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Analysis of Ship's Cathodic Protection Requirements and Maintenance

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***Abstract* - Cathodic protection methods on ships utilize the presence of sacrificial anodes to prevent corrosion of ship parts. This protection method is one of the most widely used methods because it is proven to be effective in inhibiting corrosion. Therefore, it is important for an engineer to be able to plan the cathodic protection needs and maintenance on a ship. Based on the analysis conducted on the ship KMSN 92. The calculation method used follows the ABYC Corrosion Certification Standard. The weight value of the sacrificial anode requirement is 412 kg and the number of anodes is 138 pcs.**

Keywords: sacrificial anode, ship, corrosion, cathodic protection.

I. INTRODUCTION

Indonesia is one of the largest archipelagic countries in the world with an area of 5.193.250 km^2, consisting of 2.027.087 km^2 of land and 3.166.163 km^2 of ocean [1].Indonesia's geographical location between the Asian and Australian Continents and between the Indian Ocean and the Pacific Ocean has placed Indonesia in a strategic position in terms of economic, political, socio-cultural and defence and security.

The "backbone" to maximise the potential of Indonesia's marine resources is the availability of ships as a means of transportation [2]. The ships consist of various types of vessels with different functions. However, there is a challenge that most of these vessels will experience regardless of type. The problem is corrosion that occurs on ship parts which will basically always occur.

Corrosion that occurs on ships caused by seawater will be faster because electrolytic seawater contains salt and tends to be acidic [3]. Corrosion that occurs on ship plates if not properly addressed can cause leaks or cracks in the ship. [4]. Therefore, various kinds of protection methods on ships are applied. One method that is widely used is the cathodic protection method [5]. Cathodic protection is one of the most effective methods for preventing corrosion on metal surfaces. Cathodic protection is widely used to prevent corrosion, such as on ships, offshore buoys, underwater equipment, ports, pipelines, tanks, or basically can be applied to all submerged or buried metal structures. Examples of corrosion on ships can be seen in Figure 1, and the application of protection to ships can be seen in Figure 2.

Figure 1: Rust on ships

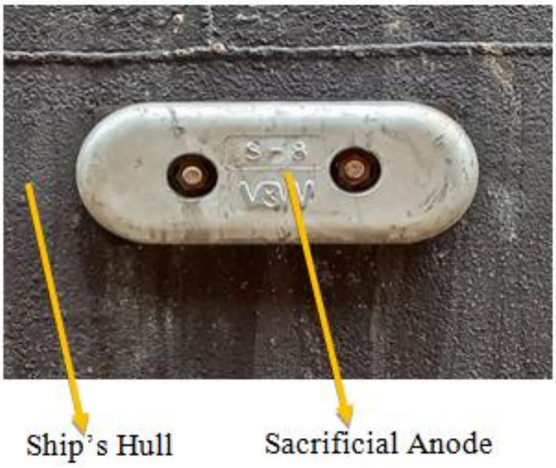

Figure 2: Ship cathodic protection

An important factor in ship construction and maintenance related to cathodic protection methods is knowing how to determine the right number of sacrificial anodes and how to maintain them annually. The writing of this article aims to provide an understanding of the analysis related to determining the need for sacrificial anodes in the cathodic protection system and their maintenance through analysis on ship KMSN 92.

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II. METHODOLOGY

In this research, technical drawing data from the KMSN 92 ship is used as a calculation reference because the drawing contains complete data on the dimensions and design of the ship. Mathematical calculation methods are used to process these data to determine the need for sacrificial anodes for the cathodic protection system on ships. Meanwhile, to understand the maintenance process of the cathodic protection system, a literature study and field observation methods were used.

2.1 Engineering Drawing of KMSN 92

Figure 3shows the design of KMSN 92 was made using CAD software.

