ISSN 2307–3489 (Print), ISSN 2307–6666 (Online)

Наука та прогрес транспорту. Вісник Дніпропетровського
національного університету залізничного транспорту, 2015, № 4 (58)

UDC 625.173.2

O. M. PATLASOV[1], S. O. TOKARIEV[2*]

[1]Dep. «Track and Track Facilities», Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan St., 2, Dnipropetrovsk, Ukraine, 49010, tel. +38 (056) 373 15 42, e-mail am_patlasov@ukr.net, ORCID 0000-0003-2081-5648
[2*]Dep. «Track and Track Facilities», Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan St., 2, Dnipropetrovsk, Ukraine, 49010, tel. +38 (056) 373 15 42, e-mail tokarevsergeyaleks@yandex.ua, ORCID 0000-0002-2607-3123

THE MEASUREMENT METHODOLOGY IMPROVEMENT OF THE HORIZONTAL IRREGULARITIES IN PLAN

Purpose. Across the track superstructure (TSS) there are structures where standard approach to the decision on the future of their operation is not entirely correct or acceptable. In particular, it concerns the track sections which are sufficiently quickly change their geometric parameters: the radius of curvature, angle of rotation, and the like. As an example, such portions of TSS may include crossovers where their component is within the so-called connecting part, which at a sufficiently short length, substantially changes curvature. The estimation of the position in terms of a design on the basis of the existing technique (by the difference in the adjacent arrows bending) is virtually impossible. Therefore it is proposed to complement and improve the methodology for assessing the situation of the curve in plan upon difference in the adjacent versine. **Methodology.** The possible options for measuring horizontal curves in the plan were analyzed. The most adequate method, which does not contradict existing on the criterion of the possibility of using established standards was determined. The ease of measurement and calculation was took into account. **Findings.** Qualitative and quantitative verification of the proposed and existing methods showed very good agreement of the measurement results. This gives grounds to assert that this methodology can be recommended to the workers of track facilities in the assessment of horizontal irregularities in plan not only curves, but also within the connecting part of switch congresses. **Originality.** The existing method of valuation of the geometric position of the curves in the plan was improved. It does not create new regulations, and all results are evaluated by existing norms. **Practical value**. The proposed technique makes it possible, without creating a new regulatory framework, to be attached to existing one, and expanding the boundaries of its application. This method can be used not only for ordinary curves, but for very short sections, the curvature of which changes abruptly to its opposite value.

Keywords: methodology; irregularity; measurement; plan of a railway track; curve assessment in plan

Introduction

On the Ukrainian railway network for the past several decades has been a tendency to increase the speed of motion [9], which obviously leads to the revision of existing and the creation of new regulatory documents. This applies to rail transport as a whole and of its individual farms. In particular, the track facilities directly involved in the maintenance and repair of road infrastructure.

Quite a significant impact on the performance of traffic safety, smooth running and ride comfort passengers in the general case affects not only the plan and profile of the railway track, but also the presence of geometric and strength irregularities. Existing regulations govern not only work to prevent occurrence of malfunctions during operation, but also the necessary course of action to eliminate them. For the track state establishment in accordance with the maintenance norms the instrumental methods was used to evaluate its status.

In practice, the geometric position of the curve in plan is checked by means of traditional methods. These include: versine method [8], Hoffer's method [4] and the method of Honikberg [6]. The first two methods, can be usually use in the operation portion of the curve, the latter is the design of the reconstruction and repairs of the road.

The above mentioned versine method based on the measurement of deflections f_i (Fig. 1) when fixed value of the chord length through a specific length [8].

doi 10.15802/STP2015/49219

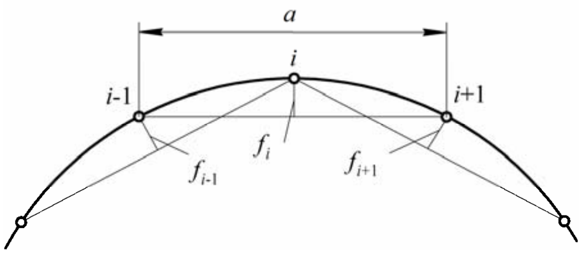

Fig.1. The bend versine
measurement scheme

Method of Hoffer, which was forgotten over the last few decades, has been modified (Fig. 2) and found further application in practice [3].

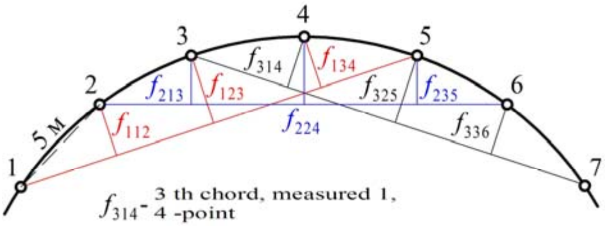

Fig.2. The Hoffer modified method

For the design of the second track and reconstruction of the existing railway survey curves can also be performed using the method of Honikberg (Fig.3).

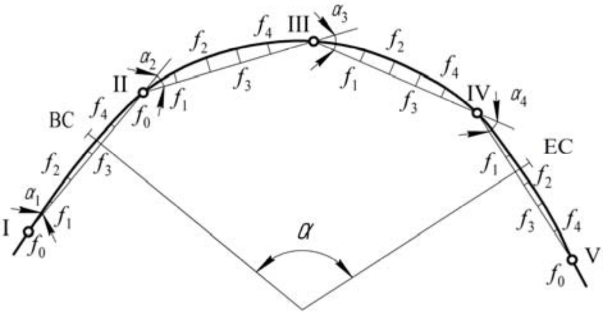

Fig.3. Curve measurement scheme
by the Honikberh method:
BC – beginning of curve; *EC* – end of curve

All above-mentioned methods linked with geometric point of view can be listed in one another.

On foreign railways, the assessment of the position of curves in the plan is treated similarly to that in the domestic railways using the versine method [12, 10].

The modern methods of valuation of railway track plan include [5, 7]:

- survey using modern total stations;
- the use of track measuring cars;
- survey using the benchmark system;
- plan survey with track measuring cars;
- use of track measuring trolleys.

