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WELDING OF RAILS WITH NEW TECHNOLOGY OF ARC WELDING

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The paper presents up-to-date achievements in application of a new method of arc welding of various rail profiles, defined as the Consumable Guide Enclosed Arc Welding (CGEAW). The welding process is based on a combination of specially prepared electrode, which core is identical in chemical composition to welded material, or belongs to its class, and self-shielded flux-cored wire. The method does not require protective atmosphere or usage of additional powdered materials (flux). The process is semiautomatic. Except the standard power source, the welding equipment has been designed by the E.O. Paton Electric Welding Institute.

Keywords: rails, welding, mechanical properties, high efficiency, welding time

INTRODUCTION

Electroslag welding (ESW) and electrogas welding (EGW) are the most common methods for single pass welding of steel materials of increased thickness. If multi-pass welding is technologically required, there is a possibility to apply one arc welding method or a combination of several methods (SMAW, GMAW, FCAW or SAW). If considering productivity and quality of the weld, all mentioned methods have their advantages and shortcomings. The methods ESW and EGW are characterized by high productivity, but due to overheating of weld metal and surrounding zone, they do not assure necessary mechanical properties of welded joints. If compared to ESW and EGW methods, welding by SMAW, GMAW, FCAW and SAW has different influence on mechanical properties of welded joints, Optimal technology for welding of steel materials of increased thickness shall have all properties that are defined as the best of all previously mentioned arc welding methods.

The first experiments focused on development of the new welding method for steel materials with increased thickness were presented in papers of Pashenko [1] and Cable [2], as well as in papers [3, 4]. The E.O. Paton Electric Welding Institute, National Academy of Sciences, Ukraine, developed the new welding method known as **Consumable Guide Enclosed Arc Welding - CGEAW).** The CGEAW method (Figure 1) is using self-shielded flux cored wire that is delivered through a longitudinal slot in a specially prepared plated-consumable electrode. Due to this concept of additional welding material, welding is performed in a narrow gap of 12 - 16 mm, and in special cases from 8 - 22 mm [5].

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In consumable electrode, there is specially prepared and applied electro-isolated layer (shield), being up to 1,5 mm thick. This layer, made of quality base metal, shall provide high quality protection of a liquid phase of weld metal by using developed gas atmosphere and formed slots. At the same time, shield helps to refine and alloy the weld metal. In order to increase the above-mentioned effects, flux-cored wire is delivered to the welding zone through the pre-prepared longitudinal slots in the plated electrode. There are two variants of CGEAW welding method developed, as depending on the geometry of the welded elements' cross section, as follows:

- Stationary consumable electrode for rods and plates of up to 80 mm width (Figure 1) - (SCE),
- Oscillatory consumable electrode for elements of up to 300 mm width - (OCE).

The basic properties of the CGEAW method are: [6]

- the amount of deposited material is up to 20 kg/h,
- possible single pass welding of steel material of up to 300 mm thickness,

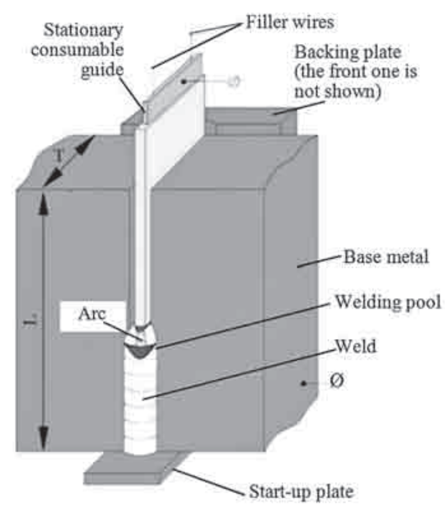


Figure 1 Stationary guide process [6]

– simple joint preparation,
– narrow-gap welding,
– fully automated process,
– simplicity of equipment usage and
– welding time is minimal.

