Wear 309 (2014) 174–191

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

# Development of a wear model for the analysis of complex railway networks

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ARTICLE INFO

*Article history:*
Received 24 July 2013
Received in revised form
6 November 2013
Accepted 9 November 2013
Available online 20 November 2013

*Keywords:*
Wheel–rail wear
Multibody modeling of railway vehicles
Statistical track analysis

ABSTRACT

In railway applications, the estimation of wear at the wheel–rail interface is an important field of study, mainly correlated to the planning of maintenance interventions, vehicle stability and the possibility of carrying out specific strategies for the wheel profile optimization. In this work the authors present a model for the evaluation of wheel and rail profile evolution due to wear specifically developed for complex railway networks. The model layout is made up of two mutually interactive but separate units: a vehicle model (composed of the multibody model and the global contact model) for the dynamical analysis and a model for the wear evaluation (composed of the local contact model, the wear evaluation procedure and the profile update strategy).

The authors propose a statistical approach for the railway track description to study complex railway lines in order to achieve general significant accuracy results in a reasonable time: in fact the exhaustive simulation of the vehicle dynamics and of wear evolution on all the railway network turn out to be too expensive in terms of computational effort for each practical purpose.

The wear model has been validated in collaboration with Trenitalia S.P.A and RFI, which have provided the technical documentation and the experimental data relating to some tests performed on a scenario that exhibits serious problems in terms of wear: the vehicle ALn 501 “Minuetto” circulating on the Aosta-Pre Saint Didier Italian line.



## 1. Introduction

The prediction of the wear phenomena at the wheel–rail interface is a fundamental issue in the railway field; in fact the consequent evolution of rail and wheel profiles involves serious effects on both dynamical and stability characteristics of vehicles. From a safety viewpoint, modifications in wheel and rail profiles may compromise the vehicle stability and also increase the derailment risk due to wheels climbing over the rail. Profile changes lead also to higher maintenance cost, mainly related to the periodical re-profiling operations of wheels and the undesirable replacements of rails, necessary to re-establish the original profiles. A reliable wear model can be used to optimize the original profiles of wheel and rail and to obtain a more uniform wear on the rolling surfaces. In such a way the overall amount of worn material can be reduced, the mean time between two maintenance interventions can be increased and, at the same time, the dynamical performance of the wheel–rail pair can be kept approximately constant between two succeeding repair interventions.

In this work the authors present a procedure to estimate the evolution of the wheel and rail profiles due to wear specifically developed for complex railway networks. The general layout of the model consists of two mutually interactive parts: the vehicle model (multibody model and 3D global contact model) and the wear model (local contact model, wear evaluation and profiles update) (see Fig. 1).

In the literature many important research works regarding wear models based both on global and local approaches to wear estimation can be found. Nowadays, both global and local approaches can be chosen to perform simulations by means of commercial multi-body softwares. In the global approach, often used by commercial multi-body software to reduce the computational load despite the model accuracy [1–3], the wear evolution is computed without taking into account the contact patch but hypothesizing that the contact between the surfaces occurs in a single point; in this way both underestimation and overestimation of the worn material are often possible. The local approaches [4–7], instead, subdivide the contact patch into adhesion and slip area, leading to more accurate results but increasing the computational time; some works in which the differences between global and local wear approaches are carefully investigated can be found in the literature [8].

However a substantial lack is present in the literature concerning wear models (both global and even more local) specifically

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http://dx.doi.org/10.1016/j.wear.2013.11.010

