Unit -1

Simple mechanism

Element or link :-

It is a mechanical member and

(i) it should hava relative motion (ii) it must be a resistant body. And (iii) it should be connected to another body.

Types of links :-

1.Rigid link :-

It is a rigid body and not having any types of deffection and solves the perpose. However, as the deformation of a connecting rod, crank etc.

2. Flexible link :-

There is a passibility of flexibility i.e., bending, extension..etc. for examples belts, rope, chains and wires are flexible links and transmit tensile forces only.

3. fluid link :-

This link is formed by using a fluid. Examples of fluid link is hydraulic presses, jacks and brakes.

4. floating link :-

A link which is not connected to the flame is called floating link.

Structure :-

It is an assemblage of a number of risistant bodies (known as embers) having no relative motion between them and ment for carrying loads having strining action. A railway bridge, a roof truss, machine frame etc.

Difference Between a Machine and a Structure

The following differences between a machine and a structure are important from the subject point of view :

1. The parts of a machine move relative to one another, whereas the members of a structure do not move relative to one another.

2. A machine transforms the available energy into some useful work, whereas in a structure no energy is transformed into useful work.

3. The links of a machine may transmit both power and motion, while the members of a structure transmit forces only.

Kinematic Pair

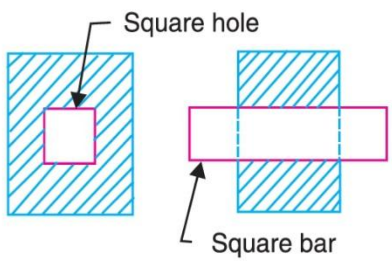
The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (*i.e.* in a definite direction), the pair is known as ***kinematic pair***.

First of all, let us discuss the various types of constrained motions.

Types of constrained motions :-

Following are the three types of constrained motions :

1. completely constrained motion :-



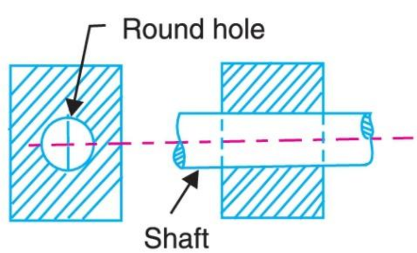
Square bar in a square hole.

When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.

Ex:-

The piston and cyclinder (in a stream engine) form a pair and the motion of the piston is limited to a definite direction (i.e., it will any reciprocate) relative to the cylinder irrespective of the direction of motion of the crank, as shown is fig.

2. incompletely constrained motion :-

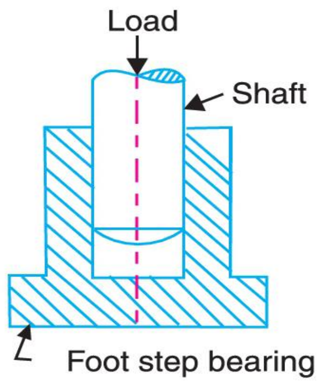


Shaft in a circular hole.

When the motion between a pair can take place in more than one direction, the motion is called an incompletely constrained motion.

3. successfully constrained motion:-

When the motion between the elements, forming a pair, is such that the constrained motion is not completed by it self, but by some other means, then the motion is said to be successfully constained motion.



Shaft in a foot step bearing.

Ex :-

Consider a shaft in a foot- step bearing as shown in fig. the shaft may rotate in a bearing or it may move upwards. This is a case of in completely constrain motion. But if the load is placed on the shaft to prevent axial upward movement of the shaft, then the motion of the pair is said to be successfully constrained motion.

Classification of kinematic pairs:-

The kinematic pairs may be classified according to the follwing considerations:

1. according to the type of relative motion between the elements :-

(a) sliding pair:-

It two links have a sliding motion relative to each other, they form a sliding pair.

Ex:-

1. the piston and cyclinder

2. tail stock on the lathe bed.

Note:- a little consideration will show, that a sliding pair has a completely constrained motion.

(b) turning pair :-

When on link has a turning or revolving motion, relative to the other, they constitute a turning pair (or) revolving pair.

Ex:-

1. a shaft with collars at both ends fitted into a circular hole.

2. lathe spindle supported in head stock.

Note :- a turning pair also has a completely constrained motion.

(c) rolling pair :-

When the links of a pair have a rolling motion to each other, they foem a rolling pair.

Ex:- ball and roller bearings are examples.

