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Dynamic Measurement of Switch & Crossing Geometry

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Abstract

The reliability of many switches & crossings plays a vital role in guaranteeing traffic stability. Regular checks on their geometry, particularly specific dimensions, are traditionally done using geometric rulers or via measuring train, that take the above measurements in a ”dynamic” way. However, compared to traditional static techniques, this dynamic monitoring is sometimes too severe and leads to excessive interventions on the network. This research aims to bridge the gap between the new dynamic and the traditional geometric measurements. The objective is to understand and quantify, via experimental protocols and numerical modelling, the phenomenon of interaction between a vehicle and a switches & crossing, in a situation of dynamic movements (train) and deformations (track). Preliminary results from multibody simulations already make it possible to study different realistic scenarios and to measure forces, displacements at different levels (track, wheels). The model validation will be carried out via experimental campaigns with Infrabel, the Belgian railway infrastructure manager company, on a selected switches & crossing with their measuring train. Notably, these experimental campaigns provided valuable insights for the upcoming analysis and validation process.

Keywords: railway dynamics, measuring train, switch, crossing, turnout, measurements, wheel-rail contact.

1 Introduction

To ensure the traffic stability in railways, the reliability of switches & crossings, which distribute trains across different lines of the network must be as high as possible. These devices, commonly referred to as 'turnouts' or 'switches', require constant attention to ensure their proper and safe operation: maintenance of actuators, heating in winter, lubrication, and geometry checks.

Currently, when checking the geometry of these devices, specific dimensions must be verified. Knowledge of these dimensions is essential to ensure that the vehicle's axles can traverse the S&C device freely and safely. Traditionally, these dimensions have always been measured using physical rulers, composed of movable elements, allowing for purely static 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 at a speed up to 40 km/h. The vehicle 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 obviously 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

2.1 Model definition

The Infrabel measuring train has been entirely 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 suspensions, the wheels and the track, in order to build a global multibody model, able to capture dynamic motion and wheel/track interactions.

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.

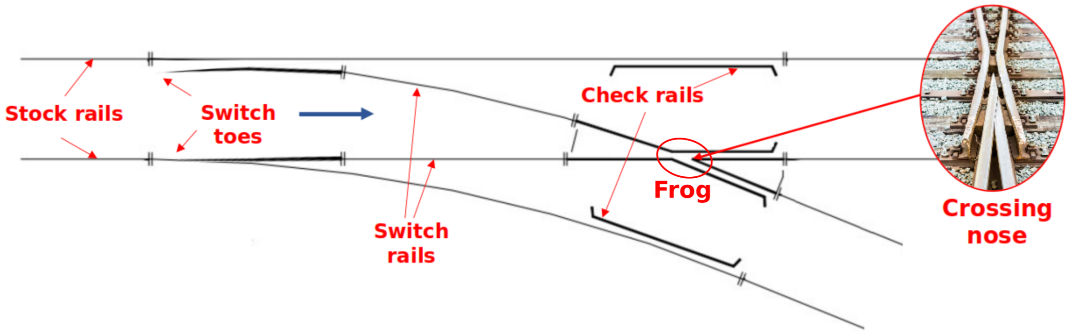

Figure 1: S&C layout with the main components

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

- A creep contact model between the wheel tread and the top of the rail (point 1 in Figure 2). It takes creepages and creep forces into account. It is included in the form of normal 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 2). It is treated as a so-called penalty contact, whose lateral stiffness and damping mainly comes from that of the rail and the track (roll flexion and lateral displacement).

- The definition of the contact between the check rail and the wheel flange (point 3 in Figure 2) is also treated as a penalty contact, but in this case, instead of a rail, a check rail interacts with the other side of the wheel flange.

