

Effect of Backing Gas Composition on Corrosion Behavior of Conventional Duplex Stainless Steel Weldments

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ABSTRACT

Duplex Stainless Steels (DSSs) are an attractive material solution in industry environments where the presence of chlorides and ammonium salts prevent the use of standard austenitic stainless steels, since these contaminants promote severe localized corrosion processes. In refining, as an example, UNS S32205 duplex stainless steel has been widely used in the past for some sections of Reactor Effluent Air-cooler (REAC) in hydrotreating plants, though it is currently being displaced by nickel-based alloys. One of the main reasons for such upgrading is the difficulties to keep corrosion properties of DSS during fabrication, which is assessed through standard tests such as ASTM⁽¹⁾ A - 923 Method C during welding procedure qualification.

As a matter of fact, welding affects the original base metal ferrite-to-austenite balanced ratio and therefore the corrosion performance of the weldment. The role of variables like welding heat input, shielding gas composition, and filler metal are well known and recorded in the technical literature. However, backing gas composition has not received enough attention.

This paper details the backing gas composition effect on the corrosion resistance of circumferential welds made on ASTM A - 790 S32205 pipes of NPS 4 (114.3 mm) diameter, wall thickness schedule 120 (11.13 mm). Four different gas mixtures were used. Standard tests require in any procedure qualification for DSSs were performed: weld metal and heat affected zone (HAZ) ferrite-to-austenite balance through metallographic examination and corrosion performance by means of standard ASTM A - 923 methods. Conclusions were drawn on the optimum backing gas that is recommended for the fabrication of DSS piping systems.

Key words: Welding, Stainless steel, Metallurgical failures, Pitting, Corrosives in refining process

⁽¹⁾ American Society of Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA.

INTRODUCTION

Duplex stainless steel (DSS) are widely used in the oil and gas industry in both upstream and downstream applications. Subsea production systems, pressure vessels and piping systems in petrochemical plants, crude units and hydrotreating units in refining plants are just some examples. DSS offer a combination of high strength and corrosion resistance, being an attractive alternative material in those applications where standard austenitic stainless steels are affected by stress corrosion cracking and severe pitting corrosion processes.

Welding is the most challenging aspect from a reliability stand point when DSS are applied. The effect of welding on original ferrite to austenite balance, precipitation of intermetallic phases, alloy element distribution and oxidation of root pass play a definite role in the corrosion resistance of the construction. Therefore, general procedure qualification rules of welding construction codes like ASME⁽²⁾ Section IX are not considered sufficient by most plant licensors and end users to guarantee the reliability of the installation. Additional requirements and control majors are usually defined. This paper focuses on one of these eventual prerequisites: backing gas composition.

The role of the backing gas is to avoid the oxidation of the root or first pass of the weldment during its execution. However, the backing gas can interact with the molten metal and hence affects the final chemical composition, microstructure and corrosion resistance of the first pass.

To shed some light on the effect of this variable, four test coupons made of from the same pipe were welded together by the same welder, with the same heats of filler metals but using four different backing gases. Results show that there is an effect of the backing gas composition on the corrosion resistance, but gas humidity is also a relevant factor to be considered by fabricators along with the control of the welding heat input and the usage of electrodes with basic coverings.

EXPERIMENTAL PROCEDURE

Four pipes made of ASTM A – 790 S32205 of NPS 4 (114.3 mm) diameter, wall thickness schedule 120 (11.13 mm) were welded together with different backing gases in order to assess their effect on the corrosion behavior of the weldment. Table 1 shows the backing gases used. The same heats of both base metal and filler metals were used. Welding was done with a combination of gas tungsten arc welding (GTAW) and shielded metal arc welding (SMAW). Chemical compositions of the heats are shown in Table 2. The ferrite content shown in the corresponded material certificate, either in percentage or ferrite number (FN) is also included. For GTAW process, welding grade argon was always used as shielding gas.

Welding parameters were monitored on each layer during the whole process (Tables 3 to 6) and the oxygen content into the bore of the pipe was kept below 0.05% through purge gas analyzer. Backing gas flow was continue until the completion of the cap passes. Interpass temperature was between 100 and 120 °C.

⁽²⁾ American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY10016-5990

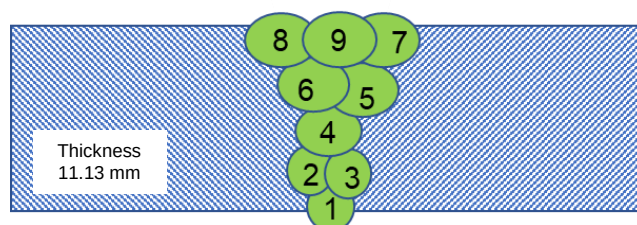


Figure 1: Welding joint. Layers 1-3 with GTAW process. Layers 4-9 with SMAW process

**Table 1
Backing gases used**

Backing gas	Composition	Impurities
1	Nitrogen (99.99%)	< 10 ppm H ₂ O < 10 ppm O ₂
2	Nitrogen (95%) – Hydrogen (5%)	< 5 ppm H ₂ O < 5 ppm O ₂
3	Argon (95%) – Hydrogen (5%)	
4	Argon (99.996%)	

**Table 2
Chemical composition of material used**

	C	Cr	Ni	Mo	N	Ferrite Content
Pipe Ø4 in. sch.120	0.017	22.35	5.50	3.21	0.177	46% Ferrite (measured by ASTM E-562)
GTAW ER-2209 Ø2.4 mm	0.008	22.8	8.8	3.10	0.14	58 FN (estimated with WRC-92)
SMAW E-2209-15 Ø2.5 mm	0.023	23.2	8.7	2.96	0.160	48 FN (estimated with WRC-92)

