INFLUENCE OF FASTENING'S TYPE ON TRACK'S DYNAMIC WORK

Kvashnin, Mikhail Ya., *Kazakh Academy of Transport and Communications n.a. M. Tynyshpayev, Almaty, Kazakhstan.*

Zhangabylova, Aigul M., *Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

Zamukhovsky, Alexander V., *Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

ABSTRACT

The authors introduce the results of measurements and analysis of mechanical vibrations of track superstructure with intermediate rail fastening types Pendrol and ZHBR65-SH regarding vibrodynamic impact of rolling stock. Full-scale experimental studies have been performed on the main section of the enlarged Ekibastuz rail track section. The data obtained can be used as a criterion for justifying selection of the most optimal type of rail fastening.

Keywords: railway track, intermediate rail fastenings, rolling stock, vibrodynamic effects, vibration displacement, oscillogram, rms value of vibration displacement.

Background. *It is generally known that with irregularities on a rigid track, which are the same in shape and size (e.g., track superstructure with concrete sleepers), dynamic additives of forces acting from wheels on rails, are higher than on an elastic track (e.g., track superstructure with wooden sleepers). This situation adversely affects the development of rail defects of contact fatigue nature and disorders of the track as a whole. Operating experience has shown that the yield of rails on the basis of defects in the seam zone has increased significantly compared to the yield of wooden sleepers. There is a more rapid formation of undulating wear of rails.*

To take full advantage of concrete sleepers and minimize disadvantages mentioned above research and practical actions are carried out in two directions.

Firstly, in all possible ways the formation of irregularities on wheels of the rolling stock and rails is prevented to avoid actions of perturbing forces that generate harmful vibration. The activities in this area include: widespread introduction of continuous welded rail track, grinding of rails, timely elimination of vertical irregularities and strengthening of specifications for the size of permitted irregularities in the thread surface of rails and wheels, as well as strengthening of control over their condition.

Secondly, different types of elastic intermediate rail fastenings are created, allowing to sufficiently reduce vibration dynamic impact on sleepers, ballast and subgrade. Identification of an optimal type of fastening would reduce the dynamic effect of the rolling stock on the track with concrete sleepers, as well as would reduce the intensity of residual deformations of the track with existing operational irregularities on rails and wheels.

Objective. *The objective of the authors is to introduce results of measurements and analysis of mechanical vibrations of track superstructure with intermediate rail fastening types Pendrol and ZHBR65-SH regarding vibrodynamic impact of rolling stock.*

Methods. *The authors use general scientific and engineering methods, modeling, mathematical methods, comparative analysis.*

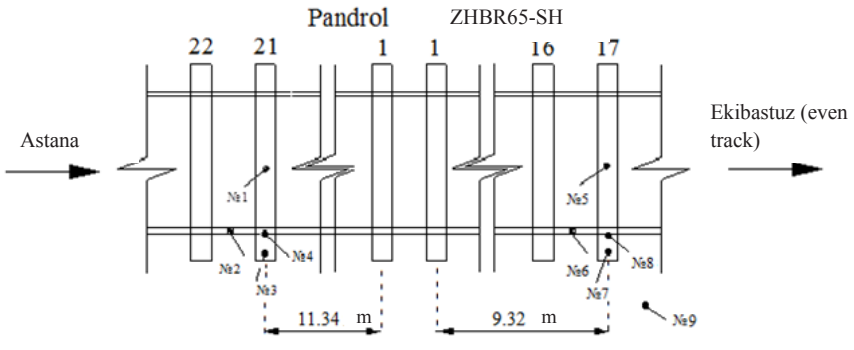
Results.

1.

Currently, on the main tracks of JSC «NC «Kazakhstan Temir Zholy» and JSC «Russian Railways» various types of intermediate rail fastenings are applied. However, the sole, universal, meeting all requirements for efficient operation, fixing elements for concrete sleepers in the Kazakhstan and Russian railways are absent. One of the most important indicators of the efficiency of rail fastenings is reduction of dynamic forces and vibrations that arise in the interaction of track and rolling stock. For this the construction of fastenings must ensure its rational spatial flexibility.

Ensuring rational spatial elasticity of rail fastenings is extremely necessary in order to elastically process dynamic effects of wheels of rolling stock on rails, to dampen high frequency vibrations that affect disorders of track, and especially on bolted joints, as well as to ensure equal elasticity of rail base. Limit criteria of parameters of vibrations generated by rail, are regulated by normative documents of a number of foreign countries [1-4], in Russia they are normalized only for buildings and structures on the criterion of human exposure [5, 6].

