

# Failure Analysis of Wire Ropes in Lifting Systems

<sup>1</sup>Avishkar Patil, <sup>2</sup>Samarth Mane, <sup>3</sup>Varad Ghule, <sup>4</sup>Yogita Funde, <sup>5</sup>Chandrashekar Dharankar

<sup>1,2,3</sup>Student, Dept. of Mechanical Engineering, AISSMS College of Engineering, Pune, Maharashtra, India

<sup>4,5</sup>Professor, Dept. of Mechanical Engineering, AISSMS College of Engineering, Pune, Maharashtra, India

**Abstract** - Wire ropes are fundamental mechanical components that find their application in lifting and hauling devices including cranes, lifts, mine haulages, and aerial tramways. Out of these, wire ropes for lifts are the most critical safety components since they are involved in the lifting of humans directly. These wire ropes have an intricate service environment with different loading forms of axial tension, bending through pulleys, torque, and dynamic loads because of starting, stopping, and emergency braking actions. The wire ropes in lift systems are very susceptible to fatigue damage owing to their frequent start/stop cycles and bending around small diameter sheaves. They are more prone to fatigue failure in the form of micro-crack formation in individual wires followed by propagation leading to eventual rupture of strands. Moreover, the requirement of traction imposes stringent conditions of wire rope surfaces, friction properties, and suitability of grooves in sheaves.

Several critical concerns specific to lift wire ropes include:

- **Fatigue and Bending Stress:** Continuous cyclic loading reduces rope life significantly, especially when improper D/d ratios (sheave diameter to rope diameter) are used.
- **Wear and Abrasion:** Contact between rope and sheave grooves leads to external wear, while internal wire movement causes fretting wear.
- **Corrosion:** Moisture, humidity, and environmental contaminants (especially in outdoor or high-rise glass elevators) accelerate corrosion, weakening wires internally.
- **Loss of Lubrication:** Inadequate lubrication increases internal friction between wires and strands, accelerating wear and reducing flexibility.
- **Unequal Load Distribution:** Improper installation or tensioning can cause uneven load sharing among ropes, leading to premature failure of specific ropes.
- **Traction Loss (Slippage):** Surface wear or contamination (oil, dust) can reduce friction between rope and traction sheave, affecting lift performance and safety.
- **Wire Breakage and Bird caging:** Localized damage, shock loading, or improper handling can cause

deformation such as bird caging, compromising rope integrity.

**Keywords:** Wire Rope, Elevator Systems, Lift Wire Ropes, Failure Mechanisms, Fatigue Failure, Bending Stress, Traction Sheave, Wear and Abrasion, Corrosion, Lubrication, Non-Destructive Testing (NDT), Magnetic Flux Leakage (MFL), Condition Monitoring, Rope Degradation, Safety in Lifts, High-Cycle Fatigue, Wire Breakage, Maintenance Strategies, Load Distribution, Service Life Prediction.

## I. INTRODUCTION

Wire ropes have widespread usage in hoisting applications like cranes, lifts, offshore platforms, and various materials handling systems because of the excellent blend of their tensile strength, flexibility, and resistance to wear that they offer. They can bear heavy loads and cope with tough operating conditions that involve bending over sheaves and drums. In particular, among all other uses of wire ropes, elevator (lift) ropes have significant safety implications since they directly facilitate vertical movement of personnel and cargo. In elevator operations, wire ropes experience cyclic and repetitive stressing due to starting, stopping, accelerating, and decelerating processes as well as continual bending around traction sheaves. Unlike in most cases, elevator wires have special criteria for traction properties, operation ease, and safety, which makes their reliability crucial in this application. The engagement of ropes with the traction wheel is vital in obtaining sufficient friction without excessive wearing and slipping during operation. During their working life, wire ropes used in lifts face complicated stresses involving axial tension, bending fatigue, torsion, and dynamic factors. These composite loading conditions have an enormous effect on the mechanical properties of the steel ropes. In addition to the above factors, there are additional variables including D/d ratio, groove shape, and environmental conditions that can influence the life span of these ropes. Under the influence of such conditions, ropes degrade continuously until they fail. Among all other modes of failures, the most important one is fatigue, since it is due to this reason that lifting ropes usually fail because of repeated bending over small diameters sheaves. Fatigue causes cracks in the stress concentration points of the steel wires that ultimately lead to wire rupture. Another mode of failure is wear caused by the rubbing of wires against each other and sheave grooves. In addition, the wire ropes used in

