CH-6

* Belts : الاحزمه

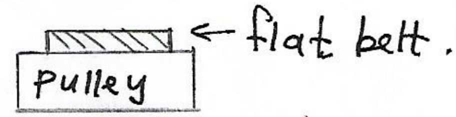
* Functioin الوظيفه

Belts are used to transmit power from one shaft to another by pulleys, which rotates at the same or different speeds.

* Types of belts : انواع الاحزمه

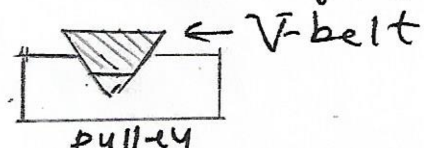
I) Flat belt : الحزام المسطح

It is used to transmit power from one pulley to another, when the distance between them not more than (8) meters → fig (a)



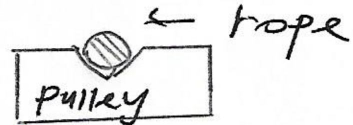
II) V-belt حزام شكل V Fig(a)

It is used to transmit power, when the distance between two pulleys is very small → fig (b)



III) Cicular belt (rope) الحبال fig(b)

It is used to transmit high power between two pulley, when the distance between them more than (8) meters → fig (b)



* Types of belt drive according fig (b) to the speed انواع النقل بالاحزمه

I) Light drive : نظام خفيف

It is use to transmit small power, with speed about 10 m/s

II) Medium drive: نظام متوسط

It is used to transmit medium power, with speed over 10 m/s.

III) Heavy drive: نظام نقل ثقيل

It is used to transmit large power, with speed about (22 m/s)

* Selection of a belt Drive: شروط اختيار الاحزمه

1) Speed of driver and driven shafts. السرعه
2) Power to be transmitted. القدره
3) Positive drive requirment. متطلبات النقل
4) space available الفراغ المسموح
5) Speed reduction ratio نسبه السرعه
6) Center distance between shafts المسافه المركزيه
7) shaft layout. وضع الاعمده
8) Service Condition شروط الصيانه

*The Conditions of the transmitted power depend on the Followings: شروط نقل الطاقه

1- velocity of belt.
2- tension in belt.
3- The arc of contact.
4- Condition of work of belt (like, T, oil, ...)

* materials of belts مواد الاحزمه

1) leather belts. من الجلد
2- Cotton or fabric belts. القطن
3) Rubber belts. المطاط
4- Balata belts البلاستيك

* Types of belt drive according to the direction of rotation:

I) open belt drive → in Same direction
II) Cross belt drive → in opposite diretion.

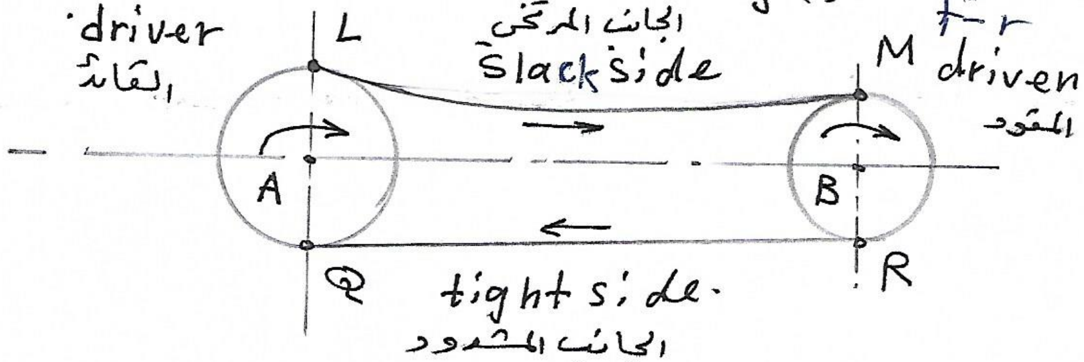
* Types of Flat belt drive: انواع الاداره بالاحزمه المسطحه

I) open belt drive : الاداره بالحزام المفتوح

يستعمل للاداره باتجاه واحد للدوران

It is used to transmit power between two parallel shafts rotating in the same direction. in this Case because ~~because~~ the tension of the driver, the belt have upper slack side and lower tension side, fig (1).

fig (1)



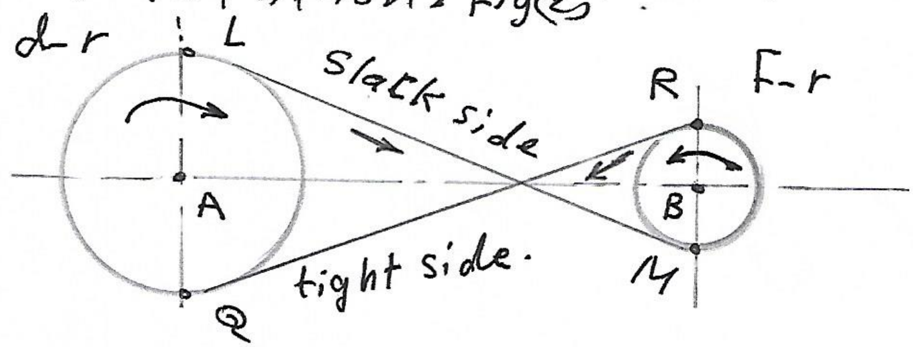
II) Crossed belt drive

نظام النقل المتقاطع

يستخدم للاداره باتجاه متعاكس للدوران

It is used to transmit power between two parallel shafts rotating in opposite direction of rotation, fig(2).

