

Steel Wire Ropes for Traction Elevators: Part One

by Dr.-Ing. Wolfgang Scheunemann, Dr.-Ing. Wolfram Vogel and Dipl.-Ing. Thomas Barthel

Learning Objectives

After reading this article, you should:

- ◆ Have developed a basic understanding of steel wire ropes for traction elevators.
- ◆ Have realized that steel wire ropes influence the entire elevator system over all phases of its utilization.
- ◆ Understand that steel wire ropes are exposed to a complex collection of stressors.
- ◆ Have learned that steel wires achieve extremely high strength

by a process of manufacture that combines forming with heat treatment.

- ◆ Have understood that a standard strand construction is little suited for elevator ropes.
- ◆ Understand that rope manufacturers advising elevator producers, elevator planners and operators are not only confronted with the rope as a machine element, but also, increasingly, the entire elevator system.

Steel wire ropes are among the oldest and most widespread machine elements, and are used in the form of stationary ropes, lashing and suspension ropes and traveling ropes. Traveling ropes of the kind used in elevators, cranes, shaft conveyors and hoisting devices are bent under tension over sheaves and coiled onto drums during operation. During these processes, steel wire ropes are exposed to a complex collective of stress factors comprising flexure, tension and compression that bring about wear.

In an application with such high safety relevance as the traction elevator, special importance is attached to steel wire rope, as it is required to comply with safety requirements appertaining to:

- ◆ An adequate service life
- ◆ Timely recognition of discard age before a hazardous state can arise
- ◆ Sufficient but simultaneously limited traction capability

At the same time, steel wire rope as a means of suspension influences

the entire elevator system over all phases of its utilization period. This includes the utilization characteristics of the elevator system. The suspension means depend on the rope design, as well as installation and operational maintenance.

The few examples listed here illustrate the closely meshed network of dependency factors and mutual influences that affect the application of steel wire ropes. Given this complexity, it is hardly surprising that rope manufacturers advising elevator producers, planners and operators are confronted with such diverse issues that affect not only the rope as a machine element, but also, increasingly, the entire elevator system. These issues, which have arisen over many years of work in the field of technical consultancy and sales at Mülheim an der Ruhr-based Pfeifer Drako Drahtseilwerk GmbH & Co. KG, have been collated and arranged systematically by topic.

The series of articles titled "Steel Wire Ropes for Traction Elevators"

Continued



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addresses these topic areas in the form of frequently asked questions and answers. In this first part of the series, the emphasis is on questions relating to the fundamental building blocks of the rope (such as the wire, strand, core and lubrication), the structure and design of the steel wire rope, and valid technical regulations. The following sections contain questions relating to:

- ◆ Rope terminations
- ◆ Assembly and handling
- ◆ Mechanical characteristics such as rope elasticity, vibration characteristics, etc.
- ◆ Prestretching and shortening of ropes
- ◆ Relubrication
- ◆ Recognition of discard age and its criteria
- ◆ Drive capability and rope grooves
- ◆ Elevator-typical rope damage

Finally, an explanation is provided on the right choice of steel wire rope for traction elevators.

Why Are Wire Ropes Used in Elevators?

Due to its construction and the structure consisting of many individual steel wires, steel wire rope offers advantages that clearly qualify it for use on elevators. Its benefits are its redundancy and the capacity to identify the possibility of the end of service life or (preferably) the correct time for discarding the rope before its condition becomes dangerous by means of externally visible criteria such as wire breakages.

In What Way Are Wire Ropes Exposed to Stress When Traveling over the Traction Sheave?

When running over the traction sheave and deflection sheaves, the



Figure 1: Fiber core, strand and wire

wires in the ropes are exposed to a high complex of stress factors comprising tension, flexural stress, torsion and compression, which contribute toward material fatigue. During flexural stress, the wires bend in relation to each other. The friction created between the wires results in additional abrasive wear. Added to this is the influence of corrosive media. With increasing use, the abrasion characteristics become more pronounced – for example, the number of wire breakages over defined reference lengths increases. Regular inspection permits the correct time for exchanging the rope to be determined or the remaining service life to be estimated.

What Is Meant by Redundancy?

