

Polythionic Acid Stress Corrosion Cracking On Proprietary UNS S34751 Similar Welded Joint

Takahiro Osuki
Nippon Steel Corporation
1-8, Fuso-cho
Amagasaki, Hyogo 660-0891
Japan

Shinnosuke Kurihara
Nippon Steel Corporation
1-8, Fuso-cho
Amagasaki, Hyogo 660-0891
Japan

Kazuhiro Ogawa
Nippon Steel Corporation
1-8, Fuso-cho
Amagasaki, Hyogo 660-0891
Japan

Akira Seki
Nippon Steel Technology Corporation
1-8, Fuso-cho
Amagasaki, Hyogo 660-0891
Japan

Yuhei Suzuki
Nippon Steel Corporation
1, Nishino-cho, Higashi-mukojima
Amagasaki, Hyogo 660-0856
Japan

Masaki Ueyama
Nippon Steel Corporation
945 Bunker Hill, Suite 600
Houston, Texas 77024
U.S.A.

ABSTRACT

It was reported in NACE ⁽¹⁾ C2019-12783 that S34751 with extra low carbon content less than 0.015 wt% achieved superior Polythionic Acid Stress Corrosion Cracking (PTA SCC) resistance without Post Weld Heat Treatment (PWHT) in hydro-treating or hydro-cracking processes in a complex refinery.

However, PTA SCC resistance of Heat Affected Zone (HAZ) and weld metal for actual welded joint of S34751 was not included in NACE C2019-12783 because of the usage of S34751 test sample with simulated HAZ heat treatment using high frequency induced heating equipment.

In this research, the sensitization property and PTA SCC resistance of S34751 similar welded joint with the slight variation of carbon content using matching welding filler were evaluated to confirm the validity of the test results using simulate HAZ heat treated sample.

Key words: Polythionic acid stress corrosion cracking (PTA SCC), Sensitization, S34751, matching welding consumable, Post Weld Heat Treatment, carbon content

⁽¹⁾ NACE International (NACE), 15835 Park Ten Pl, Houston, TX 77084, USA

INTRODUCTION

Stabilized austenitic stainless steels such as UNS S32100 or UNS S34700 are widely used in hydro-treating or hydro-cracking processes in a complex refinery. However, S32100 or S34700 are susceptible to Stress Corrosion Cracking (SCC) due to the formation of Polythionic acid (PTA) (H_2SxO_6 , $x = 3 - 6$) which causes cracking in the coarsened Heat Affected Zones (HAZ) because of the sensitization, due to the formation of a chromium (Cr) depleted zone by the precipitation of Cr based $M_{23}C_6$ carbides along grain boundaries, which occurs during actual operation.¹

To prevent PTA SCC, Stabilization Post Weld Heat Treatment (PWHT) at the temperature range of 843 °C to 900 °C for 2 to 4 hours is required for S32100 and S34700 to tie up free carbon as TiC and NbC in the coarsened HAZ. Furthermore, several kinds of PTA SCC shutdown mitigation methods are listed in NACE SP0170 such as nitrogen purging to exclude oxygen, alkaline washing of equipment surfaces, and dry air to prevent liquid water formation.² Stabilization PWHT and/or these PTA SCC mitigation methods affect not only the fabrication cost but also the cost and schedule during maintenance opportunities. Hence, a stabilized austenitic stainless steel with excellent resistance for sensitization to prevent PTA SCC without the above mitigation methods would be ideal for hydro-treating and hydro-cracking processes in a complex refinery.

It has been noted that the elimination of stabilization heat treatment (including PWHT) seems to be possible for generic UNS S34751 with extra low carbon content less than 0.02 wt% and higher Nb/C ratio over 15. Reports on proprietary S34751 indicate superior sensitization resistance within generic S34751,³⁻⁴ and S34751 has been shown to have excellent PTA SCC resistance without both stabilization PWHT through proven long-term service experience in actual plants of hydro-treating or hydro-cracking processes over 20 years.⁵⁻⁷ However, the difference of PTA SCC resistance between the generic S34751 and proprietary S34751 has never been documented under extra low carbon content less than 0.02 wt%. Therefore, it is difficult to judge the elimination of all PTA SCC mitigation methods for the usage of not proprietary S34751 but generic S34751.

