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Corrosion Rate Analysis on SA 240 TP 904L Material Experience Multiple Repair

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Abstract

Weld imperfections are likely to arise during any welding process. Due to the enormous number of joints that could result in weld defects, welding process faults could happen. Repair procedures are required to address welding defects. Multiple repairs are required if welding mistakes are made repeatedly. The duplex material used in this study is SA 240 TP 904L. By altering the repair procedure treatment 1x, 3x, 5x, and without repair, the welding process is carried out utilizing the SMAW method and E309L filler. Microstructure testing, ferrite content testing, and 3-electrode cell corrosion are the test techniques used. The relationship between the corrosion rate and the amount of ferrite content was deduced from the test data. The corrosion rate increases as the ferrite content rises due to several repairs.

1. Introduction

In the industrial business, one of the ways that components are joined together is through the process of welding. A joint that is capable of meeting the acceptance criteria will be produced by a welding technique that is of high quality. However, there are occasionally recurring faults in the welding joints, which result in the necessity of multiple repairs. Although there are no issues with the welding joint when seen visually, the quality of the welding joint may be noticed when viewed mechanically, and the welding joint's interaction with its environment during its service life will decrease.

The repair process in type 316L stainless steel can affect the mechanical properties, microstructure and corrosion resistance [1] [2]. The HAZ region is severely degraded, resulting in decreased sensitivity to pitting corrosion. High-strength low-alloy (HSLA) steel also undergoes changes in the HAZ region with intermittent coarse grain growth, ultimately contributing to the brittle fracture initiation mechanism [3].

The effect of multiple repairs on 304L material also results in lower tensile strength and corrosion resistance, Fig. 1 [4]. The decrease in corrosion resistance in austenitic stainless steel materials is due to increased ferrite content due to repeated heat input.

Fig. 1. Formation of chrome carbide on fusion lines and HAZ. [4]

The ferrite content in duplex stainless steel is essential in determining its mechanical properties and corrosion resistance. The ideal ferrite content in duplex stainless steels is usually around 50% but should be 35% to 60% to optimize their physical and mechanical characteristics [5] [6]. Deviations from the optimal ferrite content can adversely affect the properties of the alloy. Excessive ferrite content can reduce toughness, while insufficient ferrite content can decrease resistance to chloride stress corrosion cracking [5] [6].

This research aims to see how the effect of multiple repairs on duplex stainless steel type SA 240 TP 904L.

2. Research Methods

This research was conducted experimentally by performing multiple repairs on the results of SA 240 TP 904L material welding joints.

2.1 Material

SA 240 TP 904L (*austenitic stainless steel*) with a length of 150 mm, a width of 75 mm, and a thickness of 10 mm is used as the base material. This material is created to offer considerable protection against corrosion in various types of process environments. Its corrosion resistance is ensured by its high chromium and nickel content, as well as the inclusion of molybdenum and copper. Due to its extensively alloyed composition, containing 25% nickel and 4.5% molybdenum, 904L provides outstanding resistance against chloride stress corrosion cracking, pitting, and overall corrosion, surpassing that of 316L and 317L molybdenum-enhanced stainless steels.The chemical composition of the material is shown in Table 1.

At the same time, E309L is used as an electrode. This is frequently employed in the welding of dissimilar steels. It is utilized when joining Type 304 with mild or low-alloy steel, welding Type 304 clad steels, welding the initial layer of E308L, and applying stainless steel sheet linings to carbon steel. However, it is crucial to note that embrittlement or cracking may arise if these dissimilar welds encounter postweld heat treatment or serve in temperatures exceeding 700 Fahrenheit. The nominal composition of this electrode is shown in Table 2.

Table 1. Chemical composition of SA240 TP 904L [7].

Elements	Wt%
Carbon	0.020
Manganese	2.0
Phosphorus	0.04
Sulfur	0.030
Silicon	1.00
Nickel	23.0 – 26.0
Chromium	19.0 – 23.0
Molybdenum	4.0 – 5.0

Table 2. Chemical composition of 309L [8]

Elements	Wt %
Si	0.9
Mn	0.5-2.5
Cu	0.75
Mo	0.75
S	0.03
Ni	12.0-14.0
Cr	22.0-25.0
P	0.04
C	0.04

2.2 Welding

Multiple repairs were performed on three welded joints, 1x, 3x and 5x, respectively, while a joint without repair was used as a comparison.

