Automated rail welding as a model for the future in track construction

Robot-assisted gas metal arc welding for greater efficiency and safety in rail maintenance

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Manual welding is one of the most complex procedures in the production of continuous welded rails. The fault potential is high; the handling of molten steel and the usually unergonomic posture of the welder leads to an increased risk of injury and frequently causes long-term health damage. Gas metal arc welding (GMAW) leads to a considerable improvement in safety, productivity and economic efficiency – provided it is applied correctly. Automation of this procedure with the use of robots raises the work quality and safety to a new level. Robel will put these benefits to the track from September 2020.

Optimised welding procedures and material properties for use on the track

1. Improvement in process quality

Process deviations during welding mainly arise due to poor working conditions (lighting, weather, open adjacent line), insufficient technical knowledge and imperfect material. Robel optimises this work step by using welding robots specially adapted to track construction. The robots are located in a mobile cell and carry out each job with persons and the environment being protected and without being exposed to any safety risk. There are no more below-optimum results due to bad visibility, adverse environmental conditions or welder qualifications. Monitoring of the process and weld parameters ensure the integrity of the automated work sequence. Future developments envisage a transmission of the measured data to an AI system to ensure the continuous optimisation of the process.

The high level of process safety of robotic welding was already proved in other industries many years ago: Sheet metal in car manufacture and plate in shipbuilding have been welded successfully by robots for a long time. For the automation of the welding process, Robel is working together with industrial partners who bring many years of experience in robotic welding to the project. Furthermore, the company itself has been using stationary welding robots for the manufacture of bogies for more than 20 years.

2. When does a welding robot become economical?

The investment expenditure for joint welding of rails using the thermite welding process is low compared to the purchase of a mobile robot welding unit. However, the GMAW process has major advantages which lead to a reduction in costs – the investment is written off within a few years.

Low material costs

The automated welding process uses considerably less material. The costs per weld, without taking account of the shorter turnaround time, are approximately 1 to 10 compared to thermite welding.

Shorter working and possession times

A reduced preheating temperature, depending on rail type, of about 200°C to 300°C and the low local introduction of energy shorten the heating and cooling phases; thermite welding is carried out with preheating temperatures of about 900°C to 1000°C.

Flexible deployment

Many rail cross-sections and steel qualities can be welded without major retooling. Properties such as a hard austenitic manganese frog or a low-temperature ductile joint are achieved by alloying the filler materials and welding gases.

Precise work result

The process reliability is maintained in a defined temperature range. The condition and skill of the welder no longer affect speed and quality of the weld.

