Kovalchuk, O. B., Bal, O. M., & Kravets, I. B. (2024). Development of a methodology for researching the technical condition of elements of the upper structure of railway track. *Actual Issues of Modern Science. European Scientific e-Journal, 32*, 100-107. Ostrava: Tuculart Edition, European Institute for Innovation Development.

DOI: 10.47451/inn2024-08-03

The paper is published in Crossref, ICI Copernicus, BASE, Zenodo, OpenAIRE, LORY, Academic Resource Index ResearchBib, J-Gate, ISI International Scientific Indexing, ADL, JournalsPedia, Scilit, EBSCO, Mendeley, and WebArchive databases.

Oresta B. Kovalchuk, Postgraduate Student, Kyiv Institute of Railway Transport, State University of Infrastructure and Technologies; Sector Head, Lviv Scientific Research Institute of Forensic Science. Lviv, Ukraine.
ORCID: 0000-0002-8570-313X
Olena M. Bal, Candidate of Technical Sciences (PhD), Associate Professor, Department Head, Institute of Mechanical Engineering and Transport, Lviv Polytechnic National University; Senior Researcher, Lviv Scientific Research Institute of Forensic Science. Lviv, Ukraine.
ORCID: 0000-0003-2188-4098
Ivan B. Kravets, Candidate of Technical Sciences (PhD), Department of Railway Transport, Institute of Mechanical Engineering and Transport, Lviv Polytechnic National University; Researcher, Lviv Scientific Research Institute of Forensic Science. Lviv, Ukraine.
ORCID: 0000-0002-2239-849X, Scopus: 57221338019

Development of a methodology for researching the technical condition of elements of the upper structure of railway track

Abstract. To date, several specific methods have been developed for conducting a railway transport expertise to study the circumstances of a railway accident. The study of the technical condition of the elements of the upper structure of a railway track is a significant diagnostic task in forensic railway transport expertise. The need for such expertise arises from pre-trial investigation bodies, courts, legal entities, and individuals when resolving economic and civil disputes, such as criminal and administrative cases. The study aims to describe the order (algorithm) for determining the technical condition of elements of the upper structure of a railway track. This work is based on modern scientific research in forensic railway transport expertise and regulatory and technical documentation. To study the technical condition of the railway track's upper structure elements, it is necessary to develop an appropriate method. This study gives the conditions for appointing forensic experts for railway transport. The main criteria for the track's good condition and the requirements it must meet are described. The result of this study is the development of an algorithm to investigate the technical condition of the elements of the upper structure of the railway track in forensic science.

Keywords: forensic science of railway transport, traffic safety, derailment of rolling stock, technical condition of the railway track.

Ореста Богданівна Ковальчук, аспірантка, Київський інститут залізничного транспорту Державного університету інфраструктури та технологій; завідувач сектору, Львівський науково-дослідний інститут судових експертиз. Львів, Україна.
ORCID: 0000-0002-8570-313X
Олена Миронівна Баль, кандидат технічних наук, доцент., завідувач кафедри, Інститут

механічної інженерії та транспорту, Національний університет «Львівська політехніка»;
провідний науковий співробітник, Львівський науково-дослідний інститут судових експерти.
Львів, Україна.
ORCID: 0000-0002-8570-313X
Іван Богданович Кравець, кандидат технічних наук, кафедра залізничного транспорту,
Інститут механічної інженерії та транспорту, Національний університет «Львівська політехніка»;
Львівський науково-дослідний інститут судових експертиз, Львів, Україна.
ORCID: 0000-0002-2239-849X, Scopus: 57221338019

Розробка методики дослідження технічного стану елементів верхньої будови залізничної колії

Анотація. На сьогоднішній день розроблено кілька спеціальних методик, які використовуються при проведенні судової залізнично-транспортної експертизи в частині вивчення обставин залізничної пригоди. Метою дослідження є опис порядку (алгоритму) визначення технічного стану елементів верхньої будови залізничної колії. Ця робота базується на сучасних наукових дослідженнях у сфері судової залізнично-транспортної експертизи та нормативно-технічній документації. Для дослідження технічного стану елементів верхньої будови залізничної колії необхідно розробити відповідну методику. В даному дослідженні наведено умови для призначення судової експертизи залізничного транспорту. Описано основні критерії справного стану залізничної колії та вимоги, яким вона повинна відповідати. Результатом даного дослідження є розробка порядку (алгоритму) дослідження технічного стану елементів верхньої будови залізничної колії.

