Maritime Technology and Society
Vol. 3(2): 108-117 June 2024
https://doi.org/10.62012/mp.v3i2.35389

Analysis Of Needs And Placement Of Zinc Anode For New Ferry Ship Buildings

Juswan Sade, *Muh. Syaifullah. A and Paroka

Department of Ocean Engineering, Faculty of Engineering, Hasanuddin University, Indonesia
*Correspondence author: muhsyai01@mail.com ; Tel.: - 085298727078
Received 10 June 2024; Received in revised form 23 June 2024; Accepted June 2024

Abstract

Marine structures (ships, offshore platforms, underwater pipes and other floating structures) in operation are not protected from corrosion. One of the biggest sources of damage to ships is caused by seawater corrosion. Until now, the use of iron and steel as the main materials for shipbuilding is still dominant. Corrosion is a degradation process of a metal due to chemical reactions between the metal and its environment. The aim of this research is how to determine the need for zinc anode and efficient installation distance as well as the costs required in procuring cathodic protection. Cavitation is a factor that often occurs around propellers or propellers. When the propeller or propeller rotates in the water, the low pressure around the surface of the propeller can cause water vapor to form and turn into cavitation bubbles. When these bubbles burst, the erosion effect on the surface of the affected object will quickly corrode. So that the installation of the sacrificial anode at the stern is installed slightly tightly. The method used to control the rate of corrosion is by protecting the steel plate using cathodic protection. Therefore, every ship that is built needs to have zinc anode planning to control the rate of corrosion on the ship's steel plates. The number of zinc anodes required for a new construction ship with a length of 72.76 m, a width of 14 m and a draft height of 3.30 m is 55 with an addition of 30% of the total number at the stern due to the cavitation factor. The design life of the zinc anode protection is 2.5 years with a longated flush mounted (welded type) type s-8, dimensions (300 mm × 150 mm × 25 mm) weighing 8 kg. The installation distance is 3 m and 1.3 m with the installation cost being IDR. 40,530,000.

Keywords: Cavitation, Corrosion, Zinc Anode

1. Introduction

Marine structures (ships, offshore platforms, underwater pipes and other floating structures) in operation are not protected from corrosion. One of the biggest sources of damage to ships is caused by seawater corrosion. Until now, the use of iron and steel as the main materials for shipbuilding is still dominant.

Corrosion is an important thing to pay attention to in the world of industry and shipping because it is one of the challenges that causes failure in both the function and operation of equipment in carrying out its function. Corrosion incidents can cause several things, such as production facilities stopping outside of maintenance schedules, plates leaking so that the fluid inside pollutes the environment and damage often occurs which can even be fatal and cause fatalities

Corrosion is a natural event that cannot be eliminated or eliminated but can be controlled by protecting the material from reactions with the environment. One way is with cathodic protection, either a sacrificial anode cathodic protection system or an impressed current cathodic protection system. Sacrificial anode system cathodic protection and counter current system cathodic protection have been widely

E-ISSN: 2828-6669; P-ISSN: 2828-7010
This work is licensed under a Creative Commons Attribution 4.0 International License.

used in industry and construction. The design used is a combination of experience and experimental data.

Corrosion is a degradation process of a metal due to chemical reactions between the metal and its environment. In terms of construction on ships, the hull plate is the area first exposed to sea water. In this area of the hull, the underwater and above water areas are susceptible to corrosion. Corrosion on ship hull plates can result in a decrease in the strength and service life of the ship, reduce the speed of the ship and reduce the guarantee of safety and security of cargo and passengers. To avoid greater losses due to seawater corrosion, ship care and maintenance must be carried out regularly.

Figure 1. Corrosion on Ship Plates

Corrosion is defined as the destruction or damage of material due to reaction with its environment. Corrosion is damage to materials (generally metals) due to electrochemical reactions between the material and its environment. Corrosion occurs due to the process of transferring electrons from the metal to its environment. The metal acts as an anode and the environment as an electron acceptor. The corrosion process occurs naturally and cannot be prevented, but can be controlled by slowing the rate of corrosion.

