ANALYSIS OF CORROSION RATE AND REMAINING LIFE OF STEEL ON PIPELINES AT PKS PTPN 1 TANJUNG SEUMANTOH

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Abstract

Corrosion is a major cause of early failure in palm oil mill infrastructure in Aceh, Indonesia. Therefore, the aim of this study is to analyze the corrosion rate of steel used in the palm oil mill industry and determine the remaining life of the steel. Round bars and plates made of steel were used as exposure samples. This sample was cleaned of impurities and ground with sandpaper to obtain a 600 grating, then washed with clean water and rinsed with strong liquid, then presented to the climate at the PTPN I Tanjung Seumantoh palm oil mill so that it could see the rate of steel erosion due to corrosion. For exposure, steel specimens are placed on racks, and weight measurements are taken once a month to determine corrosion rate values using the ASTM G50 standard. In addition, steel thickness measurements were also carried out in 2021 and 2022 to calculate the corrosion rate using the Standard API 570 standard. Research results of the remaining life of the pipe on the wall tube is about 32 years, the remaining life for the generating pipe is about 29 years, and the remaining life for the heater pipe is about 11 years. from the calculation results obtained the longest remaining life is obtained on the wall pipe while the shortest remaining life of the pipe is found in the heater pipe because the pipe is always heated.

Keywords: Structural Steel, Weight Loss, Corrosion Rate, Atmospheric Corrosion, Remaining Life.

1. INTRODUCTION

Indonesia is a country with a plantation area of around 10.6 million hectares (Mha) in 2014, Indonesia is one of the world's leading palm oil producers [1]. Oil palm plantations in Aceh Province in 2016 covered an area of 393,270 hectares [2]. The expansion of oil palm plantations in Aceh has had a number of beneficial impacts on the community, including the availability of jobs, and providing insight to the local community. Corrosion is very susceptible in oil palm mills because the infrastructure in oil palm plantations is generally made of steel, therefore it is necessary to analyze the corrosion rate and calculate the remaining useful life to avoid sudden failures. The corrosion rate of steel in palm oil mills is higher than the corrosion rate of steel in general due to impurities produced by the palm oil manufacturing process [3]. This can cause a sudden failure that disrupts the production process. Calculation of the remaining life is the right step to prevent a sudden failure by
preparing for follow-up before a failure occurs. Therefore, this study was conducted to analyze the corrosion rate of steel pipes used at PTPN 1 Seumantoh, which is located in Aceh province, and to calculate the remaining life of the steel pipes.

Previous research has carried out measurements of atmospheric corrosion rates around palm oil mills in Aceh. The results showed that the corrosion rate around oil palms increased compared to the normal steel corrosion rate \[4,13\]. The effect of atmospheric corrosion in the palm oil mill environment has also been investigated by Priyotomo et al. by determining the corrosion rate of five types of construction steel, the results of the study obtained a corrosion rate value of <1 mpy\[3\]. Observing the corrosion of carbon steel under various types of atmospheres such as industrial, urban, rural, and marine atmospheres \[5\]. Rida et al. \[6\] carried out measurements of corrosion in the Aceh area and made a mapping of atmospheric corrosion of structural metals in the Aceh Tsunami area in 2004, the results showed a relatively good resistance for all structural steel exposed in the area with a value (<1 mpy). Furthermore, Castano et al. \[7\] analyzed the effect of SO\(_2\) on atmospheric corrosion rates using X-ray diffraction (XRD) and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS).

This study used two types of structural steel, namely round bar and plate, with a carbon content of 0.18% as shown in Figure 1. The mechanical properties and chemical composition of the samples are presented in Tables 1 and 2.

![Figure 1. Specimens (a) Plate, (b) Round bar](image)

**Table 1.** Mechanical properties of the samples \[4\]

<table>
<thead>
<tr>
<th>YIELD STRENGTH (MPA)</th>
<th>YOUNG MODULUS (GPA)</th>
<th>ELONGATION (%)</th>
<th>TENSILE STRENGTH (GPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>356</td>
<td>187.8</td>
<td>22.68</td>
<td>496.5</td>
</tr>
</tbody>
</table>

**Table 2.** Chemical composition of the samples \[4\]

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Ni</th>
<th>Al</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>0.19</td>
<td>0.44</td>
<td>0.005</td>
<td>0.017</td>
<td>0.037</td>
<td>0.023</td>
<td>Balance</td>
</tr>
</tbody>
</table>

**2. MATERIAL AND METHOD**

**2.1. Material**

There are two types of specimens were used, namely round bars and plates. Each specimen amounted to 10 pieces. Specimens are sized according to the ASTM G 50 standard \[8\] as shown in Table 3.
Table 3. Dimensions of specimens

<table>
<thead>
<tr>
<th>No</th>
<th>Specimens</th>
<th>L</th>
<th>T</th>
<th>W</th>
<th>D</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Round Bar</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Plate</td>
<td>150</td>
<td>100</td>
<td>4</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

