Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 5957-5970
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.3292

Investigation of the statistical data on the technical condition of brake equipment components of passenger carriages in operation

Vasyl Ravlyuk[1], Yaroslav Derevianchuk[2], Oleksandr Derevyanchuk[3*], Anna Krychun[4], Hanna Kravchenko[5]
[1,2]Department of Wagon Engineering and Product Quality, Ukrainian State University of Railway Transport, Feuerbach Square 7, 61050 Kharkiv, Ukraine; alyonalovskaya.vagons@gmail.com (V.R.) ravvg@kart.edu.ua (Y.D.).
[3,4]Yuriy Fedkovych Chernivtsi National University, 58012, Chernivtsi, Ukraine; o.v.derevyanchuk@chnu.edu.ua (O.D.) a.krychun@chnu.edu.ua (A.K.).
[5]High State Educational Establishment "Chernivtsi transport college", 58000, Chernivtsi, Ukraine; hannakravchenko81@gmail.com (H.K.).

Abstract: In the article, a study was conducted on improving the efficiency of braking systems in railway transport. Based on the information obtained regarding the maintenance of passenger cars, an analysis of brake equipment component failures was performed. Key trends and factors determining brake equipment component failures were identified from the collected statistical data for the reporting period. The main brake equipment components with the highest number of failures were highlighted. It was established that a significant portion of transport incidents due to brake failures in passenger cars occurs during operation, negatively impacting traffic safety. The collected data on the failures of electro-pneumatic distributors in passenger cars were systematized using the specialized software package "STATISTIKA". The research established that seasonal factors influence the total number of failures. A diagnostic system for the braking equipment of passenger trains was proposed to ensure traffic safety. The diagnostic system allows for the construction and analysis of mathematical models that describe the operational state of the braking equipment of passenger rolling stock as a whole. The diagnostic system enhances the reliability of brake operation, monitors air pressure in the brake line, ensures the inter-repair periods of passenger car components, and reduces the time required to detect failures both en route and during train stops. Recommendations for diagnosing the braking system of passenger trains were developed for continuous inspection and timely identification of failures. Their application will enable the prediction of the lifespan of pneumatic and electro-pneumatic system components in passenger cars, ensure the inter-repair operational periods of cars based on their current technical condition, and enhance traffic safety in railway transport.
Keywords: *Braking system, Control, Diagnostics, Equipment, Failure, Passenger car, Transport engineering.*

1. Introduction

To ensure the effective operation of JSC "Ukrzaliznytsia", it is necessary to implement progressive solutions aimed at high-quality passenger transportation by rail and ensuring traffic safety [1-4]. Therefore, special attention should be paid to the braking system of passenger rolling stock, as it is one of the most critical components for its operation.

The maintenance and repair system for wagons is designed to avoid forced train stops en route. All malfunctions must be detected and eliminated at maintenance points. Every day, a significant number of trains pass through warranty sections, and various malfunctions can occur during this process. Failures and malfunctions of wagon components that lead to train delays beyond the established norm or stop it en route affect the transportation process. One such component of a passenger wagon is the braking equipment [5, 6].

* Correspondence: o.v.derevyanchuk@chnu.edu.ua

The braking equipment of passenger wagons plays a critical role in ensuring traffic safety and passenger comfort during rail transportation. It is responsible for the effective stopping of the train under various operating conditions, including both normal and emergency situations. Effective operation and timely maintenance of the braking system are key to the reliability of passenger wagons, as well as the preservation of the lives and health of passengers and railway personnel.

Ensuring the reliable operation of the braking system during the operation of passenger trains is one of the main tasks of the wagon maintenance and repair system. To prevent braking system malfunctions, it is necessary to create an onboard system for passenger wagons that allows diagnosing the air distributor, electro-pneumatic distributor, and other brake elements en route.

Timely detection of faulty elements of the wagon's braking system allows for measures to improve the uninterrupted operation of the entire braking system, significantly reducing the time to eliminate malfunctions en route and improving traffic safety [7].

Existing systems for diagnosing wagon braking equipment are characterized by significant labor intensity and do not always ensure the reliability of their components at a high level. Therefore, improving the technology for diagnosing braking equipment under operating conditions and ensuring the safety of passenger train traffic is a relevant task.

2. Literature Review

The efficiency of rolling stock and railway transport equipment is an important element in ensuring the capacity and safety of railway traffic [8, 9]. This is the main task of all units of JSC "Ukrzaliznytsia".

In [10], the operation of rolling stock brakes using anti-skid devices with an electro-pneumatic valve and a system for monitoring their technical condition during passenger wagon transportation on domestic routes is considered. However, the work does not address issues related to diagnosing wagon components during their inspection at sectional stations where maintenance points are located.

The operation of the pneumatic braking system used in long freight rolling stock is considered in [11, 12]. A model for determining the longitudinal force in inter-wagon connections of rolling stock is proposed, and the longitudinal dynamics of the train are modeled for different cases of long, medium, and short brake application delay times. It is established that the number of wagons perceiving the tensile force decreases due to the increased brake application delay time depending on the train's speed. However, the studies did not focus on the reliable operation of the passenger train braking system, which requires the implementation of modern diagnostic systems for rolling stock.

In the work [13], the issues of safe and efficient operation of a significant number of wagons on the North American railway network according to the regulatory documents of the US Department of Transportation are highlighted. It was found that the current process of checking the technical condition of railway wagon components is time-consuming and heavily dependent on the qualifications of the workers. Therefore, to improve service quality and thoroughly detect wagon faults, the authors proposed a video system. This system allows for real-time image recording of wagons and the identification of structural faults, damages, and defects in wagon components to assess their technical condition. It should be noted that the work did not pay significant attention to the implementation of onboard diagnostic systems, which significantly reduced the time for technical inspection of wagons and ensured the reliable operation of the braking system of passenger rolling stock during train movement.

The state of modern modeling of pneumatic brakes with an emphasis on freight trains is highlighted in the work [14]. The classification of empirical, hydrodynamic, and hydroempirical dynamic models is considered. The use of classified models for dynamic processes occurring in pneumatic brake pipelines and train components is described. The presented models differ from other models used in hydrodynamics by the high accuracy of the obtained calculation results. Although the proposed models evaluate the qualitative and quantitative parameters of the braking system, their use on passenger rolling stock was not considered.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5957-5970, 2024
DOI: 10.55214/25768484.v8i6.3292

The article [15] presents the evolution of modeling the longitudinal dynamics of a train, which covers: systems connecting vehicles; pneumatic braking systems; acting forces that arise during train movement; braking phases of a rolling stock unit in a train and methods for their determination. The modeling of processes in the tribotechnical pair "brake pad - wheel" under different operating modes of the air distributor is considered. Modeling of train movement modes during transient processes is also analyzed. The stages of development of braking system models of rolling stock from analytical to computer models used in modern diagnostic and monitoring systems are analyzed. However, the authors paid significant attention to the processes occurring during the longitudinal dynamics of freight rolling stock.

