The body of a dynamometer wagon for special technical purposes

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Abstract. The development of new and improvement of existing railway rolling stock wagons is an urgent task of our time, providing for cost reduction, both in the process of creation and operation, and in the maintenance of the wagon fleet. The purpose of the work is to modernize the body of a dynamometer wagon for special technical purposes using modeling. To determine the loading of the structural elements of a dynamometer wagon, a calculated three-dimensional model of the wagon body was developed, the reinforcement points of the wagon frame were determined. Compression/tensile strength tests of the wagon were performed on a stand for loading the frames of wagons and elements of coupling devices. The stress-strain state of the wagon structure is determined when statically applied longitudinal test loads are applied to it. The test results and the stress-strain state of the design of the prototype wagon, under the action of statically applied longitudinal compressive and tensile test loads, showed that the proposed design of the wagon meets the established strength requirements, while no visible damage and residual deformations were found in the design of the prototype wagon. The developed design of the dynamometer wagon body can be included in both freight and passenger trains, which solves the problem of efficient and safe use of locomotives when operating trains on mountainous sections of railways of the Republic of Uzbekistan.

1 Introduction

At the present stage of the development of industry and economy of the Republic of Uzbekistan, the issue of ensuring the safety and efficiency of railway transport is becoming urgent, the solution of which requires targeted measures to improve infrastructure with the introduction of modern innovative technologies [1-5].

Over the years of independence in the Republic of Uzbekistan, in order to create a unified railway network of the country, a number of major projects have been implemented to build tracks and enhance the infrastructure of railway transport, equip the rolling stock fleet with new locomotives and wagons with improved technical and economic characteristics. For example, in 1994-2001 a new railway line “Navoi – Uchkuduk – Sultanuizdag – Nukus” was built; in 2003-2007 “Tashguzar – Kumkurgan” railway was built; in 2011-

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“Yangier Novaya – Dashtabad”, “Gallaaral – Bulungur” and “Dashtabad – Jizzakh” railway sections were built; in 2013-2016 a project for the construction of a new Angren – Pap railway was implemented; in 2017 the electrification of the “Karshi – Termez” sections was completed and “Pap – Andijan”, the “Bukhara – Miskin” railway was built [6-9].

During the construction of new railways, especially in mountainous areas of the republic, where the slope of the track exceeds 12.5‰ (for example, on the Angren – Pap railway section, the slope of the track reaches up to 27‰, on the Tashguzar – Baysun – Kumkurgan line, the slope of the track is from 12‰ to 18.5‰), important tasks when ensuring the safety of rolling stock movement, the selection of the optimal traction of the locomotive for the operation of trains, the determination of the longitudinal dynamic coupling forces of wagons and locomotives arising during ascent and descent, as well as checking the critical mass norms and conditions for passing trains. The effective solution of the tasks is possible only with the use of a dynamometer wagon for special technical purposes [10-12].

Since the dynamometer wagon is planned to be operated as part of passenger and freight trains, the body structure of the developed wagon should be designed for compression forces of 3.5 MN and stretching of 2.5 MN, according to the requirements of GOST 34093-2017 and GOST 33211-2014.

In the process of performing the work, the author’s team also took into account the issue of reducing the weight of railway rolling stock wagons. This makes it possible to reduce energy costs for transportation, achieve fuel economy, and reduce emissions into the atmosphere on the basis of a Sustainable Development Program. For this purpose, a critical analysis of modern scientific literature was made [7,9,11,13-20], which allowed us to conclude that it is necessary to use lightweight materials, as well as reinforcing technologies for their processing, including for their use in the creation of new wagons, including dynamometric.

The purpose of this work is to conduct theoretical and experimental studies to improve the metal structure of the passenger wagon model 61-907 produced by JSC “Tashkent Plant for the Construction and repair of passenger wagons” to convert it into a dynamometer wagon of special technical purpose intended for the railways of the Republic of Uzbekistan.

