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PRZEGLĄD SPAWALNICTWA Welding TECHNOLOGY REVIEW

Original Article

Measurements of railway welded rail joints with a laser device

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Abstract: One of the methods of joining rails is welding with termite, which guarantees a secure and stable connection of two sections of the rail without the need to use additional connecting elements and supporting the welded place. After joining (making a weld), appropriate mechanical processing of the joint is required in order to obtain the given rail head profile. The quality and diligence of the connection made has a major impact on safety, noise emission during the journey (wheel rolling) and the comfort of travelers. This article describes selected methods of making railway rail joints and presents the results of measurements with a portable laser measuring device Calipri C40 of the rail head within the welded rail joint made by thermite welding. An attempt to use this device for measurements of welded rail joints is shown, advantages and disadvantages as well as conclusions from the performed measurements are described.

Keywords: measurements; laser; wear; rail; rail head; rail joints; welding

Introduction

The essential element of modern railway structure is a jointless rail track, which is made of two rails permanently and inseparably connected with each other. The original method of joining rail sections in a classic track with the use of bolted rail joint bars is replaced by welding methods, in particular electric welding and thermite welding, and – in special cases – electric arc welding [1÷4].

Railway vehicles' travel on a jointless rail track is calm and quiet. There are no impacts of the wheels on the bending ends of the contiguous rails. The rails connected in a classic way with the use of bolted rail joint bars during intensive use are very quickly and excessively worn as a result of the dynamic effects of the wheels of the vehicle. The surfaces of the head of rails and rims of wheelsets of railway vehicles are mechanically damaged [5÷7].

The jointless rail track creates fewer operational limitations – it allows to drive on it at high speed, driving is safer and comfortable. A very important condition for obtaining the desired functional properties is such mastery of the technology of joining rails so that the joints are flawless, and their parameters are repeatable and, most importantly, the properties of the joints do not differ from the properties of the rails [8÷17].

Methods of contactless joining of rails – making rail joints

Rail joints are present on straight sections and track bends as well as in places where there are turnouts and track crossings [12÷17].

In the construction of the surface on railway lines, the following methods of joining rails are used [12]:

- thermite welding,
- welding with the use of mobile welding machines,
- connecting rails with the use of rail joint bars,
- welding with the use of stationary welding machines,
- making of glued-prestressed rail joints,
- connecting crossings of manganese-chrome steel with rails.

Railway rails, as large-size elements joined by thermal methods, create many technical and technological difficulties. For this reason, the number of possible welding methods is limited. In practice, two methods are used:

- welding rails with termite,
- electric flash butt welding.

The method of joining the ends of rails frequently used on Polish railway lines is thermite welding [4], which is an alutermic method with the number 71 according to EN ISO 4063 [11]. This method requires careful and precise preparation of the ends of the rails, maintenance of the heating and welding parameters, precise positioning and sealing of the mold, as well as an efficient and experienced welding team.

Before welding, the ends of the rails are prepared, facing each other end-to-end, maintaining straightness, with a slight vertical rise angle provided for shrinkage of the material after cooling. A mold with accessories is placed at the point where the rails meet and carefully sealed with refractory mass. The set is then heated with a propane-butane burner. The preheating is to dry the assembly to limit the transfer of hydrogen from moisture to the molten steel and to avoid thermal shock to the rail material which can cause cracks upon completion of welding. After igniting the thermite mixture, the mold is filled with molten cast steel.

After removing the fixture and cutting off the riser, the joint is roughly and finally machined, and then the weld is permanently and legibly marked. The joint is subjected to quality control followed by operational acceptance by the welder.

Due to the difficulties of correct and non-defective execution, rail joints are places with increased defectiveness [12,17]. For this reason, termite welded joints are subject to special inspection by qualified personnel in accordance with the reference standards EN 14730-1:2017-06 [18] and EN 14730-2:2006 [19].

Another method of making rail joints is electric flash butt welding. They are made with stationary welding machines in rail welding shops. The ends of the rail are introduced to the welding machine and set end-to-end with a slight pressure. A current flows through the contacting surfaces, which causes a pulsatile melting of the metal of the contact surfaces of the rail ends. Flashover occurs – a sudden ejection of molten metal – with simultaneous removal of the remaining contaminants from the front surfaces of the joined ends of the rails, and the rapid heating of the contact ends of the rails. After achieving the appropriate plasticity, the ends of the rails are upset by the force causing the crushing and the formation of a material flash at the welding point [18÷23]. In the welding room, after the welding process is completed, the joint is subject to quality control. Measurements of geometric dimensions are performed, horizontal and vertical straightness, visual and ultrasonic tests, hardness tests, as well as fatigue and bending strength tests. The test results should meet the requirements of the reference standard EN 14587-1:2019-03 [20] and WTWiO Id-112 [21].

