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Effectiveness Analysis of An Acid-Based Commercial Cleaner (Harpic) and A Corrosion Inhibitor (Wd-40) on A Motorcycle Fuel Tank

Aminuddin[1], Safira Maasya[2*], Tri Tunggal[3], Muhammad Alfarizhi[4], Fardin Hasibuan[5]
amintribun@gmail.com , safiramaaya@gmail.com, tritunggal@gmail.com, alfharizhi@gmail.com, fardinhasibuan12345@gmail.com

[1,2,3,4,5)]*Mechanical Engineering, Universitas Riau Kepulauan, Indonesia*

*Corresponding author: safiramaaya@gmail.com

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ABSTRACT
Corrosion in steel fuel tanks is a common problem that can impair engine performance. This study aims to evaluate the effectiveness of a low-cost restoration method on a severely corroded motorcycle tank. The methodology employed was a case study with a sequential application: a 72-hour immersion in a hydrochloric acid-based cleaner (Harpic) to dissolve iron oxides, followed by the application of a water-displacing corrosion inhibitor (WD-40) as a temporary protectant. Effectiveness was evaluated through comparative visual inspection at each stage of the process. The observational results show that this method successfully removed the majority of corrosion products (rust) and restored the base metal surface. The application of the corrosion inhibitor proved effective in preventing the occurrence of flash rust over a one-week observation period. With a total cost of approximately $9.50 USD, this method offers 90%+ cost savings compared to tank replacement. It is concluded that this combination of commercial products offers a functional and affordable solution for short-term restoration and protection, with the key caveats that the evaluation is qualitative and the protection is not permanent.

KEY WORDS: *Corrosion, Fuel Tank, Harpic, WD-40, Corrosion Inhibitor, Carbon Steel*

NOMENCLATURE

Fe	Iron
Ra	Arithmetic Mean Roughness
HCl	Hydrochloric Acid

1.0 INTRODUCTION
Corrosion, defined as the degradation of metals through chemical interactions with their surrounding environment, is a leading cause of performance deterioration in steel-based automotive components. Among these, the motorcycle fuel tank is particularly susceptible to internal corrosion, primarily driven by moisture condensation and contaminants present in fuel. This degradation frequently results in the formation of hydrated iron oxide ($Fe_2O_3 \cdot nH_2O$) particles, which pose significant risks by obstructing fuel lines and filters—potentially culminating in engine failure.

While tank replacement or professional restoration services offer definitive remediation, the financial burden—ranging from approximately $50–100 USD for restoration services and $50–150 USD for replacement—can be prohibitive, especially in developing regions. Consequently, do-it-yourself (DIY) restoration approaches have gained popularity due to their affordability and accessibility. These methods typically employ commercially available products: an acid-based cleaner to dissolve rust deposits, followed by a corrosion inhibitor to preserve the freshly exposed metal surface. However, the effectiveness of these solutions is often supported by anecdotal claims rather than empirical, systematic evaluations.

This study aims to provide a systematic assessment of a widely referenced DIY restoration approach. Specifically, it evaluates the rust removal efficacy of a commercial hydrochloric acid-based cleaner (Harpic Power Plus) and the short-term corrosion inhibition performance of a water-displacing lubricant (WD-40). The subject of the investigation is a severely corroded motorcycle fuel tank, and the analysis emphasizes visual inspection to establish an evidence-based perspective on the practical viability and limitations of this low-cost method.

1.1 Mechanism of Steel Corrosion
Steel corrosion proceeds through a well-defined electrochemical mechanism, involving simultaneous oxidation and reduction reactions that occur at spatially distinct anodic and cathodic regions on the metal surface. In fuel tank systems, the presence of moisture and dissolved ionic contaminants serves as an electrolytic medium, enabling ionic conductivity and sustaining the redox reactions necessary for corrosion.

The corrosion process in fuel tanks is initiated primarily by the ingress of water and dissolved oxygen, which facilitate electrochemical activity on the steel surface. At the anode, iron atoms undergo oxidation and release electrons (Equation 1), while at the cathode, oxygen molecules are reduced in the presence of hydrogen ions to form water (Equation 2). The coupled redox process results in the formation of ferric hydroxide (Equation 3), which subsequently dehydrates to yield hydrated ferric oxide, commonly identified as rust (Equation 4). This reaction sequence is schematically represented in Figure 1.

