https://doi.org/10.33271/nvngu/2022-1/051

O. V. Fomin[1],
orcid.org/0000-0003-2387-9946,
A. O. Lovska[2],
orcid.org/0000-0002-8604-1764,
P. O. Skok[1],
orcid.org/0000-0003-2891-0295,
A. V. Rybin[2],
orcid.org/0000-0003-4430-8018

1 – The State University of Infrastructure and Technologies, Kyiv, Ukraine e-mail: fomin1985@ukr.net
2 – The Ukrainian State University of Railway Transport, Kharkiv, Ukraine

FEASIBILITY STUDY FOR USING THE FILLERS IN THE BEARING STRUCTURE COMPONENTS OF A GONDOLA CAR

Purpose. To study the feasibility of using the fillers for the gondola car bearing structure components. This makes it possible to reduce both damage to the gondola car bearing structure components during operating modes of loading and the cost of unscheduled repairs. In addition, it can improve the efficiency of railway transport operation.

Methodology. In order to substantiate the use of aluminium foam as a filler for the gondola car bearing structure components with a closed box-section, a computational modeling of loading under the most unfavorable operating mode, such as shunting collision, has been performed. Gondola car 12-757 model built at PJSC Kryukovsky Railway Car Building Works is chosen as a prototype. The calculation is performed using the finite element method implemented in the SolidWorks Simulation (CosmosWorks) software package. The fatigue strength and natural vibration frequencies of the gondola car bearing structure with a filler of its components have been calculated. The natural vibration frequencies of the bearing structure of the gondola car are calculated. The design service life of the gondola car bearing structure has been determined. The main indicators of the gondola car bearing structure dynamics have been studied. The calculation is made in a plane coordinate system. In this case, the mathematical model is solved by the Runge-Kutta method.

Findings. The results of the conducted research have revealed that the use of aluminium foam as a filler for the gondola car bearing structure components contributes to reduction of their load-bearing capacity from 12 to 47 % compared to the prototype wagon.

Originality. The expediency of using aluminium foam as a filler of the gondola car bearing structure components by modeling its load-bearing capacity under the most unfavorable operating conditions has been scientifically substantiated.

Practical value. By reducing the loading on the gondola car bearing structure, using aluminium foam as filler for its components, it is possible to increase fatigue strength, reduce the amount of damages, and, consequently, the cost of unscheduled repairs of the wagon. The conducted research can contribute to the creation of recommendations for developing the innovative rolling stock designs with improved technical-and-economic, as well as operational performance.

Keywords: *transport mechanics, gondola car, structure loading, body strength, fatigue strength*

Introduction. The main condition for the efficient and uninterrupted operation of the transport industry is the well-coordinated exploitation of its individual components. Railway transport has long been an essential component of the transport sector.

In order to ensure the leading position of railway transport, it is necessary to provide it with competitive rolling stock. When developing the design of such a rolling stock, it is important to take into account fundamentally new innovative solutions aimed at ensuring the reliability of its operation. One of such solutions is the implementation of the multifunctionality principles into the bearing structures of the wagons. Multifunctionality means the ability of an element or unit to perform more than one function in a structure at a time.

By taking into account the proposed principle at the stage of developing the design of the bearing structures of wagons, it is possible to reduce their loading, as well as increase the useful life by improving the fatigue strength indicators. Therefore, it is important and relevant to study the possibility of taking into account the principles of multifunctionality in the bearing structures of wagons by substantiating the use of fillers in their components.

Literature review and unsolved aspects of the problem. The factors influencing the occurrence of cracks in the bearing structure of the wagon are determined in the work [1]. A methodology is provided that makes it possible to determine the causes of cracks in the zones where welded joints are located. However, the paper does not provide for measures to prevent cracking.

Measures to improve the bearing structure of a freight wagon to ensure its durability in operation are covered in the work [2]. The results of calculating the strength of the wagon bearing structure are presented here. It is important to note that these measures should be applied to freight wagons with an underframe as their bearing structure.

The modernization peculiarities of bearing structures of wagons to prolong their service life are described in the paper [3]. This paper also presents measures to improve the system for diagnosing the technical condition of the modernized bearing structures of wagons. However, this modernization consists in strengthening the individual units of wagons, rather than the entire bearing structure.