Redundancy actually means superfluity, a factor that is of extreme importance in the case of safety-relevant applications. A basic distinction is drawn here between active and passive redundancy. Active redundancy is provided by the interaction between wires laid jointly to create a rope or the multiple arrangements of suspension ropes in elevator systems. If one component fails, the remaining components take on its functions in line with their configuration. Passive redundancy relates for example to safety gears that only move into action in the event of an uncontrolled travel movement.

Structure and Components of Steel Ropes

The helical structure of the wires in the strands and the strands in the rope (Figure 1) addresses the fact that an elevator rope is bent over a sheave. This effect becomes evident if we imagine first a parallel wire bundle being bent over a sheave (Figure 2). The inner wires lying on the sheave are too long, and the outer wires are too short. Premature failure is the anticipated result. In a wire rope (Figure 3), the areas with excess length and those with insufficient length lie next to one another when running over a sheave (i.e., the strand only needs to shift marginally to achieve length compensation). For the individual wires in the strands, the same principle applies. When running over the sheave, all components – strand against strand and wire against wire – are in continuous movement.

What Makes Steel Wire So Special?

The raw material for steel wire is unalloyed carbon steel with a carbon content of 0.4 or better (0.6 to 0.8% by weight). Other materials such as silicon and manganese are only present in minimal quantities, as regulated by EN 10 016.^[1] Steel wires for elevators have nominal tensile strengths of 1370, 1570 and 1770 N/mm². Higher strength levels of up to 2500 N/mm² are possible with

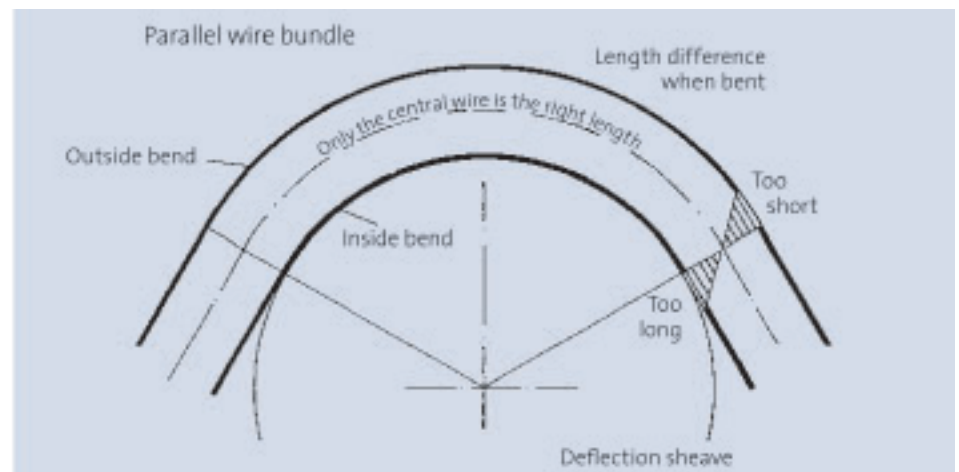


Figure 2: Parallel wire bundle running over a sheave

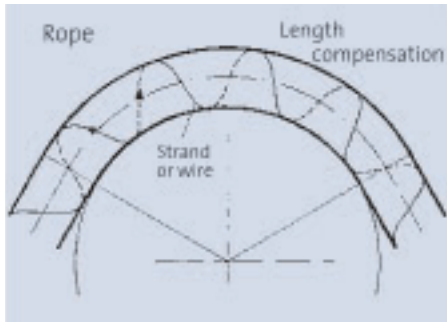


Figure 3: Rope running over a sheave

special approval. A steel wire achieves these extremely high strength levels by a process of manufacture that combines forming with heat treatment. This entails passing rolled wire with a diameter between 5 and 10 millimeters through “nozzles” (wire drawing dies) by repeated drawing when cold to gradually reduce the diameter. During this process, its tensile strength increases by a factor of 3 to 6. Between the drawing processes, the material is exposed to controlled heat treatment, which performs a process known as patenting. The relatively high tensile strength of the steel wires – characterized by extreme microstructure banding – is consequently not the result of factors such as a high content of alloying elements, but of material forming that has occurred when in a cold condition (Figures 4 and 5).

