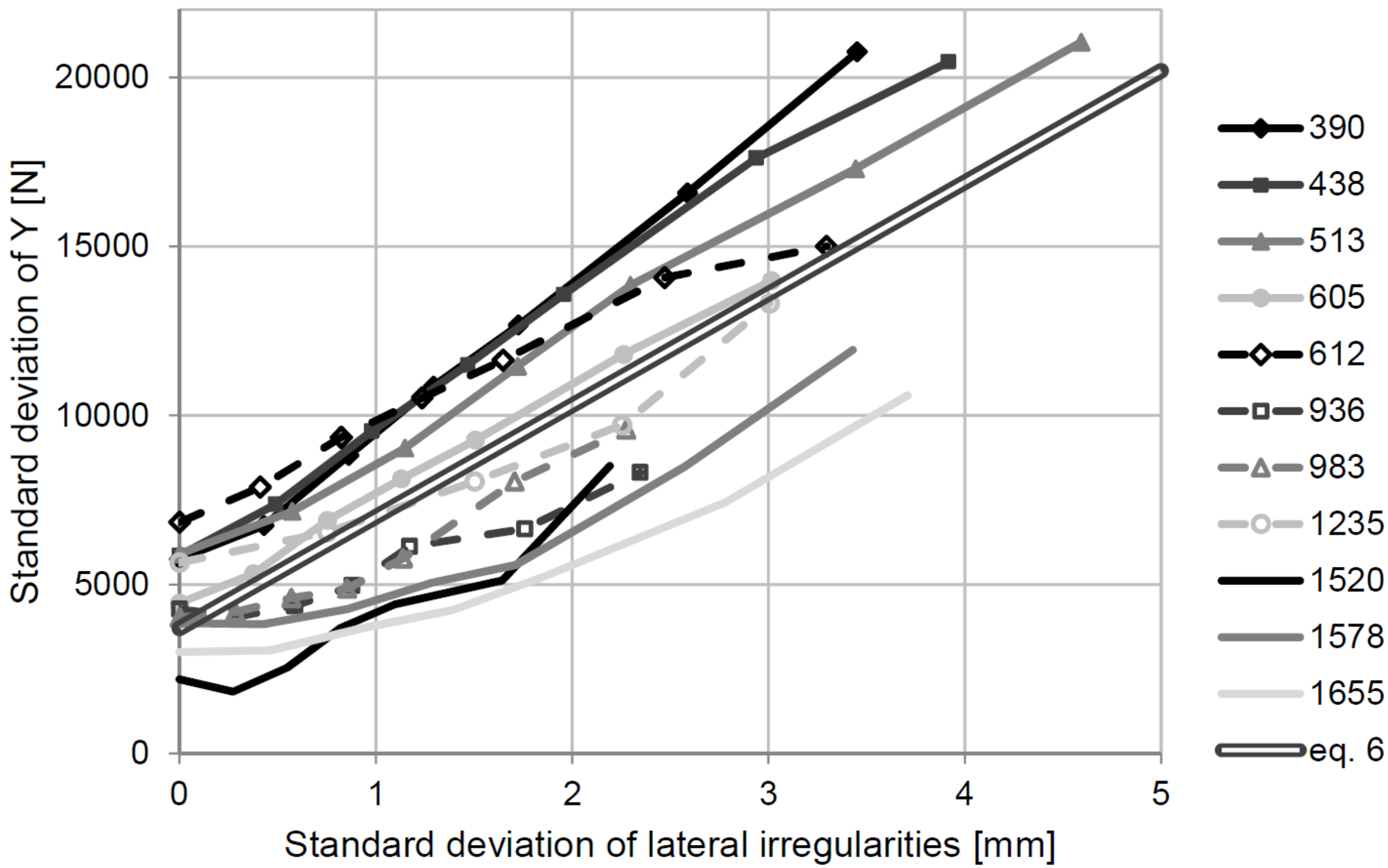
Cant deficiency 50 mm





Standard deviation of lateral irregularities

Track shift forces



eq.6 $s(Y) = 3.3 \cdot s(\delta) + 3.7$, where $s(Y)$ standard deviation of track shift forces [kN] and $s(\delta)$ the standard deviation of lateral irregularities [mm]