(d) screw pair (herical pair) :-

It two mating links have a turning as well as sliding motion between them, they form a screw pair.

Ex:- the lead screw of a lathe with nut, and bolt with a nut are examples.

(e) spherical pair :-

When one link in the form of a sphere turns inside a fixed link, it is a spherical pair.

Ex:- ball and socket joint, attachment of a car mirror, pen stand..etc.

2. **according to the type of contact between the elements :-**

(a) lower pair :-

A pair of links having surface contact between members is known as a lower pair. The contact surface of the two links are similar.

Ex:- sliding pairs, turning pairs and screw pairs form lower pairs.

(b) higher pair:-

When a pair has a point or line contact between the links, it is known as a higher pair. The contact surfaces of the two links are dissimilar.

Ex:- belt and rope drives, ball and roller bearings and cam and follower are the examples.

3. according to the type of closure:-

(a) self closed pair :-

When the two elements of a pair connected together mechanically in such a way that only required kind of relative motion occures, it is then known as self closed pair. The lower pairs are self closed pair.

(b) force- closed pair :-

When the two elements of a pair not connected mechanically but are kept in contact by the action of external forces, the pair is said to be a force- closed pair. The cam and follower is an examples.

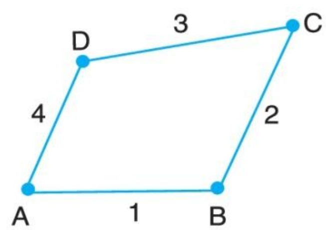
Kinematic chain:-

When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (i.e., completely or successfully constrained motion), it is called a kinematic chain.

Note :- a chain having more than four links is known as 'compound linematic chain'.

Types of joints in a chain :-

(1) Binary joint :-



Kinematic chain with all binary joints.

When two links are joined at the same connection, the joint is known as binary joint.

In order to determain the nature of chain as given by,

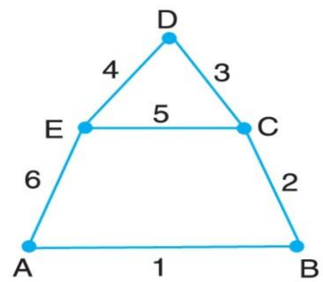
$$j + \frac{h}{2} = \frac{3}{2} l - 2$$

where j = Number of binary joints,

h = Number of higher pairs, and

l = Number of links.

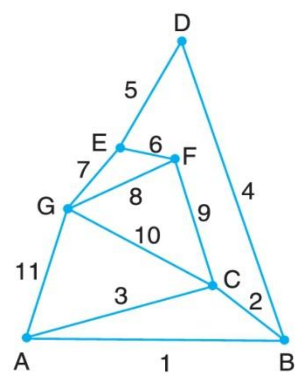
2. ternary joint :-



Kinematic chain having
binary and ternary joints.

When three links are jointed at the same connection, the joint is known as terbary joint.

3. Quaternary joint :-



Looked chain having binary, ternary
and quaternary joints.

When four links are joined at the same connection, the joint is called a quaternary joint.

Mechanism :-

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***.

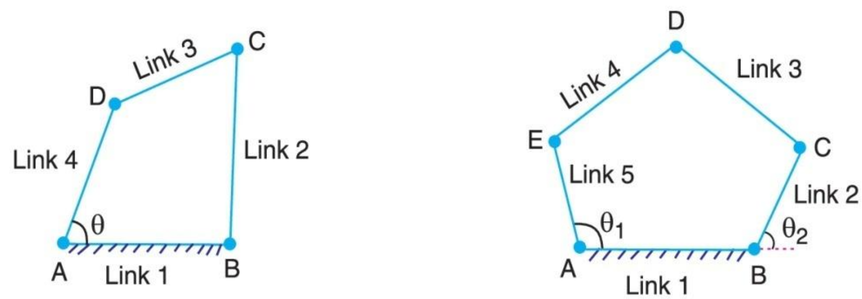
Machine :-

When a mechanism is required to transmit power or to do some particular type of work, it then becomes a machine.

Degrees of freedom for plane mechanisms :-

Number of Degrees of Freedom for Plane Mechanisms

In the design or analysis of a mechanism, one of the most important concern is the number of degrees of freedom (also called movability) of the mechanism. It is defined as the number of input parameters (usually pair variables) which must be independently controlled in order to bring the mechanism into a useful engineering purpose. It is possible to determine the number of degrees of freedom of a mechanism directly from the number of links and the number and types of joints which it includes.



