

THE EFFECT OF TIME VARIATION ON CORROSION BEHAVIOUR OF ASTM A36 IN SEAWATER FROM WEST BANGKA OF BANGKA BELITUNG ISLANDS, INDONESIA

Randi G.P. Pratama, Diah Kusuma Pratiwi*, Nurhabibah P.E. Utami

Department of Mechanical Engineering, Faculty of Engineering, Universitas Sriwijaya, South Sumatera, Indonesia

ABSTRACT

Corrosion hazards in marine environmental construction have been studied. ASTM A36 can be widely used in various industrial sectors and oil extracted offshore. The main objective of this study is to analyze the influence of variation immersion time to corrosion behaviour ASTM A36 by using seawater from Bangka Barat Regency, Bangka Belitung Islands as a corrosive media by performing Brinell hardness test, measurement of weight loss and corrosion rate, and and confirm the data obtained with the formed of microstructure. The results revealed that immersion time of 144 hours produced the highest corrosion rate of 27.97 Mpy and but has the lowest hardness number 136,924 BHN. Microstructural observations found the presence of brownish yellow and black (magnetic Fe₃O₄) corrosion patterns increased along with the increasing immersion time due to the lack of oxygen concentration during the specimen corrosion process.

Keywords: ASTM A36, Corrosion rate, Immersion time, Seawater, Fe₃O₄

1 INTRODUCTION

ASTM A36 is a structural steel that is flexible enough to be used in many structural applications. It has a good ductility, strength and toughness characteristics. With all the advantages, ASTM A36 is included in the structural class at the American Society of Testing Materials as the most commercialized material in the world due to its very flexible use in all conditions, both in industry and oil extracted offshore [1]. ASTM A36 belongs to the class of low carbon steel which is also known as mild steel. This material has a carbon percentage ranging from 0.25 to 0.29% and an iron percentage of 98%. The requirements for the tensile strength value of ASTM A36 are shown in Table 1 while the chemical composition of ASTM A36 is shown in Table 2 below:

Table 1. Requirements for the strength value of ASTM A 36 based on Standard Specification for Carbon Structural Steel [2]

UTS	,ksi (Mpa)	55-80 (400-500)
Yield Strength	,ksi (Mpa)	36 (250)
Elongation	,%	23

Table 2. ASTM A 36 chemical composition requirements based on Standard Specification for Carbon Structural Steel.

(%)	Plates Width (mm)				
	≤ 20	20-40	40-65	65-100	> 100
Carbon (c), max	0.25	0.25	0.26	0.27	0.29
Mangan (Mn)	0.18-1.20	0.18-1.20	0.18-1.20
Fosfor (P), max	0.04	0.04	0.04	0.04	0.04
Sulfur (S), max	0.05	0.05	0.05	0.05	0.05
Silicon (Si)	0.40 max	0.40 max	0.15-0.40	0.15-0.40	0.15-0.40
Copper (Cu),	0.20	0.20	0.20	0.20	0.20

Damage due to corrosion that occurs in thermodynamic system between the environment and metal is a serious and challenging problem faced by the manufacturing, petroleum and various industries, especially construction in the marine environment . Most industrial component

*Corresponding author's email: pratiwi.diahkusuma@unsri.ac.id
<https://doi.org/10.36706/jmse.v8i2.69>

[3] designs cannot be created without considering the effects of corrosion over the lifetime of the product. In addition to acid and oil, the other factors such as air humidity, water, salinity, chemicals, ammonia and acid pH are the most important corrosion agents [4].

Based on previous research [5] It is very clear that the corrosion rate is strongly influenced by environmental factors, pH, pressure time and temperature. Environmental factors in seawater are not only influenced by salinity, oxygen dissolved and marine biota but also by the content of chemical elements caused by the mining process and waste disposal into the sea. Pb content due to mining activities in the waters of West Bangka is around 0.1748 mg/L which is higher than the quality standard for Pb content in seawater for marine biota 0.008 mg/L [6].

The main objective of this study is to investigate the effect of immersion time on the corrosion rate of ASTM A36 with seawater corrosion media from Bangka Barat Regency, Bangka Belitung Islands. The results of the research on variations in immersion time of 48, 96 and 144 hours were analyzed by performing hardness tests and microstructure observations.

2 METHODOLOGY

ASTM A36 corrosion test specimens were prepared with dimensions (length 100 mm, width 50 mm, and thickness 10 mm). Specimen preparation was carried out by cleaning using distilled water and then weighing the initial weight. The process of corrosion of the test sample was conducted by the Total Immersion method in seawater corrosive media. Based on the ASTM G31-72 standard regarding to Standard Practice for Laboratory Immersion Corrosion Testing of Metals, the time required for the corrosion process to be carried out optimally is at least 48 hours so that in this study the immersion time was 48 hours, 96 hours and 144 hours.

