



WELDING OF COGIDUR BLOCKS (1.8715 GROUP 3.2) WITH SELF-SHIELDING WIRE-PROCESS 114

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Abstract – This paper presents the welding technology used for a tramway turnout, whose main components are Cogidur blocks (material No. 1.8715, Group 3.2). The blocks are joined by a butt weld using copper backing plates and a self-shielded flux-cored wire, employing the 114 welding process. The paper also provides an overview of the inspection and testing performed on the welded joint, including visual testing (VT), penetrant testing (PT), ultrasonic testing (UT), hardness testing, and macrographic examination of the weld cross-section.

Keywords –tramway turnout, Cogidur block(s), self-shielded flux-cored wire.

1. INTRODUCTION

The processes used for joining tramway switch components in accordance with EN 14811 are as follows:

- aluminothermic welding (AT);
- electric resistance welding (ET);
- flux-cored arc welding with self-shielded wire (FCAW);
- MAG welding using solid wire with inert gas shielding (MAG-IBE).

Electric resistance welding (ET) of rails is predominantly used under workshop conditions, although mobile welding equipment for on-site applications is also available. Nevertheless, aluminothermic welding (AT) remains the most commonly used rail welding process, both in workshops and in the field. Since 1996, self-shielded flux-cored arc welding (FCAW) has also been applied for rail joining. With the approval of Deutsche Bahn AG, the American company Lincoln Electric developed and introduced this process for welding railway switch components made of rail steels with tensile strength values ranging from ($R_m=685 \text{ N/mm}^2$) to ($R_m=885 \text{ N/mm}^2$). The process was intended for railway lines with axle loads of up to 10 t and operating speeds below 80 km/h.

Since self-shielded FCAW is an American welding technology, the consumables and welding equipment required for this process have traditionally been manufactured in the United States of America (USA). In Europe, particularly in France, there was a growing interest in developing a European-based technology for welding tramway switch components, using welding consumables and equipment manufactured in Europe.

This led to the development of a rail and block welding process based on the MAG welding process. In this technology, a specially designed extension is fitted to the welding torch, enabling welding to be performed within grooves with depths exceeding 150 mm.

2. EXPERIMENT

2.1 Base Material

During the fabrication of tramway switches at crossing sections, the rails were replaced with Cogidur (Hardox 400) blocks due to their higher hardness. Following welding, a groove is machined into the blocks to reproduce the rail groove geometry.

The block material is Cogidur (1.8715, Group 3.2), with a hardness exceeding 400 HB.

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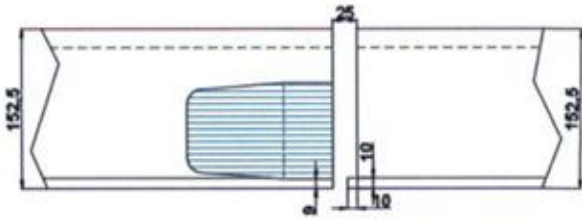


Fig 1. Joint preparation drawing of the blocks

Table 1. Chemical composition of the base material

Basic material	C %	Mn %	Si %	Ni %	Cr %
Cogidur	0,17	1,3	0,42	0,47	1,8
Basic material	Mo %	Ti %	V %	Cu %	Fe %
Cogidur	0,1	0,005	0,003	0,35	0,001

Table 2. Mechanical properties of the base material

Basic material	Rm N/mm ²	Rv N/mm ²	L %	Pv (J)	Hardness HB
Cogidur	1355	1005	13	-40°C 53J	414-427

2.2 Methodology

Prior to welding, the blocks are positioned with a root gap of 25 mm. The edges of the blocks are ground to a bright metallic surface. After verifying the alignment and concentricity of the blocks, clamps are installed to maintain the specified distance accurately.

Copper backing plates are then positioned on both sides of the blocks, while a grooved copper backing plate is previously installed underneath the joint. Prior to welding, the blocks are preheated using a propane-butane gas torch over a length of 500 mm on each side of the joint. This procedure ensures that the material is adequately preheated through the thickness of the blocks.

The preheating temperature is maintained at 150 °C, with a maximum permissible temperature of 200 °C. Following preheating, the blocks are welded using two passes. The copper backing plates are then removed, and an additional welding pass is deposited.



