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# WELDING DUPLEX STAINLESS STEELS – A REVIEW OF CURRENT RECOMMENDATIONS

## ZAVARIVANJE DUPELKS ČELIKA- PREGLED SADAŠNJIH PREPORUKA

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### ABSTRACT

A steel will not become widely accepted and used unless it can be successfully welded without too many limitations. Contemporary duplex stainless steel grades fulfill these requirements with some grade dependent differences. The duplex stainless steel family has, during the last decade, been extended with new lean grades and recently also highly-alloyed hyperduplex grades. Most welding recommendations are very similar to those of the 1990's. However, the introduction of new grades and the increased use of newer welding methods has somewhat changed the perception of what is possible. This paper discusses the state-of-the-art and trends in welding of duplex stainless steels. It is based on input from the worldwide welding community, including users and producers of steel and welding consumables as well as literature. In most cases, there is consensus on recommendations but variations reflecting differences in practices exist in particular for newer steel grades where limits in e.g. allowable energy inputs are less well documented.

### 1. Background

Duplex stainless steels play an essential role since many years in industrial sectors such as oil and gas, process industry and fabrication of chemical tankers. They have also found their way into more general transportation and construction applications. There is nowadays a wide range of grades all offering an attractive combination of high strength and good corrosion resistance, thanks to their two-phase microstructure consisting of approximately 50 % ferrite and

### REZIME

Čelik neće postati široko prihvaćen i iskorišćen, ako se ne može uspješno zavariti bez previše ograničenja. Savremeni dupleks nerđajući čelici ispunjavaju ove zahteve uz određene razlike zavisno od klase. Porodica dupleks nerđajućih čelika, tokom posljednje decenije, proširena je novim klasama i nedavno visoko-legiranim hiperdupleksima. Većina preporuka za zavarivanje je veoma slična onima iz devedesetih. Međutim, uvođenje novih klasa i povećana upotreba novih metoda zavarivanja donekle je promenila percepciju onoga što je moguće. Ovaj rad govori o najsavremenijim trendovima u zavarivanju dupleks nerđajućih čelika. Zasnovan je na inputima iz svetske zavarivačke asocijacije, uključujući korisnike i proizvođače čelika i potrošnog materijala za zavarivanje, kao i literaturu. U većini slučajeva postoji konsenzus o preporukama, ali varijacije koje odražavaju razlike u praksi postoje, posebno za nove kategorije čelika gde su granice, npr. dozvoljeni unosi toplote manje dokumentovani.

### 1. Osnova

Dupleks nerđajući čelici igraju ključnu ulogu mnogo godine u industrijskim sektorima kao što su nafta i gas, procesna industriju i izrada hemijskih tankera. Oni su takođe našli svoje mesto u opštem transportu i konstrukcijama. Danas je širok opseg klasa koje nude atraktivnu kombinaciju visoke čvrstoće i dobre otpornosti na koroziju, zahvaljujući njihovoj dvofaznoj mikrostrukturi koja se sastoji od otprilike 50% ferita i 50% austenita. Izrastavši u veliku familiju, dupleks nerđajući čelici variraju od



50% austenite. Having grown to a large family, the duplex stainless steels range from the lean grades to the highly-alloyed superduplex grades and recently also hyperduplex grades for more demanding applications [1-3].

In retrospect, the duplex conference in Beaune in 1991 [4] marks a step change in the image of duplex stainless steels. Earlier often seen as exotic, rarely used and difficult to weld materials they since then have become modern steels considered by many end users as realistic and interesting alternatives to more established stainless steels. At this conference, new grades with increased nitrogen additions and optimized compositions were presented. As a consequence many grades gained in weldability and corrosion resistance. Not only the 2205 grades became better defined but also superduplex steels were promoted and redesigned for better corrosion resistance, weldability and less tendency to formation of unwanted phases [5, 6].

