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THE SUBSTANTIATION OF THE CONCEPT OF CREATING CONTAINERS WITH VISCOUS-ELASTIC CONNECTIONS IN FITTING

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ABSTRACT

The article presents the results of the substantiation of the concept of creating new-generation containers with viscous-elastic connections in fitting. For this purpose, a mathematical modeling of the dynamic loading of containers placed on a flat wagon while maneuvering concussion was carried out. The optimal parameters of elastic-viscous bonding in fittings are determined, in which the value of the dynamic loading of the carrier structure of the container does not exceed the normalized value. The carried out researches will promote creation of new generation containers with improved techno-economic and ecological indicators.

Keywords: container, dynamic loading, durability, maneuvering concussion, container transportation.

INTRODUCTION

Maintaining the leading position of railway transport in the market of transport services leads to the commissioning of interoperable systems. One of the most successful and effective among them is container transportation due to the mobility of the container as a vehicle.

Intermodal of the container determines the load of its bearing structure under different operating conditions, depending on the type of vehicle on which the carriage is carried out. Therefore, when creating new-generation containers with improved technical-economic and operational indicators, it is necessary to take into account the adjusted values of the loads that are operating on it, as well as the adoption of new innovative solutions aimed at improving the conditions of their operation.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Improvement of bearing structures of freight wagons to reduce their dynamic loading during maneuvering concussion is carried out in [1]. The feature of the proposed bodies of freight wagons is that their supporting elements consist of pipes of a round section, and the draw-buffing gear device of the auto-coupling equipment is replaced by more efficient.

Modeling of dynamic loading of bearing structures of bodies of freight wagons during transportation on a railway ferry is carried out in [2]. The calculations are carried out in the Cosmos Works software environment using the finite element method.

It is important to note that these works do not pay attention to the issue of container refinement in order to reduce the dynamic load during maneuvering concussion.

Studies on the transfer of heat flow through the boiler of the tank-container given in [3]. In this paper, the simulation of heat flow through a multi-layer resistance made of plastic is considered.

Tests of metal and composite containers under the influence of low temperatures are given in [4]. It is determined which types of containers it is expedient to use for transportation of the given nomenclature of loads taking into account low ambient temperature.

The results of optimization of the carrier structure of the tank-container are given in [5]. The feasibility of designing and putting into operation tank-containers as vehicles is proved in the work. The advanced design of the tank container for the transport of light petroleum products has been developed.

It is important to note that the works under consideration do not pay attention to the question of determining the dynamic loading of containers under operating conditions.

The features of the mathematical modeling of the dynamic loading of containers during transportation on flat wagons are given in [6]. The research has been conducted taking into account the gap between fitting stops and fittings and in their absence.

The study of the dynamic loading of a flat wagon during transportation on a railway ferry is carried out in [7]. At the same time, the angular movements of the railway ferry with the flat wagons, placed on it, are taken into account.

The results, as well as the peculiarities, of performed theoretical and experimental research into the introduction of the joint execution of a girder beam at railroad pellet wagons, were reported in [8]. Practical implementation of the proposed solutions makes it possible to reduce the cost of manufacturing such railroad cars by 10 %. Features of the simulation of loading on the bearing structure of a wagon-platform of the joined type at combined transportation are given in [9]. The research was conducted when the wagon-platform was operated relative to the main tracks and when transported by a railroad ferry.

The task of improving the bearing structure of the container to ensure its strength under operational load conditions in the works under consideration is not raised. An overview of the main problems of the dynamics of railway wagons that are related to traffic safety, is carried out in [10]. The main criteria used in assessing the safety of rolling stock in accordance with the standards of different countries are considered.

The issues of safe operation of containers in relation to trunk gauges in the works under consideration are not covered.

The study of dynamic loads acting on a tank-container located on a flat wagon with maneuvering concussion are given in [11]. The interaction of a tank-container with a flat wagon was simulated by an elastic-dissipative bond during longitudinal loading from a hammer car 2200-2800 kN. The choice of the parameters of the shock absorber was made for the case when the gap between the fittings and the fitting stops is maximized, and the flow of the bulk cargo is absent. The given model takes into account the presence of three degrees of freedom of the container.

The maximum magnitude of the longitudinal impact force that can act on a flat wagon with a load placed on it, including containers, with maneuvering concussion, may reach a greater value [12-14].

Therefore, in order to obtain the specified value of accelerations that act on the container in operation, further research is required.

