Corrosion Rate of A36 Plate with Zinc Anode and Combination of Zinc Anode with Continuous Direct Current

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Abstract: Corrosion, in general is a process through which refined metals are converted into more stable compounds such as metal oxides, metal sulfides, or metal hydroxides. Likewise, the rusting of iron involves the formation of iron oxides via the action of atmospheric moisture and oxygen. Iron is a metal that rusts easily. Iron rust is a substance produced in corrosion events, which is in the form of a reddish-brown solid substance that is brittle and porous. The chemical formula of iron rust is Fe2O3 x H2O. The impact of corrosion events is detrimental. This corrosion rate research uses ASTM A36 plate (steel with low carbon content max 0.17 %C) for venture floating dock deck with three kinds of treatment: plate without corrosion protection (A), with zinc anode protection (B) and combined protection from zinc anode and DC electric (C). The corrosion rate is calculated using the weight loss method. The results showed the magnitude of corrosion rates in treatment A, B and C respectively: 0.66 mpy, 0.22 mpy and 0.17 mpy. Treatment with zinc anode protection and DC current produces the smallest corrosion rate value among others. Hardness values tested using Brinnnel with the values: 136.3 BHN, 205.2 BHN and 202.9 BHN respectively. The highest hardness value on the plate with zinc anode protection treatment.

1 INTRODUCTION

In recent years, weathering steel has been widely used in marine engineering structures, such as railway vehicles, bridges and berths (Yang, F. et al., 2022). Recently, a lot of efforts have been put into studying the corrosion process of steel. These include studies on metal corrosion in various indoor and outdoor environments and the influence of temperature, humidity, and corrosion ions on the corrosion rate and products (Di Sarno et al., 2021), (Ma, Y. et al., 2009), (Fan, Y. et al., 2020). Indoor environmental experiments are used to control the experimental variables and decouple the effects of different factors on corrosion behaviour (Wu, H. et al., 2019), (Irshad, H. M. et al., 2022). The marine atmosphere can significantly accelerate the corrosion rate of carbon steel. Various studies have discussed the relationship between chloride ions, water, oxygen, corrosion products, and corrosion rate in marine atmosphere through indoor accelerated corrosion experiments (Alcántara, J. et al., 2017), (Zhang, X. et al., 2019), (Zhang, Z. et al., 2023). Ma et al. (Zhang, B. et al, 2020) proposed that in an atmospheric environment, chloride ions can penetrate through the rust layer and accelerate corrosion rate, and that different chloride ion contents have different effects on the generation of corrosion products. Fan et al. (Ohtsuka, T. and Tanaka, S., 2015) analysed the rust layer structure and proposed that the delamination of the rust layer has different effects on the penetration of corrosive ions. The dense rust layer can effectively slow the corrosion rate, and the density of the inner rust layer increases with increasing corrosion time. Wang et al. (Kamimura, T. et al., 2006) suggested that there are many types of FeOOH in corrosion products and the proportion of different components changes with the corrosion duration, and γ-FeOOH gradually changes into α-FeOOH under the influence of corrosive ions and oxygen, which causes the rust layer to become dense and slows down the corrosion rate. Although various studies on the corrosion of carbon steel in a

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marine atmosphere exist, some unique environments need to be considered, such as the influence of strong electric field (Cheng, X. et al., 2017).

The unique environmental characteristics of different marine zones are responsible for the corrosion behavior distinctions. In the atmosphere, the environment corrosivity is determined by the temperature, relative humidity, chloride deposition rate, and pollutants (Jeffrey, R., & Melchers, R. E., 2009), (Feng, X. et al, 2020), resulting in the corrosion occurrence under the adsorbed thin electrolyte layer (Bhandari, J. et al, 2015). In the splash zone, the typical characteristics are the intermittent wave splashing and the sufficient oxygen (Xu, Y. et al, 2022), (Yusoff, N. H. N. et al, 2013). The tidal zone also experiences fluid erosion because of the seawater scouring (Wang, Y. et al, 2023). Besides, it also includes the full immersion stage during a single tidal cycle (Gao, F. et al, 2023). Moreover, the wet-dry cycles are the common characteristics of the above three zones, while the wetting time, frequency, and electrolyte thickness are different. The distinct feature of the full immersion zone is the difficulty in oxygen availability. In addition, the sediment and accumulation of the organisms contribute to the corrosion process underneath them (Situmeang, I. D. R., and Heltina, D., 2020).

