Željko Potkonjak [1,a], Murali Kumar [1,b], Fiazal Hussain [1,c], Rinshad Rahiman [1,d]

INFLUENCE OF VARIOUS PURGING GASES ON PITTING CORROSION RESISTANCE OF SUPER DUPLEX WELDED PIPES

UTICAJ PRIMENE RAZLIČITIH ZAŠTITNIH GASOVA SA UNUTRAŠNJE STRANE KORENA SUPER DUPLEKS CEVNIH ZAVARENIH SPOJEVA NA OTPORNOST PREMA TAČKASTOJ KOROZIJI

Original scientific paper / Originalni naučni rad

Paper received / Rad primljen

August 2024.

Paper accepted / Rad prihvaćen

February 2025.

Author's address / Adresa autora

[1] Drydocks World Dubai, PO. Box 8988, Dubai, UAE

Email / ORCID ID

[a] potkonjakz@drydocks.gov.ae / 0009-0004-1360-8418
[b] / 0009-0000-3272-0123
[c] / 0009-0005-7080-3647
[d] / 0009-0003-4403-9388

Keywords: super duplex stainless steel, gas tungsten arc welding, ASTM G48, purging gases, pitting corrosion

Ključne reči: super-dupleks nerđajući čelici, TIG zavarivanje, ASTM G48, tačkasta korozija, zaštitni gasovi

Abstract

Super duplex stainless steel (SDSS) is widely utilized in demanding industries like offshore energy, chemical, and petrochemical sectors due to its exceptional pitting corrosion resistance and mechanical properties. However, welding SDSS presents significant challenge, particularly in meeting stringent pitting corrosion test standards, influenced by various parameters such as consumables, gas combinations, and heat input controls. This study investigated the utilization of different purging gas combinations (100% Ar, 98% Ar + 2% N_2, 100% N_2) during gas tungsten arc welding (GTAW) using the Bohler Thermanit 25/09 welding consumable while keeping a constant shielding gas composition (98% Ar + 2% N_2). Welding was conducted on 6-inch, Sch 80s, ASTM A790, UNS S32750 under identical parameters for all purging gas combinations. The weld root underwent pitting corrosion testing as per ASTM G48, method A, for 24 h at temperatures of 35 and 40°C, with a maximum acceptable weight loss criterion of 4 g/m^2. Results indicated that only 100% N_2 purging gas achieved corrosion test success at 40°C with minimal weight loss. Furthermore, at 35°C, weight loss decreased significantly across all purging gas combinations. Microstructural analysis of the weld root revealed no significant metallurgical anomalies.
The study concludes that 100% N_2 purging gas enhances the pitting resistance of super duplex welded pipes, noting its cost-effectiveness and availability compared to other inert gas mixtures.

Rezime

Super-dupleks nerđajući čelici nalaze široku primenu u zahtevnim oblastima kao što su morska naftna postrojenja, hemijska i petrohemijska industrija zbog njihove izuzetne otpornosti na tačkastu koroziju kao i odličnih mehaničkih osobina. Medjutim, zavarivanje super-dupleks čelika predstavlja značajan izazov, posebno vezano za ispunjavanje kriterijuma prihvatljivosti otpornosti na tačkastu koroziju prilikom kvalifikacije procedura zavarivanja. Ovaj rad obrađuje uticaj tri razlicite kombinacije zaštitnih gasova sa unutrašnje strane za zavarivanje korena zavara (100% Ar, 98% , Ar + 2% N_2, 100% N_2) TIG postupkom na otpornost zavarenog spoja super-dupleks nerđajućih čelika prema tačkasto koroziji. Zavareni uzorci su podvrgnuti testiranju prema standardu ASTM G48 – A Metod, 24 h na 35 i 40°C koristeći kriterijum prihvatljivosti maksimalnog dozvoljenog gubitka težine od 4 g/m^2. Rezultati su pokazali da samo 100% N_2 postiže zadovoljavajuće rezultate u pogledu gubitka mase na 40°C. Analiza mikrostrukture nije pokazala nikakve vidljive strukturne anomalije u smislu formiranja neželjenih intermetalnih faza.

