Dynamic behavior of a railway crossing: comparison of the results of multibody system dynamic and explicit FEM models

V.L. Markine, X. Liu, Y. Ma

Delft University of Technology, Delft, The Netherlands
v.l.markine@tudelft.nl, xiangming.liu@tudelft.nl, yuewei.ma@tudelft.nl

The paper presents the results model comparison of the multibody system (MBS) and explicit finite element (FEM) models for analysis of wheel-rail interaction in railway crossings. Both models are parts of an integrated (experimental and numerical) tool for analysis an improvement of performance of the railway crossings. The studied type of crossings, which is a part of a double crossover, is the casted manganese steel crossing with the angle of 1:9 (Figure 1a-b). This type of crossings, which are quite common on the Dutch railway network, suffer very much from severe plastic deformation and cracks leading to the spalling damage or even to sudden fracture of the crossing nose (Figure 1c). These crossing are mainly passed in the main (facing or trailing) direction with relatively high speeds (140 km/h). The service life of such crossings in the Netherlands has become prohibitively short that in some cases is 1 year. Also, the maintenance actions performed on such a crossover have not resulted in improvement of the crossing performance. Therefore, TU Delft was asked to analyse the problem of the poor performance of the crossing and to suggest the ways of its improvement. Also, the effectiveness of the maintenance actions had to be assessed.

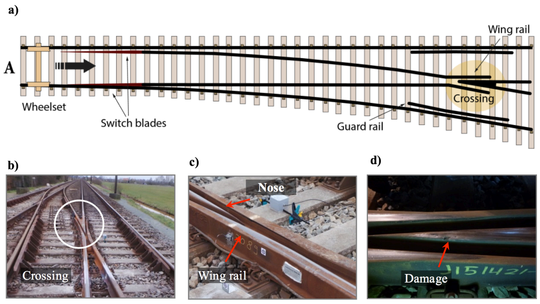
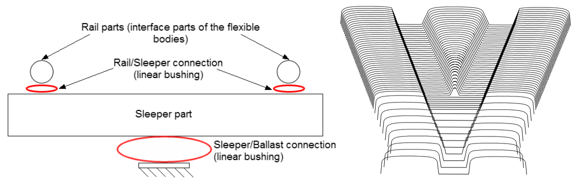


Figure 1. a) Railway turnout b) Monitored crossover c) Crossing instrumentation d) Damage at crossing nose. (Figure from [1])

In order to answer these questions an integral approach was proposed that consists of the following parts:

- Development of the multibody dynamic model for analysis of the vehicle and crossing interaction [1]
- Development of the (explicit) dynamic finite element model (FEM) of the crossing [2]
- Instrumenting of the crossing and obtaining the dynamic responses (displacements, accelerations due to impact wheel forces) [3,4,5]
- Performing long-term monitoring of the crossings by collecting the dynamic responses and periodically measuring the crossing geometry [5,6]
- Improvement of crossing performance by adjusting the crossing design (mechanical and geometrical) parameters and its implementation [1, 5]



a. b.

Figure 1 Dynamic model (a) and crossing geometry (b) developed in VI-Rail

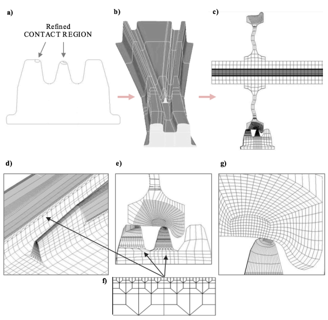


Figure 3. FE model of crossing (Figure from [1])

In order to assess performance of various crossing geometries the dynamic model of the train-turnout system has been developed in the commercial MB package VI-Rail. The model is schematically shown in Figure 1. The parameters of the vehicle model implemented in VI-Rail have been adjusted to simulate the behaviour of the passenger intercity train of the VIRM type (the wheel load of 89 kN) used in the Netherlands. The track is represented using the ‘moving track’ model implemented in VI-Rail. The wheel-rail contact forces are obtained using the FASTSIM algorithm.