Influence of Temperature

Heat damages the wire. It is said that high-strength banded forced microstructure regains its original strength of around 400 N/mm². The period of exposure to heat by fire, friction heat, radiated heat, light arcs and heat from welding also exerts an effect on the residual serviceability properties of the wire. At a temperature of 480°C, a complete microstructure transformation takes place after 15-30 minutes. At higher temperatures, just seconds can be enough to cause permanent damage to thin wires of the kind used in products such as elevator ropes.

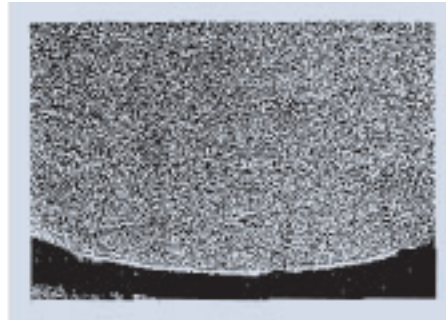


Figure 4: Material microstructure, cross section

Special Material

Consideration is being given in different quarters to the possible use of alternative wire materials made of stainless steel. However, ropes made of these materials have little to recommend them for use in traction elevators due to their inferior fatigue bending properties compared to ropes made of carbon-steel wires. They command an extremely high price and also come with a note of caution: The ropes supplied from stock by dealers generally lack a good geometry and the carefully controlled lubrication essential for elevator ropes.

What Is the Significance of Wire Nominal Tensile Strength?

The nominal tensile strength of wires can be set within broad limits. What is finally used depends on a range of factors, often also determined by traditional values. These include low sheave-hardness levels and also locally applicable regulations and customs (Figure 7). If the sheave has a low hardness level, it must be considered that the hardness of the wire depends upon its tensile strength. Experience has shown that by using soft sheave materials together with “non-hard” wires, rope impressions can be avoided in the grooves. But in seeking an explanation, it is not sufficient to state that, for instance, wires with a nominal strength of 1370 N/mm² are simply not as hard as those with a strength of 1570 N/mm². In this case, the wire strength drops only

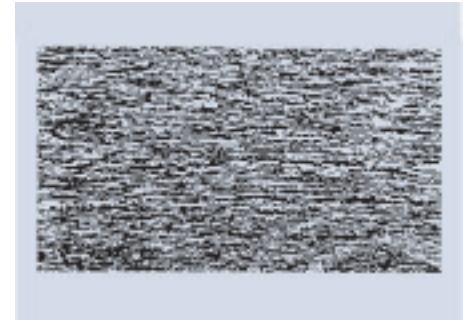


Figure 5: Material microstructure, longitudinal section

from 470 HV (445 HB) to 410 HV (390 HB). Even the “softest” wire in a rope of strength class 1370/1770 (i.e., having outside wires with a nominal tensile strength of 1370 N/mm²) is still twice as “hard” as a good sheave with a hardness of between 210 and 230 HB.

One reason why low rope grades are customary in certain localities can be regionally applicable regulations permitting low rope-safety factors. Due to high levels of contact pressure, a higher degree of groove wear or the effect of rope impressions occurs. This can be alleviated by using ropes with “non-hard” outer wires.

Rope Grade

European and international elevator-rope standards EN 12385 – Part 5^[2] and 4344^[3] have coined the term “rope grade” to describe rope strength. It defines the nominal tensile strengths of the outer and inner wires, and assigns the rope a defined minimum breaking force. Rope grade 1370/1770 means that a rope has a “mixed strength” (termed “dual tensile” in ISO 4344) in which the outer wires of the outer strands have a nominal tensile strength of 1370 N/mm² and the inner wires of the rope have a strength of 1770 N/mm². Rope grades used for suspension ropes and governor ropes are summarized in Figure 7. Based on a suitable wire material (carbon-steel content and purity level matching the targeted wire nominal tensile strength), wires in the rated-strength

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range of 1350-1800 N/mm² demonstrate practically the same fatigue-bending properties under the same degree of stress.

For elevators in high-rise buildings with greater rope weight from the need to have a large number of ropes at lower tensile strengths, higher rope grades of 1770 are frequently used to reduce the number of ropes without reducing the safety factor. Rope grades of 1770 are also preferred for the operation of drum-driven elevators and roped hydraulic elevators.

In some cases, suspension ropes with wires of 1960-grade rope are manufactured. However, these are no longer regulated in accordance with EN 81-1/1998^[5] and require special approval (a Certificate of Conformity). For governor ropes these restrictions do not apply, and 1960-grade ropes are used in combination with hardened sheaves.

