Subject Name: **Theory of machines & mechanics**

Subject Code: **ME-3003**

Semester: **3rd**

Unit – I

Mechanisms and Machines: Links, Pairs, Chains, Structure, Mechanism, Machine, Equivalent linkage, Degrees of freedom, Gruebler's & Kutzback's criterion, Inversions of four bar chain, Mechanism with lower pairs Pantograph, Straight line motion mechanisms, Davis and Ackermann's steering mechanisms, Hooke's joint, Numerical problems based on above topics.

Mechanisms: A mechanism is the mechanical portion of a machine that has the function of transferring motion and forces from a power source to an output. It is the heart of a machine. A mechanism can be considered rigid parts that are arranged and connected so that they produce the desired motion of the machine.

Machines: Machines are devices used to alter, transmit, and direct forces to accomplish a specific objective.

Kinematics: Kinematics deals with the relative motion of different parts of mechanism without taking consideration the force producing the motions. Thus, it is the study, from a geometric point of view, to know the displacement, velocity and acceleration of a part of a mechanism.

Dynamics: Dynamics deals with the calculations of forces impressed upon different parts of a mechanism. The forces can be either static or dynamic. Dynamics is further subdivided into kinetics and statics. Kinetics is the study of forces when the body is in motion whereas statics deals with forces when body is stationary.

Types of Constrained Motion:

1. Completely Constrained Motion: Completely constrained motion is a type of constrained motion in which relative motion between the links of a kinematic pair occurs in a definite direction by itself, irrespective of the external forces applied.

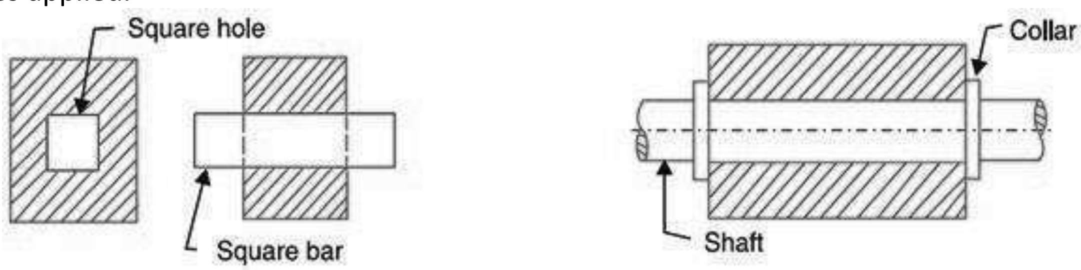


Fig. 1.1

2. Incompletely Constrained Motion: In incompletely constrained motion, the relative motion between the links depends on the direction of external forces acting on them. A good example of incompletely constrained motion is the motion of a shaft inside a circular hole. Depending on the direction of external forces applied, the shaft may slide or turn (or do both) inside the circular hole. Incompletely constrained motion is undesirable in any mechanical system. It leads to improper mechanical outputs.

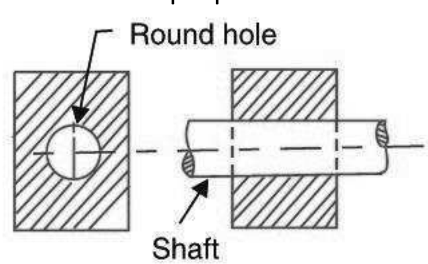


Fig. 1.2

3. Successfully constrained motion: A kinematic pair is said to be partially or successfully constrained if the relative motion between its links occurs in a definite direction, not by itself, but by some other means. A good example of successfully constrained motion is piston reciprocating inside a cylinder in an internal combustion engine and Foot Step Bearing.

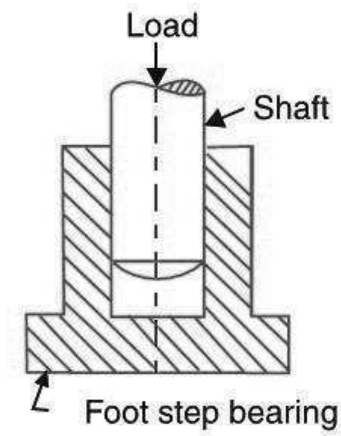


Fig. 1.3

Rigid and Resistant Bodies: A rigid body is defined as a body on which the distance between two points never changes whatever be the force applied on it. Or you may say the body which does not deform under the influence of forces is known as a rigid body. But, in real life, there would be some force under which the body starts to deform. For example, a bridge does not deform under the weight of a single man but it may deform under the load of a truck or ten trucks. However, the deformation is small.

A body is said to be a resistant body, if it does not deform for the purpose for which it is made. For example the chair, it does not deform if a person sits on it, but it will break if you put a load of 1000 kg on it. So a resistant body is rigid for the purpose for which it is used.

Links: Links are the individual parts of the mechanism. They are considered rigid bodies and are connected with other links to transmit motion and forces. Theoretically, a true rigid body does not change shape during motion. Although a true rigid body does not exist, mechanism links are designed to minimally deform and are considered rigid.

