Theory of Machines

Module : Kinematics of Machines

Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

Dr Appaso M Gadade
Assistant Professor, MED
Email: appaso.gadade@thapar.edu

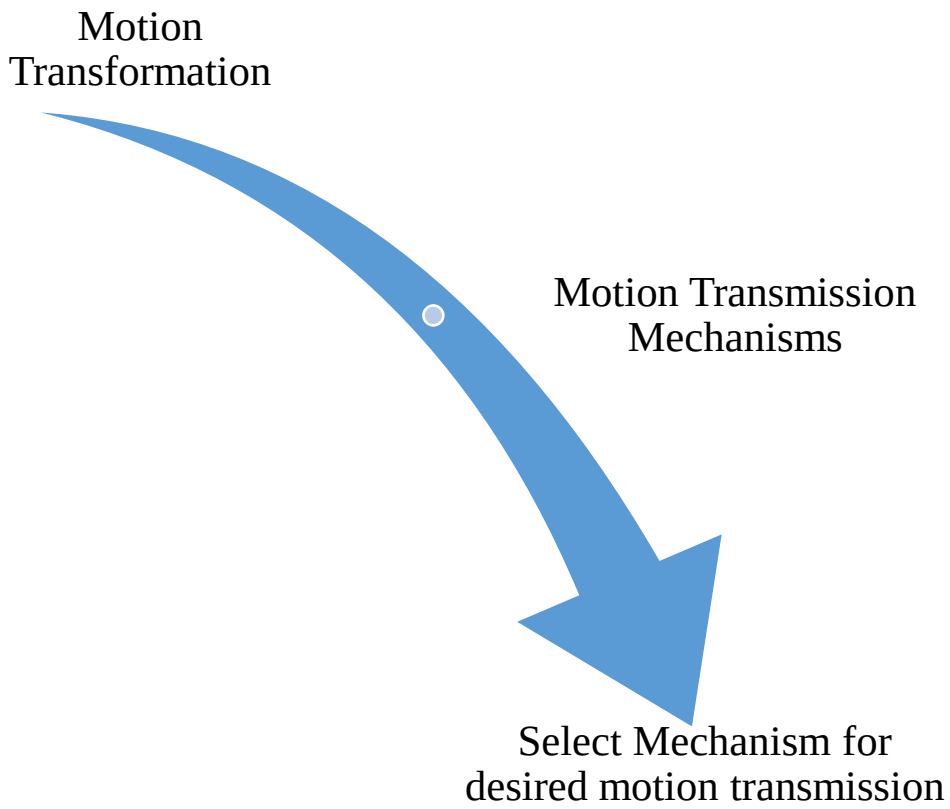
THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Lecture Contents and Learning Outcomes

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Introduction to linkages
- Gears
- Screws and Cam Mechanics
- Belts
- Ropes
- Chains

Learning Outcomes



References

1. S S Ratan “Theory of Machines” 3rd Edition, Tata Macgraw Hill Publications
2. J. J. Uicker, G. R. Pennock, and J. E. Shigley “Theory of Machines and Mechanisms” Oxford Press (2009)
3. Neil Sclater, Nicholas P. Chironis “Mechanisms and Mechanical Devices Sourcebook” 4th Edition, McGraw Hill Publications
4. R S Khurmi “A text Book of Theory of Machines” S Chand Publications

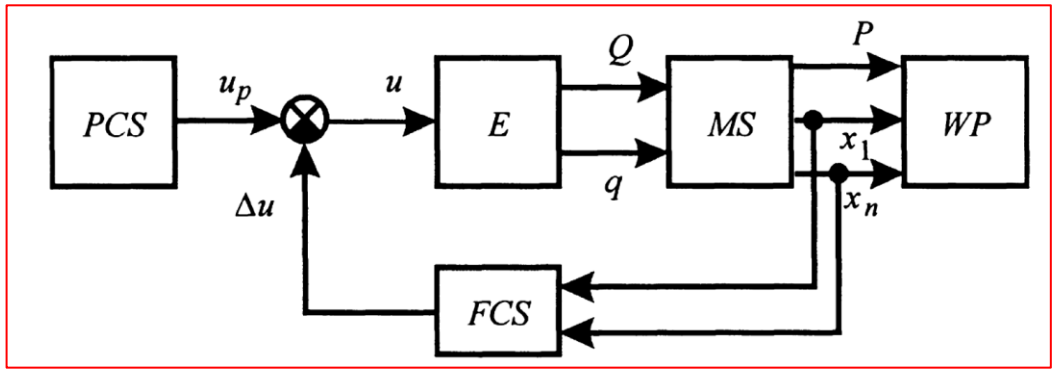
Introduction

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Modern industrial production requires working processes associated with treatment and transformation of initial raw materials into half- or fully finished products; such working processes are referred to as *technological.*
- Technological processes involve transportation of materials to the place of utilization as well as energy processes, i.e. generation and transformation of energy in forms most convenient for the respective process.
- Also, information processes, i.e. transmission and transformation of information are of great importance in modem production, ensuring execution of operations associated with control and organization of production.
- The accomplishment of many working processes requires realization of certain mechanical motions.
- The execution of working processes is also associated with the application of forces to materials in process in order to balance the weight of transported objects.
- In modem production however the overwhelming majority of working processes associated with the realization of mechanical motions is carried out by machines.

Definitions

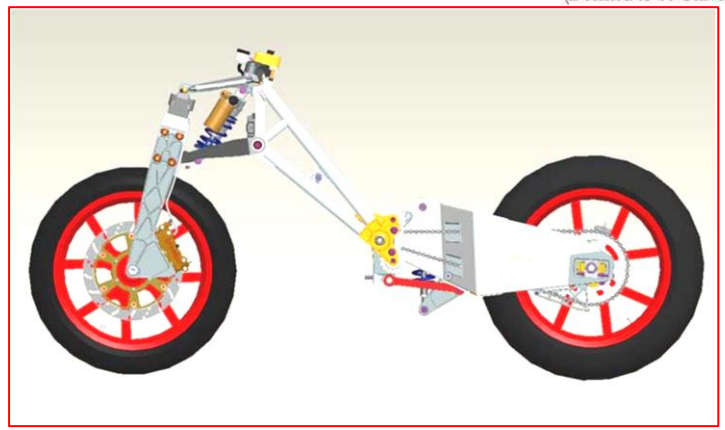
- The subject Theory of Machines may be defined as that branch of Engineering-science, which deals with the study of relative motion between the various parts of a machine, and forces which act on them.
- The knowledge of this subject is very essential for an engineer in designing the various parts of a machine.
- Kinematics: The study of motion without regard to forces
- More particularly, kinematics is the study of position, displacement, rotation, speed, velocity, and acceleration
- Kinetics: The study of forces on systems in motion.
- A mechanism: is a device that transforms motion to some desirable pattern and typically develops very low forces and transmits little power.
- A machine: typically contains mechanisms that are designed to provide significant forces and transmit significant power.

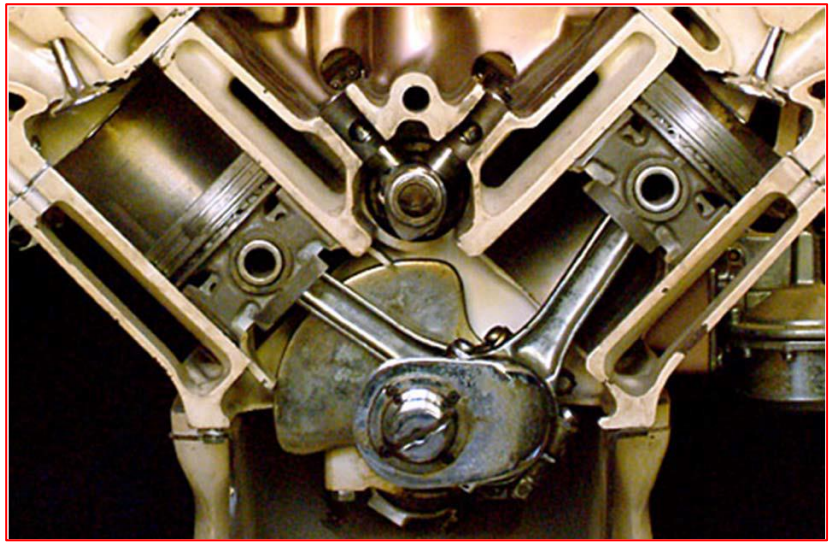


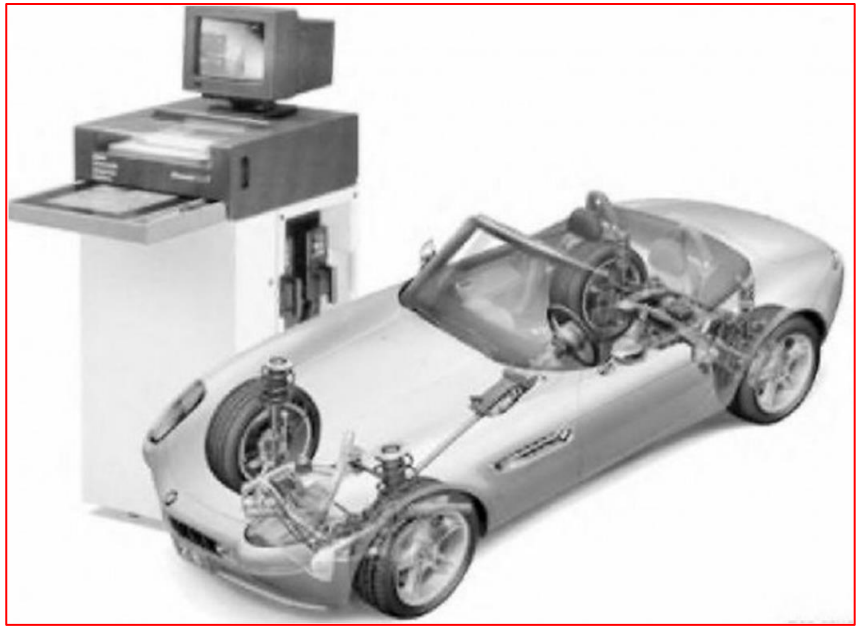
Application of Kinematics

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Any machine or device that moves contains one or more kinematic elements /linkages, such as gears, screws, cams, belts, ropes and chains.
- Bicycle is a simple example of a kinematic system that contains a chain drive to provide Torque.
- An Automobile contains many more examples of kin-systems… the transmission is full of gears.



