Measurement of Gears

GEAR MEASUREMENT

Introduction:

- Gears is a mechanical drive which transmits power through toothed wheel.
- In this gear drive, the driving wheel is in direct contact with driven wheel.
- The accuracy of gearing is the very important factor when gears are manufactured.
- The transmission efficiency is almost 99 in gears. So, it is very important to test and measure the gears precisely.

GEAR MEASUREMENT

- For proper inspection of gear, it is very important to concentrate on the raw materials, which are used to manufacture the gears, also very important to check the machining the blanks, heat treatment and the finishing of teeth.
- The gear blanks should be tested for dimensional accuracy and tooth thickness for the forms of gears.
- The most commonly used forms of gear teeth are

  1.Involute 2. Cycloidal
- The involute gears also called as straight tooth or spur gears.

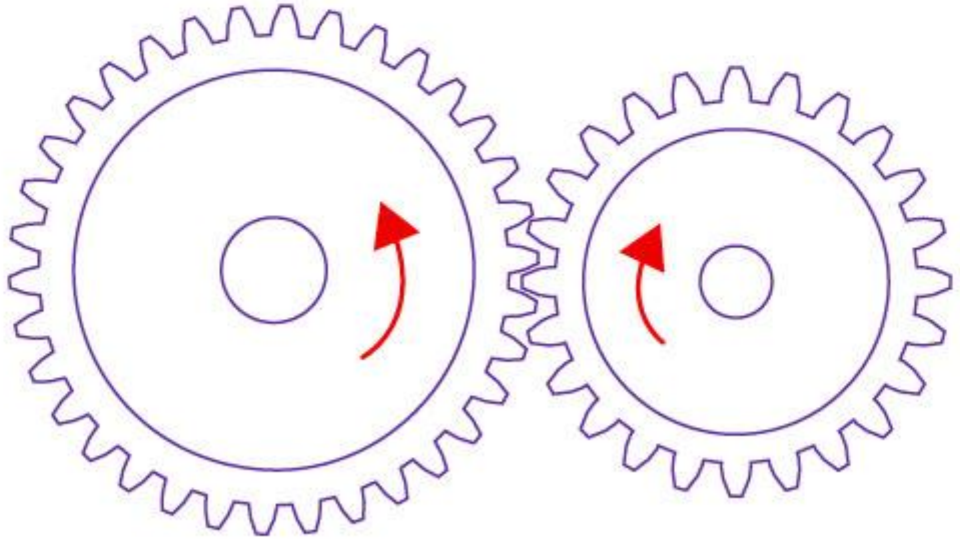
GEAR MEASUREMENT

- The cycloidal gears are used in heavy and impact loads.
- The involute rack has straight teeth.
- The involute pressure angle is either 20° or 14.5°.

Types of Gears

Types of Gears

Spur gears : These gears are the simplest of all gears. The gear teeth are cut on the periphery and are parallel to the axis of the gear. They are used to transmit power and motion between parallel shafts.



Types of Gears

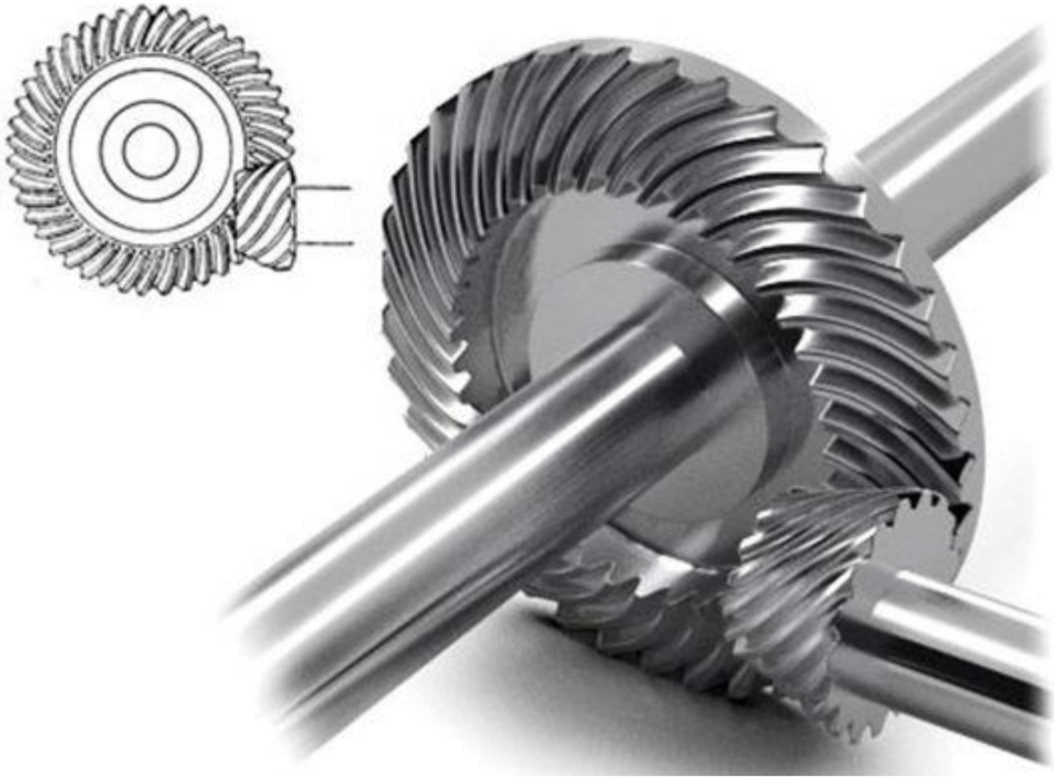
Helical gears: The gear teeth are cut along the periphery, but at an angle to the axis of the gear. Each tooth has a helical or spiral form. These gears can deliver higher torque since there are more number of teeth in a mesh at any given point of time. They can transmit motion between parallel or non-parallel shafts.

Herringbone gears: These gears have two sets of helical teeth, one right-hand and the other left-hand, machined side by side.

Worm and worm gears: A worm is similar to a screw having single or multiple start threads, which form the teeth of the worm. The worm drives the worm gear or worm wheel to enable transmission of motion. The axes of worm and worm gear are at right angles to each other.

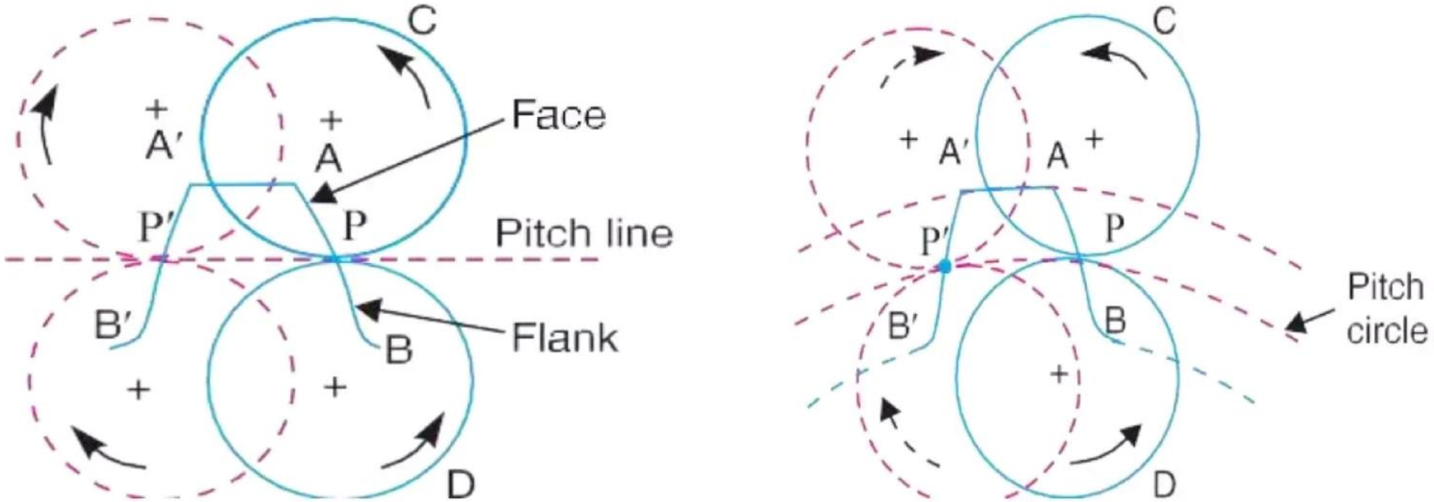
Bevel gears : These gears are used to connect shafts at any desired angle to each other. The shafts may lie in the same plane or in different planes.

Hypoid gears: These gears are similar to bevel gears, but the axes of the two connecting shafts do not intersect. They carry curved teeth, are stronger than the common types of bevel gears, and are quiet-running. These gears are mainly used in automobile rear axle drives.



FORMS OF TEETH

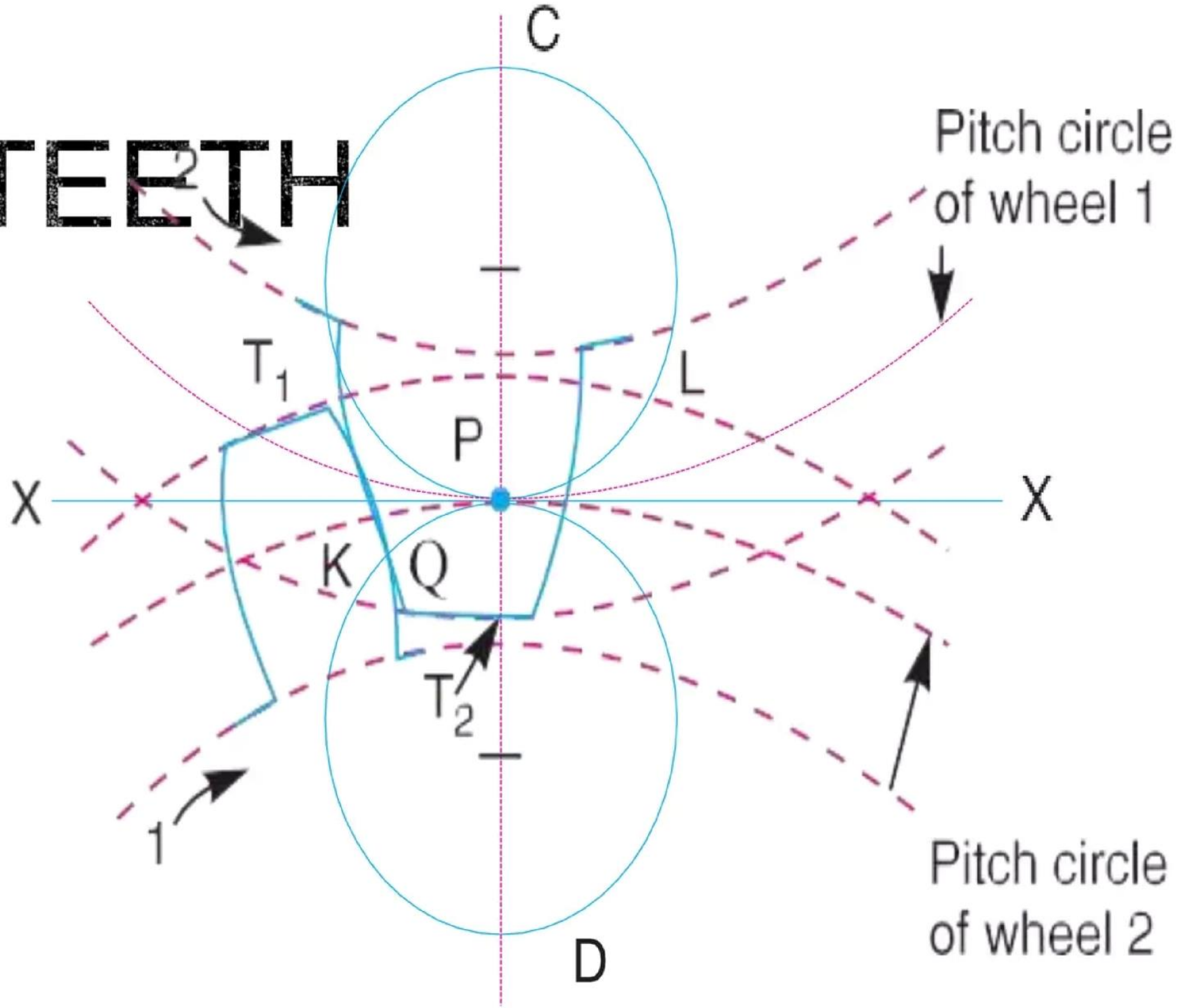
- 1. ***Cycloidal* teeth:**
- A ***cycloid*** is the curve traced by a point on the circumference of a circle which rolls without slipping on a fixed straight line.
- When a circle rolls without slipping on the outside of a fixed circle, the curve traced by a point on the circumference of a circle is known as ***epi-cycloid***.
- On the other hand, if a circle rolls without slipping on the inside of a fixed circle, then the curve traced by a point on the circumference of a circle is called ***hypo-cycloid***.