Fig 2. Preheating of the joint



Fig 3. Preheating temperature control

Since the copper backing plates are installed after the initial preheating, the joint is reheated due to heat loss and subsequent cooling of the material. Positioning the copper backing plates on a previously heated joint is difficult to perform and requires a high level of welder skill. The temperature of the block material is therefore measured, and provided that the measured temperature does not deviate by more than 10% from the recommended value, welding is continued.

Welding is performed continuously until approximately 30 mm of the joint height remains unwelded. At this stage, the copper backing plates are removed, and the weld is cleaned of slag using a pneumatic tool equipped with vibrating wires.

The remaining 30 mm of the joint height is welded using stainless steel electrode wire by the

MAG-IBE process. In the SS-FCAW process, this section is deposited using a self-shielded hardfacing wire with a hardness of approximately 30 HRC.

Throughout the welding process, the welding current is continuously monitored, with deviations kept to a minimum relative to the values specified in the WPS.

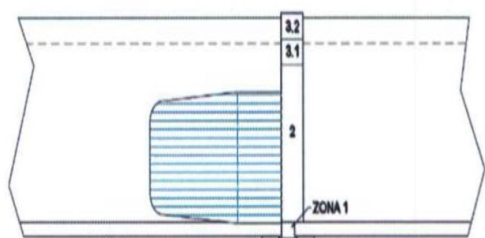


Fig 4. Welded joint – cross-sectional view along the joint height

2.3 Welding Consumables for the Joint

For welding the Cogidur blocks using the MAG-IBE process, an electrode wire conforming to EN 14341-A, classification G42 5 M/CG3Si1, commercially designated OK AristoRod 12.50, with a diameter of Ø1.2 mm, was used.

The final 30 mm of the joint was welded using stainless steel electrode wire conforming to EN 14343-A, classification G 18 8 Mn, commercially designated OK Autrod 16.95, with a diameter of Ø1.2 mm.

Table 3. Chemical composition of the welding consumables

Additional material	C %	Si %	Mn %	P %	S %
OK AristoRod 12.50	0,07	0,8	1,46	0,009	0,01
OK AutRod 16.95	0,08	0,9	6,9	0,03	0,01

Additional material	Cr %	Ni %	Mo %	Cu %	Ti %
OK AristoRod 12.50	0,02	0,01	0,01	0,02	/
OK AutRod 16.95	19,0	8,1	0,02	/	/

Table 4. Mechanical properties of the welding consumables

Additional material	Rm (N/mm ²)	Rv (N/mm ²)	Izduženje (%)	Pv (J)
OK	560	480	26	-40°C

AristoRod 12.50				60
OK AutRod 16.95	640	450	41	-20°C 130

For welding the Cogidur blocks using the SS-FCAW process, a self-shielded flux-cored electrode wire conforming to EN 17632, classification T 38 Z V N3, commercially designated NS 3M, with a diameter of Ø2.0 mm, was used. The final 30 mm of the joint was deposited using a self-shielded hardfacing electrode wire conforming to EN 14700, classification T Fe 1, commercially designated Lincore 33, with a wire diameter of Ø2.0 mm.

Table 5. Chemical composition of the welding consumables

Additional material	C %	Si %	Mn %	Al %	Cr %
Innershield NS-3M	0,2	0,26	0,36	1,36	/
Lincore 33	0,15	0,7	2,0	1,6	2,0

2.4 Welding

Two welding techniques are used. In the first technique, the electric arc is directed along the centerline of the joint, while welding is performed at higher current levels.

The second technique employs lower welding currents, while the electric arc is directed toward one side of the joint during one pass and toward the opposite side during the subsequent pass. This technique enables greater penetration into the side walls of the joint.



Fig 5. SS-FCAW welding process

The preheating temperature for the specimen welded using the MAG-IBE process was 200 °C, whereas for the SS-FCAW welding process, the preheating temperature was 150 °C.



