1702ME402 – MEASUREMENTS AND METROLOGY

UNIT IV
FORM MEASUREMENT

Lecture by
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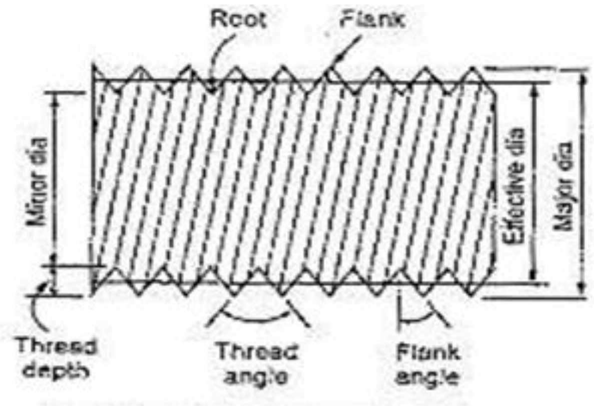
syllabus

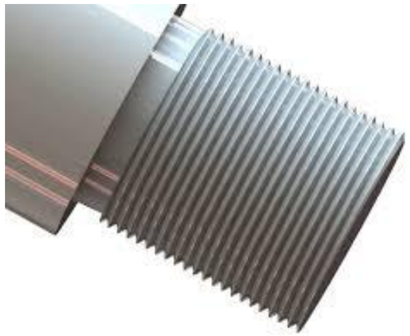
UNIT IV FORM MEASUREMENT 8

- **Thread Measurement:** Terminologies, Errors - External Thread Measurement: Pitch Gauge, Tool Maker's microscope, Floating Carriage micrometer with One, Two and Three wires - Internal Thread Measurement: Taper Parallels and Rollers method.
- **Gear Measurement:** Terminologies, Errors, Gear Tooth Vernier caliper, Profile Projector, Base pitch measuring instrument, David Brown Tangent Comparator, Involutes tester, Parkinson Gear Tester, External and Internal Radius measurements
- **Roundness measurement:** Circumferential confining gauge, Assessment using V block and Rotating centres.

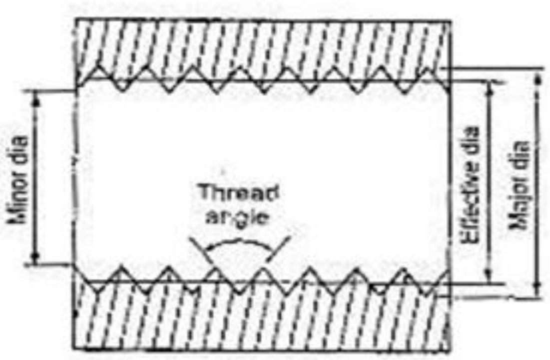
Screw Thread Measurement

- **Introduction:**
- Screw threads are used **to transmit power and motion** and also used to fasten two components with the help of nuts, bolts and studs.
- The screw threads are mainly classified into: **1) External Screw Threads 2) Internal Screw Threads.**



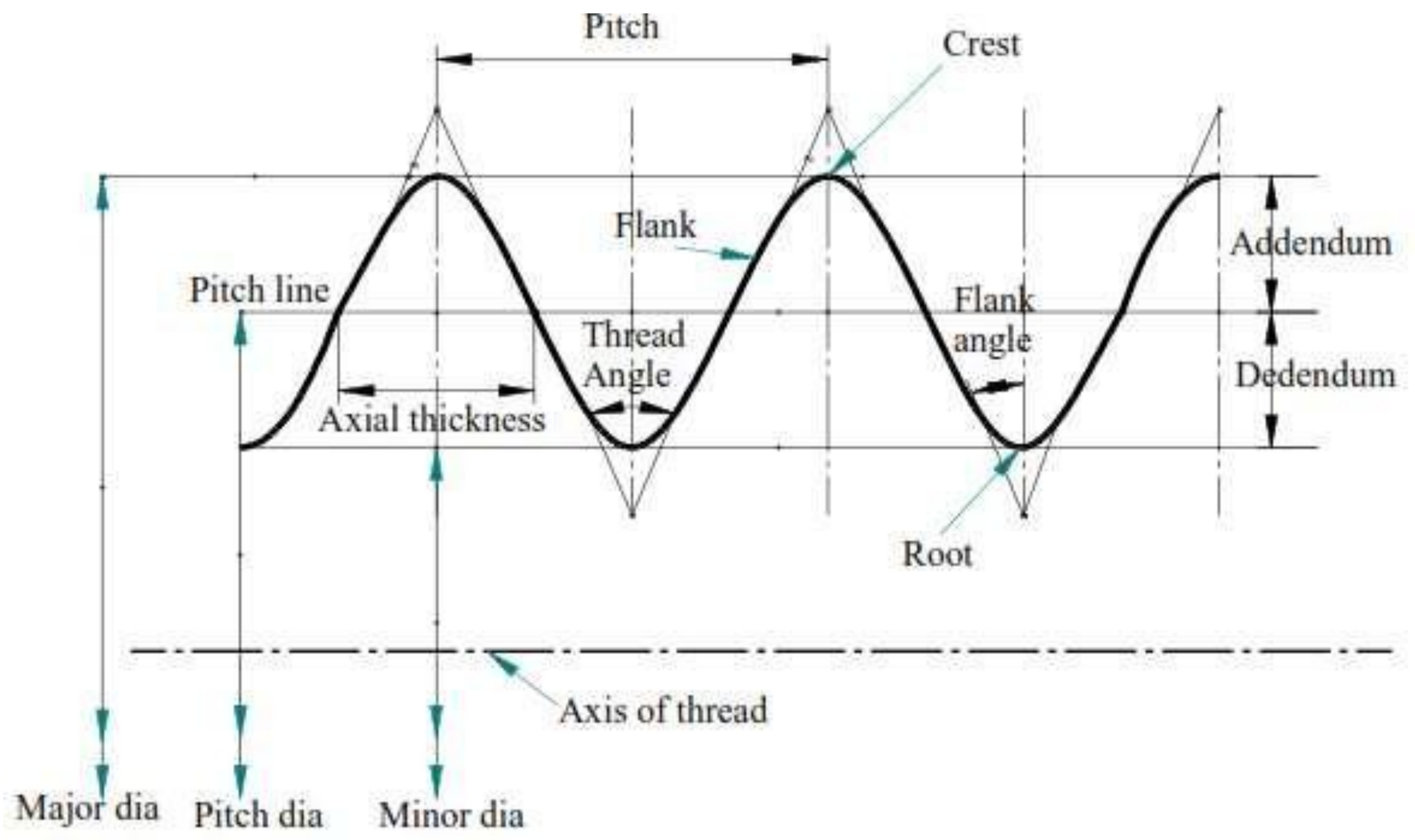


External Screw Threads



Internal Screw Threads

Screw Thread terminologies



1. **Screw Thread:** It is a continuous **helical groove** of specified cross-section produced on the external or internal surface.

