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Brake rigging dynamic simulation under braking on a track section with irregularities (the case of a passenger car)

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Introduction. The paper considers simulation of the dynamic processes of the brake rigging of a passenger car under braking on a track section with irregularities. The work objectives include the development of a "rigging brakeblock - wheel working surface" contact module in a full-scale computer model of a passenger car in the "Universal Mechanism" software package; and a computer simulation of the braking operating mode from 50 to 32 km/h considering vertical and horizontal track rail irregularities for determining the mechanism of variation of the longitudinal acceleration of the brakeblock and its angular acceleration. The subject of the study is the force interaction of the elements and dynamic processes in the brake system of passenger cars.

Materials and Methods. A new "rigging brakeblock - wheel working surface" contact module, which provides the determination of the longitudinal and angular accelerations of the brake rigging of a passenger car, is proposed to the "Universal Mechanism" software package,. The simulated modeling of the brake rigging system of a passenger car with KVZ-TsNII type II trolleys equipped with shoe brakes is carried out.

Results. A full-scale computer model of a passenger car, which includes the designed contact module "linkage brake pad - wheel working surface", has been developed in the "Universal Mechanism" software package. The car is presented as a system of solids connected by elastic and dissipative elements. Using computer simulation, the operating mode of braking was reproduced under reducing the speed of a passenger car from 50 to 32 km/h considering vertical and horizontal irregularities of a railway track. The simulation result was the laws of change in the longitudinal acceleration of the brakeblock and its angular acceleration under braking in the above speed range. Their spectra of longitudinal angular acceleration of the brakeblock were constructed. It was determined that the presence of track irregularities affects the spectral composition of the accelerations. In addition, under the superposition of the bogie-frame pitching and bouncing oscillations, when moving along an uneven track, the rigging block can move up and down the wheel-working surface within a range of up to 50 mm. The simulation functionality of the dynamic processes of the brake system of a passenger car was expanded in the "UM-Loko" software package.

Discussion and Conclusions. The results obtained can be used in the design of new rigging brake systems of passenger cars and modernization of existing ones at the engineering enterprises and railway-car repair works. This, in turn, should ensure uniform distribution of efforts across all brake rigging brakeblocks of a passenger car.

***Keywords**:* rigging, brake system, wagon, block, dynamics, simulation, braking, track with irregularities.

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Introduction. The problem of efficient and reliable operation of the brake systems of passenger cars becomes even more urgent when high-speed traffic is introduced on the Russian railways. The main part of modern brake systems is the lever transmission system of a passenger car, whose efficiency and reliability depend directly on the quality of design, operation, maintenance and repair of the brake equipment. The mechanical part of the brake system combines a rigging brake transmission, an automatic rigging transmission regulator and friction brake components (brakeblocks and pads). One of the key requirements for the brake rigging system is to provide uniform force distribution across all brakeblocks. However, under the operating conditions, there is some variation in the efforts of pressing the brakeblocks on the wheelsets both within the wagon and within each bogie. The nonuniformity of pressing brakeblocks may be one of the basic reasons for their uneven wear. The subject of the study is the force interaction of elements and dynamic processes in the brake rigging system of passenger cars. The level of theoretical studies on dynamic processes of structural elements of the traction rolling stock is quite high [1–12].

Materials and Methods. To clarify and confirm the results of theoretical studies, it is required to carry out computer simulation of the dynamic processes of the brake rigging system of a passenger car, which occurs under braking on a flat section of the track. Major causes of the dynamic processes in the contact "rigging brakeblock – wheel working surface" may be fluctuations of the car underframe when moving along a track with irregularities. This is because the brakeblocks and the brake rigging system components are structurally connected with the bogie frame, which, due to deformation of the axlebox suspension, moves with respect to the wheel pairs rolling along the rails. It is required to consider the simulation of the braking process in the presence of uneven tracks.