Fig 6. Appearance of the welded joint prior to hardfacing

After welding using the MAG-IBE process, the specimen is post-heated to a temperature of 200 °C and maintained at this temperature for 1 h. It is subsequently covered with a heat-resistant blanket and allowed to cool slowly. In the case of the SS-FCAW process, no post-heating is applied after welding; however, the specimen is covered with a heat-resistant blanket to ensure controlled cooling. The welding parameters for the MAG-IBE process are specified in the WPS. The welding current ranges from 250 A to 270 A, while the arc voltage is approximately 29 V. The welding speed ranges from 25 cm/min to 27 cm/min, depending on whether the root section or the final passes of the joint are being welded. The heat input ranges from 1.22 kJ/mm to 1.39 kJ/mm.

The welding parameters for the SS-FCAW process are specified in the WPS. The welding current ranges from 300 A to 320 A, while the arc voltage is approximately 30 V. The welding speed ranges from 22 cm/min to 24 cm/min, depending on whether the root section or the final passes of the joint are being welded. The heat input ranges from 1.83 kJ/mm to 2.09 kJ/mm.



Fig 7. SS-FCAW welded specimen

3. RESULTS AND DISCUSSION

3.1 Non-Destructive Testing

Twenty-four hours after welding, a visual and dimensional inspection was performed, covering both the welded joint itself and the parallelism of the blocks, as well as any possible deformation or shrinkage.

Subsequently, the welded specimens were subjected to liquid penetrant testing and ultrasonic testing. A critical stage occurs when the copper backing plates are removed and, following cleaning and preheating, welding is resumed. At this stage, welding imperfections such as lack of fusion and non-metallic inclusions may occur.

3.2 Destructive Testing

Since the results of the non-destructive testing of the specimens were satisfactory for both welding processes, the specimens were subjected to destructive testing, including macrostructural examination and hardness testing.

The specimen welded using the MAG-IBE process was additionally subjected to a dynamic fracture test under cyclic loading.

The destructive testing was performed by RD Dijagnostika d.o.o., Belgrade, a laboratory authorized by TÜV SÜD Industrie Service GmbH



Fig 8. Ultrasonic testing of the welded joint

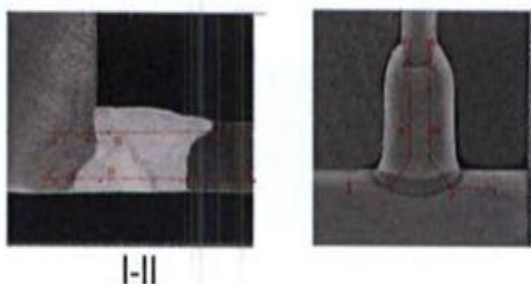


Fig 9. Macrosection of the specimen welded using the MAG-IBE process



Fig 10. Macrosection of the specimen welded using the SS-FCAW process

3.3 Hardness Testing (MAG-IBE Process)

Table 7. Hardness test results

Art./Last: - Type / Load: - Type / Charge: HV 10 – nur Informationen / only information

Nr. No.	Meßreihe Measuring Line Ligne de mesure	Grundwerkstoff Base Material Métal de base	WEZ HAZ ZAT	Schweißgut Weld Metal Métal déposé	WEZ HAZ ZAT	Grundwerkstoff Base Material Métal de base
366/24	1-5-11-7-3	423 425 420	212 214 216	161 164 158	225 224 221	430 428 427
366/24	2-6-13-8-4	426 419 422	215 218 219	163 161 157	218 216 220	431 426 424
366/24	1-5-11-7-3	421 420 425	214 212 215	159 157 155	224 220 218	432 430 427
366/24	2-6-13-8-4	420 421 427	218 220 221	161 162 158	219 223 225	428 427 424
366/24	1-5-11-7-3	414 424 426	208 210 212	158 156 154	224 221 218	420 424 425
366/24	2-6-13-8-4	422 425 427	211 213 215	159 161 163	216 214 217	415 417 419
366/24	1-5-11-7-3	417 419 421	210 212 215	157 159 161	215 217 218	421 419 417
366/24	2-6-13-8-4	415 414 418	213 216 218	155 157 159	210 212 214	414 415 418

Table 8. SS-FCAW process

HÄRTEPRÜFUNG EN ISO 9015 *)
HARDNESS TEST *) - ESSAI DE DURETÉ *)

