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CONDUCTING TECHNICAL DIAGNOSTICS OF METAL STRUCTURES OF SPECIAL SELF-PROPELLED ROLLING STOCK AND THE MAIN TYPES OF DETECTED INCOMPATIBILITIES

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This paper explores the principles of technical diagnostics aimed at detecting defects in the base metal of load-bearing structures through non-destructive testing. It is shown that under static loading conditions, there is degradation of the metal's resistance to brittle fracture in load-bearing structures with detected localized defects. Examples are provided of base metal failure during operation due to fatigue accumulation. Technical diagnostics is a crucial factor to maintain its operational condition, serving as a preventive measure to avoid failures of rolling stock, particularly related to the destruction of load-bearing structures. This can be achieved through a range of activities aimed at detecting various types of nonconformities, including defects in load-bearing structures (such as cracks, fractures, corrosion damage, etc.). The detection and timely elimination of the identified non-conformities are key to the safe and uninterrupted operation of special self-propelled rolling stock. Scientific research in the field of technical diagnostics will facilitate the development of more effective methods and tools for detecting, assessing and predicting defect progression, thereby improving reliability and extending the service life of this type of equipment. One of the major challenges faced by Ukrainian Railways is the presence of defects in the supporting structures of special self-propelled rolling stock. The resolution of this issue lies in the implementation of technical diagnostics using non-destructive testing methods. One of the main methods of non-destructive testing used in technical diagnostics is the magnetic powder method of testing. The magnetic powder method of non-destructive testing is based on the phenomenon of attraction of magnetic powder particles by magnetic scattering fluxes that arise over defects in magnetized test objects.
Keywords: *transport, special self-propelled mobile units, repair, diagnostics, modeling.*

Statement of the problem

For the safe operation of existing special self-propelled mobile units, it is necessary to take into account the negative impact of various damages on the mechanical properties of load-bearing structures, especially when assessing their technical condition based on defectoscopy results. This paper explores the principles of technical diagnostics aimed at detecting defects in the base metal of load-bearing structures through non-destructive testing. It is shown that under static loading conditions, there is degradation of the metal's resistance to brittle fracture in load-bearing structures with detected localized defects. Examples are provided of base metal failure during operation due to fatigue accumulation.

Scientific research in the field of technical diagnostics of metal structures of special self-propelled mobile units is extremely important for several key reasons:

- Enhancing safety: Timely detection and elimination of defects in metal structures prevent accidents, injuries to personnel and passengers, and damage to infrastructure.
- Extending service life: Regular and high-quality diagnostics enable timely repairs, significantly extending the operational life of special mobile units and reducing replacement costs.
- Optimizing maintenance costs: Scientifically based diagnostic methods accurately determine the condition of structures and predict repair needs, optimizing maintenance schedules and reducing unforeseen expenses.
- Increasing operational efficiency: Reliable and properly functioning equipment ensures uninterrupted and efficient operation of special self-propelled mobile units, which is critically important for their specific tasks.
- Implementing new technologies: Scientific research promotes the development and implementation of new, faster, and more accurate methods of non-destructive

testing and diagnostics, improving the quality of metal structure assessments.

● Improving the regulatory framework: Research results can be used to update and improve existing norms and standards in the field of technical diagnostics and operation of special mobile units.

Technical diagnostics (TD) of metal work of special self-propelled rolling stock (SPRS) is critical to ensure their reliable and safe operation throughout their entire life cycle. This category of rolling stock includes a variety of machinery and mechanisms used in specific industries, such as construction, mining, agriculture, railways, and others. The characteristic features of SPRS operation are:

- High dynamic and static loads: Work in harsh environments, often with overloads, vibrations, and shocks.

- Aggressive operating conditions: The exposure to environmental factors (moisture, temperature changes), as well as chemically active agents and abrasive materials.

- Specific operating conditions: Cyclic loads, long-term periods of inactivity followed by high intensity use.

- Responsibility of the tasks performed: Failure of the SPRS can lead to significant financial losses, injuries to personnel and environmental disasters.

- Design complexity: A large number of welded joints, moving elements, components and units requiring an integrated approach to diagnostics.

Despite the importance of TD, there are a number of issues that require scientific research and resolution:

- Insufficient development of diagnostic methods and means adjusted to the specifics of SPRS. Most of the existing TD methods are focused on general industrial equipment or vehicles for general-purpose use and do not fully take into consideration the design features and operating conditions of SPRS. This leads to a decrease in the accuracy and validity of diagnostics.