The corrosion pathway is summarized by the following half-cell and overall reactions:

METALOGRAM
-Mechanical Engineering and Energy-
August, 2026. Vol.02 No.3
31 August, 2026

Anodic reaction (oxidation of iron):

$$Fe\ (s) \rightarrow Fe^{2+}\ (aq) + 2e^{-} \quad (1)$$

Cathodic reaction (reduction of oxygen):

$$O_2\ (g) + 4H^{+}\ (aq) + 4e^{-} \rightarrow 2H_2O\ (l) \quad (2)$$

Overall redox reaction:

$$4Fe\ (s) + 3O_2\ (g) + 6H_2O\ (l) \rightarrow 4Fe(OH)_3\ (s) \quad (3)$$

Dehydration of ferric hydroxide (formation of rust):

$$2Fe(OH)_3\ (s) \rightarrow Fe_2O_3{\cdot}H_2O\ (s) + 2H_2O\ (l) \quad (4)$$

Several factors contribute to an accelerated corrosion rate within the fuel tank environment, including: emulsification of fuel and water due to condensation, ingress of fuel contaminated with ionic or acidic species, accumulation of acidic degradation by-products, and limited ventilation, which hinders moisture evaporation. The resulting corrosion products—primarily iron oxides and hydroxides—pose critical threats by clogging fuel lines, fouling filters, and ultimately degrading the performance and durability of fuel injection components.

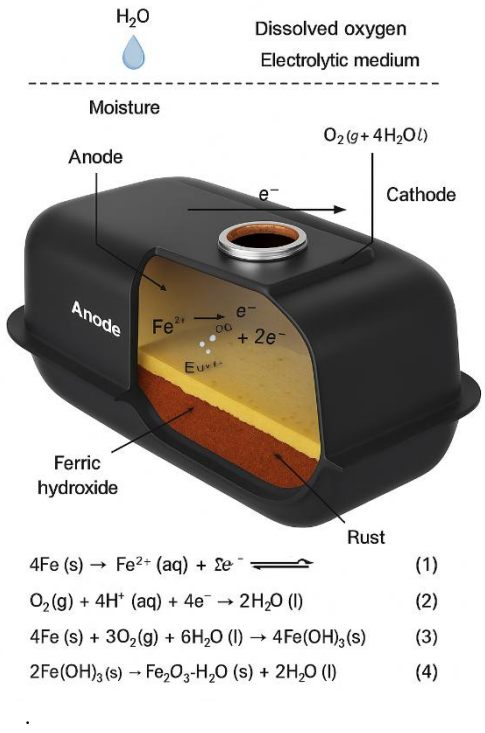

Figure 1. A 3D schematic of the electrochemical corrosion process inside a black motorcycle fuel tank. The cutaway view illustrates anodic iron oxidation and cathodic oxygen reduction, leading to ferric hydroxide formation and its dehydration into rust. Moisture and ionic contaminants act as the electrolyte enabling the redox reactions.

1.2 Acid-Based Rust Removal Mechanism

Hydrochloric acid (HCl) effectively dissolves rust through acid-base neutralization reactions involving various iron oxides and oxyhydroxides present in corrosion layers. Contrary to the simplified assumption that rust is composed of a single compound, corrosion products typically consist of multiple iron-based phases formed under varying environmental conditions.

The primary rust constituents and their respective dissolution reactions are as follows:

Iron(III) oxide (hematite):

$$Fe_2O_3 + 6HCl \rightarrow 2FeCl_3 + 3H_2O \quad (5)$$

Iron oxyhydroxide (goethite):

$$FeOOH + 3HCl \rightarrow FeCl_3 + 2H_2O \quad (6)$$

Magnetite (mixed-valence iron oxide):

$$Fe_3O_4 + 8HCl \rightarrow FeCl_2 + 2FeCl_3 + 4H_2O \quad (7)$$

These reactions yield water-soluble iron chloride salts ($FeCl_2$ and $FeCl_3$), which can be physically removed via rinsing. The rate of dissolution is influenced by several factors, including acid concentration, contact time, temperature, and the crystalline structure of the rust compounds. Among these, goethite (FeOOH) is the most prevalent rust form in atmospheric corrosion and generally exhibits slower dissolution due to its thermodynamically stable crystal lattice compared to the more amorphous structure of Fe_2O_3.

