



Premature Hoisting Wire Rope Failure in Marine Deck Cranes: Investigating Diameter Mismatch, Two-Layer Spooling, and Sustainable Maintenance Strategies

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Abstract

Hoisting wire ropes are critical components of marine deck crane systems, directly affecting operational safety, lifting efficiency, and equipment reliability. This study investigates the causes of premature hoisting wire rope failure on the deck crane of MV Roslyn and proposes maintenance strategies to extend its service life. A qualitative case study approach was employed using field observations conducted from July 2025 to February 2026. Data were collected through direct observations, inspections of wire ropes, drums, and sheaves, as well as maintenance records, lifting plans, and technical documents. The results indicate that the hoisting wire rope operated for only 200–300 hours, far below the expected service life of 1,300–1,500 hours. The main causes of failure were incompatibility between the wire rope diameter and the drum and sheave groove dimensions, the use of a two-layer spooling system, and inadequate lubrication practices. These conditions increased contact stress, friction, fatigue, and structural deformation, accelerating wire rope deterioration. Corrective actions included matching drum and sheave groove dimensions to the wire rope specification, adopting a single-layer spooling system, and improving lubrication practices, particularly in the drum area. Enhanced lubrication increased wire rope service life to approximately 600–700 operating hours. Furthermore, predictive maintenance based on operating hours supports timely replacement planning and improves vessel operational efficiency.

Keywords: hoisting wire rope, deck crane, predictive maintenance, marine operations, equipment reliability.

INTRODUCTION

The reliability of lifting equipment is a critical requirement in maritime operations because cargo handling activities directly affect vessel productivity, operational efficiency, and occupational safety. Among the major components of a deck crane system, the hoisting wire rope plays a fundamental role as the primary load-bearing element responsible for lifting, lowering, and transferring cargo. Any degradation in wire rope performance may lead to operational disruptions, increased maintenance costs, equipment downtime, and severe safety hazards. Therefore, maintaining the structural integrity and serviceability of wire ropes is essential for

ensuring sustainable crane operations in the maritime industry ([Vukelic & Vizentin, 2017](#); [Xia et al., 2026](#)).

In recent years, maritime transportation has experienced increasing operational demands due to the growth of global trade and cargo throughput. These conditions require shipboard lifting equipment to operate more intensively and under increasingly challenging environmental conditions. Consequently, wire ropes are continuously exposed to cyclic loading, bending stresses, abrasive wear, corrosion, and fatigue damage, all of which contribute to performance degradation and premature failure ([Guerra-Fuentes et al., 2020](#)). Previous studies have

reported that fatigue-induced deterioration and wear-related failures remain among the most common causes of crane wire rope replacement and operational interruptions in marine lifting systems (Guerra-Fuentes et al., 2020; Xia et al., 2026).

From a mechanical engineering perspective, the service life of a wire rope is influenced by several interacting factors, including rope construction, sheave diameter, drum groove geometry, lubrication effectiveness, operating loads, and spooling configuration. Improper matching between wire rope diameter and groove dimensions may generate excessive contact stress, resulting in localized deformation and accelerated wear. Likewise, multi-layer spooling systems have been associated with increased crushing forces, uneven load distribution, and elevated fatigue stress concentrations within wire rope structures (Chang et al., 2019; Hu et al., 2011). These conditions significantly reduce the operational lifespan of wire ropes and increase the likelihood of unexpected failures (Zhang et al., 2022).

Several recent studies have examined the effects of fatigue, lubrication performance, and tribological behavior on wire rope durability. For instance, Chang et al. (2022) demonstrated that improper groove geometry significantly increases contact pressure and accelerates material degradation in crane wire ropes. Similarly, Peng et al. (2023) found that insufficient lubrication can intensify frictional interactions among wire strands, leading to faster deterioration of mechanical properties. Despite these advances, limited empirical evidence is available regarding the combined influence of diameter incompatibility, two-layer spooling systems, and maintenance practices in real-world maritime crane operations. Most existing studies rely on laboratory simulations or theoretical models rather than operational observations aboard commercial vessels.

