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Studies on Pitting Corrosion Behaviour and Haz of GTAW of SDSS

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Abstract: Corrosion due to pitting and heat affected zone (HAZ) in weldments are the serious problems for any welding industry, which reduces the service life of the product. It is a challenging task for a metallurgist to solve the above problem. Super-duplex stainless steels present excellent combination of mechanical and corrosion resistance, due to their strict composition control and ferrite austenite phase balance. This balance may however be disturbed during welding in both the fusion and HAZ due to the rapid cooling rates and may lead to loss of the good corrosion and mechanical properties of the weldments. All the data have been collected through various literature surveys and journals. The required proposed welding procedure specification is prepared to conduct the welding test.Two experiments are carried out to analyze the issues. One weldment by argon and another weldment by argon with 2% nitrogen mixture as inert gas by Gas Tungsten Arc Welding process. Various tests will be carried out on the welded test specimen and the results will be anlysed.

Key words: Affected zone (HAZ) in weldments · Welding industry · Stainless steels present · Austenite phase balance

INTRODUCTION

"Super" duplex grades have enhanced pitting and crevice corrosion resistance when compared with 300-series austenitic stainless steels or conventional duplex alloys. This can be attributed to the enhanced levels of chromium, molybdenum and nitrogen found in these materials. Alloy 2507 is the most common "super" duplex grade.Super duplex stainless steels are a family of grades combining good corrosion resistance with high strength and ease of fabrication. Their physical properties are between those of the austenitic and ferritic stainless steels and tend to be closer to those of the ferritic and to carbon steel. These steels are very attractive for various applications because of their advantages

Literature Research: C.T. Kwok, S.L. Fong, F.T. Cheng, H.C. Man are explained about the pitting and galvanic corrosion behaviour on the autogenenous laser welded specimens of austenitic and duplex stainless steels weldments in Argon atmosphere [1]. Bravo Ivan Mendoza, Zepeda Cuauhtemoc Maldonado, Hernandez Apolinar Albiter, Piedras Eduardo Robles are details about the Dissimilar welding of superduplex stainless steel for offshore Applications joined by GTAW process and analyse the chemical composition,micro structural behaviour and HAZ portion due to welding [2]. Bengt Wallen, who analyses the corrosion rate of the Duplex and super duplex stainless steels in sea water applications and compare the behaviour of super duplex steel with super austenitic stainless steel [3].

Objective of the Research:

- To check and compare the pitting corrosion behaviour of the super duplex stainless steel weldments by using the shielding gases Argon and Argon with Nitrogen
- To analyze the HAZ area due to welding
- To check the brittle fracture behavior of the specimen by conducts the impact test at-30°C.
- To check the chemical properties of the weldment by chemical analysis.
- To calculate the heat input of welding on the specimen.

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- To check the Hardness at welding and HAZ portions.
- To study the microstructure of the specimen
- To calculate the pitting corrosion Equivalent number

Scope of the Research:

- All the above said objectives with respect to the results will be analysed and come to the conclusion that which gas could be better for GTAW process.
- This analysis (parameters) would be used for future projects in the SDSS area.
- It helps to manufacture the good strength and corrosion less products, also can satisfy the end users.

Requirements to Carry out the Test:
Material:

- Super duplex stainless steel plate: Grade S32750
- Size: 10 x 150 x 300-4 nos

Filler metal:

- SAF 2507

Machine:

- GTAW machine

Gas:

- Argon
- Argon + 2% Nitrogen mixer

Wps :

- Proposed Welding procedure specification

Tools:

- Purging attachements

Welder:

- Skilled and Qualified Tig welder

Environment:

- Clean room facility
- Testing Lab Facility

Types of Test to Be Carried out

- ASTM G48-Method 'A'
- Tensile test
- Impact test at -30°C
- Hardness test at weld and HAZ portions
- Chemical Analysis
- Microstructure analysis
- PREN Calculation

ASTM G48: These test methods cover procedures for the determination of the resistance of stainless steels and related alloys to pitting and crevice corrosion (see Terminology G 15) when exposed to oxidizing chloride environments. Six procedures are described and identified as Methods A, B, C, D, E and F. Method A-Ferric chloride pitting test.

