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ASSESSMENT OF TRACK AND TURNOUT CONDITION BASED ON GEOMETRY MEASUREMENT AND RAILHEAD CONDITION DATA

Janusz Madejski
GRAW GOLDSCHMIDT, Poland

Abstract

The paper presents the procedure of track and turnout geometry condition assessment, taking into account also the deterioration of the rail running surface. Track geometry measurements are made using manual tools, microprocessor-based portable instruments, and geometry cars. Methods of collecting track and turnout geometry data are discussed, and an exemplary equipment design features are presented. Maintaining and possible improvement of the technical condition of the permanent way call for regular inspections providing voluminous data requiring detailed analysis. The approach based on track line-speed dependent geometry parameters analysis is explained. Several synthetic track condition assessment coefficients are described, and analysis of the temporal trend of the track and turnout geometry change. Train operation safety is also affected by changes on the running surface of the rails. In addition to the track geometry, the significant reasons for train operation safety are the railhead wear being affected by the type of transport, traffic intensity and maximum allowable axle load. Determining the permanent way condition with the continuous design and maintenance characteristics is possible if measured on the minimum 200-300 m length with the measurement steps of ca 0.5 m. Comments on employing the Artificial Intelligence tools for track and turnout condition analysis are provided. Most of the inspection data collected using various equipment, like track and turnout geometry measurement data and video inspection information, can be analysed automatically by the dedicated software agents. Such an approach yields analysis results equivalent to the standard inspections, except that the trains and self-propelled trolleys can record data at higher speeds, railways staff could achieve.

Keywords: track condition, turnout condition, visual inspection, automatic defect detection, virtual templates

1 Introduction

Maintenance contracts are usually based on condition level nowadays. Specifying the condition requires defining the objective, transparent and reproducible parameters, tolerances and quality indices for turnout geometry. Therefore, the currently used systems should provide data that can fulfil the requirements mentioned above regarding the maintenance, safety and lifecycle of switches. Changing the approach from the time-based to the condition-based maintenance is needed to achieve effective and efficient maintenance. Such an approach requires reliable data sources, and its processing methodology yielding trustworthy support for the maintenance decisions.

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1.1 Geometrical data collection

Track and turnout geometry measurements may be carried out using the analogue manual track gauges and templates. However, such measurements require skilled staff. The measurement results are subjective, dependent on the attention paid to them, weather conditions and demand extra paperwork to store the results either in the forms or typing them into some files in the computer system. Moreover, this process takes time if it has to be done accurately. This approach focuses on the particular measurements with no way to easily compare the measurement results to determine the pace of the ongoing turnout geometry deterioration.
Digital track gauges improve the data collection process, as the data is stored in their memory which saves much time and possible data entry errors during the measurement report generation. Some gauges may also support the operators with the turnout specification saved in memory, suggesting the successive switch characteristic points at which the geometry has to be measured. The measurement data is next transferred to the PC. Digital trolleys have all advantages of the digital track gauges and make the work safer for the staff (no continuous bending, which is detrimental for the spine and knees – resulting in more frequent sick leaves, reducing the available staff productivity).
Track and turnout measurement cars (TRC) feature the next level in the diagnostic data collection's efficiency and scope. These cars travel at a speed corresponding to the trains operated on the railway lines, minimising their service disruptions. They provide the information on the track geometry under load as they are the full-sized rail cars (except for some self-propelled geometry measurement trolleys). TRCs can provide measurements of the track and turnout geometry, corrugation, permanent way bench shape, track clearance, catenary, accelerations, visual inspection, generating a considerable amount of data to be processed.

1.2 Measurement data processing

Safe train operation requires the railway lines maintenance being planned based on detailed inspections, scheduling improvements, safety, funds and workforce availability, and customer expectations. The relevant work planning can only be done by performing on-site inspections record defects, identifying issues, adding images, automatic identification of track irregularities, an inspection of rail profile, cracks, irregularities and missing components [1], [2], [3].
Data fusion is the process of directly combining raw data streams from different sensors of the same type. The data is subject to aggregation before it is subject to further processing. Property fusion requires the determination of a vector of these properties based on data from each sensor. The obtained features are initially associated with each other and then combined into one common vector - Fig. 1. The vector of connective features constructed in such a way, which characterises a given object globally, is transformed into the identity declaration domain (classes) using various fusion methods, e.g. neural networks, grouping methods – Fig. 2 [4].

