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A novel method for digital assessment of railway crossing degradation

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Abstract

Crossings are important yet vulnerable parts of a railway network. This warrants that, in the Netherlands (a country with the highest traffic loads in the EU [1]), crossing geometry is measured twice per year by dedicated measurement vehicles. This produces so much (point cloud) data that prioritizing and predicting is not possible by hand. It can be done by automating the assessments, by an automated process of three steps: aligning the rail cross sections, measuring degradation features, drawing conclusions from the features and visualizing/communicating the results to improve maintenance strategies. This paper encompasses the first two steps for the most common type of crossing (the 1:9 fixed UIC54 common crossing) and a case study for step three. The results show that the features yield useful information and insights for both prioritizing and predicting.

Keywords: crossing, geometry, point cloud.

1 Introduction

The busiest railway network of the EU is the network of ProRail, in The Netherlands [1]. This warrants extensive monitoring of its degradation. One of the monitoring programmes checks the geometry of switches & crossings (turnouts) for compliancy with the TSI Infra [2] regulations, so that all EU-approved rolling stock can pass through Dutch turnouts safely.

This monitoring of the geometry has been carried out by dedicated measurement trains since 2016, that scan all (remotely operated) turnouts every six months. The trains use line lasers to deliver point clouds: cross sections of the rail every 2 or 3 cm, with a precision of 0.1 mm laterally/vertically. The point clouds were already automatically analysed for the (earlier mentioned) safety-related parameters; an algorithm checks these parameters and the resulting alerts were validated by hand.

The fact that the measurement trains have been running since 2016 has resulted in a large archive of point clouds. At the start of 2022 this archive consisted of over 70.000 measurements. Because of the size and timespan of the dataset, it became possible to follow the degradation of the geometry throughout 5 years of lifetime. In other words: the standard degradation pattern of geometry could be derived. This is useful to see whether an asset is degrading normally, fast or slow. Moreover: the first measurements of a new asset could be used to predict its future degradation.

The asset that was chosen to study first, is the fixed common crossing; a part of turnouts that degrades rather unpredictable. More specifically, the straight 1:9 UIC54 fixed common crossing: a crossing that is present in 40% of all measured turnouts. Moreover, the turnout is used in varying circumstances. While being the standard turnout for railway yards, it is also used in the plain track with speeds up to 160 km/h on the straight track.

The measurement trains run data collection campaigns every spring and fall. During such a campaign, about 7000 point clouds are delivered. The consequence of such scale is that all processing steps towards degradation assessment must be automated. Moreover, the aim was to create software that is compatible with existing frameworks in ProRail. Therefore, the project was developed in Python with its repository on Azure DevOps. The software can be described in two main parts: (re)alignment of the point cloud and measuring the degradation parameters.

2 Methods

Aligning the cross sections

Laterally, it is important to keep the gauge face of the crossing at the same location. Doing this based on the crossing can be problematic, because of the flangeway and nose flare. An alternative method (Figure 1) was developed to do lateral alignment based on the stock rail field side: a location with constant geometry and not subjected to wear/deformation.