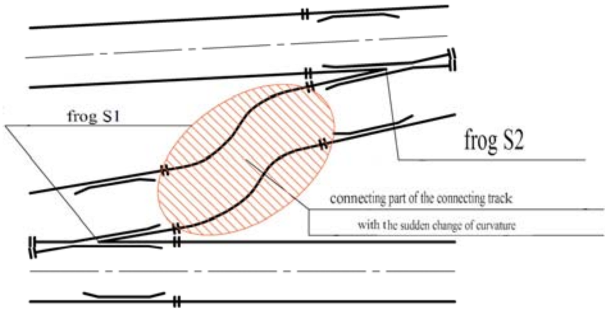

Fig.4. The crossover general scheme:
S1 – first switch; *S2* – second switch

Therefore it is necessary to create a methodology that would give the opportunity to get versine to any position on the track section in the plan and to assess its state according to the difference obtained in related deflections.

Purpose

It is important quickly, efficiently and timely to perform routine maintenance and repairs for workers of track facilities. Based on this principle, it is necessary to develop a methodology for assessing the phase position of the road in such a way as to reduce the time spent on measurement and processing of the results. Thus as much as possible to use the existing regulatory framework relating to the issue of determining the position of the curve in the plan.

Methodology

– First, it is necessary to analyze the possible methods of assessing the position of the curve in the plan and to identify their main advantages and disadvantages. The following methods are taken into account:

- the position of the joints of rails using diagonals;
- method of linear serifs (polar method);
- position of connecting track ordinates of the basic line, that is broken outside of the track;
- measurement of horizontal angles in the plan;
- the position of the curve with the ordinate from the baseline, that is located between the rail thread.

doi 10.15802/STP2015/49219

As a primary or reference, the most extensively used on the railways of Ukraine is the versine method. All other proposed methods will be theoretically checked and compared with the versine method.

Method of assessment of the joints using diagonals is to measure the distances d_1, d_2, d_3, d_4 (Fig. 5).

The measured diagonals in pairs should be compared (d_1 і d_4, d_2 і d_3).

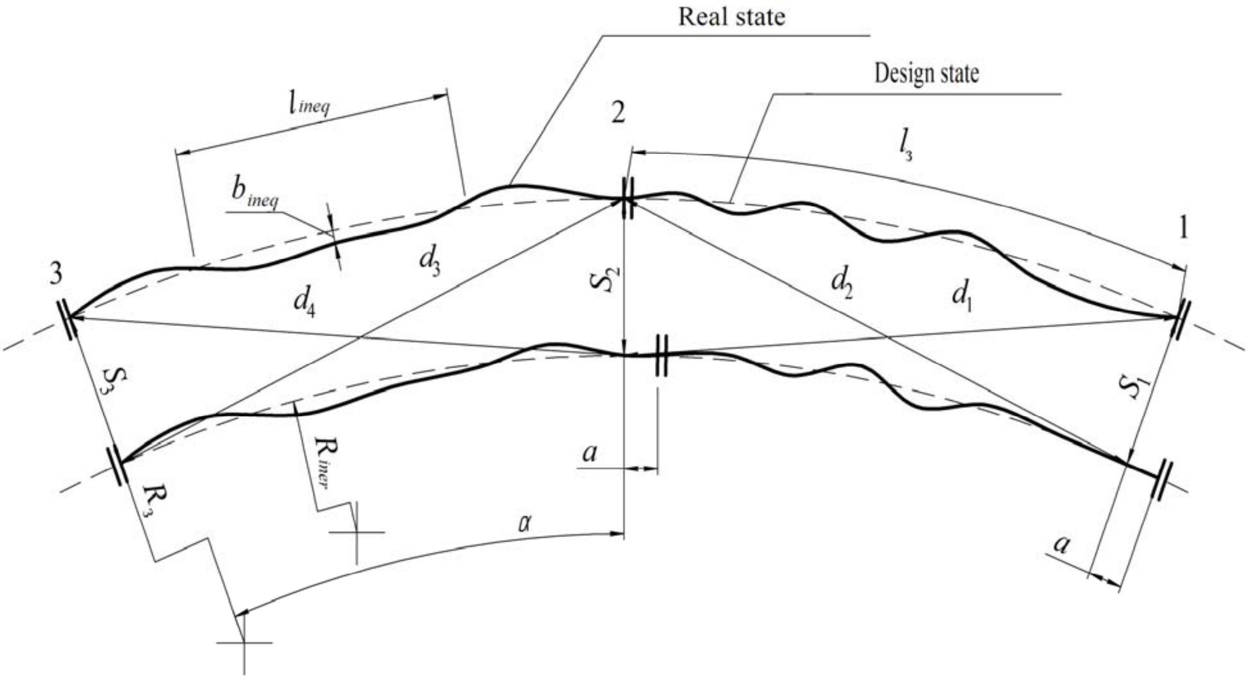

Fig. 5. The joints measuring position scheme

The diagonals must have the following value:

$$\begin{cases} d_i = \sqrt{A_i^2 + B_i^2}, \\ d_{i+1} = \sqrt{A_{i+1}^2 + B_{i+1}^2}. \end{cases} \tag{1}$$

In turn:

$$\begin{cases} A_i = R_o - (R_o - S_i)\cos\alpha, \\ A_{i+1} = R_o - (R_o - S_{i+1})\cos\alpha, \\ B_i = (R_o - S_{i+1})\sin\alpha, \\ B_{i+1} = (R_o - S_i)\sin\alpha,\ i = 1, 3, 5..., 2n+1. \end{cases} \tag{2}$$

where R_o – the radius of the outer rails; S_i – track width, measured in the appropriate section; α – the angle formed the normals to the curve at the measurement points:

$$\alpha = \frac{l_o}{R_o}, \tag{3}$$

where l_o – the length of the outer rails between the measurement points.

If the pair of the measured diagonals are not equal, there are horizontal irregularities. The difference of pairwise diagonals characterizes irregularities in plan or disagreements rail joints.