This process causes the metal to be lost to form a more stable compound. Corrosion is a chemical reaction resulting from two half-cell reactions involving electrons, causing an electrochemical reaction. The two half cell reactions are an oxidation reaction at the anode and a reduction reaction at the cathode. The occurrence of electron exchange shows the relationship between the liberated mass.

2. Methodology

The method used in this research is quantitative. In this research the data collected is based on data at PT. Indonesian Ship Industry and various sources from the bibliography to support this research.

The research procedures carried out in "Needs Analysis and Laying of Zinc Anodes for New Ferry Ship Buildings" are as follows:

a. Data Presentation

To calculate the need for cathodic protection on ships, property data related to the dimensions of the ship's structure and anode data which includes the type of anode and the material used are needed. Along with supporting data which is additional data in the calculation but is not included in the parameters above.

b. Calculation of the area of protection on the ship

The protection area calculation aims to

determine the area of the ship submerged in water as a place for installing sacrificial anode cathodic protection.

c. Calculation of corrosion rate and current demand requirements

As a result of the protection area on the ship obtained, then the corrosion rate and current demand can be calculated based on the coefficients in the Det Norske Veritas rules.

d. Calculation of anode mass requirements

After knowing the corrosion rate in determining the anode life design and current demand requirements along with the type of anode used in determining the anode mass requirement.

e. Analysis of Zinc Anode cathodic protection needs

At this stage the required mass and anode are used to determine the required number of sacrificial anodes to be installed.

f. Analysis of Zinc Anode placement

After knowing the number of anodes to be used, the placement and spacing of the zinc anodes can be determined.

g. Cost calculation analysis

At this stage it is calculated to determine how much costs are used in procuring zinc anodes as cathodic protection on ships along with installation costs.

h. Conclusion

The conclusion of this analysis is to determine the need, placement and costs in procuring zinc anode as cathodic protection for ships. In the planning, the sacrificial anode is used for a period of 2.5 years.

3. Results

3.1. Main Ship Data

Table 1. Ship Data

Parameter	Value
LOA	76.72 m
LPP	70.20 m
B	14.00 m
T	3.30 m
H	4.60 m
Tk	3.30 m

3.2. Calculation of Protection Area

Calculation of the protection area is related to determining the surface area that needs to be protected from corrosion. The purpose of these calculations is to ensure that appropriate areas of protection are applied to prevent or minimize corrosion of vulnerable metal surfaces.

In this area of the hull, the underwater or above water areas are susceptible to corrosion, where there is a reduction in the thickness of the plates on the ship's hull which makes it easier for leaks to occur due to not being able to receive external pressure from sea water, where these leaks must be avoided.

a. Simpson's Method

In this case, the Simpson method is used to estimate the area of ship protection based on the form of protection that has been determined previously. Numerical methods play a very big role in helping solve various problems in the field of calculating the area and volume of a plane. To calculate the area of each surface using the Simpson method for the skin opening in Figure 1. , use the formula:

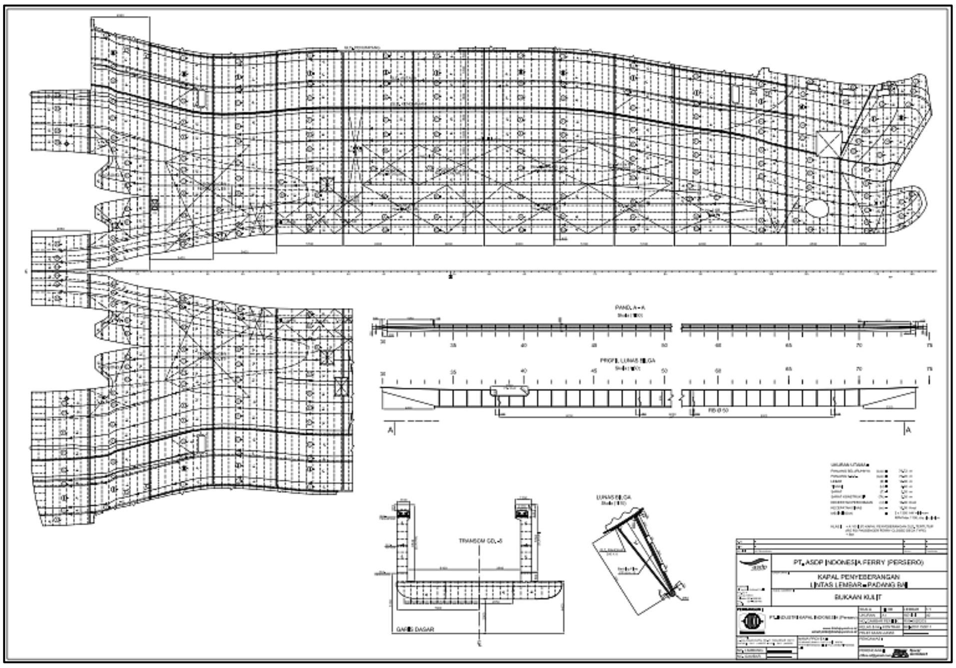

Figure 2. Opening of the ship's skin

$$A = 2 \times \frac{1}{3} \times h \times \sum \ (m^2)$$

Where :

$\sum$ = Number of times the ordinate with the Simpson factor

h = Distance between tusks

b. Protection Area Calculation Results

To get the area of protection on the ship, each part that has been detailed is added up as a whole. So that the protection area is obtained using the Simpson method as follows.

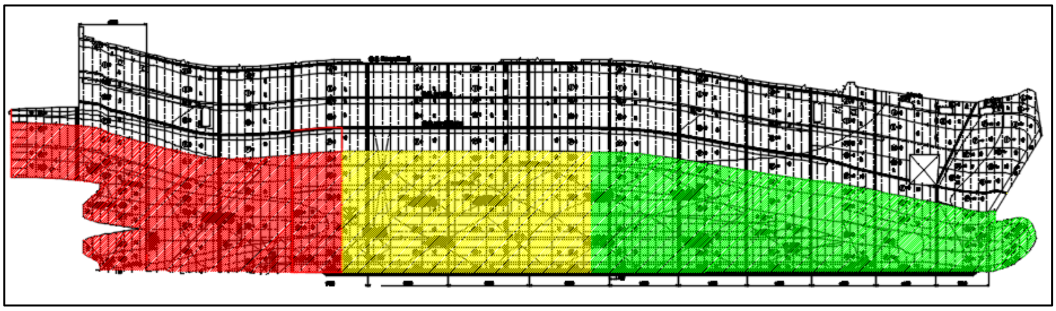

Figure 3. Area Calculation Section

In Figure 2. is the area of the ship that will be protected which has been detailed in the skin openings from the keel to the ship's draft. So the total area of all sections is 2190.55 m2.

Total Area = 2190.55 m^2

Distance between tusks = 0.6

So the area of protection obtained is as follows:

A = 2 × 1/3 0.6 × 2190.55

A = 876.2 m^2

3.3. Calculating Corrosion Rate and Current Requirement

Corrosion rate is an important parameter in understanding and measuring the level of damage that occurs to materials affected by corrosion. Corrosion rate measurements can be carried out using methods including measuring lost weight, measuring electrochemical corrosion rates, and visual observation of the level of damage that occurs to the material. Corrosion rates can be measured in various units, such as millimeters per year (mm/year), miles per year (mpy), or grams per square meter per second (g/m²/s.

a. Corrosion Rate

The thickness of the steel plate used is 10 mm. With a protection area of 967.89 m^2. In calculating the corrosion rate, the formula Equation can be used.

$$C_R = \frac{K \times m}{A \times \rho \times T} \text{ (mm/year)} \qquad (1)$$

Where :

CR = Corrosion rate (mm/year)
m = Δm = Difference between initial mass and final mass (grams)
A = Area of the ship's hull plate submerged in sea water (cm^2)
K = Constant = 8.76×10^4
T = Protection life (hours)
ρ = density of steel plate = 7.85 (gram/cm^3)

- **Initial mass of the plate**

Plate volume = Protection area × Plate thickness
= 876.2 m^2 × 0.01 m
= 8.762 m^3
Plate weight = Plate volume × Density
= 8,762 m^3 × 7,850 kg/m^3
= 68,797.4 kg

- **Final mass of the plate**

After experiencing corrosion, from the results of measurements on the ship's hull there was a reduction from the original thickness of 10 mm by 2.1 mm.