What Is the Correlation between the Strength and Hardness of Wire?

Wire hardness rises on a linear basis with nominal wire strength (Figure 6), which is lower in elevator ropes than in crane ropes. The limited nominal wire strength and resulting limited wire hardness should protect the traction sheave against wear. However, Figure 6 also shows that the wire is always far harder than the unhardened sheave (Brinell hardness HB). Measurement of the

wire micro-hardness (Vickers hardness HV), which is occasionally requested by elevator producers in the Far East, is only relevant if soft sheave material and a low rope safety factor necessitate the use of a “non-hard” wire material. Generally speaking, the correlation between wire tensile strength and wire hardness follows the progression shown in Figure 6 for all carbon steel wires with a certain scatter range. More detailed information is provided in DIN 50 150.^[4]

How Are Wires Protected against Corrosion?

Elevator ropes are customarily made from bright wires. The light lubricant coating on the wires in elevator ropes is generally sufficient as a protection against corrosion in dry lift shafts. For outdoor elevators, elevators operating in extremely damp or humid climates or in aggressive environments, the ropes should be made of galvanized wires. This type of rope has proven successful in lifts for decades. Water-resistant lubricants should be used in their manufacture and for relubrication. In the tropics, where torrential downpours of rain pose the ever-present risk of water

penetration in the lift shaft, the governor rope should be galvanized even for indoor elevators. The only drawbacks of galvanized ropes are a price markup of around 10% and, in some cases, prolonged delivery periods. Due to the higher costs involved, the lower fatigue bending strength, etc., stainless-steel ropes are little suited for use as elevator ropes.

Strands

Suspension ropes for traction elevators are regularly produced using Seale, Warrington and Filler strand constructions. The diagrams illustrate the strand constructions for a Seale (1-9-9), Warrington (1-6-6+6) and Filler (1-6-6F-12) rope, each with 19 strands. Warrington-Seale strands are less commonly used (and generally for larger rope diameters).

The strands listed above in a so-called parallel strand construction are characterized by the fact that the lay length of the wires in the wire plies is identical, with one wire from the outer ring positioned in linear formation in the channel provided between two wires below. No wires cross over each other in the strands, markedly reducing the incidence of abrasion.

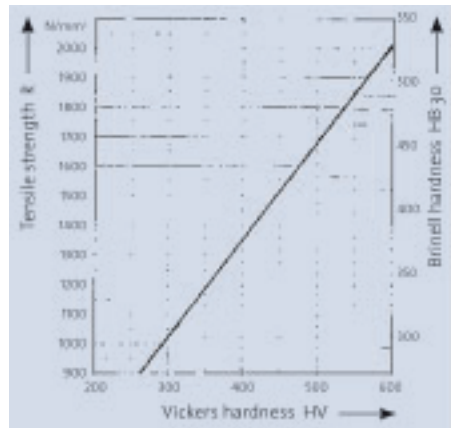


Figure 6: Tensile strength, Brinell/Vickers hardness

Country	National name of rope grade	Type	Equivalent rope grade		
			Traction elevator	Roped hydraulic elevator	Governor rope
Europe	1370/1770	Dual tensile	1370/1770		
Additionally in France, Germany, Italy, England	1570	**)	1570	-	1570
	1770	**)	1770	1770	1770
	1960	**)	-	-	1960
England	1180/1770	Dual tensile	1180/1770	-	-
USA	Traction Steel	Dual tensile	Appr. 1180/1770	-	Appr. 1180/1770
	Extra high strength traction steel	Dual tensile	Appr. 1570/1770	-	-
	IRON	Dual tensile	-	-	Appr. 700/1180
Japan	Grade E to JIS (3525)	Dual tensile	1320/1620		
	Grade A	**)	1620	1620	

Figure 7: Internationally customary rope grades

* See section 2.2.1

** Rope comprises wire with just a single nominal wire tensile strength

In standard strand constructions (known today as cross-lay constructions), wires cross over each other in the strand. In these strands, the wires make contact with each other at specific pressure points, resulting in high levels of pressure between the wires and secondary flexural stress. Due to the increased wear and the risk of internal wire breakage, standard construction is little suited for elevator ropes, but is still found in some cases in the form of thin ropes – for example, in dumbwaiters and speed limiters.

