

Władysław Grzechowiak

# The Welding of Vignoles Rails and Tram Rails Using the Two-Way (Rail-and-Road) Mobile Welding System Equipped with the AMS 100 Head

---

**Abstract:** The article discusses the resistance flash butt welding of Vignoles rails and tram rails performed using a two-way (rail-and-road) track welding system. Particular emphasis was given to the welding of tram rails.

**Keywords:** Vignoles Rails, tram rails, welding of rails, AMS 100 Head

**DOI:** [10.17729/ebis.2019.5/8](https://doi.org/10.17729/ebis.2019.5/8)

---

## Introduction

Both railway and tramway advanced track structure should enable quiet travelling at speeds competitive to those attained by other means of transport. Obviously, priorities concerning the railway track structure differ from those related to tramway one. Speeds reached by railway rolling stock are incomparably higher than those attained by trams. Other areas where the two types of rolling stock vary significantly include unitary (wheel/axle) loads, travel system design solutions and rolling stock springing systems. However, in both cases, the part of the track structure common for both means of transport is the continuous track. The elimination of the traditional method used for joining rail segments by means of bolted rail joint bars and replacing them with welding methods significantly improved the comfort of train/tram travel. One of the methods enabling the joining of rails aimed to make continuous tracks is resistance butt welding. It should be emphasized that the welding of tram (dock) rails is very innovative presently, constituting a new segment in the technology of joining tramway tracks.

Until today, dock rails have been welded primarily by means of thermit welding.

Welding technologies applied in the joining of rails must ensure the obtainment of high-quality joints. The mechanical properties of joints cannot vary from those of rails and, importantly, must be repeatable. To achieve the above-named objectives, the welding process must be subjected to approval, whereas the surveillance personnel and operators should regularly participate in training and examinations. Welding machines must be provided with systems monitoring the course of the welding process and recording its parameters. [6]

## Resistance flash butt welding of rails

### *Principles of resistance flash welding*

Flash welding is a process, where the permanent joint is obtained by the resistance heating of the interface of elements to be joined and by the flashing of liquid metal from the interface area through the flow of welding current, followed by the exertion of upsetting force.

Figures 1 and 2 present the schematic diagram of resistance flash butt welding and the thermal cycle during the above-named process. Rails to be welded, fixed on the clamps of the welding head, are pressed against each other (with their butting faces) to provide the contact of current. Power-on is followed by the flow of high-density current through interface areas characterised by a very small area and high resistance. The current melts the material of the interface, leading to the formation of liquid current bridges. Afterwards, the bridges rupture abruptly as a result of electromagnetic forces and metal vapour pressure.

The lengths and allowances during resistance flash welding:

- $l_z$  – element fixing length,
- $l$  – initial distance between fixing electrodes,
- $\Delta W$  – total allowance for the flashing of both

- elements,
- $\Delta S$  – total allowance for the upsetting of both elements,
- $\Delta C$  – total allowance for both welded elements (allowance for welding) [4].

The programme of resistance flash welding along with the thermal cycle in the weld area:

- $I_p$  – preheating current,
- $I_{wp}$  – initial flashing current,
- $I_w$  – flashing current,
- $I_s$  – upsetting current,
- $I_o$  – heat treatment current,
- $F_p$  – squeezing force during preheating,
- $F_w$  – squeezing force during flashing,
- $F_s$  – squeezing force during upsetting,
- $T$  – temperature [4].

The removal of the liquid metal of the bridges from the interface area is accompanied by the removal of all impurities. The flashing process performed at an appropriate advancing rate makes the heat of newly formed current bridges flow inside the rails being welded and heat up adjacent areas to a significantly plasticised state. In addition, the rails are subjected to resistance heating along the fixing length. If, after heating,