The practical application of any steel on a larger scale is critically dependent on the use of welding for fabrication. Productivity is a key issue in manufacturing and, with increased use of duplex stainless steels, this aspect has become more important. Most welding recommendations are still valid [4, 7] when compared with those in existence at the time of the duplex stainless steel conference in 1991. However, the use of newer welding methods and the accompanying extension of possible heat input ranges both upwards and downwards have changed the welding engineer's toolbox. Examples include methods such as laser and laser-hybrid techniques, as well as lower energy input variants of MIG/MAG welding and welding with or without addition of filler material. Also friction stir welding (FSW) has successfully been applied although productivity and tool life are still limiting factors. Welding recommendations, therefore, need to be critically reviewed and summarized for well-established as well as newer grades.

This paper discusses experiences as well as recent trends in welding of duplex stainless steels based on input from the worldwide welding community, including users and producers of steel and welding consumables, as well as literature. It is intended to assist in designing proper welding procedures and avoiding problems by summarizing important aspects of the state-of-the-art of how to weld duplex stainless steels. Largely there is consensus on recommendations, but variations in recommendation reflecting differences in practices will be highlighted.

običnih u visoko-legirane superdupleks klase a nedavno i hiperdupleks klase za zahtevnije primene [1-3].

U retrospektivi, konferencija o dupleks čelicima u Bonu, 1991. godine [4] označava ključnu promenu u slici dupleks nerđajućeg čelika. Ranije su često smatrali egzotičnim, retko korišćenim i teško zavarivim materijalom koji su od tad postali moderni čelici, koje mnogi krajnji korisnici smatraju realnim i zanimljivom alternativom za dosta odomaćenih nerđajućih čelika. Na ovoj konferenciji su predstavljene nove klase sa povećanim sadržajima azota i optimizovanog sastava. Zbog toga su mnoge klase napredovale sa aspekta zavarivanja i korozijske otpornosti. Ne samo da je klasa 2205 postala bolje definisana, već su i superdupleks čelici promovisani i redizajnirani na bolju korozijsku otpornost, zavarljivost i manju tendenciju ka stvaranju neželjenih faza [5, 6].

Praktična primena bilo kog čelika u većoj meri je kritično zavisna od upotrebe zavarivanja za izradu. Produktivnost je ključno pitanje u proizvodnji i, uz povećanu upotrebu dupleks nerđajućih čelika, ovaj aspekt je postao važniji. Većina preporuka za zavarivanje još uvek važi [4, 7] kada se uporede sa onima koje su postojale u vreme konferencije o dupleks nehrđajućim čelicima, 1991. godine. Međutim, upotreba novih metoda zavarivanja i prateće proširenje mogućeg opsega unete toplote i na gore i na dole promenili su alatke inženjera zavarivanja. Primeri uključuju metode kao što su laserska i lasersko-hibridne tehnike, kao i varijante manjeg unosa energije MIG / MAG zavarivanja i zavarivanja sa ili bez dodatnog materijala. Takođe je uspešno primenjeno i zavarivanje trenjem sa mešanjem (FSW), iako je produktivnost i životni vek alata još uvek ograničavajući faktori. Preporuke za zavarivanje, prema tome, moraju biti kritički pregledane i rezimirane za dobro ustanovljene kao i nove klase.

Ovaj rad govori o iskustvima kao i o najnovijim trendovima u zavarivanju dupleks nerđajućih čelika na osnovu doprinosa svetske zavarivačke asocijacije, uključujući korisnike i proizvođače čelika i potrošnih materijala za zavarivanje, kao i literaturu. Namena je da se pomogne u projektovanju odgovarajućih postupaka zavarivanja, izbegavajući problem, sumiranjem važnih aspekata najsavremenije tehnologije zavarivanja dupleks nerđajućih čelika. U velikoj meri postoji konsenzus o preporukama, ali će se naglasiti varijacije u preporuci koje odražavaju razlike u praksi.



A welding operation can have significant effects on mechanical properties and corrosion performance. For example, excessively high weld metal or heat-affected zone ferrite content impair properties. It is also well-established that the presence of small amounts of secondary phases can have significant deleterious effects [8-11]. Some typical problems are therefore identified and discussed in relation to welding recommendations.

