рассматривать обшивку из профилей со сквозными гофрами как наиболее целесообразную для полувагонов с высотой кузова 2365 мм.

ЗАКЛЮЧЕНИЕ

На основе выполненных численных экспериментов показано, что переход на альтернативные профили обшивки в среднем дает снизить уровень напряжений в углах гофров на 20%, а в зонах приварки к стойкам — на 35%. Отказ от профилей с периодическими гофрами позволяет исключить зависание груза в гофрах и доказывает возможность использования вибротехники при разгрузочных операциях в течение всего межремонтного периода.

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Координаты авторов: Лапшин В. Ф. – VLapshin@usurt. ru, Колясов К. М. – KKolyasov@usurt.ru, Долгих К. О. – DolgikhKO@yandex.ru.
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SIDING SHEATHING SHAPE AND CYCLES OF VIBRATION LOADING OF GONDOLA CARS

Lapshin, Vasily F., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*
Kolyasov, Constantine M., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*
Dolgikh, Constantine O., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*

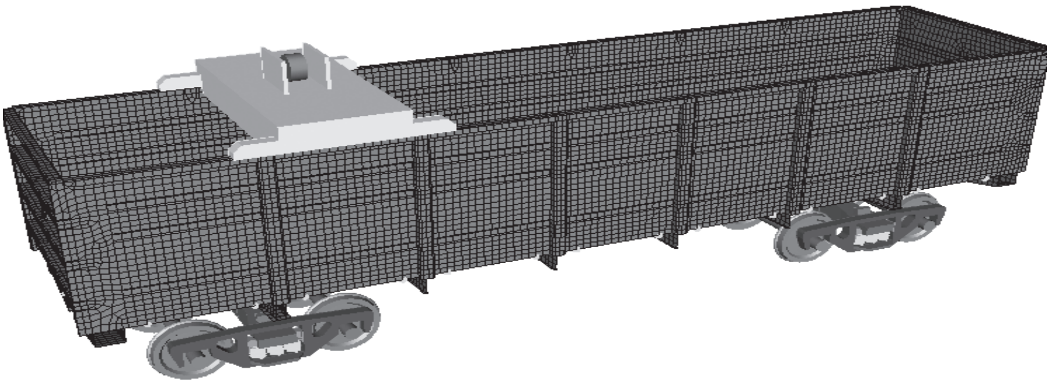
ABSTRACT

The design of the side walls of freight gondola cars, designed for the use of vibration loading technology assume their sheathing with sheet profiles. Earlier held survey of technical state of gondola cars with a body height of 2365 mm, delivered for unloading and cleaning of cargo residues using vibration equipment [3] revealed an increased damageability of elements of the side walls. About 90% of gondola cars had separations of siding sheets from the side wall pillars and cracks of up to 200 mm in the corners of middle and upper corrugations of the first and second panels. This led to the fact that a new edition of GOST 22235, in force since 2010, prohibits the delivery of cars with body height of 2365 mm for unloading using vibration technology. To increase the operational reliability of such complexes, different designs, models are offered, new calculations and experiments are conducted. The article presents the results of authors' research, conducted primarily with simulation and hybrid modeling methods, its conclusions and options of alternative sheathing profiles, tested in Yekaterinburg, showing the possibility of using overhead vibration machines for unloading gondola-cars with a height of the body of 2365 mm and with account of permissible time of operation of the rolling stock.

Keywords: railway, gondola-car, sheathing profile, loading cycles, overhead vibration machine, allowable loading time, stress concentration, cargo hovering, damageability of elements, turnaround time.

Background. *The current stage of vibration unloading technology development is characterized by the transition to gondola cars with a body height of 2365 mm instead of 1880 and 2060 mm and a maximum allowable time of such operations for a turnaround time of 168 minutes, an increase in the flow rate of cars› delivery for vibration unloading up to 16 times per month [1] and frequent violation of the requirements of GOST 22235 [2] concerning the safety of gondola cars during unloading using vibration machines.*

Earlier held survey of technical state of gondola cars with a body height of 2365 mm, delivered for unloading and cleaning of cargo residues using vibration equipment [3] revealed an increased damageability of elements of the side walls. About 90% of gondola cars had separations of siding sheets from



Pic. 1. A computer model of a mechanical system «vibration machine- body of a gondola car-bogie».

the side wall pillars and cracks of up to 200 mm in the corners of middle and upper corrugations of the first and second panels. This led to the fact that a new edition of GOST 22235, in force since 2010, prohibits the delivery of cars with body height of 2365 mm for unloading using vibration technology.

However, this ban does not solve the problem of preservation of such gondola cars, and their share in the total fleet prevails. This refers, in particular, to the car fleet for the transport of ore with the participation of JSC «Svyatogor», CJSC «PO Rezhnickel» and other partners of Sverdlovsk railway (as of 2011).

A distinctive feature of the design of the side walls of gondola cars is the use of sheet profiles as a sheathing with recurrent longitudinal corrugations with the depth of 36 mm, performing the role of stress concentrators. Since 2008 there is a search for constructive solutions for such a siding. To exclude its damage JSC SPC «Uralvagonzavod» developed the designs of side walls with the use of smooth sheet with a thickness of 4,5 mm; profiles with longitudinal end-to-end corrugations with the depth of 10 ± 2 mm [4]. Then this turned to be evident and urgent task to achieve an objective assessment of the impact of the siding profile on the permissible number of loading cycles and to find ways to improve the operational reliability of gondola cars when exposed to vibration load.

