2.3.7 Four-Bar Mechanism

(a) Consider the four-bar mechanism, as shown in Fig.2.7(a), in which the crank O_1A is rotating clockwise with uniform angular speed ω. The linear velocity of point A is $v_a = \omega \times O_1A$ and it is perpendicular to O_1A. Therefore, draw $o_1a \perp O_1A$ to a convenient scale in Fig.2.7(b). The velocity of point B is perpendicular to O_2B. Therefore, at point o_1, draw $o_1b \perp O_2B$. The relative velocity of B with respect to A is perpendicular to AB. Therefore, draw $ab \perp AB$ meeting the line drawn perpendicular to O_2B at b. Then $v_b = o_1b$, and $v_{ba} = ab$. To find the velocity of joint C, draw $ac \perp AC$ and $bc \perp BC$ to meet at c. Join o_1c. Then $v_c = o_1c$.

Now

$$v_b = v_a + v_{ba}$$
$$= o_1a + ab = o_1b$$

$$v_c = v_b + v_{cb}$$
$$= o_1b + bc = o_1c$$

and also,

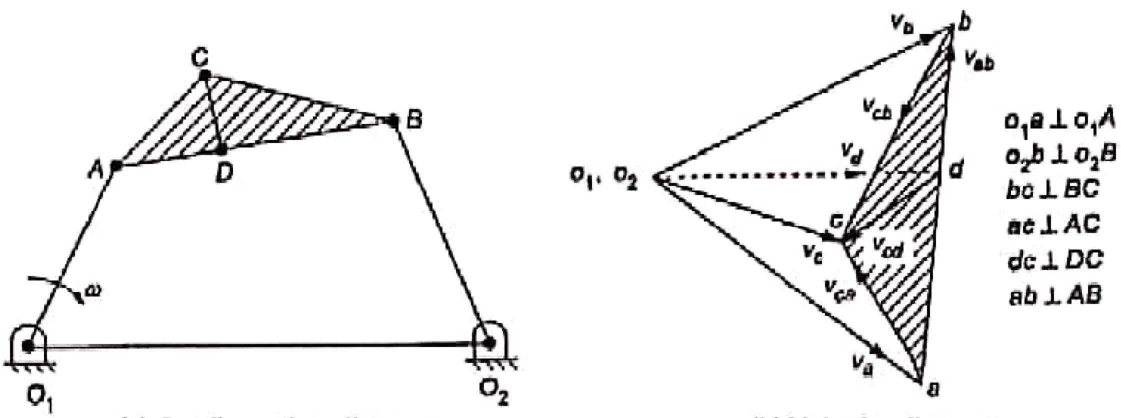
$$v_c = v_a + v_{ca}$$
$$= o_1a + ac = o_1c$$

To find the velocity of any point D in AB, we have

$$\frac{BD}{BA} = \frac{bd}{ba}$$

or

$$bd = \left(\frac{BD}{BA}\right) \cdot ba$$



(a) Configuration diagram (b) Velocity diagram

Fig.2.7 Four-bar mechanism with ternary link

Thus, locate point d in ab and join o_1d. Then $o_1d = v_d$. To find the relative velocity of C w. r. t. D, join cd. Then $v_{cd} = dc$. The velocity image of link ABC is abc.

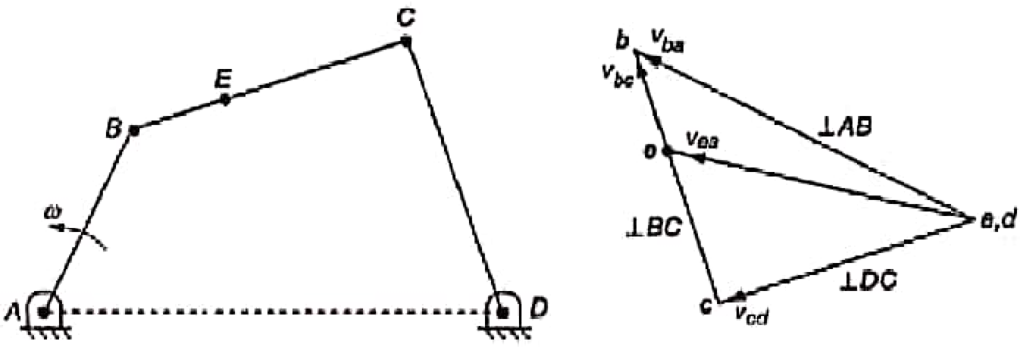
(b) Now consider the four-bar mechanism, as shown in Fig.2.8(a), in which the crank AB is rotating at angular velocity ω in the anticlockwise direction. The absolute linear velocity of B is $\omega \cdot AB$ and is perpendicular to AB. Draw $ab \perp AB$ to a convenient scale to represent v_{ba}, as shown in Fig.2.8(b). From b, draw a line perpendicular to BC and from 'a' another line perpendicular to CD to meet each other at point c. Then, $ac = v_{ca}$ and $cb = v_{bc}$. To find the velocity of any point E in BC, we have

