



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

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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 (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).

Manual skills We	lding defect	
Travel speed		V Arc length
Travel angle		Voltage
Vork angle		V Intensity
p icons:		
Travel speed	Arc length	V Intensity
Travel anole	Vork angle	Voltage

а.

Туре:	÷ .	Tungsten electrode s	stick:
Electric arc	striking:	Activate arc striking	Z Activate electrode stick consumption
ece	_		
	-	Base material:	
Туре:			

b.



С.



d.



oupon:		(Lap join						31	2	
Veld pass sequence:		3					_			_
Veld pass 1	_				_					
Movement	ine		Arc length (mm)		Ŧ		Work angle(°)		Ŧ	
			Speed (mm/s)		Ŧ		Voltage (V)		Ŧ	
			Travel angle (°)		Ŧ		Intensity (A)		Ŧ	
/eld pass 2					-	_				
Movement	line		Arc lenthg (mm)		Ŧ		Work angle(°)		Ŧ	
			Speed (mm/s)		Ŧ		Voltage (V)		Ŧ	
			Travel angle (°)		Ŧ		Intensity (A)		Ŧ	
Veld pass 3						_			_	
Movement	liner		Arc lenthg (mm)	0	Ŧ		Work angle(°)		Ŧ	
		_	Speed (mm/s)		Ŧ		Voltage (V)		Ŧ	
			Travel angle (°)	-	Ŧ	-	Intensity (A)		Ŧ	

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	compositio	n, %		
Orado	C≤	Si≤	Mn	P≤	S≤	Cr	Ni	AI
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





Weld Weld Manuf	ling Proced ling Proced	Jure Numbe Jure Qualifio	:r cation Record (yard Orsova s.a.	WPQR) Method Of Prep	aration	1 Rev Cutting in	ision: dimension, clean , remove slag aft	0 ning impur ter weldin	rities and greas g. remove spat	e, brushing ter after
Locati	in	Worl	kehon Orsona	Parent Metal S	nerification.	welding A32 / A32				
Weldi	on. ng Process:	136	מאמליום לתמוובע	Parent Metal T	nickness	Plates: 8 to	o 10 mm			
Joint 1	lype:	Fille	tweld	Welding Positic	in:	PF (Vertica	(le			
Joint D	Design			Welding Seque	nces					
Fig. 1				Fig. 2						
a a	Drocess	Size of wire	Current	Voltage	Type of curr	ent/	Wire feed spee	d Tra	avel speed	Heat Input
		uu	A	>	Polarity		m/min		cm/min	J/cm
Ŧ	136	1.2	170-180	25-26	DC+		8.0-8.5		17-18	15600
Weldi	ing Consum	ables:				Ie	<u>chnique:</u>			
Type,	Designation	_		EN 758: T 46 2 AWS A5.20: E7 W.Nr.: 1.4430	РС1Н 1Т-1 Н4	≥ ⊆	eaving: max 2 n clination of the	nm widt) wire: 90°	n °, 20° (pull)	
Diame	eter, mm:			1.2						
Gas /	Flux:					욉	st Weld Heat Tr	reatment	ر اند	

EN ISO 14175: 100%CO₂ 12 - 14 l/min

2

Details of Back Gouging/Backing:

Gas Flow Rate

Gas type

TANA L		N			c				
					4		¢		
Weld	ling Proce	dure Quali	fication Record	(WPQR)		Revision	0		
Manu	facturer:	Sh	ipyard Orsova s.a.	Method Of Pre and Cleaning:	paration Ct	rtting in dimer se paint, rem elding	nsion, cleaning ir ove slag after we	mpurities and greas elding, remove spat	e, brushing tter after
Locati	on:	Ň	orkshop, Orsova	Parent Metal S _f	becification: A3	(2 / A32			
Weldi	ng Process:	13	6	Parent Metal Th	hickness Pl	ates:9 to 12 m	E		
Joint 7	lype:	Bu	itt weld	Welding Positio	n: PC	(horizontal o	n vertical wall)		
Joint D	lesign			Welding Seque	nces				
Fig. 1				Fig. 2					
Run	Process	Size of wir	re Current	Voltage	Type of curren	t/ Wire	feed speed	Travel speed	Heat Input
-	136	1.2	170 ± 5	26 + 1	DC+	~	8.0-8.5	17 + 1	15600
2	136	1.2	180 ± 5	26±1	DC+	~	3.0-8.5	48 ± 1	5900
m	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
S	136	1.2	200±5	26±1	DC+	~	8.0-8.5	34 ± 1	9200
Weldi	ng Consum	ables:				Techni	gue:		
Type,	Designatio	-		EN 758: T 46 2	PC1H	Weavin	ng: max 2 mm v	width at pass 1, m	ax 4 mm
				AWS A5.20: E7	71T-1 H4	width a	at pass 2 and m	ax 6 mm width at	passes 3-5
Diame	eter, mm:			W.NI 1.4430		Inclinat	tion of the wire	:: 90°, 20° (pull)	
Gas /	Flux:					Post W	eld Heat Treatr	ment: -	
Gas ty	/pe			EN ISO 14175:	100%CO2	Interpa	iss temperature	e: max 200°C	
Gas F	ow Rate			12 - 14 I/min					
Detai	s of Back G	ouging/Bac	king:	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



а.

