DIGIWELD
DIGITAL EDUCATION AND TRAINING IN WELDING

Erasmus+

2021

Innovative digital tools for training in the field of welding

Digital practice modules including real life welding study cases for welding simulator

IO3 – DIGITAL PRACTICE MODULES INCLUDING REAL LIFE WELDING STUDY CASES FOR WELDING SIMULATOR

2018-1-RO01-KA202-049218

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Executive Summary

This report refers to the development of real life study cases for welding covering the most important industry topics like shipbuilding, railway, automotive, pipeline, pressure vessels and civil construction. The development of the study cases for welding simulator consists of:

- Asking industrial partner for real welding study cases that they use in process fabrication
- Elaborating teaching notes (powerpoint presentation)
- Elaborating educational materials for practical training
- Introduction of educational materials into simulator
- Development of simulated study cases by developing digital WPS
- Simulation of real life study cases for the most representative case from each category
- Recording video from simulation process for software application and DIGIWELD LMS
- Practice on simulator for further analysis of student performance

The DIGIWELD partners started to develop de study cases according to the technical specifications provided by industrial partners. Each study case contains the name of the industrial partner that agreed to provide the information as well as agreed to publish their name.

The topics approached by project partners were:

- Shipbuilding
- Railway
- Automotive
- Pipeline
- Pressure Vessel
- Civil construction

1. Introduction

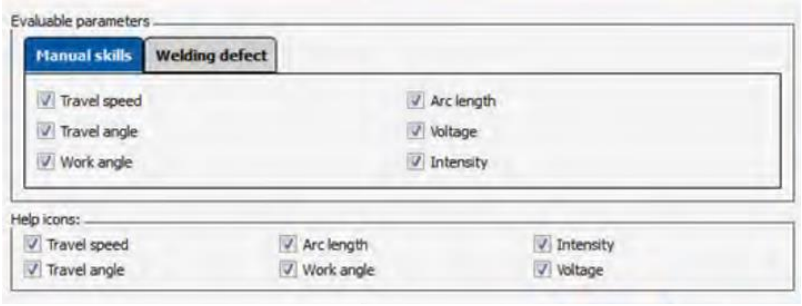
This paragraph deals with welding simulators and training in welding using augmented reality technologies. In order to become a welder, the European Guideline requires a certain number of hours for practical training. In the first chapter were presented the conditions for practical training both for real welding and simulated welding.

Fig. 1. DIGIWELD welding practice on AR welding simulator

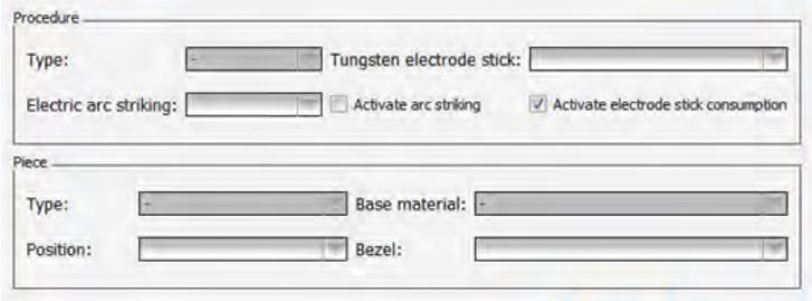
Simulation welding is not a technology is just a technique which helps the welders to perform a specific process in order to increase efficiency in terms of reducing the costs related to consumables, energy and the number of damaged products. It can be applied for specific welding procedures as training support for welders in order to gain proper skills or as new welding technique. This is a major step taking into account that the welders can improve their welding skills as well as, new welders can be trained before they will perform practical training in workshops. However, the simulation technology from welding simulators manufacturers point of view cannot cover all cases and therefore, they have developed digital tools in order to allow the engineers to elaborate specific study cases according to their needs. The limitations of the digital tools in terms of possibility to elaborate study cases (due to the lack of information from digital database) has led to the development of application as specific solution for special cases.

By programming the welding procedure specification, the computers (welding simulators) can provide the support for training on specific welding cases. Using augmented reality, virtual reality or other digital tools as technology for simulation, the welders can be trained in order to perform the welding in real life. Starting from

basic data recorded on welding simulator, the engineers can create specific welding cases according to their needs. Figure below presents few steps in programming a customized welding procedure. The application provides to the programmer different tools related to evaluation of some welding parameters (travel speed, travel angle, work angle, arc lenght, voltage and welding current intensity), welding process (type of process, electrodes), filler material (type and diameter) as well as information related to gas (type and flow).

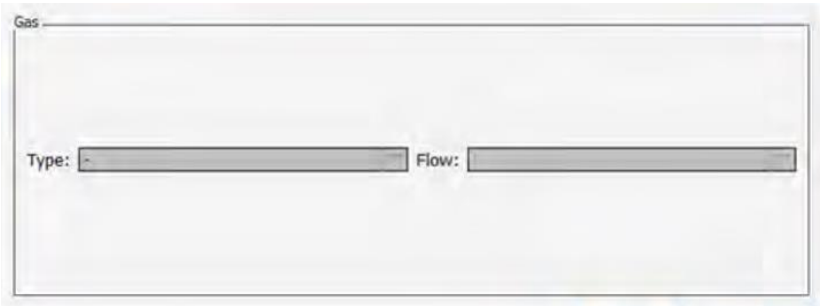


a.



b.

c.



d.

e.

Fig. 2 Steps in programming WPS (Soldamatic, Teacher software)

a. selection of manual skills, b. welding process, c. filler material, d. gas, e. welding runs

In the following lines will be presented some digital practical exercises developed for augmented reality welding simulator, covering real life welding study cases provided by industrial partners. The study cases covers the following topics related to welding in industry.

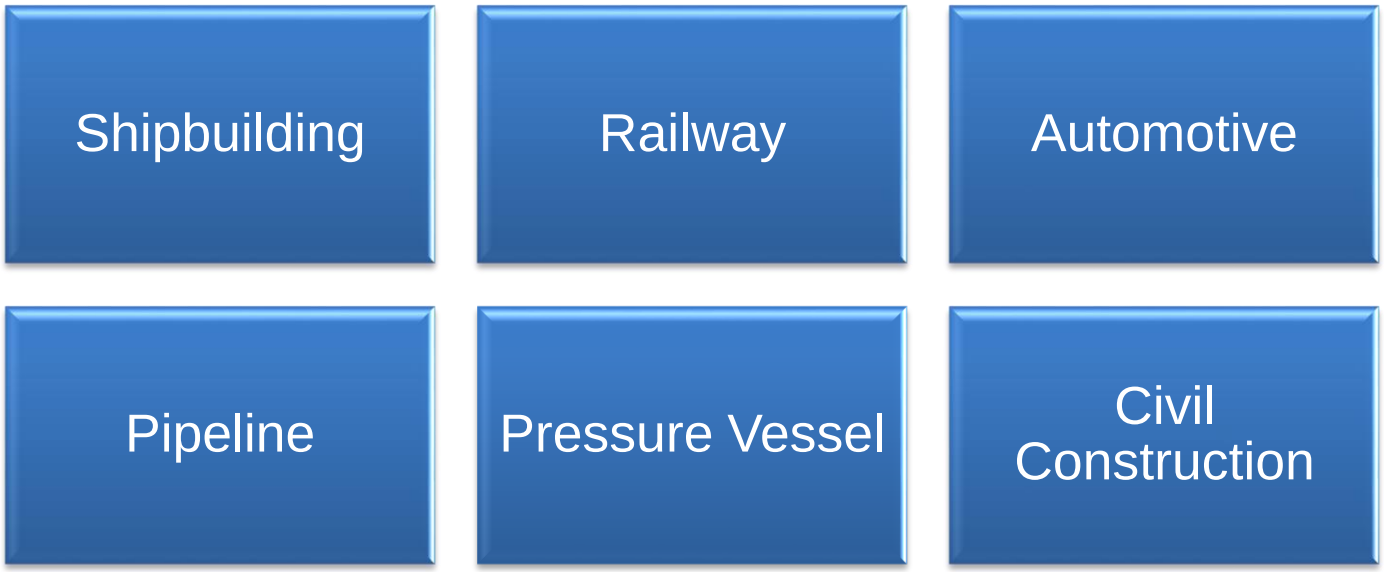


Fig. 3 Real life welding study cases simulated using AR technology

2. Study cases for shipbuilding

Shipbuilding is industry which deals very close with the welding processes. More than 90% of the joints are welded. Arc welding is the main used group of welding processes. GMAW, SAW and MMA processes are involved in the fabrication of each type of ship (river ships, short sea ships, maritime ships, etc.). The study cases were considered from river ships and they are related to the structure of a tank or barge boards, bottoms and cabins.

2.1. Board of barge

The board of a barge is component of a ship having fillet and butt joints. The fillet welds are used to create the shape of the board and the stiffening of the board. The butt welds are dedicated to create large surface as the walls membranes.

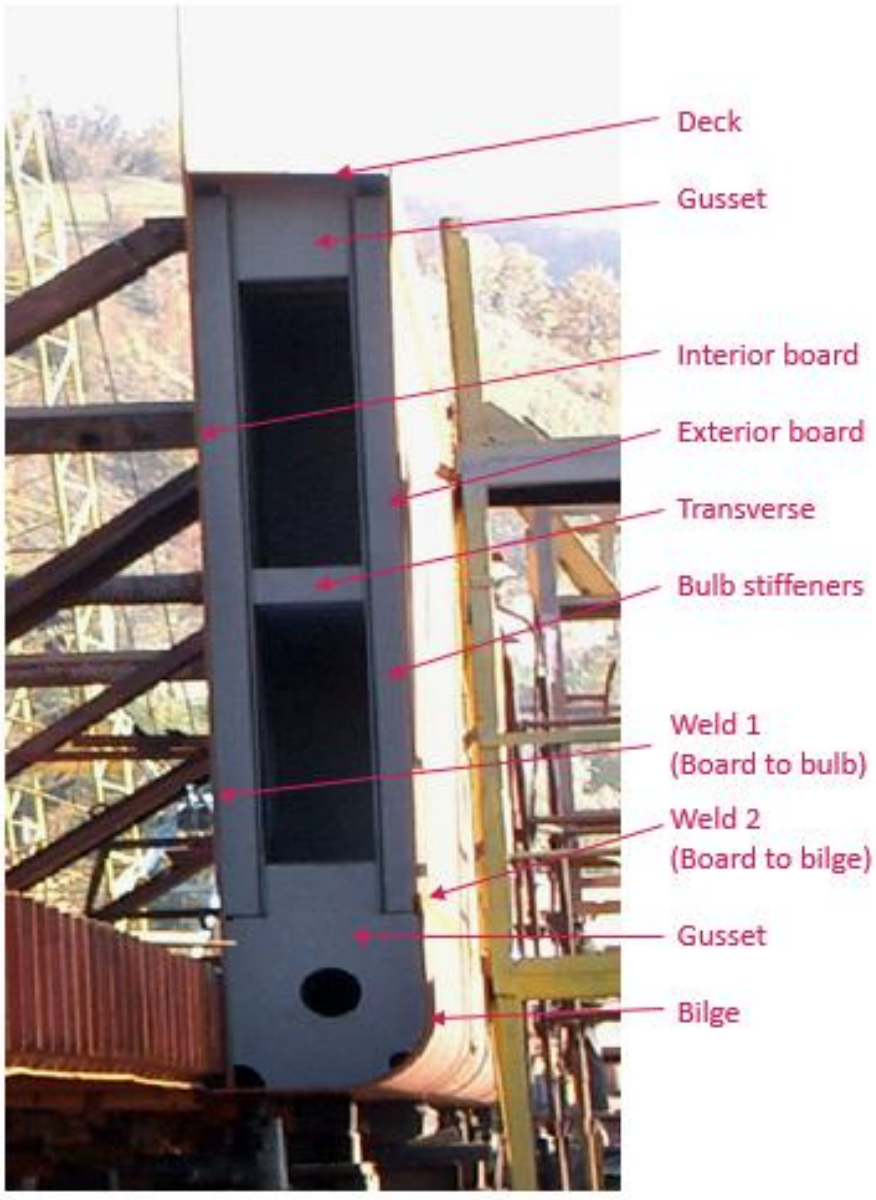


Fig. 4 Shipbuilding – description of the board of barge

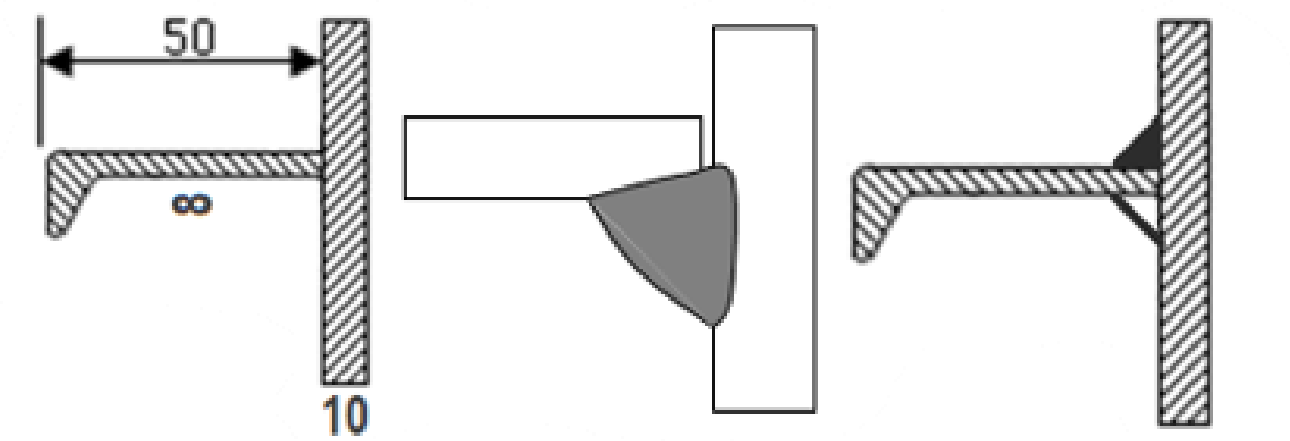
According to the figure, all the welds (the bulb stiffeners with the interior/exterior board, the bulb stiffeners with the gussets, the superior gusset with the deck, the inferior gusset with the bilge, the transverse stiffener with the bulb stiffeners, the interior wall with the bilge) from the section are fillet weld. The joint between the bilge and the exterior board is butt weld. Due to that it were considered for analysis:

- Weld of board (interior or exterior) to bulb stiffeners
- Weld of exterior board to bilge.
- Materials: A 32

Table 1 Chemical composition

Grade	Chemical composition, %							
	C≤	Si≤	Mn	P≤	S≤	Cr	Ni	Al
A32	0.18	0.5	0.9-1.60	0.040	0.040	0.20	0.20-0.40	0.020- 0.35

WPS Weld 1: interior or exterior board to the bulb stiffeners



WPS Weld 2: exterior board to the bilge

Welding Procedure Number	1		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Orsova s.a.	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Workshop, Orșova	Parent Metal Specification:	A32 / A32
Welding Process:	136	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PF (Vertical)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	170-180	25-26	DC+	8.0-8.5	17-18	15600

<u>Welding Consumables:</u> Type, Designation Diameter, mm:	 EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	<u>Technique:</u> Weaving: max 2 mm width Inclination of the wire: 90°, 20° (pull)
<u>Gas / Flux:</u> Gas type Gas Flow Rate	 EN ISO 14175: 100%CO_2 12 - 14 l/min	<u>Post Weld Heat Treatment:</u> -
Details of Back Gouging/Backing:	NO	

Welding Procedure Number			2
Welding Procedure Qualification Record (WPQR)		Revision:	0
Manufacturer:	Shipyard Orsova s.a.	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Workshop, Orsova	Parent Metal Specification:	A32 / A32
Welding Process:	136	Parent Metal Thickness	Plates: 9 to 12 mm
Joint Type:	Butt weld	Welding Position:	PC (horizontal on vertical wall)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

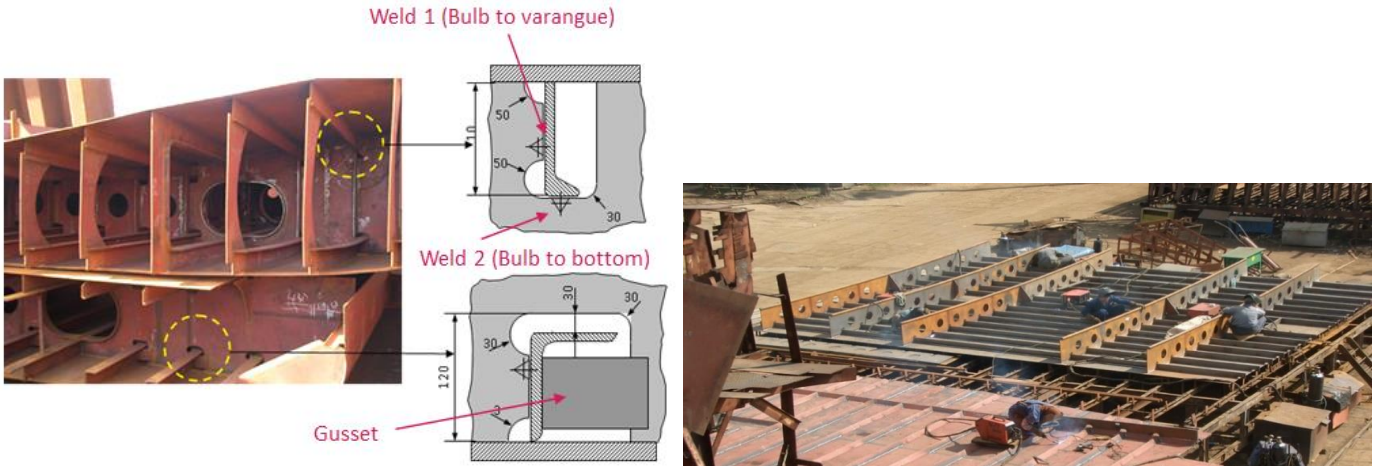
Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	170 ± 5	26 ± 1	DC+	8.0-8.5	17 ± 1	15600
2	136	1.2	180 ± 5	26 ± 1	DC+	8.0-8.5	48 ± 1	5900
3	136	1.2	190 ± 5	26 ± 1	DC+	8.0-8.5	53 ± 1	5600
4	136	1.2	200 ± 5	26 ± 1	DC+	8.0-8.5	36 ± 1	8700
5	136	1.2	200 ± 5	26 ± 1	DC+	8.0-8.5	34 ± 1	9200

Welding Consumables: Type, Designation Diameter, mm:	 EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	Technique: Weaving: max 2 mm width at pass 1, max 4 mm width at pass 2 and max 6 mm width at passes 3-5 Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	 EN ISO 14175: 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	NO	

2.2. Bottom of ship

The bottom of a ship is component of a ship having fillet joints to create the shapes and butt joints to prolonge the interior deck and the exterior shell (membrane). According to the figure, all the welds (the bulb stiffeners with the varangues and with the exterior bottom shell) from the section are fillet weld. Due to that it were considered for analysis:

- Weld of bottom plate to bulb stiffeners
- Weld of varangues to bulb stiffeners.
- Materials: A 32

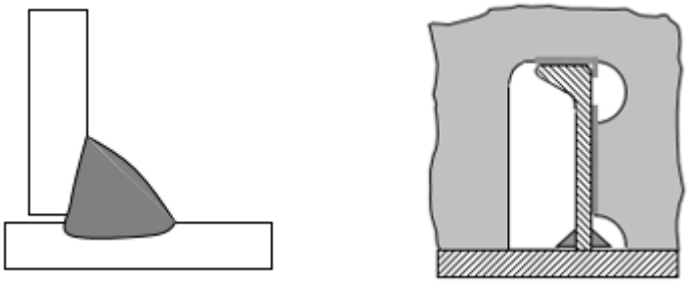


a. *b.*

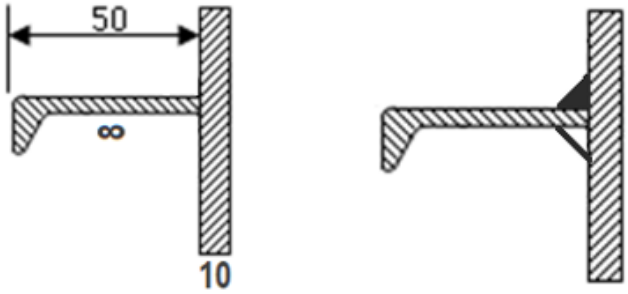
Fig. 5 Bottom of ship

a. welds, b. snapshot of welding on site

WPS Weld 1: interior or exterior board to the bulb stiffeners



WPS Weld 2: exterior board to the bilge



Welding Procedure Number			3
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Kladovo	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding; stainless steel tools to be used
Location:	Workshop, Kladovo	Parent Metal Specification:	A32 / A32
Welding Process:	FCAW	Parent Metal Thickness	Plates: 8 to 8 mm
Joint Type:	Fillet Weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	190-200	25-26	DC+	8.0-8.5	18-19	16460

Welding Consumables: Type, Designation Diameter, mm:	ISO 17633-A T 19 12 3 L R C/M 3 AWS A5.22 E316LT0-1/ -4 W.Nr.: 1.4430 1.2	Technique: Weaving: max 2 mm width at pass 1, max 4 mm width at pass 2 and max 6 mm width at pass 3 Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: Ar+18%CO_2 14 - 16 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:		

Welding Procedure Number			4
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Orsova s.a.	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Workshop, Orsova	Parent Metal Specification:	A32 / A32
Welding Process:	136	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	170-180	25-26	DC+	8.0-8.5	17-18	15600

Welding Consumables: Type, Designation Diameter, mm:	EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	Technique: Weaving: max 2 mm width Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

2.3. Cabin

The cabin is a thin structure of a ship, containing the equipment to conduct the ship. It, generally, has fillet welds on 5-7 mm thickness plates. The most met joints are the welds between the wall and it own stiffeners and the welds between the wall and the decks. They were considered for the analysis.