- The challenge of predicting the remaining resources of steel installations. Precise determination of the moment of critical defects occurrence and forecasting of the service life is a difficult task due to the multifactorial nature of damage accumulation processes. Existing wear and fracture models often do not take into account the full range of influencing factors.

- Limited possibilities of non-destructive testing (NDT) in operation.

Conducting high-quality NDT on large-sized and inaccessible elements of SPRS metal components is often technically difficult and costly. There is a need to develop more flexible, fast and highly sensitive NDT methods.

- Lack of complex systems for diagnosing and monitoring technical conditions.

Most enterprises use disparate diagnostic methods and tools, which makes it difficult to analyze the data and make reasonable decisions on maintenance and repair.

- There is a demand for integrated systems that combine various diagnostic methods, data processing, and forecasting.

- Insufficient amount of normative and technical documentation regulating the technical diagnostics of SPRS. Lack of accurate standards, methods and criteria for assessing the technical condition makes it difficult to implement effective diagnostic systems.

Analysis of the latest achievements on the identified problem

Bondarenko et al. (2023) study the dynamic interaction processes between rolling stock and track through experimental implementation [1]. The article presents the methodology and results of field tests aimed at analyzing the forces and displacements arising during train movement. The authors focus on understanding the interaction mechanisms to improve the safety and durability of railway infrastructure. The research has practical significance for optimizing the design of rolling stock and track.

Mukhamedova Z et al. (2021) addresses the issue of resource-saving maintenance and repair of special self-propelled rolling stock [2]. The article analyzes existing approaches to maintenance and proposes improvements to reduce costs and extend equipment service life. The authors emphasize the importance of implementing modern diagnostics and failure prediction methods. The study aims to enhance the operational efficiency of special rolling stock.

Fomin et al. (2024) describes the testing of load-bearing structures of special self-propelled rolling stock with a hydraulic crane and manipulator beyond their normative service life [3]. The article presents the methodology and results of tests aimed at assessing the residual strength and reliability of structures. The authors analyze detected defects and provide recommendations for further operation or repair. The study is important for ensuring the safe operation of special rolling stock after the end of its normative service life.

The article [4] provides an analysis of the technical condition of the structural elements of passenger cars. The vast majority of passenger cars have been in operation for more than 20 years and have already exhausted the resource assigned by the manufacturer. The service life of these cars has been extended several times due to the condition of the load-bearing structures. At the same time, the issue of the condition of the internal equipment of the cars, the level of its environmental safety, and the compliance of comfort systems with modern requirements was not raised. Systems for ensuring comfortable travel in passenger cars, which were designed and manufactured in the 70s-90s of the last century, do not meet modern EU requirements. The low level of comfort causes dissatisfaction among passengers who choose other carriers.

Mitrofanov et al. (2022) addresses the issue of indirect fuel rationing for special self-propelled rolling stock [5]. The article proposes a methodology for determining rational fuel consumption standards by considering various operational factors. The authors examine the benefits of indirect rationing in improving the efficiency of fuel and energy resource utilization. The study is relevant for optimizing the operating costs associated with SSRS.

Mukhamedova (2020) analyzes the assessment of reliability indicators of electromechanical equipment used in special self-propelled rolling stock [6, 7]. The article reviews the main parameters that characterize reliability and the methods used to determine them. The author evaluates the reliability of specific components of SSRS electromechanical equipment. The study's findings can be applied to predict failures and develop measures to improve reliability.

Musayev et al. (2023) examines the theoretical and practical aspects of determining the dynamic characteristics of traction rolling stock [8]. The article reviews various approaches to analyzing train dynamic behavior, including mathematical modeling and experimental studies. The authors highlight the critical importance of precise dynamic parameter evaluation to ensure the safety and efficiency of railway operations. The study offers practical insights for the design and operation of traction rolling stock.

Wang et al. (2023) proposes a vibration-theoretic approach to analyzing the vulnerability of nonlinear vehicle platoons [9]. The article examines models of vehicle movement within platoons and analyzes their stability under disturbances based on oscillation theory. The authors explore the factors influencing platoon vulnerability and propose methods for its assessment. This work contributes to the advancement of traffic management systems for autonomous vehicles.

The article analyzes possible options for the modernization of the fleet of DR-1A diesel trains, which is one of the main diesel trains in Ukraine, providing suburban transportation of passengers on the railways of Ukraine [10]. The main shortcomings in the current design are identified, as well as the reasons, according to which it is necessary to plan and implement the implementation program of the existing fleet of DR-1A diesel trains in Ukraine. An analysis of the experience of modernization of DR-1A diesel trains in countries where such rolling stock has been historically operated has been carried out. Thus, the experience of modernization of such diesel trains in the countries of the European Union – Lithuania and Latvia – was analyzed. It was concluded that it is necessary to form a program for the modernization of diesel trains to increase the efficiency of their use and restore the network of suburban communication on non-electrified sections of the railway. The complex problem of providing rolling stock for suburban transportation in non-electrified areas is defined and a complex approach to solving problematic issues with its provision is proposed.

