

SUBJECT : MECHANICS OF MACHINES (15 ME 32 T)

III SEM Mechanical

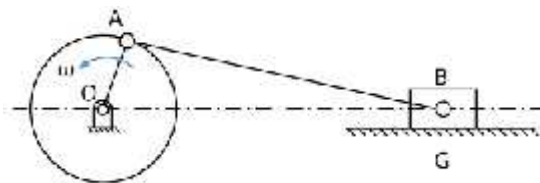
UNIT – 1 BASIC KINEMATICS

Introduction : When the number of bodies are assembled in such a way that the motion of one causes constrained and predictable motion to the others is known as a Mechanism. The function of a mechanism is to transmit and modify a motion.

A machine is a mechanism or a combination of mechanisms which , apart from imparting definite motions to the parts, also transmits and modifies the available mechanical energy in to some kind of desired work. It is neither a source of energy nor a producer of work but helps in proper utilization of the same. The motive power for the machine has to be derived from external sources.

Kinematic link or Element (Simply Link) : The kinematic link or element can be defined as each part of a machine , which moves relative to some other part.

Kinematic link or element can also be defined as a member or a combination of members of a mechanism , connecting other members and having motion relative to them . Therefore , a link may consists of one or more resistant bodies which are rigidly fastened together. So that , they do not move relative to one another . **Ex :** A slider – crank mechanism consists of four links as shown in fig .1



Links :

O & G - Frame and guides , OA – Crank , AB- Connecting rod , B- Slider .

A link or element need not be a rigid body , but it should be a resistant body.

A body is said to be resistant body , if it is capable of transmitting the required forces with negligible deformation.

Characteristics of a Link :

The link or element should have the following characteristics :

1. It should a resistant body.
2. It should have a relative motion to some other part.

Types of Links : Different types of Links are

1. **Rigid link** : A link does not undergo any deformation while transmitting the motion is known as rigid link.
2. **Flexible link** : A link which is partly deformed in a manner not affect the transmission of motion is known as flexible link.
3. **Fluid link** : A link which is formed by having a fluid in a receptacle (closed vessel) and the motion is transmitted through fluid by pressure or compression only, as in case of hydraulic jacks, brakes and presses.

Kinematic Pair : A kinematic pair or simply a pair is a joint of two links having a relative motion between them. 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 i.e. in a definite direction , then the pair is known as kinematic pair.

Types of Kinematic Pair : Kinematic pairs can be classified :

A) According to the type of relative motion between elements :

1. Sliding pair
2. Turning pair
3. Rolling pair
4. Screw pair
5. Spherical pair

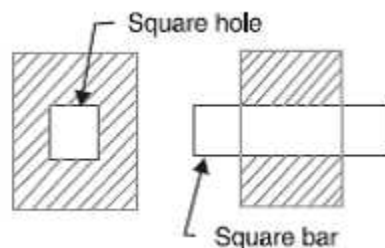
B) According to the type of contact between the elements :

1. Lower pair
2. Higher pair

C) According to the type of closure :

1. Self closed pair
 2. Force closed pair
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1.Sliding Pair : When the two elements of a pair are connected in such a way that they have only **sliding motion** relative to each other , then the pair is known as sliding pair. Sliding pair has a completely constrained motion. **Ex :** Square bar in a square hole .

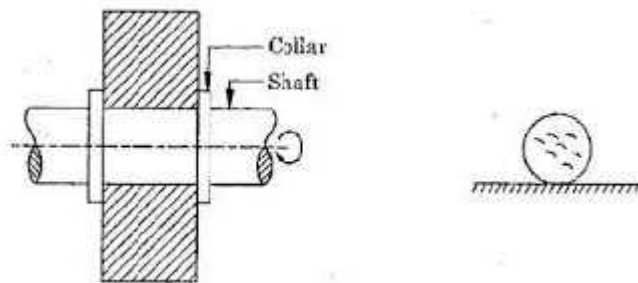


Square bar in a square hole

2. Turning Pair : When the two elements of a pair are connected in such a way that one link has a **turning or revolving motion** relative to the other , then the pair is known as turning pair.

