The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 5.4
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.5.4

Calibration of a model for dynamic vehicle – track interaction in crossing panels to comprehensive field measurements

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Abstract

A so-called Whole System Model (WSM) for railway switches and crossings (S&C) is currently under development within the European research program Shift2Rail. The objective of the WSM is that it should allow for holistic simulation-based evaluation of S&C designs and ultimately provide input for Life Cycle Cost analysis and virtual homologation. At the centre of the WSM is a multibody simulation (MBS) model that evaluates the dynamic vehicle-track interaction for a given S&C design and traffic situation and generates wheel-rail contact quantities and structural responses for the following damage calculations. This paper is focused on the MBS model and present developments for a finite element track model of an S&C crossing panel. The developments concern the model itself and a calibration to measurement data from a comprehensively instrumented S&C demonstrator installed as a part of Shift2Rail activities in the Austrian railway network. The presented track model demonstrates an overall good agreement between measurements and simulation after minor and physical track parameter adjustments. A very good agreement is obtained at the center of the crossing panel at the crossing transition while discrepancies are found across the track along the sleeper that goes underneath the crossing transition. It is hypothesized that this discrepancy is due to variations in ballast stiffness distribution under the investigated sleeper. It is concluded that the presented track model can represent the track dynamics well enough to fulfil its function within the Whole System Modelling scheme.

Keywords: multibody simulations, switch, crossing, flexible track, measurements

1 Introduction

A so-called Whole System Model (WSM) for railway switches and crossings (S&C) is currently under development within the European research program Shift2Rail [1]. The objective of the WSM is that it should allow for holistic simulation-based evaluation of S&C designs and ultimately provide input for Life Cycle Cost analysis and virtual homologation. The WSM is based on physical modelling of the mechanical aspects of S&C. The dynamic interaction between S&C and passing vehicles is considered along with loading and deterioration of S&C components over time. An iterative approach is used where damage increments in each considered damage mode are computed and accumulated in the model for increments in traffic loading. As it is not feasible for a single model to capture all relevant aspects of long-term S&C performance given the vast differences in length, time and frequency scales involved, the WSM is a framework that integrates state-of-the-art simulation tools and techniques.

At the centre of the WSM is a multibody simulation (MBS) model that evaluates the dynamic vehicle-track interaction for a given S&C design and traffic situation and generates wheel-rail contact quantities and structural responses for the following damage calculations. This paper will be focused on the MBS model and present developments for a finite element track model of an S&C crossing panel. The developments concern the model itself and a calibration to measurement data from a comprehensively instrumented S&C demonstrator installed as a part of Shift2Rail activities in the Austrian railway network. The developments from a previous version of the track model [2] concern (1) a more detailed check rail and (2) that it accounts for the depth dimension of the track superstructure to capture the structural loading stemming from lateral wheel-rail contact loads that can be significant in S&C, especially at the check rails. The calibration concerns the model's capability to capture the structural response in terms of accelerations and displacements under traffic loading and the induced bending moments in the crossing rail and the sleeper underneath the crossing transition.

2 Methods

For the present investigation the MBS model consists of a ½ vehicle, i.e. a bogie with half of the car body mass on top, and a finite element representation of the crossing panel. The vehicle and track are truncated to save computational effort, and as the study is focused on the crossing transition, this is sufficient. In the finite element track model, all rails and sleepers are represented by Timoshenko beam elements, and the connections between rails and sleepers are modelled with Kelvin bushing elements. The ballast under each sleeper is represented by discrete bi-linear bushing elements that can account for the development of sleeper voids. The model is built on the commercial MBS code Simpack and the track model is implemented with its non-linear flextrack module. The model is illustrated in Figure 1.

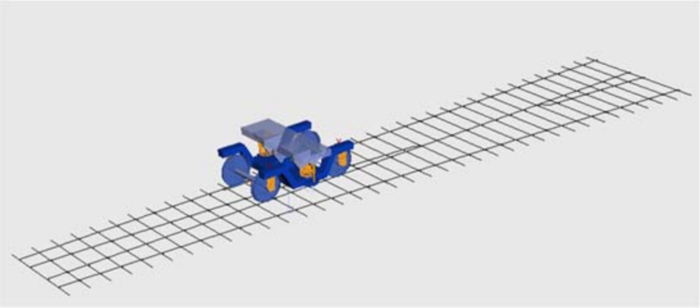

Figure 1: Simpack model with crossing panel and bogie vehicle

The measurement data used for the model calibration concern time histories of accelerations and strains from four and five locations, respectively, on the crossing rail and the sleeper underneath the crossing transition. The strain gauges are located at the bottom of the crossing and at the top of the sleeper to measure bending deformations. The data stems from the 60E1-500-1:12 turnout demonstrator installed in the Austrian network as a part of the Shift2Rail research program. The data were recorded under controlled conditions with an ER20 locomotive running through the crossing panel in the different routes and at different speeds. To allow for easier comparison to the simulation model, the measured accelerations were reconstructed to displacements using the method in [3].

To calibrate the track model against the measurements, it was first updated to correspond to the demonstrator crossing panel in terms of layout, rail pad, rail and sleeper properties. The laser-scanned crossing geometry from the demonstrator was also incorporated into the simulation model. To represent traffic the ½ vehicle model based on the Manchester Benchmark passenger vehicle [4] was adjusted to correspond to the ER20 locomotive axle load and bogie axle spacing. Vertical suspension properties were adjusted in proportion to the car body mass increase to maintain resonance frequencies. A nominal S1002 wheel profile was used in the simulations.