$$\frac{CE}{CB} = \frac{ce}{cb}$$

or

$$ce = \left(\frac{CE}{CB}\right) \cdot cb$$

Thus, locate point e in cb and join ae. Then $ae = v_{ea}$.



(a) Configuration diagram (b) Velocity diagram

Fig.2.8 Four-bar mechanism

The rubbing velocities at pins of joints are:

A : $\omega_{ab} \cdot r_a$
B : $(\omega_{ab} \pm \omega_{cb})\, r_b$
C : $(\omega_{bc} \pm \omega_{dc})\, r_c$
D : $\omega_{cd} \cdot r_d$

where r is the radius of the pin.
Use the + ve sign when angular velocities are in the opposite directions.

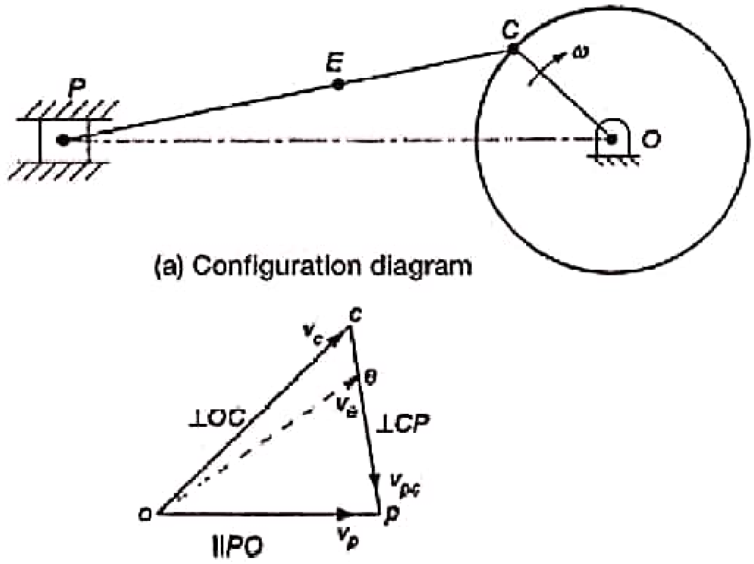
$$\omega_{cb} = \frac{bc}{BC} \quad \text{and} \quad \omega_{cd} = \frac{cd}{CD}$$

2.3.8 Slider–Crank Mechanism

Consider the slider crank mechanism, as shown in Fig.2.9(a), in which the crank OC is rotating clockwise with angular speed ω. PC is the connecting rod and P is the slider or piston.

The linear velocity of C, $v_c = OC \cdot$

To draw the velocity diagram, draw a line $oc = v_c$ from point o, as shown in Fig.2.9(b), representing the velocity of point C to a convenient scale. From point c draw a line perpendicular to CP. The velocity of slider P is horizontal. Therefore, from point o draw a line parallel to OP to intersect the



(a) Configuration diagram

(b) Velocity diagram

Fig.2.9 Slider-crank mechanism

line drawn perpendicular to CP at p. Then the velocity of the piston, $v_p = op$ and the velocity of piston P relative to crank pin C is v_{pc} = cp. To find the velocity of any point E in CP, we have

$$CE/CP = ce/cp$$

$$\text{or} \qquad ce = (CE/CP) \cdot cp$$

Thus locate point e in cp, join oe. Then $v_e = oe$

Rubbing velocities are:

$$O : \omega_{oc} \cdot r_o$$

$$P : \omega_{cp} \cdot r_p$$

$$C : \left(\omega_{oc} + \omega_{cp}\right) \cdot r_c$$

2.3.9 Crank and Slotted Lever Mechanism

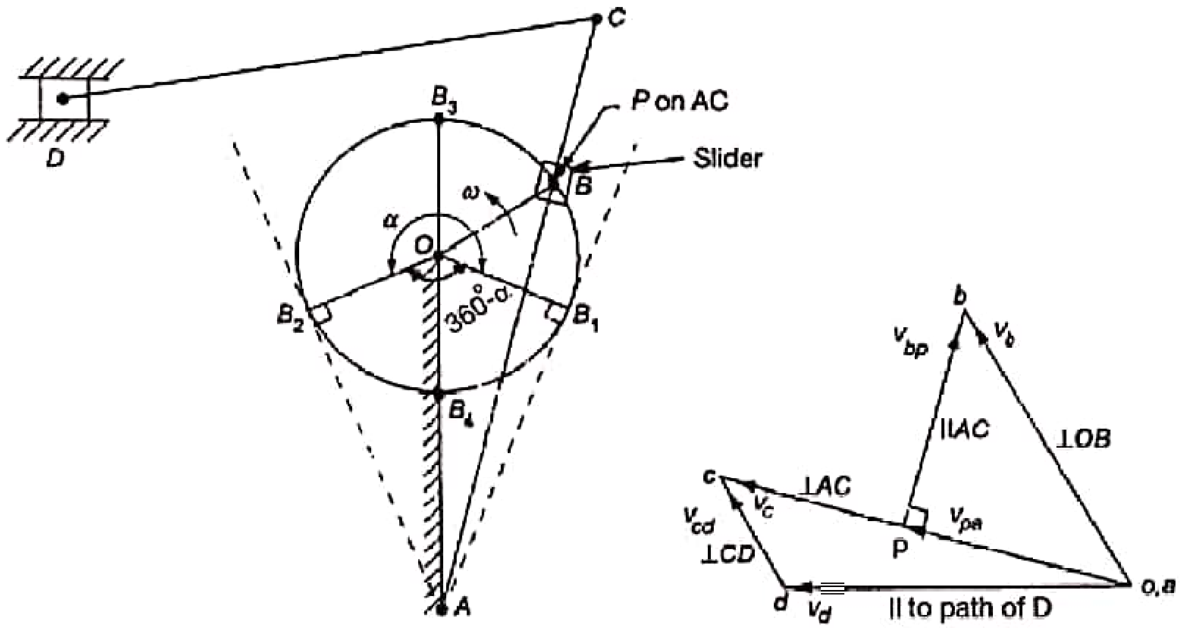
Consider the crank and slotted lever mechanism, as shown in Fig.2.10(a). The crank OB is rotating at a uniform angular speed ω. Let $OB = r$, $AC = l$, and $OA = d$. Linear velocity of B, $v_b = r\omega$. Draw $ob = v_b$ and perpendicular to OB to a convenient scale, as shown in Fig.2.10(b). v_b is the velocity of point B on the crank OB. The velocity of the slotted lever is perpendicular to AC. The velocity of the slider is along the slotted lever. Hence draw a line from b parallel to AC to meet the line perpendicular to AC at p. Now, $ap = v_{pa}$, and

$$ac = v_c = \left(\frac{AC}{AP}\right) . v_{pa}$$

From point c, draw a line perpendicular to CD and from point o draw a line parallel to the tool motion, to intersect at point d.

Velocity of cutting tool, $v_d = ad$

The component of the velocity of the crank perpendicular to the slotted lever is zero at positions B_1 and B_2. Thus for these positions of the crank, the slotted lever reverses its direction of motion.



(a) Configuration diagram (b) Velocity diagram

Fig.2.10 Crank and slotted lever mechanism

$$\text{Time of cutting stroke/Time of return stroke} = \frac{\alpha}{(360^\circ - \alpha)}$$

At positions B_1 and B_4, the component of velocity along the lever is zero, i.e. the velocity of the slider at the crank pin is zero. Thus the velocity of the lever at crankpin is equal to the velocity of crankpin, i.e. $r\omega$. The velocities of lever and tool at these points are minimum. The maximum cutting velocity occurs at B_3 and maximum return velocity occurs at B_4.

$$\text{Maximum cutting velocity} = (OB \cdot \omega)\left(\frac{AC}{AB_3}\right)$$

$$= (r\omega)\left[\frac{l}{d+r}\right] \quad (2.7a)$$

$$\text{Maximum return velocity} = (OB \cdot \omega)\left(\frac{AC}{AB_4}\right)$$

$$= (r\omega)\left[\frac{l}{d-r}\right] \quad (2.7b)$$

$$\text{Maximum cutting velocity/Maximum return velocity} = \left(\frac{d-r}{d+r}\right) \quad (2.8)$$

2.3.10 Drag Mechanism

The drag mechanism is shown in Fig.2.11(a). Link 2 rotates at constant angular speed ω. Link 4 rotates at a nonuniform velocity. Ram 6 will move with nearly constant velocity over most of the upward stroke to give a slow upward stroke and a quick downward stroke when link 2 rotates clockwise.