The document does not promote specific grades of steels, specific grades or brands of welding consumables, or the views of a particular company.

## 2. Duplex stainless steel grades

Duplex (austenitic /ferritic) stainless steels comprise a large family ranging from the lower alloyed lean grades, via the widely used 22 % Cr grades to the highly-alloyed superduplex and hyperduplex grades (Table 1). During recent years a number of so-called lean duplex stainless steels have attracted a lot of interest as cost-efficient alternatives to standard austenitic grades such as 304L (1.4307) and 316L (1.4401). Some of the Ni in these steels is often replaced by a combination of Mn and N in order to keep the alloying cost at a minimum whilst maintaining strength, corrosion resistance and a suitable phase balance. Lean duplex grades typically have a pitting corrosion resistance better or on par with standard austenitic grades [1, 2].

The classification in Table 1 is inevitably somewhat arbitrary, as there is no standardized or generally agreed method of grouping duplex steels. The intention was however to group steels in a manner reflecting composition and properties, indicating which grades can be seen as contemporary and using the common definition of superduplex as steels with a minimum Pitting Resistance Equivalent ( $PRE_N$  or  $PRE_W$ ) of 40. The very recent 24 % Cr LDX 2404 grade was grouped together with the standard 22 % Cr grades based on its  $PRE_N$  value.

For the less-alloyed grades "lean" is primarily used for almost Mo-free grades with a low Ni-content [1]. However, also grades with intermediate Mo-content or with significant Cu-additions are here classified as "lean" as they have significantly lower  $PRE_N$  than the standard 22 % Cr grades. For the very highly-alloyed grades there is a similar problem in defining the borderline between superduplex and hyperduplex. In the present paper the grades are considered hyperduplex when  $PRE_N$  or  $PRE_W$  are close to or above 50.

Operacija zavarivanja može imati značajne efekte na mehaničke osobine i performanse korozije. Na primer, preterano visok metal šava ili sadržaj ferita u zoni uticaja toplote ugrožavaju svojstva. Takođe je dobro utvrđeno da prisustvo malih količina sekundarnih faza može imati značajne štetne efekte [8-11]. Stoga se prepoznaju i razmatraju neki tipični problemi u vezi sa preporukama za zavarivanje.

Dokument ne promovise određene klase čelika, specifične klase ili brendove potrošnog materijala za zavarivanje ili poglede određene kompanije.

## 2. Klase dupleks čelika

Dupleks (austenitno / feritni) nerđajući čelici obuhvataju veliku familiju koja se kreće od slabije legiranih klasa, preko široko rasprostranjenih klasa sa 22% Cr, do visoko legiranih superdupleks i hiperdupleks klasa (Tabela 1). Tokom proteklih godina niz takozvanih dupleks nerđajućih čelika privuklo je veliko interesovanje kao isplativa alternativa standardnim austenitnim klasama kao što su 304L (1.4307) i 316L (1.4401). Deo Ni u ovim čelicima često se zamenjuje kombinacijom Mn i N, kako bi se troškovi legiranja zadržali na minimumu, dok se održava čvrstoća, otpornost na koroziju i odgovarajući fazni balans. Slabije legirane klase obično imaju otpornost na tačkastu koroziju bolju ili na istom nivou kao i standardne austenitne klase [1, 2].

Klasifikacija u tabeli 1 je neizbežno donekle arbitražna, pošto ne postoji standardizovani ili generalno dogovoreni metod grupisanja dupleks čelika. Međutim, namera je bila da se grupišu čelici na način koji odražava sastav i svojstva, ukazujući koje se klase mogu smatrati savremenim i koristeći zajedničku definiciju superdupleksa kao čelika sa minimalnim ekvivalentom otpornosti na tačkastu koroziju ( $PRE_N$  ili  $PRE_W$ ) od 40. Vrlo skoro je klasa 24% Cr LDKS 2404 grupisana zajedno sa standardnom klasom 22% Cr na osnovu svoje vrednosti  $PRE_N$ .

