Computational Investigation of Railway Track Geometry and its Dynamic Assessment

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• TGA - Track Geometry Assessment Method
• Results & Discussion
• Conclusion
Introduction and Problem Description

Life cycles of automotive and railway vehicles

Different operational conditions need to be considered

Average Values

- **Innov. cycle [years]**
- **Life cycle [years]**
- **Running performance [mio kms]**

Sources:
Statistik Austria 2006
MAN Truck & Bus AG
Siemens AG
Railway specific conditions

Similar like roadway – automobile interactions, railway track geometry significantly affects

- Vehicle durability and driving safety.

However, railway specific conditions have to be taken into account:

- No prototype testing available during development phase,
- Vehicle development guided by experience and computation,
- Final acceptance testing run must be passed.

Source: ÖBB
Railway specific conditions

Further restrictions should be overcome:

- *Improvement of comparability* of different testing tracks,
- *Improvement of objective assessment* of track geometry quality with respect to operational safety and track maintenance,
- *Improve “railway interoperability”* in EU.

- Existing track geometry standards are pure static ones.
- Proposed approach: Enhanced track geometry assessment by consideration (inclusion) of *track induced dynamics*.

Source: DB AG
Introduction and Problem Description

Overview of the vehicle/track system

Track geometry parameters:
- \( z \) ... Longitudinal level
- \( y \) ... Alignment
- \( \delta \) ... Cross level

Wheel/Rail contact forces:
- \( Q \) ... Vertical force on track
- \( \Sigma Y \) ... Sum of lateral forces of one wheelset on track

Correlation?
Assessment values for running behaviour

- Running safety (EN 14363):
  - Sum of guiding forces $\Sigma Y$ of a wheelset
  - Quotient $Y/Q$ of guiding force/wheel force

- Track loading (EN 14363):
  - Wheel force $Q$ und guiding force $Y$

Assessment values for track geometry quality

- Testing for the acceptance of running characteristics of railway vehicles (EN 14363 - Annex C):
  - Maximum values und standard deviation
  - Quality levels (QN) for the test track

→ Expert Experience: Insufficient correlation between these assessment values (Track geometry ↔ Running behaviour)

→ Project Aim: Development of a novel method which takes the vehicle/track interaction into account
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TGA (Track Geometry Assessment) Method Overview

**Preliminary stage:** Determination of transfer functions

- MBS simulations
- Set of 'representative' transfer functions

**Application stage:** Estimation of the vehicle response

- Track irregularities
- 'Representative' transfer functions
- Estimated vehicle response

**Application stage:** Assessment of the vehicle response

- Estimated vehicle response
- Evaluation & Classification
Preliminary stage - Overview

**Time (Space) domain**
- Measured excitations
  - $z(s)$
  - $y(s)$
  - $\delta(s)$
- MBS-Model
- Calculated vehicle response
  - $V_z(s)$
  - $V_y(s)$
  - $V_\delta(s)$

**Frequency domain**
- Empirical transfer function
- ETFE

- MBS-Simulations
  - Nonlinear MBS-Models with a high level of detail
  - Measured track irregularities (excitations)
  - Vehicle response due to a 'single input' excitation
- Estimation of the 'empirical transfer function' (ETFE)
- 'Loop' with different measured track irregularities
Determination of a 'representative' transfer function

Passenger coach ($v = 160$ km/h)

- Loop 1
- Loop 2...5

Calculation

Linearized model

Compare

<table>
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<th>Magnitude of the transfer function: $\sum Y_x / y$ [kN/mm]</th>
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</thead>
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</tr>
<tr>
<td>10^0</td>
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<tr>
<td>10^1</td>
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</table>

Wavelength [m]

- Representative transfer function
- $|TF|$ (track excitation Nr. 1)
- $|TF|$ (track excitation Nr. 2)
- $|TF|$ (track excitation Nr. 3)
- $|TF|$ (track excitation Nr. 4)
- $|TF|$ (track excitation Nr. 5)
- $|TF|$ linearized model
Advantages of the MBS Simulation

- 'Single input' excitations are possible
- Cost-efficient (no test runs, no measuring wheelset, ...)
- Availability of a large number of different vehicles
- Investigations concerning the influence of boundary conditions
- Wavelength-specific studies can be performed

Final step of the preliminary stage

- Calculation of categorical 'representative transfer functions'
  - Vehicle type (e.g. Locomotive, Passenger coach, ...)
  - Vehicle speed categories

→ Representative transfer functions for the application stage
Application stage

Estimation of the vehicle response

Track irregularities

\[ z(s) \] \[ y(s) \] \[ \delta(s) \]

'Representative' transfer functions

\[ H_{z\rightarrow V_z}(f_L) \] \[ H_{y\rightarrow V_y}(f_L) \] \[ H_{\delta\rightarrow V_\delta}(f_L) \]

Estimated vehicle response

\[ V_z(s) \] \[ V_y(s) \] \[ V_\delta(s) \]

\[ V(s) \]

Assessment of the vehicle response

Estimated vehicle response

\[ V(s) \]

Evaluation & Classification

EN 14363 Evaluation \[ \rightarrow \] Utilization level Calculation \[ \rightarrow \] Classification
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Results & Discussion

Estimation of the vertical force $Q$

$\rightarrow$ Very high correlation of the time history
Results & Discussion

Scatter plot of the maximum values $Q_{\text{max}}$

$Q_{11,\text{max,dyn}}$ (Reference) $[\text{kN}]$ vs. $Q_{11,\text{max,dyn}}$ (Estimation) $[\text{kN}]$

$Q_{11,\text{max,dyn}}$ (Reference) $[\text{kN}]$ vs. max. Longitudinal level $Z_{R,\text{max}}$ $[\text{mm}]$

$\rightarrow$ TGA-Method shows a higher correlation compared to the QN-Method.
Vehicle OEMs: Utilization level of vehicle response

→ Possibility to compare different test tracks
Results & Discussion

Maintenance: Dynamic factor of a locomotive

→ Enables measures based on a vehicle response estimation

\[ K_{\text{dyn},Q}(s) = \left| \frac{Q(s) - Q_0}{Q_0} \right| \cdot 100\% \]
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Conclusion

- TGA-Method
  - Novel and efficient computational method for the assessment of railway track geometry based on vehicle response estimation,
  - Takes into account the nonlinear characteristics to describe the system behaviour.

- Results achieved
  - High correlation of the assessment values,
  - Significant enhancement compared to the EU Standard method,
  - Supports the avoidance of over- and undersizing of components,
  - Enables the comparison of different test tracks,
  - Efficient maintenance strategies based on the TGA-Method.

→ Scientific contribution to the advancement of railway interoperability in Europe
Thank you for your attention!

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