The study of the technical condition of passenger wagon components can also be carried out during the implementation of STEM projects [16-18]. Involving students in solving real tasks significantly increases the effectiveness of the educational process, which corresponds to innovative strategies and teaching methods [19-23].

Modern diagnostic methods for technical means also involve the use of video surveillance systems and digital image processing of the studied objects, which allows for a significant degree of automation of the diagnostic process [24-30] and increases its accuracy [31-34].

A promising way to develop diagnostic methods for technical means is the implementation of cyber-physical systems (CPS) [35]. In such systems, physical equipment is combined with computer measurement and control devices using Internet of Things (IoT) technologies [36].

The study of literary sources [8-36] made it possible to establish that issues related to the tasks concerning the inoperative work of braking systems and their elements on passenger rolling stock of domestic and modern working fleets are quite relevant and require further development and study.

3. The Aim of the Article

This study aims to determine the operability of the braking equipment components of passenger trains by applying a diagnostic system.

To investigate the faults of the braking equipment components of passenger wagons, the following tasks need to be solved:

- Perform an analysis of the collected statistical material regarding the faults of the braking equipment components of passenger wagons;
- Systematize the material regarding the faults of brake equipment components in the specialized software package "STATISTIKA";
- Propose recommendations to improve the operability of brake equipment components of passenger wagons through the application of a diagnostic system.

4. Presentation of the Main Material

Based on the study of the current state of passenger wagon braking systems, an analysis of brake equipment faults under various operating modes was performed: charging and releasing; service braking; cut-off; full-service braking; emergency braking [37, 38]. During the technical inspection, the main focus was on the following key components of the passenger wagon brake equipment: electro-pneumatic distributors No. 305, air distributors No. 292, the electrical main line, brake fittings, brake main line, brake cylinders, spare reservoirs, etc. The technical inspection of these components was carried out in accordance with the current regulatory and technical documentation [39–41].

Based on the processing of the collected statistical material during the maintenance of passenger wagon brake equipment, a histogram was constructed (Figure 1). It shows the distribution of faults in the main components and elements of the pneumatic and electrical parts of the passenger wagon brake equipment for the period from 2019 to 2023.

For the considered period, there is a trend of decreasing the number of faults in the components and elements of the passenger rolling stock brake equipment in 2023 compared to 2019, due to the exclusion of a significant number of passenger wagons from the inventory fleet due to their technical condition and service life.

From the histogram (Figure 1), it is evident that in recent years, the components and elements of the pneumatic and electrical parts of the braking equipment of passenger wagons are the most vulnerable under operational conditions and are largely in an inoperative technical state. This indicates that the railway transport sector faces pressing issues related to improving the operability of the braking equipment components of passenger wagons to ensure train safety [8].

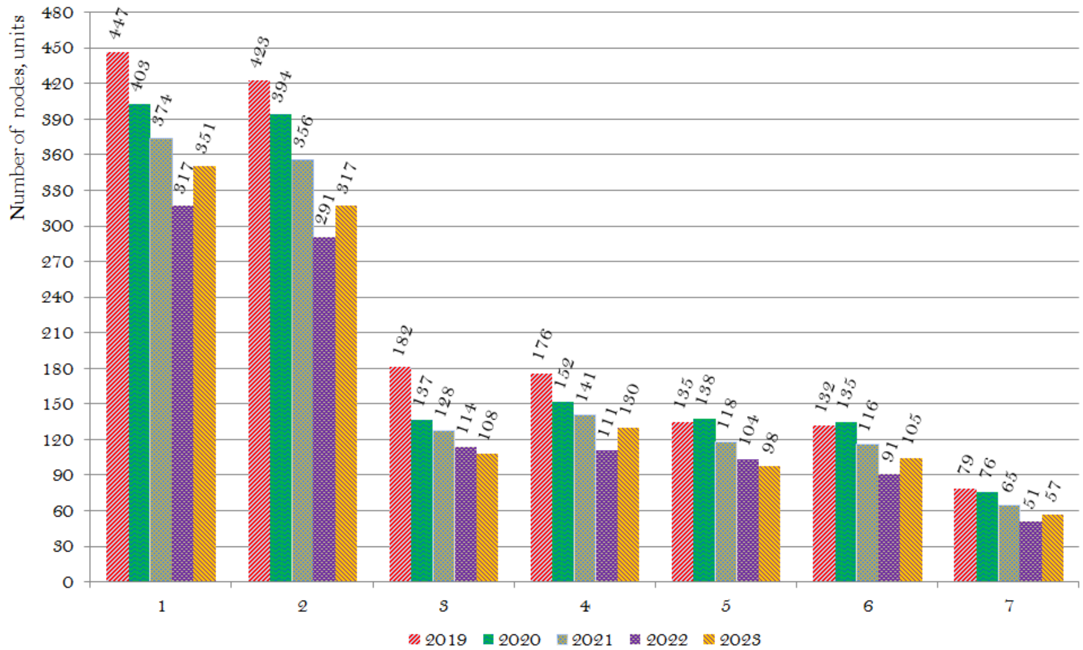

Figure 1.
Histogram of fault distribution in passenger wagon brake equipment. Number of Components, units.

1 - Electro-pneumatic distributor No. 305, 2 - Air distributor No. 292, 3 - Electrical main line, 4 - Brake fittings,
5 - Brake main line, 6 - Brake cylinder, 7 - Spare reservoir

For a qualitative assessment of the statistical material, the inspection of the braking equipment of passenger wagons was carried out throughout 2023 in the operational and repair units of the passenger complex of JSC "Ukrzaliznytsia". Based on the inspection results, the collected statistical material was processed, and a fault distribution diagram of the braking equipment components for 2023 was constructed (Figure 2).

