Theory of Machines

Theory of Machines may be defined as that branch of engineering science which deals with the study of relative motion between various elements of a machine and the forces which act on them. In kinematics, a mechanism is a mean of transmitting, controlling, or constraining relative movement.

Link:

It is the element in a machine that forms a *joint*.

Pair:

It is the combination of the *two links*.

Kinematic Pair:

It is the relative motion between the pairs is said to be *constrained*, then it is called the Kinematic Pair.

There are different types of **Kinematic Pairs**. They are classified as

- According to Type of **Motion** Kinematics are *Sliding Pair, Turning Pair, Rolling Pair, Screw Pair*, and *Spherical Pair*.
- According to Type of **Contact** Kinematics are *Lower Pair and Higher Pair*.
- According to Type of **Closure** Kinematics are *Self Closed Pair and Force-Closed Pair*.

Kinematic Chain:

It is the combination of the *Kinematic Pairs*, and the *relative motion* between them should be completely constrained.

Example: Crankshaft with bearings, Connecting rod with a crank, etc.

Inversions:

It is defined as the method of obtaining different types of mechanisms by fixing the links ends.

Types of Kinematic Chains:

- **Single Slider Crank Chain:**

The Inversion of this type of chain is ***Pendulum pump*** or ***Bull Engine***, ***Whit–worth quick return motion***, ***Rotary internal combustion engine*** or ***Gnome engine***, ***Crank & Slotted lever quick* return mechanism** and ***Oscillating Cylinder engine***.

- **Four Bar or Quadric Cycle Chain:**

The Inversion of this type of chain is the **Crank and *Lever mechanism*, *Double crank***, or ***Coupling rod*** of *Locomotive* and ***Watt's indicator*** **mechanism**.

- **Double Slider Crank chain:**

The Inversion of this type of chain is *Elliptical Trammels*, *Scotch yoke* mechanism, and *Oldham*'s *Coupling* comes under this Kinematic chain.

Mechanism:

If a link is fixed at one end and the other *links* in the *Kinematic Chain* can Transform or Transmit the motion, such a process is called the **Mechanism**.

Instantaneous Centre:

It is defined as the center which will be changed from one instant to another. The line which is drawn through an *Instantaneous center* and perpendicular to the plane of motion is called the **Instantaneous axis**.

Hooke's Joint:

It is the joint that is used to connect two *shafts* at a *small angle*. It is also called the **Universal Joint**. We can see those joints frequently in connecting the *Propeller shaft* of an *Automobile*.

Classification of kinematic pairs: (a) According to nature of relative motion: Sliding Pair: If one link of a pair has a sliding motion relative to other, then the pair is¬ called as sliding pair. Example: Rectangular rod in a rectangular hole. Turning Pair / Revolving Pair: If one link of a pair has a revolving motion relative to the¬ other, then the pair is called as turning pair. Example: Circular shaft revolving in a bearing. Rolling Pair: If one link of a pair has a rolling motion relative to the other, then the pair is¬ called as rolling pair. Example: Ball & roller bearings, and a rolling wheel on a flat surface.

Screw Pair / Helical Pair: If two mating links of a pair have a turning as well as sliding motion between them, then the pair is called as screw pair. Example: Lead Screw & the Nut of a Lathe. Spherical Pair: When one link in the form of a sphere turns inside a fixed link, then the¬ obtained pair is called as spherical pair. Example: Ball & Socket Joint. (b) According to nature of contact: Lower Pair: A pair of links having surface or area contacts between the members is¬ called as lower pair. Example: All pairs of Slider crank mechanism, nut turning on a screw, and shaft rotating in bearing. Higher Pair: A pair of links having a point or line contact between the members is called as¬ higher pair. Example: Wheel rolling on a surface, cam & follower, and tooth gears. (c) According to the nature of mechanical constraint or type of closure

Closed pair / Self closed pair: When the elements of a pair are held together mechanically, then the pair is called as closed pair Example: All Lower pairs & some higher pairs. Unclosed /

forced closed pairs: When two links of a pair are in contact either due to force¬ of gravity or some spring action, then the pair is called as unclosed pair. Example: Cam & Follower pairs.