2. **Crest:** It is **the top surface** joining two sides of thread.

3. **Root:** The **bottom of the groove** between the two flanks of the thread.

4. **Flank:** It is the surface **between crest and root** or it is the thread surface that connects crest with root.

5. **Lead:** The distance a screw thread **advances in one turn**. For a single start threads, lead=pitch, For double start, lead=2xpitch, & so on.

6. **Pitch**: The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

7. **Helix Angle**: The angle made by the **helix of the thread** at the pitch line with the axis is called as helix angle.

8. **Flank angle:** It is half the included angle of the thread or **angle made by the flank** of the thread with the perpendicular to the thread axis.

9. **Depth of thread:** It is the distance between **crest and root** measured perpendicular to axis of screw.

10. **Angle of thread:** It is the angle included between the flanks of a thread measured in an axial plane.

11. **Major Diameter:** This is the diameter of an imaginary cylinder, co-axial with the screw, which just touches the crests of an **external thread or roots** of an internal threads. It is also called as 'Nominal diameter'.

12. **Minor diameter:** This is the diameter of an imaginary cylinder, co-axial with the screw which just touches the roots of an external thread or the crest of an internal thread. This is also referred to as 'root' or 'core diameter'.

13. **Effective diameter or Pitch diameter:** It is the diameter of an imaginary cylinder coaxial with the axis of the thread and intersects the flanks of the thread such that width of the threads & width of spaces between threads are equal.

14. **Addendum:** It is the distance between the **crest and the pitch line** measured perpendicular to axis of the screw.

15. **Dedendum:** It is the distance between the **pitch line & the root measured** perpendicular to axis of the screw.

Measurement of various elements in Screw Threads

To find out the accuracy of a screw thread it will be necessary to measure the following:

1. Measurement of Major diameter:

a. Ordinary micrometer **b. Bench micrometer.**

2. Measurement of Minor diameter:

a. Using taper Parallels **b. Using rollers**

3. Measurement of Effective diameter:

a. One wire method **b. Two wire method** **c. Three wire method** **d. Using Thread MM**

4. Measurement of Pitch:

a. Pitch Measuring Machine **b. Tool Makers Microscope** **c. Screw Pitch Gauge**

5. Thread angle and form

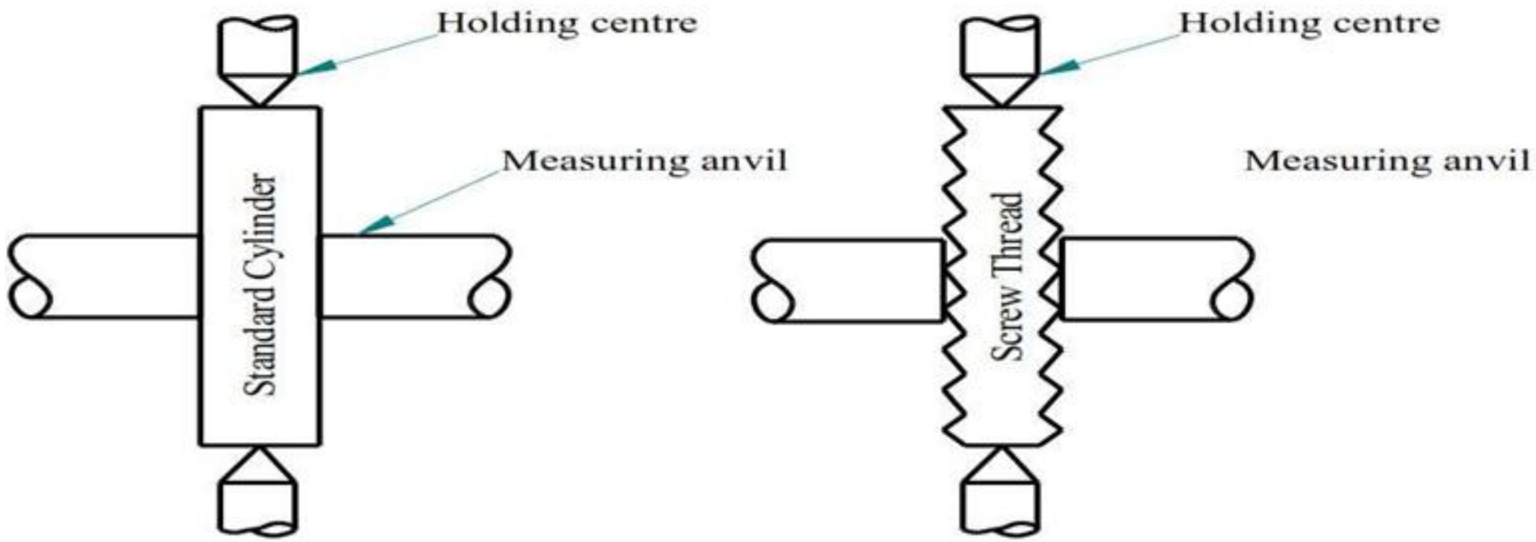
1. Measurement of Major diameter

Measurement Processes

a. Ordinary micrometer
b. Bench micrometer

i) Ordinary Micrometer:

- In this the micrometer is used as a comparator.
- This micrometer is first set over the cylinder standard having approx. same dimension.
- This standard is called **setting gauge.**



After taking this reading 'R_1' the micrometer is set on the major diameter of the thread, and the new reading is 'R_2' and then the diameter is measured by following equation:.

Then the major diameter, $D=S \pm (R_1 - R_2)$

S = Size of setting gauge

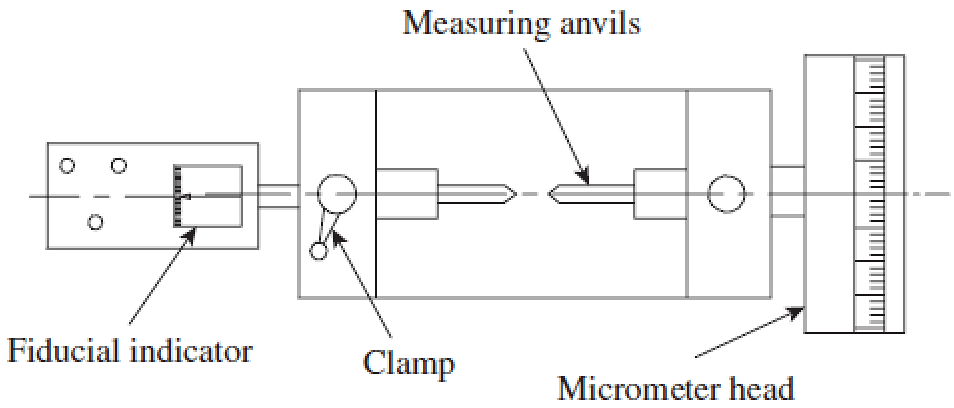
R_1 = Micrometer reading over setting gauge.

R_2 = Micrometer reading over thread.

