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Analysis Of Laying And The Need For Cathodic Protection On Single Point Mooring Type Catenary Anchor Leg Mooring Buoy 035 By PT. Pertamina Fuel Terminal Tuban

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Abstract

Corrosion is one of the most common causes of damage to mooring buoys due to oxidation on the surface of the steel plate. The purpose of this study was to determine the need and placement of cathodic protection, as well as the costs required in procuring cathodic protection on moorings, buoy using the rules of BKI (Indonesian Classification Bureau) and DNV (Det Norske Veritas Industry Norway). In the cathodic protection system, there are two methods of cathodic protection, namely Sacrificial Anode Cathodic Protection (Sacrificial Anode) and Impressed Current Cathodic Protection (ICCP). In this study, the sacrificial anode method was used because the installation is simpler so it does not require special skills and the anode connector is cathodic protected. Mooring buoy with a height of m, a diameter of meters with a cathodic protection design life of 5 years. The anode used in this study is an anode with a located flush-mounted Z9.0H1 (Welded Type) with dimensions of 355 x 85 x 45 mm. From the results of this study, it was found that the total anode mass needed to protect the mooring buoy is 26.95 kg with the installation distance between the anodes on the topside hull plate is 34.557 m and the bottom swim hull plate is 47.123 m and the estimated cost required to provide mooring buoy is IDR 4,284,900.

Keywords: Mooring Buoy, Corrosion, Zinc Anode

1. Introduction

Marine structures (ships, offshore platforms, subsea pipelines, and other floating structures) that operate are not protected from the corrosion process. Thus, maintenance management on a marine structure is very important because the construction cost of the structure is expensive. In terms of construction, the parts that are susceptible to corrosion are areas exposed to seawater, such as the hull construction. Corrosion of the slab can result in a decrease in the strength and service life of a marine structure [1].

SPM CALM Buoy #035 Pertamina Tuban Fuel Oil Terminal (TBBM) is one of the facilities owned by PT. Pertamina (Persero). Pertamina Tuban Fuel Oil Terminal (TBBM) is used for the distribution of fuel oil and becomes the Main Transit Terminal (TTU) for Pertamina Region V, which means the density of fuel oil distribution flows. In supporting the distribution process so that it continues to run better, it needs to be supported by adequate facilities, one of which is mooring buoys as a means of mooring in the process of loading and unloading shiploads. Mooring buoys that operate will of course experience a corrosion process. As a result, there will be a decrease in the thickness of the steel plate and the effectiveness of the mooring buoy as a mooring tool [2].

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Fig. 1. Corrosion that occurs in the mooring buoy [1]

Corrosion prevention methods can be used as a solution, namely by protecting the plate periodically using cathodic protection. Cathodic Protection is a technique used to control rust (corrosion) [3] on metal by making the metal surface the cathode of an electrochemical cell [9]. Cathodic protection is an effective way to prevent stress corrosion cracking (due to corrosion), by reversing the direction of the corrosion current to restore electrons that break down from certain metals, which are immune or immune so that the corrosion process on metals can be reduced or eliminated. not lost). Cathodic protection systems are commonly used to protect steel, pipelines, tanks, piles, ships, offshore platforms, and onshore oil well casings[4] [5].

Therefore, in this study, we will discuss the need for cathodic protection system planning on the mooring buoy owned by PT. Pertamina Tuban Fuel Oil Terminal (TBBM). In addition to planning for cathodic protection needs, planning for the installation/laying of cathodic protection will be analyzed in this study [6][7][8].

2. Materials and Methods

Corrosion is also defined as a decrease in metal quality due to electrochemical reactions with its environment [8]. Corrosion occurs in various forms, ranging from uniform corrosion on the entire metal surface to corrosion that is concentrated in certain parts. Protection is a treatment to protect an object from things that can damage it so that the object cannot function optimally. In this case, protection in the industrial world is needed because it has a function to protect a structure, one of the protections used is cathodic protection to protect the structure from corrosion. Cathodic protection using a sacrificial anode occurs when a metal is connected to a more reactive metal (anode). This relationship leads to a galvanic circuit. To effectively remove corrosion from metal structures, the anode material must have a potential difference large enough to generate an electric current [3].

2.1 Research Object

installation mooring buoy belonging to PT. Pertamina (Persero) will be operated in Tuban, East Java as one of the supporting facilities in the process of mooring and loading fuel oil. The cathodic protection design on the mooring buoy used is based on the Indonesian Classification Bureau in the Regulation for the Corrosion Protection and Coating System. The cathodic protection system that will be used is Located flush-mounted (Welded Type). The following is a view of the SPM (Single Point Mooring) 035 Pertamina TBBM Tuban.