The commercial product employed in this study utilizes hydrochloric acid as its active component, with an HCl concentration ranging from approximately 9% to 11%. This level of acidity is sufficient for effective rust removal while remaining within safe limits for consumer use. The product and its standard packaging are depicted in Figure 2.

Figure 2. Commercial hydrochloric acid-based cleaner (Harpic Power Plus) containing approximately 9-11% HCl as active ingredient for rust dissolution
(source Max)

1.3 Corrosion Inhibitor

To systematically evaluate the effectiveness of the corrosion removal process, clear parameters are required, moving beyond mere visual observation. The success of this method can be measured through a combination of qualitative and quantitative analysis.

1. Visual Assessment (Qualitative

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METALOGRAM
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31 August, 2026

Visual analysis is the first and most fundamental evaluation method. The observed parameters include:

a. Color and Uniformity

An ideally clean steel surface will exhibit a uniform, dull gray color. The presence of black stains or residual reddish-brown patches indicates that the cleaning was incomplete.

b. Removal of Rust Flakes

Visual evaluation confirms that no solid rust flakes remain adhered to the tank's inner surface.

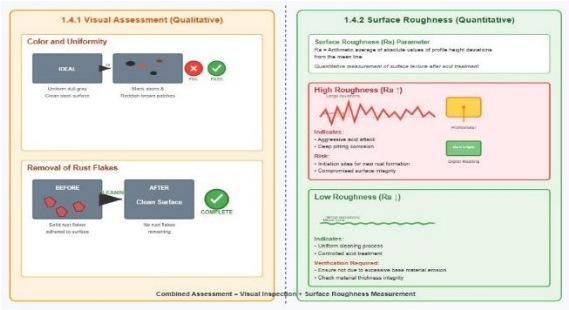
2. Surface Roughness (Quantitative)

After the rust layer is removed, the exposed steel surface will possess a certain degree of roughness resulting from the non-uniform acid attack. Surface roughness (Ra) is a quantitative parameter that measures the arithmetic average of the absolute values of the profile height deviations from the mean line. In this context:

a. High Roughness: This may indicate an aggressive acid attack or deep pitting corrosion, which can serve as initiation sites for new rust formation.

b. Low Roughness: This suggests a more uniform cleaning process. However, it is crucial to verify that this is not due to excessive erosion of the base material.

The evaluation scheme combining both visual and surface roughness parameters is illustrated in Figure 3.



Figures 3. Parameters of Cleaning Effectiveness Scheme (source: Max)

1.5 Influence of Exposure Time in Acid Cleaning

The duration of exposure to the acid solution is a critical process parameter that directly governs both the effectiveness of rust removal and the integrity of the underlying base metal. The chemical reaction between the acid and the iron oxide is not instantaneous.

If the exposure time is insufficient, the reaction may not proceed to completion, resulting in incomplete rust removal. This leaves residual corrosive patches that can continue to degrade the fuel tank. Conversely, prolonged exposure poses a significant risk. Once the protective rust layer is dissolved, the acid will begin to attack the base steel (Fe), leading to excessive etching and material loss, which can compromise the structural thickness of the tank wall.

Therefore, identifying an optimal exposure time is essential. The goal is to allow sufficient time for the complete dissolution of rust while minimizing the corrosive attack on the base metal. This principle provides the theoretical foundation for selecting and evaluating the specific duration used in this study's methodology.

2.0 METHOD

1. Initial Condition Documentation

The tank's internal surface was visually inspected and documented using high-resolution photography to establish a baseline condition before treatment.

2. Corrosion Dissolution Process

A total of 3.4 liters of a commercial hydrochloric acid-based cleaner (Harpic) was poured into the tank. The tank was then sealed and left for 72 hours at ambient temperature to allow the chemical reaction ($Fe_2O_3 + 6HCl \rightarrow 2FeCl_3 + 3H_2O$) to proceed optimally.

3. Rinsing and Drying Process

After 72 hours, the acid solution was drained. The tank's interior was thoroughly rinsed with clean water for 15 minutes until the surface pH was neutral (verified with litmus paper). To ensure no residual moisture remained to trigger flash rust, the internal surface was forcibly dried using a heat gun.

4. Corrosion Inhibitor Application

Immediately after drying, a thin, even layer of a water-displacing corrosion inhibitor (WD-40, 240 ml) was applied to the entire internal surface. The purpose was to protect the exposed steel surface from contact with atmospheric oxygen and moisture.