- This micrometer is used gently during reading because their might come error by applying extra force which will form deformation of crest of the thread

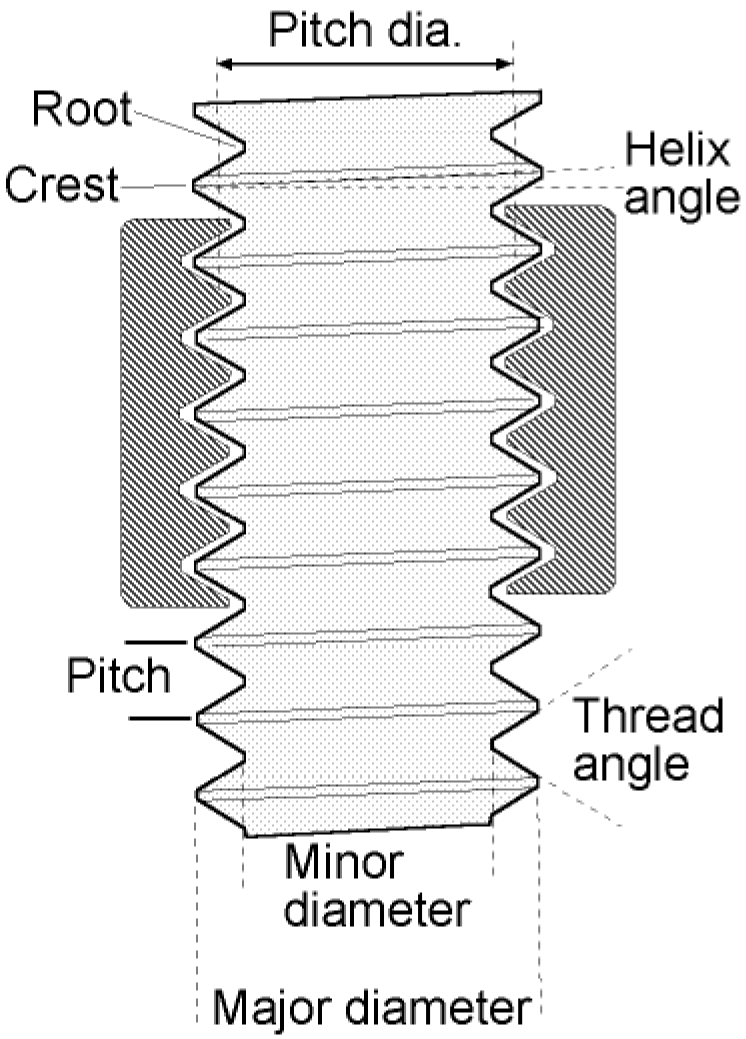
ii) Measurement by Bench micrometer:

- Bench micrometer is designed by the NPL to remove deficiencies inherent in the hand micrometer.
- In this the fiducial micrometer is used to ensure that all the readings are taken at the same pressure.
- The instrument has a micrometer head having Vernier scale to read to the accuracy of 0.002mm.
- This instrument is also used as the comparator to avoid the pitch errors of micrometer threads, zero error setting etc.
- Then the process is same as of the ordinary micrometer. Calibrated setting cylinder having the same diameter as the major diameter of the thread to be measured is used as setting standard.
- After setting the standard, the setting cylinder is held between the anvils and the reading is taken.
- Then the cylinder is replaced by the threaded work piece and the new reading is taken.



2. Measurement of Minor diameter

Minor diameter is the imaginary diameter of thread which would **touch the roots** of the external and crest of the internal threads.



For measuring minor diameter of **external threads** following methods are used:

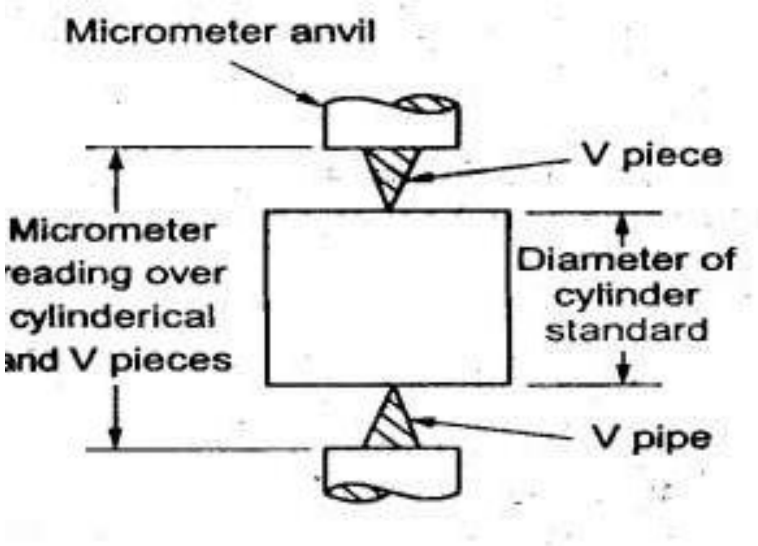
1. Two V pieces method
2. By projecting the thread on the screen

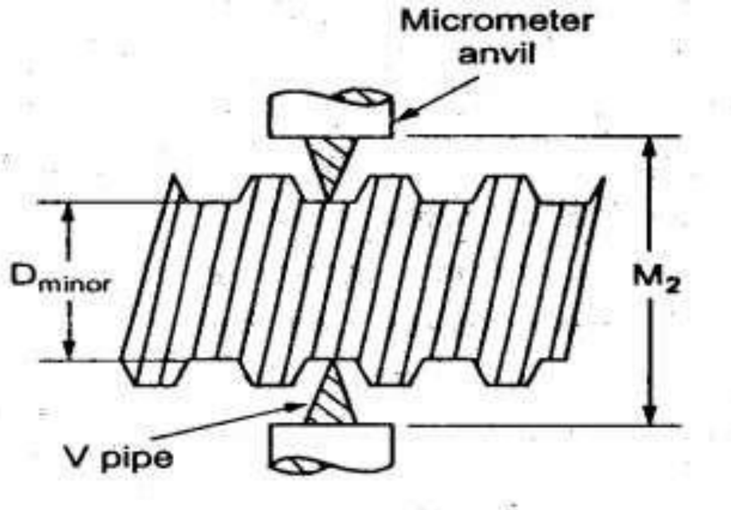
For measuring minor diameter of **internal thread** following methods are used:

1. Using taper parallels
2. By using rollers and slip gauges

V pieces method

- The minor diameter is measured by a comparative method by using **floating carriage diameter measuring machine** and small **'V' pieces** which make contact with the root of the thread.
- These V pieces are made in several sizes, having suitable radii at the edges. V pieces are made of **hardened steel**.
- The floating carriage diameter-measuring machine is a bench micrometer mounted on a carriage.