Fig. 2. SPM (*Single Point* Mooring) 035 Pertamina TBBM Tuban [9]

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2.2 Sacrificial Anode Method

In simple terms, this method uses a new metal that has a higher energy level so that a current flows from the lowest metal to the higher one. However, the anode has a life limit where it will be completely contaminated and must be replaced with a new one. The way cathodic protection works with a sacrificial anode is to use the concept of a wet corrosion cell. That is the anode cells are corroded or corroded, while not corroded is the cathode. The anode which is connected to the structure to affect the protection against corrosion is in this way called the sacrificial anode. The advantages of this method are as follows [10]:

a. Can be used without requiring external electrical energy
b. Almost does not require supervision, costs become relatively cheaper
c. The resulting protective current is never misdirected, does not require special skills
d. Installation is relatively simple, so it does not require special skills
e. The anode connector is cathodically protected.

2.3 Sacrificial Anode

In the design of cathodic protection, calculations will be made to ensure that sufficient sacrificial anode is used to provide the total current required to protect the mooring buoy during its design life. To calculate the need for a sacrificial anode, DNV RP (B401) is used [3]. The cathodic protection design used on the mooring buoy is Located flush-mounted Type Z9.0H1 (Welded Type) with a size (355 mm x 85mm x 45mm) and a mass of 9.5 kg with a protection period of 5 years. The anode data can be seen in Table 1 below.

Table 1. Design anode data [11]

Parameter	Value
Design anode life	5 Tahun
Type of anode material	Paduan Zinc Zn-Al-Cd 780 A-h/kg
Electrochemical efficiency in seawater at ambient temperature	25°C
Thickness anode	45 mm
Length anode	355 mm
Width anode	85 mm
Desain Anode Mass	9,5 kg
Factor anode utilization	0,85

3. Results

Calculation of anode requirements requires several design criteria on demand [9]. These criteria include data on the properties of the mooring buoy (Table 2), environmental data on the mooring buoy installation location mooring buoy in Tuban, East Java, and data on the anode to be installed (Table 1).

Table 2. Data properties of *mooring buoy* [1][4][5][10]

Parameter	Unit	Nilai
Height (H)	m (meter)	3,7
Load (T)	m (meter)	11
Upper Diameter	m (meter)	3,7
Base Diameter	m (meter)	11
Material specifications	-	Strengthening Carbon Steel
Plate thickness	mm (millimeter)	12

Table 3. Environmental data *Mooring buoy* [12]

Parameter	Unit	Nilai
Seawater temperature	°C	29
Density	kg/m	1025

3.1 Determination of Total Anode Required Sacrificial

anode requirement on mooring buoy PT Pertamina Terminal BBM (TBBM) Tuban using zinc

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anode (chemical composition of the alloy consists of Cadmium 0.025 – 0.150%, Pb/Lead 0.006%, Copper 0.005%, Iron 0.005%, Aluminum 0.100 – 0.500%, Silicon 0.125% and Zinc 98%) can be calculated using equation (4).

The surface area of the mooring buoy is calculated using the approximation of the area of the cone and cylinder as in equation (3). The coefficient of coating damage can be seen in Table 4 which refers to Det Norske Veritas RPB401 on Cathodic Protection Design. The layer damage factor can be calculated using equation (1).

1. Calculating layer damage factor

$$fc\ (final) = k_1 + k_2 \times tf \qquad (1)$$

If the calculated value is more than 1, fc =1 must be used in the design. The above equation is based on design purposes only, and it is not intended to visualize the actual model as a coating breakdown factor where the design of the cathodic protection system exceeds the life of the coating system. The values for k1 and k2 can be seen in the following table:

Table 4. Constans (k_1 and k_2) for the calculation of coating damage factor [7]

Depth (m)	Coating Category			
	(k1 = k2)	(k1 = k2)	(k1 = k2)	(k1 = k2)
0 < 30	0,100	0,030	0,015	0,012
> 30	0,050	0,020	0,012	0,012

2. Calculating the pipe surface area

As for calculating the surface area of the pipe being protected, the following formula is used [6]:

$$A = \pi \times (D \times 0{,}0254) \times L \qquad (2)$$

Where A is pipe surface area, D is 3.14, π is pipe diameter and L is the pipe length