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











Welding Proc	edure Nun	nber							
Welding Proc	edure Qua	lification Record	(WPQR)		Revi	ision:	0		
Manufacturer:		shipyard Kladovo	Method Of Pre and Cleaning:	paration	Cutting in base paint welding; st	dimension, cle: , remove slag a tainless steel to	aning im after wel	purities and greas ding, remove spat e used	e, brushing .ter after
Location:	-	Vorkshop, Kladovo	Parent Metal Sp	oecification:	A32 / A32				
Welding Process:		CAW	Parent Metal T	nickness	Plates: 8 to	0 8 mm			
Joint Type:		Fillet Weld	Welding Positic	un:	PA (horizo	ntal)			
Joint Design			Welding Seque	nces					
Fig. 1			Fig. 2						
Run Process	Size of w	<i>i</i> re Current A	Voltage V	Type of curr Polarity	ent/	Wire feed spe m/min	ed	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 Consur	mables:					<u>Technique:</u>			
Type, Designati	on		ISO 17633-A T	19 12 3 L R C	(M 3	Weaving: ma	ax 2 mm	width at pass 1,	max 4 mm
			AWS A5.22 E3 W.Nr.: 1.4430	16LT0-1/ -4		width at pass	s 2 and r	nax 6 mm width	at pass 3
Diameter, mm:			1.2			Inclination of	f the wir	e: 90°, 20° (pull)	
Gas / Flux:						Post Weld He	eat Trea	tment: -	

EN ISO 14175: Ar+18%CO₂ 14 - 16 l/min

Details of Back Gouging/Backing:

Gas Flow Rate

Gas type

Weldin	g Proce	dure Nun	nber		-	t,				
Weldin	g Proce	dure Qua	alification Record	(WPQR)	l	Revi	ision:	0		
Manufact	urer:		Shipyard Orsova s.a.	Method Of Pre and Cleaning:	paration	Cutting in c base paint, welding	dimension, clean , remove slag afti	ng impuritie: er welding, re	s and greas emove spat	e, brushing ter after
Location:		>	Workshop, Orsova	Parent Metal Sp	becification:	432 / A32				
Welding	Process:	H	136	Parent Metal Th	nickness	Plates: 8 to	o 10 mm			
Joint Typ	ä	Ľ	Fillet weld	Welding Positio		PA (horizo	ntal)			
Joint Desi	uä			Welding Sequer	nces					
Fig. 1				Fig. 2						
Run P	rocess	Size of w	vire Current A	Voltage V	Type of curre Polarity	ent/ V	Nire feed speec m/min	l Travel cm/	speed 'min	Heat Input J/cm
-1	136	1.2	170-180	25-26	DC+		8.0-8.5	17-	-18	15600
Welding	Consum	ables:				Te	chnique:			
Type, De	signation	=		EN 758: T 46 2	P C 1 H	Ň	eaving: max 2 m	im width		
				AWS A5.20: E7 W.Nr.: 1.4430	71T-1 H4	u U	clination of the v	vire: 90°, 20	e (pull)	
Diameter	, mm:			1.2						
Gas / Flu	×					8	st Weld Heat Tr	eatment: -		
Gas type				EN ISO 14175:	100%CO2					
Gas Flow	Rate			12 - 14 I/min						
Details o	f Back G	ouging/Ba	acking:	N						

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.



Weld 1 (Gusset to wall) Weld 2 (Gusset to deck)



а.



b.

Fig. 6 Cabin a. welds, b. snapshot of welding on site

WPS Weld: Gusset to deck



Welding Pro	cedure Nu	umber				9				
Welding Pro	cedure Qi	ualifica	tion Record	(WPQR)		Rev	/ision:	0		
Manufacturer:		Shipyar	d Kladovo	Method Of Prej and Cleaning:	paration	Cutting in base pain [†] welding; s	dimension, clean t, remove slag aft stainless steel too	ing impuritie er welding, re Is to be used	s and greas emove spat	e, brushing ter after
Location:		Works	hop, Kladovo	Parent Metal Sp	ecification:	316L/31	9L			
Welding Proces	8:	FCAW		Parent Metal Th	iickness	Plates: 7 t	o 10 mm			
Joint Type:		Fillet W	/eld	Welding Positio	:u	PA (horizo	ontal)			
Joint Design				Welding Sequer	nces					
Fig. 1				Fig. 2						
Run Proces	s Size of mn	' wire	Current A	Voltage V	Type of curr Polarity	ent/	Wire feed speed m/min	d Travel cm/	speed min	Heat Input J/cm
1 136	1.1	2	180±5	26±1	DC+		8.0-8.5	18	±1	15600
Welding Const	umables:						Technique:			
Type, Designa	tion			ISO 17633-A T	19 12 3 L R C	,М З	Weaving: max	2 mm width	at pass 1, I	max 4 mm
				AWS A5.22 E3: W.Nr.: 1.4430	16LT0-1/ -4		width at pass 2	and max 6 r	mm width	at pass 3
Diameter, mm				1.2			Inclination of th	he wire: 90°,	20° (pull)	

Post Weld Heat Treatment: -

EN ISO 14175: Ar+18%CO2

14 - 16 l/min

Details of Back Gouging/Backing:

Gas Flow Rate

Gas / Flux: Gas type

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		Chei	nical compositior	ı, %	
Crudo	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



	•								
Weld	ding Proce	dure Numbe	2		_				
Weld	ding Proce	dure Qualific	cation Record ((WPQR)	l	Rev	ision: (-	
Manu	ıfacturer:	Shipy	yard Kladovo	Method Of Prej and Cleaning:	paration b	Jutting in Jase paint Velding; st	dimension, cleanir t, remove slag afte. tainless steel tools	ng impurities and gr r welding, remove s to be used	ease, brushing patter after
Locat	ion:	Worl	kshop, Kladovo	Parent Metal Sp	becification: A	131			
Weld	ing Process:	136		Parent Metal Th	nickness F	lates: 20	to 20 mm		
Joint	Type:	Butt	Weld	Welding Positio	n:	C (horizo	ntal on vertical wa	(
Joint D	Design			Welding Sequer	nces				
Fig. 1				Fig. 2					
Run	Process	Size of wire	Current	Voltage	Type of curre	ut/	Wire feed speed	Travel speed	Heat Input
-	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
m	136	1.2	190-200	21-22	DC+		8.5-9.0	10-11	23700
Weld	ing Consum	ables:					Technique:		
Type,	, Designatio	c		EN 758, T 46 2	P C 1 H5		Weaving: max 2	mm	
Diam	eter, mm:			1.2			Inclination of the	e wire: 90°, 20° (pu	(1)
<u>Gas /</u> Gas t	<u>'Flux:</u> ype low Rate			EN ISO 14175: 14 - 16 I/min	C1 - 100%CO ₂		Post Weld Heat Interpass tempe	<u>Treatment:</u> - rature: max 200°C	
	IOW VALE			1000/07 - 4T					

Details of Back Gouging/Backing:

<mark>9</mark>

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 Proc	edure Numb	er			~			
Welding Proc	edure Qualif	ication Record ((WPQR)	L	Revi	ision: 0		
Manufacturer:	Ship	pyard Kladovo	Method Of Prepa and Cleaning:	ration b	Jutting in c Jase paint, velding; st	dimension, cleaning i , remove slag after w :ainless steel tools to	mpurities and greas elding, remove spa ^r be used	e, brushing tter after
Location: Welding Process:	Wo 136	rkshop, Kladovo 5	Parent Metal Spec Parent Metal Thic	cification: A kness P	\131 ates: 201	io 20 mm		
Joint Type:	But	t Weld	Welding Position:		D (overhe	ad)		
Joint Design			Welding Sequence	es				
Fig. 1			Fig. 2					
Run Process	Size of wire mm	e Current A	Voltage 1 V	lype of curre Polarity	nt/	Nire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1-3 136	1.2	190	21-22	ĊĊ		8,5	9.0-9.5	11400
Welding Consur	mables:					Technique:		
Type, Designati	u		EN 758, T 46 2 P	C 1 H5		Weaving: max 2 mr	F	
			1.2			Inclination of the w	ire: 90°, 20° (pull)	
Diameter, mm:								
<u>Gas / Flux:</u> Cos truco			EN ICO 14175. C	1 1008/00		Post Weld Heat Tre	<u>eatment:</u> -	
Gas Flow Rate			14 - 16 l/min	T - T00%002		ווווכו למסס ובווולבומו		
Details of Back	Gouging/Back	cing:	ON					

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

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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 Chemica	I composition
-----------------	---------------

ep				Chemica	l compositi	on, %			
Gra	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Мо	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





Weld Weld Manuf Manuf Noeldi Joint T Joint T Fig. 1 Bun Run 3 Meldii 3 Type,	ling Proce ling Proce facturer: ng Process: rype: rype: ng Process 135 135 135 135 135 135 135 135 Designatior	dure Number dure Qualific MEVA Work 135 Fillet mm 1.2 1.2 1.2 1.2	A Drobeta A Drobeta shop, Drobeta weld A 215 ± 5 255 ± 5 255 ± 5	WPQR) Method Of Pre and Cleaning: Parent Metal SF Parent Metal Th Welding Positio Welding Sequer Fig. 2 Voltage V 22 ± 1 27 ± 1	paration b paration c pecification: S nickness P n: P n: P n: P n: P n: P n: DC+ DC+ DC+ DC+	Revisit utting in dir ase paint, re velding 355J2-N lates: 8 to 10 A (horizonta nt/ Wir Weav	on: 0 tension, cleanin tmove slag after tmove slag after tmove slag after tmove slag after tmove slag after tmove slag after thove slag after	le impurities and gre r welding, remove s Travel speed cm/min 20 ± 1 31 ± 1 31 ± 1	ase, brushing atter after Heat Input J/cm 14900 13325 13325
Diame	iter, mm:			1.2		Inclir	nation of the v	wire: 90°, 20° (pull	_
Gas / I	Flux:					Post	Weld Heat Tre	eatment: -	
Gas ty	/pe			EN ISO 14175:	M21 - 18%CO ₂	+ Inter	pass temperat	ure: max 200°C	

Stick-out: 15-18 mm

rest Ar 12 - 14 I/min

2

Details of Back Gouging/Backing:

Gas Flow Rate

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

lde				Chemica	l compositi	on, %			
Gra	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Мо	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



elding Procedure Num elding Procedure Qual anufacturer: M anufacturer: Fi int Type: Fi int Type: Fi int Type: 11: 11: 11:2 11:2 11:2 11:2 11:2 11:2	ber fication Record (EVA Drobeta orkshop, Drobeta is let weld d 255 ± 5 255 ± 5	WPQR) Method Of Prepa and Cleaning: Parent Metal Thio Welding Position Welding Sequenc Fig. 2 Voltage Voltage 27 ± 1 27 ±	10 arration Cutf base arration base cification: S35 cification: Cutrent cification: Cutrent cification: Cutrent cification: Cutrent cification: Cutrent cification: Cutrent cification: Cutrent <th>Revision: Revision, deani ing in dimension, deani i paint, remove slag afte ding si2-N si2-N si2-N sing norizontal) vorizontal(vorizontal) vorizontal) vorizontal)</th> <th>D ng impurities and grea r welding, remove spa Travel speed cm/min 31 ± 1 31 ± 1</th> <th>se, brushing tter after Heat Input J/cm 13325 13325</th>	Revision: Revision, deani ing in dimension, deani i paint, remove slag afte ding si2-N si2-N si2-N sing norizontal) vorizontal(vorizontal) vorizontal) vorizontal)	D ng impurities and grea r welding, remove spa Travel speed cm/min 31 ± 1 31 ± 1	se, brushing tter after Heat Input J/cm 13325 13325
s type		EN ISO 14175: N rest Ar	A21 - 18%CO ₂ +	Post Weld Heat Tr Stick-out: 15-18 m	<u>eatment:</u> - m	
		EN 160 14175	1 007001 LCV	Post Weld Heat Tr	<u>eatment:</u> -	
s / Flux:						
ameter, mm:		1.2				
		SFA/AWS A5.18	:ER70S-6	Inclination of the	wire: 90°, 20° (pull)	
pe, Designation		EN ISO 14341-A:	:G 3Si1,	Weaving: NO		
elding Consumables:				<u>Technique:</u>		
135 1.2	255 ± 5	27±1	DC+	8.0	31 ± 1	13325
135 1.2	255 ± 5	27±1	DC+	8.0	31±1	13325
In Process Size of wi	e Current A	Voltage V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
. 1		Fig. 2				
nt Design		Welding Sequenc	es.			
int Type: Fi	let weld	Welding Position	: PB(iorizontal)		
elding Process: 18	5	Parent Metal Thio	ckness Plat	es: 10 to 12 mm		
cation: W	orkshop, Drobeta	Parent Metal Spe	cification: \$35	5J2-N		
anufacturer: M	EVA Drobeta	Method Of Prepa and Cleaning:	rration Cutt base wel	ing in dimension, cleani : paint, remove slag afte ling	ng impurities and grea r welding, remove spa	se, brushing tter after
elding Procedure Qual	fication Record (WPQR)		Revision:	0	
elding Procedure Num	ber		8			

