Top-Of-Rail Friction-Modifier (TOR-FM) Effects on Rail Curves

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Content

• Project background
• Introduction to top-of-rail friction-modifier (TOR-FM)
• Approach for studying the effect of TOR-FM on the damage of rail in curves
  – Simulations by using multi-body simulation
  – Field tests
• Conclusions
• Future work
Project background

- Financier: JVTC and Trafikverket
- Project period: March 2015 – Feb 2019
- Objective:
  - Investigate Top-of-rail friction-modifier (TOR-FM) effects and calculate its life cycle cost.
  - Deliver knowledge to Trafikverket.
- TOR wayside equipment
- Gensys software
Top-Of-Rail (TOR) and Friction Modifier (FM)

Source: Donald T Eadie presentation, Heavy haul seminal 7-8 may 2014
How friction modifier works

According to the manufacturer, a friction modifier (FM) is a water based material, which can be applied directly to the top of the rail. As wheel passes over the FM, water evaporates and a micron-scale dry film forms on the top of the rail. This film provides an intermediate coefficient of friction in the range 0.30-0.35.

Effects of TOR-FM

*as per publications

😊

• Reduce wear (40 to 60 %)
• Reduce rolling contact fatigue (RCF)
• Reduce curve squeal noise
• Reduce hunting in tangent track
• Reduce curving and rolling resistance which save fuel
• Reduced rail corrugations
• Reduced derailment potential

*Studied and implemented mainly in USA with involvement of Keltrack Technologies (LB Foster).

😢

• It can cause long braking distance
• Excess use of TOR-FM can cause wheel slippage
Research gap

Some publications have shown that friction modifier can result in an unacceptable low friction coefficient. Is this true in practice for friction modifier from different companies?

What the technical efficiency (effects on wear and cracks) of the TOR system (wayside equipment) in the Swedish heavy haul condition?

What is the economic efficiency of such system in the Swedish environment?
Possible approaches to fulfil the research gap

- Field test
- Laboratory test
- Computer based simulation
Computer based simulation

*Simulation is done by using multi body simulation (Gensys).

**Input parameters are taken from Kiruna-Luleå iron ore line and published results.
## Input parameters

### Fixed parameters

<table>
<thead>
<tr>
<th>Axle load (Tonnes)</th>
<th>Wheel profile</th>
<th>Rail profile</th>
<th>Rail inclination</th>
<th>Vehicle speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>WP4</td>
<td>60 E1 (low rail) &amp; MB1 (high rail)</td>
<td>1/30</td>
<td>60</td>
</tr>
</tbody>
</table>

### Variable parameters

<table>
<thead>
<tr>
<th>Curve radius (m)</th>
<th>Cant for respective curve radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200, 300, 400, 500, 1000, 2000, 3000</td>
<td>0.15, 0.15, 0.10, 0.10, 0.05, 0, 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Friction coefficient (µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5, 0.4, 0.3, 0.2</td>
</tr>
</tbody>
</table>
Models used for simulation

Wheel profile: WP4
Rail profile: MB1 and UIC 60E1
Damage Index (DI) method to see the probability of crack initiation

\[ T_\gamma = ( T_x \gamma_x + T_y \gamma_y ) \]

where,

- \( T_\gamma \) (N) is wear number
- \( T_x \) & \( T_y \) (N) are lateral & longitudinal creep forces
- \( \gamma_x \) & \( \gamma_y \) (unitless) are lateral & longitudinal creepage

Simulation results for a 200 m radius curve

Damage index for 200 m curve radius at 30 tonne axle load and different friction values with respect to distance on curve
Damage index at various curve radii

Damage index values (95th percentile) of circular curve and transition curve from 200 m to 3,000 m at 30 tonne axle load and various friction control, both high and low rails.
Field tests
Location of curves

- Reference curve is near Murjek
- TOR curve is near Gullträsk
Installed TOR equipment
Measurement methods

- Friction measurement
- Roughness tester
- Calipiri 40, laser equipment
- Crack enhancing dye penetrant (cleaner, penetrant and developer)
- KDN crack depth measurement equipment
- Photographs
- Swab test for carry distance
Swab test to investigate the carry distance
### SEM results

