CHOOSING THE DESIGN OF AN INTERMEDIATE FASTENING BY VIBRODIAGNOSTICS METHODS

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ABSTRACT

The article considers the main provisions of methods of vibration diagnostics of a railway track in the areas of conjugation of elastic intermediate rail fastenings Fossloh W14 and ZHBR65-SH, Pandrol Fastclip and KPP-5, a comparison is made according to the most important evaluation criteria of the results of vibration diagnostics with the results of passage of a track measuring car on the railway sections in Kazakhstan. The prospects for the use of vibration diagnostics on lines with high dynamic parameters of the operational load are forecasted.

Keywords: railway track, vibration diagnostics, dynamic parameters, assessment criteria, intermediate rail fastening, spectral density, attenuation coefficient.

Background. *In accordance with the development strategy of the transport system of the Republic of Kazakhstan up to 2020, construction of new and reconstruction of existing railways, as well as modernization of infrastructure are planned. One of the directions of the strategy is development of a network of speed and high-speed train traffic. The organization of such traffic on the railway network of Kazakhstan is closely connected to the required level of reliability of the track, its subgrade and superstructure, having a significant impact on traffic safety.*

The railways of developed countries are constantly looking for opportunities to use advanced technology, investing in the acquisition of sensors and measuring systems of different designs that solve some particular problems, but so far there is a lack of such technical means that could solve the problem in its integrity, with obtaining from this all serious potential benefits. Such sensors and measuring systems are widely used, for example, on freight railways in North America in accordance with guidance document of AAR41as since 1994 on the criteria for withdrawal of wheels on the basis of detector readings. US railways get substantial savings by increasing the service life of wheels and rails [1].

Vibrations occurring in the railway track elements (rails, sleepers, rail fastenings, etc.) while passage of train loads, greatly affect strength, and hence durability of both the work element and the whole railway track [2–5]. The professor G. M. Shakhunyants noted that the adverse influence of vibrations affects both the resistance of the track to the train loads in the longitudinal and transverse directions (creepage, change of position in plan and width of gauge), and stability and strength of the intermediate and butting rail fastenings [6].

Objective. *In this paper the authors present some results of measurements of mechanical oscillations (vibration) of track elements in two areas of different types of conjugation of intermediate rail fastenings under the influence of the moving load and the basic provisions of the response assessment methods of its structural elements to this effect.*

Methods. *The authors use general scientific and engineering methods, vibration diagnostics methods, comparative method, modeling, analytical method.*

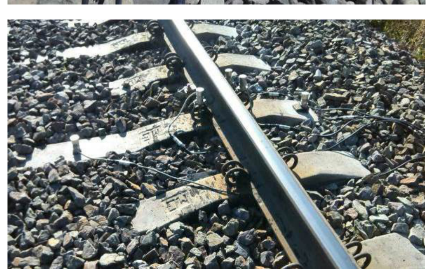
Results. *Research was carried out on the main lines of JSC «NC «Kazakhstan Railways» with the use of mobile vibration measurement complex. This complex consists of vibration sensors (velocimeters) MV-25D-V, which convert*

