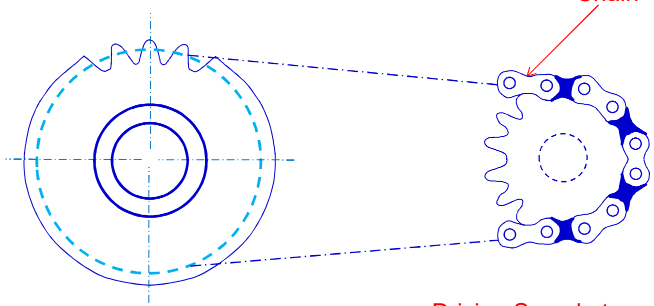
Chain Drives

A Chain Drive consists of an endless chain wrapped around two sprockets. The chain consists of a number of links connected by pin joints, while the sprocket are toothed wheels with a special profile for teeth.



Advantages of chain drives

1. Chain drives can be used for long as well as short centre distances.
2. No. of Shafts can be driven in the same or opposite direction by means of the chain from a single driving sprocket.
3. Chain drives are compact than belt drives
4. These are positive drives, because there is no slip. Hence efficiency is high

Dis Advantages of chain drives

1. These are not suitable when precise motion is required due to polygonal effect.
2. Proper maintenance is required, particularly lubrication and slack adjustment.
3. Chain drives generates noise.

Roller Chain

The roller chain consists of alternate links made of inner and outer plates. There are five parts in roller chain

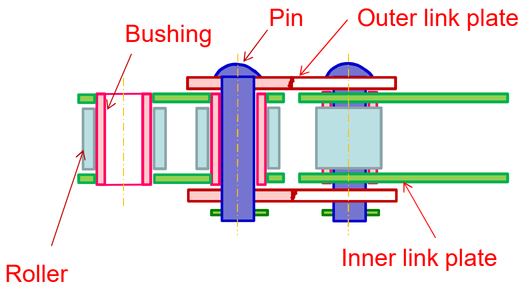
i) Pin

ii) Bush

iii) Roller

iv) Inner plate

v) Outer plate



Roller Chain

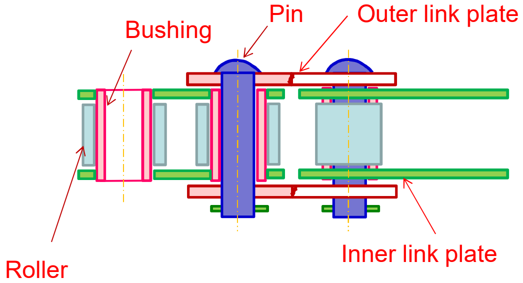
- The pin is press fitted to outer link plate

-The bush is press fitted to inner link plate

-Bush and Pin form a swivel joint and outer link is free to swivel with respect to inner link

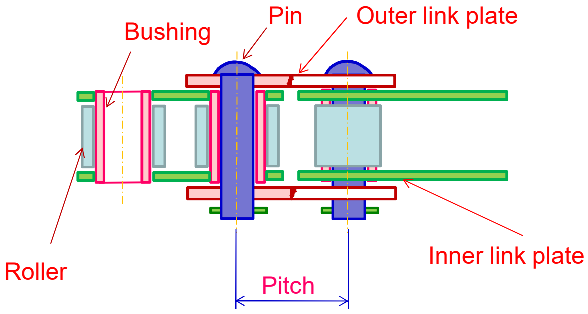
-The rollers are freely fitted on bushes and during engagement, turn with the teeth of the sprocket wheels.

- This results in rolling friction instead of sliding friction b/w roller and sprocket teeth



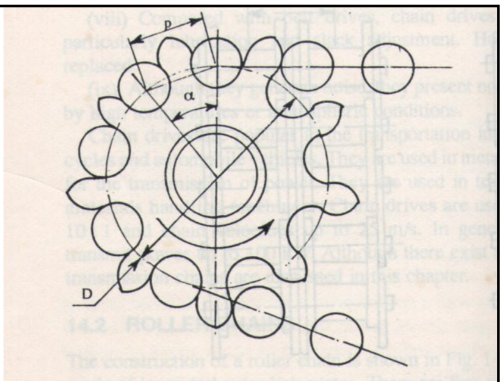
Pitch

The pitch of the chain is the linear distance between the axes of adjacent rollers.



Geometric Relationships

The engagement of the sprocket wheel is shown in the figure.



