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(2001-2024)

Mechanical Engineering

Paper-I

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Mechanical Engineering : Indian Forest Service Main Examination (Paper-I)

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Preface

B. Singh (Ex. IES)

Our country has a vast forest cover of near about 25% of geographical area and if man doesn't learn to treat trees with respect, man will become extinct; Death of forest is end of our life. Scientific management and judicial exploitation of forest becomes first task for sustainable development.

Engineer is one such profession which has an inbuilt word "Engineer – skillful arrangement" and hence IFS is one of the most talked about jobs among engineers to contribute their knowledge and skills for the arrangement and management for sustainable development

In order to reach to the estimable position of Divisional Forest Officer (DFO), one needs to take an arduous journey of Indian Forest Service Examination. Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

I feel extremely glad to launch the revised edition of such a book which will not only make Indian Forest Service Examination plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years' papers of Indian Forest Service Examination. The book aims to provide complete solution to all previous years' questions with accuracy.

On doing a detailed analysis of previous years' Indian Forest Service Examination question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Services and State Services exams. Hence, this book is a one stop shop for all Indian Forest Service Examination, CSE, ESE and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years' papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

B. Singh

CMD, MADE EASY Group

Previous Years Solved Papers

Indian Forest Service Main Examination

Mechanical Engineering

Paper-I

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SYLLABUS

Paper - I

1. Theory of Machines : Kinematic and dynamic analysis of planar mechanisms, Cams, Gears and gear trains, Flywheels, Governors, Balancing of rigid rotors, Balancing of single and multicylinder engines, Linear vibration analysis of mechanical systems (single degree and two degrees of freedom), Critical speeds and whirling of shafts, Automatic Controls, Belts and chain drives. Hydrodynamic bearings.
2. Mechanics of Solids: Stress and strain in two dimensions, Principal stresses and strains, Mohr's construction, linear elastic materials, isotropy and anisotropy, Stress-strain relations, uniaxial loading, thermal stresses, Beams: Bending moment and shear force diagrams, bending stresses and deflection of beams, Shear stress distribution. Torsion of shafts, helical springs. Combined stresses, thick and thin walled pressure vessels. Struts and columns. Strain energy concepts and theories of failure. Rotating discs. Shrink fits.
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5. MANUFACTURING MANAGEMENT: Production Planning and Control, Forecasting-moving average, exponential smoothing, Operations scheduling; assembly line balancing. Product development, Breakeven analysis, Capacity planning. PERT and CPM. Control Operations: Inventory control-ABC analysis, EOQ model, Materials requirement planning, Job design, Job standards, work measurement, Quality management-Quality control Operations Research: Linear programming-Graphical and Simplex methods, Transportation and assignment models, Single server queuing model.

   Value Engineering: Value analysis, for cost/ value, Total quality management and forecasting techniques. Project management.
6. ELEMENTS OF COMPUTATION: Computer Organization, Flow charting, Features of Common Computer Languages FORTRAN, d Base-III, Lotus 1-2-3, C and elementary programming.

■■■

1 Theory of Machines

1. Analysis of Plane Mechanism

1.1 Single cylinder vertical engine has a bore of 30.5 cm, a stroke of 40 cm, and a connecting rod 80 cm long. When the piston is at its quarter stroke and moving downwards, the net pressure on it is 65 N/cm^2.

(i) If the speed of the engine is 250 rpm and the total equivalent mass of the reciprocating parts is assumed to be 135 kg, find the net-turning moment on the crank-shaft at the above condition without considering the mass of the connecting rod.

(ii) If the actual mass of the reciprocating parts is 90 kg and that of connecting rod is 120 kg, determine the actual turning moment available at the crank-shaft for the same instant. The CG of the connecting rod is 50 cm from the small end and the radius of gyration about its centroidal axis is 30 cm.

(iii) Find out the percentage of error in the approximate calculation as in (i).