Pitting Resistance Equivalent Number (PREN): The Pitting Resistance Equivalent number (PREN) has been found to give a good indication of the pitting resistance of stainless steels. The PREN can be calculated as:

PREN = %Cr + 3.3 x %Mo + 16 x %N

Heat Input Calculation [1]:

$$\text{Heat input [J/mm]} = \frac{\text{Current x Voltage}}{\text{Travel speed}} \left[\frac{\text{A x V}}{\text{mm /sec}} \right]$$

Recommended Heat Input

Steel	Heat Input (kJ/mm)	Inter pass Temperature (°C)
SAF 2304	0.5-2.5	< 250
SAF 2305	0.5-2.5	< 250
SAF 2307	0.2-1.5	< 150

Physical property of SDSS:

- Density : 0.28 lb/in3
- Modulus of Elasticity : 29 psi x 106
- Coefficient of Thermal Expansion 68-212°F/°F : 7.2 x10-6/°F
- Thermal Conductivity : 8.7 Btu/h ft °F
- Heat Capacity : 0.12 Btu/lb/°F
- Electrical Resistivity : 31.5 W-in x 10-6

Mechanical property of SDSS:

- Ultimate Tensile Strength : min 116 ksi
- 0.2% Offset Yield Strength : min 80 ksi.

- 0.1% Offset Yield Strength : min.91 ksi
- Elongation in 2 inches, % : 15 min
- Hardness Rockwell C : 32 max.
- Impact Energy : min 74 ft.-lbs

Applications of SDSS:

- Heat exchanger tubes and pipes for production and handling of gas and oil,
- Heat exchanger and pipes in desalination plants,
- Mechanical and structural components,
- Power industry FGD systems,
- Pipes in process industries handling solutions containing chlorides,
- Utility and industrial systems, rotors, fans, shafts and press rolls where the high corrosion fatigue strength can be utilized,
- Cargo tanks, vessels, piping and welding consumables for chemical tankers.
- High-strength, highly resistant wiring [4-9].

Stress Strain Curves of Various Steels: The below fig 3.2 gives the graphical representation of stress vs strain among the various duplex and super duplex stainless steel

Chemical Composition of SDSS: The below Table 3.1 shows the chemical composition by wt % of various duplex and super duplex stainless steel grades [9].

Welding Procedure Specification: Welding Procedure Specifications (WPS) This document details the practical application of the Procedure Qualification Record (PQR).