Ex: A circular shaft revolving inside a bearing is a turning pair.

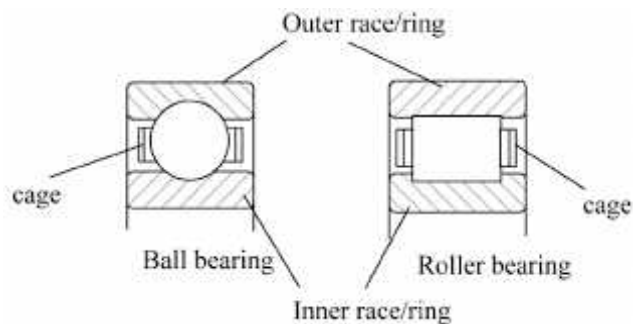
Turning pair



Shaft with collar at both ends revolving in a circular hole.

3.Rolling Pair : When the two elements of a pair are connected in such a way that they have a **rolling motion** relative to each other , the pair is known as rolling pair.

Ex : Ball and roller bearings.



Rolling pair

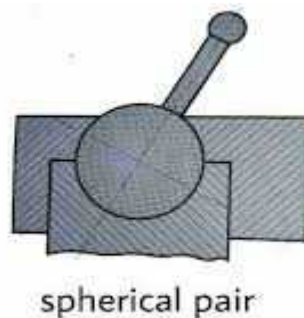
4.Screw pair : When the two elements of a pair are connected in such a way that , one element **turns about the other element by means of threads** , then the pair is known as screw pair.The motion in this case is a combination of sliding and turning.

Ex : The lead screw and nut of a lathe. Bolt and nut etc.



5.Spherical Pair : When the two elements of a pair are connected in such a way that , one link in the form of **sphere turns inside a fixed link** , then the pair is known as spherical pair.

Ex : The ball and socket joint. Attachment of car mirror , etc



6.Lower Pair : When the two elements of a pair have a **surface or area contact** between them , when the relative motion takes place , then the motion between two elements is purely sliding, then the pair is known as lower pair.

Ex : All sliding pairs , turning pairs , screw pairs form lower pairs.

7. Higher Pair : When the two elements of a pair have a **line or point contact** between them , when the relative motion takes place , the motion between the two elements is partly turning and partly sliding , then the pair is known as higher pair.

Ex: Toothed gearing, belt and rope drive, ball and roller bearings,
cam and follower.

8. Self closed pair : When the two elements of a pair are connected together mechanically in such a way that only a required kind of relative motion occurs , then the pair is known as self closed pair.

Ex : A cam and follower pair , a screw pair . The lower pairs are self closed pairs.

9. Force closed pair : When the two elements of a pair are not connected mechanically but are kept in contact by the action of external forces , then the pair is known as force closed pair .

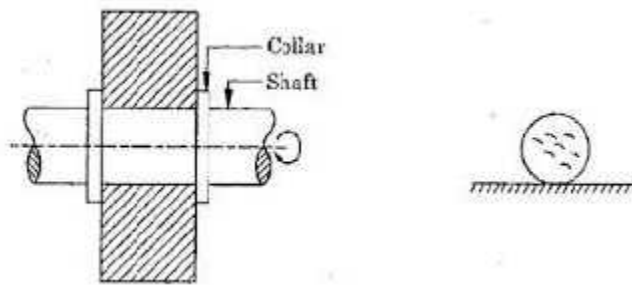
Ex : Cam and spring loaded follower pair.

Types of Constrained Motions : There are three types of Constrained Motion ,

- Completely constrained motion .
- Incompletely constrained motion.
- Successfully constrained motion.

1. Completely constrained motion : When the motion between two elements of a pair is in a definite direction irrespective of the direction of force applied , then the motion is known as **Completely Constrained Motion**.

Ex : The motion of a shaft with collars at each end in a circular hole as shown in fig. i.e. turning pair . In this case the inner shaft can have only rotary motion due to collars at the ends. In this case the force has to be applied in a particular direction for the required motion.



Completely constrained motion.

