SPECIFICATION OF WIRE ROPES

The wire ropes are specified (or designated) by the number of strands and the number of wires in each strand. For example, a 6 x 7 rope means a rope made from six strands with seven wires in each strand.

GUIDELINES FOR THE SELECTION OF WIRE ROPE

The wire rope is selected based on its application. The shows the standard designation of wire ropes and their applications.

STRESSES IN WIRE ROPES

The various types of stresses induced in a wire rope are:

1. Direct stress due to the weight of the load to be lifted and weight of the rope (σ_d):

Let W = Weight of the load to be lifted,

W = Weight of the rope, and

A = Area of useful cross-section of the rope.

$$\textbf{Direct stress}\ \sigma_d = \frac{W+W_r}{A}$$

2. Bending stress when the rope passes over the sheave or drum (σ_b):

$$\textbf{Bending stress,}\ \sigma_b = \frac{d_W E_r}{D}$$

Where E_r **= modulus of elasticity of the wire rope**

= 0.84*10^5 N/mm^2, for steel ropes of ordinary construction,

= $\frac{3}{8}$*E, E= Modulus of elasticity of the wire material

d_W= diameter of the wire,

D = diameter of sheave.

3. Stress due to acceleration (σ_a):

Due to change in speed, an additional stress is induced. The stress due to acceleration is given by

$$\sigma_a = \left(\frac{W+W_r}{g}\right)\frac{a}{A}$$

Where a = Acceleration of rope and local during hoisting (not at starting or stopping)

= $\frac{v_2+v_1}{t}$; **(v_2-v_1)** is the change in speed in 't' seconds.

4. Stress during starting and stopping (σ_{st}):

(i) When there is no slack in the rope:

$$\sigma_{st} = 2 \times \sigma_d$$

(ii) When there is slack in the rope before starting or slopping, then there will be a considerable impact load on the rope.

$$\sigma_{st} = \frac{W + W_r}{A} \left[1 + \sqrt{1 + \frac{2 . a_s . h . E_r}{\sigma_d . l . g}} \right]$$

Where a_s = Acceleration during starting or stopping,

h = Slack during starting, and

l = Length of the rope.

Effective stress:

(i) Effective stress in the rope during normal working,

$$\sigma_{en} = \sigma_d + \sigma_b$$

(ii) Effective stress in the rope during starting,

$$\sigma_{est} = \sigma_{st} + \sigma_b$$

(iii) Effective stress in the rope during acceleration of the load,

$$\sigma_{ea} = \sigma_d + \sigma_b + \sigma_a$$

RECOMMENDED FACTOR OF SAFETY FOR WIRE ROPES

The recommended factor of safety for wire ropes based on .the ultimate strength are given in Table.

Table.Recommended factor of safety for wire ropes, n' (from data book, page no. 9.1)

DESIGN OF WIRE ROPES

DESIGN PROCEDURE FOR A WIRE ROPE

1. Selection of suitable wire rope:

First select the suitable type of wire rope for the given application, from Table 3.1.

2. Calculation of design load:

Calculate the design load by assuming a larger factor of safety, say 15 (or find the design load by assuming a factor of safety 2 to 2.5 times the factor of safety given in Table 3.2).

Design load = Load to be lifted x Assumed factor of safety

3. Selection of wire rope diameter (d):

Select the wire rope diameter (d) from Table 3.4, Group 6 x 19 **(from data book, page no. 9.5 and 9.6)** by taking the design load as the breaking strength.

4. Calculation of sheave diameter (D :

Consulting Table 3.5. (**from data book, page no. 9.1)** obtain the diameter of sheave (or drum). Always larger sheave diameter is preferred.

- Ratio for 50 *m/min* of rope speeds - to be increased by 8% for each 'additional speed of 50m/min

5. Selection of the area of useful cross-section of the rope (A):

Consulting Table 3.6, select the area of useful cross-section of the rope.

Type of construction	Metallic area of rope A, mm^2
6 x 7	$0.38\ d^2$
6 x 19	$0.4d^2$
6 x 37	$0.4d^2$

6. Calculation of wire diameter (dw):

Calculate the diameter of wire using the relation

$$d_w = \frac{d}{1.5\sqrt{i}}$$

where i = Number of wires in the rope

= Number of strands x Number of wires in each strand.

