IPS Academy, Institute of Engineering & Science

Department of Mechanical Engineering
Theory of Machines Lab

Laboratory Incharge

Prof. Sharad Shukla

Laboratory Technician

Mr. Suraj Kalsekar

List of Equipments with Price

S. No.	List of Equipments	Date	Price (in Rs.)
1.	Motorized Gyroscope with Digital Tachometer	12/01/2015	18375/-
2.	Scotch Yoke Mechanism	12/01/2015	1500/-
3.	Cam Profile Analyzer	12/01/2015	19125/-
4.	Coriolli's Component of acceleration apparatus	12/01/2015	36375/
5.	Epicycle gear train	12/01/2015	34125/-
6.	Model of Inversion of 4k-bar Mechanism	16/08/2015	6500/-
7.	Model of Differential Gear Mechanism	16/08/2015	5500/-
8.	Different types of Cams Model (Set of Six)	16/08/2015	4500/-
9.	Different types of Followers Model	16/08/2015	4000/-
10.	Differential Gear Assembly (Actual Cut Section)	16/08/2015	5500/-
11.	Gear set of 4	16/08/2015	5500/-
12.	Gear set of 8	16/08/2015	10500/-
13.	Rack & Pinion Gear	16/08/2015	1000/-
14.	Epicycle Gear	16/08/2015	1650/-
15.	Epicyclic Gear(Sun & Planet Type)	16/08/2015	3250/-
16.	Cyclodial Gear	16/08/2015	1750/-
17.	Reversing Gear	16/08/2015	3000/-
18.	Worm Gear	16/08/2015	1200/-

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LAB MANUAL

Theory of Machines

IPS Academy, Indore

Institute of Engineering & Science

Mechanical Engineering Department

LAB MANUAL

Theory of Machines

(ME-403)

Name ……………………………………………….

Session ……………**Semester** …………………….

Enrollment No. ……………..

Contents

Vision of the Institute

To be the fountainhead of novel ideas & innovations in science & technology & persist to be a foundation of pride for all Indians.

Mission of the Institute

M1: To provide value based broad Engineering, Technology and Science where education in students are urged to develop their professional skills.

M2: To inculcate dedication, hard work, sincerity, integrity and ethics in building up overall professional personality of our student and faculty.

M3: To inculcate a spirit of entrepreneurship and innovation in passing out students.

M4: To instigate sponsored research and provide consultancy services in technical, educational and industrial areas.

Vision of the Department

To be a nationally recognized, excellent in education, training, research and innovation that attracts, rewards, and retains outstanding faculty, students, and staff to build a Just and Peaceful Society.

Mission of the Department

M1: Imparting quality education to the students and maintaining vital, state-of-art research facilities for faculty, staff and students.

M2: Create, interpret, apply and disseminate knowledge for learning to be an entrepreneur and to compete successfully in today's competitive market.

M3: To inculcate Ethical, Social values and Environment awareness.

Program Education Objectives (PEOs)

PEO1: To enrich graduates with fundamental knowledge of Physics, Chemistry and advanced mathematics for their solid foundation in Basic Engineering science.

PEO2: To provide graduates to design the solution of engineering problems relevant to mechanical engineering design through the process of formulating, executing & evaluating a design solution as per need with socio-economic impact consideration and related constraints.

PEO3: To provide graduates with experience in learning and applying tools to solve theoretical and open ended mechanical engineering problems.

PEO4: To provide a contemporary grounding in professional responsibility including ethics, global economy, emerging technologies and job related skills such as written and oral communication skills and to work in multidisciplinary team.

PEO5: Prepare graduates to be interested, motivated, and capable of pursuing continued life-long learning through beyond curriculum education, short term courses and other training programme in interdisciplinary areas.

Program Outcomes (POs)

Engineering Graduates will be able to:

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of Mechanical engineering problems.

PO2: Problem analysis: Identify, formulate, and analyze mechanical engineering problems to arrive at substantiated conclusions using the principles of mathematics, and engineering sciences.

PO3: Design/development of solutions: Design solutions for mechanical engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: An ability to design and conduct experiments, as well as to analyze and interpret data.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to mechanical engineering problems with an understanding of the limitations.

PO6: The engineer and society: Apply critical reasoning by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the Mechanical engineering practice.

PO7: Environment and sustainability: Understand the impact of the Mechanical engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: An understanding of professional and ethical responsibility.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO10: Communication: Ability to communicate effectively. Be able to comprehend and write effective reports documentation.

PO11: Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply this to Mechanical engineering problem.

PO12: Life-long learning: ability to engage in life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO1: Engage professionally in industries or as an entrepreneur by applying manufacturing and management practices.

PSO2: Ability to implement the learned principles of mechanical engineering to analyze, evaluate and create advanced mechanical system or processes.

Course Outcomes (COs)

CO1 Define the basics of mechanism and their inversions and able to show the displacement, velocity and acceleration in different mechanisms.

CO2 Apply different principles and methods for kinematic and dynamic analysis of mechanisms.

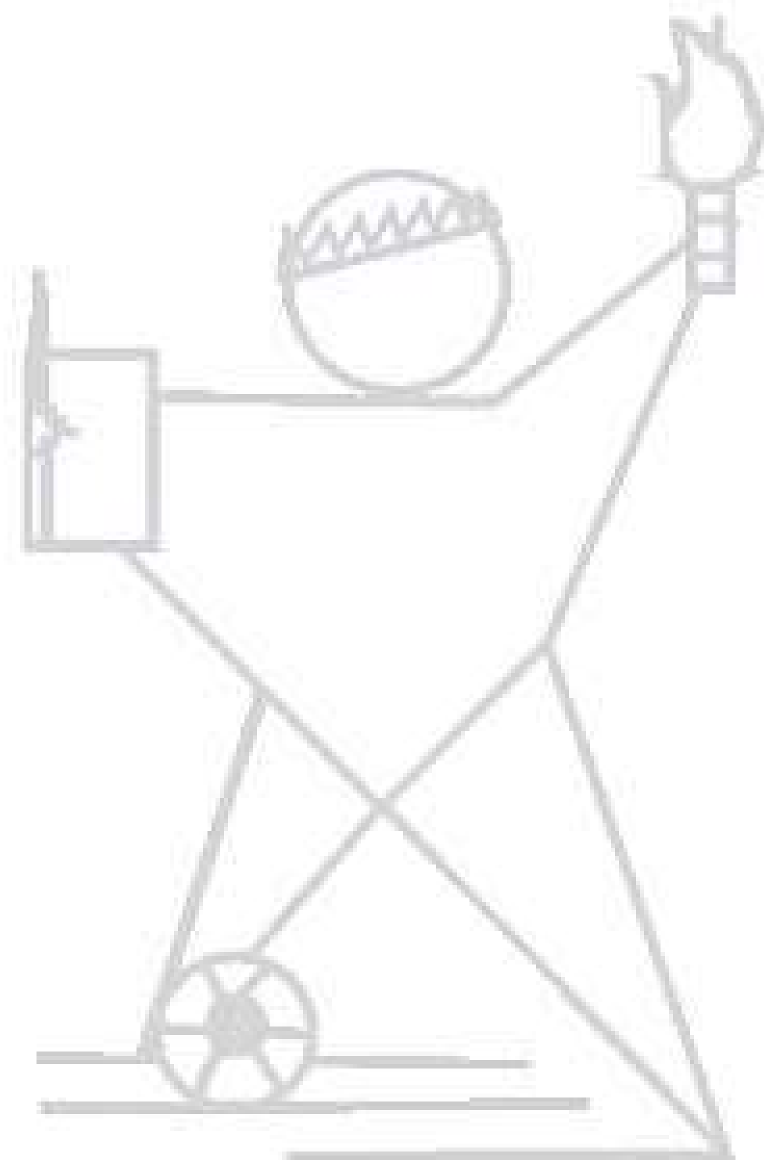
CO3 Classify cams and followers & analyze the cam design.

CO4 Elaborate different modes of power transmission and use of friction in power transmission.

CO5 Classify different types of gears and evaluate their working in various gear trains. Also make use of balancing and vibration in mechanical systems.

Content beyond syllabus

1. To draw the profiles of involute spur gear by generating method.
2. Experimental justification of the equation $T = I \times \omega \times \omega_P$ for calculating the gyroscopic couple by observation and measurement of results for independent variation in applied couple C and precession ω_p.



Laboratory Regulations and Safety Rules

1. Read the instructions mentioned in the manual carefully and then proceed for the experiment.
2. Mishandling of lab equipment will not be tolerated at all. If any student is found guilty; he/she should be punished/ discarded from the lab.
3. Care must be taken while dealing with electrical connections.
4. Issued the needed/ supporting equipments by the concerned teacher/lab.technician & return the same duly before leaving the lab.
5. If any defect or discrepancy noticed in the particular instrument/equipment while the students are using, they will be fined/ punished for the same.
6. Put your bags on the rack outside the lab before entering in lab.
7. Switch off the lights, fans and all the equipments used, before leaving lab.
8. Students will replace their chairs to its specific position before leaving the lab.

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S. No.	Experiment	Date	Grade	Signature
1	To study various types of kinematics links, pairs, chains & mechanisms.			
2	To study different types of chains and their inversions			
3	To find the velocity and acceleration of various links/points in slider-crank Mechanism using Klein's construction method			
4	To measure the various parameters comprising the Corioli's component of acceleration			
5	To study various types of cam and follower arrangements and To find out jump phenomenon of cams and followers with the help of test kit.			
6	To plot the n - ❑ (follower displacement vs. angle of cam rotation) curves for different cam follower pairs.			
7	To study various kinds of Belt drives			
8	To study various types of gear and gear trains and construct involute profile of a gear by generating method			
9	To perform the experiment for static balancing on static balancing machine.			
10	Experimental justification of the equation $T = I\,\omega\,\omega_P$ for calculating the gyroscopic couple by observation and measurement of results for independent variation in applied couple C and precession ω_p.			

Experiment No. 1

Aim: - To study various types of kinematics links, pairs, chains & mechanisms.

Apparatus Used: - Models of Kinematics links, pairs, chains & Mechanisms.

Theory: -

Kinematic Link: - A mechanism is made of a number of resistant bodies out of which some may have motions relative to the others. A resistant body or a group of resistant bodies with rigid connections preventing their relative movement is known as a link. A link also known as kinematic link or element.

Examples: - A slider-crank mechanism consists of four links: frame and guides, crank connecting rod and slider, the crank link may have crankshaft and flywheel also, forming one link having no relative motion of these.

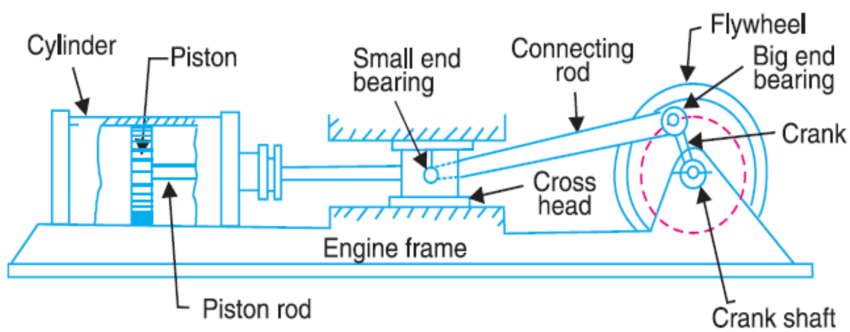


Figure: Mechanism showing different links

Types of Links:-

1. **Rigid Link:-** A rigid link is one which does not undergo any deformation while transmitting motion. Strictly speaking, rigid links do not exist.
2. **Flexible link:-** A flexible link is one which is partly deformed in a manner not to affect the transmission of motion. For example, belts, ropes, chains and wires are flexible links and transmit tensile forces only.
3. **Fluid link:-** A fluid link is one which is formed by having a fluid in a receptacle and the motion is transmitted through the fluid by pressure or compression only, as in the case of hydraulic presses, jacks and brakes.

Classifications of Links:-

1. Binary link
2. Ternary link
3. Quarternary link

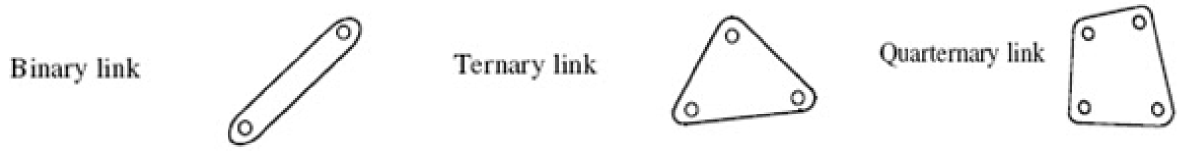


Figure: Types of Links

Kinematic Pair: - A kinematic pair or simply a pair is a joint of two links having relative motion between them.

Classifications of pairs:

1-Kinematics pairs according to nature of contact:-

a. Lower pair (links having surface or area contact)

Examples- Nut turning on a screw, shaft rotating in a bearing, universal joint etc.

b. Higher pair (Point or line contact between the links)

Examples:- when rolling on a surface, cam and follower pair, tooth gears, ball and roller bearings etc.

2- Kinematics pairs according to nature of Mechanical Constraint:-

a. Closed pair (when the elements of a pair are held together mechanically)

Examples :- all the lower pairs and some of the higher pair

b. Unclosed pair (when two links of a pair are in contact either due to force of gravity or some spring action),

Example :- cam and follower pair.

3-Kinematics pairs according to nature of relative motion:-

a. Sliding pair
b. Turning pair
c. Rolling Pair
d. Screw pair (Helical pair)
e. Spherical pair

Kinematic Chain :- A kinematic chain is an assembly of links in which the relative motions of the links is possible and the motion of each relative to the others is definite. If indefinite motions of other links, it is a non-kinematic chain.

Types of kinematics chains :-

a. Four bar chain or quadric cycle chain
b. Single slider crank chain
c. Double slider crank chain

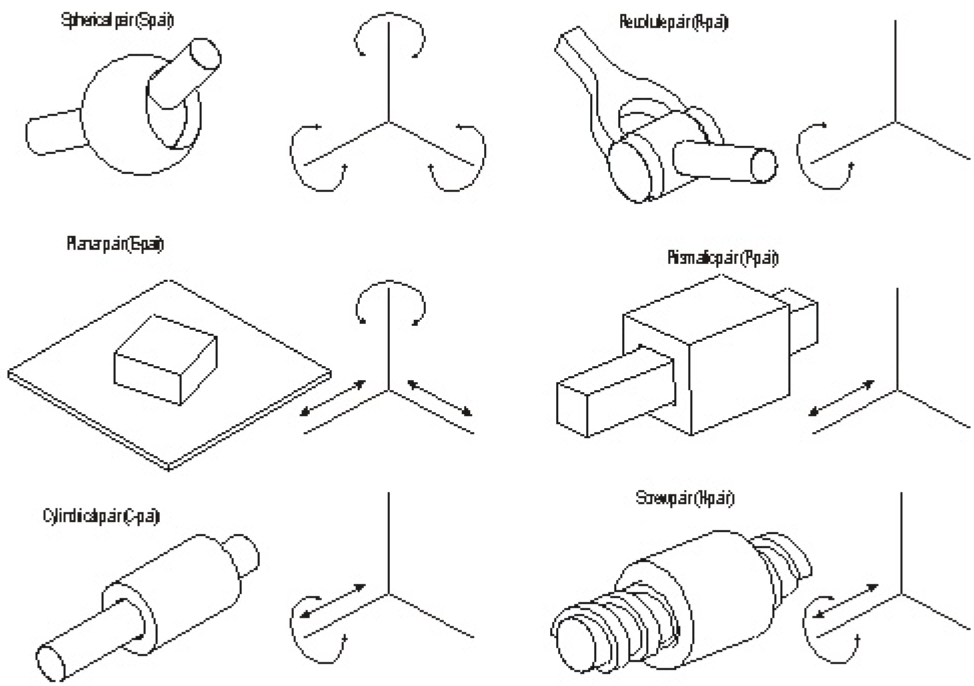


Figure: Different types of Joints

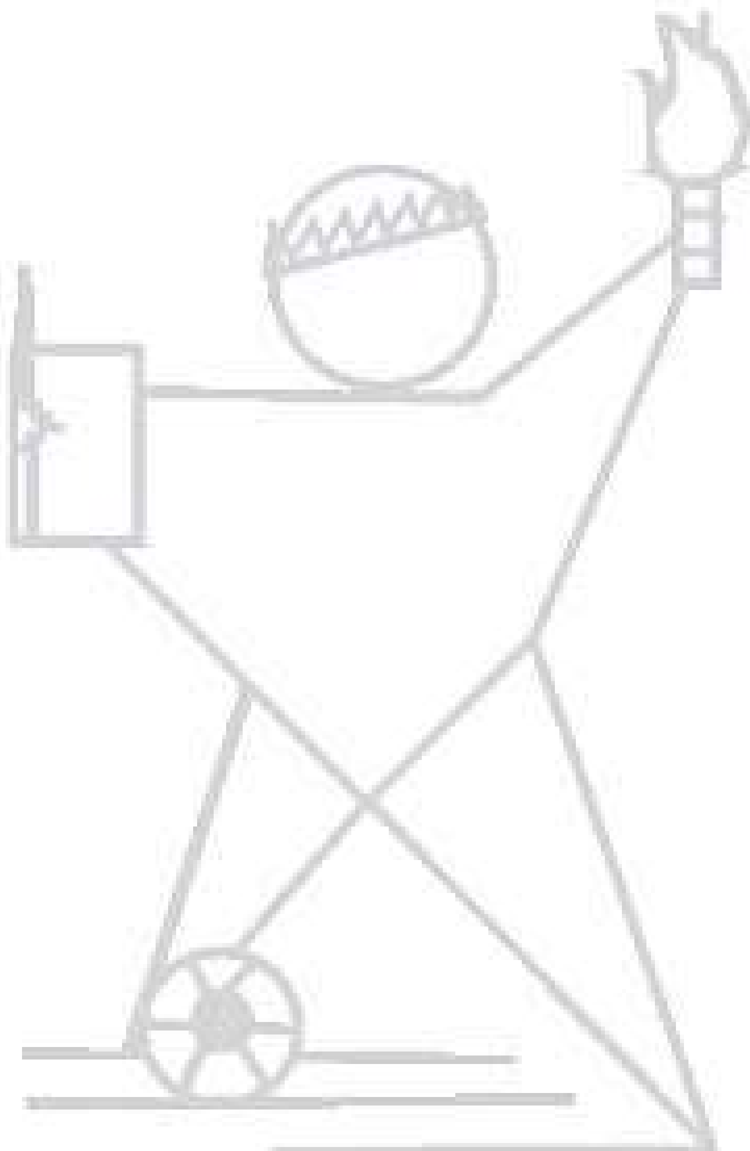
Mechanism:-

When one of the links of a kinematic chain is fixed, the chain is known as mechanism. It may be used for transmitting or transforming motion *e.g.* engine indicators, typewriter etc. A mechanism with four links is known as simple mechanism, and the mechanism with more than four links is known as compound mechanism. When a mechanism is required to transmit power or to do some particular type of work, it then becomes a machine. In such cases, the various links or elements have to be designed to withstand the forces (both static and kinetic) safely.