Sulim et al. (2018) considers the theoretical and practical determination of the parameters of an onboard capacitive energy storage system for underground rolling stock [11]. The article presents a mathematical model for calculating the required parameters of the energy storage system, taking into account the train's modes of movement. The authors also describe experimental studies aimed at confirming the theoretical results. The study is important for the development of efficient energy recuperation systems in the subway.

Vallely (2020) in his doctoral dissertation examines a holistic approach to remote condition monitoring for accurate assessment of rail infrastructure and rolling stock [12]. The work covers various aspects of monitoring, including data collection, analysis, and interpretation to predict the technical condition of objects. The author develops and justifies an integrated approach to remote monitoring that contributes to the safety and efficiency of rail transportation.

The article [13] discusses the issues of aging of the operational fleet of cars. Currently, passenger cars with an extended service life are operated on the railway network of Ukraine, which is rapidly approaching the maximum permissible. The main indicators of transport (technical, economic, environmental), reliability and safety of movement depend on the age of the cars, currently the level of development of technical means and repair technologies for the restoration of rolling stock is rapidly increasing. To improve the competitiveness of rail passenger transportation, it is necessary to update the fleet of passenger cars, which will reduce repair costs.

Purpose and task statement

The main purpose of the article is to highlight the procedure for technical diagnostics of metal structures of special self-propelled rolling stock (for example, cranes, wagons, special equipment) in order to ensure their safe and reliable operation by timely detection of defects, assessment of technical condition and prediction of residual life.

Main objectives of the study

1. Assessment of the technical condition of structures - determination of strength, resistance to cracks, corrosion, fatigue and other types of damage.

3. Prediction of residual life - determination of the possibility of further operation or the need for repair/replacement.

4. Optimization of inspection frequency - scientific justification of the terms of technical inspection based on the analysis of material degradation.

Summary of the main material

Diagnostics is generally aimed at determining the state of certain objects or living beings. Technical diagnostics is designed to determine the state of technical objects. Technical diagnostics of machines studies the signs that characterize the presence of defects in machines and, based on these signs, gives a conclusion about the technical condition of the machine.

Machine diagnostics has existed for as long as the machines themselves have existed. Its simple forms always take place when a search for malfunctions of the technical device used is carried out, even using the most elementary techniques. Simple diagnostics is the most common in technology. Diagnostics becomes more complicated when methods for detecting defects require the use of various special methods and devices, and processing the results is associated with complex mathematical calculations.

Complex diagnostics is used, as a rule, for technical devices of high responsibility, where the economic costs of its implementation are appropriate. Technical diagnostics as a science has its own terms and definitions. Let us give the main ones. The object of technical diagnostics is a product, its component or workpiece, the condition of which is to be determined. In each specific case, the object must be presented in such a formalized form that best meets the tasks of its diagnosis [1-3]

A technical parameter is a physical quantity by which the object of diagnosis is characterized. The technical parameters of an object can be its own mass, the effort it develops, speed, power, acceleration, productivity, as well as linear dimensions, safety margin, resource, etc. Over time, the object deteriorates in its technical condition and its technical parameters deteriorate.

A diagnostic sign is a phenomenon or process that accompanies a change in a technical parameter and can be registered when diagnosing a product. Examples of diagnostic signs for machines can be a decrease in speed or effort in the mechanism, loss of drive power, as well as a change in stresses in areas of damage to parts, structural vibration, etc. The indicator of a diagnostic feature is a quantitative expression of a diagnostic feature. The indicator is expressed by a physical quantity by which a diagnostic feature is measured. Retrospection is a review of past events. In relation to diagnostic tasks, retrospection consists in reviewing the statistics of changes in a technical parameter in the past, that is, until the moment of diagnosing the object. Diagnosis is the result of diagnosis. This is a specific quantity that characterizes the state of the object according to the results of its diagnosis. The value of the diagnosis can be absolute (deterministic) or probable. Forecasting is a logical continuation of diagnosis and means a prediction, a scientific forecast of the state of the object in the future. Forecasting is performed on the basis of retrospection and diagnosis data. Forecast - the result of forecasting. The methods of presenting the forecast are generally the same as those of the diagnosis. A defect is a deviation in the technical condition of an object or its individual parts. There is a somewhat narrower concept of a defect as a defect in a product obtained during its manufacture. Damage is a defect that occurs when using an object. A formalized model of an object is the result of its schematization for diagnostic purposes. The model differs from drawings, structural, kinematic, principle and other schemes in that it best corresponds to solving the problems of obtaining diagnostic data of an object. A defect model is a generalized number of possible violations in the design or operation of a machine that change its technical condition. A technical diagnostic tool is a device or other technical device designed to register a diagnostic feature and its quantitative assessment. A diagnostic method is a way of searching for a phenomenon to detect a defect, measure it and process the results obtained. A diagnostic algorithm is a general procedure for performing operations during diagnostics up to data processing and obtaining the final result. A technical diagnostic system is a set of formalized models, methods and technical means of detecting defects, as well as an algorithm for diagnosing an object. Diagnostic error is the probability that the technical condition in which the object is actually located at the moment will be found as a result of the applied system [4, 5].

