

# A rail roughness growth model for a wheelset with non-steady, non-Hertzian contact

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*Keywords: Corrugation, Rail roughness, Wheel-rail contact*

## 1 INTRODUCTION

This paper describes an ongoing investigation of rail roughness growth in which the interaction of a wheelset with the track is considered. The emphasis of this work lies on the torsional vibration of the wheelset coupled with the non-Hertzian and non-steady contact calculations, and their effects on wear predictions.

A time-domain non-linear calculation of the wheel-rail contact [1], taking account the non-Hertzian and non-steady effects, was used in simulations of rail roughness growth considering the vertical dynamics of the wheel-track system only [2, 3]. Both two-dimensional and three-dimensional contact was considered in this work and it was found that roughness does not grow for initially sinusoidal irregularities in the wavelength range of short-pitch corrugation. Findings from this work were explained due to the non-Hertzian and non-steady wheel-rail contact model which predicts wear almost in-phase with roughness. Although clearly in contradiction with reality where roughness grows under certain conditions this work leads to interesting questions about why roughness growth is predicted by a simple model but not predicted when more complexity is introduced into the wheel/rail contact model. The reason behind the difference is so far unclear and investigations are ongoing. In some theories torsional modes of the axle are seen as responsible for the generation of corrugation in some circumstances. Due to the presence of roughness, contact geometry perturbations induce a variation of forces in the vertical and tangential direction and the torsional vibration of the wheelset axle can therefore be excited. Since the wheelset axle was modelled as rigid in previous model [2, 3], a flexible axle is considered in this paper to investigate any possible mechanism for roughness growth due to the coupling between the axle torsional vibration and vertical dynamics. The torsional vibration of the wheelset is simulated in the time-domain, coupled with a 2 dimensional Boundary Element based contact model. This paper consists of four parts:

### **a. A description of the torsional vibration of a wheelset.**

An analytical model with greatly simplified wheel geometry is used here to represent wheelset torsional vibration. The wheelset consists of an axle with two wheels and is modelled as a free-free torsional bar carrying a rotational inertia at each end. The torsional vibration of the wheelset is excited by longitudinal creep forces at both wheels. The modal superposition approach is adopted to simulate the torsional vibration of the wheelset in the time-domain.

### **b. Vertical interaction between a wheelset and track**

The vertical interaction between the wheelset and the track is simulated in the time-domain, based on a previously developed model [2] but extended to include representation of a wheelset. The two rails are considered as Timoshenko beams discretely supported by pads, sleepers and ballast and the response of the rail is represented using a modal expansion technique. The sleeper is modelled as a rigid mass and the railpads and ballast are represented by linear stiff-

ness and viscous damping. The vertical wheel/rail contact in the interaction model is represented with a non-linear Hertz contact spring.

### c. Contact and wear models

When the wavelengths of roughness are short, the profile of the rail near the initial contact point can not be represented by a circular curve and this assumption of the Hertz theory is violated. The wheel-rail contact for predicting wear is modelled as non-Hertzian and non-steady [1-3], based on the Variational Method by Kalker [4]. Due to the efficiency of the 2 dimensional contact model in computations, this was used here. A Boundary Element model for wheel and rail is used to obtain the influence coefficients between the tangential stress and local relative displacement. Wear is assumed to occur due to local relative motion between the wheel and the rail. A simple frictional work model is used here and wear at a position is assumed to be proportional to the work done by the tangential stress at a position over the time during which slip occurs at that position.

### d. Numerical results.

Simulations were carried out for symmetrical and asymmetrical sinusoidal roughness on two rails. Parameter studies were performed with varying wheel inertia, vehicle speed, reference creepage and wavelength of initial roughness. It was found that the dynamic creepage is significantly higher for a flexible torsional axle than a rigid axle. Torsional wheelset modes will be excited when they are close to the roughness frequency.

For symmetrical roughness, it is found that the amplitude of the predicted wear is mainly influenced by the reference creepage but the phase angle is more controlled by the vehicle speed. The phase angle of wear mostly lags the initial roughness between  $20^\circ$  and  $100^\circ$ . In a special case in which the roughness excitation frequency is close to the 1<sup>st</sup> flexible torsional wheelset mode, the dynamic creepage is greatly higher than other cases and the phase angle of the wear is found leading the initial roughness. For most wavelengths of the initial roughness, a phase lag of over  $90^\circ$  was found at a specific combination of parameters, implying potential roughness growth.

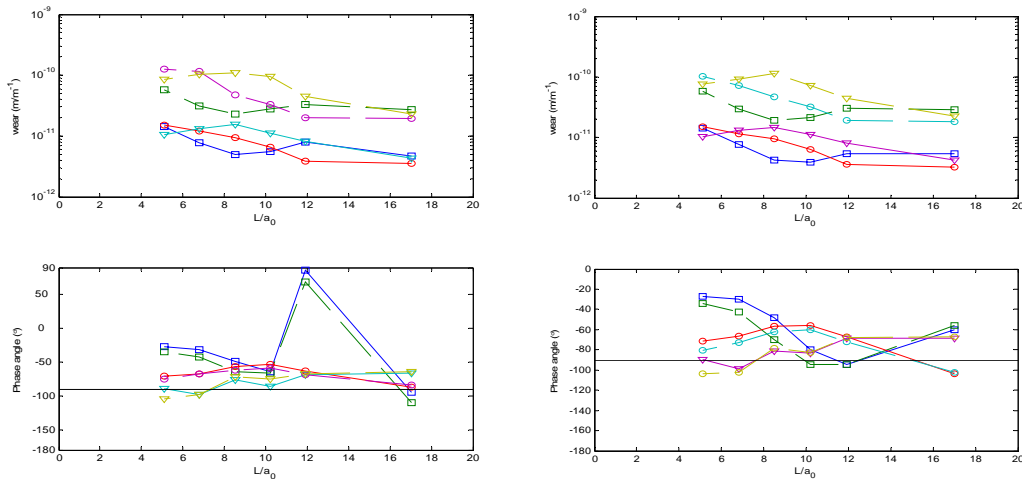


Figure 1. Wear rate and phase angle against the symmetrical roughness in both rails for the wheelset of rotational inertia  $20 \text{ kgm}^2$  (left) and  $200 \text{ kgm}^2$  (right). ( $\square$  20m/s,  $\circ$  40m/s,  $\nabla$  60m/s, —  $\xi_x = 0.1\%$ , - -  $\xi_x = 0.2\%$ ).

### REFERENCE

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