CHAPTER – 1 : KINEMATICS

KINEMATICS : It relates to the study of the relative motion between the parts of a machine. Let us consider a reciprocating engine, in this the piston is made to reciprocate in the cylinderdue to the applied steam pressure on the piston. The reciprocating motion of the piston is converted into the rotary motion of crankshaft with help of connecting rod & the crank.

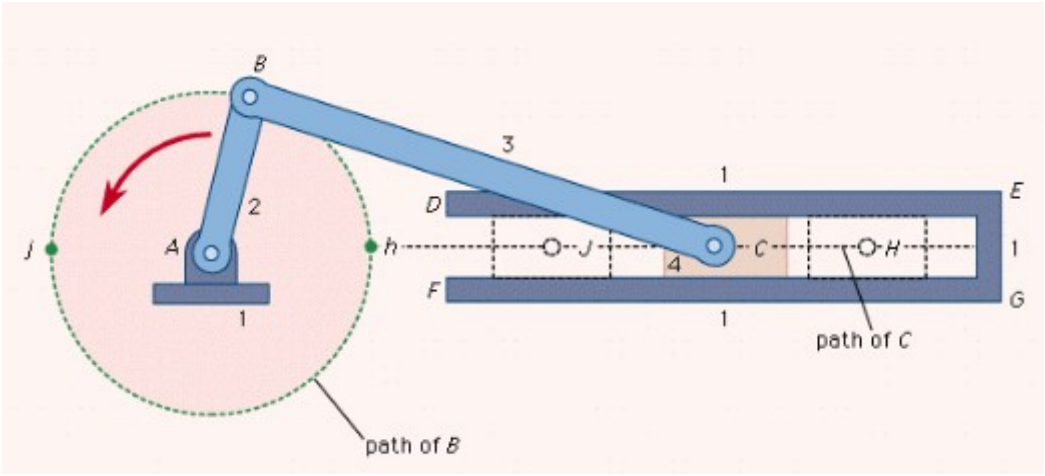


Fig. 1.1

KINEMATICS LINK/ELEMENT : Each part of a machine which has relative motion to some other part is known as kinematic link. E.g. In a steam engine, the piston & piston rod is one link; the second link is connecting rod; third link is crank; fourth link is cylinder which is fixed link.

The various types of links are :

a) Rigid Link : The link which don't undergo a any deformation while transmitting required motion & force is called rigid link. E.g. piston & piston rod.

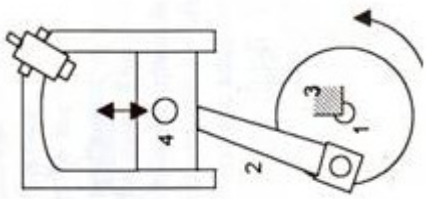


Fig. 1.2

b) Flexible Link : The links which are partly deformed while transmitting motion in such a way that they don't affect require transmission of motion are called flexible link. E.g. Chain drive, belt drive.

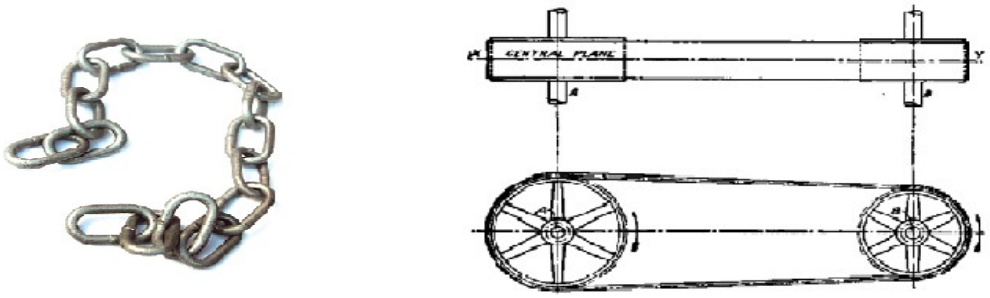


Fig. 1.3

c) Fluid Link : The link which transmit the require motion through the fluid by pressure/compression are called fluid links. E.g. hydraulic press.

