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# RESEARCH OF MECHANICAL PROPERTIES OF A REMOVABLE MODULE CONCEPT FOR TRANSPORT OF TRACKED VEHICLES BY RAILWAYS

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***Abstract*** *–In order to increase the efficiency of railway transportation of strategic cargoes by railway transport, the design of a removable module is proposed, which allows adapting the body of an open-wagon to the transportation of Hessian equipment. The research is focused on the investigation of mechanical properties of a removable module concept. This module is proposed to be mounted on an open wagon and for transport of tracked vehicles and machines by it. The study of mechanical properties includes the strength analysis under its vertical load. The analyses are performed by means of the finite element method. At the same time, the Misses criterion was applied. It was established that the maximum equivalent stresses in the structure of the removable module concept are within the permissible limits. The conducted research will contribute to the improvement of the efficiency of railway transport operation, and it will be useful developments of the design of modern concepts of wagons' removable modules with a multifunctional purpose.*

***Keywords – transport mechanics, open wagon, dynamic load, railway transport.***

## 1. INTRODUCTION

Railway transport is a leading branch of the transport system, which ensures the development of the economy of many countries. At the same time, freight transportation is an important part of railway transport [1, 2].

Currently, the fleet of freight wagons consists of large number of wagons with different design features and production technology. Transportation of wheeled and tracked machinery is mostly carried out on platform wagons (Fig. 1).

Due to lack of platform wagons, there is a need for situational adaptation of the existing fleet of wagons for such transportation. An open wagon is one of such

a) b)

*Fig.1. Transportation of wheeled and tracked machines on wagons: a) tractors; b) a digger*

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type of wagon. However, at the same time, it is necessary to adapt its design to the transportation of tracked vehicles.

## 2. AN ANALYSIS OF THE RECENT RESEARCH AND PUBLICATIONS

An analysis of publications that are devoted to the issue of an adaptation of freight wagons to transport various types of cargo are covered in many publications.

The work [3] proposes a design of a removable module of the Flat rack wagon. A feature of such a removable module is a presence of flexible connections in the fittings. It helps to reduce the longitudinal load of the removable module when it is transported by vehicles. The scientific justification of the proposed design of the removable module is presented. The authors of the work did not investigate the possibility of using this removable module for attaching tracked equipment by an open wagon.

A special accessory is proposed in the patent [4] for the possibility of transporting heavy loads in on an open wagon. This accessory is a frame installed in the open wagon body. The frame also includes a partition and a load support. The operation of this device is described, as well as the advantages of its use in comparison with known analogues. The authors did not specify the possibility of fastening tracked vehicles or machines on a wagon.

Disadvantages of the existing schemes for fastening heavy loads on railway vehicles are discussed in [5]. A special device for fixing such loads is proposed to eliminate it. The advantages of its use, as well as the principle of action, are indicated. However, this device can mostly be used to fasten containers. Regarding the attachment of tracked machinery, its use is not practical.

For the possibility of transportation of heavy loads, the authors of the work [6] developed a special design of a flat wagon. To secure cargo, a wagon is equipped with vertical racks. The technology of loading and unloading operations on this wagon is described.

A similar design of the wagon was developed by the GreenBrier Europe company [7]. Such a wagon is intended for transportation of wheeled equipment, as well as containers. To ensure immobility of wheeled machinery, special stops are provided on the wagon. In the case of transporting containers, folding nozzles are used as fasteners. Undoubtedly, these wagon designs have significant advantages in operation compared to known ones. Along with this, the developers did not specify the possibility of transporting tracked vehicles on them.

The analysis of scientific works proves that the issue of transporting containers by open wagons is relevant, however, it requires further research.

In this regard, the purpose of the study is to highlight the special design and load capacity of the removable module for the transportation of tracked vehicles by railway.

## 3. A PRESENTATION OF THE MAIN MATERIAL OF THE RESEARCH

To adapt the body of an open wagon for transportation of tracked vehicles, a removable module design is proposed (Fig. 2).

This module is installed in the body of an open wagon, and it acts as an intermediate adapter between it and the unit of tracked machinery being transported. Fastening of the removable module on an open wagon body is carried out with the help of corner fittings. It is necessary to install fitting stops in an open wagon body (Fig. 3). The transported tracked machines are secured to the removable module using the fastening brackets. (shown in Fig. 1).

