Parameters of the oscillatory process of the sleeper base in the area of the rail joint when using elastic spacers

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Abstract. The article presents the results of field tests of under-rail pads in order to assess the effect of stiffness and the number of standard and experimental pads-shock absorbers on the amplitude-frequency characteristic of vibrations that occur in the ballast layer in the rail joint zone when the rolling stock is moving. To achieve this goal, we measured the vertical vibration accelerations arising during the passage of trains in the area of the rail joint with a different number of standard under-rail shock absorbers TsP-204-M-ARS (standard) and Getzner Sylodyn NF shock absorber pads with 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 recorded, are determined, first of all, not by the material of the damper pad, but by the magnitude of the force effect. The use of experimental shock absorber pads allows to reduce and redistribute the vibration energy transmitted to the ballast layer.

1 Introduction

In connection with the global trend towards an increase in the volume of railway traffic, train speeds and axle loads, the railway track is experiencing increased dynamic loads [1]. The increase in loads leads to accelerated wear of the track superstructure elements. The rail joint is a component with particularly difficult working conditions. In the area of the rail joint and adjacent sleepers, the impact of the rolling stock significantly affects the stability of the track [2]. To solve this problem, elastic rail pads are used [3, 4, 5]. The 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 field tests of under-rail pads in order to assess the effect of stiffness and the number of standard and experimental pads-shock absorbers on the amplitude-frequency characteristic of vibrations arising in the ballast layer in the area of the rail joint during the movement of the rolling stock.

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To achieve this goal, we measured the vertical vibration accelerations arising during the passage of trains in the area of the rail joint with a different number of standard under-rail shock absorbers TsP-204-M-ARS (standard) and GetznerSylodyn NF shock absorber pads with increased elasticity (experimental). On the basis of the obtained values, the amplitude-frequency characteristic of the oscillatory process was determined.

2 Materials and methods

The object of testing is the area of the rail joint located on the second main track of the Petro-Slavyanka station. The subgrade is represented by place zero. The test site is the second main track of the Petro-Slavyanka station of the St. Petersburg - Moscow line. The measured parameters are vertical vibration accelerations in the area of the rail joint, in units of g. The characteristics of the railway track superstructure are presented in Table 1.

Table 1. Characteristics of the upper structure of the railway track

Parametr	Unit of measurement	Meaning
Railtype	-	Р65
Typeofsleepers	-	ШС-АРС
Ballastthicknessun dersleeper	m	0,4
Trackwidth	mm	1523
Level	mm	0-3
Buttgap	mm	12
Vertical and horizontal steps in a rail joint	mm	0
The force of pressing the rails with the terminal	kg	770-970

The characteristics of the standard under-rail spacers TsP-204-M-ARS (standard) are presented in Table 2.

Table 2. Characteristics of gaskets TsP-204-M-ARS

Parameter	Unit of measurement	Meaning
Category	-	II
Execution		«Д»
Thickness	mm	14
Weight	kg	0,46
Conditionaltensilestrength	MPa	≥10
ElongationatBreak	%	≥300
Staticcompressionstiffness	kN/mm	80

Sylodyn NF (Experimental) high resilience under-rail pads are made from a material the characteristics of which were obtained from the manufacturer. The characteristics are shown in Table 2.

Fig. 1. Standard gasket TsP-204-M-ARS (standard, from above) and a gasket of increased elasticity Sylodyn NF (experimental, from below) (differences in the geometry of the gaskets)

To assess the vibration effect arising in the area of the rail joint from passing trains, measuring sensors were installed at the place where vibrations are transmitted from the sleepers 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 foot of the sleeper (on the main site of the roadbed). The sensor layout is shown in Fig. 1.

At each measurement point, vibrations were recorded, propagating in three directions: in the vertical plane, in the horizontal plane across the track axis, and horizontal along the track axis. The seismic receivers were installed on a leveled site with exact observance of the measurement directions (vertical, horizontal across and along the track) Fig. 2.

When the train was moving, the travel time, the 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 trains "Sapsan" (Velaro RUS EMU) - 190 km / h.

For each type of rolling stock, at least two measurements were carried out in the interval and in the range of travel speeds. The measurements were carried out using the following set of equipment: digital seismic signal recorder ZET 048; laptop computer with licensed software; signal amplifier; power supply 220 V (if necessary).