Elasticity, created by fastenings, separates rail mass from rail base in the same way as springs separate vehicle's body from its running gears. This significantly reduces inertia forces generated during movement of wheels on track irregularities. However, at low vertical and horizontal stiffness of supports



Pic. 1. Scheme of arrangement of sensors: № 1 – on the middle of the sleeper; № 2 – on the rail base; № 3 – on the edge of the sleeper; № 4 – terminal Pandrol Fast Clip; № 5 – on the middle of the sleeper; № 6 – on the rail base; № 7 – on the edge of the sleeper; № 8 – terminal ZHBR65-SH.

a)

b)

Pic. 2. Track's general view with installed vibration sensors:
a – with fastening Pandrol; b – ZHBR65-SH.

increases static bending of rails under the wheel load, increases rotation of cross sections of rails, which creates the effect of stealing. In connection with this, there is a concept of rational (optimal) spatial elasticity whereby interaction of track and rolling stock is the best, and stresses, deformations and accumulation of the latter will be minimal. In addition, the constant elastic connection of fastening elements with rails, under-rail bearings and with each other with a predetermined tension is needed to ensure normal operation of fastenings, to prevent inelastic fluctuations of their elements and related disorders of fastening nodes.

For comparison purposes of the dynamic work of rail fastenings Pandrol and ZHBR65- SH the authors on the site of their conjugation conducted full-scale experimental studies of the response parameters of track structures under the influence of the rolling stock. The studies were conducted on the main section of the enlarged Ekibastuz maintenance rail section (UPCH-30) of Kazakhstan railways.

Vibration sensors (velocimeters) were set based on the opportunity to get the most complete picture of the elements' work of rail grid and railway track as a whole (Pic. 1). To install sensors on the rail base and elastic connection terminals of rail fastenings various accessories were used: plates, clips, clamps, hold-down bolts. In the first on concrete sleepers was performed rigid bolting of device with a metal plate, and then the plate was glued to the design under consideration.

Pic. 2 is a perspective view of sections of railway track with intermediate rail fastenings Pandrol Fast Clip (Pic. 2a) and ZHBR65-SH (Pic. 2b) and vibration detectors installed.

As means of measurement mobile vibration measurement complex was used with a set of vibration sensors and software package for data processing and visualization. Specifications and software support are described in detail in [7], and a digital signal processing technique is described in [8].

Entries of mechanical vibrations of elements of railway track were made in two sections, with the same characteristics (rail type R65, crushed stone ballast), straight stretch of track.

To ensure a detailed analysis special software was used that allows to cut out a fragment of interest of the general signal record.

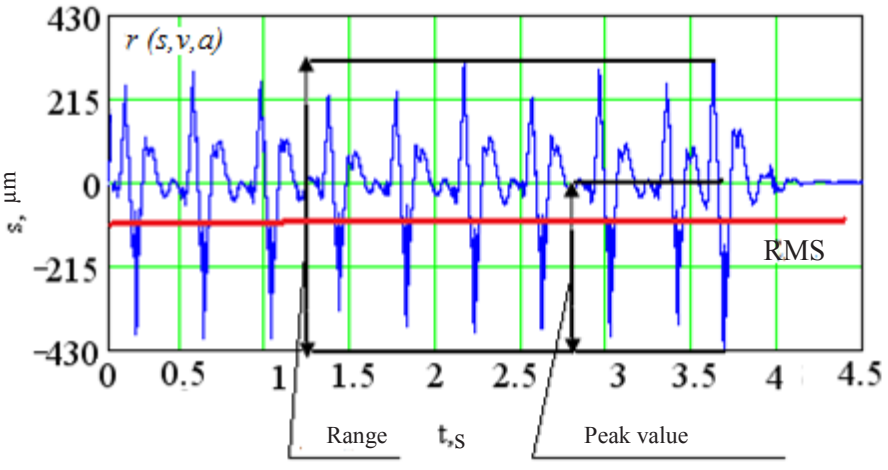
Complex of informative parameters characterizing the state of the object, included following qualitative and quantitative components of vibration process:

– vibration displacement is oscillatory movement of the body relative to equilibrium position, is used to evaluate when a movement is critical in terms of allowable stresses and clearances;

