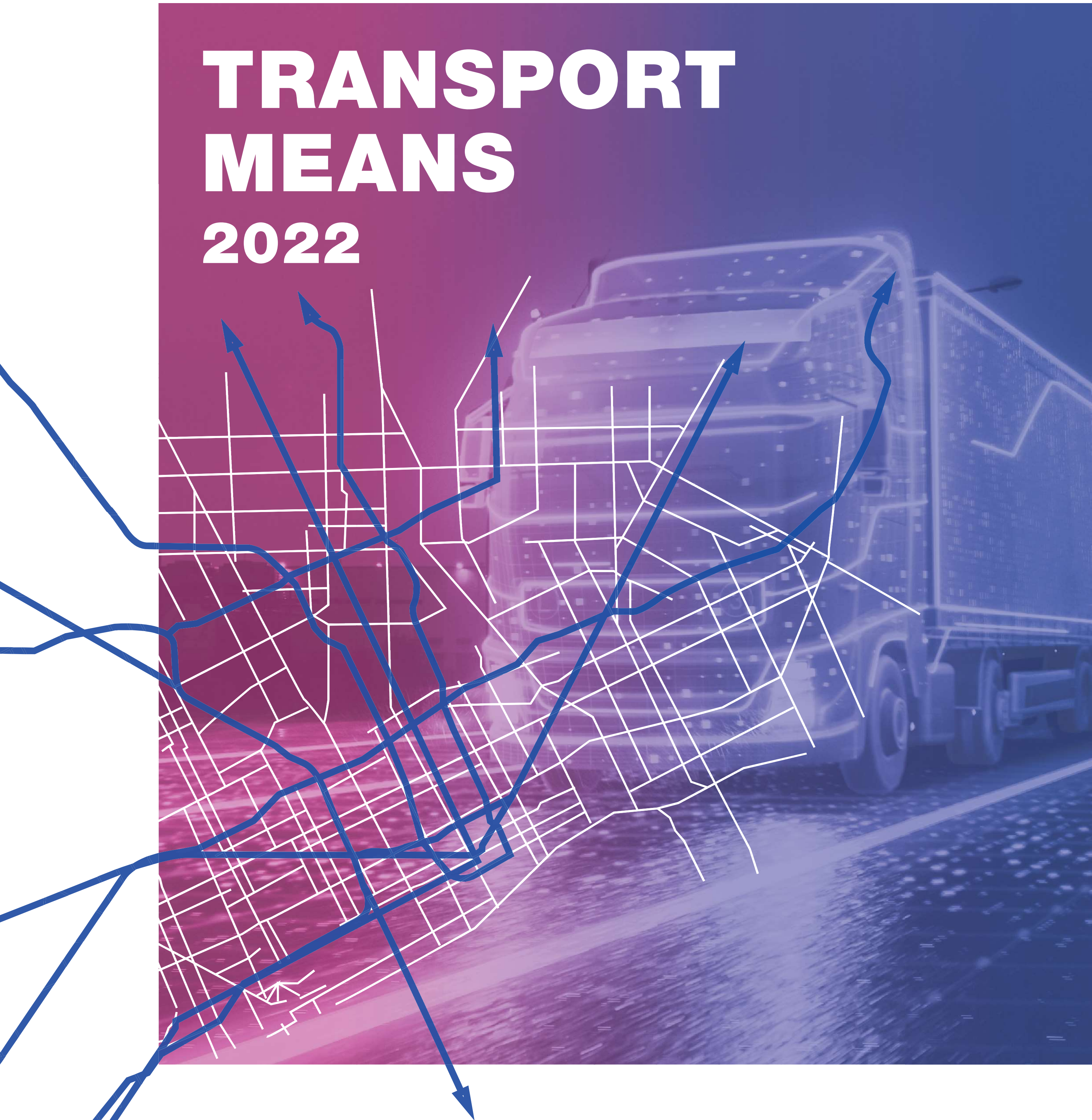
26th International Scientific Conference

October 5–7

TRANSPORT MEANS

2022



Proceedings

Part I

ktu 1922

ISSN 1822-296 X (print)
ISSN 2351-7034 (on-line)

KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPĖDA UNIVERSITY
IFToMM NATIONAL COMMITTEE OF LITHUANIA
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TRANSPORT MEANS 2022

Sustainability: Research and Solutions

PROCEEDINGS OF THE 26th INTERNATIONAL SCIENTIFIC CONFERENCE

PART I

October 05-07 , 2022
Online Conference - Kaunas, Lithuania

KAUNAS•TECHNOLOGIJA•2022

Proceedings of 26th International Scientific Conference. Transport Means 2022.

