Identification of Changes in Irreguralities for a Modernized Railway Track

Julian Kominowski, Bogdan Sowiński
Poznan University of Technology, Poland

This article describes the analysis of measurements of track irregularities for a selected section of a modernized railway track. The paper presents changes of selected irregularities resulting from the traffic load levels on the track section. The authors focused on analysing results of track geometry measurements and analysing waves of track lateral and vertical irregularities. Measurements of track irregularities were performed at the same track section by indirect and direct methods.

Keywords: railway infrastructure, diagnostic, railway track geometry.

1. INTRODUCTION

In recent years, national and union grants have translated into modernization and revitalization works on Polish railways. The length of railway lines sections on which the line speed has been increased may confirm explicit changes resulting from launched investments. Since the timetable launched in 2011, the length of sections at which speed reductions have been introduced is lower than the accumulative length of the railway line sections on which the speed has been increased [8]. Conducting investments, PKP Polish Railway Lines enhances travel comfort, aesthetics of the infrastructure elements, the travel time is being reduced, whereas the safety of performed railway traffic is increased. It is important to conduct a qualitative assessment of the completed works technical condition. A significant part of conducted modernization and revitalization processes refers to the condition of the railway line superstructure. An appropriate assessment of the condition of the track geometry exerts an impact not only on the process of acceptance of performed works, but it also transferred into future maintenance, especially from the perspective of allocated funds.

Thanks to many investments there are more and more railway lines sections in Poland with the maximum speed equal to or exceeding 160 km/h. Internal regulations of PKP PLK S.A. [11] accept direct and indirect measurements in case of surveys of the railway superstructure for the final acceptance after an overhaul or modernization for the speed of 160 km/h. Direct measurements are conducted by means of the track gauge, whereas, indirect measurements are conducted by means of the measurement trolley. The article presents results of the analysis of selected irregularities reported in direct and indirect measurements of the railway line section modernized for the speed of 160 km/h. In order to illustrate changes in irregularities the authors of the article selected measurements conducted since the line was rendered for use. Traffic load was estimated between conducted studies, on the basis of the infrastructure administrator's documentation.

The section subjected to the study referred to the fragment of the modernized railway line No. 271 Wrocław – Poznań. The purpose of the conducted modernization of the track infrastructure together with the associating infrastructure of the selected section refers to its adjusting for the speed of 160 km/h for the passenger trains and the speed of 120 km/h for freight trains as well as the load on the axle of 221 kN. Elements of solutions for the speed of 200 km/h have been implemented in the part referring to the rail track geometry, adjusting of engineering facilities for new dynamic loads and increased security requirements, and the preparation of the overhead contact line with regard to the support span. The commercial speed at the selected fragment since the track was commissioned in November 2013 has been 100 km/h. Direct measurements have been implemented by means of the track gauge, whereas, indirect measurement have been executed by means of the track geometry recording car EM120. For the purpose of the direct measurement conducting, the authors of the study used the track gauge of the infrastructure administrator, admitted to use and with valid calibration tests of the manufacturer. Automatically, registered values referred to the gauge, cant, and twist of the track as well as vertical and horizontal irregularities of the track. Three measurements were conducted for each method for the needs of the analyses. After each measurement with a direct or indirect method, the measurement system was calibrated in order to avoid any errors in measurements.

Direct measurements were conducted in the following months:

- October 2013;
- June 2014;
- September 2014.

Additionally, between the second and third measurement, in case of each method, the section subjected to measurements was closed for the Contractor to remove irregularities which occurred during the construction and exploitation as well as to adjust the track superstructure to the assumed speed of 160 km/h.

2. SELECTED IRREGULARITIES MEASURED WITH A DIRECT AND INDIRECT METHOD

On the onset, the analysis of conducted measurements will focus on width (fig. 1 and 2) and cant (fig. 3 and 4) of the track at the selected fragment of the modernized section of the railway line 271.

In compliance with the instruction [11] the deviation in the width for the track modernized for the speed of 160 km/h amounts to 2 mm for narrowings and widening, and for the twist of the track measured on the basis of 5 m, the deviation amounts to 5 mm.