5. Results Evaluation and Observation

The process's effectiveness was evaluated by visually comparing documentation of the tank's condition at three points: (a) before treatment, (b) after cleaning and drying, and (c) one week after inhibitor application. The qualitative evaluation criteria included the level of surface cleanliness from rust, color uniformity, and the presence or absence of new rust formation.

6. Methodological Limitations

It should be noted that no quantitative measurements such as surface roughness (Ra) were carried out due to instrument limitations.

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3.0 RESULT

The restoration process results are presented following the chronological sequence of the methodology steps. Each step produced distinct, measurable outcomes that demonstrate the effectiveness of this treatment approach. Figure 4 provides a visual overview of the transformation achieved through the complete process.

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(a) Initial severe corrosion

b. After 72 hours of acid cleaning

c. Final state after application of corrosion inhibitor

Figure 4. Comparative visual documentation of the tank's internal surface: (a) Initial severe corrosion, (b) After 72 hours of acid cleaning, (c) Final state after application of corrosion inhibito.

3.1 Visual Documentation of the Restoration Process

Prior to any treatment, comprehensive photographic documentation was conducted as specified in the methodology. The visual inspection revealed severe and widespread corrosion affecting approximately 95% of the internal surface area, as shown in Figure 4(a). The initial condition exhibited the following characteristics:

1. Surface Coverage: Near-complete rust coverage (95-100%)
2. Color: Predominantly reddish-brown, consistent with $Fe_2O_3 \cdot nH_2O$
3. Texture: Rough, flaky deposits with visible stratification
4. Thickness: Estimated 1-3 mm based on flake dimensions
5. Risk Assessment: High contamination risk for fuel system

The documented condition validated the necessity for restoration, with loose rust particles posing immediate risk of fuel line blockage. Figure 5 provides a detailed close-up view of this severe corrosion.

3.2 Step 2: Corrosion Dissolution Process Results

Following the application of 3.4 liters of Harpic cleaner, the dissolution process was monitored at 24-hour intervals:
After 24 Hours:

1. Solution color changed from clear to dark brown/black
2. Approximately 40% of surface rust had softened
3. Partial metal exposure in less corroded areas
4. Significant rust remained adhered (60%)

After 72 Hours (Complete Treatment):

1. Solution heavily saturated with dissolved iron compounds
2. 90-95% of original rust successfully dissolved
3. Base metal exposed across majority of surface [see Figure 4(b)]
4. Chemical reaction $Fe_2O_3 + 6HCl \rightarrow 2FeCl_3 + 3H_2O$ confirmed by rust dissolution

Figure 6 documents the intermediate stage at 24 hours, while Figure 7 shows detailed view of the final dissolution results.

Figure 5. Intermediate rust dissolution stage after 24 hours of acid exposure.

Figure 6. Final corrosion removal result after 72 hours, revealing exposed base metal.

3.3 Rinsing and Drying Process Results

The rinsing process yielded the following outcomes:
1. Rinsing Effectiveness:

1. Initial rinse water: Dark brown with suspended particles
2. After 5 minutes: Water clarity improved significantly
3. After 15 minutes: Clear rinse water achieved
4. pH Testing: Neutral pH (6.5-7.0) confirmed with litmus paper

Drying Results:

1. Heat gun application successfully removed all visible moisture
2. No water droplets or damp areas observed
3. Surface ready for immediate inhibitor application
4. No flash rust formation during drying process

3.4 Corrosion Inhibitor Application Results

WD-40 application (240 ml) produced immediate visible results, as shown in Figure 4(c):

1. Coverage: Uniform thin film across entire internal surface
2. Visual Indicator: Slight sheen confirming complete coverage

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3. Water Displacement: Tested with water droplets - immediate beading observed
4. Adhesion: Film remained stable with no pooling or dripping

3.5 Evaluation and Observation Results

Comparative evaluation at three time points revealed the complete transformation achieved through the treatment process:

1. Before Treatment:
a) 95-100% rust coverage
b) Reddish-brown coloration
c) Extensive flaking deposits

2. After Treatment (Before Inhibitor):
a) 90-95% rust removal achieved
b) Metallic gray surface exposed
c) 5-10% residual staining in deep pits
d) Increased surface roughness noted

4. One Week Post-Inhibitor:
a) 0% new rust formation
b) Protective film intact
c) Metallic appearance maintained
d) Complete prevention of flash rust

Figure 7 documents the surface condition after one week of protection.