Innovative Technologies for the Introduction of High-Speed Train Operation (on the Example of Track Maintenance in the Plan)

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Abstract

The purpose of the work is to research the process of introducing innovative technologies in the organization of high-speed train operations. The new knowledge is based on such scientific approaches as a comprehensive and detailed study of various aspects of innovative activities, which has provided an opportunity to increase the interoperability of the European transport system and recommend measures to organize high-speed train operations. The research used analysis methods to study the main directions in the introduction of innovative technologies and technical solutions in the field of, firstly, track infrastructure, scientific publications on the current state and trends in the European system of international railway transport, including innovative ways of development.
KEY WORDS: *railway; innovation activity; innovative technologies; railway curves*

1. Introduction

The Austrian scientist Joseph Alois Schumpeter in the work "The Theory of Economic Development" (1911) for the first time considered the issue of the impact of innovations on development and gave a definition of the innovation process. According to Joseph A. Schumpeter, innovation is the main source of profit, and it is the result of the introduction of innovations.

Nowadays, the role of innovation has grown significantly. World practice has normatively fixed the interpretation of the term "innovation". Thus, in conformance with international standards, innovation is defined as the final result of innovative activity, embodied in the form of a new or advanced product that had been introduced on the market, or used in the practical activity of a technological process.

The term "innovation" can be used in two senses: to describe a new product, process, or system (static aspect); to describe the process, covering such activities as research, engineering, development, organization of production, and commercialization of a new product, process or system (dynamic aspect).

So, innovation is the process of bringing a scientific idea or a technical invention to the stage of practical use that generates income, as well as technical-and-economic and other changes in the social environment associated with this process. Innovation must satisfy market demand, be a new concept and earn profit for the manufacturer.

Innovation takes on a special meaning when there is a need for rapid development in a certain direction. Thus, the strategic task of scientific and technical policy in the field of the transport system in Ukraine is to reach the European level by technical parameters and the quality of services provided by transport. In this regard, the primary and priority task for the transport industry is the expansion of scientific research concerning the problems of creating advanced technologies for the organization of international freight transportation, the formation, and functioning of an effective transport system, the development of fundamentally new management systems using advanced innovative technologies.

The Law of Ukraine "On Investment Activity" considers innovative activity as an integral part of activity aimed at the development, creation, and distribution of new products, technologies, organizational and managerial forms of development, which are the basic framework for forming or maintaining the proper competitiveness of enterprises.

The main directions in the reorganization and development of the track facilities, the introduction of high-speed traffic are based on the following components of innovative activity:

– creation and implementation of future-oriented track designs that require a reduced amount of repair and preventive work for various operating conditions (purely passenger traffic, predominantly passenger traffic, combined and freight traffic);

– expansion in the application of continuous welded rail track (as of January 1, 2022, in Ukraine, there are about 21 thousand km, of which 15% long railway spurs with a length of block-section, with a length of station-to-station block is 13% of the total length). Laying a continuous welded rail track from station to station, continuous turnouts, and new structures of resilient rail fastening on reinforced concrete sleepers allows solving the needs of domestic and transit transportation, the issue of increasing train speeds;

– creation and implementation of technologies that allow saving material and energy resources during current maintenance and all types of repairs of track infrastructure;

– reconstruction of bridges, pipes, overpasses, tunnels, and enhancement of the roadbed;

– improvement of diagnostic methods and means of monitoring the track infrastructure (application of diagnostic complexes that enable to provide diagnostics of objects with a non-contact technique);

– equipping railways with modern, reliable, high-performance machines and mechanisms, improving the structure and management system of track facilities based on information technologies.

2. Status of the Problem

Innovative technologies cover many industries. These are "smart cities" [1], and transport hubs [2], and of course, railway communication. The transition to the investment and innovation stage in the development of the Ukrainian economy requires cardinal changes in the strategy for further development of railways. The specific operating conditions of Ukrainian railways compared to those of Western Europe are characterized by a significantly larger volume of transportation work, greater traffic intensity and mass of trains, and higher axle loads from rolling stock. Increasing the carrying capacity and introducing high-speed traffic on Ukrainian railways is a more difficult task than on Western European tracks, and requires fundamental changes.