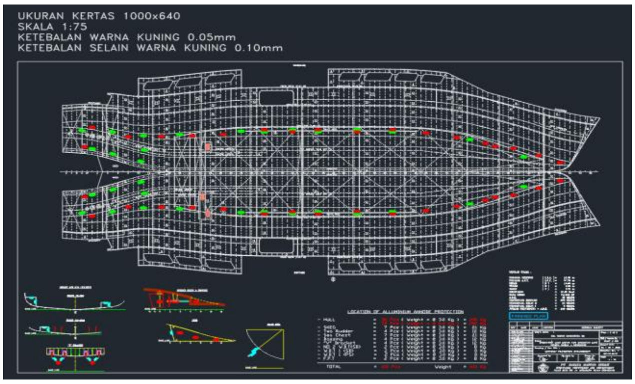

Figure 3: Engineering Drawing of KMSN 92

2.2 Ship's Specification and Drawing

Table 1 and Table 2 below contain the general specifications and ship dimensions known from Figure 3. Based on the data in Table 1 and Table 2, an analysis of the calculation of the need for the cathodic system on the KMSN 92 ship will be carried out.

Table 1: Ship's Specification Data

No	Specification Type	Value
1	Speed	12.00 Knot
2	Engine Power	2x1100 HP
3	Ship's Crew	36 people
4	Economy Class Passengers	376 people
5	Second Class Passenger	16 people
6	First Class Passenger	8 people
7	Total People	436 people

Table 2: Ship's Dimension Data

	Specification Type	Value
1	L.O.A.	62.80 m
2	L.B.P.	57.36 m
3	Width (B)	12.00 m
4	Height (H)	4.00 m

2.3 Calculation Analysis Refers to the ABYC Corrosion Certification Standard

The amount of cathodic protection required for a ship can be determined by finding the anode weight value. Anode weight can be calculated using Equation 1 below [6].

$$\textit{Anode Weight}\ \textbf{(lbs)} = \frac{[(WSA)\ x\ (Current\ Density)\ x\ (Immersion)]}{[(Energy\ Content) x\ (1000\ mA/Amp)]} \quad (1)$$

Known:
WSA (sqft): Wetted Surface Area
Current Density (mA/sqft): Electric Current Density
Immersion (hours): Time of Contact with Water (8766 h/year)
***Energy Content* (amp-hours/ pound):** Stored Energy

The approximate amount of Wetted Surface Area on the hull can be determined based on the dimensions of the hull can follow the standards below [7].

a. *WSA* = 1.0 LWL x (Width + Laden)
   For*full displacement vessel* (such as motorized yachts and sailboats)
b. *WSA* = 0.75 LWL x (Width + Laden)
   For*medium displacement vessels*
c. *WSA* = 0.5 LWL x (Width + Ladent)
   For*light displacement vessels*

The LWL (Length of Water Line) value is obtained from the equation LWL = (2%) LBP + LBP. Figure 4 displays the type of length on the ship's hull to clarify Equation 1 and the advanced standards used for the calculation process of the required anode weight.

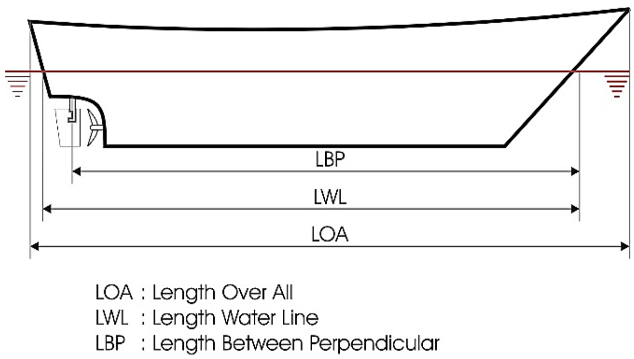

Figure 4: Hull length type

The amount of electric current (current density) required from the anode protecting the metal hull (or structure) can be determined through the relationship between the water flow rate and the quality of the metal protective paint layer on the ship. The amount is regulated through the standards shown in Table 3 and Table 4.

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Table 3: Steel Hull or Structure

Steel Hull or Structure			
	Well coated	Poor or old coating	Uncoated
Stationary (0-0.5 mph)	1.5 mA/sq-ft	2 mA/sq-ft	3mA/sq-ft
Low Velocity Water Flow (0.5-2 mph)	2 mA/sqft	4 mA/sqft	5 to 15 mA/sqft
Medium Velocity Water Flow (2 - 5 mph)	3 mA/sqft	5 mA/sqft	15 to 30 mA/sqft
High Velocity Water Flow (>5 mph)	5 mA/sqft	10 mA/sqft	25 to 100 mA/sqft

