RATIONALIZATION OF SPEED MODES FOR SAFE MOVEMENT OF TRAINS

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ABSTRACT

With the strategic predetermination for construction of high-speed railways, the question of regulating train speeds is inevitably raised in order to ensure their safety and reduce the risks of accidents. The conducted researches give variants of challenging the existing threats, rationalization of speed regimes on the country's railways. The concept of «train flow» is introduced; calculations of protective schemes are made.

Keywords: railway, high-speed line, safety, train flow, rationalization of speed regimes.

Background. *It is known that the length of high-speed rail lines in Europe is 7 thousand km, in the rapidly developing China – 22 thousand km. In Russia, a high-speed rail line HSR-2 «Moscow–Kazan» with a length of 770 km has been designed and planned for construction with the implementation of speeds of up to 400 km / h (specialized or dedicated line) [1]. At the same time, we should add that «Transport Strategy of the Russian Federation for the period until 2030» [2] provides for reconstruction of the Russian rail network in order to increase the speed of traffic on the existing combined railway lines.*

Objective. *The objective of the authors is to consider rationalization of speed regimes for safe movement of trains.*

Methods. *The authors use general scientific and engineering methods, graph construction, comparative analysis.*

Results. *Speeds have grown and will continue to grow, however, among other difficult tasks, one for this reason will remain unchanged: improving the safety of the country's transport system, rationalizing the speed regimes of trains for the sake of reducing risks and accidents on the railways.*

Since the 1990s, at the department of «Construction production» of MIIT, along with the development of an automated system of organizational regulation, optimization and normalization of railway construction, under the leadership of professor S. P. Pershin research was carried out on regulation of the speed of train traffic in order to improve the safety of transportation by clarifying the model row of models available at that time and establishing more rigorous formal relationships in them. The results of the research are reflected in the publications [3–8].

In the article [9] it is noted that a detailed study of this problem made it possible to set priorities in the analysis of extreme situations posing a threat to the safety of train traffic. It is established that such situations are generated mainly by the following reasons:

1) discrepancy between the speed regime determined by economic efficiency and the line plan;

2) forced distortion of the geometry of linear conjugations;

3) deformation of the track under the train load;

4) lateral instability of the track in the curves.

Hence the important point of ensuring the safe movement of trains is systematization of loading conditions, which is achieved by introducing such a concept as train flow. At present, it is characterized by only one gross indicator – tonnage that has passed through the section of the track per the accounting unit of time.

It is proposed to estimate the train flow by 25 parameters (average number of axis, number of trains per day according to schedule, average statistical load of the wheel, upper and lower speed limits, etc.), of which 10 are high-speed ones.

To solve the problem of justifying the high-speed modes the train flow is characterized by an interval between the maximum speed of the fastest and the lowest of the slowest (heavy) types of trains as compared with the limitations for the lack, excess and maximum elevation of the outer rail as a function of the curvature, varying from the minimum to the maximum values, characteristic of curves of a particular line. These constraints are expressed by complex dependencies acting for curves which radius is oriented to the maximum speed of the train flow (less than the criterion of flatness).

Restrictions lead to a decrease in speed, which increases the time of finding the calculated train on the route and causes an increase in the energy intensity of transportation. Reducing the influence of constraints requires the reconstruction of curves of insufficient radii. At the same time, the volume of reconstructive measures increases with the increase in the upper limit of speed of train flow and the criterion of flatness.

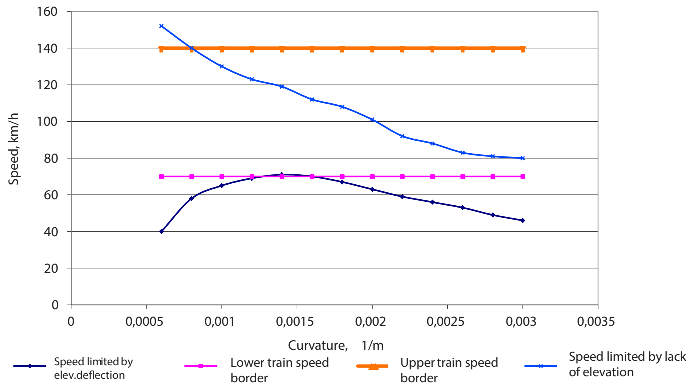
For example, in a train flow with an interval of speeds of 200–80 km / h, the criterion of flatness reaches 3410 m. Bringing the existing curves on the railroad network of the Russian Federation to this radius will require large construction costs.

