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Enhancement of a CEN56 acute crossing using an automated optimisation process

Y. Bezin[1], H. Magalhaes, P. Jorge[1] and P. Winship[2]

[1] Institute of Railway Research, School of Computing and Engineering, University of Huddersfield, United Kingdom
[2]Network Rail, the Quadrant, Milton Keynes, UK

Abstract

This paper is focused on an optimisation study of a GB 56E1 vertical acute crossing carried out as part of Shift2Rail project In2track2. The aim of the study was to achieve a design that helps minimise the impact load during wheel transfer and thus minimise the risk of degradation and fatigue failure of the cast crossing and subsequent cost of maintenance and replacement.

The optimisation process achieved using the SnC_Design tool developed in Matlab, that fully accounts for the machining operations in use by industry suppliers to achieve the rail top surface shape, and it further allows a thorough assessment of the wheel-rail interaction by generating all necessary data for multibody simulations (MBS). The evaluation process is carried out on key output criteria generated from the simulations, such as dip angle, peak force and contact pressure. The tool allows the complex tri-dimensional optimisation and the many trade-offs to be solved.

120 alternative designs, varying nose topping and three additional parameters defining the wing rail shape, were assessed via a total of 2880 simulations cases. A candidate design was selected, showing 29 % (facing) and 19 % (trailing) increased performance with respect to the current crossings used in UK network for a 56kg rail crossing. This work also shows that replacing multibody simulations by kinematic analysis, where the dip angle or other measure is accurately determined, could lead to quicker solution but it was shown to have strong limitations, so is the dip angle criteria currently used by industry.

Keywords: wheel-rail contact, impact force, crossing, optimisation, design, dip angle.

1 Introduction

In the framework of several European projects [1-2], the University of Huddersfield has collaborated with a number of industry and academic partners to develop a methodology to create a wide variety of switches and crossings models, particularly applied to the prediction of the vertical dynamic load transfer occurring at the crossing using the multibody simulation (MBS) software VI-Rail. In the last few years, the University proceeded to the evaluation of a number of key developments concerning the improved performance of the wheel-rail interaction in crossings (Figure 1), supporting the development of Network Rail NR60 mark 2 acute crossing [3] and the evaluation of the recent major refurbishment of the Newark double diamond junction [4].

This paper is focused on an optimisation study of a GB 56E1 vertical acute crossing carried out as part of Shift2Rail in the context of the European project In2track2. The aim of the study was to achieve a design that helps minimise the impact load during wheel transfer and thus minimise the risk of degradation and fatigue failure of the cast crossing and subsequent cost of maintenance and replacement.

In order to understand the effectiveness of the design achieved after the initial months and years of traffic, measurements were made on a couple of the NR60 mark 2 crossing prototypes in operation and the plastically deformed and worn shapes were compared to the newly design ones. This confirmed that the initial shape is affected by those damage mechanisms mostly in the area of the load transfer from the nose to the wing rails (or vice versa) and that the conformed shape eventually performs better than the initial design. Therefore, an optimisation of the machined shape would benefit from being closer to a deformed shape from the initial manufacturing stage. Nonetheless, current manufacturing methods are providing limited choices in this respect and the optimisation was focused on adapting the current cutting shapes that make the wing rail and the nose shapes.

Figure 1: a railway cast manganese crossing under traffic

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Methods

The optimisation process was supported by the development of a SnC_Design tool in Matlab, that fully accounts for the machining operations in use by industry suppliers to achieve the rail top surface shape, and it further allows a thorough assessment of the wheel-rail interaction by generating all necessary data for multibody simulations (MBS) as described in the recent S&C Benchmark [8,9]. The geometry data generated is based on series of Boolean operations and directly coupled with MBS, so that the evaluation process is carried out on key output criteria generated from the simulations.