The main types of inconsistencies detected

1. Cracks and tears - in areas of high stress (welds, attachment points of components).

2. Corrosion damage - loss of metal thickness, pitting or intercrystalline corrosion.

3. Deformations - curvature, deflection, loss of geometric shape due to mechanical stress.

4. Defects of welded joints – incomplete penetration, pores, slag inclusions.

5. Fatigue damage - microcracks due to cyclic loads.

6. Wear of friction units - damage to joints, bearings, fasteners.

7. Damage from impacts and overloads - localized tears, dents.

The following types of inconsistencies are most often detected during technical diagnostics of metal structures of special self-propelled rolling stock:

Defects in welded joints:

Cracks: Longitudinal, transverse, root, in the heat affected zone.

Failures and incomplete penetration: Lack of connection between welded elements.

Porosity and slag inclusions: Defects that reduce strength and corrosion resistance.

Undercuts: Reduced cross-section of the base metal near the weld.

Unevenness of the weld: Deviations from the specified dimensions and shape.

Corrosion damage:

General (pitting) corrosion: Uniform destruction of the metal surface.

Pitting corrosion: Localized pitting.

Crevice corrosion: Corrosion in narrow gaps and under seals.

Intercrystalline corrosion: Failure along the grain boundaries of a metal.

Stress corrosion cracking: Failure due to both the corrosive environment and stresses.

Deformation and geometric deviations:

Residual deformation: Distortions, deflections, twisting of structural elements.

Change in geometric dimensions: Deviations from the design values.

Fatigue cracks: The formation and development of cracks under cyclic loads.

Wear and damage to friction surfaces: Reduction in size, scoring, chipping.

Mechanical damage:

Cracks and tears: Due to impact loads, overloads or stress concentrations.

Dents and scratches: Damage to the surface due to external influences.

Distortion and breakage of individual elements.

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In view of the above, it can be argued that the identification and classification of these discrepancies is a primary task of technical diagnostics, since it is on their basis that decisions are made on the need and nature of repair work to ensure the safe and reliable operation of special self-propelled rolling stock.

Rail transport is a leading sector of the transportation system. Technical diagnostics is a crucial factor to maintain its operational condition, serving as a preventive measure to avoid failures of rolling stock, particularly related to the destruction of load-bearing structures. This can be achieved through a range of activities aimed at detecting various types of nonconformities, including defects in load-bearing structures (such as cracks, fractures, corrosion damage, etc.). One of the most common types of nonconformities in load-bearing structures is cracking in welded joints or in the base metal itself. One way to enhance the operational efficiency of special self-propelled rolling stock is to improve its load-bearing structures to ensure stable reliability indicators. This will contribute to higher operational efficiency and to the development of new designs for future special self-propelled rolling stock [6-8].

Fig. 1 – Special self-propelled rolling stock type ADM

ADM - assembly and restoration railcar for power supply services, a self-propelled two-axle vehicle with an internal combustion engine, equipped with special technological equipment (Fig. 1). It is used in construction, assembly and repair work, as well as in current maintenance of the contact network. It is equipped with a drilling rig for developing pits for railway supports of the contact network and a crane-manipulator for their installation, as well as a grounded lifting and retractable assembly platform with a telescopic tower.

Fig. 2 – Special self-propelled rolling stock type DHK^{U}

DHK^{U} - intended for repairing and dismantling work and transportation of vantage materials during in-line repair and repair of slick tires, as well as transportation of work crews with tools to the site repair and track robots (Fig. 2). A railcar can be used for supplying electricity to residents with a total power of up to 30 kW. The tires are equipped with a cantilever-type rotating jack-up crane. The crane drive is electromechanical. The capacity of freight trolley with manipulator from 1.7 to 3.5 t (for DGKu-5 from 2 to 5 t) is constant. To reload the trolley, a hydromechanical gearbox is used, which allows for smooth acceleration and reloading at low speeds.

