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# *The Comparison Study Of Cathodic Protection System Of Victim Anoda Between Zink Anoda (Zn) And Aluminum Anoda (Al)*

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**Abstract – One of the biggest sources of damage from the hull and underwater ship body is caused by seawater corrosion. Corrosion in the hull plates can result in reduced strength and lifetime of the ship and reduce the safety and security guarantees of the crew and the weapons contained. Therefore, to avoid greater losses due to seawater corrosion, corrosion protection on the hull plates is needed. To protect the hull plates from corrosion, there are 2 methods are used, first is passive protection (coating) and active protection (cathodic protection). The cathodic protection method that is often used is the sacrificial anode system, the principle of this sacrificial anode method is to protect the hulled metal by sacrificing other, more reactive metals, it is mean that there will be an electron transfer from the metal that is the more reactive (potentially more negative) sacrificed to the protected metal hull (the more positive potential) through corrosive electrolytes with the connecting conductor. While the type of sacrificial anode used is zinc anode (Zn) and aluminum anode (Al). This study aims to determine the efficiency and effectiveness of the anode stim that has been installed in KRI TJA-541 for the needs of the sacrificial anode both in technical and economic terms which are then compared with theoretical calculation results concerning the DNV RP-B401 standard. The results of calculations from field observations show that the thickness of the KRI TJA-541 coating is 150-250 µm and is in category II (DNV RP-B401) with a requirement of Zn 439 Kg or Al 153 Kg. Whereas the currently installed Zn is 1424 kg, so it can be concluded that the use of the DNV RP -B401 standard especially using Aluminum (Al) type anodes will be very beneficial both from a technical and technical perspective economical.**

**Keywords – Cathodic protection, Sacrificial anode, DNV RP-B401.**

## I. Introduction

### 1.1. preliminary

Continuity of the presence of marine elements Indonesian waters and sea borders are indispensable so that in carrying out its main tasks the Navy is highly dependent on the readiness of defense equipment, one of which is the readiness of underwater shipbuilding faced with very corrosive seawater conditions, in which seawater corrosion is one of the biggest sources of damage on the ship (Bastari, 2020).

Corrosion to the ship's hull plates can result in a decrease in strength and service life of the ship and reduce the safety, security of the crew members, and the weapons in the ship. Therefore, to avoid greater losses due to seawater corrosion attacks, the ship's hull plate needs periodic corrosion protection to slow down the corrosion rate (Bastari, 2020).

To protect the ship's hull plates from corrosion, 2 (two) methods are used, namely passive protection (coating) and active protection (cathodic protection). The cathodic protection method that is often used is the sacrificial anode system, where the principle of the sacrificial anode method is to protect the hull metal by sacrificing other, more reactive metals, meaning there will be electron displacement of the more reactive (potentially more negative) sacrificed metal to the protected metal hull (more positive potential) through a corrosive electrolyte with a connecting conductor (Anggono, 2000).

The type of sacrificial anode used is zinc anode (Zn) and aluminum anode (Al), technically aluminum anode has many advantages compared to zinc anode including longer reliability and has the characteristics of current and weight lighter (Suharyo, 2019). With the many advantages possessed by aluminum anode many shipyard companies, one of which is PT. Marina Indah Semarang, which is engaged in the dock and the shipyard has begun to switch to the aluminum anode. This can be seen from the table below.

Table 1. Amount of the ship in the dock in PT. JMI

| No | Repair Ship (year | Amount of | Use Zn | Use Al |
|---|---|---|---|---|
| 1 | 2004 | 56 | 19 | 39 |
| 2 | 2005 | 51 | 9 | 42 |
| 3 | 2006 | 55 | 10 | 45 |
| 4 | 2007 | 60 | 10 | 50 |
| 6 | 2008 | 70 | 18 | 52 |
| Total | | 294 | 66 | 228 |

Source: Eko Julianto S, Page 2, 2010

Table 2. Amount of Shipbuilding in PT.JMI

| Shipbuildin | Shipbuilding (amount) | Use Zn | Use Al |
|---|---|---|---|
| 1981-2008 | 56 | 19 | 3 |

Based on the above problems, the writer needs to do a comparative study of the calculation of the need for zinc anode installed in KRI TJA-541 with the zinc anode and aluminum anode requirements according to calculations using the standard DNV RP B401, the author wants to analyze and compare the use of zinc anode with aluminum anode from technical and economic aspects, as initial data the author has taken the data characteristic of zinc anode KRI TJA-541 and aluminum anode KRI KPL- 981.