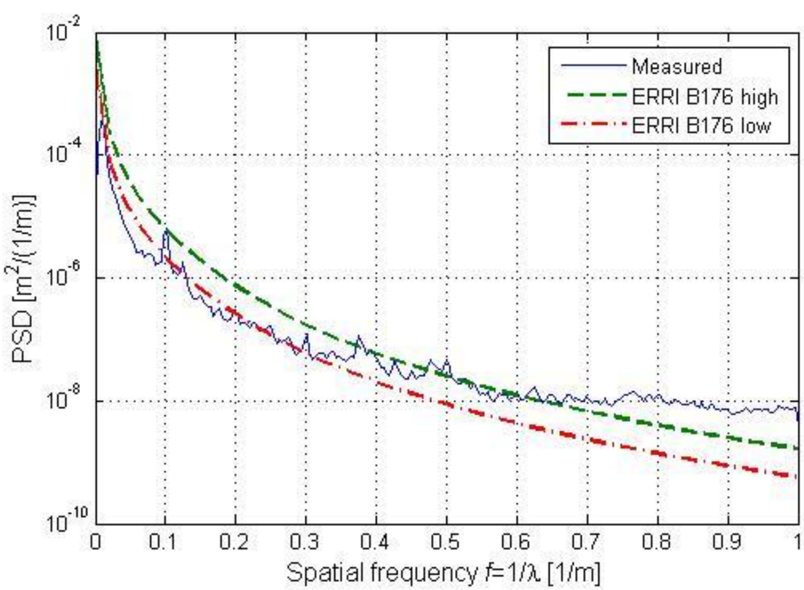
Conclusions (track shift forces)

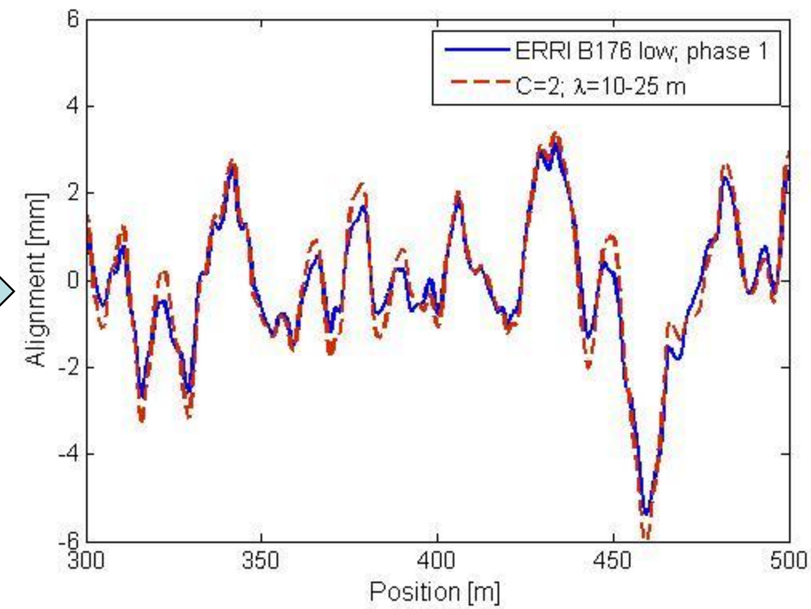
- Track shift forces follow a normal distribution for moderate levels of lateral irregularities
- A roughly linear relationship between the standard deviations of the lateral irregularities and track shift forces