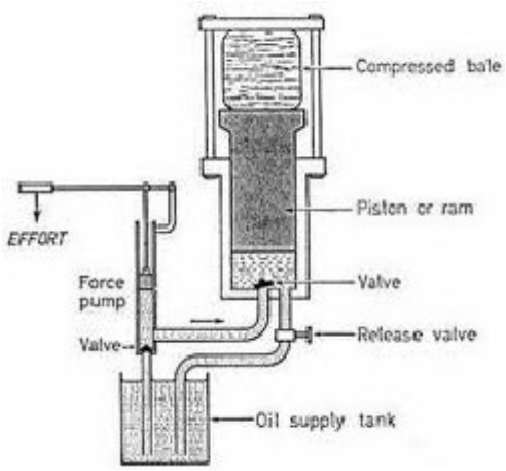


Fig. 1.4

Links are further classified depends upon its end on which it revolves/turns as binary link, ternary link & quaternary link.

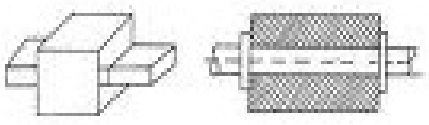
Fig. 1.5

DIFFERENCE BETWEEN STRUCTURE, MACHINE & MECHANISM :

Structure	Machine	Mechanism
Assembly of rigid links where there is no relative motion between one another.	Assembly of links where there is a relative motion between one another.	Assembly of links where by fixing one link, the motion of any other link produces definite motion of other links.
No energy is transformed in to useful work.	Transfer availbale energy into useful work.	No energy is transformed in to useful work.
Member of structure transmit forces only.	The link of machine transform both power & motion.	Mechanism transform only motion.
E.g. Bridges, Machine frame	E.g. Lathe, Milling machine	E.g. Clock, Type writter

CONSTRAINED MOTION : Various type of constrained motions are,

a) Completely constrained motion : When the motion between a pair takes place in a definite direction w.r.t. direction of force applied then the motion is called completely constrained motion. E.g. as shown in fig. a motion of square bar in square hole, in fig. b motion of shaft with collar.



(a) Fig. 1.6 (b)

b) Incompletely constrained motion : When the motion between a pair can take place in more than one direction is called incompletely constrained motion. E.g. Cicular shaft in circular hole as it may either rotate or slide in a hole.

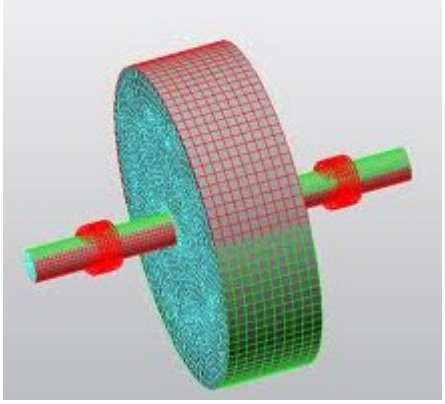


Fig. 1.7

c) Succefully constrained motion : When the relative motion between the links is not completely constrained by itself but by some other means is called the succefully constrained motion. E.g. Keyway is provided in a circular shaft moving in a circular hole which prevents its possible sliding motion & rotating motion.

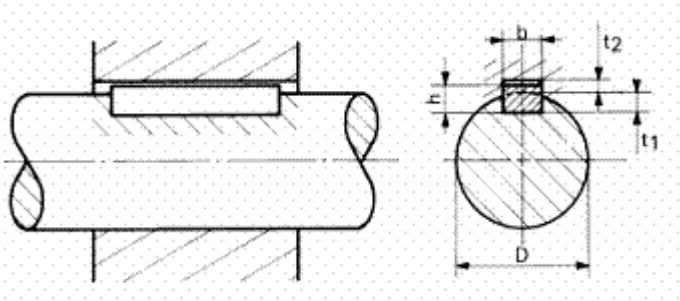


Fig. 1.8

KINEMATIC PAIR : Two links of a machine when in contact with each other are said to be a pair. Kinematic pair consist of two links which have relative motion between them.
Classification of kinematic pair as below.

a) According to nature of relative motion between links :-

1. ***Sliding Pair :*** It consists of two links connected in such a manner that one is constrained to have a sliding motion relative to other. E.g. piston & cylinder as shown in fig. 1.2, rectangular bar in rectangular hole as shown in fig. 1.6(a).
2. ***Turning Pair :*** It consists of two links connected in such a manner that one is constrained to turn about fixed axis of another link. E.g. Shaft with collar at both ends revolving in a circular hole as shown in fig. 1.6(b), bicycle wheel revolving about its axle.
3. ***Screw Pair :*** When the nature of contact between the pair of links is such that the one element can turn about the other by screw threads is called screw pair. E.g. motion of bolt in nut.

