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

Наука та прогрес транспорту. Вісник Дніпропетровського національного університету залізничного транспорту, 2015, № 3 (57)

ЗАЛІЗНИЧНА КОЛІЯ

UDC 625.1-027.45

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FORMATION OF ESTIMATED CONDITIONS FOR LIFE CYCLE OF DEFORMATION WORK OF THE RAILWAY TRACK

Purpose. The purpose of this research is to substantiate the technical limits of the railway track (under reliability status) for the formation the regulatory framework for reliability and functional safety of the railway track in Ukraine. **Methodology.** In order to achieve the goal of research analysis methods of the technical states of elements and trackforms that are typical of operation conditions of the railways in Ukraine were used. **Findings.** Technical states accordance of elements and trackforms to reliability status under existing regulations was defined. These conditions are based on the track assessments in accordance with the dimensional tape results. The status of each element of the track design affects its deformation work, but the rules are still absent that would connect state of track elements with the state of the track by estimation of the dimensional tape. The reasons on which the limits are not set were established. It was found out which researches are necessary to conduct for their installation. **Originality.** The classification of the reliability state of a railway track for permitted deviation at the track laying and maintenance was developed. The regulation importance the technical states of ballast section and subgrade for the developed classification was established. **Practical value.** Ukrzaliznytsia (UZ) is a founding member of the Council for Railway Transport of the Commonwealth. This body issued interstate standard State Standard 32192-2013 «Reliability of railway equipment. Basic concepts, terms and definitions». On this basis developed a new interstate standard «Security functional of railway equipment. Terms and definitions». At the same time UZ is a member of the cooperation of railways in International Union of Railway Transport where rules with reliable and safe operation of railways are established in all transport branches. This study will help implement these standards on the railways of Ukraine, improve the efficiency of the information in this sphere, providing mutual understanding and unity of presentation and perception of information, including contractual legal relations of economic agents with public authorities in international scientific and technical, trade and economic relations.

Keywords: state track reliability; technical condition of the track; the elements of the track; the track construction; regulatory; technical and design documentation; unit standards and content

Introduction

Reliable railways operation provides reliable joint work of the track design, technical equipment and technical personnel that performs and supervises the process implementation at all levels. The whole process of reliable operation of a track meets regulatory, organizational and administrative, technological and technical requirements.

Reliable operation of track design provides safe operation as each item individually and the system as a whole. The criteria are necessary to control the reliable operation of track design and their compliance provide the functional and safe work of the track. The formation of these criteria should be based on the standarts in accordance with the parameters describing the system state with components of the track design. Standarts are based on the parameters describing the condition of each

doi: 10.15802/stp2015/46064 © I. O. Bondarenko, 2015

track design element separately. The existing standards reflect the state parameters of each track design element and the condition of rail-sleeper grid from the point of view of its geometric position. Completely the regulatory base is absent, classifying the status impact of both items the geometry of the rail-sleeper grid and the status of the track design. It is necessary to model the deformation operation service life of the railway track for the development of missing parameters.

The deformation operation service life of the track is the process of its transition regularities from one reliable state to the other beginning from the primary pouring to the full retirement.

It is necessary to perform an analysis of existing methods of condition assessment of railway structures and to consider regulatory requirements that establish the condition of the elements and a rail-sleeper grid as a system of these elements from the point of view of the concepts of reliability theory to create conditions for evaluation modeling.

But no standard regarding a railway track, contains a technical description of its condition, that corresponds to the concept of the condition in terms of reliability.

Purpose

The aim of the research is to study the technical boundaries of the elements and construction states of the track in accordance with the conditions of reliability.

Methodology

Terms and definitions of basic concepts in reliability theory for the established operating standards are used in science and technology [6-9].

According to the classification of the basic concepts of reliability theory, there are six conditions: serviceable, unserviceable, functional, partially functional, non-functional and adjoining.