The strength and fatigue of the welded bearing structure of the wagon body are studied in the paper [4]. The reasons for defects occurring in structural elements of the wagon body are determined. However, the paper does not propose measures to prevent the occurrence of these defects in the bearing structures of the wagons.

The strength of a gondola car bearing structure when performing unloading operations is studied in the paper [5]. The calculation is performed using the tools of computer modelling by the finite element method. The most loaded zones of the gondola car bearing structure are determined. However, the research does not propose measures to ensure the strength of the gondola car in operation.

The dynamic loading and strength of the wagon bearing structure during transportation by train ferry is studied in the work [6]. Measures are proposed to adapt the wagon to a reliable fixing on the deck. It is important to note that these measures contribute to ensuring the strength of the wagon's bearing structure only when transported by ferry, and not when operating on the main-line railways.

Modernization of the wagon's bearing structures to improve their technical-and-economic indicators is performed in the work [7]. It is here that the use of magnesium alloys in their bearing structures is proposed. However, the paper does not provide the results of substantiating the use of magnesium alloys in the gondola car bearing structures for improving their strength under operating modes of loading.

Unsolved aspects of the problem. Analysis of the literature sources leads to a conclusion that it is expedient to conduct a research aimed at improving the strength of the gondola car bearing structures under the most unfavorable conditions of loading by substantiating the use of fillers in their components. This can reduce the amount of damages to the wagon's bearing structures during operation, the cost of unscheduled repairs, as well as improve the strength, dynamics and reliability of wagons. In addition, the research performed can be useful developments in the design of modern competitive structures of freight wagons.

Purpose. The purpose of the paper is to study the feasibility of using the fillers in the gondola car bearing structure components. This makes it possible to reduce both damage to the gondola car bearing structure components during operating modes of loading and the cost of unscheduled repairs. In addition, it can improve the efficiency of railway transport operation.

Methods. To study the feasibility of using the fillers in the gondola car bearing structure components, it is important to conduct a multi-method research into its dynamics and strength.

For achieving this purpose, the following tasks are set and solved:

1. To determine the fatigue strength of the gondola car bearing structure with the filler of its components.

2. To determine the fatigue strength, design service life and natural vibration frequencies of the gondola car bearing structure with the filler of its components.

3. To determine the main indicators of the gondola car bearing structure dynamics with the filler of its components.

Results. To reduce loading on the gondola car bearing structure during operating modes, it is possible to use the filler for its components with a closed box-section. In this case, it is expedient to use aluminium foam as a filler. The bearing structure components, proposed to be filled with aluminium foam, are shown in Figs. 1, 2.

To substantiate the use of aluminium foam as a filler for the gondola car bearing structure components, its spatial model has been developed in the SolidWorks software package. The presence of aluminium foam is modeled by including the elements with the characteristics indicated in Table 1 into the components of the bearing structure.

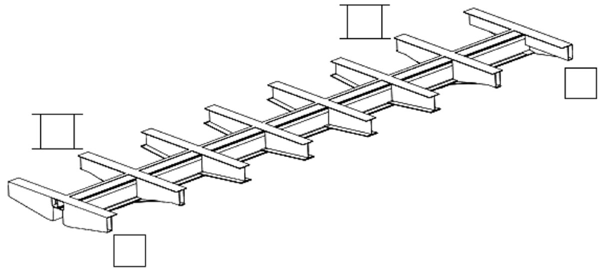

Fig. 1. Gondola car underframe

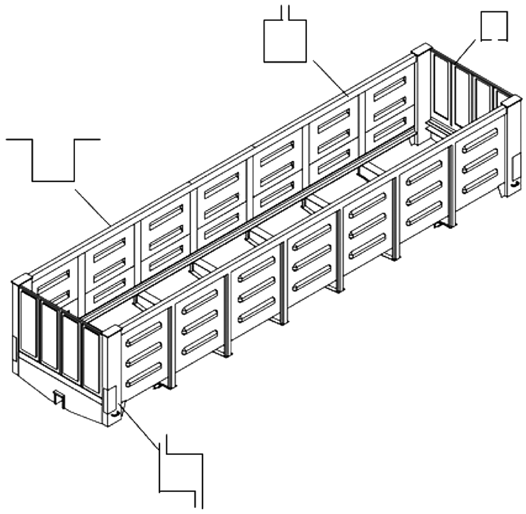

Fig. 2. Gondola car body

To determine the strength of the gondola car bearing structure, a calculation is performed using the finite element method. In this case, the SolidWorks Simulation (CosmosWorks) software package is used [8, 9].

