IMPROVEMENT OF THE SOFT CONTAINERS USE IN TRANSPORTATION OF THE BULK CARGO

Stanislav Semenov[1], Evgeny Mikhailov[1], Oleksandr Kravchenko[2], Ján Dižo[2,*], Miroslav Blatnický[2], Vadym Ishchuk[2]

[1]Department of Logistics and Transport Safety, Volodymyr Dahl East Ukrainian National University, Kyiv, Ukraine
[2]Department of Transport and Handling Machines, Faculty of Mechanical Engineering, University of Zilina, Zilina, Slovak Republic

*E-mail of corresponding author: jan.dizo@fstroj.uniza.sk

Stanislav Semenov 0000-0002-5236-4557,
Oleksandr Kravchenko 0000-0003-4677-2535,
Miroslav Blatnický 0000-0003-3936-7507,
Evgeny Mikhailov 0000-0002-6667-5348,
Ján Dižo 0000-0001-9433-392X,
Vadym Ishchuk 0000-0003-2024-382X

Resume

The advantages and disadvantages of using the soft containers for cargo transportation are analyzed. The issues of the use of soft containers in transport and technological schemes for the supply of bulk goods are considered. Approaches to the rational selection of parameters of soft containers, during the transportation of bulk cargoes, taking into account the characteristics of the transported cargoes, are defined.

Available online: https://doi.org/10.26552/com.C.2023.064

Article info

Received 7 April 2023
Accepted 29 June 2023
Online 17 July 2023

Keywords:

soft container
bulk cargo
transportation
wagon
loading
optimization

ISSN 1335-4205 (print version)
ISSN 2585-7878 (online version)

1 Introduction

Modern container technologies appeared in the middle of the 20th century and significantly influenced development of international trade. Their appearance changed the nature of cargo transportation [1-3]. The use of modern transport technologies and promising technical solutions lead to the faster and more efficient transportation of goods from the consignor to the consignee, including from the point of view of the transport process safety, [4-7].

The purpose of this article is to consider the advantages and disadvantages of using the soft containers in the transportation of bulk cargoes and to determine approaches to the rational selection of these containers parameters in transportation of the bulk cargoes, taking into account the characteristics of the transported cargoes.

2 Object of the research

When developing the transport and logistics systems for the delivery of goods, special attention should be paid to the rational choice of transport tare, which is considered as one of the types of transport equipment. It is an independent transport unit that ensures the effectiveness of transportation and performance of loading and unloading and warehouse work. This choice is related to solution of the tasks of optimizing the loading of rolling stock and the placement of goods in the warehouse, automation and mechanization of loading and unloading and transport and storage operations [8].

Currently, the cargo containers are widely used for transportation of various cargoes [9-13]. They are a type of transport equipment, used for transportation and temporary storage of goods and have constant technical characteristics and devices for mechanization of transshipment operations.

In the global practice, the volumes of transportation of bulk and bulk cargoes are growing increasingly. At the same time, the requirements for technical and environmental safety of transportation, technical condition of the rolling stock, preservation of cargo, convenience of the accepted transportation scheme for the consumer are also increasing [14-16]. In addition, from time to time there is a problem of lack of specialized railway rolling stock and transport equipment used for these transports. All this stimulates the introduction of new, effective technologies for loading, transportation and transshipment of bulk cargoes, which can more fully satisfy the needs of all the participants in the transport process [17].

One of the progressive directions of improvement of transport and logistics systems for the delivery of goods (primarily bulk goods) is the use of soft specialized containers (SC, Big-Bag or FIBC - Flexible Intermediate Bulk Conteiner) for their transportation and temporary storage, which have recently become increasingly popular application. According to the specific costs (that is, according to the costs of transport equipment per unit mass of transported products), soft containers are the most economical, especially when transporting and temporarily storing large batches of goods [18].

A soft container (hereafter SC) is actually a large bag with slings or loops and hooks for lifting and a bag-like body for filling, storing and transporting cargo. The carrying capacity of the SC usually varies from 500 to 2000 kg. Most often, the SC is made of polypropylene and has a cylindrical or parallelepiped shape. The length of one side of the container is usually in the range from 500 mm to 1200 mm and the volume is possible up to 3 m^3. The height of the SC can reach 2500 mm, with a minimum height of 800 mm. However, there are exceptions, for example, large-tonnage soft containers MK-14-10 with a capacity of up to 14 tons, which are allowed even for international transportation of dangerous goods [10].