2. Incompletely Constrained Motion : When the motion between two elements of a pair can take place in more than one direction and depends upon the direction of the force applied , then the motion is called as **Incompletely Constrained Motion**.

Ex: A circular shaft in a circular hole without collars as shown in fig.10. In this case , the shaft may rotate or slide in a hole depending upon the direction of the force applied . Each motion is independent of the other.

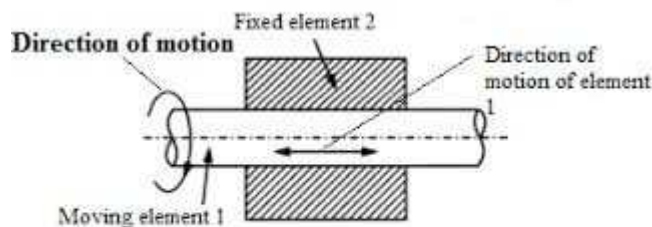
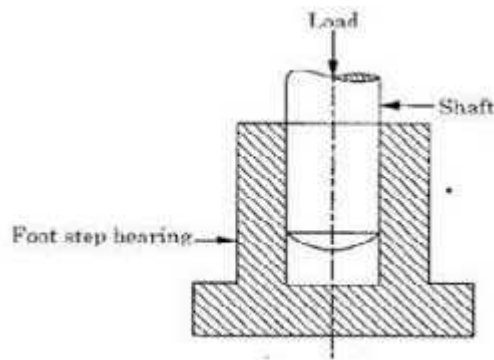


Fig 10: Incompletely Constrained Motion

3.Successfully Constrained Motion: When the motion between the elements of a pair is possible in more than one direction but made to have motion only in one direction by using some external means , then the motion is said to be **Successfully Constrained Motion**.

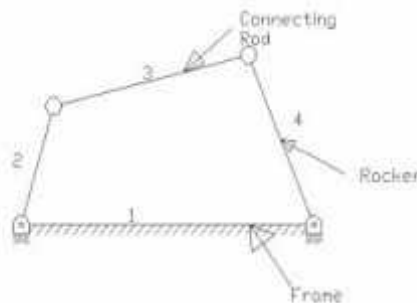
Ex: A shaft in a foot step bearing may have vertical motion apart from rotary motion as shown in fig. But due to the applied load on the shaft it is constrained to move in that direction and thus it is successfully constrained motion.



Foot step Bearing

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 , it is called Kinematic Chain.

In otherwords , kinematic chain may be defined as an assembly of links in which the relative motion of the link is possible and the motion of each is relative to the other is definite. The last link of a kinematic chain is attached to the first link.



Ex : Four bar mechanism.

The relation between the number of pairs (P) forming a kinematic chain and the number number of links (L) can be expressed as

$$L = 2P - 4$$

Another relation between the number links (L) and the number of joints (j) which constitutes a kinematic chain is given by the equatio , $j = \frac{3}{2}L - 2$.

Machine and Structure :

Machine : Machine is a combination of resistant bodies with successfully constrained motion which is used to transmit or transform motion to do some useful work.

Ex: Lathe machine , shaper machine , I.C. engine etc.

Structure : Structure is a assembly or combination of resistant bodies having no relative motion between them . They meant for taking loads having straining action.

Ex: Roof truss , railway bridge, machine frames.

Difference between Machine & Structure :

Machine	Structure
1.The parts of a machine move relative to one another.	1. The members of a structure do not move relative to one another.
2.It transforms the available energy in to useful work.	2. No energy is transformed in to useful work.
3.Links may transmit both power and motion.	3. Members of structure transmit forces only.
4.Not meant for carrying the loads.	4. These are meant for carrying the loads.
5.Ex: Lathe machine , shaper machine , I.C. engine etc	5. Ex:Roof truss , railway bridge, machine frames.

Mechanisms : When one of the links in a kinematic chain is fixed , the chain is known as mechanism. The mechanism can be used for transmitting the motion .

Ex : Type writer, engine indicator , etc.

A mechanism with four links is known as simple mechanism and the mechanism with more than four links is known as compound mechanism.

