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Research Article

The influence of chain tie placement on the strength of wagon body components during transportation by a railway ferry

Alyona Lovska[1], Juraj Gerlici[1], Ján Dižo[1,*], Miroslav Blatnický[1]

[1]Department of Transport and Handling Machines, Faculty of Mechanical Engineering, University of Žilina
Univerzitná 8215/1, 010 26 Žilina, Slovak Republic
*e-mail: jan.dizo@fstroj.uniza.sk

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Abstract: Railway ferry transportation is a crucial component of intermodal logistics, allowing for seamless wagon transfers across water routes. This study investigates the impact of chain tie placement on the structural integrity of wagon body components during railway ferry transit. Real-world fastening configurations were analyzed, revealing that the actual angles of chain tie placements deviate from regulatory standards, leading to uneven force distribution. By incorporating statistical analysis and finite element simulations, coefficients of uneven tie placement were determined, and their effects on load transmission were assessed. The results indicate that stress levels in fastening nodes frequently exceed permissible limits, highlighting a significant risk to structural integrity and transportation safety. These findings underscore the necessity for revised fastening schemes to enhance the securement of wagons on ferry decks, thereby improving operational reliability and safety.

Keywords: railway ferry transportation; a chain tie; securing a wagon on a deck; body loading; safety of railway ferry transportation

I. INTRODUCTION

Railway transport ensures the movement of a large number of goods inland as well as between continents. It has undeniable advantages compared to other modes of transport. These mainly include low resistance to movement [1, 2], favorable energy efficiency, and the high axle load in comparison with other kinds of transport [3–5]. Indeed, safe and reliable railway transport requires a suitable infrastructure [6–8], high-quality railway tracks [9–11], and effective and environmentally friendly sources of energy [12–14]. New and modern rail vehicles have been developed and designed to meet the demanding conditions of sustainable transport [15–17]. However, there are regions where it is necessary to combine railway transport with other kinds of transport. Water transport is one of them. Railway ferries specially designed for wagons allow the embarkation and disembarkation of entire wagons without the need to unload them.

The countries of the Black Sea basin are linked to the most important international transport corridors that ensure the transportation process between individual states of the Eurasian continent. To shorten the path from the sending country to the receiving country and, as a result, the time of cargo delivery and ensure its safety during transportation, the combined interaction between individual transport sectors in the general transport network has become widespread. The most promising symbiosis in this direction has developed between rail and sea modes of transport. A derivative of this combination of transport sectors is railway ferry transportation [18–21].

Analysis of the operation of wagons in international rail-water communication has revealed several significant shortcomings in the inconsistency of the structural and technological interaction of bodies with the means of securing them relative to the railway ferry decks, which prevents ensuring the strength and safety of wagons under given operating conditions [22–25].

To ensure the stability of the wagon bodies relative to the railway ferry decks, they are secured using multi-rotation fastening devices.

Research into the schemes of securing wagons to the railway ferries decks at the stations "Chornomorsk – Poromna" of the Regional Branch of the Odesa Railway of the Joint-Stock Company "Ukrzaliznytsia" allowed to conclude that the chain ties used to secure the wagons to the decks are asymmetrically arranged relative to the bodies, as a result of which, there is an uneven force load on the supporting structure of the wagon, which leads to final deformations and general damage to the structural elements. This situation is quite dangerous because a wagon can fall onto the deck, which will entail the vessel's death. Therefore, an important issue is the study of the scheme for securing wagons to the decks of railway ferries and creating solutions for their technical adaptation to safe transportation by sea.

The publication [26] considers the features of determining the forces acting on the wagon during transportation by sea. The study was conducted using the example of the Caspian Sea. The author provides a suitable method for determining the forces acting on a wagon. However, its strength in interaction with chain ties was not investigated.

The study of the strength of the supporting structure of a wagon during its transportation by sea was carried out in [27]. The authors studied the case of the impact force of a wave on the ferry hull with wagons placed on it. However, when studying the strength of the wagon, no attention was paid to the uneven placement of the ties relative to the body.