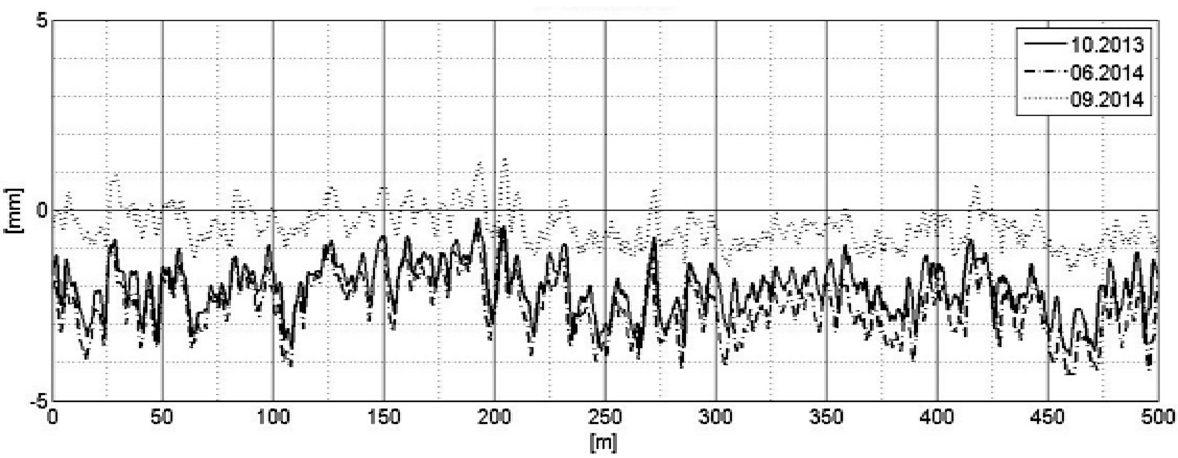

Fig. 1. The width of the track at the selected section, measured with the direct method in various periods of exploitation.

Indirect measurements were conducted in:

- November 2013;
- May 2014;
- September 2014.

The measurement step in the direct method referred to 0.5 m and in the indirect method it referred to 0.25 m, whereas the twist of the track was calculated on the measurement basis amounting to 5 m.

During the second measurement, traffic load was estimated to amount to 4.5 million tons since the moment of commissioning for use.

Measurements presented in Figure number 1 reveal "similar" courses of irregularities as well as progressive narrowing of the track being the result of the traffic load. After conducted corrective measures, a considerable enhancement is visible with regard to the width of the track. In case of measurements conducted by means of the measurement trolley, also a progressive narrowing has been observed, however, measurements conducted in such manner do not provide information on a considerable improvement regarding the width of the track as in case of measurements conducted by means of the track gauge. The third measurement conducted with the indirect method after corrective measures revealed a number of point narrowings.

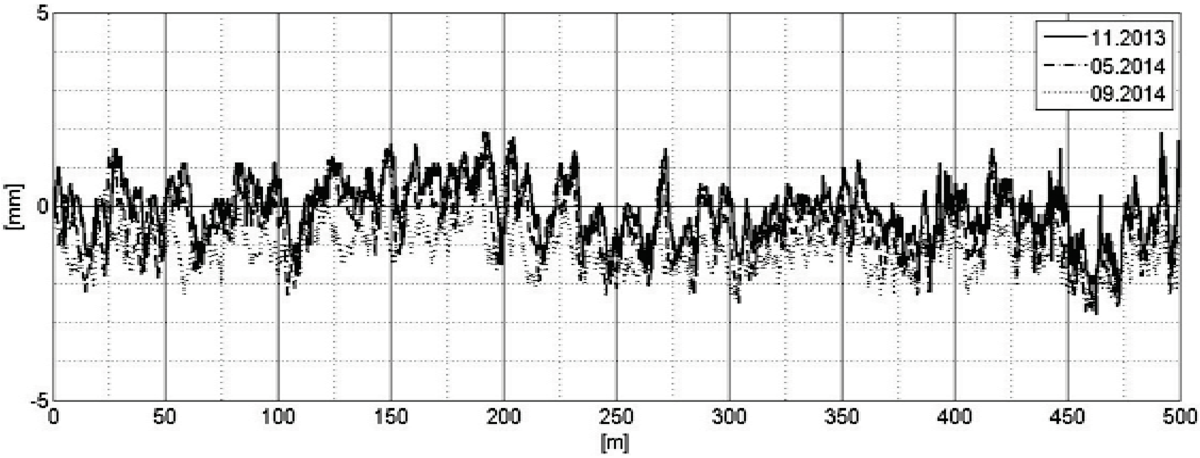

Fig. 2. The width of the track at the selected section, measured with the measurement trolley in various periods of exploitation.