7. Selection of weight of rope (W,):

Obtain the rope weight *(Wr)* from Table 3.4.

8. Calculation of various loads:

Calculate the various loads using the relations given below.

(i) Direct load, $W_d = W + W_r$

(ii) Bending load, $W_b - \sigma_b \times A = E_r . \frac{d_w}{D} \times A$

(iii) Acceleration load due to change in the speed of hoisting,

$$Wa = \left[\frac{W + W_r}{g}\right] a$$

Where $a = \frac{v_2 - v_1}{t}$ (When speed of the rope changes from v_1 to v_2 in t seconds)

(iv) Starting or stopping load:

(a) When there is no slack in the rope:

Starting load, $WS1 = 2 \cdot W_d = 2\ (W + Wr)$

(b) When there is slack in the rope:

Starting load, $W_{st} = \sigma st \times A = (W + Wr)\ [1 + \sqrt{1 + \frac{2.a_s.h.E_r}{\sigma_d.l.g}}\ ]$

9. Calculation of effective loads:

(i) Effective load on the rope during normal working, $W_{en} = W_d + W_b$

(ii) Effective load on the rope during acceleration of the load, $Wea = W_d + W_b + W_a$

(iii) Effective load on the rope during starting, $West = W_b + W_{st}$

10. Calculation of working (or actual) factor of safety (FS_w):

Working factor of safety, FS_w = $\frac{\text{Breakingloadfromtable3.4fortheselectedrope}}{\text{Effectiveloadduringacceleration } (W_{ea})}$

11. Check for safe design:

Compare the calculated working factor of safety (FS_W) with the recommended factor of safety *(n')* given in Table 3.2. If the working factor of safety is greater than the recommended factor of safety *(i. e.,* $FS_w > n'$*)*, then the design is safe and satisfactory.

If FSw<*n'*, then the design is not satisfactory. Now choose some other rope with greater breaking strength or increase the number of ropes.

12. Calculation of number of ropes:

$$\textbf{Number of ropes} = \frac{\text{Recommended factor of safety}}{\text{Working factor of safety}} = \frac{n'}{FS_W}$$

FAILURE OF ROPES

The amount of wear that occurs depends upon the pressure between the rope and the sheave and is given

$$P = \frac{2T}{dxD}$$

T = Tension in rope

d = Diameter of rope, and

D = sheave diameter

CHAIN DRIVES

TYPES OF CHAIN DRIVES

The common types of chains are:

1. Link chains (or welded chains),
2. Transmission chains (or roller chains,) and
3. Silent chains (or inverted tooth chains).

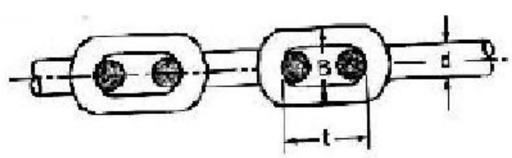
LINK CHAINS

Link chains, also known as *welded load chains,* are widely used

- In low capacity hoisting machines such as hoists, winches and hand operated cranes as the main lifting appliances.
- As slings for suspending the load from the hook or other device.

DIMENSIONS OF A LINK CHAIN

They are pitch (t) equal to the inside length of the link, outside width (B) and diameter (d) of the chain bar.



CLASSIFICATION OF LINK CHAINS

1. Depending on the ratio between the pitch and the diameter of the chain bar:

(a) Short link chains: If t ≤3 d, then the chains are known as short link chains.

(b) Long link chains: If l> 3 d, then the chains are known as long link chains.

2. Depending on the manufacturing accuracy:

(a) Pitched chains: When the permissible deviations from the nominal pitch size is within60.03 d and from the outside width is within 6 0.05 d, then the chain is called as Pitched chain.

(b) Calibrated chains :When the permissible deviations is within i 0.1 d of the nominal Size in pitch and outside width, then the chain is known as calibrated chain.

