3. THEORY OF MACHINES

UNIT: 1 MECHANISM

Mechanism

Combination of rigid/resistant bodies connected together and it move relative to each other in definite manner.

Machine

It needs input to function.

Engine

Produces its own power.

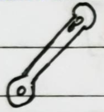
Note:

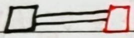
All mechanism is not a machine.

All machine is a mechanism

Link

It is rigid body used to transmit motion.





Single link.

3 Binary link

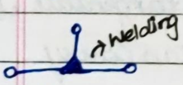
Element(e)

part of link which is connected to neighbour link.

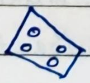
Singular link

Binary link

Ternary link.



Ternary link



quaternary link.

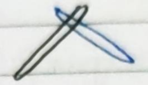
Note:-

* When springs are given in the question remove the spring because spring is not a rigid component. There Springs are not Kinematic links.

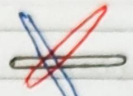
* Belt, rope and chain are considered as a links only in Tension.

Kinematic Joint

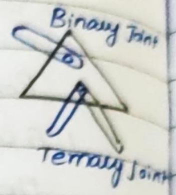
The connection between two links which permits relative motion.



Binary Joint



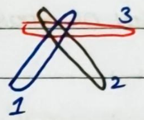
Ternary Joint.



More than 2 binary Joints are known as multiple joints

Kinematic Pair

It is a joint of two links that permits relative motion.



1-2 is a pair.

2-3 is a pair.

1-3 is a pair.

Frame

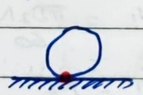
A link which is fixed is called as frame.

Classification of Kinematic pair.

*** Based on Type of contact**

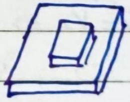
Lower pair - Surface/Area contact

Higher pair - Line/point contact.



a) point contact

High contact Stress

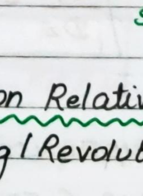


b) Surface contact

Low contact Stress

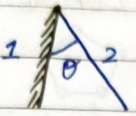
*** Based on Relative motion.**

a) Turning/Revolute/Hinge/pin



connectivity.

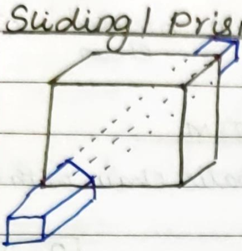
Number of independent Parameters required to Speciby the Position of a Pair.



Connectivity : 1

pair Variable : θ.

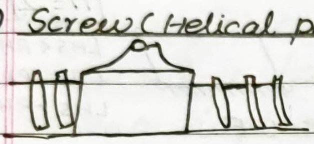
b) Sliding / Prismatic pair.



Connectivity: 1.

Pair Variable: S.

c) Screw (Helical pair)

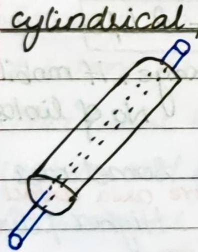


connectivity : 1.

pair variable: S or θ.

S and θ are dependent variable.

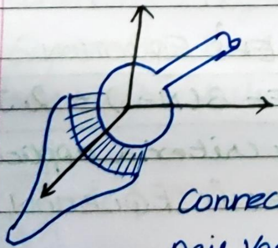
d) cylindrical pair.



connectivity : 2

pair Variable: S, θ.

e) Spherical / Globular pair



Connectivity : 3.

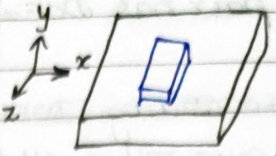
pair Variable: θ_x, θ_y, θ_z.

Eg: Ball & Socket Joint

Car Mirror

Shoulder Joint

f) planar / ~~motion~~ flat pair.



connectivity : 3.

pair Variable: x, z, θ_y.

Eg: Drafter, Duster on board.

PLANAR MOTION

The motion is said to be planar motion only when the member move in a plane (or) move in Parallel to that plane.

eg: Turning pair and sliding pair.

HIGHER PAIR

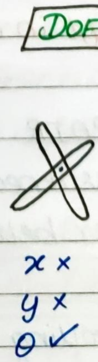
Higher pair is the pair which have line (or) point contact.

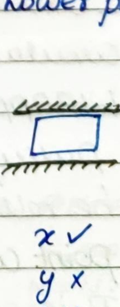
* Gears
* Ball and roller bearing
* Cam
* Rolling
* Pin in slot.