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

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 built and dependencies were revealed that characterize the level of vibrodynamic impact that occurs during the passage of trains in the area of the rail joint and at a distance of 3, 5 and , 7 shock absorber gaskets with an appropriate number of new standard shock absorber gaskets TsP-204-M-ARS (standard) and Sylodyn NF elastic shock absorber gaskets (experienced).

As a result of the Fourier transform of the vibration acceleration records, the amplitude-frequency characteristics (AFC) of the oscillatory process were obtained at the main site during the passage of various types of rolling stock in the area of the rail joint with standard TsP-204-M-ARS spacers, shown in Fig. 2-4. An example of the frequency response obtained during the passage of the Sapsan in the area of the rail joint with 5 experimental Sylodyn NF shock absorbers is shown in Fig. 5.

From the given graphs it follows that the greatest vibration energy is observed when a passenger train passes along the junction. In this case, the highest amplitude values are characteristic 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 recorded in the frequency range up to 600 Hz.

When the Lastochka electric train passes through the joint zone, the total vibration energy 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. Nonzero values of amplitudes are fixed in the range up to 600 Hz, but in the range of 400-600 Hz their values are negligible.

When the high-speed Sapsan train moves along the joint, the total vibration energy is comparable to the energy realized when the Lastochka electric train passes. The frequency response graph reveals 3 main groups of peak amplitude values, which are confined to frequencies of 40 Hz, 60 Hz, 80 Hz. Thus, the frequency response is shifted towards low frequencies to a greater extent than when the Swallow moves. Nonzero values of amplitudes are fixed in the range up to 600 Hz, but in the range of 400-600 Hz their values are negligible.

The resonant vibration frequency was found at frequencies in the range of 50-60Hz.

3 Results and discussion

The results obtained are associated with 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 parts of the chassis masses (high frequencies). Oscillations caused by the passage of the "Swallow" and "Sapsan" lie mainly in the middle frequency range due to the increased dynamic impact due to the high speed of movement, and a more perfect design of the chassis, which reduces the high-frequency component of oscillations.

The use of experimental shock absorber pads allows to reduce and redistribute the vibration energy 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 during the laying of 5 experimental Sylodyn NF shock absorbers and the movement of the Sapsan. Comparison of the graphs shown in Figures 6 and 7 indicates the 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 pad made it possible to significantly reduce the vibration amplitudes in the frequency zone above the resonance frequency of 60 Hz, but at the same time increased the vibration amplitudes in the 30-40 Hz range, which is in good agreement with previous studies. Nonzero values of amplitudes are fixed in the range up to 600 Hz, but in the range of 500-600 Hz their values are negligible. Thus, laying an elastic pad allows you to significantly (up to 2 times) reduce the vibration amplitudes of the sleeper base in the butt zone at the resonant frequency.

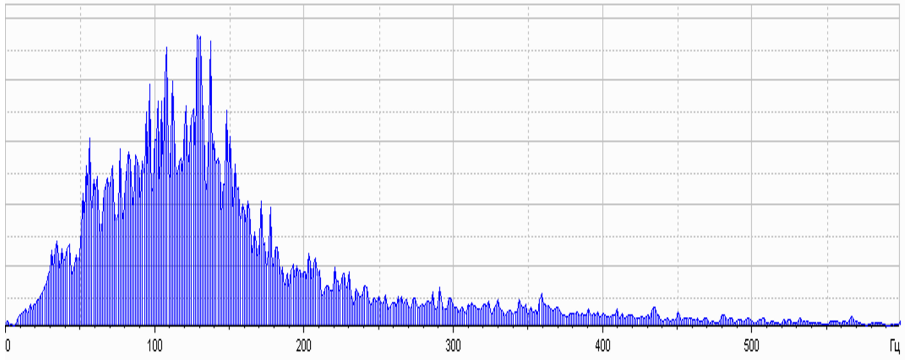

Fig. 2. Frequency response of oscillations in the ballast layer in the area of the rail joint with standard shock absorbers and the movement of a “passenger train”