Questions:-

1. Define machine & structure.
2. Define Grasshof's criterion.
3. Write types of constrained motion with examples.

Solutions:-



Experiment No. 2

Aim : - To study different types of chains and their inversions.

Apparatus Used: - Models of different types of chains and models of Inversion.

Theory: -

Types of Kinematic Chains

The most important kinematic chains are those which consist of four lower pairs, each pair being a sliding pair or a turning pair. The following three types of kinematic chains with four lower pairs are important from the subject point of view :

1. Four bar chain or quadric cyclic chain,
2. Single slider crank chain, and
3. Double slider crank chain.

1. Four Bar Mechanism:-

A four bar link mechanism or linkage is the most fundamental of the plane kinematics linkages. It consists of four rigid links which are connected in the form of a quadrilateral by four pin joints. A link that makes complete revolutions is the crank, the link opposite to the fixed link is the coupler and the fourth link a lever or rocker if oscillates or an another crank, if rotate.

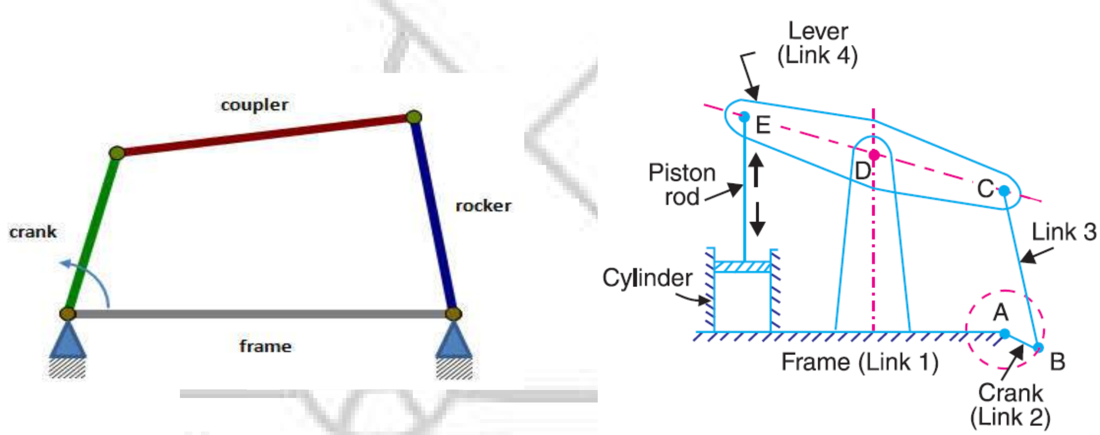


Figure: Four bar chain and Beam Engine

Inversions of Four Bar Chain

i. Beam Engine (Crank and Lever Mechanism)

A part of the mechanism of a beam engine (also known as crank and lever mechanism) which consists of four links, is shown in Figure. In this mechanism, when the crank rotates about the fixed centre *A*, the lever oscillates about a fixed centre *D*. The end *E* of the lever *CDE* is connected to a piston rod which reciprocates due to the rotation of the crank. In other words, the purpose of this mechanism is to convert rotary motion into reciprocating motion.

ii. Coupling Road of a Locomotive (Double Crank Mechanism)

The mechanism of a coupling rod of a locomotive (also known as double crank mechanism) which consists of four links, is shown in Figure. In this mechanism, the links *AD* and *BC* (having equal length) act as cranks and are connected to the respective wheels. The link *CD* acts as a coupling rod and the link *AB* is fixed in order to maintain a constant centre to centre distance between them. This mechanism is meant for transmitting rotary motion from one wheel to the other wheel.

iii. Watt's Indicator Mechanism (Double Lever Mechanism)

A Watt's indicator mechanism (also known as Watt's straight line mechanism or double lever mechanism) which consists of four links, is shown in Figure. The four links are : fixed link at *A*, link *AC*, link *CE* and link *BFD*. It may be noted that *BF* and *FD* form one link because these two parts have no relative motion between them. The links *CE* and *BFD* act as levers. The displacement of the link *BFD* is directly proportional to the pressure of gas or steam which acts on the indicator plunger. On any small displacement of the mechanism, the tracing point *E* at the end of the link *CE* traces out approximately a straight line. The initial position of the mechanism is shown in Figure by full lines whereas the dotted lines show the position of the mechanism when the gas or steam pressure acts on the indicator plunger.

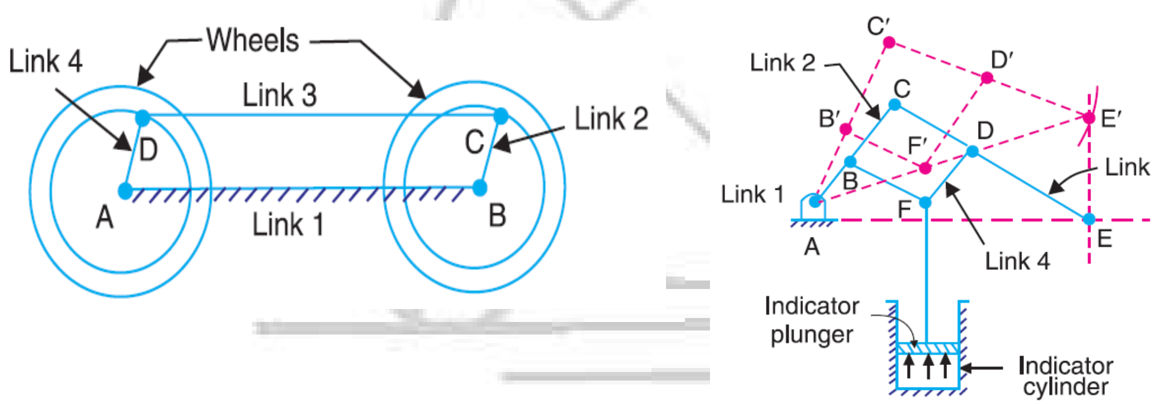


Figure: Double Crank Mechanism and Double Lever Mechanism

2. Single Slider Crank Chain

A single slider crank chain is a modification of the basic four bar chain. It consist of one sliding pair and three turning pairs. It is usually found in reciprocating steam engine mechanism.

This type of mechanism converts rotary motion into reciprocating motion and vice versa. In a single slider crank chain, as shown in Figure, the links 1 and 2, links 2 and 3, and links 3 and 4 form three turning pairs while the links 4 and 1 form a sliding pair.

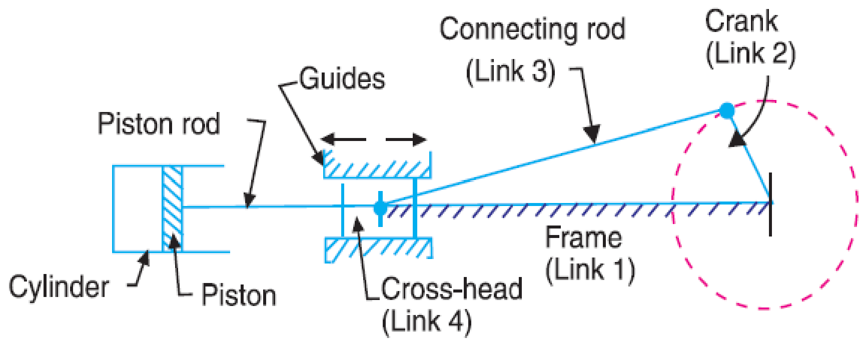


Figure: Single Slider Crank Chain Mechanism

Inversions Of Single Slider–Crank Chain

i. Pendulum Pump or Bull Engine-

In this mechanism, the inversion is obtained by fixing the cylinder or link 4 (*i.e.* sliding pair), as shown in Fig. 5.23. In this case, when the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at *A* and the piston attached to the piston rod (link 1) reciprocates. The duplex pump which is used to supply feed water to boilers have two pistons attached to link 1, as shown in Figure.

ii. Oscillating Cylinder Engine-

The arrangement of oscillating cylinder engine mechanism, as shown in Figure, is used to convert reciprocating motion into rotary motion. In this mechanism, the link 3 forming the turning pair is fixed. The link 3 corresponds to the connecting rod of a reciprocating steam engine mechanism. When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at *A*.

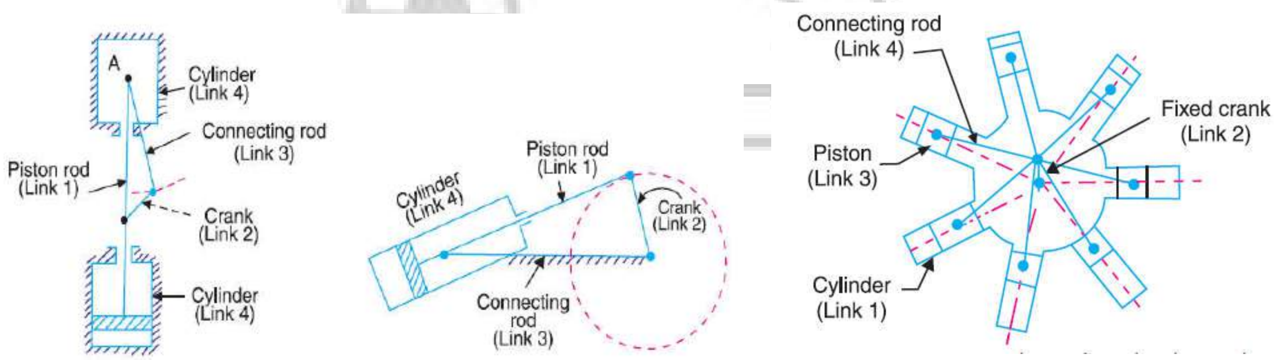


Figure: Pendulum pump, Oscillating Cylinder Engine and Gnome Engine

iii. Rotary Internal Combustion Engine or Gnome Engine-

Sometimes back, rotary internal combustion engines were used in aviation. But now-a-days gas turbines are used in its place. It consists of seven cylinders in one plane and all revolves about fixed centre *D*, as shown in Figure, while the crank (link 2) is fixed. In this mechanism, when the connecting rod (link 4) rotates, the piston (link 3) reciprocates inside the cylinders forming link1.

iv. Crank and Slotted Lever Quick Return Motion Mechanism-

In this mechanism, the link *AC* (*i.e.* link 3) forming the turning pair is fixed, as shown in Figure. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank *CB* revolves with uniform angular speed about the fixed centre *C*. A sliding block attached to the crank pin at *B* slides along the slotted bar *AP* and thus causes *AP* to oscillate about the pivoted point *A*. A short link *PR* transmits the motion from *AP* to the ram which carries the tool and reciprocates along the line of stroke *R*1*R*2. The line of stroke of the ram (*i.e.* *R*1*R*2) is perpendicular to *AC* produced. In the extreme positions, *AP*1 and *AP*2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position *CB*1 to *CB*2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position *CB*2 to *CB*1 (or through angle α) in the clockwise direction. Since the crank has uniform angular speed.

v. Whitworth quick return motion mechanism-

This mechanism is mostly used in shaping and slotting machines. In this mechanism, the link *CD* (link 2) forming the turning pair is fixed, as Figure. The link 2 corresponds to a crank in a reciprocating steam engine. The driving crank *CA* (link 3) rotates at a uniform angular speed. The slider (link 4) attached to the crank pin at *A* slides along the slotted bar *PA* (link 1) which oscillates at a pivoted point *D*. The connecting rod *PR* carries the ram at *R* to which a cutting tool is fixed. The motion of the tool is constrained along the line *RD* produced, *i.e.* along a line passing through *D* and perpendicular to *CD*. When the driving crank *CA* moves from the position *CA*1 to *CA*2 (or the link *DP* from the position *DP*1 to *DP*2) through an angle β in the clockwise direction, the tool moves from the left hand end of its stroke to the right hand end through a distance 2 *PD*.

Now when the driving crank moves from the position *CA*2 to *CA*1 (or the link *DP* from *DP*2 to *DP*1) through an angle α in the clockwise direction, the tool moves back from right hand end of its stroke to the left hand end.

A little consideration will show that the time taken during the left to right movement of the ram (*i.e.* during forward or cutting stroke) will be equal to the time taken by the driving crank to move from *CA*1 to *CA*2. Similarly, the time taken during the right to left movement of the ram (or during the

idle or return stroke) will be equal to the time taken by the driving crank to move from *CA*2 to *CA*1.

Since the crank link *CA* rotates at uniform angular velocity therefore time taken during the cutting stroke (or forward stroke) is more than the time taken during the return stroke. In other words, the mean speed of the ram during cutting stroke is less than the mean speed during the return stroke.

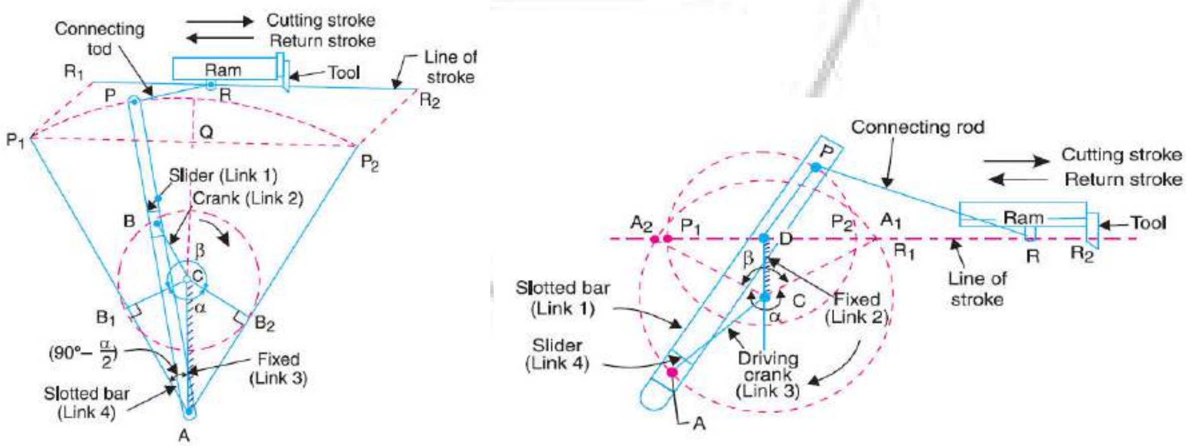


Figure: Crank and Slotted Lever Quick Return Motion Mechanism and Whitworth quick return motion mechanism

3. **Double-slider crank-chain**:

A four-bar chain having two turning and two sliding pairs such that two pairs of the same kind are adjacent is known as a double-slider-crank chain. The following are its inversions:

i. Elliptical trammel-

It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4), as shown in Figure. The fixed plate or link 4 has two straight grooves cut in it, at right angles to each other. The link 1 and link 3, are known as sliders and form sliding pairs with link

4. The link *AB* (link 2) is a bar which forms turning pair with links 1 and 3. When the links 1 and 3 slide along their respective grooves, any point on the link 2 such as *P* traces out an ellipse on the surface of link 4, as shown in Figure. A little consideration will show that *AP* and *BP* are the semi-major axis and semi-minor axis of the ellipse respectively.

ii. Scotch yoke-

This mechanism is used for converting rotary motion into a reciprocating motion. The inversion is obtained by fixing either the link 1 or link 3. In Figure, link 1 is fixed. In this mechanism, when the link 2 (which corresponds to crank) rotates about *B* as centre, the link 4 (which corresponds to a frame) reciprocates. The fixed link 1 guides the frame.

iii. Oldham's coupling-

An Oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart. The shafts are coupled in such a way that if one shaft rotates, the other shaft also rotates at the same speed. This inversion is obtained by fixing the link 2, as shown in Figure (*a*). The shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging.

