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WELDING & WELDED STRUCTURES

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Poštovani čitaoci,

Poštovani,

ovogodišnje pregrejano leto se bliži svom završetku, godišnji odmori su završeni, deca su krenula u školu, da, septembar je. Vreme je i za naš novi broj časopisa.

Ovoga puta, pored rada vezanog za raznorodne zavarene spojeve sa dupleks čelikom, skrećemo vam pažnju na izlaganje preuzeto sa TWI-The Welding Institute sajta a odnosi se na poređenje upotrebe rutilnih i celuloznih elektroda o čemu nam se čini da je sve poznato a onda se ispostavi da ima mnogo toga novog da saznamo.

Pored toga, imate prilike da pročitate izveštaj sa Godišnje skupštine IIW kao i prikaz ovogodišnjeg takmičenja u Kini.

Pred nama je takmičenje mladih zavarivača u okviru sajma zavarivanja koji se ove godine održava u Dizeldorfu, i gde učestvuju i naši predstavnici.

U očekivanju dobrih vesti, do narednog broja.

**Glavni i odgovorni urednik
Milica Antić, dipl.ing. EWE**



IN MEMORIAM



MOJCA ŠOLAR

1960 – 2017

U vrelini ovih letnjih dana, ostali smo bez prave prijateljice našega Društva, bezrezervne saradnice i osobe koja nas je podržavala na svoj specifični način.

Napustila nas je MOJCA ŠOLAR.

O njenoj radnoj karijeri je dovoljno reći da je radila na razvoju dodatnih materijala za zavarivanje u Železarni Jesenice i da je to ostavilo glavni trag u njenom trajanju.

Međutim, ona je davala neuporedivo više.

Na našim prostorima ćemo je pamtiti kao izvrsnog predavača na našim kursovima za IWE/IWT, redovnog učesnika naših savetovanja i seminara, pomagača u rešavanju naših problema ...

Družiti se s njom bila je čast, privilegija a najviše zadovoljstvo.

Verovatno nastala čarolijom, obuzeta željom za davanjem i širenjem topline, opčinjavajući nežnošću, sigurno se samo vratila svom društvu anđela. Njena ovozemaljska misija je potpuno obavljena.

Neka počiva u miru. Raj je sigurno njena nova adresa.

Milica Antić



J. Słania*, R. Krawczyk*, D. Mastoń**

TECHNOLOGY OF WELDING JOINTS MIXED WITH DUPLEX STEEL

TEHNOLOGIJA ZAVARIVANJA SPOJEVA MEŠANIH SA DUPLEKS ČELIKOM

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Ključne reči: zavarivanje, duplex čelici, mešani spojevi

Key words: welding, duplex steel, mixed joints

Results of the examinations of sample plates of mixed joints with the duplex steel were discussed. Examinations were taken on the sample plates of mixed joints of sheet plates type P355NL1 and X2CrNiMoN22-5-3 welded by the flux-cored wire DW-329A by the Kobelco company of the following category T 22 9 3 NL RC/M3 in the gas shroud M21 (Ar+18%CO₂) (plate no.1), and nickel covered electrodes E Ni 6082 by the Böhler company (plate no. 2). Results of the side bend test of welded joint, transverse tensile test, stretching of the weld metal, impact strength, micro and macroscopic metallographic examinations, and measurements of the delta ferrite content were presented.

1. Introduction

Duplex steel owes its two-phase structure a set of mechanical properties connected with ductility and plasticity as well as a high resistance to different types of corrosion. This material allows to obtain advantages from joining austenite and ferrite phases. Carefully chosen chemical composition guarantees better properties to much more expensive highalloyed austenite steel [1-7].

Presented examinations in the article were taken on the sample plates of mixed joints of sheet metal type P355NL1 and X2CrNiMoN22-5-3 welded by the flux-cored wire DW-329A produced by the Kobelco company of a following category T 22 9 3 NL RC/M3 in the gas shroud M21 (Ar+18%CO₂) (plate no. 1), and nickel coated electrodes E Ni 6082 by the Böhler company (plate no. 2).

Above experiment was done to prove the properties of a joint made by the filler material of a duplex steel structure, and a high-nickel material, as well as specifying an influence of a thermal treatment on the changes of the duplex steel structure

Diskutovano je o rezultatima ispitivanja uzoraka ploča mešanih spojeva sa duplex čelikom. Ispitivanja su sprovedena na pločastim uzorcima mešanih spojeva od limova tipa P355NL1 i X2CrNiMoN22-5-3 zavarenih punjenom žicom DV-329A kompanije Kobelco iz sledeće kategorije T 22 9 3 NL RC / M3 u zaštiti gasne mešavine M21 (Ar + 18% CO₂) (ploča br. 1) i obloženom elektrodom od nikla E Ni 6082 kompanije Bohler (ploča broj 2). Prikazani su rezultati ispitivanja bočnog savijanja zavarenog spoja, poprečnog zatezanja, istezanja metala šava, udarne žilavosti, mikro i makroskopskih metalografskih pregleda i merenja sadržaja delta ferita.

1. Uvod

Duplex čelik zahvaljujući svojoj dvofaznoj strukturi ima podešenost mehaničkih osobina vezanih za duktilnost i plastičnost, kao i visoku otpornost na različite vrste korozije. Ovaj materijal omogućava dobijanje prednosti spajanja austenitnih i feritnih faza. Pažljivo odabrani hemijski sastav garantuje bolje osobine od mnogo skupljih visoko-legiranih austenitnih čelika [1-7]. Predstavljena ispitivanja u članku su uzeti sa pločastih uzoraka mešanih spojeva od limova tipa P355NL1 i X2CrNiMoN22-5-3 zavarenih punjenom žicom DV-329A kompanije Kobelco sledeće kategorije T 22 9 3 NL RC / M3 u mešavini gasova M21 (Ar + 18% CO₂) (ploča broj 1) i niklenom obloženom elektrodom E Ni 6082 kompanije Bohler (ploča broj 2).

Gore pomenuti eksperiment je izveden radi dokazivanja osobina spoja sa dodatnim materijalom strukture duplex čelika i materijala sa visokim sadržajem nikla, kao i utvrđivanje uticaja termičkog tretmana na promene strukture duplex čelika.



2. Properties, chemical composition of materials. Schaeffler's diagram

Differences of properties between P355NL1 steel, and corrosion resistant X2CrNiMoN22-5-3 duplex steel are given in Table 1.

2. Osobine, hemijski sastav materijala, Šeflerov dijagram

Razlike osobina između čelika P355NL1 i korziono otpornog čelika X2CrNiMoN22-5-3. date su u tabeli 1.

Type		Re, MPa	Rm, MPa	A, %	HB	KV, J (-40°C)
P355NL1	Min	395	533	32.5	175	101
	Max	400	552	33.0	183	114
X2CrNiMo N22-5-3	Min	470	739	31.6	223	229
	Max	472	747	34.9	223	240

Table 1. Comparison of mechanical properties of P355NL 1 steel and X2CrNiMoN22-5-3 steel [14]
Tabela 1. Uspoređenje mehaničkih osobina čelika P355NL i X2CrNiMoN22-5-3[14]

On the base of a chemical composition of both metal sheets and used filler materials, expected structures of the welds' materials made during processes were specified. The Schaeffler's diagram was used to illustrate it. (Fig. 1)

Na bazi hemijskog sastava obe metalne ploče i korišćenih dodatnih materijala, određene su očekivane strukture materijala zavarenih spojeva napravljenih tokom procesa. Dijagram Schaeffler-a je korišćen za ilustraciju. (sl. 1).

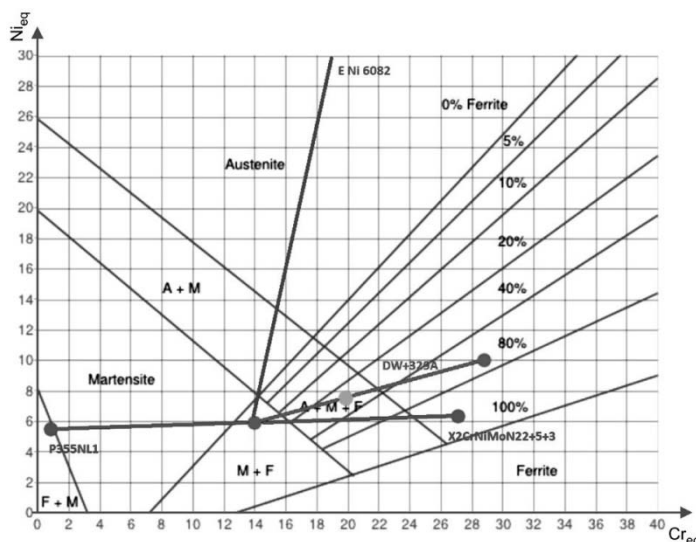


Fig. 1 The Schaeffler's diagram [17]
Sl. 1 Dijagram Schaeffler-a [17]

After calculating an equivalent of chromium and nickel (formula 1, 2) and applying the results to the diagram, following data was obtained:

an austenite-ferrite-martensite mixed structure with an approximate value of ferrite 10% by using a flux-cored duplex wire.

a diagram does not cover in its range material of such high content of nickel (clearly shows a plain austenite structure) by using nickel covered electrodes

Nakon izračunavanja ekvivalenta hroma i nikla (formula 1, 2) i primene rezultata na dijagramu, dobijeni su sledeći podaci:

mešovita struktura austenit-ferrit-martenzit sa približnom vrednošću ferita od 10% primenom dupleks punjene žice

dijagram ne pokriva u njegovom opsegu materijale sa tako visokim sadržajem nikla (jasno pokazuje jednostavnu strukturu austenita) korišćenjem niklovi obloženih elektroda

$$Cr_{eq} = Cr + Mo + 1,5Si + 0,5Nb \quad (1)$$

$$Ni_{eq} = Ni + 30C + 0,5Mn \quad (2)$$



C	Si	Mn	P	S	Cr	Ni	Mo	N	Co
0.026	0.45	1.42	0.029	0.001	22.26	5.11	3.12	0.1690	0.07

Table 2 Chemical composition of X2CrNiMoN22-5-3 metal sheet [14]

Tabela 2. Hemijski sastav ploče od čelika X2CrNiMoN22-5-3[14]

C	Si	Mn	P	S	Al	Cr	Ni	Mo	Cu
0.170	0.380	1.190	0.007	0.0029	0.033	0.180	0.014	0.004	0.160
V	Nb	Ti	B	N					
0.006	0.008	0.013	0.0003	0.0068					

Table 3. Chemical composition of P355NL 1 metal sheet [4]

Tabela 3. Hemijski sastav ploče od čelika P355NL 1[4]

C	Si	Mn	P	S	Cu	Ni	Cr	Mo	N
0.025	0.74	0.93	0.015	0.002	0.08	9.23	23.21	3.38	0.16

Table 4. Chemical composition of the flux-cored wire DW-329A – Kobelco [12]

Tabela 4. Hemijski sastav punjene žice DW-329A – Kobelco [12]

C	Si	Mn	P	S	Nb	Cr	Ni	Mo	Cu
0.024	0.40	5.16	0.006	0.005	2.22	18.83	69.70	1.0	0.02
Ti	Fe								
0.081	2.70								

Table 5. Chemical composition of the ThermanitNicro 82 coated electrode– Böhler [3]

Tabela 5. Hemijski sastav obložene elektrode ThermanitNicro 82 – Böhler [3]

It is necessary to point that the Schaeffler's diagram relates to the constant cooling conditions of the weld, thus a real result may considerably differ. Above differences result from the dynamics of a welding process, and particularly an influence of heat which is difficult to predict, and the foremost conditions of cooling the weld [8-11].

3. Technology of welding

Welding sample plates was made in the downhand position PA. An initial preheating was not applied, instead, an interpass temperature was kept on the level not higher than 150°C.

An order of applying beads is presented in the picture 2, while the real parameters obtained during the process of welding are included in the table 6.

Neophodno je ukazati na to da se dijagram Schaeffler-a odnosi na konstantne uslove hlađenja šava, tako da se pravi rezultat može znatno razlikovati. Gore pomenute razlike su rezultat dinamike procesa zavarivanja, a posebno uticaja toplote što se teško predviđa, kao i najvažniji uslovi za hlađenje šava [8-11].

3. Tehnologija zavarivanja

Ploče za uzorke za zavarivanje izrađene su u položaju PA. Početno predgrevanje nije primenjeno, umesto toga, međuslojna temperatura je održavana na nivou koji nije veći od 150°C.

Na slici 2 je prikazan redosled nanošenja zavara, dok su stvarni parametri dobijeni tokom procesa zavarivanja dati u tabeli 6.

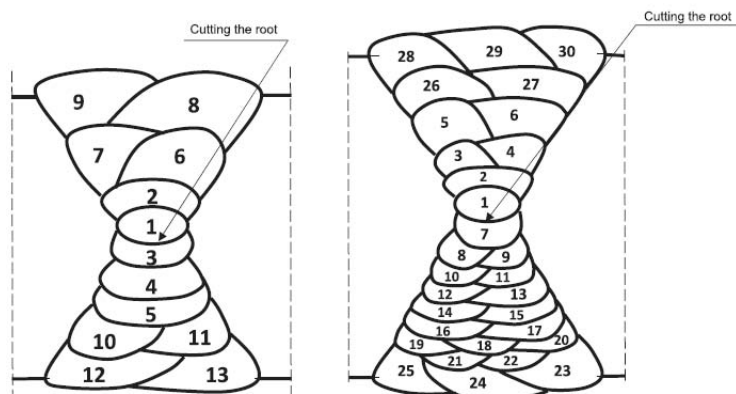


Fig. 2. An order of applying beads

Sl. 2. Redosled polaganja zavara



Used parameters allowed to obtain a proper amount of inserted heat (linear energy ranges from 0,3 to 1,7 kJ/mm), does not exceed recommended values (maximum value of a linear energy is 2,5 kJ/mm).

Korišćeni parametri dozvoljavaju postizanje odgovarajuće količine unete toplote (linearna energija se kreće od 0,3 do 1,7 kJ/mm), ne prelazi preporučene vrednosti (maksimalna vrednost linearne energije 2,5 kJ/mm).

PLATE NO. 1				PLATE NO. 2			
No. of bead	Current intensity A	Voltage V	Speed of welding cm/min	No. of bead	Current intensity A	Voltage V	Speed of welding cm/min
1	215	30.7	32.7	1	91 - 94	23.5 - 26.0	11.1
2 - 7	235 - 270	31.2 - 32.3	21.8 - 40.0	2 - 7	109 - 120	23.2 - 27.0	14.2
8 - 9	240 - 275	32.3	24.9 - 29.1	8 - 18	119 - 131	21.5 - 27.3	20.0
10 - 11	230 - 275	32.3	33.8 - 46.2	19 - 20	112 - 115	22.5 - 24.5	24.0
12 - 13	250 - 280	32.3	32.7 - 33.6	20 - 26	109 - 125	23.0 - 26.5	21.4
Linear energy of welding, kJ/cm			7.7 - 17.2	Linear energy of welding, kJ/cm			2.8 - 12.3

Table 6. Real parameters obtained during a welding process

Tabela 6. Realni parametri postignuti tokom procesa zavarivanja

Legenda: plate No- lim br. ; No of bead-broj zavara; current intensity-jačina struje; voltage-napon; speed of welding-brzina zavarivanja; linear energy of welding-linijska energija pri zavarivanju

4. Thermal treatment after welding

After welding a thermal treatment – stress relief annealing was applied (table 7) in order to delete welding stress. Then, non-destructive and destructive testing were done, and their results are presented later in the article.

4. Termička obrada posle zavarivanja

Termička obrada posle zavarivanja - žarenje za smanjenje napona (tabela 7) je primenjena kako bi se uklonili naponi nastali zavarivanjem. Zatim su obavljena ispitivanja bez i sa ržaranjem, a rezultati su predstavljeni kasnije u članku.

Type of treatment Vrsta obrade	Stress relief annealing Žarenje za smanjenje napona		
Material Materijal	P355NL1 + X2CrNiMoN22-5-3		
No. Br.	Actions Aktivnosti	Value Vrednost	[unit] jedinica
1	Place in the furnace in the maximum temperature Staviti u peć na maksimalnoj temperaturi	300	[°C]
2	Heat gradually to the temperature Postepeno zagrevanje na temperaturu	570-590	[°C]
3	Maximum speed of heating Maksimalna brzina zagrevanja	100	[°C/hour.] [°C/h]
4	Time of annealing Vreme žarenja	30	[min]
5	Cool in the furnace up to the temperature Hladiti u peći do temperature	350	[°C]
6	Maximum speed of cooling Maksimalna brzina hlađenja	100	[°C/hour.] [°C/h]
7	Afterwards, cool in the mild air Nakon toga, hlađenje na mirnom vazduhu	Yes da	-

Table 7. Parameters of a thermal treatment after welding

Tabela 7. Parametri termičke obrade posle zavarivanja

5. Non-destructive testing.

VT – visual testing

The first non-destructive testing, including 100% of the length of the examined welded joint is a visual testing, which is done according to the PN-EN ISO 17637 standard. During examination there were not any of disqualifying discrepancies specified in the PN-EN ISO 5817 standard.

5. Isptivanje bez razaranja

VT-vizuelna kontrola

Prvo ispitivanje bez razaranja koje se obavlja, obuhvata 100% dužine ispitivanog zavarenog spoja, predstavlja vizuelna kontrola, koja se vrši prema standardu PN-EN ISO 17637. Tokom ispitivanja nije bilo nijednog nedozvoljenog odstupanja od navedenih u standardu PN-EN ISO 5817.



PT – penetration testing

There was a penetration testing done according to the EN ISO 571-1 standard after visual testing. Mr. Chemie GMBH products were used. Examination included 100% of the welded joint, there were not any discrepancies.

RT – radiographic testing

The only volume examination which was taken was a radiographic testing according to the PN-EN ISO 1435 standard. The whole area of the joint during examination together with the base material was taken into account, except 20 mm scraps on both sides. SMART 300HP ANDREX lamp was used, as well as X-ray film IX100 by the Fuji Film. Radiographic images did not reveal any welding discrepancies.

6. Collecting and preparing samples to destructive testing.

A way of collecting samples according to the PN-EN ISO 15614-1 is depicted in the picture 3.

PT-ispitivanje penetrantima

Nakon vizuelne kontrole obavljeno je ispitivanje penetrantima prema standardu EN ISO 571-1. Korišćeni su proizvodi kompanije Chemie GmbH. Ispitivanjem je obuhvaćeno 100% zavarenog spoja i nije bilo nikakvih odstupanja.

RT-radiografsko ispitivanje

Jedino zapreminsko ispitivanje koje je izvršeno je radiografsko ispitivanje prema standardu PN-EN ISO 1435. Obuhvaćena je čitava površina spoja zajedno sa osnovnim materijalom, izuzev 20 mm otpatka sa obe strane. Korišćen je uređaj SMART 300HP ANDREKS, kao i rendgenski IKS100 film Fuji. Radiografske slike nisu pokazale odstupanja u zavarivanju.

6. Prikupljanje i priprema uzoraka za ispitivanje sa razaranjem

Način grupisanja uzoraka prema PN-EN ISO 15614-1 prikazan je na slici 3.

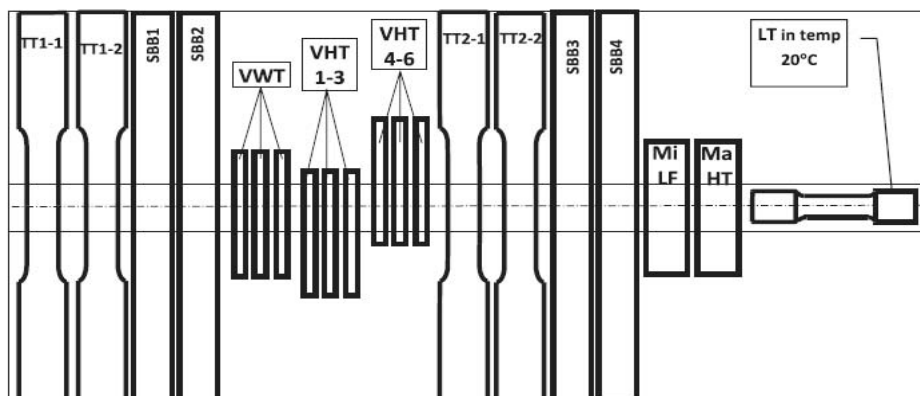


Fig. 3. Places of collecting samples from the sample plates. TT– tension-torsion, SBB – surface band bending, Mi – micro, Ma – macro, VWT, VHT – notch impact value, HT – hardness testing, LF – ferrite number, LT – tension of weld metal [15,22]

Sl. 3. Mesta za grupisanje epruveta iz uzoraka ploča. TT-zatezanje-uvijanje, SBB- savijanje preko površine, Mi-mikro, Ma-makro, VWT, VHT- vrednost udarne žilavosti, HT- ispitivanje tvrdoće, LF- feritni broj, LT-zatezanje metala šava

Whereas the methods of preparation, a scheme of taken examinations, and their results are presented underneath. All the examinations were taken in exactly the same conditions in case of both sample plates.

7. Side bend test

The test was done according to the PN-EN ISO 5173 standard on four lateral samples (fig. 4). A bending mandrel of 40 mm diameter was used. A traditional machine ZD40 used to stretch of a maximum power 400 kN was used [28].

Metode pripreme, šema preduzetih ispitivanja i njihovi rezultati dati su ispod. Sva ispitivanja su sprovedena pod istim uslovima u slučaju oba uzorka ploča.

7. Ispitivanje bočnim savijanjem

Ispitivanje je urađeno prema standardu PN-EN ISO 5173 na četiri bočna uzorka (slika 4). Korišćen je trn za savijanje prečnika 40 mm. Korišćena je tradicionalna mašina ZD40 za zatezanje maksimalne snage 400 kN [28].