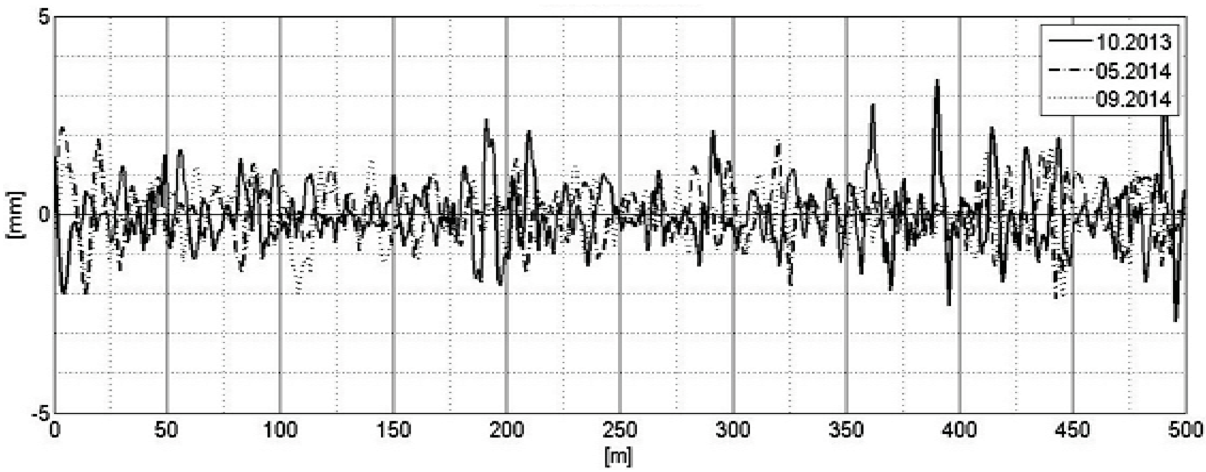

Fig. 3. The twist of the track at the selected section measured with the direct method in various periods of exploitation.

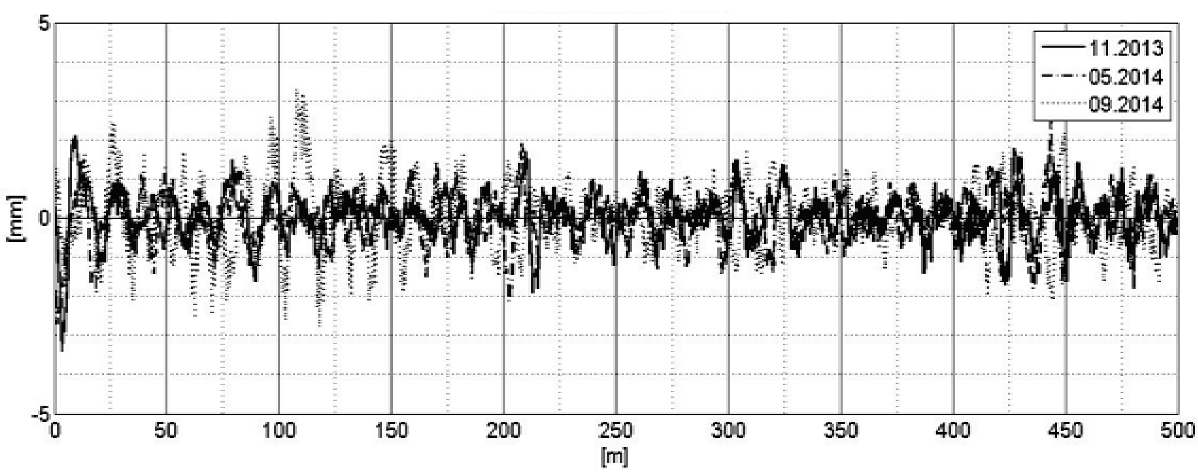

Fig. 4. Track twists at the selected section measured using indirect method in various periods of exploitation.