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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
---------	----------	-------------

epi				Chemica	l compositi	on, %			
Gra	C≤	Si≤	Mn	P≤	S≤	Cu	Ni	Мо	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 Pr Welding Pr Manufacturer Location: Welding Proce Joint Type: Joint Design Fig. 1	ocedure N ocedure O ess:	lumber Lualifica Madric 135 Fillet w	tion Record (WPQR) Method Of Pre and Cleaning: Parent Metal Sr Parent Metal Tr Welding Positic Welding Sequer Fig. 2	paration pecification: hickness bn: nces	11 Re Cutting i base pai welding \$275JR Plates: 3 PB (hori:	evision: in dimension, dear int, remove slag aft sto 3 mm zontal)	0 ing impuritie ter welding, r	es and greas	e, brushing ter after
Run Proce 1 135	ss Size o m 1.	of wire im .0	Current A 200-220	Voltage V 20-21	Type of curr Polarity cc+	rent/	Wire feed spee m/min 8	d Travel cm 55	l speed //min 5-65	Heat Input J/cm 4200
<u>Welding Cons</u> Type, Designa	sumables: ation			EN ISO 14341- SFA/AWS A5.1	A:G 3Si1, 18:ER70S-6		<u>Technique:</u> Weaving: NO Inclination of the	e wire: 90°, 3	20° (pull)	
<u>Gas Flow Rat</u>	والم			EN ISO 14175: 12 - 14 l/min	c1 - 100%CO ₂		Post Weld Heat T Stick-out: 15-18 r	reatment: - mm		
Details of Bad	ck 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	com	position
-----------	----------	-----	----------

Grade				Chemical	composit	ion, %			
Crude	Mg	Mn+Cr	Mn	Si	Fe	Cr	Zn	Ti	AI
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



Weldin	Ig Proce	dure Numbe			H				
Weldin	Ig Proce	dure Qualific	ation Record	(WPQR)		Revision:	0		
Manufac	turer:			Method Of Pre and Cleaning:	paration Ct w	ıtting in dimension, ise paint, remove s elding	, cleaning in lag after we	npurities and grea: elding, remove spa	e, brushing tter after
Location				Parent Metal Sp	becification: Al	Mg3 / AW 5754 EN	573-1:200	80	
Welding	Process:	131		Parent Metal Th	nickness Pl	ates: 2 to 2 mm			
Joint Typ	ë	Fillet (over	tweld lapped)	Welding Positic	DI: PE	(horizontal)			
Joint Des	ign			WeldingSeque	nces				
Fig. 1				Fig. 2					
Run	rocess	Size of wire	Current	Voltage	Type of curren	t/ Wire feed	speed	Travel speed	Heat Input
-	131	6.0	A 70-80	14-16	CC+	2		40-50	4200
Welding	Constant	ahlae.				Tachnique.			
Type, De	esignation			EN – ER 4043		Weaving:	Q		
						Inclination	of the wire	e: 90°, 20° (pull)	
Diamete	r, mm:			0.9					
Gas/Flu Gas tyne	×.			EN ISO 1/175	11 - 100%Ar	Post Weld H	leat Treatr	<u>ment:</u> -	
din can	u					Stick-out: 12	2-14 mm		
Gas Flow	v Rate			12 - 14 I/min					
Details o	of Back Ge	puging/Backin	:8:	ON					



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 con	position, %	
	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



Weldi	ing Procedi	ure Numbe	er		13			
Weldi	ing Proced	ure Qualifi	ication Record	I (WPQR)		Revision: 0		
Manufa	acturer:	ТАП		Method Of Prepa and Cleaning:	iration Cutti base weld	ng in dimension, cleaning paint, remove slag after v ing	impurities and gre welding, remove sp	ase, brushing atter after
Locatio		Yard	, Arad	Parent Metal Spe	cification: L415	ME PSL 2, ISO 3183/2012		
Weldin	g Process:	141+	+111	Parent Metal Thi	ckness Pipe	s: 10 to 10 mm		
Joint Ty	ype:	Butt	weld	Welding Position) Hd	ertical up on pipe)		
Joint De	esign			Welding Sequend	es.			
Fig. 1				Fig. 2				
Run	Process	Size of wire mm	Current A	Voltage 1 V	Type of current/ Polarity	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
Ŧ	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
<u>Weldin</u> Type, L Diamet	ng Consuma Designation ter, mm:	bles:		Covered electro 42 5 W3Si1 + E 42 H5 3.0, 3.2, 4.0 Tungsten electr	de: Boehler W 55 6 1 NiMo B ode: WTh2	<u>Technique:</u> Weaving: NO Inclination of the wi	re: 90°, 20° (pull)	
				3.2				
<u>Gas / F</u> Gas typ Gas Flo	lux: pe w Rate			EN ISO 14175: I: 10 - 12 l/min	1 - 100%Ar	Post Weld Heat Trea Interpass temperatu Dry electrodes: 300°	<u>ttment:</u> - re: max 200⁰C C / 2h	
Details	of Back Got	uging/Backi	ing:	NO				

