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Cranes and hoists — Selection of wire ropes, drums and sheaves

Appareils de levage à charge suspendue — Choix des câbles, tambours et poulies

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 96, *Cranes*, Subcommittee SC 3, *Selection of wire ropes*.

This first edition of ISO 16625 cancels and replaces ISO 4308-1:2003, ISO 4308-2:1988 and ISO 8087:1985, of which it constitutes a technical revision.

Cranes and hoists — Selection of wire ropes, drums and sheaves

1 Scope

This International Standard specifies the minimum practical design factors, Z_p, for the various classifications of mechanism, rope types, rope duties and types of spooling and demonstrates how these are used in the determination of the minimum breaking force of the wire rope.

It specifies the selection factors for drums and sheaves for the various classifications of mechanisms, rope types and rope duties and how these are used in the determination of the minimum practical diameters of drums and sheaves that work in association with the selected wire rope.

A list of types of cranes and hoists to which this standard applies is given in Annex A.

Annex B gives factors, additional to those mentioned above, which might need consideration when selecting the wire rope and associated equipment.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2408, *Steel wire ropes for general purposes — Minimum requirements*

ISO 4301-1:1986, *Cranes and lifting appliances — Classification — Part 1: General*

ISO 4306-1, *Cranes — Vocabulary — Part 1: General*

ISO 4309, *Cranes — Wire ropes — Care and maintenance, inspection and discard*

ISO 10425, *Steel wire ropes for the petroleum and natural gas industries — Minimum requirements and terms of acceptance*

ISO 17893, *Steel wire ropes — Vocabulary, designation and classification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4306-1 and ISO 17893 apply.

NOTE 1 In this document, “single-layer ropes” and “parallel-closed ropes”, as defined in ISO 17893, are referred to as “standard ropes” to distinguish them from “rotation-resistant ropes”.

NOTE 2 Single-layer ropes and parallel-closed ropes are also sometimes referred to as “*non*-rotation-resistant ropes”.

4 Group classification of the mechanism as a whole

The resulting classification of mechanism (M4, M5, etc.) shall be taken into account when establishing the minimum design factor and the minimum drum and sheave sizes.

The group classification of the mechanism as a whole takes account of the state of loading (light, moderate, heavy, etc.) and the class of utilization of the mechanism (based on total duration of use) as a whole, as detailed in ISO 4301-1.

NOTE Other parts of ISO 4301 (such as ISO 4301-2, covering mobile cranes) specify the classification of a particular type of crane and related crane mechanisms taking account of the rope duty (hoisting, luffing, etc.) and crane operating conditions.

5 Selection of rope

5.1 Type and construction

The wire rope selected shall conform to either ISO 2408 or ISO 10425, according to the application and/or duty.

5.2 Design factor, Z_p

The minimum design factor shall be specified in accordance with Tables 1, 2 or 3, as applicable, taking into account the classification of mechanism and the rope duty or rope hoist and, in the case of stationary ropes, the crane classification.

NOTE The design factors listed in the tables are based on long experience in the field.

Table 1 — Minimum design factors for all cranes and hoists except mobile cranes

Group classification of mechanism in accordance with ISO 4301-1:1986	Hoisting				Boom hoisting or luffing	
	Single-layer spooling		Multi-layer spooling			
	Standard rope	Rotation-resistant rope	Standard rope	Rotation-resistant rope	Standard rope	Rotation-resistant rope
M1	3,15	3,15	3,55	3,55	3,55	4,5
M2	3,35	3,35	3,55	3,55	3,55	4,5
M3	3,55	3,55	3,55	3,55	3,55	4,5
M4	4,0	4,0	4,0	4,0	4,0	4,5
M5	4,5	4,5	4,5	4,5	4,5	4,5
M6	5,6	5,6	5,6	5,6	5,6	5,6
M7	7,1	7,1	—	—	7,1	—
M8	9,0	9,0	—	—	9,0	—

Table 2 — Minimum design factors for mobile cranes

Group classification of mechanism in accordance with ISO 4301-1:1986	Running rope						
	Hoisting		Boom hoisting				Telescoping
			Working		Erecting		
	Standard rope	Rotation-resistant rope	Standard rope	Rotation-resistant rope	Standard rope	Rotation-resistant rope	
M1	3,55	4,5	3,35	4,5	3,05	4,5	3,15
M2	3,55	4,5	3,35	4,5	3,05	4,5	3,35
M3	3,55	4,5	3,35	4,5	3,05	4,5	3,35
M4	4,0	4,5	3,35	4,5	3,05	4,5	3,35
M5	4,5	4,5	3,35	4,5	—	—	—
M6	5,6	5,6	3,35	5,6	—	—	—

Table 3 — Stationary working rope and erecting rope

Crane classification	All cranes	
	Stationary ropes	Erection ropes
A1	3,0	2,73
A2	3,0	2,73
A3	3,0	2,73
A4	3,5	2,73
A5	4,0	2,73
A6	4,5	—
A7	5,0	—
A8	5,0	—

5.3 Minimum breaking force

The minimum breaking force of the rope, F_{min}, shall be calculated using Formula (1):

$$F_{min} \geq S \times Z_p \quad (1)$$

where, for hoisting ropes, S is the maximum rope tension, in kN, obtained by taking into account

— rated working load of the appliance,

— mass of the sheave block and/or other lifting attachments,

— mechanical advantage of reeving,

— efficiency of reeving (e.g. bearing efficiency), and

— the increase in force in the rope caused by the rope inclination at the upper extreme position of the hook, if the inclination with respect to the drum axis exceeds 22,5°;

or, for stationary ropes, S is the maximum rope tension, in kN, obtained by taking account of both the static and dynamic forces;

and where Z_p is the minimum design factor.

