Łukasz Rawicki
Mgr inż.
Łukasiewicz – Instytut Spawalnictwa w Gliwicach
lukasz.rawicki@is.gliwice.pl

Jacek Słania
Prof. dr hab. inż.
Łukasiewicz – Instytut Spawalnictwa w Gliwicach

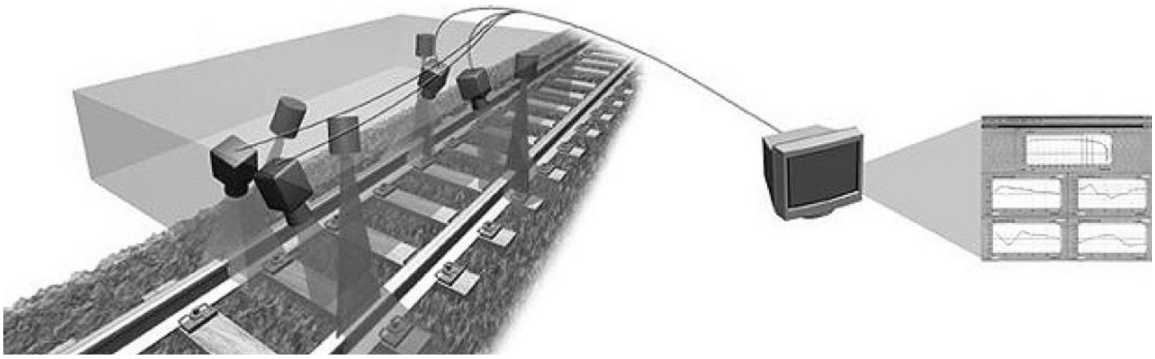
DOI: 10.35117/A_ENG_21_08_01

Defectoscopic examinations of railway rails

Abstract: Non-destructive testing is a key element in ensuring the safe operation of the railway track. They allow for the detection of discontinuities arising both at the stage of production and operation. However, non-destructive testing has some limitations due to its nature. The vast majority of them are indirect methods in which the occurrence of discontinuities is inferred from the course of specific physical phenomena. Non-destructive testing methods provide information about the properties of the tested object. Their goals are to detect and estimation the nature of the discontinuities. The article presents some of the methods that can be used in the examination of railway rails, such as visual and ultrasonic tests. Attention was also paid to unconventional tests used in practice and allowing the detection of discontinuities, such as the method of the scatter field flux and the measurement of the alternating current field.

Keywords: VT research; MFL method; MPM method; AFCM method; UT method, PA technique

