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Corossion Rate of Stainless Steel (SS 304) at Different Temperatures and Immersion Time in Seawater

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Abstract: This research investigates post-weld heattreatment and ferrite count for quality assurance of welded stainless steel in a sea water environment. The purpose of this study is to ensure quality using post weld heat treatment (PWHT) and ferrite count of welded stainless steel for maximum safety. It examines multiple grades of stainless steel, SS 304 at a high temperature of 200°C, 225°C, 250°C, 275°C and 300°C with an 'As received' (As Rcd). The research addressed the problem of corrosion and inconsistent mechanical properties that occur in stainless steel welds due to thermal cycles during welding. Welded stainless steel were heat treated at specified temperature of 200ºC, 225ºC, 250ºC, 275ºC and 300ºC, at different time 0, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50. It is then tested for corrosion properties with ferrite content measured to evaluate microstructural changes. All with the use of the following instruments which includes ferritoscope and a heat treatment furnace. Welded stainless steel specimens are subjected to PWHT at 200°C, 225°C, 250°C, 275°C and 300°C with an As Received (As-Rcd) sample used as Control. Results show that the as eceived welds exhibited the highest corrosion progression increasing from 0.71 to 2.17 over 45 hours, PWHT samples demonstrated improved corrosion resistance across all temperatures, with 225°C and 250°C showing the lowest corrosion values at most immersion times, At 45 hours corrosion values were 1.70 at 225°C and 1.75 at 250°C compared to 2.170 for 'As received'; while 200°C gave the lowest initial corrosion at 0 hour (0.26), 250°C and provided the most consistent reduction across extended exposure.

Keywords: *Quality, Microstructure, Exposure, Properties, Measured, Immersion, Values.*

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I. INTRODUCTION

Stainless steel is widely used in engineering structures, chemical processing plants, and fabrication industries due to its excellent mechanical properties and corrosion resistance. However, during welding operations, the materials undergo significant thermal cycles that alter its microstructure particularly within the heat affected zone (HAZ). These micro structural changes can influence the performance durability and reliability of welded joints, making quality assurance a critical concern in starves steel fabrication (Lippold & Kotecki, 2005).

One of the key challenges associated with welding stainless steel is the control of ferrite content in the weld metal. Ferrite plays a vital role in preventing solidification cracking during welding; however, excess or insufficient ferrite can adversely affect the mechanical properties and corrosion resistance of the welded join. Therefore, maintaining an optimal ferrite balance is essential to achieving high-quality welds that meet industrial standards and service requirements (Camillus, 2016).

Post weld heat treatment (PWHT) is another important factor that influences the properties of welded stainless steel. Heat treatment processes are often applied to release residual stress, refine microstructure, and enhance corrosion resistant. This makes the investigation of appropriate PWHT parameters is crucial for ensuring the integrity and long-term performance of welded structure (Temitope, 2020).

In modern industrial practice, quality assurance in welding goes beyond visual inspection and requires a scientific understanding of metallurgical transformations that occur during and after welding. The relationship between heat treatment processes, ferrite content, and the resulting mechanical and corrosion properties must clearly understood to ensure

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that welded components meet safety and performance standards (ASM International, 2003; Oluwaseyi, 2021).

Despite the widespread use of stainless steel, there remains a need for systematic evaluation of how post weld heat treatment affects ferrite distribution and overall weld quality. This study is therefore aimed at investigating the effects of post weld heat treatment on stainless steel, with particular emphasis on ferrite count as a key indication for quality assurance. The findings are expected to contribute to improved welding practices and more reliable stainless steel structures in industrial obligations (Lilly, 2001).

II. MATERIALS AND METHODS

This chapter throws more light on how the research works was carried out. It explained the materials to be used and methods (procedures) to be employed in carrying out the study.

➢ *Materials*

The materials used for this study include:

- Stainless steel samples – Austenitic stainless steel SS 304
- Electrodes
- Welding machine
- Linear Polarization (LP) corrosion meter

- *Welding Machine*

Welding machine (SMAW model – No. MIL-029016236) was used to cut the stainless-steel samples into desired dimensions in preparation for experimentation. The welding machine is set to direct a current (DC) with a positive polarity into the samples at a desired penetration for joining metals.