D = Pitch circle diameter

α = Pitch angle

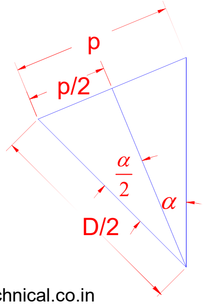
$$\alpha = \frac{360}{z}$$

Where z = number of teeth on sprocket

$$\sin\left(\frac{\alpha}{2}\right) = \frac{(p/2)}{(D/2)}$$

$$D = \frac{p}{\sin\left(\frac{\alpha}{2}\right)}$$

$$D = \frac{p}{\sin\left(\frac{180}{z}\right)} \qquad \because \alpha = \frac{360}{z}$$



The **velocity ratio i** of the chain drives is given by

$$i = \frac{z_2}{z_1} = \frac{n_1}{n_2}$$

Where n_1, n_2 = speeds of rotation of driving and driven shafts(r.p.m)

z_1, z_2 = number of teeth on driving and driven sprockets.

The **velocity of the chain** is given by

$$v = \frac{\pi D n}{60 \times 10^3} \qquad \left[\begin{array}{l} D = \dfrac{p}{\pi / z} \\ D = \dfrac{zp}{\pi} \end{array} \right] \text{for small values of } \sin$$

$$v = \frac{zpn}{60 \times 10^3}$$

Where v is the velocity in m/s.

The **Length of the chain** is always expressed in terms of the number of links

$$L = L_n \times p \qquad \begin{array}{l} L_n = No.\ of\ links\ in\ the\ chain \\ p = pitch \end{array}$$

The length of the chain may be deduced from the length of the open belt drive

$$L = 2a + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4a}$$

$$Substitute\ D = \frac{zp}{\pi}$$

$$L = 2a + \frac{\pi}{2}\left(\frac{z_1 p}{\pi} + \frac{z_2 p}{\pi}\right) + \frac{\left(\dfrac{z_2 p}{\pi} - \dfrac{z_1 p}{\pi}\right)^2}{4a}$$

$$L = 2a + \frac{\pi}{2}\left(\frac{z_1 p}{\pi} + \frac{z_2 p}{\pi}\right) + \frac{\left(\frac{z_2 p}{\pi} - \frac{z_1 p}{\pi}\right)^2}{4a}$$

$$L = 2a + \frac{\pi}{2}.\frac{p}{\pi}(z_1 + z_2) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p^2}{a}\right)$$

$$L = p \times \left(2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)\right)$$

$$L = p \times L_n$$

$$L_n = 2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)$$

Centre distance between axes of the two sprockets is given by

$$a = \frac{p}{4}\left\{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right] + \sqrt{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right]^2 - 8\left[\frac{z_2 - z_1}{2\pi}\right]^2}\right\}$$

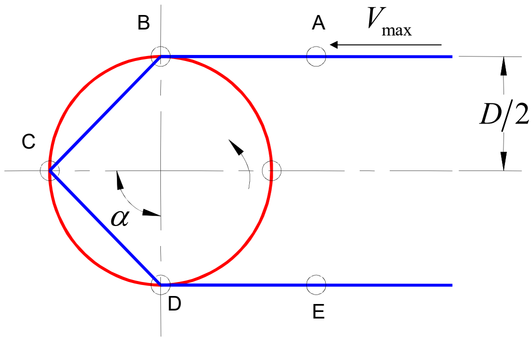
Centre distance is reduced by (0.002 to 0.004)a to account for sag.

Polygonal Effect

When the link AB at D/2 distance,

linear velocity is

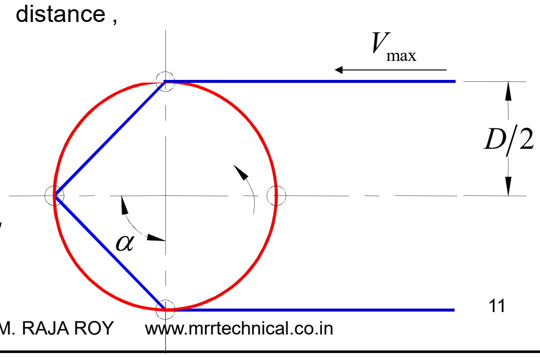
$$v_{max} = \frac{\pi D n}{60 \times 10^3} \; m/s$$