Ключові слова: судова залізнично-транспортна експертиза, безпека руху, схід рухомого складу з рейок, технічний стан залізничної колії.

Abbreviations:

RTD is regulatory and technical documentation.

Introduction

The relevance of this work is determined by the need for scientific and methodological support of forensic expert activities within the framework of the expert speciality 10.13.1 “Research of Engineering Equipment of the Upper Structure of the Track”. This involves solving diagnostic tasks to assess the technical condition of the elements of the upper structure of the track and check their compliance with the regulatory requirements for the safety of railway transport infrastructure.

The study aims to describe the order (algorithm) for determining the technical condition of elements of the upper structure of a railway track. This work is based on modern scientific research in forensic railway transport expertise and RTD. RTD on this topic is held for the first time and is registered with UkrINTEI (NDDKR registration card 0123u101166).

As of today, the Ministry of Justice of Ukraine has approved several specially developed methods for forensic railway transport expertise, in particular for analysing the circumstances of railway accidents (*Sokol, 2007*). During 2019-2020, the Lviv Research Institute of Forensic Examinations developed “Methodological Recommendations for the Study of Elastic Rail

Fasteners," which became the basis for creating a "Methodology for Studying Elements of the Upper Structure of the Track in Forensic Examination" (*Bal, 2020*).

The study of the technical condition of the elements of the upper structure of a railway track is a significant diagnostic task in forensic railway transport expertise. The need for such expertise arises from pre-trial investigation bodies, courts, legal entities, and individuals when resolving economic and civil disputes, such as criminal and administrative cases. Forensic railway transport expertise is assigned to analyse the circumstances of railway accidents or to assess the technical condition of elements of the upper and lower structure of the track, like rolling stock. The need to study the elements of the upper structure of the track also arises when checking their compliance with technical conditions and standards at the production and input control stage, i.e., even before they are laid in the structure of the railway track.

The results of the study

Investigation of the technical condition of the railway track in the presence of malfunctions of the elements of the upper structure of the track

Railway transport experts' main tasks are solving diagnostic and situational problems. One of these diagnostic tasks is to study the technical condition of the railway track.

The technical condition of the elements of the upper and lower structure of the railway track must meet the requirements of regulatory documents in force on the Railways of Ukraine, constantly guarantee reliability and ensure the safety of passenger and cargo transportation.

Among other things, the following basic requirements apply to a railway track as an engineering structure:

- the strength and stability of the railway track must ensure the safe and smooth movement of trains at the highest speeds set for this section.
- the railway track must ensure uninterrupted transportation at any time of the day and year.

Thus, the main criterion for the track's serviceability is its ability to ensure trains' safe and smooth movement at the highest speeds set for this section. (*Danilenko, 2010*; *Bondarenko, 2018*).

Therefore, to establish the technical condition of the railway track, it is necessary to comply with the requirements of regulatory documents in force on Ukraine's railway transport and the ability of the railway track to perform its functions.

To study the technical condition of a railway track, it is necessary to consider the technical condition of its elements:

- technical condition of the rails,
- technical condition of rail joints,
- technical condition of sleepers,
- technical condition of intermediate and butt joints,
- technical condition of the ballast layer,
- technical condition of the rail track as a geometric structure: technical condition of the rail track in width, technical condition of the rail track in the relative position of the rail threads in height ("level"), technical condition of the rail track in the direction in the plan (straightening).

The main and receiving and sending tracks and switches on them are considered to be in good working order if the following conditions are met:

(a) absence of acute defect rails in the track;
(b) the absence of unsuitable sleepers in the track of bushes that require a speed limit compared to the established one;
(c) there is no indentation or connection in the track through which it is required to limit the speed of trains or completely stop traffic;
(d) the track is secured from theft;
(e) the ballast prism is kept to the specified dimensions and clean;
(f) switches and blind intersections are kept according to the requirements of the PTE, established standards and tolerances, and in the absence of acute defect elements;
(g) rail joints, butt and intermediate joints, and rail connectors are kept in good condition; there are no splashes and sleepers in the joints that do not rest tightly on the ballast;
(h) roadsides, ditches, trays, mountain ditches and other drains are kept clean and ensure normal water outflow;
(i) the bridge bed, spans, supports, cones, riverbeds and fire-fighting equipment on artificial structures, the supervision of which is entrusted to the teams for the current maintenance of the track, are in good working order;
(j) railway crossings, approaches, decking, fences, main and spare barriers, warning signs and lighting are in good working order;
(k) signal and road signs in order;
(l) materials are stored in designated locations and cleaned on time upon completion of work.

