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Investigation of wear of wheels and rails when the center of mass of cargo in gondola cars shifts

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Wear factor
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Abstract

At higher train speeds, the dynamic characteristics of the wagon are negatively affected by the uneven distribution of the mass of the body with the cargo over the springs, caused by asymmetric loading. It is well known that the safety of train traffic and the safety of transported goods depend on the method of placement and securing of goods. Determining the displacement of the center of mass of the cargo relative to the axes of symmetry of the railway car allows you to timely identify dangerous deviations in its stability and thereby significantly increase safety during the movement of the train. For stability and transportation safety, the center of mass must be at the intersection of the central longitudinal and transverse axes. A slight shift in the center of mass is possible if you need to transport non-standard cargo. Sometimes, when transporting several goods, there is a need for their asymmetrical arrangement in the wagon. Displacement of cargo relative to the center of mass of the wagon is possible during transportation. Therefore, there is a need to evaluate the effect of loading asymmetry on the dynamic characteristics of the wagon and to establish the allowable values of cargo displacement.

Introduction

New operating conditions on the railways associated with integration into the international system of transport corridors lead to the need for the development and implementation of technical progress on the main lines, the modernization of rolling stock, the improvement of transportation technology, and the increase in the speed of railway rolling stock. The increase in maximum train speeds will help speed up the delivery of passengers and goods, as well as increase the capacity of railways. Increasing the maximum allowable speeds is one of the means of raising the route speeds of trains. All this will strengthen the integration processes between countries, but this will lead to the need to control and quantify the dynamic load of the rolling stock to ensure safe and reliable communication on the railways [1-3].

Determining the permissible speeds and carrying capacity, the cost of maintaining the rolling stock and track facilities, as well as increasing the turnaround time of wagons significantly, depends on the design and technical condition of the freight rolling stock of the railways. The issue of wear and tear of rolling stock and track parts has always been of great importance for railway transport, the uninterrupted operation of which is associated with the reliability of rolling stock and track elements. The wear of the wheel flanges and the inner side surfaces of the rail heads is one of the most pressing problems for railway transport. Losses from wear of the interacting elements of wheels and rails reach significant values. An important aspect of this problem is to ensure the safety of train traffic, taking into account the wear of wheel flanges and rails. In addition, it is important that energy losses during wear increase the resistance to the movement of the rolling stock and, accordingly, the cost of energy resources [4-7].

Material and Method

The root cause of wear is force actions on the contacting bodies, which are determined by the dynamic interaction of the wheel and the rail. Therefore, an important aspect of reducing the intensity of wheel and rail wear is to reduce the dynamic loading of the interacting surfaces. When freight trains move along a track, the parameters of which are designed for the passage of high-speed passenger trains, the nature of the inscribing of freight wagon bogies into curved sections of the track inevitably changes with an increase in the angles of the running on the outer rail. This leads to an increase in lateral wear of the rails and wheels. In this direction, the condition for reducing wear is a decrease in the transverse horizontal forces of interaction between the wheel and the rail and a decrease in the angles of running of wheelsets on the rail in the curve, that is, a decrease in the values that determine the value of the wear factor [8, 9].

To assess the wear of wheels and rails, the wear factor is defined as a characteristic equal to the product of the guiding force and the angle of the wheel on the rail. Therefore, for a detailed analysis of the physical phenomena that occur when the wheel flange slides along the side edge of the rail, it is necessary to investigate the corresponding dependences of the guiding force and the angle of the running of the wheelset [4, 8].

Carrying out a preliminary assessment of the dynamic characteristics of the wagon can be achieved by using mathematical modeling. Modeling makes it possible to determine the dynamic performance of wagons when they move along straight and curved sections of the railway track with real irregularities in the vertical and horizontal planes, taking into account the real rolling surface of the wheel and the profile of the rail head [10-12].

In the study of spatial oscillations of gondola wagons, the following assumptions were introduced: it is assumed that the wagons consist of 12 solid bodies (cargo, body, two bolsters, four side frames, and four wheelsets) (Figure 1). The bogie frame scheme is supposed to be articulated. The elastic-viscous and inertial properties of the track base in the vertical and horizontal planes are taken into account.