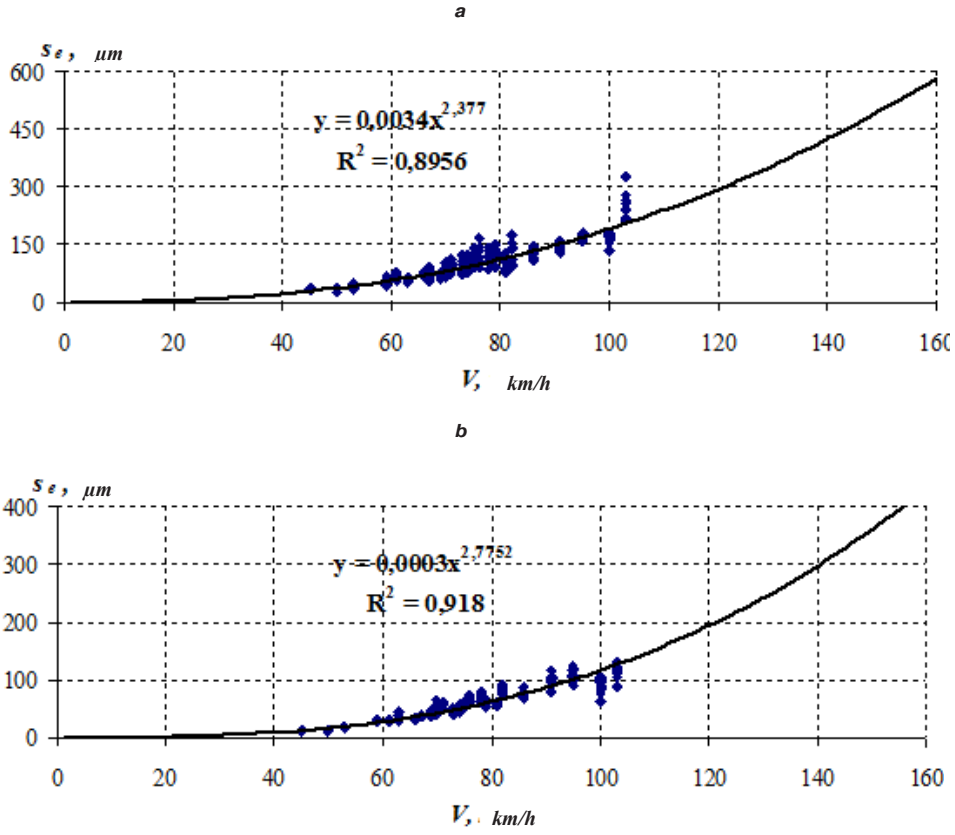
– vibration speed is time derivative of vibration displacement, which characterizes oscillation power

$$P = mv, \qquad (1)$$

where P, m, v are respectively, power, mass of the object, speed of mechanical vibrations;



Pic. 3. Curve of polyharmonic vibration.



Pic. 4. The dependence of RMS value of vibration displacement on the rail base (a) and in the middle of the concrete sleeper (b) on the speed of the electric locomotive VL-80.

– vibration acceleration is time derivative of vibration speed that characterizes inertial force acting on the object at vibration

F = ma, (2)

where F, a are inertial force and vibration acceleration.

2.

To quantify mechanical vibrations, the following parameters were used: range, peak value, rms value (RMS) (Pic. 3).

Range $r_r(s_r, v_r, a_r)$ is a difference between the highest and the lowest values of fluctuating value.

Peak value $r_p(s_p, v_p, a_p)$ is the highest absolute value of maximum deviations of fluctuating values.

RMS is the most important parameter, since it takes into account temporal development of considered oscillations and it directly reflects the value associated with the signal's energy and therefore damaging capability of these oscillations. If there are N discrete values of fluctuating value, then rms value is:

$$r_e(s_e,\upsilon_e,a_e)=\sqrt{\frac{1}{N}\sum_{i=1}^{N} r_i^2}\ , \qquad (3)$$

where s_e, v_e, a_e are respectively, RMS of vibration displacement, vibration speed and vibration acceleration.

The analysis of records, carried out with the participation of authors, of movement of rolling stock at speeds from 45 to 103 km/h in test site with intermediate rail fastenings FOSSLOH, laid on the main line of the enlarged Almaty maintenance section, presented in detail in [8], showed the following:

• correlation dependences of peak and RMS values on vibration speed and vibration acceleration of track elements from the speed of rolling stock have a low coefficient of reliability of approximation. This circumstance is caused by the fact that the conditions of contact interaction of sleepers with ballast base and effective coefficient of friction of sleepers on ballast change with each passage of the train and as a result, bending modes of a higher order change;

• correlation dependences of peak and RMS values on vibration displacement of track elements from speed of the rolling stock have a higher coefficient of reliability of approximation;

• The highest coefficients of reliability of approximation were obtained for correlation dependence of RMS of vibration displacement on the speed of electric locomotive VL-80 on the rail base (Pic. 4a; $R^2 = 0,8956$) and in the middle of the sleeper (Pic. 4b; $R^2 = 0,918$).

