Influence of the Magnitude of the Working Stroke of the Constant Contact Side Bearings of Freight Cars on the Parameters of the Interaction of Rolling Stock and Track When Moving in Curved Sections of the Track

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Keywords: Freight car, parameters of elastic side bearings, interaction of rolling stock and track, mathematical modeling.

Abstract: This article is devoted to the study of the dynamic processes of the movement of a freight car along a curved section of a railway track. Based on the developed simulation model of the movement of a freight car equipped with constant contact side bearings, the influence of the working stroke of a constant contact side bearing on the dynamic parameters of the interaction of rolling stock and track in curved sections of the track is investigated. The paper presents the results of a study of the effect of the parameter under study on the coefficient of the wheel's stability margin from rolling into the top of rail and shows that side bearings with an increased working stroke of the elastic element are a more preferable design option compared to side bearings with a standard working stroke according to the criterion of excluding complete side rolling of the body to the side support, which leads to an improvement in the parameters interactions of wheel sets of freight cars with rails when moving in curved sections of the track.

1 INTRODUCTION

To date, rail transport is the main component of the transport system of the Russian Federation, which ensures the functioning of the country's economy. In this regard, the solution of issues to improve the efficiency of its functioning is a very urgent task. One of the ways to improve the efficiency of railway transport is to improve the design of railway rolling stock, aimed at improving the reliability of its operation while reducing the economic costs associated with its operation.

The modern development of computer technology makes it possible to conduct research as close as possible to the results of field experiments, which significantly reduces the time and economic costs when developing new design options for various technical objects. This approach is widely used in various industries, including transport engineering.

To date, a separate direction has been formed in the field of research on the dynamic processes of the movement of rail carriages, called "dynamics of wagons", within the framework of which theoretical provisions have been developed to describe the dynamic processes occurring during the movement of wagons along both straight and curved sections of the track. The application of these theoretical provisions makes it possible to investigate the impact of design improvement measures on the expected changes in the running qualities of freight cars. One of the directions in improving the design of freight cars is the improvement of the connection points of the body of the freight car with the running gear, which are carried out in the form of independent assembly units, which are called bogies. An urgent problem in this area is the reduction of the tendency of freight cars to tortuosity of movement in straight and flat curves. The solution to this problem is to equip the car with elastic constant contact side bearings, which, due to the additional friction forces arising between the car body and the bogie, make it possible to effectively extinguish the tortuous movement of the bogie under the car.

It should be noted that the constant contact side bearings have found wide application in the design of foreign and a number of domestic freight cars. Side bearings of this type are mass-produced in various modifications by several manufacturers and the designs of bogies of freight cars of the largest foreign manufacturers of running gear are adapted to their use. However, to date, issues related to taking

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into account the peculiarities of domestic railway transport, when adapting design variants of foreign manufacturers for it, remain not fully investigated.

This article is devoted to one of such issues, namely, the assessment of the influence of the value of the working stroke parameter of the elastic element of the side bearing on the dynamic parameters of the interaction of rolling stock and track in curved sections and the choice on their basis of a rational value that provides the required dynamic indicators of the movement of rail carriages.

2 MATERIALS AND METHODS

To date, a significant number of scientific papers have been devoted to the study of the movement of railway rail carriages along curved sections of the track, which affect a variety of research areas. Among them, issues related to ensuring traffic safety and improving the technical parameters of rail crews, designed to reduce the loads acting on the elements of rolling stock and railway track, occupy one of the leading positions. Within the framework of this direction, the issues of choosing rational variants of the railway track design in curves are considered (Akkerman, 2021; Akkerman, 2020; Akkerman, 2020; Shkurnikov, 2020; Romanenko, 2020), as well as the issues of studying the influence of rolling stock parameters on the dynamic indicators of rolling stock movement (O'Donnell, 2005; Gabets, 2016; Wolf, 2005; Gadzhimetov, 2020; Davydov, 2021; Davydov, 2021; Tarmaev, 2019).

