RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING
e-ISSN: 2773-4765

RPMME

Vol. 7 No. 1 (2026) 272-281
https://publisher.uthm.edu.my/periodicals/index.php/rpmme

Analysis of Corrosion Using Natural Disperse in a Water Emulsion, Palm Oil Acts as a Corrosion Inhibitor

Satheisvaran Thiagaraju[1], Hanis Zakaria[1*], Anelka John Koshy[1]

[1] *Faculty of Mechanical and Manufacturing Engineering, Department of Mechanical Engineering, Universiti Tun Hussien Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

*Corresponding Author: hanisz@uthm.edu.my
DOI: https://doi.org/10.30880/rpmme.2026.07.01.029

Article Info

Received: 10 December 2025
Accepted: 9 March 2026
Available online: 28 February 2026

Keywords

corrosion inhibition, palm oil emulsion, potentiodynamic polarization, ASTM A516, mild steel, electrochemical techniques.

Abstract

This study investigates the use of palm oil-in-water emulsions as natural corrosion inhibitors for ASTM A516 mild steel in 1M HCl solution. Electrochemical techniques, specifically potentiodynamic polarization (PDP), were used to evaluate the efficacy of palm oil emulsions in varying ratios. A three-electrode system—with mild steel as the working electrode, platinum as the counter electrode, and Ag/AgCl as the reference electrode—was employed. Results demonstrated the potential of palm oil emulsions to significantly inhibit corrosion, reducing the corrosion rate by creating a protective film over the metal surface. The optimal emulsion ratio and conditions for maximum inhibition efficiency were determined. These findings contribute to the development of eco-friendly corrosion mitigation strategies.

1. Introduction

The research emphasizes the critical challenges posed by corrosion, focusing on its safety, environmental, and economic implications. Corrosion is defined as the process of material deterioration due to environmental exposure, affecting both metallic and non-metallic elements. Brahim (2021) describes it as a physiochemical process that degrades materials like metals, plastics, and paints due to electrochemical reactions. These reactions involve oxidation and reduction processes facilitated by an anode, cathode, and electrolyte containing charged ions, ultimately leading to material weakening and failure[1]. Corrosion is broadly categorized into external corrosion, caused by environmental factors such as high temperatures, excessive humidity, salinity, and acidity, and internal corrosion, which compromises the structural integrity of metals from within. Both types significantly reduce the efficiency and lifespan of equipment, presenting major concerns for industries reliant on these materials[1].

Industrially, corrosion imposes substantial economic challenges. NACE International's 2013 study estimated the global cost of corrosion at USD 2.5 trillion, equivalent to 3.4% of the world's GDP. Effective prevention methods could reduce these costs by 15-35%, translating to annual savings between USD 375 billion and USD 875 billion[2]. Addressing corrosion is critical for sectors like oil and gas, manufacturing, and construction, where materials prone to corrosion are indispensable yet expensive to replace. The study underscores the importance of developing cost-effective, environmentally friendly corrosion inhibitors for industrial sustainability and economic efficiency[3].

The study aims to analyze the effectiveness of palm oil-in-water emulsions as a natural corrosion inhibitor for ASTM A516 mild steel in 1M HCl solution using electrochemical methods, such as potentiodynamic polarization (PDP). It seeks to determine the relationship between polarization resistance, corrosion rate, and current density (icorri_{\text{corr}}) for varying emulsion ratios (94:6, 93:7, 92:8, 91:9, and 90:10) to evaluate inhibitory performance. Using a vacuum high-speed homogenizer at 40,000 rpm, palm oil and water are emulsified, and PDP techniques are employed to study the corrosion rate[2].

This study is significant for demonstrating how palm oil-in-water emulsions can serve as organic corrosion inhibitors during processes like wet abrasive blasting. Fatty amide molecules in the emulsion act as cathodic agents, reducing the anodic activity of iron and mitigating corrosion by limiting water presence on the metal surface. Additionally, organic inhibitors offer environmental benefits, aligning with sustainable practices while maintaining the effectiveness required to protect metals and alloys. The findings of this research could contribute to safer and more environmentally friendly industrial processes, particularly in sectors where metal corrosion is a persistent challenge.