[IFS (Mains) 2002 : 10+3+2 = 15 Marks]

Solution:

Given, Cylinder bore, d = 30.5 cm, Cylinder stroke, $l = 2r$ = 40 cm, Length of connecting rod, L = 80 cm

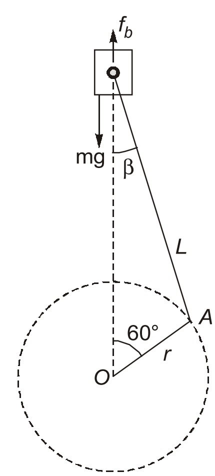
Net pressure on piston at quarter stroke,

$$P_{net} = 65\ \text{N/cm}^2$$

$$n = \frac{L}{r} = \frac{80}{20} = 4$$

$$\text{Engine speed, } N = 250 \text{ rpm} \Rightarrow \omega = \frac{(2\pi N)}{60} = \frac{2\pi \times 250}{60} = 26.179 \text{ rad/s}$$

(i) When the piston is at its quarter stroke and mass of connecting rod is neglected.



$$x = r(1 - \cos\theta)$$

$$\frac{l}{4} = r(1 - \cos\theta) \quad \text{[outer stroke]}$$

$$\frac{2r}{4} = r(1 - \cos\theta)$$

$$\cos\theta = \frac{1}{2}$$

or $$\theta = 60^\circ$$

and $$\sin\beta = \frac{\sin\theta}{4} = \frac{\sin 60^\circ}{4} = 0.2165$$

$$\beta = 12.50$$

$$\text{Force on piston, } f_g = P_{net} \times \left(\frac{\pi}{4} d^2\right) = 65 \times \frac{\pi}{4}(30.5)^2 = 47.49 \text{ kN}$$

Accelerating force/Inertia force, $$f_b = mr\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$f_b = 135\times\left(\frac{20}{100}\right)\times\left(\frac{2\pi(250)}{60}\right)^2\left[\cos 60^\circ + \frac{\cos 120^\circ}{4}\right] = 6.939 \text{ kN}$$

Net force on the piston, $f_p = f_g - f_b + mg = 47.46 - 6.939 + \left(\frac{135\times 9.81}{10^3}\right) = 41.845$ kN

Crank effort, $f_t = \frac{F_p}{\cos\beta}(\sin(\theta+\beta)) = \frac{41.845}{\cos(12.50^\circ)}\sin(12.50^\circ + 60^\circ) = 40.877$ kN

Net turning moment $= f_t \times r = 40.908 \times 0.2 = 8.1812$ kN-m

(ii) ΔT = correction torque

$\Delta T = m_c b\, \alpha_c\, (l - L)$

m_c = mass of connecting rod = 120 kg

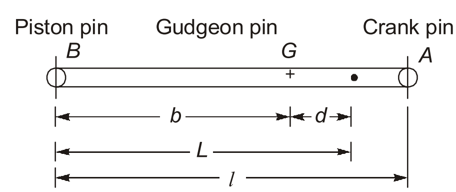
Mass at the crank pin $= 120\times\left(\frac{50}{80}\right) = 75$ kg

Mass at gudgeon pin = 120 – 75 = 45 kg

Total reciprocating mass = 45 + 90 = 135 kg

Inertia force, f_b remains same = 6.939 kN

f_g = 47.46 kN



Torque (T_1) due to net reciprocating masses remains same,

T_1 = 8.1816 kN-m

As, α_c = Angular acceleration of connecting rod

$$\alpha_c = -\omega^2\sin\theta\left[\frac{n^2-1}{(n^2-\sin^2\theta)^{3/2}}\right] = -(26.16)^2\sin 60^\circ\left[\frac{4^2-1}{(4^2-\sin^2 60^\circ)^{3/2}}\right]$$

$$= -(592.96)\times(0.2518) = -149.307 \text{ rad/sec}^2$$

As, $L = b + d$

$L = b + \frac{K^2}{b}$; k = radius of gyration

$$L = 50 + \frac{(30)^2}{50} = 68 \text{ cm}$$

$\Delta T = m\,\alpha_c\, b\,(l - L) = 120 \times (-149.352) \times 0.5\,(0.8 - 0.68)$

$\Delta T = -1.0753$ kN-m

The correction torque (T_c), $T_c = (\Delta T)\frac{\cos\theta}{\sqrt{n^2-\sin^2\theta}} = -1.0753\frac{\cos 60^\circ}{\sqrt{4^2-\sin^2 60^\circ}} = -0.1376$ kN-m