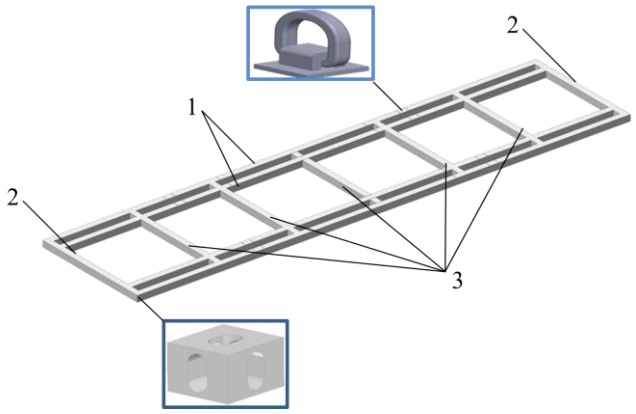


*Fig.1. A removable module for placing tracked machines on an open wagon*

In this case, it is possible to use slings or elastics. The supporting structure of the removable module (Fig. 2) includes four longitudinal beams (1), two cantilever beams (2) and five intermediate transverse beams (3).

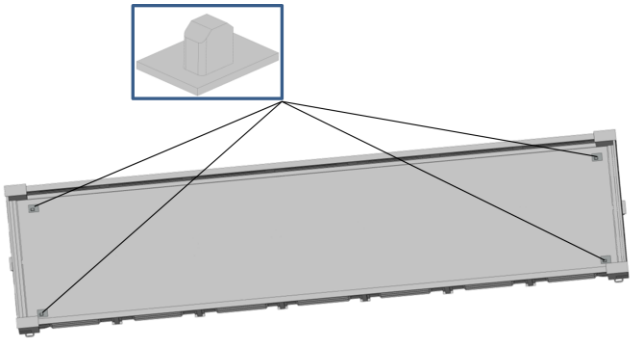

*Fig.3. Positions of fitting stops on an open wagon body*

At the same time, the profile of the detachable module is a square pipe (Fig. 4).

To determine the strength of the removable module when vertical loads are perceived, its calculation was carried out. The calculation scheme of the removable

module is shown in Fig. 5.

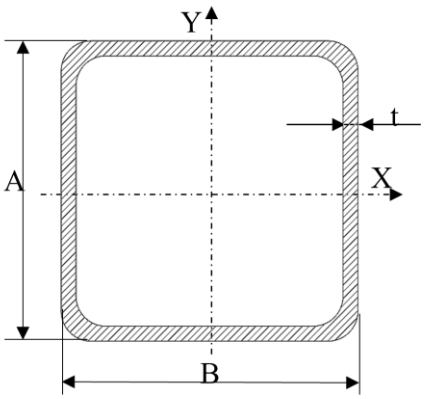


*Fig.4. A cross-section of a square pipe: A - the height of the pipe; B - width; t - the pipe wall thickness*

It is considered that the module perceives the vertical load $P_v$, which includes the vertical static and dynamic force components, as well as the loads acting on it from the fastening means. Since they are placed at an angle to the horizontal plane of the removable module, this load was divided into two components, i. e. vertical $P_c^v$ and horizontal $P_c^h$. These components were determined considering the angle of inclination of the sling, which is 45°.

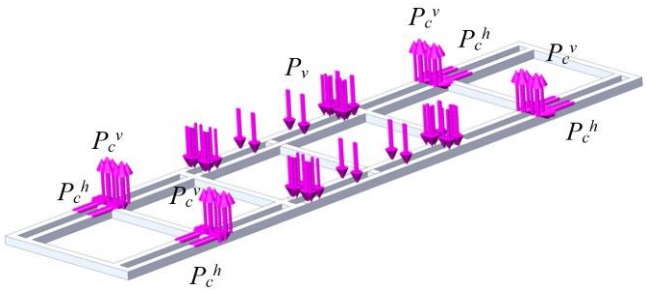


*Fig.5. A calculation scheme of the removable module*

The vertical dynamic load perceived by the lifting module $P_{ct}^v$ was determined by the formula [8]:

$$P_c^v = P_{ct}^v \cdot k_{dv} \quad (1)$$

where $k_{dv}$ is the coefficient of vertical dynamics.