Depending upon the number of ends provided:

1. Binary Link (a): Having two ends for turning pairs.

2. Ternary Link (b): Having three ends for turning pairs.

3. Quaternary Link (c): Having four ends for turning pairs.

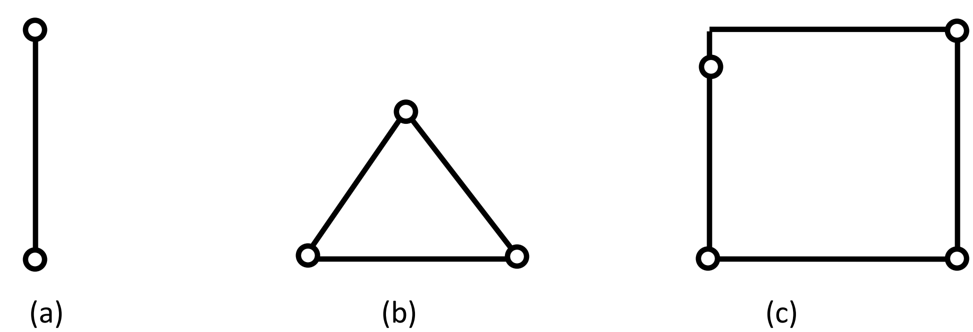


Fig. 1.4

KINEMATIC PAIR: – A kinematic pair or simply a pair is a joint of two links having relative motion between them.

Classification of Pairs:

1-Kinematics pairs according to nature of contact:-

(i) **Lower pair (links having surfaced or area contact): -** If the joint by which two members are connected has surface contact, the pair is known as lower pair. E.g. pin joints, shaft rotating in bush, slider in slider crank mechanism.

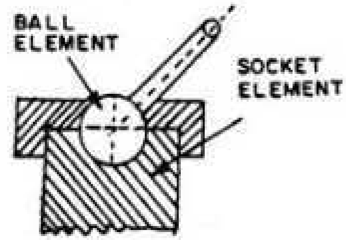


Fig. 1.5

(ii) **Higher pair (Point or line contact between the links): -** If the contact between the pairing elements takes place at a point or along a line, such as in a ball bearing or between two gear teeth in contact, it is known as a higher pair.

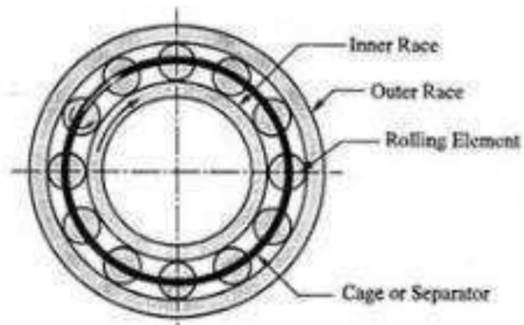


Fig. 1.6

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

(i) **Closed pair (when the elements of a pair are held together mechanically): -** Elements of pairs held together mechanically due to their geometry constitutes a closed pair. They are also called form-closed or self-closed pair.

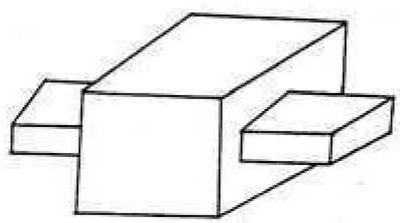


Fig. 1.7

(ii) **Unclosed pair (when two links of a pair are in contact either due to force of gravity or some spring action): -** Elements of pairs held together by the action of external forces constitute unclosed or force closed pair .Eg. Cam and follower

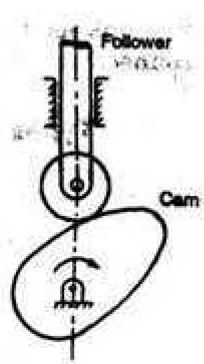


Fig. 1.8

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

(i) Sliding pair: - Sliding pair is constituted by two elements so connected that one is constrained to have a sliding motion relative to the other. DOF = 1.

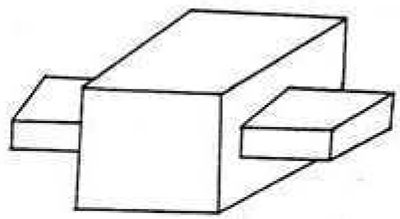


Fig. 1.9

(ii) Turning pair: - When connections of the two elements are such that only a constrained motion of rotation of one element with respect to the other is possible, the pair constitutes a turning pair. DOF = 1.

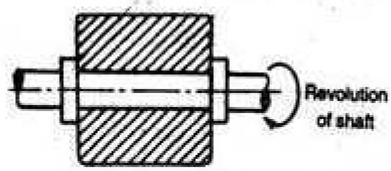


Fig. 1.10

(iii) Rolling Pair: - When the pairing elements have rolling contact, the pair formed is called rolling pair. e. g. Bearings, Belt, and pulley, DOF = 1.

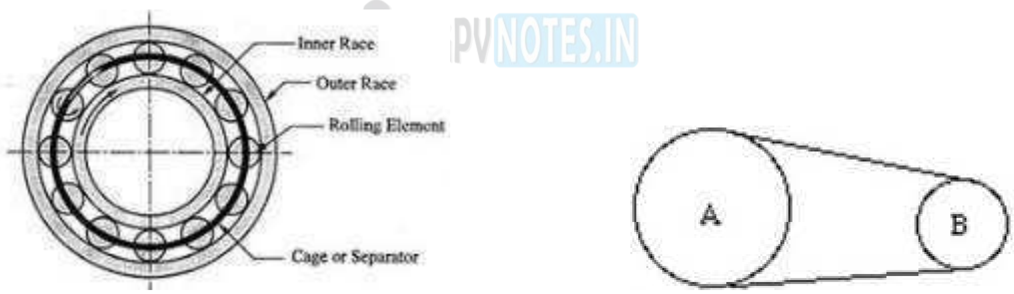


Fig. 1.11

(iv) Screw pair (Helical pair): - When the nature of contact between the elements of a pair is such that one element can turn about the other by screw threads, it is known as screw pair e.g. Nut and bolt DOF = 1.

