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DEPARTMENT OF MECHANICAL ENGINEERING

ME3491 THEORY OF MACHINES

COURSE MATERIAL

Inversion of Mechanism: The process of fixing the links of a kinematic chain in such a way that one link is fixed at a time to get different mechanisms is called inversion of mechanism. The number of the inversions will be equal to the number of links of a kinematic chain.

Inversions and Grashof Criterion: The Grashof's law states that for a four-bar linkage system, the sum of the shortest and longest link of a planar quadrilateral linkage is less than or equal to the sum of the remaining two links, then the shortest link can rotate fully with respect to a neighboring link. Consider a four-bar-linkage. Denote the smallest link by S, the longest link by L and & other two links by P and Q. Grashof's Law condition must be satisfied, i.e $S+L \leq P+Q$

Inversions of Four Bar Mechanism:

Double Crank Mechanism: The mechanism of coupling rod of a locomotive is known as the double crank mechanism which consists of four links is shown in figure 15.

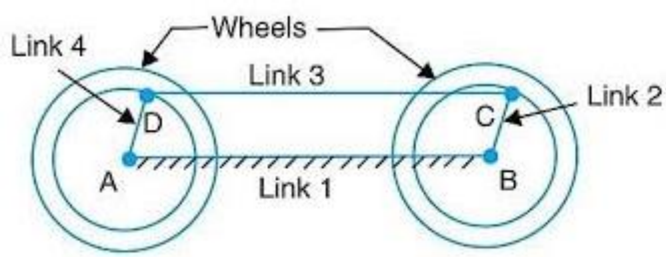

Fig 15: Double Crank mechanism

In this mechanism, the links AD and BC having equal length act as cranks and are connected to their own respective wheels. The link CD acts as a coupling rod and the link AB is fixed in order to maintain a fixed centre to centre distance between them. This mechanism is meant for transmitting rotary motion from one wheel to the other wheel.

Crank and lever mechanism or Mechanism of Beam Engine

The mechanism of beam engine also known as crank and lever mechanism which consists of four links is shown in figure 16. In this mechanism, when the crank rotates about fixed centre A. The lever oscillates about a fixed center D.

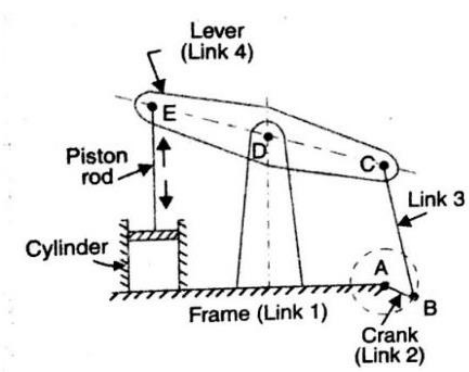

Fig 16; Crank and Lever Mechanism

The end E of the lever CDE is connected to the piston rod that reciprocates due to the rotation of the crank. In other words the purpose of this mechanism is convert the rotary motion into the reciprocating motion.

Double lever mechanism or Watt's indicator mechanism:

A Watt's indicator mechanism also known as Double lever mechanism that consists of four links, is shown in figure 17. The four links are: fixed link 1, link AC with link CE and link BFD. It is noted that BF and FD form one link because these two parts have no relative motion among them. The link of

