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CONCEPT OF CHANGES IN TECHNICAL CONDITIONS FOR RAILWAY TRACKS MAINTENANCE Id-1 (D-1) IN THE FIELD OF TRACK GEOMETRY QUALITY ASSESSMENT

Abstract: The article describes reasons for the need of introducing changes in the internal PKP Polskie Linie Kolejowe S.A regulations in the field of track geometry quality assessment. It presents the new threshold limits of parameters determining the quality of the track geometry, with proposing a threshold method of their evaluation. In addition, the article discusses possibility of introducing further parameters of track geometry quality assessment, including an innovative approach to inspection of track twist.

Keywords: Inequalities track geometry; Diagnostics; Quality of geometric Track limits

Introduction

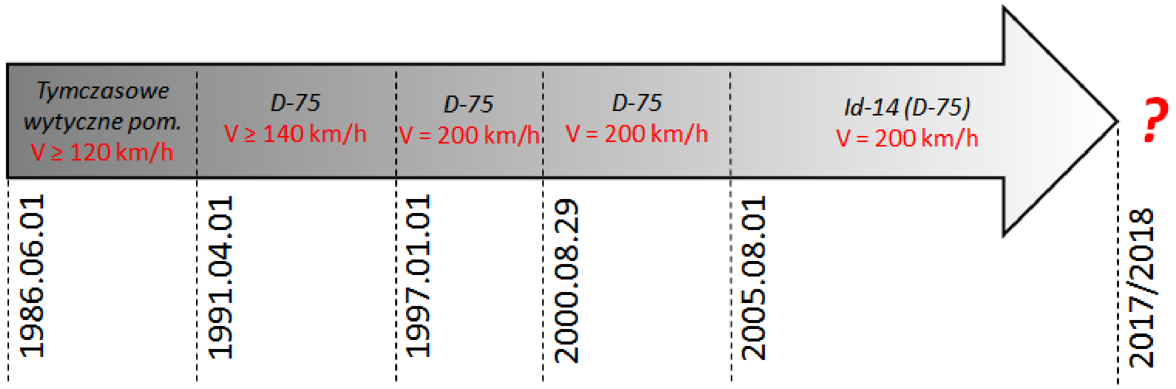
Track geometry quality is one of the most important elements determining the status of the railway line. Proper selection of a set of measured parameters and their tolerances provides the ability to use the railway line in a safe manner, with rational spending of maintenance. Infrastructure managers may freely choose the criteria for assessing the quality of geometric track, guided above all his experience and the state of contemporary knowledge [5], with a big influence on the final shape of the legislation are also other factors such as policy adopted to maintain the current state of infrastructure, possessed the financial resources, the availability of measuring vehicles and equipment for maintenance works.

The article presents selected issues concerning the assessment of the quality of geometric track in the draft change *Technical Conditions Railway Surface Maintenance Id-1 (D-1)* [19]. The concept is based on past experience PKP Polish Railway Lines SA with regard to maintenance of railway tracks taking into account the evaluation criteria used by the other European infrastructure managers, which were presented in the report [8].

Additional explanation requires used in the title of the article the concept of track geometry quality, which in accordance with [13] can be defined as: an assessment of deviations of the measured (calculated) from the average value or nominal made for a set of parameters defining the position of rail in vertical and horizontal plane affecting the safety or the peacefulness of driving. This definition in country is far less common, occurs among others in [3], [8]. In author's opinion, the definition of track geometry quality should come permanently to the railway terminology, as a definition of representing the product of railway tracks diagnostics [1] and the geometric arrangement of the track [1].