For values of Z_p, see 5.2. Alternatively, in circumstances when rotation-resistant ropes are used for hoisting and the mass of the sheave block and other lifting attachments and the efficiency of the reeving are not required to be taken into account, the design factor shall be at least 5.

In the case of appliances with grabs, where the mass of the load is not always equally distributed between the closing ropes and the holding ropes during the whole of cycle, the value of S to be applied shall be determined as follows.

a) If the hoist mechanism automatically ensures an equal division of the hoisted load between the closing and holding ropes, and any difference between the loads carried by the ropes is limited to a short period at the end of the closing or the beginning of the opening:

   1) for closing ropes, S = 66 % of the mass of the loaded grab divided by the number of *closing* ropes;

   2) for holding ropes, S = 66 % of the mass of the loaded grab divided by the number of *holding* ropes.

b) If the hoist mechanism does *not* automatically ensure an equal division of load between the closing ropes and the holding ropes during the hoisting motion and, in practice, almost all the load is applied to the closing ropes:

   1) for closing ropes, S = total mass of the loaded grab divided by the number of closing ropes;

   2) for holding ropes, S = 66 % of the total mass of the loaded grab divided by the number of holding ropes.

NOTE For the more common wire rope classes and constructions and, where applicable, rope grade, minimum breaking force factors given in ISO 2408 and ISO 10425 enable the minimum breaking force value to be calculated for a given nominal rope diameter. It should be noted, however, that the minimum breaking force factor used by the rope manufacturer can be greater than that given in the above-mentioned International Standards, resulting in higher minimum breaking force values being specified.

5.4 Diameter

In the process of selecting a wire rope to satisfy the minimum breaking force requirement as given in 5.3, the situation can arise where, for practical reasons (e.g. availability, preferred sizes), the minimum breaking force exceeds the required minimum value, leading to a higher design factor than the minimum quoted in 5.2. In such cases, the selected nominal wire rope diameter, d, is to be used when calculating the diameter of sheaves and drums; see 6.2.

NOTE The nominal diameter of a given rope type, construction or class, minimum breaking force and, where applicable, grade, is established by the rope manufacturer.

6 Drums and sheaves

6.1 Sheave material

The manufacturer shall take account of the type of spooling when selecting the sheave material or sheave groove lining material.

Single-layer spooling

Where spooling at the drum is single-layer, the choice of sheave material can be critical, as deterioration of the wire rope is most likely to be through bending fatigue — particularly if the fleet angle is not excessive.

If all of the sheaves are made of a polymer material or have a polymer groove lining, there is a possibility of internal fatigue damage going largely unnoticed in service unless discard criteria and/or the frequency between inspections is/are significantly modified from that given in ISO 4309 and closely followed. Such an arrangement should generally be avoided; see B.3.1 for recommendation.

If the fleet angle is higher than recommended, then the most severe deterioration experienced in the reeving system can be in the form of increased wear/abrasion and scrubbing damage occurring between wraps on the drum as a result of higher-than-normal transverse loading at the extremity of travel.

Multi-layer spooling

Where spooling at the drum is multi-layer, it can be expected that deterioration of the wire rope will be at its greatest at those sections that coincide with the crossover zones at the drum rather than at those sections that simply run through sheaves. In such cases, polymer sheaves or sheaves having a polymer groove lining, as well as steel sheaves, may be used, provided other properties, such as limiting radial pressures, are not exceeded for the selected material.

6.2 Calculation of minimum drum and sheave diameters

The minimum pitch circle diameter of drums and sheaves for “hoisting” ropes shall be calculated using Formulae (2) or (3).

NOTE Any increase in pitch circle diameter from the calculated values will enhance the bending fatigue resistance of the rope.

$$D_1 \geq h_1 \times t \times d \tag{2}$$

or

$$D_2 \geq h_2 \times t \times d \tag{3}$$

where

D_1 is the minimum pitch circle diameter of the drum;

D_2 is the minimum pitch circle diameter of the sheave;

d is the nominal diameter of the selected rope;

h_1 is the selection factor for the drum (ratio of the pitch circle diameter of the drum to the nominal diameter of the rope) in accordance with Tables 4 and 5;

h_2 is the selection factor for the sheave (ratio of the pitch circle diameter of the sheave to the nominal diameter of the rope);

t is the rope type factor in accordance with Table 6.

Table 4 — Selection factors h_1, h_2 and h_3 — Hoisting and boom hoisting/luffing ropes — Cranes and hoists other than mobile cranes

Group classification of mechanism in accordance with ISO 4301-1:1986	Drums, h_1	Sheaves, h_2	Compensating sheaves, h_3	
	min.	min.	min.	preferred min.[a]
M1	11,2	12,5	11,2	12,5
M2	12,5	14,0	12,5	14,0
M3	14,0	16,0	14	16,0
M4	16,0	18,0	16,0	18,0
M5	18,0	20,0	18,0	20,0
M6	20,0	22,4	20,0	22,4
M7	22,4	25,0	22,4	25,0
M8	25,0	28,0	25,0	28,0

[a] These factors are particularly recommended to limit radial pressure at rope entry/exit zones when single-layer spooling where bending fatigue is usually the principal mode of deterioration.