2.2. Method

2.2.1. Sample preparation and exposure

In this study, a material (steel) with the same criteria as steel at PTPN 1 Tanjung Seumantoh was used as a sample. Samples were cut according to ASTM G 50 standard sizes, after which they were ground using silicon carbide abrasive paper with grit 180 to 600, and the specimens were cleaned with ethyl alcohol, then dried. Specimen exposure was carried out after specimen preparation was completed. Exposure was carried out around PTPN Tanjung Seumantoh for 12 months, measurements were carried out every month for 12 months to determine the value of the corrosion rate. The process of measuring the corrosion rate is carried out by weighing the initial weight and final weight, the process of cleaning corrosion products using a grinder according to ASTM G 50 [8]. The exposure process can be seen in Figure 2.

Figure 2. Specimen Exposure Process

2.2.2. Corrosion Rate Measurement

The weight loss method was applied in this study. Measurements were carried out for 12 months, with time interval measurements every month. The result of measuring the final weight value is reduced by the initial weight to get the thickness difference value. For measurement of corrosion rate using Eq. (1).

\[
\text{Corrosion Rate (CR)} = K \frac{W}{(A \times t \times \rho)}
\]  

(1)

Where \( K \) is the corrosion rate unit's conversion constant, \( W \) is the mass loss in grams, \( A \) is the surface area in cubic meters, \( t \) is the exposure time in hours and density in grams per cubic meter. In the meantime, the following Eq. (2) was used to determine the cross-sectional area.

\[
A = 2[(1 \times w) + (w \times h) + (hx 1)]
\]  

(2)

Where \( K \) is the corrosion rate unit's conversion constant, \( W \) is the mass loss in grams, \( A \) is the surface area in cubic meters, \( t \) is the exposure time in an hour, and density in grams per
cubic meter. In the meantime, the following Eq. (2) was used to determine the cross-sectional area. Specimens are sized according to the ASTM G 50 standard [18, 19] as shown in Table 3.

In addition to the ASTM G 50 standard, the calculation of the corrosion rate also uses the API 570 standard for comparison [17, 18]. The data needed to calculate the corrosion rate is the previous thickness and actual thickness. For measurement of corrosion rate using Eq. (3).

\[

cr = \frac{t_{\text{Previous}} - t_{\text{Actual}}}{\text{Time between } t_{\text{Previous}} \text{ and } t_{\text{Actual}}}
\]

The thickness measurement process will be carried out in 2021 and 2022. The thickness measurement will be carried out in stages due to production activities at PTPN, thickness measurements on the heater pipe are carried out when the engine is off. Thickness measurement using an ultrasonic thickness gauge. The ultrasonic thickness gauge can be seen in Figure 3. The thickness measurement process at PTPN 1 Tanjung Seumantoh can be seen in Figure 4. The thickness measurement result can be seen in Table 4.

![Figure 3. Ultrasonic thickness gauge](image)

![Figure 4. The process of measuring the thickness of steel pipes at PKS Seumantoh](image)

<table>
<thead>
<tr>
<th>No</th>
<th>Tipe</th>
<th>Fluida</th>
<th>Diameter</th>
<th>2021</th>
<th>2022</th>
<th>Required Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wall Pipe</td>
<td>Liquid</td>
<td>8”</td>
<td>8.55</td>
<td>8.33</td>
<td>1,134 mm</td>
</tr>
<tr>
<td>2</td>
<td>Generating Pipe</td>
<td>Liquid</td>
<td>10”</td>
<td>9.12</td>
<td>8.86</td>
<td>1,414 mm</td>
</tr>
<tr>
<td>3</td>
<td>Heater Pipe</td>
<td>Liquid</td>
<td>12”</td>
<td>9.23</td>
<td>8.64</td>
<td>1,696 mm</td>
</tr>
</tbody>
</table>
2.2.3. Remaining Life

The remaining life calculation is done after getting the value of the corrosion rate of each pipe. To get the required data, it takes a long time to get the value of the difference in thickness in the pipe \[10, 14\]. To calculate the remaining life, Eq. (4) was used in this experiment:

\[
\text{Remaining Life} = \frac{t_{\text{Actual}} - t_{\text{Required}}}{\text{Corrosion Rate}}
\]  

(4)

Where \( t_{\text{Actual}} \) is Pipe thickness at current inspection and \( t_{\text{Required}} \) is the minimum thickness required for operation. For the minimum pipe thickness required for onshore pipe shall be determined accordingly to ASME B31.4 for water, liquids, and oil pipelines \[15, 16\].

2.2.4. X-Ray Diffraction (XRD) Analysis

The results of the morphology test using SEM with 2000X magnification on the test specimens before and after being cleaned of corrosion products have not been able to explain in detail the corrosion products that occur in the two types of construction steel \[11, 20\]. Therefore, an XRD (X-Ray diffraction) test analysis was carried out to see the compounds formed as a result of the corrosion process that occurred at PTPN Tanjung Seumantoh.