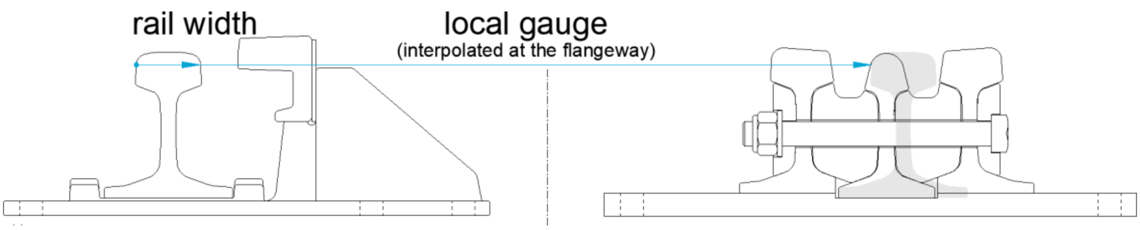

Figure 1 - How the lateral alignment is done based on the stock rail field side

Vertically, it is important that the theoretical top-of-rail remains at 0. In practical terms, top-of-rail might go below 0 due to wear and might go over 0 in crossings with raised wing rails. The wear is partially dealt with, by fitting a new rail head on the worn rail head. This only works partially, because fits can't be made on rail heads that have been worn across the full width. Raised wing rails are dealt with by assuming no factory tolerances: the practical top of rail is given a vertical coordinate based on the design drawing of the detected crossing type.

Rotation is done by taking the (earlier determined) top-of-rail of both wing rails and making them horizontal.

Measuring the degradation
The geometry of crossings can degrade in several ways. To simplify this complex system, cross sections are divided in nine relevant parts (in two steps) as described in Figure 2.

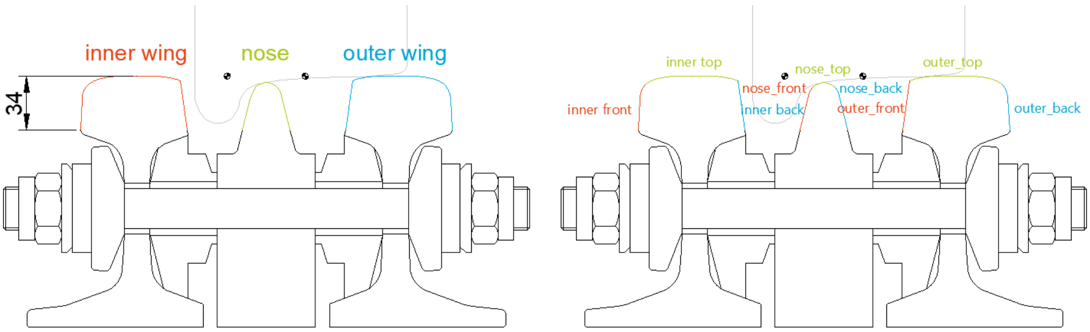

Figure 2 – Example of how a cross section would be divided in nine relevant parts

The division allows to easily distinguish and measure the various degradation phenomena (i.e. lipping, height loss and lateral wear). Measuring the degradation mechanisms is done by comparing the measured parts with the design of those parts. Figure 3 provides an example for a wing rail flare, where two straight rulers are projected and then moved on to the measurement. The maximum distance between the trimmed rulers and the measurement part is then stored as the local wear.

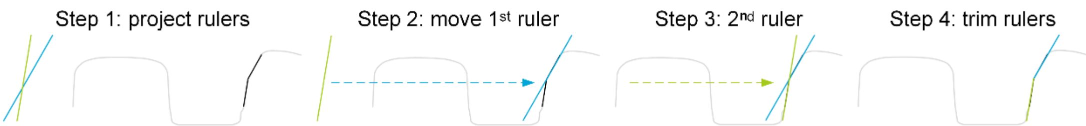

Figure 3 - Example comparison of the measurement part (black) and design (blue/green) at the wing rail flare

Figure 4 provides some more examples of measurement methods that have been implemented. A complete description of the method can be found in [3].

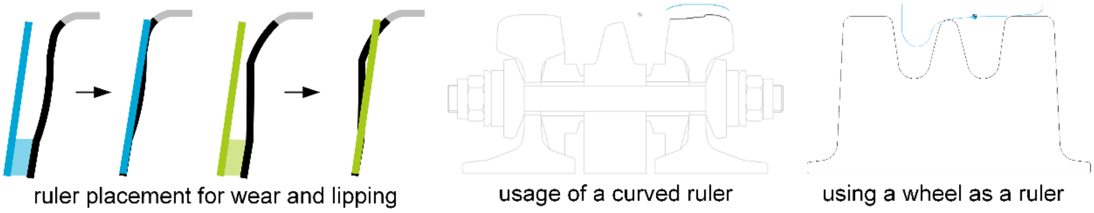

Figure 4 - Some other examples of special ruler

3 Results

One of the outputs of the software is an animation that visualises the differences between the design and the measurement. Figure 5 shows a frame for such an animation for the parameter of wing height loss: the lost height due to a combination of wear and plastic deformation. Note that the green rulers are not UIC54-shaped, because this is a raised wing rail crossing.