The welding of rails in the track with mobile welding machines is based on the same technology. In this method of welding, mobile welding machines are used, placed on road-rail vehicles. The manufactured joints must meet the quality criteria in accordance with the EN 14587-22009 standard [22]. These are the same requirements as for welding with stationary welding machines.

Calipri measuring instrument

The significant development of the laser measurement technique, including both equipment (cameras, laser modules), as well as image processing and analysis algorithms, has resulted in a significant increase in the interest in the application of these technologies in the field of measuring parameters of rolling stock objects and railway infrastructure. A portable Calipri C40 measuring instrument equipped with a computer installed with specialized instrumentation for laser measurement of the parameters of wheelsets, brake discs and rails. The Calipri C40 is a multifunctional device that is used for contactless inspection and verification of the condition and wear of surfaces, as well as the geometrical dimensions of vehicle elements and railway infrastructure. This device enables the following measurements [23]:

- outline of the rail head,
- outline of the rolling profile, tread wear, diameter on the rolling circle of a wheelset,
- distance between wheel discs of a wheelset,
- wear of the brake disc.

Figures 1 to 4 show a view of the place where the rails are welded, the measurement of the rail head and the measurement of the weld head of the rails.

Fig. 1. View of the contactless joining of rails made by thermite welding

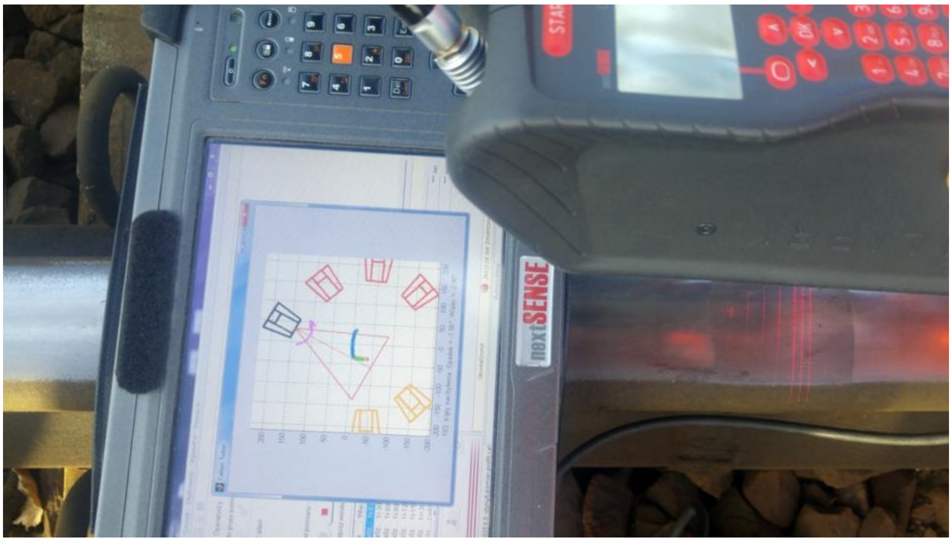

Fig. 2. View of the measurement of the head profile and rails welds after thermite welding

Rail head measurements using the Calipri instrument

Many studies deal with the subject of diagnostics of the railway track, in particular the measurements of rails or the quality of workmanship as well as techniques for testing rail joints [21÷29]. In this article (the analyzed case) the following measurements were performed: measurements of the contactless connection of rails made by thermite welding (Fig. 1) – at the weld with the riser (Figs. 2, 5), and the rail head profile connected at places distant from the welded joint every 300 mm for each of the rails to be joined, five measurements in front of and behind the weld (Fig. 3, 4, 6). This measurement was also aimed at determining possible changes in the profile geometry after the thermal effect on the joined elements. All measurements were automatically saved in the memory of the measuring instrument, which allowed for an immediate evaluation of the geometry and comparison of the measurement results. The device enables measurement with a resolution of 0.001 mm, but for the purposes of this article, the obtained results were rounded to 0.1 mm. The uncertainty of rail head profile measurement with the Calipri device is ≤ 0.1mm. In Figures 5 and 6, light green defines the reference rail profile 60E1 (UIC60) [26] and dark green defines the rail head profile. The Calipri instrument determines the parameters: d – WH – head width, RH – head radius, crown radius, W1 – wear 0° (vertical wear of the rail head 0°), W2L – wear -90° (left side wear of the rail head -90°), W2R – wear +90° (right side wear of the rail head +90°), W3L – wear -45° (left side wear of the rail head -45°), W3R – wear +45° (right side wear of the rail head +45°), AW – wear area mm^2, AWP – wear area percent %.

