What's Wrong With Our Hoist Ropes?

A GUIDE TO EXTENDING THE SERVICE LIFE OF ELEVATOR ROPES

Abstract

Hoist ropes are a frustrating and expensive aspect of maintaining traction elevators, especially in busy high-rise buildings. Citywide Elevator Consultants performs thousands of elevator maintenance audits each year, often identifying and reporting unsatisfactory conditions or warning signs relating to wire ropes.

This article was written to focus on the maintenance and repair practices that can extend (or reduce) hoist rope service life. The article mentions, but does not focus on, the many factors in elevator engineering that also account for variances in hoist rope life.

The technical information in this article has been compiled from Citywide's audit records and from the excellent set of Technical Bulletins and Service Bulletins published by Wirerope Works, Inc. (manufacturer of Bethlehem Wire Rope). The sixteen Bulletins cover most aspects of elevator ropes, explaining not only their construction, but also the many important aspects of application engineering, installation, and maintenance that significantly influence the service life of elevator ropes.

Introduction

Citywide Elevator Consultants perform many elevator maintenance audits each month as part of our Maintenance Monitoring service. The Maintenance Evaluation Report, which rates each elevator car in a building on twenty-one specific categories, often contains "unsatisfactory" ratings for hoist ropes on one or more cars. These ratings include photographs showing the condition of the ropes and a short descriptive term for the unsatisfactory condition such as "buildup", "rouge", "excessive lubrication", or "crown wear".

Fig. 1: When an elevator hoist rope fails

It's important for a building manager and their maintenance technician to understand what these ratings mean, as they are an indication that the hoist ropes in question may need to be replaced sooner than expected. Worse, some conditions may be signs of imminent catastrophic failure. (Figure 1). In some cases, the service life of the hoist ropes can be extended with better attention to maintenance. Often, unfortunately, the life of the existing ropes has already been irreversibly shortened, but steps can be taken to get more service life from the new replacement ropes.

Rope replacement is an expensive project and requires the elevator to be out of service for an extended time, possibly inconveniencing building occupants and visitors. So it is valuable to understand how and why hoist ropes wear out and what maintenance practices are essential to extending the service life of ropes as much as possible.

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It's important to recognize that, regardless of how well maintenance is performed, the service life of hoist ropes on different elevators will vary considerably due to design and usage factors that can be different among elevators in the same building. For the most part, those are unavoidable factors. The main purpose of this article is to explain the value of certain maintenance actions that can be planned and monitored that can make a significant difference in hoist rope life.

The numerous engineering differences among elevators that can impact rope wear will be mentioned throughout the article to explain why some ropes are likely to last longer than others in spite of good maintenance.

Background and Problem Definitions

Elevator rope construction

To fully understand how hoist ropes wear out, it's helpful to know something about hoist rope construction and the mechanical stresses that occur while an elevator is moving.

Figure 2 is a cross-section of a typical hoist rope, showing the fiber (sisal) core supporting the strands which are bundles of individual wires.

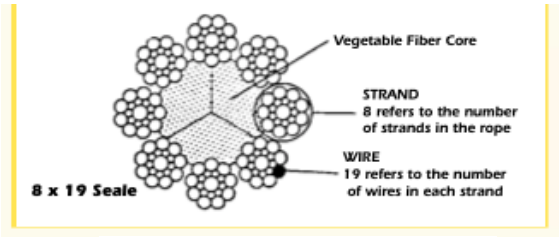

Fig. 2: Hoist Rope Construction

The core serves to keep the strands in proper relation to each other. The purpose of using a fiber core rather than steel is to increase the elasticity of the rope, reducing the bending stresses that occur as the rope passes over and under sheaves.

The fiber core has a certain moisture content when the hoist rope is new. During rope manufacture a light coating of lubricant is applied to the individual wires before the strands are formed, then residual lubricant is wiped from the strands before the rope is "closed", forming the final rope structure.

The fiber core, the moisture in the core, and the lubricant are all relevant to what occurs once the hoist rope is placed in service.

Initially, the lubricant serves to not only keep the strands from fretting (abrading) against one another as the rope flexes, but also to prevent moisture loss from the fiber core which would cause the core to shrink, reducing its diameter.

