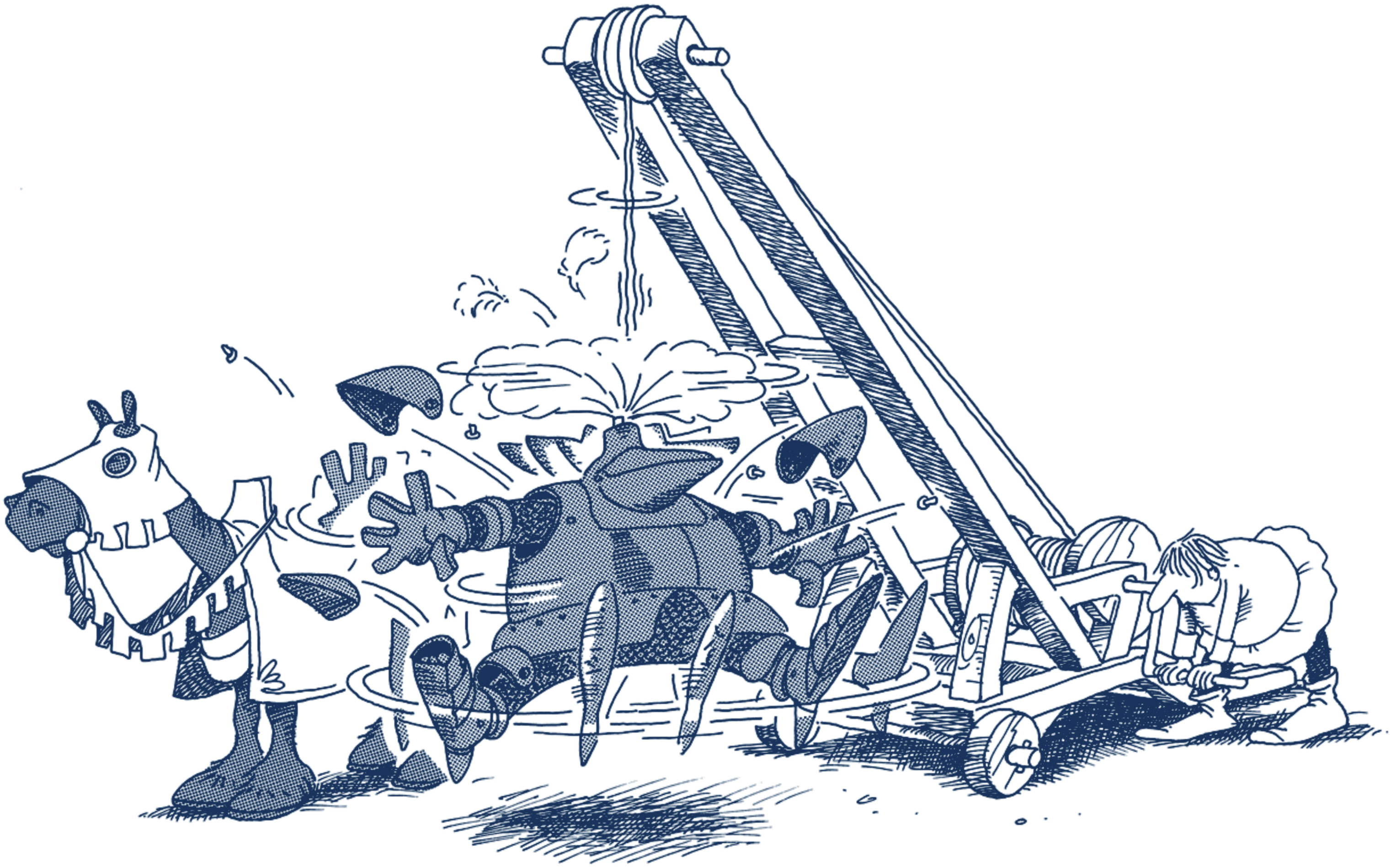
WIRE ROPE
TECHNOLOGY AACHEN



The rotation characteristics of steel wire ropes

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Content

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1. Introduction

In order to determine why a wire rope tends to rotate under load, let us first look at a bundle of six parallel strands which have been arranged round a fibre core (Fig. 1).

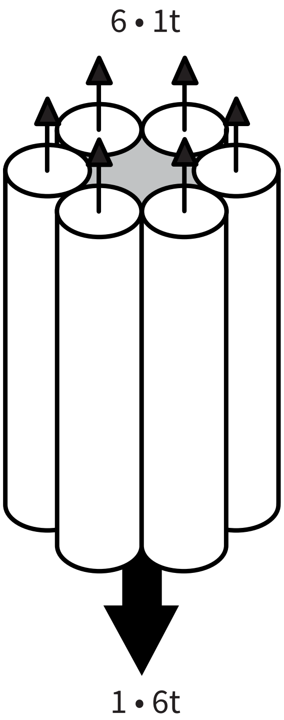


Fig. 1: Bundle of strands

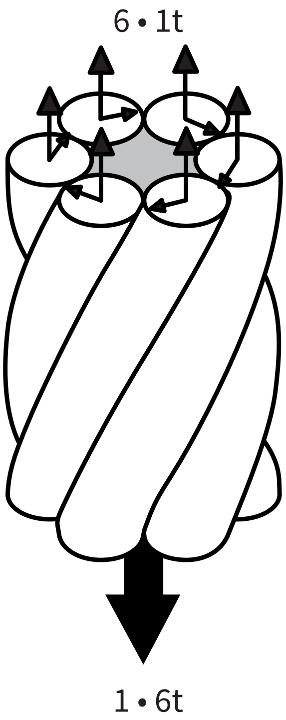


Fig. 2: Closed wire rope

By way of example, when lifting a load of six tonnes by means of such a bundle, each strand will be loaded and stretched by one tonne. The fibre core is virtually unstrained.

When running over a sheave, the bundle is bent round its neutral fibre – its axis. The strands positioned at the outside are lengthened and consequently additionally loaded; whereas the strands positioned on the inside are shortened and either partially or even completely unloaded (Fig. 3).

During this process, enormous pulling forces and tremendous changes of load occur within the strands. This will lead to a quick failure of the bundle.

Let us now examine a wire rope with six outer strands closed helically around a fibre core (Fig. 2).

When the closed rope is bent around a sheave, each strand along its length comes to lie alternately on the outside of the bend, where it is lengthened, and on the inside, where it is shortened. Within one and the same strand, bending therefore causes lengthening (and pulling forces) in one place and – a few millimeters further on – shortening (and compression forces) in another.

By slightly shifting the strands from the area of compression (where there is too much material) to the area of lengthening (where there is a shortage of material) a large part of the changes in lengths and forces caused by bending can be reduced (Fig. 4).

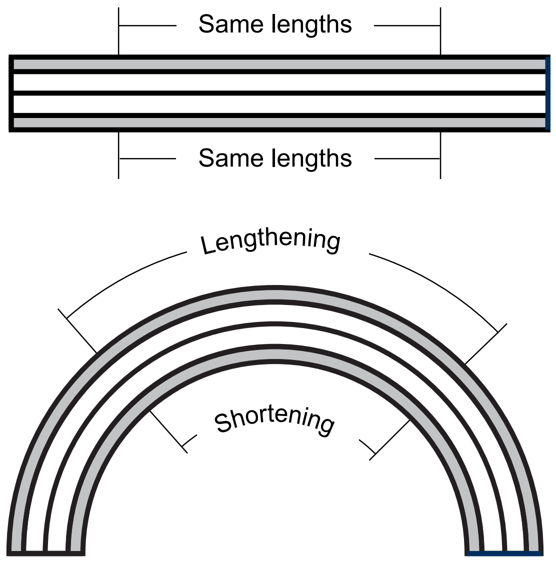


Fig. 3: The change of lengths when bending a bundle of strands

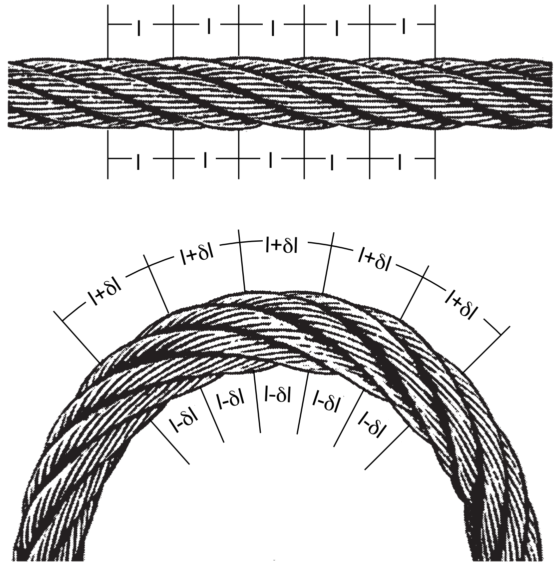


Fig. 4: Reduction of tension in a wire rope

When bent around the same sheave, a rope with a helical arrangement of strands will therefore be subjected to much lower bending stress than a rope with a parallel, bundle-like arrangement of strands. This is the reason why a closed wire rope running over sheaves will have a considerably longer service life than a simple bundle of strands.

However, this improvement of the bending characteristics will cost the user dearly. When lifting a load of six tonnes with the help of the closed rope (Fig. 3), a force Fa will be generated in each strand because of its inclination against the rope axis. This force Fa amounts to approximately 1.06 tonnes (Fig. 5).

Result: In the closed rope the same outer load will therefore create stresses in every single strand which are approximately 6% higher than the stresses in the strands of the bundle.

Even more serious than that is the fact that in each strand a force component Fc is generated in the tangential direction of the rope. In connection with lever arm R to the centre of the rope, this force component builds up a moment which will tend to rotate the rope round its own axis (Fig. 6). This brochure will analyse the problems resulting from this phenomenon.

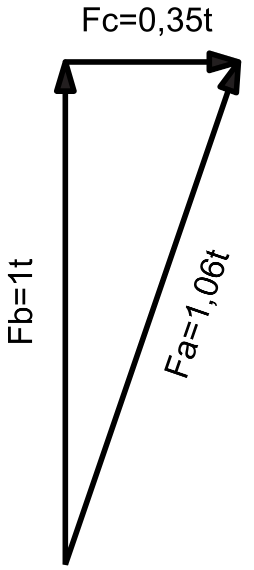


Fig. 5: Force components of the strands

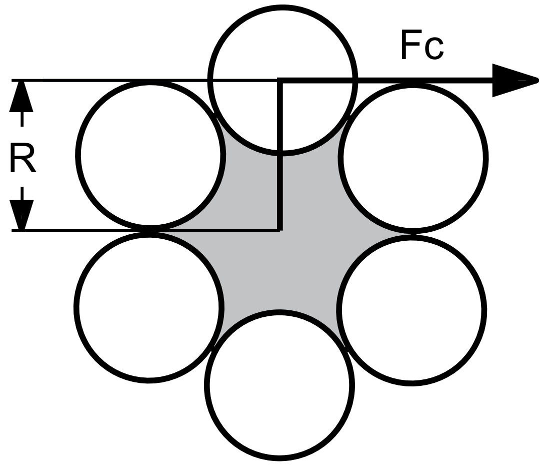


Fig. 6: The moment of the wire rope

2. The moment of non-rotation-resistant ropes

The total of the products consisting of the tangential force components of the strand forces Fc and their lever arms R equals the moment of a wire rope. Given the six-strand rope of Fig. 6, the moment of the rope is calculated as:

$$M = 6 \cdot Fc \cdot R$$

In the case of multi-layer wire ropes, the calculation of the moment cannot be carried out with satisfactory accuracy, because our knowledge of the load distribution as a function of the load is insufficient. Consequently, the moments as functions of the loads have to be determined by experiment. These experiments are typically carried out in the following way:

The one end of the rope to be tested is firmly fixed in a pull tester. The other end is attached to a measuring device which can record the moment as a function of the load. The construction of the measuring device and the circuit arrangement of the gauges will compensate for any potential influences of temperature and bending.

During the whole experiment the data for load, moment, rope elongation and other values of interest, such as rope diameter or the stress in individual wires, are recorded and fed into a computer. They are partly plotted during the test in the dependence required.

The construction of the measuring device permits a defined twist of the rope before the start of the test, in order that curves for different grades of twist can also be determined. The most important factors of influence on the moment of a wire rope are illustrated by the following two examples:

2.1. Example 1:

Two ropes of the same construction of 10mm and 20mm diameter respectively, are both stressed with identical loads. Which of the two ropes will develop the greater moment?

At first one might guess that the 20mm rope would show the lower moment since it has a breaking load approximately four times greater than the smaller rope and that its stress was considerably less. In reality, however, the stronger rope will exert a moment exactly twice as great as the moment of the thinner rope.

The explanation is fairly simple. Because of the identical construction of the ropes and their identical angle of lay, the outer load causes the same force components Fc in tangential direction. Yet, in the 20mm rope this force component Fc has a lever arm of double the length (Fig. 7).

Same force • double lever arm
= double moment.

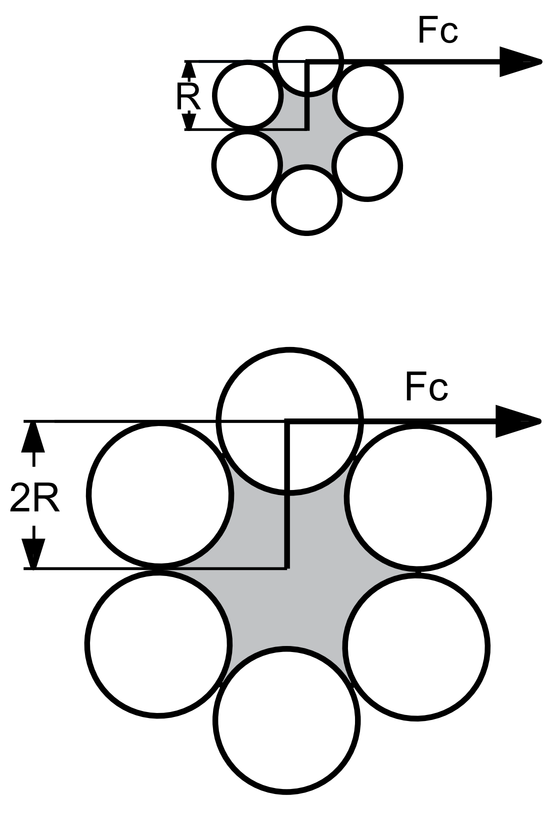


Fig. 7: The influence of the nominal rope diameter on the moment

The following rule can be deduced from these facts:

The moment of a rope construction increases proportionally to the diameter of the rope.

In practice this means:

The smaller the rope diameter,
the more resistant the system will be to rotation.

This is a definite advantage of steel wire ropes with a large metallic cross-sectional area and high tensile strength wires.

2.2. Example 2:

Two ropes of the same diameter are stressed by loads of one tonne and two tonnes respectively. How will the different loads influence the moments of the ropes?

The double outer load causes a force component Fc in the second rope that is exactly twice as high as the one in the first rope (Fig. 8). With lever arm R of the same length, the moment of the rope with the double force will be exactly twice as high.

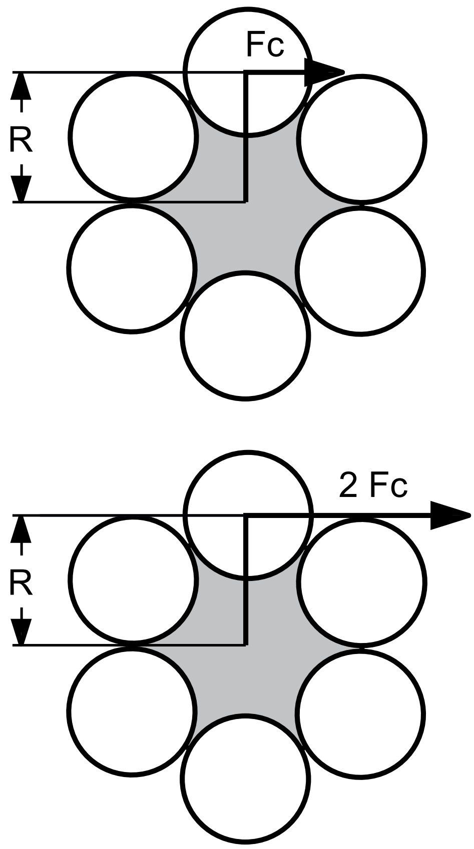


Fig. 8: The influence of the load on the moment of the rope

The following rule can be deduced from this:

The moment of a non-rotation-resistant rope increases proportionally to the load applied.

These two simple examples show that the moment of a steel wire rope is proportionally dependent on rope diameter and on the load applied to it.

The moment is proportional to the product load • diameter.

Furthermore, the moment of the rope depends on its construction, i.e. on the number of strands and their design, on the lay lengths and the type of lay (regular or Langs lay). For instance, in a single-layer wire rope the force component

$$Fc = Fa \cdot \sin \alpha$$

grows with the increasing angle of lay α, i.e. with decreasing lay length of the rope.