Plate volume = Protection area × Plate thickness
= 876.2 m^2 × 0.0079 m
= 6.92 m^3
Plate weight = Plate volume × Density
= 6.92 m^3 × 7,850 kg/m^3
= 54,322 kg

So, the initial Δm and final mass = 68,797.4 kg – 54,322 kg is 14,475.4 kg.

Total protection area = 876.2 m^2
Protection Age = 2.5 years
The difference in plate mass = 14,475.4 kg
Constant = 8.76×10^4
Density of steel = 7.85 (gram/cm^3)

So the corrosion rate is obtained as follows:

$$C_{R\ (corrosion\ rate)} = \frac{8{,}76 \text{ x } 10^4 \times 14.475.400 \text{ gram}}{8.762.000 \text{ cm}^2 \times 7{,}85 \text{ gram/cm}^3 \times 21.900}$$

= 0,084 cm/year

= 0,84 mm/year

Figure 4. Plate Thickness Test Results

For the critical point from BKI regarding plate thickness > 10 mm, the maximum reduction in plates on the ship's hull is 3 mm. From the test results in Figure 3. , during 1 period of operation the ship experienced a decrease in the plate of 2.1 mm, so it had not exceeded the tolerance limit.

b. Current requirements

To obtain the required current demand value first, the result of the damage factor, you can refer to Equation 2 and Table 2 and 3.

Table 2. Density-averaged current design based on depth and climate

Depth (m)	Average Current Density Design (A/m2)			
	Tropical (>20°C)	Sub Tropical (12-20°C)	Temperate (7-12°C)	Very Cold (<7°C)
0 ≤ 30	0.070	0.080	0.100	0.120
>30	0.060	0.070	0.080	0.100

Table 3. Constants for calculation of coating damage factors

Depth (m)	Coating Category			
	(k1 = 0.1) k2	(k1 = 0.050) k2	(k1 = 0.020) k2	(k1 = 0.010) k2
0 < 30	0.100	0.030	0.015	0.012
>30	0.050	0.020	0.012	0.012

$$fc_{(Last)} = k_1 + k_2 \cdot tf \quad (2)$$

fc = k1 + k2 × tf

= 0,05 + 0,02 × 2,5

= 0,175 Ampere

In calculating current requirements, it can be seen in Equation 3 and refer to Table 2

$$I_c = Ac \times fc \times ic \quad (3)$$

$$= 876,2 \times 0,175 \times 0,060$$

$$= 9,2 \text{ Ampere}$$

So, the current requirement for the zinc anode is 9.2 amperes with a damage factor of 0.175 amperes.

3.4. Determining Zinc Anode Needs

Designing the surface area of the ship's hull submerged in sea water is very necessary, to determine how many anodes are needed, where to place the sacrificial anodes, and so on.

After knowing the thickness size along with the required current required for the zinc anode and the rate of corrosion that occurs on the ship's plate, the next step is to calculate the need for a sacrificial anode to slow down the rate of corrosion that occurs.

a. Zinc Anode Mass

In determining the required sacrificial anode weight, it can be seen in Equation 4 as follows.

$$m = \frac{Ic \times T \times 8760}{\mu \times \varepsilon} \quad (4)$$

Protection current requirement (Ic) = 9.2 Amperes
Protection life (T) = 2.5 years
Sacrificial anode utilization factor (μ) = 0.85
Electrochemical efficiency (ε) = 700 Ah/kg

$$m = \frac{9,2 \times 2,5 \times 8.760}{0,85 \times 700}$$

Anoda mass = 338,6 kg ≈ 339 kg

b. Addition of Zinc Anode Due to Cavitation

Cavitation is a common fluid mechanics phenomenon that can occur whenever a fluid is used in a machine that induces pressure and velocity fluctuations in the fluid. As a result, pumps, turbines, even plates are all destructive consequences of cavitation that can occur. Cavitation gives rise to a series of effects that occur due to propulsion which can influence the rate of corrosion on the ship's stern plate

So the tolerance from BKI for the stern of the ship being protected, approximately 25% or 30% of the total anode weight must be applied in complete protection coverage.