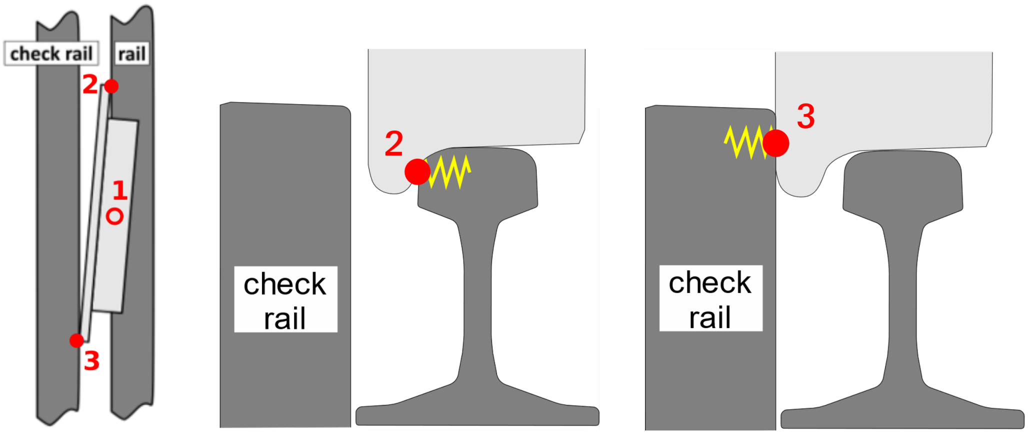

Figure 2: representation of the three methods of contact between the wheel and the rail. 1: contact between the wheel tread and the top of the rail. 2: contact of the wheel flange with the rail. 3: contact between the check rail and the wheel flange.

For the future validation of the model, experiments were conducted on an existing and representative S&C in Brussels. The details of the experimental campaign are explained in Section 3.

2.2 Preliminar results of the model

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 action has to be taken by Infrabel are 2 mm for the distance between the check rail and the closest rail 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.

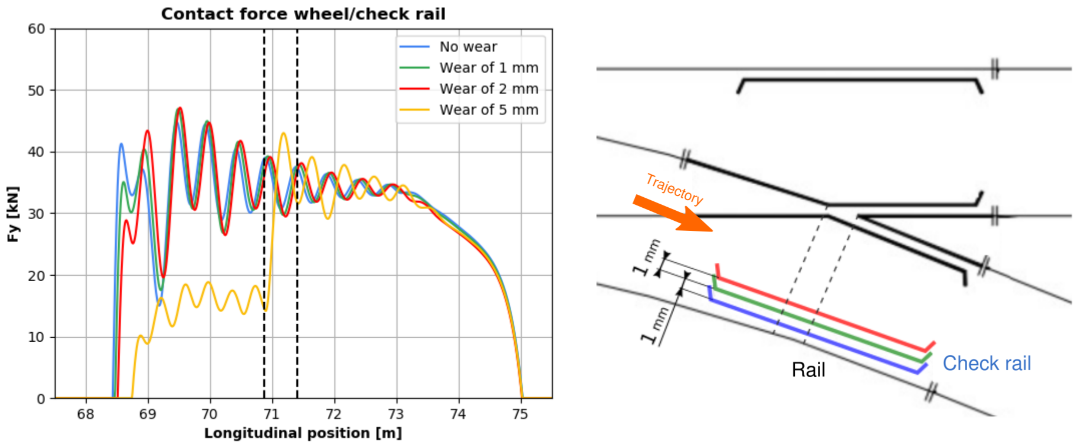

Figure 3: Lateral forces between the check rail and the inner face of the flange of the wheel. Blue: nominal check rail. Green: offset 1 mm from the nominal value. Red: offset 2 mm from the nominal value. Yellow: offset 5 mm from the nominal value. The distance between the two dashed lines represents the frog zone.

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.

3 Experimental campaign

3.1 Procedure

To feed the numerical model with valuable field data, experiments were conducted on an existing and representative S&C in Brussels that also exemplified the current challenges between static (digital ruler) and dynamic (measuring train) measurements.

A strategic placement of sensors in the track and measuring train, including accelerometers and displacement sensors was carried out in the past months. Various conditions were investigated during these experiments, including static configurations, different velocities, trains travelling in both directions, and switch deviation of the train to the main and diverging routes.

