ROPES, BLOCKS-AND-TACKLES

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1. Wire rope reeving systems

The system of the wire rope reeving differs from one crane type to another. Two of the main reeving systems are indicated in the following figures. In container cranes, the safety of the wire rope against rupture should be a factor of six. For grab-unloaders the system in Fig. 2 with a main trolley and an auxiliary trolley is very popular. However, other systems should be mentioned, such as:

– machinery trolleys with complete hoisting winches on the trolley;

– the 'fleet through' reeving system;

– the 'in bight of line' system.

In heavy duty grab-unloaders the safety of the wire ropes against rupture should be approximately eight. In other crane types many different wire rope reeving systems are used, each system suitable for the special duty. Examples are:

– stacking cranes;

– laddle cranes;

– overhead travelling cranes;

– tower cranes;

– slewing cranes for general cargo – and_or grabbing duties;

– level-luffing cranes for general cargo – and_or grabbing duties;

– off-shore cranes.

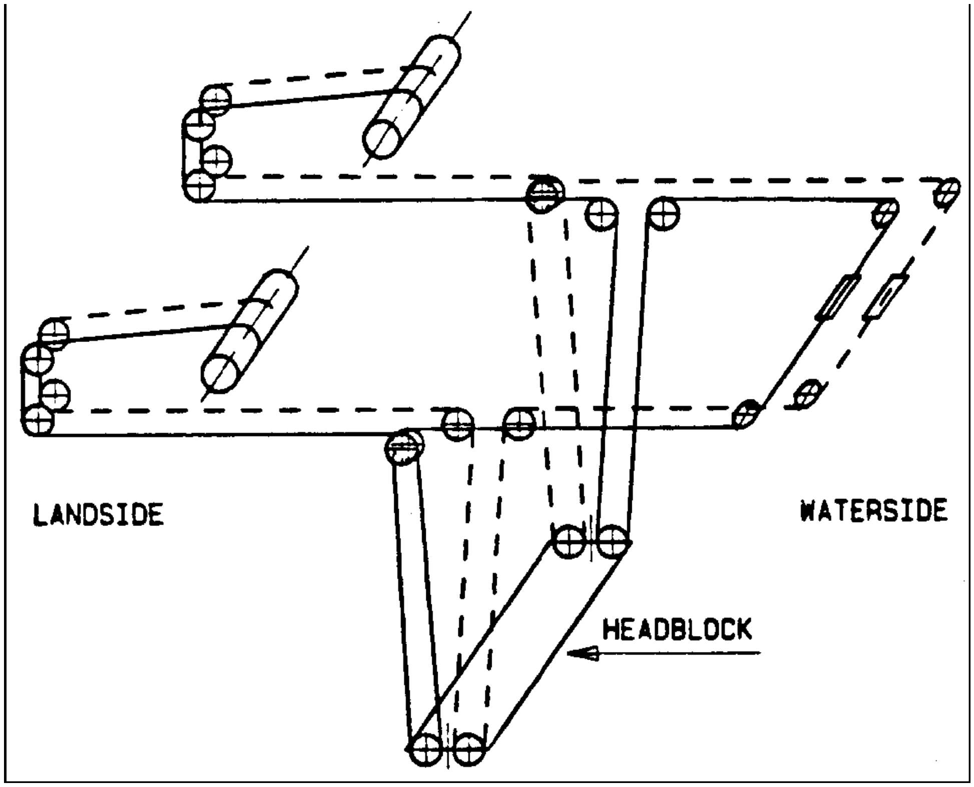

Fig. 1 Normal hoist wire rope scheme for a container crane

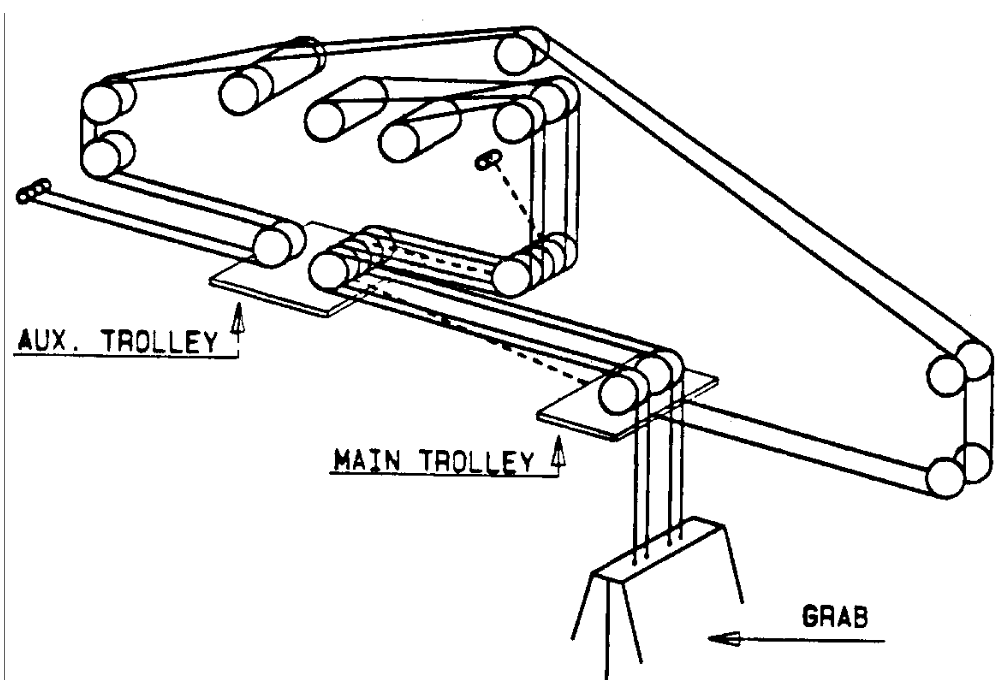

Fig. 2 Wire rope scheme for grab-unloader with main and auxiliary trolley

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2. Influencing the lifetime of wire ropes

The main points that influence the lifetime, wear and tear of wire ropes are:

- ✓ the rope reeving system;
- ✓ the chosen type of wire ropes;
- ✓ the diameter of the drums and sheaves;
- ✓ the influence of reversed bendings;
- ✓ the distance between the cable sheaves;
- ✓ the speeds with which the wire ropes run through the sheaves;
- ✓ the ratio between normal working load and the maximum load in the wire ropes;
- ✓ the safety factor; being the ratio between the breaking load and the normal working load;
- ✓ the choice of the hardness in the groove of the sheaves;