The difficult state of the domestic innovative and high-tech component of the transport industry is explained by the insufficient level of investment, limited funding from the state and local budgets, the lack of funds for the simple reproduction of fixed assets, and the lack of investments under the terms of concessions. The deficiency of investment has led to the rapid aging of rolling stock and transport infrastructure, which causes the non-compliance of the technical and technological level of domestic transport with European requirements. In this regard, JSC "Ukrzaliznytsia" faces the task of ensuring the development of the material and technical base, the introduction of innovative diagnostic technologies, and infrastructure maintenance [3, 4]. It is noted that Ukrzaliznytsia suffers from aging locomotives and rolling stock [5], as well as from badly worn infrastructure [6], which entails "bottlenecks" in transport. Currently, out of 27 thousand km of tracks, 9.8 km are operated with overdue repairs, another 1 030 km of tracks are subject to speed limits from 15 to 60 km/h. An important step in increasing the viability of the railway will be the search for ways to attract investments into the system, and the introduction of innovative technologies.

The classic form of traffic organization, which is to use the infrastructure for the transportation of both passengers and freight (combined traffic) has become an obstacle in the transition to innovation-based growth in Ukraine. Disadvantages in the organization of such traffic are insufficient passenger comfort and the impossibility of applying new progressive rolling stock. A possible solution to this problem is the separation of freight traffic from passenger traffic. Such actions were proposed to be carried out on the railways of Ukraine back in 2007 and were partially resolved only on the eve of Euro-2012.

When separating freight and passenger traffic, directions were set depending on the structure of train flows: categories and mass of operating trains, and travel speed [7]: purely high-speed passenger traffic; combined movement of high-speed passenger and freights collecting and suburban trains; accelerated movement of purely passenger trains; combined movement of accelerated passenger trains with freight collecting and suburban trains; freight traffic.

The directions also differ in operating conditions, plan and longitudinal profile parameters, and have different possibilities for realizing the maximum speed of movement: 120-160 is accelerated movement, and 161-200 km/h is high-speed movement. To implement these tasks, the authors in [8, 9] reviewed innovative technologies for diagnostics and maintenance of track infrastructure and provided recommendations for the further development of railway infrastructure through innovative development and improvement of scientific and technical potential.

Research methods and solutions to current transport problems are presented in the materials of the International Scientific Conference "Transport of the 21st Century" [10].

Proposals for using the idea of innovation of the entire permanent way complex were substantiated and implemented on specific objects [11, 12].

The Cost Report for Purposeful Innovation – Project INNOTRACK [13] presents the results of studies that can reduce the life cycle cost of railway infrastructure (LCC) while simultaneously improving the characteristics of reliability, availability, maintainability and train traffic safety (RAMS). The article [14] presents an innovative method of assessing the state of ballast and soil. Fractal analysis, which allows determining the main cause of track irregularities in the vertical plane, was carried out on the Austrian federal railways network (about 4 000 km of tracks), as well as on the Swiss federal railways network (5 000 km). In addition, several lines in the USA (Amtrak), Belgium (InfraBel) and Denmark (BaneDanmark) were evaluated. Paper [15] describes a risk-based approach that can be used for economic justification of the condition of railway infrastructure by comparing infrastructure maintenance costs based on life cycle, train operating costs, travel time costs, safety, and social and environmental impacts.

3. Calculation Methodology

In order to find an option for optimal reconstruction of the transport corridor section, the railway line is considered as a complex system consisting of devices and structures that, due to unsatisfactory technical conditions, can limit the level of train speeds in each specific section. One of the reasons for the speed limit is the presence of deviations in the plan of a track. These deviations are the result of the accumulation of residual deformations that emerge after laying the track and develop during operation. Any significant change in the design parameters of the curve of tracks leads to a change in the operating modes of track circuits, which the main element are ensuring the safety of train traffic. A change in the track parameters causes a change in the electrical properties of the rails and can lead to failures in the track circuits operation [16].

For example, offers for the introduction of high-speed passenger trains in the Kyiv-Lviv direction were considered. The existing state of the railway infrastructure does not allow for an increase in the speed of passenger trains to more than 120 km/h. In this direction, work was carried out on diagnosing and monitoring the condition of the track, determining the design parameters of the curves and the maximum permissible speed. During monitoring, the impact of the track geometrical parameters on the intensity of accumulation of deformations, which also depends on the parameters of the curves, was established. Thus, an incorrectly installed elevation of the outer rail leads to track shifts, track width disorders, and speeding-up in side wear of the rails.