fig (2)



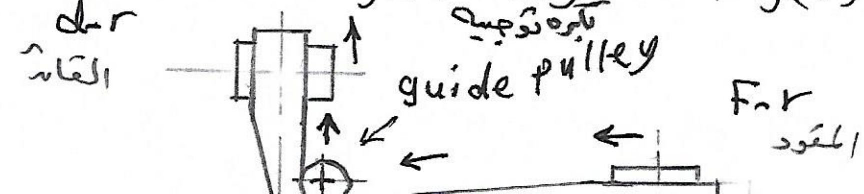
III) Quarter turn belt drive

نظام الاداره بربع دوره

يستخدم للاعمده المرتبه بزاويه ٩٠°

It is used to transmit power between two shafts arranged at right angle, fig(3)

fig (3)



IV - Belt drive with idler pulleys نظام النقل مع البكرات الوسيطة (الحرة)

This's type with idler pulleys is used to transmit power between parallel shafts, when open drive cannot be used due to small angle of contact on the smaller pulley → fig (4).

يستخدم هذا النظام لنقل القدره بين الاعمده المتوازيه عندما تكون زاويه التماس مع البكره الصغيره قليله جداً لا تسمح باستعمال النظام المفتوح.

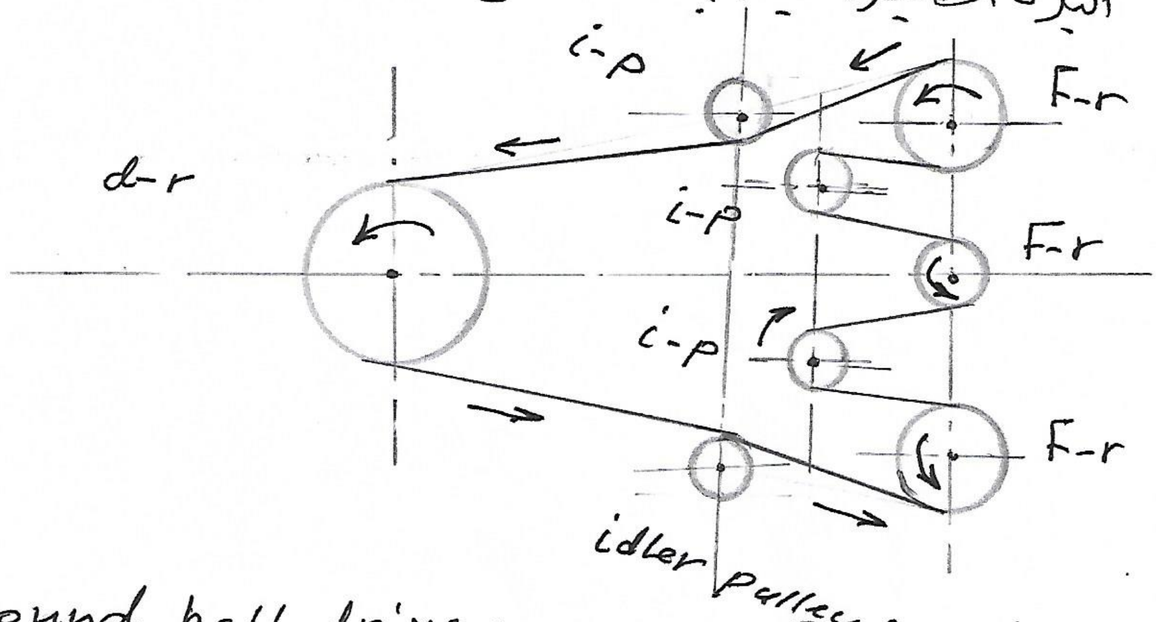


Fig (4) :

V - Compound belt drive : نظام النقل المركب

It is used to transmit power from one shaft to another through number of pulleys, when the distance between them is so long, fig (5).

يستخدم لنقل القدره لمسافات طويله.