The publications [28, 29] determined the conditions for securing the wagon on the deck of a railway ferry. The angles of the chain ties that must be observed for reliable fastening of the body are given. Similar information is also contained in regulatory documents [30, 31], which specify the conditions for securing wagons on the decks of ferries operated in the Black Sea. However, in practice, the specified angles are not always observed, which causes an asymmetric load on the body from the chain ties.

In the work [32], a study of the stability of the equilibrium of a container during its transportation by a railway ferry was carried out. The angles of the roll of the railway ferry at which the stability of the container is observed are determined. At the same time, the authors did not study the effect of the placement of chain ties on the stability of the container.

Analyzing the publications devoted to the dynamics and strength of wagons during their transportation on railway ferries, it can be concluded that the placement of chain ties and the effect of their placement on the loading of the components of the wagon bodies were not paid attention to.

Therefore, the purpose of the study is to identify the effect of the placement of chain ties on the strength of the components of the wagon body during railway ferry transportation.

II. DETERMINATION OF COEFFICIENTS CONSIDERING THE PLACEMENT OF CHAIN TIES IN THE SPACE

Based on the research of typical schemes of fastening of wagon structures to the decks of railway ferries, real cases of fastening to individual elements of the wagon bodies were identified **Fig. 1**.

(a) (b) (c) (d)

Figure 1. *Figure caption Randomness of the places of fastening of chain ties to the structural elements of wagons: a) a covered wagon on the ferry "Heroi Shipki"; b) an open wagon on the ferry "Greifswald"; c) a hopper wagon on the ferry "Petrovsk"; d) a flat wagon on the ferry "Heroi Odessa"*

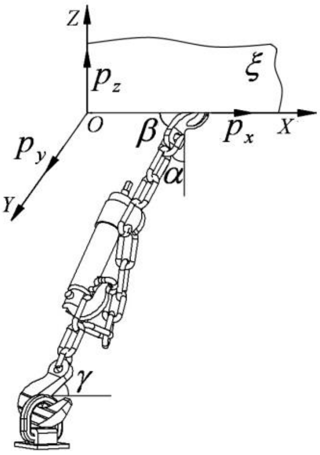


Figure 2. *A chain tie placement relative to the wagon body: p_x, p_y, p_z - projections of the force from the chain tie applied to the fastening zone on the body on the axis of the Cartesian system, respectively; α, β, γ - angles of chain tie placement relative to the plane of the wagon body, respectively*

It was established that they have a static character and are fastened to the elements of the construction of the wagons, which are not intended for this at all.

In rough sea conditions, the wagon body will perceive the load at the nodes of its interaction with the chain ties, the magnitude of which depends on their location relative to the plane of the wagon body.

The location of the chain tie in the space and the scheme of applying the load to the car body through it are shown in **Fig. 2**.

The angles of the chain tie placement relative to the plane of the wagon body in the case of symmetrical fastening according to [28–31] are listed in **Table 1**.

Table 1. *Angles of placement of chain ties relative to the plane of the wagon body*

Angle	*Value*
α	< 30°
β	30° to 60°
γ	< 60°

where $t_{(p,k)}$ - a value of the Student's test for a given probability and magnitude:

$$\Delta\sigma = t_{\alpha}(n) \cdot \Delta S_{\overline{\sigma}} , \qquad (2)$$

where $\Delta^2\sigma$ - an absolute error of the measurement result.

Based on the calculations, it became possible to state that the number of studied sample elements, i.e., chain ties, is sufficient to obtain a valid estimate [34, 35].

For the composite sample, analytical dependencies were determined, and coefficients were obtained that consider the unevenness of the fastening of chain ties relative to the wagon body.

The coefficients of unevenness of the fastening of ties relative to the plane of the wagon body are given in **Table 2**.

The table (**Table 2**) shows that the discrepancy between the coefficients considering the unevenness of the placement of chain ties relative to the wagon body, obtained based on physical measurements and using regulatory documents, is approximately 1%.