The optimal number of elements in the finite element model of the gondola car bearing structure is determined using the graphical-analytical method [10, 11]. Isoperimetric tetrahedrons are used as finite elements [12, 13]. The number of grid points is 120,917 and the number of elements is 384,184. In this case, the maximum element size is 100 mm, the minimum is 20 mm. The maximum aspect ratio is 644.99, the percentage of elements with an aspect ratio of less than 3 is 25.7, more than 10 is 31.4. The number of elements in the circle is 8. The element size increase ratio is 1.6. The model is fixed in the zones of resting of the bearing structure on the bogies.

The calculation is made for the case of shunting collision. When compiling the design model, the vertical static loads P_v^{st}, the expansion pressure of the bulk cargo P_b (bituminous coal), as well as the longitudinal load P_l, acting on the bearing structure from the automatic coupling device are taken into account

Table 1

Aluminium foam characteristics

Property	Value	Unit of measurement
Elasticity modulus	$5.3 \cdot 10^9$	Pa
Poisson's ratio	0.3	
Mass density	800	kg/m^3
Ultimate tensile strength	$5.0 \cdot 10^7$	Pa
Yield point	$1.05 \cdot 10^6$	Pa

(Fig. 3). It is also taken into account that the expansion pressure of the bulk cargo on the side walls of the gondola car acts according to the law of a triangle. The expansion pressure is applied to the end walls according to the trapezoidal law.

The strength calculation results are shown in Fig. 4.

Thus, the maximum equivalent stresses recorded in the zone of the bolster beam interaction with the centre sill are about 340 MPa. Maximum displacements that occur in the middle of the underframe are about 4.7 mm. Therefore, the strength of the gondola car bearing structure is ensured [14, 15].

A comparative analysis of the maximum equivalent stresses arising in a typical gondola car bearing structure, taking into account the use of a filler, is presented in Table 2.

The difference between the maximum equivalent stresses in a typical gondola car bearing structure and with account of using the filler is shown in Fig. 5.

Taking into account the use of aluminium foam as a filler for the gondola car bearing structure components, its dead weight increases by 16.2 % compared to a structure without a filler. However, to reduce the sprung mass of the wagon, it is possible to optimize the components of its structure by the criterion of minimum material consumption.

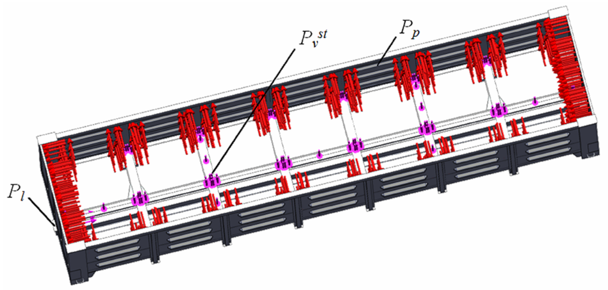

Fig. 3. Calculation scheme of the gondola car bearing structure

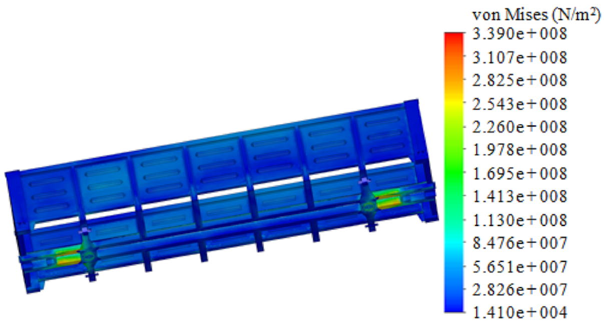

Fig. 4. Stress state of the gondola car bearing structure

Table 2

The strength calculation results of the gondola car bearing structure in the *1st* design mode (collision)