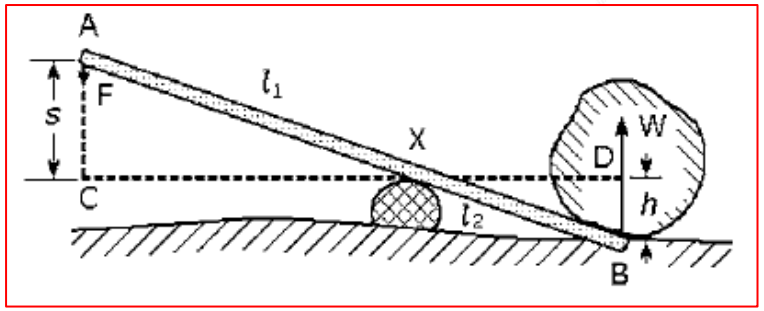


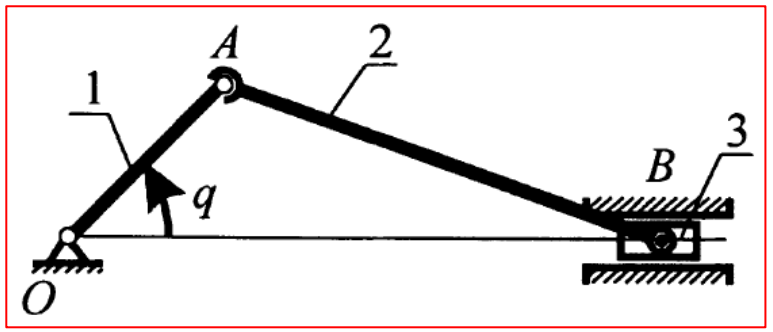


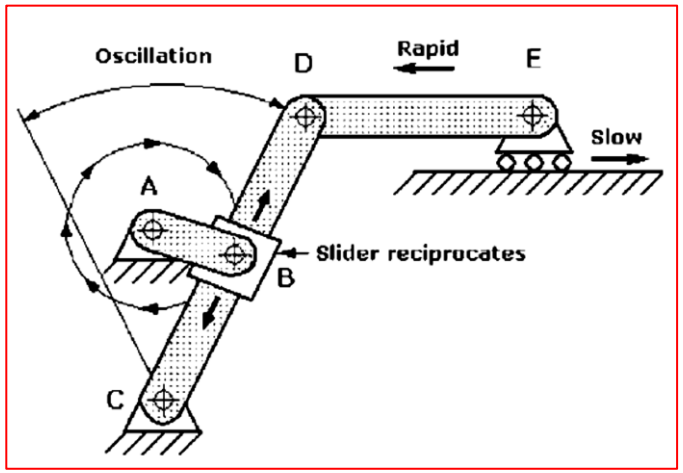
Linkages

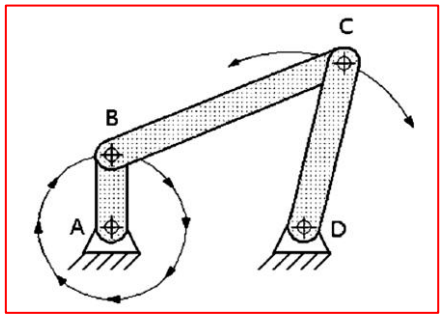
THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Linkages are the basic building blocks of all mechanisms.
- All common forms of mechanisms (cams, gears, belts, chains) are in fact variations on a common theme of linkages.
- A mechanical linkage is an assembly of bodies connected to manage forces and movement.
- Linkages are perhaps the most fundamental class of machines that humans employ to turn thought into action
- From the first lever and fulcrum, to the most complex shutter mechanism, linkages translate one type of motion into another



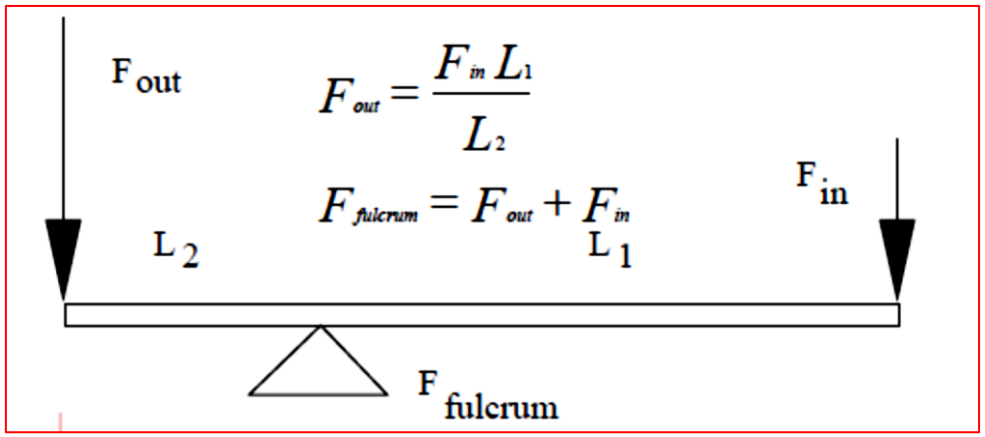






Lever: 2- bar Linkage

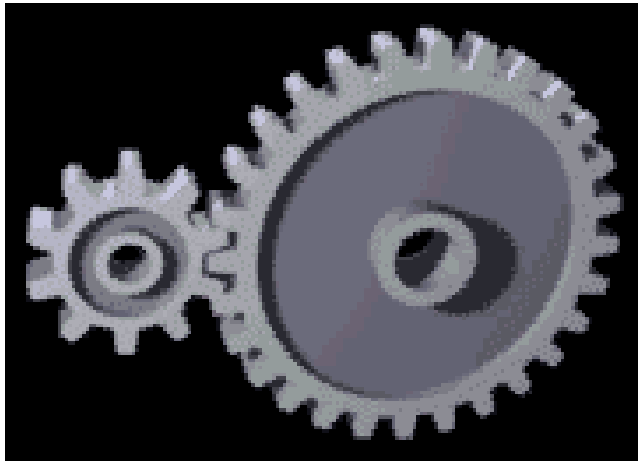
- A lever (link) can be used with a fulcrum (pivot) against the ground (link) to allow a small force moving over a large distance to create a large force moving over a short distance.
- The forces are applied through pivots, and thus they may not be perpendicular to the lever



Gears

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Definition: A Gear is a machine component, which is used to transmit mechanical power from one shaft to the other by successively engaging its teeth.
- Gears are one of the most used method of mechanical power transmission in the machines.



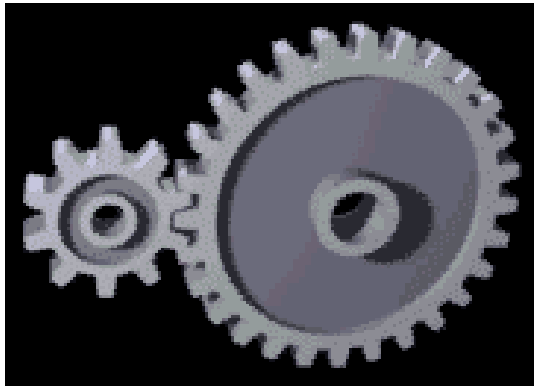
- Advantages of Gear drive:
  1. It is positive drive hence velocity remains constant.
  2. Provisions for changing velocity ratios can be made with the help of gear box
  3. Its efficiency is very high
  4. It can be used even for low speeds
  5. It can transmit high torque values
  6. It is compact in construction

- Dis-advantages of Gear drive:
  1. They are not suitable when shafts are distant
  2. At high speeds noise and vibration happens
  3. It requires lubrication
  4. It has no flexibility

Gears: Types

- Gears can be classified according to the relative positions of shaft axes as follows

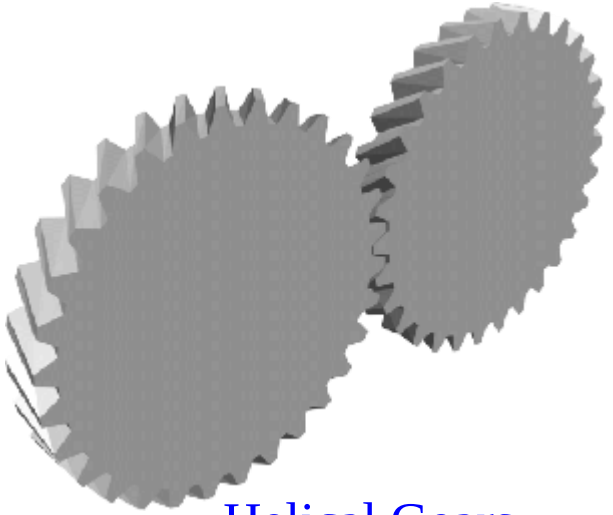
1. Parallel shafts: Spur, Helical, Rack and pinion, Double Helical and Herringbone gears
2. Intersecting shafts: Straight Bevel Gears and Spiral Bevel Gears
3. Skew shafts: Crossed helical gears, Worm Gears, Hypoid gears



Spur Gears

Automobile Gear box

Rack and pinion

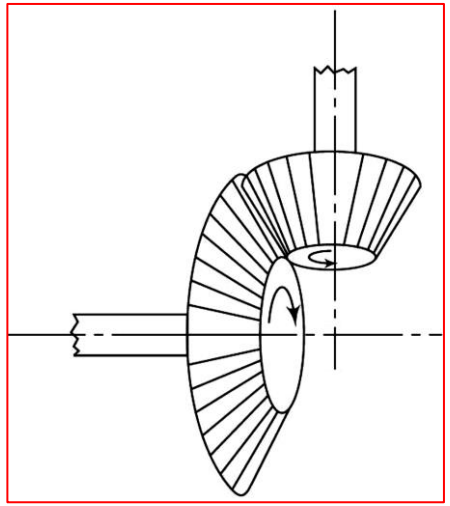


Helical Gears

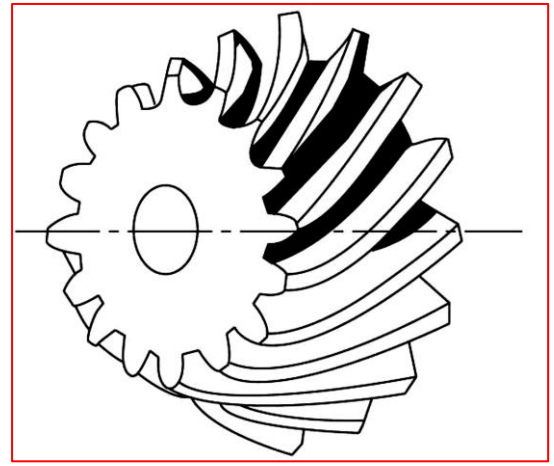
Double Helical Gears

Gears: Intersecting Shafts

- Kinematically, the motion between two intersecting shafts is equivalent to the rolling of two cones, assuming no slipping. These gears are known as bevel gears



1. Straight bevel gears: The teeth formed on the cones are straight, radial to the point of intersection of the shaft axes and vary in cross section throughout their length. Usually used for right angled shafts with low speed.
2. Spiral/helical bevel gears: When the teeth of the bevel gears are inclined at an angle to the face of bevel. They are smoother in action and quitter then straight bevel gears. There exists axial thrust. Application: Differential of automobile.