Corrosion is a natural process that transforms metals into chemically stable states like oxides, hydroxides, or sulphides, leading to material deterioration through chemical and electrochemical reactions with the environment[4]. This phenomenon, impacting metals, ceramics, and polymers, results in reduced strength, appearance, and functionality. Metallic corrosion, in particular, has significant economic and structural implications and requires four essential components: anode, cathode, electrolyte, and metallic conductor. Removing any of these components can prevent corrosion, but practical applications often necessitate mitigation strategies[5]. Corrosion manifests as uniform corrosion, characterized by even material loss, or localized corrosion, such as pitting, which involves severe attack in confined areas. Uniform corrosion, typically modelled using Log-normal distribution, provides conservative estimates for strength loss, while localized corrosion requires complex modelling to address its irregular geometries and stress effects[6]. Corrosion monitoring techniques, classified into physical and electrochemical methods, are critical for understanding corrosion behaviours and developing mitigation strategies[7]. Specific examples of corrosion include copper, which reacts with oxygen and environmental elements to form greenish-blue malachite through multiple oxidation steps[8], and silver, which tarnishes through reactions with sulphur compounds, producing black silver sulphide[9]. Similarly, iron corrodes in the presence of water and air, undergoing electrochemical reactions that form iron hydroxide, as represented by anodic and cathodic reactions[10]. Effective corrosion inhibitors, such as palm oil-in-water emulsions used in wet abrasive blasting, mitigate these processes by forming protective barriers that reduce electrochemical activity at the metal surface[10]. These insights underscore the importance of corrosion management to preserve material integrity and reduce economic losses across industries.

Corrosion is a persistent issue in industries, especially oil and gas, where pipelines face corrosion risks throughout their lifecycle. Wet abrasive blasting, a common cleaning method, often exacerbates corrosion by stripping the passive oxide layer and exposing metal to moisture and air, leading to rust. Factors such as metallic ions, water impurities, dissolved oxygen, and drying time influence flash corrosion during this process[11].
The blasting process involves spraying abrasive grains carried by a liquid or gas medium under pressures of 0.2 to 1.2 MPa, with jet velocities of 200 to 800 m/s. Material removal typically ranges from 0.01 to 0.1 mm, and nozzle angles above 30° enhance surface strengthening[12]. To mitigate corrosion, inhibitors are used to form a protective barrier on the metal surface, reducing oxygen diffusion and water access. Organic inhibitors are favored for their efficiency, low toxicity, and environmental compatibility, providing a hydrophobic shield against degradation.

2. Methodology

The study utilized Potentiostat Metrohm Autolab analysis to assess the effectiveness of palm oil-in-water emulsions as corrosion inhibitors, employing the potentiodynamic polarization (PDP) technique to evaluate efficiency through electrochemical reactions involving stearic acid. A comprehensive process map was developed to ensure the research objectives were met, focusing on increased efficiency and achieving reliable results. The research framework was organized into three key aspects: the preparation of oil-in-water emulsions using palm oil as the primary inhibitor, monitoring the corrosion process to evaluate the emulsion's inhibitory performance, and analyzing the corrosion rate to quantify its effectiveness.