The use of steel plates on the deck floating dock of ships is a common thing used as a shipbuilding material because it is quite adequate. But iron and steel are so reactive that they have a tendency to corrode in corrosive areas, namely seawater. Corrosion is a natural symptom that commonly occurs in ship plates as a result of interaction with the surrounding environment so that it undergoes mass changes in corrosive environments. This study tested the corrosion rate on the ship's floating dock deck plate with Zinc Anode and DC electric current. The determination of the exact protection on the ship's floating dock deck plate was tested using the experimental method of seawater solution and Zinc Anode with electric current. The addition of DC electric current to the Zinc Anode will increase higher protection on steel plates so that the risk of damage is lower and can be used longer.

This study aims to analyze corrosion rate by calculating weight loss and testing hardness on A36 plate for deck floating dock venture 3 with zinc anode protection and DC current and zinc anode without using DC current.

2 METHODS

The steps carried out in this experiment are as follows:

1. Prepare tools, equipment that will be used to make corrosion rate test experiments, starting from preparing plastic measuring cups, sea water, plates, USB Port cables, and Zinc Anode
2. The first experiment is a corrosion rate experiment with a plate and seawater put into a measuring cup and then calculated the corrosion rate every 168 hours (7 days), 336 hours (14 days), 504 hours (21 days), up to 720 hours (30 days).
3. The second trial was with the plate method protected with Zinc Anode from 168 hours (7 days), 336 hours (14 days), 504 hours (21 days), to 720 hours (30 days).
4. The third trial is that the plate is protected with DC Electric Current and Zinc Anode along 168 hours (7 days), 336 hours (14 days), 504 hours (21 days), up to 720 hours (30 days).
5. After 720 hours (30 days) the results were calculated using the corrosion rate formula with the weight loss method.

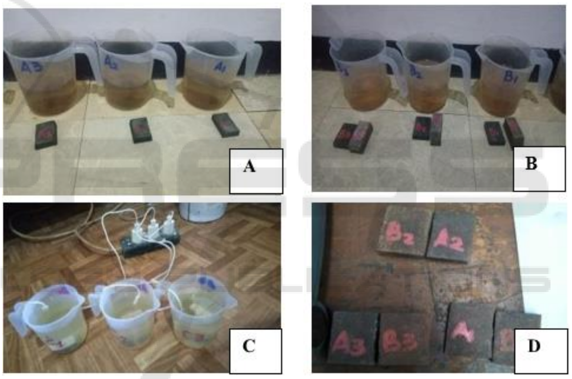

Figure 1: A36 Plate Material with treatment: A Without Corrosion Protection, B. With Zinc Anode Protection, C. With Zinc Anode Protection and DC Current, D A36 Plate Experimental Results.

3 RESULTS AND DISCUSSION

3.1 Corrosion Rate

Figure 1 shows a comparison of corrosion rate of protected versus unprotected carbon steel A36. The result of corrosion rate experiments with plates without using protection resulted in the greatest corrosion rate of 0.66 mpy. Corrosion protection the best is to use protection with zinc anode fed by DC current. The corrosion rate on this plate is 0.17 mpy (the lowest). The results of the immersion test without the protection tested on sodium chloride solution for 30 days showed the greatest weight loss and the corrosion rate was 0.66 mpy. This is due to the high dissolved salts causing an increase in the conductivity of the salt solution (Irshad, H. M. et al., 2022), the steel undergoes corrosion due to the presence of the Cl- ion where the Cl- ion will break the passive layer on carbon steel or prevent the formation of a passive layer on carbon steel (Situmeang, I. D. R., and Heltina, D., 2020). On protected carbon steel, less weight loss was observed than the unprotected carbon steel. It can be seen from Figure 1 that the rate of corrosion of steel protected by an anode of zinc sacrificed and DC current was slower compared to the rate of corrosion of unprotected carbon steel plate A 36. The results of the calculation of corrosion rates with time and treatment variations are presented in Table 1 and Figure 2 below:

Table 1: Calculation of Corrosion Rate of A36 plate.

Sample	Wo (gr)	W4 (week4) (gr)	W (gr)	Cr (mpy)	Average Cr (mpy)
A1	95,00	92,80	2,20	0,89	
A2	92,00	91,00	1,00	0,41	0,66
A3	93,00	91,30	1,70	0,69	
B1	93,00	92,60	0,40	0,16	
B2	102,00	101,00	1,00	0,41	0,22
B3	99,00	98,80	0,20	0,08	
C1	78,40	78,40	0,00	0,00	
C2	79.40	79,30	0,10	0,05	0,17
C3	76,00	76,00	0,00	0,00	

