Jerzy Cejmer
mgr inż.
Instytut Kolejnictwa w Warszawie, Zakład Dróg Kolejowych i Przewozów
jcejmer@ikolej.pl

Marcin Kowalski
dr inż.
P.U.T. Graw sp. z o.o.
kowalski@graw.com

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iTEC measurement trolley - the results of tests of the inertial measurement system

Abstract: The article describes the course of research and development undertaken to develop the innovative inertial electronic trolley for measurement of track versines. The described trolley is designed both for the routine daily track diagnostics and the track acceptance measurements of tracks with the maximum line speed of 160 km/h and above. The authors set out the detailed results of field tests and analyses performed to confirm the effectiveness of this measurement method.

Keywords: Inertial trolley; Inertial measurement system; Track measurement

Introduction

Auto registered measurement trolleys TEC are widely used for many years for routine diagnostic measurements tracks. Measurements of these trolleys are presented in a manner similar to the measurement results of trolley EM120 and the achieved accuracy of the measurements of individual parameters for assessing the state of paths are quite satisfactory for the purpose of this diagnostic. In addition, a foil operator's keyboard allows easily recording the results of visual inspection of the track, and save the results as a function of distance in a file with the measurement results. These advantages combined with a considerable shortening of the duration of measurements and facilitation of their performance, compared to measurements based on classic hand measurement trolley made that it is today difficult to imagine diagnostics in factories of PKP PLK SA without using trolleys TEC.

With the demand for measurements of acceptance investment work in tracks, especially for tracks designed for speeds of 160 km/h and larger, it has become increasingly common expectation to increase the accuracy of measurements of the versines. The measurement trolleys TEC make possible to measure the differences in the value of the versines with the accuracy better than ± 1 mm so that the shape of the charts of versines on the basis of 10 m is shown correctly. However, calculations based on the three-point method give the error approximately ± 10 mm, which cannot be unaccepted.

For this reason, works have begun on an innovative inertial measurement system of versines designed for installation on auto registered trolley. To conduct the research and development, GRAW sp. O.o. received funding from the Innovative Economy program (1.4). The project created a prototype trolley iTEC with the innovative inertial measurement system (Fig. 1).

1. Prototype of the trolley iTEC.

The course of study

In the construction of the inertial measurement system, the newest, small-sized and low-energy components were used, such as semiconductor accelerometers and gyroscopes typed on the basis of trials and tests carried out in the framework of the research project. The main part of the innovation system is recording and processing measured signals. It allows the calculation of desired geometric parameters of the track from measurement signals. The first trial was carried out on the siding track, and the measurement results of the curve radii obtained from the prototype inertial system were compared with the results of measurements taken by GPS-RTK technique.

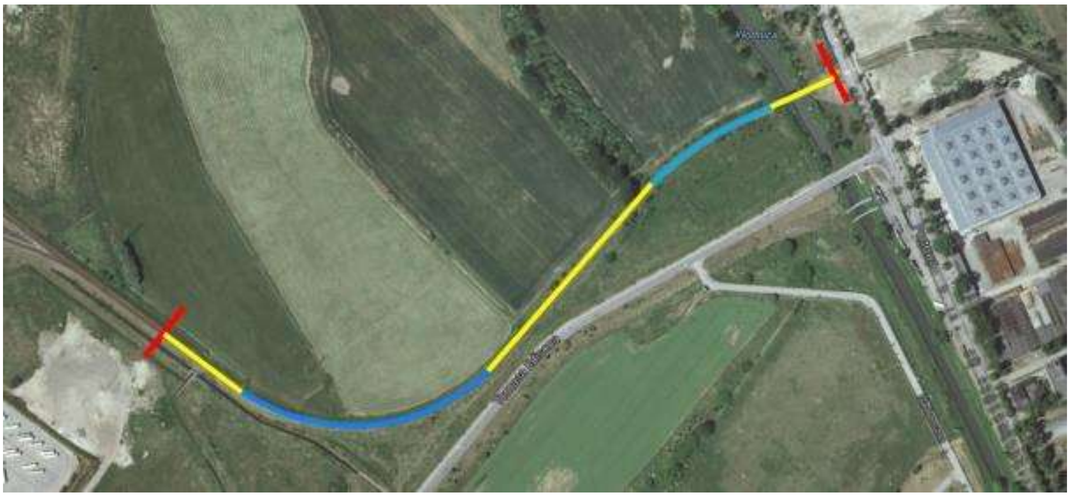
Figure 2 shows a satellite image of the track on which the measurements were carried out and the results of calculations and comparisons of both methods are shown in Tables 1 and 2. The tested segment consisted of 3 straight lines and 2 arcs with radii of 200 and 300 meters. In the tests, 10 measurements were carried out with the trolley iTEC in both directions (with respect to the track kilometres) and at different speed of measurements. It is apparent from the results that there is a very high repeatability (standard deviation of the mean value of the two versines on the arcs was less than 0.2 mm). Moreover, there is a good agreement with the results of independent measurements performed using an accurate GPS/RTK.