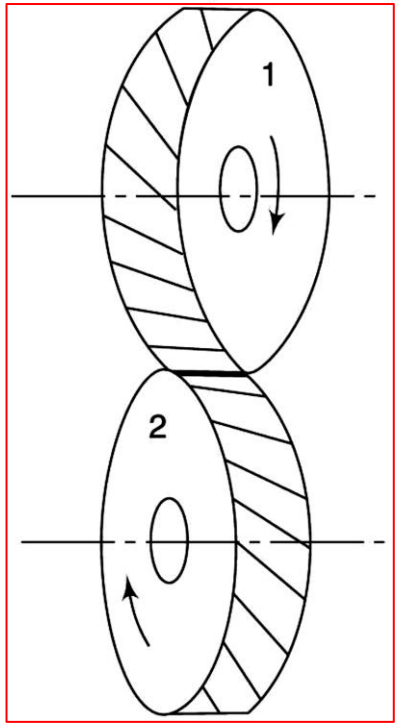
Straight Bevel Gear

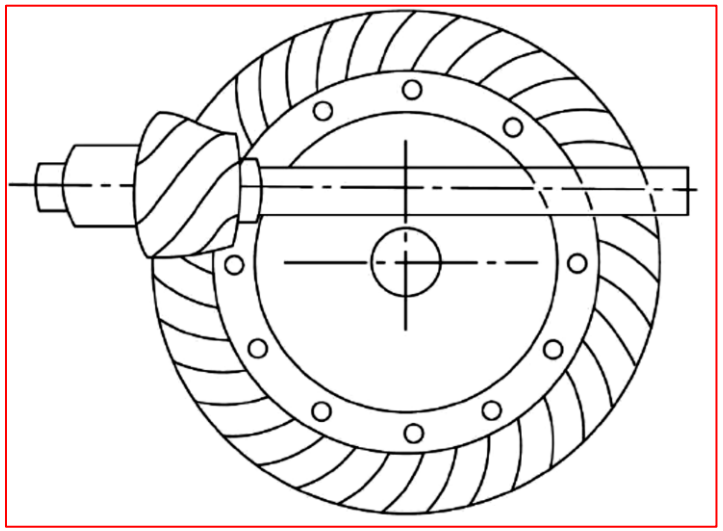
Spiral Bevel Gear

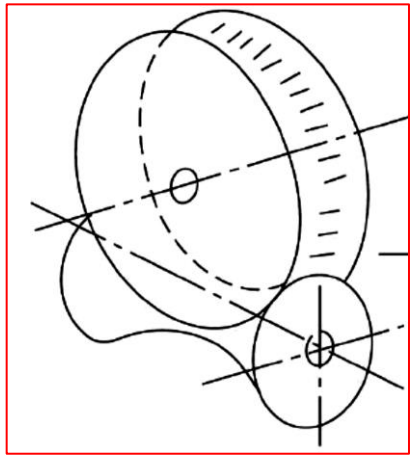
Gears: Skew Shafts

- In case of parallel and intersecting shafts, a uniform rotary motion is possible by pure rolling contact. But in case of skew (non-parallel, non-intersecting) shafts, this is not possible.

1. Crossed Helical Gears: Its use is limited to light loads only. These gears are used to drive feed mechanisms on machine tools, camshafts and oil pumps in small IC engines.
2. Worm Gears: It is a special case of a spiral gears in which larger wheel has a hollow or concave shape.
3. Hypoid Gears: Hypoid gears are approximations of hyperboloids.







Belts, Ropes and Chain Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Utilization

- used for transmission of power from one shaft to another by means of pulleys which rotate at same or different speeds

Factors to be selected in transmission system

- Centre distance between the driver and driven pulley shaft
- Operational speed
- Amount of power to be transmitted

Power transmitted depends on the following factors

- Velocity of belt
- Tension under which the belt is placed on the pulley
- Arc of contact between the belt and the smaller pulley
- Operating conditions under which the belt is used.

Types of Belts Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Light Drives

- These are employed to transmit small powers at belt speeds up to about *10 m/sec*.
- *Applications*: Agricultural machines and small machine tools

Medium Drives

- These are employed to transmit medium power at belt speeds greater than *10 m/sec* but up to *22 m/sec*.
- *Application*: Machine tools

Heavy Drives

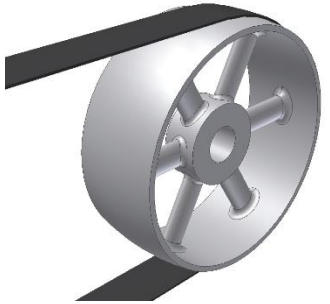
- These are employed to transmit large powers at belt speeds greater than *22 m/sec*.
- *Application*: Compressors and generators

Types of Belts Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

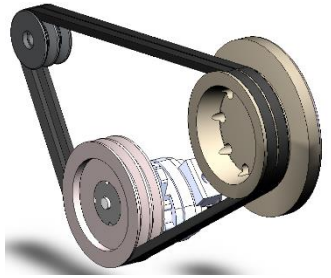
Flat Belt

- The application of flat belts is frequently employed in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another. Flat belts are used when the centre distance between the two pulleys is not more than *8 meters*.
- *Application:* light duty power transmission and high performance conveying



V-Belt

- The V-belt is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another, when the two pulleys are very near to each other.



Circular Belt or Rope

- The circular belt or rope is mostly used in the factories and workshops, where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are more than *8 meters* apart.

Terminology of Flat Belt Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

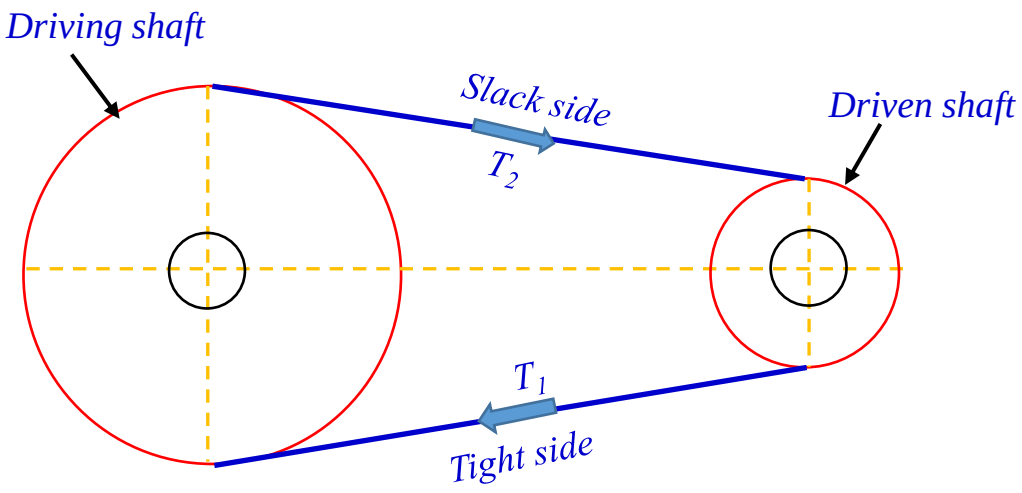
Driver: Driver in a transmission system is the one which drives or supplies power to other mechanical element.

Driven: Driven in a transmission system is the one which follows the driver or receives power from driver.

Tight side: is the portion of the belt in maximum tension. Denoted by T_1 Newton.

Slack side: is the portion of the belt in minimum tension. Denoted by T_2 Newton.

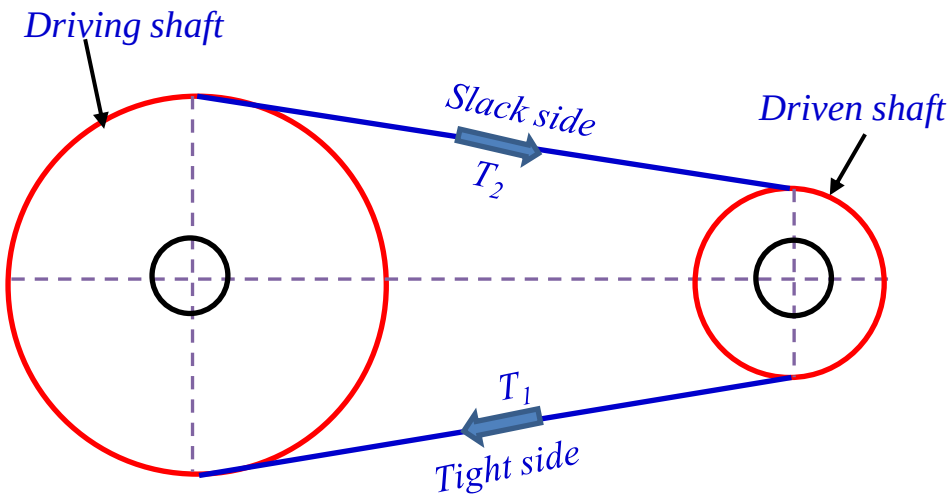
Arc/angle of contact: It is the portion of the belt which is in contact with pulley surface.



Types of Flat Belt Drives

Open Belt Drives

- The driver and driven pulley rotates in same direction.
- Belt is passed over driver and driven.
- Driver pulley pulls the belt from one side and delivers to other side.
- Tension is more in lower side then upper side.