When designing a strand, it is important to take into consideration the fact that most wires in the strand cross section appear in the form of ellipses. Consequently, the process of designing and monitoring the structure of high-performance elevator ropes is performed nowadays using the latest data-processing methods.

What Is a Seale Strand?

The world’s most frequently used strand construction for elevator ropes is the 19-wire Seale strand (1-9-9). Because of the thick outer wires, the Seale strand offers a higher degree of resistances against external wear in use when running over the traction sheave and the deflection points.

What Is a Warrington Strand?

The Warrington strand features far thinner wires in the outer wire

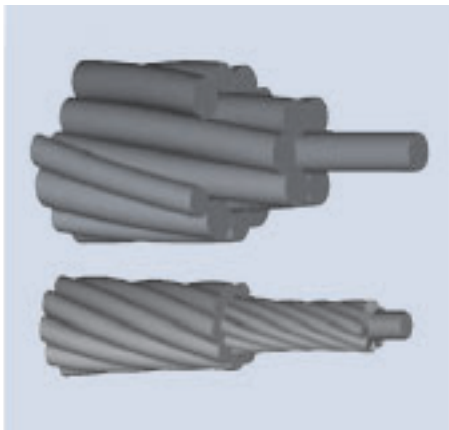


Figure 8: Position of strand wires in parallel constructions

circle than a Seale strand. This makes for a marked reduction in flexural stress. During fatigue bending tests on round grooves, ropes made of Warrington strands with a 1-6-6+6 construction achieve around a 20-40% longer service life than comparable ropes made using Seale strands. Ropes made from Warrington strands are used in traction elevators with double-wrap drives and in roped hydraulic elevators. Consequently, both Seale and

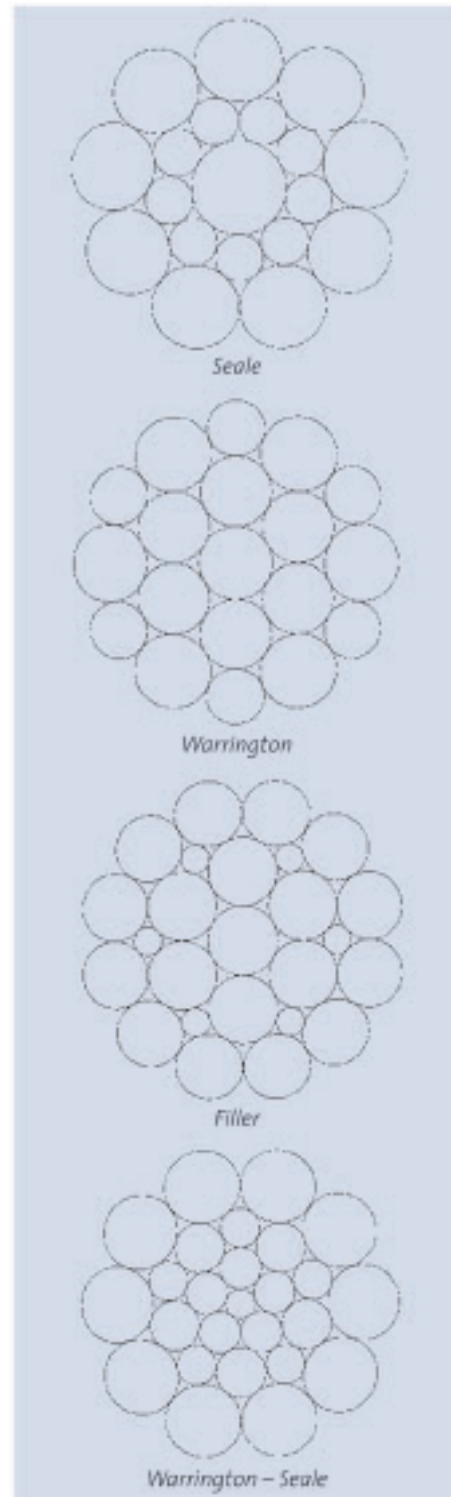
Warrington are encountered as strand constructions for elevator ropes in countries such as Germany and the U.K.

What Is a Filler Strand?