Measurement Process:

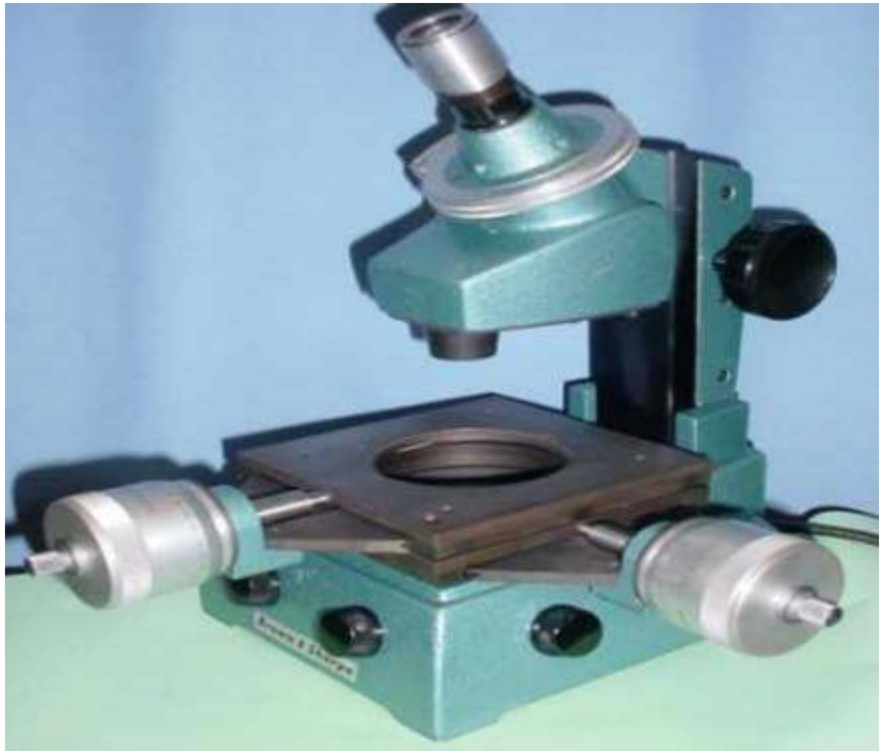
- The threaded work piece is mounted between the centres of the instrument and the V pieces are placed on **each side of the work piece** and then the reading is noted.
- After taking this reading the work piece is then replaced by a standard reference cylindrical **setting gauge**.
- The minor diameter of the thread = $D \pm (R_2 - R_1)$
- Where, D = Diameter of cylindrical gauge

R_2 = Micrometer reading on threaded workpiece,

R_1 = Micrometer reading on cylindrical gauge.

By projecting thread on screen

- If the threads are very sharp or have no radius at the root.
- The measurement of minor diameter is done by projecting the thread form on a screen.
- This projected form is compared with the use of the Tool Makers Microscope.

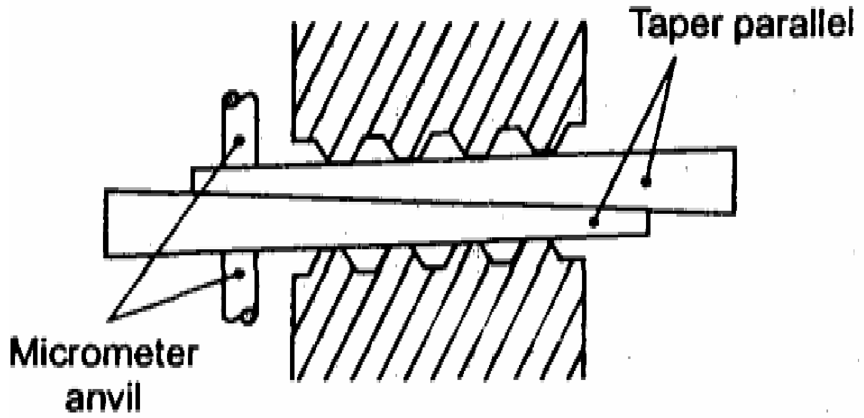


For measuring minor diameter of internal thread:

a. Using taper Parallels b. Using rollers

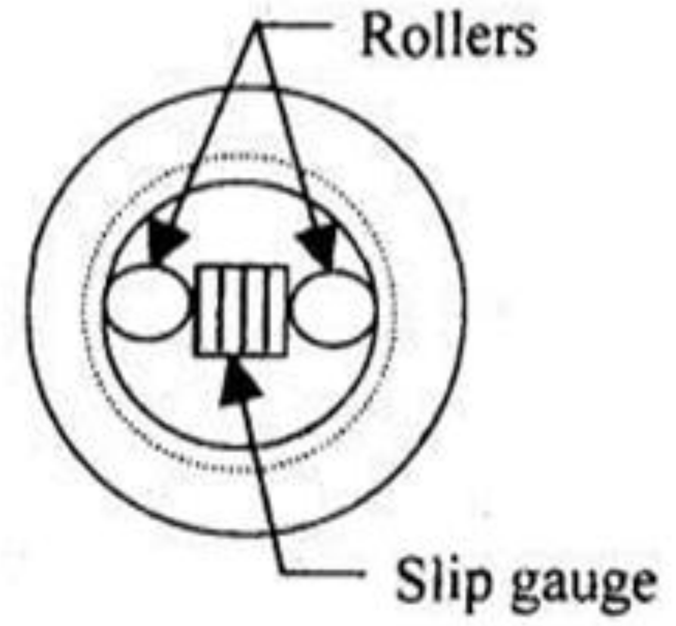
Using taper Parallels

- For the internal thread of the **minor diameter of diameter less than 200mm is** measured using the taper parallels.
- The taper parallels are the pairs of the wedges having parallel outer edges.
- The taper parallels are inserted inside the thread and adjusted **until firm contact is** not established with the minor diameter.
- Then the diameter of the outer edges of the taper parallels is measured **using the micrometer.**



2. Using Rollers:

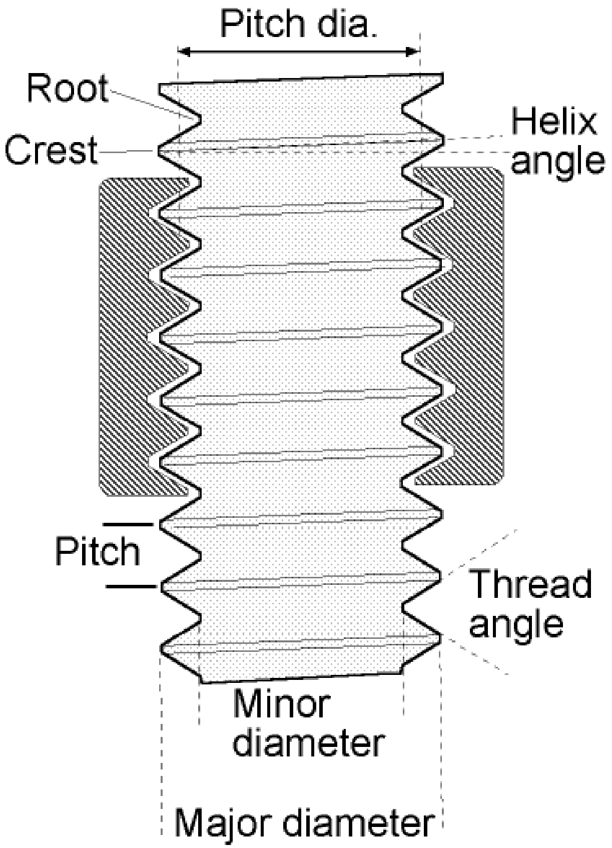
- For **more than 200mm diameter** this method is used.
- Precision rollers are inserted inside the thread and proper slip gauge is inserted between the rollers.
- The minor diameter is then the length of slip gauges plus twice the diameter of roller.