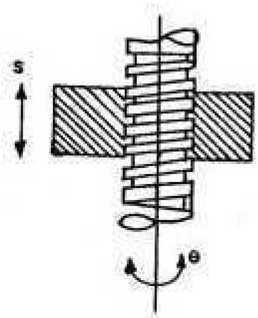


Fig. 1.12

(v) Spherical pair: - A spherical pair will have surface contact and three degrees of freedom. e. g. Ball and socket joint. DOF = 3.

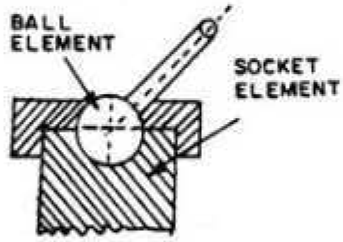


Fig. 1.13

Types of Joints: The usual types of joints in a chain are:

➢ **Binary Joint:** If two links are joined at the same connection; it is called a binary joint. For example. Fig. 1.14 shows a chain with two binary joints named B.

➢ **Ternary Joint:** If three links are joined at a connection, it is known as a ternary joint. It is considered equivalent to two binary joints since fixing of any one link constitutes two binary joints with each of the other two links. In Fig. 1.14 ternary links are mentioned as T.

➢ **Quaternary Joint:** If four links are joined at a connection, it is known as a quaternary joint. It is considered equivalent to three binary joints since fixing of any one link constitutes three binary joints. Fig. 1.14 shows one quaternary joint.

In general, if ‘n’ numbers of links are connected at a joint, it is equivalent to (n-1) binary joints.

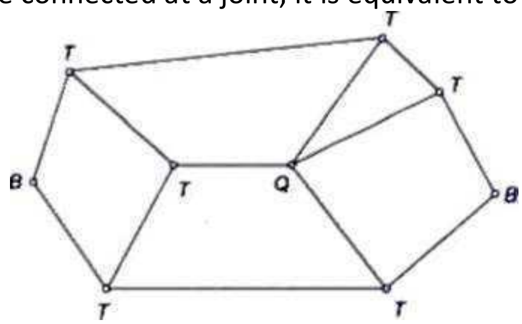


Fig. 1.14

Degrees of freedom (DOF): The **degree of freedom (DOF) of a rigid body is** defined as the number of independent movements it has. Figure 1.15 shows a rigid body in a plane. To determine the DOF of this body we must consider how many distinct ways the bar can be moved. In a two dimensional plane such as this computer screen, there are 3 DOF. The bar can be translated along the x axis, translated along the y axis, and rotated about its centroid.

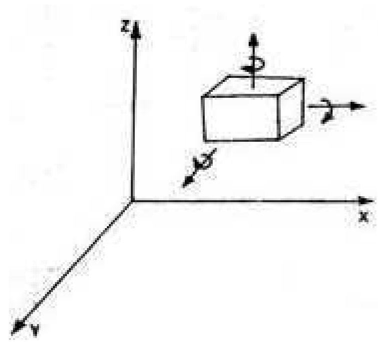


Fig. 1.15

Possible Motions:

1. Three translations along x, y and z axes.
2. Three rotations about x, y and z axes.

So an object in free space has six degrees of Freedom.

A fixed object has zero degree of freedom.

GRUBLER'S RULE

Degrees of freedom/mobility of a mechanism: It is the number of inputs (number of independent coordinates) required describing the configuration or position of all the links of the mechanism, with respect to the fixed link at any given instant.

Grubler's equation: Number of degrees of freedom of a mechanism is given by

$$F = 3(n-1)-2P_1-P_2$$

Where,

F = Degrees of freedom

n = Number of links = $n_2 + n_3 + \ldots\ldots + n_j$, where, n_2 = number of binary links, n_3 = number of ternary links…etc.

P_1 = Number of lower pairs, which is obtained by counting the number of joints. If more than two links are joined together at any point, then, one additional lower pair is to be considered for every additional link.

P_2 = Number of higher pairs

Chains: 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 other is definite.

In case the motion of a link results in definite motions of the other links, it is non-kinematic chain.

A Redundant Chain does not allow any motion of a link relative to other.

Linkage: - A linkage is obtained if one of the links of a kinematic chain is fixed to the ground. If motion of any of the moveable links results in definite motions of others, the linkage is known as Mechanism.

Structure: If one of the links of a redundant chain is fixed, it is known as a structure or a locked system.

Four – Bar Chain: -

The simplest and the basic kinematic chain is a four bar chain or quadric cycle chain, as shown in Fig. 1.16 .It consists of four links, each of them forms a turning pair at A, B, C and D. The four links may be of different lengths. According to Grashof 's law for a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths if there is to be continuous relative motion between the two links.

A very important consideration in designing a mechanism is to ensure that the input crank makes a complete revolution relative to the other links. The mechanism in which no link makes a complete revolution will not be useful. In a four bar chain, one of the links, in particular the shortest link, will make a complete revolution relative to the other three links, if it satisfies the Grashof 's law. Such a link is known as **crank** or **driver**. In Fig. 1.16, AD (link 4) is a crank. The link BC (link 2) which makes a partial rotation or oscillates is known as **lever** or **rocker** or **follower** and the link CD (link 3) which connects the crank and lever is called **connecting rod** or **coupler.** The fixed link AB (link 1) is known as **frame** of the mechanism. When the crank (link 4) is the driver, the mechanism is transforming rotary motion into oscillating motion.