For the implementation of high-speed operation, such measures as modernization of railway tracks with the replacement of turnouts with gentler ranks of crosspieces, the overall repair of the roadbed, increasing the radii of curves of the main tracks, reconstruction of crossings, construction of overpasses instead of crossings and approaches to them were considered. The results of traction calculations are taken as the basis for evaluating various options (Table). For their implementation, the "MoveRW" program developed by the Ukrainian State University of Science and Technology was used. Calculations were made for domestic rolling stock "Tarpan" of nine cars with the weight of a train of 500 tons. The authors considered the following options:

Option 1°–°the existing state of the infrastructure, the maximum speed on turnouts at stations is 120 km/h, on station-to-station blocks – 160 km/h

Option 2°–°minimal straightening of curves within the existing roadbed; the maximum speed on turnouts at stations is 120 km/h, and on station-to-station blocks – 160 km/h.

Option 3°–°replacement of turnouts, the maximum speed on which can be realized is 160 km/h, on station-to-station blocks is 160 km/h

Option 4°–°reconstruction of curves of small radii to a radius of 1500 m with a shift of the existing track up to 15 m, maximum speed on turnouts, and station-to-station blocks is 160 km/h.

Option 5°–°reconstruction of curves of small radii to a radius of 1500 m with a shift of the existing track up to 15 m, maximum speed on turnouts, and station-to-station blocks is 200 km/h.

Table

Running time of passenger trains

Section	Distance, km	Running time on options, minutes				
		Option 1	Option 2	Option 3	Option 4	Option 5
		120/160	120/160	160/160	160/160	200/200
Kyiv-Korosten	156	75	75	71	70	66
Korosten-Shepetivka	149	77	75	71	70	64
Shepetivka-Zdolbuniv	70	33	32	29	29	28
Kyiv-Zdolbuniv together	375	185	182	171	169	158
Implementation of the maximum speed of movement 160 (200), km (%)		89 (23.7)	110 (29.3)	185 (49.3)	215 (57.3)	127 (33.9)
Reduction of time by options		137	140	151	153	164
Estimated costs, million euros		-	143.5	421.1	609.4	642.6

Notes: in the numerator the maximum speed by stations, in the denominator – by station-to-station blocks; the time spent by a passenger train on the route, excluding stops at separate points, is 322 minutes (the existing condition of the railway track in curves).

The "smoothing" technique is often used to place curves in the design position. This principle is the basis of the work of the track renewal train. Despite the low accuracy, this method is widely used on the roads of "Ukrzaliznytsia" due to its simplicity and lack of preliminary work and calculations. As a result of performing straightening works in order to reduce volumes of landslides, the curve does not correspond to the original passport data, it can become multi-radius from a single-radius (compound).

4. Results of Calculations

The authors considered a curve that, according to the project documentation, was arranged with a radius of 570 m, a rotary angle of 77°08′, and the elevation of the outer rail of 110 mm, which allowed to set a maximum speed of 100 km/h. After a certain period of operation, the condition of the curve has deteriorated. Fig. 1 shows the graph of the versine (the method of arrows from a 20-meter chord), which characterizes the state of the curve, and the permissible speed of movement, the minimum value of which is about 75-80 km/h.