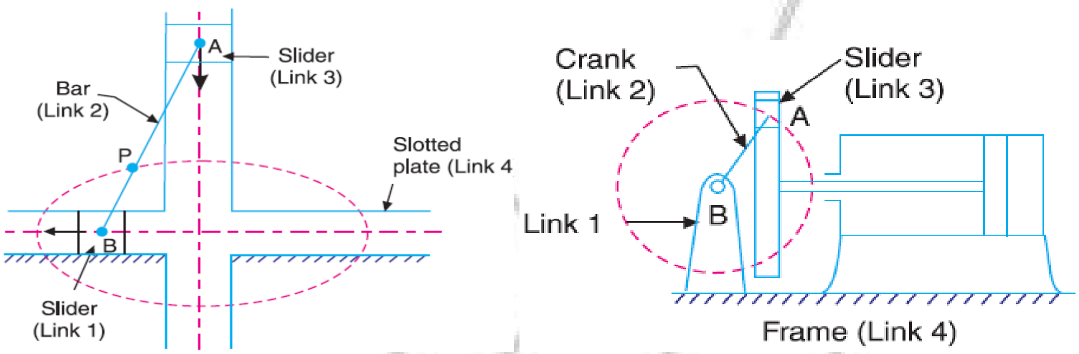


Figure: Elliptical trammel and Scotch yoke

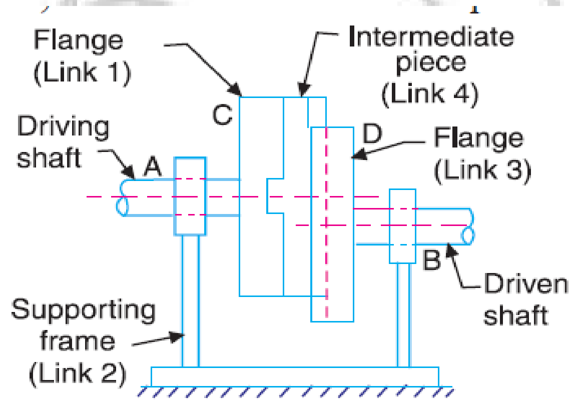


Figure: Oldham's coupling

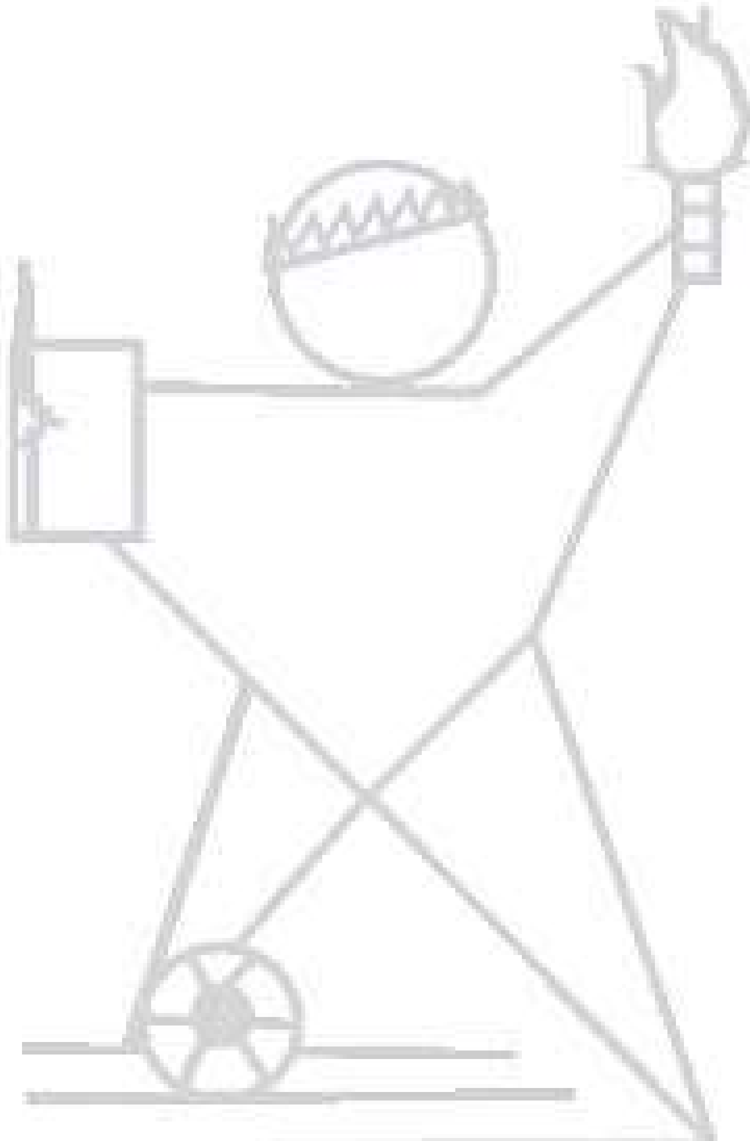
Applications:-

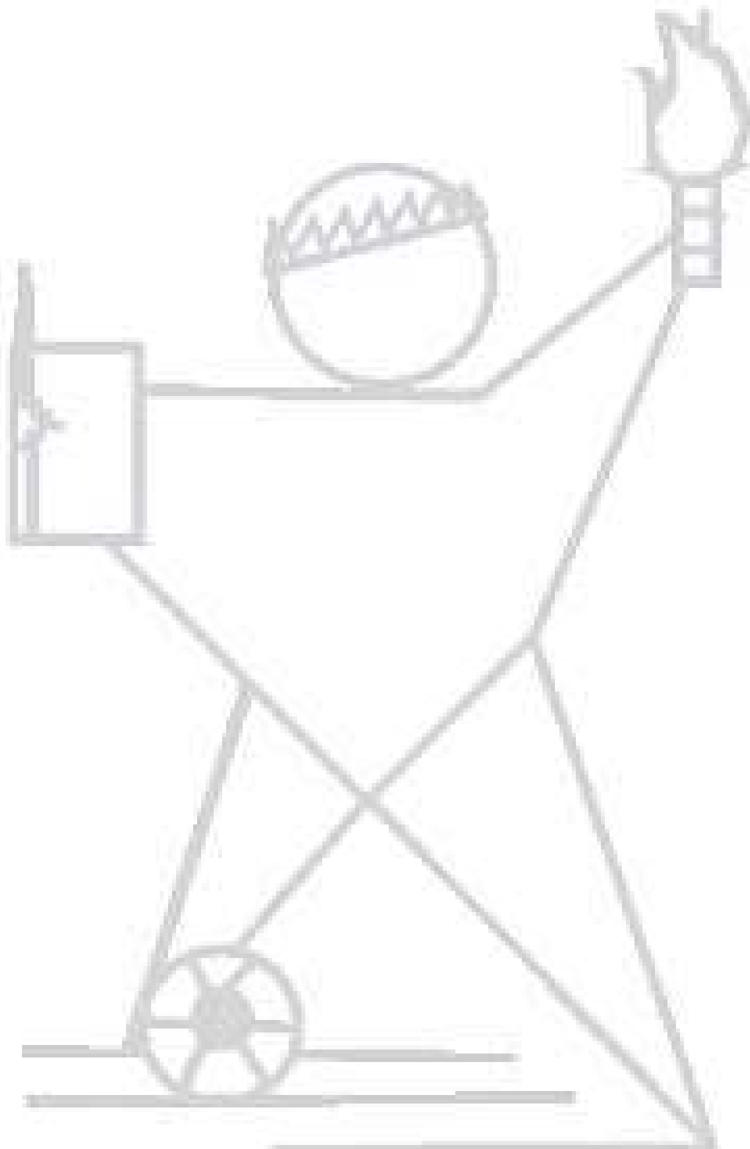
1. In reciprocating engine.
2. In reciprocating compressor.
3. In Whitworth quick – return mechanism and Rotary engine.
4. In Oscillating cylinder engine and crank & slotted-lever mechanism.
5. In hand pump.
6. In scotch yoke.

Questions :-

1. What are the of inversions of four bar mechanism & give their applications also?
2. What are the of Inversions of single slider crank mechanism & give their applications also?
3. What are the of Inversions of Double slider crank mechanism & give their applications also ?
4. Define degree of freedom & give examples ?
5. Define Kutzbach & grubler's criterian.

Solution:-





Experiment No. 3

Aim:- To find the velocity and acceleration of various links/points in slider-crank Mechanism using Klein's construction method

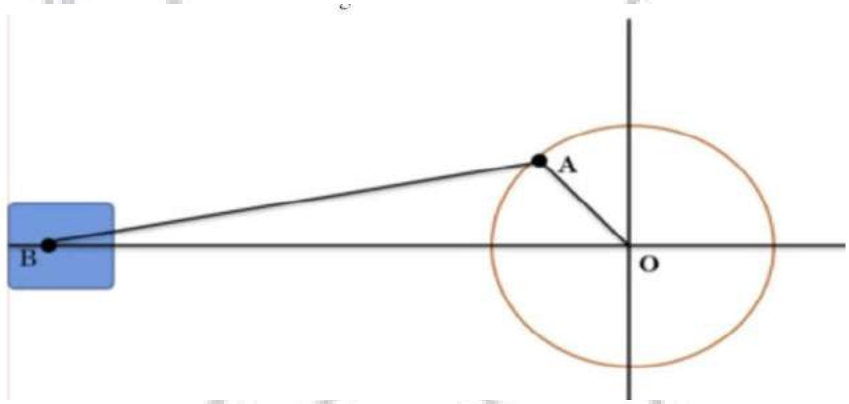
Introduction

The Klein's construction is graphical method to obtain the velocity, acceleration of links or important points on the links. In Klein's construction, the velocity and the acceleration diagrams are made on the configuration diagram itself. The line that represents the crank in the configuration diagram also represents the velocity and acceleration of its moving end in the velocity and acceleration diagrams respectively. This construction is drawn directly on the configuration diagram. However, it is applicable only for the slider-crank mechanism.

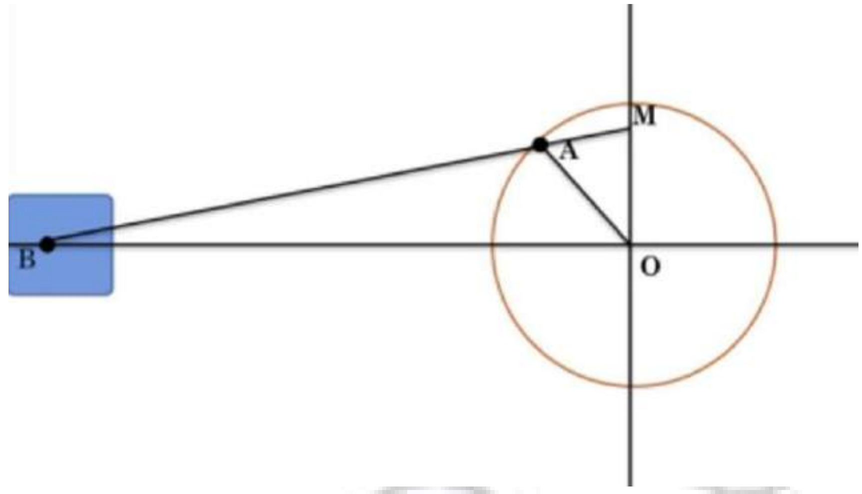
Steps of Klein's construction method

Steps to find the velocity and acceleration of various links

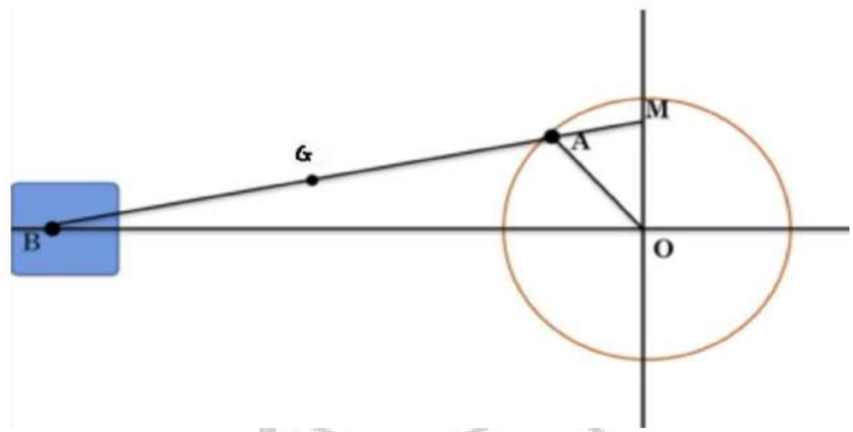
Step 1. Draw the basic configuration diagram by measuring the angle made by crank and also other dimension of crank and connecting rod.



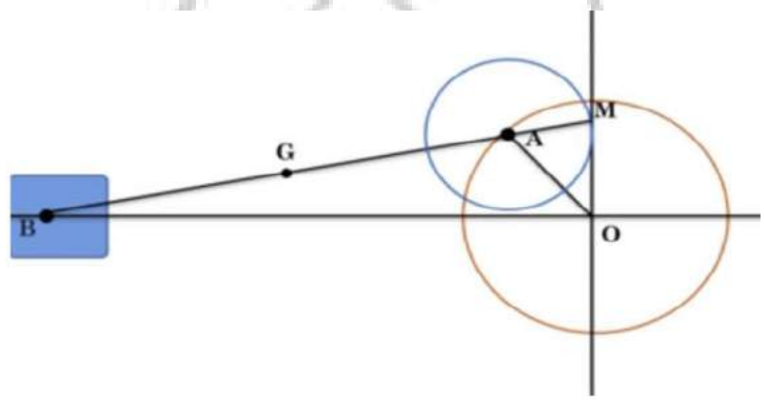
Step 2. Extend the connecting rod upto the vertical centre line of the crank circle and mark point M , the triangle created ΔOAM is the velocity triangle.



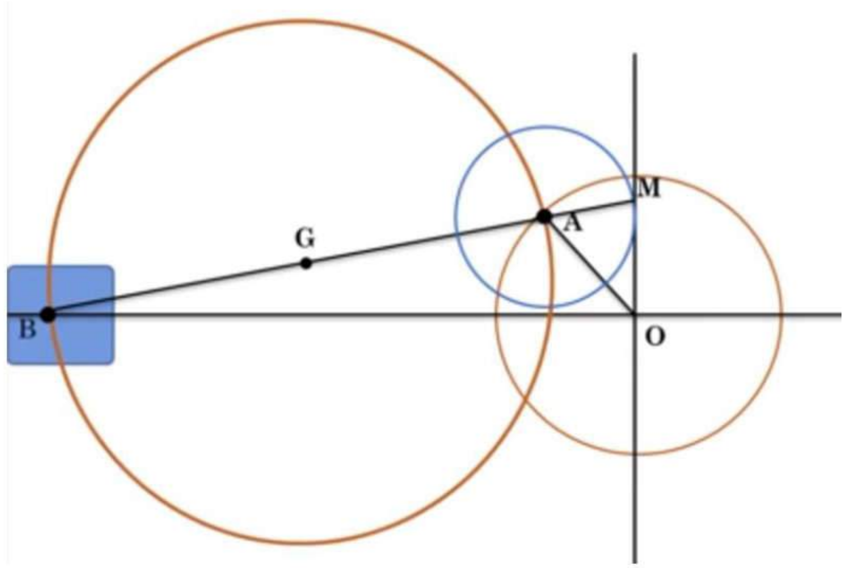
Step 3. Locate the midpoint of the connecting rod as point G.



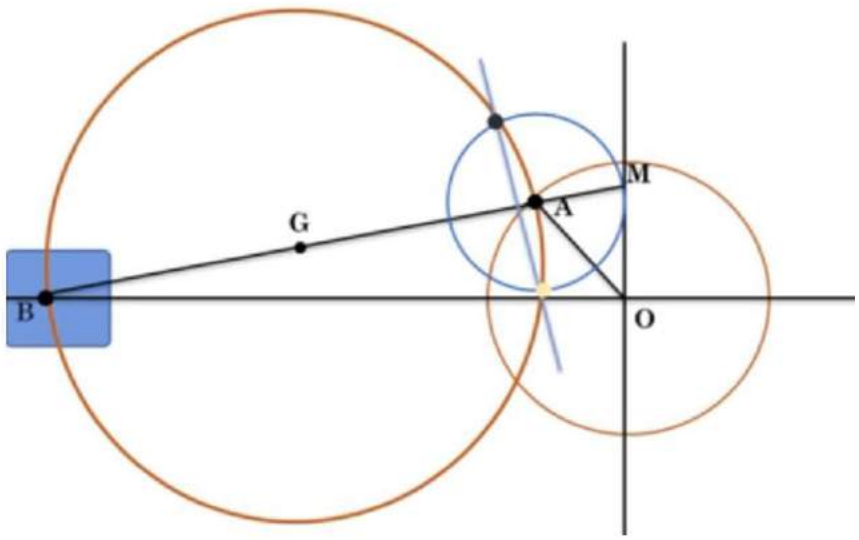
Step 4. With Centre as "A" and radius equal to AM draw the circle.



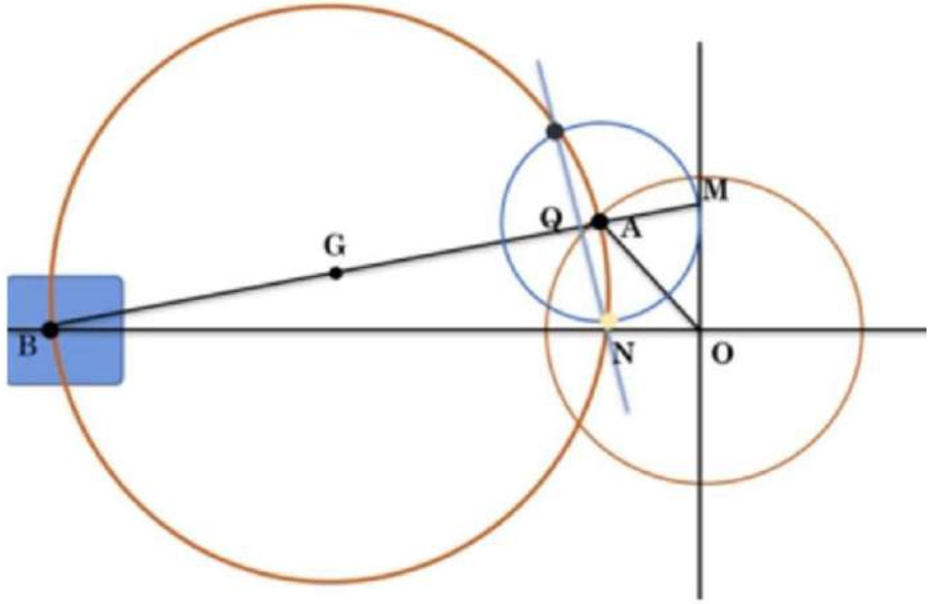
Step 5. With Centre as "G" and radius equal to GA or GB draw the circle.



Step 6. Both circles will intersect each other at two points, join these two points.



