ROUTE VERTICAL ALIGNMENT DESIGN IN THE PROCESS OF ITS REGULATION

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1. INTRODUCTION

It is the specific vertical and horizontal design of a rail track that, to a large extent, determines the course of its degradation processes, the amount of extra outlays needed to maintain railways as well as uneasiness related to driving. Modeling the rail track in the final phase of its building and then exploiting, referred to as adjustment, is nowadays performed by automatic tamping machines, which, however, involve measurement activities and – quite frequently – designing track adjustment.

Adjusting a rail track is performed in order to adjust an incorrect or deformed position of track axis to the position which corresponds to technical parameters required for a given railway line. Adjustment design is based on geodesic measurements of rail track height with the use of fixed point iteration, i.e. basing on the indicators of track axis adjustment located on poles.

The profile of an existing railway track performed in this way is the basis for calculating the value of track lift. These values are then written on ties and are used by machine operators as specification to lift and tamper a track. The method is convenient but it most often involves measuring the track profile the day before.

Implementing broad scale use of digital track meters in railway assessment to measure track geometry (irregularities) and considerable costs of purchase of modern track machines make it necessary to search for new solutions which utilize the potential we already have.

In a number of research papers, the possibilities were presented of utilizing digital track meter measurements to determine nominal values, design horizontal track adjustment and determine the profile of a railway line [1,2,3,4,5].

The application of the method presented in one of the papers [5] used to determine the line profile on the grounds of the measured track irregularities will serve to design route vertical alignment and calculate the values for track lifting. In practice it will facilitate the process of designing track adjustment.

2. CHARACTERISTICS OF THE METHOD

The measurements were performed on the track No. 501 of SKM line (Fast Urban Railway) in Gdańsk between 3,000 km and 3,726 km. Repair works consisted in lifting and tamping the track to eliminate warping and considerable differences in separate track height in cross-section.

The surface in this section in made of type 60E1 rails on concrete ties PS94 with K type affixing on muck ballast.

The rail tracks make a horizontally straight section and vertically - 7,1 $^{0}/_{00}$ tilting up to km 3,153 and then - 7,8 $^{0}/_{00}$.

In the first stage of tests vertical alignment of railway tracks was performed with the use of fixed points located on traction poles, and irregularities were measured with TEC 1435 track meter.

The results of the irregularity measurement i.e. tilt, warping and vertical irregularities are presented in figure 1.

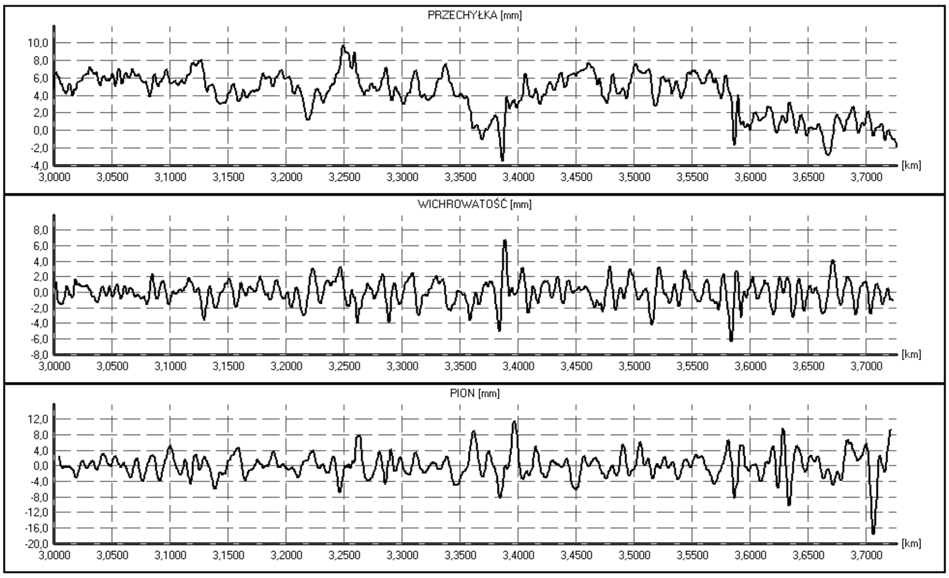

Fig. 1. The graph illustrating track irregularities prior to its repair: tilt, warping and vertical irregularities as appropriate.