(*a*) Four bar chain. (*b*) Five bar chain.

Consider a four bar chain, as shown in fig (a). we say that the number of degrees of freedom of a four bar chain is 'one'.

Now, let us consider a five bar chain, as shown in fig (b). we say that the number of degrees of freedom is 'two'.

Number of degrees of freedom of a mechanism is given by,

$$n = 3(l - 1) - 2j - h$$

Where,

l = number of links.

J = number of binary joints or lower pairs.

h = number of higher pairs.

This equations is called 'kutzbach criterion' for the movability of a mechanism having plane motion.

Application of kutzbach criterion to plane mechanisms :-

Application of Kutzbach Criterion to Plane Mechanisms

We have discussed in the previous article that Kutzbach criterion for determining the number of degrees of freedom or movability (n) of a plane mechanism is

$$n = 3(l - 1) - 2j - h$$

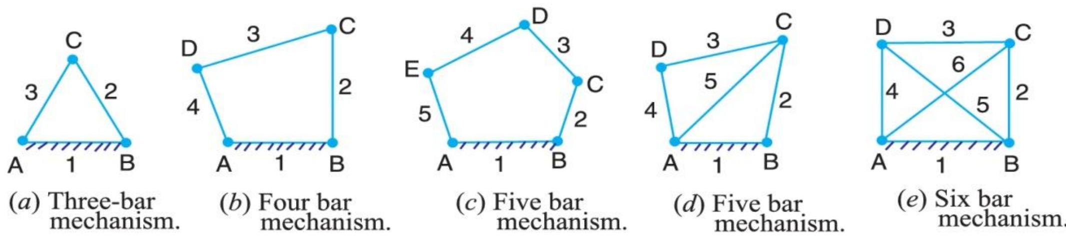


Fig. 5.16. Plane mechanisms.

1. The mechanism, as shown in Fig. 5.16 (a), has three links and three binary joints, *i.e.* $l = 3$ and $j = 3$.

$\therefore$ $$n = 3(3 - 1) - 2 \times 3 = 0$$

2. The mechanism, as shown in Fig. 5.16 (b), has four links and four binary joints, *i.e.* $l = 4$ and $j = 4$.

$\therefore$ $$n = 3(4 - 1) - 2 \times 4 = 1$$

3. The mechanism, as shown in Fig. 5.16 (c), has five links and five binary joints, *i.e.* $l = 5$, and $j = 5$.

$\therefore$ $$n = 3(5 - 1) - 2 \times 5 = 2$$

4. The mechanism, as shown in Fig. 5.16 (d), has five links and six equivalent binary joints (because there are two binary joints at B and D, and two ternary joints at A and C), *i.e.* $l = 5$ and $j = 6$.

$\therefore$ $$n = 3(5 - 1) - 2 \times 6 = 0$$

5. The mechanism, as shown in Fig. 5.16 (e), has six links and eight equivalent binary joints (because there are four ternary joints at A, B, C and D), *i.e.* $l = 6$ and $j = 8$.

$\therefore$ $$n = 3(6 - 1) - 2 \times 8 = -1$$

It may be noted that

(a) When $n = 0$, then the mechanism forms a structure and no relative motion between the links is possible, as shown in Fig. 5.16 (a) and (d).

(b) When $n = 1$, then the mechanism can be driven by a single input motion, as shown in Fig. 5.16 (b).

(c) When $n = 2$, then two separate input motions are necessary to produce constrained motion for the mechanism, as shown in Fig. 5.16 (c).

(d) When $n = -1$ or less, then there are redundant constraints in the chain and it forms a statically indeterminate structure, as shown in Fig. 5.16 (e).

The application of Kutzbach's criterion applied to mechanisms with a higher pair or two degree of freedom joints

Grubler's criterion for plane mechanisms and inversion of mechanism :-

Grubler's Criterion for Plane Mechanisms

The Grubler's criterion applies to mechanisms with only single degree of freedom joints where the overall movability of the mechanism is unity. Substituting $n = 1$ and $h = 0$ in Kutzbach equation, we have

$$1 = 3\,(l - 1) - 2\,j \qquad \text{or} \qquad 3l - 2j - 4 = 0$$

This equation is known as the Grubler's criterion for plane mechanisms with constrained motion.