DETERMINE THE PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the article is to substantiate the concept of the creation of containers with elastic-viscous connections in fitting. To achieve this goal, the following tasks are defined:

a) Improvement of the bearing structure of containers in order to reduce the dynamic load in the most adverse operating conditions;

b) Determination of dynamic loading of containers taking into account measures for improvement through mathematical modeling.

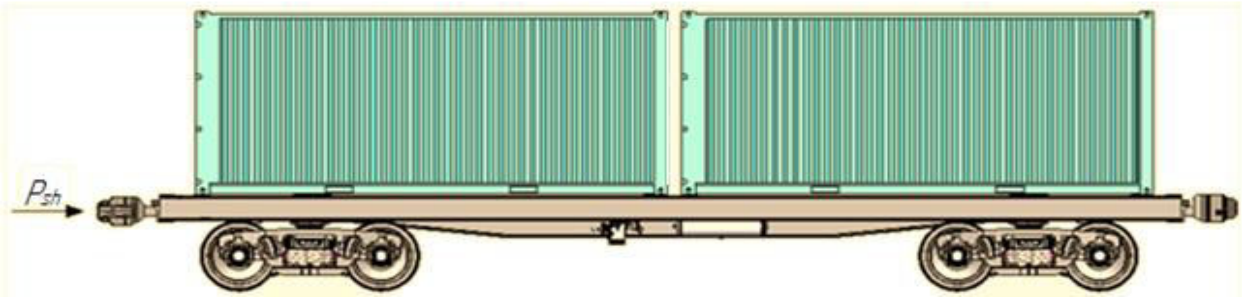

Figure-1. Scheme of longitudinal action on a flat wagon with containers placed on it.

THE MAIN PART OF THE STUDY

In order to reduce the shock loads between the container fittings and the fitting stops of the flat wagon while maneuvering concussion (Figure-1), in the case when the impact load exceeds the friction force between the horizontal planes of the fittings and fitting stops, setting the container of the elastic elements in the fittings are proposed (Figure-2).

In order to determine the dynamic load of the container during maneuvering concussion, taking into account measures for improvement, a mathematical model (1) is compiled, which takes into account the movement of a container placed on a flat wagon.

The model takes into account the force of dry friction that occurs when the container fittings move relative to the horizontal planes of the fitting stops and the elastic bond between the fitting stops and fittings [11]. The study of the dynamic loading of the container was carried out in a flat coordinate system.

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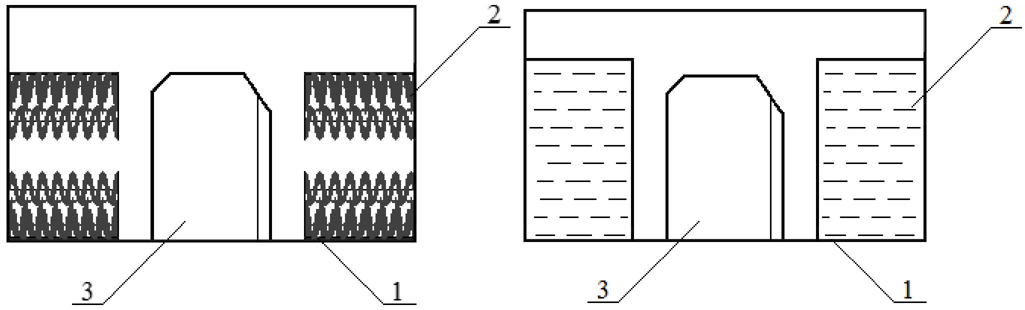

Figure-2. Fitting stops with elastic and viscous ties 1 - fitting; 2 - elastic (a), viscous (b) element; 3 - fitting stop.

$$\begin{cases} M_{fw}^{load} \cdot \ddot{q}_1 = P_{sh} - \sum_{i=1}^{n} \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + C_f (q_1 - q_2) \right), \\ M_c \cdot \ddot{q}_2 = \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + C_f \cdot (q_1 - q_2) \right), \end{cases} \quad (1)$$

where M_{fw}^{load} - gross weight of the flat wagon; P_{sh} - the magnitude of the longitudinal force acting on the coupler; n - the number of containers placed on the flat wagon; F_{ff} - friction force between fitting stops and fittings; M_c - the weight of the container; C_f - stiffness of elastic elements in container fittings; q_1, q_2 - coordinates determining the displacement of the flat wagon and the container relative to the longitudinal axis.