Objective. *The objective of the authors is to investigate sheathing profiles and cycles of vibration loading of gondola cars.*

Methods. *In a study of loading of a body of a gondola car we used computer modeling technique described in [5]. The methodology is based on the model of «vibration machine – body of a gondola car-bogie», which includes not only absolutely solid bodies (sub-models «vibration machine», «bogie»), connected by joints and force elements, but also elastic bodies (sub-model «body of a gondola car»).*

Ideology of the model is based on the principles of hybrid modeling method, implemented in a research environment «universal mechanism» [6]. When forming a general model of a mechanical system «vibration machine-body of a gondola car-bogie» contact interaction «point-plane» was taken into account, included in the standard set of software procedures of the analytical software environment. The elastic properties of the body were reflected by the module of programming elastic bodies UMFEM. Loading of a body was performed through the application of vibration load to the top cord, which corresponds to the conditions of unloading of gondola cars using overhead vibration devices (Pic. 1).

The algorithm for solving the problem involved two steps:

– Assessment of the force impact of the vibration machine on the body during unloading, obtaining values of dynamic stresses in the siding elements;

– Finding the permissible time [T] (the number of cycles until fatigue damage) of loading of a body by a driving force of a vibration machine. The total number of cycles for the overhaul period was determined in accordance with existing rules [7].

Three variants of the body structure with modified siding profile of the side wall were identified as the object:

1) sheet profile with longitudinal periodic corrugations according to TU 14–101–789–2008 with a thickness of the upper sheet of 3,6 mm and of the lower sheet – 4,5 mm;

2) smooth sheets with a thickness of 4,5 mm;

3) sheet profile with a longitudinal end-to-end corrugations according to TU 14–101–789–2008 with a thickness of the upper sheet of 3,6 mm and of the lower – 4,5 mm.

At the first stage stress state of the side wall elements was estimated. Calculations were made using the following parameters of overhead vibration machine: the amplitude of the driving force is 88 kN, the weight is 7500 kg, loading frequency is 24 Hz. The vibration machine was mounted above the first bogie with an overlap of two pillars with bearing surfaces (pivoted and the first intermediate pillars, Pic. 1).

In determining the permissible number of loading cycles the result largely depends on the assumed acceptable safety factor in fatigue strength [n]. As is well known [7], for the elements of the body values of the coefficient [n] depend on the reliability of the source data and the type of structural element. With this in mind, for the body siding the permissible value is [n] = 1,5.

Results.

The results of numerical experiments

When the loading frequency of the driving force of 24 Hz of an empty gondola car (which corresponds with a certain degree of approximation to purification process), the maximum dynamic stresses occur in the corners of the upper corrugations of the first and second panels, wherein their value is 49–55 MPa. For the welding zones of the sheets of the siding to bear-

ing elements of the side wall the highest stresses are fixed at welding points of the second, the sixth and the seventh panels to vertical pillars, the stress level in which was 52–66 MPa.

The calculations show that in the body structure with alternative sheathing the maximum stress level is within the range of 34–51 MPa and 38–50 MPa – for smooth sheets (option 2) and for longitudinal end-to-end corrugations (option 3), respectively. Characteristically, in the sheathing of smooth sheets maximum values occur in sheets welded to the upper rail, while at the siding with end-to-end corrugations – in the area of welding to the pivoted and the intermediate pillars. Wherein the values of total stresses for alternative options of sheathing are on average by 20–35% lower than in the base option 1 – with periodic longitudinal corrugations.

The advantage of alternative profiles is that they except cargo hovering in pimples, which is typical for gondola cars with the sheathing made of sheets with periodic horizontal corrugations. We have calculated the stresses in this embodiment for cargo hovering in the corrugations. It has been established that the maximum occurs in the middle and lower corrugations of the first, the second, the sixth, the seventh panels where stress reaches 100 MPa. Cargo hovering also leads to an increase in stresses up to 84 MPa in the areas of welding of sheets of the sheathing to the supporting elements of the side wall.

It is clearly seen that the sheathing profile has a significant impact on the level of dynamic stresses and on the nature of their distribution along the elements of the side wall.

At the second stage a number of loading cycles was estimated in terms of allowable exposure time of the vibration machine» on the body of a gondola car before fatigue damage. Calculations revealed that for the typical design (option 1) allowable time during the turnaround time should not exceed 85 minutes. In the case of cargo hovering this figure drops to 46 minutes.

In the transition to alternative siding profiles it is possible to substantially increase exposure time of the vibration machine on the gondola car during unloading operations. So, for the option with smooth siding allowable time is 500 minutes, and it is limited to the load of sheets of the second panel in the area of welding to the top cord. In the remaining elements of the side walls the same figure grows to about 2000 minutes, which corresponds to 1,5–2 years of operation of the gondola car in closed routes [1]. However, this siding has an insufficient bending stiffness, buckling between pillars. In addition, due to the greater thickness of the siding sheet the unladen weight of the gondola car increases. A similar value [T] suggests to use profiles with longitudinal end-to-end corrugations (option 3).

The obtained results allow us to consider siding of profiles with end-to-end corrugations as the most suitable for gondola cars with a body height of 2365 mm.

Conclusion. *On the basis of numerical experiments it is shown that the transition to alternative sheathing profiles gives a possibility to reduce on average the stress level in the corners of the corrugations by 20%, and in the areas of welding to the pillars by 35%. Refusal to use profiles with periodic corrugations enables to eliminate cargo hovering in corrugations and proves the possibility of using vibration equipment for unloading operations throughout the turnaround time.*

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Information about the authors:
Lapshin, Vasily F. – D. Sc. (Eng.), professor at the department of railway cars of Ural State University of Railway Transport (USURT),Yekaterinburg, Russia, VLapshin@usurt.
Kolyasov, Constantine M. – Ph. D. (Eng.), associate professor, head of the department of railway cars of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, KKolyasov@usurt.ru,
Dolgikh, Constantine O. – assistant lecturer at the department of railway cars of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, DolgikhKO@yandex.ru.

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