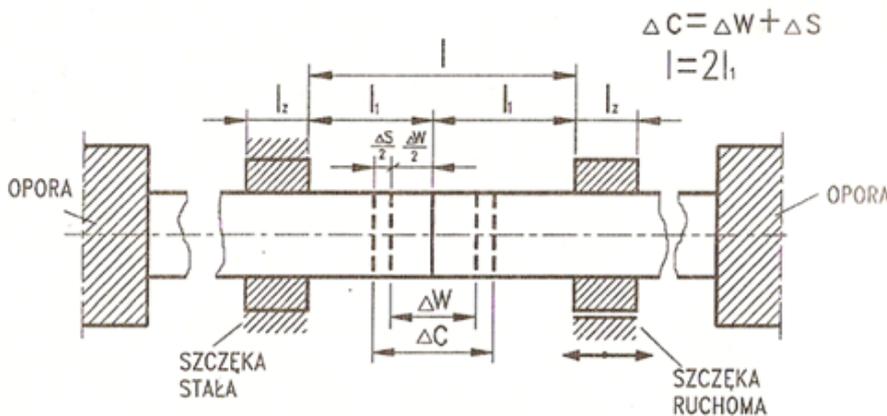


Fig. 1. Schematic diagram of resistance flash butt welding

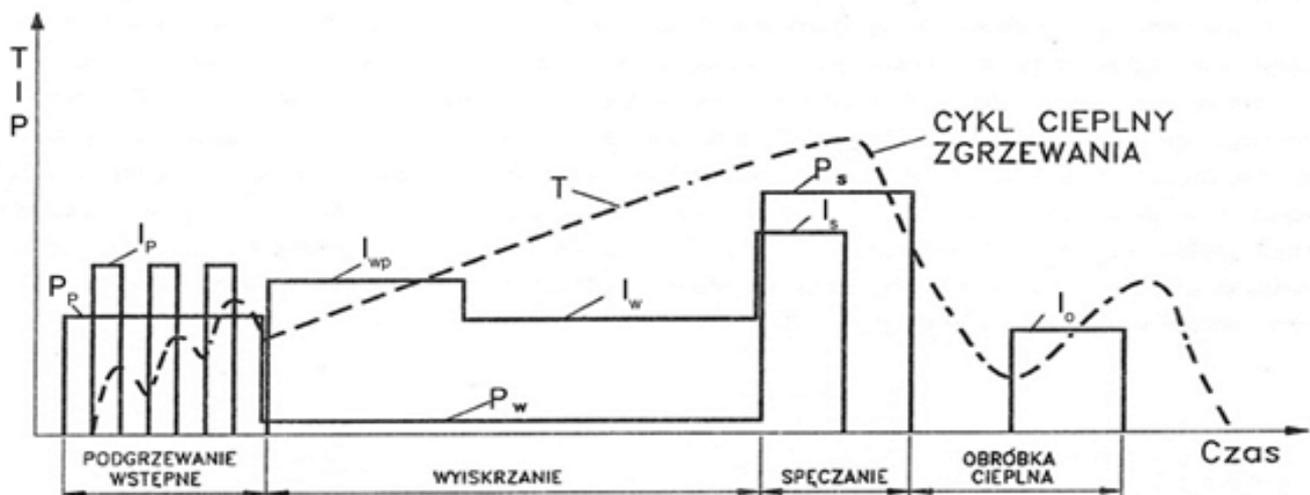


Fig. 2. Thermal cycle during resistance flash butt heating

the layer of liquid metal is formed on contact surfaces and the adjacent areas are heated and, consequently, plasticised at an appropriate depth, the process of upsetting involving the use of significantly higher force and travel rate of welding head clamps is performed. As a result, the liquid metal along with impurities (if any) is pushed outside to the flash. The rate of upsetting must be between several and between ten and twenty times higher than the rate of flashing. In cases of steels requiring heat treatment, the welding process is followed by the flow of one or several current impulses through the newly made joint. Through resistance heating, the above-named operation makes it possible to adjust the cooling rate of the joint or to perform appropriate heat treatment operations [4].

### **Rail steels**

Because of their chemical composition, rail steels are rated among hard-to-weld steels. The content of carbon is restricted within the range of 0.40 to 0.82%, manganese is restricted within the range of 0.65 % to 1.70%, and the content of silicon is restricted within the range of 0.13% to 1.12%. Certain steels also contain chromium (up to 1.25%). In terms of the chemical composition, rail steels are also recognised as unalloyed medium-carbon steels with normal or higher manganese content and as low-alloy chromium steels. In the as-rolled state, the above-named steels have the pearlitic structure [6].