When passing an electric locomotive VL-80 on the site of conjugation of fastenings at speeds of 65 and 85 km/h were defined peak and RMS values of vertical vibration displacement of the rail base in the center of between-sleepers box and vertical

Table 1

Peak and RMS values of vertical vibration displacement of the rail base in the center of between-sleepers box and vertical vibration displacement of the middle of sleeper

Parameters	Pandrol		ZHBR65-SH		Reduction, % in relation to Pandrol	
Locomotive speed, km/h	65	85	65	85	65	85
Peak values of vertical vibration displacement of rail base and vertical vibration displacement of the middle of the sleeper, μm	603,71	786,01	446,74	526,49	26	33
RMS value of vertical vibration displacement of rail base, μm	204,77	273,74	176,10	221,80	14	19
Peak values of vertical vibration displacement of the middle of the sleeper, μm	172,40	198,01	135,62	146,21	21	26
RMS value of vertical vibration displacement of the middle of the sleeper, μm	57,92	65,99	51,88	55,98	10	15

vibration displacement of the middle of sleeper, shown in Table 1.

Conclusions. *Analysis of fluctuations of track elements with intermediate rail fastenings Pandrol and ZHBR65-SH showed the following:*

– The type of intermediate rail fastening significantly affects quantitative characteristics of the response of the track structure to vibrodynamic impact of rolling stock;

– As the main criteria of qualitative and quantitative assessment of the vibrodynamic impact of rolling stock on the track to compare track's dynamic work with various types of intermediate rail fastenings it can be recommended to take peak and RMS values of vibratation displacement of rail base in the center of the between-sleepers box and the middle of sleepers;

– The dependence of values of vibration displacement of rail and sleepers can be well approximated by the dependence of the form $y=ax^b$, where a is the scale factor, b is the exponent determined experimentally;

– Peak and RMS values of vibration displacement of rail base characterize bending vibrations of the rail, and peak and RMS values in the middle of the sleeper– bending vibrations of railway sleepers;

– An intermediate rail fastening ZHBR65-SH in the context of track's dynamic work under rolling load has significantly better values than the intermediate rail fastening Pandrol;

– For Pandrol fastening in terms of economic efficiency, achievement of high service life of all track elements and optimal conditions for their operation more research is needed.

REFERENCES

1. EN13481-6:2002 Railway applications – Track – Performance requirements for fastening systems – Part 6: Special fastening systems for attenuation of vibration.

2. VDI 3837:2006 Ground-borne vibration in the vicinity of local public transport railways. http://www.complexdoc.ru/text/%D0%93%D0%9E%D0%A1%D0%A2%20%D0%A0%20%D0%98%D0%A1%D0%9E%2014837-1-2007/88. Last accessed 13.03.2015.

3. NS8176:1999 Vibration and shock – Measurement of vibration in buildings from land based transport and guidance for evaluation of its effects on human beings. http://www.complexdoc.ru/text/%D0%93%D0%9E%D0%A1%D0%A2%20%D0%A0%20%D0%98%D0%A1%D0%9E%2014837-1-2007/87. Last accessed 13.03.2015.

4. DIN45673 Mechanical vibration – Resilient elements used in railway tracks. http://www.beuth.de/en/article/din45673/. Last accessed 13.03.2015.

5. GOST 31191.5-2007 (ISO 2631-5: 2004) Vibration and shock. Measurement of overall vibration and evaluation of human exposure. Part 5. Vibration containing multiple shock pulses [*GOST 31191.5-2007 (ISO 2631-5:2004) Vibracija i udar. Izmerenie obshhej vibracii i ocenka ee vozdejstvija na cheloveka. Chast' 5. Vibracija, soderzhashhaja mnozhestvennye udarnye impul'sy*].