The purpose of the final project is:

a. Reviewing the need for an anode zinc already installed on KRI TJA-541.

b. Comparing the anode zinc requirement that has been installed on KRI with the anode zinc calculation result (Zn) according to DNV RPB401 standard.

c. Comparing the anode zinc requirement that has been installed on KRI with the anode aluminum (Al) calculation results according to DNV RPB401 standard.

### 1.2. The working principle of cathodic protection.

Cathodic protection is a means of electrochemical corrosion protection wherein the oxidation reaction of the galvanic cell is concentrated at the anode and eliminates corrosion at the cathode as the structure to be electrically protected is made negative so that acts as a cathode. The other electrodes are electrically made positive and act as anodes to create a system of electrical circuits in the same direction as if it were corroded (Sasono, 2010)

The use of zinc anode and aluminum anode as cathodic protection is a sacrificial anode method (Sulistijono, 2011). The benefits of cathodic protection of zinc anode and aluminum anode are as follows:

a. Can be used even if there is no power source

b. Does not incur additional costs to the speed of marine corrosion

c. Supervision is easy, so it does not require people who are truly experts

d. The current might not flow in the wrong direction, so protection does occur. (Morgan, 1987)

e. Simple and easy installation

The weakness of this system is the current available depends on the anode area (wet surface area of the ship) of course.

The weakness of this system is the current available depends on the anode area (wet surface area of the ship) of course is more consumptive if the structure is very large protected.

## II. Materials And Methods

### 2.1. Anode calculation steps

a. Determine the area to be protected

$Ac = (1.7T + 0.7B) \times Lpp$ (2.1)

Information :

Ac : Area of underwater area to be protected ($m^2$)

T : Draft (m)

B : Ship width (m)

Lpp : Distance between vertical lines (m)

b. Determine current density

In DNV RP-B401 determines currents based on the depth conditions of the protected area in water and environmental conditions (Benjamin, 2006), so the following Table is obtained

Table 3. Current density design

| Depth (m) | Design Current Densities ($A/m^2$) | | | |
|---|---|---|---|---|
| | Tropical (>20ºC) | Sub Tropical | Temperat e | Arctic (<7ºC) |
| 0≤30 | 0.070 | 0.080 | 0.100 | 0.120 |
| >30 | 0.060 | 0.070 | 0.080 | 0.100 |

Source: DNV RP B401

c. Determine average current requirements

$Ic : Ac \times fc \times ic$ (2.2)

(DNV RP B401,1993)

Information :

Ic: Average current demand for the principal surface area (A)

Ac: Structure area ($m^2$)

Ic: Current density ($A / m^2$)

Fc: Coating breakdown factor

(Fontana, 1986)

d. Determine the breakdown coating factor

Coating breakdown factor (FC) is used to anticipate an increase in current density (IC) / protection current in the cathodic protection design, if FC = 0 means the coating paint 100% working optimally which then reduces the current density or protection current to zero (0), meaning that it is only with coating and does not require protection from sacrificial anodes whereas if Fc = 1 means that the quality of paint is very poor, it can be considered a plate without a protective coating layer or paint (Mutia, 2007).

Fc : K1 + (K2 x tf) (2.3)

For K1 and K2 are constants in the coating breakdown factor (Fc) or coating damage calculation, the coating category can be seen in the table below.

Table 4. Constanta of (K1 dan K2) Coating breakdown factor

| Depth (m) | Category Coating Breakdown factor | | | |
|---|---|---|---|---|
| | I (K1:0.1 ) K2 | II (K1:0.05 ) K2 | III (K1:0.02 ) K2 | IV (K1:0.02 ) K2 |
| 0≤30 | 0.10 | 0.03 | 0.015 | 0.012 |
| >30 | 0.05 | 0.02 | 0.12 | 0.012 |

Source : DNV RP B401

Category I: One layer of primary paint, approximately 50 µm nominal DFT (Dry Film Thickness)

Category II: One coat of primary paint, plus a minimum of one layer of intermediate top coat, 150-250 µm nominal DFT (Dry Film Thickness)

Category III: One coat of primary paint, plus a minimum of two layers of intermediate top coat, 300 µm nominal DFT (Dry Film Thickness)

Category IV: One coat of primary paint, plus a minimum of three layers of intermediate top coat, 450 µm nominal DFT (Dry Film Thickness)

e. Calculation of mass of sacrificial anode

$$M = \frac{Ic\ average\ .tf.8760}{u.\varepsilon} \quad (2.4)$$

(DNV RP B401,1993)

Where:
Ic: Average current (demand for design current)
Tf: Age of protection (years)
8760: Constant from yearly to hourly
U: Use a factor of the sacrificial anode (ampere)
ε: Anode material electrochemical efficiency (ampere-hour/kg)

Table 5. Design electrochemical

| Material of Anoda | (ε) |
|---|---|
| Al | 2000 |
| Zn | 700 |

Source: DNV RP B401

g. Determine the use factor of the sacrificial anode

The anode use factor, depending on the anode design, regarding the dimensions and location of the anode core, the use factor in Table 6 is a conservative estimate of the anode design detail and is used for design calculations (Gerianto, 2011), one form of sacrificial anode design can be seen in Figure 1.