Construction of cycloidal teeth of a gear.

FORMS OF TEETH

- 1. ***Cycloidal* teeth:**

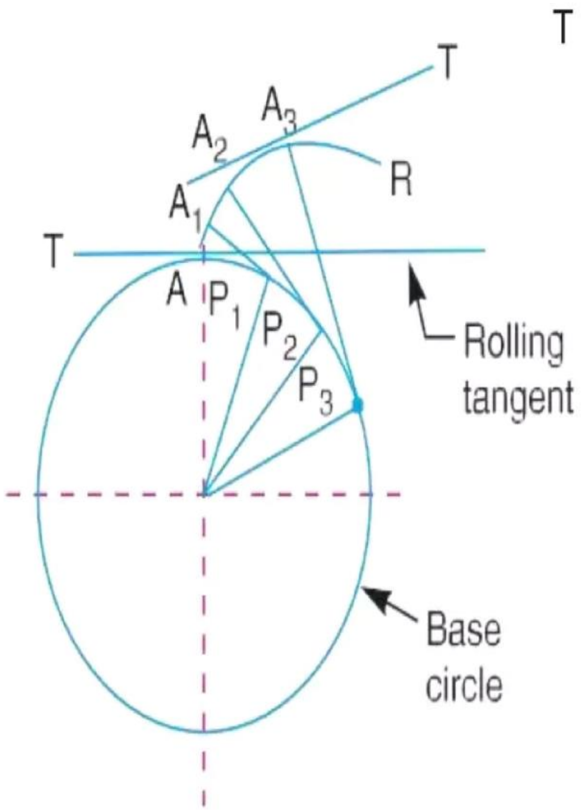


Construction of two mating cycloidal teeth.

FORMS OF TEETH

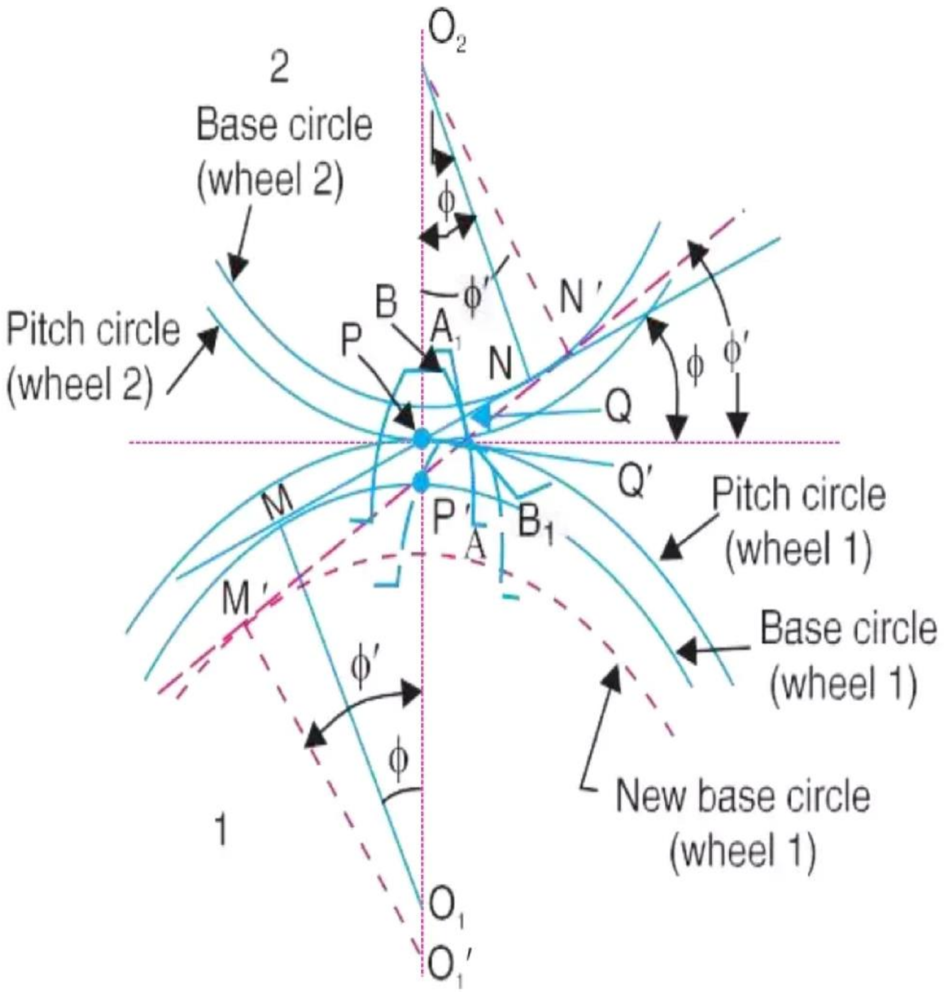
2. **Involute Teeth**

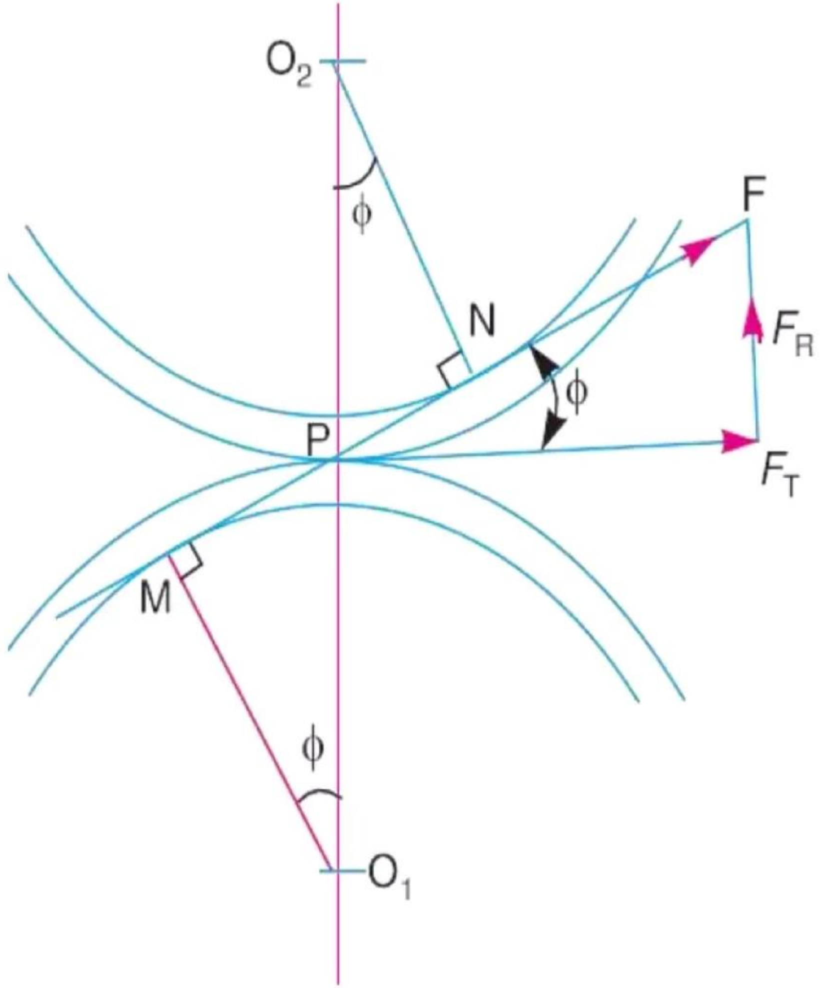
- An involute of a circle is a plane curve generated by a point on a tangent, which rolls on the circle without slipping or by a point on a taut string which in unwrapped from a reel as shown in Fig.
- Let *A* be the starting point of the involute. The base circle is divided into equal number of parts *e.g.* *AP*1, *P*1*P*2, *P*2*P*3 etc.
- The tangents at *P*1, *P*2, *P*3 etc. are drawn and the length *P*1*A*1, *P*2*A* 2, *P*3*A* 3 equal to the arcs *AP*1, *AP*2 and *AP*3 are set off.
- Joining the points *A*, *A*1, *A*2, *A*3 etc. we obtain the involute curve *A R.*
- A little consideration will show that at any instant *A* 3, the tangent *A* 3*T* to the involute is perpendicular to *P*3*A* 3 and *P*3*A* 3 is the normal to the involute. In other words, ***normal at any point of an involute is a tangent to the circle*.**



