Ropes and rope constructions

Barthel, Thomas; Scheunemann, Wolfgang; Vogel, Wolfram

The six articles in a series entitled "Steel Wire Ropes for Traction Lifts" delve into questions of concern to rope makers and users in recent years. These articles are intended to help answer questions frequently asked and to support troubleshooting whenever a combination of elevator and suspension ropes behaves in an unexpected fashion. Many of the answers stem from research projects or from work carried out with lift owners or operators when searching for the cause of a problem. At this juncture the authors would like to thank all those involved for their frankness and openness.

When is an 8-strand rope with steel wire core used?

The 8-strand rope with steel wire core (Fig. 18) offers most of the benefits and only few of the drawbacks of 8-strand ropes with fibre core.

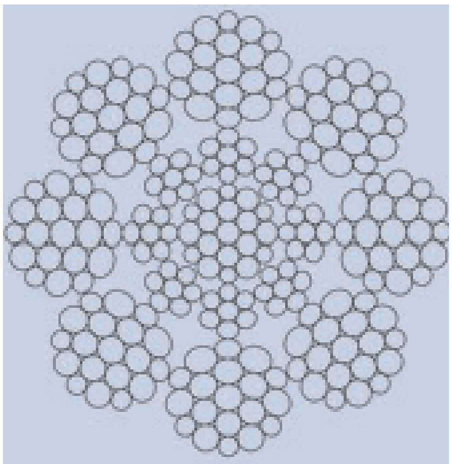


Fig. 18: Draffko 205 T, 8 x 19 W + IWRC

Benefits:

- 8-strand ropes are rounder than 6-strand ropes,
- 8-strand ropes with steel core keep their round cross-section in operation and are consequently ideally suited for grooves with a large undercut,
- 8-strand ropes are flexible and offer good fatigue bending characteristics,
- No permanent and elastic elongation,
- Low rope diameter under load, also over time and
- High breakage force relative to diameter.

Field of application:

The 8-strand rope offers an easy-maintenance solution for high-duty elevators, and is used preferably for rope lengths of between 50 and 100 m.

It is important to ensure that the rope termination – as of course applies to all elevator ropes – is secured against rotation. When used for extreme shaft heights, the ropes should untwist as little as possible during installation. The grooves of the drive sheave should be inspected when changing ropes.

When is a 9-strand rope with steel wire core used?

The 9-strand elevator rope was developed in 1955 as probably the first elevator rope with steel wire core, in the form of the DRAKO 300 T (Fig. 19).

Benefits:

- A very round cross-section, consequently low contact pressure between the rope and groove,
- A large number of thinner wires, consequently very good fatigue bending characteristics. In addition, a special arrangement of the wires in the strands and the strands in the rope helps to prevent wire overcrossing, and so reduces the danger of internal wire breakage invisible from the outside.
- Minimal permanent and elastic elongation and consequently good stop accuracy even in high shafts.

Field of application:

The 9-strand elevator rope is the best solution as a suspension rope for all elevator installations with large shaft heights and also for traction drive elevators with a large number of deflection sheaves.

It is important to ensure that the rope termination is secured against rotation. When used for extreme shaft heights, the ropes should untwist as little as possible during installation. It is expedient for a marking line to be provided on the rope as an aid to checking and if necessary correcting the rope alignment. The grooves of the drive sheave should be inspected when changing ropes.

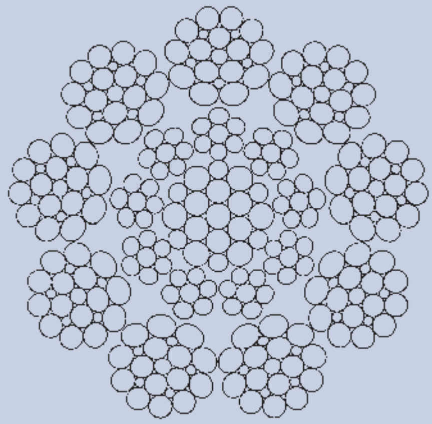


Fig. 19: Drako 300 T, 9 x 25 F + IWRC

What are parallel laid ropes?