Technical diagnostics was conducted on the metal structures of special self-propelled rolling stock to detect nonconformities (deformations, fractures, breaks, cracks) in structural elements. Technical diagnostics refers to the set of measurement, calculation, and logical operations that, based on their results, allow an assessment of the actual condition of the inspected object and, accordingly, enable the adoption of necessary management measures.

The condition of the frame metal structures was assessed using non-destructive testing (NDT) methods. One of the primary NDT methods used during technical diagnostics was the magnetic particle testing method. Magnetic particle testing is based on the phenomenon of magnetic flux leakage at defects, which attracts magnetic powder particles applied to the magnetized objects under inspection.

Table 1

Main types of nonconformities detected in load-bearing structures during technical diagnostics

Nonconformity type	Quantity, pcs
Cracks in the base metal	33
Cracks in welded joints	27
Cracks in the water heater suspension brackets	23
Total	83

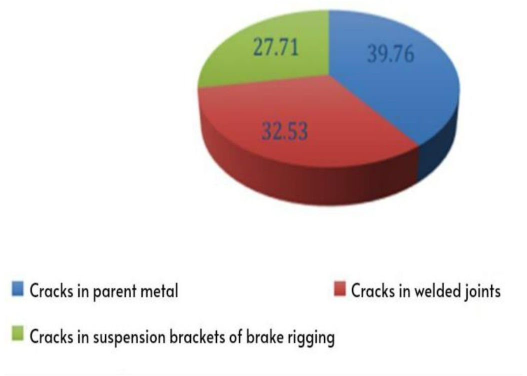

Fig. 3 – Distribution of the main types of non-conformities as a percentage

Figure 3 shows that the non-conformities are generally distributed in approximately equal proportions, with a slight increase (7%) in cracks detected in the parent metal, amounting to 39.76% as a consequence of metal aging. This conclusion is supported by an analysis of the age structure of the SSRS (special self-propelled rolling stock) fleet, obtained from open sources, indicating that 619 units or 81.5%, have been in operation for more than 20 years. The average age of the SSRS fleet is 35 years.

Figure 4 shows the distribution diagram of the main non-conformities by type of special self-propelled rolling stock. As can be seen from the diagram, the highest number of non-conformities is associated with two types of rolling stock:

1) railcars of the mounting diesel railcar series;

2) trolleys of the freight crane multipurpose rail trolley series.

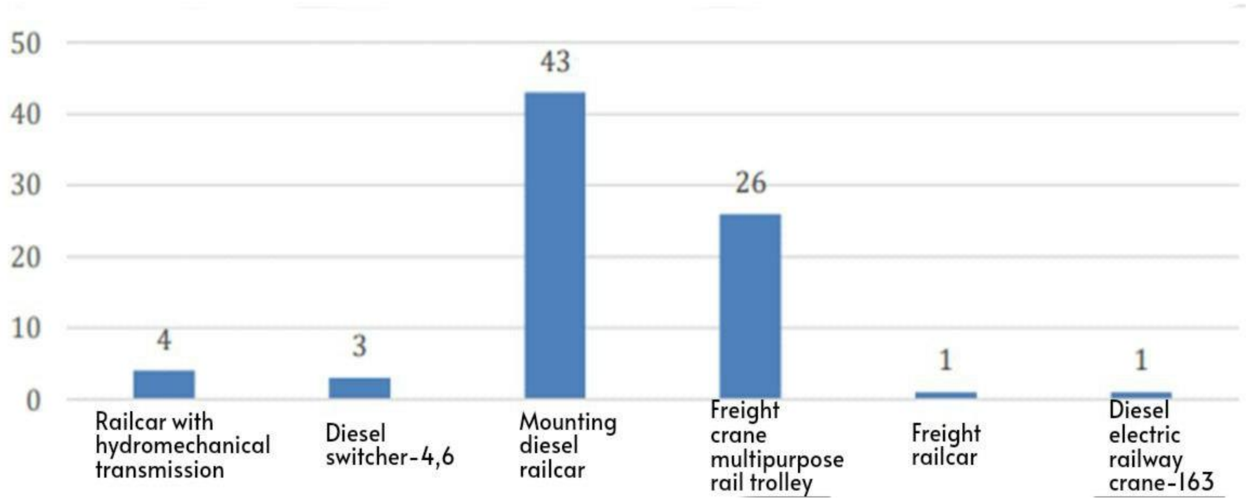

Fig. 4 – Distribution of the main non-conformities by type of special self-propelled rolling stock