The influence of these data can be summarized in one factor which we call torque factor k. This factor k is a characteristic feature of a particular rope construction. Our equation for the moment of a rope now looks like this:

Moment of the rope = k • load • nominal rope diameter

Fig. 9 shows the factor k of different wire rope designs. Even in an unloaded condition many Langs lay ropes have a strong tendency to unlay if the rope ends are not secured against rotation. This may lead to the assumption that these ropes will also develop a greater moment under load with their rope ends fixed, but this is not always true.

Generally speaking, the moments of special wire rope are lower than the moments of regular lay ropes of the same construction. This is in contrast to many standard ropes which frequently display the opposite property. Langs lay ropes with one loose end tend to unlay considerably, even when they are unloaded. This, however, must not lead to the general assumption that Langs lay ropes develop a higher moment when under load with both ends fixed.

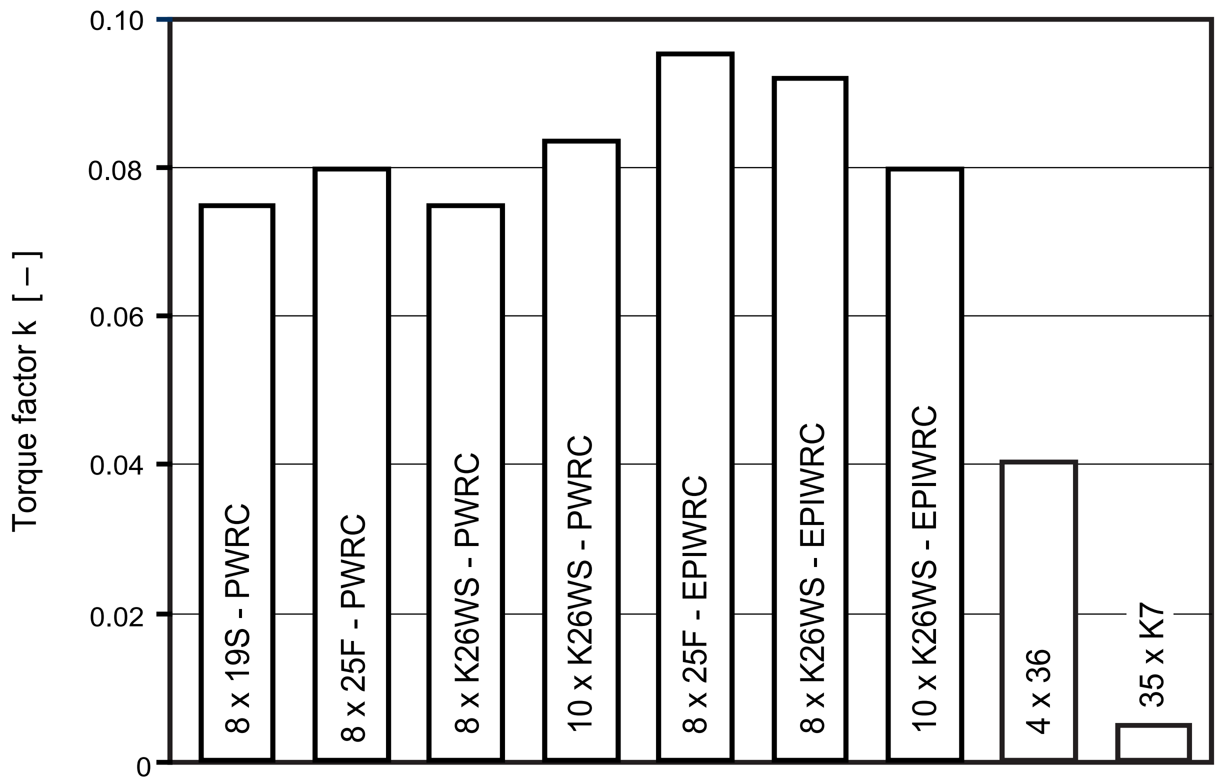


Fig. 9: Torque factor k for different special wire ropes

3. The angular rotation of non-rotation-resistant ropes

A non-rotation-resistant rope under load will always tend to reduce its internal moment by lengthening its lay, i.e. by unlaying. A pull test in which one rope end is allowed to rotate freely can determine the exact angle at which the moment caused by the load is reduced to zero. Typically throughout the test, load, elongation and angular rotation are measured continuously by a precision potentiometer and are fed into a computer. During or after the test, diagrams of the angular rotation can be plotted against load or elongation.

Fig. 10 illustrates the angular rotation per length unit for different rope constructions with one rope end being allowed to rotate freely (pull test on a swivel).

When comparing a regular lay rope 8 x 25F + IWRC with a regular lay rope of the same design, the result of their rotation characteristics is, once again, clearly in favour of the Langs lay rope. If these two ropes rotated freely, as the attachment to a swivel would allow them to, both ropes would break at loads below their minimum breaking loads.

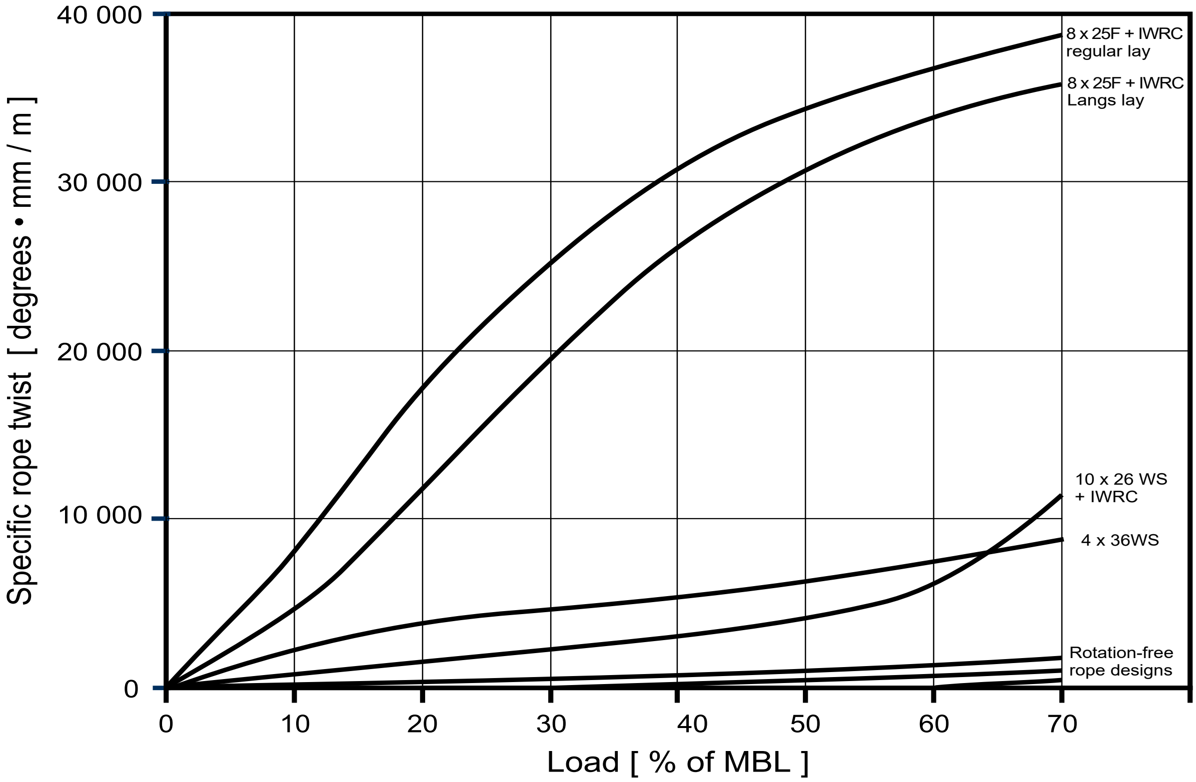


Fig. 10: Angular rotation of different wire rope designs when under load

The regular lay rope would break at about 75% of its minimum breaking load, the Langs lay rope at only 40%. This is one of the reasons why non-rotation-resistant ropes must not be fitted with a swivel. The actual design factor of the reeving system is dangerously reduced by the use of a swivel in combination with these rope constructions.

In addition, these ropes would continually rotate forwards and backwards when being stressed and unstressed. They would inevitably be subject to extreme internal wear and enormous material fatigue. This is another reason why non-rotation-resistant ropes should never be fitted with a swivel.

4. Why do rotation-resistant ropes not rotate under applied axial load?

The fundamental principle of rotation-resistant ropes is that an independent wire rope core (IWRC) is covered with an outer strand layer closed in the opposite direction. The moment of the outer layer is in the opposite direction of the moment of the IWRC and, in the ideal case, it will compensate it completely.

Fig. 11 shows the cross section of an 18x7 rope. The following statements also apply to 17x7 ropes with eleven outer strands, to 19x7 ropes with a core strand, as well as to 18x19, 17x19 and 19x19 ropes where the seven-wire strands are replaced by 19-wire Seale strands. This also applies to compacted strand versions of all these constructions.

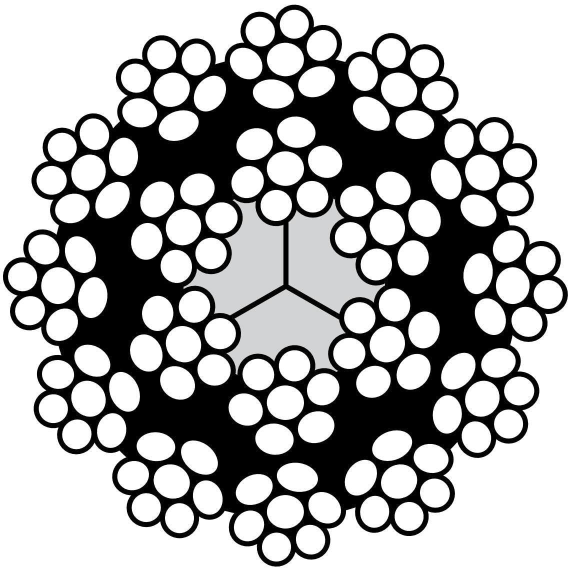


Fig. 11: 18x7 wire rope

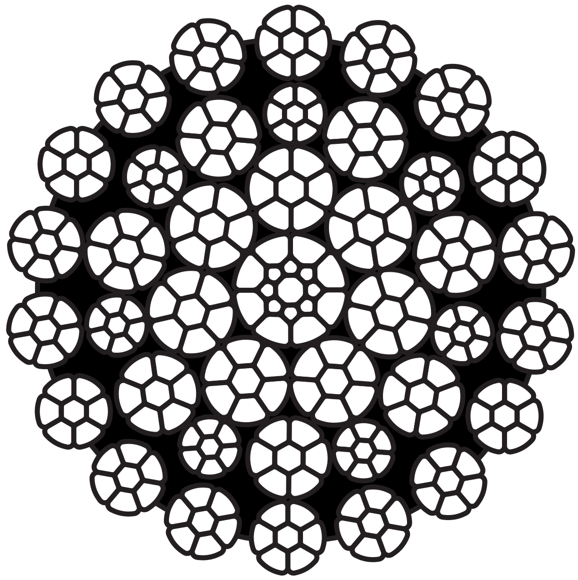


Fig. 12: 40 x K7 wire rope

In an 18x7 rope, an outer load generates tangential forces in the six strands of the IWRC, tending to rotate the rope with lever arm R in one direction. The tangential forces created in the twelve outer strands work with lever arm 2 x R in the opposite direction.

Providing the strands are evenly loaded (and they should be!) and therefore the force components Fc in tangential direction of the IWRC and of the outer layer are even, the proportion of moments results in:

$$6 \cdot Fc \cdot R : 12 \cdot Fc \cdot 2R$$

The proportion of moments amounts to:

$$6 : 24$$

If the IWRC was closed in the same direction as the outer strands, the moment of the rope would amount to:

$$12 \cdot Fc \cdot 2R + 6 \cdot Fc \cdot R = 30 \cdot Fc \cdot R$$

Since the moments subtract, however, due to their opposite direction, the actual moment results in:

$$12 \cdot Fc \cdot 2R - 6 \cdot Fc \cdot R = 18 \cdot Fc \cdot R$$

Evidently, closing the IWRC in the opposite direction reduces the moment to 60% of the amount it would produce if the IWRC rope was closed in the same direction.

It is self-evident that a wire rope with such a high residual moment can at best be rotation-resistant, but never rotation-free.

Fig. 12 shows the cross section of a rope 40 x K7. Here twenty-one strands in the IWRC generate a moment in one direction, whereas only eighteen strands in the outer layer create a counteracting moment.

The disadvantage for the IWRC strands of having shorter lever arms is compensated in this rope by the advantage of having a greater metallic area, and consequently by having greater force components Fc. The numerical superiority of the strands in the IWRC accounts for the rest. This design makes it possible to compensate the moments of the IWRC and the outer strands for an extremely extensive load spectrum. Only if they are stressed to approximately 60% of their minimum breaking load do 40 x K7 ropes show a slight tendency to unlay.

5. The moment of rotation-resistant ropes

As deduced above, the equation that determines the moment of a rope reads

$$\text{Moment} = k \cdot \text{load} \cdot \text{diameter} .$$

The left hand side of the equation – the moment – will become zero if one of the three factors on the right hand side becomes zero.

This means that the moment is zero if the load is zero – that is evident. Moreover, the moment becomes zero if the rope diameter is zero. Since in this case the breaking load would also be zero, this is not a very helpful condition.

Consequently, when producing a rotation-resistant rope, it must be the prime objective of the engineer to design a sophisticated rope geometry that will reduce the factor k to zero. Fig. 13 shows the factor k for different rotation-resistant ropes depending on the load.

As illustrated, trying to reduce the factor k of an 18x7 rope to zero was not very successful. Factor k being 0.055, corresponds to 60% of the value of non-rotation-resistant ropes (which confirms our calculation on page 9). The torque factors of 35 x K7 and 40 x K7 ropes will typically be close to zero for the whole load spectrum.

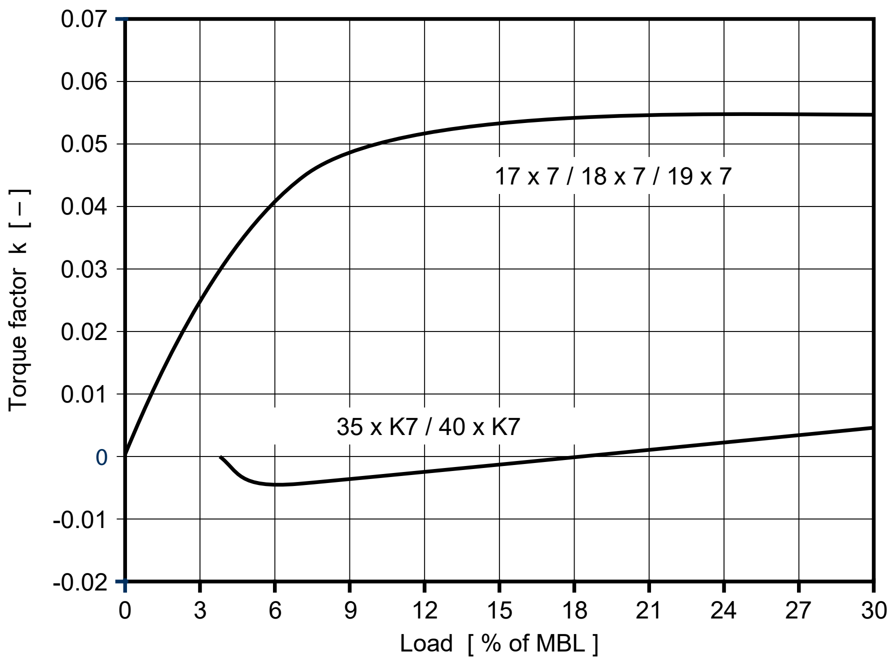


Fig. 13: Torque factor of different wire rope designs in dependence on load

6. The rotation angle of rotation-resistant ropes

By definition a wire rope is rotation-resistant, if the moments of the IWRC and of the outer strands, caused by an outer load, almost compensate each other completely. Given the possibility to rotate freely, a rope of that design will only rotate very slightly under load, until a new state of equilibrium between the IWRC and the outer layer is established.

If, for instance, the moment of the outer layer is predominant, the rope will unlay and lengthen the lay of its outer layer. At the same time the IWRC - closed in the opposite direction - will close and shorten its lay length. The lengthening of the outer layer will take some of its stress away and reduce its moment, whereas the simultaneous shortening of the rope core will lead to additional stress and to the increase of the moment of the IWRC.

Progressive twisting of the rope will decrease the moment of the outer layer and increase the moment of the IWRC until an equilibrium of the two moments is established.

If twisting of the rope is required until the equilibrium of moments is achieved, the lengthening of the outer layer and the simultaneous shortening of the IWRC will lead to a redistribution of forces and moments. In the new equilibrium the rope core will take an overproportional part of the load.