To illustrate the severity of the problem, operational observations conducted aboard MV Roslyn revealed a substantial discrepancy between the expected and actual service life of the hoisting wire rope. While industry references generally indicate a normal service life ranging from 1,300 to 1,500 operating hours under proper operating and maintenance conditions, the observed wire rope experienced significant deterioration after only 200–300 operating hours.

Table 1. Comparison Between Expected and Actual Wire Rope Service Life

Indicator	Industry Standard	MV Roslyn Observation
Service Life (Operating Hours)	1,300–1,500 hours	200–300 hours
Operational Condition	Standard maintenance and proper configuration	Diameter mismatch, two-layer spooling, inadequate lubrication
Failure Risk	Moderate	High
Maintenance Frequency	Periodic	Frequent replacement required

Source: Operational Observation aboard MV Roslyn (2025–2026)

The substantial reduction in operational lifespan indicates the existence of underlying mechanical and maintenance-related deficiencies that require comprehensive investigation. Preliminary inspections identified several anomalies, including incompatibility between wire rope diameter and groove dimensions, the application of a two-layer spooling arrangement, visible wear patterns on sheave surfaces, and insufficient lubrication coverage. These findings suggest that the premature deterioration of the wire rope may result from the interaction of multiple mechanical and operational factors rather than a single isolated cause.

The urgency of this study lies in the increasing need to improve the reliability and sustainability of marine lifting systems while minimizing operational disruptions and safety risks. Premature wire rope failures not only increase maintenance expenditures and equipment downtime but also elevate the probability of catastrophic lifting accidents that may endanger crew members, cargo, and vessel assets. Given the limited availability of empirical studies investigating real-world crane operations under maritime conditions, this research provides valuable practical evidence regarding the mechanisms underlying accelerated wire rope degradation and offers maintenance-based solutions to enhance operational reliability and extend component service life.

Furthermore, this study contributes to the existing body of knowledge by integrating concepts from wire rope mechanics, tribology, fatigue theory, contact stress analysis, and

maintenance engineering to explain the observed degradation phenomena within an actual shipboard operational environment. The findings are expected to support maritime operators, maintenance engineers, and shipping companies in developing more effective predictive maintenance strategies and improving crane system performance.

Research Question

Based on the foregoing discussion, this study seeks to address the following research questions:

1. Why did the hoisting wire rope on the deck crane of MV Roslyn experience a significantly shorter service life compared with the expected operational lifespan?
2. To what extent do diameter incompatibility, two-layer spooling configuration, and lubrication practices contribute to accelerated wire rope degradation?
3. How do mechanical wear, fatigue mechanisms, and contact stress interactions affect the reliability of the hoisting wire rope system?
4. What sustainable maintenance strategies can be implemented to improve wire rope service life and enhance the operational reliability of marine deck cranes?

METHODS

Research Design

This study employed a qualitative descriptive approach using an operational case study design to investigate the factors contributing to the premature degradation of hoisting wire ropes in a marine deck crane system. A qualitative case study was considered appropriate because it enables an in-depth examination of complex technical phenomena occurring within a real operational environment, particularly when multiple interacting factors influence equipment performance and reliability (Yin, 2018). The study focused on identifying the root causes of accelerated wire rope deterioration and formulating sustainable maintenance strategies to improve operational reliability.

Research Site and Period

The research was conducted aboard MV Roslyn, specifically on the TTS Single Deck Crane KL 30T–28M system utilized for cargo handling operations. Data collection was carried out during routine vessel operations from July 2025 to February 2026. This period allowed

continuous observation of crane utilization, maintenance activities, and the progression of wire rope degradation under actual operating conditions.

Research Object

The primary object of investigation was the hoisting wire rope system, including its associated components such as the wire drum, sheaves, groove profiles, and lubrication mechanisms. Particular attention was given to the compatibility between wire rope dimensions and lifting specifications, spooling configurations, operational loading conditions, and maintenance practices.

Data Sources

This study utilized both primary and secondary data sources to ensure comprehensive analysis and triangulation of findings.

Primary Data. Primary data were obtained through:

- Direct observation of crane operations and cargo handling activities.
- Visual inspections of hoisting wire ropes, drum grooves, and sheave surfaces.
- Monitoring of spooling behavior during lifting operations.
- Observation of lubrication practices and maintenance procedures implemented by the ship's crew.