A tolerance of 30% zinc anode mass addition is used so that:

$$\Sigma M_{total} = (339 \times 0,3) + 339 \quad (5)$$

$$= 440 \text{ kg}$$

c. Number of Zinc Anodes

After getting the mass of the sacrificial anode, then calculate the number of sacrificial anodes needed to protect the area of the ship that is submerged in water. The sacrificial anode designed is a zinc alloy with a welded type with type S-8 size (L × W × H) (300 mm × 150 mm × 25 mm) with a net weight of 8 kg. So the calculation of the number of sacrificial anodes required can be seen in Equation 6 as follows.

$$\Sigma AK = \frac{m}{mAK} \quad (6)$$

Number of sacrificial anodes in the draft section of the vessel

Total sacrificial anode mass = 339 kg
Mass of sacrificial anode per unit = 8 kg
So the number of zinc anodes obtained is as follows:

$$= \frac{339 \text{ kg}}{8 \text{ kg}} = 42 \text{ kg}$$

Number of additional sacrificial anodes in the stern section

Mass addition of 30% of total weight = 101 kg
Sacrificial anode weight per unit = 8 kg
So the number of anodes is obtained as follows:

=

$$\frac{101\ \text{kg}}{8\ \text{kg}} = 13$$
buah

Number of sacrificial anodes required

Total mass of sacrificial anode = 440 kg

Weight per unit = 8 kg

So that the sacrificial anode requirements are obtained as follows:

$$= \frac{440\ \text{kg}}{8\ \text{kg}} = 55 \text{ buah}$$

The total number of zinc anode cathodic protection required for new ship buildings is 42 with an addition of 30% for critical areas in the stern section as a safety factor. So the need for zinc anodes is 55 pieces.

3.5. Zinc Anode Laying Plan

The number of sacrificial anodes required is 55 which will be installed on the ship's draft section. The installation of sacrificial anodes on ships is arranged according to the area of the ship's hull plate or the area below the waterline and divided according to the distance between the anodes. So the distance between anodes is in Equation (7):

$$J_{AK} = \frac{\mathit{Ship\ Area} - \mathit{anoda\ length\ x\ number\ of\ anoda}}{\Sigma\ \text{AKanoda}\ \mathit{total}} \quad (7)$$

Ship area = 181.44 m

Anode length = 300 mm ≈ 0.3 m

Number of anodes = 55 pieces

So that the distance between the Zinc Anode is obtained as follows:

$$= \frac{181{,}44\ \text{m} - (0{,}3\text{m} \times 42\ )}{55} = 3\ \text{m}$$

Meanwhile, at the stern of the ship the zinc anodes are installed slightly tightly due to the cavitation factor which can accelerate the rate of corrosion, so the distance between the sacrificial anodes at the stern can be calculated as follows:

$$J_{AK} = \frac{(\text{Jarak antar anoda} - \text{panjang anoda})}{2} \quad (8)$$