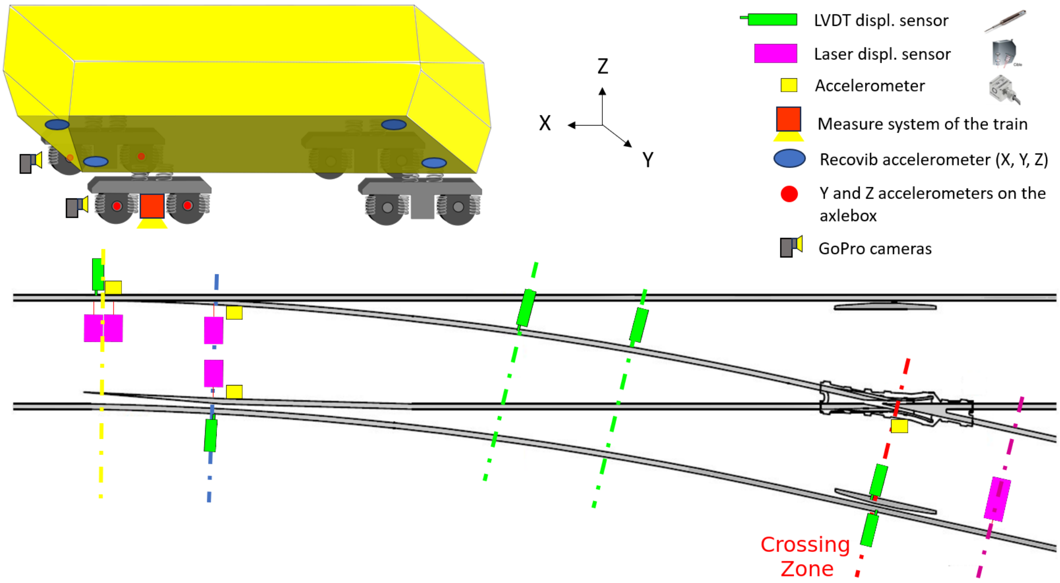

Figure 4: Overall view of the sensors on the measuring train and on the switch & crossing.

The measuring train is equipped with its own measurement system, enabling the collection of data related to the rail, such as gauge, profiles, cant, etc. Additionally, accelerometers are installed on the axle box. For this project, four extra Recovib accelerometers (Figure 4) were added to the carbody, extending the data collection capabilities to this specific location. Furthermore, two GoPros were fixed to the train, recording the wheel/rail contacts very closely (Figure 5).

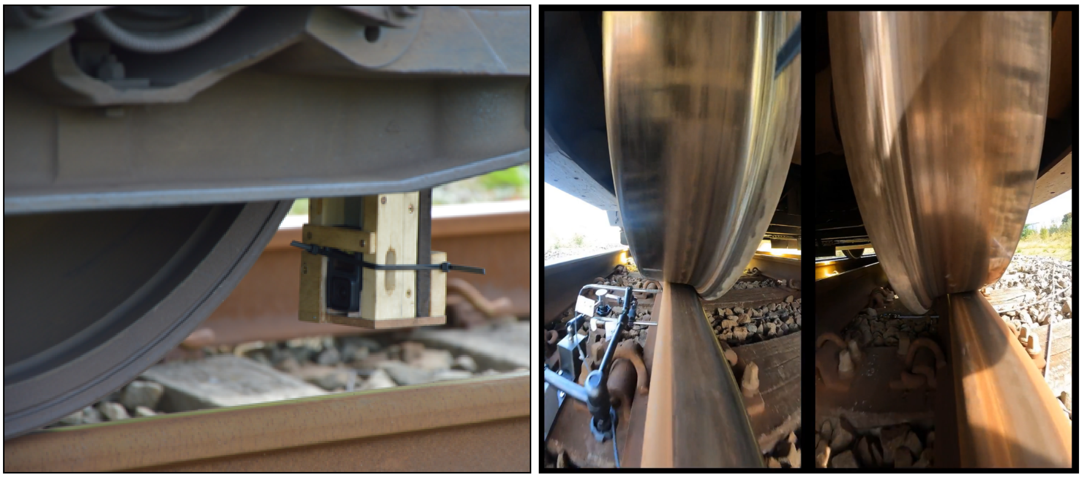

Figure 5: GoPro camera attached to the train (left) and instant capture of the camera's video recording (right).