Difference between Machine & Mechanism :

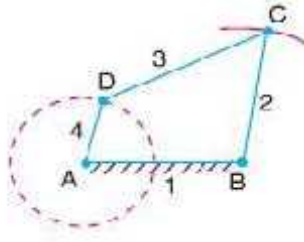
Machine	Mechanism
1. A machine have number of mechanisms for transmitting mechanical work or power.	1. A mechanism is the skeleton outline of the machine to produce motion between various links.
2. A machine is a practical development of any mechanism.	2. A mechanism is a part of a machine.
3. Machine modifies mechanical work.	3. Mechanism transmits and modies motion.
4. Ex : Lathe machine , shaper machine , I.C. engine	4. Ex : Type writer, engine indicator , etc

Inversion of Mechanism : In a mechanism one of the links of a kinematic chain is always fixed , therefore we can obtain as many mechanisms as the number of links in a kinematic chain by fixing the different links in a kinematic chain. This method of obtaining different mechanism by fixing different links in a kinematic chain is known as inversion of mechanism.

Types of Kinematic Chains : Following are the different types of Kinematic chains :

1. Four bar chain or Quadric cycle Chain .
2. Single Slider crank Chain .
3. Double Slider Crank chain .

Four Bar Chain or Quadric Cycle chain :



Four Bar chain

A simple form of four bar chain as shown in fig. It consists of four links, each of them forms a turning pair at A , B , C and D. These four links may be of different lengths.

According to the 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.

In this four bar chain , the shortest link will make a complete revolution relative to other three links , if it satisfies the Grashof's law , such a link is known as crank or driver i.e, link 4(AD). The link 2 (BC) makes a partial rotation is known as lever or rocker or follower and the link 3(CD) connects the crank and lever is called connecting rod or coupler. The fixed link 1 (AB) is known as frame of the mechanism.

When the crank i.e. link 4 is driver , the mechanism is transforming rotary motion in to oscillating motion.

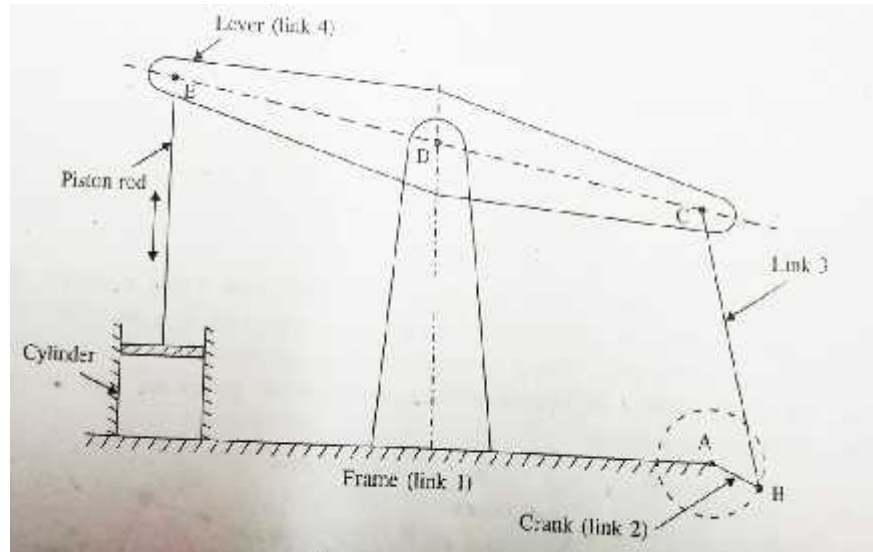
Inversion of Four Bar Chain : Following are the some important inversions of Four Bar Chain:

- 1) Beam Engine (Crank and lever mechanism)
- 2) Coupling rod of a locomotive (Double crank mechanism)
- 3) Watt's indicator mechanism (Double lever mechanism)

1. Beam Engine (Crank and lever mechanism): The beam engine consists of a four links as shown in fig and it is also known as crank and lever mechanism. In this

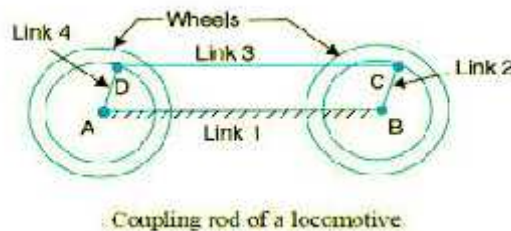
mechanism , when the crank 'AB' rotates about the fixed centre 'A' , the lever 'CDE' ,oscillates about a fixed centre 'D'.