The soft polymer containers, according to the parameters that determine their useful life, have the following components: disposable containers - are used exclusively in circulation once, then they go to disposal and, accordingly, to recycling, SC of cyclic using - which have the ability to be used in several cycles of their loading/unloading and multi-turn SC - containers that are used in chains of loading/unloading during the long time specified in the characteristics of this container. The frequency of the SC use in the cyclic transport process depends on the parameters responsible for its safety margin. Disposable SCs have a safety margin of 5:1, cyclic SCs have a safety margin of 6:1 (can be used several times) and reusable containers have a safety margin of 8:1. The order of the safety factor allows to use the SC for storing products in them with the construction of a stack with the levels of their arrangement on top of each other up to 7 tiers.

The SCs are reliable and durable, convenient for transportation and storage of various bulk goods, easy to manufacture. Depending on the specifics of the cargo, some SCs are additionally provided with protection elements against ultraviolet radiation, temperature changes, atmospheric moisture and static electricity.

Undoubtedly, the soft containers cannot be as widely used in modern transport and logistics systems of cargo delivery as the traditional metal cargo containers. However, for transporting a number of loads, they are almost an ideal solution. Such cargoes include, first of all, bulk cargoes, for example, powdery materials (flour, cement), granular (salt, sugar, grain, mineral fertilizers, various chemical products), as well as small-, medium- and large lumpy cargoes (construction materials, ferroalloys, concentrates). In addition to bulk products, the SC can also be used for transportation and storage of bulk and bulk cargoes, agricultural and forest products [14].

In recent decades, the soft containers have proven themselves as a universal type of transport equipment, as they can be structurally adapted to any loading and unloading mechanisms and various loading and unloading stations [19]. Their use in developed countries today has practically supplanted traditional means of transporting the bulk cargo, such as circulating metal containers, dumpcars truck and completely replaced plywood drums and barrels [20-21].

With the advent of SC, it became possible to solve many technological problems quite simply and effectively. So, for example, can store products in open areas for a long time. Costs for loading and unloading operations and cargo losses at various stages of their circulation also decreased. The analysis of the available information regarding the technologies of using the soft containers in the transportation of bulk cargo allows to note the following advantages of these technologies over traditional ones [14]:

- lack of need for scarce specialized rolling stock;
- absence of physical losses of transported goods;
- maintaining the quality and cleanliness of transported goods;
- protection of rolling stock and the surrounding environment from the negative impact of transported goods;
- no need to clean the body of the rolling stock after transporting the bulk cargo;
- simple mechanisms for introduction into the technological process during the SC loading/unloading;
- the possibility of temporary storage of cargo during transshipment at open port sites, which allows saving working capital for the construction of warehouses;
- improvement of the quality of working conditions of workers, including from the point of view of sanitary and hygienic conditions.

Taking into account these significant advantages, the rail transportation of bulk cargo using SC has recently become widespread.

In the technical conditions (TU) for loading and fastening cargo in an open rolling stock [22] there are recommended schemes for loading the soft containers in semi-wagons only for several of their standard sizes, which have a cross section of the bag in the form of a circle. However, the analysis of scientific and technical information and Internet data shows that several dozens of SC standard sizes are actually used for the bulk cargo transportation.

When planning transportation and choosing the necessary SC parameters, the transport characteristics of the bulk cargo should be taken into account. For example, the full use of the cargo capacity and capacity of the wagons with certain parameters of the soft containers depends significantly on the bulk weight of the cargo. At present, this issue receives relatively little attention. For example, work [23] analyzed options for transporting bulk goods in bags and in soft containers. Options for calculating the placement of cargo in the wagon were considered and a technical and economic calculation of the efficiency of transportation was carried out. Further, the other factors, which appear during transportation, such as movement of transport means (wagons, containers, cargo etc.), have to be considered, as well, [24-25]. That influences the running properties of a train-set, safety of transportation, dynamics of individual vehicles in a train-set, braking distances and other factors, which relate with the investigated issue [26-29].

