UDC 620.179.1, 625.143

DOI: 10.20535/2523-4455.mea.263459

Analysis of Application the Device with Nonstandard Scanner Installation for Rail Condition Monitoring

I. K. Shapovalov[f], ORCID 0000-0002-8665-7868
D. V. Pareniuk, PhD, ORCID 0000-0002-0734-3183
K. S. Drozdenko[s], PhD Assoc.Prof., ORCID 0000-0002-7653-600X
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" ROR 00syn5v21
Kyiv, Ukraine

V. P. Mishchenko[s], ORCID 0000-0003-4927-2376
Ultracon-Servise LLC
Kyiv, Ukraine

***Abstract*—In this work, the possibility of application the device with a non-standard (side) piezoelectric sensor installation for rail condition monitoring is considered. The aim of this device application is reducing the risks of using single-strand flaw detectors on railway tracks with fixation system on the rail in the form of two rebords. Also, the application of this device allows you to obtain a new qualification criterion for the integrity of the rail, which is located in the railroad groundwork. This criterion is the presence of a signal from the opposite face of the rail head, which, in addition to the possible detection of a 30B.1-2 defect (DG) or 113 also allows you to record developed defects of the rail neck, passing into its head and implemented by sounding the rail head of the linear section of the track in the transverse direction (from the working to the non-working face). The study of round ultrasonic transducers of different frequencies was carried out. It has shown impossibility of using 10 MHz transducers. The results of statistical estimation of rail thickness and corresponding amplification levels are presented. The presence of statistically significant differences in the monitoring of different frequencies sensors and different sensors of the same frequency (which is relevant only for 5 MHz) was found. The difference between the maximum and minimum average in the test group of measured values of rail thickness was 0.06 mm, and between amplification levels — 17 dB.**

Keywords — nondestructive testing; pulse echo method; mirror-shadow method; rail head.

I. Introduction

An important part of railway tracks and railway transport operation is the use of nondestructive testing methods to monitor the condition of both movable and stationary facilities.

Trains are one of the fastest and most powerful overland means of transportation and movement, which plays a significant role in the sustainable economic development of the modern world. To use this transport, it is necessary to ensure the smooth and safe movement of trains along qualitatively nested and reliable tracks. The railway tracks required for train traffic are known to consist of rails, supports, sleepers and a roadbed to distribute the load of the train.

Rail defects can occur during production or operation. Damaging factors include friction on the wheels of trains, the action of the weight of the train, the influence of the external environment (weather conditions, climate features, etc.) [1]. These factors significantly affect the maximum possible service life of both rail and rolling stock.

The most common method of rail diagnostics is the method of nondestructive acoustic control associated with developments of S. Sokolov. He was the first who proposed a shadow method using continuous acoustic waves to detect defects in the material [2]. Also, in the 1930s, he formulated the principles of acoustic control, and later created the field of acoustic instrumentation.

In 1940, F. Fierston formulated the basic principles of pulse echo testing. In 1943, pulse echo flaw detectors were launched in the USA. In 1949, the production of ultrasonic flaw detectors in the USSR was started [3].

One of the ways which can improve the work of railway transport is to increase the intervals between the controlling means passages and enhance the speed of their operation. For this purpose, one can use special software and mathematical information processing tools, as well as additional scanning devices.

DOI: 10.20535/2523-4455.mea.263459

The purpose of this work is to investigate the possibility of using an additional scanner installed on the side surface of the rail to solve the above problem.

II. APPLICABLE CONTROL METHODS

During the rail condition monitoring, three main methods — visual inspection, use of eddy currents or ultrasound are used.

A. Visual inspection

Visual inspection is the easiest and most accessible. It is applied, as a rule, before other methods. According to the current methodology of rail control, the operator's use of this method is difficult due to the fact that the field of view is limited by the flaw detector's trolley and also a necessity to withstand the established speed of control. This requires either a visual inspection of additional staff or only a superficial inspection.

B. Eddy current control method

Eddy current control method is based on the principle of electromagnetic induction with using a coil or coil system as a scanner. The general principle of operation is shown in Fig. 1 [4].

