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Comparative Studies on Incoloy 800 H weldments exposed to air oxidation at 600 °C

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Abstract

In this research work, attempts have been made to study the hot corrosion behavior of Incoloy 800 H weldments subjected to air oxidation at 600 °C. Incoloy 800H samples are being welded using Gas Tungsten Arc welding and Pulsed Current Gas Tungsten Arc welding processes employing ERNiCrMo-3. Hot corrosion studies were performed on the coupons showing the various zones of the weldments. Weight gain or loss measurements were carried out using Thermogravimetric analysis. The corrosion products were revealed using XRD, SEM/EDAX analysis.**Keywords**: Incoloy 800H; Gas Tungsten Arc Welding; Pulsed Current Gas Tungsten Arc Welding; Hot corrosion; SEM/EDAX analysis

Introduction

Incoloy 800 H, a Fe-Ni based superalloy is widely employed in high temperature environments, such as steam generator tubes, reformer tubes, pyrolysis tubes in the refinery and petrochemical industrials, nuclear power reaction tubes and gas turbines as reported by the researchers [1-5]. Dehmolaeib et al. [6] evaluated the micro-structure and mechanical properties of Incoloy 800 H after exposing it to 15 years of service. The authors observed the improvement in hardness and strength and decrease in the ductility and toughness due to the formation of primary carbides and secondary precipitates after long time exposure. Khalid et al. [7] performed high temperature air oxidation studies on two super alloys Incoloy 825 and Incoloy 800 H exposed at 1000 and 1200 °C. It was reported that Incoloy 800 H exhibited better oxidation resistance as compared to Incoloy 825. Tan et al. [8] conducted the grain boundary engineering (GBE) on Incoloy 800 H employed in supercritical water to evaluate the air oxidation behavior at 550 °C. It is worthy to note that GBE resulted in the spallation resistance of the Incoloy 800H and also reduce the corrosion rate.

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It is evident from the literatures that no systematic work has been reported on the corrosion studies on Incoloy 800H weldments exposed in air oxidation at high temperatures hitherto. In the present investigations, the Incoloy 800 H welds obtained by two different welding techniques such as GTAW and PCGTAW were studied for hot corrosion behavior at 600 °C in air. The corrosion products have been systematically characterized using SEM/EDAX analysis.

2. Experimental Work

2.1. Candidate Metals and welding procedure

The chemical composition of the candidate and filler metal employed in this study is represented in Table 1. The dimensions of the candidate metals employed in this research work has the dimensions of 100 mm x 50 mm x 5 mm. Standard V-groove butt configurations having root face of 1 mm and an included angle of 45 ° was employed to weld these similar metals by GTAW and PCGTAW process using ERNiCrMo-3 filler metal. A specially designed fixture employing the copper back plate was used to avoid bending and distortions while welding. The process parameters employed in the GTA and PCGTA welding of Inconel 800H is represented in Table 2.

Table 1. Chemical Composition of the base/filler metals

	Chemical Composition (% Weight)							
Base Metal/ Filler Wire	C	Si	Mn	Cr	Ni	Mo	Fe	Others
Incoloy 800H	0.072	0.362	1.042	20.523	32.156	0.102	41.737	Cu – 0.426 Co – 0.063 Ti – 0.426 Nb – 0.011 Al – 0.332 V – 0.001 S – 0.015 P – 0.021
ENiCrMo-3	0.08	0.175	0.25	20.0	61.0	9.0	2.0	Nb – 3.15 Al – 4.0 Ti – 0.3 P – 0.03 S – 0.015

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2.2 Macrostructure and Microstructure Examination

Metallographic examination was carried out on the composite region [parent metals + weld + HAZs] of the weldment as shown in Fig.1(c). The composite region of the weldments were polished using the emery sheets of SiC with grit size varying from 220 to 1000 and followed by disc polishing using alumina to obtain a mirror finish of 1μ on the weldments. Electrolytic etching (10% oxalic acid solution; 6 V DC supply and 1 A/Cm^2) was employed to examine the microstructure of Inconel 625.

2.2. Hot Corrosion Studies

Coupons were sliced to 30mm x 10mm x 5mm for composite region and 10mm x 10mm x 5mm for individual samples and were used for the corrosion studies. Before the corrosion run, the samples were polished down to 1 μ finish accuracy. The corrosion studies were performed for 50 cycles at 600 °C. Each cycle constitutes one hour of heating and 20 min of cooling. At the end of every cycle, the color/texture and weight changes were recorded. The weight changes have been measured for every cycle and thermogravimetric plots were constructed based on the results. The weight changes were measured using electronic weighing balance with a sensitivity of 1 mg. Furthermore the hot corroded samples were characterized for XRD, SEM/EDAX analysis to understand the corrosion behavior.