RAIL WELDING USING CGEAW METHOD

Welding of rails is particularly interesting for CGEAW method. Rail welding is an integral part of railways overhauling. Quality of the welded joint affects technical and operational parameters of the upper (working) rail surface, as well as the speed of transport means, train, tram or a crane. Properties of material used for rails dictate the selection of technology, and additional materials for rails welding. If considering also on-site conditions, air flow, air temperature and moisture, as well as temperature of rail material, welding activity is very demanding and complex [7]. In the beginning of rail transport development, joining of rails was performed by riveting. Nowadays it is performed by welding. Welding provides homogeneous welded joints of rails, which significantly reduces the resistance in movement of all transport means - trains, subways, trams and industrial transport, thus increasing their speed [8]. In this way, dynamic forces that directly affect stability of driving (driving without an impact) are substantially reduced, thus prolonging the lifetime of rails' working surface. Due to the fact that welding of rails is done on site during traffic interruption, the following requirements must be fulfilled:

– time used for welding must be reduced to minimum in order to fit into time-frame of traffic hold,
– welding equipment must be portable,
– welding shall be easily adaptable to all forms of cross-sections of used rails,
– longitudinal shifts of rails must be turned off, and
– quality of welded joints shall not depend on welders' performance.

The most commonly used rail welding procedures are: flash-butt welding, gas-pressure, aluminothermic and arc welding. None of those rail welding procedures does fully meet the above requirements. The main disadvantage of flash-butt welding is expensive equipment of large dimensions, which makes its on-site application difficult. Furthermore, this procedure requires shifting of rails that are welded, which complicates the whole process of overhauling. Shortcomings of rail joints welded by gas-pressure were observed during the 80's, when many welds fractures occurred due to increased axial load. This welding process was then replaced by flash-butt welding [9]. It should be noted that gas-pressure welding had wide application in the USA, in workshops for rail welding. Rail welding with coated electrodes (SMAW) is nowadays mostly used for welding of tram and crane rails. Application of this welding procedure has two main drawbacks: it depends on welders' competence, because of which welds quality is not provided continuously, and welds have low productivity. The Berlin Transport Company (BVG), which maintains the Berlin Metro, faced problems with protection of weld bath due to strong air currents, and therefore they had to give up the MAG welding process. Application of the rail welding procedure with coated electrode resulted in lower productivity of welds. By applying the procedure of innershield-welding with flux-cored wire (Figure 2), the MIG/MAG process proved as a correct choice, if using the TransSynergic device. In comparison with SMAW, its productivity was increased by 30 % [10].

Figure 2 Specially optimized burner characteristic for TransSynergic system [10]

The Japanese Nippon Steel Corporation developed a procedure for automatic arc welding of rails, which provides a high quality welded joint if combined with additional material and special heat treatment [11,12]. Irregardless of the automated welding process, the time required for one quality weld is still high (65 min), i.e. productivity of the process remained low (Table 1).

Table 1 **Results of welding time study (AREA standard 132 lb – 59,87kg) [11]**

Pre-treatment / min.		Welding time / min.
Groove setup	Welding preparation	
33	12	20
Post-treatment / min		
Post-treatment preparation	Heating-trimming-cooling	
6	20	

The most widely used procedure for welding of all rail profiles is aluminothermic welding (Figure 3).

The process is characterized by unstable quality of welded joints, and the main parameters that determine the quality are selection of additional material TERMITES (mixture of oxide and aluminum), and the preparation of welding. Therefore, the subjective factor is very visible in this welding process, which requires highly skilled workforce. The CGEAW rail welding process produces a full-

Figure 3 Types of rail profiles

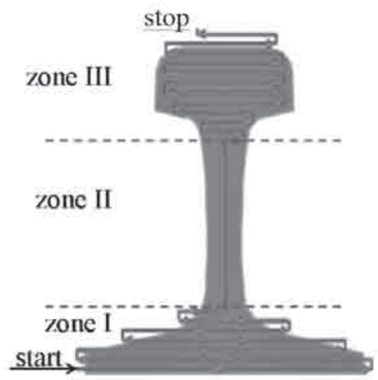


Figure 4 Schematic presentation of electrode movement during CGEAW

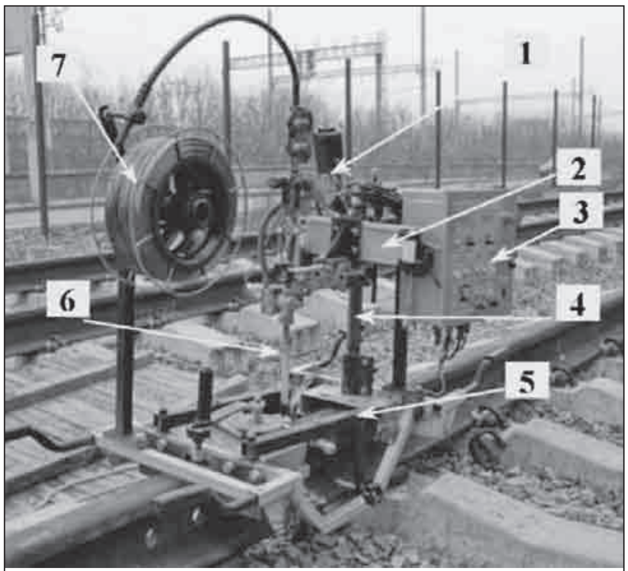
Figure 5 Ceramic backing with metal insert