Torque due to weight of mass at crank pin,

$T_3 = m_a g = 75 \times 10 \times 0.2 \sin 60^\circ = 0.129$ kN-m

Net torque (T') on the crank shaft,

$T' = T_1 - T_c + T_3 = 8.1816 - 0.1376 + 0.129 = 8.173$ kN-m

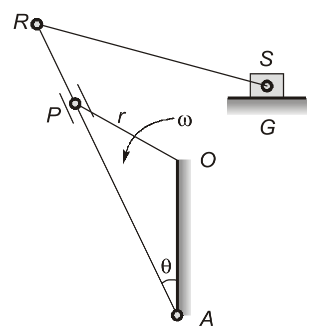
(iii) $$\% \text{ error} = \frac{T'-T}{T}\times 100 = \frac{8.173 - 8.1816}{8.1816}\times 100 = 0.1051\%$$

1.2 A crank and slotted lever quick return motion mechanism has the following specifications :
Distance between fixed centres = 200 mm, Length of the driving crank = 100 mm
Sketch the mechanism. Determine the inclination of the slotted bar with the vertical in the extreme position and the ratio of cutting stroke to return stroke.

[IFS (Mains) 2004 : 10 Marks]

Solution:

Given, A crank and slotted lever mechanism



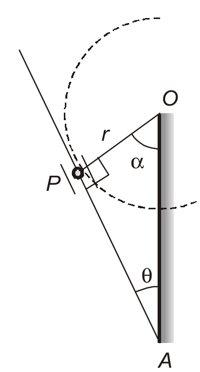
Inclination of slotted bar with the vertical in the extreme position is θ. (say)

Distance between fixed centres, $OA = 200$ mm

Length of crank, $r = 100$ mm

In the extreme position:

From Δ OPA,



$$\cos\alpha = \frac{r}{OA}$$

$$\cos\alpha = \frac{100}{200} = 0.5$$

$$\alpha = 60°$$

and From triangle AOP, $\theta = 90° - 60° = 30°$

The inclination of the slotted bar with the vertical in extreme position = 30°.

And ratio of cutting stroke to return stroke,

$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{360° - 2\alpha}{2\alpha} = \frac{360°}{2\alpha} - 1 = \frac{360°}{120°} - 1 = 2$$

1.3 Derive an expression for the acceleration of the piston of a reciprocating engine. The following details pertain to a single cylinder vertical engine:
Bore = 20 cm, Stroke = 40 cm, Connecting rod length = 80 cm, Mass of reciprocating part = 140 kg, Net gas pressure at the piston when the crank angle is 45° = 65 N/cm^2 and Speed of the engine = 300 rpm.
Determine the turning moment on the crank shaft when the crank angle is 45°.

[IFS (Mains) 2005 : 7+8 = 15 Marks]

or

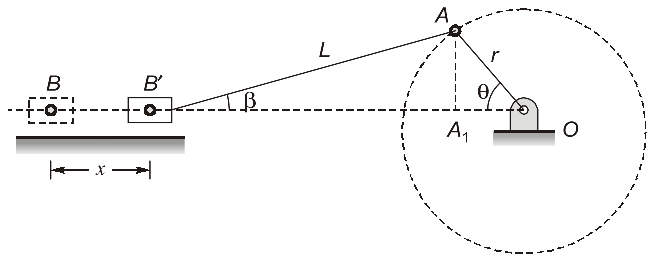
With usual notations show that the velocity of slider of slider-crank mechanism is expressed approximately by

$$V_P = \omega r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$$ where n = Length of the connecting rod/crank radius.

[IFS (Mains) 2008 : 10 Marks]

Solution:

Acceleration of the piston of a reciprocating engine.



$$x = \text{displacement of piston from inner dead centre.}$$

$$x = BB' = BO - B'O = BO - (B'A_1 + A_1O)$$

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

Taking, $(n = L/r)$

$$n^2\cos^2\beta = n^2(1-\sin^2\beta) = n^2\left(1-\frac{AA_1^2}{l^2}\right) = n^2\left(1-\frac{\sin^2\theta}{n^2}\right)$$

$$= n^2 - \sin^2\theta$$

$\Rightarrow$

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

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

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

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

When connecting rod is very large compared to crank, n^2 will be large and

$$\left(\sqrt{n^2-\sin^2\theta}\right) \approx n$$

So,

$$x = r(1-\cos\theta)$$

Now,

$$V = \frac{dx}{dt} = \frac{dx}{d\theta}\times\frac{d\theta}{dt} = \frac{d}{d\theta}\left[r\left\{(1-\cos\theta)+\left(n-\sqrt{n^2-\sin^2\theta}\right)\right\}\right]\frac{d\theta}{dt}$$

$$V = \omega r\left[(0+\sin\theta)+0-\frac{1}{2}(n^2-\sin^2\theta)^{-1/2}(-2\sin\theta\cos\theta)\right]$$