3. Measurement of Effective diameter

- Effective diameter is the imaginary diameter in **between major and minor diameter.**
- The effective diameter measurement is carried out by the following methods.

1. **Wire Methods**
2. **Thread Micrometer**



3. Measurement of Effective diameter – Wire Method

- The effective diameter measurement is carried out by the following methods.

1. One Wire Method 2. Two Wires Method 3. Three Wires Method

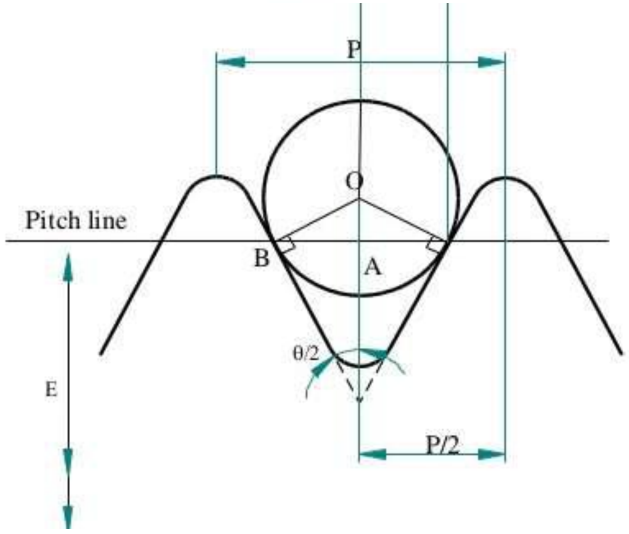
- This methods are based on the **size of the wire.**

- The size of the wire whose diameter **makes the contact** with **the flank of the thread on the effective diameter** this size of wire is known as **Best Size of Wire.**

- This size is decided by the following equation:

$$d = \frac{p}{2} sec\theta$$

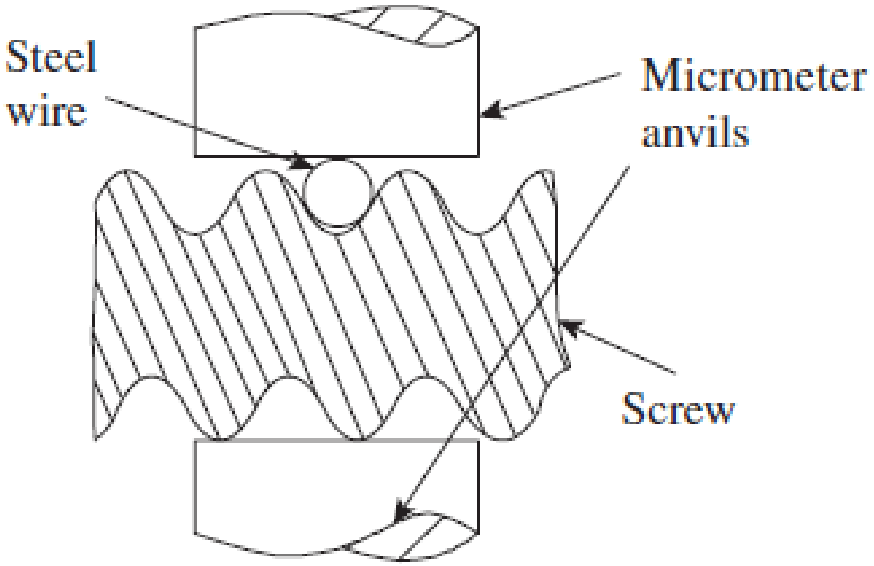
Where p= pitch and θ= thread angle



One Wire Method

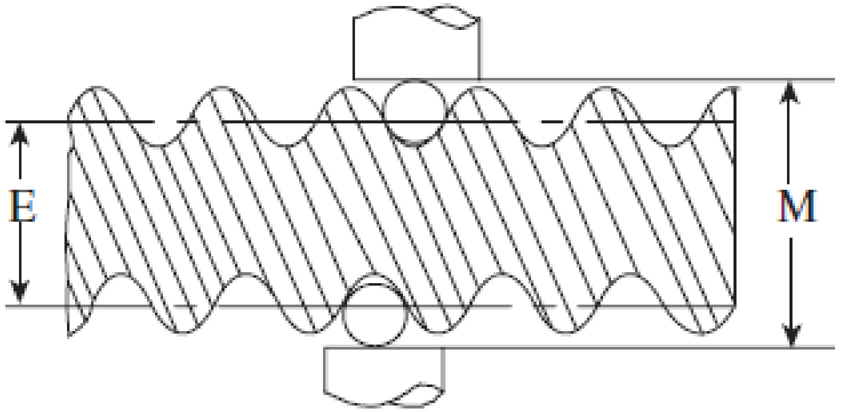
- In this method, **only one wire is** used. The wire is placed between the two threads at one side and on the other side the anvil of the measuring micrometer contacts the crests.
- First, the micrometer reading 'd_1' is noted on a **standard gauge** whose dimension is approximately same to be obtained by this method.
- Now, the setting gauge is replaced by thread and the new reading is taken i.e. 'd_2' then effective diameter **$D = S \pm (d_1 - d_2)$**.

  Where, S = Size of setting gauge.
- Actual measurement over wire on one side and threads on other side = **size of gauge ± difference in two micrometer readings.**

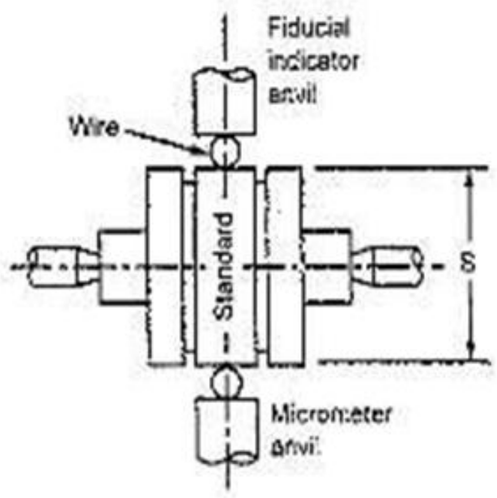


Two Wire Method

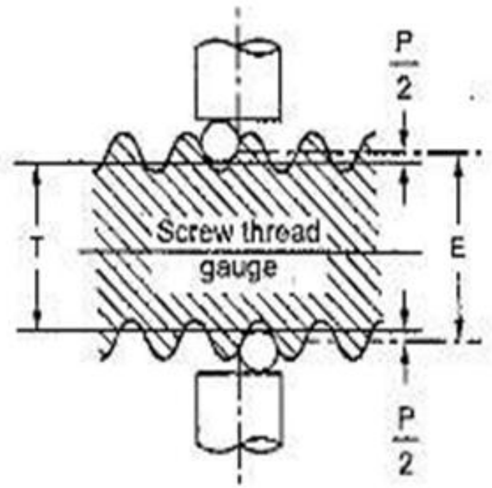
- The effective diameter can not be measured directly but can be calculated from the measurements made.
- In this method, **wires of exactly known diameters** are chosen such that they contact the **flanks** at their straight portions.
- If the size of the wire is such it contacts the flanks at the pitch line, it is called the **'best size'** of wire which can be determined by geometry of screw thread.
- The screw thread is mounted between the centers & wires are placed in the grooves and reading M is taken.