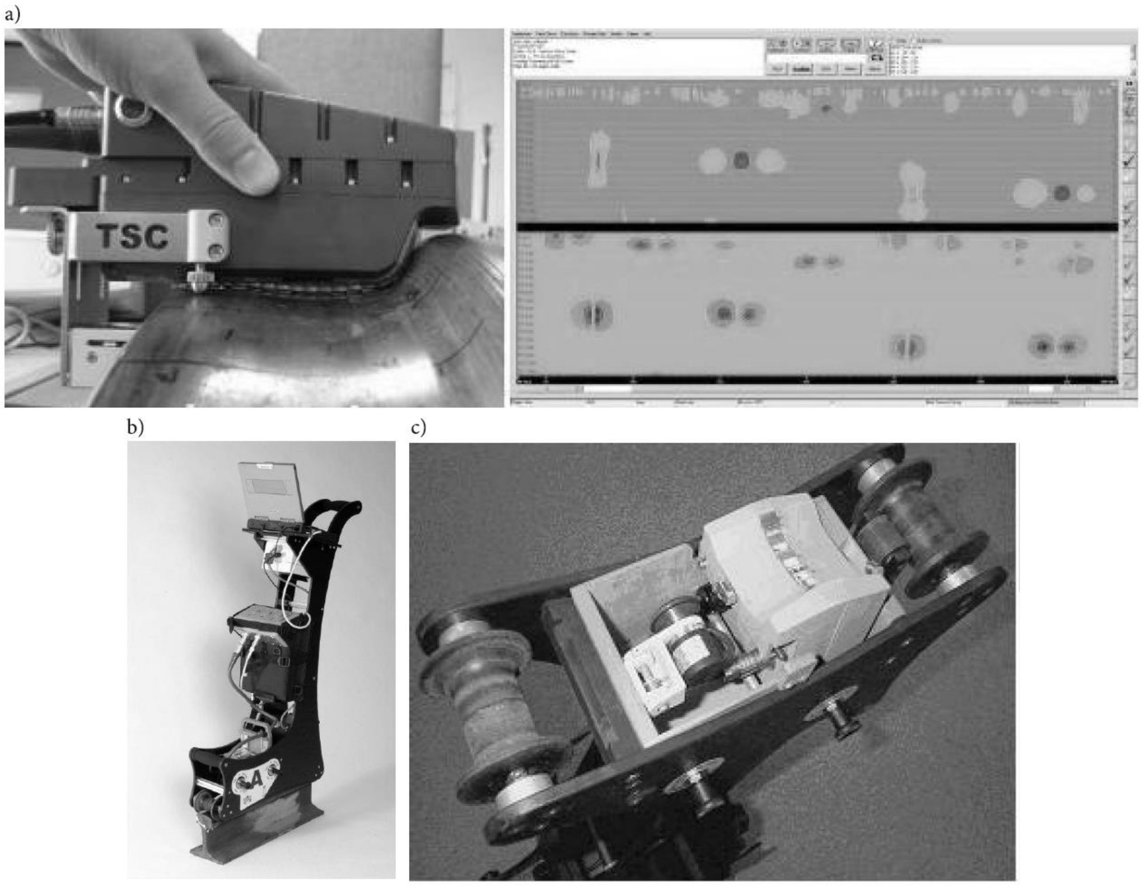
Defectoscopy plays a very important role in the process of detecting rail cracks. Maintaining the railway surface at the appropriate level requires systematic tests. The rails are joined by resistance welding or by thermite welding. The mentioned joining technologies generate the possibility of defects that are detected by diagnostic methods, including visual, magnetic, and ultrasonic tests. It is a decisive factor in the safety of railway networks. The principle of defect assessment in defectoscopic tests is to compare the size of defects with their patterns. The parameters taken into account are geometrical quantities such as length or the defect area. Regardless of the rules of operation of each railroad, the maintenance of railways will always require the removal of a certain part of the rails due to cracks or damage caused in the production process or during their operation [10]. The basic research in the visual inspection of railway rails is the use of high-speed cameras [7]. During the passage of the inspection train, the image is recorded, which is then analyzed using the appropriate software. Visual inspection systems are used to measure the rail head profile and loosening in rail joints. The use of visual inspection does not provide complete information and does not detect internal defects that can be obtained with the use of ultrasonic tests. On the other hand, visual systems make it possible to check the entire surface of the rail as well as to check the absence of fasteners, sleepers, or ballast. Figure **1** shows an example of a railroad track inspection with cameras [7].



1. Railway track inspection with cameras [7]

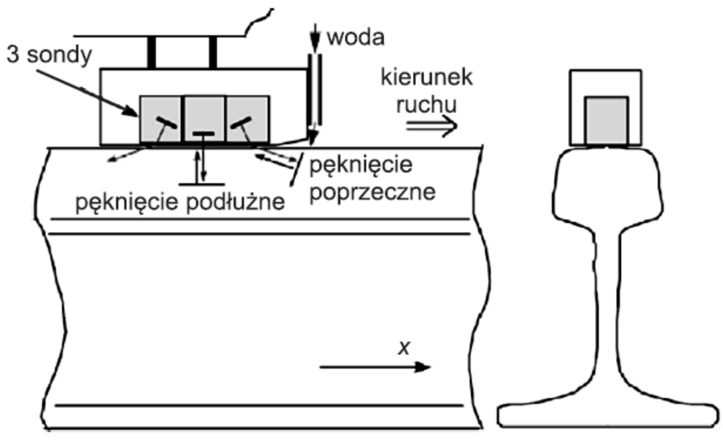
The method of magnetic metal memory MPM is based on the registration of local scattering fields on the surface of the tested object in order to determine the zones of stress concentration and homogeneity of the metal structure. The application of the method does not require the use of special magnetizing devices. The test can be performed without preliminary preparation of the controlled surface. To perform the test, devices with independent power supply characterized by small dimensions are needed [12]. The MPM method enables the initial diagnosis of fatigue wear and the prediction of the reliability of the facility. The significant disadvantages of the considered method include the poor reproducibility of the results. The method is applicable to the testing of railway rails in both manual and automatic modes. Defectoscope wagons are used for automatic tests [13].