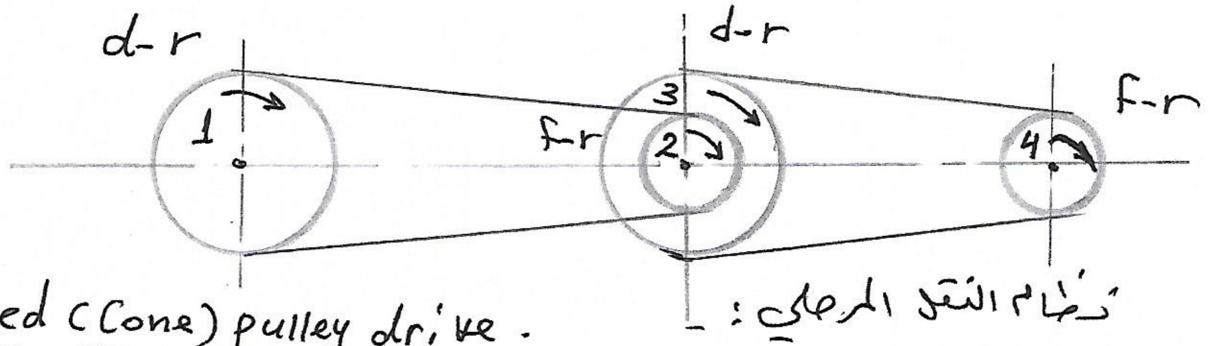


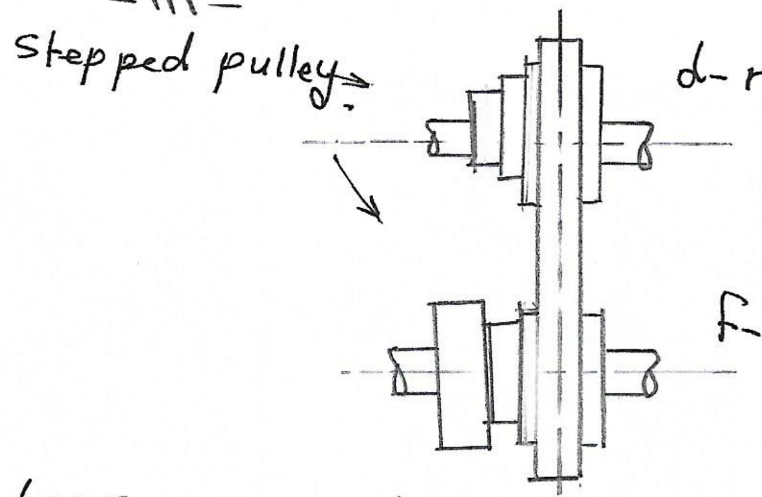
fig (5)

VI, Stepped (Cone) pulley drive. نظام النقل المرحلي :

It is used for changing the speed of follower when the speed of of driver is constant. fig (6).

يستخدم لتغير سرعه التابع عندما تكون سرعه القائد ثابته.

Fig (6)

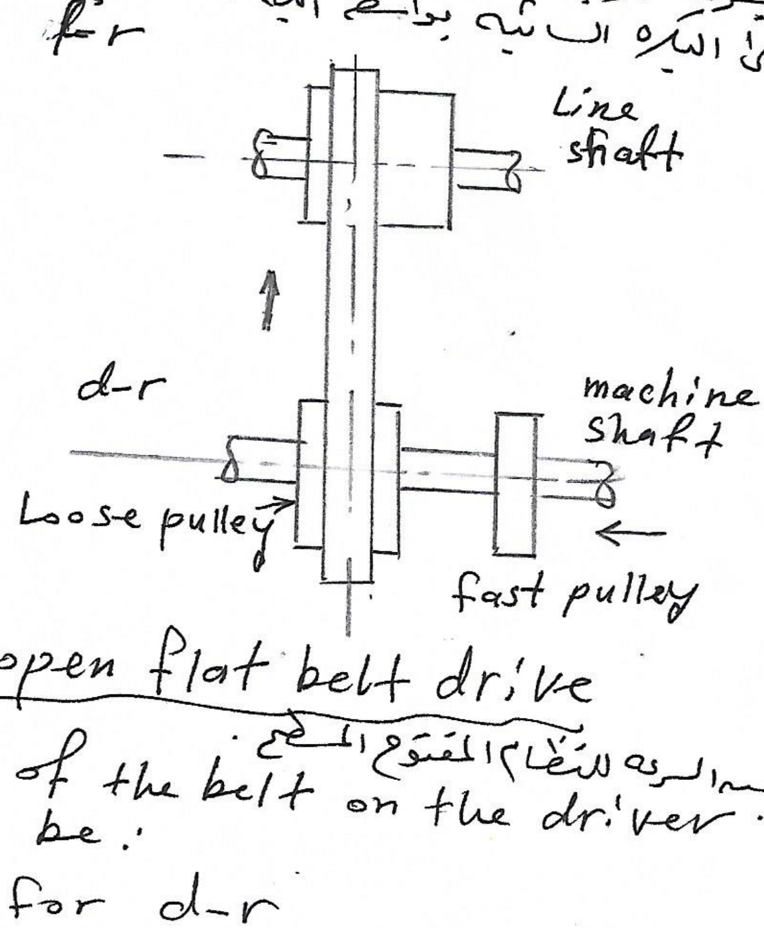


VII) Fast and loose pulley drive. نظام النقل والبكرة الثابتة والحرة.

It is used to transmit power from driver to follower with speed or without speed by pushing the belt on the Loose pulley by mean - fig(7)

تستخدم لنقل القدرة من القائد الى المقود بسرعة او بدون سرعة عن طريق نقل الحزام الى البكرة السائبة بواسطة آلية.