Table 3. Chemical composition of corrosive media

Test Parameters	Units	Results
Dissolved solid (TDS)	mg/L	31,3
Salinity	ppt	27
Temperature	°C	24,1
Conductivity	µS/cm	47,9
pH	-	7,00
Dissolved Oxygen	mg/L	8,9

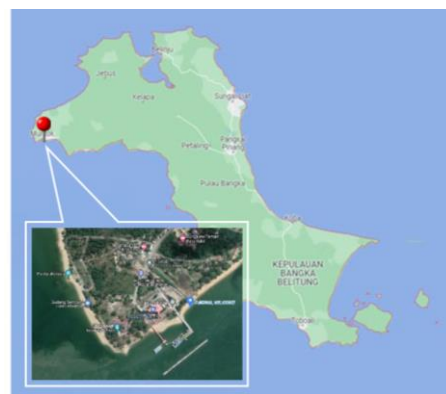


Figure 1. The sites of seawater corrosive media

The sites of seawater corrosive media and the test results of its chemical composition are shown in Figure 1 and Table 3. Microstructure observation was conducted by using Optical microscope. Samples preparation are; cutting, mounting, polishing and etching with 2% Nital.

Hardness testing was conducted by using Brinell method to analyze changes in the hardness value of ASTM A36 based on variations of immersion time in corrosive media. The loading used is 3000 kgf. Hardness Brinell Number (BHN) obtained by using Equation 1 below.

$$BHN = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \quad (1)$$

Calculation of the corrosion rate was conducted by comparing the changes of thickness and weight reduction of the specimens before and after the immersion process in corrosive media for 48, 96, and 144 hours. Calculation of corrosion rate shown by equation 2 below [7]:

$$CR (mpy) = \frac{(K \times \Delta W)}{(A \times T \times D)} \quad (2)$$

where; W = weight loss (gr), K = Constan factor, D = Density (g / cm³), A = area of sample (cm²), T = time exposure of the metal (hours).

3 RESULTS AND DISCUSSIONS

Based on thickness measurement of the specimens in Table 4, the results show that the immersion time is directly proportional to the thickness reduction of the specimen after the corrosion process. The longer of immersion time, the longer the interaction of the specimen surface with the corrosive media, the more corrosive ions are formed and attacked the surface of the specimens [8]. Based on the data obtained, it

shows that the longer immersion time will initiate the higher weight loss of the specimen. The highest weight reduction occurred in the 144 hour specimen with the weight loss of 1.016 g, while the lowest weight loss occurred in 48 hours specimen with a weight loss of 0.372 grams, as shown in table 5.

Table 4. ASTM A36 thickness reduction

Material	Immersion time	Initial Thickness (mm)	Thickness after Corroded (mm)	Thickness reduction (mm)
ASTM A36	48	10,16	10,14	0,02
	96	10,16	10,10	0,06
	144	10,16	10,06	0,10

Table 5. ASTM A36 Weight reduction

Material	Immersion time	W ₀ (gr)	W ₁ (gr)	ΔW (gr)
ASTM A36	48	377,613	377,241	0,372
	96	376,449	375,644	0,805
	144	379,458	378,442	1,016

Table 6. ASTM A36 Brinell Hardness number

Material	Immersion time	BHN
ASTM A36	As received	140,390
	48	139,628
	96	137,729
	144	136,924

Hardness number of ASTM A36 decreases along with the decrease in the ductility value of the material which is measured by the length of time immersion as shown in table 6. The formation of corrosion directly affected to decreasing the quality of the metal becomes brittle, rough, and easily crushed. Figure 2 shows the different of ASTM A36 corrosion rates based on different immersion times. Based on the data obtained, 144 hours of immersion time has the highest corrosion rate 27.97 Mpy. There was no significant change in the value of the corrosion rate of the 96 hour specimen with a value of 27.03 Mpy. The lowest corrosion rate was recorded in the 48-hour specimen with a corrosion value of 25.23 Mpy. As previously mentioned, the corrosion rate of seawater on the specimen surface is initiated by hydrostatic pressure, organic materials, salinity, temperature, pollution, oxygen solubility and pH of seawater [9]. Unprotected surfaces exacerbate corrosion rates and initiate the faster surface degradation [10].

