Degradation Processes and Wear of Railway Switches and Crossings: The Swiss Experience

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Abstract

Using databases of the Swiss Federal Railways (SBB), statistical analyses are carried out on the expected lifetime of railway switches (points) and crossings (components). They are attributed to different parameters which influence the speed of degradation or wear.

1. Introduction

Railway switches and crossings (S&C) are representing an important asset of railway networks. Millions of these devices are installed on all railway networks in the world, in an innumerable amount of types. Approximately 25,000 of these devices allow the trains on the Swiss railway network to run as they do today. In case of planned or unplanned disruptions they form an even more important asset, allowing trains to use other routes than usual, or to use a track in the opposite direction, to assure a reliable train service for the passengers. This however comes with a cost: 20 to 40 percent of the track maintenance budget is spent on the inspection, maintenance and renewal of S&C. This relative high expenditure (the maintenance cost of one switch or crossing equals the maintenance costs of 300 to 500 meters of plain track) is mainly due to the nature of S&C that make them absolute and relative more expensive to maintain than plain track (straights and curves):
- S&C have special components e.g. switch tongues, frogs and slide plates, which are, due to their specific geometry, exposed to high static and dynamic forces, thus showing high wear rates and specific deterioration;
- S&C have moving parts, which require more frequent inspections and maintenance actions e.g. greasing, to avoid poor reliability;
- S&C form a potential safety hazard, due to moving parts, which in case of malfunctioning (or worse: breaking) can cause serious accidents, thus requiring immediate action in case problems are detected – where plain track sometimes can sustain its function due to built-in redundancy.

While for plain track (straights, curves) for different geometrical degradation modes (e.g. cant, twist, level, gauge) and component deterioration and wear (e.g. cracks, gauge corner cracking, head checks, (wave) corrugation) the relation with track parameters (e.g. sub-soil quality, type of sleepers) [4] and train load (e.g. number and amount of trains, axle loads) is known, the knowledge on degradation and deterioration processes of S&C has remained rudimentary.
The knowledge on plain track deterioration resulted in different decision support models allowing an optimisation of the use of condition monitoring results, e.g. the use of the results from the measuring car for long, mid and short term maintenance and renewal planning [2, 5]. For S&C however, this information was for a long time only gathered through inspection on-site and stocked in a non-digitized way. Only recently this has changed with the introduction of new specific S&C-inspection vehicles (or equipping existing inspection vehicles with the proper utilities), online condition monitoring and computerisation and standardisation of the on-site inspection by maintenance personnel.

The need for a decision support model has been proven in a previous study [1]. Beside this the need for more reliable S&C requiring less or less costly maintenance and renewal is one of the reasons to introduce S&C as a separate sub-project in the INNOTRACK-project (www.innotrack.eu) and the recent establishment of an UIC Sub-committee on S&C maintenance.

2. Description of this study

After the results presented in the introduction above, two aspects were considered as important research topics:

A. Determining degradation and wear rates of switch (components) using the „DfA“ and other SBB databases, attribute them to their main “cause” (time, MGT) and determine other important parameters (axle loads, number of axles, type of trains, speed etc.) for which correlations might exist;

B. Optimise (in economical and/or technical way) the way in which repair or replacement actions are used to overcome different types of wear or degradation on component, switch/crossings, local, regional and national level.

Until now only work on part A has been partly executed and this is what will be presented further in this article.

3. Methodology

Trains running over railway tracks cause degradation of these tracks and its components (rail, rail fastenings, railpads, sleepers, ballast etc.). The speed of this degradation depends mainly on:

- the track geometry: train tracks in bad geometrical condition will cause “rollercoaster”-behaviour of the train, which results in higher dynamic loads from the train on the track;
- the state of the track material: bad sleepers or worn rails will provide a unsmooth running path, resulting in vibrations, which as a result cause faster degradation of other track components.

Beside the relation – regarding rail track degradation – train loads vs. track geometry and the state of the track material, there is also a relation between track geometry and the state of the material: bad material causes more track geometry degradation. This relation is also valid in the other way: bad track geometry will in the same negative way affect the state of the track material.

To repair the bad track geometry, maintenance and renewal actions like tamping and grinding are carried out. To repair worn track materials, they can be replaced or repaired at site. These relations are all presented in figure 1.
The track loads which cause the degradation of track geometry and track material can be divided into several different parameters, affecting the degradation rate, e.g. train speed, type and condition of the trains and axle loads. Track parameters influencing the degradation rate (beside geometrical state of the track and the state of the materials) are e.g. the sub-base condition or the quality of initial installation. Material parameters which have an influence are e.g. metal hardness or running surface profile.