The solution of the mathematical model (1) is carried out in the software environment of MathCad [15-17]. In this case, it was reduced to a normal Cauchy form, with subsequent integration by the Runge-Kutta method.

On the basis of the calculations, acceleration was obtained, which is based on the improved design of the container placed on the flat wagon while maneuvering concussion (Figure-3).

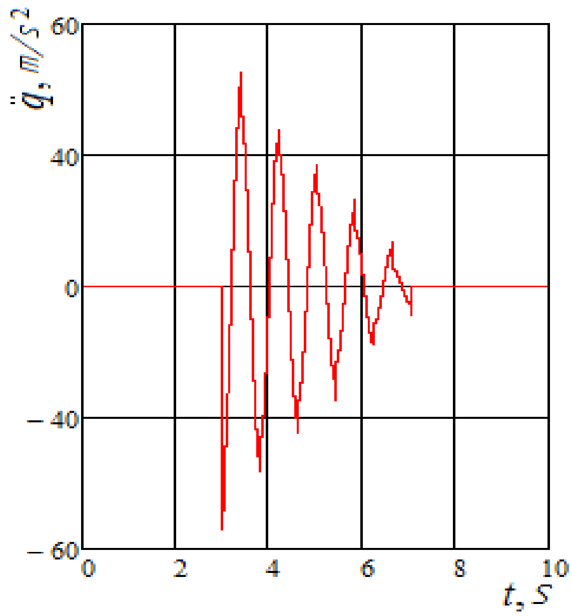

Figure-3. Accelerations that act on a container with elastic connections in the fittings, located on a flat wagon while maneuvering concussion.

This acceleration value was about 50 m/s^2 (5g). That is, exceeds the normative value of acceleration by 60% [18].

At the same time, the stiffness of the elastic elements was in the range 220-1700 kN/m. Consequently, the elastic connection between fittings and fitting stops under this calculation scheme does not compensate the full value of dynamic load acting on the container.

Therefore, the case of viscous interaction between the fitting of the container and the fitting stops of the flat wagon (Figure-2, b) is considered.

The mathematical model of the dynamic loading of the container during maneuvering concussion, taking into account the presence of viscous couplings in the fittings, is given below:

$$\begin{cases} M_{fw}^{load} \cdot \ddot{q}_1 = P_{sh} - \sum_{i=1}^{n} \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + \beta_f (\dot{q}_1 - \dot{q}_2) \right), \\ M_c \cdot \ddot{q}_2 = \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + \beta_f (\dot{q}_1 - \dot{q}_2) \right), \end{cases} \quad (2)$$

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where β_f - coefficient of viscous resistance in the fittings of the container.

Accelerations that act on a container with viscous connections in the fittings, located on a flat wagon with a maneuvering concussion are shown in Figure-4.

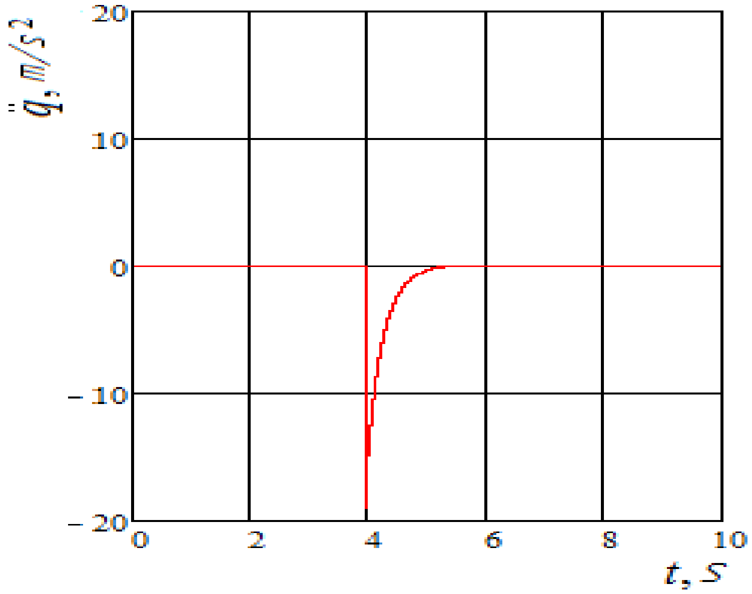

Figure-4. Accelerations that act on a container with viscous connections in fittings, placed on a flat wagon while maneuvering concussion.