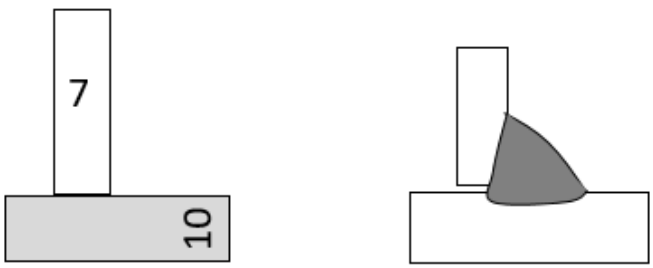
a.

b.

Fig. 6 Cabin

a. welds, b. snapshot of welding on site

WPS Weld: Gusset to deck



Welding Procedure Number	6		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Kladovo	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding; stainless steel tools to be used
Location:	Workshop, Kladovo	Parent Metal Specification:	316 L / 316 L
Welding Process:	FCAW	Parent Metal Thickness	Plates: 7 to 10 mm
Joint Type:	Fillet Weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	180 ± 5	26 ± 1	DC+	8.0-8.5	18 ± 1	15600

Welding Consumables:		Technique:
Type, Designation	ISO 17633-A T 19 12 3 L R C/M 3 AWS A5.22 E316LT0-1/ -4 W.Nr.: 1.4430	Weaving: max 2 mm width at pass 1, max 4 mm width at pass 2 and max 6 mm width at pass 3
Diameter, mm:	1.2	Inclination of the wire: 90°, 20° (pull)
Gas / Flux:		Post Weld Heat Treatment: -
Gas type	EN ISO 14175: Ar+18%CO_2	
Gas Flow Rate	14 - 16 l/min	
Details of Back Gouging/Backing:		

2.4. Hull

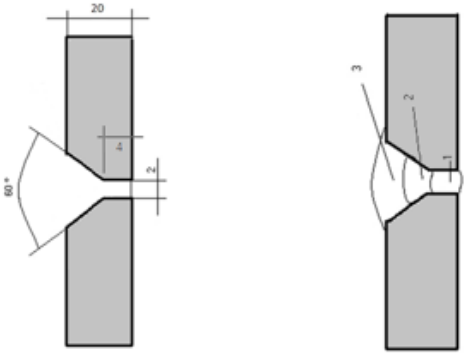
The hull is welded when build the ship, but any repairing of the hull should be done by welding, as well. The welding is done in manual mode, but mechanized is also possible. The most used processes are GMAW and MMA processes and materials A 131.

Table 2 Chemical composition

Grade	Chemical composition, %				
	C≤	Mn≤	Si≤	S≤	P≤
A131	0,21	2,50	0,50	0,035	0,035

Fig. 7 Welding hull

WPS Weld 1: interior or exterior board to the bulb stiffeners



Welding Procedure Number	7		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Kladovo	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding; stainless steel tools to be used
Location:	Workshop, Kladovo	Parent Metal Specification:	A131
Welding Process:	136	Parent Metal Thickness	Plates: 20 to 20 mm
Joint Type:	Butt Weld	Welding Position:	PC (horizontal on vertical wall)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	136	1.2	200-210	22-23	DC+	8.5-9.0	11-12	24000
2	136	1.2	200-210	22-23	DC+	8.5-9.0	11-12	24000
3	136	1.2	190-200	21-22	DC+	8.5-9.0	10-11	23700

Welding Consumables: Type, Designation Diameter, mm:	EN 758, T 46 2 P C 1 H5 1.2	Technique: Weaving: max 2 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: C1 - 100%CO_2 14 - 16 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	NO	

2.5. Bow of hull

The bow assures stability to a ship, and due to that it should welded on the hull. Due to its position, the welding of the bow is done in horizontal and overhead positions. The welding is done in manual mode, but mechanized is also possible. The most used processes are GMAW and MMA processes and materials A 131.

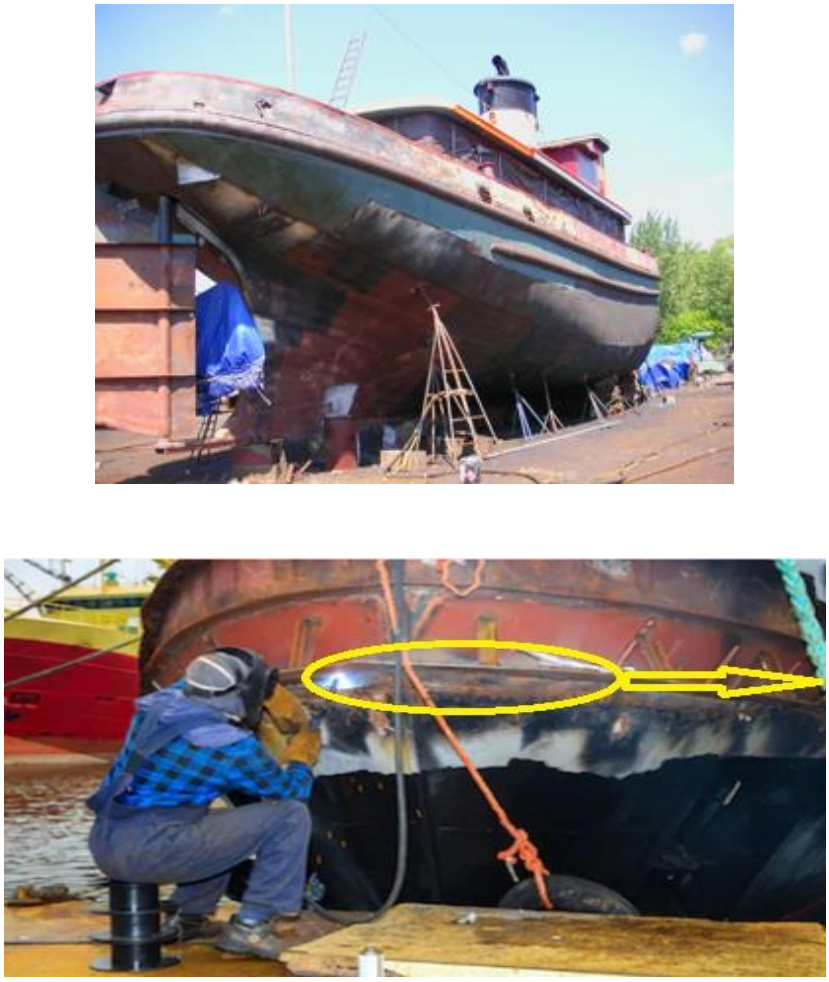
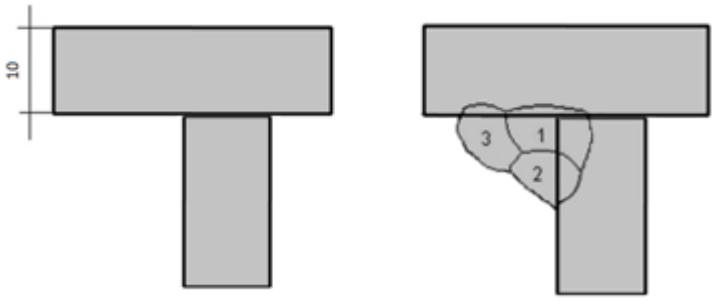


Fig. 8 Welding bow of hull

WPS Weld: fillet weld of the bow of the hull



Welding Procedure Number	8		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	Shipyard Kladovo	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding; stainless steel tools to be used
Location:	Workshop, Kladovo	Parent Metal Specification:	A131
Welding Process:	136	Parent Metal Thickness	Plates: 20 to 20 mm
Joint Type:	Butt Weld	Welding Position:	PD (overhead)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1-3	136	1.2	190	21-22	CC+	8,5	9.0-9.5	11400

Welding Consumables:		Technique:
Type, Designation	EN 758, T 46 2 P C 1 H5	Weaving: max 2 mm
Diameter, mm:	1.2	Inclination of the wire: 90°, 20° (pull)
Gas / Flux:		Post Weld Heat Treatment: -
Gas type	EN ISO 14175: C1 - 100%CO_2	Interpass temperature: max 200°C
Gas Flow Rate	14 - 16 l/min	
Details of Back Gouging/Backing:	NO	

3. Study cases for railway

The railcars are welded structures. Hundreds of meters of GMAW welds can be measured on a railcar. TIG and MMA welding processes are, also, applied on a railcar body. The materials used to build a railcar body are the steels, mainly. Low alloy steels having, generally, 360-500 Mpa Yield strength, are used to build the chassis. The rest of the body is produced of lower strength steels or of aluminium alloys (mainly for passenger railcars). If a vessel is mounted on the chassis, the vessel will be build according to the legislation regarding the pressure vessels erection. The arc welding processes could be applied in robot, automated, mechanized or manual regime.

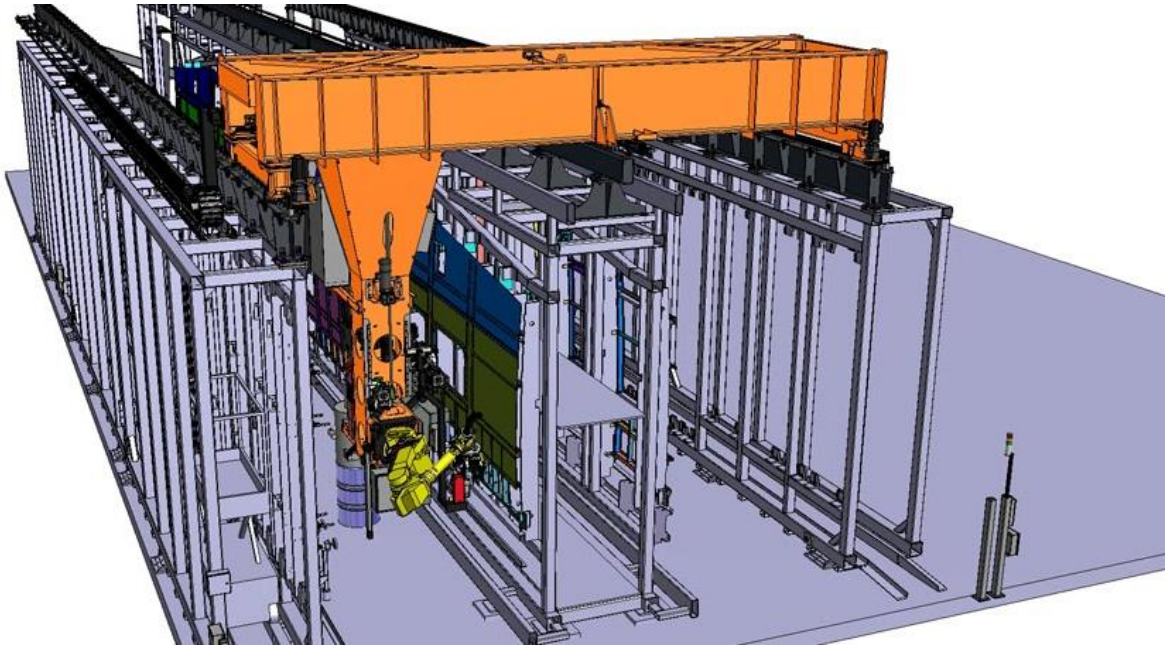


Fig. 9 Railcars

3.1. Side longeron

The side longeron is one of the two identical components of the chassis which are directly loaded by the freight carriage. It is built as welded structure and is sustained by the two bogies of the car. It is designed to contain steel plates from 8 to 20 mm thickness, depending on the position and functionality of the plate.

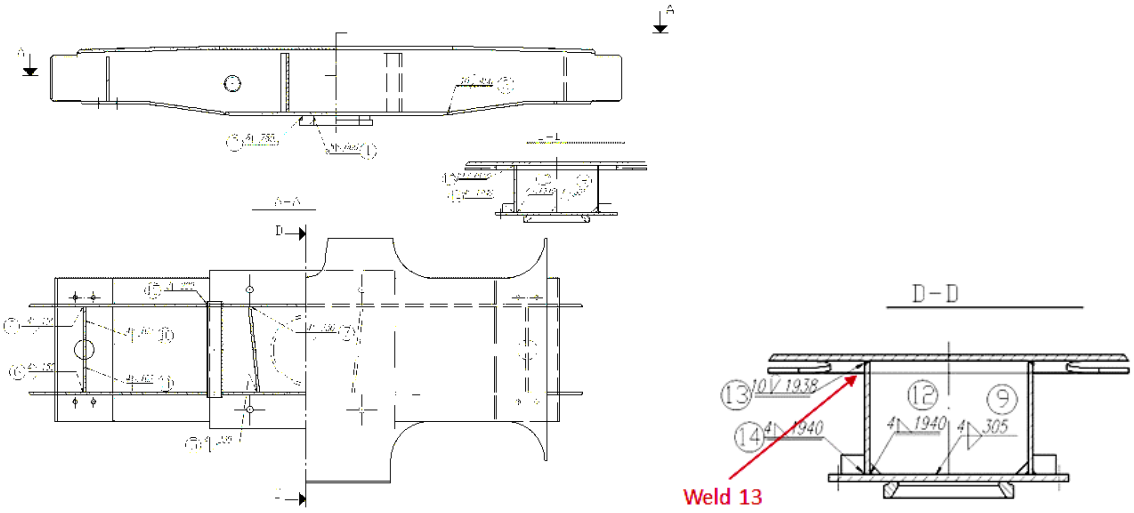


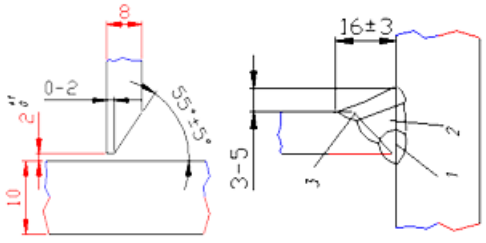
Fig. 10 Railway stock welding welding design (detail)

According to the figure, all the welds (the lateral sheets with the bottom sheet, the stiffeners with the four sheets) from the section are simple fillet weld, without preparation. The joint between the lateral sheets and the superior sheet is a special fillet weld, having a specific preparation of the groove. That weld it will be considered for the project purposes. The materials used in welding application were S355J2-N.

Table 3 Chemical composition

Grade	Chemical composition, %								
	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Mo	V
S355J2-N	0,20	0,50	0,90-1,55	0,035	0,030	0.35	0.50	0.10	0.12

WPS Weld: vertical sheets with superior sheet



Welding Procedure Number			9
Welding Procedure Qualification Record (WPQR)		Revision:	0
Manufacturer:	MEVA Drobeta	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Workshop, Drobeta	Parent Metal Specification:	S355J2-N
Welding Process:	135	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	215 ± 5	22 ± 1	DC+	6.0	20 ± 1	14900
2	135	1.2	255 ± 5	27 ± 1	DC+	8.0	31 ± 1	13325
3	135	1.2	255 ± 5	27 ± 1	DC+	8.0	31 ± 1	13325

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: NO Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: M21 - 18%CO_2 + rest Ar 12 - 14 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C Stick-out: 15-18 mm
Details of Back Gouging/Backing:	NO	

3.2. Pivot Girder

The pivot girder (crossbeam) is a complex and rigid beam supporting at the ends on the side rails and supporting the rotational torque between the chassis and the cargo box. It is a strongly reinforced welded construction to take over the wagon's payloads and the possible unevenness of the railway. It houses the rotating torque that allows the two bogies to change their position relative to each other at the curves.

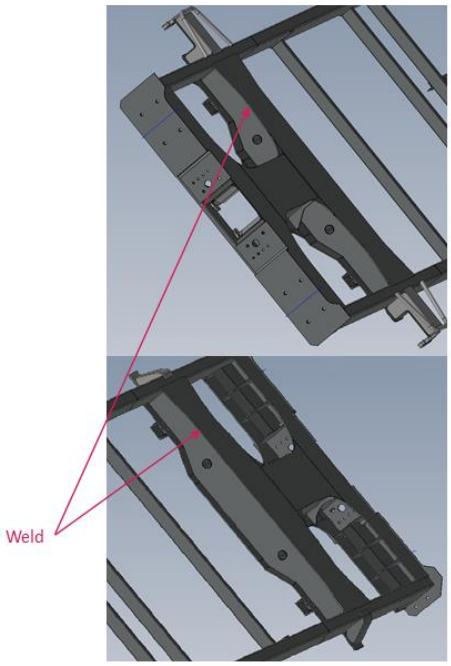


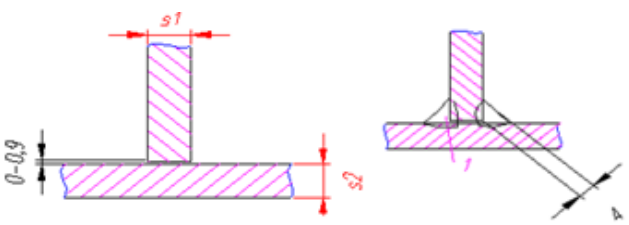
Fig. 11 Welding pivot girder

Most of the welds are fillet welds. The weld considered for the project purposes is a simple fillet weld between the side walls and the superior plate. The materials used in welding application were S355J2-N.