SELECTION OF LINK CHAINS

The general formula for selecting link chains in tension is given by

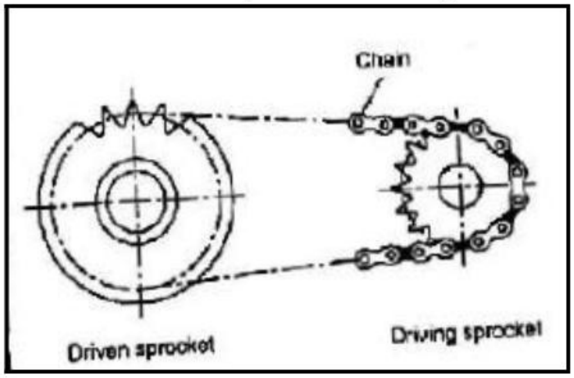
$$P_{safe} = \frac{P_{br}}{n}$$

P_{safe}= Safe load carried by the chain,

P_{br}= Breaking load of the chain, and

n = Factor of safety

TRANSMISSION (OR ROLLER) CHAINS



CHAIN MATERIALS

- Link plates are made of cold-rolled, medium-carbon or alloy steels such asC45, C50 and 40 Crl.
- Pins, bushings and rollers are made of carburizing steels such as CIS, C20, and 30 Ni4 Crl.

SPECIFICATION OF A ROLLER CHAIN

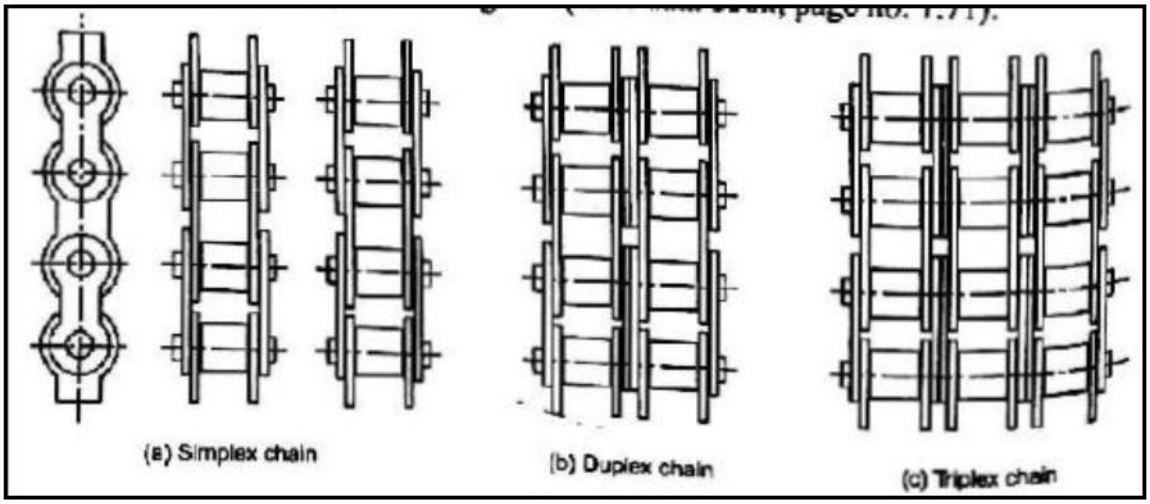
Roller chain is specified by three dimensions - pitch, width and diameter.

Pitch: It is the distance from centre to centre of adjacent pins or rivets.

Width: It is the nominal width of the link or the length of the pin.

Diameter: It refers to the actual outside diameter of the roller.

Roller chains are available in single-row or multi-row construction such as simplex, duplex or triplex strands as shown in Fig. (Refer data book, page no. 7.71).



Shows a sprocket driving a chain in a counter clockwise direction.