- *Electrodes*

Stainless steel electrodes were used to join the materials using welding machine. It is a crucial component in welding and corrosion testing.

- *Linear Polarization (LP) Corrosion Meter:*

This is a device used to measure the corrosion rate of metals in various environments. All the samples were taken for corrosion test using accelerated corrosion test method with the use of linear polarization resistant meter.

III. RESULTS AND DISCUSSIONS

➢ *Determination of Corrosion Rate of Work Samples*

The environment a material is use affects its corrosion behaviour, so the rate of corrosion of work samples was investigated after post weld heat treatment using seawater. One of each set of the welded samples were 'As – received' sample regarded as control was not subjected to post weld heat treatment, while the order fifteen samples were subjected to post weld heat treatment in the heat treatment furnace. Corrosion tests were conducted on the samples at various temperature and immersion time using linear polarization spectrometer and the results is reported accordingly (App B).

- *Corrosion Rate of SS 304 Samples in Seawater*

The results of corrosion rate with immersion time for stainless-steel (SS 304) samples are as shown in Table 1 and presented in Figures 1, and depicted in Figures 2 (a – f) respectively, while the average plot was shown in Figures 2.

Table 1 LPR Corrosion Rate (mpy) of Post Weld Heat Treated SS 304 in Sea Water

Immersion				**Temperature**		
Time(min)	**As Rcd.**	**200°*C***	**225°*C***	**250°*C***	**275°*C***	**300°*C***
0	0.71	0.26	0.33	0.44	0.50	0.59
5	0.84	0.72	0.53	0.68	0.71	0.70
10	1.19	0.90	0.89	0.88	0.83	1.0
15	1.39	1.07	1.19	1.08	1.10	1.16
20	1.55	1.16	1.33	1.18	1.27	1.29
25	1.76	1.32	1.39	1.38	1.36	1.47
30	1.82	1.48	1.47	1.53	1.49	1.52
35	1.93	1.56	1.56	1.54	1.62	1.61
40	2.14	1.62	1.64	1.68	1.67	1.78
45	2.17	1.74	1.70	1.75	1.78	1.81
Average rate	1.55	1.183	1.203	1.214	1.233	1.283
Ferrite Count (*FN*)		0.6	1.0	0.9	0.6	0.8

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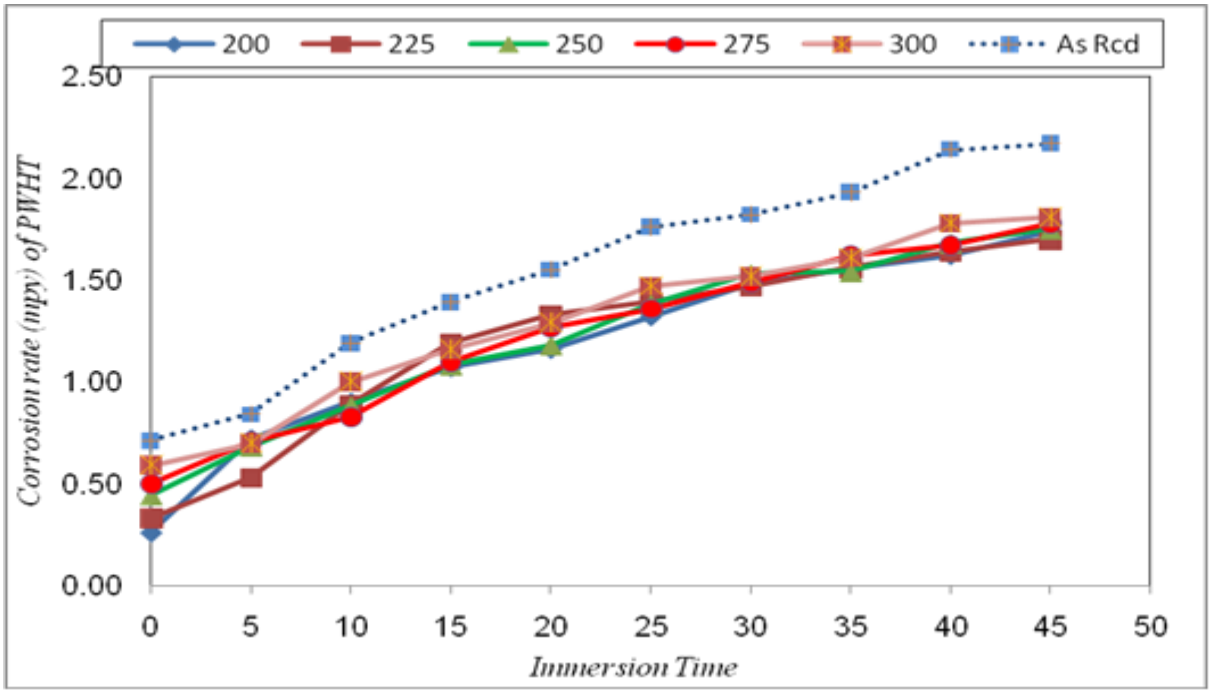