Measurements of track twists using the track measuring trolley in each case indicated irregularities of similar shape. Measured track twist in each measurement was within allowed limits of deviation. The highest increases of the amplitude were noticed during first measurements, which might be resulting from the fact that these measurements were performed prior to the acceptance and due to the related contamination of the railheads occurring during the production or construction processes.

Intermediate measurements of the track twists (figure 4) indicate that deviation limits (5 mm [11]) for performer measurements have not been exceeded. After conducted repair works (09.2014) the measurements indicated slight increase of the track twists amplitude.

Furthermore, analysis of vertical irregularities (figures 5 and 6) and horizontal irregularities was performed. This analysis was also conducted with the use of the trolley track gauge and track geometry recording car EM120.

In accordance with the manual [11], deviation limit for vertical irregularities of railroads after modernization for speed up to 160 km/h is 3 mm.

During the first measurement with the use of the trolley track gauge, high amplitudes were noticed. That might be related to the state of track prior to commissioning. Likewise in case of track twists, it can be assumed that such high amplitudes are resulting from surface contamination created at the construction site, during transport or production or from slight dynamic loads. The second measurement also revealed that the allowed limits were exceeded; however, the amplitudes were smaller. Characteristics of measurements in September 2014 indicated that the allowed limits were not exceeded.

During analysis of measurements taken in relation to vertical irregularities with use of track geometry recording car at the selected section of railroad, it is possible to notice a slight decrease of the amplitude values due to the performed correction works. Measurement of the status of

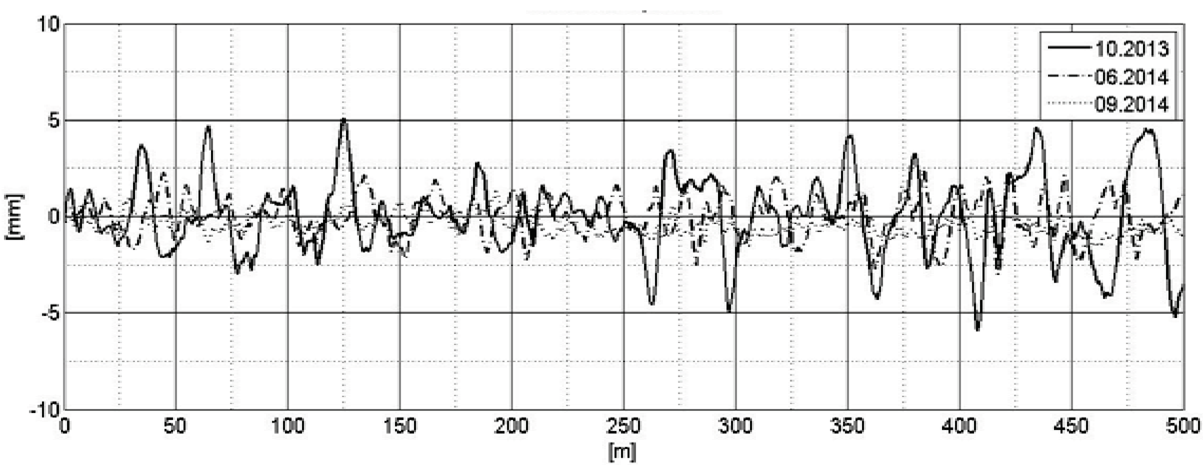

Fig. 5. Vertical irregularities of the left rail of the selected section measured with direct method in various periods of exploitation.

