1) In an epicyclic gear train, an arm carries two arms A and B having 36 and 45 teeth respectively. If the arm rotates at 150 rpm in the anticlockwise direction about the centre of the gear A which is fixed, determine the speed of gear B. If the gear A instead of being fixed, makes 300 rpm in the clockwise direction, what will be the speed of gear B.

RSK Ex 13.4 p.no: 438

Nov 2015

Soln:

$T_A = 36$

$T_B = 45$

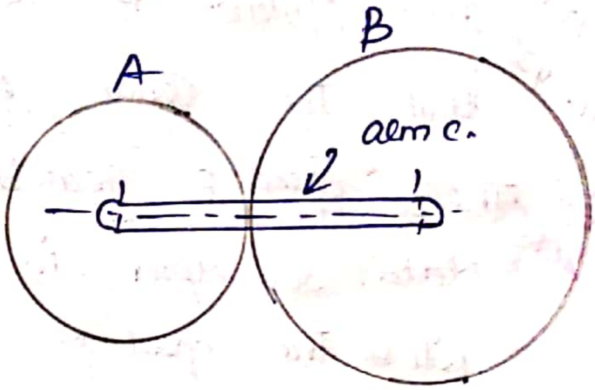
$N_C = 150$ rpm. (+) AC

Tabulation Method

Step No	Conditions of Motion	Arm C	Gear A	Gear B.
1.	Arm fixed. Gear A rotates through +1 Revolution	0	+1	$-\frac{T_A}{T_B}$.
2)	Arm fixed - Gear A rotates through +x revolution	0	+x	$-x.\frac{T_A}{T_B}$.
3)	Add +y revolution to all elements	+y	x+y	$-x.\frac{T_A}{T_B} + y$.
4)	Total motion	y	x+y	$y - x\, T_A/T_B$.

①

Step No 1 ⇒ $\frac{N_A}{N_B} = -\frac{T_B}{T_A}$



$$\frac{+}{N_B} = \frac{T_B}{T_A}$$

$$N_B = -\frac{T_A}{T_B}$$

Speed of Gear B when Gear A is fixed

$$N_B = y - \frac{x \cdot T_A}{T_B}$$

+ since the speed of arm is 150 rpm (+)

$$y = +150$$

Also Gear A is fixed

so $x + y = 0$

$$x = -150.$$

$$N_B = 150 + \cancel{150}^{30} \times \cancel{36}^{4}/\cancel{45}\ \cancel{5}$$

$$= 270\ (+)\ \text{rpm}.$$

Speed of Gear B when gear A Makes 300 rpm (+)(−)

$$N_B = y - x \times \frac{T_A}{T_B}.$$

$$x+y = -300.$$

$$x = -300 - y$$

$$= -300 - 150$$

$$= -450 \text{ rpm}$$

$$N_B = 150 + 450 \times 36/45$$

$$= \pm 510 \text{ rpm (anticlockwise)}.$$

1) April 2015 – 6 39

2) Nov 2015 – 1 – easy ⇒ 1 p.no:33 33

3) April 2016 – 3 27

4) Nov 2016 – 5 4 17

5) April 2017 ✓ 2 – 2 9

6) Nov 2017. – 4 ⇒ easy pblm (some what big) 8 p.no3

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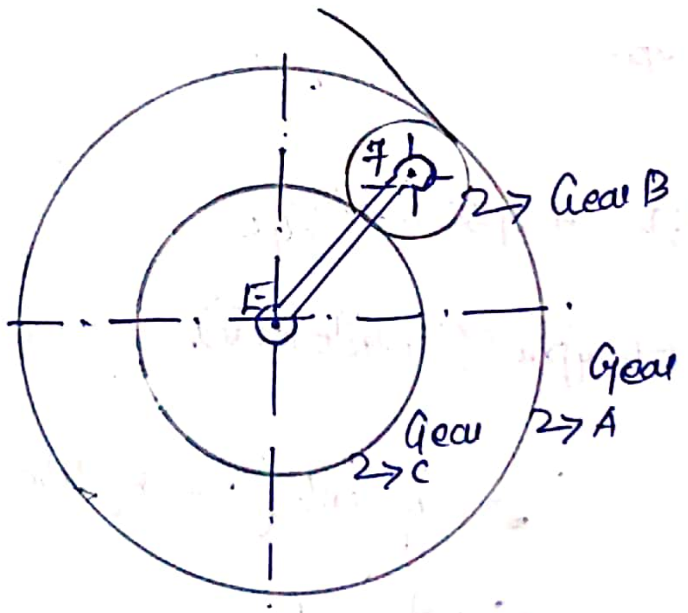
13.6
RSK
April 2017

Q) An epicyclic gear consists of 3 gears A, B & C as shown in the fig. The Gear A has 72 internal teeth and gear C has 32 external teeth. The gear B meshes with both A and C and is carried on an arm EF which rotates about the centre of A at 18 rpm. If the gear A is fixed, det the speed of gears B and C.

Soln:



Soln: Gn data

(D)

$T_A = 72$

$T_C = 32$

$N_{\cancel{B}\,E7} = 18$ rpm.

$N_A = 0.$

$$\frac{N_C}{N_B} = \frac{T_B}{T_C}$$

$$\frac{1}{N_B} = \frac{T_B}{T_C}$$

$$N_B = T_C/T_B\ (-)$$

To find

1) $N_B = ?$

2) $N_C = ?$

Step No	Conditions of Motions	Arm E7	Gear C	Gear B	Gear A.
1.	Arm fixed. Gear C rotate through +1 revolution	0	+1.	$-\frac{T_C}{T_B}$	$-\frac{T_C}{T_B}\times\frac{T_B}{T_A} = -T_C/T_A.$ How?
2)	" " " " " " +x "	0	+x	$-\frac{xT_C}{T_B}$	$-xT_C/T_A$
3)	Add +y revolutions to all element	+y	$\cancel{x+}y$	+y	+y
4)	Total Motion	$\cancel{x+y}\ y$	$x+y$	$y-\frac{xT_C}{T_B}$	$y-\frac{xT_C}{T_A}$

(D)

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Speed of Gear C

$$y = 18 \text{ rpm}$$

$$N_C = x + y$$

&

$$y - x \cdot T_C/T_A = 0$$

$$y = x \; T_C/T_A$$

$$x = y \cdot T_A/T_C$$

$$= 18 \times 72/32$$

$$= 40.5 \text{ rpm}$$

$$N_C = x + y$$

$$= 18 + 40.5$$

$= 58.5$ rpm. in the direction of arm.

Speed of Gear B

$$N_B = y - x \cdot \frac{T_C}{T_B}$$

$$y = 18 \text{ rpm}$$

$$x = 40.5 \text{ rpm}$$

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$d_A/2 = d_B + d_C/2$ (from fig)

$T_A/2 = T_B + T_C/2$ $\because$ Teeth $\propto$ Diameter

$72/2 = T_B + 32/2$

$T_B = 36 - 16$

$T_B = 20$

$\therefore N_B = 18 - 40.5 \times 32/20$

$= -46.8$ rpm

$= 46.8$ in the opposite direction to arm. rpm.

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3) Fig shows a differential gear used in a motor car. The pinion A on the propellar shaft has 12 teeth & gears with the crown gear B which has 60 teeth. The shaft P and Q form the rear axles to which the road wheels are attached. If the propellar shaft rotates at 1000 rpm and the road wheel attached to axle Q has a speed of 210 rpm, while making a turn, find the speed of road wheel attached to axle P.

RSK 401 13.18

May 2016

Soln:

Soln:

Gn data

$T_A = 12$

$T_B = 60$.

A
B
D.

$N_{\theta} = N_D = 100$

$N_A = 1000$ rpm.

$N_{\theta} = N_D = 210$ rpm.

To find

1) Speed of road wheel = ?

Step No	Condition of Motion.	Gear B	Gear C	Gear F	Gear D
		Revolution of Elements			
1	Gear B fixed. Gear C rotate through +1 revolution	0	+1	$+\frac{T_C}{T_E}$	$-\frac{T_C}{T_F} \frac{}{T_D} = -1.$
2	" " " " " +x revolution	0	x	$+\frac{x T_C}{T_E}$	$-x$
3	Add ty revolutions to all elements	y	x+y	y +	y
4	Total Motions	y	x+y	$x T_C / T_{IE} + y$	y−x.

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$N_c = x + y$

$N_B / N_A = T_A / T_B$

$N_B = 1000 \times 12/60$

$= 200 \text{ rpm} = y$

$y - x = 210$

$200 - x = 210$

$x = 200 - 210$

$= -10 \text{ rpm}$

$\therefore$ Speed of road wheels $= N_c = x + y$

$= -10 + 200$

$= 190 \text{ rpm.}$

2017

RGPV

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Nov 2017

(4)

RSK 427

13.4

Soln:

$T_A = 40 \quad T_D = 90.$

From Fig $d_D = d_A + d_B + d_C$ $\quad (\because d_B = d_C)$

$\Rightarrow d_D = d_A + 2d_B$

$T_D = T_A + 2T_B$

$90 = 40 + \cancel{40}T_B$

$2T_B = 50 \Rightarrow T_B = 25 = T_C$

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Step No	Conditions of motions	Revolution of elements: Arm	Gear A	Cmd Gear BC	G... D
1.	Arm fixed. Gear A rotates through −1 revolutions	0	−1	T_A/T_B	T_A/T_D
2)	Arm fixed. Gear A rotates through −x revolutions	0	−x	$x\,T_A/T_B$	$x\,T_A/T_D$
3)	Add −y revolutions to all elements	−y	−y	−y	−y
4)	Total motions	−y	−x−y	$-y+x\,T_A/T_B$	$-y+x\,\frac{T_A}{T_D}$

i) When A makes one revolution clockwise, D makes half a revolution (+).

$-y = ?$

$$N_A/N_B = T_B/T_A \qquad \frac{N_A}{\cancel{N_B}}\cdot\frac{\cancel{N_B}}{N_D} = T_B/T_A\cdot\frac{T_D}{\cancel{T_B}}$$

$$N_B = N_A\cdot T_A/T_B \qquad N_A/N_D = T_D/T_A$$

$$= (+)\ T_A/T_B$$

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$-x-y = -1$

$x+y = 1.$

$-y + x \, T_A/T_D = 0.5$

$-y + x \, 40/90 = +0.5$

$-y + (1-y) \cdot 40/90 = 0.5$

$-y + 0.44 - 0.44y = 0.5$

$-y - 0.44y = 0.5 - 0.44$

$y + 0.44y = -0.5 + 0.44$

$1.44y = -0.06$

$y = -0.04$

So speed of arm

$-y = 0.04$ (+ive) anticlockwise

2) When A makes one revolution & D is stationary:

$-y = ?$

$x + y = 1$

$x^{T_A/T_D} - y = 0$

$x^{T_A/T_D} = y$

$(1-y)\, 0.44 = y$

$0.44 = y + 0.44y$

$0.44 = 1.44y$

$y = 0.30$

$-y = -0.30.$

(Clockwise)

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Soln:-

$T_A = 18$

$T_B = 45$

$T_C = 21$

$N_A = 90$ rpm

$N_D = -450$ rpm

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To find

N_7 & $N_F = ?$

Teeth

$\cancel{A}\ \cancel{B}\cancel{C}\ D\ E$

$$\frac{d_E}{2} = d_B + d_A/2$$

$$\frac{T_E}{2} = T_B + T_A/2$$

$$\frac{T_E}{2} = 45 + 18/2$$

$$T_E = 108.$$

IIIly

$$d_D/2 = d_C + d_A/2$$

$$T_D/2 = T_C + T_A/2$$

$$T_D/2 = 21 + 9$$

$$T_D = 60.$$

(b)↓

$$d_D/2 = d_A/2 + d_B/2 + d_C/2$$

$$T_D/2 = T_A/2 + T_B/2 + T_C/2$$

$$= 9 + 22.5 + 10.5$$

$$T_D = 84.$$

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Step No.	Conditions of motion	Rev. of elements: Arm 7	Gear A	Comp. Gear BC	Gear D	Gear E
1.	Arm fixed. Gear A rotates through +1 revolution	0	1	$-\frac{T_A}{T_B}$	$\frac{T_A}{T_B}\cdot\frac{T_C}{T_D}$	$-\frac{T_A}{T_E}$
2.	" " " " " " x revolution	0	x	$-\frac{xT_A}{T_B}$	$-x\frac{T_A}{T_B}\cdot\frac{T_C}{T_D}$	$-x\frac{T_A}{T_E}$
3.	Add +y revolutions to all the elements	+y	+y	+y	+y	+y
4)	Total Motions	y	x+y	$y-x\frac{T_A}{T_B}$	$y-x\cdot\frac{T_A}{T_B}\cdot\frac{T_C}{T_D}$	$y-x\frac{T_A}{T_E}$

i) Speed of arm.

$N_A = 90$

$x+y = 90$

$y - x\cdot\frac{T_A}{T_B}\cdot\frac{T_C}{T_D} = -450$

$y - x\ 18/45 \times 21/84 = -450$

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$\cancel{y=0}$

$$y - 0.1x = -450.$$
$$\underline{-\ y \pm x = \ _{-}90}$$
$$-1.01x = -540$$
$$x = 491.$$

$$x + y = 90$$
$$y = -401 \text{ rpm.}$$

(ii) $N_F = ?$

$$= y - x\, T_A/T_F$$
$$= -401 - 491 \cdot 18/108$$
$$= \underline{483}$$

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..1/2015
k Bansal
(Neb/Google)

Soln:

$N_C = 900.$

$T_C = 21$

$T_D = 28$

$T_E = 14$

$T_F = 84$

To find

1). $N_M = ?$

Step No	Conditions of Motion	Arm M	Gear C	Revolution of elements Cmd Gear E-D	Gear 7
1	Arm fixed. Gear C rotates through +1 revolutions	0	+1	$-\frac{T_C}{T_D}$	$-\frac{T_C}{T_D}\cdot\frac{T_E}{T_7}$
2.	" " " " " " x revolution	0	x	$-x\,T_C/T_D$	$-x\frac{T_C}{T_D}\cdot\frac{T_E}{T_7}$
3)	Add +y revo.	+y	+y	+y	+y
4)	Total Motions	y	x+y	$+y-x\,T_C/T_D$	$y-x\frac{T_C}{T_D}\cdot\frac{T_E}{T_F}$

$N_M = y.$

$N_C = 900$

$x + y = 900.$

$N_7 = 0$

$\Rightarrow y - x\cdot T_C/T_D\cdot T_E/T_7 = 0$

$\Rightarrow y - x\cdot 21/28\cdot 14/84 = 0.$ $\Rightarrow y = 0.125x$

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$$- \quad y + x \quad 0.125 = 0.$$

$$y + x = 900$$

$$1.125x = 900$$

$$x = 7200.$$

$$9y = 900$$

$$y = 100 \text{ rpm.}$$

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1)

Soln:

$$N_{AB} = 120 \text{ rpm}$$

$$V_{BA} = r_{BA}\,\omega$$

$$V_B = r_{BA} \cdot \omega_{BA}$$

$$= 0.04 \times \frac{2 \times \pi \times 120}{60}$$

$$= 0.503 \text{ m/s}.$$

1

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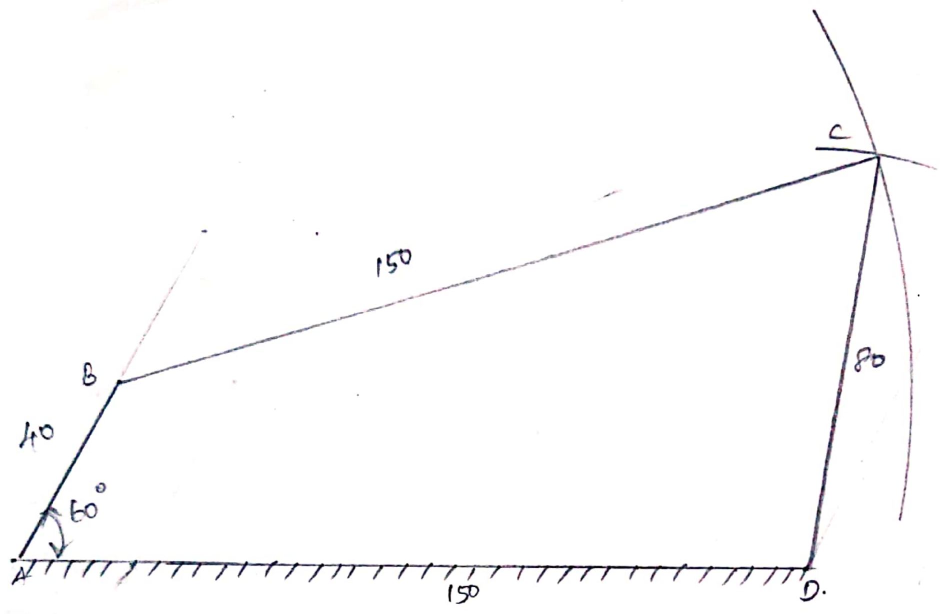

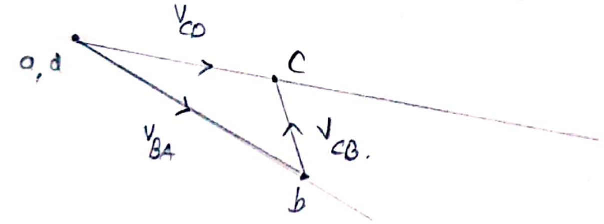

$V_{CD} = 0 \cdot 385 \text{ m/s}$

$V_{CD} = 0 \cdot 385 \text{ m/s}$.

$$\omega_{CD} = \frac{0 \cdot 385}{0 \cdot 08}$$

$= 4 \cdot 81 \text{ rad/s}$.