Technically the condition of the track structural elements are described for rails in [5, 12, 14, 15, 19], for fasteners – [5, 10, 12, 19, 21], for sleepers – [3, 5, 12 13, 15], for ballast – [5, 10, 12, 15, 20], for roadbed – [5, 10, 11, 12, 13, 15, 17, 19].

There are no difficulties to establish compliance with reliability status for track design elements. That is, in accordance with the requirements of the design criteria is determined the serviceable and fault conditions: for rails is determined by [12, 13], for fasteners – [4, 12, 21], for sleepers – [3, 5, 12, 15], for ballast – [5, 10, 11, 12, 15, 18, 20], for roadbed – [5, 11, 12, 13, 15, 17, 18].

In accordance with the requirements of establishment and maintenance there are functional, partially functional, non-functional and adjoining conditions.

For a rail-sleeper grid as system the conditions are described in [5, 10, 14, 16, 18]. But there are difficulties with the classification. Thus, depending on the speeds the requirements for elements relative to the conditions are changed. For example, the requirements for a functional track state by the rails condition for the first category are different from a functional track condition for the same category at speeds of 101-120, 121-140, 141-160, 161-200 km/h. Functional condition of a track by the rails condition for the fourth category, with load intensity more than 30 million gross tonnes km. to km. per year differs from the functional condition of the same category at a lower load intensity and in the first case the new elements of the track are laid and in the second the old one.

Thus, it is necessary to classify the track condition by the track elements state and indicators of a track measurement tape.

Consider the compliance of reliability conditions to requirements for the track classification by categories.

According to [18] serviceable and unserviceable condition of a rail-sleeper grid for high-speed, the first, second, third and fourth categories with load intensity of 30 million gross tonnes km. to km. per year are defined as for elements in accordance with the regulatory requirements and design documents.

For the fourth (with a lower load intensity), fifth, sixth and seventh track categories of functional and nonfunctional conditions are defined by the requirements of the establishment and maintenance

But for all track categories in accordance with requirements of establishment and maintenance are determined functional, partially functional, non-functional and adjoining conditions.

The main parameter of establishing the technical condition of element and track design classification is the speed of movement. Permissible speed of passenger and freight trains movement is established by geometric shapes of both in loaded and

doi: 10.15802/stp2015/46064
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unloaded conditions, so they should be taken to determine the boundaries of the track design technical condition by the corresponding condition of reliability.

As to the condition of the ballast edge the state of reliability should include not only the geometric contour, but also its impurity.

In addition, there is a problem with the definition of the railbed condition in the normative literature, as applied term «soundness» roadbed [1, 2] corresponds to the modulus of elasticity under the rail base value of 50 MPa in summer and 75 to 80 MPa in winter, that is applied at:

− the determination of the stresses in the track elements [15];

− calculations of the rail binds laying conditions of jointless track [10];

− definition of permissible speeds [15];

− definition diagrams of sleepers in track design [18].

The railway track meets these values of module elasticity, if its sites are located on the roadbed with the modulus of deformation of more than 40 MPa, that is, the roadbed consists of rocky or dry soils, compacted in accordance to the norms [5]: sand-clay; light sandy loam; medium clay; heavy clay.

In other cases, the elastic modulus does not correspond to the input conditions of these calculations.

Thus, it is necessary lead the track state to the conditions of operating rules fulfillment (normalized stiffness of the track that is used on the railways of the Europe, [22]) to meet the strength and stability.

The value of the actual modulus of the under rail elasticity for structures are specified in [18], and ranges from 7.4…to 69.6 MPa in summer.

The value of the average elastic modulus is about 27 MPa. It should be understand that this is almost in twice (1,85) lower than it is required by the initial conditions, so the effects will be in the increased variability under the influence of the rolling stock, on average, in the vertical plane на 67%, horizontal 24%

Thus, in view of this, to ensure the dependability of a track at the level set by the criteria [18] at the specified resource (missed tonnage or the number of years) between upgrades, enhanced capital and capital repairs without additional investments and not provided by the interrepair schemes and maintenance is impossible.

