

# Loads of road vehicles during piggyback transportation

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**Abstract.** The impact of rail transportation on road vehicles that are placed in flatcars is considered in the article. The features of piggyback transportation and the dynamic forces acting on road vehicles in railway rolling stock are determined. The change dependences of the values of dynamic forces for different masses of road vehicles in the longitudinal and transverse directions are established. It is concluded that road vehicles that are used in regular piggyback transportation will experience significant dynamic loads of structural elements, which requires monitoring of their technical condition. Consequently, the infrastructure of piggyback terminals that load and unload road vehicles onto railway rolling stock should include the availability of automobile service facilities.

## 1 Introduction

The growth of foreign trade between the countries of Europe and Asia [1] and the increase in the share of Asian countries [2] in total world trade determine the need to accelerate integration processes, develop international transport corridors and equip them with modern technological equipment to ensure the flow of goods. The transport system of Russia claims to promote cargo flows through its territory within the framework of the project «Silk Road Economic Belt» [3]. The solution of these tasks can be achieved by organizing multimodal and intermodal transport. The variety of these transport is piggyback service [4]. This technology has such advantages as: improving the transportation quality of general cargo [5, 6], reducing transportation costs [7, 8], reducing the negative impact of transport on the environment [9, 10], etc.

The attempts to introduce piggyback transportation in Russia have been undertaken since the beginning of the 90s of the 20th century [11]. The most important tasks that have not yet been fully resolved include: the formation of a terminal infrastructure network and a fleet of specialized railway rolling stock, the development of regulatory documents and tariff policies, the integration of national piggyback technology with foreign transport systems [12]. Therefore, piggyback transportation in Russia was organized only at the level of pilot reforms [4, 13]. In some cases, transportation turned out to be unsatisfactory and lead to damage to road vehicles [11]. In this regard, the task of studying the interaction of the elements of the «road vehicle – flatcar» system and studying the impact of rail transportation on road vehicles are on the front burner. The determination of dynamic shock

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loads acting on road vehicles during their rail transportation will allow to evaluate the conditions of their operation activity and set up a maintenance operation and repair program for piggyback transportation.

## **2 Literary review**

A number of studies are devoted to solving the problems of the interaction of railway rolling stock and road vehicles during the piggyback transportation. A review of scientific works allows us to identify several main subject areas of research:

- generalization – the literature reviews and implementation of piggyback transportation practice [4, 11, 14-17];
- technologies – the analysis of existing multimodal and intermodal technologies [8, 16, 18];
- infrastructure – the development of infrastructure, terminals and transport network [19-21];
- ecology and sustainable development – the assessment of the piggyback transportation impact on the environment [9, 10, 22, 23];
- economy – the assessment of the developing piggyback transportation costs, their competitiveness, investments [7, 24];
- interaction – the mutual influence of railway cars and road vehicles, the calculation of the fatigue endurance of their load-bearing constructions [25-28].

Despite the availability of work devoted to solving the problems of improving the efficiency and quality of piggyback transportation, there is currently no comprehensive assessment of the impact of rail transportation on road vehicles placed in railway rolling stock during piggyback transportation.

## **3 Determining the conditions for the transport of road vehicles in flatcars**

The organization of regular piggyback traffic creates a new form of road vehicles operation that are constantly involved in them. Road vehicles are transported by rail for a significant part of their operating time. This significantly reduces the overhaul and other technical and operational performance indicators. And at the same time, they are experienced by shock dynamic loads at the stage of moving along the railways, comparable with the movement on the roads. The frequency of car maintenance and repair is mainly based on time between overhaul. As a result, the realization of maintenance service of overhaul does not adequately match the actual operating conditions and may impair the maintenance of road vehicles in a technically sound state.

Transportation of road vehicles on the territory of Russia by rail is regulated by a number of documents [29-31]. They provide conditions, as well as methods of allocation and fastening the road vehicle in a flatcar. The main conditions for road vehicles are the critical mass, the surface of area exposed to wind load, the height of gravity center, the number of tiers in height, the position depending on the surface of the flatcar floor, fasteners, structural elements used for fixing, loading schemes. Basically, the listed conditions have normalized values.

It is determined that dynamic forces act on a road vehicle in the process of railway transportation. As a result, translational movement, tipping over or rolling of a flatcar may occur with it. The forces that are taken into account during placing and fixing road vehicles in a flatcar are given in Table 1.