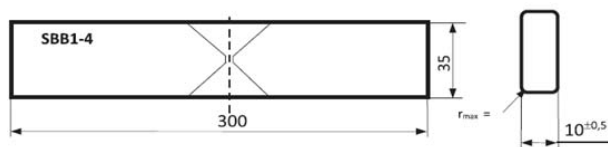


Fig. 4. A way of preparing samples to the side bend [18]

Sl. 4 Način pripreme uzoraka za bočno savijanje [18]

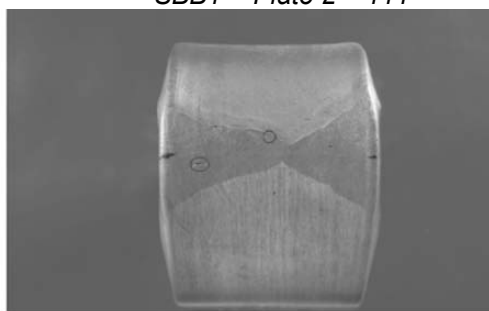
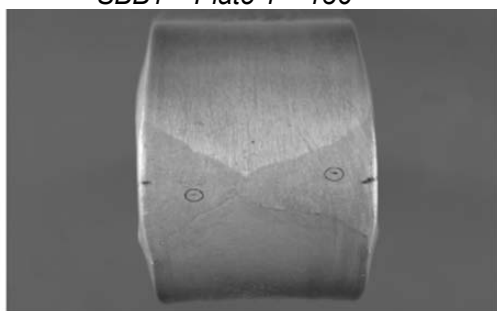
Pictures of the samples after side bend are presented in the picture 5.

Slike uzoraka nakon bočnog savijanja prikazane su na slici 5.



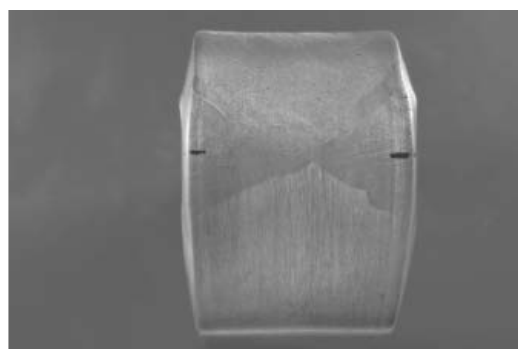
SBB1 – Plate 1 – 136

SBB1 - Plate 2 – 111



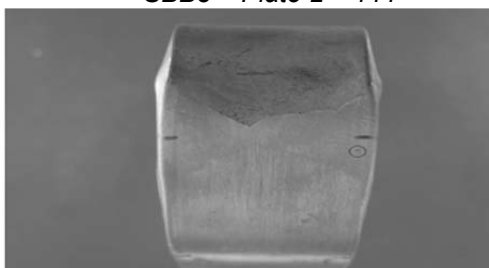
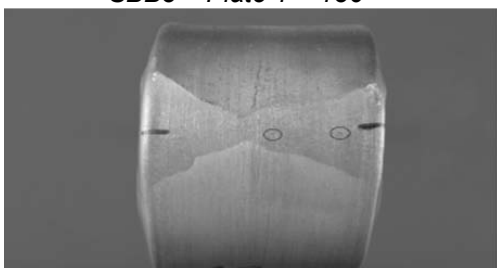
SBB2 – Plate 1 – 136

SBB2 – Plate 2 – 111



SBB3 – Plate 1 – 136

SBB3 – Plate 2 – 111



SBB 4 – Plate 1 – 136

SBB 4– Plate 2 – 111

Fig. 5 Pictures of the samples after side bend

Sl. 5 Slike uzoraka posle bočnog savijanja



Bending tests did not reveal any discrepancies in the base materials, welds and heat-affected zones. In case of both sample plates there appeared only slight cracks, which do not disqualify the joint. A result of an examination was positive (table 8, Fig. 5)

Testovi savijanja nisu otkrili nikakva odstupanja u osnovnim materijalima, zavarima i zonama uticaja toplote. U slučaju obe ispitne epruvete uzoraka pojavile su se neznatne prsline, koje ne diskvalifikuju spoj. Rezultat pregleda bio je pozitivan (tabela 8, slika 5)



Fig. 6. A phenomena of non-axial deformation of bent samples
Sl. 6 Pojava neaaksijalne deformacije savijenih uzoraka

It is vital to point that PN-EN ISO 15614-1 standard allows to use 2 tests of bending longitudinal samples instead of 4 tests of side bend in case of mixed joints. It is done to avoid a problem of non-axial deformation of samples during examination, which is caused by too high difference of a resistance and plasticity of both materials. It was observed in the above experiment (Fig. 6). Above test was done in order to examine the joint in difficult technological conditions, therefore more risky 4 side bends were made [15, 18, 22].

8. Transverse tensile test

Transverse tensile test was done on four samples prepared according to the picture 7 in the room temperature in accordance with the PN-EN ISO 4136 standard. Sizes of the samples were fixed to the possibilities of the tensile testing machine of 400kN power. Taking into account a high tensile strength of the duplex steel, it was necessary to take two samples from the joint. A minimum criteria for the joint was equal to 470MPa [23].

Važno je ukazati na to da standard PN-EN ISO 15614-1 dozvoljava korišćenje 2 ispitivanja podužnim savijanjem umesto 4 ispitivanja bočnim savijanjem u slučaju mešoviti zavarenih spojeva. To je i učinjeno da bi se izbegao problem neaaksijalne deformacije uzoraka tokom ispitivanja, što je uzrokovano previsokom razlikom otpornosti i plastičnosti oba materijala. To je uočeno u gore navedenom eksperimentu (slika 6). Prethodno ispitivanje je obavljeno kako bi se ispitao spoj u teškim tehnološkim uslovima, zbog čega je urađeno rizičnije savijanje sa 4 strane. [15, 18, 22].

8. Ispitivanje poprečnim zatezanjem

Ispitivanje poprečnim zatezanjem obavljeno je na četiri uzorka pripremljena prema slici 7 na sobnoj temperaturi u skladu sa standardom PN-EN ISO 4136. Veličine uzoraka bile su fiksirane na mogućnosti mašine za ispitivanje zatezanjem snage 400 kN. Uzimajući u obzir visoku zateznu čvrstoću dupleks čelika, bilo je potrebno uzeti dva uzorka iz spoja. Minimalni kriterijumi za spoj su bili jednaki 470MPa [23].

Sample	An angle of bend, °	Plate 1 (136)	Plate 2 (111)
SBB1	180	Lack of cracks	Openings l1=0.2mm. l2=0.8 mm
SBB2	180	Openings l1=1.2mm. l2=0.4mm	Openings l1=1.7mm. l2=0.5 mm
SBB3	180	Openings l1=0.7mm. l2=1.2mm	Lack of cracks
SBB4	180	Openings l1=1.5mm. d=0.5mm	Opening l1=1.3mm

Table 8 Results of the side bend tests
Tabela 8. Rezultati ispitivanja bočnim savijanjem

Legenda: sample-uzorak; an angle of bend- ugao savijanja; plate-lim; lack of cracks-bez prsline; opening- otvaranje



Sample	Plate 1 - 136		Plate 2 - 111	
	Rm, MPa	Breaking place	Rm, MPa	Breaking place
TT1-1	536	P355NL1 material	557	P355NL1 material
TT1-2	525	P355NL1 material	558	P355NL1 material
TT2-1	520	P355NL1 material	559	P355NL1 material
TT2-2	524	P355NL1 material	546	P355NL1 material

Table 9 Results of the tension tests
Tabela 9. Rezultati ispitivanja zatezanjem

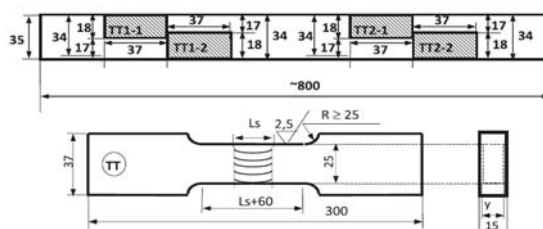
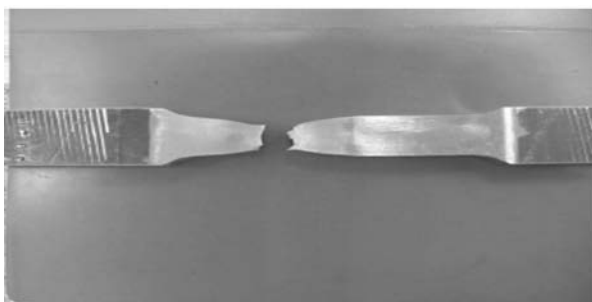


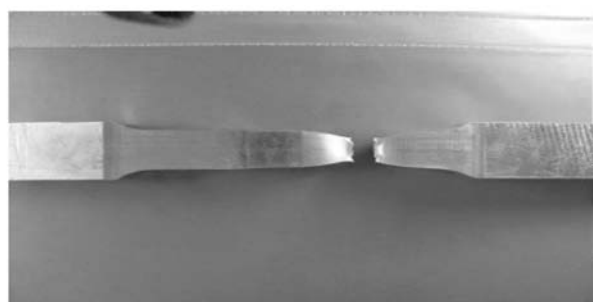
Fig. 7. A way of taking and preparing samples for tension [23]
Sl. 7. Način uzimanja i pripreme uzoraka za zatezanje [23]

Pictures of the samples after transverse tensile are presented in the picture 8.

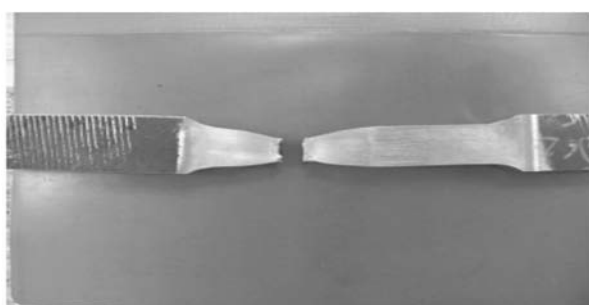
Slike uzoraka nakon poprečnog zatezanja prikazane su na slici 8.



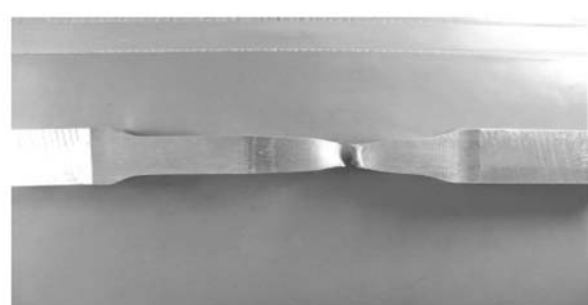
TT1 – 1 – Plate 1 – 136



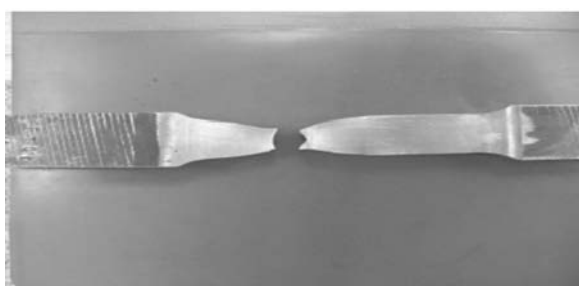
TT1 – 1 – Plate 2 – 111



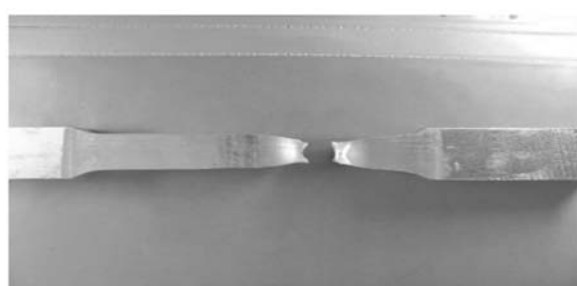
TT1 – 2 – Plate 1 – 136



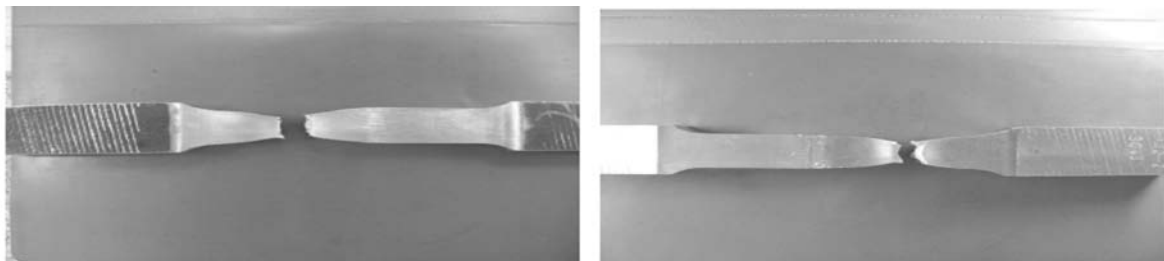
TT1 – 2 – Plate 2 – 111



TT2 – 1 – Plate 1 – 136



TT2 – 1 – Plate 2 – 111



TT2 – 2 – Plate 1 – 136

TT2 – 2 – Plate 2 – 111

Fig. 8. Pictures of the samples after transverse tensile

SI. 8. Slike uzoraka posle poprečnog zatezanja

Tension tests proved that duplex steel is characterised by the greater tensile strength than the P355NL1 steel – samples were broken in the structural steel (fig. 8). An examination has finished positively, because a minimal resistance of the joint was obtained (table 9).

Ispitivanja zatezanjem su dokazala da se dupleks čelik odlikuje većom zateznom čvrstoćom od čelika P355NL1 - uzorci su se polomili na delu konstrukcionog čelika (slika 8). Ispitivanje se završilo pozitivno, jer je postignuta minimalna otpornost spoja (tabela 9).

9. Weld metal tensile test

Weld metal tensile test was done according to the PN-EN ISO 876 standard in order to measure tensile strength of the same weld. A way of preparing a sample presents picture 9 [13].

9. Ispitivanje zatezanjem metala šava

Ispitivanje zatezanjem metala šava je izvedeno u skladu sa standardom PN-EN ISO 876 kako bi se izmerila zatezna čvrstoća istog šava. Način pripreme uzorka predstavljen je na slici 9 [13].

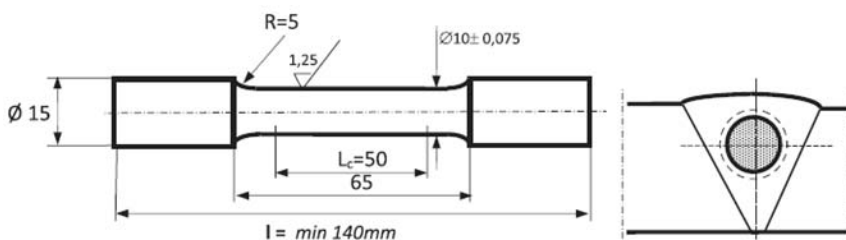


Fig. 9. A way of taking and preparing a sample to stretch the weld metal. [26]

SI. 9. Način uzimanja i pripreme uzorka za istezanje metala šava [26]

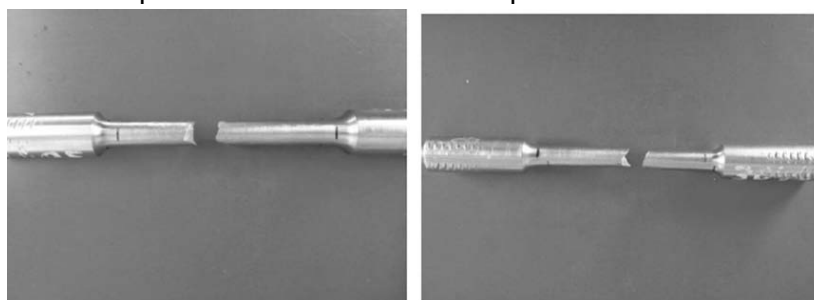
Sample	Re, MPa	Rm, MPa	Elongation, %	Result of the examination
LT1-1- Plate 1 - 136	384	513	27.8	Positive
LT1-1- Plate 2 - 111	416	675	44.4	Positive

Table 10 Weld metal tensile tests' results

Tabela 10. Rezultati sipitivanja zatezanjem metla šava

Pictures of the samples after tensile testing of the weld metal are presented in the picture 10.

Slike uzoraka nakon ispitivanja zatezanjem metala šava prikazane su na slici 10.



LT – 1 – Plate 1 – 136

LT – 1 – Plate 2 – 111

Fig. 10 Pictures of the samples after tension of the weld metal

SI. 10. Slike uzoraka posle zatezanja metala šava



Except of measuring tensile strength of the weld, there was also a measurement of elongation A5, and the limit of plasticity. An examination was taken in the room temperature. Following criteria were taken into account: $Re \geq 315\text{MPa}$, $A \geq 21\%$, $Rm \geq 470\text{MPa}$ (table 10) [26]. Higher resistance and plasticity values were obtained in case of the plate no. 2, which is the result of using nickel based electrodes.

10. Impact strength test

Due to the mixed connection, except of a standard threeset samples taken from the weld and three from heat-affected zones, an additional set was used from the heat-affected zone of the second material. Recommendations from PN-EN ISO 9016 and PN-EN ISO 148-1 standards were used. Pictures 11 and 12 depict a way of taking each set. An examination was = 300 J weight [24, 25]

Pictures of the samples after an impact strength test are presented in the picture 13.

Osim merenja zatezne čvrstoće šava, takođe je mereno izduženje A5 i granica plastičnosti. Ispitivanje je izvršeno na sobnoj temperaturi. U obzir su uzeti sledeći kriterijumi: $Re \geq 315\text{MPa}$, $A \geq 21\%$, $Rm \geq 470\text{MPa}$ (tabela 10) [26]. Dobijene su veće otpornosti i plastičnosti u slučaju ploče br. 2, što je rezultat korišćenja elektroda na bazi nikla.

10. Ispitivanje energije udara

Zbog mešovitog spoja, izuzev standardnih šesnaest uzoraka uzetih iz šava i tri iz zona pod uticajem toplote, korišćen je dodatni set iz zona uticaja toplote drugog materijala. Korišćene su preporuke standarda PN-EN ISO 9016 i PN-EN ISO 148-1. Slike 11 i 12 prikazuju način uzimanja svakog seta. Ispitivanje je obavljeno uz = 300 J opseg. [24, 25]

Slike uzoraka nakon ispitivanja energije udara su prikazane na slici 13.

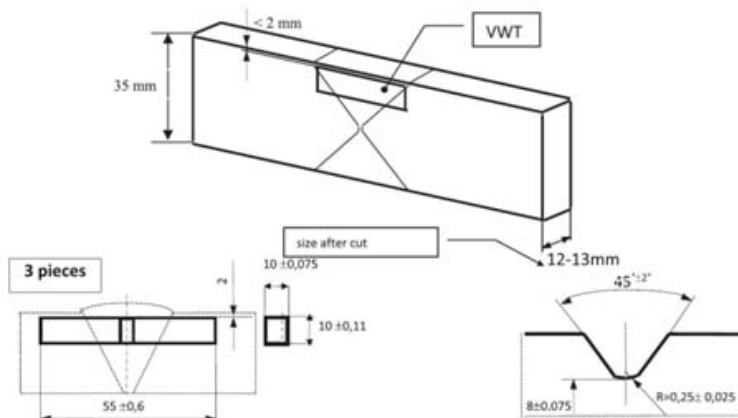


Fig. 11. A way of preparing samples taken from the weld to the impact strength tests [14]
Sl. 11. Način pripreme uzoraka uzetih iz metala šava za ispitivanje udarom [14]

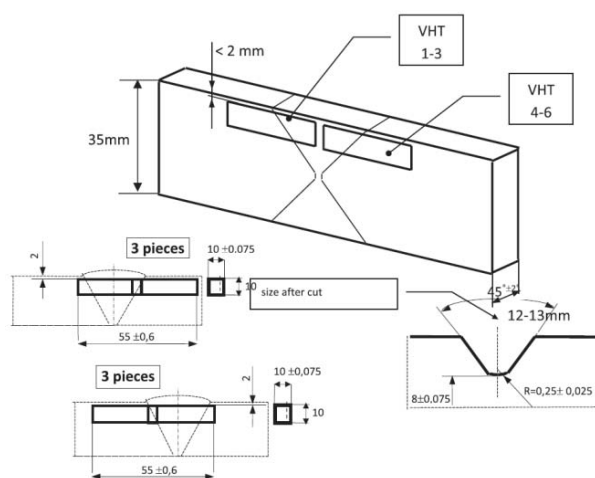


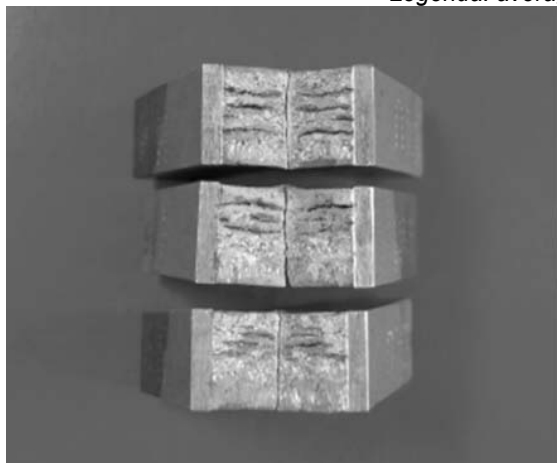
Fig. 12. A way of preparing samples taken from the heat-affected zones to the impact strength tests [14]
Sl. 12. Način pripreme uzoraka uzetih iz zona uticaja toplote za ispitivanje udarom [14]



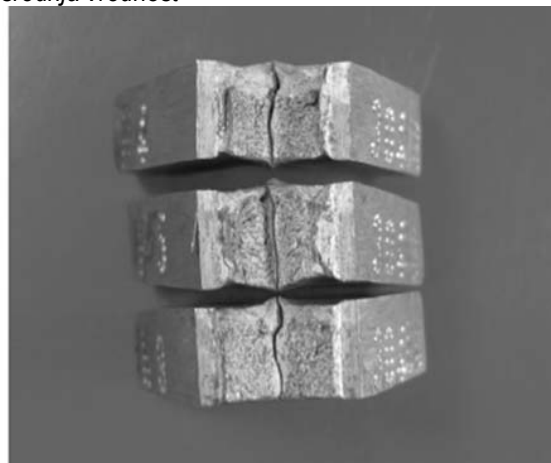
Plate	Sample	1, J	2, J	3, J	Average, J
1 – 136	VWT1/2 – P355NL1	88	26	26	47
	VHT1/2 – weld	14	5	6	8
	VHT1/2 – X2CrNiMoN22-5-3	33	36	18	29
2 – 111	VWT1/2 – P355NL1	140	130	138	136
	VHT1/2 – weld	128	128	133	130
	VHT1/2 – X2CrNiMoN22-5-3	75	110	59	81

