INVESTIGATION OF THE INFLUENCE OF AN INTERMEDIATE ADAPTER ON THE DYNAMIC LOAD OF A SUPPORTING STRUCTURE OF A PLATFORM WAGON

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Summary: This article is focused on a presentation of the results of the theoretical justification of the use of an intermediate adapter placed between the main supporting structure of a platform wagon and the cargo. Such a decision will contribute to reducing the vertical load of both the supporting structure of a platform wagon and ensuring the safety of the cargo transported on it. The mathematical modelling of the vertical load of a platform wagon supporting structure when moving along the joint unevenness of the track was carried out to substantiate the use of the designed intermediate adapter. In this regard, a corresponding mathematical model was created. There is taken into account an oscillating system consisting of four bodies: the platform wagon supporting structure, two bogies (the 18-100 model) and the cargo. At the same time, the cargo is considered up to the full carrying capacity of the platform wagon. The track is considered elastic-viscous. The mathematical model was solved in the MathCad software. The initial conditions (displacement and velocities) are set to be close to zero. The results of the solution established that the accelerations acting on the platform wagon supporting structure are reduced by 8.4 % compared to those acting on the typical structure without the designed intermediate adapter. The acceleration acting on the cargo placed on the platform wagon frame is 11.9 % lower in comparison with the standard load perception scheme.

The strength analysis of the adapter was calculated considering the determined values of the accelerations. At the same time, the finite element method was used for the strength analysis of the adapter in the SolidWorks Simulation software. It was determined that the calculated maximum stresses in the adapter structure are 4.1 % lower than permissible stress values. Therefore, the strength condition of the adapter is met. The performed research will contribute to a creation of developments in the design of modern designs of railway vehicles.

Keywords: transport mechanics, platform wagon, supporting structure, dynamic load, intermediate adapter, railway transportation.

1. Introduction

The development of a competitive environment in the transportation market necessitates the need to increase the efficiency of rail transport operation. A key aspect of rail transportation of cargo is ensuring their safety under operational loads [1, 2].

Currently, platform wagons are one of the most used wagons in international transportation of cargo. When cargo is transported by platform wagons, their supporting structures are subjected to cyclic loads caused by rail irregularities, as well as transient modes of movement of wagons within a trainset. As a result, the cargo may be damaged, especially when they are not secured safely. Such a circumstance requires a necessity to compensate the corresponding losses of the cargo owners. In this regard, it is expedient to implement solutions aimed at reducing the dynamic load of the cargo during transportation by improving the load-bearing structures of wagons.

The analysis of the latest studies devoted to the issue of improving freight wagon designs in order to reduce the impact of dynamic loads on the load-bearing structure allow to conclude their relevance [3–7].

However, this analysis made it possible to prove the feasibility of research on the creation of solutions aimed at reducing the load on the load-bearing structures of platform wagons, and, accordingly, the safety of the cargo transported on them.

An intermediate adapter (**Fig. 1**) is designed to reduce the impact of vertical dynamic loads on the supporting structure of a platform wagon.

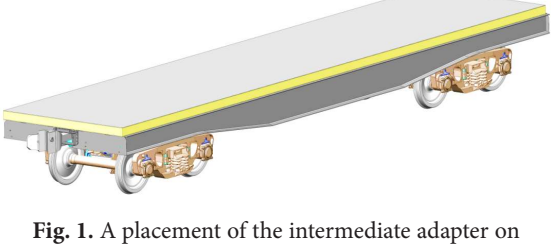

Fig. 1. A placement of the intermediate adapter on a platform wagon

The special feature of the adapter is a fact, that it consists of two metal sheets 1 (**Fig. 2**). An energy-absorbing material 2 with elastic-frictional characteristics is located between them.

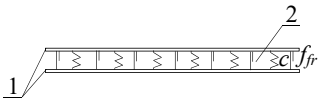

Fig. 2. A scheme of the intermediate adapter: c – stiffness of the energy-absorbing material; f_{fr} – a friction coefficient

The use of the designed intermediate adapter between the wagon frame and the load will contribute to the absorption of vertical dynamic loads that occur during bouncing fluctuations and reduce their impact on the load.

2. Materials and methods

A mathematical model of the dynamic loading of the platform wagon in the vertical plane was carried out to justify the proposed technical solution. It means, that bouncing oscillations were considered as one of the most common types of oscillations occurring in operation of freight wagons [8].

The study was carried out on the example of a platform wagon, a model 13-401. The platform wagon consists of four bodies: a frame, two bogies (a model 18-100) and the load placed on the frame. The cargo is considered loaded up to the full carrying capacity of the platform wagon. It is assumed that the wagon runs through a joint of rails, which has elastic characteristics [9]. The solution of the system of differential equations of motion was carried out in the MathCad software complex.

Moreover, as a part of the research, the calculation of the strength of the intermediate adapter was carried out using the finite element method, which was implemented in the SolidWorks Simulation software [10].

