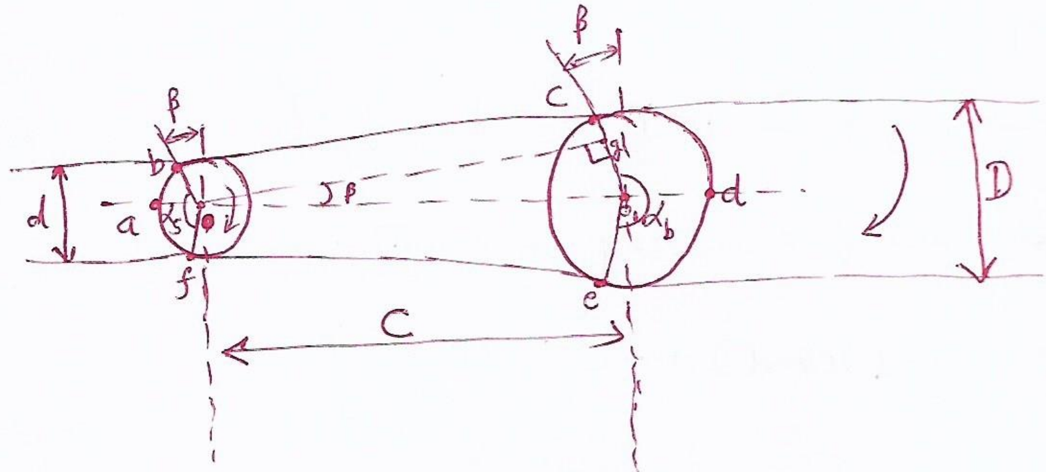
# Unit-3(ii)

# Belt drive

## # Belt Length – Geometrical Relationships :-

→ Open Belt drive.




$\alpha_s$ = wrap angle for smaller pulley (degrees)
$\alpha_b$ = wrap angle for bigger pulley (degrees)
D = diameter of ~~sm~~ big pulley (mm)
d = diameter of small pulley (mm)
C = Center distance (mm)

→ Draw line $\overline{og}$ perpendicular to line $\overline{O_1C}$. The area ogcb is a rectangle.

$\therefore$ ob = gc

From triangle $ogo_1$,

$$\sin\beta = \frac{O_1g}{OO_1} = \frac{O_1C - gC}{OO_1} = \frac{O_1C - ob}{OO_1} = \frac{D/2 - d/2}{C} = \frac{D-d}{2C}$$

$$\therefore \sin\beta = \frac{D-d}{2C}$$

also $\alpha_s = (180 - 2\beta)$ and $\alpha_b = (180 + 2\beta)$

$$\therefore \alpha_s = 180 - 2\sin^{-1}\left(\frac{D-d}{2C}\right)$$

$$\alpha_b = 180 + 2\sin^{-1}\left(\frac{D-d}{2C}\right)$$

The length of the belt (L) is given by :-

$$L = arc(fab) + \overline{bC} + arc(cde) + \overline{ef}$$

$$= \frac{d}{2}(\pi - 2\beta) + C\cos\beta + \frac{D}{2}(\pi + 2\beta) + C\cos\beta$$

$$L = \frac{\pi(D+d)}{2} + \beta(D-d) + 2C\cos\beta \quad \text{———} \quad (a)$$

For small values of β,

$$\beta = \sin\beta = \left(\frac{D-d}{2C}\right)$$

$$\text{and } \cos\beta = 1 - 2\sin^2\left(\frac{\beta}{2}\right) = 1 - \frac{\beta^2}{2} = 1 - \frac{(D-d)^2}{8C^2}$$

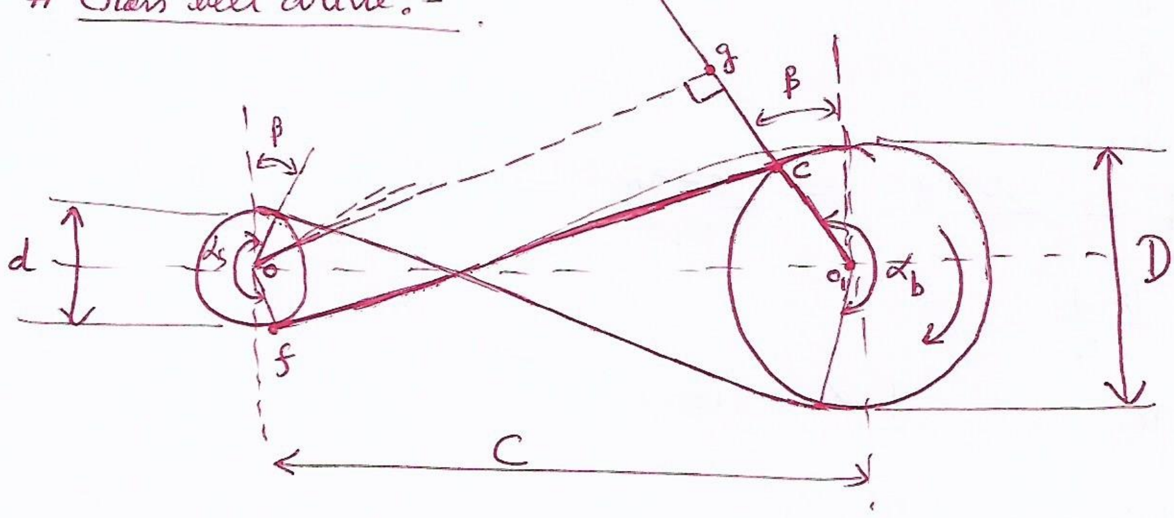
Substituting these values of $\beta$ and $\cos\beta$ in eqn (a).