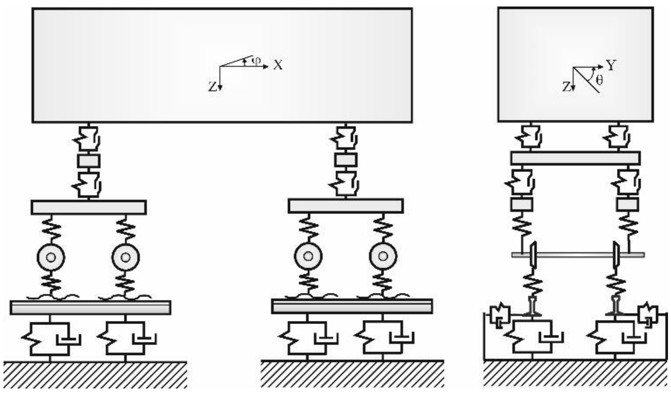

Figure 1. Calculation scheme of a 4-axle freight wagon

The center of mass of the wagon body is placed at the origin of the coordinate system, and the center of mass of the cargo is shifted by the values A_x in the longitudinal direction and A_y in the transverse direction. Taking into account the equations of relations, the differential equations of the oscillations of the wagon are compiled using the d'Alembert principle.

Results

When conducting a theoretical study, the influence of the displacement of the center of mass of the cargo in the body of a gondola wagon in the longitudinal and transverse directions, as well as in both directions at the same time, was considered. In the course of theoretical studies, taking into account the processes of oscillation of a freight wagon and cargo with displacements of the center of mass of cargo in a gondola wagon, the dependences of the wear factor were obtained taking into account the speed of movement along curved sections of the track with a radius of 350 m and 600 m with an elevation of the outer rail of 130 and 120 mm, respectively. The stationary motion was studied in order to establish the influence of only the considered factor.

The displacement of the center of mass of the load in the longitudinal direction was considered within the limits of 3 m, which is allowed according to the regulatory documents for lightweight loads. The transverse displacement of the load was considered in the range from 0 to 0.2 m. For cargo weighing 63 tons, at which the calculations were carried out, a longitudinal displacement of 0.15 m is allowed. On the route, this value can be 0.2 m. The joint displacement of the center of mass of the cargo along the transverse and longitudinal axes is considered within and from 0 to 0.15 m.

The results of analytical modeling showed that the most unfavorable option in terms of wear of wheels and rails is the transportation of light loads with a displacement of the center of mass of the load in the longitudinal direction. Graphs of changes in the wear factor, guiding force and, wheelset hunting when driving in curved sections of the track are shown in Figure 2.