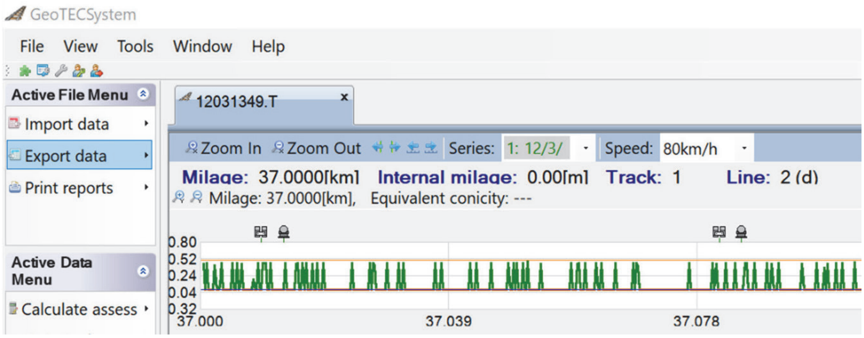

Figure 1 Equivalent conicity assessment based on railhead wear measurement for left and right rails, the back-to-back distance of wheels in a wheelset, and their tread profiles

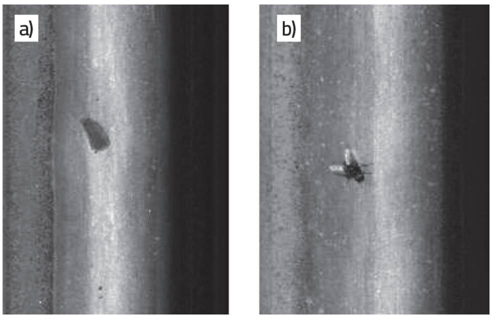

Figure 2 Automatic detection of imprints and elimination of the false ones

2 Laser measurement of track and turnout geometry

Laser measurement capability is demonstrated here by two exemplary systems: a TSP trolley with laser cameras [5] and the TMS track recording car [6]. Their capabilities are shown for the measurement of the railhead wear assessment and the turnout geometry. In essence, the measurement in their case is done by measuring the rail/turnout surface profile and comparing it to the reference profile.

2.1 Railhead wear measurement

Two laser cameras carry out the railhead wear measurement for each rail in the track, installed in a way that makes them immune to the ambient lighting conditions. The measured parameters are as follows – reported by the trolley's PC software (Fig. 3). This is an important parameter fotrack quality assessment [7-10].

- vertical consumption – understood as the difference between the nominal profile and the profile measured after the profile has been adjusted by taking into account the rail foot location,
- side wear,
- assessment of the running edge profile,
  - the angle of inclination of the side surface of the rail head α,
  - calculation of the equivalent conicity (in the office system),
  - measurement of the inclination of the rails.

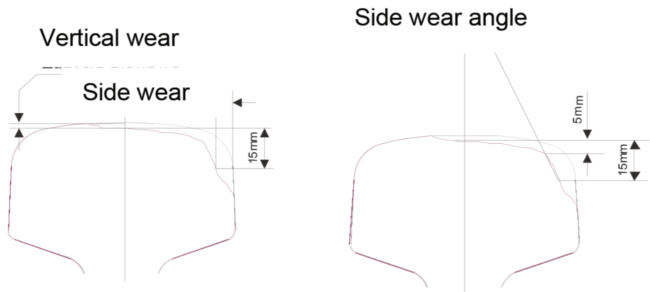

Figure 3 Definition of the main cross-section parameters of the rail

2.2 Turnout geometry measurement

An example of the TRC - TMS [6] can carry out track and turnout measurement autonomously. However, two persons have to be present on-board because of the regulations on some railways (operator and his assistant). After switching the TMS to the turnout mode, the measurements are made with the set of 8 measurement sensors (4 for each side) – Fig. 4.