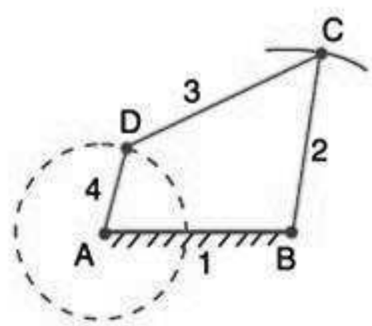


Fig. 1.16 Four bar Chain

Inversions of Four Bar Chain

Inversions of mechanism: A mechanism is one in which one of the links of a kinematic chain is fixed. Different mechanisms can be obtained by fixing different links of the same kinematic chain. These are called as inversions of the mechanism. By changing the fixed link, the number of mechanisms which can be obtained is equal to the number of links. Excepting the original mechanism, all other mechanisms will be known as inversions of original mechanism. The inversion of a mechanism does not change the motion of its links relative to each other.
Though there are many inversions of the four bar chain, yet the following are important from the subject point of view:

Grashof's Criterion
The following nomenclature is used to describe the length of the four links. Because it is encountered so often, further exploration is in order. The mechanism for an automotive rear-window wiper system is shown in Figure a. The kinematic diagram is shown in Figure. Notice that this is a four-bar mechanism
s = length of shortest link
q = length of the other intermediate length links
p = length of one of the intermediate length links
l = length of the longest link
Grashof's Theorem states that a four-bar mechanism has at least one revolving link if:
$s + l \leq p + q$
Conversely, the three non fixed links will merely rock if:
$s + l > p + q$
All four-bar mechanisms fall into one of the five categories listed in Table.

Case	Criteria	Shortest Link	Category
01.	$s + l < p + q$	Frame	Double Crank
02.	$s + l < p + q$	Side	Crank – Rocker
03.	$s + l < p + q$	Coupler	Double Rocker
04.	$s + l = p + q$	Any	Change Point
05.	$s + l > p + q$	Any	Triple Rocker

1. Double Crank Mechanism: - A double crank, or crank-crank, is shown in Fig. 1.17. As specified in the criteria of Case 1 of Table, it has the shortest link of the four-bar mechanism configured as the frame. If one of the pivoted links is rotated continuously, the other pivoted link will also rotate continuously. Thus, the two pivoted links, 2 and 4, are both able to rotate through a full revolution. The double crank mechanism is also called a drag link mechanism.

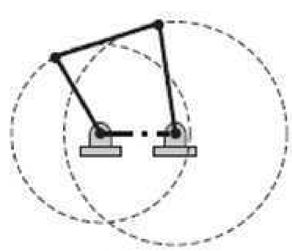


Fig. 1.17 Double Crank

2. Crank-Rocker Mechanism: - A crank-rocker is shown in Fig. 1.18. As specified in the criteria of Case 2 of Table, it has the shortest link of the four-bar mechanism configured adjacent to the frame. If this shortest link is continuously rotated, the output link will oscillate between limits. Thus, the shortest link is called the crank, and the output link is called the rocker. The wiper system in Figure is designed to be a crank-rocker. As the motor continuously rotates the input link, the output link oscillates, or "rocks." The wiper arm and blade are firmly attached to the output link, oscillating the wiper across a windshield.

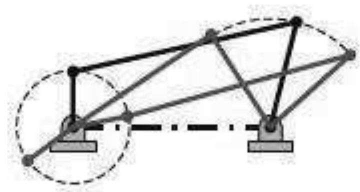


Fig. 1.18 Crank and Rocker

3. Double Rocker Mechanism: - The double rocker, or rocker-rocker, is shown in Fig. 1.19. As specified in the criteria of Case 3 of Table, it has the link opposite the shortest link of the four-bar mechanism configured as the frame. In this configuration, neither link connected to the frame will be able to complete a full revolution. Thus, both input and output links are constrained to oscillate between limits, and are called rockers. However, the coupler is able to complete a full revolution.

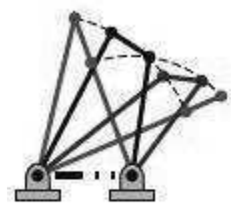


Fig. 1.19 Double Rocker

4. Change Point Mechanism: - A change point mechanism is shown in Fig. 1.20. As specified in the criteria of Case 4 of Table, the sum of two sides is the same as the sum of the other two. Having this equality, the change point mechanism can be positioned such that all the links become collinear. The most familiar type of change point mechanism is a parallelogram linkage. The frame and coupler are the same length, and so are the two pivoting links. Thus, the four links will overlap each other. In that collinear configuration, the motion becomes indeterminate. The motion may remain in a parallelogram arrangement, or cross into an anti parallelogram, or butterfly, arrangement. For this reason, the change point is called a singularity configuration.

Fig. 1.20 Change Point Mechanism

5. Triple Rocker Mechanism: - A triple rocker linkage is shown in Fig. 1.21. Exhibiting the criteria in Case 5 of Table, the triple rocker has no links that are able to complete a full revolution. Thus all the three moving links will rock.

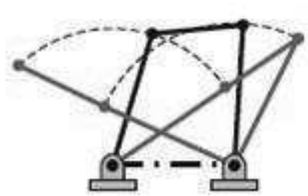


Fig. 1.21 Triple Rocker

Slider Crank Mechanism: - A single slider crank chain is a modification of the basic four bar chain. It consists 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 Fig. 1.22 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.