Reasons for change

Changes in the approach to the assessment of track inequality has become a necessity primarily due to the large current outdated requirements and the need to adapt the internal regulations of PKP Polish Railway Lines SA the provisions of general law, in particular [18]. Existing rules for evaluating the quality of geometric track were laid around 1986, when were implemented to use measuring trolleys EM-120 and adopted for use *"Temporary guidelines for measuring and evaluating the state of the tracks with the measuring trolleys EM-120"*. In following years the principle of assessment did not subject to major changes, just their scope was expanded for increasing speed. Initially, in the year 1991., With the advent of *"Instructions for making measurements, testing and assessment condition of the tracks D-75"* to speed V≥140 km/h, and next in year 1997 at the occasion of next revision of the above mentioned instructions to speed V≤200 km/h. Subsequent amendments to the regulations did not introduce changes in the assessment of track geometry quality (Fig. 1).



1. The history of amendment to the rules on assessing the track geometry quality

No introduction of major changes over the last 30 years, caused that currently used operating tolerances for speeds higher than 120 km / h are a set of very strict values that are uncommon for most infrastructure managers in Europe [7]. In addition to the above mentioned speed displacement values authorized to operate a little different from the displacement values of acceptance, which cannot be achieved between repair cycles appropriately long life of exploitation, Table 1.

Tab. 1. Track parameters

Prędkość	Nierówności pionowe [mm]		Nierówności poziome [mm]		Wichrowatość toru [‰]		Poszerzenie toru [mm]		Zwężenie toru [mm]	
[km/h]	Eksp.	Odb. 1)	Eksp.	Odb. 1)	Eksp.	Odb. 1)	Eksp.	Odb. 1)	Eksp.	Odb. 1)
200	4	2/2	3	3/3	1,0	0,6/0,8	4	2/3	3	2/2
180	5	---	4	---	1,2	---	5	---	3	---
160	6	3/4	6	4/5	1,6	1,0/1,2	6	2/5	4	2/3
140	7	4/6	8	5/6	2,0	1,0/1,6	8	3/6	5	3/4

1) …/… - wartości dopuszczalne odchyłek przy odbiorze ostatecznym odpowiednio: po modernizacji / po naprawie bieżącej

So "sharp" deviation perfectly fulfills its role at a time when the railway was one of the organization, acting on the basis of their own rules and their interpretations, combining the roles of the infrastructure manager, operator and control bodies. Currently, in turn, functions have been separated, which is associated with the need to establish a set of deviations, which on one hand would ensure the achievement of the required level of security and peacefulness of driving and respect these requirements would be monitored by external supervisors. On the other hand, the deviation should allow the infrastructure manager to get the opportunity to efficient planning of maintenance, with optimal use of resources. However, in both cases should be used advantage of modern diagnostics. The following proposals to change the rules is to implement the solution taking into account the above aspects.

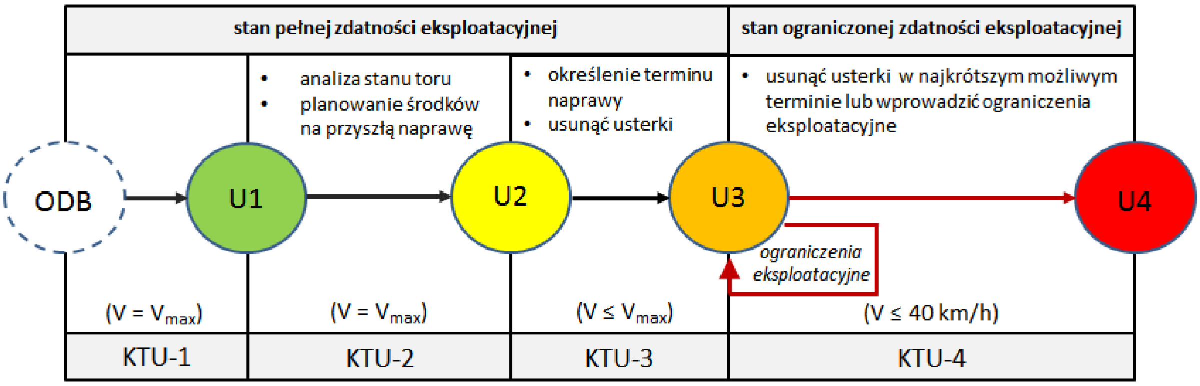
A threshold assessment of track inequalities