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1.28 RSK

The Crank and Connecting rod of a theoritical steam engine are 0.5 m and 2m long respy. The Crank makes 180 rpm in the clockwise direction. When it has turned 45° from the inner dead centre position determine the

1) Velocity of piston
2) angular Velocity of Connecting rod
3) Velocity of point E on the Connecting rod 1.5m from the Gudgeon pin
4) Velocities of rubbing at the pins of the Crank shaft, Crank & Cross head when the dia of their pins are 50mm, 60mm and 30mm respy.
5) Position and linear Velocity of any point G on the Connecting rod which has the least Velocity relative to Crank shaft.

Soln:-

Crank length = 0.5 m

Connecting rod, l = 2m.

$N_{crank} = 180$ C-W

$\theta = 45°$.

To find

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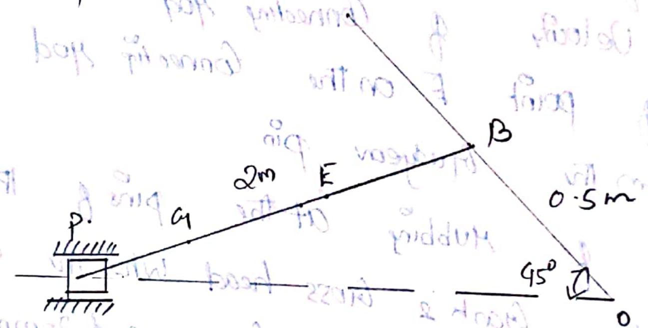
1) Velocity of piston $V_P = ?$

2) $\omega_{CR} = ?$

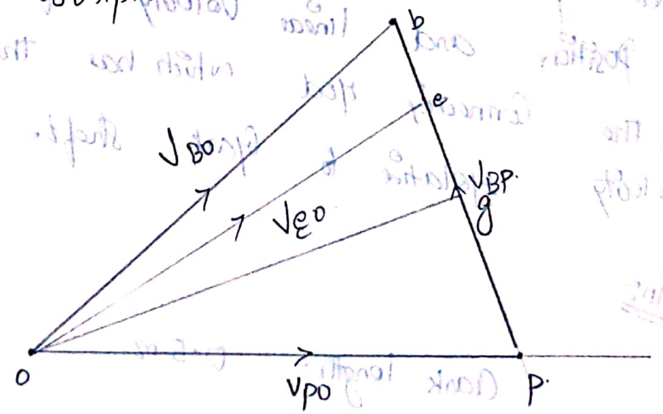
3) $V_E = ?$ (at $x = 1.5m$ from the gudgeon pin)

4) $V_{rubbing} = ?$

5. Position & linear velocity of any point 'G'.



$N_{BO} = 180\ rpm$



$$\frac{BG}{BP} = \frac{bg}{bp} \Rightarrow BG = BP \times bg/bp$$

$$= 2 \times \frac{3.5}{6.7}$$

$$= 1.47\ m$$

$$\omega_{BO} = \frac{2\pi N}{60}$$

$$= \frac{2\times\pi\times 180}{60}$$

$$= 18.84 \text{ rad/s.}$$

$$V_{BO} = \omega_{BO} \times BO$$

$$= 18.84 \times 0.5$$

$$= 9.42 \text{ m/s.}$$

$V = r \times \omega$

1) Velocity of piston

$V_p =$ Vector $OP = 8.15$ m/s.

2) Angular Velocity of Connecting rod

$$\omega_{BP} = \frac{V_{BP}}{BP} = \frac{6.8}{2}$$

$$= 3.4 \text{ rad/s}$$

3) Velocity of point E on the CR 1.5 m from the Gudgeon pin

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$$\frac{BE}{BP} = \frac{be}{bp}$$

$$be = \frac{BE}{BP} \times bp$$

$$= \frac{0.5}{2} \times 6.8$$

$$= 1.7$$

$V_{EO} = 8.5$ m/s.

4) Position and linear velocity of any point G on the CoR which has the least velocity relative to crank shaft

$$\frac{BG}{BP} = bg/bp$$

$$\Rightarrow BG = BP \times bg/bp$$

$$= 2 \times 3.5/6.7$$

$$= 1.47m$$

$V_{GO} = 8$ m/s.

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5) Velocity of rubbing

$d_O = 0.05m$

$d_B = 0.06m$

$d_P = 0.03m$

a) Rubbing Velocity at the pin of Crank Shaft

$V = r \times \omega$

$= 0.05/2 \times 18.852$

$= 0.47 \ m/s$

b) " " " " " " Cross head

$V = r \times \omega$

$= 0.03/2 \times 3.4.$

$= 0.05 m/s$

c) " " " " " Crank

$V = r\omega$

$= 0.06/2 \ (18.852 + 3.4)$

$\simeq 0.667 \ m/s.$

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PART - B

Nov/Dec 2013.

11 (a) What is Kinematic inversion? Explain the four different inversions of slider crank mechanism.

Kinematic Inversions :

* If link 1 is fixed and other links are in relative motion, then it is known as one mechanism

* If link 2 is fixed and other links are in relative motion, then it is known as another mechanism.

* If different links are fixed to get different mechanisms, then the different mechanisms are known as Kinematic inversions.

Single Slider Crank Chain :

It is a modification of basic four bar chain. It consists of one sliding pair and three turning pairs.

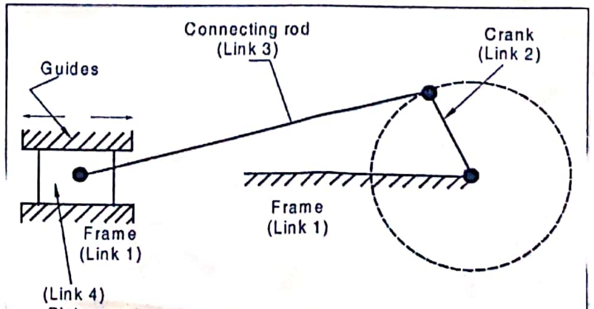

Fig. 1.26 Single slider crank chain

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By fixing in turn, different links in a kinematic chain, an inversion is obtained.

1. Pendulum pump (or) Bull engine
2. Oscillating cylinder engine
3. Rotary internal combustion engine (or) Gnome engine
4. Crank and slotted lever quick return motion mechanism.
5. Whitworth quick return motion mechanism

1) Pendulum pump:

Here, the link 4 is fixed, when the crank rotates, the connecting rod oscillates about a pin pivoted to the fixed link 4 at A and the piston attached to the piston rod reciprocates. This type of mechanism is used in duplex pump to supply feed water to the boilers.

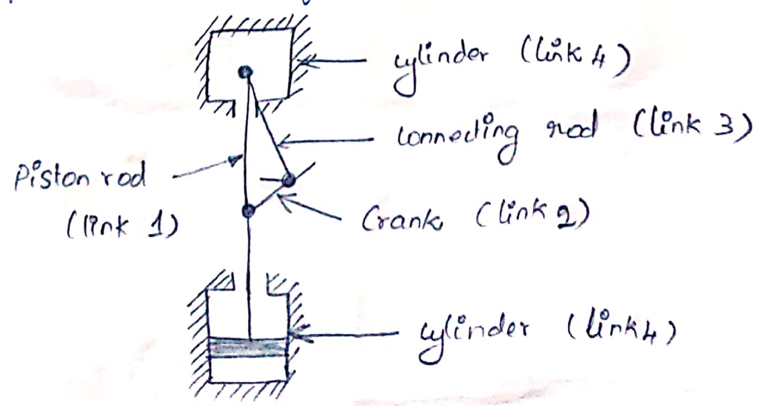

fig: Pendulum pump

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2) Oscillating cylinder engine

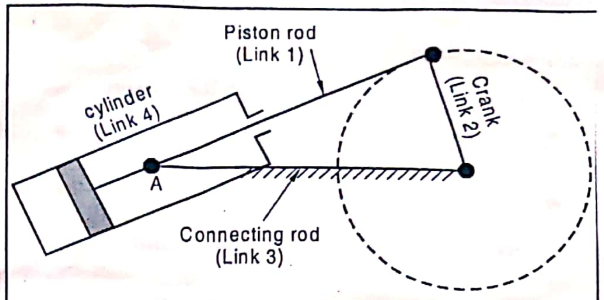
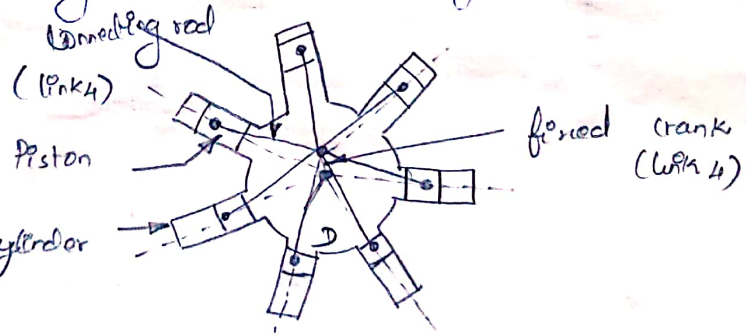


Fig. 1.28 **Oscillating cylinder engine**

This mechanism is used to convert rotary motion into oscillatory motion. Here link 3 is fixed. When the crank rotates, the piston attached to piston rod reciprocates and the cylinder oscillates about a pin pivoted to link at A.

3) Rotary internal combustion engine:



It consists of 7 cylinders and all revolve about fixed centre D. Here link 2 is fixed. When link 4 rotes, the link 3 reciprocates inside the cylinders.

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4) Crank and Slotted lever quick return motion mechanism :

This mechanism is used in shaping machines and slotting machines. The link connects the AP with ram which carries the tool and reciprocates.

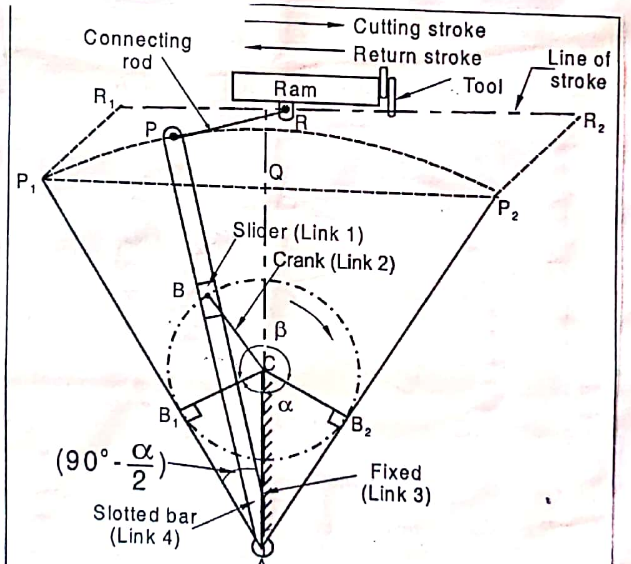

Fig. 1.30 Crank and slotted lever quick return motion mechanism

The cutting stroke occurs when the crank rotates from CB_1 to CB_2. The return stroke occurs when the crank rotates from position CB_2 to CB_1. (ie) through an angle α.

Scanned by CamScanner

5) Whit worth quick return motion mechanism

This mechanism is also mostly used in shaping machines and slotting machines.

Here the link 2 is fixed. The driving crank CA rotates with uniform speed. The link 4 is attached to the crank pin A. It slides along the slotted bar PA.

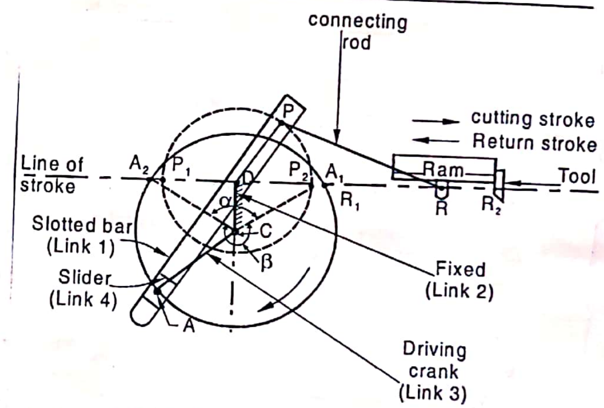

Fig. 1.31 Whitworth quick return motion mechanism

So the slotted bar PA Oscillates about a pivoted point D. The connecting rod PR connects the slotted bar and ram which carries the tool and reciprocates.

Since β is greater than α, CA rotates with uniform angular velocity. Thus it executes the quick return motion.

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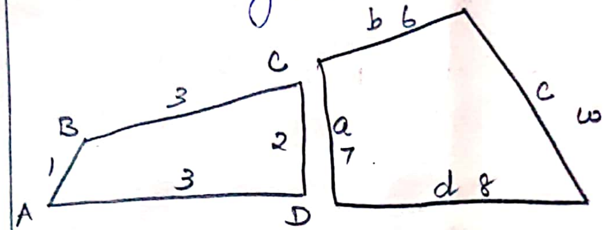
11. (b) (i) Find the maximum and minimum transmission angles for the mechanisms shown in fig. This indicates the dimensions in standards units of leng.

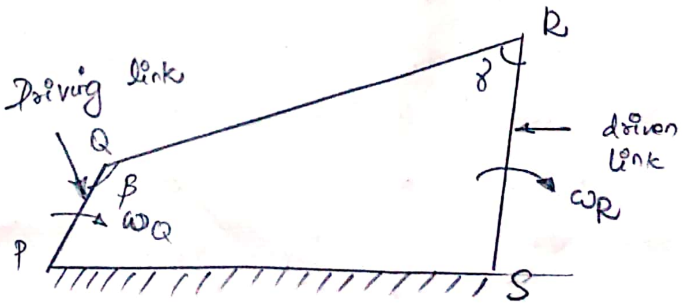
Transmission angle :



When the transmission angle $\gamma = 90°$, the mechanical advantage is maximum.

Mechanical advantage :

It is defined as the ratio of driven link torque to driver link torque. The mechanical advantage of 4 bar mechanism varies depending on the position of the links.



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T_R = Driven torque

T_Q = Driving torque.

$$(M.A)_{Ideal} = \frac{T_R}{T_Q} = \frac{\omega_Q}{\omega_R}$$

$$= \eta \times \frac{T_R}{T_Q} \text{ (considering friction)}$$

Transmission angle (γ).

It is defined as the angle between driver link (RS) and link QC. If the angle γ is too small, the mechanical advantage approaches zero.

11.(b) (ii) Write short notes on toggle mechanisms.

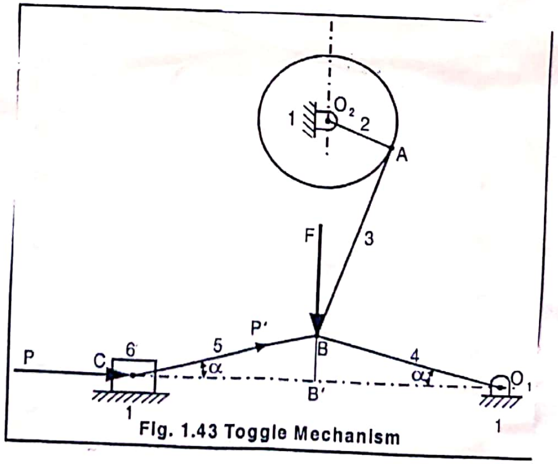

Fig. 1.43 Toggle Mechanism

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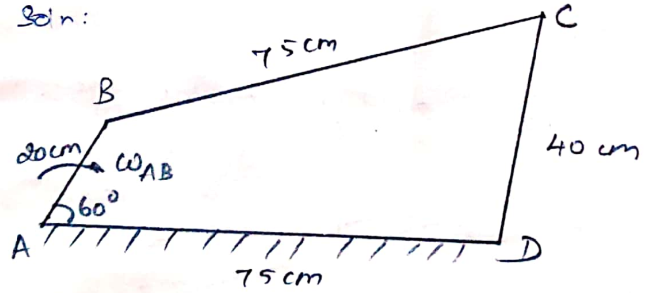
Toggle mechanisms are used, where large resistances are to be overcome through short distances. This mechanism is used in rock crushers, presses, riveting machines etc.

12.(a)(i) Draw the velocity polygon for the four bar mechanism shown in fig and determine V_{BA}, V_{CB} and V_{CD}. Also find ω_{AB}, ω_{BC} and ω_{CD}. In this four bar chain ABCD, AD is fixed. The crank AB rotates at 120rpm clockwise.

Soln:



Velocity diagram.

The linear velocity V_{BA} (or) V_B can be found out by $V_B = \omega_{AB} \times AB$.

angular velocity AB = ω_{AB}

$$\omega_{AB} = \frac{2\pi \times 120}{60} = 12.57 \text{ rad/s}.$$

$V_{AB} = \omega_{AB} \times AB = 12.57 \times 0.2 = 2.51$ m/s.

ie) $V_{BA} = 2.51$ m/s.

The direction of V_{BA} is $\perp$ to line AB.

We know $V_{BA} = 2.51$ m/s & is $\perp$ to AB.

$V_{CB} \perp BC$

$V_{CD} \perp CD$.

Similarly, from point d, draw line perpendicular to CD to get V_{CD}. But both the above 2 lines intersect at c.

We can measure,

$V_{CB} = bc = 1$ m/s

$V_{CD} = dc = 1.91$ m/s

To find angular velocity of BC & CD.