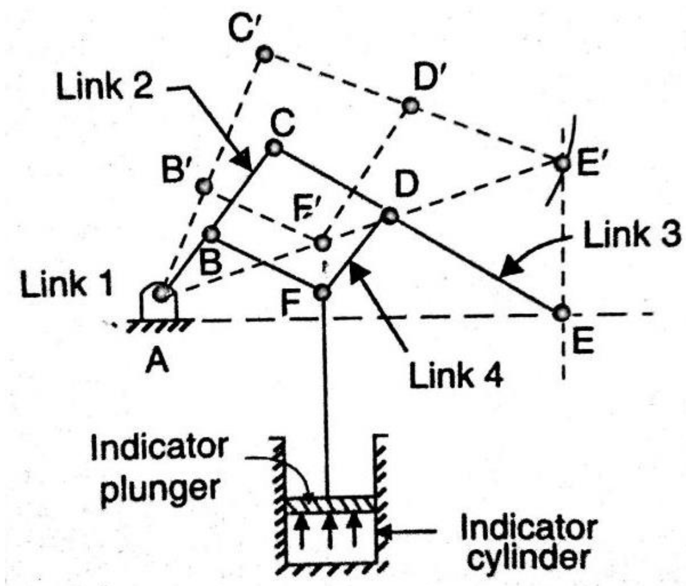

Fig 17: Double lever Mechanism

CE and BFD act as lever. The displacement vector of the link BFD is directly proportional to the pressure of gas that acts on the indicator plunger. On any small displacement of the mechanism, the tracing point of E at end of link CE trace out approximately straight line. The initial position of the mechanism is shown in figure 17 by full lines where the dotted line indicate the position of the mechanism when the gas acts on the indicator plunger.

Inversions of Slider crank Chain:

There are following inversions of a single slider chain mechanism:

1) Reciprocating engine mechanism (1st inversion)
2) Oscillating cylinder engine mechanism (2nd inversion)
3) Crank and slotted lever mechanism (2nd inversion)
4) Whitworth quick return motion mechanism (3rd inversion)
5) Rotary engine mechanism (3rd inversion)
6) Bull engine mechanism (4th inversion)
7) Hand Pump (4th inversion)

1) Reciprocating engine mechanism (1st inversion): In this mechanism, link 1 is fixed, link 2 works as crank, link 4 works as a slider and link 3 connects link 2 with 4, it is called connecting rod. Between links 1 and 4 sliding pair has been provided as shown in Figure 18.

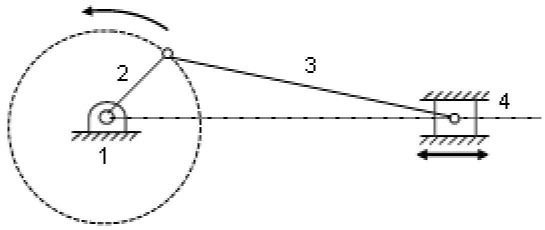

Fig 18: Reciprocating Engine Mechanism

This mechanism is also known as slider crank chain mechanism or reciprocating engine mechanism because it is used in reciprocating engines. It is also used in reciprocating pumps as it converts rotary motion into reciprocating motion and vice-versa.

2) Oscillating cylinder engine mechanism (2nd inversion):

The arrangement of oscillating cylinder engine mechanism is shown in Figure 19. It 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.

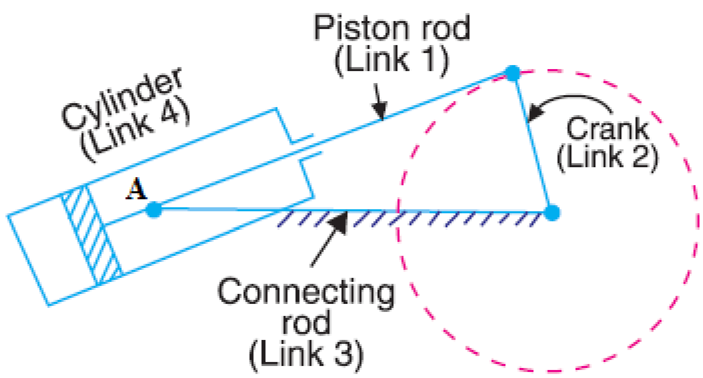

Fig 19: Oscillating Cylinder Engine

Whitworth quick return motion mechanism (3rd inversion): 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. 5.27. 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*.

