

Analysis of Corrosion Resistance and Hardness of Iron Based on Paint Layer Variations on Car Chassis

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ABSTRACT – Iron materials are widely used in engineering applications, especially in the automotive industry. However, iron is highly susceptible to corrosion when exposed to aggressive environments. Surface coating using paint is a common and practical method to improve corrosion resistance. Nevertheless, the effectiveness of the number of paint layers on corrosion resistance, changes in material thickness, and hardness characteristics in the context of learning practicums still needs to be evaluated systematically. This study aims to analyze the effect of the number of paint layers on iron materials through an experimental approach based on practical work. Four iron specimens were used, consisting of one uncoated sample as a control and three samples with one, two, and three layers of paint applied to one surface. The thickness of the material was measured using calipers and an ultrasonic thickness gauge. Corrosion testing was carried out by immersing the samples in an HCl solution for 24 hours, followed by measuring the change in mass and calculating the corrosion rate. Hardness testing was only carried out on uncoated samples using a portable Leeb hardness tester. The research data was obtained from three practical groups and analyzed comparatively. The results showed that an increase in the number of paint layers caused an increase in the thickness of the iron material. Corrosion testing showed that uncoated samples had the highest corrosion rate, while painted samples experienced a decrease in corrosion rate as the number of layers increased. In addition, an inverse relationship between material thickness and corrosion rate was identified. Hardness test results on uncoated samples showed relatively uniform values, indicating the initial mechanical properties of the material were homogeneous. Consistent results were obtained in all three practical groups despite numerical variations. It can be concluded that the number of paint layers affects the thickness of the material and the corrosion resistance of iron in the context of practical work. Painting has been proven to be effective in reducing the rate of corrosion, with the level of protection increasing as the number of layers increases. The consistency of results between groups shows that the testing method used is suitable for comparative analysis in the Technical Materials Workshop practical activities

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1.0 INTRODUCTION

Corrosion is one of the main problems in metal materials, especially in iron materials that are widely used in the automotive industry. The corrosion process can cause a decrease in mechanical properties, a reduction in material thickness, and component failure if not properly controlled. Based on a review journal by Prakash et al. (2024), corrosion can cause material loss due to chemical and electrochemical reactions between metals and the environment [1]. In automotive components, corrosion not only affects strength and safety, but also affects the service life and aesthetic quality of the product. Furthermore, according to Ellianto et al. (2020), the chassis is the main part of a vehicle that supports all the components in the vehicle [2]. Therefore, corrosion protection efforts are an important aspect in the design and maintenance of automotive materials.

One commonly used protection method to reduce the rate of corrosion is surface coating using paint. The paint layer acts as a physical barrier that limits direct contact between the metal material and the corrosive environment, such as water, oxygen, and electrolyte solutions. According to Lubis et al. (2025), the effectiveness of paint coating is greatly influenced by several factors, including the number of layers, layer thickness, and the quality of adhesion between the coating and the substrate [3]. Adding more layers of paint can theoretically increase the thickness and durability of the coating, but it is necessary to examine the extent to which this increase provides significant protection against the rate of corrosion. This is supported by research by Ashwijuwan et al. (2024), which states that the thicker the paint layer on galvanized steel, the better the corrosion resistance during immersion testing in acidic and alkaline solutions [4].

In addition to corrosion resistance, the mechanical characteristics of the base material, particularly hardness, also play an important role in determining the performance of the material during use. Hardness testing on uncoated iron materials is necessary to ensure that the differences in corrosion rates are not caused by variations in the initial mechanical properties of the material, but are purely due to the effects of the coating treatment. Thus, hardness analysis is an important supporting parameter in the evaluation of coating systems.

Experimental corrosion testing is often conducted using immersion in acid solutions to simulate aggressive environments. Hydrochloric acid (HCl) solutions are widely used because they accelerate corrosion reactions, allowing differences in corrosion resistance between specimens to be observed in a relatively short time. This is supported by research by Septianingsih et al. (2014), which shows that HCl contains Cl^- ions that are very aggressive, so that when metal is combined with this strong acid, the metal will corrode and rust [5]. Variations in the concentration of the corrosive solution also provide an overview of the response of the material and paint coating to different levels of environmental aggressiveness.