Reducing the criterion of flatness and, as a consequence, the volume of reconstruction of the line plan can be achieved by reducing the maximum speed of fast trains, but, as calculations have shown, the restrictions cease to be effective only in train traffic with an interval of speeds of 80–50 km / h.

Economic difficulties are not the only obstacle to increasing the speed of passenger trains. It is necessary to reckon with the restriction on the excess of the elevation of the outer rail, which is introduced for safety reasons for the movement of freight trains: the minimum speed of their movement should not be less than the limit. This restriction disappears in train traffic with boundary speeds of 100–60 km / h, observed at a point at speeds of 120–70 km / h and in the interval of radii of 800–625 m at speeds of 140–70 km / h and higher (Pic. 1).

Consequently, the excessive difference in the border speeds of the train flow (over 50 km / h in the conditions of the examples considered for the railway line Moscow–Krasnoye) generates an extreme situation threatening traffic safety.

The most radical measure of its elimination is to increase the speed at the lower boundary of the speed interval of the



Pic. 1. Speed characteristics of the train flow 140–70 km / h.

train flow. Thus, at the boundary speeds of 200–80 km / h, the restriction on the excess elevation is no longer valid, although due to a lack of elevation in the curves of a radius of 333 m, it is necessary to reduce the maximum train speed to 116 km / h.

At a speed on the lower border of the train flow of 70 km / h, the maximum speed should not exceed 120 km / h, otherwise it is necessary to increase the level of freight train speeds.

For West-European roads, freight train speeds of 100–110 km / h are common, freight speeds of 160 km / h are already being realized. The appearance of such speeds on the railways of Russia is associated with the modernization of bogies and braking devices. In addition, it is necessary to ensure uniformity of axial loads along the length of the composition, which requires a rigid weight control during loading.

From the above reasoning, one can see the expediency of creating specialized high-speed passenger lines, the movement of freight trains on which will be excluded, or organized in containers, as it is supposed to implement at HSR Moscow–Kazan.

In addition to the deviation of the speed regime from the allowable, distortion of the geometry of curvilinear conjugations contributes, for example, due to a lack of space on the existing subgrade, to occurrence of extreme situations. Therefore, for any setting, it is necessary to calculate the width of the main site and the broadening of the roadbed from the outside of the curve, since the variety of conditions does not allow to resort to normative generalizations.

To determine the impact on the development of extreme situations of deformability of the track, the model of an infinitely long beam on a continuously-discontinuous base developed in the early 1970s can be used. By simulating the impact of a changing wheel load on a detached support with varying vertical stiffness using random numbers distributed according to Gauss's law, a schematized dynamic track profile is obtained as a one-time implementation of the wheel's trajectory and a source of dynamic additive from the wheel passage along this trajectory.

Calculations carried out by S. P. Pershin [8], revealed the decisive influence on the deformability of the track of variations in the wheel load, increasing with increasing speed. A stronger deforming effect of freight trains on the track as compared with passenger trains was also established. The function of accumulation of irreversible deformations, in the order of the first approximation, is assumed to be linear. The essential influence of irreversible deformations on the general deformability indicators is revealed. The carried out researches will allow to receive statistical characteristics of elastic deflections and pressures on sleepers as a function of speed for each type of trains and take into account irreversible precipitation, increasing as tonnage passes. The availability of such information helps to directly establish the frequency of road alignments and repairs, which is a complex function of the speed regime, the tonnage passed, the level and nature of the loading of the track.

To determine the impact of transverse stability of the track on the development of extreme situations, the complex motion of a car bogie is considered taking into account the factors that can significantly increase the resistance to its rotation relative to the car body. With a certain amount of this resistance, a real threat to traffic safety is created. A set of measures should be proposed that preclude occurrence of extreme situations of this kind.

Conclusion. *The change in speed regimes of train operation in general and the increase in the speed of passenger trains in particular entail a whole range of organizational and technical measures, which require a deeply thought-out approach to planning. It is necessary to understand that in order to reliably predict extreme situations arising from the train movement at high speeds, it is necessary to thoroughly study normal situations with development of models for the behavior of the most complex system «railway» adequate to real conditions, taking into account the interaction of all its components.*

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