Multibody models of railway vehicle and track with flexible wheelsets and rails

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Since the 19th century and with the development of the railway industry, several authors have tried to understand the wheel-rail interaction and calculate contact forces to ensure the stability of the vehicle, avoid the risk of derailment and understand the wear mechanism of the wheel and the rail, and also the mechanism of noise generation. In 1882, Hertz proposed the first theory of the mechanical contacts [1], it was adopted for the resolution of normal wheel-rail contact problem. In this theory, the shape of the wheel-rail contact surface is assumed to be elliptical without friction. In addition to the Hertz theory, Carter [2] solved, in 1926, the rolling contact problem by taking into account friction by modeling the wheel with a cylinder and the rail with a semi-infinite plane. Nevertheless, this theory considers only longitudinal creepage. Different authors have extended this theory to other configurations: Johnson [3] in 1958 for longitudinal and transversal creepages with circular contact shape, Haines-Ollerton [4] in 1963 and Vermeulen-Jonhson [5] in 1964 for elliptical contact shape. More recently, with the increase of computational resources, wheel-rail interaction problem were solved using finite element method (Vo and al. [6] in 2014, Arslan and al. [7] in 2012, Zefeng and al. [8] in 2011, etc.). Nevertheless, high computational cost is the main drawback of these simulations, although only just a small part of the rail (≤ 1m) is considered. In order to study the rolling over kilometers, multibody models of vehicle-track interaction used by railway companies use mainly rigid components, allowing real time calculations in low frequency ranges, but these models do not properly estimate real interaction forces because of the strong hypothesis of the components rigidity. To improve these models, it's necessary to include a maximum of flexible components by coupling finite elements analysis with the multibody dynamics simulations, and by using model reduction methods in order to reduce degrees of freedom of the finite element model and calculation time.

The main objective of this study is to develop multibody models of a railway vehicle and track with flexible wheelsets and/or flexible rails. In a second step, these models will be subjected to excitations involved by the rail and/or the wheel irregularities (wheel flat, rail joint, etc). To estimate the efficiency of these models, wheel-rail contact forces will be compared for different configurations, and their effects on stability of vehicle and derailment will be evaluated.

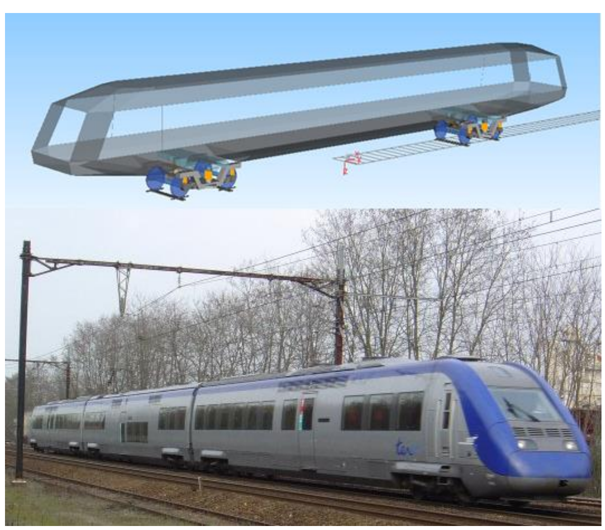

Fig. 1: ZTER and its model in SIMPACK

SIMPACK software is used to develop a multibody model of ZTER vehicle rolling on a straight track (Fig. 2). ZTER is a French regional passenger train, operated by the French national railways company (SNCF). The wheelsets are linked to the bogies by primary suspensions, and the bogies are linked to the carbody by secondary suspensions. Track components are: Rails, railpads, sleepers and ballast.

To integrate the flexibility of wheelsets and rails, ABAQUS finite elements code is used to develop finite elements models of wheelset and track and to calculate their eigenmodes and eigenfrequencies (Fig. 2).

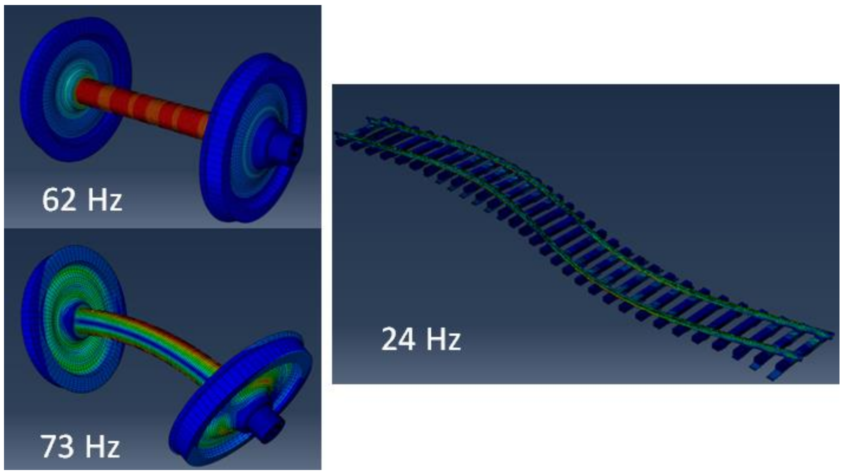

Fig. 2: First eigenmodes and eigenfrequencies of the wheelset and the track

In order to couple finite elements models with the multibody dynamics simulations, the Craig-Bampton method [9] is used to reduce the finite elements model, by retaining some nodes and some of their DOFs (Bearing nodes, contact nodes distributed on the rolling surface of the wheels and distributed nodes on railhead).

These models will be used to reduce the proportion of physical tests by numerical simulations in order to certify railway systems and ensure the stability and safety of trains.

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