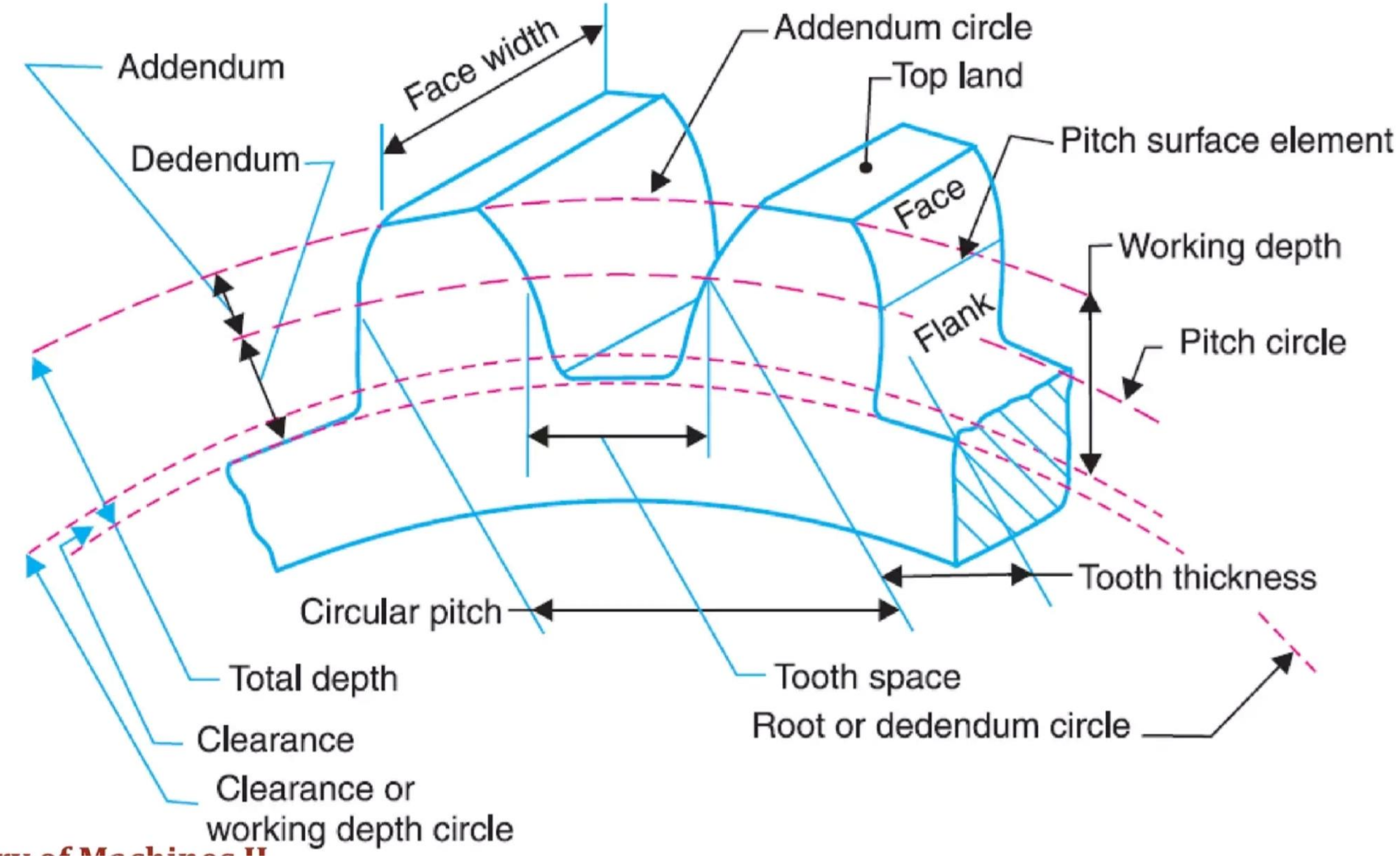
FORMS OF TEETH

2. **Involute Teeth**

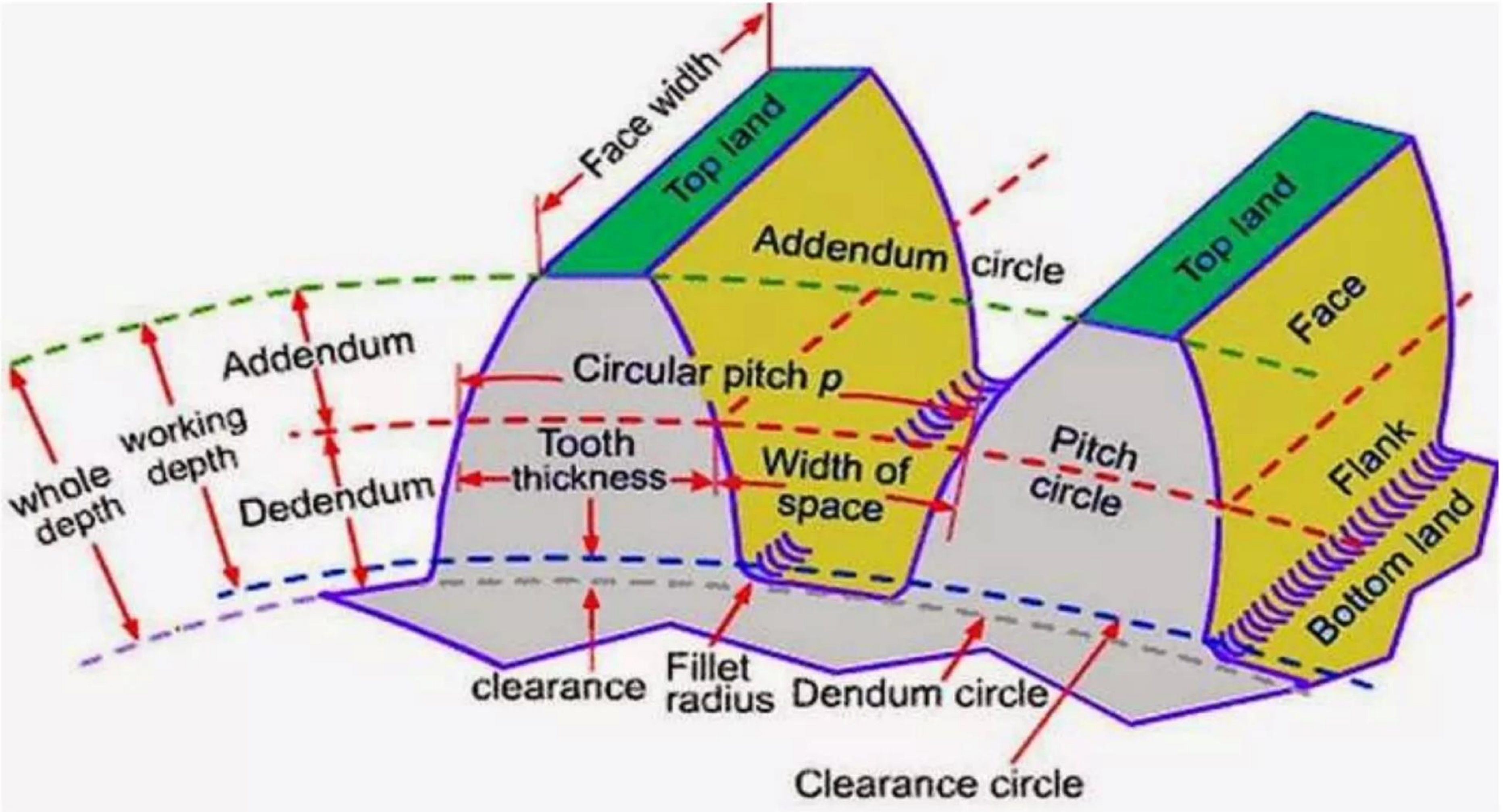




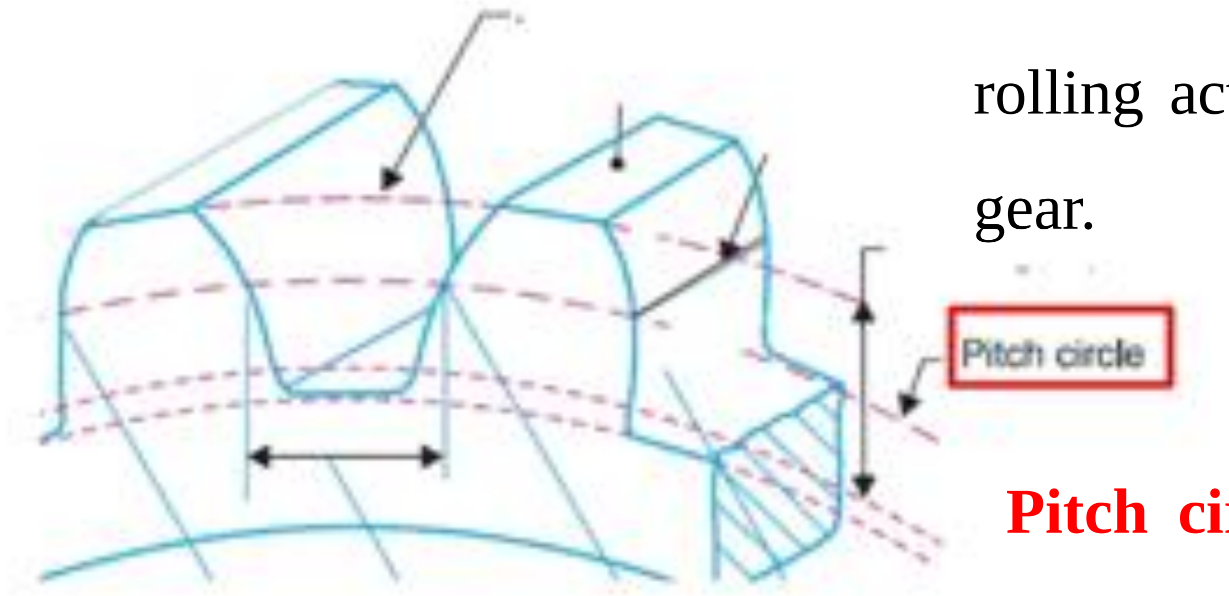
Gear terminology



GEAR TERMINOLOGY

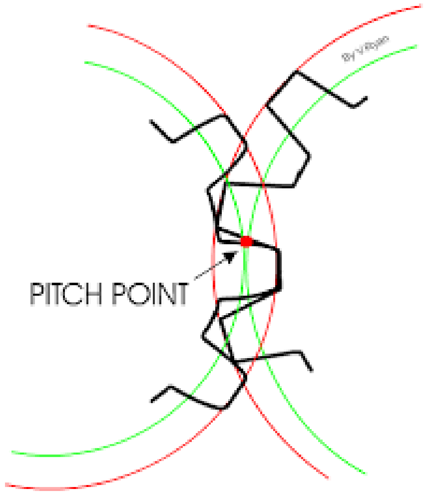


Gear terminology



Pitch circle: It is an imaginary circle which by pure rolling action would give the same motion as the actual gear.

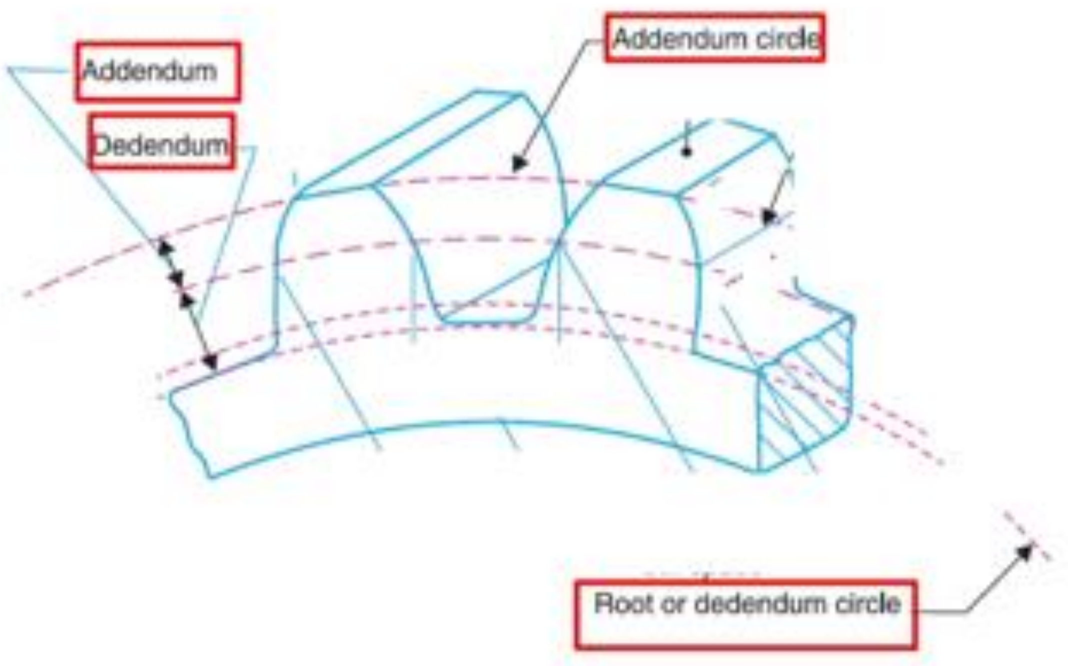
Pitch circle diameter: It is the diameter of the pitch circle. The size of the gear is usually specified by the pitch circle diameter. It also known as pitch diameter.



Pitch point: It is a common point of contact between two pitch circles.

Pitch surface: It is the surface of the rolling discs which the meshing gears have replaced at the pitch circle.

Gear terminology



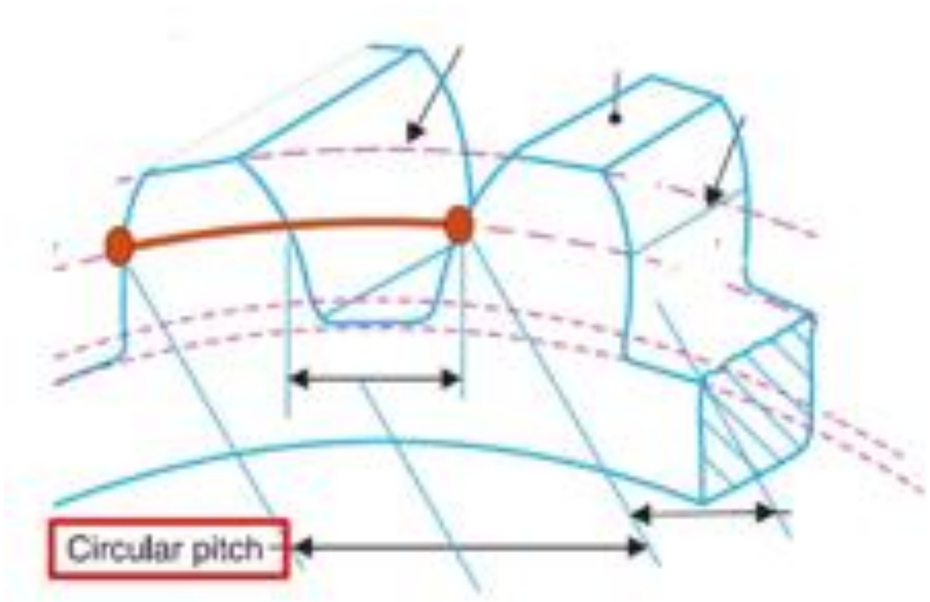
Addendum: It is the radial distance of a tooth from the pitch circle to the top of the tooth.

Addendum circle: It is the circle drawn through the top of the teeth and is concentric with the pitch circle.

Dedendum: It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.

Dedendum circle: It is the circle drawn through the bottom of the teeth. It is also called root circle.

