Measurement of the Geometry of the Transverse Cross-section of a Railway

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Abstract. *In this paper a design of a device for the measurement of the transverse cross-section geometry of a railway (especially railhead) using the virtual method has been presented. The procedure for the determination of the geometry consists in the approximation of the adjacent points of the railhead profile with a circle of a given radius. Based upon this approximation and the co-ordinate system given, the point of contact between the spherical measuring tip and the measured surface is determined.*

Keywords: railway geometry, measurements, error reduction

1. Introduction

The Metrology and Quality Testing Group within the Institute of Manufacturing Systems and Automation has developed two versions of a measuring device for the determination of the geometry of the transverse cross-section of a rail which may be employed for the verification of the rail manufacturing process or rail wear. The measurement is done by recording consecutive points of contact of the measuring ball with the upper or side surfaces of the rail (a contact method). Two incremental displacement transducers positioned perpendicularly with respect to each other, which makes it possible to determine the centre of the ball measuring tip in the x-y plane, were employed in the device. The measurement is done in the transverse cross-section of the rail, and the results of consecutive positions of the measuring tip are transferred in the digital form to a master PC, where the data are stored.

2. Description of the measuring device design

Fig. 1 shows the prototype version of the device with the transducers of linear displacement (VIS) mounted and with the transducer supporting electronics included. The device was designed to be rail mounted. A clamp device was used to obtain a positive mounting and fixed positioning of the device on the rail sides with the upper railhead as a datum. An essential part of the device is a swivelling (180º) arm designed so as to obtain access of the measuring tip to all points of the measured surface. The arm is provided with a catch, which permits to lock it after each swing (when measuring the opposite sides of the rail). The information on the side of the rail that is currently measured is given to the programme based upon the reading of a micro-switch mounted onto the body of the measuring arm. When measuring the right side of the rail with respect to the axis of symmetry, the switch status is “on” (the right side of the rail in the drawing). With the left side, the status is “off”. The lower end of the measuring arm is fitted with the spherical measuring tips. When in process of measuring, the arm may be translated in the plane perpendicular to the rail axis (x-y plane). Each movement of the arm is measured by two measuring rules oriented perpendicularly with respect to each other (a simultaneous measurement of the measuring tip

motion along the x and y axes).
Incremental transducers of linear displacement of two different makes were employed. The first one was from the Japanese manufacturer (Mitutoyo company) and the second from the Polish manufacturer (VIS). Both have a non-standard synchronic series interface with the different format of the transferred frame and data. Additionally, the VIS transducer needs the converter to TTL negative logic voltage (-1.7 to - 0.8 V for a logic “one”, and -0.8 to 0 V, for a logic “zero”).

Fig. 1 A prototype device for the measurement of rails

Due to the high speed of the data transfer from the linear displacement transducers, the rulers in the device are driven by a 16-bit Fujitsu MB90F562 microcontroller, which transfers data to the master computer. The readings from these transducers, which determine the co-ordinates of the measuring point (axis of the measuring ball), will be read by the measuring system only after the “read” switch has been pressed. Dedicated software for the master computer was written in Delphi 3.0. It permits to display (VDU) the position of measuring points as points of contact of the measuring tip with the surface of the rail, or as an image of a circle and its centre representing the profile of the measuring ball. The programme makes it also possible to transfer the measuring data to the AutoCad for further processing. Fig. 2 shows a display with exemplary results of measurements of a railhead with a standard profile of the railhead in the background (there are standardised profiles of railheads in the programme library).

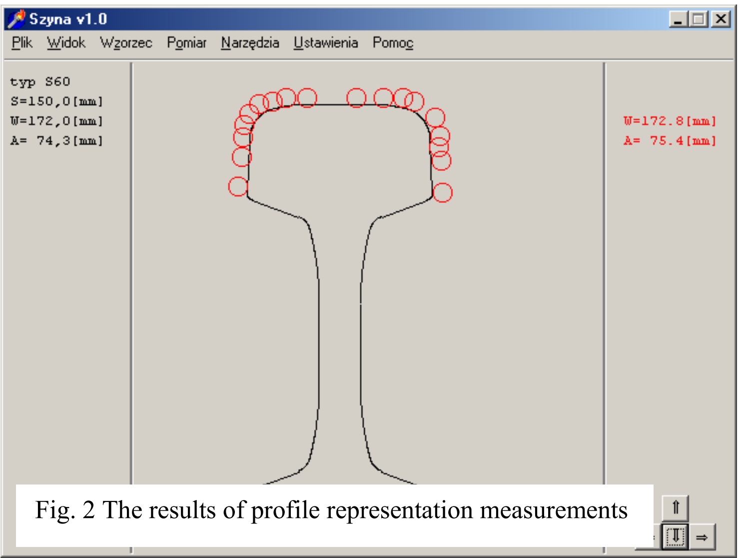

Fig. 2 The results of profile representation measurements

3. Representation of the profile

The programme includes two measuring options which make it possible to present the results in many different ways. With the first function it was assumed that the result of the measurement represents the co-ordinates of the centre of the measuring ball and a visual representation of the measuring ball (with a given diameter) which is tangent to the surface of the measured rail. This will allow obtaining a representation of the profile, especially with respect to the profile of the standard rail (Fig. 2). An arbitrary line between the consecutive positions of the measuring ball centre as well as point of contact of the measuring ball with the standard rail profile reflect faults in the actual shape of the rail but do not allow to determine the actual dimensions of the measured rail.The second measuring function of the programme (together with the prepared algorithm) permits to determine approximately co-ordinates of the points of contact between the measuring ball and the surface of the measured rail. It may be assumed that with practically acceptable accuracy these points represent the actual profile of the rail. The in-built "zoom" function may be used for the visualisation of even small irregularities of the rail profile with respect to the ideal profile. The programme permits printout of the measuring data in the form of co-ordinates (x, y) as well as the printout of the computer display.

