Studies on Corrosion Behaviour of IN718 alloy Gas Tungsten Arc Welds

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***Abstract*—Inconel 718 alloy is a material that has been extensively used in gas turbine engine components in marine-based industrial applications because of its superior mechanical and corrosion resistant properties. When it comes to welding of IN718 alloy, corrosion resistance gets affected due to the segregation of niobium and formation of intermetallic laves phase in the fusion zone of the welds. The present work is aimed to evaluate the corrosion behaviour of IN718 alloy welded with Gas tungsten arc welding (GTAW) process. In order to improve the corrosion resistance of welds, a post weld heat treatment (PWHT) was employed, i.e., solutionizing treatment at 1080^{0}C followed by direct aging condition (1080STA). In the present work, the corrosion resistance of IN718 alloy GTA welds was studied by employing Cyclic Potentiodynamic Polarization test on the fusion zones of as-welded and PWHT conditions in a salt environment of 3.5Wt% NaCl solution. The established cyclic potentiodynamic polarization curves in as-welded and 1080STA conditions shown better corrosion resistance for the 1080STA condition.**

Keywords*—Inconel 718 alloy, Gas tungsten arc welding (GTAW), Solutionizing and Post weld heat treatments (PWHT), Cyclic Potentiodynamic Polarization and 3.5wt % NaCl solution.

I. INTRODUCTION

Inconel 718 is a nickel-based superalloy extensively used in many industrial applications, significantly in gas turbine engine blades in marine applications, space vehicles, reciprocating engine components and many more [1,2]. On account of the slow precipitation kinetics of principal strengthening precipitates γ'' (Ni_3Nb) and γ' (Ni_3Al) in annealed IN718 alloy, it renders high strength, good mechanical characteristics, corrosion resistance and resistance to strain age cracking [3]. Nevertheless, IN718 alloy also confronts weldability problems such as microfissuing and solidification cracking in the heat affected zone and formation of Nb rich intermetallic Laves phase at interdentritic regions of weld during solidification of weld metal [4]. In order to overcome the above weldability problems, several researchers worked on welding parameters and post weld heat treatments (PWHT), on mechanical and microstructural behaviour [5-10]. Very few studies were reported on the corrosion resistance behaviour of IN718 alloy welds [11].

In present work, IN718 alloy plates of 3mm were welded using Gas Tungsten Arc Welding process with similar IN718 alloy plates. Welding is followed by a post weld heat treatment at 1080^{0}C chosen as a modified route to overcome the welding associated problems. The primary objective of the work is to study the effect of PWHT (1080STA) on corrosion behaviour of the GTA weldment and to compare with that of the as-welded condition.

II. METHODOLOGY

A. Material and Fabrication

IN718 plates of 3mm thickness were welded by gas tungsten arc welding process, using a filler wire of same alloy (TABLE I). TABLE II contains the list of welding parameters that were used and the gas tungsten arc welds of IN718 alloy is shown in Fig.1. Specimens were cut from welded joints using a wire electric discharge machine (Wire EDM). These specimens were subjected to post weld heat treatment, i.e., solutionizing treatment at 1080^{0}C/20min/FC followed by direct aging (720^{0}C/8h/FC followed by 620^{0}C/8h/AC). Both the PWHTed specimen and the as-welded specimen were prepared for further characterizations.

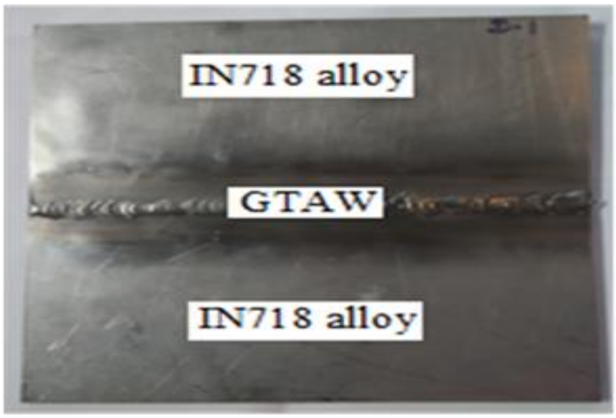

Fig. 1. Images GTAW IN718 alloy weldments

TABLE I. WEIGHT% COMPOSITION OF BASE METAL IN718 AND WIRE FILLER

Material	Composition					
Filler (IN718)	***Ni***	***Cr***	***C***	***B***	***S***	***P***
	50	17	0.05	0.005	0.015	0.015
	Si	***Ti***	***Al***	***Mo***	***Nb***	***Fe***
	0.35	0.65	0.45	2.80	4.75	Balance
IN718 alloy	***Ni***	***Cr***	***C***	***B***	***S***	***P***
	53	18.2	0.02	0.003	0.002	0.0005
	Si	***Ti***	***Al***	***Mo***	***Nb***	***Fe***
	0.12	0.97	0.51	3.13	5.08	Balance