Fig (7)



* <u>Velocity ratio for open flat belt drive</u>

Peripheral velocity of the belt on the driver and driven pulley be: سرعة السير للنظام المفتوح المسطح

$V_1 = \frac{\pi d_1 n_1}{60}$ → for d-r

$V_2 = \frac{\pi d_2 n_2}{60}$ → for f-r

But $V_1 = V_2 \Rightarrow \cancel{\pi} d_1 n_1 = \cancel{\pi} d_2 n_2$

∴ Velocity ratio with no slip:

$$\boxed{R_V = \frac{N_2}{N_1} = \frac{d_1}{d_2}} \quad \text{--- (1)} \quad \text{or} = \frac{d_1 + t}{d_2 + t}$$ with thickness of belt.

شهد السرعة للنظام المركب

* Velocity ratio for Compound belt drive:

$V_1 = \pi d_1 n_1$, $V_2 = \pi d_2 n_2$, $V_3 = \pi d_3 N_3$, $N_4 = \pi d_4 N_4$

But $V_1 = V_2 \neq V_3 = V_4 \rightarrow \frac{\cancel{N_2}}{N_1} \times \frac{N_4}{\cancel{N_3}} = \frac{d_1}{d_2} \times \frac{d_3}{d_4}$

$$\boxed{R_V = \frac{N_4}{N_1} = \frac{d_1}{d_2} \times \frac{d_3}{d_4}}$$

* Slip of belt:

When the frictional grip between belt and pulley insufficient, we get slip of belt, and this reduce the velocity ratio and power, and induse heat between belt and pulley.

let $S_1\%$, $S_2\%$ a slipe between d-r and f-r

∴ Velocity of passing belt over d-r per second

$$V_1 = \frac{\pi d_1 N_1}{60} - \frac{\pi d_1 N_1}{60} * \frac{S_1}{100} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{S_1}{100}\right) \quad \text{--- (1)}$$

and for f-r

$$V_2 = \frac{\pi d_2 N_2}{60} = V_2 - V_2 * \frac{S_2}{100} = V_2\left(1 - \frac{S_2}{100}\right) \quad \text{--- (2)}$$

By sub V_1 from (1) in (2) we get - Because $V_1 = V_2$

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

$$\therefore \frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{S_2}{100} - \frac{S_1}{100} + \cancel{\frac{S_1}{100} * \frac{S_2}{100}}\right)$$ → Very Small

By neglecting $\frac{S_1}{100} * \frac{S_2}{100}$ → Very small

$$\therefore \frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1-\frac{S_1}{100}-\frac{S_2}{100}\right) = \frac{d_1}{d_2}\left(1-\frac{S_1+S_2}{100}\right) \to S$$

But $S = S_1 + S_2 \rightarrow$ total slip.

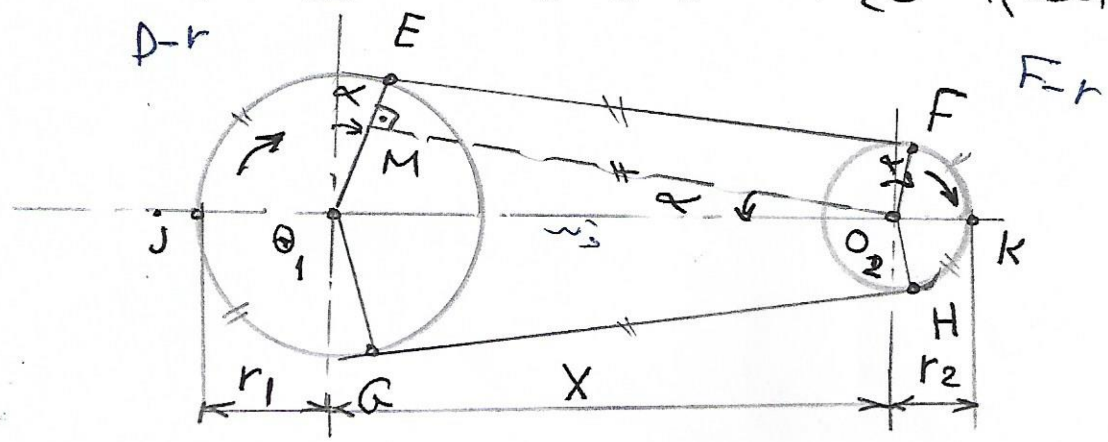
$$\therefore \boxed{\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1-\frac{S}{100}\right)} \quad \text{------ (3)}$$

by taking thicknes of belt

$$\therefore \frac{N_2}{N_1} = \frac{d_1+t}{d_2+t}\left(1-\frac{S}{100}\right)$$

* length of an open belt drive — حساب طول الحزام في النظام المفتوح

$EF = GH$
$JG = JE$
$Fk = kH$



From fig we know that the two pulleys rotate in Same direction.

let
- r_1, r_2 radius of Large and small pulley
- X - Center distance
- L - Length of belt = ?

In order to Calculet the length of belt, at first we draw line parallel to Ef from O_2.

