UNIT- IIIrd

* friction
  - ⇒ Types of friction
  - ⇒ law of friction
  - ⇒ Angle of friction
  - ⇒ Angle of repose, ladder, wedge, belt friction

Belt Derive

⇒1) Types of belt

⇒1) velocity Ratio

⇒1) effect of slip on V.R., length of belt

⇒1) Ratio of tension and power transmission by ~~threat~~ flat belt

friction

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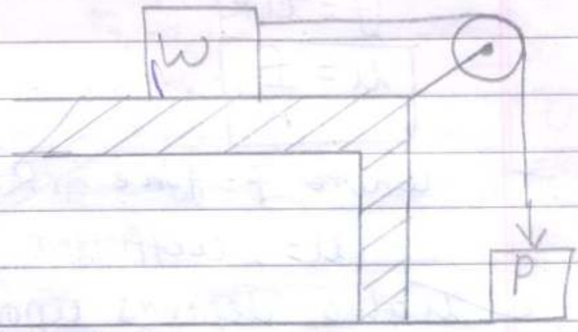
friction :-

When a body slides on another body it experiences a force which tends to resist motion. This force is called force of friction.

we perform an experiment ~~or ex~~ by placing a block of wood of known weight on a table by attach a string passes overcome by effort P.



when a weight of W (wood) cann't move a limiting effort and after this limit the ~~weig~~ effort increasing then body move, this limiting value of effort is called limiting force and this friction to resist of body W is called limiting friction.

on dividing the total weight of P by total weight of body (W). In each case we find the number which is nearly constant. following results give as law of friction

=> (I) The direction of friction is opposite to the direction in which the body to move.

(II) The magnitude of friction is upto a certain limit excatly equal to force tends to produce motion

(III) only a certain amount of friction come into play. The max^m amount is called limiting friction.

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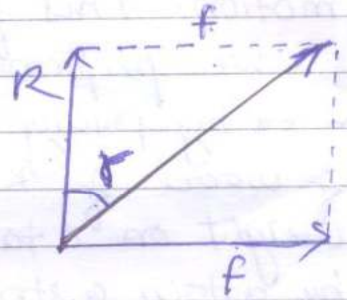
(IV) The magnitude of limiting friction bears a constant ratio μ.

This ratio of μ depend upon the nature of surface.



$f \propto R$

$\boxed{f = \mu R}$

$\boxed{\mu = \frac{f}{R}}$

where f = force, R = Normal Reaction

μ = coefficient of friction.

μ also depends upon the nature of surface.

Angle of friction :-

If the Normal Reaction R and the force of friction f compounded into a single force. This force is called Resultant or Total Reaction.

$\because \quad \tan \gamma = \frac{F}{R}$

$\boxed{\tan \gamma = \mu}$

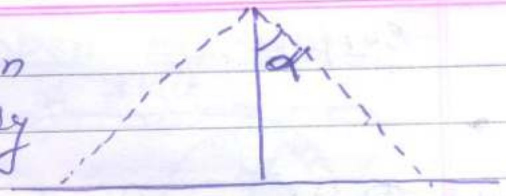
where γ = angle of friction.

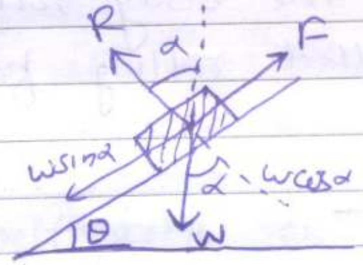
Angle of Repose:-

when grains (sand, food grains etc) are heaped there exists a limit of inclination of the surface.

Beyond the this limit grains start rolling down. The limiting angle up to which the grain repose. that is called, angle of Repose. It is denoted by "α".

When a body known weight W is stationary at a inclined plane with the angle for horizontal as shown in figure.





α = angle of Repose

from the figure

$F = w \sin\alpha$ —(1)

$R = w \cos\alpha$ —(2)

(1)/(2) $\tan\alpha = \frac{F}{R}$ —(3)

∴ Angle of friction $\tan\phi = \frac{F}{R}$ —(4)

From (3) & (4)

$\tan\alpha = \tan\phi$

$\boxed{\alpha = \phi}$

So that angle of limiting friction is the same as angle of repose.