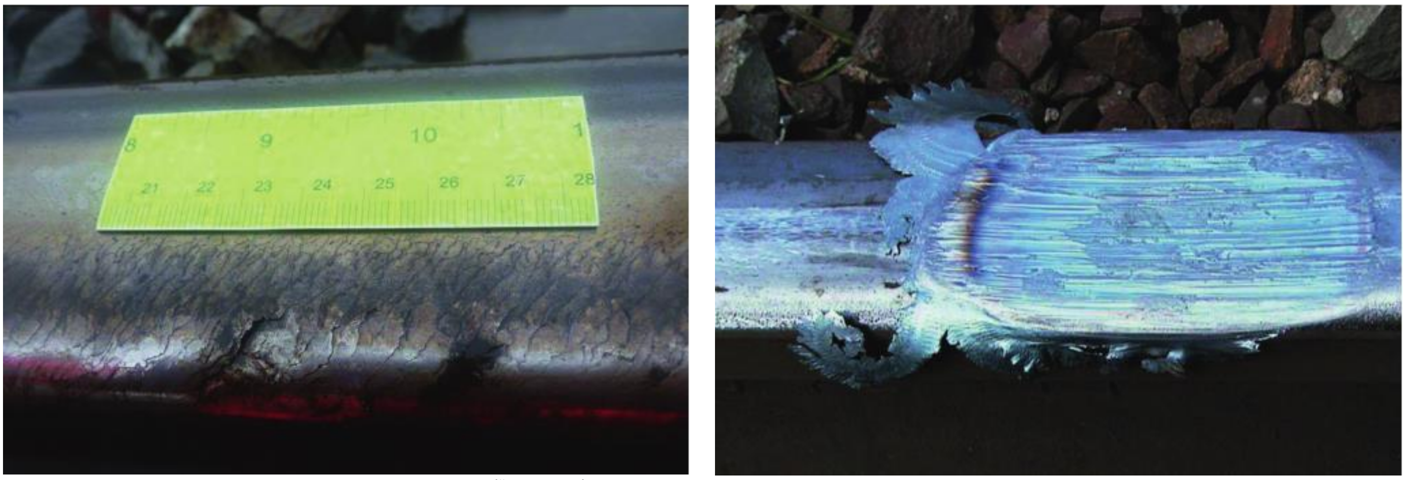

Fig. 1a/1b: Repair, don't throw away: Head checks ("oblique") and deep wheel slip marks, which normally require a closure rail replacement, can be repaired or built up and optimised with automated GMAW welding *Source: SBB and Alfred Wöhnhart archive from Handbuch Eisenbahninfrastruktur*

Furthermore, the automated GMAW system comprises all components for the most varied applications within the scope of welding for track construction, such as:

- joint welding of rails; final weld when inserting closure rail sections;
- repair of faults or damage after a preceding cutting step at the location concerned in almost all areas of the rail cross-section or at important components of switches (e.g. wear, crushing, rolling contact fatigue and corrugations);
- the complete rebuilding of running edges, frogs or wheel slip marks (Fig. 1, Fig. 2).

3. High material quality for durable rails

The welding method determines the width of the heat affected zone (HAZ): The GMAW process reduces the HAZ due to lower pre-heating temperatures and a welding area which is smaller by up to 50 per cent compared to thermite welding (Fig. 3, Fig. 4, Fig. 5). The height of the hardness peaks as well as the loss of hardness can be precisely adjusted using special filler materials. For special applications, the hardness peaks are relaxed again with a subsequent local heat treatment. The ground face becomes finer grained (Fig. 6), the rail surfaces considerably more robust and the contact surface for the wheel is smaller. The result is a longer rail service life.

The values for the strength and elasticity listed in EN 14587-2 for flash welding were used as test values to provide the positive proof of suitability of the GMAW process (Tab. 1). The material used for GMA welding combined with a markedly reduced working temperature leads to optimum material quality: the weld is more elastic, the susceptibility to fracture is reduced significantly.

Automated GMA welding compared to the current processes in track construction

Outstanding welding quality is achieved with flash welding machines. However, this combination of electric machine and machine tool, originally from stationary utilisation, is associated with high purchase costs and is used exclusively for joint welding. It is not possible to carry out small repairs economically; build-up welding is completely impossible.

Thermite welding requires a considerably lower investment in plant and machinery; however, the costs per weld are higher due to high material and staff costs. Moreover, the process is inflexible, error-prone and, due to the high temperatures and bad ergonomics, a constant threat to the health of the operator. For the good quality of thermite welds well trained, tested and certified welders are an indispensable requirement.

The new GMAW process using welding robots is cheaper than flash welding and more precise and safer than thermite welding. The greatest benefit is the flexible setup of the system – from build-up welding via joint welding to 3D reconstruction in various support vehicles (Fig. 6).

Safety for users, environment and traffic

The safety of man and environment over the complete process period is an essential condition for the successful application of welding technology in railway construction. Robel embraces the patented combination of enclosing and monitoring.

- The robot is used exclusively in a closed work space monitored by sensors. Unintentional entry to this

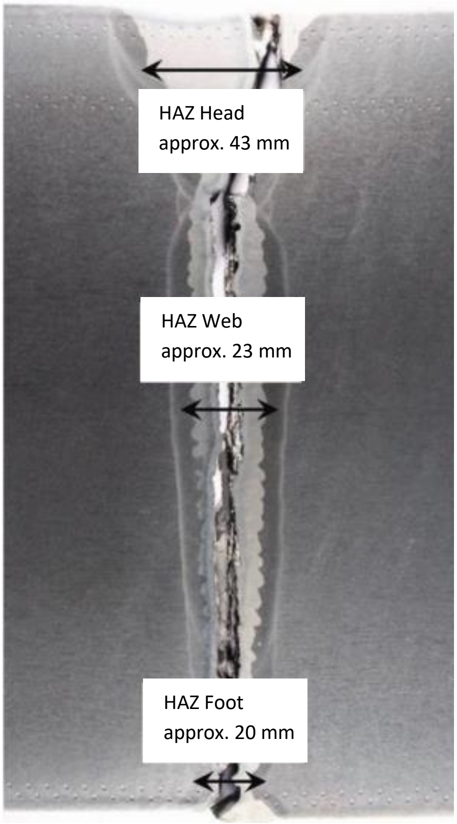

Fig.2: Minimising weak points: The GMAW process reduces the heat affected zone by 50 per cent compared to thermite welding.