Secondary Data. Secondary data were collected from:

- Maintenance records and inspection reports.
- Wire rope replacement histories.
- Operating-hour logs.
- Crane manufacturer manuals and technical specifications.
- Relevant scientific literature and technical standards related to wire rope maintenance and crane operations.

The use of multiple data sources enhances the credibility and validity of case study findings by facilitating data triangulation (Creswell & Poth, 2018).

Data Collection Procedures

Data collection was conducted through four complementary techniques.

1.) Observation

Direct observations were performed during cargo loading and unloading operations to examine crane utilization patterns, lifting

procedures, load characteristics, and operational practices. Particular emphasis was placed on identifying factors that could contribute to excessive mechanical stress and premature wire rope wear.

2.) Technical Inspection

Comprehensive inspections were undertaken to evaluate the physical condition of the hoisting wire rope and supporting components. The inspection process focused on identifying mechanical defects such as:

- Surface wear,
- Broken strands,
- Twisting,
- Birdcaging,
- Flattening,
- Crushing,
- Groove deformation,
- Imprint marks on sheaves and drums.

Additionally, measurements and visual assessments were conducted to evaluate the compatibility between wire rope diameter and groove dimensions.

3.) Documentation Review

Relevant operational documents were examined, including maintenance records, wire rope replacement histories, operating-hour data, lifting plans, and technical manuals. These documents provided historical evidence regarding maintenance performance and equipment reliability.

4.) Literature Review

A review of contemporary scientific literature, industrial guidelines, and technical standards was conducted to establish the theoretical foundation of the study and facilitate comparison between observed operational conditions and recommended engineering practices.

Analytical Framework

The analytical framework was developed by integrating concepts from wire rope mechanics, fatigue theory, tribology, contact stress analysis, and maintenance engineering. Previous studies have demonstrated that wire rope degradation is strongly influenced by cyclic loading, bending fatigue, frictional wear, lubrication effectiveness, and contact stress concentrations generated by incompatible drum and sheave geometries

([Nabijou & Hobbs, 1994](#); [Ridge et al., 2001](#); [Xia et al., 2026](#)).

Accordingly, four key operational variables were examined:

1. Wire rope diameter compatibility with drum and sheave grooves.
2. Spooling configuration, particularly the application of two-layer spooling.
3. Lubrication effectiveness and maintenance practices.
4. Mechanical wear and fatigue-related damage mechanisms.

Data Analysis

The collected data were analyzed using qualitative content analysis combined with gap analysis techniques. The analytical procedure consisted of four stages:

Data Reduction

Relevant information was extracted and categorized according to operational, mechanical, and maintenance-related factors associated with wire rope degradation.

Data Display

The reduced data were systematically organized into descriptive narratives, inspection findings, operational records, and comparative analyses to facilitate interpretation.

Gap Analysis

Observed operational conditions were compared against applicable technical standards, manufacturer recommendations, lifting plans, and maintenance guidelines. Gap analysis was employed to identify discrepancies between actual practices and recommended engineering requirements ([Singh & Ahuja, 2015](#)).

Interpretation and Conclusion Development

The final stage involved synthesizing empirical findings with theoretical concepts from wire rope mechanics, fatigue behavior, tribology, and reliability engineering. This process enabled the identification of root causes underlying premature wire rope failure and the formulation of sustainable maintenance recommendations.

Trustworthiness of the Study

To enhance the rigor of the research, methodological triangulation was applied through the integration of observational evidence, technical inspections, operational documentation,

and literature review. Cross-verification among these data sources strengthened the reliability and credibility of the findings while reducing the potential for researcher bias (Creswell & Poth, 2018; Miles et al., 2021).

RESULTS

This study investigated the causes of premature hoisting wire rope failure in the deck crane system of MV *Roslyn*. The findings revealed that the actual service life of the hoisting wire rope ranged between 200 and 300 operating hours, significantly lower than the expected operational lifespan of approximately 1,300–1,500 hours under normal operating and maintenance conditions. This substantial discrepancy indicates the presence of critical mechanical and operational deficiencies affecting wire rope reliability.

Service Life Performance of the Hoisting Wire Rope

The comparison between the expected and observed service life is presented in **Table 2**.

