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Determining the strength indexes of the bearing structure of the flat wagon of articulated type made from round pipes

Oleksij Fomin[a], Juraj Gerlici[b], Alyona Lovska[c], Mykola Gorbunov[d] , Kateryna Kravchenko[b]*, Tomáš Lack[b]

[a]State University of Infrastructure and Technologies, Department of Cars and Carriage Facilities, 04071, Kyrylivska str., 9, Kyiv, Ukraine
[b]University of Zilina, Faculty of Mechanical Engineering, Depatrment of Transport and Handling Machines, Univerzitna 1, 010 26 Zilina, Slovak Republic
[c]Ukrainian State University of Railway Transport, Department of Wagons, 61050, Feuerbach Square 7, Kharkov, Ukraine
[d]Volodymyr Dahl East Ukrainian National University, Institute of Transport and Logistics, Department of Railway, Automobile Transport and Handling Machines, Central Avenue 59a, 93400 Sewerodonetsk, Ukraine

Abstract

In the article the parameters of the structural strength of the flat wagon of articulated type made from round pipes has been determined. The model of the strength of the bearing structure of a flat wagon of an articulated type from round pipes is present. The calculation is based on the finite element method implemented in the CosmosWorks programming environment. Isoparametric tetrahedra were used when constructed the finite-element model of the bearing structure. The strength parameters of the bearing structure of a flat wagon of an articulated type from round pipes were determined.

Keywords: flat wagon; round pipes; strength; stressed state.

* Corresponding author. Tel.: +421(41)513 2660; fax: +421(41)513 2551.
E-mail address: Kateryna.Kravchenko@fstroj.uniza.sk

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1. Introduction

Development of the competitive environment in the rail transportation market with its higher efficiency requires the introduction of the new generation rolling stock along with combined transportation systems Lovskaya and Rybin (2016).

At the present stage of development of the railway industry it is necessary at the stage of designing cars to implement new innovative solutions for their design by Fomin and Gerlici et al. (2020), Dizo (2016), Dizo (2015), Stastniak (2019). In order to improve the efficiency of combined transportation along international transport corridors the found use the articulated flat wagon structure based (Fig. 1) Kotek and Florková (2014).

To ensure the efficiency of the transportation process, it is necessary to develop and implement wagon-platforms of a new generation with improved technical and economic indicators.

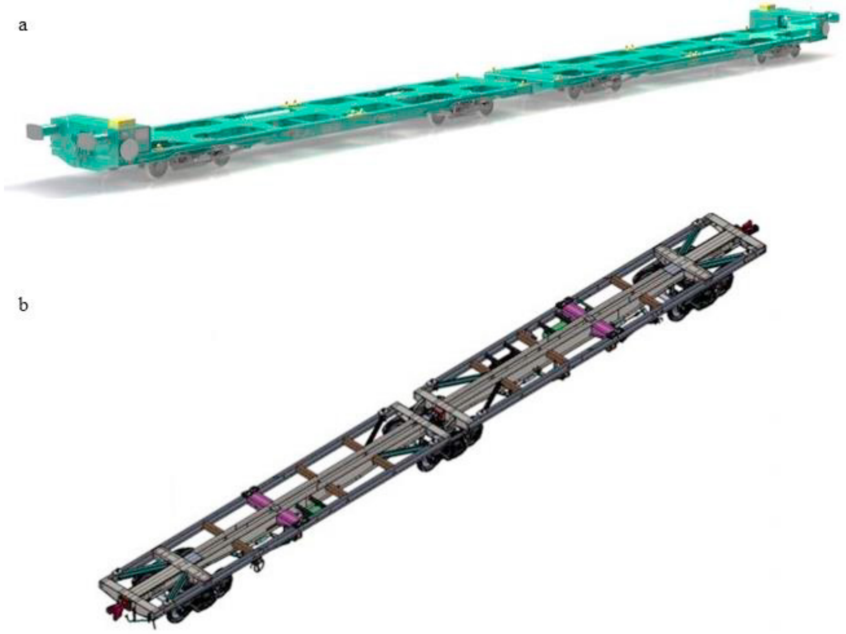

Fig. 1. Flat wagons of articulated type: (a) model FLA 2x40'; (b) model 13-9894.