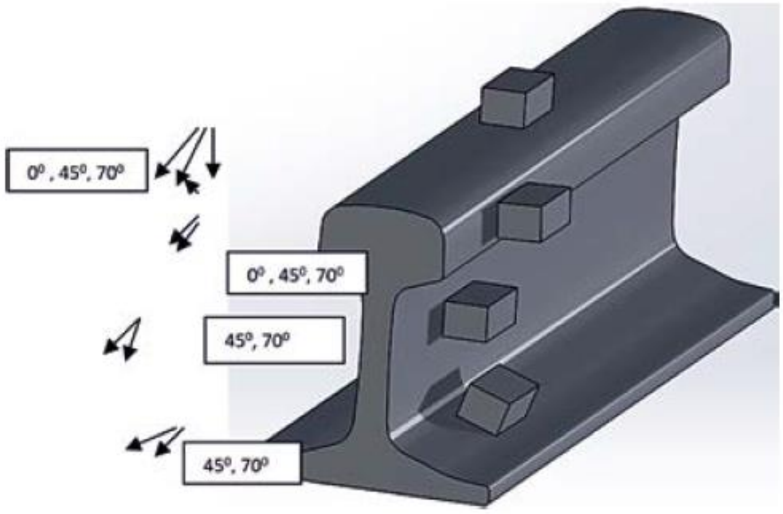
The AC field measurement method (AFCM) was used in the eighties of the last century as a method of a contactless potential drop of alternating current [1, 10]. It was used to measure the depth of cracks. It is an electromagnetic method of measuring the depth of cracks in metals. The test is based on the flow of alternating current close to the surface of the conductor and does not depend on the geometry of the component. In elements without discontinuities, the electric current flows smoothly. When discontinuities are encountered, the flow of the electric current is disturbed. It flows around the ends and down the crack. The magnetic field above the metal surface which is related to the current is also disturbed. The test does not require electrical or magnetic contact of the sensors used. It can be used without removing the protective coating (paint, oil, rust). When the sensors are removed, the current decreases proportionally to the square. The signal drops slowly even after disconnecting from the tested surface for a distance greater than 5 mm [11]. The unevenness of the surface or a thicker layer of the protective coating poses fewer problems than when testing with eddy current sensors placed at a shorter distance than with the AC field measurement method. The technology has found application in the railway industry as well as in the testing of rails. Attention is focused here on the dimensioning of fatigue cracks on rails, where it is not possible with the use of ultrasonic tests and visual inspection. In ACFM tests, pencil sensors are used as well as multi-element matrix sensors. Detection of defects is possible in all directions, but it is best if the defects are at an angle of 0-30o and 60o-900 to the direction of the probe. Figure **2** shows the equipment and imaging during the ACFM test [1, 11].