$$= \frac{3\ \text{m} - 0{,}3\ \text{m}}{2} = 1{,}3\ \text{m}$$

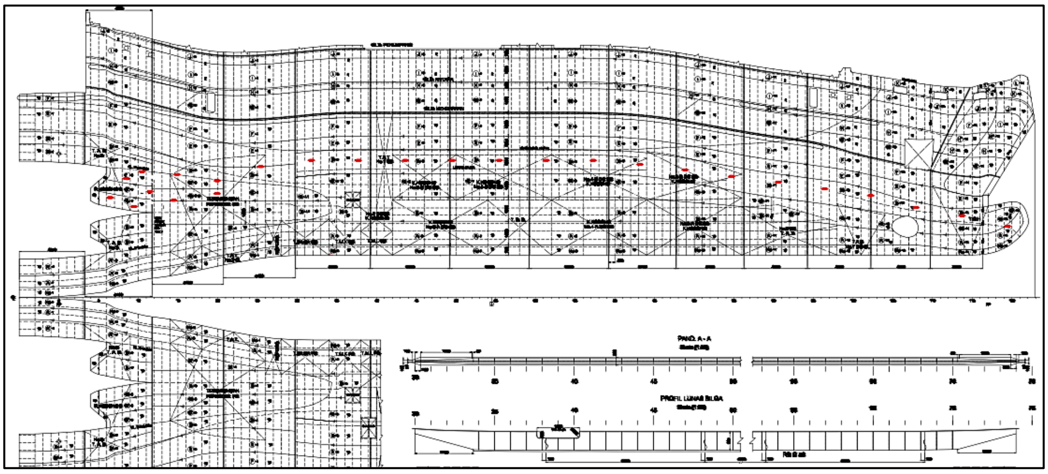

Figure 5. The placement of the zinc anode is visible in the skin opening (the zinc anode is red)

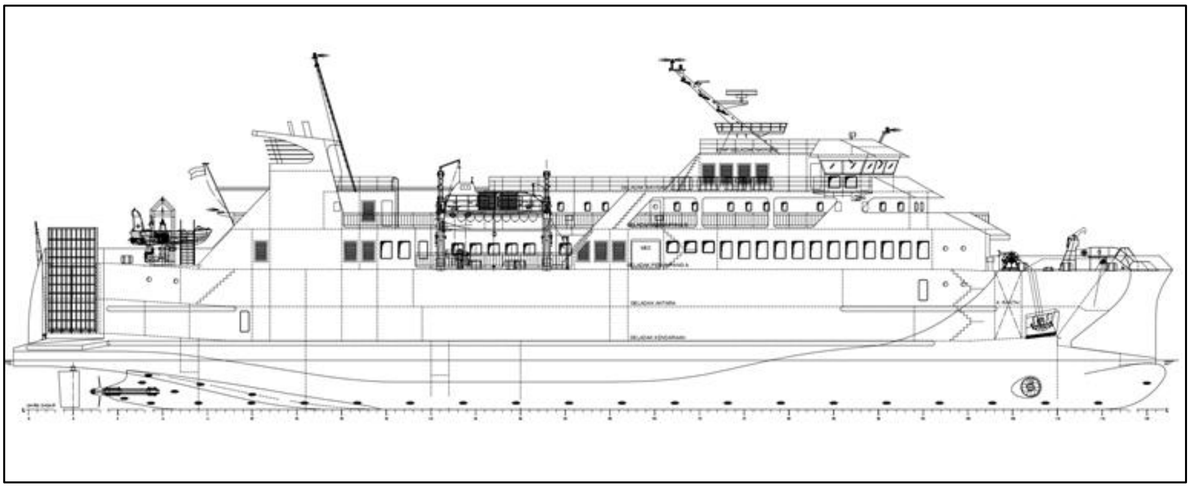

Figure 6. Zinc anode placement visible from the side of the ship

5. Conclusions

a. After processing data regarding cathodic protection planning, namely zinc anode on new construction ships, the following conclusions were obtained:
b. Corrosion protection is especially important in the shipping industry because corrosion can cause serious damage to ships and other maritime infrastructure.
c. The use of zinc anodes as part of a cathodic protection system is an effective method for controlling the rate of corrosion on ship steel plates.
d. This research shows that for a new ship with a length of 72.76 m, a width of 14 m, and a draft height of 3.30 m, 55 zinc anodes are required with an additional 30% at the stern due to the cavitation factor.
e. The design life of zinc anode protection is 2.5 years with type S-8 anode with dimensions of 300 mm × 150 mm × 25 mm and weight 8 kg, installed at a distance of 3 m and 1.3 m according to different parts of the ship.
f. Proper placement of zinc anodes, both on the cargo and at the stern of the vessel, is a crucial step to ensure effective protection against corrosion.

This study provides valuable insight into the need and placement of zinc anodes for new ferry structures, which can serve as a practical guide for planning cathodic protection on similar vessels in the future.

References

[1] Ariani, B. Pengantar Korosi Perkapalan. Banda Aceh, Aceh: Syiah Kuala University Press, (2021).