Therefore, even ropes which are not completely rotation-free, such as 17x7, 18x7, 17x19 and 18x19 ropes, will find an equilibrium of moments after a certain twist, despite their great moment when unlayed. But, as we have seen, this equilibrium is only possible if the IWRC is stressed overproportionally and the outer strands are stressed underproportionally.

The consequences of disproportional stressing in practical operation are serious. Ropes with 17x7, 18x7, 17x19 and 18x19 constructions and their compacted versions tend to show greater wear and more wire breaks in the highly strained rope core, particularly in those places where the outer strands cross over the strands of the IWRC and impose additional high pressure on them. This means that the deterioration of the ropes in the course of progressive fatigue occurs in those areas which are not accessible to visual inspection.

The only strands that can be inspected visually are the barely stressed outer strands. They will always give the impression that the rope is in good shape. Consequently, within the ropes of these designs rope failures occur quite often before the discard number of visible wire breaks is reached.

When allowed to rotate freely, a rope which is not completely rotation-free can only establish an equilibrium of moments by overtwisting its IWRC. Therefore, in a pull test with rope ends allowed to rotate freely, the overproportionally loaded IWRC will break prematurely.

This is why 17x7, 18x7, 19x7 ropes and their 19-wire strand and compacted versions, when attached to a swivel, achieve only about 70% of their minimum breaking loads. Fig. 14shows the breaking loads of different ropes when tested with a freely rotating swivel.

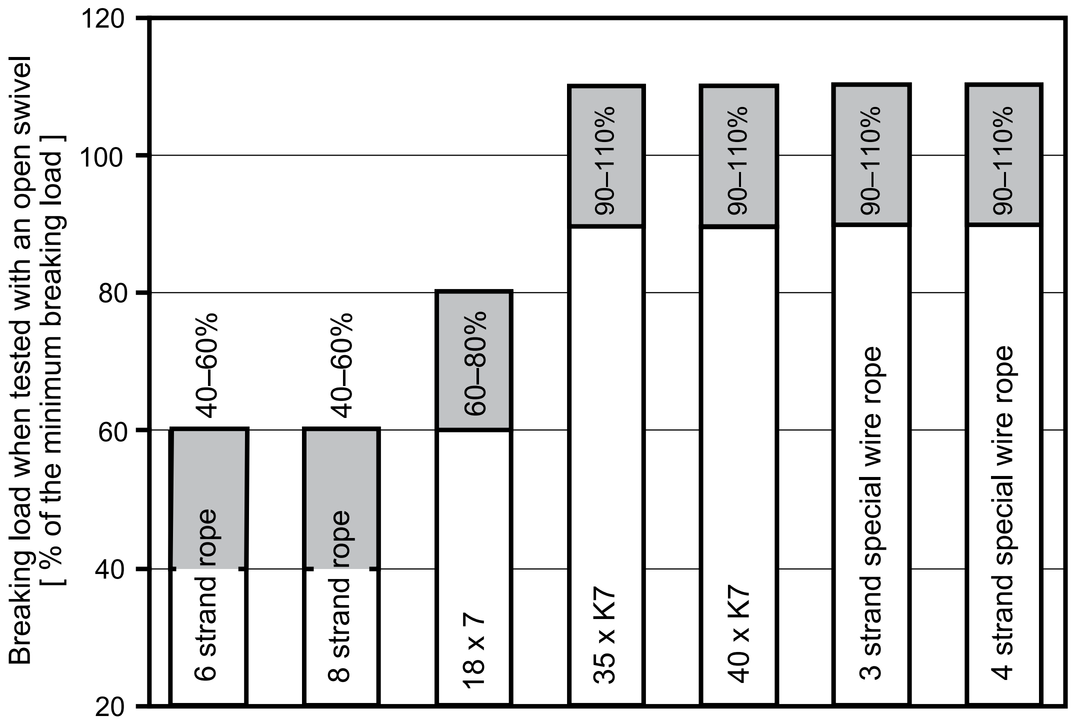


Fig. 14: Breaking loads of different wire rope designs in a break test with an open swivel

7. The angular rotation of rotation-free ropes

A wire rope is rotation-free if the moments of the IWRC and the outer strands generated in the rope by an outer load add up to exactly zero. A rope of that design will not rotate under load when allowed to rotate freely. With the cross-sections and the lever arm proportions in balance, as is the case with e.g. 35 x K7 and 40 x K7 ropes, there is no tendency to twist whatsoever, even up to very high loads.

Only minimal moments are generated which can be reduced to zero by the slightest rotations that are barely measurable. The homogeneity of the load distribution is not disturbed in these ropes, so that even when attached to a swivel in a break test they will produce their full minimum breaking load. Fig. 15 shows the angular rotation of different rope constructions in a break test attached to an unlocked swivel.

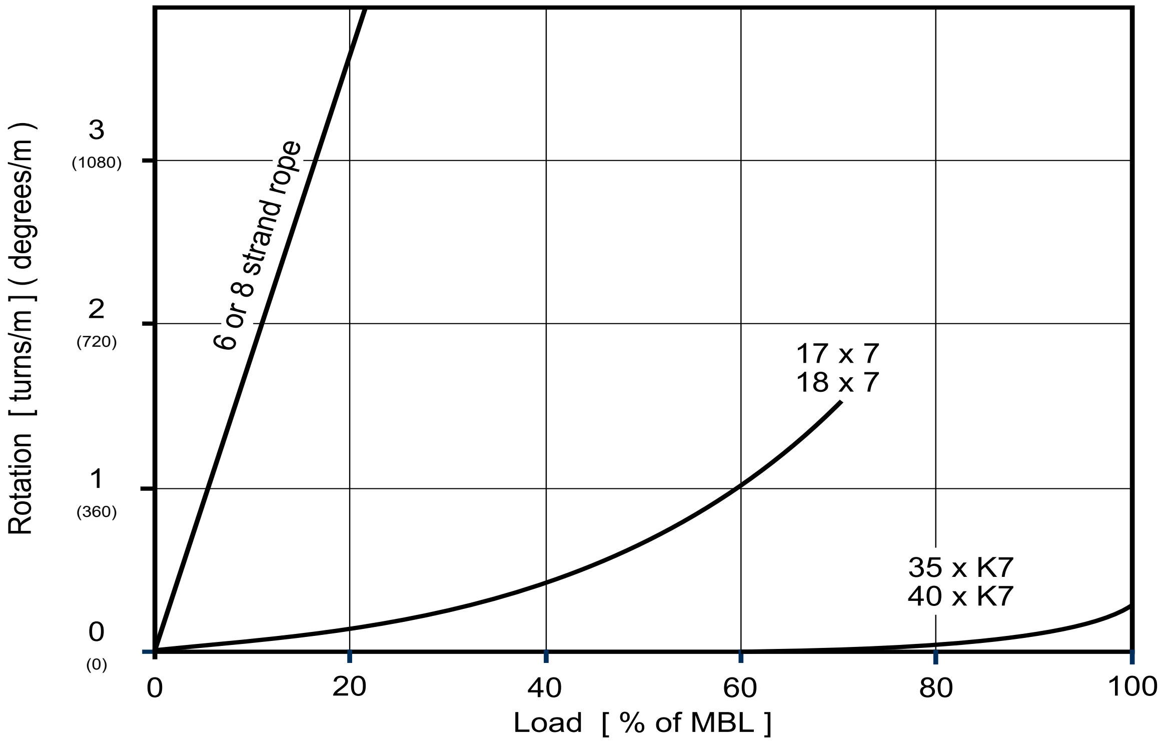


Fig. 15: Angular rotation of different rope constructions in a break test with an open swivel

It must be stressed emphatically that 35 x K7 and 40 x K7 ropes can be used with a swivel without creating excessive loading for the IWRC. On the contrary, the use of a swivel is even recommended with these ropes. The swivel enables twist that has been built up by the reeving system and by other factors of influence to be released.

8. Intermezzo: Why are rotation-free ropes so rotation-resistant?

The strands of a wire rope are arranged at a certain angle to the rope axis. Under load the strands try to get in line with the rope axis (straighten) by twisting the rope round its own axis.

The rope manufacturer tries to make the rope rotation-resistant by closing the outer strands in the opposite direction to the inner strands, such that the outer strands will try to twist the rope in the one direction, whereas the inner ones will try to twist it in the other.

The outer strands have a clear advantage with respect to the rope twist because they are further away from the centre of the rope and consequently have the longer lever arm.

This can be compared with a competition in which two teams try to push a turnstile in opposite directions. The competition is not exactly fair because the one team pushes the turnstile at the end of its bars and thus benefits from the considerably longer lever arm, whilst their opponents are pushing it near the centre (Fig. 16).

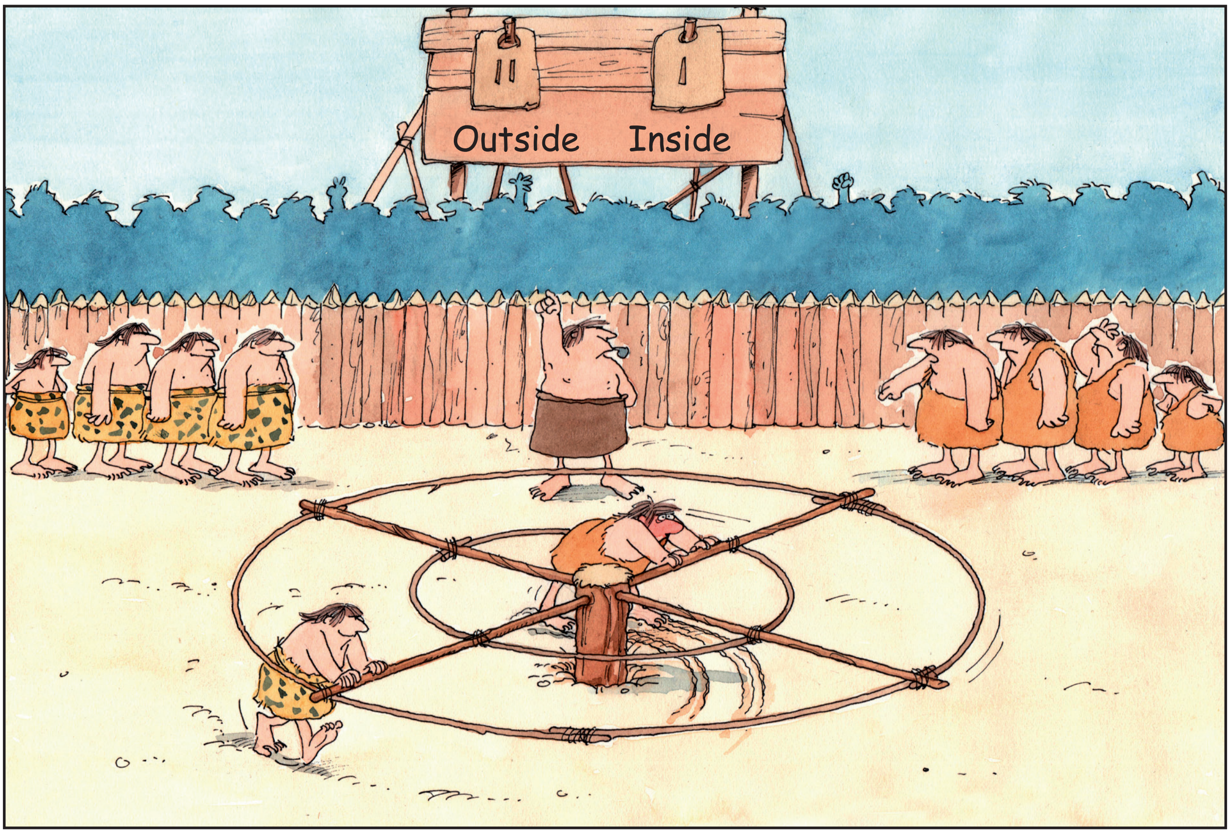


Fig. 16: Due to their longer lever arms the outer strands have an advantage.

If those pushing the turnstile near the centre do not stand a chance when the number of competitors of both teams is equal, how much harder must it be when they are outnumbered by twice as many pushers at the outer end of the bars (Fig. 17)?

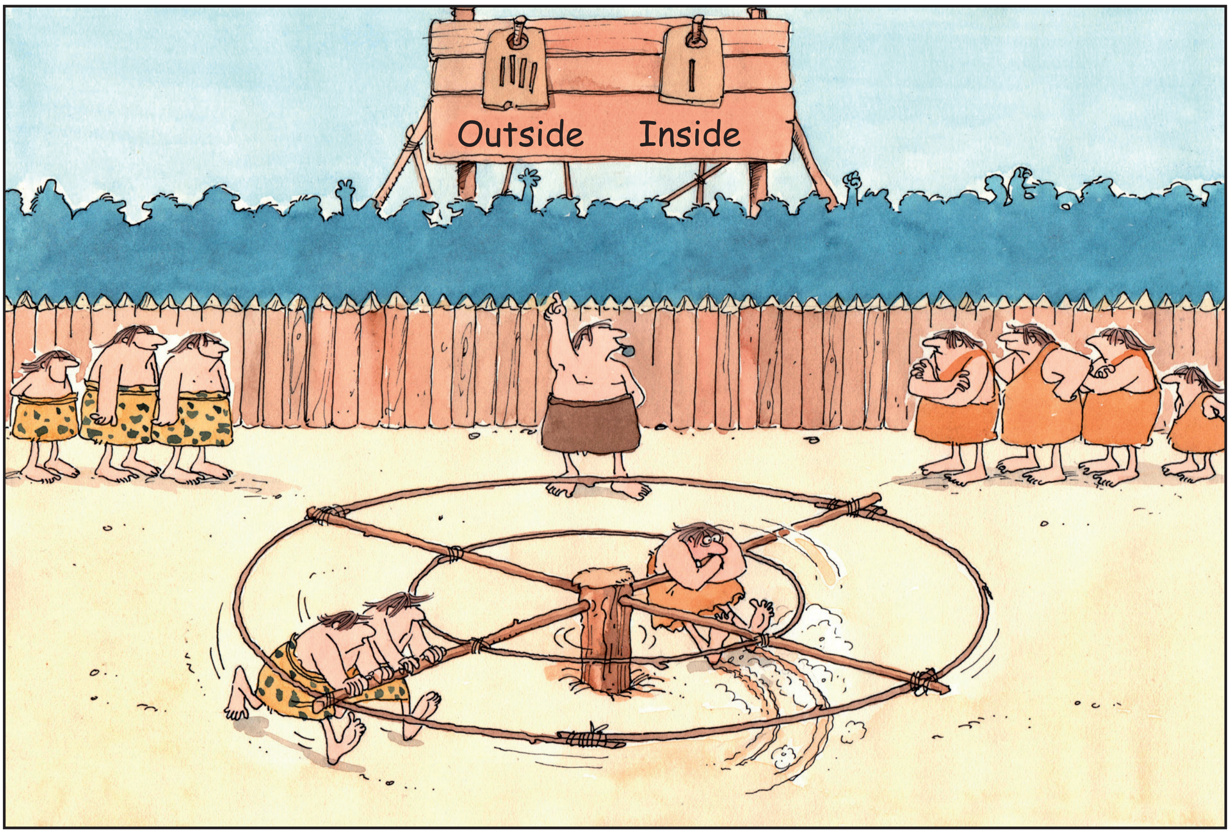


Fig. 17: In an 18x7 rope the metallic cross-section of the outer strands is twice that of the IWRC.

This is exactly what happens in 18x7 or 18x19 ropes. These constructions contain six inner strands which must compete with twelve outer strands of the same diameter, and with lever arms twice as long. Ropes of that design can only be reasonably rotation-resistant if the inner strands are hopelessly overloaded.

Being well aware of these problems, rope designers have given extra support to the inner strands of 35 x K7 and 40 x K7 ropes. During manufacture, a large number of strands are densely packed by parallel closing.

By applying additional compaction, the IWRC is reinforced even further. The result is that the metallic cross section of the IWRC is now considerably greater than that of the outer strands. Or, if applied to our turnstile example, many athletes on the inside with the short lever arm fight against a few on the outside with a long lever arm (Fig. 18). The result is excellent stability against rotation.