At the given value of viscous resistance in the fittings of the container acceleration was about 20 m/s^2 (2g).

In this case, the total viscous resistance to the displacement of one container should be in the range of 10 - 50 kN · s / m.

To determine the dynamic loading of the tank-container during maneuvering concussion (Figure-5), taking into account the presence of elastic bonds in the fittings, a mathematical model (3) is compiled.

Gasoline is accepted as bulk cargo. Determination of the hydrodynamic characteristics of the bulk cargo was carried out taking into account the maximum allowable loading of the boiler of the tank-container in accordance with [19]. The movement of bulk cargo was described by a set of mathematical pendulums [11].

On the basis of the calculations, acceleration was obtained, which is based on the improved design of the tank-container placed on flat wagonwhile concussion (Figure-6).

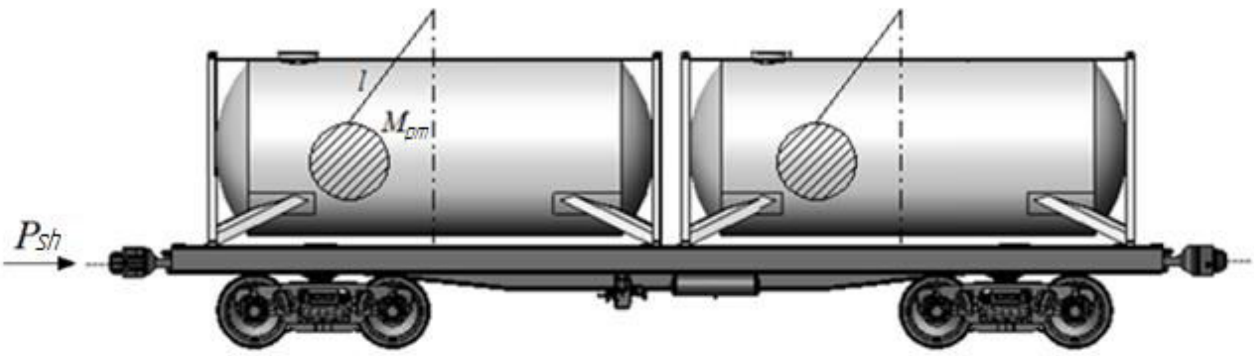

Figure-5. Scheme of longitudinal action on a flat wagon with tank containers placed on it.

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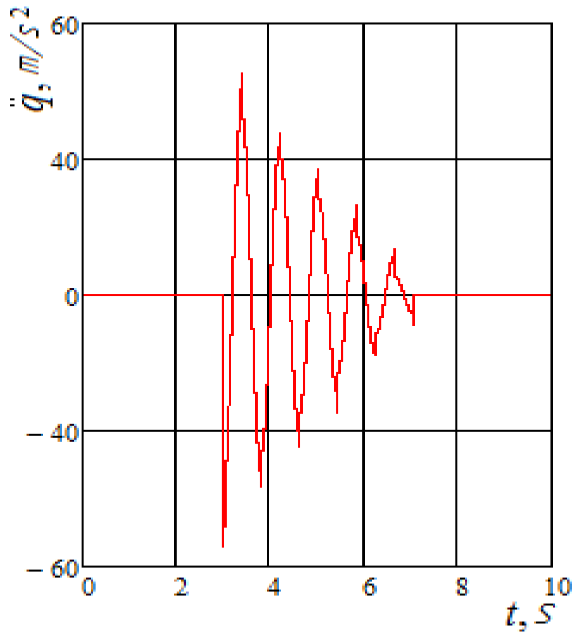

Figure-6. Accelerations that act on a tank-container with elastic connections in the fittings, located on a flat wagon while maneuvering concussion.

$$\begin{cases} M_{fw}^{load} \cdot \ddot{q}_1 = P_{sh} - \sum_{i=1}^{n} \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + C_f (q_1 - q_2) \right), \\ M_c \cdot \ddot{q}_2 = \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + C_f \cdot (q_1 - q_2) + M_{pm} \cdot l \cdot q_3 \right), \\ I_{pi} \cdot \ddot{q}_3 = M_{pm} \cdot l \cdot \ddot{q}_2 - g \cdot M_{pm} \cdot l \cdot q_3, \end{cases} \quad (3)$$

where M_{fw}^{load} - gross weight of the flat wagon; P_{sh} - the magnitude of the longitudinal force acting on the coupler; n - the number of tank containers placed on the flat wagon; F_{ff} - friction force between fitting stops and fittings; M_c - the weight of the tank container; C_f - stiffness of elastic elements in the tank container fittings; M_{pm} -mass of the pendulum simulating the displacement of the bulk cargo in the tank-container; l – the length of the suspension of the pendulum; I_{pi} - moment of inertia of the pendulum; q_1, q_2, q_3 - coordinates determining the displacement, respectively, of the flat wagon, tank-container and bulk cargo relative to the longitudinal axis.