Table 2. *Coefficients considering the uneven placement of chain ties relative to the wagon body*

Type of a wagon	***Coefficient of unevenness of chain tie placement along the height of the wagon body, k_h***		***The coefficient of unevenness of the placement of chain ties from the deck rim to the vertical plane of the wagon body, k_b***	
	Calculation based on physical measurements	***Calculation based on regulatory documents***	***Calculation based on physical measurements***	***Calculation based on regulatory documents***
Open wagon	1.17	1.09	1.17	1.10
Covered wagon	0.97	0.91	1.36	1.27
Hopper wagon	1.04	0.97	1.24	1.15
Tank wagon	0.96	1.02	1.08	1.10

To analyze the randomness of the placement of chain ties relative to the wagon bodies, about 100 wagon fastenings on the decks of railway ferries were studied.

The sample included the following types of wagons: open wagons - 21, covered wagons - 41, autonomous refrigerated wagons (ARVs) converted to covered wagons - 39 and tank wagons - 13, while the number of chain ties used for fastening was for open wagons - 156, for covered wagons - 310, for ARVs converted to covered wagons - 304 and for tank wagons - 104.

It can be stated, using the dependences of mathematical statistics and the probability theory, that the number of studied sample elements, i.e., chain ties, is sufficient to obtain its valid estimate.

The sample size was determined by the formula [33]:

$$n = \frac{t^2_{(p,k)} \cdot \sigma^2}{\Delta^2 \cdot \sigma} , \qquad (1)$$

Therefore, when assessing the force transmitted by the chain tie to the wagon body, it is necessary to introduce into the calculation correction coefficients that consider the angles of placement of the chain ties relative to the plane of the wagon body and, therefore, the forces transmitted through them to the supporting structure of the wagon. Then, it is given the following formulation:

$$p = p_c \cdot \kappa_h \cdot \kappa_b , \qquad (3)$$

where p_c - the force transmitted through the chain tie to the wagon body [kN], κ_h, κ_b - coefficients considering the geometric unevenness of the placement of the chain tie along the height of the wagon body and from the deck rim to the vertical plane of the wagon body, respectively.

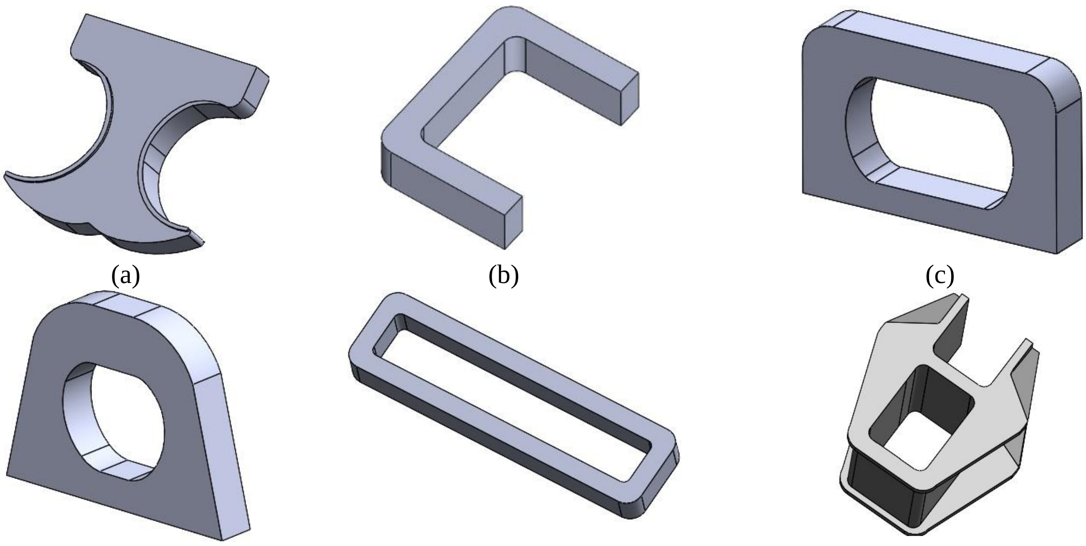
III. Determination of the Strength of the Joints of the Wagons with Chain Ties