Rouging

During the first few years of rope usage, the lubricant on the wires is gradually squeezed outward to the outer surface of the rope. This loss of lubricant must be replaced with a proper application of new lubricant, otherwise the fiber core will begin to dry out. If the core dries out and shrinks, the strands will come into increasingly close contact, leading to fretting and abrasion as the rope is bent and unbent each time it passes over a sheave.

Figure 3 is a cross-section of rope where the fiber core has shrunk, with the strands wearing upon each other. Flattening of the contacting wires is easy to see in certain spots. This abrasion produces fine steel particles that are thrown to the surface of the rope and become a rust-colored dust known as rouge. Figure 4 is a photo of ropes passing over a drive sheave exhibiting significant rouging.

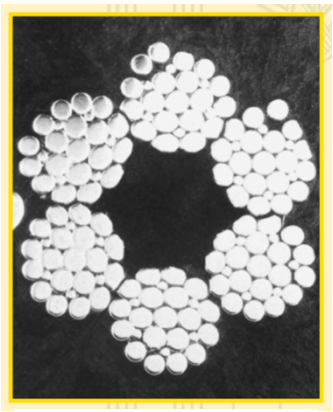

Fig.3: Internal rope wear

Fig. 4: Rouging

Rouge is not the same as surface rusting that might occur on the ropes if they were unlubricated and exposed to airborne moisture. Rouge is a loose powder that will eventually be found on other surfaces surrounding the hoisting machine. That powder is material that has been internally worn away from the rope strands, reducing the rope's cross-sectional area, reducing the strength of the rope, and consequently the rope factor of safety.

Buildup

If the outer surfaces of the hoist ropes have been heavily re-lubricated after internal strand wear has started, the fine steel wear particles may contaminate the surface oil, along with dust from construction and other environmental contaminants. Figure 5 shows the appearance of buildup. Studies have shown that lubrication buildup can contain as much as 90 percent solid contaminants, and as much as 2 percent water.

Fig. 5: Buildup

Rouge and buildup are thus symptoms of internal damage that has already occurred within the rope. The prevention for this destructive process is timely application of the correct lubricating oil once it is noticed that the factory lubrication is being depleted. Experienced elevator maintenance personnel can check regularly to determine the right time and the proper method for re-lubricating ropes. The lubricant used must not contain solvents or detergents which can dissolve the remaining oil between the wires. New lubricant must be applied slowly over time using a wick type method.

Excessive lubrication can be the result of trying to re-lubricate ropes too quickly and with more lubricant than the ropes can absorb. Extra lubricant on the surface of the ropes can attract abrasive contaminants, causing buildup and accelerating wear of the sheave grooves as well as the ropes.

Crown Wear

Crown wear refers to visible abrasion of the outer wires of a rope, as can be seen in figure 6. Significant crown wear results in thinning of the wires, leading to increased bending and fatigue stress as the rope passes over sheaves. An eventual result can be fatigue breaks as seen in figure 7. There are many circumstances that might lead to accelerated crown wear, some of which relate to abnormal sheave groove wear. Maintenance can play a role in preventing premature crown wear by regular attention to the condition of drive sheave grooves, making measurements when needed. This is especially important before installing new ropes, since worn grooves may provide insufficient support to new ropes which will initially be of larger diameter than the retired ropes. This will lead to a short life for the new ropes.

Fig. 6: Crown wear

Fig. 7: Crown fatigue breaks

Sheave Wear

Aside from internal abrasion and wear, wear-out of the sheaves as well as the ropes will accelerate due to improper contact and/or excessive contact pressure between rope and groove as well as bending fatigue.

There are various ways this can occur, many of which are related to design decisions made by the application engineer to adapt the elevator machinery to the spaces available in the hoistway and machine rooms.

Design features which can account for reduced rope life include those which increase the number of sheaves around which the hoist ropes must pass: 2:1 roping, basement machines, and double-wrapped drive sheave. In the case of double-wrapped, the ropes must approach some of the grooves at a slight angle (the fleet angle). The fleet angle becomes more severe when the secondary and primary sheaves are placed closer together. A fleet angle greater than about 1-1/2 degrees may cause significant abnormal sheave wear.