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5957-5970, 2024
DOI: 10.55214/25768484.v8i6.3292

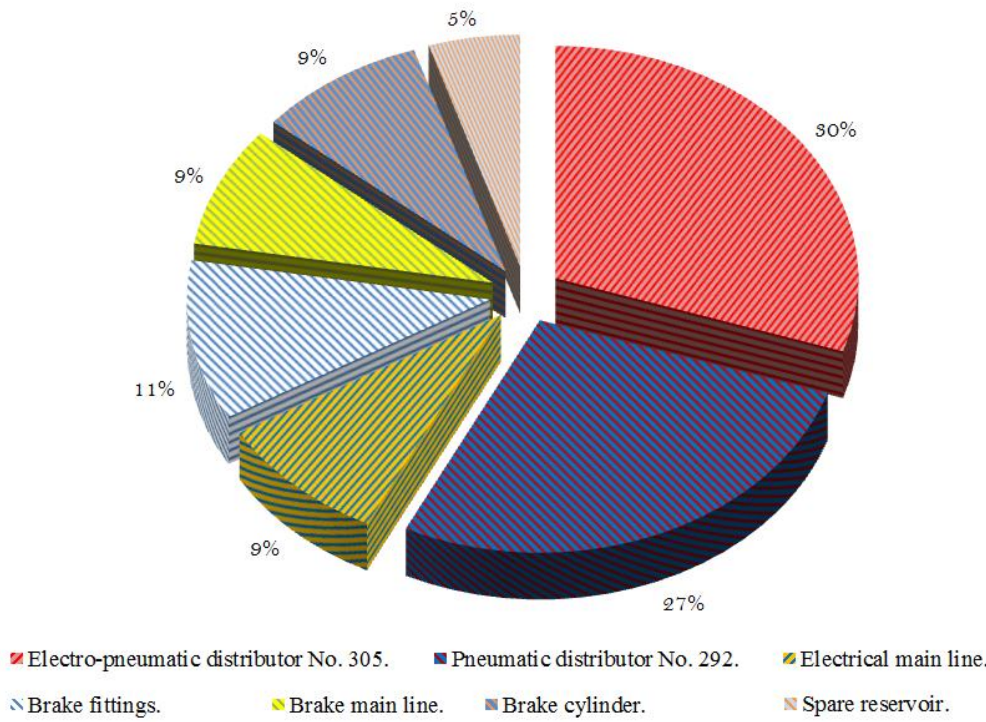

Figure 2.
Diagram of the distribution of faults in brake equipment components.

Based on the analysis of the diagram, the main types of faults in percentages are highlighted as follows:

- Faults in electro-pneumatic distributors No. 305, which occur due to inoperative brake and release solenoid valve, faulty pneumatic relay, clogged throttle holes; damaged (punctured) diode; damaged electrical contacts, etc., accounting for 30%;
- Faults in pneumatic distributors No. 292, which occur due to clogged throttle holes and filters; wear of the main and cut-off spool; wear of the sleeve and main piston, etc., accounting for 27%;
- Faults in the electrical main line, particularly due to damaged contacts of the electrical part of the connecting hoses, breakdown of the electrical wire to the body, damage or reduction of wire insulation resistance, lack of contact in terminal boxes, damage or breakage of wires, etc., accounting for 10%;
- Faults in brake fittings appear due to inoperative end valve, stop valve, and disconnecting valve, etc., accounting for 10%;
- Faults in the brake main line occur due to damaged pipes, loss of tightness at coupling joints, etc., accounting for 9%;
- Faults in brake cylinders appear due to worn seals, sagging or broken return springs, wear or bending of the rod, damage to the seal between the body and the cover, etc., accounting for 9%;
- Faults in spare reservoirs occur due to local wear, corrosion and mechanical damage, overdue testing, etc., accounting for 5%.

Based on the results of the technical inspection conducted under operating conditions at the formation and turnover point, as well as along the route, the distribution of faults in EPR No. 305 is shown (Figure 3).

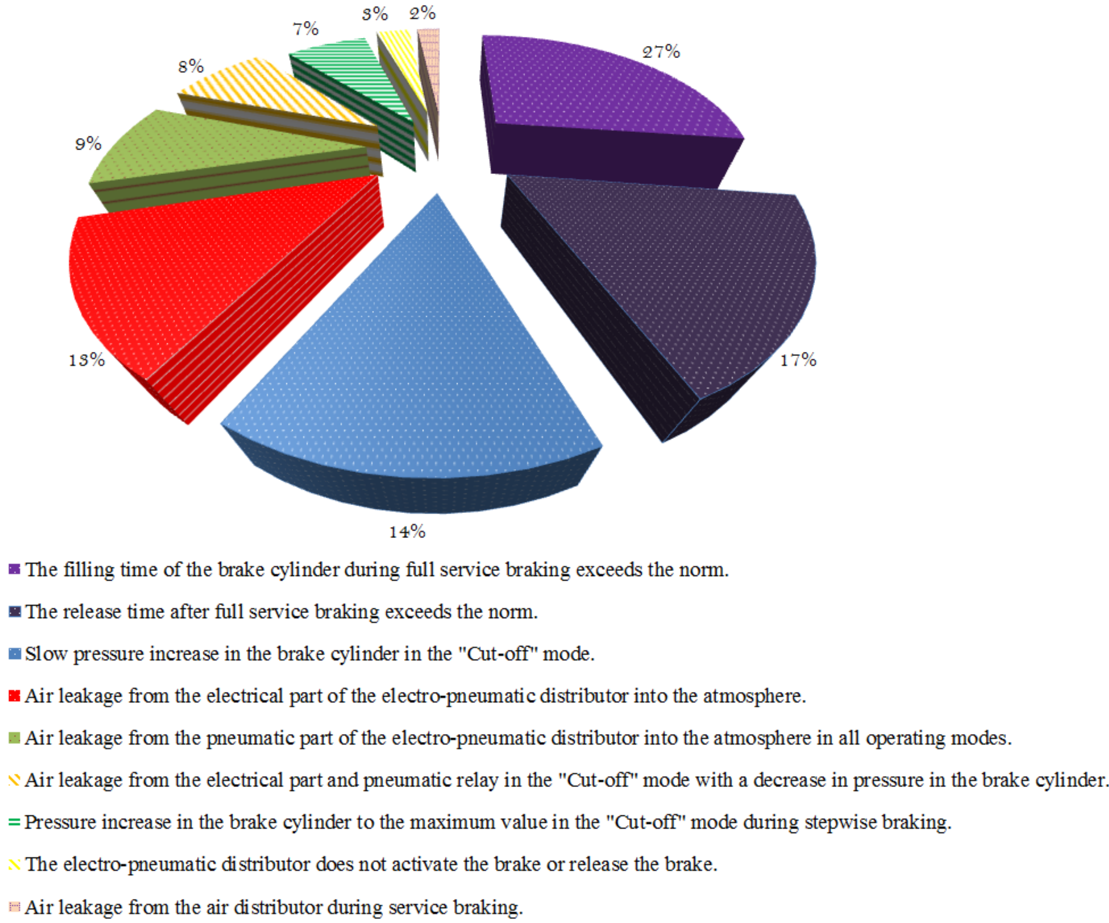

Figure 3.
Diagram of brake equipment failures due to electro-pneumatic distributor malfunctions.