Rail steel grades are specified in PN EN 13674-1:2011, whereas tram rails are referred to in PN EN 14811:2010 (Table 1).

### **Welding process-related requirements [3]**

This study does not discuss issues connected with requirements concerning rails as the requirements related to rails used in railway applications are dramatically different from those used in the tramway infrastructure such as, for instance, the minimum length of supplied rails. In railway standards, the minimum length of rails should amount to 30 m, whereas rails used when building tramway tracks are 18 metres long. Rails having a length of 30 metres are acceptable as long as they are deliverable to a construction site.

To ensure the problem-free welding process, rail ends should be perpendicular in relation to the rolling surface and rail head. The acceptable deviation from the aforesaid perpendicularity amounts to  $\pm 0.6$  mm. The rail interface as well as the interface between the rail and the electrodes of the welding head should be subjected to grinding so that metallic lustre is achieved. The surface of the interface should be free from irregularities and mechanical damage. Rail markings located on the rail web (so-called convex stamps) should be removed. Electrodes used in the welding process should correspond to the rail section. Welding can be performed without restrictions if the temperature in the rail exceeds  $+5^{\circ}\text{C}$ . In cases, where temperature in the rail is restricted within the range of  $+5^{\circ}$  to  $-10^{\circ}\text{C}$ , the ends of the rails (2 metres in length, on each side) should be preheated to a temperature restricted within the range of  $+15^{\circ}$  –  $+20^{\circ}\text{C}$ . Electrodes should fully (i.e. with their entire surface) adhere to the cleaned surface of the rail.

Table 1. Rail steels [1],[2]

Steel grade	Hardness HBW	Application	Rail section
R 260	260–300	railway applications tramway	49E1, 60E1 49E1, 60R1, 60R2
R 290 GHT	290–330	tramway	60R2
R 340 GHT	340–380	tramway	60R2
R350 HT	350–390	railway applications tramway	49E1, 60E1 49E1

## Welding process

The principle of operation of welding heads is consistent with the previously discussed principles of resistance flash welding. The welding process includes the following phases:

- welding preparation (appropriate approach of the butting faces of the rails),
- flashing aimed to even up butting faces,
- preheating,
- flashing proper,
- flashing performed at an increasing rate,
- upsetting under current characterised by a high shortening rate,
- upsetting,
- cutting off flash,

- heat treatment.

A welding programme developed for a given steel grade and rail section does not need to include all of the above-presented phases.

Schematic diagrams of welding phases present the following parameters changing in time:

- current –  $I$  [A],
- squeezing force –  $F$  [kN],
- distance (rail shortening /electrode displacement) –  $s$  [mm].

In certain welding heads, pressure –  $P$  [MPa] is recorded instead of force. Another parameter recorded by welding heads is voltage –  $U$  [V].

Two-way welding systems provide the repeatability of high-quality joints. The above-named

