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.

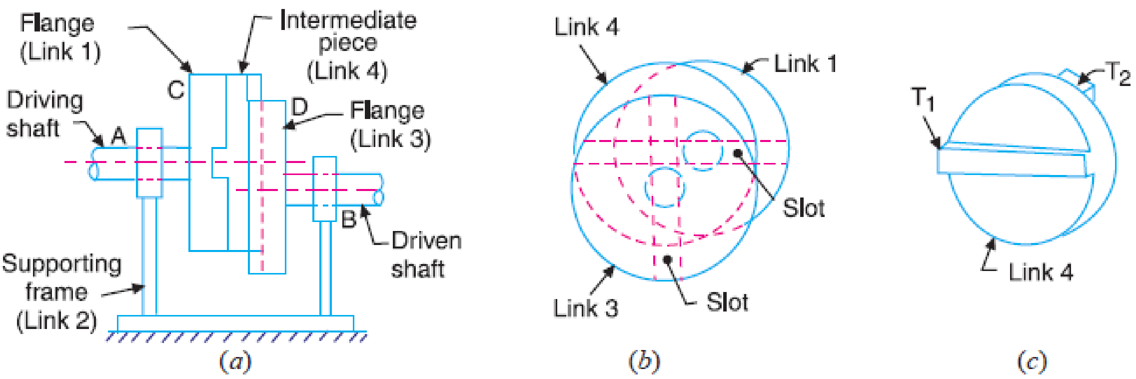


Fig.32. Oldham's coupling.

If the distance between the axes of the shafts is constant, the centre of intermediate piece will describe a circle of radius equal to the distance between the axes 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 axes of the shafts in metres.

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

$$v = \omega . r$$

Common Mechanisms - Straight line mechanism, Dwell mechanism

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.33. It is made up of bars connected by turning pairs. The bars BA and BC are extended to O and E respectively, such that

$OA/OB = AD/BE$

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, $OD/OE = AD/BE$

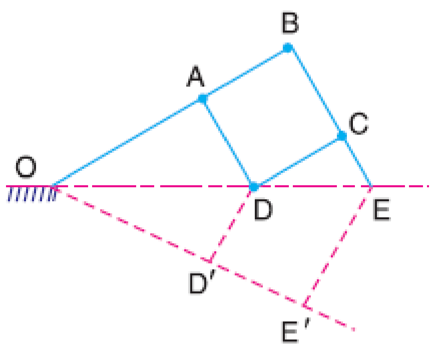


Fig. 33. Pantograph.

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.

Straight Line Mechanisms

One of the most common forms of the constraint mechanisms is that it permits only relative motion of an oscillatory nature along a straight line. The mechanisms used for this purpose are called ***straight line mechanisms***. These mechanisms are of the following two types:

1. in which only turning pairs are used, and

2. in which one sliding pair is used.

These two types of mechanisms may produce exact straight line motion or approximate straight line motion, as discussed in the following articles.

1. Exact Straight Line Motion Mechanisms made up of Turning Pairs

Following are the two well-known types of exact straight line motion mechanisms made up of turning pairs.

1. *Peaucellier mechanism*. It consists of a fixed link OO_1 and the other straight links O_1A, OC, OD, AD, DB, BC and CA are connected by turning pairs at their intersections, as shown in Fig.34. The pin at A is constrained to move along the circumference of a circle with the fixed diameter OP, by means of the link O_1A. In Fig.34,

$AC = CB = BD = DA; OC = OD;$ and

$OO_1 = O_1A$

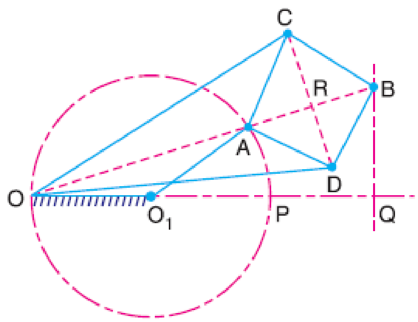


Fig.34. Peaucellier mechanism

It may be proved that the product $OA \times OB$ remains constant, when the link O_1A rotates. Join CD to bisect AB at R.

Now from right angled triangles ORC and BRC, we have

$OC^2 = OR^2 + RC^2$ ...***(i)***

and $BC^2 = RB^2 + RC^2$ ...***(ii)***

Subtracting equation ***(ii)*** from ***(i)***, we have

$OC^2 - BC^2 = OR^2 - RB^2$
$= (OR + RB)\,(OR - RB)$
$= OB \times OA$

Since OC and BC are of constant length, therefore the product $OB \times OA$ remains constant. Hence the point B traces a straight path perpendicular to the diameter OP.

