Wear and Rolling Contact Fatigue: development of an innovative tool for simultaneous wheel and rail damage evaluation

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Wear and the rolling contact fatigue are the main responsible for a decrease in wheels and rails life. A change in wheel and rail profile directly influences the vehicle dynamic behavior, comfort and stability. It impacts also on the economical aspect, increasing the costs related to maintenance operations necessary to re-establish wheel and rail profiles and to ensure a running in safety condition. Hence, a suitable madel able to predict rail and wheel profile evolution and fatigue damage can be a powerful tool in maintenance planning optimization and a useful aid in a better managing of wheel and rail damage. To this purpose, the Authors present an efficient and innovative modelling approach suitable for different railway scenarios, that combines togheter a wear model to evaluate the wheel and rail profile evolution and a RCF crack prediction model. The proposed model is capable to predict simultaneosly the profiles shape evolution due to wear and the total RCF damage both for the wheel and for the rail. Thanks to the numerical efficiency and accuracy of wear and RCF model, an online implementation within vehicle multibody models it is possible.

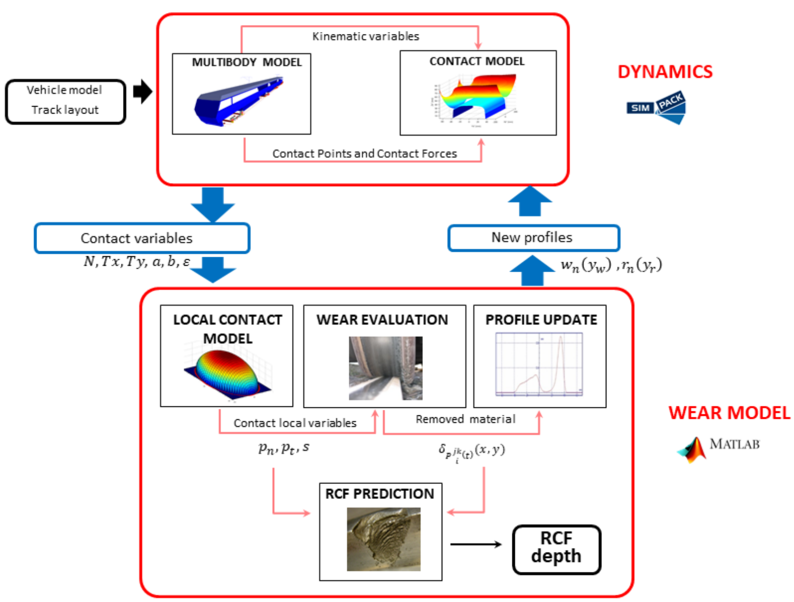

Fig. 1 Model general layout

More specifically, the general layout of the whole model (see Fig. 1) is made up of three main parts: the dynamic block, the wear model and the RCF crack depth prediction model. The first block consists of the 3D multibody model of the benchmark vehicle (modelled in Simpack Rail environment and used to accurately reproduce the dynamics of the vehicle) and of the global contact model, developed by the Authors in previous works [1] and implemented in C/C++, creating a loop. The global contact model exploits, for the contact point detection, a very efficient algorithm, while the contact forces (normal and tangential) and the global creepages on the contact patch are calculated through Hertz's and Kalker's global theories. Starting from the outputs of the dynamic simulations (position and shape of the contact patches, contact pressures, etc.), the wear model, based on a local contact model (in this case the Kalker's FASTSIM algorithm), calculates the specific volume of removed material and its distribution along the wheel and rail profiles through a suitable experimental law that correlates this volume to the friction power produced by the tangential contact pressures [5]. In parallel with the wear evaluation, a RCF damage calculation procedure has been implemented. The RCF model allows to predict crack growth and its depth, starting from the outputs of the local contact model (contact stresses, etc,) and of the wear model, and by using an experimental relationship between the shear stresses in the wheel-rail contact and the crack length [4].

In fact, wear and RCF are deeply connected: wear affects wheel and rail profile shape impacting on stresses magnitude in the wheel–rail contact leading to more or less RCF damage. Furthermore, in presence of high wear rate, short cracks may also be worn off. The wear model and the RCF model interact at the end of each process step, combining the depth of removed material by wear and the crack depth in order to consider the effect of wear rate on crack growth.

Once calculated the volume of material removed by wear, the new updated profiles of wheel and rail are obtained by subtracting this material from the old ones through an appropriate update strategy, different for the wheel and rail to take into account the different time scale characterizing the wear evolution of the two components (the distance travelled by the vehicle are considered for the wheels while, for the rail, the total tonnage burden on the track).

The total crack depth, including the effect of wear, and its distribution along wheel and rail profiles are the output of the RCF model while the wear model provides the worn profiles. The new updated wheel and rail profiles are then fed back as inputs to the vehicle model and the whole model architecture can proceed with the next discrete step. The estimation of wheel and rail wear is, therefore, a discrete process and the evolution of the wheel and rail is described through several intermediate profiles.

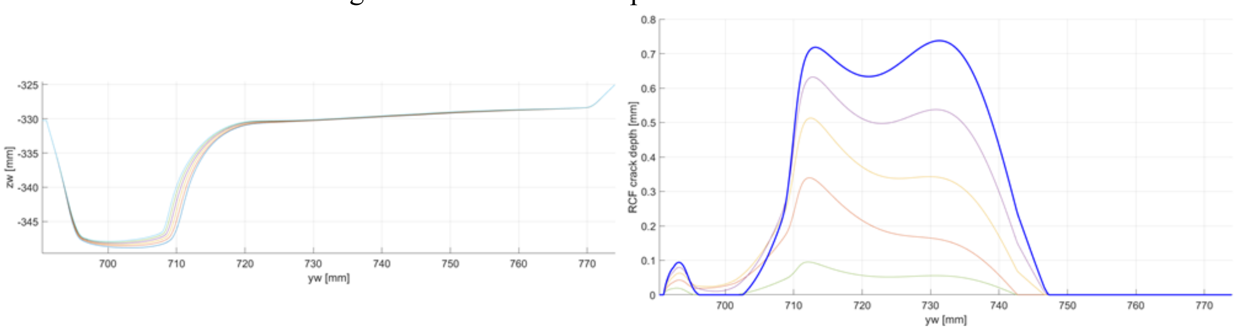

Fig. 2 Example of simulated wheel wear and crack depth evolution

After the development of the whole model architecture, a preliminary wear model validation considering a subway and tramway scenarios has been carried out considering technical and experimental data provided by Hitachi Rail Italy and Gest SpA.

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