Table 5 — Selection factors h_1, h_2 and h_3 — Mobile cranes

Rope duty and classification of mechanism in accordance with ISO 4301-1:1986		Drums, h_1			Sheaves, h_2			Compensating sheaves, h_3		
		Std. rope	R-R rope		Std. rope	R-R rope		Std. rope	R-R rope	
		min.	min.	preferred min.[a]	min.	min.	preferred min.[b]	min.	min.	preferred min.[c]
Hoisting	M1 to M6	16,0	18	20	18	18	20	14	18	20
Boom hoisting/ luffing	M1 to M6	14	16	20	16	16	20	12,5	16	20
Telescoping	M1 to M4	—	—	—	14	—	—	10	—	—

[a] These factors are particularly recommended for limiting radial pressure and attendant rope distortion effects at cross-over zones associated with multi-layer spooling.

[b] These factors are particularly recommended for limiting radial pressure and enhance bending fatigue performance on single-layer spooling mechanisms.

[c] These factors are particularly recommended for limiting radial pressure at rope entry/exit zones when single-layer spooling where bending fatigue is usually the principal mode of rope deterioration.

Table 6 — Rope type factor t for various rope types

Number of outer strands in rope	Rope type factor t
3	1,25
4 to 5	1,15
6 to 10	1,00
8 to 10 – plastic impregnation	0,95
10 and greater — rotation-resistant	1,00

7 Exceptional conditions

For exceptional conditions, such as the handling of molten metal, extremely dirty and/or corrosive environment,

a) no classification group lower than M5 shall be used, and

b) the Z_p value shall be increased by 25 % up to a maximum of 9,0.

8 Care and maintenance, inspection and discard

The selection of ropes, drums and sheaves according to this International Standard cannot alone ensure safe operation of the rope for indefinite periods.

For drums and sheaves, the instructions provided by the manufacturer on care and maintenance, inspection and discard shall be followed.

For wire ropes, ISO 4309 applies.

Annex A
(normative)

Applicable cranes and hoists

This International Standard is applicable to the following cranes and hoists, the majority of which are defined in ISO 4306-1:

a) overhead travelling cranes;

b) hoists – wire rope;

c) portal or semi-portal cranes;

d) portal or semi-portal bridge cranes;

e) cable and portal cable cranes (hoist and trolley mechanisms only);

f) mobile cranes;

g) tower cranes;

h) railway cranes;

i) floating cranes;

j) deck cranes;

k) derrick and guy derrick cranes;

l) derrick cranes with rigid bracing;

m) cantilever cranes (pillar, jib, wall or walking);

n) general-purpose offshore cranes.

Annex B
(informative)

Other rope-related design and rope selection aspects

B.1 General

In addition to the selection procedure (see Clause 5) and the determination of the minimum diameter of rope drums and sheaves (see Clause 6), other rope-related design aspects might need particular consideration when selecting the rope type, construction, core type, finish of the wires and type and direction of lay for a given machine type and rope duty.

The information and recommendations given in Annex B are intended to assist the designer in this process.

B.2 Types of drum and rope selection

B.2.1 Types of drum

B.2.1.1 General

Drums may be either non-grooved or grooved.

For maximum rope life, the drum should hold the rope in a single layer. In cases where this is not possible, due to space restrictions, two or more layers are required to accommodate all of the rope.

A grooved drum provides better rope spooling performance and less rope wear than a smooth drum where multi-layer spooling is used.

When multi-layer spooling is used, it should be realized that after the first layer is spooled onto a drum, the rope crosses the underlying rope in order to advance across the drum in the second layer. The zones at which the laps in the upper layer cross those in the lower layer are known as the crossover zones and the rope in those areas is susceptible to increased abrasion and crushing.

For multi-layer spooling, the drum flanges should project above the last layer of rope by a minimum of 0,5 times the nominal rope diameter.

The direction of spooling of the rope, particularly on a smooth drum, is important. It should be related to the direction of lay of the rope (see Figure B.1).

When using a grooved drum, ropes of either lay direction may be selected although the same lay direction as those for a smooth drum are often selected as first choice.

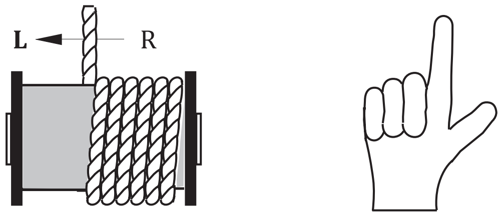
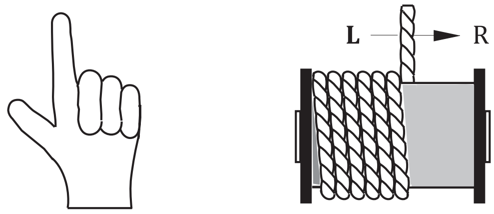
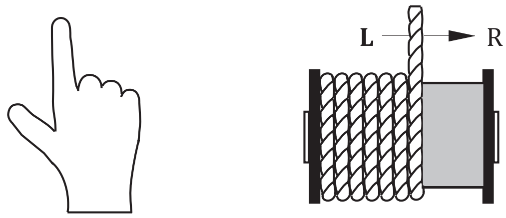
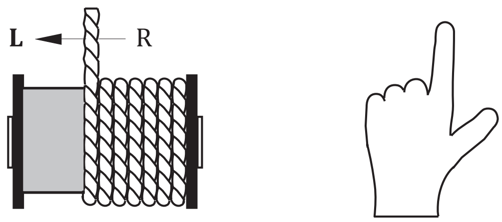
	**a) Right-hand lay rope — underwind** Start rope at right-hand flange for right-hand lay rope
	**b) Left-hand lay rope — underwind** Start rope at left-hand flange for left-hand lay rope
	**c) Right-hand lay rope — overwind** Start rope at left-hand flange for right-hand lay rope
	**d) Left-hand lay rope — overwind** Start rope at right-hand flange for left-hand lay rope
Thumb indicates the side of the rope anchorage.	

