Engineering Science and Technology, an International Journal 19 (2016) 1076–1083

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: http://www.elsevier.com/locate/jestch

Full Length Article

Effect of welding parameters on pitting behavior of GTAW of DSS and super DSS weldments

Prabhu Paulraj *, Rajnish Garg

University of Petroleum & Energy Studies, Dehradun, Uttarakhand 248007, India

A R T I C L E I N F O

Article history:
Received 5 October 2015
Received in revised form
15 January 2016
Accepted 31 January 2016
Available online 19 February 2016

Keywords:
Duplex stainless steels
Super duplex stainless steels
GTAW
Pitting corrosion
Heat input
Secondary austenite
Inter-metallic phases

A B S T R A C T

This work focuses on the effect of welding parameters on corrosion behavior of welded duplex stainless steel (DSS) and super duplex stainless steel (SDSS). The effect of welding parameters, such as heat input, inter-pass temperature, cooling rate, shielding/back purging gas, on corrosion behavior was studied. DSS and SDSS pipes were welded with Gas Tungsten Arc Welding (GTAW) process. After welding, the test samples were non-destructively tested to ensure no defects and test samples were prepared for microstructural examinations and ferrite content measurements. The root region had complex microstructure because of the repetitive heating of the zone during different weld layers. It was observed that at low heat input desirable microstructure was formed. The test samples were subjected to corrosion tests, i.e. ASTM G48 test for the determination of pitting corrosion rate, potentiodynamic polarization tests, and potentiostatic tests to verify susceptibility of the alloys to corrosion attack. DSS weldments had CPT in between 23 °C to 27 °C and SDSS weldments had CPT between 37 °C to 41 °C in potentiostatic measurements. The corrosion test results were correlated to the microstructures of the weldments. The pitting resistance of individual phases was studied and the effect of secondary austenite on corrosion attack was also observed.

© 2016, The Authors. Publishing services by Elsevier B.V. on behalf of Karabuk University

1. Introduction

Duplex stainless steels (DSS) [22% Cr] and super duplex stainless steels (SDSS) [25% Cr] are composed of unique ferrite/austenite microstructure which makes them superior material than conventional AISI 316 austenitic stainless steels [1,2]. Super duplex stainless steels are upgraded versions of DSS. They exhibit a higher pitting resistance [Pitting Resistance Equivalent Number (PREN) > 40]. The combination of mechanical properties and the higher corrosion resistance make DSS and SDSS attractive materials in aggressive corrosive seawater environments.

GTAW uses a non-consumable tungsten electrode (EWTh2) to produce arc and filler wire to join the material and it is shielded by an inert gas like helium or argon to protect the molten weld pool from the atmospheric contaminants [3]. GTAW is a major fabrication process for DSS and SDSS materials being used in offshore and marine industries. Despite these advantages, mechanical and corrosion properties could be deteriorated if the weld parameters are not controlled during a welding operation. Rapid heating and cooling cycles may lead to ferritization and precipitation of hazardous inter-metallic phases like sigma, Chi, and secondary austenite. In order to take full benefits of mechanical and corrosion properties of DSS and SDSS, the welding thermal cycle should be controlled carefully.

The local breakdown of the passive protective layer is the cause of pitting in DSS and SDSS [4]. The susceptibility of pitting corrosion is measured by various tests namely, (a) gravimetric test (ASTM G48), (b) potentiodynamic polarization techniques (ASTM G5), and (c) critical pitting temperature (CPT) measurements (ASTM G150) [5]. Gravimetric tests measure the weight loss in the specimen after immersion of the sample in chloride solution. The polarization techniques analyze pitting potential (E_{pit}) and corrosion potential (E_{corr}) and corrosion current density (i_{corr}). The higher positive values of (E_{pit}), (E_{corr}) and ($E_{pit} - E_{corr}$) indicate better pitting corrosion resistance of the material. The CPT evaluation gives maximum allowable working temperature for the specimen by potentiostatic measurements.

The pitting resistance depends on number of variables like the austenite/ferrite ratio, the presence of inter-metallic phases, elemental partitioning between both phases, and PREN value. The PREN is a measure of pitting behavior of DSS and SDSS. It is given by the equation PREN = %Cr + 3.3%Mo + (16–30)%N. Due to different element partitioning and volume fraction, both phases have different PREN values. The pitting resistance of DSS and SDSS is controlled by PREN value of the weaker phase. It has been observed that the best corrosion resistance is achieved when both phases attain equal PREN value [6].

* Corresponding author. Tel.: +65 93627424, fax: +91 4312500133.
E-mail address: paulrajprabhu1@gmail.com (P. Paulraj).
Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2016.01.013
2215-0986/© 2016, The Authors. Publishing services by Elsevier B.V. on behalf of Karabuk University

Table 1
Base material chemical composition (% wt).