Types of joints: Binary Joint: If two links are joined at the same connection, it is called a binary joint.¬ Example: A joint with two binary joints named B as shown in the below figure. Ternary Joint: If three links are joined at a connection, it is known as a ternary joint.¬ Example: Ternary links are named T as shown in the below figure. Quaternary Joint: If four links are joined at a connection, it is known as quaternary¬ joint.

Distinguish between 'Machine' and 'Mechanism'.

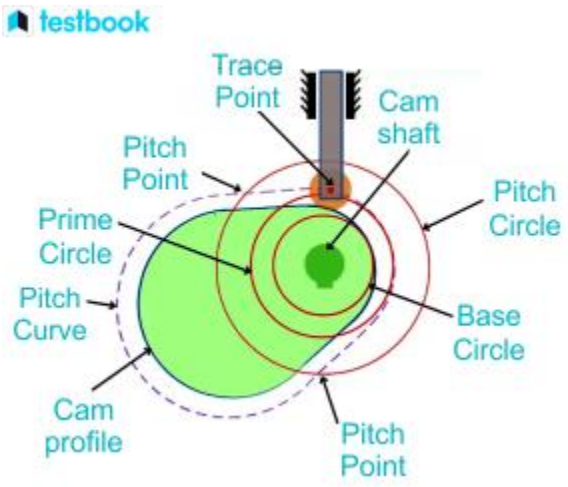
Machine: It is a mechanism which receives energy and transforms it into some usefulwork.¬ A machine transmits power¬ & performs some particular type of work. All machines are mechanisms.¬ Mechanism: When one of the links of a kinematic chain is fixed, then it is known as mechanism.¬ Thus mechanism is a constrained chain. A mechanism transmits¬ & modifies a motion. All mechanisms are not machines.¬ Q.7) Distinguish between Structure and Machine Ans) Machine: It is a mechanism or a combination of mechanisms.¬ The parts of a machine move relative to one another.¬ A machine transforms the available energy into some useful work.¬ The links of a machine may transmit both power and motion.¬ Structure: It is an assembly of a number of resistant bodies having no relative motion between them.¬ The members of a structure do not move relative to one another.¬ A structure does not move relative to one another.¬ The members of a structure transmit forces only.¬

What is the cam and follower?

A cam and follower mechanism is a profiled shape mounted on a shaft that causes a lever or follower to move. Cams are used to convert rotary to linear (reciprocating) motion. As the cam rotates, the follower rises and falls in a process known as reciprocating motion.

Cam and Follower Nomenclature

Now let's learn about Cam and Follower terminology. Refer to the figure below to understand the terminology better.



Trace Point

It is an imaginary point that is used to trace the profile of a cam. It is at the centre of a roller follower. Since the roller centre serves as the trace point, the movement of the follower will be explained in terms of how this roller centre moves.

If the follower has a flat face, the tracepoint is n the area of the follower's face that makes touch with the cam surface when it is in one of its extreme positions. Typically, the extreme position is when the follower is most closely situated to the cam centre.

Base Circle

The base circle is the smallest circle that can be created using the cam centre as its centre and touching the cam profile.

Pitch Curve

Consider kinematic reversal when defining the pitch curve. This four-link system has a fixed link, a cam, a roller, and a follower in the kinematic inversion. In this four-link mechanism, this link is fixed, but if we create a kinematic inversion holding cam fixed, it will move in the kinematic chain. A curve adjacent to the cam profile will be produced by the location of the roller's centre. After kinematic inversion with the cam set, this is where the tracepoint or roller centre is located.

Prime Circle

Prime circle is the smallest circle that can be drawn from the cam centre and which is tangential to the pitch curve. This circle is perpendicular to the pitch curve and has its centre at the camshaft axis.

Cam Profile

The surface of a cam where the follower joins is known as the cam profile.

Pressure Angle

A pressure angle is created between the normal to pitch curve and the line of motion of the follower.

Now, we will learn about different types of cam and followers

Types of Cam

There are different types of cam for different needs. Here is a list of different types of cam.

Disc or Plate Cam

The follower moves radially from the cam's rotational centre in the disc cam style of the cam. Due to its straightforward layout and size, which allow for installation in far-off places, this cam is very well-liked. Disc or plate cams are used in IC engines and machine tools.

Cylindrical Cam

The circumferential outlines are cut on the cylinder's surfaces while the cylinder is rotated about its axis in the cylindrical cam. They also come in two varieties. In the first variety, a groove with a positive oscillating motion is cut into the surface of the cam and roller. The other has a cylinder as the working surface. The spring-loaded follower in this kind of cam corresponds to a cylinder rotating around a parallel plane.

