Inspecting crossing geometry

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Tool development for manual inspections of crossing geometry

By

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# Contents

1 Introduction .................................................................................................................. 5
   1.1 Motivation .............................................................................................................. 6
   1.2 Research goal ....................................................................................................... 6
   1.3 Scope .................................................................................................................... 6
   1.4 Project outline ..................................................................................................... 6

2 Inspection methods ..................................................................................................... 7
   2.1 3D mould with multiple rail profiles .................................................................... 7
   2.2 Nominal rail profile as 2D mould .......................................................................... 7
   2.3 Single wheel profile as 2D mould ......................................................................... 8
   2.4 Transition zone measurements ............................................................................ 9

3 Case studies ................................................................................................................ 10
   3.1 Oudewater crossovers ....................................................................................... 10
   3.2 Gilze-Rijen crossovers ....................................................................................... 12
   3.3 Gouda western entry tracks ............................................................................... 14

4 Conclusions and recommendations .......................................................................... 15
   4.1 Conclusions ......................................................................................................... 15
   4.2 Recommendations .............................................................................................. 15
   4.3 Future work ......................................................................................................... 16

5 Bibliography .............................................................................................................. 17
Introduction

Turnouts allow trains to change from one track to another. Therefore, they are an essential part of infrastructure to create and operate a railway network. This project focuses on the (common) crossing; the part of the turnout where the inner rails cross through one another. Because of the shape of the wheels, it is necessary to create a discontinuity in the rail at this location. As a consequence, wheels experience a disturbed support which causes wear, deformation and fatigue on the crossing.

Figure 1 - Definitions around railway turnouts

In the Netherlands, this problem has a high priority. This is because the Dutch railway network is unique in two ways; it is very dense and it has a high utilisation. Per km² of land area, the Netherlands has the second highest amount of track length (right after Switzerland). Per km of track, the Netherlands has the second highest amount of passenger kilometres (right after Japan). The consequence is a set of 7000 that are relatively heavy loaded.

In order to extend the lifetime of these crossings, they have to be monitored and maintained. In present practise, some deformations have to be cut off and cracks have to be ground away. This ensures safe wheel passages and prevents fatigue related failures. Such practises are described well, within the current norms.

A less clear topic however, is the maintenance of geometry. Geometry is defined as the cross-sectional shape of the rail, like depicted in Figure 2. As soon as the geometry of a crossing changes due to deformation and wear, the vehicle behaviour is influenced. Unfavourable geometry can lead to a big amplification of dynamic forces from passing wheelsets. For this reason, maintainers seek for favourable ways to assess and control the shape of worn/deformed crossings.
1.1 Motivation

Determining how a given shape (geometry) of the rail should be changed, is not an easy task. Grinders and welders currently do that based on experience; looking at the rail shape, the worn spots, cracks and loose bolts. While these insights vary from person to person, the current practice still works well enough for reactive maintenance. The wish is to take maintenance a step further than that though. Contractors mention terms like ‘preventive grinding’, with which they express the ambition to make the transition from reactive maintenance to preventive maintenance. The benefits of that can be found in less maintenance and less emergency repairs. Both contribute to making the maintenance more efficient (and thus cheaper).

1.2 Research goal

The need for this project lies in the knowledge which is required for the preventive maintenance. In order to determine the required maintenance actions, one must be able to assess the quality of any geometry on-site; not in terms safety, but in terms of expected vehicle dynamics. This project aims to help with that, by developing assessment methods/tools for on the track. The methods/tools should be usable at the track and contribute to preventive geometry maintenance. Overall, the research goal is formulated as:

*Finding and defining workable methods/tools for the execution of preventive geometry maintenance.*

1.3 Scope

This report is the end product of the course ‘Additional Thesis Work’. This means that this report is close to but different than the MSc thesis report [1] of the author. The scope of both projects / reports is compared in Figure 3. Note that the only overlap consists of track visits. These visits contribute to gaining more experience with the practical matters, which was beneficial for both projects.

1.4 Project outline

The work on this additional project started in May 2018. During this month, the first preparations were made for the first relevant track visit. This report was delivered in July 2019. In between, this project ran parallel with the main thesis project and two regular TU Delft courses.
2 Inspection methods

During this project, four inspection methods were developed. The first method was the 3D mould, as suggested at the start of the project. The other three methods were developed during the project, based on further insights.