Currently, during automatic measurements for each parameter are determined three classes of deviations: A, B and C. Deviations exceeding the classes A and B are counted for statistical purposes [11], and therefore are not directly applicable in the diagnosis. Therefore, one from major changes included in the concept is the introduction of multithreshold assess the geometric track quality having practical significance. Such an approach known from [14], has been successfully implemented by many European infrastructure managers [7]. After analyzing the regulations eleven infrastructure managers and taking into account their abilities have been proposed four assessment thresholds, whose definitions and reference to [14] shown in the table 2.

Tab. 2. Definitions and reference to [14]

Próg	Opis progu	Odniesienie do [11]
U1	Próg czujności - po przekroczeniu progu U1 zaleca się wykonać analizę stanu toru oraz zaplanować środki na przeprowadzenie prac utrzymaniowych.	AL (ang. *Alert Limit)*
U2	Próg działań prewencyjnych – usterki przekraczające próg U2 zaleca się usunąć w najbliższym cyklu utrzymaniowym oraz przed osiągnięciem progu U3. Szczegółowe zalecenia określa inspektor diagnosta, biorąc pod uwagę wielkości przekroczenia odchyłek dopuszczalnych oraz stopień rozwoju usterek.	IL (ang. *Interventional Limit*)
U3	Próg działań interwencyjnych - po przekroczeniu progu U3, należy usunąć usterki w najkrótszym możliwym terminie lub wprowadzić ograniczenie eksploatacyjne.	IAL-1 (ang. *Immediate Action Limit*)
U4	Wartości graniczne - przekroczenie progu U4 powinno skutkować wstrzymaniem ruchu do czasu usunięcia usterki.	IAL-2 (ang. *Immediate Action Limit*)

Presented in Table 2 assessments thresholds allow you to create a model of diagnostic of geometric track quality, according to the diagram shown in Figure 2. In the presented model, immediately after the acceptance of the works (ODB), begins with the life path that continues undisturbed, until the threshold U1. After crossing the threshold U1 section of the track stays in the state of full operational suitability ($V=V_{max}$), but it is recommended to perform the analysis of the measurements and where necessary enclose track section in the schedule of planned work, which should result in securing funds for the next budget period. In terms of the threshold U1 most important information eventually will be the size of the standard deviation calculated in sections of length 200 m to the inequality of vertical, horizontal and deviation.



2. The target diagnostics model included in the concept

Parameter values in excess of the threshold U2, due to the size of the defects, and the potential of the coincidence, can affect driving calmness and, in extreme cases safety. These factors cause that the correct interpretation of these values is crucial from the point of view of maintaining the track and at the same time it is the most difficult stage of diagnosis of the quality of geometric track. Therefore, recommendations for further operating conditions of the track exceeds the fault threshold U2 seems inspector diagnostician, so a person familiar with the considered track section and has the necessary knowledge and experience. Typically, a threshold U2, it is expected that the track remains in full operational suitability ($V=V_{max}$), and the task of the inspector is to identify the most appropriate diagnostician, in his opinion, the deadline to remove defects. In exceptional cases, e.g. the occurrence of turbulent ride observed during the tour, allowed the introduction of operating restrictions ($V<V_{max}$).

Exceeded the value of defects indicated for the next threshold U3, makes it necessary to remove the defects as soon as possible, i.e. for:

– track twist - 7 days and in the absence of the possibility to remove them should stop movement and, if relevant, in order to minimize the effects of potential derailment, be restricted to speed 20 km/h,
– Warning: The speed limit on sections of track with high value twist favors derailed due to the increase in the coefficient of friction in the quasi-static conditions;
– track gauge, inequality, vertical and horizontal - 14 days and in case of inability to remove them within the prescribed period, until you delete them enter the speed limit for speed classes for which the size of the defects are below the acceptable threshold U3;
– cants - 14 days and in case of inability to remove them within the prescribed period, pending their removal must enter the speed limit by at least 10%.