A significant part of the research in this area is devoted to improving the running gear of freight cars. One of the directions in this area is the equipment of the car with constant contact side bearings, which significantly reduce the tendency of the bogie of the freight car to tortuous movement and improve the parameters of interaction between the rolling stock and the railway track. A significant number of works by various scientists have been devoted to the choice of the rational value of the parameters of supports of this type.

However, to date, despite the research carried out, not all issues in this direction are fully investigated. One of such issues is the choice of the magnitude of the working stroke of the elastic element of the side bearing. At the same time, the value of the working stroke is understood as the maximum possible amount of compression of the elastic element of the side pole, after compression to which the side bearing becomes a solid with the possibility of further compression only by the amount of plastic deformation of the metal structural elements of the bearing. The magnitude of the working stroke is determined by the design of the side bearing and, most often, is limited by the stop in the design of the side bearing. The lack of research in this area is largely due to the fact that the magnitude of the working stroke of the side bearing is laid by the manufacturer at the design stage of this support and is limited by the design features of the placement of the bearing between the body and the bogie. However, many manufacturers have several variants of the working stroke of side bearings, which can be equipped with exactly the same bogies of freight cars. In this connection, the development of computational methods for studying the influence of this parameter on the dynamic indicators of the movement of freight cars in the curve and the selection on their basis of rational values of the values of the working stroke of the side bearing is an urgent task aimed at improving the safety of train traffic and increasing the efficiency of rolling stock operation.

The main feature of the movement of freight cars along curved sections of the track is the appearance of centripetal acceleration, which occurs when moving even at a constant speed. To neutralize the centrifugal force in the curves, the out rail is laid with some elevation relative to the inner one. The centrifugal force acting towards the out rail of the curve, due to the elevation of the out rail, can be extinguished completely, partially or even excessively (while the resulting force acts towards the inner rail). In practice, for such cases, depending on the degree of compensation of centrifugal force, the concepts of sufficient, insufficient and excessive elevation are used,

At the same time, it is obvious that a situation is possible in which the elevation value will be determined to a greater extent by the speed of passenger trains and will be excessive for the movement of freight trains. In this case, it is possible to close the bearings from the inside of the curve, which can lead to a redistribution of the load from the weight of the car between the out and inner rails, as well as to a change in the parameters of the interaction of the rolling stock and the track. Similarly, it is possible for a car to move along a curve with a lack of elevation. In this case, it is possible to side-roll the body to external bearings. At the same time, it is obvious that a sufficiently large amount of the working stroke of the bearing can avoid the redistribution of the load between the nodes of the body support on the bogie, which in turn will affect the change in the parameters of the interaction of wheels with rails. Thus, in order to choose a rational value of the working stroke of the elastic element of the side support, it is necessary to conduct studies of the influence of this value on the movement parameters in the curved sections of the path.

To date, in the practice of domestic and world freight car building, two main schemes of load transfer from the body to the chassis have been formed. In the first case, the vertical and horizontal loads from the body are transferred to the bolster of the bogie through the central support (center bowl) located on the bolster of the bogie (Fig. 1, a). To limit the deviation of the body from the equilibrium position, side poles (bearings) installed on the body and their corresponding poles located on the bolster of the bogie are used.

The second variant of load transfer (Fig. 1, b) is a combination of a center bowl with elastic side supports of continuous contact. In this case, the side supports serve not only to limit the side rolling of the car body, but also to transfer part of the vertical load to the running gear, even when the latter is in a state of stable equilibrium relative to the bolster. At the same time, in the process of turning the bogie relative to the body, friction forces arise between the body bearings and the side poles, which leads to a significant decrease in the tortuosity of the carriage movement.