Note:-

Whenever a turning (or) sliding pairs are used (planar) it arrests two motion and permits only one Relative motion.

$\boxed{DOF = 1}$ → Lower pair.





In planar Mechanism, higher pair has DOF = 2.

Note:-

In pure rolling DOF = 1.

Except pure rolling all the higher pair have DOF = 2.

BASED ON CLOSURE

a) Form closed / Self closed.

b) Force closed. (Spring in cam follower)

Note:-

Higher pairs are force closed.

Lower pairs are self closed.

BASED ON MOTION

a) Completely constrained

one input and one output

eg:- Square rod in square hole ← only translate

Shaft with collar → only rotate

b) partially constrained (or) Successfully constrained

When the motion is constrained by any external force.

eg:
- * Foot Step bearing
- * Doctor Syringe
- * piston-cylinder of IC engine

c) Incompletely constrained motion

It has more than one relative motion.

eg:- Circular shaft in a circular hole.

WRAPPING PAIR

Pulley is assumed to be rolling over belt.

point contact.

It is called rolling pair.

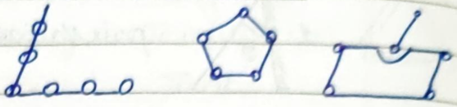
DEGREE OF FREEDOM

Number of independent parameters required to specify the position of the link.

x, y, θ

For planar Mechanism $\boxed{DOF = 3}$

KINEMATIC CHAIN

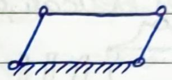


a) open chain b) closed chain c) hybrid chain

MECHANISM

A kinematic chain with one link fixed.

$$\boxed{n = 2j - 4}$$



LHS < RHS [unconstra

LHS = RHS [constrain

LHS > RHS [structure]

LINKAGE

Mechanism consists of only lower pair.

KINEMATICALLY EQUIVALENT

$$\boxed{1\,HP = 2\,LP}$$

For planar linkage, if mobility is even No of links are odd.

Note:-

Lower pair sometimes known as full joint → More area contact. Higher pair sometimes known as half joint.

GRUBLER'S EQUATION

$$\boxed{DOF = 3(N-1) - 2J_1}$$

Grubler criteria applicable when DOF = 1.

KUTZBACH'S EQUATION

$$\boxed{DOF = 3(N-1) - 2\underbrace{J_1}_{\substack{\text{Sliding pair}\\\text{Turning pair}\\\text{Pure rolling}}} - \underbrace{\overset{h}{J_2}}_{\text{higher pair}}}$$

Link: DOF

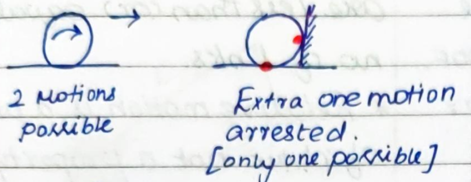
Pair: Connectivity

Chain: Movability

Mechanism: Mobility.

REDUNDANT CONSTRAINT.

No extra movement arrested by drawing another Constraint



This is not redundant constraint

Note:-

Mininum number of link required is four to make a Simple Mechanism

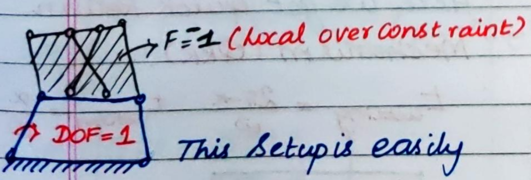
STRUCTURES

$\boxed{DOF = 0}$

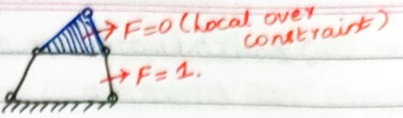
*No input is required to Specify the relative motions.

* Whenever triangle is formed, there will be no-relative motion and it will be consider as a single link.

* When $\boxed{DOF = -1}$ over constrained system. (ie) Super structure. even if one member fails No problem.



This Setup is easily rotatable.



HIGHER ORDER JOINT

$\boxed{\text{1 Ternary Joint = 2 binary joints}}$

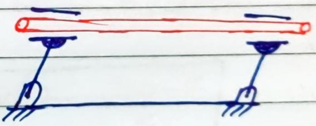
$\boxed{\text{1 quaternary Joint = 3 binary joints}}$

n-link means (n-1) joints.

INCONSISTENCIES IN KUTZBACH EQUATION.

1) Whenever the links are parallel remove one link.(ie) it is redundent link

2) When any one of the link are moved without disturbing the input/output link then that motion is Redundant motion (ie) Redundant DOF



Whenever two slider pairs are parallel it causes unnecessary motion.