Studija je pokazala da se korišćenjem 100% N_2 značajno poboljšava otpornost na tačkastu koroziju cevnih zavarenih spojeva super-dupleks nerđajućih čelika uz istovremeno značajno smanjenje troškova proizvodnje

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The paper was published in its original form in the Proceedings of the 33rd Conference with international participation "Welding 2024" held in Vrnjačka Banja, Serbia from October 2 to 5, 2024.

1. Introduction

SDSSs are widely used across various industries, especially in harsh environments requiring materials with exceptional resistance to corrosion. The term “Super-Duplex” denotes a highly alloyed, high-performance duplex steel with a pitting resistance equivalent[1] (PREN) of >40. Referred to as duplex because of its mixed microstructure with approximately equal proportions of ferrite and austenite. This two-phase microstructure guarantees higher resistance to pitting and stress corrosion cracking in comparison with conventional stainless steels [1].

Cost, availability, and performance are all major factors in material selection [2]. As industry standards evolve, there is an increasing demand for materials suitable for design life requirements extending up to 50 years. SDSS offers a favorable balance between these three criteria making it a strong candidate for such stringent design.

Aside from the excellent corrosion performance of the base material, quality control of SDSS fabrications is another important factor in ensuring localized corrosion resistance at the welded joints. Due to the complex metallurgy of SDSS, welding processes can lead to possible precipitation of undesirable intermetallic phases and compounds inducing a decrease in toughness and/or corrosion resistance [3].

During welding qualifications, the ASTM G48 (Method A) corrosion test is frequently employed to evaluate the localized pitting corrosion resistance of SDSS in chloride-containing environments [4]. Recently, the industry-standard test temperature for this procedure has decreased from 40°C to 35°C, though many end-user specifications still mandate the original 40°C [5]. The primary purpose of the G48 test, in relation to weld metal, is to determine whether intermetallic phases or other corrosion-sensitive defects have formed during the welding process [6, 7].

The primary aim of the G48 test is to simulate the environment within a localized corrosion site on a given stainless-steel surface. As per the Method A test procedure, A corrosion test coupon is exposed to a 6% $FeCl_3$ solution for a short time (24 h) at a material specific temperature range. At the end of the test, the specimen is examined for weight loss and pitting corrosion against the required acceptance criteria.

Traditionally, 100% argon (Ar) has been used as a purging gas to prevent oxidation of the root pass and minimize the formation of heat tint oxide scales adjacent to the weld. However, fabricators have also utilized gas mixtures such as 98% Ar + 2% nitrogen (N_2) and 100% N_2. Currently, the preferred purging gas in the industry is 100% Ar [8]. However, during welding trials at Drydocks World, some failures were reported during Procedure Qualification Record (PQR) corrosion testing. These failures were like those reported and investigated by others and have been attributed to N_2 loss from the root pass [9]. The extent of nitrogen loss is influenced by the nitrogen concentration gradient between the purge gas and the weld metal [10, 11]. A reduction in N_2 results in a decreased PREN[1], leading to reduced corrosion resistance of the austenitic phase and subsequent preferential corrosion in the weld root during the G48 test [12].

In this study, the corrosion performance of SDSS in the weld root was investigated, particularly in relation to the G48 test, using different purging gases (100% Ar/ 98% Ar + 2%N_2/ 100% N_2).

2. Materials and methods

2.1. Base material and welding consumables

Welding was performed on 6-inch Sch 80S ASTM A790 S32750 pipes using the Gas Tungsten Arc Welding (GTAW) process. This paper focused on using welding consumable Bohler Thermanit 25/09 (AWS A5.9, ER2594) with a diameter of 2.4 mm. The chemical compositions of the base material and consumable are provided in Table 1.