From the above it is clear that failure to remedy defects in excess of the threshold U3, cause that track moves in a state of limited suitability of exploitation, which involves the introduction of operating restrictions, usually by reducing the speed. In the case of non-repair and further degradation of the track, it is possible to introduce further restrictions on speed, so that always the value of the parameter was below the threshold set by the U3 for a given speed. While the operation of the track wit crossed defects values threshold for U3 is allowed only in exceptional cases and provided that the introduction of speed limits to 40 km/h. This operation may be carried out until the value indicated for U4 threshold which after exceeding the movement should be stopped.

The presented model of diagnostics fits into obligatory in PKP Polish Railway Lines SA classification system lines for their operational suitability (KTU) (Fig. 2). Classification is introduced to optimize the disposal of available resources, taking into account the technical condition of the line and the conditions of its operation. Classification rules are presented in module B1 to [19].

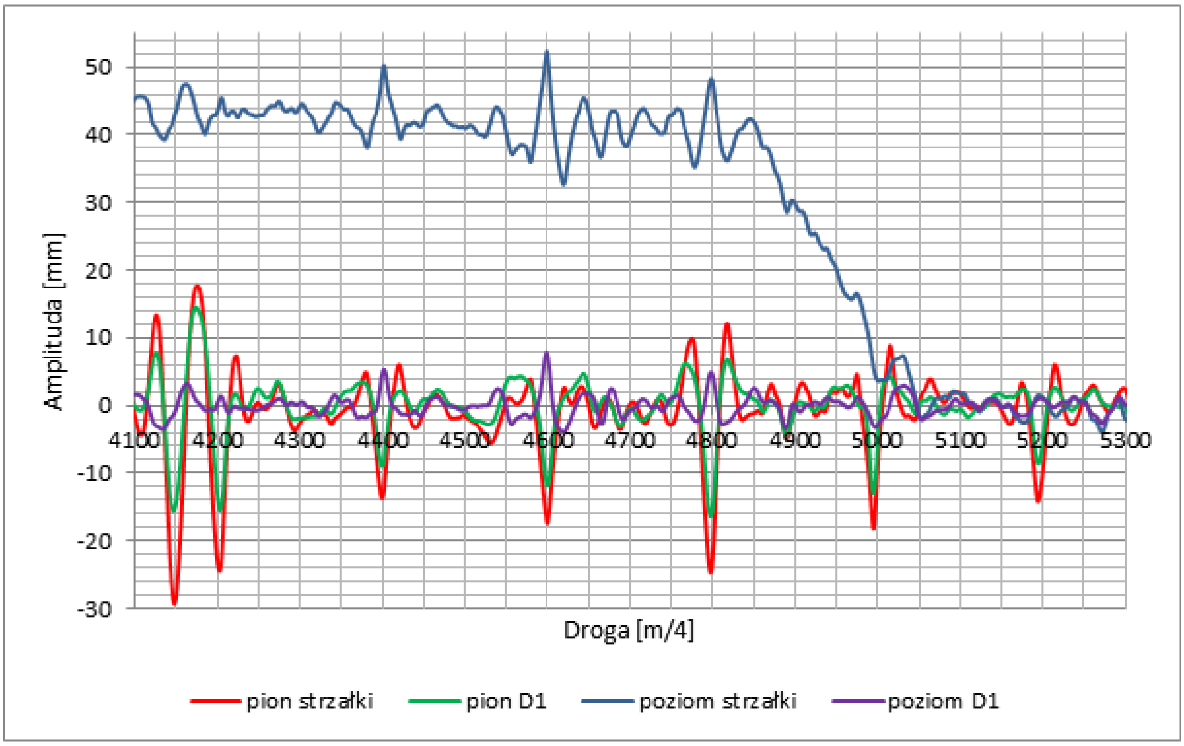
Measured parameters

The progress made in recent years in the field of measurement technology now allows, in an automated manner, to control the large number of parameters, which is why the concept of changes to the regulations provides for the implementation of new evaluation parameters are not yet included in the provisions of the infrastructure manager. Table 3 shows the target set of parameters defining the geometric quality of the track, which should be evaluated after the amendment of regulations [19].