Taking into account the modern capabilities and existing technologies for production of the SCs, it is possible to manufacture them in almost any shape with a fairly wide range of basic parameters (width, height, load capacity). At the same time, use of the SCs, which have a square cross section, is promising, as they allow the most complete use of the useful floor area of the cargo room of the rolling stock. Therefore, the purpose of the this work is to determine approaches to the rational selection of parameters of such soft containers during the transportation of a bulk cargo, taking into account the characteristics of the transported cargo.

3 Research methodology

Next is considered the issue of choosing the rational parameters of SCs that have a square cross-section, in accordance with the bulk mass of the transported cargo. At the same time, several conditions must be met:

- loading the wagon G_L with cargo should be as complete as possible (of course, not exceeding its stenciled carrying capacity $G_L^{\max}$,
- the number of used soft containers K should be minimal: $K \to K_{\min}$,
- the strength of SC at the required load capacity is provided technologically.

The combination of the two main parameters will be considered - width b_i and height h_j - as the ij - standard size of a soft container, which has a square cross-section.

The number of containers K_{ij} of the ij - standard size that can be placed in a gondola car can be calculated as follows

$$K_{ij} = N_{ij} \cdot M_{ij} \cdot Z_{ij}, \quad (1)$$

where:
N_{ij} - the number of containers of the ij-th standard size that can be loaded across the width of a gondola car;
M_{ij} - the number of containers of the ij-th standard size that can be loaded along the length of a gondola car;
Z_{ij} - the number of loading tiers of containers of the ij-th standard size in a gondola car.

The working volume of one such container will be $V_{ij} = b_i^2 \cdot h_j$ and its mass is $G_{ijk}^* = V_{ij}^* \cdot \gamma_k$, where γ_k is the bulk mass of bulk cargo.

If the internal dimensions of the gondola car body are known (B - width, L - length, H - height), it can be recorded:

$$\begin{aligned} N_{ij} &= \langle (B-x)/b_i \rangle \\ M_{ij} &= \langle (L-x)/b_i \rangle \\ Z_{ij} &= \langle (H-\Delta)/h_{ij} \rangle \end{aligned}, \quad (2)$$

where:
x - allowance for gaps when installing the SC in the body,
Δ - the height to which regulatory documents allow containers of the upper tier to protrude above the side of an open rolling stock in height.

The sign $\langle \ldots \rangle$ here indicates the whole part of the result of division of the corresponding expression with rounding down.

The total loading of the wagon with loose cargo of a bulk mass γ_k using K_{ij} soft containers will add up to:

$$G_{ijk}^W = K_{ij} \cdot G_{ijk}^* = N_{ij} \cdot M_{ij} \cdot Z_{ij} \cdot b_i^2 \cdot h_j \cdot \gamma_k. \quad (3)$$

A rational choice of the soft containers parameters (b_i and h_j), in accordance with the transport characteristics of the cargo being transported (first of all, in accordance with the given value of the bulk mass γ_k) and the available means of transport, will allow to reduce the costs of containerization of railway transportation of a bulk cargo while obtaining all the known advantages of container transportation. At the same time, it is necessary to solve an optimization problem, which can be formulated as an integer optimization problem. One of the variants of the objective function for solving such a problem can be written in the form

$$K_{ij} = f(N_{ij}, M_{ij}, Z_{ij}, \gamma_k) \to \min, \quad (4)$$

where:
$N_{ij} = f(b_i, x),\ M_{ij} = f(b_i, x),\ Z_{ij} = f(h_j, \Delta)$.

When formulating the system of limitations of the problem, one should take into account the internal geometric dimensions of the body of a gondola car, the technological possibilities of the SC production and the requirements of the Technical conditions of loading [22], which forbid that the containers of the upper tier, when loaded into a semi-car, protrude above its side by more than 1/3 of their height (and generally no more than 400 mm).

In addition, several safety conditions of the transport process must be met, namely: the mass G^*_{ijk} of the loaded container with the bulk cargo must not exceed its maximum carrying capacity $G^*_{\max}$; loading G^W_{ijk} of the wagon with K_{ij} bulk cargo containers should be as complete as possible (of course, not exceeding its stenciled carrying capacity $G^W_{\max}$).