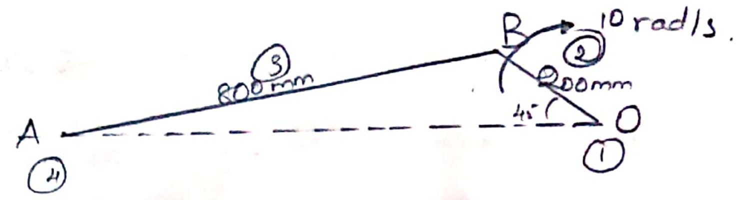
$$\omega_{BC} = \frac{V_{CB}}{BC} = \frac{1}{0.75} = 1.333 \text{ rad/s}$$

(anticlockwise about B)

$$\omega_{CD} = \frac{V_{CD}}{CD} = \frac{1.91}{0.4} = 4.775 \text{ rad/s}$$

(clockwise about D).

12. (a) (ii) Locate all the instantaneous centers of the slider crank mechanism as shown in fig. The lengths of crank OB and connecting rod AB are 200 mm & 800 mm. If the crank rotates clockwise with angular velocity of 10 rad/s, find (1) velocity of slider A (2) Angular velocity of connecting rod AB.



Soln:

$\omega_{OB} = 10 \text{ rad/s}$.

$V_{BO} = V_B = \omega_{OB} \times OB = 10 \times 0.2 = 2 \text{ m/s}$

To locate instantaneous centres

1. Since there are 4 links, the number of instantaneous centers,

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6.$$

2.

Links	-	1	2	3	4
Instantaneous centers		12 13 14	23 24	34	

3. Since the slider crank mechanism has 3 turning pairs and one sliding pair, there will be fixed and permanent instantaneous centres. These are I_{12}, I_{23} & I_{34}.

4. Mark 4 points on the circle to indicate I_{12}, I_{23}, I_{34} & I_{14}.

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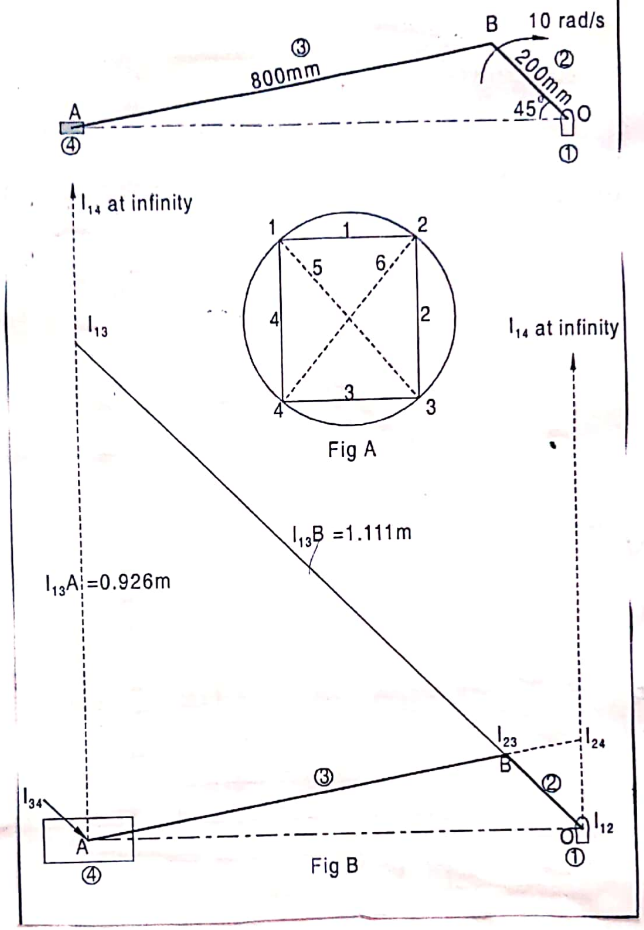

Fig A

Fig B

$I_{13}A = 0.926$ m

$I_{13}B = 1.111$ m

To find velocity of A

$$\frac{V_A}{I_{13}A} = \frac{V_B}{I_{13}B} \quad (or)$$

$$V_A = I_{13}A \times \frac{V_B}{I_{13}B}$$

$$= 0.926 \times \frac{2}{1.111} = 1.667 \text{ m/s}$$

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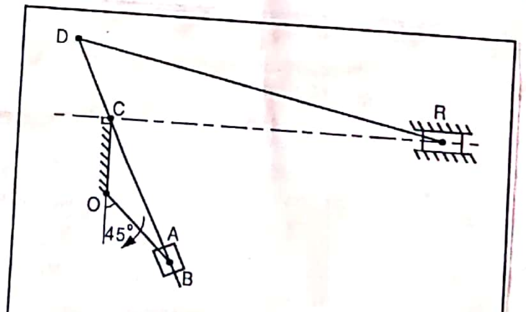
W.K.T

$$\frac{V_A}{I_{13}A} = \frac{V_B}{I_{13}B} = \omega_{AB}$$

$$\omega_{AB} = \frac{V_A}{I_{13}A} = \frac{1.667}{0.926} = 1.8 \text{ rad/s}$$

12. (b) In a whitworth quick return mechanism as shown in fig, crank OA rotates at 30 rpm in clockwise direction. The dimensions of various links are OA = 150 mm, OC = 100 mm, CD = 125 mm and DR = 500 mm. Determine velocity of B, V_{AB}, V_{RD} and the angular velocity of the link BC.



All Dimension in mm.

Gn:

$N_{AO} = 30$ rpm

$\omega_{AO} = 2\pi \times 30 \times 60 = 3.142$ rad/s

$OA = 150$ mm $= 0.15$ m

$OC = 100$ mm $= 0.1$ m

$CD = 125$ mm $= 0.125$ m

$DR = 500$ mm $= 0.5$ m

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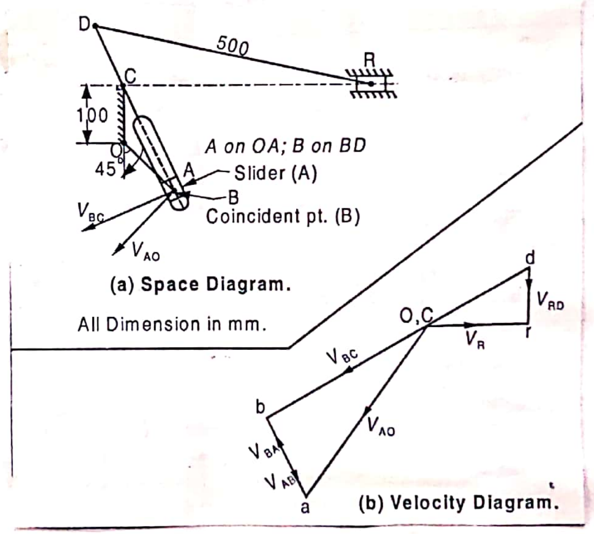
$V_{AO} = V_A = \omega_{AO} \times OA$

$= 3.142 \times 0.15 = 0.47 \text{ m/s}.$

(1) Since O & C are fixed points, therefore these are marked at the same place in velocity diagram.

Such that vector oa = $V_{AO} = V_A = 0.47$ m/s.



(a) Space Diagram.

(b) Velocity Diagram.

(2) From point c, draw cb ⊥ to BC to represent the velocity of the coincident point B with respect to C. The vectors cb & ab intersect at b.

(3) Now from point d, dr ⊥ to DR to represent the velocity of R with respect to D.

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V_{BC} = vector cb = 0.246 m/s

Velocity of A with respect to B.

V_{AB} = vector ba = 0.15 m/s

Velocity of R with respect to D.

V_{RD} = vector dr = 0.12 m/s.

$$\omega_{BC} = \frac{V_{BC}}{CB} = \frac{0.246}{0.241} = 1.02 \text{ rad/s.}$$

13.(a) A cam operates on offset roller follower. The least radius of the cam is 50mm, roller diameter is 30mm & offset is 20mm, the cam rotates at 360 rpm. The angle of ascent is 48°, angle of dwell is 42° & angle of descent is 60°. The motion is to be SHM during ascent and uniform acceleration & deceleration during decent. Draw the cam profile.

Soln:

Assume Life = 40 mm

To draw the profile of the cam when the line of stroke is offset by 20mm from the axis of the cam shaft.

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1. Draw base circle of $r = 50mm$ with centre O.

2. Draw OA = base circle of radius + radius of the roller.
   $= 50 + 15 = 65 mm$

3. Draw an offset circle of radius equal to 20mm with centre O.

4. Join OA. From OA, draw angle $AOS = 90°$ & angle $SOT = 30°$ & angle $TOP = 60°$.

5. Divide the angle AOS into 6 equal parts and mark 0, 1, 2, ...6 and angle TOP into 6 equal parts as in displacement diagram

6. Now transfer the lengths 1B, 2C ...5'N, 6'P from displacement diagram

7. Now draw circles with radius equal to radius of the roller keeping A, B, C, ...P as centre

8. Join the bottoms of the circles with a smooth curve as shown in fig. This curve is known as profile of the cam.

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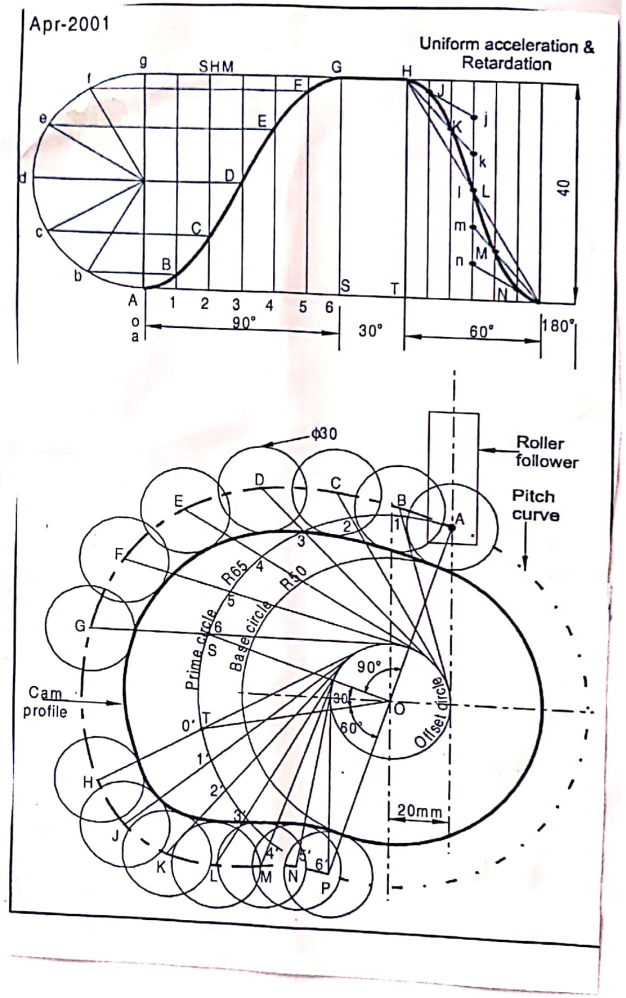

13. (c) A flat faced mushroom follower is by a symmetrical cam with circular arc and nose profile. The axis of tappet pass the cam axis. Total angle of action is 162 10mm and base circle diameter 40 mm. acceleration is 1/2 the period of retardation the lift. The cam rotates at 1200 rpm.

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Determine

1. The nose & flank radii &
2. The maximum acceleration and retardation during lifting

Soln:

$$r = r_1 + h - r_2$$
$$= 20 + 10 - r_2$$
$$= 30 - r_2$$

$$PE = PA = r_f$$

$$\angle P = \frac{\text{Angle of action}}{2} = \frac{162}{2} = 81^\circ$$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 1200}{60} = 125.66 \text{ rad/s}$$
$$= 130.9 \text{ rad/s}$$

$$\angle O_1PO_2 = \frac{1}{2}\angle O_1O_2P \quad \text{— (1)}$$

$$\angle PO_1O_2 = 180^\circ - 81^\circ = 99^\circ$$

$$\angle O_1PO_2 + \angle O_1O_2P = 180^\circ - \angle PO_1O_2 = 180^\circ - 99^\circ$$

$$\angle O_1PO_2 + \angle O_1O_2P = 81^\circ \quad \text{— (2)}$$

On solving (1) & (2)

$$\angle O_1PO_2 = \theta = 27^\circ$$
$$\angle O_1O_2P = \alpha = \frac{81}{1.5} = 54^\circ$$

From ΔO_1O_2P, $\frac{O_1O_2}{\sin\theta} = \frac{O_1P}{\sin\alpha} = \frac{O_2P}{\sin 99^\circ}$

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$$\frac{30-r_2}{\sin 27^\circ} = \frac{r_f - 20}{\sin 54^\circ} = \frac{r_f - r_2}{\sin 99^\circ}$$

$$r_f = (21 - r_2) \times \frac{\sin 54^\circ}{\sin 27^\circ} + 15$$

$$r_f = 53 - 1.81\, r_2 \quad \text{—— (3)}$$

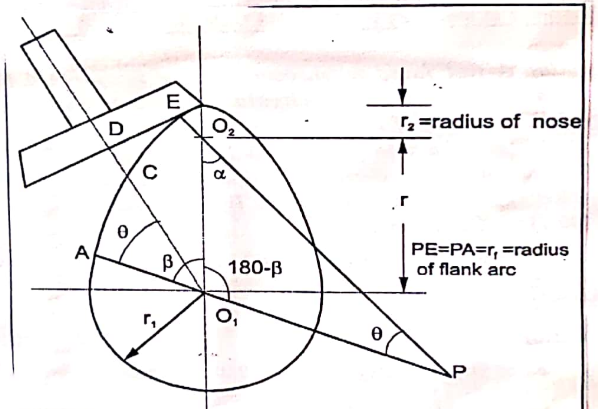

Fig. 9.32

$$\angle\beta = \frac{\text{Angle of action}}{2} = \frac{162}{2} = 81^\circ$$

Similarly

$$r_f = (30 - r_2)\frac{\sin 99^\circ}{\sin 27^\circ} + r_2 = 65.27 - 2.18\, r_2 \quad \text{—— (4)}$$

$$r_f = 65.77 - 1.18\, r_2$$

Solving (3) & (4) $\Rightarrow$ $r_2 = 13.6\,\text{mm}$

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$r_f = 73.46 - 1.782 r_2$

$= 49.22 mm$

Centre distance $r = 30 - r_2$

$= 16.4 mm$

Acceleration:

(i) When $\theta = 0^\circ$

$f = \omega^2 (r_f - r_1) \cos\theta$

$= 125.66^2 \times (0.04922 - 0.02) \times 1$

$= 461.4 m/s^2$

(ii) When $\theta = \beta$

$f = -\omega^2 r \cos(\beta - \theta)$

$= -\omega^2 r$

$= 125.66^2 \times 0.0164$

$= -258.90 m/s^2$

4.(a) (i) Two 15mm module 20° pressure angle spur gears have addendum equal to one module. The pinion has 25 teeth and gear 50 teeth. Determine whether interference will occur or not. If it occurs, to what value should the pressure angle be changed to eliminate interference?

Soln:

$\phi = 20^\circ$; $m = 15mm$; Addendum = 1 module

$T = 50$, $t = 25$

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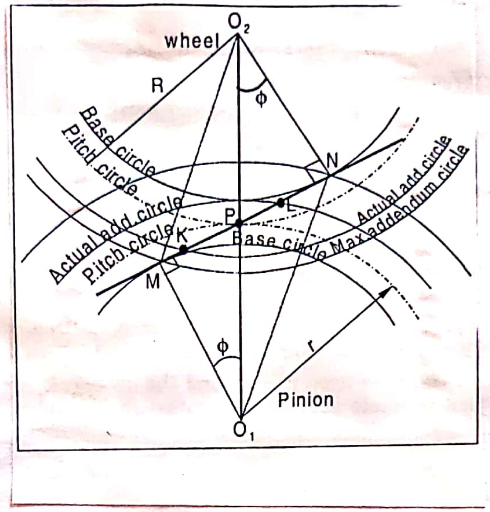

max $R_A = O_2M$ & max $r_A = O_1N$

where max $r_A = O_1N = \sqrt{(O_1M)^2 + (MN)^2}$

$= \sqrt{(r_b)^2 + ((r+R)\sin\phi)^2}$

$r_b = r\cos\phi$

Max $R_A = O_2M = \sqrt{(O_2N)^2 + (MN)^2}$

$= \sqrt{(R_b)^2 + [(r+R)\sin\phi]^2}$

Pitch circle radius $R = \frac{mT}{2} = \frac{15 \times 50}{2} = 187.5\,mm$

$r = \frac{mt}{2} = \frac{15 \times 25}{2} = 187.5\,mm$

Max $R_A = \sqrt{(R\cos\phi)^2 + [(R+r)\sin\phi]^2}$

$= \sqrt{(375\cos 20)^2 + [(375+187.5)\sin 20]^2}$

$= 401.5\,mm$

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$$R_A = R + \text{Addendum}$$
$$= 375 + 15 = 390\ mm.$$

Since actual addendum radius of wheel is not exceeding the max R_A, no interference occurs.

14. (b) (i) An epicyclic gear train consists of 3 gears 1, 2 & 3 as shown. The gear has 72 teeth & gear 3 has 32 teeth. The gear 2 meshes with both gear 1 & 3 & is carried on an arm A which rotates about the centre O_2 at 20 rpm. If the gear 1 is fixed, determine the speed of gears 2 & 3.