نقاط افتراق الحزام عن البكرتين

where EG, FH, points at which the belt leave the large and small pully

$\therefore O_2M \perp O_1E \rightarrow$ because the tangent $\perp$ radius So that the parallel line.

المماس عمودي على نصف القطر وكذلك الخط الموازي له

and let $\alpha = \angle MO_2O_1$ in radians.

and triangle $\Delta\, O_1 M O_2$ a right triangle.
The length of belt be:

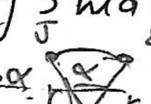
$$L = \text{Arc } GJE + EF + \text{Arc } FKH + HG$$
$$= 2\,(\text{Arc } JE + EF + \text{Arc } FK \quad \text{---} \; (1)$$

From $\Delta\, O_1 O_2 M$ right triangle.

$$\sin\alpha = \frac{O_1 M}{O_1 O_2} = \frac{O_1 E - EM}{O_1 O_2} = \frac{r_1 - r_2}{X}$$

But $\sin\alpha = \alpha = \dfrac{r_1 - r_2}{X}$ — α — very small.

and $\text{Arc } \widehat{JE} = r_1 * \left(\frac{\pi}{2} + \alpha\right)$ $\quad \widehat{JE} = r\cdot\alpha$



— (2)

$\text{Arc } FK = r_2 * \left(\frac{\pi}{2} - \alpha\right)$ — * طول القوس = الزاوية × نصف القطر — (3)

$EF = MO_2$, and fro $\Delta\, O_1 M O_2$ - مربع الوتر = مجموع مربع الضلعين .

$$\therefore EF = MO_2 = \sqrt{(O_1 O_2)^2 - (O_1 M)^2} = \sqrt{X^2 - (r_1 - r_2)^2}$$

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

By expand this equation by binomial theorem يحل المعادلة بالمتوالية الثنائية يحصل على

$$EF = X\left[1 - \frac{1}{2}\left(\frac{r_1 - r_2}{X}\right)^2 + \cdots = X - \frac{(r_1 - r_2)^2}{2X} \quad \text{--} \; (4)\right.$$

By sub (2) (3) (4) in (1) $\rightarrow$ we get.

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

But $\dfrac{r_1 - r_2}{X} = \alpha \rightarrow$ from $\sin\alpha$

$$\therefore L = \pi(r_1 + r_2) + 2\frac{(r_1 - r_2)}{X} * (r_1 - r_2) + 2X - \frac{(r_1 - r_2)^2}{X}$$

$$L = \pi(r_1+r_2) + \frac{2(r_1-r_2)^2}{\cancel{X}} + 2X - \frac{(r_1-r_2)^2}{X}$$

$$= \pi(r_1+r_2) + 2X + \frac{(r_1-r_2)^2}{\cancel{X}}$$

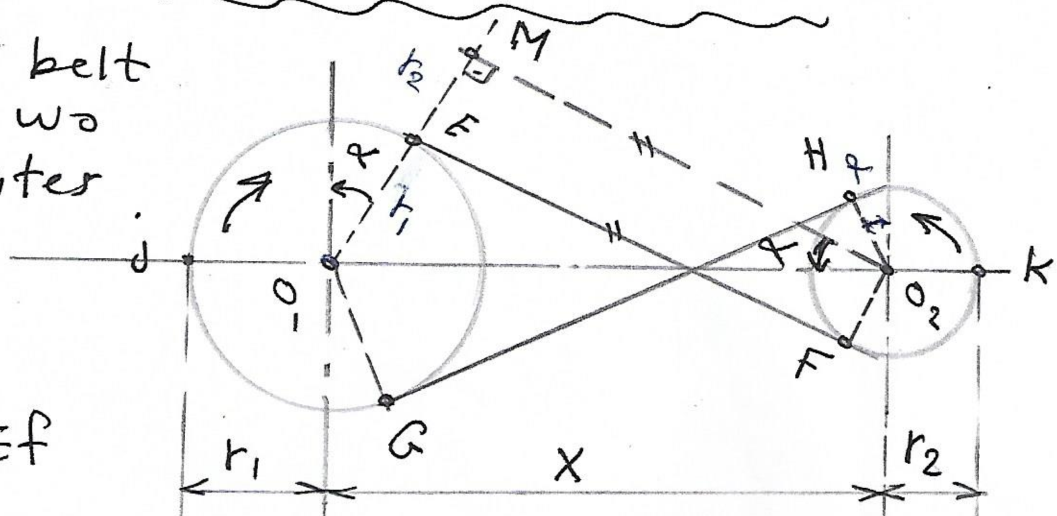
$$\boxed{L = \frac{\pi}{2}(d_1+d_2) + 2X + \frac{(d_1-d_2)^2}{4X}}$$

* Length of a cross belt drive

In the cross belt drive, the two pulley's rotates in opposite direction.