But to evaluate geometric inequalities, their length l_{ineq} and amplitude b_{ineq} placed between the joints or between the cross-sections are almost not possible. Therefore, the assessment method application of the joints using diagonals makes it impossible to get the versine at intermediate points in the future. In this case it is necessary to identify the additional points on the irregularities. If the joints are not on squares (overlapping joints on the value of (a), the task on the assessment of horizontal irregularities is complicated. Moreover, as the source the radius and length of the outer and inner rail filaments between the points of measurement should be known. This method is appropriate to use in areas where the rails have the same length, i.e. in a straight line.

When using the method of linear serifs (the so-called polar method) the base with the length S should be set outside of the track. The checkpoints

doi 10.15802/STP2015/49219

divided the track into segments of any length (Fig. 6). From the first base station the distance a_i is measured to control points. From the second base station the distance b_i is measured to the same checkpoint.

Tha angles α_i, β_i can be found with the formula:

$$\begin{cases} \alpha_i = \arccos\left(\dfrac{S^2 + a_i^2 - b_i^2}{2a_i S}\right), \\ \beta_i = \arccos\left(\dfrac{S^2 - a_i^2 + b_i^2}{2b_i S}\right). \end{cases} \qquad (4)$$

The coordinates X_i and Y_i for each point of measurement can be set from the expression:

$$\begin{cases} X_i = S\dfrac{\mathrm{tg}\,\beta_i}{\mathrm{tg}\,\alpha_i + \mathrm{tg}\,\beta_i}, \\ Y_i = S\dfrac{\mathrm{tg}\,\alpha_i \cdot \mathrm{tg}\,\beta_i}{\mathrm{tg}\,\alpha_i + \mathrm{tg}\,\beta_i}. \end{cases} \qquad (5)$$

The test measured coordinates for each point can be done on the other side of the curve, with the set on the new basic line and following the same procedure.

The measurement error increases with increasing distances a_i and b_i, therefore, the basis S should be placed as close as possible to the track. The main disadvantage is the fact that when determining the curvature of the track in adjacent points, it may suddenly change due to the measurement errors.

Next on the list for comparison is a method of ordinate measuring from the baseline, set outside of the track. For this purpose it is necessary to fix a baseline, if it is possible, within the subgrade. For further measurement of ordinates a baseline should be divided into a control point for measurement, the distance between which a_1, a_2, a_3, …, a_n they are not necessarily identical (Fig. 7).

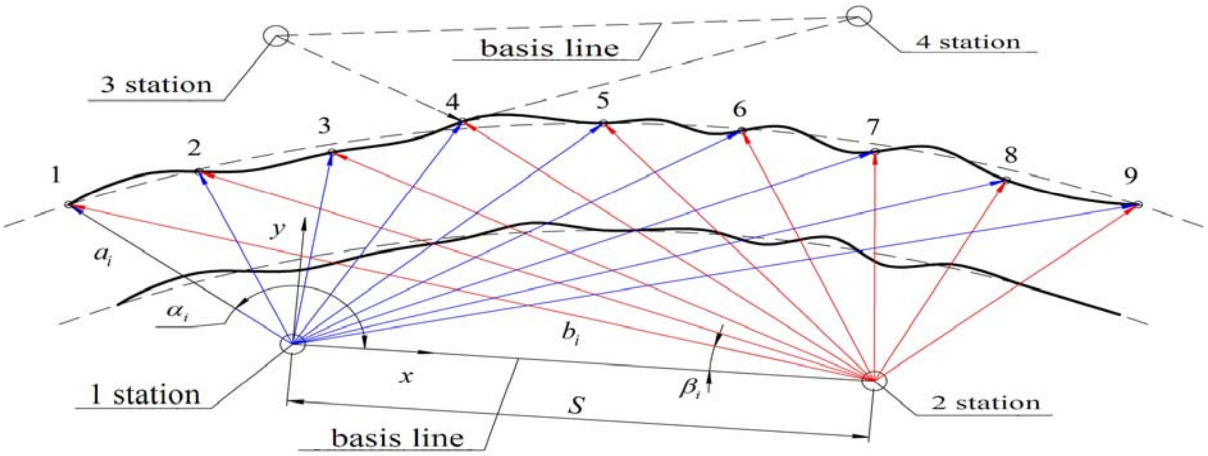

Fig. 6. The linear serif method

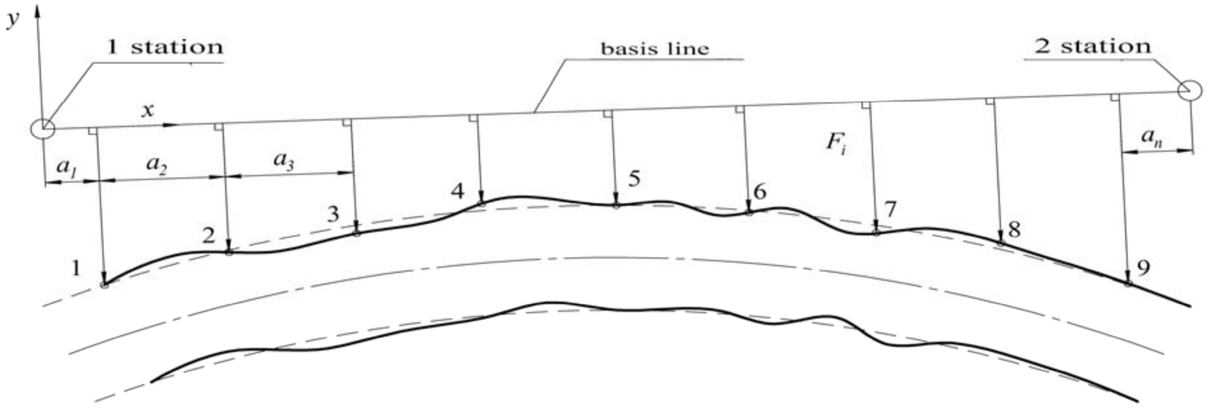

Fig. 7. The ordinate measurement scheme from the basic line is broken on the sidelines

From control points perpendicular to the baseline the segments are laid before crossing with a rail thread of the track.

During the survey the great attention should be paid to the deposition of the perpendicular line from the baseline. To perform such an operation is difficult, especially when the ordinate value is more than 1 000 mm. The geometric position of the curve is determined by the results of the measured ordinates.