A little consideration will show that a plane mechanism with a movability of 1 and only single degree of freedom joints can not have odd number of links. The simplest possible machanisms of this type are a four bar mechanism and a slider-crank mechanism in which $l = 4$ and $j = 4$.

Inversion of Mechanism

We have already discussed that when one of links is fixed in a kinematic chain, it is called a mechanism. So we can obtain as many mechanisms as the number of links in a kinematic chain by fixing, in turn, different links in a kinematic chain. This method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as ***inversion of the mechanism***.

It may be noted that the relative motions between the various links is not changed in any manner through the process of inversion, but their absolute motions (those measured with respect to the fixed link) may be changed drastically.

Types of kinematic chains :-

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.

These kinematic chains are discussed, in detail, in the following articles.

1. Four bar chain or Quadric cycle chain :-

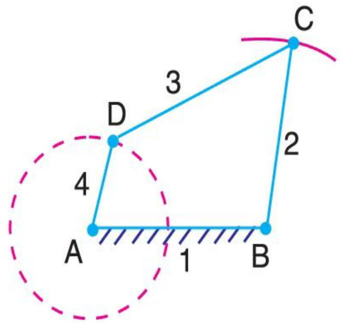


Fig. 5.18. Four bar chain.

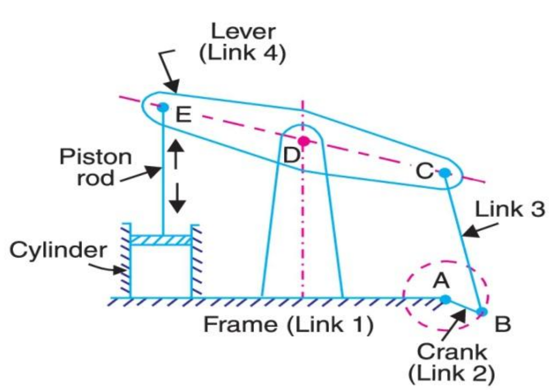
The simplest and the basic kinematic chain is a four chain or quadraic cycle chain as shon in figure. It consists of four links, each of them forms a turning pair at A, B, C and D. the four links may be of different lengths. According to ‘ Grashoft’s law’ for a four bar mechanism, the sum of the shortest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

A mechanism is to ensure that the input crank makes a complete revolution relative to the other chains.

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. 5.18, *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 *A B* (link 1) is known as ***frame*** of the mechanism.

Inversion of four bar chain:-

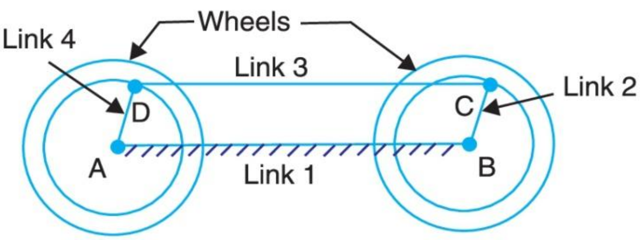
(i) beam engine (crank and lever mechanism) :-



Beam engine.

A part of the mechanism of a beam engine (also known as crank and lever mechanism) which consists of four links, is shown in fig. in this mechanism, when the crank rotates about a 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 works, the purpose of this mechanism is the convert rotaty motion into reciprocating motion.

(ii) .coupling rod of a locomotive (Double crank mechanism):-

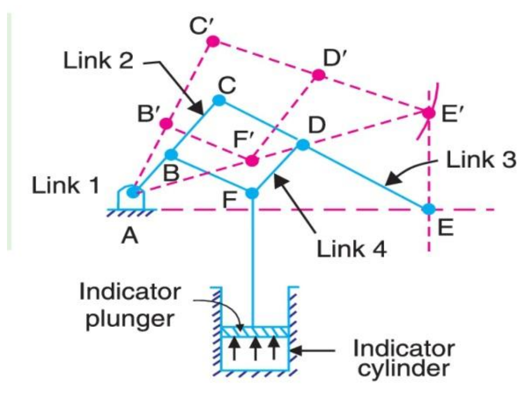


Coupling rod of a locomotive.

2. ***Coupling rod 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 Fig.

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 *A B* 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):-



Watt's indicator mechanism.

3. ***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.

2. single slider crank chain :-

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 Fig. 5.22, 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.