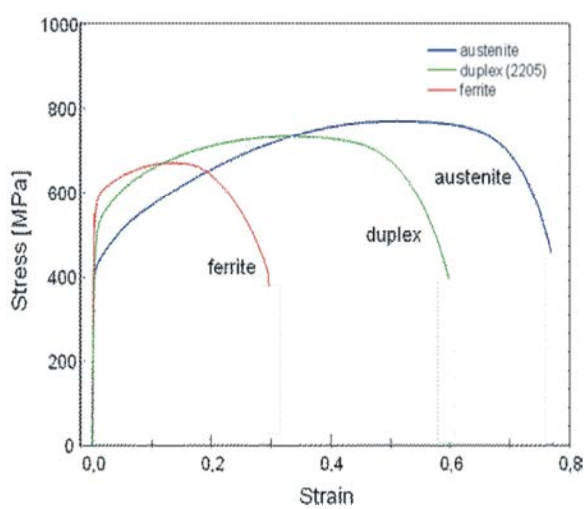

Fig 9.1: Stress strain curves-Austenite, ferrite and duplex

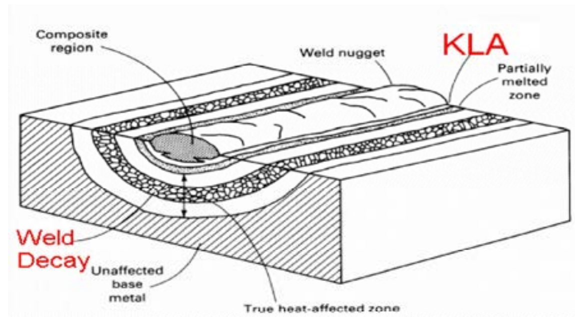

Fig 12.1: Detailed view of heat affected weld zones

It should contain enough information to give direction to the welder and should address all variables associated with the welding process defined in QW250 including non essential and supplementary.

Heat Affected Zone: The HAZ [10-13] is the portion of the weld joint which has experienced peak temperatures high enough to produce solid-state microstructural changes but too low to cause any melting. Every position in the HAZ relative to the fusion line experiences a unique thermal experience during welding, in terms of both maximum temperature and cooling rate [14] Thus, each position has its own microstructural features and corrosion susceptibility. The partially melted region is usually one or two grains into the HAZ relative to the fusion line. It is characterized by grain boundary liquation, which may result in liquation cracking. [15] These cracks, which are found in the grain boundaries one or two grains below the fusion line, have been identified as potential initiation sites for hydrogen-promoted underbead cracking in high-strength steel [16].

Regions in the Fusion Weld:

- Fusion Zone (Weld Material)
- Heat Affected Zone
- Base Material

Pitting Corrosion: Pitting corrosion, or pitting, is a form of extremely localized corrosion that leads to the creation of small holes in the metal. The driving power for pitting corrosion (Fig 12.1) is the depassivation of a small area, which becomes anodic while an unknown but potentially vast area becomes cathodic, leading to very localized galvanic corrosion. The corrosion penetrates the mass of the metal, with limited diffusion of ions. The mechanism of pitting corrosion is probably the same as crevice corrosion.[17-21]

Table 10.1: Details of Chemical composition of the SDSS metals (wt.%).

UNS No and Grades	Type	C	Mn	P	S	Si	Cr	Ni	Mo	N	Cu
S32205	2205	0.030	2.00	0.030	0.020	1.00	19.5-21.5	4.5-6.5	3.0-3.5	0.14-0.20	...
S32750	2507	0.030	1.20	0.035	0.020	0.80	24.0-26.0	6.0-8.0	3.0-5.0	0.24-0.32	0.50

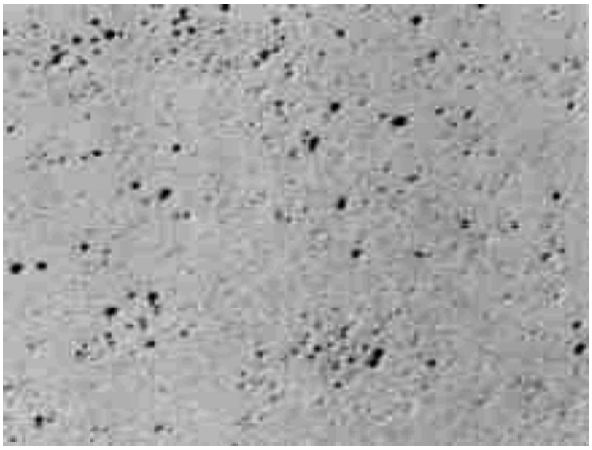

Fig 13.1: Schematic diagram of Pitting corrosion

Corrosion Categories: Corrosion of stainless steels can be categorized as one of [4]:

- General Corrosion
- Pitting Corrosion
- Crevice Corrosion
- Stress Corrosion Cracking
- Sulfide Stress Corrosion Cracking
- Intergranular Corrosion
- Galvanic Corrosion
- Contact Corrosion

Occurance of Pitting: Under certain conditions, particularly involving high concentrations of chlorides (such as sodium chloride in sea water), moderately high temperatures and exacerbated by low pH (i.e. acidic conditions), very localized corrosion can occur leading to perforation of pipes and fittings etc.