Based on this background, this study aims to evaluate the effect of the number of paint layers on the corrosion resistance of iron materials, analyze changes in thickness due to coating, and examine the hardness value of uncoated materials as a basis for comparison. This study also presents a comparison of test results from several practicum groups to assess the consistency and reproducibility of experimental data in the context of learning in the 2025B Automotive Engineering Technology D4 Program Technical Materials Workshop.

1.1 Literature Review

Iron is one of the most widely used metals in engineering applications, particularly in the automotive industry, because it has good mechanical strength, is easy to shape, and has a relatively low production cost. However, iron has a major drawback in that it is highly susceptible to corrosion, especially when exposed to environments containing water, oxygen, and electrolytes. According to Utomo et al. (2015), corrosion in iron generally occurs through an electrochemical mechanism that causes the formation of corrosion products in the form of iron oxide, which leads to a reduction in the thickness and structural integrity of the material [6].

Based on a review journal by Afandi et al. (2015), surface coating using paint is a widely used protection method to control the rate of corrosion in iron materials [7]. The paint coating acts as a barrier coating that inhibits the diffusion of corrosive substances to the metal surface. Several studies have shown that increasing the number of paint layers can increase the thickness of the protective layer and extend the diffusion path of corrosive ions, thereby reducing the corrosion rate of the material. However, the effectiveness of protection is not only determined by the thickness of the layer, but also by the uniformity of the coating and the quality of adhesion between the paint layer and the metal substrate.

Paint layer thickness is an important parameter in evaluating coating systems because it is directly related to the layer's ability to withstand penetration by a corrosive environment. Non-destructive layer thickness measurements are generally performed using an ultrasonic thickness gauge, which is capable of providing accurate measurement results on coated materials. A coating that is too thin has the potential to fail, while a coating that is too thick can cause residual stress and peeling [8].

In addition to surface protection aspects, the mechanical properties of the base material, particularly hardness, also affect the performance of the material during use. The Leeb hardness test is a *non-destructive testing* (NDT) method used to evaluate the characteristics of a material and quickly determine the hardness of a metal material [9]. Relatively uniform hardness values indicate material structural homogeneity, so that variations in the corrosion rate can be directly attributed to the coating treatment, rather than differences in the initial mechanical properties of the material.

Corrosion testing using immersion in acidic solutions, such as hydrochloric acid (HCl), is often used to simulate aggressive environmental conditions. This method allows for the evaluation of corrosion rates based on mass changes

and the calculation of corrosion rates in units of mm/year or mils per year (MPY). Previous studies have shown that an increase in environmental acidity accelerates the corrosion process, but the application of a multi-layer coating system can significantly reduce the rate of material degradation[10].

2.0 MATERIAL AND METHODS

2.1 Material

The material used in this study was square iron specimens with nominal dimensions of 4 cm × 4 cm and an initial thickness of approximately 3.7 mm. The specimens were made from the same material and were assumed to have uniform mechanical properties. There were a total of four specimens for each group of experiments, which were differentiated based on the number of paint layers applied to one side of the surface.

The specimens were divided as follows:

- Sample 1: without paint coating (used as a control sample),
- Sample 2: coated with one layer of paint,
- Sample 3: coated with two layers of paint,
- Sample 4: coated with three layers of paint.

The corrosive solution used in the corrosion test is a mixture of mineral water and hydrochloric acid (HCl) solution. Each test cup contains 183 ml of mineral water and 17 ml of HCl solution, bringing the total volume of solution per cup to 200 ml. This solution was chosen to create a corrosive environment that could accelerate the corrosion reaction within a relatively short testing period.

