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## Original Research Article

# Enhanced corrosion resistance of motorcycle rear sprockets by salt bath nitrocarburizing and post oxidation

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### ABSTRACT

Motorcycle rear sprockets functioning in tropical monsoon and coastal surroundings often experience accelerated corrosion, which can significantly reduce their service life and reliability. This paper inspects the effectiveness of salt bath nitrocarburizing followed by post-oxidation as a surface modification method to enhance the corrosion resistance of motorcycle sprockets. Both treated and untreated sprockets were evaluated using a neutral salt spray test conducted in accordance with ASTM B117 standards. The duplex-treated samples confirmed a substantial improvement in corrosion performance, remaining free from visible rust for 168 hours; however, untreated sprockets exhibited corrosion after approximately 48 hours of exposure. The enhanced resistance is attributed to the formation of a stable and protective oxide layer produced during the post-oxidation stage. These results indicate that duplex salt bath nitrocarburizing with post-oxidation can effectively improve the corrosion durability of motorcycle sprockets operating in hostile service environments.

## 1. Introduction

Motorcycle rear sprockets are critical drivetrain components exposed to combined rolling–sliding contact, cyclic loading, and environmental exposure during its operational life. These conditions enforce severe tribological demands, where friction, wear, and corrosion combinedly govern functional performance and service life. In hostile environments such as humid and coastal regions, chloride-laden moisture accelerates electrochemical degradation. This resulting in pitting corrosion, material loss, and premature failure of steel components. Subsequently, corrosion-induced degradation significantly reduces service life and increases maintenance requirements.

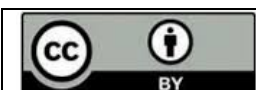
To address these challenges, surface engineering techniques are extensively employed to improve surface properties without altering its bulk mechanical integrity. Case hardening treatments are particularly effective, as they selectively alter the surface while retaining a tough core. These treatments improve wear resistance, hardness, and corrosion resistance through measured modification of surface composition and microstructure [1,2]. Between these, nitrocarburizing has gained substantial attention due to its ability to improve both tribological performance and corrosion resistance in ferrous materials used in automotive applications [3,4].

Salt bath nitrocarburizing is a thermochemical diffusion process involving the simultaneous enrichment of nitrogen and

carbon into the surface of ferrous materials. This process typically conducted within the ferritic temperature range of 530–570°C. This process results in the formation of a compound layer mainly consisting of  $\epsilon$ -Fe<sub>2-3</sub>(C,N) and  $\gamma'$ -Fe<sub>4</sub>(N,C) phases, along with an underlying diffusion zone [3–5]. The compound layer improves wear resistance and reduces friction, whereas the diffusion zone contributes to enhanced fatigue strength and load-bearing capacity. Due to these advantages, nitrocarburizing is broadly applied to engineering components such as gears, shafts, and sprockets [6].

However, the compound layer formed during nitrocarburizing fundamentally contains micro-porosity, which can act as favoured pathways for the ingress of corrosive species, thus limiting corrosion resistance. To mitigate this limitation, post-oxidation treatments are employed to form a thin and dense magnetite (Fe<sub>3</sub>O<sub>4</sub>) layer on the surface. In established industrial processes such as Quench–Polish–Quench (QPQ), this oxide layer improves corrosion resistance by sealing surface porosity and enhancing barrier properties [7,8]. A similar protective mechanism is expected in treatments involving nitrocarburizing followed by post-oxidation.

Despite widespread research on nitrocarburizing and post-oxidation treatments, most studies are limited to standard laboratory samples or alloy steels under controlled conditions. Research on actual automotive components, particularly



motorcycle sprockets subjected to realistic service atmospheres, remain limited. Additionally, quantitative evaluation of corrosion resistance using standardized salt spray testing for such components is still fairly underexplored.

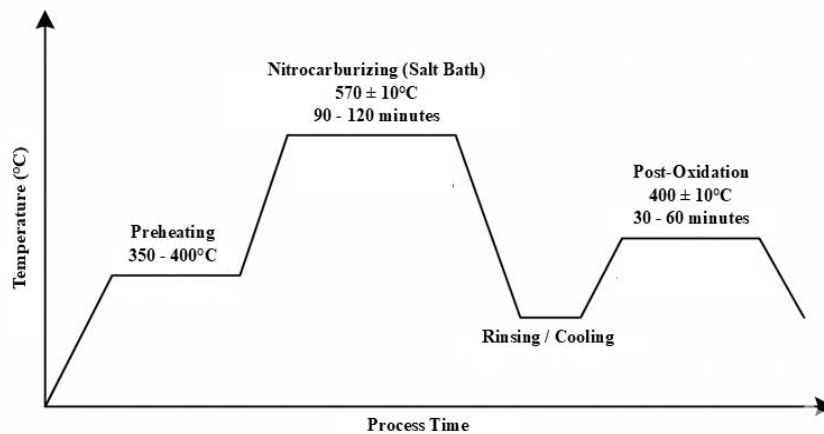
Therefore, this study gauges the effectiveness of salt bath nitrocarburizing followed by post-oxidation in improving the corrosion resistance of motorcycle rear sprockets. The corrosion behaviour of untreated and treated sprockets is investigated using neutral salt spray testing (ASTM B117), with emphasis on corrosion initiation time, rust formation characteristics, and comparative performance analysis.