fig (1)

draw $O_1M \parallel Ef$ and $\perp O_1M$



Length of cross belt drive may be determine as follows:

$$l = \overset{\frown}{GJE} + Ef + \overset{\frown}{FKH} + HG$$

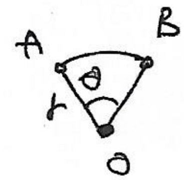
$$= 2(\overset{\frown}{JE} + Ef + \overset{\frown}{Fk}) \quad \text{--- (1)}$$

from R. triangle $\Delta\, O_1O_2M$

$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E + EM}{O_1O_2} = \frac{r_1+r_2}{X}$$

Since $\sin\alpha \simeq \alpha$ very small

$$\therefore \sin\alpha = \alpha = \frac{r_1+r_2}{X} \quad \text{--- (2)}$$



$\overset{\frown}{AB} = r\theta =$

$$\text{Arc } \overset{\frown}{J.E} = r_1\left(\frac{\pi}{2}+\alpha\right) \quad \text{--- (3)}$$

$$\text{Arc } \overset{\frown}{Fk} = r_2\left(\frac{\pi}{2}+\alpha\right) \quad \text{--- (4)}$$

$$Ef = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2}$$

مربع الوتر = مجموع مربع الضلعين
في المثلث القائم الزاوية

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

$$\therefore EF = x\sqrt{1 - \left(\frac{r_1 + r_2}{x}\right)^2}$$ تفتح هذه العلاقة بواسطة المتوالية الثنائية

Expanding this equation by binomial theorem.

$$\therefore EF = x\left[1 - \frac{1}{2}\left(\frac{r_1 + r_2}{x}\right)^2 + \cdots = x - \frac{(r_1 + r_2)^2}{2x}\right. \quad \text{--- (5)}$$

By substituting (2) (3), (4) (5) in (1) we get

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

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

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

$$= \pi(r_1 + r_2) + 2\alpha(r_1 + r_2) + 2x - \frac{(r_1 + r_2)^2}{x}$$

But $\sin\alpha = \alpha = \frac{r_1 + r_2}{x}$ because very small.

$$\therefore L = \pi(r_1 + r_2) + \frac{2(r_1 + r_2)^2}{x} + 2x - \frac{(r_1 + r_2)^2}{x}$$

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

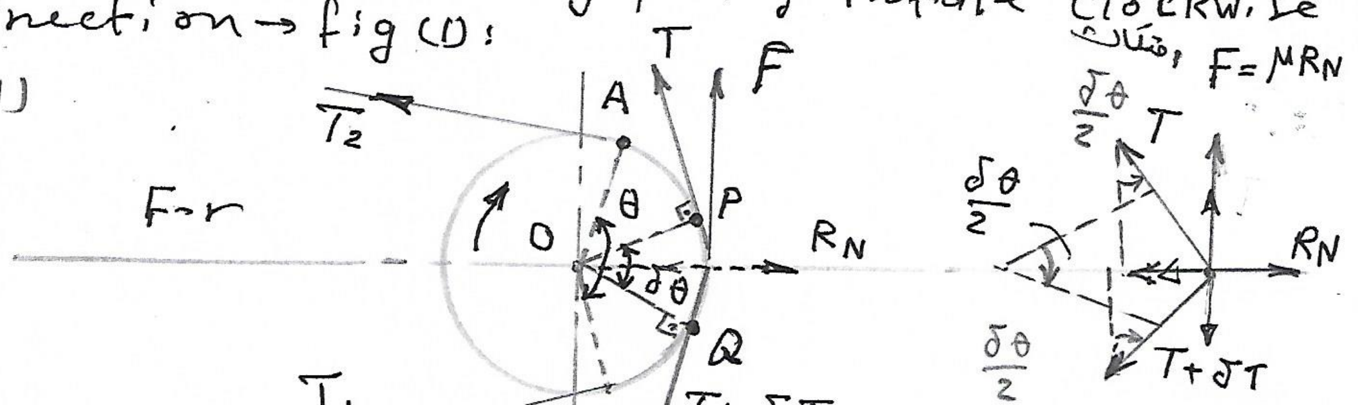
$$\boxed{L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 + d)^2}{4x}}$$

نسبة الشد في الأحزمة المسطحة

* **Ratio of driving tension for flat belt drive**

assume the driving pulley rotate clockwise direction → fig (1): عقارب

Fig(1)



let
- T_1 - tension in tight side
- T_2 - tension in slack side
- θ - Angle of contact in radians

If we consider a small arc PQ is in equilibrium under the following forces

- T at P tension
- $T+\delta T$ at $\rightarrow Q$ tension
- R_N - normal reaction
- $F = \mu * R_N$ - frictional force

اذا اعتبرنا الجزئ PQ في حالة توازن
تحت تأثير هذه القوى

→ and resolving these forces horizontally and take

$\Sigma f_H = 0$

$$\therefore R_N = (T+\delta T)\sin\frac{\delta\theta}{2} + T\sin\frac{\delta\theta}{2} \quad \text{--- (1)}$$

since $\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$ → very small

$$\therefore R_N = (T+\delta T)\frac{\delta\theta}{2} + T * \frac{\delta\theta}{2} = \frac{T.\delta\theta}{2} + \frac{\delta\theta.\delta T}{2} + \frac{T.\delta\theta}{2}$$