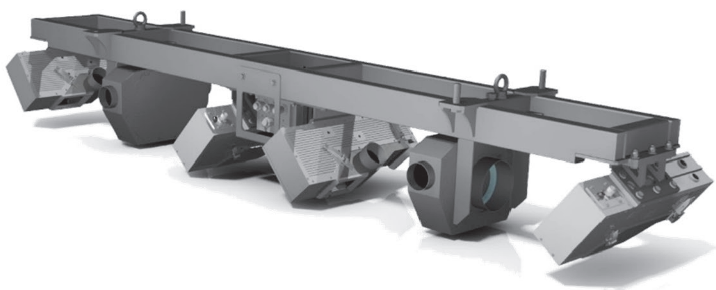

Figure 4 Laser track and turnout measurement system installed under the TMS vehicle body

The use of TMS requires careful planning as the vehicle passes some paths in the switches in one direction of its measurement ride and will complete measurement of their other legs (paths) during its nest measurement rides. A significant advantage of using the TMS is that it is treated as a train by the automation systems. Therefore, it does not require granting track possession to the measurement teams working in the track either with the manual track gauges or with the trolleys.

The off-line measurement data processing system provides the detailed turnout condition reports for the specific regions (or even country-wide) and the condition change over time, which can also be related to maintenance/repair costs. The exemplary measurement results, including the use of the reference profiles in the form of the virtual templates, are shown in Fig. 5 and Fig. 6. The automatic turnout geometry analysis includes, among others:

- Detection of turnout section (e.g., frog, blade, end)
- Detection of turnout characteristic points,
- Comparison with the mechanical templates,
- Checking measured parameters against tolerances in sections and at points.

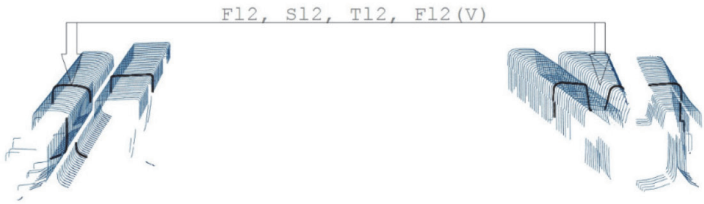

Figure 5 Optical measurement of turnout and rail cross-section

Figure 6 Virtual templates applied automatically during measurement data analysis

3 Visual inspection system

The visual inspection system allows recording the infrastructure condition during a train's passage and then carrying out analysis off-line. Such an approach is equivalent to the standard inspections, except that the train can record data at high speeds, without disturbing the typical traffic of trains or without affecting the railway line safety systems. Collecting the results by the inspection train and subsequent image processing in the office makes the inspection much more efficient and eliminates the need to maintain significant infrastructure staff [11], [12], [13]. The occurrence of particular damage types on the Polish Railway Lines (PRL) network was analysed To determine the causes of wear of railway rails. Attention was paid to three damage types that occur only on running surface of the railhead. The damages classified in the Catalogue of Rail Damages of PRL were quantitatively defined, taking into account their occurrence on chosen railway lines. The digital visual inspection (Fig. 7) system provides the possibility of saving the digital images of the rolling surfaces of both rails and rail surrounding (sleepers and ballast). Its resolution makes an assessment of the surface defects possible. For the track areas, the digital image resolution makes visual inspection possible of civil engineering objects in the track infrastructure. The main system components included the lighting subsystem for clear images of high contrast in any environment and lighting conditions, high-resolution cameras for rail surface defects recognition, and high-resolution cameras for the area surrounding the rails, covering the entire sleeper length. Data acquired by this system made automatic detection possible of defects like:

- rail surface anomalies,
- head check defect,
- rail edge anomalies,
- corrugation
- missing fastening elements,
- misplaced fastening elements,
- wheel burn on rail,
- break/discontinuity,
- periodical imprints.