## 2. Objectives

The key objective of this study is to evaluate the effectiveness of surface treatment, comprising salt bath nitrocarburizing followed by post-oxidation, in enhancing the corrosion resistance of motorcycle rear sprockets.

The specific objectives are:

- To investigate the corrosion behaviour of untreated and treated motorcycle rear sprockets under neutral salt spray conditions (ASTM B117).
- To compare corrosion performance based on corrosion initiation and progression characteristics.



**Figure 1:** Schematic representation of salt bath nitrocarburizing followed by post-oxidation.

### 3.2.1 Salt bath nitrocarburizing

Salt bath nitrocarburizing was performed using a cyanate and nitrate based molten salt bath (commercial systems such as Tenifer or Tufftride). The specimens were immersed in the bath maintained at  $570 \pm 10^\circ\text{C}$  for 90–120 min.

During treatment, simultaneous diffusion of nitrogen and carbon into the steel surface resulted in the development of a compound layer consisting of  $\epsilon\text{-Fe}_2\text{-3(C,N)}$  and  $\gamma'\text{-Fe}_4\text{(N,C)}$  phases, supported by an underlying diffusion zone [3–5]. This modified surface layer enhances the tribological performance and corrosion resistance of medium carbon steels [6].

### 3.2.2 Post-oxidation treatment

Following nitrocarburizing, the samples were rinsed to remove residual salts and subjected to post-oxidation in a steam environment at  $400 \pm 10^\circ\text{C}$  for 30–60 min.

This treatment produces a thin and adherent magnetite ( $\text{Fe}_3\text{O}_4$ ) layer, which improves corrosion resistance by sealing surface porosity and reducing the ingress of corrosive species [7], [8]. Similar post-oxidation treatments reported in literature

## 3. Materials and methods

### 3.1 Material and specimen preparation

Commercial motorcycle rear sprockets manufactured from medium carbon steel (CK45 grade) were used as test samples. The components were selected from a standard commuter motorcycle application to guarantee relevance to actual service conditions.

Prior to treatment, all samples were cleaned and degreased using appropriate solvents to remove surface impurities, followed by rinsing it with distilled water and drying under ambient conditions to obtain a uniform initial surface state.

### 3.2 Surface treatment

The surface treatment is a combination of salt bath nitrocarburizing followed by post-oxidation. This thermochemical surface treatment is employed to improve wear resistance, surface hardness, and corrosion resistance of ferrous components [3,4]. The temperature time profile of the process is shown in Fig. 1.

have demonstrated improved surface stability and corrosion performance.

### 3.3 Salt spray corrosion test

Corrosion performance of untreated and treated sprockets was evaluated using a neutral salt spray (NSS) test in accordance with ASTM B117-19, ISO 9227:2022, and ISO 9844:2021 standards.

The test was carried out in a salt spray chamber using a  $5 \pm 1$  wt.% NaCl solution prepared with distilled water. The operating conditions were kept as follows:

- Temperature:  $35 \pm 1^\circ\text{C}$
- pH of collected solution: 6.5–7.0
- Air pressure: 12 psi
- Specific gravity:  $1.030\text{ g/cm}^3$
- Specimen orientation:  $15^\circ\text{--}30^\circ$  inclination

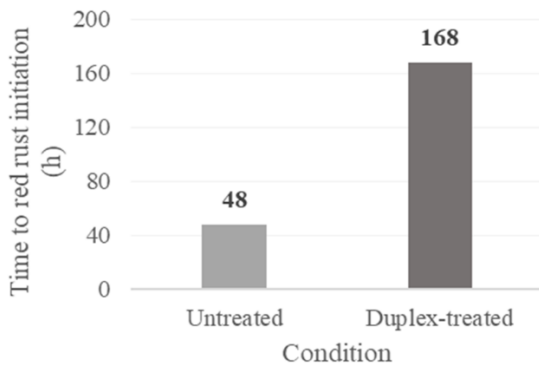
The test was conducted under nonstop salt fog exposure. Specimens were inspected at 24-hour intervals to monitor corrosion evolution. The exposure duration was not predefined and continued until the appearance of visible red rust, which was considered the failure criterion.