Avoidance of excessive use of force on the track at the execution of conditions of the track and rolling stock maintenance in functional and non-functional condition, but in serviceable condition there were no additional force effect in the system track-crew-track. It is possible only if the track is equally stressed-stained. Thus, it is necessary that even in a failed state, the stiffness of the track was at the same level throughout its length, and did not receive additional shocks from rolling stock.

The uniform track stiffness can be ensured only at the renovation of the condition of the roadbed. After all, it was built more than a century ago and for other operational requirements than applied today. For design requirements the roadbed is designed for loading of locomotives 30 kN, 50 kN cars, design speed of 80 km / h. According to the existing requirements [5]: under the load from the carriage 294 kN and a design speed of 120 km/h. Modern standart technological processes do not provide for renovation of the roadbed. Therefore, after the repair of the rail-sleeper grid replacement, the track design would not meet the terms of strength, durability and equal strain.

It is believed that the distribution of trains in the implementation of high-speed services will remove the factors that lead to the breakdown of the geometric dimensions of the track and wear of its elements, without removing the roadbed condition. Combined movement of freight and passenger trains intensively affects the track disorder and wear of its elements than the impact from the movement of freight or passenger trains separately. But it will give an effect, which is not significantly affect the reliability pointer and durability without eliminating the main cause – the accumulation of permanent deformation at operation of not strong, not sustainable, uneven elastic track.

It is also believed that the distribution of trains flows will lead to the retention of established standards for size and geometric environs of the track in valid values for long-term operation, that is the following of the track in a functional condition with the maximum value of the coefficient of track technical use.

But the distribution of trains will solve the problem only partially. It is necessary to change the technology of current track maintenance: remove the work from the local track linings if the track conditions of strength, durability and reliability are not kept. These works involves the reduction of track

doi: 10.15802/stp2015/46064
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Наука та прогрес транспорту. Вісник Дніпропетровського національного університету залізничного транспорту, 2015, № 3 (57)

elasticity in the places of work. Consider the reduction of track elasticity in the places of work with local track lining, when missed tonnage of the sector was less than 140 million tons km. br. after the replacement of a rail-sleeper grid repair. If the missed tonnage of the section is to 25 million tons km. br., while executing these works by sleeper tampers the elasticity of the track is reduced by 50-60%, and machines on 35-25%. If the missed tonnage is 26-140 million tons km. br. at the performing such work by any means the reducing is 25-20%. It helps to increase the intensity of local residual deformations, which are contrary to the requirement to prevent excessive force on the track and the compliance of the strength and stability conditions for a long period of operation.

Thus, it is necessary to set the condition of under sleeper bases and associate them with track condition.

Findings

The technical concept of reliability is based on the definition of such indicators:

− reliability (all possible types of system failures, depending on the application and the external environment; the possibility of each failure or, in the alternative, the intensity of occurrence of each failure; failure effects on system capability);

maintainability (the time of maintenance; the time of detection, recognition and localization of faults; restore the system that refused (unscheduled maintenance);

durability (criteria for the limit condition of the system; the average operation time of the system);

− operation and maintenance (all possible modes of operation and maintenance in the service life of the system; the human factor.

Thus, on the basis of the normative literature, the classification of the technical condition of the railway track at the reliability conditions is presented in the section methodology in table 1.

The data given in table 1, are fully reflect the condition of the secure ways depending on the speed of rolling stock for design, that collected of both new and used items of the track. But the speed of movement is influenced by the geometrical parameters of the elements, for example the wear of rails over which they are considered defective. And if the old suitable rails lie on the track, the presence of even allowable wear does not affect the track width, as they are put to other edge, but affect the deflection of the rail under load by reducing the area of resistance. Thus, the permissible deviations of old suitable structural elements of construction and choose a margin of safety, sustainability and reliability, and require the compensation due to the characteristics of under sleeper bases.

