Influence of the instability form on the traffic safety of freight rolling stock

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Traffic safety
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Instability form

Abstract

The purpose of the paper is a theoretical study of the influence of longitudinal forces of a quasi-static nature and the instability form of freight wagons in a train on the wheel derailment stability. Knowledge of the laws of train movement under various control modes is necessary when programming the equations of train movement when it is necessary to determine the exact position of the train on the railway track and the stability of the wagons at the time of interest. As a result of theoretical studies, the values of the factor of stability against lift by longitudinal forces were obtained, taking into account the forms of instability. The relevance of this study relates to the need to control the longitudinal forces arising during the train movement, taking into account the increase in speeds, masses, and lengths of trains (especially freight trains) and the locomotive power increase.

Introduction

Elevating the maximum speeds makes it necessary to increase the braking efficiency of the rolling stock. The main limitation of the magnitude of the braking force of the rolling stock is the force of adhesion of the wheels to the rails and the stability of the wheel from the derailment. Numerous studies make it possible to obtain the absolute values of the longitudinal dynamic forces during braking and also demonstrate that the forces depend on the weight and length of the train, brake parameters, train speed, braking mode, characteristics, and condition of the draft gear, the size of the gaps in the shock absorbing elements and traction devices, and their distribution along the length of the train at the time of the start of braking [1-3].

Knowledge of the laws of movement of a slowed-down train is necessary when programming the equations of train movement when it is necessary to determine the exact position of the train on the railway track at the point of interest. In the presence of correctly compiled train motion equations, it is not particularly difficult to accurately calculate the length of the braking distances and evaluate the effectiveness of various braking systems.

Ensuring the safety of the movement of heavy trains is possible only if there is a well-controlled brake that does not cause large longitudinal forces in the composition under any braking modes. Therefore, it is necessary to more accurately investigate the dependence of the wheel stability coefficient on derailment on various factors and develop measures to increase the braking efficiency of the rolling stock. The purpose of the paper is a theoretical study of the influence of longitudinal forces of a quasi-static nature and the instability form of freight wagons in a train on the stability of a wheel from the derailment.

Material and Method

It is known that when carrying out traction calculations and solving problems related to the optimization of energy costs for traction, the train is considered as a one-dimensional mechanical system of solid bodies connected by elastic-viscous bonds. An increase in the weight and length of trains leads to the need to consider the body of a freight wagon, taking into account the tare weight of the wagon and weight of the cargo, as an elastic massless beam carrying a uniformly distributed load (Fig. 1) [4-5].

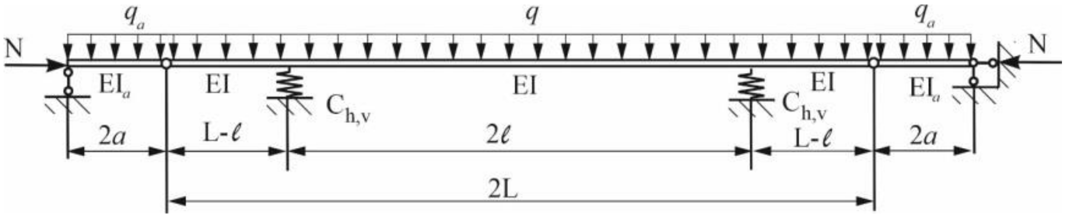


Figure 1. Scheme of a freight wagon, taking into account its weight and loading mode

Here q_a – own weight of two coupler assemblies, respectively related to two lengths of coupler bodies; q – the empty weight of the wagon body together with the suspended equipment and two bolsters in an empty state, referred to its length. When taking into account the loading, the cargo weight is added to the body weight and is considered to be evenly distributed along the entire length; 2ℓ – wheelbase; $2L$ – the distance between coupler followers; $2a$ –automatic coupler body double length from a pulling face to the shank end; $C_{h,v}$ – the horizontal (vertical) stiffness of spring suspension of one bogie.

The nominal bending stiffness of a gondola wagon body is approximately equal to three times the stiffness of the center sill (in the corresponding directions) [4]. In works [4,6], the most unfavorable sections of an automatic coupler from the point of view of strength were established. Rod system in the displacement method has a degree of static indeterminacy equal to 6. The table of reactions of compressed-bent rods from single displacements and loads is given in the work [7]. The basic system of the displacement method, taking into account the symmetry of the rod system, is shown in Fig. 2.

