

ROBOTIZIRANO ZAVARIVANJE U ĐURO ĐAKOVIĆ SPECIJALNA VOZILA

Robotic welding in Đuro Đaković Special Vehicles

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¹ĐĐ specijalna vozila

Ključne riječi: uređaj za zavarivanje, robot, zavareni spoj, senzor, WPS, OTC - Daihen.

Sažetak

U radu je opisan postupak elektrolučnog zavarivanja MAG postupkom na robotskoj stanici. Također biti će opisana robotska stanica te način programiranja. Nadalje će navesti senzore koje mi koristimo prilikom *on* - line programiranja. Na jednom našem sklopu ćemo pokazati kompletan proces zavarivanja sa pratećom dokumentacijom (WPQR, WPS...).

Keywords: welding machine, robot, welded joint, sensor, WPS, OTC – Daihen.

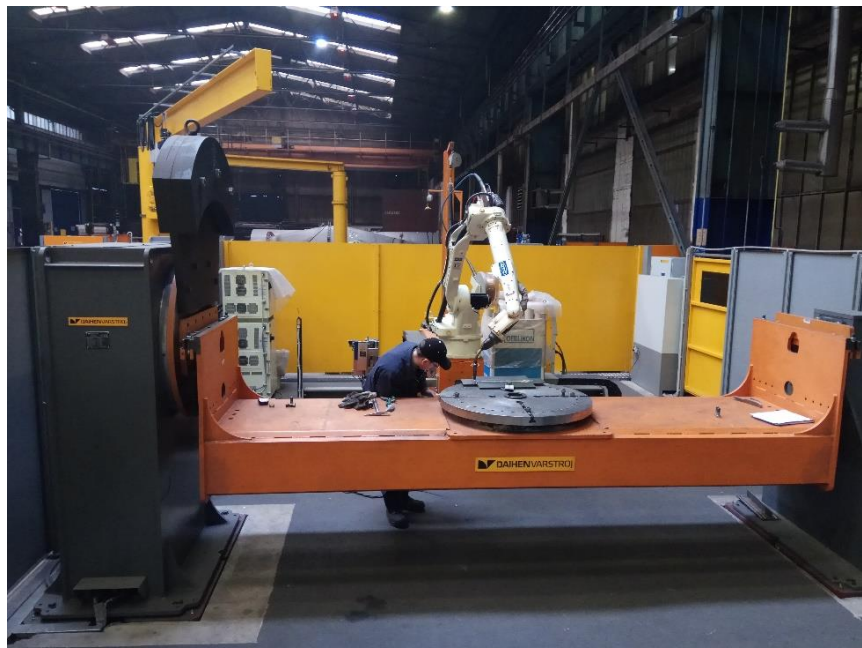
Abstract

In this paper the procedure of electro welding by MAG process on a robot station will be described. There will also be a description of the robot station and the programming mode. We will also describe the sensors that we use in the on-line programming. On one of our assemblies we will show a complete welding process with accompanying documentation (WPQR, WPS ...).

1. UVOD

Tvrtka Đuro Đaković Specijalna Vozila (SV) trenutno je u posjedu 3 stanice za robotsko zavarivanje. Prve dvije stanice su od proizvođača Daihen OTC Varstroj:

- **Robot VRC FD-B4L-1dm/MIG:** s jednim okretno nagibnim pozicionerom (P2000NV ROBO) koji je prikazan na slici 1.



Slika 1 Robotska stanica VRC FD-B4L-1dm/MIG

- **Robot VRC FD-B4L-2dm/MIG:** s jednim okretno nagibnim pozicionerom (P3000NV-M+S ROBO) i s jednim nagibnim pozicionerom (P-7500V), prikazan na slici 2.



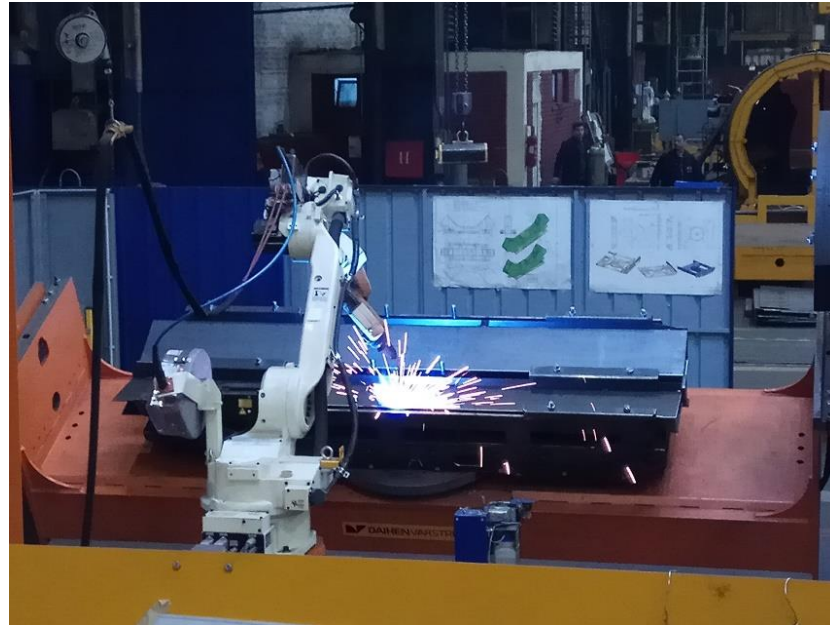
Slika 2 Robotska stanica VRC FD-B4L-2dm/MIG