[1] PREN = %Cr + (3.3 x %Mo) + (16 x %N) initially derived by K Lorenz, G. Medawar, Thyssenforschung 1, 3 (1969): p. 97-108

Table 1. *Chemical composition (wt.%) and PREN of parent pipe and weld consumable*

Tabela 1. *Hemijski sastav (mas.%) i PREN osnovne cevi i dodatnog materijala za zavarivanje*

Item	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	W	N	PREN
S32750	0.01	0.36	0.76	0.022	0.001	25.2	7.0	3.79	0.27	-	0.29	>40
Thermanit 25/09	0.01	0.44	0.37	0.021	0.001	25.05	9.41	3.87	0.10	0.02	0.26	42

2.2. Gas combinations and welding parameters

Three purging gas combinations were used:

a. 100% Ar (99.995% Ar),

b. 98% Ar + 2% N_2, and

c. 100% N_2, (>99.9% N_2)

The welding trials were performed in the 5G position. For consistency, the shielding gas composition was kept the same (98% Ar + 2% N_2) throughout the study.

Welding was conducted with controlled heat inputs (maximum of 1.5 kJ/mm) and interpass temperatures kept below 100°C. Cold pass technique was employed, and oxygen content in the purging gas was maintained below 100 ppm. Shielding gas flow rates were maintained between 10 and 15 l/min, while purging gas flow rates ranged from 20 to 25 l/min. Key welding parameters are detailed in Table **2**.

Table 2. *Welding process parameters used for each welding trial with different purging gases*

Tabela 2. *Parametri procesa zavarivanja korišćeni za svaki ispitni zavar sa različitim zaštitnim gasovima za zavarivanje korenog zavara*

Welding Trial	Purging	Consumable	Amperage (A)	Voltage (V)	Welding speed (mm/min)	Heat Input (kJ/mm)
100Ar.Thr	100% Ar	Thermanit 25/09	81 - 160	9.5 - 13.5	49 - 122	0.54 - 1.11
98Ar.Thr	98%Ar+2%N_2	Thermanit 25/09	73 - 160	10.4 -13.6	31 - 106	0.78 - 1.39
100N2.Thr	100%N_2	Thermanit 25/09	86 - 165	10.2 -13.5	51 - 111	0.60 - 1.11

2.3. Post-welding inspection plan

Following the completion of welding trials 100Ar.Thr, 98Ar.Thr, and 100N2.Thr, several inspection tests were completed, including the ASTM G48 test. Details have been provided in following sections.

2.3.1. Visual inspection

All welding trials were visually assessed according to Norsok M-601 Annex B for discoloration.

2.3.2. Radiographic examination

All welding trials underwent radiographic examination in accordance with EN ISO 10675-1 (Level 1).

2.3.3. G48 Pitting corrosion test

As per ASTM G48 Method A, corrosion test coupons were prepared with full wall thickness (25 mm along the weld and 50 mm across the weld) and pickled in a 20% HNO_3 + 5% HF solution at 60°C for 5 minutes. After pickling, the corrosion test coupons were exposed to a 6% $FeCl_3$ solution for 24 hours at 40°C and 35°C.

2.3.4. Ferrite content examination

Ferrite content was determined using the manual counting method as per ASTM E562. Only the weld root analysis has been included for the purpose of this study.

2.3.5. Microstructural examination

Specimens were etched in a 40% NaOH solution and then examined under bright microscopic light (50× to 500×). The present study dealt solely with the weld root analysis.

2.3.6. Charpy V-Notch impact test

Charpy impact tests were conducted in accordance with ASTM A370. Only the weld centerline for the 100 N_2 purging gas was assessed.

3. Results and discussion

3.1. Visual examination results

Welding trials *100Ar.Thr, 98Ar.Thr* and *100N2.Thr* underwent visual examination. The 100% N_2 purging gas welding trials exhibited less heat tinting compared to those welded with 100% Ar and 98% Ar + 2% N_2. The reduced discoloration observed with 100% N_2 could be attributed to its superior inertness, which more effectively displaced oxygen and other reactive gases, thereby minimizing oxidation and heat tinting on the weld surface. In contrast, while both 100% Ar and the Ar-

N_2 mixtures also offered protection against oxidation, they were less effective than 100% N_2 in maintaining a cleaner weld appearance. These findings highlighted the benefits of using 100% N_2 for achieving optimal weld quality and visual aesthetics in highly demanding applications.