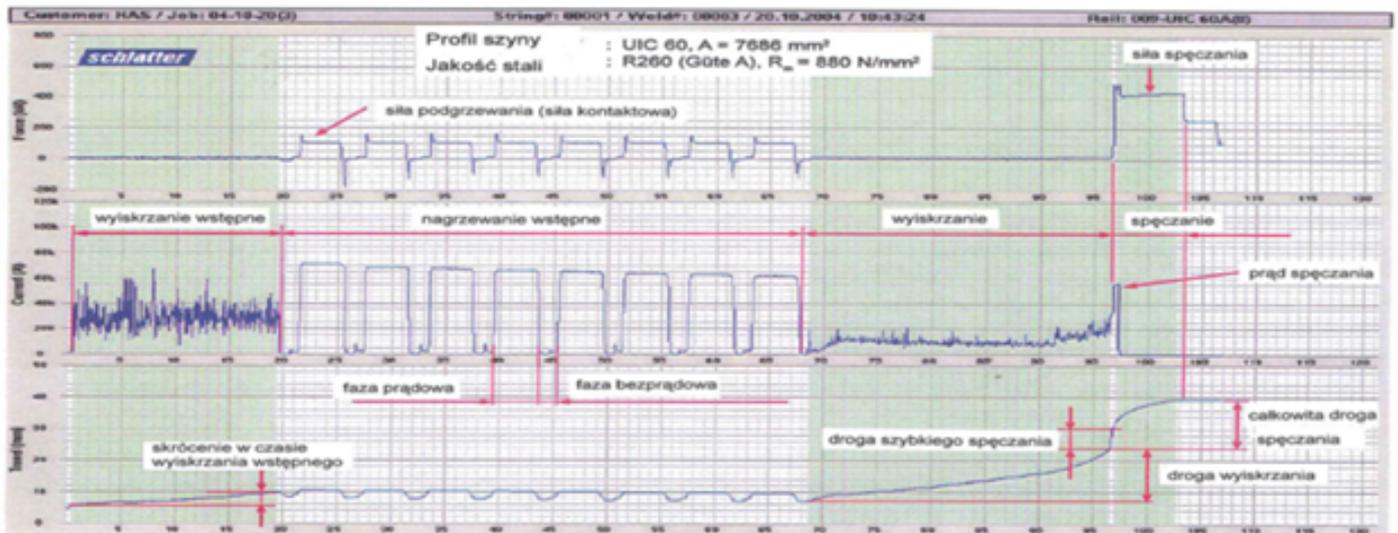


Fig. 3. Exemplary diagram from the recorder, containing marked welding phases

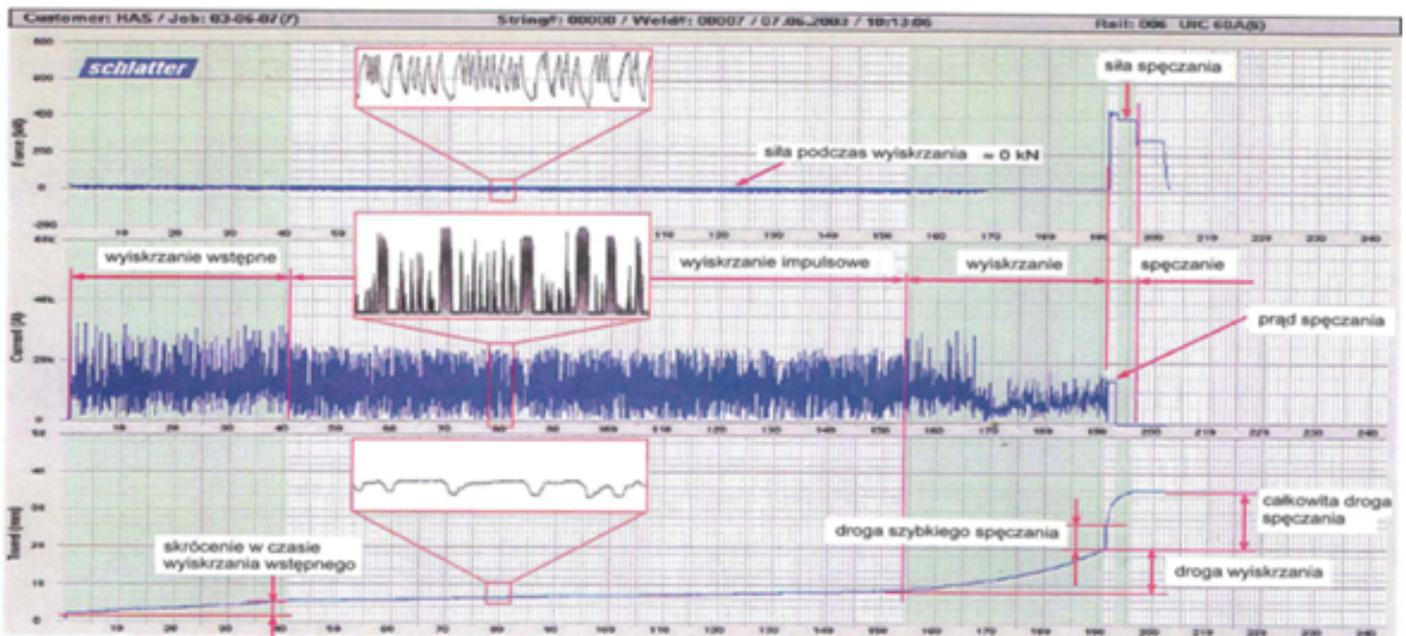


Fig. 4. Butt welding with pulsed flashing; force, current, distance in the function of time