On the grounds of the measurement of track axis location in relation to fixed points track adjustment was designed, which resulted in repair works with the use of PT800 tamping machine.

3. MAIN POINTS OF VERTICAL ALIGNMENT DESIGN METHOD

A diagram illustrating the proposed method is presented below, in figure 2.

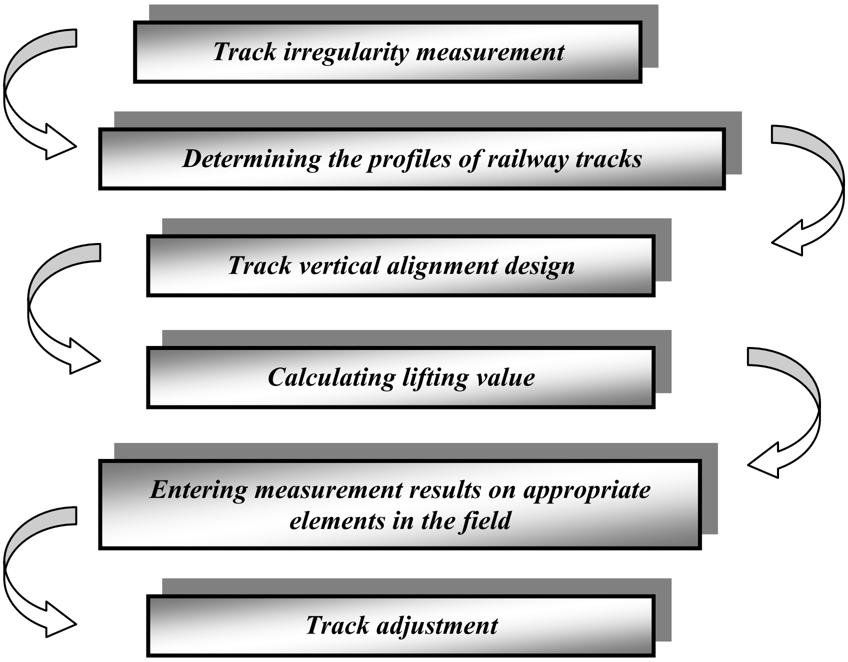

Fig. 2. The outline of the idea of the proposed method.

On the basis of measured vertical irregularities of 1 m (Fig. 3), rail track profile was determined; its graph is presented in figure 7. This stage has been elaborated on in the research paper [5].