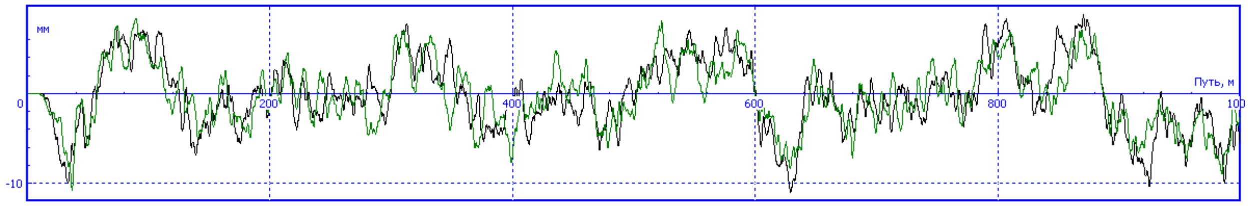

Fig. 1. An example of the vertical track rail irregularities

Files of vertical and horizontal irregularities of track rails, which are a generalization of the measurement results, are available in the UM-Loko software package. Fig. 1 shows vertical irregularities on a track of 1000 m long as an example.

Research Results. The simulation results of the dynamic processes of the lever transmission of the brake system on a flat track are presented in Fig. 2. The picture of the "wheel – rail" contact patches for all four wheelsets of the car, in the presence of track irregularities, is shown in Fig. 3. Comparison of simulation results with Fig. 2 provides the conclusion that the presence of irregularities causes the emergence of vertical oscillations of the car underframe and, as a result, a significant change in the forces within the "wheel – rail" contact patch.

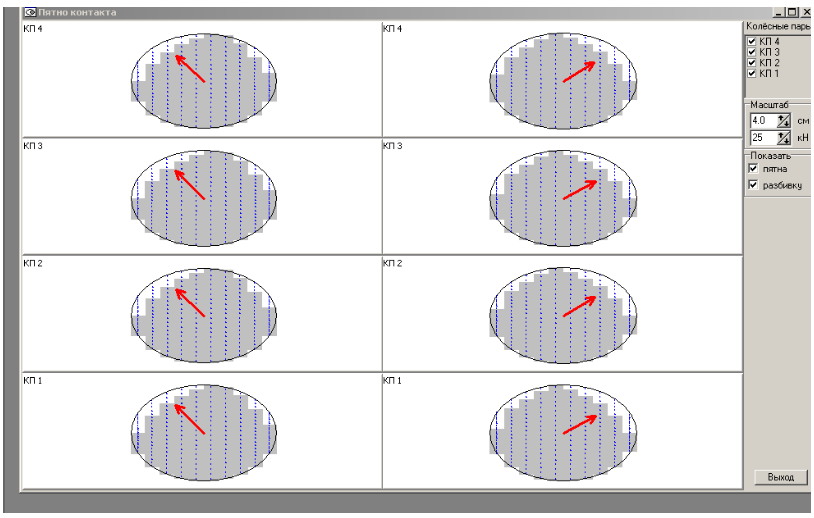

Fig. 2. "Wheel – rail" contact patches and force distribution (on level)

When moving along a track with irregularities, the oscillations of the truck-frame bouncing have an amplitude reaching 18 mm; frequencies of 0.8 are visible in the spectrum of vibrations; 0.95 and 1.07 Hz. The last frequency is close to the natural frequency of the car-body pitching.

Pitching oscillations of the bogie frame have amplitude up to 0.0025 rad. In the spectrum, there are frequencies of 0.25; 0.8; 0.95; 3.7 and 3.9 Hz.

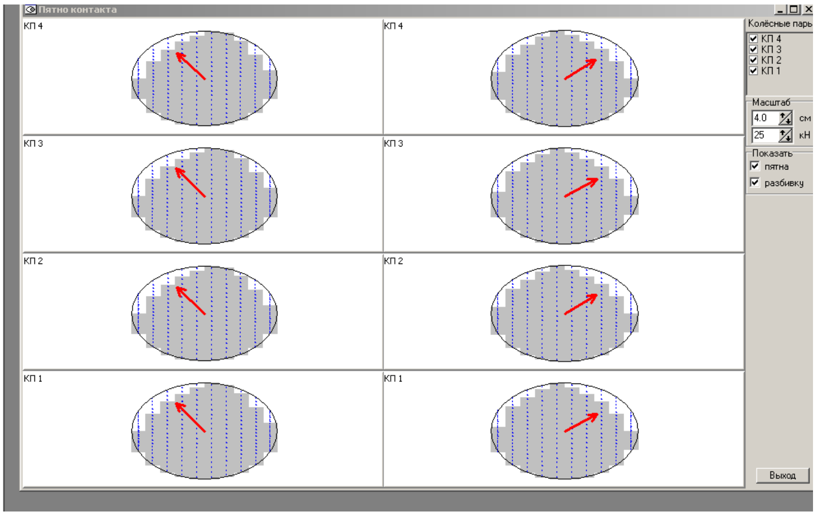

Fig. 3. “Wheel – rail” contact patches and force distribution (uneven track)

Fig. 4 and 5 show a graph of the longitudinal acceleration of the rigging brakeblock under braking in the presence of track irregularities and its spectral composition.