Translating Cam

A cam that can move in a horizontal plane is referred to as a translating cam. The follower is also attached, in which the motion is interrupted with the aid of a spring. Occasionally, groove cams are used to accomplish follower motion without the need for a spring.

Radial Cam

One of the most popular kinds of "cams" is the radial cam. A rotating plate or disc known as a "radial cam" has an outer circumference that is shaped to generate the necessary movement (typically linear) to a "follower" that is pressed up against it.

Wedge Cam

If the cam has linear motion, we call it a wedge cam. The four-link wedge cam system consists of two fixed links and one link that resembles a cam wedge. Depending on the shape of this

wedge, the follower will vacillate in the vertical direction alongside this prismatic pair or this guide as this cam oscillates in the horizontal direction.

Types of Followers

There are different types of followers for different needs. Here is a list of different types of followers.

Linear Follower

We refer to a follower as a linear follower if it moves linearly. Now let's talk about a translating follower, or what we refer to as radial translating since the axis of that prismatic pair goes through the cam centre. When the follower axis crosses the camshaft's centre, the follower is referred to as tangentially translating. It is referred to as an offset translation follower if there is a slight offset, which indicates that the follower's translation axis does not travel through the centre of the cam.

Oscillating Follower

The cam continues to spin as before, but because of the shape of the cam, the follower oscillates instead, and this is where the follower is hinged. This is why it is known as an oscillating follower.

Knife-edge Follower

We refer to a follower as a knife-edge follower if its only connection to the sensor is a knife-edge. Due to the extremely high wear rate, a knife-edge follower is never used, so the knife-edge is only notional. Too much contact tension will result.

Roller Follower

A roller follower is a follower that is hinged to a roller and in touch with a roller cam. The follower that is attached here oscillates, and the cam itself rotates. When a lot of electricity needs to be transmitted, like in stationary IC engines, it is used.

The roller needs a lot of areas if a larger roller can't be used because the pin needs to be big enough to transmit force between the cam and the follower, and the roller needs to be at least twice as big as the pin.

Flat-Face Follower

A flat-face follower is one that has a follower surface that is flat and in touch with the cam. Instead of being flat, the trailing surface could also be curved. It is known as a curved face because the cam rotates and the follower that sits here oscillates. If there isn't much room available, as there was in the case of cars, we can use a flat-face follower.

Advantages and Disadvantages of Cam and Follower

Here are some advantages and disadvantages of cam and follower:

Advantages of Cam and Follower

Benefits of Cam and Follower are:

- The device that changes rotary motion into reciprocating motion is straightforward.
- Any desired motion of the follower can be accomplished with proper design.
- The system can withstand strong shocks and vibrations.
- They are reliable and adaptable.

Disadvantages of Cam and Follower

Cons of Cam and Follower are:

- There is side thrust and friction resistance operating as the follower passes over the cam. This

- results in the cam experiencing frequent wear and tear.
- More room is needed for the cam and follower arrangement.
- The expense of manufacturing is high, and accuracy is required.