Let p = Chain pitch,

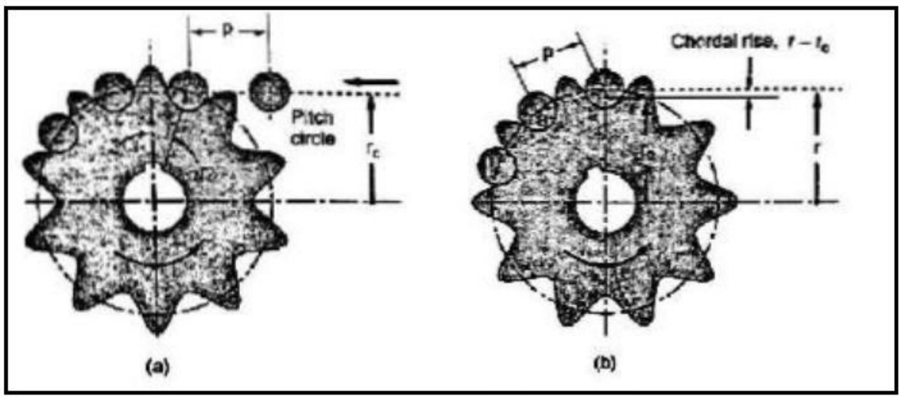
a = Pitch angle,

$\alpha/2$ = Angle of articulation,

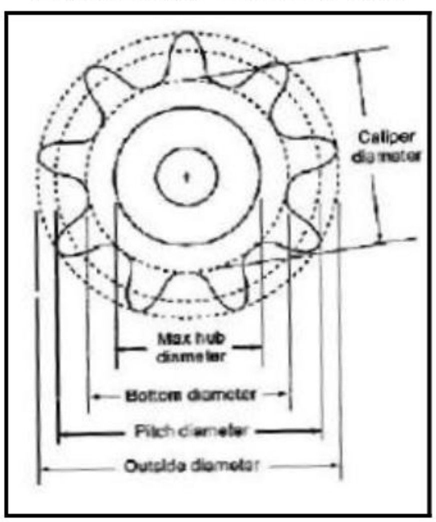
D = Pitch circle diameter of the sprocket, and

z = Number of teeth on the sprocket.

CHORDAL (OR POLYGONAL) ACTION



SPROCKET DIAMETERS



The equations for those diameters are :

(i) Pitch diameter = $\frac{p}{\sin(\frac{180}{z})}$

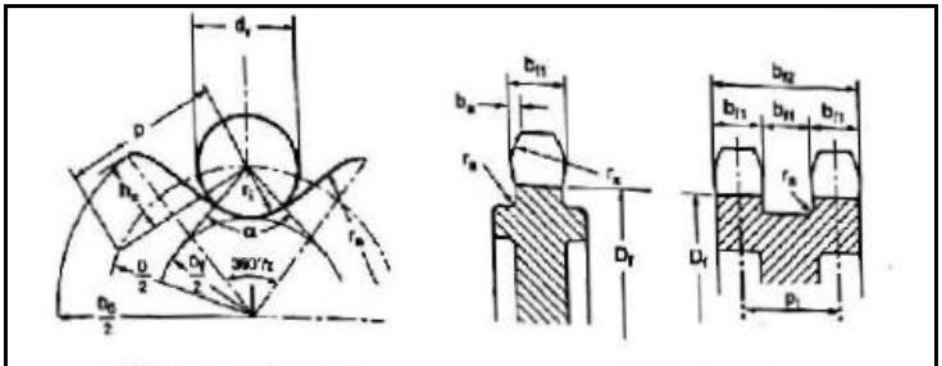
(ii) Outside diameter = $\mathbf{p[0.6 \cot (\frac{180}{z})]}$

(iii) Bottom diameter = Pitch diameter – Roller outside diameter

(iv) Caliper diameter = Pitch diameter x cos $(\frac{90}{z})$ − Roller outside diameter

