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Analysis of the corrosion rate and remaining life of the B3 waste transport roll-off tank composed of 316L stainless steel

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Abstract. Corrosion has eroded the shell and head of the roll-off tank used to carry B3 waste. This influence will effect on the functioning of the waste containment tanks, as well as the general safety of the public. The goal of this study was to examine the viability of employing a roll off tank by completing a visual inspection and engineering calculations using ASME VIII and API 510 standards to determine the corrosion rate and remaining life in the roll-off tank. This study employs a quantitative approach. Tank design data was acquired using SA-240/G316L material with an initial shell and head thickness of 6 mm and an actual thickness of 5.45 mm shell and 5.50 mm head. The corrosion rate and remaining life analysis yielded a Thickness Required shell value of 4.33 mm and a head value of 4.33 mm, with a shell and head Corrosion Rate value of 0.04 mpy, a Maximum Allowable Working Pressure (MAWP) value of shell and head of 0.63 Bar, and a shell and head remaining life value of 28 years and 30 years, respectively. It may be established that the roll-off tank is still operationally viable. Maintenance and testing regularly to improve roll-off tank performance

Keywords: Corrosion rate; remaining life; roll-off tank

1. INTRODUCTION

Corrosion causes many problems in the industrial sector, particularly in metal components. Because of the high cost of treatment due to corrosion, many businesses do research to find ways to reduce corrosion control costs. An engineer in the sector of building, in particular, must have knowledge and skills to understand the corrosion rate of metals [1]. Corrosion management and treatment efforts are critical for reducing direct and indirect losses [2]. Whereas direct corrosion losses in the form of building material loss, workplace safety, and environmental contamination due to corrosion products in the form of chemicals that poison the environment [3]. In the meantime, indirect losses include reduced capacity and higher maintenance expenses [4].

PT. ABCD uses tanks as a tool to support operational activities in the waste management services industry, namely to carry B3 garbage from clients to PT. ABCD. The roll-off tank holds liquid waste such as oil production waste, drilling mud, acid waste, mercury waste, and pesticide trash [5]. Due to corrosion, the high intensity of tank use depletes the shell and tank head material [6].

To reduce corrosion losses, researchers employed the Corrosion Monitoring method with the Non-Destructive Test (NDT) methodology with visual inspection adhering to the ASME VIII Div 1 standard to examine the corrosion rate and remaining life in the roll-off tank [7] and *API 510* [8][9]. This is the context for the research to examine the corrosion rate and remaining life in the roll-off tank.

The goal of this study was to establish the viability of employing a roll-off tank by doing a visual examination and engineering calculations from technical data by ASME VIII and API 510 standards to calculate the value of corrosion rate and remaining life in the roll-off tank [6].

2. METHOD

The suggested implementation period runs from September 1, 2022 until September 30, 2022. PT. ABCD, located in Jl. Raya Narogong, Bogor, conducted a study on the results of corrosion rate and remaining life analysis in roll-off tanks built of 316L stainless steel material for B3 waste.

3.1. Research methods

The following is the procedure for locating and getting the data required for the research:

3.2.1. Data collection

This is a stage in which data and information about corrosion rate and tank roll-off are collected. The data gathered will aid in answering the objectives established at the start of the research activities' implementation. This activity employs both primary and secondary data collection approaches.

- Primary data.

The following are the primary data acquired in this study: 1) Technical data on roll off tank design. 2) Actual roll-off tank technical data.

- Secondary data.

Secondary data was gathered through book searches as well as the internet, where the literature offers information on corrosion rate study and remaining life assessment. This strategy is used for a variety of reasons, including the fact that not all research is conducted.

3.2.2. Observation

Is a field-based research stage that involves watching and analyzing the corrosion rate and remaining life in a 316L stainless steel roll-off tank using the corrosion monitoring method using a visual inspection approach in by the ASME VIII Div 1 standard.