Measuring Process



(a) First operation



(b) Second operation

- Effective diameter E is calculated by **E = T + P**

  Where, T = Dimension under the wires = **M - 2d**

  M = Dimension over the wires

  d = Diameter of each wire

  P = Compensating factor should be added to T value and it depends on diameter of **wire, pitch & angle** of the screw thread.

- Here, The diameter under the wires 'T' can also be determined by,

  $T = S - (R_1 - R_2)$

Where, S = The diameter of the standard.

R_1 = Micrometer reading over standard and wires.

R_2 = Micrometer reading over screw thread and wires

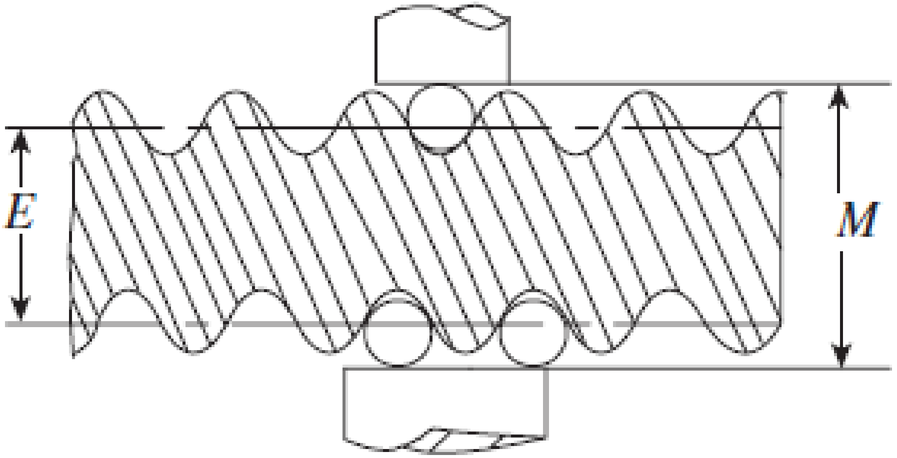
P = 0.866 *p* - d => For metric thread.

P = 0.9605 *p* - 1.1657 d => For Whitworth thread.

Where, *p* = Pitch

Three Wire Method

- The three-wire method is the accurate method.
- In this method, three wires of equal and precise diameter are placed in the grooves at opposite sides of the screw.
- In this, **one wire on one side and two on the other side** are used.
- The wires either may be held in hand or hung from a stand. This method ensures the alignment of micrometer anvil faces parallel to the thread axis.



Case i) In case of Whitworth Thread:

$$M = D + 3.1657d - 1.6p$$

where, D = Outside Diameter

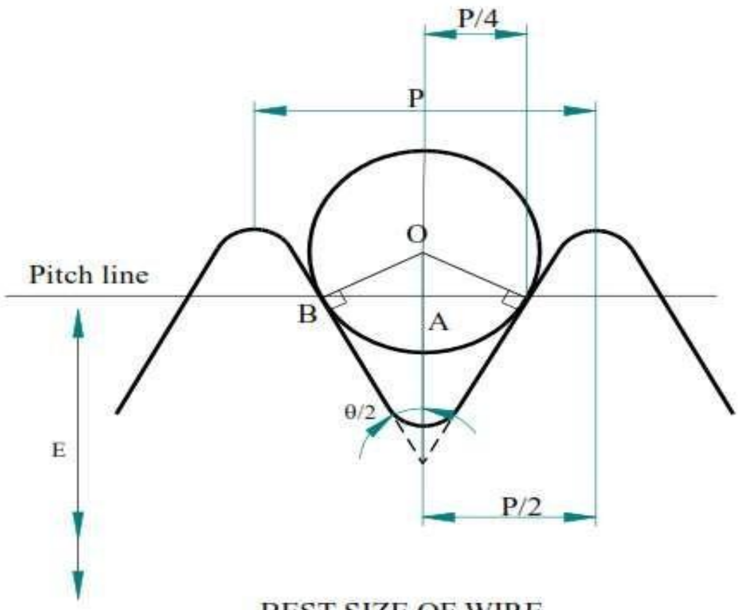
Case ii) In case of Metric Thread:

$$M = D + 3d - 1.5155p$$

We can practically measure the value of M & then compare with the theoretical values using the formula derived above. After finding the correct value of M, as d is known, E can be found out.

Best Size Wire:

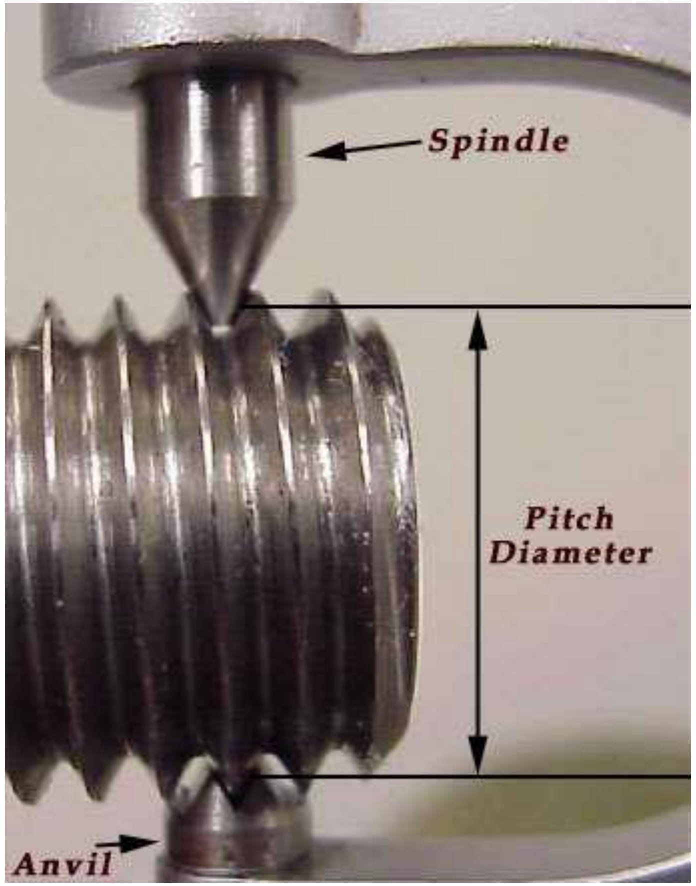
- Best size wire is one in which, the wire is having such a **diameter that it makes contact with the flanks of the thread** on the effective diameter or pitch line.
- It is recommended that for measuring the effective diameter, always the best size wire should be used and for this condition the **wire touches the flank** at mean diameter line within ±1/5 of flank length.



