Kinematics and Dynamics of Machines

5. Cams

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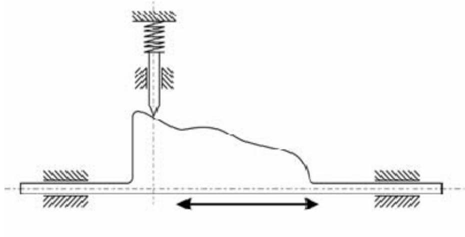
Introduction

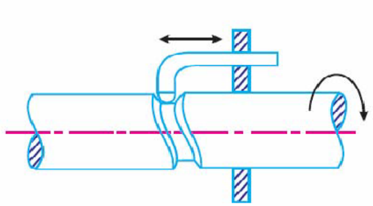
- A cam mechanism is a two-link system in which the cam is always a driving link.
- This mechanism transforms a rotational or translational motion of the cam into a prescribed reciprocating or oscillating motion of the follower.
- The transfer of motion is achieved through the contact between the cam and the follower. This contact exists only if there is a compressive force between the cam and the follower.
- *the main objective of cam design is to find a cam profile needed to obtain a desired follower motion..*

Different types of cams

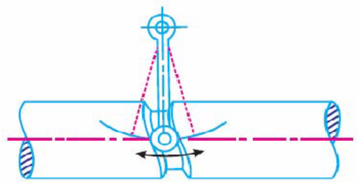
1. Disc cams
2. Translation cams
3. Cylindrical cams



Translational cam



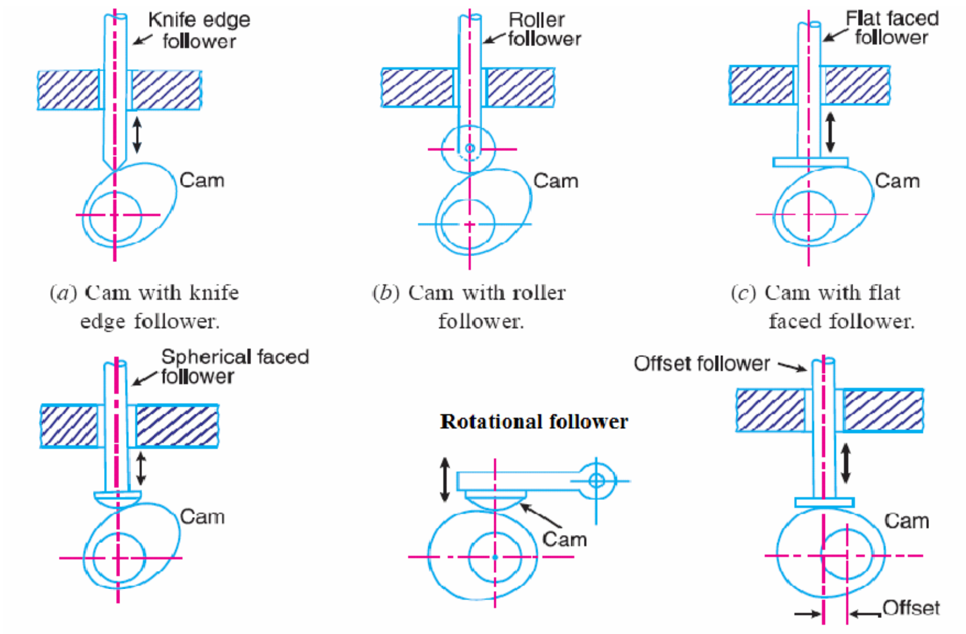
(*a*) Cylindrical cam with reciprocating follower.



(*b*) Cylindrical cam with oscillating follower.

Classification of followers

- According to the surface in contact:
  1. Knife edge follower
  2. Roller follower
  3. Flat faced or mushroom follower
  4. Spherical faced follower
- According to the motion of the follower:
  1. Reciprocating or translating follower
  2. Oscillating or rotational follower
- According to the path of motion of the follower:
  1. Radial follower
  2. Off-set follower



(a) Cam with knife edge follower.
(b) Cam with roller follower.
(c) Cam with flat faced follower.
(d) Cam with spherical faced follower.
(e) Cam with rotational follower.
(f) Cam with offset follower.