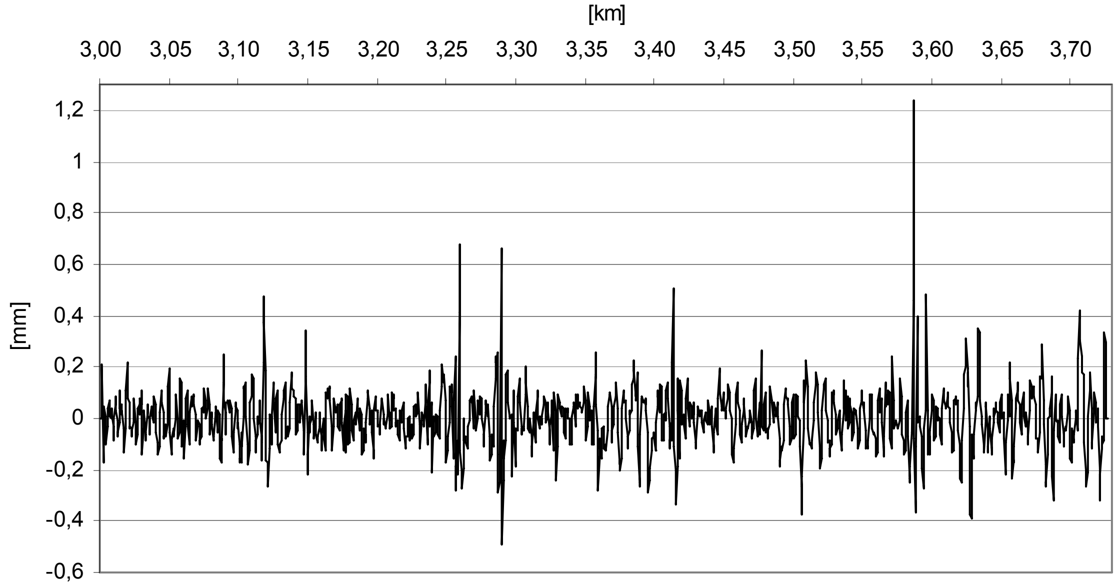

Fig. 3. The graph of vertical irregularities as measured along 1 m.

The method of mapping out the route contour of the railway track was based on the classic definition of the horizontal irregularity of the track and conversion of the deformation function determined this way.

Classic definition of the horizontal irregularities [7] is linked with the measurement of the height of the track course (track levelling) in equal distance l, most often every 5 meters (Fig. 4).

Value of the horizontal irregularity hn can be written in this form:

$$\Delta h_n = h_n - \frac{h_{n-1} + h_{n+1}}{2}$$

where: hn-1, hn, hn+ - height measured in the point A, B and C.

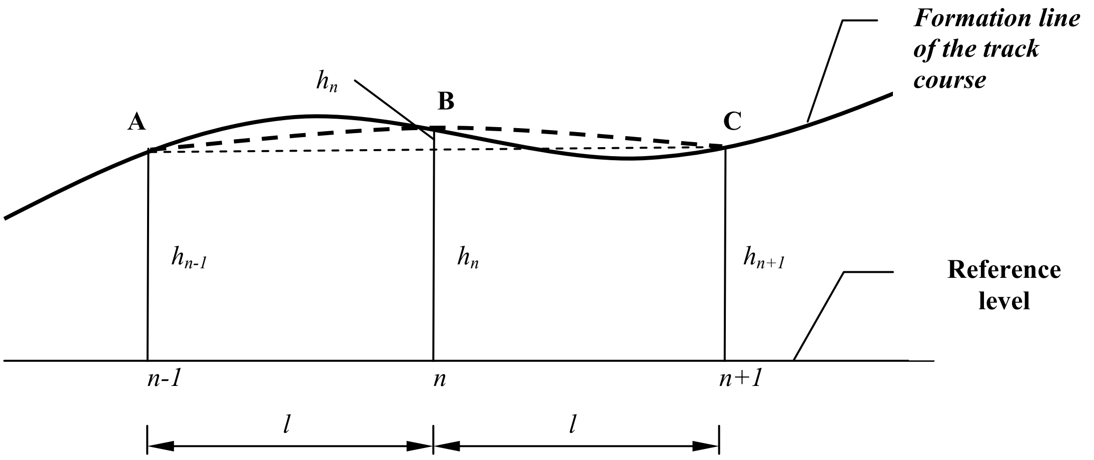

Fig. 4. Scheme of the measurement of the horizontal irregularities.

In practice the measurements derived from he track gauge do not give the information about the height of the points, but the values of vertical irregularities, measured usually on the basis of one meter and counted into 10 meters long chord.

In the further part of the analysis it was assumed that the frst two points A an B have the values of ordinates equal zero, and the value of the vertical irregularity h$_B$ was measured with the track gauge (Fig. 5).