Tab. 3. The target set of parameters defining the geometric quality of the track

Lp.	Parametr	Jednostka	U1	U2	U3	U4
Parametry podstawowe						
1	Nierówności pionowe (*D1 lub system cięciwowy*)	[mm]	X	X	X	X
2	Nierówności poziome (*D1 lub system cięciwowy*)		X	X	X	X
3	Nierówności pionowe (*D2 tylko dla V > 160 km/h*)			X	X	
4	Nierówności poziome (*D2 tylko dla V > 160 km/h*)			X	X	
5	Szerokość toru - poszerzenie		X	X	X	X
6	Szerokość toru - zwężenie			X	X	X
7	Gradient szerokości toru (*baza 1 m*)			X		
8	Przechyłka		X	X	X	X
9	Wskaźnik wichrowatości bazowej	[%]		X	X	X
10	Wichrowatość toru (*baza 3 m*)	[‰]				X
Parametry statystyczne						
11	Odchylenie standardowe nierówności pion. (200 m)	[mm]	X	X		
12	Odchylenie standardowe nierówności poz. (200 m)		X	X		
13	Odchylenie standardowe przechyłki (200 m)		X	X		
14	Syntetyczny wskaźnik stanu toru „J” (1000 m)		X	X		

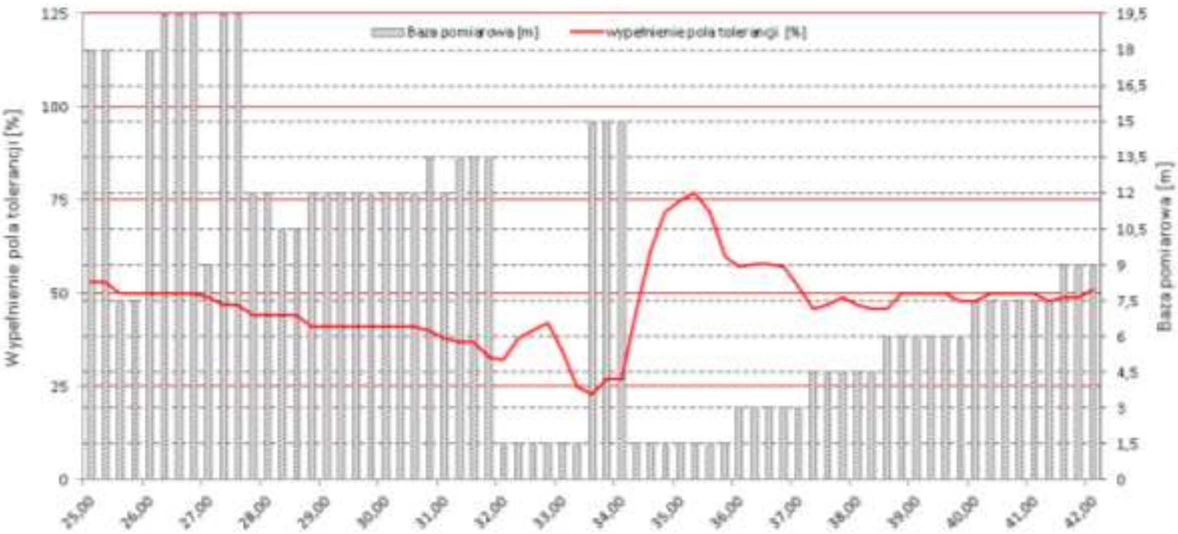
One of the proposed changes concerns a method for measuring horizontal and vertical inequalities. Currently, the measurement of these parameters is performed as a measure of "arrows" measured on the basis of symmetrical about 10 meters long. This measurement, although relatively simple to perform and gives results easy to interpret, is associated with a number of limitations and errors. The most important of these is unreal reproduction of inequality, which is caused by the presence of the transfer function of the measuring system. Moreover, the use of the measurement system does not allow direct comparison of results obtained from vehicles with different measurement bases. Therefore, the concept provides for an amendment to the measurement for compliance with the methodology proposed in [13]. This standard provides for the measurement of inequality in specific wavelengths: $D1 \in \langle 3; 25\rangle$ m and $D2 \in \langle 25; 70\rangle$ m, wherein the inequality of the wavelength D2 will be evaluated on lines with a speed greater than 160 km / h. This is currently the most widely used in Europe way to evaluate inequality of the track. This method, although it is not without drawbacks, has a number of advantages, the most important to take into account (as conventional) outside the amplitude of the wavelength at which there is a disparity and allows to compare the measurement results with each other regardless of the measurement system used in a vehicle.