Under the action of the induced magnetic field, a Foucault current is formed in the control object and affects the current in the coil. By changes in the resulting current, the presence or absence of a defect is determined.

C. Acoustical control method

Acoustic methods of nondestructive control are based on recording and study of parameters of elastic oscillations propagating in the testing object. This group of methods can be used for the control of all materials conducting acoustic waves.

The most popular among the methods of this group are those that use ultrasound[5]. The use of ultrasound allows detecting irregularities of the structure, internal defects, etc. The use of ultrasound consists in the application of the properties of the medium and acoustic vibrations.

Acoustic oscillations are mechanical oscillations (in our case of rail metal) in a wide frequency range (50 Hz — 50 MHz) around its equilibrium position. Acoustic waves are movement in the specified environment of mechanical deformation. Most often, a 2.5 MHz transducer is used to monitor the condition of the rails [6].

Within the framework of the study, immersion and contact transducers are of greatest interest. Contact transducers operate in tight contact with the object of control. Immersion converters require a thick layer of liquid between the inspection object and the sensor.

III. OBJECT OF CONTROL

The object of control during consideration of this problem is rail with deformable head (Fig. 2). The use of single-strand flaw detectors with double-board support rollers for the testing of such rails can lead to damage to these rollers and failure of the undercarriage of the flaw detectors. It should also be noted that the working environment organization of the single-strand flaw detector operator excludes possibility to obtain the visual information about the presence of the specified defect in the controlled rail.

III. APPLICABLE SCANNERS

The proposed scanner should have a direct transducer (Fig. 3).

This transducer in widely adopted devices UDS2-73 [7] and UDS2-77 [8] is used to implement pulse echo and mirror-shadow control methods.

