- Flywheel
- Governor
- Cams
- Balancing
- Gyroscope.

Single slider crank Mechanism Analysis :- kinematics

m - mass of reciprocating parts

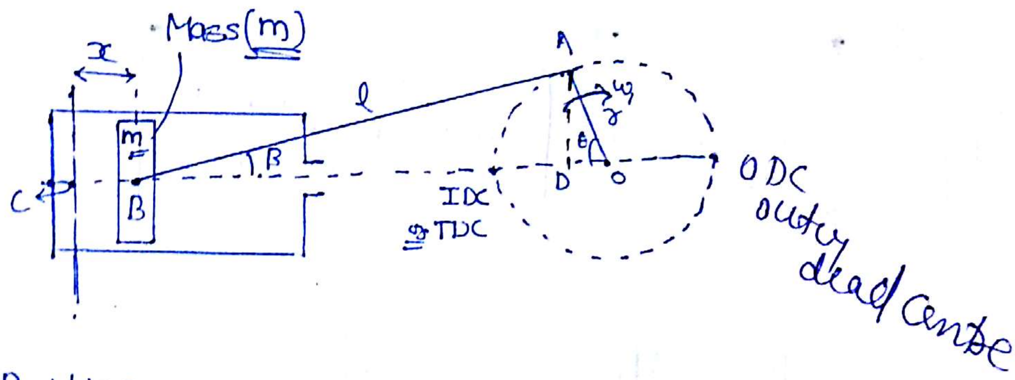
r - crank radius

l - connecting rod length

$n = \frac{l}{r}$ (obliquity ratio)

ω - crank speed

θ - crank angle from TDC/IDC (Top/Inner Dead centre.)



Position

$$x = CB = CO - BO$$

$$x = (r+l) - (BD+DO)$$

$$x = (r+l) - (l\cos\beta + r\cos\theta)$$

AD

$$l\sin\beta = r\sin\theta$$

$$\sin\beta = \frac{r}{l}\sin\theta = \frac{\sin\theta}{n}$$

$$\cos\beta = \sqrt{1-\sin^2\beta} = \frac{\sqrt{n^2-\sin^2\theta}}{n}$$

$$x = r + nr - \left[nr \times \frac{\sqrt{n^2-\sin^2\theta}}{n} + r\cos\theta \right]$$

Piston position

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

$$v = \frac{dx}{dt} = \frac{dx}{d\theta} \times \frac{d\theta}{dt} = \omega r \left[\sin\theta - \frac{(-2\sin\theta\cos\theta)}{2\sqrt{n^2-\sin^2\theta}} \right]$$

$$V = r\omega \left[\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2-\sin^2\theta}} \right]$$

if n is large.

Piston Velocity

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

$$a = \frac{dv}{d\theta} \times \frac{d\theta}{dt} = r\omega^2 \left(\cos\theta + \frac{\cos 2\theta}{n} \right)$$

Piston acc^n

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

Connecting Rod :-

w.r.t. B (pure rotation)

$$\omega_{C.R.} = \frac{d\beta}{dt}$$

$$l \sin\beta = r \sin\theta$$

$$l \cos\beta \cdot \frac{d\beta}{dt} = r \cos\theta \cdot \frac{d\theta}{dt}$$

$$\frac{d\beta}{dt} = \frac{\omega \cos\theta}{n \cos\beta}$$

$$\omega_{C.R.} = \frac{\omega \cos\theta}{n \frac{\sqrt{n^2 - \sin^2\theta}}{n}}$$

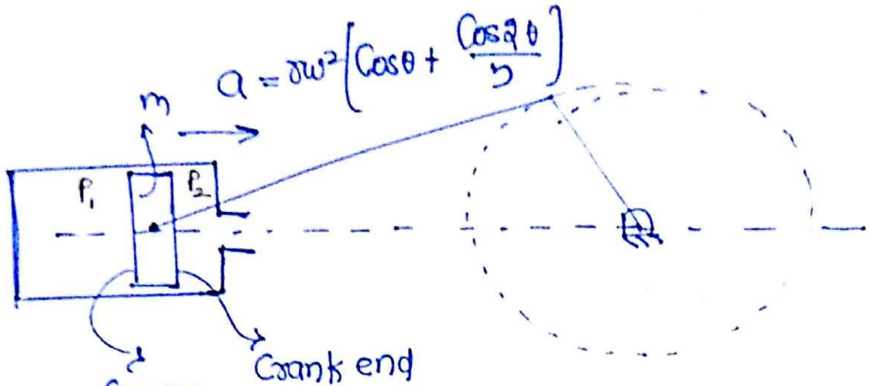
if n is large.