The end 'E' of the lever CDE is connected to a piston rod which reciprocates in the cylinder due to the crank rotation. The main purpose of this mechanism is to convert the rotary motion in to the reciprocating motion.



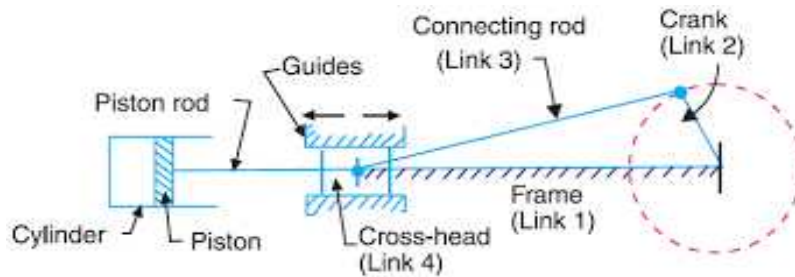
Beam Engine

2.Coupling Rod of a Locomotive: The mechanism of coupling rod of a locomotive is also known as double crank mechanism and it consists of four links as shown in fig. In this mechanism , the links 'AD' and 'BC' having equal lengths and are act as cranks.



These cranks are connected to their respective wheels. The link 'CD' acts as a coupling rod between two cranks. The link 'AB' is fixed in order to maintain the constant centre to centre distance between the wheels. This mechanism is used for transmitting rotary motion from one wheel to the other wheel.

Single Slider Crank Chain : A simple single slider crank chain is as shown in fig , and it is a modification of basic Four Bar Chain.



Single Slider Crank Chain.

It consists of one sliding pair and three turning pairs. Such mechanisms are usually found in reciprocating steam engine and it converts the rotary motion in to reciprocating motion and vice-versa.

It consists of link 1, and 2, link 2 and 3 , and links 3 and 4 are the three turning pairs whereas the link 4 and 1 is a sliding pair. Link 1 is the frame of the engine, link 2 is the crank, link 3 is the connecting rod and link 4 is of cross head. When the crank rotates, the cross head reciprocates in the guides and thus the piston reciprocates in the cylinder.

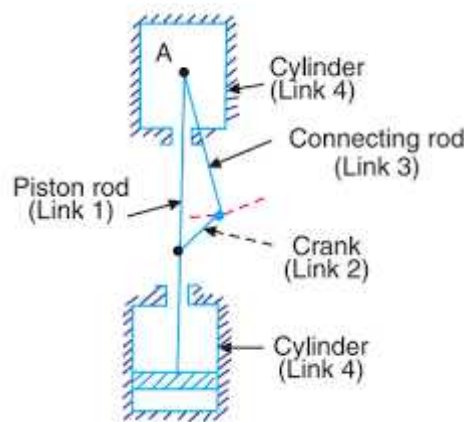
Inversions of Single Slider Crank Chain :

There are four inversions of single slider crank chain are possible and these are :

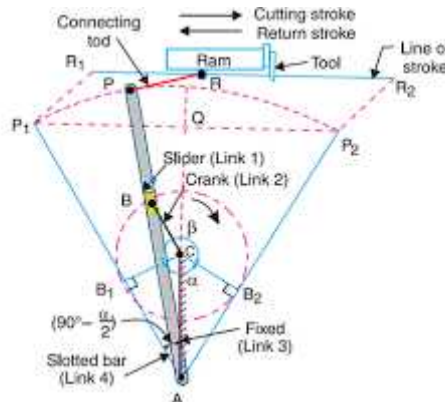
1. Pendulum pump or Bull Engine.
2. Oscillating Cylinder Engine.
3. Rotary internal combustion engine ,or Gnome engine.
4. Crank and slotted lever quick return motion mechanism.
5. Whitworth quick return motion mechanism.