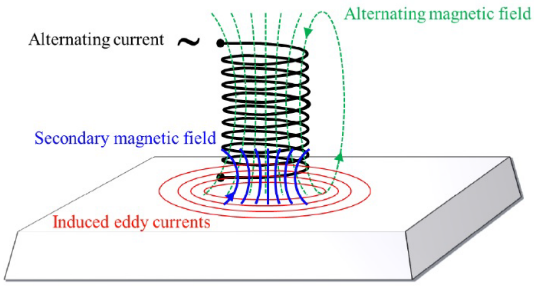

Fig. 1 Principle of eddy current registration

Fig. 2 Damaged rail

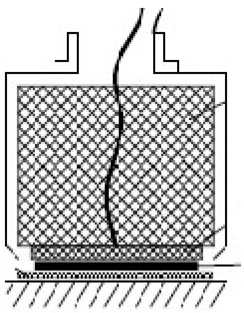

Fig. 3 Direct transducer

DOI: 10.20535/2523-4455.mea.263459

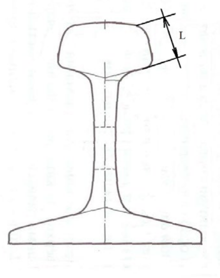

Fig. 4. Controlled rail

Fig. 5 Deformed inspected object

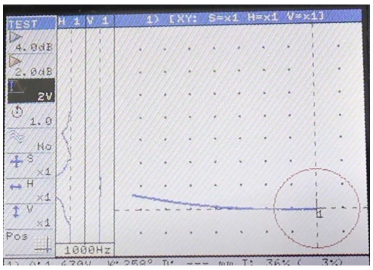

Fig. 6. Eddy current flaw detector screen in case of scanner skew

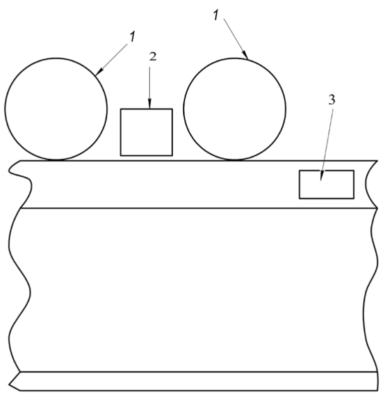

Fig. 7 Updated flaw detector structure diagram

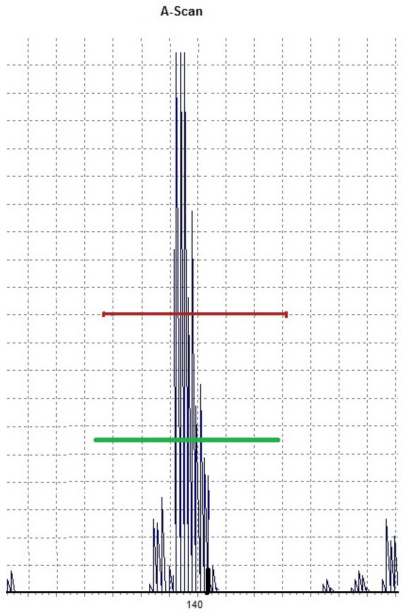

Fig. 8 Presence of signal (i.e. no defect)

Due to the shape peculiarity of the controlled object, it is necessary to use a typical carriage of a rail flaw detector [7], [8], which is installed on the working edge of the rail, but its width should correspond to the parameter L in Fig. 4.

The use of such a scanner structure allows both to use additional eddy current scanners for rail testing and to control the shape of the rail, using a minimum of converters. An example of an acoustic contact loss situation is shown in Fig. 5.

In a case of acoustic contact loss, the signal on the device screen disappears. If we use an eddy current sensor (when it is installed on the same working edge of the rail), the scanner will skew, which will cause a typical jump [9] on the device screen (Fig. 6) [10].

A typical structure diagram of a single-strand flaw detector is shown in Fig. 7 by elements 1 and 2, where 1 are support two-board rollers and 2 is a typical flaw detector carriage.

The updated flaw detector structure diagram is shown in Fig. 7 by elements 1-3, where 3 is a new scanner.

IV. Control procedure

We propose to consider the actuation factor of the bottom signal strobe as the main information parameter. If this signal disappears, it is decided that the inspection object is defective. In Fig. 8 you can see the presence of a signal in the strobe.

The inspection procedure of controlled zone and its comparison with controlled zone when using complimentary control methods — eddy current and visual is shown in the work [11]. The limiting factor in its use is the size of near zone r_n, which depends on the size of the transducer and its frequency [12]:

DOI: 10.20535/2523-4455.mea.263459

$$r_n = \frac{a^2}{\lambda}, \quad (1)$$

where a is radius of the radiating plate; λ is wavelength in the material of controlled object [12].

In view of the preliminary given factors, Fig. 5 and referring to the source [13], it can be argued that the installation of an ultrasonic sensor at the specified point will allow detecting a defect having a classification index of 30 B.1-2 (DG) or 113 in document[14] with a greater probability than provided by modern devices.

It should be noted that the monitoring area for the device should be configured in a special way. In addition to amplification, the following parameters must be determined: delay h_1, duration of sweep h_2, beginning of strobe s_1, length of strobe s_2. The total length of the monitoring area H_1 should exceed the thickness of the inspection object H — in our task, the thickness of the rail head at the location of the sensor installation.

Since in this case we are only interested in the area around the bottom signal, let us introduce ratios:

$$H_1 \approx 1.1H \quad (2)$$

$$H_1 = h_1 + h_2 \quad (3)$$

In the ratios (2) and (3) $h_1 = 0.9H$ and $h_2 = 0.2H$. This corresponds to the stated requirement for displaying only the bottom signal ring.

Separately, it is necessary to determine the parameters of the strobe — its beginning and extent. The beginning is determined indirectly. For the given task, its middle should be placed on the bottom signal, that is, on H. The length of the strobe should be $(0.1 \div 0.2)H$ depending on the type of rail. Then the start of the strobe and the extension are defined as:

$$s_1 = H - 0.1H \quad (4)$$

$$s_2 = 0.1H \quad (5)$$

Depending on the nature of inspected object, the parameters of the control area and strobe can be changed. The main attention when changing the specified parameters should be paid to maintaining the informational value of the displayed ray pattern and the absence of unnecessary signals in the working field.