4. Virtual measurement

When developing this method, it was taken into account that the measurement is done by contact and the measuring element is a ball. The dimension of the ball has significant influence on the point of contact with the measured rail and, as a consequence, on the recorded co-ordinates of the measuring point. The transformation of the ball centre displacements given by the transducers to the co-ordinates of the contact point between the measuring ball and the surface of the rail must be carried out taking into account both the diameter of the measuring ball and the effect of the direction of approach. Therefore, it was assumed that the measuring point is located at the bottom point of the ball and a circle with the radius R represents the railhead curvature. This radius is assumed to have an arbitrary value or its value is determined as shown in Fig. 3.

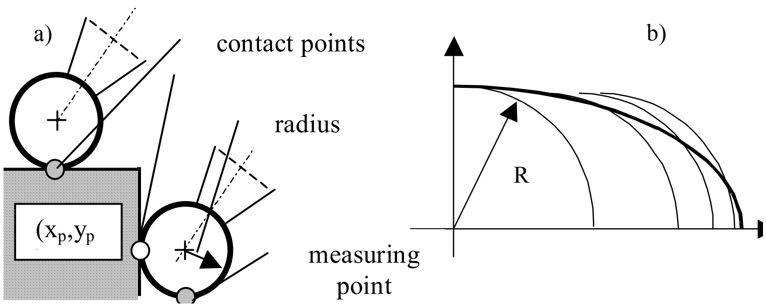

Fig. 3 Virtual measurement
a) Illustration of the error in the function of the measuring point
b) A method for the selection of a circle representing the curvature of the railhead

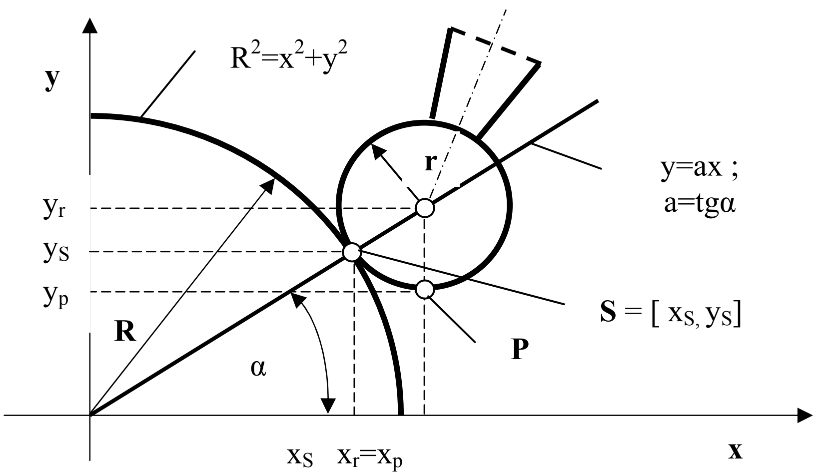

Fig. 4 Scheme for the determination of the virtual measuring point

A method for the representation of the railhead curvature (dark line) is shown in Fig. 3b, and a method for the calculation of the actual value of the virtual measuring point is shown in Fig. 4
The equation of a straight line which passes through the centres of circles with the radius **R**, the centre of the measuring ball and the centre of the co-ordinate system is:

$$y = tg\,(\alpha)\,x$$

Then, the co-ordinates of the contact point between the ball and circle **S** are given by:

$$x_s^2 = R^2/(1+a^2) \quad \text{and} \quad y_s^2 = a^2 * R^2/(1+a^2)$$

If the value of the measuring point is known, then the co-ordinate of the centre of the measuring ball is also known (Fig. 4). Thus the calculation of the co-ordinate of point **S** is straight-forward. The virtual and actual points of contact are the same only when the derivatives of the rail profile and of the circle are the same (Fig. 5), which is shown by dashed lines.

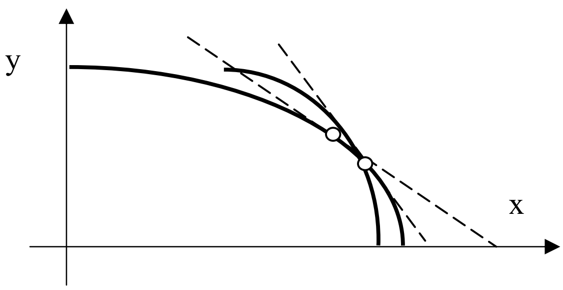

Fig. 5 Illustration of derivative value errors in the measuring point

As the actual profile is not known, the error of the measuring method may only be estimated. In the presented method of the virtual measurement the results obtained were satisfactory and the presented device may be used not only to the representation of the rail profile but also for the evaluation of its linear and angular errors.
The device may also give satisfactory results for the measurement of other machine elements, where the overall dimensions do not exceed 140x140 mm.

References

[1] Polski Komitet Normalizacji, Miar i Jakości, Szyny normalnotorowe PN-84/H-93421.
[2] „Metrologia wielkości geometrycznych” Władysław Jakubiec, Jan Malinowski, WNT Warszawa 1999.
[3] http://www.powerslider.de/Diplomarbeit/Recherche/Recherche__Gruppierung/recherche__gruppierung.html
[4] http://www.fme.fujitsu.com/