Taking this into account, the system of constraints of a problem is formulated as follows:

$$b_i^{\min} \leq b_i \leq b_i^{\max}; h_j^{\min} \leq h_j \leq h_j^{\max}; \\ G^W_{ijk} \to G^W_{\max}; G^*_{ijk} \leq G^*_{\max}. \quad (5)$$

4 Results and discussion

For example, Figures 1 and 2 show some results of optimization of the dependency $K_{ij} = f(N_{ij}, M_{ij}, Z_{ij}, \gamma_k) \to \min$ with variable SC parameters. Solving the problem of discrete optimization was carried out using the optimization block of the MS Excel package.

In the calculations, the following is accepted: the vehicle is an all-metal gondola car model 12-295 with a carrying capacity of 71 tons with internal dimensions of the body V = 2.89 m, L = 12.69 m, H = 2.05 m; bulk mass of cargo γ_k = 0.7 to 1.8 t/m^3; $G^W_{\max}$ = 70 t; $G^*_{\max}$ = 1.5 t.

After analyzing the graphs of the indicated dependencies, it is possible to choose a rational ratio of the soft containers' parameters with a square cross-section (namely, their width b_i and height h_j), which achieves the maximum use of the wagon's carrying capacity for a set value of the bulk mass of the transported bulk cargo.

At the same time, the minimum number of such soft containers is used for transportation. Thus, for example, for the selected type of rolling stock and the bulk mass of the cargo γ_k = 1.5 t/m^3 according to Figures 1 and 2, the optimum, from the point of view of the efficiency of loading the car body with bulk cargo in SC with the minimum number of containers, will be the soft containers with the parameters $b_i^{opt} \approx 1\,\text{m}$ and $h_i^{opt} \approx 1\,\text{m}$.

The authors believe that the method proposed in the paper for determining the rational parameters of flexible containers, which considers the characteristics of the