The computer software of the measuring device also enables a direct graphic comparison of the successive measured rail head profiles, and thus a quick analysis of the measurements made. The detailed results are summarized in Table I. The adopted symbols and abbreviations are consistent with the markings in the software interface of the measuring device.

Fig. 3 View of the measurement with the Calipri laser device of the rail head profile 600 mm in front of the contactless joint of thermite-welded rails, the laser module in one of the seven measuring positions – auxiliary, side based

Fig. 4. View of the measurement with the Calipri laser device of the rail head profile 60 cm in front of the non-contact joint of thermite-welded rails, the laser module in one of the seven measurement positions – the top

Table I. Results of measurements of the rail profile within the welded joint, designations as shown in Figure 6

Dimension designation according to Fig. 6	Measurement distance from the welded joint [cm]										
	-150	-120	-90	-60	-30	welded joint	+30	+60	+90	+120	+150
d [mm]	72.2	72.2	72.1	72.1	72.3	72.2	71.8	72.0	72.1	72.0	72.1
W1 [mm]	-0.3	-0.4	-0.4	-0.5	-0.3	-9.9	0.1	0.0	-0.1	-0.1	0.0
W2L [mm]	-1.1	-1.2	-1.2	-1.2	-1.2	-5.9	-0.8	-0.9	-0.9	-0.8	-0.9
W2R [mm]	-1.1	-1.0	-1.0	-1.0	-1.1	-7.4	-1.1	-1.2	-1.3	-1.1	-1.2
W3L [mm]	-1.4	-1.5	-1.5	-1.5	-1.4	-5.7	-0.9	-1.1	-1.1	-1.1	-1.1
W3R [mm]	-1.8	-1.8	-1.7	-1.8	-1.7	-7.7	-1.5	-1.7	-1.8	-1.7	-1.2
RH [mm]	513.9	488.2	686.9	515.0	680.0	–	513.6	600.3	628.0	621.8	647.0

On the basis of the results obtained during the measurement (Table I), it can be stated that the tested joint was made correctly, and the deviations are within the tolerance limits. It should be noted here that the device is not suitable for measuring the side profile of the thermite welded joint due to welding residues. They do not have a significant impact on the entire joint. It is important to measure the rail head, whether all welding residues have been properly removed and whether the machining (grinding) has distorted the profile, especially the top and side surfaces of the rail head. These are surfaces that directly interact with the wheels of the rail vehicle. Maintaining the correct profile is of great importance for the quality of the joint and wheel-rail cooperation, and thus also on the generation of noise and vibrations.