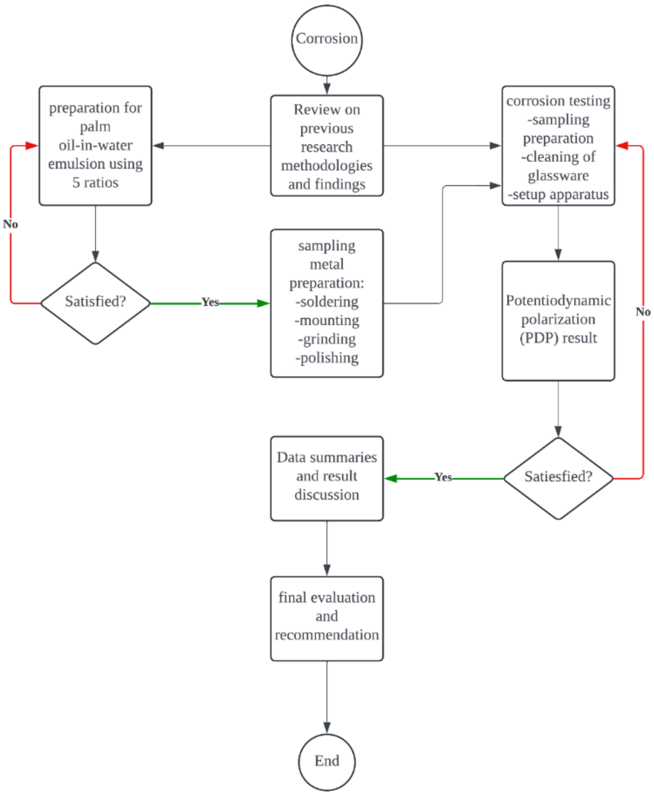

Figure 1 Full Process Flow for Corrosion Testing

2.1 Preparation Palm Oil-In-Water Emulsion Ratio

To produce the emulsions, the water volume ratio needed was calculated in advance in the beaker before the appropriate amount of oil was added. Following that, a 1000 mL solution of water and oil was emulsified in a vacuum high-speed blender for 9 minutes at predetermined rotating rates. The next subtopic provides more information on the technical specifications of the vacuum blender.

Table 1

Palm oil (%)	Water (%)
10	90
9	91
8	92
7	93
6	94

Details procedure to produce emulsion:

I. Vacuum for 1.10 minutes to remove all the air inside the solution.
II. Select fan mode to H and start the stirring process for 3 minutes.
III. Repeat the process for 9 minutes for each solution with vacuum in between stiring process.

A vacuum high-speed blender was used to mix oil and water according to the ratio, producing an oil-in-water emulsion through high-speed homogenization.

Table 2

Specificat ions	Descript ions
Power	1.3 kW
Blade speed	45000 rpm
Pressure	Vacuum pressure (0 bar)
Weight	8.5 kg
Jar total capacity	2.5 L

Figure 2 Vacuum High-Speed Blender

2.2 Sample Metal Selection

Metallic steel is the most often used metal in industrial manufacturing due to its advantageous properties such as cost, strong mechanical capability, and availability. A mild steel is a kind of carbon steel that is primarily made up of iron and carbon. The mechanical and chemical characteristics resulting from carbon's increase of the properties of pure iron are proportional to the amount of carbon present. They contain the lowest carbon content in mild steel products, ranging from 0.05 to 0.25%. As a result, this metal type is often known as low-carbon steel.

Table 3

Advantages	Description
Mechanical Properties	• High malleability due to being less brittle and less prone to fracture under pressure. • Higher tensile strength and impact resistance than carbon steels. • They are also magnetic due to their ferrite component.
Chemical properties	• Higher chromium content mild steel enhances corrosion resistance and toughness.
Weldable	• Mild steel can be welded quickly and easily.
Strength to weight ratio	• Carbon steel is one of the lightest metals. It boasts a remarkable strength-to- weight ratio despite its smaller weight.

	• It is a tough and long-lasting metal. Material that is easier to work with throughout the production process.
Ductile	a) It may deform and stretch without irreversibly deforming, even when subjected to quite strong forces. This characteristic makes them easier to shape, bend, and weld.
Cost	Mild steel is one of the most affordable steel grades. As a result, it is a low-cost production choice. It can be made fast and cheaply.

2.3 Material Preparation

ASTM A516 mild steel samples were cut using a CNC wire-cut machine, then ground and polished with 240–1200 grit sandpaper. The specimens were cleaned with acetone, air-dried, and mounted in epoxy resin. Finally, the samples were polished to expose a 10mm x 10mm area, with five samples prepared for testing.