Table 11 Results of the impact strength tests
Tabela 11. Rezultati ispitivanja udarom

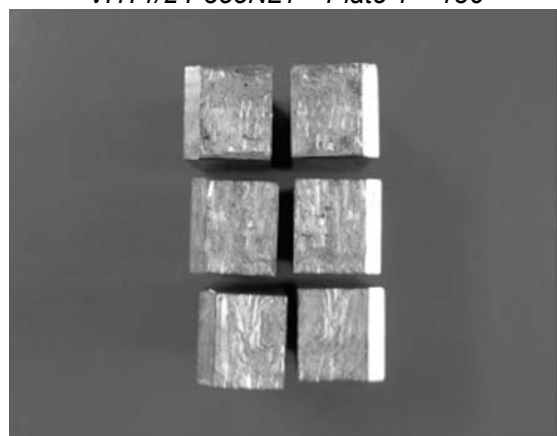
Legenda: average-srednja vrednost



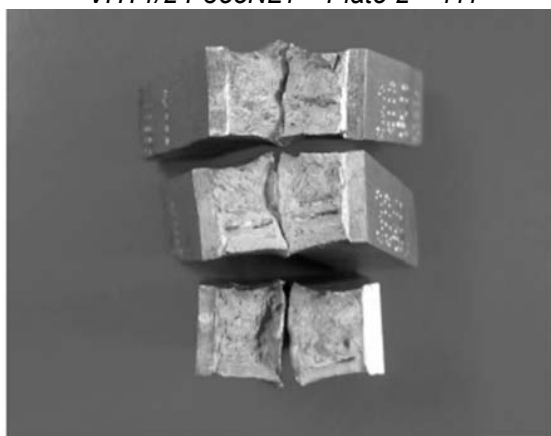
VHT1/2 P355NL1 – Plate 1 – 136



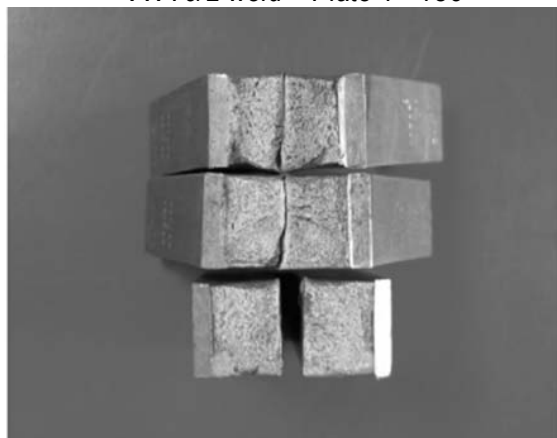
VHT1/2 P355NL1 – Plate 2 – 111



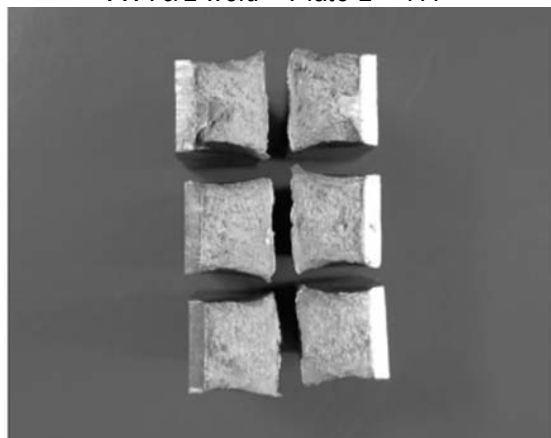
VWT0/2 weld – Plate 1 - 136



VWT0/2 weld – Plate 2 – 111



VHT1/2 X2CrNiMoN22-5-3 – Plate 1 –



136 VHT1/2 X2CrNiMoN22-5-3 – Plate 2 – 111

Fig. 13. Pictures of samples after an impact strength test
SI. 13. Slike uzoraka posle ispitivanja udarom



Impact strength tests have finished negatively in case of the plate no. 1. A required value of breaking operation equals to 27 J was not obtained both for P355Ni1 material, and also 40 J for the duplex steel (table 11). It is caused by an increase of embrittlement activated by the carbon diffusion from the carbon steel into the weld during a thermal treatment, and an occurrence of the brittle sigma phase.

In case of using nickel based filler material (plate no. 2) much higher breaking operation values were obtained.

Elements included in the chemical composition of used electrodes mostly nickel, niobium and titanium, which are stabilizers, stopped carbon diffusion. Moreover, they caused appearance of carbides, which increase embrittlement and decrease resistance of the material to corrosion. Pictures prove that samples taken from the nickel welded joint (plate no. 2) broke in a plastic way, while the fracture of samples from the plate no. 1 is evidently brittle.

11. Macroscopic examination

Macroscopic examination was taken according to PN-EN 1321 standard on a previously taken and etched metallographic specimen (fig. 14). Adler's solution was used to etch. [20]

Ispitivanje udarom negativno je završeno u slučaju ploče br. 1. Potrebna vrednost jednaka 27 J nije dobijena ni za materijal P355Ni1, niti 40 J za dupleks čelik (tabela 11). To je uzrokovano povećanjem krтости aktivirane difuzijom ugljenika od ugljeničnog čelika u šav pri termičkoj obradi i pojavom krte sigma faze.

U slučaju korišćenja dodatnog materijala na bazi nikla (ploča broj 2) dobijene su mnogo veće vrednosti.

Elementi sadržani u sastavu upotrebljenih elektroda uglavnom niki, niobijum i titan, koji su stabilizatori, zaustavili su difuziju ugljenika. Štaviše, oni su izazvali pojavu karbida, čime se povećava krčnost i smanjuje otpornost materijala na koroziju. Slike pokazuju da su uzorci uzeti iz niklom zavarenog spoja (ploča broj 2) lomili plastično, dok je prelom uzoraka sa ploče br. 1 očigledno krt.

11. Makroskopsko ispitivanje

Makroskopsko ispitivanje je izvedeno u skladu sa standardom PN-EN 1321 na prethodno uzetom i obrađenom metalografskom uzorku (slika 14). Za nagrizanje je korišćen Adlerov rastvor [20]

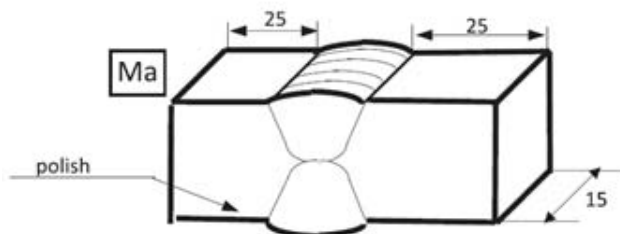


Fig. 14. A way of preparing a metallographic specimen [10]

Sl. 14. Način pripreme metalografske eperuvete [10]

Macroscopic pictures of plates are presented in the picture 15.

Makroskopske slike ploča su prikazane na slici 15.

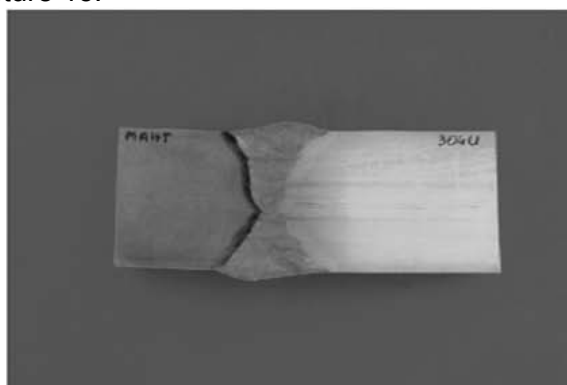


Plate no. 1

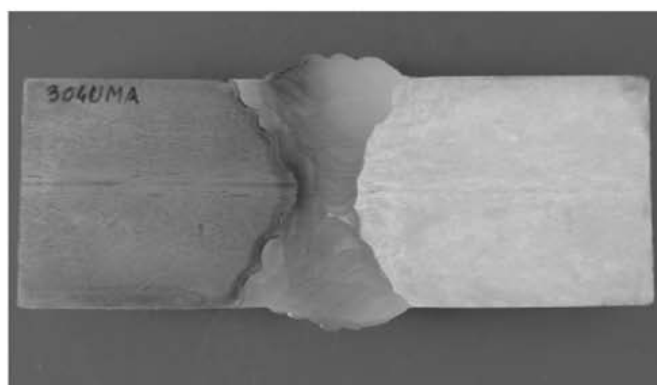


Plate no. 2

Fig. 15. Macroscopic pictures of plates

Sl. 15. Makrostrukture na limovima



Macroscopic examination did not reveal any of unaccepted discrepancies in the section of examined plates (fig. 15)

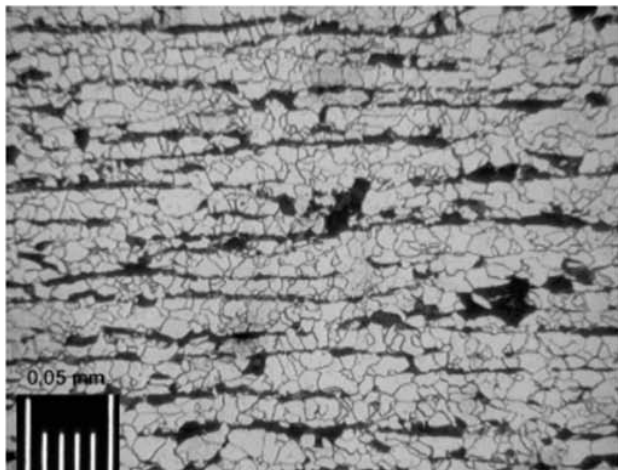
Makroskopski pregled nije otkrio nijedno od neprihvatljivih odstupanja u delu ispitanih ploča (slika 15).

12. Microscopic examination

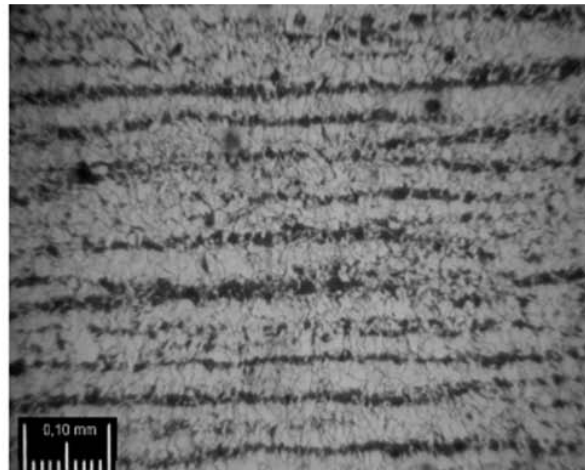
Microscopic images were taken on the metallographic specimen etched by the agent consisting of nital and Mi20Fe (fig. 16). Zoom 200:1 was used. An examination was taken according to the PN-EN 1321 standard [20]

12. Ispitivanje mikrostrukture

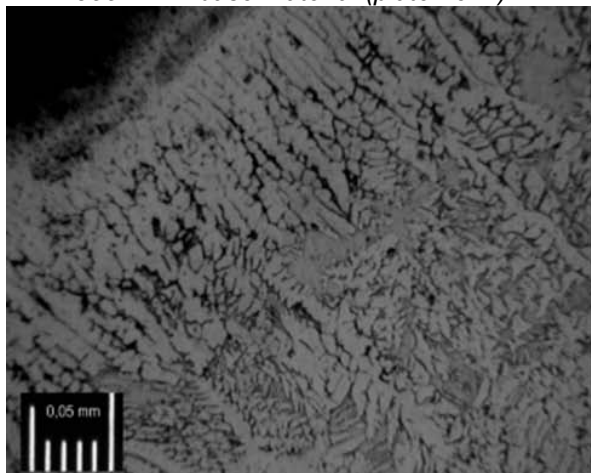
Mikroskopske slike su uzete na metalografskom uzorku koji je nagrižen agensom koji se sastoji od nitala i Mi20Fe (slika 16). Uvećanje je 200: 1. Ispitivanje je izvedeno prema standardu PN-EN 1321 [20]



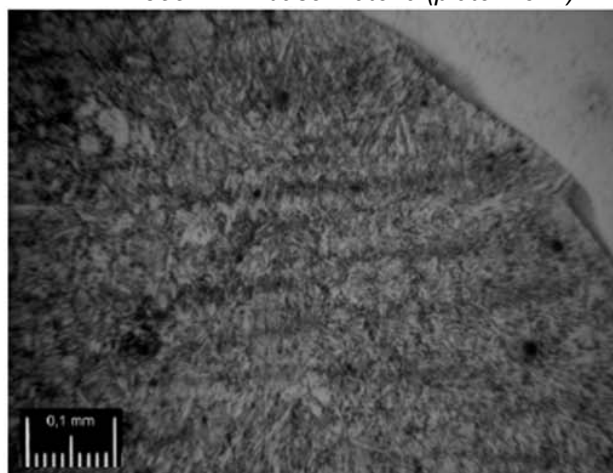
P355NL1 – base material (plate no. 1)



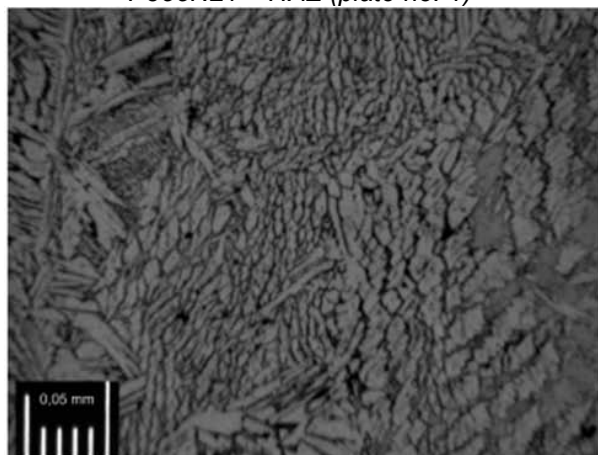
P355NL1 – base material(plate no. 2)



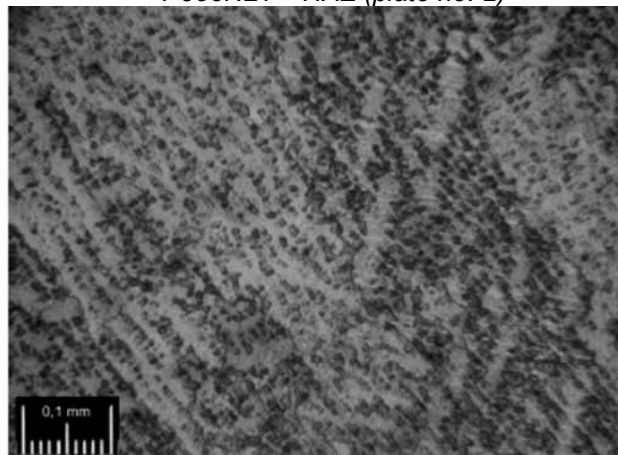
P355NL1 – HAZ (plate no. 1)



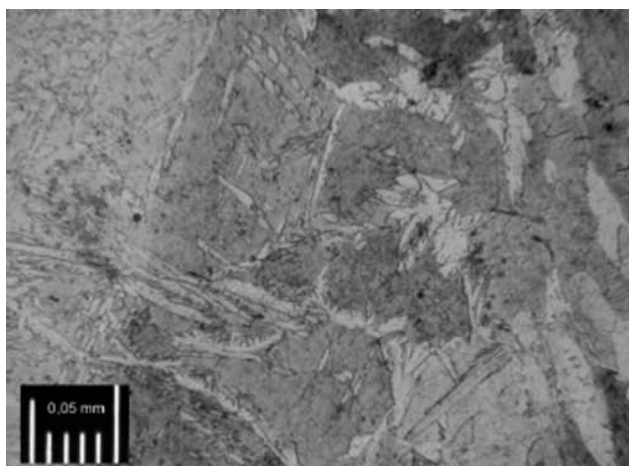
P355NL1 – HAZ (plate no. 2)



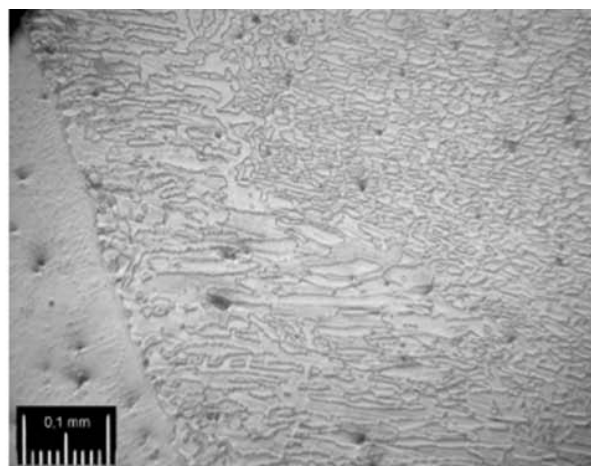
weld (plate no. 1)



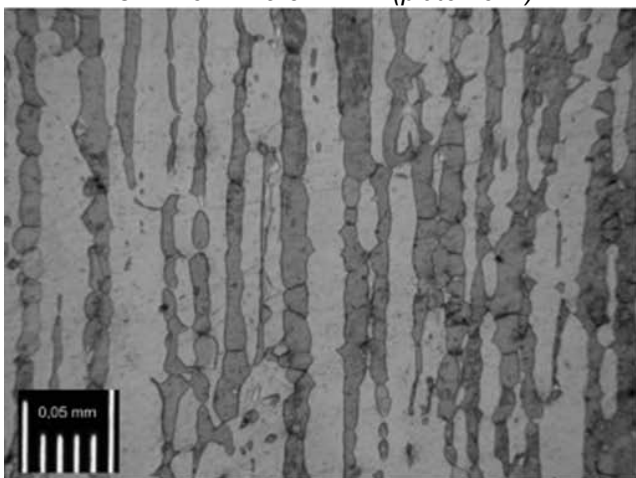
weld (plate no. 2)



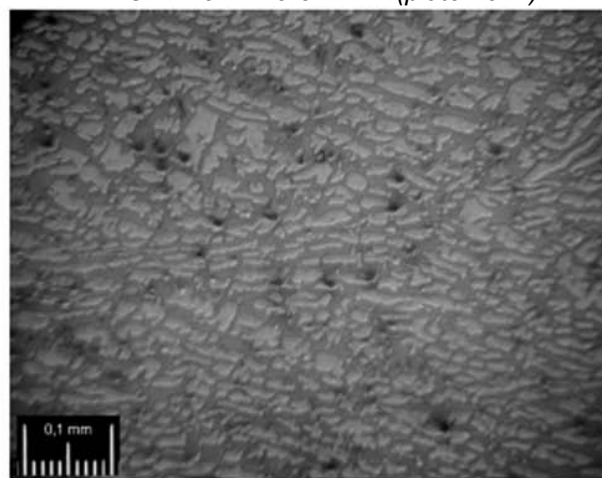
X2CrNiMoN22-5-3 – HAZ (plate no. 1)



X2CrNiMoN22-5-3 – HAZ(plate no. 2)



X2CrNiMoN22-5-3 – (plate no. 1)



X2CrNiMoN22-5-3(plate no. 2)

Legenda: plate no-lim br.; HAZ-ZUT; weld-metal šava

Fig. 16. Microscopic pictures of plates

Sl. 16. Mikrostrukture limova

A structure of a heat-affected zone on the side of the duplex steel in case of the plate no. 1 includes about 40-50% ferrite. The weld indicates a ferrite-austenite structure with a required share of ferrite i.e. 30-70%. Microscopic examination in case of the plate no. 2 does not reveal any microcracks or other discrepancies. It was stated that the base material on the side of the carbon steel has a ferrite-pearlite structure, and on the side of the duplex steel has a ferrite-austenite structure with a ferrite content of about 45%. The weld is characterised by the ferrite-austenite structure of grown austenite grains with a ferrite content not exceeding a value of 85% near the weld line (fig. 16).

13. Hardness test

Hardness test by the Vickers method was done on the metallographic specimen, previously used in the macroscopic examination. Hardness test was done according to the PN-EN ISO 9015-1 standard along specified measurement lines (fig.17). Vickers testing device was used 430 SVD with the load of HV10 [19].

Struktura zone uticaja toplote na strani dupleks čelika u slučaju ploče br. 1 sastoji se od oko 40-50% ferita. Metal šava pokazuje strukturu ferita-austenita sa potrebnim udelom ferita tj. 30-70%. Mikroskopski pregled u slučaju ploče br. 2 ne otkriva nijednu mikroprslinu ili druga odstupanja. Ustanovljeno je da osnovni materijal na strani ugljeničnog čelika ima feritno-perlitnu strukturu, a na strani dupleks čelika ima feritno-austenitnu strukturu sa sadržajem ferita od oko 45%. Šav karakteriše feritno-austenitna struktura sa krupnim austenitnim zrnima i sadržajem ferita koji ne prelazi vrednost 85% u blizini linije stapanja (slika 16).

13. Ispitivanje tvrdoće

Ispitivanje tvrdoće po Vickersovoj metodi obavljeno je na metalografskom uzorku, ranije korišćenom za makroskopski pregled. Ispitivanje tvrdoće je obavljeno prema standardu PN-EN ISO 9015-1 duž određenih mernih linija (slika 17). Korišćeni uređaj je Vickers 430 SVD sa opterećenjem HV10 [19].