2.2 Equipment and Function

1. Tools and Materials Coating samples before testing:
 - **Metal Sample/Plate 4 x 4:** As a sample for observation and testing experiments.
 - **Vernier Caliper:** Used to manually measure the thickness of uncoated and coated samples.
 - **Sandpaper:** Used to smooth the surface of the sample to be used.
 - **Marker:** Used to mark samples.
2. Hardness Testing Tools and Materials:
 - **4 x 4 Metal Sample/Plate:** Used as a test sample with a smooth, clean surface, free from rust or paint coatings to ensure maximum hardness test results.
 - **High Precision Hardness Tester Type Leeb:** Used to read the surface hardness value of the material digitally using the reflection method from the impact device type D.
 - **Impact Device Type D and Connecting Cable:** Used to drop a small ball that impacts the sample and sends the reflection signal to the *High Precision Hardness Tester Type Leeb*.
 - **Calibration Block:** Used before testing to check and ensure that the device's readings are still accurate.
 - **Table:** Used to place or support the device and metal plate to be tested so that it does not shift or vibrate during testing.
3. Thickness Testing Tools and Materials:
 - **4 x 4 Metal Samples/Plates** (which have been painted with one, two, and three coats): Ensure that the samples are free of dust, oil, and dirt, and clean the samples using a soft cloth.
 - **Ultrasonic Thickness Gauge:** Used to measure non-destructive thickness using ultrasonic waves.
 - **Couplant** (liquid/ultrasonic gel): Used to coat the surface of the object so that ultrasonic waves can propagate well from the probe to the material.
4. Corrosion Testing Tools and Materials
 - **Plastic Beaker:** Used for prepared corrosive solutions.
 - **Raffia rope:** Used to tie samples that have been tied using raffia rope.
 - **Scissors:** Used to cut raffia rope.
 - **Cloth/Rag:** Used to clean up spilled solution.
 - **Plastic bag:** Used to cover the top surface of the glass before leaving it for 24 hours.
 - **Rubber band:** Used to secure the top surface of the glass after it has been covered with a plastic bag.
 - **Digital Milligram Scale:** Used to measure the mass of the sample before and after soaking for 24 hours.

- **Uncoated and Coated 4 x 4 Metal Plates:** Used as test samples to observe the effect of acidic, basic, or water solutions on the color coating on the surface and the metal itself.
- **Mineral Water:** Used as a mixture for the HCl solution.
- **HCL solution:** Used for corrosive materials on samples where changes in mass, color, or damage to metal or paint coatings can be observed after 24 hours of immersion.
- **Baking Soda (NaCO₃):** Used to neutralize the HCL solution before disposal.

2.3 Initial Measurement and Surface Preparation

Before any treatment is carried out, all specimens are first weighed using digital scales to obtain their initial mass. Next, the initial thickness of each specimen is measured using calipers at several points to ensure the uniformity of the initial dimensions of the material.

After initial measurement, one side of each specimen's surface is sanded. The sanding process is performed on one side only with the aim of:

1. Remove the oxide layer or surface dirt,
2. Uniform the surface condition before the paint coating process,
3. Improve the adhesion of the paint to the material surface.

After the sanding process is complete, the specimens are weighed and measured again to determine the changes in mass and dimensions resulting from surface preparation. This data is used as a comparison to ensure that the changes that occur in the next stage are due to the coating and testing processes, not the initial condition of the specimens.

2.4 Coating Application Procedure

The coating process was carried out on only one side of the sanded specimen surface. The first sample was not coated and was used as a control. The second sample was given one coat of red paint. The third sample was given two coats of paint in a combination of red and blue, while the fourth sample was given three coats of paint in a combination of red, blue, and yellow.



Figure 1. Coating and Drying Process

Each coat of paint was applied gradually and allowed to dry before the next coat was applied. The use of different paint colors was intended to facilitate the identification of the number of coats on each specimen. After the coating process was complete, the specimens were weighed again and their thickness was measured to determine the effect of the number of coats on the mass and thickness of the material.

2.5 Hardness Test Method

Hardness testing was conducted using a portable Leeb hardness tester. This test was only performed on samples without paint coating, which served as control samples. The test was conducted on one side of the specimen surface at three different test points, namely in the center, upper right, and lower left of the specimen surface.



Figure 2. Hardness Testing Device

The selection of several test points aims to determine the uniformity of the material's mechanical properties. The hardness values obtained are used as initial characteristic data for iron materials and are not used as parameters for comparison between specimens that have been coated with paint.

2.6 Thickness Measurement Method

Specimen thickness was measured using two methods, namely a caliper and an ultrasonic thickness gauge. The caliper was used to measure the thickness of the specimens before and after sanding, while the ultrasonic thickness gauge was used to measure the thickness of the specimens after the paint coating process.