2.1 3D mould with multiple rail profiles

The initial idea of the project, was to look at deviations from the nominal profile. To do so, the proposal was to work with a so-called 3D mould; a frame with several nominal cross-sections of the crossing geometry. When an inspector, grinder or welder would put this mould on the track they would see the deviations from the nominal profile.

Figure 4 - A bad grinding result (in blue)

This would help to prevent situations like the one in Figure . In this case, the grinding tool has been moved up and down the nose, but not enough. This is perfectly natural; these people are working at night with very heavy machines which they displace by hand. Because of this, the grinding is too much concentrated in a certain area which disturbs the wheel support at a critical part of the crossing. This is not always visible with the human eye. For this reason, a 3D mould could help by providing feedback to the maintenance crew.

2.2 Nominal rail profile as 2D mould

Along with the 3D crossing mould sections, a 2D mould of a standard (UIC54) rail profile was created. The profile was based on the international standards [2]. The idea was to track the shape and depth of the wing rail wear, by using this profile, like shown in Figure .

Figure 5 - Comparison of the nominal rail profile and laser measurements (Gilze-Rijen, 30-12-2018)
2.3 Single wheel profile as 2D mould

In the same way as the nominal wheel profile, a wheel profile was made. The used wheel is a new standard wheel (S1002) according to the international norms [3]. The idea was to simply put the wheel on the rail and see to what extend wear patterns mimic the nominal wheel profile.

While (like described later) this worked quite well, the wear patterns did not always fully match the wheel profile. An example is shown in Figure 6. Colleagues pointed out that more wheel profiles should be added, because the wheel profile is subjected to wear and deformation. Because of this, three additional wheel profiles were developed (Figure 7).

Figure 6 - A situation where the nominal wheel profile does not fit well

Figure 7 - New laser cutter design, with four wheel profiles and ruler markings
2.4 Transition zone measurements

The last inspection method came in to the project in a later phase. Based on experience with the wear patterns (especially Figure 2), the idea arose to measure the location of characteristic spots of the running surfaces with respect to the centre of the crossing. This was done by noting 4 numbers per running direction: two on the wing rail and two on the nose like displayed in Figure 3. This results consists of 8 numbers per crossing.

Figure 8 - Measuring the running surface

BAM Rail is interested to further look in to this method. They already wondered whether this can be done based on BBMS data (high resolution pictures from an inspection train, that are provided every half year). To put this idea to the test, a pilot session was done at BAM Rail Maintenance in 's Hertogenbosch, at the 11th of July 2019. The conclusions were that it is possible to do this at the computer, but that it requires experience from computer and from outside to do create reliable numbers.

It is quite easy to pick a wrong point of reference. Therefore, multiple pictures (either from BBMS or site visits) are required to track the development of the wear pattern. The recommendation is to apply this method for analysis of a crossing design, but not (yet) for large scale maintenance steering. The youngest proposal, is to track a few crossings in Leiden (all from manufacturer BWG, all implemented in March/April 2019).

Figure 9 - Running surface assessment pilot, in Den Bosch
For this project, 7 relevant track visits were made. Dates and locations are listed in Table 1. Other track visits that are irrelevant for this project, have not been listed. This chapter describes how the previously mentioned inspection methods performed on the track and what insights they delivered.

<table>
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<th>Date</th>
<th>Location</th>
<th>Rail 2D</th>
<th>Wheel 2D</th>
<th>Rail 3D</th>
<th>Laser scan</th>
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<td>-</td>
<td>-</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 1 – Relevant track visits in chronological order