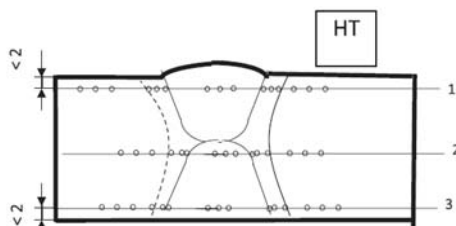


Fig. 17. A way of doing a hardness test [19]
SI. 17. Način merenja tvrdoće

nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	158	151	160	173	193	219	276	290	290	266	258	258	251	245	243
2	150	146	146	202	212	206	272	262	304	279	279	279	243	245	240
3	139	138	140	177	199	206	274	281	287	276	276	274	240	233	242

Table 12 Results of hardness tests of the plate 1 – method 136
Tabela 12. Rezultati ispitivanja tvrdoće na limu 1- postupak 136

Nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	149	153	151	202	224	249	187	172	177	258	240	237	227	235	228
2	150	149	153	183	186	201	197	209	199	279	266	260	227	230	228
3	149	149	146	183	202	235	191	193	173	251	225	233	233	238	235

Table 13 Results of hardness tests of the plate 2 – method 111
Tabela 13. Rezultati ispitivanja tvrdoće na limu 2- postupak 111

Results of the hardness tests are depicted in the picture 18 Rezultati ispitivanja tvrdoće prikazani su na slici 18

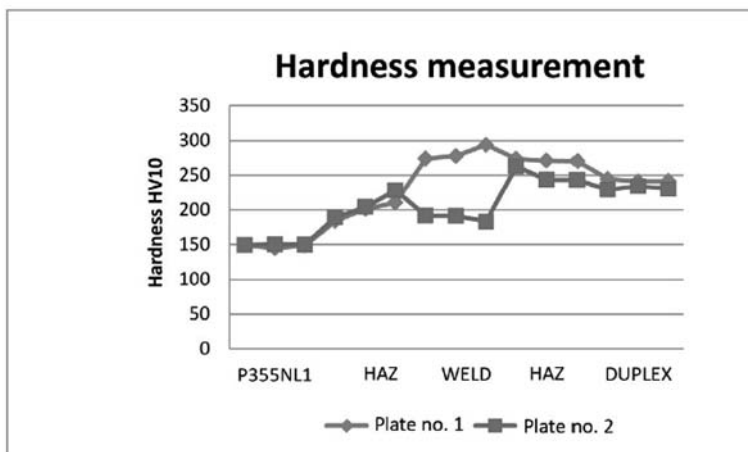


Fig. 18. Results of the hardness measurement
SI. 18. Rezultati merenja tvrdoće

In case of the plate no. 1, the lowest hardness was stated inside the P355NL1 metal sheet, its value is much higher in the duplex steel, and definitely the highest in the weld (table 12, 13). Hardness of both base materials plate no. 2 is very close to the measurement of the plate no. 1, whereas in case of the weld much lower hardness was observed in the joint made by the nickel based electrodes. It is caused by the high plastic properties of mentioned electrodes.

It is vital to point that according to the PN-EN ISO 15614- 1 standard hardness test is not done for the

U slučaju ploče br. 1, najmanja tvrdoća je na limu P355NL1, njegova vrednost je mnogo viša u dupleks čeliku i definitivno najviša u metalu šava (tabela 12, 13). Tvrdoća oba osnovna materijala na ploči br. 2 je veoma blizu merenju ploče br. 1, dok je u slučaju metala šava u spoju sa elektrodom na bazi nikla, zabeležena znatno niža tvrdoća. To je uzrokovano visokim plastičnim svojstvima pomenutih elektroda.

Važno je naglasiti da se prema standardu PN-EN ISO 15614- 1 standardno ispitivanje tvrdoće se ne



materials from the group 10 including duplex steel. In case of above sample plates an examination was taken only to do an experiment [15].

14. Examining a content of delta ferrite

Examining a content of delta ferrite was taken according to the PN-EN ISO 8249 standard by the Fischer MP 30E-S Feritscope (fig. 19) on the previously used for an examination a metallographic specimen. Measurements refer an area of the weld, the duplex steel, and the black steel [21].

In case of both sample plates a content of delta ferrite in the structural steel ranges from 96 to 100%. There was a considerable decrease of ferrite share (plate no. 1) in the duplex steel from the joint welded by the flux-cored wire in comparison to plate no. 2. The weld made by the duplex wire is characterized by the dual microstructure. A device cannot measure a content of delta ferrite in the nickel weld due to insufficient sensitivity of the feritscope. Thus, it can be stated that a share of delta ferrite does not exceed 0,1%.

radi na materijalima grupe 10, uključujući i dupleks čelik. U slučaju gore navedenih uzoraka, Ispitivanje je preduzeto samo radi eksperimenta [15].

14. Ispitivanje sadržaja delta ferita

Ispitivanje sadržaja delta ferita obavljeno je u skladu sa standardom PN-EN ISO 8249 uređajem Fischer MP 30E-S Feritscope (slika 19) na prethodno korišćenom metalografskom uzorku. Merenja obuhvataju površinu metsala šava, dupleks čelik i crni čelik [21].

U slučaju oba uzorka, sadržaj delta ferita u konstrukcijskom čeliku se kreće od 96 do 100%. Postojalo je značajno smanjenje feritnog udela (ploča broj 1) u dupleks čeliku iz spoja zavarenog punjenom žicom u odnosu na ploču br. 2. Šav dobijen žicom od dupleks čelika, karakteriše dvojna mikrostruktura. Uređaj ne može izmeriti sadržaj delta ferita u šavu od nikla zbog nedovoljne osjetljivosti feritskopa. Stoga se može konstatovati da udeo delta ferita ne prelazi 0,1%



Fig. 19. The Fisher MP 30E-S Feritscope
Sl. 19. Fisher MP 30E-S Feritscope

No.	Zone	1, %	2, %	3, %	4, %	5, %	Average %
1	Weld	43.0	39.0	48.0	50.0	40.0	44.00
2	X2CrNiMoN22-5-3	26.0	33.0	32.0	26.0	27.0	28.80
3	P355NL1	95.0	96.0	99.0	95.0	97.0	96.40

Table 14 Results of examining a content of delta ferrite – plate 1 – method 136

Tabela 14. Rezultati ispitivanja sadražaja delta ferita –lim 1- postupak 136

No.	Zone	1. %	2. %	3. %	4. %	5. %	Average %	
1	Weld	Out of range of the device (sensitivity 0.1%)						
2	X2CrNiMoN22-5-3	45.0	44.8	45.6	45.6	44.3	45.06	
3	P355NL1	98.9	100.0	99.2	98.3	97.7	98.80	

Table 15 Results of examining a content of delta ferrite – plate 2 – method 111

Tabela 15. Rezultati ispitivanja sadražaja delta ferita –lim2- postupak 111



15. Summary and conclusions

A part of examinations taken on the samples from the plate no. 1 (welded by the flux-cored wire) has finished negatively. Impact strength tests showed too low breaking operation, while examining a content of ferrite, and the macroscopic examinations revealed a lack of a required share of the α structure in the weld. It is a result of an appearance the brittle sigma phase connected with the carbon diffusion caused by the thermal treatment of the weld.

All the examinations taken on the plate no. 2 have finished positively. Despite a thermal treatment after welding there was not any increase of embrittlement. The weld metal based on nickel, and the foremost stabilizing elements, which are included in the content of electrodes, kept carbon diffusion, and therefore the joint obtained high plastic and resistance properties.

Welding different types of joints of the duplex steel with a low-alloyed steel does not make any troubles. Difficulties appear during a thermal treatment. A proper solution is a use of materials based on nickel, and particularly a precise choice of parameters, which do not allow to overheat the joint.

References

Literatura

- [1] J. Nowacki, *Stal dupleks i jej spawalność*, Warszawa 2009.
- [2] A. Lisiecki, *Welding of titanium alloy by Disk laser*. Proc. Of SPIE 8703, *Laser Technology 2012: Applications of Lasers*, 87030T (January 22, 2013), DOI : 10.1117/12.2013431.
- [3] T. Węgrzyn, J. Mirosławski, A. Silva, D. Pinto, M. Miros, *Oxide inclusions in steel welds of car body*, *Materials Science Forum* 636-637, 2010.
- [4] A. Lisiecki, *Diode laser welding of high yield steel*. Proc. Of SPIE 8703, *Laser Technology 2012: Applications of Lasers*, 87030S (January 22, 2013), DOI : 10.1117/12.2013429.
- [5] T. Węgrzyn, *Mathematical Equations of the Influence of Molybdenum and Nitrogen in Welds*. Conference of International Society of Offshore and Polar Engineers ISOPE'2002, Kita Kyushu, Japan 2002, Copyright by International Society of Offshore and Polar Engineers 4, ISBN 1-880653-58-3, Cupertino – California – USA 2002.
- [6] T. Węgrzyn, *The Classification of Metal Weld Deposits in Terms of the Amount of Oxygen*, Proceedings of the Conference of International Society of Offshore and Polar Engineers ISOPE'99, Brest, France 1999, International Society of

15. Rezime i zaključak

Deo ispitivanja na uzorcima sa ploče br. 1 (zavarena punjenom žicom) završena je negativno. Ispitivanja udarom su pokazale su suviše niske vrednosti energije, dok su ispitivanje sadržaja ferita i makroskopski pregledi pokazali nedostatak potrebnog udela α strukture u metalu šava. To je rezultat prisustva krte sigma faze koja je povezana sa difuzijom ugljenika izazvanom termičkom obradom zavarenog spoja.

Sva ispitivanja obavljena na ploči br. 2 su pozitivno završeni. Uprkos termičkoj obradi nakon zavarivanja, nije bilo povećanja krtosti. Metal šava na bazi nikla i najzastupljeniji elementi za stabilizaciju, koji su sadržani u elektrodi, održali su difuziju ugljenika, a samim tim i zavareni spoj dobija visoke osobine plastičnosti i otpornosti.

Zavarivanje različitih vrsta spojeva dupleks čelika sa nisko legiranim čelikom ne čini nikakve probleme. Teškoće se javljaju tokom termičke obrade. Pravilno rešenje je korišćenje materijala baziranih na niklu, a naročito precizan izbor parametara, koji ne dozvoljavaju pregrevanje zavarenog spoja.

Offshore and Polar Engineers 4, 212-216, Cupertino – California, USA 1999.

[7] T. Węgrzyn, J. Piwnik, D. Hadrys, *Oxygen in steel WMD after welding with micro-jet cooling*, *Archives of Metallurgy and Materials* 58, 4, 1067-1070 (2013).

[8] Ł. Konieczny, R. Burdzik, T. Figlus, *The possibility to control and adjust the suspensions of vehicles*, J. Mikulski (Ed.): *Activities of Transport Telematics*, pp. 378-383, TST 2013, CCIS 395.

[9] T. Węgrzyn, J. Piwnik, J. Łazarz, D. Hadrys, *Main micro-jet cooling gases for steel welding*, *Archives of Metallurgy and Materials* 58, 2, 556-559 (2013).

[10] R. Burdzik, *Identification of structure and directional distribution of vibration transferred to car-body from road roughness*, submitted to *Journal of Vibroengineering* 16(1), 324-333 (2014).

[11] K. Lukaszewicz, A. Kriz, J. Sendor, *Structure and adhesion of thin coatings deposited by PVD technology on the X6CrNiMoTi17-12-2 and X40CrMoV5-1 steel substrates*, *Archives of Materials Science and Engineering* 51 40-47 (2011).

[12] Metrode – katalog produktów.

[13] Böhler – katalog produktów.



- [14] Atesty blach.
- [15] PN-EN ISO 15614-1:2008 – Specyfikacja i kwalifikowanie technologii spawania metali – Badanie technologii spawania – Część 1: Spawanie łukowe i gazowe stali oraz spawanie łukowe niklu i stopów niklu.
- [16] PN-EN ISO 15609-1:2007 – Specyfikacja i kwalifikowanie technologii spawania metali – Instrukcja technologiczna spawania – Część 1: Spawanie łukowe.
- [17] PN-EN ISO 17633:2010 – Materiały dodatkowe do spawania – Druty elektrodowe proszkowe i pręty do spawania łukowego w osłonie gazu i bez osłony gazu elektrodą metalową stali nierdzewnych i żaroodpornych – Klasyfikacja.
- [18] PN-EN ISO 5173:2010 – Badania niszczące spoin w materiałach metalowych – Badanie na zginanie.
- [19] PN-EN ISO 9015-1:2011 – Badania niszczące złączy spawanych metali – Badanie twardości – Część 1: Badanie twardości złączy spawanych łukowo.
- [20] PN-EN 1321:2000 – Spawalnictwo – Badania niszczące metalowych złączy spawanych – Badania makroskopowe i mikroskopowe złączy spawanych
- [21] PN-EN ISO 8249:2005 – Spawanie – Określanie liczby ferrytu (FN) w stopiwie nierdzewnych chromowo-niklowych stali austenitycznych i ferrytyczno-austenitycznych dupleks.
- [22] PN-EN 13445-4:2009 – Nieogrzewane płomieniem zbiorniki ciśnieniowe – Część 4: Wytwarzanie.
- [23] PN-EN ISO 4136:2011 – Badania niszczące złączy spawanych metali – Próba rozciągania próbek poprzecznych.
- [24] PN-EN ISO 9016:2011 – Badania niszczące złączy spawanych metali – Badanie udarności – Usytuowanie próbek, kierunek karbu i badanie.
- [25] PN-EN ISO 148-1:2010 – Metale – Próba udarności sposobem Charpy’ego – Część 1: Metoda badania.
- [26] PN-EN 876:1999 – Spawalnictwo – Badania niszczące spawanych złączy metali – Próba rozciągania próbek wzdłużnych ze spoin złączy spawanych.
- [27] www.e-spawalnik.pl.



COMPARISON OF THE USE OF RUTILE AND CELLULOSIC ELECTRODES

TYPES OF ELECTRODES AND THEIR COMPOSITIONS

POREĐENJE UPOTREBE RUTILNIH I CELULOZNIH ELEKTRODA

TIPOVI ELEKTRODA I NJIHOV SASTAV

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Ključne reči: zavarivanje, elektroda, REL

Key words: welding, electrode, manual arc welding

Many types of manual metal arc (MMA) electrodes are available on the market. Depending on the main constituent of their flux, they are grouped into three categories: cellulosic, rutile and basic. All electrodes consist of a core wire (typically 2.5–6mm diameter) coated by a flux. The core wire is generally made of low-quality riming steel and the fluxes contain many elements allowing refinement of the weld microstructure.

The composition of the flux impacts the electrodes' behaviour. The main constituents of the different types of electrodes and the shielding gas created for each are described in Table 1 (Bowniszewski, 1979).

Mnogo vrsta elektroda za ručno elektrolučno zavarivanje (REL) je dostupno na tržištu. U zavisnosti od sastava glavnog sastojka njihovih obloga, oni su grupisani u tri kategorije: celulozne, rutilne i bazične. Sve elektrode se sastoje od jezgra - žice (obično 2.5-6mm prečnika) i presvučene su oblogom. Jezgro-žica se generalno pravi od nisko-kvalitetnog umirenog čelika i obloge sadrže mnoge elemente koji omogućavaju rafinaciju mikrostrukture metala šava.

Sastav obloge utiče na ponašanj elektroda. Glavni sastojci različitih tipova elektroda i stvoreni zaštitni gasovi za svaki od njih, su opisani u Tabeli 1 (Bovniszevski, 1979).

Electrode type Tip elektrode	Main constituent Glavni sastojak	Shielding gas created Stvoreni zaštitni gas
Rutile Rutilna	Titania (TiO ₂) Rutil (TiO ₂)	Mainly CO ₂ Uglavnom CO ₂
Basic Bazična	Calcium compounds Jedinjenja kalcijuma	Mainly CO ₂ Uglavnom CO ₂
Cellulosic Celulozna	Cellulose Celuloza	Hydrogen + CO ₂ Vodonik +CO ₂

Table 1 Main constituent of the three possible types of electrodes and shielding gas created by its combustion.

Tabela 1. Glavni sastojci tri moguća tipa elektroda i zaštitni gasovi nastali njihovim sagorevanjem

MMA electrodes' main characteristics have been extensively described (Bosward, 1980). The following paragraphs are a summary of general purpose electrode (rutile and cellulosic) characteristics of interest.

The rutile electrode

The difference between the E6012 and E6013 electrodes is that the E6012 covering contains sodium, while the covering of E6013 contains

Glavne karakteristike elektroda za REL je detaljno opisao (Bosvard, 1980). Sledeći paragrafi predstavljaju pregled karakteristika od interesa, elektroda opšte namene (rutilnih i celuloznih).

Rutilna elektroda

Razlika između elektroda E6012 i E6013 je da obloga kod E6012 sadrži natrijum, a obloga E6013 sadrži kalijum. One mogu da rade i sa



potassium. They can both run under direct current (DC+) but only the latter is suitable for running under alternative current (AC). Working with a constant current is recommended to counterbalance the unsteadiness of the welder's hand.

With a high proportion of titanium dioxide (also called titania) the rutile electrode gives a smooth bead surface, easily removal slag and a smooth arc. During the combustion, the flux coating will mainly create carbon dioxide.

This flux also contains cellulose. Even though the cellulose content is far lower than for a cellulosic electrode (up to 10% according to Boniszewski), its presence, along with that of moisture, means that these electrodes produce relatively high levels of hydrogen: up to 25ml/100gm weld metal. This restricts their use to mild steels with a thickness lower than 25mm and thin-section low-alloy steels of the C/Mo and 1Cr1/2Mo type.

Rutile electrodes can be used to weld in all positions apart from vertical down position. Deposition can be improved through the addition of iron powder, which leads to more metal being deposited at the same current. However, electrodes with added iron powder can only be used in a flat position.

Rutile electrodes have a medium penetration, quiet arc and create little spatter (Bosward, 1980). They create a large amount of self-releasing slag which requires little cleaning after welding.

They are probably the most widely used general purpose electrodes (TWI website). However, these electrodes should not be used on structures where high toughness is required (Bosward, 1980).

jednosmernom strujom (DC +), ali je samo ova druga pogodna za rad sa naizmeničnom strujom (AC). Rad sa konstantnom strujom se preporučuje kao protivteža nestabilnosti ruke zavarivača.

Sa visokim procentom titan dioksida (poznat i kao rutil) rutilna elektroda daje glatku površinu zavora, lako uklanjanje šljake i miran luk. Tokom sagorevanja, iz obloge će se uglavnom stvarati ugljen dioksid.

Ova obloga takođe sadrži i celulozu. Iako je sadržaj celuloze daleko niži nego kod celuloznih elektroda (do 10% prema Boniszewski), svojim prisustvom, zajedno sa onima iz vlage, znači da ove elektrode proizvode relativno visoke nivoe vodonika: do 25ml /100gm metala šava. Ovo ograničava njihovu upotrebu na ugljenične nelegirane čelike debljine manje od 25mm i tanke preseke nisko-legiranih čelika tipa C / Mo i 1Cr1/2Mo.

Rutilne elektrode mogu da se koriste za zavarivanje u svim položajima osim vertikalno naniže. Nanošenje se može poboljšati dodavanjem praha gvožđa, što dovodi do toga da se više metala nanosi pri istoj struji. Međutim, elektrode sa dodatkom gvožđa u prahu se mogu koristiti samo u vodoravnom (koritastom) položaju.

Rutilne elektrode imaju srednje prodiranje, miran luk i stvaraju malo prskanje (Bosward, 1980). One stvaraju veliku količinu samo-oslobađajuće troske koja zahteva malo čišćenje posle zavarivanja.

Oni su verovatno najčešće korišćeni elektrode za opštu namenu. Međutim, ove elektrode ne treba da se koriste na objektima u kojima se zahteva visoka žilavost (Bosward, 1980).

Impact value requirement (AWS as welded) Vrednost udarne žilavosti (AWS u zavarenom stanju)	Testing temperature Ispitna temperatura	Yield strength requirement Napon tečenja(MPa)	Typical tensile requirement Zatezna čvrstoća (MPa)
E6012			
Not specified Nije specificirano	0°C	330	430
E6013			
Not specified Nije specificirano	0°C	330	430

Table 2 Typical mechanical properties obtained with E6012 and E6013 AWS A5.1/A5.1M, 2012.

Tabela 2. Tipične mehaničke osobine koje se postižu elektrodama oznaka E6012 i E6013 po AWS A5.1/A5.1M, 2012.



The cellulosic electrode

Similarly to rutile electrodes, the differences between E6010 and E6011 cellulosic electrodes are the electrical parameters used during welding and their type of covering. The covering of E6010 contains sodium; E6011 contains potassium. They can both run under direct current (DC+) but only the latter is suitable for running under alternative current (AC). The MMA process can be used in DCEN, DCEP or AC but again a constant current is recommended to counterbalance the unsteadiness of the welder's hand.

The gas shield generated by cellulosic combustion contains hydrogen, carbon monoxide and carbon dioxide. Between 30 and 45ml hydrogen/100gm can be found in the weld (TWI website). This has two consequences: good protection of the weld pool and a high level of diffusible hydrogen in the weld metal and heat-affected zone (HAZ). The high percentage of hydrogen is the cause of the high deposition rate and deeper penetration by the creation of the punchy arc (Clyne, 1984) for which this kind of electrode is well known.

Another consequence of the hydrogen content of the gas shield is the requirement for a higher voltage (around 70V).

However, the high hydrogen content in the shielding gas is also this electrode's main drawback. It causes a high level of diffusible hydrogen in the weld, which is one of the parameters influencing hydrogen cracking (also called cold cracking) if good practices are not followed and preventive actions are not taken.

The high hydrogen level means that any steel welded with these electrodes should have a very high resistance to hydrogen-induced cold cracking. These electrodes are mainly used on low-carbon, non-alloyed steel. They should be used only with due consideration of the steel composition, restraint and need for preheat.

One other advantage of cellulosic electrodes is their ability to weld in the stove piping (or vertical down) position. E6010 electrodes are sometimes called 'stove pipe electrodes'. This position can enhance the weld and helps to improve efficiency and productivity, thanks to quick cooling of the slag. This method of welding should be performed by an experienced welder who can put down welds in quick succession, to maintain a hot welding condition and enable hydrogen to escape. On thick-wall pipe, the welder can experience difficulty controlling the weld pool because of its increase in size and the risk for it to over-run the arc and flood the joint (Spiller, 1991). It should be noted that any

Celulozne elektrode

Slično rutilnim elektrodama, razlike između E6010 i E6011 celuloznih elektroda su električni parametri za zavarivanje i njihov tip oblaganja. Obloga kod E6010 sadrži natrijum; kod E6011 sadrži kalijum. One mogu da rade sa jednosmernom strujom (DC+), ali samo ova druga je pogodna za rad sa naizmeničnom strujom (AC). Postupak REL može da koristi u DCEN, DCEP ili AC, ali se opet preporučuje konstantna struja kao protivteža nestabilnosti ruke zavarivača.