Treća robotska stanica je od proizvođača Motoman Yaskawa:



Slika 3 Robotska stanica

- **Robot VRC FD-B4L-1dm/MIG** s jednim okretno nagibnim pozicionerom (P2000NV ROBO):



Slika 4 Robotska stanica

Ova robotska stanica se sastoji od sljedećih dijelova:

- Manipulator FD-B4L :

Na slici 5 prikazan je navedeni manipulator, a njegove specifikacije navedene su u tablici 1.



Slika 5 Manipulator [1]

Tablica 1 Specifikacije manipulatora [1]

Specification	Value
Number of Axes	6
Maximum Payload Capacity	8.8 lbs (4 kg)
Positional Repeatability	$\pm 0.003''$ (± 0.08 mm) (Note 1)
Horizontal Reach	79.06" (2008 mm)
Vertical Reach	138.75" (3575 mm)
Drive Capacity	4650 W

- Robotska vozna pruga R3.500 Y- os:

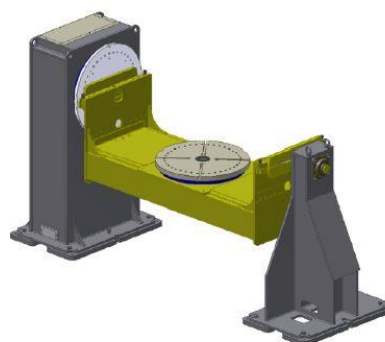
Naziv	VOZIČEK ROBOTSKI z Y-osjo 1,0m KPL.
Neto hod robota	L - 2.000mm
Max. hitrost gibanja	20 m/min
Max. nosilnost (1 voziček),	600 kg
Ponovljivost pozicioniranja	± 0.2 mm
Pogonski sistem - X-os	2kW; AC servomotor
Pogonski sistem - Y-os	1,2kW; AC servomotor



Slika 6 Specifikacije vozne pruge [1]

- Okretno nagibni pozicioner P2000NV ROBO:

Tehnični podatki	P-2000NV ROBO
Max. nosilnost	2.000kg
Max. hitrost vrtenja	3,3min-1
Max. moment (vrtenje)	4.115Nm
Kot vrtenja	+/-200°
Max. radij vrtenja (pri nagibu 0°)	3.750/2= 1.875mm
Max. radij vrtenja (nagib +/-90°)	1.500mm
Max. hitrost nagiba	2,8min-1
Max. moment (nagib)	12.200Nm
Lastni moment jarma (Δa=400mm)	-4.800Nm
Δa - razdalja med vpenjalno ploščo in osjo vrtenja	400mm
Kot nagiba	+/-210°
Ponovljivost pozicioniranja R100mm	+/-0,2mm



Slika 7 Specifikacije pozicionera [1]

- Izvor za zavarivanje Welbee Inverter P500L:

1.2 Zavarivački izvor za robotsko zavarivanje WB-P500L	1kom
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Sadrži:

- zavarivački izvor
- robotsko sučelje
- agregat za hlađenje kompresorski

SPECIFIKACIJE/MODEL	Welbee Inverter P500L
Model	WB - P500L
Broj faza	Tri faze
Nazivna frekvencija	50/60 Hz
Priključni napon	400 V
Raspon priključnog napona	400 V ± 15%
Priključna snaga	25 kVA, 22.9 kW
Nazivna primarna struja	36 A
Nazivna izlazna struja	DC: 500 A, Pulse: 400 A
Nazivni izlazni napon	DC: 39 V, Pulse: 34V
Raspon struje zavarivanja	30 - 500 A
Raspon napona zavarivanja	12 - 45 V
Maksimalni napon bez opterećenja	80 V
Nazivna intermitencija (Duty Cycle)	DC: 60 % , Pulse: 80%
Broj JOB-ova	100
Najviša temperatura	160 °C
Radna temperatura	- 10 do 40 °C
Dozvoljena radna vlažnost okoline	20 - 80% (bez kondenzacije)
Temperatura skladištenja	- 20 do 55 °C
Dozvoljena vlažnost - skladištenje	20 - 80% (bez kondenzacije)
Vanjske dimenzije (WxDxH)	395mm x 710 mm x 762 mm
Masa	83 kg
Statička karakteristika	Konstantna naponska karakteristika

Slika 8 Specifikacija izvora za zavarivanje [1]

- Sustav za čišćenje pištolja:

Čišćenje pištolja je nužno za pouzdan i pravilan rad na robotskoj stanici. Zbog dugotrajnog i brzog radnog ciklusa nužno je čišćenje pištolja. Sustav čišćenja ima raspršivač sredstava i škare za reguliranje dužine žice. Na slici 9 je prikazan čistač pištolja koji se nalazi na robotskoj stanici u ĐĐ SV.