Table 4 Chemical composition

Grade	Chemical composition, %								
	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Mo	V
S355J2-N	0,20	0,50	0,90-1,55	0,035	0,030	0.35	0.50	0.10	0.12

WPS Weld: side wall to superior plate



Welding Procedure Number			10
Welding Procedure Qualification Record (WPQR)			Revision: 0
Manufacturer:	MEVA Drobeta	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Workshop, Drobeta	Parent Metal Specification:	S355J2-N
Welding Process:	135	Parent Metal Thickness	Plates: 10 to 12 mm
Joint Type:	Fillet weld	Welding Position:	PB (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	255 ± 5	27 ± 1	DC+	8.0	31 ± 1	13325
2	135	1.2	255 ± 5	27 ± 1	DC+	8.0	31 ± 1	13325

Welding Consumables:		Technique:
Type, Designation	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6	Weaving: NO
Diameter, mm:	1.2	Inclination of the wire: 90°, 20° (pull)
Gas / Flux:		Post Weld Heat Treatment: -
Gas type	EN ISO 14175: M21 - 18%CO_2 + rest Ar	
Gas Flow Rate	12 - 14 l/min	Stick-out: 15-18 mm
Details of Back Gouging/Backing:	NO	

3.3. Railcar body structure

The exterior plate of a rail car is joined by welding on the resistance structure. Generally, overlapping welds can be meet where to exterior sheets are joined to the same element of structure. The materials used in welding application were S355J2-N.

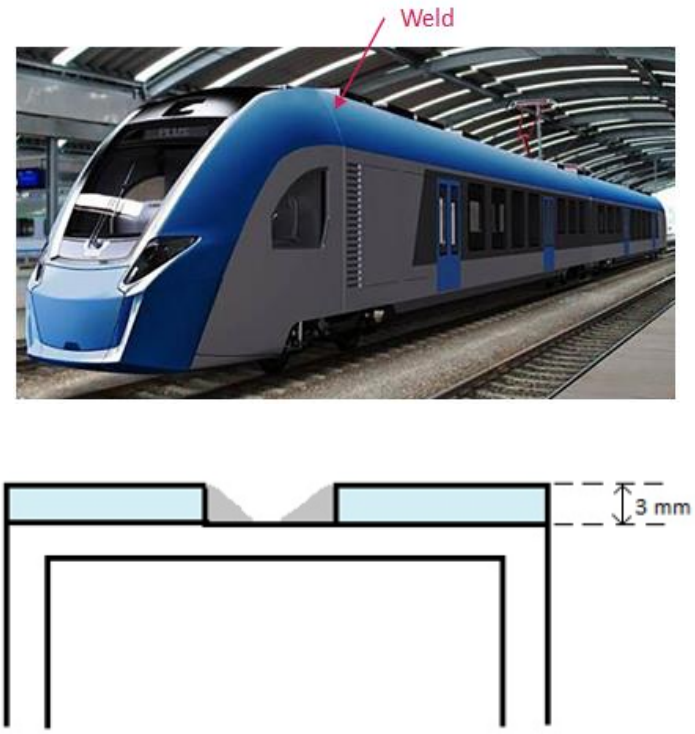


Fig. 12 Welding railcar body structure

Table 5 Chemical composition

Grade	Chemical composition, %								
	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Mo	V
S355J2-N	0,20	0,50	0,90-1,55	0,035	0,030	0.35	0.50	0.10	0.12

WPS Weld: outside wall to structure

Welding Procedure Number			11
Welding Procedure Qualification Record (WPQR)			Revision: 0
Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	S275JR
Welding Process:	135	Parent Metal Thickness	Plates: 3 to 3 mm
Joint Type:	Fillet weld	Welding Position:	PB (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.0	200-220	20-21	cc+	8	55-65	4200

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: NO Inclination of the wire: 90º, 20º (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: c1 - 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: - Stick-out: 15-18 mm
Details of Back Gouging/Backing:	NO	

4. Study cases for automotive

Automotive industry is known as high consumer of joining processes, from resistance welding, to arc welding and different bonding processes. Arc welding is limited applied due to the low thickness of all pieces of a car body or the pieces of the chassis. GMA, TIG, MMA and oxy-gas welding processes are involved in the fabrication of the car bodies.

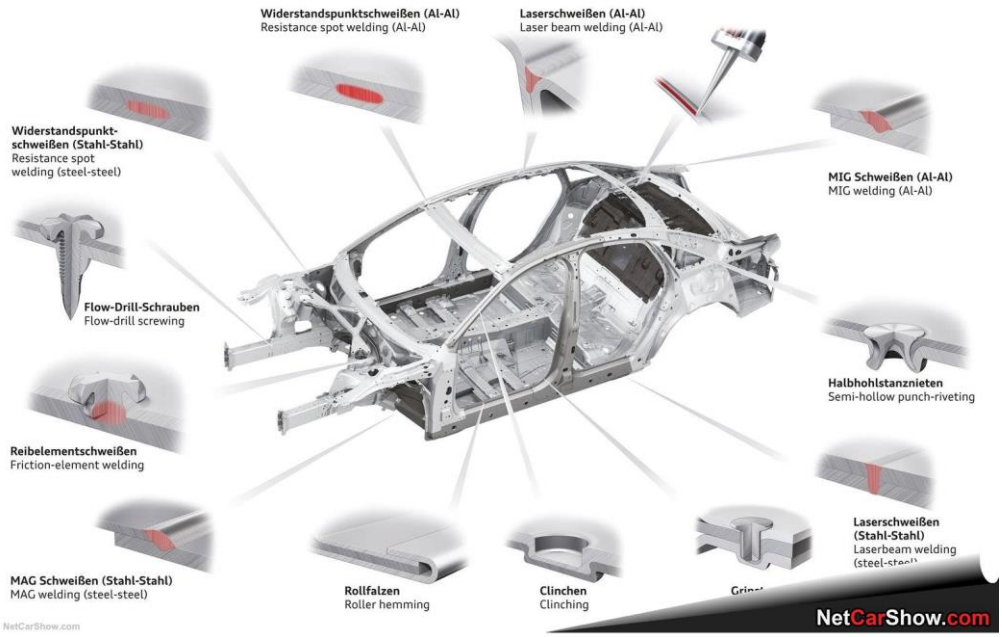


Fig. 13 Welding in automotive industry

The main involved materials are steels and aluminium alloys. The met grades of steels are carbon steels, HSLA, TRIP and TWIP steels. Most of the steel elements are from formed plates. The aluminum alloys could be met in cast or formed pieces. Regarding the application of the arc welding processes, most of them are done by robot welding. Some small length welds are done manually.

4.1. Car body structure

A car body has many welds. Most of them are resistance spot welds, but arc welding joints can be meet, as well. Depending on the car, its body can be build by steel or aluminium. The elements of a body are done mainly of formed sheets (up to 3 mm thickness) and by specific laminated profiles.

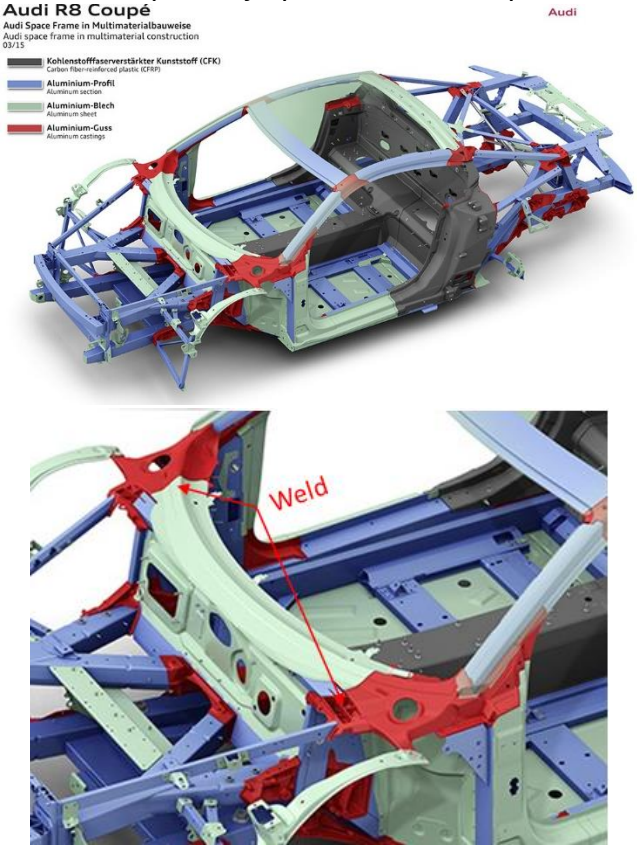


Fig. 14 Welding body car structure

All these elements are joined together by welding and/or by bonding. If the thickness is higher than 1.0 mm, arc welding becomes an option for the joining process.

Table 7.6 Chemical composition

Grade	Chemical composition, %								
	Mg	Mn+Cr	Mn	Si	Fe	Cr	Zn	Ti	Al
AW-5754	2.60-3.60	0.10 – 0.60	0.00-0.50	0.00-0.40	0.00-0.40	0.00-0.30	0.00-0.30	0.00-0.15	rest

WPS Weld: profile to create the skelet of the structure

Welding Procedure Number			12
Welding Procedure Qualification Record (WPQR)			Revision: 0
Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:		Parent Metal Specification:	AlMg3 / AW 5754 EN 573-1:2008
Welding Process:	131	Parent Metal Thickness	Plates: 2 to 2 mm
Joint Type:	Fillet weld (overlapped)	Welding Position:	PB (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	131	0.9	70-80	14-16	cc+	7	40-50	4200

Welding Consumables: Type, Designation Diameter, mm:	EN – ER 4043 0.9	Technique: Weaving: NO Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: I1 - 100%Ar 12 - 14 l/min	Post Weld Heat Treatment: - Stick-out: 12-14 mm
Details of Back Gouging/Backing:	NO	

5. Study cases for pipeline

Pipeline is the fifth transportation method and occupies important place in the economy of a country. Each pipeline is done of succession of segments joined together by welding.

Fig. 15 Welding pipeline

The main processes used to build a pipeline are the TIG, MMA and GMAW processes. Often mixture of those is used. For instance, the root is prefered to welded by TIG process because TIG is able to create a proper root of the welding. The filling passes are done by GMAW or MMA processes, due to their higher productivity. The welding is done in manual mode, mainly, but mechanized (trucks) and automated processes (orbital) are used for better quality and higher productivity.

5.1. BRUA pipeline

BRUA pipeline is produced of segments of pipes which are butt welded to create the length necessary to cross Bulgaria, Romania, Hungary and Austria (B.R.U.A.).

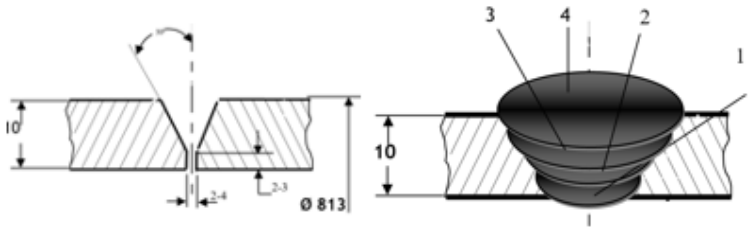
Fig. 16 BRUA pipeline

The pipe has a diameter of 813 mm, and the thickness of the wall is 10 mm. The welding is done after specific preparation of the groove. The materials used in welding application were L415 (X60).

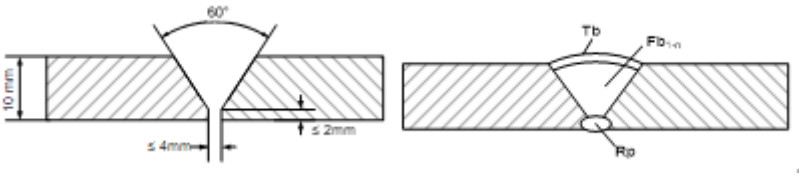
Table 7 Chemical composition

Grade	Chemical composition, %			
	C≤	Mn	P≤	S≤
L415 ME PSL 2	≤0.28	≤ 1.40	≤0.030	≤0.030

WPS Weld 1: butt weld of the pipe segments



WPS Weld 2: butt weld of the pipe segments



Welding Procedure Number			13
Welding Procedure Qualification Record (WPQR)			Revision: 0
Manufacturer:	TATI	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Yard, Arad	Parent Metal Specification:	L415 ME PSL 2, ISO 3183/2012
Welding Process:	141+111	Parent Metal Thickness	Pipes: 10 to 10 mm
Joint Type:	Butt weld	Welding Position:	PH (vertical up on pipe)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	141	3.0	120-140	20-22	DC-	-	15	10600
2	111	3.2	100-120	18-20	DC+	-	12-14	9600
3,4	111	4.0	110-130	21-25	DC+	-	13-15	12000

Welding Consumables: Type, Designation Diameter, mm:	Covered electrode: Boehler W 42 5 W3Si1 + E 55 6 1 NiMo B 42 H5 3.0, 3.2, 4.0 Tungsten electrode: WTh2 3.2	Technique: Weaving: NO Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: I1 - 100%Ar 10 - 12 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C Dry electrodes: 300°C / 2h
Details of Back Gouging/Backing:	NO	

Welding Procedure Number			14
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	HABAU PPS PIPELINE SYSTEMS	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Yard, Arad	Parent Metal Specification:	L415 ME PSL 2, ISO 3183/2012
Welding Process:	111	Parent Metal Thickness	Pipes: 10 to 10 mm
Joint Type:	Butt weld	Welding Position:	PH (vertical up on pipe)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1-2	111	3.2	80-95	26-28	DC+	-		
3-n	111	3.2/4.0	110-120/ 140-180	27-28/ 28-30	DC+	-		

Welding Consumables: Type, Designation Diameter, mm:	Covered electrode: Boehler FOX DMO Kb, EN ISO 3580-A : E Mo B 4 2 H5 3.2, 4.0	Technique: Weaving: max 3 x Ø electrod Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: I1 - 100%Ar 10 - 12 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C Dry electrodes: 300°C / 2h
Details of Back Gouging/Backing:	NO	

5.2. BRUA end piece with flange

Sometimes it is necessary to conenct two ends of pipes by using mechanical methods. The most used solution is to use end pieces with flanges which are welded to the ends of the pipes. There are many design solutions for such technology of joining: lap joint flange, neck flange, slip on flange, etc. The materials used in welding application were L415 ME PSL1 (X52).

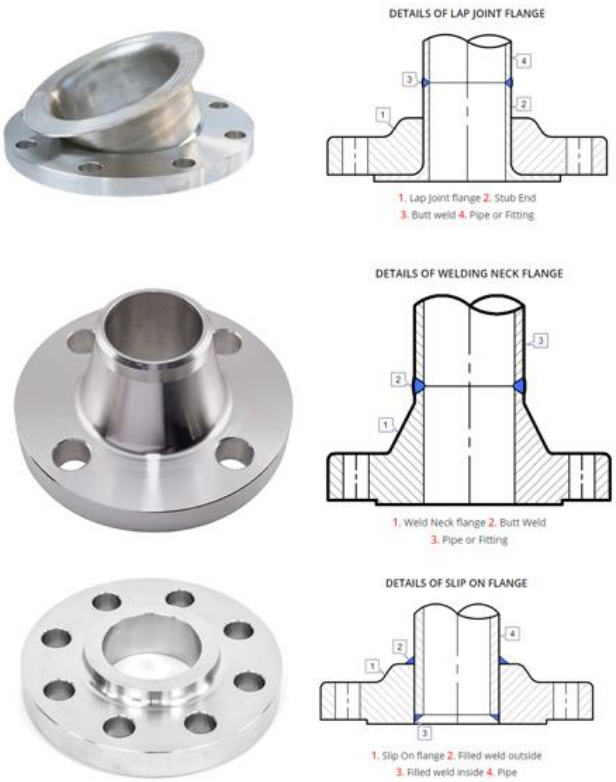
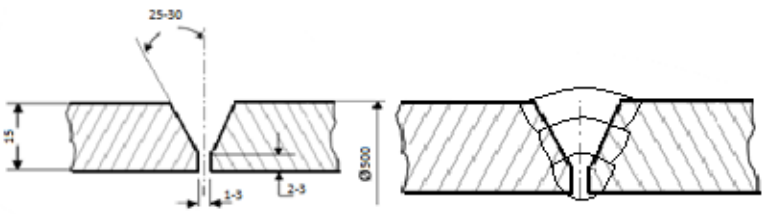


Fig. 17 Welding BRUA end piece with flange

Table 8 Chemical composition

Grade	Chemical composition, %					
	C≤	Si≤	Mn	P≤	S≤	V+Nb+Ti≤
PSL1, Grade X52	0,28	-	1,30	0,03	0,03	0,15

WPS Weld: butt weld of the pipe to the end of the piece



Welding Procedure Number			15
Welding Procedure Qualification Record (WPQR)			Revision: 0
Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	API 5L - PSL1, Grade X52
Welding Process:	135	Parent Metal Thickness	Pipes: 15 to 15 mm, diameter: 500 mm
Joint Type:	Butt weld	Welding Position:	PH (vertical up on pipe)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	190-200	22-23	CC+	6,5	20-21	11940
2	135	1.2	250-260	28-29	CC+	9	22-23	15000
3,4	135	1.2	250-260	28-29	CC+	9	20-21	20000

Welding Consumables: Type, Designation Diameter, mm:	EN 14341-A G 42 4 C G4 Si1 3.2	Technique: Weaving: NO Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: M21 - 82%Ar+18%Ar 15 - 18 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	NO	

6. Study cases for pressure vessel

Pressure vessels are equipment working at high pressures, storing gases. They can have different shapes, but shapes made of sections of spheres, cylinders, and cones are the most used. They are formed of succession of circular shells (cylinders) having the same diameter and welded together until the desired length is obtained. It is closed with two heads of the two ends. A pressure vessel contains, also, nozzles to connect to different equipment or networks, and specific saddles to lean on.