Fig. 1.9

4. ***Rolling Pair :*** If the two links have their relative motion of rolling nature is called rolling pair. E.g. railway wheel rolling over a fixed rail, ball bearing & roller bearing.

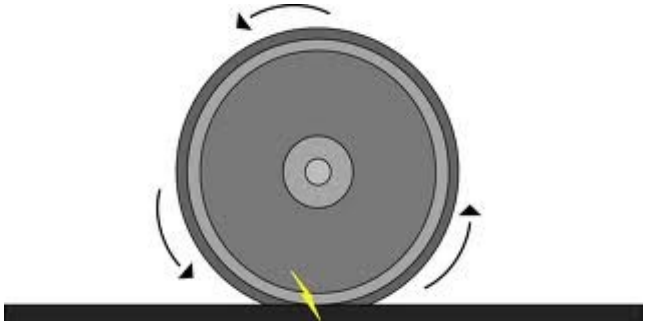


Fig. 1.10

5. ***Spherical Pair :*** When two elements are connected that one link having sphere turns about other fixed link is called spherical pair. E.g. ball & socket joint, ballpen stand.

Fig. 1.11

b) According to nature of contact between the links :-

1. ***Lower Pair :*** When two elements have surface contact while in motion & relative motion is purly turning or sliding then such pair is called lower pair. E.g. All sliding, turning & screw pairs are lower pair.
2. ***Higher Pair :*** When two elements have line or point contact during relative motion between them is called higher pair. E.g. motion of gears, cams & followers, belts & rope drive.

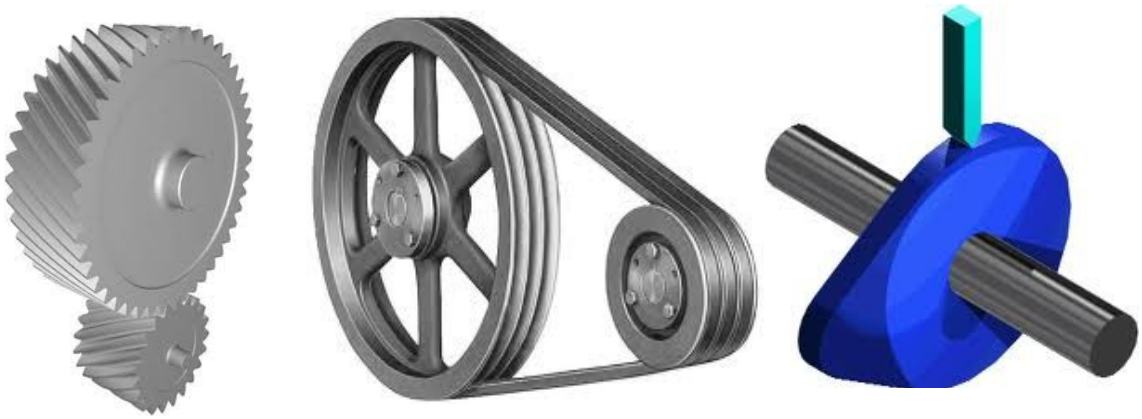


Fig. 1.12

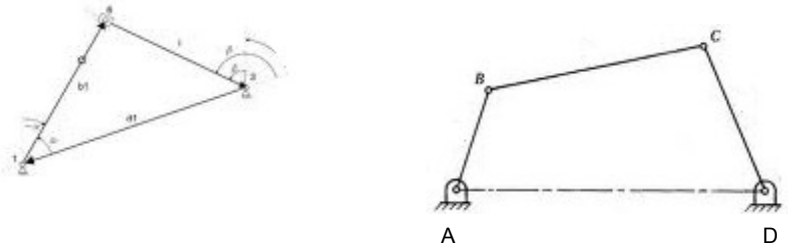
c) According to mechanical arrangement :-

1. ***Closed Pair :*** When the links of pairs are held together mechanically, they form a

closed pair. All lower pairs are example of closed pair.