The problems of measurement of this method is that the values of ordinates are set according to the outside edge of the rail. And therefore, it is also necessary to determine the wear of the rail head at each point. And also the fact that the stations for baselines need to fix reliably it cannot be ignored, because during the crossing of trains on a site is not only by their displacement. This all leads to significant thief of working time.

Alternatively, the position of the curve in the plan can be measured with horizontal angles. Usually these cases arise within the seam zone during the connecting of two rails (Fig. 8).

The angular displacement of the rails during operation may occur due to insufficient lateral stability of a rail-sleeper grid, due to the stiffness of the rails, which are trying to recover the initial shape to the bending, the reducing the regulatory pressing force of the terminals, hijacking ways and the presence of temperature forces in the rails in the summer, that can lead to a zero gaps and incorrect location of the sleepers in the curve.

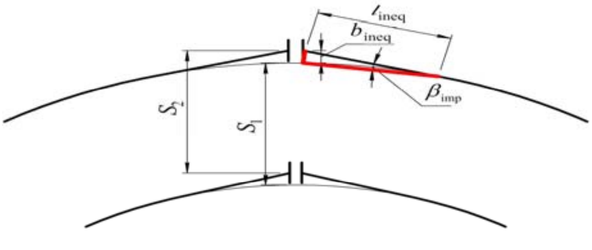

Fig. 8. Plan angle measurement scheme

The question how to measure the value of the angle of impact arises immediately. To date, the only value that characterizes the so-called angle of impact, is the rate of loss of kinetic energy at impact in switch rail [1]:

$$\omega^2_{\text{c-o}} = V^2 \sin^2 \beta_{imp}, \qquad (6)$$

where V – speed.

The maximum angle of impact, in turn, is formed by a number of other factors:

$$\cos\beta_{imp} = \cos\beta_{\text{n}} - \frac{\delta_{\max}}{R_0}, \qquad (7)$$

where β_n – initial arrow angle; δ – the gap between the crest of the wheel and rail; R_0 – the initial radius of switch rail.

The radius value is:

$$R_0 = \frac{V^2}{j_0}, \qquad (8)$$

where j_0 – fast (pulsed) centrifugal acceleration.

At the present time in different countries of the instantaneous magnitude of centrifugal acceleration in the design adopted in the range from 0.4 to 1.0 m/s2 [13]. However, as shown the theoretical and experimental studies, these values can reach 2-2.5 m/s2 [11]. It is also necessary to take into account the fact that the conditions of interaction within the switch and curve are significantly different. This is, firstly, the speed of movement. Secondly, the presence or absence of superelevation. Thirdly, the design features of the switch rail which, unlike conventional rail in a curve are not fixed. And there are more many other factors that affect the interaction of track and rolling stock. Therefore, to assess the position of the curve in terms of the magnitude of impact angles is possible, but not entirely correct. The speed limit in the zone of angles arise in the plan can be set by changing the width S_2 relative to the regulated value S_1 [2].

The latest from considered methods is the position of the curve with the ordinate from baselines rail that is located between the filaments (Fig. 9). The ordinate dimension from the rails to the base line, broken on the outside of the track or between the track is taken as bases(see Fig. 7).

The problem of using this method is that current regulations do not regulate the procedure for the use of the measured ordinates.

The authors propose to estimate the position of the horizontal curve on the ordinate, the value of which is mathematically given by the deflections, comparing which can get the status of the curve.

doi 10.15802/STP2015/49219

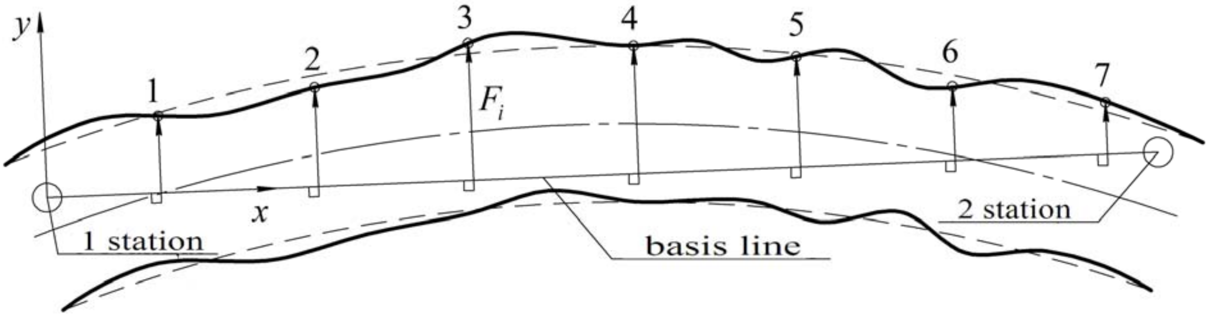

Fig. 9. The ordinate measurement scheme from the basic line is located between rails

Fig. 10 shows the calculated scheme of the transition from the axis, measured along the perpendicular to the baseline, omitted at the points *A, F, B,* to the versine *FE*, measured from the center of the chord length *a*.

Denote the versine of *FE* in *i* point using f_i. Ordinates, measured in the i-th and neighboring points, in accordance F_i and F_{i-1}, F_{i+1}. From geometrical considerations we can write the formula for the determination of versine f_i, measured from the center of the chord length *a*.

Given the fact that in real conditions, the angle α has a value close to zero, so $\cos\alpha \approx 1$, then we can write:

$$f_i = F_i - \frac{1}{2}\left(F_{i+1} + F_{i-1}\right). \qquad (9)$$

where F_i, F_{i-1}, F_{i+1} – ordinates, measured from bais line, mm.

For testing the methods it is necessary to conduct field measurements in real conditions. In practice, to fix the base for the measurements (see Fig. 9) between the rails is difficult. It is proposed to consolidate and remove ordinates track template (Fig. 11). Obtained values of the ordinates must be transformed into the versine at the value of the chord *a*. Actually, the question arises about the chord length when this method will provide accurate information.

According to [2] the curves are estimated by the difference in adjacent deflections only when the chord length is *a=20* m. Show that for short irregularities in plan, the length of which is less than the length of the chord, it makes no difference how long the chord to assess the condition of the curve is. The allegations are originate from the following calculations.