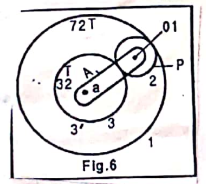
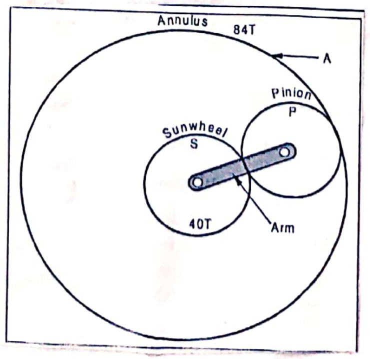


Fig.6

soln:

$T_S = 32$; $T_A = 72$



$N_{arm} = y = 100$

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From fig

$$\frac{D_A}{2} = D_P + \frac{D_S}{2}$$

$$\frac{T_A}{2} = T_P + \frac{T_S}{2}$$

$$\frac{72}{2} = T_P + \frac{32}{2}$$

$$\Rightarrow T_P = 20.$$

Case (i) If gear 1 is fixed, then $N_A = 0$.

To find N_S

$$N_A = 0 = y - x\frac{T_S}{T_A}$$

$$= 100 - x\frac{32}{72}$$

$$\Rightarrow x = 225$$

$$N_S = x + y = 225 + 100 = 325 \text{ rpm}$$

To find N_P

$$N_P = y - x\frac{T_S}{T_P}$$

$$= 100 - 225 \times \frac{32}{50}$$

$$= 260 \text{ (clockwise)}.$$

Write short notes on speed ratio of a planetary gear train.

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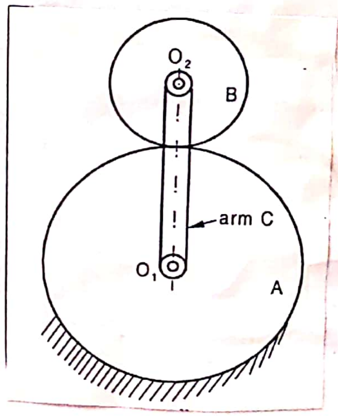
epi means upon, cyclic means an

When the gears are arranged & such a manner that one or more gears rotate upon & around another gear, then the gear train is known as epicyclic gear train. This is called as Planetar gear train.

When gear A is fixed; arm C is rotated, the gear B rotates about its own axis O_2 & it revolves upon and around the gear A. Such a motion is known as epicyclic & the gear train is epicyclic gear train.



They are much useful for transmitting high velocity ratios.

Applications :

- → Wrist watches
- ⇒ Back gear of lathe
- ⇒ Differential in Automobiles
- ⇒ Hoists
- ⇒ Pulley blocks.

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Velocity Ratio :

Two methods :

i) Tabulation method

ii) Formula (or) Algebraic method

The tabulation method is easier & hence it is mostly used for solving problems in epicyclic gear train. The tabulation method will explained clearly while solving the following problems.

Derive the force analysis of a body resting on an inclined plane with force inclined to the plane.

Resolving the forces ||el to plane,

$$\Sigma F_x = P\cos\theta - W\sin\alpha - \mu R_N = 0.$$

$$\therefore P\cos\theta = W\sin\alpha + \mu R_N$$

$$\Rightarrow \Sigma F_y = R_N + P\sin\theta - W\cos\alpha = 0.$$

$$\Rightarrow \boxed{R_N = W\cos\alpha - P\sin\theta}$$

$$\Rightarrow P\cos\theta = W\sin\alpha + \mu(W\cos\alpha - P\sin\theta)$$

$$\therefore P = \frac{W(\sin\alpha + \mu\cos\alpha)}{\cos\theta + \mu\sin\theta}$$

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$$P = \frac{W \sin(\alpha+\phi)}{\cos(\theta-\phi)}$$

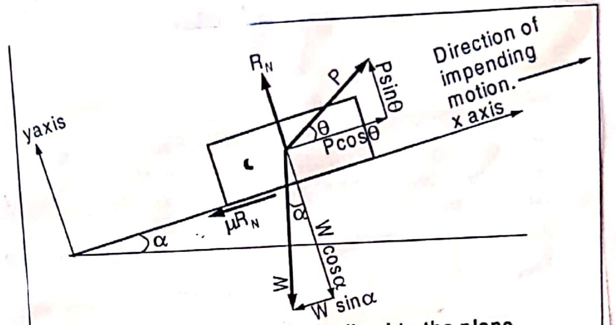

Fig. 5.7. Force acting inclined to the plane

15) a) List the properties of friction

ii) Types of friction:

Depending on the contacting surface, friction is classified into two types.

1. Static friction
2. Rolling friction
3. Pivot friction

1) Static friction

The friction experienced when the body is at rest, is known as static friction

2) Dynamic friction

When the body is under motion, if the friction is experienced, the such friction is known as dynamic friction.

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(a) Sliding friction

The friction experienced, when one body slides over another is known as sliding friction.

(b) Rolling friction

The friction experienced when roller rolls over the surface is known as Rolling friction

(c) Pivot friction

The friction experienced when the pivot is rotating on a bearing surface, is known as pivot friction.

A vertical shaft 140mm diameter rotating at 120 rpm rests on a flat end foot step bearing. The shaft carries a vertical load of 30 kN. The coefficient of friction is 0.06. Estimate the power lost in friction, assuming uniform pressure & uniform wear.

Soln:

$D = 140\ mm$ $\quad R = 70mm$ $\quad N = 120\ rpm$

$W = 30\ kN$ $\quad \mu = 0.06$

$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 120}{60} = 12.56\ rad/sec$$

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i) Uniform Pressure

$$T = \frac{2}{3} \mu W R$$

$$= \frac{2}{3} \times 0.06 \times 30 \times 10^3 \times 70 \times 10^{-3}$$

$$= 84 \text{ Nm.}$$

$P = T \cdot \omega$

$$= 84 \times 12.56 = \underline{1055.04 \text{ W}}$$

ii) Uniform wear

Total friction torque $= \frac{1}{2} \mu W R$

$$= \frac{1}{2} \times 0.06 \times 30 \times 10^3 \times 70 \times 10^{-3}$$

$$= 63 \text{ N.m}$$

$$P = T\omega$$

$$= 63 \times 12.56 = \underline{791.28 \text{W}}$$

15.b) ii) A multi plate disc clutch transmits 55 KW of power at 1800 rpm. Coefficient of friction ~~for~~ the friction ~~for~~ surface is 0.1. Axial intensity of intensity of pressure is not to exceed 160 KN/m². The internal radius is 80 mm & 0.7 times the external radius. Find the number of plates needed to transmit the req. torque.

Power $= 55\ kW$

$N = 1800\ rpm$

$\mu = 0.1$

$P = 160\ kN/m^2$; $r_2 = 80mm = 0.7 r_1$

$\Rightarrow r_1 = 114.3\ mm$

Soln :

$r_2 = 80mm = 0.08m$

$r_2 = 0.7 r_1 \Rightarrow r_1 = \frac{80}{0.7} = 114.3\ mm$

$\mu = 0.1$

Power $= 55\ KW$

$N = 1800\ rpm$

$R = \frac{r_1 + r_2}{2} = 97.15\ mm = \underline{\underline{0.09715\ m}}$

Frictional Power transmitted $= \frac{2\pi N T}{60}$

$55 \times 10^3 = \frac{2\pi \times 1800 \times T}{60}$

$T = \frac{55 \times 10^3 \times 60}{2\pi \times 1800} = 291.8\ N\text{-}m$

$T = n\mu WR$ $\quad n =$ no. of active frictional surfaces

$\Rightarrow 291.8 = n \times 0.1 \times W \times 0.09715$

$W = 2\pi C (r_1 - r_2)$

$= 2\pi \times 160 \times 10^3 \times 0.08\ (0.1143 - 0.08)$

where $C = p r_2$;

$W = 2758.6\ N$

$T = n \mu W R$

$291.8 = n \times 0.1 \times 2758.6 \times 0.09715$

$$n = \frac{291.8}{0.1 \times 2758.6 \times 0.0915}$$

No. of active surfaces $n = 10.88 \simeq 11$

No. of plates $= 11 + 1 = 12$ plates.

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Nov/Dec 2017

1) A pinion having 30 teeth drives a gear having 80 teeth. The profile of the gears is involute with 20° pressure angle, 12 mm module & 10 mm addendum. Find the length of path of contact, arc of contact and the contact ratio.

(RSK) (12.3 - 398)

Soln:-

Given data

$t = 30$

$T = 80$

Pr angle, $\phi = 20^\circ$

$m = 12$ mm

Addendum $= 10$ mm

To find

1) Length of path of contact $= ?$
2) Arc of contact $= ?$
3) Contact ratio $= ?$

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1) Length of path of Contact:

$$KL = KP + PL$$

$$KP = \sqrt{R_A^2 - R^2 \cos^2 \varphi} - R \sin \varphi$$

$$R_A = R + \text{Addendum}$$

$$R = mT/2$$

$$= \frac{12 \times 80}{2}$$

$$= 480 \text{ mm}$$

$$R_A = 480 + 10 = 490 \text{mm.}$$

$$KP = \sqrt{(490)^2 - (480)^2 \cos^2 20^\circ} - 480 \sin 20^\circ$$

$$= 27.3 \text{ mm}$$

$$PL = \sqrt{r_A^2 - r^2 \cos^2 \varphi} - r \sin \varphi$$

$$r = mt/2 \qquad , \qquad r_A = r + \text{addendum}$$

$$= \frac{12 \times 30}{2} \qquad = 180 + 10$$

$$= 180 \text{mm} \qquad = 190 \text{ mm}$$

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$$PL = \sqrt{190^2 - 180^2 \cos^2 20 - 180 \sin 20^\circ}$$

$26.98 \simeq 25\ mm$

So, Length of path of Contact

$= KP + PL$

$= 27.3 + 25$

$= 52.3\ mm.$

2) **Length of arc of Contact:**

Length of arc of Contact

$$= \frac{\text{Length of Path of Contact}}{\cos \varphi}$$

$$= \frac{52.3}{\cos 20^\circ}$$

$= 55.6\ mm$

3) **Contact Ratio** (or) No of pair of teeth in Contact

$$\text{Contact Ratio} = \frac{\text{Length of arc of Contact}}{(P_c)\ \text{Circular pitch}}$$

$P_c = \pi \times m = \pi \times 12 = 37.68$

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So,

$$\text{Contact Ratio} = \frac{55.6}{37.68}$$

$$= 1.47$$

$$\simeq \text{Say } 2.$$

April/May 2007 (RSK 12.6 L401)

Q) The following data related to pair of 20° involute gear in Mesh.

* Module = 6mm
* No of teeth on pinion = 17,
* " " " " gear = 49
* Addenda on pinion and gear wheel = 1 module

Find

1) The No of pairs of teeth in Contact

2) The angle turned through by the pinion and the gear wheel when one pair of teeth is in Contact and

(iii) The ratio of sliding to rolling motion when the tip of a tooth on the larger wheel

a) is just Making Contact

b) is just leaving Contact with its Mating tooth

c) is at the pitch point.

Soln:

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soln:

Gn data

* $m = 6$ mm
* $t = \cancel{12}\ 17$
* $T = 49$
* Addenda on pinion and Gear wheel = 1 Module

= 6 mm.

1) No of pair of teeth in Contact (or) Contact Ratio

$R_A = R +$ Addendum	$r_A = r +$ addendum
$R = mT/2$	$r = mt/2$
$= \frac{6 \times 49}{2}$	$= 6 \times 17/2$
$= 147$ mm	$= \cancel{36}.51$ mm
$R_A = 147 + 6$	$r_A = 51 + 6$
$= 153$ mm.	$= 57$ mm.

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$KP = \sqrt{153^2 - (147)^2 \cos^2 \phi} - 147 \sin 20^\circ$

$= 15.5\,mm$

$PL = \sqrt{57^2 - 51^2 \cos^2 20} - 51 \sin 20$

$= 13.41\,mm$

$KL = KP + PL$

$= 15.5 + 13.41$

$= 28.91\,mm$

Length of arc of Contact = $\frac{\text{Length of path of Contact}}{\cos \phi}$

$= \frac{28.91}{\cos 20^\circ}$

$= 30.8$ mm.

Contact Ratio = $30.8 / \pi \times m$

$= 1.6$

$\simeq 2.$

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2) **Angle turned by the pinion and gear wheel when one pair of teeth is in contact**

a) Angle turned through by the pinion

$$= \frac{\text{Length of arc of contact} \times 360^\circ}{\text{Circumference of pinion}}$$

$$= \frac{30.8 \times 360^\circ}{2\pi r}$$

$$= \frac{30.8 \times 360^\circ}{2\pi \times 51}$$

$$= 34.6^\circ$$

b) " " " " Gear wheel

$$= \frac{30.8 \times 360^\circ}{2\pi \times 147}$$

$$= 12^\circ$$

3) **Ratio of sliding to rolling motion**

Let ω_1 = Angular Velocity of pinion

ω_2 = " " " Gear wheel.

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W.K.T $\frac{\omega_1}{\omega_2} = T/t$

Gear $\left(\frac{\omega_1}{\omega_2}\right)_{pinion} = t/T$

$\omega_2 = \omega_1 \times t/T$

$= \omega_1 \times 17/49$

$= 0.34\,\omega_1$

$\omega_1 = \omega_2 \times 0.34$

$\omega_1 = 0.34\omega_2$

b) At the (

&

Rolling Velocity

$V_R = r\omega_1 = \omega_2 R$ $\quad V_R = \omega_2 147.$

$V_R = 51\omega_1$ $\quad (\because r = 51)$

a) At the instant when the tip of a tooth on the layer wheel is just making contact with the mating teeth (i.e) when the engagement commences

$V_S = (\omega_1 + \omega_2)\,KP$

$= (\omega_1 + 0.34\,\omega_1) \times 15.5$

$= 20.77\,\omega_1$

$V_S/V_R = \frac{20.77\,\omega_1}{51\omega_1} = 0.40.$

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b) At the instant when the tip of a tooth on the larger wheel is just leaving the contact with its mating teeth (when engagement terminates),

$$V_s = (\omega_1 + \omega_2)\ PL$$

$$= (\omega_1 + 0.34\,\omega_2) \times 13.41$$

$$= 17.9\,\omega_1$$

$$V_s/V_R = \frac{17.9\,\omega_1}{51\,\omega_1}$$

$$= 0.350.$$

c) At the pitch point

At the pitch point, the sliding velocity is zero.

$$V_s/V_R = 0/V_R = 0.$$

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Nov/Dec 2016

Two Mating gears have 20 and 40 involute teeth of Module 10 mm and 20° pr. angle. The addendum on each wheel is to be made of such a length that the line of contact on each side of the pitch point has half the max. possible length. Det the addendum ht for each gear wheel.

Soln:

$T = 40$

$t = 20$

$m = 10\,mm$

$\phi = 20^\circ$

* Addendum ht for larger gear wheel $= R_A - R$

* " " " smaller " " $= r_A - r$.

$r = mt/2 = 10 \times 20/2 = 100\,mm$

$R = mT/2 = \frac{10 \times 40}{2} = 200\,mm.$

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Teeth

line of contact on each side = 1/2 Max. possible length.

$KP = \frac{1}{2} MP$

$= \frac{1}{2} r \sin\phi$

$\sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi = \frac{r\sin\phi}{2}$

$\sqrt{R_A^2 - 200^2\cos^2 20^\circ} - 200\sin 20^\circ = \frac{100 \times \sin 20^\circ}{2}$

$\sqrt{R_A^2 - 35320.8}$ $= 171.01 + 68.40$

$= 85.5$

$R_A = 206.4\ mm.$

* Addendum ht for larger wheel $= R_A - R$

$= 206.4 - 200$

$= 6.5\ mm.$

lly for smaller gear wheel

$PL = \frac{1}{2} PN$

$\sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi = \frac{R\sin\phi}{2}$

$\sqrt{r_A^2 - 100^2\cos^2 20} - 100\sin 20 = \frac{200 \times \sin 20^\circ}{2}$

$r_A = 116.2\,mm$

Add. ht for smaller wheel $= r_A - r$

$= 116.2 - 100$

$= 16.2\,mm.$

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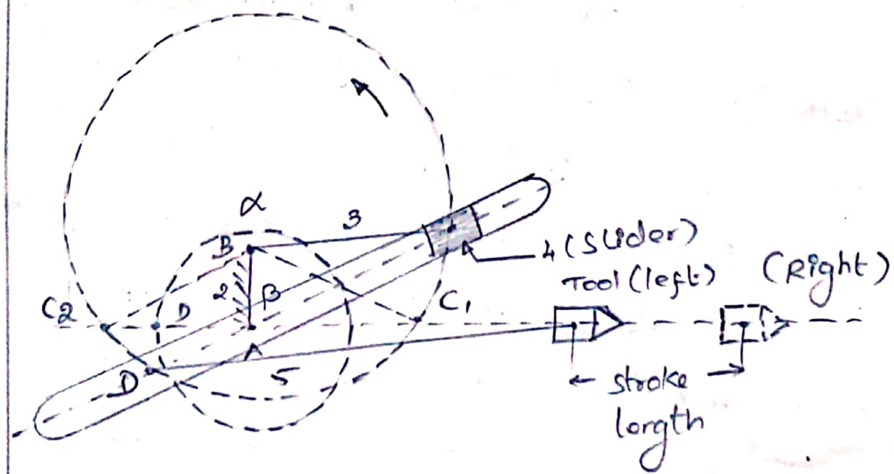
May/June 2014 Part-B

11. (a) Explain the working of two different types of quick-return mechanisms. Derive an expression for the ratio of time taken in forward and return stroke for one of these mechanisms.