Zaštitni gas nastao sagorevanjem celuloznih komponenti sadrži vodonik, ugljen monoksid i ugljen dioksid. Između 30 i 45 ml vodonika / 100gm može se naći u šava. Ovo ima dve posledice: dobru zaštitu zavarivačke kupke i visok nivo difundovanog vodonika u metalu šava i uticaja toplote zonu (ZUT). Visok procenat vodonika je uzrok visoke stope deponovanja i dubljeg prodiranja, stvaranjem robusnog luka (Cline, 1984) za koji je ova vrsta elektrode, dobro poznata.

Druga posledica sadržaja vodonika u zaštitnom gasu je zahtev da se koristi viši napon (oko 70V).

Međutim, visok sadržaj vodonik u zaštitnom gasu je takođe glavni nedostatak ove elektrode. On izaziva visok nivo difundovanog vodonika u metalu šava, koji je jedan od parametara za nastanak vodonikom izazvanih prslina (koje se još nazivaju hladne prsline) ako se ne primenjuje dobra praksa i ne preduzmu preventivne mere.

Visok nivo vodonika znači da svaki zavareni spoj sa ovim elektrodama treba da ima vrlo visoku otpornost na vodonikom indukovane hladne prsline. Ove elektrode se uglavnom koriste na nisko-ugljeničnim, nelegiranim čelicima. Njih treba koristiti samo uz uvažavanje sastava čelika, ukrućenja i potrebe za predgrevanjem.

Druga prednost celuloznih elektroda je njihova sposobnost zavarivanja cevovoda (ili u položaju vertikalno na dole). E6010 elektrode se ponekad nazivaju "elektrode za gasovode". Ovaj položaj može unaprediti šav i pomaže da se poboljša efikasnost i produktivnost, zahvaljujući brzom hlađenju troske.

Ovaj način zavarivanja treba da primenjuju iskusni zavarivači koji mogu da izvedu šavove u brzom nizu, da zavareni spoj ostane u uslovima toplog stanja i omogući vodoniku da izađe. Na debljim zidovima cevi, zavarivač može imati poteškoća pri kontroli zavrivačke kupke zbog povećanja njene veličine i rizika da prebrzo vode luk i „poplave“ spoj (Spiller, 1991). Treba napomenuti da bilo koja vrsta celulozne elektrode zahteva visoko stručne zavarivače, tako da se pri zavrivanju cevovoda



type of cellulosic electrode requires a highly skilled welder, so stove pipe welding especially should not be carried out without care and proof of competence of the welder.

The amount of spatter created will limit the use of very high current (Bosward, 1980). A large amount of fume is also produced by cellulosic electrodes (Welding and Cutting, 2013) but the amount of slag to remove after each weld is small.

The mechanical properties of the cellulosic electrodes are presented in Table 3. Impact values are available up to -30°C in the as-welded condition.

Required impact value (AWS as welded) Zahtevana energija udara (AWS u zavarenom stanju)	Testing temperature Ispitna temperatura	Typical yield strength Tipični napon tečenja (MPa)	Typical tensile strength Zatezna čvrstoća (MPa)
E6010			
27J	-30°C	330	430
E6011			
27J	-30°C	330	430

Table 3 Typical mechanical properties obtained with E6010 and E6011, AWS A5.1/A5.1M, 2012.

Table 3 Tipične mehaničke osobine koje se postižu elektrodama E6010 i E6011, po AWS A5.1/A5.1M, 2012.

Its characteristics of deep penetration, high deposition rates and ability to be used in vertical down position means that the main use for these electrodes is for cross-country pipelining, although they are used to a more limited extent for welding storage tanks.

In a more industrial environment the use of this type of electrode is usually restricted to the root pass of the welding procedure. After root pass, a hot pass should be deposited within the next ten minutes to limit the cooling of the welding pass and allow hydrogen to escape. This limitation should be specified in the welding procedure specification.

Again, these electrodes require a skilled welder. This is particularly relevant when working with a pipe of outside diameter below eight inches, because the vertical down welding position can be difficult.

Conclusion of the comparison

In accordance with European standard (EN 1011-2:2004) the necessary preheat temperature and duration can be determined depending on the steel's carbon equivalent and the amount of diffusible hydrogen created by the electrode. This determines where electrodes are classified on a five-point scale, from A to E.

Category A corresponds to electrodes creating an amount of diffusible hydrogen greater than 15ml/100g of deposited metal. Category E relates

posebno treba voditi računa o zavarivačevoj umešnosti i dokazima o njihovoj kompetentnosti.

Količina prskanja koja se stvara ograničava korišćenje vrlo visokih struja (Bosvard, 1980). Velika količina dima takođe se stvara celuloznim elektrodama (zavarivanje i sečenje, 2013. godine) ali količine troske koje treba ukloniti su male.

Mehaničke osobine celuloznih elektroda su prikazane u Tabeli 3. Vrednosti udarne žilavosti su dostupne do -30°C u zavarenom stanju.

Njihove karakteristike dubokog prodiranja, visoke stope deponovanja i sposobnost da se koriste u položaju vertikalno na dole znače da je glavna primena ovih elektroda za cevovode kroz nenaseljena mesta, iako se koriste u manjoj meri za zavarivanje skladišnih rezervoara.

U većini industrijskog okruženja, korišćenje ove vrste elektrode je obično ograničeno na koreni prolaz. Nakon korenog prolaza, vrući prolaz treba obaviti u narednih deset minuta da bi se ograničilo hlađenje zavara i dozvolio izlazak vodonika. Ovo ograničenje treba navesti u specifikaciji tehnologije zavarivanja.

Opet, ove elektrode zahtevaju veštog zavarivača. Ovo je posebno važno kada se radi na cevima spoljašnjeg prečnika ispod osam inča, jer zavarivanje u položaju vertikalno na dole može biti teško.

Zaključak poređenja

U skladu sa evropskim standardom (EN 1011-2:2004) neophodna temperatura predgrevanja i trajanje mogu se odrediti u zavisnosti od ekvivalenta ugljenika čelika i količine difundovanog vodonika stvorenog elektrodom. Ovo određuje da se elektroda klasifikuje na pet tačaka skale, od A do E.

Kategorija A odgovara stvaranju količine difundovanog vodonika većem od 15ml/100g deponovanog metala. Kategorija E se odnosi na



to electrodes creating an amount of diffusible hydrogen lower than 3ml/100g of deposited metal. Both types of electrode belong to category A for preheat determination.

According to Boniszewski (1979), despite the reasonable quality and toughness of the weld obtained with cellulosic electrodes (100J Charpy-V obtained at -10°C), because of the high preheat temperature required, they are usually avoided for high technology fabrication such as offshore structures or pressure vessels.

Cellulosic electrodes are more difficult to use and consequently require a skilled welder. Their big advantage is the increased speed they enable through the stove pipe technique or vertical down welding – but not weld quality. They are suitable in cases such as when large quantities of pipe must be welded or a lot of vertical down welding is required, not for one-off jobs. The speed of travel can be as high as 300mm/min.

In any case, the use of cellulosic electrodes is generally limited to the root run of a multi-pass procedure. The use of a hot pass is vital in the case of cellulosic electrodes.

The following table summarises the comparison and the previous conclusions.

elektrode koje stvaranju količine difundovanog vodonika manje od 3ml / 100g deponovanog metala. Obe vrste elektroda pripadaju kategoriji A za određivanje predgrevanja.

Prema Boniszewskom (1979), bez obzira na odgovarajući kvalitet i žilavost metala šava dobijen primenom celuloznih elektroda (100J Šarpi-V dobijenih na -10°C), zbog potrebne visoke temperature predgrevanja, njih obično treba izbegavati kod zahteva visoke tehnologije izrade kao „offshore“ konstrukcije ili posuda pod pritiskom. Celulozne elektrode je teže koristiti i stoga zahtevaju kvalifikovane zavarivače. Njihova velika prednost je povećana brzina omogućena kroz tehniku zavarivanja vertikalno naniže - ali ne kvalitet šava. One su pogodne u slučajevima kada se velike količine cevi moraju zavariti ili je potrebno mnogo zavarivanja vertikalno na dole, ali ne jednokratnih poslove. Brzina zavarivanja može biti visoka oko 300mm / min.

U svakom slučaju, upotreba celuloznih elektroda je uglavnom ograničena na koreni prolaz kod višeslojnog zavarivanja. Upotreba toplog prolaza je vitalna u slučaju celuloznih elektroda.

Sledeća tabela sumira poređenje i prethodne zaključke.

Characteristic Karakteristika	Rutile electrode Rutilna elektroda	Cellulosic electrode Celulozna elektroda
Current (A) Jačina struje (A)	Lower Manja	Higher Veća
Voltage (V) Napon (V)	Lower Manja	Higher Veća
Penetration Uvarivanje (prodiranje)	Lower Manja	Higher Veća
Amount of spatter Udeo prskanja	Lower Manja	Higher Veća
Slag removal Uklanjanje troske	Self-releasing Samouklanjajuća	Need brushing Potrebno čišćenje
Cleaning Čišćenje	Very little required Zahtevano vrlo malo	Always needed Uvek potrebno
Position Položaj	All except vertical down Svi izuzev vertikalno na dole	All including stove pipe/vertical down Svi uključujući vertikalno na dole
Ease of use Lakoća korišćenja	Easy Lako	Require skilled welder Zahteva obučenog zavarivača
Fume creation Stvaranje dima	Lower amount of fume Manji udeo dima	Greater amount of fume Veći udeo dima
Hydrogen cracking risk Rizik od vodoničnih prslina	Low risk if correct pre-heat Mali rizik ako je korektno predgrevanja	High risk Veliki rizik



Single or multipass weld Jednoslojni ili višeslojni šav	Single and multipass Jednoslojni i višeslojni	Multipass višeslojni
Preheat precautions Predgrevanje	Require preheat in accordance with BS EN ISO 1011-2:2004 Zahteva se predgrevanje u saglasnosti sa BS EN ISO 1011-2:2004	Require preheat in accordance with BS EN ISO 1011-2:2004 Zahteva se predgrevanje u saglasnosti sa BS EN ISO 1011-2:2004
Post weld heat treatment Termička obrada posle zavarivanja	Hydrogen bake out can be used to help diffusible hydrogen removal Sušenje elektroda se može koristiti za uklanjanje vodonika	

Table 4 Comparison of electrode characteristics
Tabela 4. Upoređenje karakteristika elektroda

Guidance and best practice to avoid hydrogen cracking in the case of cellulosic electrode use

Hydrogen cracking occurs at near ambient temperature if three conditions are met: diffusible hydrogen in the weld, tensile stresses and susceptible microstructure (Kihara, 1970).

Tensile stresses cannot be avoided but they can be reduced with a sensible design. The microstructure can be controlled to some extent by selecting material less sensitive to hydrogen cracking (with a low carbon equivalent [EN 1011-2: 2004]). Finally, the reduction of the diffusible hydrogen content in the weld can be managed by selecting a consumable with low hydrogen content (which is not the case with cellulosic electrode) or by improving the hydrogen release of the weldment.

The hydrogen content in the weld metal depends on the cooling rate from welding temperature (Folkhard et al, 1973). As a comparison, samples extracted after welding with cellulosic electrodes and cooled in still air have lower diffusible hydrogen content than samples quenched in iced water. The cooling rate can be decreased by an increase of preheat and interpass temperature.

When the thickness increases the degassing time (and the welding time) for the weld increases, and so the amount of degassing hydrogen increases. Also, the additional heat of the next run leads to degassing of the previously deposited bead and to a more refined microstructure. However, residual stresses will increase.

The cooling conditions of the root run are critical to the hydrogen content in the weld. Refining or reheating the second pass helps to release diffusible hydrogen.

Additional guidance and best practice in the use of cellulosic electrodes

First of all, only welders with recent qualifications specifically relating to the use of cellulosic

Uputstvo i najbolja praksa za izbegavanje vodoničnih prslina u slučaju celulozних elektroda

Vodonične prsline se javljaju na temperaturi, bliskoj sobnoj ako se ispune tri uslova: difundovani vodonik u šavu, zatezni naponi i podložna mikrostruktura (KIHARA, 1970).

Zatezni naponi se ne mogu izbeći, ali mogu da se smanje pogodnim dizajnom. Mikrostruktura se može kontrolisati donekle izborom materijala koji je manje osetljiv na vodonikom izazvane prsline (sa niskim ekvivalentom ugljenika [EN 1011-2: 2004]). Konačno, smanjenjem difundovanog vodonika u šavu može se upravljati izborom potrošnog materijala sa niskim sadržajem vodonika (što nije slučaj sa celuloznom elektrodom) ili poboljšanjem oslobađanja vodonika u zavarenim spojevima.

Sadržaj vodonika u metalu šava zavisi od brzine hlađenja od temperature zavarivanja (Folkhard et al, 1973). Kao poređenje, uzorci posle zavarivanja celuloznim elektrodama i ohlađen na vazduhu imaju niži difundovani vodonik nego uzorci gašeni u ledenoj vodi. Brzina hlađenja može se smanjiti povećanjem predgrevanja i međuslojne temperature. Kada se debljina povećava, vreme degazacije (i vreme zavarivanja) za šav, raste i tako udeo degazacije povećava vodonik. Takođe, dodatna toplota narednog prolaza dovodi do degazacije prethodno deponovanog zavara i do rafiniranije mikrostrukture. Međutim, zaostali naponi će se povećati.

Uslovi hlađenja korenog prolaza su kritični za sadržaj vodonika u šavu. Rafinacija ili ponovno zagrevanje drugog prolaza pomaže da se oslobodi difundovani vodonik.

Dodatno uputstvo i najbolja praksa za korišćenje celulozних elektroda

Pre svega, samo zavarivačima sa važećim kvalifikacijama posebno u vezi sa upotrebom celulozних elektroda treba dozvoliti da sprovede bilo



electrodes should be allowed to carry out any welding activity with them.

A preheat identical to the one required for rutile electrodes should be applied before welding to reduce the cooling rate of the weld and allow for hydrogen release.

The use of cellulosic electrodes should be limited to the root run and always followed by a hot pass with another electrode to allow the removal of most of the diffusible hydrogen and refinement of the weld macrostructure. Additionally, single-pass fillet welds should be avoided as this is likely to increase the sensitivity to hydrogen cracking. This is because the HAZ hardness, and the amount of diffusible hydrogen, is likely to be higher without subsequent reheating from successive passes.

Cellulosic electrodes should not be dried as they rely on hydrogen in the atmosphere to shield the weld pool. They should be used directly from the manufacturer's packaging. In case the electrode is damp it can be dried in an oven at 120°C. If electrodes become soaked they need to be discarded and thrown away. Guidance on consumable storage can be found in AWS A5.1/A5.1M.

kakvu aktivnost zavarivanja sa njima.

Predgrevanje identično onom koje je potrebno za rutilne elektrode, treba primeniti pre zavarivanja za smanjenje brzine hlađenja šava i oslobađanje vodonika.

Upotrebu celuloznih elektroda treba ograničiti na koreni zavar uvek praćen toplim prolazom drugom elektrodom da bi se uklonila većina difundovanog vodonika i prečistila makrostruktura šava. Dodatno, jednoslojne ugaone šavove treba izbegavati jer će ovo verovatno povećati osetljivost na vodonične prsline. To je zato što tvrdoća ZUT, i količina difundovanog vodonika, bivaju veći bez naknadnog ponovnog zagrevanja od naknadnih slojeva.

Celulozne elektrode ne treba sušiti jer se oslanjaju na vodonik iz atmosfere da bi se zaštitila zavarivačka kupka. Njih treba koristiti direktno iz pakovanja proizvođača. U slučaju da je elektroda vlažna, može se sušiti u sušnici na 120°C. Ako elektrode postanu natopljene, moraju da budu odbačene i bačene. Vodič za pripremu skladištenja potrošnog materijala mogu se naći u AWS A5.1 / A5.1M.

Table A.3
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classification		Storage Conditions ^{a,b}		
A5.1	A5.1M	Ambient Air	Holding Ovens	Drying Conditions ^c
E6010, E6011	E4310, E4311	Ambient Temperature	Not recommended	Not recommended
E6012, E6013, E6019, E6020, E6022, E6027, E7014, E7024, E7027	E4312, E4313, E4319, E4320, E4322, E4327, E4914, E4924, E4927	80°F ± 20°F [30°C ± 10°C] 50% max. relative humidity	20°F to 40°F [10°C to 20°C] above ambient temperature	275°F ± 25°F [135°C ± 15°C] 1 hour at temperature
E6018, E7015, E7016, E7018, E7028, E7018M, E7048	E4318, E4915, E4916, E4918, E4928, E4918M, E4948	Not recommended	50°F to 250°F [30°C to 140°C] above ambient temperature	500°F to 800°F [260°C to 425°C] 1 to 2 hours at temperature

^a After removal from manufacturer's packaging.

^b Some of these electrode classifications may be designated as meeting low moisture absorbing requirements. This designation does not imply that storage in ambient air is recommended.

^c Because of inherent differences in covering composition, the manufacturers should be consulted for the exact drying conditions.

In case of high hydrogen cracking risk it is possible to post-heat (also called hydrogen baking) the weld by either maintaining the minimum interpass temperature or raising the temperature to 200–300°C immediately after welding, before the weld region cools to below the minimum interpass temperature (EN 1011-2: 2004).

Conclusion

Only welders with recent qualification to use specifically cellulosic electrodes should be allowed to carry out any welding activity with them.

Use of cellulosic electrode should be restricted to the root run, before the weld is filled using rutile

U slučaju visokog rizika od vodoničnih prsline moguće je naknadnim dogrevanjem (takođe nazvano „uklanjanje vodonika“) šava bilo održavanjem minimalne međuslojne temperature ili podizanje temperature do 200-300°C odmah posle zavarivanja, pre nego što se oblast šava ohladi na ispod minimalne međuslojne temperature (EN 1011-2: 2004).

Zaključak

Samo zavarivačima sa važećim kvalifikacijama za korišćenje celuloznih elektroda treba dozvoliti da sprovedu bilo kakvu aktivnost zavarivanja sa njima.

Korišćenje celulozne elektrode treba ograničiti na korene prolaze, pre ipune sa rutilnom elektrodom.



electrodes. The hot pass should be deposited a maximum of ten minutes after completion of the root pass.

Preheat should be selected in accordance with BSI BS EN 1011-2, taking into account material grade and restraint of the weld.

Vrući prolaz se sme odložiti najviše deset minuta nakon završetka korenog prolaza.

Predgrevanje treba da bude izabrano u skladu sa BSI BS EN 1011-2, uzimajući u obzir klasu materijala i krutost zavarenog spoja.

References

Reference

1. ASME B31.3 A106 grade B.
2. AWS A5.1/A5.1M, 2012: 'Specification for carbon steel electrodes for shielded metal arc welding'.
3. Boniszewski T, 1979: 'Manual metal arc welding – old process, new developments, Part II: Understanding MMA electrodes, metallurgist and materials technologist.' Vol. 11. No. 11.
4. Bosward I, 1980: 'A guide to electrode selection, welder.' Vol. 41, No. 210, pp10-13.
5. BSI BS EN 1011-2: 'Welding — Recommendations for welding of metallic materials — Part 2: Arc welding of ferritic steels.' 2004
6. Clyne A J, 1984: 'Evaluation of low hydrogen electrodes for pipeline girth welding.' British Gas R&D.
7. Folkhard, H, Schabereiter H, Rabendteiner G, Rettenbacher H, 1973: 'New knowledge on the hydrogen content of welded joints as a basis for the crack free welding of high-tensile pipeline steel with cellulosic electrodes.' International welding conference, pp39/44.
8. Kihara H, Terai K, Yamada S., Nagano, T, 1970: 'Study on preheating temperature in welds of high strength steel structure.' Trans Jap. Welding Society, 1, pp119/129.
9. Welding and cutting: 'Selection of stick electrodes (part 1) welding and cutting.' Vol. 123, No. 4, 2013.
10. Spiller K R, 1991: 'Process options and manual techniques for welding pipework fabrications, Process pipe and tube welding.' Ed: W Lucas. Publ: Abington, Cambridge, CB1 6AH, UK, Abington publishing; ISBN 1-85573-012-X. Chapter 1, pp1-20.
11. TWI webpage: <http://www.twi-global.com/technical-knowledge/job-knowledge/welding-consumables-part-1-082/>



STRUCTURAL STEEL, CE MARKING AND ISO 3834 KONSTRUKCIONI ČELICI, CE OZNAČAVANJE I ISO 3834

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Ključne reči: Standard, zavarivanje, zahtevi kvaliteta

Abstract: Standard, welding, quality requirements

ISO 3834, Quality Requirements for Fusion Welding of Metallic Materials, is a specification that was first published as an EN specification, EN 729, almost 20 years ago, becoming an ISO specification in 2005. It spells out in Parts 2, 3 and 4 what is regarded as best practice with regard to the control of welding and its associated activities. Not being a mandatory specification it has, to a large extent, been ignored by welding fabricators who have adopted the attitude that they will implement the requirements when they have to. That point has now been reached for many companies with the publication of the Construction Products Regulations (CPR) and a number of related specifications that reference ISO 3834 and will therefore directly affect the structural steel industry.

The CPR is the UK version of the European Construction Products Directive and requires structural steel work that is placed on the market to be CE marked. CE marking may be applied to the steel work provided that the manufacturer can demonstrate that the components comply with the relevant harmonised standards – a harmonised standard being a standard that is regarded by the European Commission as satisfying the Essential Safety Requirements set out in the Directive. The CE marking of construction products becomes mandatory in the summer of 2014 at which time fabricators must be able to demonstrate compliance with BS EN 1090, Execution of Steel Structures and Aluminium Structures, the harmonised standard for construction products.

The CPR requires that the manufacturer implements a factory production control (FPC) system to ensure that products comply with the design and service criteria by means of written procedures and inspections and tests. BS EN 1090

ISO 3834, Zahtevi kvaliteta za zavarivanje topljenjem metalnih materijala, je specifikacija koja je prvi put objavljena kao EN specifikacija, EN 729, pre skoro 20 godina. ISO specifikacija je nastala 2005. godine. U delovima 2, 3 i 4, navodi se ono što se smatra najboljom praksom u vezi sa kontrolom zavarivanja i pratećim aktivnostima. S obzirom da specifikacija nema obavezujući karakter, u velikoj meri, biva ignorisana od strane proizvođača zavarivanjem koji su usvojili stav da će implementirati zahteve kada to moraju. Ta tačka je sada postala interesantna za mnoge kompanije objavljivanjem propisa za konstrukcije (CPR) i niza povezanih specifikacija vezanih za ISO 3834 i stoga će direktno uticati na industriju čeličnih konstrukcija.