Critical Pitting Temperature: The above fig shows the occurances of pitting corrosion at various critical temperature [11]. This is based on a standard ferric chloride laboratory test, but does predict outcomes in many service conditions.

Corrosion causes Corrosion can cause a variety of problems, depending on the applications:

- Perforation, Loss of strength, Degradation of appearance, where corrosion products or pitting can detract from a decorative surface finish,

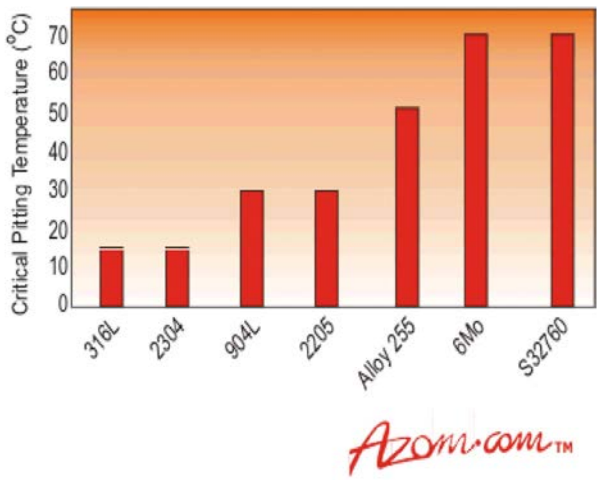

Fig 13.2: Temperature at which pitting corrosion is likely to occur.

- Finally, corrosion can produce scale or rust which can contaminate the material being handled; this particularly applies in the case of food processing equipment.

Shielding Gas

The Roll of Argon::

- It is an inert gas, which does not react in the welding process
- Consequently it does not promote oxidation or affect the chemical composition of the weld metal
- For this reason argon is widely used as the base gas in most of the shielding gases used for SS welding
- The argon arc is very directional with a tendency to give finger shaped penetration into the work piece.

The Roll of Nitrogen:

- Improving tensile strength and has a beneficial effect on resistance to pitting corrosion.
- Nitrogen can be advantageously added when welding nitrogen alloyed steels such as S32205,S32750,254 SMO
- The addition of upto 2% nitrogen in a binary or tertiary gas mixture will raise the partial pressure of nitrogen above the weld pool.This helps to control the nitrogen content in the weld.

Inert gas of Argon Deatils (QW-408 A):

The below Table 15.4.1 shows the details of gas mixture composition and flow rate of argon.

Category	Gas(es)	Mix/ single	%Comp	Purity	Flow rate (Lpm)
Shielding	Argon	Single	NA	99.995%	10-15.
Trailing	-	-	-	-	-
Backing	Argon	Single	NA	99.995%	15-25.

Welding Parameters and Heat Input Calculation of Test Sample with Argon as Inert Gas

The below table 15.5.1 shows the details of welding parameter and its particulars.

Electrode/wire		Current					
AWS Class	Size (mm)	Type and Polarity	Amp	Voltage (Volts)	Speed (mm/ min)	Heat Input (J/mm)	Inter pass Temp (°C)
ER 2594	2	DC EN	85	11	55.4	1013	90-92
ER 2594	2	DC EN	100	12.3	77.4	953	90-92
ER 2594	2	DC EN	130	13.5	102.3	1029	90-92
ER 2594	2	DC EN	145	14	86.2	1413	90-92
ER 2594	2	DC EN	140	13.7	83.3	1382	90-92
ER 2594	2	DC EN	140	13.7	108	1066	90-92
ER 2594	2	DC EN	140	13.7	79	1457	90-92
ER 2594	2	DC EN	125	13	79	1234	90-92
ER 2594	2	DC EN	125	13	99.7	978	90-92

Inert gas of Argon + 2 % Nitrogen Deatils(QW-408 B)

The below table 15.6.1 shows the details of gas mixture composition and flow rate.