3. Differences in the measurement of "arrows" method of chord and inequality on the waves D1

Examples of differences in the measurement of vertical and horizontal inequality using the chordal method ("measurement" arrows ") and measuring the imbalances in the wavelength range D1 shown in Figure 3. As can be seen from the above the drawing, due to the filtering of the measurement signal waves D1 deletes the information about certain values of signal components, including fixed with "arrows" occurring in horizontal curves. Therefore, when the transition to the measurement of waves D1 and D2 becomes necessary to also illustrate the curvature of the track. The concept provides for a gradual transition to measure waves D1 and D2 together with the implementation of the service of new vehicles and modernization of measurement previously used.

Another of the important changes concerns a method for the assessment of track twist. In the case of this parameter factor having the greatest impact on its assessment of is the selection of measurement base. Currently, PKP Polish Railway Lines SA to evaluate the track twist uses only one base measuring 5 meters long, which necessitates the use of very restrictive limits, for which undoubtedly should be considered the current deviation used for speeds greater than 120 km / h [20]. According to the proposed concept, track twist would be a subject to control by means of indicator twist the base, as discussed in [6], which is a synthetic assessment of twist calculated to 13 datums in the field $\lambda \in \langle 1{,}5; 19{,}5\rangle$ m, so it takes into account the most common spacing truck and spacing bogie centers for railway vehicles [19]. Such a "comprehensive" evaluation allows you to increase the limit values of deviations track twist used in diagnosis, while maintaining a high level of security. This indicator, although it contains the complete information of twist calculated for only one datum, it is easy to assess, mainly because of the opportunity to illustrate it with a single graph (Fig. 4) and the use of fixed limits expressed in percentages.



4. Graphic presentation of the ratio twist base

In addition, the concept of the amendment provides for the introduction of regulations for evaluation under the threshold U1 and U2 also ultimately, the standard deviation measured at distances of 200 m, for the following parameters: horizontal and vertical inequalities and cants. The standard deviations above. Parameters of the formula 1, will form the basis for monitoring changes in the track and to facilitate planning funds to carry out repairs.

$$S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \hat{x})^2} \qquad (1)$$

where: n – the number of registered measurements in the 28nalysed section of the track,

x_i – parameter value at the point I,

$\hat{x}$ – average parameter value over a defined length.

The project of permitted deviations

Discussed concept includes new limits on deviations for all of the parameters determining the geometric track quality. In particular, the biggest changes concern the limits of deviations for speeds greater than 120 km / h. These values are modified based on the experience of other infrastructure managers in Europe who are in this speed range apply higher limits than the values used by PKP Polish Railway Lines S.A. A summary of some permitted deviation, the meaning of which can be compared to a threshold assessment U3 indicated in the draft changes in regulations [20], used by PKP Polish Railway Lines SA and other infrastructure managers are shown in Table 3.