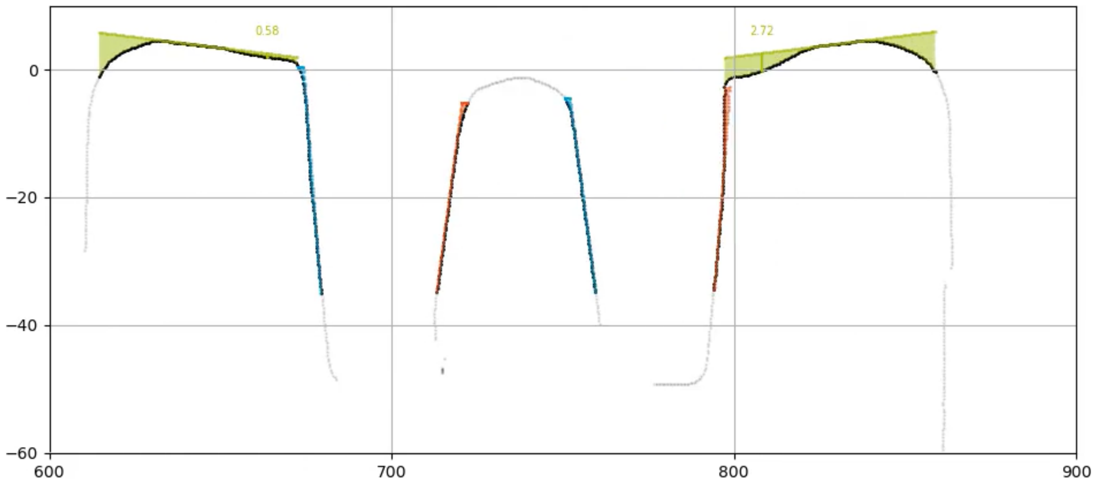

Figure 5 – Wing height losses on a constructed high wing rail crossing

Figure 6 shows a few other examples. The left image shows the measurement of flange-back contact. In the middle, the measurement of height loss on a UIC54 rail head is demonstrated. The right image shows a height loss measurement and lipping measurements on a cast manganese crossing.

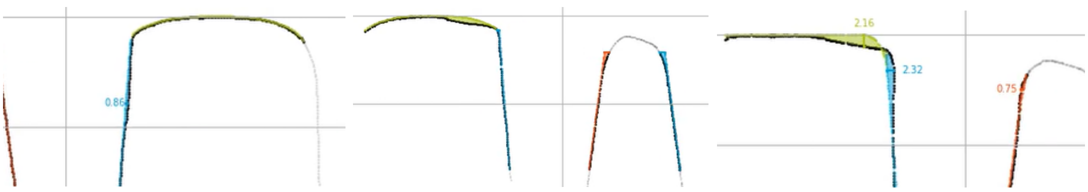

Figure 6 – Examples: flange-back contact, wing height loss on a UIC54 wing and lipping of a cast crossing

Like mentioned in Figure 4, a wheel-shaped ruler was also implemented (Figure 7). This (second) animation shows how an S1002 wheel would dip in the crossing, if it could only move vertically. The wheel position is stored for each cross section, to create a wheel dip graph like proposed in [4].