3.2. Radiographic examination results

Welding trials *100Ar.Thr, 98Ar.Thr* and *100N2.Thr* underwent radiographic examination. The examination results were considered acceptable with no indications of porosity. This result demonstrated that the choice of purging gas, whether it is 100% Ar, 98% Ar + 2% N_2, or 100% N_2, did not adversely affect the weld quality in terms of defects. Notably, the absence of porosity in the trial welded with 100% N_2 highlighted that, despite its distinct chemical properties, nitrogen provided effective shielding without compromising the integrity of the weld, underscoring the gas's suitability in producing high-quality welded joints.

3.3. G48 Pitting corrosion test results

The ASTM G48 Method A test was completed as detailed in section 2.3.3. Results are detailed below and shown in Figure 1.

3.3.1. Tests at 40°C

Trial 100Ar.Thr exhibited weight loss of 53 g/m² at the 6 o'clock position and 2.29 g/m² at the 9 o'clock position.

Trial 98Ar.Thr showed weight loss of 61.8 g/m² at the 6 o'clock position and 26.04 g/m² at the 9 o'clock position.

Trial 100N2.Thr achieved near-zero weight loss of 0 g/m² at the 6 o'clock position and 0.09 g/m² at the 9 o'clock position, with no visible pits under 20X magnification. This demonstrates the highest pitting resistance among all conditions tested.

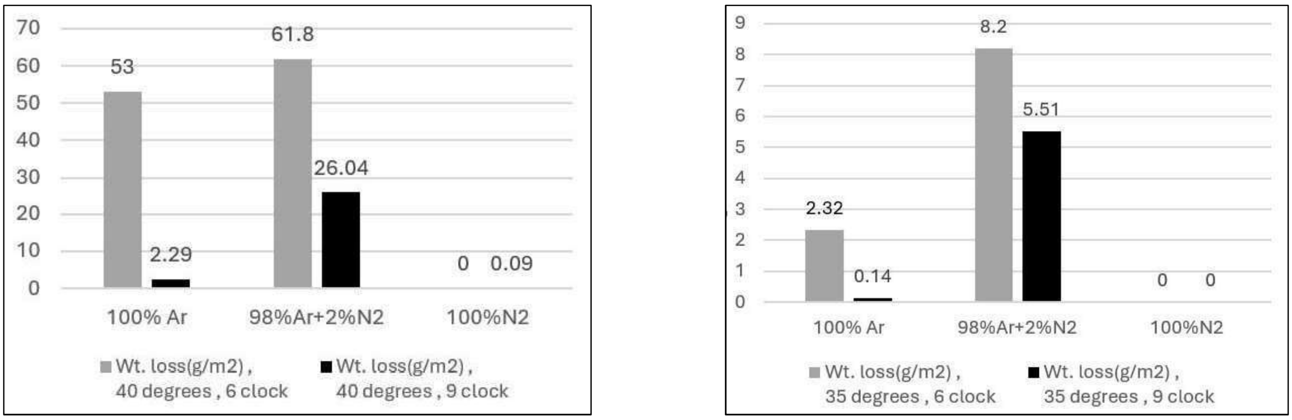
3.3.2. Tests at 35°C

Trial 100Ar.Thr exhibited weight loss of 2.32 g/m² at the 6 o'clock position and 0.14 g/m² at the 9 o'clock position. Minor pitting was observed at the root surface in the 6 o'clock position.

Trial 98Ar.Thr showed weight loss of 8.2 g/m² at the 6 o'clock position and 5.51 g/m² at the 9 o'clock position, with formation of root pits.

Trial 100N2.Thr achieved negligible weight loss of 0 g/m² at the 6 o'clock position, demonstrating the best corrosion resistance with minimal pitting.

Like the results at 40°C, 100% N_2 purging gas consistently provided the best pitting resistance at 35°C.



(A) Tested at 40°C *(B)Tested at 35°C*

(A) Testirano na 40°C *(B) Testirano na 35°C*

Figure 1. *Summary of G48, Method A, weight loss measurements (g/m²). All tests were made in 6% $FeCl_3$ at 40°C (A) and 35°C (B).*

Slika 1. *Rezime merenja gubitka mase (g/m²) prema metodi G48, Metod A. Sva ispitivanja su izvedena u 6% $FeCl_3$ na 40°C (A) i 35°C (B).*

3.4. Ferrite examination test results

Ferrite content was evaluated and the results are illustrated in Figure 2.