Table 2. Comparison of Expected and Actual Wire Rope Service Life

Parameter	Expected Condition	Actual Condition
Service life	1,300–1,500 hours	200–300 hours
Maintenance frequency	Periodic maintenance	Frequent replacement
Operational reliability	High	Low
Failure risk	Moderate	High

The results indicate that the wire rope experienced a lifespan reduction of approximately 80%, suggesting that degradation mechanisms were occurring at a significantly accelerated rate.

Diameter Incompatibility Between Wire Rope drum and Sheave Groove

Field inspections identified incompatibility between the installed wire rope diameter and the groove dimensions of the drum and sheave system. Visible imprint marks and abnormal wear patterns were observed on the sheave groove sidewall, indicating excessive contact pressure.



Figure 1. Diameter incompatibility between the hoisting wire rope and the groove dimensions of the drum and sheave observed MV *Roslyn*.

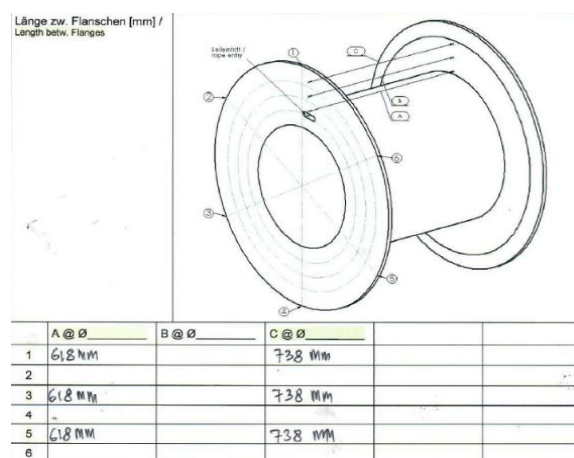
This condition resulted in:

- Increased localized contact stress.
- Uneven load distribution.
- Surface deformation of the wire rope.
- Accelerated abrasive wear.
- Reduced structural integrity of the lifting system.

The observed imprint marks on the sidewall of the sheave groove indicate that the wire rope was operating under conditions exceeding the optimal contact geometry recommended by the crane manufacturer.

Impact of Two-Layer Spooling Configuration

Operational observations revealed that the deck crane utilized a two-layer spooling arrangement.



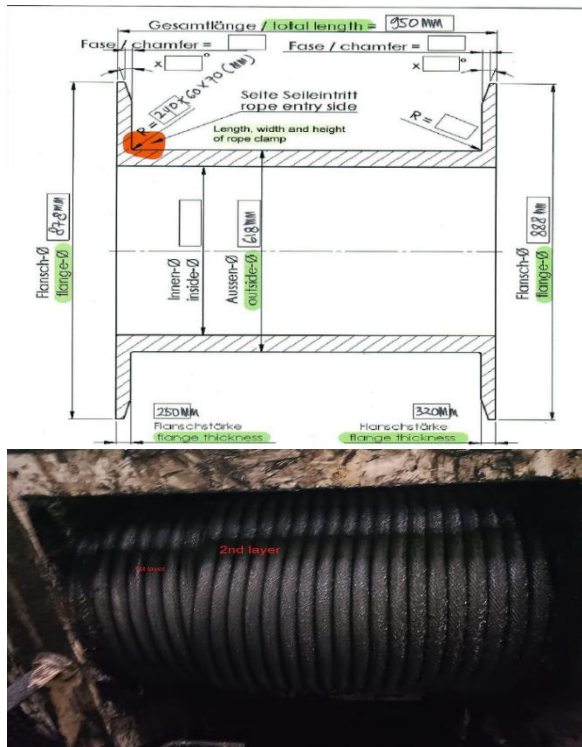


Figure 2. Actual two-layer spooling configuration of the deck crane drum on MV Roslyn.

Table 3. Observed Consequences of Two-Layer Spooling

Observed Condition	Operational Impact
Increased radial pressure	Wire crushing
Inter-layer contact	Surface deformation
Uneven winding pattern	Localized stress concentration
Additional bending cycles	Accelerated fatigue damage

The two-layer spooling configuration generated additional compressive loads between rope layers. As a consequence, the wire rope experienced increased deformation and fatigue accumulation during repetitive lifting cycles.

