Prediction of rolling contact fatigue loci: a comparison between dynamic and a simplified quasi-static approaches

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EXTENDED ABSTRACT

1 Introduction

The prediction of the fatigue and wear on wheels and rails is a key to improve the service life of a railway track and the rolling stock. Thus, it is necessary to accurately determine the wheel/rail contact loci and stress [1]. In practice, the rails experience contact with a range of different wheel profiles that will pummel the rail surface at different positions, with different intensities. The goal of a pummelling analysis is to understand the accumulated effect of a large population of wheelsets [2]. Since many simulations must be performed, it is desirable to employ fast simplified models that are capable to predict contact points and forces [3], that must be validated with more accurate models.

This work evaluates the capabilities of a simplified quasi-static simulation [3] to generate pummelling analysis, in comparison with the results obtained through multibody dynamics simulations carried out in SIMPACK and VAMPIRE. Considering track parameters and vehicle loads of a heavy haul railway in Brazil, these simulations are computed to obtain the accumulated contact pressure for new and worn rails subjected to the traffic of a family of wheels with different geometric profiles.

2 Methods

The Brazilian heavy haul wagon GDE-Ride Control, a three-piece bogie wagon with 31.5 tons per axel, was modeled inside SIMPACK and VAMPIRE. This model was based on the one presented by [4]. The wheel-rail contact forces in SIMPACK and VAMPIRE are calculated from Kalker's theory, which defines the relationship between the creepages and the creep force. Normal and tangential wheel-rail contact forces for the contact points are calculated using FASTSIM in SIMPACK. While VAMPIRE use Hertzian contact theory to determinate the normal forces and an off-line look-up table to calculate the transversal contact. The quasi-static model employed here is described in [3]. The model evaluates the bidimensional interaction between a single wheelset and the track. Wheel and rail profiles are described as a set of circular arcs. An elastic contact model is implemented with a master-master contact approach in the software GIRAFFE [5]. Only gravitational and inertial forces are applied at the planar projection of the vehicle gravity center. Only normal contact forces are evaluated, and the contact pressure is calculated applying Hertz Theory.

The scenario simulated consisted in a tangent section of 150 m, a transition spiral for entry the curve with 61.7 m, a curve section to the left with a constant radius of 371.6 m, a transition with 61.7 m and a final tangent section from 150 m; totaling 619 m traveled at a constant speed of 65 km/h (18.05 m/s). The track gauge is 1.0 m and the curve section has a superelevation of 57.2 mm. The total mass of the loaded wagon is 110,000 kg.

For the pummeling analysis ten wheelsets with different wheel profiles were considered. The profiles were obtained from measurement of actual wheels, the same used by [3]. The rails used are also from [3], it is applied in a linearized form where the abscissa axis 'x' represents the arcs that compose the rail profile with their respective lengths, being 0 mm on the x-axis the outermost point of the rail. The accumulated pressure was calculated in the tangent and curve section for the front wheelset.

3 Results and discussions

Only the results for worn rails are discussed in the present extended abstract. The results are shown in Figure 1. Considering the left rail of the tangent, the contact occurs on the top of head for both dynamic models. However, GIRAFFE present a contact locus in the inner side of the rail, different from the others two methods. Considering the right rail, a good agreement is observed with the contact in the top of head. Considering the curve and the left rail, two contact loci appear, on the top of head and on the outer shoulder of the rail for the SIMPACK and VAMPIRE with difference in the magnitude, while GIRAFFE present a contact locus in the inner shoulder instead of the outer shoulder. For the right rail, as in the left, VAMPIRE and SIMPACK present similar contact loci with different pressure magnitude. While GIRAFFE presents significant differences in the distribution as in magnitude.

As showed in Figure 1, GIRAFFE's quasi-static model for the tangent section provides a good correlation with the results obtained by dynamic simulations. The GIRAFFE quasi-static model for the curve section presents significant differences, mostly on the right rail, for the dynamic models. For the curved section in the GIRAFFE model, in addition to the gravitational force, a horizontal force is applied pointing to the right side (since the curve is to the left), which represents the centrifugal force of the related curve. However, in its present version the quasi-static model does not include creep forces, present in dynamic simulations. As shown by [4], the creep forces contribute to the expected lateral positioning of the wheelsets. As this is not considered currently by GIRAFFE model, this seems to be an important improving for further research. Moreover, contact pressure results may differ in distinct tools when using distinct techniques, such as Hertzian, semi-Hertzian or other approaches.

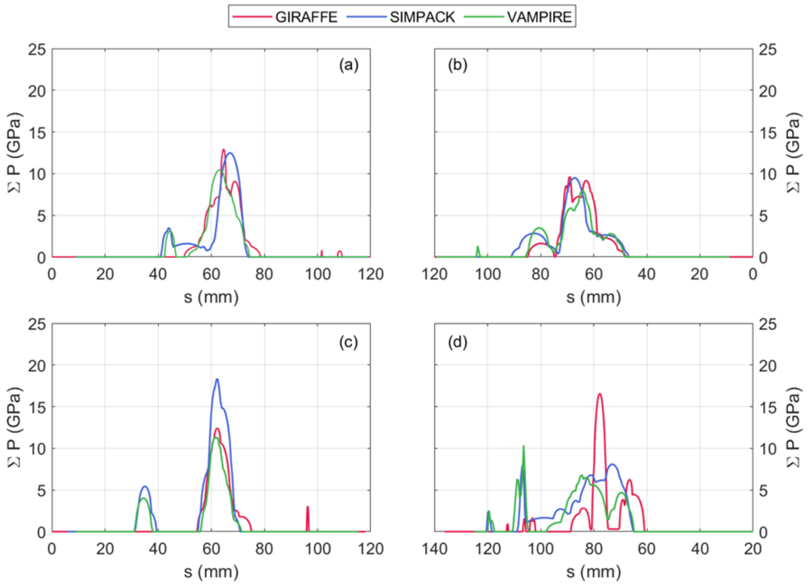

Figure 1: Contact pressure accumulation for worn rails (a) left rail in tangent;(b) right rail in tangent; (c) left rail in curve; (d) right rail in curve.

The VAMPIRE and SIMPACK results show a good correlation in all cases. The observed differences are the result of the how contact is calculated in each software, SIMPACK uses the FASTSIM algorithm that present an error for creep force estimation due to the parabolic traction bound compared with CONTACT algorithm used to calculate the look-up table by VAMPIRE [6].

4 Conclusions and outlook

In this work we compare a quasi-static simplified model with two dynamic models to analyze the wheel-rail contact conditions. The results showed that the quasi-static model has a good correlation with the dynamic models for the tangent conditions. For the curves, differences were observed in the distribution of pressures due to the absence of creep forces in the quasi-static model. The comparison between the dynamic models also showed distinct results due to the difference in how the contact is calculated.

The improvement of the quasi-static models, particularly in curve scenarios, claim the inclusion of the creep forces, contributing to evaluate a steady-state lateral average position of wheelsets. In this scenario, even differences are expected in distinct wheelsets within a bogie. This will be addressed in future work.

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