$$L = \frac{\pi(D+d)}{2} + \left(\frac{D-d}{2C}\right)(D-d) + 2C\left[1 - \frac{(D-d)^2}{8C^2}\right]$$

$$= \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{2C} + 2C - \frac{(D-d)^2}{4C}$$

$$\boxed{\therefore L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C}}$$

# Cross belt drive :-




→ Draw a line $\overline{og}$ perpendicular to the extension of line $\overline{O_1C}$. The area of cg is a rectangle.

$\therefore cg = of$

From triangle $ogo_1$,

$$\sin\beta = \frac{o_1g}{oo_1} = \frac{o_1c + cg}{oo_1} = \frac{o_1c + of}{oo_1}$$

$$= \frac{D/2 + d/2}{C} = \frac{D+d}{2C}$$

$$\therefore \sin\beta = \frac{D+d}{2C}$$

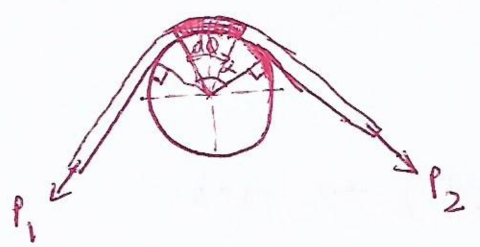
$$\alpha_s = \alpha_b = (180 + 2\beta)$$

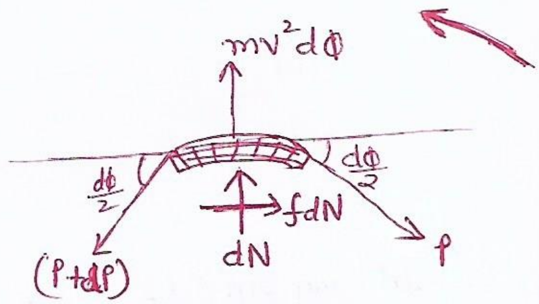
or $\alpha_s = \alpha_b = 180 + 2\sin^{-1}\left(\frac{D+d}{2C}\right)$

$$\boxed{L = 2C + \frac{\pi(D+d)}{2} + \frac{(D+d)^2}{4C}}$$

# Analysis of Belt tension :-

flat belt :-




$P_1$ = Belt tension in the tight side (N)

$P_2$ = Belt tension in the loose side (N)

$m$ = mass of the one meter length of belt (kg/m)

$v$ = belt velocity (m/s)

$f$ = Coefficient of friction

$\alpha$ = angle of wrap for belt (radians).

Centrifugal force = mass × acceleration.

The length of element is $(r\,d\phi)$ and the mass per unit length is $m$.

$\therefore$ mass of element $= m r\, d\phi$

acceleration $= \left(\frac{v^2}{r}\right)$

$\therefore$ centrifugal force $= (m r d\phi)\left(\frac{v^2}{r}\right) = mv^2 d\phi$

Considering equilibrium of forces in X and Y directions :-

$$(P+dP)\cos\left(\frac{d\phi}{2}\right) - P\cos\left(\frac{d\phi}{2}\right) - f dN = 0 \quad \text{—— (a)}$$

$$(P+dP)\sin\left(\frac{d\phi}{2}\right) + P\sin\left(\frac{d\phi}{2}\right) - mv^2 d\phi - dN = 0 \quad \text{—— (b)}$$

For small values of $\left(\frac{d\phi}{2}\right)$,

$$\cos\left(\frac{d\phi}{2}\right) \simeq 1$$

$$\sin\left(\frac{d\phi}{2}\right) \simeq \frac{d\phi}{2}$$

Substituting these values in Eqn. (a).