In NACE C2019-12783, the effect of the slight variation of carbon content on PTA SCC resistance for S34751 was investigated using simulated HAZ sample, and it was clarified that PTA SCC resistance of S34751 was susceptible to slight variation of carbon content within the extra low carbon content (less than 0.02 wt%) and the strict control of carbon content less than 0.015 wt% was mandatory to achieve higher PTA SCC resistance of S34751.⁸

In this study, the effect of the slight variation of carbon content on PTA SCC resistance for the similar welded joint of S34751 using matching welding filler was investigated to confirm the validity of the test results using simulated HAZ sample.

EXPERIMENTAL PROCEDURE

Test material

Chemical compositions of materials were shown in Table 1. Items 1 and 2 were satisfied with the chemical composition range of S34751. Item 1 contained carbon content similar to proprietary S34751. Item 2 contained higher carbon content than Item 1 but remain within the chemical composition range of generic S34751. After the production of plates with 20 mm (0.7874 in) thickness using hot forging and hot rolled processes, all items were solution heat treated over 1040 °C and water quenched to room temperature.

Table 1
Chemical compositions of materials used. (wt%)

Item	C	Si	Mn	P	S	Ni	Cr	N	Nb	Nb/C
1	0.012	0.40	1.40	0.030	<0.001	10.3	17.4	0.080	0.35	29.2
2	0.018	0.38	1.47	0.034	<0.001	9.95	17.1	0.078	0.29	16.1
S34751	0.005-0.020	1.00 max	2.00 max	0.045 max	0.030 max	9.0-13.0	17.0-19.0	0.06-0.10	0.20-0.50	15 min

Production of similar welded joint using matching filler

After machining the wall thickness of plates from 20 mm to 12 mm and bevel configuration shown in Figure 1, Gas Tungsten Arc Welding (GTAW) was applied inside the bevel using matching welding filler. Table 2 shows the chemical composition of matching welding filler used.⁹ The diameter of used matching filler was 1.2 mm and the applied heat input range was varied from 0.8 kJ/mm to 1.2 kJ/mm. Pre heat and PWHT were not applied for the production of similar welded joints of Items 1 and 2 shown in Table 1. The used shielding gas was pure Ar gas. The residual ferrite content at the cap position of weld metal was 8.7 %.

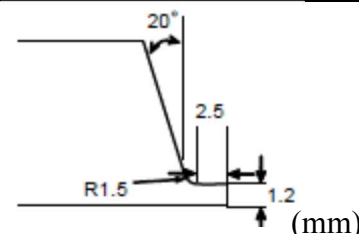


Figure 1: Bevel configuration.

Table 2
Chemical compositions of matching welding filler used. (wt%)

C	Si	Mn	P	Ni	Cr	N	Nb
0.03	0.40	1.5	0.008	7.01	19.6	0.154	0.41

Aging condition

To simulate the sensitization treatment, similar welded joints were subjected to aging heat treatments at 550 °C up to 1,000 hours. This aging temperature was chosen because it corresponds approximately to the nose temperature of the Time-Temperature-Sensitization (TTS) diagram for S34700.¹⁰

Microstructure observation test

Cross section microstructure taken from the aged test samples were etched according to ASTM⁽²⁾ A262 Practice A, which was the 10% oxalic acid etch test.¹¹ The etched microstructure was classified into step structures without a ditch around the grains, dual structures with partial ditches around the grains, and ditch structures with one or more grains with fully ditched grain boundary.

Sensitization Test

Aged test samples were immersed according to ASTM A262 Practice E and bent at the center of their simulated HAZ thermal treated zone.¹² After that, the cross section microstructure of the tested samples was observed to evaluate Intergranular SCC (IGSCC) susceptibility using optical microscopy in the as polished condition.

PTA SCC Test

Aged test samples were U-bent with a bend radii from 0.5 to 1.0 of the sample thickness. Test samples were then immersed in a solution of 1% K₂S₄O₆ acidified by H₂SO₄ to a pH of 2.0 at room temperature for 100 hours in accordance with Hosoya, Yamamoto and Kagawa (1985).¹³ This test was used instead of ASTM⁽²⁾ G35-98 because the preparation of the Wackenroder solution in ASTM⁽²⁾ G35-98 requires caution due to using H₂S.¹⁴ A penetrant test and investigation for PTA SCC through a 10-power binocular magnifying glass was conducted for the samples removed from the beaker.

⁽²⁾ ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959 USA