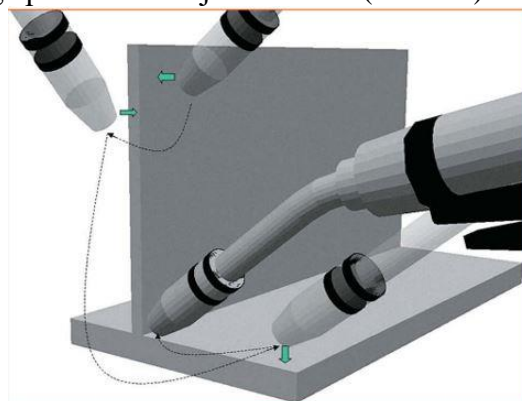
Slika 9 Čistač pištolja

2.1 Senzori na robotskoj stanici

Na navedenim robotima imam dvije vrste senzora:

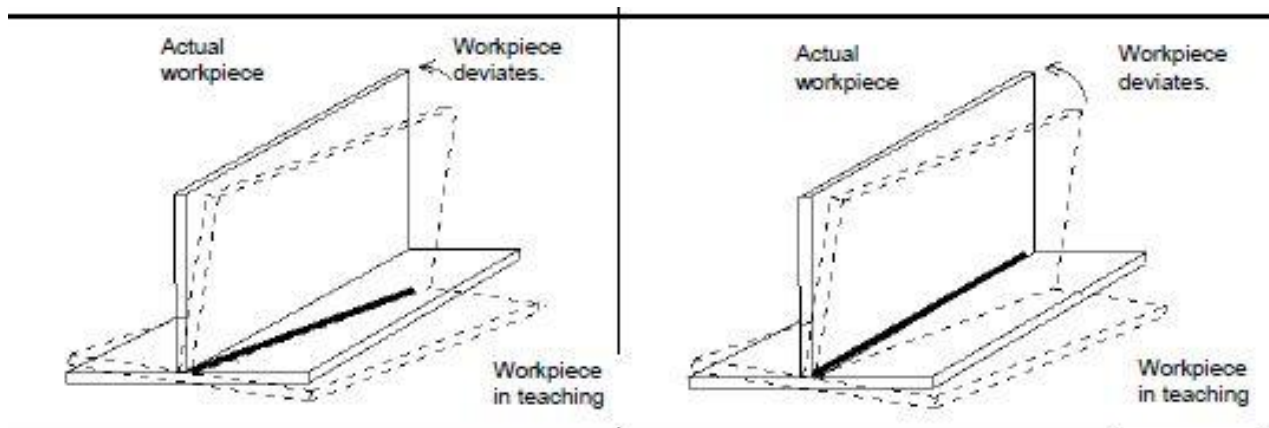
- Touch senzor,
- Arc senzor,

Touch senzor služi da dodirnom ili kontaktom žice dodatnog materijala detektira gdje se radni komad nalazi i na osnovu toga preračuna i mjesto zavara (slika 10).



Slika 10 Touch senzor [2]

Arc senzor je senzor koji traži mjesto zavarivanja tijekom samog izvođenja zavarivanja. Tako, ukoliko dođe do nekakve deformacije ili izmjene putanje zavarivanja, senzor će to detektirati i prilagoditi se novoj putanji/smjeru zavarivanja.



Slika 11 Arc senzor [1]

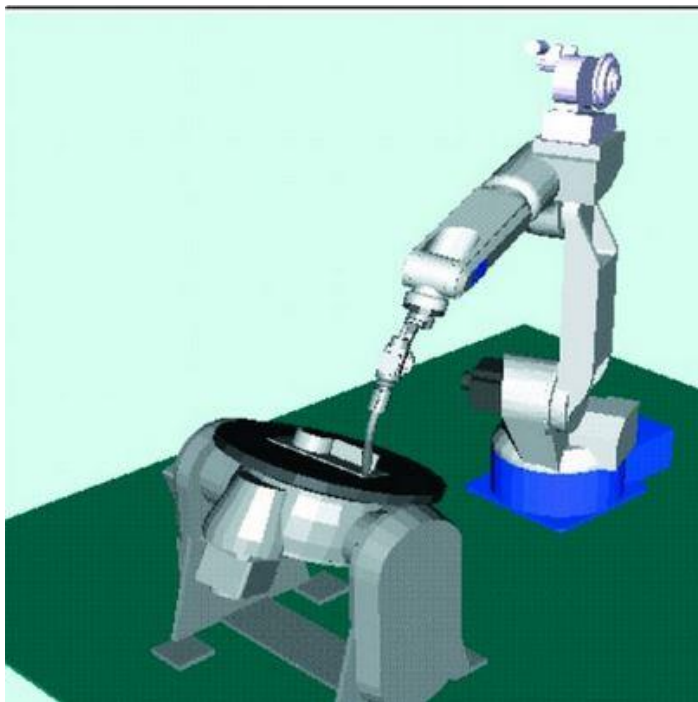
3. PROGRAMIRANJE ROBOTIZIRANOG ZAVARIVANJA