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

If n^2 is large compared to $\sin^2\theta$

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

Acceleration of piston,

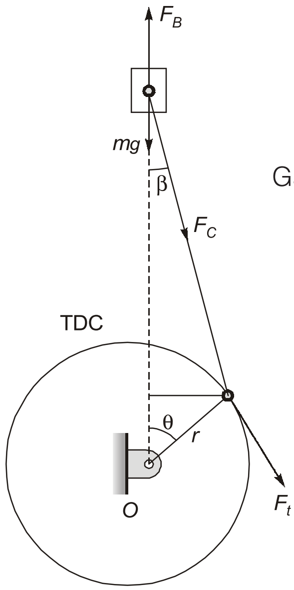
$$a = \frac{dv}{dt} = \left(\frac{dv}{d\theta}\frac{d\theta}{dt}\right) = \frac{d}{d\theta}\left[r\omega\left(\sin\theta+\frac{\sin 2\theta}{2n}\right)\right]\omega$$

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

For the given single cylinder vertical engine:

Bore, $d = 20$ cm, Stroke, $l = 2r = 40$ cm, Connecting rod length, $L = 80$ cm, Mass, $m = 140$ kg

Net piston pressure, P_{net} = 65 N/cm², Engine speed, N = 300 rpm, $r = \frac{\text{Stroke}}{2} = \frac{40}{2}$ = 20 cm



$$\omega = \frac{2\pi N}{60} = \frac{2\pi(300)}{60} = 31.4 \text{ rad/s}$$

$$\text{crank angle, } \theta = 45°$$

$$\text{Gas pressure force, } F_p = P_{net} \times \left(\frac{\pi}{4}d^2\right)$$

$$F_P = (65) \times \frac{\pi}{4}(20)^2 = 20.41 \text{ kN}$$

$$\text{Inertia force, } F_b = mr\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$F_b = 140 \times \left(\frac{20}{100}\right) \times (31.4)^2\left[\cos 45° + \frac{\cos 90°}{4}\right] = 19.52 \text{ kN}$$

F = Net force on the vertical engine piston = $F_p + mg - F_b$

$$F = 20.41 + \left(\frac{140 \times 9.81}{1000}\right) - 19.52 = 2.263 \text{ kN}$$

$$\text{Turning moment, } T = F_t \times r = \frac{F}{\cos\beta}\sin(\theta + \beta) \times r$$

and, $$L \sin\beta = r \sin\theta$$

$$\sin\beta = \frac{\sin\theta}{n} = \frac{\sin 45°}{4} = 0.1767 = 10.182°$$

So, $$T = \frac{2.263 \times 10^3}{\cos(10.182°)}\sin(45° + 10.182°) \times 0.2$$

Turning moment on crank-shaft at 45° crank angle,

$$T = 377.516 \text{ N-m}$$

1.4 (i) In a four-bar mechanism, S and L are the lengths of the shortest and the longest links, P and Q are the lengths of the remaining links. State the condition for at least one link to make a full revolution. Sketch and name the mechanism.

(ii) Define pressure angle in a cam-follower and state its importance. Show it on a sketch.

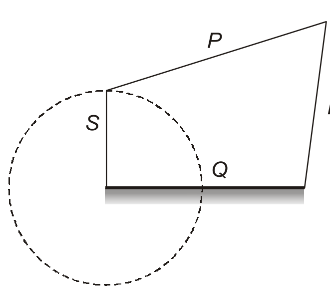
[IFS (Mains) 2007 : 10 Marks]

Solution:

According to Grashof's Law a four-bar mechanism has at least one link to make a full revolution if the sum of the lengths of the largest and the shortest links is less than the sum of lengths of the other two links.