3. Results

3.1. Macrostructure and Microstructure Examination

The microstructure studies on the Incoloy 800 H weldments are represented in Fig.1. The microstructure at the weld zone was found to be cellular and inter-dendritic in case of GTA and PCGTA weldments respectively. Typical grains and grain boundaries were witnessed at the HAZ of both the weldments. Coarse grains were observed at the HAZ owing to the heat generated during welding. However the width of the HAZ is found to be larger in case of GTA as compared to PCGTA weldments.

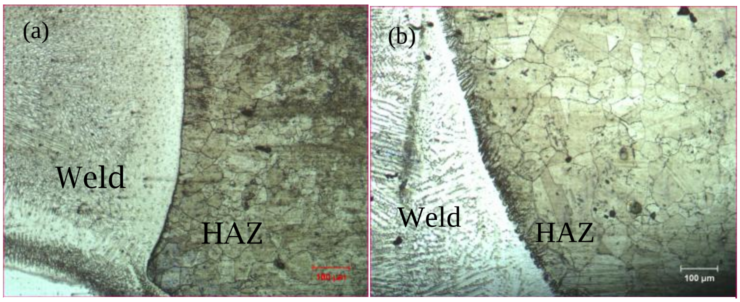

Fig. 1 Microstructure of the Incoloy 800 H (a) GTA (b) PCGTA weldments

3.2. Hot Corrosion Studies

Visual examination on the hot corroded samples clearly witnessed that there were no indications of weight loss in the various zones of the GTA and PCGTA weldments. At the end of 50th cycle, the parent metal zone was totally turned to brownish with slight yellowish patch appearance. Greyish color changes with the black spot formation was observed at the HAZ of GTA weldments whereas black patches and spots on the yellowish colour surface was appeared on the HAZ of PCGTA weldments. Typical blue tarnish layer was formed at the weld zone of the GTA weldments whereas the blue tarnish layer was crushed with the black spots on the PCGTA weldments.

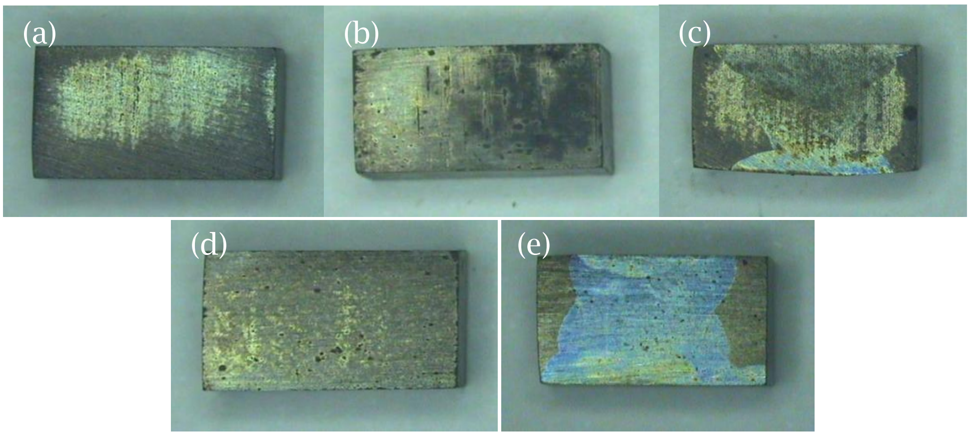

Fig.2 Hot corroded samples of (a) Parent metal; GTA weldments of (b) HAZ (c) Weld and PCGTA weldments of (d) HAZ (e) Weld zone respectively at the end of 50th cycle

Thermogravimetric analysis on the weldments clearly indicates that there were no observable changes during the corrosion cycle in all the zones of the weldment except parent metal. Fluctuations in the weight changes were observed at the parent metal. The oscillatory behaviour of the weight changes however needs precise investigation and attention.

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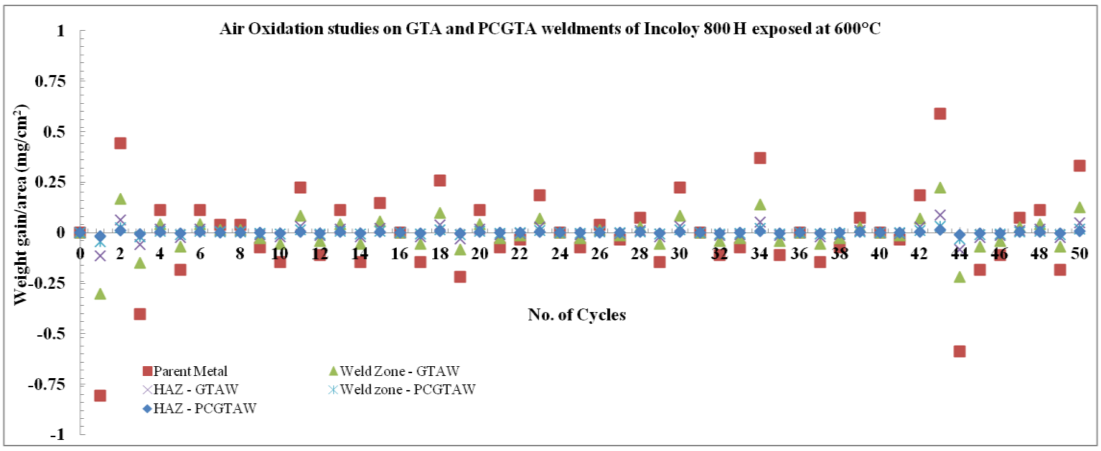