The complete transformation through all treatment steps is summarized quantitatively in Table 1.

Table 1. Comparative analysis of tank condition at each treatment step

Parameter	Step 1: Before Treatment	Step 3: After Rinse & Dry	Step 5: One Week Post-Inhibitor
Rust Coverage	95-100%	5-10% (residual stains)	0% (no new rust)
Surface Color	Reddish-brown	Metallic gray	Metallic gray (maintained)
Loose Deposits	Extensive flaking	None	None
Base Metal Exposure	0%	90-95%	90-95%
pH Status	N/A	Neutral (6.5-7.0)	N/A
Flash Rust Risk	N/A	High	None observed
Surface Protection	None	None	Hydrophobic film present

3.3 Intermediate Result (After 24-Hour Exposure)

After the initial 24-hour immersion period in the acid-based cleaner, a notable change in the tank's internal condition was observed. The chemical dissolution process was visibly underway, with the top layer of rust beginning to soften and detach from the base metal. This was evidenced by the acidic solution itself becoming discolored and opaque, indicating that iron oxide particles were being successfully suspended within the liquid, as shown in Figure 5.

However, visual inspection confirmed that significant portions of the internal surface remained covered in the original, stubborn rust layer. While the cleaner demonstrated its effectiveness in initiating the rust removal process, this intermediate assessment highlighted that the 24-hour exposure time was insufficient for the complete restoration of the severely corroded tank, justifying the decision to extend the treatment period.

Figure 8. The tank's interior after 24 hours of exposure to the acid cleaner. Partial rust removal is evident, with suspended particles visible in the solution

3.4 Final Results (After 72 Hours of Exposure and Cleaning)

After 72 hours of full exposure to the acid-based cleaner and subsequent rinsing and drying, the internal surfaces of the tank showed dramatic changes. Visual analysis confirmed that most of the severe and flaking rust had been successfully dissolved and removed. Much of the surface exposed the underlying base metal, achieving the primary goal of the restoration.

However, the cleaning was not completely uniform. Although the overall condition improved significantly, some residual imperfections remained. Dark gray or black spots were visible in some areas, indicating deep oxidation or reaction byproducts that were not completely rinsed away. Additionally, pinholes and a rougher texture were visible on certain surfaces, most likely related to areas where the initial corrosion was most severe. Despite these minor defects, the process was very effective in removing rust particulates that posed a direct threat to the fuel system. The final state, prior to application of the

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corrosion inhibitor, is documented in Figure 6.

Figure 6. Internal surfaces of the tank after 72 hours of acid treatment followed by rinsing and drying with a heat gun. Most of the rust is gone, but there are still some stains left.

3.5 Post-Treatment Analysis and Short-Term Inhibition

After the internal surfaces were completely dry, a corrosion inhibitor (WD-40) was applied to create a protective barrier against immediate re-rusting, also known as flash rust. The inhibitor works by displacing any remaining microscopic moisture and leaving a thin, oily film that isolates the bare metal from atmospheric oxygen.

A follow-up inspection was conducted one week after treatment. Observation and analysis of the interior of the tank showed that the surfaces remained clean and free of new rust formation. The metallic luster was maintained, and there was no evidence of the reddish-brown oxidation that typically occurs on unprotected steel exposed to moisture. These results indicate that the application of WD-40 provided effective short-term corrosion protection.

Figure 7. Internal surfaces of the tank one week after coating with corrosion inhibitor. The surfaces remained clean with no evidence of new rust formation.

4.0 DISCUSSION

4.1 Effectiveness of Acid-Based Rust Removal

The results demonstrate that the HCl-based cleaner (Harpic) was highly effective in dissolving Fe_2O_3 deposits, achieving approximately 90-95% rust removal. This success can be attributed to several factors:

1. Chemical Efficiency

The dissolution reactions proceeded as theoretically predicted, with the 9-11% HCl concentration proving sufficient for breaking down various iron oxide compounds. The extended 72-hour exposure time was critical for complete reaction, particularly for dissolving crystalline goethite (FeOOH) which requires longer contact times than amorphous rust.

2. Process Optimization

The comparison between 24-hour and 72-hour results clearly demonstrates that exposure time is a critical parameter. At 24 hours, only 40% rust removal was achieved, while 72 hours yielded over 90% removal. This suggests a non-linear dissolution rate, likely due to:

1. Initial rapid dissolution of loose, amorphous rust
2. Slower secondary phase for adhered, crystalline deposits
3. Diffusion limitations as dissolved products accumulate

Optional Upgrade: Permanent Protection
For long-term durability, add a fuel-resistant epoxy coating (~$16-23 USD). This brings the total DIY cost to ~$26-32 USD, which is still 67-80% cheaper than buying a new tank.