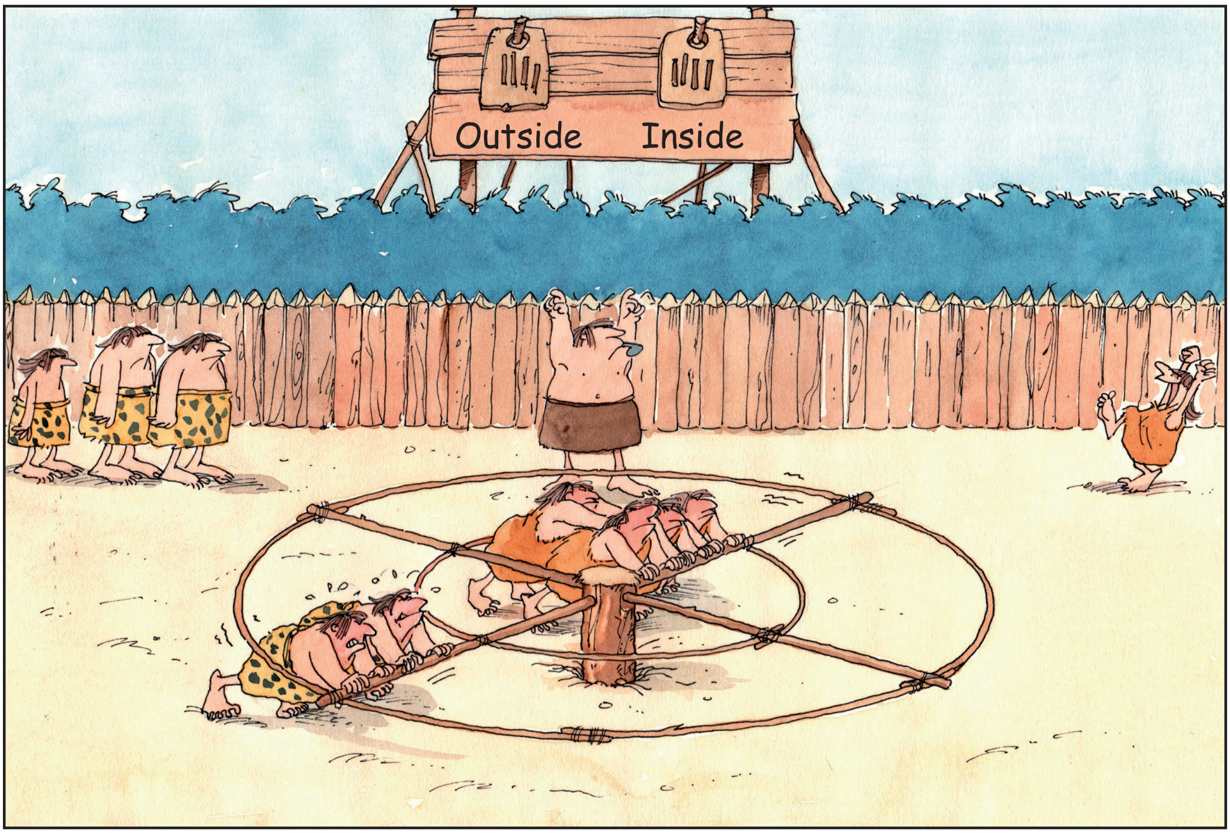


Fig. 18: In the rotation-free ropes the metallic cross-section of the IWRC is considerably greater than that of the outer strands. Because of this an equilibrium is established.

9. The stability of the hook blocks of cranes

The stability or the extent of the rotation of a hook block does not only depend on the design of the wire rope. The geometry of the reeving is also of considerable influence. In the following, the influencing factors are considered by reference to a two-part-reeving system.

A wire rope will always tend to reduce its moment by rotating round its own axis. With two- and multiple-part reevings, however, this rotation will act to lift the load (Fig. 19 and Fig. 20). The internal energy of the rope is transformed into potential energy of the load. The system will rotate until the equilibrium of moments is established.

The higher the load must be lifted in order to create the same angular twist of the block, the more energy the must rope expend. The higher the load must be lifted for generating the same angular twist, the more stable the block will be against twisting.

Fig. 19 shows two blocks of different width, i.e. of different distances between the two falls. In Fig. 19 – narrow width – the load has lifted only slightly when the block is twisted, for example, by 180°. Little lifting energy is required before the rope cables – the system has little stability.

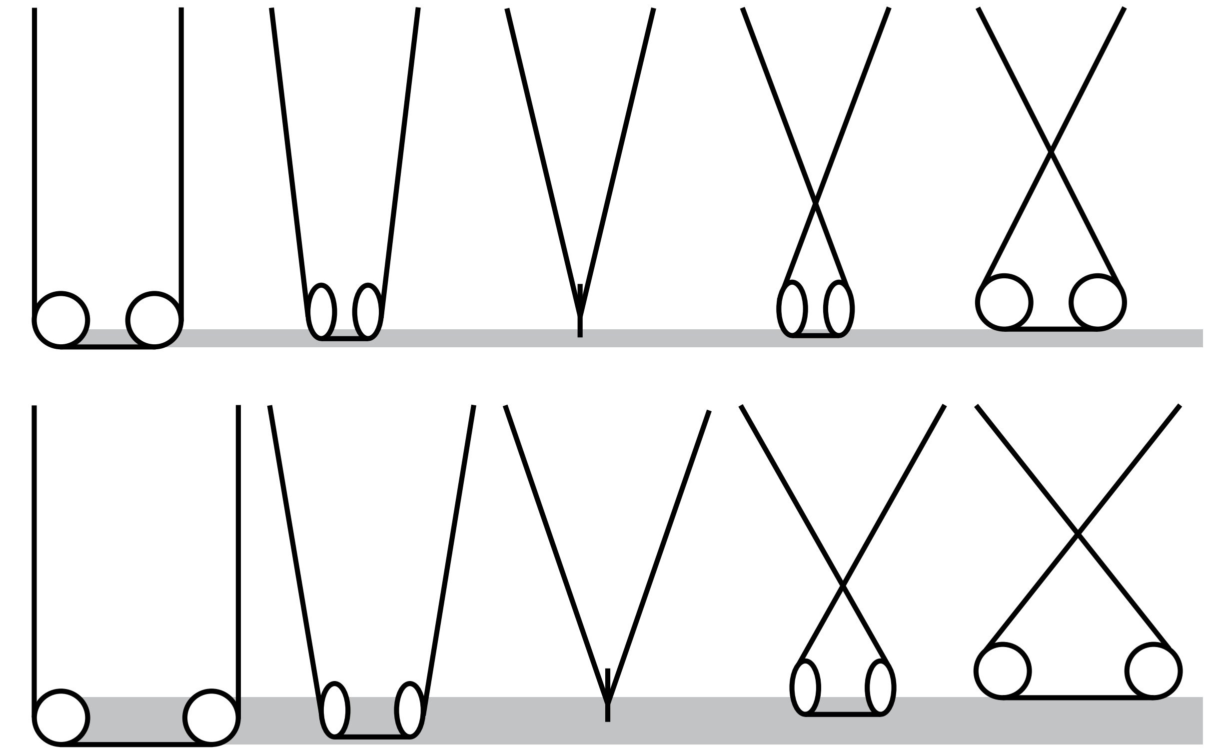


Fig. 19: The influence of width on the stability of the block. If the width is great, the reeving system must expend a lot of lifting energy when twisting.

In Fig. 19 – greater width – the load has lifted considerably higher when the block is twisted by the same 180°. A much greater lifting energy is required before the rope cables. Therefore, the system with the greater hook block width is much more stable.

Fig. 20 shows two blocks of equal width but different free rope lengths, i.e. different lifting heights. In Fig. 20 – great lifting height – the load is lifted only slightly when the block is twisted by 180°. Only little energy is needed before the rope cables. Therefore, the system with great lifting height has little stability.

In Fig. 20 – smaller lifting height and the same twist of block by 180° - the load is lifted considerably higher. Much greater lifting energy is required before the rope cables. Therefore, the system with a lower lifting height is considerably more stable.

If there are no additional influences, such as wind pressure or slewing of the crane, the stability of the reeving system against rotation can be determined by means of a fairly simple formula. The prerequisite is that the lifting height is much greater than the width of the block.

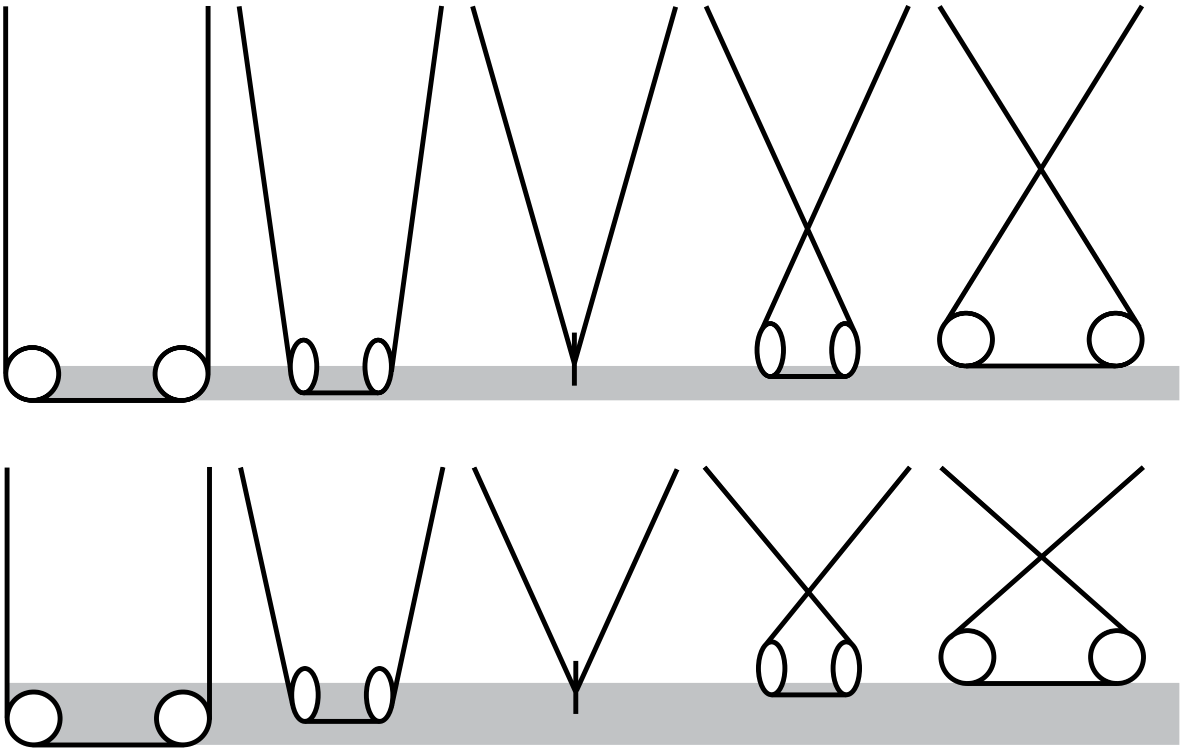


Fig. 20: The influence of the lifting height on the stability of the block. If the free rope length is small, the system must expend a lot of energy when twisting.

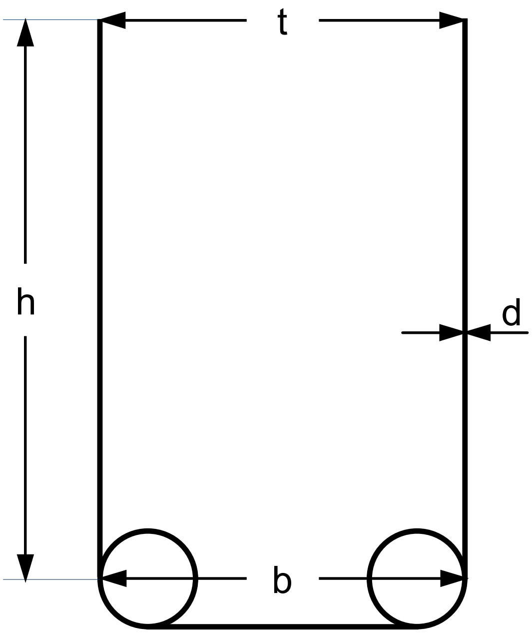


Fig. 21: Dimensioning the reeving

The maximum permissible value for the torque factor of the rope, before the block cables, can be determined by the following formula (in conjunction with Fig. 21):

$$k \leq \frac{b \cdot t}{4.8 \cdot h \cdot d}$$

where

k	is the torque factor of the wire rope
b	the spacing of the ropes at the block
t	the spacing of the ropes at the top
d	the nominal rope diameter
h	the lifting height

The torque factors of some popular rope designs are illustrated in Fig. 9.

If k is considerably below the calculated value, there is no danger of cabling. If the factor k is less than but very close to the permissible value, cabling may be possible because of destabilising influences such as wind pressure or additional moments caused by slewing the crane.

As can be seen from the formula, the stability of the block is the greater:

- the smaller the torque factor k of the rope
- the greater the spacing t at the top
- the greater the spacing b at the bottom
- the smaller the lifting height h and
- the smaller the nominal rope diameter d

The formula shows that a reeving system is increasingly more stable against rotation with decreasing rope diameter. For the crane designer this is yet another good argument for choosing the smallest rope diameter possible.

It is noteworthy that the rope load does not appear in the formula. That means that the stability of the block is the same under a load of one tonne as it is under a load of two tonnes.

At first this might sound illogical, because doubling the load will double the moment of the rope which will try to twist the block. However, this twist would require lifting twice the amount of load and consequently twice the lifting energy would be necessary.

The formula for the permissible factor k can be rearranged to allow the calculation of the maximum lifting height h before cabling must be expected:

$$h \leq \frac{b \cdot t}{4.8 \cdot k \cdot d}$$

For calculating the minimum width b of the basis (same distance at the top and at the bottom), for which a reeving system is stable, the formula reads as follows:

$$b \geq \sqrt{k \cdot 4.8 \cdot h \cdot d}$$

What we have so far explained for two-part reeving systems naturally applies to three- and multiple-part reevings as well. Here the calculation follows the formulae in Fig. 24.

Usually the stability of a reeving system against rotation increases with the number of parts. A numerical example: The permissible lifting height of 141 metres for four-part blocks with square basis is considerably higher than the permissible lifting height of 100 metres for a two-part block (Fig. 22).

If a third part is attached to the block of a two-part reeving system, the result will be a three-part arrangement as illustrated in Fig. 23. The permissible lifting height of 67 metres is decisively lower than that for a block with a two-part line (Fig. 22).

The reason for this is that the third part, compared to the two part-reeving, does not widen the spacing; however, there are now three instead of previously two parts attempting to twist the block.

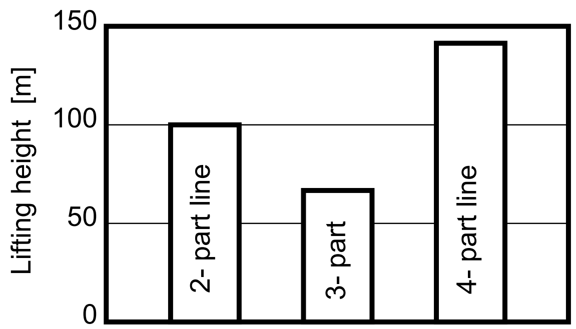


Fig. 22: The influence of the number of parts on the maximum permissible lifting height

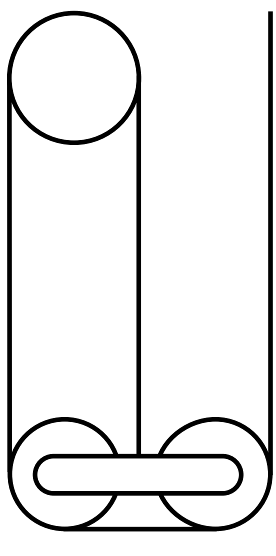


Fig. 23: A comparatively unstable three-part reeving

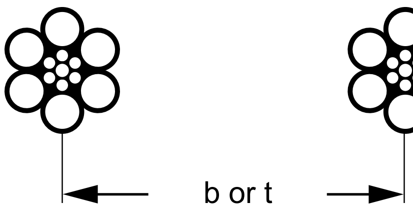
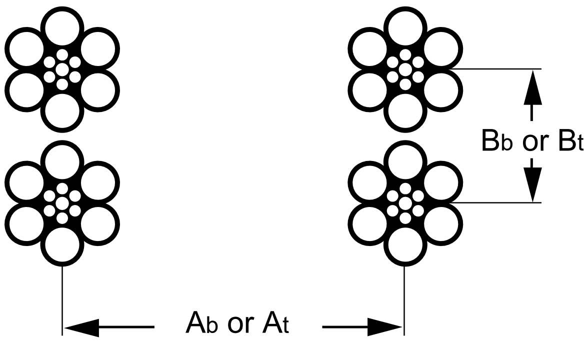
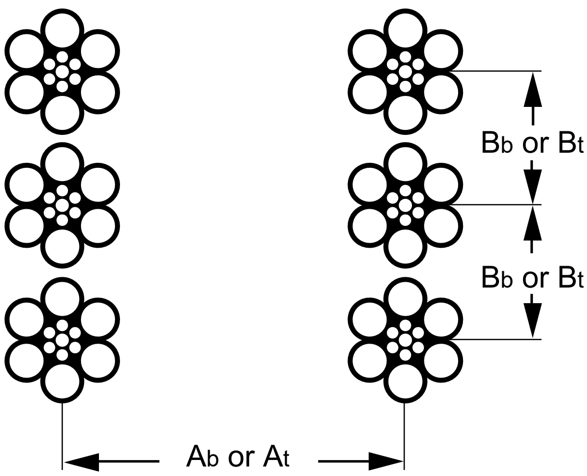
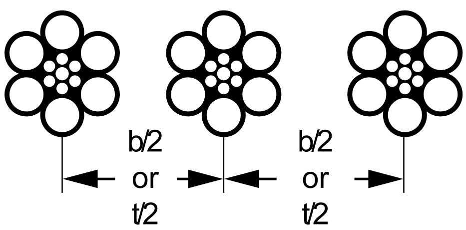
	Two-part line: $k < \frac{b \cdot t}{4.8 \cdot h \cdot d}$
	Four-part line: $b = (A_b^2+B_b^2)^{1/2}$ $t = (A_t^2+B_t^2)^{1/2}$ $k < \frac{b \cdot t}{4.8 \cdot h \cdot d}$
	Six-part line: $b = (A_b^2+B_b^2 \cdot 8/3)^{1/2}$ $t = (A_t^2+B_t^2 \cdot 8/3)^{1/2}$ $k < \frac{b \cdot t}{4.8 \cdot h \cdot d}$
	Three-part line: $k < \frac{b \cdot t}{7.2 \cdot h \cdot d}$

Fig. 24: The calculation of the stability of a block for two-, four-, six-, and three-part reeving systems. Subscripts: t = top and b = bottom.