All welds were made using the SMAW process with E309L electrodes. The welding process was performed in the 1G position with a seam angle 60^0. Welding parameter data is shown in Table 1.

Table 1. Welding parameter

Current (A)	70 -105
Travel speed (mm/s)	1-3
Voltage (V)	20 - 27
polarity	DCEN

The repair process is done by grinding, from the capping to the hot-pass section. The welds were removed to a depth of 45-50% of the material thickness. The result of the grinding is shown as a dashed line in Fig. 2.

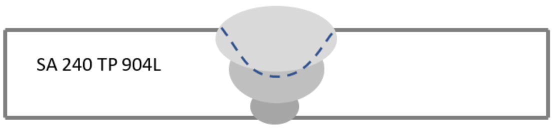


Fig. 2. Weld bead scraping

2.3 Ferrite content testing

Ferrite content testing is carried out on the welding area to determine the ferrite content due to multiple repairs that have been carried out. The tool used in this test is a ferrite scope.

2.4 Corrosion Testing

Schematic corrosion testing using a three-electrode cell following ASTM G5 standards, as shown in Fig. 3.

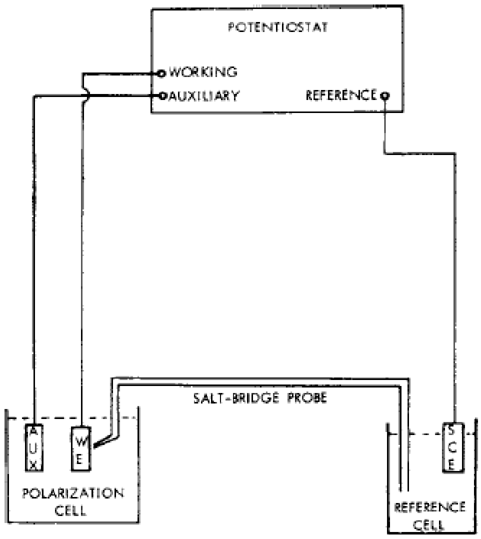


Fig. 3. Schematic of corrosion testing with three electrode cells [9].

In this corrosion test process, the test specimens were dipped for 55 minutes into a 3.5% NaCl electrolyte solution. The amount of solution used in this study is according to the requirement.

2.5 Microstructure Testing.

Following the welding process, a microstructure analysis is performed to identify the type of phase that has been formed. During the etching process, a solution consisting of HCL and HNO3 in a ratio of 50:50 was utilized. The specimen was photographed with a magnification of 200x so that photographs of the microstructure could be taken in the upper weld metal, lower weld metal, fusion line, and base metal.

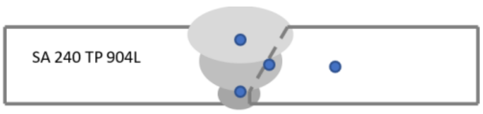
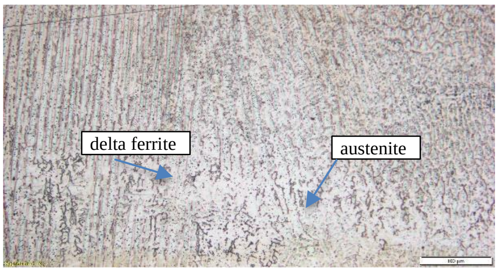


Fig. 4. Microstructure photo-taking location

3. Results and Discussion

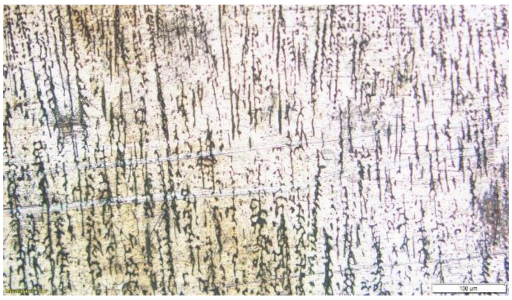
3.1 Micro Test Results

It is clear from looking at the results of the microstructure test that the most significant effect takes place in the lower area of the weld metal. This is because the area affected by repeated repairs is the lower weld metal. The phase structure formed where melting occurs (the weld metal) is typically a delta ferrite structure (primary ferrite), which is shown in black, and austenite, which is shown in white. The outcomes of the microstructure metallographic examination are depicted in Fig.s 4(a)–4 (d).



