Utilization of the Ultrasonic Diagnostic Method in Rail Status on a Defined Railway Section

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Abstract **– In the article we deal with the issue of non-destructive diagnostics of a specified part on the railway, namely the rail. The chapters are devoted to the non-destructive defectoscopic method, or more precisely an ultrasonic test, which is performed by DIO 562 device and it also includes data processing from the measurement. The article briefly describes location and character of defects on the rails and actual process of measurement. The measurement was performed on a standard length of 10 km, with the use of a device capable of copying shape of the rails during the ultrasonic examination. The evaluation of the measurement was processed in specialized software DIO 2000 on the PC. Based on this evaluation, three manual inspections were implemented to determine the character of defects. The conclusion of this article is a precise determination of character and origin of these selected defects, and suggestion for their removal or replacement according to the valid regulations.**

Keywords **–ultrasound, non-destructive diagnostics, rails, rail defects.**

1. Introduction

The railway is one of the most heavily trafficked infrastructures.

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Due to the transport of a large number of persons and different types of cargo, all components placed on the railway have to be permanently inspected and maintained in a functional condition. The tools of non-destructive defectoscopy which are used for this purpose have to be reliable and capable to diagnose the largest measured section. Covering as many parts of the rail superstructure as possible. These facts make the tools for non-destructive defectoscopy, so as ultrasonic testing which is very helpful for safety retention of the transport of persons and cargo.

2. Ultrasonic Method

Ultrasonic devices for detecting internal defects in materials, which are using the transition and reflection method, are referred to as universal ultrasonic defectoscopes. The device is composed of several elements, which provide various operations related to its function like generation of ultrasound waves, capturing reflections from wavesand data processing itself. Schematic representation of such a device can be seen in Fig. 1 [1]. The basic principle of this device is that signals are transformed directly in the piezoelectric probe, which means that electric signal is transformed to mechanical work [8]. This transformation creates a pulse thanks to piezoelectric transducers. These are transmitted directly to the material which has to be tested [3].

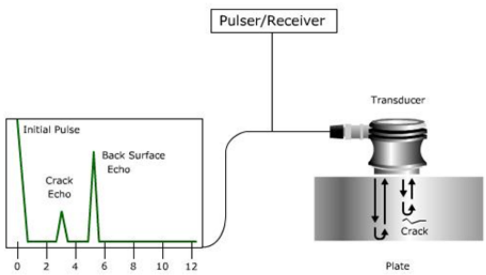

Figure 1. Principe of ultrasonic testing

One of the two methods used in ultrasonic defectoscopy is the transition technique. Its principle lies in the weakening of the ultrasound signal, during the transition through the tested material, or more precisely to the place where the error is found. With this method, it is necessary to use two probes, the first one sends the ultrasonic signal into the material, and the other at the opposite end receives this signal. The probe arrangement for this method can be seen in Fig. 2, [3].

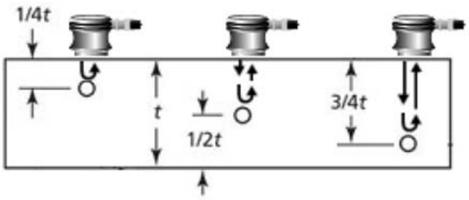

Figure 1. Reflective ultrasonic method

The probe is an important element of the ultrasonic device, it serves to transmit and capture the ultrasonic signal into the test material. These signals are received and transmitted using piezoelectric transducers. They are able to vary by changing the size of the incoming electrical signal. This process changes an electrical impulse to mechanical motion and results in the UT signal being transmitted to the material. [2]

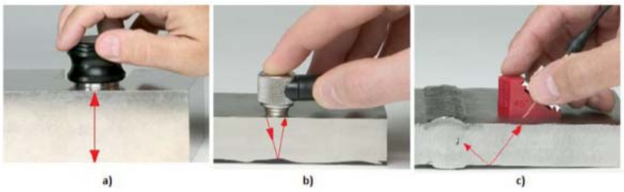

Figure 2. Demonstration of probes used for the ultrasonic method (a) direct, b) direct double c) angular probe)

In terms of piezoelectric sensor construction, we distinguish three basic types of ultrasonic probes:

- Direct probe - ultrasonic waves from direct probes are transmitted directly to the test object, i.e. perpendicular to its surface. The shape of these probes may be circular or rectangular. They are produced with varying degrees of sensitivity and damping. Their use is limited to materials in which errors are located parallel to the surface. These probes are not able to find cracks situated perpendicular to the surface of the component;
- Double probe: for double probes, we encounter a structure containing two transducers. The first is to transmit the ultrasound signal to the test material, the second is to reprocess it and return to the probe. These two inverters are separated by acoustic isolation. Their most frequent use is to detect errors near the surface, or to test the thickness of the material itself;
- Angle probe: We can use it wherever it is impossible to use a direct probe. The ultrasound signal is transmitted at a certain angle, such as 35 °, 60 °, 45 °, and 70 °. This angle is defined by a wedge shaped body, which is mostly made of plexiglass. When the UT signal is sent to the material at a certain angle, it occurs in the fracture, which in practice means transforming the longitudinal wave to the transverse [4].

2.1. Device Calibration

Due to the correct setting and the course of the ultrasonic test, it is not necessary to calibrate the device, and the probe correctly. For this purpose special calibration blocksand measurements complying with STN EN 12 223 are determined for this purpose [9]. The calibration blocks have a precisely defined geometry, surface quality and material [6] in accordance with the relevant standard. The scales used for calibrating NDT devices using the ultrasonic method generally apply to the principle that they are to be made of material with the same acoustic properties as the material of the test object. Scars are known in various shapes, they contain artificial defects that mimic those real. Artificial defects generally have the form of flat-bottomed bores, rectangular grooves or cylindrical boreholes. Such artificial defects are best reflected by ultrasound waves, even though these defects are even greater than those of real errors. Calibration scale K1 and K2 were used to calibrate the DIO 562/49 [5].

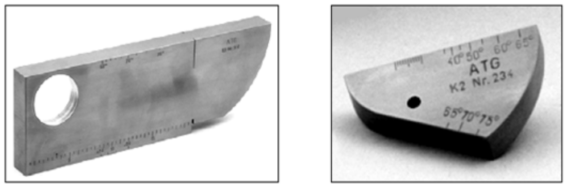

Figure 4. Calibration blocks K1, K2 [2]

In Fig. 5 we switched the setting of the time base for the direct probe using K1 calibration block. The block has several features that facilitate checking and calibrating many of the parameters and functions of the transducer as well as the instrument which includes range setting, sensitivity, resolution, linearity, dead zone, beam spread, beam angle and time base. [5]

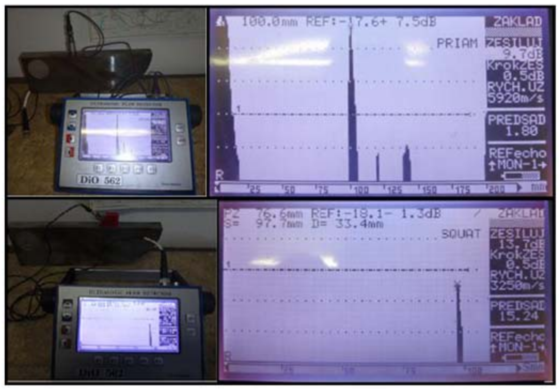

Figure 5. Calibration of the straight and 70° angle probe on calibration block K1

Verifying the point and angle of the angular probe exit is shown in Figure 6. This calibration was performed on calibration gauges K2. This miniature calibrating block is primary used in field measurement for checking the characteristics of angle-beam transducers. With that miniature block, beam angle and exit point can be easily checked.

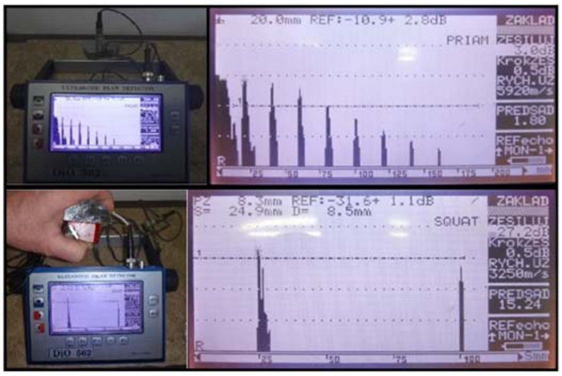

Figure 6. Calibration of the straight and 70° angle probe on calibration block K2

Calibration was performed prior to the start of the measurement, caliber K2 was also used during the test, in accordance with the valid rules applicable to ultrasound measurement.