Figure 3. Thickness Testing Process

The use of an ultrasonic thickness gauge allows for non-destructive thickness measurement and provides results that are more representative of the total thickness of the material after coating.

2.7 Corrosion Testing Method

Corrosion testing was carried out using the static immersion method with HCl solution. Each specimen was hung using raffia string tied to a stick so that the specimen did not touch the bottom of the glass and its entire surface was immersed in the solution.



Figure 4. Corrosion Test Samples/Plates

The top of the glass is covered with plastic and sealed with tape to minimize the entry of air from the outside environment. The immersion process is carried out for 24 hours at room temperature. During immersion, visual observations are made of bubble formation and the condition of the specimen surface.

The solution measurements for each group are as follows:

GROUP	CONCENTRATION	HCl 37%	CLEAN WATER
GROUP 5	0.5 M	8 mL	192 mL
GROUP 7	1.0 M	17 mL	183 mL
GROUP 9	1.5 M	25 mL	200 mL

After the immersion time is complete, the specimens are removed from the solution, cleaned, dried, and weighed again to obtain the final mass.

2.8 Corrosion Rate Calculation

The corrosion rate is calculated using the mass loss method based on the change in mass before and after immersion. The parameters used in the calculation include the initial mass, final mass, surface area of the specimen exposed to the solution, immersion time, and the density of iron material of 7.86 g/cm^3 .

The corrosion rate is calculated in units of mm/year and MPY (mils per year) for analysis and comparison between variations in the number of paint layers.

The formula for calculating the corrosion rate is as follows:

1. Formula 1: Corrosion Rate in mm/year

$$CR \left(\frac{\text{mm}}{\text{year}} \right) = \frac{K \times \Delta m}{A \times t \times \rho}$$

2. Formula 2: Corrosion Rate in MPY (Mils Per Year)

$$CR (\text{MPY}) = \frac{534 \times \Delta m}{A \times t \times \rho}$$

Explanation:

- CR = Corrosion Rate
- K = 8.76×10^4 (conversion constant)
- $\Delta m = m_1 - m_2$ (grams) = mass lost
- A = exposed surface area (cm^2)
- t = immersion time (hours)

- $\rho = 7.86 \text{ g/cm}^3$ (density of iron)
- 534 = constant for converting weight loss (mg) to material depletion rate in miles per year (MPY)

3.0 RESULTS AND DISCUSSION

3.1 Result

3.1.1 Effect of the Number of Coating Layers on Material Thickness

The results of material thickness measurements show that adding more coating layers increases the thickness of the iron material. The uncoated sample had the lowest thickness compared to samples with one, two, and three coating layers. The increase in thickness occurred gradually as the number of layers applied increased, in the context of the Engineering Materials Workshop practicum.

Table 1. Measurement Data for Each Group

SAMPLE	LAYER	GROUP 5	GROUP 7	GROUP 9
1	0	3.80	3.50	3.85
2	1	3.87	3.90	3.94
3	2	3.92	3.94	3.95
4	3	3.97	4.75	3.99

Based on the measurement results using an ultrasonic thickness gauge, samples with one coat of paint showed an increase in thickness compared to uncoated samples. Samples with two and three coats of paint showed a more significant increase in thickness. This pattern of thickness increase was observed consistently in all three groups of experiments, despite variations in absolute values due to technical differences during the coating and measurement processes.

The differences in initial thickness between uncoated samples indicate manufacturing tolerances in the specimens, but these variations did not affect the main trend of the analysis. The highest thickness value in the sample with three coats of paint in Group 7 was likely influenced by the greater thickness of the paint application and the sensitivity of the ultrasonic measurement method to protective coatings.

3.1.2 Mass Loss After Corrosion Testing

Corrosion testing using the immersion method in HCl solution for 24 hours caused mass changes in all test samples. Samples without paint coating experienced the greatest mass change, while painted samples showed smaller mass changes.