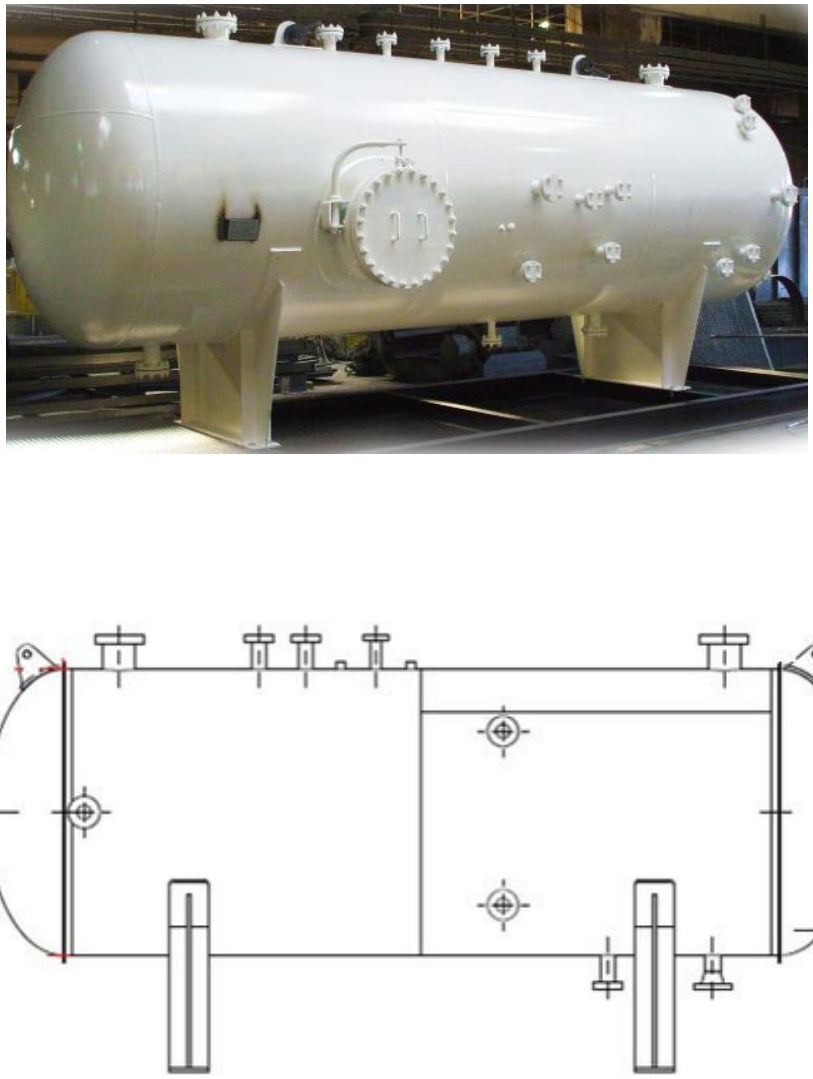


Fig. 18 Pressure vessel

They are made of specific steel, grade P, welded by different processes, according to regulations in force:

- USA - ASME Boiler and Pressure Vessel Code (BPVC);
- EU - Pressure Equipment Directive.

6.1. Membrane wall (shell ring to shell ring and two rings welded together)

The shell is done by rolling a plate with specific thickness to a specific diameter. The ends of the plate are welded together, after preparation of groove. The welding is, generally, done to the interior on the ceramic backing support or flux support, or without support but with root welding from the outside.

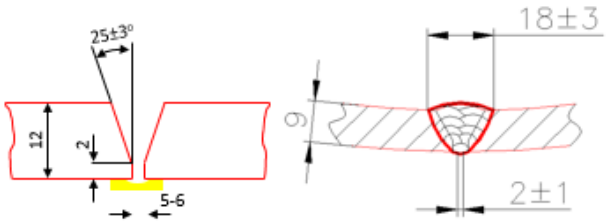
Fig. 19 Welding membrane wall

Two or more shell rings are welded together, end to end. The welding to create the shell ring is done in horizontal position. The welding of two shell rings together are done in vertical up position. Sometimes, the shell rings are rotating and the weld is performed in horizontal position. The rotation speed is equal to the travel for welding speed. Both can be manually or mechanized performed. The materials used in welding application were P265GH-SR EN 10028-2:2004.

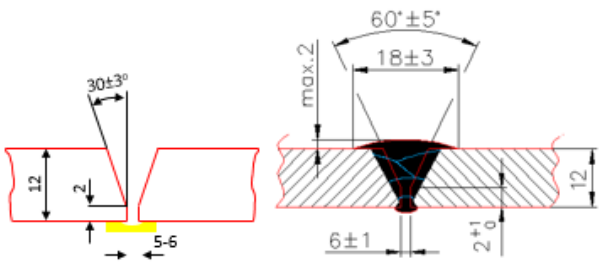
Table 8 Chemical composition

Grade	Chemical composition, %										
	C≤	Si≤	Mn ≤	P ≤	S ≤	Cr ≤	Mo ≤	Ni ≤	Al tot ≥	Cu ≤	Nb ≤
P265GH-SR	0.2	0.4	1.4	0.025	0.02	0.30	0.08	0.30	0.02	0.30	0.01

WPS Weld: butt weld of the end of the plate to form shell ring



WPS Weld: two shell rings (butt weld of the shell rings segments)



Welding Procedure Number			16
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	-	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Ploiești	Parent Metal Specification:	P265GH
Welding Process:	136	Parent Metal Thickness	12 to 12 mm
Joint Type:	Butt weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	220-240	25-26	DC+	9-9.5	16-17	19400
2-5	135	1.2	240-260	28-29	DC+	10-10.5	18-20	21000
root	135	1.2	220-240	25-26	DC+	9-9.5	22-24	1500

Welding Consumables: Type, Designation Diameter, mm:	EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	Technique: Weaving: NO Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	Ceramic backing	

Welding Procedure Number	17		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	-	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Ploiești	Parent Metal Specification:	P265GH
Welding Process:	136	Parent Metal Thickness	12 to 12 mm
Joint Type:	Butt weld	Welding Position:	PH (vertical up)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	220-240	25-26	DC+	9-9.5	16-17	19400
2-5	135	1.2	240-260	28-29	DC+	10-10.5	18-20	21000

Welding Consumables: Type, Designation Diameter, mm:	EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	Technique: Weaving: NO Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	Ceramic backing	

6.2. Mounting nozzles

The nozzles are elements to allow the visit of the inside or to introduce or exit gases and/or liquids. They are pipes, generally with flanges, built of the same material as the vessel, and which are welded to the shell ring of the vessel.

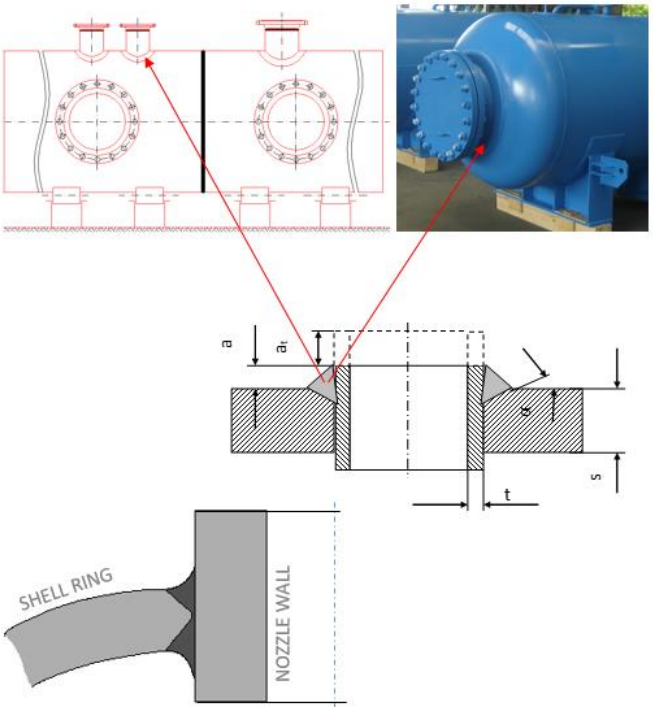


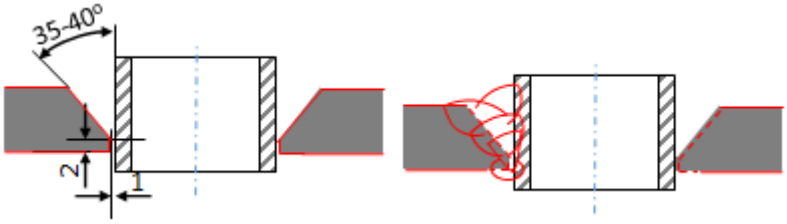
Fig. 20 Welding nozzles

The weld is a fillet weld done in the exterior of the shell ring. Id the pressure inside the vessel is very high, it could be recommended to have welds at the inside, as well. The materials used in welding application were P265GH-SR EN 10028-2:2004.

Table 9 Chemical composition

Grade	Chemical composition, %										
	C≤	Si≤	Mn ≤	P ≤	S ≤	Cr ≤	Mo ≤	Ni ≤	Al tot ≥	Cu ≤	Nb ≤
P265GH-SR	0.2	0.4	1.4	0.025	0.02	0.30	0.08	0.30	0.02	0.30	0.01

WPS Weld: filled weld of nozzle wall and the shell rings



Welding Procedure Number			18
Welding Procedure Qualification Record (WPQR)		Revision:	0
Manufacturer:	-	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Ploiești	Parent Metal Specification:	P265GH
Welding Process:	136	Parent Metal Thickness	6 to 12 mm
Joint Type:	Fillet weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	141	3.0	130-140	20-21	DC-	-	14	12150
2-4	135	1.2	240-260	28-29	DC+	10-10.5	18-20	21000
root	135	1.2	220-240	25-26	DC+	9-9.5	22-24	1500

<u>Welding Consumables:</u> Type, Designation Diameter, mm:	141: Tungsten electrode: WTh2 3.2 136: EN 758: T 46 2 P C 1 H AWS A5.20: E71T-1 H4 W.Nr.: 1.4430 1.2	<u>Technique:</u> Weaving: max 3 mm Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
<u>Gas / Flux:</u> Gas type Gas Flow Rate	141: EN ISO 14175: C1 - 100%CO_2 12 - 14 l/min 136: EN ISO 14175: C1 - 100%CO_2 12 - 14 l/min	<u>Post Weld Heat Treatment:</u> - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	NO	

6.3. Membrane wall

The membrane walls are used in boilers to make heat exchangers. It is about huge networks of welded pipes for forming a wall. There are sheets of sheet between the pipes. The pipes are welded by these sheets of sheet metal. The materials used in welding application were:

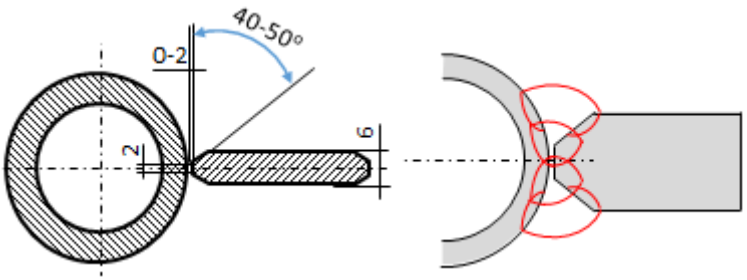
- For pipes: SA210GrA1
- For plates: S275JR

Table 11 Chemical composition

Grade	Chemical composition, %						
	C≤	Si≤	Mn	P≤	S≤	N≤	Cu≤
Pipes: SA210GrA1	0,27	0,10	0,93	0,048	0,058		
Plates: S275JR	0,21	-	1,5	0,035	0,035	0,012	0,40

Fig. 21 Welding membrane wall

WPS Weld: filled weld of the wall to the pipes



Welding Procedure Number			19
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	-	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Ploiești	Parent Metal Specification:	Pipes (Ø50x5 mm): SA210GrA1 Plates (6 mm): S275JR
Welding Process:	136	Parent Metal Thickness	6 to 5 mm
Joint Type:	Fillet weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.0	200-210	25-26	DC+	9.0-9.5	60	5000
2	135	1.0	240-260	26-28	DC+	9.0-9.5	60	6250

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: max 3 mm to pass 2 Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: M21 - 18%CO_2 + rest Ar 12 - 14 l/min	Post Weld Heat Treatment: - Interpass temperature: max 200°C
Details of Back Gouging/Backing:	NO	

Civil constructions refer, generally, to structures dedicated to civil purposes, as residential buildings, fair halls, industrial halls, bridges, gyms, towers, crosswalks for hard traffic roads and else. They replace the concrete structure of construction with metal structure; some of their elements are fastened using screws, but most of the components are connected by welding. The welding creates forms, by putting in specific position the components. Due to that, the most welds are fillet welds.

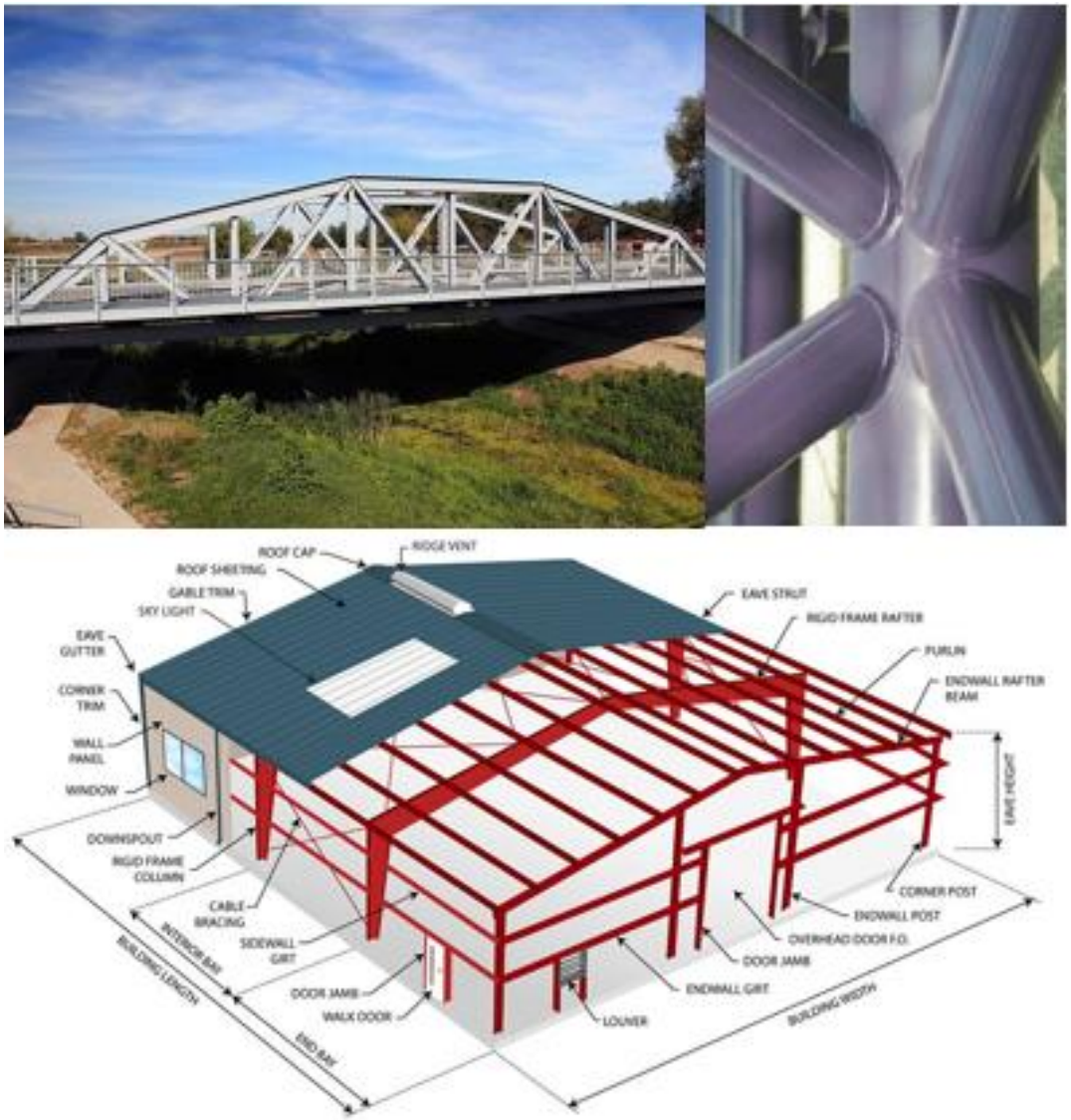


Fig. 22 Welding civil construction

Such structure is formed of beams, girders and other types of elements which are fixed each other by specific nodes. The nods are based on gussets having appropriate shape and dimensions. The elements ends are not directly welded each other, but each element is welded with the gusset. Gussets are used for the stiffening of different intersections of elements which are or not welded together.

7.1. Stiffening two parallel girders

Some elements of a civil constructions are designed as multiple beams fixed together in parallel position in order to create stiff horizontal or vertical wall. In such cases the welding is done between each beam and the stiffener. The weld can join together in direct manner or gusset, as intermediary element, is needed.

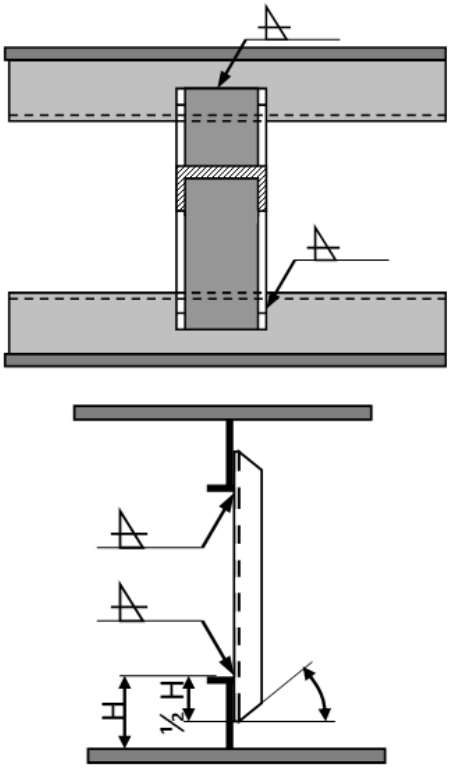


Fig. 23 Stiffening two paralle girders

Such combination creates a double node, which is a resistance node and the three elements (or five if gussets are required) can be different types of laminated profiles. The connecting element could be an U profile, or a T profile or rectangular pipe, or else. The materials used in welding application were S235 and S355.

Table 12 Chemical composition

Grade	Chemical composition, %										
	C ≤	Si ≤	Mn	P ≤	S ≤	Cu	Ni	Mo	V	Nb	Cr
S355J2	0,2	0,5	0,90-1,55	0,035	0,03	0.35	0.5	0.1	0.12	0.05	0.03

7.2. Stiffening two elements crossing by gusset

Some elements of a civil constructions are designed to cross each other, and the joint to require extra stiffening. In such cases the welding is done between each element and the stiffening gusset.

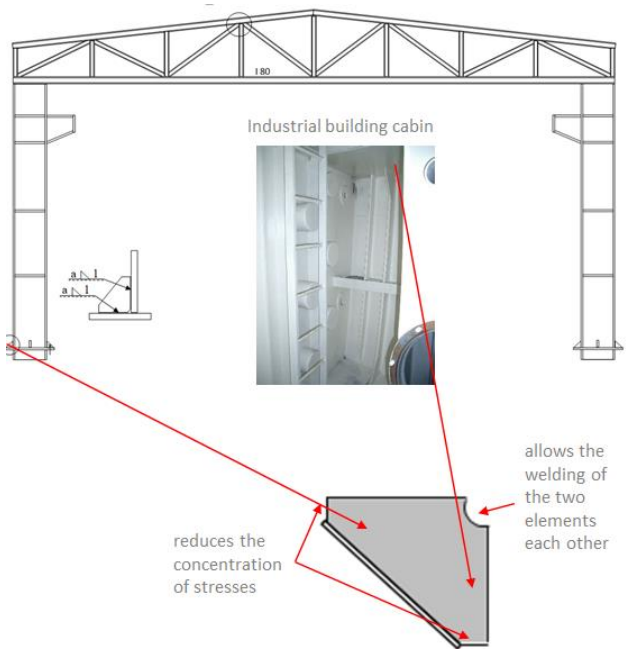


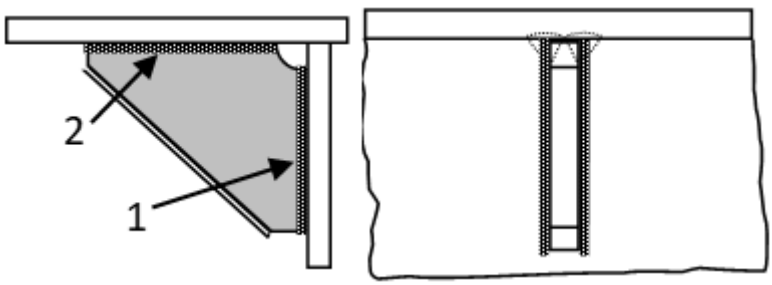
Fig. 24 Stiffening two elements crossing by gusset

All three elements are made of metal sheets and the gusset has specific form to allow the welding of the two elements each other and to reduce the concentration of stresses in the node. The materials used in welding application were S235 and S355.