Step 7. This line will intersect the connecting rod at point "Q" and line of stroke at point "N". Name these two points.



Step 8. Now OAM is the velocity triangle and the OAQN is the acceleration diagram. Which can be used to find the required velocity of acceleration of the links of various points on the links.

Problems:-

Que.1. The crank and connecting rod of a reciprocating engine are 200 mm and 700 mm respectively. The crank is rotating in clockwise direction at 120 rad/s. Find with the help of Klein's construction:

1. Velocity and acceleration of the piston,
2. Velocity and acceleration of the mid point of the connecting rod, and
3. Angular velocity and angular acceleration of the connecting rod, at the instant when the crank is at 30° to I.D.C. (inner dead centre).

Que.2. In a slider crank mechanism, the length of the crank and connecting rod are 150 mm and 600 mm respectively. The crank position is 60° from inner dead centre. The crank shaft speed is 450 r.p.m. clockwise. Using Klein's construction, determine

1. Velocity and accelera-tion of the slider,
2. Velocity and acceleration of point D on the connecting rod which is 150 mm from crank pin C, and
3. angular velocity and angular acceleration of the connecting rod.

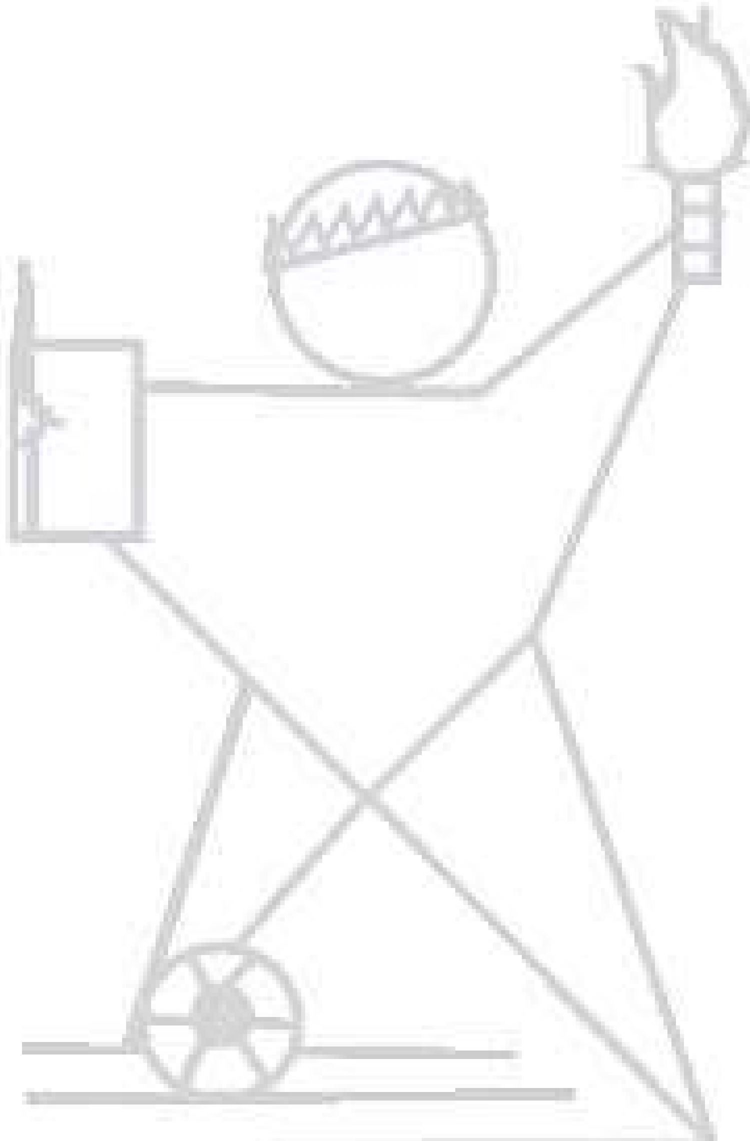
Que.3. The crank of a reciprocating engine is rotating in clockwise direction with a constant angular velocity of 30 rad/sec. The lengths of crank and connecting rod are 200 mm and 750 mm respectively. Using Klein's construction find

1) Velocity of piston

2) Velocity of midpoint of connecting rod

3) Acceleration of piston

4) Angular acceleration of connecting rod when the crank has turned through 30 degrees from inner dead center.



Experiment No. 4

Aim: To Measure the various parameters comprising the Corioli's component of acceleration.

Theory:

The apparatus has been designed to enable the student to measure the various parameters comprising the Corioli's component of acceleration. To maintain this acceleration long enough for measurements to be taken the conventional slider mechanism is replaced by two streams of water flowing radially outwards from an inverted T shape tube which rotates about its vertical axis so that the water in passing along the tube is subjected to Corioli's component acceleration.

Consider the motion of the slider B on the crank OA. Let OA rotates with constant angular velocity ω rad / sec. and slider B have the velocity v radially outwards relative v outwards relative to the crank centre O. The velocity diagram for the slider in two position separated by angular displacement dθ.

On the same diagram v_1 represents the resultant choice of velocity of slider. This velocity has two components vu and vu in radial and tangential directions respectively.

$$\text{Tangential Component} = vu = vs + s\mu$$

$$= r \sin \delta\theta + \blacklozenge (r + \delta r)$$

$$= r\,\delta\theta + \omega\theta\, r \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Rate of change of tangential velocity} = \frac{r\delta\square}{\delta\Delta t} + \frac{\omega\theta \blacklozenge \square r}{\Delta\delta t}$$

$$= \omega r + \omega r = 2\omega r \qquad \ldots\ldots\ldots\ldots (2)$$

Equation (2) represents the Corioli's component of acceleration .This acceleration is made up of two component, one due to the increase of radius and other from changing direction of the crank.

Hydraulic Analogy:

Consider the diagram , short column of fluid if length dr at a distance r from axis of rotation of the tube ,as shown in figure, then velocity of fluid relative to the tube r and the angular velocity of the tube is ω, the Corioli's component of acceleration of the column is 2ωr in a direction perpendicular to, and in a place of rotation of the tube .The torque δT applied by the tube to produce this acceleration then,

$$\frac{\delta\ \omega\ \delta◆2\ \omega r}{g}$$

Where δ◆ is the weight of the short column of fluid.

If w is the specific weight of the fluid and a is the cross sectional area of the tube outlet, then

δ◆ = ◆ a δ r

$$\delta T = \frac{2rW\omega ar\delta r}{g}$$

and the complete torque applied to column of length 1 is given by

$$T = \frac{2rW\omega ar\delta r}{g}$$

$$T = \frac{\omega W r a l^2}{g}$$

or Corioli's component of acceleration

$$Ca = \frac{2gT}{\omega a l^2} \quad \text{(Considering both tubes)}$$

Apparatus :

The apparatus consist of two brass tube, projected radialiy from centre Perspex header tube, are rotated by direct D.C motor, mounted vertically in a ball bearing housing. The torque supplied by the motor is measured by a voltmeter and ammeter provided in the central panel. The speed of rotation of the motor is measured by RPM meter. Water from the pump flows to the header tube through the flow control valve. A rotameter is provided to measure the water flow rate. The water leaving the radial tubes returns to the via pump via sump. The splash tank and all the accessories mounted on the fabricated frame

Procedure :

1. Check the bypass valve is fully open
2. Check the position of dimmerstat, it must be zero position
3. After switching the main switch, with the help of dimmerstat increase the speed of motor up to certain speed.

4. Now start the water pump and with the help of bypass valve adjust water level constant (any level) in the vertical header tube.
5. Take the reading on the voltmeter, ammeter, rpm indicator, rotameter.
6. Now switch off the pump and take reading of voltmeter and ammeter
7. Repeat the procedure by varying speed of the shaft and take the readings.

Observations:

Length of Rotating Arm : 0.3 m

Dia of the tube outlet = 9 mm

Cross Sectional area of tube = 6.36×10^{-6}

N = No of Revolutions (RPM Indicator), V = Velocity through the tube

P = Power, T= Torque, ❒ = Density of water, L = Length of arm

V = Voltmeter reading, I = Ammeter reading, a = area of the tube

g = gravitational constant

1. **Observation Table** : Pump **On** Position

S. No.	Speed (rpm)	Flow rate (LPH)	Voltmeter	Ammeter

2. **Observation Table** : Pump **Off** Position

S. No.	Speed (rpm)	Flow rate (LPH)	Voltmeter	Ammeter

Calculation :

Torque T_1,

We have, P =V I

$$P = \frac{2\pi NT}{60} \text{Watt}$$

$$T1 = \frac{v \times I \times 60}{2\pi N} \qquad \text{(off condition)}$$

Frictional Torque (T_2) =

$$T2 = \frac{v \times I \times 60}{2\pi N} \qquad \text{(on condition)}$$

Net Torque T$= (T1 - T2)$

Now Corioli's Component of Acceleration

$$Ca = \frac{T}{2g\rho a L^2} \ m/sec^2$$

Now calculating Corioli's component of Acceleration theoretically :

$$V = q / a \quad m/sec$$

Where

V = Velocity through the tube

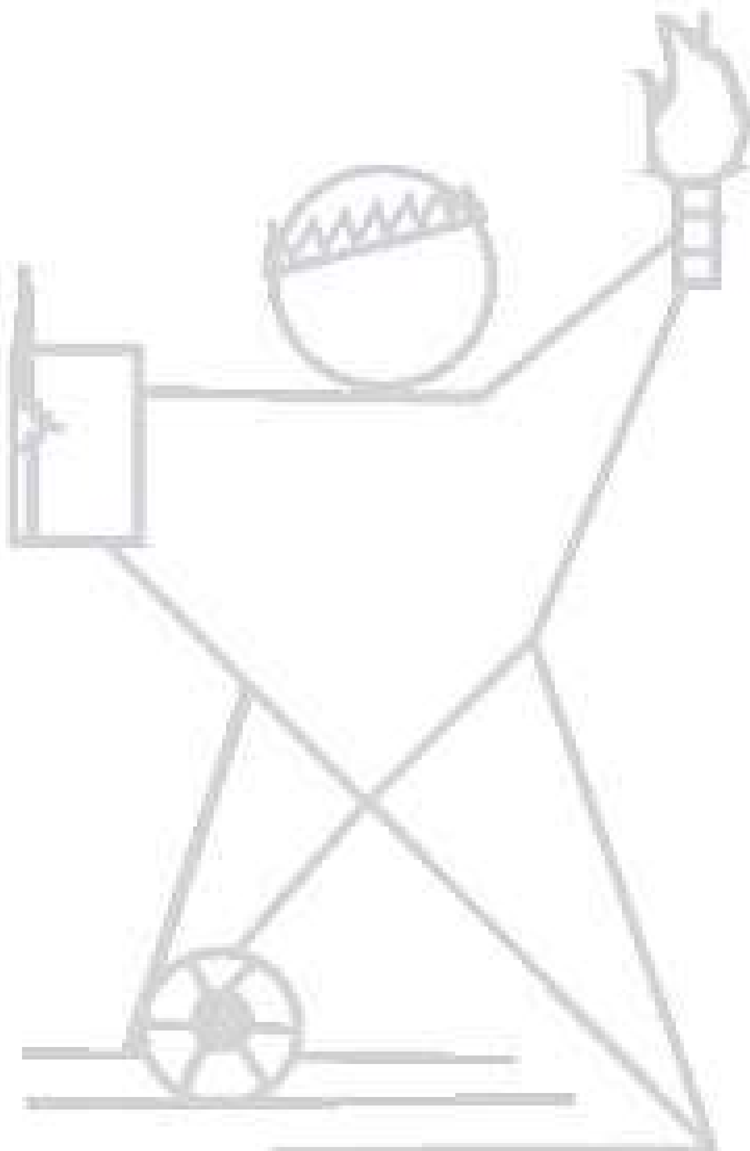
q = Volumetric flow rate

a = Cross Sectional area of tube

$Ca_{theoretical} = 2 \times$ ◆ $\times V$

$$\omega = \frac{2\pi N}{60} \quad rad/sec$$

Calculation :



Experiment No. 5

Aim: - To study various types of cam and follower arrangements and to find out jump phenomenon of Cam and follower with the help of test kit.

Apparatus Used: - Cam and follower arrangements.

Cam & Follower: - A cam is a mechanical member used to impart desired motion to a follower by direct contact. The cam rotates whereas the follower may be reciprocating or oscillating. A cam and the follower combination belong to the category of higher pairs.

Types of Cams:

According to shape of Cam

1. **Translation or Wedge or flat Cam:** - This cam has a wedge which gives translatory motion. The follower may either translate or oscillate. Sometimes, instead of using a wedge a flat plate with a groove can also be used hence this cam is also called as Flat Cam.

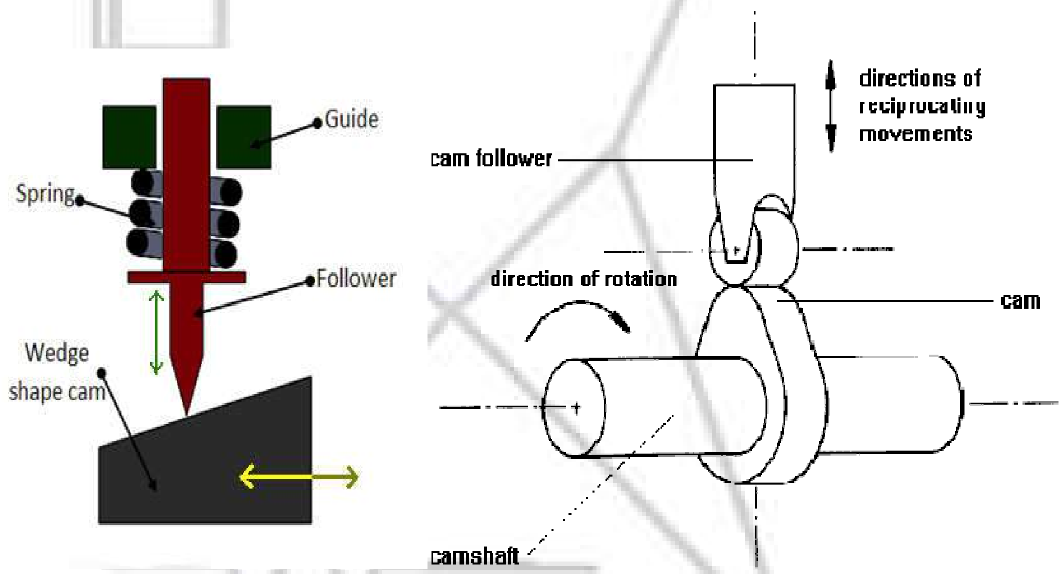
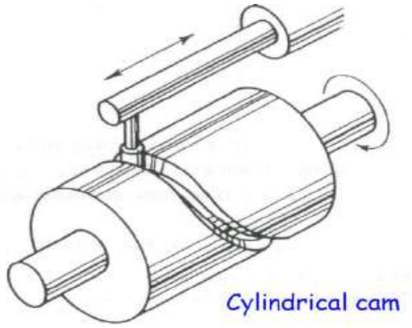


Figure. Wedge Cam and Radial Cam

2. **Radial or Disc Cam: -** A cam in which the follower moves radially from the centre of rotation of the cam is known as a radial or a disc cam.

3. **Cylindrical or Drum Cam :-** In a cylindrical cam, a cylinder which has a circumferential contour cut into a surface of rotation. The follower may reciprocate or oscillate in a plane parallel to the axis of cam.



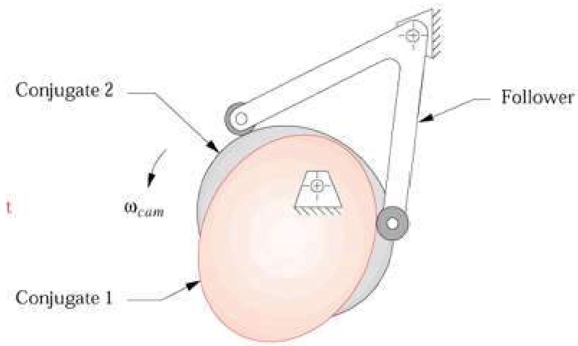


Figure. Cylindrical and Conjugate Disc Cam

4. **Conjugate or Double Disc cams :-** A conjugate cam is a double disc cam, the two discs being keyed together and are in constant touch with the two rollers of a follower. It is used for low noise, high speed and dynamic loads.
5. **Globoidal cams :-** A globoidal cam can have two types of surfaces, convex or concave. A circumferential contour is cut on the surface of rotation of the cam to impart motion to the follower which has an oscillatory motion. These type of cam are used for indexing and other special applications.