In the world practice of car building, two values of the working stroke of the elastic element are used – standard (Standard Travel) and increased (Long Travel according to the terminology of MINER Enterprises Inc. and Extended Travel according to the terminology of A. Stucki Company (Davydov, 2013)). The standard stroke value for MINER Enterprises Inc. products is 5/16” (0.0079 m), the increased one is 5/8” (0.0159 m). For the variants of bearings A. Stucki Company the standard stroke value is 1/4” (0.00635 m), and the increased one is 5/8” (0.0159 m). At the same time, new models of side bearings by these companies are developed and produced exclusively with an increased working stroke of the elastic element (5/8”).

To assess the influence of the magnitude of the working stroke of the side bearing, an imitation gondola car equipped with side bearings was developed in the "Universal Mechanism" program. The car model included 23 bodies connected by mechanical connections. The total number of degrees of freedom for all bodies of the mechanical system was 134. The capabilities of the Universal Mechanism program allow us to take into account changes in the geometric and inertial parameters of individual parts of the car, as well as the impact on the movement of the car of vertical and horizontal irregularities of the railway track both on straight and curved sections of the railway track. This software package has shown high reliability of the results obtained and a number of studies have been carried out with its application in the field of modeling dynamic processes of interaction between railway rolling stock and track.

When modeling, the parameter of vertical rigidity of the elastic element of the side bearing was assumed to be equal to 1.45 kN/m, which ensured the transmission of 85% of the load from the body weight through the side bearings. The value of the working stroke was assumed to be equal to 0.0079 and 0.0159 m, with other parameters being equal. The loaded mode of carriage movement was simulated. In order to isolate the influence of only

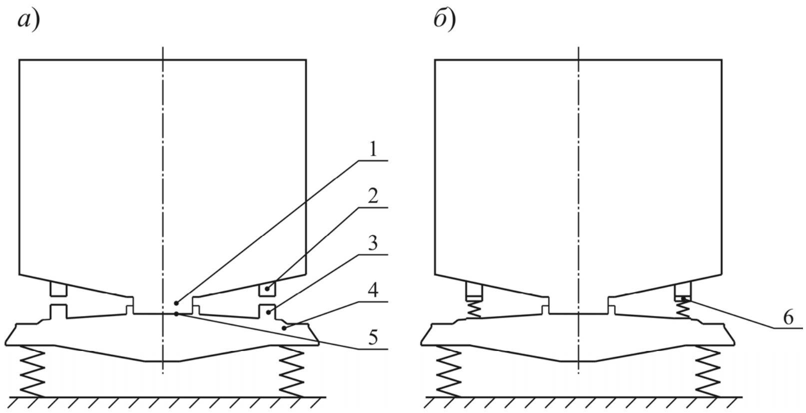

Figure 1: The scheme of supporting the body of a freight car on the running gear: a – through the center bowl; b – through the center bowl and the constant contact side supports; 1 – the center bowl of the body; 2 – the bearing of the body; 3 – the bearing of the bogie; 4 – the bolster; 5 – the center bowl of the bolster; 6 - the elastic side support of constant contact.

the magnitude of the working stroke of the side bearing, the mode of movement of the car along the path without irregularities, both in the horizontal and vertical planes, was studied.

The increase in the working stroke of the elastic element of the side bearing is explained by the fact that, compared with the standard value, it improves the passage of curved sections of the track by the car. In the situation under consideration, the car body is side-rolled onto an external side bearing. At the standard value of the working stroke, complete compression of the elastic element of the bearing is possible. In this case, significant forces of vertical pressing of the support bearing against the body bearing may occur, since their maximum value is determined not by the rigidity of the elastic element of the bearing, which is already compressed to the maximum value, but by the values of the outstanding horizontal accelerations acting on the body. At the same time, there will be a redistribution of the vertical load between the center bowl and the compressed side bearing, towards an increase in the load on the latter. All this will lead to an increase in the moment of resistance to turning, compared with what the side bearings should create and ultimately worsen the car's fit into the curve. The increase in the working stroke is designed to exclude the possibility of complete compression of the side bearing when the car passes the curved sections of the track and thereby ensure the preservation of the calculated values of the moment of resistance to the bogie turning relative to the car body.