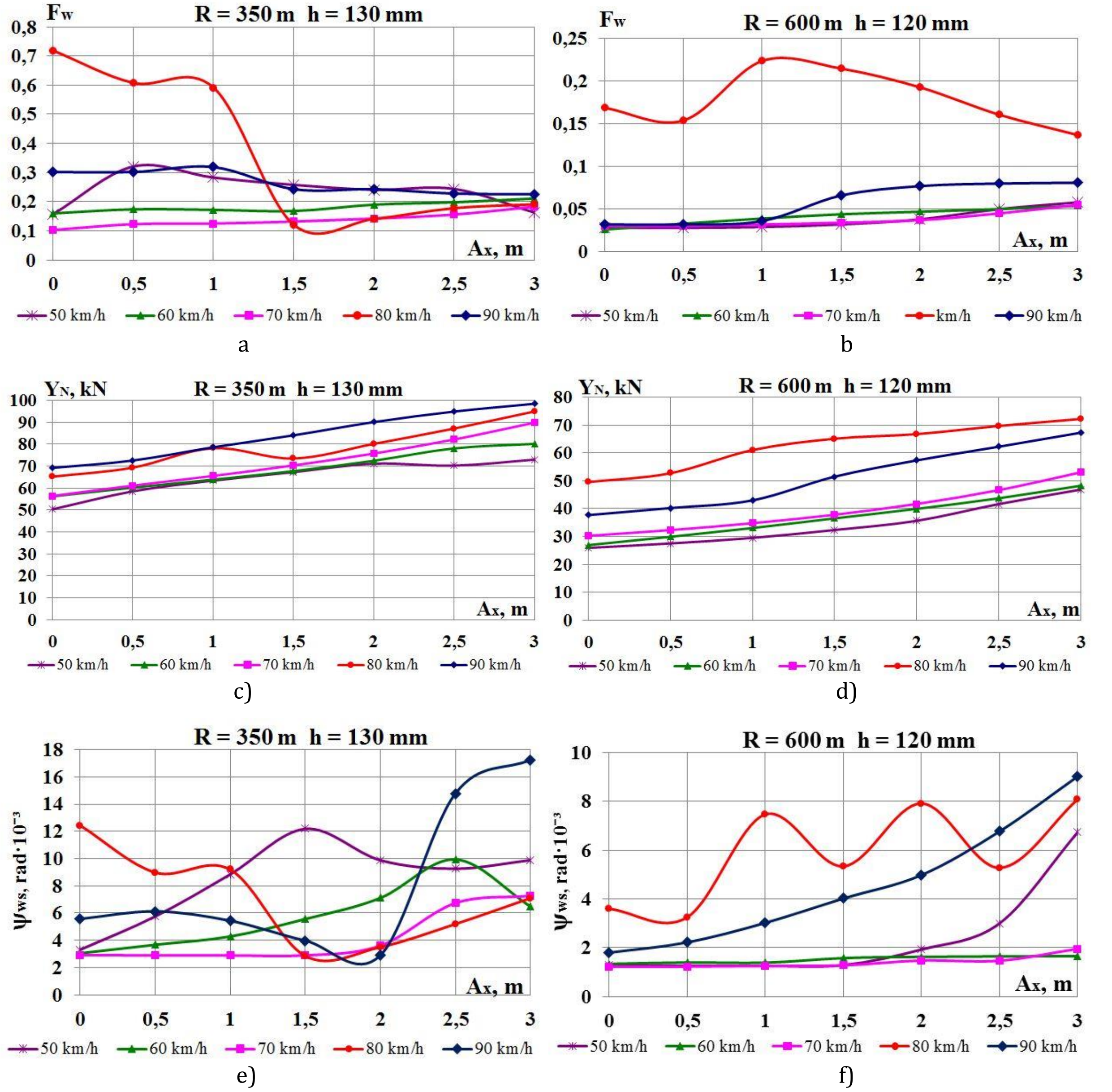

Figure 2. Dependency graphs: a, b) F_w – wear factor; c, d) Y_N – directing force acting from the side of the rail on the wheel; e, f) ψ_{ws} – wheel set hunting

As can be seen from Figure 2(a, b), in general, with an increase in the longitudinal displacement of the center of mass of the cargo, the wear factor increases, but not significantly, in the entire speed range, except for a speed of 80 km/h. The level of the wear factor in curves with a radius of 350 m is, on average, two times higher than the corresponding values in curves with a radius of 600 m. This can be explained by large levels of guiding forces Y_N (Figure 2c,d) and hunting angles ψ_{ws} (Figure 2e,f) in the 350 m curves. At a speed of 80–90 km/h, the values of ψ_{ws} with an increase in the longitudinal displacement from 0 to 3 m significantly differ from the speed range of 50–70 km/h.

The nature of the change in the hunting angles ψ_{ws} of gondola wagons on bogies of the base model 18-100 can be associated with a loss of motion stability when the dynamic transverse vibrations of the hunting of wagon parts cease to fade, acquiring a stable character (self-oscillations). Wheelsets, after the loss of stability of the movement, continuously oscillate within the track clearance, while the amplitude of self-oscillations can change within the gap in the rail track, but vibration damping is not observed. The side frames of the bogie are subjected to self-oscillations of hunting since the dynamic movements of the wheelsets occur predominantly in antiphase. The wagon body, in turn, begins to wag due to the antiphase dynamic movements of the bogies [10].