$$(P+dP) - P - f dN = 0 \Rightarrow dP - f\,dN = 0$$

$$\therefore dN = \frac{dP}{f} \quad \text{—— (c)}$$

Similarly, substituting $\sin\left(\frac{d\phi}{2}\right)$ as $\left(\frac{d\phi}{2}\right)$ in eqn (b) :-

$$(P+dP)\left(\frac{d\phi}{2}\right) + P\left(\frac{d\phi}{2}\right) - mv^2 d\phi - dN = 0$$

Neglecting the differential of second order $(dP \times d\phi)$ :-

$$P d\phi - mv^2 d\phi - dN = 0$$

Substituting eqn (c) in above expression :-

$$(P - mv^2) d\phi - \frac{dP}{f} = 0$$

$$\frac{dP}{(P - mv^2)} = f\,d\phi$$

Integrating the above expression :-

$$\int_{P_2}^{P_1} \frac{dP}{(P-mv^2)} = f\int_0^{\alpha} d\phi$$

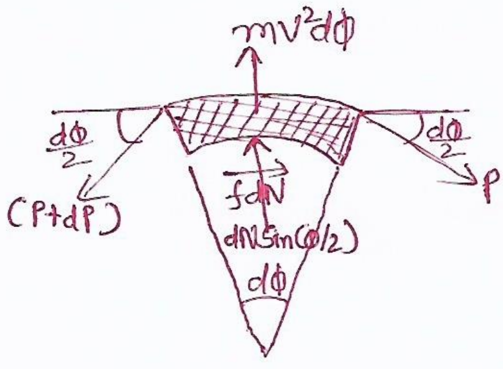
$$\left[\log_e(P-mv^2)\right]_{P_2}^{P_1} = f\left[\phi\right]_0^{\alpha}$$

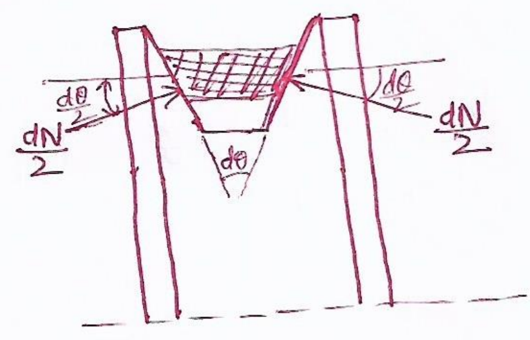
$$\log_e(P_1-mv^2) - \log_e(P_2-mv^2) = f\alpha .$$

$$\log_e\left[\frac{P_1-mv^2}{P_2-mv^2}\right] = fa$$

$$\boxed{\frac{P_1-mv^2}{P_2-mv^2} = e^{fa}}$$

# V-belt drive :-




The normal reaction, which acts on two sides of the V-belt, is assumed as $\left(\frac{1}{2}dN\right)$ on each side. The resultant reaction in the XY plane is $\left[dN \times \sin\left(\frac{\theta}{2}\right)\right]$, where $\theta$ is the belt angle.

Considering the equilibrium of forces in X and Y directions, we have

$$(P+dP)\cos\left(\frac{d\phi}{2}\right) - P\cos\left(\frac{d\phi}{2}\right) - fdN = 0 \quad \text{—— (a)}$$

For small values of $\left(\frac{d\phi}{2}\right)$,

$$\cos\left(\frac{d\phi}{2}\right) \simeq 1$$

$$\sin\left(\frac{d\phi}{2}\right) \simeq \frac{d\phi}{2}$$

Substituting these value in eqn ⓐ & ⓑ

$$(P+dP) - P - f dN = 0$$

$$\therefore\ dN = \frac{dP}{f} \quad \text{— ⓒ}$$

$$(P+dP)\left(\frac{d\phi}{2}\right) + P\left(\frac{d\phi}{2}\right) - mv^2 d\phi - dN \sin\left(\frac{\theta}{2}\right) = 0$$

Neglecting the term of second order differential ($dP \times d\phi = 0$).

$$P d\phi - mv^2 d\phi - dN \sin\left(\frac{\theta}{2}\right) = 0$$

Substituting eqn ⓒ in above expression,

$$(P - mv^2) d\phi - \frac{dP}{f} \sin\left(\frac{\theta}{2}\right) = 0$$

$$\frac{dP}{(P - mv^2)} = \frac{f\, d\phi}{\sin\left(\frac{\theta}{2}\right)}$$

Integrating above expression:-

$$\int_{P_2}^{P_1} \frac{(dP)}{(P - mv^2)} = \frac{f}{\sin\left(\frac{\theta}{2}\right)} \int_0^{\alpha} d\phi$$

$$\boxed{\frac{P_1 - mv^2}{P_2 - mv^2} = e^{f\alpha / \sin(\theta/2)}}$$

## ...tion for maximum power :-

... belt is given an initial tension $P_i$ in order to transmit power. The initial tension depends upon length of the belt, the elasticity of belt material, the geometry of pulleys and the centre distance. In order to drive an expression for initial tension, the following assumptions are made :-

(i) The length of the belt is constant.