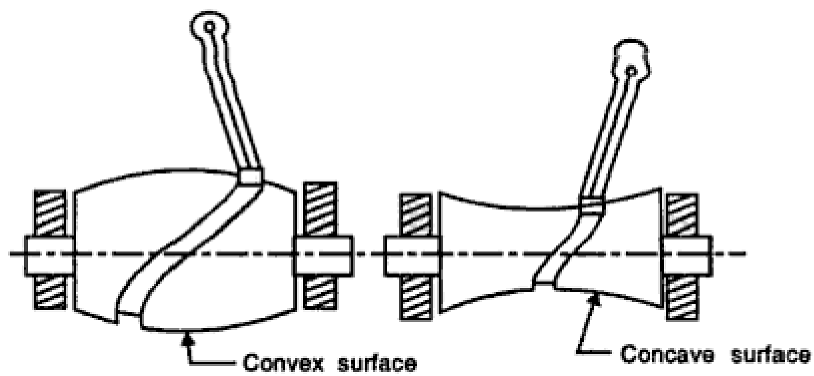


Figure. Globoidal Cam

According to Follower Movement

a. **Rise-Return-Rise (R-R-R) :-** In this, there is alternate rise and return of the follower with no periods of dwells. Its use is very limited in the industry. The follower has a linear or an angular displacement.
b. **Dwell-Rise-Return-Dwell (D-R-R-D) :-** In such a type of cam, there is rise and return of the follower after a dwell. This type is used more frequently than the R-R-R type of cam

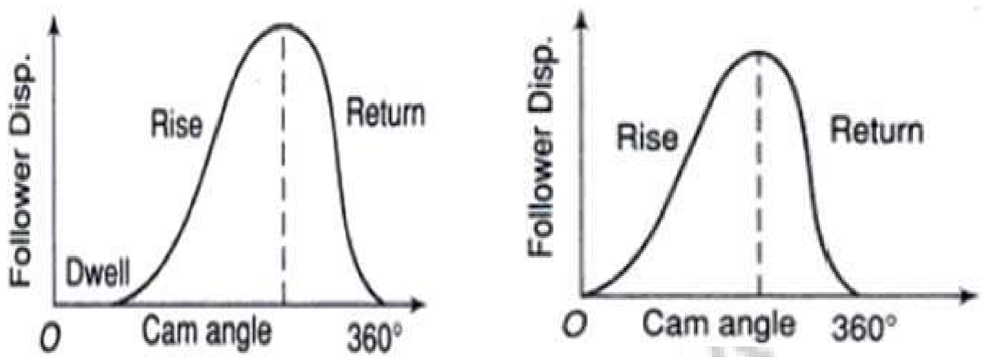


Figure. R-R-R and D-R-R-D

c. **Dwell-Rise-Dwell-Return (D-R-D-R) :-** It is most widely used type of cam. The dwelling of the cam is followed by rise and dwell and subsequently by return and dwell as shown in fig.

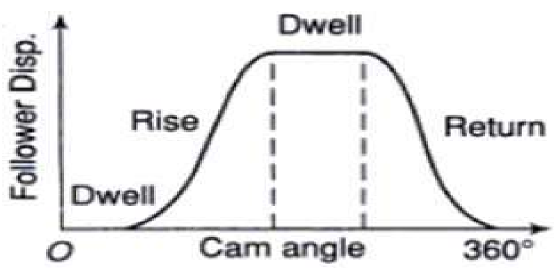


Figure. D-R-D-R

According to Manner of Constraint of the Follower

a. Pre-loaded Spring Cam:- In this type of cam, a helical compression spring is used in the preloaded (compressed) condition to maintain the contact between the cam and follower.

b. Positive-Drive Cam:- this type of cam do not require any external force to maintain the contact between the cam and follower like cylindrical cam and wedge cam.

Types of Followers

A. According to shape

1. Knife-edge Follower
2. Roller Follower
3. Flat or Mushroom Follower
4. Spherical Follower

B. According to Movement

1. Reciprocating Follower
2. Oscillating Follower

C. According to Locating of Line of Movement

1. Radial Follower
2. Offset Follower

Figure. Knife Edge and Rollar Follower

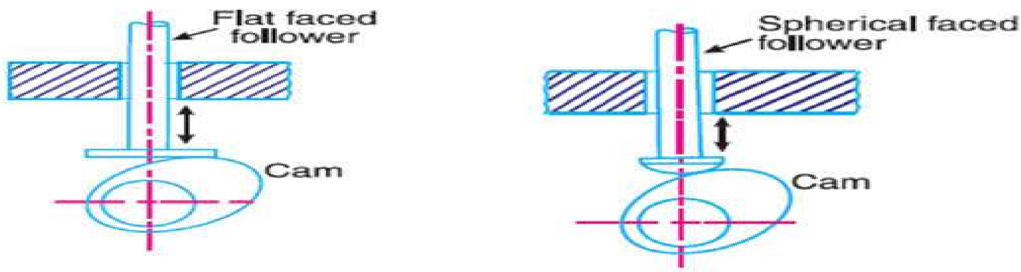


Figure. Flat faced and spherical Faced Follower

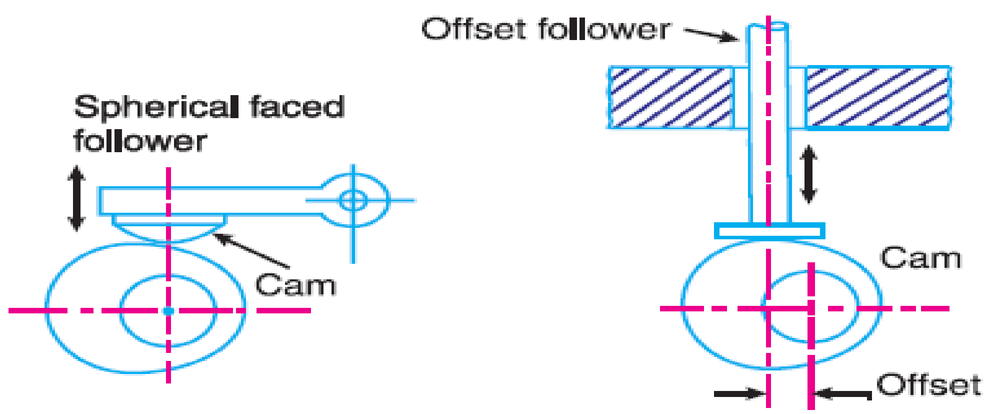


Figure. Radial Follower and Offset Follower

Applications:-

Following are the applications of cam and followers.

1.
2.
3.
4.
5.

Appratus Used:- Cams and followers test kit.

Theory:- The machine is a motorized unit consisting of a cam shaft driven by a DC motor. The shaft runs in a double ball bearing. At the end of the cam shaft a cam can easily mounted. As the follower is properly guided in gun metal bushes and the type of the follower can be changed to suit the cam fitted to note the follower displacement for the angle of CAM rotation. A spring is used to provide controlling force to the system. Weights on the follower rod can be adjusted as per requirements. The arrangement is provided to vary the speed of cam shaft. The machine is particularly very useful for testing the cam performance for jump phenomenon during operation. This machine clearly shows the effect of change of inertia forces on jump action of cam follower during the operation. It is used for testing various cam and follower pairs, i.e. (1) Circular arc cam with mushroom follower, (2) Tangent cam with roller follower, and (3) An eccentric cam with knife edge follower.

Cam Jump: - In cam follower system, the follower is pressed against the cam surface by means of a Retaining spring .Due to inertia of follower and beyond a particular speed, during a part of cam rotation the follower may lose contact with the cam this phenomenon is known as cam jump ors are bounce which is a type of vibration. This is a transition condition, which occurs only with high speed, highly flexible cam follower system. With jump, cam and followers separate owing to exclusive unbalanced force excluding the spring force during the period of negative acceleration. This is absolutely undesirable, as the fundamental function of cam follower system is to constrain and to produce desired follower motion. But due to jump it cannot be achieved. Also the life of cam flank surface reduces due to hammering action of followers on cam and noise is generated which further result in vibrations of this system. The jump phenomenon can be avoided by limiting the speed of cam or by increasing the stiffness of retaining spring.

Assembly: - The unit is provided with the push rod in two bush bearings. The same unit is to be used for the flat face and roller follower. While assembling the unit following precautions should be taken.

1. The horizontality of the upper and lower glands should be checked by spirit level.

2. The supporting pillers should be properly tightened with the lock nuts.

Specifications:

A. The following Types of cams are selected to very jump speed

a) Circular Arc cam, b) Eccentric cam and c) Tangent cam

B. The following type of followers are selected to verify jump speed

a) Mashroom follower, b) Roller follower and c) Knife edge follower

Compression Springs

The approximate stiffness are 4.5 kg/cm and 5.5 kg/cm for the bigger and smaller spring respectively.

Weights

a. All weights have a central hole so that they can be accommodated in the push rod. Total weight provided is 1600 gms.

b. The weights of the reciprocating parts are as follows –

i. Push rod with lock nut ________ Kg

ii. Rest plate and two lock nuts – 784 kg

iii. Spring, seat and lock nut __________Kg

iv. Weight of spring – ___________ (1/3 of the spring weight is to be taken as reciprocating weight)

v. Roller follower – _________ gms

vi. Mushroom follower – ________ gms

vii. Knife edge follower – ________ gms

Procedure:-

1. To plot n-❑ (follower displacement Vs. angle of cam rotation) curve for different cam follower pairs. The n- ❑ plot can be used to find out the velocity and acceleration of the follower system.

2. For this experiment, arrange the set up as shown in fig. The exact profile of the cam is obtained by taking observations n Vs. ❑. Where n= displacement of the follower from rotation initial position and ❑ = angle of cam rotation with reference from axis of symmetry chosen. By differentiating the n- ❑ curve once and twice, the velocity and acceleration curves can be plotted for the follower and cam under study.

3. Speed – To observe the phenomenon of jump. For this, use of a stroboscope is necessary. The speed of cam rotation and stroboscope frequency on neon lamp are gradually and simultaneously increased and at the time jump to occur the follower is seen to loose contact with the cam. When jump occurs the follower pounds on the cam surface giving a good thumping sound.

Upward inertia force = Downward retaining force

$$\frac{w\omega^2 r}{g} = (W + S)$$

This is the equilibrium of force equation when the jump will just start

Where,

W = Follower assembly weight.

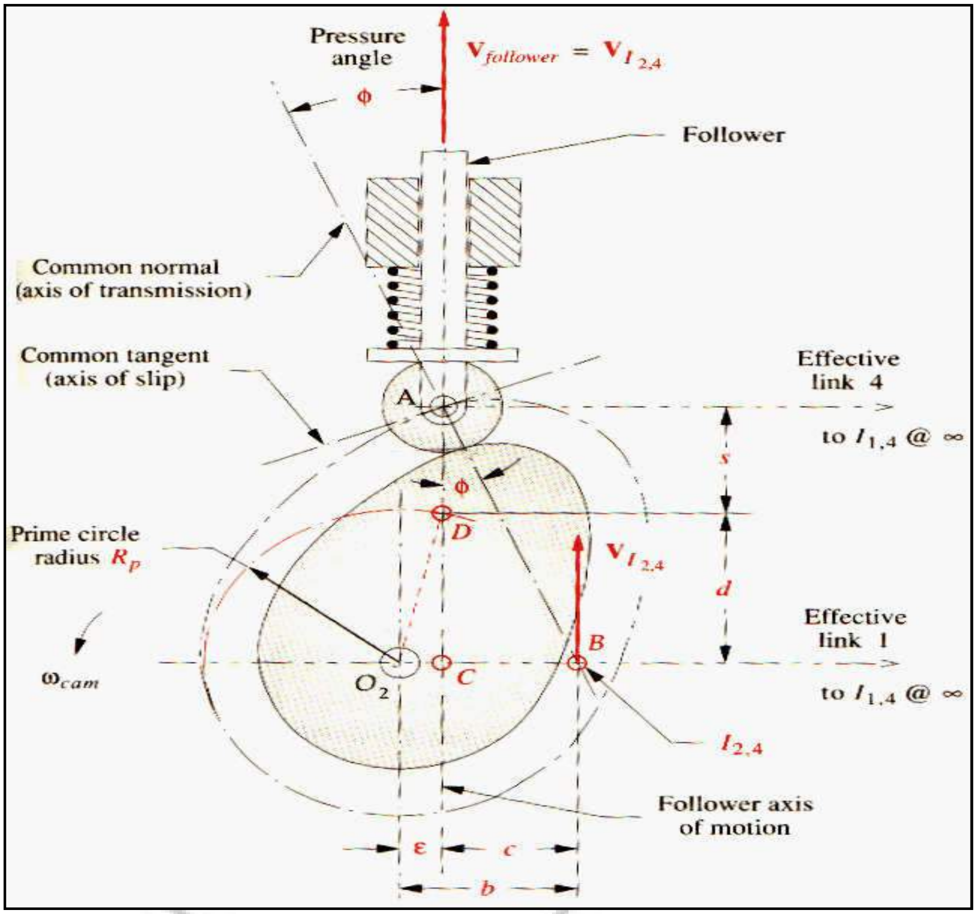
S = Spring force

◆ = Angular velocity of cam

r = Distance according to geometry of cam.

1. To study the effect of follower assembly weight on the jump speed when spring force is kept constant.
2. To study this effect keep the initial spring compression at a certain level and observe jump speed for different follower weights by adding successively and plot the graph of follower weights Vs. jump speed. This relation shows that as the follower weights increases the jump speed goes on decreasing.

1. To study the effect of spring compression on the jump speed with constant follower weight.
2. To study this, keep the follower assembly weight the same and go on observing the jump speed for various sets of initial spring compression and plot graph of spring force Vs. jump speed.



Observation:-

Result Table without load

Speed of camshaft for different followers

Type of cam	Roller Follower	Mushroom Follower	Knife edge Follower
Eccentric			
Circular arc			
Tangent			

Result Table with load = 1 kg

Speed of camshaft for different followers

Type of cam	Roller Follower	Mushroom Follower	Knife edge Follower
Eccentric			
Circular arc			
Tangent			

Result:-

Application:-

(i) Cams are used in Automatic machines

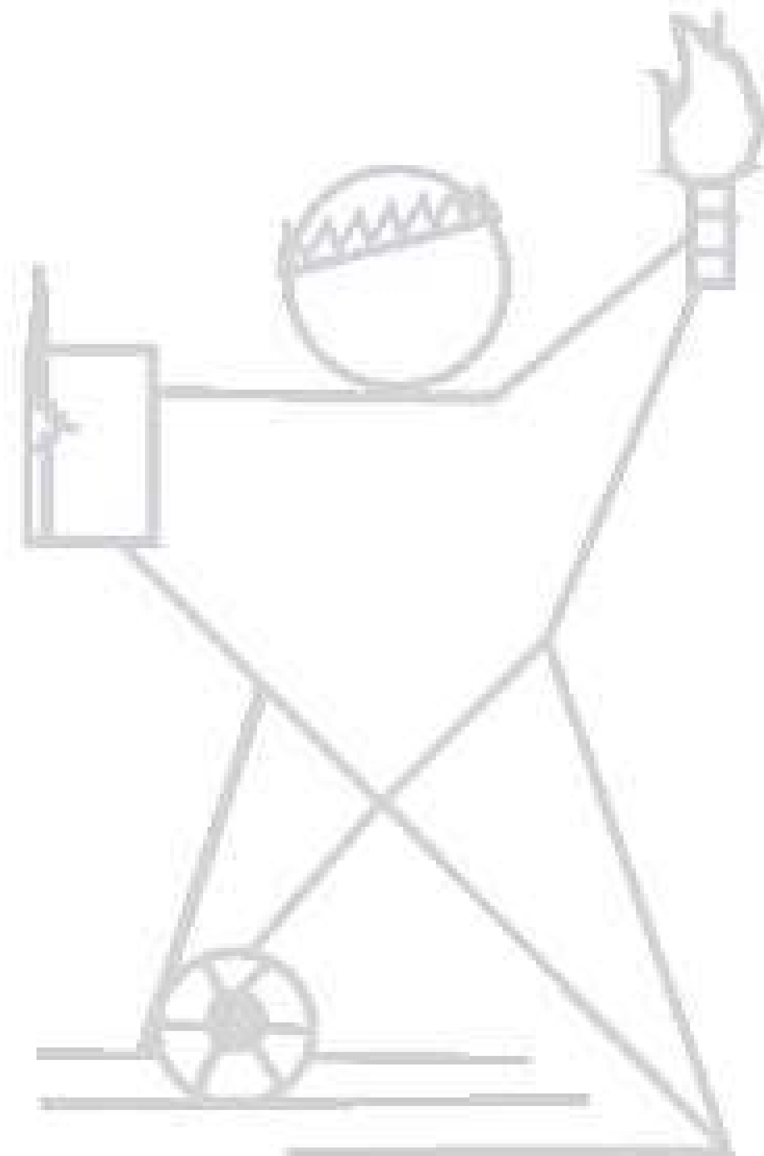
(ii) In internal combustion engine

(iii) In machine tools

(iv) Printing Control mechanisms

Questions:-

i. Define about cam & follower, Classification of cam & follower, advantage & disadvantage, Applications.
ii. Define Disc cam nomenclature.
iii. Define the cut off-set position of follower motion.



Experiment No. 6

Aim: To plot the n - ❑ (follower displacement vs. angle of cam rotation) curves for different cam follower pairs.

Introduction:

A cam may be defined as a rotating or a reciprocating element of a mechanism which imparts a rotating, reciprocating or oscillating motion to another element termed as follower.

Theory:

Cam mechanism and its uses:

In most of the cases the cam is connected to a frame, forming a turning pair and the follower is connected to the frame to form a sliding pair. The cam and the follower form a three link mechanism of the higher pair type. The three links of the mechanism are:-

(a) The cam, which is the driving link and has a curved or a straight contact surface

(b) The follower, which is the driven link and it, gets motion by contact with the surface of the cam.

(c) The frame, which is used to support the cam and guide the follower.

The cam mechanism is used in clocks, printing machines, automatic screw cutting machines, internal combustion engines for operating valves, shoe-making machinery etc.

Description:

The machine is a motorized unit a camshaft is driven by a D.C. Motor. The shaft runs in a double ball bearing. At the end of the cam shaft a cam can be easily mounted. As the follower is properly guided in gun- metal bushes and the type of the follower can be changed to suit the cam under test. A graduated circular protractor is fitted coaxial with the shaft and a dial gauge can be fitted to note the follower displacement for the angle of cam rotation. A spring is used to provide controlling force to the system.

Weights on the follower rod can be adjusted as per the requirements. An arrangement is provided to vary the speed of camshaft. The machine is particularly very useful for testing the cam performance for jump phenomenon during operation. The machine clearly shows the effect of change of inertia forces on jump action of cam follower during the operation. It is used for testing various cam and follower pairs, i.e.

1) An eccentric arc cam with Knife edge follower

2) Tangent cam with roller follower

3) Circular cam with Mushroom follower

Utilities required:

Electricity Supply: Single phase, 220 volts DC, 5-15 Amp socket with earth connection.