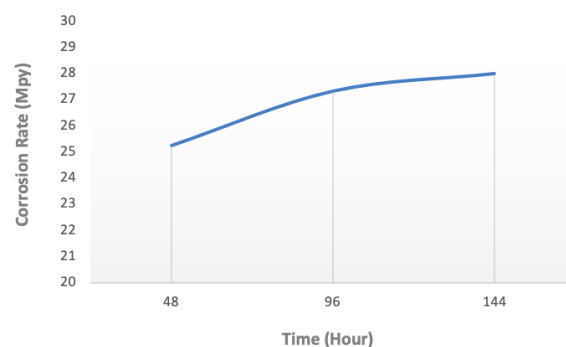


Figure 2. Corrosion rate ratio

The presence of ferrite (α) and perlite phases in the ASTM A36 specimen are shown in Figure 3. The ductile and malleable ferrite phase is present in a white colored pattern with a carbon solubility of 0.008% at room temperature. While the pearlite (P) phase which is present in a black pattern has strong and hard properties with its solubility in iron carbon of 0.8% [11].

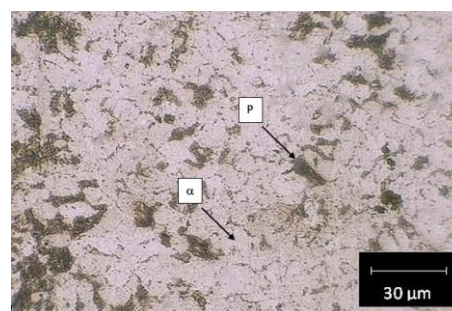
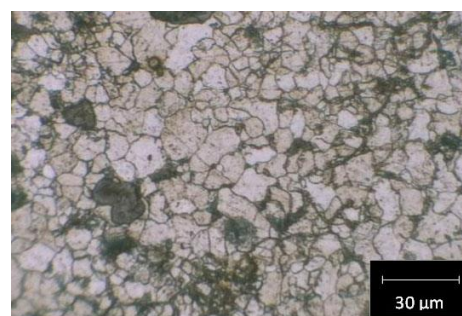
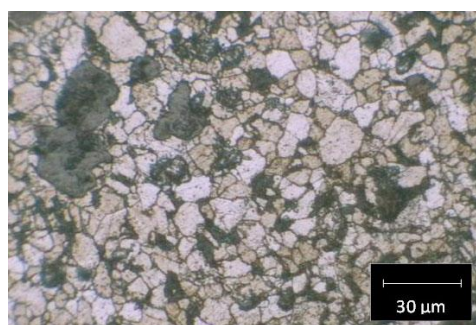


Figure 3. Optical Microscope characterization of ASTM A36 before corroded

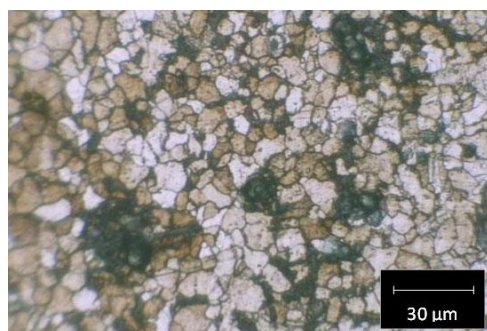
The correlation between corrosion rate and microscopic phenomena that occur in ASTM A36 specimens based on variations in immersion time was observed by using an optical microscope with a magnification of 450x as shown in Figure 4. Based on the data obtained, there are differences in the appearance of the microstructure of the sample which is influenced by the presence of uniform corrosion and intergranular corrosion.



(a)



(b)



(c)

Figure 4. Optical microscope characterization of ASTM A36 with variation immersion times (a) 48 Hours (b) 96 hours (c) 144 hours

Figure 4(a) shows the presence of uniform corrosion which is the most common attack in various work environments and also responsible for any material reduction in industry [12]. The size of the corroded area is in line with the length of time exposure of the metal to corrosive media. It is shown by the increasing size of the corrosion shape as the increase of time exposure to the corrosive media (as shown in Figures 4(b) and 4(c)).

96 and 144 hours specimens as shown in Figures 4(b) and 4(c), a brownish-yellow pattern was formed which gradually turned darker to uniform corrosion perfectly formed along with the length of immersion time [13]. The presence of brownish-yellow rust and black rust based on research [14] are forms of the Fe_3O_4 phase which is a magnetic iron oxide due to lack of oxygen during the corrosion process. The reaction results in the formation of brownish yellow rust involving the iron oxide itself. The longer exposure time of specimen with corrosive media, it will initiate the formation of new corrosion layer on entire surfaces. The corrosion rate is closely related to the decrease of hardness value on the sample surface followed with the reduction in ductility.