10. The stability of twin-drum systems

Compared to single-drum systems with one drum only, twin-drum systems have quite a few advantages. For instance, the same number of lines allows twice the lifting speed. In many cases only the use of a twin-drum system can guarantee single-layer spooling. In the case of a left-hand and a right-hand drum with a right-hand lay and a left-hand lay rope, the moments of the ropes will neutralize each other. Therefore, a lifting system of this kind is very resistant to rotation, even if non-rotation-resistant ropes are used (Fig. 25).

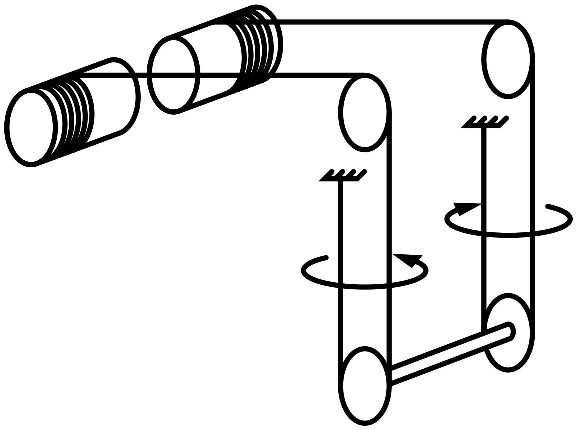


Fig. 25: Crane with left-hand lay and right-hand lay wire ropes

For constructional reasons it is often necessary to operate a twin-drum system with only one rope with both its ends fastened to the drum. In this case it is essential that the pitch of the drum is in the opposite direction to the lay of the rope. With regard to the pitch of the drum, Fig. 26 illustrates the correct arrangement of a left-hand grooved drum and a right-hand lay rope. The disadvantage of this arrangement is the slight travelling of the load in the direction of the spooling during the lifting operation.

Fig. 27 shows a twin drum, half of which is grooved left-handed, the other half right-handed. During the lifting operation there is no travelling of the load, but the rope is enormously strained on twist by the “wrong” grooving of one side of the drum.

Whichever direction of lay is chosen, it will never be suitable for both drums. One of the drums will always severely twist the rope. In units where this arrangement causes problems, the compensating sheave should – if possible – be replaced with a balance. This opens up the possibility of installing a left-hand lay and a right-hand lay rope. The reeving will be the same as shown in Fig. 25.

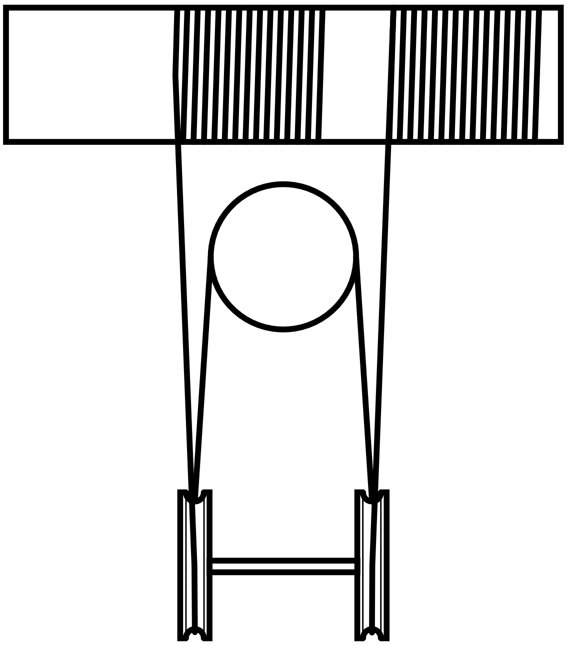


Fig. 26: Crane with two left-hand lay rope drums

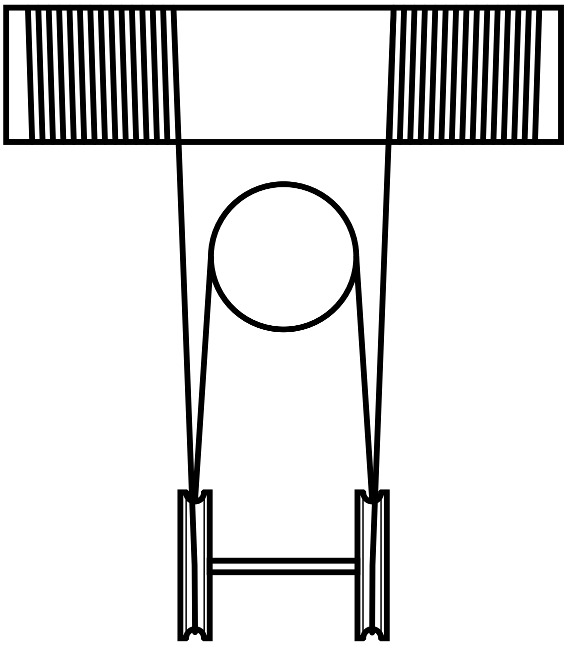


Fig. 27: Crane with one left-hand lay and one right-hand lay drum

In cases where there is no design change possible, the use of a 4 strand rope construction can proove very helpful. On the one hand this rope construction is comparatively rotation-resistant, but in contrast to other rotation-resistant constructions it has no IWRC and is consequently very tolerant to enforced twisting.

For the sake of completeness it must be mentioned that an arrangement as shown in Fig. 26 can be more advantageous, as it keeps the fleet angle between the drum and the first sheave in the block low. This is why it is occasionally preferred in practice.

11. Twin-drum systems: One left- and one right-hand lay rope or two rotation-resistant ropes?

As to the stability of the hook block against rotation, it seems that lifting devices with one right-hand lay and one left-hand lay non-rotation-resistant rope are as good as lifting devices with two rotation-resistant ropes.

In lifting devices with left-hand lay and right-hand lay non-rotation-resistant ropes, great moments are generated in both ropes when lifting the load. As these moments have the same value and are in opposite directions they neutralize each other. Therefore, the block will not rotate.

In lifting devices with two rotation-resistant ropes (preferably they should be left-hand lay and right-hand lay, too) the moments of the IWRC and the outer layer neutralize each other within the ropes; likewise, the hook block will not rotate.

We now consider the enforced change to these equilibria by either slewing the crane round its axis or by moments caused by wind pressure or any other destabilising factors. How strong, then, are the counteracting moments in the reeving, which – caused by enforced rotation – stabilize the system?

Fig. 28 illustrates the change of moments of the non-rotation-resistant 8 strand rope in comparison to a rope 40 x K7. The disturbances in the 40 x K7 rope cause changes of the moment considerably higher than in the 8 strand rope. The counteracting moments in the rotation-resistant rope are four to five times higher than in the non-rotation-resistant rope. Consequently, when simply lifting a load and transporting it in a straight line and without any other destabilising moments, both systems are equally good. If, however, there are disturbing moments, such as slewing the crane round, a lifting device with two rotation-resistant ropes is distinctly superior to one fitted with a left-hand and a right-hand lay rope.

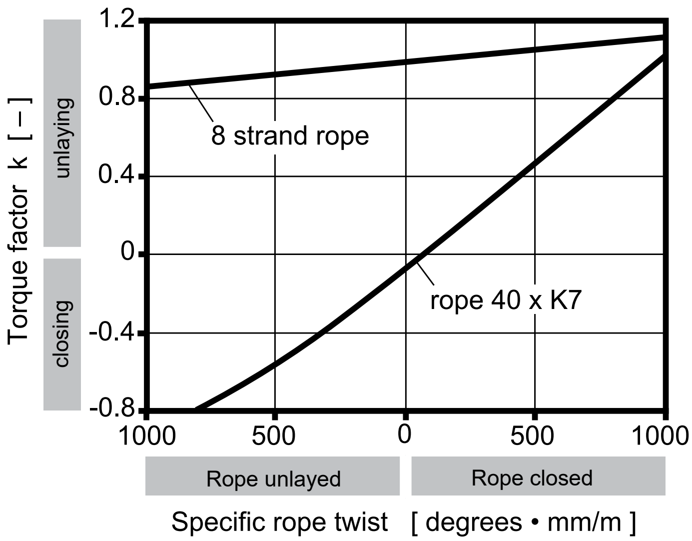


Fig. 28: When rotation is enforced, for instance by slewing the crane, rotation-resistant ropes develop much greater counteracting moments than non-rotation-resistant ropes.

12. The change of moments of wire ropes by enforced rotation

So far we have tried to analyse the tendency of ropes and reeving systems to rotate when under load. Frequently, however, there is also a tendency to rotate when unloaded. This phenomenon is discussed in the following section.

If a rope which is fixed and secured against rotation at both ends is twisted by force, the result will be lay lengthening on the one side and lay shortening on the other side of the rotation. A numerical example may illustrate this effect:

A rope of 200 lay lengths is fixed and secured against rotation at both ends (Fig. 29). The rope is grabbed exactly in the middle, so that there are one hundred lay lengths on the left and one hundred lay lengths on the right. Then the rope is twisted by force through five turns. This results in 100 plus 5 lays which have been added by force on the left side, i.e. that is 105 shortened lay lengths.

On the right side there are now 100 minus the 5 lay lengths which have been subtracted, i.e. 95 (lengthened) lay lengths (Fig. 30). The total number of lays will remain constant provided both ends of the rope are fixed and secured against rotation.

The lay shortening in the closing sense on the left side of the rope has built up an enormous moment effective in the unlaying sense. The extremely unlayed right side of the rope has built up a strong moment in the closing sense.

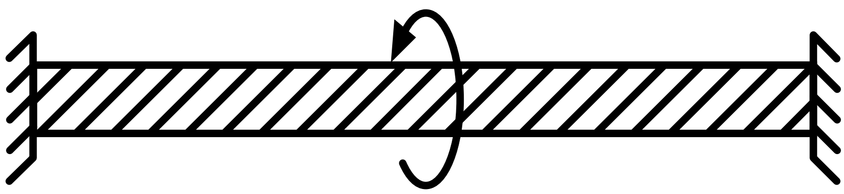


Fig. 29: Twisting a wire rope by force...

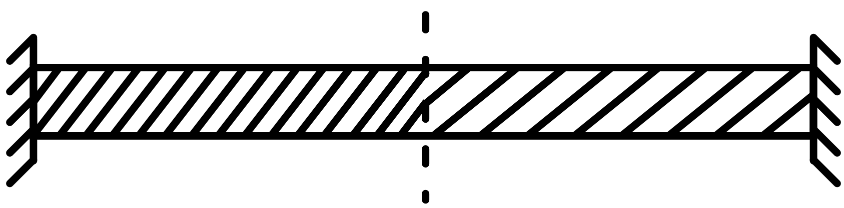


Fig. 30: ...causes lay shortening on the one side (left) and lay lengthening on the other (right).

How great are the moments caused by enforced rotation? It will become evident that non-rotation-resistant ropes and rotation-resistant ropes will react very differently to enforced rotation.

Fig. 31 illustrates the influence of enforced rotation on the moment of a non-rotation-resistant rope. It is obvious that the change of the moment is not excessively great and that it rapidly decreases in percentage with increase in the loading.

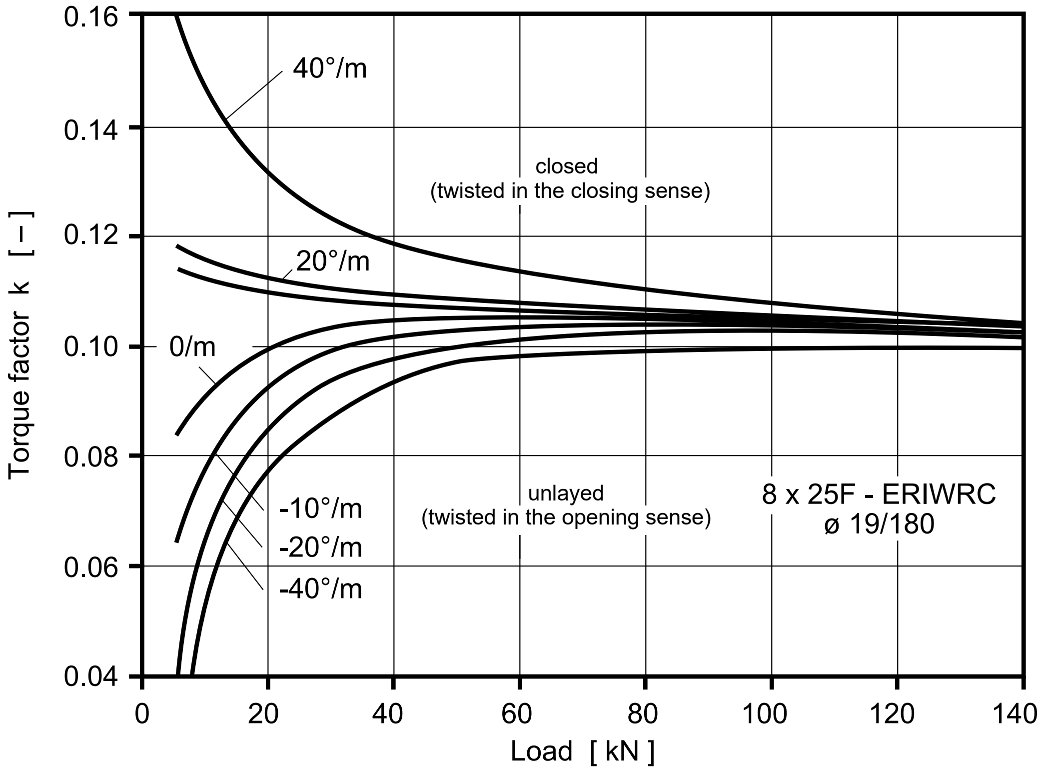


Fig. 31: The changes of the torque factor of a non-rotation-resistant wire rope caused by enforced rotation. The factor k is hardly changed.

The following rule can be deduced:

The change of the moment of non-rotation-resistant ropes by enforced rotation is rather small.

Fig. 32 shows the change of the moment by enforced rotation of a rotation-resistant rope (35 x K7). Whereas the moment of the non-twisted rope is nearly zero, twisting it in the lay lengthening or lay shortening sense causes the moment to increase rapidly.

The reason for this phenomenon is the different influence of enforced rotation on the IWRC and the outer strands respectively:

When the rope is unlayed (twisted in the opening sense), the lay length of the outer layer is lengthened and that of the IWRC is shortened.

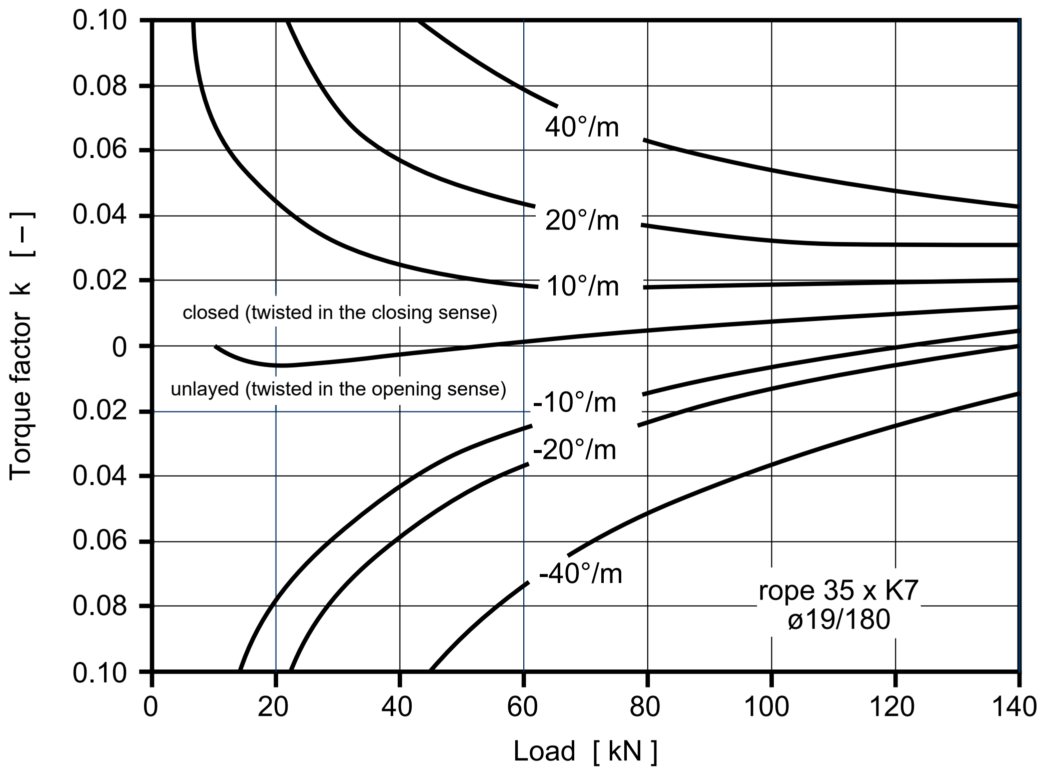


Fig. 32: The changes of the torque factor of a rotation-resistant rope, caused by enforced rotation. The factor k is changed considerably.