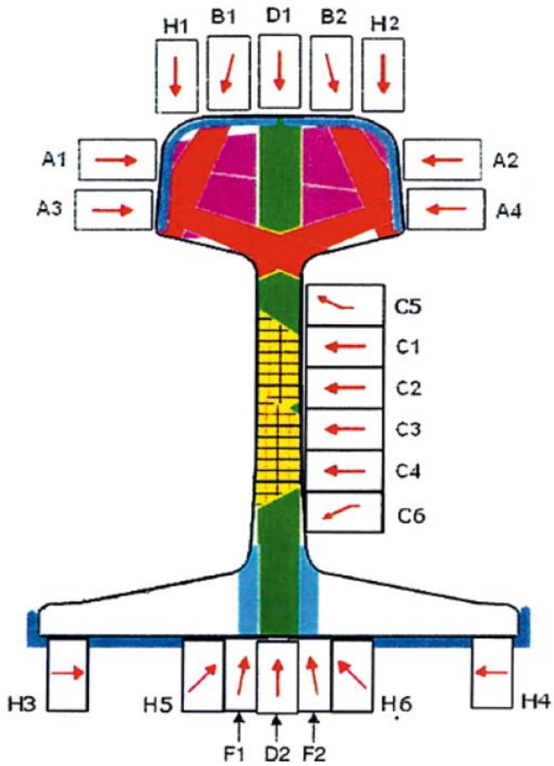
2. ACFM technique [1]

The answer to the question of what is in the volume of the test element is provided by ultrasonic tests. They enable the detection of internal defects and the assessment of their size. As in the case of visual examinations, it is possible to monitor the development of the defect and compare it with the previously performed examinations [3, 6]. Detecting defects in rails is one of the first applications of ultrasonic testing. Defectoscopic systems used in test stands in smelters and in mobile track testing equipment are very advanced. The use of an appropriate number of heads allows the examination of the rail cross-section area, except for the foot part. Defects that cannot be detected during ultrasonic testing are defects that arise beneath the surface and develop into horizontal crack. Transverse fatigue cracks are especially dangerous. The test heads used for the tests are single and double longitudinal wave heads and transverse wave heads with a beam introduction angle of 45o and 70o [6]. Figures **3** and **4** show the methods of applying ultrasonic probes during ultrasonic testing.



