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# *Evaluation of Dissimilar Joint Properties Between UNS S32750 and API X65*

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***ABSTRACT***

The excellent properties of super duplex stainless steels (SDSS) are mainly due to their balance of ferrite - austenite since this balance is highly likely to change during welding and undesirable phases can be created. In this work, gas tungsten arc welding (GTAW) process was used to join UNS S32750 SDSS to API X65 high strength low alloy (HSLA) steel. The properties of weldments were investigated by the impact test, potentiodunamic and cyclic polarization tests. Zero resistance ammeter (ZRA) tests were also used for investigation of behavior of galvanic corrosion on the weld metal – HSLA base metal. The results indicated that the amount of austenite in weld metal was higher than SDSS base metal and did not create undesirable phases. Toughness of weldment was higher than base metals and corrosion behavior of weld metal was like SDSS base metal and presented an excellent corrosion resistance comparing with HSLA base metal. The results of ZRA showed that HSLA was eroded in galvanic couple weld metal – HSLA and the mechanism of corrosion was pitting corrosion.

***KEYWORDS***

Super Duplex Stainless Steel, High Strength Low Alloy Steel, Welding, Toughness, Corrosion Behavior.

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## 1- INTRODUCTION

Duplex (DSS) and super duplex (SDSS) stainless steels consist of approximately equal amounts of austenite and ferrite, which combine the attractive properties of austenitic and ferritic stainless steels such as high strength, highly resistant to chloride stress corrosion cracking, and have excellent pitting and crevice corrosion resistance [1].

Due to their corrosion resistance and improved mechanical properties, these steels are extensively used in petrochemical and chemical industries as pipes, pumps, pressure vessels, separators and heat exchangers. Moreover, SDSS are widely used in offshore equipment in contact with aggressive chemicals such as $H_2S$, $CO_2$ and $Cl^-$.

The best properties of DSS and SDSS are obtained through the ferrite-austenite ratio close to 50: 50 [1]; and detrimental phases such as sigma (σ), chi (χ), secondary austenite ($\gamma_2$), chromium carbides and nitrides are not present, which affect the corrosion resistance and toughness in the SDSSs [2].

In welding operations, very low heat inputs lead to high ferrite contents and intense chromium nitride precipitation. On the other hand, high heat inputs and/or long exposure to temperatures in the 600–1000 ◦C range may cause precipitation of brittle intermetallic phases such as σ or χ [1, 2]. In general, welding specifications must be designed to obtain the phase proportions (ferrite/austenite ratio) near 1:1 and to avoid σ and Cr2N precipitation by controlling and limiting the heat input to 0.5–2.0 kJ/mm for DSSs and 0.5-1.5 kJ/mm for SDSSs.

With the growing application of new materials and higher requirements for the materials, a great need arises for the component or structure of dissimilar materials. Dissimilar joint of SDSS and high strength low alloy steel (HSLA) pipes have been widely employed in the oil and gas industry. The joining of dissimilar materials is generally more challenging than that of the similar materials because of differences in the chemical, physical and mechanical properties of the base metals welded [2].

Therefore, it is critical to understanding the microstructure–property relationships in joints between SDSS and HSLA. Although certain amounts of research work have been carried out on the microstructure and properties of dissimilar joints between SDSS and HSLA [3-4], the information on the properties of this joint, especially galvanic corrosion resistance, is very scarce. Therefore, the aim of this study is to describe the microstructural features and electrochemical behavior of dissimilar weld joints between an SDSS and a HSLA by potationdynamic, cyclic polarization and Zero resistance ammeter (ZRA) tests produced by gas tungsten arc welding (GTAW).

## 2- EXPERIMENTAL PROCEDURE

The materials employed in this study were API X-65steel and UNS S32750 SDSS, both supplied in seamless pipe shapes with an internal diameter of 508 mm (20 in) and nominal thickness of 4 mm (0.15 in). The GTAW process with direct electrode, negative polarity (GTAW-DCEN) was chosen for welding. Joint was carried out by GTAW with ER25.10.4.L consumable welding rod. The following were the welding parameters: current: 110A; voltage: 17 V; and welding speed: 1.42 mm $s^{-1}$.

The microstructural of weldments were examined by high-resolution optical microscope (OM), scanning electron microscope (SEM) and X-ray diffractometer (XRD). Impact tests of the weld joint were investigated in accordance with ASTM E23 with the sub-size dimension of 55mm×10mm×2.5mm at -20 $^{o}$C. The corrosion resistances of the base metals and WM were evaluated by potationdynamic and cyclic polarisation tests according to ASTM G5 and ASTM G61 standards, respectively. ZRA tests were also used for the investigation of behavior of galvanic corrosion on weld metal – HSLA base metal.

Microstructure of WM consisted of ferrite (δ), and austenite (γ) (Fig.1). Volume fraction of ferrite and austenite in WM was 37% and 63%. The large amount of austenite is attributed to chemical composition in filler metal – mainly the Ni and N elements content and migration of carbon element from HSLA to WM.