Material grade	Cr	Mo	Ni	N	C	PREN	Remarks
UNS S31803	22.9	3.03	7.92	0.15	0.017	35.15	DSS – Low PREN
UNS S31803	22.9	3.04	7.63	0.17	0.019	36.30	DSS – High PREN
UNS S32750	25.1	3.75	8.86	0.21	0.028	41.40	SDSS – High PREN
UNS S32750	25.1	3.71	8.9	0.2	0.016	40.36	SDSS – Low PREN

Recent studies have found that cooling rate is one of the important parameters to achieve a desired microstructure [7]. A slow cooling promotes a diffusion phenomenon, which leads to an efficient partitioning of phases. At the same time with slow cooling rates, there are chances of precipitation of unwanted inter-metallic phases such as sigma phase. A rapid cooling leads to equal partitioning of phases (i.e. partitioning coefficient = 1 for all elements), and it may also form hazardous chromium nitrides. Cooling rate depends on various parameters like the heat input ([current × potential]/travel speed), the inter-pass temperature, the material thickness, the thermal properties of material, etc. A cooling time between 1200 °C and 400 °C is more critical than a cooling rate in the lower temperature region, because in this temperature region, major austenite reformation and secondary phase precipitation might take place [8].

Shin et al. [9] studied the effect of the heat input on the pitting behavior of DSS welds. It was found that at the low heat input, insufficient reheating effect during subsequent passes caused formation of acicular type secondary austenite, which led to the reduction of the pitting resistance. Kordatos et al. [7] suggested that a continuous network of grain boundary austenite formed in the fusion zone after a faster cooling in the ferrite region restricts the corrosion propagation. Kobayashi et al. [10] quoted that secondary austenite is the reason for the loss of chemical balance and of the resistance of the passive layer. There have been a lot of researches on effect of post-weld heat treatments (solution annealing) of duplex stainless steels [11,12]. However, practically, it is very difficult from industry point of view to carry out solution annealing heat treatments for larger products. Hence, it is very important and necessary to control weld parameters, such as heating/cooling rates to get the best corrosion properties of the material.

From the literature review, it has been found that there have been limited studies on the corrosion behavior of welded DSS and SDSS. The main purpose in this work is to study the (a) effect of weld parameters like heat input ([current × potential]/travel speed), inter-pass temperature, cooling rate, and shielding/backing gases on the corrosion resistance of the weld. The following studies were undertaken in this work – (a) pitting resistance of welded pipe joints, (b) the CPT for DSS and SDSS weldments, (c) the correlation between pitting behavior and microstructure of the weldments, (d) the effect of phase balance on corrosion properties of the weld.

2. Experimental details

2.1. Materials

The materials used in this study were 50.8 mm (2 inch) pipes of DSS and SDSS with 5.54 mm thickness and 150 mm length. The materials were selected with varied composition in order to get low and high PREN values for our studies. Table 1 gives the chemical composition of materials used for welding experiments.

A typical microstructure of base material is shown in Fig. 1. The islands of austenite in the ferrite matrix are clearly observed.

The welding consumable filler-wire composition is given in Table 2. Filler wires used for our welding trials are manufactured by Sandvik, and 2 mm diameter wires were used for all welding trials.

2.2. Welding process

Gas Tungsten Arc Welding (GTAW) with Direct Current Electrode Negative (DCEN) polarity was used to weld the pipes. Welding was carried out (a) by varying welding heat input and (b) by varying shielding gas/back-purging gas composition and inter-pass temperature. The general welding specifications for first part of the study are given in Table 3.

In the second part of the work, welding experiments were carried out to study the effect of shielding gas, the purging gas, and the inter-pass temperature on the corrosion properties of DSS and SDSS by keeping other parameters constant. During experiments, one of the above parameters was varied and others were kept constant. Tables 4 and 5 show welding variable details of our studies. A mixture of argon and nitrogen (Ar + N) was used as shielding/purging gas.

In total, 24 joints were investigated in this study which can be summarized as: (a) four DSS – low PREN joints by varying the heat input; (b) four DSS – high PREN joints by varying the heat input;

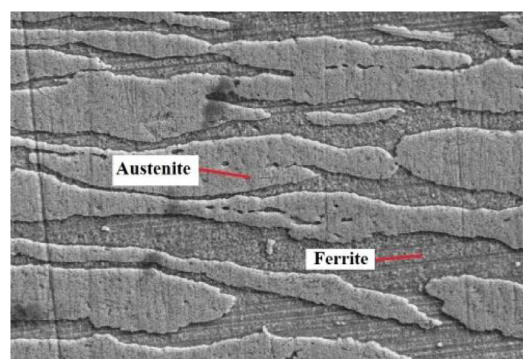

Fig. 1. Typical base material microstructure.

Table 2
Filler-metal chemical composition (% wt).

Base metal	Filler Grade	C	Si	Mn	P	S	Cr	Ni	Mo	N
DSS	22.8.3.L	≤0.02	0.5	1.6	≤0.02	≤0.015	23	9	3.2	0.16
SDSS	25.10.4.L	≤0.02	0.3	0.4	≤0.02	≤0.015	25	9.5	4	0.25

Table 3
Welding specifications.

Welding position	5G (Pipe fixed in horizontal position)
Groove design	Single V groove 70° groove angle 1 mm root face, 2.5 mm to 4 mm root gap
Welding current (A)	80–150
Arc voltage (V)	10–12
Welding speed (mm/min)	40–80
Number of weld passes	4–5
Inter-pass temperature (°C)	100–140
Gas flow rate (L/min)	13–18
Heat input (kJ/mm)	0.75–1.25

Download English Version:

https://daneshyari.com/en/article/477503

Download Persian Version:

https://daneshyari.com/article/477503

Daneshyari.com