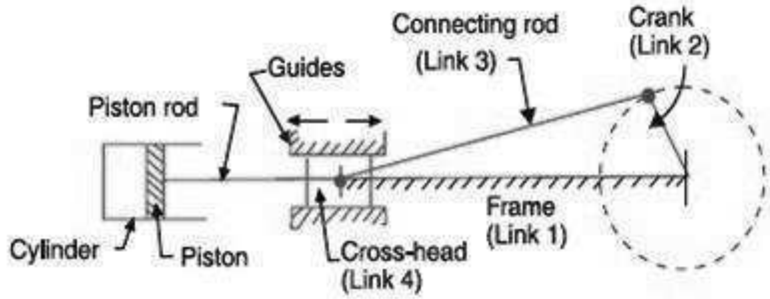


Fig. 1.22 Slider Crank Mechanism

Inversions of Single Slider Crank Chain

We have seen in the previous article that a single slider crank chain is a four-link mechanism. We know that by fixing, in turn, different links in a kinematic chain, an inversion is obtained and we can obtain as many mechanisms as the links in a kinematic chain. It is thus obvious, that four inversions of a single slider crank chain are possible. These inversions are found in the following mechanisms.

1. 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. 1.23. 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 has two pistons attached to link 1, as shown in Fig.

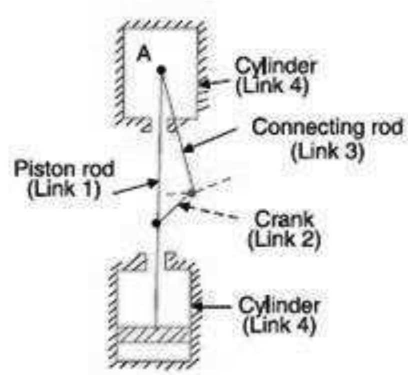


Fig. 1.23 Pendulum Pump

2. Oscillating cylinder engine: - The arrangement of oscillating cylinder engine mechanism, as shown in Fig. 1.24, 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.

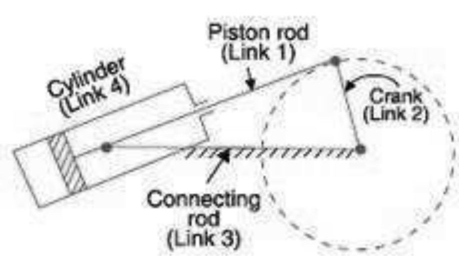


Fig. 1.24 Oscillating Cylinder Engine

3. 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 Fig. 1.25, 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 link 1.

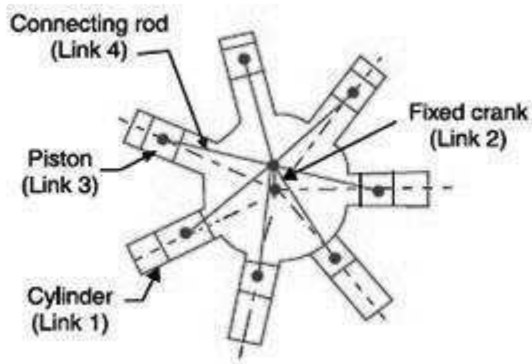


Fig. 1.25 Rotary Internal Combustion Engine

4. Crank and slotted lever quick return motion mechanism: - This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link AC (i.e. link 3) forming the turning pair is fixed, as shown in Fig. 1.26. 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_1R_2. The line of stroke of the ram (i.e. R_1R_2) is perpendicular to AC produced.

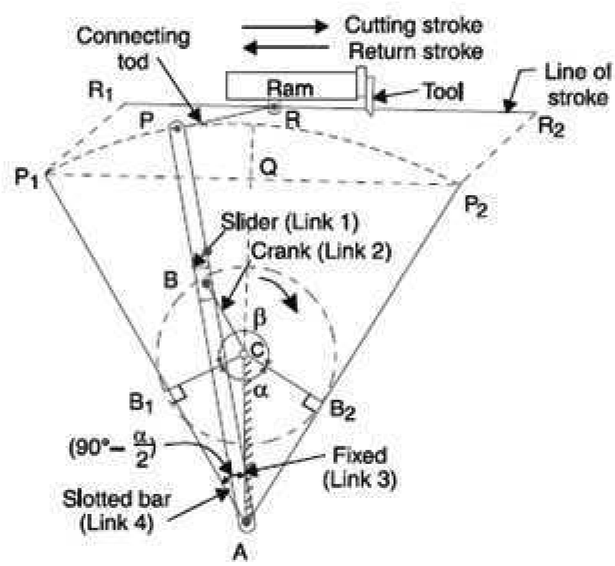


Fig. 1.26 Crank and Slotted Lever Quick Return Motion Mechanism

5. 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 shown in Fig. 1.27. 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.