When the rope is twisted in the lay shortening sense, the lay length of the outer layer is shortened and that of the IWRC is lengthened.

In both cases, however, the IWRC will react exactly in the opposite way to the outer strands.

The following rule can be deduced:

The change of the moment of <u>rotation-resistant</u> ropes by enforced rotation is extreme.

This theoretical analysis determines the consequences for practical operation. When using rotation-resistant ropes it must be ensured that these ropes are not twisted by force. In a twisted state, a rope that is otherwise rotation-resistant can possess higher moments than a non-rotation-resistant rope.

The following section will discuss the mechanisms that lead to the twisting of a rope and how this can be avoided.

13. The twisting of wire ropes enforced by sheaves

In order to guarantee the correct operation of the rope, the reeving has to be designed in a way that the rope parts will enter the sheaves in exact alignment with them. In practice, however, a slight fleet angle between the rope and the plane of the sheave cannot always be avoided. This is particularly the case in multiple-part reeving systems, where the rope enters the successive sheaves under a certain fleet angle.

This fleet angle has the effect that the rope does not enter the sheaves at the lowest point of the groove. It first touches the groove on the flange and then rolls into the bottom of the groove (Fig. 33). This rolling action twists the rope.

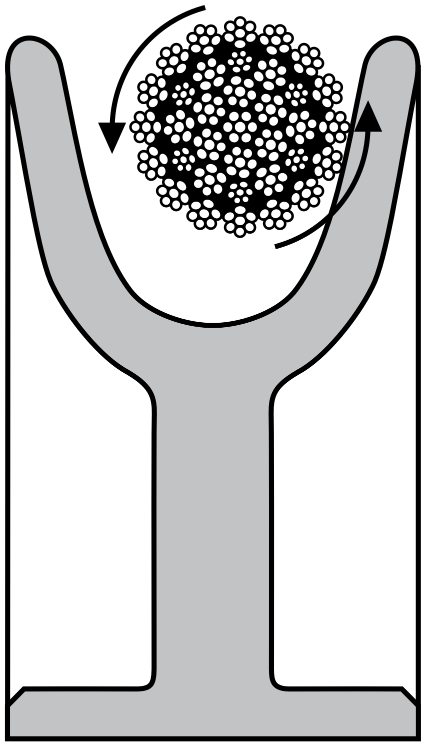


Fig. 33: The wire rope rolls into the bottom of the groove.

Fig. 34 shows the contact of the rope at the flange and the twisted position at the bottom of the groove for a fleet angle of 1°. It is recognizable that for small angular deflections the twist of the rope is also small. Fig. 35 shows the contact of the rope at the flange and the twisted position at the bottom of the groove for a fleet angle of 5°. It is obvious that for great fleet angles the twist of the rope is overproportionally great.

Due to the greater friction at the point of contact this effect is more severe when plastic sheaves are used. With steel sheaves it is easier for the rope to slide into the bottom of the groove. The negative effect of the friction adds up when multi-part reeving systems are used with several deflection sheaves in a row.

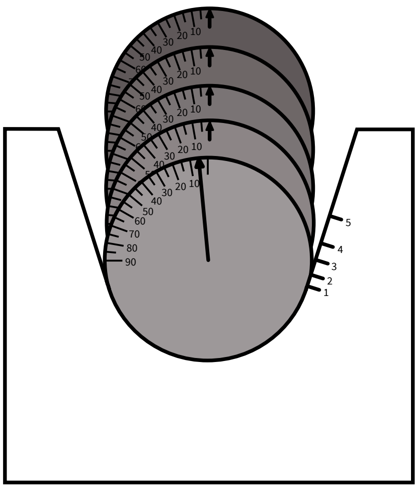


Fig. 34: Slight twist of a rope when the fleet angle is 1°

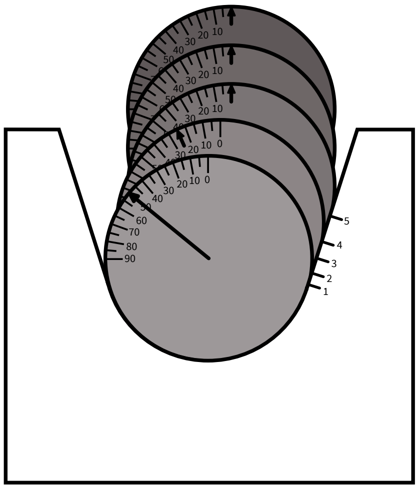


Fig. 35: Great twist of a rope when the fleet angle is 5°

If the cause of rope damage cannot be found, it is often helpful to examine the discarded rope with regard to potential changes of its lay length. Either prints are taken of the rope's surface over equal distances, in order to measure the lay length on paper, or the lay length is measured directly on the rope.

A diagram showing the lay length versus the rope length will clearly differentiate between rope zones twisted in the lay lengthening sense and those twisted in the lay shortening sense.

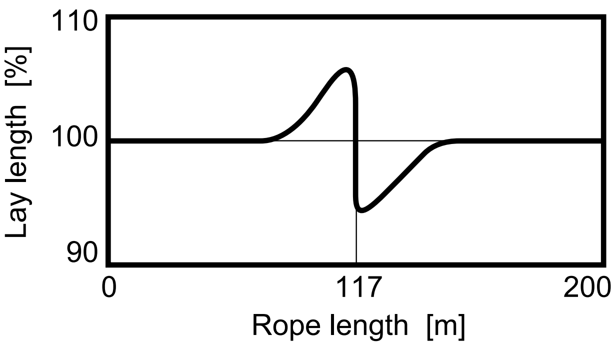


Fig. 36: Change of rope lay length caused by a sheave

Fig. 36 shows the lay length of a discarded rope along the rope length. For most parts of the rope the lay length corresponds with the desired value of 100%. However, in the area of 117 metres a very distinct deviation from the desired value can be recognized.

To the left of that point, approximately 20 metres of the rope have been unlayed and the lay length has been lengthened. To the right of that point, about 20 metres of the rope have been closed and the lay length has been shortened. One may conclude that the rope zone 117m ± 20m passes one of the sheaves at a large fleet angle. By means of a reeving diagram it is usually quite easy to pinpoint the sheave responsible.

We have seen that the twisting of a rope caused by an excessive fleet angle brings the danger of changes to the structure of the rope. Additionally, twist of that kind may unlay and totally unload the outer strands of a wire rope so that the whole load ends up being carried by the IWRC.

It is quite possible that the IWRC, which is now totally overstressed, will fail prematurely, although the outer strands on inspection would suggest that the rope is in perfect condition. A situation like this is extremely dangerous. Therefore, the maximum permissible fleet angle in any reeving system is generally limited to 4°.

Because of the different reactions of IWRC and outer strands, rotation- resistant and rotation-free wire ropes with a steel core that is closed in the opposite direction react much more sensitively to rotation by force than conventional ropes do. Therefore DIN 15 020 limits the maximum permissible fleet angle for those ropes to 1.5°. The revised text of ISO 4308 limits the same to 2°.

Crane designers and users are well- advised to stay within these values.

14. The twisting of wire ropes enforced by drums

The rope is wound on the drums at the angle α, which is the gradient angle of the drum (Fig. 37).

The fleet angle β between the rope and the lead sheave is variable. In Fig. 37, for instance, the angle would be exactly zero if the drum was half full.

If the drum is full, angle β will be at its maximum.

At both flanges of the drum the rope is deflected from the groove at an angle of $\beta+\alpha$ and $\beta-\alpha$ respectively.

The maximum permissible fleet angle $\beta-\alpha$ on drums is generally limited to 4°, for rotation-resistant and rotation-free wire ropes to only 1.5° (DIN 15020) or 2° (revised text of ISO 4308). Crane designers and users are well-advised to stay within these values.

The deflection of the rope on the drum leads – in the same way as the deflections on sheaves – to the rope rolling into the bottom of the groove, which results in a continuous twisting of the rope. In order to minimise that twist and stop the natural tendency of the rope to unlay, the following rule must be observed:

A left-hand drum must be operated with a right-hand lay rope,
a right-hand drum must be operated with a left-hand lay rope.

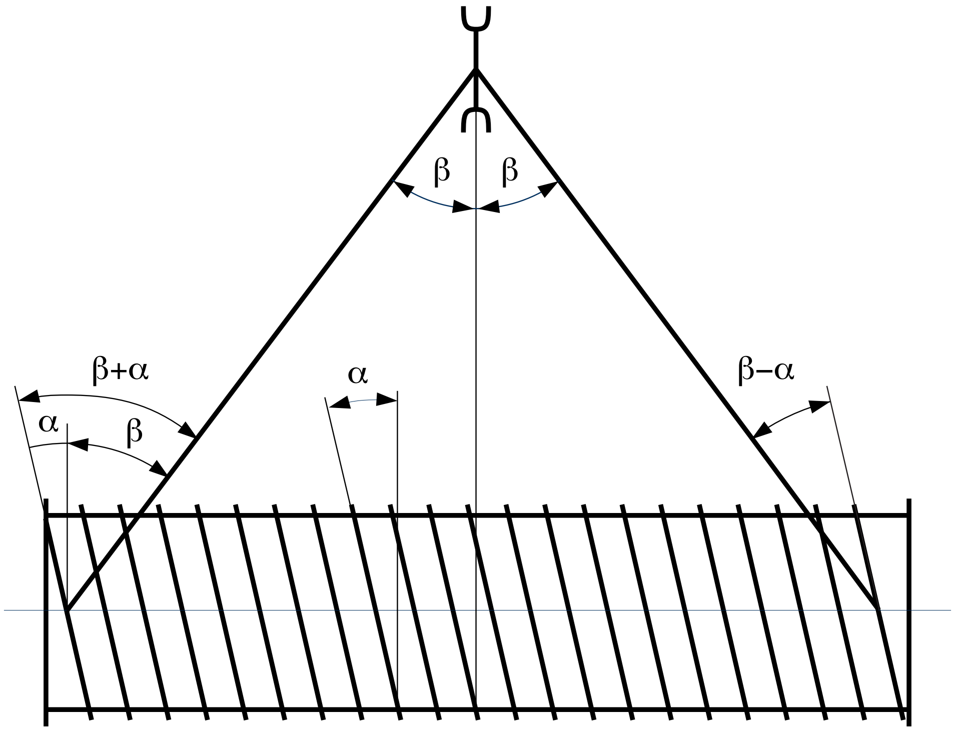


Fig. 37: Fleet angles at the drum and the sheave

A violation of this rule will lead to severe unlaying of the rope on the drum in the opening sense (increase of lay length) and – on the other hand – to an equally severe twisting of the rest of the rope in the closing sense (decrease of lay length) (Fig. 38).

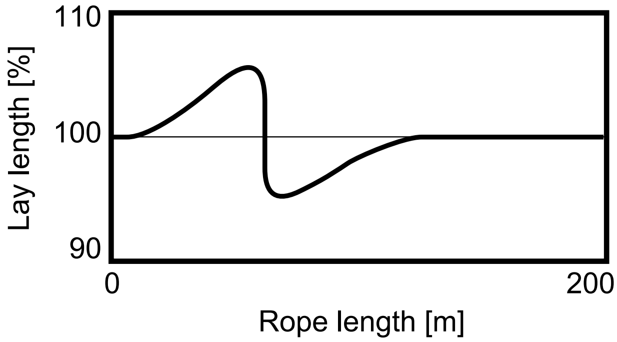


Fig. 38: The change of the lay length caused by a drum with the wrong direction of grooving

Exceeding this twist will cause irrepairable damage to the rope, such as the formation of bird cages in the unlayed zone, or parts of the IWRC protruding in the closed zone of the rope (termed ‘popped cores’).

Quite often both defects occur within the same rope: Fig. 39 shows the damage along the unlayed zone of a rope and Fig. 40 shows the damage in the closed zone of the same rope.

Fig. 39: Surplus length of the outer strands caused by unlaying the rope

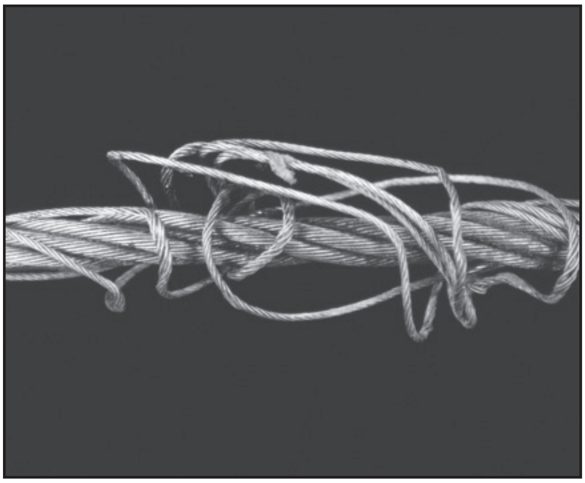


Fig. 40: Surplus length of the inner strands caused by closing the same rope

Apart from choosing the correct direction of lay, the conditions of the lifting device can also be improved by its design. It is evident that the angle β decreases with the growing distance between lead sheave and drum (Fig. 37).

The maximum possible angle β+α can be reduced by shifting the sheave or the drum sideways. Of course, this makes sense only with single-layer drums. It must be remembered, however, that this measure increases the fleet angle on the sheave.

If the diameter of the drum is increased, its width becomes more narrow for a given rope length. This solution, however, is more expensive because of the higher driving moments required.

But increasing the drum diameter not only diminishes β. It also reduces α considerably, because the shift of the rope on the drum can now be distributed over a much wider circumference. Consequently, the maximum of α+β is distinctly reduced by this solution (Fig. 41).

Further advantages can be gained by using specially designed drum systems (e.g. Lebus), in which, for large sections of the circumference, the angle α is zero and the shift into the neighbouring windings can be managed within short zones.

With multiple-layer spooling the rope is wound on the drum, alternating from layer to layer in a right-handed and a left-handed helix. According to the rule of the opposite direction of lay it would be necessary to change the direction of the rope lay from layer to layer. As this is not possible, the direction of lay should be chosen according to the rope layer which is working the most, or even according to the direction of the reeving, because the influence of the direction of lay decreases with the increasing numbers of layers.

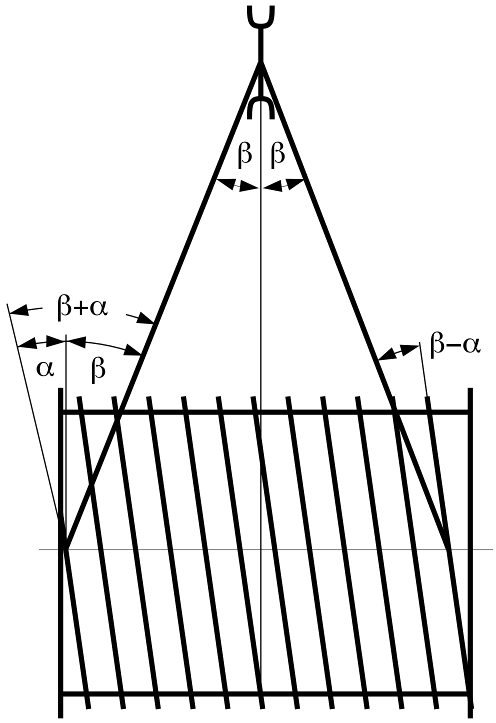


Fig. 41: Reducing the angles by increasing the diameter of the drum

15. The twisting of wire ropes during installation

One of the most frequent causes for the twisting of ropes is incorrect installation. When installing wire ropes, particularly rotation-resistant ones, meticulous care must be taken to ensure that the ropes are installed without any twist. Great care must also be taken not to unwind the rope at the side of the reel or coil during installation as this will introduce one turn per length of the circumference of the reel or coil.

As described above, rotation-resistant ropes are particularly sensitive to these incorrect procedures due to the counteraction of the inner and outer layers. In reeving systems that use rotation-resistant ropes attached to a swivel, any twist that was possibly introduced during the installation can unlay.