(ii) The belt has linear ~~velocity~~ elasticity.

When the driving pulley begins to rotate, the elongation on the tight side is proportional to $(P_1 - P_i)$, while the contraction on the loose side is proportional to $(P_i - P_2)$. For constant belt length, the elongation on the tight side is equal to the contraction on the loose side. Therefore :-

$$(P_1 - P_i) = (P_i - P_2) \Rightarrow \therefore P_i = \frac{1}{2}(P_1 + P_2) \quad \text{—— (a)}$$

from eqn :-

$$\frac{P_1 - mv^2}{P_2 - mv^2} = e^{fa}$$

$$\frac{P_2 - mv^2}{P_1 - mv^2} = \frac{1}{e^{fa}} \Rightarrow \frac{P_2 - mv^2}{P_1 - mv^2} = \frac{e^{-fa}}{1}$$

$\Rightarrow$ Applying Componendo & dividendo :-

$$\frac{(P_2 - mv^2) + (P_1 - mv^2)}{(P_2 - mv^2) - (P_1 - mv^2)} = \frac{e^{-fa} + 1}{e^{-fa} - 1}$$

$$\frac{(P_1 + P_2) - 2mv^2}{(P_2 - P_1)} = \frac{e^{-fa} + 1}{e^{-fa} - 1}$$

Substituting eqn (a) in above expression :-

$$\frac{2P_i - 2mv^2}{-(P_1 - P_2)} = \frac{e^{-fa} + 1}{e^{-fa} - 1}$$

$$P_1 - P_2 = 2(P_i - mv^2) \times \frac{(1 - e^{-fa})}{(1 + e^{-fa})}$$

Therefore power :-

$$P = (P_1 - P_2)v = 2(P_i \ldots {}^3) \times (1 - e^{-fa} \ldots)$$

Differentiating power with respect to v and equating the result zero,

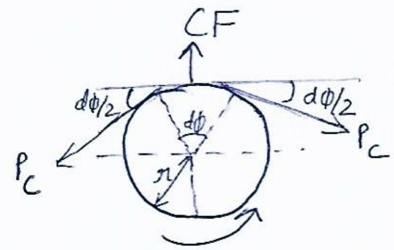
$$\frac{\partial}{\partial v}(\text{power}) = 0 \quad \text{or} \quad \frac{\partial}{\partial v}(P_i v - m v^3) = 0$$

$$\text{or} \quad P_i - 3 m v^2 = 0$$

The optimum velocity of the belt for maximum power transmission is given by :-

$$\boxed{V = \sqrt{\frac{P_i}{3m}}}$$

# Condition for maximum power (Alternative approach) :-




When the belt passes over the pulley, the centrifugal force due to its own weight tends to lift the belt from the surface of pulley.

Length of belt element $= r\,d\phi$

mass of element $= m r\,d\phi$

The acceleration of belt element rotating about the axis of pulley is $\left(\frac{v^2}{r}\right)$

Centrifugal force = mass x acceleration $= m v^2 d\phi$ —— (a)

The centrifugal force induces belt tension $P_c$. By symmetry, the Centrifugal force induces equal tension on two sides of belt. Resolving the forces acting on the belt element in vertical direction,

$$CF = 2 P_c \sin\left(\frac{d\phi}{2}\right) \quad \text{—— (b)}$$

from (a) & (b) :-

$$m v^2 d\phi = 2 P_c \sin\left(\frac{d\phi}{2}\right) \quad \text{—— (c)}$$

For small values $\sin\left(\frac{d\phi}{2}\right) = d\phi$ —— (d) from c & d :-

$$P_c = mv^2 \quad \text{--- (e)}$$

A belt can transmit maximum power, when the following two conditions are simultaneously satisfied :-

(i) The tension in the belt reaches the maximum permissible value for the belt cross section.