2. *Hart's mechanism*. This mechanism requires only six links as compared with the eight links required by the Peaucellier mechanism. It consists of a fixed link OO_1 and other straight links O_1A, FC, CD, DE and EF are connected by turning pairs at their points of intersection, as shown in Fig.35. The links FC and DE are equal in length and the lengths of the links CD and EF are also equal. The points O, A and B divide the links FC, CD and EF in the same ratio. A little consideration will show that $BOCE$ is a trapezium and OA and OB are respectively parallel to FD and CE.

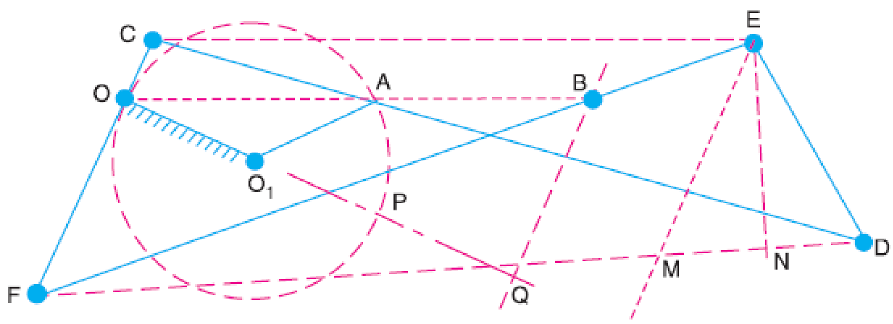


Fig. 35. Hart's mechanism.

2. Exact Straight Line Motion Consisting of One Sliding Pair-Scott Russell's Mechanism

It consists of a fixed member and moving member P of a sliding pair as shown in Fig.36. The straight link PAQ is connected by turning pairs to the link OA and the link P. The link OA rotates about O. A little consideration will show that the mechanism OAP is same as that of the reciprocating engine mechanism in which OA is the crank and PA is the connecting rod. In this mechanism, the straight line motion is not generated but it is merely copied.

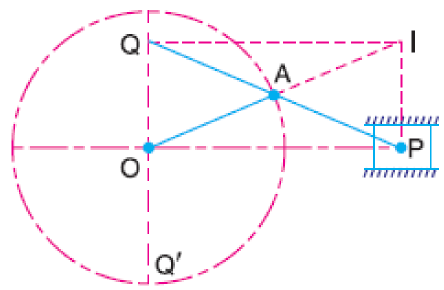


Fig. 36. Scott Russell's mechanism

Approximate Straight Line Motion Mechanisms

1. ***Watt's mechanism***
2. ***Modified Scott-Russel mechanism***
3. ***Grasshopper mechanism***
4. ***Tchebicheff's mechanism***
5. ***Roberts mechanism***

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.37. 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.

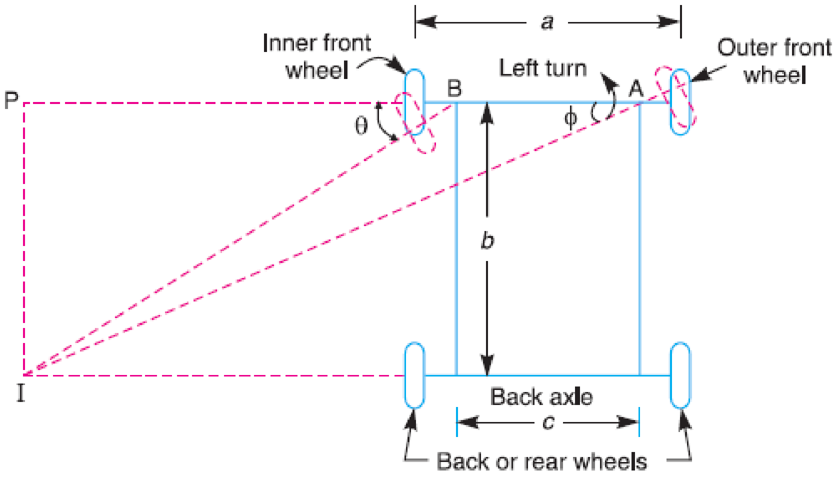


Fig. 37. Steering gear mechanism.

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.

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. 38. 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. 38.

2. When the vehicle is steering to the left, the position of the gear is shown by dotted lines in Fig. 38. 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.