Metoda s kojom se trenutno programira u tvrtci Đuro Đaković Specijalna Vozila je *on* - line programiranje. *On* -line programiranje se vrši na samoj robotskoj stanici gdje kreiramo program s Teach pendant (slika 13.)



Slika 12 Teach pendant privjesak za programiranje

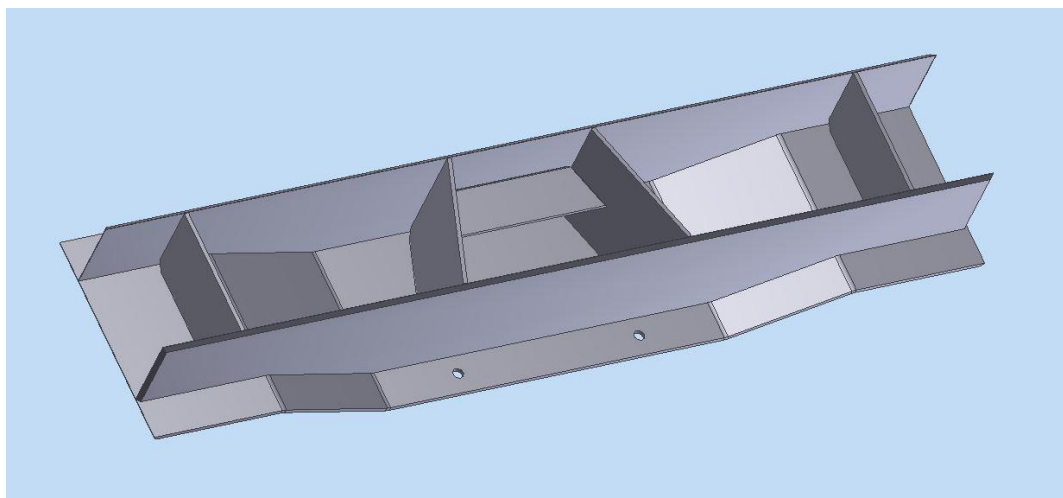
Uz pomoć teach pendants pomiću i kreiraju se putanje na temelju kojih se robot giba. Nedostatak online programiranja je robotska stanica zauzeta dok se programira komad te se ništa drugo ne može zavariti. Iz tog razloga odlučeno je da će se u sljedećem razdoblju osigurati si *off*-line programiranje (slika13) gdje će biti omogućeno programiranje s računalne jedinice a u isto vrijeme robot neće biti zauzet te će moći zavarivati.



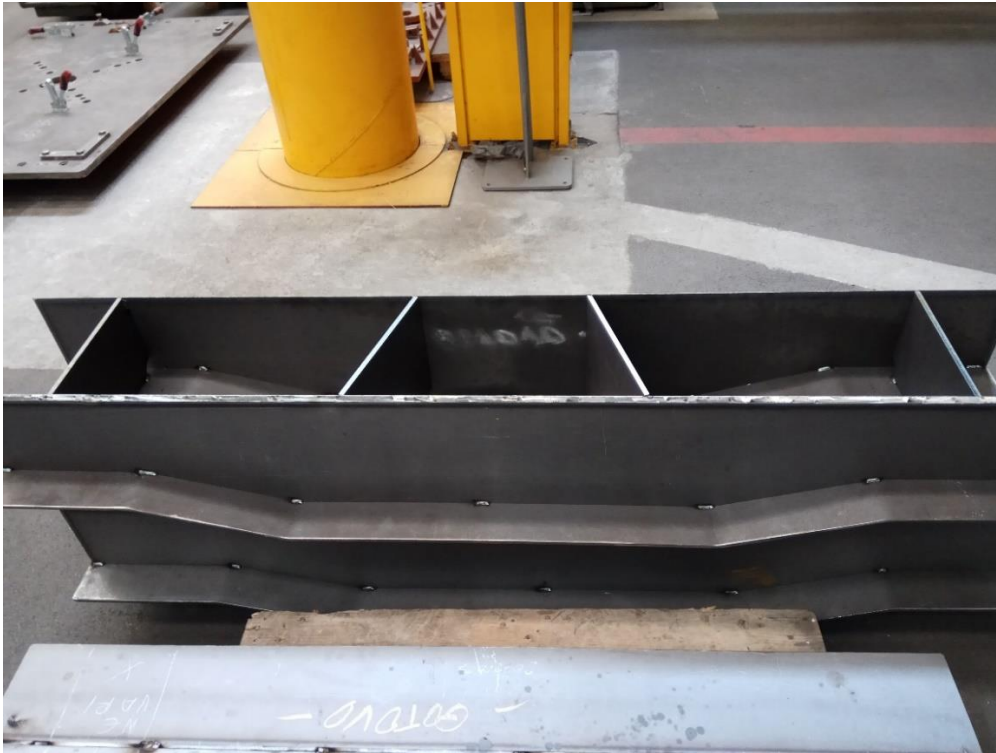
Slika 13 *Off*-line programiranje robotskog manipulatora [3]