By neglecting $\frac{\delta T.\delta\theta}{2}$ → very small

$$\therefore R_N = T.\delta\theta \quad \text{--- (2)}$$

By resolving force vertically → we have

$$\therefore F = \mu.R_N = (T+\delta T)\cos\frac{\delta\theta}{2} - T\cos\frac{\delta\theta}{2} \quad \text{--- (3)}$$

But $\cos\frac{\delta\theta}{2} \simeq 0 = 1$ → very small

$$\therefore \mu R_N = T + \delta T - T = \delta T$$

and $R_N = \frac{\delta T}{\mu}$ --- (4)

By equating R_N from (2) and (4) → we get

$$T.\delta\theta = \frac{\delta T}{\mu} \rightarrow \frac{\delta T}{T} = \mu.\delta\theta$$

$\therefore$ By integrating both sides and limit $T_2, T_1 \rightarrow 0 \rightarrow \theta$

$$\therefore \int_{T_2}^{T_1}\frac{\delta T}{T} = \mu\int_0^\theta \delta\theta \xrightarrow{or} \log_e\left[\frac{T_1}{T_2}\right] = \mu\theta \rightarrow \frac{T_1}{T_2} = e^{\mu\theta} \quad \text{--- (5)}$$

$\therefore \boxed{2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta}$ → by corresponding

* Determining the angle of contact. تعيين زاوية التماس

1) angle of contact for open belt drive fig (1)

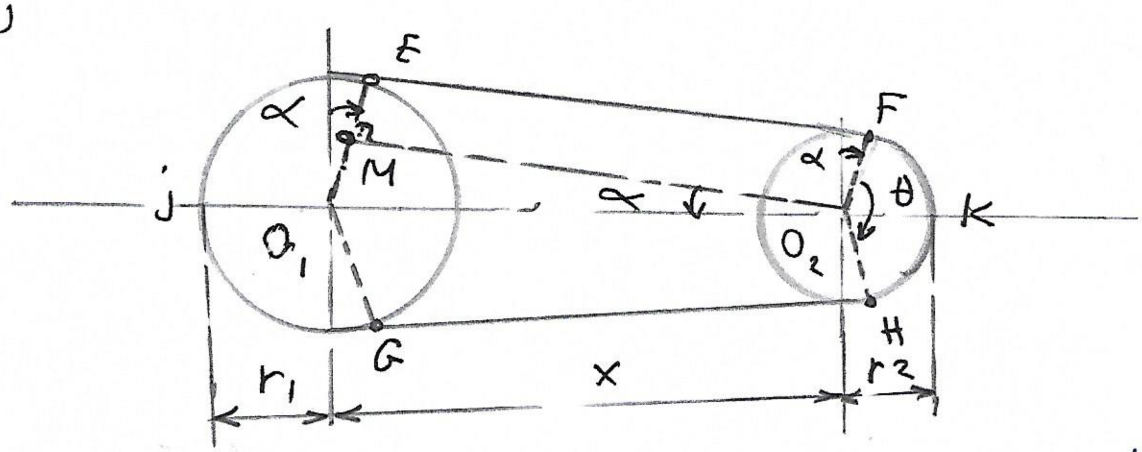


fig (1)

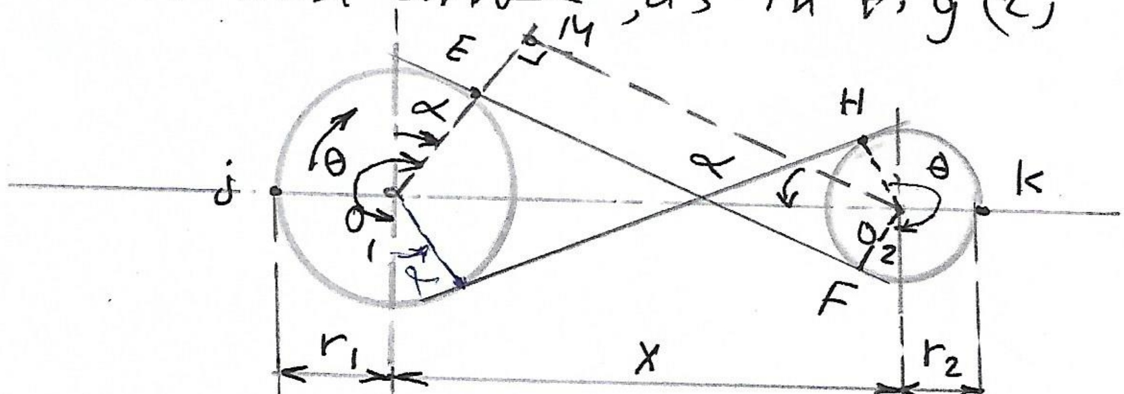
$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E - ME}{O_1O_2} = \frac{r_1 - r_2}{x}$$

$= (180+2\alpha)\frac{\pi}{180}$ rad

∴ angle of contact θ on small pulley

$$\boxed{\theta = (180 - 2\alpha)\,\frac{\pi}{180}\ \text{rad.}} \quad \text{--- (1)}$$