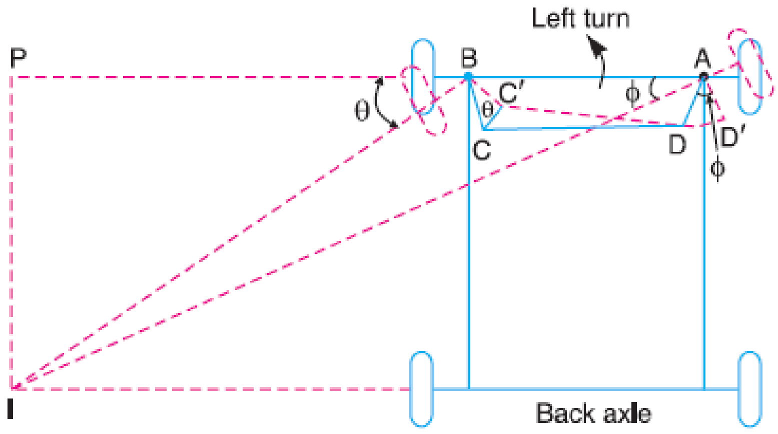


Fig. 38. Ackerman steering gear

Methods for Determining the Velocity of a Point on a Link

Though there are many methods for determining the velocity of any point on a link in a mechanism whose direction of motion (*i.e.* path) and velocity of some other point on the same link is known in magnitude and direction, yet the following two methods are important from the subject point of view.

1. Instantaneous centre method, and **2.** Relative velocity method.

The instantaneous centre method is convenient and easy to apply in simple mechanisms, whereas the relative velocity method may be used to any configuration diagram

Velocity of a Point on a Link by Instantaneous Centre Method

The instantaneous centre method of analysing the motion in a mechanism is based upon the concept that any displacement of a body (or a rigid link) having motion in one plane, can be considered as a pure rotational motion of a rigid link as a whole about some centre, known as instantaneous centre or virtual centre of rotation.

Consider two points *A* and *B* on a rigid link. Let v_A and v_B be the velocities of points *A* and *B*, whose directions are given by angles α and β as shown in Fig.1. If v_A is known in magnitude and direction and v_B in direction only, then the magnitude of v_B may be determined by the instantaneous centre method as discussed below:

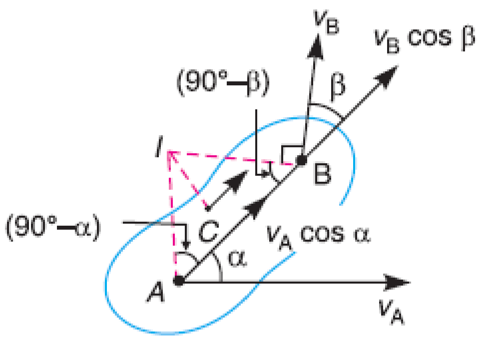


Fig.1. Velocity of a point on a link.

Draw *AI* and *BI* perpendiculars to the directions v_A and v_B respectively. Let these lines intersect at *I*, which is known as instantaneous centre or virtual centre of the link. The complete rigid link is to rotate or turn about the centre *I*. Since *A* and *B* are the points on a rigid link, therefore there cannot be any relative motion between them along the line *AB*.

Properties of the Instantaneous Centre:

The following properties of the instantaneous centre are important from the subject point of view:

1. A rigid link rotates instantaneously relative to another link at the instantaneous centre for the configuration of the mechanism considered.

2. The two rigid links have no linear velocity relative to each other at the instantaneous centre. At this point (*i.e.* instantaneous centre), the two rigid links have the same linear velocity relative to the third rigid link. In other words, the velocity of the instantaneous centre relative to any third rigid link will be same whether the instantaneous centre is regarded as a point on the first rigid link or on the second rigid link.

Number of Instantaneous Centres in a Mechanism

The number of instantaneous centres in a constrained kinematic chain is equal to the number of possible combinations of two links. The number of pairs of links or the number of instantaneous centres is the number of combinations of *n* links taken two at a time. Mathematically, number of instantaneous centres,

$$N = \frac{n(n-1)}{2}, \text{ where } n = \text{Number of links.}$$

Types of Instantaneous Centres

The instantaneous centres for a mechanism are of the following three types:

1. Fixed instantaneous centres, **2.** Permanent instantaneous centres, and **3.** Neither fixed nor permanent instantaneous centres.

The first two types *i.e.* fixed and permanent instantaneous centres are together known as ***primary instantaneous centres*** and the third type is known as ***secondary instantaneous centres***.