Whitworth Quick-Return Mechanism :

This is used in shaping and slotting machines to cut metals. In this mechanism, link 2 is fixed, link 3 rotates, link 4 reciprocates and link 1 oscillates.



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Forward stroke :

The crank rotates counter- clockwise fr BC_1 to BC and then BC_2, the point D will move from D_1 to D and to D_2 ; as a result link 6 will move from E_1 to its extreme right position E_2.

The distance between extreme left and right positions is the stroke length. The movement of tool 6 from E_1 to E_6 is known as forward stroke.

Return stroke :

When the crank further rotates counter clockwise BC_2 to BC_1, the point D will move from D_2 to D_1, the tool will move from E_2 to E_1. The movement of tool from E_2 to E_1 is known as return stroke or backward stroke.

Time for cutting stroke $= \frac{\alpha}{2\pi N}$

Time for return stroke $= \frac{\beta}{2\pi N}$

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$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{(\alpha/2\pi N)}{(\beta/2\pi N)} = \frac{\text{Angle } \alpha}{\text{Angle } \beta}$$

$$= \frac{360^\circ - \beta}{\beta} = \frac{\alpha}{360^\circ - \alpha}$$

The time req. for cutting stroke greater than return stroke. Since this mechanism achieves return stroke quicker than forward stroke, it is called as quick return mechanism.

$E_1 F_2 = 2AD$.

Crank and Slotted Lever Quick Return Motion Mechanism :

This mechanism is mostly used in shaping and slotting machines.

Link 1 is a slider, which slides in a slotted lever; link 3 is fixed, link 2 is crank. The link 5 transmits the motion from link OC to ram which carries the tool.

Time for cutting stroke = $\alpha/2\pi N$

Time for return stroke = $\beta/2\pi N$

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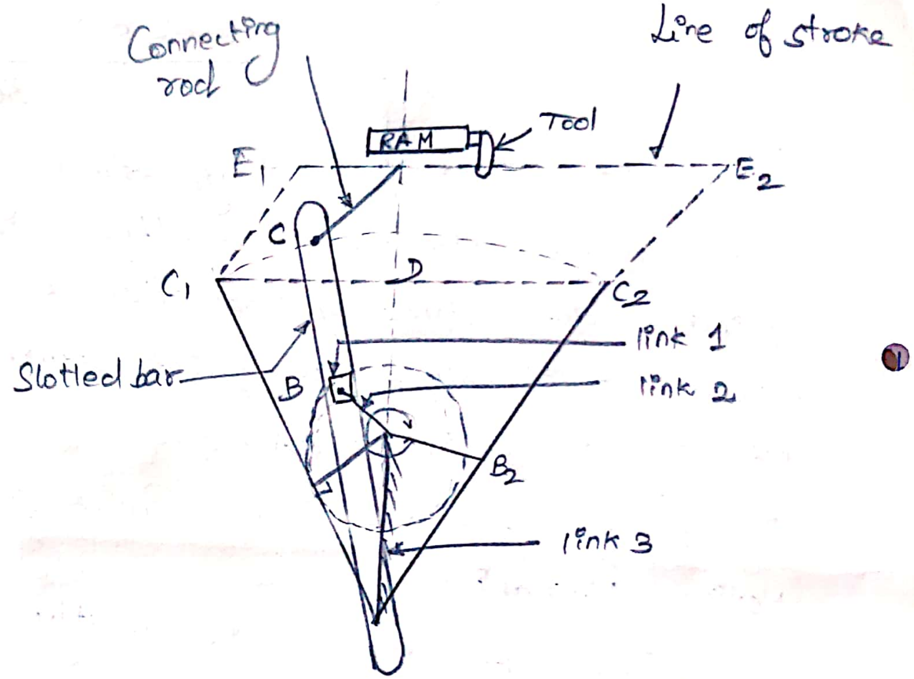

The ratio of cutting stroke to return stroke time Q will be given by,

$$Q = \frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{(\alpha/2\pi N)}{(\beta/2\pi N)} = \frac{\alpha}{\beta}$$

$$= \frac{\alpha}{360^\circ - \alpha} = \frac{360^\circ - \beta}{\beta}$$

Since β is less than α, the time req. for return stroke is less than cutting stroke. Thus it is also called as quick return mechanism.

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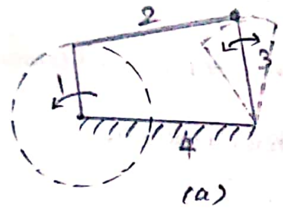
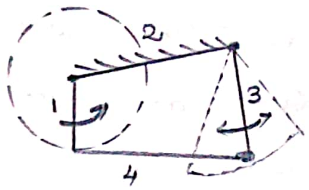
Sketch and explain any 3 Kinematic inversions of four-bar chain.

First / Second Inversion (Crank-Rocker Mechanism)



(a)



(b)

In fig (a) → link 1 is the crank
link 4 is fixed
link 3 oscillates

In fig (b) → link 2 is fixed
link 3 oscillates

The mechanism thus obtained is known as crank-rocker mechanism (or) rotary-oscillating converter.

Beam Engine :-

Beam Engine is an example of crank-rocker mechanism, where one link oscillates while the other rotates about the fixed link.

Thus this mechanism is used to convert rotary motion into reciprocating motion.

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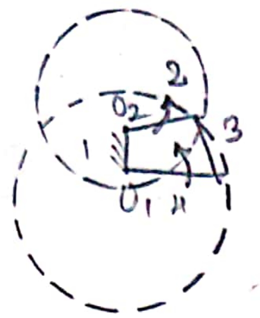
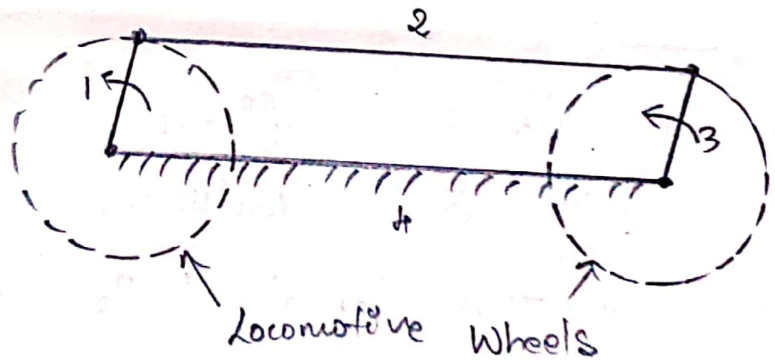
Third Inversion (Double - Crank Mechanism)



If the shortest link is fixed, the adjacent links 2 & 4 would make complete revolutions. The mechanism thus obtained is known as crank - crank mechanism (or) Double - crank Mechanism.

Coupling of Locomotive wheels :-



Coupled wheels of a locomotive is an example of a double- crank mechanism where both rotate about the points in the fixed link.

Since links 1 and 3 work as two cranks, the mechanism is also called as rotary- rotary converter.

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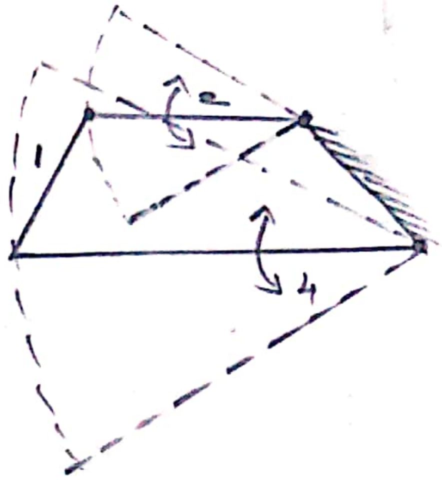
Fourth Inversion (Double - Rocker Mechanism)

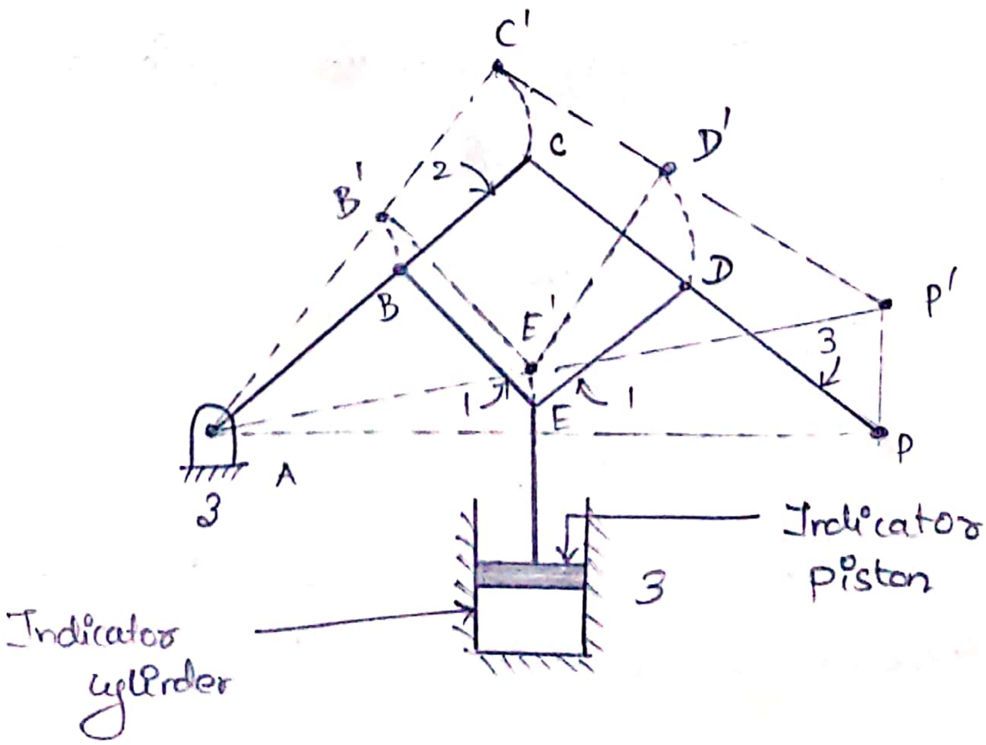
If the link opposite to shortest link is fixed, link 3 is fixed, then link 1 is made coupler and other two links 2 & 4 would oscillate. The mechanism thus obtained is known as rocker-rocker or double-rocker mechanism.



Applications :

1) Watt's indicator mechanism
2) Pantograph
3) Ackermann Steering

1) Watt's indicator mechanism



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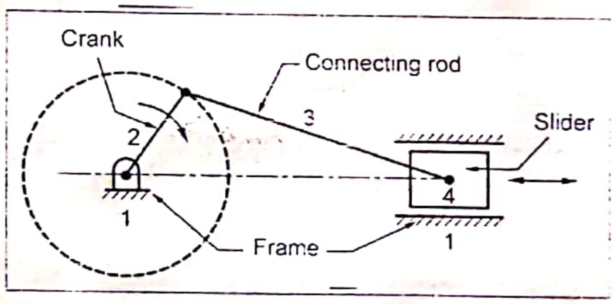
This mechanism was invented by James Watt for his steam engine to guide the piston rod along straight line. It is also known as simplex indicator.

Links ABC and CBP act as levers and due to this, the mechanism is also known as double-lever (or) rocker mechanism.



In fig. continuous lines depict the initial position of the mechanism, whereas the dotted lines show the position of the mechanism, when steam or gas pressure acts on the indicator piston.

The point P traces the variation of pressure in the cylinder. It may be noted that

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the point P traces approximately the straight line motion (PP') corresponding to motion of E. For this reason, this mechanism is also known as straight line generator mechanism.

2) Pantograph

This device is used to reproduce a displacement exactly in an enlarged or reduced scale.

3) Ackermann Steering

The Ackermann steering mechanism is used for changing the direction of the wheel axles with reference to the chasis, so as to move the vehicle in any desired path. This mechanism is Ackermann Steering.

12(a) i) Derive an expression for the relationship between the angular velocities of links in terms of known link lengths, angular positions of links and angular velocity of input link, for a four-bar linkage.

In this link, AB is the driver link, BC is the coupler, CD is the driven link & DA is the frame.

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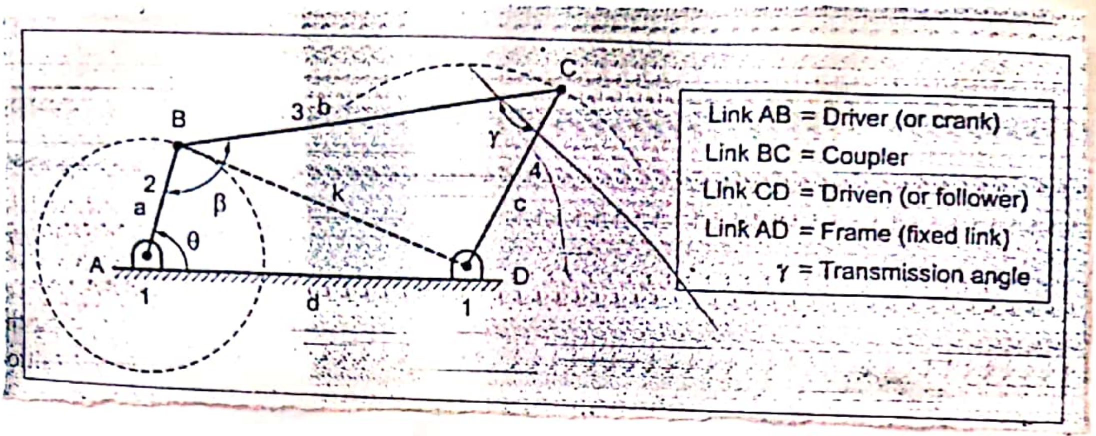

Transmission angle (γ): The angle between the coupler link and the driven link is known as transmission angle.

Equation for mechanical advantage:

Let θ = Crank angle

γ = Transmission angle

β = Angle between the coupler link and the driver link

a, b, c, d = Lengths of links AB, BC, CD & DA respectively

$$MA = \frac{T_{CD}}{T_{AB}} = \frac{\omega_{AB}}{\omega_{CD}} = \frac{c \sin \gamma}{a \sin \beta}$$

The mechanical advantage of the 4 bar mechanism is directly advantage to the sine of angle γ between the coupler and the follower.

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6

1.(i) In a slider-crank mechanism, the length of crank OB and connecting rod AB are 125 mm & 150 mm respectively. The centre of gravity G of the connecting rod is 275 mm from the slider A. The crank speed is 600 rpm clockwise. When the crank has turned 45° from the inner dead centre position, determine velocity of the slider A, velocity of the point G & angular velocity of the connecting rod AB.

soln:

$OA = 15\,cm$ $\quad N_{OA} = 300\,rpm$

$AB = 60\,cm$ $\quad \angle AOB = 45°$.

Step: 1

1. First draw line of stroke

2. At any point O on the line of stroke draw a crank OB of length 15cm & $\theta = 45°$.

3. Draw an arc of radius 60 cm to cut the line of stroke.

4. Locate midpoint C on AB at a distance ~~AC~~ $AC = 30\,cm$

Step: 2

Speed of input link $N_{OA} = 300\,rpm$

$$\omega_{OA} = \frac{2\pi N_{OA}}{60} = \frac{2\pi \times 300}{60}$$

$$= 31.42\ rad/s$$

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$V_{OA} = \omega_{OA} \times OA = 31.42 \times 0.15 = 4.713 \text{ m/s}$

Step: 3

1. From any arbitrary point o, draw vector oa perpendicular to OA.
2. The vectors ab & ob intersect at point b

Step: 4

(i) Velocity of slider $V_B = V_{ob}$ = vector ob

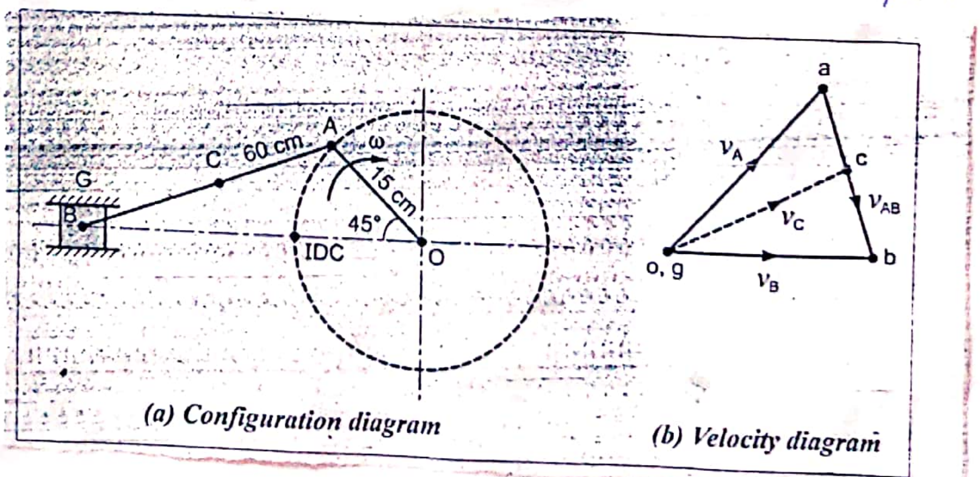
$= 4 \text{ m/s}$

(ii) Angular velocity of connecting rod AB,

$$\omega_{AB} = \frac{V_{AB}}{AB} = \frac{3.35}{0.60} = 5.58 \text{ rad/s}$$

(iii) Velocity of mid-point C, V_c = vector oc

$= 4.1 \text{ m/s}.$



(a) Configuration diagram

(b) Velocity diagram

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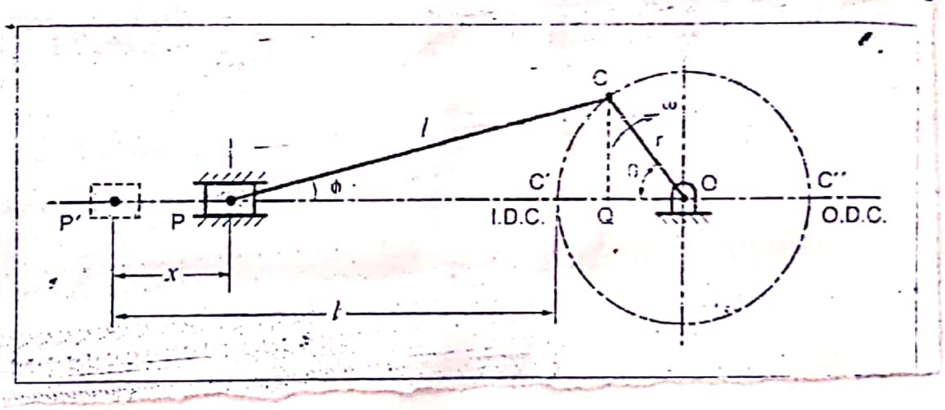
b) By analytical method, derive the velocity and acceleration for the reciprocating steam engine mechanism.