3. Results

Based on the solution of the set-up mathematical model of the vertical load of the platform wagon supporting structure it was found out, that the maximum accelerations act in its centre of gravity at the moment of passing the rail unevenness and they

equal to the value of 3.8 m/s^2. During the subsequent oscillating process, the acceleration value decreases and amounts to the value of 2.5 m/s^2 (**Fig. 3**). Therefore, when the proposed solution is taken into account, accelerations acting on the platform wagon supporting structure are reduced by 8.4 % compared to the standard platform wagon design.

The acceleration acting on the bogies was about 9.5 m/s^2. The acceleration acting on the load placed on the platform wagon frame was 2.8 m/s^2. The resulting acceleration value is by 11.9 % lower than the acceleration, which results from the load acting in a case of the standard load wagon scheme.

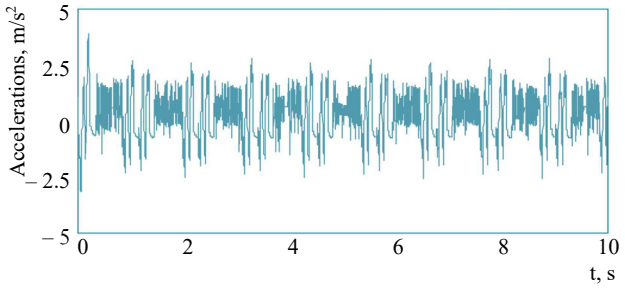

Fig. 3. Acceleration of the platform wagon supporting structure in the centre of gravity

The strength analysis the intermediate adapter was carried out using the finite element method. The calculation results showed that the maximum stresses occur in its corner parts and amount up to the value of 201.3 MPa. This value is 4.1 % lower than the permissible one. Therefore, the strength condition of the intermediate adapter is met [11]. The maximum movements take place in the upper sheet of the adapter and it reaches the values to 1.9 mm.

4. Discussion and scope of application

The use of the designed intermediate adapter between the wagon frame and the load is proposed to reduce the load on the platform wagon supporting structure in the vertical plane. The reduction of vertical loads is achieved by the application of the dissipative forces, which arise in the adapter during bouncing fluctuations.

A mathematical model of the vertical load of the platform wagon supporting structure was carried out in order to substantiate the proposed decision. It was established that the designed intermediate adapter allows to reduce accelerations acting on the platform wagon supporting structure by 8.4 % by in comparison with the standard design of a platform wagon (**Fig. 3**). The acceleration perceived by the load is 11.9 % lower than that acting on it, considering the typical load perception scheme.

The strength calculation of the designed intermediate adapter was carried out. This was performed by means of the finite element method. It was implemented in SolidWorks Simulation. The calculation results showed that the maximum stresses in the designed intermediate adapter structure are by 4.1 % lower than the permissible value. At the same time, the stresses of 201.3 MPa (steel grade 09G2S, III calculation mode) were accepted as the permissible value.

A limitation of this study is that it considers the presence of the model 18-100 bogies under the platform wagon supporting structure.

The shortcoming of the study is that it takes into account only translational movements of the platform wagon in the vertical plane, i.e. bouncing oscillations.

The advantage of this study is the fact, that the reduction of the vertical load on the platform wagon supporting structure is achieved by using a removable intermediate adapter. Such a solution does not require significant modification or improvement of the platform wagon supporting structure.

The engineering industry, particularly railway transport is the field of practical use of the obtained results.

The further research will be the experimental justification of the proposed solution. This can be implemented, for example, by the method of similarity on a scaled sample of the research object in the laboratory conditions.

The conducted research will contribute to the creation of developments in the design of modern designs of railway vehicles.

5. Conclusions

The dynamic load of a platform wagon with an intermediate adapter for placing cargo is determined. The results of the calculation showed that the maximum accelerations acting in the center of gravity of the platform wagon supporting structure occur equal to the value of 3.8 m/s^2 and they appear during wagon running on through a rail unevenness. It was found out, that the proposed technical solution leads to reduction of acceleration acting on the platform wagon supporting structure by 8.4 % compared to the standard platform wagon design. The acceleration acting on the bogies was about 9.5 m/s^2. The acceleration acting on the load placed on the platform wagon frame was of 2.8 m/s^2. The resulting acceleration value is by 11.9 % lower compared with acceleration acting to the load in case of the typical load perception scheme.

The strength of the designed intermediate adapter under the conditions of its vertical load was investigated. It was established that the maximum stresses occur in its corner locations, and they reach the maximal values of 201.3 MPa, which is by 4.1 % lower than the permissible value. Therefore, the strength of the designed adapter is met. The maximum movements take place in the upper sheet of the adapter and the maximal value is of 1.9 mm.

The conducted research will contribute to the creation of developments in the design of modern deigns of railway vehicles.

Conflict of interests

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

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Data availability

The manuscript has no associated data.

Use of an artificial intelligent

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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