Wire Ropes

Wire ropes are used in extensively in industries for hosting and materials handling equipment. They are also used in stationary applications such as guy wires.

Advantages

i) High strength to weight ratio
ii) Silent operation even at high velocities
iii) Greater reliability

Construction of wire ropes

Wire ropes consists of number of strands, each strand comprising several steel wires.

The number of wires in each strand is generally 7, 19 or 37, while the number of strands is usually six.

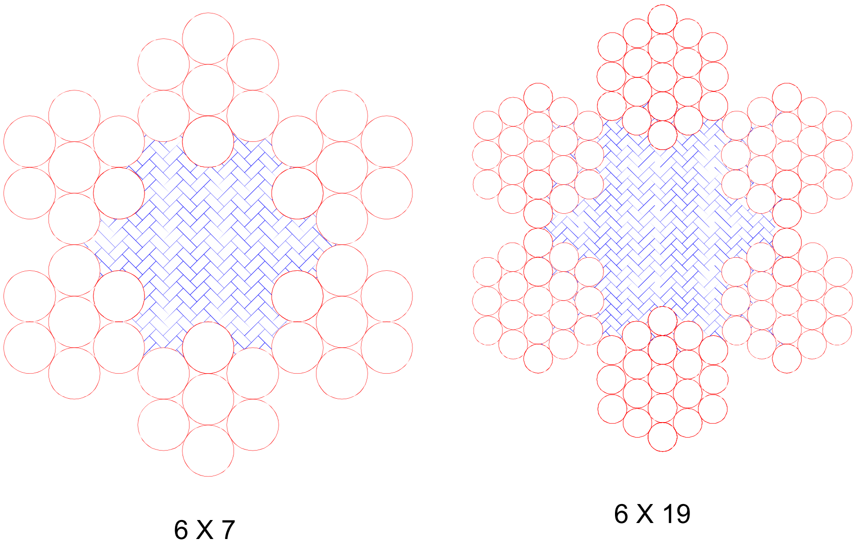
The individual wires are first twisted into the strands and then strands are twisted around a fibre or steel core.

The Specification of wire rope includes two numbers, such as 6X7 or 6X19.

The first number indicates the no.of strands in the wire rope.

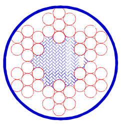
The second number gives the no.of steel wires in each strand.

Popular constructions are shown in the next slide.



Nominal diameter(d_r)

Nominal diameter of the wire rope indicates the diameter of the smallest circle enclosing the wire rope.



The tensile designation of the wire ropes in the DATA BOOK indicates, Minimum ultimate tensile strength(in N/mm^2) of the individual wires.

Core : central portion of the wire rope is called core.

The fibre core consists of natural fibres like jute or cotton.

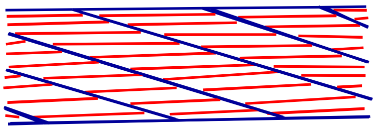
The steel core consists of another strand of fairly soft wires with lower tensile strength.

Rope lay

The lay of the rope refers to the manner in which the wires are helically laid into strands and strands into ropes.

Regular lay

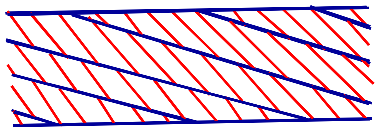
When the wires in the strands are twisted in a direction opposite to that of the strands, the rope is said to be regular lay rope



Regular Lay

Lang lay

When the wires in the strands are twisted in same direction as strands, the rope is said to be Lang lay rope



Lang Lay

Stresses in Wire ropes

When the wire rope passes around sheave or drum, the wires are subjected to bending stresses. The bending stresses in individual wires is given by

$$\sigma_b = \frac{M_b . y}{I} \quad and \quad y = \frac{d_w}{2}$$

$$\frac{E}{R} = \frac{M}{I} = \frac{f}{y}$$

$$where\, d_w = diameter\, of\;\; individual\;\; wire(mm)$$

$$\therefore\ \sigma_b = \frac{M_b . d_w}{2I} \qquad ---(a)$$

$$\frac{M_b}{I} = \frac{2\sigma_b}{d_w} \quad ---(b)$$

But

$$\frac{E}{r} = \frac{M_b}{I}$$

Radius curvature in the above equation is equal to the radius of the sheave. i.e r = D/2