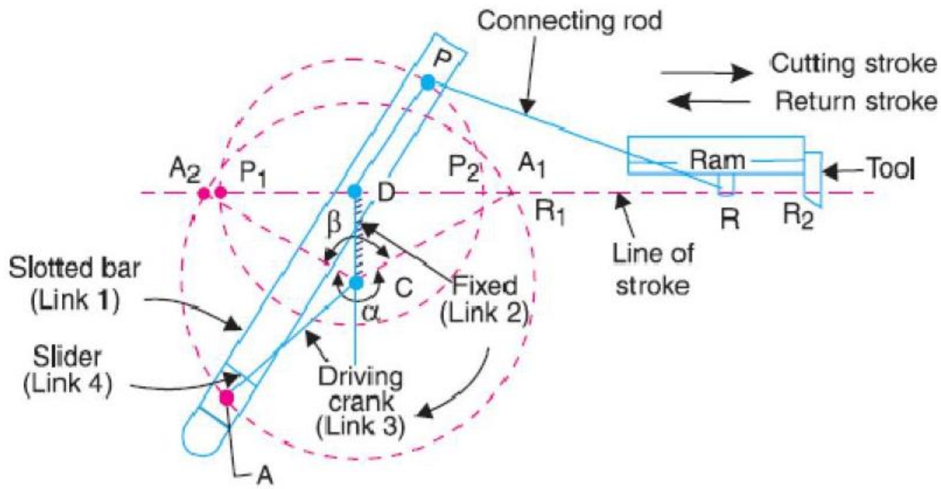

Fig 20: Whitworth quick return motion mechanism

If the driving crank *CA* moves from the position *CA*1 to *CA*2 (or the link *DP* from the position *DP*1 to *DP*2) through an angle α in the clockwise direction, the tool moves from the left hand end of its stroke to the right hand end through a distance 2 *PD*. Now when the driving crank moves from the position *CA*2 to *CA*1 (or the link *DP* from *DP*2 to *DP*1) through an angle β in the clockwise direction, the tool moves back from right hand end of its stroke to the left hand end.

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

Bull Engine Mechanism (4th inversion): In this mechanism, the inversion is obtained by fixing the cylinder or link 4 (*i.e.* sliding pair), as shown in Figure-21. 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.

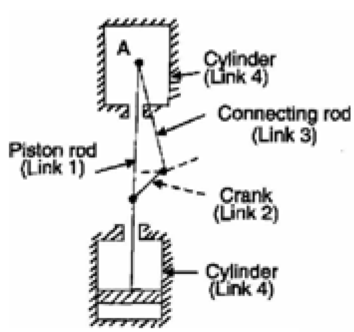

Fig 21: Bull Engine Mechanism

Inversions of Double Slider Crank Chain:

Elliptical trammels: It is an instrument used for drawing ellipses. This is inversion of double slider crank chain. This is obtained by fixing the slotted plate (link 4). 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 as shown in figure 22. The link *AB* (link 2) is a bar which forms turning pair with links 1 and 3.

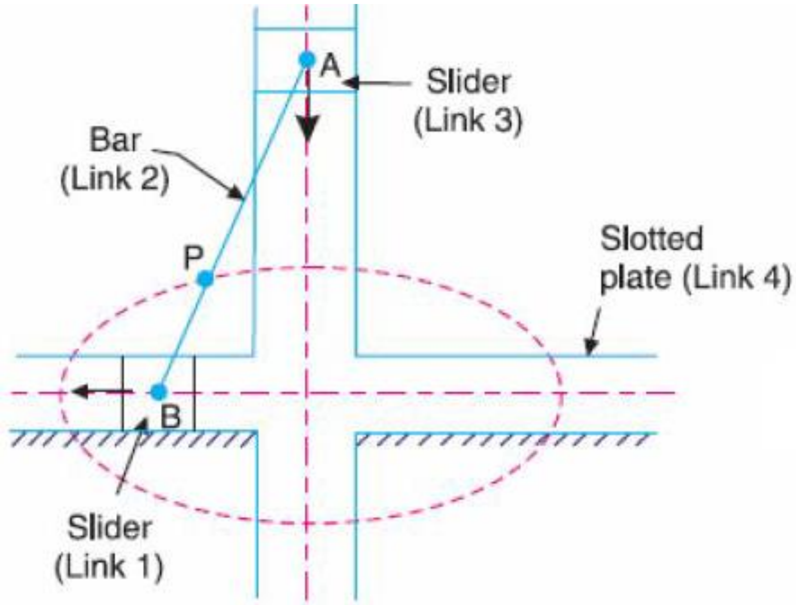

Fig 22: Elliptical Trammels

If 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. *AP* and *BP* are the semi-major axis and semi minor axis of the ellipse respectively.