## 4. Results

### 4.1 Salt spray corrosion test results

The corrosion behaviour of untreated and treated motorcycle rear sprockets was evaluated using a neutral salt spray test, with time to visible red rust taken as the failure criterion.

A clear difference in corrosion resistance was observed. The untreated sprocket displayed red rust after 48 h, while the treated sprocket showed delayed corrosion initiation, with red rust appearing after 168 h under identical test conditions.



**Figure 2:** Time to first red rust initiation of untreated and treated motorcycle sprockets under ASTM B117 salt spray conditions.

As shown in Fig. 2, the treated sprocket exhibited a considerably longer corrosion initiation time, indicating improved resistance to chloride-induced degradation.

### 4.2 Comparative corrosion performance

The salt spray test results are summarized in Table 1.

**Table 1:** Salt spray corrosion test results of untreated and treated sprockets

Specimen Type	Exposure Time (h)	White Rust	Red Rust
Untreated Sprocket	48	Not observed	Observed
Treated Sprocket	168	Not observed	Observed

### 4.3 Improvement in corrosion resistance

The treated sprocket demonstrates a substantial improvement in corrosion resistance compared to the untreated condition. The time to red rust initiation increased from 48 h to 168 h, corresponding to an improvement factor of:

$$\text{Improvement Factor} = \frac{168}{48} = 3.5$$

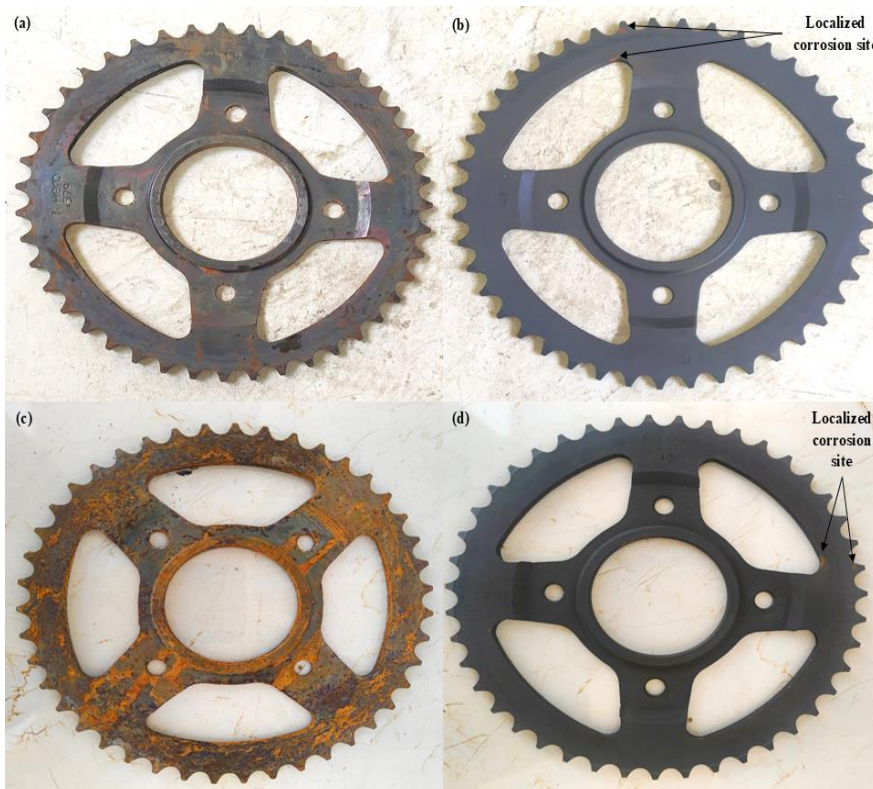
This specifies that the surface treatment salt bath nitrocarburizing followed by post-oxidation process enhances corrosion resistance by approximately 3.5 times under salt spray exposure.

### 4.4 Observational findings

No white rust development was observed in either condition during the test duration. However, red rust appeared significantly earlier in the untreated sprocket, demonstrating rapid corrosion progression in the absence of surface treatment.

In contrast, the treated sprocket displayed delayed corrosion initiation. The comparative corrosion behaviour after salt spray testing and subsequent atmospheric exposure is shown in Fig. 3.

As observed in Fig. 3, the untreated sprocket developed widespread and uniform red rust after salt spray exposure, which further propagated during approximately 120 days of atmospheric exposure. In contrast, the treated sprocket showed only localized corrosion sites, which remained limited and did not display significant spread over time.



**Figure 3:** Comparison of corrosion behaviour of untreated and treated sprockets after salt spray testing and subsequent atmospheric exposure.