Figure 3 Mild steel samples

Below are the technical parameters used in metal preparation

Table 4

Parameters	Description
Size	1 cm^3
Type of metal	ASTM A516 mild steel

2.4 Corrosion Testing (Electrochemical Techniques)

The electrochemical methods used were open circuit potential (OCP) values and potentiodynamic polarization (PDP) curves. A three-electrode glass cell with a platinum electrode as counter and a silver chloride (AgCl) electrode as reference electrodes. Metrohm Autolab Potentiostat instruments were used in all studies.

Table 5

Parameters	Description
Polarization curve range	-1100 mV to -200 mV
Scan rate	0.33 mV
Area of specimens exposed	1 cm^2
Volume of solution	150 mL
Duration to run test	200 seconds

Table 5 Setting parameters (retrieved from [13])

2.5 Potentiodynamic Polarization Measurement

Electrochemical measurements will be conducted using a Metrohm Autolab potentiostat with Nova 1.10 software to record Tafel polarization curves. A 250 ml three-neck flask will hold the reference electrode (Ag/AgCl), counter electrode (Pt), and working electrode (mild steel). The IE will be calculated using:

$$IE(\%) = \frac{[I_{corr} - I'_{corr}]}{I_{corr}} \times 100$$

Where, I_{corr} and I'_{corr} are current densities (A) of corrosion with and without the inhibitors, respectively.

3. Results And Discussions

This study examines palm oil emulsions as a green corrosion inhibitor for ASTM A516 mild steel in 1M HCl, using potentiodynamic polarization to assess corrosion rate, polarization resistance, and corrosion current density. Results are compared to previous work using palm oil leaf extract [14], highlighting the potential of natural inhibitors.

3.2 Corrosion Analysis

Corrosion rate analysis was conducted following the ASTM G31-72 standard using a Metrohm Autolab instrument, with results expressed in mm/year. Five ASTM A516 mild steel samples were used as working electrodes, immersed in a 1M HCl solution diluted with distilled water. Palm oil emulsion, serving as a green corrosion inhibitor, was added to the electrolyte in various ratios (94:6, 93:7, 92:8, 91:9, and 90:10). The experiments aimed to assess the impact of inhibitor concentration on corrosion behavior.

Polarization experiments showed that the polarization curves for all ratios shifted to the right compared to the control, indicating enhanced corrosion resistance. Among the tested ratios, the 94:6 emulsion, with the highest inhibitor concentration, demonstrated the lowest corrosion rate, characterized by a lower corrosion current density (Icorr) and higher polarization resistance (Rp). These findings confirm the efficiency of palm oil emulsion as a corrosion inhibitor and align with previously reported studies on palm oil-based inhibitors [15].

However, the 96:4 ratio exhibited an increased corrosion rate, potentially due to reduced emulsion stability during the experiment and inconsistencies in sample handling prior to testing. These results are detailed in Table 4.2, providing insights into the effectiveness of palm oil emulsions for corrosion prevention in mild steel exposed to acidic environments.

Table 6

Emulsion Sample	Water (%)
1	94%
2	93%
3	92%
4	91%
5	90%

Table 4.2. Samples

Table 7

Emulsion Ratio	icorr (A)	Corrosion Rate (mm/year)	Polarization Resistance (□)	□a (V/dec)	□c (V/dec)
94:6	0.0024939	28.929	10.647	0.11428	0.13147
93:7	0.0002251	2.6158	46.593	0.04943	0.04722
92:8	0.0002771	3.2199	72.91	0.06010	0.20579
91:9	0.0018302	1.2670	6.0721	0.04455	0.06011
90:10	4.5134E-5	0.5244	226.62	0.04416	0.05045

Table 5 Polarization experiments

3.3 Potentiodynamic Polarization (PDP) Studies

Metrohm Autolab software was used to evaluate all of the data. Figure. 4.1 shows the mild steel potentiodynamic polarization (PDP) curves at room temperature in a 1M HCl solution with a palm oil-in-water inhibitor. The shift in current densities in the cathodic ($2H^+(aq) + 2e^- \rightarrow H_2(g)$) and anodic ($2Fe(s) \rightarrow 2Fe^{2+}(aq) + 4e^-$) branches to lower values demonstrates how the palm oil-in-water emulsion mitigates corrosion. Furthermore, the corrosion potential (Ecorr) shifts somewhat in the direction of a more positive value, as seen in