During the experiments, a series of 50 measurements was performed — 10 for each of the 5 sensors used. The thickness of the rail at the installation point was 71 mm. The list of sensors that have been applied is as follows:

1. P111-1,25-C20-003 №624.
2. P111-2,5-C12-004 №1001
3. P111-2,5-C12-004 №894
4. P111-5-C6-004 №420
5. P111-5-C6-004 №424

During the experiments, it was found that sensors with a frequency of 10 MHz are not suitable for monitoring.

Pre-calibration of the device UD3-71 [15] was performed on the standard sample SO3-R [16] for each of the transducers.

After that, measurements were carried out at 10 different points of the rail P-50[1] at 10 different points of the rail head working edge. Conditional amplification values, which are achieved when the bottom signal crosses the level of 50% of the screen height and the thickness of the rail head (its depth), were measured.

V. Statistical Analysis of the Results

Statistical analysis was carried out in several stages. The first stage consisted in generalizing and grouping the obtained results. The second — in determining a correspondence to the normal distribution of results in the obtained groups. The third — in the selection of methods used for analysis (parametric [17] or non-parametric [18] tests) and their application.

The results of the first stage are presented in Table 1.

The rationale for possibility of using small samples is similar to that used for electroencephalogram signals in the work [19].

Next, the correspondence of results distribution in the data groups to the normal probability law was determined. For this purpose, the graphical method and the Shapiro-Wilk test [20] were used as shown in Fig. 9. It should be noted that for all groups, the hypothesis of a normal distribution of results was confirmed.

After that, statistical analysis was performed using Student's t-test for samples with a normal distribution of results [21]. At the same time, the statistical parameter p was selected equal to 0.05, in accordance with the principles given in the work [22]. Statistical comparison was made for two large groups of results: comparison between groups of different frequencies results and comparison between different sensors of the same frequency. Detailed description of such statistical analysis features is given in the work [23].

Table 1 Obtained results

Name and number of transducer	Sensitivity, dB	Measured depth, mm
P111-2,5-C12-004 №1001	62	71,04
	53	71,04
	59	71,15
	55	70,89
	57	70,97
	57	70,93
	52	70,97
	52	70,59
	52	70,9
	58	70,82

[1] HOST R51685-2000

DOI: 10.20535/2523-4455.mea.263459

A. Comparison of measured depth values

Comparison of the results between different frequencies shows for the measured depth values the presence of statistically significant discrepancies between the obtained results for all the studied frequencies used by the given piezoelectric transducers (Table 2).

At the same time, there was no difference in measured depth values for different sensors using the same frequency (Table 3).

B. Comparison of obtained amplification values

Comparison of results between different frequencies shows for measured amplification values the presence of statistically significant discrepancies between the obtained results for frequencies of 1.25 MHz and 5 MHz and also for 2.5 MHz and 5 MHz (Table 4).

It should be noted that for different sensors, operating at a frequency of 2.5 MHz, statistically significant discrepancies are absent for measured values of amplification (Table 5).

TABLE 2 COMPARISON OF DEPTH MEASUREMENT FOR DIFFERENT FREQUENCIES

Variable	T-tests: Group 1: 1,25 Group 2: 2,5				
	Mean 1	*Mean 2*	*t-value*	*df*	*p*
1.25 MHz and 2.5 MHz, mm	70,04	70,84	-10,01	28	0,00

TABLE 3 COMPARISON OF DEPTH MEASUREMENT FOR DIFFERENT SENSORS OF ONE FREQUENCY

Variable	T-tests: Group 1: 1081 Group 2: 894				
	Mean 1	*Mean 2*	*t-value*	*df*	*p*
2.5 MHz, mm	70,93	70,76	1,64	18	0,12

TABLE 4 COMPARISON OF AMPLIFICATION LEVEL FOR FREQUENCIES 2.5 AND 5 MHZ

Variable	T-tests: Group 1: 2,5 Group 2: 5				
	Mean 1	*Mean 2*	*t-value*	*df*	*p*
2,5 MHz and 5 MHz, dB	55,85	71,1	-15,97	38	0,00