2. ***Unclosed/open Pair :*** When two links of a pair are not held together mechanically but held in contact by the action of external forces are called unclosed pair. E.g. cam & follower as shown in fig. 1.12.

KINEMATIC CHAIN : It is a combination of kinematic pairs in which each link forms a part of two kinematic pairs & the relative motion between the link is completely/successfully constrained.



(a) Fig. 1.13 (b)

Fig. 1.13(a) shows the arrangement of three links forming three pairs but the relative motion between the links is not possible hence it is known as **locked chain** & form a structure.
Fig. 1.13(b) shows the arrangement of four links AB, BC, CD & DA joined by pin joints form a kinematic chain where there are four kinematic pairs AB-BC, BC-CD, CD-DA & DA-AB. By moving link AB, other links also get the constrained movement.

The following relationship holds for a kinematic chain.

- **n = 2p – 4**
  Where n = No. of links & p = No. of pairs
- Also **n = 2/3(J + 2)**
  Where J = No. of joints

TYPES OF KINEMATIC CHAIN : The various types of kinematic chains are,
a) Four bar chain/Quadric kinematic chain :- It consist of four links, each of them forming turning pairs. The four links may be of different lengths. As shown in fig. 1.13(b), link AD is fixed. The link which rotates completely is known as crank as link AB & link which partial rotation is called lever as link BC.

b) Single slider crank chain :- It consist of one sliding pair & three turning pairs. It is usually formed in receprocating steam engine mechanism & IC engine mechanism. As shown in fig. 1.14 this type of mechanism converts receprocating motion into rotary motion & vice versa.

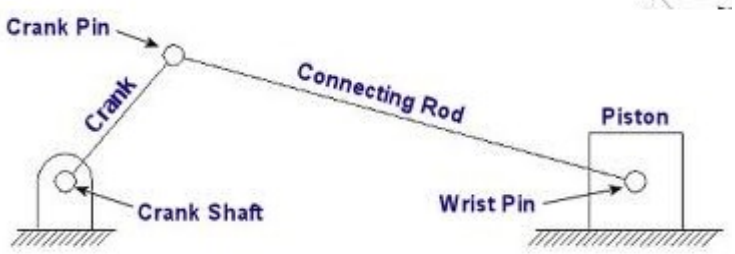


Fig. 1.14

c) Double slider crank chain :- As shown in fig 1.15 a kinematic chain consisting of two turning pair & two sliding pairs is called double slider crank chain. Here link 1 & 4 as one sliding pair and link 3 & 4 as second sliding pair. Link 1 & 2 as well as link 2 & 3 as turning

pair.

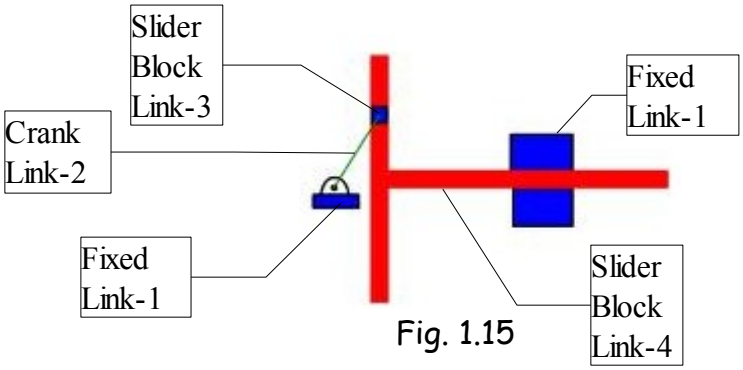


Fig. 1.15

INVERSION : In kinematic chain when any one link is fixed it becomes mechanism. So it is possible to obtainas many mechanisms as the number of links by fixing different linkes in turn in kinematic chain. Method of obtaining different mechanisms by fixing different links in turn of the basic kinematic chain is known as inversion of mechanism.