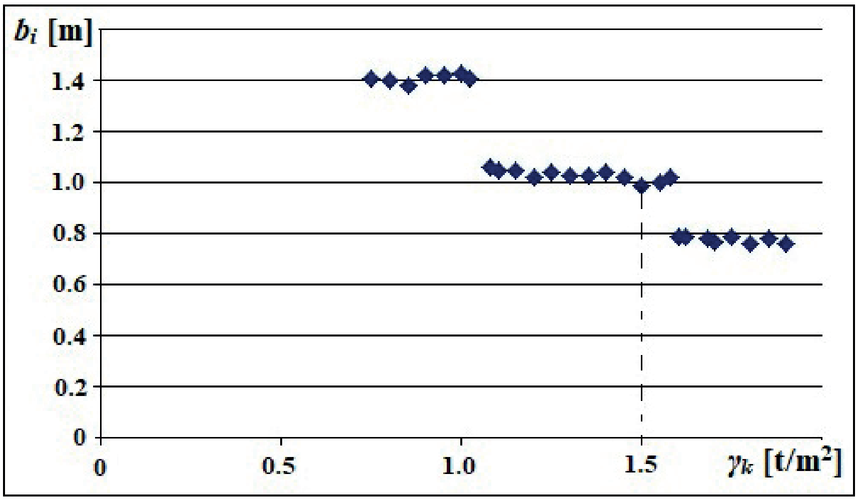

***Figure 1** Graph of dependence* $b_i^{opt} = f(\gamma_k)$

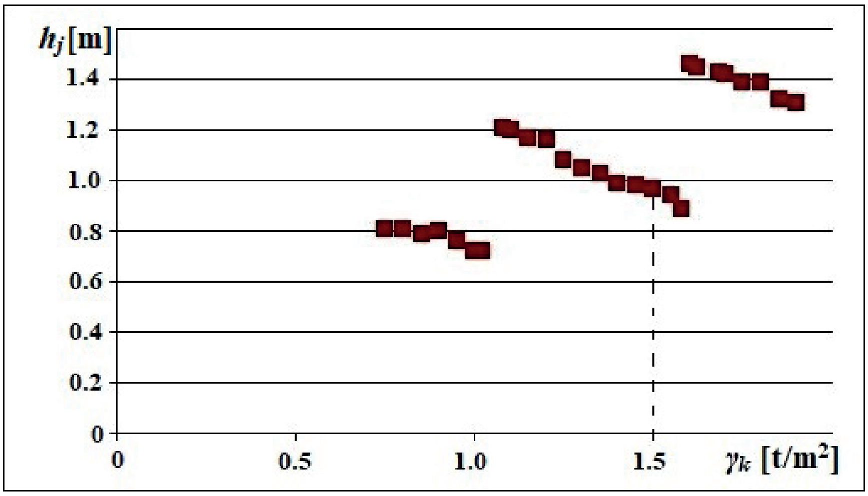

***Figure 2** Graph of dependence* $h_i^{opt} = f(\gamma_k)$

transported cargo and the geometric parameters of the cargo space of a vehicle, is quite simple and boils down to formulating and solving a discrete optimization problem. The objective function and the system of constraints of the problem in the reviewed work, in authors' opinion, are presented in full details. The graphs given in the work are presented only to illustrate how the proposed method can be used in practice. Those graphs are constructed based on solving the integer optimization problem for a specific bulk density of a bulk cargo and given geometric parameters of the vehicle cargo space. The solution of the discrete optimization problem, for the case under consideration, was carried out using the optimization block of the MS Excel package. Other mathematical programs can also be used to solve similar problems.

5 Conclusions

1. When developing the transport and logistics systems for delivery of goods, special attention should be paid to the rational choice of the transport equipment used. One of the progressive directions for improving the bulk cargo delivery systems is the use of soft specialized containers (SC) for the transportation and temporary storage of such a cargo.
2. Modern technological capabilities for production of the SC allow their production of almost any shape with a fairly wide range of basic parameters (width, height, load capacity).
3. It seems promising to use the SCs, which have the shape of a square in their cross section. With a rational selection of their parameters, such containers would allow the most complete use of the usable area of the cargo space of vehicles.
4. The paper proposes a method for selecting the rational parameters of soft containers having the shape of a square in their cross section in accordance with the characteristics of the cargo being transported and the dimensions of the cargo space of the vehicle. The method is based on optimizing the values of the geometric parameters of a flexible container (its width and height), taking into account the bulk density of the transported bulk cargo and the geometric parameters of the cargo space. The choice of rational geometric parameters of the soft container is carried out when solving the integer optimization problem according to the criterion of the most complete vehicle loading with the minimum number of used SCs.
5. A rational choice of the soft containers' parameters in accordance with the transport characteristics of the transported bulk cargo and parameters of the cargo space of the vehicle, would reduce the cost of containerization of the transportation of bulk cargo while obtaining all the known advantages of container transportation.

Acknowledgment

This research was supported by the project KEGA 031ZU-4/2023: Development of key competencies of the graduate of the study program Vehicles and Engines and the project VEGA 1/0305/23: „The research of dynamic properties of mechanical systems of railway vehicles with flexible structural components when running on a track".

Conflicts of interest

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.

References

[1] GRAWE, S. J., DAUGHERTY, P. J., ROATH, A. S. Knowledge synthesis and innovative logistics processes: enhancing operational flexibility and performance. *Journal of Business Logistics* [online]. 2011, **32**(1), p. 69-80. eISSN 2158-1592. Available from: https://doi.org/10.1111/j.2158-1592.2011.01006.x

[2] MAJERCAK, J., MAJERCAKOVA, E., NEDELIAKOVA, E. Management of optimization in logistics leads to savings in transport costs. In: 18th International Conference on Transport Means Transport Means 2014: proceedings. 2014.

[3] KOSTRZEWSKI, M. Implementation of distribution model of an international company with use of simulation method. *Procedia Engineering* [online]. 2017, **192**, p. 445-450. ISSN 1877-7058. Available from: https://doi.org/10.1016/j.proeng.2017.06.077

[4] Transport Logistics. Shared solutions to common challenges - OECD [online]. 2002. Available from: https://www.itf-oecd.org/sites/default/files/ docs/02logisticse.pdf

[5] MIKHAILOV, E., DIZO, J., KLIUIEV, S., SEMENOV, S., LACK, T., KRAVCHENKO K. Mechatronic system of control position of wheel pairs by railway vehicles in the rail track. *AIP Conference Proceedings* [online]. 2019, **2198**, 020009. Available from: https://doi.org/10.1063/1.5140870

[6] MIKHAILOV, E., SEMENOV, S., KLIUIEV, S., DIZO, J., BLATNICKY, M., GERLICI, J., HARUSINEC J., KOVTANETS, M. Clarification of features of the wheel movement with a perspective constructive scheme on a rail. *Applied Sciences* [online]. 2020, **10**, 6758. eISSN 2076-3417. Available from: https://doi.org/10.3390/app10196758