3.1 Oudewater crossovers

At the 12th of June 2018, the first track visit in Oudewater took place. The reason for the track visit was the implementation of a pilot, with the German crossing design. The track layout (Figure 10) is simple but interesting. Crossovers are short tracks that connect two main tracks, to allow rail vehicles to switch to the other track. This does not happen often though. In the regular situation, crossover turnouts are mostly subjected to traffic running through the main track. For this reason, relatively short turnouts are exposed to high tonnages and high vehicle speeds. This makes them the most critically loaded turnouts. An ideal location for a pilot. During the first visit, the crossings were installed. At the 14th of May 2019 the crossings were repaired, due to a clear case of fatigue cracks. In between, several inspections and measurements were carried out to follow the pilot. Some of the inspections included opportunities to get experienced with the new inspection methods that were mentioned in the previous chapter.
The 3D mould sadly faced a major drawback; the longitudinal frame was not stable enough. While the 3D mould was designed as cross sections with two longitudinal beams, the laser cutter did not have the right length of material available during the production of the 3D mould. For this reason, the longitudinal beams were delivered in two pieces that had to be bolted together. The bolted connection was not stable enough to carry its loads and thus the frame failed after the first try. While there was only one try for the entire 3D mould, the impression was that it did not work that well due to all kinds of real-world tolerances. Factory tolerances of the milling/grinding, installation tolerances (room/angle between wing and nose).

The cross sections were still usable, but only as cross sections. Similarly to the full 3D mould, the cross sections in their current form described the nominal shape. The problem with tolerances still existed. Moreover, as the crossing was subjected to wear and deformation these phenomena also posed problems for the cross sections. Wear was what we wanted to detect, but deformation posed a problem. The shapes had to fit precisely around the rail, which was becoming harder every month.

The nominal rail mould had similar issues, because it also was made to precisely fit around the rail. It was working better than the nose moulds though; as long as the wing rail was not subjected to lipping. Wing rails have more width than the nose rail, which probably results in less deformation. Therefore, this tool was quite well suitable to do analyses like Figure 12.

The wheel profile however performed much better. Because it did not have to fit exactly around the rail profiles, it also worked in the deformed state. It was impossible to detect deviations from the nominal profile, like with the crossing moulds and nominal rail mould. However, as the insights throughout the project developed, one can argue that this is actually not necessary. A wheel can touch both the wing rail and nose at the same time and therefore inspectors should refrain from measuring the cross sections independently from each other. Geometrical quality can only be assessed both at the wing and nose in unison.
3.2 Gilze-Rijen crossovers

At the 30th of November 2018, an inspection in Gilze-Rijen was performed. Complaints about nuisance (noise) were the reason for the inspection. Again, the main purpose of this inspection was to do a 3D measurement of the geometry. Along with these measurements, the inspection methods of this project were further developed.

In Figure 12, it can be derived that Gilze-Rijen is slightly different than, but still similar to Oudewater. The only difference is the (disused and partially removed siding) and the station in the middle.

Turnouts 1A / 1B feature Kloos crossings and 29A / 29B feature constructed BWG crossings. All turnouts are subjected to very similar traffic conditions. However, it must be noted that the Kloos crossings and BWG crossings are subjected to different running directions.

In this case study, there was more emphasis on collaboration with the laser measurements. Matlab was used to create an import tool, from the measuring device to AutoCAD. By doing so, it was possible to create files like the one displayed in Figure 13. While this work was not directly relevant to this project, it lead to insight that still benefited the development of the inspection methods.

Figure 12 – Gilze-Rijen track layout, passenger trains in black, crossovers in grey, decoupled tracks in white

Figure 13 - 3D AutoCAD file of the 29A laser scan
In Figure 14 it can be seen how the CAD files helped trying new measurement tools digitally, before they were fabricated. This prevented some shortcomings of new tool designs, but also inspired additional features like addition of a miniature level (waterpas).

In Figure 15 a different application of the 3D model; this comparison showed the relation between the width of the wing contact and stress of the wing contact. The narrower the contact, the higher the stress, the more likely that fatigue damages occur. This was (outside this project and inside the main thesis project) confirmed by simulations.
3.3 Gouda western entry tracks

At the 17th of June 2019, BAM Rail sent an invitation to join an inspection at Gouda’s railway station. Gouda was an interesting case to inspect, because all tracks were renewed roughly one year on beforehand and all turnouts were delivered by the same manufacturer (Kloos). Reason for the inspection was a suspicion by BAM Rail, about the delivered quality of the crossing geometry from the factory. An overview of the track layout is depicted in Figure 16.