3. Calculating the current demand requirement.

If the respective area (Ac) of each protected unit is multiplied by the design current density (ic) and the layer damage factor (fc), it will be obtained [7]:

$$Ac = ((\pi \times r^2 \times t) + (\pi\ (r + R)\ b)) \qquad (3)$$

Where r is 3.14, π is the length of the radius of the mooring buoy, R is the length of the top radius of the mooring buoy, and b is the length of the mooring buoy

4. Calculating the anode mass requirement

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

As for calculating the mass required for the sacrificial anode, the following equation is used [7]:

Where m is zinc alloy sacrificial anode mass (kg), Ic is protection current requirement (Amperes), T is protection life (years), T = 5 years [2], µ is sacrificial anode use factor 0.85, and ε is electrochemical efficiency (Ah/kg) 780, zinc alloy.

The anode mass requirement which has been calculated using equation (4) can then be determined the anode requirement be installed on the mooring buoy by using the anode design size. So the number of sacrificial anodes needed in the Mooring Buoy cathodic protection system is:

$$\Sigma\ \mathrm{AK} = \frac{m}{m\ \mathrm{AK}} \qquad (5)$$

Where AK is the number of sacrificial anodes, m is the mass of required sacrificial anode, and mAK is mass per unit sacrificial anode.

5. Determining the distance between the sacrificial anodes

After obtaining the number of anodes to be used for protection, it can be determined the placement or distance between the anodes on the mooring buoy using the following equation.

$$\mathrm{J}_{\mathrm{AK}} = \frac{K - (Panjang\ Anoda\ x\ Jumlah\ Anoda)}{\Sigma\ \mathrm{AKtotal}} \qquad (6)$$

Where J AK is the distance between sacrificial anodes (m), K is the circumference of the mooring buoy (m), and AKtotal is the total number of installed sacrificial anodes (pieces).

3.2 Recapitulation of Research Results

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Based on the equation used with DNV RP (B401) "Cathodic Protection Design", the following results were obtained:

Table 6. Results of calculation of anode requirement

No.	Description	Unit	Value
1.	The surface area of the pipe	m^2	59,019
2.	Protection design life	year	5
3.	Length anode	mm	355
4.	Width anode	mm	85
5.	Thickness anode	mm	45
6.	Distance between anodes on topside hull-plate	m	34,557
7.	Distance between anodes on bottom swim hull-plate	m	47,123
8.	Total required anode	unit	3

3.3 The distance between the anodes

The position of the sacrificial anode placement is based on the calculation results by welding using a welding wire electrode for the sacrificial anode installation process with a mooring buoy.

3.4 Design Cost Required

Below is a table of the results of the calculation of the economic analysis for the cathodic protection of the sacrificial anode on 1 (one) mooring buoy.

Table 7. Economic analysis calculation of cathodic protection on the mooring buoy

No.	Description	Unit	Coefficient	Price (Rp)	Total price (Rp)
A	Labor				
	1. Worker	OH	3	75.000	225.000
	2. Welder	OH	2	120.000	240.000
	3. Foreman	OH	1	75.000	75.000
				The total price of labor	540.000
B	Materials				
	1. Welding wire electrode	pcs	15	3.000	45.000
	2. Zinc Anode	pcs	3	990.000	2.970.000
				The total price of material	3.015.000
C	Equipment				
	1. Welding Set	Set//hour	1,5	114.000	171.000
	The total price of equipment				171.000
D	The total price of labor, materials, and equipment (A+B+C)				3.726.000
E	Overhead + profit (15%)15% × D				558.900
F	Unit price (D+E)				4.284.900

Based on Table 7, it is known that the overall cost required in the design of sacrificial anode cathodic protection requirements for 1 (one) mooring buoy with a diameter of 3,700 m and a height of 3,700 m is Rp. 4,284,900 to protect the mooring buoy for 5 years

4. Conclusions

After processing data regarding the design of the sacrificial anode cathodic protection system on the mooring buoy, the following conclusions are obtained:

1. The total anode required for 1 (one) mooring buoy with a diameter of 3,700 m and a height of 3,700 m and a protection design life of 5 years is 3 anodes with an elongated flush-mounted (welded type) type Z9.0H1 anode dimensions (355 mm). x 85mm x 45mm).
2. The installation distance between the anodes

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used on the topside hull plate is 34.557 m and for the bottom swim, the hull plate is 47.123 m.

3. The cost required for the manufacture of cathodic protection is Rp. .4.284.900.

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