(v) Maximum hub diameter $\mathbf{= p [\cot (\frac{180}{z}) - 1] – 0.03}$

TOOTH FORM



(a) Tooth profile of sprocket (b) Rim profile for sprocket

DESIGN OF SILENT CHAIN

SILENT (OR INVERTED-TOOTH) CHAIN

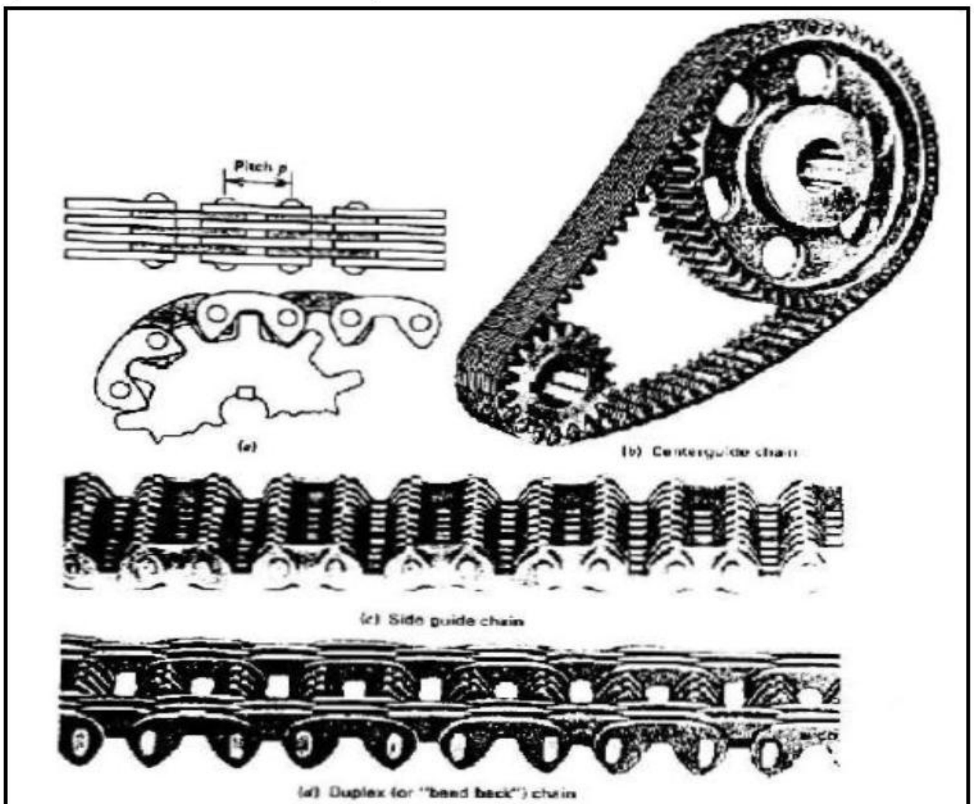


Fig. 4.11. Inverted-tooth (silent) chains

TYPES OF SILENT CHAINS

Depending upon the type of joint between links, the silent chains are classified into:

(i) Reynolds chain: In Reynolds chain, the links are connected by pins resulting in sliding friction.

(ii) Morse chain: In Morse chain, the rocker pins are used.

DESIGN PROCEDURE OF ROLLER CHAIN

1. Selection of the transmission ratio (i):

Select a preferred transmission ratio, i **(from data book, page no. 7.74)**

1, 1.12, 1.25, 1.4, 1.6, 1.8, 2, 2.25, 3.15, 4, 4.5, 5, 5.6, 6.3 and 7.1

From the pitch range obtained, consulting Table 4.4, select a suitable standard pitch.**(From data book, page no. 7. 74)**

2. Selection of number of teeth on the driver sprocket (Z_1):

Select the number of teeth on the driver sprocket (Z_1)….**[From data book, page no. 7.74]**

3. Determination of number of teeth on the driven sprocket (Z_2):

$Z_2 = i^* Z_1$….[From data book, page no. 7.74]

Recommended value of Z_2:Z_{2max} = 100 to 120 ….**[From data book, page no. 7.74]**

4. Selection of standard pitch (p):

$a = (30 \text{ to } 50)p$

$a = 30p_{max}$ $a = 50p_{min}$

From the pitch range obtained, consulting table 4.4, select a suitable standard pitch.

[From data book, page no. 7.74]

5. Selection of the chain:-

(From data book, page nos. 7.71, 7.72 and 7. 73.

This table gives some details for a few Chains.)

