STAGE 7

TRIENNIAL REPORT
1 July 2012–30 June 2015

REVIEW
1 July 1995–30 June 2012

PLANS
1 July 2015–30 June 2018

Chalmers Railway Mechanics – a NUTEK/VINNOVA Competence Centre
Chalmers University of Technology
The influence of corrugation on tangential forces and rolling contact fatigue

Roger Lundén, Jens Nielsen and Anders Ekberg
Chalmers / CHARMEC, Gothenburg, Sweden

Presentation at 19th Nordic Seminar on Railway Technology in Luleå 14-15 September 2016
Background – subsurface RCF
Aim and scope

- Investigate the influence of corrugation on surface initiated RCF
- Short-pitch rail corrugation (Swedish “standard case”)
- Vertical / longitudinal dynamics
- Influence of vehicle speed, tractive effort, roughness level, axle load and unsprung mass
- Quantification in the form of and $F_{I_{surf}}$ and $T_{\gamma}$ values
Rail roughness spectra

(a) Roughness measured at sections Stockholm–Gothenburg
(b) Roughness spectra used in the parametric study
Vehicle-track interaction

Coupled longitudinal and vertical vehicle–track interaction model used in DIFF. The wheelset is suspended by a primary suspension in the longitudinal direction (not shown)
Equations of motion

\[ M_w \ddot{x} + c_w (\dot{x} - v) + k_w (x - vt) = F_x \]
\[ M_w \ddot{z} = W - F_z \]
\[ I_w \dot{\Omega} = T - F_x R_w \]

Creepages

\[ \gamma_x^{\text{rigid}}(t) = \frac{\dot{x}(t) - R_w \Omega(t)}{v} \]
\[ \gamma_x^{\text{elastic}}(t) = \frac{h \dot{\beta}(t)}{v} \]
Fatigue index

\[ F_{I_{\text{surf}}} (t) = f - \frac{2\pi abk}{3F_z} \]

Energy dissipation model

\[ T\gamma = F_x\gamma_x \]

Contributions to RCF:
- negligible for \( T\gamma < 15 \) N
- maximum for \( T\gamma = 65 \) N
- negative for \( T\gamma > 175 \) N (caused by high wear rate)
Rail irregularity and time histories

Speed 200 km/h, axle load 15 tonnes, friction coefficient 0.5, average traction \( f = 0.3 \), “Corrugated rail”
(a) Rail irregularity and vertical and longitudinal forces
(b) longitudinal creepage, \( F_{I_{surf}} \) and \( F_x \gamma_x \)
Mean traction coefficient

- Will increase peak magnitudes of $F_{I_{surf}}$ and $T_\gamma$
- Corrugation will shift risk of RCF to lower $f$ magnitudes
- Saturation effect especially for $F_{I_{surf}}$

Solid lines: ISO 3095, dashed: corrugated rail

$\mu = 0.5$
$f = 0.1, 0.2, 0.3, 0.4$
Speed and corrugation

Not a massive influence of speed and corrugation at high $f$

$$FI_{\text{surf}}(t) = f - \frac{2\pi abk}{3F_z}$$

cf $FI_{\text{sub}} \propto \frac{F_z}{4\pi ab}$
Speed and corrugation

\[ f = 0.3 \text{ worst regarding RCF} \]
Axle load and unsprung mass

- In contrast to the case of $F_{l_{\text{sub}}}$, which showed no influence of unsprung mass
- Increased axle load will decrease in the RCF impact if the prescribed torque is kept constant

Speed 200 km/h, average traction $f = 0.3$, spectrum: ISO3095 (blue bars), “Corrugated rail” (red) High axle load = 18 tonnes (nominal 15 tonnes), high unsprung mass = 1500 kg (nominal 1000 kg)
Concluding remarks

- Local maxima in damage indices are obtained adjacent to troughs in the rail irregularity, and that these positions are associated with high magnitudes of longitudinal creepage.
- The tractive force is the dominating influential parameter on RCF.
- For a given tractive force the corrugation level will have a fairly moderate influence.
- Increasing speed 200 → 300 km/h actually decreases RCF impact (though longitudinal force increases with speed) for scenarios studied.
- Future studies will include full slip, braking, low pas filtering of forces and instationary wheel–rail contacts.
Article:

Many Thanks!!