With this knowledge a general degradation curve (figure 2) is analyzed for different components of or a complete switch or crossing.

The switch or crossing (component) is installed with an initial quality (Qi). During its usage in track it degrades because of the track loads. If the minimum quality (Qmin) or an intervention level is (almost) reached maintenance or renewal actions are carried out. If the degradation is e.g. related to geometrical degradation this action can be tamping; if it is wear of the switch rail, it can be the replacement of this switch rail, grinding or welding.
Some of the open questions regarding this degradation curve are:
1. Which form does the trend line of the degradation curve have: e.g. linear, progressive, regressive or instantaneous? (figure 3)
2. How do other factors which are not incorporated in the graph (speed, axle loads etc.), influence the degradation curves’ trend? (figure 4)
3. What is exactly on the x-axis? (time, MGT)
4. What are exactly the quality indices on the y-axis for different forms of wear and degradation?
5. What is the minimum quality ($Q_{\text{min}}$) and how does this relate to the safety limit?

![Figure 3 – Linear, progressive, regressive and instantaneous degradation curves](image)

![Figure 4 – The effect of different speeds on a degradation curve](image)

In order to answer these questions different SBB databases have been gathered and the analyses are currently under way.

The dataset of the DfA database consists of usable information on 6125 switches and crossings on the SBB part of the Swiss railway network. They can be divided into different categories abbreviated with HG (from the German *Hauptgleise* = main line track) and NG (*Nebengleise* = secondary track/sidings). These two indications are then divided into 3 categories of which “1” indicates the most important track with a daily track load of more than 30,000 gross tonnes. All tracks providing access to the main stations and important lines like the Gotthard corridor are all HG1.

The numbers of S&C per category are listed in table 1.
Table 1 – Number of S&C per track category.

<table>
<thead>
<tr>
<th>Track category</th>
<th># of S&amp;C</th>
</tr>
</thead>
<tbody>
<tr>
<td>HG1</td>
<td>4064</td>
</tr>
<tr>
<td>HG2</td>
<td>1081</td>
</tr>
<tr>
<td>HG3</td>
<td>544</td>
</tr>
<tr>
<td>NG1</td>
<td>197</td>
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<tr>
<td>NG2</td>
<td>136</td>
</tr>
<tr>
<td>NG3</td>
<td>47</td>
</tr>
<tr>
<td>other/unknown</td>
<td>53</td>
</tr>
</tbody>
</table>

4. Results

The first results have already been published [6]. Data analyses have been carried out to determine correlation between expected total switch or crossing life time and:
- track category;
- switch frog angle (1:7, 1:9, 1:12 etc);
- switch curvature (if the switch has a straight and a curved part, or has two curved directions; the latter is reason for a reduced life time expectancy).

Only for the track category a significant relationship can be found: higher track category (HG1 = high) means faster complete switch replacement, although the standard deviations of the results are high. The relationship with axle loads still hast to be verified.

For the switch frog angle the 1:7, 1:8 and 1:9 tend to have a longer life expectancy then the 1:12 - 1:16. This may be due to the 1:7 - 1:9 being only limited used in the diverting direction, e.g. to factory connections on main lines and in station entrances just before the platform where train speeds and thus loads are limited. In the mean time, the 1:12 - 1:16 switches being used for heavy traffic on main lines where loads and speeds in both diverting and straight directions are high shorter lifetimes are registered.

Regarding switch curvature – easy to test in Switzerland where approximately 50% of the switches are in curves – no difference in expected lifetime could be found.

These results have still to be verified through interviews with experts on local switch and crossing replacement politics, which can have a big effect on the results as found so far.

5. Next steps in this project

This project will continue to combine the data with more accurate information on:
- cumulative tonnage (in stead of years);
- axle loads (since axle loads have a non linear relationship with geometrical behaviour of plain track);
- actual train speeds when passing the switch;
- type of trains;
- the effect of the sub base condition;
- S&C maintenance and renewal politics.
The tests will not only be carried out for complete S&C but it will also involve the analyses for specific S&C components, e.g. the moving point rails (switch blades) or the frog. These parts are often subject to single replacement or repair actions, e.g. welding on repair patches on worn rails. A database with approximately 100,000 component replacements and maintenance actions of the last 10 years is available.

6. Acknowledgements

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References