Note R - Simplex, DR - Duplex, TR – Triplex

6. Calculation of Total load on The Driving Side of the Chain (P_T):

$$\begin{Bmatrix} \text{Total load on the} \\ \text{Driving side } (P_T) \end{Bmatrix} = \begin{Bmatrix} \text{Tangential force} \\ \text{due to} \\ \text{power transmission}(P_t) \end{Bmatrix} + \begin{Bmatrix} \text{Centrifugal tension}(P_c) \\ \text{due to speed} \\ \text{of the chain} \end{Bmatrix} + \begin{Bmatrix} \text{Tension} \\ \text{due to chain} \\ \text{sagging}(P_S) \end{Bmatrix}$$

$P_T = P_t + P_c + P_s$ ….[From data book, page no. 7.78]

(i) To find tangential force (P_t):

$$P_t = \frac{1020\,N}{v} \text{...[From data book, page no. 7.78]}$$

Where N = Transmitted power in KW, and

$$v = \text{Chain velocity in m/s} = \frac{z_1 \times p \times N_1}{60 \times 1000} \text{ or } \frac{z_1 \times p \times N_2}{60 \times 1000}$$

(ii) To find centrifugal tension (P_c):

$P_c = mv^2$...[From data book, page no. 7.78]

Where m = Mass of chain / meter,

V= velocity of chain , m/s

(iii) To find tension due to sagging (P_s):

$P_s = k \cdot w \cdot a$

where k = Coefficient of sag taking into account the arrangement of chain drive,

W = Weight of chain / meter = m- g, and

a = Centre distance in meter.

Coefficient for sag, k ...**[From data book, page no. 7.76]**

7. **Calculation of service factor (K_s):**

The service factor is used to account for variations in the driving and driven sources for roller chains.

Service factor, $K_s = k_1 . k_2 . k_3 . k_4 . k_5 . k_6$...**[From data book, page no. 7.76]**

k_1= Load factor , **(from data book, page no.7.76)**

k_2=Factor for distance regulation, **(from data book, page no.7.76)**

k_3 = Factor for centre distance of sprockets, **(from data book, page no.7.76)**

k_4 = Factor for position of sprocket **(from data book, page no.7.77)**

k_5 = Lubrication factor **(from data book, page no.7.77)**

k_6 = Rating factor**(from data book, page no.7.77)**

8. **Calculation of design load:**

Design load = Total load on the driving side of the chain x Service factor

Design load = **P_T x K_s**

9. **Calculation of working factor of safety (FS_w):**

Factor of safety = $\frac{\text{Breaking load Q}}{\text{Design load}} = \frac{Q}{P_T \times K_s}$

Where Q is breaking load got **from data book, page no.7.72**

10. Check for factor of safety:

[Refer From data book, page no. 7.77]

If the working factor of safety (FS_w) is greater than the recommended minimum value of factor of safety (n') then the design is safe and satisfactory.

11. Check for the bearing stress in the rollers:

Calculate the bearing stress in the roller using the formula

$$\sigma = \frac{Tangential\ load}{Bearing\ area} = \frac{P_t * K_s}{A}$$

Where A is Bearing Area got **From data book, page no. 7.72**

Take the values for allowable bearing stress,$[\sigma]$, N/mm^2 …[**From data book, page no. 7.77]**

$\sigma < [\sigma]$. The design is safe and satisfactory.

12. Calculation of actual length of chain (L):

Calculate the number of links(l_p) using the formula

$$L = 2a_p + \frac{Z_1+Z_2}{2} + \frac{\left[\frac{Z_1+Z_2}{2\pi}\right]^2}{a_p}$$ **…[From data book, page no. 7.75.]**

$$a_p = \frac{a_0}{p} = \frac{Initial\ centre\ distance}{pitch}$$

$$L = l_p \times p$$

13. Calculation of exact centre distance:

Exact centre distance, $a = \frac{e + \sqrt{e^2 + 8M}}{4} \times p$ **…[From data book, page no. 7.75.]**

Where $e = I_p - \left(\frac{Z_1+Z_2}{2}\right)$ **…[From data book, page no. 7.75.]**

$M = \left(\frac{Z_1+Z_2}{2\pi}\right)^2$ = **Constant**

14. Calculation of pitch circle diameters (pcd) of sprockets:

Pcd of smaller sprocket, $d_1 = \frac{p}{\sin\left(\frac{180}{Z_1}\right)}$

Pcd of Larger sprocket, $d_2 = \frac{p}{\sin\left(\frac{180}{Z_2}\right)}$ **…[From data book, page no. 7.78.]**