Table 6. Design of useful factor sacrificial anode

| Type of anode | Useful Factor |
|---|---|
| Long slender stand-off | 0.9 |
| Long flush-mounted | 0.85 |
| Short flush-mounted | 0.80 |
| Bracelet, Half shell | 0.80 |
| Bracelet, Segmented | 0.75 |

Source: DNV RP B401

h. Determine the number of sacrificial anodes

$$N = \frac{W}{W@} \qquad (2.5)$$

Where :
N: Number of anodes (fruit)
W: Total weight of sacrificial anode (kg)
W @: Weight of sacrificial anode design (kg)

i. Determine installation distance

$$J_{ak} : \frac{LPP}{\sum AK_{total}} \qquad (2.6)$$

Where :
Jak: Distance between victim anode (m)
LPP: Distance between vertical lines (m)
ΣAktotal: Total number of sacrificial anodes (fruit)

### 2.2 Conceptual Framework

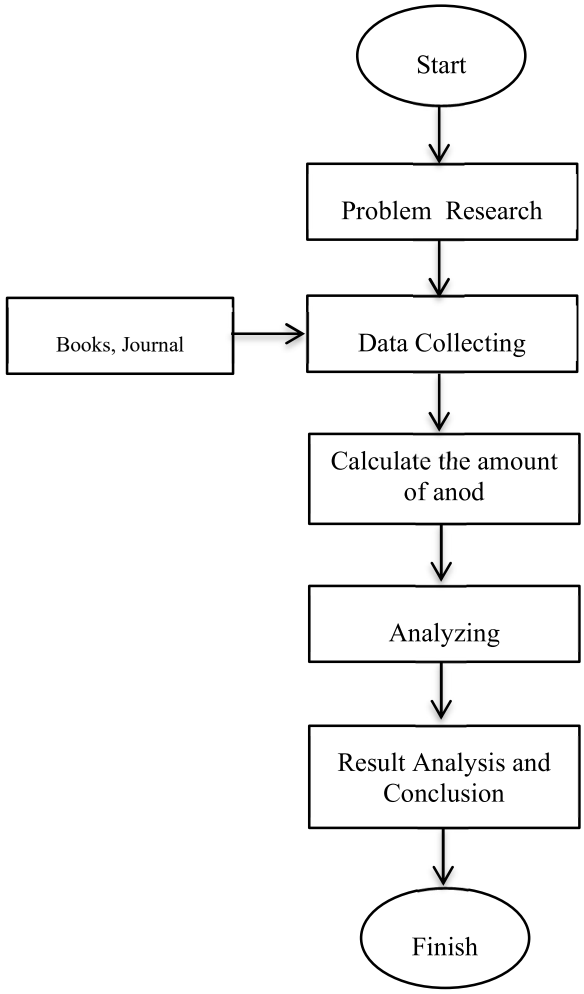


Figure 1. Conceptual Framework of Research

## III. Result And Discussion

Preliminary data for zinc anode KRI TJA-514 needs following the KRI catalog book and the results of anode need calculations using standard DNV RP-B401 1993 have been discussed in the chapter above, from the results of field observations with the calculation results have found very significant differences (Kenneth, 1991), therefore This comparative study needs to be carried out to find out the efficient use of sacrificial anodes, this comparative study covers from 3 aspects namely:

a. Characteristics of Zinc anode and Aluminum anode.

b. Technical and Economic Aspects.

c. Calculation of Sacrificial anodes.