The coefficient of vertical dynamics $k_{dv}$ is considered as a random function with a probable distribution of the form:

$$P\left(k_{dv}\right) = 1 - \exp\left(-\frac{\pi}{4} \cdot \frac{k_{dv}^2}{\overline{k_{dv}^2}} \cdot \beta^2\right) \quad (2)$$

where $\overline{k_{dv}}$ is the average probable value of the coefficient of vertical dynamics, $\beta$ is a distribution parameter.

The coefficient $k_{dv}$ is defined as the quantile of expression (3) for the calculated one-sided probability $P(k_{dv})$:

$$k_{dv} = \frac{\overline{k_{dv}}}{\beta} \cdot \sqrt{\frac{4}{\pi} \cdot \ln \frac{1}{1 - P\left(k_{dv}\right)}} \quad (3)$$

The calculation was carried out under the loading condition the removable module from the tracked unit with the weight of 22.6 tons. The finite element method (FEM) was used as the calculation method. It is implemented in SolidWorks software [9, 10]. The FE model is formed by tetrahedra (Fig. 6).

*Fig.6. A finite element model of the removable module*

The number of the elements is 52,965. At the same time, the model has 17,121 nodes. The boundary conditions included the fixing of the model using corner fittings.

The calculation results are shown in Fig. 7 to Fig. 9. It was established that the most loaded zones of the designed removable module are in its corner parts (Fig. 7). The maximum stresses are of 114.3 MPa (Fig. 8), which is lower than permissible value [8].

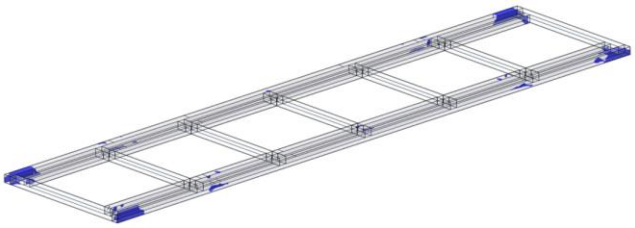

*Fig.7. The most loaded areas of the removable module*

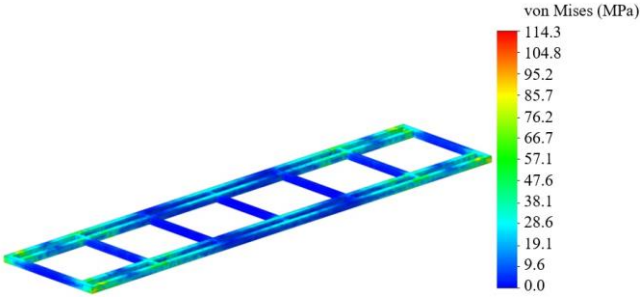


*Fig.8. A stress distribution in the removable module*

The maximum movements occurred in the second sector of the removable module from the side of the console, and they are equal to the value of 2.42 mm (Fig. 9).

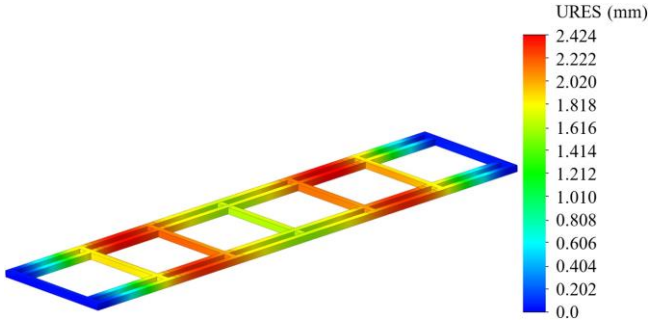


*Fig.9. Displacements in nodes of the removable module*

Therefore, the strength of the removable module under the considered load scheme of its design is ensured.

## 4. CONCLUSION

To adapt open wagons body for transportation of tracked vehicles, a removable module design is proposed. The peculiarity of such a module is that it acts as an intermediate adapter between the body of a wagon and on tracked machinery, providing the possibility of its placement, and fixing on an open wagon.

To study the strength of the removable module, a calculation was made. It was established, that the maximum stresses in its design are of 114.3 MPa and occur in the corner parts. The maximum movements occur in the second sector of the removable module from the side of the console, and they are amounted to the value of 2.42 mm. The obtained calculation results indicate that the strength of the removable module under the considered calculation scheme is ensured.

The conducted research will contribute to the improvement of the efficiency of railway transport operation and will be useful developments in the design of modern concepts of removable modules of multifunctional purpose.

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