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On the Question of the Oscillatory Process of the Under-Rail Base in the Zone of the Rail Joint with Under-Rail Pads of Different Elasticity

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Abstract: *The article presents the results of full-scale tests of rail pads in order to assess the effect of stiffness and the number of standard and experimental rail pads-shock absorbers on the amplitude-frequency characteristic of oscillations that occur in the ballast layer in the rail joint zone during the movement of rolling stock. To achieve this goal, we measured the vertical vibration accelerations that occur during the passage of trains in the rail junction area with a different number of standard rail pads-shock absorbers TsP-204-M-ARS (standard) and pads-shock absorbers of increased elasticity (experimental). On the basis of the obtained values, the amplitude-frequency characteristic of the oscillatory process was determined by means of the Fourier transform. The main (carrier) frequencies, at which the maximum amplitudes of vibration accelerations are fixed, are determined, first of all, not by the material of the shock absorber gasket, but by the magnitude of the force impact. The use of experimental pads-shock absorbers makes it possible to reduce and redistribute the energy of vibrations transmitted to the ballast layer.*

Keywords: *Fourier analysis, rail padding, elasticity, Sapsan, high-speed movement, vibration acceleration, shock absorber pads.*

Introduction

In connection with the global trend to increase the volume of rail traffic, train speeds and axle loads, the railway track experiences increased dynamic loads [1]. The increase in loads leads to accelerated wear of the track superstructure elements. The rail joint is a node with particularly difficult working conditions. In the area of the rail junction and adjacent sleepers, the shock effect of the rolling stock significantly affects the stability of the track [2]. To solve this problem, elastic under-rail pads are used [3, 4, 5]. Gaskets are made of various materials: high-strength polyethylene (HDPE), various elastomers, including natural rubber, polyurethane [6]; recycled rubber [7], reinforced rubber [8, 9].

This article presents the results of full-scale tests of rail pads in order to assess the effect of stiffness and the number of standard and experimental rail pads-shock absorbers on the amplitude-frequency characteristic of oscillations that occur in the ballast layer in the rail joint zone during the movement of rolling stock.

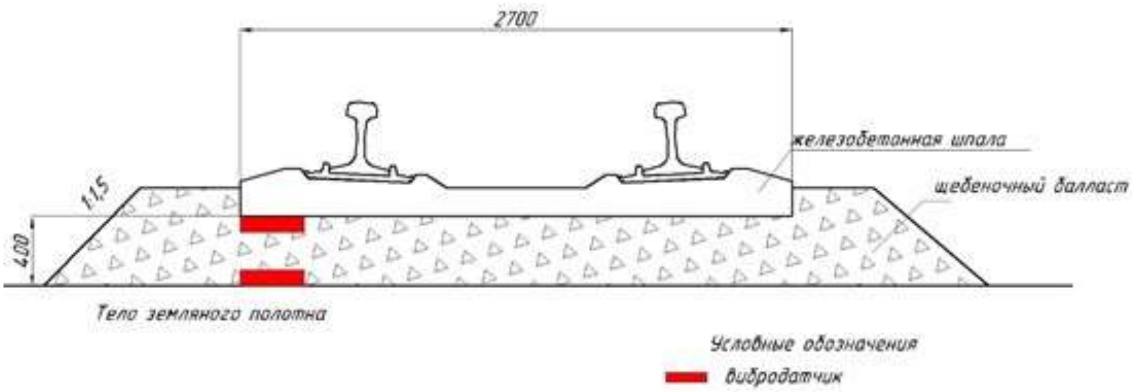
To achieve this goal, we measured the vertical vibration accelerations that occur during the passage of trains in the rail junction area with a different number of standard rail pads-shock absorbers TsP-204-M-ARS (standard) and pads-shock absorbers of increased elasticity (experimental). Based on the obtained values, the amplitude-frequency characteristic of the oscillatory process was determined.

Materials and methods

The test object is the area of the rail junction, located on the second main track of the Petro-Slavyanka station. The subgrade is represented by zero place. The test site is the second main track of the Petro-Slavyanka station on the St. Petersburg - Moscow line. The measured parameters are vertical vibration accelerations in the area of the rail joint, in units of g.