Experimental Procedure:

1. Fix the required cam & follower assembly on the apparatus.
2. Fix the dial gauge at top of follower shaft to get the follower displacement.
3. To find out the angular displacement, rotate the cam manually.
4. Note the angular displacement of cam and vertical displacement of the follower with the help of protractor & dial gauge respectively.
5. Draw the n - ❑ (follower displacement Vs rotation of cam) curve.
6. Now remove the dial gauge from the follower shaft.
7. Switch on the main power supply.
8. Slowly increase the rpm of the motor with the help of dimmerstat provided at the control panel & check the jump of the follower with the help of stroboscope.
9. If jump of the follower is not appears then again adjust the speed of the motor. At certain speed jump of the follower will occur. When jump occurs the follower makes a good thumping sound on cam surface. This speed is the jump speed.
10. Decrease the speed of the motor to the minimum value.
11. Now put some weight on the follower shaft plate and keep the spring tension constant.
12. Increase the speed of the motor and find out the jump speed.
13. Now vary the weight on the follower shaft plate and get the two or three jump speeds of the follower at constant spring tension.
14. Plot the curve for follower weight Vs jump speed.
15. Now get the jump speed by varying the spring tension and keeping the follower weight constant.
16. Repeat the procedure for other two cam & follower assemblies.

Observation table:

Eccentric cam with knife edge follower.

S.No.	Rotation of Cam (N)	Follower Displacement (n in mm)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		

Nomenclature:

N = Revolutions per minute

n = Displacement, mm

S = Spring Force.

W = Follower assembly weight, kg

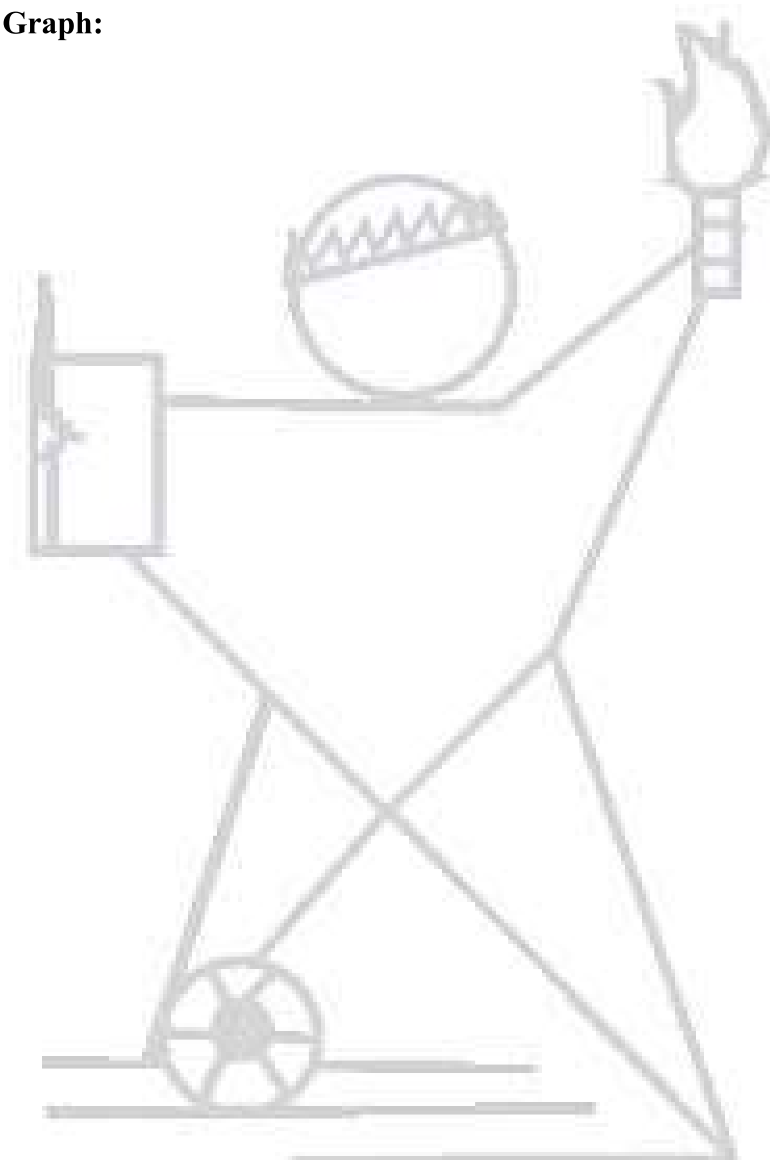
◆ = Angular velocity of cam, rad/sec

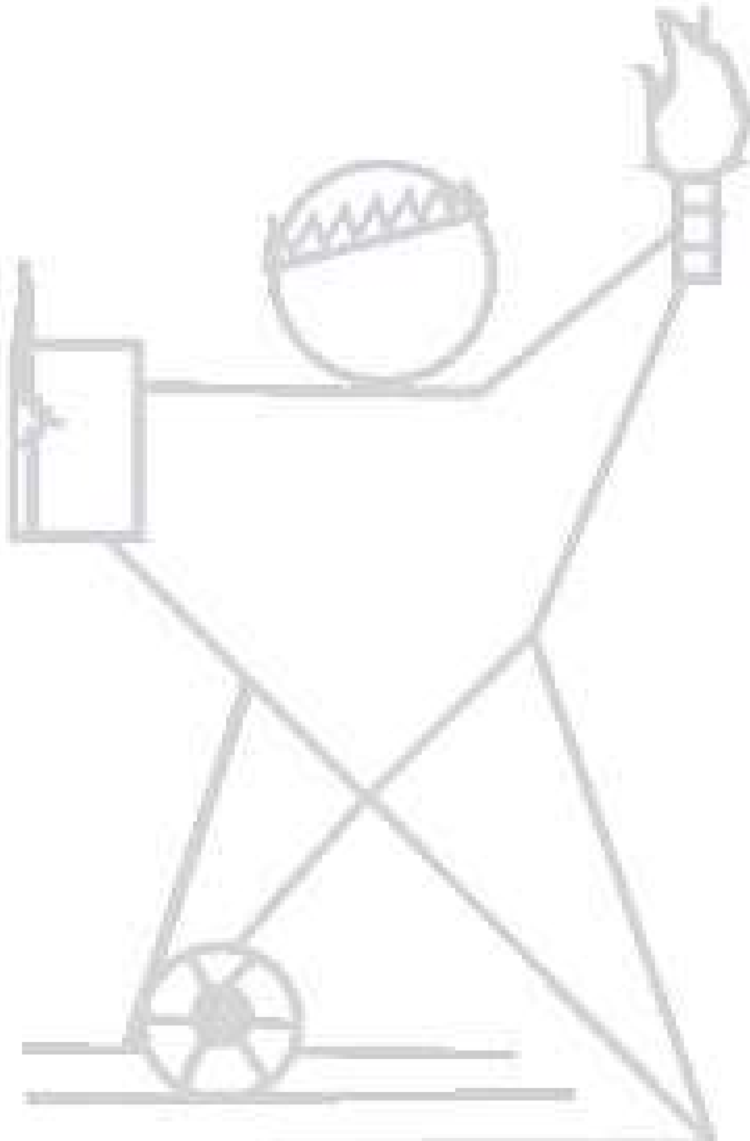
❑ = Cam Angle

Precautions & Maintenance Instructions:

1. Always lubricate the cam before starting the apparatus.
2. Tighten all the nuts properly before starting the apparatus.
3. Do not increase the speed of the motor at once.

Calculation and Graph:





Experiment No. 07

Aim: - To study various kinds of Belt drives.

Theory:

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. The amount of power transmitted depends upon the following factors:

1. The velocity of belt.
2. The tension under which the belt is placed on the pulleys.
3. The arc of contact between the belt and the smaller pulley.
4. The conditions under which the belt is used.

Selection of a Belt Drive

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

1. Speed of the driving and driven shaft. 2. Speed reduction ratio,

3. Power to be transmitted, 4. Centre distance between the shafts,

5. Positive drive requirements, 6. Shafts layout,

7. Space available, and 7. Service conditions.

Types of Belt Drives

The belt drives are usually classified into the following three groups:

1. Light drives. These are used to transmit small powers at belt speeds upto about 10m/s, as in agricultural machines and small machine tools.
2. Medium drives. These are used to transmit medium power at belt speeds over 10m/s but up to 22m/s, as machine tools.
3. Heavy drives. These are used to transmit large powers at belt speeds above 22 m/s, as in compressors and generators.

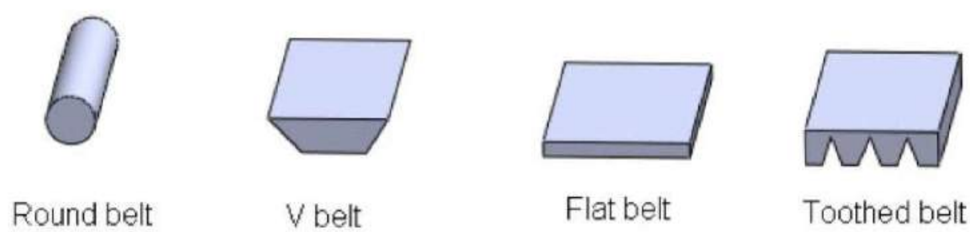
Types of Belts

Though there are many types of belts used these days, yet the following are important from the subject point of view:

1. **Flat belt: -** The flat belt is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another, when the two pulleys are not more than 8 meters apart.

2. **V-Belt: -** The V-belt is mostly used in the factories and workshop, where a moderate amount of power is to be transmitted, from one pulley to another, when the two pulleys are very near to each other.

3. **Circular belt or rope: -** The circular belt or rope, is mostly used in the factories and workshops, where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are more than 8 meters apart.



Materials used for belts

The material used for belts and ropes must be strong, flexible, and durable. It must have a high coefficient of friction. The belts, according to the material used, are classified as follows:

1**. Leather belts**. The most important materials for the belt is leather. The best leather belts are made from 1.2 metres to 1.5 metres long strips cut from either side of the back bone of the top grade steer hides. The hair side of the lather is smoother and harder than the flesh side, but the flesh side is stronger. The fibers on the hair side are perpendicular to the surface, while those on the flesh side are interwoven and parallel to the surface.

Therefore for these reasons, the hair side of a belt should be in contact with the pulley surface. This gives a more intimate contact between the belt and the pulley and places the greatest tensile strength of the belt section on the outside, where the tension is maximum as the belt over the pulley.

2. Cotton or a fabric belts. Most of the belts are made by folding canvass or cotton duck to three or more layers (depending upon the thickness desired) and stitching together. These belts are woven also into a strip of the desired width and thickness. They are impregnated with some filler like linseed oil in order to make the belts waterproof and to prevent injury to the fibers. The cotton belts are cheaper and suitable in warm climates, in damp atmospheres and in exposed positions. Since the cotton belts require little attention, therefore these belts are mostly used in farm machinery, belt conveyor etc.

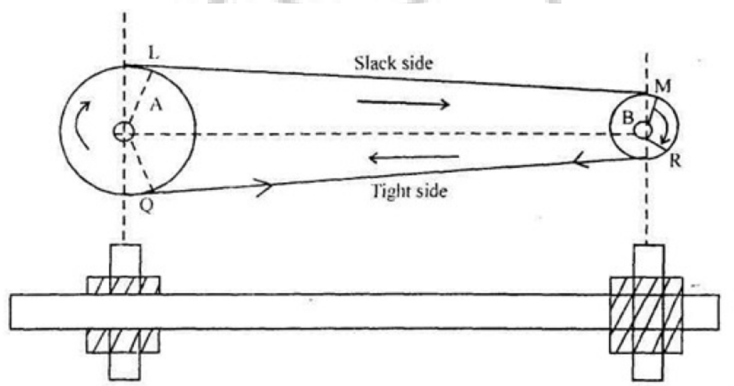
3. Rubber belt. The rubber belts are made of layers of fabric impregnated with rubber composition and have a thin layer of rubber on the faces. These belts are very flexible but are quickly destroyed if allowed to come into contact with heat, oil or grease. One of the principle advantages of these belts is that they may be easily made endless. These belts are found suitable for sawmills; pare mills where they are exposed to moisture.

4. Balata belts. These belts are similar to rubber belts except that balata gum is used in place of rubber. These belts are acid proof and waterproof and it is not affected by animal oils or alkalies. The balata belts should not be at temperatures above 400 ^{0}C because at this temperature the balata begins to soften and becomes sticky. The strength of balata belts is 25 percent higher than rubber belts.

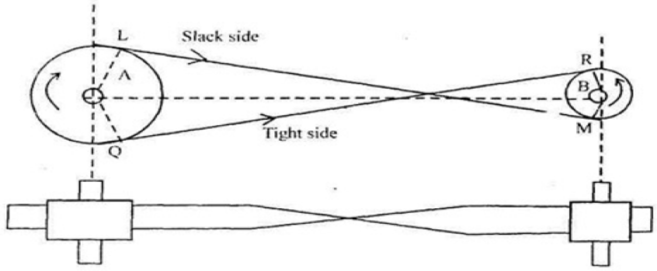
Types of Flat Belt Drives

The power from one pulley to another may be transmitted by any of the following types of belt drives.

1. Open belt drive. The open belt drive is used with shafts arranged parallel and rotating in the same direction. In this case, the driver A pulls the belt from one side (i.e. lower side RQ) and delivers it to the other side (i.e. upper side LM). Thus the tension in the lower side belt will be more than that in the upper side belt. The lower side belt (because of more tension) is known as tight side whereas the upper side belt (because of less tension) is known as slack side.



2. Crossed or twist belt drive. The crossed or twist belt drive is used with shafts arranged parallel and rotating in the opposite directions. In this case, the driver pulls the belts from one side (i.e. RQ) and delivers it to the other side (i.e. LM). Thus the tension in the belt RQ will be more that that in the belt LM. The belt RQ (because of more tension) is known as tight side, where as belt LM (because of less tension) is known as slack side.



3. Quarter turn belt drive. The quarters turn belt drive also known as right angle belt drive is used with shafts arranged at an angle and rotating in one definite direction. In order to prevent the belt from leaving the pulley, the width of the face of the face of the pulley should be greater or equal to 1.4 b, where b is the width of belt. In case the pulleys cannot be arranged, when the reversible motion is desired, then a quarter turn belt drive with guide pulley may be used.

4. Belt drive with idle pulleys. A belt drive with an idler pulley, used with shafts arranged parallel and when an open belt drive cannot be used due to small angle of contact on the smaller pulley. This type of drive is provided to obtain high velocity ratio and when the required belt tension cannot be obtained by the other means. When it is desired to transmit motion from one shaft to several shaft, all arranged in parallel, a belt drive with many idler pulleys, may be employed.

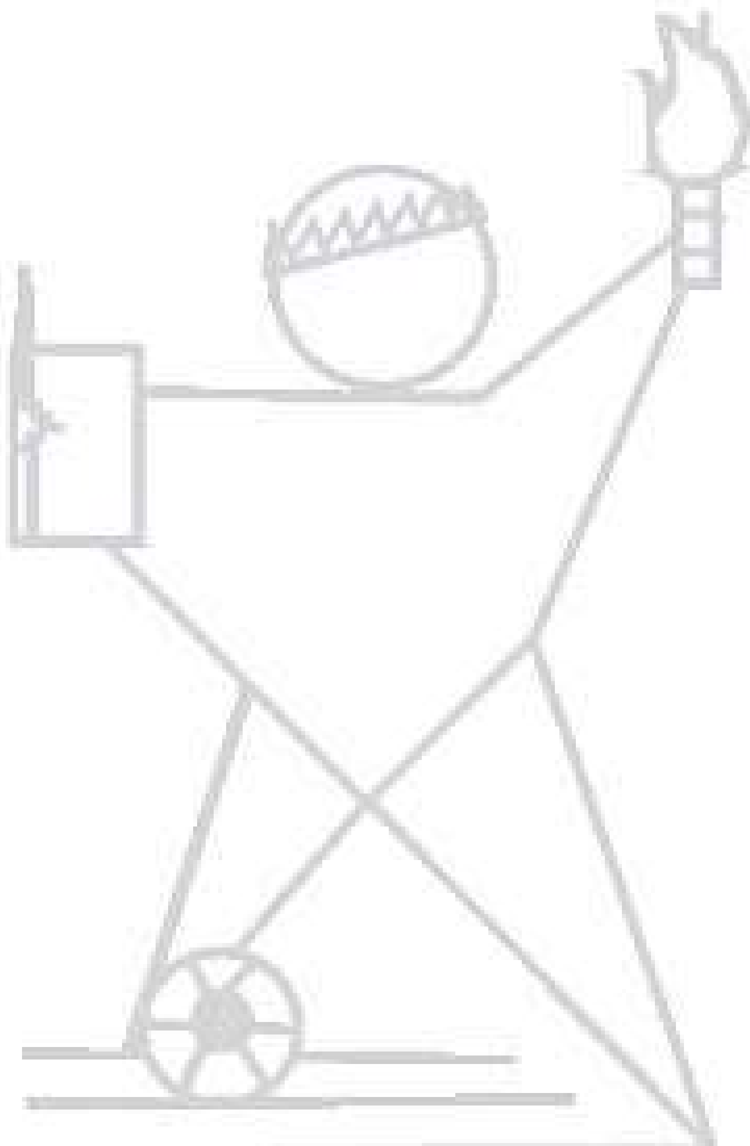
5. Compound belt drive. A compound belt drive, is used when power is transmitted from one shafts to another through a number of pulleys.