3) For cam and follower DOF=1 but it will Show as 2.(ie) Roller can be rotated.

4) Whenever there is closed loop with 3 sliding pair Add +1 with DOF.

B. PAUL EMPRICAL RELATION.

$$\boxed{F = N-(2L+1)}$$

$$\boxed{j = N+L-1}$$

F = DOF

N = No of link

L = No of independent loop

This is applicable only for lower pairs.

4) CONTINUATION OF INCONSISTENCY OF KUTZBACH.

In this mechanism distance between the centre and (radius 1 + radius 2) are same. So add +1 to DOF. We get DOF=0 but answer is DOF=1.

UNIT:2 INVERSIONS OF MECHANIS

SIMPLE MECHANISM.

Four links $N=4$

Degree of Freedom $F=1$.

No higher pair $h=0$.

Note:

*The maximum possible inversions are less than (or) equal to the no of links.

* Relative motion is a property of chain not a property of Mechanism.

GRASHOF LAW

In a four bar Mechanism, if one link has to rotate completely it must be a shortest link.

$$\boxed{S+L \leq P+q}$$

Key points :-

*Shortest link fix: Double crank.

*Adjacent to Shortest fix: crank Rocker.

*opposite to Shortest: Double Rocker.

* There are three distinct inversions are possible in Simple four bar Mechanism.

INVERSIONS OF FOURBAR MECHANISM

(i) When Shortest link is fixed.

* Coupling Rod of Locomotive.

Here we get Quick Return Mechanism (QRR).

$$t_{cutting} = \frac{2\pi-\alpha}{\omega} \quad t_{return} = \frac{\alpha}{\omega}$$

$$\boxed{QRR = \frac{2\pi-\alpha}{\alpha}}$$

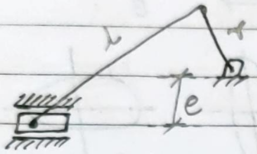
(ii) Adjacent to Shortest fix

- * Wiper Mechanism.
- * Beam engine.
- * Sewing machine.

(iii) opposite to shortest link fix

- * Wall mounted fan.

SINGLE SLIDER CRANK MECHANISM



Grashof law.

[Offset slider-crank] $\boxed{r+e \le l}$ Then only crank will rotate completely.

Inline slider crank → $\boxed{r \le l}$

VERBATUM: What we are getting.

ACTUAL: Modified Mechanism.

INVERSIONS OF SINGLE SLIDER CRANK MECHANISM.

[1st Inversion]

(i) Cylinder fixed. (Crank Rocker)

- * pump/compressor [input to crank]
- * Ic engine [input to slider]

INLINE SLIDER CRANK MECHANISM

- * Stroke length $L_s = 2r$.
- * QRR = 1 [No Quick Return].

OFFSET SLIDER CRANK MECHANISM

* $L_s = \sqrt{(l+r)^2-e^2} - \sqrt{(l-r)^2-e^2}$

* $\boxed{QRR = \frac{180+\alpha}{180-\alpha}}$

Offset slider Crank Mechanism is also Quick Return Mechanism.

[2nd Inversion]

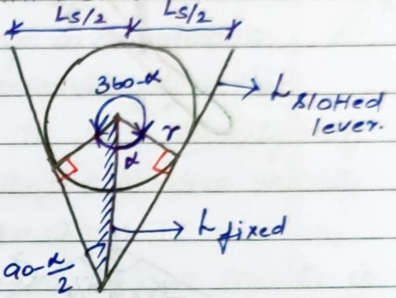
(ii) Slider fixed (Rocker - Rocker)

- * pendulum pump / Hand pump.

(iii) Connecting Rod fixed [3rd Inversion] (Crank - Rocker)

- * Oscillating cylinder engine
- * ~~Whitworth Quick Return mech.~~
- * Crank and slotted lever Mechanism

CRANK AND SLOTTED LEVER MECHANISM



$$\boxed{\cos\alpha/2 = \frac{r}{L_{fixed}}}$$

$$\boxed{\cos\frac{\alpha}{2} = \frac{L_s/2}{L_{slotted\ lever}}}$$

$$\boxed{L_s = \frac{2rL_{slotted\ lever}}{L_{fixed}}}$$

$$\boxed{QRR = \frac{360-\alpha}{\alpha}}$$

Note:

If α is less it is good for QRR. If α is less, r is more. So we get good QRR.

Advantage of More "r".

- * L_s will be more.
- * QRR will be more.

