# Abstract

Rail transport remains, nowadays in Europe, a considerably popular means of transport. In some countries, new tracks are built in order to improve the railway mesh and thus facilitate the transport of people and goods. However, a train running on a track represents, especially for rail freight transport, a huge mass moving on a flexible support that indubitably generates vibrations. These vibrations sometimes cause cosmetic damages in surrounding buildings or discomfort for people being close to the track. In order to assess the potential vibration levels caused by a running railway vehicle, numerical models are developed. These numerical models usually provide a relevant representation of the reality for a largely reduced cost in comparison with an actual prototype construction or expensive experimental measurements. Due to the fundamentally different behavior of the vehicle and the soil, two-step models were developed to overcome the difficulty to build a monolithic model. However, depending on the distribution of the system constitutive elements in the steps, simplification hypotheses and reductions are considered. This problem does not occur when co-simulation is used since both software programs interact during the simulation.

This work studies the construction of a co-simulated vehicle/track/soil model dedicated to ground-borne vibration assessment. The proposed model couples a multibody software that simulates the upper subsystem including the vehicle and a finite element software for the lower subsystem simulation including the soil. However, the principal objective targeted by the present work is an investigation of the effect of co-simulation on the results in the specific case of railway dynamics. Different co-simulation techniques, previously studied theoretically, are applied to a two-dimensional model coupling the vehicle, the track and a reduced version of the soil inside a same program. The principal aim of this study is to validate the implementation of co-simulation techniques and also to compare the results obtained with a co-simulated model and the corresponding monolithic modeling for railway dynamics problems. After validating the co-simulation between an in-house multibody software and a commercial finite element software, a more comprehensive and three-dimensional modeling of the soil is built.

Regarding the co-simulation techniques, the conclusions obtained using a theoretical two-degree of freedom model and the vehicle/track/soil models including either a reduced or comprehensive soil modeling remain similar. Principally, it is showed that the Gauß-Seidel sequential approach provides more accurate results than the corresponding Jacobi parallel approach. Furthermore, the displacement/displacement coupling type reveals a more accurate but less damped behavior than the displacement/force coupling type. Moreover, considerable differences are noticed in the results depending on how the track is distributed between the upper and lower subsystems. Indeed, it is demonstrated that cutting at the ballast level provides more accurate and robust results than at the level of the railpads or the wheel/rail contact. Finally, the co-simulated model built in this work is compared with an already validated two-step model and it is showed that the results obtained are similar as soon as the soil rigidity is not too low.