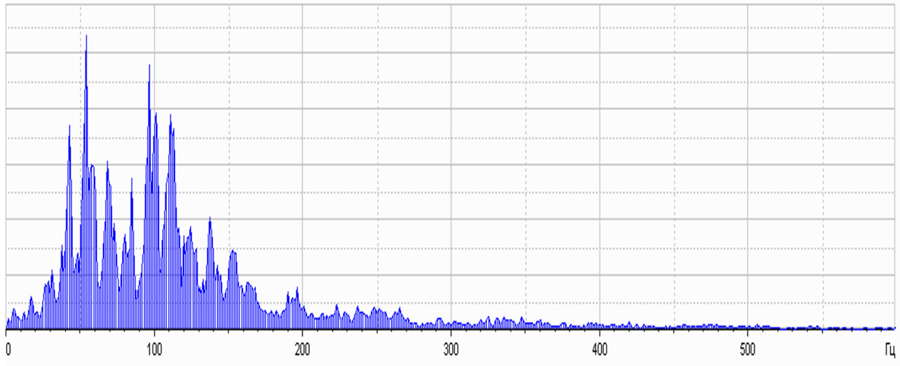

Fig. 3. AFC of oscillations in the ballast layer in the area of the rail joint with standard shock absorbers and the movement of the "Lastochka"

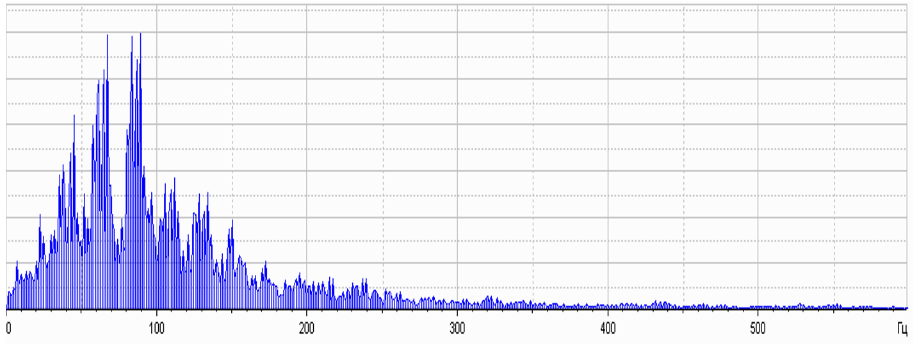

Fig. 4. AFC of oscillations in the ballast layer in the area of the rail joint with standard shock absorbers and movement of the "Sapsan"

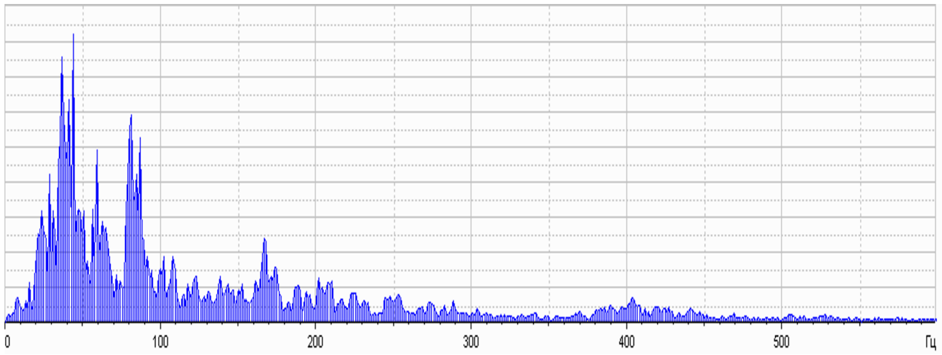

Fig. 5. AFC of oscillations in the ballast layer in the area of the rail joint during the laying of 5 experimental Sylodyn NF shock absorbers and the movement of the "Sapsan"

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

4 Conclusions

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

1. The main (carrier) frequencies, at which the maximum amplitudes of vibration accelerations are recorded, are determined by the magnitude of the force effect, which in turn depends on the design features of the rolling stock (the distance between the bogies) and the speed of its movement.
2. The resonant frequency of the railway track is in the range of 50-60 Hz.
3. The use of experimental pads-shock absorbers allows 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 margin and the service life of the ballast, and reduce stresses at the main site of the subgrade. These effects will improve the operational properties of the railway track as a whole.

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