For the instrumented S&C, sensors were strategically placed in critical zones identified and agreed upon as crucial for analysis with our industrial partner Infrabel (see Figure 4). The chosen sensors include accelerometers and displacement sensors, specifically LVDT displacement sensors that are continuously in contact with the rail (see the sensors in the right picture in Figure 5), as well as laser displacement sensors to measure parts of the rail where physical contact is not possible. Subsequently, an analysis of the critical *Crossing Zone* (Figure 4) is presented in the following section, serving as an illustrative example derived from the measurements conducted in the experiment.

3.2 Results

Concerning the *Crossing Zone*, the check rail plays a significant role in guiding the train in the correct direction when crossing the intersection zone. Therefore, tolerances for dimensions, such as flangeway gap (Figure 6), must be very strict. LVDT sensors (represented by green rectangles) measure the lateral displacements of the check rail and the rail, allowing for quantifying the temporal evolution of the flangeway gap value, a very important data for the S&C maintenance.

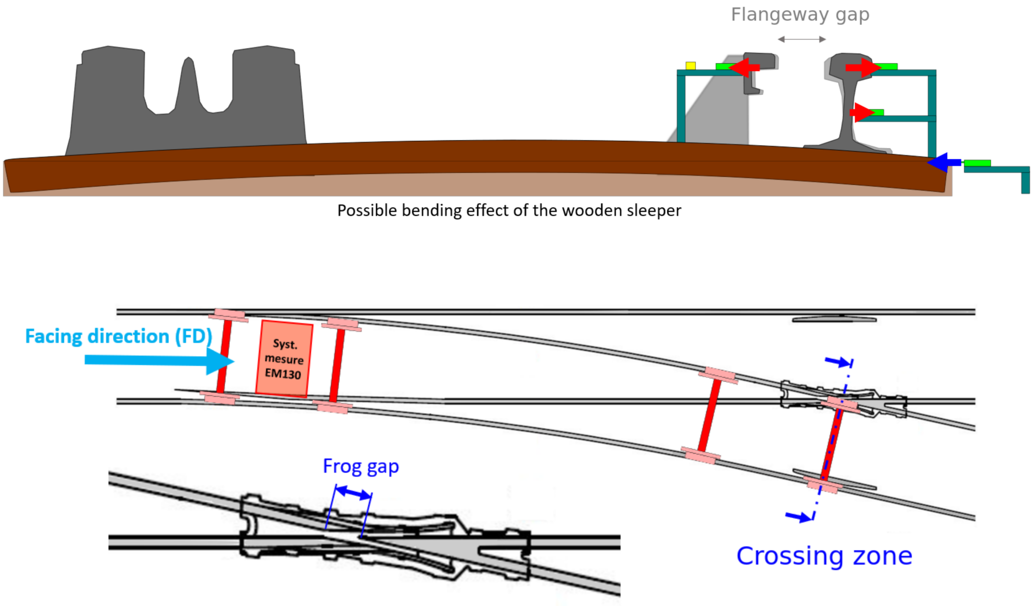

Figure 6: Cross-sectional view of the crossing zone when the first wheel axle arrives.

The measuring train consists of two bogies, each with two axles (as illustrated by the four axles highlighted in red in Figure 6). One observe that the flangeway gap, representing the distance between the check rail and the rail in the *Crossing Zone*, tends to widen when the first and third axles enter this zone.

Additionally, it has been observed that the rail exhibits a similar behavior in both facing and trailing directions, though with different increment values in the flangeway gap.