(ii) The belt is on the point of slipping i.e maximum frictional force is developed in the belt

Suppose :- b = width of belt ; t = thickness of belt ; $\sigma_t$ = maxm permissible tensile stress,

$$P_{max} = bt\sigma_t$$

Since there is tension due to centrifugal force,

$$P_1 = P_{max} - P_c \quad \text{--- (f)}$$

Also :- $\frac{P_1}{P_2} = e^{f\alpha}$ or $P_2 = \frac{P_1}{e^{f\alpha}}$

The power transmitted by the belt is given by :-

$$\text{Power} = (P_1 - P_2)v = \left[P_1 - \frac{P_1}{e^{f\alpha}}\right]v = P_1 v \underbrace{\left[1 - \frac{1}{e^{f\alpha}}\right]}_{K}$$

$$\text{Power} = P_1 vK = (P_{max} - P_c)vK = (P_{max} - mv^2)vK$$

$$\text{Power} = (P_{max}v - mv^3)K$$

The power transmitted will be maximum when,

$$\frac{\partial(\text{Power})}{\partial v} = 0$$

$$P_{max} - 3mv^2 = 0 \quad \text{--- (i)}.$$

The optimum velocity of the belt for maximum power transmission is given by :-

$$v = \sqrt{\frac{P_{max}}{3m}} \quad \text{--- (ii)}$$

from eqn (e) & (i) :-

$$P_{max} - 3mv^2 = 0$$

$$P_{max} - 3P_c = 0$$

$$P_c = \frac{P_{max}}{}$$

from eqn f.

$$P_1 = P_{max} - P_c$$

$$P_1 = 3P_c - P_c$$

$$\boxed{P_1 = 2P_c}$$

# Velocity Ratio of a belt drive:-

It is the ratio between the velocities of the driver and the follower or driven

Let :- $d_1$ = diameter of the driver
$d_2$ = diameter of the driven or follower
$N_1$ = Speed of the driver in rpm
$N_2$ = Speed of the driven in rpm

∴ length of the belt that passes over the driver in one minute :- $\pi d_1 N_1$

Similarly, length of the belt that passes over follower, in one minute :- $\pi d_2 N_2$

Since the length of belt that passes over the driver in one minute is equal to the length of belt that passes over the follower in one minute, therefore :-

$$\because \pi d_1 N_1 = \pi d_2 N_2$$

$$\text{Velocity Ration (VR)} = \frac{N_2}{N_1} = \frac{d_1}{d_2}.$$

when thickness of the belt (t) is considered, then velocity ratio :-

$$\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}$$

# Slip of the belt :- In belt drive mechanism, we have assumed a firm frictional grip between the belts and the pulleys. But sometimes, the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt with it. This is called slip of the belt and is generally expressed as a percentage.

The result of the belt slipping is to reduce the velocity ratio of the system.

Let $S_1\%$ = slip b/w the driver and the belt.

$S_2\%$ = slip b/w the belt and the follower.

Velocity of the belt passing over the driver per second,

$$V = \frac{\pi d_1 N_1}{60} - \frac{\pi d_1 N_1}{60} \times \frac{S_1}{100} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{S_1}{100}\right) \quad \text{—(i)}$$

and velocity of the belt passing over the follower per second,

$$\frac{\pi d_2 N_2}{60} = V - V\left(\frac{S_2}{100}\right) = V\left(1 - \frac{S_2}{100}\right)$$

$$\frac{\pi d_2 N_2}{60} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{S_1}{100}\right)\left(1 - \frac{S_2}{100}\right)$$

$$\therefore \frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{S_1}{100} - \frac{S_2}{100}\right) \qquad \left(\text{Neglecting } \frac{S_1 \times S_2}{100 \times 100}\right)$$

$$= \frac{d_1}{d_2}\left[1 - \frac{(S_1 - S_2)}{100}\right] = \frac{d_1}{d_2}\left(1 - \frac{S}{100}\right) \qquad \{S = S_1 + S_2\}$$

$$\boxed{\frac{N_2}{N_1} = \frac{d_1}{d_2}\left[1 - \frac{S}{100}\right]}$$

If thickness of the belt (t) is considered, then :-

$$\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left[1 - \frac{S}{100}\right]$$

# Creep of the belt :- When the belt passes from the slack side to the tight side, a certain portion of the belt extends and it contracts again when the belt passes from the tight side to the slack side. Due to these changes of length, there is a relative motion between the belt and the pulley surfaces. This relative motion is termed as creep. The total effect of creep is to reduce slightly the speed of the driven pulley or follower.

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \times \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$$

## Selection of flat-Belts from Manufacturer's catalogue :-

In practice, the designer has to select a belt from manufacturer's catalogue. For the selection of a proper belt for a given application, the following information is required :-

1. power to be transmitted
2. the input and the output speeds.
3. the centre distance depending upon the availability of space
4. type of load.

→ The maximum power transmitted by the belt is obtained by multiplying the rated power by a load correction factor.

$$(KW)_{max} = F_a (KW) \longrightarrow \text{actual power transmitted by the belt in a given application.}$$

$(KW)_{max}$ → Power transmitted by the belt for design purpose

$F_a$ → load correction factor

→ The power transmitting capacities of the belt are developed for 180° of arc of contact. The actual arc of contact will be different in different applications. When the arc of contact is less than 180°, there will be an additional tension in the belt, to account for which a factor called "arc of contact factor" '$F_d$' is used in calculations. It is not advisable to use an arc of contact less than 150° for flat belt drive. Therefore, minimum arc of contact should be 150°.