Consider the case depicted in Fig. 12. Let there exist a curve, which in the *i* point has a horizontal inequalities with amplitude b_{ineg} and length $l_{ineq} \leq a$.

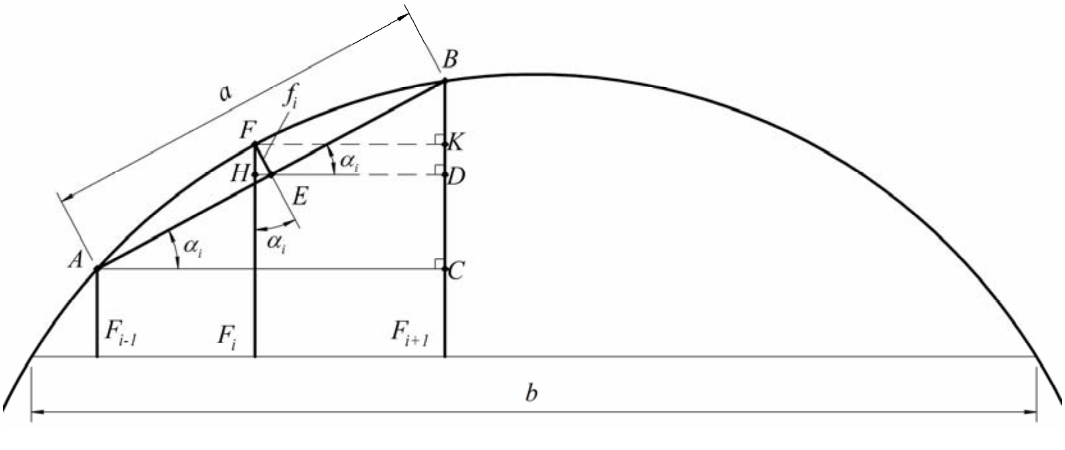

Fig. 10. Design scheme of transition from the measured ordinates *F* to versine *f*

doi 10.15802/STP2015/49219

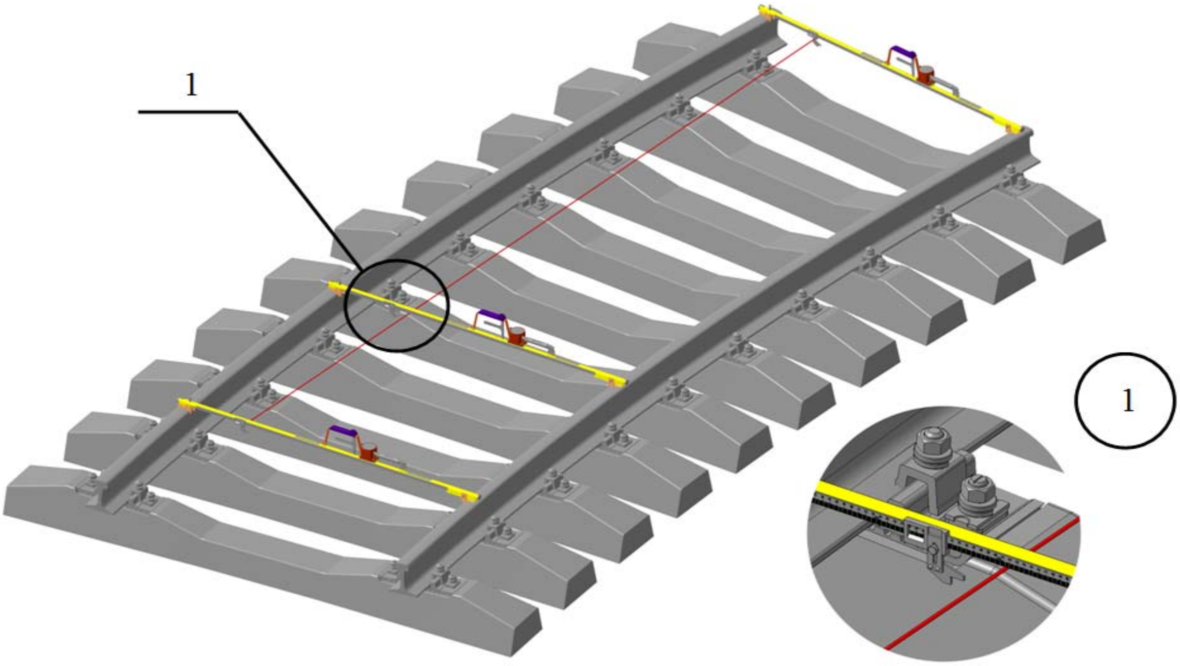

Fig. 11. Measuring with the track pattern ЦУП-2Д

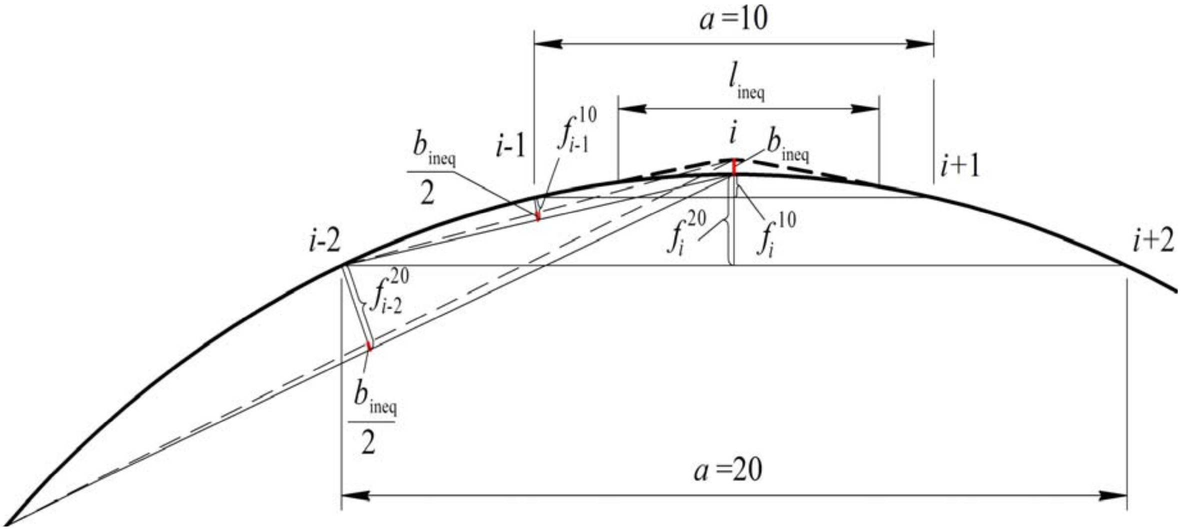

Fig. 12. The determine correlation scheme between
versine differences at different chord length