Based on the analysis of the diagram, the main types of electro-pneumatic distributor malfunctions are highlighted as follows (in percentages):

- The filling time of the brake cylinder during full-service braking exceeds the norm due to clogged calibrated holes, misadjusted brake solenoid valve, sticking brake valve of the pneumatic relay, etc., which accounts for 21%.
- The release time after full-service braking exceeds the norm due to a misadjusted release solenoid valve, clogged calibrated holes, loss of flexibility of the pneumatic relay diaphragm, etc., which accounts for 19%.
- Slow pressure increase in the brake cylinder in the "Cut-off" mode occurs due to damage to the brake solenoid valve, which accounts for 15%.
- Air leakage from the electrical part of the electro-pneumatic distributor into the atmosphere occurs due to damaged gaskets, faulty release solenoid valve, etc., which accounts for 13%.
- Air leakage from the pneumatic part of the electro-pneumatic distributor into the atmosphere in all operating modes can occur due to a faulty brake valve of the pneumatic relay, damage or wear of the pneumatic relay seal, etc., which accounts for 11%.

- Air leakage from the electrical part and pneumatic relay in the "Cut-off" mode with a decrease in pressure in the brake cylinder occurs due to a faulty brake valve of the pneumatic relay, damage to the release valve of the pneumatic relay, faulty release solenoid valve, damage or wear of the pneumatic relay seal, etc., which accounts for 8%.
- Pressure increase in the brake cylinder to the maximum value in the "Cut-off" mode during stepwise braking occurs due to a faulty brake solenoid valve, a punctured diode, etc., which accounts for 7%.
- The electro-pneumatic distributor does not activate the brake or release the brake due to a damaged power circuit of the solenoid valve coils, faulty solenoid valves, etc., which accounts for 4%.
- Air leakage from the air distributor during service braking occurs due to damage to the switching valve due to defects in the operation of individual elements of the switching valve - damage to the seat or valve of the switching piston, which accounts for 4%.

  Table 1 provides statistical research data on the detection of electro-pneumatic distributor malfunctions No. 305, obtained for different mileage of passenger cars during their maintenance.

The optimal number of statistical data was determined by the formula [42, 43].

$$n = \frac{t^2 \cdot \sigma^2}{\delta} \quad (1)$$

where t – the value of Student's criterion for a given sample; σ – root mean square deviation of the random variable under study; δ – absolute error of the measurement result.

The average mileage of a passenger wagon after technical maintenance (TM-3) was 78.38 thousand km, and after depot repair (DR) was 148.89 thousand km.

Table 1.
Averaged statistical data on the faults of electro-pneumatic distributor No. 305.

Month of Observation	Number of Faults	Average Mileage Interval after TO-3, N, thousand km	Average Mileage Interval after DR, N, thousand km	Month of Observation	Number of Faults	Average Mileage Interval after TO-3, N, thousand km	Average Mileage Interval after DR, N, thousand km	Month of Observation	Number of Faults	Average Mileage Interval after TO-3, N, thousand km	Average Mileage Interval after DR, N, thousand km
1	31	77.53	47.79	29	27	104.71	208.53	57	34	63.49	145.61
2	29	72.42	156.75	30	26	71.32	123.5	58	36	89.84	223.16
3	27	45.26	104.75	31	27	97.95	138.38	59	39	88.16	243.1
4	26	98.87	165.54	32	28	39.1	56.46	60	41	32.76	201.84
5	25	94.13	119.87	33	29	102.36	179.17	61	42	97.13	74.87
6	23	116.41	93.76	34	31	120.18	243.75	62	39	71.15	53.59
7	22	99.56	178.94	35	32	52.48	170.18	63	37	95.14	207.89
8	24	81.09	84.99	36	33	120.46	177.43	64	36	33.17	49.27
9	25	99.3	176.14	37	36	117.37	146.51	65	34	79.28	195.02
10	27	98.26	64.71	38	34	33.55	201.03	66	31	112.83	171.94
11	28	117	194.43	39	33	70.93	196.06	67	33	109.41	174.1
12	30	41.02	77.57	40	32	69.64	59.12	68	34	106.22	170.99

13	27	66.48	246.14	41	30	67.12	144.96	69	35	104.39	230.16
14	26	98.35	54.69	42	29	69.64	77.54	70	36	58.25	120.22
15	25	77.26	129.93	43	30	116.9	244.49	71	39	62.79	120.61
16	23	65.79	45.45	44	31	33.76	60.99	72	41	62.61	175.01
17	23	38.33	90.7	45	32	33.46	152.31	73	43	41.57	86.71
18	22	99.68	206.06	46	34	100.23	127.28	74	42	115.5	136.86
19	21	71.61	151.43	47	36	30.1	115.88	75	40	69.39	241.69
20	23	36.37	118.33	48	37	96.53	157.55	76	39	76.34	107.77
21	24	48.54	135.3	49	40	51.84	110.75	77	37	51.75	85.25
22	25	47.45	149.23	50	36	115.03	127.36	78	33	37.65	224.54
23	25	88.96	198.5	51	35	34.26	240.84	79	35	66.25	66.49
24	27	87.29	180.34	52	34	100.26	213.84	80	36	117.83	178.92
25	33	110.86	114.63	53	32	71.94	185.62	81	37	63.07	154.76
26	31	74.41	231.54	54	31	52.17	186.62	82	39	88.18	185.07
27	30	83.04	142.15	55	32	87.95	235.74	83	41	121.84	137.1
28	29	83.76	44.25	56	33	94.45	142.28	84	43	111.88	49.18

Based on the obtained statistical data on the faults of electro-pneumatic distributors No. 305 in passenger wagons, the collected material for 2023 was systematized and processed using the specialized software package "STATISTIKA". The histogram (Figure 4) shows the experimental random variables of electro-pneumatic distributor faults, which are described by the normal distribution law.

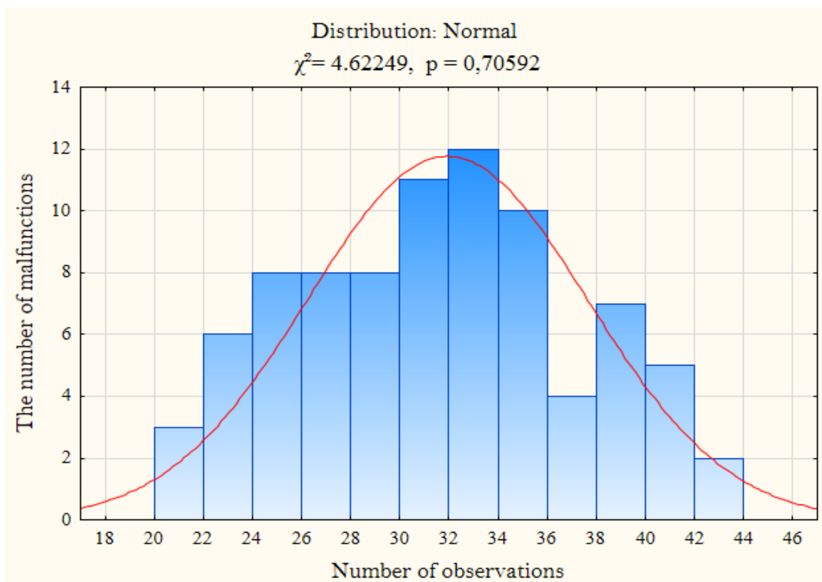

Figure 4.
Results of statistical data processing regarding faults in electro-pneumatic distributor No. 305 components.