Figure B.1 — Correct method for locating rope anchorage point on drum

B.2.1.2 Non-grooved drums

Any looseness or uneven spooling will result in excessive wear, crushing and distortion of the rope.

B.2.1.3 Grooved drums

With grooved drums, the bottom layer of rope will spool correctly and the grooves will give a degree of support to the rope, thereby reducing the unit contact pressure.

There are two forms of groove:

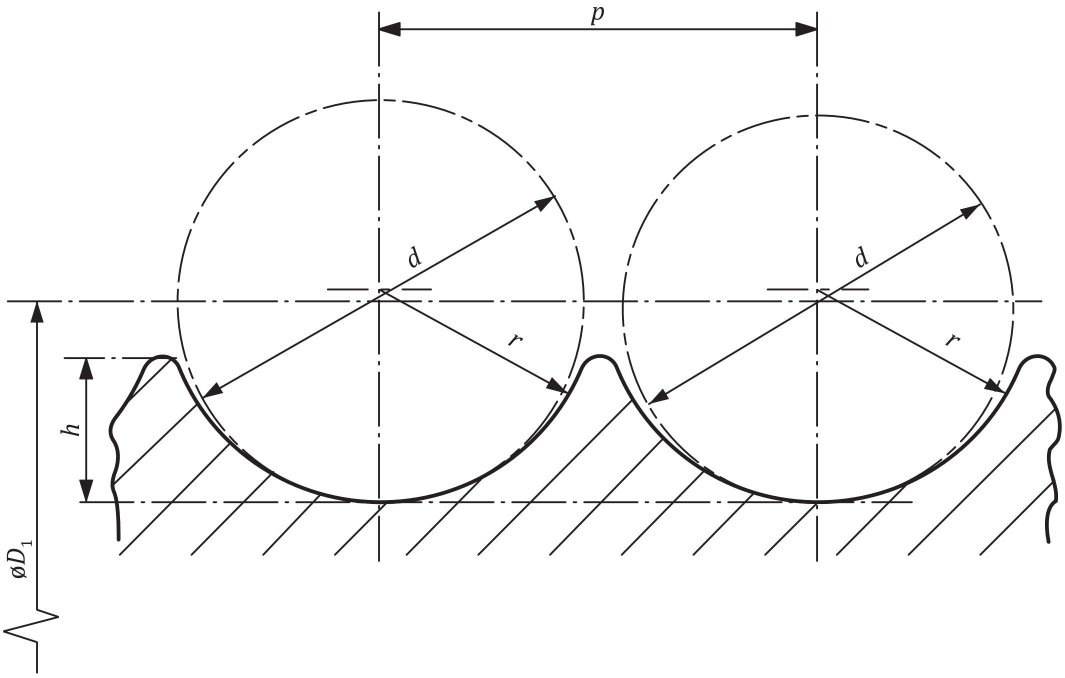
a) spiral groove, machined in a continuous spiral around the barrel, which ensures satisfactory spooling of the first layer of rope (not recommended for more than three layers);

b) parallel groove, machined parallel to the drum flanges.

A section of the drum barrel periphery is either plain or spiral grooved to facilitate transfer of the rope from one parallel groove to the next. This form of grooving is used with multi-layer spooling to reduce rope damage at crossover zones.

The relationship between the actual rope diameter and the diameter of the drum, pitch of the drum groove and type of groove system is important.

The contour at the bottom of the grooves should be circular, and it is recommended that the groove radius, *r*, should lie within the range 0,525 *d* to 0,550 *d*, with 0,537 5 *d* as the optimum (see Figure B.2).



Key

d nominal diameter of rope

h depth of groove

p pitch of groove

r radius of groove

ϕD_1 pitch circle diameter of rope drum

Figure B.2 — Drum groove design

B.2.2 Spooling aids

Rope wedges or starter strips may be used to guide the rope across the barrel into its correct position for spooling at the commencement of the second layer.

Similarly, side plates may be used to ensure satisfactory spooling of the second and successive layers.

B.2.3 Selection of rope when considering drum type

Where multi-layer spooling is required, a rope with a steel core is recommended. Wire ropes with steel cores are less likely to distort.

Ropes manufactured with compacted outer strands or compacted ropes have an even greater resistance to crushing and distortion.

Ropes with polymer impregnation can be selected to restrict distortion and reduce the ingress of moisture resulting from environmental conditions.