Table 2

Distribution of the main non-conformities by types of special self-propelled rolling stock

	Railcar with hydromechanical transmission	Diesel switcher-4.6	Mounting diesel railcar	Freight crane multipurpose rail trolley	Freight railcar	Diesel electric railway crane-163
1	2	3	4	5	6	7
Cracks in parent metal	1	3	16	12	1	-
Cracks in welded joints	2	1	15	8	-	1
Cracks in suspension brackets of brake rigging	1	-	16	6	-	-

The primary non-conformities detected in supporting structures during technical diagnostics are fatigue cracks of various types. As shown in Table 2, the most common defects include cracks in parent metal, cracks in welded joints and cracks in suspension brackets of brake rigging (Fig. 5).

Fig. 5 – Non-conformities detected in supporting structures during technical diagnostics

Fatigue failure is the failure of metals under the action of constant (cyclic) loads. The physical nature of fatigue failure of metals is quite complex and not fully understood. One of the main consequences of fatigue failure is considered to be the occurrence and growth of cracks [9].

Fatigue failure compared to failure from a single application of static load has a number of features:

- it occurs at stresses lower than those under static load, usually lower than the yield strength;
- fractures occur on the surface or under the surface in specific places of stress concentration (ruptures, deformation). Local stress concentration occurs as a result of damage to materials as a result of constant loading or due to poor-quality processing, atmospheric exposure or aggressive environment, etc.;
- fracture occurs in several stages, which determine the processes of fatigue accumulation in the material, crack formation, gradual development and fusion of some of them into one main defect and rapid destruction of the material [11];
- the failure has a characteristic fracture structure, which reflects the sequence of processes that occurred. The fracture consists of a fracture center (place of microcrack formation). The fracture center is adjacent to the surface of the sample (part) and has small dimensions and a smooth surface [12-13]. The fatigue zone is formed by the sequential development of a fatigue crack. In this zone, characteristic grooves are observed, which have a ring configuration, which indicates the jump-like advancement of the fatigue crack [15]. The fatigue zone develops until the stresses in the working cross-section, which are decreasing, increase so much that they cause its instantaneous failure. This last stage of failure is characterized by the dolam zone.

The resolution of the specified issue must be based on pre-repair diagnostics of the condition and timely scheduling of special self-propelled rolling stock for repair. It should also involve additional diagnostics at repair facilities, the selection of technologies that ensure the required repair quality and the determination of the necessary scope of work.

Conclusions

The detection and timely elimination of the identified non-conformities are key to the safe and uninterrupted operation of special self-propelled rolling stock. Scientific research in the field of technical diagnostics will facilitate the development of more effective methods and tools for detecting, assessing and predicting defect progression, thereby improving reliability and extending the service life of this type of equipment.

The conducted study revealed that one of the major challenges faced by Ukrainian Railways is the presence of defects in the supporting structures of special self-propelled rolling stock. The resolution of this issue lies in the implementation of technical diagnostics using non-destructive testing methods.

References

[1] I. Bondarenko, V. Lukoševičius, R. Keršys, and L. Neduzha, «Investigation of Dynamic Processes of Rolling Stock-Track Interaction: Experimental Realization», *Sustainability*, vol. 15(6), article 5356, 2023. **doi: 10.3390/su15065356**.

[2] Z. Mukhamedova, «Resource-saving maintenance and repair of special self-propelled rolling stock», *Psychology and Education Journal*, vol. 58(1), pp. 3550-3555, 2021. **doi: 10.17762/pae.v58i1.1305**.

[3] O. Fomin, M. Tereshchuk, A. Cherkashin, O. Ptashnyi, Ie. Gunko, and I. Rodionov, «Testing of the Bearing Structures of a Special Self-Propelled Rolling Stock with Hydraulic Crane and Manipulator Device Beyond the Limits of the Normal Service Period», in Proc. of the 28th Int. Sci. Conf., Kaunas, Lithuania, 2024, pp. 804-809. **doi: 10.5755/e01.2351-7034.2024.p804-809**.

[4] I. Martynov, Yu. Kalabuxin, A. Trufanova, and S. Martynov, «Analiz vidmov lehkovykh avtomobiliv» [«Analysis of passenger cars failures»], *Komunalne hospodarstvo mist – Municipal economy of cities*, vol. 6, № 187, pp. 289-294, 2024. **doi: 10.33042/2522-1809-2024-6-187-289-294**. (Ukr.)