- ✓ the deviation, or fleet-angle between the wire rope and the sheave, respectively between the drum groove and wire rope;
- ✓ the greasing or lubrication of the wire ropes and the frequency of greasing or lubrication;
- ✓ the way in which the wire ropes might run through dirt, ore residues, abrasive materials, etc.;
- ✓ mechanical damage through hitting cell-guides or coamings in the ships;
- ✓ internal and external corrosion.

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3. Drum diameters and wire rope sheave diameters

Almost every country has its own standards for these diameters (D) in relation to the rope diameter (d). Some standards indicate that the wire rope sheave diameter should be increased when the speed of the wire rope, running through the sheave, is more than V=4m/sec. Then

$$Dv = (V:4)D.$$

A general warning is that the drum diameter and wire rope sheave should not be made too small in diameter. For faster cranes:

$$D/d = 30$$

For fast unloaders:

$$D/d = 36$$

Where D = wire rope sheave diameter or drum diameter, centre to centre of wire rope, and d = wire rope diameter.

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4. The choice of wire ropes

Without going into too much detail, it can be stated that the choice is mainly between ordinary (regular) or cross lay wire ropes and Lang's lay wire ropes.

Both types should preferably be used with a steel core.

They should be galvanized and always fully lubricated or greased. The tensile strength should be approximately 1770N/mm^2.

The safety factor, being the ratio between the minumum breaking load and the normal working load, must be in accordance with the national standards.

Wire ropes, such as the well-known Casar wire ropes, the Diepa wire ropes, the Bridon–Dyform wire ropes, and others can, under certain circumstances, give a longer lifetime than cross lay and Lang's lay wire ropes.

This can normally only be proven by trials on the cranes; the outcome of which is difficult to predict.