Table 13 Chemical composition

Grade	Chemical composition, %										
	C ≤	Si ≤	Mn	P ≤	S ≤	Cu	Ni	Mo	V	Nb	Cr
S355J2	0,2	0,5	0,90-1,55	0,035	0,03	0.35	0.5	0.1	0.12	0.05	0.03

WPS Weld: fillet welds of the gusset and the plates



7.3. Intersection with I beams

Welding Procedure Number	21		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:	ALPHA CONSTRUCT	Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Drobeta	Parent Metal Specification:	S355
Welding Process:	135	Parent Metal Thickness	Plates: 7 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PE (overhead) and PF (vertical up)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
PE	135	1.2	220-230	22-23	DC+	9	35	8700
PF	135	1.2	210-220	22-23	DC+	9	20	13860

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: NO Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: M21 - 18%CO_2 + rest Ar 12 - 14 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

In some nodes beams are welded together even if their dimensions differ very much. Such nodes are classic structural nodes.

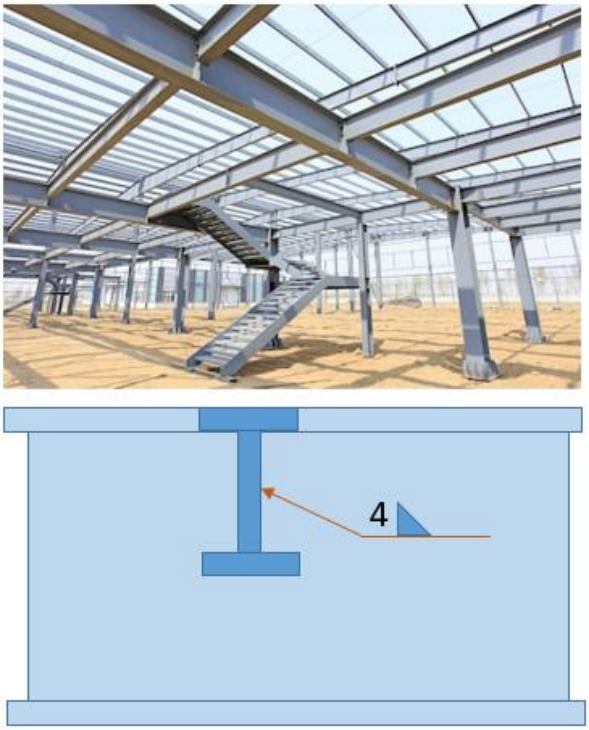


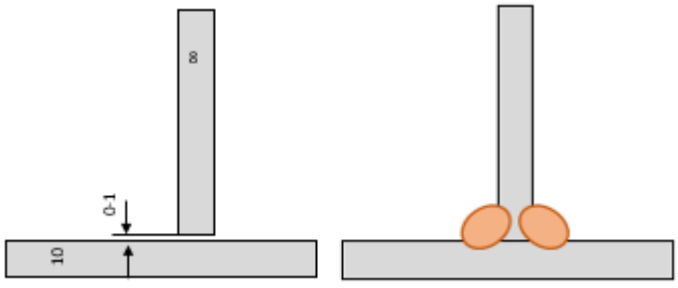
Fig. 25 Welding intersection with I beams

The largest beam is cut to allow the passage of the smallest beam, after which the two are welded to each other, through fillet weld. The materials used in welding application were S235 and S355.

Table 7.14 Chemical composition

Grade	Chemical composition, %				
	C≤	Mn≤	Si≤	S≤	P≤
S235J2	0.17	1.40	-	0.040	0.040

WPS Weld: filled weld



Welding Procedure Number	22		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	S235
Welding Process:	135	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PF (vertical up)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1,2	135	1.2	160-180	22-23	DC+	8	15-16	14000

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: NO Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: C1 - 100%CO_2 12 - 14 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

7.4. Node of two elements of a bridge

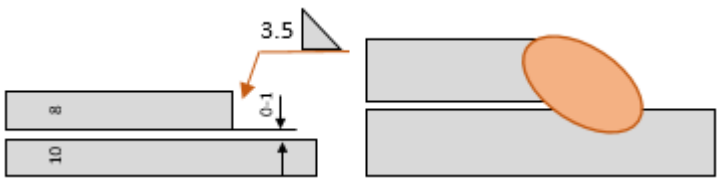
Two or more beams could met in a node by using gussets as support. The beams are not weled each other, but each is welded to the gusset. So, in a node there are several shorts fillet weld, actually overlapping joints. The materials used in welding application were S235 and S355.

Table 7.15 Chemical composition

Grade	Chemical composition, %				
	C≤	Mn≤	Si≤	S≤	P≤
S235J2	0.17	1.40	-	0.040	0.040

Fig. 26 Two elements of a bridge

WPS Weld: fillet / overlapped weld



Welding Procedure Number	23		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	S235
Welding Process:	135	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PF (vertical up)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1,2	135	1.2	200-220	24-25	DC+	9	16-17	17800

Welding Consumables: Type, Designation Diameter, mm:	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: NO Stick-out: 15-17 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	EN ISO 14175: M21 – 82%Ar+18%CO_2 12 - 14 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

7.5. Structural beam node

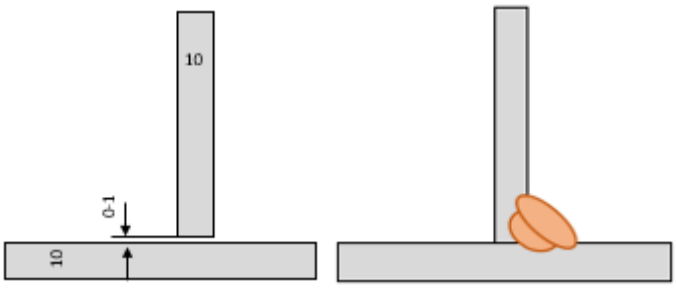
The structural beams nodes are vital in structures. They create the network, which assures the resistance and the mechanical behaviour of the structure. In a node can meet two or more ends of beams, welded directly each other or using linking elements. The material used in welding application was S275JR.

Table 16 Chemical composition

Grade	Chemical composition, %				
	C≤	Mn≤	Si≤	S≤	P≤
S275JR	S275JR	1.18	1.5	0.03	0.035

Fig. 27 Structural beams node

WPS Weld: fillet weld



Welding Procedure Number			24
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	S275
Welding Process:	111	Parent Metal Thickness	Plates: 8 to 10 mm
Joint Type:	Fillet weld	Welding Position:	PF (vertical up)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	111	3,25	125	20	DC+	-	15	10000
2	111	3,25	100	19	DC+	-	14	8142

Welding Consumables: Type, Designation Diameter, mm: V	EN ISO 2560-A, E 38 A R 11 1.2	Technique: Weaving: max 3 mm Inclination of the wire: 90º, 20º (pull)
Gas / Flux: Gas type Gas Flow Rate	-	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

Structural tubes are often met in the structure of a building having large openings (fair halls, gyms, etc.). The tubes are joined together in specific nodes: all ends welded together, or all ends meet in a gusset, or all ends enters a specific fixing device and the joining in such device is done with mechanical elements.

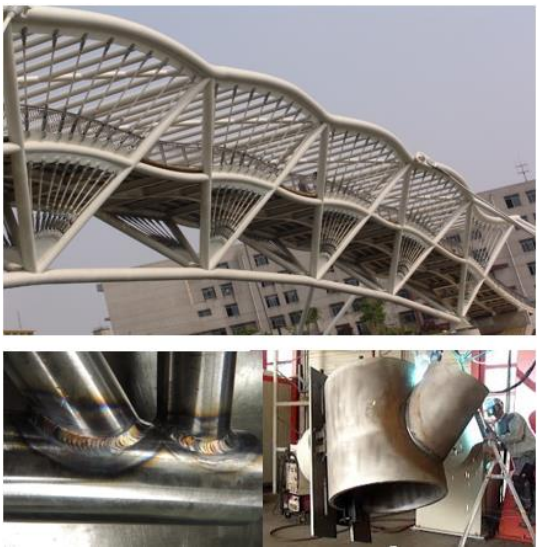


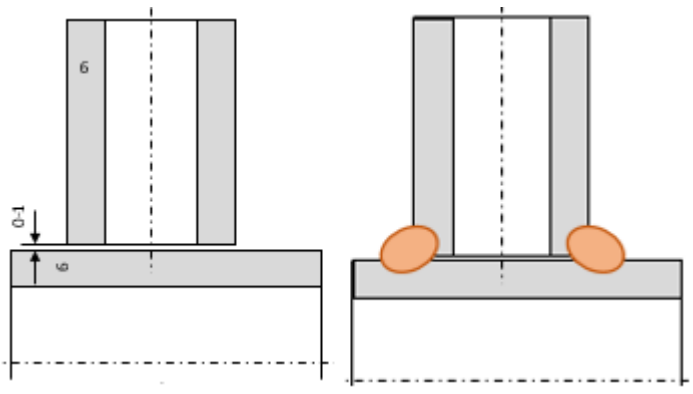
Fig. 28 Welding structural tube nodes

When weld the ends directly, the structure is easier than using gussets. The material used in welding application were S275JR.

Table 17 Chemical composition

Grade	Chemical composition, %				
	C≤	Mn≤	Si≤	S≤	P≤
S275JR	S275JR	1.18	1.5	0.03	0.035

WPS Weld: fillet weld



Welding Procedure Number	25		
Welding Procedure Qualification Record (WPQR)		Revision:	0

Manufacturer:		Method Of Preparation and Cleaning:	Cutting in dimension, cleaning impurities and grease, brushing base paint, remove slag after welding, remove spatter after welding
Location:	Madrid	Parent Metal Specification:	S275
Welding Process:	135	Parent Metal Thickness	Tubes: 6 to 6 mm, diameters: 100 mm
Joint Type:	Fillet weld	Welding Position:	PA (horizontal)

Joint Design	Welding Sequences
Fig. 1	Fig. 2

Run	Process	Size of wire mm	Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135	1.2	130-150	21-22	DC+	6,5	14-15	11760

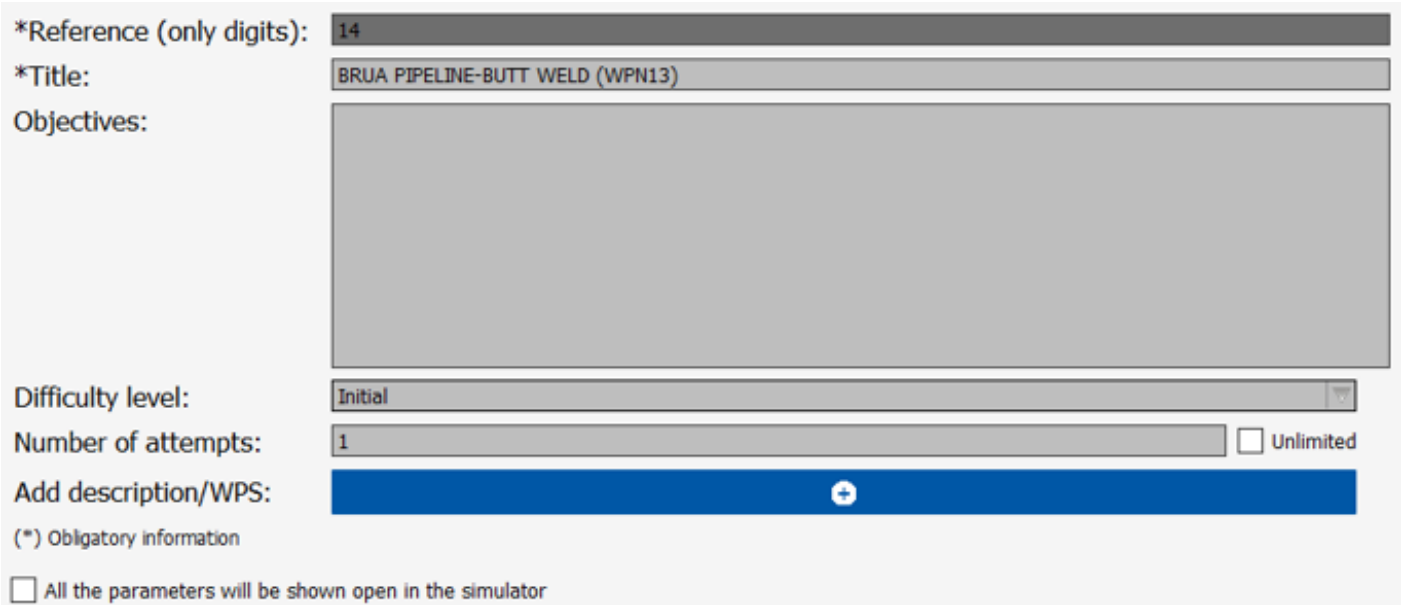
Welding Consumables: Type, Designation Diameter, mm: V	EN ISO 14341-A:G 3Si1, SFA/AWS A5.18:ER70S-6 1.2	Technique: Weaving: max 3 mm Inclination of the wire: 90°, 20° (pull)
Gas / Flux: Gas type Gas Flow Rate	 EN ISO 14175: M21 - 18%CO_2 + rest Ar 12 - 14 l/min	Post Weld Heat Treatment: -
Details of Back Gouging/Backing:	NO	

8. Digital simulation of welding study cases

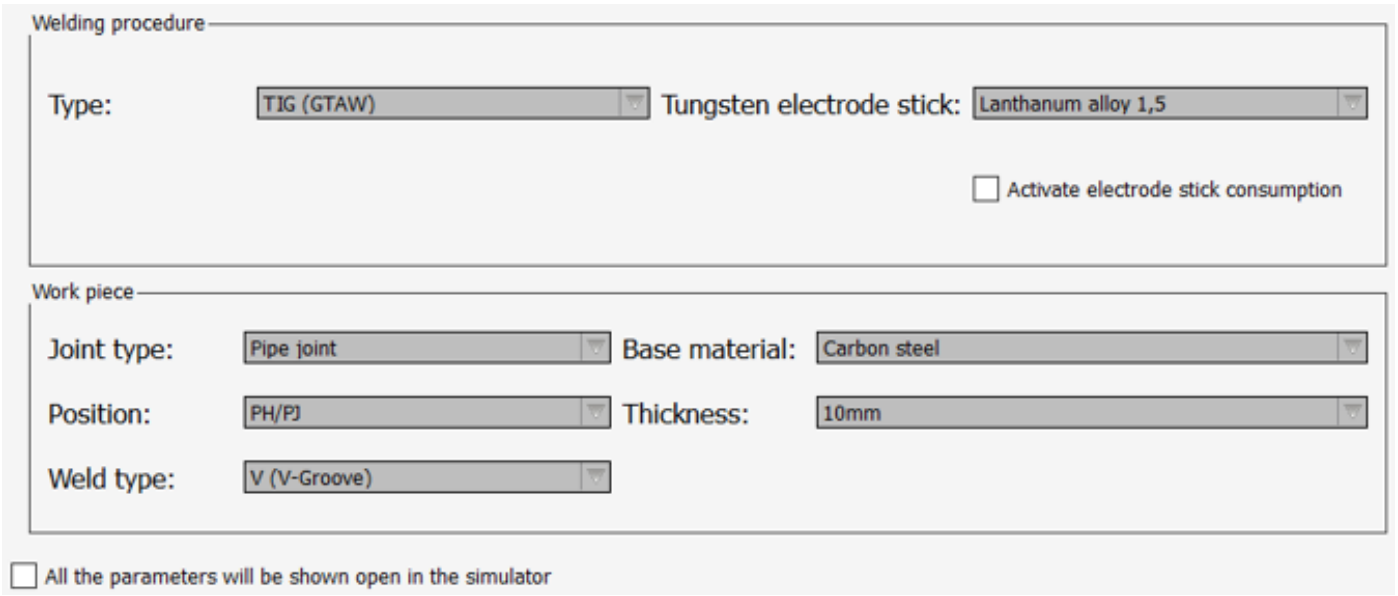
This paragraph intends to present three study cases simulated on AR welding unit covering technical specifications presented above for all welding processes detailed in this book.