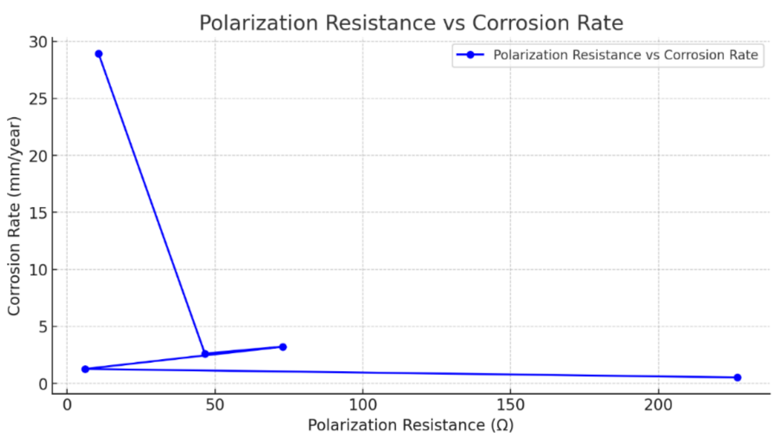

Figure 4 Polarization Resistance vs Corrosion Rate

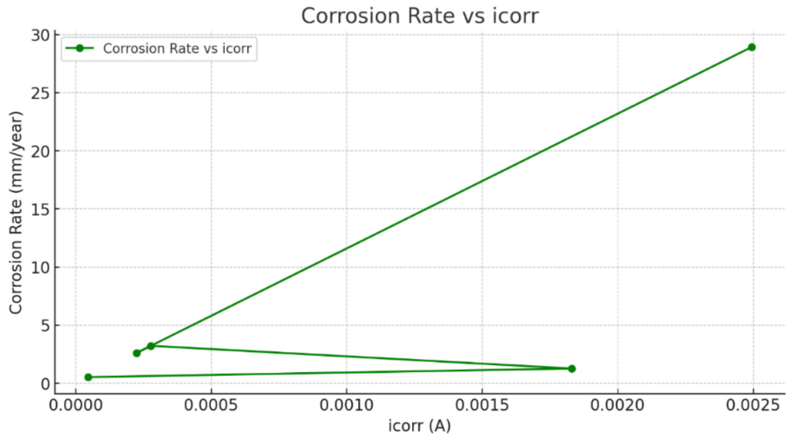

Figure 5 Corrosion Rate vs icorr

3.4 Discussion

3.4.1 Corrosion Rate and Inhibition Efficiency

Corrosion rates and inhibition efficiencies were evaluated to determine the performance of palm oil emulsions as corrosion inhibitors for mild steel. At a 94:6 water-to-oil emulsion ratio, the corrosion rate was measured at 28.929 mm/year, indicating a limited protective effect. In contrast, at a 90:10 ratio, the corrosion rate decreased significantly to 0.5244 mm/year, showcasing the superior performance of higher palm oil concentrations in reducing corrosion.This trend is consistent with findings from a referenced study on palm oil leaf extract, where a 25% extract concentration achieved an inhibition efficiency of 83.67% and a corresponding corrosion rate of 0.44 mm/year[14]. The results suggest that increasing the inhibitor concentration enhances the formation of a protective barrier on the metal surface, effectively reducing corrosion.The mechanism involves the adsorption of the inhibitor onto the metal surface, minimizing anodic metal dissolution and cathodic hydrogen evolution. This behavior aligns with observations in the literature, reinforcing the potential of palm-based emulsions as effective, eco-friendly corrosion inhibitors.