$$\boxed{\omega_{C.R.} = \frac{\omega \cos\theta}{n}}$$

$$\alpha_{C.R.} = \frac{d\omega_{c.r.}}{dt} = \frac{d\omega_{C.R.}}{d\theta} \times \frac{d\theta}{dt}$$

$$\boxed{\alpha_{C.R.} = \frac{-\omega^2 \sin\theta}{n}}$$

Kinetic Analysis of Single - Slider Crank Mechanism :-



m - mass of reciprocating piston

P_1 & P_2 - Pressure of gases on cover end

A_1 & A_2 - Area of piston exposed to gas pressure on Cover end (A_1) & Crank end (A_2)

$$A_1 = \frac{\pi}{4} d^2 \qquad d = \text{Cover dia}$$

$$A_2 = \frac{\pi}{4}\left(d^2 - d_1^2\right) \qquad d_1 = \text{dia of rod.}$$

(i) Piston effort (effective driving Force on Piston) F :

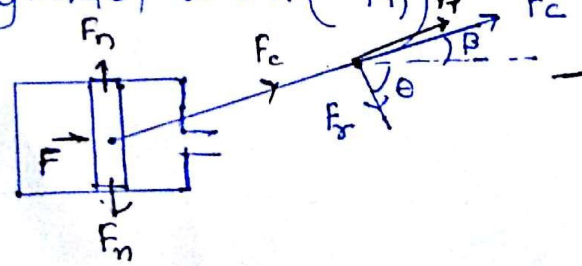
$$F = F_p - ma - f \pm \underbrace{mg}_{\text{in case of vertical}}$$

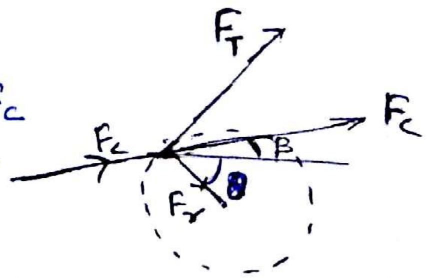
F_p = Net gas pressure force.

$$F_p = P_1 A_1 - P_2 A_2$$

Inertia effort on Connecting rod & Crank are neglected

(ii) Trust on Cylinder walls (F_n)





$$F_c \cos\beta = F \quad \Rightarrow \quad F_c = \frac{F}{\cos\beta}$$

$$F_n = F_c \sin\beta \quad \Rightarrow \quad F_n = F \tan\beta$$

(iii) F_r (Redial thrust on crank bearing)

$$F_r = F_c \cos(\theta + \beta)$$

$$F_r = \frac{F \cos(\theta + \beta)}{\cos\beta}$$

(iv) crank effort $(F_t) \rightarrow$

$$F_t = F_c \sin(\theta + \beta)$$

$$\boxed{F_t = \frac{F}{\cos\beta} \sin(\theta + \beta)}$$

(v) Turning Moment:- M_t

$$M_t = F_t r$$

$$M_t = \left(\frac{F}{\cos\beta} \sin(\theta + \beta)\right) r$$

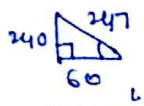
$$\boxed{M_t = \frac{F r \sin(\theta + \beta)}{\cos\beta}}$$

$M_t = F(t)$ because θ also function of time

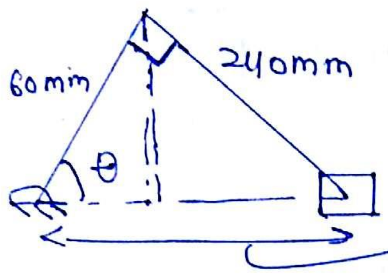
* M_t is varying i.e. why there will be fluctuation in speed. (Thus we need flywheel)

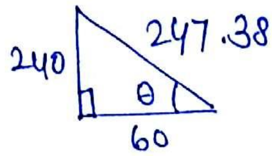
Que A slider crank mechanism with crank radius 60 mm and connection rod length is 240 mm is shown in fig. The crank is rotating with a uniform speed of 10 rad/s, counter c.w. For the given configration the speed in m/s of the slider is.