8.1. GTAW simulation for welding of BRUA pipeline

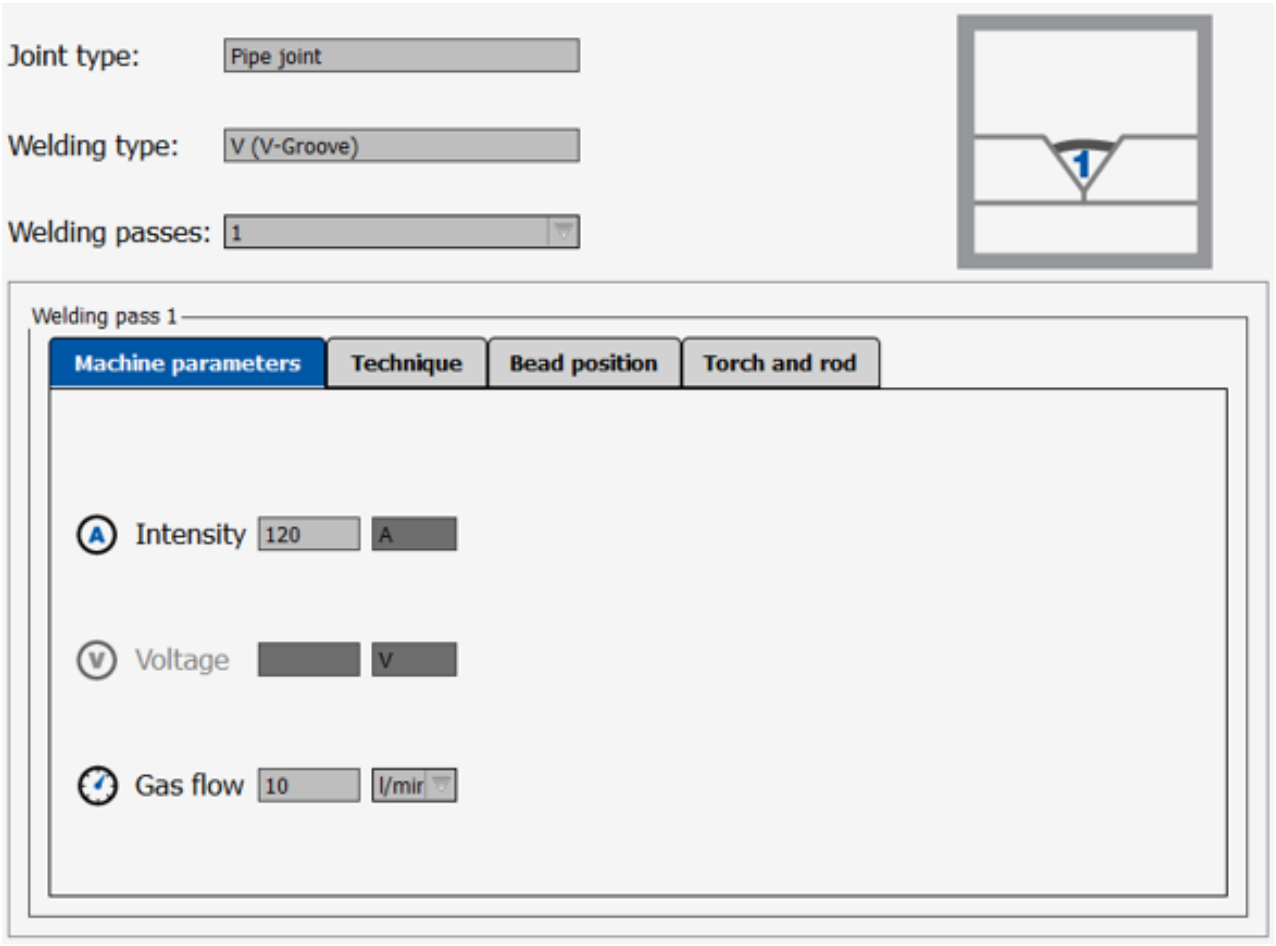
Introduction parameters – General information

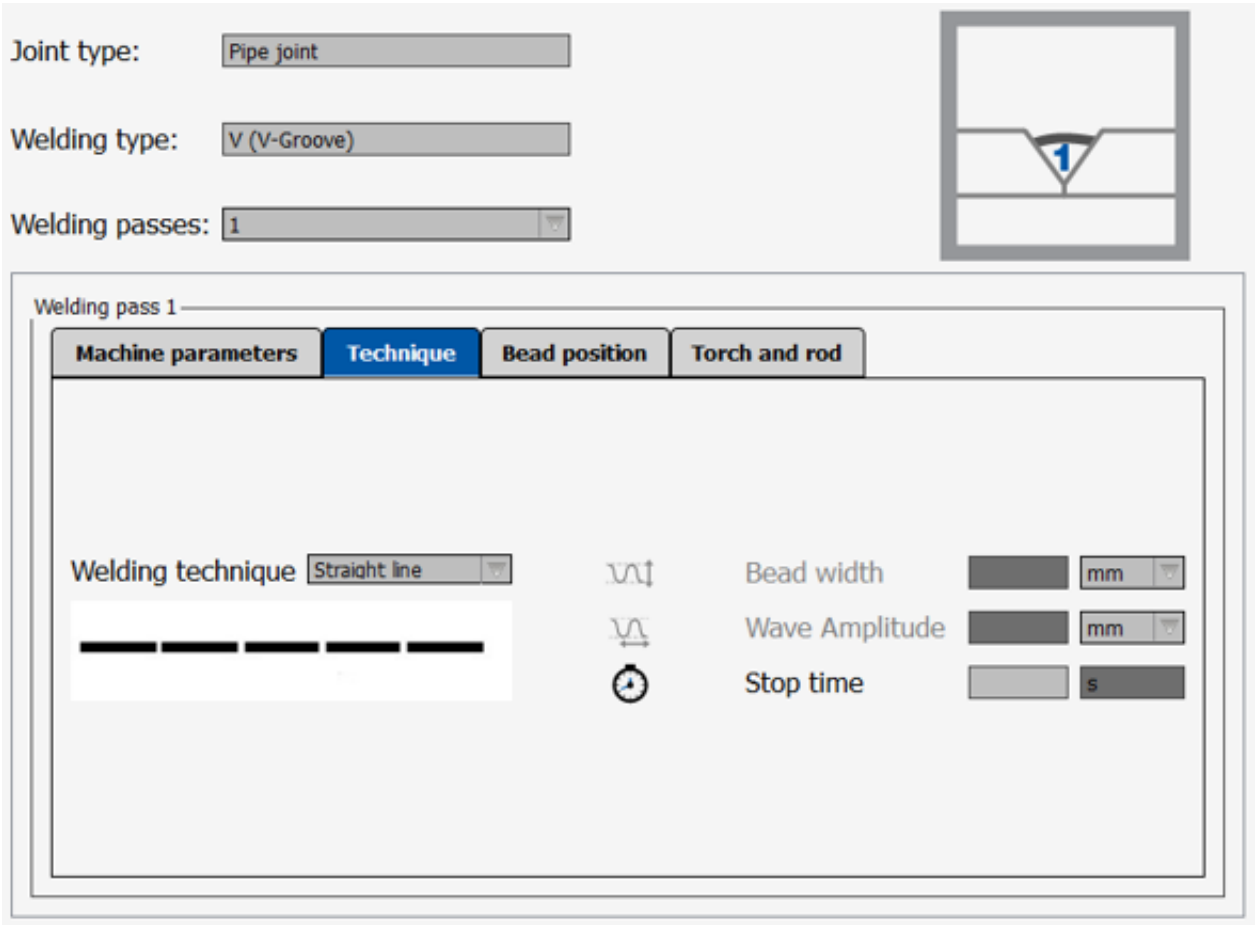


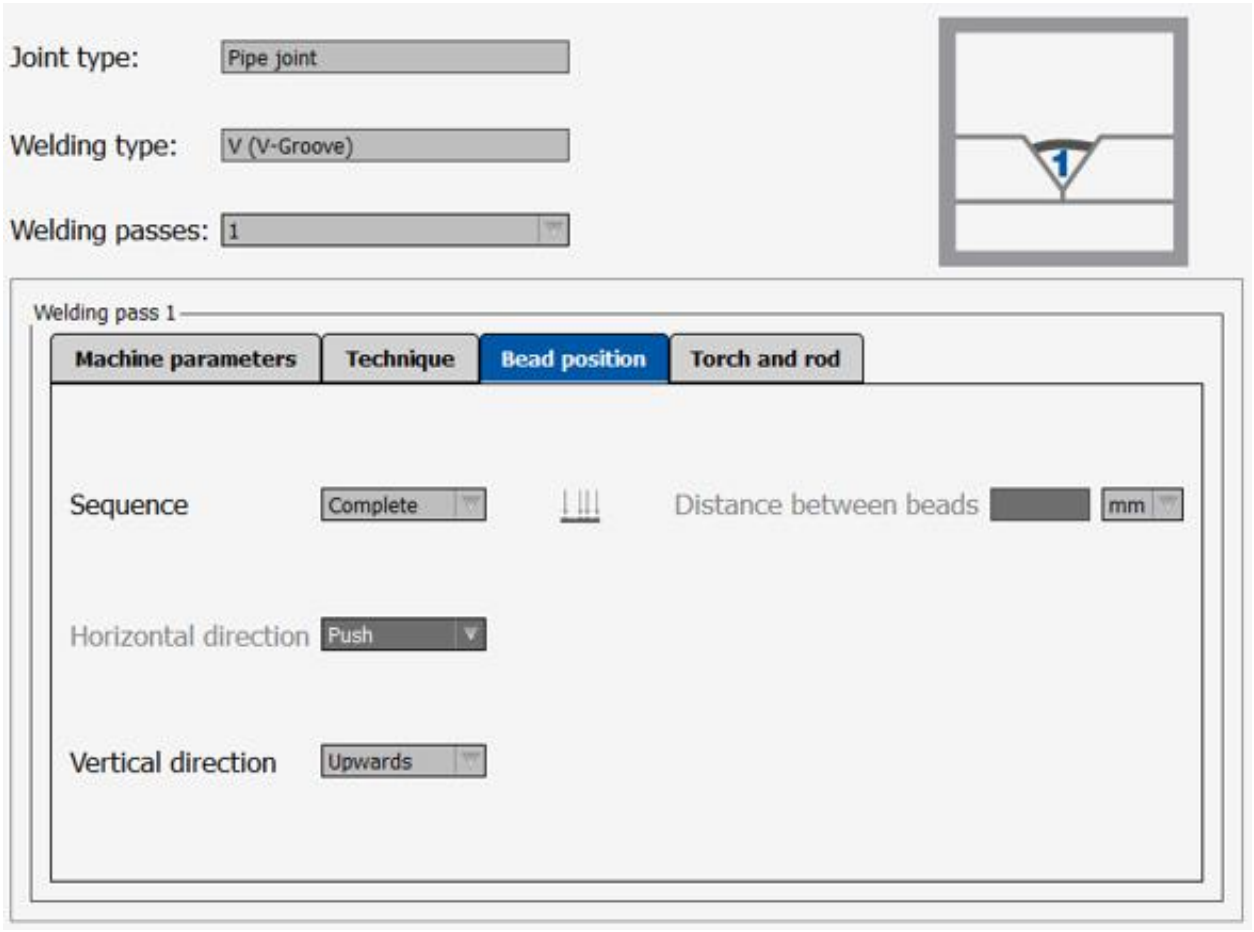
Introduction parameters – Welding procedure

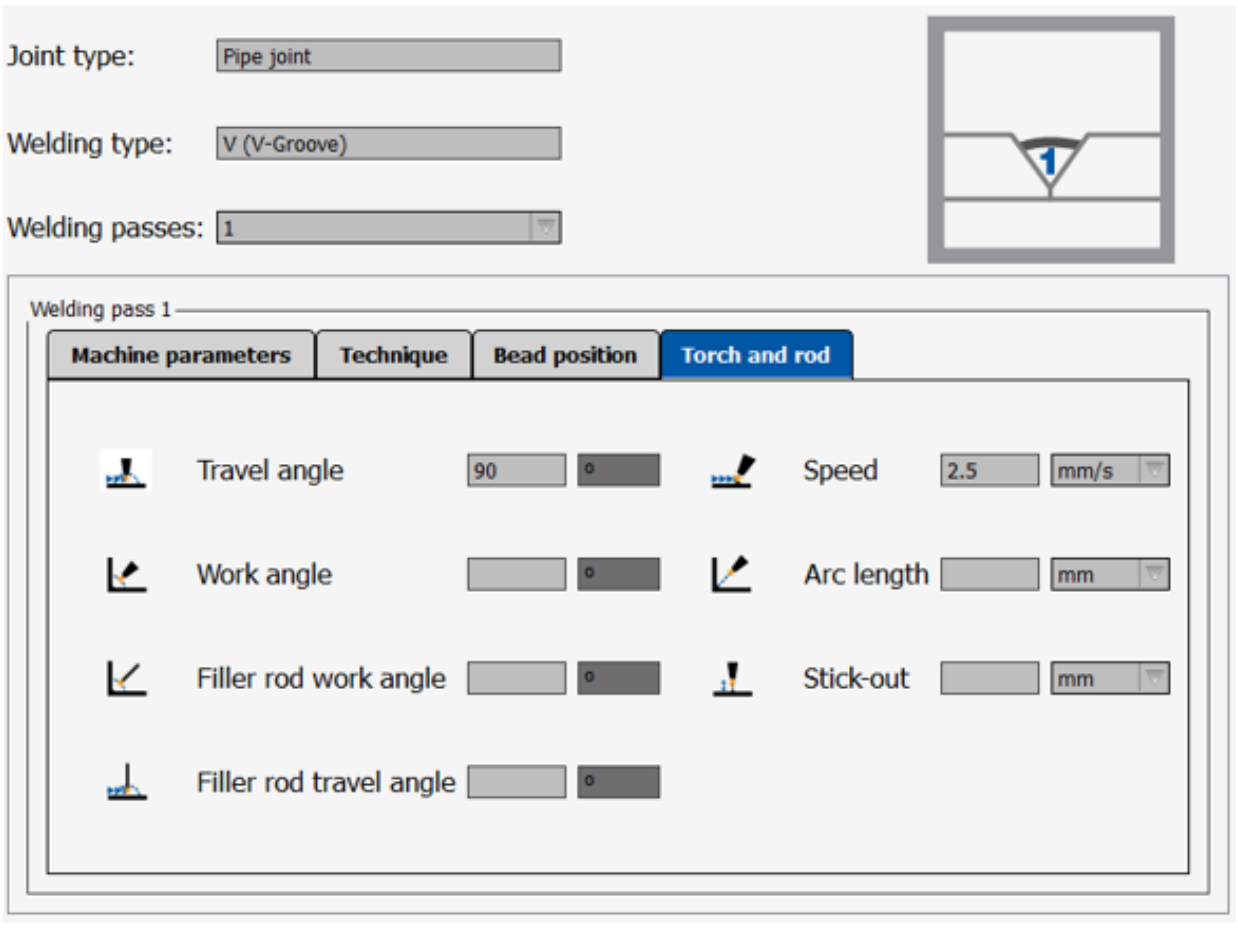


Introduction parameters – Beads


Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
1
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Intensity
120
A
Voltage
V
Gas flow
10
l/mir

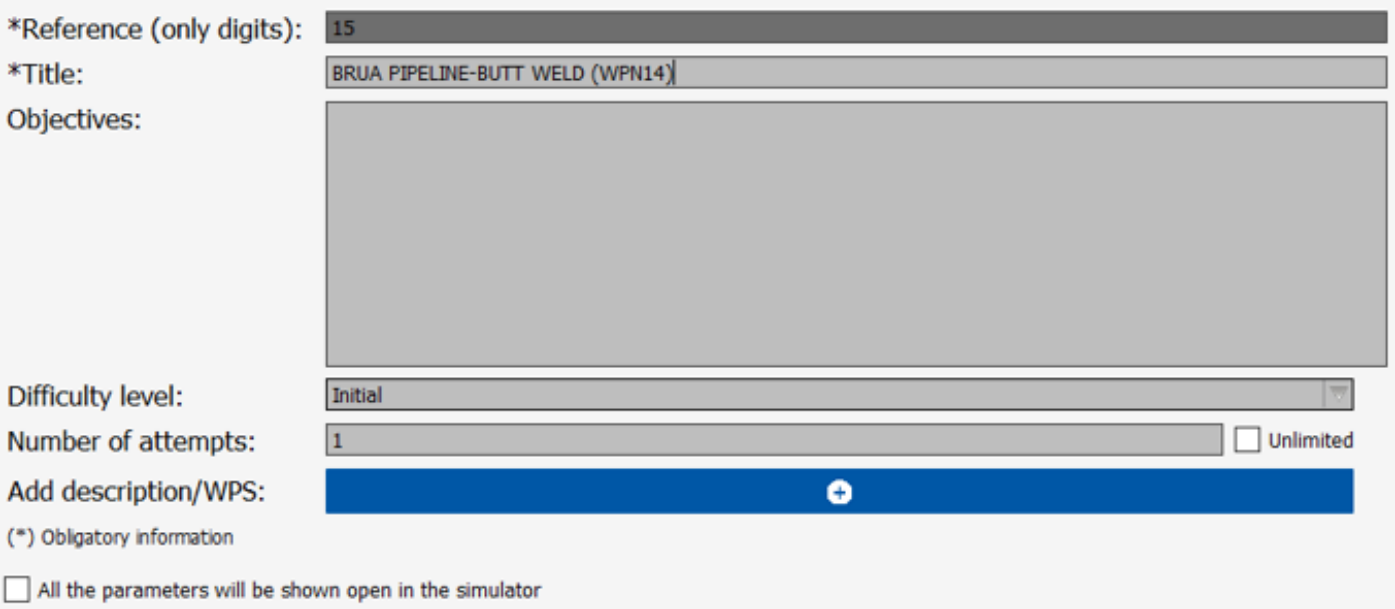

Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
1
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Welding technique
Straight line
Bead width
mm
Wave Amplitude
mm
Stop time
s


Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Sequence
Complete
Distance between beads
mm
Horizontal direction
Push
Vertical direction
Upwards

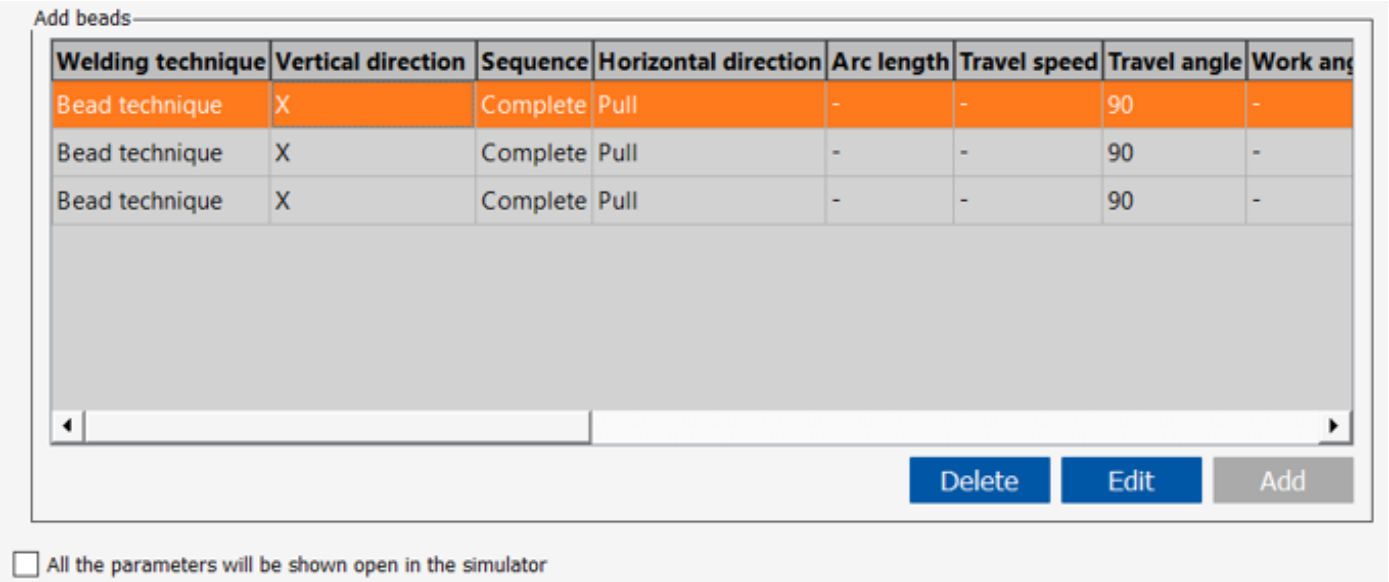

Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Travel angle
90
Speed
2.5
mm/s
Work angle
Arc length
mm
Filler rod work angle
Stick-out
mm
Filler rod travel angle