BEST SIZE OF WIRE

Effective Diameter Measurement

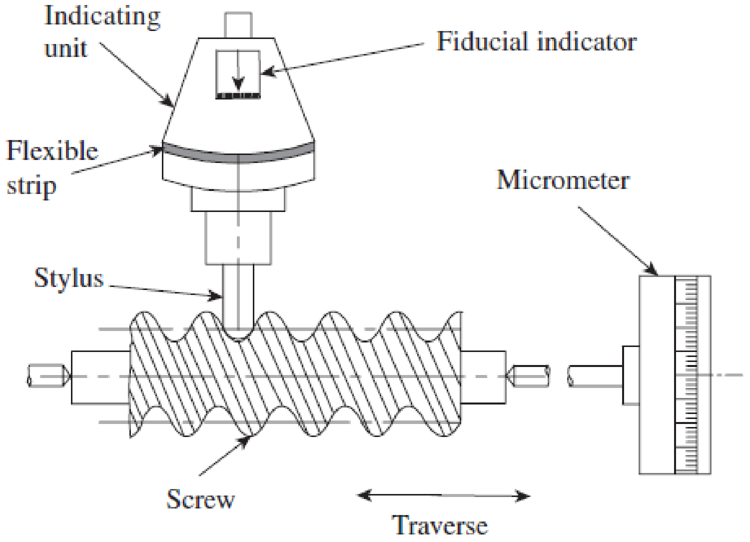
- This method is simple and rapid.
- The thread micrometer is same as ordinary micrometer except that it has special contact points to suit the end screw threads form that is to be checked.
- The contact points are selected on the basis of the types of the thread and the pitch of the thread to be measured.
- Then the anvils are then made to contact the thread to be checked and the reading is taken, which will give the pitch diameter or effective diameter.
- In this the actual reading is the
- measurement of the major diameter on one side and minor diameter of the other side which gives us the effective diameter.
- If the thread is of the whithworth thread the relation between the outer diameter and the pitch is as follow: $\mathbf{E} = D - 0.6403p$



4. Pitch Measurement

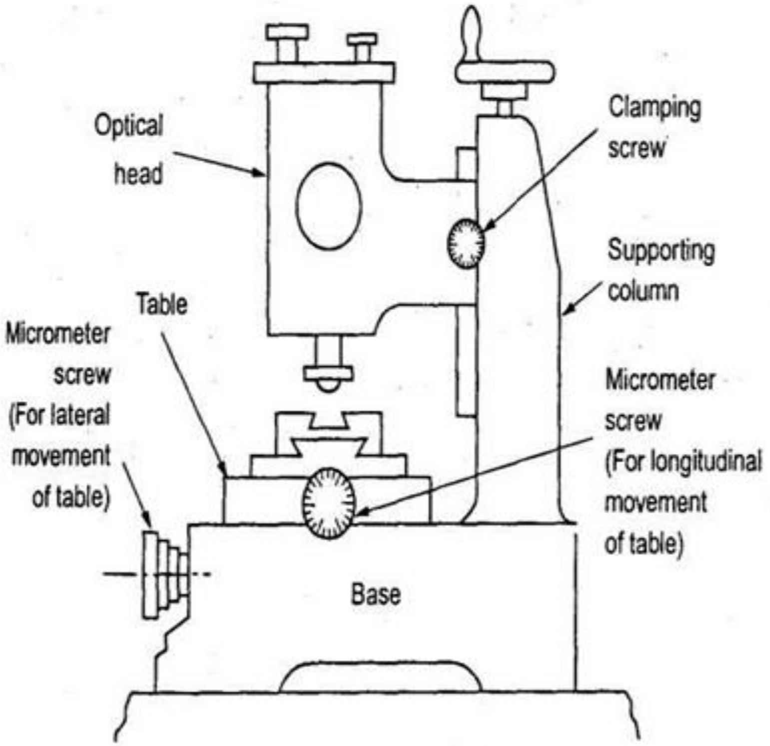
i) Pitch Measuring Machine:

- ✓ The principle of this method of measurement is to move the **stylus** along the screen parallel to the axis from one space to the next.
- ✓ The pitch-measuring machine provides a relatively simple and accurate method of measuring the pitch.
- ✓ Initially, the **micrometer** reading is set near the **zero** on the scale.
- ✓ Spring loaded head permits the stylus to move up the flank of the thread and down into the next space as it is moved along.
- ✓ Accurate positioning of the stylus between the two flanks is obtained by ensuring that the pointer T is always opposite to its index mark when readings are taken.
- ✓ When the pointer is accurately placed in position, the micrometer reading is noted.
- ✓ The stylus is then moved along into the next thread space, by rotation of the micrometer, and a second reading taken.
- ✓ The **difference between the two readings** is the pitch of the thread.
- ✓ Readings are taken in this manner until the whole length of the screw thread has been covered.



ii. Tool Makers Microscope:

- Worktable is placed on the base of the instrument.
- The **optical head** is mounted on a vertical column it can be moved up and down.
- Work piece is mounted on a glass plate.
- A **light source** provides horizontal beam of light which is reflected from a mirror by **90 degree upwards** towards the table.
- Image of the outline of contour of the work piece passes through the objective of the optical head.
- The image is projected by a system of three prisms to a ground glass screen.
- The measurements are made by means of **cross lines** engraved on the ground glass screen.
- The screen can be rotated through 360°.
- Different types of graduated screens and eyepieces are used.



Applications:

1. Linear measurements.

2. Measurement of pitch of the screw.

3. Measurement of pitch diameter.

4. Measurement of thread angle.

5. Comparing thread forms.

6. Centre to center distance measurement.

iii. Screw pitch gauge:

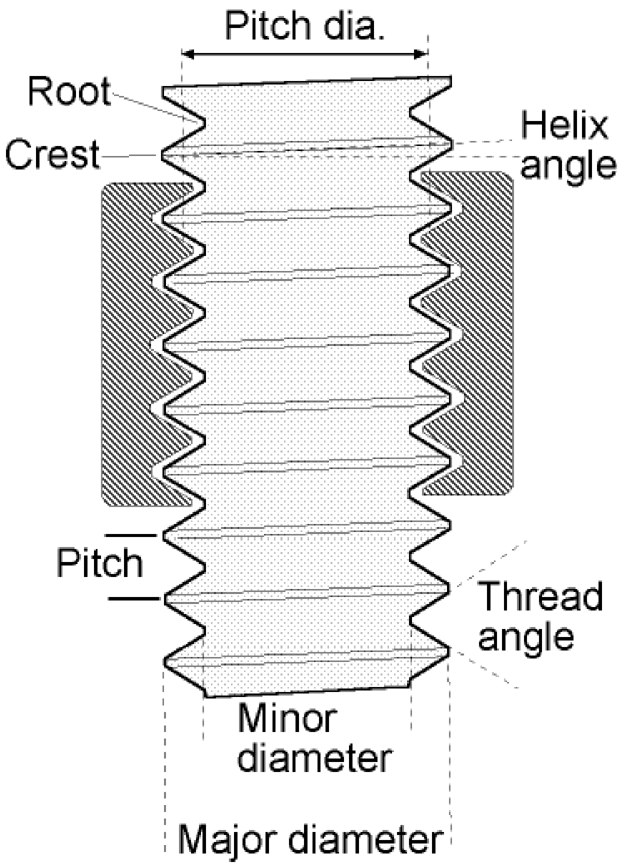
- It is used to directly compare the pitch by just selecting the proper pitch value entered in the pitch gauge and comparing it with the actual screw thread.