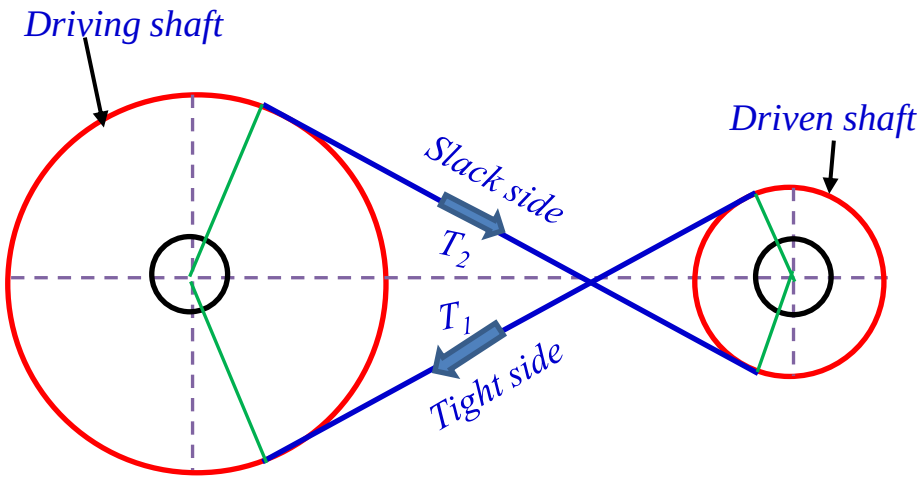


Types of Flat Belt Drives

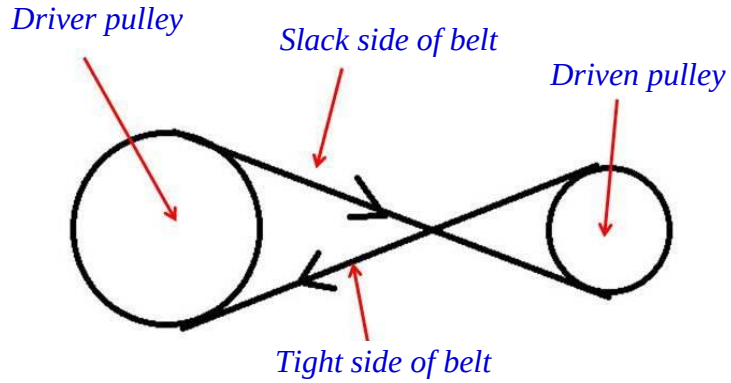
THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Cross Belt Drives

- Both the pulleys rotates in opposite direction.
- It is used when shafts arranged parallel and rotating in the opposite direction.
- Driver pulley pulls the belt from one side and delivers to other side.
- Tension is more in lower side then upper side.
- In case of cross belt drive, at a point where the belt crosses, it rubs against each other and there will be excessive wear and tear.



Cross belt drive

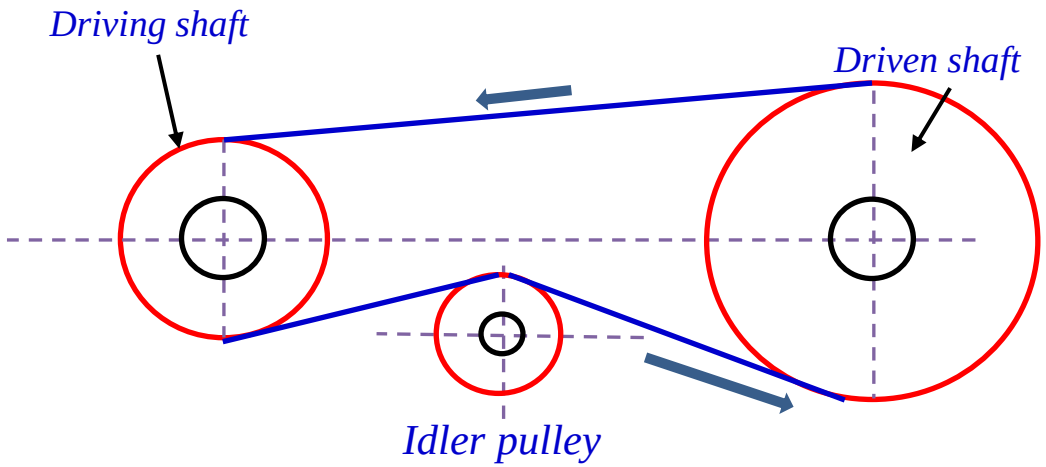


Cross belt drive

Types of Flat Belt Drives

Belt Drive with Idler pulley

- A belt drive with an idler pulley is used with shafts arranged parallel and when an open belt drive cannot be used due to small angle of contact on the smaller pulley.



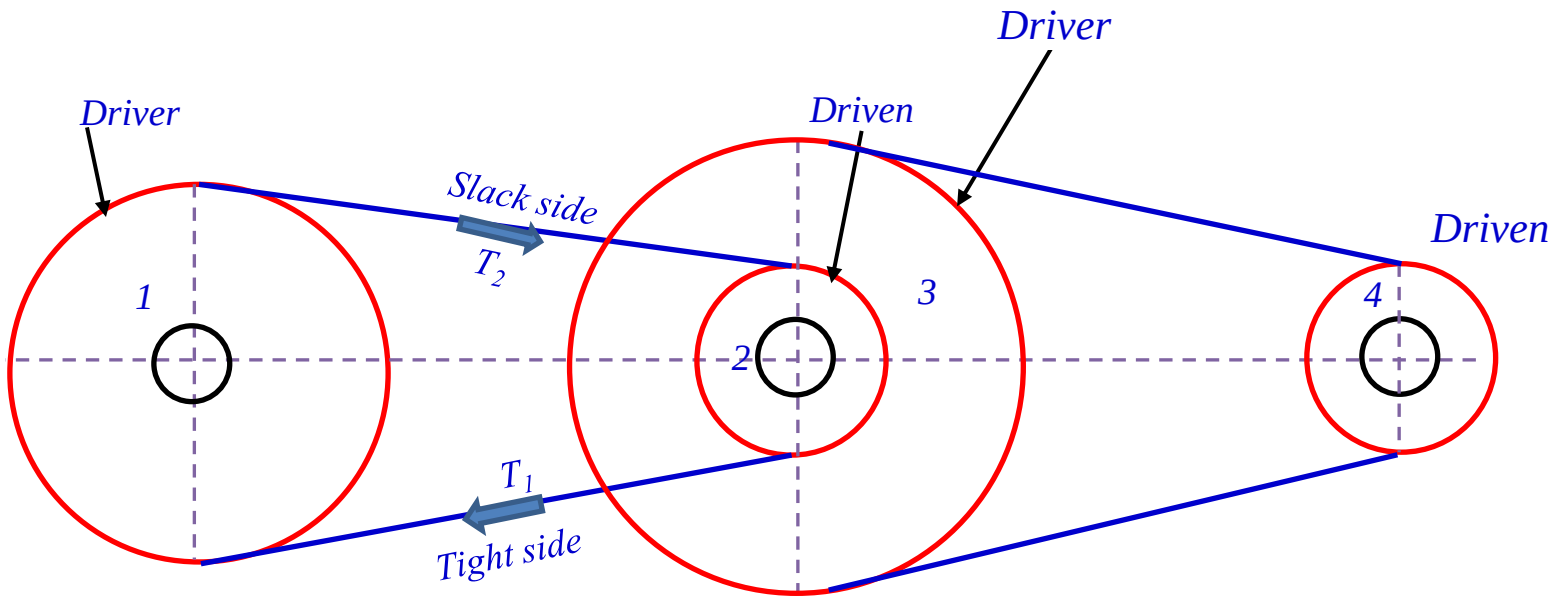
Belt drive with single idler pulley

Types of Flat Belt Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Compound Belt Drive

- A compound belt drive, is used when power is transmitted from one shaft to another through a number of pulleys.

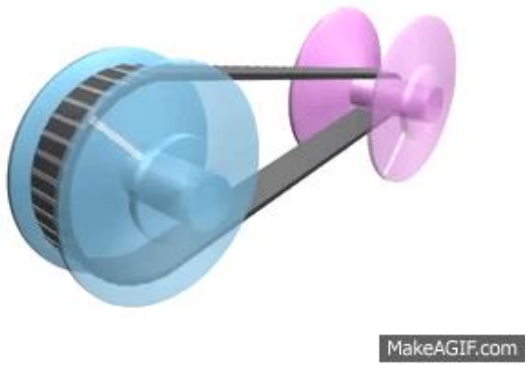


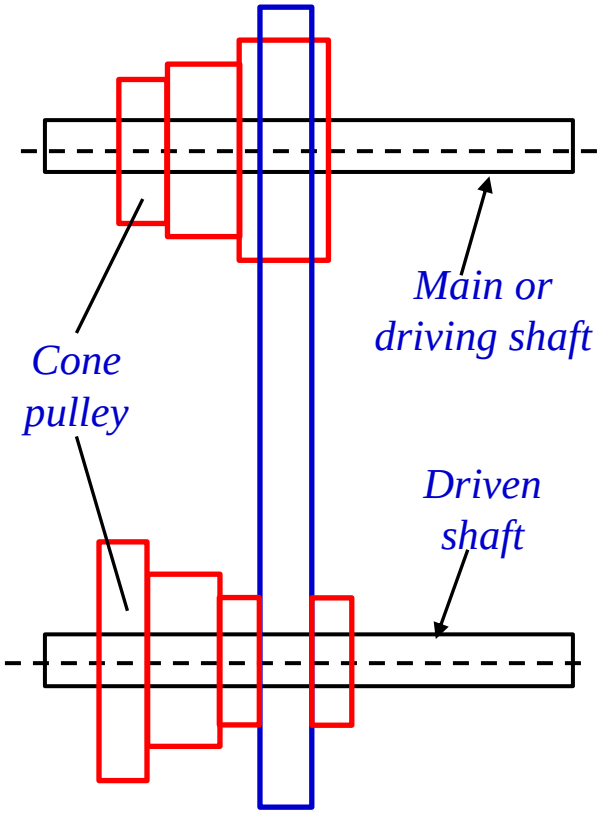
Compound belt drive

Types of Flat Belt Drives

Stepped or Cone Pulley Drive

- A stepped or cone pulley drive is used for varying the speed of the driven shaft although the driving shaft runs at constant speed.
- This is achieved by shifting the belt from one part of the steps to the other of varying diameter.