2. Analysis of recent research

Definition of capacity indexes of a flat wagon for transporting containers and loading/unloading works is conducted with the system ACTS by Chlus and Krason (2012). And the capacity calculation at a static mode was conducted under Nastran software. The numerical data of the designed loads on a flat wagon were taken in accordance with the PNEN12663 and BN – 77/3532 – 40 standards Lovskaya and Rybin (2016). The capacity of a flat wagon was calculated with consideration of four load diagrams on its structure:

- compressive force of 2 MN along the buffer axle,
- compressive loads of 0.4 MN along the diagonal at the level of the buffers,
- tensile loads of 1 MN along the buffer axles,
- vertical inertia loads on the carrying structure of a flat wagon taking into account an acceleration of 1.95 g.

The features of development of a high-speed articulated flat wagon for container transportation are given by Kozhokar (2013). The engineering solutions taken during the flat wagon designing made it possible to transport simultaneously two 40-ft or 45-ft containers or four 20-ft containers.

It should be mentioned that the problem of dynamic loads on the carrying structures of wagon bodies in train ferry transportation was not considered in these studies Lovskaya and Rybin (2016).

Study by Marinoshenko (2015) substantiates the efficiency to use flat wagons in container transportation, for example, tank containers built at Transmash (Russia). The flat wagon structure capacity is 73 tons; and 1CC, 1C and 1CX containers can be transported Lovskaya and Rybin (2016).

The research into the dynamics of a rail wagon with the open charge level is given by Niezgoda et al. (2015). The calculation was made under MSC Adams software. And the research into the flat wagon tip stability was conducted while running on a 250-m radius curve with consideration of various traffic speeds Lovskaya and Rybin (2016).

The simulation of dynamic loading on freight wagon bodies, whose bearing elements are made from round pipes, was performed by Fomin and Prokopenko et al. (2019), Fomin and Lovska (2020). The authors determined the accelerations acting on wagons at shunting interaction using mathematical modeling and computer simulation (Fomin (2019)).

But the studies do not touch the problem of the capacity modelling of the flat wagon carrying structure [Lovskaya and Rybin (2016).

The authors Fomin et al. (2019), Fomin and Prokopenko et al. (2019) determined the dynamic loads that act on the bodies of freight wagons when they are transported by a railroad ferry. The calculations were carried out using computer simulation of the main types of railroad ferry oscillations. They substantiated the necessity to take into consideration the loads acting on wagons when they are transported by railroad ferries at the design stage under conditions of car building facilities.

The research into loading and reliability of rail wagons with the methods of dynamics for a body system is presented by Lysikov et al. (2007). The technique considered was used in the research of dynamic loading and fatigue resistance of the long-base flat wagon frame intended for container transportation Lovskaya and Rybin (2016).

The authors Sapronova et al. (2017) defined the feasibility of using the coupled implementation of a girder beam. The research was conducted theoretically and experimentally using a pellet wagon as an example. The proposed measures would help reduce the cost of making new wagon structures Fomin and Prokopenko et al. (2019).

The studies do not give consideration to the investigation into the flat wagon dynamics in rail operation Lovskaya and Rybin (2016).

3. The aim and objectives of the article

The aim of the article is to determine the parameters of the structural strength of the flat wagon of articulated type made from round pipes. In order to achieve this aim, the following objectives are defined Fomin and Gerlici et al. (2019), Fomin and Bukatova et al. (2019):

1. To create a model of the strength of the bearing structure of a flat wagon of an articulated type from round pipes Fomin and Hauser et al. (2018).

2. Determine the strength parameters of the bearing structure of a flat wagon of an articulated type from round pipes Fomin and Lovska (2020), vol. 72.