To assess the vibration impact that occurs in the area of the rail junction from passing trains, the measuring sensors were installed at the point where vibrations are transmitted from the sleeper to the ballast, i.e. on the surface of the ballast at the end of the sleeper and in the under-rail section at a depth of 40 cm from the bottom of the sleeper (on the main platform of the subgrade). The layout of the sensors is shown in Figure 1.

a)



b)

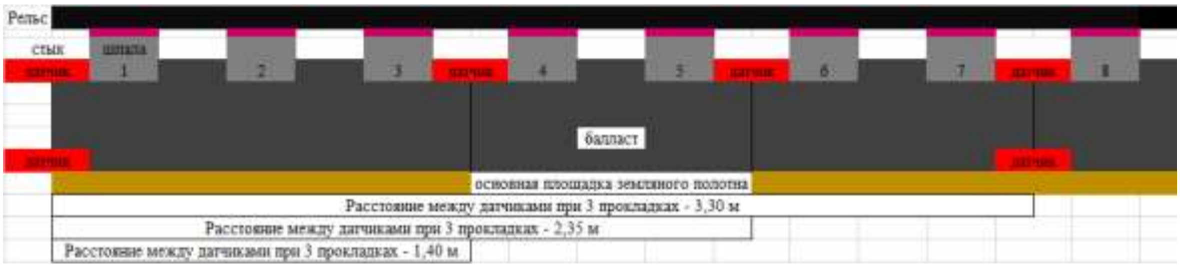


Рис. 1. Схема размещения вибродатчиков на экспериментальном участке

а-(поперечный разрез); (- вибродатчик); б-(продольный разрез)

At each measurement point, vibrations propagating in three directions were recorded: in the vertical plane, in the horizontal plane across the track axis, and horizontally along the track axis. The seismic receivers were installed on a leveled area with exact observance of the measurement directions (vertical, horizontal across and along the path).

When the train was moving, the travel time, type of rolling stock and its speed were recorded.

Passenger trains moved along the experimental section at speeds of 85-95 km/h, high-speed electric trains "Lastochka" (Siemens Desiro ES2G) - 170 km/h, high-speed electric train "Sapsan" (Velaro RUS EVS) - 190 km/h.

For each type of rolling stock in the interval and range of speeds, at least two measurements were made.

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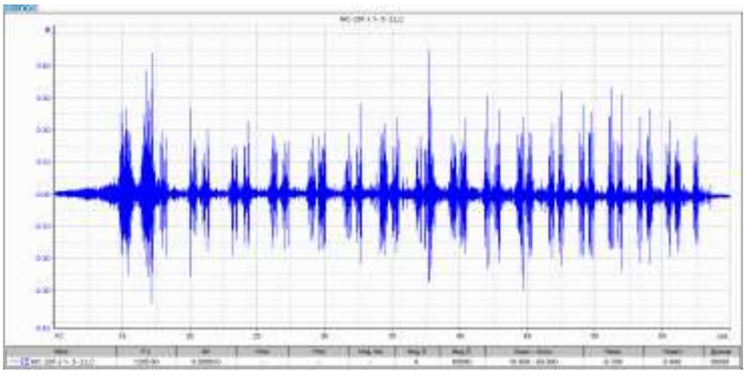
The measurements were carried out using the following set of equipment: digital seismic signal recorder ZET 048; portable computer with licensed software; signal amplifier; power supply 220 V (if necessary).

Based on the recordings of vibration accelerations obtained during the movement of various types of rolling stock, the amplitude-frequency characteristics of the oscillations were obtained by means of the Fourier transform.

Analysis of results

Based on the results of measuring vibration accelerations, depending on the type of rolling stock moving at different speeds and having different axial loads, comparative diagrams were constructed and dependencies were identified that characterize the level of vibrodynamic impact that occurs when trains pass in the rail junction area and at a distance of 3, 5 , 7 pads-shock absorbers with the corresponding number of new standard pads-shock absorbers TsP-204-M-ARS (standard) and pads-shock absorbers of increased elasticity (experimental) laid on the way.

a)



b)

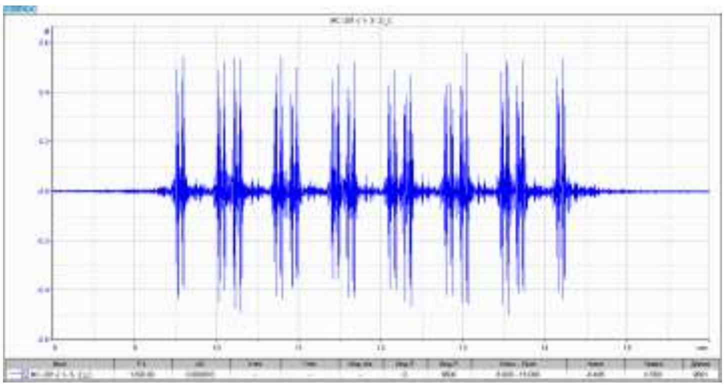


Fig.2. Graph of vibration accelerations of the main subgrade area in the area of the rail joint with old standard shock absorber pads.