RCF predictions based on dynamic multibody simulations

Generation of irregularities

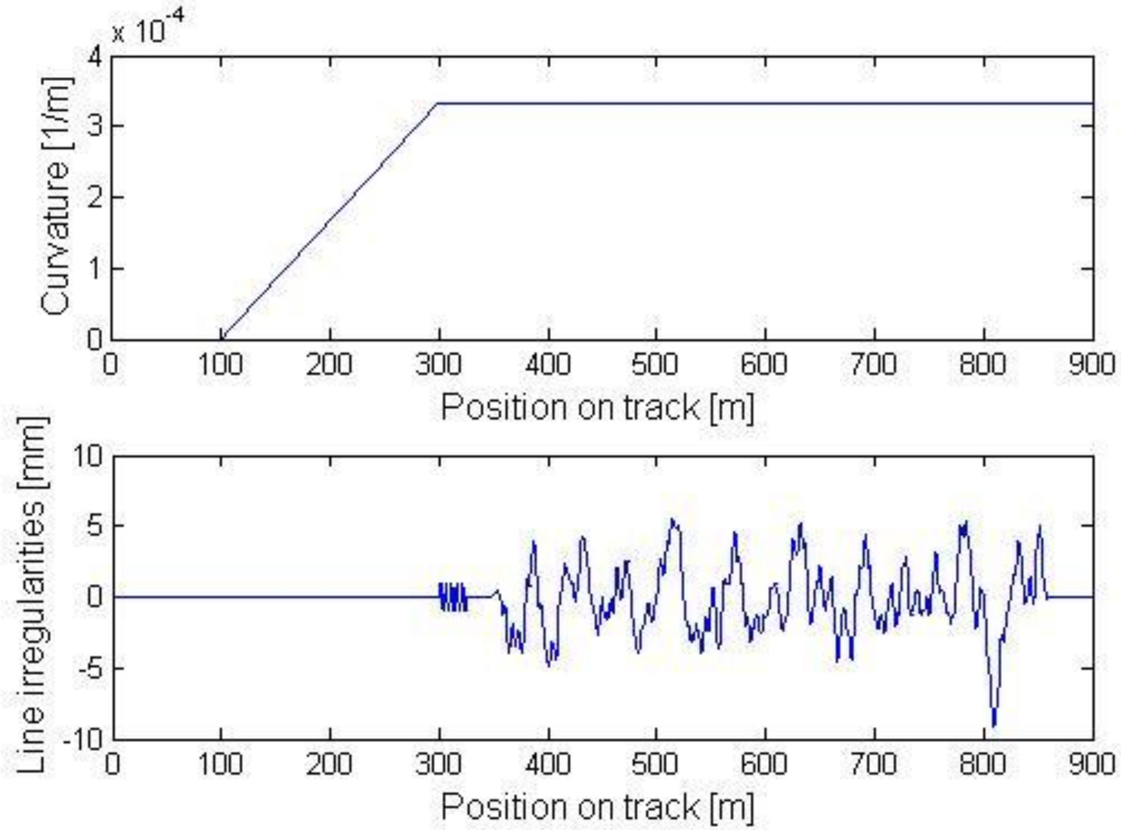
- Random lateral irregularities generated from power spectral densities (PSD)
- PSD:s from ERRI B176 RP1, Preliminary studies and specifications – specification for a bogie with improved curving characteristics, Utrecht, Netherlands, 1989





Track geometry

- Curves with radii between 500 to 3000 metres with lateral irregularities.
- Cant deficiency kept constant at 39 mm.



