Repair Ability of Incoloy 800 in Vent Gas Wash Tower Pipe System

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Abstract

The objective of this research project is to study repair ability of Incoloy 800 welded pipes that were used in wash Tower system. Failure of these pipes was caused by pitting corrosion from corrosive HCl environment in Wash Tower. Types of filler metals were varied in this research which consists of ERNiCrCoMo-1, ERNiCrMo-1, ERNiCu-7 and ERNiMo-7. As-welded specimens were immersed in a solution of 37% HCl concentration for 74 hours at room temperature for corrosion test. For samples used ERNiCrCoMo-1 as a filler metal showed pitting corrosion at weld bead. For ERNiMo-7as a filler metal was corroded at HAZ were pronounced explicitly.

Keywords: *Incoloy 800, Repair ability, Corrosion*

1 Introduction

The Vent Gas Wash Tower in petrochemical plant is a treatment unit before gas expose to environment. Corrosive gases inside the tower consist of Hydrochloric Acid (HCl), Chorine (Cl_2) and some pollutants. Normally, HCl residual value of gas before releasing to outside environment shall not exceed 10 ppm (UOP recommended). Therefore selected pipe material shall be able to resist corrosive media at high temperature service.

The Incoloy 800 was used in the Vent Gas Wash Tower in petrochemical plant. Incoloy 800 [1, 2] is grouped in Nickel-Chromium-Iron alloy and is a widely used material for construction of equipment that must have high strength and resist oxidation, carburization, and other harmful effects of high-temperature exposure.

However, it is found that after 9 months of service corrosion is observed. Hazard gas is leaked near the weld as shown in figure 1. Failure analysis was conducted in order to investigate the root cause of corrosion and prepare corrective action to prevent any leakage.

Figure 1: Incoloy 800 pipe leakage by corrosion attack.

The investigation of failure pipe showed that many corroded holes appeared in Heat Affected Zone (HAZ) as shown in figure 2. The possible assumptions of this corrosion may be the result of:

- Welding heat may damage corrosion properties of heat affected zone.
- The filler metal is not compatible with Incoloy 800 resulting in galvanic corrosion.

Therefore the objective of this research is to study repair ability of Incoloy 800 by selecting suitable filler metal and controlling welding heat input. This research will propose filler metal that can e be used in HCl environment.

Figure 2: Corroded holes at HAZ of the Incoloy 800 pipe after 9 months of service.

2 Methodology

2.1 *Base Metal Preparation*

Incoloy 800 pipe was used as a base metal with the diameter of 203.2 mm and the thickness of 3.2 mm. Typical chemical composition of Incoloy 800 was showed in table 1. Incoloy 800 was grouped as P-No. 45 according to ASME Section IX [3]. The pipe sample was cut into 200 mm in length on each piece. The detail joint preparation and fit-up was shown in Figure 3. Argon gas back purging was also used to prevent root oxidation.

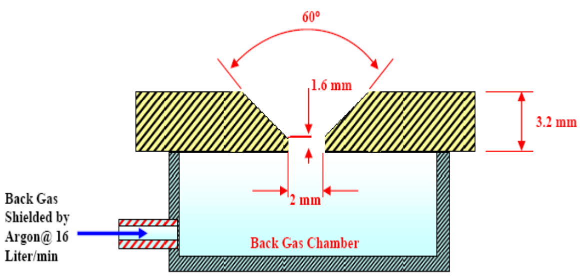


Figure 3: Joint detail for Incoloy 800 weld.

2.2 *Filler Metal Types*

The ERNiMo-7 (Inconel 665) was previously used for joining of Incoloy 800 pipe resulting in severe corrosion attack by HCl environment as shown in figure 2. In this research, four filler metal classifications used to comparatively study repair ability of Incoloy 800 were ERNiCrCoMo-1 (Inconel 617), ERNiCrMo-3 (Inconel 625), ERNiMo-7 (Inconel 665) and ERNiCu-7 (Monel 400). Table 2 showed typical chemical compositions of these filler metals. All filler metals were specified in AWS A 5.14 (Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods) [4]. Filler metal with the diameter of 2.4 mm was used in this study.

2.3 *Welding Procedure*

In this study, all welding variables were controlled by using Welding Procedure Specification (WPS) as shown in Table 4. Gas tungsten arc welding (GTAW) process was used in this study. Practically, welding current and travel speed for each filler metal type were not the same because of different viscosity and wetting ability on Incoloy 800 base metal. Therefore welding variables shown in figure 4 were specified in range. Hence, welder shall control welding variables in specified range in order to make satisfactory welds.