Types of friction :-

(i) sliding friction

(ii) Rolling friction

(i) Sliding freition:-

This friction is generated when the body slides to other body or

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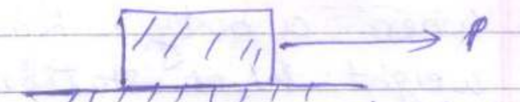
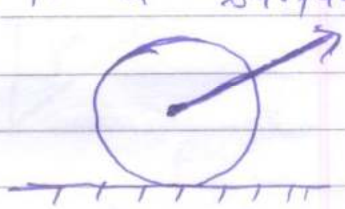
surface.



Sliding friction

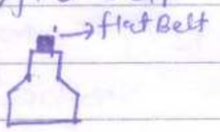
(ii) Rolling friction
This friction is generated when the body rolling to a surface is called rolling friction.



Rolling friction

* **Belt :-**
Power is transmitted from one pulley to other pulley by a flexible shift is known as Belt.

Types of Belt :-
① flat Belt ② V - Belt ③ Circular Belt



Belt Drive :-
The Belt drive are generally used when the distance b/w 2 shaft centers is considerably less then 10 m.

A belt is a continuous band of flexible material passing over pulley's to transmitt motion from one shaft to another shaft. The grip b/w belt and pulley is obtained by friction. There are two types of drive
(A) Open belt drive
(B) cross " "

(A) Open Drive Belt / Open Belt Drive:-

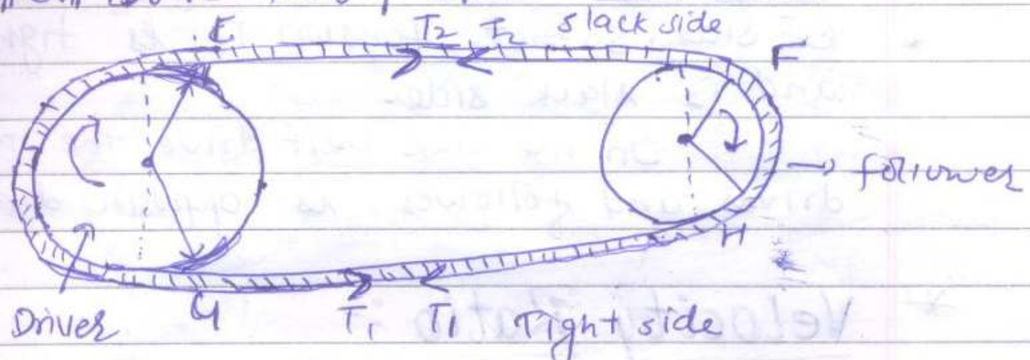


fig:- Open Belt Drive

Driver pull the belt at HG side and deliver EF side. The Tension in HG side is grater than the EF side. so that HG side is called Tight side and EF side is called slack side. ~~so th~~ so that

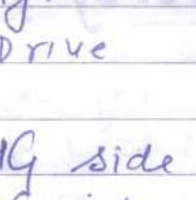
mathematically

$$\boxed{T_1 > T_2}$$

$$T_{eff} = T_1 - T_2$$

or $\boxed{\text{effective tension} = T_1 - T_2}$

(flat belt)



(B) Cross Belt Drive:-

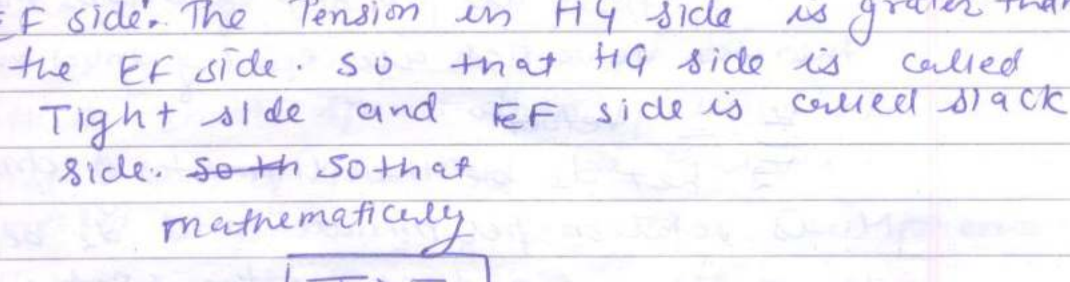


fig- cross Belt drive

Driver pull the lower belt side HG and deliver the upper belt side EF.