[2]Beni Hartanto, S. Pemasangan Zinc Anoda Protection (ZAP) sebagai Perlindungan Aktif Korosi Kapal. Majalah Ilmiah Bahari Jogja, Vol.21, No.1, 21-27, 2023

[3] Biro Klasifikasi Indonesia, Guidance for The Corrosion Protection and Coating System, Volume G, Chapter 1, Section 8 B.2, Edition 2019, BKI, Jakarta, 2019

[4] Carlton, J. Marine Propellers and Propulsio Second Edition. USA: Elsevier Ltd, (2007).

[5] Dahlstrom, D. D. Marine Corrosion Protection Guidebook. Amsterdam, Belanda: Elsevier, (2011).

[6] Dwisetiono, & Mahendra, T. I. Proteksi Katodik Mennggunakan Zinc Anode Untuk Menghambat Korosi pada Lambung Kapal Port LINK VII Jakarta. Jurnal Teknik dan Sains Fakultas Teknologi Fakultas Teknologi Lingkungan dan Mineral Universitas Teknologi Sumbawa, Volume 3 Nomor 1, 56-62, (2022).

[7]Equipment,I.M. Dasar Penyebab Korosi Kapal. Diakses dari Inameq.com: https://inameq.com/hullandoutfitting/painting/dasarpenyebabkorosikapal/, (2023).

[8] Gapsari, F. Pengantar Korosi. Malang: UB press, (2017).

[9] Ghali, E. Corrosion Prevention and Protection:Practical Solutions. New Jersey, America: Wiley, (2004).

[10] Hermawan, H. Pengantar Proteksi Katodik. Canada : Laval University Press, (2019).

[11] Hetharia, Perencanaan Kapal 1. Ambon: Universitas Pattimura Ambon, (2019).

[12]LEMBAYUNG, L. Tahap Pmebuatan Kapal Baru. Diakses dari latarlembayung.wordpress.com: https://latarlembayung.wordpress.com/2012/11/25/tahap-pembuatan-kapal-baru/, (2023).

[13] Made Rai Ratih Cahya, P. a. Penerapan Hitungan Volume Metode Simpson untuk Menghitung Volume Kapal dan Topografi Darat. Jurnal Rekayasa Hijau, No.1, Vol.2, 90-100, (2018).

[14] Molland, A. F. Ship Resistance and Propulsion. Cambridge: University Press, (2011).

[15] R.Roberge, P. Corrosion Engineering: Principle and Practice. Wiley: McGraw Hill, (2008).

[16] Roberge, P. R. Handbook of Corrosion Engineering. United States of America: McGraw-Hill, (1999).

[17] Sasono, E. J. Efektivitas Penggunaan Anoda Korban Paduan Aluminium Pada Pelat Baja Kapal Aisi E 2512 Terhadap Laju Korosi di Dalam Media Air Laut. Tesis, 1-91, (2010).

[18] Sasono, E. J. Aplikasi Metode Numerik Dalam Perhitungan Luas dan Volume Badan Kapal Yang Berada di Bawah Permukaan Air Laut. Kapal, Vol.3, No.3, 83-88, (Oktober2006).

[19] Sunarto, & Septian, D. Analisa Kebutuhan Anoda Korban Seng Pada Plat Bottom Kapal di Pt. Indonesia Marina Shipyard. Jurnal Keilmuan dan Terapan Teknik , Volume 04, Nomor 01, 92-108, (2015).

[20] Sunarto, D. S. Analisa Kebutuhan Anoda Korban Seng Pada Plat Bottom Kapal di Pt. Indonesia Marina Shipyard. Wahana Teknik, Volume 04, Nomor 01, 92-108, (Juni 2015).

[21] Supomo, H. Korosi Perkapalan. Jawa Timur: Airlangga University Press, (2023).

[22] Uhlig, H. H., & Revie, R. W. Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering. New Jersey, America: Wiley, (2008).

[23] Widianingrum, W. Analisis Peletakan dan Kebutuhan Proteksi Katodik Pada Mooring Buoy di Pertamina Fuel Terminal Luwuk. Jurnal Inovasi Sains dan Teknologi Kelautan, Volume 2, Nomor 2, (2021).