Consider a four bar mechanism *ABCD* as shown in Fig.2. The number of instantaneous centres (N) in a four bar mechanism is given by

$$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

The instantaneous centres I_{12} and I_{14} are called the ***fixed instantaneous centres*** as they remain in the same place for all configurations of the mechanism. The instantaneous centres I_{23} and I_{34} are the ***permanent instantaneous centres*** as they move when the mechanism moves, but the joints are of permanent nature. The instantaneous centres I_{13} and I_{24} are ***neither fixed nor permanent instantaneous centres*** as they vary with the configuration of the mechanism.

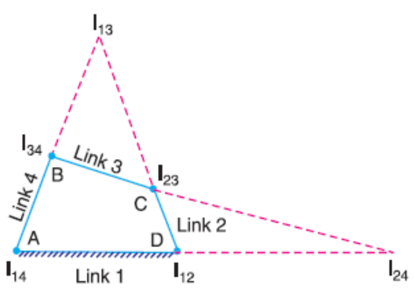


Fig. 2. Types of instantaneous centres.

Aronhold Kennedy (or Three Centres in Line) Theorem

The Aronhold Kennedy's theorem states that ***if three bodies move relatively to each other***, ***they have three instantaneous centres and lie on a straight line.***

Rubbing Velocity at a Pin Joint

The links in a mechanism are mostly connected by means of pin joints. The rubbing velocity is defined as **the algebraic sum between the angular velocities of the two links which are connected by pin joints, multiplied by the radius of the pin.**

Consider two links *OA* and *OB* connected by a pin joint at *O* as shown in Fig.3.

Let ω_1 = Angular velocity of the link *OA* or the angular velocity of the point *A* with respect to *O*.

ω_2 = Angular velocity of the link *OB* or the angular velocity of the point *B* with respect to *O*, and

r = Radius of the pin.

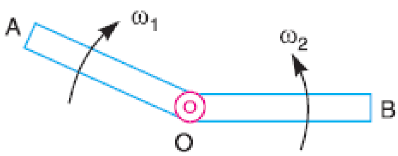


Fig. 3. Links connected by pin joints

According to the definition,

Rubbing velocity at the pin joint *O*

$= (\omega_1 - \omega_2)\, r$, if the links move in the same direction

$= (\omega_1 + \omega_2)\, r$, if the links move in the opposite direction

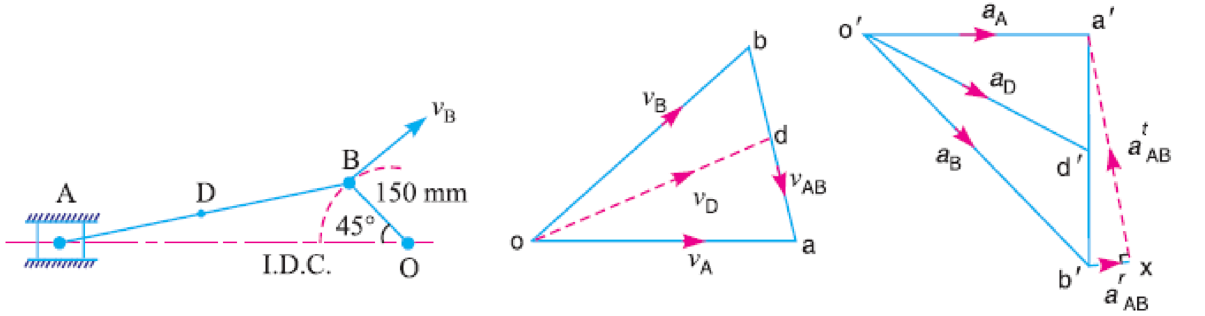
Velocity and Acceleration of a Point on a Link by Relative Velocity Method

Problem 1. *The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 r.p.m. The crank is 150 mm and the connecting rod is 600 mm long. Determine:* **1.** *Linear velocity and acceleration of the midpoint of the connecting rod, and* **2.** *angular velocity and angular acceleration of the connecting rod, at a crank angle of 45° from inner dead centre position.*

Solution. Given : N_{BO} = 300 r.p.m. or $\omega_{BO} = 2\,\pi \times 300/60 = 31.42$ rad/s; *OB* = 150 mm = 0.15 m ; *BA* = 600 mm = 0.6 m

We know that linear velocity of *B* with respect to *O* or velocity of *B*,

$v_{BO} = v_B = \omega_{BO} \times OB = 31.42 \times 0.15 = 4.713$ m/s



(*a*) Space diagram. (*b*) Velocity diagram. (*c*) Acceleration diagram.