2 Research methods

The work uses the SolidWorks 2021 software package. In addition, the engineering program Ansys Workbench 2021 and the finite element method were used in the calculation process, which helped to carry out theoretical studies and experimental studies of the 61-907 DM model for the railways of the Republic of Uzbekistan.

The experimental results of the research were processed using the program developed by the authors and a special technique of static tests for the strength of the body of a prototype dynamometer wagon.

Compression/tensile strength tests of the wagon were performed on a stand for loading the frames of wagons and elements of coupling devices. The stress-strain state of the wagon structure is determined when statically applied longitudinal test loads are applied to it.

3 Results and discussion

The design of the passenger wagon model 61-907. The frame of the passenger wagon model 61-907 consists of a ridge beam (figure 1), which is welded from two channels No. 30 in the end parts and an I-beam No. 30B2 in the central part, two pivot beams having a closed box section, the floor of the wagon with cross beams and strapping (figure 2), consisting of two...
side beams made of from an equal floor corner of 100 × 100 × 10 mm, and corrugated sheathing, sprengel beams, to which the wagon equipment is suspended.

Fig. 1. General view of the ridge beam of the frame of the passenger wagon model 61-907:
1 – end beam; 2 – pivot beam; 3 – channel No. 30; 4 – auxiliary beam; 5 – wing; 6 – reinforcing cross beam; 7 – I-beam 30B2; 8, 10 – buffer stops; 9 – strap

Theoretical part

At the first stage, theoretical studies were carried out to assess the structural strength of the passenger wagon body using modern engineering systems by the finite element method, the results of which determined the places of reinforcement of the frame.

To determine the loading of the structural elements of the dynamometer wagon, a calculated three-dimensional model of the wagon body was developed in the SolidWorks 2021 software package.

As a result of the theoretical studies of the loading of the body structure of the passenger wagon model 61-907 using the finite element method in the engineering program Ansys Workbench 2021, it was determined that an increase in the stresses of compressive and tensile longitudinal loads transmitted to the elements of the wagon body through coupling devices, according to the requirements of GOST 34093-2017 and GOST 33211-2014, leads to a slight increase in the stress-strain state of the elements of the side walls and roof. Approximate locations for measuring stresses in the structural elements of the wagon body are shown in figure 3. The dependences of the stresses arising in the elements of the passenger wagon body on the acting compressive longitudinal loads are shown in figure 4.
At the same time, it was determined that the obtained stress values in the nodes of the wagon frame are close to the permissible ones, and in some cases exceed them, and therefore it is necessary to increase the cross-sectional area of the body frame nodes with the help of reinforcing elements in proportion to the stresses arising from tensile and compressive loads so that the stresses from them meet the requirements and do not exceed the permissible values.

Fig. 3. Places of stress measurement in the structural elements of the passenger wagon body (prototype wagon)

Fig. 4. Dependences of stresses arising in the elements of the passenger wagon body (prototype) on the acting compressive longitudinal loads: 1–11 – places of stress measurement (see figure 3)

To operate the dynamometer wagon being developed as part of freight trains and meet the requirements of GOST 34093-2017 and GOST 33211-2014, the backbone beam of the frame of the dynamometer wagon, unlike the analog wagon, in the central part, made of I-beam No. 30, must be reinforced on both sides along the entire length with plates 8 mm thick connecting the edges upper and lower shelves on both sides of the wall (Figure 5, a). In addition, the lateral longitudinal beam of the carriage frame between the doorways, made of a corner of 100 × 100 × 10 mm, must be reinforced with an equal angle with a cross-sectional dimensions of 75 × 75 × 5 mm (Figure 5, b). The reinforced lateral longitudinal beams of the frame are connected to the rear stops in the ridge beam by special braces, the cross section of which consists of two channels No. 30 forming an I-beam (Figure 5, c). The beam has a narrowing at the point of attachment to the longitudinal beam without changing the cross-section profile [18-20].
Fig. 5. a – the spine beam of the frame with reinforced plates; b – the lateral longitudinal beam of the frame with reinforced corners; c – the cantilever part of the frame with reinforced braces; d – general view of the frame of the wagon with reinforced elements.