The sample variance estimates of the population, i.e., the unbiased estimate, and the standard deviation, which is the estimate of the root mean square deviation based on the unbiased variance estimate, are calculated. Descriptive statistics for calculating the mean and sample variance are performed according to the following formulas:

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5957-5970, 2024
DOI: 10.55214/25768484.v8i6.3292

$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N}; \quad (2)$$

$$S^2 = \frac{\sum_{i=1}^{N} \left(x_i - \overline{x}\right)^2}{N-1}, \quad (3)$$

where N - the volume of the given sample; x_i - the i-th element of the sample.

It has been determined that the Chi-square criterion χ^2=4.622, the variance S^2=32.44, and the mean arithmetic value of malfunctions is 31.94.

Based on the results of the technical inspection of brake equipment faults distribution for 2023, it was established that the highest percentage of faults is attributed to electro-pneumatic distributors, accounting for 30%. This fully confirms the interim conclusion that the number of faults in electro-pneumatic distributors No. 305 depends on the season and increases mainly during periods of decreasing ambient air temperature, thus significantly increasing their total number (Figure 5). As a result, the operating conditions of the electro-pneumatic distributor components deteriorate – decreasing insulation quality, unsatisfactory condition of electrical contacts, destruction of solenoid valve coils, reduced quality of rubber seals and gaskets, damaged valve seats, and decreased lubricant quality, which ultimately leads to brake equipment component failures during train operation. Additionally, due to the loss of tightness in rubber seals, gaskets, and valve seats, the risk of air leaks increases, worsening both the operation of the components and the technical characteristics of the passenger wagon brake system as a whole.

The presented fault results and the conducted analytical studies of the electro-pneumatic distributor No. 305 operation process allowed for the first-time identification of several negative factors affecting the operability of their components under operational conditions. Moreover, these faults lead to increased operational costs, extended train travel time to the destination, and reduced traffic safety levels [44, 45].

ISSN: 2576-8484
Vol. 8, No. 6: 5957-5970, 2024
DOI: 10.55214/25768484.v8i6.3292

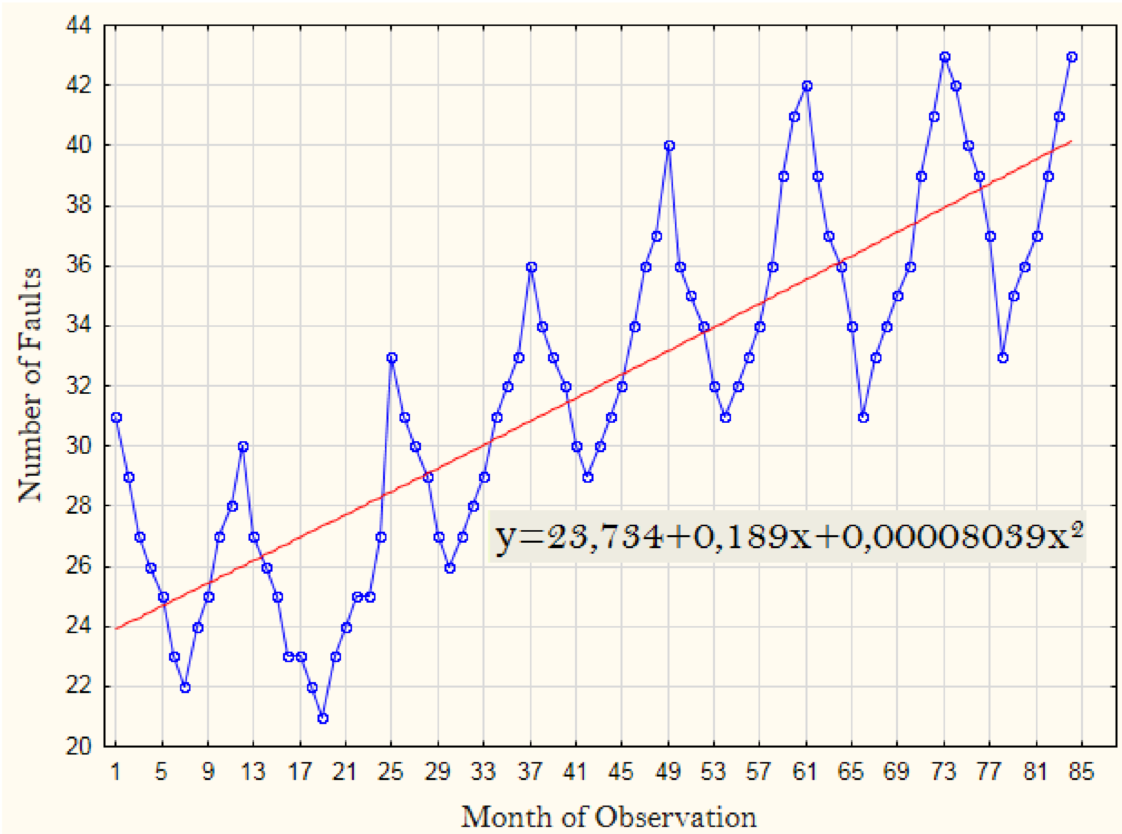

Figure 5.
Graphical distribution of the number of faults in electro-pneumatic distributors No. 305.

To reduce the number of transport incidents on railway transport due to faults in the braking equipment of passenger wagons, diagnostic systems need to be applied [46]. These systems combine the functions of assessing the technical condition of the passenger train's braking system and transmitting diagnostic information to a database. This will enable prompt technical decisions regarding the possibility of further movement of the passenger train.

The main criteria for the effectiveness of diagnostic systems are the reliability and promptness of obtaining information about the technical condition of the passenger wagon's braking system, the speed of processing and transmitting diagnostic information, the degree of autonomy and protection from natural and man-made interferences, and the consistency of the diagnostic system's operation with the passenger transportation process [47–49].

The braking system of a passenger wagon is characterized by structural quantitative parameters that reflect various physical quantities. The values of these parameters can be initial, permissible, and limit. During operation, structural parameters change, which generally leads to the deterioration of the technical condition of the passenger wagon's braking system components.

To obtain an approximate assessment of the technical condition of the passenger train's braking system, a set of direct and indirect signs (diagnostic parameters) is identified. These reflect the most probable defects associated with reduced operability and the occurrence of faults in the braking system [50].