i.e. $$S + L < P + Q$$

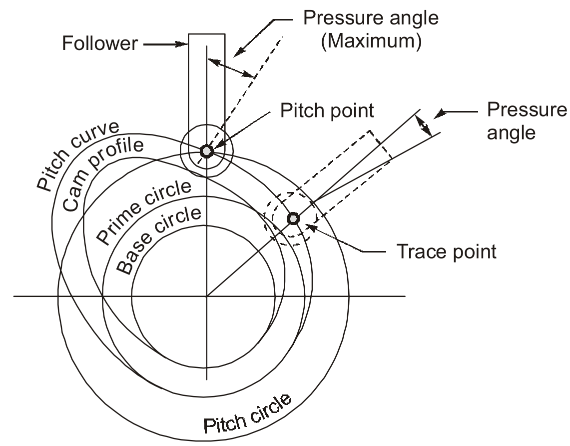
Further, if the link adjacent to the shortest link is fixed, the chain acts as Crank-rocker mechanism in which the shortest link will revolve and the link adjacent to the fixed link will oscillate.



and if the shortest link is fixed, the chain will act as a double-crank mechanism in which the links adjacent to the fixed link will have complete revolutions.

(ii) The pressure angle, representing the steepness of the cam profile, is the angle between the normal to the pitch curve at a point and the direction of the follower motion.

It varies in magnitude at all instants of the follower motion. A high-value of the maximum pressure angle is not desired as it might jam the follower in the bearings. As the pressure angle decreases, it makes the cam surface more convex and longer. This results in reduced velocity of the follower and more time for the same rise. This also reduces the dwell period for a fixed angle of action. Thus the minimum value of pressure angle cannot be reduced from a certain value. The size of the base circle controls the pressure angle. As base circle size increases, pressure angle reduces.



1.5 In a vertical double-acting steam engine running at 360 rpm, the cylinder diameter is 0.3 m, piston rod diameter is 40 mm and length of connecting rod is 0.7 m. When the crank has moved 120° from top dead centre, the pressure of steam at the covered end is 0.35 N/mm² and that at the crank end is 0.03 N/mm². If the weight of the reciprocating parts is 500 N and length of stroke is 300 mm, find: (i) piston effort, (ii) force on connecting rod, and (iii) turning moment on the crank shaft for the given crank position.

[IFS (Mains) 2012 : 10 Marks]

Solution:

Given: Speed, $N = 360$ rpm, $\omega = \frac{2\pi N}{60} = \frac{2\pi(360)}{60} = 37.68$ rad/s

Cylinder diameter, $d_1 = 0.3$ m

$$A_1 = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}(0.3)^2 = 0.07065 \text{ m}^2$$

Piston diameter, $d_2 = 40$ mm

$$A_2 = \frac{\pi}{4}d_2^2 = \frac{\pi}{4}(0.040)^2 = 1.2561 \times 10^{-3} \text{ m}^2$$

Length of connecting rod, $l = 0.7$ m

Crank radius, $r = 150 \times 10^{-3}$ m

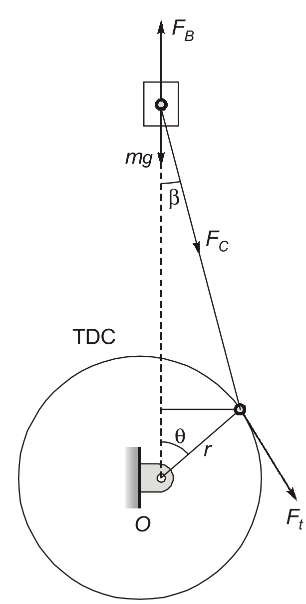
$$n = \frac{l}{r} = \frac{0.7 \times 10^3}{150} = 4.67$$

Pressure at covered end, $P_1 = 0.35$ N/mm²

Pressure at crank end, $P_2 = 0.03$ N/mm²

Weight, $W = 500$ N

$$\text{Mass, } m = \frac{W}{g} = \frac{500}{9.81} = 50.968 \text{ kg}$$



Pressure force on piston, $F_P = P_1A_1 - P_2(A_1 - A_2)$

$$= (0.35 \times 10^6 \times 0.07065) - [(0.03 \times 10^6(0.07065 - 1.256 \times 10^{-3})]$$

$$= 22645.68 \text{ N}$$

$$\text{Inertia force, } F_b = mr\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$F_b = 50.968 \times 0.150 \times (37.68)^2\left[\cos 120° + \frac{\cos 240°}{4.67}\right] = -6589.414 \text{ N}$$