In the rope constructions illustrated so far, the rope core and the outer strands are laid independently of each other in separate work processes. These ropes are durable and relatively insensitive to loosening as a result of external effects, for example due to rope deflection. In a parallel laid rope, the rope core and strands are laid in a single work process with the same length of lay, whereby the outer strands are placed in linear formation in a bed formed by two strands of the rope core, Fig. 20. These ropes demonstrate a high breakage force and in some cases very high fatigue bending characteristics in laboratory testing with short rope lengths. However, they are sensitive to untwisting during installation and/or due to rope deflection, which is practically impossible to avoid in a 2:1 suspension.

The use of deflection sheaves can also be highly critical with this type of rope. Experience has shown that their use is unproblematic for ropes of up to around 40 metres in length. To extent to which rope lengths in excess of this work satisfactorily depends on the experience of the respective rope manufacturer, but in particular upon the elevator installation itself.

Which suspension ropes are used for roped hydraulic elevators?

In the case of roped hydraulic elevators, the suspension ropes only run over deflection sheaves with round grooves. The

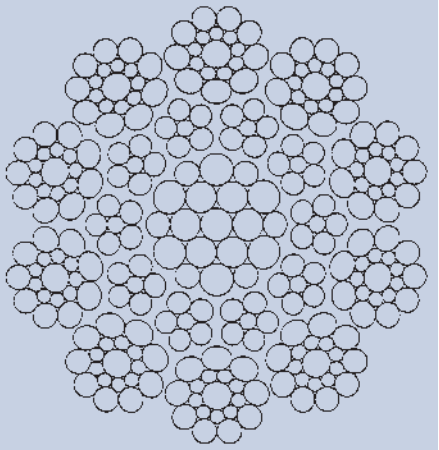


Fig. 20: Drako 310 T, 10 x 19 S + PWRC

absence of a drive sheave means that for instance liberally lubricated ropes can be used. Furthermore, the use of round grooves makes for higher specific rope tensile forces. The typically used rope constructions here are 6-strand ropes with fibre core which have been exposed to a particularly rigorous pre-stretching process (Fig. 15), and 8- and 9-strand ropes with steel wire core (Fig. 18 and Fig. 19). The customary rope grade is 1770, and for ropes with a steel wire core occasionally even 1570 and 1570/1770.

What are compensating ropes (tensioned balance ropes)?

For traction elevators with rated speeds of over 2.5 m/s, tensioned balance ropes are stipulated as a method of weight compensation and to limit compensating weight jump brought about by the safety gear or the buffer. The suspension and balance ropes differ fundamentally in terms of their application conditions. The experience of past decades has culminated in special balance rope constructions permitting greater rope service life, quieter running and consistent rope lengths. These constructions are based on the following requirements:

- Improved lubrication,
- An extremely round cross-section and consequently minimal contact pressure between the rope and groove,
- A large number of thin wires and consequently extremely good fatigue bending characteristics,
- Use of thicker and consequently fewer ropes and tensioning sheaves,
- Use of thicker ropes with small D/d = 30 and consequently the ability to select flexible multiple-wire rope constructions, Fig. 21.

Rope rotation cannot be excluded, as frequently 2 tensioning sheaves are arranged side by side. This can be sparked initially by alignment errors. Premature rope damage is possible, in particular in the case of ropes with steel wire core. Ropes with a natural fibre core respond under typically low balance rope forces to changing humidity in the shaft (construction phase, monsoon climatic conditions etc.) by marked changes in length. Artificial fibre cores have been shown to provide a solution to the problem. 6-strand ropes with a high weight and artificial fibre core are recommended as balance ropes. For rope diameters of d = 13 mm to 25 mm, for instance, 6 x 25 fillers and for larger nominal rope diameters, 6 x 36 Warrington Seale constructions are used.

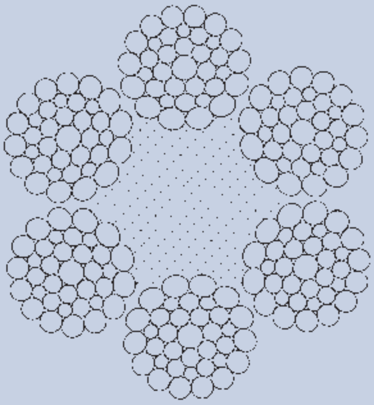


Fig. 21: 6 x 36 WS + NFC

What are overspeed governor ropes?