Source: ROBEL Bahnbaumaschinen GmbH

workspace or danger to passers-by from the arc (electric ophthalmia, dazzling) is impossible.

- Noise and exhaust emissions, fine particulate dust and the process gases arising are encapsulated, extracted, treated and removed.
- The operator works at a safe, ergonomic operating and control station outside the robot workspace and monitors the automatic process from there.

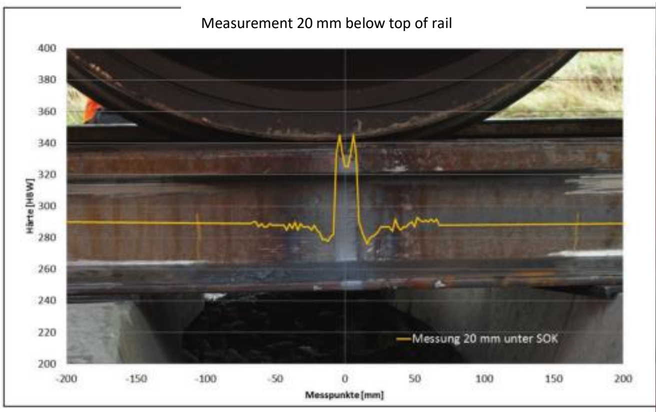

Fig.3: Maximum strength: The filler materials used for automated welding harden the material and thus reduce the heat affected zone – this is not impaired by the wheel.

Source: Plasser & Theurer

Fig. 4: Dents caused by wear in the annealing zone of a thermite weld

Source: ÖBB

	Minimum deflection [mm]	Minimum bending force for approval and production [kN]
	Steel qualities R220, R260, R260Mn and R350HT	Steel qualities R260, R260Mn and R350HT
Rail profile 60E2 EN 14587-2; Table A.1	**>= 20**	**>= 1600**
Rail profile 60E2 – R260 ROBEL	**34.8**	**1723**

Table 1: Higher elasticity, lower susceptibility to fracture: comparison of the values achieved with automated welding with those for standard EN 14587-2 applicable to flash welding.

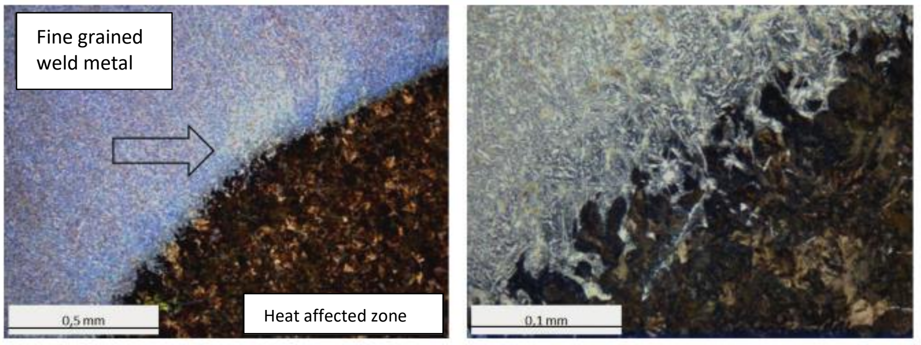

Fig. 5: Metallurgical examinations of etched sample rail sections with 3% HNO3 show clearly a finer grained ground face at the transition from the weld metal to the heat affected zone.
Source: ROBEL Bahnbaumaschinen GmbH

Fig. 6: Instead of replacing parts, the original geometry is reconstructed quickly in layers and thus completely reinstated. *Source: ROBEL Bahnbaumaschinen GmbH*

Due to this protective concept, the use of the track construction robot is considerably faster and more cost effective than setting up a conventional work site. The safety assessment required is carried out largely standardised and automated. This facilitates planning of the work site and reduces the time for securing and set-up of the site to a minimum.
All welding parameters, such as welding current and voltage, wire feed and gas flow as well as the energy required, are recorded via defined controls and, if required, combined with an active control which further improves the welding process and consistently avoids scrap and mistakes. In addition, there is the option of recording the current environmental conditions, date and time, GPS and line data of the work site as well as the rail condition and to store this data for future evaluation. Thus, based on the available data and the traffic utilisation, preventive measures for maintenance of the rails can be arranged for every line section that is worked on by automated means.

