Increasing traffic safety of passenger cars by modernizing the central cradle suspension of the passenger trolley

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Abstract. To implement the conditions for ensuring the established volume of transportation on the serviced site with complete safety and minimal costs for performing the required volume of work, it is necessary to maintain a fleet of passenger cars in a technically sound condition, carry out maintenance and repair of passenger cars in accordance with the current rules and tasks established by the railway, as well as carrying out effective commercial and economic work, developing or modernizing car parts and assemblies to ensure the required safety and, accordingly, carrying out developments with minimal costs for Russian Railways as a whole under the current system, which manages to satisfy the maximum needs of enterprises by using a minimum amount of resources. Sufficient production of some types of products is not carried out to the detriment of others, because the country has achieved a high level of labor productivity, modern technologies are used that allow saving raw materials, fixed assets are not idle, but are used at full capacity. For some parts and assemblies, the possibility of modernization can be absolutely simple and practical, in terms of costs they are economical and have a minimum payback period.

1 Introduction

Bouncing, when the sprung parts of the car move up and down parallel to the original position along the z–z axis by a value ±z (Fig. 1, b), occurs under the action of vertical dynamic forces that cause equal accelerations at the ends of the body. Longitudinal rolling or galloping – when the sprung parts of the car perform a rotational movement relative to the y-y axis at a certain angle ±θ (Fig. 1, c) - occurs from wheel impacts at the joints, the presence of potholes on one wheelset, or from imbalance of the body. Galloping of the carriage usually occurs simultaneously with bouncing. Lateral oscillations is when the car body and bogie move along the y-y axis (Fig. 1d). This type of oscillation occurs together with oscillations of lateral rolling (Fig. 1, e) under the action of horizontal lateral forces parallel to the axis. Wobbling, when the body rotates around a vertical axis at a certain angle ±ψ (Fig. 1, e), is caused by the conicity of the wheel rolling surface, incorrect installation of wheelsets, unequal wheel diameters, and tortuosity of the track. Twitching (Fig. 1, g) is the movement of the car along the x-x axis. It appears when the train starts moving or braking due to the imbalance of the

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progressively moving masses of the locomotive. These vibrations can appear separately or together with other types, so the car makes a complex movement. Knowing the reasons for the occurrence of vibrations and their nature, it is possible to determine the conditions for stable and safe movement of the car, select rational parameters for its spring suspension and the draft gears of the automatic coupling device. The dynamic characteristics of the car include periods of various types of oscillations, dynamics coefficients and critical speeds. In the dynamics of cars, a distinction is made between natural oscillations, which occur from an initial push without any further influence on the bolster structure of any external forces, and forced oscillations, which arise under the influence of a periodically changing force, which is usually called a disturbing force. The frequency of natural vibrations $\nu_c$ depends on the mass of the car's bolster parts and the rigidity of the spring suspension. The frequency of forced oscillations $\nu_{in}$ is equal to the frequency of changes in the disturbing force.

\[ \nu_{in} = \nu_{c} \]

Fig. 1. Main types of vibrations

When the frequencies $\nu_{in}$ and $\nu_c$ are equal, i.e., when $\nu_{in} : \nu_c = 1$, the amplitude of oscillations increases significantly, and the phenomenon of oscillation resonance occurs, i.e., the coincidence of the periods of free oscillations with the period of manifestation of the disturbing force. The phenomenon of oscillation resonance is characterized by large amplitudes or, if limiting oscillations of the device are used, by excessively large forces. These forces and movements cause increased wear and tear of car parts and threaten traffic safety. The phenomenon of resonance occurs at a certain speed, which is called critical. To dampen vibrations and prevent resonance phenomena, spring suspension is provided with the required value of the relative friction coefficient, which ensures the condition of non-increase of vibrations.

\[ 4\phi f_{st} \geq \frac{\pi h}{2} \]  

where $\phi$ is the coefficient of relative friction in the spring suspension; $f_{st}$ – static deflection of spring suspension; $h$ is the height of the track unevenness.

The circular frequency of natural vibrations of the car is determined by formula (1)
where \( g \) is the acceleration of free fall;

\( f_{st} \) – static deflection of spring suspension.

*The* static deflection of springs is determined by formula (2)

\[
f_{ct} = \frac{g}{4c_1}
\]

where \( G \) is the weight of the car body;

\( c_1 \) is stiffness of one spring set.

Figure 2 shows the transfer of load from the car body to the rails through the bogie components.

**Fig. 2.** Transfer of load from the car body to the rails

Figure 3 shows the lateral rolling of the car body, in which the springs of one side of the bogie are compressed more intensely relative to the other side.

**Fig. 3.** Lateral rolling of the car body

Figure 4 shows a map of the curve on the Taishet – Irkutsk-Passazhirsky section.

Increased wear of rails in curves is a consequence of wheels slipping (vertical wear) and pressing them against the side edges of the rail heads under the influence of transverse forces (lateral wear). Rail wear largely depends on the radius of the curve, increasing intensively in curves with a radius of less than 700-800 m.
A transition curve is a section of a path - an element of the road plan that connects traveling straight lines with circular curves and circular curves with each other.

Fig. 4. Map of the curve on the Taishet – Irkutsk-Passazhirsky section

Methods for identifying and eliminating cracks and faults in the components of a passenger car are additionally shown in the pictures of cracks in the components of a passenger car with identifying and eliminating methods.

Fig. 5. Cracks in welded joints of non-cradle type trolleys

Fig. 6. Diagram of the KVZ-TsNII passenger trolley with spring support
2 Methods and materials

Fault analysis is a method of identifying and analyzing factors that may contribute to the occurrence of some undesirable event. Table 1 presents an analysis of malfunctions of springs, assemblies and parts of the central heating pump in the period from December 2020 to December 2022.

**Table 1.** Analysis of malfunctions of springs, assemblies and parts of the central heating plant

<table>
<thead>
<tr>
<th>Cracks in beams and welds</th>
<th>Cracks in axlebox and TsLP</th>
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<th>Brake shoe unit</th>
<th>Units and parts of the TsLP</th>
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**Fig. 7.** Number of rejected cars during maintenance and scheduled repairs for December 2020

**Fig. 8.** Number of rejected cars during maintenance and scheduled repairs for December 2021
Based on the results of maintenance diagrams and planned repairs, cracks in the terminal box covers, as well as springs, components and parts of the CCS (central cradle suspension) were identified during the period from December 2020 to December 2022.

3 Results and discussion

The higher the speed of movement of the vehicle along the rails, the more pronounced the role of dynamic loads in the overall picture of the distribution of forces applied to its elements. The source of dynamic loads is a number of disturbing factors, the main of which are unevenness of the upper track structure in the vertical and transverse directions, as well as the kinematic tendency of the wheelsets to develop their transverse vibrations in the track, due to the conical shape of the treading surface. To solve this problem, it is proposed to install CCS spring supports (Fig. 10), which will limit the load on the springs and reduce the formation of cracks and breaks in the coils.

4 Conclusion

This article discusses the traffic safety of a passenger car. According to the processed values of the parameters of the car’s technical condition obtained as a result of statistical analysis, the main deviation was identified, which led to a large number of cars being uncoupled due to cracks formed in the components and parts of the central steel line. This suggests that the problem is in the transfer of loads and their distribution when passing through dangerous sections of the track (curves and transition curves). To solve this problem, it is proposed to install a CCS spring support, which will limit the load on the springs and reduce the formation of cracks and breaks in the coils.
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