Note:

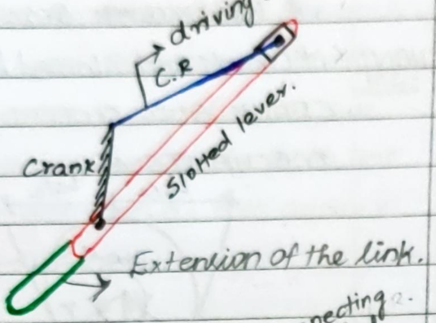
When any link is greater than the sum of other three links then it cannot form a chain.

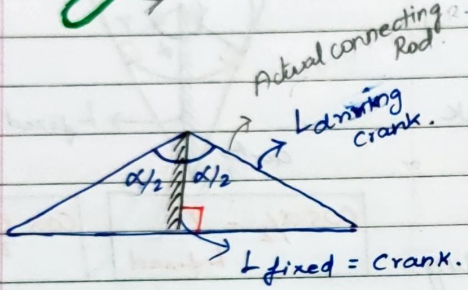
(iv) Crank fixed [IVth Inversion]

↱ Aircraft engine.

* Rotary IC engine/Gnome engine.

* Whitworth Quick Return Mechanism [Shaper Machines]





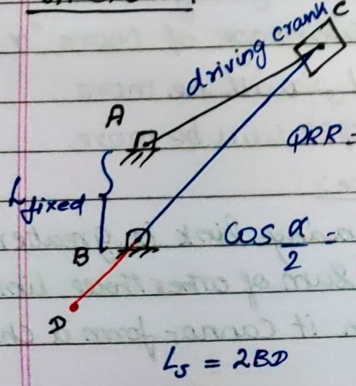
$$\boxed{\cos\frac{\alpha}{2} = \frac{L_{fixed}}{L_{driving\ crank}}}$$

L_s can be increased by increasing extension

(L_s) Stroke length = diameter of the extended link.

$$\boxed{QRR = \frac{360-\alpha}{\alpha}}$$

In exam:



$$QRR = \frac{360-\alpha}{\alpha}$$

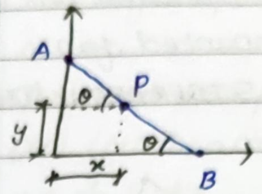
$$\cos\frac{\alpha}{2} = \frac{L_{fixed}\ (\rightarrow AB)}{L_{driving\ crank}\ (\rightarrow AC)}$$

$L_s = 2BD$

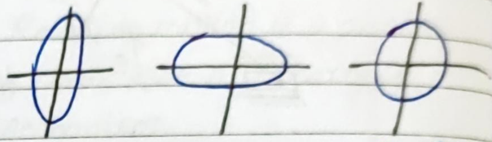
INVERSION OF DOUBLE SLIDER CRANK MECHANISM.

Ist Inversion [Slotted link] fixed

* Elliptical Trammel.



$$\boxed{\frac{x^2}{AP^2} + \frac{y^2}{BP^2} = 1.}$$



AP < BP	AP > BP	AP = BP.
Vertical ellipse	Horizontal ellipse	Circle

A and B trace lines. [1 horizontal 1 vertical]

C trace circle.

All other points trace ellipse.

2nd INVERSION: Slider fixed

* Scotch yoke Mechanism

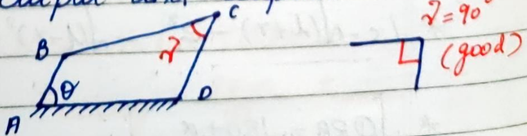
↳ Sine functions.

3rd INVERSION: Link connecting (↗ Shortest link) both slider is fixed.

* Oldham's coupling [Lateral Misalignment]

TRANSMISSION ANGLE.

It is the angle between the output and coupler.



'θ' - Angle between Input and coupler.

When $\theta = 0^\circ$ $\gamma = \gamma_{min}$

When $\theta = 180^\circ$ $\gamma = \gamma_{max}$

Note:-

Generally $\gamma = 90^\circ$ [good] But ±40° is Acceptable.

γ Varies from 50° to 130°

MECHANICAL ADVANTAGE

$$M.A = \frac{F_{out}}{F_{in}} = \frac{V_{in}}{V_{out}}$$

$$M.A = \frac{T_{out}}{T_{in}} = \frac{\omega_{in}}{\omega_{out}}.$$

If η is given

$$M.A = \eta \frac{V_{in}}{V_{out}}$$

$$M.A = \eta \frac{\omega_{in}}{\omega_{out}}.$$

TOGGLE POSITION

(i) Four bar Mechanism.