Considering the determined coefficients, the strength of the brackets for pulling up the cars during shunting operations (**Fig. 3**), which are often used for their fastening on the decks, was calculated. Spatial models of such brackets were built for this purpose according to the album of their drawings (**Fig. 4**), and the calculation was carried out using the finite element method in SolidWorks Simulation [36–38].

The determination of the elements number of the finite element model was carried out by the graph-analytical method. The method is based on the graphical (geometric) representation of admissible solutions and the objective function of the problem. The essence of the method in solving this problem is to construct the dependence of the maximum equivalent stresses on the number of finite elements.

(a) (b) (c)

Figure 3. *Clamps for pulling up the car during shunting operations: a) on an open wagon; b) on a hopper wagon; c) on a flat wagon*



(a) (b) (c) (d) (e) (f)

Figure 4. *Spatial models of brackets: a) on an open wagon; b), e) on a covered wagon; c) on a hopper wagon; d) on a tank wagon; f) on a platform wagon*

Table 3. *Loads acting on elements of wagon bodies from chain ties*

Type of a wagon	***Load [kN]***		
	P_x	P_y	P_z
Open wagon	117.60	93.90	183.60
Covered wagon	112.30	84.50	177.40
Tank wagon	116.50	88.40	176.20
Hopper wagon	105.30	82.60	174.50
Flat wagon	111.70	85.20	174.30