Table 1

The states classification reliability of the railway track with permitted deviations at the organization and supporting of a track

The speed of passenger / freight trains, km/h.	Condition			
	Functional condition	Nonfunctional condition	Partly functional	Nonserviceable condition
Clearance allowances to the track width, mm				
>140-160/ >80-120	+5, -3	-	-	+6, -4
>120-140/ >80-120	+8, -4	+9, -5	+21, -9	+29,-11
≤ 120/ ≤ 80	+8, -4	+9,-8	+21, -9	+29,-11
Standarts of track width elimination, mm/m				
>140-160/ >80-120	1/1	1/1,01	1/1,25	1/2,5
>120-140/ >80-120	1/1	1/1,01	1/1,5	1/2,5
>80-120/ >60-80	1/1	1/1,01	1/1,75	1/2,5
≤ 80/ ≤ 60	1/1	1/1,01	1/2	1/2,5

doi: 10.15802/stp2015/46064
© I. O. Bondarenko, 2015

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Continuation of the table 1

The speed of passenger / freight trains, km/h.	Condition			
	Functional condition	Nonfunctional condition	Partly functional	Nonserviceable condition
The permissible deviations according to the mutual position of trackways height, mm				
Subsidence				
>140-160/ >80-120 either-direction	4	5,5	6	45
one-way	6	8	10	45
>80-140/ >60-120	10	11	21	45
≤ <80/ ≤ 60	10	11	26	45
Twists				
>140-160/ >80-120 (on length 10 m)	8	9	16	50
>120-140/ >80-120 (on length 20 m)	8	9	16	50
≤ 120/ ≤ 80 (on length 20 m)	8	9	17	
The difference in adjacent deflections (mm) measured at the mid-chord, length of 20 m in circular curves				
>140-160/ >80-120	3	4	5	10
>120-140/ >80-120	5	6	8	10
≤ 80-120/ ≤ 60-80	8	9	10	10
The biggest deviation from a uniform rise of arrows at ease curves				
>140-160/ >80-120	2	3	4	90
>120-140/ >80-120	3	4	5	90
>80-120/ >60-80	5	6	10	90
≤ 80/ ≤ 60	10	11	26	90
Nominal distance (m) between the axes of the sleepers leader/continuous of the track				
>140-160/ >80-120	±0,01	-	±0,02	-
≤ 140/ ≤ 120	±0,07/0,03	-	±0,08/0,04	-
The steepness of the elimination of superelevation, mm/m				
>140-160/ >80-120	0,4	0,5	0,7	4,5
>120-140/ >80-120	0,7	0,9	1,0	4,5
>80-120/ >60-80	0,7	1,3	1,4	4,5
≤ 80/ ≤ 60	1,4	1,8	1,9	4,5
Permissible irregularities on the running surface of rails in welded joints (the numerator), the rest of the length (the denominator), mm				
>140-160/ >80-120	0,3/0,3	0,5/0,7	1/	6/4
>120-140/ >80-120	0,5/0,7	1/1	1/2	6/4
≤ 120/ ≤ 80	1/1	2/2	2/3	6/4

doi: 10.15802/stp2015/46064
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End of table 1

The speed of passenger / freight trains, km/h.	Condition			
	Functional condition	Nonfunctional condition	Partly functional	Nonserviceable condition
Standards and tolerance of the rails tilt device				
>140-160/ >80-120	1/20	-	-	min1/40 max 1/12
≤ 140/ ≤ 120	1/20	-	-	min1/60 max 1/12
Depth of wave-like unevenness or potholes, mm				
>140-160/ >80-120	1,0	1,9	2,0	4,0
>120-140/ >80-120	1,0	1,5	2,0	4,0
≤ 120/ ≤ 80	2,0	2,5	3,0	4,0
Deflection of the ends (mm), including wrinkling and saddle				
>140-160/ >80-120	0,8	0,9	1,0	6,0
>120-140/ >80-120	0,9	1,0	2,0	6,0
>80-120/ >60-80	1,9	2,0	3,0	6,0
≤ <80/ ≤ 60	2,9	3,0	4,0	6,0