Actual welding current, arc voltage, travel speed and heat input for each filler metal were monitored and shown in table 3. Welds were visually accepted before corrosion test. It can be observed that higher heat input (28.8 kJ/cm) was required for ERNiMo-7 (Inconel 665) since low welding current and high speed for ERNiMo-7 produced unacceptable weld profiles. For ERNiCrCoMo-1, ERNiCrMo-3, and ERNiCu-7 can welded by normal heat input (< 11 kJ/cm).

2.4 *Actual Corrosion Test in Vent Gas Wash Tower*

Welded samples from each filler metal were placed into actual vent gas wash tower service in order to evaluate their corrosion properties in actual corrosive environment. In actual service, operating pressure was 6 Bar and operating temperature was 80-110°C. Hydrochloric (HCl) acid was found to be the maximum of 10 ppm. The samples will then be observed for surface condition and possible corrosion attack after 70 hours in service.

2.5 *Laboratory Test in Liquid Hydrochloric acid*

Corrosion in actual service might take at least 7-9 month; therefore, in this study, accelerated corrosion test was performed by using hydrochloric acid with 38% concentration and PH of 0.74. Temperature was held constant at 50 °C throughout experiment. The tests were performed for 70 hours and then the samples were weighted to determine weight loss per exposed area.

3 Results and Discussions

Figure 4 showed 4 specimens after the exposure of 70 hours in the vent gas wash tower. The sample welded with ERNiCrCoMo-1 showed severe oxidation scales and corrosion product. ERNiCrCoMo-1 could not resist HCl environment according to filler metal manufacturer's recommendation. The other filler metals showed no sign of corrosion since, in actual service, it required much longer time for corrosion to occur. Therefore accelerated tests were performed as described in 2.5. The results were shown in figure 5. It can be seen that the corrosion rate of the sample welded with ERNiCrCoMo-1 was the highest with the corrosion rate of 376.4401 grams/m^2. The sample welded with ERNiMo-7 had corrosion rate as high as 340.376 grams/m^2 and most corrosion occurred in heat affected zone area. ERNiCrMo-3 and ERNiCu-7 gave lower corrosion rate of 204.1859 and 226.1319 grams/m^2, respectively.

Figure 6 showed photography of specimens after immersion in hydrochloric acid for 70 hours. ERNiCrMo-3 and ERNiCu-7 weld metal showed no corrosion on weld face as it could be seen in figure 6a and 6b, respectively. However uniform corrosion was appeared at heat affected zone and base metal area. Most of metal loss came from Incoloy 800 base metal (anodic reaction).

Figure 6c showed localized corrosion in ERNiCrCoMo-1 weld metal surface. Many pit holes were dispersed only weld region whereas Incoloy 800 pipe was still the mill-received surface. This was because ERNiCrCoMo-1 (Inconel 617) having corrosion properties according to Technical Data [5] had poor corrosion resistance when this material exposed to either liquid or gaseous hydrochloric acid environment. Thus ERNiCrCoMo-1 filler metal (Inconel 617) used for welding of Incoloy 800 pipe was not recommended for the vent gas wash tower service (poor service weldability). However, Inconel 617 had excellent corrosion resistance to phosphoric acid.

ERNiMo-7 welded (Inconel 665) specimen required higher heat input comparing with those of other filler metal used in this study. It can be clearly seen in figure 6d that severe localized corrosion occurred at heat affected zone area. Figure 7 and Figure 8 showed the crevice corrosion at the weld toe region of cover pass side and root pass side. These crevice corrosions appeared to be at small *overlap* between weld metal and base metal. Liquid weld pool of ERNiMo-7 was quite viscous and tended to promote overlap therefore higher heat input was usually required. This might damage corrosion properties at heat affected zone area. Figure 9 showed localized attack corrosion at coarse grain region at heat affected zone. The coarse grain was resulted from higher heat input condition.

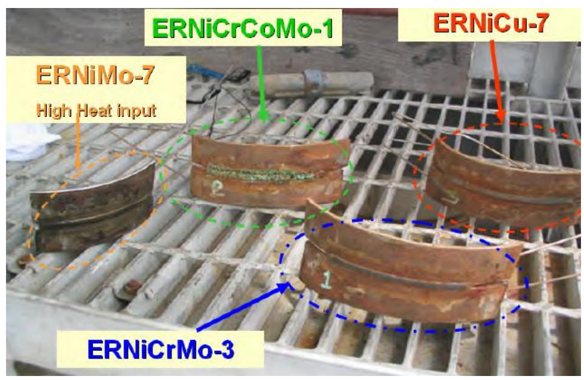


Figure 4: Appearances of welded specimens after placing in the vent gas wash tower

Table 1: Chemical Compositions of Incoloy 800 pipe.