The examination was performed using the manual counting method in accordance with ASTM E562.

Trial 100Ar.Thr displayed a ferrite content of 53% in both the weld root. The high ferrite content was consistent with the use of 100% Ar as the purging gas, which did not significantly affect the ferrite stability.

Trial 98Ar.Thr displayed a slight reduction in ferrite content, with 51% ferrite in the weld root. The presence of 2% N_2 in the purging gas contributed to a modest decrease in ferrite content, though it remained relatively high compared to the 100% N_2 condition.

Trial 100N2.Thr showed a significant reduction in ferrite content, with values dropping to 34% in the weld root. The drastic reduction was attributed to the role of N_2 as a strong austenite stabilizer, which promotes the formation of austenite and reduces the amount of ferrite in the weld.

The ferrite examination confirmed that the choice of purging gas had a notable impact on ferrite content in super duplex welds. The use of 100% N_2 as a purging gas resulted in a substantial decrease in ferrite content due to its austenite stabilizing effect. This finding supports the conclusion that 100% N_2 not only enhances pitting corrosion resistance but also significantly alters the microstructural properties of the weld metal, aligning with its role as a strong austenite stabilizer.

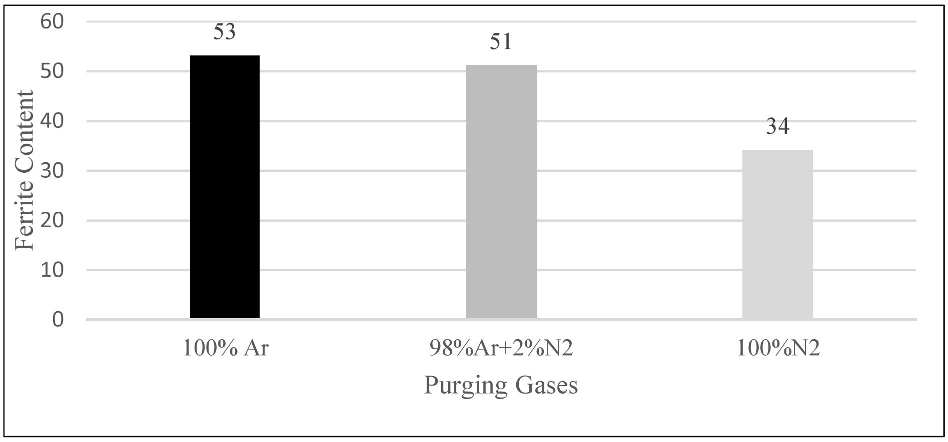


Figure 2. *Summary of ferrite content examination of the weld roots using different purging gases.*

Slika 2. *Rezime ispitivanja sadržaja ferita u korenu zavara pri upotrebi različitih zaštitnih gasova za izavarivanje korenog zavara.*

3.5. Microstructural analysis

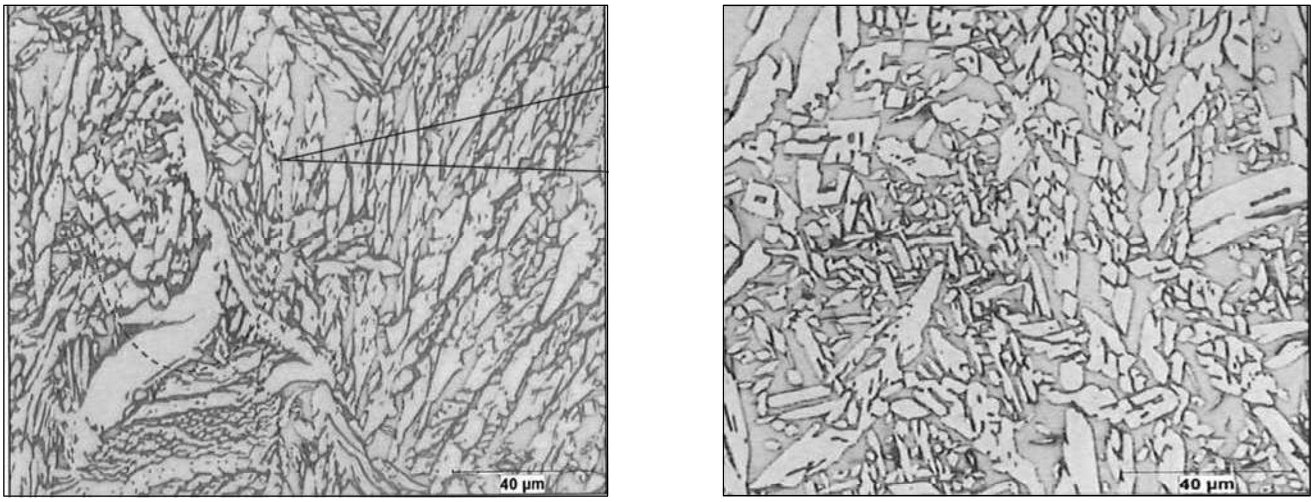
Microstructural analysis was performed across all welding trials. The findings are presented in in Figures 3A, 3B and 3C.