Lage der Messungspunkte (Stellen) *)
Location of measurement points (Stellen) *)

Art./Last: - Type / Load: - Type / Charge: HV 10 (Anforderung / requirement: max. - 425 HV)

Nr. No.	Meßreihe Measuring Line Ligne de mesure	Grundwerkstoff Base Material Métal de base	WEZ HAZ ZAT	Schweißgut Weld Metal Métal déposé	WEZ HAZ ZAT	Grundwerkstoff Base Material Métal de base
1114/24	1-5-11-7-3	378 386 381	336 327 340	301 304 305	344 348 351	388 392 401
1114/25	2-6-13-8-4	358 380 408	319 330 342	311 318 321	305 369 378	377 384 398

3.4 Fracture Testing

A load test was performed on a CQB429 AWBW Cogidur-to-Cogidur-VMS specimen in accordance with procedure T15002P01. The specimen had a total length of 1200 mm and was welded using the MAG-IBE process at VOSSLOH MIN SKRETNICE d.o.o., Niš.

The four-point bending test was carried out at the Vossloh Cofiger Technology Center in Reichshoffen, France. The distance between the supports was 1100 mm, while two laser sensors were used to measure the displacement amplitude.

Prior to testing, the hydraulic cylinder was certified and the laser sensors were calibrated. The maximum applied stress was 130 MPa, with a stress amplitude ranging from 13 to 130 MPa. The test consisted of 3,000,000 cycles at a frequency of 5 Hz. The test was conducted from 24 June to 1 July 2024.

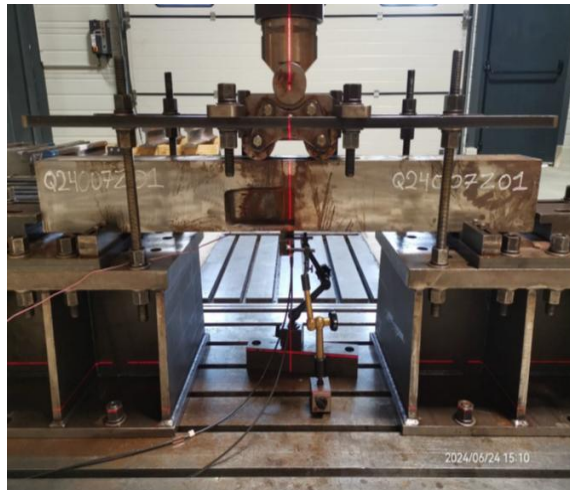


Fig 11. Fracture testing apparatus

Following the fracture test, no cracks were detected in the welded joint, indicating that the welding procedure was successfully performed.

A fracture test of the Cogidur specimen itself was not performed, since fracture testing of rail-to-rail and rail-to-Cogidur block specimens had previously been conducted. Both specimens successfully passed the fracture test. The rail-to-rail specimen withstood 5,200,000 cycles, after which a crack appeared in the welded joint; however, the crack length was less than 3 mm.

4. CONCLUSIONS

Welding using the MAG-IBE process is considerably more demanding than welding using the self-shielded FCAW process. This is primarily due to the lower heat input associated with the MAG process, which increases the likelihood of lack of

fusion at the side walls of the joint.

In addition, productivity is significantly lower for the MAG-IBE process than for the SS-FCAW process. The SS-FCAW process also requires a lower preheating temperature and does not require post-heating of the welded specimen. The hardness measured in the heat-affected zone (HAZ) is considerably lower for the MAG-IBE process, ranging from 210 to 225 HV, whereas for the SS-FCAW process it ranges from 311 to 370 HV. However, the SS-FCAW process provides significantly greater penetration into the side walls of the joint. This is consistent with the higher heat input values: 1.22–1.39 kJ/mm for MAG-IBE compared with 1.83–2.09 kJ/mm for SS-FCAW.

Based on the results presented above, it can be concluded that the SS-FCAW process provides greater reliability and productivity and is less sensitive to variations in welding technique and strict control of the welding parameters.

If the MAG-IBE process is applied, the use of a 1.6 mm diameter welding wire could be considered in order to increase the heat input and, consequently, improve penetration into the side walls of the joint.

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