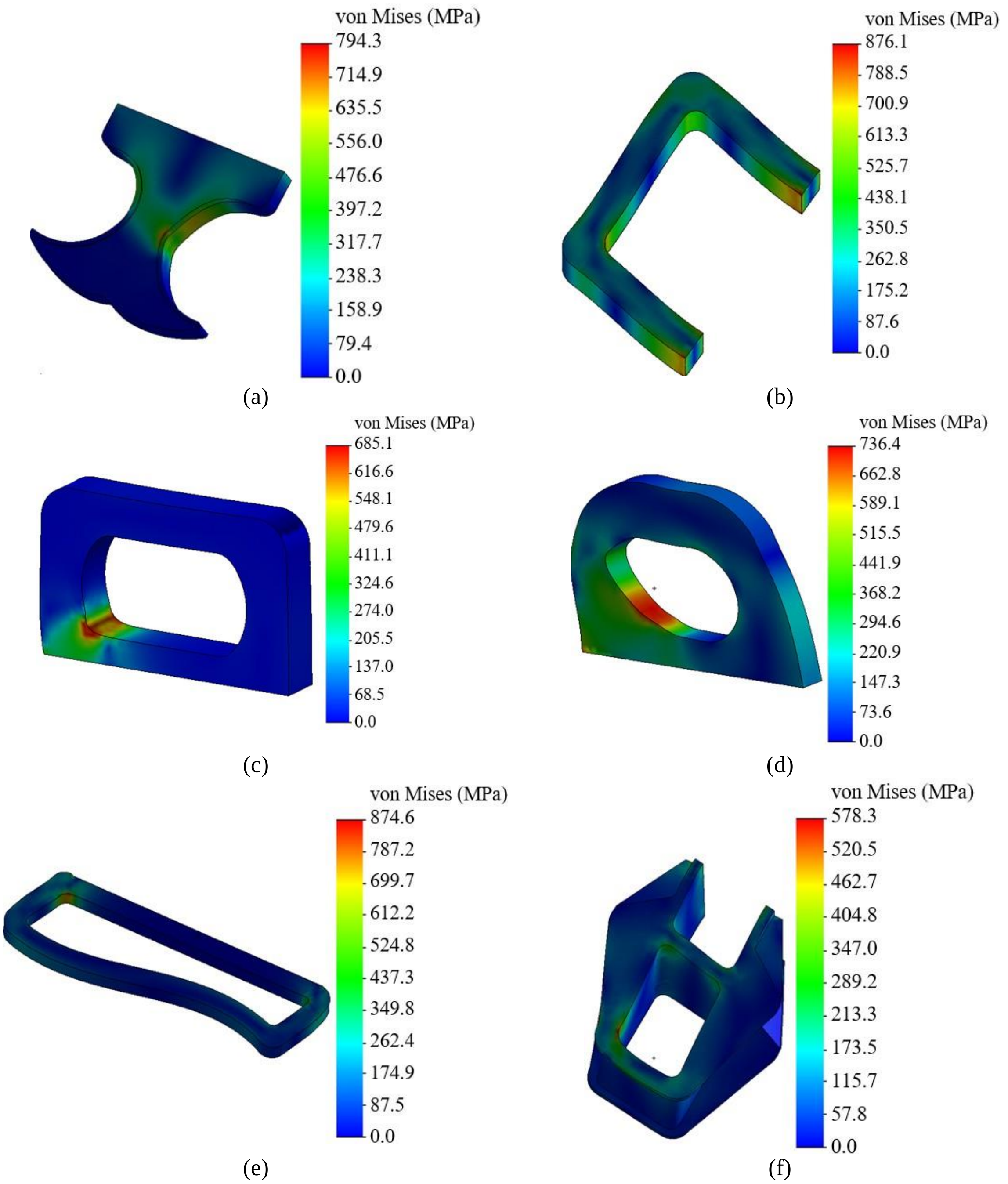


Figure 5. *Stress-strain state of the wagon fastening units on the decks (strain scale 10:1): a) an open wagon; b), e) a covered wagon; c) a hopper wagon; d) a tank wagon; f) a flat wagon*

When this dependence begins to be described by a horizontal line, this is the optimum number of finite elements. The features of determining the loads acting on the car and perceived by the nodes of their fastening on the decks of the railway ferry are highlighted in the work [39, 40]. At the same time, the determination of these loads was carried out under the most unfavourable hydrometeorological conditions of the Black Sea navigation area, i.e. the wave height, the wind pressure, and others. **Table 3** shows the loads acting on the elements of the wagon bodies from chain ties. Since the tie has the appropriate angles of placement in space, the load from it on the body was decomposed into three components.

As sufficient statistical material was not collected regarding the placement of chain ties relative to the body of the flat wagon and the hopper wagon during the field studies, the calculations considered the most unfavourable fastening options recorded during the studies. That is, the loads given in **Table 3** for the flat wagon and the hopper wagon do not consider the coefficient of uneven placement.

The largest deviations of the geometry of the chain ties placement in the space from those established by the standards [28-30] and achieved during the field studies were considered.

Fig. 5 shows the results of the calculation of the fastening nodes.

It can be concluded, analysing the obtained results, that the stresses that arise in the fastening nodes exceed the permissible ones several times – 310.5 MPa. This proves the need to improve the wagon bodies for safe interaction with the fastening means of railway ferries.

IV. Conclusions

1. The coefficients of unevenness of the placement of chain ties for securing wagon bodies on the decks of railway ferries were determined. For this purpose, field studies of wagon fastening schemes were carried out. The obtained coefficients allow to determine the specified value of the load transmitted from chain ties to the elements of the wagon structures.

2. The strength of the nodes of the interaction of wagons with chain ties was calculated. It was established that the stresses in the fastening nodes are several times higher than the permissible values. This situation contributes to damage to the bodies and violation of the safety of their transportation by sea. Therefore, there is a need to improve wagon bodies in order to ensure the reliability of their fastening on the decks of railway ferries.

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Author Contributions

A. Lovska: Conceptualization, Software, Formal Analysis, Investigation, Data curation, Visualisation, Project Administration.