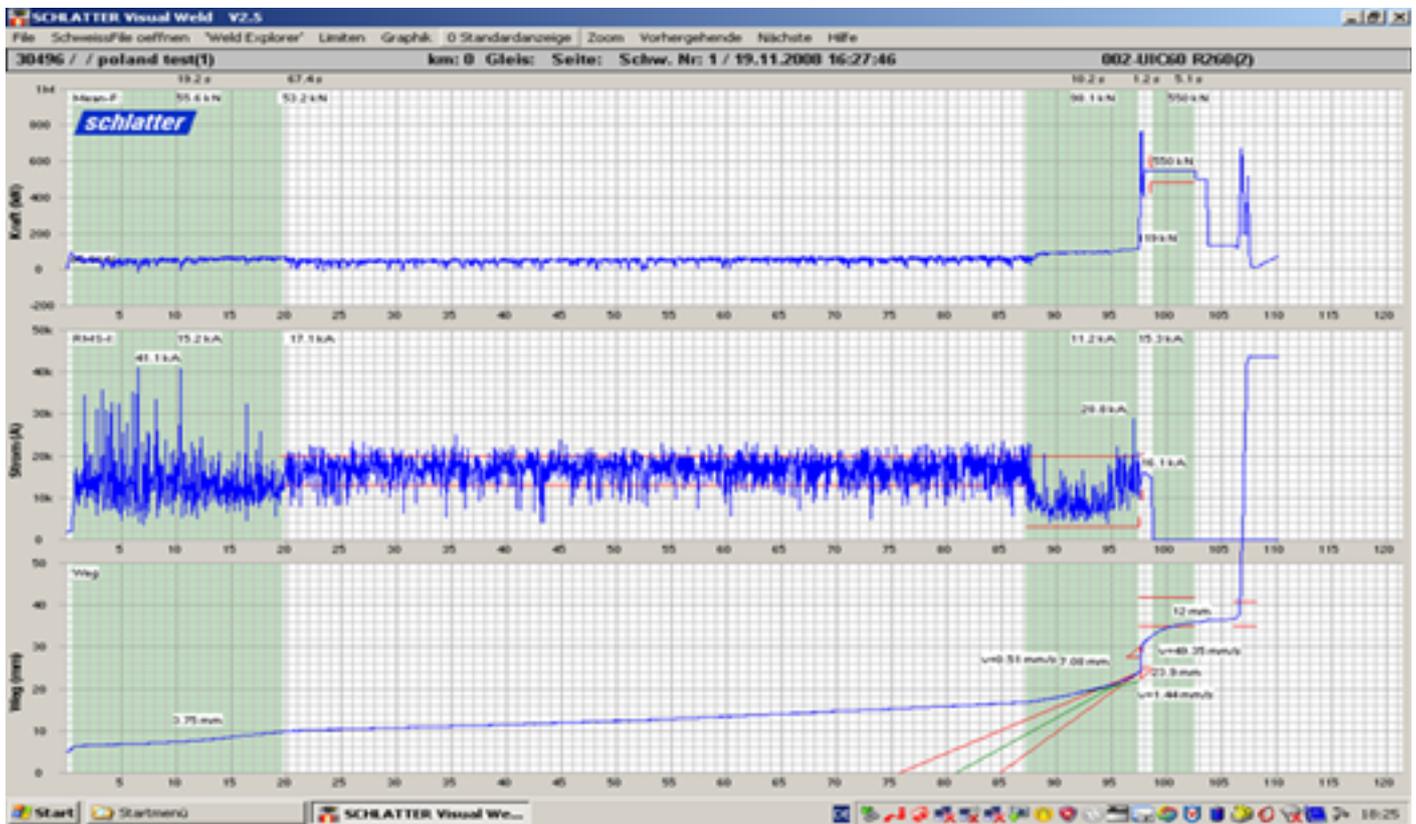


Fig. 5. Butt welding with pulsed flashing; force, current, distance in the function of time (assessment result: positive)