CPR je u Velikoj Britaniji verzija Evropske Direktive o građevinskim proizvodima i zahteva da čelične konstrukcije koje se stavljaju na evropsko tržište budu sa CE znakom. CE znak može da se primeni na čelične konstrukcije pod uslovom da proizvođač dokaže da su komponente u skladu sa relevantnim harmonizovanim standardima-usaglašeni standard je standard koji Evropska komisija smatra zadovoljavajućim za osnovne sigurnosne zahteve navedene u Direktivi. CE označavanje građevinskih proizvoda postaje obavezno u leto 2014. godine u kada proizvođači moraju biti u stanju da dokažu poštovanje BS EN 1090, Izrada čeličnih i aluminijumskih konstrukcija, harmonizovani standardi za građevinske proizvode.

CPR zahteva da proizvođač primenjuje sistem fabričke kontrole proizvodnje (FCC) kako bi se osiguralo da su proizvodi u skladu sa kriterijumima projektovanja i korišćenja, putem pisanih procedura i inspekcija i ispitivanja. BS EN 1090



Part 1, clause 6.3, which states that an FPC system conforming to EN ISO 9001 and made specific to the requirements of BS EN 1090 is regarded as acceptable. Welding, however, is identified in ISO 9001 as a "special process" and therefore additional controls are required to ensure that welding and its related activities are competently managed – compliance with the relevant part of ISO 3834 satisfies this requirement and is therefore specified in BS EN 1090. The CPR also requires that the FPC system is accredited by a notified body (NB), an NB being an independent third party approved by the government—in the UK via the UK Accreditation Service (UKAS).

BS EN 1090 Part 2 – Steels – divides construction products into four Execution Classes (EXC). EXC1 includes unwelded items, welded items not subject to dynamic loading and items in steels with a specified minimum yield strength below 355MPa. EXC2, 3 and 4 are for increasingly onerous service conditions and for all steels of S355 grade and above. Manufacturers working to EXC1 are required to comply with ISO 3834 Part 4 Elementary Quality Requirements, to EXC2 with ISO 3834 Part 3, Standard Quality Requirements and to EXC classes 3 and 4 with ISO 3834 Part 2 Comprehensive Quality Requirements. Because of the requirement with respect to S355 steels it is likely that most fabricators will need to comply with ISO 3834 Part 3 as a minimum. In addition to the parts mentioned above ISO 3834 has a further three parts, these being part 1, Criteria for the selection of the appropriate level of quality requirements; part 5, Documents with which it is necessary to conform to claim conformity and part 6 Guidelines on implementing ISO 3834. Table 1 below summarises the requirements contained in parts 2, 3 and 4.

deo 1, tačka 6.3, navodi da se FPC sistem u skladu sa EN ISO 9001 i izveden prema zahtevima standarda BS EN 1090, smatra prihvatljivim. Zavarivanje je, međutim, identifikovano u ISO 9001, kao "specijalni proces" i stoga se zahtevaju dodatne kontrole kako bi se osiguralo da se zavarivanje i srodne aktivnosti stručno vode - usaglašenost sa relevantnim delom ISO 3834 zadovoljava ovaj uslov i stoga je navedeno u BS EN1090. CPR takođe zahteva da se FPC sistem akredituje od strane IMENOVANOG tela (NB), NB je nezavisna treća stranakuju je odobrila vlada-u Velikoj Britaniji preko akreditacionog tela Velike Britanije (UKAS).

BS EN 1090 deo 2 - Čelici - deli građevinske proizvode u četiri izvršne klase (EXC). EXC1 obuhvata nezavarene, zavarene koji nisu izloženi dinamičkom opterećenju i proizvode od čelika sa specificiranim minimalnim naponom tečenja ispod 355MPa. EXC2, 3 i 4 su za sve otežane uslove rada i za sve čelike od kvaliteta S355 pa navise. Od proizvođača koji rade na EXC1 se traži da u skladu sa ISO 3834 deo 4 ispune osnovne zahteve kvaliteta; za EXC2 da prema ISO 3834 deo 3, ispune standardne zahteve kvaliteta i da EXC klase 3 i 4 ispune prema ISO 3834 deo 2- sveobuhvatne (opšte) zahteve kvaliteta. Zbog zahteva u vezi sa čelikom S355, vrlo je verovatno da će većina proizvođača morati da ispuni kao minimum u skladu sa ISO 3834 deo 3. Pored navedenih delova, ISO 3834 ima još tri dela, a to su deo 1, kriterijumi za izbor odgovarajućeg nivoa zahteva kvaliteta; deo 5, Dokumenti koji su neophodni za ispunjenje zahteva podobnosti i deo 6- Smernice za primenu ISO 3834. Tabela 1 ispod sumira zahteve sadržane u delovima 2, 3 i 4.

Requirement	Comprehensive Quality Requirements Part 2	Standard Quality Requirements Part 3	Elementary Quality Requirements Part 4
Contract review	Full documented review	Less extensive review	Establish that capability and information is available
Design review	Design for welding to be confirmed	Design for welding to be confirmed	As above
Sub-contractor	Treat like a main fabricator		Must comply to standard
Welders/Operators	Qualified to EN 287/1 or ISO 14732		
Welding co-ordination	Welding co-ordination personnel with appropriate technical knowledge according to ISO 14731, or persons with similar knowledge		Not demanded but responsibility of manufacturer
Inspection personnel	Sufficient and competent qualified personnel to be available		



Production equipment	Required to prepare, cut, weld, transport, lift, together with safety equipment and PPE		No demands
Equipment maintenance	Has to be carried out. Maintenance plan necessary	No specific demands - must be adequate	No demands
Production plan	Necessary	More restricted plan necessary	No demands
Welding Procedure Specifications (WPS)	Instructions to be available to Welder. See ISO 15609/1		No demands
Weld Procedure Qualification	To appropriate part of ISO 15614 - qualified as application standard or contract demands		No demands
Work instructions	Welding Specification or dedicated instructions to be available (WPS) – see ISO 15609/1		No demands
Batch testing of consumables	Only if specified in contract	Not specified	No demands
Storage and handling of welding consumables	As per supplier recommendations as minimum		
Storage of parent materials	Protection required from influence by the environment, identification shall be maintained		No demands
Post Weld Heat Treatment	Specification and complete record	Confirmation to Specification necessary	No demands
Inspection before - during - after welding	As required by specification and/or contract		As specified in contract
Non-conformances	Procedures must be available		
Calibration	Procedures must be in operation	Not specified	Not specified
Identification	Required when appropriate	Required when appropriate	Not specified
Traceability	Required when appropriate	Required when appropriate	Not specified
Quality records	As required by contract and product liability, retained for 5 years minimum		

Zahtev	Sveobuhvatni (Opšti) zahtevi kvaliteta deo 2	Standardni zahtevi kvaliteta deo 3	Elementarni zahtevi kvaliteta deo 4
Preispitivanje ugovora	Potpuno dokumentovano preispitivanje	Manje obimno preispitivanje	Utvrđivanje raspoloživih mogućnosti i informacija
Preispitivanje konstrukcionog rešenja	Projekat za zavarivanje se mora potvrditi	Projekat za zavarivanje se mora potvrditi	Kao gore
Podugovaranje	Smatrati za glavnog proizvođača		Mora se pridržavati standarda
Zavarivači/ Operateri	Kvalifikovani prema EN ISO 9606 ili 14732		
Koordinacija u zavarivanju	Osoblje za koordinaciju sa odgovarajućim tehničkim znanjem prema ISO EN 14731, ili osobe sa sličnim znanjem		Ne traži se, ali je odgovoran proizvođač
Osoblje za kontrolisanje	Na raspolaganju dovoljno kompetentnog kvalifikovanog osoblja		
Oprema za proizvodnju	Zahtevana za pripremu, sečenje, zavarivanje, transport, podizanje zajedno sa zaštitnom opremom i lična zaštitna sredstva		Ne zahteva se



Održavanje opreme	Treba da se sprovodi. Potreban je plan održavanja	Nema specifičnog zahteva- mora biti adekvatno	Ne zahteva se
Plan proizvodnje	Potreban	Potreban je manje oštar	Ne zahteva se
Specifikacija tehnologije zavarivanja	Uputstva moraju biti naraspologanju zavarivaču. Videti ISO EN 15609/1		Ne zahteva se
Kvalifikacija tehnologije zavarivanja	Prema odgovarajućem delu ISO EN 15614- kvalifikuje se prema standardu primene ili zahtevima ugovora		Ne zahteva se
Radna uputstva	Specifikacija tehnologije zavarivanja ili pripadajuća uputstva na raspolaganju (WPS)- videti ISO EN 15609/1		Ne zahteva se
Ispitivanje šarže potrošnog materijala za zavarivanje	Samo ako je specificirano ugovorom	Nije specificirano	Ne zahteva se
Skaldisštenje i rukovanje potrošnim materijalom za zavarivanje	Minimum prema specifikaciji proizvođača		
Skladištenje osnovnog materijala	Zahtevana zaštita od uticaja okuženja, identifikacija se mora održavati		Ne zahteva se
Termička obrada posle zavarivanja	Specifikacija i kompletan zapis	Potrebno je potvrđivanje specifikacije	Ne zahteva se
Kontrolisanje pre –tokom- posle zavarivanja	Kako se zahteva po specifikaciji i/ili ugovoru		Kako je specificirano u ugovoru
Neusaglašenosti	Mora da postoji procedura		
Kalibracija	Nije specificirano		Nije specificirano
Identifikacija	Zahteva se kada je svrsishodno	Zahteva se kada je svrsishodno	Nije specificirano
Sledljivost	Zahteva se kada je svrsishodno	Zahteva se kada je svrsishodno	Nije specificirano
Zapisi o kvalitetu	Kako se zahteva ugovorom ili odgovornošću proizvoda, čuva se minimum 5 godina		

Table 1 summarises the requirements contained in parts 2, 3 and 4.

Tabela 1. Sumarni prikaz zahteva sadržanih u delovima 2, 3 i 4.

Most of the work involved in achieving compliance is in the production and implementation of written procedures and the qualification of welding procedures. Whilst there is no mandatory requirement either in the CPR or EN 1090 for the fabricator to have independent accreditation to ISO 3834 it is inevitable that self-certification will not be acceptable and that purchasers will demand third party accreditation.

Although the implementation of a competent FPC system, whilst being time-consuming, is relatively straightforward there is one area that fabricators may have difficulty complying with. EN 1090 Part2 clause 7.4.3 requires welding co-ordination personnel as specified in ISO 14713, Welding Co-ordination – Tasks and Responsibilities, to be appointed when welding EXC2, EXC3 and EXC4 components. Any individual involved in any way with welding activities is regarded as a welding co-ordinator - from the chief designer to the storeman.

Većina radova koji su uključeni u postizanje saglasnosti je u proizvodnji i primeni pisanih procedura i kvalifikacija tehnologije zavarivanja. Dok ne postoji obavezan zahtev uslov ni u CPR ni EN 1090 za proizvođača da ima nezavisnu akreditaciju po ISO 3834, neizbežno je da samosertifikacija neće biti prihvatljiva i da će kupci zahtevati akreditaciju preko treće strane.

Iako primena kompetentnog FPC sistem, zahteva dosta vremena, a relativno je jednostavna, postoji jedna oblast gde proizvođači mogu imati problema sa ispunjavanjem zahteva. EN 1090 deo 2 klauzula 7.4.3 zahteva za koordinaciju zavarivanja, osoblje kao što je specificirano u ISO 14713, Koordinator i u zavarivanju - Zadaci i odgovornosti, da bude imenovano, kada se zavaruju komponente EXC2, EXC3 i EXC4. Svaki pojedinac koji je uključen na bilo koji način u aktivnosti zavarivanja se smatra



It is, however, the appointment of an individual called the Responsible Welding Co-ordinator (RWC) that may be problematic. Table 14, taken from EN 1090 Part2, requires the RWC to have either "basic", B, "specific", S or "comprehensive", C knowledge. Table 15 specifies similar requirements for the welding of stainless steels.

koordinatom zavarivanja - od glavnog projektanta do magacionera. Međutim, imenovanje pojedinca koji se zove odgovorni koordinator za zavarivanje (RCW) može biti problematično. Tabela 14, preuzeta iz EN 1090 deo 2, zahteva da RWC ima ili "osnovni", B, "specifični" S ili "sveobuhvatni", C nivo znanja. Tabela 15 navodi slične zahteve za zavarivanje nerđajućeg čelika.

EXC	Steels (steel group)	Reference standards	Thickness (mm)		
			$t \leq 25^a$	$25 < t \leq 50^b$	$t > 50$
EXC2	S235 to S355 (1.1, 1.2, 1.4)	EN 10025-2, EN 10025-3, EN 10025-4 EN 10025-5, EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	B	S	C ^c
	S420 to S700 (1.3, 2, 3)	EN 10025-3, EN 10025-4, EN 10025-6 EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	S	C ^d	C
EXC3	S235 to S355 (1.1, 1.2, 1.4)	EN 10025-2, EN 10025-3, EN 10025-4 EN 10025-5, EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	S	C	C
	S420 to S700 (1.3, 2, 3)	EN 10025-3, EN 10025-4, EN 10025-6 EN 10149-2, EN 10149-3 EN 10210-1, EN 10219-1	C	C	C
EXC4	All	All	C	C	C

^a Column base plates and endplates ≤ 50 mm.
^b Column base plates and endplates ≤ 75 mm.
^c For steels up to and including S275, level S is sufficient.
^d For steels N, NL, M and ML, level S is sufficient.

Table 2 Copy of Table 14 from EN 1090 Part 2

Tabela 2. Kopija tabele 14 iz EN 1090 deo 2

^a) kolona osnovni limovi i ploče ≤ 50 mm

^b) kolona osnovni limovi i ploče ≤ 75 mm

^c) za čelike do i S275, nivo S je dovoljan

^d) za čelike N, NL, M i ML, nivo S je dovoljan

EXC	Steels (steel group)	Reference standards	Thickness (mm)		
			$t \leq 25$	$25 < t \leq 50$	$t > 50$
EXC2	Austenitic (8)	EN 10088-2:2005, Table 3 EN 10088-3:2005, Table 4 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 2	B	S	C
	Austenitic-ferritic (10)	EN 10088-2:2005, Table 4 EN 10088-3:2005, Table 5 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 3	S	C	C
EXC3	Austenitic (8)	EN 10088-2:2005, Table 3 EN 10088-3:2005, Table 4 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 2	S	C	C
	Austenitic-ferritic (10)	EN 10088-2:2005, Table 4 EN 10088-3:2005, Table 5 EN 10296-2:2005, Table 1 EN 10297-2:2005, Table 3	C	C	C
EXC4	All	All	C	C	C

Table 3 Copy of Table 15 from EN 1090 Part 2

Tabela 3. Kopija tabele 15 iz EN 1090 deo 2



The qualifications of International Welding Specialist (IWS), International Welding Technologist (IWT) and International Welding Engineer (IWE) are quoted in ISO 14713 as examples of qualifications that would be regarded as fulfilling the requirement of B, S and C respectively. Other qualifications of the RWC may be accepted by the accrediting body auditor following a formal interview but the appointment of a suitable qualified and experienced RWC is a potential problem area for many fabricators.

In addition to the requirements of the CPR and EN 1090 there are several additional specifications that require the implementation of ISO 3834 and its related specification ISO 14713. In order to be included in the Register of Qualified Steelwork Contractors (RQSC), administered by UKAS, it is necessary to comply with the National Highways Sector Scheme for Quality Management in Highway Works document 20 - The Execution of Steelwork in Transportation Infrastructure Assets, fortunately known as "NHSS 20". This document is mandated in Appendix A of the Specification for Highway Works and describes the quality management system requirements for fabricators providing "transportation infrastructure assets" – this includes road side furniture, overhead gantries, crash barriers, bridges etc. NHSS 20 specifies that the quality systems shall comply with both ISO 9001 and the appropriate part of ISO 3834 – including the appointment of an RWC with qualifications and experience in accord with the execution class of EN 1090.

One final specification that should be mentioned is EN 15085-Railway Applications- Welding of Railway Vehicles and Components. This specification is in four parts and adopts a similar approach with respect to the classification of railway components and the quality assurance systems for the control of manufacture as EN 1090. Fabricators are required to be independently third party certified and to comply with either ISO 3834 Part 2, Part 3 or Part 4 depending on the certification level (execution class in EN 1090). There are numerous specific requirements regarding welding and its related activities in EN 15085 – far more that can be covered in a brief article such as this – reference to the specification is therefore essential. It should be remembered that the requirements of EN 15085 apply not only to the main contractor but also to any subcontractors - this includes the repair welding of items such as forgings and castings.

Kvalifikacije Međunarodnog Specijaliste zavarivanja (IWS), Međunarodnog Tehnologa zavarivanja (IWT) i Međunarodnog Inženjera zavarivanja (IWE) su citirani u ISO 14713 kao primer kvalifikacija koje se mogu smatrati ispunjavanjem uslova B, S i C. Druge kvalifikacije RCW mogu biti prihvaćene od strane ocenjivača akreditacionog tela, nakon formalnog intervjua, ali imenovanje odgovarajuće kvalifikovanog i iskusnog RCW predstavlja potencijalni problem prostor za mnoge proizvođače. Pored zaheva CPR i EN 1090 postoji nekoliko dodatnih specifikacije koje zahtevaju primenu ISO 3834 i njene prateće specifikacije ISO 14713. Da bi se uključiti u Registar kvalifikovanih ugovarača čeličnih konstrukcija (RQSC), kojim upravlja UKAS, neophodno je da se usaglase sa šemom menadžmenta kvalitetom Nacionalnog sektora za magistralne autoputeve u dokumentu 20 – Izvođenje čeličnih konstrukcija u saobraćajnoj infrastrukturi imovine, poznat kao "NHSS 20". Ovaj dokument je obavezujući i dat u Prilogu A u specifikaciji za radove na magistralnim autoputevima i opisuje zahteve sistema menadžmenta kvalitetom za proizvođače koji obezbeđuju "sredstva saobraćajne infrastrukture" - to uključuje opremu za saobraćajnice, nadzemna pokretna postolja, barijere protiv sudara, mostovi itd. NHSS 20 specificira da sistemi kvaliteta moraju biti u skladu i sa ISO 9001 i odgovarajućim delom ISO 3834 - uključujući i imenovanje RCW sa kvalifikacijama i iskustvom u skladu sa klasom izvođenja po EN 1090.

Jedna konačna specifikacija koju treba pomenuti je EN 15085-Železničke primene - zavarivanje šinskih vozila i komponenti. Ova specifikacija je u četiri dela i usvaja sličan pristup u odnosu na klasifikaciju železničkih komponenti i sistema za osiguranje kvaliteta za kontrolu proizvodnje po EN 1090. Od proizvođača se zahteva da budu sertifikovani od strane nezavisne treće strane u skladu sa bilo ISO 3834 deo 2, deo 3 ili deo 4 u zavisnosti od nivoa sertifikacije (izvođenje klasa po EN 1090). Postoje brojni specifični zahtevi u pogledu zavarivanja i pratećih aktivnosti u EN 15085 - teško mogu biti obuhvaćene u kratkom članku, kao što je ovaj - pozivanje na specifikaciju je od suštinskog značaja. Treba imati na umu da su zahtevi EN 15085 primenjuju ne samo na glavnom izvođaču radova, već i na sve kooperanate - ovo uključuje popravke zavarivanjem stvari kao što su otkovci i odlivci.

METHOD TO CALCULATE ULTRASONIC WAVE VELOCITY BY USING CHEMICAL COMPOSITION OF AUSTENITIC STAINLESS STEELS METODE IZRAČUNAVANJA BRZINE ULTRAZVUČNIH TALASA KORIŠĆENJEM HEMIJSKOG SASTAVA AUSTENITNOG NERĐAJUĆEG ČELIKA

NASTAVAK IZ PREDHODNOG BROJA
2.deo

CONTINUED FROM PREVIOUS ISSUE
Part 2

3.6.2 Partial differential equation

Equations (1) and (2) were partially differentiated with respect to each parameter E , ν , and ρ to simulate a deviation in ultrasonic wave velocity caused by a deviation in each parameter.

Partial differentiation of Eq. (1) with regard to E gives Eq. (9).

$$\frac{\partial C_L}{\partial E} = \frac{1}{2} \left(\frac{(1-\nu)}{\rho(1+\nu)(1-2\nu)} \right)^{1/2} \frac{1}{E^{1/2}} \quad (9)$$

Partial differentiation of Eq. (1) with regard to ν gives Eq. (10).

$$\frac{\partial C_L}{\partial \nu} = \left(\frac{E}{\rho} \right)^{1/2} \left(\frac{\nu(2-\nu)}{(1-\nu)(1+\nu)^3(1-2\nu)^3} \right)^{1/2} \quad (10)$$

Partial differentiation of Eq. (1) with regard to ρ gives Eq. (11).

$$\frac{\partial C_L}{\partial \rho} = -\frac{1}{2} \left(\frac{E(1-\nu)}{(1+\nu)(1-2\nu)} \right)^{1/2} \rho^{-3/2} \quad (11)$$

Partial differentiation of Eq. (2) with regard to E gives Eq. (12).

$$\frac{\partial C_S}{\partial E} = \frac{\sqrt{2}}{4} \left(\frac{1}{\rho(1+\nu)} \right)^{1/2} E^{(-1/2)} \quad (12)$$

Partial differentiation of Eq. (2) with regard to ν gives Eq. (13).

$$\frac{\partial C_S}{\partial \nu} = -\frac{\sqrt{2}}{4} \left(\frac{E}{\rho} \right)^{1/2} (1+\nu)^{(-3/2)} \quad (13)$$

Partial differentiation of Eq. (2) with regard to density ρ gives Eq. (14).

$$\frac{\partial C_S}{\partial \rho} = -\frac{\sqrt{2}}{4} \left(\frac{E}{(1+\nu)} \right)^{1/2} \rho^{(-3/2)} \quad (14)$$

Moreover, Eq. (6) was partially differentiated with respect to d to simulate a deviation in ρ caused by a deviation in d and Eq. (15) can be given.

$$\frac{\partial \rho}{\partial d} = -\frac{12}{Nd^4} \left(\sum_{i=1}^n M_i a_i + \frac{A}{1-A} Mc \right) \quad (15)$$

3.6.2 Delimične diferencijalne jednačine

Jednačine (1) i (2) su delimično diferencirane u odnosu na svaki parametar E, ν , i ρ da simulira odstupanje u brzine ultrazvučnog talasa usled odstupanja svakog parametra.