3 Results

The agreement between measurements and simulation is studied for the structural response in terms of accelerations and displacements as well as bending strains in the crossing rail and the sleeper underneath the crossing transition. A good agreement between measurements and simulation is achieved for the vertical dynamics at the crossing transition. Figure 2 presents the vertical displacement for the crossing rail at the crossing transition and a corresponding point on the sleeper underneath the crossing transition in measurements and simulation. The results concern a bogie passage in the facing move in the through route of the crossing panel at 120 km/h. The agreement is overall very good, and the only adjustments made to the simulation model to obtain this level of agreement were to adjust the ballast stiffness to the overall track displacement and to increase the nominal rail pad stiffness by 50% from 25 to 37.5 kN/mm. A good agreement is also found for the crossing and sleeper bending at the crossing transition in the centre of the track.

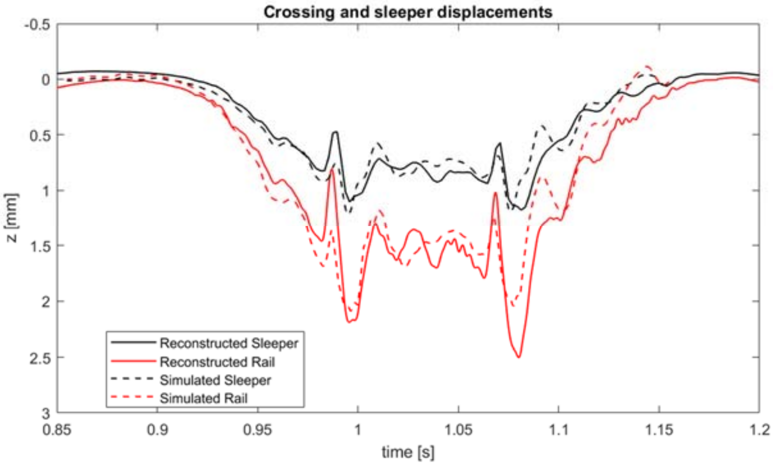

Figure 2: Simulated and measured displacements for rail and sleeper at the crossing transition for one bogie passage. The measured displacements have been reconstructed from measured accelerations

The agreement in results for measurements across the track are not as good, as the simulation model predicts more sleeper rotation and less sleeper bending and thus also a different sleeper bending moment distribution. The discrepancy appears to be due to the unknown ballast stiffness distribution under the sleeper at the installation site. A uniform ballast stiffness distribution was assumed in the model. The time histories for measured and simulated sleeper displacements at five locations along the sleeper underneath the crossing transition are shown in Figure 3. While the trajectories are qualitatively in good agreement, the simulation model overestimates the sleeper displacements towards the field side of the crossing panel at measurement points *a1d* and *a1e*. Measurement point *a1* is located at the crossing transition.

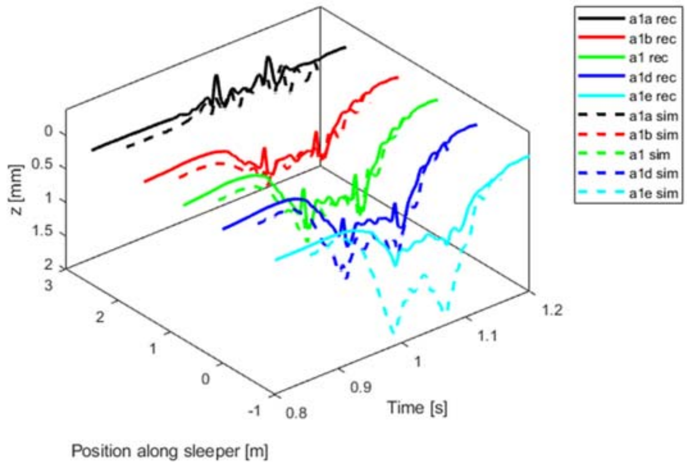

Figure 3: Time histories for measured and simulated sleeper displacements at five locations along the sleeper underneath the crossing transition. The measured sleeper displacements have been reconstructed from measured accelerations

4 Conclusions and Contributions

The presented track model demonstrates an overall good agreement between measurements and simulation after minor and physical track parameter adjustments. A very good agreement is obtained at the centre of the crossing panel at the crossing transition while discrepancies were found across the track along the sleeper that goes underneath the crossing transition. It is hypothesised that this discrepancy is due to variations in ballast stiffness distribution under the investigated sleeper. Further analysis of measurement data from additional crossing panels is desired to study the influence of the local ballast conditions. It is concluded that the presented track model can represent the track dynamics well enough to fulfil its function within the Whole System Modelling scheme.

Acknowledgements

The current study is part of the on-going activities in CHARMEC—Chalmers Railway Mechanics. Parts of the study were funded within the European Union's Horizon 2020 research and innovation programme in the project In2Track3 under grant agreement No 101012456.

References

[1] Shift2Rail Joint Undertaking which is part of the European Union's Horizon 2020 research and innovation programme: https://shift2rail.org/

[2] Pålsson B.A. (2020) A Parameterized Turnout Model for Simulation of Dynamic Vehicle-Turnout Interaction with an Application to Crossing Geometry Assessment. In: Klomp M., Bruzelius F., Nielsen J., Hillemyr A. (eds) Advances in Dynamics of Vehicles on Roads and Tracks. IAVSD 2019. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-030-38077-9_41

[3] Milosevic, M.D.G. (2021), Towards model-based condition monitoring of railway switches and crossings, Licentiate Thesis, Chalmers University of Technology, Sweden

[4] Iwnicki, S. (1998) Manchester Benchmarks for Rail Vehicle Simulation, Vehicle System Dynamics, 30:3-4, 295-313, https://doi.org/10.1080/00423119808969454