Using multibody simulations of railway vehicles negotiating the crossing allows consideration for multiple vehicle types and axle loads, their unsprung mass and speed, as well as a range of curving configuration to laterally offset the various wheelset against checkrail positions in both directions. A number of representative wheel profiles, shown to have a major incidence on the severity of the wheel load transfer [5] were used. A fast kinematic analysis of wheel-crossing pairs can be performed in parallel to the dynamics MBS. The performance of certain wheel-vehicle and crossing combination is evaluated based on the wheel vertical motion, the derive dip angle, the resulting raw and the low pass filtered force (P2), expected to lead to foot fatigue failure, ballast settlement and void [6-7]. Additional criteria used are peak contact pressure and contact energy to indicate plastic deformation and wear intensity respectively.

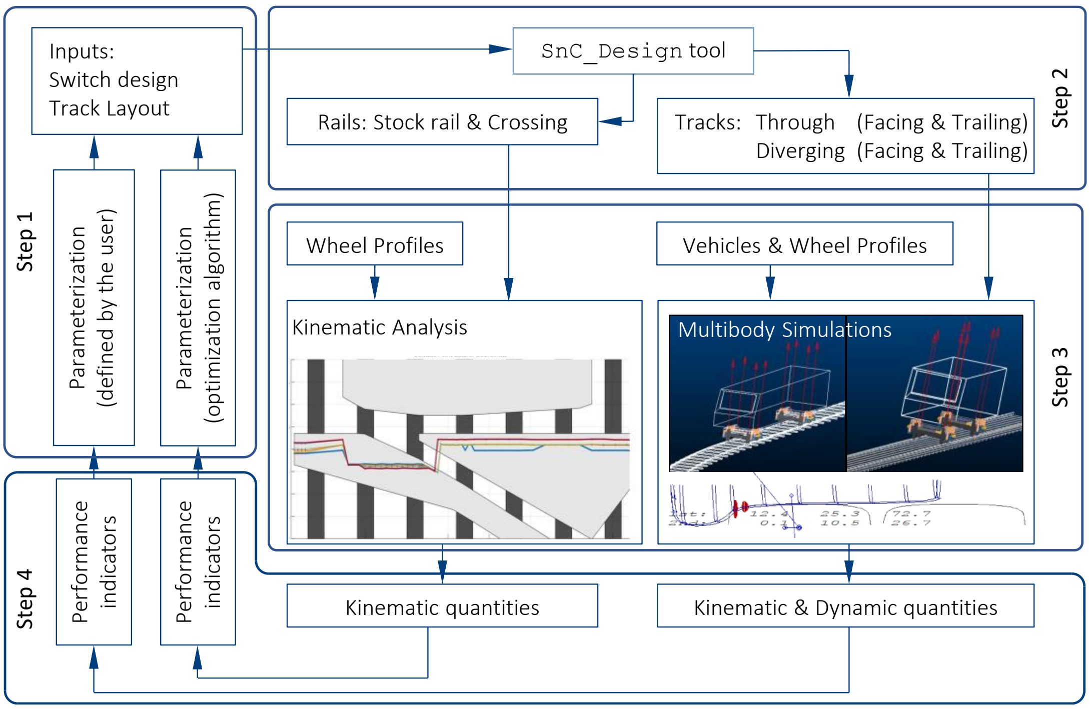

Figure 2: evaluation process based on UK TRK012 assessment for crossing fatigue

To ensure the best load transfer, it is necessary to find the optimum relative shape between the wing rail and the nose toping. Because this depends on the type of wheel passing and its lateral position, as well as the traveling direction, the problem is a complex tri-dimensional one composed of many trade-offs. In previous studies, the work was carried out on a few deterministic designs, by way of trying different options in terms of shape of wing rail (slope and corner radius), as well as different ways of machining the nose topping. In the current In2Track2 project, the newly developed methodology as allowed to scan for a wider range of parameters and a wider range of values for these parameters so that up to 120 alternative designs were assessed via a total of 2880 simulations cases.

3 Results

Initially, five crossing designs obtained from previous European and Network Rail projects were assessed. The work revealed that simplified kinematic analysis (dip angle estimate) as used by the industry to evaluate performance of crossing designs, do not correlate well with from the more accurate multibody simulations results. However, the dip angle determined with the multibody simulation shows a good correlation with the P1 dynamic force result, meaning that a simplified kinematic analysis does not capture sufficiently well the wheel vertical motion. With the multibody simulations established as a more robust mean of evaluation of the crossing design, 120 multibody simulations considering the five initial designs were analysed in detail. The design converted from the variant 4 of the NR60mk2, as defined in a previous Network Rail project [10], showed the best overall performance.