Fig 1 Corrosion Rate of SS-304 in relation to Immersion Time

- *Corrosion Rate with Immersion Time for Stainless Steel Samples for SS 304*

From the result obtained (as seen in Table 1 and plotted in Figure 1), it could be noted that Austenitic stainless still has no corrosion value if not weld. But to be used for any purpose has to go thru joining and welding. This welding process input some amount of ferrite, which may cause corrosion. So, post weld heat treatment (PWHT) is used to reduce the corrosion rate after welding and still retain its quality for quality assurance.

As seen in the graph (Figure 1) the material going through PWHT have a reduced corrosion rate at temperature of 200°C than the as received material, so PWHT at temperature 200°C takes less time with a less corrosion rate thereby saving time by avoiding rework.

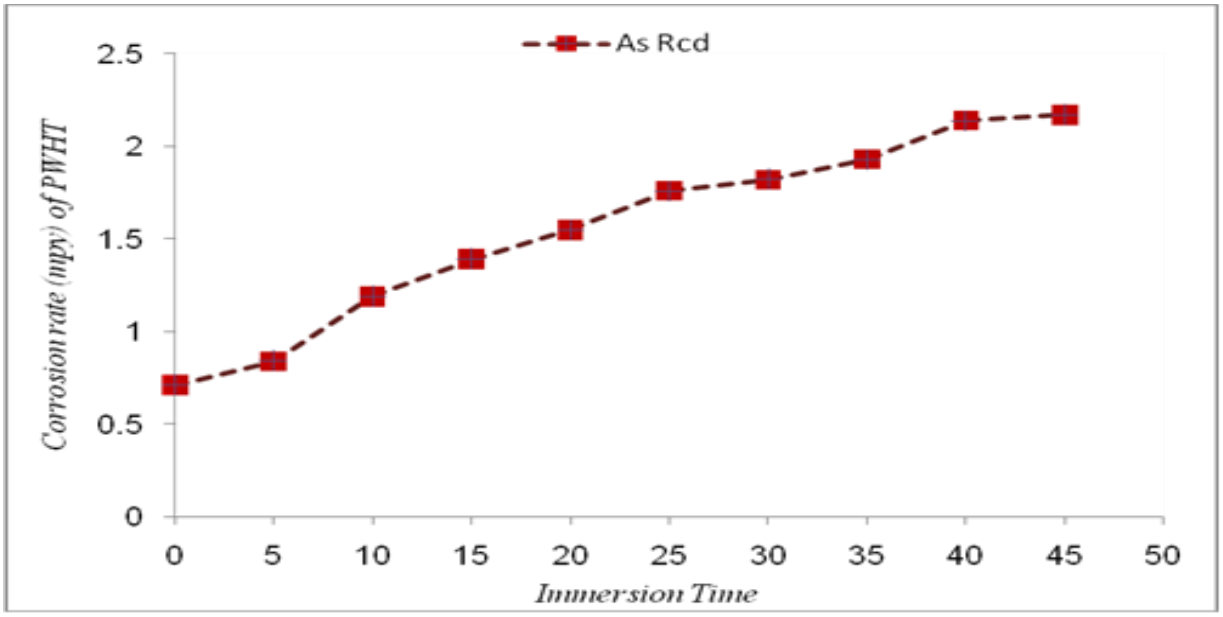


Fig 2 (a) Corrosion Rate Vs Immersion Time as ‘as Received of Stainless Steel for SS 304