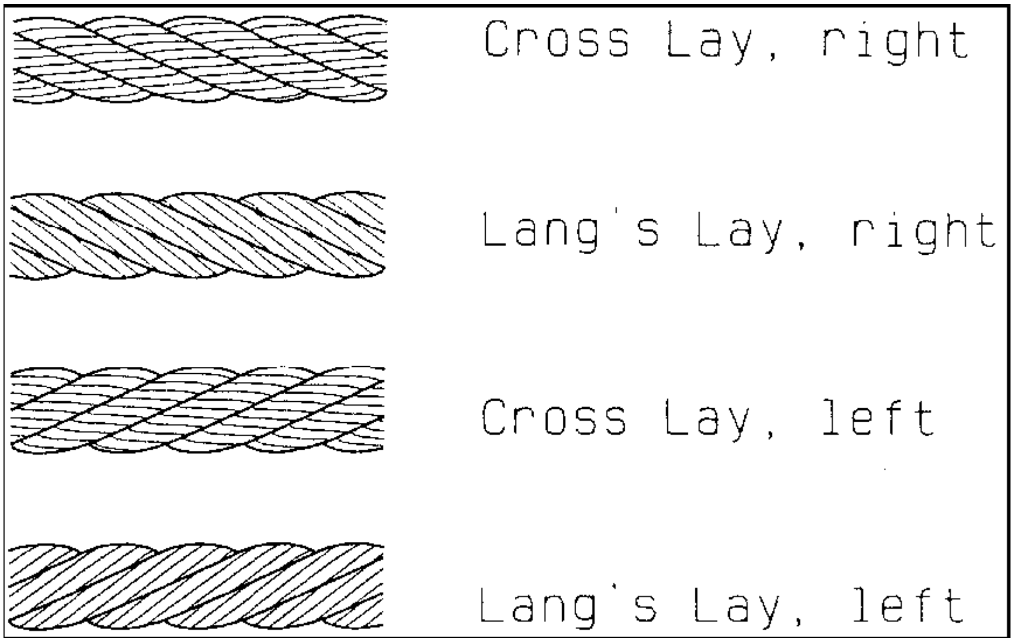

Fig. 3. Wire rope types

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5. Fleet angles; grooves on drums and in wire rope sheaves

Deviation into the direction of the groove.

(a) Deviation by the groove $L2 = (L : \pi \cdot D) \cdot S$

Maximum deviation $L1$

Fleet angle between the drum

and the sheave $V1 = (L1 - L2) : L = 1 : \ldots.$

(b) Fleet angle between the wire

rope and the sheave $V2 = L1 : L = 1 : \ldots.$

Deviation against the direction of the groove

(c) Deviation against the direction of the groove $L2 = (L : \pi \cdot D) \cdot S$