The study of the influence of the magnitude of the working stroke of the side bearing on the dynamic parameters of the movement of the car in curves was carried out using a simulation model of the movement of the rail carriage developed in the software package "Universal Mechanism". This software package has proven itself as a reliable and effective tool for computer modeling of various modes of movement of rolling stock.

For the possibility of studying various variants of the structural design of the side supports of the body, a generalized design scheme of the side support of continuous contact has been developed (Figure 2).

The generalized scheme of the support (Figure 2, a) includes the body of the support 1, fixed on the bolster of the bogie and the cap of the support 2, on the upper plane of which there is a contact surface with the side bearing of the car body. An elastic-dissipative element 3 is located between the housing and the support cap.

The use of a parametric description made it possible to model various variants of the structural design of the body supports by setting the values of parametric characteristics without the need to change the structure of the model.

When studying the influence of paremeters of side bearings on the running qualities of freight cars, it is necessary to consider three modes of movement of the car along the curve:

1. The movement of the car with a shortage of elevation. In this mode of movement, the magnitude of the centrifugal force is not fully compensated by the gravity of the car due to the inclination inside the curve and the resulting force directed outward of the curve acts on the body of the car

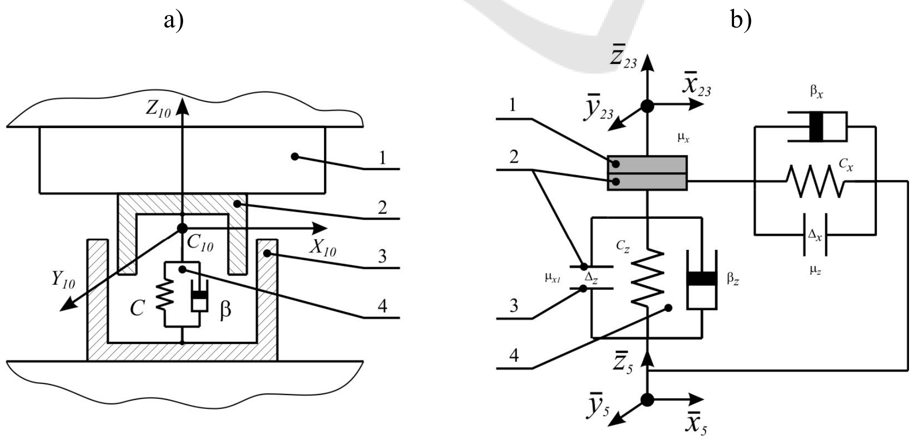

Figure 2: Design scheme of the side support of the continuous contact of the body: a – the schematic diagram of the support; b – the design scheme (projected onto the XCZ plane); 1 – the side bearing of the body; 2 – the cap of the side support; 3 – the support body (mounted on the bolster of the bogie); 4 - the elastic-dissipative element.

2. Movement in an equilibrium position. In this mode of movement, the magnitude of the centrifugal force is fully compensated by the gravity of the car due to the inclination inside the curve and on the body of the car is in a static equilibrium position.
3. The movement of the car with an excess of elevation. In this mode of movement, the magnitude of the projection of gravity on the transverse axis of the car body turns out to be greater than the magnitude of the centrifugal force on the car body, the resulting force directed inside the curve acts.

The occurrence of the considered modes of movement is determined by the ratio of the magnitude of the elevation of the out rail in the curve and the speed of movement of the car along the curve. The value of the elevation of the out rail in the curve, which ensures the equilibrium mode of movement of the car, is determined by the expression (Verigo, 1986):

$$h = 12{,}5\frac{V^2}{R},$$

where V is the speed of movement, km/h;

R is the radius of the curve, m

Within the framework of this work, the movement of the car along a curve with a radius of 600 m was simulated. From expression (1), for the given values of elevation and a given radius, the corresponding values of the equilibrium velocity of the carriage along the curve can be found.