3, Limitations Observed

The 5-10% residual staining and pitting indicates that some corrosion had progressed beyond simple surface oxidation into the steel substrate. These areas represent locations where rust removal alone cannot restore the original surface integrity.

4.2 Implications of Post-Treatment Surface Condition

Although free of rust, the final surface exhibited characteristics requiring further analysis:

1. Surface Roughness Considerations

The visually apparent increase in surface roughness, while not quantitatively measured, has important implications:

2. Positive aspect

Increased surface area may enhance adhesion if permanent coatings are later applied

3. Negative aspect

Rougher surfaces provide more nucleation sites for future corrosion

5. Practical impact:

The rough texture may trap contaminants more readily than smooth surfaces

6. Material Loss Assessment

The etching effect observed suggests measurable material loss occurred during treatment. While this was not quantified due to equipment limitations, the implications include:

1. Potential wall thickness reduction in severely corroded areas
2. Possible compromise of structural integrity if treatment is repeated multiple times
3. Need for thickness measurements in critical applications

4.4 Safety and Environmental Considerations

While not extensively covered in the results, important considerations include:

1. Chemical Hazards:

HCl vapor generation during treatment requires adequate ventilation

Proper PPE essential due to acid's corrosive nature

Neutralization of waste acid before disposal

2. Environmental Impact:

Dissolved iron chlorides require proper waste treatment

WD-40 aerosol propellants contribute to VOC emissions

Alternative eco-friendly inhibitors should be investigate

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4.5 Economic Analysis

Figure 8. A cost analysis of fuel tank restoration: The DIY (Do It Yourself) method is significantly cheaper than buying a new tank or using professional services. You can save up to 94%
(Source: Author)

Figure 8 above shows an economic analysis comparing the do-it-yourself (DIY) method for fuel tank restoration against other alternatives. The analysis indicates that the DIY method, costing approximately $9.50, is significantly more cost-effective than purchasing a new OEM tank ($52-$97), a used tank ($19-$32), or undergoing professional restoration ($23-$32). This results in a substantial cost saving of 90-94% compared to buying a new tank. The infographic also notes that even with an optional upgrade for permanent protection, the DIY method remains up to 80% cheaper than a new tank, highlighting its considerable economic advantage.

4.6 Recommendations for Method Improvement

Based on the observed results, several improvements could enhance the method:

1. Pre-treatment mechanical cleaning to remove loose rust before acid application
2. Intermediate agitation during acid exposure to improve dissolution uniformity
3. Multiple rinse cycles with pH monitoring between each
4. Application of fuel-resistant coating after inhibitor for permanent protection
5. Quantitative measurements (Ra, thickness) for objective assessment

5.0 CONCLUSION

This case study successfully demonstrated that a sequential restoration method using a commercial acid cleaner (Harpic) for 72 hours followed by a corrosion inhibitor (WD-40) can effectively restore a severely corroded motorcycle fuel tank. The key findings include:

1. High Rust Removal Efficiency: The method achieved 90-95% rust removal, successfully eliminating the corrosion products that pose risks to fuel system operation.
2. Critical Time Parameter: A 72-hour exposure period proved necessary for optimal results, with shorter durations yielding incomplete rust removal.
3. Effective Short-term Protection: WD-40 successfully prevented flash rust formation for the one-week observation period, validating its use as a temporary protective measure.
4. Method Limitations: The protection is explicitly temporary and fuel-soluble, surface roughness increases due to acid etching, and approximately 5-10% residual staining remains in deeply corroded areas.
5. Cost-Effectiveness: At approximately $9.50 USD total cost (90%+ savings versus replacement), this method offers a viable alternative for budget-conscious restoration projects, provided users understand its limitations.

This method is validated as a practical, low-cost alternative for motorcycle fuel tank restoration, particularly suitable for temporary rehabilitation or as a preparatory step before applying permanent protective coatings. Users must fully understand the technical limitations, temporary nature of protection, and safety requirements when implementing this approach. Future work should focus on quantitative surface analysis and development of fuel-resistant coating systems compatible with this pre-treatment method.

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