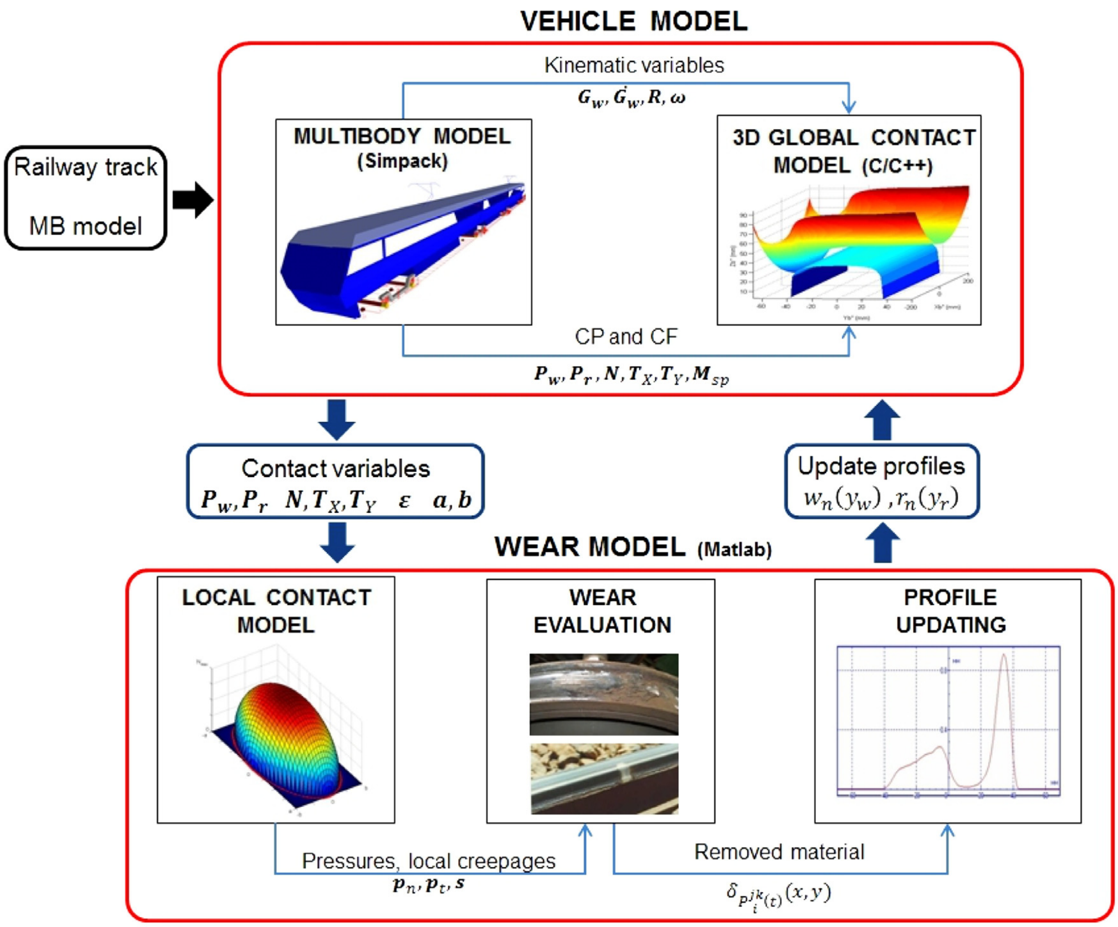


**Fig. 1.** General architecture of the model.

developed for complex railway network applications. In this case the computational load needed to carry out the exhaustive simulation of vehicle dynamics and wear evaluation turns out to be absolutely too high for each practical purpose. The authors previously worked on this issue [9], developing a wear model for the evaluation of wheel wear based on the local approach and statistical methods to reduce the computational time.

To overcome the main critical issue of wear prediction models, the authors propose a track statistical [1,10] approach to obtain relevant results in a reasonable time; more specifically the authors suggest the replacement of the entire railway net with a discrete set of $N_c$ different curved tracks (classified by radius, superelevation and traveling speed) statistically equivalent to the original net. This approach allows a substantial reduction of the computational load and, at the same time, assures a good compromise in terms of model accuracy. In the literature, important results concerning this topic have been obtained in [10].

The present work has been carried out in collaboration with Trenitalia S.p.A. and RFI that provided the experimental data concerning the Aosta-Pre Saint Didier railway line and the vehicle ALSTOM *DMU Aln 501 Minuetto* (which in this scenario exhibits serious problems in terms of wear) necessary for the preliminary model validation.

## 2. General architecture of the model

The general architecture of the model developed for studying the wear phenomena on complex railway lines is shown in the block diagram in Fig. 1 in which two different main parts are present: the *vehicle model* necessary to perform the dynamical analysis and the *wear model*.

The *vehicle model* consists of the multibody model of the benchmark railway vehicle and the 3D global contact model that, during the dynamical simulation, interact directly online creating a loop. At each time integration step the first one evaluates the kinematic variables (position, orientation and their derivatives) relative to the wheelsets and consequently to each wheel–rail contact pair. At this point, starting from the kinematic quantities the 3D global contact model calculates the global contact variables (contact points and contact forces, contact areas and global creepages), this model is based both on an innovative algorithm for the detection of the contact points (developed by the authors in the previous works [11,12,26–29]) and on Hertz's and Kalker's global theories for the evaluation of the contact forces [13–15,21,25]. The global contact variables are then passed to the multibody model to carry on the vehicle dynamics simulation.

The dynamic simulations have been performed in the commercial Multibody Software (MBS) Simpack. In particular, the multibody model has been defined in the Simpack Rail environment, while the wheel–rail 3D global contact model, implemented in C/C++ language, has been customized by the authors through a specifically developed FORTRAN routine defined within the Simpack User routine module.

The main inputs of the *vehicle model* are the multibody model of the railway vehicle and the corresponding railway track, represented in this work by the ALSTOM *DMU Aln 501 Minuetto* and the Aosta-Pre Saint Didier line respectively (a critical scenario in Italian Railways in terms of both wear and stability). In wear estimation research activities the track description is a critical task