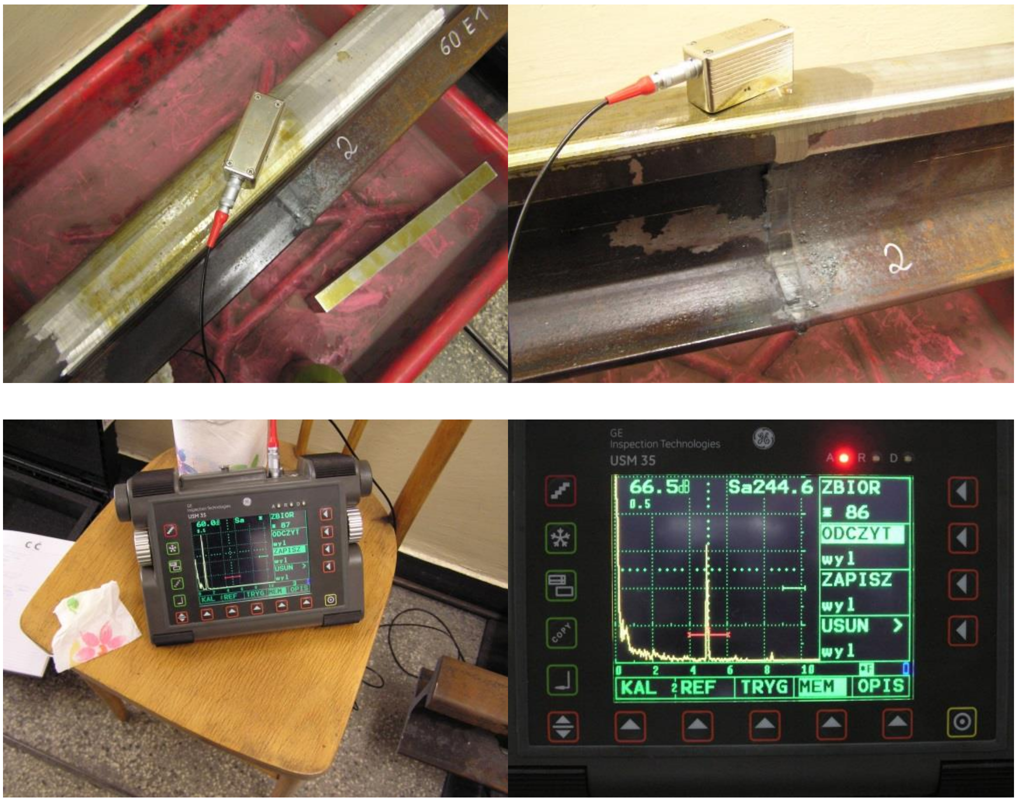


3. Running the heads during the rails test [6]



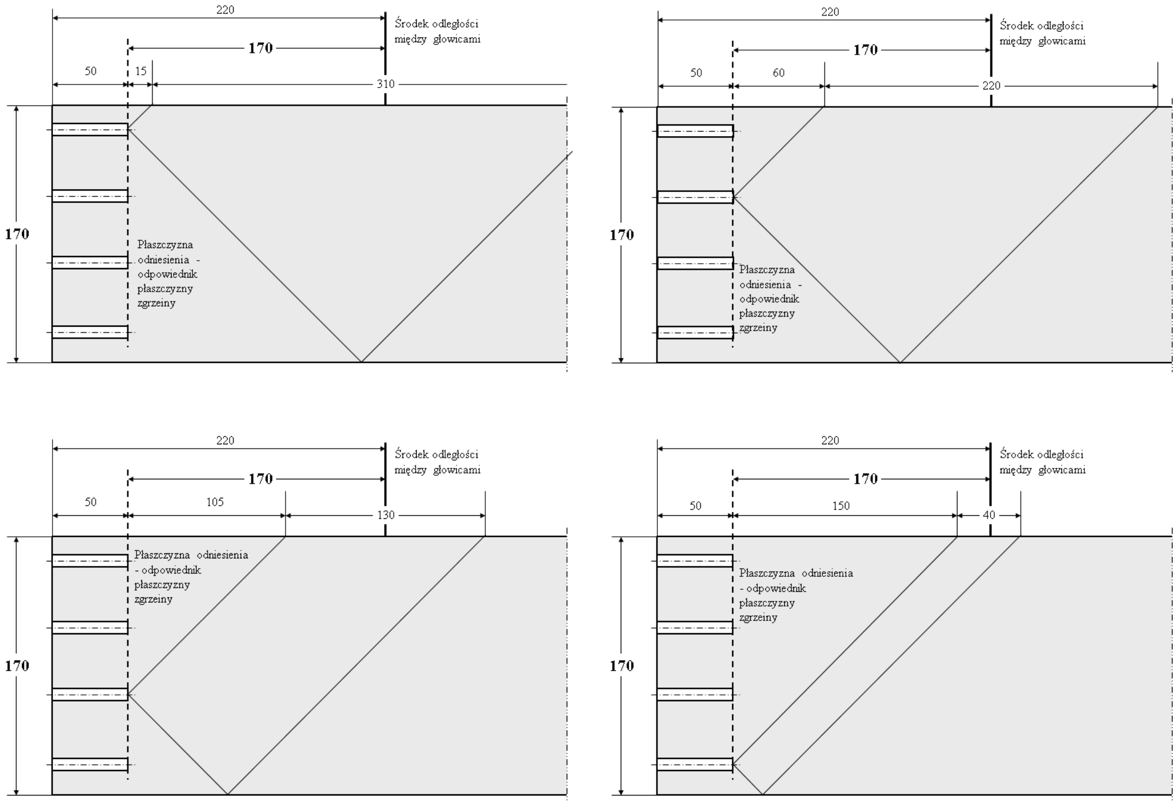
4. The arrangement of the heads for testing rails at the last stage of production [6]

The rails test fixed on the track causes the introduction of ultrasonic waves from the head surface through the layer of liquid coupling to the test surface. Access from the bead surface is impossible and the developing wear cracks in the bead cannot be detected. Transverse cracks in the rails usually begin at the outer edges of the bead. Not detected earlier, they lead to destruction. Fluid coupled turret assemblies do not produce the correct results in detecting vertical cracks in the head that most often appear in the center of the head. Unfavorable orientation and the development of cracks in the longitudinal and transverse directions are very dangerous. The purpose of testing welded joints in rail joints is to detect defects occurring in the entire cross-section of the joint. The tests cover joints and welds made during surface repairs and others, depending on the needs [7]. The echo technique uses a single head that initially acts as a pulse transmitter, then is "switched" to act as a receiver. The signal sent by the head to the material bounces off the discontinuity or the opposite surface and returns to the head. By measuring the time from the moment of sending the impulse to its return and receiving it by the head, it is possible to determine, knowing the speed of the ultrasonic wave in the material, the distance between the head and the obstacle. Based on the height of the non-compliance echo on the defectoscope screen, its approximate size can be determined. Figure **5** shows an example of an examination with the ultrasonic echo technique.