### 3.1 Characteristics of Zn and Al

Table 7. Caracteristic Zn dan Al

| No | Parameter | Zn | Al |
|---|---|---|---|
| 1 | Density | 7060 $kg.m^{-3}$ | 2695 $kg.m^{-3}$ |
| 2 | Capacity | 780 $Ah.kg^{-1}$ | 2640 $Ah.kg^{-1}$ |
| 3 | Reduction (weight) | 10,7 $kg.Ay^{-1}$ | 3,2 $kg.Ay^{-1}$ |
| 4 | Reduction (Volume) | 1518 $ml.A^{-1}y^{-1}$ | 1180 $ml.A^{-1}y^{-1}$ |
| 5 | Output | 6,5 $A.m^{-2}$ | 6,5 $A.m^{-2}$ |
| 6 | Tail (SSC) | -1050 mV | -1050 mV |

Source: Corrosion for science and engineering students, page 321

From the table above, we can see the most basic difference between zinc anode and aluminum anode. From the aspect of current density, the capacity and wear of aluminum anode are superior to zinc anode, this is proven if, at the same volume, year and weight of aluminum anode are more durable, this is also caused by the value of the galvanic zinc anode series is smaller than aluminum against aluminum steel, meaning the zinc anode is more reactive to steel than aluminum. The farther the distance of the metal in the galvanic series, it shows the more reactive between the two metals, so that in the perspective of the potential, the zinc anode is superior to the aluminum anode.

### 3.2 Technical and Economic Aspects.

The roughness of the underwater surface greatly determines the value of resistance on the ship, both roughness caused by the growth of oysters or the presence of anodes, the more anodes installed, the ship's resistance is also greater. Therefore, in the installation and determine the need for the number of anodes must be calculated (NACE, 1978).

While from the economic side will have implications for the costs to be incurred by the owner. The following table is the price of anode per kg and costs incurred for purchase.

Table. 8 Total Price Zn in each Category

| No | Anode Type | Category I | Category II | Category III | Category IV |
|---|---|---|---|---|---|
| 1 | Zink Anode (Zn) Existing | 64.080.000 | 64.080.000 | 64.080.000 | 64.080.000 |
| 2 | (Zn) calculation | 52.065.000 | 19.755.000 | 8.910.000 | 7.695.000 |
| 3 | (Al) calculation | 20.500.000 | 7.650.000 | 3.750.000 | 3.350.000 |

Source: Data Analytic

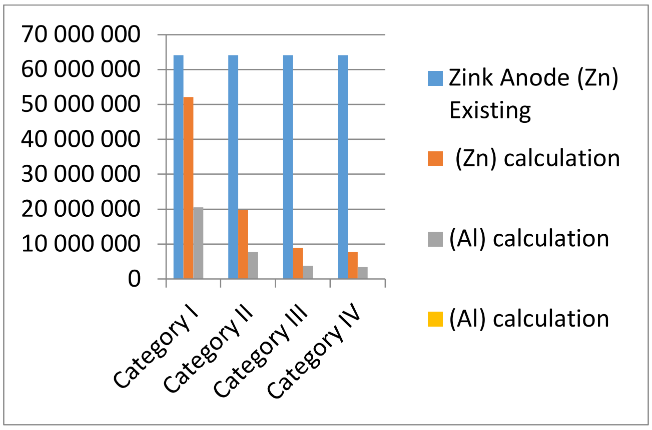


Figure 2. Total Price Zn in each Category

From the economical comparison results, it is known that the costs incurred for the purchase of installed anode zinc are far greater than the cost of purchasing the anode zinc as calculated and the value will be even greater when compared with the purchase of aluminum anode. This means that currently there is an economical waste of money that should have been minimized (PT. BKI, 2006).

### 3.3. Calculation of Sacrificial anodes.

a. Existing of zinc anode KRI TJA-541 Vs Calculation of zinc anode requirement uses DNV standard.

According to the data, the total amount or weight of Zn installed in the KRI is 1424 kg with details of 4 kg for the sea chest area and 9 kg for the stomach area with the following installation concepts. The concept of the installation formation 3-1-3-1-3 and so according to the picture above, according to the author is not quite right when referring to the formula (2.7) in chapter two. Pimpro PT.DPS and Quality Control also confirmed this, he said that the zinc anode on KRI TJA-541 was excessive, as a comparison data for the installation of zinc anode when the author served in KRI WIR-379 as follows:

From the existing data above it is clear that the installation of the sacrificial anode on the KRI TJA-541 needs to be addressed, indeed from the protection side of the KRI TJA-541 it will be far better if compared to the KRI WIR-379, but in terms of KRI detention and the cost of purchasing the sacrificial anode, KRI WIR will be superior in terms of technical and economical.

Whereas in calculations that refer to DNV RPB401 the anode requirements are classified according to the thickness of the KRI coating. The following table compares the zinc anode data KRI TJA-541 which is installed according to the calculation.