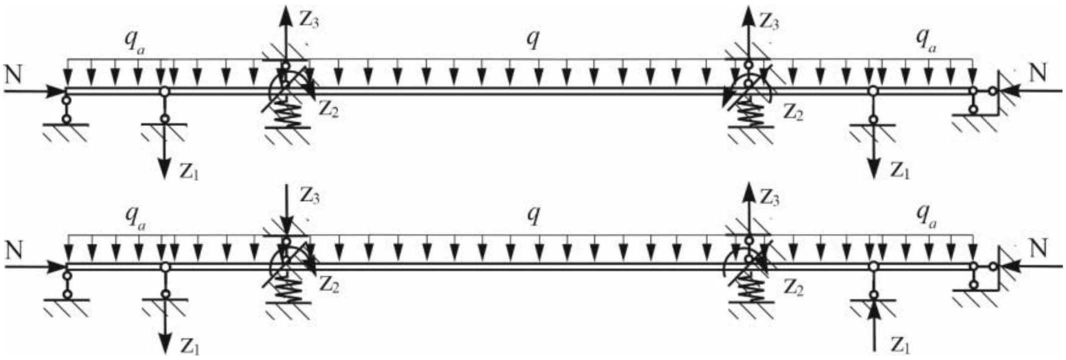


Figure 2. The basic system of the displacement method, taking into account the symmetry of the rod system

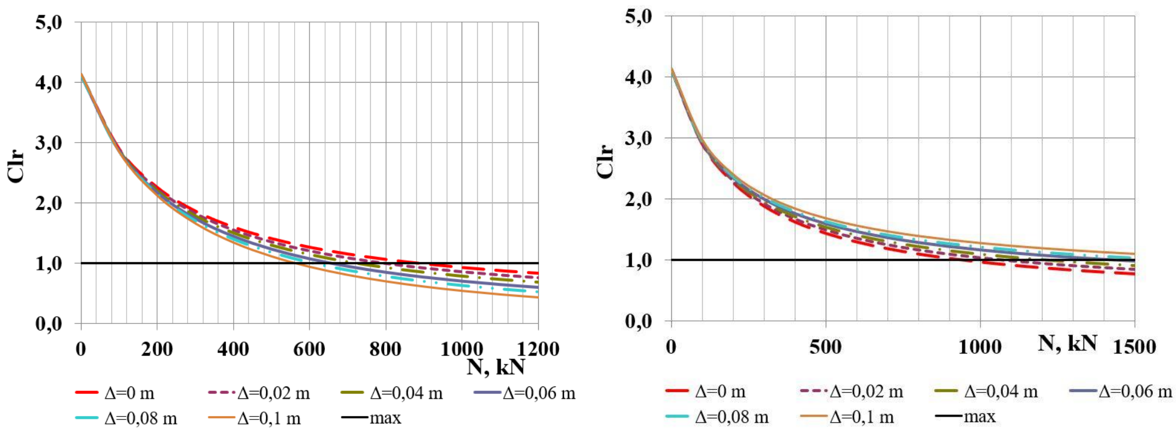
When searching for the minimum critical forces of a symmetrical and symmetrically loaded system, it suffices to find two smaller critical parameters for a direct-symmetrical and skew-symmetrical grouping of unknowns. Expressions for the functions of the displacement method for compressed-bent rods are taken in accordance with [7]. The critical parameter v_i or the length reduction factor, which depends on the instability form, is determined by expanding the determinant composed of expressions for the coefficients at unknown [4-5].

A theoretical study [5] made it possible to obtain dependences for determining the critical parameter for some instability forms, taking into account the rigidity, the weight of the elements of the hinge-rod system, and the gap in the rail track.

Results

Most of the existing methods used to assess the safety of the movement of wagons set permissible limits for the values of the parameters, beyond which there is a possibility of an emergency situation. The stability factor of wagons against derailment, as is known, is estimated by the ratio of horizontal transverse (lateral) forces to vertical forces acting at the point of contact of the wheel flange with the rail head [7-8].

Let us calculate the stability of the wheelset of a wagon under the action of compressive longitudinal forces according to the dependences for straight [4] and curved sections of the railway track [7-8] in the presence of a difference in the heights of the axles of two adjacent wagons. It is envisaged that the loss of stability of wagons occurs according to the I-st (loaded front bogie) and according to the II-nd form (unloaded front bogie). The calculations took into account the difference in height between the longitudinal axles of automatic couplers in a freight train from 0 to 0.1 m with a step of 0.02 m. Behind the wagon under study, the difference between the axle levels of the automatic couplers is taken equal to Δ_2=0.04 m.



a *b*

Figure 3. Resistance coefficient of an empty wagon lift: *a* – unloaded front bogie; *b* – loaded front bogie

The given results confirm that the loss of stability of wagons in the I-th and II-nd form occurs with a significant difference in the magnitude of the longitudinal compressive force. Consequently, the stability loss of freight wagons as part of a train should be divided into two stages: stability loss of the body on suspension springs and the stability loss of the wheelset, which results directly in the derailment.

Conclusion

The use of the method of determining the critical parameter for the I-th and II-nd forms of instability under the action of quasi-static longitudinal forces will allow us to justify the cause of the derailment, as well as to develop and put into practice the technical measures to prevent the lift of the carriages, widening and shear of the track. Using the methodology in compiling the process flow diagrams for driving the trains will make it possible to recommend rational train driving not only at the lowest energy costs but to implement technical measures to improve the stability of freight rolling stock, which in turn will allow removing some existing restrictions on permissible speeds and increasing the train speed.

In order to carry out continuous analysis in train conditions of the value of the resulting longitudinal compressive forces and to prevent large compressive forces, it is necessary to equip locomotives with a system for monitoring and recording longitudinal forces arising on the automatic coupler of the wagons.

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