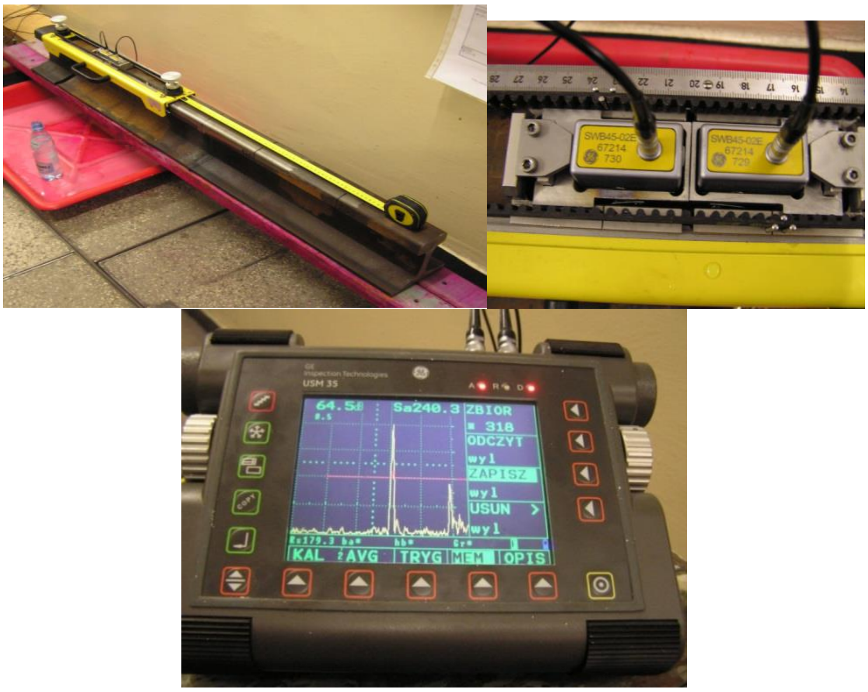


5. An example of use of the ultrasonic echo technique [4]

In the tandem technique, a system of two angular heads, transmitting and receiving, is used, set at a constant distance from each other during the search of the connector. In order to examine the entire volume of the joint, the system of heads moves several times along the joint, changing the distance between the heads so as to search a different area of the joint each time [3]. The positioning of the heads in the tandem technique and the location of indications on the example of reference samples is shown in Figure **6**. In Figure **7**, you can see an instrument for testing rails in the tandem technique. 2T45o heads are mounted on special guides. The millimeter-scale makes it easier to set the heads in appropriate positions in relation to each other. Power cables led from the top make it easier to move the heads in relation to each other and enable their stable mounting [4, 14].

