DEL120 - RisicOmodel SpoordeformatiE

On this wiki a hybrid methodology is described where a data-driven approach and a model-driven approach are combined to enhance model predictions of railway track displacement due to regular train traffic. All the models developed within the hybrid methodology are open-source and can be found in Noordam & Zuada Coelho (2021).

Model description

The numerical model consists of two parts; the dynamic train-track interaction model and the long-term cumulative settlement model.

Dynamic train-track interaction model

The dynamic train-track interaction model is based on the model described in Zhai & Sun (1994). A schematic representation of the model is shown in Figure 1.

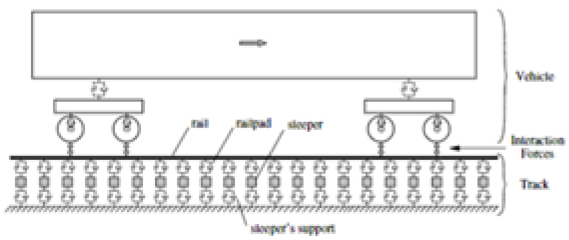

Figure 1. Schematisation of the dynamic train track interaction model (Zuada Coelho et al., 2021).

The dynamic train-track interaction model consists of two separate systems: a train system and a track and subsoil system. The train system is a model which consists of masses and linear springs and dampers. In Figure 1 the train model is shown which consists of one wagon, which is modelled as a moving mass. The wagon is connected with springs and dampers to two bogies, which are also modelled as moving masses. The bogies are connected with springs and dampers to the wheels which are modelled as moving masses. Note that the configuration of the vehicle is not limited to the one as shown in Figure 1, but it can be extended to take into account different axle configurations.

The track and subsoil system consist of a two dimensional finite element system. As the numerical model is to be used at network level, it needs to be computationally efficient. Therefore the finite element system solely consists of rod elements, Timoshenko beam elements and masses. The rail is modelled with Timoshenko beam elements. At every 0.6 m, the rail elements are connected to railpads. The railpads are connected to the sleepers and the sleepers are connected to the sleeper’s support, both by rod elements. The sleeper’s support represents a combination of ballast bed and subsoil and is modelled as a spring damper element.

The dynamic stiffness and damping of the sleeper’s support are determined by the cone-model based on one-dimensional wave propagation (Wolf & Deeks, 2004). The calculated dynamic stiffness and damping for railway loading depend on the subsoil layering and geomechanical properties and train velocity (Zuada Coelho *et al.* 2021).

Cumulative settlement model

Results of the dynamic train track interaction model are used as input for the cumulative settlement model. The used cumulative settlement model is described in detail in Varandas *et al.* (2014). This model is a semi empirical explicit settlement model for the ballast, which is a function of the number of load cycles and the amplitude of the applied force in the ballast.

Data-driven model

The data driven model consists of an inverse analysis where the numerical results are optimised with experimental results. The inverse analysis is performed using the Levenberg Marquardt method (More 1977), which is a method to solve non-linear least square problems.

Data description

Along the track, multiple datasets are available which can be used to improve the numerical model: Interferometric synthetic aperture radar (InSAR) which can be used to map height changes, loaded track deformation measurements and axle accelerations of a moving train. While each dataset can be used to make better predictions, this example focuses on the use of axle acceleration measurements to improve the dynamic train-track interaction model.

Figure 2 presents data measured with an accelerometer on the front axle of a moving train along one segment of the railway track. The top figure shows the velocity of the train and the bottom figure shows the acceleration of the front axle.

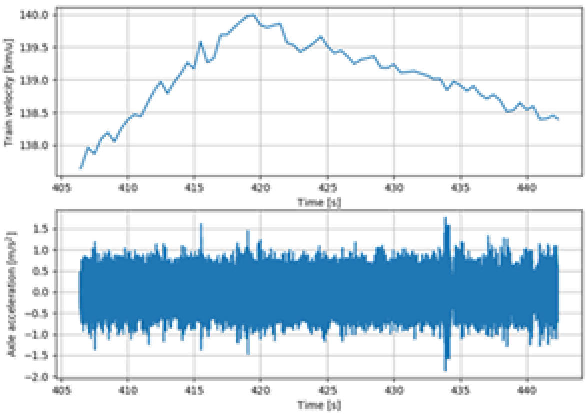

Figure 2. Time history of: (top) train velocity and (bottom) axle acceleration measurements.

Example assesment of railway track settlement

Hybrid model results

The hybrid model results follow from the combination of the model-driven with the data-drive results. These models are combined my means of the inverse analysis. For the inverse analysis, the sleeper support stiffness is iteratively optimised. The target of the inverse analysis is the front axle velocity amplitude at the sleeper passing frequency.

Figure 3 shows the converging pathway of the solution.

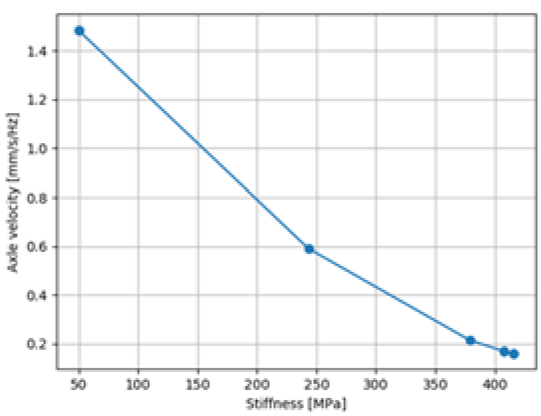

Figure 3. Inverse analysis converging pathway, Axle velocity versus stiffness.

From Figure 3, it can be seen that within 5 iterations, convergency occurs for the dynamic stiffness, at 416 MPa. The resultant dynamic stiffness of 416 MPa is applied to the sleeper support in the dynamic train-track interaction model. The cumulative settlement model is then used to recalculate the cumulative settlement after one year, while taking into account both passenger trains as cargo trains. Figure 4 presents the comparison between the initial predicted and the updated long-term cumulative settlement for the segment in analysis.

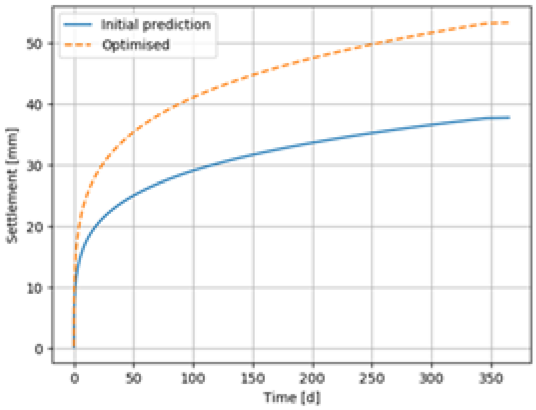

Figure 4. Time history of the cumulative settlement. Comparison between the initial prediction of the dynamic stiffness and the optimised dynamic stiffness.

From Figure 4 it follows that the optimised dynamic stiffness has significant influence on the cumulative settlement after one year of train traffic. Where using the first guess of the dynamic stiffness results in a settlement after one year of 38 mm, using the optimised dynamic stiffness results in a total settlement of 53 mm.

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