3.2. Flowchart of corrosion rate analysis and remaining life in the tank

Figure 1 depicts the flow of the corrosion rate and the remaining life analysis process in the tank.

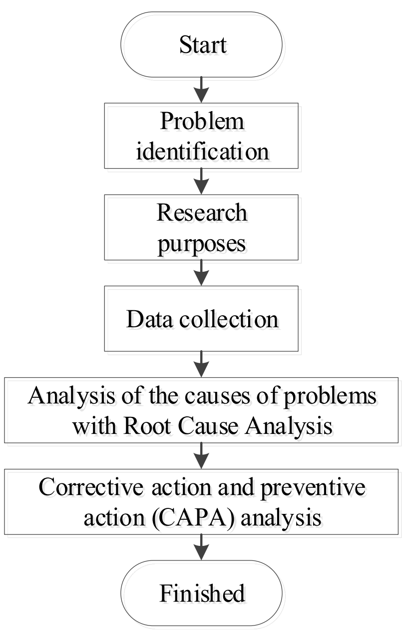

Figure 1. Flowchart of corrosion rate analysis in the roll-off tank

a) Start

Researchers will be sent to the field to undertake research that will be carried out.

b) Literacy study

Collect roll-off tank design data from firms, as well as other supporting data such as corrosion rate and remaining life references from ASME VIII Division 1 as a standard reference for assessing roll-off tank conditions.

c) Observation

Using the corrosion monitoring method, conduct direct observations in the field to observe and assess the corrosion rate and remaining life in the roll-off tank [10].

d) Corrosion monitoring

Researchers made observations by utilizing an ultrasonic thickness gauge to measure the thickness of the tank's shell and head [11].

e) Corrosion rate analysis results.

Calculations are used to explain the results of the corrosion rate and remaining life analysis in the roll-off tank.

f) Result report.

Report on the findings of the corrosion rate and remaining life analysis in the roll-off tank, and make recommendations based on the findings.

3. RESULTS AND DISCUSSION

3.1 Corrosion monitoring

The corrosion monitoring technique attempts to determine the corrosion rate of a metal so that the corrosion rate may be used to predict when and how long the workpiece can be used [12]. Analysis of corrosion rate and remaining life in roll-off tanks using the Corrosion Monitoring method with the Non-Destructive Test (NDT) approach with visual inspection following the ASME VIII Div 1 standard, namely by making comparisons between roll-off tank design data and actual technical data regarding roll-off tank. The corrosion rate and remaining life values of the roll off tank are then determined using the two data points [13].

3.2 Visual inspection

Visual inspection is one of the NDT (Non-Destructive Testing) methods for evaluating conditions and providing quality comparisons of workpieces to be tested against applicable standards [14]. An ultrasonic thickness gauge is one of the tools used in visual inspection to evaluate the thickness of metal material [14]. The maintenance department, as the supervisor of maintenance operational activities, performs the visual inspection procedure. Checking the condition of the roll off tank entails inspecting the existing tank and using an ultrasonic thickness gauge to measure the thickness of the shell and tank head [6]. In checking the condition of the existing tank, uniform corrosion spots were found on the head rear at the 90° point as shown in **Figure 2**, and damage to the paint coating on the surface of the tank shell as shown in **Figure 3**.

Figure 2. Uniform rust on the tank head

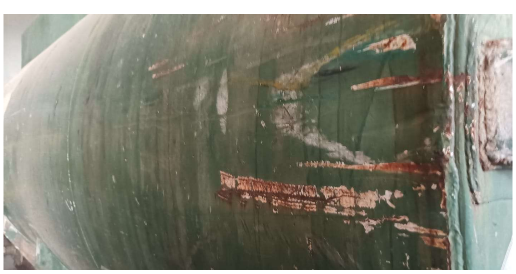

Figure 3. Scratches on the tank's paint covering

There are 18 test points in the process of checking the thickness of the shell and tank head using an ultrasonic thickness gauge, as shown in **Figure 4**. **Figure 5** namely shell 1, 2, and 3 with point degrees of 0°, 90°, 180°, and 270°, and on the head front and head rear with point degrees of 0°, 90°, 180°. **Table 1** shows how to collect actual data on the status of the plate thickness in the roll off tank.