It is necessary to perform calculations to determine the parameters of deformation of the track for the boundaries determination of the under sleeper condition bases. Possible combination of the technical characteristics of the ballast and roadbed will be defined out of the condition classification boundaries of a rail-sleeper grid (table 1), by the allowable speed of trains on sections of the road with defective sleepers and mountings, and unsuitability sleepers or fasteners in [12].

Originality and Practical value

The classification of conditions the railway track reliability is developed at the allowed tolerances at the maintenance and improvement of rail track. The necessity of rationing the technical condition of the ballast and roadbed for designed classification was established.

Ukrzaliznytsia is one of the founders of the Council for rail transport of the States-participants of the Commonwealth and a member of OCRR. These bodies have issued standards that should be used and by our state: OCRR [23…25]; The Council of States-participants of the Commonwealth – interstate standard State standart 32192-2013 «Reliability of railway equipment. Basic concepts terms and definitions» and on its basis a new interstate standard «Security functional of railway equipment. Terms and definitions» is developed. This study will help with the implementation of these standards on the Railways of Ukraine. It also will provide the increasing of information efficiency in this area to ensure mutual understanding, unity of the representation and perception of information, including the legal relations of business entities with each other, governments, intergovernmental scientific and technical, trade and economic relations.

Conclusions

One of the new aspects of the interaction process between the track and rolling stock is solving of reliability and functional safety of the track problems. Given that the Ukrainian railways have no normative documents of these area, the area of research is important.

Analysis of regulatory framework the regulatory, technical and design documentation of railway track and its components have helped to define with:

− technical conditions of track design for a development of railway track reliability conditions classification;

doi: 10.15802/stp2015/46064
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− the need to establish the technical condition of the ballast and roadbed through the parameters of the track deformation.

Common materials that are listed in the paper permit the establishment of the characteristics and functional reliability of the track, and dependencies which are linked by these characteristics.

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doi: 10.15802/stp2015/46064
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ФОРМУВАННЯ ОЦІНОЧНИХ УМОВ ЖИТТЄВОГО ЦИКЛУ ДЕФОРМАТИВНОЇ РОБОТИ ЗАЛІЗНИЧНОЇ КОЛІЇ

Мета. Дане дослідження спрямоване на обгрунтування меж технічних станів залізничної колії (відповідно станам надійності) для можливості формування нормативної бази з надійності та функціональної безпеки залізничної колії України. **Методика.** Для досягнення мети дослідження використано методи аналізу технічних станів елементів та конструкцій колії, характерних для умов експлуатації залізниць України. **Результати.** Визначено відповідність технічних станів елементів та конструкції колій станам надійності за існуючими нормами. Вони базуються на оцінці станів колії за результатами колієвимірної стрічки. Стан кожного елементу конструкції колії впливає на її деформативну роботу, але досі відсутні норми, які б пов'язували стан елементів колії зі станом колії за колієвимірними стрічками. Обгрунтовано причини, за якими межі технічних станів не встановлено, та з'ясовано, які дослідження необхідно провести для їх встановлення. **Наукова новизна.** Розроблено класифікацію станів надійності залізничної колії за допустимими відхиленнями при влаштуванні й утриманні рейкової колії. Встановлена необхідність нормування технічних станів баластної призми та земляного полотна для розробленої класифікації. **Практична значимість.** Укрзалізниця є одним із засновників Ради із залізничного транспорту держав-учасників Співдружності. Цим органом видано міждержавний стандарт ГОСТ 32192-2013 «Надежность железнодорожной техники. Основные понятия термины и определения» та на його основі розроблено новий міждержавний стандарт «Безопасность функциональной железнодорожной техники. Термины и определения». У той же час Укрзалізниця є членом організації співпраці залізничних доріг Міжнародного союзу залізничного транспорту, де встановлені в усіх транспортних галузях норми з надійної та безпечної роботи залізниць. Дане дослідження допоможе впровадженню таких стандартів на залізницях України. Стандарти забезпечать підвищення інформаційної ефективності в розглянутій сфері, встановлюючи взаєморозуміння, єдність подання та сприйняття інформації, в тому числі, в договірно-правових відносинах між суб'єктами господарської діяльності, з органами влади, в міждержавних науково-технічних та торговельно-економічних відносинах.