elevators are prone to corrosion, inadequate lubrication, and unbalanced loads among various ropes, leading to faster degradation. Lack of lubrication increases friction and affects the flexibility of the ropes, whereas incorrect tensioning might result in unbalanced load distribution and consequently in premature failure of specific ropes. Moreover, the loss of traction owing to contamination and wear can be hazardous for the operation of the elevator. Considering the high level of safety concerns, the continuous assessment and condition monitoring of lift ropes is required. The techniques of inspection, diameter measurements, and non-destructive testing (e.g., magnetic flux leakage – MFL) are commonly used to diagnose any defects at an early stage and avoid possible accidents. Therefore, gaining knowledge about the degradation processes in wire ropes is crucial to increase the safety and lifespan of lifting systems. This paper seeks to make such a contribution. Specifically, the processes responsible for rope degradation and their relationship to mechanical loads and environmental factors will be discussed in the context of elevator operations.

## II. PROBLEM STATEMENT

The wire ropes employed in lifting devices like cranes, elevators, and hoists function in challenging environments characterized by axial tensile loads, cyclic flexure, twisting, and dynamic loads. Further, the oscillations due to load fluctuation, movement of the motors, and misalignment of components create variable stress, which promotes fatigue and wear. The exposure to the surrounding elements such as moisture, temperature variation, and corrosion adds up to the deterioration of the ropes. The result is gradual damage that ultimately causes failure. This process is a significant concern not only for safety but also for economic implications. Particularly, elevator systems, where high levels of reliability are essential, face severe safety threats and financial losses when these ropes fail. Unfortunately, little has been done to incorporate all factors such as mechanical loads, vibrations, and environmental influences in the same assessment. This study seeks to explore how wire ropes perform in real-world settings utilizing techniques like Finite Element Analysis (FEA), particularly in terms of vibrations and their effects on failure.

## III. OBJECTIVE

The primary objective of this research is to analyze the failure mechanisms of wire ropes used in lifting systems and to establish a relationship between their mechanical properties, operating conditions, and modes of degradation. The study aims to improve the understanding of how different factors contribute to wire rope failure and to propose methods for enhancing their performance and service life.

The specific objectives of this study are as follows:

- To identify and classify major wire rope failure modes this includes fatigue failure, wear, corrosion, fretting, and vibration-induced damage under various operating conditions.
- To analyze the influence of mechanical properties on failure behaviour.
- Evaluate how parameters such as tensile strength, modulus of elasticity, wire diameter, strand configuration, and core type affect the resistance of wire ropes to different failure mechanisms.
- To study the effect of operational and environmental conditions and investigate the impact of loading conditions (static, dynamic, cyclic), bending over sheaves, lubrication quality, and environmental exposure (moisture, temperature, corrosive agents) on rope degradation.
- To evaluate stress distribution using Finite Element Analysis (FEA).
- Develop a simulation model to identify critical stress regions within the wire rope and predict potential failure initiation points under realistic loading scenarios.
- To establish a correlation between rope properties and failure modes.
- Create a systematic relationship (tables/analysis) linking material and structural properties with specific types of failures.
- To suggest preventive measures and design improvements
- Recommend strategies such as optimized material selection, improved lubrication practices, proper rope selection, and maintenance techniques to reduce failure risk.
- To enhance safety, reliability, and service life of wire ropes.
- Provide insights that can be applied in real-world lifting systems to minimize accidents, reduce maintenance costs, and improve operational efficiency.

## IV. METHODOLOGY

### 1. Problem Definition

Identify key issues related to wire ropes in overhead cranes:

- Rope-induced vibrations.
- Variable tension during lifting.
- Bending stresses over sheaves and drums.
- Fatigue and wear under repeated loading.
- Define objectives: improving load stability, reducing sway, and increasing rope life.

## 2. Material Selection & Rope Modelling

Select suitable wire rope type (e.g., 6×19, 6×36, or compacted ropes).

Define material properties:

- Young’s modulus.
- Tensile strength.
- Density.
- Damping characteristics.

Model the rope as:

- Equivalent flexible cable (continuous model), or
- Discrete mass-spring-damper system.

## 3. Finite Element Analysis (FEA)

Perform FEA on wire rope and associated components:

- Stress and strain distribution.
- Contact stresses (rope–drum, rope–sheave).
- Bending stress analysis.
- Evaluate critical regions for failure or fatigue.

## 4. Dynamic Simulation (Multibody Dynamics)

- Develop dynamic model of crane system including rope flexibility.
- Simulate.
- Lifting and lowering operations.
- Acceleration/deceleration effects.
- Load sway and rope oscillations.

## 5. Validation & Result Analysis

Compare simulation results with theoretical calculations or available data.

Analyze:

- Reduction in sway angle.
- Stress reduction in rope.
- Improvement in stability and safety.