Za manje legirane klase "siromašne" se prvenstveno koristilo za klase gotovo bez Mo sa niskim sadržajem Ni [1]. Međutim, i klase sa srednjim sadržajem Mo ili sa značajnim Cu-dodacima ovde su klasifikovane kao "siromašne" jer imaju značajno niže vrednosti  $PRE_N$  od standardnih 22% Cr klasa. Za veoma visoko legirane klase, postoji slični problem u definisanju granične linije između superdupleksa i hiperdupleksa. U ovom radu klase se smatraju hiperdupleksom kada su vrednosti  $PRE_N$  ili  $PRE_W$  blizu ili iznad 50.



UNS No. USN br.	EN No. EN br.	Common designation Uo bičajena oznaka	Main alloying elements Glavni legirajući elementi							PRE <sub>N</sub>	PRE <sub>W</sub>
			Cr	Ni	Mo	N	Cu	W	Other Ostalo		
<b>Early grades</b> <b>Ranije klase</b>											
S32900	1.4460	329	25	5.5	1.7	0.09				32.0	32.0
S31500	1.4424	3RE60	18.5	4.5	2.6	0.07				28.2	28.2
S32404		UR50	21	6.5	2.5	0.07	1.5			30.4	30.4
<b>Contemporary grades</b> <b>Savremene klase</b>											
<b>Lean duplex, PRE<sub>N/W</sub> ~ 20-30</b> <b>Siromašni dupleks, PRE<sub>N/W</sub> ~ 20-30</b>											
S32001	1.4482	19D	20	1.6		0.13	0.3		5 Mn	22.1	22.1
S32101	1.4162	LDX 2101	21.5	1.5	0.3	0.22	0.3		5 Mn	26.0	26.0
S32202	1.4062	UR2202	22	2	0.3	0.2	0.2			26.2	26.2
S82011		ATI 2102	21.5	1.5	0.3	0.22			2.5 Mn	26.0	26.0
S32304	1.4362	2304	22.5	4.8	0.3	0.1				25.1	25.1
	1.4655	-	23	4.5	0.3	0.1	2			25.6	25.6
S32003		ATI 2003	21.5	3.5	1.8	0.18				30.3	30.3
<b>Standard 22% Cr duplex, PRE<sub>N/W</sub> ~ 35</b> <b>Standardni 22% Cr duplex, PRE<sub>N/W</sub> ~ 35</b>											
S82441	1.4462	LDX 2404	24	3.6	1.6	0.27			3 Mn	34.0	34.0
S31803	1.4462	2205	22	5.3	2.8	0.16				34.0	34.0
S32205	1.4462	2205	22.3	5.7	3.2	0.18				35.7	35.7
<b>25% Cr duplex, PRE<sub>N/W</sub> ~ 35-40</b> <b>25% Cr Dupleks, PRE<sub>N/W</sub> ~ 35-40</b>											
S31200		44LN	25	5	2	0.15				34.0	34.0
S31260		DP3	25.2	7.2	3.2	0.14	0.5	0.3		38.0	38.5
S32506		SD40	25	6.5	3.3	0.17				38.6	38.6
S32550	1.4507	255	26	5.5	3	0.17	1.7			38.6	38.6
S32950		7Mo Plus	26.5	4.5	1.5	0.25				35.5	35.5
<b>Superduplex, PRE<sub>N/W</sub> ~ 40-50</b> <b>Superdupleks, PRE<sub>N/W</sub> ~ 40-50</b>											
S32520	1.4507	2507Cu	25	7	3.5	0.25	1.5			40.6	40.6
S32750	1.4410	2507	25	7	4	0.27				42.5	42.5
S32760	1.4501	Zeron 100	25.4	6.9	3.8	0.27	0.7	0.7		42.3	43.4
S32808		DP28W	27.5	7.7	1	0.35		2		36.4	39.7
S32906	1.4477	SAF 2906 <sup>®</sup>	29	7	2.3	0.35				42.2	42.2
S39274		DP3W	25	7	3.2	0.26	0.5	2		39.7	43.0
S39277		AF918	25.5	7.3	3.8	0.26	1.7	0.9		42.2	43.7
<b>Hyperduplex, PRE<sub>N/W</sub> ~ &gt; 50</b> <b>Hiperdupleks, PRE<sub>N/W</sub> ~ &gt; 50</b>											
S32707		SAF 2707 HD <sup>®</sup>	27	6.5	4.8	0.4			1 Co	49.2	49.2
S33207		SAF 3207 HD <sup>®</sup>	32	7	3.5	0.5				51.6	51.6
<sup>a</sup> Average of steel producers' data when available. Otherwise based on standards and specifications. <sup>a</sup> Srednja vrednost podataka proizvođača kada sun a raspolaganju. U suprotnom, zasnovan na standardima ili specifikacijama <sup>b</sup> PRE <sub>N</sub> = Cr + 3.3 × Mo + 16 × N. <sup>c</sup> PRE <sub>W</sub> = Cr + 3.3 × (Mo + 0.5 × W) + 16 × N.											