Component name	Stresses, MPa		
Body	Permissible stresses	Typical structure	Structure with a filler
End plate	345	74.2	46.0
Corner post	345	48.5	32.3
Vertical post	345	211.5	148.6
End door top cord	345	107.3	87.7
End door intermediate post	345	78.3	53.1
End door centre post	345	61.2	32.3
Underframe			
Bolster beam	345	105.7	92.2
Head stock	345	75.7	62.3

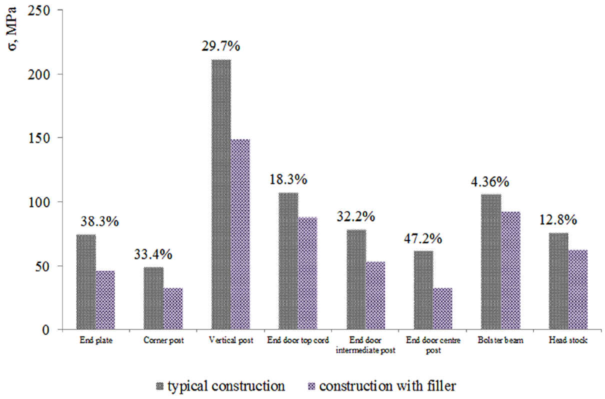

Fig. 5. The difference between the maximum equivalent stresses in a typical gondola car bearing structure and with account of using the filler

The fatigue strength of the gondola car bearing structure with the use of aluminium foam as a filler for its components has been calculated.

The calculation is performed based on the static analysis results, shown in Fig. 4. In this case, the number of tests amounts to 10^7 cycles. The fatigue curve has been obtained based on the elasticity modulus of 09G2C steel grade using the options of the SolidWorks Simulation (CosmosWorks) software package.

The conducted research makes it possible to determine the most loaded zones of a gondola car bearing structure (Fig. 6). These include the zones of the bolster beam interaction with the centre sill.

The calculations performed make it possible to conclude that the fatigue strength of a gondola car bearing structure at a specified test base is ensured. Thus, the fatigue strength of the gondola car bearing structure with a filler increases by 7 % compared to the typical structure.

To determine the design service life of a gondola car bearing structure, the method described in the work by Professor P. A. Ustich is used

$$T_n = \frac{\left(\sigma_{-1L}/[n]\right)^m \cdot N_0}{B \cdot f_d \cdot \sigma_{sw}(k_{dv} + \psi_\sigma / K_\sigma)^m}, \quad (1)$$

where σ_{-1L} is the average value of the endurance limit; n is the permissible safety factor; m is an indicator of the fatigue curve rate; N_0 is the number of tests; B is the coefficient characterising a period of continuous operation of an object, s; f_d is the effective frequency of dynamic stresses; σ_{sw} is static weight load stress; k_{dv} is the vertical dynamics coefficient; ψ_σ is the sensitivity coefficient; K_σ is the overall factor for fatigue strength reduction.

The following input parameters are taken in the calculations: $\sigma_{-1L} = 245$ MPa; $n = 2$; $m = 8$; $N_0 = 10^7$; $B = 3.07 \cdot 10^6$ s; $f_d = 2.7$ Hz; $k_{dv} = 0.35$; $\psi_\sigma / K_\sigma = 0.2$.

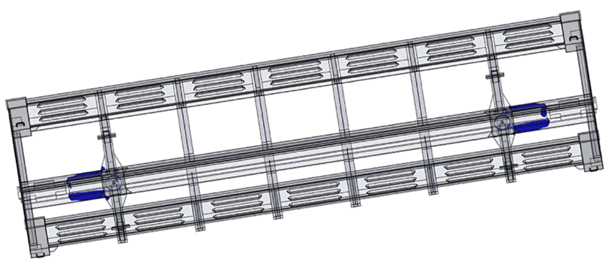

Fig. 6. The most loaded zones of a gondola car bearing structure

The calculations performed indicate that the design service life of the gondola car bearing structure is not less than 32 years.

It is important to note that the obtained value of the design service life should be specified taking into account additional research into the longitudinal load acting on the gondola car bearing structure.

Also, within the framework of the research, the values of the natural vibration frequencies of the gondola car bearing structure have been determined. The calculation is performed according to the scheme shown in Fig. 3. The calculation results are given in Table 3.

Based on the data in Table 3, it can be concluded that the values of natural vibration frequencies are within permissible limits, since the first natural vibration frequency has a value of more than 8 Hz [14, 15].