1. Pendulum Pump or Bull Engine Mechanism : The pendulum pump or Bull engine inversion can be obtained by fixing the link 4 i.e cylinder (sliding pair) as shown in fig.

In this mechanism when the crank (link 2) rotates , the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 (cylinder) at 'A' and the piston attached to the piston rod (link 1) reciprocates. In this case , the duplex pump is used to supply the feed water to the boilers , therefore two pistons are attached to the link 1 as shown in fig .



Crank and Slotted Lever Quick Return Motion Mechanism :



These mechanisms are generally used in shaping machines , slotting machines and rotary internal combustion engines. A simple form of crank and slotted lever quick return mechanism as shown in fig. The link 3(AC) corresponds to the connecting rod, which is fixed forming a

turning pair. The driving link 2 i.e the crank BC 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 causing the AP to oscillate about the pivoted pin A. The short link PR transmits the oscillatory 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.

The forward or cutting stroke occurs when the crank rotates from the position CB_1 to CB_2 (or through an angle β) in clockwise direction. The return stroke occurs when the crank rotates from the position CB_2 to CB_1 (or through an angle α) in clockwise direction.

Therefore ,

Since the crank has a uniform angular speed.

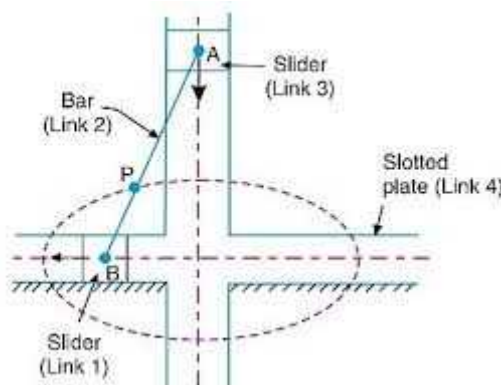
Therefore,

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360 - \beta}$$

OR

$$= \frac{360 - \alpha}{\alpha}$$

Double Slider Crank Chain : The kinematic chain which consists of two sliding pairs and two turning pairs is known as double slider crank chain.



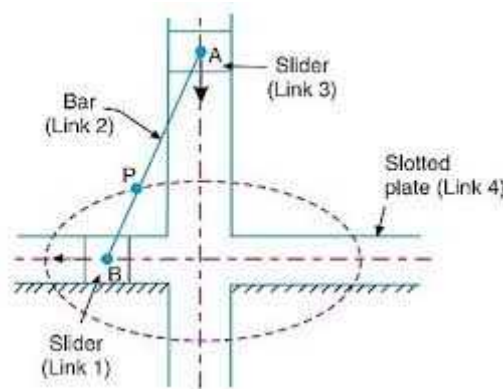
Double Slider Crank Mechanism.

A simple form of double slider crank chain as shown in fig. In this mechanism link 1 and link 2 form one turning pair and link 2 and link 3 form the second turning pair. The link 3 and link 4 becomes one sliding pair and link 1 and link 4 becomes the second sliding pair.

Inversion of Double slider Crank Chain : There are three main important inversions of double slider crank chain and these are :

1. Elliptical Trammel.
2. Scotch Yoke Mechanism.
3. Oldham's Coupling.

1. Elliptical Trammel. Elliptical trammel is an instrument used for drawing ellipse. This inversion can be obtained by fixing the slotted plate i.e link 4 as shown in fig.



Elliptical Trammel.

In a slotted plate (link 4) two straight grooves are cut at right angles to each other. The link 1 and link 3 are known as sliders and form the sliding pairs with link 4. The link 2 (AB) is a bar which forms turning pair with links 1 and 3 as shown in fig. When the sliders i.e. link 1 and 3 slides along their respective grooves, any point on the link 2 such as P traces out an ellipse on the surface of link 4 (slotted plate) as shown in fig.