The microstructure of *Trial 100Ar.Thr* exhibited a combination of ferrite and austenite, along with the presence of secondary austenite. The weld root showed evidence of intermetallic sigma phase, which was confirmed by V2LA etching. Fine and secondary austenite pockets were noted, indicating a generally stable microstructure with some localized phase formation.

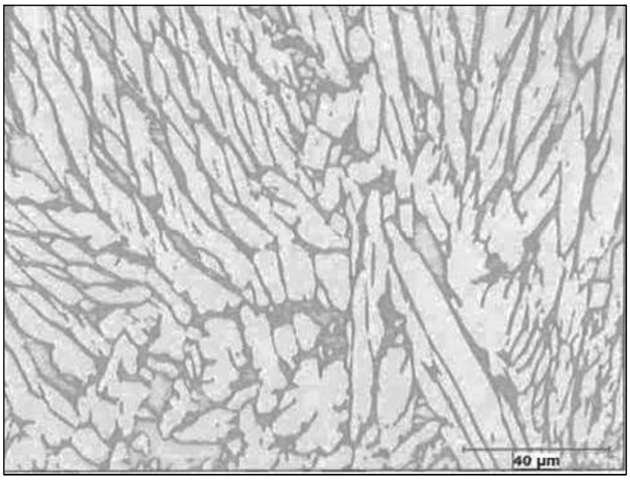
The microstructure of *Trial 98Ar.Thr* also revealed a combination of ferrite and austenite, including secondary austenite. No metallurgical anomalies such as carbides, nitrides, or intermetallic phases were detected in the weld root. Although anomalies were absent in the standard examination, it was noted that the sample failed corrosion testing.

Trial 100N2.Thr displayed a microstructure of ferrite and austenite, including secondary austenite. No metallurgical anomalies such as carbides, nitrides, or intermetallic phases were observed in the weld root. The absence of detrimental phases and the stable microstructural properties aligned with the excellent pitting resistance demonstrated by this welding trial.

The microstructural examinations confirmed that the choice of purging gas affects the microstructure of SDSS weld root. The use of 100% N_2 purging gas resulted in a stable microstructure without significant metallurgical anomalies, consistent with the observed superior pitting corrosion resistance. The presence of secondary austenite and the absence of detrimental phases such as sigma phase or carbides contributed to the overall integrity of the weld. Further analysis of the corrosion-failed samples could provide additional insights into the correlation between the microstructure and corrosion performance.



(A) *100Ar.Thr* (B) *98Ar.Thr*



(C) *100N2.Thr*

Figure 3. *Microstructures of weld root runs for the welding trials using different purging gas combinations; including 100% Ar (A), 98% aAr + 2% N_2 (B) and 100% N_2 (C)*

Slika 3. *Mikrostrukture korena zavara u slučajevima ispitnih zavara izvedenih sa različitim kombinacijama zaštitnih gasova za zavarivanje korenih zavara: (A) 100% Ar, (B) 98% Ar + 2% N_2 i (C) 100% N_2*

3.6. Charpy V-Notch impact test results

Given the superior performance in pitting corrosion tests with 100% N_2 purging gas, Charpy impact testing was conducted to assess the impact toughness of the welds at -46°C. The results are summarized in Table 3.