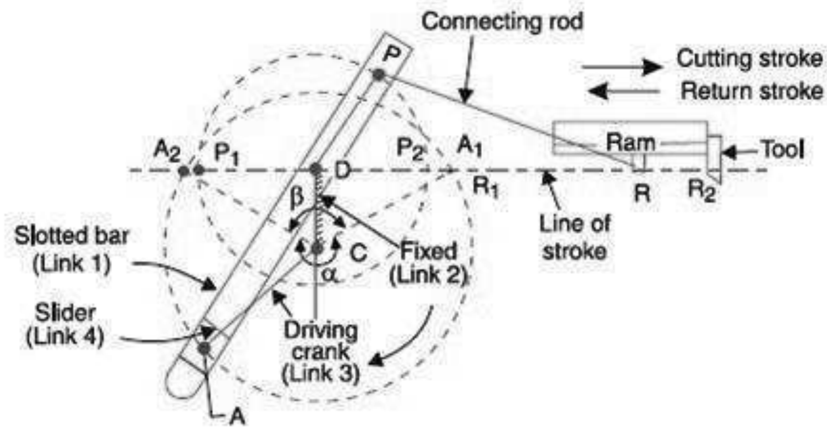


Fig. 1.27 Whitworth Quick Return Motion Mechanism

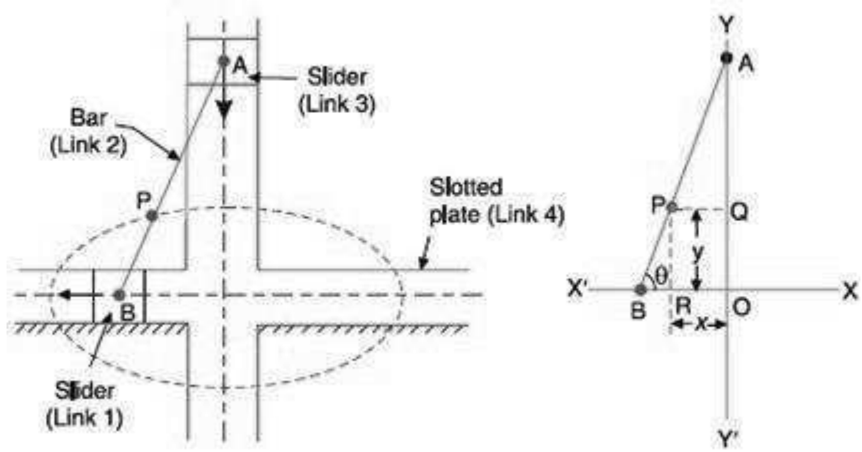
Double Slider Crank Chain

A kinematic chain which consists of two turning pairs and two sliding pairs is known as double slider crank chain, as shown in Fig. 1.28. We see that the link 2 and link 1 form one turning pair and link 2 and link 3 form the second turning pair. The link 3 and link 4 form one sliding pair and link 1 and link 4 form the second sliding pair.

Inversions of Double Slider Crank Chain

The following three inversions of a double slider crank chain are important from the subject point of view:

1. Elliptical trammels: - It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4), as shown in Fig. 1.28. 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 Fig. 1.28 (a). A little consideration will show that AP and BP are the semi-major axis and semi-minor axis of the ellipse respectively. This can be proved as follows:



(a) (b)

Fig. 1.28 Elliptical Trammel

Let us take OX and OY as horizontal and vertical axes and let the link BA is inclined at an angle θ with the horizontal, as shown in Fig. 1.28 (b). Now the co-ordinates of the point P on the link BA will be

$x = PQ = AP \cos \theta$; and $y = PR = BP \sin \theta$

Or $x/AP = \cos \theta$; and $y/BP = \sin \theta$

Squaring and adding,

$(x/AP)^2 + (y/BP)^2 = \cos^2 \theta + \sin^2 \theta = 1$

This is the equation of an ellipse. Hence the path traced by point P is an ellipse whose semi major axis is AP and semi-minor axis is BP.

2. Scotch yoke mechanism: - 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 Fig. 1.29, 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.

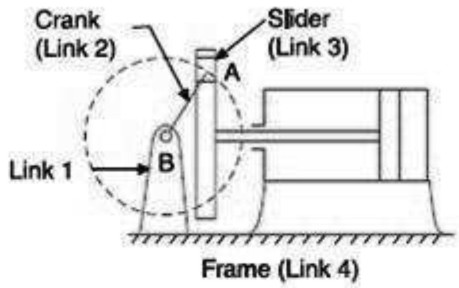
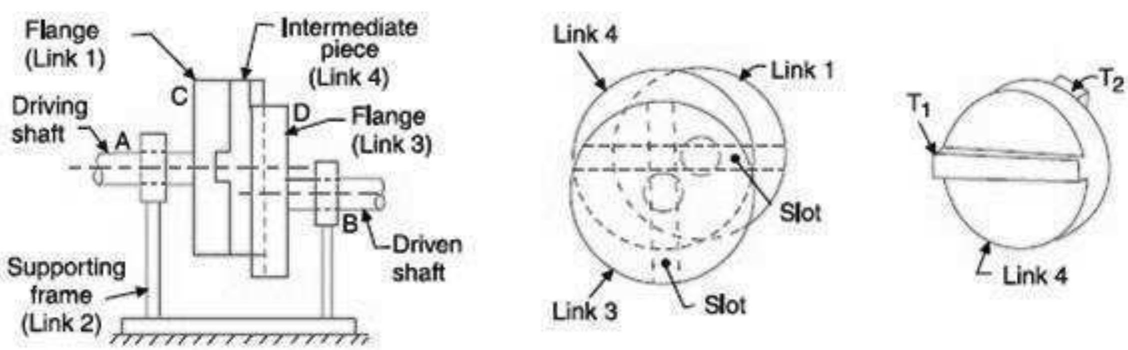


Fig. 1.29 Scotch and Yoke Mechanism

3. 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 Fig. 1.30 (a). The shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging.



(a) (b) (c)

Fig. 1.30 Oldham's coupling

The link 1 and link 3 form turning pairs with link 2. These flanges have diametrical slots cut in their inner faces, as shown in Fig. 1.30 (b). The intermediate piece (link 4) which is a circular disc, have two tongues (i.e. diametrical projections) T_1 and T_2 on each face at right angles to each other, as shown in Fig. 1.30 (c). The tongues on the link 4 closely fit into the slots in the two flanges (link 1 and link 3). The link 4 can slide or reciprocate in the slots in the flanges.

When the driving shaft A is rotated, the flange C (link 1) causes the intermediate piece (link 4) to rotate at the same angle through which the flange has rotated, and it further rotates the flange D (link 3) at the same angle and thus the shaft B rotates. Hence links 1, 3 and 4 have the same angular velocity at every instant. A little consideration will show that there is a sliding motion between the link 4 and each of the other links 1 and 3. If the distance between the axis of the shafts is constant, the centre of intermediate piece will describe a circle of radius equal to the distance between the axis of the two shafts. Therefore, the maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the centre of the disc along its circular path.