Governor ropes are an essential functional element of the overspeed controller, which engages the safety device when an overspeed situation is detected. The governor rope runs in a moulded groove of the governor wheel. When the safety device is triggered, force is transmitted by friction between the rope and groove. Consequently the metered rope lubrication plays a significant role. During recent years, increasingly stringent demands have been made on breaking forces, which are increased as a result of larger rope diameters, higher rope grades or the use of full steel constructions.

Generally traditional 6-strand rope constructions with fibre core are used as governor ropes, in most cases 6 x 19 Warrington + FC as illustrated in Fig. 15. These are generally speaking ropes with a diameter of 6 mm or 6.5 mm in rope grades 1770 and in some cases even 1960. However, EN 81 excludes rope grade 1960 for use in suspension ropes, but allows it for governor ropes. With increasing shaft heights and consequently rope lengths, the degree of rope strength required also increases. This results in the use of governor ropes with rope diameters of between d = 8 mm and 10 mm, and in some cases up to 13 mm with an 8 x 19 Warrington or 8 x 19 Seale + IWRC rope construction, Fig. 18.

A certain proportion of modern overspeed controllers do not decelerate the governor rope by blocking the governor wheel, but by means of closing brake shoes. The governor rope required for this design must not have excessively fine wires or strands. Although most of the above described rope constructions have proven successful in the various different overspeed governor designs, determining the type of rope construction used should lie within the sphere of responsibility of the overspeed governor producer.

If ropes with fibre core are used as governor ropes in particularly tall buildings, preference should be given to ropes with synthetic fibre cores. However, in this case these should be subjected to rigorous pre-stretching in order to limit their elongation in operation. This is particularly important given that governor ropes must be pre-tensioned and the tensioning path is limited. In the USA, a certain proportion of governor ropes of strength class IRON are still encountered. The nominal tensile strength stipulated for the outer wires in these ropes of 700 N/mm² is due to the brass brake shoes used in some speed governors. Using steel ropes complying with higher rope grades, presumably these would be at risk of excessively fast wear.

Rope core

Depending on the intended application, two different core types are used in elevator ropes: Fibre cores made of natural or synthetic fibres, and steel wire cores.

What is a fibre core?

In elevator ropes, fibre cores made of natural or synthetic fibres are used. Natural fibres – generally Sisal – are the most widespread for application in ropes. Due to their flexibility, ropes with fibre cores are able to adjust up to a certain extent to the relevant groove shape. The benefits of fibre cores

- Resistance to contact pressure,
- Relatively low elastic rope elongation and
- Low deformability.

The drawbacks are that

- Good yarn qualities (i.e. thin, even yarns) are expensive and not easy to come by,
- The material absorbs moisture from the ambient air and
- Rotting is a possibility.

The fibre core fulfils the role of a lubricant store. Its ability to absorb high quantities of grease can also become a drawback, however. Storing too much lubricant during manufacture and giving off too much during operation result in fast rope diameter shrinkage, as grease pressed out of the fibre core equates to a loss of volume in the fibre core.

Artificial fibres such as polypropylene (PP), which is in popular use for crane ropes and cable car ropes, are also used for elevator cables. Ropes with this type of core are frequently involved where groove wear takes place on the sheave with a hardness of below 200 HB. Despite the many benefits, it must be borne in mind that fibre cores for elevator ropes with small diameters of 7 mm and below made of natural fibres cannot always be manufactured to an adequate degree of diameter accuracy, no matter how meticulously produced.

However, fibre cores made of polypropylene offer the benefit of immunity to rotting in humid environments and also to volume change. The drawbacks of the PP core are its high elastic elongation and associated increased risk of rope impressions being created in sheaves.

For governor ropes and balance ropes in installations involving long rope lengths, in particular in environments with high levels of humidity, chemical fibre cores should be the preferred choice. Natural fibres absorb moisture, making the core thicker and the rope shorter. Where longer governor rope lengths are used, the relatively low tensioning path usually remaining is not sufficient. Polyamide fibres have produced excellent results as fibre cores for ropes running in round grooves due to their resistance to pressure. However, they come at a relatively high price. Fig. 22 provides a comparison of the various fibre materials available for fibre cores in elevator ropes.