Cam and Follower Applications

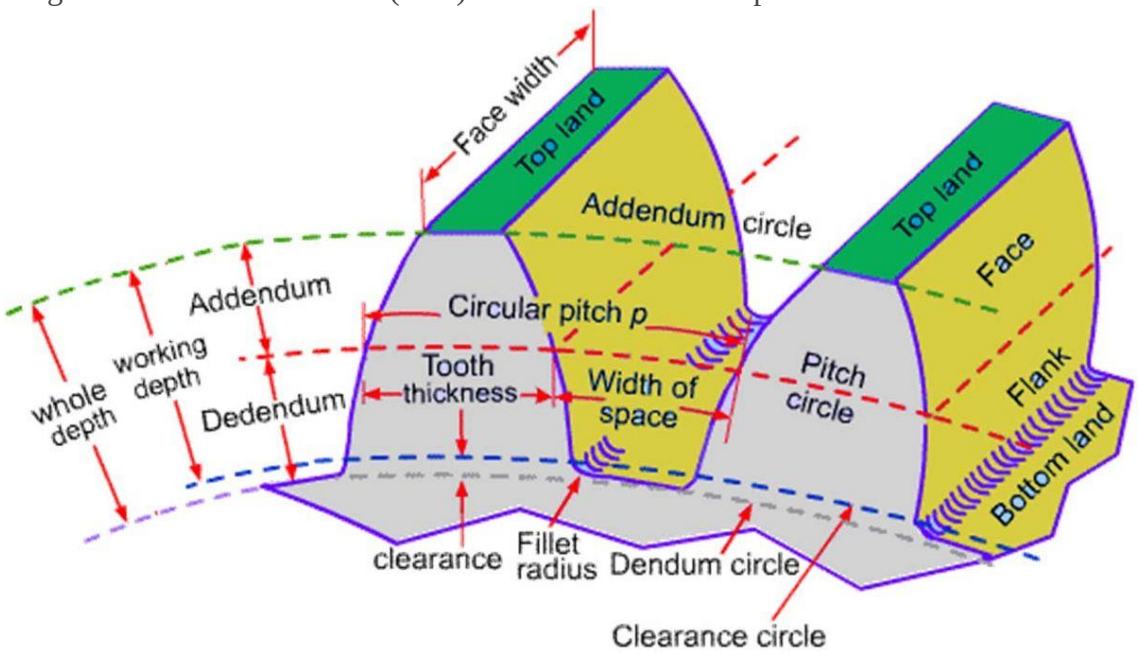
There are lots of applications of cam and follower as mentioned below:

- In hanging clocks, Cam and Follower are utilised.
- They are utilised In automatic lathe tools in the feed mechanism.
- Screw equipment includes the Cam and Follower.
- Cam and Follower are gear-cutting machinery.
- This device in the printing equipment aids in screen printing. Both the push and the draw assist in positioning objects for printing and printing itself.
- These are the primary components that make up the hydraulic system.
- Even in machinery designed for the textile industry, the cam and follower mechanism enables the sewing of the fabric with just one press and pull.
- In that instance, fluid pressure affects the mechanism.
- Various components that are automatically in motion are used in automated equipment such as cams and followers.

A gear or gearwheel is a rotating machine part typically used to transmit rotational motion and/or torque by means of a series of teeth that engage with compatible teeth of

another gear or other part. The teeth can be integral saliences or cavities machined on the part, or separate pegs inserted into it.

Basic Gear Terminology Face Width is the length of the teeth in the axial direction. Outside Diameter (O.D.) is the diameter of a circle around the outer surface, or tops of the gear teeth. Pitch Diameter (P.D.) is the diameter of the pitch circle.



Pitch Circle Diameter (PCD) – Gear Terminology

The pitch circle diameter (PCD) is the diameter of the pitch circle. A gear is a friction wheel with teeth, and the pitch circle corresponds to the outer circumference of the friction wheel and is the reference circle for determining the pitch of the gear teeth.

Addendum is the height of the tooth above the pitch circle. Dedendum is the depth of the tooth below the pitch circle. Whole Depth is the total length of a tooth space equal to the sum of the addendum and dedendum. Clearance is the distance between the outside diameter of a gear and the root diameter of its mate.

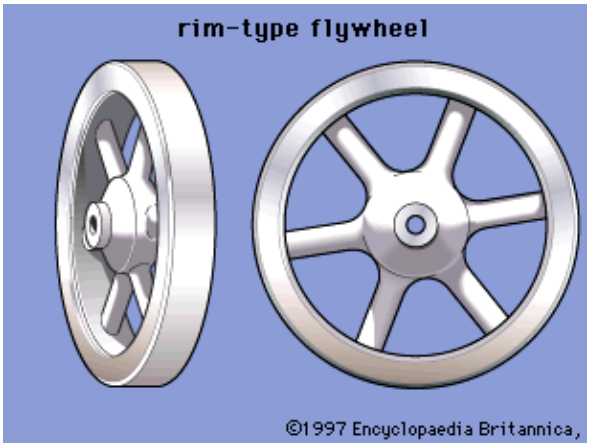
The axial length of a gear tooth is called the face width. By increasing the face width, greater bending strength and tooth surface strength can be obtained. When the face width of the part is smaller than that of the mating part, the face width that is engaged with the mating part is called effective face width.

Top land is the (sometimes flat) surface of the top of a gear tooth.

The tooth surface on the end of the tooth located above the pitch circle is called tooth face, and the tooth surface on the root of the tooth below the pitch circle is called tooth flank.