The FEM model of the crossing developed here uses the novel (as compared to the existing FE wheel-rail models e.g. [7]) features specifically developed for the explicit FE analysis of wheel-rail interaction, such the adaptive mesh refinement procedure based on coupling the 2-D (kinematic) and 3-D models (Figure 2), and selection of the optimal contact interface parameters (contact stiffness, element size and integration time step) introduced in [8].

Both crossing models were verified against the accelerations obtained from the crossing due to passing trains (the crossing instrumentation - 3-D accelerometer is shown in Figure 1b). The numerical models and the results of their validation are briefly presented in the paper.

Since the behaviour of a crossing is sensitive to both track features and vehicle characteristics, it is necessary to take into account the dynamic behaviour of both track and vehicle. For the conditions mentioned above, using a multibody system (MBS) dynamic simulation is necessary. However, the MBS simulation has its limitations, since the stress and strain results are not available from MBS (e.g. for the rail fatigue analysis). In this case the FEM model can be used to consider the rail material behaviour on a local scale such as the plastic deformations and hardening.

The main purpose of the paper is to compare the results of the both models to make sure that they adequately describe the dynamic behaviour of the same crossing, so that the models can be used to complement each other e.g. in multi-scale analysis procedure.

Therefore, the dynamic responses of the wheelset and crossing interaction conducted by the multi-body system model and the finite element model were compared. The parameter settings, initial conditions and simulation results are compared and discussed. The parameters such as the rail pads and ballast stiffness, damping parameters, axle load and velocity were set to the same values. The initial conditions in both models at the position where the wheelset starts rolling in FE model are checked to make sure that there are no big difference exists at the beginning of the simulation. The results such as impact location including transition zone, wheelset displacement and contact forces and pressure are compared.

It is found that in general the results are comparable, however some deviations still exist. The deviation in impact location could be explained by the preload stage and the absence of primary suspension in FE model. The difference in the magnitude of the contact forces and pressure is closely related to the stiffness and damping parameters which should be tuned. More conclusions and recommendations are in the full paper.

References

[1] C. Wan, V.L.Markine, I.Y.Shevtsov, Improvement of vehicle–turnout interaction by optimizing the shape of crossing nose, Vehicle System Dynamics, 52, 1517-1540, 2014.

[2] Ma, Y., Mashal, A. A., & Markine, V. (2018). Modelling and experimental validation of dynamic impact in 1:9 railway crossing panel. *Tribology International*, *118*, 208-226. DOI: 10.1016/j.triboint.2017.09.036

[3] V. L. Markine and I. Y. Shevtsov, (2013) An Experimental Study on Crossing Nose Damage of Railway Turnouts in The Netherlands, presented at the *Proceedings of the Fourteenth International Conference on Civil, Structural and Environmental Engineering Computing* (CC2013), 2013.

[4] Liu, X, Markine, VL & Shevtsov, I (2015). Performance study of a double crossover for facing and trailing directions. In M Rosenberger, M Plochl, K Six & J Edelmann (Eds.), *Proceedings of the 24th international symposium on dynamics of vehicles on roads and tracks, IAVSD 2015* (pp. 1-9). Boca Raton: CRC Press.

[5] V.L. Markine, C. Wan, (2016) Performance Optimised Geometry of Railway Crossings: Design and Implementation, *International Journal of Railway Technology*, 5(2), 1-25, 2016. doi:10.4203/ijrt.5.2.1

[6] Liu, X, Markine, VL & Shevtsov, I (2016). A performance study of railway crossings in facing and trailing directions. In J Pombo (Ed.), *Proceedings of the 3rd international conference on railway technology: Research, development and maintenance* (pp. 1-10). Stirlingshire: Civil-Comp Press.

[7] M. Wiest, E. Kassa, W. Daves, J. C. O. Nielsen, and H. Ossberger, "Assessment of methods for calculating contact pressure in wheel-rail/switch contact," *Wear,* vol. 265, pp. 1439-1445, 10/30/ 2008

[8] Ma, Y, Mashal, AA & Markine, VL (2016). Numerical analysis of wheel-crossing interaction using a coupling strategy. In J Pombo (Ed.), *Proceedings of the 3rd international conference on railway technology: Research, development and maintenance* (pp. 1-19). Stirlingshire: Civil-Comp Press.