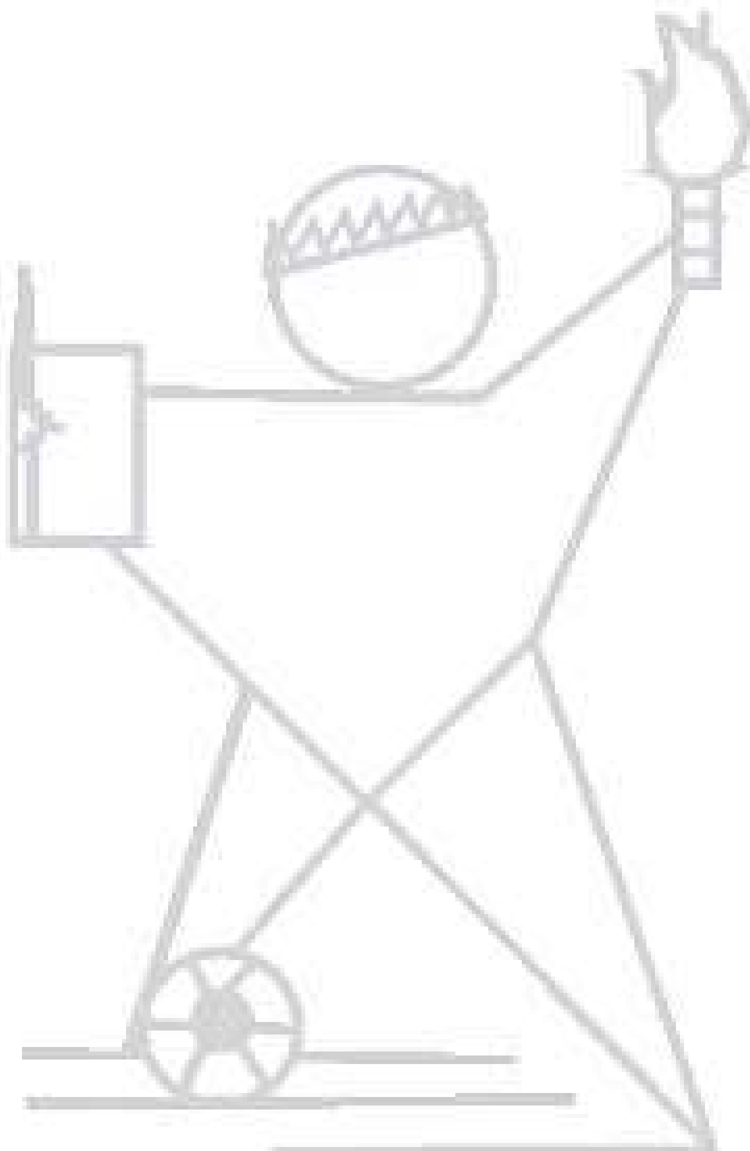
6. Stepped or cone pulley drive. A stepped or cone pulley drive, is used for changing the speed of the driven shaft while the main or driving shafts runs at constant speed. This is accomplished by shifting the belt from one part of the steps to the other.

7. Fast and loose pulley drive. A fast and loose pulley drive, is used when the driven or machine shaft is to be started or stopped when ever desired without interfering with the driving shaft. A pulley which is keyed to the machine shaft is called fast pulley and runs at the same speed as that of machine shaft. A loose pulley runs freely over the machine shaft and is incapable of transmitting any power. When the driven shaft is required to be stopped, the belt is pushed on the loose pulley by means of sliding bar having belt forks.

Questions:

1. What do you mean by flexible drive? Compare Rigid drive and flexible drive.
2. Explain the rope drive and give its types.
3. Explain about chain drive and give its types.
4. Draw a neat sketch of 6 × 19 and 6 × 37 rope.





Experiment No. 08

Aim: - To study various types of gear, gear trains and to construct involute profile of a gear by generating method.

Apparatus Used: - Models of different types of gears and gear trains.

Gear:-

Definition: -To transmit a definite motion of one disc to the other or to prevent slip between the surfaces, projections and recesses on the two disc can be made which can mesh with each other. This leads to the formation of teeth on the discs and the motion between the surfaces changes from rolling to sliding. The discs with teeth are known as gears. Gears are used to transmit motion from one shaft to another shaft or between shafts.

Classification of Gear: -

Gears can be classified according to the relative position of their shaft axis are follows:

A: Parallel Shaft

1. Spur gear
2. Spur rack and pinion
3. Helical gears or Helical spur gear
4. Double helical and Herringbone gear

B: Intersecting Shaft

1. Straight bevel gear
2. Spiral bevel gear
3. Zerol bevel gear

C: Skew Shaft

1. Crossed- helical gear
2. Worm gears (Non-throated, Single throated, Double throated)

Spur Gear:-

The gear teeth are straight along the length and are parallel to the axis.In a pair of mating spur gears, the axes of the component gears are parallel, that is, they are mounted on shafts which are parallel to each other. These are not subjected to axial thrust due to teeth load.

Spur Rack and Pinion:-

It is the special type of spur gear where it is made of infinite diameter. The spur rack and pinion combination converts rotary motion into translator motion, or vice-versa.

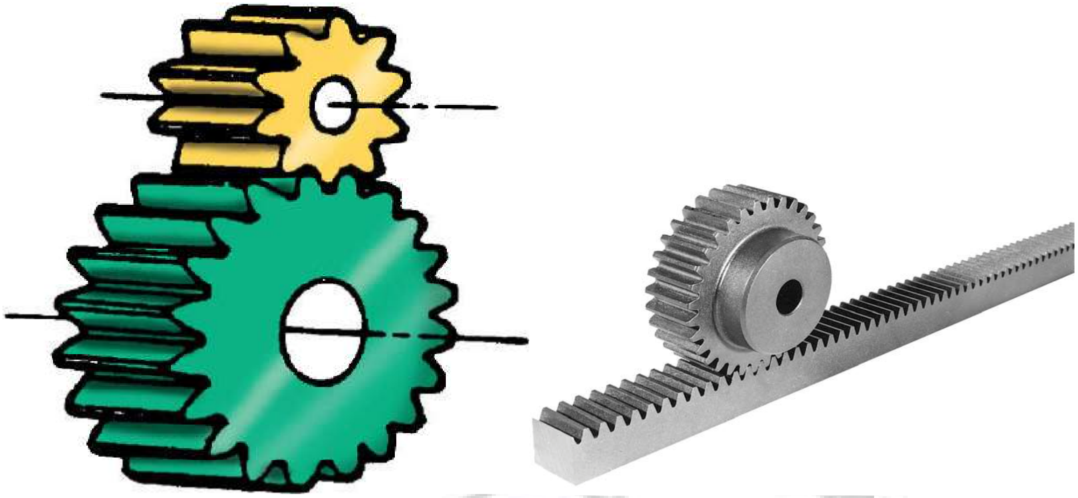


Figure. Spur Gear and Spur Rack and Pinion

Helical Gears:-

In helical gears, the teeth are curved, each being helical in shape. Two mating gears have the same helix angle, but have teeth of opposite hands. At the beginning of engagement, contact occurs only at the point of leading edge of the curved teeth. As the gears rotate, the contact extends along a diagonal line across the teeth. Thus the load application is gradual which result in now impact stresses and reduction in noise. Therefore, the helical gears can be used at higher velocities then the spur gears and have greater load carrying capacity.

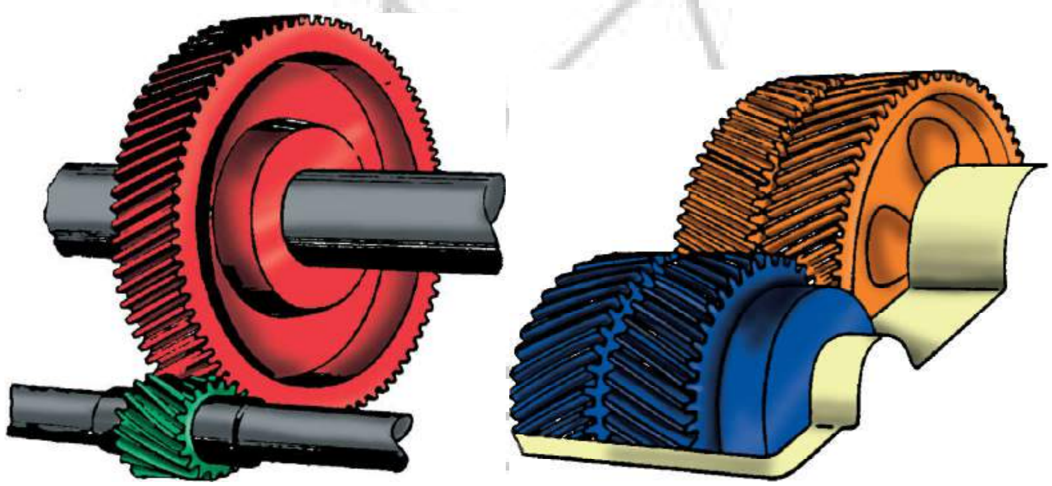


Figure. Helical Gears and Double Helical Gears

Double helical and herring bone gears:-

A double helical gear is equivalent to a pair of helical gears secured together, one having a right hand helix and the other a left hand helix. The tooth of two raw is separated by a grooved used for too run out. If the left and the right inclinations of a double helical gear meet at a common apex and there is no groove in between, the gear is known as herring bone gear.

Crossed–Helical Gear: -

The use of crossed helical gear or spiral gears is limited to light loads. By a suitable choice of helix angle for the mating gears, the two shafts can be set at any angle.

Worm Gear: -

Worm gear is a special case of spiral gear in which the larger wheel, usually, has a hollow or concave shape such that a portion of the pitch diameter is the other gear is enveloped on it. The smaller of two wheels is called the worm which also has larger spiral angle.

Bevel Gear:-

Kinematically, the motion between two intersecting shafts is equivalent to the rolling of two cones, assuming no slipping. The gears, in general, are known as bevel gear. When teeth formed on the cones are straight, the gear is known as straight bevel and when inclined, they are known as spiral or helical bevel.

Gear Trains

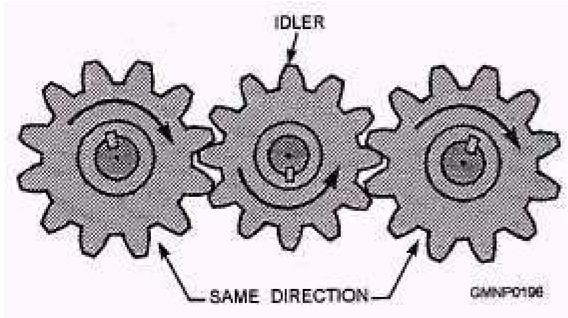
Gear Train: - A gear train is a combination of gears used to transmit motion from one shaft to another. It becomes necessary when it is required to obtain large speed reduction within a small space. The following are the main types of gear trains:

1. Simple gear train
2. Compound gear train
3. Reverted gear train
4. Planetary gear train

Simple Gear Train: - A series of gears, capable of receiving and transmitting motion from one gear to another is called a simple gear train. In it, all the gear axes remain fixed relative to the frame and each gear is on a separate shaft.

Train Value = Number of teeth on driving gear / Number of teeth on driven gear

Compound Gear Train: - When a series of gears are connected in such a way that two or more gears rotate about an axis with the same angular velocity, it is known as compound gear train. In this type, some of the intermediate shafts.



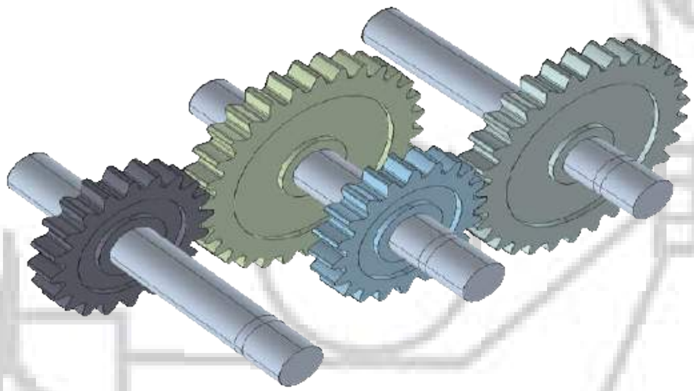


Figure. Simple and Compound Gear Train

Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear

Reverted Gear Train: - If the axes of the first and last wheels of a compound gear coincide; it is called a reverted gear train. Such an arrangement is used in clocks and in simple lathes where 'back gear' is used to give a slow speed to the chuck.

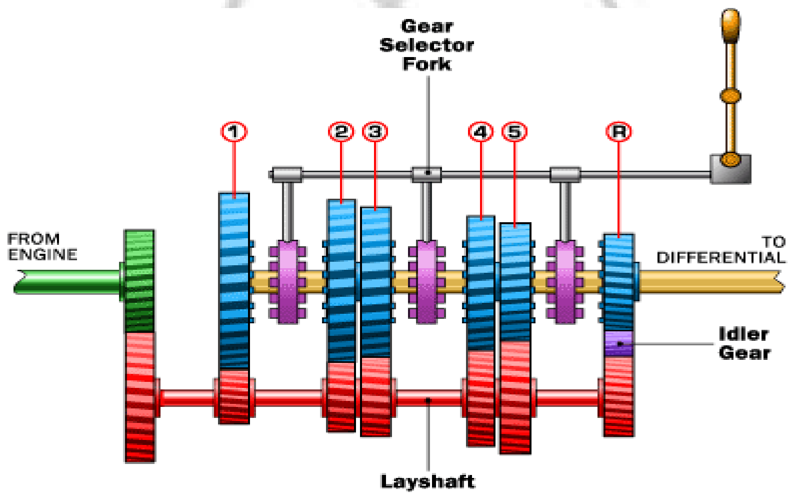


Figure. Reverted Gear Train

Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear

Planetary or Epicyclic Gear Train: - When there exists a relative motion of axis in gear train, it is called a planetary or an epicyclic gear train (or simply epicyclic gear or train). Thus in an epicyclic train, the axis of at least one of the gears also moves relative to the frame.

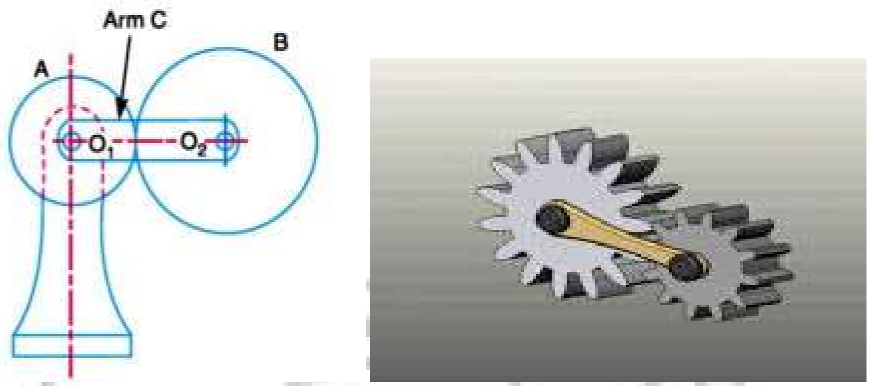


Figure. Planetary or Epicyclic Gear Train

Consider two gear wheels S and P, the axis of which are connected by an arm a. if the arm ‘a’ is fixed, the wheels S and P constitute a simple train. However, if the wheel s is fixed so that the arm can rotate about the axis of S, the wheel P would also move around S. therefore, it is an epicyclic gear train.

Applications:-

Following are the applications of gears and gear trains.

1.
2.
3.
4.
5.

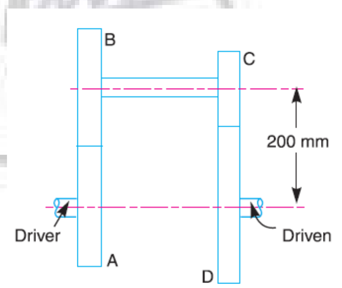
Following are the applications of gear trains.

1.
2.
3.
4.
5.

Question:-

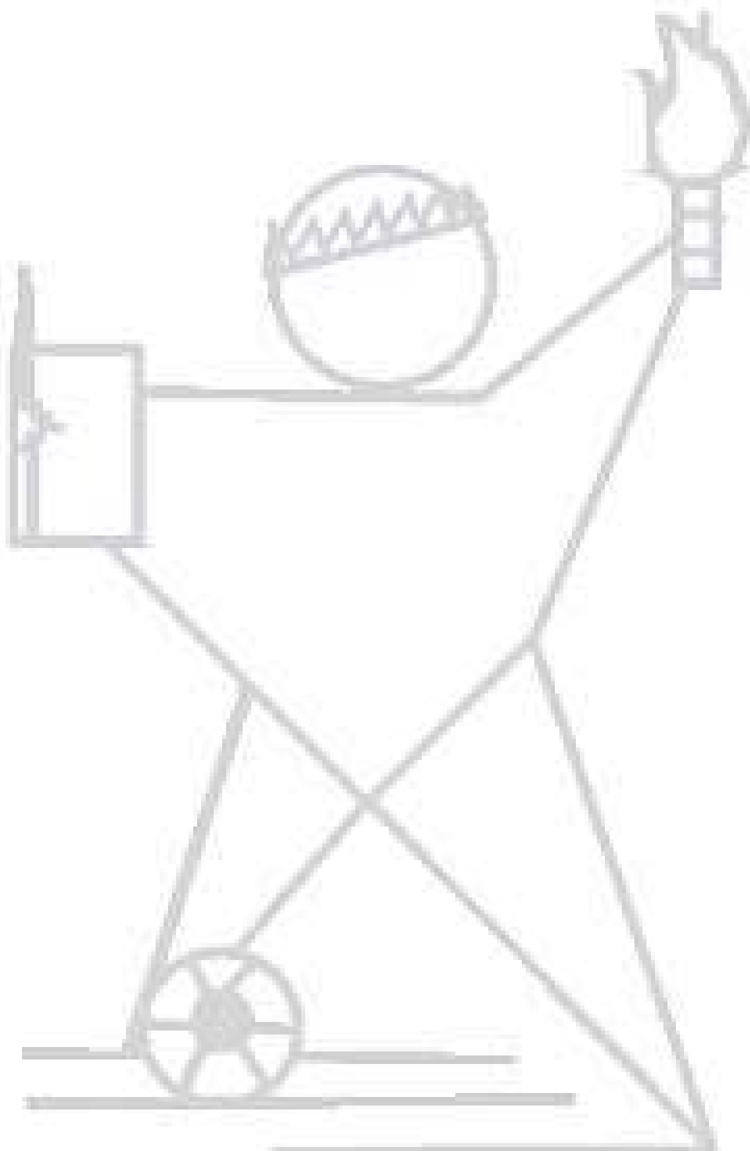
1. Explain the Gear terminology with neat sketch.
2. The arm of an epicyclic gear train rotates at 100 rpm in anticlockwise direction. The arm carries two wheels A and B having 36 and 45 teeth respectively. The wheel A is fixed and the arm rotates about the centre of wheel A. Find the speed of wheel B. What will be the speed of B, if the wheel A instead of being fixed, makes 200 rpm, clockwise? Solve by both the methods i.e. algebraic method and tabular method.