Table 4: Aluminium Hull or Structure

Aluminium Hull or Structure			
	Well coated	Poor or old coating	Uncoated
Stationary (0-0.5 mph)	0.5 A/sq-f	1 mA/sqft	2 mA/sqft
Low Velocity Water Flow (0.5-2 mph)	1 mA/sqft	2 mA/sqft	4 to 8 mA/sqft
Medium Velocity Water Flow (2 - 5 mph)	2 mA/sqft	3 mA/sqft	5 to 12 mA/sqft
High Velocity Water Flow (>5 mph)	3 mA/sqft	5 mA/sqft	10 to 25 mA/sqft

2.4 Maintenance Procedure of Ship Cathodic Protection System

This journal not only discusses the analysis of cathodic protection needs on ships but also contains proper maintenance procedures. The cathodic protection maintenance procedures discussed in this journal are formulated based on literature studies and direct observations at ship docking service providers.

Literature study is the process of searching for data or references from libraries, the internet and other related sources [8].The data from the literature study is intended to be supporting data or secondary data that complements and validates the cathodic protection maintenance procedures obtained through direct observation.

The direct or field observation method is an observation activity carried out without going through intermediaries and the observer is directly involved in the activities being observed. Based on the observation, the cathodic protection maintenance process is part of the general maintenance of the ship when docking takes place. The Ship Cathodic Protection System Maintenance Procedure Chart Diagram is presented in Figure 5. This procedure is also applied to the KMSN 92 Ship. Cathodic protection maintenance procedures are carried out in stages and sequentially because the previous stage will affect the next stage. The stage starts from setting the bearing (kneel block) to recoating the protective coating which will be explained further in the discussion.

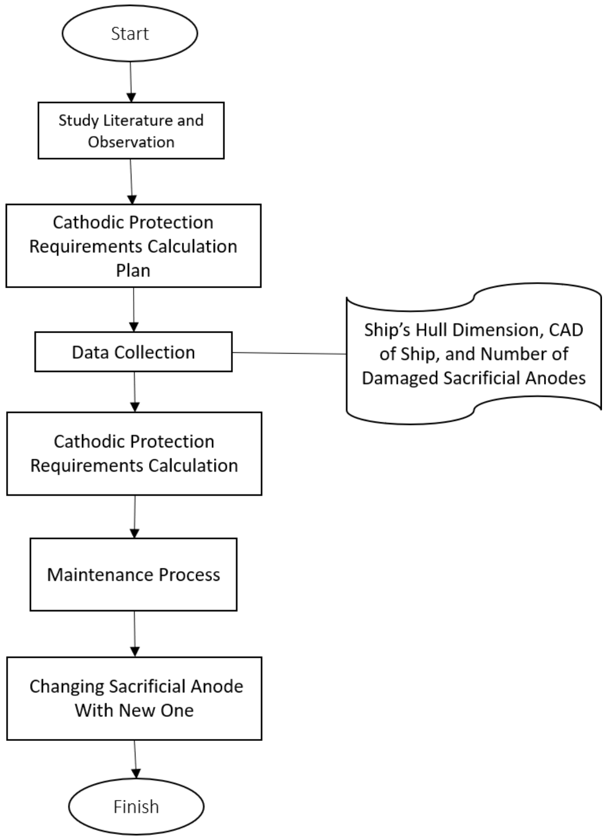

Figure 5: Flowchart of ship cathodic protection system maintenance procedure

III. RESULTS AND DISCUSSION

The results and analysis of the two issues raised will be explained in this journal. In the first problem, the results are obtained in the form of anode weight, number of anodes, and distance from one another. In the second problem, the correct procedure for pre-treatment of the ship's cathodic protection system is known.

3.1 Analysis of Sacrificial Anode Needs for Ship Cathodic Protection Systems

As explained in the previous section, the calculation of the sacrificial anode follows the provisions of the ABYC Corrosion Certification Standard and the following results are obtained.

$$\textbf{\textit{Anode Weight}}\ \textbf{(lbs)} = \frac{[(WSA)\ x\ (Current\ Density)\ x\ (Immersion)]}{[(Energy\ Content) x\ (1000\ mA/Amp)]}$$

LWL = (2%) LBP + LBP

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Known :
LOA = 62.8 m
LPP = 57.36 m
Width (Beam) = 12 m
Laden (Draft) = 2.7 m
Speed =12 Knot
= 12 x 1,15078
= 13.8 m/s
LWL = (2%) (57.36) + 57.36
= 58.51 m

To obtain the values of variables such as wetted surface area, current density, immersion, and energy content, further analysis is required first.