Table 9. Comparison Total Weight Zn

| No | Consumption of Zn | Total Weight |
|---|---|---|
| 1 | Zn Existing | 1424 |
| 2 | Zn Category I | 1157 |
| 3 | Zn Category II | 439 |
| 4 | Zn Category III | 198 |
| 5 | Zn Category IV | 171 |

Source: Data Analytic from Author

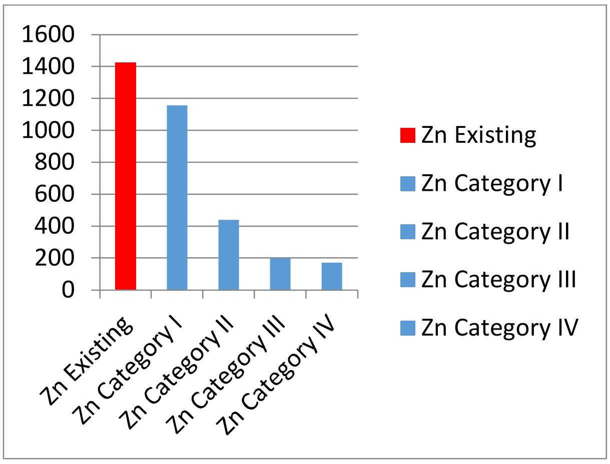


Figure 3. Comparison Total Weight Zn

Base on the comparison data above which states that currently, the installed zinc anode weighs 1424 kg whereas according to calculations using the DNV standard in category I which in this category I the thickness of the coating is only 50 µm only requires anode zinc of 1157 kg, whereas if KRI uses a coating with category II anodes needed only 439 kg. This means that when viewed from the protection point of view, the current conditions have fulfilled the requirements and can even be said to have been overprotecting, because in terms of numbers far greater than the calculation results. However, from a technical and economic standpoint, it is certainly not efficient, the large amount of anode zinc attached will have implications for the greater KRI resistance which will later hamper the KRI rate so that the performance of the KRI decreases while the economic side is faced with the amount of anode zinc attached this will have implications for the purchase of zinc anode, of course, if the amount of zinc anode is higher, the cost will also be higher.

b. Existing data Zn KRI TJA-541 Vs Calculation of Aluminum anode (Al) requirements with DNV standard.

The comparison of the zinc anode attached with the calculation shows a significant difference, especially when compared to the use of aluminum anode which has many advantages over the aluminum anode, of course, the difference will be more significant. The following is a table comparing the use of Zn in the KRI with an anode aluminum according to calculations.

Table 10. Comparison Total Weight Zn and Al

| No | Consumption | Total Weight |
|---|---|---|
| 1 | Zn Existing | 1424 |
| 2 | Al Category I | 410 |
| 3 | Al Category II | 153 |
| 4 | Al Category III | 75 |
| 5 | Al Category IV | 67 |

Source: Data Analytic from Author

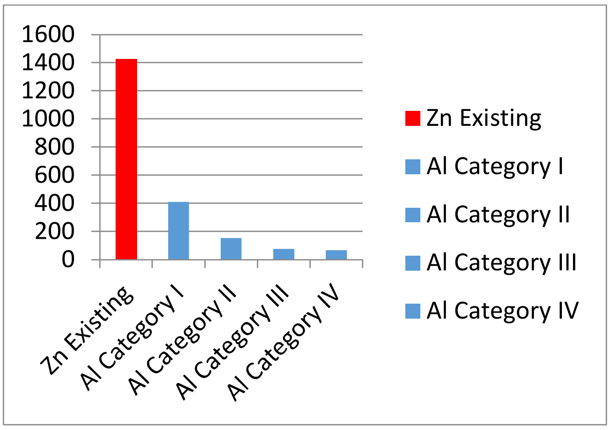


Figure 4. Comparison Total Weight Zn and Al

So with the results above, of course using an aluminum anode is very beneficial because the aluminum anode has several advantages, namely longer reliability and also has lighter current and weight characteristics compared to the zinc anode.

## IV. CONCLUSION.

a. Based on the DNV RPB401 standard, cathodic protection of sacrificial anodes on KRI TJA-54 is overcapacity, the indication can be seen from the large number of anode zinc anode casualties installed, the thickness of the plate is still within the tolerance limit of> 80% even though the ship has only been docked for 6 years (last docking in 2008) and has met the safe but inefficient requirements.

b. The results of the calculation of anode requirements (Zn and Al) using the DNV standard are much smaller than the anode currently installed, the weight of the installed Zn is 1424 kg while the weight of Zn and Al according to recalculation in each category is still much smaller.

c. The results of the calculation of needs between Zn and Al calculations show the use of aluminum is more efficient than zinc anode.

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