$\boxed{M.A = \infty}$ $M.A = \frac{T_o}{T_i} = \frac{\omega_i}{\omega_o \to 0}$

It is used to crush Rock.

Toggle position means extreme position of output link.

At toggle position $M.A = \infty$ only when input is crank.

(ii) Slider crank Mechanism.

pump compressor

Input - crank.

$\boxed{M.A = \infty}$ $M.A = \frac{F_o}{F_i} = \frac{V_i}{V_o \to 0}.$

At toggle position $MA = \infty$

I.C engine

Input - Slider.

$\boxed{M.A = 0}$ $M.A = \frac{F_o}{F_i} = 0$

Even if we given input, output(F_o) is zero

This is called as dead point.

UNIT 3 VELOCITY ANALYSIS.

1) Pure translation.

* change in position.

* No change in orientation

* All points have same Velocity

* Velocity Vectors are parallel & equal

* Relative Velocity is zero.

2) pure Rotation

* No change in position

* change in orientation.

* Relative Velocity is there.

Note:-

* Along the link Velocity may present but Relative Velocity must be zero.

* Whenever relative Velocity is present, it is due to Rotation only.

* Relative Velocity is always ⊥.

* Velocity vectors are parallel but not equal.

3) Rotation + Translation

Both position and orientation Changes.

RELATIVE VELOCITY METHOD

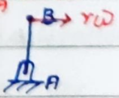
$$\boxed{V_B = V_A + V_{B/A}}$$

Pure Translation

$V_B = V_A$

Pure Rotation.

$V_B = V_{B/A} = r\omega$



Along the link.

$$\boxed{V_A \cos\alpha = V_B \cos\beta.}$$

Perpendicular to the link.

$$V_B \sin\beta = -V_A \sin\alpha + r_{AB}\omega_{AB}.$$

INSTANTANEOUS CENTRE OF VELOCITY (I-CENTRE)

* point where the whole body is assumed to be rotating.

* At Instantanoous centre, Relative velocity is zero. So it is known as instantaneous centre of zero relative velocity.

No of I-centers.

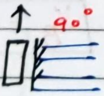
$$\text{No of I-centers} = \frac{n(n-1)}{2}$$

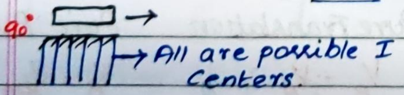
ARONHOLD KENNEDY THEOREM.

If three bodies are in relative motion, then their I-centers must be collinear. (ie) lie on the same line.

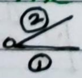
Note:-

* Whenever body is sliding it means it is rotating at infinite. So I-center will be at infinite. Infinite means perpendicular to the stroke length.





* For rotating ~~point~~ body, pin joint will be the I-center.



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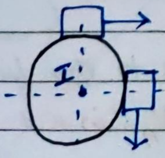

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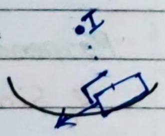


I-CENTRES FOR HIGHER PAIR

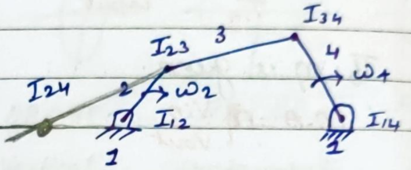
a) pure Rolling (Rolling without slipping)

For pure rolling, contact point is the instantaneous centre.

b) Rolling with slipping

I centre will be at contact point with common normal.

ANGULAR VELOCTTY THEOREM.

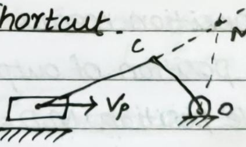


$$\boxed{\omega_2 I_{12} I_{24} = \omega_4 I_{14} I_{24}}$$

* When two bodies rotate in same direction, I center lies outside

* When two bodies rotate in opposite direction. I center lies inside

Shortcut.



$$\boxed{V_P = OM \times \omega_{crank}}$$

Extend coupler and draw perpendicular from fixed to get OM.

VELOCITY OF RUBBING.

$$\boxed{V_{Rubbing} = r_{Pin} \times \omega}$$

3-2-1 Principle.

When 3-2-1 principle is used to support and locate a three dimensional work-piece during machining, the No of degree of freedom that are restricted is 9

3 pins = It arrests 4 Rotation - 1 linear.

2 pins = It arrests 2 Rotation - 1 linear

1 pin = It arrests 1 linear.