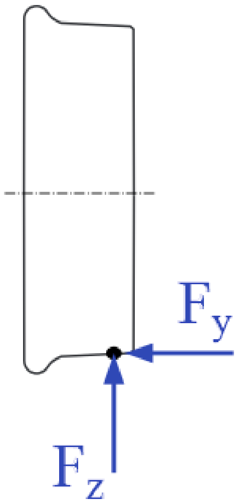
RCF indices

- Surface initiated RCF with a shakedown map based criterion

  (A. Ekberg, E. Kabo and H. Andersson, *An engineering model for prediction of rolling contact fatigue of railway wheels*, Fatigue & Fracture of Engineering Materials & Structures, vol 25, pp 899-909, 2002.)

  $$FI_{\mathrm{surf}} = \mu - \frac{2abk}{3F_{\mathrm{z}}}$$

  $$\mu = \frac{F_{\mathrm{lat}}}{F_{\mathrm{z}}} = \frac{\sqrt{F_{\mathrm{x}}^{2} + F_{\mathrm{y}}^{2}}}{F_{\mathrm{z}}}$$

  a and *b* are the semi axes of the contact point

  k is the yield stress in pure shear

- RCF damage

  (E. Kabo, A. Ekberg, P. T. Torstensson and T. Vernersson, *Rolling contact fatigue prediction for rails and comparisons with test rig results*, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Volume 224, pp 303-317, 2010.

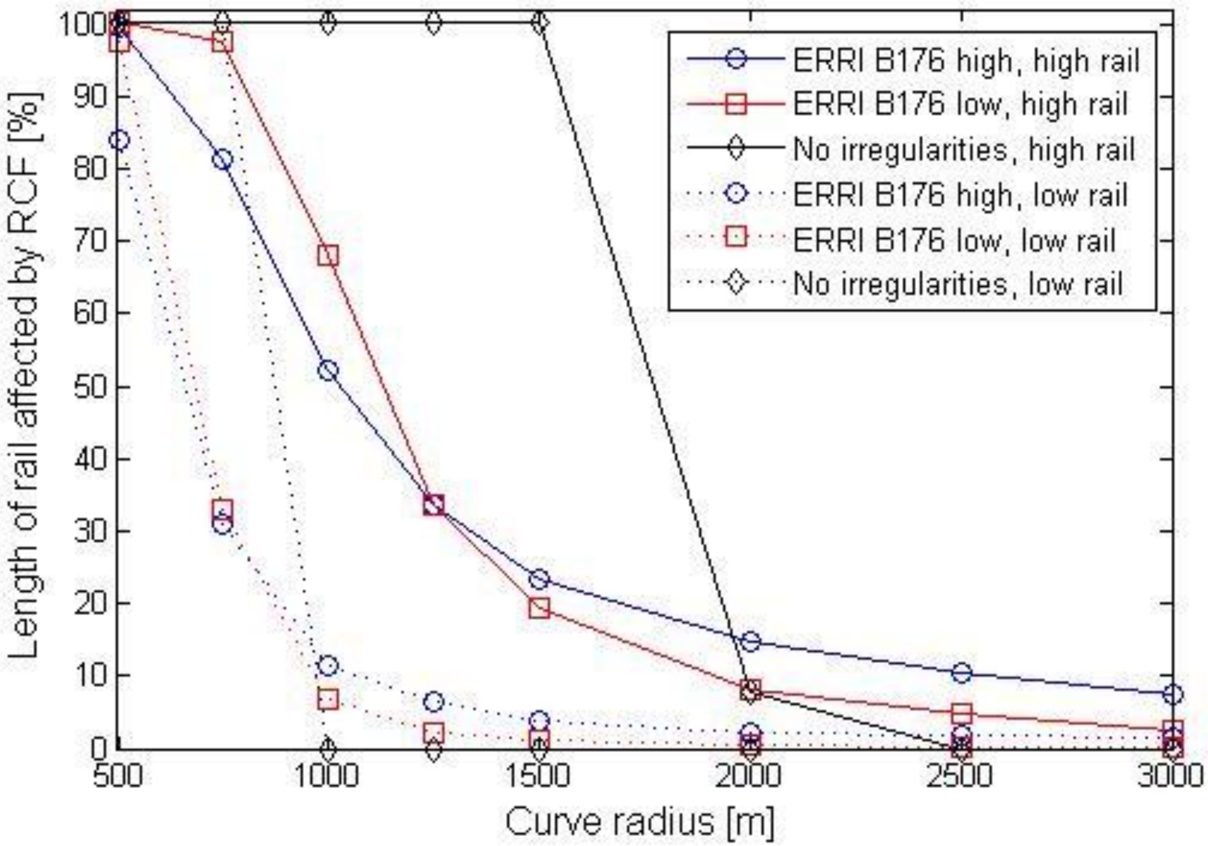
  $$D_{\mathrm{surf}} = \frac{\left(FI_{\mathrm{surf}}\right)^{4}}{10} \quad \forall FI_{\mathrm{surf}} \geq 0$$