Study the strength of the bearing structure of the flat wagon from round pipes Fomin and Prokopenko et al. (2018). A strength model was developed for determining the parameters of the structural strength of the flat wagon of articulated type made from round pipes Fomin and Gerlici et al. (2020). The calculation is based on the finite element method implemented in the CosmosWorks programming environment by Fomin et al. (2019), Fomin et al. (2019), Fomin et al. (2020). The analytical model of the bearing structure of the flat wagon Fomin and Bazyl et al. (2019) under I rated condition (jump) is found in Fig. 2. In this case the longitudinal load $P_l = 2.5\ MN$ by Alyamovskiy (2015), DSTU 7598:2014, DIN EN 12663-2-2010 was applied on the fitting stops. It has been taken into account, that the flat wagon is carrying four containers of dimension type 1CC Fomin and Lovska (2020). The vertical load from containers P_k was applied on the horizontal surfaces of the fitting stops as a external load Lovska (2020).

Isoparametric tetrahedra were used when constructed the finite-element model of the bearing structure by Fomin et al. (2019), Okorokov et al. (2018), Lovska (2020). Optimal number of elements of the mesh is determined using of semigraphical method by Vatulia et al. (2019), Vatulia et al. (2018), Kondratiev et al. (2019), Fomin and Lovska (2020), vol. 72. In this case the number of elements of the lath was 5406526 Lovskaya, (2020), number of units was 1538366. Maximum dimension of the lath element is 15 mm, minimum – 3 mm Fomin (2018), maximum ratio of the sides of elements – 3078.9, the percentage of elements with a side ratio of less than three – 87.6, more than ten – 0.212. The number of elements in a circle is 8 Fomin and Lovska (2020), vol. 72. The ratio of increase in the size of an element is 1.7. The fastening of the model was in the areas of supporting of the bearing structure on the running gear. The results of calculation for the strength of the bearing structure of the flat wagon are shown below.

The maximum equivalent stresses thus occur in the console parts of the longitudinal tie rod and are about 200 MPa, that is, do not exceed the permissible stresses Fomin and Lovska (2020), vol. 72.

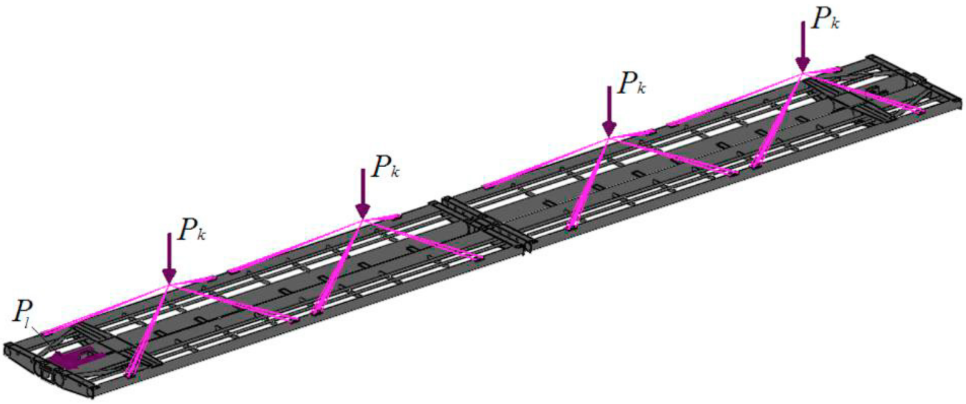

Fig. 2. Analytical model of the bearing structure of the articulated flat wagon made from round pipes.