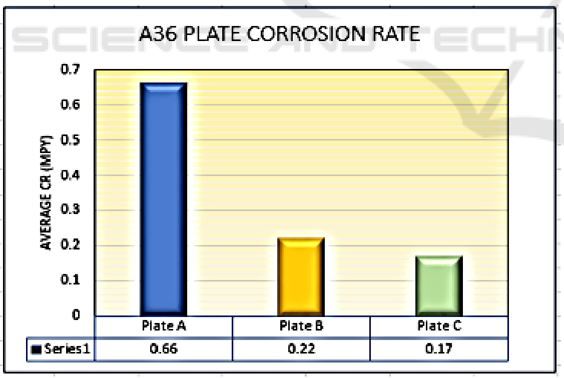

Figure 2: Corrosion Rate on Various Treatments.

A zinc anode's protective properties result from a strongly negative reduction potential, which is more negative than the metal it is protecting. Oxidants, which corrode metals, will oxidize the zinc anode rather than the protected metal structure, thus preventing the structure from being corroded.

3.2 Hardness Test

The results of the hardness test calculation can be seen in Table 2 and Figure 3 below:

Table 2: The Hardness Brinnel Number.

Sample	Point I (BHN)	Point II (BHN)	Point III (BHN)	Average (BHN)	(BHN)
A1	128	144	146	139.3	
A2	131	152	127	136,7	136.3
A3	141	110	148	133.0	
B1	219	196	247	220.7	
B2	177	169	164	170.0	205.2
B3	233	248	194	225.0	
C1	174	192	181	182.3	
C2	236	249	250	245.0	202.9
C3	162	177	205	183.3	

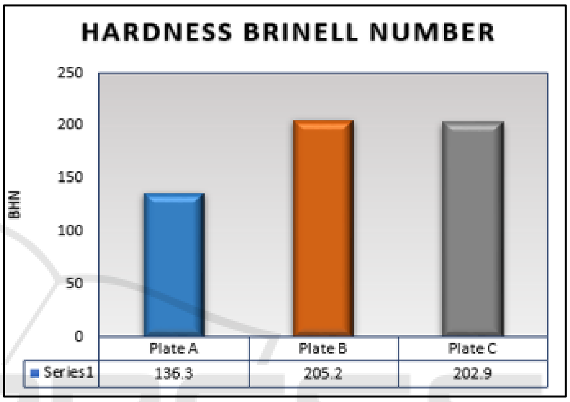

Figure 3: A36 plate hardness test on various treatments.

The result of hardness testing without protection is 136.3 BHN, while with Zinc Anode protection is 205 BHN and on a combined treatment between Zinc Anode and DC Current is 202.9 BHN (Fig. 3). This result is above the minimum limit of marine plate hardness. Cathodic protection is an effective way to prevent stress corrosion cracking (cracking due to corrosion), by restoring the direction of the corrosion current to restore electrons that decompose from certain metals, which are immune or immune so that the corrosion process on metals can be reduced or eliminated.

The principle of cathodic protection is to provide electrons for the metal structure to be protected. The underlying theory is that if current flows from the positive pole to the negative pole (conventional electrical theory) the structure will be protected if current enters from the electrodes. Conversely, the corrosion rate will increase if the current enters through the metal to the electrode. In the process of corrosion in case of scratches or peeling of the coating. The presence of water vapor, CO2 gas in the air and other particles, a mini voltaic cell occurs with Zn as the anode and Fe as the cathode. Zn will oxidize first because its Eo value is smaller than Fe, so electrolytic corrosion (an electrochemical reaction that oxidizes metals) does not occur.

From the calculation of the corrosion rate of plates using protection, better results are obtained compared to no protection. This happens because of the potential difference, then the electron current will flow from the installed anode and will resist the electron current from the nearby metal, so that the metal turns into a cathode region. This is what slows down the plate experiencing the corrosion rate while on the contrary the plate without protection will release electrons causing damage to the plate so that it is easy to corrode.

4 CONCLUSION

1. From the results of the three experiments, results were obtained that showed that corrosion occurred which was characterized by a decrease in the weight of objects.
2. After calculating the corrosion rate value using the weight loss, the result is a slower corrosion rate when using zinc anode protection and DC current, followed by zinc anode protection and finally without using protection.
3. From the three experiments, it was obtained that the value of corrosion rate with protection with zinc anode and DC current was 0.17 mpy or corrosion rate was 17%, then with zinc anode protection with a value of 0.22 mpy or corrosion rate was 22% and the last one was without protection the value obtained was 0.66 mpy or corrosion rate was 66%.
4. With this research, it has become the initial stage to be applied directly, so that the use of this method can save routine repair costs in the shipping industry.

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