Sol



$n = \frac{l}{r} = 4$





247.38 mm

$\sin\theta = \frac{240}{247.38}$

$\theta = 75.96^\circ$

$60 \sin\theta = 240 \sin(90-\theta)$

$\tan\theta = 4$

$\theta = 75.96^\circ$

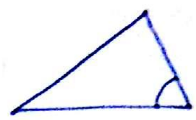
$$V = r\omega\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$$

$$V = \frac{60 \times 10}{1000}\left\{0.97 + \frac{0.470}{2 \times 4}\right\}$$

$$V = 0.617 \text{ m/s}$$

Q In a certain slider crank mechanism, length of c.r. & crank are equal $(l = r)$. if the crank rotate with uniform ro $\omega = 14$ rad/s & $l = 300$ mm the max. accn of of slider is.

1 $$a = r\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$



$$n = 1$$

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

a_{max} when $\theta = 0^\circ$

$$\boxed{a_{max} = r\omega^2\left[1 + \frac{1}{n}\right]} \quad \underline{\underline{n = 1}}$$

$$a_{max} = (0.300)^2 \times 2 \times 14^2$$

$$a_{max} = \underline{\underline{117.6 \text{ m/s}^2}}$$

Q A single cylinder 2-stoke verticle engine. has a bore of 30 cm and stroke of 40 cm ~~ch~~ with a c.r. of 80 cm long. The mass of reciprocating part is 120 kg when piston is a quater stroke & moving down, the pressure on it is 70 N/cm² if the speed of engine crank shaft is 250 rpm (cw). Find turning moment on crank shaft. Neglect mass & Inertia effect on Connecting rod.

Sol^n

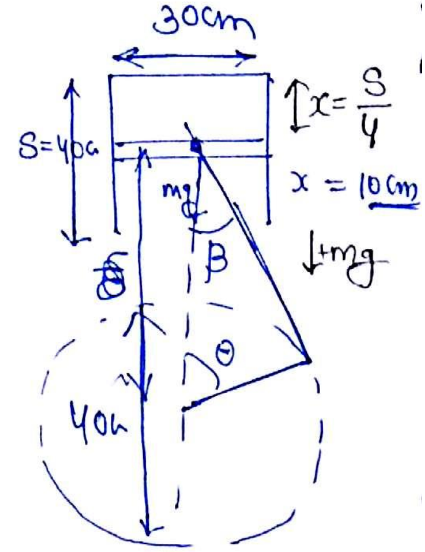
$$F = F_p - ma - f + mg$$

$$F_p = P_1 \times A = P_1 \times \frac{\pi}{4} d^2$$

$$= 70 \times \frac{\pi}{4} (30)^2 \text{ N}$$

$$F_p = 49480.08 \text{ N}$$

$$F_p = \underline{49.48 \text{ KN}}$$



C.r. = l = 80 cm.

S = 40 cm ⇒ r = 20 cm.

m = 120 kg.

P = 70 N/cm^2

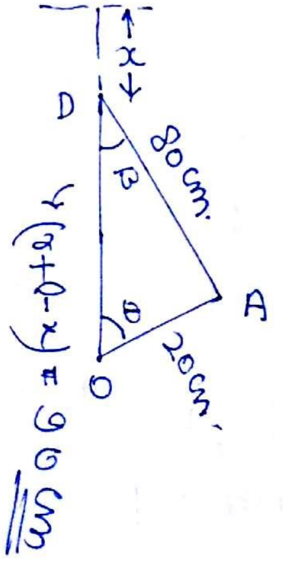
N = 250 rpm

$$\omega = \frac{2\pi \times 250}{60}$$

$$\omega = 26.18 \text{ rad/s}$$

M_t = ?