2.Scotch Yoke Mechanism : The scotch yoke mechanism is used for converting the rotary motion into the reciprocating motion. This inversion can be obtained by fixing link 1 or link 3.

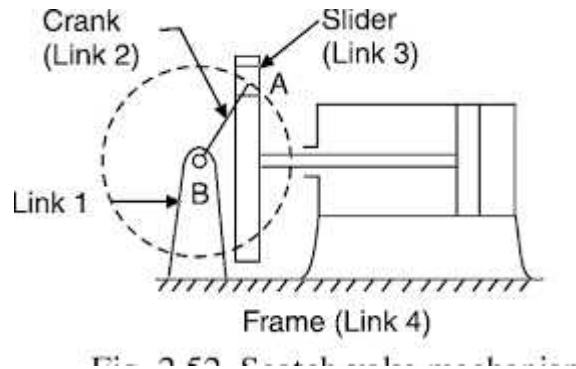
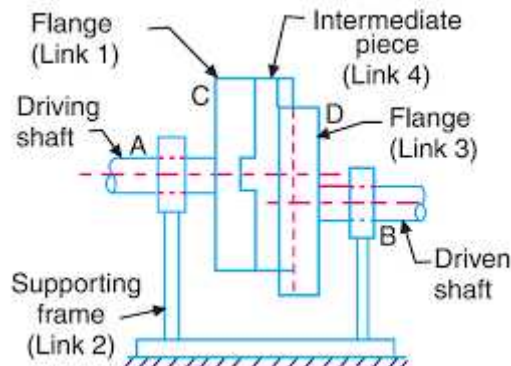


Fig shows the scotch yoke mechanism in which link 1 is fixed and which guides the frame. When the link 2 i.e. the crank rotates about B as centre , the link 4 corresponds to the frame reciprocates.

3.Oldham's Coupling: This mechanism is used for connecting two parallel shafts whose axis are at small distance apart from each other. These shafts are connected in such a way that when one shaft rotates , the other shaft also rotates at the same speed. The above inversion can be obtained by fixing the link 2 corresponds to the crank as shown in fig.



The two shafts to be connected have two flanges link 1 and link 3, which are rigidly fastened at their ends by forging. The link 1 and link 3 become turning pairs with link 2. The flanges have diametral slots cut in their inner faces as shown in fig. The intermediate piece i.e. link 4 which is a circular disc have two diametral projections T_1 and T_2 on each face at right angles to each other. The diametral projections on the link 4 closely fits in to the slots in the two flanges link 1 and link 3 . The link 4 can slide or reciprocates in the slots of the flanges.

EXERCISES

I] Question Bank Questions from DTE :

REMEMBERING :

1. List the different types of constraint motion. Explain any one.
2. Define kinematic link. Briefly explain its types.
3. Define following terms : a) structure b) mechanism.
4. Define kinematic chain. Name the different types of kinematic chains.
5. Define inversion of mechanism.

UNDERSTANDING :

1. Explain kinematic chain. Give its relation.
2. Explain the following terms :
a) Sliding pair b) turning pair c) screw pair d) spherical pair e) rolling pair
3. Explain lower pair and higher pairs. *Give one ex for each.*
4. Explain self closed pair and force-closed pair.
5. Differentiate between machine and a structure.
6. Classify different kinematic pairs.

APPLICATION :

1. Explain with a neat sketch completely constrained motion.
2. Explain with sketch four bar chain and mention its inversions.
3. Explain with sketch single slider crank chain and mention its inversions.
4. Explain with sketch double slider crank chain and mention its inversions.
5. Explain with a neat sketch beam engine.
6. Explain with a neat sketch four bar chain.
7. Explain With a neat sketch double crank mechanism.
8. Explain With a neat sketch single slider crank chain.
9. Explain with a neat sketch bull engine.
10. Explain with a neat sketch crank and slotted lever quick return motion mechanism.
11. Explain with a neat sketch elliptical trammel.
12. Explain with a neat sketch Scotch yoke mechanism.
13. Explain with a neat sketch Oldham's coupling.

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