$$\text{Force on piston, } F = F_P + mg - F_b = 22645.68 + 500 - (-6589.414) = 29735.09 \text{ N}$$

$$\text{Piston effort, F} = 29735.09 \text{ N} = 29.735 \text{ kN}$$

$$\text{Force in the connecting rod, } F_C = \frac{F}{\cos\beta}$$

and

$$\sin\beta = \frac{\sin\theta}{n} = \frac{\sin 120°}{4.67} = 0.1854$$

$$\beta = 10.687°$$

$$F_C = \frac{F}{\cos\beta} = \frac{29735.09}{\cos 10.687} = 30.259 \text{ kN}$$

$$\text{Turning moment on crank shaft, } T = \frac{F}{\cos\beta}\sin(\theta+\beta)\times r = \frac{29.735}{\cos 10.687}\sin(10.687+120)\times 0.150$$

$$= 3.44 \text{ kN-m}$$

1.6 In a quick-return motion of the crank and slotted lever type, the ratio of maximum velocities during return and forward motions is 2. If the length of stroke is 250 mm, find:

(i) the length of the slotted lever;

(ii) ratio of times of cutting and return strokes;

(iii) maximum cutting velocity per second if the crank rotates at 30 r.p.m.

[IFS (Mains) 2013 : 10 Marks]

Solution:

Given: Quick-Return motion of crank and slotted lever type.

Ratio of maximum velocities during return and forward motion = 2

$$\frac{V_{S\max}(\text{Return})}{V_{S\max}(\text{Forward})} = \frac{C+r}{C-r} = 2$$

Where,

r = Crank radius

C = Centre distance between fixed centres

So,

$$\frac{C+r}{C-r} = 2$$

$$C + r = 2C - 2r$$

$$3r = C$$

$$\Rightarrow \quad \cos\beta = \frac{1}{3}$$

$$\beta = 70.528°$$

Ratio of times of cutting and return strokes

$$= \frac{2\theta}{2\beta} = \frac{360° - 2\beta}{2\beta} = \frac{360°}{2\times 70.528°} - 1 = 1.552$$

$$\text{Length of stroke, } L_S = 250 \text{ mm}$$

$$\text{Length of the slotted lever, } L = \frac{(L_S/2)}{\sin(90^\circ - \beta)} = \frac{(250/2)}{\sin(90^\circ - 70.528^\circ)}$$

$$= 374.985 \approx 375 \text{ mm}$$

Maximum cutting velocity per second, N= 30 rpm

$$\omega = \frac{2\pi N}{60} = \frac{2\pi(30)}{60} = 3.14 \text{ rad/s}$$

$$(V_{S\max}) = \omega r \times \frac{L}{C+r} = 3.14 \times r \times \frac{375}{3r+r}$$

$$= 3.14 \times \frac{375}{4} = 294.375 \text{ mm/s} = 0.295 \text{ m/s}$$

1.7 A slider-crank reciprocating mechanism has the following data: Radius of the crank = 480 mm, Length of the connecting rod = 1600 mm, Angular velocity of the crank = 20 rad/s. Find the velocity and acceleration of the piston for the crank position of θ = 45° from the inner dead centre.

[(IFS Mains) 2017 : 8 Marks]

Solution:

Given, Radius of crank (r) = 480 mm, Length of connecting rod (l) = 1600 mm, Angular velocity (ω) = 20 rad/s, Crank Position (θ) = 45°

$$\text{Velocity of the piston, } V = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2 - \sin^2\theta}}\right]$$

$$\text{Here, } n = \frac{l}{r} = \frac{1600}{480} = 3.33$$

$\because$ n^2 is large compared to $\sin^2\theta$,

$$\text{Velocity, } V = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2n}\right]$$

$$V = 0.480 \times 20\left[\sin 45^\circ + \frac{\sin 90^\circ}{2 \times 3.33}\right] = 8.23 \text{ m/sec.}$$

$$\text{Acceleration of the piston, } a = r\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right] 0.480 \times (20)^2 \times \left[\cos 45^\circ + \frac{\cos 90^\circ}{3.33}\right]$$

$$= 135.76 \text{ m/s}^2$$

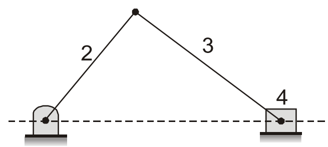
1.8 What do you mean by the inversions of a kinematic chain? List down all the inversions of a single slider-crank chain. Explain briefly any two.