B.3 Sheaves, rollers and rope selection

B.3.1 General

Sheaves are used when it is necessary to change the direction of a rope within a crane or hoist. Sheaves should be free-running and designed to afford adequate support to the rope, avoiding excessive bending stresses, radial pressure and inertias. If reverse bending is unavoidable, a spacing of at least 20*d* or a time lapse of at least 0,25 s is recommended to allow the rope to recover from one bend before spooling into the reverse bend.

Traditionally, sheaves are manufactured from ferrous materials, but the use of polymer sheaves and sheaves with polymer linings/inserts is increasing. The use of a ferrous sheave in a high-use area will increase the likelihood of exterior rope wear occurring that will be an aid to rope inspection. For many uses, polymer sheaves and sheaves with polymer linings/inserts increase rope life, but the mode of deterioration can change. If there are no practical means for recognizing the modes of deterioration of the rope and particularly when spooling is on a single layer, it is recommended that at least one ferrous sheave (usually the one closest to the drum) be included in the reeving arrangement.

B.3.2 Sheave groove profile

For optimum rope life, the sheave groove profile should be correctly matched to the rope diameter.

If the groove is too small, the rope will be “pinched” as it is forced into the groove under the influence of load, thus damaging both the rope and the sheave.

If the groove is too large, there could be insufficient support for the rope, which can become flattened and distorted under load, thus accelerating rope deterioration.

The groove radius, *r*, should lie within the range 0,525*d* to 0,550*d*, with 0,537 5*d* as the optimum, where *d* is the nominal rope diameter.

Sheaves should have a smoothly finished groove, free from ridges, of depth not less than 1,5 times the nominal rope diameter. The profile at the bottom of the groove should be circular. The angle between the sides of the sheave, ω, (see Figure B.3) should be between 45° and 60°. It should be greater if the fleet angle exceeds the values given in B.4; however, this might not apply for mobile cranes, particularly in respect of the reeving through telescopic sheave assemblies.

B.3.3 Rope rollers

Rope rollers can be installed at appropriate intervals where it is necessary to support the rope over a long catenary so as to prevent contact with the machine structure. Rollers are not generally intended for deflecting or changing the direction of the rope because their relatively small diameter can subject the rope to unacceptably high compressive and bending stresses, and can induce twist into the rope.

Surface embrittlement of rope can result from the use of steel sheaves and rollers over which a rope bends at high speed or high rates of velocity change and particularly where small-angle deflections occur. Consideration should be given to non-metallic materials for rollers or roller linings.

B.4 Fleet angle and rope selection

Figure B.4 a) shows a wide spiral-grooved drum with a pitch angle, α, and a deflection sheave. If the rope is spooling towards the flanges of the drum, it will be deflected at the sheave by a fleet angle, β_{left}, or β_{right}. On the drum, it will be deflected by an angle ($\beta_{left} + \alpha$) or ($\beta_{right} - \alpha$).

Rope which is spooling on and off a drum or running over sheaves under a fleet angle will be twisted by rolling down into the bottom of the drum or sheave groove along the flange (see Figure B.5). This action changes the lay length of the rope and will affect rope performance and spooling. In the worst case, it leads to structural damage such as a “birdcage”. The fleet angles, therefore, need to be kept to a minimum.

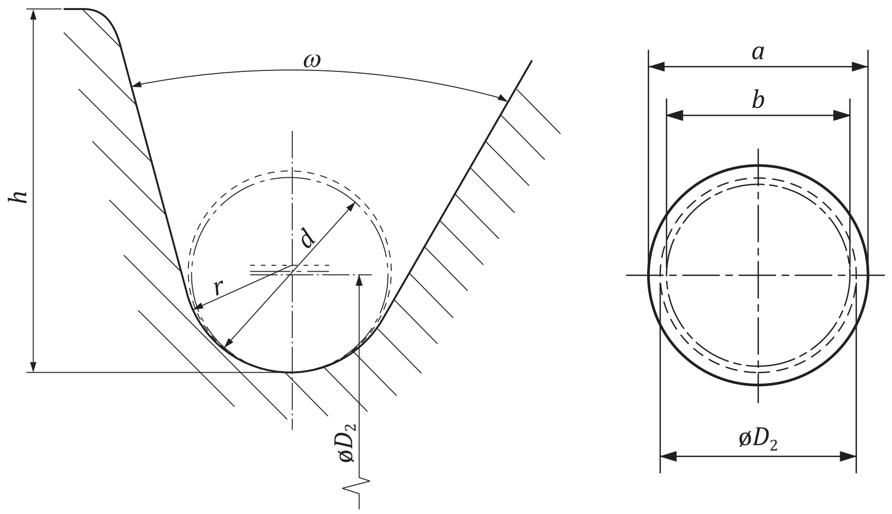
The fleet angles in the reeving system should be no greater than 2° for rotation-resistant rope and 4° for standard rope. Fleet angles can be reduced by, for example,

a) decreasing the spooling range (see Figure B.4), or

b) increasing the distances between sheaves and drums.

When a rope is spooling in multiple layers on the drum, the fleet angle at the flanges should be greater than 0,5° to avoid rope pile-up.

NOTE The drawing in Figure B.4 shows the support provided in the sheave groove for wire rope, for different dimensions of the sheave and rope. It is not suggested that a sheave should be designed with differing angles between the sheave flanges.



