Improvement of train-track interaction in turnout crossings

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Abstract

Turnouts are important elements of railway infrastructure that provide flexibility of the system by enabling railway vehicles to be guided from one track to another at a railway junction (Figure 1). Due to discontinuity in the rail geometry introduced in the crossing nose, the turnouts experience high impact loads from passing vehicles, which makes the turnout sensitive to various types of rail damage such as excessive wear, plastic deformations, surface cracking and crumbling, shelling, global fracture etc. Damage of the crossing nose has become a serious problem of the Dutch Railways: currently every week 2 crossings must be replaced urgently.

Figure 1: Crossing panel of turnout and damage of crossing nose

A number of research papers on damage in turnouts have been published recently [1]-[5]. This study, which follows the research presented in [2]-[5], is based on the numerical and experimental analysis of the dynamic behaviour of the train-turnout system and on the methods of numerical optimisation.

Firstly, the dynamic interaction between the vehicle and turnout was analysed experimentally using the instrumented crossing (Figure 2). The measured data comprising of (among others) the 3-D accelerations of the crossing nose and locations of the maximum wheel forces on the crossing nose (Figure 2) were collected on several turnouts. The measured data [2] confirmed the numerical results presented in [3] that the crossing nose geometry has significant influence on the dynamic forces in the crossing area, which is also shown in Figure 3.

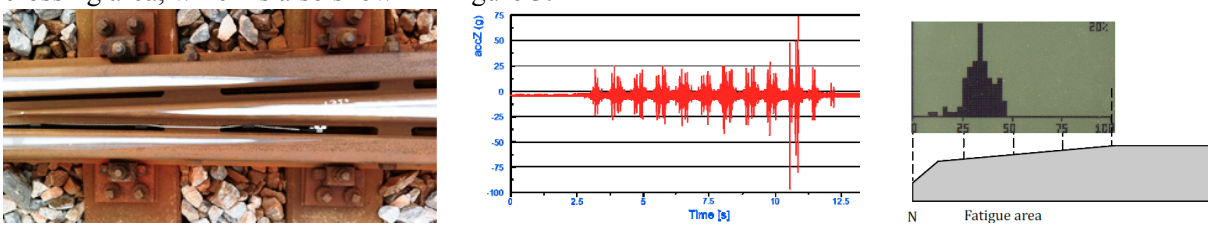

Figure 2: Instrumented crossing nose, acceleration and fatigue area measurement data

The dynamic analysis of the vehicle and turnout interaction is performed using the commercial package VI-Rail, which uses the multi-body formalism. The numerical model was validated using the collected geometry and acceleration measurement data. To reduce the computational efforts the turnout model was simplified to flexible 'moving track'. The vehicle model is based the passenger train operating on the Dutch railway network. The rail geometry in the crossing (1:15) was described by defining two wing rails, crossing nose and track gauge (Figure 4), outside the crossing the standard UIC-54 rail is used.

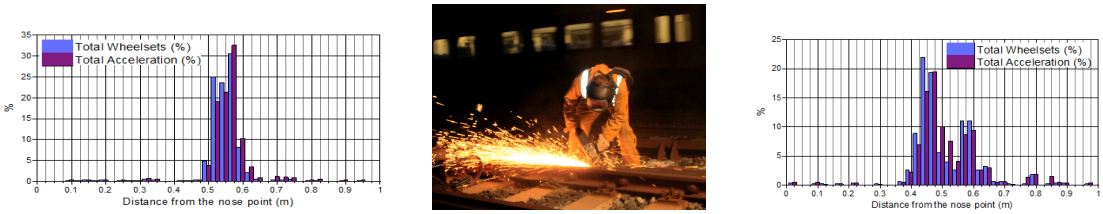

Figure 3: Distribution of maximum wheel forces along crossing nose before and after grinding

To optimise the shape of the crossing nose its geometry must be parameterised first. The geometry is defined by four cross-sections (A-D) located on the certain distances from the beginning of the crossing nose (cross-section A) as shown in Figure 4. The shape of the crossing nose after grinding totally depends on the welder's experience. The location and the shape of the cross-sections controlled by the welder during the grinding process differ from the ones used during the manufacturing process of the crossing nose (additional cross-section E in Figure 4).

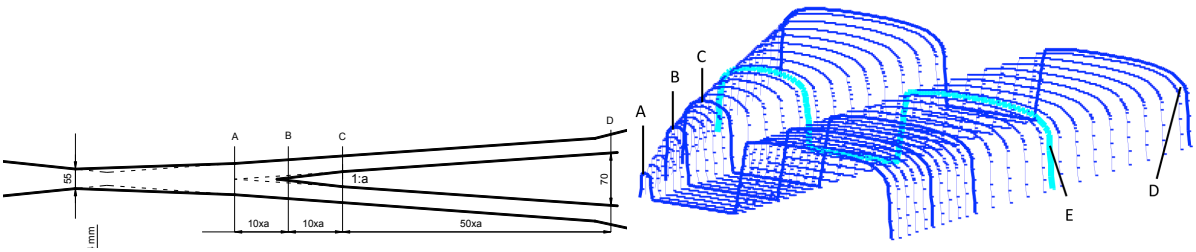

Figure 4: Definition of crossing nose geometry

The cross-sections to be varied during the optimisation have been defined using B-splines, the parameters of which are then chosen as the design variables. The weighted combined objective function $F_0(x) \equiv w_1 \frac{S}{S^*} + w_2 \frac{W}{W^*} \quad \to \min$ accounts for impact damage (the normal pressure S) and wear (W) of the crossing nose. Constrains were imposed on the values of the design variables to avoid unrealistic rail shapes and on the stability of the vehicle. The (Pareto) set of compromised solutions of this multi-criteria optimisation problem has been found using a numerical optimisation method[6]. Finally, one optimum design was chosen from the Pareto solutions and its robustness was checked by performing multiple simulations of the vehicle passing the turnout for various initial disturbances of the vehicle.

References

[1] E. Kassa and J. C. O. Nielsen, "Dynamic interaction between train and railway turnout: full-scale field test and validation of simulation models," *Vehicle System Dynamics,* vol. 46, pp. 521-534, 2008.

[2] V. L. Markine and I. Y. Shevtsov, "Experimental Analysis of the Dynamic Behaviour of Railway Turnouts," in *The Eleventh International Conference on Computational Structures Technology*, Dubrobnik, Croatia, 2012.

[3] V. L. Markine, M. J. M. M. Steenbergen, and I. Y. Shevtsov, "Combatting RCF on switch points by tuning elastic track properties," *Wear,* vol. 271, pp. 158-167, May 18 2011.

[4] C. Wan, V. L. Markine, and I. Y. Shevtsov, "Simulation of Train-Turnout Interaction and Validation using Field Measurements," in *Proceedings of the First International Conference on Railway Technology: Research, Development and Maintenance*, Las Palmas de Gran Canaria, Spain, 2012.

[5] C. Wan, V. L. Markine, I. Y. Shevtsov, and "Improvement of vehicle–turnout interaction by optimising the shape of crossing nose," *Vehicle System Dynamics,* 2014.

[6] R. G. Strongin, D. L. Markin, and M. V. Markina, "Reduction of multi-extremum multi-criterion problems with constraints to unconstrained optimization problems: theory and algorithms.," *Computational Mathematics and Modeling,* vol. 6, pp. 242–248, 1995.