Value of the ordinate in pint C can be derived from the expression:

$$y_C = -2\Delta h_B + 2y_B - y_A = -2\Delta h_B$$

or in general way for an arbitrary point will be written:

$$y_n = -2\Delta h_{n-1} + 2y_{n-1} - y_{n-2}$$

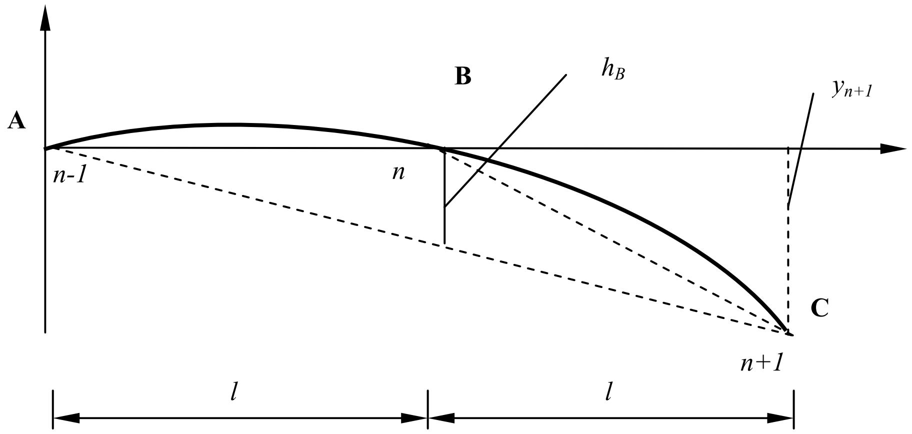

Fig. 5. Scheme of determining the deformation function.

Counting the value of ordinates in subsequent point we will receive the deformation function. The graph, because of the assumption, will be turned through the point A (point zero on the graph). The shape will be similar to the deformation of the track in reality (Fig. 6).

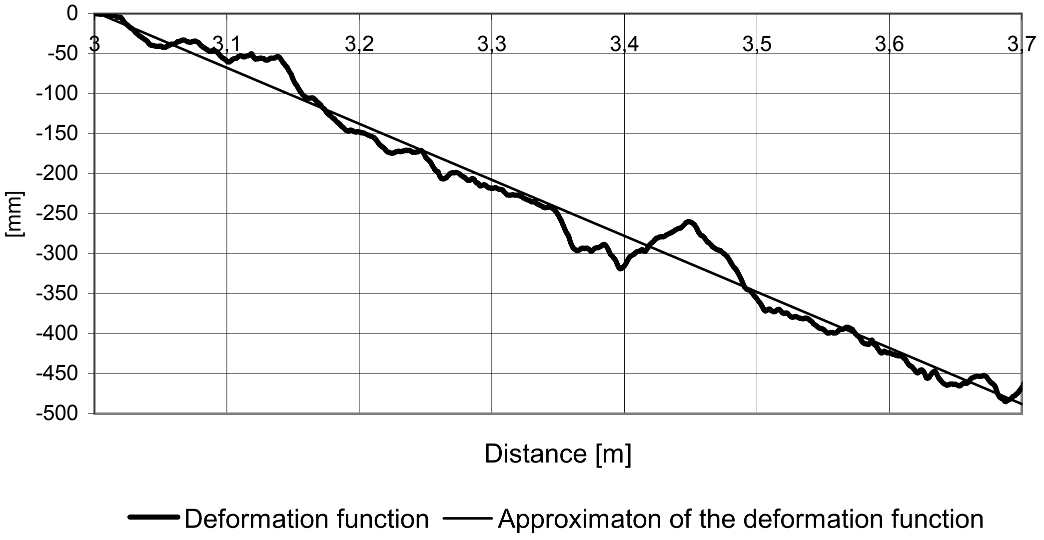

Fig. 6. The graph of the deformation function.

Next, the deformation function is approximated with the aid of linear function:

$$y^{1} = a + bx$$

The unknown a and b are counted using the method of minimal squares, in this case solving the system of equations:

$$\begin{cases} \sum_{i=1}^{N} y_i = Na + b\sum_{i=1}^{N} x_i \\ \sum_{i=1}^{N} x_i y_i = a\sum_{i=1}^{N} x_i + b\sum_{i=1}^{N} x_i^{2} \end{cases}$$

where: **N – number of the measured irregularities,**
i – number of the irregularity,
y –value of the ordinate of the deformation function [mm],
x – distance [m].