4. EKSPERIMENTALNI DIO

U ovom dijelu rada biti će prikazan proces na jednom proizvodu iz asortimana ĐĐ Specijalna vozila koji se zavaruje na robotskoj stanici. Izabrani proizvod je poprečni nosač vagona Zacns, njegov 3D model prikazan je na slici 14, dok izrađeni je na slici 15.



Slika 14 3D prikaz poprečnog nosača vagona Zacns



Slika 15 Poprečni nosač vagona Zacs

Materijal od kojeg je izrađen poprečni nosač je S355J2+N, ulazni certifikat 3.1 za navedeni materijal prema HRN EN ISO 10204: 2004 prikazan je na slici 16.

A01 AroclerMittal Ostrava a.s. Vrátnimovská 699 707 02 Ostrava-Kunčice Česká republika TEL.: +420-595662303		A02 INSPECTION CERTIFICATE EN 10204:2004		Z02 Ostrava, 30.05.2016 A03 Document No. 1000513317		A04 AcelorMittal												
Purchaser's Order No. and/or Item No. 07 HR-APR16-OST																		
07 Manufacturer's Job No. 1661 80235 0 6		A10 Delivery Advise No. 8150709555/000330 16/16/001597		A05 Customer's order STROJOPROMET-ZAGREB d.o.o. ZAGREBACKA 6 10292 SENKOVEC Croatia														
08 Supplier's Order No. 310025487570		Product, Dimensions, Steel designation, Condition, Terms of Delivery, Any supplementary requirements: B01, B02, B03, B04, B05, B09 Hot rolled Steel in Sheets acc. to CSN EN 10051:2011 Quality S355J2 + N acc. to CSN EN 10025-2:2005, Test report 3.1 acc. to EN 10204:2004 Size 1500 x 15 x 9000 mm.																
13 Actual weight 18 258,000 KG																		
73 Chemical Analysis of Liquid Alloy (%)																		
77 Heat No.	Test	C [%]	MN [%]	SI [%]	P [%]	S [%]	N [%]	CU [%]	Ni [%]	CR [%]	MO [%]	V [%]	AL [%]	B [%]	Ti [%]	ASB [%]	B03	
78223E	H	0.18	0.25	0.022	0.008	0.005	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	Pieces	Bunches
07 Heat No.	Test	AS [%]	SN [%]	CA [%]	CEV [%]													
78223E	H	0.003	0.003	0.003	0.003													
74 Continuation: see Attachment																		
5 Test results		2 Tensile test acc. to EN ISO 6892-1:2009						4 Charpy impact test acc. to EN 10043-1:2010										
Heat No.	C00 Specimen No.	C05 Coil ID No.	C02	C11 Yield of proof	C12 Tensile strength	C07 Ratio	C13 Elongation on AS	C03 Test temperature				C40 KV2	C41	10.00				
				>355	>470	>0.00	26.0					C04 min	C04 max	3 (100%)				
	C04 Regulation											-20.00	27.0					
78223E	Z0344870	11162200576	1	402	552	0.73	21.7					C43	C42					
78223E	Z0344875	11162200676	0		0.90													
75 Continuation: see Attachment																		
Bend test according to EN ISO 7438:2005								B05, B06, B07										
S2 Bend Test																		
S3 Rehbend test																		
Environmental product declaration: EPD-BFS-2010111-E																		
C03 The mass activity ionizing radiation value in liquid alloy analysis does not exceed 100 Bq/kg								B05, B06, B07										
Z01 The manufacturer confirms that each product is in full compliance with Order & requirements, the Purchase Contract's requirements and that it has been tested in full compliance with technical requirements								HR00017_CPR2013-07-01_FC_V005 http://www.ancelorMittal.eu/0017_CPR2013-07-01_FC_V005_EN_WW.pdf EN 10025-1										
D01 This inspection and the test work carried out on the delivered product or on a product test piece								Z02, Z03, A05										
AcelorMittal Ostrava a.s. Vrátnimovská 699, 707 02 Ostrava-Kunčice Czech Republic								WORKS INSPECTOR INSPECTION No. 1 Ludvík Malinský PRČENÍ: +420 595668540										

Slika 16 Ulazni certifikat 3.1 za navedeni materijal

Atest postupka (WPQR):

TUV NORD

QUALIFICATION OF A WELDING PROCEDURE (WPQR)
CERTIFICATE 07/202/9090/Z/0009/17/V/0005

Insp. Authority: TUV NORD Systems GmbH & Co. KG
File No.: 158A/16 BB
WPQR-No.: 158A/16 BB Revision: 0
Contract Ref.: ...