INVERSION OF FOUR BAR KINEMATIC CHAIN :

a) Beam Engine : Beam engine is also known as crank & lever mechanism. In this mechanism rotary motion of crank is converted into receprocating motion of piston. As shown in fig. 1.15(a) link 1 is fixed, link 2 is crank which rotates, link 3 is a lever which oscilate about fixed point. One end of lever 3 is connected to piston rod & other end with link 2.

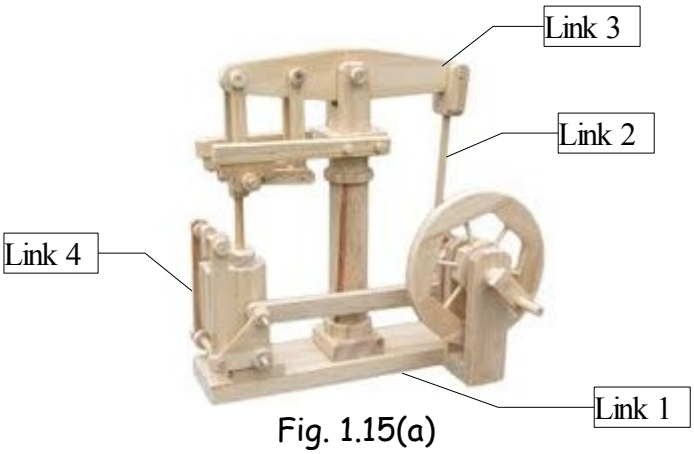


Fig. 1.15(a)

b) Locomotive coupling rod : It is also known as double crank mechanism. As shown in fig. 1.15(b) it consists of four links. Link 2 & 4 having equal length act as a crank & connected to the respective wheels. Link 3 act as a coupling rod & link 1 is fixed. This mechanism is used for transmitting rotary motion from one wheel to other wheel.

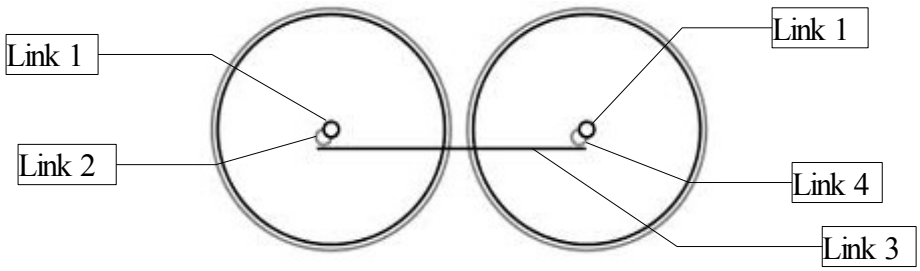


Fig. 1.15(b)

c) Watt's strainght line mechanism : As shown in fig. 1.15(c), links AB & CD are parallel. They are connected with link BC. AB & CD are levers & fixed at pint A & D respectively. For small displacement of lever AB & AD, point P on link BC will trace an appx. straight line for small angular movement of link 2 & 4.

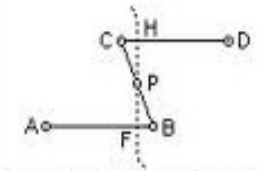


Fig. 1.15(c)

d) Ackermann stearing gear : As shown in fig. 1.15(d), two long links AB & CD are not equal in length. They remain parallel when vehicle travelling in straight line. Two short links BC & AD both are equal in length and make make angle 'a' vertical line. When vehicle is steared, the inner wheel 3 & 4 will turn through larger angle '0', while outer wheel 1 & 2 will turn through smaller angle 'a'. The axis of each wheel when extended they meet at one point 'I' known as instanteneous centre.