**Table 3
Welding parameters of test coupon with nitrogen (N₂) as backing gas**

Pass	Process	Current (A)	Voltage (V)	Travel speed (cm/min)	Heat Input (kJ/cm)
1	GTAW	149	10.0	4.6	19.4
1	GTAW	150	9.9	4.4	20.1
1	GTAW	159	11.2	5.0	21.4
2	GTAW	159	11.2	13.9	7.7
2	GTAW	159	10.9	12.5	8.3
3	GTAW	190	11.6	18.6	7.3
3	GTAW	190	11.5	18.8	7.0
4	SMAW	76	23.4	11.6	9.2
5	SMAW	77	23.8	8.6	12.8
6	SMAW	70	22.9	10.9	8.8
7	SMAW	71	23.0	8.8	11.1
8	SMAW	71	22.8	10.9	8.9
9	SMAW	71	22.6	7.8	12.3

Table 4
Welding parameters of test coupon with nitrogen (N₂) (95% volume) – hydrogen (H₂) (5% volume) as backing gas

Pass	Process	Current (A)	Voltage (V)	Travel speed (cm/min)	Heat Input (kJ/cm)
1	GTAW	136.4	11.4	4.3	21.6
1	GTAW	142	11.2	3.9	24.5
1	GTAW	141.8	11.5	4.1	24.1
2	GTAW	149.8	11.5	11.4	9.1
2	GTAW	149.5	12.0	12.9	8.3
3	GTAW	149.5	11.8	12.0	8.8
3	GTAW	149.5	12.2	11.0	9.9
4	SMAW	74	24.0	12.0	8.9
5	SMAW	75	23.8	10.7	10.0
6	SMAW	74	24.0	12.5	8.5
7	SMAW	72	23.0	11.0	9.0
8	SMAW	73	24.0	8.6	12.2
9	SMAW	71	24.0	8.9	11.4

Table 5
Welding parameters of test coupon with argon (Ar) (95% volume) – hydrogen (H₂) (5% volume) as backing gas

Pass	Process	Current (A)	Voltage (V)	Travel speed (cm/min)	Heat Input (kJ/cm)
1	GTAW	131.8	10.9	5.1	16.8
1	GTAW	131.5	10.7	4.1	20.6
1	GTAW	131.5	10.8	15.3	5.6
2	GTAW	152	12.3	15.9	7.0
2	GTAW	151.8	12.1	16.0	6.9
3	GTAW	152	11.8	8.9	12.2
3	GTAW	151.8	12.0	9.5	11.5
4	SMAW	74	23.5	13.3	7.8
5	SMAW	73	24.0	9.0	11.7
6	SMAW	72	23.0	13.1	7.6
7	SMAW	67	24.0	9.7	10.0
8	SMAW	69.5	24.0	10.5	9.5
9	SMAW	69.5	24.0	12.0	9.5

Welding parameters registered show fluctuations characteristic of manual welding. However, all the heat input figures are within the range typically allowed for DSSs in the industry: 5 – 25 kJ/cm.¹

Once welding was completed, the joints were examined radiographically not showing meaningful indications.

Table 6
Welding parameters of test coupon with argon as backing gas

Pass	Process	Current (A)	Voltage (V)	Travel speed (cm/min)	Heat Input (kJ/cm)
1	GTAW	145	10.1	6.0	14.6
1	GTAW	149	10.6	5.8	16.3
1	GTAW	149	10.1	5.1	17.9
2	GTAW	179	12.0	10.9	6.8
2	GTAW	179	12.0	13.2	9.8
3	GTAW	179	11.6	13.1	9.5
3	GTAW	179	11.3	13.5	9.0
4	SMAW	71	23.0	11.2	8.8
5	SMAW	74	23.3	7.6	13.5
6	SMAW	71	23.0	9.1	11.0
7	SMAW	70	22.3	9.8	9.5
8	SMAW	71.5	22.4	11.6	8.3
9	SMAW	73	23.5	7.1	14.5

The weldments were subjected to the following tests:

- Measurement of ferrite to austenite content in the deposit weld metal by ASTM E – 1245 in sections transverse to the weld.² Three areas were tested in each section: root pass, mid thickness and cover pass.
- Measurement of ferrite to austenite content in the heat affected zone (HAZ) by ASTM E – 1245. HAZ was deemed as fusion line plus 0.5 mm.
- Evaluation of the presence of intermetallic phases in test specimens which include base metal, HAZ and weld metal by means of ASTM A – 923 Method C.³
- Evaluation of the presence of intermetallic phase in the HAZ accordingly ASTM A – 923 Method B. HAZ was deemed as fusion line plus 0.5 mm.
- Microstructural characterization of the weldments by optical microscopy and scanning electron microscopy (SEM) and energy-dispersive X-ray spectrometry (EDS).
- Assessment of the presence of intermetallic phases through metallographic techniques.

RESULTS

Measurement of ferrite to austenite content. Weld metal

The method of image analysis in accordance with ASTM E – 1245 was chosen for the ferrite to austenite determination. It yields a precise estimation and it is faster than manual point counting method.⁴ Four sections were taken from each pipe. The sections were spaced 90° from each other. They were polished and etched with Beraha agent which colors the ferrite. The percentage of this latter phase was measured in three areas (root pass, mid thickness and cover pass) as shown in figure 2. The number of fields measured were between 20 and 30. A magnification of x300 was deemed enough to clearly resolve the microstructure.