This acceleration value was about 50 m/s^2 (5g), that is, exceeded the permissible value [20]. In this case, the overall stiffness of the elastic elements on the one tank-container was in the range of 420-530 kN/m.In order to reduce the dynamic loading of the tank-container placed on the flat wagon while maneuvering concussion, the option of performing fitting with viscous bonds is also considered. The mathematical model of the dynamic loading of the tank-container during maneuvering concussion, taking into account the presence of a viscous coupling fittings, is given below.

Accelerations that act on a tank-container with viscous connections in fittings, located on a flat wagon while maneuvering concussion are shown in Figure-7. At the given value of the viscous resistance in the fittings of the tank-container acceleration was about 40 m/s^2 (4g) and does not exceed the normalized value [20].

$$\begin{cases} M_{fw}^{load} \cdot \ddot{q}_1 = P_{sh} - \sum_{i=1}^{n} \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + \beta_f (\dot{q}_1 - \dot{q}_2) \right), \\ M_c \cdot \ddot{q}_2 = \left(F_{ff} \cdot sign(\dot{q}_1 - \dot{q}_2) + \beta_f (\dot{q}_1 - \dot{q}_2) + M_{pm} \cdot l \cdot q_3 \right), \\ I_{pi} \cdot \ddot{q}_3 = M_{pm} \cdot l \cdot \ddot{q}_2 - g \cdot M_{pm} \cdot l \cdot q_3, \end{cases} \quad (4)$$

Where β_f - coefficient of viscous resistance in the fittings of the tank-container.

In this case, the overall viscous resistance to thedisplacement of one tank-container must be in the range 9 - 54 kNs/m.

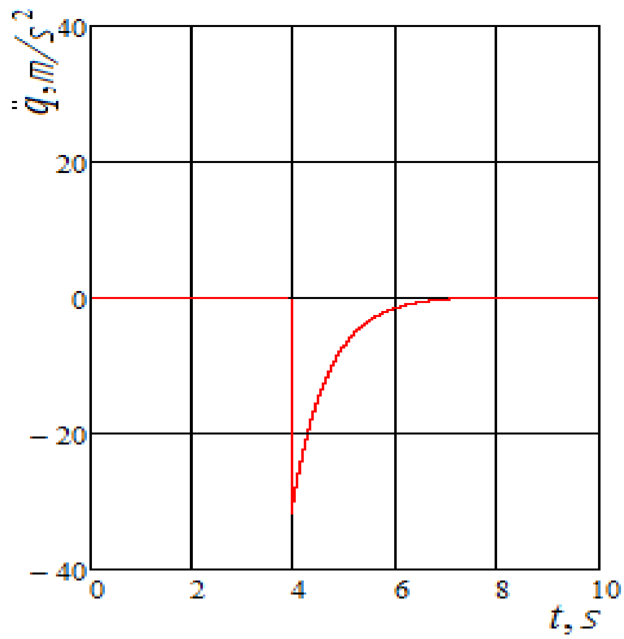

Figure-7. Accelerations acting on a tank-container with viscous connections in fittings, placed on a flat wagon while maneuvering concussion.

CONCLUSIONS

Based on the research carried out, the following conclusions can be drawn:

a) In order to reduce the dynamic loading of containers placed on a flat wagon while maneuvering concussion is proposed to set in fittings the viscous bonds;

b) A mathematical modeling of the dynamic loading of containers of advanced design, placed on a flat wagon during maneuvering concussion was carried out. It is established that the maximum accelerations acting on the container do not exceed the normalized. In this case, the total viscous resistance to the displacement of one container should be in the range of 10 - 50 kN·s/m, and for the tank container - 9 - 54 kN·s/m.

c) The conducted researches will promote increase of efficiency of operation of interoperable transport through international transport corridors.

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