Scotch yoke mechanism: This mechanism is used for converting rotary motion into a reciprocating motion. In the figure 23 as the crank 3 rotates, the horizontal portion of the link 1 slides in the fixed link 4. It is most commonly used in control valve actuators in high pressure oil and gas pipe lines.

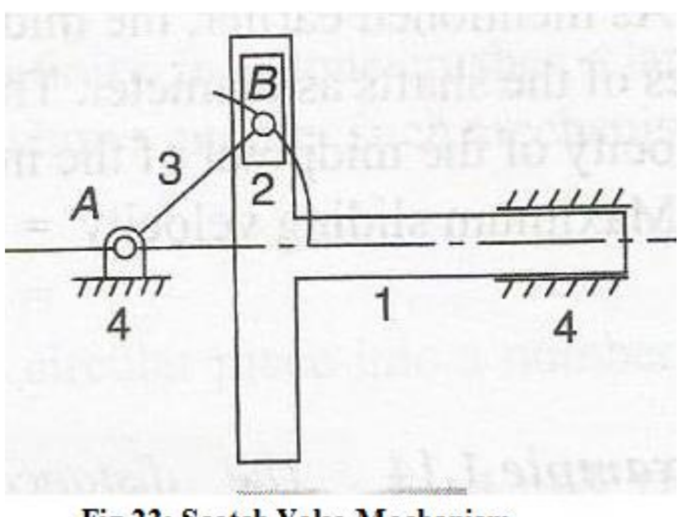

Fig 23: Scotch Yoke Mechanism

Oldham's coupling**:** An oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart or whose axes do not coincide. The shafts are coupled in such a way that if one shaft rotates, the other shaft also rotates at the same speed. The link 1 and link 3 form turning pairs with link 2.

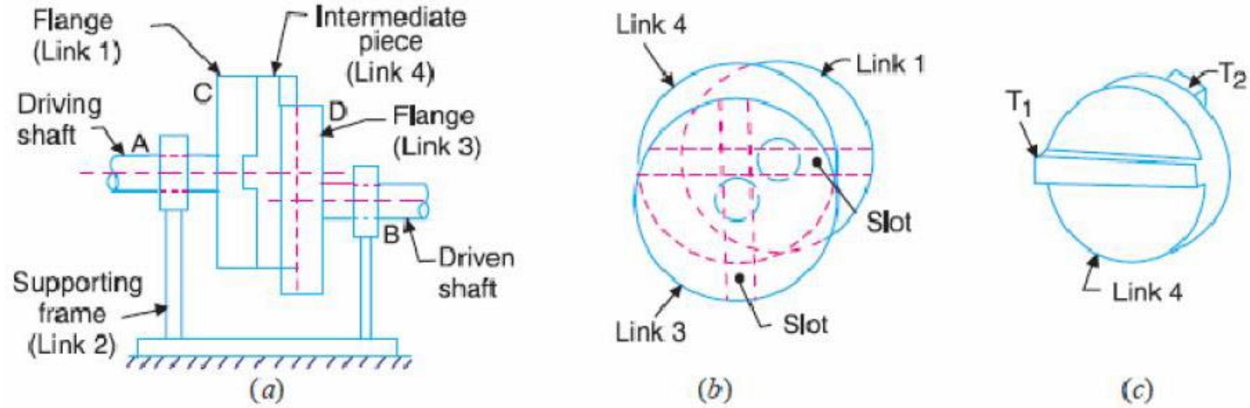

Fig 24: Oldham's coupling.

The flanges C and D have diametrical slots cut in their inner faces. The intermediate piece (link 4) which is a circular disc, has two tongues (*i.e.* diametrical projections) *T*1 and *T*2 on each face at right angles to each other. 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. There is a sliding motion between the link 4 and each of the other links 1 and 3.