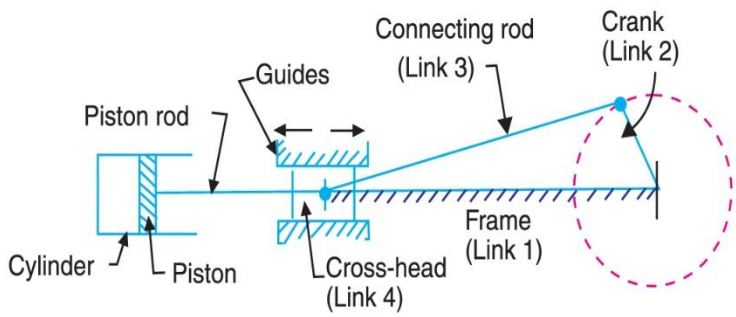


Fig. 5.22. Single slider crank chain.

The link 1 corresponds to the frame of the engine, which is fixed. The link 2 corresponds to the crank ; link 3 corresponds to the connecting rod and link 4 corresponds to cross-head. As the crank rotates, the cross-head reciprocates in the guides and thus the piston reciprocates in the cylinder.

Inversion of single slider crank chain :-

(i) Pendulum pump or Bull engine :-

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. 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 Fig. 5.23.

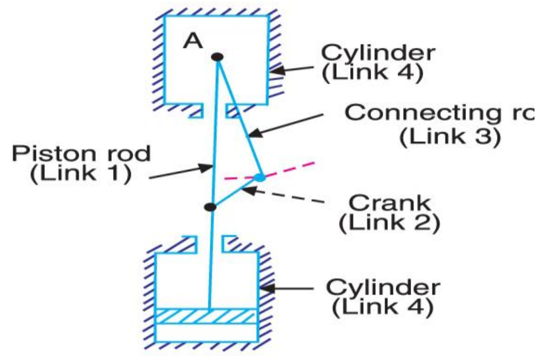


Fig. 5.23. Pendulum pump.

(ii) oscillating cyclinder engine :-

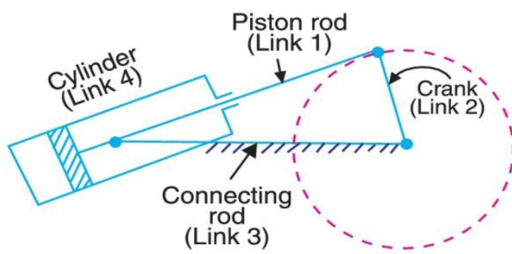


Fig. 5.24. Oscillating cylinder engine.

The arrangement of oscillating cyclinder engine mechanism, as shown in figure. Is used to convert reciprocating motion into rotary motion. In this mechanism, the links 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 cyclinder (link 4) oscillates about a pin pivoted to the fixed link at A.

(iii) rotary internal combustion engine or gnome engine :-

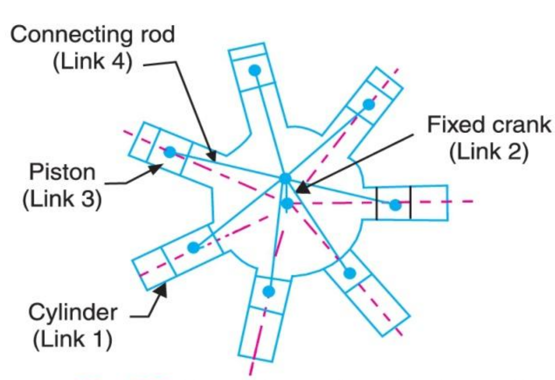


Fig. 5.25. Rotary internal combustion engine.

It consists of seven cyclinders 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 cyclinders forming link 1.

(iv) crank and slotted lever quick return motion mechanism :-

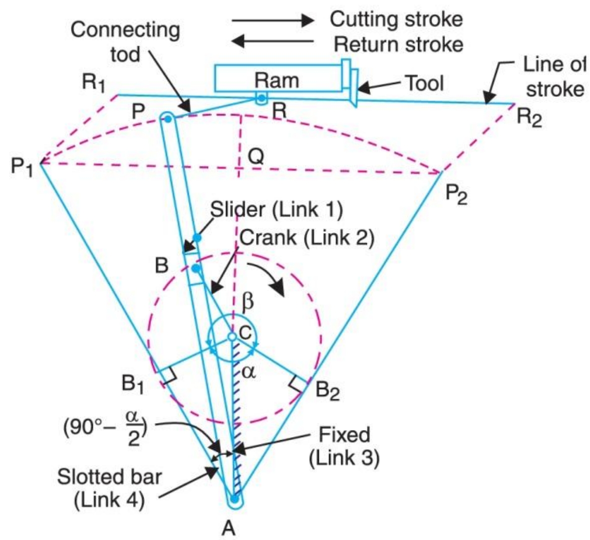


Fig. 5.26. Crank and slotted lever quick return motion mechanism.