The Pension in GH side is grater then to that EF side. so that tension T_1 is tight side and T_2 slack side.

In the cross belt drive the motion of drives and followes is opposite direction.

* Velocity Ratio :-

The velocity Ratio of a belt drive may be defined as the ratio of velocity of drives and followes.

If there are no slip of drives and followes the the velozities are equal of drives and followes

$\frac{V_1}{V_2}$ = ~~Velocity~~

Let d_1 be the diameter of drives and N_1 is rotation per minute and d_2 be the dia of follower and N_2 be the rotation per minute.

The velocity of drives $\boxed{V_1 = \pi d_1 N_1}$ —(1)

and " " followes $\boxed{V_2 = \pi d_2 N_2}$ —(2)

$\because \frac{V_1}{V_2} = \frac{\text{velocity of driver pulley}}{\text{velocity of follower pulley}}$ —(3)

at No slip ~~both~~ = ~~as~~ $V_1 = V_2$ then

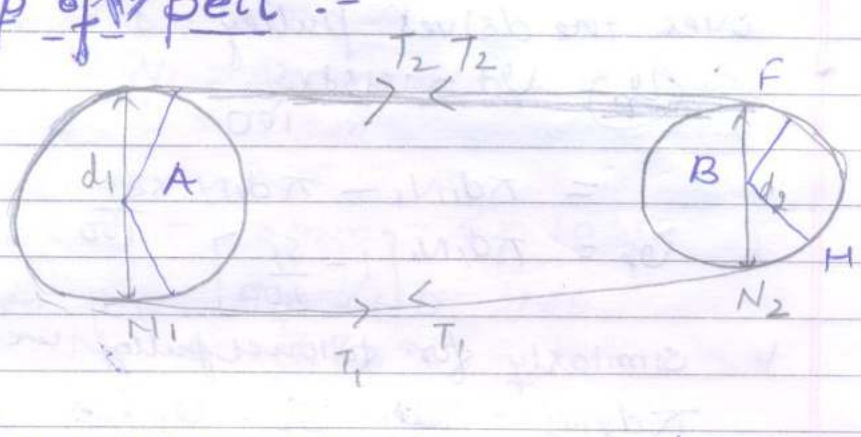
from (1), (2) & (3) we have

$$1 = \frac{\pi d_1 N_1}{\pi d_2 N_2}$$

$$d_1 N_1 = d_2 N_2$$

$$\boxed{\frac{d_1}{d_2} = \frac{N_2}{N_1}}$$

Slip of the Belt :-



If the friction grip b/w the driving shaft and belt. Then the velocity of belt will be equal to the velocity of pulley. But If the friction grip is not sufficient then belt rotate with a small speed then pulley (v). This is called a slip of the Belt and this is generaly expressed as precentage of velocity v. This phenomena will occur with the follower also.

This also causes forward motion of the Belt without carrying the follower pulley with ~~slip~~ it. The region of belt slipping is to reduce the velocity of the system.

Let S_1% is the slip b/w driver and belt and S_2% is the slip b/w follower and Belt.

The velocity of ~~pulley A on~~ Belt passing over driver pulley

Let d_1 be the diameter of driver pulley and N_1 be the rotation then the velocity of driver pulley is $\boxed{V_d = \pi d_1 N_1}$

similarly

follower velocity $\boxed{V_f = \pi d_2 N_2}$

The velocity of the belt after passing

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over the driver pulley is

v_p $v_d - \frac{v_d \times S_1}{100}$

$= \pi d_1 N_1 - \pi d_1 N_1 \times \frac{S_1}{100}$

$v_p = \pi d_1 N_1 \left[1 - \frac{S_1}{100}\right]$

similarly for follower pulley we can write as

$\pi d_2 N_2 = v_p - v_p \times \frac{S_2}{100}$

$= v_p \left[1 - \frac{S_2}{100}\right]$

$\pi d_2 N_2 = \pi d_1 N_1 \left[1 - \frac{S_1}{100}\right]\left[1 - \frac{S_2}{100}\right]$

$$\boxed{\frac{N_2}{N_1} = \frac{d_1}{d_2}\left[1 - \frac{S_1}{100}\right]\left[1 - \frac{S_2}{100}\right]}$$

$$\boxed{S = S_1 + S_2}$$

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

If t_1 be the thickness of given belt then

$$\boxed{\frac{N_2}{N_1} = \frac{d_1 + t_1}{d_2 + t_1}\left[1 - \frac{S}{100}\right]}$$

Q An engine shaft running at 240 rpm is required to drive a m/c by means of a belt. The pulley on the engine shaft is 1.5 m diameter and that of the m/c shaft 0.75 m. If the belt thickness is 5 mm, find the speed of belt when

(I) There is no slip

(II) There is total slip 2%.