Let ω = Angular velocity of each shaft in rad/s, and

r = Distance between the axis of the shafts in meters.

∴ Maximum sliding speed of each tongue (in m/s),

$v = \omega . r$

Pantograph

A pantograph is an instrument used to reproduce to an enlarged or a reduced scale and as exactly as possible the path described by a given point. It consists of a jointed parallelogram ABCD as shown in Fig. 1.31. It is

made up of bars connected by turning pairs. The bars BA and BC are extended to O and E respectively, such that
OA/OB = AD/BE

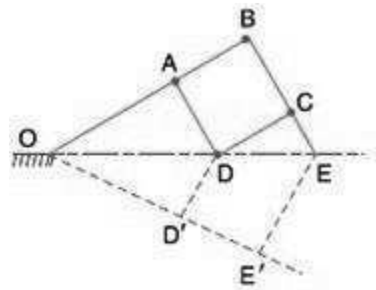


Fig. 1.31 Pantograph

Thus, for all relative positions of the bars, the triangles OAD and OBE are similar and the points O, D and E are in one straight line. It may be proved that point E traces out the same path as described by point D.
From similar triangles OAD and OBE, we find that
OD/OE = AD/BE
Let point O be fixed and the points D and E move to some new positions D′ and E′. Then
OD/OE = OD′/OE′
A little consideration will show that the straight line DD′ is parallel to the straight line EE′. Hence, if O is fixed to the frame of a machine by means of a turning pair and D is attached to a point in the machine which has rectilinear motion relative to the frame, then E will also trace out a straight line path. Similarly, if E is constrained to move in a straight line, then D will trace out a straight line parallel to the former.
A pantograph is mostly used for the reproduction of plane areas and figures such as maps, plans etc., on enlarged or reduced scales. It is, sometimes, used as an indicator rig in order to reproduce to a small scale the displacement of the crosshead and therefore of the piston of a reciprocating steam engine. It is also used to guide cutting tools. A modified form of pantograph is used to collect power at the top of an electric locomotive.

Steering Gear Mechanism

The steering gear mechanism is used for changing the direction of two or more of the wheel axles with reference to the chassis, so as to move the automobile in any desired path. Usually the two back wheels have a common axis, which is fixed in direction with reference to the chassis and the steering is done by means of the front wheels.
In automobiles, the front wheels are placed over the front axles, which are pivoted at the points A and B, as shown in Fig. 1.32. These points are fixed to the chassis. The back wheels are placed over the back axle, at the two ends of the differential tube. When the vehicle takes a turn, the front wheels along with the respective axles turn about the respective pivoted points. The back wheels remain straight and do not turn. Therefore, the steering is done by means of front wheels only.

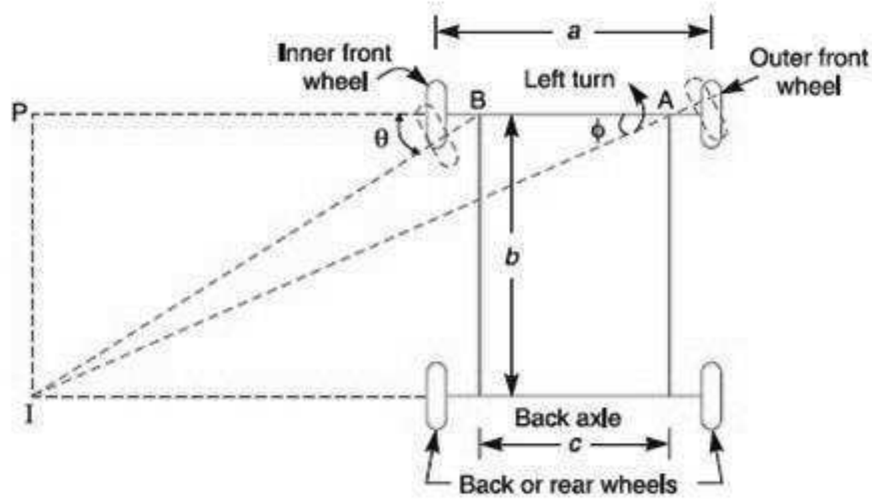


Fig. 1.32 Steering Gear Mechanism

In order to avoid skidding (i.e. slipping of the wheels sideways), the two front wheels must turn about the same instantaneous centre I which lies on the axis of the back wheels. If the instantaneous centre of the two front wheels do not coincide with the instantaneous centre of the back wheels, the skidding on the front or back wheels will definitely take place, which will cause more wear and tear of the tyres.

Thus, the condition for correct steering is that all the four wheels must turn about the same instantaneous centre. The axis of the inner wheel makes a larger turning angle θ than the angle ϕ subtended by the axis of outer wheel.

Let a = Wheel track,

b = Wheel base, and

c = Distance between the pivots A and B of the front axle.

Now from triangle IBP,

$\cot\theta = BP/IP$

And from triangle IAP,

$\cot\phi = AP/IP = (AB + BP)/IP = AB/IP + BP/IP = c/b + \cot\theta$ $\quad (\because IP = b)$

$\therefore \cot\phi - \cot\theta = c / b$

This is the fundamental equation for correct steering. If this condition is satisfied, there will be no skidding of the wheels, when the vehicle takes a turn.