Tab. 4. List of selected admissible deviations used by PKP S.A. and other infrastructure managers

Prędkość [km/h]	Polska PKP PLK [19][5)]	Norma EN13848 [11]	Czechy SZDC [17]	Węgry MAV [13]	Słowacja ZSR [5]	Niemcy DB Netz AG [12]	Szwecja Trafikverket [14]	Hiszpania REFER [9]
Szerokość toru – poszerzenie [mm]								
200	4 (20)	28	20	20	20 (13) 1)	20 2)	28	28
180	5 (20)	28	20	20	20 (13) 1)	20 2)	28	28
160	6 (20)	35	27	25	25 (20) 1)	27 2)	33	35
140	8 (20)	35	27	25	25 (20) 1)	27 2)	33	35
120	9 (25)	35	27	30	30 (20) 1)	27 2)	33	35
Nierówności pionowe D1 [mm]								
200	3 3) (12)	20	12	18,1	13	11 4)	20	20
180	4 3) (12)	20	12	18,9	13	11 4)	20	20
160	6 3) (14)	23	13	19,8	17	14 4)	23	23
140	8 3) (14)	23	13	20,8	17	14 4)	23	23
120	10 3) (17)	26	16	21,8	22	17 4)	26	26
Nierówności poziome D1 [mm]								
200	4 3) (9)	12	9	11,2	8	11 4)	12	12
180	5 3) (9)	12	9	11,9	8	11 4)	12	12
160	6 3) (14)	14	11	12,6	10	14 4)	14	14
140	7 3) (14)	14	11	13,5	10	14 4))	14	14
120	9 3) (17)	17	14	14,5	13	17 4)	17	17

1) wartości w nawiasach dotyczą pomiaru na prostej
2) podane wartości dotyczą progu SR_{100} – odpowiednik U2
3) pomiar cięciwowy na bazie: 5,0/5,0
4) pomiar cięciwowy na bazie: 2,6/6,0 - nierówności pionowe i 4,0/6,0 dla nierówności poziome
5) wartości w nawiasach zawarto w projekcie nowelizacji [19] i dotyczą nierówności na falach D1

The current in the company PKP Polish Railway Lines SA deviations acceptable parameters of geometric track quality, in terms of higher speeds, is graded for each class speed of 1 mm, see table 1. At the same time it should be noted that, according to [13], the uncertainty of measurement parameter track gauge and vertical inequalities is ± 1 mm, and for the horizontal inequalities is set to ± 1,5 mm. In extreme cases, the measurement uncertainty can determine the qualifying section of the line to the class speed, because the example of other infrastructure managers decided to accept deviations permitted grouped in ranges of speed. The proposal to modify the limits of deviations for all of the parameters determining the geometric track quality is presented in Table 4.

