Analysis of the Track Irregularities in Railway Switch & Crossing via the Multibody Approach

Raül Acosta Suñé, Paul Fisette, Nicolas Docquier

Institute of Mechanics, Materials and Civil Engineering
Université catholique de Louvain
Place du Levant 2, 1348 Louvain-la-Neuve, Belgium
[raul.acostasune, paul.fisette, nicolas.docquier]@uclouvain.be

EXTENDED ABSTRACT

1 Context & objectives

The reliability of many switches & crossings (S&C, also called "turnouts"), that distribute trains along the various lines of the network, plays a vital role in guaranteeing traffic stability. Their geometry requires constant attention to ensure that they work properly and safety. Therefore, certain specific dimensions must be checked. Traditionally, these measurements have always been taken with the help of special rulers, consisting of movable elements, which are purely limited to geometric measurements.

Recently, Infrabel, the Belgian railway infrastructure manager company, has developed an onboard system on one of its measuring trains that takes the above measurements in a "dynamic" way. The measuring train allows for a more complete monitoring of the rail: gauge, cant, rail profiles, etc. However, compared to traditional techniques, this dynamic monitoring is sometimes too severe and leads to excessive interventions on the network. These additional interventions increase significantly maintenance costs and might impact traffic punctuality as they might occur during rush hour.

This research therefore aims to bridge the gap between the new dynamic and the traditional geometric measurements. Wheel/rail interaction problems having been already widely studied in the literature [1][2], our objective is to understand and quantify, via experimental protocols and numerical modelling, the phenomenon of interaction between a vehicle and a S&C, in a situation of dynamic movements (train) and deformations (track).

2 Model and methods

A complete measuring train has been modelled using the ROBOTRAN [3] symbolic multibody software. The outcome of this modelling work required gathering a series of data related to the train bodies, the wheels, the suspensions and the track, in order to build a global multibody model.

A S&C presents some particular elements to be carefully considered in the model that directly influence its dynamics and whose dimensions are very sensitive, such as for example the switch toes, the crossing nose or the check rail (see Figure 1). The latter has the key function to keep the wheels guided to prevent them from drifting into the wrong side of the crossing nose.

Regarding the wheel/rail contact model, three methods of contact are implemented for the possible contact locations in S&C:

- The creep contact model between the wheel tread and the top of the rail (point 1 in Figure 1). It takes creepages and creep forces into account. It is included in the form of vertical kinematic constraints (perfect rigid wheels on a profiled rail) and tangent frictional forces according to the well-established Kalker non-linear model [4].
- The modelling of the intermittent contact of the wheel flange with the rail (point 2 in Figure 1). It is treated as a so-called penalty contact, whose lateral deflection and stiffness mainly comes from that of the rail (roll flexion and lateral displacement).
- The definition of the contact between the check rail and the wheel flange (point 3 in Figure 1) is also treated as a penalty contact, but in this case instead of rail, a check rail interacts with the other side of the wheel flange.

To validate the model, experiments are being planned on an existing and representative S&C, in Brussels, via a strategic location of sensors in the track and in the measuring train: accelerometers, displacement sensors and optic fibres are envisaged in the next months. Various conditions will be investigated: static configurations, different velocities, train travelling in both directions, switch deviating the train to the main and to the diverging route, etc.

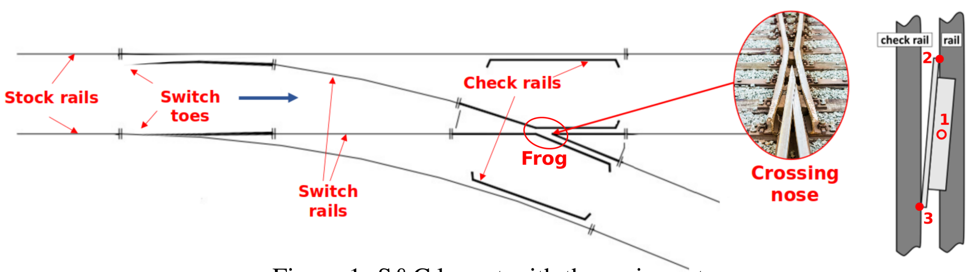

Figure 1: S&C layout with the main parts

3 Results

Preliminary results from multibody simulations are already able to highlight the dynamic impact of several parameters in a highly sensitive S&C place, i. e. the crossing nose where the wheel momentarily loses its first contact and is subjected to flange contacts due to the presence of the guiding check rails.