TABLE 5 COMPARISON OF AMPLIFICATION LEVEL FOR DIFFERENT SENSORS OF ONE FREQUENCY

Variable	T-tests: Group 1: 1081 Group 2: 894				
	Mean 1	*Mean 2*	*t-value*	*df*	*p*
2.5 MHz, dB	55,7	56,0	-0,24	18	0,81

TABLE 6 COMPARISON OF AMPLIFICATION LEVEL FOR DIFFERENT SENSORS OF THE SAME FREQUENCY IN CASE OF STATISTICALLY SIGNIFICANT DIFFERENCE BETWEEN THEM

Variable	T-tests: Group 1: 424 Group 2: 420				
	Mean 1	*Mean 2*	*t-value*	*df*	*p*
5 MHz, dB	73,1	69,1	3,36	18	0,0035

Graphical interpretation of the obtained results is shown in Fig. 10. It can be seen from the given figure that although the average values for both samples are close, for one of the transducers the spread of the obtained values was much greater.

For sensors operating at 5 MHz, statistically significant discrepancies were found for measured amplification values (Table 5).

Graphical interpretation of the obtained results is shown in Fig. 11. In this case, the average values are different, although the spread of values was approximately the same.

CONCLUSIONS

The possibility of acoustic transducers with a non-standard installation site (working or non-working edge of the rail) application for rail control as a part of existing on the modern market rail flaw detectors is analyzed.

Additionally, the possibility of using eddy current devices as complementary to these ultrasonic transducers is considered.

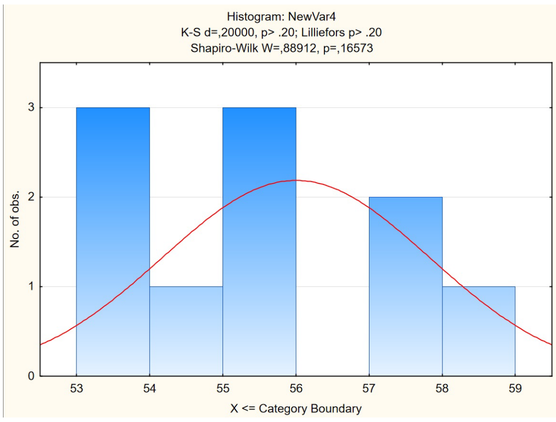

Fig. 9. Analysis of compliance the results distribution in the group with the normal probability law

Fig. 10 Values of amplification for various 2.5 MHz sensors

DOI: 10.20535/2523-4455.mea.263459

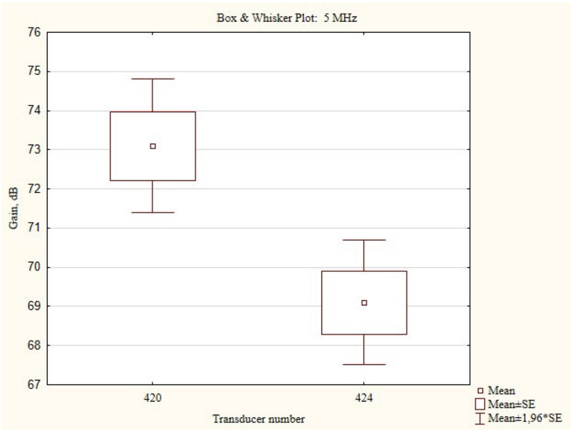

Fig. 11 Values of amplification for different sensors operating at 5 MHz

During the experiments, the amplification value and the thickness (depth) of the rail head were used as information parameters. The range of amplification values obtained had a minimum value of 52 dB and a maximum value of 77 dB, with an increase in amplification values when using a 5 MHz transducer.

The numerical values of measured parameters, obtained during the experiment, were estimated by establishing the correspondence of the distribution in test groups to the normal law. To do this, the Shapiro-Wilk method, graphical analysis, as well as statistical analysis using the parametric method — the Student t-test was applied.