Therefore, the speed limits in curves with a radius of 350 m and 600 m must be adhered to since it is due to a sharp decrease in the safety factor from the derailment of wheels and an increase in the wear factor of the side edge of the wheel flange.

Conclusion

Ensuring the safety of train traffic requires the development of measures to reduce the intensity of wear of parts of the undercarriage of locomotives, wagons, and track elements. The study of the processes of interaction between the rolling stock and the track by experimental methods requires a lot of time and money. When considering traffic safety in extreme situations, full-scale experiments are associated with a certain risk. To reduce field studies, mathematical modeling is used to study the processes of interaction between the rolling stock and the track. Modeling makes it possible to determine the dynamic performance of wagons when they move along straight and curved sections of the railway track with real irregularities in the vertical and horizontal planes, taking into account the real wheel rolling surface and the profile of the rail head.

Based on the conducted analytical modeling, it is possible to draw the following conclusions:

- a more significant effect on the dynamic processes of the interaction is exerted by the transverse displacement of the center of mass of the cargo compared to the longitudinal displacement;
- the longitudinal displacement has a much greater effect on the guiding forces and the hunting of the wheelsets and, consequently, on the wear factor of the wheels and rails, than the transverse displacement of the center of mass of the cargo.

References

1. Muradian, L., Pitsenko, I., Shaposhnyk, V., Shvets, A., & Shvets, A. (2023). Predictive model of risks in railroad transport when diagnosing axle boxes of freight wagons. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 237(4), 528-532. https://doi.org/10.1177/09544097221122043
2. Shatunov, O. V., & Shvets, A. O. (2019). Study of dynamic indicators of flat wagon with load centre shift. Science and Transport Progress, 2 (80), 127–143. https://doi.org/10.15802/stp2019/165160
3. Shvets, A., Shvets, A., & Kasianchuk, V. (2020). Research of strength characteristics of element of the unit rolling stock. Railroad car fleet, 1 (157), 7–12.
4. Fomin, O. V., Shvets, A. O., Bolotov, O. M., & Saparova, L. S. (2020). Definition of indicators wear in an uneven load freight rolling stock. Bulletin of Certification of Railway Transport, 1, 19–29.
5. Shvets, A. O., Bolotov, O. M., Saparova, L. S., & Shvets, A. O. (2019). Wear wheels and rails at the uneven loading of gondola cars. Bulletin of Certification of Railway Transport, 1(53), 4–17.
6. Shvets, A. O. (2021). Research of stability of the freight rolling stock in noncentral interaction automatic couplers two cars. Bulletin of Certification of Railway Transport, 2 (66), 50-62.
7. Zhang, D, Tang, Y, Sun Z., & Peng, Q. (2020). Optimising the location of wagon gravity centre to improve the curving performance. Vehicle System Dynamics, 1–15. https://doi.org/10.1080/00423114.2020.1865546
8. Shatunov, O. V., Shvets, A. O., Kirilchuk, O. A., & Shvets, A. O. (2019). Research of wheel-rail wear due to non-symmetrical loading of a flat car. Science and Transport Progress, 4, 102–117. https://doi.org/ 10.15802/stp2019/177457
9. Shvets, A. O. (2022). Determination of the form of loss the freight cars stability taking into account the gap in the rail track. Strength of Materials and Theory of Structures, 109, 485-500. https://doi.org/10.32347/2410-2547.2022.109.485-500
10. Lazaryan, V. A., Dlugach, L. A., & Korotenko, M. L. (1972). Stability of rail vehicle movement. Kiev: Naukova dumka.
11. Blokhin, E. P., Pshinko, O. M., Danovich, V. D., & Korotenko, M. L. (1998). Effect of the state of car running gears and railway track on wheel and rail wear. Railway Bogies and Running Gears: Proceedings of the 4th International Conference, 313-323. Budapest, Hungary.
12. Shatunov, O. V., & Shvets, A. O. (2020). Flat cars coupling dynamics when transporting long cargo. Science and Transport Progress, 4 (88), 114-131. https://doi.org/10.15802/stp2020/213381