For an ideal (theoretical) curve $f_{t\,i-2}^{20} = f_{\text{t}i}^{20}$ and $f_{t\,i-1}^{10} = f_{t\,i}^{10}$. In case of occurrence of irregularities and offsets of the i-th point on the value b_{ineq} the following relations are fair:

$$\begin{cases} f_i^{20} \approx f_{t\,i}^{20} + b_{ineq}; \\ f_{i-2}^{20} \approx f_{t\,i-2}^{20} - \dfrac{b_{ineq}}{2}; \end{cases} \quad \begin{cases} f_i^{10} \approx f_{t\,i}^{10} + b_{ineq}; \\ f_{i-1}^{10} \approx f_{t\,i-1}^{10} - \dfrac{b_{ineq}}{2}. \end{cases} \tag{10}$$

Then, the difference of the deflections at 20 meter chord would be:

$$\Delta f^{20} = f_i^{20} - f_{i-2}^{20} = \frac{3}{2} b_{ineq}. \tag{11}$$

For the 10 meters chord the result is similar:

$$\Delta f^{10} = f_i^{10} - f_{i-1}^{10} = \frac{3}{2} b_{ineq}. \tag{12}$$

doi 10.15802/STP2015/49219

Therefore, the difference in adjacent versine at 20-and 10-meter chord are the same, that gives grounds to assert the requirement of assessing the state of the curve only on the statutory regulations of the chord length. Accordingly, the phrase in paragraph 2.1.2 [2] «…the difference of adjacent versine, measured from the midpoint of the chord length of 10 m shall be no greater than 5 mm» is incorrect and inappropriate.

The section was divided in 1 m and the dimensions of the versine was carried out at 10-meter chord (the curve radius R≈300 m).

Table 1

The measurement results of the curve position in plan

№ of point	F_i, mm	$f_{i\,mes}$,mm	f_i^{calc},mm	Absolute error, mm
1	302			
2	326			
3	344			
4	362			
5	374			
6	388	37	35	2
7	401	38	39	1
8	405	37	38	1
9	402	34	31	3
10	401	33	31	2
11	405	34	35	1
12	398	29	30	1
13	390	28	30	2
14	381	27	28	1
15	366	27	28	1
16	352	21	20	1
17	336	19	18	1
18	315			
19	304			
20	275			
21	260			
22	239			

Table 1 shows the actual F_i ordinate measured versine f_i^{meas} and calculation versine f_i^{cal}, obtained by the ordinate transformation using the proposed method.

Findings

A comparison of the calculated with the proposed method and measured versine showed a small absolute error, which is well within the measurement error. Thus, it can be assume that the technique can be used to assess the status of the curve track section with an abrupt change of curvature.

Originality and Practical value

The proposed improved method of estimating the position of the curve in plan, quickly changes its curvature and has bumps that are shorter than the chord length.

The results showed that this method is quite simple and convenient to use to perform naturals measurements using the least amount measuring means. And also thanks to the simplified method for data processing and the lack of controversy regarding the existing regulatory framework the speed limit on a given stretch of road can be set at once.

Conclusions

1. The existing methods of estimating the geometric position of the normal curves in plan in the operation and design of repairs to the track are analyzed.
2. A comparative analysis was realised and the main advantages and disadvantages, limits of the application of existing methods were determined. The most suitable option for detailed analysis was determined.
3. The mathematical combination of the existing and proposed methods was developed.
4. The qualitative and quantitative verification were conducted. The results showed the adequacy of the proposed methodology and the absence of contradictions.
5. The suggestions regarding the editing of paragraph 2.1.2 Instructions on the device and maintenance of the tracks of the Ukrainian Railways [2] were provided.

LIST OF REFERENCE LINKS

1. Даниленко, Э. И. Стрелочные переводы железных дорог Украины. Технология производства. Эксплуатация в пути. Расчеты и проектирование / Э. И. Даниленко, А. П. Кутах, С. Д. Тараненко. – Киев : Киев. ин-т ж.-д. трансп., 2001. – 296 с.
2. Інструкція з улаштування та утримання колії залізниць України : ЦП-0269 / Е. І. Даніленко, А. М. Орловський, М. Б. Курган [та ін.]. – Київ : Поліграфсервіс, 2012. – 465 с.
3. Корженевич, И. П. Комбинированный способ съемки плана железнодорожной линии / И. П. Корженевич // Вісн. Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. – Дніпропетровськ, 2007. – Вип. 14. – С. 81–85.
4. Корженевич, И. П. Новые способы съемки железнодорожных кривых / И. П. Корженевич // Вісн. Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. – Дніпропетровськ, 2006. – Вип. 12 – С. 53–56.
5. Корженевич, И. П. Обеспечение точности съемки кривых при возрастании скоростей движения поездов / И. П. Корженевич, Н. Г. Ренгач // Вісн. Дніпропетр. нац. ун–ту залізн. трансп. ім. акад. В. Лазаряна. – Дніпропетровськ, 2003. – Вип. 2. – С. 174–177.
6. Курган, М. Б. Визначення раціональних параметрів залізничних кривих для заданого рівня максимальної швидкості / М. Б. Курган, С. Ю. Байдак, Н. П. Хмелевська // Транспортні системи і технології : зб. наук. пр. / Держ. екон.-технол. ун-т трансп. – Київ, 2013. – Вип. 21. – С. 57–63.
7. Пикалов, А. С. Повышение эффективности реконструкции железнодорожного пути за счет применения современных технологий : автореф. дис. … канд. техн. наук : 05.23.11 / Пикалов Александр Сергеевич ; Сиб. гос. ун-т путей сообщения. – Новосибирск, 2013. – 24 с.
8. Правила і технологія виконання робіт при поточному утриманні залізничної колії : ЦП-0084 / Е. І. Даніленко, М. І. Карпов, В. Ф. Сушков [та ін.]. – Київ : Транспорт України, 2002. – 156 с.
9. Транспортна стратегія України на період до 2020 року [Electronic resource] : затв. розпорядженням Каб. Міністрів України від 20 жовт. 2010 р. № 2174-р. – Available at : http://zakon1.rada.gov.ua/laws/show/2174-2010- %D1%80. – Title from the screen. – Accessed : 26.06.2015.
10. Jodlbauer, G. Digitales Aufzeichnungs system für Gleisbaumaschinen / G. Jodlbauer, J. Neubert // EI-Eisenbahningenieur. – 2014. – № 8. – P. 22–26.
11. Kim, S. J. A Study on the Running Safety of F26 Turnout and Vehicle Model / S. J. Kim, B.-G. Eom, H. S. Lee // Intern. J. of Railway. – 2012. – Vol. 5. – Iss. 4. – P. 156–162. doi: 10.7782/ijr.2012.5.4.156.
12. Track Safety Standards Compliance Manual [Electronic resource] // Office of Safety Assurance and Compliance. – 2002. – 423 p. – Available at: URL: hsdl.org/?view&did=15770. – Title from the screen. – Accessed : 26 .06.2015.
13. Tunna, J. Regional Fast Rail Project: Turnout Safety Analysis [Electronic resource] / J. Tunna, X. Shu // Transportation Technology Center. – 2006. – 68 p. – Available at: ptv.vic.gov.au/ assets/PTV/PTV%20docs/VRIOGS/RFR-Turnout-Safety-Analysis.pdf. – Title from the screen. – Accessed : 26.06.2015.
14. UIC Code 513 R. Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles. − Paris : Int. Union of Railways, 1995. – 81 p.

