Multibody simulation of the wear of railway wheel profiles with local and global application of the Archard's law

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1 Introduction

The numerical computation of the wear of wheel transversal profiles can enable a better planning of the re-turning operations needed to restore the original profile shape. Several scholars have developed different numerical tools that are able to calculate the worn material corresponding to a specific mission of the vehicle, through the launch of dynamic simulations followed by the estimation of the worn material via suitable wear laws [1]. The wear laws can be classified according to the strategy adopted for their application, which can be either global or local. When a wear law is applied globally, the removed material is related to the contact patch parameters on a "macro" scale, i.e., forces and creepages. On the other hand, when a local application is chosen, the worn material is calculated in each cell of the contact patch grid, as a function of the contact patch parameters evaluated on a "micro" scale, namely contact pressures and slip velocities. The global approach ensures faster computational times, but it requires the definition of an a priori strategy to spread the worn material along the wheel profile transversal coordinate. Conversely, the local approach estimates the wear depth in each element of the contact patch grid, but of course it requires a higher computational effort. Therefore, a comparison of the two approaches in terms of their accuracy, numerical stability and computational efficiency is essential in view of the development of new efficient tools. Furthermore, nowadays commercial multibody (MB) software packages include dedicated add-ons for the calculation of the wheel worn profile, so assessing their modelling capabilities against other in-house codes can be of great interest to gain further insights into the reliability of such modules.

Lewis et al. [2] compared the global and local approaches in the application of the energetic law proposed by Sheffield University (USFD) [3], considering an articulated train running on the Italian Cuneo-Limone line, which is characterized by a high tortuosity. Nonetheless, in this reference, only the USFD law was applied, and a comparison with the results of a wear module implemented in a commercial MB code was not performed. Ignesti et al. [4] compared the results of the Simpack wear module, based on a global approach, with the outputs of a Matlab user-written wear routine, relying on a local approach. However, two different laws were used in the two methods, namely a global application of the Krause-Poll law [5] and a local application of the USFD law. Therefore, in the present paper, the global and local approaches are compared, considering the application of the same wear law. Whilst the above references evaluated "energetic" wear laws, that calculate wear as a function of the dissipated energy, this work considers the Archard's wear law [6], that relates the amount of worn material to the normal load on the contact patch and is directly available in the Simpack wear module.

2 Methodology

The numerical tool proposed in the paper adopts the typical approach for the calculation of worn profiles, i.e., it launches a cascade of dynamic simulations of a reference vehicle-track system, modelled in Simpack, followed by the estimation of the removed material, see Figure 1. Due to the difficulties of an online update of the wheel profile during the simulation, in each MB simulation, the wheel profile is considered as unchanged. The numerical computation is managed with a Matlab script, that at each iteration generates a new batch file, which launches the Simpack simulation via a QtScript file. The main outputs of the simulation are stored in a text file that is fed back to the Matlab script, which eventually calculates the worn profile to be used in the dynamic simulation at the subsequent iteration.

The reference vehicle modelled in Simpack is the Aln663 diesel railcar, equipped with the FIAT bogie and with a maximum travel speed of 120 km/h. The model, described in detail in [7] and sketched in Figure 1, includes the following bodies: one coach, two bolsters, two bogie frames, four wheelsets and eight axle-boxes. Each axle-box is connected to the bogie frame with a helical spring and with a control arm including a rubber joint. Therefore, the primary suspension is modelled with two force elements: a flexicoil element simulates the vertical (axial) and shear stiffness of the spring, while a bushing element reproduces the behavior of the rubber joint. The secondary suspension stage instead relies on helical spring, that are modelled through the definition of shear spring elements, that allow to set the stiffness value in all directions. The wheel-rail contact forces are calculated via the FASTSIM algorithm, which is built-in in Simpack.

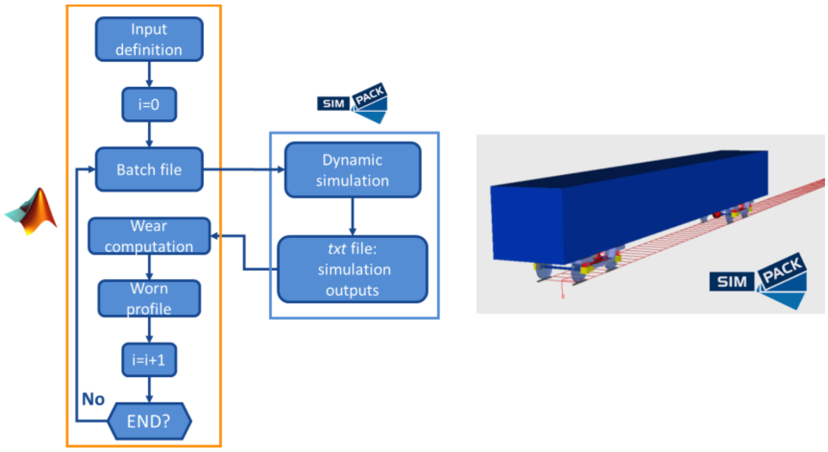

Figure 1: Architecture of the proposed tool for the evaluation of the worn profile

The computation of the worn profile is performed by dedicated Matlab functions, that implement the Archard's wear law in global and local forms. When the local approach is selected, the Matlab user-written function for wear computation calculates the distribution of contact pressures and sliding speeds over the contact patch for each contact point in each time-step. The Simpack wear module estimates the amount of worn material using the global approach. However, to obtain a higher control on the stability of the computation [7], the authors developed a global wear algorithm that mimics the computation of the Simpack wear module. Preliminary simulations were launched for a single iteration of the computation, considering a very short track featuring curves with radii of 400, 600, 800 and 1000 m [8]. The global algorithms proved to compute a higher wear on the tread, and a lower wear on the flange, compared to the local algorithm, see Figure 2, which also shows a good agreement between the Matlab and Simpack global methods. The next step of the proposed activity is a further comparison between the two approaches, considering a longer track and a loop of dynamic simulations launched with an update of the wheel profile at each iteration.

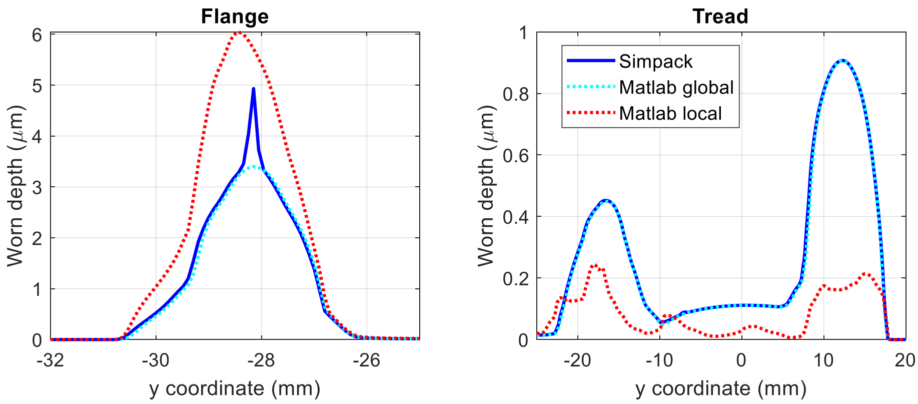

Figure 2: Preliminary comparison of the two approaches

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