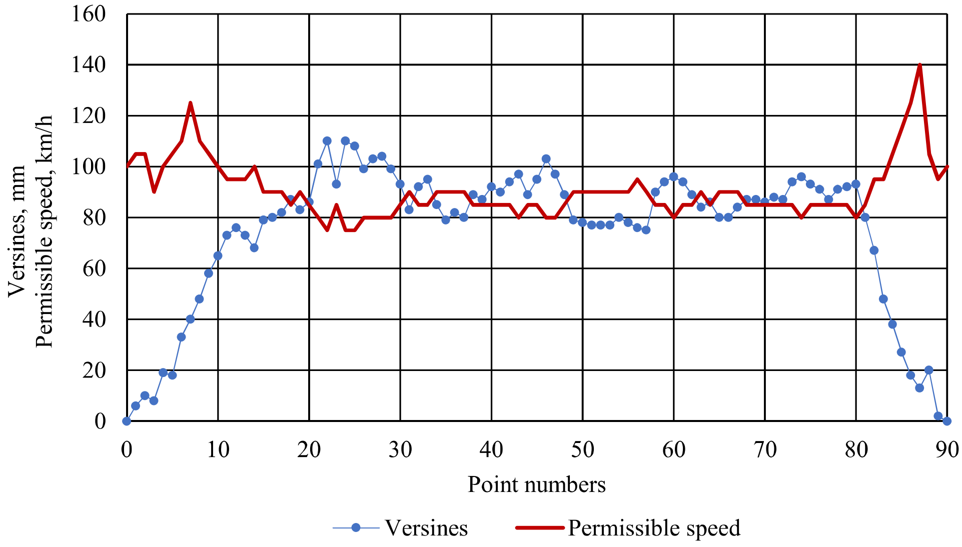

Fig. 1 Graphs of versines and permissible speed of movement

When correcting the curve by the "smoothing" technique, the shape of the curve changed, and it turned from a single-radius into a compound with radii of 526, 555, 628, 562, 592, and 489 (Fig. 2). At the same time, minimal shifts (± 200 mm) were ensured when correcting the existing curve (Fig. 3).