- Predicted RCF damages are for the leading axle of the first bogie

Rolling contact fatigue

Freight wagon negotiating curves with lateral irregularities generated from PSD:s. Cant deficiency 39 mm.

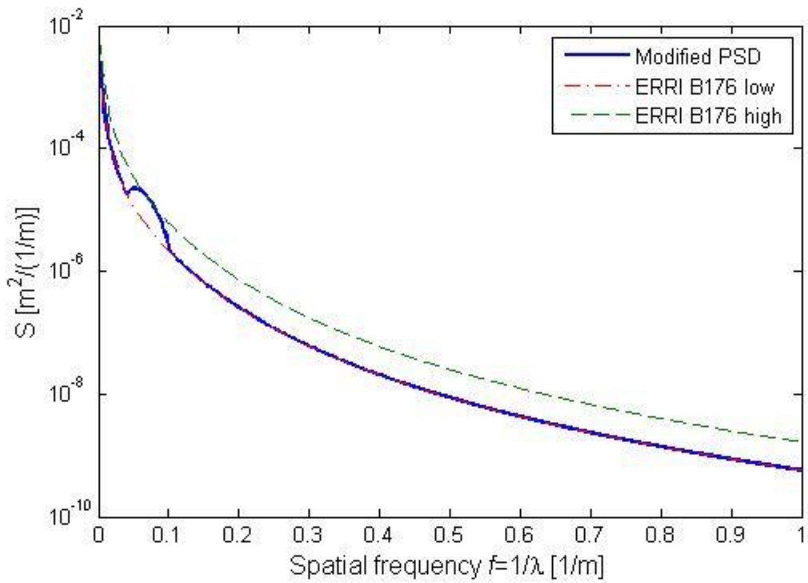
Length of rail with predicted RCF damage