To determine the main indicators of the gondola car bearing structure dynamics with a filler in its components, the calculation of the dynamic loading in the vertical plane has been performed. The calculation scheme is shown in Fig. 10. In this case, a mathematical model developed by Professor Yu. V. Diomin is used.

The equations of the design model motion are as follows

$$M_1 \cdot \frac{d^2}{dt^2} q_1 + C_{1,1} \cdot q_1 + C_{1,3} \cdot q_3 + C_{1,5} \cdot q_5 = -F_{FR} \cdot \left(\operatorname{sign}\left(\frac{d}{dt} \delta_1 \right) + \operatorname{sign}\left(\frac{d}{dt} \delta_2 \right) \right); \quad (2)$$

$$M_2 \cdot \frac{d^2}{dt^2} q_2 + C_{2,2} \cdot q_2 + C_{2,3} \cdot q_3 + C_{2,5} \cdot q_5 = F_{FR} \cdot l \cdot \left(\operatorname{sign}\left(\frac{d}{dt} \delta_1 \right) + \operatorname{sign}\left(\frac{d}{dt} \delta_2 \right) \right); \quad (3)$$

$$M_3 \cdot \frac{d^2}{dt^2} q_3 + C_{3,1} \cdot q_1 + C_{3,2} \cdot q_2 + C_{3,3} \cdot q_3 + B_{3,3} \cdot \frac{d}{dt} q_3 = F_{FR} \cdot \operatorname{sign}\left(\frac{d}{dt} \delta_1 \right) + k_1 (\eta_1 + \eta_2) + \beta_1 \left(\frac{d}{dt} \eta_1 + \frac{d}{dt} \eta_2 \right); \quad (4)$$

$$M_4 \cdot \frac{d^2}{dt^2} q_4 + C_{4,4} \cdot q_4 + B_{4,4} \cdot \frac{d}{dt} q_4 = -k_1 (\eta_1 - \eta_2) - \beta_1 \cdot a \cdot \left(\frac{d}{dt} \eta_1 - \frac{d}{dt} \eta_2 \right); \quad (5)$$

$$M_5 \cdot \frac{d^2}{dt^2} q_5 + C_{5,1} \cdot q_1 + C_{5,2} \cdot q_2 + C_{5,5} \cdot q_5 + B_{5,5} \cdot \frac{d}{dt} q_5 = F_{FR} \cdot \operatorname{sign}\left(\frac{d}{dt} \delta_2 \right) + k_1 (\eta_3 + \eta_4) + \beta_1 \left(\frac{d}{dt} \eta_3 + \frac{d}{dt} \eta_4 \right); \quad (6)$$

$$M_6 \cdot \frac{d^2}{dt^2} q_6 + C_{6,6} \cdot q_6 + B_{6,6} \cdot \frac{d}{dt} q_6 = -k_1 \cdot a \cdot (\eta_3 - \eta_4) - \beta_1 \cdot a \cdot \left(\frac{d}{dt} \eta_3 - \frac{d}{dt} \eta_4 \right), \quad (7)$$

where M_i are inertial coefficients of the vibration system elements; C_{ij} is elasticity characteristic of the vibration system elements; B_{ij} is scattering function; a is half the bogie base; q_i are generalized coordinates corresponding to translational and angular displacements around the vertical axis of the wagon body, the first and second bogies, as well as the load, respectively; k_s is spring suspension stiffness; β_i is the damping factor; F_{FR} is friction force in the spring set.

Table 3

Natural vibration frequencies of the gondola car bearing structure

Vibration form	Frequency, Hz	Vibration form	Frequency, Hz
1	13.5	6	35.2
2	17.6	7	40.6
3	26.0	8	41.7
4	32.2	9	46.9
5	32.9	10	52.1

Therefore, the first two equations characterize the displacements of the body during vibrations of jumping and galloping, the second to sixth equations – the elements of the wagon running gear.

The input parameters to the mathematical model are given in Table 4.

Initial displacement and velocities are taken equal to zero [16–18].

The solution to the mathematical model is performed in the MathCad software package using the Runge-Kutta method [19, 20]. The calculation results are given in Figs. 7–10.