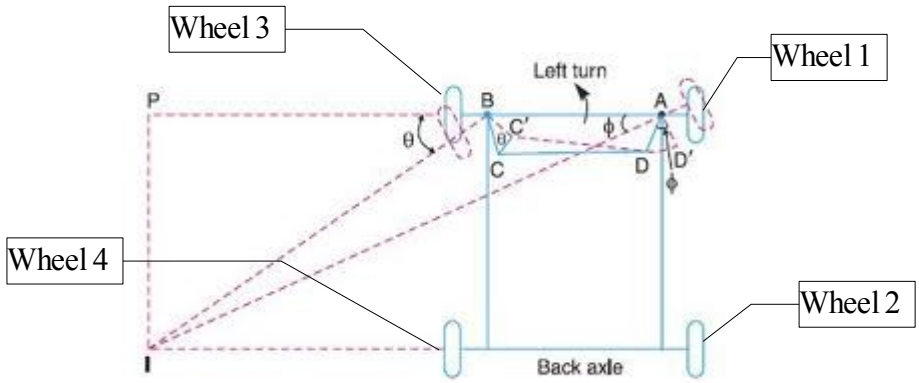


Fig. 1.15(d)

INVERSION OF SINGLE SLIDER CRANK CHAIN :

a) Reciprocating engine mechanism : In this mechanism, the inversion is obtained by fixing the link 4 as shown in fig. 1.16. When link 2 (crank) rotates, the link 3(connecting rod) oscillates about pin pivoted to the fixed link 4 & cross head/piston reciprocates in the cylinder.

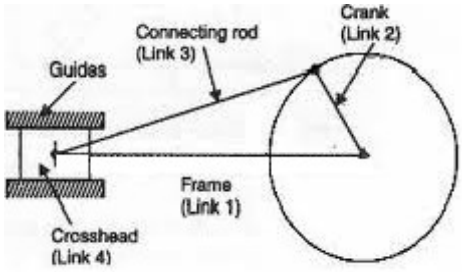


Fig. 1.16

b) Oscillating cylinder engine : In this mechanism as shown in fing. 1.17, link 3 is fixed. When the link 2(crank) rotates, the link 1 (piston rod) receprocates & link 4(cylinder) oscillates.

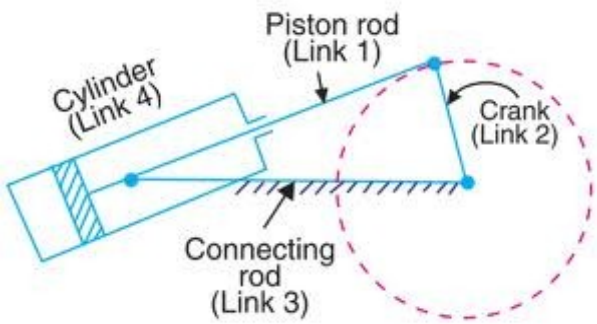


Fig. 1.17

c) Crank & slotted lever type quick return motion mechanism : As shown in fig. 1.18, in this mechanism the link 3 is fixed, the link 2 revolves about centre C. A slider link 1 attached to the crank pin at B slides along the sotted link 4 & make the slotted lever oscillated about pivoted point A. Link PR transmits motion from slotted link to ram which receprocates with the tool along the line of stroke which is prependicular to fixed link 3. This mechanism is mostly used in shaping machine & slotting machine. Here B>a, hence during cuttnig stroke ram speed is less than that during forward stroke. As ram moves quicker than it moves in forward direction this mechanism is known as quick return mechanism.

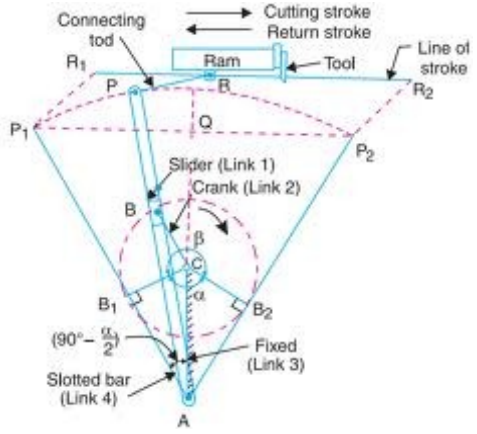


Fig. 1.18

d) Hand Pump : As shown in fig. 1.19, by keeping the link 3 fixed, this type of inversion is obtained. This mechanism is mostly used for operating hand pump.