**Table 1.** Dynamic forces acting on a road vehicle [32]

Names	Characteristic
longitudinal inertial force	it occurs when the speed of movement of a railway carriage changes (start of movement, acceleration, braking, collision of cars)
transverse inertial force	it occurs when the direction of movement changes (the passage of curves, turnouts), as well as during movement due to the interaction of the railway track and the flatcar (wobble, transverse and lateral rolling of the car)
vertical inertial force	it occurs during movement (fluctuations in bouncing and pitching of a car, wheel bumps on rails at the joints)
wind load	it occurs when a flatcar moves and acts on parts of a unit of equipment protruding beyond the wagon in the direction across the path
force of friction	it occurs between the supporting surfaces of the unit of technology and the floor of the body of a railway carriage. The force of friction keeps a unit of technology from possible movements in the back of a railway carriage

#### 4 Calculation of the load acting on the structural elements of a road vehicle

The stabilization of the road vehicle position in the back of a flatcar is ensured by fasteners, for example, tension wires and wheel chocks (Fig. 1). Dynamic forces act on certain structural elements of a road vehicle through fasteners during transportation. Stretch marks transfer loads to towing hooks, hinges, axle shafts of axles, chassis, technological holes of frames, as well as other fastening parts. The load is transmitted directly to the wheels through the wheel chocks.



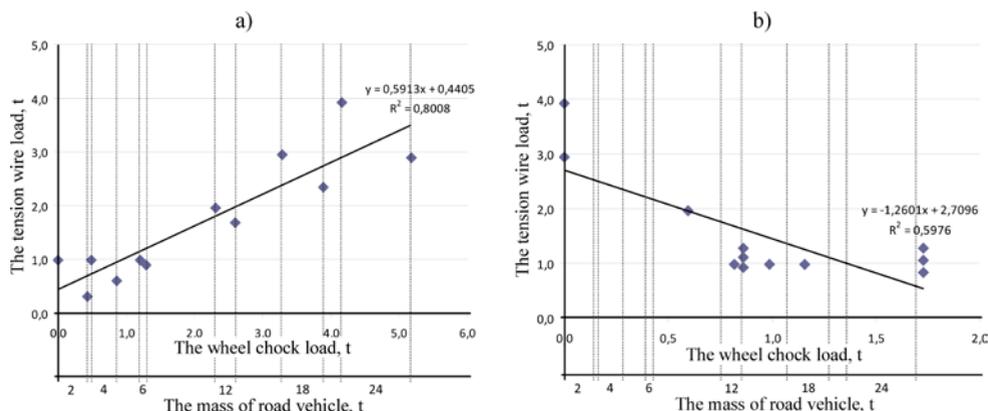
**Fig. 1.** Piggyback fasteners [13].

In accordance with the methodology [29], the calculation of the dynamic forces values acting on the structural elements of a conventional road vehicle, placed in flatcar and secured by two means of attachment – tension wires and wheel chocks. It should be noted that this technique does not contain an exact indication of the shared distribution of efforts attributable to each type of fasteners when they are used together. Therefore, the limitations of efforts on the fasteners together with their characteristics were set in the calculations. An example of the result of calculating the loads acting on the elements of a road vehicle weighing 24 tons is presented in Table 2.

**Table 2.** The calculated values of the dynamic forces acting on the structural elements of a road vehicle

Fastener	Structural element	The load acting on the structural element in the corresponding direction, t	
		longitudinal	transverse
tension wire	recovery point, loop, axle shaft, chassis, technological hole of the frame, etc.	2.90÷3.92	1.28÷3.92
wheel chock	wheel	4.16÷5.18	0.0÷1.73

The dependences of changes in the values of dynamic forces acting in the longitudinal and transverse directions were established for road vehicles of various weights (in the range from 2 to 24 tons). The values of the dynamic forces attributable to the structural elements of road vehicles placed in a single flatcar with open sides and secured by two fasteners (tension wires and wheel chocks) are shown in Fig. 2.



**Fig. 2.** The values of the dynamic forces acting on the structural elements of a road vehicle in the longitudinal (a) and transverse (b) directions.

An analysis of the load values indicates that the structural elements of road vehicles used for fastening during transportation in flatcars experience rather high loads. The main structural element exposed to dynamic loads is the undercarriage. The value of the loads is directly proportional to the mass of the road vehicle: the load of the elements increases and acts in different directions with its increase.

## 5 Conclusion

This article presents an assessment of the impact of rail transportation on road vehicles placed in railway rolling stock. The main structural element of road vehicles exposed to dynamic loads is the undercarriage. The values of dynamic forces acting on structural elements with different masses of road vehicles in the longitudinal and transverse directions are established. A significant reduction in the values of technical and operational performance indicators that determine the maintenance and repair program will be formed for road vehicles that are constantly involved in piggyback transportation. It is proposed to consider this form of operation as «passive operation activity» with the introduction of adjustments to the organization of maintenance and repair for these road vehicles. Maintenance of a technically sound state should be carried out at the automotive service

facilities included in the infrastructure of the piggyback terminals. At that terminals loading and unloading of road vehicles on railway rolling stock is carried out.

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