## 6. Conclusion & Recommendations

Summarize findings related to:

- Rope performance.
- Vibration control.
- Design improvements.
- Provide practical recommendations for real crane systems.

This research uses a systematic method to examine the failure mechanisms of wire ropes, which combines theoretical evaluation, data acquisition, and numerical modeling. The procedure involves analyzing the correlation among wire rope characteristics, operation parameters, and failure types under practical operational circumstances. A comprehensive review of previous studies, standard regulations, and technical reports is undertaken to recognize typical wire rope failures, which include fatigue, wear, corrosion, and fretting. Necessary data on material attributes, wire rope construction (such as strands' arrangement and rope core composition), and operational parameters are acquired to build a solid base.

Industry standards such as ISO and technical guidelines are also consulted for conventional wire rope failure standards and inspection methods. Failure mechanisms based on literature review are categorized and evaluated accordingly.

## V. FINITE ELEMENT ANALYSIS

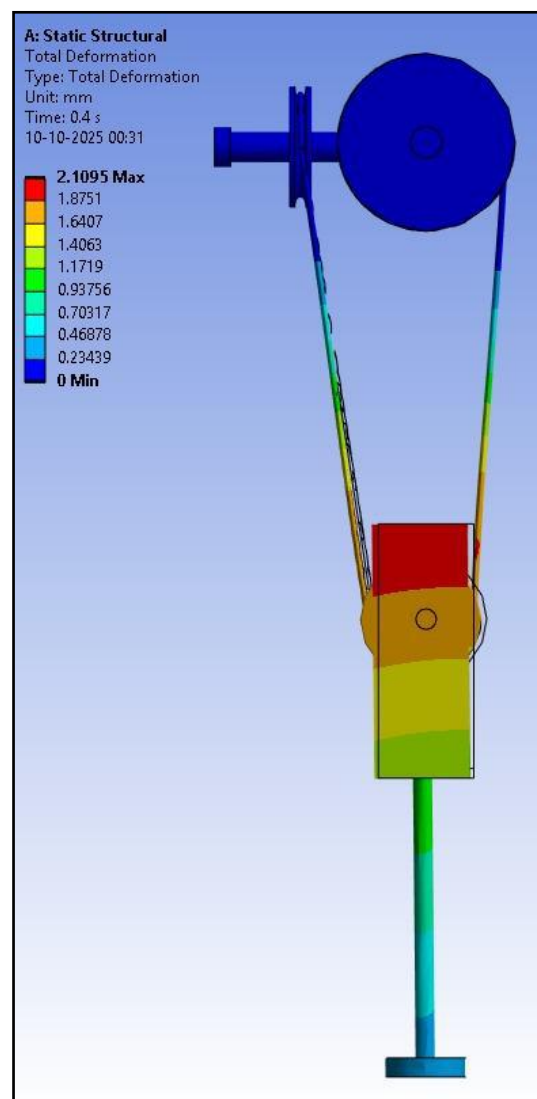


Figure 1: Total Deformation - Drum and Rope Assembly

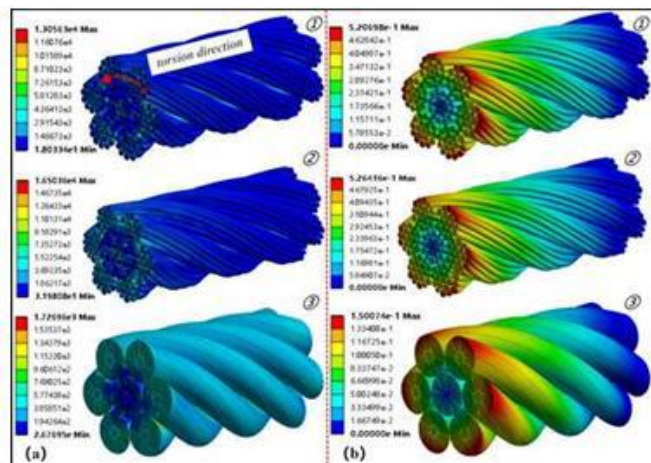


Figure 2: Finite Element Analysis of Wire Rope

## VI. CONCLUSION

The current research offers an analysis of failure characteristics of wire ropes in lifting applications, considering the influence of mechanical and operational factors on the wire rope's performance along with its environment-related aspects. Due to the complex helical design of wire ropes and their constant exposure to multiple load states, including tension, bending, and vibrations, wire ropes tend to deteriorate rapidly. Fatigue, wear, and corrosion are identified as the three main failure mechanisms for wire ropes. Out of all these mechanisms, fatigue proves to be the most important one, which is primarily caused by bending stresses and load variations. Wear results in the erosion of the wire rope due to the presence of friction, while corrosion considerably weakens the rope due to its negative impact on fatigue strength.