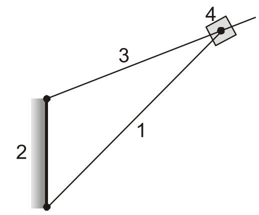
[(IFS Mains) 2018 : 8 Marks]

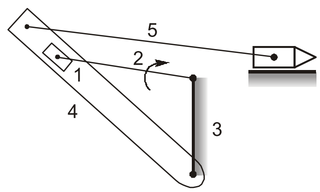
Solution:

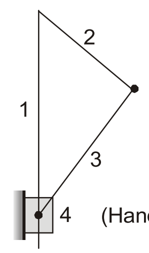
(a) Inversion of a kinematic chain is nothing but different mechanism obtained by fixing different links of the same kinematic chain.

By changing the fixed link, the number of mechanism which can be obtained is equal to the number of links. The inversion of kinematic chain does not change the motion of its links relative to each other.

<table>
<tr><th colspan="2">Single slider crank chain Inversions</th></tr>
<tr>
<td>(i) First inversion (When link 1 is fixed)


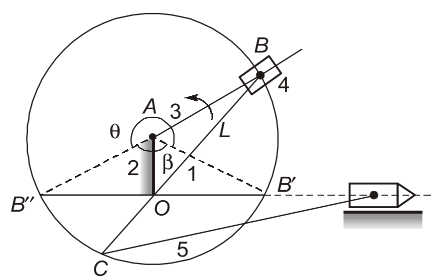
(Reciprocating engine)</td>
<td>(ii) Second inversion (link 2 is fixed)


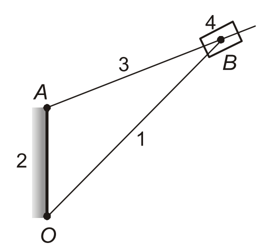
(Whitworth quick return mechanism)</td>
</tr>
<tr>
<td>(iii) Third inversion (link 3 is fixed)


(Crank & slotted lever mechanism)</td>
<td>(iv) Fourth inversion (link 4 is fixed)


(Hand pump)</td>
</tr>
</table>

- Second inversion (Whitworth quick return mechanism).

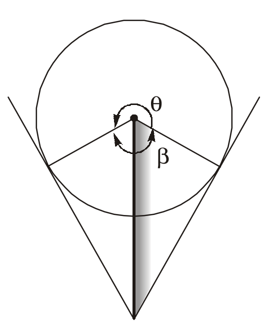


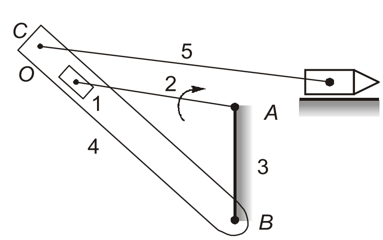


This mechanism is used in workshops to cut metals.
Slider 4 rotates in a circle about *A* and slider on link 1. *C* is a point in link 1 extended backwards where link 5 is pivots. The other end of link 5 is pivoted to the tool, the forward stroke of which cuts the metal.

$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\theta}{\beta}$$

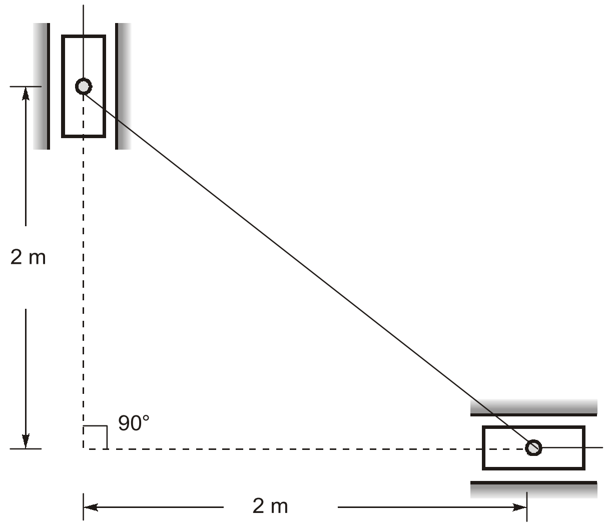
- Third inversion (Crank and slotted lever mechanism).