Gear terminology



$$p_c = \frac{\pi D_1}{T_1} = \frac{\pi D_2}{T_2} \quad \text{or} \quad \frac{D_1}{D_2} = \frac{T_1}{T_2}$$

Circular pitch: It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth. It is usually denoted by P, Mathematically,

$$\textbf{Circular pitch} = P_C = \frac{\pi D}{T}$$

D = Diameter of the pitch circle, and

T = Number of teeth on the wheel

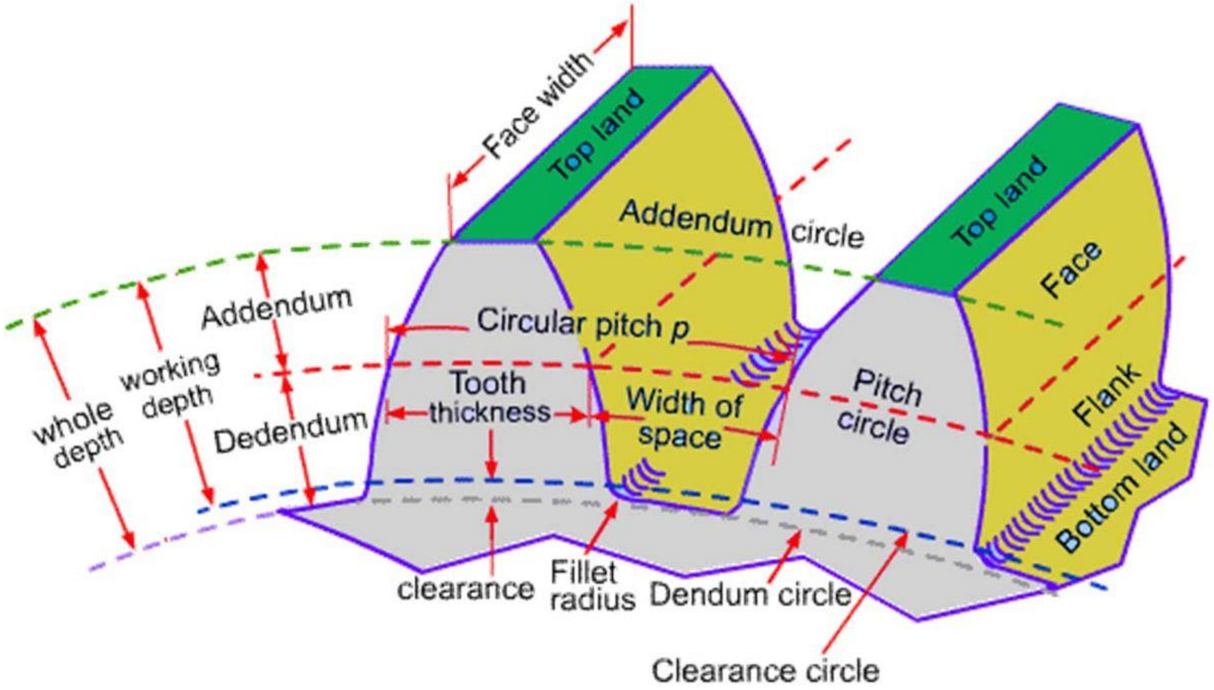
A little consideration will show that the two gears will mesh together correctly, if the two wheels have the same circular pitch.

Gear terminology

Diametral pitch : It is the ratio of number of teeth to the pitch circle diameter in millimeters. Is is denoted by P_d Mathematically

$$P_d = \frac{T}{D} = \frac{\pi}{P_C}$$

Module It is the ratio of the pitch circle diameter in millimeters to the number of teeth. It is usually denoted by m. Mathematically, Module, m = D/T

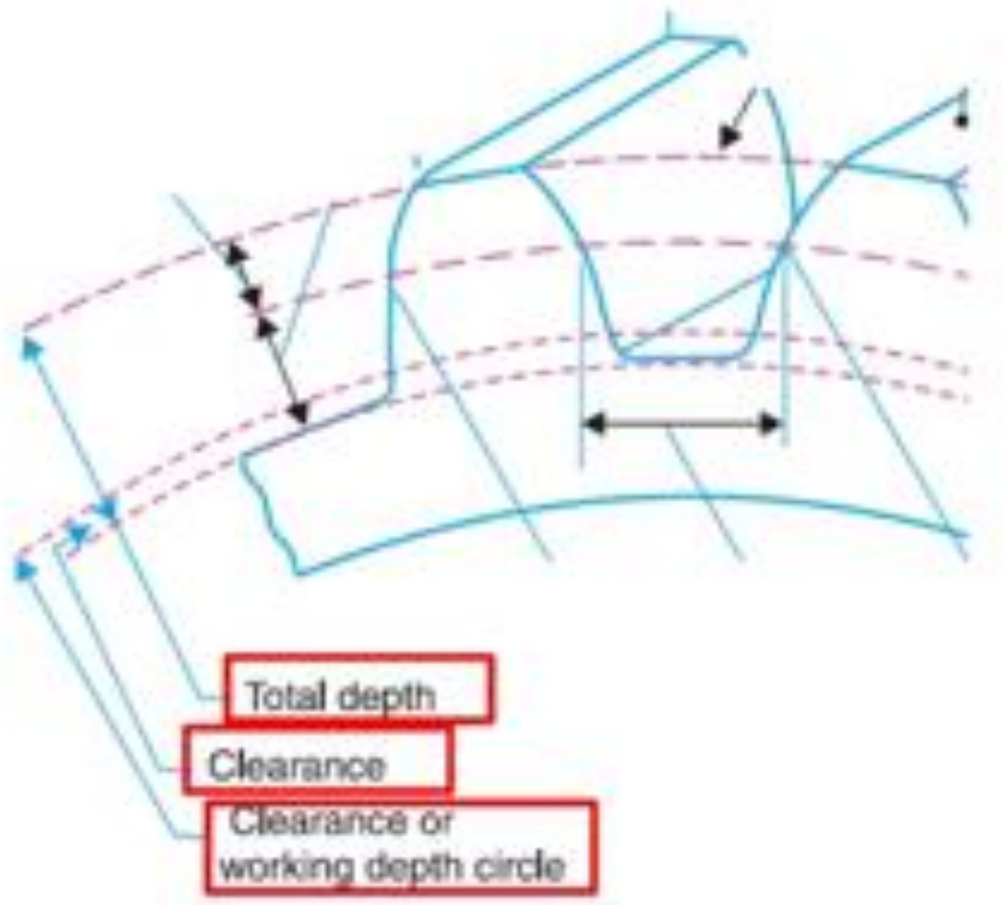


Gear terminology

Clearance: It is the radial distance from the top of the tooth to the bottom of the tooth, in a meshing gear.

A circle passing through the top of the meshing gear is known as clearance circle.

Total depth: It is the radial distance between the addendum and the dedendum circles of a gear. It is equal to the sum of the addendum and dedendum.

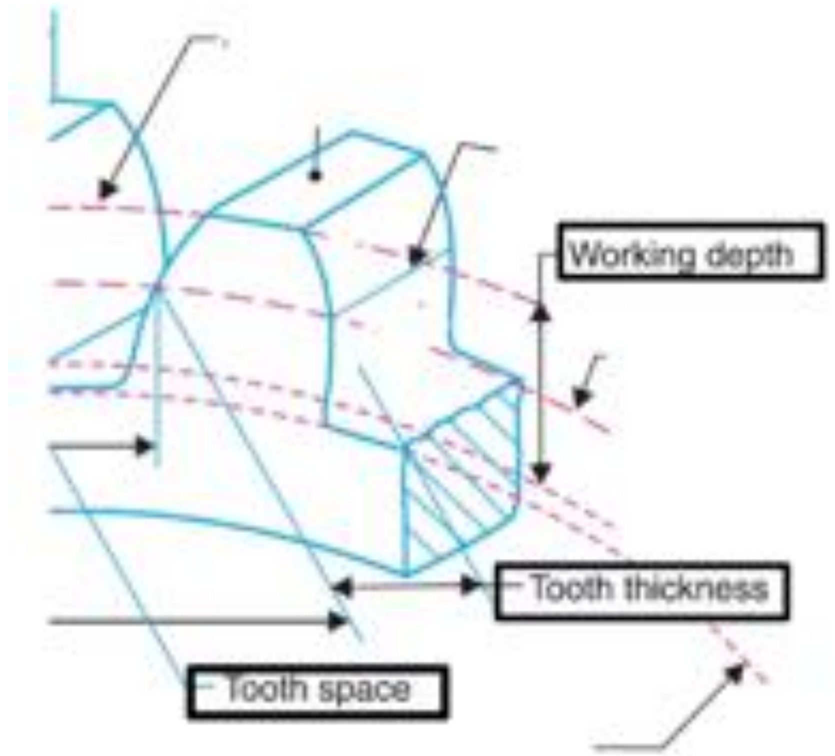


Gear terminology

Working depth: It is the radial distance from the addendum circle to the clearance circle. It is equal to the sum of the addendum of the two meshing gears.

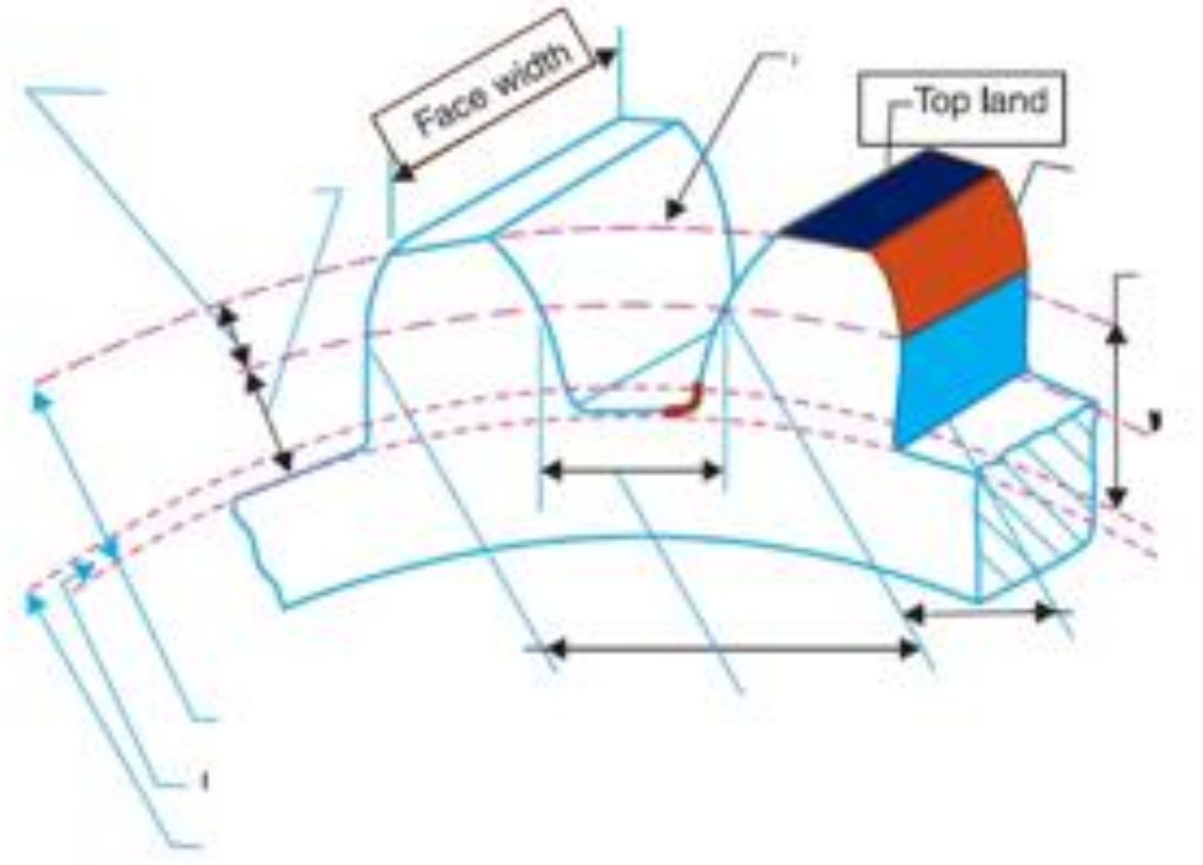
Tooth thickness : It is the width of the tooth measured along the pitch circle.

Tooth space : It is the width of space between the two adjacent teeth measured along the pitch circle.



Backlash: It is the difference between the tooth space and the tooth thickness, as measured along the pitch circle.

Gear terminology



Face of tooth : It is the surface of the gear tooth above the pitch surface.

Flank of tooth: It is the surface of the gear tooth below the pitch surface.

Profile: It is the curve formed by the face and flank of the tooth.

Top land: It is the surface of the top of the tooth.

Face width: It is the width of the gear tooth measured parallel to its axis.

Fillet radius. It is the radius that connects the root circle to the profile of the tooth.