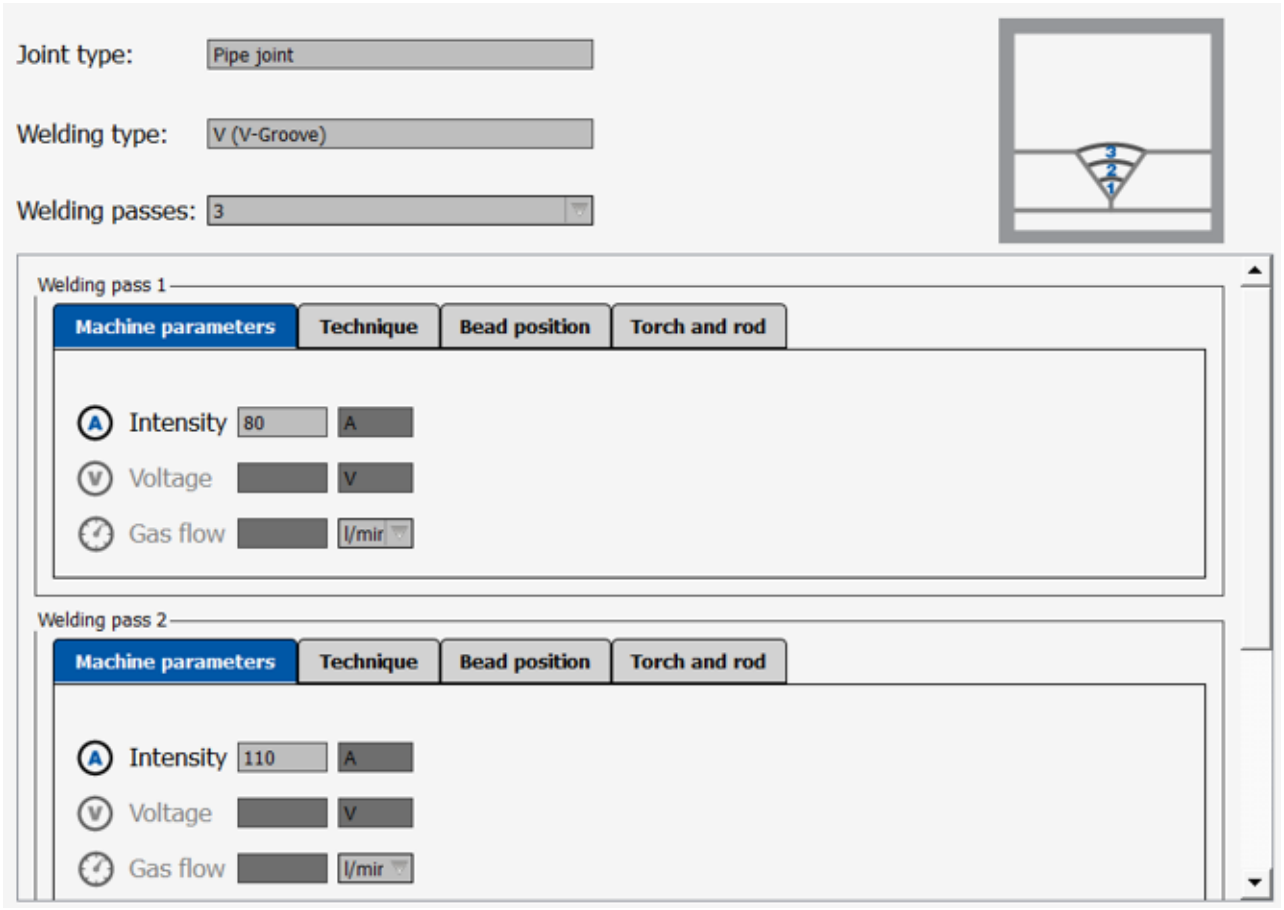
8.2. MMA simulation for welding of BRUA pipeline

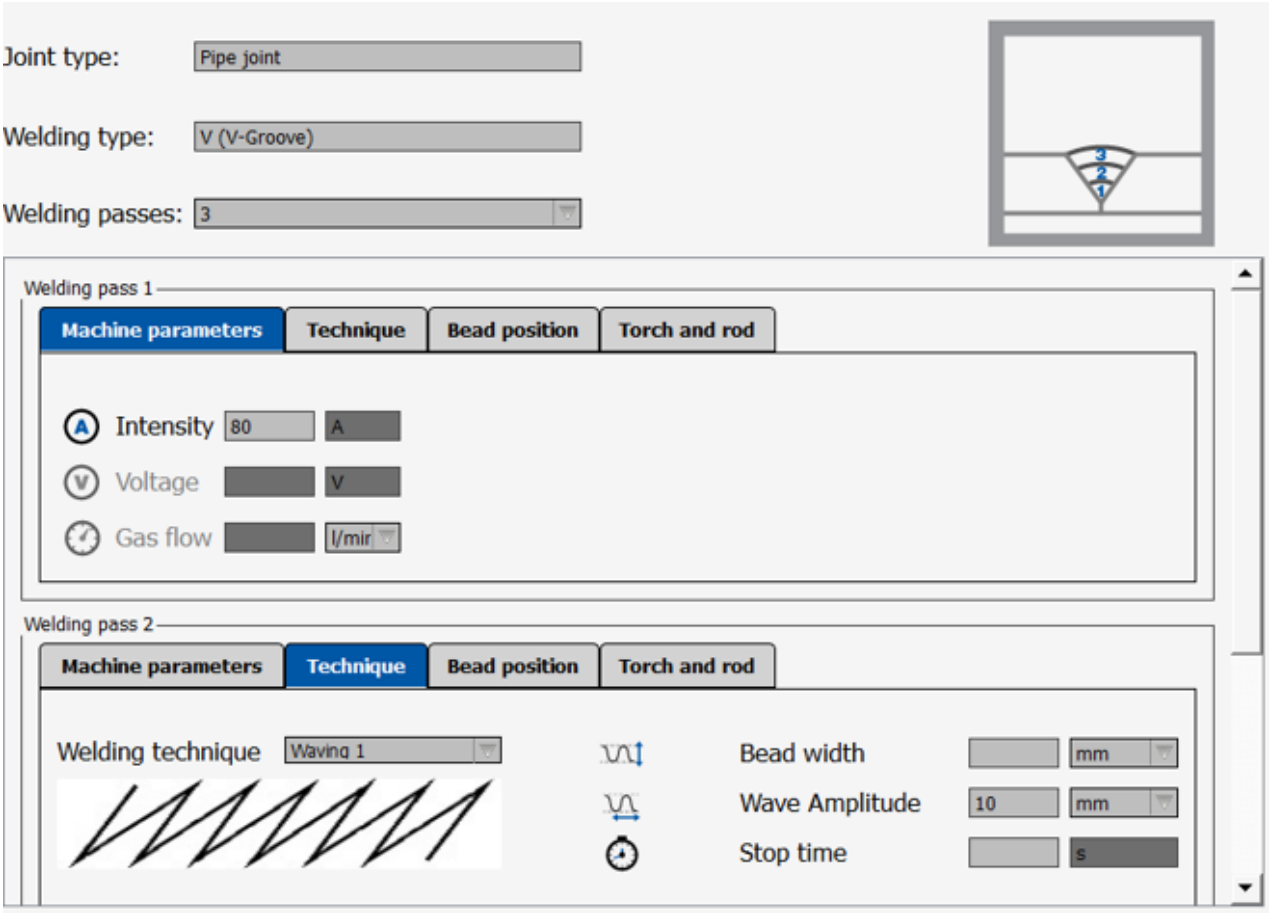
Introduction parameters – General information

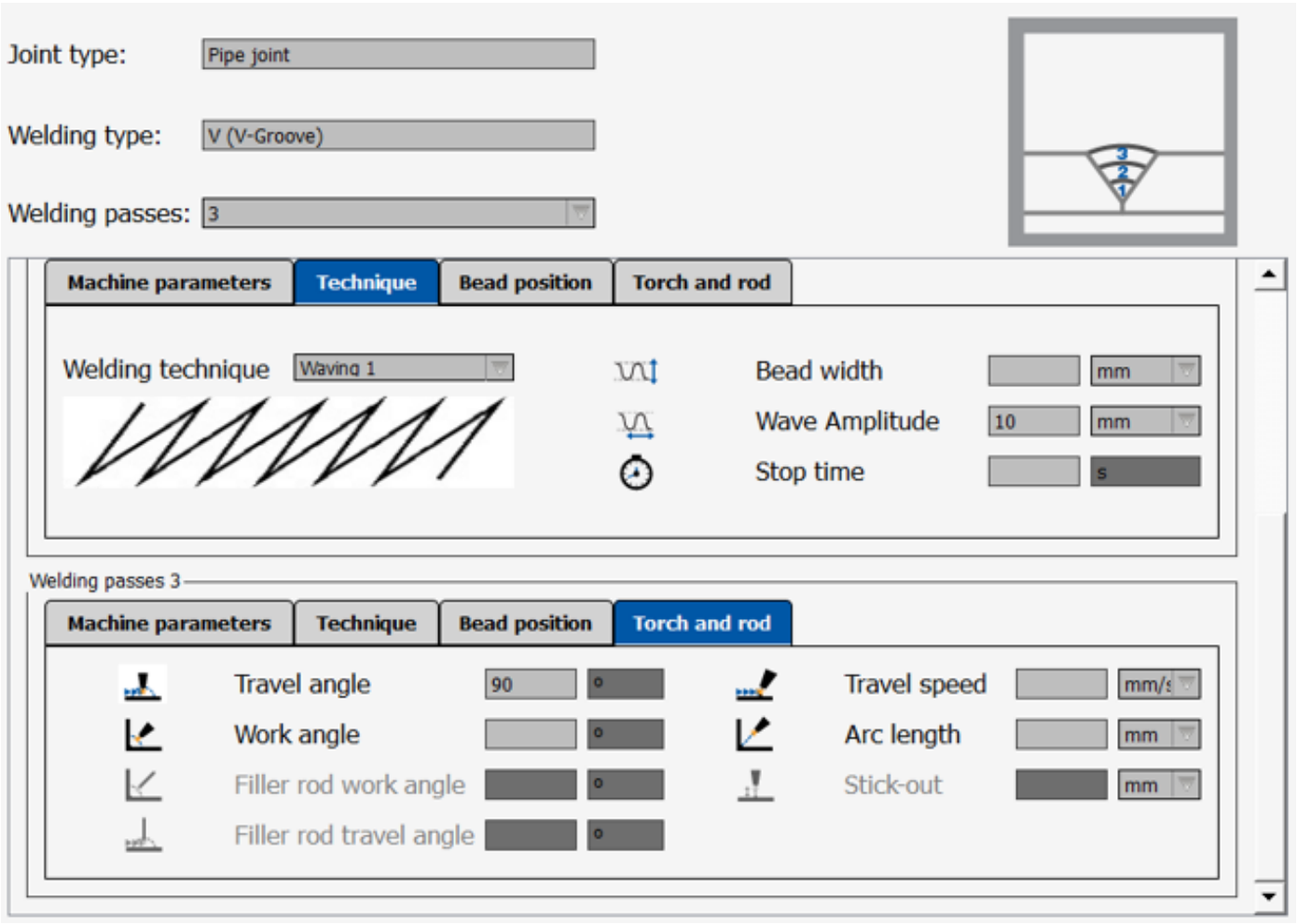


Introduction parameters – Beads



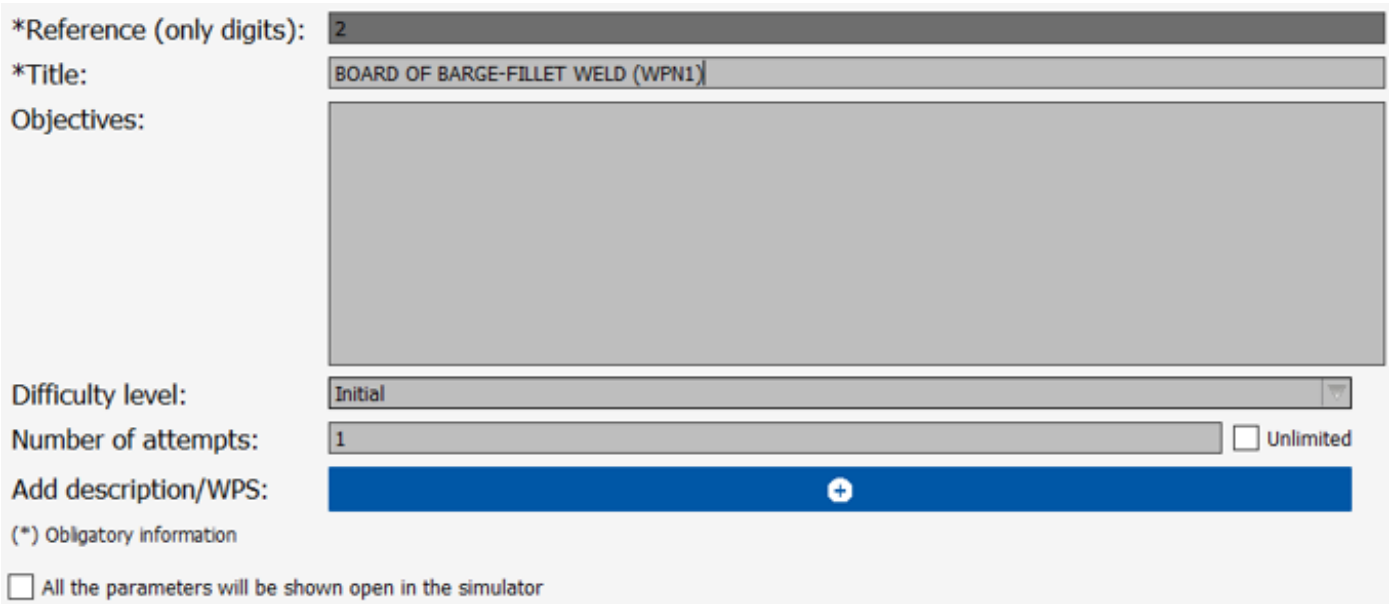

Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
3
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Intensity
80
A
Voltage
V
Gas flow
l/mir
Welding pass 2
Machine parameters
Technique
Bead position
Torch and rod
Intensity
110
A
Voltage
V
Gas flow
l/mir


Joint type:
Pipe joint
Welding type:
V (V-Groove)
Welding passes:
3
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Intensity
80
A
Voltage
V
Gas flow
l/mir
Welding pass 2
Machine parameters
Technique
Bead position
Torch and rod
Welding technique
Waving 1
Bead width
mm
Wave Amplitude
10
mm
Stop time
s

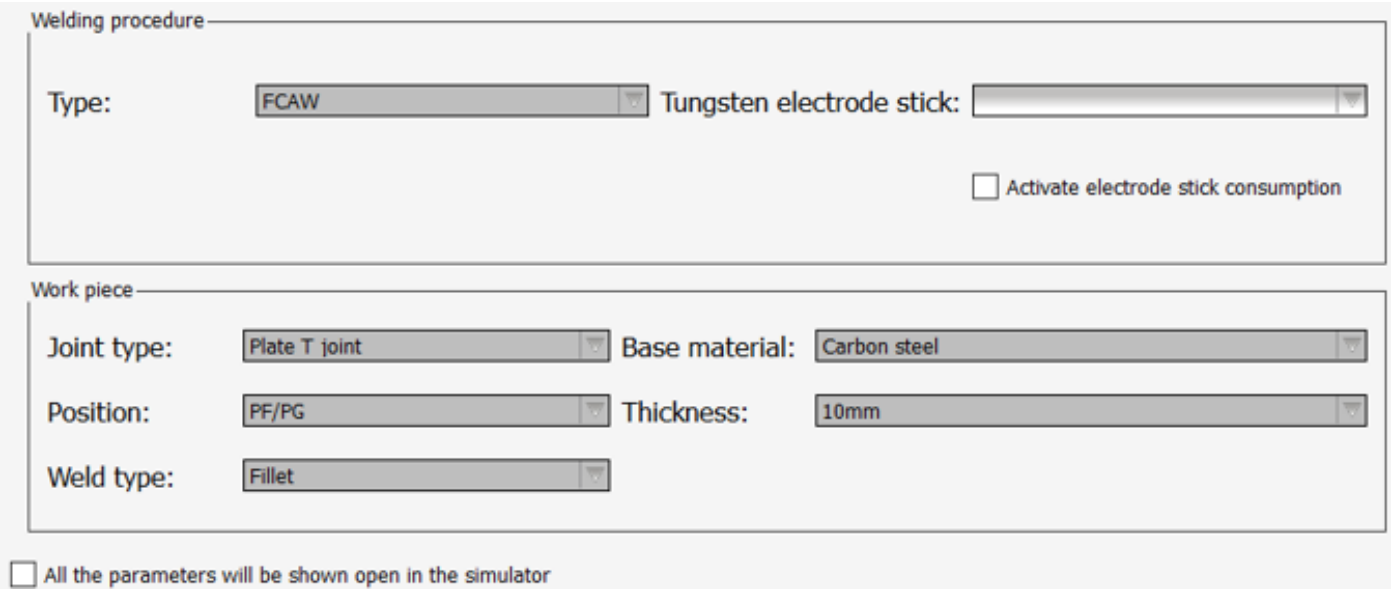


8.3. GMAW simulation for welding of board of barge

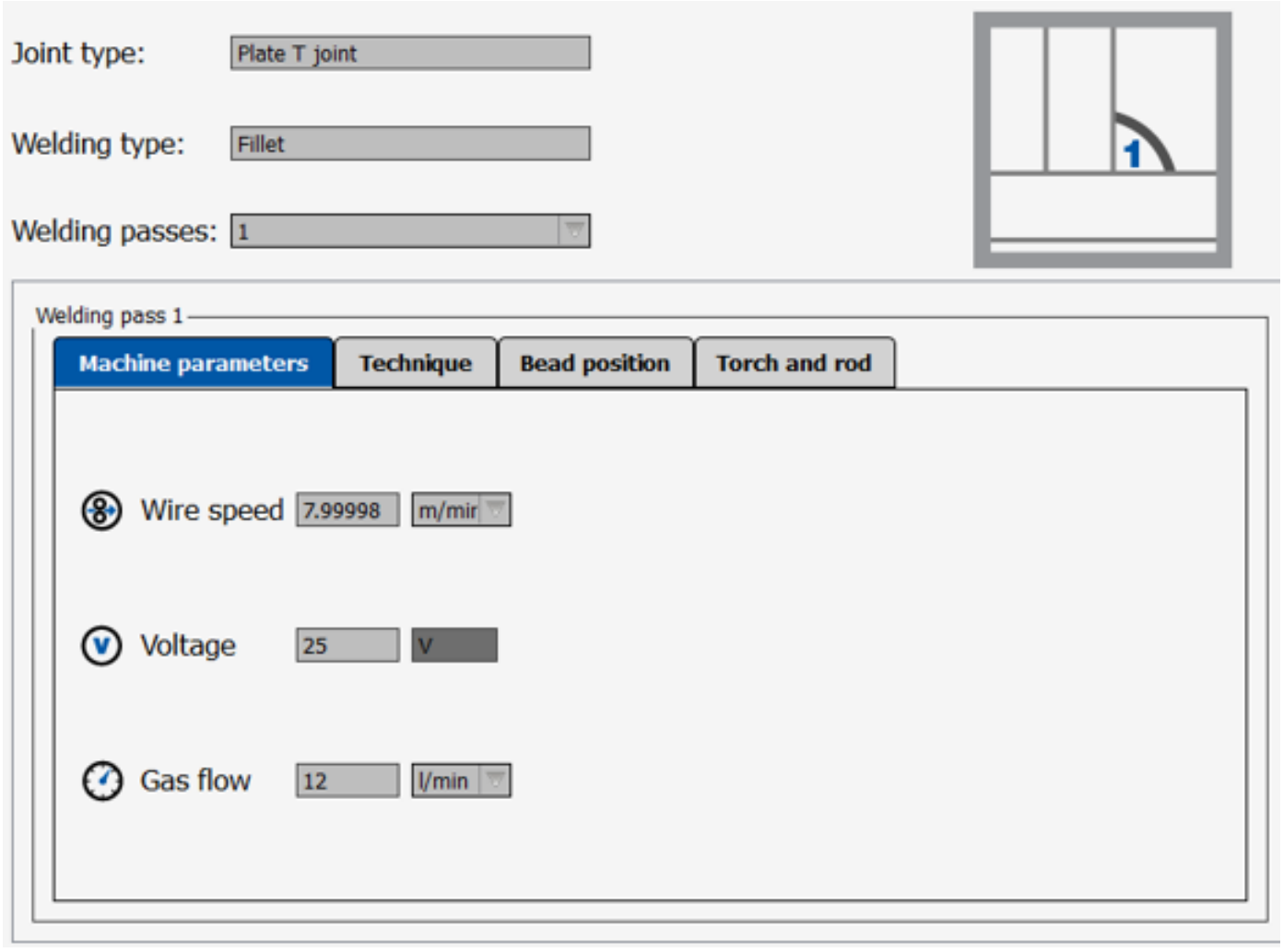
Introduction parameters – General information

