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Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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TRACK GEOMETRY MEASUREMENT AS PREVENTIVE MAINTENANCE DATA SOURCE

Janusz Madejski
GRAW, Silesian University of Technology, Poland

Abstract

Train or metro operating safety may be ensured only if the actual track geometry is known. This requirement includes also knowledge of the horizontal and vertical rail head wear. Analysis of this data is the source of cost effective and rational maintenance decisions. Moreover, the earlier the necessary repair is done, the less expensive it will be, as one may . Therefore, expenditures on measurement equipment are the most effective investment – saving costs of possible accidents and costly repairs if they are made late. This is even more evident in case of track network revitalization, as one has to decide where and what should be repaired first. Any measurement method or tool without the objective data logging feature, makes it virtually impossible to collect all data that would be necessary for the detailed diagnostic reasoning on a line or railway network level, being useful only for direct measurement of some track parameter in a particular point. The principle of track geometry measuring trolley is described that can record all aspects of track alignment and riding quality on plots and tabular reports, so that maintenance service can locate efficiently the specific locations needing maintenance. The measurement results obtained with the trolley – also of the rail head wear – are described along with several track condition assessment methods.

Keywords: track geometry measurement, rail head wear measurement, turnout geometry measurement, track condition assessment, track condition reporting

1 Introduction

Rail transport is one of the safest forms of surface transportation [1], yet railways, metro and trams must carry out regular inspection and maintenance to minimise effect of the continuous infrastructure deterioration which could disrupt freight operations and passenger services. All such work has to be inspected, and the relevant measurement data has to be saved for reference, for checking the infrastructure deterioration rate, or – in the worst case – in the investigation procedures after the eventual accidents.

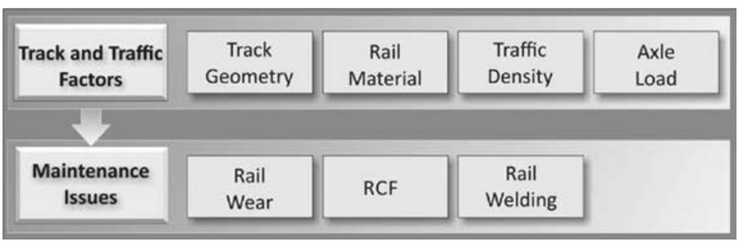

Figure 1 Track maintenance issues

Rail wear, plastic flow, and rolling contact fatigue (RCF) become more and more important issues for railways nowadays. They are the major factors of loss of rail head section and development of surface cracks, depending on conditions like train speed, axle load, rail-wheel materials type, size and profile, track construction, characteristics of bogie type, total load carried (MGT), curvature, traffic type, corrosion, and environmental conditions [2], [3] (Figure 1).

1.1 Crucial role of correctness of rail head/turnout and wheel profiles

The track rails guide the conical, flanged, linked wheels, so the cars stay on track without any active control both in the tangent track and in moderate curves (down to a radius of about 500 m). On sharper curves, the width of the wheel tread is not enough to maintain this effect, and in addition, the wheel flange rests on the high rail side face. If the rail head is side-worn or the flange is worn, then flange climbing is likely and the wheelset may run outside the rail. Tram cars are designed nowadays with low floor levels, so they are the exception as rail cars, as their wheels are not linked, therefore, much benefit in vehicle guidance is lost. Because of that, the tram tracks calls for as much attention as railway lines, even as the line speed is lower. As maintaining the correct rail head/turnout profile is crucial for safety of train operation and extending the track life, it is important to monitor the rail head/turnout profile and to compare it with the desired profiles, usually using the templates specified in the pertinent regulations. Rail profile grinding was initially developed by mining railroads of western Australia to control wear on curves and a dramatic decrease in rail wear was observed with the increase in rail life of up to 80% [4]. Therefore, the profile measurement systems are being needed more and more nowadays to monitor the profile [5]. Efficiency of rail/turnout profile assessment is significantly increased by use of the 'virtual templates' applied to profiles measured by a special trolley [6], or track/turnout recording vehicles [7], [8].
All requirements concerning the correct rail head (also turnout) and wheel profiles, as well as the track geometry quality, become even more complex in case of the Tram-Train concept initially developed in Karlsruhe in Germany, which is now spreading rapidly through Europe [9], [10]. The main idea has been to link a street tram network to the existing local passenger rail network. In this case, the wheel-rail interface is a key to the vehicle's safe operation and controlling factor of the maintenance costs of such system.