[7] KOSTRZEWSKI, M., KOSACKA-OLEJNIK, M., WERNER-LEWANDOWSKA, K. Assessment of innovativeness level for chosen solutions related to Logistics 4.0. *Procedia Manufacturing* [online]. 2019, **38**, p. 621-628. ISSN 2351-9789. Available from: https://doi.org/10.1016/j.promfg.2020.01.080

[8] NEDELIAKOVA, E., PANAK, M., SIPUS, D. Innovative trends in process-oriented quality management within railway transport. *Periodica Polytechnica Transportation Engineering* [online]. 2017, **45**(2), p. 84-89. ISSN 0303-7800, eISSN 1587-3811. Available from: https://doi.org/10.3311/PPtr.9582

[9] FOMIN, O., GERLICI, J., LOVSKA, A., KRAVCHENKO, K., FOMINA, Y., LACK, T. Determination of the strength of the containers fittings of a flat wagon loaded with containers during shunting. *IOP Conference Series: Materials Science and Engineering* [online]. 2019, **659**, 012056. ISSN 1757-8981, eISSN 1757-899X. Available from: https://doi.org/10.1088/1757-899X/659/1/012056

[10] AKHUNDOV, E. A., BATISHEV, I. A., SHISHENIN, E. A., VAGENGEIM, S. G. Flexible bulk container BK3: a new page in international rules on the transport of dangerous goods. *Transactions of the Krylov State Research Centre* [online]. 2018, **2**, p. 151-159. ISSN 2542-2324, eISSN 2618-8244. Available from: https://doi.org/10.24937/2542-2324-2018-2-S-I-151-159

[11] FOMIN, O., GORBUNOV, M., GERLICI, J., VATULIA, G., LOVSKA, A., KRAVCHENKO, K. Research into the strength of an open wagon with double sidewalls filled with aluminium foam. *Materials* [online] 2021, **14**(12), 3420. eISSN 1996-1944. Available from: https://doi.org/10.3390/ma14123420

[12] MIKHAILOV, E., SEMENOV, S., SHVORNIKOVA, H., GERLICI, J., KOVTANETS, M., DIZO, J., BLATNICKY, M., HARUSINEC, J. A study of improving running safety of a railway wagon with an independently rotating wheel's flange. *Symmetry* [online]. 2021, **13**(10), 1955. eISSN 2073-8994. Available from: https://doi.org/10.3390/sym13101955

[13] BUKOWSKI, T., RICHMOND, M. A Holistic view of the role of flexible packaging in a sustainable world. the flexible packaging association [online] 2018. Available from: https://perfectpackaging.org/wp-content/uploads/2018/09/FPA- Holistic-View-of-Sustainable-Packaging.pdf

[14] MIHAJLOV, E. V. *Technologies of cargo transportation in soft containers / Tehnologii perevezennja vantazhiv u m'jakih kontejnerah* (in Ukrainian). Beu Bassin: Lap Lambert Academic Publishing, 2018. ISBN 978-613-9-57815-3.

[15] STOMA, M., CABAN, J., DUDZIAK, A., KURANC, A. Selected aspects of the road traffic safety management system. *Communications - Scientific Letters of the University of Zilina* [online]. 2021, **23**(2), p. F33-F42. ISSN 1335-4205, eISSN 2585-7878. Available from: https://doi.org/10.26552/COM.C.2021.2.F33-F42

[16] CABAN, J., DROZDZIEL, P., STOMA, M., DUDZIAK, A., VRABEL, J., STOPKA, O. Road traffic safety in Poland, Slovakia and Czech Republic - statistic analysis. In: 12th International Science-Technical Conference Automotive Safety, Automotive Safety 2020: proceedings [online]. IEEE. 2020. eISBN 978-1-7281-5812-9. Available from: https://doi.org/10.1109/AUTOMOTIVESAFETY47494.2020.9293507

[17] PAVLIC SKENDER, H., ZANINOVIC, P. A., SRICA, E. Review of modern transportation technologies with focus on containerization. *Pomorski Zbornik / Journal of Maritime and Transportation Science* [online]. 2019, **57**(1), p. 111-121. ISSN 0554-6397, e ISSN 1848-9052. Available from: https://doi.org/10.18048/2019.57.08