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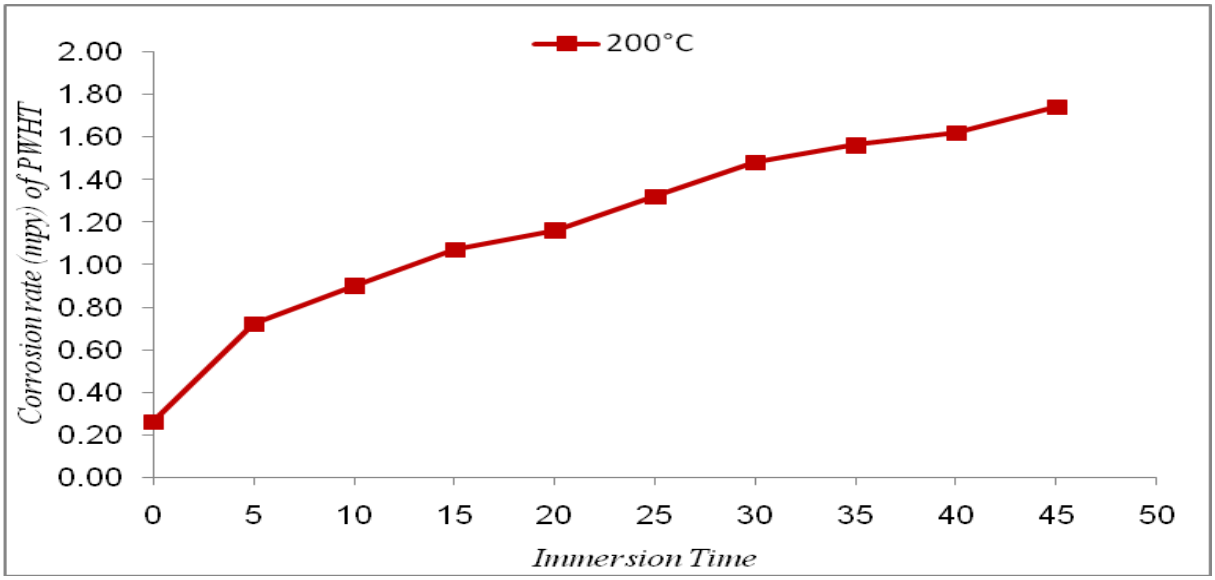