1.2 Effect of track geometry on vehicle behaviour in the track

On curves, the outer rail is usually at a higher level than the inner rail (except the tram track), unless the line speed is very low, of max about 15 km/h. However, a particular superelevation may be most effective for a limited range of speeds only. Speed reduction below the lower value of the speed range for the particular superelevation results in the excessive wear of the lower rail head, so speed reductions in a poor quality track may even make its deterioration faster.
Yet another important factor affecting safety of rolling stock operation is the track twist. This parameter should be carefully monitored as it may be a cause of the car wheel unloading, which may lead to derailment. Such risk appears if the track cant varies considerably over the vehicle wheelbase. This is effect is especially detrimental for vehicles with the suspension stiff in torsion. In addition, if cant irregularity is cyclic and its resultant effect on trains travelling at a particular line speed corresponds to the natural frequency of some vehicles passing there, there is a risk of resonant harmonic oscillation – cyclic roll – in these vehicles, which may lead to their extremely improper movement.
Similarly, cyclic errors caused by changing vertical track unevenness can result in vehicles lifting off the track, especially of the cars whose suspension is too stiff when they are empty. In such case, the vehicle wheelsets become momentarily unloaded vertically, so the flanges do not fulfil their function properly, or wheel tread contact is inadequate. It may also happen that the track may be simply grossly distorted because of earthworks.

1.3 Main causes of accidents

Statistical analyses examining the accident cause, type of track and derailment speed [11] revealed that the main cause of derailments were broken rails or welds. Track geometry, excluding wide gauge, was the second cause of derailments on main lines – Table 1. However, for the main track, wide gauge was also one of the most important causes of accidents (3.9%).

Table 1 Main causes of accidents (based on [11])

Main track		**Siding track**		**Yard track**	
Cause	Frequency	Cause	Frequency	Cause	Frequency
Broken rails or welds	15.3%	Broken rails or welds	16.5%	Broken rails or welds	16.4%
Track geometry	7.3%	Wide gauge	14.2%	Wide gauge	13.5%

Train operation safety related issues require, therefore, measuring equipment for rail head profile and track geometry, making it possible to enter and save annotations with visual inspection results (e.g., broken rails or welds), addressing this way the most important causes of accidents [12], [13].

2 Design requirements for track geometry measurement devices

All issues discussed above have to be addressed with the relevant measurement devices, which will provide objective data needed for diagnostics of track and turnouts geometry. Measurement of wheel geometry is not discussed here, albeit the approach demonstrated in this paper makes it possible to take wheel profile into consideration too. The decision was made to develop equipment to be used by maintenance services, acting either based on the information obtained from the periodic track and turnouts measurements of main lines made with the track recording vehicles e.g. [7], or checking the side and yard track network. Therefore, the general design requirements were selected as follows:

- Hardware features
  - portable
  - ruggedized
  - resistant to adverse climatic conditions
  - no calibration required before the measurement session
  - easy to assemble and disassemble
  - long operating time, best on hot swappable batteries
- Control system
  - custom made, to be independent from closed architecture of commercially available products
  - immediate access to functions needed most often
  - capability to work at night – backlit display
  - collection of visual inspection results has to be possible
  - capability to collect and store measurement data for a number of measurement sessions
  - measurement data file has to contain metadata describing its contents, measurement date and time, operator data, and device ID
  - collected measurement data has to be tamper-proof, protection from any corrections to measurement results has to be ensured
  - measurement data has to be transferred to the PC for analysis and archiving
- Software
  - measurement data from different devices, providing the same type of information (e.g., track geometry, rail head profile, et.) has to be processed by common software system
  - the user has to be able to specify tolerances
  - routine analysis tasks have to be done using predefined functions

3 Devices for track and turnout geometry measurement

According to maintenance issues discussed in Section 1 the relevant devices were designed meeting design requirements put forth in Section 2. Two field tested devices are presented below:
· trolley for track geometry and rail head profile measurement – TEP [6]
· optical system for rail and turnouts profile measurement – Scorpio [8]

3.1 Track geometry and rail head profile trolley

The trolley (Figure 2) can measure track gauge, cant, horizontal and vertical unevenness, twist, gradient, distance and rail head profile (non-contact laser vision system), including grooved rails. It is possible to merge measurement data files to represent longer track segments than measured in a single measurement session. This way, obtaining a complete information on the track condition is possible as it contains – its geometry data along with the rail head vertical- and horizontal wear.

Figure 2 Track geometry and rail head profile trolley

Test measurements shown in Figure 3 were taken in the tram track on the sharp curve. They revealed that rail head profile data can be collected 15 times faster with the trolley than with some other laser based reference device. Moreover, the developed trolley guarantees synchronisation of rail head profile with track geometry data. As regards rail head profile data processing (Figure 4), it was 30 times faster, and moreover, retains information about location of the profiles.