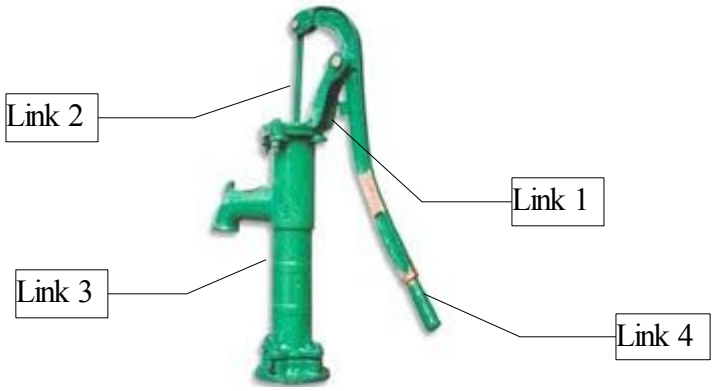


Fig. 1.19

INVERSION OF DOUBLE SLIDER CRANK CHAIN :

a) Scotch yoke mechanism : As shown in fign 1.20, this is an inversion of double slider crank chain which can be used for transforming rotary motion into receprocating motion. Here fixing link 1, rotary link 2(crank), link 4 will receprocate in link 1 & link 3 will receprocate in link 4.

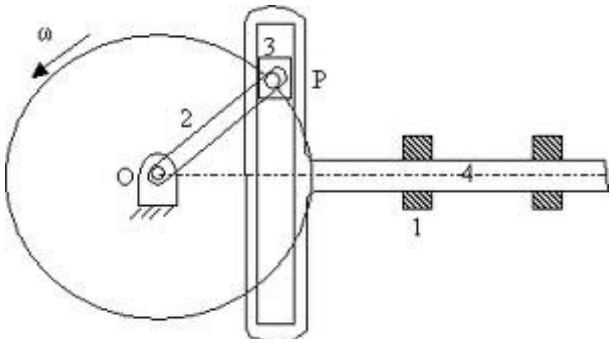


Fig. 1.20

b) Elliptical trammel mechanism : As shown in fig. 1.21 in this mechanism, two perpendicular slots are cut in a single plate as link 4. Two sliding blocks, one in each slot (link 1 & 3) are placed forming sliding pair with link 4. The blocks are connected by pin jonints through link 2. When link 1 & 3 slide along the respective slots, the point P on the link 2 will trace an ellipse on the surface of link 4.

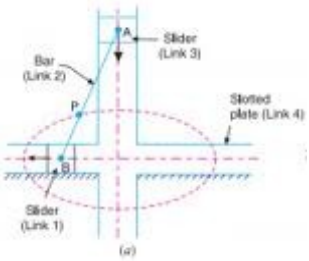


Fig. 1.21

c) Oldham's Coupling : As shown in fig. 1.22 oldham's coupling is used to connect to parallel shafts where axes are at a small distance apart. The shafts have flanges at the ends, in which slots are cut. These form link 1 & link 3. The intermediate piece form the link 4 which slides or receprotes in link 4 & link 3. The link 2 is fixed. When the driving shaft rotates, the driving flange link 1 rotates along with the shaft which causes the rotation of intermediate link 4 which also slider along the slots in link 1 & link 3 as a result of which the driven flnage link 3 also start rotating. The driven shaft also rotates as it is connected to given flange link 3.

Let us, peripherical velocity or sliding velocity of the disc.

= Angular velocity of the shaft (w) X Distance between shaft (r)

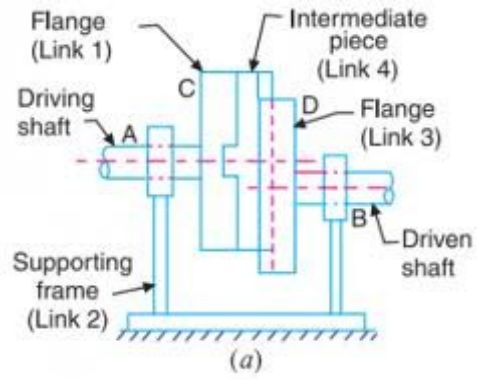

Flange
(Link 1)
Intermediate
piece
(Link 4)
C
D
Flange
(Link 3)
Driving
shaft
A
B
Driven
shaft
Supporting
frame
(Link 2)
(a)

Fig. 1.22

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