In the next stage it is necessary to introduce the correction of the counted ordinates of the deformation function. Values of the new ordinates is derived from the expression:

$$y_i^{0} = y_i - bx_i$$

In the case discussed, we receive the final graph of the route contour of the railway line (Fig. 7).

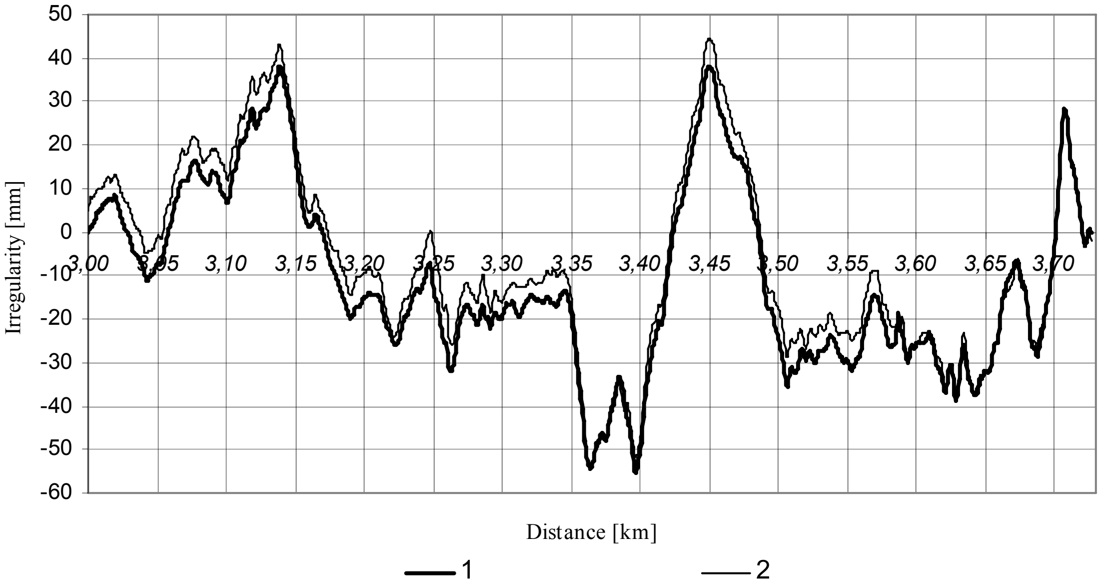

Fig. 7. The determined line profile: 1 – left track, 2 – right track.

During the next stage track vertical alignment should be designed. In reality there are three ways of approaching the problem. First of all, the track can be lifted according to the existing alignment, which will often involve additional works, e.g. lifting the traction network. Secondly, alignment can be designed in a way it is parallel to the existing alignment, i.e. a fixed value lower than the existing alignment. The third way is designing new alignment still following its basic design rules.

The presented example involved parallel alignments, 6 mm lower that existing alignment.

The final stage of vertical track adjustment is calculating the values of track lifting i.e. the difference between the designed and actual ordinates. The graph of rail track lifting in the tamping process in illustrated in figure 8.