Smaller sprocket outside diameter, $d_{01} = d_1 + 0.8d_r$

Larger sprocket outside diameter, $d_{02} = d_2 + 0.8d_r$

Where d_r **is the roller diameter**

UNIT – I: DESIGN OF TRANSMISSION SYSTEMS FOR FLEXIBLE ELEMENTS (PART –A)

1. What are the factors upon which the coefficient of friction between the belt and pulley depends? (May/june2012) (May/June 2014)

Soln. *The coefficient of friction between the belt and the pulley depends upon the following factors:*

1. *The material of belt;*
2. *The material of pulley;*
3. *The slip of belt; and*
4. *The speed of belt.*

According to C.G. Barth, the coefficient of friction (μ) for oak tanned leather belts on cast iron pulley, at the point of slipping, is given by the following relation, i.e.

$$\mu = 0.54 - \{42.6/(152.6 + v)\}$$

Where, v = Speed of the belt in meters per minute.

2. Brief the term "crowning of pulley". (May/June 2014)

Soln. *Pulleys are provided. a -slight conical shapes (or) convex shapes in their rim's r surface in order to Prevent the belt from running off the pulley due centrifugal force. This is known as crowning, of pulley. Usually the crowning height t may be 1/96 of pulley face width.*

3. What are the materials used for belt-drive? (May/June 2013) (May/June 2016)

Soln. Leather,, cotton fabrics ,rubber, animal's hair, silk, rayon, woolenetc

4. What do you mean by Galling of roller chains? (Nov/Dec 2010) (May/june2012) (Nov/Dec 2010)

Soln. *The pin pressure faces have suffered from severe galling where the surfaces have articulated and fused together.*

5. When do you prefer chain drive to a belt or rope drive? (May/Jun 2016

Soln.

Chain drives are preferred for velocity ratio less than 10, chain velocities upto 25 m/s, and for power ratings up to 125KW

DESIGN OF TRANSMISSION SYSTEMS FOR FLEXIBLE ELEMENTS (PART –A)

6. What are the five parts of roller chain? (April/May 2010)

Soln.

The five parts of roller chain are

1. Pin link 2. Pin 3. Bushing 4. Roller and 5. plates

7. Sketch and name the different types of compound wire ropes. (April/May 2010)

Soln. *They are two type namely*

a) Fiber ropes

b) Wire ropes.(a) Based on nup4ber of strands and wires..

i) 6x7 ii) 6 x 19 iii) 6 x 37 iv) 8 x 19 ropes.

(b) Based on the direction of wire I a with respect to strands in twisting.

i) Cross -lay ropes.

ii) Parallel-lay ropes.

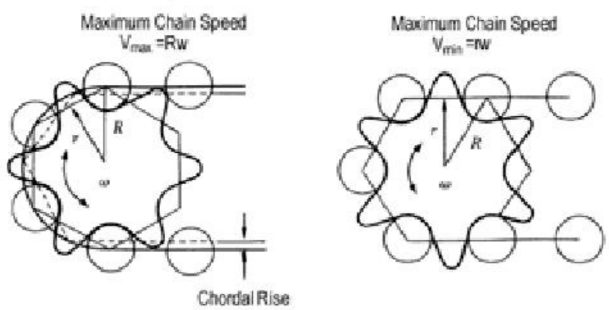
iii) Compound laid ropes.

8. How are the ends of flat-belt joined? (April/May 2011)

Soln. (i) Cemented joints (ii) Laced joints (iii) Crest joints. (iv) Hinged joints.

9. What is chordal action (Polygonal action) in chain drives? (Nov/Dec 2012)

Soln. *When chain passes over the sprocket, it moves as a series of chords instead of a continuous arc as in the case of a belt drive. It results in varying speed of the chain drive. This phenomenon is known as* chordal action



10. Give an expression for ratio of tensions in a flat belt drive. (Apr/May2011)

Soln. Tension ratio, $\frac{T_1}{T_2} = e^{\mu\alpha}$ ...[neglecting centrifugal tension]

$\frac{T_1 - mv^2}{T_2 - mv^2} = e^{\mu\alpha}$ ....[considering centrifugal tension]