First, to determine the calculation equation used to find the wetted surface area, it is necessary to know the KMSN 92 including full, medium, or light displacement vessels. The three types of ships are determined by their ability to withstand and transport certain loads, as well as movement on the water's surface. In the design of large cargo ships such as KMSN 92 ship measurements are made according to the standard light displacement vessel because the installation of cathodic protection is always under an empty ship draft. A light displacement vessel is an empty ship's weight including the ship's hull, ship's machinery, and ship's fixed equipment. [9].

WSA = 0.5 LWL x (Wide + Draft)
= 0.5(58.51) x (12 + 2.70)
= 430.05 m^2
= 430.05 x 10.7639
= 4,629.01 ft^2

Second, in determining the current density value, it is based on the influence of the fast seawater current passing through the hull and the type of protective coating used. On this ship, the plate is made of steel with three protective coatings. In addition, the ship is moving at a speed of 12 knots or 13.8 m/s so it can be determined that the current density value is 5.

Third, the search for immersion or contact time with water is adjusted to the maintenance standards of the Indonesian Classification Bureau, which is for 5 years as a time interval until a special survey is carried out [10].

Immersion = (Total hours/year) x (Target anode life)
= (8766 hours/year) x (5 year)
= 43,820 hours

Furthermore, to assess the energy content, it is determined by the type of sacrificial anode material to be used, which is aluminium or zinc anode. [11]. Aluminum Anode is the result of an alloy between aluminium, zinc and indium. Aluminum type anodes have been developed especially for their use in seawater and marshes. Its characteristics are light weight, large patronage to the steel plate, larger anode capacity and stability, thus providing better results in its application as an anode-sacrifice. The energy content value of the aluminum anode is 1108 amp-h / pound.

Zinc Anode is made of 99.995% purity material and produces a capacity of 780 ampere hours (Ah) per kg. Suitable for use as cathodic protection for pipes and in water or swamps with a current resistance of 100 ohms per cm. Zinc anodes are also widely used in shipping but are more suitable for ships on land and sea. However, zinc anode has a disadvantage because it will accelerate the formation of sediment in seawater so that it can have a negative effect on the environment [12].

Therefore, the sacrificial anode used on the Ship KMSN 92 is an aluminum anode with an energy content value of 1108 amp-h/pound. Based on the variables that have been determined, the following are the results of the calculation of sacrificial anode requirements.

$$\textit{Anode Weight}\ \text{(lbs)} = \frac{[(WSA)\ x\ (Current\ Density)\ x\ (Immersion)]}{[(Energy\ Content) x\ (1000\ mA/Amp)]}$$

$$\textit{Anode Weight}\ \text{(lbs)} = \frac{[(4{,}629.01)\ x\ (5)\ x\ (43{,}830]}{\left[(1{,}108) x \left(1{,}000 \frac{mA}{Amp}\right)\right]}$$

$$= 915.56\ pounds$$

$$= 412\ \text{kg}$$

The weight of the anode per unit selected on the ship is 3 kg according to the wishes and costs owned. Therefore, the division of location points and anode spacing during placement can follow the following provisions.

$$\textbf{Number of Sacrificial Anode} = \frac{Total\ anode\ weight}{anode\ weight\ per\ pcs}$$

$$= \frac{412\ kg}{3\ kg}$$

$$= 138\ \text{pcs}$$

There are 138 pcs of sacrificial anodes needed where 15% of the total number will be placed on the rear structure of the ship (AFT), namely the skeg, rudder, and sea chest. 15% in AFT = 0.15 X 138 = 21pcs.