→ There are two varieties of dunlop transmission belts :-

(i) HI-SPEED duck belting is used in general purpose applications.

(ii) FORT duck belting is recommended for heavy duty applications.

The range of optimum belt velocity for these two belts is 17.8 to 22.9 m/s.

The power transmitting capacities of the belts are as follows:-

HI SPEED → 0.0118 KW per mm width per ply

FORT → 0.0147 KW per mm width per ply.

There is a specific term 'power rating' or 'load rating' of flat belts. 'Power rating' of flat belt is defined as the power transmitting capacity of the belt per mm width per ply at 180° arc of contact.

The standard widths of these belts (in mm) are as follows:-

3-ply → 25, 40, 50, 63, 76,

4-ply → 40, 44, 50, 63, 76, 90, 100, 112, 125, 152,

5-ply → 76, 100, 112, 125, 152,

6-ply → 112, 125, 152, 180, 200.

The preferred diameters (in mm) of cast iron and mild steel pulleys are as follows:-

100, 112, 125, 140, 160, 180, 200, 224, 250, 280, 315, 355, 400, 450, 500, 560, 630, 710, 800, 900 and 1000.

The basic procedure for selection of flat belt consists of the following steps:-

(i) The optimum belt velocity of Dunlop belts is from 17.8 to 22.9 m/s. Assume some belt velocity such as 18 m/s in this range and calculate the diameter of the smaller pulley by following relationship:-

$$d = \frac{60(1000)v}{\pi n}$$ {where n is the input speed or rpm of smaller pulley}.

The diameter of the bigger pulley is obtained by the following relationship:-

$$D = d\left[\frac{\text{Speed of smaller pulley}}{\text{Speed of bigger pulley}}\right] = d\left[\frac{\text{Input speed}}{\text{output speed}}\right]$$

Modify the values of d and D to the nearest preferred diameters. Determine the correct belt velocity for these preferred pulley diameters and check whether the actual velocity is in the range of optimum belt velocity.

(ii) Determine the load correction factor $F_a$. Find out the maximum power for the purpose of belt selection by the relation:- $(KW)_{max} = F_a(KW)$

(iii) Calculate the ~~[illegible]~~ angle of wrap for the smaller pulley by the following relationship:- $\alpha_s = 180° - 2\sin^{-1}\left(\frac{D-d}{2C}\right)$

Find out the arc of contact factor $F_d$.

(iv) Calculate the corrected power by the following relationship :-

$$(KW)_{corrected} = (KW)_{max} \times F_d$$

(v) Calculate the corrected power rating for the belt by the following relationship :-

For HI-SPEED belt :-

$$\text{Corrected KW rating} = \frac{0.0118\,v}{(5.08)}$$

{ where v is the correct belt velocity in m/s. }

For FORT belt, :-

$$\text{Corrected KW rating} = \frac{.0147\,v}{(5.08)}.$$

(vi) Calculate the product of (width × number of plies) = $\dfrac{(KW)\ \text{corrected}}{\text{Corrected KW rating of belt}}$

Calculate the belt width by assuming suitable number of plies. In this step, there are number of alternative solutions. A belt whose width is near the value of standard width is optimum solution. For this belt, select the standard belt width.

(vii). Calculate the belt length by using the following relationship :-

$$L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C}.$$

# Pulleys for Flat Belts :- The pulleys for flat belts consists of three parts - rim, hub and arms or web. The rim carries the belt. The hub connects the pulley to the shaft. The arms or web join the hub with the rim. There are two types of pulleys that are used for flat belts viz - Cast iron pulleys and mild steel pulleys.

The minimum pulley diameter depends upon the following two factors :-

(i) the number of plies in the belt

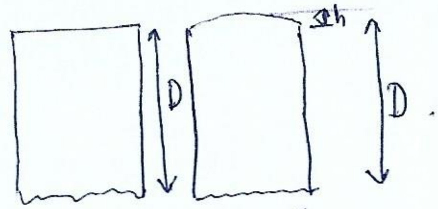
(ii) the belt speed.

Crowning of pulley :- There is a specific term, 'crowning' of pulley in flat belt drive. The thickness of the rim is slightly increased in the centre to give it a convex or conical shape. This is called 'crown' of the pulley. The crown is provided only on one of the two pulleys.