If the listed conditions are met, the track is considered to be kept in excellent, good, satisfactory, or unsatisfactory condition, respectively, when evaluated in points according to the readings of the track measuring car. A kilometre is also considered unsatisfactory if it has at least one indentation, which requires reducing the set train speeds or closing it (*Instruction, 2012*; *Technical instructions…, 2012*).

There are 5 degrees of deviations from the norms of rail track maintenance.

The first-degree margins include margins within tolerances that ensure the safety and smoothness of train traffic. With such deviations, the established train speeds do not decrease, and no work is required to eliminate them.

The 2nd-degree margins include margins that do not require a reduction in the set speed and do not threaten the safety of train traffic but affect the smoothness of train traffic. They are the basis for assigning and carrying out scheduled preventive work.

Single 3rd degree indentations include indentations that do not require a decrease in the set speed and do not threaten the safety of train traffic, but affect the smoothness of train traffic and the intensity of accumulation of residual track deformations. They are the basis for assigning and carrying out scheduled preventive work.

The 4th degree includes indentations, the presence of which at set speeds worsens the smoothness of movement and leads to an intensive accumulation of residual track deformations. These indentations should be eliminated first.

The 5th degree includes deviations that increase the forces of interaction between the track and rolling stock to such critical values that in the presence of unfavourable combinations with

deviations in the content and loading of rolling stock, violations of the train driving mode and other conditions can lead to too rapid a growth of deformations and a threat to traffic safety. These deviations must be eliminated immediately.

Penalty points are awarded for deviations of the 3rd-5th degrees. Detected by track-measuring cars, the 2nd-degree deviations are considered only for scheduled preventive track work.

Other station tracks – sorting, traction, cargo, etc. - are considered in good working order, provided that they are safe traffic at the set speeds. These tracks are checked both by track-measuring trolleys and by manual track measurement within the established time frame.

Field inspections and measurements are systematically performed using special equipment to control the technical condition of the railway track.

Railway track crawlers and crossing attendants inspect their sections constantly. The track Foreman checks the railway track once a week, the roadmaster and the track Foreman check the track once every two weeks, and the Senior Road Master and the site manager check their section once a month. Commission monthly, quarterly, autumn, and spring inspections are also conducted.

The width and level of the rail track are checked using track templates, bogies, and track cars.

Track measuring car data provides complete information about the rail track's technical condition (*Technical instructions…, 2012*). On the belts of track measuring cars, data on the relative position of rail threads in height (level), on local subsidence (bumps, depressions) of each rail thread, on the width of the track, on the position of rail threads in the horizontal plane are continuously recorded in the form of a diagram.

Classification of all track faults divides them into five stages. Deviations within the established tolerances are a fault of the first stage. The most significant and unacceptable deviations belong to the fifth degree. Each deviation from the norms of rail track maintenance is decoded and evaluated in points. A qualitative assessment of the technical condition of the rail track based on the readings of the track measuring car is established depending on the sum of points per kilometre for all types of deviations and their degree.

Flaw detection trolleys and wagons equipped with electromagnetic and ultrasonic flaw detectors detect defects in track rails.

Investigation of the technical condition of the railway track in the presence of damage to the track

Over the last period, the number of theft cases of elements of the upper track structure has increased. It is worth noting that, in such circumstances, the main problem is the possibility of a threat to traffic safety due to the absence of stolen elements in the track.

As the practice of forensic railway transport expertise has shown, most often, there are steals of elements of intermediate and butt fasteners.

Rail fasteners, for their purpose, are divided into two groups: 1 – intermediate, 2 – butt. The first provides fastening of the rails to the sub–ref supports, and the second connects the rails at the joints. Thus, rail fasteners connect individual elements of the upper structures of the track into a single structure – a rail-sleeper grid and ensure the operation of this integral structure (*Danilenko, 2010*).