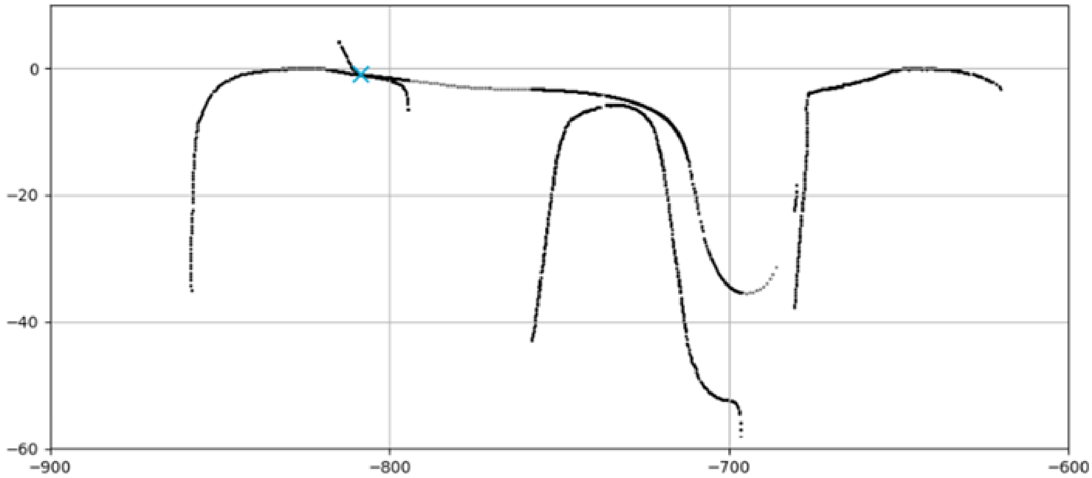

Figure 7 - Wheel dip measurement
(the blue X marks where the projected wheel touches the measurement)

The parameter wing height loss was further investigated, by following its development over time. Figure 8 the wing height loss at a fixed point on the crossing, for 17 cast manganese crossings. A big dot represents a measurement and the small dots simply represent what measurements are of the same crossing.

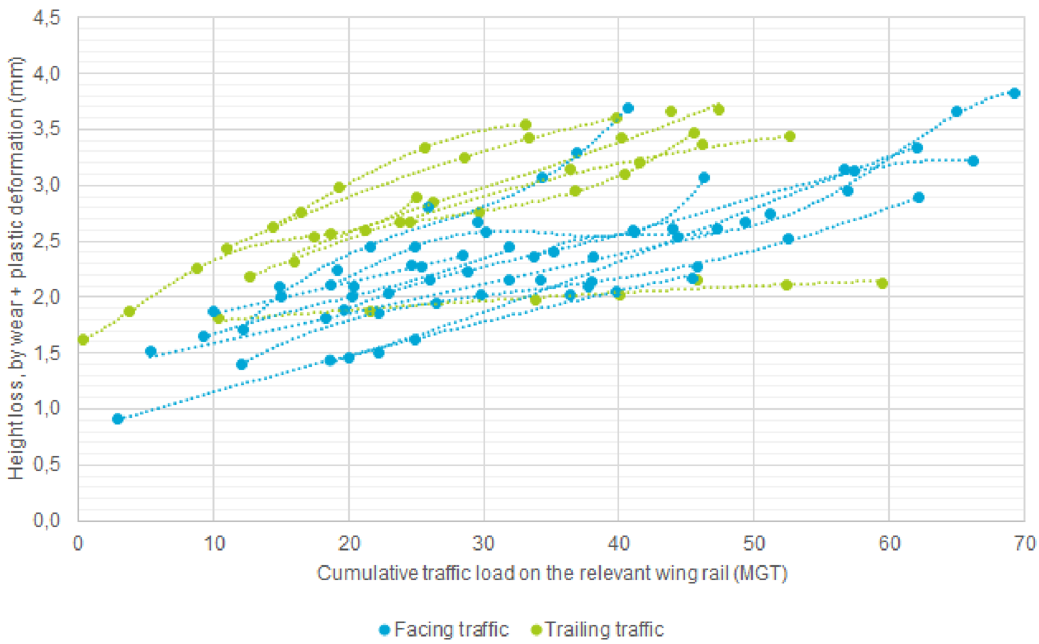

Figure 8 – Wing height loss for cast 1:9 manganese crossings

Figure 9 shows the same plot for 19 constructed R350HT high wing rail crossings. It is easy to see that the softer manganese steel loses height quicker than the harder R350HT steel.