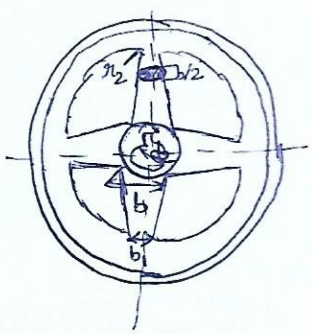
The objectives of providing crown are as follows :-

@ the crown on the pulley helps to hold the belt on the pulley in

(b) The crown on the pulley prevents the belt from running off the pulley.
(c) The crown on the pulley brings the belt to running equilibrium position near the midplane of the pulley.




Flat pulley        Pulley with Crown




Cast Iron pulley.

## Proportions of Cast Iron pulleys :-

(a) Number of arms :-

(i) For pulleys up to 200 mm diameter, use webs.
(ii) For pulleys above 200 mm diameter and upto 450 mm, use 4 arms
(iii) For pulleys above 450 mm diameter, use 6 arms.

(b) Cross-section of arms :- Elliptical

(c) Thickness of arm b near boss :-

$$b = 2.94\sqrt[3]{\frac{aD}{4n}} \text{ for Single belt.}$$

$$b = 2.94\sqrt[3]{\frac{aD}{2n}} \text{ for Double belt.}$$

{ a = width of pulley
D = diameter of pulley
n = number of arms in pulley }

(d) Thickness of arm $b_1$ near rim = use taper 4 mm per 100 mm (from boss to rim)

(e) Radius of the cross-section of arms = $r = \frac{3}{4}b$

(f) Minimum length $l$ of the bore = $l = \frac{2}{3}a$

(g) $\frac{d_1 - d_2}{2} = 0.412 \times \sqrt[3]{aD} + 6\text{mm}$ for single belt.

$d_1 - d_2 = 0.529 \times \sqrt[3]{aD} + 6\text{mm}$ for double belt.

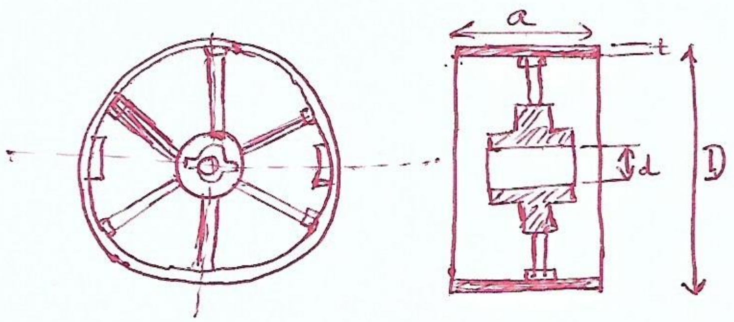
(h) Radius $r_1$ and $r_2$ :-

(i) Thickness of rim :-

Rim thickness $= \left(\frac{D}{200} + 3\right)$ mm for single belt.

Rim thickness $= \left(\frac{D}{200} + 6\right)$ mm for double belt.

# Proportions of mild steel pulley :-




(a) Arrangement of arms :- Pulleys up to 300 mm width are normally supplied with a single row of spokes. Wider pulleys requiring double row of spokes sometimes used.

(b) Minimum length of bars :- The length of bars is equal to half width of face, subject to a minimum of 100 mm in case of pulleys with 19 mm diameter spokes and minimum of 132 mm for pulleys with 22 mm diameter spokes. The length of bars is practically greater than the width of the pulleys.

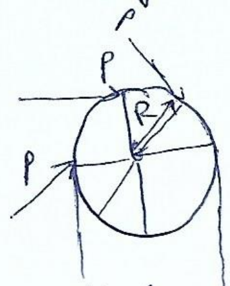
(c) Thickness of rims :- 5 mm (for all pulleys).

# Arms of Cast Iron pulley :- There are three important things about the arms of the pulley. They are as follows :-

(i) Arms of pulley have elliptical cross-section.
(ii) major axis of elliptical cross-section is in the plane of rotation.
(iii) Major axis of elliptical cross-section is usually twice the minor axis.

> Elliptical cross section reduces aerodynamic losses during the rotation of pulley as

→ The design of these arms illustrates the application of simple formula for bending stresses. It is assumed that the belt wraps around the rim of the pulley through approximately 180° and one-half of the arms carry the load at any moment.