Tab. 1. The results of 10 measurements obtained from the trolley iTEC on two test curves. The mean value of the versines and the length of the radius of the arc were calculated.

Measurements by trolley iTEC					
Arc 1			Arc 2		
Passing	Mean versine [mm]	Radius [m]	Passing	Mean versine [mm]	Radius [m]
1	41,4	302,1	1	-62,4	200,4
2	41,3	302,9	2	-62,7	199,3
3	41,5	301,4	3	-62,5	199,9
4	41,4	302,3	4	-63	198,4
5	41,5	301,4	5	-62,6	199,7
6	41,4	301,6	6	-62,9	198,7
7	41,5	301,5	7	-62,5	199,9
8	41,4	301,8	8	-62,8	199,1
9	41,4	301,6	9	-62,9	198,8
10	41,4	302,2	10	-62,9	198,7

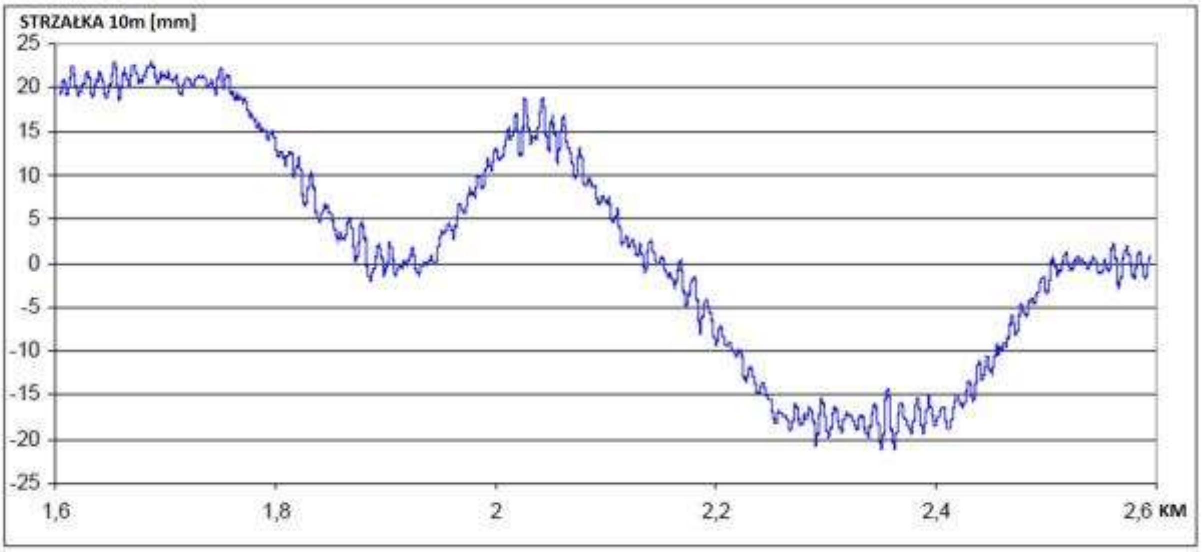
Tab. 2. The results of 3 measurements obtained from the measurer GPS/RTK on two test curves. The mean value of the versines and the length of the radius of the arc were calculated.

Measurements by GPS/RTK					
Arc 1			Arc 2		
Passing	Mean versine [mm]	Radius [m]	Passing	Mean versine [mm]	Radius [m]
1	42,9	291,6	1	-62,6	199,7
2	41,2	303,6	2	-62,1	201,2
3	41,6	300,6	3	-62,5	200,1