Figure 4. An ultrasonic thickness gauge is used in the inspection process

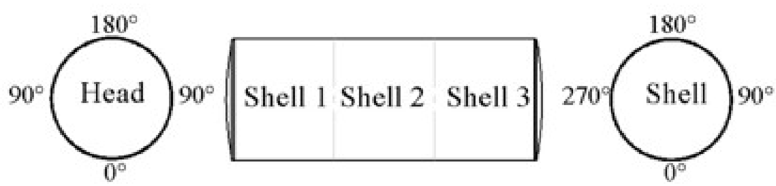

Figure 5. Thickness data collecting points sketch

Table 1. Actual shell thickness and tank head data

Actual Roll off Tank Thickness Data					
Point of Location	**0°**	**90°**	**180°**	**270°**	**Thickness (Nominal)**
Shell 1	5,85	5,85	5,80	5,75	
Shell 2	5,75	5,45	5,70	5,45	6 mm
Shell 3	5,80	5,55	5,45	5,80	
Head Front	5,75	5,50	5,75	-	6 mm
Head Rear	5,85	5,50	5,75	-	

According to **Table 1**, the smallest thickness for shell is found in shell 2 and shell 3 with location points of 90°, 180°, and 270° and a measurement value of 5.45 mm, while the thickness of the head is found in head 1 with location points of 90°, 180°, and 180° and a measurement value of 5.50 mm.

Table 2. Maintenance Department roll-off tank design data

Data on Roll-off Tank Design			
Roll off tank	**Remarks**	**Roll off tank**	**Remarks**
Vessel Type	Horizontal Low Pressure in Bejana	Design of Pressure	5 Bar (72,5 Psi)
Design Standard	ASME VIII	Design of Temperature	38°C
Shell Materials	SA240G-316L, 16700 Psi, (115 Mpa)	Head of Material	SA240G-316L 16700 Psi, (115 Mpa)
Shell Outer Diameter	2000 mm	Outer Diameter of the Head	1976 mm
Shell Inside Diameter	1988 mm	Inner Diameter of the Head	1964 mm
Nominal Thickness Shell	6 mm	Head Thickness Nominal	6 mm

Data on Roll-off Tank Design			
Roll off tank	**Remarks**	**Roll off tank**	**Remarks**
Shell length	5000 mm	Capacity	15 m^3
Welding Efficiency	1	Type Head	Only Flanged Head
Shell Allowable Stress	16700 Psi (115 Mpa)	Year of production	2010

The roll off tank is based on tank technical data from the maintenance department, as shown in Table 2.

4.1 Engineering calculation results

Following the collection of primary data (as shown in **Table 1** and **Table 2**) and secondary data, the following step is to compare the two primary data sets using formulae. The first step is to determine whether the shell and head are eligible based on the actual thickness values from Table 2. Use the Thickness needed (T.req) calculation for shell and head in Figures 4 and 5 to determine the minimum allowed thickness values [7].

$$\text{Required thickness (shell)}= \frac{P\times Ri}{S\times E-0{,}6\times p} \tag{1}$$

$$= \frac{0{,}5 \times 994}{115 \times 1 - 0{,}6 \times 0{,}5}$$

$$= 4{,}33\ mm$$

$$\text{Head thickness is necessary}= \frac{P\times Do}{2\times S\times E-0{,}2\times P} \tag{2}$$

$$= \frac{0{,}5 \times 1988 \times 0{,}99}{2 \times 115 \times 1 - 0{,}2\ \times 0{,}5}$$

$$= 4{,}33\ mm$$

Based on the estimates in formulas (1) and (2), it is possible to deduce that the shell and head in the roll off tank are still operational. Because the minimum shell and head thickness values in table 1 (4.33mm 5.45mm) and (4.33mm 5.50mm) are less than the actual shell and head thickness values [15]. Next, compute the corrosion rate on the shell and head under long-term conditions, or conditions between the nominal thickness at the start of manufacture and the actual thickness conditions, with a distance of 12 years between the two.