3. The speed ratio of the reverted gear train, as shown in Figure, is to be 12. The module pitch of gears A and B is 3.125 mm and of gears C and D is 2.5 mm. Calculate the suitable numbers of teeth for the gears. No gear is to have less than 24 teeth.



4. Explain differential gear box with neat sketch.

Answer-



The involute System

The curved surface of the gear tooth profile must be of a definite geometric form if the gears are to operate smoothly with a minimum of noise and vibration. The most common form in use today is the involute profile.

In the involute system, the shape of the tooth depends basically upon the pressure angle. The pressure angle is either $14\frac{1}{2}$ degrees or 20 degrees. The pressure angle determines the size of the base circle. The involute curve is generated from the base circle.

Calculations-

Pitch Circle diameter = ---

Circular Pitch = ---

Addendum = ----------------

Clearance = -----------------

Addendum circle diameter = --

Dedendum =--

Dedendum circle diameter = --

Tooth Thickness = ---

Construction Steps -

1. With centre O, draw the pitch circle of PCD calculated.

2. At any point P on it, draw a tangent TT'.
3. Again through P, draw the line of action LL' inclined at θ (equal to 20^0) to TT'.
4. Through O, draw a line OE inclined at θ to OP (it will be perpendicular to LL').
5. With centre O and radius OE, draw the base circle.
6. Draw the addendum and dedendum circles of diameters calculated.
7. On the pitch circle, mark points 1,2,3 etc., distance equal to tooth thickness.
8. To draw involute as shown in figure 2 of involute profile, draw the lines 1'1, 2'2, 3'3, etc. which are tangential to the circle and equal in length to the arc lengths, P' 1', 2' etc. are the involute.
9. Place the tracing paper in such a manner that the arc AB coincides with base circle. While the curve passes through say the point 1.
10. Pick a few points on the curve between the addendum circle and the base circle join these points by means of French curve.
11. Complete one side of the tooth profile by drawing a radial line below the base circle and then join it with the bottom of the tooth space by a fillet of radius r equal to $\frac{\text{tooth thickness}}{4}$
12. Reverse the tracing paper and plot the curve through the point 2 in the same manner, thus completing a tooth profile.
13. Repeat the construction for each tooth.

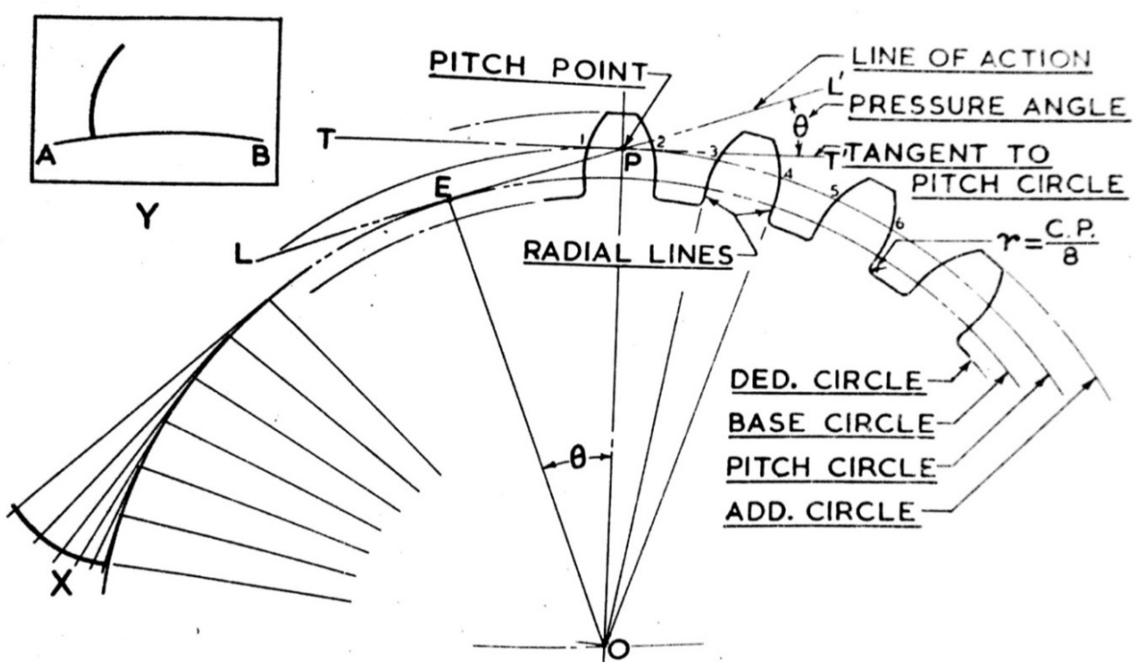


Figure: Construction of Involute Teeth Profile

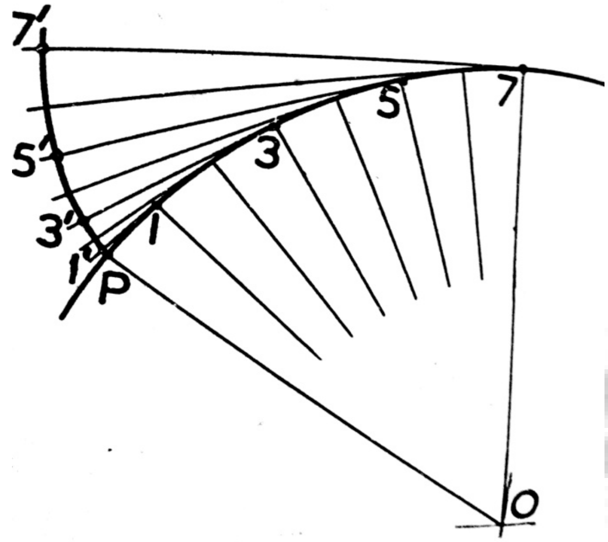


Figure: Involute Profile

Problem – Draw the profile of an involute teeth for a gear having 24 teeth and module equal to 8.33 mm and assuming a pressure angle of 20^0.

Solution-

EXPERIMENT No: 09

Aim: - To perform the experiment for static balancing on static balancing machine.

Apparatus Used: - Static Balancing Machine

Theory: - A system of rotating masses is said to be in static balance if the combined mass centre of the System lies on the axis of rotation. Whenever a certain mass is attached to a rotating shaft, it exerts some Centrifugal force, whose effect is to bend the shaft and to produce vibrations in it. In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft. The process of providing the second mass in order to counteract the effect of the centrifugal force of the first mass, is called balancing of rotating masses.

The following cases are important from the subject point of view:

1. Balancing of a single rotating mass by a single mass rotating in the same plane.
2. Balancing of a single rotating mass by two masses rotating in different planes.
3. Balancing of different masses rotating in the same plane.
4. Balancing of different masses rotating in different planes.

Procesure: - Remove the belt, the value of weight for each block is determined by clamping each block in turn on the shaft and with the cord and container system suspended over the protractor disc, the number of steel balls, which are of equal weight are placed into one of the containers to exactly balance the blocks on the shaft. When the block becomes horizontal, the number of balls N will give the value of weight for the block.

Fig. Experimental model for Static Balancing

For finding out Wr during static balancing proceed as follow:

1. Remove the belt.
2. Screw the combined hook to the pulley with groove. This pulley is diff. than the belt pulley.
3. Attached the cord end of the pans to above combined hook.
4. Attached the block no.-1 to the shaft at any convenient position and in vertical downward direction.
5. Put steel balls in one of the pans till the blocks starts moving up. (upto horizontal position).
6. Number of balls give the Wr value of block-1. Repeat this for 2-3 times and find the average no. of balls.

7. Repeat the procedure for other blocks.

Observation:-

S. No.	Plane	Mass (m) kg	Radius (r) meter	Centrifugal Force/◆^{2} =(m.r) kg-m	Distance from R.P	Couple ÷◆^{2} = (m×r×l) kg-m^2

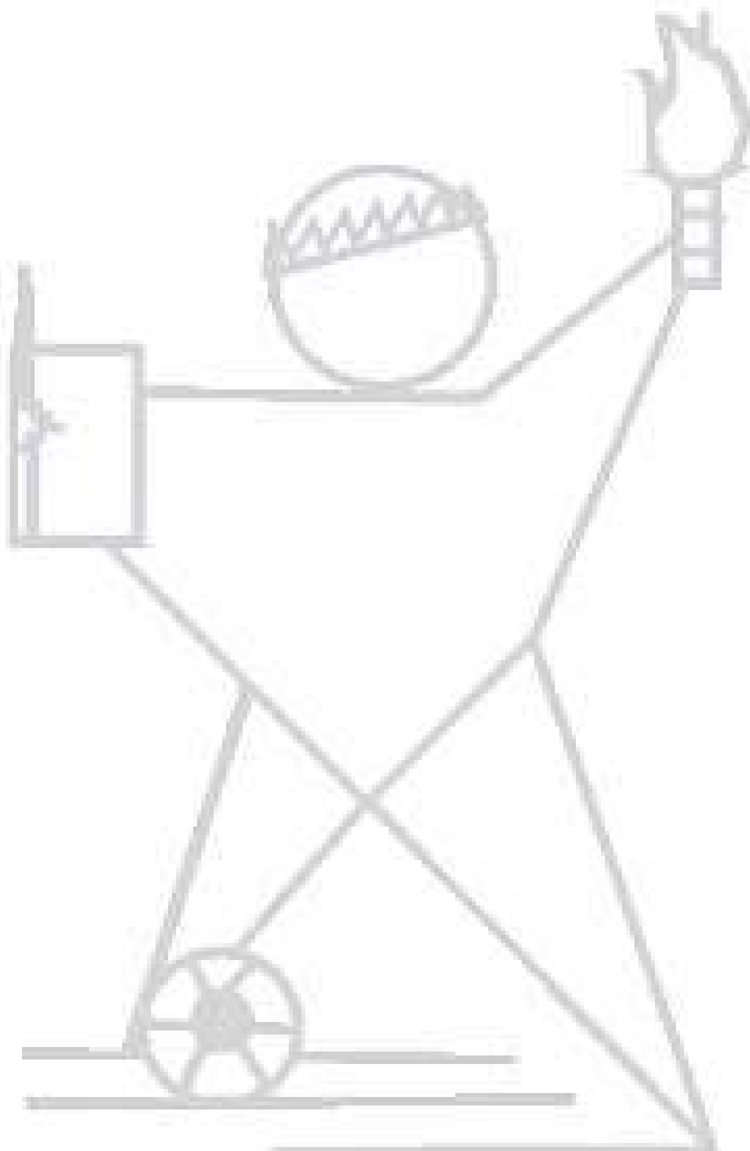
Calculation: - The balancing masses and angular positions may be determined graphically as given below:-

1. First of all, draw the couple polygon from the data which are calculated in table to some suitable scale. The vector distance represents the balanced couple. The angular position of the balancing mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle.

2. Then draw the force polygon from the data, which are calculated in table to some suitable scale. The vector distance represents the balanced force. The angular position of the mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle in the clockwise direction from mass.

Precautions:-

1. Couple should be represented by a vector drawn perpendicular to the plane of the couple.
2. Angular position measure carefully in clockwise direction.
3. Vector diagram should be represent with suitable scale.



Experiment No. 10

Aim: Experimental justification of the equation T = I ω ω_P for calculating the gyroscopic couple by observation and measurement of results for independent variation in applied couple C and precession ω_p.

Introduction:

Axis of spin: If a body is revolving about an axis, the latter is known as axis of spin (Refer Figure, where OX is the axis of spin).

Precession: Precession means the rotation about the third axis OZ (Refer Figure) that is perpendicular to both the axis of spin OX and that of couple OY.

Axis of Precession: The third axis OZ is perpendicular to both the axis of spin OX and that of couple OY is known as axis of precession.

Gyroscopic Effect:

To a body revolving (or spinning) about an axis say OX, (Refer Figure) if a couple represented by a vector OY perpendicular to OX is applied, then the body tries to process about an axis OZ which is perpendicular both to OX and OY. Thus, the couple is mutually perpendicular.

The above combined effect is known as precessional or gyroscopic effect.

Gyroscope:

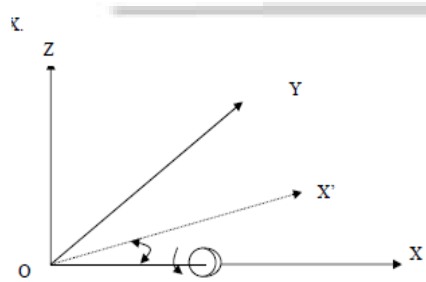
It is a body while spinning about an axis is free to rotate in other directions under the action of external forces.

Theory:

Gyroscopic couple of a plane disc:

Let a disc of weight 'W' having a moment of inertia I be spinning at an angular velocity ω about axis OX in anticlockwise direction viewing from front (Refer Figure).

Therefore, the angular momentum of disc is Iω. Applying right–hand screw rule the sense of vector representing the angular momentum of disc which is also a vector quantity will be in the direction OX as shown.



A couple whose axis is OY perpendicular to OX and is in the plane Z, is now applied to prices the axis OX.

Let axis OX turn through a small angular displacement from OX to OX' in time δt. The couple applied produces a change in the direction of angular velocity, the magnitude & the magnitude remaining constant. This change is due to the velocity of precession.

Therefore, 'OX' represents the angular momentum after time dt.

Change of angular momentum = $\overrightarrow{OX'} - \overrightarrow{OX} = \overrightarrow{XX'}$

Angular displacement = $\frac{XX'}{dt} - \frac{OX \times d\theta}{dt}$

As, XX ' = OX × dθ in direction of XX'

Now as rate of change of angular momentum

Couple applied = C =T

We get

$$T = OX\frac{d\theta}{dt}$$

But OX = I ω

Where, I = Moment of Inertia of disc

ω = Angular Velocity of disc.

$$T = I\omega\frac{d\theta}{dt}$$

And in the limit dt is very small

We have

$$\frac{d\theta}{dt} = \omega p$$

Where ω_p = Angular velocity of precession of yoke about vertical axis.

Thus, we get – $T = I \times \omega \times \omega p$

The direction of the couple applied on the body is clockwise when looking in the direction XX' and in the limit this is perpendicular to the axis of ω and of ω p. The reaction couple exerted by the body on its frame is equal in magnitude to that of C, but opposite in direction.

Description:

The set up consists of heavy disc mounted on a horizontal shaft, rotated by a variable speed motor. The rotor shaft is coupled to a motor mounted on a trunion frame having bearings in a yoke frame, which is free to rotate about vertical axis. A weight pan on other side of disc balances the weight of motor. Rotor disc can be move about three axis. Weight can be applied at a particular distance from the center of rotor to calculate the applied torque. The gyroscopic couple can be determined with the help of moment of inertia, angular speed of disc and angular speed of precession.

Utilities Required:

Electricity Supply: Single Phase, 220 V AC, 50 Hz 5-15 amp socket with earth connection.

Tachometer and Bench Area Required: 1 m x 1 m

Experimental procedure:

1. Set the rotor at zero position.
2. Start the motor with the help of rotary switch.
3. Increase the speed of rotor with dimmer stat & stable it & measure the R.P.M. with the help of tachometer.
4. Put the weight on weight pan then yoke rotate at anticlockwise direction.
5. Measure the rotating angle (30^0, 40^0) with the help of stopwatch.
6. Repeat the experiment for the various speeds and loads.
7. After the test is over set dimmer stat to zero position and switch off main supply.

Observation & calculation:

Data: $g = 9.81$ m/sec^2, $r = 0.15$ m, $W = 5.42$ kg, $L = 0.225$ m

Observation table:

S.No.	N (RPM)	W (kg)	dθ (degree)	dt (sec)
1				
2				
3				
4				
5				

Calculations:

$T = I \times \omega \times \omega p$, kg-m =----------------

$I = \frac{W}{g} \times \frac{r^2}{2}$, kg-m-sec^2 = -----------------

$\omega = \frac{2\times\pi\times N}{60}$, rad/sec = --------------------

$\omega p = \frac{d\theta}{dt} \times \frac{\pi}{180}$, rad/sec = ---------------

Tact = wL, kg-m = --------------------

Nomenclature:

dθ = Angle of precession

dt = Time required for this precessions, sec

g = Acceleration due to gravity, m /sec2

I = Moment of inertia of disc, kg m sec2

L = Distance of weight for the center of disc, m

N = RPM of Disc spin.

r = Radius of disc, m

T_{the} = Theoretical Gyroscopic couple, kg-m

T_{act} = Actual Gyroscopic couple, kg-m

W = Weight of rotor disc, kg

w = Weight on pan, kg

ω = Angular velocity of disc, rad/sec

ω_p = Angular velocity of precession of yoke about vertical axis, rad/sec

Precautions & maintenance instructions:

1. Never run the apparatus if power supply is less than 180 volts and above than 230 volts.
2. Before start the motor set dimmer stat at zero position.
3. Increase the speed gradually.

Question:-

1. What do you understand by gyroscopic couple ? Derive a formula for its magnitude.
2. Explain the application of gyroscopic principles to aircrafts.
3. Describe the gyroscopic effect on sea going vessels.
4. Explain the effect of the gyroscopic couple on the reaction of the four wheels of a vehicle negotiating a curve.
5. Discuss the effect of the gyroscopic couple on a two wheeled vehicle when taking a turn.