Key

a overall diameter of sheave

b tread diameter of sheave

h depth of sheave groove

ω angle between sides of sheave

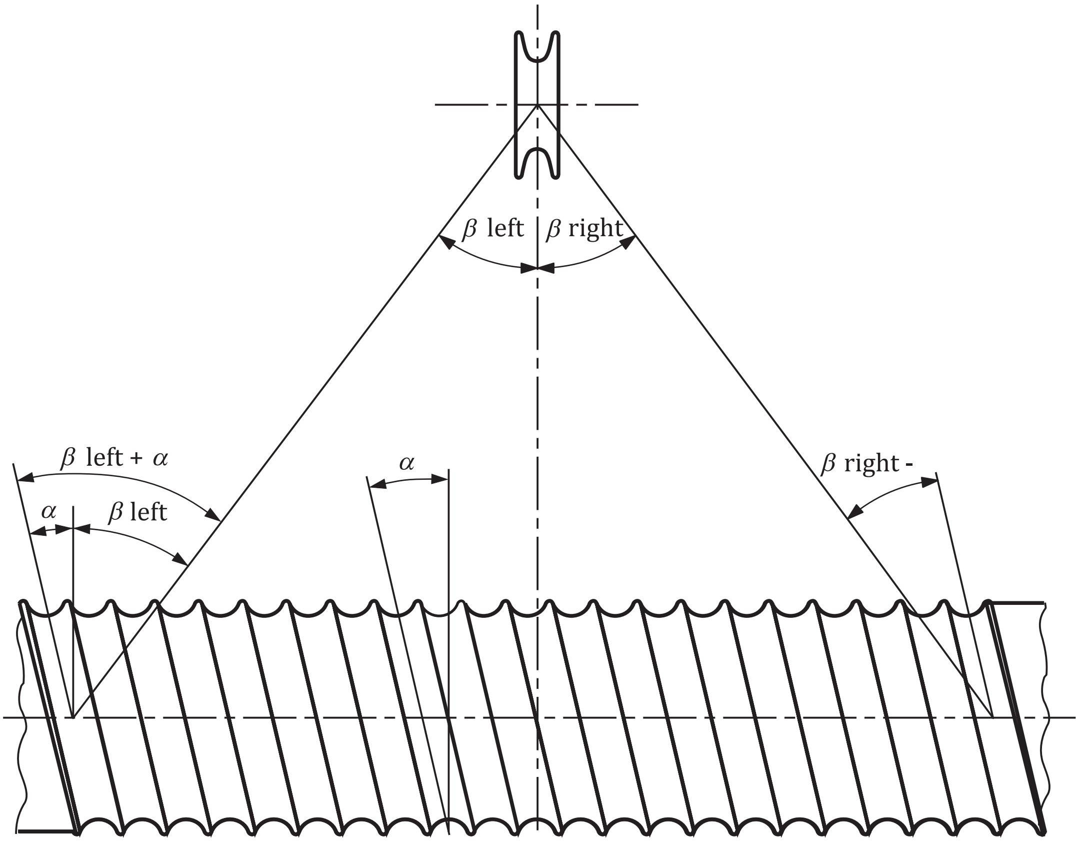
d nominal diameter of rope

r radius of groove in sheave

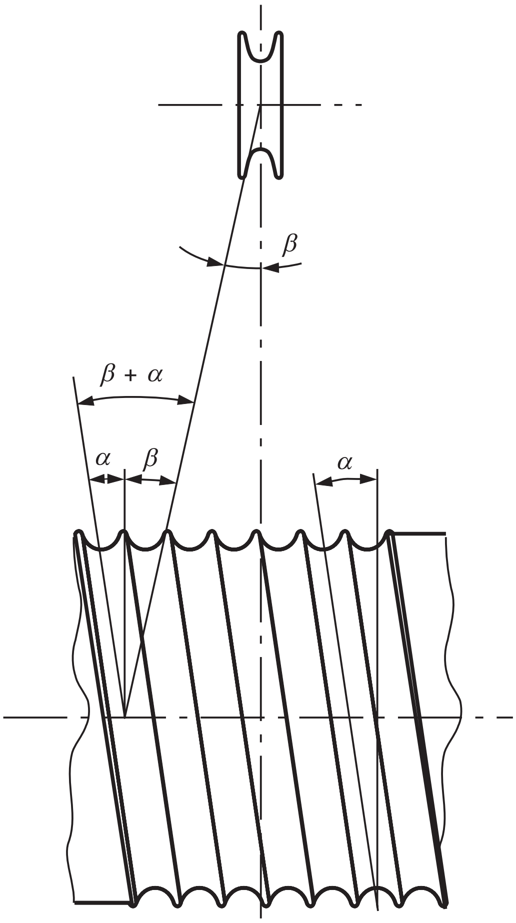
ϕD_2 pitch circle diameter of rope sheave

Figure B.3 — Sheave groove

Not drawn to scale



a) Fleet and groove angles



b) Reduction in fleet angle achieved by increasing diameter of drum and reducing drum width