Table 4

Input parameters to the mathematical model

Parameter	Dimensionality	Values
M_1	t	15.3
M_2	$t \cdot m^2$	348.6
M_3, M_5	t	4.3
M_4, M_6	$t \cdot m^2$	3.0
l	m	4.86
a	m	0.925
k_S	kN/m	8000
k_1	kN/m	100 000
β_1	kN · s/m	200

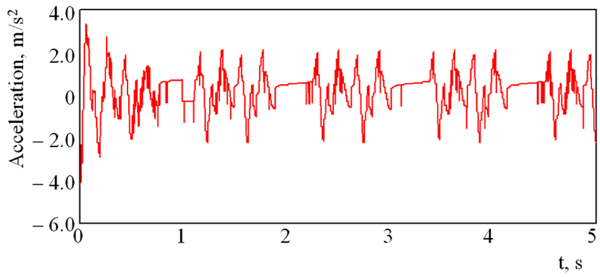

Fig. 7. Acceleration of the gondola car body in the center of mass

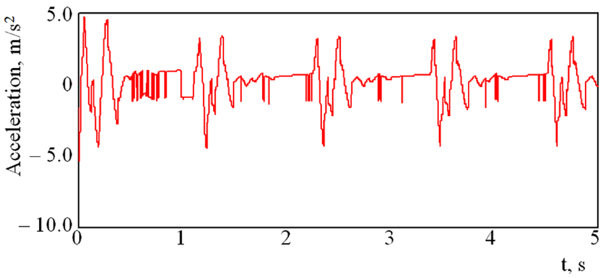

Fig. 8. Acceleration of the bogies

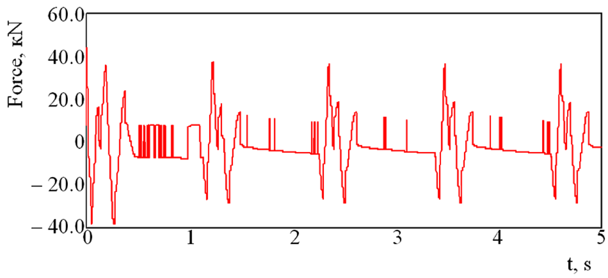

Fig. 9. Force in the spring suspension of the bogie

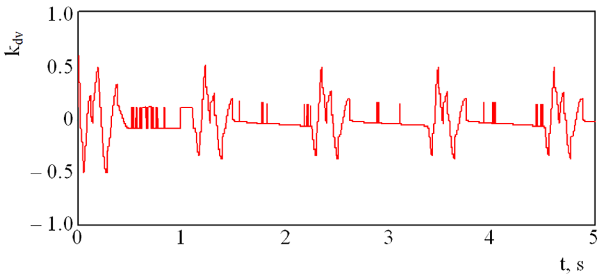

Fig. 10. Vertical dynamics coefficient

The maximum acceleration of the gondola car body in the center of mass is 4.2 m/s². The accelerations of the bogies are equal to 5.3 m/s². The forces in the spring suspension of the bogies are about 44.2 kN, and the coefficient of vertical dynamics is 0.58.

The calculations performed make it possible to conclude that the studied dynamics indicators of the gondola car with a filler in its components are within permissible limits. Gondola car movement can be assessed as excellent [14, 15].

Conclusions.

1. The strength of the gondola car bearing structure with the filler in its components has been determined. The calculation is performed using the finite element method. The maximum equivalent stresses are recorded in the zone of the bolster beam interaction with the centre sill and amount to about 340 MPa. The maximum displacements occur in the middle of the underframe and are approximately 4.7 mm. Therefore, the strength of the gondola car bearing structure is ensured.

2. The fatigue strength, design service life and natural vibration frequencies of the gondola car bearing structure with the filler of its components have been determined. Thus, the number of tests amounts to 10^7 cycles. The calculations performed make it possible to conclude that the fatigue strength of a gondola car bearing structure at a specified number of tests is ensured. It should be noted that the fatigue strength of the gondola car bearing structure with a filler increases by 7 % compared to the typical structure.

The design service life of the gondola car bearing structure with the filler in its components is not less than 32 years.

The modal analysis results indicate that the values of natural vibration frequencies are within permissible limits. At that, the first natural vibration frequency has a value of more than 8 Hz.