When the link AB at $\frac{D}{2} Cos\left(\frac{\alpha}{2}\right)$ distance ,

linear velocity is

$$v_{min} = \frac{\pi D n . \cos\left(\frac{\alpha}{2}\right)}{60 \times 10^3} \; m/s$$

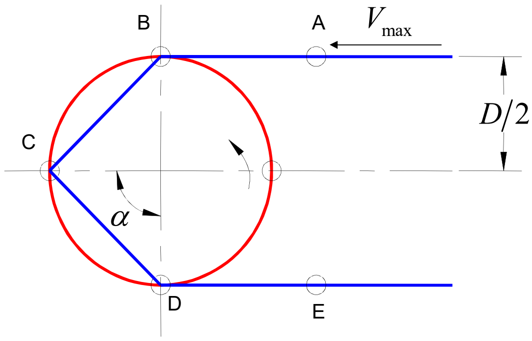


Polygonal Effect

When the link AB at D/2 distance,

linear velocity is

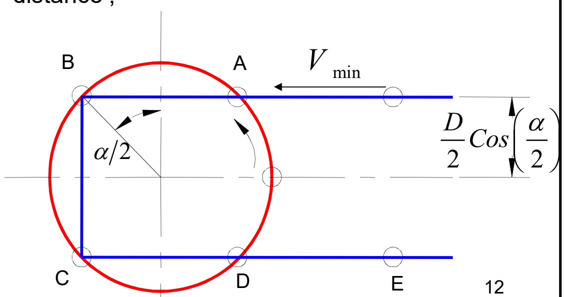
$$v_{max} = \frac{\pi D n}{60 \times 10^3} \; m/s$$



When the link AB at $\frac{D}{2} Cos\left(\frac{\alpha}{2}\right)$ distance ,

linear velocity is

$$v_{min} = \frac{\pi D n . \cos\left(\frac{\alpha}{2}\right)}{60 \times 10^3} \; m/s$$



The variation in the velocity is given by

$$v_{\max} - v_{\min} \infty \left[1 - \cos\left(\frac{\alpha}{2}\right)\right]$$

$$v_{\max} - v_{\min} \infty \left[1 - \cos\left(\frac{180}{z}\right)\right]$$

As the number increases to infinity the variation will be zero.

Minimum no. of teeth on the driving sprocket are 17.

13

Power Rating of Roller Chains

$$Power\ \ transmitted\ \ kW = \frac{P_1 v}{1000}$$

Where P_1 = allowable tension in the chain(N)

v = average velocity of chain (m/sec)

$$kW\ rating\ \ of\ \ chain = \frac{kW \times K_s}{K_1 \times K_2}$$

Where K_s = Service factor - > Takes into consideration of shock & vibration

K_1 = Multiple strand factor

K_2 = Tooth correction factor

14

PB1 It is required to design a chain drive to connect a 10Kw 1440rpm electric motor to a centrifugal pump running at 720rpm.
The service conditions involve moderate shocks Find

i) Power rating
ii) Determine the pitch circle diameters of driving and driven sprockets.
iii) Determine the no. of chain links
iv) Specify the correct centre distance between the axes of the sprockets.

Assume : K_s=1.3, K_1=1, K_2=1 and pitch(p)=19.05mm

Sol : Given data
Power (KW) = 10Kw
N1=1440rpm
N2=720rpm

$$i)\ kW\ rating\ of\ chain = \frac{kW \times K_s}{K_1 \times K_2} =$$

PB1 It is required to design a chain drive to connect a 10Kw 1440rpm electric motor to a centrifugal pump running at 720rpm.
The service conditions involve moderate shocks Find

i) Power rating
ii) Determine the pitch circle diameters of driving and driven sprockets.
iii) Determine the no. of chain links
iv) Specify the correct centre distance between the axes of the sprockets.

Assume : K_s=1.3, K_1=1, K_2=1 and pitch(p)=19.05mm

Sol : Given data
Power (KW) = 10Kw
n1=1440rpm
n2=720rpm

$$i)\ kW\ rating\ of\ chain = \frac{kW \times K_s}{K_1 \times K_2} = \frac{10 \times 1.3}{1 \times 1} = 13KW$$

ii) Pitch circle diameter of driving sprocket (D_1):

$$D_1 = \frac{p}{\sin\left(\frac{180}{z_1}\right)}$$

Assume no. of teeth on the driving sprocket = 17.