The joints of the rails are called joints. The most common design of a rail joint for a link track is a conventional mechanical patch-bolt joint. The composition of the bolt fastening of a mechanical joint includes two linings and four (with a four-hole pad) or six (with a six-hole pad) butt bolts with nuts and washers.

It should also be noted that the joint is the track's weakest and most stressful point. When the rolling stock passes through the joint, additional shock-dynamic actions are created on the track due to a significant (approximately twice) elastic drawdown of the rail thread and a gap. As a result, residual deformations in the ballast accumulate much more intensively in the joint zone, and sleepers and rail ends wear out. Therefore, the requirements for holding joints are quite high.

According to the requirements of regulatory documentation, namely instructions for the device and maintenance of the track of Railways of Ukraine (*Instruction, 2012*), in the absence of one butt bolt at the end of the rail with four-piece linings or two-with six-piece ones, the speed of trains is limited to 25 km per hour. If all the bolts at the end of the rail are missing, train traffic stops.

In order to establish the technical condition of the railway track after the theft of butt bonding elements and whether this technical condition meets the requirements of traffic safety, the expert needs to know the following information: the established speed of trains on this section, the type and number of stolen elements. It is significant whether the elements are stolen from the same joint or different ones.

According to the requirements of the instruction on the device and maintenance of the track of Railways of Ukraine (*Instruction, 2012*), defective intermediate rail fasteners (considering the missing ones) include: on the track with wooden sleepers – unsuitable linings, essential crutches and screws; on the track with reinforced concrete sleepers – unsuitable linings, embedded and terminal bolts, terminals, screws and anchors or fasteners that have wear, in which they lose their functions.

The defect rate of fasteners is calculated on a link and non-link track per kilometre or picket or link with a length of 25 m.

In order to establish the technical condition of the railway track after the theft of elements of intermediate rail fastening and whether this technical condition meets the requirements of traffic safety, the expert needs to know the following information: the type of fastening, the plot of sleepers (the number of sleepers per one km), the set speed of trains on this section. The track is located in a straight or curved section (if in a curve, then you need to specify the radius of the curve), the number of stolen elements. It is significant whether the elements are stolen in a row or selectively since it depends on what conditions the permissible speed of movement will be set – if there is a defective fastener or a cluster unsuitability.

The main stages of conducting a study of the technical condition of the elements of the upper structure of the track and the railway track in general

The first stage is preparatory.

At the preparatory stage, the expert gets acquainted with the resolution (resolution) on the appointment of an expert examination and other materials and finds out whether the technical parameters of the elements of elastic rail fasteners are provided in the initial data. If they are not present, it is necessary to inspect the research objects to obtain technical parameters that will be

subject to detailed research in the future.

The second stage is a detailed study.

During a detailed study, the actual technical parameters of the elements of the upper track structure are compared with the standard ones.

According to the task assigned to the expert, the study of IBC elements can be performed in one of two directions. The need to study the elements of the IBC may arise both at the stage of operation, i.e., when it is necessary to determine the technical condition of the track and at the stage of input control, when it is necessary to establish compliance with the technical parameters of the IBC elements with regulatory documents (technical conditions and state standards).

The third stage is the analysis of the study results and the formation of conclusions.

The study results are summed up at this stage, and conclusions are formed.

The third stage of studying the elements of the upper track structure at the entrance control stage is to determine whether they meet the technical conditions and state standards.

When studying the elements of the upper structure of the track in operation, the third stage is to determine the technical condition of the track by comparing the set speed on this section of the track with the permissible one. Provided that the set speed does not exceed the permissible speed limit, the technical condition of the track will be operational.

Discussion

The technical condition of the elements of the upper track structure is determined by analysing data obtained through full-scale inspection using special measuring devices (templates, track measuring and Flaw Detection cars, etc.), analysing data from the database of regulatory documents in force on the Railways of Ukraine, and performing particular calculations.

When conducting forensic examinations, this study can be performed when it is necessary to establish the technical condition of the element as a separate unit, for example, when determining whether the element meets the requirements of DSTU or other regulatory documents. Alternatively, if a specific section of railway track needs to be examined after the rolling stock derails. Since the condition of each structural element of a railway track affects its overall technical condition.

The study of the technical condition of the track on the section of rolling stock derailment is performed to establish compliance of the actual condition with the proper (regulatory) one, i.e., to establish malfunctions of the elements of the upper structure of the track before a railway accident.