UNIT: 4 ACCELERATION ANALYSIS

- Velocity direction will always be in the direction of motion.
- Acceleration direction can be along the direction of velocity (or) opposite to the direction of velocity.

ACCELERATION IN TANGENTIAL DIRECTION.

$$\boxed{a_t = \frac{dv}{dt}}$$

For circular Motion

$$\boxed{a_t = r\alpha}$$

$$a_t = \vec{\alpha} \times \vec{r}.$$

Tangential acceleration is due to change in velocity.

NORMAL / CENTRIPETAL / RADIAL ACCELERATION

$$\boxed{a_n = \frac{v^2}{r}}$$

$$a_n = -\omega^2 r.$$

$$a_n = -\omega^2 \vec{r}.$$

Normal acceleration is due to change in direction. It is directed towards the centre.

UNIFORM CIRCULATION MOTION

Speed is constant.

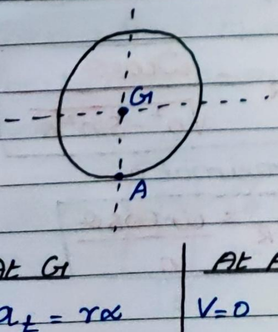
Velocity is changing.

$a_t = 0$ $a_n = v^2/r = \omega^2 r$

TOTAL ACCELERATION

$$a = \vec{a}_t + \vec{a}_n$$

ROLLING WITHOUT SLIPPING.



At G	At A
$V = r\omega$ $a_t = r\alpha$	$V=0$ $a_t = 0$
$a_n = 0$	$a_n = \omega^2 r.$
$a = r\alpha + 0$	$a = \omega^2 r.$

VELOCITY AND ACCELERATION ANALYSIS OF SYSTEMS WITH SIMULTANEOUS ROTATION AND SLIDING.

Acceleration along the link.

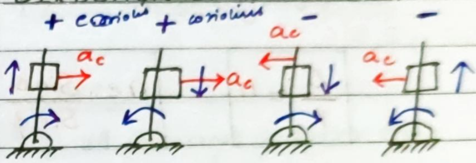
$$a_{\text{along link}} = f - \omega^2 r.$$

↳ Acceleration of slider

Acceleration perpendicular to link

$$a_{\text{perpendicular to link}} = r\alpha + 2v\omega.$$

DIRECTION OF CORIOLIS



- coriolis component is present for Crank and slotted leaver Mechanism.
- In crank and slotted lever Mechanism four times coriolis component will become zero.

KLIEN'S CONSTRUCTION OF VELOCITY AND ACCELERATION

VELOCITY.

The actual velocity triangle has to be rotated by 90° opposite to the sense of ω to get Klein's velocity Triangle.

Factor : ω.

ACCELERATION.

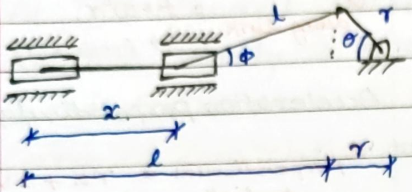
The actual ~~velocity~~ ~~tria~~ acceleration diagram has to be rotated by 180°. to get Klein's acceleration diagram.

Factor : ω^2.

Klien's Construction is used only when crank angular velocity (ω) const.

UNIT-5 KINEMATIC AND DYNAMIC ANALYSIS OF ~~CONNEC~~ SINGLE SLIDER CRANK MECHANISM.

ANALYSIS OF PISTON



obliquity Ratio

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

position equation of piston/ Slider

$$\boxed{x = (l+r) - r\sqrt{n^2 - \sin^2\theta} - r\cos\theta}$$

$x = f(\theta)$ only

Case (i) When $n = 1$. → $l = r$

$$\boxed{x = 2r(1-\cos\theta)} \rightarrow \text{SHM}$$

When $\theta = 0°$ $x = 0$

$\theta = 90°$ $x = 2r$

$\theta = 180°$ $x = 4r$.

$$\boxed{\text{Stroke length} = 4r}$$

(i) Velocity of piston

$$V_p = 2r\omega\sin\theta.$$

(ii) Acceleration of piston

$$a_p = 2\omega^2 r\cos\theta.$$

At $\theta = 0°$	At $\theta = 90°$	At $\theta = 180°$
$V_p = 0$	$V_p = 2r\omega$ → Max.	$V_p = 0$
$a_p = 2\omega^2 r$	$a_p = 0$	$a_p = -2\omega^2 r$

Here acceleration is maximum at both $\theta = 0°$ and $\theta = 180°$.

Case (ii) When $n > 1$ (ie) $\frac{l}{r} > 1$

(Accurate)

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

Approximate analysis.