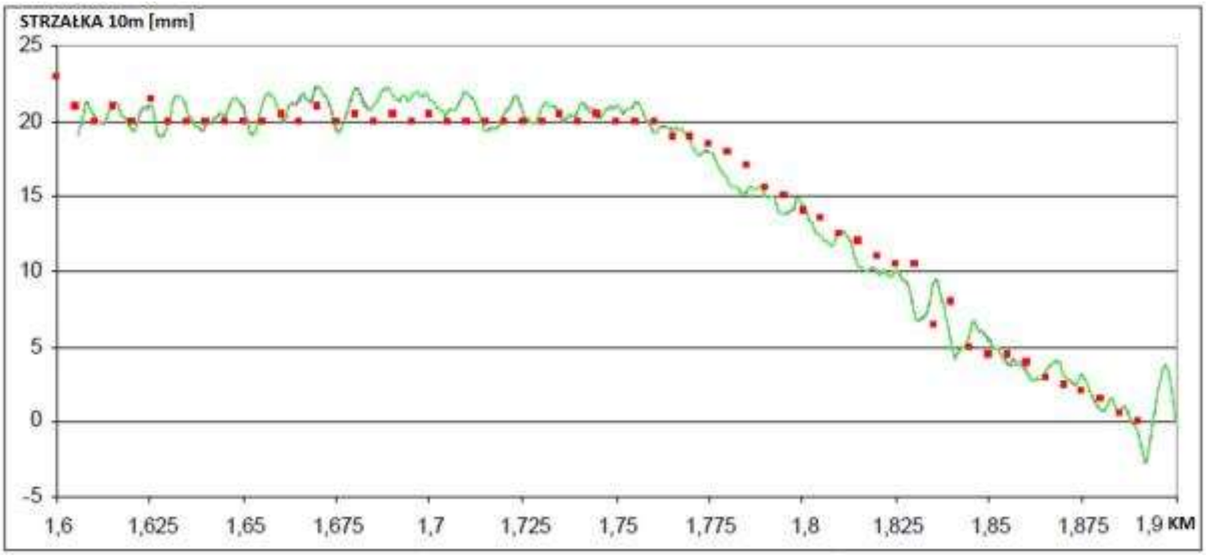
2. Satellite image test track (Gliwice) with the indicated test section.

After the finishing own tests, the detailed study of innovative inertial measurement system of versines was commissioned the Institute of Railway. The studies were carried out both on the testing track in Żmigród and under conditions of main track. Figure 3 shows the course of the versines, characteristic of the experimental track in Żmigród. The course was repeatedly measured by the inertial system. We studied both the repeatability of indications of the inertial system and the agreement with the results of measurements made by the measurer of versines.



3. Distribution of versines on the test track in Żmigród section with 1.6-2.6 km (arcs 600 m, 700 m, 800 m).

Figure 4 shows the results of the difference values between two measurements made in the inertial system on the path with the length of about 300 m and the values measured in the measurer of versines. As it is seen, a very good agreement of the results of both methods was obtained for the entire length of the arc R600 resulted. The maximum values of the differences on the basis of 10 m were less than 0.3, and usually, these differences do not exceed 0.15 mm.



4. Comparison of the results of measurements performed with the versines measurer (red) with measurements made by the trolley iTEC (green). The arc had the radius of 600 m.

Tab. 3. Results of measurements carried out in the versines measurer and trolley iTEC

Nominal radius [m]	Number of measure	versine [mm]		Real radius [m]
		Mean	Standard deviation	
150	21	86,01	5,41	145
	22	86,92	3,06	144
	23	85,86	5,43	146
	24	86,79	3,13	144
	versines measurer	85,7	5,56	146
150	21	82,19	2,57	152
	22	82,83	2,28	151
	23	82,21	2,61	152
	24	82,83	2,26	151
	versines measurer	81,63	4,12	153
600	1	20,84	0,94	600
	2	20,75	0,77	602
	3	20,83	0,94	600
	4	20,77	0,78	602
	versines measurer	20,3	0,61	615
700	1	17,76	1,37	704
	2	17,69	1,54	707
	3	17,76	1,37	704
	4	17,69	1,54	707
	versines measurer	18,1	0,38	691
800	1	15,20	1,82	822
	2	15,23	1,14	821
	3	15,20	1,83	822
	4	15,25	1,14	820
	versines measurer	15,19	0,35	823
900	17	13,89	0,77	900
	18	14,02	1,55	892
	19	13,93	0,76	897
	20	13,93	1,54	897
	versines measurer	13,9	0,70	899