**Table 1.** Typical content [wt. %] of main alloying elements and Pitting Resistance Equivalents (PRE<sub>N</sub><sup>b</sup> and PRE<sub>W</sub><sup>c</sup>) of common wrought duplex stainless steels

**Tabela 1.** Tipični sadržaj (tež.%) glavnih legirajućih elemenata i ekvivalenata otpornosti na tačkastu koroziju (PRE<sub>N</sub><sup>b</sup> i PRE<sub>W</sub><sup>c</sup>) uobičajenih dupleks nerđajućih čelika



### 3. Welding recommendations

The overall aim of welding recommendations is to assist welding engineers in designing welding procedures. These procedures should reliably and with desired productivity result in weldments fulfilling requirements on mechanical properties and corrosion resistance.

Although it should be made clear that microstructural features are not to be confused with properties, it is important to be aware that they will govern the performance of the weldment. Welding therefore has to be performed in such a way that a suitable ferrite content (Figure 1) and freedom from deleterious phases, such as nitrides or intermetallics, is ensured in the weld metal and the heat-affected zone [7, 12, 13].

Generally speaking, too rapid cooling may result in excessive amounts of ferrite and nitride formation in all duplex stainless steels, although austenite formation occurs at higher temperature and is more extensive in grades with higher nitrogen content. Slow cooling, or repeated heating to temperatures in the range of approximately 600-1000 °C, will on the other hand result in formation of intermetallic phases in particular in the more highly-alloyed grades [11]. In practice intermetallic formation will rarely be a problem in welding of standard or lean grades, whereas strict control of welding procedures is required for highly-alloyed superduplex and hyperduplex grades. Whenever unwanted phases form or the ferrite content is excessively high, toughness and corrosion resistance will suffer. Carbide formation is not discussed here; as modern duplex stainless steels are very low in carbon and chromium-carbide formation is, therefore, not a practical problem.

Recommendations aiming at controlling the microstructure can broadly speaking be divided into two categories:

1. Methods of controlling the cooling rate including pre-heat and interpass temperature and arc energy (heat input).
2. Composition of the fused weld metal that is governed by choice of steel grade, filler material, shielding gas and dilution