(a)

(b)



(c)

(d)

Fig. 5. Microstructure of weld metal (a) without repair, (b) repair 1x, (c) repair 3x, and (d) repair 5x [10].

3.2 Ferrite Content *Test Results*

The weld metal of the stainless steel 904L workpiece is subjected to ferrite number testing to determine the value of the ferrite number present in the weld metal. Table 2 displays the findings of an analysis conducted on the ferrite number.

Table 2. Test Results *of Ferrite Content*. [10]

No	Specimens	*Ferrite number* (FN)
1	Without *repair*	8.0
2	*Repair* 1x	11.2
3	*Repair* 3x	12.1
4	*Repair* 5x	16.2

3.3 Corrosion results

The variation with five times the repair had the highest corrosion rate value, with a value of 0.043865 (mm/years); the variation without repair had the lowest value of 0.0038275 (mm/years). The 5x repair variation had the most significant corrosion rate value. The test results to determine the ferrite content provide evidence that the formation of ferrite elements as a result of the repeated process of repair is responsible for the difference in the rates of corrosion experienced by each specimen.

Table 3. Corrosion testing results [10]

Types of Variations	*Corrosion rate (mm/year)*
Without *repair*	0,0038275
Repair 1x	0,006888
Repair 3x	0,03835
Repair 5x	0,043865

4. Conclusion

The various repair processes performed on materials made of duplex stainless steel contribute to a deterioration in the material's resistance to corrosion. It is possible from the results of the testing and the experiments that increasing the repair frequency can lead to an increase in the ferrite content in the weld metal area. This can be demonstrated by comparing the microstructure of specimens with no repair, one repair, three repairs, and five repairs, with the conclusion being that specimens with five repairs have the highest ferrite content. The increased amount of ferrite in the material causes a higher corrosion rate. Therefore, we can conclude that the number of repair activities that are executed leads to increasing corrosion rates, which are characterized by the amount of ferrite content that is created.

References

[1] Iman Agha Ali, "The effect of repeated repair welding on mechanical and corrosion properties of stainless steel 316L," *Materials & Design*, vol. 54, pp. 331-341, February 2014.

[2] Zeeshan Ahmad, "Effect of multiple repair welding on mechanical performance and corrosion resistance of quenched and tempered 30CrMnSiA steel," *Journal of the Brazilian Society of Mechanical Sciences and Engineering* , vol. 39, p. 1233–1243, 2017.

[3] J. Kristin R. Carpenter, "The effects of multiple repair welds on a quenched and tempered steel for naval vessels," *Welding in the World* , vol. 65, 2021.

[4] P. W. Bimantoro, "Pengaruh Multiple Repair Welding pada Pengelasan GTAW dan Smaw

Terhadap Struktur Mikro, Ferrite Number, Sifat Mekanik dan Laju Korosi pada Material," Surabaya, 2016.

[5] B. Holmes, M. Gittos, M. Dodge and K. Sotoudeh, "Ferrite Measurement in Duplex Stainless Steels," in *CORROSION 2019*, Nashville, Tennessee, USA, March 24 2019.

[6] "Langley Alloys," 2023. [Online]. Available: https://www.langleyalloys.com/knowledge-advice/what-is-ferrite-content-in-duplex-stainless-steel/. [Accessed June 2023].

[7] ASME Sect. II A Material, 2015.

[8] ASME Sect. II C Specifications for Welding Rods, Electrodes, and Filler Metals, 2015.

[9] A. G5, "Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements," 1999.

[10] A. S. Adi, " Analisis Multiple Repair Pada Pengelasan Material SA 240 TP 904l Terhadap Struktur Mikro, Ferrite Content, Kekerasan, dan Laju Korosi," Surabaya, 2018.