Maximum deviation $L3$

Fleet angle between the drum and the sheave $V3 = (L3 + L2) : L = 1 : \ldots.$

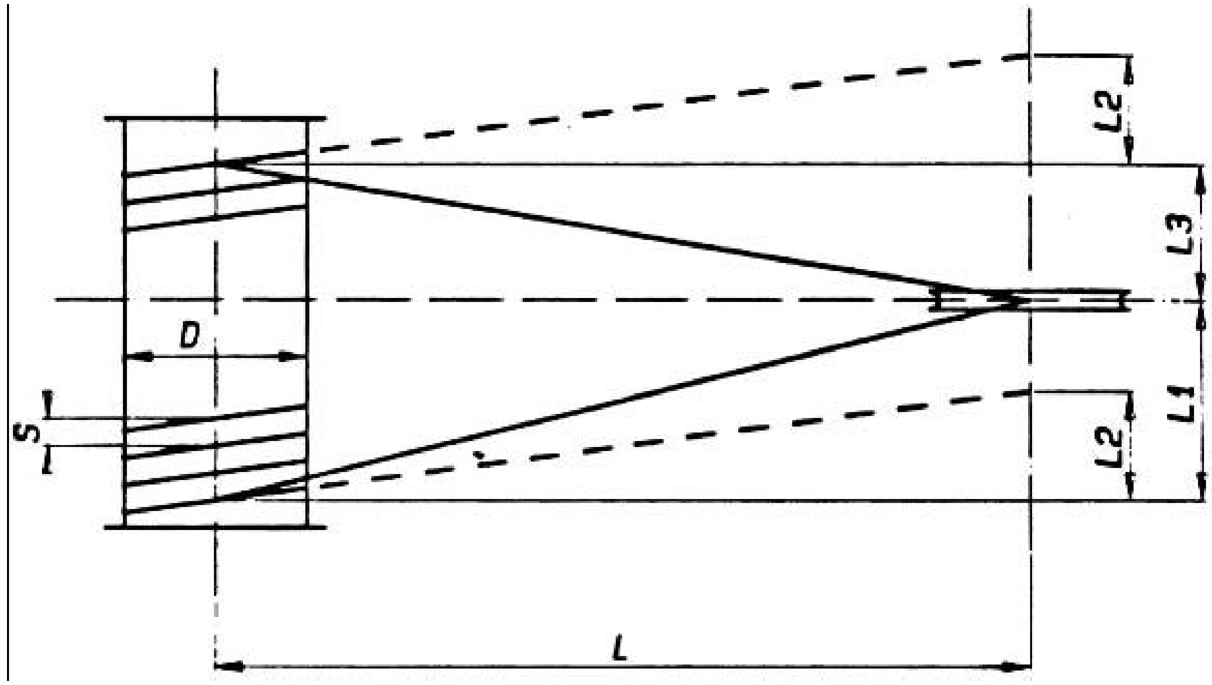

Fig. 4 Fleet angles on drums and sheaves

(d) Fleet angle between the wire

rope and the sheave $V4 = L3 : L = 1 : \ldots.$

(Where *S*=the pitch and *D*=the drum diameter.)

$V1$ and $V3$ should be approximately 1:20.

$V2$ and $V4$ should be at least 1:16, but normally approximately 1:20.

(When degrees are measured it is preferably that $L1$:L and $L3$:L should not result in an angle of more than 2,5 degrees; the preferred maximum is 2 degrees.)

It is better to have the sheave in such a position that the maximum deviation *into* the direction of the groove, and the maximum deviation *against* the direction of the groove are equal, and preferably 1:20.

Controlling the drum grooves. In order to control whether the wire rope is bending off too sharply over the rim of the groove on the drum, when running off into the direction of the groove, and when it is running off from the drum against the direction of the groove, a drawing should be made when $V1$ and $V3$ have lower figures.

Professor Ernst indicated figures in his book *Die Hebezeuge* and the Belgian standards NBN–E 52-004 (1980) give the following useful diagrams (see Figs 5–6).

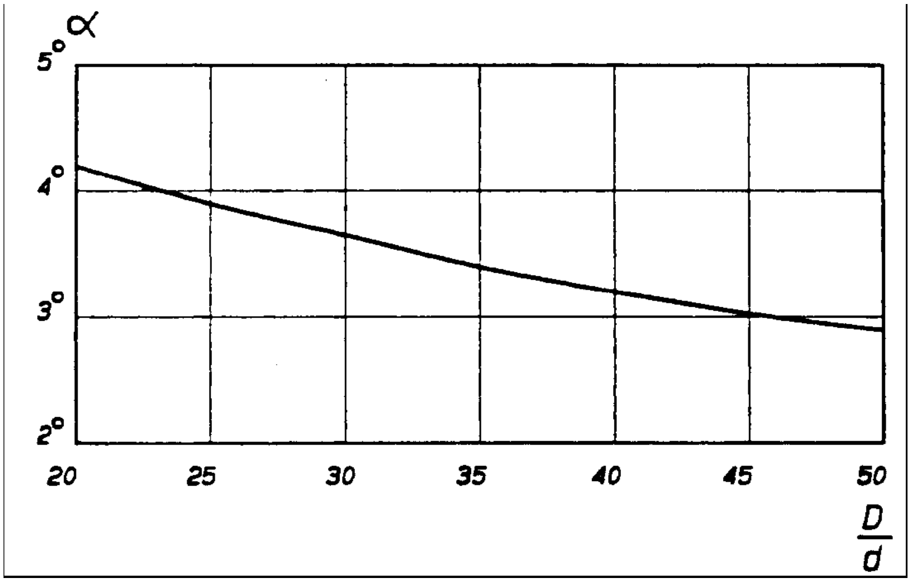

Fig. 5 Wire rope running off from the drum; maximum allowable deviation into the direction of the groove, measured from the tangent of the groove