Despite meeting the minimum acceptance criterion of 27 J, the impact toughness results were not as promising as anticipated. Several coupons welded in the 5G position exhibited reduced impact energy, indicating a potential compromise in toughness. This outcome is noteworthy considering the improved pitting resistance associated with the use of 100% N_2 purging gas.

The observed decrease in impact toughness could be attributed to the high nitrogen content in the weld, which can form chromium nitrides. The formation of these nitrides might contribute to embrittlement and reduced impact energy. Further analysis will be performed to understand the specific effects of nitrogen on the mechanical properties and to determine if there are any correlations between the presence of nitrides and the observed decrease in impact energy.

Table 3. *Summary of Charpy impact testing for 100N2.Thr welding trials*

Tabela 3. *Rezime Charpy ispitivanja udarne žilavosti 100N2.Thr ispitnih zavara*

Charpy Impact Trial and sample	WCL 1	WCL 2	WCL 2	Average
100N2.Thr 10x9x55	52 J	47 J	65 J	55 J
100N2.Thr 10x7.5x55	28 J	35 J	35 J	33 J

4. Future directions

While the use of 100% N_2 and 98% Ar + 2% N_2 combinations demonstrates superior pitting corrosion resistance, excessive nitrogen can lead to the formation of chromium nitrides, which might adversely affect toughness properties. Additionally, high nitrogen content can further reduce ferrite levels that typically fall within the commonly accepted range of 30–70%.

To address these issues, future research will focus on the following approaches:

- *Modified Gas Combinations*: Trials will be conducted using 100% N_2 as the purging gas while employing 100% Ar as the shielding gas. This combination aims to reduce nitrogen content and mitigate the formation of chromium nitrides, potentially improving toughness without compromising corrosion resistance.
- *Filler Material Adjustments*: The use of 1.6 mm diameter filler rods will be evaluated for the initial three passes of welding. This adjustment is intended to provide better control over the weld pool and improve overall weld quality, potentially balancing the impacts of nitrogen on both microstructure and mechanical properties.

These modifications will help optimize the balance between corrosion resistance, toughness, and ferrite content, ensuring that the welds meet the required performance standards.

5. Conclusions

- *Optimal pitting corrosion resistance* – The use of 100% N_2 as a purging gas, combined with a shielding gas of 98% Ar/2% N_2, delivers the best pitting corrosion performance for super duplex stainless steel welded pipes, meeting ASTM G48 Method A test requirements at both 40 and 35°C.
- *Variation in weight loss* – Weight loss observed in corrosion tests was notably higher at the 6 o'clock position of the weld coupon compared to the 3 o'clock and 9 o'clock positions. This variation is attributed to the start/stop points of welding and the relatively higher oxygen content during the initial phases of welding.
- *Performance of other gas combinations* – While 100% Ar and 98% Ar/2% N_2 purging gas combinations also provide acceptable pitting corrosion resistance, they are more suitable for applications where the corrosion test temperature is limited to 35°C.
- *Impact on ferrite and austenite content* – The use of 100% N_2 as a purging gas significantly reduces ferrite content and increases austenite in the weld root. This change contributes to enhanced corrosion resistance, highlighting the benefits of nitrogen in stabilizing austenite.
- *Radiographic evaluation* – No evidence of porosity was detected in radiographic evaluations of welds made with 100% N_2 purging gas, indicating that the use of nitrogen does not adversely affect the quality of the weld.