2) For cross belt drive, as in fig (2)



$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E + ME}{O_1O_2} = \frac{r_1 + r_2}{x}$$

∴ angle of contact for small pulley

$$\boxed{\theta = (180 + 2\alpha)\,\frac{\pi}{180}\ \text{rad}} \quad \text{--- (2)}$$

عندما يدور الحزام بسرعة تتولد قوة طرد مركزية
تضاف الى قوة الشد ← الشد المركزي

* Centrifugal tension:

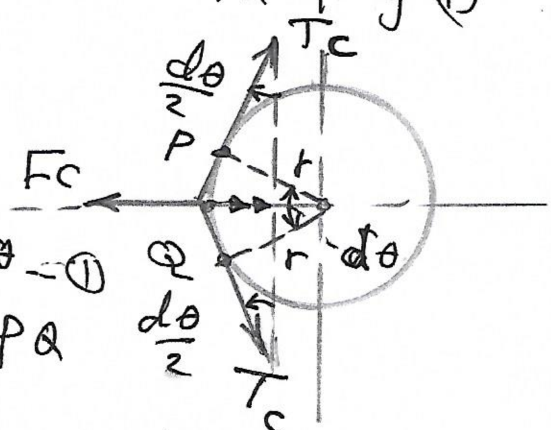
قوة الشد المركزي

when the belt run on pulley with speed in which induce centrifugal force, which added to the tension, and name as centrifugal tension → as in fig (1)

Length of Fig (1)

→ Arc $\overset{\frown}{PQ} = r \cdot d\theta$

and mass of $PQ = m \cdot r \cdot d\theta$ --- ①



By sub ① in fc → we get

Centrifugal force on PQ

$F_c = m r \omega^2 = m \cancel{r} d\theta \times \frac{v^2}{\cancel{r}} = m \cdot d\theta \cdot v^2$

* By resolving centrifugal tension horizontally and equating with a centrifugal force we get

$T_C \sin\left(\frac{d\theta}{2}\right) + T_C \cdot \sin\left(\frac{d\theta}{2}\right) = F_c = m\, d\theta \cdot v^2$

since $\sin \frac{d\theta}{2} \approx \frac{d\theta}{2}$ → very small

$\therefore \cancel{2}\, T_C \left(\frac{\cancel{d\theta}}{\cancel{2}}\right) = m \cdot \cancel{d\theta} \cdot v^2$

$\therefore \boxed{T_C = m \cdot v^2}$ --- ①

* Maximum tension in belt:

أعظم شد في الحزام

may be calculet from max-m stress as follow

$\sigma = \frac{T}{A} = \frac{T}{b * t}$

where | T - tension
b - width
t - thickness

$\therefore \boxed{T = \sigma * b * t}$ --- ①

when ~~we~~ have centrifugal force:

$\therefore \boxed{T = T_1 + F_c}$ --- ②

* power transmitted by belts القدرة المنقولة بالأحزمة

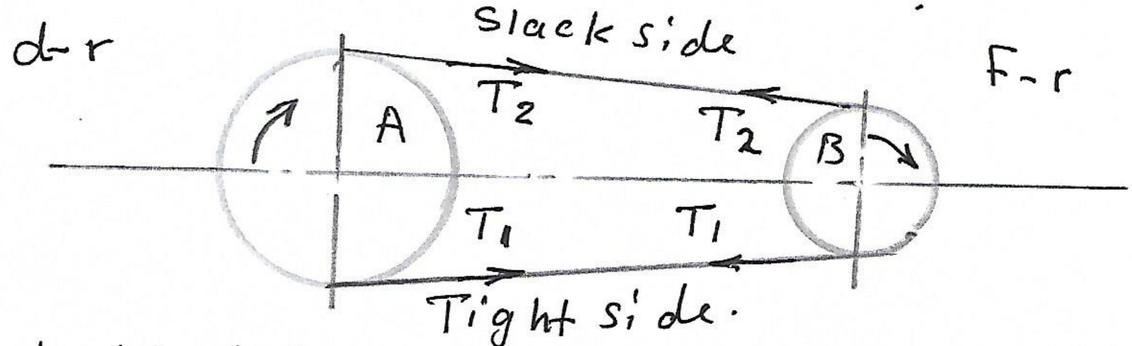


fig (1)

For flat belt drive

T_1, T_2 - tension for tight and slack side.
r_1, r_2 - radius of d-r and f-r pulley
V - velocity of belt in m/s

driving force → $F_d = T_1 - T_2$

the work done in second $W = (T_1 - T_2) * S \rightarrow N.m/s$ الشغل في وحدة الزمن

The power transmitted $P = \frac{(T_1 - T_2) * S}{t} = V$

$$\boxed{P = (T_1 - T_2) \cdot V} \rightarrow W \rightarrow 1 \, N.m/s$$ القدرة

Torque

$T = (T_1 - T_2) * r_1 \rightarrow$ for d-r

$T = (T_1 - T_2) * r_2 \rightarrow$ for f-r العزم