D=drum diameter, centre to centre of wire rope

d=wire rope diameter

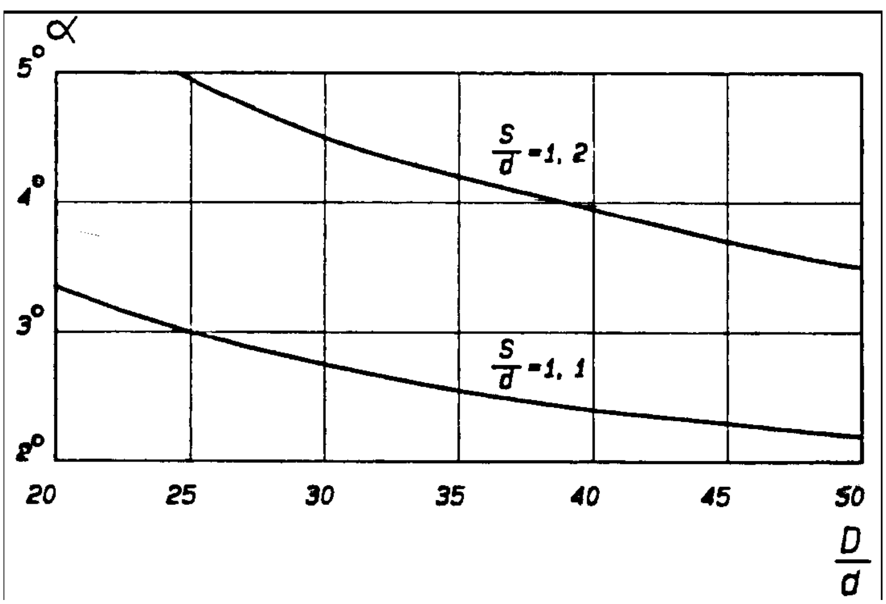

Fig. 6 Wire rope running off from the drum; maximum allowable deviation against the direction of the groove, measured from the tangent of the groove

D=drum diameter, centre to centre of wire rope

d=wire rope diameter

S=pitch

The grooves on drums and in sheaves. On the drums the grooves must be deep enough to guide the wire ropes correctly.

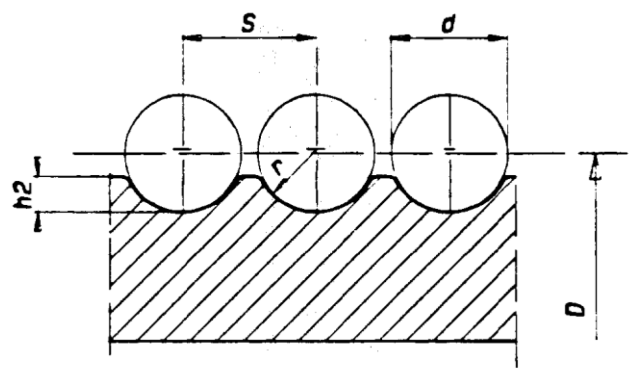

Fig. 7 Grooves on drums

$$h_2 \simeq 0{,}3d$$
$$r \simeq 1{,}05 \cdot (d:2)$$
$$S_{min} \simeq 1{,}1d$$

Drum material = Fe510 (S355)