MEASUREMENT OF GEAR ELEMENTS

The analytical inspection of the gears consists in determining the following teeth elements in which manufacturing errors may be present.

1. Runout
2. Pitch
3. Profile
4. Lead
5. Back lash
6. Tooth thickness
7. Concentricity
8. Alignment
9. Composite errors.

MEASUREMENT OF GEAR ELEMENTS

(1) Runout:

- Runout means the **eccentricity** in the pitch circle.
- Gears that are eccentric tend to have periodic variation in sound (vibration) during each revolution
- The runout in the gears is measured by means of gear eccentricity testers·
- The gear is held in the mandrel in the centers
- The dial indicator of the tester possesses special tip depending upon the module of the gear to be checked.
- The tip is inserted in between the tooth spaces. The gear is rotated tooth by tooth.

- The maximum variation is noted from the dial indicator reading which gives the runout of the gear. The runout is twice the eccentricity.

There are various methods of measuring the gear tooth thickness.

1. Chordal thickness method (measurement of tooth thickness by gear tooth Vernier caliper)

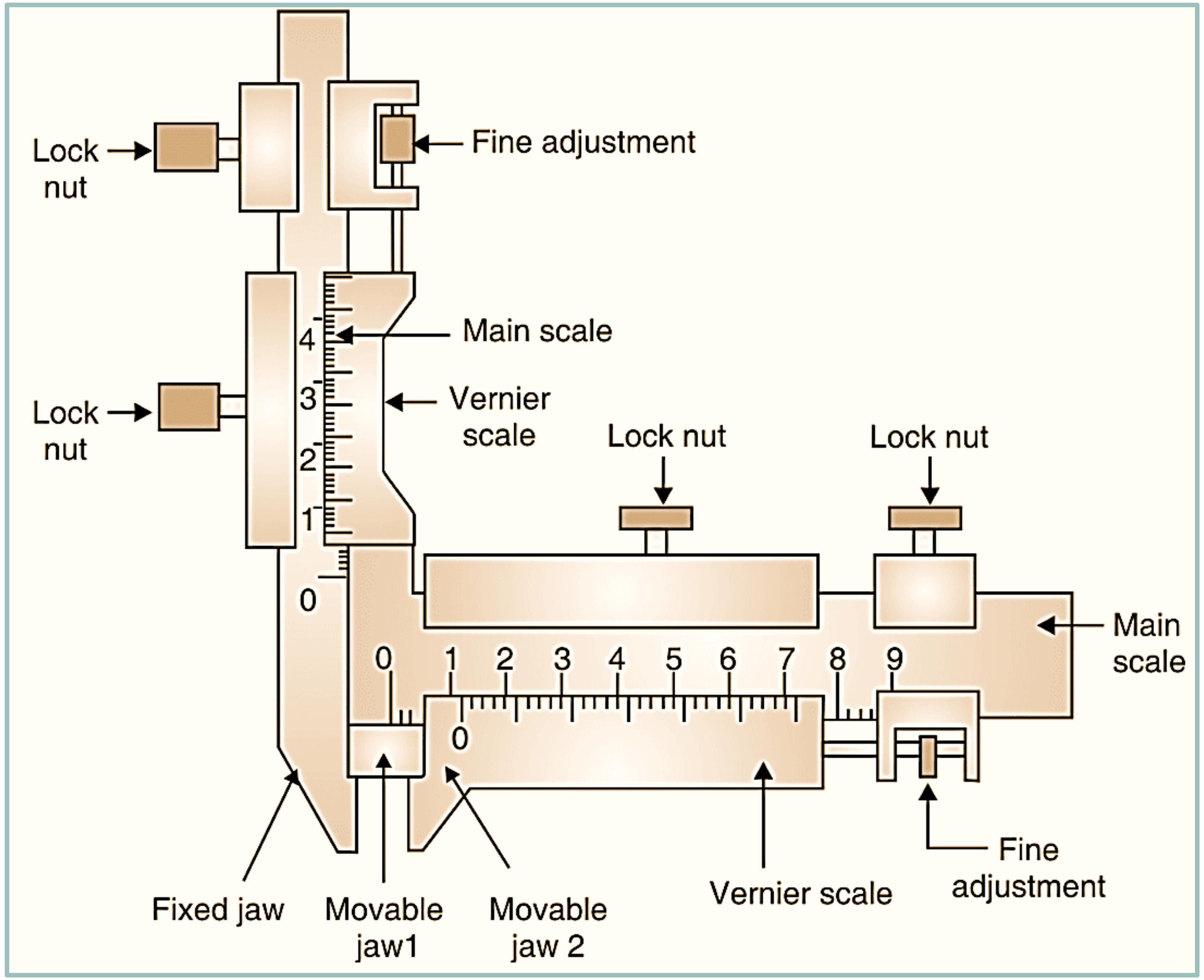
2. Constant chord method.

3. Base tangent method.

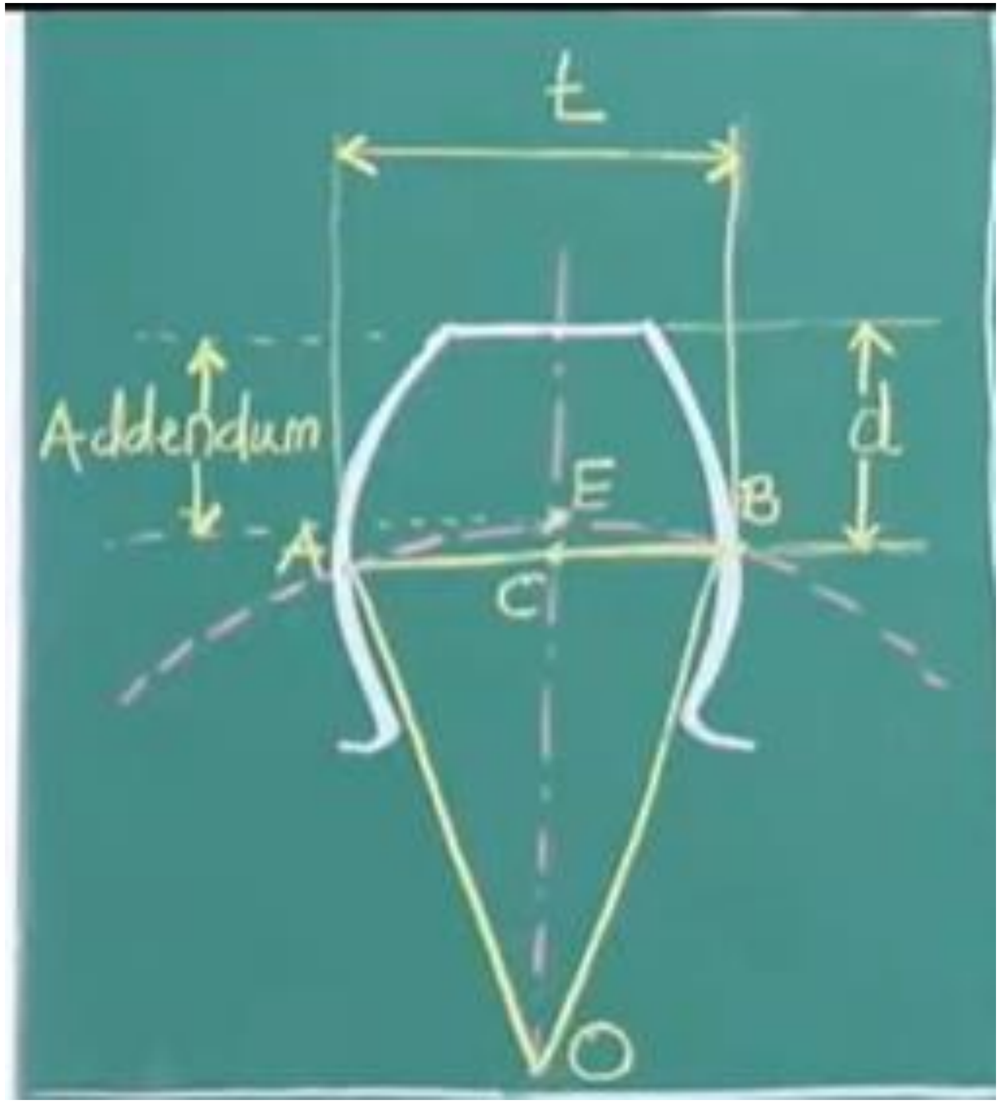
4. Parkinson Gear Tester

Chordal thickness method:

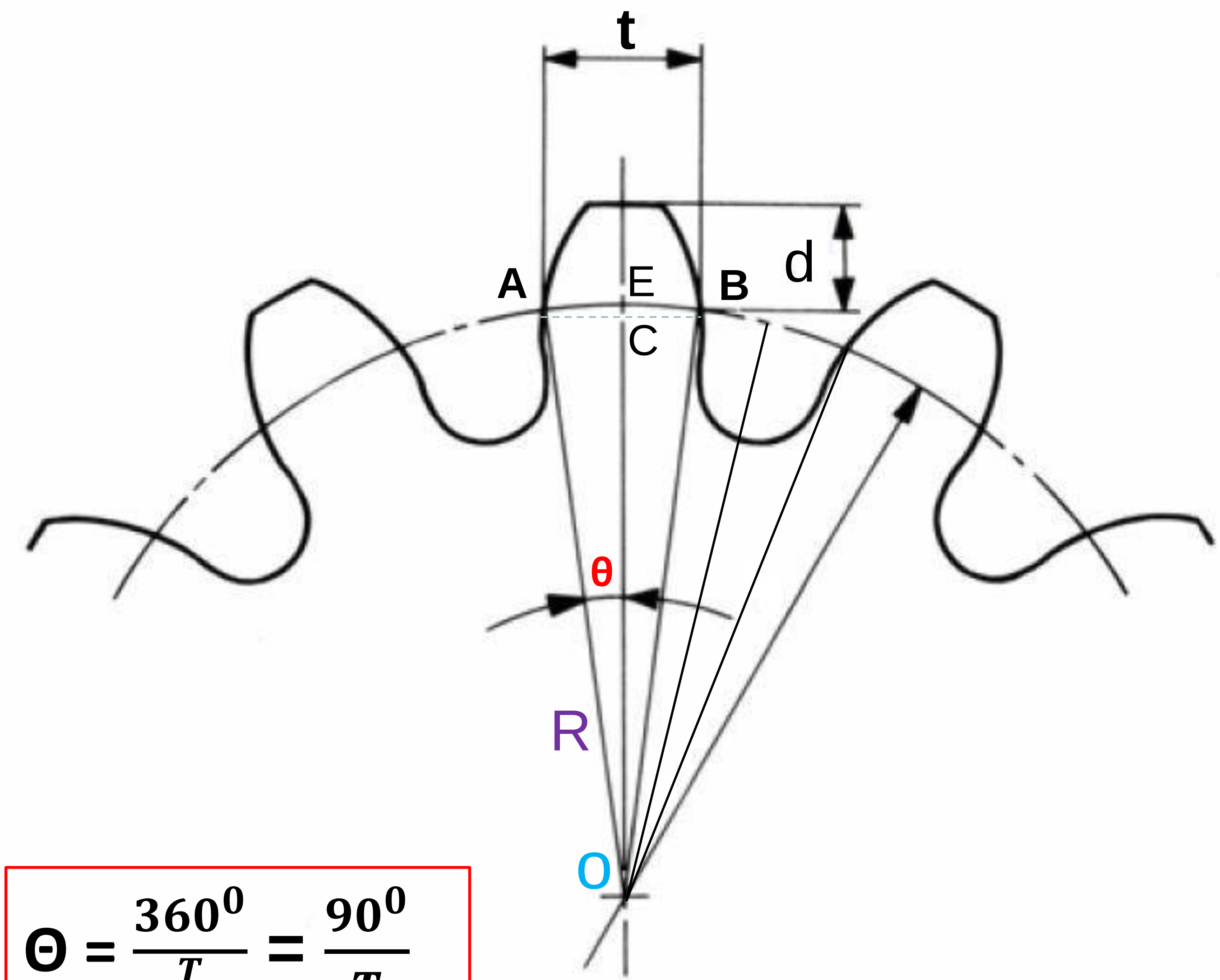
- In this method, gear tooth Vernier calliper is used to measure the thickness of gear tooth at the pitch line.
- The gear tooth vernier calliper consists of two perpendicular vernier arms with vernier scale on each arm.
- One of the arms is used to measure the thickness of gear teeth and other for measuring depth.