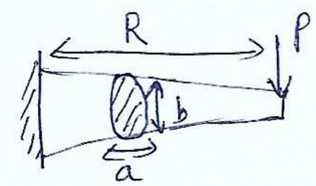



The torque transmitted by the pulley is given by:-

$$M_t = PR\left(\frac{N}{2}\right)$$

$\left\{\begin{array}{l} P = \text{tangential force at the end of each arm (N)} \\ R = \text{radius of rim (mm)} \\ N = \text{number of arms.} \end{array}\right.$

$$P = \frac{2M_t}{RN} \quad \text{— (a)}$$




$$M_b = PR \quad \text{— (b)}$$

from (a) & (b) :- $M_b = \dfrac{2M_t}{N}$ — (c)

Since Major axis is in plane of rotation :-

$$I = \frac{\pi a b^3}{64} \quad \{b = 2a\}$$

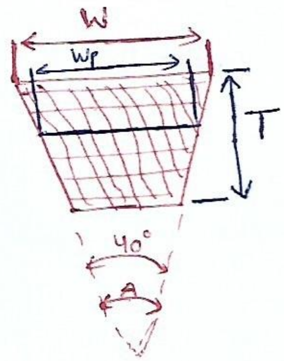
$$I = \frac{\pi a^4}{8} \quad \& \quad y = \frac{b}{2} = a.$$

The bending stress in the arm is given by :-

$$\boxed{\sigma_b = \frac{M_b y}{I}} \rightarrow \left\{ \begin{array}{l} \text{In this eqn, substitute :-} \\ y = \frac{b}{2} = a \; ; \; I = \frac{\pi a^4}{8} \end{array} \right\}$$

↳ from this (a) can be found out, and $b = 2a$.

# Selection of V-belts :-




(i) Pitch width ($W_p$) :- It is the width of the belt at its pitch zone. This is the basic dimension for standardization of belt and corresponding pulley groove.

(ii) Nominal top width (W) :- It is the top width of the trapezoidal outlined on the cross-section of the belt.

(iii) Nominal height (T) :- It is the height of the trapezium outlined on the cross-section of the belt.

(iv) Angle of belt (A) :- It is the included angle obtained by extending the sides of the belt. The standard value of the belt angle is 40°.

(v) Pitch length ($L_p$) :- It is the length of the pitch line of the belt. This is the circumferential length of the belt at the pitch width.

→ There are six basic symbols — Z, A, B, C, D & E — for the cross-section of V-belts.

→ The selection of the cross-section depends upon two factors, namely the power to be transmitted and speed of the faster shaft.

→ The calculation of V-belts are based on preferred pitch diameters of pulley and pitch lengths.

→ The number of belts required for a given application is calculated by the following relationship :-

Number of belts :- $$\frac{(\text{transmitted power in KW}) \times (F_a)}{(\text{KW rating of single V-belt}) \times (F_c) \times (F_d)}$$

$F_d$ = correction factor for arc of contact
P = drive power to be transmitted (KW)

$P \times F$

# Basic procedure for selection of V-belts :- The designer has to select a V-belt from the catalogue of the manufacturer. Following information is required for the selection :-

(i) Type of driving unit (ii) Type of driven machine (iii) operational hours per day
(iv) Power to be transmitted (v) Input & output speeds (vi) Approximate centre distance depending upon the availability of space.

The basic procedure for the selection of V-belts consists of following steps :-

(i) Determine the correction factor according to service ($F_a$). It depends upon the type of driving unit, the type of driven machine and the operational hours per day.

(ii) Calculate the design power by following relationship,

$$\text{Design power} = F_a (\text{transmitted power})$$

(iii) Plot a point with design power as X-coordinate and input speed as Y co-ordinate in the figure given in data book. The location of this point decides the type of cross-section of the belt.

(iv) Determine the recommended pitch diameter of smaller pulley from data book. It depends upon the cross-section of the belt. Calculate the pitch diameter of bigger pulley by following relationship :-

$$D = d\left[\frac{\text{speed of smaller pulley}}{\text{speed of bigger pulley}}\right]$$

The above values of D & d are compared with the preferred pitch diameters given in data book. In case of nonstandard values, nearest values of d & D should be taken from databook.

(v) Determine the pitch length of belt (L) by following relationship :-

$$L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C}$$

(vi) Compare the above value of (L) with preferred pitch length L from data book. In case of non standard value, nearest value of pitch length from data book should be taken.

(vii) Find out the correct centre distance C by substituting the above value of L in the following equation :-

$$L = 2C + \pi(D+d) + (D-d)^2$$

(viii) Determine the correction factor ($F_c$) for belt pitch length from data book. It depends upon the type of cross-section and the pitch length of belt.

(ix) Calculate the arc of contact for smaller pulley by following relationship :-

$$\alpha_s = 180 - 2\sin^{-1}\left(\frac{D-d}{2C}\right)$$

Determine the correction factor($F_d$) for arc of contact from databook.

(x) Depending upon the type of belt cross-section, determine power rating ($P_r$) of single V-belt. It depends upon three factors - speed of faster shaft, pitch diameter of smaller pulley and speed ratio.

(xi) Number of belts $= \dfrac{P \times F_a}{P_r \times F_c \times F_d}$