Figure 3 Exemplary track geometry and rail head measurement results

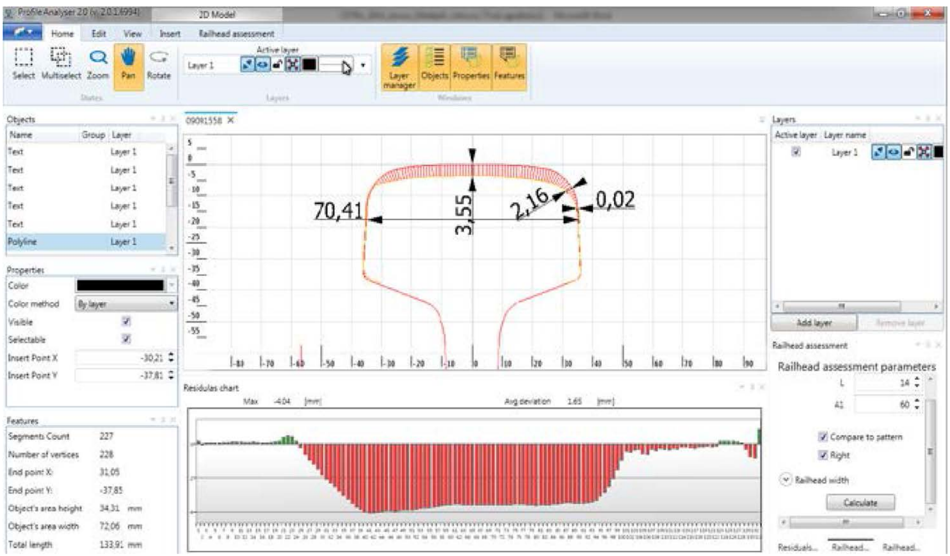

Figure 4 Rail head wear processing example

Several track geometry readings can be overlaid to reveal track deterioration proceeding faster at particular locations. Information about the track geometry is presented along with the information about the defects and events in the track.

Rail head profile can be analysed to support rail grinding technology, providing information about grinding indices, and analyses for the low and high rails separately in the curves. Evaluation and presentation of a number of track condition assessment results is available, e.g. distribution of tolerance exceedings – Figure 5.

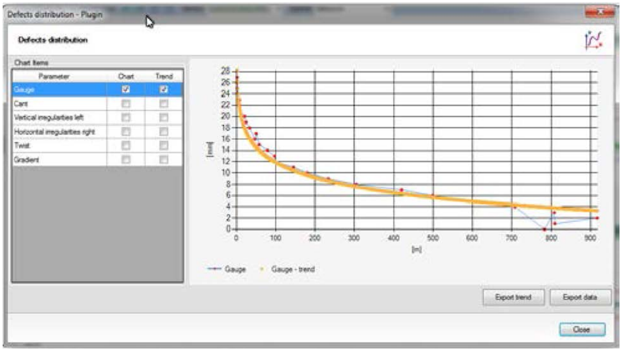

Figure 5 Exemplary analysis of distribution of defect types in the track

3.2 Optical rail and turnouts profile measurement system

The device is composed from the rigid datum frame, movable laser measurement head and its drive system. The measurement result is the 3D model of the measured object (e.g. turnout), being the exact representation of the measured object both in the lateral and transverse directions. Merging of multiple measurements into one object, generating the arbitrarily selected 2D profiles, calculation of the longitudinal profiles, and generating measurement reports.

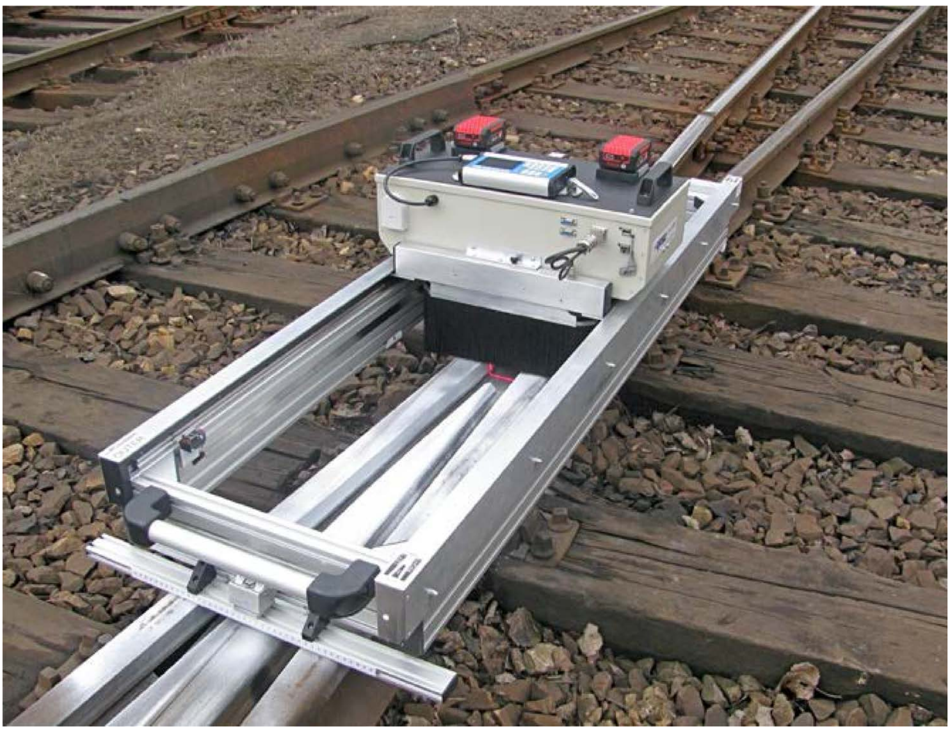

Figure 6 Optical system for track and turnout measurement

4 Conclusions

Presented devices were designed to collect track and turnouts geometry data, as required for ensuring train operation safety. Both devices were field tested, and verified using independent measurement methods, outperforming them.

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