3. Rail Defects

In connection with the increase in speeds and masses on the railway vehicles, railway lines had to undergo some modernization. This has led to an increase in durability and reliability of rails, frogs and crossings. From a safety point of view, these components require a regular and thorough analysis of the origin and causes of the defects that could lead to their decommissioning [7]. Diagnosis of these errors occurs in several ways, and due to the interconnectedness of the NIS associated in the UIC, all errors have to be recorded unambiguously and uniformly. The importance of such a recording lies mainly in the determination of the cause, the occurrence of error and operational measures taken during handling of the rail. In the classification of the rails, rails and crossings, regardless their type and shape, we distinguish three basic types of errors: cracks, fractures and mechanical damage [2].

- Damage - This type of error is diagnosed mostly by the visual method seen as development of cracks or by a defectoscopic device, no further action is required for this type of error;
- Cracks - can occur at any point in the profile or the entire length of the rail and components. There may be one crack or multiple cracks that form a continuous line. The development of these cracks can, in some cases, get to the brick;
- Fragmentation is a fault in which it is visibly divided into two or more parts, or a rail from which a piece of material has been separated, resulting in a gap of at least 10mm deep and 50mm long [10].

The errors found in the rail, crossings, and hearts can be located in its various parts. For this reason we classify them as faults at the ends of the rail, at the center of their length in the area of welds and welds, and hidden language and switch errors [1].

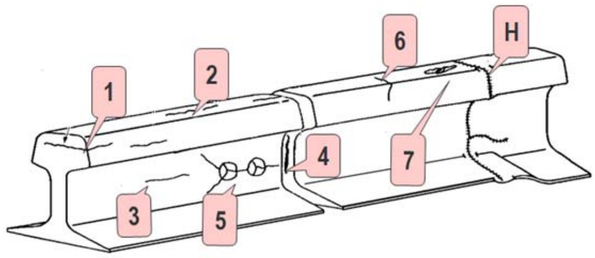

Figure 7. Illustration of rail faults (1. Horizontal head cracking, 2.Vertical head crack, 3.Web of rail crack, 4.Shrink hole (Lunker), 5.Holecrack, 6.Kidney-shaped defect, 7.Shell-shaped, H.Welding) [3]

Many rail faults can deteriorate over time; therefore the regulation of specific defects sets which are out the scope for measures are designed to eliminate the risk of spreading these errors. Depending on the category if the error is not removed, it is necessary to identify and monitor it, or to take the necessary measures for a while.

4. Measuring Device

The model DiO 562 is a two-channel ultrasonic flaw detector for manual field inspection as well as for automated scanning. Its use is suited for testing with two independent channels at the same time. There are two independent receivers and two transmitters. The display is divided into two parts for each channel. The gate display: two gates in the first (second) channel. The pitch of tone is distinguishing the gates [4].

Figure 8. Dio 562 device with a special positioning probe [3]

At the basic inspection of the DIO 562 defectoscopic device, the daily standard of the measuring section is up to 10 km, therefore the device contains a device that facilitates manual test run. The device includes 3 probes that are fixed in its construction to facilitate the inspection of the controlled sections. The kit contains 3 probes, one direct and 2 x 70 ° probe and one water container placed on the construction. The water is used as a contact substance, and at lower temperatures it is diluted with ethanol. [3]

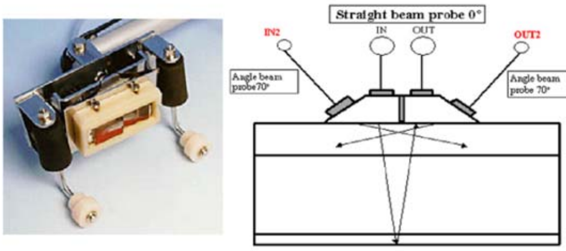

Figure 9. Combined probe used with DIO 562 device, for rail testing [2]

4.1. Process and Evaluation of the Measurement

During the measurement, we encountered number of cases that were evaluated, based on echo reflections in the frozen record of the course of primary control, by the device as errors. Examples of these situations can be seen in Fig. 10. In its first part, we can see the echo caused by the hole in the clutch chamber, we can see the change in distance of the reflected signal, compared to the original height of the rail. The second part describes the transition from the "S" type to the "R" type. This change occurred when we were leaving the railway station, or more precisely the speed zone. As seen on the illustration a stronger echo from the lower rail profile "S" (2a) is clearly distinguished, on the lower scale after the R-type ramp (2b). In the third part, we can see a standard measurement of the rail height with a direct probe, which runs virtually during the entire part of the basic test.