Then the remaining 117 pcs anodes will be placed on the hull of the ship. The distance between anode placement points

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between one another or aluminum anode space (AAP) is as follows.

$$AAP = \frac{(2LWL)+(2Draft)}{Number\ \ of\ anodes\ \ on\ the\ hull}$$

$$= \frac{(2\ x\ 58.51)+(2\ x\ 2.70)}{117}$$

$$= 1.05\ m$$

3.2 Ship Cathodic Protection System Maintenance Procedures

a) Block Bearing Positioning

Before the ship enters the dock, adjustments are made to the concrete pads on the dock. This arrangement is in the form of adjusting the position of the bearing against the ship's engineering drawings where the bearing must not be in a vulnerable position, namely at a point around certain engine parts. Bearings are arranged so that they are at a point of the ship's frame away from the engine. To avoid high deformation of the lower hull plate above the concrete bearing is usually given another bearing made of wood.

Figure 5: Keel block

b) Graving Dock Door Opening

The second step is to open the graving dock door. Initially, the door was filled with seawater as ballast so that the door would not sway when closed. Therefore, in order to make the door lighter, the water in the door is removed from the door first so that the door is half-floating and easier to pull using heavy vehicles.

Figure 6: Graving dock

c) Parking Ship into the Dock

After the graving dock door is open, the captain can immediately park his ship on the dock according to the direction of the dock. When the ship is in position, the dock door will be closed again.

d) Draining Water in the Dock

Once the vessel is in a suitable position and the dock door is closed. Then the ship will be rebalanced with ropes tied between the ship and the edge of the dock. After that, the water in the dock will be drained slowly until it runs out using a pump.

e) Water Jet Treatment

The next stage in the ship protection system maintenance process is cleaning the ship with a water jet.When a ship sails in the open sea the surface of the ship will experience continuous contact with seawater and the organisms in it.Water jet cleaning utilizes high-pressure fresh water to remove salts and marine organisms from the ship's surface.

f) Sacrificial Anode Removal

Removal of the sacrificial anode is done by removing the bolts connecting the anode to the hull. A sacrificial anode that must be replaced is characterized by the number of corroded anode parts, which is about above 30%.

Figure 7: Rusted sacrificial anode

g) Sandblasting

Sandblasting is a method to clean the surface of contaminated materials such as rust, paint, salt, oil and so on or to obtain the character of the material profile either to roughen or refine, this method is often applied to surfaces with the aim of increasing the adhesion of the coating on metal-based surfaces.[13].The surface cleaning method with sandblasting is done by spraying abrasive material, usually

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silica sand or steel grit with relatively high pressure on a surface.

Figure 8: Sandblasting

h) Installation of New Anode

After the previous process, the damaged sacrificial anode was removed. Re-installed at previous point with new sacrificial anode. The paired anodes are of the same type and number as the previously damaged anodes. To avoid gaps in the bolt thread hole, after the sacrificial anode is installed on the bolt, it is affixed using cement so that seawater cannot enter later.

Figure 9: Installation of new anodes

i) Replacement of Thinning Ship Metal Plate

Although various kinds of corrosion protection have been carried out, due to the accumulation of corrosion over the years on the metal plate of the ship's surface, the thickness of the plate will gradually decrease so that it must be replaced when it is below the standard.

The replacement of the metal plate itself is done with the help of a welding machine, both for cutting and reassembling the metal plate. In addition to corrosion, metal plate replacement can also be caused by deformation of the plate.The minimum standard for the thickness of ship metal plates is regulated in the BKI, which sometimes differs from section to section.

j) Protective Recoating of Ship's Hull

Protective coatings are usually applied to metal surfaces by applying paint or chemicals specifically designed to protect the surface from corrosion. There are several types of protective coatings that are commonly used, such as epoxy paint, polyurethane paint, alkyd paint, and so on.

The protective coating process protects metal surfaces from corrosion by forming a protective layer that blocks the access of water and oxygen to the metal surface [14]. Protective coating resurfacing is the final stage in the ship maintenance process, when this stage is complete, the ship can conduct sea trials and sail again.

Figure 10: Protective recoating of ship's hull

IV. CONCLUSION

Based on the analysis and calculation of the problem to find the need for a cathodic protection system and its maintenance procedures on the ship. The results showed that the need for sacrificial anodes for the Ship KMSN 92 Belt amounted to 412 kg with 138 pcs of anodes and an AAP of 1.05 m for anodes made of aluminum and weighing 3 kg / pcs. The cathodic protection maintenance procedure itself is carried out in stages and sequentially from the positioning of the bearings to the resurfacing of the ship's protective coating.

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