Flywheel

flywheel heavy wheel attached to a rotating shaft so as to smooth out delivery of power from a motor to a machine. The inertia of the flywheel opposes and moderates fluctuations in the speed of the engine and stores the excess energy for intermittent use. To oppose speed fluctuations effectively, a flywheel is given a high rotational inertia; *i.e.*, most of its weight is well out from the axis. A wheel with a heavy rim connected to the central hub by spokes or a web (wheel A in the Figure) has a high rotational inertia. Many flywheels used on reciprocating engines to smooth out the flow of power are made in this way. The energy stored in a flywheel, however, depends on both the weight distribution and the rotary speed; if the speed is doubled, the kinetic energy is quadrupled. A rim-type flywheel will burst at a much lower rotary speed than a disk-type wheel of the same weight and diameter. For minimum weight and high energy-storing capacity, a flywheel may be made of high-strength steel and designed as a tapered disk, thick at the centre and thin at the rim (*see* Figure B).In automobile engines the flywheel serves to smooth out the pulses of energy provided by the combustion in the cylinders and to provide energy for the compression stroke of the pistons. The larger the rotational inertia of the flywheel, the smaller the changes in speed resulting from the intermittent power supply and demand. In power presses the actual punching, shearing, and forming are done in only a fraction of the operating cycle. During the longer, nonactive period, the speed of the flywheel is built up slowly by a comparatively low-powered motor. When the press is operating, most of the required energy is provided by the flywheel.



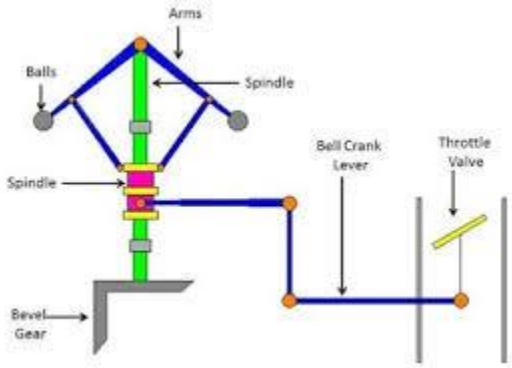
Coefficient of fluctuation of energy: It is the ratio of the maximum fluctuations of energy to the work done per cycle. where, I = moment of inertia of the flywheel, ω = mean rotational speed, Cs = coefficient of fluctuation of speed.

The difference between the maximum and minimum speeds during a cycle is called the maximum fluctuation of speed. The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed.

Governor: -

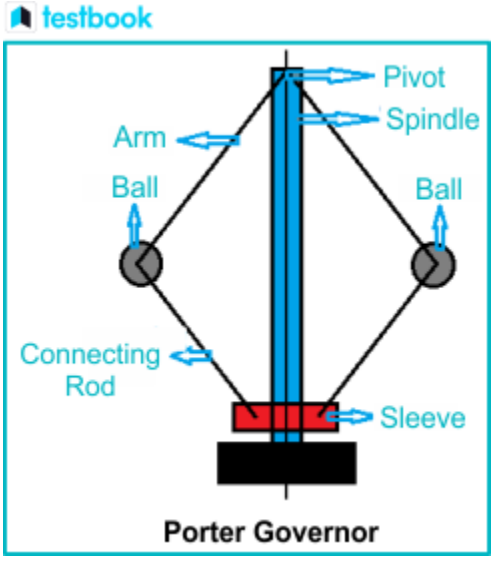
The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid and governor ensures to supply this excess fuel to the engine.

The Watt governor is a type of centrifugal governor that was invented by James Watt in the 18th century. It is used to regulate the speed of steam engines, and it works by controlling the amount of steam that enters the engine. The governor consists of two main components: the flyballs and the spindle.



What is Porter and Watt governor?

In porter governor balls are placed at the junction of upper and lower arms. In case of proell governor the balls are placed at the extension of lower arms. The sensitiveness of watt governor is poor at high speed and this limits its field of application. Porter governor is more sensitive than watt governor.



The Hartnell Governor is a type of mechanical governor used to regulate the speed of engines, such as those used in power generation and industrial machinery. The Hartnell Governor was

invented in the late 19th century by James Hartnell, an English engineer, and has since become a widely used tool for controlling the speed of engines.