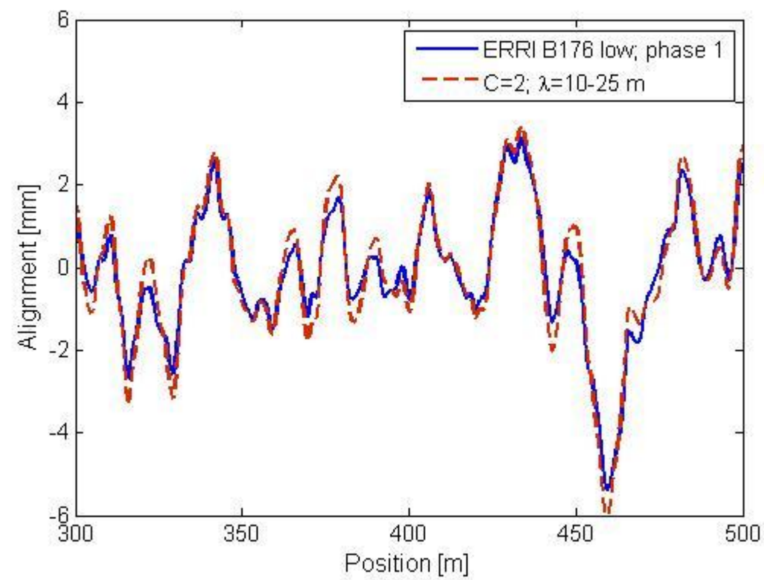


Modification of PSD:s

Modification of the ERRI B176 PSD:s

to amplify irregularities in wavelength spans

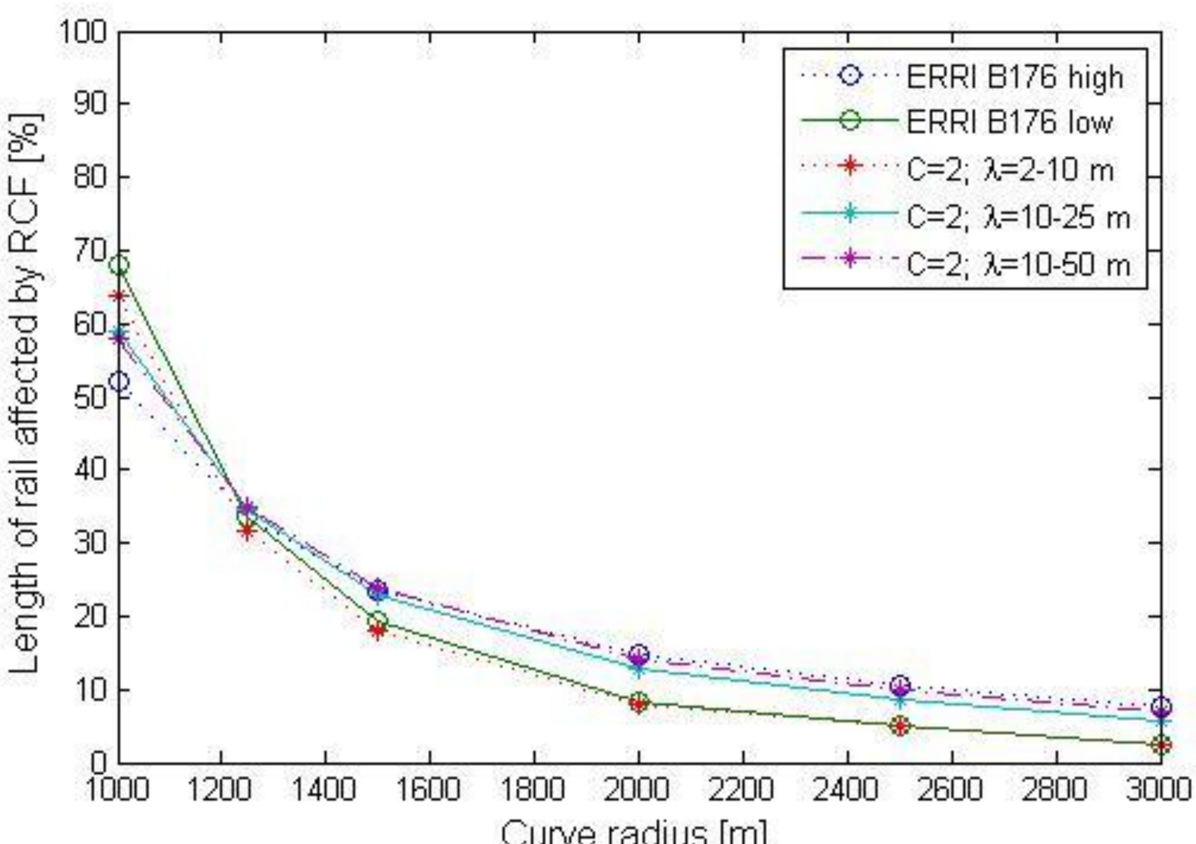




Rolling contact fatigue

Freight wagon negotiating curves with generated lateral irregularities from modified PSD:s.

Length of rail with predicted RCF damage



Conclusions (RCF)

- At sharp curves the portion of the track affected by RCF decreases with increasing magnitude of lateral irregularities
  - Degradation mechanism shifts from wear to mixed wear/RCF
- At shallow curves the portion of the track affected by RCF increases with increasing lateral irregularities
- For shallow curves the most efficient RCF mitigation measure is to reduce the longwave content of the lateral irregularities

Thanks for your attention!