Delimična diferencijacija jednačine (1) u odnosu na E daje jednačinu (9).

$$\frac{\partial C_L}{\partial E} = \frac{1}{2} \left(\frac{(1-\nu)}{\rho(1+\nu)(1-2\nu)} \right)^{1/2} \frac{1}{E^{1/2}} \quad (9)$$

Delimična diferencijacija jednačine (1) u odnosu na ν daje jednačinu (10).

$$\frac{\partial C_L}{\partial \nu} = \left(\frac{E}{\rho} \right)^{1/2} \left(\frac{\nu(2-\nu)}{(1-\nu)(1+\nu)^3(1-2\nu)^3} \right)^{1/2} \quad (10)$$

Delimična diferencijacija jednačine (1) u odnosu na ρ daje jednačinu (11).

$$\frac{\partial C_L}{\partial \rho} = -\frac{1}{2} \left(\frac{E(1-\nu)}{(1+\nu)(1-2\nu)} \right)^{1/2} \rho^{-3/2} \quad (11)$$

Delimična diferencijacija jednačine (2) u odnosu na E daje jednačinu (12).

$$\frac{\partial C_S}{\partial E} = \frac{\sqrt{2}}{4} \left(\frac{1}{\rho(1+\nu)} \right)^{1/2} E^{(-1/2)} \quad (12)$$

Delimična diferencijacija jednačine (2) u odnosu na ν daje jednačinu (13).

$$\frac{\partial C_S}{\partial \nu} = -\frac{\sqrt{2}}{4} \left(\frac{E}{\rho} \right)^{1/2} (1+\nu)^{(-3/2)} \quad (13)$$

Delimična diferencijacija jednačine (2) u odnosu na ρ daje jednačinu (14).

$$\frac{\partial C_S}{\partial \rho} = -\frac{\sqrt{2}}{4} \left(\frac{E}{(1+\nu)} \right)^{1/2} \rho^{(-3/2)} \quad (14)$$

Šta više, jednačina (6) je delimično diferencirana u odnosu na d da bi simulirali odstupanje ρ uzrokovano odstupanjem d i može se dati jednačina (15)

$$\frac{\partial \rho}{\partial d} = -\frac{12}{Nd^4} \left(\sum_{i=1}^n M_i a_i + \frac{A}{1-A} Mc \right) \quad (15)$$

4. Results and Discussions

4.1 Acoustic Anisotropy Concerning Transverse Wave Velocity Ratio

Table 5 shows the measured values of transverse wave velocity ratio. Since transverse wave velocity ratio of T.P.No.1-1 ~ 1-6 is very small, it is evident that acoustic anisotropy for these materials is not observed.

	Dimension	Ref. No.	C	Si	Mn	P	S	Ni	Cr	Mo	Fe
Young's Modulus	GPa	7			198.0			205.0	253.0	327.0	190.0
		11	4.8	113.1	158.6			206.1	248.2	324.1	196.5
		Ave.	4.8	113.1	178.3			205.55	250.6	325.55	193.25
Poisson's Ratio	None	12		0.44	0.24			0.31	0.30	0.30	0.29
		13						0.31	0.21	0.29	0.29
		Ave.		0.44	0.24			0.31	0.255	0.295	0.29
Atomic Weight	None	7	12.01	28.09	54.94	30.97	32.07	58.69	52.00	95.94	55.85
		10	12.01	28.09	54.94	30.97	32.07	58.69	52.00	95.94	55.85
		Ave.	12.01	28.09	54.94	30.97	32.07	58.69	52.00	95.94	55.85

Table 4 Reference data of Young's modulus, Poisson's ratio and atomic weight of elementary substance

Tabela 4 Referentni podaci o Jungovom modulu, Poasonovog odnosa i atomske mase elementarnih supstanci

T.P. No.	AISI No.	Transverse Wave Velocity Ratio
1-1	304	1.003
1-2	304	1.002
1-3	304	1.000
1-4	304L	1.002
1-5	310S	1.004
1-6	316	1.004

Table 5 Measured values of transverse wave velocity ratio

Tabela 5. Izmerene vrednosti koeficijenta brzine transverzalnog talasa transverse wave velocity ratio- odnos brzine transverzalnog talasa

4.2 Measured Values of Density, Young's modulus and Poisson's ratio

Table 6 shows the measured values of ρ , E and ν of T.P. No.1-1 ~ 1-6. It was observed that ρ of AISI type 304 stainless steel (T.P.No.1-1 ~ 1-3) and AISI type 304L stainless steel (T.P.No.1-4) slightly decreased with the increase in carbon content, although the concentration of Ni and Cr were almost the same. Error between E measured by ultrasonic testing and one by strain gauge method, was in a range of approximately -2 ~ 3 % as shown in Table 4. Error between ν measured by ultrasonic testing and one by strain gauge method was in a range of approximately -5 ~ 5 %. E and ν measured by ultrasonic testing were compared with the calculated ones.

4.3 Comparison between Calculated Values and Experimental Ones

4.3.1 Lattice parameter

Fig. 2 shows the relation between experimental values and ones calculated by Eq. (5). In this figure, the calculated values were within an allowable margin of error, (we assumed that a few percent of error could be allowed, based on our experience), when compared with experimental values

4. Rezultati i diskusija

4.1 Akustična anizotropija u odnosu na odnos brzina transverzalnog talasa

Tabela 5 prikazuje izmerene vrednosti odnos brzine transverzalnog talasa. S obzirom da je odnos brzine transverzalnog talasa za T.P.No.1-1 ~ 1-6 vrlo mali, evidentno je da nije utvrđena akustična anizotropija za ove materijale.

4.2 Izmerene vrednosti gustine, Jungovog modula i Poasonovog odnosa

Tabela 6 prikazuje izmerene vrednosti ρ , E i ν za T.P. No.1-1 ~ 1-6.

Uočeno je da se ρ , kod AISI 304 tipa nerđajućeg čelika (TPNo.1-1 ~ 1-3) i tip 304L nerđajućeg čelika (TPNo.1-4) neznatno smanjio s povećanjem sadržaja ugljenika, iako su koncentracija Ni i Cr bili gotovo isti. Greška između izmerenog E ultrazvučnim ispitivanjem i metodom merača naprežanja, bila je u rasponu od oko -2 ~ 3% kao što je prikazano u tabeli 4. Greška između izmerenih ν ultrazvučnim ispitivanjem i metodom merača naprežanja je u rasponu od oko -5 ~ 5%.

E i ν izmerene ultrazvučnim ispitivanjem su upoređene u odnosu na izračunate vrednosti.

4.3 Poređenje izračunatih i eksperimentalnih vrednosti

4.3.1 Parametar rešetke

Sl. 2 prikazuje odnos između eksperimentalnih vrednosti i izračunatih prema jedn. (5). Na ovoj slici, izračunate vrednosti su bile unutar dozvoljenih margina greške, (pretpostavili smo da nekoliko procenata greška može biti dozvoljeno, na osnovu našeg iskustva), u odnosu na eksperimentalne vrednosti.

4.3.2 Density

Fig. 3 shows the relation between experimental values and the calculated ones of ρ . In this figure, the calculated values were smaller than experimental ones and a margin of error was less than 2.2%. Then we can say that an error caused by the calculation of lattice parameter was within an allowable margin.

4.3.2. Gustina

Sl. 3 prikazuje odnos između eksperimentalnih vrednosti i izračunatih za ρ . Na ovoj slici, izračunate vrednosti su bile manje od eksperimentalnih i margina greške bila je manja od 2,2%. Onda možemo reći da je greška uzrokovana izračunavanjem parametra rešetke unutar dozvoljenih margina.

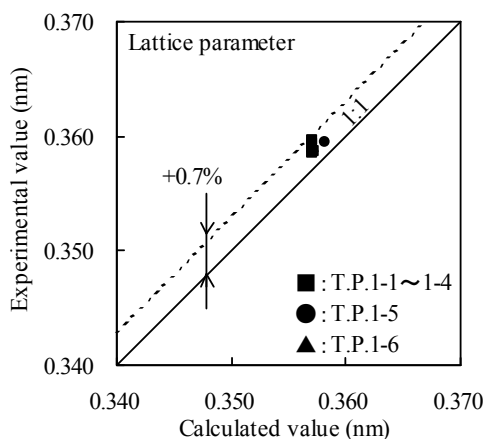


Fig. 2 Relation between experimental values and calculated ones of lattice parameter
Sl. 2: Odnos između eksperimentalnih i izračunatih vrednosti parametra rešetke

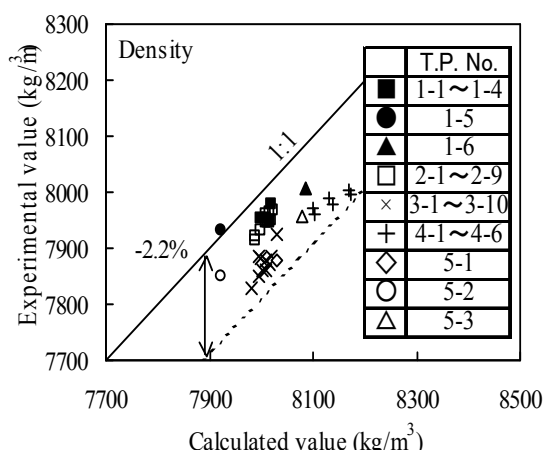


Fig. 3 Relation between experimental values and calculated ones of density
Sl. 3: Odnos između eksperimentalnih i izračunatih vrednosti gustine

T.P.No.	AISI No.	Density (kg/m ³)	Young's Modulus (GPa)			Poisson's Ratio		
			Ultrasonic Testing	Strain Gauge	Error (%)	Ultrasonic Testing	Strain Gauge	Error (%)
1-1	304	7945	200.9	199.3	-0.8	0.288	0.292	+1.39
1-2	304	7953	202.0	202.0	0.0	0.299	0.283	-5.35
1-3	304	7955	201.3	200.4	-0.45	0.290	0.285	-1.72
1-4	304L	7977	203.4	199.5	-1.92	0.284	0.277	-2.46
1-5	310S	7933	195.8	192.0	-1.94	0.289	0.292	+1.04
1-6	316	8007	199.2	204.8	+2.81	0.272	0.285	+4.78

Table 6. Experimental values of density, Young's Modulus and Poisson's ratio
Tabela 6: Eksperimentalne vrednosti gustine, Jungovog modula i Poasonovog odnosa ultrasonic testing—ultrazvučno ispitivanje; strain gauge—merač naprežanja; error—greška

4.3.3 Young's modulus

Fig. 4 shows the relation between experimental values and calculated ones of E . The calculated values were smaller than experimental ones, and a margin of error except T.P.No.5-2 (AISI type 310S in Table 2) was less than 5.7%. It seemed that a margin of error mainly depended on the lack of data concerning Young's modulus necessary for calculation. Especially, it was hard to find out data concerning phosphorus and sulfur.

4.3.3 Jungov modul

Sl. 4 prikazuje odnos između eksperimentalnih vrednosti i izračunatih za E . Izračunate vrednosti su bile manje od eksperimentalnih i margina greške osim za T.P.No.5-2 (tip AISI 310S u tabeli 2) je bila manja od 5,7%. Činilo se da je margina greške uglavnom vezana za nedostatak podataka za Jungov modul potrebnih za izračunavanje. Posebno je bilo teško saznati podatke koji se odnose na fosfor i sumpor.

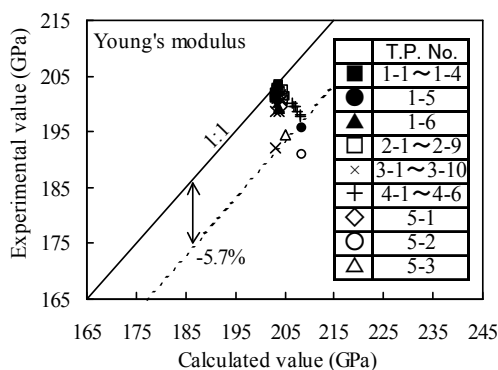


Fig. 4 Relation between experimental values and calculated ones of Young's modulus
Sl. 4. Odnos između eksperimentalnih i izračunatih vrednosti za Jungov modul

4.3.4 Poisson's ratio

Fig. 5 shows the relation between experimental values and the calculated ones of ν . Calculated values were almost constant, and were independent of experimental ones. It seemed that a margin of error depended on the lack of data concerning Poisson's ratio of non-metallic elements such as carbon, phosphorus and sulfur.

4.3.4 Poasonov odnos

Sl. 5 prikazuje odnos između eksperimentalnih i izračunatih vrednosti za ν . Izračunate vrednosti su gotovo konstantne, i bile su nezavisne od eksperimentalnih. Činilo se da margina greške uzrokovana nedostatkom podataka za Poasonov odnos nemetalnih elemenata kao što su ugljenik, fosfor i sumpor.

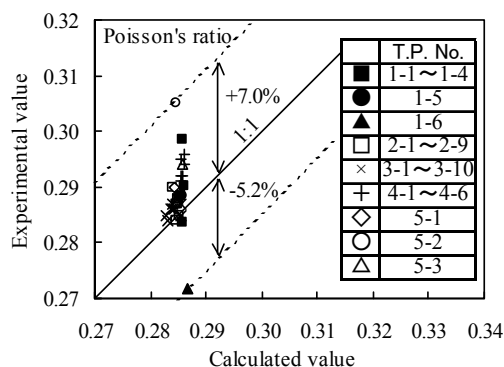


Fig. 5 Relation between experimental values and calculated ones of Poisson's ratio
Sl. 5. Odnos između eksperimentalnih i izračunatih vrednosti Poasonovog odnosa

4.3.5 Longitudinal wave velocity

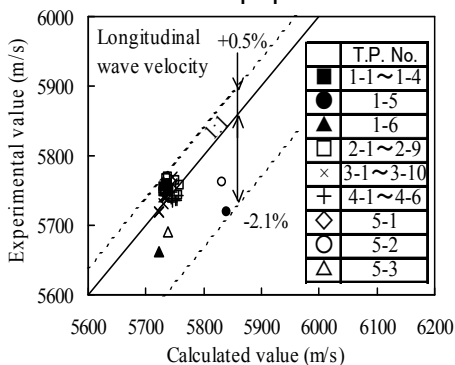
Fig. 6 (a) shows the relation between experimental values and calculated ones of C_L . Since a margin of error was from 0.5% to -2.1%, we can say that longitudinal wave velocity of austenitic stainless steel would be able to be estimated within an allowable margin of error in accordance with the method shown in this paper.

4.3.5 Brzina longitudinalnog talasa

Sl. 6 (a) prikazuje odnos između eksperimentalnih i izračunatih vrednosti za C_L . S obzirom da je margina greške bila od 0,5% do -2,1%, možemo reći da će brzina longitudinalnog talasa austenitnog nerđajućeg čelika biti u mogućnosti da se proceni u okviru dozvoljene margine greške u skladu sa metodom prikazan u ovom radu.

4.3.6 Transverse wave velocity

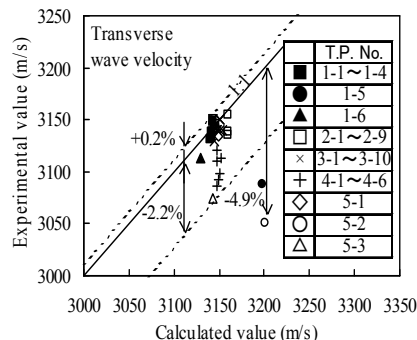
Fig. 6 (b) shows the relation between experimental values and calculated ones of C_s . A margin of error except AISI type 310S stainless steel was from 0.2% to -2.2%, and a maximum error of AISI type 310S was -4.9%. It is necessary to reexamine the method for estimating transverse wave velocity of AISI type 310S. Hence, we can say that transverse wave velocity of austenitic stainless steel except AISI type 310S can be estimated within an acceptable margin of error in accordance with the method shown in this paper.



(a) Longitudinal wave velocity
(a) Brzina longitudinalnog talasa

4.3.6 Brzina transverzalnog talasa

Sl. 6 (b) prikazuje odnos između eksperimentalnih i izračunatih vrednosti za C_s . Margina greške osim za AISI tip 310S nerđajući čelik je od 0,2% do -2.2%, a maksimalna greška za AISI tip 310S je -4.9%. Potrebno je preispitati metode za procenu brzine transverzalnog talasa za tip AISI 310S. Dakle, možemo reći da se brzina transverzalnog talasa austenitnog nerđajućeg čelika, osim za AISI tip 310S može proceniti u prihvatljivoj margini greške u skladu sa metodom prikazanom u ovom radu.



(b) Transverse wave velocity
(b) Brzina transverzalnog talasa

Fig. 6 Relation between experimental values and calculated ones of ultrasonic wave velocity
Sl.6. Odnos između eksperimentalnih i izračunatih vrednosti brzine ultrazvučnog talasa

4.4 Behavior of Deviation

4.4.1 Deviation in longitudinal wave velocity

Fig. 7 shows the relation between longitudinal wave velocity and the ratio of a deviation in each parameter ρ , E and ν in Eq. (1) to the value calculated by Eq. (1), based on the assumption that one of these parameters was variable and others were constant. Zero of the horizontal axis shows that each parameter is equal to experimental value and ratio of a deviation in each parameter is zero. Longitudinal wave velocity increased with the increase in the deviation of E and ν . On the contrary, ρ decreased with the increase in ρ . Curve of ρ and E was reversed, because Eq. (1) shows that longitudinal wave velocity is in proportion to a square root of E/ρ .

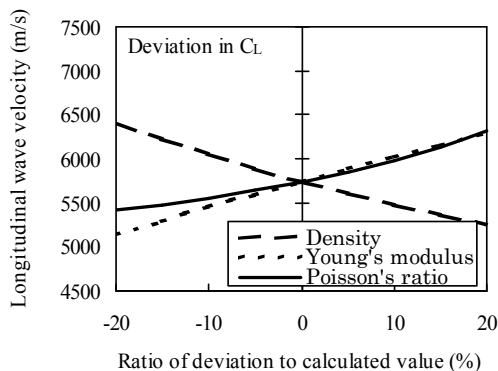


Fig. 7 Relation between longitudinal wave velocity and ratio of deviation in factor of Eq. (1)
Sl. 7. Odnos između brzine longitudinalnog talasa i odnos odstupanja faktora jedn. (1)

4.4 Ponašanje odstupanja

4.4.1 Odstupanje brzine longitudinalnog talasa

Sl. 7 prikazuje odnos između brzine longitudinalnog talasa i odnos odstupanja svakog parametra ρ , E i ν u jednačini. (1) od izračunatih vrednosti prema jedn. (1), zasnovan na pretpostavci da je jedan od tih parametara bio promenljiv a ostali su bili konstantni. Nula na horizontalnoj osi pokazuje da je svaki parametar jednak eksperimentalnoj vrednosti i da je odnos odstupanja u svakom parametru nula. Brzina longitudinalnog talasa se povećava sa porastom odstupanja E i ν . Naprotiv, ρ opada sa povećanjem ρ . Krive ρ i E su obrnute, jer jedn. (1) pokazuje da je brzina podužnog talasa proporcionalna kvadratnom korenu iz E/ρ .

4.4.2 Deviation in transverse wave velocity

Fig. 8 shows the relation between C_S and the ratio of a deviation of each parameter ρ , E and ν in Eq. (2) to the value calculated by Eq. (2). In Fig. 8, C_S decreased with the increase in a deviation of ρ and ν , and increased with the increase in E , because Eq. (2) shows that transverse wave velocity is in proportion to a square root of E/ρ .

Comparing a curve of C_S with that of C_L , a deviation in C_S was definitely smaller than that in C_L , because $\sqrt{[1/(2(1+\nu))]}$ in Eq. (2) is smaller than $\sqrt{[(1-\nu)/((1+\nu)(1-2\nu))]}$ in Eq. (1). For example, when $\nu = 0.288$ (experimental value in Table 5) of T.P.No.1-1, $\sqrt{[1/(2(1+\nu))]}$ was 0.62 and $\sqrt{[(1-\nu)/((1+\nu)(1-2\nu))]}$ was 1.14.

4.4.2 Odstupanje brzine transversalnog talasa

Sl. 8 prikazuje odnos između C_S i odnos odstupanja svakog parametra ρ , E i ν u jednačini. (2) od izračunatih vrednosti prema jedn. (2). Na sl. 8, C_S je smanjen sa povećanjem odstupanja ρ i ν , a raste sa povećanjem E , jer jed. (2) pokazuje da je brzina transversalnog talasa proporcionalna kvadratnom korenu iz E/ρ .

Upoređujući krivu C_S sa C_L , odstupanje C_S je definitivno manje nego C_L , jer $\sqrt{[1/(2(1+\nu))]}$ u jednačini (2) je manje od $\sqrt{[(1-\nu)/((1+\nu)(1-2\nu))]}$ u jednačini (1). Na primer, kada je $\nu = 0.288$ (eksperimentalna vrednost u tabeli 5) za TPNo.1-1, $\sqrt{[1/(2(1+\nu))]}$ je 0.62 i $\sqrt{[(1-\nu)/((1+\nu)(1-2\nu))]}$ je 1.14.

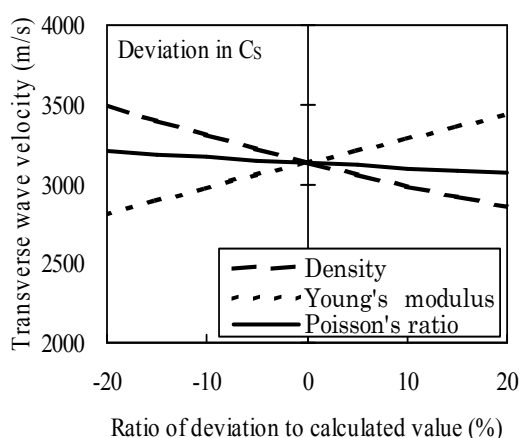


Fig. 8 Relation between transverse wave velocity and ratio of deviation of parameter ρ , E and ν in Eq.(2) to calculated value

Sl. 8. Odnos između brzine transversalnog talasa i odnosa odstupanja parametara ρ , E i ν u jedn. (2) za izračunate vrednosti

4.4.3 Deviation in density

Fig. 9 shows the relation between density and the ratio of a deviation in lattice parameter to that calculated by Eq. (5). In Fig.9, ρ increased rapidly with the decrease in a deviation in d .