### 3. Preporuke za zavarivanje

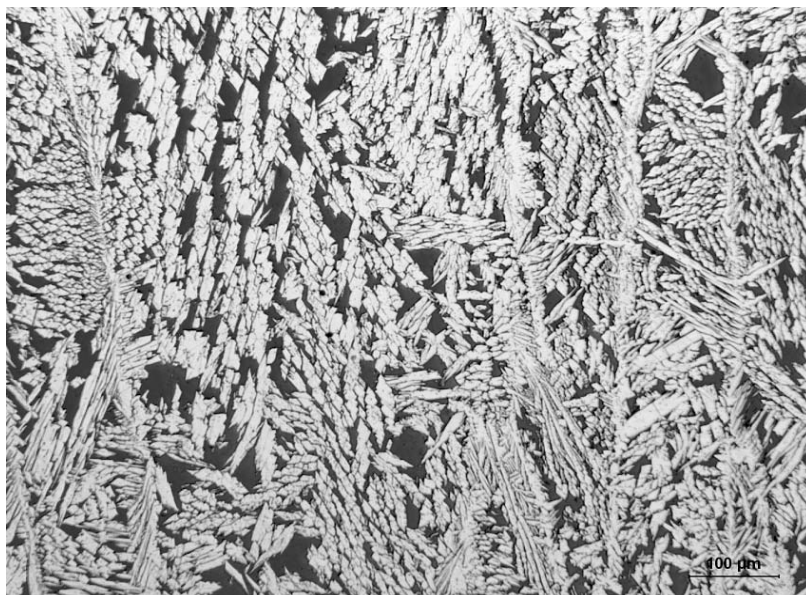
Opšti cilj preporuka za zavarivanje je pomoć inženjerima zavarivanja u izradi tehnologija zavarivanja. Ove tehnologije treba pouzdano i uz željenu produktivnost da rezultuju zavarivanjem koje ispunjava zahteve mehaničkih svojstava i otpornosti na koroziju.

Iako bi trebalo da bude jasno da mikrostrukturne karakteristike ne treba mešati sa svojstvima, važno je imati u vidu da će oni upravljati osobinama zavarenog elementa. Zbog toga, zavarivanje mora biti izvedeno tako da se u metalu šava i zoni uticaja toplote [7, 12, 13] obezbeđuje odgovarajući sadržaj ferita (slika 1) i bez štetnih faza, kao što su nitridi ili intermetalne faze.

Uopšteno govoreći, suviše brzo hlađenje može rezultovati prevelikim količinama ferita i nitrida u svim dupleks nerđajućim čelikama, iako se formiranje austenita javlja na višoj temperaturi i obimnije je kod klasa sa većim sadržajem azota. Sporo hlađenje ili ponovljeno zagrevanje u opsegu temperature od oko 600-1000 °C, s druge strane, će rezultovati stvaranjem intermetalnih faza, naročito kod više visoko legiranih klasa [11]. U praksi, intermetalna faza će retko biti problem u zavarivanju standardnih ili siromašnih klasa, dok je stroga kontrola tehnologije zavarivanja potrebna za visoko legirane superdupleks i hiperdupleks klase. Kad god je oblik neželjene faze ili sadržaj ferita izuzetno visok, žilavost i otpornost na koroziju će trpeti. Ovde se ne govori o formiranju karbida; budući da moderni dupleks nerđajuć čelici imaju vrlo nizak sadržaj ugljenika i nastanak hrom-karbida, praktično i nije problem.

Preporuke koje imaju za cilj kontrolu mikrostrukture mogu se široko razdvojiti u dve kategorije:

1. Metode kontrole brzine hlađenja, uključujući temperaturu predgrevanja i međuslojnu temperaturu i energiju luka (uneta toplota)
2. Sastav metala šava, koji se reguliše odabirom klase čelika, dodatnog materijala za zavarivanje, zaštitnog gasa i stepena mešanja.



*Ferrite is coloured blue and austenite is white.  
Ferit je obojen plavo a austenit belo.*

**Figure 1.** Example of desired duplex weld metal microstructure, free from intermetallic phases and nitrides and with suitable ferrite/austenite balance

**Slika 1.** Primer poželjne mikrostrukture metala šava, bez intermetalnih faza i nitrida sa pogodnom odnosom ferit/austenit

### 3.1 Arc energy and interpass temperature

Recommended maximum interpass temperature and arc energy ranges are presented in Table 2. There is sometimes some confusion regarding recommendations as the heat input is often incorrectly used synonymously with arc energy (or energy input). In this paper recommendations are therefore presented as arc energy (alternatively energy input) regardless of the terminology used in the source. Arc energy does not consider the efficiency of individual welding methods and is therefore a somewhat arbitrary guideline but on the other hand practical for general recommendations. The arc energy ranges should obviously be used as indications (see e.g. example in Figure 2), as they consider neither the efficiency of the welding method nor the thickness of the material.