The use of FEA allows gaining important information regarding stress distribution within wire rope structure and identifying the key areas that could be vulnerable to failure. It has been found that the concentration of stress may usually appear on contact between wires and under the influence of repeated bending. Such knowledge of stress distributions will help in predicting wire rope failures.

Additionally, this work allows establishing the correlation between the key wire rope features like tensile strength, modulus of elasticity, type of construction, and core properties and their failure resistance. From the analysis it follows that choosing appropriate rope parameters in combination with lubrication and maintaining measures play a vital role in enhancing performance and increasing its service life.

To conclude, achieving enhanced safety and reliability of wire ropes presupposes using optimized design, efficient analytical approaches, and advanced maintenance techniques.

Proper inspection, selecting quality materials, and providing adequate operating conditions are some methods to reduce failure risks of wire rope.

## REFERENCES

- [1] Haas, T. N. (2007). Numerical (FEA) Evaluation of Crane End Buffer Impact Forces [Doctoral dissertation, University of Stellenbosch].
- [2] Haniszewski, T., Gaska, D. (2017). Numerical Modelling of I-Beam Jib Crane with Local Stresses in Wheel Supporting Flanges.
- [3] Huang, B. *et al.* (2023). NVH Analysis of Construction Hoist.
- [4] Kowal, L., Sinka, T. (2020). Drum Design Optimization Impact of winding drum shell ribbing of a hoisting machine on its strength and manufacture costs. *Mining Machines*, No. 4/2020 (164).
- [5] Mangalekar, S., Bankar, V., Chaphale, P. (2016). Design and Analysis of Central Drum in Mine Hoist. *International Research Journal of Engineering and Technology (IRJET)*, 03(06), 1111-1114.
- [6] Maw, N., Karbalai, D. (1989). Application of finite element modelling to winch drum design. *Transactions of the Institute of Marine Engineers*, 101, 225-234.
- [7] Mehendale, S. A., Wankhade, S. R. (2016). Design and Analysis of EOT Crane Hook for Various Cross Sections. *International Journal of Current Engineering and Scientific Research (IJCESR)*, 3(12), 53-58.
- [8] PSG College of Technology, Faculty of Mechanical Engineering. (n.d.). Design Data: Data Book of Engineers. *Kalaikathir Achchagam*.
- [9] Suratkar, A., Shukla, V., Zakiuddin, K. S. (2013). Design Optimization of Overhead EOT Crane Box Girder Using Finite Element Analysis. *International Journal of Engineering*.
- [10] Baillet, L., Limam, A., Tessier, C. (2002). Dynamic Behaviour of Overhead Travelling Cranes: Numerical and Experimental Approaches. *Journal of Sound and Vibration*, 255(3), 433-461.
- [11] M. Polat, R. Kösel, and İ. Kılavuz, "Experimental investigation of bending fatigue, breaking load and corrosion performance of steel wire ropes with independent wire rope core (IWRC) and impregnated plastic core (EPIWRC)," *METAL 2021 Conference, Brno, Czech Republic*, 2021.
- [12] Y. A. Onur and C. E. İmrak, "Discard fatigue life of stranded steel wire rope subjected to bending over sheave fatigue," *Mechanics & Industry*, vol. 18, 2017.
- [13] X. Chang, X. Chen, Y. Dong, H. Lu, W. Tang, Q. Zhang, and K. Huang, "Friction and wear behavior between crane wire rope and pulley under different contact loads," *Lubricants*, vol. 10, no. 337, 2022.

- [14] D. Bruski, "Determination of the bending properties of wire rope used in cable barrier systems," *Materials*, vol. 13, no. 3842, 2020.

#### **AUTHORS BIOGRAPHY**



**Mr. Avishkar J Patil,**  
Student, Dept. of Mechanical Engineering, AISSMS College of Engineering, Pune, Maharashtra, India.



**Mr. Samarth Y Mane,**  
Student, Dept. of Mechanical Engineering, AISSMS College of Engineering, Pune, Maharashtra, India.



**Mr. Varad R Ghule,**  
Student, Dept. of Mechanical Engineering, AISSMS College of Engineering, Pune, Maharashtra, India.

#### **Citation of this Article:**

Avishkar Patil, Samarth Mane, Varad Ghule, Yogita Funde, & Chandrashekar Dharankar. (2026). Failure Analysis of Wire Ropes in Lifting Systems. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(4), 242-246. Article DOI <https://doi.org/10.47001/IRJIET/2026.104035>

\*\*\*\*\*