Cams

1. Introduction:

A *cam* is a rotating machine element which gives reciprocating or oscillating motion to another element known as *follower*. The cam rotates usually at constant speed and drives the follower whose motion depends upon the shape of the cam. Almost always the cam is the driver and the follower is the driven.

In a cam mechanism, the three essential members are:

- The cam which has a curved surface or straight surface,
- The follower and
- The frame which supports and guides.

2. Types of Followers:

The followers which are having either reciprocating or oscillating motion, are generally classified as:

- **According to the surface in contact**: The followers, according to the surface in contact, are as follows:

- **Knife edge follower**: When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig. (a).
- **Roller follower:** When the contacting end of the follower is a roller, it is called a roller follower, as shown in Fig. (b).

- **Flat faced or mushroom follower:** When the contacting end of the follower is a perfectly flat face, it is called a flat-faced follower, as shown in Fig. (c).

![Diagram](image.png)

- **According to the motion of the follower:** The followers, according to its motion, are of the following two types:
  - (a) **Reciprocating or translating follower.** When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower. The followers as shown in Fig. (a) to (c) are all reciprocating or translating followers.
  - (b) **Oscillating or rotating follower.** When the uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower, it is called oscillating or rotating follower. The follower, as shown in Fig. below, is an oscillating or rotating follower.

![Diagram](image.png)
According to the path of motion of the follower:

- **Radial follower.** When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower. The followers, as shown in Fig. (a) to (c), are all radial followers.

- **Off-set follower.** When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower. The follower, as shown in Fig. below, is an off-set follower.

### Note:
Radial or disc cam. In radial cams, the follower reciprocates or oscillates in a direction perpendicular to the cam axis.

3- Terms Used in Radial Cams:

Fig. below shows a radial cam with reciprocating roller follower. The following terms are important in order to draw the cam profile.

1. **Base circle.** It is the smallest circle that can be drawn to the cam profile.
2. **Trace point.** It is a reference point on the follower and is used to generate the *pitch curve*. In case of knife edge follower, the knife edge represents the trace point and the pitch curve corresponds to the cam profile. In a roller follower, the centre of the roller represents the trace point.
3. **Pressure angle.** It is the angle between the direction of the follower motion and a normal to the pitch curve. This angle is very important in designing a cam profile. If the pressure angle is too large, a reciprocating follower will jam in its bearings.
4. **Pitch point.** It is a point on the pitch curve having the maximum pressure angle.
5. **Pitch circle.** It is a circle drawn from the centre of the cam through the pitch points.
6. **Pitch curve.** It is the curve generated by the trace point as the follower moves relative to the cam. For a knife edge follower, the pitch curve and the cam profile are same whereas for a roller follower, they are separated by the radius of the roller.
7. **Prime circle.** It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve. For a knife edge and a flat face follower, the prime circle and the base circle are identical. For a roller follower, the prime circle is larger than the base circle by the radius of the roller.
8. **Lift or stroke.** It is the maximum travel of the follower from its lowest position to the topmost position.

3- **Motion of the Follower:**

The follower, during its travel, may have one of the following motions.
1. Uniform motion or uniform velocity,
2. Simple harmonic motion.
3. Uniform acceleration and uniform retardation.
4. Cycloidal motion.
**1- Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Velocity:**

The displacement, velocity and acceleration diagrams when a knife-edged follower moves with uniform velocity are shown in Fig. (i) (a), (b) and (c) respectively. The abscissa (base) represents the time (*i.e.* the number of seconds required for the cam to complete one revolution) or it may represent the angular displacement of the cam in degrees. The ordinate represents the displacement, or velocity or acceleration of the follower.

Since the follower moves with uniform velocity during its rise and return stroke, therefore the slope of the displacement curves must be constant. In other words, $AB_1$ and $C_1D$ must be straight lines. A little consideration will show that the follower remains at rest during part of the cam rotation. The periods during which the follower remains at rest are known as **dwell periods**, as shown by lines $B_1C_1$ and $DE$ in Fig. (i) (a). From Fig. (i) (c), we see that the acceleration or retardation of the follower at the beginning and at the end of each stroke is infinite. This is due to the fact that the follower is required to start from rest and has to gain a velocity within no time. This is only possible if the acceleration or retardation at the beginning and at the end of each stroke is infinite. These conditions are however, impracticable.
In order to have the acceleration and retardation within the finite limits, it is necessary to modify the conditions which govern the motion of the follower. This may be done by rounding off the sharp corners of the displacement diagram at the beginning and at the end of each stroke, as shown in Fig. (ii) (a). By doing so, the velocity of the follower increases gradually to its maximum value at the beginning of each stroke and decreases gradually to zero at the end of each stroke as shown in Fig. (ii) (b). The modified displacement, velocity and acceleration diagrams are shown in Fig. (ii). The round corners of the displacement diagram are usually parabolic curves because the parabolic motion results in a very low acceleration of the follower for a given stroke and cam speed.

**Example(1):** 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.

The stroke of the follower is 40 mm and the minimum radius of the cam is 50 mm. The follower moves with uniform velocity during both the outstroke and return strokes. Draw the profile of the cam when (a) the axis of the follower passes through the axis of the cam shaft, and (b) the axis of the follower is offset by 20 mm from the axis of the cam shaft.