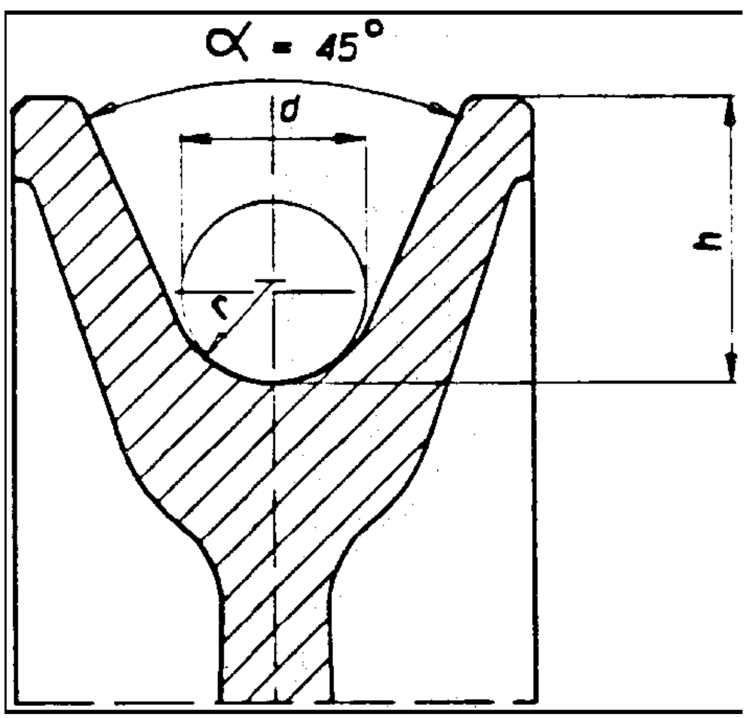

Fig. 8 Wire rope sheave

$h = 1{,}5d$ to $2d$

$r \simeq 1{,}05(d:2)$

Hardness of the material in the grooveG260 to 350 HBr.

Occasionally wire rope sheaves, made of a type of nylon are chosen. Strangely enough the use of only nylon wire rope sheaves can lead to unexpected, sudden wire rope breakage. *Note*: The CEN standards will mention αG52 degrees instead of αG 45 degrees.

Controlling the wire rope sheave opening. This is diagrammatically displayed in Fig. 9.