The analysis showed the possibility of obtaining the desired results (namely, a signal from the opposite side of the rail head) and using such an installation of a scanner to detect 30B.1-2 defects (DG) or 113.

In addition, during the analysis, a statistically significant difference between the measured rail head thickness values in the case of using different frequencies sensors was established, while this difference is absent for different sensors of the same frequency.

During the analysis of obtained amplification values a statistically significant difference between 5 MHz sensors and other frequency sensors (1.25 MHz and 2.5 MHz) was established. At the same time, for 5 MHz sensors, there is a statistically significant difference in a case of sensor change (for the sensor P111-5-K6-004 No. 420, the average amplification level in group was 69.1 dB, for the transducer P111-5-K6-004 No. 424, the amplification value was 73.1 dB), which was not observed for sensors of other frequencies. A possible reason for this is the small diameter of the contact zone of the transducer.

CONTRIBUTION OF AUTHORS

I. K. Shapovalov — formalization of work.

D. V. Pareniuk — processing of experimental data; carrying out the calculations.

K. S. Drozdenko — introduction; analysis of literature; setting the problem.

V. P. Mishchenko — specialized scientific consultation.

References

[1]. S.-G. Kwon, T.-G. Lee, S.-J. Park, J.-W. Park, and J.-M. Seo, «Natural Rail Surface Defect Inspection and Analysis Using 16-Channel Eddy Current System», *Appl. Sci.*, vol 11, no 17, 2021, **DOI:** 10.3390/app11178107.

[2]. S. Y. Sokolov, «Zur Frage der Fortpflanzung ultra-akustischer Schwingungen in verschiedenen Korpern [On the question of the propagation of ultra-acoustic vibrations in different bodies]», *«Elektrische Nachrichten-Technik»*, vol 11, pp 454–461, 1929.

[3]. V. P. Radko i V. O. Troitskyi, «Akustychnyi kontrol [Acoustic control]», *Entsyklopediia Suchasnoi Ukrainy: elektronna versiia*. NAN Ukrainy [NAS of Ukraine], 2001, [Online]. Available at: https://esu.com.ua/search_articles.php?id=43558.

[4]. A. Dey, J. H. Kurz, and L. Tenczynski, "Detection and evaluation of rail defects with non-destructive testing methods", in *9th World Conference on Non-Destructive Testing (WCNDT 2016)*, Munich, Germany. 13-17 June 2016.
URL: https://www.ndt.net/search/docs.php3?id=19511

[5]. V. A. Troickij, *Kratkoe posobie po kontrolyu kachestva svarnyh soedinenij [Quick guide to quality control of welded joints]*. Kyiv: Phoenix, 2006.

[6]. A. A. Markov and D. A. Shpagin, *Ultrazvukovaya defektoskopiya relsov [Ultrasonic flaw detection of rails]*. SpB: «Obrazovanie — kultura», 1999.

[7]. U. Service, «UDS2-73 Ultrasonic Double Rail Flaw Detector», *UDS2-73*, 2014. **URL:** http://ultracon-service.com.ua/index.php/en/our-devices/item/31-uds2-73-ultrasonic-rail-flaw-detector-en.

[8]. U. Service, «UDS2-77 Ultrasonic Single Rail Flaw Detector», 2014. **URL:** http://ultracon-service.com.ua/index.php/en/our-devices/item/91-uds2-77-ultrasonic-single-rail-flaw-detector.

[9]. P. Solutions, «Defektoskop vihretokovyj portativnyj VD3-81 [Portable eddy current flaw detector VD3-81]», 2017.
URL: https://www.youtube.com/watch?v=14hWAFKBvFI.

[10]. U. Service, «EDDYCON C Eddy Current Flaw Detector», 2014. **URL:** http://www.ultracon-service.com.ua/index.php/en/our-devices/item/44-eddy-current-flaw-detector-eddycon-c.