- The calliper is so set that it slides on the top of tooth of gear under test and the lower ends of the calliper jaws touch the sides of the tooth at the pitch line.
- The reading on the horizontal vernier scale gives the value of **chordal thickness (W)** and the reading on the vertical vernier scale gives the value of **chordal addendum(d).**
- These measured values are then compared with the calculated values.



t = thickness of the tooth ;d= depth of the tooth



$$\Theta = \frac{360^0}{\frac{T}{4}} = \frac{90^0}{T}$$

1) To find out t

t =AB

From the triangle COB

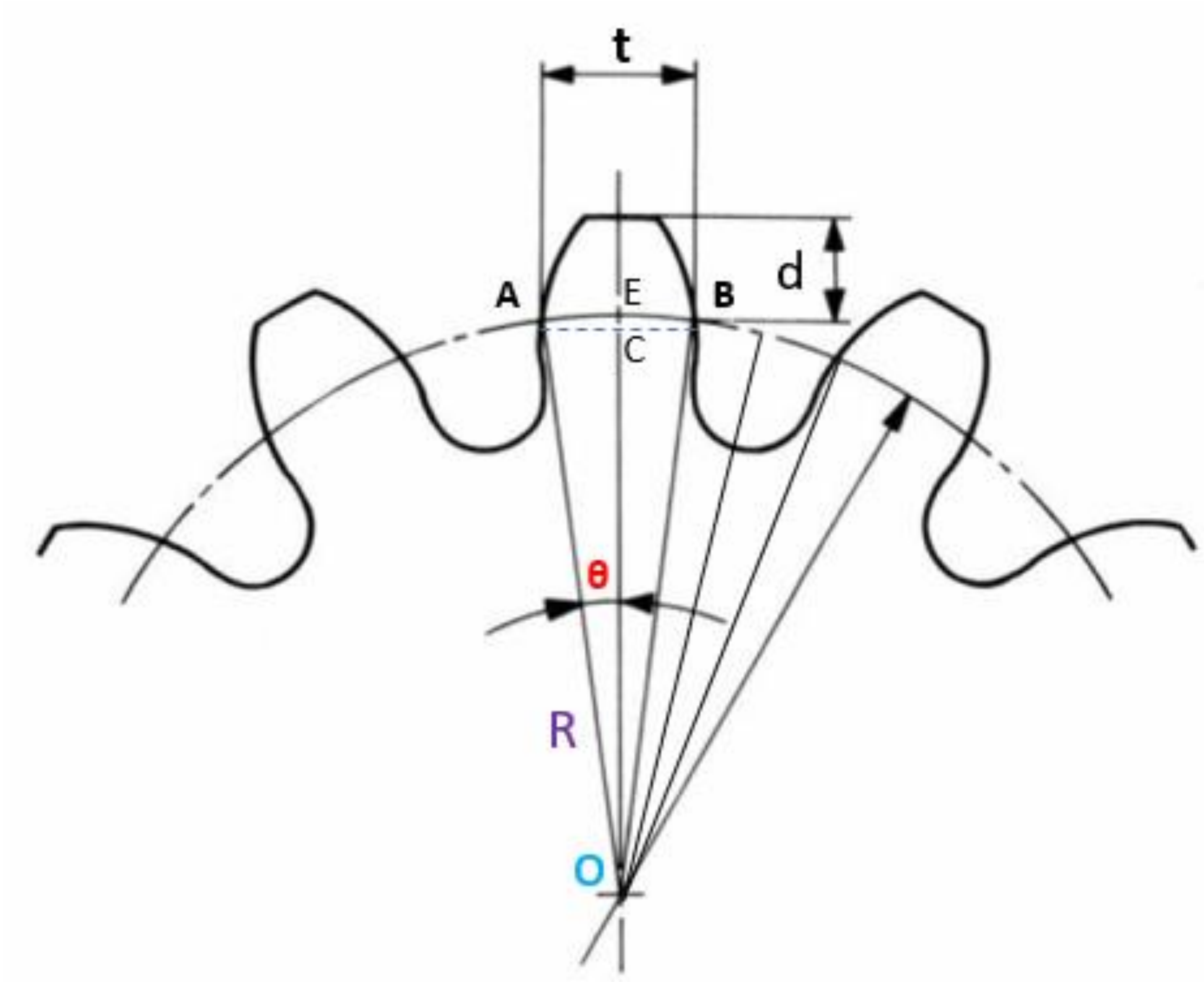
Concept of circular pitch

$$\text{Sin } \theta = \sin \frac{90^0}{T} = \frac{CB}{0B}$$

$$\text{Sin } \theta = \sin \frac{90^0}{T} = \frac{CB}{R}$$

$$CB = \sin \frac{90^0}{T} \times R$$

$$CB = R \times \sin \frac{90^0}{T}$$



$$\text{Module(m)} = \frac{D}{T}$$

$$D = mT$$

$$2R = m\ T$$

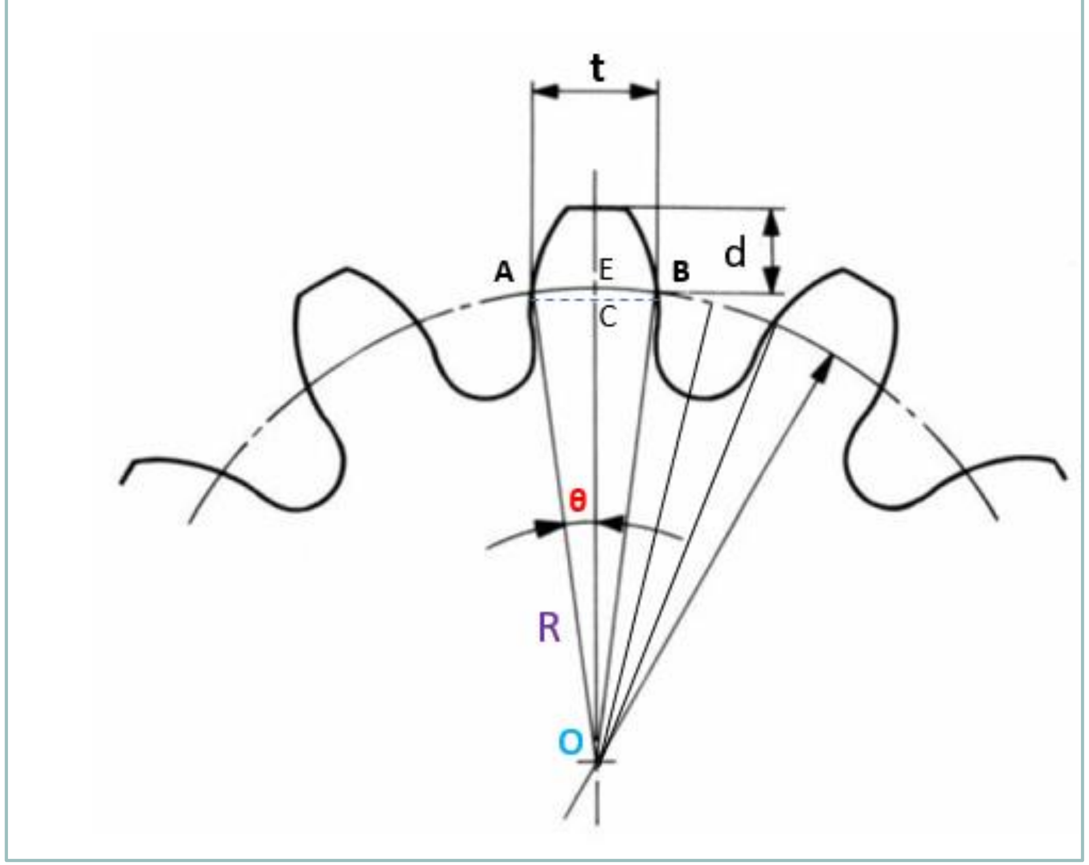
$$R = \frac{mT}{2}$$

$$CB = \sin\frac{90^0}{T} \times R$$

$$CB = \frac{mT}{2} \times \sin\frac{90^0}{T}$$

$$t = AB = 2CB$$

$$t = AB = 2CB = = \frac{mT}{2} \times \sin\frac{90^0}{T}$$



To find out addendum depth (d)

To find out OC

From the triangle COB

$$\text{Cos } \varphi = \frac{OC}{OB} = \frac{OC}{R}$$

$$OC = R \times \text{Cos } \phi$$

$$\text{Addendum} = a = \frac{1}{\text{Diameterical Pitch}}$$

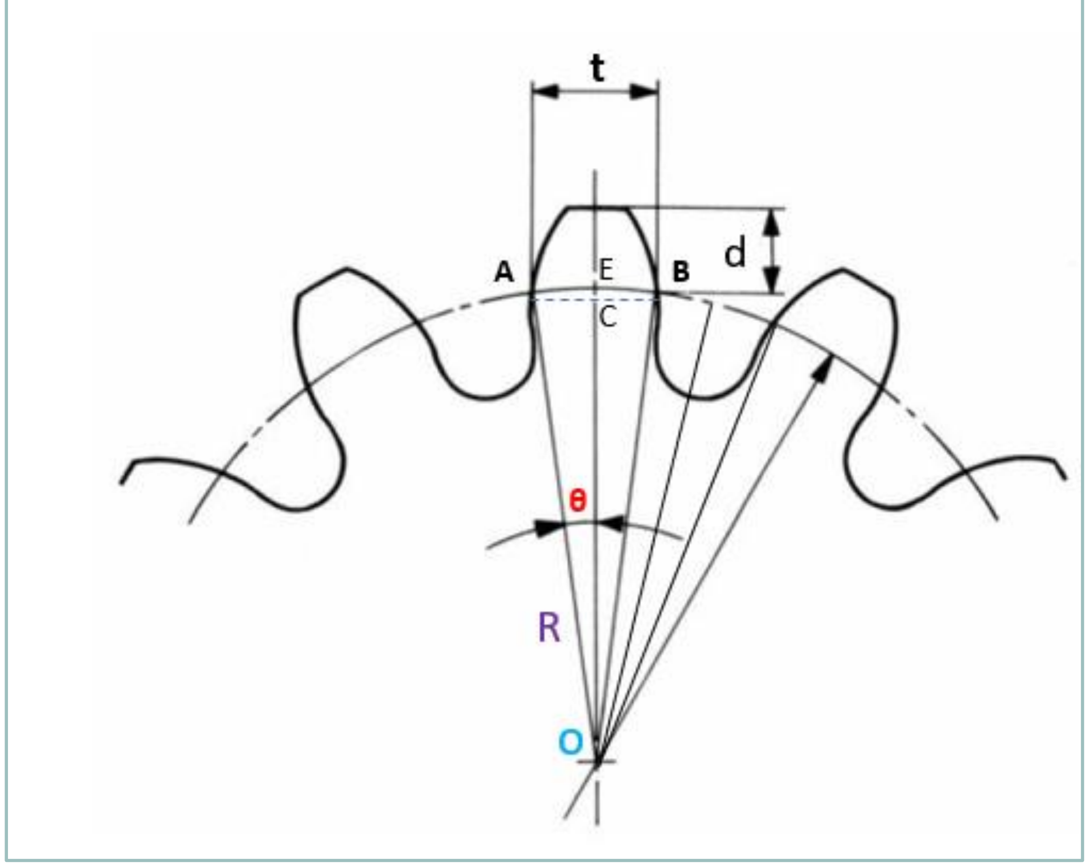
$$= \frac{1}{T/D}$$

$$\text{Addendum} = a = \frac{D}{T} = \text{Module (m)}$$

d = OD -OC ----------(1)

OD = OE +addendum

OD = R +a



To find out addendum depth (d)

d = OD -OC

= R +a - R × Cos φ

= R +M - R × Cos ϕ

$$= \frac{MT}{2} + M - \frac{MT}{2} \text{Cos}\phi$$

$$\mathbf{d = m\left(1 + \frac{T}{2}\,[1 - \text{Cos}\,\varphi]\right)}$$

The Vernier method described above is not very satisfactory because of the following reasons:

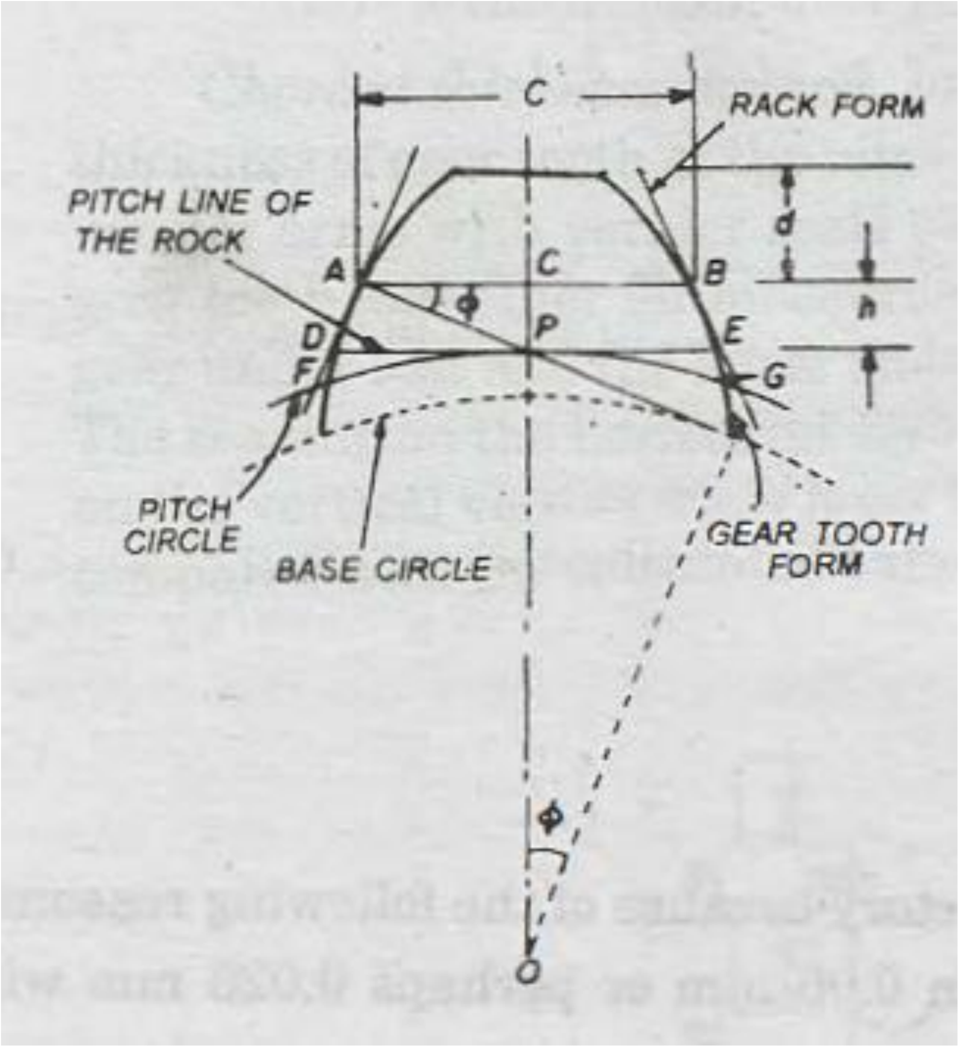
- The vernier itself is not reliable to closer than 0.05 mm or perhaps 0.025 mm with practice,
- The measurements depend on two vernier readings, each of which is a function of the other,
- measurement is made with an edge of the measuring jaw, not its face, which again does not lead itself to accurate measurement.

Constant Chord Method

- In gear tooth collinear method, both the chordal thickness and chordal addendum are dependent upon the number of teeth.

- Hence, for measuring a large number of gears for set, each having different number of teeth would involve separate calculations. Thus the procedure becomes laborious and time consuming.

- The constant chord method does away with these difficulties. It enables to employ one setting for all the gears having the same pitch and pressure angle irrespective of the number of teeth.
- The constant chord is defined as the chord joining those points, on opposite faces of .the tooth, which make contact with the mating-teeth when the centre line of the tooth lies on the line of the gear centres.



- **AB** is known as constant chord. The value of AB and its depth from the tip, where it occurs, can be calculated mathematically and then verified by instrument.

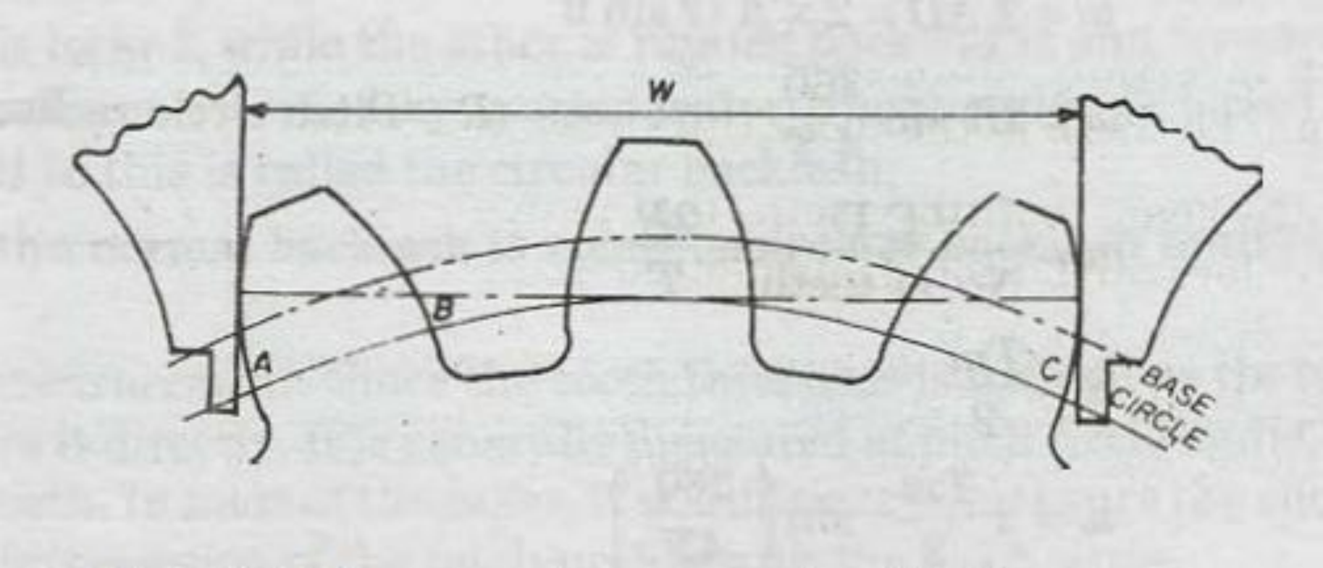
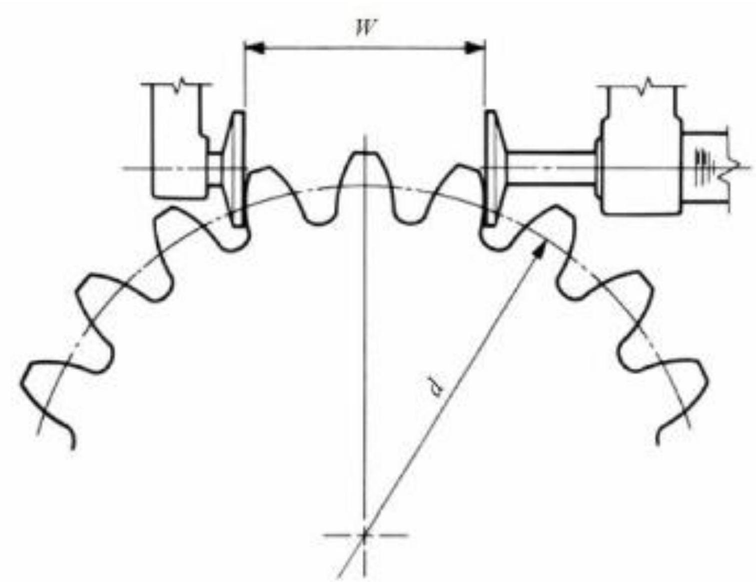
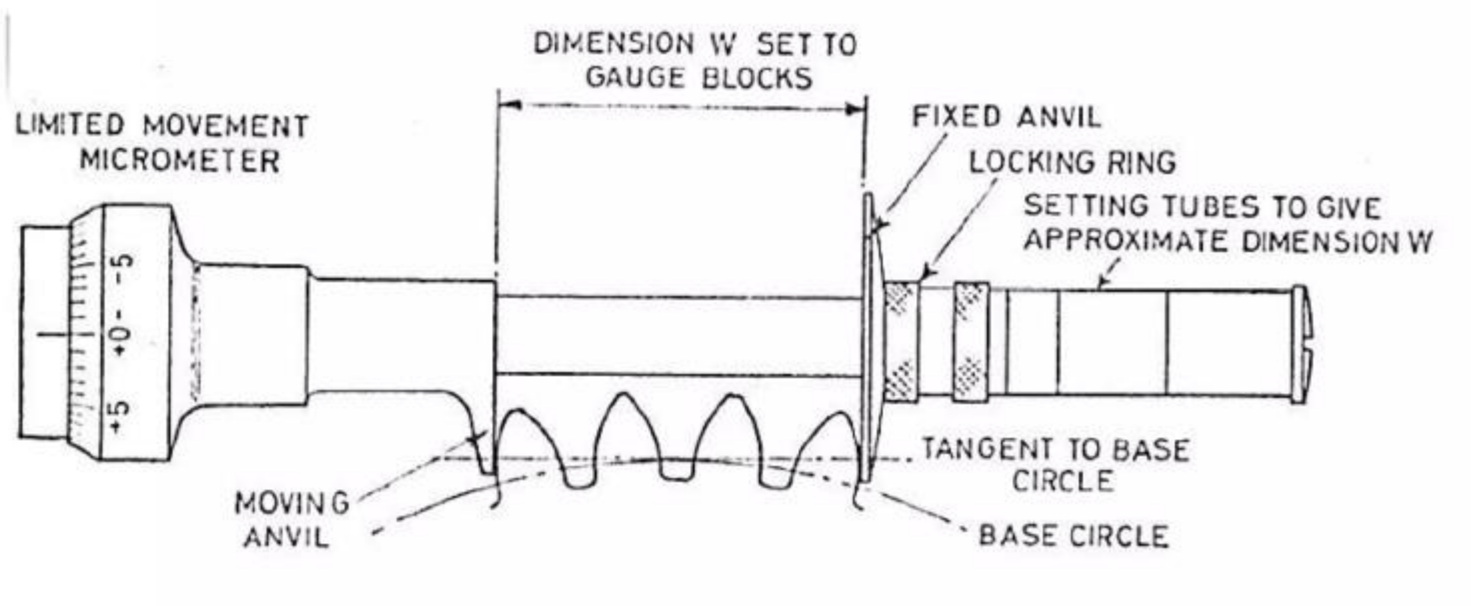


Fig. 6.30. Measurement over a number of teeth

- The advantage of the constant chord method is that for all number of teeth (of same module) value of constant chord is same. Secondly, it readily lends itself to a form of comparator which is more sensitive than the gear tooth vernier.