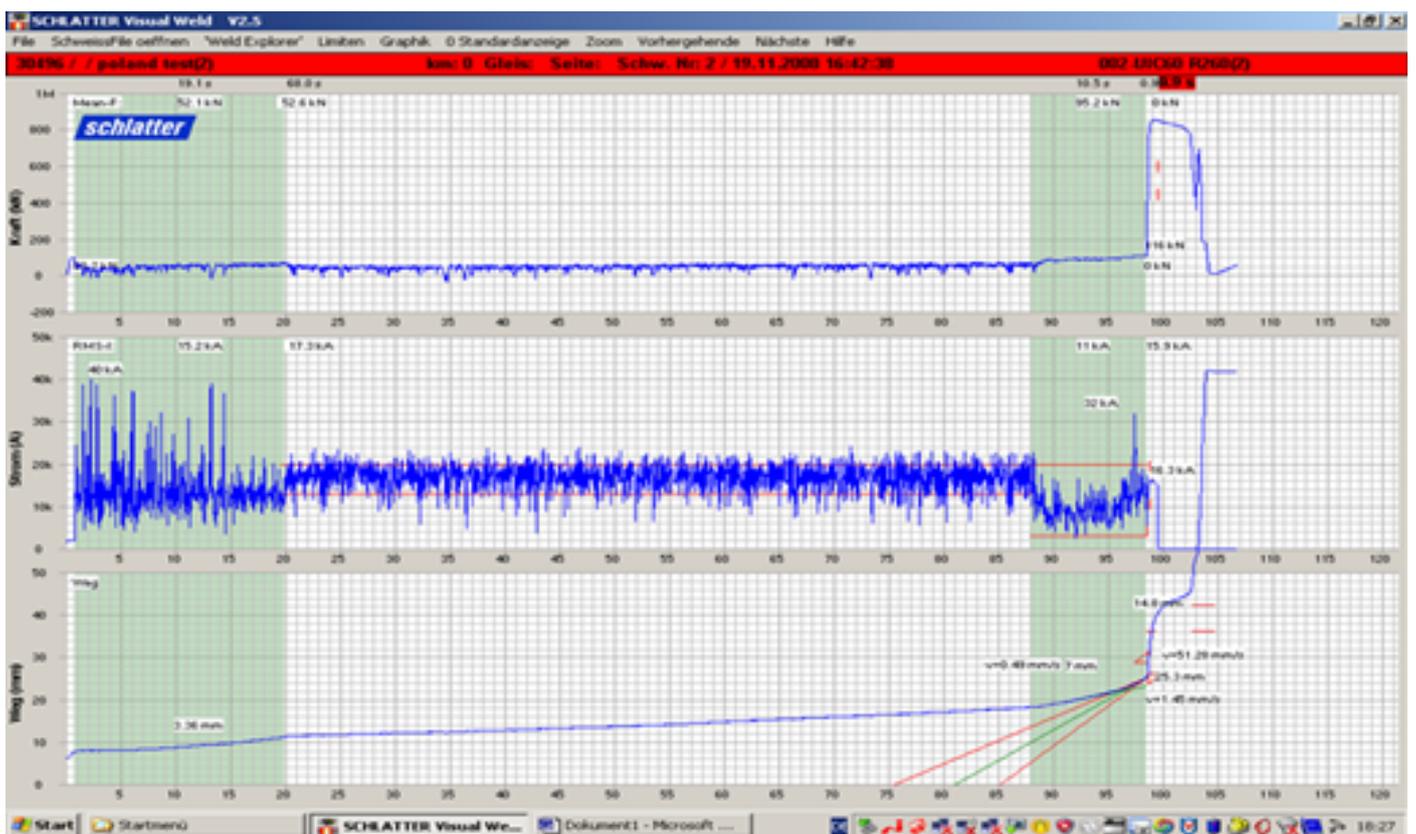


Fig. 6. Butt welding with pulsed flashing; force, current, distance in the function of time (assessment result: negative)

functionality is possible because of, among other things:

- adjustability of current characteristics (continuous flashing, impulse flashing and multi-impulse flashing) to changeable material

- characteristics of the rail (chemical composition, structure, size of the rail section),
- automatic alignment of rail ends in the vertical and horizontal plane,
- control of weld cooling time,

- heat treatment of the weld,
- computer-aided systems controlling the process, operating modes and quality management [6].

In each case, the board computer prepares the print-out related to the analysis of process parameters and qualification of the weld (Fig. 3).

The next diagram, (Fig. 4) presents a welding process divided into the following phases:

- welding preparation,
- initial flashing,
- impulse flashing (also referred to as pulsed flashing),
- flashing at an increasing rate,
- upsetting,
- cutting off flash.

Figures 5 and 6 present diagrams (from the recorder) containing assessment; the red bar in the graph (see Fig. 6) indicates the improper course of the welding process and the necessity of cutting the welded joint out.

## Two-way welding system

### *Two-way welding system with a rail welding head*

Two-way rail welding system Supra Road Flex with head AMS 100 (Fig. 7) is used for the welding of rails directly on the track. The welding head is mounted on a lorry equipped with a



Fig. 7. Two-way rail welding system Supra Road Flex with head AMS 100

road-and-rail chassis. Because of its power supply system, the welding system can work autonomously.

The (rail) running gear of the system is provided with its own drive and lifting system enabling the lifting of the vehicle for riding on the track so that the wheels for travelling on the road do not come into contact with rails. In turn, when the vehicle travels on roads, wheels for travelling on the track are lifted up and blocked. The vehicle can be placed on the track at the railway crossing or by means of an auxiliary ramp. The welding machine can weld short rails (having a length of 6 metres) and long rails (up to 340 metres in length) of profile 60E1, 54E1, 49E1, Ri 60 and derivative profiles. The welding system is characterised by a high efficiency of up to 30 welds per an 8-hour working shift.

### *Welding head AMS 100*

The head satisfies the same quality-related standards as stationary butt welding machines manufactured by Schlatter. The housing of the head makes it possible to grab the rail with clamps provided with copper electrodes. The welding process is controlled by the SWEP type processor (Schlatter). The welding process control system monitors and records welding parameters including, distance, force and current in the function of time.

The welding process can be programmed on an individual basis. The welding process programme can be divided into a maximum of 10 steps. Parameters monitored at each step include force, distance and current in the function of time.

Figures 8–11 illustrate the universal application of the welding head. Electrodes can be exchanged directly at the construction site. The welding machine is equipped with a complete set of electrodes for the welding of rails 49E1 and 60E1 (railway rails) or dock rails 60R1 and 60R2 (tram rails).

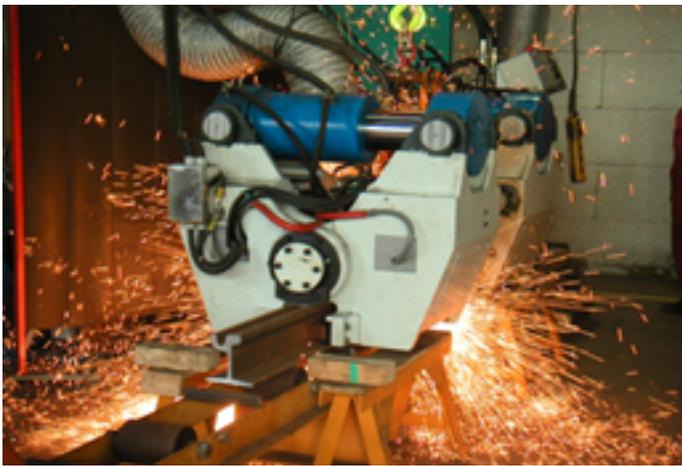


Fig. 8. Welding head during the welding of the tram (dock) rail



Fig. 9. Element of the cutter for removing flash in the groove of the dock rail



Fig. 10. Removed flash (within the groove)



