Prediction of wheel profile wear and rolling contact fatigue for the Stockholm commuter train

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Overview

- Project goals
- Scope of this presentation
- Methods
- Results
- Conclusions
Project

- The main goals of the project are:
  - To create one model for prediction of the total expected life of wheels and rails
  - Selection of reference vehicles, lines and curves for validation of the models
  - Perform/collect measurements
  - Validation of the model
  - Apply the model to investigate the influence of different parameters (wheel/rail profiles, vehicle suspension, axle load, track condition etc.)
Scope of this presentation

• To study the behavior of two reference vehicles with respect to wear and RCF of the wheels.
  o Two wear and two RCF prediction models have been used in combination with vehicle dynamics simulations.
  o Multi-body simulations in Gensys provided the input to the wear and RCF models
Methods

- Two reference vehicles, running on the Stockholm commuter network, have been selected.
Methods – RCF models

• Two RCF initiation prediction models have been studied and compared:
  o 1) based on the shear stress (SI-model)
  o 2) based on the energy dissipation (DI-model)
Methods – RCF models

• Surface initiated RCF index (SI) of the form:

\[ SI = (\tau - k) > 0 \]

\[ FI = \frac{(\tau - k)}{p} > 0 \]

\( \tau \) is the shear stress \([\text{N/m}^2]\)

\( k \) is the yield stress in shear \([\text{N/m}^2]\)

\( p \) is the contact pressure \([\text{N/m}^2]\)
Methods – RCF models

• Rail RCF model based on $T_\gamma$ (DI-model)

\[
T_\gamma = T_x \cdot \gamma_x + T_y \cdot \gamma_y
\]

- $T_x$ is the longitudinal creep force [N]
- $T_y$ is the lateral creep force [N]
- $\gamma_x$ is the longitudinal creep [-]
- $\gamma_y$ is the lateral creep [-]
Methods – wear models

- Two wear prediction models have been studied and compared:
  - 1) wear model according to Pearce and Sheratt (based on the energy dissipation)
  - 2) Archard’s wear model
Methods – wear models

- Pearce and Sheratt (PSH) wear model

\[ A_W = C \cdot T \cdot \gamma \]

- \( A_W \) = worn-off area per wheel revolution
- \( T \) = creep force
- \( \gamma \) = creepage
Methods – wear models

- Archard wear model (AR)

\[
V_w = k \cdot \frac{N \cdot s}{H} \quad \Rightarrow \quad \Delta z = k \cdot \frac{p_z \cdot \Delta s}{H}
\]

- \( V_w \) = wear volume
- \( s \) = sliding distance
- \( N \) = normal force
- \( H \) = hardness
- \( k \) = wear coefficient
- \( \Delta z \) = wear depth
- \( p_z \) = contact pressure
Methods – wear models

Wear coefficient, \( k \) (dry) \( [10^{-4}] \)

- \( k_1 = 300-400 \)
- \( k_2 = 1-10 \)
- \( k_3 = 30-40 \)
- \( k_4 = 1-10 \)
Results - curving

Long transition curve

- $10^{-3}$

- Position [m]

- Angle of attack [rad]

- $R=\infty \rightarrow R=300 \text{ m}$
# Methods - simulations

<table>
<thead>
<tr>
<th>$R_m$ [m]</th>
<th>$V_{vehicle}$ [km/h]</th>
<th>Rail profiles</th>
<th>% of $L_{tot}$</th>
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</thead>
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<tr>
<td>338</td>
<td>60</td>
<td>1, 2, 3</td>
<td>2.4</td>
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<td>2035</td>
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<td>1</td>
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<tr>
<td>Straight</td>
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<td>0</td>
<td>44.9</td>
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</tbody>
</table>
Results - RCF

- Calculated RCF damage on wheel profile
Results - RCF

- Limitation of the creep forces for high creepages (full slip) for SI-model.

\[
SI = \frac{F_T}{F_z} \cdot p_0 - k > 0
\]

\[
DI : T \gamma = T_x \cdot \gamma_x + T_y \cdot \gamma_y
\]
RCF inspections vehicle B

High lateral creep forces
Results - wear

- Calculated wear depth on wheel profile
Results - wear

- Wear map for single contact in curve

![Wear map for single contact in curve](image)

- $k_2 = 1-10$
- $k_3 = 30-40$
Results - wear

- Calculated wear depth $d_z$ for single contact
Conclusions

- The following main conclusions can be drawn for the RCF prediction models:
  - Both RCF models predict more damage for vehicle B than for vehicle A due to the better steering performance of vehicle A.
  - Under poor adhesion conditions, however, the models behave differently:
    - The SI-model predicts less damage for high creepages, due to the independence on creepage.
    - Previous research, however, has also shown that high creepage has no effects on RCF life.
  - The RCF inspections of the wheels of vehicle B show that the steering of the axles under certain circumstances can be poor.
Conclusions

• The following main conclusions can be drawn for the wear prediction models:
  o Both wear models predict more wear for vehicle B than for vehicle A due to the better steering performance of vehicle A
  o The Archard’s wear model predicts more wear due to the large influence of the sliding velocity in the wear map, therefore, especially for vehicle B.
Thank you for listening!