WPS No.: 02-ROB-016/1
Manufacturer: DB Specijalna vozila d.d.
Address: Dr. M. Budaka 1, 35000 Slavonski Brod, Croatia
Requirements: Directive 2014/68/EU / EN ISO 15914-1:2004+A1:2008+A2:2012

RANGE OF APPROVAL	ISO 4063: 135 - MAG Automatic Robotic arc welding with solid wire, - S or G Spray or Globular transfer (P, BW, bs mb) T, P, BW: ss mb, bs, ml; F/W: ml ISO 9682-1: Single-bevel preparation with backing EN 10028-3, P460NL1 (1.8915), cover Group 1 acc: ISO/TR 15908 / Re ≤ 460 N/mm ² (Plate) > 500 mm, >150mm for PA or PC rotated position
Welding Process:	ISO 4063: 135 - MAG Automatic Robotic arc welding with solid wire, - S or G Spray or Globular transfer (P, BW, bs mb) T, P, BW: ss mb, bs, ml; F/W: ml
Weld type/execution:	ISO 9682-1: Single-bevel preparation with backing
Groove shape:	EN 10028-3, P460NL1 (1.8915), cover Group 1 acc: ISO/TR 15908 / Re ≤ 460 N/mm ² (Plate) > 500 mm, >150mm for PA or PC rotated position
Parent Material / Group:	EN 10028-3, P460NL1 (1.8915), cover Group 1 acc: ISO/TR 15908 / Re ≤ 460 N/mm ²
Parent Material Thickness:	(15mm, deposit thickness e=10mm) 7,5mm to 30mm
Pipe Outside Diameter:	(Plate) > 500 mm, >150mm for PA or PC rotated position
Filler Material Type/ Designation:	EN ISO 14341-A - D 46 7 M21 2N2, CARBOFIL N2 / OERLIKON /
Gas/flux:	Shielding gas: ISO 14175 - M21
Type of Welding Current:	DC+
Heat input:	0,438 to 3,076 kJ/mm (ISO 5947: PA) All position except for PQ and J-L045 in acc. EN ISO 15914-1 when requirements concerning for impact energy and hardness only position PA (P).
Welding Positions:	ISO 5947: PA) All position except for PQ and J-L045 in acc. EN ISO 15914-1 when requirements concerning for impact energy and hardness only position PA (P).
Preheat Temperature:	≥ 150°C
Interpass Temperature:	≥ 150°C
Post-Weld Heat-Treatment:	
TEMPERATURE LIMITATION:	Impact test has been conducted at -20°C with above mentioned parent and filler metal combination. Temperature restrictions according to the used parent and filler metal have to be considered.
SCOPE EXTENSION/ LIMITATION:	Parent and filler material has to be in accordance to European Standards - filler material acc: to EN 13479.
SPECIAL ADVICE FOR MANUFACTURING:	See instructions of EN 1011 „Recommendations for welding of metallic materials“
EVIDENCE FOR QUALITY ASSURANCE:	For low temperature applications, testing of toughness has to be conducted additional by procedure qualification test and / or production test.

30 Slavonski Brod, 25.02.2017.

Notified body (0045) for pressure equipment
Božek
TUV NORD Systems GmbH & Co. KG
Große Bahnstraße 31, D-22525 Hamburg

31 Endosse: 1. WPS of Manufacturer No.02-ROB-016/1 Date: 01/2017
2. Supervision of test welding - Welding process Report No. 155A/16 BB Date: 19.01.2017 Inspector: Čorić
3. Results of examinations Report No. 155A/16 BB Date: 27.01.2017 Inspector: Čorić

32 *Abbreviations see back page

Region: 6090
Mobile: +355 96 318 6850 / Fax: +355 95 426 947 / e-mail: nb0045@tuv-nord.com
Übersetzung des Originaldokuments Translation of certified test Certificate of a welding Procedure/Qualification Test (EN 15914-1:2004+A1:2008+A2:2012) Translation des Originaldokuments

Slika 17 WPQR dokumentacija za zavarivanje poprečnog nosača

Atest operatera prema HRN EN 14732 standardu

TUV NORD

PRÜFUNGSZERTIFIKAT 07/202/9090/Z/0345/17/S/0005
BEDIENER VON SCHWEISSEINRICHTUNGEN

TUV NORD Systems GmbH & Co. KG
Große Bahnstraße 31, D-22525 Hamburg
Tel. +420 236 587 219, Fax +420 236 587 240