The tasks performed by lubricants will be illustrated at a later juncture. However, it may be stated that special requirements are imposed on the evenness of the core and also metered lubrication. The influence of the rope core on the service life of ropes is frequently underestimated.

What is a steel wire core?

Steel wire cores increase the metallic cross-section and so reduce tensile stress in the individual wires. Ropes with steel wire core are subject to lower elongation under the same load conditions as ropes with a fibre core. The steel wire core can take on widely differing forms, Fig. 9. The steel wire core can be manufactured separately (independently) in a preceding work step prior to laying with the strands, Fig. 18 and Fig. 19. Another variant is to produce the steel wire core and the strands in a single work step, i.e. in parallel, Fig. 20. The outer strands and the strands of the steel wire core are placed – in a similar way to the wires in parallel laid ropes – so that they make linear contact with each other.

Fibre material	Grease absorption, approx.	Pros	Cons
Natural fibre Sisal	Up to 17 %	Good grease absorption, pressure-resistant, little longitudinal elasticity	Sensitive against high air humidity
Natural fibre Hemp	Up to 22 %	Good grease absorption, good strand bed, little longitudinal elasticity	In the diameter less stable than Sisal, Sensitive against high air humidity
Natural fibre Jute	Up to 20 %		Only for ropes with less than 6 mm diameter
Chemical fibre Polypropylene	Up to 12 %	Regularly thick	Little pressure-resistant, plastifiable, Can smelt out under high temperatures
Chemical fibre Polyamide	Up to 8 %	Very pressure-stable, Regular	Little grease absorption, expensive, High longitudinal elasticity, (rope production problematic), Meltable
Chemical fibre Aramide, e. g. Kevlar	Little	In fibre form nearly as tension-proof as steel, temperature-proof up to about 350°	In fibre form hard to be processed as fibre insert. Very expensive

One factor that all ropes with steel cores have in common is that the ropes must not be permitted to rotate during installation. Although it is true to say that ropes should always be laid with care, the negative influence of rope rotation in ropes with fire cores is less pronounced than is the case in ropes with steel wire cores. While in ropes with fibre cores all the strands become evenly longer or shorter when the rope rotates, in ropes with steel wire cores the outside and inside strands loosen to a different degree. This can result in pronounced differences in terms of load carrying capacity and consequently serve to shorten service life.

How important is the lubrication of strands and cores during manufacture?

Wires, strands and cores are important components of the rope, which however are only able to interact ideally in the presence of lubrication between the wires. The only reason a rope is able to bend so easily is because the wires are capable of displacement relative to each other. Lubrication reduces friction between the wires. However, in particular in the case of elevators, it is totally false to assume that "the more the better". On the contrary, an elevator rope which is subjected to frequent bending over sheaves over a service life of many years must be lubricated well but to a precisely metered degree. It should be noted in this context that the lubricant does not impair the necessary traction, which is determined by the geometry of the traction sheave but also by the coordinate of friction between rope and sheave. Thought should also be given to the risk of contamination by grease or oil spun off under central force. Traction elevators differ considerably depending on their design in terms of the traction reserve, in other words the difference between the theoretically available traction and the traction used. Elevator ropes are only seldom produced specifically for one elevator installation. The rope manufacturer must always base his calculation on the worst case scenario and should only lubricate elevator ropes as a rule with a relatively minimal quantity, with extreme care and as evenly as possible. Degreasing ropes to resolve the problem of excessive lubricant is extremely time consuming and cost intensive. Due to the long service life of ropes in elevator installations, particular attention is attached to relubrication. Here, the same requirements apply as for initial lubrication, whereby steps must be taken to ensure that lubricants used for initial and subsequent lubrication are chemically compatible. For application in traction elevators, lubricants containing bitumen are not ideal, as they tend to form highly viscous adhesive encrustations on both sheaves and ropes. Friction-reducing elements such as molybdenum sulphide or Teflon particles should be dispensed with, as their influence on traction can be very difficult to predict and they unnecessarily add to the cost of the application.

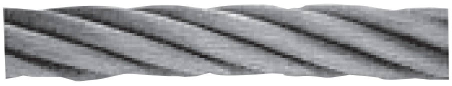
What is the significance of the direction of lay?