4 CONCLUSIONS

ASTM A36 with immersion time of 144 hours produced the highest corrosion rate of 27.97 Mpy, while the 48 hours specimen has the lowest corrosion rate of 25.23 Mpy. The hardness value is inversely proportional to the immersion time where the longer the specimen immersion time, the lower the specimen hardness value itself. The presence intensity of brownish yellow and black corrosion patterns (magnetic Fe_3O_4) increased along with the increasing immersion time due to the lack of oxygen concentration during the specimen corrosion process.

REFERENCES

- [1] N. P. Eka Utami, Ellyanie, and J. D. Nasution, "The effect of Lead (Pb) Hot dipping on seawater corrosion rate in ASTM A36 Steel," *IOP Conference Series: Materials Science and Engineering*, vol. 620, no. 1, 2019, doi: 10.1088/1757-899X/620/1/012108.
- [2] ASTM International, "Standard Specification for Carbon Structural Steel," 2015, doi: 10.1520/A0036_A0036M-14.
- [3] L. T. Popoola, A. S. Grema, G. K. Latinwo, B. Gutti, and A. S. Balogun, "Corrosion problems during oil and gas production and its mitigation," *International Journal of Industrial Chemistry*, vol. 4, no. 1, pp. 1–15, 2013, doi: 10.1186/2228-5547-4-35.
- [4] O. S. I. Fayomi, I. G. Akande, O. O. Oluwole, and D. Daramola, "Effect of water-soluble chitosan on the electrochemical corrosion behaviour of mild steel," *Chemical Data Collections*, vol. 17–18, pp. 321–326, 2018, doi: 10.1016/j.cdc.2018.10.006.
- [5] A. A. Rosidah, V. A. Setyowati, S. Suheni, and R. Rijayanto, "The effect of time variation on the steels corrosion rate in 0.5 M H_2SO_4 solution," *Journal of Mechanical Engineering, Science, and Innovation*, vol. 1, no. 2, pp. 49–55, Oct. 2021, doi: 10.31284/j.jmesi.2021.v1i2.2183.
- [6] A. Komalasari, B. Afriyansyah, M. Ihsan, and M. A. Nugraha, "Bioakumulasi Logam Berat Pb dan Cu terhadap *Penaeus merguensis* di Perairan Teluk Kelabat Bagian Dalam," *Jurnal Kelautan Tropis*, vol. 22, no. 1, p. 1, Apr. 2019, doi: 10.14710/jkt.v22i1.3727.
- [7] S. Sundjono, G. Priyotomo, L. Nuraini, and S. Prifiharni, "Corrosion behavior of mild

- steel in seawater from northern coast of java and southern coast of Bali, Indonesia,” *Journal of Engineering and Technological Sciences*, vol. 49, no. 6, pp. 770–784, 2017, doi: 10.5614/j.eng.technol.sci.2017.49.6.5.
- [8] M. Pramudita and M. Nasikin, “The Effect of Immersion Time on The Ability of Tannins to Inhibit The Corrosion Rate of Mild Steel in 1M H₂SO₄ Solution ARTICLE HISTORY ABSTRACT,” 2020. [Online]. Available: <http://jurnal.untirta.ac.id/index.php/WCEJ>
- [9] Y. Hou, D. Lei, S. Li, W. Yang, and C. Q. Li, “Experimental Investigation on Corrosion Effect on Mechanical Properties of Buried Metal Pipes,” *International Journal of Corrosion*, vol. 2016, 2016, doi: 10.1155/2016/5808372.
- [10] B. U. Oreko, “Corrosion Rates and its Impact on Mild Steel in Some Selected Environments Assessment of Inhibitive Drugs for Corrosion Inhibition Applications in Petrochemical Plants-A Review View project Product development View project,” 2016.
- [11] J. Martin, *Materials for Engineering (3rd edition)*, 3rd ed. Cambridge: WOODHEAD PUBLISHING LIMITED, 2006.
- [12] O. Sunday Isaac Fayomi and A. Patricia Idowu Popoola, “Corrosion propagation challenges of mild steel in industrial operations and response to problem definition,” in *Journal of Physics: Conference Series*, Dec. 2019, vol. 1378, no. 2. doi: 10.1088/1742-6596/1378/2/022006.
- [13] H. Zhang *et al.*, “The effect of immersion corrosion time on electrochemical corrosion behavior and the corrosion mechanism of eh47 ship steel in seawater,” *Metals (Basel)*, vol. 11, no. 8, Aug. 2021, doi: 10.3390/met11081317.
- [14] D. Chen *et al.*, “A corrosion sensor for monitoring the early-stage environmental corrosion of A36 carbon steel,” *Materials*, vol. 7, no. 8, pp. 5746–5760, 2014, doi: 10.3390/ma7085746.