[11]. D. Pareniuk and I. Shapovalov, «Ohliad zon kontroliu reiky pry nestandartnomu vstanovlenni skaneru [Inspection of rail control zones with non-standard installation of the scanner]», in *Proceedings of the 14th International scientific and practical conference*, 2022, pp 151–155, [Online]. Available at: https://sci-conf.com.ua/xiv-mizhnarodna-naukovo-praktichna-konferentsiya-modern-directions-of-scientific-research-development-13-15-07-2022-chikago-ssha-arhiv/.

[12]. R. M. Halahan, *Teoretychni osnovy ultrazvukovoho neruinivnoho kontroliu [Theoretical foundations of ultrasonic non-destructive testing]*. Kyiv: National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 2019.

[13]. V. V. Rybkin, A. M. Orlovskyi, M. I. Umanov, R. Markul, i P. Panchenko, *Klasyfikatsiya ta kataloh defektiv i poshkodzhen' elementiv strilochnykh perevodiv na zaliznytsyakh Ukrayiny. TSP-0284. Klasyfikatsiya ta kataloh defektiv i poshkodzhen' reyok na zaliznytsyakh*

DOI: 10.20535/2523-4455.mea.263459

Ukrayiny. TSP-0285. [Classification and catalog of defects and damage to switch elements on railways of Ukraine. CPU-0284. Classification and catalog of rail defects and damage on Ukrainian railways. CPU-0285.], K. : Inpres, 2013.

[14]. UIC, *UIC Code Rail Defects*. 2002.

[15]. U. Service, «UD3-71 Flaw Detector for Ultrasonic Testing of Rails and Welds», *UD3-71 Flaw Detector*, 2014. **URL:** http://www.ultracon-service.com.ua/index.php/en/our-devices/item/92-ud3-71-flaw-detector-for-ultrasonic-testing-of-rails-and-welds

[16]. U. Service, «SO-3R calibration block», *Ultrasonic Calibration Blocks*, 2014. **URL:** http://www.ultracon-service.com.ua/index.php/en/component/k2/item/105-so-3r-calibration-block.

[17]. P. Sedgwick, «A comparison of parametric and non-parametric statistical tests.», *BMJ*, vol 350, p h2053, Apr. 2015, **DOI:** 10.1136/bmj.h2053.

[18]. D. G. Altman and J. M. Bland, «Parametric v non-parametric methods for data analysis», *BMJ*, vol 338, 2009, **DOI:** 10.1136/bmj.a3167.

[19]. D. Pareniuk, «Method of evaluation of the minimal sample size for acoustical signal therapy monitored via electroencephalographic activity of human brain», *ScienceRise*, no 2, pp 75–82, 2021, **DOI:** 10.21303/2313-8416.2021.001736.

[20]. A. Nabou, M. D. Laanaoui, M. Ouzzif, i M. houssaini, *Shapiro-Wilk Test to Detect The Routing Attacks In MANET*. 2021. **DOI:** 10.21203/rs.3.rs-473896/v1

[21]. Student, «The Probable Error of a Mean», *Biometrika*, vol 6, no 1, pp 1–25, Apr 1908, **DOI:** 10.2307/2331554.

[22]. D. V. Pareniuk, A. V. Pareniuk, K. S. Drozdenko, and S. A. Naida, «Study of the Combined Effect of Stress Factor and Musical Signal on the Psychophysical State of Human», *Mikrosystemy, Elektron. ta Akust.*, vol 9, no 26, 2021, **DOI:** 10.20535/2523-4455.mea.228179.

[23]. K. Drozdenko *et al.*, «The Influence of a Low-Frequency Musical Fragment on the Neural Oscillations», *Arch. Acoust.*, vol 47, no 2, pp 169–179, 2022, **DOI:** 10.24425/aoa.2022.141647.