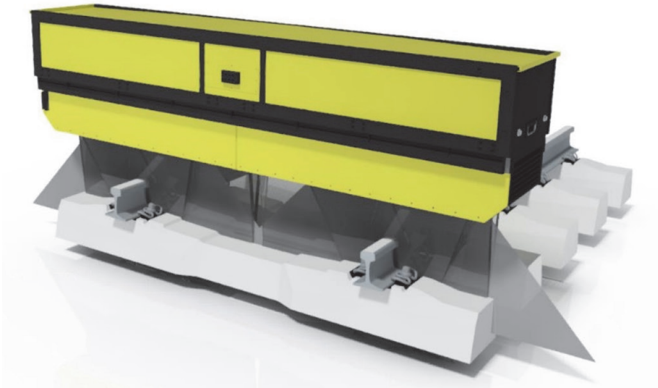

Figure 7 Track and turnouts visual inspection module

The images saved for the visual inspection needs are displayed on several monitors in real-time to enable the operators checking the infrastructure condition continuously. Detailed analysis is done in postprocessing the visual inspection data – Fig. 8, Fig. 9. Although most automatic detection algorithms generally try to minimise both false positive and false negative ratios, our approach focuses on minimising false negatives even at the cost of increasing the false positive detection rate to provide 100 % certainty that no major faults would be missed.

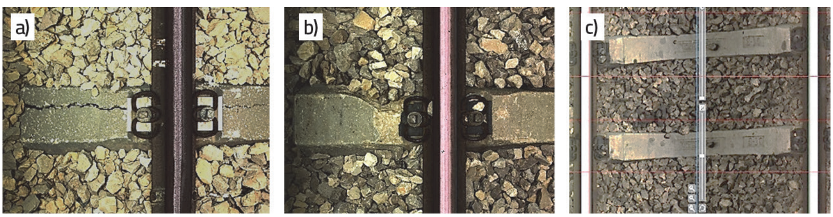

Figure 8 Examples of automatically recognised track sleeper defects: a) Sleeper cracks, b) Sleeper chipping, c) Displaced sleepers

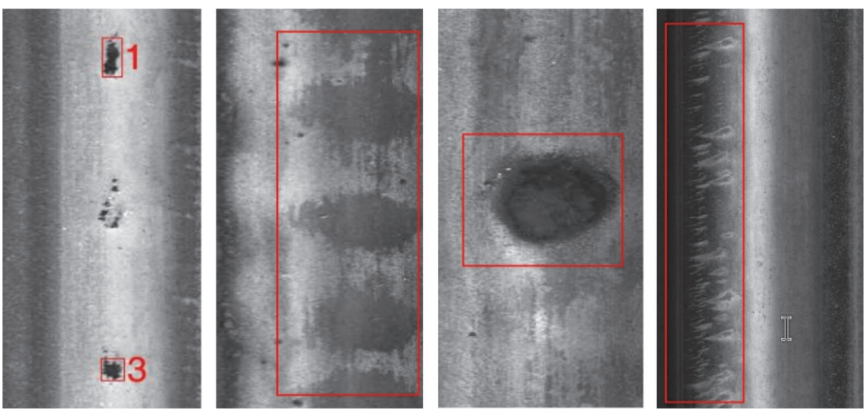

Figure 9 Example of automatic defect detection (imprint, short waviness, squat, HCH)

Track overview camera provides a vision of the track bedding and additional infrastructure elements like fasteners or fishplates. Missing or damaged fasteners detection can be done using images from those cameras. This method is robust and easily extendable since any given infrastructure element with a known location on the track can be found.
The images from the cameras will be recorded and fully synchronised with the measurement systems. Also, the selected camera's preview may be displayed on the control monitor installed on the vehicle. The recorded images can be transferred to the office system, and they can be made available in the operators' off-line software. The operator can specify the picture-taking distance increment.

4 Conclusions

Currently available digital track and turnout geometry measurement devices and systems provide a vast amount of diagnostic data that have made the predictive maintenance possible. Complex condition indices can be used now involving the measured geometrical parameters and also obtained from the automatic visual inspection data analysis.

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