Thus, the performed strengthening of the frame of a passenger wagon analog of the model 61-907 on the basis of theoretical studies conducted to assess the structural strength of the wagon body will increase the cross-sectional area of the wagon frame nodes in proportion to the stresses arising from tensile and compressive loads so that the stresses from them meet the requirements and do not exceed the permissible values.

The experimental part. At the next stage of research, a program and methodology for static strength tests of the body of a prototype dynamometer wagon model 61-907-DM for the railways of the Republic of Uzbekistan were developed. According to the developed program and methodology, the prototype dynamometer wagon model 61-907-DM was subjected to static strength tests, according to GOST 33788-2016, the purpose of which was to assess the stress-strain state at the control points of the elements of the metal structure of the wagon under the action of statically applied longitudinal compressive and tensile test loads. Static tests were performed on a special stand for loading the frames of wagons with longitudinal static loads transmitted through coupling devices, which allows loading the structure of the wagon when it is evaluated for strength with compression forces of 3.5 MN and stretching of 2.5 MN according to the requirements of GOST 34093-2017 and GOST 33211-2014.

Before the tests were carried out, the strain gauges were glued to the studied points of the structure of the load-bearing elements of the wagon, obtained from the results of strength calculations. The schemes of the strain gauge sticker on the prototype wagon are shown in Figures 6 and 7.
Fig. 6. Diagram of the arrangement of strain gages on the frame of a prototype dynamometer wagon.

Fig. 7. Diagram of the arrangement of strain gages on the body of a prototype dynamometer wagon.

Fig. 8. General view of a prototype dynamometer wagon on a stand for loading the frames of wagons with longitudinal loads.
Evaluation of the test results by static longitudinal loads was carried out by comparing the obtained maximum stresses with the permissible values. At the same time, the conditions for the strength of the wagon structure were:

- absence of visible damage to structural elements (cracks in welds or base metal, violation of geometry, loss of stability of structural elements);
- the values of stresses at the studied points that do not exceed the permissible values.

Thus, the test results and the stress-strain state of the design of the prototype wagon, under the action of statically applied longitudinal compressive and tensile test loads on it, showed that the proposed design of the wagon meets the established strength requirements, no visible damage and residual deformations were found in the design of the prototype wagon [18-20].

5 Conclusion

Thus, the developed design of the dynamometer wagon body can be included in both freight and passenger trains, which solves the problem of efficient and safe use of locomotives when operating trains on mountainous sections of railways of the Republic of Uzbekistan. It follows from the material presented above that:

1. The paper describes the need to develop a dynamometer wagon for special technical purpose to select the optimal traction of a locomotive during the operation of trains, to determine the longitudinal-dynamic coupling forces of wagons and locomotives that occur during ascent and descent, as well as to check the critical mass norms and conditions for passing trains.
2. The design of the body of the passenger wagon model 61-907 is presented as a prototype for upgrading it into a dynamometer wagon;
3. The results of theoretical studies for which a calculated three-dimensional model of the wagon body was constructed and the dependences of the stress-strain state of the wagon body elements on their cross-section were determined by the finite element method in the engineering program Ansys Workbench 2021. The results obtained made it possible to determine the places of reinforcement of the frame of the body of the dynamometer wagon.
4. A program and methodology of static tests for the strength of the body of a prototype dynamometer wagon model 61-907-DM for the railways of the Republic of Uzbekistan has been developed, according to which tests were performed using a stand for loading the frames of wagons with longitudinal static loads transmitted through coupling devices, the results of which determined that the proposed design of the wagon meets the established requirements for strength, visible damage and no residual deformations were found in the design of the prototype wagon.

Thus, the developed design of the dynamometer wagon body can be included in both freight and passenger trains, which solves the problem of efficient and safe use of locomotives when operating trains on mountainous sections of railways of the Republic of Uzbekistan.

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