Ropes made using the Filler strand construction also offer very good fatigue bending properties. Based on fatigue bending tests, the 8 X 21 Filler strand with fiber core (strand: 1-5-5F-10) has been adopted by Canadian elevator standards. Elevator ropes with a diameter of more than 16 millimeters (5/8 inch) should be designed with a Filler construction (1-6-6F-12) due to their improved flexibility. The Filler construction is particularly well suited for six-strand ropes. The Filler strand is sensitive to geometrical distortion. This applies in particular where the wire diameter deviates from the nominal diameter. In the case of ropes with rope diameters lower than 10 millimeters, Filler construction is not advisable due to the extreme thinness of the Filler wires.

What Is a Warrington-Seale Strand?

Warrington-Seale strands are used where large rope diameters are involved in which the outer wires of a Seale strand would become excessively thick, but a high abrasive resistance is imperative. This applies in the case of compensating ropes with a diameter around 24 millimeters and for suspension ropes with a diameter around 22 millimeters. It is advisable to convert to this strand



construction when using rope diameters in this range. In some cases, well-lubricated ropes with a 6 X 26 Warrington-Seale construction (strand structure: 1-5-5+5-10) have proven the ideal solution for elevator drive systems with a large number of sheaves positioned closely with one behind

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the other and reverse bending. Ropes produced using Warrington-Seale construction are sensitive to disturbances to the rope geometry and/or running on traction sheaves with V-grooves or U-groove with undercut. They should be used with round grooves.

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Dr.-Ing. Wolfgang Scheunemann is technical director and head of the Technical Competence Center at Pfeifer Drako Drahtseilwerk GmbH & Co. KG.

Dr.-Ing. Wolfram Vogel is head of Research and Development at Pfeifer Drako Drahtseilwerk.

Dipl.-Ing. Thomas Barthel is head of Testing for Elevator Technology at Pfeifer Drako Drahtseilwerk.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 133 of this issue.

- ◆ Why are wire ropes used in elevators?
- ◆ In what way are wire ropes exposed to stress when traveling over the traction sheave?
- ◆ What is meant by redundancy?
- ◆ Why do the wires in the strands and the strands in the rope have a helical structure?
- ◆ What makes steel wire so special?
- ◆ What is the significance of nominal wire tensile strength?
- ◆ What is the correlation between the strength and hardness of wire?
- ◆ How are wires protected against corrosion?
- ◆ What is a Seale strand?
- ◆ What is a Warrington strand?
- ◆ What is a filler strand?
- ◆ What is a Warrington-Seale strand?



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1. What are the safety requirements for the use of running ropes?
 - a. Adequate service life.
 - b. Lubrication properties.
 - c. Sufficient traction capability.
 - d. Ride quality.
 - e. Both a and c.
2. What is *not* an advantage for the use of steel wire ropes in elevators?
 - a. Low mass.
 - b. Active redundancy.
 - c. Low noise.
 - d. Externally visible discard criteria due to usage.
3. What is redundancy?
 - a. Multiple arrangements.
 - b. A group of elevators.
 - c. A special screwdriver.
 - d. A possibility to decrease safety.
4. What happens by drawing the wires?
 - a. Low strength results.
 - b. High strength results.
 - c. The steel's color can be seen.
 - d. Low elasticity modulus.
5. What is a strand in parallel construction?
 - a. An Aramid strand.
 - b. A standard strand.
 - c. A filler strand.
 - d. A fiber core.
6. How many wire diameters do you need for a Seale strand?
 - a. Two.
 - b. Three.
 - c. Four.
 - d. Five.
7. What is *not* used to protect wire from corrosion?
 - a. Zinc coating.
 - b. Lubrication.
 - c. Covering.
 - d. Cleaning with acid.
8. What is a rope grade?
 - a. The definition of corrosion protection.
 - b. The definition of rope diameter.
 - c. The definition of rope strength.
 - d. The definition of rope material.
9. Which type of stress is rope wire exposed to when running over sheaves?
 - a. Tension.
 - b. Flexural.
 - c. Torsion.
 - d. All of the above.
10. Which is an influence temperature can cause on steel wire rope properties?
 - a. Loss of lubrication.
 - b. Increase in strength.
 - c. Increase in lubrication.
 - d. Loss of diameter.

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