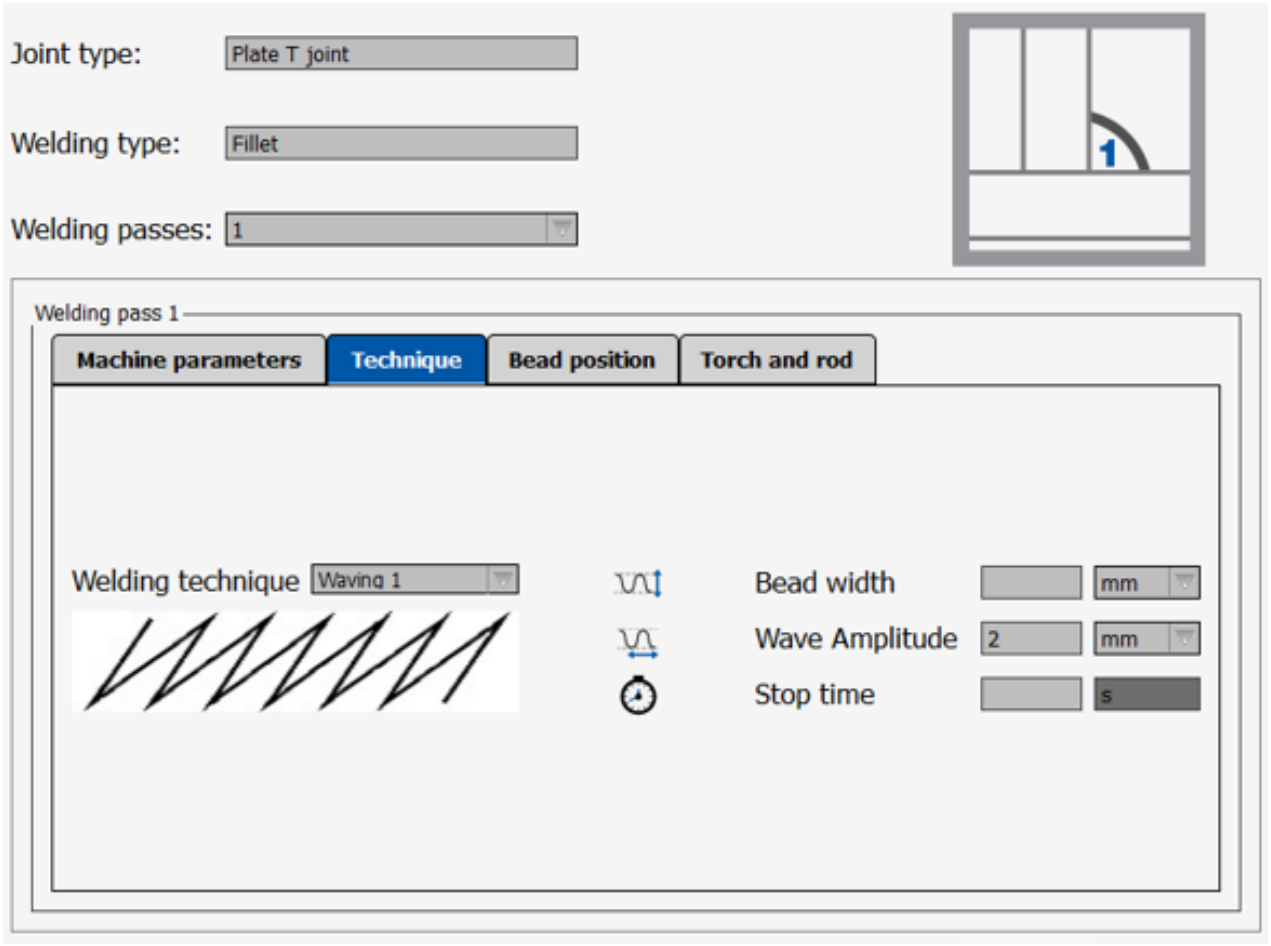


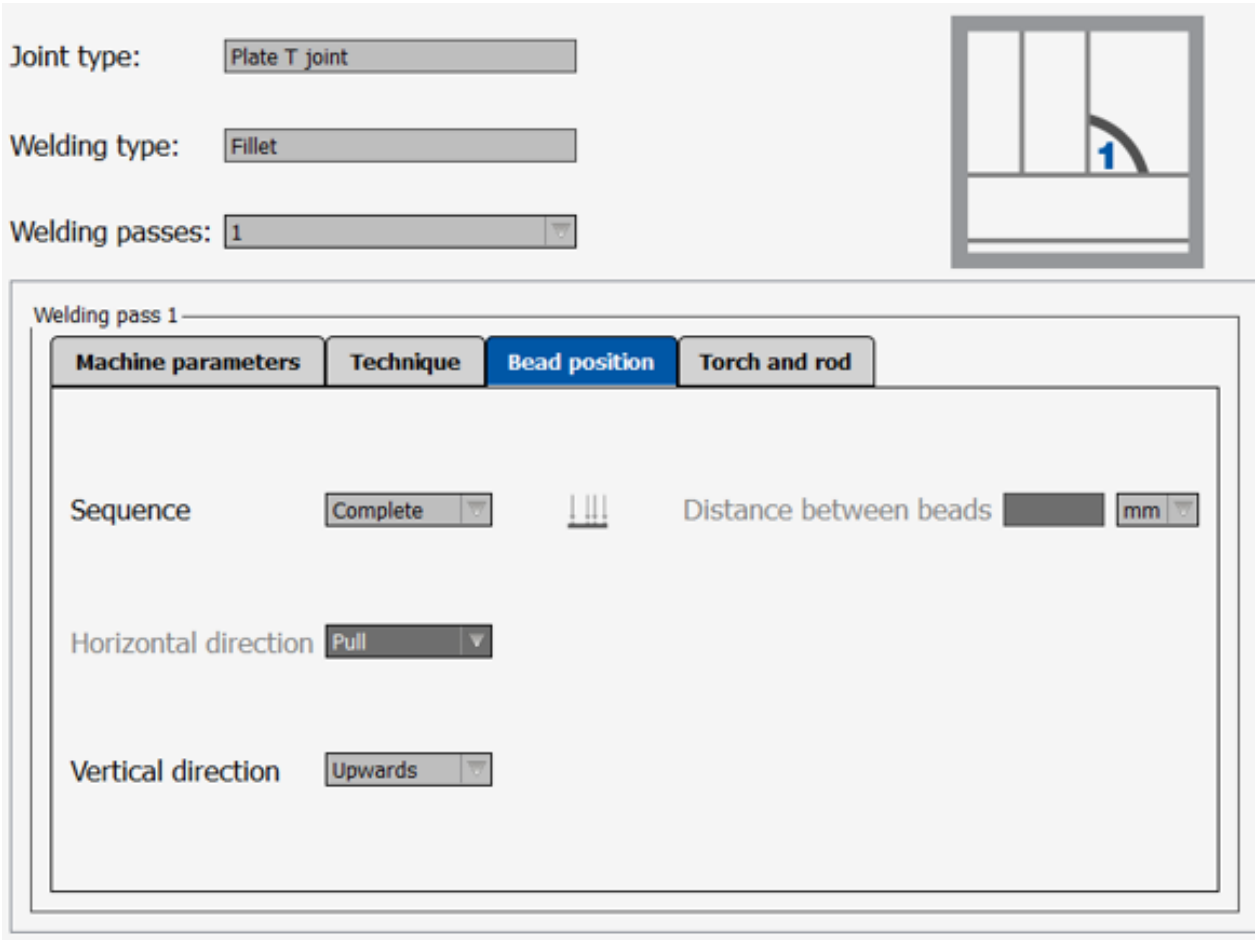
Introduction parameters – Welding procedure

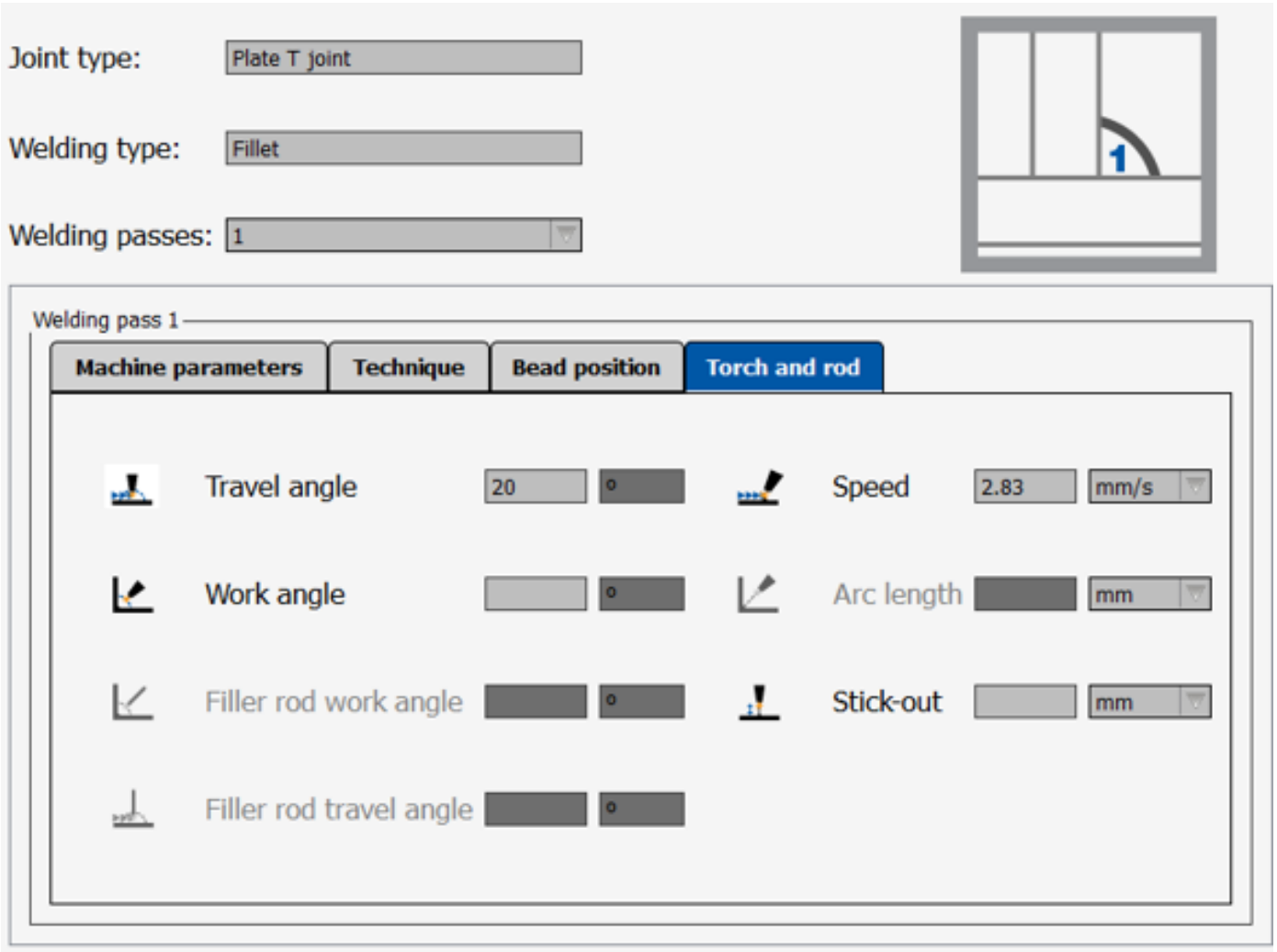


Introduction parameters – Beads




Joint type:
Plate T joint
Welding type:
Fillet
Welding passes:
1
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Welding technique
Waving 1
Bead width
mm
Wave Amplitude
2
mm
Stop time
s


Joint type:
Plate T joint
Welding type:
Fillet
Welding passes:
1
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Sequence
Complete
Distance between beads
mm
Horizontal direction
Pull
Vertical direction
Upwards


Joint type:
Plate T joint
Welding type:
Fillet
Welding passes:
1
1
Welding pass 1
Machine parameters
Technique
Bead position
Torch and rod
Travel angle
20
°
Speed
2.83
mm/s
Work angle
°
Arc length
mm
Filler rod work angle
°
Stick-out
mm
Filler rod travel angle
°

9. Practice and analysis of simulated welding

This paragraph intends to present an example of simulated welding using AR welding simulator. The welding process taken into consideration was gas metal arc welding taking into account that this welding process has large application in welding industry. In the following lines is presented a real welding study case that have been simulated on welding simulator. Taking into account that gas metal arc welding (GMAW) represents one of the most used welding process in industry, the welding exercise chosen and presented in this book is focused on GMAW.

Summary Report

Summary report presents the overall parameters of the process that have been simulated during practical exercises. There are reported the following items:

- Exercise description
- Time of welding
- Skils
- Technical parameters
- Defects
- Observations

Name: TORONJO, MARTA
Course: DIGIWELD COURSE
Exercise: PRACTICE 1

EXERCISE REPORT

Exercise description

Procedure:	MIG/MAG (GMAW)	Tungsten:	
Piece:	T-joint	Base material:	Carbon steel
Position:	PF/PG	Filler material:	ER 70S-6 wire
Diameter:	1.2 mm	Gas:	Argon-CO2

Time of welding

Exercise time:	2min 43s	Arc time:	0min 44s

Skills

✖ **Travel speed:**	**67%**	✔ **Arc length:**	**100%**
✖ **Travel angle:**	**0%**	✔ **Work angle:**	**100%**
✔ **Straightness:**	**89%**	✔ **Stick out:**	**100%**
Tig travel angle:		Tig work angle:	
All skill parameters:	76 %	**Selected parameters:**	**76 %**

Technical parameters

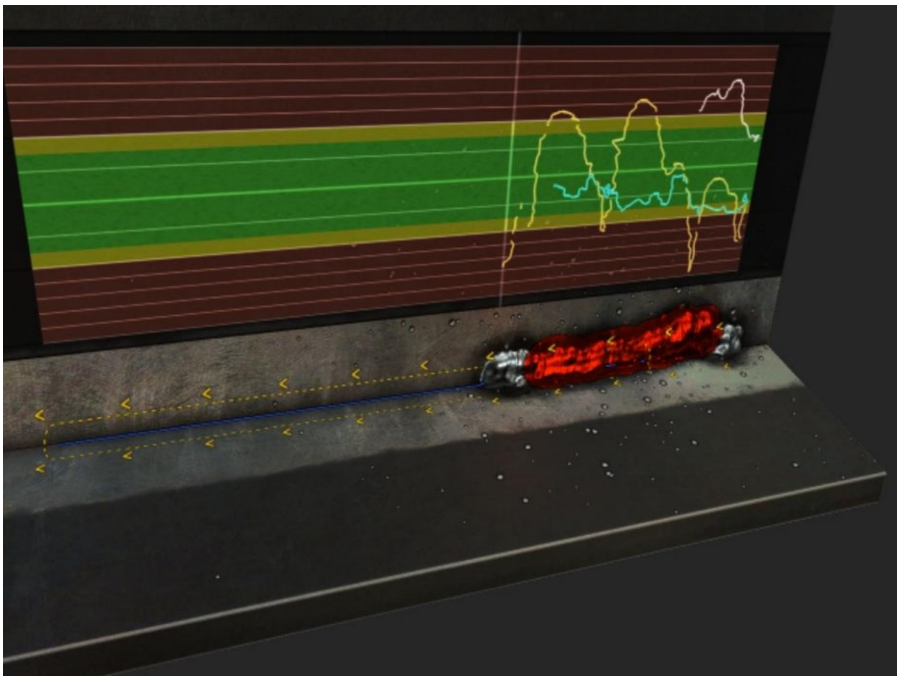
✔ **Voltage:**	**100%**	✔ **Amperage:**	**100%**
✔ **Gas:**	**100%**		
All tecnical parameters:	100 %	**Selected parameters:**	**100 %**

Defects

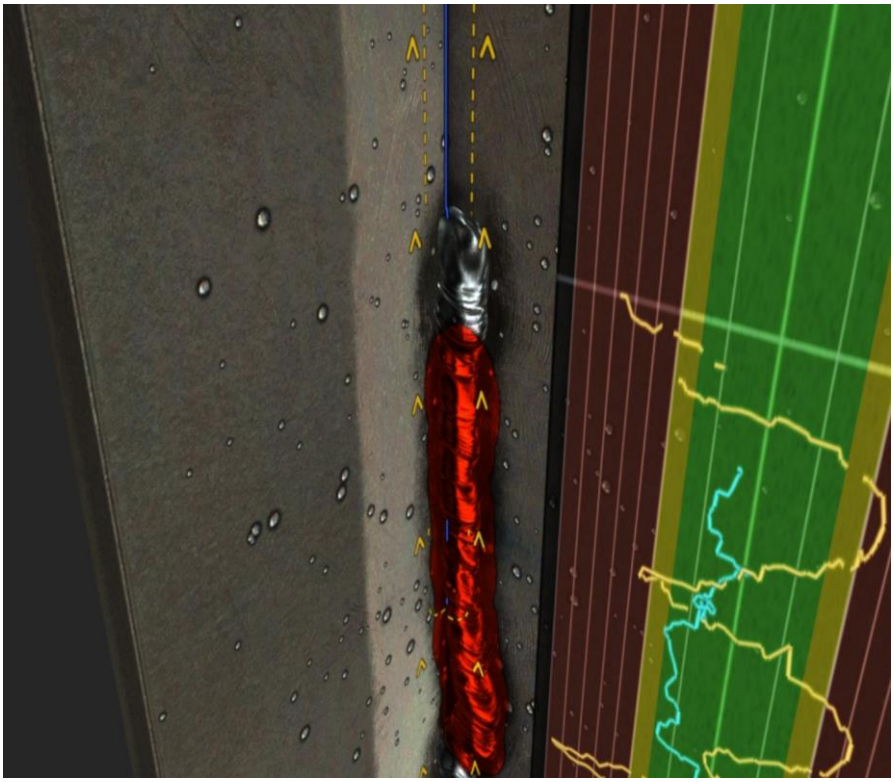
Porosity:	Inclusion:
Splatters:	

Observations:

The welding simulator records the welding process and presents how the practice module run. The analysis module allows the welding trainer to evaluate the performance of the students by providing specific angle views of the welds or main defects that might occur. Obviously, the system allows snapshots from video recorded during welding practices as well as real-time information on welding parameters.



a.



b.

Fig. 29 Snapshot of welding simulation

a. normal view, b. specific angle view

Performance

The front panel of figure above presents the technical parameters of the welding process and the skills of the welder. The performance of the welder is also presented as graph bars.