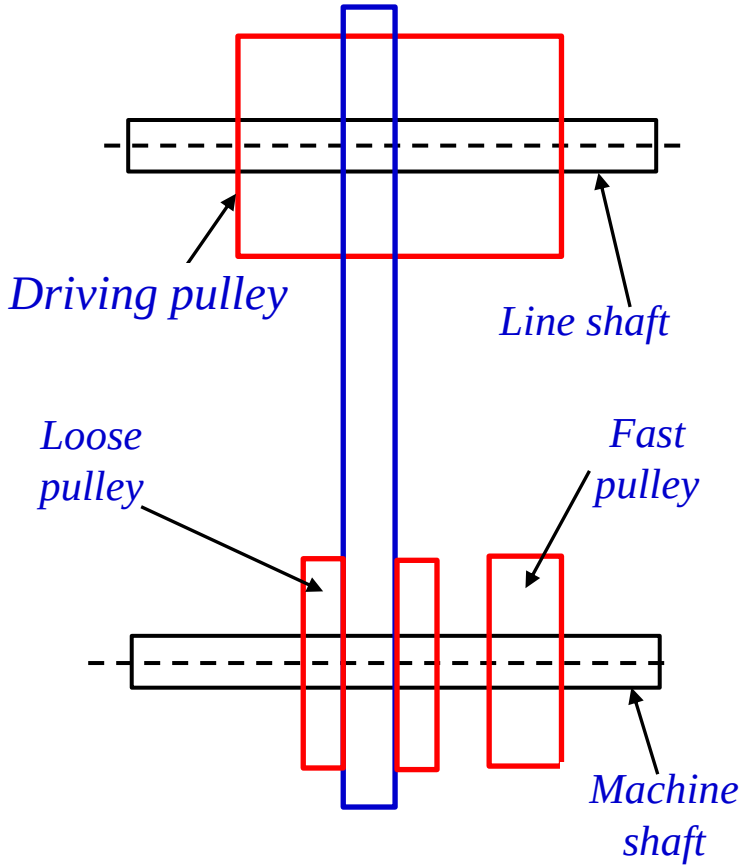
Stepped or cone pulley drive

Types of Flat Belt Drives

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Fast and Loose Pulley Drive

- A fast and loose pulley drive, is used when the driven shaft is to be started or stopped when ever required without interfering with the main shaft.
- A pulley which is keyed to the machine shaft is called ***fast pulley*** and runs at the same speed as that of machine shaft. A loose pulley is one which runs freely over the machine shaft and is incapable of transmitting any power.
- When the driven shaft is required to be stopped, the belt is pushed on to the loose pulley by means of sliding bar having belt forks.



Fast and loose pulley drive

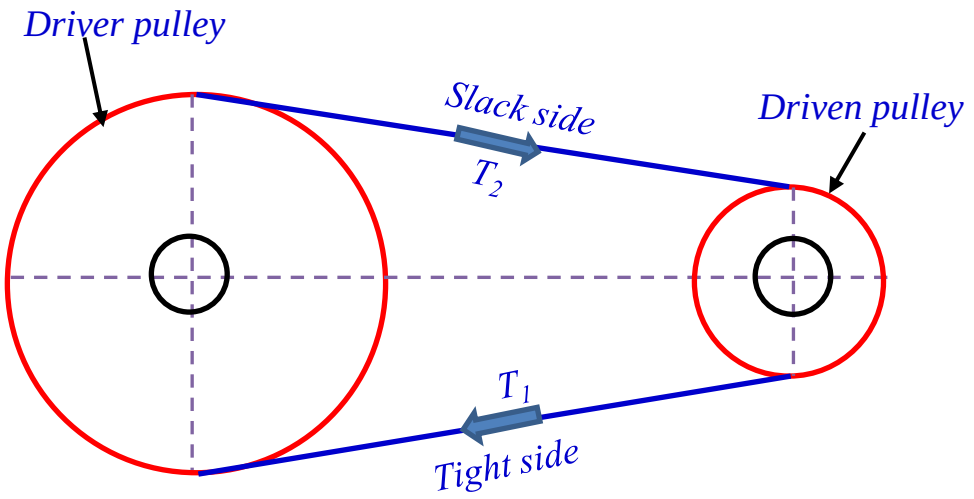
Velocity Ratio of Belt Drive

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Velocity Ratio

It is defined as the ratio between the velocities of the follower and the driver.

d_1 = Diameter of the driver; d_2 = Diameter of the follower; N_1 = Speed of the driver in r.p.m.; N_2 = Speed of the follower in r.p.m.; t = thickness of the belt



Length of the belt passes over the driver in one minute is $\pi d_1 N_1$

Length of the belt passes over the driven in one minute is $\pi d_2 N_2$

Since the length of the belt passes over the driver in one minute is equal to length of belt that passes over the driven

$$\pi d_1 N_1 = \pi d_2 N_2$$

Hence, velocity ratio is $\boxed{\frac{N_2}{N_1} = \frac{d_1}{d_2}}$

When the thickness of the belt is considered, then the velocity ratio is defined as: $\boxed{\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}}$

Velocity Ratio of Compound Belt Drive

Let us assume that pulley 1 is driving the pulley 2. Also, the pulleys 2 and 3 are mounted on the same shaft. Hence, the pulleys 2 and 3 will rotate with the same speed. Therefore the pulley 1 also drives the pulley 3 which, in turn, drives the pulley 4.

d_1 = Diameter of the pulley 1; N_1= Speed of the pulley 1 in *r.p.m.*; d_2, d_3, d_4, and N_2, N_3, N_4 = Corresponding values of diameters and speed for pulleys 2, 3 and 4.

The velocity ratio for pulleys 1 and 2 $\frac{N_2}{N_1} = \frac{d_1}{d_2}$ → 1

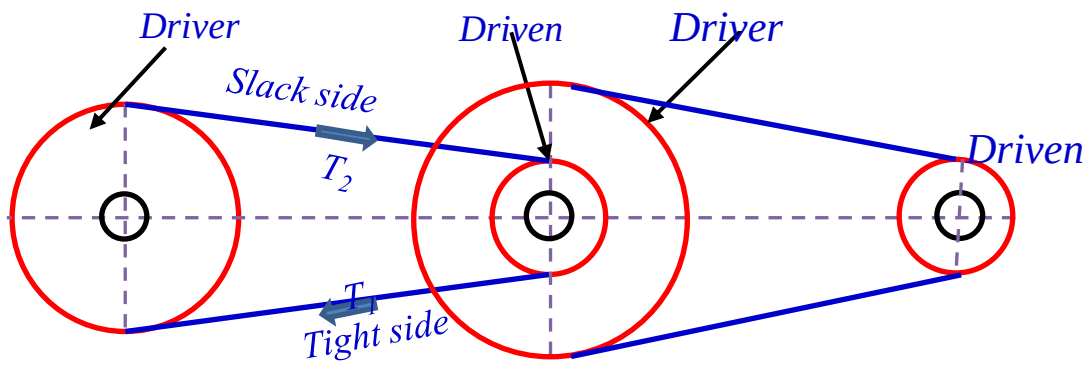
The velocity ratio for pulleys 3 and 4 $\frac{N_4}{N_3} = \frac{d_3}{d_4}$ → 2

Now, multiplying equation (1) and equation (2)

$$\frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} \quad \rightarrow 3$$

Since, the pulleys 2 and 3 are mounted on the same shaft. Therefore, $N_2 = N_3$

$$\frac{N_4}{N_1} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} \quad \rightarrow 4$$



Slip of Belt

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

The motion of belts and shafts supposing a firm frictional grip between the belts and the shafts. But occasionally, the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt with it. This may also cause some forward motion of the belt without carrying the driven pulley with it.

This is called ***slip of the belt*** and is generally expressed as a percentage.

s_1 % - Slip between the driver and the belt; s_2 % - slip between the belt and the follower

Velocity of the belt passing over the driver /second $v = \frac{\pi d_1 N_1}{60} - \frac{\pi d_1 N_1}{60} \times \frac{s_1}{100} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{s_1}{100}\right)$ → 1

Velocity of the belt passing over the follower/second $\frac{\pi d_2 N_2}{60} = v - v \times \frac{s_2}{100} = v\left(1 - \frac{s_2}{100}\right)$ → 2

$$\frac{\pi d_2 N_2}{60} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{s_1}{100}\right)\left(1 - \frac{s_2}{100}\right) = \frac{\pi d_1 N_1}{60}\left(1 - \frac{s_1 + s_2}{100}\right) = \frac{\pi d_1 N_1}{60}\left(1 - \frac{s}{100}\right)$$ → 3

where, $s = s_1 + s_2$

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{s}{100}\right)$$ → 4

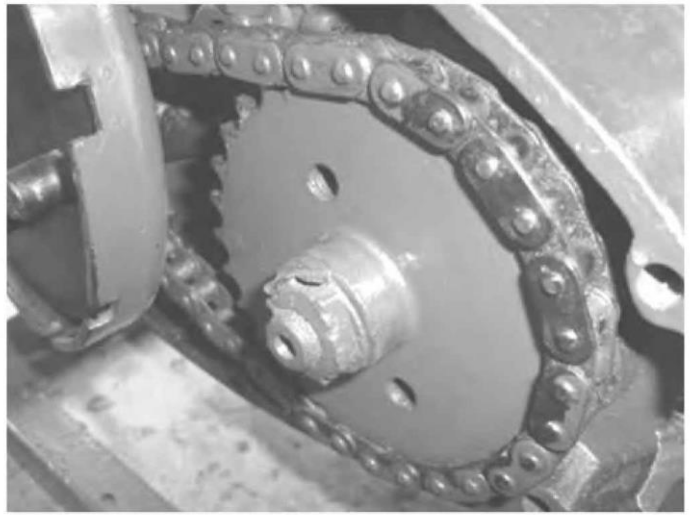
When the thickness *(t)* of the belt is considered, then the velocity ratio is defined as: $\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left(1 - \frac{s}{100}\right)$ → 5

Chains

A chain is regarded in between the gear drive and the belt drive.

Made up of metals, occupy lesser space give constant velocity ratios.

Used for longer centre distances.



Advantages:

- Constant velocity ratio due to no slip, it is positive drive
- No effect of overloads over velocity ratio
- Oil and grease on surfaces does not affect velocity ratios
- Chain occupies less space as made up of metals
- Lesser loads are put on the shafts
- High transmission efficiency due to no slip
- Through one chain only, motion can be transmitted to several shafts

Disadvantages:

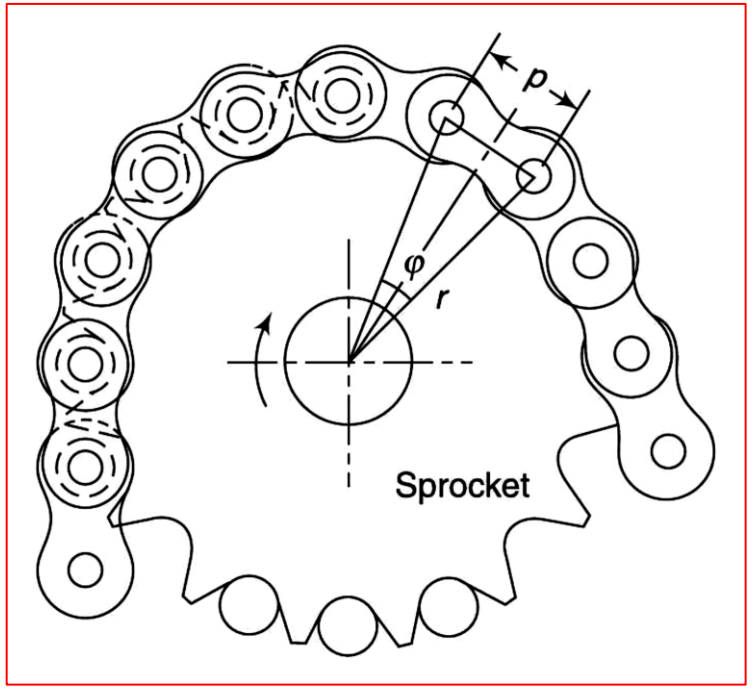
- Heavier as compared to belt
- Gradual stretching and increase in length of chain
- Lubrication of parts is required
- Costlier as compared to belts

Chains contd..