Figure B.4 — Fleet angle

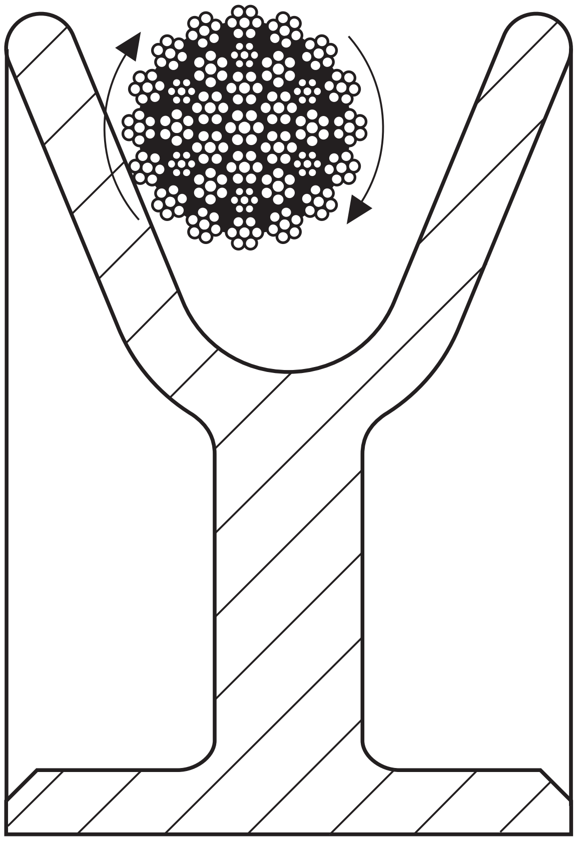


Figure B.5 — Twisting of rope resulting from the fleet angle

B.5 Rope velocity and acceleration and rope selection

Rope performance can be affected by high rates of rope velocity and acceleration/deceleration, more so when rope contact length/angle with the sheave is short and sheave inertia effects are high. In some cases it might be necessary to select a rope construction that forfeits some bending fatigue performance for added resistance to wear.

B.6 Rotation and the use of swivels

B.6.1 General

Rotation is a factor which can affect the efficient operation of a rope and in some circumstances can cause premature deterioration. All ropes are liable to some degree of rotation in service, and in single-fall lifts with unguided loads, a rotation-resistant rope is considered essential.

B.6.2 Swivels

To limit the hazard of a rotating load during a lifting operation and to ensure the safety of personnel within the lifting zone, it is preferable to select a rotation-resistant rope that will only rotate a small amount when loaded — see a) below. With such ropes, the purpose of a swivel is to relieve the rope of any induced rotation resulting from angular deflections at a sheave or drum.

Other rotation-resistant ropes having less resistance to rotation when loaded — see b) below — are likely to require the assistance of a swivel to minimize the hazard. In such cases, however, it should be recognized that excessive rope rotation can have an adverse effect on rope performance and can also result in a reduction in the breaking force of the rope, the magnitude of which will depend on the rotational properties of the selected rope and the magnitude of the load being lifted.

Each such lifting operation should be assessed by a competent person and the crane manual should reference the approval for use of a swivel based on a maximum lift condition and inspection of the rope at specified periods.

The following is a summary of general guidance on the use of a swivel, based on the rotational property of the rope:

a) rotational property less than or equal to one turn per 1 000d and lifting a load equivalent to 20 % F_{min} — a swivel can be used;

b) rotational property greater than one turn but no greater than four turns per 1 000d and lifting a load equivalent to 20 % F_{min} — a swivel may be used subject to the recommendations of the rope manufacturer and/or approval of a competent person;

c) rotational property greater than four turns per 1 000d and lifting a load equivalent to 20 % F_{min} — a swivel should not be used.

Where d is the nominal rope diameter, F_{min} is the minimum breaking force of the rope, and one turn is equal to 360°.

B.7 Height of lift and multi-part reeving

In the selection of the rope the rotational characteristics of the rope type should be recognized. If one end of the rope is free to rotate (single-part reeving), some rope types cannot be used.

If both ends of the rope are fixed (stationary rope and rope used in multi-part reeving), the torsional value should be considered. The torsional value has the effect of causing angular displacement of the sheave block in multi-part reeving arrangements, and adequate rope spacing related to the height of lift should be achieved so that excessive angular displacement (cabling of the reeving) is prevented.

The stability of the reeving system decreases with

a) decreasing spacing between the rope parts,

b) an uneven number of parts,

c) increasing height of lift, and

d) increasing torsional value (torque factor) of the rope type.

The rotational characteristics (turn and torsional values) of the rope types considered for selection should be provided by the wire rope manufacturer. If necessary, the wire rope manufacturer should also be asked for assistance.

B.8 Causes of rope deterioration

B.8.1 General

The main causes of the deterioration of a crane or hoist rope in service are fatigue, wear or abrasion, mechanical damage and, depending upon the working environment, corrosion.

One or more of these causes can be present, or dominant, depending on the duty. It is essential to select the rope most suitable for each duty, and the rope manufacturer or supplier is generally the best source of advice.

B.8.2 Bending fatigue

Fatigue in running ropes is normally caused by repeated bending of ropes under tensile loading, such as when they run through sheaves or spool on and off a drum.

The main factors affecting the bending fatigue life of the rope are, therefore, the type of spooling (i.e. single-or multi-layer) the load on the rope (i.e. line pull), the ratio of sheave and drum diameter to rope diameter, the number of sheaves, the direction of travel and the frequency of cycling. Other factors, such as the shape and condition of the sheave groove profile, the sheave groove material, the fleet angle and the dynamic loading, will also have an influence on the ultimate life of the rope.

In general, rope performance will increase as the tensile load decreases, assuming the dimensions of the mechanism remain unchanged. It also increases significantly with an increase in the selection factors, h_1 and h_2.