Table 4

			U1						U2						U3						U4
			V ≤ 40	40 < V ≤ 60	60 < V ≤ 80	80 < V ≤ 120	120 < V ≤ 160	160 < V ≤ 200	V ≤ 40	40 < V ≤ 60	60 < V ≤ 80	80 < V ≤ 120	120 < V ≤ 160	160 < V ≤ 200	V ≤ 40	40 < V ≤ 60	60 < V ≤ 80	80 < V ≤ 120	120 < V ≤ 160	160 < V ≤ 200	V ≤ 40
Nierówności pionowe baza symetryczna (5/5)	baza 10 m	[mm]	—	—	—	—	—	—	20	16	14	10	8	6	34	26	22	15	12	10	50
Nierówności pionowe D1	3-25m	[mm]	17	14	12	11	8	6	21	18	16	14	10	8	28	28	21	17	14	12	41
Odchylenie standardowe nierówności pionowych D1	na 200 m odcinku	[mm]	—	2,75	2,75	2,10	1,70	1,50	—	4,00	4,00	2,90	2,20	1,80	—	—	—	—	—	—	—
Nierówności pionowe D2	25-70 m	[mm]	—	—	—	—	—	—	—	—	—	—	—	16	—	—	—	—	—	22	—
Nierówności poziome baza symetryczna	baza 10 m	[mm]	—	—	—	—	—	—	20	16	14	8	8	5	28	24	20	15	12	7	53
Nierówności poziome D1	3-25 m	[mm]	15	12	12	9	6	3	18	18	18	12	8	6	22	22	20	17	14	9	44
Odchylenie standardowe nierówności poziomych D1	na 200 m odcinku	[mm]	—	2,10	1,80	1,50	1,30	1,10	—	3,20	3,20	1,85	1,25	1,20	—	—	—	—	—	—	—
Nierówności poziome D2	25-70 m	[mm]	—	—	—	—	—	—	—	—	—	—	—	13	—	—	—	—	—	17	—
Przechyłka		[mm]	10	10	8	8	8	6	15	15	13	10	10	8	20	20	18	15	15	10	30
Odchylenie standardowe przechyłki	na 200 m odcinku	[mm]	—	3,10	3,10	2,70	2,50	2,00	—	—	—	—	—	—	—	—	—	—	—	—	—
Wskaźnik wichrowatości bazowej	wypełnienie pola tolerancji	[%]	—	—	—	—	—	—	75						100						—
Wichrowatość toru	baza 3 m	[‰]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Szerokość toru zwężenie		[mm]	—	—	—	—	—	—	-7	-7	-5	-5	-5	-3	-9	-9	-7	-7	-7	-5	-11
Szerokość toru poszerzenie		[mm]	15	15	15	15	10	10	30	30	25	20	15	15	32	32	32	25	20	20	35
Gradient szerokości toru na bazie 1 m	baza 1 m	[mm]	—	—	—	—	—	—	6	5	5	4	3	3	—	—	—	—	—	—	—
Syntetyczny wskaźnik stanu toru "J"	na odcinku 1000 m	[mm]	—	4,1	3,8	3,4	2,6	1,60	—	5,5	4,8	4,2	3,2	2,2	—	—	—	—	—	—	—

Legenda:
— nie podlega ocenia przy danym progu

5. Proposed to modify deviation tolerance values for all parameters defining the geometric quality of the track

Summary

Implementation of the presented model of diagnostics geometric track quality will provide a sufficiently long time trouble-free operation of the track. In addition, it enables a more rational disposal of funds intended for maintenance of the infrastructure which is under the management of PKP Polish Railway Lines SA. The proposed concept is consistent with contemporary standards of quality assessment of track geometry, applied by the European infrastructure managers. However, before implementing it requires fine-tuning at several points, it is in particular to establish limit values of standard deviations for the individual parameters and to consider changes in the lower range of the assessment of the waves D1. The presented method of assessing, in the case of deviations exceeding the threshold of U2, will require inspectors of diagnostics subjective decision for further action. Therefore, great importance must be applied for their proper training.

Moreover, the concept fits into increasing use to assess the quality of the track geometry measurement vehicles. Ultimately, PKP Polish Railway Lines SA strives to perform at least once a year, measurements over all tracks and the main core, using one of the already operated vehicles: EM-120, UPS80 or a new track recording, which is currently going through a phase of dynamic tests, (Fig. 5). In addition, control systems of geometric track quality will feature other vehicles test, which basically are designed for other tasks. This approach will provide greater accessibility to measurements performed under load in an automated manner, which will, among others, assess the track geometry quality based on a wider range of information than that obtained with manual measurements, and relieve manual measuring units.

6. New measuring draisine for PKP Polish Railway Lines SA [Material PKP PLK SA IG]

In addition, in order to ensure the rapid removal of defects discovered after the tour track recording on the main roads, the Company intends to create dedicated teams for this purpose adjustment track (TWU). TWU ultimately may consist of: measuring unit equipped with a bogie, 20 hoppers type 411vb providing supplement crushed in an amount necessary to implement the lifting of 25 mm, high-class track tamping CSM-09, ballast profiling and optional dynamic track stabilizer DGS. Currently, there is a pilot implementation of the first such team.

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