Wels	ling Proced	Annha Munha				14				
Weld	ling Proced	ure Qualifi	cation Record	I (WPQR)		Re	vision:	0		
Manu	facturer:	HAB/	AU PPS LINE SYSTEMS	Method Of Pre and Cleaning:	eparation	Cutting i base pai welding	in dimension, clea nt, remove slag af	ining im fter wel	purities and gre ding, remove sp	ase, brushing atter after
Locati	on:	Yard,	, Arad	Parent Metal S	pecification:	L415 ME	PSL 2, ISO 3183/2	2012		
Weldi	ing Process:	111		Parent Metal T	hickness	Pipes: 1(0 to 10 mm			
Joint 7	Type:	Butty	weld	Welding Positi	ion:	PH (vert	ical up on pipe)			
Joint D	Jesign			WeldingSeque	ences					
Fig. 1				Fig. 2						
		Size of	Current	Voltage	Type of curr	rent/	Wire feed spee	T b	ravel speed	Heat Input
Run	Process	wire mm	A	~	Polarity		m/min		cm/min	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+		•			
<u>Weldi</u>	ing Consuma	bles:					Technique:			
Type,	Designation			Covered elect	trode: Boehlei	r FOX	Weaving: max	3 x Ø e	lectrod	
Diame	eter, mm:			DMO Kb, EN B 4 2 H5 3.2, 4.0	ISO 3580-A : E	Ŵ	Inclination of th	ie wire:	90°, 20° (pull)	
Gas/	<u>Flux:</u>						Post Weld Heat	Treatm	<u>ent:</u> -	
Gas ty	/pe			EN ISO 14175	: I1 - 100%Ar		Interpass tempe.	rature:	max 200°C	
				10 - 12 l/min			Dry electrodes: 3	300°C /	2h	

Gas Flow Rate

Details of Back Gouging/Backing:

2

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			Chemic	al composi	ition, %	
	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



Velding Proced Velding Proced Velding Process: /elding Process: /elding Process: /elding Process /elding Consuma /elding Consuma /pe, Designation	lure Numbe lure Qualific 135 135 135 135 112 1.2 1.2 1.2 1.2 1.2 1.2 1.2	rid cation Record veld A 190-200 250-260 250-260	I (WPQR) Method Of Pre and Cleaning: Parent Metal S Parent Metal S	eparation pecification: hickness on: Type of curr Polarity Polarity 3 42 4 C G4 Si1	15 Rel base pai welding PH (verti PH (verti	vision: 0 ri dimension, deaning nt, remove slag after v PSL1, Grade X52 5 to 15 mm, diameter: 1 ical up on pipe) tical up on pipe) by tical up on pipe) 6,5 9 9 1 Chinique: Weaving: NO Inclination of the wi	impurities and gre welding, remove sp 500 mm Travel speed cm/min 20-21 20-21 20-21 20-21 20-21	ase, brushing latter after Heat Input J/cm 11940 15000 20000
<u>s / Flux:</u> s type s Flow Rate tails of Back Go	uging/Backi	:9	EN ISO 14175 82%Ar+18%Ar 15 - 18 l/min NO	: M21 -		<u>Post Weld Heat Trea</u> Interpass temperatu	tment: - re: max 200°C	
elding Consuma pe, Designation ameter, mm:	bles:		EN 14341-A G 3.2	i 42 4 C G4 Si1		<u>Technique:</u> Weaving: NO Inclination of the wi	re: 90°, 20° (pull)	
4 135	1.2	250-260	28-29	Ş		6	20-21	20000
135	1.2	250-260	28-29	÷		6	22-23	15000
135	1.2	190-200	22-23	÷		6,5	20-21	11940
n Process	Size of wire mm	Current A	Voltage V	Type of curr Polarity	ent/	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1			Fig. 2					
it Design			Welding Seque	ences				
nt Type:	Butt v	weld	Welding Positi	ion:	PH (verti	ical up on pipe)		
elding Process:	135		Parent Metal T	hickness	Pipes: 19	5 to 15 mm, diameter: !	500 mm	
ation:	Madr	rid	Parent Metal S	pecification:	API 5L - F	PSL1, Grade X52		
nufacturer:			Method Of Pre and Cleaning:	sparation	Cutting i base pai welding	in dimension, cleaning nt, remove slag after v	impurities and gre welding, remove sp	ase, brushing latter after
elding Proced	ure Qualific	cation Record	I (WPQR)		Re	vision: 0		
elding Proced	ure Numbe	2			15			

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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

۵					Cher	nical com	position,	%			
rad	6	Sic	Mn	Р	S	Cr	Мо	Ni		Cu	Nb
Ū	64	212	≤	≤	≤	\leq	\leq	\leq		\leq	\leq
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)



Weld	ding Procedu	ure Numb	er			16				
Weld	ding Procedu	ıre Qualif	ication Record	I (WPQR)		Re	vision:	0		
Manu	ıfacturer:	() 		Method Of Pre and Cleaning:	paration	Cutting i base pai welding	in dimension, clear nt, remove slag af	ning impuriti ter welding, I	ies and grea remove spa	ise, brushing atter after
Locat	ion:	Ploi	ești	Parent Metal S _I	pecification: F	265GH				
weld	ing Process:	136		Parent Metal T	hickness	L2 to 12	mm			
Joint	Type:	Butt	weld	Welding Positi	on:	PA (hori	zontal)			
Joint D	Design			WeldingSeque	nces					
Fig. 1				Fig. 2						
Run	Process	Size of wire	Current A	Voltage V	Type of curre Polarity	ent/	Wire feed spee m/min	d Travel cm/	speed /min	Heat Input J/cm
-	135	1.2 1.2	220-240	25-26	5 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
Weld	ing Consumat	oles:					Technique:			
Type,	, Designation			EN 758: T 46 2	2 P C 1 H		Weaving: NO			
Diam	eter, mm:			AWS A5.20: E W.Nr.: 1.4430 1.2	71T-1 H4		Stick-out: 15-17 Inclination of th	mm e wire: 90°,	20° (pull)	
<u>Gas /</u> Gas t	<u>' Flux:</u> Ype			EN ISO 14175:	100%CO.		Post Weld Heat 1	reatment: -		

Interpass temperature: max 200°C

EN ISO 14175: 100%CO₂ 12 - 14 l/min

Ceramic backing

Details of Back Gouging/Backing:

Gas Flow Rate

Weldi	ing Procedure	Numbe				17				
Weldi	ing Procedure	Qualific	ation Record	I (WPQR)		Rev	vision:	0		
Manufa	scturer:			Method Of Pre and Cleaning:	paration	Cutting ir base pain welding	ı dimension, cle. ıt, remove slag a	aning in after we	mpurities and grea	sse, brushing atter after
Locatio	ë	Ploies	ti	Parent Metal S	pecification:	P265GH				
Weldin	g Process:	136		Parent Metal T	hickness	12 to 12 r	mm			
Joint Ty	/pe:	Butt w	reld	Welding Positi	on:	PH (vertic	cal up)			
Joint De	esign			Welding Seque	inces					
Fig. 1				Fig. 2						
Run	Process v	ze of vire mm	Current A	Voltage V	Type of curr Polarity	ent/	Wire feed spe m/min	ed	Travel speed cm/min	Heat Input J/cm
tı	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
Weldin	ig Consumables						echnique:			
Type, E	Designation	1		EN 758: T 46 2	2 P C 1 H		Veaving: NO			
Diamet	ter, mm:			AWS A5.20: E W.Nr.: 1.4430 1.2	71T-1 H4		Stick-out: 15-1) nclination of th	7 mm he wire	:: 90°, 20° (pull)	
<u>Gas / F</u> Gas typ	lux: De			EN ISO 14175-	100%CO.	<u>~1</u>	ost Weld Heat	t Treatn	<u>ment:</u> -	

Interpass temperature: max 200°C

Details of Back Gouging/Backing:

Gas Flow Rate

Ceramic backing

12 - 14 I/min

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
------------------	-------------

ð					Cher	nical com	position,	%			
rad	~	Qic	Mn	Р	S	Cr	Мо	Ni		Cu	Nb
ŋ	5		VI	YI	YI.	\leq	\leq	\leq		\leq	\leq
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



Weld	ling Procec	dure Numbe	ir		18			
Weld	ling Proced	lure Qualific	cation Record	(WPQR)		Revision: 0		
Manuf	facturer:			Method Of Prep. and Cleaning:	aration Cut basi	ting in dimension, cleanin e paint, remove slag afteı ding	g impurities and gre welding, remove sp	ase, brushing Jatter after
Locati	on:	Ploie	ști	Parent Metal Spe	cification: P26	5GH		
Weldi	ng Process:	136		Parent Metal Thi	ckness 6 to	12 mm		
Joint T	lype:	Fillet	weld	Welding Position	n: PA(horizontal)		
Joint D	esign			Welding Sequent	ces			
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
H	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
Weldi	ng Consuma	ables:		141: Tungsten e	ectrode: WTh	2 Technique:		
Type,	Designation	_		3.2		Weaving: max 3 m	E	
Diame	eter, mm:			136: EN 758: T /	162РС1Н таци	Stick out: 1E 17 m	\$	
				W.Nr.: 1.4430	***	Inclination of the v	" vire: 90°, 20° (pull)	
Gas /	Flux:			141:		Post Weld Heat Tre	atment: -	
Gas ty	/pe			EN ISO 14175: C 12 - 14 I/min	:1 - 100%CO ₂	Interpass temperat	ure: max 200°C	
Gas Fl	ow Rate			136: EN ISO 14175: C 12 - 14 I/min	:1 - 100%CO ₂			
Detail	s of BackGo	uging/Backi	:Su	NO				

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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			Cher	nical compo	sition, %		
Ciddo	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





	ase, brushing atter after						Heat Input J/cm	5000	6250			
	impurities and gre. velding, remove sp						Travel speed cm/min	60	60	to pass 2		re: 90°, 20° (pull)
tevision: 0	gin dimension, cleaning aint, remove slag after v g	Ø50x5 mm): SA210GrA1 (6 mm): S275JR	mu	rizontal)			Wire feed speed m/min	9.0-9.5	9.0-9.5	<u>Technique:</u> Weaving: max 3 mm		Stick-out: 15-17 mm Inclination of the wi
19 R	Cutting base pi weldin	on: Pipes (i Plates (6 to 5 n	PA (hor			f current/ larity	Ct	5¢		3-6	
	Preparation 1g:	al Specificati	al Thickness	sition:	duences		Type of Po			41-A:G 3Si1	A5.18:ER705	
(WPQR)	Method Of and Cleanin	Parent Meti	Parent Met	WeldingPo	WeldingSe	Fig. 2	Voltage V	25-26	26-28	EN ISO 143 SFA/AWS / 1.2		
er ication Record		ești		tweld			Current A	A 200-210 240-260 EN SFA				
ure Numb ure Qualif		Ploi	136	Fille			Size of wire mm	1.0	1.0	<u>bles:</u>		
ding Proced ding Proced	ufacturer:	tion:	ding Process:	Type:	Design		Process	135	135	ling Consuma , Designation	ieter, mm:	
7. Civil	construct	ion	Weld	Joint	Joint	Fig. 1	Run	1	2	<u>Weld</u> Type	Diam	

Technique:	Weaving: max 3 mm to pass 2		Stick-out: 15-17 mm	Inclination of the wire: 90°, 20° (pull)	Post Weld Heat Treatment: -		Interpass temperature: max 200°C		
	EN ISO 14341-A:G 3Si1,	SFA/AWS A5.18:ER70S-6		1.2		EN ISO 14175: M21 - 18%CO2 +	rest Ar	12 - 14 l/min	NO
Welding Consumables:	Type, Designation	Diameter, mm:			Gas / Flux:	Gas type		Gas Flow Rate	Details of Back Gouging/Backing:

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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

a					Chemica	al compos	sition, %	6			
rad	С	Si	Mo	Р	S	Cu	Nii	Mo	V	Nb	Cr
G	≤	≤		≤	≤	Cu	INI	IVIO	v	IND	CI
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

e					Chemica	al compos	sition, %	6			
Grad	С	Si	Mn	Р	S	Cu	Ni	Мо	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



Wel	ding Procedure	: Number		21			
Wel	ding Procedure	Qualification Rec	ord (WPQR)		Revision: 0		
Manu	ıfacturer:	ALPHA CONSTRUC	T Method Of Pr and Cleaning:	eparation bas	tting in dimension, cleaning se paint, remove slag after Iding	g impurities and gre welding, remove sp	ase, brushin atter after
Locat	ion:	Drobeta	Parent Metal S	pecification: S3	55		
Weld	ling Process:	135	Parent Metal 1	hickness Pla	tes: 7 to 10 mm		
Joint	Type:	Fillet weld	Welding Posit	ion: PE	(overhead) and PF (vertica	(dn)	
			4				
Fig. 1	Design		Weldingsequi Fig. 2	ences			
Run	Si Process v	ize of Current wire A	Voltage V	Type of current Polarity	t/ Wire feed speed m/min	Travel speed cm/min	Heat Inpu J/cm
ЪЕ	135	1.2 220-230	22-23	DC+	6	35	8700
Ъ	135	1.2 210-220	22-23	DC+	6	20	13860
Weld	ling Consumables	50			Technique:		
Type	, Designation		EN ISO 14341	-A:G 3Si1,	Weaving: NO		
Diam	eter, mm:		SFA/AWS A5.	18:ER70S-6	Stick-out: 15-17 mr Inclination of the w	n ire: 90°. 20° (pull)	

Post Weld Heat Treatment: -EN ISO 14175: M21 - 18%CO2 + rest Ar 12 - 14 I/min 2 Gas Flow Rate Details of Back Gouging/Backing: Gas / Flux: Gas type

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.