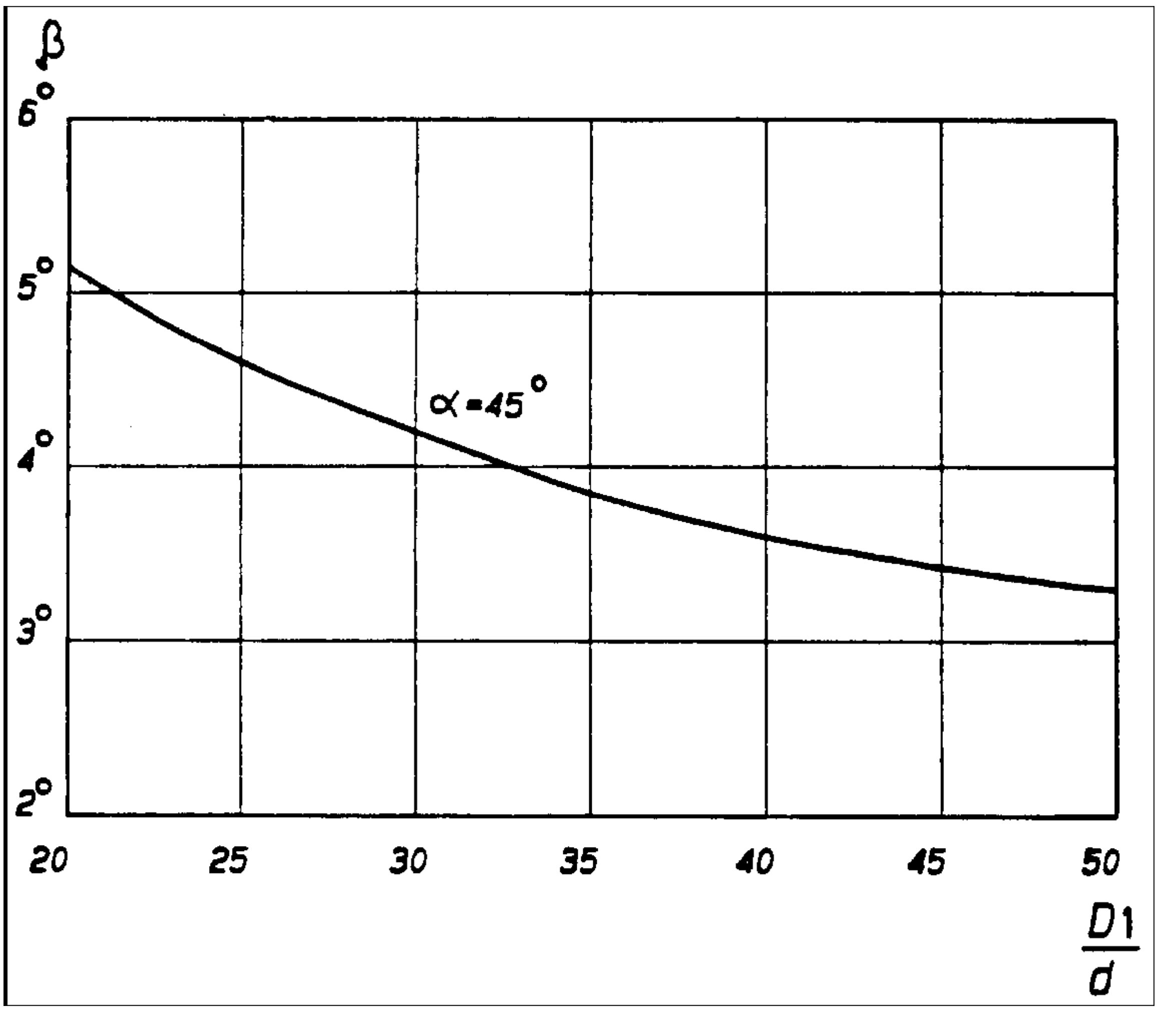

Fig. 9 Wire rope running off from the wire rope sheave

Maximum allowable fleet angle measured from the tangent of the groove (only for the controlling of the sheave opening). D1=wire rope sheave diameter, centre to centre of wire rope d=wire rope diameter α=45 degrees (see Fig. 8).

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6. The bending angle over sheaves; the ultimate tensile limit

The bending angle over a sheave should be at least some 60 degrees and should cover preferably at least 1,5Bthe lay lengths in order to avoid shortening the wire rope's lifetime. Another important feature is the ultimate tensile limit. The ultimate tensile limit is approximately 50 percent of the minimum breaking load of the wire rope.

Through occasional heavy shocks, a miscalculation, or added tensioning of the wire ropes by a tensioning winch, the wire rope can occasionally be overloaded. Then the load in the wire rope could reach the ultimate tensile limit. If this occurs, the wire rope may then have a very short lifetime and may even rupture unexpectedly.

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7. The lifetime of wire ropes

The main points that influence the lifetime and the wear and tear of wire ropes were listed. Occasionally the lifetime of a wire rope is extremely short because of mechanical damage from hitting the cell-guides or coamings in a ship. Table 1 lists some lifetime ideas for the wire ropes in container quay cranes. They can be considered as averages.

It has to be said that the lifetime of the very fast running wire ropes in Lang's lay construction was, in general, no better than that of the ordinary or cross lay wire ropes.

Table 1 Lifetime of wire ropes

		Lifetime in moves	
Client	*Case*	*Hoisting wire ropes*	*Trolley travelling wire ropes*
P	A	140 000	64 000
	B	120 000	100 000
	C	84 000	120 000
	D	55 000	46 000
Q	K	175 000	120 000
	L	140 000	106 000
	M	110 000	138 000
R		After 100 000 moves the wire ropes are changed	After 100 000 moves the wire ropes are changed
S		80 000	?
T		64 000	?
U		250 000	Machinery trolley

Note: The boom hoist wire ropes are normally changed once every five years or sometimes even once every ten years.

Pressures between the wire rope and sheaves or drums. The tensile loads and the bending loads are the main causes for fatigue, although mechanical damage is often the main reason why a wire rope should be changed.

If it is assumed that the wire rope is running in and over a well-fitted groove; the pressure between the wire rope and the groove is given by

$$P = \frac{F}{D/2 \cdot d} \mathrm{N/mm^2}$$

where

P=pressure in the groove (N_mm2)

F=the wire rope force (N)

D/2=the radius of the sheave or drum (mm)

d=the wire rope diameter (mm)

The maximum permitted pressure *P*max (N/mm2) is – on steel Fe 510 (S 355) approximately 7,0N/mm^2; on manganese or alloyed steels approximately 20,0N/mm^2.

Maintenance. Wire ropes and wire rope sheaves should be regularly inspected. Greasing is most important even though the wire ropes have already been greased, externally and internally during fabrication. If the internal greasing has not been performed correctly, the lifetime of a wire rope is dramatically reduced.

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8. Wire rope strength

Although there are many types of construction of wire ropes, only a summary of the minimum Breaking Load is given for one type of wire rope with a tensile strength of 1770N/mm^2 and a steel core.

Wire rope diameter (mm)	*Minimum breaking load* (kN)	*Tensile strength* (N/MM^2)	*Weight per 100 m* (kN)
20	250	1770	1,59
22	305	1770	1,93
24	363	1770	2,29
26	425	1770	2,69
28	494	1770	3,12
30	567	1770	3,58
32	645	1770	4,08
34	728	1770	4,60
36	817	1770	5,16

Note: The wire rope hardness of such a wire rope is between 400 and 500 HBr.