[18] SOLOVIOVA, L., STRELKO, O., ISAIENKO, S., SOLOVIOVA, O., BERDNYCHENKO, Y. Container transport system as a means of saving resources. *IOP Conference Series: Earth and Environmental Science* [online]. 2020, **459**, 052070. ISSN 1755-1307, eISSN 1755-1315. Available from: https://doi.org/10.1088/1755-1315/459/5/052070

[19] SINGH, P., SINGH, J., ANTLE, J., TOPPER, E., GREWAL, G. Load securement and packaging methods to reduce risk of damage and personal injury for cargo freight in truck, container and intermodal shipments. *Journal of Applied Packaging Research* [online]. 2014, **1**(6), p. 47-61. ISSN 1557-7224. Available from: https://doi.org/10.14448/japr.01.0005

[20] FOMIN, O., GORBUNOV, M., LOVSKA, A., GERLICI, J., KRAVCHENKO, K. Dynamics and strength of circular tube open wagons with aluminum foam filled center sills. *Materials* [online]. 2021, **14**(8), 1915. eISSN 1996-1944. Available from: https://doi.org/10.3390/ma14081915

[21] FOMIN, O., GERLICI, J., VATULIA, G., LOVSKA, A., KRAVCHENKO, K. Determination of the loading of a flat rack container during operating modes. *Applied Sciences* [online]. 2021, **11**(16), 7623. eISSN 2076-3417. Available from: https://doi.org/10.3390/app11167623

[22] Technical conditions for loading and securing cargo on open rail vehicles/Tehnicheskie uslovija pogruzki i kreplenija gruzov na otkrytom podvizhnom sostave (in Russian). Moscow: Transport, 1990.

[23] SCHERBAKOV, A., LUNYAKOV, M., SMIRNOV, V., KAIGORODOVA, V., VERBOVA, N. Options for placement and transport of bulk goods by rail. *Transportation Research Procedia* [online]. 2022, **63**, p. 1498-1504. ISSN 2352-1457, eISSN 2352-1465. Available from: https://doi.org/10.1016/j.trpro.2022.06.161
[24] GORBUNOV, M., GERLICI, J., KARA, S., NOZHENKO, O., CHERNYAK, G., KRAVCHENKO, K., LACK, T. New principles schemes of freight cars bogies. *Manufacturing Technology* [online]. 2018, **18**(2), p. 233-238. ISSN 1213-2489, eISSN 2787-9402. Available from: https://doi.org/10.21062/ujep/83.2018/a/1213-2489/MT/18/2/233
[25] PIEKARSKI, W., STOMA, M., DUDZIAK, A., ANDREJKO, D., SLASKA-GRZYWN, B. How location shapes environmental awareness among inhabitants of Eastern Poland - an empirical study. *Polish Journal of Environmental Studies* [online]. 2016, **25**(2), p. 733-740. ISSN 1230-1485, eISSN 2083-5906. Available from: https://doi.org/10.15244/pjoes/60722
[26] CHUDZIKIEWICZ, A., MELNIK, R. Statistical analysis of vibration for the rail vehicle suspension monitoring system. In: 13th Mini Conference on Vehicle System Dynamics, Identification and Anomalies VSDIA 2012: proceedings. 2012.
[27] MELNIK, R., SOWINSKI, B. Application of the rail vehicle's monitoring system in the process of suspension condition assessment. *Communications - Scientific Letters of the University of Zilina* [online]. 2013, **15**(4), p. 3-8. ISSN 1335-4205, eISSN 2585-7878. Available from: https://doi.org/10.26552/com.C.2013.4.3-8
[28] YEVTUSHENKO, A., KUCIEJ, M., TOPCZEWSKA, K. Effect of the temporal profile of the friction power on temperature of a pad-disc brake system. *Journal of Theoretical and Applied Mechanics* [online]. 2019, **57**(2), p. 461-473. ISSN 1429-2955, eISSN 2543-6309. Available from: https://doi.org/10.15632/jtam-pl/105465
[29] YEVTUSHENKO, A., TOPCZEWSKA, K., KUCIEJ, M. Analytical determination of the brake temperature mode during repetitive short-term braking. *Materials* [online]. 2021, **14**(8), 1912. eISSN 1996-1944. Available from: https://doi.org/10.3390/ma14081912