Insp. Authority: TUV NORD Systems GmbH
Prüf-Nr.: 2017-0345

2 Hersteller-Schweißanweisung: 02-ROB-016/1
3 012917
4 Name des Bedieners: Iger Čižak (U210)
5 Legitimation: 110817430
6 Art der Legitimation: Personalausweis
7 Geburtdatum und -ort: 1962-09-16, Slavonski Brod, Kroatien
8 Beschriftet bei: Duro Čižaković, Specijalna vozila d.d.
9 Verschriftl. / Prüfdatum: PED 2014/68/EU, EN ISO 14732

10 Prüfung der Funktionsanweisung: Bestanden
11 Fachkunde: Nicht geprüft

12	Prüftechnik	Gefäßbereich
13 Schweißprozess(e)	135 MAG mit Maschenrost "On-line" Robot.	Alle Varianten der Prozessgruppe 13
14 Schweißanrichtung	OTC-DEIHEN FD-4BL Robot Schweißanheit	"On-line" Robot: OTC-DEIHEN FD-4BL Robot Schweißanheit
15 Details für vollmechanisches Schweißen		
17 Schutzprüfung / Korrosionswiderstandsprüfung	erfüllt	erfüllt
18 Automatisches Kontrollen der Leuchtgeräusche	erfüllt	erfüllt
19 Automatisches Mehrtragungsgeräusche	erfüllt	erfüllt
20 Schweißposition	erfüllt	erfüllt
21 Einzeltrag- Mehrtragertechnik	erfüllt	erfüllt
22 Schweißabsicherung	erfüllt	erfüllt
23 Schweißsensitivitäten	erfüllt	erfüllt
24 Details für automatisches Schweißen		
25 Nahsensor	ohne Sensor	mit oder ohne Sensor
26 Lichtmessgerät	ohne Sensor	nur ohne Sensor
27 Einzeltrag- Mehrtragertechnik	Mehrtragertechnik	Einzel- oder Mehrtragertechnik
28 Art der Schweißanrichtung	erfüllt	erfüllt

29 Zusätzliche Informationen: Werkstoff: P460NL1, Zusatz: 14341-A-G 46 7 M21 2N2 (Carbofil N2, Oerlikon), Position: PA, 1 + 15

30 Der Qualifizierung liegt zugrunde:
31 - Schweißverfahrensprüfung (siehe 4.1.1) --
32 - Schwelstechnische Prüfung vor Fertigungsprüfung (siehe 4.1.2) X
33 - Schweißprüfung (siehe 4.1.3) X
34 - Fertigungsprüfung oder Schweißprüfung (siehe 4.1.4) --

35 Ergebnis der Prüfung für die Qualifizierung siehe Dokument Nr. 012917-7. Verlängerung nach 5,3 a
36 Datum des Schweißens: 2017-01-19
37 Gültig bis: 2023-01-16

38 Bestätigung der Gültigkeit durch die Schweißfachperson / Prüfer für die folgenden 6 Monate (unter Bezug auf 5.3)

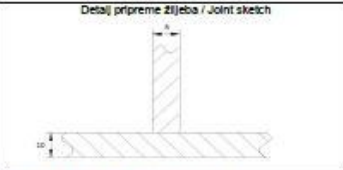

Datum	Unterschrift	Stellung oder Titel
2022-01-16		
2021-01-16		
2020-01-16		
2019-01-16		
2018-01-16		
2017-01-16		

Übersetzung des Formblattes auf der Rückseite = Übersetzung des Zertifikates auf der Rückseite = Traducción del formulario en verso

Übersetzung des Formblattes auf der Rückseite = Übersetzung des Zertifikates auf der Rückseite = Traducción del formulario en verso