$$D_1 = \frac{19.05}{\sin\left(\frac{180}{17}\right)} =$$

ii) Pitch circle diameter of driven sprocket (D_2):

$$D_2 = \frac{p}{\sin\left(\frac{180}{z_2}\right)}$$

$$i = \frac{z_2}{z_1} = \frac{n_1}{n_2}$$

$$z_2 = \frac{n_1}{n_2} \times z_1 =$$

$$D_2 = \frac{19.05}{\sin\left(\frac{180}{z_2}\right)} =$$

ii) Pitch circle diameter of driving sprocket (D_1):

$$D_1 = \frac{p}{\sin\left(\frac{180}{z_1}\right)}$$

Assume no. of teeth on the driving sprocket = 17.

$$D_1 = \frac{19.05}{\sin\left(\frac{180}{17}\right)} = 103.67mm$$

ii) Pitch circle diameter of driven sprocket (D_2):

$$D_2 = \frac{p}{\sin\left(\frac{180}{z_2}\right)}$$

$$i = \frac{z_2}{z_1} = \frac{n_1}{n_2}$$

$$z_2 = \frac{n_1}{n_2} \times z_1 = \frac{1440}{720} \times 17 = 34$$

$$D_2 = \frac{19.05}{\sin\left(\frac{180}{34}\right)} = 206.46mm$$

iii) No. of chain links (L_n) :

Assume a=40p => a=40X19.05 = 762mm.

$$L_n = 2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)$$

$$= 2\left(\frac{762}{19.05}\right) + \left(\frac{17+34}{2}\right) + \left(\frac{34-17}{2\pi}\right)^2 \times \left(\frac{19.05}{762}\right) =$$

iii) No. of chain links (L_n) :

Assume a=40p => a=40X19.05 = 762mm.

$$L_n = 2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)$$

$$= 2\left(\frac{762}{19.05}\right) + \left(\frac{17+34}{2}\right) + \left(\frac{34-17}{2\pi}\right)^2 \times \left(\frac{19.05}{762}\right) = 105.6$$

$$L_n = 106 \, links$$

iv) Correct Centre distance.

$$a = \frac{p}{4}\left\{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right] + \sqrt{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right]^2 - 8\left[\frac{z_2 - z_1}{2\pi}\right]^2}\right\}$$

21

iv) Correct Centre distance.

$$a = \frac{p}{4}\left\{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right] + \sqrt{\left[L_n - \left(\frac{z_1 + z_2}{2}\right)\right]^2 - 8\left[\frac{z_2 - z_1}{2\pi}\right]^2}\right\}$$

$$a = 762.026mm$$

$$a = 762.026 \times 0.998 = 760.47mm$$ (After compensating the sag)

22

PB2 A simple chain No. 10B is used to transmit power from a 1400 rpm electric motor to a line shaft running at 350rpm. The number of teeth on the driving sprocket wheel are 19. Calculate

i) Power to be transmitted.

ii) Tension in the chain

iii) Factor of safety for the chain based on the breaking load.

Assume : K_s=1.0, K_1=1.0, K_2=1.11, pitch(p)=15.875mm

Power rating = 11.67Kw, Breaking load=22.7KN

Sol : Given data

n1=1440rpm

n2=350rpm

Z_1=19

i) Power to be transmitted

$$Power\ rating = \frac{kW \times K_s}{K_1 \times K_2}$$

PB2 A simple chain No. 10B is used to transmit power from a 1400 rpm electric motor to a line shaft running at 350rpm. The number of teeth on the driving sprocket wheel are 19. Calculate

i) Power to be transmitted.

ii) Tension in the chain

iii) Factor of safety for the chain based on the breaking load.

Assume : K_s=1.0, K_1=1.0, K_2=1.11, pitch(p)=15.875mm

Power rating = 11.67Kw, Breaking load=22.7KN

Sol : Given data

n1=1400rpm

n2=350rpm

Z_1=19

i) Power to be transmitted

$$11.67 = \frac{kW \times 1.0}{1.0 \times 1.11}$$

KW = 12.98KW

ii) Tension in the chain

$$v = \frac{zpn}{60 \times 10^3} = \frac{19 \times 15.875 \times 1400}{60 \times 10^3} =$$

$$kW = \frac{P_1 v}{1000}$$

$$12.98 = \frac{P_1 v}{1000}$$

ii) Tension in the chain

$$v = \frac{zpn}{60 \times 10^3} = \frac{19 \times 15.875 \times 1400}{60 \times 10^3} = 7.04 m/\sec$$