If the cylinder of an oscillating cylinder engine is made in the form of a guide and the piston in the form of a slider, then crank and slotted lever mechanism is obtained.

1.9 State Kennedy's theorem. Locate all the instantaneous centres for the following mechanism:

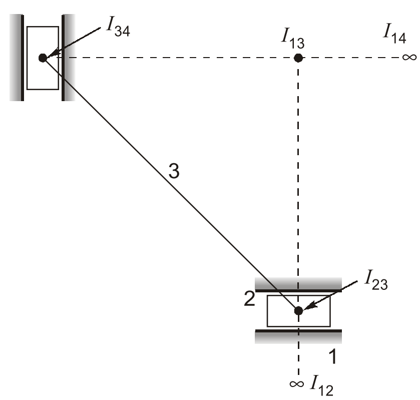


[(IFS Mains) 2018 : 8 Marks]

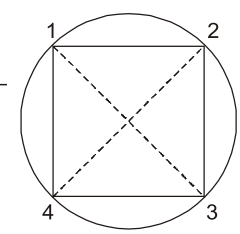
Solution:

- **Kennedy's Theorem**: According to Kennedy's theorem if three planer bodies have relative motion among themselves, then their I-centres must lie on a straight line.
  Total number of links of given mechanism, $n = 4$

  Total number of instantaneous centres, $N = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$



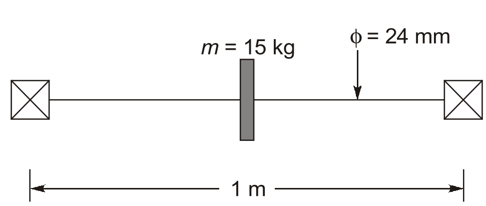
Links	1	2	3	4
	12	23	34	—
	13	24		
	14			



1.10 A rotor has a mass of 15 kg and is mounted midway on a 24 mm diameter horizontal shaft supported at the ends by two bearings. The bearings are 1 m apart. The shaft rotates at 2500 rpm. If the centre of mass of the rotor is 0.11 mm away from the geometric centre of the rotor due to a manufacturing defect, find the amplitude of the steady-state vibration and the dynamic force transmitted to the bearing. Take Young's modulus (E) = 210 GPa.

[(IFS Mains) 2020 : 10 Marks]

Solution:



Given: $N = 2500$ rpm, $E = 210$ GPa, $e = 0.11$ mm

For simply supported beam:

$$\omega_n = \sqrt{\frac{g}{\delta}} = \sqrt{\frac{g}{\frac{(mg)L^3}{48EI}}}$$

$$= \sqrt{\frac{48gE\frac{\pi}{4}D^4}{mgL^3}} = 104.615 \text{ rad/s}$$

$$A = \frac{e}{\left(\frac{\omega_n}{\omega}\right)^2 - 1} = \frac{0.11}{\left(\frac{104.615}{26.18}\right)^2 - 1} = -0.1309 \text{ mm}$$

-ve sign shows that deflection is out of phase of centrifugal force.

$$\text{Dynamic load on each bearing} = \frac{m\omega_n^2 A}{2} = \frac{kA}{2} = \frac{15(104.615)^2}{2} \times \frac{(0.1309)}{1000}$$

$$F_D = 21.49 \text{ N}$$

2. Cams

2.1 What is the function of a follower in a cam-follower pair? Sketch any four different types of follower.

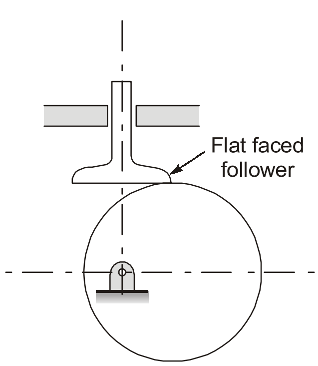
[IFS (Mains) 2005 : 8 Marks]

Solution:

In a cam-follower pair, a cam is generally the driver and follower is a driven member which is specially designed to follow cam profiles. The follower motion may be rotating, reciprocating or oscillating. A cam imparts desired motion to the follower by direct contact. The output followers motion is then used to serve different purposes like operating valves in IC engines, machine tools, printing control mechanism, etc.

Different types of followers:

1. Flat - faced followers



2. Spherical faced followers