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Sol^n As per given data

$N_1 = 240$ rpm

$d_1 = 1.5$ m

$d_2 = 0.75$ m

$t = 5$ mm $= 5 \times 10^{-3}$ m

(1) when the slip is 0 then

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

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

$$= \left\{\frac{1.5+0.005}{0.75+0.005}\right\} \times 240$$

$$= \frac{1.505}{.755} \times 240$$

$$N_2 = 478 \text{ rpm}$$

(1) when the $S = 2\%$

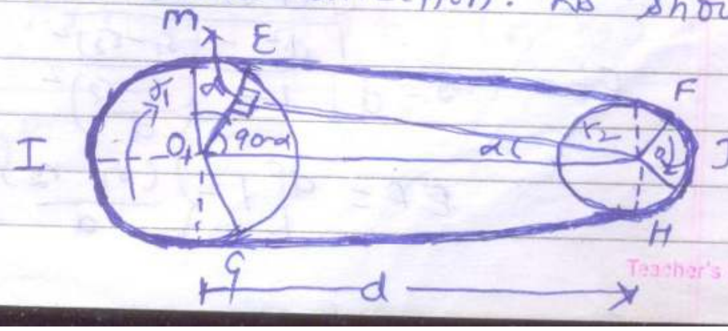
$$N_2 = 478\left[1 - \frac{2}{100}\right]$$

$$= 478 \times \frac{98}{100}$$

$$= 468.84 \text{ rpm}$$

Length of Open Belt Drive:

The arrangement of open belt ~~drive~~ connecting the two pulleys. Those pulleys rotate in the same direction. As shown in figure



$EF = mO_2$

$$\sin\alpha = \frac{mO_1}{O_1O_2}$$

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Consider a open Belt two pulley system as shown in figure. consider the O_1 and O_2 are centre of driver and follower pulleyes respectively and radius r_1 and r_2 respectively. $(r_1 > r_2)$

The Belt leaves by driver point E and G and follower leaves F and H.

we draw a parallel line O_2m to the EF. we find that this line is prependicular to the O_1E as shown in figure.

The distance b/w O_1 and O_2 is d. Then

Length of open belt $= 2[\text{Arc}(IE) + EF + \text{arc}(FJ)]$ — (4)

$$\sin\alpha = \frac{O_1m}{O_1O_2}$$

$$= \frac{O_1E - mE}{O_1O_2} = \frac{r_1 - r_2}{d}$$

$$\boxed{\sin\alpha = \frac{r_1 - r_2}{d}}$$

If α is very small than $\sin\alpha \approx \alpha$

then $\boxed{\alpha = \frac{r_1 - r_2}{d}}$ — (1)

$\text{Arc } IE = r_1(\pi/2 + \alpha)$ — (2)

$\text{Arc } FJ = r_2(\pi/2 - \alpha)$ — (3)

$$EF = mO_2 = \sqrt{(O_1O_2)^2 - (mO_1)^2}$$

$$= \sqrt{d^2 - (r_1 - r_2)^2}$$

$$EF = mO_2 = d\sqrt{1 - \left(\frac{r_1 - r_2}{d}\right)^2}$$

$$EF = d\left[1 - \left\{\frac{(r_1 - r_2)}{d}\right\}^2\right]^{1/2}$$

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Expending the above expression by Binomial theorem

$$(1+x)^n = 1 + nx + \frac{n(n+1)}{\lfloor 2}x^2 + \frac{n(n+1)(n+2)}{\lfloor 3}x^3 + \ldots$$