(i) Velocity of piston

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

(ii) Acceleration of piston.

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

(iii) position of slider.

$$\boxed{x = r(1-\cos\theta)} \quad \text{SHM}$$

When $\theta = 0°$	When $\theta = 90°$
$x = 0$	$x = r$
$V_p = 0$	$V_p = r\omega$
$a_p = \omega^2 r\left[1 + \frac{1}{n}\right]$ → Max	$a_p = -\frac{\omega^2 r}{n}$

When $\theta = 180°$	When $\theta = 270°$
$x = 2r$	$x = r$
$V = 0$	$V = -r\omega$
$a_p = \omega^2 r\left[-1 + \frac{1}{n}\right]$	$a = -\frac{r\omega^2}{n}$

$$\boxed{\text{Stroke length} = 2r}$$

Acceleration is maximum only at $\theta = 0°$. When $n > 1$.

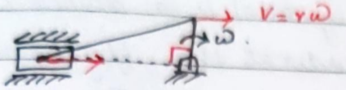
ANALYSIS OF CONNECTING ROD.

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

Approximate.

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

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



$\boxed{V_P = V_c}$

At $\theta = 90°$ velocity is same and direction also same so it is pure translation.

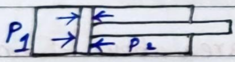
$\therefore \omega_{CR} = 0.$

Note:-

$\omega_{CR} = \frac{\omega \cos\theta}{n}$ $(\omega_{CR})_{max}$ at $\theta = 0°$

$\alpha_{CR} = \frac{-\omega^2 \sin\theta}{n}$ $(\alpha_{CR})_{max}$ at $\theta = 90°$

DYNAMIC ANALYSIS OF SLIDER CRANK MECHANISM.



(i) Gas Force (F_g)

$$F_g = P_1 \frac{\pi}{4} D^2 - \left[P_2 \frac{\pi}{4} D^2 \underset{-}{+} P_2 \frac{\pi}{4} d^2\right]$$

Take P_2 common.

If piston 'd' is not given.

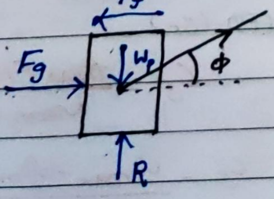
$$F_g = P_1 \frac{\pi}{4} D^2 - P_2 \frac{\pi}{4} D^2$$

(ii) Friction Force (F_f)

Friction Force always opposes the motion.

(iii) Inertia Force ($m_p a_p$)

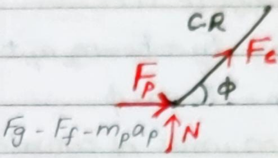
Inertia Force always opposes the motion.



piston effort (F_p)

It is the force which are transmitted from piston to connecting Rod.

$$\boxed{F_p = F_g - F_f - m_p a_p}$$



Horizontal direction

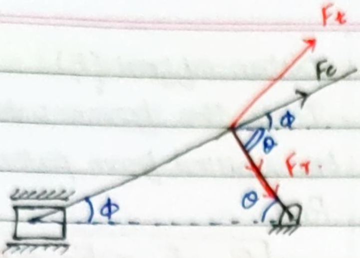
$\boxed{F_p = F_c \cos\phi}$

Vertical direction

$\boxed{N = F_c \sin\phi}$ ↳ Side Thrust.

Note:-

- * F_c is always greater than F_p because of Normal force (ie) side thrust.
- * In horizontal cylinder, Wpiston don't contribute to motion.
- * In vertical cylinder, when piston moves up, Wp opposes motion. When piston moves down, Wpiston supports motion.
- * In the above analysis, mass of the connecting Rod is neglected.



(i) piston effort (Fp)

Vertical cylinder

$F_p = F_g - F_f - m_p a_p \pm mg$

$F_p = F_c \cos\phi$

(ii) Thrust on walls of cylinder (N)

$N = F_c \sin\phi$

(iii) Radial Thrust on bearing (Fr)

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

(iv) crank effort (Ft)

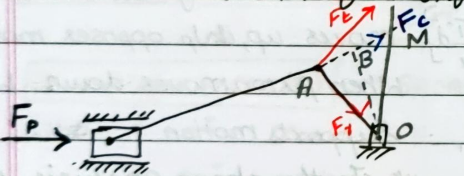
$F_t = F_c \sin(\theta+\phi)$

(v) Turning moment (or) Torque.