Consider a reciprocating steam engine mechanism OCP. Let crank OC rotates with angular velocity ω rad/s & the connecting rod PC makes angle ϕ with the line of stroke PO.



Let r = Crank radius

l = Length of the connecting rod

θ = Angle made crank with IDC

ϕ = Inclination of connecting rod to the PO.

$n = \frac{l}{r}$

Velocity of the Piston (v_p) :-

$x = P'P = OP' - OP = (P'C' + C'O) - (PQ + QO)$

$PQ = l\cos\phi$, $QO = r\cos\theta$

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$\therefore x = (l+r) - (l\cos\phi + r\cos\phi)$

$= r[(1-\cos\theta) + n(1-\cos\phi)]$

$l\sin\phi = r\sin\theta$

$x = r\left[(1-\cos\theta) + \frac{\sin^2\theta}{2n}\right]$

$V_{PO} = V_P = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2n}\right]$

Acceleration of the Piston. (a_p) :-

$a_p = \omega^2 \cdot r\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$

Angular velocity (ω_{pc}) :-

$CQ = l\sin\phi = r\sin\theta$

$\therefore \sin\phi = \frac{r}{l}\sin\theta = \frac{\sin\theta}{n}$

$$\boxed{\omega_{pc} = \frac{\omega\cos\theta}{(n^2-\sin^2\theta)^{1/2}}}$$

Angular Acceleration of the Connecting Rod (α_{pc}):-

$\alpha_{pc} = \frac{d(\omega_{pc})}{dt}$

$\Rightarrow \frac{d(\omega_{pc})}{d\theta} = \frac{d}{d\theta}\left[\frac{\omega\cos\theta}{(n^2-\sin^2\theta)^{1/2}}\right]$

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$$\boxed{\alpha_{PC} = -\frac{\omega^2 \sin\theta\,(n^2-1)}{(n^2-\sin^2\theta)^{3/2}}}$$

13.(a) A cam is designed for a knife-edge follower with the following data:

(i) cam lift = 40mm during 90° of cam rotation with SHM

(ii) Dwell for the next 30°

(iii) During the next 60° of cam rotation, the follower returns to original position with SHM

(iv) Dwell for the remaining 180°

Draw the profile of the cam when the line of stroke is offset 20mm from the axis of the camshaft.

Soln:

Given data:

$L = 40$ mm

Angle for rise $\theta_0 = 90°$

Angle for dwell $\theta_d = 30°$

Angle for return $\theta_r = 60°$

Radius of base circle $r_b = 40$ mm

$N = 200$ rpm

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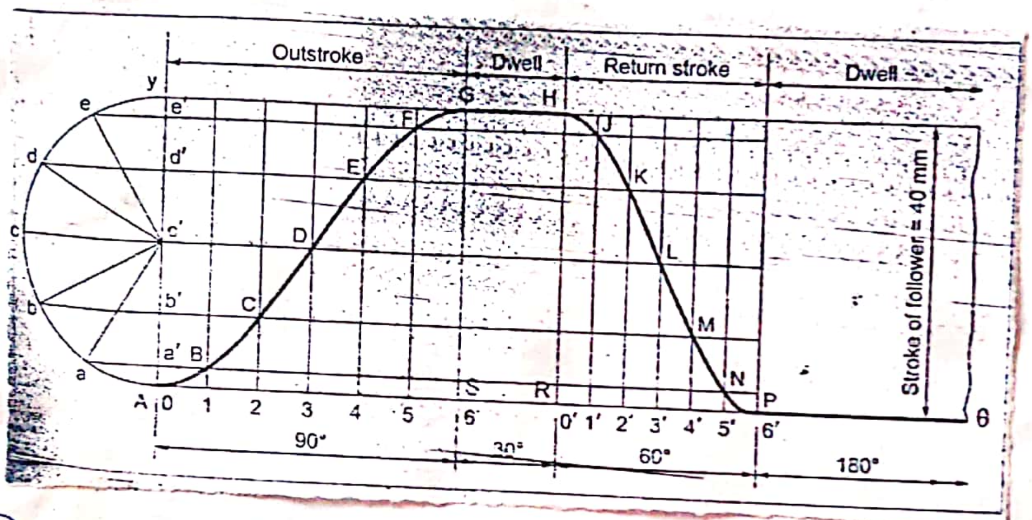
(i) Construction of displacement diagram :

Since the follower is moving with SHM during both outward & return strokes, therefore draw the displacement diagram of the follower.



(ii) Profile of the cam when the axis of follower passes through the axis of camshaft :

The cam profile when the axis of the follower passes through the axis of the camshaft is drawn as shown in fig.

(iii) Maximum velocity & acceleration :

$l = 40\ mm$

$\theta_0 = 90^0 = 90^0 \times \left(\frac{\pi}{180^0}\right)$

$= 1.57\ rad.$

$\theta_r = 1.047\ rad$

$N = 200\ rpm$

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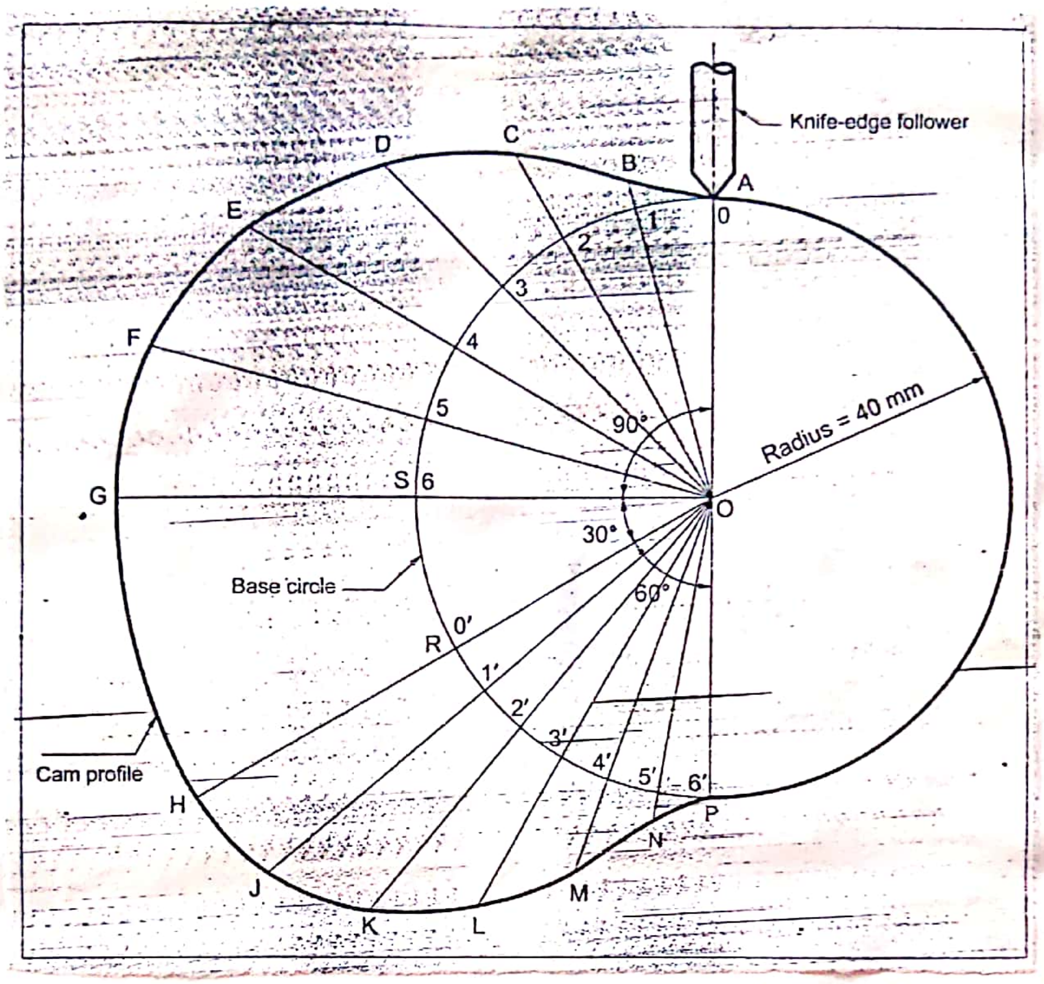
9

Pg : 3.44



Maximum velocity of follower during forward and return strokes :

Maximum velocity during forward stroke,

$$(V_o)_{max} = \frac{\pi L \omega}{2\theta_o} = \frac{\pi \times 0.04 \times 20.94}{2 \times 1.57} = 0.838 \text{ m/s}$$

Maximum velocity during return stroke,

$$(V_r)_{max} = \frac{\pi L \omega}{2\theta_r} = -\frac{\pi \times 0.04 \times 20.94}{2 \times 1.047} = -1256.64 \text{ mm/s}$$

$$= -1.256 \text{ m/s}$$

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Given

Maximum acceleration during forward & return strokes :

$$(a_o)_{max} = \pm \frac{\pi^2 L \omega^2}{2\theta_o^2} = \pm \frac{\pi^2 \times 0.04 \times (20.94)^2}{2 \times (1.57)^2}$$

$$= \pm 35.114 \, m/s^2$$

$$(a_r)_{max} = \mp \frac{\pi^2 L \omega^2}{2\theta_r^2} = \mp \frac{\pi^2 \times 0.04 \times (20.94)^2}{2 \times (1.047)^2}$$

$$= \mp 78.9568 \, m/s^2$$

13. (b) In a cam with translating roller follower, the follower axis is offset to the right of cam hinge by 12mm. The roller radius is 10 mm & the cam rotates in the counter direction. Lay out the rise portion of the cam profile to meet the following specification : Rise takes place during 180° of cam rotation of which for the first 90° the rise is with constant acceleration & the rest is with constant retardation. The lift of the cam is 30 mm & the least radius of cam is 25 mm.

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Given data :

Offset = 12 mm

Radius of roller $r_r = 7.5mm$

$\theta_o = 180°$

$L = 30mm$

$r_b = 25mm$

Soln:

. Construction of displacement diagram :

Since the follower is moving with UARM during both outward stroke, draw the displacement diagram of the follower in fig.

Profile of the cam when the axis of the follower is offset by 12 mm towards the right from the cam axis ;

The cam profile when the axis of the follower is offset from the axis of the camshaft is drawn in fig.

(a) Draw a base circle with minimum radius of the cam with O as centre.

(b) Draw another circle with minimum radius with same centre with radius equal to minimum radius of the cam plus roller radius

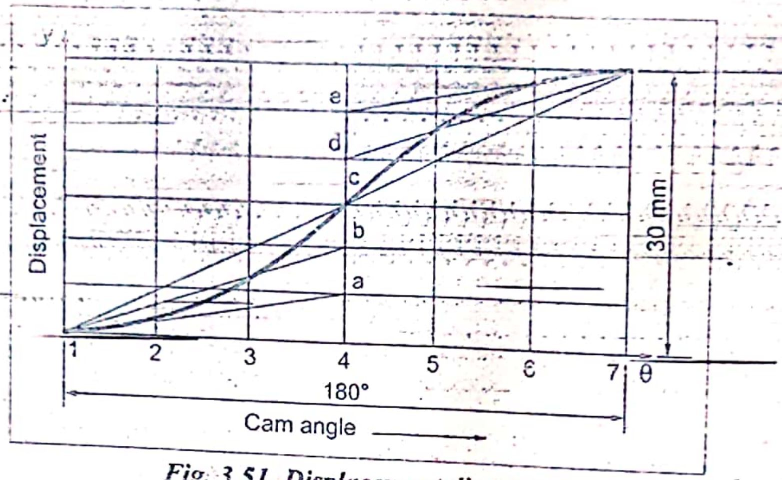
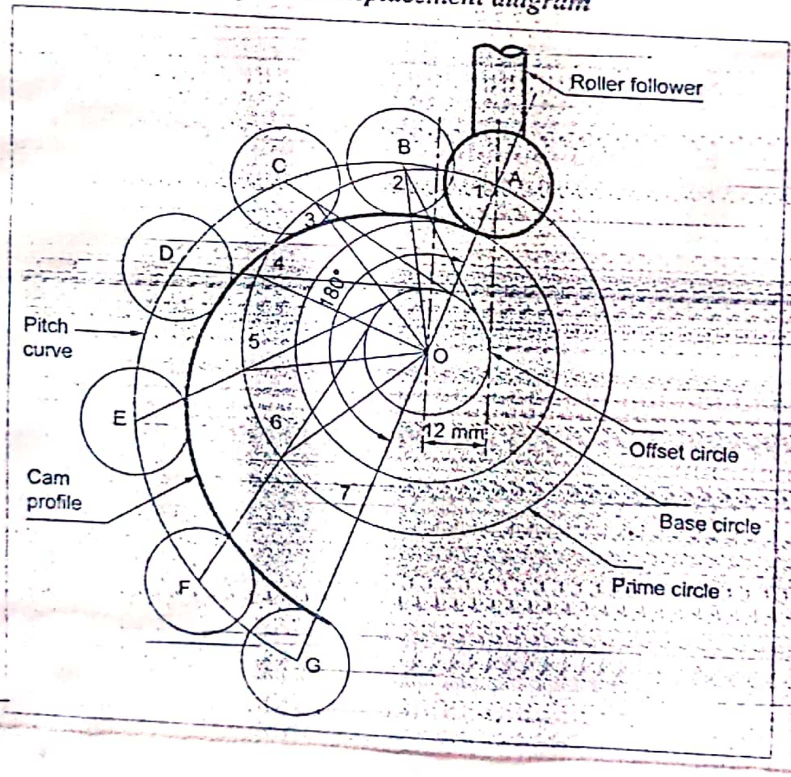


Fig. 3.51. Displacement diagram



(d) Since the axis of the follower passes through the axis of the camshaft, therefore mark trace point A. ~~No~~

(e) Divide cam angles θ_o and θ_r into same number of equal even parts.

Two gear wheels mesh externally to give a velocity ratio of 3 to 1. The involute teeth has 6mm module & 20° pressure angle. Addendum is equal to one module. The pinion rotates at 90 rpm. Determine :

(i) No. of teeth on pinion to avoid interference and the corresponding number on the wheel & arc.

(ii) The length of path and arc of contact.