$$(1-x)^n = 1 - nx + \frac{n(n-1)}{\lfloor 2}x^2 - \ldots$$

$$EF = d\left[1 - \frac{1}{2}\frac{(r_1-r_2)^2}{d^2} + \ldots\right]$$

$$EF = d\left[1 - \frac{1}{2}\frac{(r_1-r_2)^2}{d^2}\right]$$

$$\boxed{EF = d - \frac{(r_1-r_2)^2}{2d}}$$

putting the value from 2, 3, 4 in a

we have

Length of open belt drive

$$L_{open} = 2\left[r_1\left(\frac{\pi}{2}+\alpha\right) + d - \frac{(r_1-r_2)^2}{2d} + r_2\left(\frac{\pi}{2}-\alpha\right)\right]$$

$$= 2\left[\frac{\pi}{2}(r_1+r_2) + \alpha(r_1-r_2) + d - \frac{(r_1-r_2)^2}{2d}\right]$$

$$L_{open} = \left[\pi(r_1+r_2) + 2\alpha(r_1-r_2) + 2d - \frac{(r_1-r_2)^2}{d}\right]$$

$$\because \alpha = \frac{r_1 - r_2}{d}$$

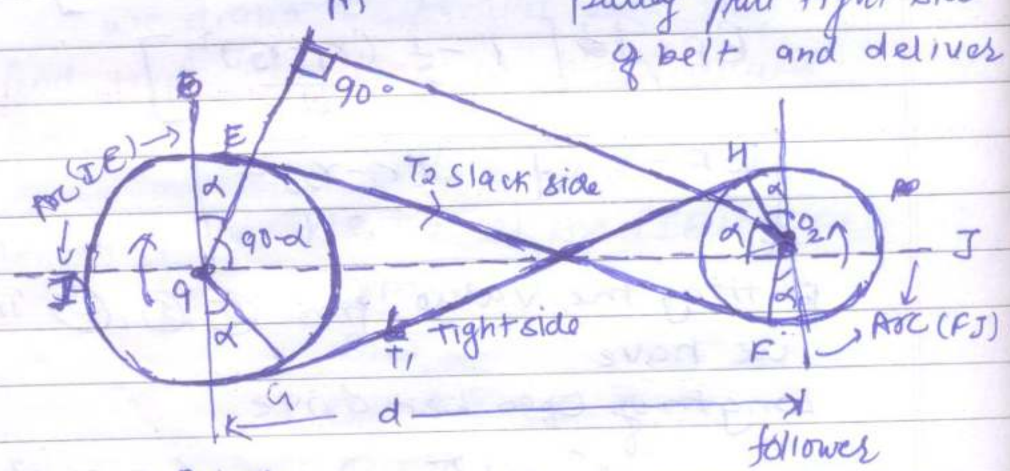
$$L_{open} = \left[\pi(r_1+r_2) + \frac{2(r_1-r_2)^2}{d} + 2d - \frac{(r_1-r_2)^2}{d}\right]$$

$$\boxed{L_{open} = \pi(r_1+r_2) + 2d + \frac{1}{d}(r_1-r_2)^2}$$

This eqⁿ

Length of Cross Belt Drive :-

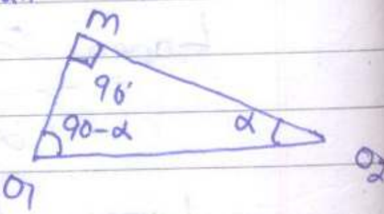
The arrangement of cross belt drive as shown in figure. In this case both pulleys are rotating in opposite side. Here R_1 and R_2 are radius of larger pulley and ~~larger~~ smaller pulley respectively and d distance b/w centre to centre. Consider $R_1 > R_2$ than driver pulley pull tight side of belt and delives



to slack side of belt. Draw a MO_2 line parallel to EF. We find the line MO_2 is ⊥ to line O_1E driver belt leaves point E and G and follower F & H

The triangle O_1O_2M we can write

$$\sin\alpha = \frac{O_1M}{O_2O_1}$$



$$\boxed{\sin\alpha = \frac{r_1+r_2}{d}} \quad \text{— (1)}$$

$O_1M = O_1E + EM$

$L_{cross} = 2[\text{Arc}(IE) + EF + \text{Arc}(FJ)]$

$\text{Arc}(IE) = r_1[\pi/2 + \alpha]$ — (2)

$\text{Arc}(JF) = r_2[\pi/2 + \alpha]$ — (3)