Condition of Sheave and failure mode of hoisting wire

Inspection activities also identified visible wear on the sidewall sheave groove surfaces and **failure mode of hoisting wire**.



Figure 3. Imprint marks on sidewall of the sheave surface and failure mode of hoisting wire

Imprint marks on sidewall of the sheave surface and failure mode of hoisting wire, indicating prolonged exposure to excessive contact forces.

Furthermore, abnormal groove wear altered load transfer characteristics between the wire rope and the supporting components, further accelerating deterioration.

Lubrication Performance

The investigation found that lubrication practices were not performed consistently during cargo handling operations, in conjunction with conditions of diameter incompatibility between the hoisting wire rope and the groove dimensions of the drum and sheaves, resulting in excessive contact pressure and accelerated wear.



Figure 4. Manual application of lubrication the entire wire and the wire winding section on the drum

As a result:

- Internal friction between strands increased.
- Corrosion protection decreased.
- Surface wear accelerated.
- Fatigue resistance deteriorated.

After implementing more frequent lubrication practices especially in the wire winding section on the drum during cargo operation every oow watch change and daily the entire wire manually, wire rope service life increased to approximately 600–700 operating hours, demonstrating the importance of lubrication management in extending operational durability.

DISCUSSION

The findings provide evidence that premature wire rope failure MV *Roslyn* was not caused by a single factor but rather by the interaction of multiple mechanical, operational, and maintenance-related deficiencies.

Why Did the Hoisting Wire Rope Experience a Significantly Reduced Service Life?

The first research question sought to identify the reasons behind the exceptionally short operational lifespan of the hoisting wire rope.

The results indicate that the reduction in service life was primarily associated with:

1. Diameter incompatibility between the wire rope and groove geometry.
2. Application of a two-layer spooling configuration.
3. Insufficient lubrication practices.
4. Progressive wear and fatigue accumulation.

These factors collectively generated unfavorable operating conditions that accelerated structural degradation. Similar findings were reported by [Chang et al. \(2022\)](#), who demonstrated that geometric incompatibility between wire ropes and supporting grooves substantially increases contact pressure and wear rates.

Consequently, the premature replacement cycle observed MV *Roslyn* reflects the cumulative effects of mechanical overload, frictional wear, and fatigue damage.

Impact of Diameter Incompatibility on Wire Rope Degradation

The second research question examined the role of diameter incompatibility in accelerating wire rope deterioration.

From a mechanical standpoint, compatibility between wire rope diameter and groove dimensions is essential for ensuring uniform stress distribution. When the groove diameter is smaller than recommended, contact forces become concentrated over a smaller surface area.

According to Hertzian contact theory, localized contact pressure increases significantly when contact surfaces are geometrically incompatible. This condition promotes:

- Plastic deformation,
- Groove damage,
- Surface flattening,
- Accelerated wear.

The imprint marks identified on the sidewall groove during inspection strongly support this mechanism.

These findings are consistent with previous studies indicating that improper groove dimensions are among the leading causes of premature crane wire rope failures ([Chen et al., 2024](#); [Nabijou & Hobbs, 1994](#)).

Impact of Two-Layer Spooling on Fatigue Development

The third research question addressed the contribution of the two-layer spooling system to wire rope degradation.

The results demonstrate that multi-layer spooling generated additional radial compression between wire rope layers. This phenomenon increased crushing forces and intensified bending stresses during lifting operations.

From the perspective of fatigue theory, repeated bending under elevated stress concentrations accelerates crack initiation and propagation within individual wires. Over time, these microstructural defects develop into broken strands and eventual wire rope failure.

The findings support the recommendations of ISO 4309, which generally favors single-layer spooling arrangements due to their superior load distribution characteristics and lower risk of rope deformation.

Therefore, the two-layer spooling configuration can be considered a major contributing factor to the accelerated fatigue observed in the study.

Role of Tribological Wear and Lubrication Deficiency

Another important finding concerns the relationship between lubrication effectiveness and tribological degradation.