## 5. Discussion

### 5.1 Effect of surface treatment on corrosion resistance

The salt spray results validate a substantial improvement in corrosion resistance for the treated sprocket compared to the untreated condition. The increase in time to red rust initiation from 48 h to 168 h confirms that the salt bath nitrocarburizing followed by post-oxidation treatment successfully delays corrosion under chloride-rich exposure. This is further supported by Fig. 3, which shows a clear reduction in corrosion harshness after both salt spray testing and subsequent atmospheric exposure.

This improvement is credited to the combined effect of nitrocarburizing and post-oxidation. Nitrocarburizing adjusts the surface through nitrogen and carbon diffusion, forming a compound layer that improves surface stability and resistance to environmental degradation [3], [4]. However, the inherent porosity of this layer can act as preferential locations for corrosion initiation [7].

Post-oxidation mitigates this limitation by forming a dense magnetite ( $\text{Fe}_3\text{O}_4$ ) layer, which acts as a defensive barrier against chloride ingress and enhances corrosion resistance [5], [6], [9].

### 5.2 Barrier mechanism and corrosion delay

The enhanced corrosion resistance of the treated sprocket can be explained by the barrier effect of the oxide layer. The  $\text{Fe}_3\text{O}_4$  layer displays low permeability to aggressive ions, thereby reducing electrochemical activity at the metal surface and delaying corrosion initiation.

As observed in Fig. 3, the untreated sprocket shows extensive and uniform red rust formation after salt spray exposure, followed by significant propagation during atmospheric exposure. In contrast, the treated sprocket shows only localized corrosion sites, which remain limited and do not propagate significantly over time. This specifies that although localized defects may initiate corrosion, the oxide layer effectively curbs its lateral propagation.

In the absence of such a protective layer, the untreated surface is directly exposed to the saline environment, resulting in rapid oxidation and early development of corrosion products. The delayed initiation and limited propagation observed in the treated condition approve that surface treatment suppresses corrosion kinetics by restricting interface between the substrate and the corrosive medium.

Comparable behaviour has been reported in previous studies, where post-oxidation following nitrocarburizing improves corrosion resistance by sealing surface defects and reducing chloride-induced degradation [6, 9, 10].

### 5.3 Practical significance for automotive components

From an application viewpoint, the observed 3.5-fold improvement in corrosion resistance is noteworthy for motorcycle sprockets operating in aggressive environments such as humid and coastal regions. Corrosion in such conditions accelerates material degradation, leading to reduced service life and increased maintenance.

Visual evidence (Fig. 3) further highlights this improvement, where the untreated sprocket displays severe and widespread corrosion after environmental exposure, while the treated sprocket retains surface integrity with only minor localized corrosion. This validates the effectiveness of the

treated surface in resisting corrosion propagation under practical conditions.

The results indicate that salt bath nitrocarburizing followed by post-oxidation surface treatment improves component durability without changing bulk properties. The use of industrially recognized processes such as salt bath nitrocarburizing followed by post-oxidation supports its applicability for extensive implementation.

Moreover, unlike many studies limited to laboratory specimens, the present work evaluates an actual engineering component under standardized testing and subsequent environmental exposure, thereby reinforcing the practical relevance of the findings.

### 5.4 Limitations and scope for future work

The present study is limited to macroscopic corrosion evaluation based on salt spray testing and visual inspection. Detailed characterization of surface layers, including microstructural analysis and phase identification, was beyond the scope of this work.

Future investigations may focus on correlating corrosion performance with microstructural features such as compound layer thickness, diffusion zone characteristics, and oxide layer morphology. Additionally, combined evaluation of wear, fatigue, and corrosion behaviour would provide a more comprehensive assessment of treated sprocket performance.

## 6. Conclusions

The effectiveness of surface treatment, comprising salt bath nitrocarburizing followed by post-oxidation, on the corrosion resistance of motorcycle rear sprockets was evaluated using neutral salt spray testing.

The key conclusions are:

- The treated sprocket displayed delayed corrosion initiation, with red rust appearing at 168 h compared to 48 h for the untreated condition.
- An improvement factor of approximately 3.5 in corrosion resistance was accomplished under identical test conditions.
- Corrosion in the treated sprocket remained localized with negligible propagation, even after prolonged atmospheric exposure.
- The improved performance is credited to the formation of a dense surface layer that acts as a barrier to chloride ingress.
- The surface treatment of salt bath nitrocarburizing followed by post-oxidation process provides an effective and industrially feasible approach for enhancing corrosion resistance and service life of motorcycle sprockets in saline environments.

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## Authors' contributions

All authors contributed equally to the conception, design, experimental work, data analysis, interpretation of results, and

preparation of the manuscript. All authors reviewed and approved the final version of the manuscript for publication.

### Conflicts of interest

The author declares no conflict of interest.

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### Data availability

No new data were created.

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