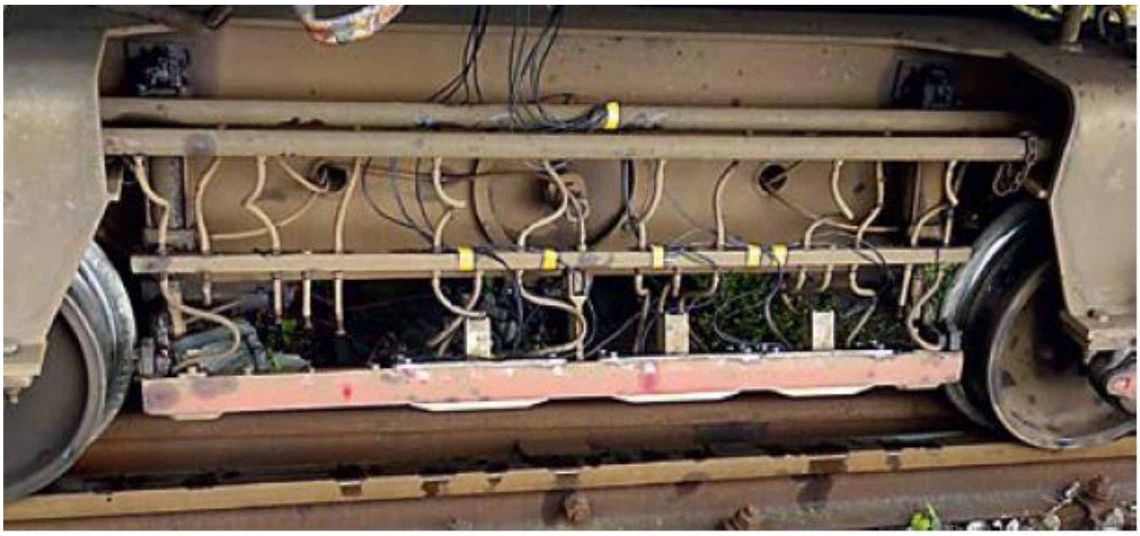


6. Cases of the indicators location on the example of samples with reference reflectors [4]



7. Tandem test equipment [10]

The test from the rail running surface makes it possible to use multi-channel flaw detectors with the use of single and double ultrasonic heads with different angles of ultrasonic wave introduction as shown in Figure **8**. The speed of inspection cars is about 50 km/h. For the production and contact of the head with the running surface of the rail, it is necessary to use a coupling agent, which is water.



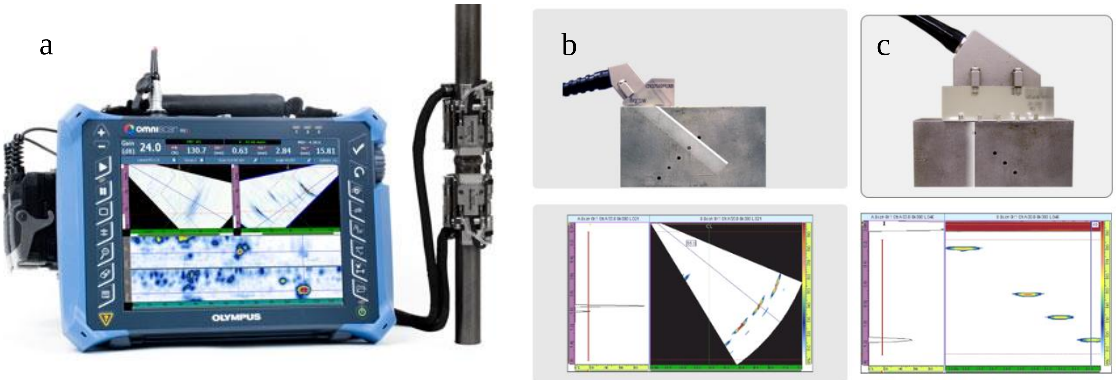
8. Skid of a wagon bogie with mounted UT heads [6]

The images viewed on the monitors make it possible to qualify the defects. The use of trolleys for testing rails in the field of local testing with the use of longitudinal and transverse wave heads with angles of 0^o, 45^o, 70^o. The examination is recorded by means of a computer system that enables the examination to be viewed at any time. Connections of rails with turnout frogs require manual tests. Straight sections of rails can be tested with the use of hand trolleys and inspection trolleys as shown in Figure **9**.

9. RDM-12 trolley for testing railway rails [6]

A breakthrough in the application of ultrasonic testing is the Phased Array PA technique, which is an extension of conventional ultrasonic testing with the echo technique. In the Phased Array technique, mosaic heads have been used, containing a number of small, independently controlled transducers (usually 16-64) [5]. The use of a mosaic head enables the introduction of a series of ultrasonic beams, processing of the received signals, and their analysis in graphic form with amplitude coded by a color palette. The resulting S-scan showing the position of the indications against the contour of the weld groove significantly facilitates the subsequent evaluation and characterization of the detected indications [5].