(iii) contact ratio

(iv) Max. velocity of sliding

Given data : $\frac{\omega_P}{\omega_G} = \frac{T_G}{T_P} = 3$

$m = 6mm$

$a_p = a_w = 1$ module

$\phi = 20°$

$N_P = 90 rpm$

W.K.T $a_w = A_w \cdot m$

$= 1 \times$ module

$\therefore A_w = A_p = 1$

i) No. of teeth on each wheel so that interference is just avoided:

$$T_{G(min)} = \frac{2A_W}{\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2\phi} - 1}$$

$$= \frac{2 \times 1}{\sqrt{1+\frac{1}{3}\left(\frac{1}{3}+2\right)\sin^2 20^\circ} - 1}$$

$= 44.94 \simeq 45$

$$T_p = \frac{T_G}{G} = \frac{45}{3} = 15$$

ii) Length of path of contact :

Pitch circle radii of pinion & gear wheel are given by $r = \frac{mT_p}{2} = \frac{6 \times 15}{2} = 45\,mm$

$$R = \frac{mT_G}{2} = \frac{6 \times 45}{2} = 135\,mm$$

$r_A = r +$ Addendum $= 45 + 6 = 51\,mm$

$R_A = R +$ Addendum $= 135 + 6 = 141\,mm$

$$KP = \sqrt{(R_A^2) - R^2\cos^2\phi} - R\sin\phi$$

$= 15.37\,mm$

$$PL = \sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi$$

$= 13.12\,mm$

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∴ Length of path of contact, $KL = KP + PL$

$$KL = 15.37 + 13.12$$
$$= 28.49 \text{ mm}$$

iii) Maximum velocity of sliding between the teeth :

$$\omega_p = \frac{2\pi N_p}{60} = \frac{2\pi \times 90}{60} = 9.42 \text{ rad/s}$$

$$\text{velocity ratio} = \frac{\omega_p}{\omega_G} = \frac{T_G}{T_p} = 3$$

$$\omega_G = \frac{\omega_p}{3} = \frac{9.42}{3} = 3.14 \text{ rad/s}$$

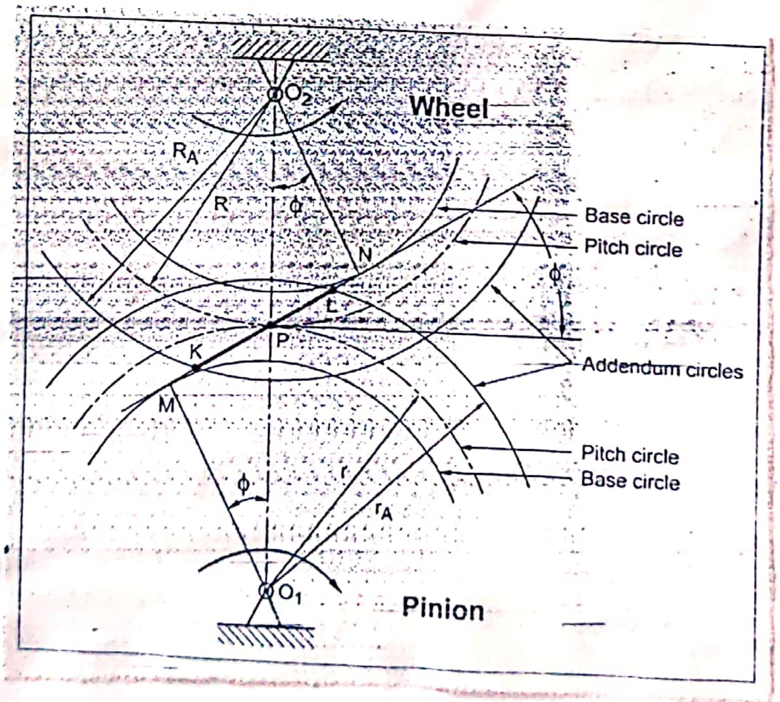
$$V_s = (\omega_p + \omega_G) \times KP$$
$$= (9.42 + 3.14) \times 15.37$$
$$= 0.193 \text{ m/s}$$

14. (b) (i) Derive an expression to determine the length of path of contact between two spur gears of different size.

When the pinion rotates in clockwise direction, the contact between a pair of teeth begins at point K and ends at point L. ∴ the length of path of contact is KL.

* Point K is located on the flank near the base circle of pinion or the outer end of the tooth face on the wheel.

* The point K is the intersection of the addendum circle of wheel & the common tangent. The point L is the intersection of the addendum circle of pinion & the common tangent.



The lengths KP and PL are known as the path of approach & path of recess respectively. The total length KL is called the path of contact

$r = O_1 P$

$R = O_2 P$

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$r_A = O_1L$

$R_A = O_2K$

Radius of base circle of pinion,

$O_1M = O_1P\cos\phi = r\cos\phi$

Radius of base circle of wheel,

$O_2N = O_2P\cos\phi = R\cos\phi$

$KN = \sqrt{(O_2K)^2 - (O_2N)^2}$

$PN = O_2P\sin\phi = R\sin\phi$

$KP = KN - PN$

$\Rightarrow \boxed{KP = \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi}$

$ML = \sqrt{(O_1L)^2 - (O_1M)^2} = \sqrt{r_A^2 - r^2\cos\phi}$

$MP = O_1P\sin\phi = r\sin\phi$

$PL = ML - MP$

$\Rightarrow \boxed{PL = \sqrt{(r_A)^2 - r^2\cos^2\phi} - r\sin\phi}$

~~For~~ Length of path of contact is given by

$\boxed{KL = KP + PL}$

$KL = \left[\sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi\right] + \left[\sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi\right]$

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$$KL = \sqrt{(R_A)^2 - R^2\cos^2\phi} + \sqrt{(r_A)^2 - r^2\cos^2\phi} - (R+r)\sin\phi$$

14. (ii) Briefly explain the sub-classification of compound gear trains with neat sketches.

The compound gear trains can be subdivided into two types :

1. Reverted gear train
2. Non-reverted gear train

* A compound gear train in which the first and last gears are co-axial is called as reverted gear train

* Any compound gear train in which the first and last gears are not co-axial is called non-reverted gear train.

Applications : The reverted gear trains are used in:

→ Automotive gear boxes

→ Lathe back gears

→ Clocks

Train value of reverted gear train is the same as that for the compound gear train.

Train value = $\dfrac{\text{Product of no. of teeth on the drivers}}{\text{Product of no. of teeth on the drivens}}$

$$\left(\frac{N_4}{N_1}\right) = \left(\frac{T_1}{T_2}\right)\left(\frac{T_3}{T_4}\right)$$

where $N_1, N_2, N_3, N_4 \rightarrow$ Speed of the gears 1,2,3,4.

$T_1, T_2, T_3, T_4 \rightarrow$ No. of teeth of the gears 1,2,3,4

$$\boxed{r_1 + r_2 = r_3 + r_4}$$

$r = \dfrac{mT}{2}$ where m is module

$r_1 = \dfrac{mT_1}{2}$; $r_2 = \dfrac{mT_2}{2}$; $r_3 = \dfrac{mT_3}{2}$; $r_4 = \dfrac{mT_4}{2}$

On substituting $\boxed{T_1 + T_2 = T_3 + T_4}$

15) a) Two pulleys, one 450 mm diameter & the other 200 mm diameter are in parallel shafts 1.95 m apart & are connected by a crossed belt. Find the length of the belt req. & the angle of contact between the belt & each pulley. What power can be transmitted by the belt when the larger pulley rotates at 200 rpm, if the max. permissible tension in the belt is 1 kN & the coefficient of friction between the belt & pulley is 0.25 ?

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Given data : $d_1 = 450\,mm$

$r_1 = 0.225\,m$

$d_2 = 200\,mm$

$r_2 = 0.1\,m$

$x = 2.1\,m$

$N_1 = 225\,rpm$

$T_1 = 1\,KN$

$\mu = 0.25$

(i) Length of the belt required (L) :

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

$$= \pi(0.225 + 0.1) + 2 \times 2.1 + \frac{(0.225+0.1)^2}{2.1}$$

$$= 5.271\,m$$

(ii) Power transmitted (P) :

$T_1 = 1000\,N$

$$v = \frac{\pi d_1 N_1}{60} = \frac{\pi \times 0.45 \times 200}{60} = 4.71\,m/s$$

To find θ :

$$\theta = (180^\circ + 2\alpha) \times \frac{\pi}{180^\circ}\ rad$$

$$\sin\alpha = \frac{r_1 + r_2}{x} = \frac{0.225+0.1}{2.1} = 0.1547$$

$$\Rightarrow \theta = (180^\circ + 2 \times 8.9^\circ)\frac{\pi}{180^\circ} = 3.452\ rad$$

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To find T_2 :

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$\frac{1000}{T_2} = e^{0.25 \times 3.452} = 2.37$$

$$\Rightarrow T_2 = \frac{1000}{2.37} = 421.94 \text{ N}$$

To find P :

$$P = (T_1 - T_2)v$$
$$= (1000 - 421.94) \times 4.71$$
$$= \underline{\underline{2.723 \text{ kW}}}$$

15.(b) i) Derive an expression for the effort req. to raise a load with screw jack taking friction into consideration.

If the nut is rotated so that the screw moves against the axial load W, then it is treated as body is moving upwards on the inclined plane.

Gn data : $m = 10$ tonnes

$$W = 10000 \times 9.81 = 98100 \text{ N}$$

$p = 30$ mm ; $l = 1.4$ m

$d = 90$ mm ; $\mu = 0.21$

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Soln: $\tan\alpha = \frac{P}{\pi d} = \frac{0.03}{\pi \times 0.09} = 0.106$

Force to be applied at the end of the lever (P):

$$P = W\tan(\alpha+\phi) = W\left[\frac{\tan\alpha + \tan\phi}{1-\tan\alpha \cdot \tan\phi}\right]$$

$$= 31705 \text{ N}.$$

$$T = P \times \frac{d}{2} = 31705 \times \frac{0.09}{2} = 1426.74 \text{ Nm}$$

∴ Force to be applied at the end of the lever is gn by $F = \frac{T}{l} = \frac{1426.74}{1.4} = \underline{\underline{1019.09 N}}$

Mechanical efficiency (η):

$$\eta_{\text{screw jack}} = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

$$= \frac{0.106}{\tan(6.05^\circ + 11.86^\circ)}$$

$$= \underline{\underline{32.79\ \%}}$$

(ii)(b) A ... press ... by mean ... is ... extern ... the

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A 150mm diameter value, against a steam pressure of 2 MN/m² is acting, is closed by means of a square threaded screw 50mm in external diameter with 6mm pitch. If the coefficient of friction is 0.12. find torque req. to turn the handle.

Soln:

Gin data: $D = 150mm$

$P_{steam} = 2 MN/m^2$

$d_o = 50 mm$

$p = 6mm$

$\mu = \tan\phi = 0.12$

Mean diameter $d = d_o - \frac{p}{2} = 0.05 - \frac{0.006}{2}$

$= 0.04 m$

$\tan\alpha = \frac{p}{\pi d} = \frac{0.006}{\pi \times 0.047} = 0.0406$

$\alpha = 2.33^\circ$

$\mu = \tan\phi = 0.12 \Rightarrow \phi = 6.84^\circ$

Load on the value, W = Pressure × Area

$= P_{steam} \times \frac{\pi}{4} D^2$

$$W = 2 \times 10^6 \left[\frac{\pi}{4} (0.15)^2 \right]$$

$$= \underline{\underline{35343}} \text{ N}$$

$$P = W \tan(\alpha + \phi) = 35343 \tan(2.33° + 6.84°)$$

$$= 5705.33 \text{ N}$$

$\therefore$ Torque req. to turn the handle;

$$T = P \times \frac{d}{2}$$

$$= 5705.33 \left(\frac{47 \times 10^{-3}}{2} \right)$$

$$= \underline{\underline{134.07 \text{ Nm}}}$$

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Friction Clutches:-

* A Friction clutch has its principal application in the transmission of power of shafts and M/c which must be started and stopped frequently.

* Its application is also found in cases in which power is to be delivered to machines partially (or) fully loaded.

* In automobile, friction clutch is used to connect the engine to the driven shaft.

* In operating such a clutch, care should be taken so that the friction surfaces engage easily & gradually brings the driven shaft upto proper speed.

* The proper alignment of the bearing must be maintained and it should be located as close to the clutch as possible.

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Single Disc (or) plate clutch

* A Single disc (or) plate clutch, Consists of a Clutch plate whose both sides are faced with a friction Material.

Consider Uniform Wear

$$T = \frac{1}{2} \mu W (r_1 + r_2)$$

μ = Co-efficient of friction

W = load

r_1 = Ext. radius

r_2 = Int. radius

Consider Uniform Pressure

$$T = \frac{2}{3} \mu W \frac{(r_1^3 - r_2^3)}{r_1^2 - r_2^2}$$

$$P_{max} \cdot r_2 = C$$

$$P_{max} \cdot r_1 = C$$

$$P_{avg} = \frac{W}{\pi (r_1^2 - r_2^2)}$$

Nov 16

1) A leather faced. Conical clutch has a cone angle of 30°. If the intensity of pressure b/w the contact surface is limited to 0.35 N/mm² and the breadth of the conical surface is not to exceed of one third of the mean radius. Det the dimensions of the contact surface to transmit 22.5 kW at 2000 rpm. Assume uniform wear and take co-efficient of friction as 0.15.

Soln:

gn data

Conical clutch

$2\alpha = 30°$

$P = 0.35 \ N/mm^2$

$b = 1/3 \ R.$

$P = 22.5 \times 10^3 W$

$N = 2000 \ rpm$

Assume uniform wear

$\mu = 0.15$

To find

* $r_1, r_2, b = ?$

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$$\boxed{P = \frac{2\pi N T}{60}}$$

$$22.5 \times 1000 = \frac{2 \times \pi \times 2000 \times T}{60}$$

$$T = 107.43 \text{ Nm.}$$

$$\boxed{b = R/3 \qquad \frac{r_1 - r_2}{\sin\alpha} = \frac{r_1 + r_2}{2 \times 3} = \frac{r_1 + r_2}{6}}$$

$$6r_1 - 6r_2 = 0.2588\, r_1 + 0.2588\, r_2$$

$$6r_1 - 0.2588 r_1 = 6r_2 + 0.2588 r_2$$

$$5.741 r_1 = 6.2588 r_2$$

$$r_2 = 0.917 r_1$$

$$\boxed{W = 2\pi C (r_1 - r_2)} \quad \boxed{P_{max} \times r_2 = C}$$

$$= 2\pi \times P_{max} \times r_2 \;\; (r_1 - r_2)$$

$$= 2 \times \pi \times 0.35 \times 10^6 \times 0.917 r_1 \times (r_1 - 0.917 r_1)$$

$$= 167\,291.978\, r_1^2$$

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$$\boxed{T = \tfrac{1}{2}\,\mu W\,(r_1+r_2)\,\mathrm{Cosec}\,\alpha}$$

$$= \tfrac{1}{2} \times 0.15 \times 167291.978 \times r_1^{2} \times (r_1 + 0.914 r_1)\,\mathrm{Cosec}\,\cancel{15}\,20$$

$$107.43 = \cancel{70324.051}\ 92934\ r_1^{3}$$

$\cancel{r_1 = 0.115\,m = 115.17\,mm}$ $\quad r_1 = 104.9$

$r_2 = 96.19$

$\cancel{r_2 = 105.6\,mm}$

24052.9

$$\cancel{b = \frac{r_1 - r_2}{\sin\alpha} = \frac{115.17 - 105.6}{\sin 20^\circ}}$$

$\cancel{b = 27.98\ mm}$

$\cancel{b = \frac{r_1 + r_2}{6} =}$

$r_1 = 0.10495\ m = 104.95\ mm$

$r_2 = 0.096\ m = 96.23\ mm$

$b = R/6 = 33.53\ mm$

(or)

$b = (r_1 - r_2)/\sin\alpha = 33.69\ mm$ //

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Nov 15

1) Soln:
The external and internal radii of a friction plate of a single plate clutch are 120 mm and 60 mm respectively. The total axial thrust with which the friction surfaces are held together is 1500N. For uniform wear, find the maximum, minimum & avg. pressure on the contact surfaces..

Given:

$r_1 = 120\ mm = 0.12m$

$r_2 = 60mm = 0.06m$

$W = 1500N$

Uniform wear,

To find

1) $P_{max} = ?$

2) $P_{min} = ?$

3) $P_{avg} = ?$

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Maximum pr

$P = W/A$

$P_{max} \cdot r_2 = C$

$P_{max} = C/r_2$

$W = 2\pi C (r_1 - r_2)$

$1500 = 2 \times \pi \times P_{max} \times 0.06 \times (0.06)$

$$\boxed{P_{max} = 66348 \ N/m^2}$$

Min pr

$1500 = 2 \times \pi \times P_{min} \times 0.12 \times 0.06$

$P_{min} = 33174 \ N/m^2$

Avg. pr

$$P = \frac{W}{\pi (r_1^2 - r_2^2)}$$

$P = 44232 \ N/m^2$

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April 17:

A single plate clutch transmits 25 kW at 900 rpm. The Max. pr. intensity b/w the plate is 85 kN/m². The Outer dia of the plate is 360 mm. Both the side of the plates are effective and the Coefficient of friction is 0.25. Determine the

(i) Inner radius of the plate

(ii) Axial force to engage the clutch.

Soln:

gn data

$$P_{max} = 85,000 \ N/m^2$$

$$\cancel{r_2} = P = 25,000 \ W$$

$$N = 900 \ rpm$$

$$r_1 = 0.36 \ m$$

$$n = 2.$$

$$\mu = 0.25$$

To find

1) $r_2 = ?$

2) $W = ?$

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$$P = \frac{2\pi N T}{60}$$

$$25{,}000 = \frac{2\pi \times 9000 \times T}{60}$$

$$T = 265.39\,Nm$$

$$T = \frac{1}{2} n \mu W (r_1 + r_2)$$

$$265.39 = \frac{1}{2} \times 2 \times 0.25 \times W(0.36 + r_2)$$

$$W = 2\pi C (r_1 - r_2)$$

$$P_{max} \cdot r_2 = C$$

$$85{,}000 \times r_2 = C$$

$$265.39 = \cancel{\tfrac{1}{2}} \times \cancel{2} \times 0.25 \times 2 \times \pi \times 85{,}000 \times r_2 \, (0.36 - r_2)(0.36 + r_2)$$

$$265.39 = 133450 \times r_2 \, (0.36^2 - r_2^2)$$

$$\cancel{265.39} =$$

$$1.988 \times 10^{-3} = \cancel{r_2\, 0.3}\; 0.1296 r_2 - r_2^3$$

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$\frac{r_2}{2} = 0.36$ m/l.

$N = 2\pi c(r_1 - r_2)$

$= 1868.3 N$.

Screw Friction

Nomenclature :-

1) Helix → It is the curve traced by a particle while describing a circular path at a uniform speed and advancing in the axial direction at a uniform rate.

2) Pitch

It is the distance from a point of a screw to a corresponding point on the next thread, measured parallel to the axis of the screw.

3) Lead.

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$r_2 = 0.35$

$W = 2\pi G\,(r_1 - r_2)$

$= 2 \times \pi \times 85{,}000 \times 0.35 \times 0.01$

$W = 1868.3\ N$

It is the distance, a screw thread advance axially in one turn.