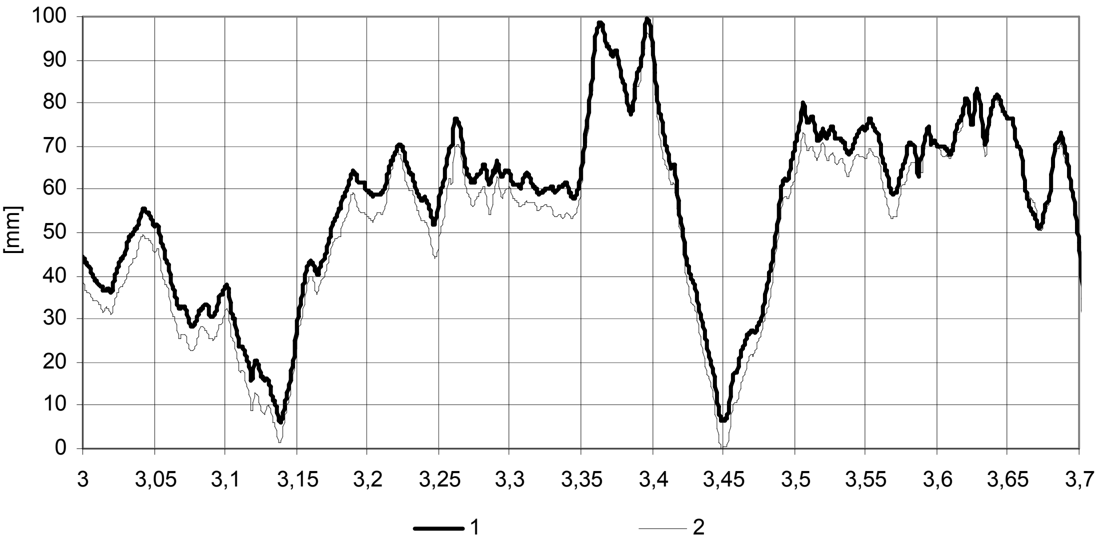

Fig. 8. The graph illustrating track lifting: 1 – left track, 2 – right track.

The last phase is writing lifting-related measurement results on ties and adjustment with the use of tamping machine. After the repair works are completed, quality check should be performed consisting in measuring the track height in cross section including fixed points. What is more, track irregularity measurement was performed with the use of TEC 1435 track meter (Fig. 9).

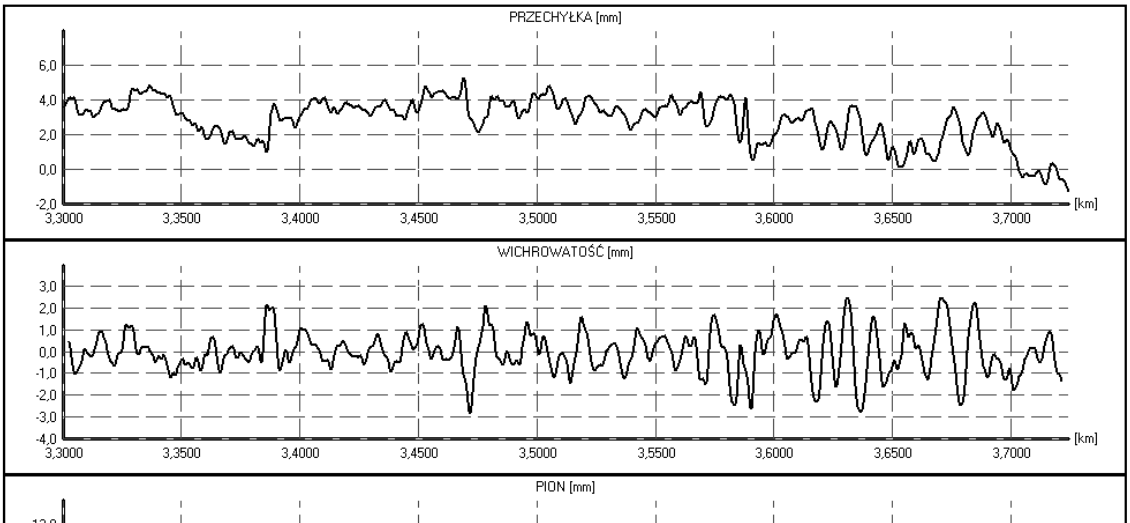

Fig. 9. A fragment of irregularity graph in section 3,3 – 3,726 after the repair.

3. CONCLUSION

The presented method of determining rail track lifting on the grounds of measured vertical irregularities may in the future be applied in railway maintenance, especially in designing works relating to track axis adjustment.

Further research will be performed to verify the proposed method in the field, in experimental sections, to correct the method algorithm and to create software to design track lifting in the process of its tamping.

Research conducted so far with the use of TEC 1435 meter suggest that it is necessary to improve the reproduction of vertical and horizontal measurements. It mainly involves the unreliability of irregularity values and is a result of damage, wear and tear of rail head, the method of measurements and measurement base length.

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