Table 2. Mass Loss Data Due to Corrosion Testing in Each Group

SAMPLE	GROUP 5	GROUP 7	GROUP 9	Δm AVERAGE
1	0,36	0,25	0,49	0,36
2	0,29	0,08	0,16	0,17
3	0,22	0,03	0,33	0,19
4	0,30	-0,1	0,19	0,13

The test results show that adding more layers of paint tends to reduce mass change due to corrosion. This trend is consistent across all three groups, indicating that paint layers play a role in reducing the intensity of material degradation during immersion.

However, in certain samples, very small mass changes were found, even negative values. The observed negative Δm values indicate the presence of corrosion products or solution residues on the surface of the specimens, so the data is still presented as an experimental phenomenon in the context of corrosion testing practicums.

3.1.3 Corrosion Rate of Iron Materials

The corrosion rate of iron materials was calculated based on the mass loss method and expressed in units of mm/year and MPY. The calculation results showed that uncoated samples had the highest corrosion rate, while samples with paint coatings showed a significant decrease in corrosion rate.

Table 3. Appendix of Corrosion Test Results in Group 5

SAMPLE	COATING	MM/YEAR	(MPY)	DESCRIPTION
1	0	10,45	0,064	Highest corrosion
2	1	8,42	0,051	Moderate corrosion
3	2	6,39	0,039	Relatively low corrosion
4	3	8,71	0,053	Moderate corrosion

Table 4. Appendix of Corrosion Test Results in Group 7

SAMPLE	COATING	MM/YEAR	(MPY)	DESCRIPTION
1	0	7,25	0,044	Highest corrosion
2	1	2,32	0,014	Moderate corrosion
3	2	0,87	0,005	Low corrosion
4	3	-2,90	0,017	Mass increase/ indication of protective layer formation

Table 5. Appendix of Corrosion Test Results in Group 9

SAMPLE	COATING	MM/YEAR	(MPY)	DESCRIPTION
1	0	14,22	0,086	Highest corrosion
2	1	4,64	0,028	Moderate corrosion
3	2	9,57	0,058	High corrosion
4	3	5,51	0,033	Moderate to high corrosion

Table 6. Average Corrosion Test Results for Each Group

SAMPLE	COATING	CR (MM/YEAR)	CR (MPY)
1	0	10,64	0,0646
2	1	5,12	0,031
3	2	5,61	0,034
4	3	3,77	0,0343

Samples with one coat of paint had a lower corrosion rate than samples without coating. Samples with two and three coats of paint showed a further decrease in corrosion rate. This pattern was observed consistently across all groups in the

practicum, indicating that the number of coats of paint affects the corrosion resistance of iron materials, in the context of the 2025B Automotive Engineering Technology D4 in subject Engineering Material Workshop practicum.

3.1.4 Relationship Between Thickness and Corrosion Rate

Analysis of the relationship between material thickness and corrosion rate shows an inverse relationship. Samples with greater material thickness tend to have a lower corrosion rate. This relationship is evident when thickness data is compared with the average calculated corrosion rate values.

Table 7. Relationship Between Material Thickness and Corrosion Rate (mm/Year)