А. М. ПАТЛАСОВ[1], С. А. ТОКАРЕВ[2*]

[1]Каф. «Путь и путевое хозяйство», Днепропетровский национальный университет железнодорожного транспорта имени академика В. Лазаряна, ул. Лазаряна, 2, Днепропетровск, Украина, 49010, тел./факс +38 (056) 373 15 42,
эл. почта am_patlasov@ukr.net, ORCID 0000-0003-2081-5648
[2*]Каф. «Путь и путевое хозяйство», Днепропетровский национальный университет железнодорожного транспорта имени академика В. Лазаряна, ул. Лазаряна, 2, Днепропетровск, Украина, 49010, тел./факс +38 (056) 373 15 42,
эл. почта tokarevsergeyaleks@yandex.ua, ORCID 0000-0002-2607-3123

УСОВЕРШЕНСТВОВАНИЕ МЕТОДИКИ ИЗМЕРЕНИЯ ГОРИЗОНТАЛЬНЫХ НЕРОВНОСТЕЙ В ПЛАНЕ

Цель. В масштабах всего верхнего строения пути (ВСП) существуют такие конструкции, где стандартные подходы к принятию решения о дальнейшей их эксплуатации не совсем корректны или приемлемы. В частности, это касается участков пути, которые достаточно быстро меняют свои геометрические параметры: радиус, кривизну, угол поворота и тому подобное. В качестве примера, к таким участкам ВСП

doi 10.15802/STP2015/49219

можно отнести те стрелочные съезды, в пределах которых находится составляющая, так называемая соединительная часть, на достаточно короткой длине существенно меняющая кривизну. Оценить положение в плане такой конструкции на основе существующей методики (по разнице в смежных стрелах изгиба) практически невозможно. Поэтому в исследовании предлагается дополнить и усовершенствовать методику оценки положения кривой в плане по разнице в смежных стрелах изгиба. **Методика.** Проанализированы возможные варианты измерения горизонтального положения кривых в плане. Определена наиболее адекватная методика, которая не противоречит существующей по критерию возможности использования установленных нормативов. Во внимание также принималась простота измерений и расчета. **Результаты.** Качественная и количественная верификация предложенной и существующей методик показала очень хорошее совпадение результатов измерений. Это дает основания утверждать, что данную методику можно рекомендовать работникам путевого хозяйства в оценке горизонтальных неровностей в плане не только в кривых, но и в пределах соединительной части стрелочных съездов. **Научная новизна.** Усовершенствована существующая методика оценки геометрического положения кривых в плане. При этом не создаются новые нормативы, а все полученные результаты оцениваются по существующим нормам. **Практическая значимость**. Предлагаемая методика дает возможность, не создавая новую нормативную базу, привязываться к существующей, и расширяет границы ее применения. Данную методику можно применять не только для обычных кривых, но и для очень коротких участков, кривизна которых резко меняет свое значение на противоположное.

Ключевые слова: методика; неровность; измерения; план пути; оценка состояния кривых в плане

О. М. ПАТЛАСОВ[1], С. О. ТОКАРЄВ[2*]

[1]Каф. «Колія та колійне господарство», Дніпропетровський національний університет залізничного транспорту імені академіка В. Лазаряна, вул. Лазаряна, 2, Дніпропетровськ, Україна, 49010, тел./факс +38 (056) 373 15 42, ел. пошта am_patlasov@ukr.net, ORCID 0000-0003-2081-5648
[2*]Каф. «Колія та колійне господарство», Дніпропетровський національний університет залізничного транспорту імені академіка В. Лазаряна, вул. Лазаряна, 2, Дніпропетровськ, Україна, 49010, тел./факс +38 (056) 373 15 42, ел. пошта tokarevsergeyaleks@yandex.ua, ORCID 0000-0002-2607-3123

