Optimization of Crossing Geometry in Railway Turnouts

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Introduction

Damage on running surface of crossing nose

RCF due to severe impact loads

wheel passing a crossing

vertical wheel movement

vertical contact force

point of transition

Photo: DB AG (A. Zoll)
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Elastic track model (FEM) implemented in SIMPACK (user routine of DB Netz AG)
Comparison of measured and simulated vertical contact forces of two passing wheels

Summation: \[ Q = T_0 + R_1 + R_2 + T_3 \]
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Optimization of geometry

Crossing geometry „Kinked Ramp“ for EH 60-500-1:12 (Trajectory of profiling tool)

All measures given in mm.
Optimization of geometry

Crossing geometry „MaKüDe“ for EH 60-500-1:12

Wheel profile S1002
Comparison of vertical wheel movement (quasi-static)

Vertical wheel movement

Distance [m]

Vertical displacement [mm]

Kinked ramp (S1002)  Kinked ramp (worn)  Kinked ramp (short)  Wing rail MaKüDe (S1002)  Wing rail MaKüDe (worn)  Current standard (S1002)  Current standard (worn)  Current standard (hollow worn)

Begin of wing rail
Nose tip
Wheel transition
End of crossing nose
Facing move
Evaluation of Contact Stresses

MBS simulation

Creepages, Friction coeff., Penetration in contact patch

3D Stress calculation

CONTACT (Prof. J. J. Kalker)

DB Netz AG, Dirk Nicklisch, I.NVT 8
Calculation of equivalent contact stresses according to v. Mises

\[
\sigma_e = \sqrt{\frac{1}{2} \left[ (\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2 \right] + 3 \cdot (\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2)}
\]

(Figures from PhD thesis of Dr. André Theiler, IfB Berlin [1])
Discussion of simulation results

Normal forces and equivalent stresses in relation to Standard geometry

![Bar chart showing normal forces and equivalent stresses](chart.png)
Discussion of simulation results

Time histories of Normal force and von Mises stress

- Normal force
- Equivalent stress

Distance [m]

Normal force [kN]

von Mises stress [MPa]

Running direction (facing move)
Overview

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Simulation methodology

I. Simulation of dynamics

II. 3D elasto-plastic contact simulations

III. Summation and smoothing of total profile change
   a) Plasticity calculation
   b) Wear calculation

Source: CHARMEC, see [2]
Parameter variation

Simulation Schedule

- Facing move on through route
- Stochastic vehicle parameters:
  - Six different wheel profiles
  - Three lateral wheel positions
  - Three vehicle speeds: 90, 120, 160 km/h
  - Two vehicle types: BR101 and BR411
- \(6 \cdot 3 \cdot 3 \cdot 2 = 108\) possible combinations
- Creation of a sample set based on estimated probability distributions
- Reduction of sample size by Latin Hypercube Sampling

Wheel profiles

Initial lateral wheel positions on crossing entry
Simulation results

Comparison with field measurements

• Degradation rate is larger during the first weeks after installation and then it seems to stabilise

• Comparison of measured and simulated profiles after five weeks of traffic

• Good qualitative agreement
  - Largest degradations found for similar longitudinal positions along crossing nose
  - Same order of degradation magnitude
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Conclusions

- Optimization of crossing geometry is essential to reduce the dynamic loads and consequently the Life Cycle Cost of railway turnouts.
- The simulation model developed by DB has been successfully validated by wayside force measurements on an in-service crossing of type EH 60-500-1:12.
- When comparing different crossing designs the maximum equivalent stresses calculated with CONTACT may show different trends than the maximum normal forces as the locations of the maximum stresses may differ significantly from those of the maximum forces.
- For relevant conclusions regarding material degradation the elasto-plastic material behavior has to be taken into account using calibrated non-linear material models.
- The related simulation methodology developed in INNOTRACK has been demonstrated on a crossing of R350HT steel showing good qualitative agreement between simulation and measurement after five weeks of train traffic.
Future work

Remaining tasks

- Validation of simulation methodology for a longer period of operation (done for 5 weeks of traffic only)
- Investigation of 3 different crossing materials regarding plastic deformation and wear
- Further improvement of crossing geometry „MaKüDe“
- Comparison of long-term degradation of innovative crossing geometries
Thank you for listening!

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