[5] A. Mitrofanov, A. Ivaschenko, A. Avsievich, V. Avsievich, and O. Golovnin, «Indirect Fuel Rationing for a Special Self-Propelled Rolling Stock», *Energies*, vol. 15(3), article 836, 2022. **doi: 10.3390/en15030836**.

[6] Z.G. Mukhamedova, «Assessment of reliability indices of electromechanical equipment of special self-propelled rolling stock», *Journal of Science and Innovative Development*, vol. 3(5), pp. 135-140, 2020. **doi: 10.36522/2181-9637-2020-5-16**.

[7] Z. Mukhamedova et al., «Calculating the fatigue strength of load-bearing structures of special self-propelled rolling stock», *Scientific Reports*, vol. 14(1), article 19205, 2024. **doi: 10.1038/s41598-024-70169-0**.

[8] J. Musayev, A. Zhauyt, S. Ismagulova, and S. Yussupova, «Theory and Practice of Determining the Dynamic Performance of Traction Rolling Stock», *Applied Sciences*, vol. 13(22), article 12455, 2023. **doi: 10.3390/app132212455**.

[9] P. Wang, X. Wu, and X. He, «Vibration-Theoretic Approach to Vulnerability Analysis of Nonlinear Vehicle Platoons», *IEEE Transactions on Intelligent Transportation Systems*, vol. 24, no. 10, pp. 11334-11344, 2023. **doi: 10.1109/TITS.2023.3278574**.

[10] D. Lomotko, O. Krasnoshtan, O. Kava, B. Novytskyi, and S. Pyshnyak, «Визначення оптимальних структур модернізації дизель-поїздів ДР-1А для відновлення логістики приміських пасажирських залізничних перевезень на неелектрифікованих ділянках залізниці» [«Defining of optimal modernization structure of DR-1A diesel momor units for suburban passenger rail logistics development on non-electrified railway lines»], *Informatsiini ta upravliaiuchi systemy na zaliz-nychnomu transporti – Information and control systems at railway transport*, № 3, pp. 43-52, 2023. **doi: 10.18664/ikszt.v28i3.290118**. (Ukr.)

[11] A.O. Sulim, O.V. Fomin, P.O. Khozya, and A. Mastepan, «Theoretical and practical determination of parameters of on-board capacitive energy storage of the underground rolling stock», *Scientific Bulletin of National Mining University*, iss. 5(1), pp. 79-87, 2018. **doi: 10.29202/nvngu/2018-5/8**.

[12] P. Vallely, «A Holistic Approach to Remote Condition Monitoring for the Accurate Evaluation of Railway Infrastructure and Rolling Stock», doctoral dissertation, University of Birmingham, UK, 2020.

[13] Мартинов І., Труфанова А., Сергієнко М. «Analiz osoblyvostei ekspluatatsii kuzoviv pasazhyrskykh vahoniv» [«Analysis of peculiarities of passenger car body wear»], *Zbirnyk naukovykh prats Ukrainskoho derzhavnoho universytetu zaliznychnoho transportu – Collection of Scientific Works of the Ukrainian State University of Railway Transport*, vol. 196, pp. 129-139, 2021. **doi: 10.18664/1994-7852.196.2021.242250**. (Ukr.)

ПРОВЕДЕННЯ ТЕХНІЧНОГО ДІАГНОСТУВАННЯ МЕТАЛОКОНСТРУКЦІЙ СПЕЦІАЛЬНОГО САМОХІДНОГО РУХОМОГО СКЛАДУ ТА ОСНОВНІ ТИПИ НЕВІДПОВІДНОСТЕЙ, ЩО ВИЯВЛЯЮТЬСЯ

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У цій статті досліджуються принципи технічної діагностики, спрямованої на виявлення дефектів основного металу несучих конструкцій за допомогою неруйнівного контролю. Показано, що в умовах статичного навантаження відбувається погіршення стійкості металу до крихкого руйнування в несучих конструкціях з виявленими локалізованими дефектами. Наведено приклади руйнування основного металу під час експлуатації *внаслідок накопичення втоми. Технічна діагностика є вирішальним фактором для підтримки його експлуатаційного стану, слугуючи профілактичним заходом для уникнення відмов рухомого складу, зокрема пов'язаних з руйнуванням несучих конструкцій. Цього можна досягти за допомогою комплексу заходів, спрямованих на виявлення різних видів невідповідностей, включаючи дефекти несучих конструкцій (такі як тріщини, розломи, корозійні пошкодження тощо). Виявлення та своєчасне усунення виявлених невідповідностей є ключем до безпечної та безперебійної експлуатації спеціального самохідного рухомого складу. Наукові дослідження в галузі технічної діагностики сприятимуть розробці більш ефективних методів та інструментів для виявлення, оцінки та прогнозування прогресування дефектів, тим самим підвищуючи надійність та продовжуючи термін служби цього типу обладнання. Однією з основних проблем, з якими стикається Українська залізниця, є наявність дефектів у несучих конструкціях спеціального самохідного рухомого складу. Вирішення цієї проблеми полягає у впровадженні технічної діагностики з використанням методів неруйнівного контролю.*