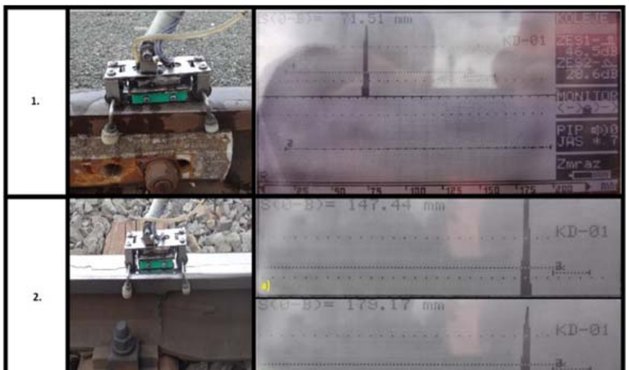

Figure 10. Selected examples of individual obstacle evaluation during basic control

After the basic inspection, according to the regulations, the oversight of the errors followed due to their more detailed control or identification. Among the mistakes we encountered on measured rail there were:

- Error 2222C, peeling material from the edge;
- Error 2251D, a rare place on the rail's driveway, caused by skidding vehicle wheels;
- Error 5122, thanks to visual control, found a damaged frog [6].

Material peeling from the rail's running edge– this error was located on the left-hand lane of the crosshairs marked 8a. The last change of the switch language at this section was in 2000 and is a classic S49 rail profile. The test was conducted with the DIO 562, but due to the technical design and the shape of the switch language, it was not possible to use a continuous control device. Error identification was performed using a 5MHz angular 70 ° probe at 35dB.

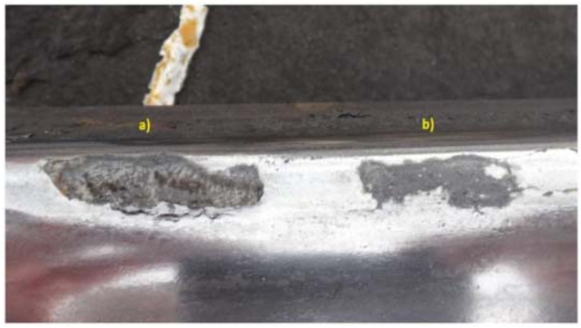

Figure 11. Measured part with defect (measured site a, b)

On the tongue of the crossing, a series of consecutive defects was found on a total length of 170 mm. In Fig. 11 we can see the details of two of these defects. On the basis of a detailed inspection carried out according to the regulations, we can read from the DIO 562 device that in the case of a) it is an error with depth h = 4.6 mm and length l = 13.5 mm, while in case b) relatively less damage with h = 0.3 mm, l = 11.9 mm. According to the valid regulations, on the basis of which this error was identified, it can be said that this type of damage occurs due to contact and sliding forces, which are created between the rail and the track vehicle.

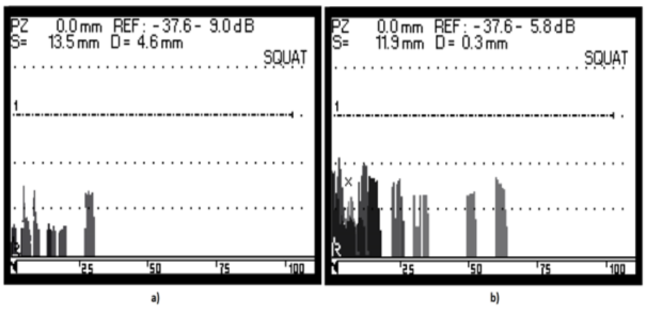

Figure 12. The results of the measured parts a, b

The designation "C" is characteristic of this type of error because the maximum depth of defect h = 10 mm has not been exceeded, i.e. it is recommended to replace the rail (tongue or hedge) for the selected section or to repair the damaged section [2].