J. Gerlici: Conceptualization, Methodology, Formal analysis, investigation, Writing – original draft preparation.

J. Dižo: Methodology, Validation, Investigation, Data curation, Writing – review and editing, Project Administration.

M. Blatnický: Validation, Investigation, Supervision, Writing – review and editing, Visualisation, Project administration.

Disclosure Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID

A. Lovska http://orcid.org/0000-0002-8604-1764

J. Gerlici https://orcid.org/0000-0003-3928-0567

J. Dižo http://orcid.org/0000-0001-9433-392X

M. Blatnický http://orcid.org/0000-0003-3936-7507

References

[1] M. Gorbunov, K. Kravchenko, G. Bureika, J. Gerlici, O. Nozhenko, G. Vaičiunas, V. Bučinskas, S. Steišunas, Estimation of sand electrification influence on locomotive wheel/rail adhesion processes. Eksploatacja i Niezawodnosc – Maintenance and Reliability. 21 (3) (2019) pp. 460–467. https://doi.org/10.17531/ein.2019.3.12

[2] P. Šťastniak, L. Smetanka, P. Drozdziel, Computer aided simulation analysis for wear investigation of railway wheel running surface. Diagnostyka 20 (3) (2019) pp. 63–68. https://doi.org/10.29354/diag/111569

[3] D. Alic, A. Miltenovic, M. Banic, R. V. Zafra, Numerical Investigation of Large Vehicle Aerodynamics Under the Influence of Crosswind. Spectrum of Mechanical Engineering and Operational Research 2 (1) (2024) pp. 13–23. https://doi.org/10.31181/smeor21202526

[4] E. Szczepański, P. Gołębiowski, B. Kondracka, Evaluation of the technological process of wagon processing at shunting stations using the simulation model. Scientific Journal of Silesian University of Technology. Series Transport 120 (2023) pp. 249–267. https://doi.org/10.20858/sjsutst.2023.120.16

[5] J. Matej, J. Seńko, J. Caban, M. Szyca, H. Gołębiewski, Influence of unsupported sleepers on flange climb derailment of two freight wagons. Open Engineering 14 (11) (2024) pp. 20220544. https://doi.org/10.1515/eng-2022-0544

[6] L. Ézsiás, R. Tompa, S. Fischer. Investigation of the possible correlations between specific

characteristics of crushed stone aggregates. Spectrum of Mechanical Engineering and Operational Research 1 (1) (2024) pp. 10-26. https://doi.org/10.31181/smeor1120242

[7] S. Fischer. Investigation of the Settlement Behavior of Ballasted Railway Tracks Due to Dynamic Loading. Spectrum of Mechanical Engineering and Operational Research 2 (1) (2025) pp. 24-46. https://doi.org/10.31181/smeor21202528.

[8] Y. Bao, W. Zhai, Ch. Cai, X. Yuan, Y. Li, Impact coefficient analysis of track beams due to moving suspended monorail vehicles. Vehicle System Dynamics 60 (2) (2022) pp. 653–669. https://doi.org/10.1080/00423114.2020.1828595

[9] G. Bureika, G. Vaičiunas, D. Shi, A. C. Zanuy, Influence of track geometry condition monitoring on railway infrastructure maintenance processing. Transport Problems 17 (4) (2022) pp. 211-220. https://doi.org/10.20858/TP.2022.17.4.18

[10] S. Steišunas, G. Bureika, G. Vaičiunas, M. Bogdevičius, O. Lunys, Estimation of ambient temperature impact on vertical dynamic behaviour of passenger rail vehicle with damaged wheels. Journal of Mechanical Science and Technology 32 (11) (2018) pp. 5179–5188. https://doi.org/10.1007/s12206-018-1016-9

[11] S. Fischer, D. Harangozó, D. Németh, B. Kocsis, M. Sysyn, D. Kurhan, A. Brautigam. Investigation of heat-affected zones of thermite rail welding. Facta Universitatis, Series: Mechanical Engineering 22 (4) (2024) pp. 689-710. https://doi.org/10.22190/FUME221217008F