SAMPLE	COATING	THICKNESS	CR
1	0	3,71	10,64
2	1	3,90	5,12
3	2	3,93	5,61
4	3	4,23	3,77

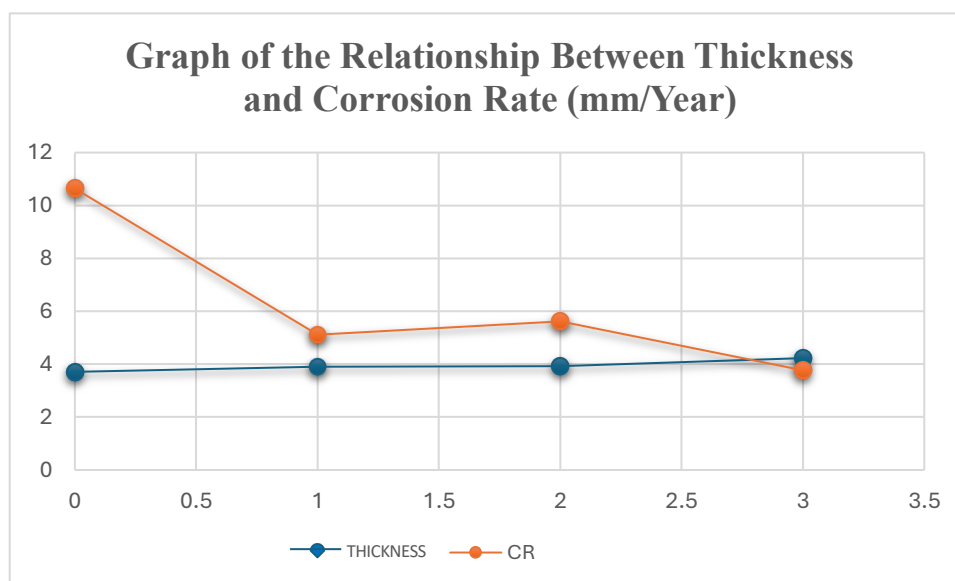


Figure 4. Graph of the Relationship Between Thickness and Corrosion Rate

These results indicate that the increase in thickness due to paint coating tends to contribute to an increase in the material's resistance to corrosion, in the context of a practical experiment with varying numbers of paint layers.

3.1.5 Hardness Test Results for Uncoated Steel Samples

Hardness testing was performed on uncoated samples as control samples. Testing was performed at three different points on one side of the specimen using a portable Leeb hardness tester. The test results showed that the hardness values of the material were relatively uniform with little variation between test points.

Table 8. Hardness Test Results on Uncoated Samples

TEST POINT	HARDNESS (HV)
CENTER	226

UPPER RIGHT	220
LOWER LEFT	220
AVERAGE	222

The uniformity of these hardness values indicates that the iron material has homogeneous initial mechanical properties before being coated with paint. These hardness data are used as the initial characteristics of the material and are not used as a parameter for comparison between painted samples.

3.2 *DISCUSSION*

3.2.1 *Effect of Coating Layers on Material Thickness*

The increase in material thickness with the number of paint layers is due to the accumulation of protective layers adhering to the material surface. In the manual painting process, each coat of paint gradually adds to the thickness of the material, so that samples with more layers have greater thickness.

Variations in thickness between groups can be attributed to differences in paint application techniques, drying time between layers, and operator skills during the coating process, in the context of a laboratory-scale experiment.

3.2.2 *Effect of Coating on Corrosion Resistance*

The paint layer acts as a physical barrier between the iron material and the corrosive environment. With the paint layer, direct contact between the HCl solution and the metal surface is limited, thereby reducing the rate of electrochemical reactions that cause corrosion.

The more layers of paint applied, the greater the resistance to the diffusion of aggressive ions toward the metal surface. This explains the observed decrease in corrosion rate in samples with two and three layers of paint in the context of corrosion testing experiments.

3.2.3 *Relationship Between Thickness and Corrosion Rate*

The inverse relationship between material thickness and corrosion rate shows that layer thickness plays an important role in increasing corrosion resistance. Thicker layers require more time for corrosive solutions to penetrate to the metal surface, so the material degradation process takes place more slowly.

These results are in line with the concept of surface protection through coating, where coating thickness tends to increase the effectiveness of protection against aggressive environments.

3.2.4 *The Role of Uncoated Samples as Controls*

Uncoated samples were used as controls to ensure that the observed differences in corrosion rates were due to the influence of the coating, rather than differences in the initial properties of the material. The relatively uniform hardness test results indicate that the iron material has homogeneous initial mechanical properties.

Thus, the differences in corrosion resistance between samples can be directly attributed to the amount of paint coating applied, in the context of the Engineering Materials Workshop practicum.

3.2.5 *Consistency of Results Between Practicum Groups*

The similarity in testing results obtained from the three practicum groups shows that the testing method used has an adequate level of repeatability. Although there are numerical variations between groups, the general pattern of increased thickness and decreased corrosion rate is maintained.

The test results show consistency in trends between groups, in the context of the Engineering Materials Workshop conducted by three different groups, so that the data obtained is suitable for use in workshop-based comparative analysis.

4.0 CONCLUSION

Based on the test results and analysis conducted, it can be concluded that the number of paint layers has an effect on the thickness of the iron material. Adding more paint layers causes a gradual increase in material thickness, as observed in all test samples in the context of the Engineering Materials Workshop practicum.