Characteristic malfunctions in the track that can lead to the derailment of rolling stock can be:

- unsuitability of sleepers, transfer and bridge beams;
- unsuitability of fasteners;
- excess slope of the track width diversion or increase in the outer rail;
- excess deviations of the track in plan, level or width;
- track discharge; rail breakage;
- non-fit of the tip to the frame rail and others (*Guidelines, 2012*).

Conclusion

The methodology for studying the technical condition of the elements of the upper structure of the railway track will provide a systematic approach to assessment and control, which is key to ensuring the safety and reliability of railway transport.

This method will allow specialists to assess the causes of incidents and determine responsibility objectively, check the compliance of the technical condition of the elements of the upper structure of the track with the requirements of technical conditions, state standards, and regulatory documents, analyse the technical condition of the elements of the track in the event of railway accidents or disputes, and determine responsibility.

A clearly defined procedure (algorithm) for studying the technical condition of the elements of the upper structure of the railway track will allow us to systematise processes and ensure a high level of accuracy and objectivity in assessing the technical condition of the railway track.

Also, in the future, the algorithm can be adapted to new technologies and methods, which ensures continuous improvement of research processes.

Conflict of interest

The authors declare that there is no conflict of interest.

References:

Bal, O. (2020). *Methodological recommendations for the study of elastic rail fasteners: research report*. Lviv.: LNDISE. (In Ukrainian)

Bal, O., Bondarenko, I., Kovalchuk, O. & Grythyshyn, P. (2024). Improving the safety indicators of Ukrainian railways: a study of the longitudinal stability of the railway track. *MATEC Web of Conferences EOT 2023. 3rd International Scientific and Practical Conference "Energy-Optimal Technologies, Logistics and Safety on Transport"*.

Bondarenko, I., & Bal, O. (2018). *Reliability of the railway track: Textbook*. Kyiv: Trade Union Book. (In Ukrainian)

Charter of Joint Stock Company "Ukrzaliznytsia". (2015). Resolution dated September 02, 2015. (In Ukrainian). https://zakon.rada.gov.ua/laws/show/735-2015-%D0%BF#Text

Danilenko, E. (2010). *Railway track. Device, design and calculations, interaction with rolling stock. Textbook for higher educational institutions*. Vols. 1-2. Kyiv: Inpres. (In Ukrainian)

Guidelines on the Procedure for Internal Investigation of the Causes of Rolling Stock Derailments on the Railways of Ukraine. (2012). CRB-0036. Kiev. (In Ukrainian)

Instruction for the Device and Maintenance of the Track of Railways of Ukraine No. CP/0269 dated May 01, 2012. (In Ukrainian). https://budstandart.ua/normativ-document.html?id_doc=82294&minregion=8121

On Railway Transport. (1996). Law of Ukraine No. 273/96-BP dated July 04, 1996. (In Ukrainian). https://kodeksy.com.ua/pro_zaliznichnij_transport.htm

On Standardisation. (2014). Law of Ukraine No. 1315-VII dated June 05, 2014. (In Ukrainian). https://kodeksy.com.ua/pro_standartizatsiyu.htm

On Transport. (1994). Law of Ukraine No. 232/94-BP dated November 10, 1994. (In Ukrainian). https://kodeksy.com.ua/pro_transport.htm

Rules of Technical Operation of Ukrainian Railways. Order No. 411 dated October 20, 1996. (In Ukrainian)

Sokol, E. N. (2007). *Train wrecks (Forensic examination. Elements of theory and practice). Monograph*. Kyiv: Phoenix. (In Ukrainian)

Technical Guidelines for Assessing the Condition of the Rail Track According to the Indicators of Track

Measuring Cars and Ensuring the Safety of Train Traffic in Case of Deviations from the Standards of Rail Track Maintenance. (2012). CP/0267. Kyiv. (In Ukrainian)
Technical Instructions for the Device, Installation of Repairs and Maintenance of Non-Jointed Tracks on the Railways of Ukraine. (2012). CP-0266. Kyiv. (In Ukrainian)
Technical Instructions on the Rules of Entrance Control for Receiving Materials of the Upper Structure of the Track. (2012). VNDUZ 32.205.001-2012 CPU/CPU-0272. Kyiv. (In Ukrainian)