6. SN2.2.4 / 2.1.8.566-96. Sanitary norms. Industrial vibration, vibration in residential and public buildings. 2.2.4. Physical factors of industrial environment. 2.1.8. Physical factors of environment [*SN2.2.4/2.1.8.566-96. Sanitarnye normy. Proizvodstvennaja vibracija, vibracija v pomeshhenijah zhilyh i obshhestvennyh zdanij. 2.2.4. Fizicheskie faktory proizvodstvennoj sredy. 2.1.8. Fizicheskie faktory okruzhajushhej prirodnoj sredy*].

7. Kvashnin, N.M. The study of mechanical vibrations of railway track. Ph.D. (Eng.) thesis [*Issledovanie mehanicheskih kolebanij zheleznodorozhnogo puti. Dis... kand. teh. nauk*]. Almaty, 2010, 144 p.

8. Sergienko, A.B. Digital signal processing [*Cifrovaja obrabotka signalov*]. St. Petersburg, Piter publ., 2002, 608 p.

Information about the authors:

Kvashnin, Mikhail Ya. – Ph.D. (Eng.), associate professor of Kazakh Academy of Transport and Communications n.a. M. Tynyshpayev, Almaty, Kazakhstan, kvashnin_mj55@mail.ru.

Zhangabylova, Aigul M. – Ph.D. student of Moscow State University of Railway Engineering (MIIT), Moscow, Russia. zhangabylova82@mail.ru.

Zamukhovsky, Alexander V. – Ph.D. (Eng.), associate professor of Moscow State University of Railway Engineering (MIIT), Moscow, Russia, miit.ppx@gmail.com.

Article received 02.03.2015, revised 13.03.2015, accepted 11.06.2015.

ПЕРСПЕКТИВЫ РАЗВИТИЯ ТЯЖЕЛОВЕСНОГО ДВИЖЕНИЯ НА ЖЕЛЕЗНЫХ ДОРОГАХ ОБСУЖДЕНЫ НА РЕГИОНАЛЬНОМ СЕМИНАРЕ МСЖД В САНКТ-ПЕТЕРБУРГЕ

20-22 мая в Санкт-Петербурге состоялся семинар Международного союза железных дорог (МСЖД) «Повышение эффективности грузовых перевозок путем использования тяжеловесных и длинносоставных поездов», инициированный и организованный ОАО «РЖД» в рамках Азиатско-Тихоокеанской региональной ассамблеи МСЖД.

В мероприятии приняли участие более 40 представителей железнодорожных компаний, транспортных администраций, вагоностроительных предприятий, транспортных вузов и научно-исследовательских институтов России, Казахстана, Монголии, Китая, Швеции, Франции, Австралии.

В ходе семинара были рассмотрены перспективы развития тяжеловесного движения в регионах, вопросы, связанные с особенностями содержания инфраструктуры и строительством инновационного подвижного состава, преимущества и экономический эффект от внедрения тяжеловесных перевозок.

На основе представленных докладов, комментариев к ним и итогового обсуждения выработаны рекомендации по совершенствованию инфраструктуры для обеспечения соответствия новым эксплуатационным требованиям, а также по внедрению технических средств для организации движения тяжеловесных поездов, созданию инновационного тягового подвижного состава и совершенствованию нормативной правовой базы.

(По сообщению пресс-службы ОАО «РЖД» http://press.rzd.ru/news/public/ru? STRUCTURE_ID=654&layer_id=4069&id=85956) ●

PROSPECTS FOR DEVELOPMENT OF HEAVY TRAFFIC ON RAILWAYS DISCUSSED AT UIC REGIONAL SEMINAR IN SAINT PETERSBURG

A seminar of the International Union of Railways (UIC) was held in St. Petersburg between 20-22 May 2015.

The seminar on «Improving the Efficiency of Freight Transport by using Heavy and Long Trains» was initiated and organized by JSC Russian Railways as part of the UIC Asia-Pacific Regional Assembly.

The event was attended by over 40 representatives from railway companies, transport administrations, wagon constructors, transport universities and research institutions in Russia, Kazakhstan, Mongolia, China, Sweden, France and Australia.

The seminar discussed the prospects for developing heavy-duty traffic in the regions, issues relating to the specifics of maintaining infrastructure and constructing innovative rolling stock, the advantages and the economic benefits of introducing heavy traffic.

On the basis of the reports presented at the seminar, the follow-up comments and closing discussions, recommendations were made to improve the infrastructure to meet new operational requirements, as well as to introduce the technical means for organizing such heavy-duty trains, create innovative traction rolling stock and improve the legal framework.

(JSC Russian Railways press service http://press.rzd.ru/news/public/ru? STRUCTURE_ID=654&layer_id=4069&id=85956) ●