Where D = Dia of sheave   E = Modulus of Elasticity

$$\frac{M_b}{I} = \frac{2E}{D} \quad ---(c)$$

From (b) & c)

$$\frac{2\sigma_b}{d_w} = \frac{2E}{D} \quad \rightarrow \quad \sigma_b = \frac{Ed_w}{D}$$

Modulus of Elasticity E is replaced with Effective Modulus of Elasticity E_r because wires are subjected to screw effect.

$$\sigma_b = \frac{E_r d_w}{D}$$

Equivalent Bending load P_b

$$P_b = \sigma_b . A \quad Where\ A = \text{Metallic cross section of rope}$$

$$P_b = \frac{A E_r d_w}{D}$$

Pressure between rope and sheave

Amount of wear that occurs depends upon the pressure.

$$2P = p(d_r D)$$

$$p = \frac{2P}{d_r D}$$

where

$P = tension\ in\ rope(N)$

d_r = nominal diameter of wire rope(mm)

$D = sheave\ diameter(mm)$

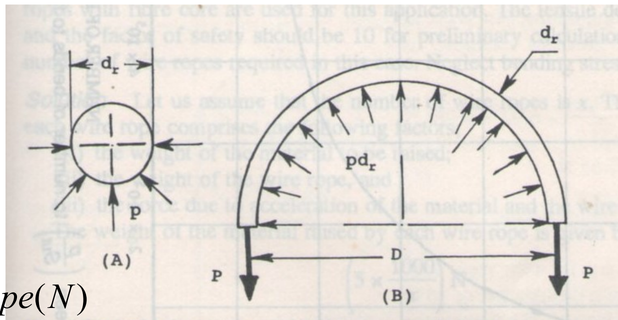


Fig. 23.5 Forces acting on wire rope around sheave

Pb: A temporary elevator is assembled at the construction site to raise building materials such as cement, to a height of 20m. It is estimated that the maximum weight of the material to be raised is 5kN. It is observed that the acceleration in such applications is $1 m/s^2$. 10mm diameter 6X19 construction – wire ropes with fibre core are used for this application. The tensile designation is 1420 and factor of safety should be 10 for preliminary calculations. i)Determine the no. of wire ropes required in this case. Neglect bending stress. ii) Determine the true factor of safety taking bending stress.

[Assume Breaking load = 44kN, mass of 100m wire=34.6kg]

Given Data :

Height = Length of the rope = 20m

Weight to be raised = 5kN = 5 X 1000N

Acceleration of the rope = $1 m/sec^2$

Nominal dia of wire rope = d_r = 10mm

Ultimate tensile strength (S_{ut}) = $1420 N/mm^2$

Factor of safety = 10

Let us assume that no.of wire ropes required are **x**

The forces acting on each wire rope comprises of

i) Weight of the material to be raised (W_m)

ii) Weight of the wire rope (W_r)

iii) Force due to acceleration of the material and wire rope (F)

Working load = $W_m + W_r + F$

$$Factor\ \ of\ \ safety = \frac{Breaking\ \ load}{working\ \ load}$$

i) Weight of the material to be raised by each rope

iii) The force (F) = $(m_m+m_r).a$

$$m = m_m + m_r$$

$$Factor\ \ of\ \ safety = \frac{Breaking\ load}{working\ load}$$

ii) Determine the true factor of safety taking bending stresses

Assume

Sheave diameter(D) = 45d_r

Wire diameter(d_w) = 0.063d_r

Effective Modulus of Elasticity(E_r) = 83000N/mm^2

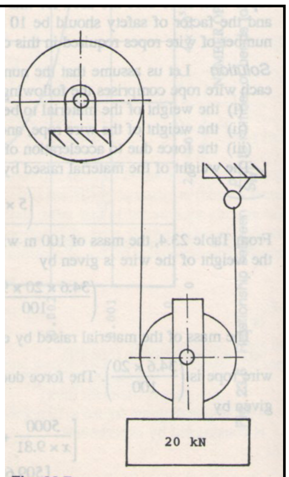
Metallic Area = $0.40d_r^2$

$$Equivalent\ \ bending\ \ load(P_b) = \frac{A.E_r.d_w}{D}$$

$$Working\ load = \frac{5000}{x} + 67.89 + \left[\frac{509.68}{x} + 6.92\right] + 4648$$
$$= 7477.65N$$

$$Factor\ \ of\ \ safety =$$

Pb2 : 6 X19 wire rope with fibre core and tensile designation of 1570 is used to raise the load of 20kN as shown in Figure. The nominal diameter of the wire rope is 12mm and the sheave has 500mm pitch diameter. Determine pressure between rope and sheave