The development and creation of a technical diagnostic system are based on studying the processes occurring in the braking components of passenger wagons and their possible faults. The diagnostic system includes the construction and analysis of mathematical models that describe the braking equipment and the main line of the passenger wagon as a whole in terms of operable condition [51].

The application of a diagnostic system for wagon braking equipment will allow for the detection and reduction of component faults, with subsequent entry of the results into an electronic database. Special attention should be paid to faults that recur periodically. In such cases, notifications are sent to the personnel responsible for maintenance, repair, and inspection of the wagon braking equipment components [40].

For continuous monitoring and timely detection of faults in the passenger train's braking system, diagnostic recommendations have been developed, which will allow:

- Monitoring the magnitude and polarity of the voltage on the working wire of the wagon's electro-pneumatic distributor;
- Monitoring the air pressure in the brake main line and pneumatic cylinder according to the braking system's operating mode;
- Monitoring the number of operations of the pneumatic and electro-pneumatic brakes of the passenger wagon in real-time, with subsequent recording of pressure and voltage parameters in an electronic database [51].

These recommendations will enable the prediction of the resource of the pneumatic and electro-pneumatic system components of the passenger wagon, ensure their inter-repair operational periods based on the current technical condition, and enhance the safety of train operations on railway transport.

5. Conclusion

An inspection of the braking equipment components of passenger wagons was carried out during their maintenance. Based on the conducted inspection and collected statistical material, a fault distribution diagram of the braking equipment components for 2023 was constructed. It was established that the highest number of faults is attributed to electro-pneumatic distributors No. 305, accounting for 30% of the total number of inspected components. Based on the processed statistical material regarding the faults of the braking equipment components, it was determined that the highest percentage is due to the unsatisfactory performance of electro-pneumatic distributor No. 305. It was specifically determined that 21% of faults are due to the excessive filling time of the brake cylinder during full service braking, 19% are due to the excessive release time after full service braking, and 15% result from the slow pressure increase in the brake cylinder in the "Cut-off" mode. These primary faults negatively impact both the overall operation of the braking system and the safety of train operations.

Methods of mathematical statistics were applied to determine the distribution of faults in electro-pneumatic distributors No. 305 used in the braking system of passenger wagons. The collected statistical data on the faults of distributors No. 305 were processed and systematized using the specialized software package "STATISTIKA". It was established that the random variables –faults of electro-pneumatic distributors – follow a normal distribution law. It was determined that the trends in the number of faults increasing or decreasing depend on the seasonal factors affecting them. The calculation has been performed which shows that the χ^2=4.622, S^2=32.44 and $\overline{x}$ =31.94.

It is proposed to use a diagnostic system for the braking equipment of passenger trains to ensure safety. The diagnostic system includes the construction and analysis of mathematical models and allows for the description of the operable state of the passenger wagon's braking equipment as a whole.

Recommendations for the application of the diagnostic system have been developed, which allow for monitoring the magnitude and polarity of the voltage on the working wire of the passenger wagon's electro-pneumatic distributor, monitoring the air pressure in the brake main line and pneumatic cylinder according to the braking equipment's operating mode, and monitoring the number of operations of the pneumatic and electro-pneumatic brakes of the passenger wagon during train operation. The application of the diagnostic system enables the prediction of the resource, ensures their inter-repair operational periods based on the current technical condition, and enhances the safety of train operations on railway transport.

Copyright:

References

[1] Lovskaya, "Computer simulation of wagon body bearing structure dynamics during transportation by train ferry," *EasternEuropean Journal of Enterprise Technologies*, vol. 3, no. 7 (75), pp. 9-14. 2015. https://doi.org/10.15587/1729-4061.2015.43749

[2] J. Dižo, "Analysis of a Goods Wagon Running on a Railway Test Track," *Manufacturing Technology*, vol. 16, no. 4, pp. 667–672. 2016. https://doi.org/10.21062/ujep/x.2016/a/1213-2489/mt/16/4/667

[3] J. Gerlici, A. Lovska, G. Vatulia, M. Pavliuchenkov, O. Kravchenko, and S. Solčanský, "Situational Adaptation of the Open Wagon Body to Container Transportation," *Applied Sciences*, vol. 13, no. 15 (8605). 2023. https://doi.org/10.3390/app13158605

[4] I. Elyazov, V. Ravlyuk, A. Rybin, and V. Hrebeniuk, "Determination of parameters of abnormal wear of brake pads of freight cars," *E3S Web of Conferences*, vol. 166, no. 07004. 2020. https://doi.org/10.1051/e3sconf/202016607004

[5] S. Panchenko, J. Gerlici., G. Vatulia, A. Lovska, V. Ravlyuk, and A. Rybin, "Method for determining the factor of dual wedge-shaped wear of composite brake pads for freight wagons," *Communications. Scientific Letters of the University of Zilina*, vol. 26, no. 1, pp. B31-B40, 2023. https://doi.org/10.26552/com.C.2024.006

[6] S. Panchenko, J. Gerlici, G. Vatulia, A. Lovska, A. Rybin, and O. Kravchenko, "Strength Assessment of an Improved Design of a Tank Container under Operating Conditions," *Communications - Scientific Letters of the University of Zilina*, vol. 25 no. 3, pp. B186-B193, 2023. https://doi.org/10.26552/com.c.2023.047

[7] Systema upravlinnia bezpekoiu rukhu AT "Ukrzaliznytsia": STP 01.03 - 003:2023 [Traffic safety management system: STP 01.03 – 003:2023]. 2023. 91 p.

[8] Analiz stanu bezpeky rukhu poizdiv na zaliznytsiakh Ukrainy za 2022 rik [Analysis of the state of train traffic safety]. Retrieved from https://old.dsbt.gov.ua/sites/default/files/imce/Bezpeka_DTP/2023/analiz_avariynosti_2022_1.pdf [Accessed 29-09-2024].

[9] Brake failures have been a problem for trains – since the 1880 s, Bangor Daily News, July 11, 2013. Retrieved from https://www.bangordailynews.com/2013/07/11/news/brake-failures-have-been-a-problem-for-trains-since-the-1880s/ [Accessed 29-09-2024].

[10] O. Fomin, and D. Turovets, "Vykorystannia protyiuznykh prystroiv z elektropnevmatychnym klapanom ta system kontroliu yikh tekhnichnoho stanu na pasazhyrskykh vahonakh vnutrishnoho spoluchennia,". *Podilskyi visnyk: silske hospodarstvo, tekhnika, ekonomika*, vol. 1, no. 38. 2023. https://journals.pdu.khmelnitskiy.ua/index.php/podilian_bulletin/article/view/149

[11] A. Nasr, and S. Mohammadi, "The effects of train brake delay time on in-train forces," *The manuscript was received on 16 August 2009 and was accepted after revision for publication on 30 March 2010. JRRT306 Proc. IMechE Vol. 224 Part F: J. Rail and Rapid Transit*, vol. 6, pp. 523-534. 2009. https://doi.org/10.1243/09544097JRRT306

[12] Sebeşan, C. Crăciun, and A. Maria, "The use of ringfeder characteristics for evaluation of longitudinal dynamic forces in train," *U.P.B. Sci. Bull., Series D*, vol. 76, vol. 2, pp. 77-88. 2014.