Pitch circle: A circle through the of a wrapped chain round a sprocket.

Observation: A chain is wrapped round the sprocket in the form of a pitch polygon and not in the form of pitch circle.

Let T = Number of teeth on sprocket, ϕ = Angle subtended by chord of the link at the centre of the sprocket, r = radius of pitch circle



Then

$$p = 2r\sin\frac{\phi}{2} = 2r\sin\frac{1}{2}\left(\frac{360^0}{T}\right) = 2r\sin\frac{180^0}{T}$$

or

$$r = \frac{p}{2\sin\frac{180^0}{T}} = \frac{p}{2}\operatorname{cosec}\frac{180^0}{T} \quad \rightarrow (1)$$

Chains Length

Let R and r = Radii of pitch circles for two sprockets, T and t = Number of teeth for two sprockets, L = Length of chain, C = Centre distance between sprockets = kp, p = Pitch of the train

Length for corresponding belt is given by

$$L = \pi(R+r) + \frac{(R-r)^2}{C} + 2C$$

The first term in the equation is half the sum of the circumference of the pitch circles for the belt.

In case of a chain, it will be $(pT + pt)/2$

Replacing R and r in the second term by

$$R = \frac{p}{2}\operatorname{cosec}\frac{180^o}{T} \quad \text{and} \quad r = \frac{p}{2}\operatorname{cosec}\frac{180^o}{t}$$

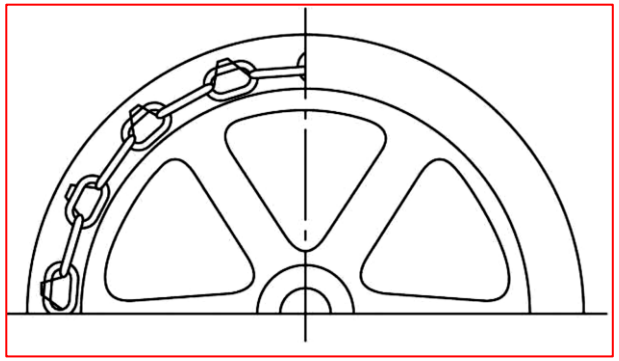
$$L = \frac{pT+pt}{2} + \frac{\left(\frac{p}{2}\operatorname{cosec}\frac{180^\circ}{T} - \frac{p}{2}\operatorname{cosec}\frac{180^\circ}{t}\right)^2}{kp} + 2kp$$

$$L = p\left[\frac{T+t}{2} + \frac{\left(\operatorname{cosec}\frac{180^\circ}{T} - \operatorname{cosec}\frac{180^\circ}{t}\right)^2}{4k} + 2k\right] \quad (2)$$

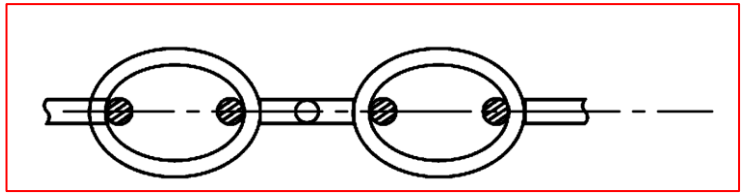
Classification of Chains

Hoisting Chains:

- Hoisting chains include *oval link* or *stud-link* chains
- The *oval link* chain is also known as coil chain
- Such chains are used for lower speeds only



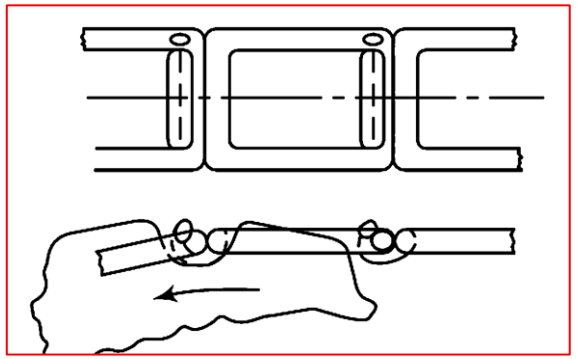
Oval Chain



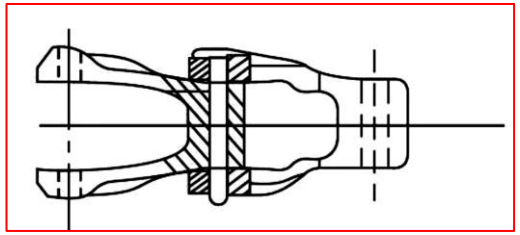
Stud Chain

Conveyor Chains:

- Conveyor chains are of detachable or *hook joint type* or of the *closed end pintle type*
- Such chains are used for low speed agricultural machinery



Hook joint type

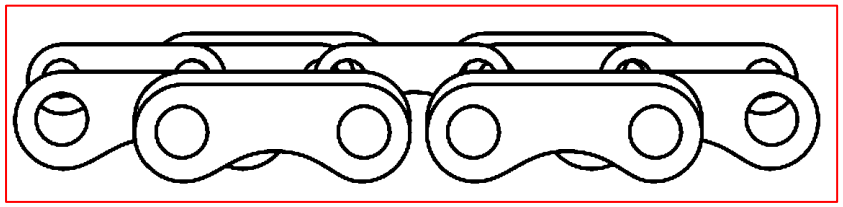


Closed end pintle type

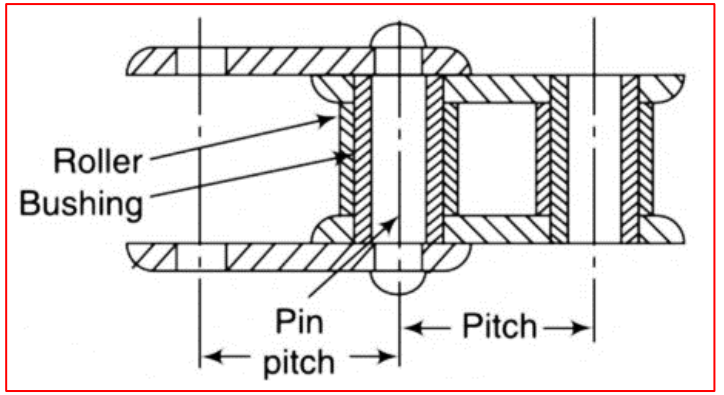
Classification of Chains

Power transmission Chains:

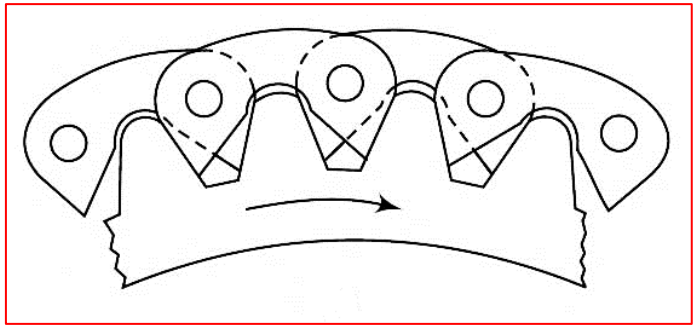
- These chains are made up of steel in which the wearing parts are hardened.
- Accurately machined and run on carefully designed sprockets



Block Chain



Roller chain



Silent chain or inverted tooth chain

Ropes

- The rope drives are widely used where a large amount of power is to be transmitted, from one pulley to another, over a considerable distance
- It may be noted that frictional grip in case of rope drives is more than that in V- belt drive
- If large amounts of power are to be transmitted by the flat belt, then it would result in excessive belt cross-section
- In many spinning mills, the line shaft on each floor is driven by ropes passing directly from the main engine pulley on the ground floor
- The rope drives use the following two types of ropes : Fibre ropes, and Wire ropes
- The fibre ropes operate successfully when the pulleys are about 60 metres apart, while the wire ropes are used when the pulleys are up to 150 metres apart

Fibre Ropes

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

- Made up from fibrous materials such as hemp (fibres of cannabis plant), manila (Philippine plant) and cotton
- Since the hemp and manila fibres are rough, therefore the ropes made from these fibres are not very flexible and possesses poor mechanical properties
- The hemp ropes have less strength as compared to manila ropes
- When the hemp and manila ropes are bent over the sheave (or pulley), there is some sliding of fibres, causing the rope to wear internally
- In order to minimise this defect, the rope fibres are lubricated with a tar, tallow (animal fat) or graphite
- The hemp ropes are suitable only for hand operated hoisting machinery and as tie ropes for lifting tackle, hooks etc
- The cotton ropes are very soft, smooth and lubrication is not necessary
- It may be noted that manila ropes are more durable and stronger than cotton ropes, but the cotton ropes are costlier than manila ropes.

Advantages of Fibre Ropes

- They give smooth, steady and quiet service
- They are little affected by out door conditions.
- The shafts may be out of strict alignment.
- The power may be taken off in any direction and in fractional parts of the whole amount.
- They give high mechanical efficiency.