Quite often, especially with large cranes, new ropes are attached to the old ones and are pulled by them into the reeving system. When installing ropes in this way, it is vital that the connection of the rope ends is not rigid. A rigid connection would allow a twisted old rope to pass on its twist to the new rope by unlaying during the installation process. In this case the new rope would be damaged to such an extent that it would fail within a very short period of time.

Instead, the ropes can be connected by Chinese Fingers with a welded-in swivel, or by two or more strands which serve as connecting elements between the two rope ends.

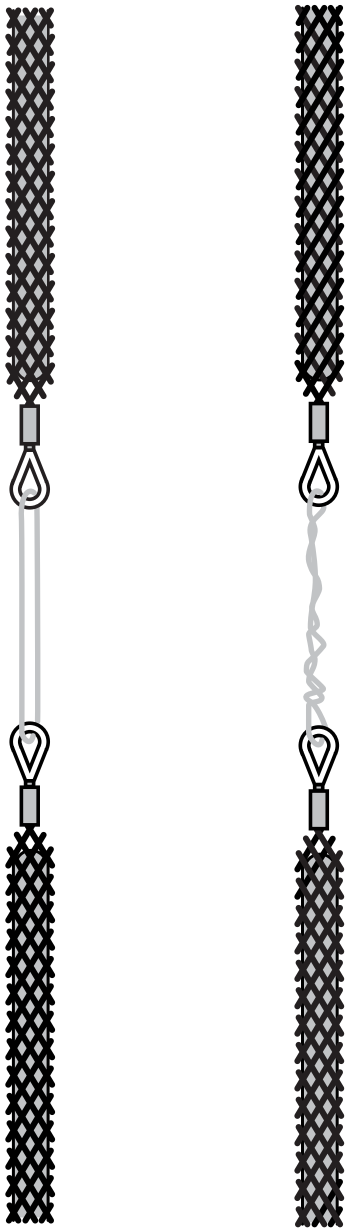


Fig. 42: Rope connection by means of Chinese Fingers. Before (left) and after installation (right).

The latter case has one distinct advantage: after the installation of the new rope the strands will reveal how many turns the discarded rope has unlayed (Fig. 42).

When installing Langs lay ropes, rotation of the rope ends must be avoided.

Even the slightest twist will lead to great differences in length between external and internal rope components. Later these differences will be accumulated by the drums and sheaves at one point, where they will eventually appear as birdcages.

In many cases it is advisable to paint a straight line on the rope parallel to the axis during the production process. This will make it easier to detect any twist after installation.

If necessary, this twist can be compensated by twisting the rope end back at the fixed point. However, operations like these should always only be carried out by specialists.

With reference to installation, the Langs lay versions of special wire ropes with a plastic layer between the IWRC and the outer strands are much safer than conventional Langs lay ropes. The indentations of the plastic coating with the IWRC and the outer strands counteract any tendency of the unloaded rope to twist, thereby providing a problem-free installation.

In all cases where absolute security against twist cannot be guaranteed during installation, the use of ropes with plastic infill is highly recommended.

16. Why must non-rotation-resistant wire ropes not be operated with a swivel?

If a non-rotation resistant rope is attached to a swivel, it will unlay under load. The twist leads to an enormous shift of the forces within the rope: the outer strands will be unloaded, internal components will be overloaded. The breaking load and with it the safety of non-rotation-resistant ropes is severely reduced, if the rope is allowed to rotate freely.

When the rope is unloaded, the line moving towards the swivel may possibly rotate back to its original non-twisted state. The more often these ropes are loaded and unloaded, the greater the internal wear and the fatigue of inner strands will be by continually opening and closing at the swivel. As these defects cannot be detected by visual inspection of their interior, they represent an additional safety risk.

Non-rotation-resistant ropes, such as the six- and eight-strand types, must be attached in such a way that they are secured against twist. They must never be fitted with a swivel.

17. Why should 17x7, 18x7 and 19x7 ropes not be fitted with a swivel?

As mentioned above, 17x7, 18x7, and 19x7 ropes lose more than 30% of their breaking load when undergoing a break test with a swivel. This reduction of safety would already prohibit the use of a swivel. What is more, even under minimal loads, ropes of this construction show considerable twists. Attaching these ropes to a swivel would therefore cause permanent twisting and unlaying - as it does with 6- and 8-strand ropes. This mechanism would inevitably lead to increasingly dangerous internal wear and to premature fatigue of the inner strands, which are not accessible when inspecting the rope's exterior.

18. Twist in the reeving system caused by an open swivel

All the arguments so far prohibit the use of a swivel with non-rotation- resistant ropes and 17x7, 18x7, 19x7 ropes and their variations for safety reasons. In many cases another problem crops up when a swivel is used with these ropes: twist is built up in the reeving system. An example may illustrate this:

A new, non-rotation-resistant rope has been installed on a simple crane with one sheave and one drum (Fig. 43). We have made sure that the rope has not been twisted during installation. The wire rope is attached to the hook by means of a swivel.

When lifting a load, the swivel will rotate until the entire rope length between the swivel and the first sheave is completely unlayed.

Fig. 44 shows that in our example the swivel has completed eight revolutions, represented by eight dots on the rope.

When lifting the load further, part of the twisted rope length – in our example half of it – will move over the sheave. After this operation, half of the revolutions induced by the swivel, represented by four dots, will be found between the sheave and the drum (Fig. 45). In this area a relatively strongly twisted rope zone meets non-twisted rope.

The twisted zones will transfer part of their twist to the as yet non-twisted zones, i.e. the four revolutions will be spread evenly across the whole rope length between sheave and drum (Fig. 46).

Now the crane is moved into a different position or just slews, and the load is set down. When lowering the hook, part of the twisted rope length (in our case half of it) will travel from the stretch between the sheave and the drum into the line to the swivel.

In our example, two revolutions leave the section between sheave and drum (Fig. 47). At the same time non-twisted rope spools off the drum into the same stretch. The two revolutions remaining between the drum and sheave now spread evenly in that section, while the line attached to the swivel returns to its non-twisted state once the load is put down (Fig. 48).

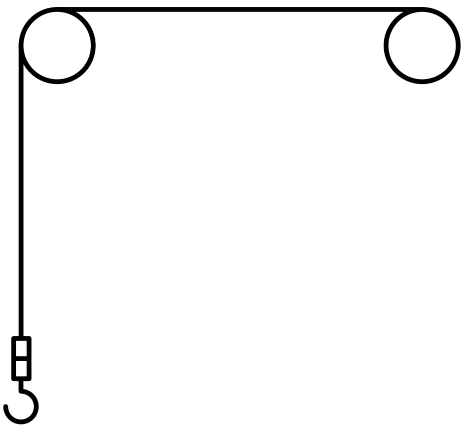


Fig. 43: Before lifting the load the wire rope is non-twisted.

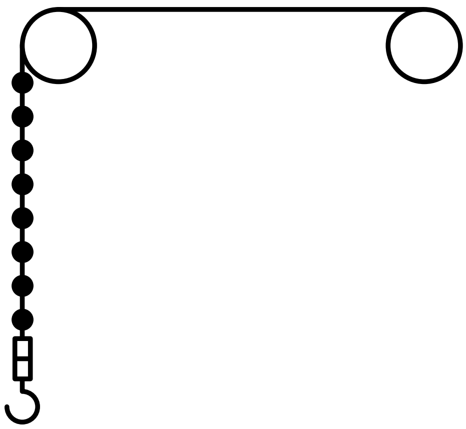


Fig. 44: When the load is lifted, the swivel carries out eight complete revolutions.

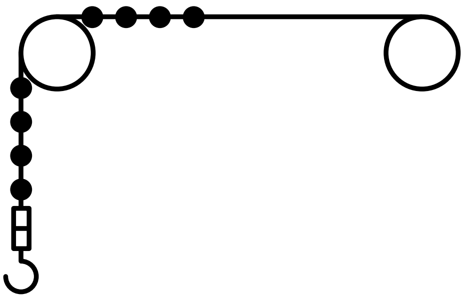


Fig. 45: While lifting the load, half of the twisted rope length passes over the sheave.

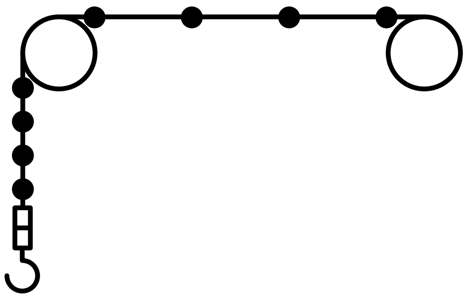


Fig. 46: The twist spreads evenly along the rope length.

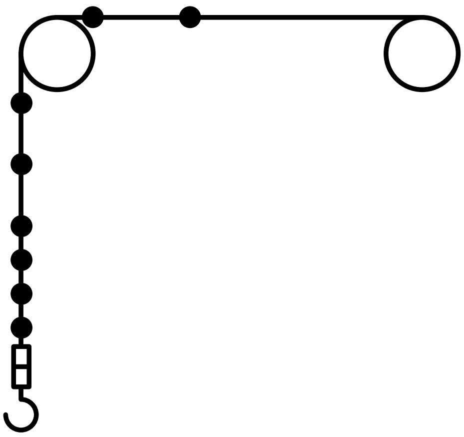


Fig. 47: Part of the twisted rope length runs back over the sheave.

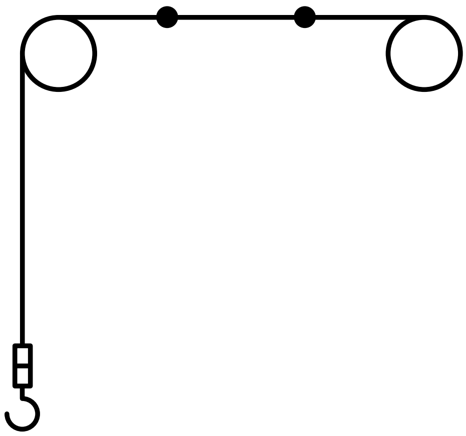


Fig. 48: After one lifting operation two revolutions remain within the reeving system.

We have now returned to the starting position, and the process described above could start all over again.

We started with a non-twisted rope, but after only one lifting operation two complete revolutions have entered the rope. The twisted zones are trapped between the sheave and the drum and cannot unlay at the swivel to regain their initial, non-twisted state. On the contrary, with every additional lift, the amount of rope twist will increase.

It is a fallacy to believe that twist introduced into the rope by loading it, will be eliminated when the rope is unloaded. Due to the ‘mixing phenomenon’, part of the twist will always remain in the system. After poisoning a barrel of wine with a glass of arsenic, it cannot be expected to become drinkable again just by skimming off a glass of the mixture from the barrel.

The increase of twist within the system in the course of further lifting operations may lead to different consequences for the rope. The twist might overstress some elements of the rope and lead to their premature failure. More often, however, the twist will lead to differences in the lengths of strands in different layers, which then results in the formation of birdcages or corkscrews.

Fig. 49 illustrates an example of birdcaging on the drum.

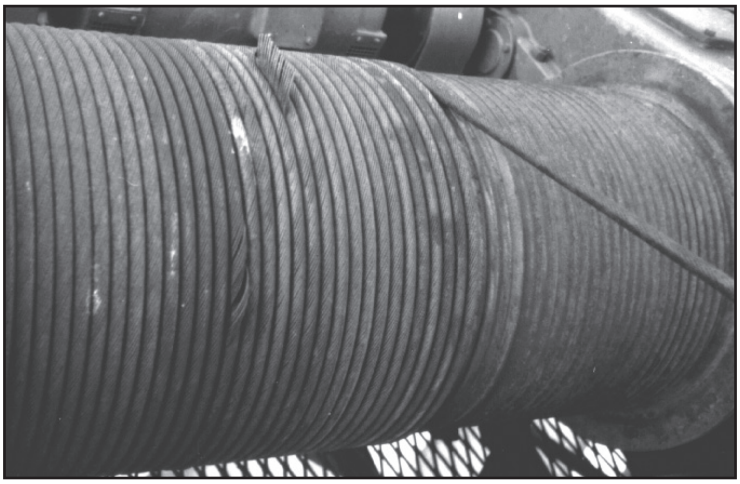


Fig. 49: Birdcaging on the rope drum

When a twisted rope is unloaded abruptly, a very dangerous situation called ‘slack-rope formation’ may occur. What actually happens is, that when the heavily twisted rope is unloaded it manages to rid itself of part of the twist by forming a loop (Fig. 50). When the rope is loaded again, the loop might tighten and form a kink. This can happen within a split second and might not be noticed in time by the crane operator – the consequence could well be a broken rope.

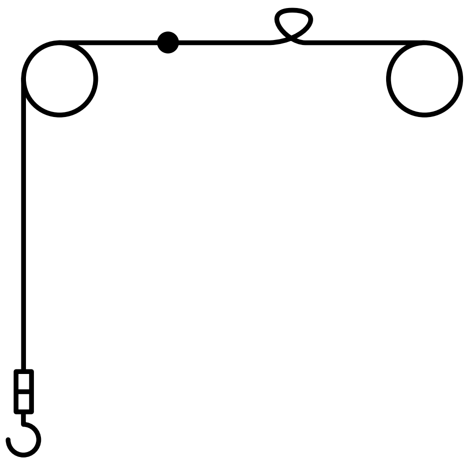


Fig. 50: Formation of a loop when a twisted rope is sagging or slack

19. Why may rotation-resistant ropes be fitted with a swivel?

The problems we dealt with above do not exist when using rotation-resistant ropes such as 35 x K7 or 40 x K7 ropes. Neither is the breaking load reduced when they are used with a swivel, nor do these ropes tend to twist and unlay when the load changes. These ropes are extremely resistant to rotation, so that the swivel – under normal circumstances – does not turn when the rope is being loaded or unloaded. Consequently these ropes do not suffer from the wear and premature fatigue that occur in the other cases described above.

35 x K7 or 40 x K7 ropes can be fitted with a swivel.

20. Why should rotation-resistant ropes be fitted with a swivel?

Rotation-resistant wire ropes will not unlay under outer loads. However, we have discussed situations where external forces attack the rope tangentially and twist it. For example, a wire rope will be twisted by force when running into the bottom of the groove on a sheave or a drum at a certain fleet angle.

This twist will cause a very high moment in a rotation-resistant rope. If the rope is attached to a swivel, this moment can reduce itself by rotating the swivel - in the ideal case until the moment is zero.

The use of a swivel with ropes like 35 x K7 or 40 x K7 ropes does not have any adverse effects. If the rope works as it should, the swivel is dispensable. If, however, the rope is twisted by force, the swivel will serve as a valve through which the twist can escape.

35 x K7 or 40 x K7 ropes should be fitted with a swivel.

One solution that is frequently used, is the attachment of a locked swivel which, in order to allow a twisted rope to rotate back to its non-twisted state, is only opened from time to time for a certain number of load cycles.

For rotation-free ropes the swivel has no disadvantages whatsoever. On the contrary, twist which were introduced by external influences can leave the reeving system visa the swivel.

On the other hand, with non-rotation-resistant ropes the swivel brings nothing but disadvantages. It reduces the breaking load, speeds up fatigue and allows twists to enter the reeving system.

21. What can be done if twist is built up in the reeving system despite the use of a swivel?

As we have demonstrated above, every drum tends to twist the incoming rope. This mechanism always builds up twist in the reeving system. Using a swivel as an end connection will make it possible to reduce the twist that was caused by the drum or by some other mechanisms. To achieve this end the twist must travel from its origin via all the sheaves until it arrives at the swivel. This can only happen if twisted rope can move over every single sheave. Under certain working conditions of cranes it may occur that a single sheave in the reeving system does not rotate at all, so that the twist cannot travel any further and consequently does not arrive at the swivel. The reeving system of the tower crane (Fig. 51) may illustrate the problem.

If, over a long period, only lifting operations are carried out without any trolley motions, sheave A does not rotate at all. So, twist that was introduced into the reeving by the drum or by other mechanisms cannot travel beyond this sheave and unlay at the swivel.

After a time, the twist would become apparent by a rotation of the hook block, particularly if the rope is unloaded. The fact that the twist shows itself when the rope is unloaded, is a clear indication that it is not lack of rotation resistance of the rope that is responsible for the twist, but accumulated twist that cannot travel on to the swivel. This problem can be solved by moving twisted rope beyond sheave A.

To achieve this end, the trolley must be moved along the whole length of the boom several times, if necessary, in combination with simultaneous lifting operations. During this procedure, the swivel will usually turn and allow the rope to regain its non-twisted state.