A distinction is made when considering the direction of lay between right and left-hand lay ropes. As rule, elevator ropes are right-hand lay ropes, i.e. the outer strands form a right-hand helix. As a result of twist due to load, a torque created by the attempt of the elevator rope to reverse the laying status under torsional load, elevator installations used to frequently be equipped with right and left-hand lay ropes in pairs. This allowed compensation of the forces acting on the guide rails of the car and counterweight resulting from the twist due to load. However, as these forces are only small relative to those forces generally absorbed by the guide rails, in modern elevator installations priority is given to the requirement that all suspension ropes be as nearly identical as possible, i.e. should always originate from the same source of manufacture. The mixed use of left and right-hand lay ropes, which can only be produced using separate manufacturing processes, has generally been abandoned. In drum-driven elevators, the drum pitch must be selected to match the direction of rope lay, i.e. "right-lay rope – left-hand drum".

What do regular lay and Lang lay mean?

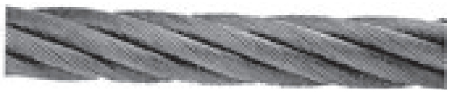
In the same way as the strands in the rope, the wires in the strands can be laid in left or right-lay wires. Regular lay is used to describe a different lay direction for the outer strands in the rope and the wires in the outer strands. If the wires in the strand and the strands in the rope have the same lay direction, this is described as Lang lay. In regular lay ropes, the visible outer wires follow approximately the direction of the rope axis. In Lang lay ropes, the visible outer wires are inclined at a steep angle to the rope axis.

What characterizes a regular lay rope?



Regular lay ropes are hard-wearing and easy to mount. They have only a slight tendency to untwist when hanging freely in the shaft. The elastic elongation is lower than is the case in Lang lay ropes. These benefits mean that the majority of elevator manufacturers use exclusively regular lay ropes.

What characterizes a Lang lay rope?



In round grooves, Lang lay ropes achieve greater bending resistance than regular lay ropes.

However, they are more sensitive to diagonal pull and place more stringent demands in terms of installation. Steps must be taken when hanging the ropes freely in the shaft to prevent untwisting, as otherwise the wires will work loose and result in premature rope damage. The degree to which Lang lay ropes are accepted differs widely around the world. While they are given equal status in countries such as England, in Germany their use is subject to certain provisos.

Lang lay or regular lay rope?

An inferior quality or carelessly mounted Lang lay rope entails a substantially greater hazard potential than an inferior quality regular lay rope. An elevator company aiming to change over to Lang lay ropes should ensure that they choose a design which has been thoroughly tried and tested over a number of years.

Why pre-formed ropes?

In pre-formed ropes, the inner tensions of the wires used in the strands and the strands used in the rope are reduced, with the result that when the rope binder is removed, pre-formed ropes do not spring open. This substantially simplifies the processes of cutting to length and installing. Pre-formed ropes are also known as low-tension or low-twist ropes. Preformed elevator ropes have become the standard design in Europe today.

Why are ropes pre-stretched?

Elevator ropes are pre-stretched in order to induce compaction of the rope structure, which otherwise only takes place after the first load cycles after hanging, prior to commissioning. This means that the permanent rope elongation (= permanent elongation) which accompanies compaction of the rope structure is reduced, so minimizing the amount of work involved in shortening the ropes after only a short period of use.

How are ropes pre-stretched?

Experienced elevator rope manufacturers use suitable measures to achieve a prestretching effect during laying by applying around 30 % of the rope breaking force. More intensive pre-stretching calls for a separate work process. ISO 4344 restricts the maximum tensile force applied during pre-stretching to 55 % of the minimum breaking force. Generally speaking, several stretching processes are required.

When does it make sense to pre-stretch a rope?

The most notable effect is achieved when pre-stretching 8-strand ropes with natural fibre cores. Here, 0.2 % permanent rope elongation can be achieved, as the strands become permanently more deeply embedded in the fibre core. In the case of ropes with steel wore core, the effect of pre-stretching on permanent elongation is relatively low. In addition, the prestretching effect is partially lost due to handling of pre-stretched full steel ropes during the hanging process.

Authors

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 GmbH & Co. KG

Dipl.-Ing. Thomas Barthel is Head of Testing for Elevator Technology at Pfeifer DRAKO Drahtseilwerk GmbH & Co. KG