3. The main indicators of the gondola car bearing structure dynamics with the filler in its components have been determined. Thus, the maximum acceleration of the gondola car body in the center of mass is 4.2 m/s². The accelerations of the bogies are equal to 5.3 m/s². The forces in the spring suspension of the bogies are about 44.2 kN, and the coefficient of vertical dynamics is 0.58. Therefore, the gondola car movement can be assessed as excellent.

References.

1. Milovanovic, V., Dunic, V., Rakic, D., & Zivkovic, M. (2013). Identification causes of cracking on the underframe of wagon for containers transportation – Fatigue strength assessment of wagon welded joints. *Engineering Failure Analysis*, *31*, 118-131. https://doi.org/10.1016/j.engfailanal.2013.01.039.

2. Šťastniak, P., Kurčík, P., & Pavlík, A. (2018). Design of a new railway wagon for intermodal transport with the adaptable loading platform. *MATEC Web of Conferences*, *235*. 00030. https://doi.org/10.1051/matecconf/20182.

3. Płaczek, M., Wróbel, A., & Buchacz, A. (2016). A concept of technology for freight wagons modernization. *IOP Conf. Series: Materials Science and Engineering*, *161*(2016). https://doi.org/10.1088/1757-899X/161/1/012107.

4. Antipin, D. Y., Racin, D. Y., & Shorokhov, S. G. (2016). Justification of a Rational Design of the Pivot Center of the Open-top Wagon Frame by means of Computer Simulation. *Procedia Engineering*, *150*, 150-154. https://doi.org/10.1016/j.proeng.2016.06.738.

5. Bulychev, M., & Antipin, D. (2019). Improvement of strength calculation procedure of car side upper framing in gondola cars. *Bulletin of Bryansk State Technical University*, *3*(76), 58-64. https://doi.org/10.30987/article_5c8b5ceb111c58.12769482.

6. Lovska, A., & Fomin, O. (2020). A new fastener to ensure the reliability of a passenger coach car body on a railway ferry. *Acta Polytechnica*, *60*(6), 478-485.

7. Woo Geun Lee, Jung-Seok Kim, Seung-Ju Sun, & Jae-Yong Lim (2016). The next generation material for lightweight railway car body structures: Magnesium alloys. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, *232*(1), 25-42.

8. Fomin, O., & Lovska, A. (2020). Establishing patterns in determining the dynamics and strength of a covered freight car, which exhausted its resource. *Eastern-European Journal of Enterprise Technologies*, *6*(7(108)), 21-29. https://doi.org/10.15587/1729-4061.2020.217162.

9. Vatulia, G., Komagorova, S., & Pavliuchenkov, M. (2018). Optimization of the truss beam. Verification of the calculation results. *MATEC Web of Conferences*, *230*, 02037. https://doi.org/10.1051/matecconf/201823002037.

10. Vatulia, G. L., Lobiak, O. V., Deryzemlia, S. V., Verevicheva, M. A., & Orel, Ye. F. (2019). Rationalization of cross-sections of the composite reinforced concrete span structure of bridges with a monolithic reinforced concrete roadway slab. *IOP Conference Series: Materials Science and Engineering*, *664*, 012014. https://doi.org/10.1088/1757-899X/664/1/012014.

11. Bondarenko, V., Skurikhin, D., & Wojciechowski, J. (2020). The Application of Lithium-Ion Batteries for Power Supply of Railway Passenger Cars and Key Approaches for System Development. *Advances in Intelligent Systems and Computing*, *109*, 114-125.

12. Dižo, J., Steišunas, S., & Blatnický, M. (2016). Simulation analysis of the effects of a rail vehicle running with wheel flat. *Manufacturing Technology*, *16*(5), 889-896.

13. Fomin, O. (2015). Improvement of upper bundling of side wall of gondola cars of 12-9745 model. *Metallurgical and Mining Industry*, *1*, 45-48.

14. *Freight wagons. Requirements for strength and dynamic properties. GOST 33211-2014* (2016). Moscow: Standartinform. Retrieved from http://docs.cntd.ru/document/1200121493.

15. *Freight wagons. general requirements for calculations and design of new and modernized wagons of 1520 mm gauge (non-self-propelled). DSTU 7598:2014* (2015). Retrieved from http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=73763.