a

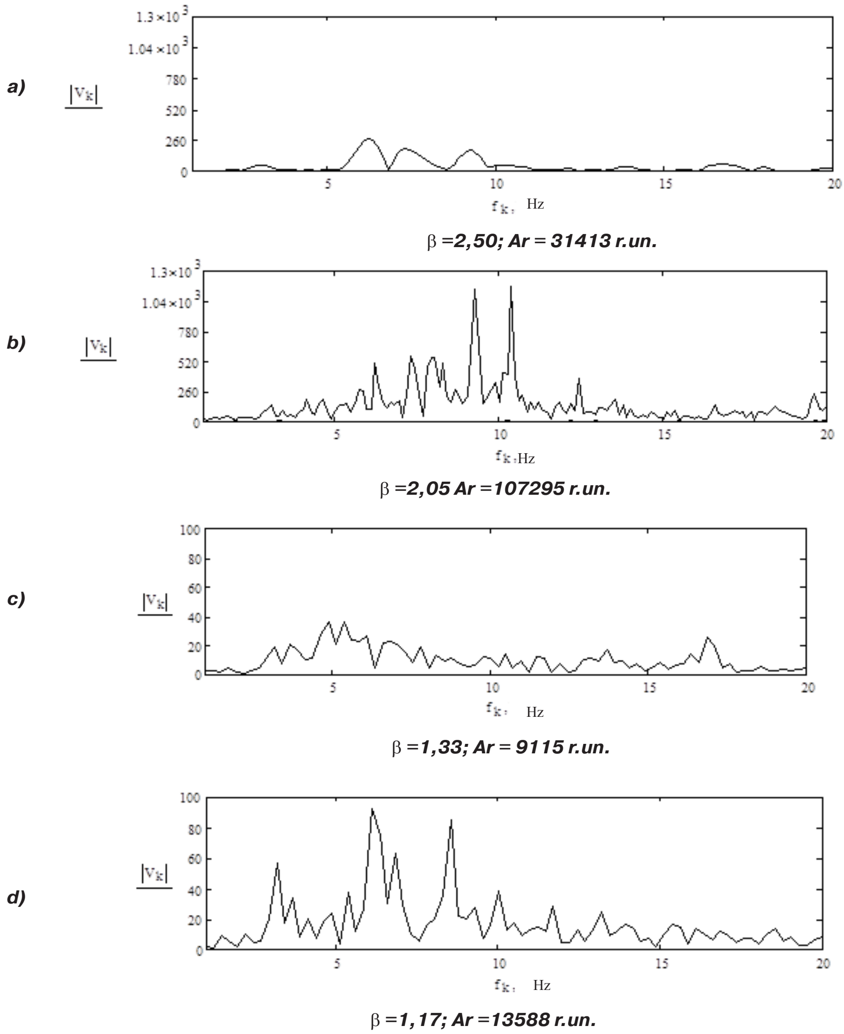
b

c

d



Pic. 1. Options of vibration sensors installation: a) – intermediate fastening Fossloh W-14; b) – ZHBR65-SH; c) – Pandrol Fastclip, d) KPP-5.



Pic. 2. The graph of the spectral density of vibration speed of rail base oscillation of track structure with fastenings Fossloh W14 (a) and ZHBR-65SHD (b), Pandrol Fastclip (c), KPP-5 (d) when an electric locomotive VL-80^c at a speed of 85 km/h passes.

mechanical oscillation (vibration) transforming them into an electric signal. Analog signal digitization is done in the electronic unit of ADC model E-14–440. Collection of digital data from the ADC, the overall management of measurements and signal processing are realized using a special PC software such as «Notebook».

Vibration sensors are installed at two sections of the test section of a railway track in accordance with the proposed scheme. The scheme of the sensors installation depends on the objectives of the study and may vary in the course of vibration diagnostics in a fairly wide range (Pic. 1). In order to minimize interference of oscillations of structures with different types of rail fastenings on the coupling parts the distance between the sections should be the maximum possible, and the length of the measuring path does not affect the measurement result. Records (at least five) of the process of oscillation of elements of the railway track from the impact of the train load are done.

The analog signal from the vibration sensors to the ADC is converted to a digital form and provided to the real values of the vibration speed on the basis calibration coefficients derived for each sensor during its calibration. The construction of amplitude-time dependencies (vibrograms) for each element is made separately (for rails, sleepers, rail fastenings).

With the use of a Fast Fourier Transform (FFT) the construction of spectral density of dispersion of the signal graphs (amplitude-frequency dependency) – vibration spectra is carried out. RMS of vibration speed is calculated. With the integration operation by the numerical method of amplitude-time dependencies of vibration speed the construction of amplitude-time dependence of vibration displacement (oscillogram) is done, and with the use of FFT graphs of vibration displacement spectrum (amplitude-phase-frequency dependencies of vibration displacement) are constructed.