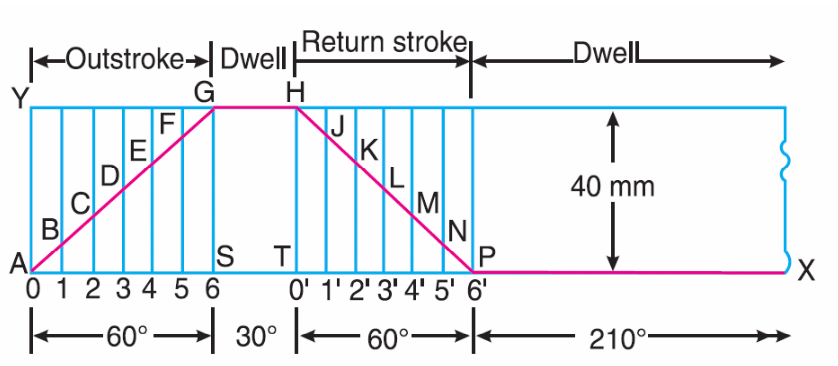
Design of cam profile for radial cam

- In drawing a radial cam profile, there are two basic steps:

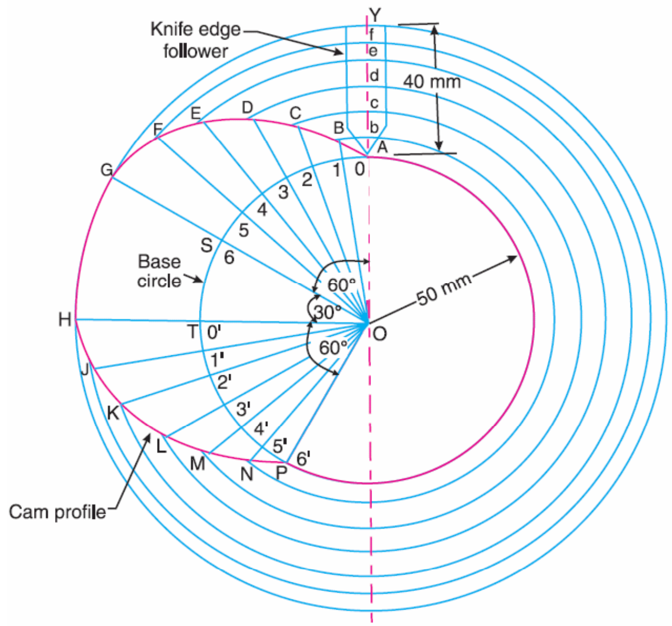
1. Draw the displacement diagram
2. Construct the follower in its proper position at each angular position

- In constructing the cam profile, the principle of kinematic inversion is used, i. e. the cam is imagined to be stationary and the follower is allowed to rotate in the opposite direction to the cam rotation.

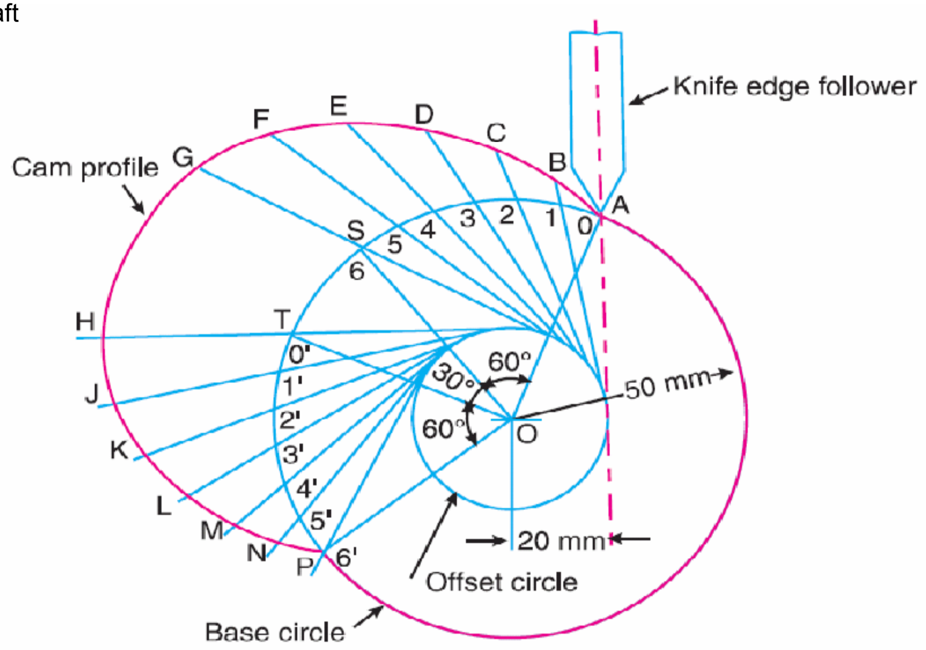
Example : *A cam is to give the following motion to a knife-edged follower :*
1. Outstroke during 60° of cam rotation ; 2. Dwell for the next 30° of cam rotation; 3. Return stroke during next 60° of cam rotation, and 4. Dwell for the remaining 210° of cam rotation.



a) Profile of the cam when the axis of the follower passes through the axis of the cam shaft



b) Profile of the cam when the axis of the follower is 20mm off-set from the axis of the cam shaft