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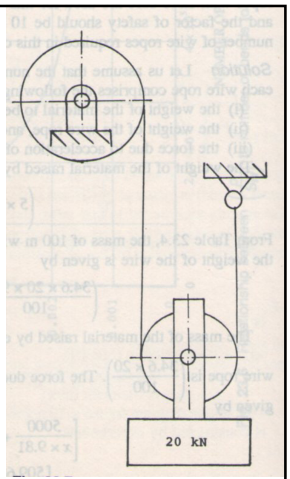

$$p = \frac{2P}{d_r D} =$$

Wire Rope	Breaking Load(N)	Wire Diameter dw in mm	Area of the wire rope in mm^2
6X7	$480d^2$	0.106d	$0.38d^2$
6X19	$510d^2$	0.063d	$0.40d^2$

Sheave Diameters

Type of wire rope	Minimum Sheave Diameter	Preferred Sheave diameter
6X7	42d	72d
6X19	20d 30d	30d 45d

d= Dia of the rope

Pb3 : A crane is used to lift a load of 30KN through a wire rope. The weight of the crane hook is 5KN. The load is to be lifted with an acceleration of 1m/sec^2. Considering only normal working conditions and neglecting the self weight of the rope, Calculate the diameter of the wire rope. Use the following particulars for the design.

Ultimate stress for the rope material= 1800N/mm^2.

Factor of safety = 6

Young's Moudulus for rope material = 80KN/mm^2.

Cross sectional area of the rope = 0.40d^2(d=dia of rope)

Assume rope drum diameter D=45d

Dia of wire d_w=0.063d

Given Data :

Let d= dia of the wire rope

F= Load that is being lifted = 30KN= 30X1000 N

W= Weight of the hook = 5KN = 5X1000N

a= 1m/sec^2

Er=80KN/mm^2

Sut=1800MPa

F.S=6

A=0.40d^2

Total load Ft= Direct load(Fd) + Bending load(Fb) + Load due to acceleration (Fa)

Direct load on wire rope Fd= F+W=

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a= 1m/sec^2

Er=80KN/mm^2

Sut=1800MPa

F.S=6

A=0.40d^2

Total load Ft= Direct load(Fd) + Bending load(Fb) + Load due to acceleration (Fa)

Direct load on wire rope Fd= F+W= 30000+5000 = 35000N

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Bending Load

$$F_b = \frac{E_r d_w A}{D}$$

$$= \frac{80\times10^3\times0.063\times d\times0.40\times d^2}{45d} = 44.8d^2 \quad N$$

Load due to acceleration

$$F_a = \left(\frac{F+W}{g}\right).a$$

$$= \left(\frac{35000}{9.81}\right)\times1 = 3567.8\,N$$

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Total Load $F_t = F_d + F_b + F_a$

$$= 35000 + 44.8d^2 + 3567.8$$

$$= 38567.8 + 44.8d^2$$

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$$Total\ \ Load\ \ F_t = F_d + F_b + F_a$$
$$= 35000 + 44.8d^2 + 3567.8$$
$$= 38567.8 + 44.8d^2$$

$$Working\ \ Stress = \frac{Total\ load}{C.S.A}$$
$$= \frac{38567.8 + 44.8d^2}{0.40d^2}$$

$$Working\ \ Stress = \frac{Ultemate\ Tensile\ Stress}{Factor\ of\ \ Safety}$$
$$= \frac{1800}{6} = 300N/mm^2$$

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$$300 = \frac{38567.8 + 44.8d^2}{0.40d^2}$$

Pb4 : A hand operated winch has a drum of 400mm diameter. Suggest a suitable wire rope for handling a load of 5KN with following data and find factor of safety.

Assusme 6X19 wire rope therefore

Beaking load = $510d^2$

Cross sectional area of the rope = $0.40d^2$

Sheave dia D=30d

Dia of wire d_w=0.063d where d is dia of rope in mm

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Dia of wire d_w=0.063d where d is dia of rope in mm

$$Factor\ of\ Safety = \frac{Breaking\ load}{Working\ load}$$

$$Breaking\ load = 510d^2$$

$$Working\ load = Load\ to\ be\ raised + Bending\ load$$

$$30d = D$$

$$30d = 400$$

$$d = 13.34 \approx 14mm$$

$$d_w = 0.063 \times d = 0.063 \times 14 = 0.882mm$$

$$Breaking\ load = 510d^2 = 510 \times 14^2 = 99960N$$