Ключові слова: *транспорт, спеціальний самохідний рухомий склад, ремонт, діагностика, моделювання.*

Перелік використаних джерел

[1] Investigation of Dynamic Processes of Rolling Stock-Track Interaction: Experimental Realization / Bondarenko I., Lukoševičius V., Keršys R., Neduzha L. *Sustainability*. 2023. Vol. 15(6). Article 5356. DOI: https://doi.org/10.3390/su15065356.

[2] Mukhamedova Z. Resource-saving maintenance and repair of special self-propelled rolling stock. *Psychology and Education Journal*. 2021. Vol. 58(1). Pp. 3550-3555. DOI: https://doi.org/10.17762/pae.v58i1.1305.

[3] Testing of the Bearing Structures of a Special Self-Propelled Rolling Stock with Hydraulic Crane and Manipulator Device Beyond the Limits of the Normal Service Period / O. Fomin et al. *Transport Means 2024* : Proceedings of the 28th International Scientific Conference, Kaunas, Lithuania, 2-4 October 2024. Pp. 804-809. DOI: https://doi.org/10.5755/e01.2351-7034.2024.p804-809.

[4] Аналіз відмов легкових автомобілів / Мартинов І., Калабухін Ю., Труфанова А., Мартинов С. *Комунальне господарство міст*. 2024. Т. 6, № 187. С. 289-294. DOI: https://doi.org/10.33042/2522-1809-2024-6-187-289-294.

[5] Indirect Fuel Rationing for a Special Self-Propelled Rolling Stock / A. Mitrofanov et al. *Energies*. 2022. Vol. 15(3). Article 836. DOI: https://doi.org/10.3390/en15030836.

[6] Mukhamedova Z.G. Assessment of reliability indices of electromechanical equipment of special self-propelled rolling stock. *Journal of Science and Innovative Development*. 2020. Vol. 3(5). Pp. 135-140. DOI: https://doi.org/10.36522/2181-9637-2020-5-16.

[7] Calculating the fatigue strength of load-bearing structures of special self-propelled rolling stock / Z. Mukhamedova et al. *Scientific Reports*. 2024. Vol. 14(1). Article 19205. DOI: https://doi.org/10.1038/s41598-024-70169-0.

[8] Theory and Practice of Determining the Dynamic Performance of Traction Rolling Stock / Musayev J., Zhauyt A., Ismagulova S., Yussupova S. *Applied Sciences*. 2023. Vol. 13(22). Article 12455. DOI: https://doi.org/10.3390/app132212455.

[9] Wang P., Wu X., He X. Vibration-Theoretic Approach to Vulnerability Analysis of Nonlinear Vehicle Platoons. *IEEE Transactions on Intelligent Transportation Systems*. 2023. Vol. 24, no. 10. Pp. 11334-11344. DOI: https://doi.org/10.1109/TITS.2023.3278574.

[10] Визначення оптимальних структур модернізації дизель-поїздів ДР-1А для відновлення логістики приміських пасажирських залізничних перевезень на неелектрифікованих ділянках залізниці / Д. Ломотько та ін. *Інформаційні та управляючі системи на залізничному транспорті*. 2023. № 3. С. 43-52. DOI: https://doi.org/10.18664/ikszt.v28i3.290118.

[11] Theoretical and practical determination of parameters of on-board capacitive energy storage of the underground rolling stock / Sulim A.O., Fomin O.V., Khozya P.O., Mastepan A. *Scientific Bulletin of National Mining University*. 2018. Iss. 5(1). Pp. 79-87. DOI: https://doi.org/10.29202/nvngu/2018-5/8.

[12] Vallely P. A Holistic Approach to Remote Condition Monitoring for the Accurate Evaluation of Railway Infrastructure and Rolling Stock : doctoral dissertation. University of Birmingham, 2020. 207 p.

[13] Мартинов І., Труфанова А., Сергієнко М. Аналіз особливостей експлуатації кузовів пасажирських вагонів. *Збірник наукових праць Українського державного університету залізничного транспорту*. 2021. Вип. 196. С. 129-139. DOI: https://doi.org/10.18664/1994-7852.196.2021.242250.

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