Fig 2 (b) Corrosion Rate Vs Immersion Time at 200°C Temperature for SS 304

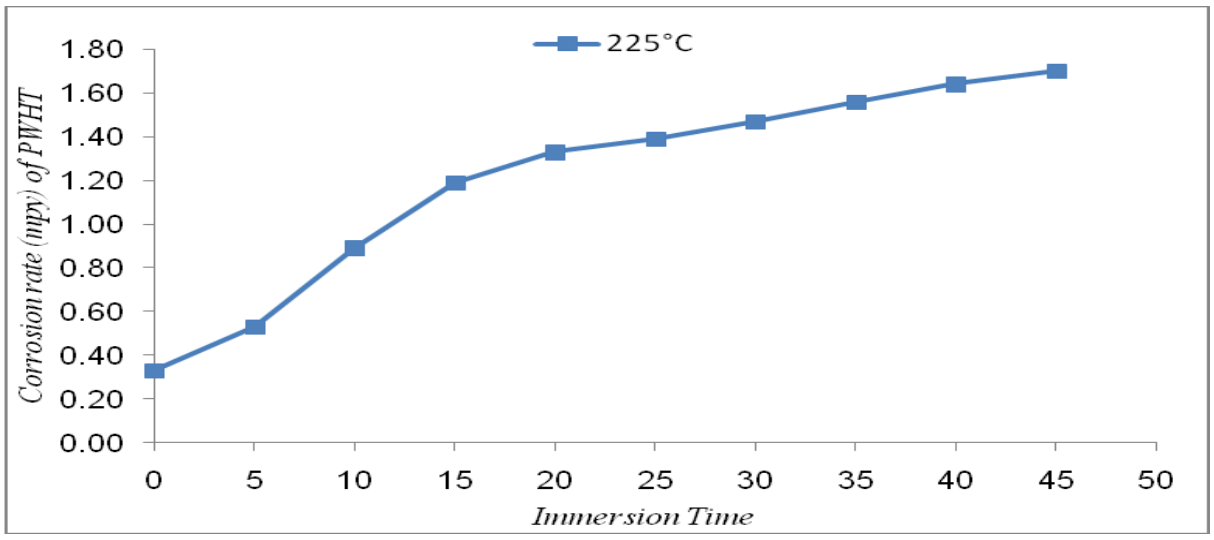


Fig 2 (c) Corrosion rate Vs Immersion time at 225°C Temperature for SS 304