Base tangent method



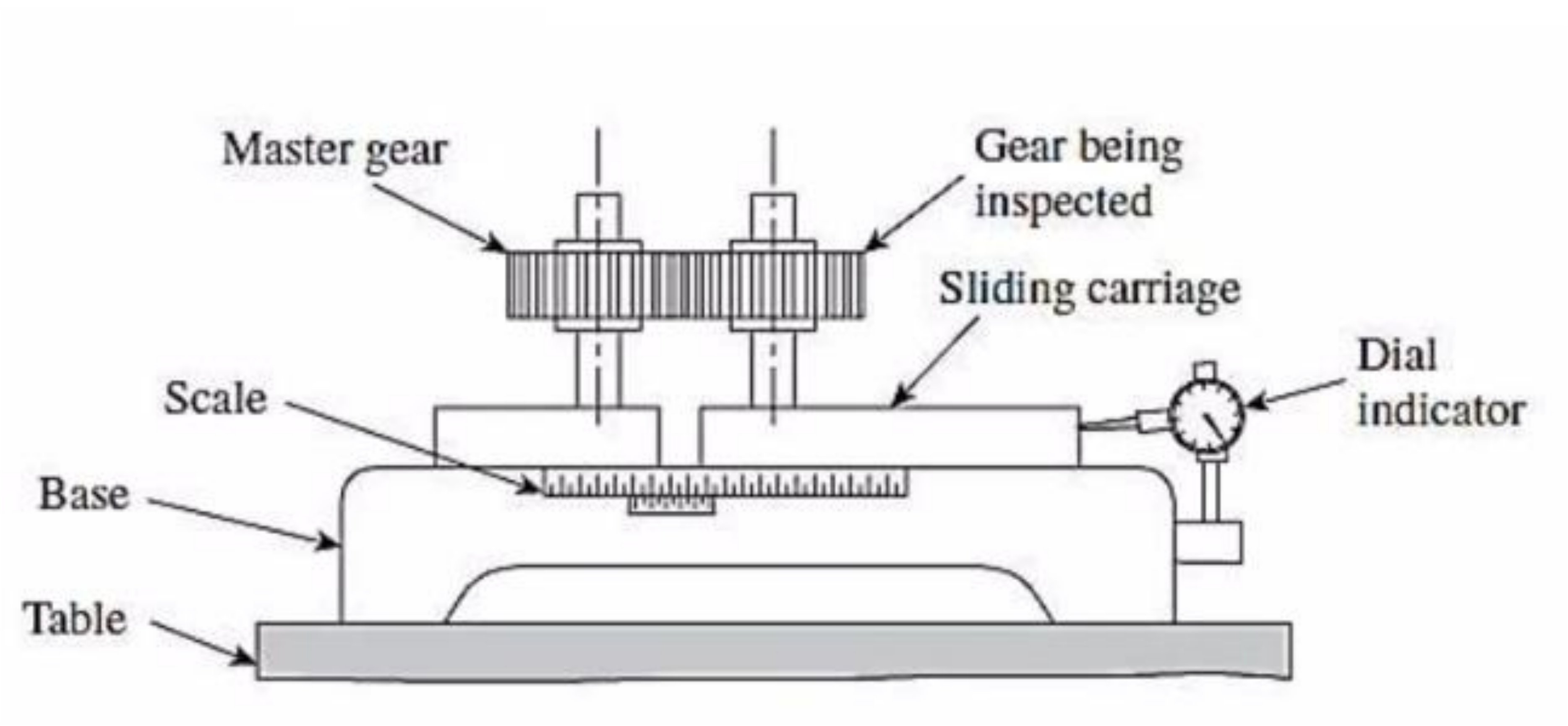
David Brown base tangent comparator

Measurement by this method uses either a micrometer with flanked anvils or the David Brown Tangent comparator as shown in Figure

Base tangent method

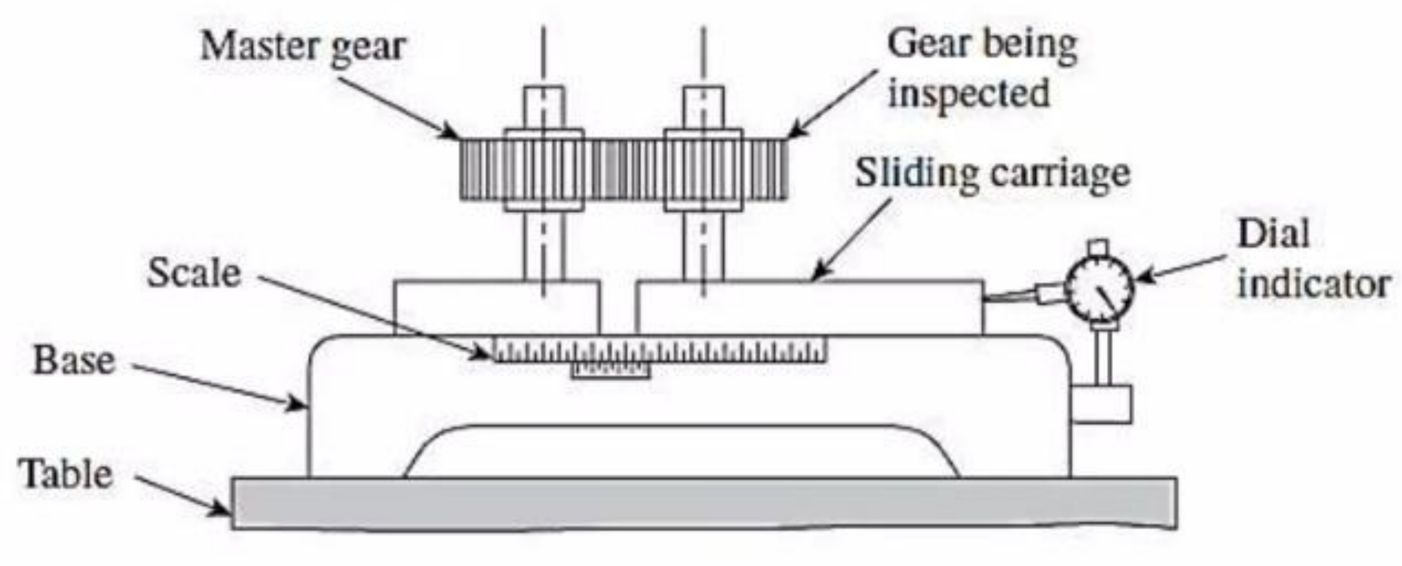
- In this method the span of confinement number of teeth is measured by the David brown tangent comparator
- This instrument essentially consists of a fixed anvil and a movable anvil.
- There is a micrometer on the moving anvil side and this has a very limited movement on either side of the setting.
- The anvils of the comparator are first set of the base tangent length with the help of the slip gauges
- The slip Gauges are replaced by the gear which is to be measure
- Reading are the taken by the comparator

Parkinson Gear Tester



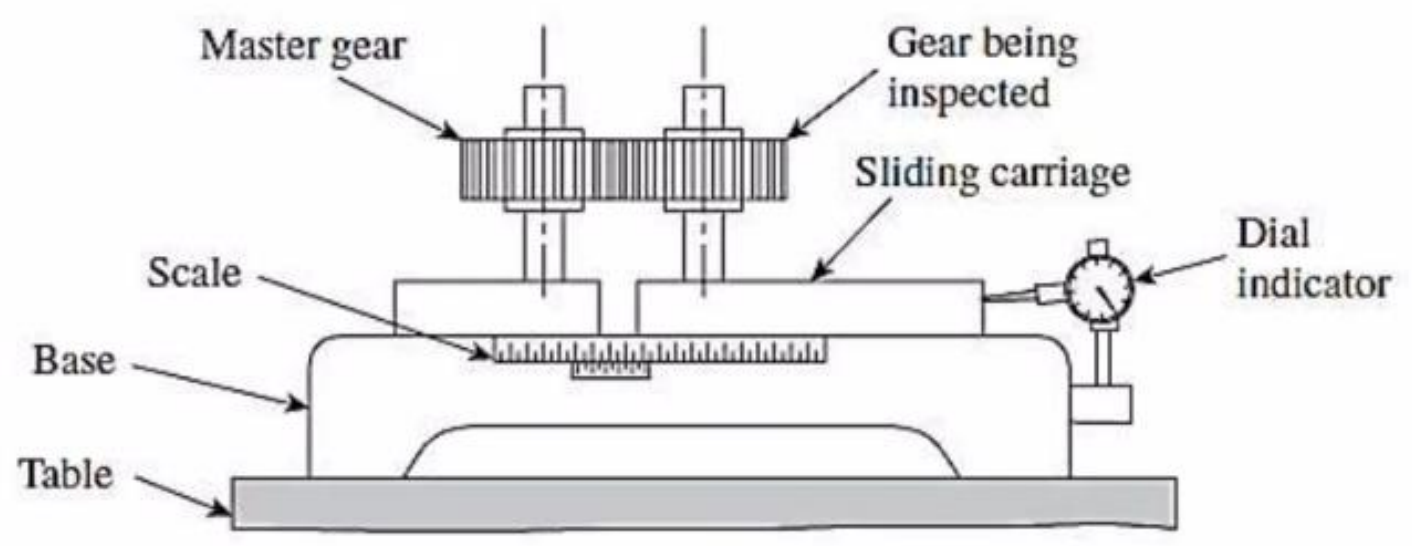
The gear being inspected is mesh with a standard gear and Dial indicator is used to capture radial errors

Parkinson Gear Tester



- Standard gear is mounted on a fixed frame, the gear being inspected is fixed to a sliding carriage.
- Dial indicator primarily measure irregularities in the gear under inspection.
- A dial indicator of high resolution is used to measure the composite error, errors due to runout , tooth-to-tooth spacing, and profile variations.

Parkinson Gear Tester



- A Vernier scale enables measurement of the centre distance up to 25 μm.
- The dial indicator is set to zero
- Gear under inspection is rotated. Radial variations are indicated by the dial indicator.
- This variation is plotted on a graph sheet, which indicates the radial variations in the gear for one complete rotation.

Some limitations of Parkinson gear tester are :

1. Generally 300 mm diameter gear is maximum, usually 150 mm or smaller diameter gears are also tested.

2. There is a low friction in the movement of the floating carriage and a high sensitivity of the sensing unit is important.

3. The accuracy is of the order of± 0.001 mm.

4. Rolling test does not reveal all errors, since the device is sensitive to cumulative position errors.

5. Measurements are directly dependent upon the master gear or reference gear

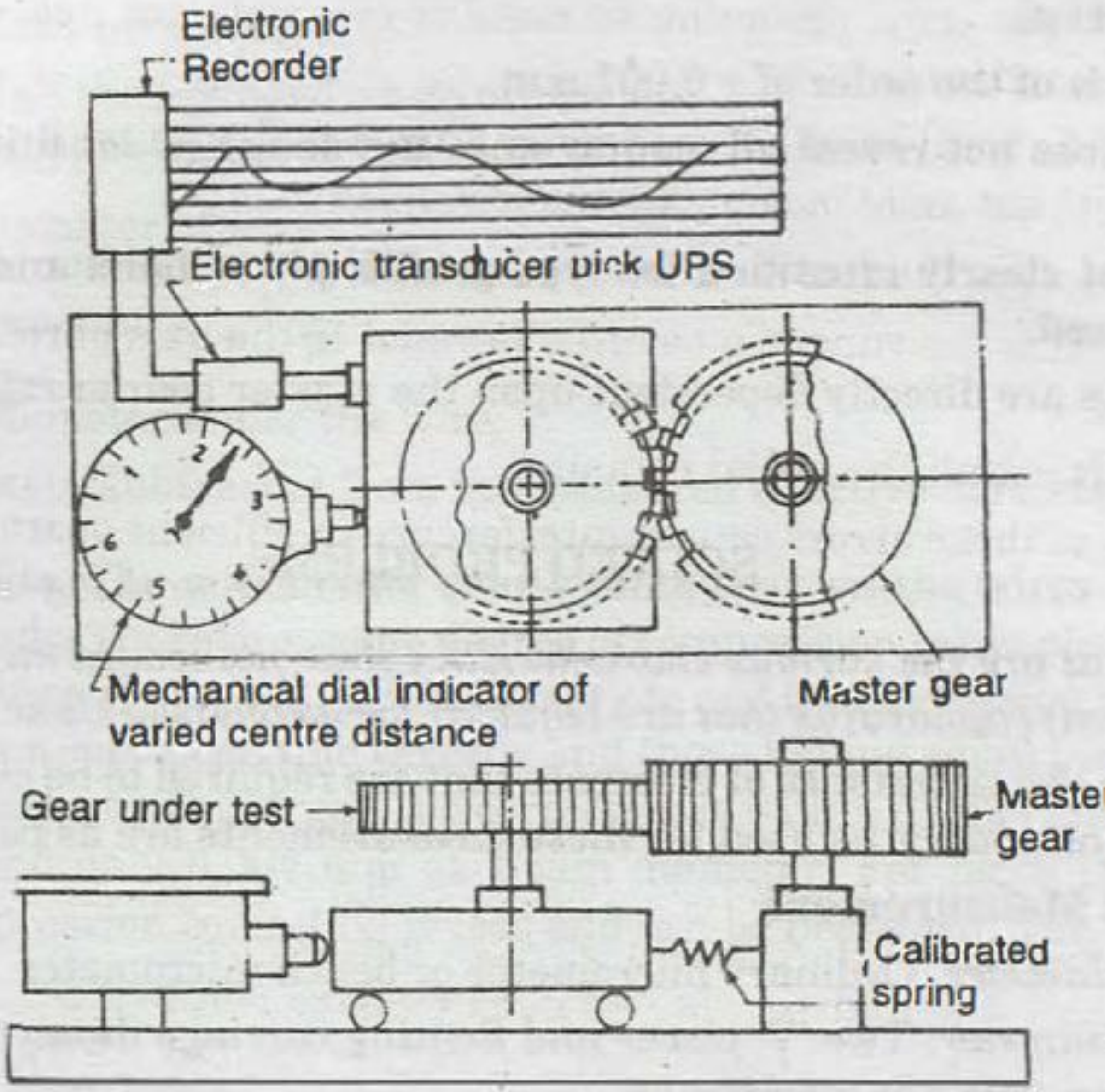


Fig. 6.35. Parkinson Gear Tester