Fig. 3 Thermogravimetric analysis of GTA and PCGTA weldments of Incoloy 800H subjected to air oxidation at 600°C

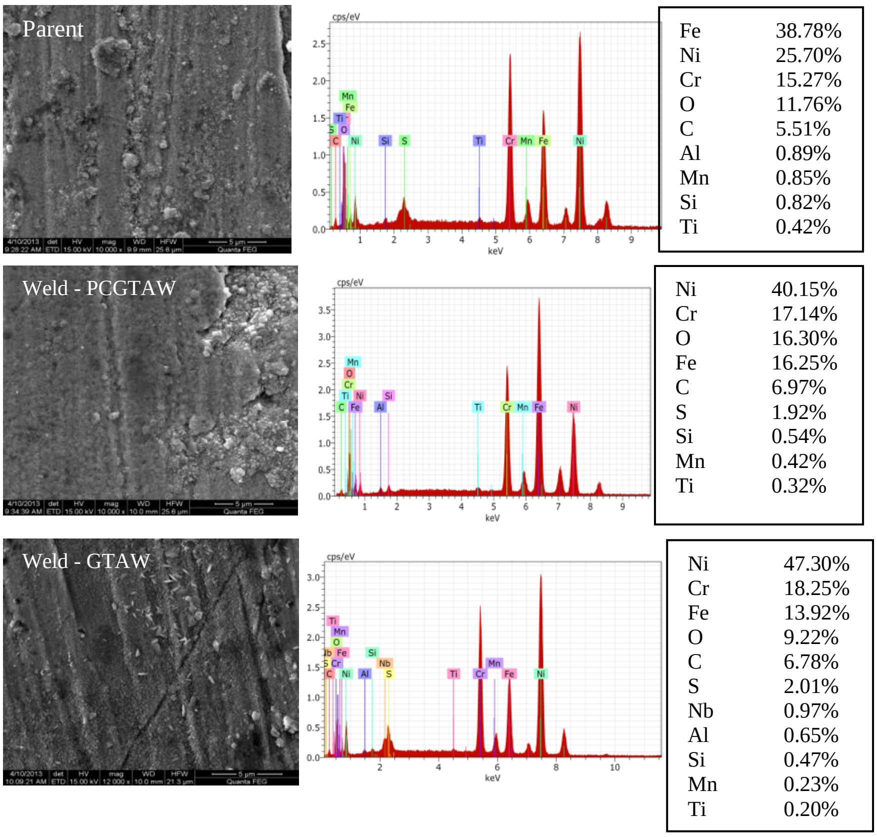

Fig.4 SEM/EDAX analysis on the hot corroded GTA and PCGTA samples subjected to air oxidation at 600 °C

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SEM/EDAX analysis has been performed on the hot corroded samples of the parent metal zone and the weld zones of Incoloy 800 H weldments. It is well understood that the oxides such as NiO, Cr_2O_3, FeO formed the predominant phases as high intensity peaks in almost all the zones of the weldments.

4. Discussions

It is evident that both GTA and PCGTA welding techniques could be employed for Incoloy 800H samples. From the microstructure studies, it is inferred that no segregation or formation of new phases have been obtained. Segregation in the weld interface normally deteriorates the mechanical properties and high temperature corrosion resistance adversely.

It is well understood from the thermogravimetric plot that the parent metal of Incoloy 800H was subjected to corrosion as compared to other zones. The formation of NiO and Cr_2O_3 layer initially protected well the surface of the parent metal; however the presence of lesser amounts of NiO from the SEM/EDAX results clearly indicate that the NiO could have spalled from the metal and that's the reason why spallation would have occurred in the parent metal. The presence of Nb, Ti, Mn, Al in the weld zone formed the oxides which formed the protective layers in addition to the regular oxides provided increased corrosion resistance to the weld zones.

5. Conclusions

- The corrosion resistance is higher for all the zones of the weldment except parent metal
- The increased corrosion resistance in the weld zone is predominantly due to the regular oxide scales as well as the oxides formed with the alloying elements Nb, Al, Ti, Si, Mn present in the filler metal
- The oscillation tendency in the weight changes of the parent metal requires further investigation and assessment.

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