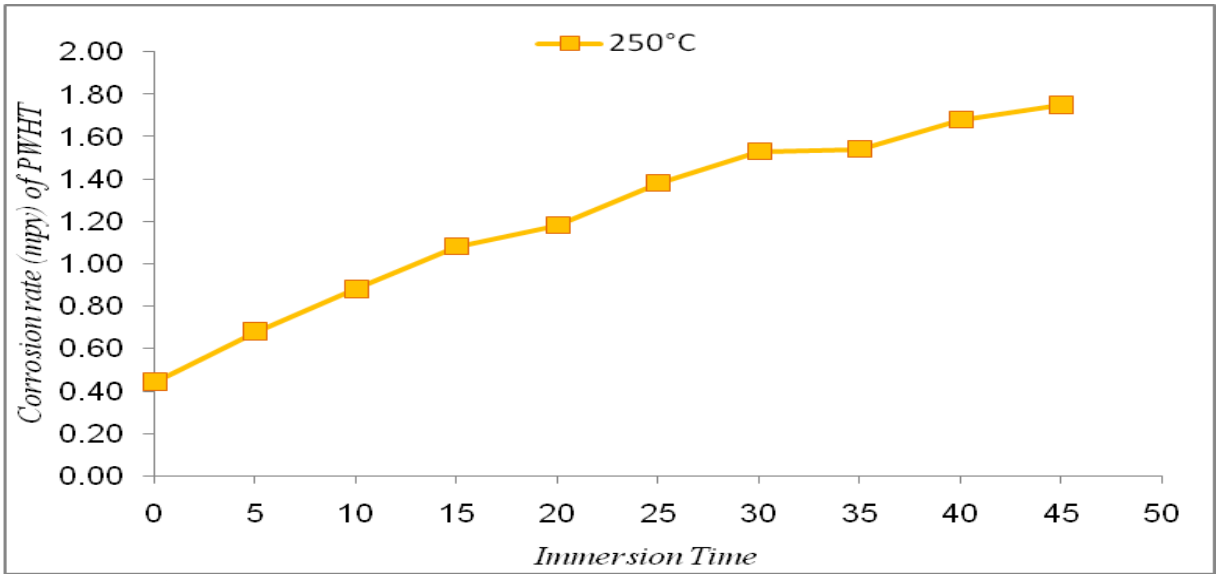


Fig 2 (d) Corrosion Rate Vs Immersion Time at 250°C Temperature for SS 304

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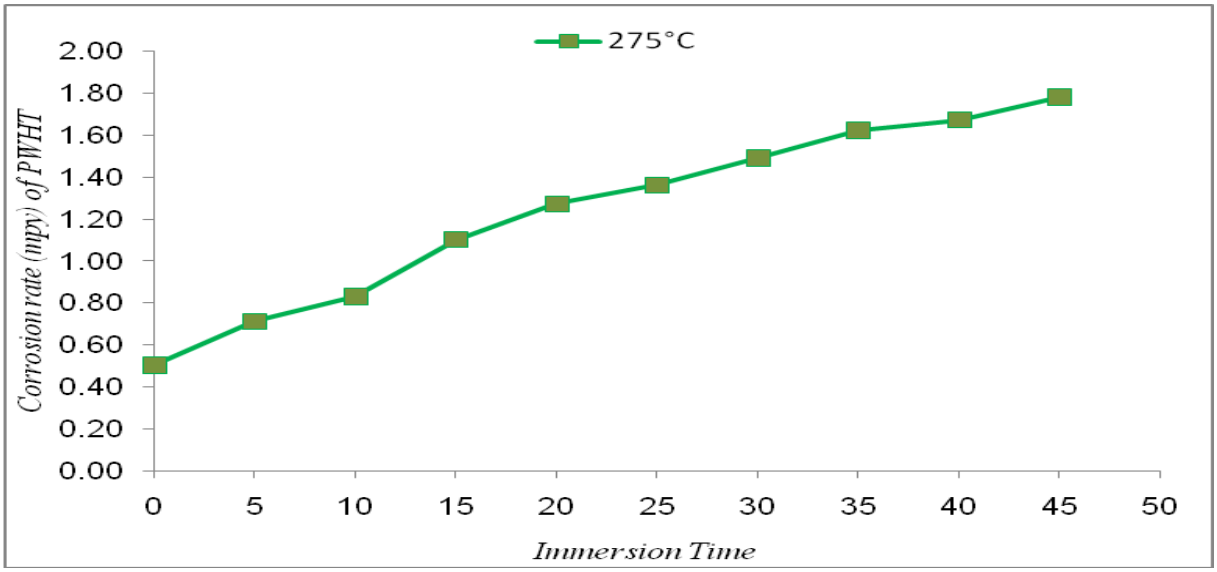


