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# JUSTIFICATION OF METHODS FOR IMPROVING THE SPRING SUSPENSION OF HIGH-SPEED ELECTRIC TRAINS

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**ABSTRACT**

*The article presents research on the substantiation of methods for improving the spring suspension systems of high-speed electric trains.*

The increase in rolling stock speeds, driven by economic factors, necessitated limiting the amplitude of their vibrations and improving passenger comfort. This led to the use of spring suspensions with elastic ties with high static deflection and special dampers that dissipate vibration energy and limit their amplitude [1÷2].

Globally, significant attention is being paid to the development and safety of high-speed electric rolling stock (specifically, electric trains and high-speed electric multiple units), and the improvement of their spring suspension systems using modern tools and equipment, utilizing advanced technologies. In developed countries such as the USA, England, France, Spain, Germany, Japan, China, Russia, and elsewhere, special attention is being paid to improving the controlled spring suspension systems when designing and building new electric multiple units and high-speed electric multiple units [1, 2, 3, 4].

The current trend toward significantly increasing travel speeds on Uzbekistan's railways requires, first and foremost, improving the running properties and dynamic characteristics of electric rolling stock (specifically, high-speed electric multiple units) [5]. Maximum travel speed is determined by the interaction of the track and the rolling stock (RS), the resistance of the RS to overturning, to derailment due to wheel flanges rolling on them, and the acceleration of the commuter train body to ensure the necessary comfort for commuter train crews [3,4].

Research on this topic has been and is being conducted by leading scientists worldwide, such as C.A. Brebbia (Wessex Institute of Technology, UK), G.M. Carlomagno (University of Naples di Napoli, Italy), A. Varvani-Farahani (Ryeson University, Canada), S.K. Chakrabarti (USA), S. Hernandez (University of La Coruna, Spain), S.H. Nishida (Saga University, Japan). In the CIS, authoritative scientific schools and leading scientists from MIIT, PGUPS, MAI, VNIIZhT, JSC VNIITI, JSC Russian Railways, and others have worked on these issues.

In Uzbekistan, the problems of optimizing spring suspension systems for rolling stock were studied by Academician of the Academy of Sciences of the Republic of Uzbekistan, Professor, Doctor of Engineering Sciences A.D. Glushchenko, Professors Sh.S. Fayzibaev, G.A. Khromova, A.A. Shermukhamedov, Z.G. Mukhamedova, R.V. Rakhimov, Ya.O. Ruzmetov, O.R. Khamidov, D.O. Radzhibaev, as well as their students [6,7,8,9].

In all high-speed train carriages, a separate vibration damping system is used in different suspension stages to ensure the damping properties of the chassis. This allows for the creation of an effective damping system and ensures adequate passenger comfort. As a rule, vertical vibration dampers are installed in the axlebox suspension stage; vertical dampers are installed in the central stage – drift dampers (horizontal transverse) and horizontal wobble dampers (along the track axis) of the torsion spring type [2,3,4].

In [2,3,7,8], a detailed analysis of spring suspension designs developed in Russia and abroad, where air springs are used as elastic and dissipative elements, is presented, and their mathematical models are discussed. As is well known, air springs consist of an elastic shell with reinforcing components. Inside the air springs are rubber-metal shock absorbers, which support the body when there is no air in the air spring, as well as in emergency situations when the elastic shell ruptures.

In general, the following general conclusions can be drawn from our systematic analysis of foreign scientific, technical and patent literature:

1. New high-speed electric trains, designed for operation at higher speeds, will operate successfully if their performance and track impact indicators are better, or at least no worse, than those achieved. The performance of high-speed rolling stock is assessed based on key indicators, primarily:

- the safety factor ($K_{SF}$) of a wheelset against derailment under the condition of the wheel flange rolling onto the railhead;

- the smoothness indicators in the vertical and transverse directions ($w_V$ and $w_{TD}$), as well as the expected vibration acceleration levels in specified frequency ranges and the fatigue time dependent on them;

- the vertical dynamics coefficient ($K_{VD}$) and the frame force ($F_R$);

- the vertical and horizontal accelerations ($a_V$ and $a_H$);

- the lateral stability factor ($K_{LSF}$) against overturning in a curve under the action of lateral forces;

- the degree of damping of the vibration modes;

- stability against derailment under the condition of the wheel flange rolling onto the railhead.

In a number of cases, when investigating the causes of train crashes and accidents, clearly visible marks (scratches and even grooves) were repeatedly discovered on the railhead in the accident zone. These marks began on the inner side of the rail and moved diagonally to the outer side, showing the trajectory of the wheel flange after rolling onto the rail. The immediate cause of derailment is a combination of two factors: a decrease in pressure on the wheel in the vertical direction (the so-called "unloading") and the action of a force in the transverse direction. A wheel can slide its flange onto the rail only when the resultant force acting on it overcomes the frictional force between the flange of the wheel and the rail.

2. To determine the stability margin, use the formula

$$К_{STAB} = \frac{tg\beta - \mu}{1 + \mu tg\beta} \cdot \frac{P_B}{P_Б} \geq [К_{STAB}], \quad (1)$$

where $\beta$ is the angle of inclination of the wheel flange generatrix with the horizontal (depending on the wheel tread profile ($\beta$ = 60...70°)), $\mu$ is the coefficient of friction of the wheel surfaces (assumed to be $\mu$ = 0.25); $P_V$ is the vertical load from the advancing wheel on the rail; $P_L$ is the lateral force of interaction between the advancing wheel flange and the railhead; $[К_{STAB}]$ is the permissible value of the stability margin.

For safety reasons, in Russia and Uzbekistan, the stability margin factor for passenger cars of high-speed electric trains is $[К_{STAB}]$ = 1.6.

3. The average ride quality index ($w_{RQI}$) should be no more than 3.25 for passenger cars of locomotive-hauled trains, electric and diesel multiple unit cars, railcars, and loaded subway cars (Table 1).

**Ride Quality Assessment on Russian and Uzbekistan Railways**

Table 1.

| Ride Quality Index, $w_{RQI}$ | Qualitative Ride Quality Assessment |
|---|---|
| <1 | excellent |
| <2 | good |
| <3,25 | satisfactory |
| >3,25 | unsuitable |

4. As rail transport speeds increase, even greater attention must be paid to reducing rolling stock vibrations. Vibration levels in rolling stock are assessed according to the international standard ISO 2631 and GOST 311-91 using measurements of the root-mean-square vibration acceleration. The impact of vibration on humans is considered in relation to: their health and comfort; sensitivity to vibration; and susceptibility to motion sickness.

5. Central pneumatic suspension of high-speed electric train cars allows for the best results in terms of ride quality and track impact on rolling stock designed for high speeds when using pneumatic springs in it [2, 7, 8, 9].

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