The tolerance limits beyond which immediate action has to be taken by Infrabel are 2 mm for the distance between the check rail and the rail closest to it. So, a train rolling over a check rail with different values of wear up to the limit has been simulated. The results (Figure 2) show that the contact between the inner side of the flange and the check rail occurs later (in time) when the check rail is worn.

For higher values of wear, the check rail might even fail to guide the wheels and to prevent them from drifting into the gap of the frog. For example, in the case of a wear of 5 mm, the check rail does not hold enough laterally the wheel before entering in the frog. Therefore, once in the frog zone, a new peak of force appears to counteract the tendency of the wheels to deviate from the main trajectory.

Other simulations are able to highlight the effect of removing the check rail and the dynamic problems of guidance that it entails and also the difference in contact forces when there is an hypothetical continuous rail -no gap and no check rail- instead of a crossing zone.

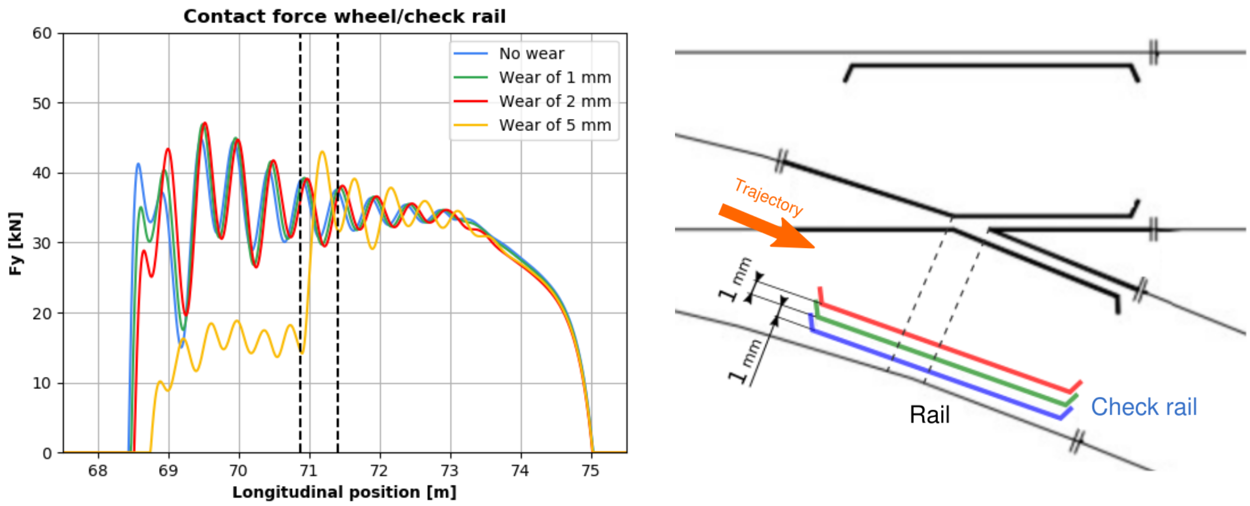

Figure 2: Lateral forces between the check rail and the inner face of the flange of the wheel. Blue: nominal check rail. Green: offset 1 mm from the nominal value. Red: offset 2 mm from the nominal value. Yellow: offset 5 mm from the nominal value. The distance between the two dashed lines represents the frog zone.

4 Conclusions and perspectives

Train dynamics impacts S&C measurements and should be taken into account in the measuring train operation. The current gap between the traditional methods and the measuring train generated by the dynamics of the train itself highlights the need for a better understanding of their behaviour. At this point, the multibody simulations of the vehicle have already been able to study different realistic scenarios and to measure forces, displacements or contact wear at different levels (track, wheels). This multibody model is going to be validated with the field measurements, as it will be shown during the oral presentation.

Acknowledgments

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References

[1] S-CODE. Funded by Shift2Rail. Convention nº 730849. (2021). Retrieved 16 April 2021, from http://www.s-code.info/

[2] IN2TRACK. Funded by European Union's Horizon. Convention nº 730841 (2021). Retrieved 16 April 2021, from https://projects.shift2rail.org/s2r_ip3_n.aspx?p=IN2TRACK

[3] N. Docquier, A. Poncelet, P. Fisette. ROBOTRAN: a powerful symbolic generator of multibody models. Mechanical Sciences, 4:199–219, 2013.

[4] J.J. Kalker, Three-Dimensional Elastic Bodies in Rolling contact, 1990, Dordrecht, The Netherlands: Kluwer Academic Publishers.