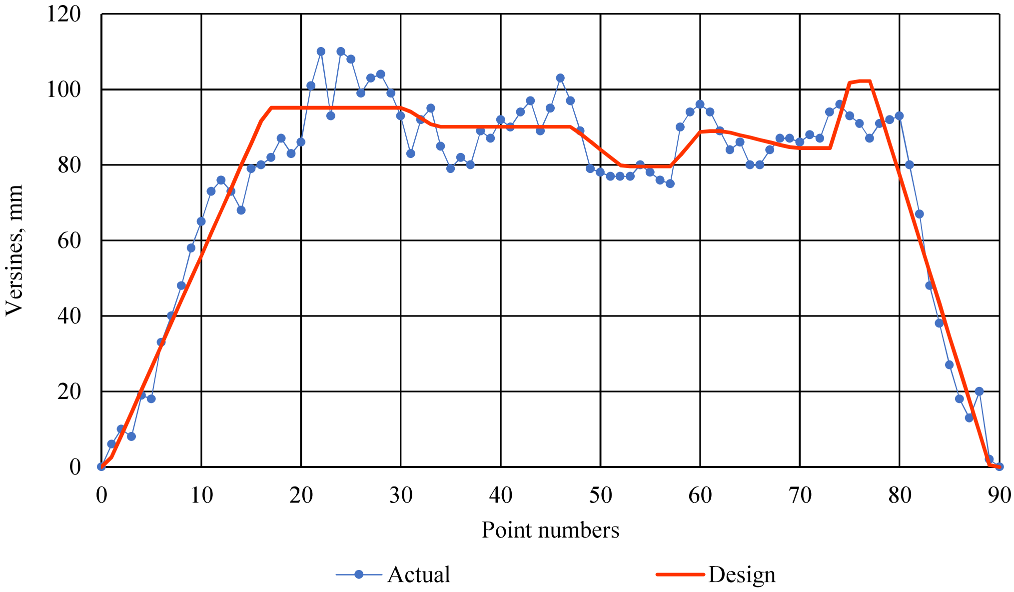

Fig. 2 The compound curve formed after straightening by the smoothing technique

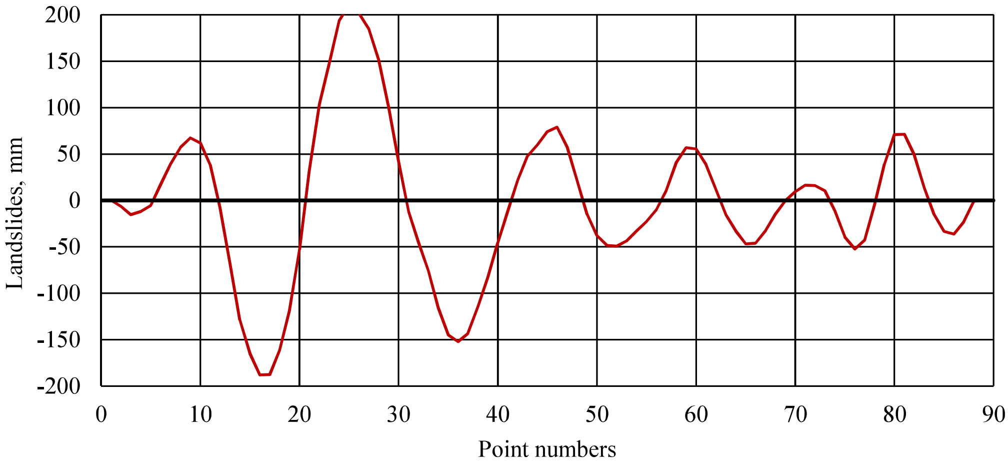

Fig. 3 The graph of landslides when constructing a 6-radius curve

The permissible speed of movement in single curves is determined under the condition of not exceeding the normative value of unbalanced accelerations (α), the speed of their change in time (t) – $\psi = \alpha/dt$ and the right-of-way of elevating the outer rail (h) along the length of the transition curve (l) $i = dh/dl$. In the case of the presence of compound curves, it is necessary to define the permissible speed based on the interface parameter as well [7]. The smallest value of the radius of the compound curve, 489 m, became the determining factor affecting the level of permissible speed (Fig. 4). The application of a compound curve ensured the minimum amount of work on straightening, but did not ensure the maximum speed of 100 km/h, which was set for a single-radius curve.

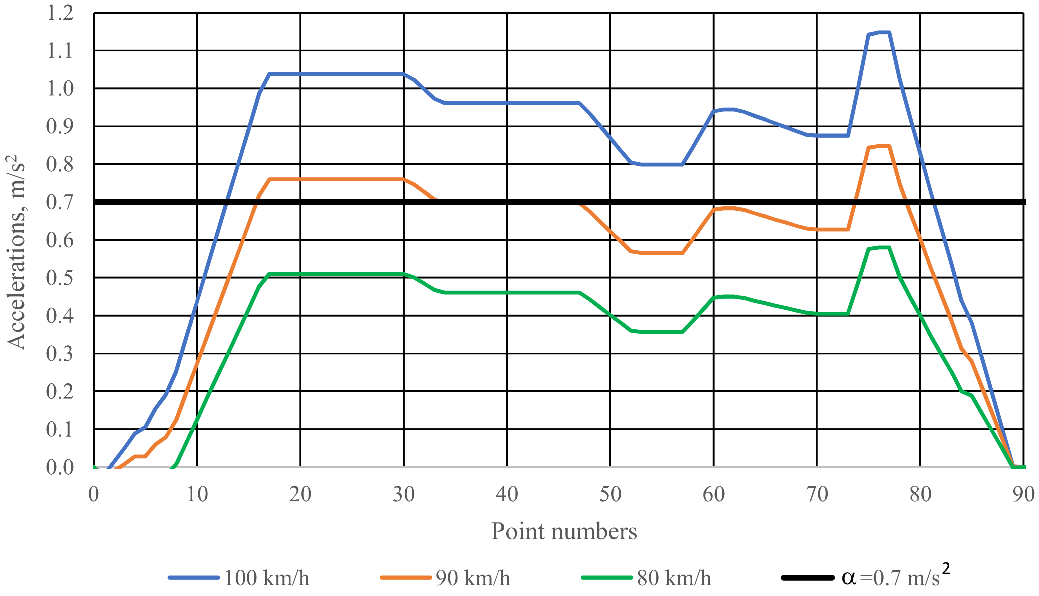

Fig. 4 Change of unbalanced accelerations along the curve at different speeds

5. Conclusions

The analysis of projects of overall repairs and modernization of the track, as well as on-site surveys, showed that irregularities in the plan and profile emerge in curves, therefore, during the modernization of the track, work should be carried out to set the axis of the track in the design position in the profile and the plan with the reconstruction of the design radii.

The analysis of the tapes of track-testing cars within the curved sections of the track and the calculations performed by the authors demonstrated that the presence of deviations in the plan worsen the assessment of the railway track condition and, as a result, reduce the smoothness and comfort of the driving.

Evaluating the existing practice of straightening curves, as a rule, by the "smoothing technique", the authors come to a conclusion about the need to develop and implement new, more effective technologies for the operation of high-performance corrective-straightening machines, ensuring the economic efficiency of automating work on track surfacing.

The formation of multi-radius curves instead of single-radius curves in order to reduce the volume of landslides during straightening not only destabilizes the track quicker but also causes the emergence of numerous transition zones, which, if it is improperly arranged, pose a threat to the safety of train traffic.

The use of innovative technologies in the execution of a complex track works with the aim of introducing high-speed train operation will allow to qualitatively solve the task of ensuring high indicators in the freight transportation and passenger comfort.

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