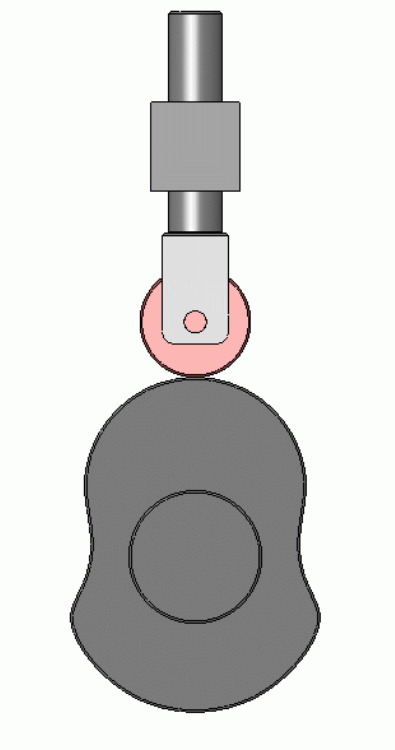
- Note: The diameter of manila and cotton ropes usually ranges from 38 mm to 50 mm. The size of the rope is usually designated by its circumference or ‘girth’

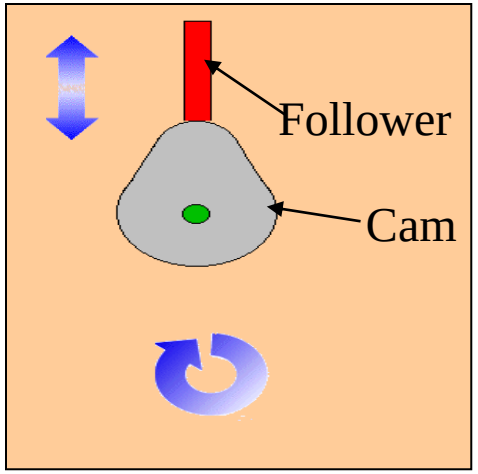
Wire Ropes

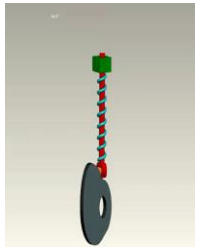
- When a large amount of power is to be transmitted over long distances from one pulley to another (i.e. when the pulleys are upto 150 metres apart), then wire ropes are used
- Used in elevators, mine hoists, cranes, conveyors, hauling devices and suspension bridges
- The wire ropes run on grooved pulleys but they rest on the bottom of the grooves and are not wedged between the sides of the grooves

- Advantages over cotton ropes:
  1. These are lighter in weight
  2. These offer silent operation
  3. These can withstand shock loads
  4. These are more reliable
  5. They do not fail suddenly
  6. These are more durable
  7. The efficiency is high
  8. The cost is low.

Cam and Follower

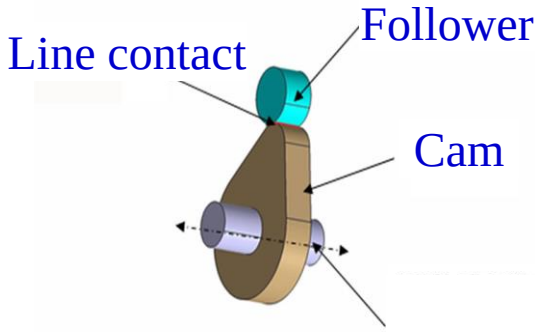






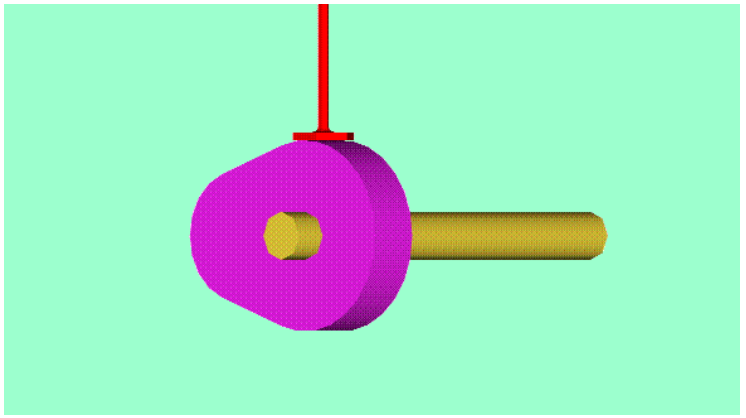
Introduction

- A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower
- The cam and the follower have a line contact and constitute a higher pair



- Applications:

1. Operating the inlet and exhaust valves of internal combustion engines;
2. paper cutting machines;
3. spinning and weaving textile machineries;
4. feed mechanism of automatic lathes;

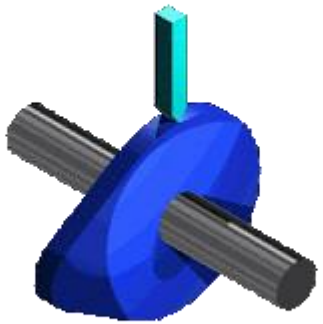


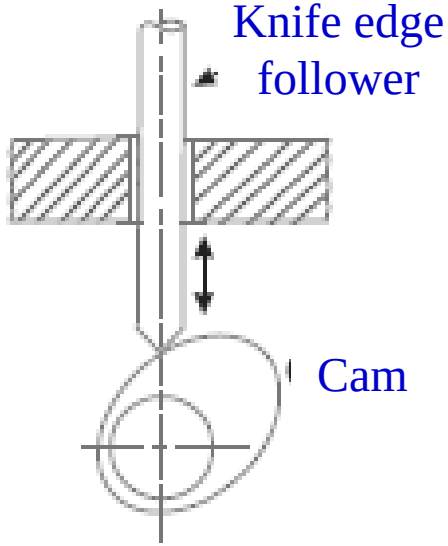
Types of Followers

According to surface in contact

Knife Edge Follower

- When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower.
- Knife edge follower is used very less in practice because the small area of contact surfaces result in large wear.



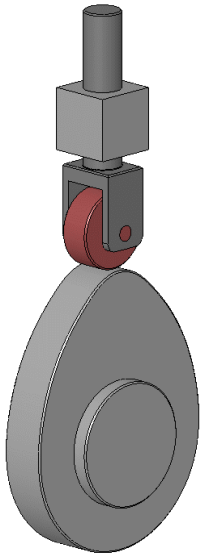


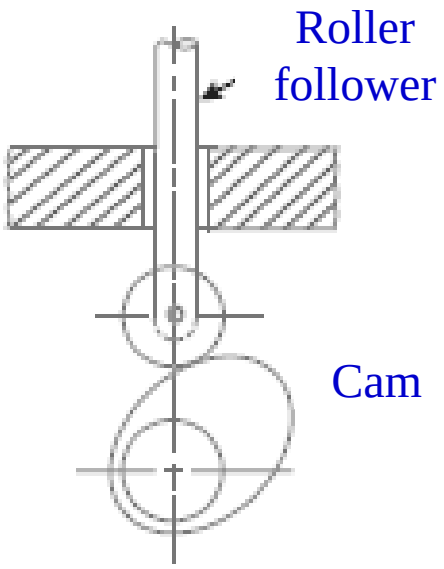
Types of Followers

According to surface in contact

Roller Follower

- When the contacting end of the follower is a roller, it is called a roller Follower.
- Since the rolling motion takes place between the contacting surfaces (i.e. the roller and the cam), therefore the rate of wear is greatly reduced.
- Application: Oil, Gas and Aircraft engine



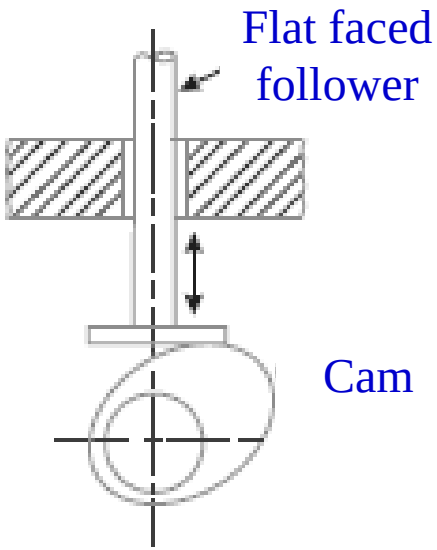


Types of Followers

According to surface in contact

Flat-face follower:

- When the contacting end of the follower is a perfectly flat face, it is called a flat-faced follower.
- Application: In automobile engine

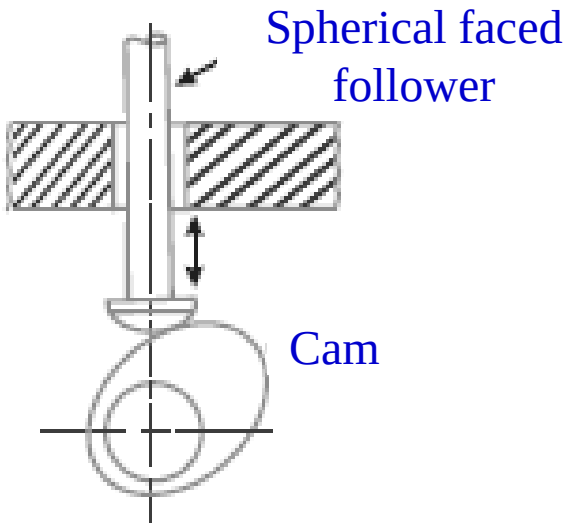


Types of Followers

According to surface in contact

Spherical Faced Follower

- When the contacting end of the follower is of spherical shape, it is called a spherical faced follower. The flat end of the follower is machined to a spherical shape.
- Application: in automobile engine

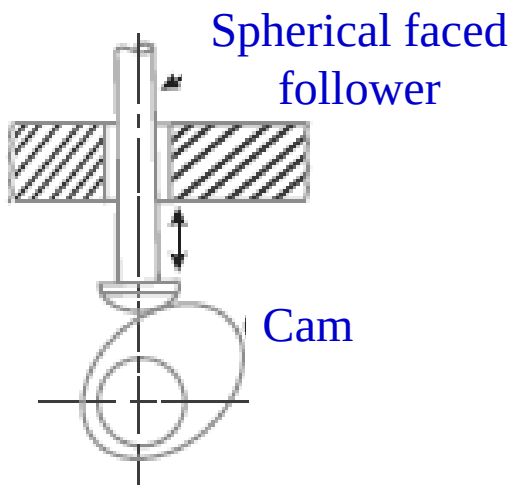


Types of Followers

According to the motion of follower:

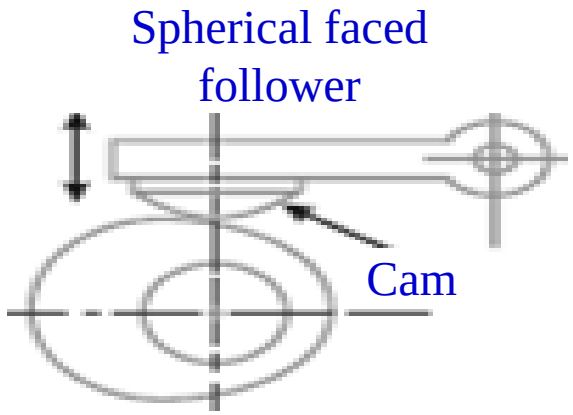
Reciprocating or Translating Follower

- When the follower reciprocates in guides as the cam rotates uniformly.
- Example: knife edge follower, roller follower, flat faced follower, spherical faced follower