User friendliness from welder to machine operator

The sensitive interface between man and robot is based on program-controlled work. The controller can be operated largely intuitively; no programming knowledge is required. Any necessary additional skills are acquired by the users in a course lasting several days. After only about two weeks of training, the operators are able to carry out even more complicated set-ups on the robot. In addition, Robel provides support with an optional 24/7 online service: experts connect live to the operation, optimise the process steps or remove faults via remote maintenance.

Future-proof through automation

The robot welding technology changes the work processes of rail maintenance at a fundamental level and thus provides solutions for the most urgent topics in track construction – lack of staff, process speed, work safety and environmental protection:

- Resurface welding from a few millimetres to several metres of rail and of switch components increases the life of these elements of railway infrastructure.
- Instead of replacing parts, the original geometry is reinstated quickly. This reconstruction of switch components and frogs in layers is similar to a 3D printing process (Fig. 7).
- Well-known repair procedures, such as cutting out rail faults followed by build-up welding, require considerably less time and staff.

Current process	New process	Delta investment costs	Delta process costs
A three-person permanent-way gang cuts out a piece of rail and then resurfaces it in several layers. At the end the surface is finished by grinding.	A welding robot in a container above the damaged section carries out all the tasks. It is operated by only one member of staff.	€ 600,000 purchase cost for the robot container	- 2 staff € 95,000/year - 50% process time = 2 times the number of work sites in the same time
Joint welding by means of thermite welding	Joint welding by robot in basic rail vehicle	€ 450,000 purchase cost for robot vehicle	- thermite welding pack - 70% process time 3 times the number of welds per shift = less waiting time for the permanent-way gang
Replacement of frog with two-way excavator, track vehicle and permanent-way gang (6 persons)	A welding robot in a container repairs the frog by means of 3D printing. It is operated by 2 people.	€ 600,000 purchase cost for the robot container compared to about € 2 million cost for a track vehicle and road-rail excavator	- 4 staff € 190,000/year - frog - 4 thermite welding packs - 20% process time

Table 2: Automated GMA welding compared to conventional methods

- Joint welding of rail joints becomes faster, leading to considerably lower heat input and less overhang. This reduces the cooling time; shearing off is no longer required (Fig. 8).
- The operator does not come into contact with the work area at any time; the work is carried out irrespective of high temperatures, hazardous substances and weather conditions.
- If a laser is used for welding, this can also be used for cutting tasks.

Conclusions

Welding is a critical process in rail maintenance and an important cost and time factor for maintenance companies. In view of the increasingly complex requirements made on track construction, in particular with regard to speed as well as process and work safety, there is no way around optimisation of the welding process. The new GMAW process in conjunction with automation by using a welding robot provides one possible answer to the question how welding can be made even safer, more economical and more precise.

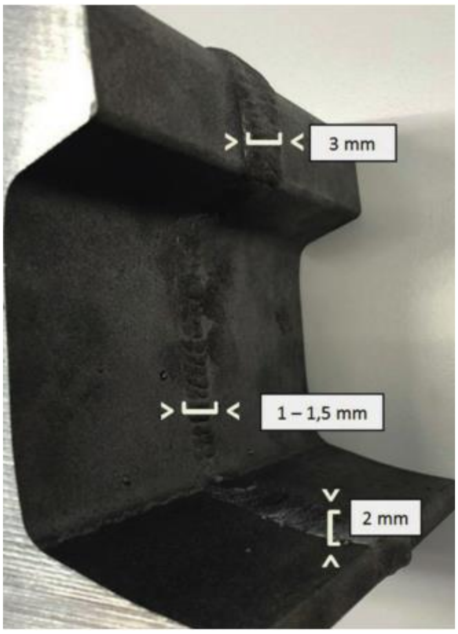

Fig. 7: The projecting weld bead of an automated joint welding at the current state of development: Sufficient material for finish grinding is available at the railhead; no further work is required at the rest of the rail.
Source: ROBEL Bahnbaumaschinen GmbH

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