$$kW = \frac{P_1 v}{1000}$$

$$12.98 = \frac{P_1 \times 7.04}{1000} \Rightarrow P_1 =$$

ii) Tension in the chain

$$v = \frac{zpn}{60 \times 10^3} = \frac{19 \times 15.875 \times 1400}{60 \times 10^3} = 7.04 m/\sec$$

$$kW = \frac{P_1 v}{1000}$$

$$12.98 = \frac{P_1 \times 7.04}{1000} \quad \Rightarrow \quad P_1 = 1839.4N$$

ii) Factor of Safety

$$f_s = \frac{Breaking\ load}{Working\ load}$$

ii) Tension in the chain

$$v = \frac{zpn}{60 \times 10^3} = \frac{19 \times 15.875 \times 1400}{60 \times 10^3} = 7.04 m/\sec$$

$$kW = \frac{P_1 v}{1000}$$

$$12.98 = \frac{P_1 \times 7.04}{1000} \quad \Rightarrow \quad P_1 = 1839.4N$$

ii) Factor of Safety

$$f_s = \frac{Breaking\ load}{Working\ load} = \frac{22 \times 1000}{1839.49} = 12.34$$

PB3 Design a roller chain drive for driving a compressor by 12KW rated electric motor, running at 1200 r.p.m. The compressor speed is around 350r.p.m. Number of teeth on pinion are 25

Assume : K_s=1.25, K_1=1.0, K_2=1.0, pitch(p)=15.875mm
Breaking load = 44.5KN

Sol : Given data
n1=1200 rpm
n2=350rpm
Z_1=25

Pitch Circle Dia of the sprocket pinion

$$D_1 = \frac{p}{\sin\left(\frac{180}{z_1}\right)}$$

$$D_1 = \frac{15.875}{\sin\left(\frac{180}{25}\right)} = 127mm$$

PB3 Design a roller chain drive for driving a compressor by 12KW rated electric motor, running at 1200 r.p.m. The compressor speed is around 350r.p.m. Number of teeth on pinion are 25 . Velocity ratio = 3.5

Assume : K_s=1.25, K_1=1.0, K_2=1.0, pitch(p)=15.875mm
Breaking load = 44.5KN

Sol : Given data
n1=1200 rpm
n2=350rpm
Z_1=25

Pitch Circle Dia of the sprocket pinion

$$D_1 = \frac{p}{\sin\left(\frac{180}{z_1}\right)}$$

$$D_1 = \frac{15.875}{\sin\left(\frac{180}{25}\right)} = 127mm$$

Pitch Circle Dia of the sprocket gear

$$D_2 = \frac{p}{\sin\left(\frac{180}{z_2}\right)}$$

$$D_2 = \frac{15.875}{\sin\left(\frac{180}{88}\right)} = 448.8mm$$

Velocity of Chain

$$v = \frac{\pi D_1 N_1}{60} = \frac{\pi \times 0.127 \times 1200}{60} = 8m/\sec$$

Pitch Circle Dia of the sprocket gear

$$D_2 = \frac{p}{\sin\left(\frac{180}{z_2}\right)}$$

$$D_2 = \frac{15.875}{\sin\left(\frac{180}{88}\right)} = 448.8mm$$

Velocity of Chain

$$v = \frac{\pi D_1 N_1}{60} = \frac{\pi \times 0.127 \times 1200}{60} = 8m/\sec$$

Load on Chain

$$KW = \frac{P_1 v}{1000}$$

$$Power\ rating = \frac{kW \times K_s}{K_1 \times K_2}$$

$$12 = \frac{kW \times 1.25}{1 \times 1}$$

$$KW = 9.6 Kw$$

Load on Chain

$$KW = \frac{P_1 v}{1000}$$

$$9.6 = \frac{P_1 \times 8}{1000}$$

$$P_1 = 1200 N$$

Assume distance equal to 30p

Number of links in the chain is given by

$$L_n = 2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)$$

$$L_n = 119.82 \quad say\, 120 links$$

Assume distance equal to 30p

Number of links in the chain is given by

$$L_n = 2\left(\frac{a}{p}\right) + \left(\frac{z_1 + z_2}{2}\right) + \left(\frac{z_2 - z_1}{2\pi}\right)^2 \times \left(\frac{p}{a}\right)$$

$$L_n = 119.82 \quad say\, 120 links$$