Davis Steering Gear

The Davis steering gear is shown in Fig. 1.33. It is an exact steering gear mechanism. The slotted links A M and BH are attached to the front wheel axle, which turn on pivots A and B respectively. The rod CD is constrained to move in the direction of its length, by the sliding members at P and Q. These constraints are connected to the slotted link AM and BH by a sliding and a turning pair at each end. The steering is affected by moving CD to the right or left of its normal position. C ’D’ shows the position of CD for turning to the left.

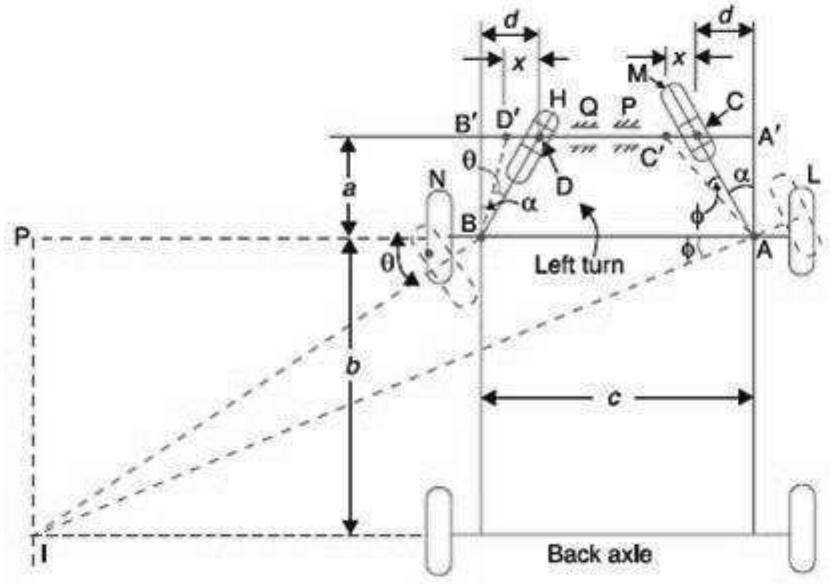


Fig. 1.33 Davis Steering Gears

Ackerman Steering Gear

The Ackerman steering gear mechanism is much simpler than Davis gear. The difference between the Ackerman and Davis steering gears are:

1. The whole mechanism of the Ackerman steering gear is on back of the front wheels; whereas in Davis steering gear, it is in front of the wheels.

2. The Ackerman steering gear consists of turning pairs, whereas Davis steering gear consists of sliding members.

In Ackerman steering gear, the mechanism ABCD is a four bar crank chain, as shown in Fig. 1.33. The shorter links BC and AD are of equal length and are connected by hinge joints with front wheel axles. The longer links AB and CD are of unequal length. The following are the only three positions for correct steering.

1. When the vehicle moves along a straight path, the longer links AB and CD are parallel and the shorter links BC and AD are equally inclined to the longitudinal axis of the vehicle, as shown by firm lines in Fig.

2. When the vehicle is steering to the left, the position of the gear is shown by dotted lines in Fig 1.34. In this position, the lines of the front wheel axle intersect on the back wheel axle at I, for correct steering.

3. When the vehicle is steering to the right, the similar position may be obtained. In order to satisfy the fundamental equation for correct steering, the links AD and DC are suitably proportioned. The value of θ and ϕ may be obtained either graphically or by calculations.

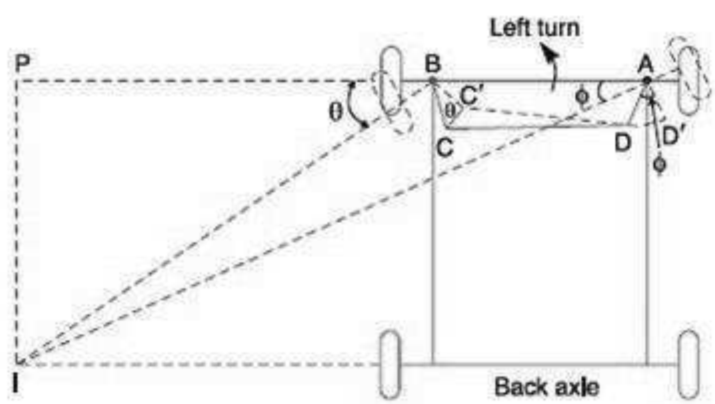


Fig. 1.34 Ackermann's Steering Gears

Universal or Hooke's Joint

A Hooke's joint is used to connect two shafts, which are intersecting at a small angle, as shown in Fig. 1.35. The end of each shaft is forked to U-type and each fork provides two bearings for the arms of a cross. The arms of the cross are perpendicular to each other. The motion is transmitted from the driving shaft to drive shaft through a cross. The inclination of the two shafts may be constant, but in actual practice it varies, when the motion is transmitted. The main application of the Universal or Hooke's joint is found in the transmission from the gear box to the differential or back axle of the automobiles. It is also used for transmission of power to different spindles of multiple drilling machines. It is also used as a knee joint in milling machines.

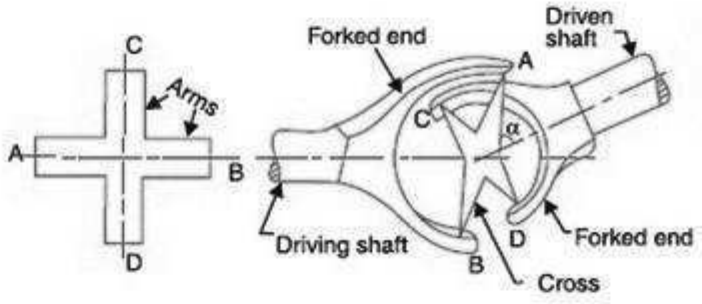


Fig. 1.35 Hooke's Joint