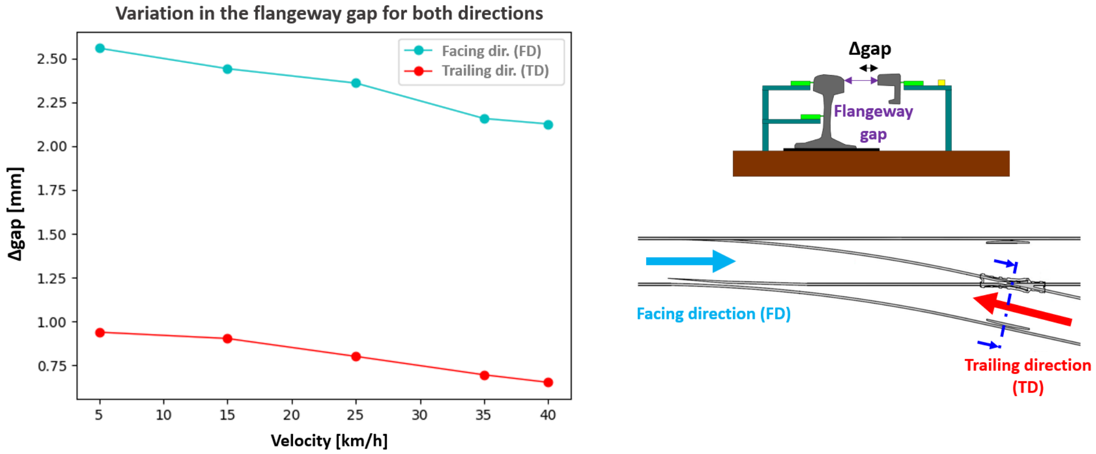

Figure 7: Comparison of the variation in the value of the flangeway gap for both directions at each speed regime.

Analysis of Figure 7 reveals, firstly, a trend towards lower flangeway gap values at higher speeds. Secondly, a notable discrepancy in values arises when the train travels in opposite directions, with the flangeway gap being approximately 1.5 mm higher in the facing direction (FD).

These findings highlight not only the speed-dependent nature of flangeway gap values but also the impact of the train direction on the flangeway gap as previously suspected by Infrabel. This emphasises the necessity for a comprehensive analysis to account for these variations.

The variation in values for each direction may be attributed to differences in the train configuration and trajectory before entering the track device. The rail curvatures differ before the point and before the heel, influencing the impact and lateral forces when the train enters the switch.

Another hypothesis to explain this behaviour is the possible role of creep contact forces on the tread, compensating for the lateral forces generated by the check rail.

A third hypothesis involves the bending of the sleeper, which could induce a lateral displacement of the sensors.

These dynamic effects, along with those influenced by speed, are planned to be analysed in more detail using the vehicle/track multibody model.

4 Concluding remarks

Train dynamics impacts S&C measurements and must be taken into account in the measuring train operation. Indeed, the current gap between the traditional digital rulers and the measuring train generated by the inherent dynamics of the vehicle underscores the need for a better understanding of their behaviour.

At this stage, the preliminary multibody simulations have already been able to study different realistic scenarios and to measure displacement and forces, displacements at different levels (track, wheels). Notably, they have already highlighted the dynamic impact of several parameters at a critical point of the track, namely the crossing frog. At this point, the wheel momentarily loses its initial contact and is subjected to interactions with the tread due to the occurrence of impacts with the guiding check rails.

Regarding the experimental campaign, it was conducted in the second half of the previous year, and the initial analysis of the collected data already reveals some specific behaviours of the switch. In the example shown in this paper, the results highlight the influence of the direction of the train when it passes through the S&C or the (lower) influence of the velocity on the measurements.

At this stage, the modelling and experimental phases are progressing concurrently. The approach involves these two complementary phases, with parameters of the model that are being adjusted based on the results of the experimentation. This will enable the model to extrapolate and study cases that may be impractical to explore exclusively through experimentation due to physical limitations.

Once an in-depth analysis of the dynamic effect caused by the passage of the train is completed, we will achieve the goal of bridging the gap between static measurements (digital ruler) and dynamic measurements (measuring train).

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References

[1] S-CODE. Funded by Shift2Rail. Convention n° 730849. (2021). Retrieved 16 April 2021, from http://www.s-code.info/

[2] IN2TRACK. Funded by European Union's Horizon. Convention n° 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.