Tables 2 and 3 present a summary of feedback received on a request for information circulated to a number of highly-regarded experts within the worldwide welding community, including users and producers of steel and welding consumables. The replies reflect the opinion as of today. Lack of data on some steel grades appearing in Table 1 indicates less interest and experience of these grades within the group who replied but does not suggest that these steels are less suitable or less weldable than comparable grades. Fortunately replies were received for grades within each of the groups in Table 1 permitting an overview and comparison of welding characteristics as presented in Tables 2 and 3.

### 3.1 Energija luka i međuslojna temperatura

Preporučena maksimalna međuslojna temperatura i opseg energije luka prikazani su u tabeli 2. Nekoliko je zabuna u vezi sa preporukama, jer se unos toplote često pogrešno koristi kao sinonim za energiju luka (ili unos energije). U ovom radu su preporuke prezentovane kao energija luka (alternativno unos energije) bez obzira na izvornu terminologiju. Energija luka ne uzima u obzir efikasnost pojedinačnih postupaka zavarivanja i stoga je donekle proizvoljna smernica, ali s druge strane je praktična za opšte preporuke. Očigledno je da energetski opseg treba koristiti kao indicaciju (videti primer na slici 2), jer ne uzima u obzir efikasnost postupka zavarivanja ni debljinu materijala.

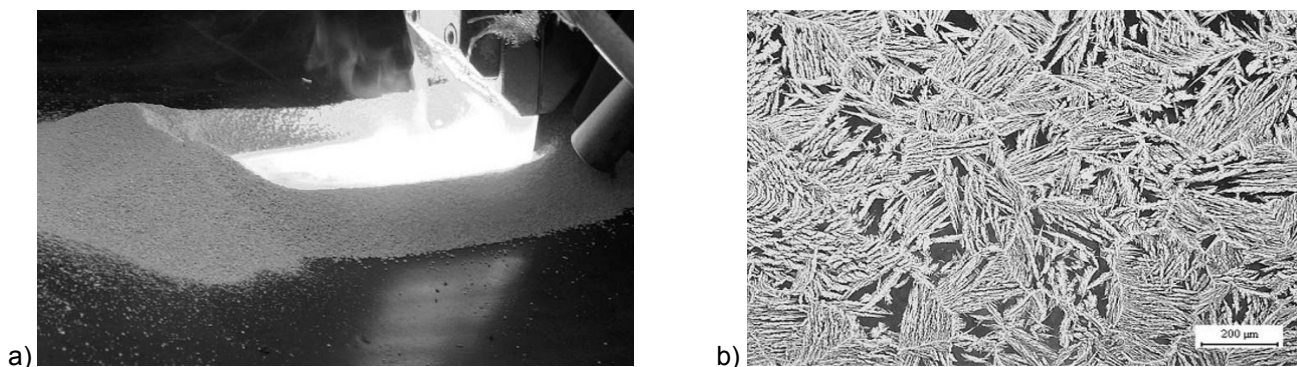
Tabele 2 i 3 predstavljaju rezime povratnih informacija dobijenih po zahtevu od velikog broja visoko cenjenih eksperata u okviru svetske asocijacije za zavarivanje, uključujući korisnike i proizvođače čelika i potrošnih materijala za zavarivanje. Odgovori odražavaju sadašnje mišljenje. Nedostatak podataka o nekim vrstama čelika koje se pojavljuju u Tabeli 1 ukazuju na manje interesovanja i iskustva sa ovim klasama u grupi koja je odgovorila, ali ne ukazuje na to da su ovi čelici manje pogodni ili manje zavarljivi od uporedivih klasa. Na sreću su dobijeni odgovori za klase unutar svake od grupa u tabeli 1 koja omogućava pregled i upoređivanje karakteristika zavarivanja kao što je prikazano u tabelama 2 i 3.