This mechanism is mostely used in shaping machines, slotting machine and in rotates internal combustion engines.

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.

(v) whitworth Quick return motion mechanism :-

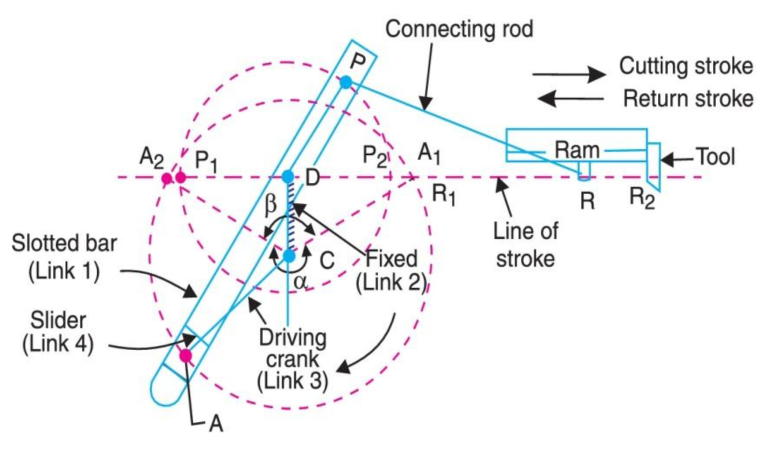


Fig. 5.27. Whitworth quick return motion mechanism.

This mechanism is mostely used in shaping and slotting machins. In this mechanism, the link CD (link 2) forming the turning pair is fixed, as shown in figure. The link 2 corresponding 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.

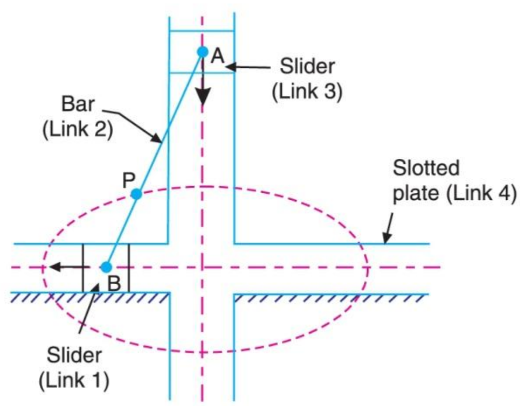
3. Double slider crank chain:-

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. 5.34. 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.

Inversion of double slider crank chain :-

(i) Elliptical trammels :-



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. 5.34. 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 *A B* (link 2) is a bar which forms turning pair with links 1 and 3.

(ii) scotch yoke mechanism:-

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. 5.35, 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.

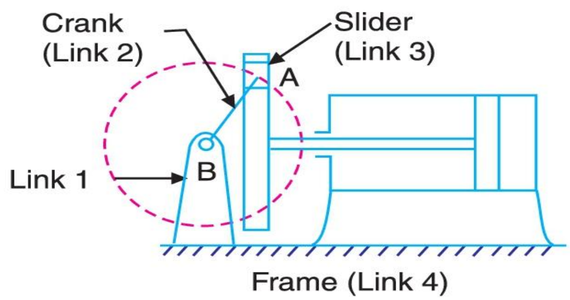
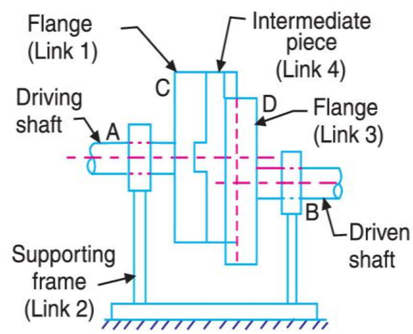


Fig. 5.35. Scotch yoke mechanism.

(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 shafts also rotates at the same speed.

The link 1 and 3 form turning pairs with link 2. These flanges have diametrical slots cut in their inner faces as shown in fig.