$T = F_t \times r = F_c \sin(\theta+\phi)\, r$

$T = \frac{F_p}{\cos\phi} \sin(\theta+\phi)\, r$

Shortcut method to find Torque.



$$\boxed{\begin{aligned} T &= F_p \times OM \\ T &= F_t \times OA \\ T &= F_c \times OB \end{aligned}}$$

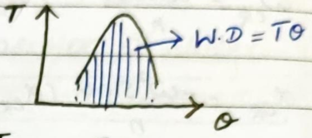
UNIT 6 FLYWHEEL.

Flywheel.

*Flywheel is a device which reduces the flutuations of Speed by increasing "I".

*Fluctuations are more in Single cylinder engine than the multicylinder engine.

* Area under T-θ diagram represents Work Done.



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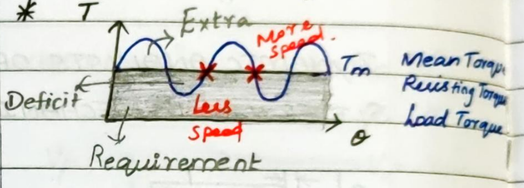


Sum of area above = Sum of area below

MAXIMUM FLUCTUATIONS OF ENERGY

$$\boxed{\Delta E_{max} = \frac{1}{2} \underset{\text{More}}{I} \underbrace{(\omega_{max}^2 - \omega_{min}^2)}_{\text{Less}}}$$

$$\boxed{\Delta E_{max} = I\omega^2 C_s}$$

Flywheel should have high Moment of Inertia (I).

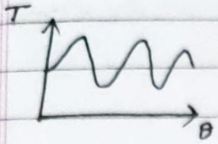
COEFFICIENT OF FLUCTUATIONS OF ENERGY (CE)

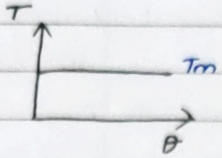
$$\boxed{C_E = \frac{\Delta E_{max}}{W.D/cycle}}$$

COEFFICIENT OF FLUCTUATIONS OF SPEED (Cs)

$$C_s = \frac{\text{Max Fluctuation of Speed}}{\text{Mean Speed.}}$$

$$C_s = \frac{\omega_{max} - \omega_{min}}{\frac{\omega_{max} + \omega_{min}}{2}}$$





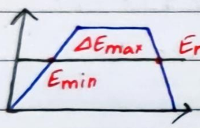
$W.D = \int_0^{\theta_{cycle}} T\,d\theta$ $\quad W.D = T_m \times \theta$

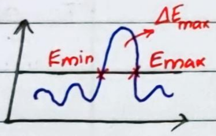
$$\boxed{T_{mean} = \frac{1}{\theta_{cycle}} \int_0^{\theta_{cycle}} T\,d\theta}$$

$$\boxed{Power = T_{mean} \times \omega_{mean}}$$

Note:

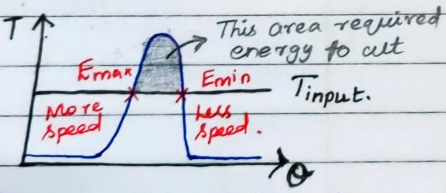
If there is only one area above Tmean. Then those two points are E_{max} and E_{min}. That area will be Max fluctuations of Energy (ΔE_{max}).





FLYWHEEL IN PUNCHING PRESS

In punching press output is varying and input is constant.



FORMULA FOR PUNCHING OPERATION.

PUNCH	CYCLE
θ	θcycle → 360°
t (Punch thickness)	$L_s = 4r$ $\quad 180° \to 2r$ $360° \to 4r.$
T_p	T_{cycle}

$$\boxed{\frac{\theta°}{360°} = \frac{t}{4r} = \frac{T_p}{T_{cycle}}.}$$

The above formula is for Slider crank Mechanism. If nothing is specified.

$$\boxed{\frac{t}{2L_s} = \frac{T_p}{T_{cycle}}.}$$

Note:-

In question if L_s is given take $2L_s$.

Note:-

If in question 30 holes/min is given

1 rotation = 1 hole

30 rotation = 30 hole.

∵ 30 rotation/min = 30 rpm.

DESIGN OF FLYWHEEL

$$\boxed{V = \sqrt{\frac{\sigma_c}{e}}}$$

Every material has some σ_{max}

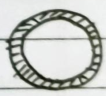
If ω increases, V also increases, so σ_c increases. Here ω is limited to σ_c.

MOMENT OF INERTIA (I)

a) Disc

$I = \frac{mr^2}{2}$

b) Rim



$I = mr^2$

[Good to use as flywheel]