$$\text{Shell corrosion rate} = \frac{t.nom - t.act}{years\ between\ t.nom\ and\ t.act} \tag{3}$$

$$= \frac{6\ -\ 5{,}45}{2022 - 2010}$$

$$= 0{,}04\ mpy$$

$$\text{Rate of corrosion (head)} \quad = \frac{t.nom - t.act}{years\ between\ t.nom\ and\ t.act} \tag{4}$$

$$= \frac{6\ -\ 5{,}50}{2022 - 2010}$$

$$= 0{,}04\ mpy$$

The long-term corrosion rate for the shell and head of the roll off tank is calculated using formulae (3) and (4) to be 0.04 mpy. Next, check the roll off shell and tank head for the Maximum Allowable Working Pressure (MAWP).

$$\text{MAWP (shell)} = \frac{S \times E \times t}{Ri - 0{,}6 \times t} \tag{5}$$

$$= \frac{155 \times 1 \times 5{,}45}{994 - 0{,}6 \times 5{,}45}$$

$$= 0{,}63\ \mathrm{N/mm^2}$$

$$= 6{,}3\ \mathrm{Bar}$$

$$\text{MAWP (head)} = \frac{2 \times E \times S \times t}{D - 0{,}2 \times t} \tag{6}$$

$$= \frac{2 \times 1 \times 155 \times 5{,}50}{1988 - 0{,}2 \times 5{,}50}$$

$$= 0{,}63\ \mathrm{N/mm^2}$$

$$= 6{,}3\ \mathrm{Bar}$$

The MAWP value for the shell is 6.3 Bar, and the MAWP value for the head is 6.3 Bar, based on the computations in formulas (5) and (6). As a result, the maximum permitted pressure for the roll-off tank to operate is 6.3 Bar. Finally, use the API 510 standard to compute the remaining life of the roll-off the tank.

$$\text{Remaining Life (shell)} = \frac{t.act - t.req}{CR} \tag{7}$$

$$= \frac{5{,}45 - 4{,}33}{0{,}04}$$

$$= 28\ \text{Year}$$

$$\text{Remaining Life (head)} = \frac{t.act - t.req}{CR} \tag{8}$$

$$= \frac{5{,}50 - 4{,}29}{0{,}04}$$

$$= 30\ \text{Year}$$

The calculation results of formulas (7) and (8) indicate that the shell and head of the roll off tank have a minimum remaining life of 28 years. That means the roll off tank can continue to run for another 28 years. Based on the calculation results from formulas (1) to (6), it can be concluded that the roll off tank is still classified as feasible to operate because the permitted value of the shell and head thickness is less than the actual thickness of the shell and head (4.33 mm 5, 45 mm) with a Corrosion Rate value of shell (0.04 mpy) and head (0.04 mpy) and a Maximum Allowable Working Pressure value of shell (6.3 Bar) and heads (6.3 Bar). The remaining life value is 28 years, implying that the roll off tank can continue to operate for another 28 years

4. CONCLUSION

The visual inspection revealed damage to the tank in the form of uniform corrosion at the head rear point of 90°. As well as damage in the form of scratches on the paint coating on the surface of the tank shell. The engineering calculation revealed that the roll off tank was still categorized as feasible to operate due to the value of the shell thickness and the permitted head being less than the actual thickness. Namely the shell (4.33 mm 5.45 mm) and head (4.33 mm 5.50 mm), with a Corrosion Rate value of shell (0.04 mpy) and head (0.04 mpy), Maximum Allowable Working Pressure (MAWP) value of shell (6.3 Bar) and head (6.3 Bar), and remaining life value of 28 years, implying that the roll off tank can still operate for another 28 years.

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