УДОСКОНАЛЕННЯ МЕТОДИКИ ВИМІРЮВАННЯ ГОРИЗОНТАЛЬНИХ НЕРІВНОСТЕЙ У ПЛАНІ

Мета. В масштабах всієї верхньої будови колії (ВБК) існують такі конструкції, де стандартні підходи до прийняття рішення щодо подальшої їх експлуатації не зовсім коректні або прийнятні. Зокрема, це стосується ділянок колії, які досить швидко змінюють свої геометричні параметри: радіус, кривизну, кут повороту тощо. Як приклад, до таких ділянок ВБК можна віднести ті стрілочні з’їзди, в межах яких є складова, так звана з’єднувальна частина, котра на досить короткій довжині суттєво змінює кривизну цієї частини. Оцінити положення у плані такої конструкції за існуючою методикою (за різницею в суміжних стрілах вигину) практично неможливо. Тому в дослідженні пропонується доповнити та удосконалити методику оцінки положення кривої у плані за різницями в суміжних стрілах вигину. **Методика.** Проаналізовано можливі варіанти вимірювання горизонтального положення кривих у плані. Визначено найбільш адекватну методику, яка не суперечить існуючій за критерієм можливості використання встановлених нормативів. До уваги також приймалась простота вимірювань та розрахунку. **Результати.** Якісна й кількісна верифікація приведеної методики показала дуже добрий збіг результатів вимірювань запропонованої та існуючої методик. Це дає підстави стверджувати, що дану методику можна рекомендувати працівникам колійного господарства щодо оцінки горизонтальних нерівностей у плані не лише в кривих, а й у межах з’єднувальної частини стрілочних з’їздів. **Наукова новизна.** Вдосконалено існуючу методику оцінки геометричного положення кривих у плані. При цьому не створюються нові нормативи, а все базується на існуючих. **Практична значимість.** Запропонована методика дає можливість, не створюючи нову нормативну базу, прив’язуватись до існуючої, та розширює межі її застосування. Дану методику можна застосовувати не тільки для звичайних кривих, а й для дуже коротких ділянок, кривизна яких різко змінює своє значення на протилежне.

Ключові слова: методика; нерівність; вимірювання; план колії; оцінка стану кривих у плані

doi 10.15802/STP2015/49219

REFERENCES

1. Danilenko E.I., Kutakh A.P., Taranenko S.D. *Strelochnyye perevody zheleznykh dorog Ukrainy. Tekhnologiya proizvodstva. Ekspluatatsiya v puti. Raschety i proyektirovaniye* [Turnouts of Ukrainian Railways. The production technology. Exploitation in the way. Calculations and Design]. Kiev, Kievskiy institut zheleznodorozhnogo transporta Publ., 2001. 296 p.
2. Danilenko E.I., Orlovskyi A.M., Kurhan M.B. *Instruktsiia z ulashtuvannia ta utrymannia kolii zaliznyts Ukrainy : TsP*-0269 [Manual for installation and maintenance of the tracks of the Railways of Ukraine: TsP-0269]. Kyiv, Polihrafservis Publ., 2012. 465 p.
3. Korzhenevich I.P. Kombinirovannyy sposob semki plana zheleznodorozhnoy linii [Combined survey of the plan of the railway line]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan], 2007, issue 14, pp. 81-85.
4. Korzhenevich I.P. Novyye sposoby semki zheleznodorozhnykh krivykh [New ways of survey of rail curves]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan], 2006, issue 12, pp. 53-56.
5. Korzhenevich I.P., Rengach N.G. Obespecheniye tochnosti semki krivykh pri vozrastanii skorostey dvizheniya poyezdov [Ensuring the accuracy of survey of curves with increasing speeds of trains]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan], 2003, issue 2, pp. 174-177.
6. Kurhan M.B., Baidak S.Yu., Khmelevska N.P. Vyznachennia ratsionalnykh parametriv zaliznychnykh kryvykh dlia zadanoho rivnia maksymalnoi shvydkosti [Determination of rational parameters of railway curves for a given level of maximum speed]. *Transportni systemy i tekhnolohii: zbirnyk naukovykh prats Derzhavnoho ekonomiko-tekhnolohichnoho universytetu transportu* [Transport Systems and Technologies : Proc. of the State Economic and Technological University of Transport], 2013, issue 21, pp. 57-63.
7. Pikalov A.S. *Povysheniye effektivnosti rekonstruktsii zheleznodorozhnogo puti za schet primeneniya sovremennykh tekhnologiy*. Avtoreferat Diss. [Improving the efficiency of the reconstruction of the railway track through the use of modern technologies. Author's' abstract.]. Novosibirsk, 2013. 24 p.
8. Danilenko E.I., Karpov M.I., Sushkov V.F. *Pravyla i tekhnolohiia vykonannia robit pry potochnomu utrymanni zaliznychnoi kolii: TsP-0084* [The rules and technology of performance of works with the current maintenance of the railway: TsP-0084]. Kyiv, Transport Ukrainy Publ., 2002. 156 p.
9. *Transportna stratehiia Ukrainy na period do 2020 roku* [The transport strategy of Ukraine for the period till 2020]. Available at: http://zakon1.rada.gov.ua/laws/show/2174-2010- %D1%80 (Accessed 26 June 2015).
10. Jodlbauer G., Neubert J. Digitales Aufzeichnungs system für Gleisbaumaschinen. *EI-Eisenbahningenieur,* 2014, no. 8, pp. 22-26.
11. Kim S.J., Eom B.-G., Lee H.S. A Study on the Running Safety of F26 Turnout and Vehicle Model. *Intern. Journal of Railway,* 2012, vol. 5, issue 4, pp. 156-162. doi: 10.7782/ijr.2012.5.4.156.
12. Track Safety Standards Compliance Manual. *Office of Safety Assurance and Compliance,* 2002, 423 p. Available at: hsdl.org/?view&did=15770 (Accessed 26 June 2015).
13. Tunna J., Shu X. Regional Fast Rail Project: Turnout Safety Analysis. Transportation Technology Center, 2006. 68 p. Available at: ptv.vic.gov.au/ assets/PTV/PTV%20docs/VRIOGS/RFR-Turnout-Safety-Analysis.pdf (Accessed 26 June 2015).
14. UIC Code 513 R. Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles. Paris, Int. Union of Railways Publ., 1995. 81 p.

Prof. V. D. Petrenko, D. Sc. (Tech.) (Ukraine); S. V. Ivanchak, (Ukraine), Chief engineer of the Track service of Prydniprovska Railway recommended this article to be published

Received: June 15, 2015
Accepted: Aug. 14, 2015

doi 10.15802/STP2015/49219