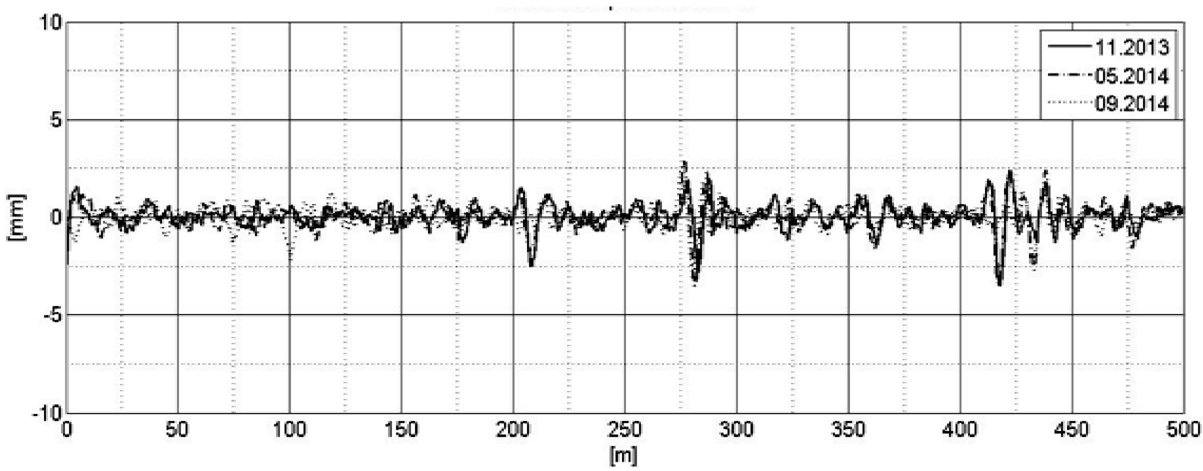

Fig. 6. Vertical irregularities of the left track at the selected section measured with indirect method in various periods of exploitation.

railroad taken in November 2013 was performed on a track that was newly commissioned. In the period between measurements taken at the beginning of exploitation and after 6 months, no works influencing track geometry were performed at the selected section. All measurements clearly indicate that this value was exceeded in some points.

It is worth mentioning that the visible peaks of the vertical irregularities of the new track may result from the selected indirect measurement method, which is influenced by the dynamic impact of the vehicle in places of substructure's stiffness loss related to arc connections before rails welding. Additionally, slight shifts of measurements were also noticed at the same section, probably due to inaccurate measurement of the road by the measuring system.

Table No. 1 presents selected statistic values of vertical and horizontal irregularities taken with use of two methods prior to and after performance of works related to improvement of the railroad geometry and adjustment to the speed of 160 km/h.

decreased for these irregularities. Energy values indicate aggregated decrease of the irregularities amplitudes in comparison to the status of surface after commissioning. Significant differences of values of measurements taken with the trolley track gauge and track geometry recording car were noticed, especially in case of measurements of horizontal irregularities. Due to the fact that measurements were taken with two different methods on two subsequent days, such significant differences raise doubts. For this reason, further analysis was performed on the basis of measurements taken with use of track geometry recording car.

3. METHODS FOR ESTIMATING KILOMETRES TRAVELLED

Spectral densities of vertical irregularities at the described section confirm the increase of the vertical irregularities amplitudes. Analysis of results presented in figure 7 will focus on vertical irregularities length of waves. Recorded wave

Table 1. Selected statistical values of measurements performed prior to and after repair works.

Measurement	Vertical irregularities			Horizontal irregularities		
	Standard deviation	Scope of alterations	Band energy	Standard deviation	Scope of alterations	Band energy
EM120 – 05.2014	0.828	13.0	0.838	0.985	7.4	2.190
EM120 – 09.2014	**0.712**	**11.9**	**0.726**	**0.965**	**6.1**	**1.405**
Track gauge – 06.2014	1.056	10.8	1.068	3.328	17.6	12.338
Track gauge – 09.2014	**1.019**	**7.0**	**1.031**	**2.378**	**16.7**	**4.179**

When analysing statistical values, an improvement of railroads surface state is visible taking into account vertical and horizontal irregularities. In both cases standard deviation, scope of alterations and band energy values have lengths of vertical irregularities are within the scope from approximately 7 m to approximately 50 m. During measurements of the tested section, two dominant waves of vertical irregularities were identified with length of approx. 9 and 12 m.