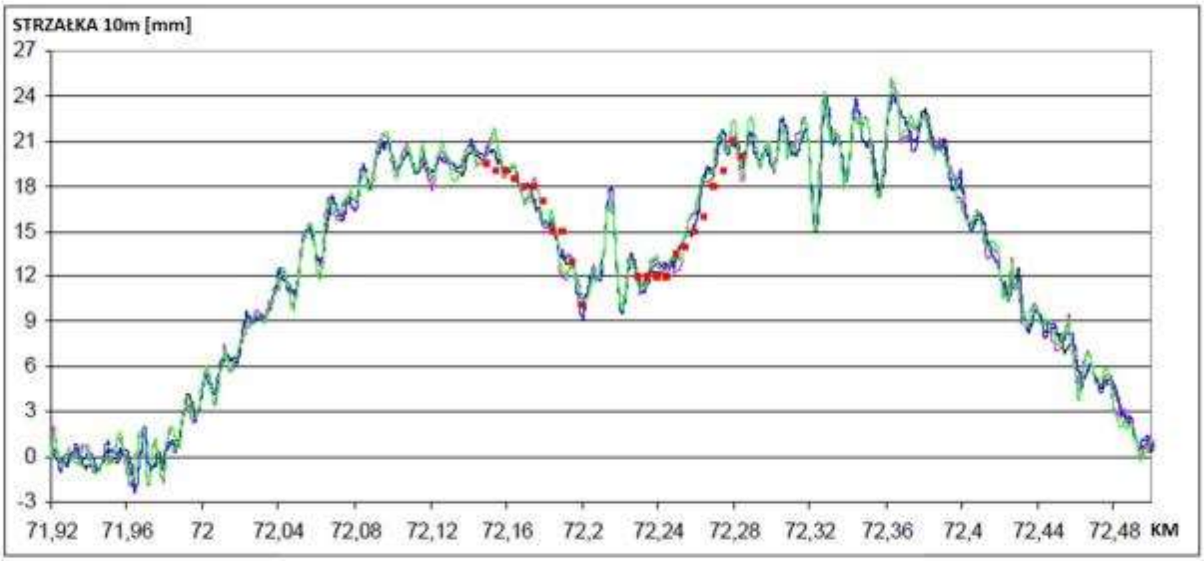
Summarizing results of studies conducted in Żmigród are shown in Table 3. It includes the average values of the versines, and their standard deviations and the current value of the measured arc radius calculated based on the average value of the versines. The chart shows that the value of the versines obtained from the inertial method are very close to the values obtained from the wire measurer of versines. Therefore, the new method of measuring the versines used in trolley iTEC, allows determining the effective radius of the arc with high accuracy. The high accuracy is particularly visible in the comparison of both methods on curves with the radius of 150 m, where - due to the high value of the versines - the measurement with the wire measurer is the most accurate.The study of the prototype of metrological inertial system was carried out by employees from Railway Institute on the trail Koniecpol-Julianka. The study was conducted on a straight track and on curves R1050-R3000. The results of measurement repeatability of the versines on the basis of 10 m are shown in Table 4. As it can be seen, the average values of the differences are close to zero and the standard deviations do not exceed 0.4 mm.

Tab. 4. Results of measurements carried out in the versines measurer and trolley iTEC for arcs R1050 – R3000

Number of measure	Mean error [mm]	Standard deviation
1 – 3 (arc R1050)	0,04	0,30
2 – 4 (arc R1050)	-0,03	0,28
5 – 1 (arc R1050)	0,00	0,27
6 – 2 (arc R1050)	0,14	0,25
7 – 9 (arcs R1920, R2500, R3000)	-0,05	0,29
8 – 10 (arcs R1920, R2500, R3000)	-0,04	0,37

For the purposes of assessing the possibility of reproducing by the studied measurement system more complex shapes of track, additional measurement of the unusual track section was conducted. According to the design, the measured track section should run in an arc with the radius of 674 m, but in its middle part, a flattening occurred at a railroad crossing. It caused that a platform arc appeared. Measurements of the versines using the inertial method and the versines measurer are in good agreement. The shape of the track distortion is shown in Figure 5.

The results of the inertial system show that the versines measured in the system are in good agreement with values measured by the versines measurer on the basis of 10 m. What is more, the inertial system allows reproducing even unusual, complex shapes of tracks. It is worth noting that the research conducted by the Institute of Railway related also to exploitation properties of the prototypic inertial system, including the technology of measuring the conditions of the open track. Taking measurements in such conditions requires interrupting measurements during the travel time of train and their resume after the train drove. These studies have shown that it is possible to interrupt and resume measurement without compromising accuracy under the developed measurement technology.



5. Comparison of the results of measurements performed with the versines measurer (red) with measurements made by the trolley iTEC (green) on a railway crossing in the vicinity of 72.2 [km].

After completion of the development and testing of a prototype by the project, GRAW sp. O.o. has developed a production version of trolley iTEC (Figure 6).

6. Production version of the trolley iTEC.

Summary
Measurement of versines and holes takes place contactless in the inertial system. To meet the increasing demand for energy, trolley is equipped with an external battery, which if it is necessary can be easily replaced without interrupting the measurement session. The trolley is also provided with a GPS so that the measurement results can be easy identified in space and time. Taking account of the demands of users, who see the need for inertial measurements not only during the acceptance works, but also in many daily diagnostics, the trolley can communicate via Bluetooth with smartphones and tablets. Suitable software enables duplicating operator panel of the trolley on screens of these mobile devices and entering descriptive information about the state of the track by a person not dealing directly with the trolley. Thanks to the excellent metric and operating properties the trolley iTEC is being more widely used in the country and abroad.