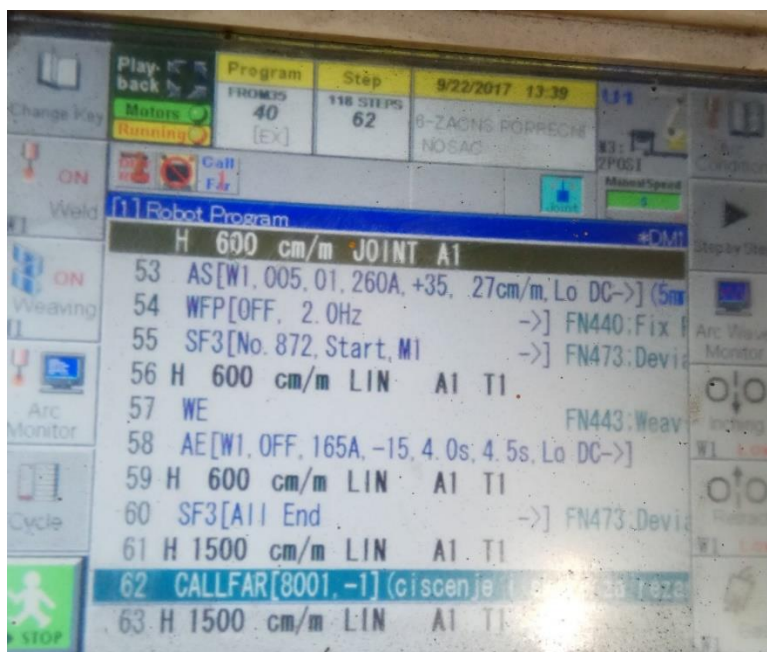
Slika 18 Atest operatera

Uputa za zavarivanje - WPS:

BUREAU DAKOVIĆ INŽENJERING I PROMET POSREDOVANJE U PROMETU		UPUTA ZA ZAVARIVANJE WELDING PROCEDURE SPECIFICATION (WPS)			Reg.ozn.dok./ Doc.Reg.No. 08-ROB-017/01				
Objekt Object	VAGON ZACNS 45m3 ČELO POSTOLJA	Crtež broj Supporting drawing No.	493.03.001.00						
Postupak zavarivanja Welding procedure	MAG-D(135)	Osnovni materijal / Base metal							
Broj predloška skice Supporting WPAR No.	WPQR BR: 156A/168B	Oznaka Mark	Grupa Group	Dimenzija / debljina Dimension / Thickness					
Ime zavarivača Welder's name		S355J2+N	GR:1.2	LIM 8-LIM 10					
Tip procesa Welding process type	AUTOMATIZIRAN-ROBOTIZIRAN	Simbol vrste spoja Sign of joint design	4	Položaj zavarivanja Welding position	PB				
Vrsta spoja Joining type	FW-KUTNI	Način štjeljenja Gouging							
Detalj pripreme zljeba / Joint sketch		Redoslijed zavarivanja / Welding sequence							
									
Parametri zavarivanja / Welding parameters									
Sloj broj Pass No.	Proces zavarivanja Welding process	Promjer DM Wire Dia (mm)	Jakost struje Current (A)	Napon Voltage (V)	Vrsta i polaritet Type / polarity	Protok plina Gas flow rate (l/min)	Brzina zavarivanja Travel speed (cm/min)	Brzina žice Wire speed (cm/min)	Učinek toplote Heat input (kJ/cm)
1	MAG(135)	1,2	230-260	20-26	DC(+)	14-18	20-30		
Dodatni i pomoćni materijal Filler and auxiliaries metal		Temperatura predgrijavanja Preheat temperature		RT 20 °C			°C		
Naziv i proizvođač Designation and manufacturer		CARBOFIL 1, OERLIKON		Medijalna temperatura Interpass temperature		MAX 180 °C °C			
Klasifikacija Classification		EN14341-A: G3 S11 EN440		Toplinska obrada Heat treatment		Da / Yes G			
Tip obloge Coat type				Tehnika rada Welding technique		Ravno / String Njhanje / Wave bead			
Sastav praška Flux composition				Max. širina gušenice Max. layer width		mm			
Promjer i vrsta W-wire Size and type W-wire				Početno i međujazno čišćenje Cleaning initial and interpass					
Sukanje DM To dry FM				Ostalo Other		PROVAR BRUSITI			
Zaštitni plin / zaštita korijena Shielding gas / Backing gas		M 21-EN 14175-82%Ar+18%Co2		Standard / Norma EN 14732 / EN 15614-1					
Napomena / Comment:									
Izdanje / Edition		Izradio/Prepared by MARIO JAGUNIĆ dipl.Ing.IWE		Odobrio / Ratify		IVAN ŽAKIĆ dipl.Ing.CIWE			
Datum / Date		02.08.17		Datum / Date		02.08.17			

Slika 19 Uputa za zavarivanje

Parametre zavarivanja i koordinate robotske ruke i pištolja unosimo u Teach pendant.



Slika 20 Zaslon Teach pendanta s unesenim parametrima zavarivanja

Nakon unosa podataka potrebno je isprobati program bez operacije zavarivanja preko naredbe *check - go*. Tako da vidimo dali se radni komad nalazi u koliziji sa robotskom stanicom. U slučaju da je ispravno programirano, program se pušta u rad.

4. ZAKLJUČAK

Analiza koju smo napravili nakon navedenog radnog komada je:

Vrijeme zavarivanja koje je potrebno kako bi ručno zavarilo navedeni komad iznosi 8 sati, dok kod robotiziranog zavarivanja je potrebno 3 sata. Iz vremena je vidljivo kako je ušteda ogromna. Naravno ako se radi o serijskoj proizvodnji. Također kvaliteta zavara je neusporedivo bolje nego kod ručnog zavarivanja.

5. LITERATURA

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