Corrosion testing showed that uncoated samples experienced the highest corrosion rate compared to coated samples. Coating was able to reduce the corrosion rate of iron materials, with a greater reduction tendency as the number of coats increased. This indicates that coating acts as protection against the corrosive environment under the test conditions used.

Analysis of the relationship between material thickness and corrosion rate shows an inverse relationship, where samples with greater thickness tend to have lower corrosion rates. The increase in thickness due to paint coating contributes to the increased corrosion resistance of iron materials in a laboratory-based practicum context.

The hardness test results on samples without paint coating showed relatively uniform hardness values at several test points. This uniformity indicates that iron materials have homogeneous initial mechanical properties, so that samples without coating can be used as representative controls in evaluating the effect of paint coating on corrosion resistance.

5.0 AUTHORS CONTRIBUTION

Anindya Keisha Abimanyu Anggoro Kasih (Conceptualization; Methodology; Formal analysis; Writing - original draft)

Ahmad Rafie Mirza Azzamahsyari (Methodology; Software; Validation; Investigation; Writing - review & editing)

Maulidiah Camelia Insani (Data curation; Formal analysis; Visualization; Writing - review & editing)

Susi Tri Umaroh (Resources; Project administration; Supervision; Funding acquisition)

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7.0 REFERENCES

- [1] S. S. Prakash, M. K. Srinath, S. Praveen, M. Y. Narayanan, R. Bharath, and T. Ahmed, "A Review on Corrosion Resistant Materials and Coatings," *Mech. Eng. Dep.*, p. 6, 2024, [Online]. Available: https://www.researchgate.net/publication/381639352_Prakash_et_al_2024
- [2] M. Sariski, D. Ellianto, and Y. E. Nurcahyo, "Rancang Bangun dan Simulasi Pembebanan Statik pada Sasis Mobil Hemat Energi Kategori Prototype," vol. 4, no. 2, pp. 53–58, 2020.
- [3] K. Dan, D. Rekat, S. N. Lubis, U. Budiarto, and P. Manik, "Jurnal teknik perkapalan," vol. 13, no. 4, pp. 1–14, 2025.
- [4] H. A. Ashwijuwan and Y. Winardi, "Efek Ketebalan Terhadap Ketahanan Korosi Lapisan Cat Pada Baja Galvanis" *J. Progr. Stud. Tek. Mesin UM Metro*, vol. 13, no. 01, pp. 120–124, 2024, [Online]. Available: <http://ojs.ummetro.ac.id/index.php/turbo%0AEfek>
- [5] I. K. Kromat, D. Septianingsih, and E. G. Suka, "Pengaruh Variasi Konsentrasi Asam Klorida Terhadap Laju Korosi Baja Karbon Rendah Astm A 139 Tanpa Dan Dengan," vol. 02, no. 02, pp. 147–155, 2014.
- [6] S. Utomo, J. T. Kimia, F. Teknik, and U. M. Jakarta, "PENGARUH KONSENTRASI LARUTAN NaNO 2 SEBAGAI INHIBITOR," vol. 7, no. 2, 2015.
- [7] Y. K. Afandi, I. S. Arief, J. Teknik, S. Perkapalan, and F. T. Kelautan, "Analisa Laju Korosi pada Pelat Baja Karbon dengan

Variasi Ketebalan Coating,” vol. 4, no. 1, pp. 1–5, 2015.

- [8] “Studi Eksperimen Pengaruh Tebal Cat dan Kekasaran pada Pelat Baja Karbon Rendah Terhadap Kerekatan Cat dan Biaya Proses,” vol. 5, no. 2, 2016.
- [9] U. Non, D. Mutu, B. Dengan, A. Rebound, L. Hardness, and M. R. Rizaldimasfa, “INTISARI Dalam lingkup keteknikan dan industri,” pp. 0–1, 2024.
- [10] D. Prayoga and A. A. Rosidah, “Analisis Pengaruh Jenis Cat dan Jumlah Pelapisan Spray Coating Baja Karbon Rendah ASTM A36 Terhadap Kekasaran dan Laju Korosi pada Media NaCl 5 %,” no. Senastitan V, 2025.