3.4.2 Corrosion Rate and Inhibition Efficiency

An inverse relationship was observed between polarization resistance (Rp) and corrosion rate, with higher Rp values indicating better corrosion resistance due to the formation of a protective barrier. For example, the 90:10 emulsion ratio displayed the highest Rp (226.62 Ω), resulting in the lowest corrosion rate (0.5244 mm/year), while the 94:6 ratio had a lower Rp (10.647 Ω) and a higher corrosion rate (28.929 mm/year). Similarly, a direct correlation was noted between corrosion current density (Icorr) and corrosion rate, where higher Icorr values indicated more active corrosion. The 94:6 ratio exhibited the highest Icorr (0.0024939 A) and the highest corrosion rate, whereas the 90:10 ratio had the lowest Icorr (4.5134E−5 A) and a significantly reduced corrosion rate. These findings align with the referenced study, where palm oil leaf extract reduced Icorr and improved corrosion inhibition efficiency.

3.5 Comparative Analysis with Reference Study and Recommendation for Future Work

The results of this study are consistent with previous research on palm oil leaf extract, as both studies demonstrate that higher concentrations of inhibitors enhance corrosion resistance by forming a protective barrier on the metal surface. This barrier prevents further interaction between the metal and corrosive substances, reducing corrosion rates. In the referenced study, Langmuir adsorption isotherm analysis was employed to characterize the inhibitor's behavior on metal surfaces, indicating a well-defined interaction between the inhibitor and the surface. Similarly, applying adsorption models such as Langmuir to palm oil emulsions could provide valuable insights into their adsorption characteristics on mild steel. To build upon these findings, it is recommended to investigate the influence of temperature and salinity on the corrosion inhibition efficiency of palm oil emulsions, as these factors could alter the performance of the inhibitor. Additionally, comparative studies using weight loss and electrochemical impedance spectroscopy (EIS) methods would offer deeper insights into the corrosion mechanisms and provide more comprehensive data on the effectiveness of the emulsions. Lastly, utilizing Langmuir adsorption isotherm modeling could enhance the understanding of how palm oil emulsions adsorb onto mild steel surfaces, shedding light on their potential as effective corrosion inhibitors.

4. Conclusion & Recommendations

The most natural process which shall not be wished to occur either in construction of industries or in oil and gas field is corrosion process since it has potential to danger everyone which increases operating cost of an organization. There are certain steps that can be taken in order to effectively reduce and minimize corrosion, corrosion inhibitors may be applied in a bid to reduce the corrosion procedure. From the research that have been carried out, palm oil emulsion can be used in place of blasting or painting process because it is an environmental friendly corrosion inhibitor. Based on the findings of this study, the interpretations include: Through electrochemical approach, potentiodynamic polarization (PDP), inhibition efficiency and corrosion rate increases with an increase in the inhibitor concentration. The findings achieved reveal the fact that palm oil-in-water emulsion possess the characteristics to avoid corrosion on the mild steel surface immersed in 1M HCL solution.

4.1.1 Finding the Best Proportion of The Emulsion

For future research, a number of concentrations of palm oil to water emulsion should be used in order to determine the highest concentration that yields the best corrosion inhibition. Since scientists are able to experiment with different emulsion ratios, they are able to identify that dilution that gives the least corrosion rate. To achieve this, extensive PDP and EIS investigations will be performed to link the emulsion ratio to the film formation and corrosion inhibitory effects.

4.1.2 Establishing Effective Storage and Stability Methods

Further research should focus on developing suitable storage techniques for palm oil-in-water emulsions. This includes investigating the long-term stability of the emulsion under varying conditions such as temperature fluctuations, exposure to light, humidity levels, and potential contamination. By subjecting the stored emulsion to these different scenarios, researchers can identify the conditions that may degrade its chemical stability or reduce its effectiveness as a corrosion inhibitor. Additionally, studies should examine methods to enhance emulsion stability, such as incorporating stabilizing agents or using optimized packaging materials to prolong its shelf life and maintain its efficacy.

By addressing these areas, future research can provide a deeper understanding of the practical applications and limitations of palm oil-in-water emulsions in industrial corrosion prevention.

Acknowledgement

This research was supported by Ministry of Higher Education (MOHE) through Fundamental Research Grant scheme (FRGS/1/2021/TK0/UTHM/03/31).