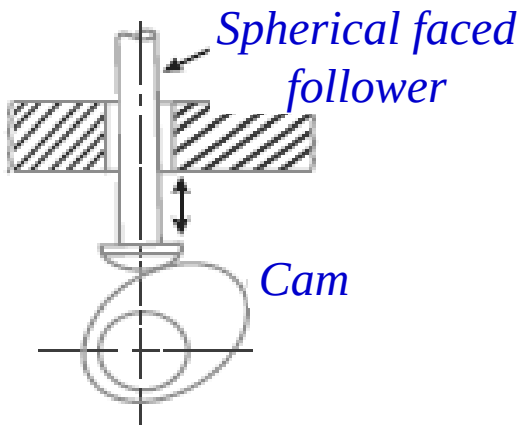
Oscillating or Rotating Follower

- When the uniform rotary motion of the cam is converted into oscillatory motion of the follower, it is called oscillating or rotating follower



Types of Followers

According to the path of motion of the follower:

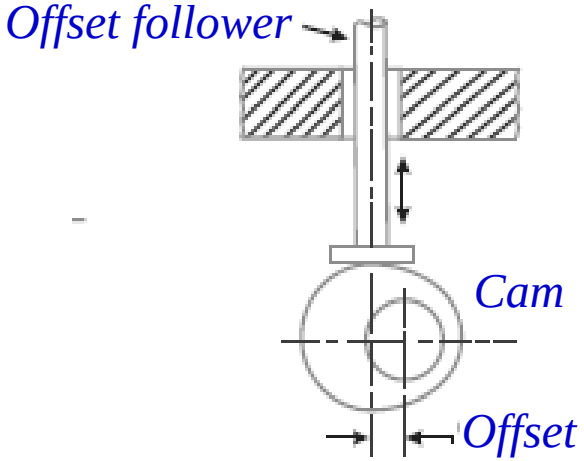


Radial Follower

- When the motion of follower is along an axis passing through the centre of the cam, it is known as radial follower.

Offset Follower

- When the motion of follower is along an axis away from the axis of the cam centre, it is called an offset follower.



Terminology used in Cam

Base Circle

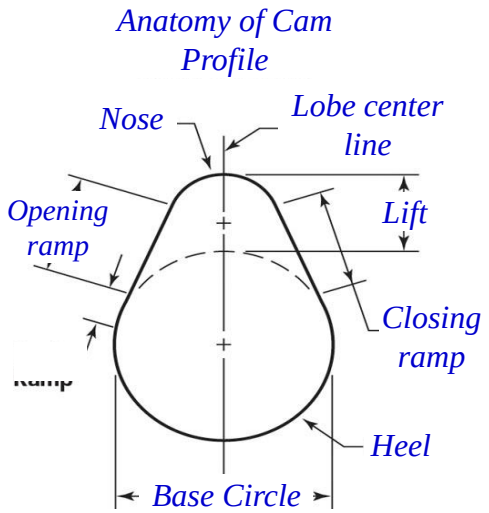
- It is the smallest circle that can be drawn to the cam profile.

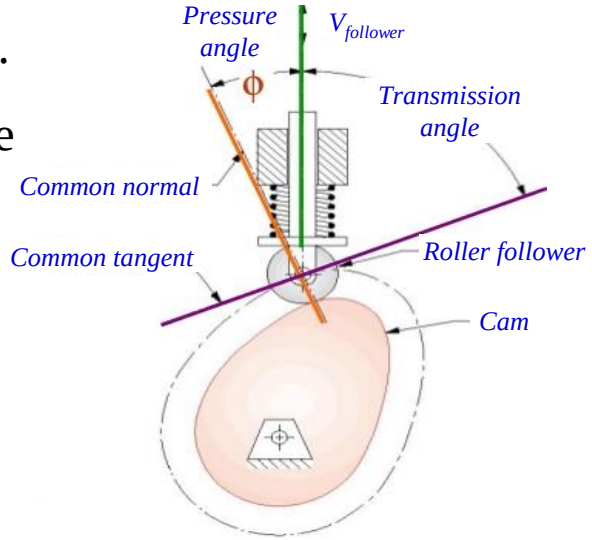
Trace Point

- 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.

Pressure angle

- It is the angle between the direction of the follower motion and a normal to the pitch curve.
- For translating follower angle is less than 30˚





Terminology used in Cam

Pitch Point

- It is a point on the pitch curve having the maximum pressure angle

Pitch Circle

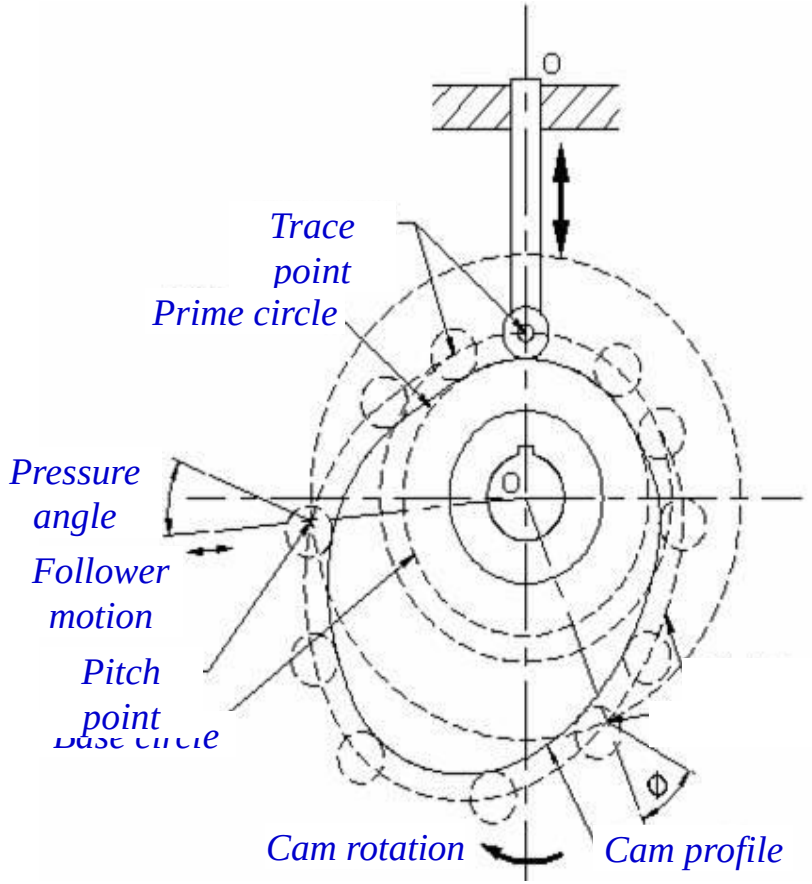
- It is a circle drawn from the centre of the cam through the pitch points

Pitch Curve

- It is the curve generated by the trace point as the follower moves relative to the cam

Lift or Stroke

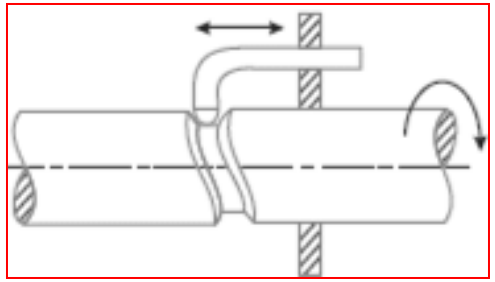
- It is the maximum travel of the follower from its lowest position to the topmost position



Classification of Cam

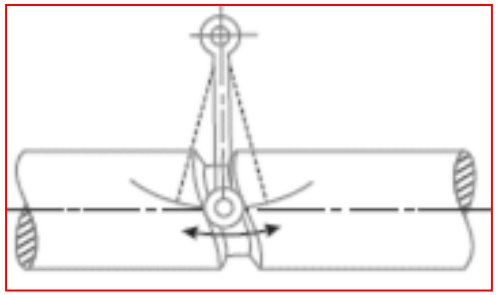
Radial or Disc Cam

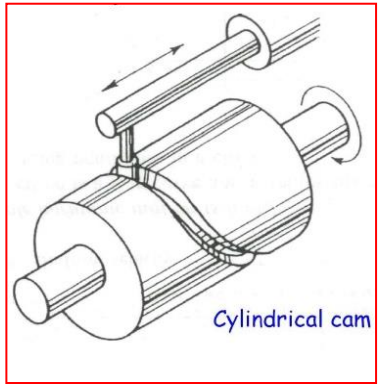
- In radial cams, the follower reciprocates or oscillates in a direction perpendicular to cam axis

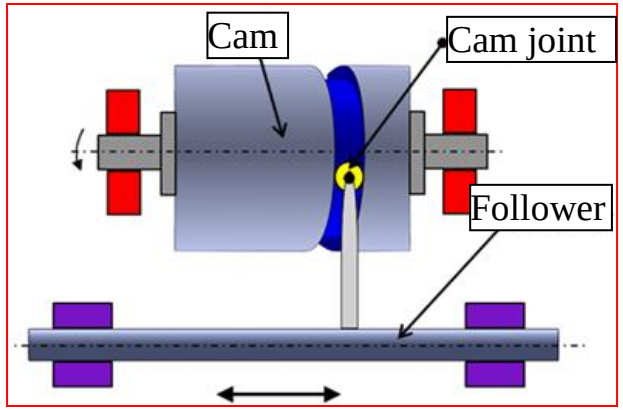


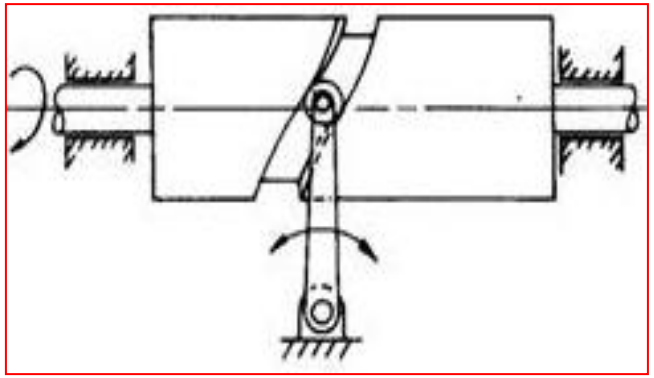
Cylindrical Cam

- In cylindrical cams, the follower reciprocates or oscillates in a direction parallel to the cam axis.
- The follower rides in a groove at its cylindrical surface.
- A cylindrical grooved cam with a reciprocating and an oscillating follower









Thank You

Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

Dr Appaso M Gadade

Assistant Professor, MED

Email: appaso.gadade@thapar.edu

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)