The X-ray tube measurement had to have a voltage of 40 kV and a current of 30 mA before XRD (X-Ray Diffraction) data were collected \[12, 21\]. The XRD (X-Ray Diffraction) test results are presented in the form of a spectrum that indicates the intensity (counts) in relation to the diffraction angle of 2\(\theta\) (\(^{\circ}\)).

Table 5. Relative corrosion resistance based on corrosion rate \[8\].

<table>
<thead>
<tr>
<th>Relative Corrosion Resistance</th>
<th>Approximate Metric Equivalent</th>
<th>pm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mpy</td>
<td>mm/year</td>
</tr>
<tr>
<td>Outstanding</td>
<td>(&lt; 1)</td>
<td>(&lt; 0.02)</td>
</tr>
<tr>
<td>Excellent</td>
<td>1–5</td>
<td>0.02–0.1</td>
</tr>
<tr>
<td>Good</td>
<td>5–20</td>
<td>0.1–0.5</td>
</tr>
<tr>
<td>Fair</td>
<td>20–50</td>
<td>0.5–1</td>
</tr>
<tr>
<td>Poor</td>
<td>50–200</td>
<td>1–5</td>
</tr>
<tr>
<td>Unacceptable</td>
<td>200+</td>
<td>5+</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Measurement results of potential value for specimens performed for 12 months with measurement time intervals every month. Measurement results for 12 months can be viewed in Figure 5. Morphological tests on the round bar show that the corrosion formed in cylindrical steel is (uniform corrosion). The corrosion products formed are dominated by black grains (pearlite) compared to white grains (ferrite) \[9,10\]. The granules are in the form of small granules that are in the form of lines and are connected to each other, so that their shape is like a blooming flower. Whereas in plate steel, the corrosion that forms on the surface structure is (pitting corrosion). The white grains (ferrite) and black grains (pearlite) are intertwined and are very small even though magnification up to 2000X has been carried out. If we observe the whole sample and compare it with the corroded sample, it is clear that the texture has changed to be very rough, due to a chemical reaction that forms white ferrite and black pearlite. Figure 6. Shown morphology test for specimens: a. Round bar, b. Plate.
The results of the corrosion rate analysis using the thickness value measurement results in 2021 and 2022 refer to the API 570 standard.

Wall Pipe
Corrosion Rate (CR) = (8.55 - 8.33)/1 = 0.22 mpy
Remaining Life = (8.33 - 1.134)/0.22 = 32 year

Generating Pipe
Corrosion Rate (CR) = (9.12 - 8.86)/1 = 0.26 mpy
Remaining Life = (9.12 - 1.414)/0.26 = 29 year

Heater Pipe
Corrosion Rate (CR) = (9.23 - 8.64)/1 = 0.59 mpy
Remaining Life = (8.64 - 1.696)/0.59 = 11 year

The results of the corrosion rate analysis show that the corrosion rate on the wall pipe is about 0.22 mpy, the corrosion rate for the generating pipe is around 0.26 mpy, and the highest corrosion rate is obtained in the heater pipe with a corrosion rate of 0.59 mpy.

The XRD result shows that there is a corrosion compound formed as a result of the reaction of iron oxide (Fe₂O₃) at an angle of 2θ = 37º for plate-type steel. For cylindrical-
type steel, the peaks that appear are not as conspicuous as the peaks that occur in plate steel. The XRD results of the round bar and plate can be seen in Figure 7.

![XRD results of the round bar and plate](image)

**Figure 7.** The XRD results of the round bar and plate

4. **CONCLUSION**

Morphological tests on the round bar show that the corrosion formed in cylindrical steel is (uniform corrosion). The corrosion products formed are dominated by black grains (pearlite) compared to white grains (ferrite). The granules are in the form of small granules that are in the form of lines and are connected to each other, so that their shape is like a blooming flower. Whereas in plate steel, the corrosion that forms on the surface structure is (pitting corrosion). The white grains (ferrite) and black grains (pearlite) are intertwined and are very small even though magnification up to 2000X has been carried out. If we observe the whole sample and compare it with the corroded sample, it is clear that the texture has changed to be very rough, due to a chemical reaction that forms white ferrite and black pearlite. Research results of the corrosion rate analysis show that the corrosion rate on the wall pipe is about 0.22 mpy, the corrosion rate for the generating pipe is around 0.26 mpy, and the highest corrosion rate is obtained in the heater pipe with a corrosion rate of 0.59 mpy. While for the calculation of the remaining life on each pipe, the remaining life of the pipe on the wall tube is about 32 years, the remaining life for the generating pipe is about 29 years, and the remaining life for the heater pipe is about 11 years. From the calculation results obtained the longest remaining life is obtained on the wall pipe while the shortest remaining life of the pipe is found in the heater pipe because the pipe is always heated.

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