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Author X, Author Y;* ***data collection:*** *Author Y;* ***analysis and interpretation of results:*** *Author X, Author Y, Author Z;* ***draft manuscript preparation:*** *Author Y, Author Z. All authors reviewed the results and approved the final version of the manuscript.*

An author name can appear multiple times, and each author name must appear at least once. For single authors, use the following wording:

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

References

Journal

[1] X. Xu, S. Liu, K. Smith, Y. Cui, and Z. Wang, "An overview on corrosion of iron and steel components in reclaimed water supply systems and the mechanisms involved," *J Clean Prod*, vol. 276, 2020, doi: 10.1016/j.jclepro.2020.124079.

[2] G. Jacobson, "New ground in the study of corrosion management," *Mater Perform*, vol. 55, no. 4, pp. 28–32, 2016, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84963594564&partnerID=40&md5=f1e4277c1647a18a095b2b1b8b33db01

[3] M. Udhayakumar, N. Radhika, and A. K L, "A Comprehensive Review on Nanocrystalline Coatings: Properties, Challenges and Applications," *J Bio Tribocorros*, vol. 8, Sep. 2022, doi: 10.1007/s40735-022-00683-z.

[4] J. Cui, D. Wang, and N. Ma, "Case studies on the probabilistic characteristics of ultimate strength of stiffened panels with uniform and non-uniform localized corrosion subjected to uniaxial and biaxial thrust," *International Journal of Naval Architecture and Ocean Engineering*, vol. 11, no. 1, pp. 97–118, Jan. 2019, doi: 10.1016/j.ijnaoe.2018.02.011.

[5] J. Cui and D. Wang, "A study of container ship structures' ultimate strength under corrosion effects," *Ocean Engineering*, vol. 130, pp. 454–470, Jan. 2017, doi: 10.1016/j.oceaneng.2016.11.061.

[6] "Corrosion - Formation of Corrosion Cells — Steemit." Accessed: May 26, 2024. [Online]. Available: https://steemit.com/corrosion/@rahim.rahman/corrosion-formation-of-corrosion-cells

[7] T. Palomar, B. Ramirez Barat, and E. Cano, "Evaluation of Cleaning Treatments For Tarnished Silver: The Conservator´s Perspective," *International Journal of Conservation Science*, vol. 9, pp. 81–90, Mar. 2018.

[8] "Corrosion." Accessed: Jun. 07, 2024. [Online]. Available: https://2012books.lardbucket.org/books/principles-of-general-chemistry-v1.0/s23-06-corrosion.html

[9] "Online Corrosion course." Accessed: Jun. 07, 2024. [Online]. Available: https://corrosion-doctors.org/Principles/Course.htm

[10] U. O, I. Mbabuike, B. Oreko, and E. D.T., "Corrosion Rates and its Impact on Mild Steel in Some Selected Environments," *The Journal of Scientific and Engineering Research*, vol. 3, pp. 34–43, Jan. 2016.

[11] O. Ali, *Corrosion is a natural process that converts a refined metal into a more chemically-stable form such as oxide, hydroxide, or sulfide.* 2020.

[12] E. Mattsson, "Basic Corrosion Technology: for Scientists and Engineers, Second Edition," *Basic Corrosion Technology: for Scientists and Engineers, Second Edition*, pp. 1–204, Jan. 2023, doi: 10.1201/9781003421443/BASIC-CORROSION-TECHNOLOGY-SCIENTISTS-ENGINEERS-EINAR-MATTSSON.

[13] A. Kushairi *et al.*, "Oil palm economic performance in Malaysia and r&d progress in 2018," *J Oil Palm Res*, vol. 31, no. 2, pp. 165–194, 2019, doi: 10.21894/JOPR.2019.0026.

[14] N. I. H. Salleh and A. Abdullah, "Corrosion inhibition of carbon steel using palm oil leaves extract," *Indonesian Journal of Chemistry*, vol. 19, no. 3, pp. 747–752, 2019, doi: 10.22146/ijc.39707.

[15] "Die Casting: Processes, Materials, Applications, Costs | RapidDirect Blog." Accessed: Jun. 26, 2024. [Online]. Available: https://www.rapiddirect.com/blog/what-is-die-casting/