To assess traffic safety under the conditions of excluding the possibility of a wheelset derailment, the wheel stability coefficient against derailment is used in the work, which is determined by the expression (Verigo, 1986):

$$\lambda = \frac{tg\beta - \mu}{\mu \cdot tg\beta + 1} \cdot \frac{P_1}{P},$$

where β is the angle of inclination of the cone–shaped surface of the wheel forming the ridge with the horizon, rad.;

μ – coefficient of friction of the interacting surfaces of wheels and rails;

P_1 is the vertical component of the reaction forces of the oncoming wheel on the rails, H;

P is the horizontal component of the reaction forces of the oncoming wheel on the rails, H.

When modeling, the parameter of vertical rigidity of the elastic element of the side bearing was assumed to be equal to 1.45 kN/m, which ensured the transmission of 85% of the load from the body weight through the side bearings, in accordance with (GOST 9246-2013). The value of the working stroke was assumed to be equal to 0.0079 and 0.0159 m, with other parameters being equal. The loaded mode of carriage movement was simulated. In order to isolate the influence of only the magnitude of the working stroke of the side support, the mode of movement of the car along the path without irregularities, both in horizontal and vertical planes, was studied. Modes of movement with a deficit and excess of elevation were studied. The mode of movement with an equilibrium speed was not considered in the framework of the study, because there is no side rolling of the body, and consequently, the deformation of elastic elements, which is limited by the magnitude of the working stroke, is not observed.

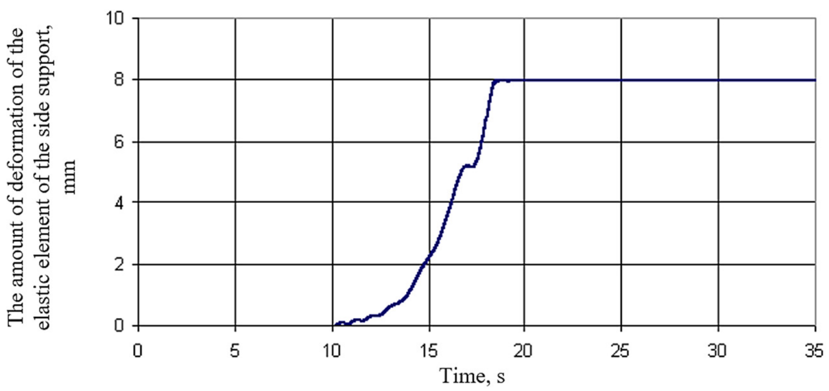

Figure 3: The amount of deformation of the elastic element of the side bearing when moving along a curve with a radius of 600 m, having an elevation of the out rail of 130 mm at a speed of 36 km/h, with a working stroke of 0.0079 m.

3 RESULTS AND DISCUSSION

As a result of the experiments carried out, it was found that for modes of movement with an excess of elevation, in the case of the use of side supports with a working stroke of 0.0079 m, it is possible to side-roll the car body to internal bearings with their complete closure. As an example, Figure 3 shows the dependence of the deformation of the elastic element of the side support to full compression, consider the movement of the car along a curve with a radius of 600 m, having an elevation of the out rail 130 mm at a speed of 36 km/h.

Figure 4 shows the change in the coefficient of the wheel stability margin from rolling into the rail head

From the graphs presented in Figures 3 and 4, it can be seen that for the case of side rolling of the body to internal bearings, a decrease in the value of the stability margin coefficient is observed. This is explained by the fact that the side rolling of the body to the internal side bearings leads to a redistribution of the vertical load between the wheel pairs and, as a consequence, a change in the parameters of the interaction of the wheels with the rails.

When studying the movement of a car equipped with side bearings with an increased working stroke, the closure of the sliders is not observed. However, at the same time, there is the occurrence of lateral vibrations, with a significant attenuation period, which can be explained by the not sufficiently satisfactory operation of friction dampers of bogie vibrations at low speeds.