Ni	Fe	Cr	Al	Ti	Mn	Si	C	Cu
29.96%	47.31%	20.17%	0.251%	0.212%	0.655%	0.222%	0.063%	0.021%

Table 2: Chemical Compositions of ERNiCrCoMo-1, ERNiMo-7, ERNiCrMo-3 and ERNiCu-7**.**

AWS Classification[a]	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni	Co	Al	Ti	Cr	Nb Plus Ta	Mo	V	W	Other Elements Total
ERNiCrCoMo-1	N06617	0.05	1.0	3.0	0.06	0.015	1.0	0.50	Rem	10.0	0.8	0.60	20.0	-	8.0	-	-	0.50
ERNiCrMo-3	N06625	0.10	0.50	5.0	0.02	0.015	0.50	0.50	58.0	-	0.40	0.40	20.0	3.15	8.0	-	-	0.50
ERNiMo-7	N10665	0.02	1.0	2.0	0.04	0.03	0.10	0.50	Rem	1.0	-	-	1.0	-	26.0	-	1.0	0.50
ERNiCu-7[k]	N04060	0.15	4.0	2.5	0.02	0.015	1.00	Rem	62.0	-	1.25	1.5	-	-	-	-	-	0.50

Table 3: Actual welding current, arc voltage, travel speed and heat input for each filler metal for ERNiMo-7, ERNiCrCoMo-1, ERNiCrMo-3 and ERNiCu-7.

Heat input=(I*E*60)/(S)	High Heat	Normal	Normal	Normal
I (amp)	120	80	85	87
E (volt)	12	10.5	10.5	10.5
Speed (cm/min)	3	5	5	5
	ERNiMo-7	**ERNiCrCoMo-1**	**ERNiCrMo-3**	**ERNiCu-7**
J/cm	28800	10080	10710	10962
KJ/cm.	**28.8**	**10.08**	**10.71**	**10.962**

Table 4: Welding Procedure Specification (WPS) for joining of Incoloy 800 pipes.

Welding Procedure Specification (WPS)

Process: TIG (GTAW) **Type of Process:** Manual

Electrode Type: EWTH-1 (AWS A 5.12) **Electrode Size:** 2.4 mm

Filler Metal Specification: AWS A 5.14 **Classification:** Typical in experimental **Filler Size:** 2.4 mm

Shielding Method: Argon Gas **Shielding Flow Rate:** 12 LPM **Gas Cup Size:** 8 mm

Base Metal Spec: Incoloy 800 (P-No. 45) **Thickness:** 3.2 mm

Welding Position: Flat **Joint Design:** Single-V Butt Joint

Surface Preparation: Solvent Clean and wire brushing interpass

Temperature Control

Pre-heating: 20 °C (minimum)

Interpass Temperature: < 200 °C

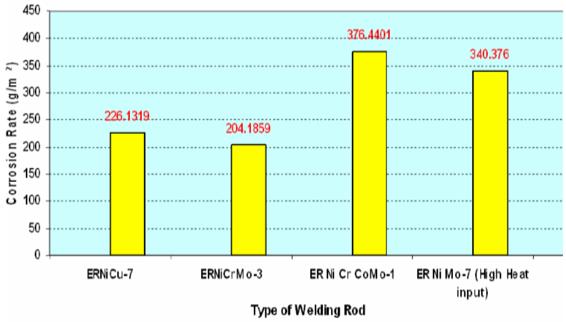


Figure 5: Corrosion rate resulting from accelerated corrosion test in HCl 38% for 70 hours

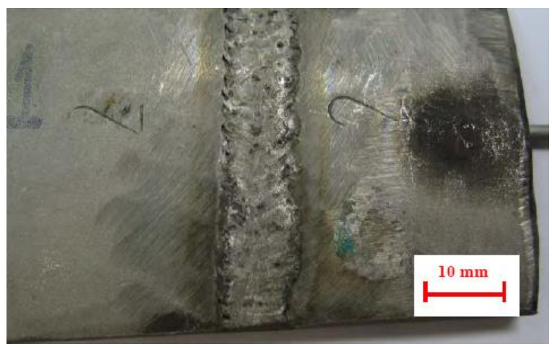
4 Conclusions

In this study, four types of filler metals were used to comparatively study repair ability of Incoloy 800 pipe. This research will propose filler metal that can be used to repair Incoloy 800 pipe used for fabrication of the vent gas wash tower. It can be concluded that:

- Using ERNiCrCoMo-1 or Inconel 617 filler metal for joining of Incoloy 800 pipe gave unsatisfactory results in hydrochloric acid environment since pitting corrosion apparently occurred in weld metal.
- ERNiMo-7 or Inconel 665 requiring higher heat input condition can damage corrosion resistance of heat affected zone (HAZ) of Incoloy 800.
- ERNiMo-7 or Inconel 665 filler metal had tendency to promote overlap weld resulting in crevice corrosion.
- ERNiCu-7 (Monel 400) and ERNiCrMo-3 (Inconel 625) were recommended for this application and satisfactory results both in fabrication weldability and service weldability for welding of Incoloy 800 pipe and they can be used in hydrochloric acid service.

(a)

(b)



(c)

(d)

Figure 6 (cont): Specimens welded by (a) ERNiCu-7, (b) ERNiCrMo-3 (c) ERNiCrCoMo-1 and (d) ERNiMo-7 tested in HCl 38 % for 70 hours

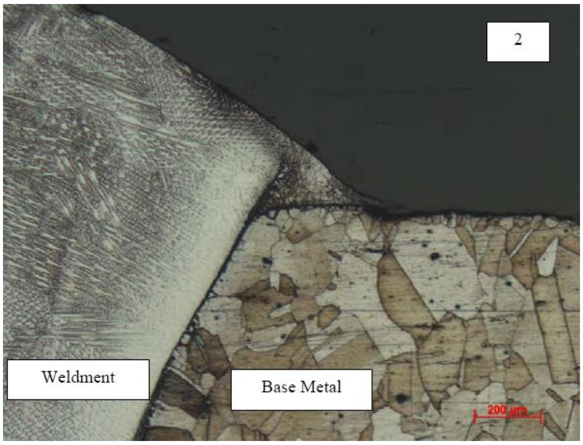


Figure 7: Microstructure of cover pass region of ERNiMo-7 (Inconel 665) weldment and Incoloy 800 base metal was founded crevice corrosion at weld toe.

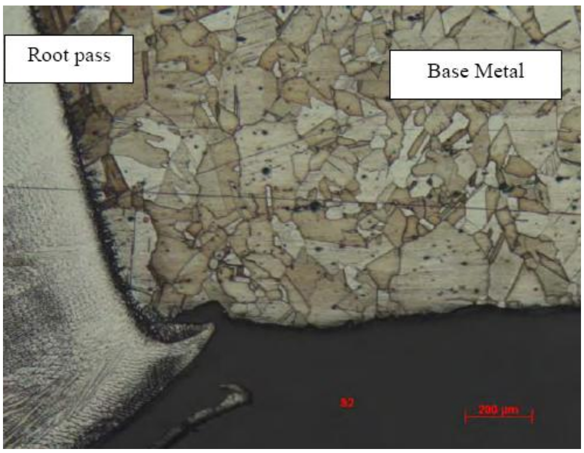


Figure 8: Microstructure of root pass region of ERNiMo-7 (Inconel 665) weldment and Incoloy 800 base metal was founded crevice corrosion at weld toe.

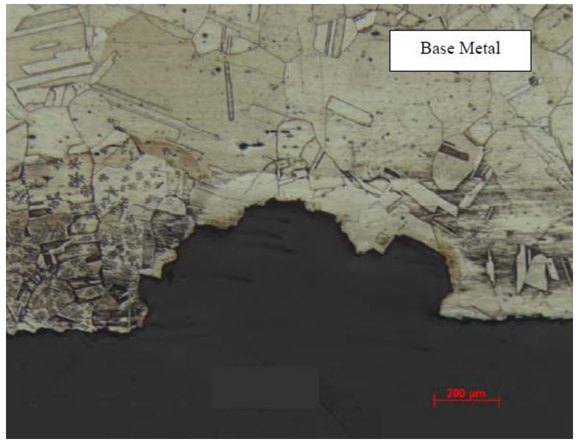


Figure 9: Microstructure on root pass side of Incoloy 800 base metal with welded by ERNiMo-7 filler was founded localized corrosion at HAZ.

Acknowledgments

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