Надійшла до редакції 03 червня 2022 року
Прийнята до друку 19 серпня 2022 року

УДК 620.179.1, 625.143

DOI: 10.20535/2523-4455.mea.263459

Аналіз можливості використання пристрою для контролю стану рейки із нестандартним встановленням сканеру

Шаповалов[f] І. К., ORCID 0000-0002-8665-7868
Паренюк Д. В., PhD, ORCID 0000-0002-0734-3183
Дрозденко[s] К. С., к.т.н. доц., ORCID 0000-0002-7653-600X
Національний технічний університет України
"Київський політехнічний інститут імені Ігоря Сікорського" ROR 00syn5v21
Київ, Україна

Міщенко[s] В. П., ORCID 0000-0003-4927-2376
ТОВ "УЛЬТРАКОН-СЕРВІС"
Київ, Україна

***Анотація*—На даний момент потяги є одним із найшвидших та найпотужніших засобів транспортування та пересування по суші, який відіграє значну роль у сталому економічному розвиткові сучасного світу. Для використання вказаного транспорту потрібно забезпечити безперебійне та надійне пересування потягів по якісно вкладеним та надійним коліям. Залізничні колії необхідні для руху поїздів, і складаються з рейок, опор, шпал і дорожнього полотна для розподілу навантаження поїзда. Рейки постійно підлягають дії пошкоджуючих факторів — тертя об колеса потягів, дій ваги потягів та погодних факторів. Ці фактори суттєво впливають на максимально можливий термін експлуатації як рейкового, так і рухомого складу. Рейки постійно піддаються дії навантаження внаслідок тертя об колеса поїзда, теплової зміни довжини, а також дефекти рейки можуть виникати через корозію, викликану зовнішнім середовищем чи пошкодження під час виробництва або експлуатації (механічним чи термічним).**

Саме тому в даній роботі було розглянуто можливість застосування пристрою для контролю стану рейки із нестандартним (боковим) встановленням п’єзоелектричного датчика. Застосування даного сканеру спрямоване на зменшення ризиків використання на залізничних шляхах однониткових дефектоскопів, що мають систему фіксації на рейці у вигляді двох реборд. Також використання зазначеного пристрою дає змогу отримати новий кваліфікаційний критерій цілісності рейки, яка розміщена у залізничному полотні, а саме наявність сигналу від протилежної грані головки рейки, котрий окрім можливого виявлення дефекту 30В.1-2(ГД) або 113 дає змогу також реєструвати розвинені дефекти шийки рейки, що переходять у її головку і реалізується шляхом прозвучування головки рейки лінійної ділянки колії у поперечному напрямі (від робочої до неробочої грані).

Було досліджено особливості використання круглих ультразвукових перетворювачів різних частот, що показало неможливість використання перетворювачів частотою 10 МГц. Під час проведення дослідів було виконано серію із 50 вимірювань – по 10 на кожен із 5 застосовуваних датчиків. Товщина рейки у точці встановлення складала 71 мм. Вимірювання виконувались на 10 різних точках рейки Р-50 у 10 різних точках робочої грані головки рейки, де вимірювались умовні значення підсилення, що досягається при перетині донним сигналом рівня 50% висоти екрану та товщина головки рейки (її глибина).

У роботі представлені статистичні результати оцінки отриманих експериментальних значень товщини рейки та відповідних їм рівнів підсилення — отримані чисельні значення експериментів було оцінено шляхом встановлення відповідності розподілу у тестових групах нормальному законові із використанням методу Шапіро-Вілка та графічного аналізу, із подальшим статистичним аналізом із використанням параметричного методу — t-критерію Стьюдента. Проведений аналіз показав можливість отримання бажаних результатів (а саме сигналу від протилежної сторони головки рейки) та використання такого встановлення сканеру для виявлення дефектів 30В.1-2(ГД) або 113 по європейському стандартові. Було виявлено наявність статистично значимих відмінностей при проведені контролю датчиками різної частоти та різними датчиками однієї частоти (що актуально лише для 5 МГц). Визначена різниця між максимальним і мінімальним середнім у тестові групі виміряним значенням товщини рейки склала 0,06 мм, а між рівнями підсилення – 17 дБ.

Ключові слова — неруйнівний контроль; ехо-імпульсний; дзеркально-тіньовий; головка рейки.