In the Phased Array technique, it is possible to control the ultrasonic beam introduction angle, which makes it possible to obtain any angle of incidence or refraction of the beam by activating the indicated transducers of the head in programmed sequences. One head makes it possible to carry out scans at different angles. The advantage of this technique is also the shortening of the research time, which is related to, inter alia, with no need to replace the heads, and thus recalibrate the equipment [8]. Figure **8** shows an example of a calibration block and head in PA tests. The imaging of non-compliance and the system for the semi-automatic PA test are shown in Figure **9**. In the PA technique, an ultrasound beam is introduced into the test object in order to scan the volume of the tested material with the use of transverse waves. The frequencies used, the ranges of the transducers used, as well as the characteristics of the ultrasonic beams used, do not differ from those used in traditional ultrasonic testing. The principle of the test is very similar to the classical ultrasonic method. The acceptance of the indication consists in measuring the maximum echo amplitude in relation to the established echo of the reference reflector [9]. Figure **10a** shows a flaw detector with a scanner for PA tests. Figures **10b** and **10c** show examples of line scan and sector scan images.



10. Apparatus for testing with the PA technique: a) flaw detector and scanner, b) oblique probe and test results using a sector scan, c) straight probe and test results using a linear scan [5]

Source materials

[1] Cost H.: Pomiar głębokości pęknięć – aktualna technika pomiarowa. Tech Control

[2] Costain J., Pearson N.R.: Możliwości współczesnych skanerów den zbiorników działających w oparciu o metodę strumienia rozproszenia pola magnetycznego. Badania Nieniszczące i Diagnostyka, 2017, nr 1–2, s. 20–23

[3] Deputat J.: Nowe Techniki Badań Ultradźwiękowych. Pracownia Ultradźwiękowych badań materiałów. IPPT PAN Warszawa

[4] Hottowy G.: Materiały własne firma Ekstplast

[5] Kaczmarek K: Prezentacja. Nowoczesne techniki badań ultradźwiękowych oraz ich zastosowanie. Gliwice 2017

[6] Kowalczyk D., Antolik Ł., Mikłaszewicz I.: Wady szyn kolejowych, a badania ultradźwiękowe Badania nieniszczące i diagnostyka, 2019, nr.4, s.9-13

[7] Lesiak P., Wlazło M.: Badania wad Head Checking w szynach kolejowych metodą optyczną, Prace naukowe Politechniki Warszawskiej, Transport zeszyt 104, 2014

[8] Mackiewicz S.: Badania złączy spawanych techniką Phased Array w świetle wymagań PN-EN ISO 13588. Przegląd Spawalnictwa nr 12/2015, s. 101-106

[9] Mackiewicz S.: Ultradźwiękowe badania złączy spawanych techniką Phased Array. XXI Nieniszczące Badania Materiałów. Zakopane 18-20 marca 2015

[10] Makuch J.: Prezentacja. Diagnostyka szyn, wady w szynach. Katedra Mostów i Kolei. Politechnika Wrocławska. Wrocław 2015
[11] Nichoha V, Shkliarskyi V.: Metoda strumienia rozproszenia pola magnetycznego w diagnostyce szyn kolejowych oraz jej miejsce wśród mobilnych środków badania nieniszczącego, Problemy kolejnictwa Zeszyt 180, wrzesień 2018, s.23-27
[12] Roskosz M., Witoś M., Żurek Z.H., Fryczkowski K.: Porównanie możliwości diagnostycznych metod magnetycznej pamięci metalu, szumu Barkhausena i niskoczęstotliwościowej impedancji. Przegląd Spawalnictwa, 2016, nr 10, s. 57–62
[13] Sikora R., Chady T.: Badania nieniszczące metodami elektromagnetycznymi. Przegląd Elektrotechniczny, 2016, nr 9, s. 1–7
[14] Wytyczne PKP Polskie Linie Kolejowe S.A. Id-17:2005.: Wytyczne ultradźwiękowych badań złączy szynowych, zgrzewanych i spawanych. Warszawa 2005