TABLE II. WELDING PARAMETERS USED DURING GTA WELDING PROCESS

Welding parameter	Selection
Current	110A
Voltage	18V
Speed	6mm/s
Heat Input	330J/mm

B. Microstructural characteristics

The specimens of as-welded and PWHT conditions are flattened by grinding. For metallography, specimens are polished using emery papers of grade 1/0, 2/0, 3/0 and 4/0 followed by disc polish with a diamond paste of 0.5 and 1 micron until the mirror finish is obtained. The mirror finished metallographic specimens were etched using a mixed acid solution, i.e. prepared using 76mL H_2O + 20mL HNO_3+ 100mL HCl+ 2mL HF. Microstructural studies were carried by Optical microscopy for both as welded and post weld heat treated specimens after the corrosion test.

C. Corrosion Studies

GillAC 1130 equipment was used to study the cycle polarization studies in a salt environment that contain 3.5% NaCl solution with a sweep rate of 0.1667mV/sec. An area of 0.1257cm^2 is exposed to the test environment. Based on the loop area, repassivation (E_{rp}) potential, and the hysteresis obtained, the corrosion resistance of specimens was evaluated.

III. RESULTS AND DISCUSSIONS

A. Microstructure Studies

Optical microscopy of fusion zone in both as welded and 1080STA conditioned IN718 alloy welds are shown in Figs. 2. (a)&(b). It clearly depicts, fusion zone of as-welded IN718 alloy comprise of coarse laves and delta phases. Whereas 1080STA resulted in less Nb rich intermetallic Laves phase and complete dissolution of the delta phase resulting in better corrosion resistance of PWHTed specimen.

Fig. 2. (a) Microstructure of as-welded specimen

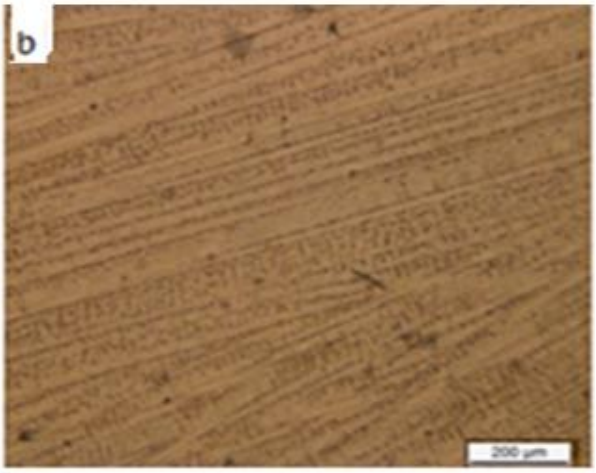

Fig. 2. (b) Microstructure of 1080STA specimen

B. Corrosion Studies

The cyclic potentiodynamic polarisation curve of as welded and 1080STA conditioned IN718 alloy welds are shown in Fig.3.2 from the curves, it is clear that corrosion potential (E_{corr}) of PWHTed specimen is more positive when compared to the as-welded specimen indicating improved pitting corrosion resistance. The difference between pitting potential (E_{pit}) and protection potential (E_{rp}) is known as the relative corrosion resistance ΔE [12-15]. Its magnitude indicates the pitting resistance, i.e., higher the ΔE magnitude lower is the pitting resistance. Also, the area under the hysteresis loop is an indicator of corrosion resistance, smaller the area higher the corrosion resistance vice versa.

Obtained cyclic potentiodynamic polarisation curves Fig.3 depict that both the conditions have lesser current density during reverse scan than forward scan that indicates both conditions are showing native hysteresis. But ΔE of 1080STA specimens is less compared to the as-welded specimen. TABLE.III describes the magnitudes of E_{corr}, E_{pit}, E_{rp}, ΔE. Hysteresis loop area of the 1080STA specimen was smaller than that of the as-welded specimen, indicating that 1080STA specimen is having higher corrosion resistance compared to as-welded specimen. This can be attributed to the relatively less amount of Nb segregation.

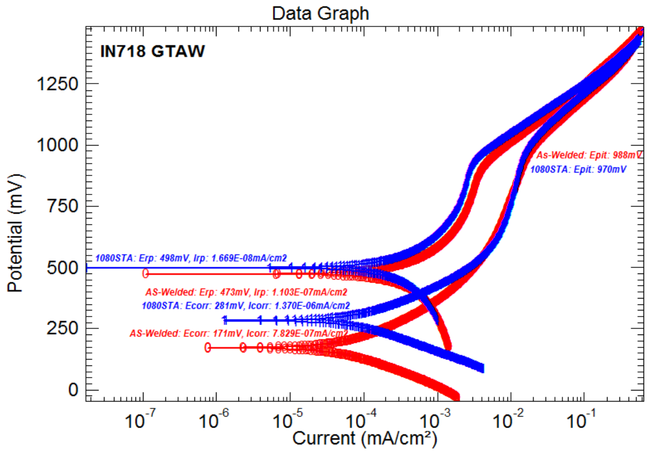

Fig. 3. Cyclic Potentiodynamic Polarization Curves of As-Welded (Red) and 1080STA (Blue) IN718 alloy welds.