4.4.3 Odstupanje gustine

Sl. 9 pokazuje odnos između gustina i odnos odstupanja parametra rešetke u odnosu na izračunate prema jedn. (5). Na sl.9, ρ je nagli porast pri smanjenju odstupanja d .

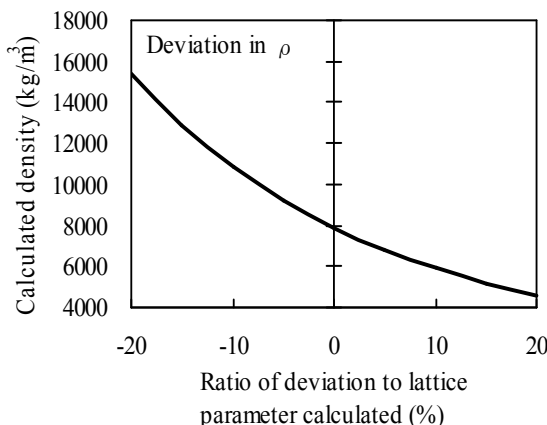


Fig. 9 Relation between density and ratio of deviation to lattice parameter calculated

Sl. 9. Odnos između gustine i odnosa izračunatog odstupanja parametra rešetke

4.4.4 Deviation in partial differentiation of $\partial\rho/\partial d$ with regard to lattice parameter

Fig. 10 shows the relation between $\partial\rho/\partial d$ and the ratio of a deviation in d to the calculated value.

In Fig. 10, $\partial\rho/\partial d$ increased rapidly with the increase in a deviation in d . Since figures of $\partial\rho/\partial d$ was minus, it seemed that the curve in Fig. 9 corresponded with the deviation of $\partial\rho/\partial d$ in Fig. 10.

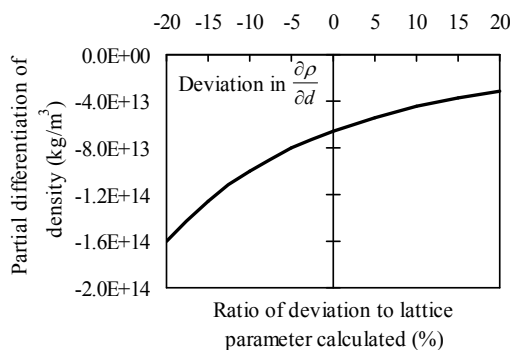


Fig.10 Relation between $\partial\rho/\partial d$ and ratio of deviation to d
Sl.10. Odnos između $\partial\rho/\partial d$ i odnos odstupanja d

4.4.5 Deviation in partial differentiation of $\partial C/\partial\rho$ with regard to density

Fig. 11 shows the relation between $\partial C/\partial\rho$ and the ratio of a deviation to ρ . In this figure, zero at horizontal axis represents that a deviation in ρ of experimental value shown in Table 5 is zero. In Fig. 11, $\partial C/\partial\rho$ of C_L increased moderately with the increase in the ratio of a deviation to ρ . On the other hand, $\partial C/\partial\rho$ of C_S increased slightly with the increase in the ratio of a deviation to ρ .

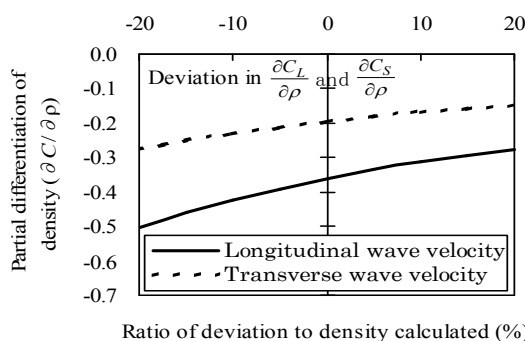


Fig.11 Relation between $\partial C/\partial\rho$ and ratio of deviation to ρ
Sl.11. Odnos $\partial C/\partial\rho$ i odnos odstupanja ρ

4.4.6 Deviation in partial differentiation of $\partial C/\partial E$ with regard to Young's modulus

Fig. 12 shows the relation between $\partial C/\partial E$ and the ratio of a deviation in E to the calculated value.

Since $\partial C/\partial E$ in Fig. 12 decreased with the increase in the ratio of deviation to E , the increment of C_L in Fig. 7 and that of C_S in Fig. 8 decreased gradually.

In Fig. 12 the decrement of $\partial C_L/\partial E$ was larger than that of $\partial C_S/\partial E$.

4.4.6 Odstupanje parcijalne diferencijacije $\partial C/\partial E$ u odnosu na parametar rešetke

Sl. 10 pokazuje odnos između $\partial\rho/\partial d$ i odnos odstupanja d prema izračunatoj vrednosti.

Na sl. 10, $\partial\rho/\partial d$ je naglo poraslo sa porastom odstupanja d . S obzirom da su slike $\partial\rho/\partial d$ bile u minusu, to znači da kriva na sl. 9 odgovara odstupanju $\partial\rho/\partial d$ na sl. 10.

4.4.5 Odstupanje parcijalne diferencijacije $\partial C/\partial\rho$ s obzirom na gustinu

Sl. 11 pokazuje odnos između $\partial C/\partial\rho$ i odnos odstupanja ρ . Na ovoj slici, nula na horizontalnoj osi predstavlja odstupanje ρ eksperimentalnih vrednosti prikazano u tabeli 5 koje iznosi nula. Na Sl. 11, $\partial C/\partial\rho$ C_L raste umereno sa povećanjem odnosa odstupanja ρ . S druge strane, $\partial C/\partial\rho$ C_S se blago povećava sa povećanjem odnosa odstupanja ρ .

4.4.6 Odstupanje parcijalne diferencijacije $\partial C/\partial E$ s obzirom na Jungov modul

Sl. 12 pokazuje odnos između $\partial C/\partial E$ i odnos odstupanja E prema izračunatim vrednostima.

S obzirom daje $\partial C/\partial E$ na sl. 12 smanjeno sa povećanjem odnosa odstupanja do E , prirast C_L na sl. 7 i dok C_S sa sl. 8 se postupno se smanjuje.

Nasl. 12 opadanje $\partial C_L/\partial E$ je veće nego $\partial C_S/\partial E$.

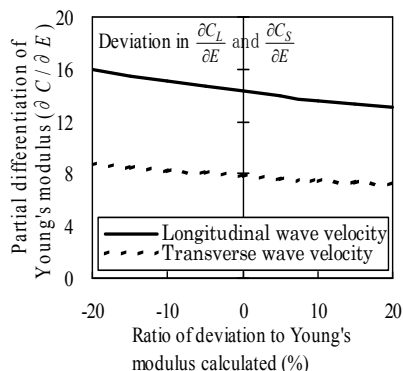


Fig.12 Relation between $\partial C/\partial E$ and ratio of deviation to E
SI.12. Odnos između $\partial C/\partial E$ i odnos odstupanja E

4.4.7 Deviation in partial differentiation of $\partial C/\partial v$ with regard to Poisson's ratio

Fig. 13 shows the relation between $\partial C/\partial v$ and the ratio of a deviation to v . In this figure, zero at horizontal axis represents that the deviation in v is zero. In Fig. 13 the increment of $\partial C_L/\partial v$ was considerably larger than that of $\partial C_S/\partial v$.

4.4.7 Odstupanje u parcijalne diferencijaciji $\partial C/\partial v$ with obzirom na odnos Poissonov

Sl. 13 prikazuje odnos između $\partial C/\partial v$ i odnos odstupanja v . Na ovoj slici, nula na horizontalnoj osi predstavlja odstupanje v koje je nula. Na sl. 13 prirast $\partial C_L/\partial v$ bio znatno veći od $\partial C_S/\partial v$.

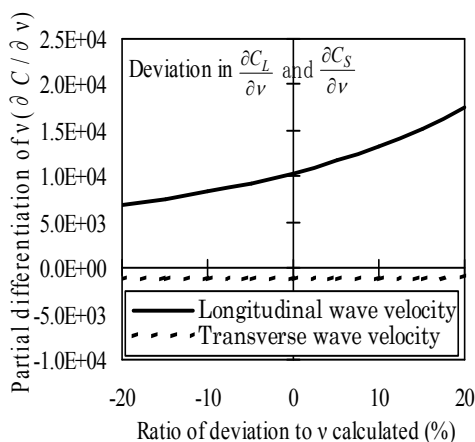


Fig.13 Relation between $\partial C/\partial v$ and ratio of deviation to v
SI.13. Odnos $\partial C/\partial v$ i odnos odstupanjav

5. Conclusions

- (1) In calculating both lattice parameter and density by using chemical composition of material used, the calculated values were within an allowable margin of error, when assuming a few percent of error can be allowed, based on our experience. However, the calculated values of Young's modulus and Poisson's ratio were beyond an allowable margin of error, because it was impossible to find out data of elementary substance.
- (2) Acoustic anisotropy concerning transverse wave velocity ratio of T.P. No.1-1 \sim 1-6 was not observed.
- (3) The calculated value of longitudinal wave velocity were within an allowable margin of error.

5. Zaključci

- (1) Pri izračunavanju i rešetke parametara i gustine, koristeći hemijski sastav materijala, izračunate vrednosti su bile unutar dozvoljenih margina greške, kada je pretpostavljeno da nekoliko procenata greške može biti dozvoljeno, na osnovu našeg iskustva. Međutim, izračunate vrednosti Jungovog modula i Poasonovog odnosa su bili van dozvoljene margine greške, jer je bilo nemoguće saznati podatke osnovne supstance.
- (2) Akustična anizotropija vezana za odnos brzina transverzalnog talasa za T.P. No.1-1 \sim 1-6 nije uočena.
- (3) Izračunata vrednost brzine longitudinalnog talasa su unutar dozvoljenih margina greške.

Similarly, the calculated values of transverse wave velocity except AISI type 310S stainless steel were within an allowable margin of error.

(4) The calculated value of density was gradually decreased with the increase in the ratio of a deviation in lattice parameter.

(5) Longitudinal wave velocity increased with the increase in a deviation of Poisson's ratio, and was in proportion to a square root of E/ρ .

(6) Transverse wave velocity decreased with the increase in a deviation of Poisson's ratio, and was in proportion to a square root of E/ρ .

(7) The deviation in longitudinal wave velocity due to the deviation of each parameters in Eqs. (1) and (2) was considerably larger than that in transverse wave velocity.

References

Literatura

- 1) Handbook for Non-destructive Inspection (New Version), Edited by The Japanese Society for Non-Destructive Inspection. Nikkan Kogyo Shimbun (1992), p.1283
- 2) H.M.Ledbetter, H.W.Austin ; Effect of Carbon and Nitrogen on the Elastic Constants of AISI Type 304 Stainless Steel, Materials Science and Engineering, 70(1985), p.143-149.
- 3) H.M.Ledbetter ; Manganese contributions on the elastic constants of face centred cubic Fe-Cr-Ni stainless steel, JOURNAL OF MATERIALS SCIENCE, 20(1985), p.2923-2929.
- 4) H.M.Ledbetter, S.A.Kim, J.Mater ; Molybdenum effect on Fe-Cr-Ni alloy elastic constants, Res.3(1), Jan/Feb (1988), p.40-44.
- 5) H.M.Ledbetter ; Sound velocities and elastic constants of steels 304, 310, and 316, Metal Science, December (1980), p.595-596.

Slično tome, izračunate vrednosti brzina transverzalnog talasa, osim za AISI tip 310S nerđajućeg čelika su unutar dozvoljenih margina greške.

(4) Izračunata vrednost gustine je postepeno smanjena sa porastom odnosa odstupanja parametara rešetke.

(5) Uzdužna brzina talasa povećala s povećanjem odstupanje Poasonovog odnosa, i bio je u odnosu na kvadratni koren od E/ρ .

(6) Brzina transverzalnog talasa se smanjuje s povećanjem odstupanja Poasonovog odnosa, i proporcionalan je kvadratnom korenu iz E/ρ .

(7) Odstupanje brzine transverzalnog talasa zbog odstupanja svakog parametara u jednačinama (1) i (2) bio je znatno veći nego kod brzine transverzalnog talasa.

- 6) Handbook of X-ray Diffraction, Rigaku, (2000), p.72-78
- 7) Material Data Book, Institute of Metallurgy in Japan, Maruzen, (2004), p.31, p.44.
- 8) W.C.Leslie ; Iron and Its Dilute Substitutional Solid Solutions. MATALLURGICAL TRANSACTIONS. Vol.3, January (1972), p.5-26.
- 9) S.Nishikawa ; Introduction of Material Engineering, Agne Gijutu Center (2001), p.92-96,
- 10) S.Nishikawa ; Introduction of Material Engineering, Agne Gijutu Center (2001), p.122,
- 11) S.Kohara ; Introduction of Metaragical Science, Asakura Shoten (2000), p.280-281.
- 12) Werner Köster ; H.Franz. et al. POISSON'S RATIO FOR METALS AND ALLOYS. METALLURGICAL REVIEWS. (1961), No.21, Vol.6, p.18-19.
- 13) R.M.German ; Science of Powder Metallurgy, Uchida Rokakuho (1996), p.524-529.



GODIŠNJA SKUPŠTINA IIW

Ovogodišnja, jubilarna, 70. skupština Međunarodnog instituta za zavarivanje - (International Institute of Welding) održana je u Šangaju, Kina u izvanrednoj organizaciji Kineske zavarivačke asocijacije i Asocijacije mašinskih inženjera Kine. Odličnu organizaciju je pratilo preko 1100 učesnika iz 43 zemlje članice IIW-a.

Podatak da je bilo preko 1100 učesnika ne umanjuje činjenica da je broj učenika iz Kine bio oko 600, jer je i cifra od oko 500 učesnika iz ostalih zemalja respektabilna. Važno je napomenuti da je organizacija bila na veoma visokom nivou. Veliki broj članova Kineske zavarivačke asocijacije uz pomoć još većeg broja volontera uspjeli su da se ovogodišnja Skupština, sastanci radnih grupa i Komisija, kao i socijalni program odvija besprekorno. Treba napomenuti da je mesto održavanja bio Šangajski kongresni i izložbeni centar u čijem sastavu je i hotel gde je velika većina učesnika bila smeštena.

Sednica Godišnje skupštine IIW-a je održana 25. juna. Nažalost, i ove godine jedini predstavnik iz Srbije je bio dr Vencislav Grabulov, izvršni rukovodilac DUZS CertPers.



dr Vencislav Grabulov, izvršni rukovodilac DUZS CertPers



Delegati iz: Brazila, Novog Zelanda, Srbije, Nemačke, Slovenije

Što se godišnje skupštine tiče, pored redovnih aktivnosti kao što su: usvajanje izveštaja o radu, finansijskog izveštaja, kadrovskih promena u Bordu direktora, status zemalja aplikanata i stanja sa plaćanjem članarina članova IIW-a, doneta je odluka da se 71. Godišnja skupština IIW-a ne održi u Istanbulu (kako je bilo odlučeno pre dve godine u Helsinkiju) iz bezbednosnih razloga. Tako da je organizacija 71. Godišnje skupštine IIW-a dodeljena Zavarivačkoj asocijaciji Indonezije.

Na sastancima Međunarodne grupe za ovlašćivanje (IAB grupe) odnosno Komisije A (26.06.2017.) koja se bavi pravilima za obrazovanje osoblja u zavarivanju i sertifikacijom kompanija, Komisije B (27.06.2017.) koja se bavi primenom pravila i ovlašćivanje i sastanku zemalja članica (28.06.2017.) diskutovano je o izmenama i dopunama relevantnih dokumenata za održavanje kurseva za obrazovanje i obuku osoblja u zavarivanju. Diskutovano je o stanju novih kurseva kao i o stanju saradnje u delu primene usaglašenih međunarodnih ispita. Posebno su razmatrani predlozi za izmenama u dokumentu za edukaciju Međunarodnih inspektora za zavarivanje u delu izvođenja praktičnog dela ispita primenom harmonizovanih plastičnih uzoraka.

Usvojeni su izveštaji o ocenjivačkim posetama nacionalnih tela za ovlašćivanje i doneti odgovarajući zaključci.



dr Vencislav Grabulov i Jim Guilt, predsednik IAB grupe



dr Vencislav Grabulov i Daglas Luciano, predsednik IIW

Na sednici Grupe B – IAB grupe koja je održana dana 27.06.2017. godine su bili uvršteni izveštaji glavnog ocenjivača IAB grupe g-na Christiana Ahrens-a o nadzornoj poseti ANB i ANB CC za Srbiju



(DUZS CertPers i Zavod Cert) gde je bilo predloženo da se produži akreditacija ANB i ANB CC za Srbiju i za naredni ciklus. Predlozi su usvojeni jednoglasno.

Za nas, posebno značajna je bila sednica Radne grupe IIW-a za regionalnu saradnju gde je i formalno doneta odluka da se Četvrti regionalni kongres MIZ-a za zemlje jugoistočne Evrope održi u Srbiji oktobra 2018. godine.

U cilju definisanja detalja u vezi sa Kongresom dogovoreno je da se tokom septembra 2017. godine održi radni sastanak predstavnika zavarivačkih asocijacija iz regiona u Beogradu. Zaključci sa tog sastanka treba da se dostave Sekterarijatu IIW-a uz popunjenu prijavu kao dokument IIW-a do kraja septembra 2017 godine. Nažalost ovaj sastanak Radne grupe za regionalnu saradnju je bio poslednji koji je održan pod rukovodstvom Chris Smallbone –a kome je istekao mandat. Inače, gospodin Chris Smallbone je bio veoma zaslužan za razvoj saradnje zemalja jugoistočne Evrope u području zavarivanja, najpre kao predsednik IIW-a a kasnije kao predsednik radne grupe za međunarodnu saradnju.

Sastanak Komisije XIV koja se bavi obrazovanjem održan je 29.07.2017. godine.

Kao prateća manifestacija Skupštini IIW-a, kao što je uobičajeno održana je Međunarodna konferencija sa temom "Zelene tehnologije zavarivanja za efikasnu i pouzdanu proizvodnju".

Impozantan skup je pored plenarne sesije imao i 36 sesija po 6 podtema: Automatizacija u postupcima zavarivanja i spajanja, Simulacije u zavarivanju, Zavarivanje materijala visoke čvrstoće, Dodatni materijali za zavarivanje, Nano/mikro zavarivanje i spajanje i Ostalo.

Impozantni kongresni centar je omogućio da se u dva dana izloži preko 250 radova uz oko 150 radova prikazanih u okviru 8 poster grupacija.

Domaćin je organizovao i tehničke posete koje su obuhvatile i posetu jednom od tehničkih univerziteta u Šangaju, pogonima za zavarivanje robotskim i laserskim tehnologijama, termocentrali, pogonima za održavane ultrabrzih vozova ..

Kada se tome doda i bogat socijalni program, ostaje samo zadovoljstvo i iskrene čestitke organizatorima.

Dr Vencislav Grabulov, IWE
Izvršni rukovodilac DUZS CertPers

MEĐUNARODNO TAKMIČENJE ZAVARIVAČA „ARC CUP“ 2017 – ŠANGAJ

U periodu od 24-30.06.2017., u vreme održavanja 70. godišnje Skupštine IIW, održano je 5. međunarodno takmičenje zavarivača službenog naziva „ARC CUP“ 2017.

Takmičenje je održano u Šangaju u organizaciji International Institute of Welding (IIW), Chinese Welding Society (CWS) i Organizing Committee of Arc Cup International Welding Competition (OC ARCIWC) i uz podršku Education and Training Department of China Machinery Industry Federation i BRICS Business Council Skills Development Working Groups.

Ukupno je učestvovalo više od 300 takmičara iz 73 ekipe uključujući i ekipe iz 11 zemalja: Rusija, Indija, Kina, Južna Afrika, Kazahstan, Slovačka, Mongolija, Ukrajina, Vijetnam, Kamerun i Nigerija. Najveći broj ekipa došao je iz Kine: 26 ekipa iz preduzeća u državnom vlasništvu Kine, 10 ekipa iz privatnog sektora kao i 18 ekipa stručnih koledža iz Kine. Tokom samog takmičenja više od 1000 gostiju iz zemlje i inostranstva su bili uključeni u razne aktivnosti vezane za samo takmičenje.

Samo takmičenje kao i prethodne godine, organizovano je u 6 kategorija: postupcima 311, 111, 135, 141, robotsko zavarivanje i zavarivanje gotovog proizvoda (sklop koji je trebalo završiti u kombinaciji postupaka 111, 141 i 136).

Na kraju treba spomenuti da su najbolji rezultat i 1. mesto u ekipnom deli takmičenja podelile 3 ekipe: 2 ekipe iz Kine: CRRC Group (China Railway Rolling Stock Corporation), CEEC Group (China Energy Engineering Corporation Limited) i ekipa iz Rusije.



Zajednička fotografija svih učesnika

ČASOPIS ZAVARIVANJE I ZAVARENE KONSTRUKCIJE

Cenovnik oglasnog prostora u četiri uzastopna broja 2017

	A4	2/2	1/1	1/2	1/4	1/8
dimenzije (mm)		2 x 210 x 297	210 x 297	180 x 120	90 x 120	90 x 60
DIN	crno/beli	-	39 000	23 000	16 000	10 000
	kolor	105 000	75 000	-	-	-

- U cene nije uračunat PDV 20%.
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 - za kolor film ili CD (Adobe Photoshop / CorelDRAW);
 - izrada filma sa CD: 10 % od cene angažovanog prostora.
- Na web prezentaciji DUZS-a, (www.duzs.org.rs), na strani Marketing, objavljuje se pregled firmi-oglašivača sa podacima o glavnim grupama proizvoda/usluga i adresom web prezentacije. Svi posetioci naše web prezentacije mogu da posete i web prezentacije oglašivača, preko aktivnih linkova koji se nalaze na ovoj stranici!

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