At the next stage of the work, a simulation of the movement of a freight car with a lack of elevation was carried out. In this case, similar observations were obtained. For a car equipped with side bearings with a working stroke of 0.0079 m, it is possible to roll the car body to external bearings with their full closure, while for a design variant with a working stroke increased to 0.0159 m, the closure of the bearings is not observed in the entire speed range under study. At the same time, in the case of side rolling of the body with full closure of the bearings, there is a decrease in the value of the coefficient of the wheel stability margin from rolling into the rail head.

At the same time, it should be noted that in the absence of closing of the side bearing with a full choice of the working stroke, the parameters of the interaction of wheel pairs and rails are identical for both values of the working stroke, regardless of the presence of a deficit or excess of elevation.

4 CONCLUSIONS

Summing up the research, we can make an unambiguous conclusion that in the absence of a complete side rolling of the body on the side bearing, the parameters of the interaction of the wheel pairs of freight cars with rails, when moving in curved sections of the track, do not depend on the magnitude of the working stroke of the elastic element of the side support, but are determined solely by the distribution of loads between the wheel pairs, which, in turn, it is determined by the distribution of loads between the side supports and the bogie center bowl and largely depends on the elastic-dissipative parameters of the elastic elements of the side bearings. Thus, the choice of the parameter of the working stroke of the side support should be made according to the criterion of

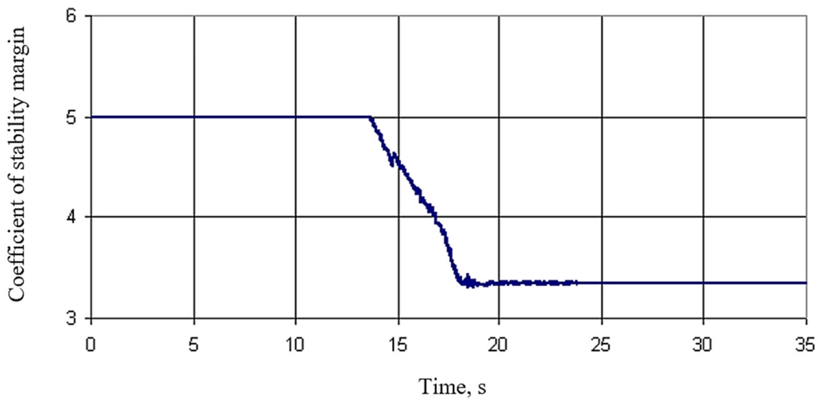

Figure 4: Graph of the change in the coefficient of stability margin from rolling the outer wheel of the first wheelset onto the rail head when moving along a curve with a radius of 600 m, having an elevation of the out rail of 130 mm at a speed of 36 km/ h, with a working stroke of 0.0079 m.

the side rolling of the body to the side supports when driving along curved sections of the track. At the same time, the use of side bearings with an increased working stroke avoids the complete side rolling of the body to the side support, which leads to an improvement in the parameters of the interaction of wheel pairs of freight cars with rails when moving in curved sections of the track and is more appropriate compared to side bearings with a standard working stroke of the elastic element.

The studies carried out clearly indicate that side bearings with an increased working stroke have advantages over side bearings with a standard working stroke in terms of ensuring the best driving qualities of a freight car in curves. At the same time, this parameter is not decisive, due to the fact that it only limits the maximum load at which the side bearing is completely closed and which is determined by the parameter of vertical stiffness of the elastic element of the side bearing. It is quite obvious that when choosing the parameters of the side bearing, it is necessary to select the optimal value of the vertical stiffness parameter based on the results of experiments on the simulation model. At the same time, as a test calculation, it is necessary to check the selected parameters for the absence of complete closure of the side bearings of the car body and the bogie at a given value of the working stroke of the side bearing and, if necessary, make its adjustment of the working stroke in the direction of increase. The application of this approach will allow obtaining sufficiently accurate results and reduce the time of experiments to determine the parameters of side bearings.

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