4) Depth of thread:

It is the distance b/w the top and bottom surfaces of a thread

5) Single threaded screw:

If the lead of the screw is equal to th its pitch, it is known as single threaded screw.

6) Multi threaded screw:

If more than one thread is cut in one lead distance of a screw, it is known as multi threaded screw.

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7) Helix angle

It is the slope (or) inclination of the thread with the horizontal.

$$\tan\alpha = P/\pi d$$

$$= nP/\pi d$$

α = helix angle

P = pitch

d = Mean dia. of the Screw

n = No. of threads in one lead.

Types of thread :

1) External thread

2) Internal thread.

Problems:

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1) ② The Cutter of a broaching M/c is pulley by Square threaded Screw of 55mm external diameter and 10mm pitch. The Operating nut take the axial load of 400N on a flat Surface of 60mm internal diameter and 90mm external diameter. If the Coefficient of friction is 0.15 for all Contact Surfaces on the Nut, determine the power required to rotate the Operating nut, when the Cutting speed is 6m/min.

Soln:

Square threaded Screw	Nut
$d_0 = 55mm$	$D_2 = 60mm$
$p = 10mm$	$D_1 = 90mm.$
$W = 400N$	

$\mu = 0.15$

$V = 6m/min$

To find

$P = T\omega$

$\omega = 2\pi N/60$

$= \dfrac{2\pi \times 600}{60}$

$= 62.8\ rad/s$

$, N = \dfrac{\text{Cutting Speed}}{\text{pitch}}$

$= \dfrac{6000}{10}$

$= 600\ rpm$

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$$\boxed{T = P \times d/2 + \mu_1 W R}$$

R = Mean radius of the nut @ collar

(2)

$P = W \tan(\alpha + \varphi)$

$= \cancel{W \left(\frac{\tan\alpha + \tan\varphi}{1 - \tan\alpha \tan\varphi} \right)}$

$\tan\alpha = P/\pi d$

$= \frac{10}{\pi \times}$

$= \cancel{400 \times}$

$= 400 \times (\tan(1.145 + 8.53))$

$d_i = d_o - P/2$

$= 55 - 10/2$

$= 86.4\,N.$

$= 50\,mm$

$R = \frac{R_1 + R_2}{2}$

$\tan\alpha = 10/\pi \times 50$

$\alpha = \cancel{1.145}$ 3..

$\alpha = 3.65$

$= \frac{45 + 30}{2}$

$\mu = \tan\varphi$

$= 37.5\,mm.$

$0.15 = \tan\varphi$

$\varphi = 8.53$

$T = 86.4 \times 25 + 0.15 \times 400 \times 37.5$

$= 4.41\,Nm.$

$P = T\omega$, N = Cutting speed

$= 277\,W.$

$= 6/0.01$

$= 600\,rpm$

Nov 16

(2) The mean dia of the screw jack having pitch of 10mm is 50 mm. A load of 20 kN is lifted through a distance of 170mm. Find the W-D in lifting the load and efficiency of the screw jack when (i) the load rotates with the screw (ii) the load rests on the loose head which does not rotate with the screw. The external & internal diameter of the bearing surfaces of the loose head are 60mm & 10mm respectively. The co-efficient of friction for the screw as well as the bearing surface may be taken as 0.08.

Soln:

Screw jack

$p = 10\,mm$

$d_m = 50\,mm$

$W = 20{,}000\,N$

$S = 170\,mm$

$\mu = 0.08$

Bearing surface

$D_1 = 60\,mm$

$D_2 = 10\,mm$

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i) When the load rotates with the screw

$W = T \times 2\pi N$
Done

$N = 140/10 = 14$ revolutions.

$T = P \times d/2$

$P = W (\tan(\alpha + \phi))$
force

$\tan\alpha = P/\pi d$ $\mu = \tan\phi$

$= \frac{10}{\pi \times 50}$ $\phi = 4°57$

$\alpha = 3.65°$.

$P = 2890N$
Force

~~$W = 2890 \times 2 \times \pi \times 14$~~

$T = 2890 \times 25$

$= 72.25 Nm.$

$W = 4413.4 Nm.$

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$$\eta = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

$$= \frac{\tan 3.65^\circ}{\tan(3.65^\circ + 4.57^\circ)}$$

$= 44.1\%$.

(ii) When the load does not rotate with the screw

$W.D = T \times 2\pi N$

$T = P \times d/2 + \mu_1 W R$

$= \cancel{40.41}\ 72.25 + 0.08 \times 20{,}000 \times 17.5$

$= 100.25$ Nm.

$W.D = 10702$ Nm. //

$$\eta = T_0/T = \frac{W \tan\alpha \times d/2}{100.25}$$

$= 31.8\%$

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3) An electric motor drives power screw moves in a horizontal plane against a force of 75 kN at a speed of 300 mm/min. The screw has a single square thread of 6 mm pitch on a major dia of 40 mm. The coefficient of friction at the screw threads is 0.1. Estimate the power of the motor.

Nov 14 (i)

Soln:

$W = 75,000 N$

$V = 300 mm/min$

$= 0.3 m/min$

$p = 6 mm$

$d_o = 40 mm$

$\mu = 0.15$

To find

1) power = ?

$$\boxed{P = \frac{2\pi N T}{60}}$$

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$$\boxed{N = \frac{\text{Speed of the Nut}}{\text{pitch of the Screw}}} \qquad \frac{mm}{min} \quad \frac{rev}{mm}$$

$$= \frac{300}{6} \quad \frac{mm}{min} \quad \frac{rev}{mm}$$

$= 50$ rpm.

$$\boxed{T = F \times d/2} + \cancel{\mu W R}^{\,0}$$

R = Mean Radius of the Collar

$$\boxed{F = W \tan(\alpha + \phi)}$$

Force req at the Circum of the Screw

d = Mean dia $\boxed{d = d_o - P/2}$

$= 40 - 6/2$

$= 37$ mm

$$\boxed{\tan\alpha = P/\pi d}$$

$= \frac{6}{\pi d}$

$= \frac{6}{\pi \times 37}$

$\alpha = 2.956^\circ$

$F = 75 \times 1000 \times \tan(\ )$

$= 11431.86$ N.

$$\boxed{\mu = \tan\phi = 0.1}$$

$\phi = 5.71$

$T = 11431.86 \times \frac{37}{2000}$

$= 211.48$ Nm.

$P = 1100$ W.

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Apr'17 Soln:

Q) The following data relate to a screw jack.

* Pitch of The threaded screw = 8mm
* Diameter of The threaded screw = 40mm
* Co-efficient of friction b/w screw and nut = 0.1
* Load = 20,000N

Assuming that the load rotates with the screw, determine the

(i) Ratio of torque required to raise and lower the load
(ii) Efficiency of the machine.

Soln:

$p = 8mm$

$d = 40mm$

$\mu = 0.1$ $\qquad \mu = \tan\phi$

$W = 20,000N$ $\qquad \phi = 5.710$

* Torque required to raise the load $\qquad \tan\alpha = P/\pi d$

$\alpha = 3.645$

$T_1 = W(\tan(\alpha + \phi))\, d/2$

$= 20,000 \times \tan(9.355)\, \frac{20}{1000}$

$= 65.86\, Nm.$

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* Torque required to lower the load

$$T_2 = W \tan(\phi - \alpha)\, d/2$$

$$= 14.42 \text{ Nm.}$$

$$T_1/T_2 = 14.42 / 65.80$$

$$= 4.50$$

$$\eta = \frac{\tan \alpha}{\tan(\alpha + \phi)}$$

$$= \frac{\tan 3.645}{\tan 9.35}$$

$$= 38.6\%$$

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b) Soln:

$d_0 = \cancel{45}\ 50\ mm$

$p = 10mm$

$R = 60mm$

$\mu = 0.12$ / $\mu_1 = 0.10$

$W = ?$

$F = 120N$

$d = d_0 - P/2$

$= 50 - 5$

$= 45mm$

$L = 400mm$

$\tan\alpha = P/\pi d$

$F = W\tan(\alpha+\varphi)$

$\tan\alpha = \frac{10}{\pi \times 45}$

$T = F \times d/2 + \mu WR$

$\alpha = 4.0450°$

$\mu = \tan\varphi$

$T = W\tan(\alpha+\varphi) d/2 + \mu WR$

$0.12 = \tan\varphi$

$(120 \times 0.4) \times 2$

$\varphi = 6.84°$

$= W \cdot 0.192 \times 0.0225 + 0.10 \times W \times 0.06$

$= 0.00432W + 0.006W.$

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$$P(120 \times 0.4 \times 2) = W(0.192) \times 0.0225 + 0.10 \times W \times 0.03$$

$$96 = W[0.01032]$$

$W = 13114N$ $\qquad$ $W = 13695N$

$$\eta = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

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Belt, Ropes & Chain Drive:

* The belts (or) ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed (or) at different speeds.

Selection of belt drive:

Following are the various important factors upon which the selection of a belt drive depends

1) Speed of the driving & driven shaft
2) Speed reduction ratio.
3) Power to be transmitted
4) Centre distance b/w the shafts
5) Positive drive requirements
6) Shaft layout
7) Space available
8) Service conditions

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April 16 1) Following data is given for a rope pulley transmitting 24 kW.

* Dia of pully = 40cm
* Speed = 110 rpm
* Angle of groove = 45°, angle of lap = 60°
* $\mu = 0.28$, No of ropes = 10
* Mass in kg/m length of ropes = $53C^2$ kg/m²

and Working tension is limited to $12\ 2C^2$ KN, Where C = girth of rope in cm. Find

(i) Initial tension

(ii) dia of each rope.

Soln:

gn data

$p = 24{,}000\,W$

$d = 400\,mm$

$N = 110$ rpm

Angle of groove, $2\beta = 45°$, $\beta = 22.5°$

$\theta = 160°$.

$180° = \pi$ radi

2.79 radians

$\mu = 0.28$.

$n = 10$.

$m = 53C^2$ kg/m²

$T = 122C^2$ KN, C = girth of rope in m'

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To find

1) $T_1 = ?$
2) $d_1 = ?$

$$P = \frac{\text{Total power transmitted}}{\text{No of ropes}}$$

$$= \frac{24{,}000}{10}$$

$= 2400\ W.$

$$\boxed{V = \frac{\pi d N}{60}}$$

$$= \frac{\pi \times 0.4 \times 110}{60}$$

$= 2.3\ m/s$

$$\boxed{P = (T_1 - T_2) \times V}$$

$2400 = (T_1 - T_2) \times 2.3$

$$\boxed{T_1 - T_2 = 1042.2N}$$

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Also

$$\cancel{2.3 \log} \ln \frac{T_1}{T_2} = \mu \theta \operatorname{cosec} \beta.$$

$$\cancel{2.3 \log} (T_1/T_2) = 0.28 \times 2.8 \times \operatorname{cosec} 22.5^\circ$$

$$\cancel{\log (T_1/T_2)} = \cancel{0.890}. \quad \ln T_1/T_2 = 2.0486$$

Sin θ cosec force

$$\boxed{T_1/T_2 = 7.786}$$

$$7.786 T_2 - T_2 = 1042.2 N$$

$$6.786 T_2 = 1042.2 N$$

$$\boxed{T_2 = 153.8 N}$$

$$\boxed{T_1 = 1195.7 N}$$

Diameter of rope

$$\boxed{T = T_1 + T_c} \quad T_c = mv^2$$

$$122 c^2 \times 10^3 = 1195.7 + mv^2$$

$$122 \times 10^3 \times c^2 = 1195.7 + 53 c^2 \times 2.3^2$$

$$122000 c^2 = 1195.7 + 280.37 c^2$$

$$c = 0.099 m$$

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$\pi \times d_1 = 0.0992$

$d_1 = 31.57 \text{ mm}.$

Q) No 16 :- (Belts)

A Compressor requiring 90 kW to operate at 250 rpm. The drive is by V- belt from an electric motor running at 750 rpm. The dia of the pulley on the Compressor shaft must not be greater than 1m while the Centre distance b/w the pulleys is limited to 1.75m. The belt speed should not exceed 1600m/min. Det the no. of 'V' belts required to transmit the power if each belt has a cross sectional area of 375mm², density 1000 kg/m³ and an allowable tensile stress of 2.5 MPa. The groove angle of the pulley is 35°. The Coefficient of friction b/w the belt and pulley is 0.25. Also Calculate the length of each belt.

Soln:

gn data

$P = 90 \text{ kW} = 90,000 \text{W}$

$N_c = 250 \text{ rpm}.$

V belt

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$N_m = 450 rpm$

$d_c = 1m.$

$x = 1.75 m$

$V = 1000 m/min.$

To find

1) No of 'V' belts = ?

$A = 375 mm^2 = 375 \times 10^{-4} m^2$

$\rho = 1000 kg/m^3$

$\sigma = 2.5 \times 10^6 N/m^2$

$2\beta = 35^0$

$\mu = 0.25$

To find

2) d = ?

* $power = (T_1 - T_2) \times V$

$$\boxed{T_1/T_2 = \mu\theta \cdot \operatorname{cosec}\beta.}$$

$= 0.25 \times$

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$$\boxed{\theta^\circ = 180^\circ - 2\alpha.}$$

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

$\sin \alpha =$

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

$N_c d_c = N_M d_M$

$250 \times 1 = 750 \times d_M$

$d_M = 0.33 m$ //.

$$\sin \alpha = \frac{1 - 0.33}{2 \times 1.75}$$

$\alpha = 11^\circ.$

$\theta = 158^\circ.$

So, $\ln(T_1/T_2) = \mu\theta \operatorname{cosec} \beta$

$\ln(T_1/T_2) \; 0.25 \times \cancel{158^\circ} \; 2.76 \times \operatorname{cosec} 17.5^\circ$

$\ln(T_1/T_2) = 2.295$, $T_1/T_2 = 9.92$ N

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$T = T_1 + T_c$

$\boxed{\begin{aligned} T &= \text{Maximum Tension in the belt} \\ &= \sigma \cdot A \end{aligned}}$

$T = 2.5 \times 10^6 \times 375 \times 10^{-6}$

$T = 937.5\,N.$

$T = 937.5 = T_1 + mv^2$

$\cancel{T_1}$

$m = ?$

$\rho = m/V$

$m = \rho \times A \times L$

$= 1000 \times 375 \times 10^{-6} \times 1$

$m = 0.375\ kg$

$T_c = 267\ N.$

$T_1 = 670.5. \quad , T_2 = 67.59N.$

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$P = 16.07 kW$.

No of 'V' belts = of belt.

Nov 15

3) Determine the Maximum power that can be transmitted using a belt of 100mm x 10mm with an angle of lap of 160°. The density of the belt is 1000 kg/m³ and the co-efficient of friction may be taken as 0.25. The tension in the belt should not exceed 1.5 N/mm²

Soln:

To find

$$P_{max} = (T_1 - T_2) V_{max} = ?$$

Belt, $b = 100mm$

$t = 10mm$

$180° =$

$\boxed{\text{angle of lap, } \theta} = 160°$.

$\rho = 1000 \, kg/m^3$

$\mu = 0.25$

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$\sigma_{max} = 1.5\ N/mm^2$

$T_1/T_2 = e^{\mu\theta}$

$T_{max} = \sigma \times A$

$T_1/T_2 = e^{2.00}$

$= 1500N$

$T_{max} = T_1 + T_c$

$1.5 \times 10^6 = T_1 + mv^2$

$\rho = m/V$

$m = \rho \times V$

$= 1000 \times 0.1 \times 0.01 \times 1$

$= 1kg$

$\cancel{1.5 \times 10^6 = T_1 +}$

$\boxed{T_c = T_{max}/3}$

$T_c = 500N$

$1500 = T_1 + 500$

$\boxed{T_1 = 1000N}$, $T_2 = (500N)$

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$$\boxed{V_{max} = \sqrt{T_m/3m}}$$

$$= \sqrt{1500/3\times1}$$

$$V_{max} = 22.36 m/s.$$

$$P = 11.18 kW.$$

April 15

4) A Flat Belt, 8mm thick and 100mm wide transmits power b/w two pulleys, running at 1600m/min. The mass of the belt is 0.9 kg/m length. The angle of lap in the smaller pulley is 165° & the coefficient of friction b/w the belt & pulley is 0.3. If the max. permissible stress in the belt is 2 MN/m², Find, (i) Max. Power transmitted (ii) Initial tension in the belt.

April 15

Soln:

$t = 8mm$

$b = 100mm$

$V = 1600 m/min$

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$m = 0.9 \ kg/m$

$\theta = 165^{\circ}$.

$\mu = 0.3$

$\sigma = 2 \times 10^{6} \ N/m^{2}$

<u>To find</u>

1) $P_{max} = ?$

2) $T_0 = ?$

$P_{max} = (T_1 - T_2) \ V_{max}$

$T_1/T_2 = e^{\mu\theta}$

$180^{\circ} = \pi$

$$\boxed{T_1/T_2 = 2.372}$$

$T_{max} = \sigma A$

$= 2 \times 10^{6} \times 0.1 \times 0.08$

$$\boxed{T_{max} = 16{,}00N}$$

$T_c = 533.34N$

$T_c = T_{max}/3$,

23 M

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$T = T_1 + T_c$
$\quad m$

$1600 = T_1 + 533$

$T_1 = 1067 N$

$T_2 = 450 N$

$P_{max} = (1067 - 450) \times v_{max}$

$v_{max} = \sqrt{T/3m}$

$= \sqrt{1600/3 \times 0.9}$

$= 24.34 m/s$

$P_{max} = 15.017 kW$

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