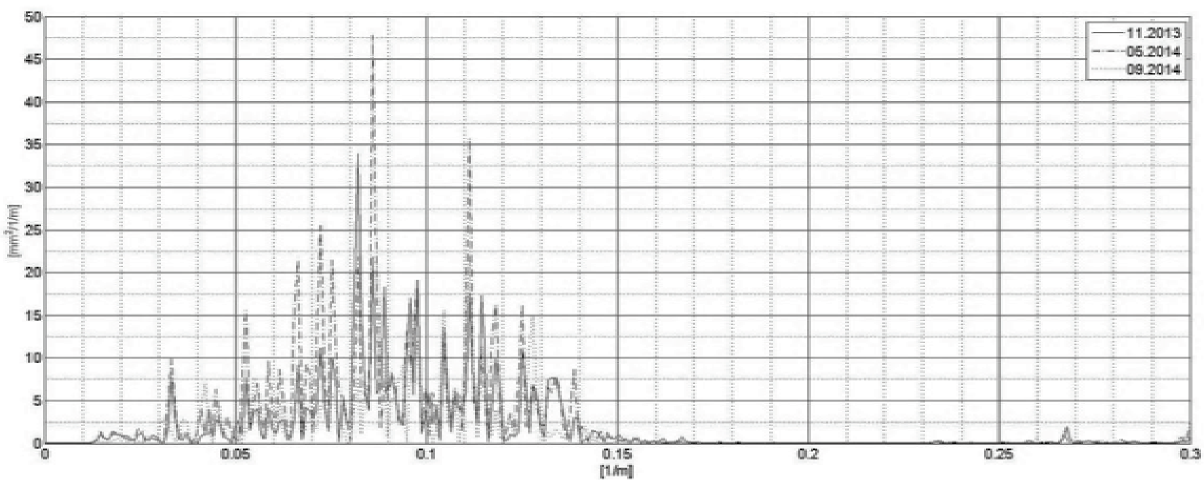

Fig. 7. Power spectral density of vertical irregularities measured with indirect method in various periods of exploitation.

Measurement taken in September 2014 shows decrease of the vertical irregularities amplitude values, which might indicate improvement of the railway infrastructure state after implemented repair works.

Spectral density of horizontal irregularities (figure 8) also proves the decrease of values of the horizontal irregularities amplitude. Recorder wave lengths of the horizontal irregularities are within the scope from approximately 7 m to 100 m.

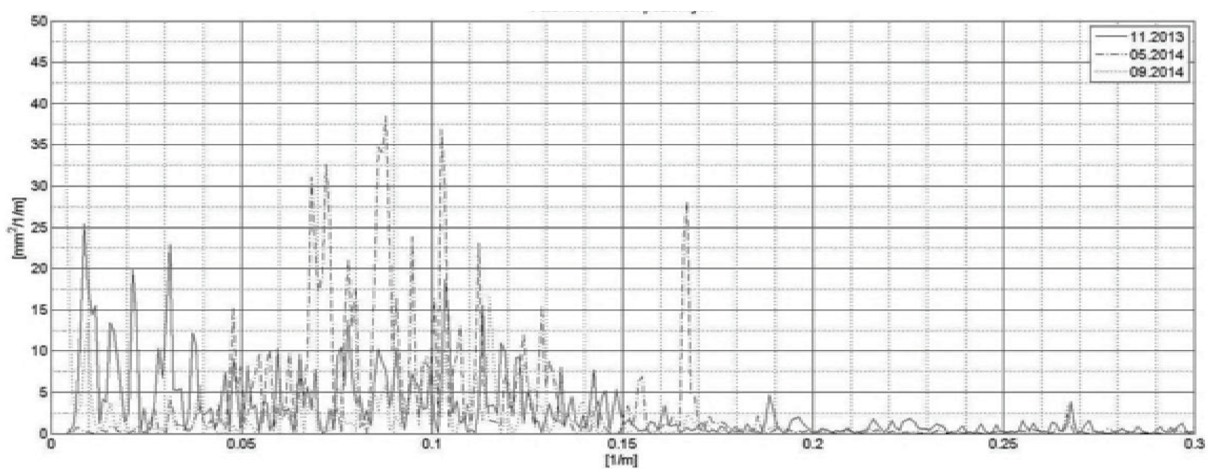

Fig. 8. Power spectral density of horizontal irregularities measured with indirect method in various periods of exploitation.

measuring cycles. In the data related to vertical irregularities values of coefficients indicate their greater variability between individual measurements. It can be estimated that vertical irregularities evolution is faster and more visible than in case of horizontal irregularities.

Pearson correlation coefficient may be used as one of the parameters specifying evolution of irregularities. Due to the fact that lengths of irregularity waves are within similar limits, it is necessary to apply this coefficient to their power spectral density (table 2).