TABLE III. RESULTS FROM CYCLIC POLARISATION TEST

Specimen	E_{corr}	E_{pit}	E_{rp}	ΔE
As-Welded	171mV	988mV	473mV	515mV
1080STA	281mV	970mV	498mV	472mV

IV. CONCLUSIONS

- From the obtained results, it is clear that solutionized and aged at 1080^{0}C specimen of IN718 GTAW alloy weldment has shown better corrosion resistance than as-welded IN718 GTAW welds.
- Improved corrosion resistance is attributed to the less segregation of Nb rich intermetallic laves phases in the fusion zone of the post weld heat treated specimen.

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REFERENCES

[1] Dilkush, Raffi Mohammmed, G Madhusudhan Reddy, K SrinivasaRao, Comparative Studies on Microstructure, Mechanical and Pitting Corrosion of Post Weld Heat Treated IN718 Super alloy GTA and EB Welds, IOP Conf. Series: Material Science and Engineering 330(2018) 012051.

[2] EnesAkca, Ali Gursel, A Review on Superalloys and IN718 Nickel Based INCONEL Super alloy, Periodicals of Engg. And natural science vol.3. no.1 (2015) ISSN 2303-4521.

[3] G. D. Janaki Ram, A. Venugopal Reddy, K. Prasad Rao and, G. Madhusudhan Reddy, Control of Laves phase in Inconel 718 GTA welds with current pulsing, Science and Technology of Welding and Joining 2004 Vol. 9 No. 5

[4] G. D. Janaki Ram, A. Venugopal Reddy, K. Prasad Raoand G. Madhusudhan Reddy Microstructure and mechanical properties of Inconel 718 electron beam welds, Materials Science and Technology 2005 VOL 21 NO 10

[5] G. Madhusudhana Reddy, C.V.Srinivasa Murthy, K Srinivasa Rao, K.PrasadaRao,Improvement of Mechanical properties of Inconel 718 electron beam welds influence of welding techniques and postweld heat treatment Int J AdvmanufTechnol 2009 43:671-680.

[6] Dr. Manikandan, M. Kamaraj, Prasad Kalvala, Sivakumar, Effect of Weld cooling rate on Laves phase formation in Inconel 718 fusion zone, journal of materials processing technology Feb 2014.

[7] Dr.Manikandan, M. Kamaraj, Prasad Kalvala, Sivakumar, Laves Phase Control in IN718 weldments, Materials Science Forum January 2012

[8] Yunpeng Mei, Yongchang Liu, ChenxiLui, Chong Li, Effect of base metal and welding speed on fusion zone microstructure and HAZ hot cracking of electron beam welded IN718.

[9] X. Cao,B.Riaux, M. Jahazi, A Birur, Effect of pre- and post-weld heat treatment on metallurgical and tensile properties of IN718, J Mater Sci 2009 44:4557-4571

[10] J Andersson, G.P. Sjoberg, L. Viskari, M.C. Chaturvedi, effect of solution heat treatments on superalloys 718, Material Science and technology 2012 vol 28 No5 609-619.

[11] Dilkush, RaffiMohammmed, K.S.S. Siva Prasad, K. Jyothi, G Madhusudhan Reddy, K SrinivasaRao, Studies on microstructure and pitting Corrosion of as welded IN718 gas tungsten arc welds, SSRG International Journal of Mechanical Engineering may 2017.

[12] Z.F. Yin, W.Z. Zhao , W.Y. Lai a, X.H. Zhao, Electrochemical behaviour of Ni-base alloys exposed under oil/gas field environments, Corrosion Science 51 (2009) 1702–1706.

[13] H.R. ZareieRajani, S.A.A. AkbariMousavi , F. MadaniSani,Comparison of corrosion behavior between fusion cladded and explosive cladded Inconel 625/plain carbon steel bimetal plates, Materials and Design 43 (2013) 467–474.

[14] B.E. Wilde, A critical appraisal of some popular laboratory electrochemical tests for predicting the localized corrosion resistance of stainless alloys in sea water, Corrosion 28 (1972) 283.

[15] W. Stephen Tait, An Introduction to Electrochemical Corrosion Testing for Practicing Engineers and Scientists. 1994.