The requirements for sheave or drum sizes, for simplicity, are usually directly related to the selected nominal rope diameter, but it is the relationship of the sheave or drum diameter to the outer wire diameter of the rope that will influence the rope performance most of all.

The comparative bending fatigue life of a round-strand, lang lay rope tends to be greater than that for an ordinary (or regular) lay rope of the same construction when running through a sheave.

In the case of multi-layer spooling, it is to be expected that the rope will deteriorate more extensively at the crossover zones than at those sections of rope that just run through a sheave(s) before the rope is able to achieve its full bending fatigue life potential. In such cases, the potential for extended bending fatigue life might be overshadowed by the need for the rope to be more crush-resistant, thus, in some cases, requiring a construction offering fewer outer wires and/or strands.

B.8.3 Corrosion

Corrosion, in combination with fatigue, is often a main cause of wire rope deterioration in service. Except under very dry conditions, there is always some corrosion of unprotected (bright or uncoated) steel wires.

In some respects, the requirements for corrosion resistance and fatigue resistance are contradictory. For the former, a small number of large outer wires is an advantage, whereas for the latter a large number of small wires is preferred. Choice of construction is, therefore, nearly always a compromise. To inhibit the onset of corrosion, ropes should be given frequent applications of suitable dressings during their working life. If there is a risk of severe corrosion, it is preferable to use a rope with zinc-coated (galvanized) wires.

B.8.4 Abrasion

Abrasion occurs primarily in the outer wires. Ropes with fewer large outer wires, e.g. 6 × 19 Seale, exhibit longer rope life under abrasive conditions than those with many smaller outer wires, e.g. 6 × 36 Warrington-Seale. Ropes with compacted outer strands and ropes that are compacted are both designed to provide a longer rope life under abrasive conditions than those without compacted outer strands or those that are not compacted.

B.8.5 Relative fatigue and abrasion resistance

The requirements for fatigue resistance are almost opposite to those for abrasion resistance. Generally, as the number of outer wires increases, the resistance to fatigue increases, whereas the resistance to abrasion decreases.

B.8.6 Crushing

If crushing is anticipated to be a primary cause of deterioration when multi-layer spooling, consideration should be given to selecting a rope with compacted outer strands or a compacted rope.

In addition to selecting the correct rope type and construction, there are two other options for the designer to consider for limiting the extent of crushing: increase h_1 and decrease S.

B.9 Elongation and rope selection

Elongation of a wire rope can occur for a number of reasons:

a) settling of the rope's components during the "bedding-in" process (this is normally referred to as *permanent constructional extension* and occurs relatively early in the service life of the rope);

b) elastic stretch due to tension in the rope;

c) temperature change;

d) rope rotation that lengthens the rope lay.

A rope with a fibre core will have much greater elongation than a rope with a steel core. If values of elongation are required for the rope types considered for selection, these should be made available by the wire rope manufacturer, based on the specific circumstances of the application.

B.10 Temperature and rope selection

B.10.1 Wire rope

Account should be taken of the maximum temperature that could be reached by the wire rope in service. Underestimation of the temperature involved can lead to a dangerous situation.

Stranded ropes with fibre cores or fibre centres can be used up to a maximum of 100 °C.

Stranded ropes with steel cores and spiral ropes (i.e. spiral strand and locked coil) can be used up to 200 °C although some de-rating of the working load limit is necessary, the amount being dependent upon the exposure time at high temperature and the diameters of the wires. For operating temperatures between 100 °C and 200 °C the loss in strength can be assumed to be 10 %.

For temperatures above 100 °C, special lubricants may be necessary and greater losses in strength than stated above will need to be taken into account. The crane rope manufacturer or wire rope manufacturer should be contacted.

The strength of steel wire ropes will not be adversely affected by operating temperatures as low as −40 °C and no reduction of the working load limit is necessary; however, rope performance might be reduced depending upon the effectiveness of the rope lubricant at low temperatures.

For when the rope is fitted with a termination, see also B.10.2.

B.10.2 Terminations

In addition to the guidance given in B.10.1 for wire rope, and unless otherwise specified by the crane manufacturer or wire rope manufacturer, the following operating temperatures should not be exceeded:

— turn-back eye with aluminium ferrule: 150 °C,

— Flemish eye with steel ferrule: 200 °C,

— socket filled with a lead-based alloy: 80 °C,

— socket filled with zinc or a zinc-based alloy: 120 °C,

— socket filled with resin: refer to resin socketing system designer's instructions.

B.11 Termination selection for ropes

There are two forms of rope termination which permit the connection of wire ropes to other components:

a) by forming an eye (protected by a thimble) at the end of the rope;

b) by use of a fitting attached to the rope.

An eye is made by conventional splicing of the rope or by forming a Flemish eye or turn-back eye and securing it with a ferrule.

Different types of rope termination have different efficiencies and performance levels. The Performance level can also be affected by the rope type selected; hence, consideration should be given to International Standards listed in the Bibliography.

B.12 Lubrication by the manufacturer

Wire ropes are generally lubricated, at least during the stranding process (i.e. production of the strands).

Lubrication at final closing can be required for applications and for duties where operational and/or environmental conditions are severe. Extreme temperature conditions can require the use of special lubricants. Discussion with the wire rope manufacturer at the enquiry stage is recommended.

If the environment requires that the rope not to be lubricated, discussion with the wire rope manufacturer at the enquiry stage is recommended. There are special requirements for the frequency of rope inspections when a rope is not lubricated.

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