Maintenance cannot do anything to reduce the effect of these design factors unless there is an installation error that can be corrected. However, as previously mentioned, abnormal sheave groove wear may require repair or replacement of sheaves before the installation of new ropes to avoid short service life.

Rope Tension

Another important factor in rope and sheave wear for which maintenance is responsible is proper tensioning of ropes. The technical bulletin recommends re-tensioning at six weeks of service, again at six months, then checked annually. If rope tensions are not maintained to be within a 10 percent range then the sheave grooves will begin to wear unevenly, as shown in fig.8, eventually causing some ropes to take on more load and others to slip, accelerating wear. Once this type of wear has progressed beyond a certain amount, re-tensioning will no longer correct the problem, and the condition will continue to get worse. When new ropes are installed, if the uneven sheaves are not replaced or re-machined, the new set of ropes will also be impossible to tension properly and will wear even more quickly than the previous set.

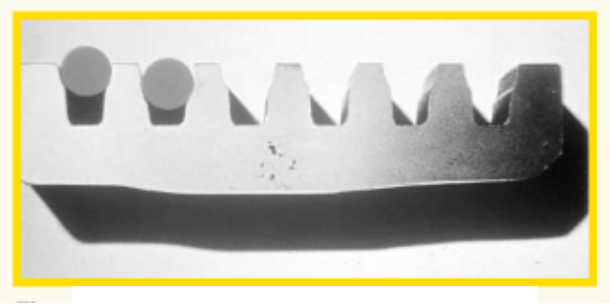

Fig.8: Uneven sheave wear.

Twist and Torque

An improperly sized or abnormally worn sheave groove shape, or sheave misalignment, can result in the rope developing uneven twist throughout its length, with extreme tightening or untwisting in certain places. See figure 9. This can be a sign of imminent rope failure. Releasing and turning the shackles to "spin out" the twist, along with re-tensioning, may sometimes extend the rope life, but the condition causing this problem needs to be found and corrected.

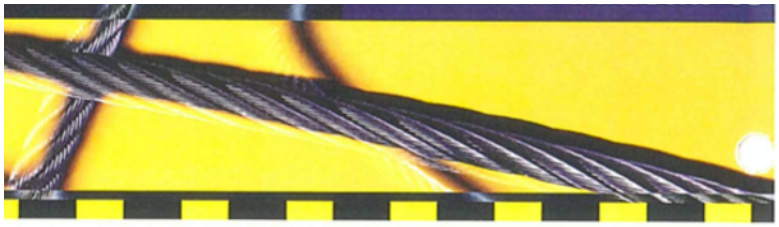

Fig. 9: Hoist rope torque and twist.

Solution Summary

1. There are effective steps that can be taken by maintenance once the elevator is in service to optimize hoist rope life:
    a. Rope tension measurement and adjustment after six weeks, after six months, and then annually.
    b. Check for depletion of factory rope lubrication during routine maintenance,
    c. Install rope lubrication applicators when needed. Remove once re-lubrication is adequate.
    d. Keep machine room cleaned of carbon dust and other contaminants that can be airborne and cause lubricant buildup.
    e. Clean ropes when buildup is noticed, to minimize the abrasive action of trapped solids.
    f. Be alert to uneven and extreme twisting and untwisting anywhere along the rope, as this can be an indication of imminent rope failure.
    g. Before installing new hoist ropes, carefully examine and measure the drive sheave grooves and other sheaves for uneven wear. Re-machine or replace sheaves as needed.

2. Many engineering factors unique to each elevator can contribute to hoist rope life being shorter or longer than average. These factors are often a compromise between adequate traction and satisfactory rope life, choices made to fit the elevator machinery into the available hoistway or machine room space. These conditions are generally not possible to change once the elevator has been installed.

Conclusions

Hoist ropes require careful examination and maintenance by an experienced elevator technician on a regular basis to get the longest possible service life.

Traction elevator configurations with more than two hoist rope sheaves such as basement machine, 2:1 roping, and/or double-wrapped will experience more rapid wear than the basic overhead machine configuration. Maintenance cannot mitigate these factors. However, there are well-defined maintenance tasks that can be performed on a regular schedule to avoid premature retirement of hoist ropes, and to ensure the best possible results with new hoist ropes.

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