5. Zaključci

- *Optimalna otpornost na tačkastu koroziju* – Upotreba 100% N_2 kao zaštitnog gasa za zavarivanje korenog zavara u kombinaciji sa zaštitnim gasom 98% Ar/2% N_2, je ostvarila najbolju otpornost na tačkastu koroziju kod zavarenih cevi od super-dupleksnog nerđajućeg čelika, ispunjavajući zahteve ASTM G48 (Metod A) testa na temperaturama od 40 i 35°C.
- *Varijacije u gubitku mase* – Gubitak mase tokom korozionih ispitivanja bio je znatno veći na poziciji 6 sati na zavarenom uzorku u poređenju sa pozicijama 3 i 9 sati. Ova varijacija je pripisana početnim i završnim tačkama zavarivanja, kao i relativno višem sadržaju kiseonika u početnim fazama zavarivanja.
- *Performanse drugih gasnih kombinacija* – Iako su kombinacije zaštitnih gasova za zavarivanje korenog zavara 100% Ar i 98% Ar/2% N_2 takođe obezbedile prihvatljivu otpornost na tačkastu koroziju, one su ipak pogodnije za primene gde je temperatura korozionog testa ograničena na 35°C.
- *Uticaj na sadržaj ferita i austenita* – Upotreba 100% N_2 zaštitnog gasa za zavarivanje korenog zavara je značajno smanjila sadržaj ferita i povećala udeo austenita u korenu zavara. Ova promena poboljšava otpornost na koroziju, ističući prednosti azota u stabilizaciji austenita.
- *Radiografska evaluacija* – Nisu otkriveni znaci poroznosti u radiografskim analizama zavara izvedenih sa 100% N_2 kao zaštitnim gasom za ispiranje, što ukazuje na to da azot ne utiče negativno na kvalitet zavara.

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4. Međunarodna konferencija o procesima zasnovanim na trenju – 2025

6–8. septembar 2025, IIT Tirupati, Indija

Indijski institut za tehnologiju Tirupati (IITT), zajedno sa Indijskim institutima za tehnologiju u Patni (IITP) i Dharvadu (IITDh), kao i Indijskim institutom za nauku u Bangalore-u (IISc), organizuje 4. Međunarodnu konferenciju o procesima zasnovanim na trenju (ICFP 2025) od 6. do 8. septembra 2025. godine na IITT. Ova konferencija, sa tradicijom dugom 10 godina (od 2014.), predstavlja globalnu platformu za najnovija dostignuća u proizvodnim procesima zasnovanim na trenju, koji se primenjuju u različitim materijalima i industrijama. Obuhvata širok spektar naučnih tema – od osnovnih mehanizama deformacije materijala do industrijskih primena inženjerskih materijala. Fokus je na naprednim metodama trenja u metaloprerađivačkoj industriji, zavarivanju trenjem, linearnom zavarivanju trenjem, aditivnoj proizvodnji zasnovanoj na trenju i srodnim procesima. Konferencija će okupiti istraživače, inženjere i stručnjake iz industrije, čime će doprineti jačanju saradnje između industrijskih kompanija, istraživačkih laboratorija i akademskih institucija. Izvor: https://www.iitdh.ac.in/4th-international-conference-friction-based-processes-2025-iit-tirupati-india-during-6-8-september

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7. Međunarodna konferencija o zavarivanju i ispitivanju bez razaranja i

25. Nacionalna konferencija o zavarivanju i inspekciji i

14. Nacionalna konferencija o NDT i

3. Nacionalna konferencija o aditivnoj proizvodnji

Iranski institut za zavarivanje i ispitivanje bez razaranja (IWNT) organizuje „7. Međunarodnu konferenciju o zavarivanju i ispitivanju bez razaranja“ u saradnji sa Univerzitetom Malek Ašar. Ova konferencija je jedno od vodećih međunarodnih okupljanja posvećenih inovativnim i fundamentalnim dostignućima u oblasti nauke i inženjerstva zavarivanja, kao i ispitivanja bez razaranja. Cilj konferencije je pružanje foruma za naučnike, inženjere i studente iz akademske i industrijske zajednice širom sveta kako bi predstavili svoja istraživanja, podelili najnovija naučna i tehnička dostignuća, razmenili ideje i iskustva, uspostavili poslovnu ili istraživačku saradnju i pronašli globalne partnere za buduće projekte. Pored konferencijskih sesija, događaj će uključivati radionice, izložbe, panel diskusije, kao i takmičenja u tehničkim i fotografskim disciplinama, a u organizaciji stručnjaka iz akademske i industrijske sfere. Izvor: https://www.icwndt.ir/en/index.php

Bojan Gligorijević