![Figure 16 - Situation in Gouda. Passenger trains in black, shunting tracks in grey, 1:9 turnouts in red, 1:15 turnouts in blue](image)

For the inspection, all 1:9 turnouts within the passenger train routes were selected. These turnouts are most critical because of the small crossing angle (which causes fast varying geometry) and because of the high tonnages (980,000 to 1,280,000 ton axle load in January 2019 [4]).

All crossings were photographed in three ways. First of all a top view, with tape measure starting at the center of the crossing. Second, a front view with a wheel profile. Lastly, a picture of the factory reference tag.

![Figure 17 - Example pictures, made at crossing 213A](image)

Along with the pictures, measurements were made with the tape measure according to the transition zone measurement method. These were all noted down for later analysis.
4 Conclusions and recommendations

As the last part of this report, this chapter sums up the conclusions and recommendations. After that, a section is dedicated to describe future developments around this project.

4.1 Conclusions

The wheel profile mould allowed inspectors and maintainers to talk about wheel-rail interaction without extensive knowledge of the physics. Moreover, it was much easier to survey deviating wear behavior by seeing whether the standard wheel profile was not fitting the running surface (Figure ).

The nominal rail mould served a similar purpose; it made the depth and shape of wear easier recognizable on the wing rails. However, determining the exact depth of the wear was not possible yet, with the current design. Another drawback was the incompatibility of the mould with deformations. As soon as the rail deforms too much, the cross sections doesn’t fit.

The 3D mould had two major issues: the frame was not stable enough and the cross sections also suffered from rail deformation.

The first attempt of running surface measurements was already useful for BAM, so it is worth the effort to further develop this method. Using this method for maintenance steering is not (yet) recommended, but following the evolution of wear patterns will most certainly lead to valuable insights.

4.2 Recommendations

The usage of geometry moulds in crossings certainly has a potential. It is important to keep a few aspects of the system (like deformation and tolerances) in mind though. For this reason, it is recommended to work with half cross sections instead of full cross sections (like shown in the future work section). This improvement step is already discussed in the next section: future work.

Also important is the difference between analyzing and measuring. While the moulds provide useful insights, it is not recommendable to use them for exact measurements (yet). This because the current mould only feature one rail. This may cause unwanted rotation and translation (and thus wrong interpretation) like shown in Figure . Existing moulds for the switch blades feature moulds for both rails, with a stick in between. This would be a recommended next step, after the previously mentioned transition to half cross sections has been made succesfully.

As soon as this works well, it would still be possible to go back to the principle of a 3D mold. This time not for one rail, but for two rails. Moreover, not with full nominal cross sections but with half cross sections.

The last step would be to provide the fully developed crossing moulds to all relevant parties, so that it can be used during manual surveys.

Two last suggestions:

- try a miniature level (waterpas), which can be glued on to a cross section.
- try to find a way to measure the distance between the mold and the rail reliably
4.3 Future work

As a result of this project, the initiative at ProRail is to create 100 times the 4 wheel moulds. At the week in which this report is delivered, Laserbeest Delft will deliver two quotations for this. One for the old version (without ruler markings) and one for the new version (with ruler markings). The new version requires more laser time, which will be more expensive. Depending on ProRail, one of the quotations will be chosen. The next step is to introduce the wheel profiles to the contractors, manufacturers, inspectors, line managers, grinders and welders. At the 19th of September, BAM (Andrew van Eck) already offered the opportunity to do this for their crew. However, all parties have expressed the wish to do a single presentation at a central location.

Along with the wheel profile project, new moulds were ordered at Laserbeest. While the toolset incorporates some existing tools like wheels and a rail profile, it also features new tools. The new tools allow the assessment of a cross section like the rail profile mould, while solving the problem with deformations (the rail profile mould does not fit if lipping occurred). To tackle the lipping problem, the moulds are based on the milling profiles. Fitting these on the rail will hopefully show the differences between wear patterns and geometry designs. Hopefully, these insights will lead to design improvements.

Figure 18 – Latest tools design. From top to bottom: wheel profiles, milling profiles, radius measurers and a rail head profile.

As described earlier, BAM Rail offered to help with further development of the running surface measurement method. Depending on the allowed time this will be done with certain intervals, in Leiden.
5 Bibliography