[13] B.W. Schlake, S. Todorovic, J. R. Edwards, J. M. Hart, N. Ahuja, and C. P. L. Barkan, "Machine vision condition monitoring of heavy-axle load railcar structural underframe components," *JRRT376, Proc. IMechE*, vol. 224, Issue 5, Part F: J. Rail and Rapid Transit. pp. 499-511, 2010. https://doi.org/10.1243/09544097JRRT376

[14] Q. Wu, C. Cole, M. Spiryagin, et al. "Freight train air brake models," *Int J Rail Transp*, vol. 11, pp. 1–49, 2023. https://doi.org/10.1080/23248378.2021.2006808

[15] Qing Wu, M. Spiryagin, and C. Cole "Longitudinal train dynamics: an overview, Vehicle System Dynamics," *International Journal of Vehicle Mechanics and Mobility*, vol. 54, 2016. https://doi.org/10.1080/00423114.2016.1228988

[16] V. Kovalchuk, A. Androsenko, O. Derevyanchuk, N. Volkova, and Y. Piven, "Development of pedagogical skills of students of technology and pedagogical specialties using STEM technologies,"*Edelweiss Applied Science and Technology*, vol. 8, no. 4, pp. 498-506, 2024. https://doi.org/10.55214/25768484.v8i4.1125

[17] O. V. Derevyanchuk, V. I. Kovalchuk, V. M. Kramar, H. O. Kravchenko, D. V. Kondryuk, A. V. Kovalchuk, and B. V. Onufriichuk, "Implementation of STEM education in the process of training of future specialists of engineering and pedagogical specialties," *Proceedings of SPIE*, vol. 12938, pp. 214-217, 2024. https://doi.org/10.1117/12.3012996

[18] Serhiy Balovsyak, Oleksandr Derevyanchuk, Vasyl Kovalchuk, Hanna Kravchenko, and Maryna Kozhokar, "Face Mask Recognition by the Viola-Jones Method Using Fuzzy Logic," *International Journal of Image, Graphics and Signal Processing (IJIGSP)*, vol. 16, no. 3, pp. 39-51, 2024. https://doi.org/10.5815/ijigsp.2024.03.04

[19] N. Ridei, D. Pavlenko, O. Plakhotnik, T. Gorokhova, and A. Popova, "Concept of forming the company innovation strategy. *Academy of Strategic Management Journal*," vol. 18 (Special Issue 1), pp. 1-6, 2019.

[20] N. M. Ridei, N. M. Tytova, V. I. Tymoshenko, V. V. Moroz, and N. V. Bibik, "Improvement of Methodological Approaches to Determining Directions of Financial Security of Ukraine. Universal Journal of Accounting and Finance," vol. 9, no. 4, pp. 613–622. 2021. https://doi.org/10.13189/ujaf.2021.090409

[21] N. Ridei, N. Tytova, V. Khodunova, T. Sydorenko, and G. Voronova, "Communication strategies in the management of socio-cultural activities: analysis and optimization of the impact of globalization on regional development in Ukraine," *Financial and Credit Activity: Problems of Theory and Practice*, vol. 1, no. 54, pp. 509-524, 2024.

[22] N. Tytova, V. Bogoliubov, V. Yefymenko, L. Makarenko, L. Mova, and N. Kalientsova, "Axiological concept of informatization of education in the age of globalization challenges," *Journal of management Information and Decision Sciences*, vol. *24*, no. 2, pp. 1-9, 2021.

[23] M. Zhang, Y. Cheng, J. Gu, Y. Yang, L. Chen, and B. Cui, "Digital Evaluation of Innovative Logistics Talents Based on Improved SAGA-FCM Algorithm," *In: Hu, Z., Zhang, Q., He, M. (eds) Advances in Artificial Systems for Logistics Engineering IV. ICAILE 2024. Lecture Notes on Data Engineering and Communications Technologies, 223, Springer, Cham*, pp. 374-383, 2024. https://doi.org/10.1007/978-3-031-72017-8_34.

[24] O. V. Derevyanchuk, H. O. Kravchenko, Y. V. Derevianchuk, and V. V. Tomash, "Recognition images of broken window glass," *Proceedings of SPIE*, vol. 12938, pp. 210-213, 2024. https://doi.org/10.1117/12.3012995

[25] S. V. Balovsyak, O. V. Derevyanchuk, I. M. Fodchuk, O. P. Kroitor, Kh. S. Odaiska, O. O. Pshenychnyi, A. Kotyra, and A. Abisheva, "Adaptive oriented filtration of digital images in the spatial domain," *Proc. SPIE 11176, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments*, vol. 11176, pp 111761A-1–111761A-6, 2019. https://doi.org/10.1117/12.2537165

[26] S. V. Balovsyak, O. V. Derevyanchuk, H. O. Kravchenko, O. P. Kroitor, and V. V. Tomash, "Computer system for increasing the local contrast of railway transport images," *Proc. SPIE, Fifteenth International Conference on Correlation Optics*, vol. 12126, pp. 121261E1-7, 2021. https://doi.org/10.1117/12.2615761.

[27] S. Balovsyak, K. Odaiska, O. Yakovenko, I. Iakovlieva, "Adjusting the brightness and contrast parameters of digital video cameras using artificial neural networks," *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 12938, pp. 129380I, 2024.

[28] N. Yadav, and A. Sinha, "Augmented Reality and its Science," *International Journal of Education and Management Engineering (IJEME)*, vol.12, no. 6, pp. 33-44, 2022. https://doi.org/10.5815/ijeme.2022.06.04.

[29] M. Segura, R. Osorio, and A. Zavala, "Extended Reality Model for Accessibility in Learning for Deaf and Hearing Students (Programming Logic Case)," *International Journal of Modern Education and Computer Science (IJMECS)*, vol. 15, no. 4, pp. 1-17, 2023. https://doi.org/10.5815/ijmecs.2023.04.01.

[30] Taras Basyuk, Andrii Vasyliuk, Yuriy Ushenko, Dmytro Uhryn, Zhengbing Hu, and Mariia Talakh, "Modeling and Development of a Computer Simulator with the Formation of Working Scenarios for Training Operator Personnel in the Search for Objects," *International Journal of Modern Education and Computer Science (IJMECS)*, vol. 16, no. 4, pp. 87-112, 2024. https://doi.org/10.5815/ijmecs.2024.04.07.