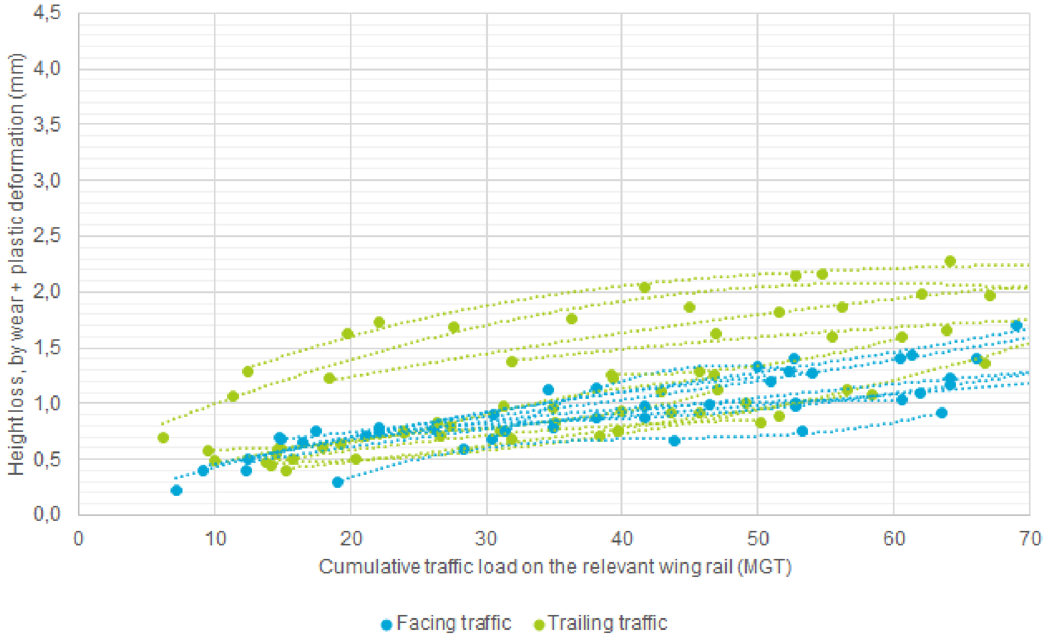

Figure 9 - Wing height loss for constructed 1:9 R350HT high wing rail crossings

Another application of Figure 9 could be to use it as an early warning system. Figure 10 proposes a way of detecting 1:9 R350HT high wing rail crossings that are losing height faster than usual. Because crossings appear to lose height very fast in their early days, the first measurement (within half a year) could already tell whether the crossing is performing well or not. Such a tool is useful to find crossings that need more attention. Perhaps there are issues with gauge, cant or support at those crossings.