[12] S. Fischer, S. Kocsis Szürke. Detection process of energy loss in electric railway vehicles. Facta Universitatis, Series: Mechanical Engineering 21 (1) (2023) pp. 81-99. https://doi.org/10.22190/FUME221104046F

[13] S. Fischer, S. Hermán, M. Sysyn, D. Kurhan, S. Kocsis Szürke. Quantitative analysis and optimization of energy efficiency in electric multiple units. Facta Universitatis, Series: Mechanical Engineering (2025). https://doi.org/10.22190/FUME241103001F

[14] S. Kocsis Szürke, G. Kovács, M. Sysyn, J. Liu, S. Fischer. Numerical Optimization of Battery Heat Management of Electric Vehicles. Journal of Applied and Computational Mechanics 9 (4) (2023) pp. 1076-1092. https://doi.org/10.22055/jacm.2023.43703.4119

[15] P. Šťastniak, L. Smetanka, M. Moravčík, Development of modern railway bogie for broad track gauge - Bogie frame assessment. Manufacturing Technology 17 (2) (2017) pp. 250–256. https://doi.org/10.21062/ujep/x.2017/a/1213-2489/MT/17/2/250

[16] D. Zhang, S.-M. Wang, Y.-Y. Tang, Y-Q. Ni, J.-W. Guo, Q-Y. Peng, A novel method for evaluating load restraint assemblies to ensure the safety of railway freight transportation. Scientific Reports 14 (1) (2024) pp. 4612. https://doi.org/10.1038/s41598-024-54772-9

[17] B. V. Coto, P. Luque Rodríguez, D. Álvarz Mántaras, J. A. Perez, Influence analysis of secondary suspension preload on the dynamic response of Y-25 bogie based on multibody simulations. Vehicle System Dynamics (2025) pp. 1-23 https://doi.org/10.1080/00423114.2025.2460494

[18] M. Lasota, M. Jacyna, L. Szaciłło, Fault tree method as a decision-making tool for assessing the risks of transportation of dangerous loads. Scientific Journal of Silesian University of Technology. Series Transport 123 (2024) pp. 133–154. https://doi.org/10.20858/sjsutst.2024.123.6

[19] Z. Ali, G. Bognár, Investigation of the Impact of Surface Roughness, on a Ship's Drag (Hull Resistance). Acta Polytechnica Hungarica 21 (2) (2024) pp. 7–32. https://doi.org/10.12700/APH.21.2.2024.2.1

[20] S. K. Sahoo, B. B. Choudhury, P. R. Dhal. Exploring the Role of Robotics in Maritime Technology: Innovations, Challenges, and Future Prospects. Spectrum of Mechanical Engineering and Operational Research 1 (1) (2024) pp. 159–176. https://doi.org/10.31181/smeor11202414

[21] A. Tuswan, B. Zubaydi, A. Piscesa, Ismail. Dynamic characteristic of partially debonded sandwich of ferry ro-ro's car deck: A numerical modeling. Open Engineering 10 (1) (2020) pp. 424–433. https://doi.org/10.1515/eng-2020-0051

[22] O. Melnyk, S. Onyshchenko, O. Onishchenko, Development measures to enhance the ecological safety of ships and reduce operational pollution to the environment. Scientific Journal of Silesian University of Technology. Series Transport 118 (2023) pp. 195–206. https://doi.org/10.20858/sjsutst.2023.118.13

[23] A. Dávid, A. Galieriková, J. Tengler, V. Stupalo, The northern sea route as a new route for maritime transport between the far east and Europe. Communications - Scientific Letters of the University of Zilina 23 (2) (2021) pp. A74–A79. https://doi.org/10.26552/com.C.2021.2.A74-A79

[24] E. Brumercikova, B. Bukova, I. Rybicka, P. Drozdziel, Measures for increasing performance of the rail freight transport in the north-south direction. Communications - Scientific Letters of the University of Žilina 21 (3) (2019) pp. 13–20. https://doi.org/10.26552/com.C.2019.3.13-20

[25] E. Di Gialleonardo, S. Melzi, D. Trevisi, Freight trains for intermodal transportation: optimisation of payload distribution for reducing longitudinal coupling forces. Vehicle System Dynamics 61 (10) (2023) pp. 2532–2550. https://doi.org/10.1080/00423114.2022.2120025

[26] I. N. Zemlezin. Methodology for calculating and studying the forces acting on a wagon during transportation on sea ferries (in Russian). Moscow: Transport (1970) 104 p.