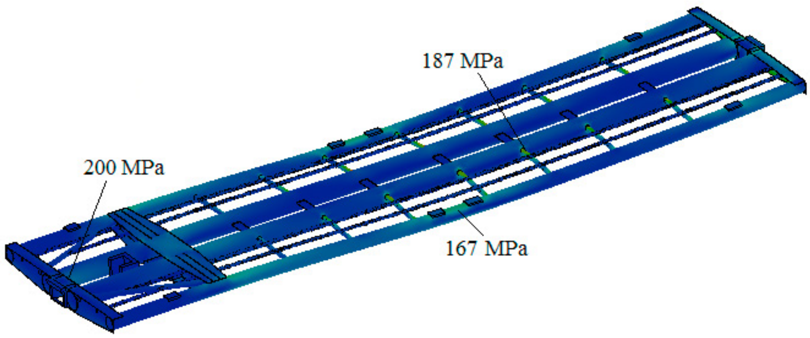

Fig. 3. The stressed state of the section of the articulated flat wagon (side view).

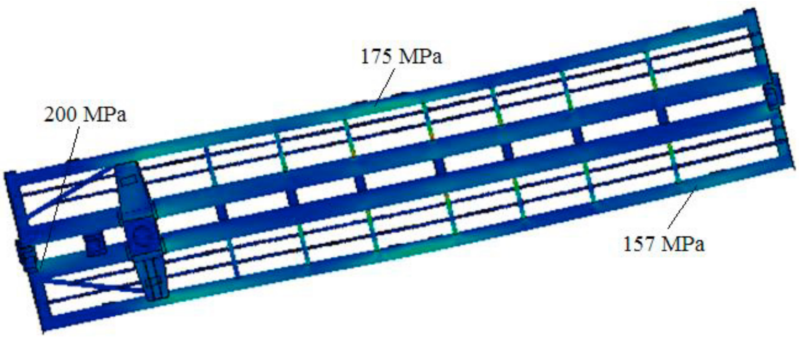

Fig. 4. The stressed state of the section of the articulated flat wagon (bottom view).

The maximum movements in the units of structure were in the middle parts of the sections and were 3.8 mm (Fig.5), the maximum deformations were $2.3 \cdot 10^{-3}$.

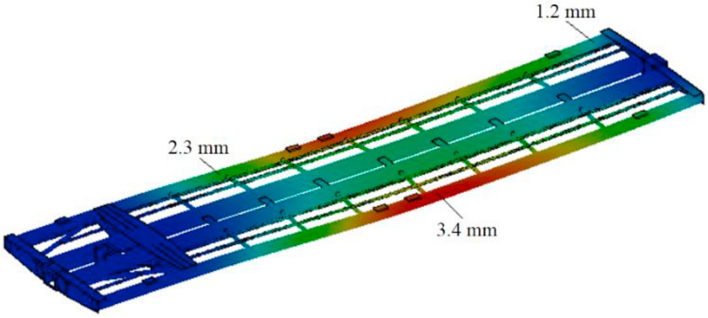

Fig. 5. Displacement in the nodes of a section of an articulated flat wagon.

Conclusions.

The following conclusions can be drawn based on the research carried out:

1. Model of an articulated flat wagon made from round pipes has been created. In this case the calculation was carried out under I rated condition (jump). That is the longitudinal load $P_l = 2.5\ MN$ was applied on the fore stops. It has been taken into account, that the flat wagon was carrying four containers of dimension type 1CC. The vertical load from containers P_k was applied on the horizontal surfaces of the fitting stops as a remote load.

2. Mathematical model of the bearing structure dynamic load of the flat wagon from round pipes in the main operational modes was done. Calculation was done using the finite element method. It has been found that maximum equivalent stresses occur in the console parts of the longitudinal tie rod and are about 200 MPa, that is, do not exceed the permissible stresses. Maximum deformations in the unites of the structure were in the middle parts of the sections and were 3.8 mm, the maximum deformations were $2.3 \cdot 10^{-3}$ Fomin and Vatulia et al. (2020), Fomin 2019).

The conducted researches will increase the efficiency of the operation of intermodal transportation and also will promote developing of recommendations relating to designing of modern constructions of articulated flat wagons. The improved bearing structure of the flat wagon has a container of about 6.2 tons, which is 4% less than the container of the prototype wagon (6.5 tons) Fomin and Lovska (2020), Fomin (2018).

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