Table 2. Pearson correlation coefficient of the vertical and horizontal irregularities spectral density.

	Vertical irregularities	Horizontal irregularities
Measurement 1 – 2	0.818	0.988
Measurement 2 – 3	0.790	0.924
Measurement 1 – 3	0.740	0.906

When analysing results presented in table 2, it has to be stated that the correlation coefficient is very high. It indicates that lengths of occurring vertical and horizontal irregularities waves remained unchanged.

Pearson correlation coefficient indicates high correlation of horizontal irregularities spectra of measurements taken in November 2013 and May 2014. Correlation values of all horizontal irregularities measurements remain at a high value of over 0.9, which may indicate slight alterations of these irregularities wave lengths between

4. CONCLUSION

The analysis of selected irregularities measured with use of the track geometry measuring car EM120 has shown that after approximately 8 months of exploitation track twists remained unchanged. Direct and indirect measurements prior to corrective measures indicated progressive reduction of the track as well as the increase of the vertical irregularities amplitudes that might be a natural result of shift of the dynamic load. On the other hand, during direct measurement after geometry improving procedures, widening of the track was shown and maintenance of allowed measurement within the limits. When analyzing the width with the indirect method, progressive reduction was stated. Additionally, spectral densities of the vertical and horizontal irregularities demonstrated the increase of amplitudes, confirming progressing process of the track irregularities changing that took place between November 2013 and May 2014. Presented spectral and statistical values (Table 1) in the band confirm the decrease of the irregularities amplitudes after corrective measures, which indicates the improvement of the surface status.

Results of the direct measurements of vertical irregularities and track twists indicate surprising improvement of the track status since its commissioning. The Analysis of measurement results of the selected irregularities taken with the direct or indirect method has shown their analogical process. During construction, commissioning and exploitation of the railroad adjusted to the speed up to 160 km/h differences within the limit of 2-3 mm are of high importance in relation to the accepted deviations [11].

A general opinion related to a perfect geometry of a new track adjusted to exploitation at high speeds, in the analyzed case turned out to be false. Measured waves of vertical and horizontal irregularities have a negative impact on a technical condition of the rolling stock i.e. they decrease travelling comfort and increase noise. The vertical irregularities power spectral density analysis confirms the hypothesis that the geometric features of these irregularities are emerging during the construction process and at the beginning of exploitation of the modernized track. Along with the exploitation time and traffic load, the length of irregularities waves remains unchanged, while their amplitudes increase visibly.

REFERENCES

[1] El-Sibaie M., Zhang, Y-J., Objective track quality indices, Transportation Research Record: Journal of the Transportation Research Board, p.81-87, Washington 2004

[2] EN: European Standard EN 13848-1-6: Railway applications – Track – Track geometry quality. European Committee for Standardization (CEN), ISBN: 97-8058-069-07-30, 2008.

[3] Firlik B., Czechyra B., Chudzikiewicz A.: Condition Monitoring System for Light Rail Vehicle and Track, Key Engineering Materials Vol. 518 (2012), pp 66-75

[4] Internal instruction Id-8, PKP Polish Railway Lines, Warszawa 2005.

[5] Internal instruction Id-9, PKP Polish Railway Lines, Warszawa 2005.

[6] Internal instruction Id-14, PKP Polish Railway Lines, Warszawa 2005.

[7] Lichtenberger B., Track compendium, Eurail Press, Hamburg 2011.

[8] Instrukcja o oględzinach, badaniach technicznych i utrzymaniu rozjazdów Id-4, PKP Polskie Linie Kolejowe S.A., Warszawa 2005.

[9] Massel A., Odwracanie trendu degradacji infrastruktury, Rynek Kolejowy, nr 6/2014

[10] Sowinski B., Interrelation between wavelengths of track geometry irregularities and rail vehicle dynamic properties, Archives of Transport, Tom issue 1-2, Nr vol. 25-26, 2013.

[11] Warunki techniczne utrzymania nawierzchni na liniach kolejowych Id-1, PKP Polish Railway Lines, Warszawa 2005.

Julian Kominowski
Poznan University of Technology, Poland
julian.kominowski@put.poznan.pl