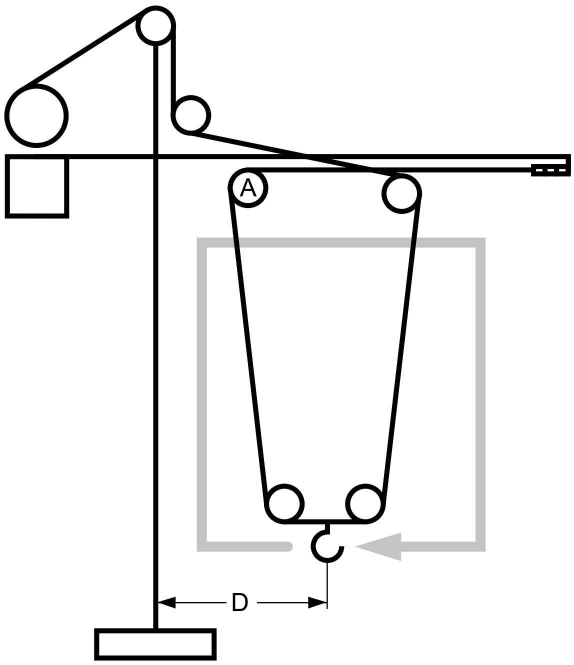


Fig. 51: When lifting and lowering the hook, sheave A does not rotate. Sheave A only rotates if distance D changes

Normally, after several turns of the swivel, the twist will have disappeared. If, however, the swivel does not turn, it will be necessary to check whether it is working properly. The swivel should turn easily by hand. It must also be hinge-mounted to the jib so that even a sagging rope can turn the swivel.

Fig. 52 shows a swivel fixed rigidly to the jib. It is impossible for a sagging rope to turn this swivel. Fig. 53 shows the correct solution of using a hinge-mounted swivel.

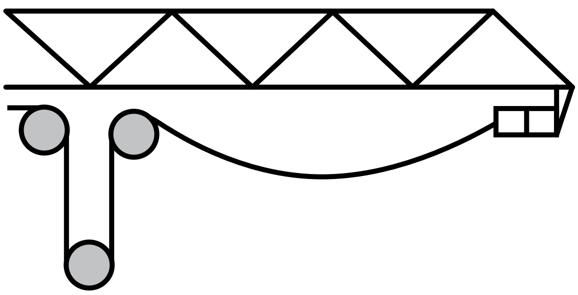


Fig. 52: Fixed swivel with limited working ability

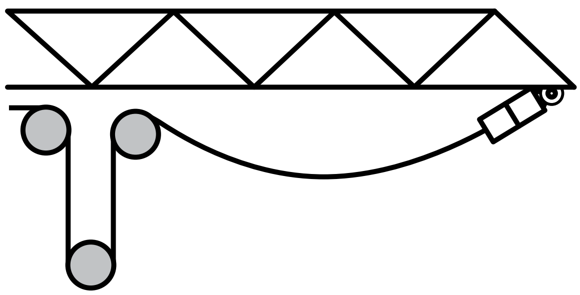


Fig. 53: Hinge-mounted swivel. The swivel is in line with the sagging rope.

The swivel must be hinge-mounted so that it can stay in line with the rope. The swivel is part of the reeving system and not part of the construction.

The swivel is not always popular because it can reduce the lifting height of the crane. This disadvantage can be eliminated by using rope end connections with a built-in swivel. These are much shorter than the combination of a conventional end connection with a separate swivel, and in addition to that they have the advantage of being in line with the rope at any time.

Fig. 54 shows a wedge socket with a built-in swivel.

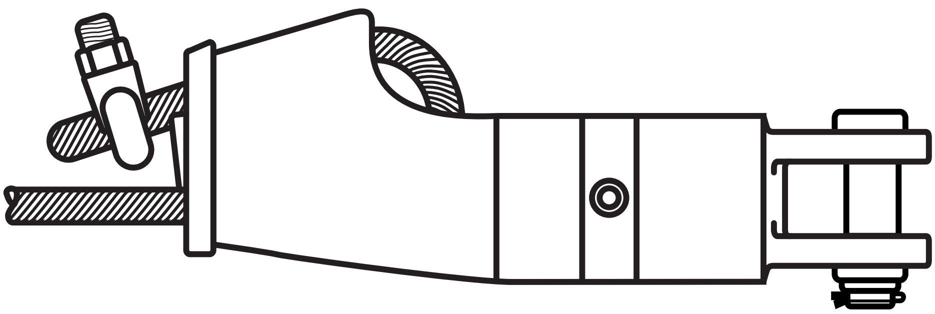


Fig. 54: Wedge socket with a built-in swivel

22. Special topic: How to connect grab ropes

Cranes with four-rope grabs are operated with two holding ropes and two closing ropes (Fig. 55). In order to prevent the rotation of the grab under load, the holding ropes as well as the closing ropes are both fitted with right-hand and left-hand lay designs.

When connecting the closing ropes to the grab ropes, it must be ensured that the left-hand lay closing rope is connected to the left-hand lay grab rope, and the right-hand lay closing rope to the right-hand lay grab rope (Fig. 56). If a left-hand lay grab rope was connected to a right-hand lay closing rope, both ropes would try to twist the connecting link in the same direction: the ropes would therefore unlay each other under load (Fig. 57).

On the one hand this would considerably reduce the breaking load of the wire ropes; and on the other, the disturbed geometry might lead to structural changes in the rope, such as wavy deformations or birdcages. Additionally, the continual unlaying and closing of the ropes would lead to torsion fatigue near their end connections.

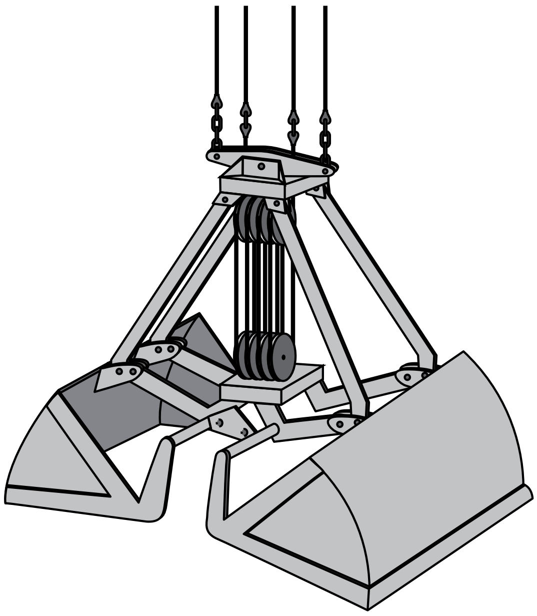


Fig. 55: Four-rope grab with two holding and two closing ropes

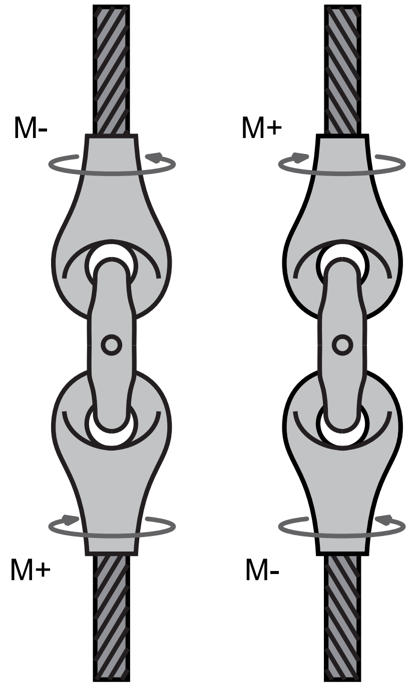


Fig. 56: Correctly connected grab ropes

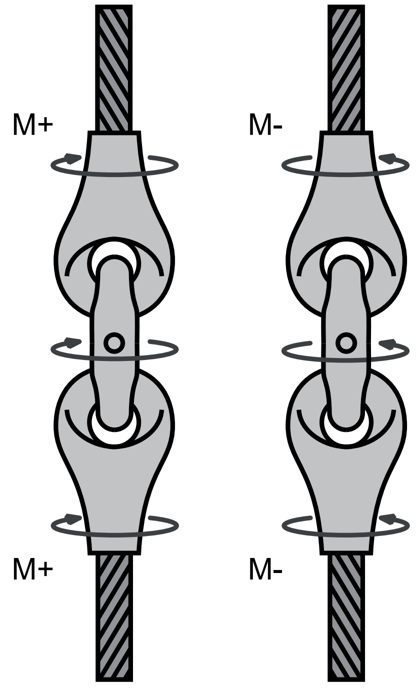


Fig. 57: Incorrect connection of grab ropes. The ropes unlay each other.

There is also the danger that the rope composition within the grab will disintegrate when the ropes are unloaded, so that coal or ore dust, for example, could enter the rope. It is true that the rope would close again under the next load, but it would also have a clearly enlarged diameter, so that it might not pass the sheaves in the way it should. So there is the danger that in later operations the grab will not open automatically, or that the rope must be pulled through the sheaves with undue force.

A similar danger occurs when the connected ropes do have the same direction of lay but are of different design or have different diameters (Fig. 58). As desired, the moments work against each other, but nevertheless, their values are different.

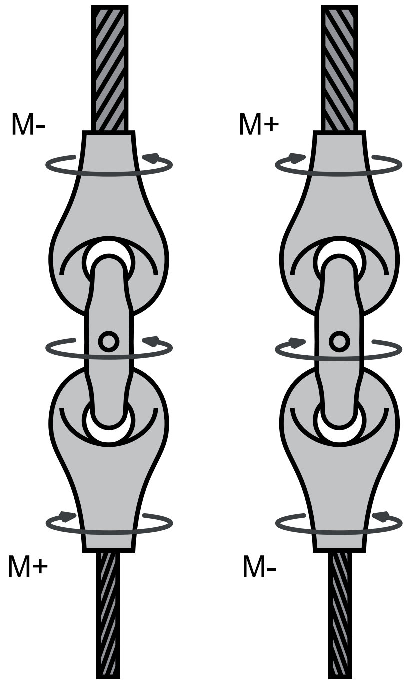


Fig. 58: Connection of wire ropes with equal direction of lay but different diameters

The rope with the greater moment (in cases where the ropes have different diameters, this will usually be the larger one) will unlay under load and close the rope with the smaller moment (usually the smaller one). Unfortunately, connecting ropes of different diameters cannot always be avoided. Many cranes work with different grab sizes when unloading vessels of different sizes. Quite often the different grabs are fitted with closing ropes of different diameters.

Sometimes four-rope cranes also operate without a grab. In such cases the four ropes should be connected by an equaliser. Frequently the left-hand lay and the right-hand lay holding ropes, as well as the left-hand lay and right-hand lay closing ropes, are connected by a piece of rope and fitted with a hook block (Fig. 59).

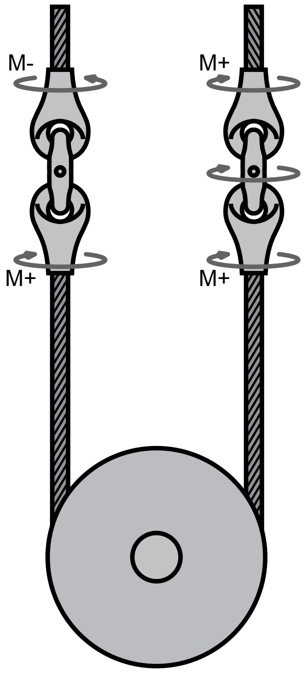


Fig. 59: Connection not secured against rotation between two ropes with different directions of lay

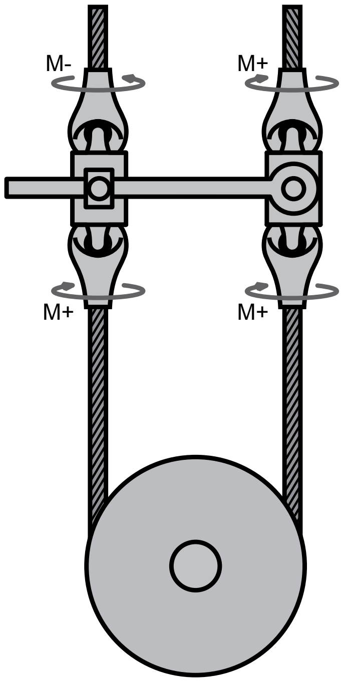


Fig. 60: Connection secured against rotation between two ropes with different directions of lay

Naturally, the direction of lay of the balancing rope can correspond with the direction of lay of only one of the ropes to which it is connected. Inevitably, the other one has a different direction of lay so that the ropes will always tend to unlay each other.

As a consequence of the slight movements of the hook block, part of the twisted piece of rope will repeatedly travel along the sheave into the other line, so that after a certain working period a connection of this kind will cause the mutual destruction of the three ropes. A rotation resistant balancing rope would not perform the job any better.

Connections of this kind may only be carried out if their rotation around their longitudinal axes is prevented by means of a mechanical device. Fig. 60 illustrates an example of how this can be achieved: a crossbar prevents the connection from rotating.

As, however, the distances between the connections can change, the crossbar must not be fixed rigidly at both sides. A sliding joint on one side must allow the relative shift of the connections.

23. First Aid

If a hook block rotates, it should first be checked to see whether the rotation occurs under load or only when the rope is unloaded (Fig. 61).

Apart from a few exceptions the following rule applies:

If the hook block rotates under load, there is a problem with the rope.

In this case the wire rope is not sufficiently rotation-resistant.

Again, with only a few exceptions, the following rule applies:

If the hook block rotates without being loaded, there is a problem with the crane.

The wire rope has been twisted by the crane. It now twists the block in order to regain its non-twisted state.

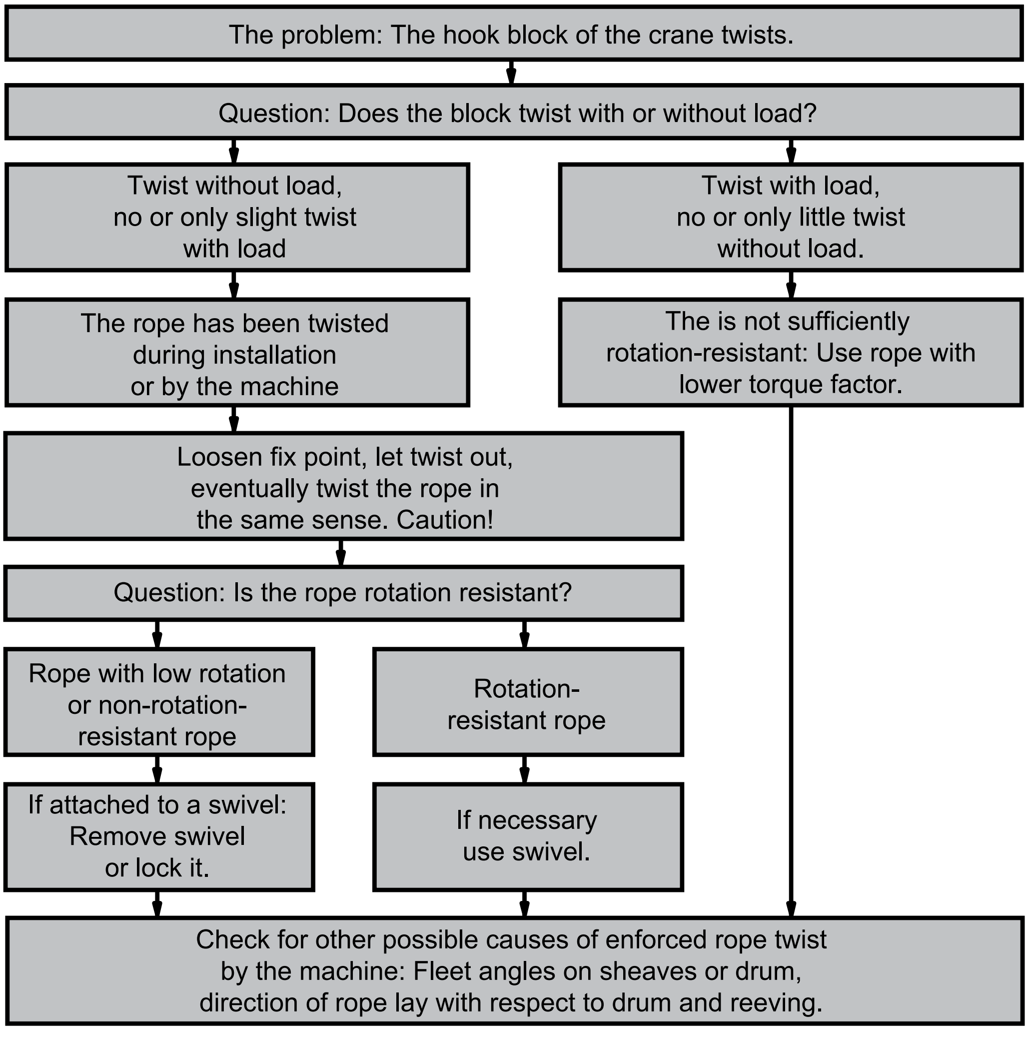


Fig. 61: First aid - What to do in the event of a rotating hook block.

24. Final remarks

The subject of the rotatation characteristics of steel wire ropes is very complex. This brochure could only discuss the more basic questions. If you have a specific problem not covered in this publication, please feel free to contact the author:

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We will do our best to help you.

„Maybe we should use rotation resistant ropes!“

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