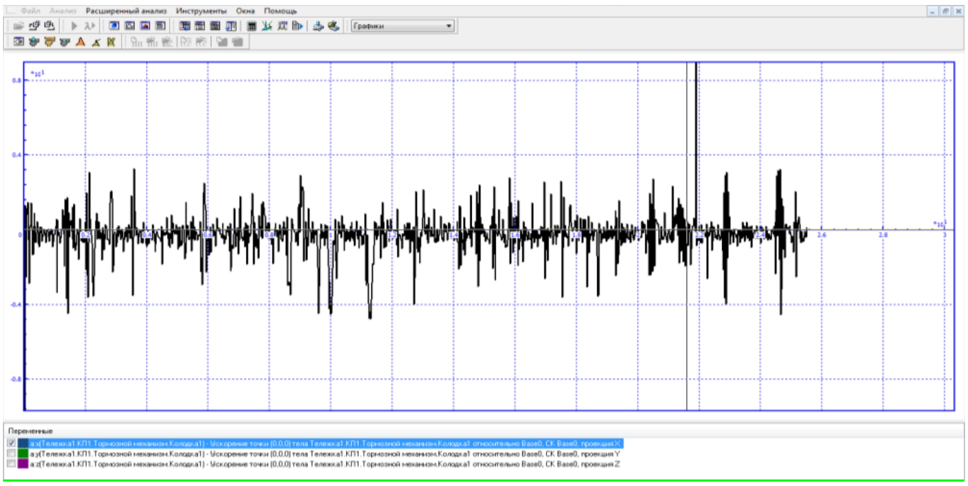

Fig. 4. Longitudinal acceleration of the rigging brakeblock under braking (track irregularities)

Fig. 6 and 7 show a graph of the angular acceleration of the rigging brakeblock under braking in the presence of track irregularities and its spectral composition.

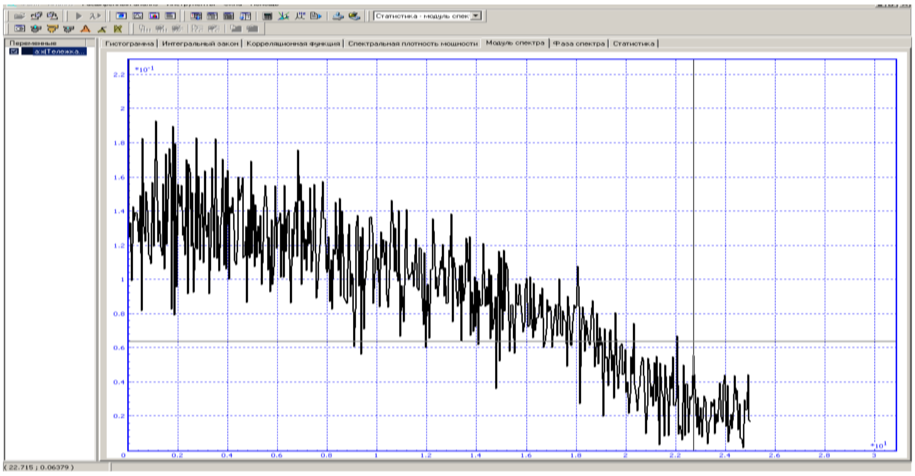

Fig. 5. Spectral composition of longitudinal acceleration of rigging brakeblock (track irregularities)