Category	Gas(es)	Mix/ single	%Comp	Purity	Flow rate (Lpm)
Shielding	Argon and N2	Mixture	98% Ar + 2% N2	99.995%	10-15.
Trailing	-	-	-	-	-
Backing	Argon and N2	Mixture	98% Ar + 2% N2	99.995%	15-25.

Welding parameters and Heat input calculation of test sample with Argon + 2% Nitrogen mixture as inert gas

The below table 15.7.1 shows the details of welding parameter and its particulars.

Electrode/wire		Current					
AWS Class	Size (mm)	Type and Polarity	Amp	Voltage (Volts)	Speed (mm/ min)	Heat Input (J/mm)	Inter pass Temp (°C)
ER 2594	2	DC EN	85	11	58.2	964	90-92
ER 2594	2	DC EN	100	12.2	78	938	90-92
ER 2594	2	DC EN	130	13.6	103.2	1028	90-92
ER 2594	2	DC EN	145	14.1	89.6	1369	90-92
ER 2594	2	DC EN	140	13.7	86.2	1335	90-92
ER 2594	2	DC EN	140	13.6	106.2	1076	90-92
ER 2594	2	DC EN	140	13.8	81	1431	90-92
ER 2594	2	DC EN	125	13.1	83.3	1179	90-92
ER 2594	2	DC EN	125	13.2	101.7	973	90-92

- The addition of nitrogen also compensates for losses in the arc during the welding of nitrogen alloyed steels.
- Nitrogen is a very important alloying element in DSS

  Improves corrosion resistance
  Improves austenite reformation

- At TIG welding, the loss of nitrogen is compensated by using Ar + 1-2%N2 as a shielding gas.

WPS and PQR Details
JOINTS (QW-402) Details

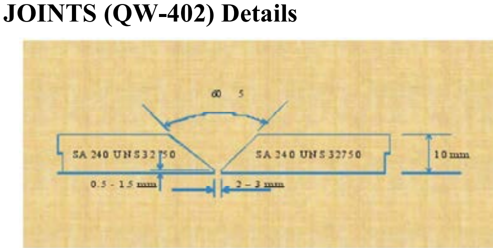

Fig 15.1: Shows the details of weld configuration

Electrical Characteristics (QW-409):

- Current AC or DC Polarity : DC
- Tungsten Electrode Size and Type : Ø 2.4 / 3.0 mm and EWTh2 (Pure Tungsten, 2% Thoriated, etc.)
- Volts (Range) : 15-16
- Amps (Range) : 110-150
- Mode of Metal Transfer for GMAW: NA
- Electrode Wire feed speed range: NA
- Pulsing Current: None
- Polarity : EN
- Heat input (J/mm):-
- Others : None

Technique (QW-410):

- String or Weave Bead: Root-String, Fill and Cap-Weave
- Orifice / Nozzle / Gas Cup Size : Ø 10/12/14 mm
- Method of Back Gouging: By grinding (where applicable)
- Initial and Interpass Cleaning : Brushing and Grinding
- Oscillation: NA
- Contact Tube to Work Distance: NA
- Multiple or Single Pass (per side): Multiple pass
- Multiple or Single Electrodes: NA
- Travel Speed (Range): See weld data sheet Table
- Peening: Not allowed
- Other: Weaving to be limited to 3 times of filler wire diameter
- Electrode spacing: NA
- Use of thermal process: None

CONCLUSION

This paper reveals all the data regarding the base material, filler metal, process and shielding gases have been collected and studied through various literature surveys and journals. Pitting corrosion behavior and heat affected zone are analyzed through various papers.

The required proposed welding procedure specification for super duplex stainless steel have been prepared with respect to the proposed WPS two sets of welding were carried out with argon and argon with 2% nitrogen as inert gases. All the essential parameters were noted during welding and heat inputs are calculated on the representative test specimen.

Procedure qualification record has been prepared based on the parameters noted during sample specimen welding. Moreover, characteristics and weldability of the super duplex stainless steel also been analyzed.

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