Fig 2 (e) Corrosion Rate Vs Immersion Time at 275°C Temperature for SS 304

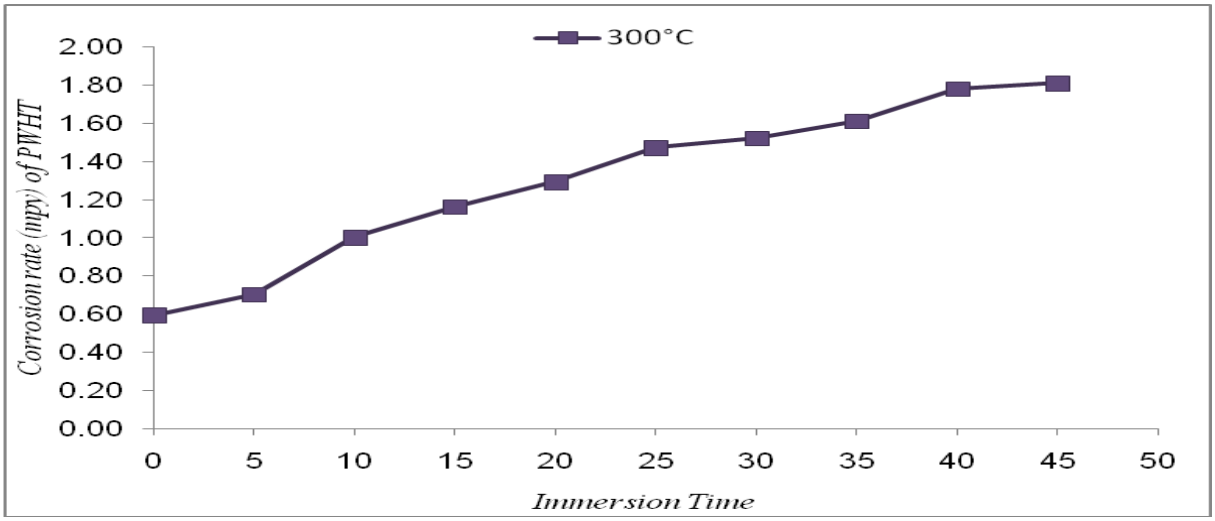


Fig 2 (f) Corrosion Rate Vs Immersion Time at 300°C Temperature for SS 304

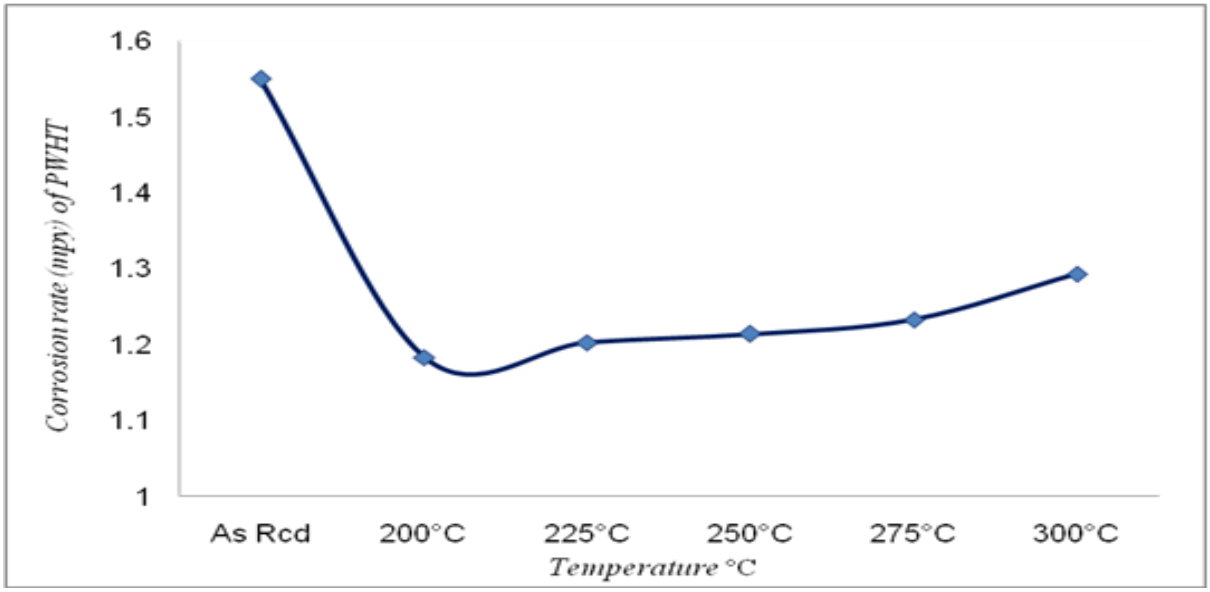


Fig 3 Average Corrosion Rate at Different Temperature for SS 304

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Figure 2(a) shows that corrosion rate of SS 304 'As Received' (control) was 0.72 mpy at zero (0) immersion time, but as immersion time increased, corrosion rate increases. Also, it was found that corrosion rate of SS 304 increases with increase temperature. Similarly, corrosion rate of the other uncontrolled SS 304 samples increases with increase immersion time. It was also, observed that corrosion rate of uncontrolled SS 304 samples reduced during post weld heat treatment process. Results obtained revealed that heat treatment should be carry out on welded stainless steel to be use in corrosive environment to prevent or reduce corrosion.

From the result obtained Table 1 and plotted in Figure 1 (a - f), it could be noted that Austenitic stainless steel has no corrosion value if not weld. But to be used for any purpose has to go through joining and welding. This welding process input some amount of ferrite, which may cause corrosion. So, post weld heat treatment is used to reduce the corrosion rate after welding and still retain its quality for quality assurance.

As seen in the graph (Figure 2) the material going through PWHT have a reduced corrosion rate at temperature of 200°C than the as received material, so PWHT at temperature 200°C takes less time with a less corrosion rate thereby saving time by avoiding rework.

Still from Table 1 and Figure 3 for SS 304, it was investigated that at temperature of 300°C, average corrosion rate was 1.28. At temperature of 200°C average corrosion rate was 1.18 that is, the minimum corrosion rate.

IV. CONCLUSION

In conducting accelerated corrosion test using linear polarization resistant (LPR) corrosion meter to get the corrosion level of the samples, the researcher observed that the LPR corrosion rate indicates that post weld heat treatment of SS304 is susceptible to corrosion in seawater, with increasing corrosion rates observed with immersion time and temperature. The findings suggest that Stainless Steel (SS 304) may not be suitable for applications in seawater at high temperatures. In using post weld heat treatment and ferrite count of the work piece to enhance the quality of welded joint, the researcher conclude that the post weld heat treatment and Ferrite Count results indicate that the welded components have achieved the desired microstructure and properties within a 5-second interval. The results also indicate that the PWHT process has been effective in relieving residual stresses and improving corrosion resistance.

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