#### Pure FM

<table>
<thead>
<tr>
<th>Elements wt%</th>
<th>C*</th>
<th>O*</th>
<th>Mg</th>
<th>Si</th>
<th>S</th>
<th>Fe</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure FM</td>
<td>12.62</td>
<td>21.95</td>
<td>4.625</td>
<td>7.205</td>
<td>24.76</td>
<td>0.69</td>
<td>25.695</td>
</tr>
<tr>
<td>Sample from Reference (no FM present)</td>
<td>37.55</td>
<td>18.81</td>
<td>1.31</td>
<td></td>
<td></td>
<td></td>
<td>42.30</td>
</tr>
</tbody>
</table>

### Sample taken at a several distance from the TOR equipment

<table>
<thead>
<tr>
<th>Distance from TOR (m)</th>
<th>C*</th>
<th>O*</th>
<th>Mg</th>
<th>Si</th>
<th>S</th>
<th>Fe</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56.73</td>
<td>12.63</td>
<td>0.53</td>
<td>0.77</td>
<td>11.59</td>
<td>1.11</td>
<td>16.51</td>
</tr>
<tr>
<td>6</td>
<td>59.18</td>
<td>28.93</td>
<td>0.71</td>
<td>1.15</td>
<td>1.58</td>
<td>6.26</td>
<td>2.24</td>
</tr>
<tr>
<td>10.2</td>
<td>46.66</td>
<td>33.59</td>
<td>1.57</td>
<td>1.64</td>
<td>0.16</td>
<td>7.43</td>
<td>0.00</td>
</tr>
<tr>
<td>13.8</td>
<td>50.58</td>
<td>23.48</td>
<td>0.24</td>
<td>0.41</td>
<td>7.26</td>
<td>7.94</td>
<td>10.21</td>
</tr>
<tr>
<td>19.8</td>
<td>44.44</td>
<td>28.69</td>
<td>0.00</td>
<td>0.28</td>
<td>0.35</td>
<td>25.93</td>
<td>0.92</td>
</tr>
<tr>
<td>72</td>
<td>38.55</td>
<td>31.81</td>
<td>0.00</td>
<td>0.27</td>
<td>0.00</td>
<td>29.15</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* Carbon and oxygen are common content in cotton swab, so they can be ignored

** Fraction of other elements such as W, Na, Zn, Al, Pt were also detected during SEM, but they can be ignored as they might have come from atmosphere.
Comparing claims of the manufacturer company with SEM results

- **Carry distance claimed by the manufacturer company**
- Standard product: 1.6 - 3.2 km at an application rate of 0.5 litres/1000 axles.
- Premium (ER) product: 3.2 - 6.4 km at an application rate of 0.25 litres/1000 axles.


- **What we have noticed by using the premium product at an application rate of 1 litre/1000 axles**
  - Visually: friction modifier was seen until 5-10 m.
  - Swab test: No friction modifier detected at and after 70 m.

Another possible test to check the carry distance of this friction modifier

- Fluorescent test: No present knowledge of chemistry of fluorescent material with FM.
- X ray test: Could be tested in the future, but it needs costly and sophisticated handheld x-ray equipment.
Conclusions

• From the theoretical results (simulation)
  – According to the damage index method, friction coefficient of approximate \( \mu = 0.30 \) is needed to control crack on curves sharper than 1,000 m radius.
  – On curves sharper than 300 m, a transition curve is more prone to crack initiation than a circular curve.
  – On curve larger than 1,000 m, probability of crack initiation is zero irrespective of the friction coefficient.

• From the field results
  – Wayside equipment does not seem to be a suitable method of application and very small carry distance is seen as compared to the claims of the manufacturer.
  – On board TOR-FM system could be a smart alternative to wayside equipment.
Future research

- Perform SEM/swab test by taking samples from wheels.
- Study the effect of snow and water by using the new hand held equipment.
- Investigate and compare friction modifier from different suppliers.
- Investigate on-board TOR system.
- More simulation by using
  - More realistic friction values and wear constant from a new handheld device developed by Prof. Jan Lundberg.
  - Figure out more tribological equations, which can be used in simulation.
Thank You

Questions?

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