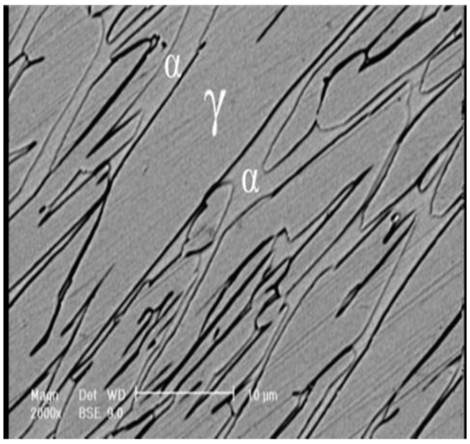


**Fig. 1: Microstructure of WM.**

Fig.2 shows X-ray diffraction pattern of SDSS and WM. Only δ and γ phases were detected and detrimental phases did not detect, which is advantageous to mechanical properties and corrosion resistance of the joint.

The results of Charpy impact test for base metals and weldment in -20$^{o}$C are given in Table 1. The fracture energy amounts of base metals and weldment determine that the ductile fracture happened to all of them, and fracture energy of weldment was higher than that of both base metals. High fracture of weldment is attributed to the volume fraction of the austenite (64%) in weld metal.

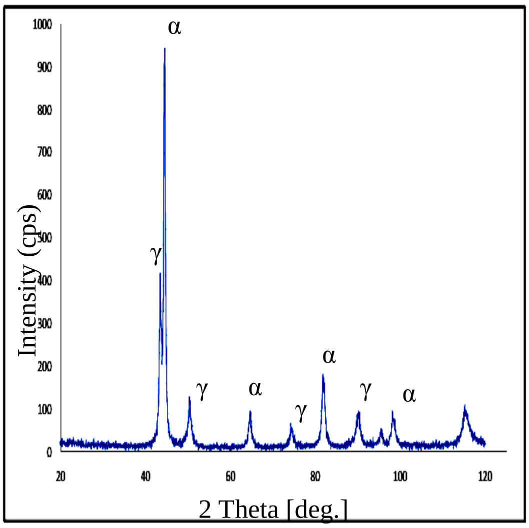


**Fig.2 X-ray diffraction pattern of SDSS and WM**.

**Table 1: Impact strength of base metals and WM**

| Sample | Impact strength (j) |
|---|---|
| High strength low alloy steel base metal | 33±2 |
| Super duplex stainless steel base metal | 33±2 |
| Weld sample | 41±2 |

During the test of ZRA galvanic current density is negative. Therefore, the anode and cathode of the pair are the HSLA base metal and WM respectively. In this study the galvanic current density and galvanic potential profiles present very few individual events, especially after the first hour of the test; this is typical in uniform corrosion processes.

The statistical analysis of signal fluctuation was used to obtain the localization index (LI). This index could be useful to discriminate between different corrosion mechanisms. LI was calculated as:

$$LI = \frac{\sigma_i}{i_{rms}} \qquad (1)$$

Where ($\sigma_i$) is standard deviation of the galvanic current density values and ($i_{rms}$) is the root mean square of the current density; therefore, LI is always between 0 and 1. Several authors indicate that LI values higher than 0.1

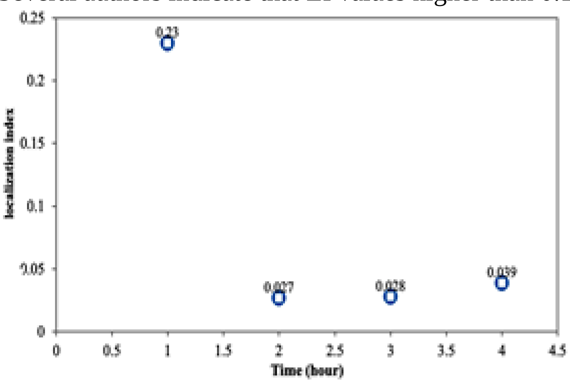


**Fig. 3: Localisation index (LI) values of the HSLA base metal/ WM pair calculated for each hour of the ZRA test at ambient temperature.**

are associated with a typical localized corrosion process, while LI values closer to 0 (lesser than 0.05 or 0.01, depending on authors) are associated with a uniform corrosion process [5].

Fig. 3 is shown the LI values of the HSLA base metal/ WM pair calculated for each hour of the test. The results indicated that during first hour, LI values are higher than 0.1, verifying that the probability of localized corrosion accrued, and after that, LI values are lower than 0.05, indicating uniform corrosion developed.

## 3- CONCLUSIONS

The investigation of welding between UNS S32750 SDSS and API X-65HSLA by GTAW reach the following conclusions:

•Toughness of weldment was higher than the base metals.

•Corrosion behavior of WM was like SDSS base metal and presented an excellent corrosion resistance compared to HSLA base metal.

•The results of ZRA showed that HSLA was corroded in the pair of HALA base metal/ WM. Scanning electron microscope (SEM) micrograph of HSLA base metal after ZRA test showed localized and uniform corrosion on the surface.

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