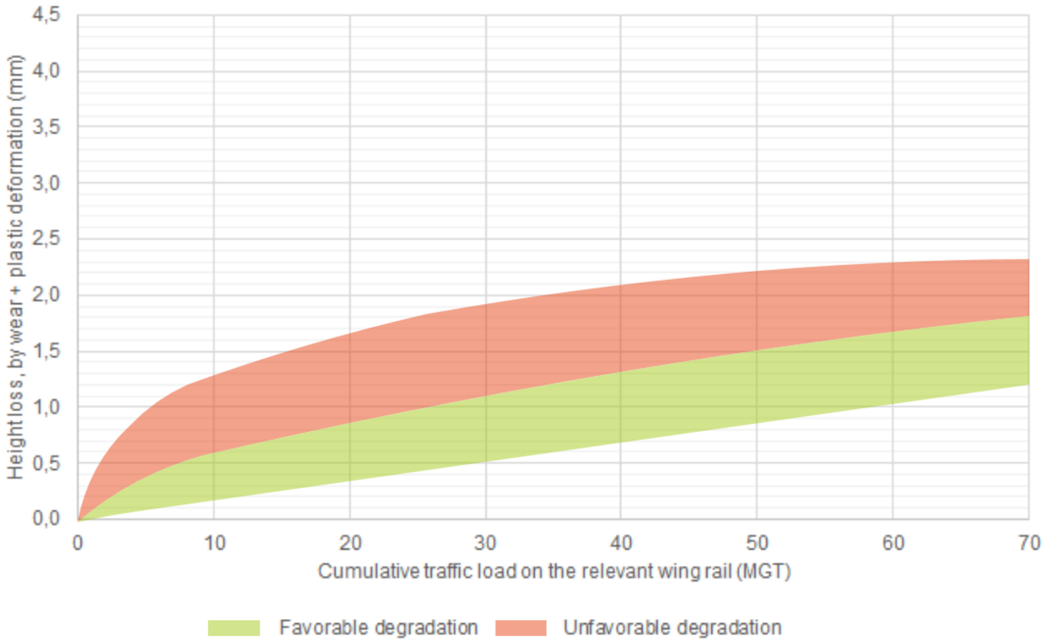

Figure 10 – Proposed implementation

4 Conclusions and Contributions

Conclusions

This paper started with proposing a way of aligning cross section measurements of fixed crossings, in such a way that they can be analysed in a consistent way. Issues regarding automatic lateral alignment, vertical alignment and rotation were solved for most cases.

The second part of the software does the actual measuring, by comparing measurements with the original designs. This was done by dividing each cross section in a few characteristic parts and projecting a relevant ruler over each part.

The results section showed that the outcome of the measurements can be studied over time. This reveals both the standard and unfavourable paths of degradation.

Outlook / future research

Attempts have been made to compare degraded nose profiles with their designs. This was not yet possible with the current level of longitudinal alignment (and attempts to improve it). Better longitudinal alignment of the cross sections in the future will enable studies of nose degradation and improve the quality of (reduce noise in) the other parameters.

This study has been limited to the degradation of 1:9 common crossings. It would be interesting to compare this with other crossing angles, or to try this method on switch blades and obtuse crossings.

Point clouds that were used for this measurement consisted of cross sections every 2 or 3 cm, with a lateral/vertical precision of 0.1 mm. With unlimited processing/storage capacity, this could be increased to cross sections every 5 mm with an extra digit for lateral/vertical (0.01 mm).

Measurement trains have been running since 2016, which provides about five years of data in 2022. Given the fact that a lot of crossing surpass five years of lifetime, it would be interesting to update the case studies that are mentioned in this paper as soon as more data comes available. This would ultimately provide a study on geometry degradation over the whole lifetime of both short-lived and long-lived crossings. This would ease the analysis of why some crossings fail earlier than others.

The current method does not work for severely worn crossings. One of the measurement companies (Eurailscout) suggested to try alignment based on the IMU (accelerometer and gyro) signals. This will however come with its own drawbacks: it will introduce cant and track deflection. Finding out whether the current method, IMU-based method or a combination could be used to (also) measure severely worn crossings could be an interesting future project.

References

[1] European Commission, „Fifth report on monitoring development of the rail market,” 8 12 2016. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2016:780:FIN.

[2] European Commission, [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A02014R1299-20190616&from=EN. [Opened 2022 5 18].

[3] J. Wegdam, „Assessing crossing degradation | TU Delft Repositories,” 25 5 2021. [Online]. Available: (This document is yet to be uploaded. URL will follow asap.).

[4] D. Nicklisch en V. Sauer, „Messung und Bewertung der Überlaufgeometrie starrer Herzstücke,” *EI-Eisenbahningenieur,* nr. September, pp. 18-23, 2013.