penetration square-butt weld of rails ends with the oscillation of the consumable electrode with variable amplitude, which depends on the part of welded rail (Figure 4). During the welding of the rail base section (zone I - Figure 4), the ceramic backing with a metal insert is used to establish the arc (Figure 5). Along with moving into the web (zone II), copper shaping members are manually enclosed to both web and head (zone III) of rail sections, without interruption of the welding process.

The CGEAW welding process can be referred to as improvement of the conventional enclosed or puddle arc welding. Due to automation, productivity of CGEAW procedure is increased for 2-3 times. Also, welded joints are of extremely high quality and, more importantly, very stable. Moreover, the critical impact of welders' competence is eliminated.

The E.O. Paton Electric Welding Institute developed special equipment and materials for welding of all types of rails with the CGEAW welding procedure. The ARS-4 welding device is presented in Figure 6.

Although the welding of large cross-section steel is presented, preheating of rails' ends is not done. Exception shall be made if metal temperature is < 5 °C, in the case of which a joint shall be heated up to 250 - 300 °C. This procedure can be applied for welding of rails if the air temperature is higher than - 5 °C. The ARS-4 device is characterized by simplicity and portability. Because of its changeable shaping members, it can be easily used for welding of rails of different types and sizes. As a source of power, there is the



1-The mechanism for delivering of flux-cored wire;
2-Rails for horizontal positioning of electrode;
3-Control Panel; 4-Holder for positioning of electrode by height; 5-Manual mechanism with copper coating;
6-Consumble electrode/wire; 7-Welding wire on coil

Figure 6 ARS-4 device for rails welding

Forsaz-500 inverter [13]. Power can be provided by a three-phase network of 380 V, as well as by independent power sources of 25-30 kW, with the power required for welding of up to 15 kW. Time required for arc welding of P65 rails (rails of 65 kg) at arc current of 250 - 300 A is approximately 15-20 min, which allows a team of five people (two welders and 3 support staff) to provide 16 high-quality welds during one shift. Flux-cored wire PP ANPM-4 (E.O. Paton Institute) is used for welding of rails and within appropriate welding technology, it assures necessary mechanical properties of welded joints. Table 2 presents results of mechanical tests conducted on weld metals and welded rail joints gained by CGEAW procedure.

Table 2 **Mechanical properties of CGEAW welds**

Weld metal Hardness	280 - 320 HB
Weld metal Tensile Strength	800 - 900 MPa
3 - Point Slow Bend Test results: - Rupture Load - Deflection	 1 500 – 1 650 kN 16 - 22 mm

In the period 2009-2011, the CGEAW welding procedure was extensively used in Ukraine to weld more than 1 200 rail joints of P65, T62 and LK-1 types within tram lines reconstruction in Kyiv and Lvov. The main advantages of this welding procedure are:

– high productivity of 2-3 welds per hour,
– no shielding gas (atmosphere) or flux required,
– significantly higher and more stable quality of welded joints in comparison with manual arc welding and aluminothermic welding,
– no preheating or heat treatment of welds,
– low power consumption - required power of up to 15 kW,

– equipment is easily adapted for welding of rails of different shapes and sizes,
– high mobility, which is very important for overhauling works.

CONCLUSION

Aluminothermic welding, as the most common process for welding of rails, does not fulfill necessary technical and economic requirements. Practical application of CGEAW rails welding procedure proved economical. If compared to conventional methods of arc welding, the advantages of this process are found in the fact that the equipment is portable, welding preparation is simple, and welding process enables extremely large deposition rate of filler material. The required slot between welded rails is 12-16 mm, which can be used as a good indicator of process effectiveness. An additional advantage of the CGEAW method of rails welding is absence of the need for shielding atmosphere.

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Note: The responsible person for English language is M. Šuto, M.A., J.J. Strossmayer University of Osijek