Continuous geometry measurement for diagnostics of tracks and switches

Janusz Madejski  GRAW, Silesian University of Technology
Juliusz Grabczyk  GRAW
“Track geometry measurements are made using the manual tools, microprocessor based portable instruments, and geometry cars. However, any measurement method or tool without 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.”
Continuous geometry measurement for diagnostics of tracks and switches

- Introduction
- Synthetic assessment of track condition according to Polish regulations
- Track geometry data collection
  - Track gauges
  - Geometry cars
- Integration of diagnostic data from different sources
  - GeoTEC database
  - Stationary geometry car readings database
- Conclusions
Diagnostics of tracks and switches

Synthetic methods of the geometrical assessment of track condition:

- methods based on values of the geometrical parameters measured at a particular point
- methods using the synthetic assessment of the geometrical parameters measured continuously along the track
- methods of the indirect assessment in which the geometrical parameters of the track feature only one of the main factors influencing the final assessment coefficient.
Synthetic assessment of track condition according to Polish regulations

- Threshold analysis of geometric parameters of track
- Report format requirements
- Synthetic evaluation of track maintenance condition
- Five parameter track defectiveness
- Formal requirements connected with measurements made with geometry cars
Parameters currently included in the regulations ...
### What do we have to determine?

<table>
<thead>
<tr>
<th>Group of geometrical parameters</th>
<th>Parameter definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>vertical</td>
<td>cant</td>
</tr>
<tr>
<td></td>
<td>twist</td>
</tr>
<tr>
<td>irregularities of track rails in the vertical plane</td>
<td></td>
</tr>
</tbody>
</table>
Continued ...

<table>
<thead>
<tr>
<th>Group of geometrical parameters</th>
<th>Parameter definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>track gauge</td>
</tr>
<tr>
<td></td>
<td>gradient of track gauge</td>
</tr>
<tr>
<td></td>
<td>irregularities of track rails in the horizontal plane</td>
</tr>
</tbody>
</table>
Trend removal

\[ A_n \quad A_m \quad A_{n+k} \]

\[ L \text{ - reference length} \]

Input signal

Moving average

\[ B_j = \frac{\sum (A_{n+1} - A_{n+k})}{k} \]

Observed value

\[ C_m = A_m \cdot B_j \]
The A and B class deviations are only counted for statistic purposes. Class C deviations are called track defects and listed in the report. The 50% value of a class C deviation gives the class A deviation value, while 75% of class C is the class B deviation. Defects which exceed the C class boundaries by 25% are additionally marked with an asterisk “*”.
Chaining of defects

e.g. $d = 10[m]$

boundary value

$(a < d) \land (b < d)$

Value $= 0$

Fault 1 length

Fault 2 length

c $> d$
Synthetic assessment

Standard deviations are calculated using the formula:

\[ S = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2} \]

Where:
- \( n \) - the number of signals registered on the analyzed track section,
- \( x_i \) - value of parameter at point \( i \),
- \( \bar{x} \) - average value of signal.
Coefficient J

The synthetic track quality coefficient $J$ provides a quantitative evaluation of track condition. This coefficient is calculated using the following formula:

$$J = \frac{S_z + S_y + S_w + 0.5 \cdot S_e}{3.5}$$

Where:
- $S_z$: standard deviation of vertical irregularities
- $S_y$: standard deviation of horizontal irregularities
- $S_w$: standard deviation of track twist
- $S_e$: standard deviation of track gauge
Allowable deviations of track geometrical parameters depending on line speed

**Line speed: 30 km/h**
Twist 25 mm/5m, cant 25 mm, \( J \text{ 12.0 mm} \)

**Line speed: 90 km/h**
Twist 15mm/5m, cant 18 mm, \( J \text{ 6.6 mm} \)

**Line speed: 160 km/h**
Twist 8mm/5m, cant 8 mm, \( J \text{ 2.0 mm} \)
Defectiveness for each measured track parameter is calculated from the relation:

\[ W = \frac{\sum_{i=1}^{n} l_i}{l} \]

where:
- \( n_p \) - number of samples of signals exceeding acceptable deviations on analysed section,
- \( n \) - number of samples of signals on analyzed section.
Calculation of W5 defectiveness coefficient
... so the five parameter defectiveness is defined as:

\[ W_5 = 1 - (1 - W_e)(1 - W_g)(1 - W_w)(1 - W_x)(1 - W_y) \]

where:
- \( W_e \) - defectiveness of track gauge,
- \( W_g \) - defectiveness of cant,
- \( W_w \) - defectiveness of twist,
- \( W_z \), \( W_y \) - are arithmetic averages for vertical and horizontal irregularities, respectively, as determined from the defectiveness of left and right rails.
Evaluation of track geometry condition basing on $W_5$

<table>
<thead>
<tr>
<th>Evaluation of line</th>
<th>$W_5$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>New lines</td>
<td>$W_5 &lt; 0.1$</td>
</tr>
<tr>
<td>Lines in good condition</td>
<td>$W_5 &lt; 0.2$</td>
</tr>
<tr>
<td>Lines in sufficient state</td>
<td>$W_5 &lt; 0.6$</td>
</tr>
<tr>
<td>Lines indicating insufficient condition</td>
<td>$W_5 &gt; 0.6$</td>
</tr>
</tbody>
</table>
How to collect track geometry data? – Using track gauges ...
What is the output?

**Tolerances:**
- $-8,0 \text{ mm} < \text{Gauge} < 10,0 \text{ mm}$
- $-2,0 \text{ mm} < \text{Gradient} < 2,0 \text{ mm}$
- $-18,0 \text{ mm} < \text{Cant} < 18,0 \text{ mm}$
- $-3,0\% < \text{Twist} < 3,0\%$
- $-16,0 \text{ mm} < \text{Vertical} < 16,0 \text{ mm}$
- $-15,0 \text{ mm} < \text{Horizontal} < 15,0 \text{ mm}$

**Events and defects filter:**
hectometer marker, sleeper replacement necessary, bridge, flyover, tunnel, fish bar bolts missing, crossover, flash, crossing, rail's flat, platform, burr, skewed sleepers, sleeper fixing bolts missing, side wear, broken rail, broken weld joint
Track gauge readings - plot

Diagnostics of tracks and switches
Geometry car readings
Diagnostic data sources – from raw data to synthetic parameters

- raw geometry car files
- database of geometry cars’ measurements
- user interface (displaying, printouts)
- GeoTEC database
- evaluation of the track geometry; storing of track quality indices
- analysis system for the track quality indices
- database of track quality indices
New parameters offering better understanding of the track condition ...
An example of a new parameter: \(Spm\)

\(Spm\) : it is the maximum value of the ratio of the measured parameter overshoot and its allowable lower or upper limit value:

\[
Spm = \left| \frac{x_{extr}}{a} \right|
\]

where:

- \(x_{extr}\) – extremal measured value
- \(a\) - upper or lower allowable limit value
How to get what we really need to know about the track?

Raw measurement data

List of defects

Intelligent diagnostic module

Diagnostics of tracks and switches
Conclusions

- To evaluate the track geometry condition one has to know also these geometrical parameters that decide the dynamical effects of the train ride, i.e., track gauge gradient, track twist, as well as horizontal and vertical irregularities.

- Knowledge of the synthetic track quality coefficients is required to take the economically justified decisions connected with planning of major overhauls of the longer track sections. These decisions call for analysis of the track geometry changes in time.

- This attitude will effectively supplements the switch geometry assessment made basing on measurements in characteristic points.