Ключові слова: стан надійності колії; технічний стан колії; елементи колії; конструкція колії; нормативно-технічна та конструкторська документація; норми влаштування та утримання

doi: 10.15802/stp2015/46064 © І. О. Bondarenko, 2015

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

Наука та прогрес транспорту. Вісник Дніпропетровського національного університету залізничного транспорту, 2015, № 3 (57)

ЗАЛІЗНИЧНА КОЛІЯ

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ФОРМИРОВАНИЕ ОЦЕНОЧНЫХ УСЛОВИЙ ЖИЗНЕННОГО ЦИКЛА ДЕФОРМАЦИОННОЙ РАБОТЫ ЖЕЛЕЗНОДОРОЖНОГО ПУТИ

Цель. Данное исследование направлено на обоснование границ технического состояния железнодорожного пути (согласно состояниям надежности) для возможности создания нормативной базы по надежности и функциональной безопасности железнодорожного пути Украины. **Методика.** Для достижения цели исследования использованы методы анализа технических состояний элементов и конструкций пути, характерных для условий эксплуатации железных дорог Украины. **Результаты.** Определено соответствие технических состояний элементов и конструкций пути состояниям надежности по существующим нормам. Они базируются на оценке состояний пути по результатам путеизмерительной ленты. Состояние каждого элемента конструкции пути влияет на его деформативную работу, но до сих пор отсутствуют нормы, которые связывали бы состояние элементов пути с состоянием пути по оценке путеизмерительной ленты. Обоснованы причины, по которым границы технических состояний не установлены, и выяснено, какие исследования необходимо провести для их установки. **Научная новизна.** Разработана классификация состояний надежности железнодорожного пути за допустимыми отклонениями при устройстве и содержании железнодорожного пути. Установлена необходимость нормирования технических состояний балластной призмы и земляного полотна для разработанной классификации. **Практическая значимость.** Укрзализныця является одним из основателей Совета по железнодорожному транспорту государств-участников Содружества. Этот орган издал межгосударственный стандарт ГОСТ 32192-2013 «Надежность железнодорожной техники. Основные понятия термины и определения» и на его основе разработал новый межгосударственный стандарт «Безопасность функциональная железнодорожной техники. Термины и определения». В то же время Укрзализныця является членом организации сотрудничества железных дорог Международного союза железнодорожного транспорта, где установлены во всех транспортных отраслях нормы надежной и безопасной работы железных дорог. Данное исследование поможет внедрению таких стандартов на железных дорогах Украины. Стандарты обеспечат повышение информационной эффективности в рассматриваемой сфере, устанавливая взаимопонимание, единство представления и восприятия информации, в том числе, в договорно-правовых отношениях между субъектами хозяйственной деятельности, с органами власти, в межгосударственных научно-технических и торгово-экономических отношениях.

Ключевые слова: состояние надежности пути; техническое состояние пути; элементы пути; конструкция пути; нормативно-техническая и конструкторская документация; нормы устройства и содержания

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Prof. V. D. Petrenko, D. Sc. (Tech.) (Ukraine); Prof. D. V. Laukhin, D. Sc. (Tech.) (Ukraine) recommended this article to be published

Received: Jan. 15, 2015
Accepted: May 16, 2015

doi: 10.15802/stp2015/46064 © I. O. Bondarenko, 2015