Wire ropes consist of numerous steel wires and strands that continuously slide against one another during operation. Without adequate lubrication, friction coefficients increase substantially, leading to elevated temperatures, abrasive wear, and material loss.

The marine environment further exacerbates this problem through:

- Saltwater exposure,
- Moisture penetration,
- Corrosive contaminants,
- Grease degradation.

The observed improvement in service life following enhanced lubrication practices provides empirical evidence supporting the importance of lubrication in preserving wire rope integrity.

This result aligns with the findings of [Peng et al. \(2023\)](#), who reported that effective lubrication significantly reduces wear progression and enhances fatigue resistance in marine wire rope systems.

Implications for Sustainable Maintenance Management

The final research question concerned the identification of sustainable maintenance strategies capable of improving wire rope reliability.

Based on the findings, several maintenance interventions are recommended:

1. Alignment of wire rope diameter with drum and sheave groove specifications.
2. Transition from two-layer spooling to single-layer spooling where technically feasible.
3. Implementation of structured lubrication schedules.
4. Routine monitoring of groove wear and wire rope condition.
5. Adoption of predictive maintenance based on operating hours and condition assessment.

The implementation of these measures is expected to reduce premature failures, minimize operational downtime, improve cargo-handling efficiency, and enhance overall safety performance.

The results demonstrate that premature hoisting wire rope failure aboard MV *Roslyn* originated from the interaction of geometric incompatibility, multi-layer spooling, inadequate lubrication, and fatigue-related deterioration. Diameter mismatch increased contact stress, two-layer spooling intensified crushing and bending fatigue, while insufficient lubrication accelerated wear and corrosion. Together, these factors substantially reduced wire rope service life. The findings further indicate that sustainable maintenance practices, particularly proper dimensional matching, optimized spooling configurations, enhanced lubrication management, and predictive maintenance programs, can significantly improve wire rope reliability and operational performance deck crane systems Mv Roslyn.

CONCLUSION

This study investigated the causes of premature hoisting wire rope failure in the deck crane system of MV *Roslyn* and evaluated sustainable maintenance strategies to improve operational reliability. The findings demonstrate that the service life of the hoisting wire rope was substantially lower than the expected operational standard, reaching only 200–300 operating hours

compared with the normal lifespan of approximately 1,300–1,500 hours. This premature degradation was primarily attributed to the combined effects of diameter incompatibility between the wire rope and the drum/sheave grooves, the application of a two-layer spooling configuration, inadequate lubrication practices, and excessive contact stress during lifting operations.

The results further indicate that diameter mismatch increased localized contact pressure and bending stress, accelerating wear, deformation, and structural deterioration of the wire rope. Meanwhile, the two-layer spooling system generated additional radial compression and uneven load distribution, which intensified fatigue accumulation and increased the risk of crushing damage. Furthermore, insufficient lubrication contributed to higher friction levels, accelerated tribological wear, and reduced protection against corrosion within the harsh marine environment.

The study confirms that wire rope degradation is a multidimensional phenomenon influenced by mechanical design compatibility, operational practices, and maintenance effectiveness. Therefore, sustainable maintenance strategies should emphasize the alignment of wire rope and groove dimensions, optimization of spooling configurations, implementation of systematic lubrication programs, and adoption of predictive maintenance based on operating hours and condition monitoring. The implementation of enhanced lubrication practices during the observation period demonstrated a positive impact, increasing the wire rope service life to approximately 600–700 operating hours.

In practical terms, the findings provide valuable guidance for ship operators, maintenance personnel, and maritime companies seeking to improve crane reliability, reduce maintenance costs, minimize operational downtime, and enhance safety performance during cargo handling operations. Future research is recommended to incorporate quantitative approaches, finite element analysis, and long-term reliability assessment to further evaluate the influence of wire rope design parameters and operational loading conditions on the durability of marine lifting systems.

Practical Implications

The findings suggest that maritime operators should prioritize compatibility verification

between wire rope dimensions and crane components during installation and replacement processes. In addition, routine inspection of groove wear, optimization of spooling arrangements, and predictive maintenance scheduling can significantly reduce the likelihood of premature wire rope failure. These measures can contribute to safer lifting operations, improved equipment availability, and more sustainable maintenance management in marine cargo-handling systems.

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