[27] A. Lovska, J. Gerlici, J. Dizo, V. Ishchuk. The strength of rail vehicles transported by a ferry considering the influence of sea waves on its hull. Sensors 24 (1) (2024) 183. https://doi.org/10.3390/s24010183

[28] Instructions for securing cargo for the m/v "PETROVSK" PR (in Russian). No. 002CNF001 – LMPL – 805. – MIB (2005) 52 p.

[29] Cargo secuaring menual transocean line a/s ms “Greifswald” – Germanischer Lloyd (2001) p. 39.

[30] CARGO SECURING MANUAL for m/v "Geroi Plevny" No. 2512. 02 (in Russian). Ministry of Transport of Ukraine. State Department of Maritime and River Transport. Odessa (1997) 51 p.

[31] BULGARIAN NAVY FLEET SHIPPING COMPANY, AD – VARNA (In Bulgarian). Instructions for securing cargo. m/k "HEROES OF ODESSA". – Varna (1997) p. 83.

[32] G. Vatulia, J. Gerlici, A. Lovska, Ye. Krasnokutskyi, J. Harušinec, P. Stastniak. Investigation into the dynamic load of the container with sandwich panel walls when transported by train ferry. TransNav 18 (1) (2024) pp. 205–209. https://doi.org/10.12716/1001.18.01.21

[33] M. G. Medvedev, I. O. Pashchenko. Probability Theory and Mathematical Statistics (in Ukrainian). Kyiv: "Lira-K" (2008) 536 p.

[34] M. I. Zhaldak, N. M. Kuzmina, G. O. Mykhalin. Probability theory and mathematical statistics (in Ukrainian). Kyiv. NPU named after M.P. Dragomanov (2020) 750 p.

[35] E. P. Zaitsev. Probability theory and mathematical statistics. Basic course with individual tasks and solutions to typical options (in Ukrainian). Kremenchuk: Publishing house "Kremenchuk" (2012) 439 p.

[36] A. Lovska, I. Stanovska, V. Kyryllova, A. Okorokov, R. Vernigora. Determining the vertical load on a container with a floor made of sandwich panels transported by a flat wagon. Eastern-European Journal of Enterprise Technologies 6/7 (132) (2024) pp. 6–14. https://doi.org/10.15587/1729-4061.2024.315059

[37] J. Gerlici, A. Lovska, M. Pavliuchenkov, Study of the dynamics and strength of the detachable module for long cargoes under asymmetric loading diagrams. Applied Sciences 14 (8) (2024) 3211. https://doi.org/10.3390/app14083211

[38] J. Gerlici, A. Lovska, G. Vatulia, M. Pavliuchenkov, O. Kravchenko, S. Solcansky, Situational adaptation of the open wagon body to container transportation. Applied Sciences 13 (15) (2023) 8605. https://doi.org/10.3390/app13158605

[39] A. Lovska. Dynamics and strength of rail cars in ferry transportation, 1st Edition, Baltija Publishing, Riga, Latvia 2023. https://doi.org/10.30525/978-9934-26-346-0

[40] G. L. Vatulia, A. O. Lovska, Ye. S. Krasnokutskyi, Research into the transverse loading of the container with sandwich-panel walls when transported by rail. IOP Conference Series: Earth and Environmental Science 1254 (1) (2023) 012140. https://doi.org/ 10.1088/1755-1315/1254/1/012140