UNS No. UNS br.	EN No. En br.	Common designation Uobičajena oznaka	Max.interpass [°C] Maksimalna međuslojna	Arc energy <sup>a</sup> [kJ/mm] Energija luka		Comments <sup>b</sup> Komentari <sup>b</sup>
				Min.	Max.	
<b>Early grades/ Ranije klase</b>						
S31500	1.4424	3RE60	250	0.5	2.5	
<b>Contemporary grades/Savremene klase</b>						
<b>Lean duplex, PRE<sub>N/W</sub> ~20-30/ Siromašni dupleks</b>						
S32101	1.4162	LDX 2101	150/250	0.1/0.5	1.5/2.5	< 1.0 kJ with SAW/sa EPP
S32202	1.4062	UR2202	150	0.5	2	
S82011		ATI 2102	150/250	0.5/1	3	
S32304	1.4362	2304	150/250	0.5	2.5	> 1.5 kJ/mm for SAW, t = 16 mm
S32003		ATI 2003	150/250	0.5/1.0	2/2.5	
<b>Standard 22% Cr duplex, PRE<sub>N/W</sub> ~35</b>						
S31803	1.4462	2205	150/250	0.5	2/2.5	> 1 kJ/mm for SAW, t = 16 mm
S32205	1.4462	2205	150/250	0.4/0.5	2.5/3.5	
<b>25% Cr duplex, PRE<sub>N/W</sub> ~35-40</b>						
S32550	1.4507	255	120/150	0.5	1.5/1.8	
<b>Superduplex, PRE<sub>N/W</sub> ~40-50</b>						
S32520	1.4507	2507Cu	120/150	0.5	1.5/1.8	
S32750	1.4410	2507	100/150	0.2/0.3	1/1.5	> 0.5 kJ/mm for SAW, t= 16 mm, < 2.5 kJ/mm for SAW, >12 mm
S32760	1.4501	Zeron 100	100/150	0.3/0.5	1.5/1.8	
S32906	1.4477	SAF 2906 <sup>®</sup>	100/150	0.2/0.5	1.5	< 2.5 kJ/mm for SAW, t > 12 mm
<b>Hyperduplex, PRE<sub>N/W</sub> ~&gt; 50</b>						
S32707		SAF 2707 HD <sup>®</sup>	100	0.2	1.5	< 2 kJ/mm for SAW, t > 15 mm
S33207		SAF 3207 HD <sup>®</sup>	100	0.2	1.0	
<sup>a</sup> Arc energy (Energy input): $E = (\text{Voltage} \times \text{Current}) / \text{Welding speed (travel speed)}$ / Energija luka (Uneta energija) $E = (\text{Napon} \times \text{Jačina struje}) / \text{Brzina zavarivanja (brzina kretanja)}$ <sup>b</sup> Generally Uočeno < 0.5 kJ/mm if t < 2 mm.						

**Table 2.** Recommended maximum interpass temperature and arc energy (energy input) intervals for a selection of duplex stainless steel grades

**Tabela 2.** Preporučeni intervali maksimalne međuslojne temperature i energije luka (unos energije) za izbor klase dupleks nerđajućeg čelika



**Figure 2.** An appropriate ferrite/austenite balance was achieved and the weld metal was free from intermetallics.

**Slika 2.** Odgovarajući odnos ferit/austenit je postignut i u metalu šava nema intermetalnih faza

a) The cladding was deposited with electroslag strip cladding in one layer using a 60 mm wide strip consumables with a linear energy input of approximately 11 kJ/mm

a) Prevlaka je naneta navarivanjem pod troskom trakom širine 60 mm sa unetom linijskom energijom od približno 11 kJ/mm

b) Microstructure of 22 %Cr duplex cladding layer on mild steel

b) Mikrostruktura nanetog sloja od 22% dupleks čelika na ugljenični čelik

Nastavak u sledećem broju