$EF = MO_2 = \sqrt{(O_1O_2)^2 - (MO_1)^2}$

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$$EF = \sqrt{d^2 - (r_1+r_2)^2}$$

$$= d\left[1 - \left\{\frac{r_1+r_2}{d}\right\}^2\right]^{1/2}$$

Expending the above expression by Binomial theorem

$$(1-x)^n = 1 - nx + \frac{n(n-1)}{\lfloor 2}x^2 - \cdots\cdots$$

$$EF = d\left[1 - \frac{1}{2}\frac{(r_1+r_2)^2}{d^2}\right]$$

$$\boxed{EF = d - \frac{(r_1+r_2)^2}{2d}} \quad \text{—(4)}$$

Now (2), (3), (4) putt in (1) we have

$$L_{cross} = 2\left\{r_1\left(\frac{\pi}{2}+\alpha\right) + d - \frac{(r_1+r_2)^2}{2d} + r_2\left(\frac{\pi}{2}+\alpha\right)\right]$$

$$= 2\left[\frac{\pi}{2}(r_1+r_2) + \alpha(r_1+r_2) + d - \frac{(r_1+r_2)^2}{2d}\right]$$

$$= \left[\pi(r_1+r_2) + 2\alpha(r_1+r_2) + 2d - \frac{(r_1+r_2)^2}{d}\right]$$

putt the value of α

$$L_{cross} = \pi(r_1+r_2) + 2\frac{(r_1+r_2)^2}{d} + 2d - \frac{(r_1+r_2)^2}{d}$$

$$\boxed{L_{cross} = \pi(r_1+r_2) + 2d + \frac{(r_1+r_2)^2}{d}}$$

Q Two pulley cross belt arrangement

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Joule - N×m
J/s = watt

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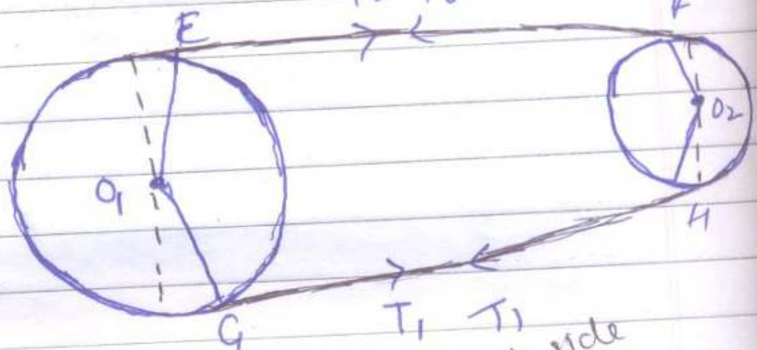
* Power Transmitted By open Belt Drive :-

An open belt drive system as shown in figure. Drives pass the Belt one side to another side.



Delivers same. The tension T_1 (Tight side) is grater than T_2 (slack side) then both pulleys rotate in same direction

Let v m/s is the velocity of Belt.

The circumference of pulley system than effective tension = $T_1 - T_2$

Than work done per sec = $(T_1 - T_2) \times v$

So As we know that work done is change into power so

$\boxed{\text{power} = (T_1 - T_2) \times v}$ watt

Q Two pulley set by belt apart 6m. 800mm and 350mm diameters of larger pulley and a Smaller publey respectively. If that time pulley is rotate by cross belt system. The changing of open belt drive in this system. How much length is reduce.

Ans?

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As per given data

$d = 6m$

$d_1 = 800\ mm = 800 \times 10^{-3} m = .8m$

$d_2 = 350\ mm = .35\ m$

$r_1 = \frac{d_1}{2} = .4m, \quad r_2 = \frac{.35}{2} m = .175m$

Length of cross belt drive

$= \pi (r_1 + r_2) + 2d + \frac{(r_1 + r_2)^2}{d}$

$L_{cross} = 3.14(.4 + .175) + 2 \times 6 + \frac{(.4 + .175)^2}{6}$

$= 1.8055 + 12 + 0.0551$

$L_{cross} = 13.86\ m = 1386\ cm$

$L_{open} = \pi(r_1 + r_2) + 2d + \frac{(r_1 - r_2)^2}{d}$

$= 1.8055 + 12 + 0.008439$

$= 13.81\ m = 1381\ cm$

Reduced length $= L_{cross} - L_{open}$

$= 1386 - 1381$

$= 5\ cm$

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left[\frac{E+\sqrt{f_2}}{E+f_1}\right]$$

$E \Rightarrow$ Young's modulus