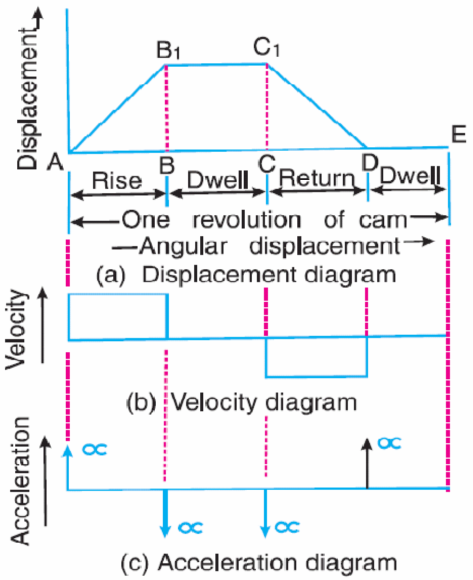
Motion of the follower

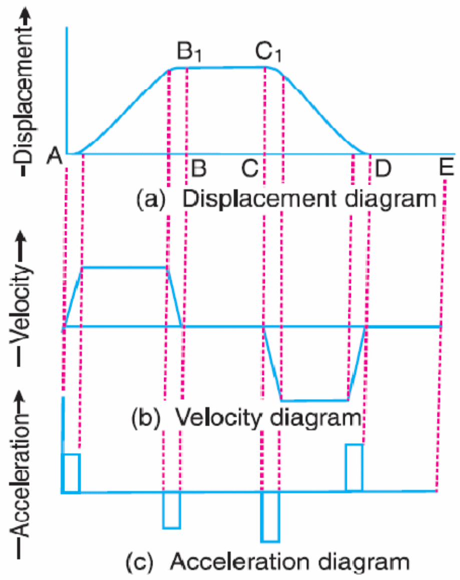
- A follower, during its travel, may have one of the following motions:

1. Uniform velocity
2. Uniform acceleration and retardation
3. Simple harmonic motion ($S=\frac{h}{2}(1-\cos\frac{\pi\theta}{\theta_0})$
4. Cycloidal motion ($S=h\,(\frac{\theta}{\theta_0}-\frac{1}{2\pi}\sin\frac{2\pi\theta}{\theta_0})$

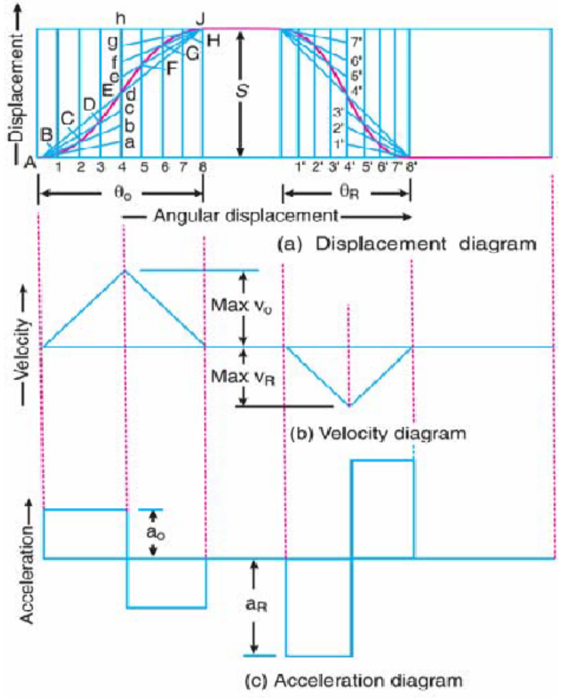
- The displacement of the follower does not depend on the angular velocity of the cam. However, the velocity and acceleration of the follower do depend on it.
- Comparing harmonic and cycloidal cams One can see that the displacement curves look sufficiently close. However, the differences at specific angles may be significant.
- The harmonic cam does not satisfy all the smoothness requirements. The jump in acceleration while passing through special points means a jump in inertial forces. For high-speed cams when there are design constraints on forces or noise, this cam may not be acceptable.