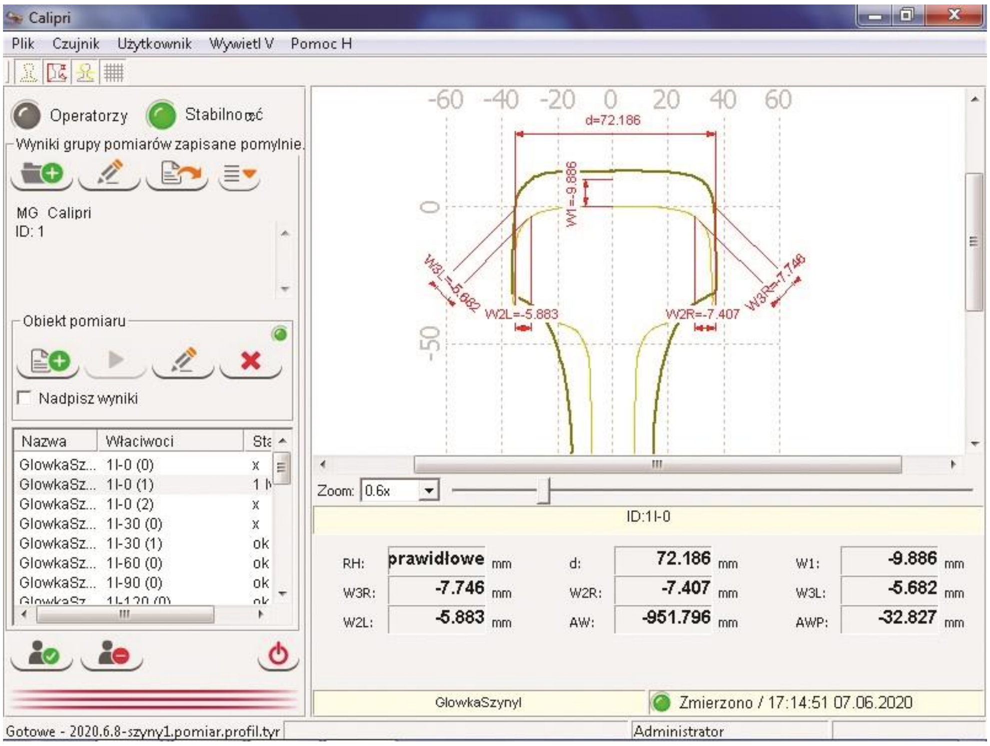

Fig. 5. Measurement results of the rail head in the place of termite welding, visible measurement of the riser, view from the program

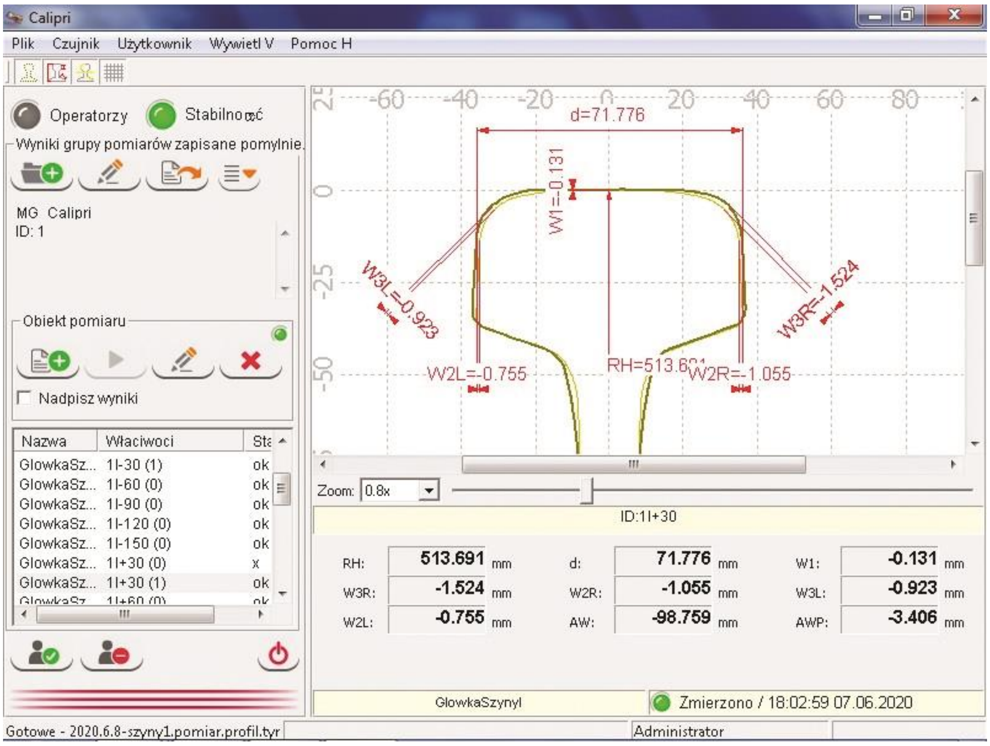

Fig. 6. Railhead measurement results +30 cm behind the welded joint, view from the program

Summary

The CALIPRI C40 measuring device has been designed for quick control, contactless measurements of railway infrastructure elements. The contactless measurement is fast, the software and the available interface allow you to quickly evaluate a given object in field conditions. It is particularly important in the case of joining rails in the thermite welding technology, where it is necessary to evaluate the profile of the rail head after machining. A more detailed analysis of the measurements can be carried out stationary on the computer due to the fact that all results are saved in the device cache. In addition to measuring the rail profile, the Calipri device is used to control the wear of the train wheel profile, measure its diameter, analyze the wear of brake discs, rails and switches, as well as measure the distance between the inner surfaces of the wheels of a wheelset.

In the considered case, it was used to assess the quality of rail joints in the thermite welding technology for a jointless rail track.

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