Grado		Chemica	al composition	, %	
Grade	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 Recor	d (WPQR)		levision: 0		
Manufacturer:		Method Of Prepar and Cleaning:	ation Cuttin base p weldin	g in dimension, deaning aint, remove slag after g	; impurities and gre welding, remove sp	ase, brushing atter after
Location:	Madrid	Parent Metal Spec	ification: \$235			
Welding Process:	135	Parent Metal Thic	kness Plates	8 to 10 mm		
Joint Type:	Fillet weld	Welding Position:	PF (ver	tical up)		
Joint Design		Welding Sequence	N			
Fig. 1		Fig. 2				
Run Process v	ize of Current wire A	Voltage Ty V	/pe 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+	ø	15-16	14000
Welding Consumable				<u>Technique:</u>		
Type, Designation Diameter, mm:		EN ISO 14341-A:0 SFA/AWS A5.18:1	3 3Si1, ER70S-6	Weaving: NO Stick-out: 15-17 mn		
		1.2		Inclination of the wi	ire: 90°, 20° (pull)	
<u>Gas / Flux:</u> Gas type		EN ISO 14175: C1 12 - 14 I/min	100%CO ₂	Post Weld Heat Trea	itment: -	

Details of Back Gouging/Backing:

Gas Flow Rate

2

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		Chemica	al composition	, %	
Grade	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 P	Procedure N	lumber				23				
Welding F	Procedure Q	ualification R	ecord	(WPQR)		R¢	evision:	0		
Manufacture	:ua			Method Of Pre and Cleaning:	paration	Cutting base pai welding	in dimension, cle int, remove slag	eaning ir after we	mpurities and gre elding, remove sp	ase, brushing atter after
Location:		Madrid		Parent Metal S	pecification:	S235				
Welding Pro	cess:	135		Parent Metal T	hickness	Plates: 8	3 to 10 mm			
Joint Type:		Fillet weld		Welding Positi	on:	PF (verti	ical up)			
Joint Design				Welding Seque	nces					
Fig. 1				Fig. 2						
Run Prod	Size ess win	e of Curre re A	ut	Voltage V	Type of curr Polarity	rent/	Wire feed sp m/min	eed	Travel speed cm/min	Heat Input J/cm
1,2 13	1.1	2 200-2	20	24-25	DC+		6		16-17	17800
<u>Welding Co</u> Type, Desig	insumables: Ination			EN ISO 14341-	A:G 3Si1,		<u>Technique:</u> Weaving: NO			
Diameter, n	Ë			SFA/AWS A5.	18:ER70S-6		Stick-out: 15-1 Inclination of t	17 mm the wire	2: 90°, 20° (pull)	
<u>Gas / Flux:</u> Gas type				EN ISO 14175:			Post Weld Hea	t Treatr	<u>ment:</u> -	

M21 - 82%Ar+18%CO₂ 12 - 14 l/min

9

Details of Back Gouging/Backing:

Gas Flow Rate

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



Fig. 27 Structural beams node

WPS Weld: fillet weld



24 24 Revision: 0 paration Cutting in dimension, deaning impurities and grease, brush base paint, remove slag after welding, remove spatter afte welding pecification: S275 hickness Plates: 8 to 10 mm prickness Plates: 8 to 10 mm prickness Plates: 8 to 10 mm fnickness Privertical up) con: Privertical up) con: Priver speed fraces Travel speed for polarity Write feed speed polarity Travel speed fraces 15 bC4 14 bC4 14 travel 15 A, E 38 A R 11 Technigue: Inclination of the wire: 90°, 20° (pull)

Details of Back Gouging/Backing:

Gas Flow Rate

Gas type

2

ı,

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		Chemica	al composition	, %	
Grade	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	Qualificati	ion Record	I (WPQR)		Re	vision: 0		
Manufactu	rer:			Method Of Pre and Cleaning:	sparation t	Cutting i Dase pain Velding	n dimension, cleaning nt, remove slag after	g impurities and gre welding, remove sp	ase, brushing atter after
Location:		Madrid		Parent Metal S	pecification: S	\$275			
Welding Pr	ocess:	135		Parent Metal T	hickness 1	Tubes: 6	to 6 mm, diameters:	100 mm	
Joint Type:		Fillet we	p	Welding Positi	on: F	PA (horiz	zontal)		
Joint Design				WeldingSeque	inces				
Fig. 1				Fig. 2					
Run Pro	siz bcess w n	re of irre nm	Current A	Voltage V	Type of curre Polarity	ent/	Wire feed speed m/min	Travel speed cm/min	Heat Input J/cm
1	135 1	1.2	130-150	21-22	DC+		6,5	14-15	11760
Welding C	onsumables						Technique:		
Type, Desi	ignation			EN ISO 14341	A:G 3Si1,		Weaving: max 3 mn	-	
Diameter,	mm: V			SFA/AWS A5.	18:ER70S-6		Inclination of the w	ire: 90°, 20° (pull)	
				1.2					
Gas / Flux:							Post Weld Heat Trea	atment: -	
Gas type				EN ISO 14175:	M21 - 18%CO	+ 2			
Gas Flow F	Rate			rest Ar 12 - 14 I/min					
Details of	Back Gougin	g/Backing:		N					