Eventually, the NR56 crossing was parameterised to create 120 alternative versions, leading to 2880 multibody simulations. This parameterisation considers variations of the nose topping and the wing rail machining (Figure 3), which are the parts of the crossing details that show higher damage based on site observations. A candidate design for the NR56 mark 2 was selected, showing 29 % (facing) and 19 % (trailing) increased performance with respect to the current crossings used in UK network for a 56kg rail crossing. Those values are based on the performance indicators and traffic considered, which may vary from site to site.

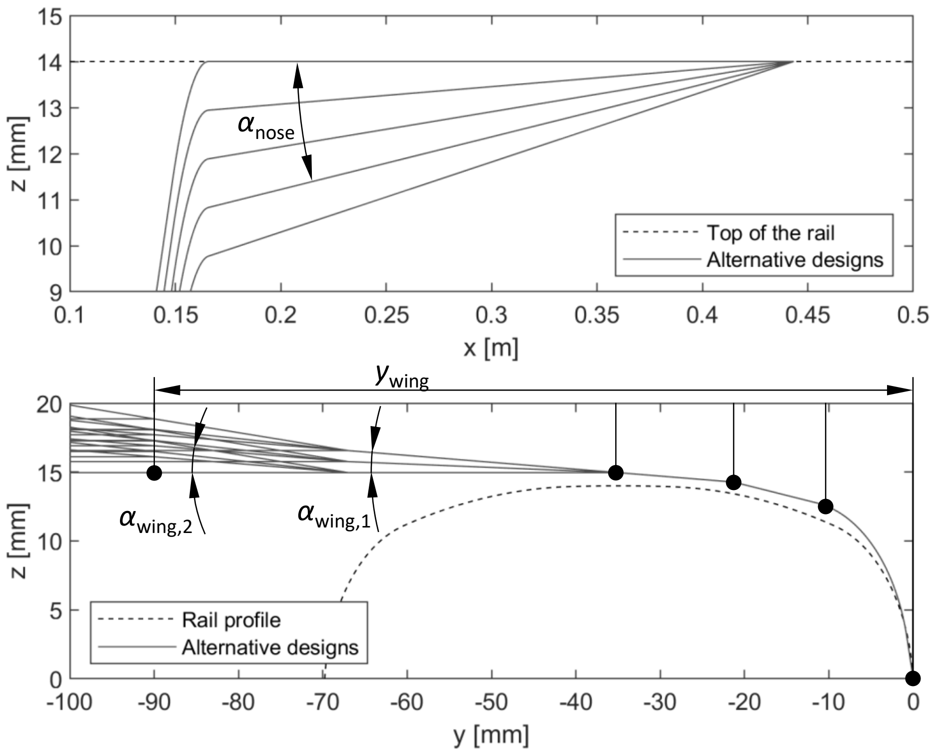

Figure 2: parametric variation of wing rail shape and nose topping

4 Conclusions and Contributions

This work on railway crossing optimisation clearly confirms previous conclusions that the crossing design performance depends strongly on the wheel profile and the travelling direction [1,5]. Therefore, adjusting performance criteria weights depending on traffic is a key point to determine an optimised crossing for a given site, however for practical reasons infrastructure managers only want harmonised and few designs choices to roll out on their infrastructure and compromises will always be necessary. Nonetheless the proposed methodology allows to minimise those compromises. Note that only few features were selected to enhance the crossing design, in terms of the wheel load transfer, and other features of the crossing must be considered to enhance for example, the transition between the closure rails and the leg end of the crossings where dynamic effects and failures are also present. Also, integrating the workflow used in this project with an optimisation algorithm is an ambitious but tangible achievement that would allow to enhance even further the crossing performance. Here, the replacement of multibody simulations by improved kinematic analysis, where the dip angle or other measure is accurately determined, could lead to quicker solution than using multibody simulations but it was shown to have strong limitations, so is the dip angle criteria currently used by industry.

Acknowledgements

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