a- (passenger train); b- (swallow);

As a result of the Fourier transform of the vibration acceleration records, the amplitude-frequency characteristics (AFC) of the oscillatory process on the main platform were obtained during the passage of various types of rolling stock in the area of the rail joint with standard gaskets TsP-204-M-ARS, shown in Figures 4-6. An example of the frequency response obtained during the passage of the "Sapsan" in the zone of the rail joint with 5 experimental pads-shock absorbers Sylodyn NF.

It follows from the above graphs that the highest oscillation energy is observed when a passenger train passes through the junction. In this case, the highest amplitude values are typical for the frequency range from 50 to 150 Hz, and the highest peak values are observed at frequencies of 50-60 Hz, 90-110 Hz and 120-140 Hz. In this case, non-zero amplitudes are fixed in the frequency range up to 600 Hz.

When the electric train "Lastochka" passes through the junction area, the total energy of vibrations is much lower, the peak values of the amplitudes are observed in the range of 40, 60, 90 and 110 Hz, and in general the graph is shifted towards low frequencies. Non-zero values of the amplitudes are fixed in the range up to 600 Hz, but in the range 400-600 Hz their values are negligible.

When the high-speed Sapsan train moves along the junction, the total vibration energy is comparable to the energy realized during the passage of the Lastochka electric train. On the frequency response graph, 3 main groups of peak amplitude values are identified, which are confined to frequencies of 40 Hz, 60 Hz, 80 Hz. Thus, the frequency response shifts towards low frequencies to a greater extent than when the Swallow moves. Non-zero values of the amplitudes are fixed in the range up to 600 Hz, but in the range 400-600 Hz their values are negligible. The resonant oscillation frequency was found at frequencies in the range of 50-60 Hz.

The results obtained are due to the fact that the undercarriage of a passenger train causes oscillations in a wide frequency range, associated primarily with the force effect of the rolling stock (low and medium frequencies) and the oscillation of the unsprung masses of the undercarriage (high frequencies). The oscillations caused by the passage of the "Swallow" and "Sapsan" lie mainly in the middle frequency range due to the increased dynamic effect due to the high speed of movement, and a more advanced design of the chassis, which reduces the high-frequency component of the oscillations.

The use of experimental pads-shock absorbers makes it possible to reduce and redistribute the energy of vibrations transmitted to the ballast layer. An example of this fact is the frequency response of oscillations in the ballast layer in the area of the rail joint when laying 5 experimental Sylodyn NF shock absorber pads and moving the Sapsan. Comparison of the graphs shown in Figures 6 and 7 indicates smoothing of peak values and their redistribution in the ranges of 30-45 Hz and 80-90 Hz. This is due to the fact that the elastic gasket made it possible to significantly reduce the oscillation amplitudes in the frequency zone above the resonant frequency of 60 Hz, but at the same time increased the oscillation amplitudes in the range of 30-40 Hz, which is in good agreement with previous studies. Non-zero values of the amplitudes are fixed in the range up to 600 Hz, but in the range 500-600 Hz their values are negligible. Thus, the laying of an elastic pad allows you to significantly (up to 2 times) reduce the vibration amplitude of the undersleeper base in the butt zone at the resonant frequency.

Reducing the vibrodynamic impact on the ballast layer in the resonant frequency ranges will increase the bearing capacity and service life of the ballast, reduce stresses on the main subgrade area [10-13]. These effects will improve the operational properties of the railway track as a whole.

Conclusion

The study of vertical vibration accelerations of the ballast in the area of the rail joint with a different number of standard pads-shock absorbers TsP-204-M-ARS (standard) and pads-shock absorbers of increased elasticity (experimental) allow us to draw the following conclusions:

1. The main (carrier) frequencies, at which the maximum amplitudes of vibration accelerations are fixed, are determined by the magnitude of the force effect, which in turn depends on the design features of the rolling stock (distance between bogies) and its speed.

2. The resonant frequency of the railway track is in the range of 50-60Hz.
3. The use of experimental pads-shock absorbers makes it possible to reduce and redistribute the energy of vibrations transmitted to the ballast layer due to the shift of the resonant frequency. Reducing the vibrodynamic impact on the ballast layer will increase the bearing capacity and service life of the ballast, reduce stresses on the main subgrade area. These effects will improve the operational properties of the railway track as a whole.

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