$$M_t = F_t r = \frac{F r \sin(\theta + \beta)}{\cos\beta}$$



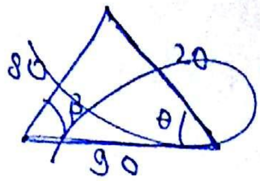
$$OD = OC - CD$$

$$OD = r + l - \frac{S}{4}$$

$$OD = 20 + 80 - 10$$

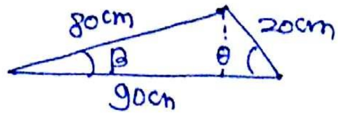
$$OD = \underline{90 \text{ cm}}$$

$$\cos\theta = \frac{(20)^2+(90)^2-(80)^2}{2\times 20\times 90}$$



$$\cos\theta = 0.58$$

$$\boxed{\theta = 54.31^\circ}$$



$$\cos\beta = \frac{(80)^2+(90)^2-(20)^2}{2\times 80\times 90}$$

$$\boxed{\beta = 11.71^\circ}$$

$$\boxed{n = 4}$$

$$a = r\omega^2\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

$$a = (0.20)(26.18)^2\left\{\cos 54.31 + \frac{\cos(2\times 54.31)}{4}\right\}$$

$$a = 69.02\ m/s^2$$

$\Rightarrow$ $ma = 69.02 \times 120$ $\Rightarrow$ $mg = 120 \times 9.81$

$\Rightarrow$ $ma = 8.28\ KN$ $\Rightarrow$ $mg = 1.17\ KN$

$$\boxed{F = 49.48 - 8.28 + 1.17}\ KN$$

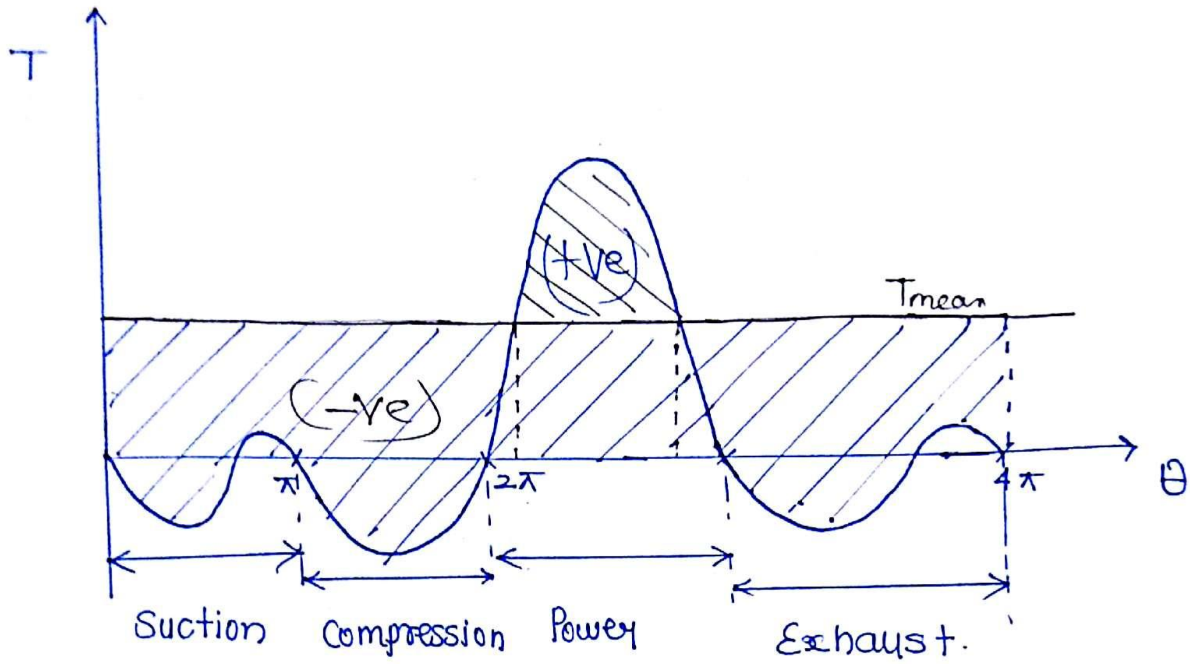
$$F = 42.37\ KN$$

$$M_t = \frac{42.37\times 0.20}{\cos 11.71}\sin(54.31+11.71)$$

$$M_t = 7.90\ KN\text{-}m$$

Turning Moment diagram of 4-stroke ~~an~~ IC engine:

Time period = 4π



$$(W.D.)_{cycle} = \int_0^{T_{period}} T\,d\theta$$

$T - T_{mean} = \pm\alpha$

$$(T_{period})_{4\text{-stroke}} = 4\pi$$ for 4-stroke IC engine.

- During suction after closing of suction valve fuel have some flow energy which ~~mo~~ push down piston below we can say that it is +ve work same during exhaust after closing of exhaust valve ... ...}

Assuming, load ~~or~~ Restoring torque $= T_{mean} = T_{load} =$ Constant

$$T_{mean} \times 4\pi = WD/cycle$$

So

$$\boxed{T_{mean} \times T_{period} = \int_0^{T_{period}} T\,d\theta = (W.D.)_{cycle}}$$