Fig. 11. Universal electrode for the welding of dock rails

### ***Application of resistance butt welding in tramway infrastructure***

In terms of tramway infrastructure, welding processes involve Vignoles rails and dock rails. Recent years have seen a growing interest of tramway transport companies in the joining of rails by means of resistance butt welding. The above-named increase in the popularity of the resistance butt welding technology is related to the use of two-way mobile welding systems, the mobility of which in urban infrastructure is highly appreciated. The ease of travel enables the intensification of work efficiency. Resistance butt welding is becoming a competitive alternative to thermit (fusion) welding, which, apart from being more laborious, is, because of the emission of thermite reaction accompanying gases, environmentally unfriendly.

Exemplary applications of resistance butt welding in tramway infrastructure are the following:

- Karlsruhe (Germany) – first investment stage involved the making of welds in a 3.5 km long tunnel; the final number of welds amounted to 600,
- Leipzig (Germany) – 120 welds,
- Magdeburg (Germany) – approximately 140 welds (process in progress),
- Amsterdam (Holland) – 400 welds,
- Hannover (Germany) – welding of rail into segments having a length of 120 m.

Presently, the welding of rails in tramway infrastructure primarily involves Vignoles rails of profile 49E1.

Also in Poland, the STRABAG company attempted to make welds joining dock rails of profile 60R2.

The test joints were subjected to a static bend test. The below-presented results justify an optimistic approach to the issue.

The tests were performed at Laboratorium PKP Polskie Linie Kolejowe SA Centrum Diagnostyki /Polish Railways Laboratory – Diagnostic Centre/. Table 2 contains the results of strength-related tests of the test joints. The assessment of all of the specimens proved positive, the bending force and deflection exceeded limit values. The quality of the joints was confirmed by visual tests, geometrical measurements and defectoscopic tests [7]. The above-named, successfully performed, tests were followed by the making of welded joints of a dock rail (profile 60R1) on a tram trackway in Gdańsk.

## Summary

The (pressure) welding of tram (dock) rails is a thing of the future. Because of the fact that the cross-section of the tram rail is asymmetric, the development of a tram rail welding programme poses a challenge for manufacturers of welding heads. However, the above-named issue is non-existent in the welding of Vignoles rails. It should be noted that the application of (pressure) welding in the joining of tram rails can quicken track-related works. Pressure welding constitutes an alternative process when joining tram rails. Particularly in cities with their high-density housing development, the elimination of (fusion) thermit welding, emitting

significant amounts of smoke, is fully justified.

## References

- [1] PN EN 13674-1:2011. Kolejnictwo – Tor – Szyna.Cz.1: Szyny kolejowe Vignole'a o masie 46 kg/m i większej.
- [2] PN EN 14811+A1:2010. Kolejnictwo – Tor – Szyny specjalne – Szyny rowkowe i związane z nimi profile konstrukcyjne.
- [3] WTWiO zgrzein w szynach kolejowych nowych łączonych zgrzewarkami stacjonarnymi. Wymagania i badania. Id-112. Warszawa, 2013.
- [4] Klimpel A.: Technologia zgrzewania. Wydawnictwo Politechniki Śląskiej, Gliwice, 1995.
- [5] Warunki wykonania i odbioru szyn kolejowych. Wymagania i badania. Id-106. Warszawa, 2010.
- [6] Grzechowiak W., Wróblewski P.: Zgrzewanie szyn zgrzewarkami dwudrogowymi. IV Ogólnopolska Konferencja Naukowo-Techniczna. Spawalnictwo Dróg Szynowych – Jakość, Niezawodność, Bezpieczeństwo. Bochnia, 2014.
- [7] Grzechowiak W., Zaręba J.: Zgrzewanie szyn tramwajowych zgrzewarką dwudrogową. VII Ogólnopolskie Warsztaty Techniczne pt. Spawalnictwo Dróg Szynowych – nowoczesne technologie. Warszawa, 2019