[31] Vo Hoai Viet, Huynh Nhat Duy, "Object Tracking: An Experimental and Comprehensive Study on Vehicle Object in Video", International Journal of Image, Graphics and Signal Processing (IJIGSP), vol. 14, no. 1, pp. 64-81, 2022. https://doi.org/10.5815/ijigsp.2022.01.06

[32] Dun Nan Liu, Rui Hou, Wen Zhuo Wu, Jing Wen Hua, Xuan Yuan Wang, and Bo Pang, "Research on infrared image enhancement and segmentation of power equipment based on partial differential equation," *Journal of Visual Communication and Image Representation*, vol. 64, 2019, 102610, https://doi.org/10.1016/j.jvcir.2019.102610

[33] Serhiy Balovsyak, Oleksandr Derevyanchuk, Hanna Kravchenko, Yuriy Ushenko, and Zhengbing Hu, "Clustering Students According to their Academic Achievement Using Fuzzy Logic," *International Journal of Modern Education and Computer Science (IJMECS)*, vol. 15, no. 6, pp. 31-43, 2023. https://doi.org/10.5815/ijmecs.2023.06.03

[34] Serhiy Balovsyak, Oleksandr Derevyanchuk, Vasyl Kovalchuk, Hanna Kravchenko, and Maryna Kozhokar, "Face Mask Recognition by the Viola-Jones Method Using Fuzzy Logic," *International Journal of Image, Graphics and Signal Processing (IJIGSP)*, vol. 16, no. 3, pp. 39-51, 2024. https://doi.org/10.5815/ijigsp.2024.03.04

[35] Rasmiyya Sh. Mahmudova, "Cyber-physical Systems: Security Problems and Issues of Personnel Information Security Culture", *International Journal of Education and Management Engineering (IJEME)*, vol. 13, no. 2, pp. 18-26, 2023. https://doi.org/10.5815/ijeme.2023.02.03

[36] Keerti Naregal, and Vijay Kalmani, "Exploratory Analysis of Access Control Mechanisms for Cloud-Based Iot", *International Journal of Education and Management Engineering (IJEME)*, vol. 13, no. 3, pp. 39-46, 2023. https://doi.org/10.5815/ijeme.2023.03.05

[37] S. Panchenko., J. Gerlici., G. Vatulia, A. Lovska, V. Ravlyuk, and J. Harusinec, "Studying the load of composite brake pads under high-temperature impact from the rolling surface of wheels," *EUREKA: Physics and Engineering*, vol. 4, pp. 155-167, 2023. https://doi.org/10.21303/2461-4262.2023.002994

[38] 38. V. Ravlyuk, M. Ravliuk, V. Hrebeniuk, and V. Bondarenko, "Process features and parametric assessment of the emergence of the excessive wear for the brake pads of freight car bogies," *IOP Conf. Series: Materials Science and Engineering*, vol. 708, no. 012025, 2019. https://doi.org/10.1088/1757-899X/708/1/012025

[39] Instruktsiia z remontu halmovoho obladnannia vahoniv: TsV - TsL - 0013 [Repair instructions: TsV - TsL - 0013]. 2004. 160 p.

[40] Instruktsiia z ekspluatatsii halm rukhomoho skladu na zaliznytsiakh Ukrainy: TsT - TsV - TsL - 0015 [Operating instructions for rolling stock brakes: TsT - TsV - TsL - 0015]. 2004. 146 p.

[41] Pravyla tekhnichnoi ekspluatatsii zaliznyts Ukrainy [Rules of technical operation of railways of Ukraine]. 2002. 133 p.

[42] L. V. Kamkina, A. A. Nadtochii, A. M. Hryshyn, Yu. D. Stohnii, Osnovy naukovykh doslidzhen: navchalnyi posibnyk [Fundamentals of scientific research: a study guide]. 2013. 89 p.

[43] L. L. Dzhavala, Yu. M. Sliusarchuk, Y. Ya. Khromiak, V. M. Tsymbal, Teoriia ymovirnostei, matematychna statystyka ta imovirnisni protsesy: navchalnyi posibnyk [Fundamentals of scientific research: a study guide]. 2015. 364p.

[44] S. Panchenko, A. Lovska, V. Ravlyuk, A. Babenko, O. Derevyanchuk, O. Zharov, and Y. Derevianchuk, "Detecting the influence of uneven loading of the brake shoe in a freight car bogie on its strength," *Eastern-European Journal of Enterprise Technologies*, vol. 5, no. 7(125), pp. 6-13. 2023 https://doi.org/10.15587/1729-4061.2023.287791

[45] S. Panchenko, J. Gerlici, A. Lovska, V. Ravlyuk, J. Dižo, J. Harušinec, "Study on the Strength of the Brake Pad of a Freight Wagon under Uneven Loading in Operation," *Sensors*, vol. 24, no. 2: 463, 2024. https://doi.org/10.3390/s24020463

[46] Vahony vantazhni. Systema tekhnichnoho obsluhovuvannia ta remontu za tekhnichnym stanom: STP 04 - 010:2018 [Freight cars. Maintenance and repair system according to technical condition: STP 04 - 010:2018] 2018. 25 p.

[47] V. G. Ravlyuk, "Determining the technical condition of rolling stock bushings by means of vibration diagnostics," *Eastern European journal of advanced technologies*, vol. 2, no 7(74), pp. 11-15, 2015. https://doi.org/10.15587/1729-4061.2015.39036

[48] V. V. Bondarenko, D. I. Skurikhin, R. I. Vizniak, V. H. Ravlyuk, and V. I. Skurikhin, "Experimental study of the method and device for wheel-sets acoustic monitoring of railway cars in motion," *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, no. 4, pp. 30-36, 2019. https://doi.org/10.29202/nvngu/2019-4/7

[49] V. G. Ravlyuk, S. V. Mykhalkiv, A. V. Rybin, Ia. V. Derevianchuk, O. A. Plakhtiy, "Forecasting of wear of pads of modernized brake system devices of bogies of freight cars using ARIMA models," *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, no. 6, pp. 48-54. 2020. https://doi.org/10.33271/nvngu/2020-6/048

[50] A. M. Babaiev, and D. V. Dmytriiev. Pryntsyp dii, rozrakhunky ta osnovy ekspluatatsii halm rukhomoho skladu zaliznyts: navchalnyi posibnyk [Fundamentals of scientific research: a study guide: a study guide]. 2007. 176 p.

[51] V. Ravluyk, I. Derevianchuk, I. Afanasenko, and N. Ravluyk, "Development of electronic diagnostic system for improving the diagnosis reliability of passenger car brakes," *Eastern-European Journal of Enterprise Technologies*, vol. 2, no. 9(80), pp. 35-41, 2016. https://doi.org/10.15587/1729-4061.2016.66007