16. Lovska, A. (2018). Simulation of loads on the carrying structure of an articulated flat car in combined transportation. *International Journal of Engineering & Technology*, *7*(4.3), 140-146. https://doi.org/10.14419/ijet.v7i4.3.19724.

17. Pospelov, B., Rybka, E., Meleshchenko, R., Borodych, P., & Gornostal, S. (2019). Development of the method for rapid detection of hazardous atmospheric pollution of cities with the help of recurrence measures. *Eastern-European Journal of Enterprise Technologies*, *1*(10(97)), 29-35. https://doi.org/10.15587/1729-4061.2019.155027.

18. Kliuiev, S. (2018). Experimental study of the method of locomotive wheel-rail angle of attack control using acoustic emission. *Eastern–European Journal of Progressive Technologies*, *2/9*(82), 69-75. https://doi.org/10.15587/1729-4061.2018.122131.

19. Vatulia, G., Lobiak, A., Chernogil, V., & Novikova, M. (2019). Simulation of performance of cfst elements containing differentiated profile tubes filled with reinforced concrete. *Materials Science Forum*, *968*, 281-287.

20. Alieinykov, I., Thamer, K. A., Zhuravskyi, Yu., Sova, O., Smirnova, N., Zhyvotovskyi, R., ..., & Shyshatskyi, A. (2019). Development of a method of fuzzy evaluation of information and analytical support of strategic management. *Eastern-European Journal of Enterprise Technologies*, *6*(2(102)), 16-27. https://doi.org/10.15587/1729-4061.2019.184394.

Дослідження доцільності використання наповнювачів у складових несучої конструкції напіввагона

О. В. Фомін[1], *А. О. Ловська*[2], *П. О. Скок*[1], *А. В. Рибін*[2]

1 – Державний університет інфраструктури та технологій, м. Київ, Україна, e-mail: fomin1985@ukr.net

2 – Український державний університет залізничного транспорту, м. Харків, Україна

Мета. Встановлення доцільності використання наповнювачів у складових несучої конструкції напіввагона. Це сприятиме зменшенню пошкоджень складових несучої конструкції напіввагона при експлуатаційних режимах навантаження, скороченню витрат на позапланові види ремонту, а також підвищенню ефективності експлуатації залізничного транспорту.

Методика. Для обґрунтування застосування піноалюмінію в якості наповнювача складових несучої конструкції напіввагона, що мають замкнений переріз, проведене комп'ютерне моделювання навантаженості при найбільш несприятливому експлуатаційному режимі – маневрове співударяння. В якості прототипу обрано напіввагон моделі 12-757 побудови ПАТ «Крюківський вагонобудівний завод». Розрахунок здійснений за методом скінчених елементів, реалізованого у програмному комплексі SolidWorks Simulation (CosmosWorks). Проведено розрахунок на втомну міцність несучої конструкції напіввагону з наповнювачем його складових. Розраховані власні частоти коливань несучої конструкції напіввагона. Визначено проектний строк служби несучої конструкції напіввагона. Досліджені основні показники динаміки несучої конструкції напіввагона. Розрахунок здійснений у плоскій системі координат. При цьому розв'язок математичної моделі здійснений за методом Рунге-Кутта.

Результати. Результати проведених досліджень дозволили встановити, що використання піноалюмінію в якості наповнювача складових несучої конструкції напіввагона сприяє зменшенню їх навантаженості в порівнянні з вагоном-прототипом від 12 до 47 %.

Наукова новизна. Проведено наукове обґрунтування доцільності використання піноалюмінію в якості наповнювача складових несучої конструкції напіввагону шляхом моделювання його навантаженості за найбільш несприятливого режиму експлуатації.

Практична значимість. За рахунок зменшення навантаженості несучої конструкції напіввагона шляхом використання піноалюмінію в якості наповнювача його складових стає можливим покращити втомну міцність, зменшити кількість пошкоджень, а, відповідно, й витрат на позапланові види ремонту вагона. Проведені дослідження сприятимуть створенню рекомендацій щодо проектування інноваційних конструкцій рухомого складу з покращеними техніко-економічними, а також експлуатаційними показниками.

Ключові слова: *транспортна механіка, напіввагон, навантаженість конструкції, міцність кузова, втомна міцність*

The manuscript was submitted 30.06.21.