1. Uniform velocity

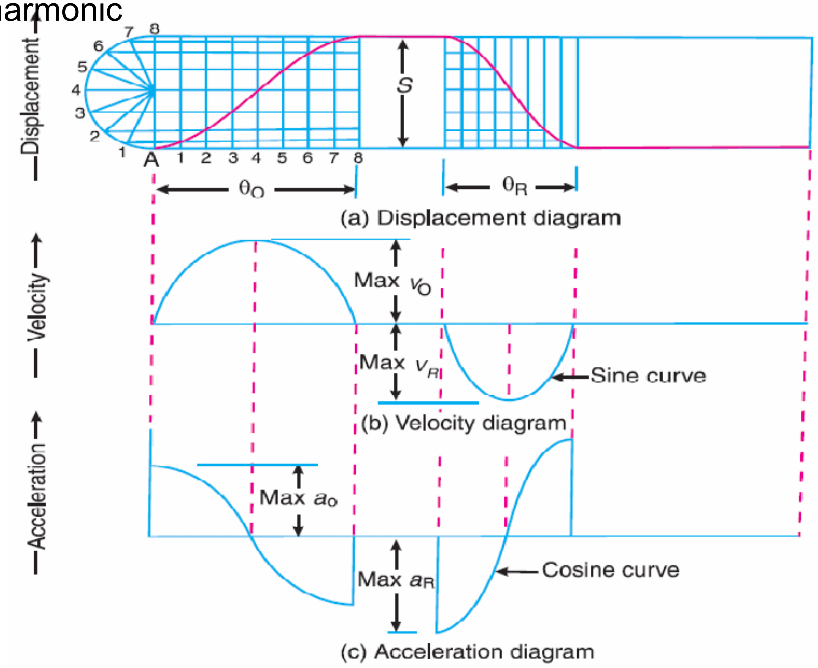




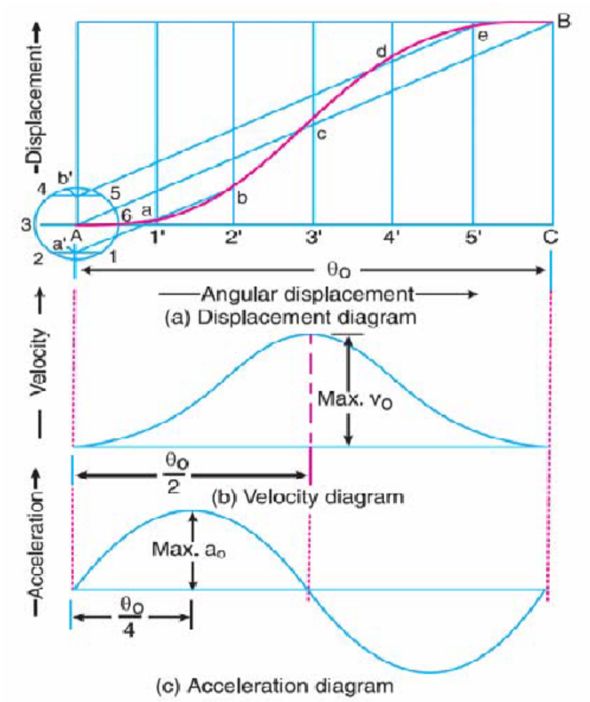
2. Uniform acceleration and retardation



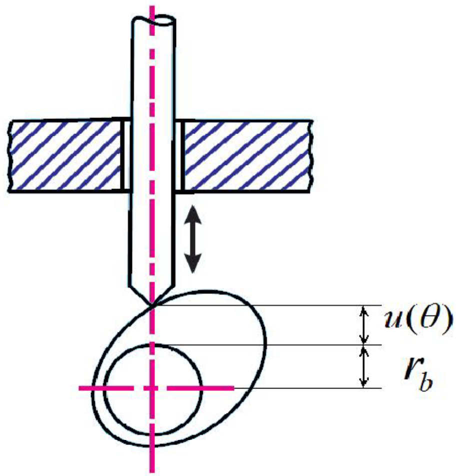
3. Simple harmonic



4. Cycloidal



Effect of base circle



Effect of base circle

- The expression for the position of the follower:

$$D(\theta) = u(\theta) + r_b$$

- shows that its velocity and acceleration do not depend on the base radius r_b. However, a corresponding point on the cam does depend on this radius:

$$\mathbf{r_D} = D(\theta)[\cos\theta, \sin\theta]^T$$

$$\dot{\mathbf{r}}_D = \dot{D}(\theta)[\cos\theta, \sin\theta]^T + D(\theta)[\cos(\theta+\pi/2), \sin(\theta+\pi/2)]^T$$

- The first term in the previous equation represents the translational component of the velocity vector, and it is equal to the follower velocity.
- The second term represents the angular (tangential with respect to the follower) component of the cam velocity vector.
- The follower does not have this component. It means that the tangential velocity is associated with the velocity of sliding of the follower along the cam profile.
- Although the tangential velocity does not affect the kinematics of motion transfer, it is important in the wear analysis of cams with knife or flat-faced followers since wear is proportional to the coefficient of friction, the normal contact force, and the velocity of sliding.

Pressure Angle

- The angle between the normal to the cam profile and the axis of the follower is called the *pressure angle.* This angle affects the transverse force *Ft*, creating a bending moment on the follower. Thus, it is desirable to keep this angle within an acceptable minimum.
- the pressure angle depends nonlinearly on base circle radius. Thus, in each particular case the relationship between the two must be investigated to optimize the design.