Further, after the pre-filtering of the digitized signal from the vibration sensors in the lower frequency range (from 0 to 1000 Hz) based on the differentiation graphing of the amplitude-time-dependency of vibration acceleration (accelerograms) is produced. Using FFT graphs of amplitude-phase-frequency dependencies of vibration acceleration – vibration acceleration spectra (spectral dispersion

Table 1

The technical state data of railway track as a result of the passage of the track measuring car and vibration diagnostics of interface areas

Section		1st section (UPCH-46)		2nd section (UPCH-30)	
Fastening type		Fossloh W-14 (4035 km)	ZHBR-65SHD (4036 km)	Pandrol Fastclip (227km)	KPP-5 (228km)
Technical characteristics of the track: class; group and category of a track		1B1		1B2	
Rails R-65, jointless track		P-65		P-65	
Locomotive speed; km/h		85		85	
Passed tonnage; million tons • km.brutto		305,4		236,4	
Year of the last overhaul of the track		2006		2010	
Score of track state (in July the first section, the second section in August) 2015		10	40	40	150
Assessment criteria	n, pcs	28	39	35	47
	υs, mm/s	39,24	56,32	59,02	83,35
	υr, mm/s	98,1	115,82	78,72	97,6
	β	2,50	2,05	1,33	1,17
	Ar, r.un.	31413	107296	9115	13588
	As, r.un.	15646	34955	7918	9643
		2,01	3,07	1,15	1,40

Note: *n* – number of detected faults of the 2nd degree on the outcome of July (1st section) and August (2nd section) 2015; υ*s* – RMS of vibration speed of sleeper oscillation; υ*r* – RMS of vibration speed of rail oscillation; β – attenuation coefficient; A*r* – area of spectral density of dispersion (spectrum of vibration speed) of a rail; A*s* – area of spectral density of dispersion (spectrum of vibration speed) of a sleeper; ϒ – ratio of spectrum area of vibration speed of a rail to spectrum area of vibration speed of a sleeper.

density graphs) are constructed. The RMS of vibration acceleration is calculated.

It should be noted that the FFT represents a valid Fourier transform approximation for a finite time interval Δt, and hence to improve the accuracy of approximation the distance between the points should be as small as possible. Furthermore, FFT algorithms require that the number of points is equal to 2 in the degree N, i.e. $n = 2^N$, where N is an integer. As a result transition in the analysis of the signal from the time domain to the frequency domain can occur in real time. The problem of «spreading» of the spectrum is achieved using a signal recording technology, in which the recording equipment starts and stops recording when the signal level is close to zero.

Measurement and analysis of oscillations (vibration) of the superstructure elements of the track in a number of areas of conjugation with different types of intermediate rail fastenings revealed their basic patterns and a the following criteria for evaluation to compare work of track structures in the dynamics:

– peak and RMS values of vibration speed of oscillations of the rail at the center of the between sleeper box and in the middle of the sleeper on the track axis, characterizing the bending vibrations of these elements and the resulting mechanical stresses in them;

– damping coefficient β of amplitude of vibration speed of oscillations of a rail in relation to oscillations of a sleeper, areas of spectra of vibration speed of oscillation of a rail Ar and a sleeper As in the frequency range up to 20 Hz and their ration, characterizing the change of the vibrational capacity and vibration damping due to dissipation of mechanical energy;

– ratio of the dynamic forces generated when a train is moving on the rail base in the center of the between-sleeper box, to static forces, characterizing the dynamic force impact on the rail;

– ratio of the dynamic forces generated when a train is moving in the middle of the sleepers on the rail axis, to static forces, characterizing the dynamic force effect on the sleeper.