Figure 13. Detail of the measured part with damage 2251D

Damage caused by the slipping of the track-side vehicle – the damage shown in Figure 61 was located on the right straight of the track near the 2nd measured point. The last replacement of the rail was in 2002 and it was a R65 profile. Measurement was performed using a direct 3.5MHz probe and 32dB output. The extent of damage to the rail was 50 mm in length and its depth was measured by increasing the echo from the direct probe at the defect transition. The measurement results can be seen in Fig.14 where we can see a clear increase in UT signal echoes when passing through a lower cross section of the profile on the damaged site.

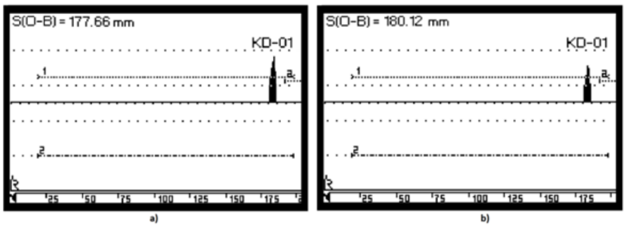

Figure 14. Measurement results of the slipping section (a) standard rail height in front of the damage site, (b) rail height at the point of damage)

The designation "D" is characteristic of this type of defect. Since the maximum depth of defect which has not exceed the value of h = 6 mm, we recommend increased observation rate for this section due to the possible development of the defect [4]. In this case, it is necessary to repair the sliding site, because of the possibility of its development.

In a special case on the measured section a defect was detected by a visual check on railway crossing. The railway frog, which is the toughest part of the railway crossing construction, it is impossible to measure it with DIO 562 and the device used in the previous measurements, due to its shape and tenacity. The data are obtained directly by manual device with the use of angled probes. Due to the toughness of the frog, which often has to withstand a high impact load, an EPOCH device was used for this measurement to improve the sensitivity of data obtained [5].

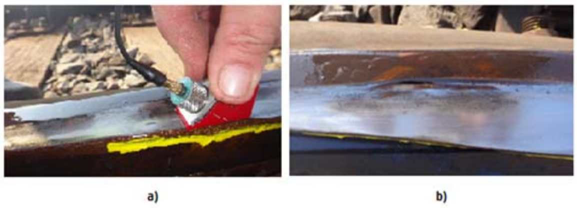

Figure 15. Railway frogmeasurement (a. measurement with 70 ° probe, b. defect discovered during visual inspection)

The last defect marked with the number 5122 was caused by the periodic bumping of the train wheels, which created an undercut. Since the defect was located on the railway frog, which is the toughest section of railway, ultrasound testing was relatively difficult. In these defects, the capillary method is prioritized. Nevertheless, after the ultrasonic equipment was exchanged and different probes used, it was possible to obtain necessary surface defect data. The one we could find is based on the ultrasonic measurement extends to a depth of 11.52 mm. It is located on the surface of the rail and its length does not exceed 32.41 mm. According to the valid statutes defining the repairs of railway frogs, the defect of this character and its range, it is recommended repair by thermal welding [1].

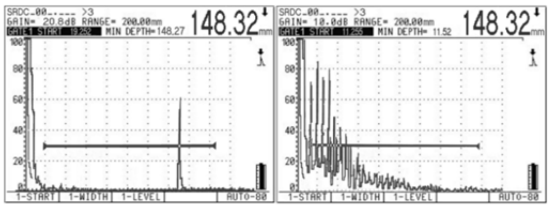

Figure 36. Results of measurement of cross section with damaged heart

5. Conclusion

Regular and timely diagnosis of the parts condition on the railway goes hand in hand with reliability and safety of railroads. Fatal consequences that may arise as a result of some defects need to be identified and removed in the shortest possible time. For this reason, a large number of regulations, protocols, measurement procedures have been developed to make the elimination of these defects as effective as possible.

During the practical part, all of the measurement was made in field. We have encountered different defects with different orientated orientations and origin, which were placed on the railway and components similar to turnout constructions. These various mistakes were identified and measured thanks to ultrasonic devices DIO 532 and EPOCH. After measurement they were classified and methods of their repair have been proposed.

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