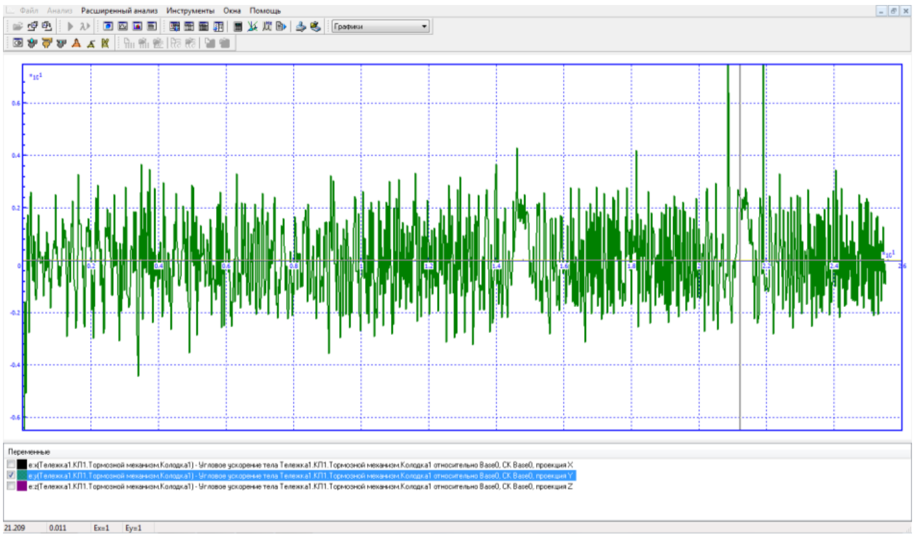

Fig. 6. Angular acceleration of rigging brakeblock (track irregularities)

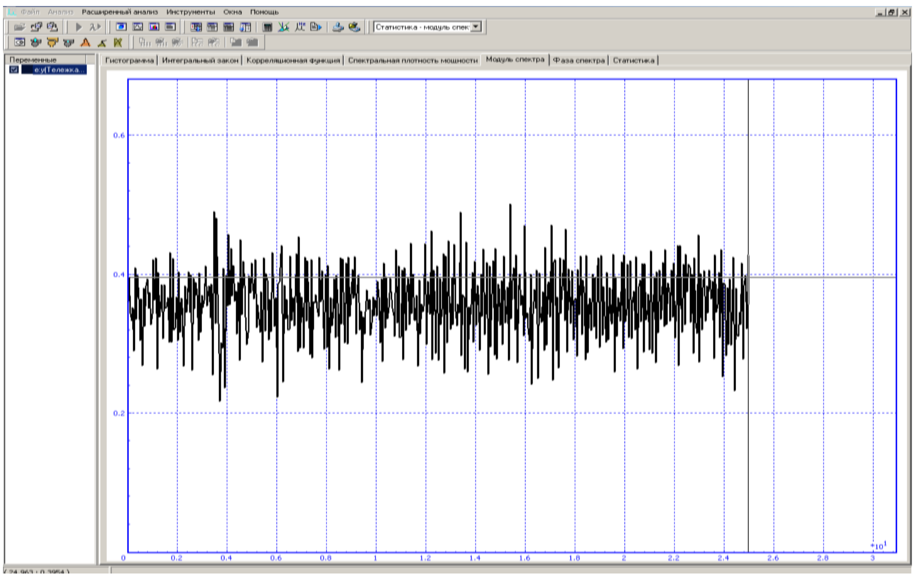

Fig. 7. Spectral composition of angular acceleration (track irregularities)

The simulation results show that in the presence of track irregularities, the longitudinal and angular vibrations of the brakeblocks occur in the frequency range up to 25 Hz, and their spectral composition is somewhat different from the case when braking occurs on level.

Discussion and Conclusions. A full-size computer model of a passenger car is developed in the "Universal Mechanism" software package. A car is presented as a system of solids connected by elastic and dissipative elements. The structure of the model includes the developed "rigging brakeblock – wheel working surface" contact. Using the computer model, the operating mode of braking from 50 to 32 km/h is reproduced. The option when the track has vertical and horizontal irregularities of lengths of rails is considered. Because of the simulation, the variation pattern of the longitudinal acceleration of the brakeblock and its angular acceleration under braking from 50 to 32 km/h were obtained, and their spectra were constructed. The track irregularities affect the spectral composition of accelerations. In addition, under the superposition of bouncing and pitching oscillations of the bogie frame when moving along the uneven track, the rigging brakeblock can move up and down along the wheel working surface with a swing up to 50 mm. The results obtained can be used under the design of new and modernization of existing brake rigging systems of passenger cars at machine-building enterprises and car repair enterprises to provide an even force distribution across all brakeblocks.

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Claimed contributorship

I. A. Yaitskov: academic advising; analysis of the research results; exploratory study on the practical implementation of the methodology involved. V.V. Kosarevskii: setting the research objective and task; collecting and processing of material; computational analysis; text layout; drawing conclusions.

All authors have read and approved the final manuscript.