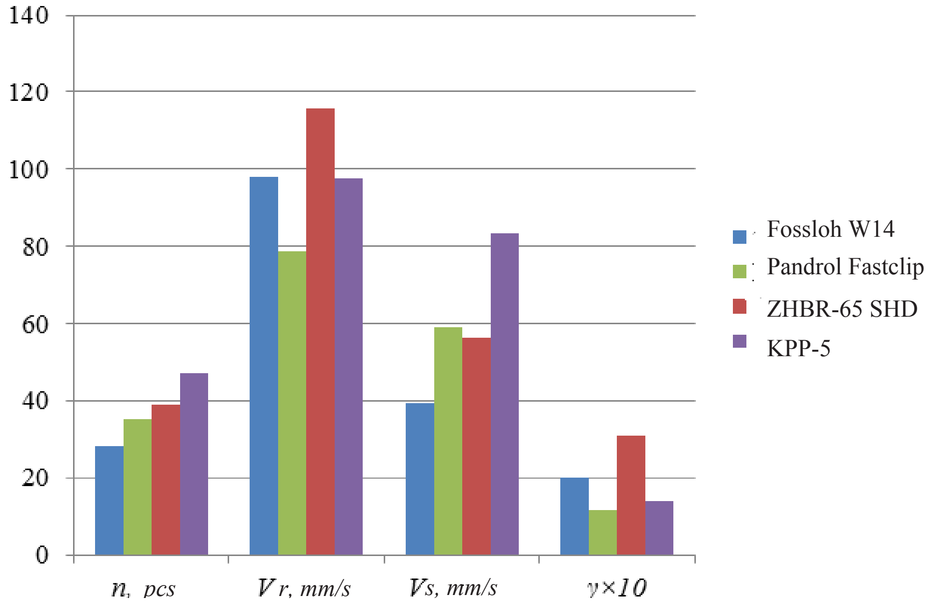
Pic. 2 shows the graphs of the spectral density of vibration speed (power spectra) of the rail base fluctuations in the areas of interface of track structures with fastenings Fossloh W14 and ZHBR65-SH, Pandrol Fastclip and KPP-5, with the passage of an electric locomotive VL-80ᶜ at a speed of 85 km/h.

Comparing the response of track structures in the areas of interface on the area Ar of the power spectrum and attenuation coefficient β of amplitude of vibration speed of rail vibrations in relation to the sleepers fluctuations, it can be concluded that the fastening Fossloh W 14 at a speed of electric train of 85 km/h damps vibrations better than the fastening d ZHBR-65SHD (Pic. 2a, b). From comparison to the same parameters of sections with fastenings Pandrol Fastclip and KPP-5 it follows that the best damping properties that is the best ability to dampen vibration, has a track section with fastening Pandrol Fastclip (Pic. 2c, d).

Now a computerized car laboratory KVL-P2.1 (track measuring car № 056) is used on the railways of Kazakhstan, where collection, decoding, storage and correlation with data standards, obtained by means of measurement of the car [7–9], are automated.

Table 1 shows the technical status data of railway track as a result of the passage of the track measuring car and vibrodiagnostics of areas of conjugation of track structures with different types of rail fastenings.

Pic. 3 shows the correlation diagram of the final number of derogations of the 2nd degree and the assessment criteria resulting from vibration



Pic. 3. The relationship of the final number of derogations of the 2nd degree and results of vibration diagnostics of the track superstructure on the sites of conjugation of various designs of rail fastenings.

diagnostics of track superstructure on the conjugation areas. The above diagrams show that the assessment criteria adopted during the vibration diagnostics, adequately reflect the state of the track defined by the results of the passage of a track measuring car.

Conclusions. *Implementation of the proposed methodology of vibration diagnostics will make it possible to produce a rapid analysis of a railway track in areas with different types of rail fastenings on dynamic parameters and allow to make optimal decisions when planning the maintenance and repair of the track, taking into account the impact of circulating rolling stock.*

Made optimal design decisions will lead to an increase in service life and reduction of the costs of current maintenance of track and improvement of safety of rail transport on the whole.

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