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

*Reference (only digits):	14
*Title:	BRUA PIPELINE-BUTT WELD (WPN13)
Objectives:	
Differente classels	
Difficulty level:	TUG9
Number of attempts:	1 Unlimited
Add description/WPS:	٠
(*) Obligatory information	
All the parameters will be show	wn open in the simulator

Introduction parameters – Welding procedure

Welding procedure				
Туре:	TIG (GTAW)	Tungsten ele	ectrode stick	Lanthanum alloy 1,5
				Activate electrode stick consumption
Work piece				
Joint type:	Pipe joint	Base material:	Carbon steel	<u>ज</u>
Position:	PH/PJ	Thickness:	10mm	7
Weld type:	V (V-Groove)	8		
All the parameters	will be shown open in the simulator			



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Joint type:	Pipe joint			
Welding type:	V (V-Groove)			1
Welding passes:	1	V		
Welding pass 1— Machine par	ameters Technique	Bead position	Torch and rod	
(A) Intens	sity 120 A			
Voltag	v V			
🕜 Gas flo	ow 10 I/mir 🔻			
Joint type: Welding type: Welding passes	Pipe joint V (V-Groove)			
Welding pass 1— Machine par	rameters Technique	Bead position	Torch and rod	
Welding te	chnique Straight line	- <u>77</u> <u>77</u>	Bead width Wave Amplitude Stop time	mm 🔻



IO3 – Technical Report

ing type: V (V-Groo	we)			1
ing passes: 1		199		
ding pass 1 Machine parameters	Technique	Bead position	Torch and rod]
Sequence	Complete		Distance betwe	een beads mm '
Horizontal direction	Push			
	Ununda	-		

Joint type:	Pipe joint
Welding type:	V (V-Groove)
Welding passes	: 1
Welding pass 1—	
Machine pa	rameters Technique Bead position Torch and rod
A	Travel angle 90 P Speed 2.5 mm/s 🔻
K	Work angle Mrc length mm
K	Filler rod work angle
<u></u>	Filler rod travel angle

8.2. MMA simulation for welding of BRUA pipeline

Introduction parameters – General information

*Reference (only digits):	15
*Title:	BRUA PIPELINE-BUTT WELD (WPN14)
Objectives:	
Difficulty level:	Initial
Number of attempts:	1 Unlimited
Add description/WPS:	•
(*) Obligatory information	
All the parameters will be show	vn open in the simulator

Introduction parameters – Beads

Welding technique	Vertical direction	Sequence	Horizontal direction	Arc length	Travel speed	Travel angle	Work an
Bead technique	х	Complete	Pull			90	
Bead technique	х	Complete	Pull	-	-	90	-
A share the share to use	v		D 11			00	
sead technique	*	Complete	Pull	-	-	90	-
sead technique	*	Complete	Pull	-	-	90	-

All the parameters will be shown open in the simulator



IO3 – Technical Report

Joint type: Pipe	e joint			
Welding type: V(V	/-Groove)			
Welding passes: 3		V		 ¥
Welding pass 1				^
Machine paramete	ers Technique	Bead position	Torch and rod	
A Intensity	80 A			
Voltage	V			
🕜 Gas flow	l/mir 🔻			
Welding pass 2				
Machine paramete	ers Technique	Bead position	Torch and rod	
(A) Intensity	110 A			
Voltage	V			
Gas flow	l/mir 🔽			-

Joint type: Pipe joint						
Welding type: V (V-Groov	e)					
Welding passes: 3		7			¥	
Welding pass 1						^
Machine parameters	Technique Bea	ad position	Torch and rod]		
A Intensity 80	A					
Voltage	V					
🕜 Gas flow	l/mir 🔻					
Welding pass 2						
Machine parameters	Technique Bea	ad position	Torch and rod			
Welding technique	Waving 1	·	MAI Bea Ma ⊘ Sto	ad width ave Amplitude op time	mm ⊽ 10 mm ⊽ s	



IO3 – Technical Rep	port
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Joint type: Pip	pe joint					
Welding type: V	(V-Groove)					
Welding passes: 3		7			<u> </u>	
Machine parame	ters Technique	Bead position	Torch and rod			-
Welding technic Welding passes 3	que Waving 1	1	VAt Bea VA Wa ⊙ Sto	ad width ve Amplitude p time	mm 🐨	
Machine parame	ters Technique	Bead position	Torch and rod			
<u>.</u>	Travel angle	90 0	<u></u>	Travel speed	i mm/s 🖂	
🗠	Work angle	0		Arc length	mm 🔻	
	Filler rod work ang	le •	<u>.</u>	Stick-out	mm	
	Filler rod travel an	gle 📃 🔹				-

8.3. GMAW simulation for welding of board of barge

Introduction parameters – General information

*Reference (only digits):	2			
*Title:	BOARD OF BARGE-FILLET WELD (WPN1)			
Objectives:				
Difficulty level:	Initial			
Number of attempts:	1 Unlimited			
Add description/WPS:	•			
(*) Obligatory information				
All the parameters will be shown open in the simulator				



Introduction parameters – Welding procedure

Welding procedure		_
Туре:	FCAW Tungsten electrode stick:	
	Activate electrode stick consumption	
Work piece		_
Joint type:	Plate T joint Base material: Carbon steel	
Position:	PF/PG Thickness: 10mm	
Weld type:	Fillet	
All the parameter	will be shown open in the simulator	

Introduction parameters – Beads

Joint type:	Plate T joint	
Welding type:	Fillet	
Welding passes:	1	

Welding pass 1				
Machine parameters	Technique	Bead position	Torch and rod	
Wire speed 7.99	9998 m/mir			
Voltage 25	V			
		_		
Gas flow 12	I/min 💿			





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
Fime 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 %
Fechnical parameters			
✔ Voltage:	100%	✓ Amperage:	100%
✔ Gas:	100%		
All tecnical parameters:	100 %	Selected parameters:	100 %
Defects			
Porosity:		Inclusion:	

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.







Fig. 29 Snapshot of welding simulation a. normal view, b. specific angle view

b.

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.



Technical parameters:

Amperage	100%
Voltage	100%
Defects:	

Time:

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