5. Flank Angle and Thread form Measurement

Flank angle

- **Flank Angle** is the angle formed by **a flank and a perpendicular to the thread axis in an axial** plane.
- It is also called the **half thread angle.**
- For this measurement we have to **measure the thread angle.**
- To measure the thread angle the following methods is used:

1. Optical Projection



5. Thread form and flank angle Measurement

Thread form

- The ideal and actual forms are compared for the measurement.
- Types of **thread gauges** are,
- **1. Plug Screw Gauge** **2. Ring Screw Gauge** **3. Caliper Screw Gauge**

Errors in Screw Threads

The error in screw thread may arise during the manufacturing or storage of threads. The error either may cause due to the following six main elements in the thread.

1. Major diameter error **2. Minor diameter error** **3. Effective diameter error**
4. Pitch error **5. Flank angles error** **6. Crest and root error**

1. Major diameter error

It may cause reduction in the **flank contact** and interference with the matching threads.

2. Minor diameter error

It may cause interference, reduction of flank contact.

3. Effective diameter error

If the effective diameter is small the threads will be thin on the external screw and thick on an internal screw.

4. Pitch error

Pitch error is defined as the total length of thread engaged either too high or too small. The various pitch errors may be classified into

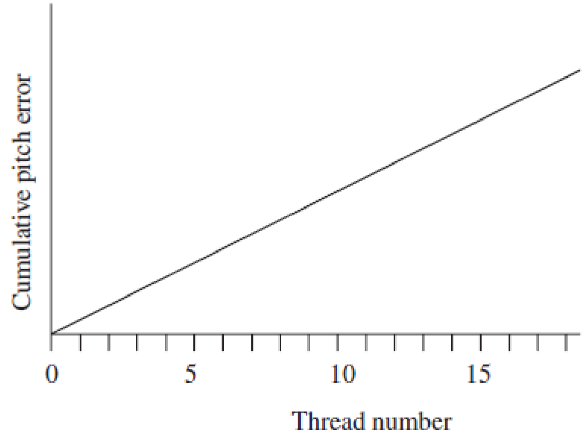
1. Progressive error 2. Periodic error. 3. Drunken error 4. Irregular error.

i) Progressive Pitch error:

The pitch of the **thread is uniform** but is longer or shorter its nominal value and this is called progressive error. This error occurs whenever the **tool–work velocity ratio is incorrect but constant**.

Causes of Progressive error:

1. Incorrect linear and angular velocity ratio.
2. Incorrect gear train and lead screw.
3. Saddle fault.
4. Variation in length due to hardening.

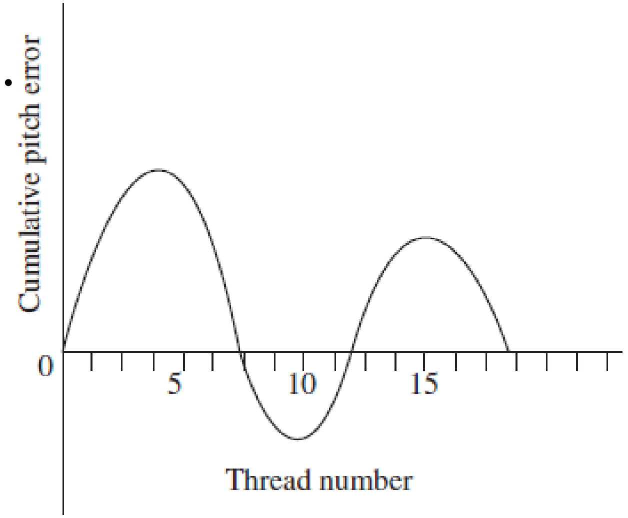


ii) Periodic Pitch error:

In this the pitch error causes the errors to **repeat at certain time** of interval. when the **tool–work velocity ratio is not constant**.

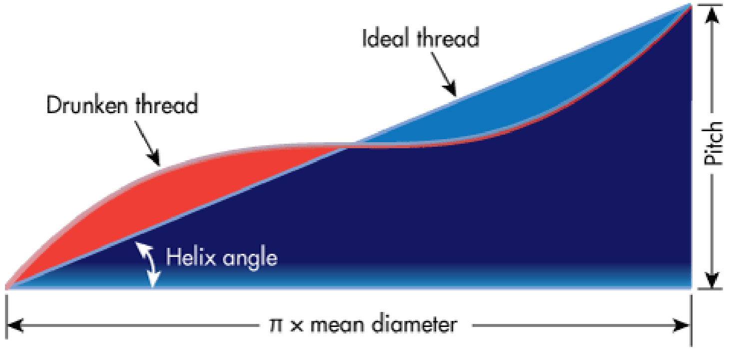
Causes of Periodic error:

1. Un-uniform tool work velocity ratio.
2. Teeth error in gears.
3. Lead screw error.
4. Eccentric mounting of the gears.



(iii) Drunken error:

It is error due to the **irregular form of helical groove** on a cylindrical surface. In this case pitch measured parallel to the axis is always same, but problem is with the thread is not cut to its true helix. Due to this flank surface will not be as a straight edge, it will be as curved form.



(iv) Irregular error:

These are the errors randomly take place on threads without any specific reason.

Causes of Irregular error:

1. Machine fault.
2. Non-uniformity in the material.
3. Cutting action is not correct.
4. Machining disturbances.

Effect of pitch error:

1. It increases the effective diameter of the bolt and decreases the diameter of nut.
2. The functional diameter of the nut will be less.
3. It reduces the clearance.
4. It increases the interference between mating threads.

Gear Measurements

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

1.Spur gear

Cylindrical gear whose tooth traces is straight line.

These are used for transmitting power between parallel-shafts.

2.Spiral gear

The tooth of the gear traces is in the form of curved lines.

3. **Helical gears**

These gears are used to transmit the power between parallel shafts as well as non-parallel and non-intersecting shafts. It is a cylindrical gear whose tooth traces is straight line.

4. **Bevel gears**

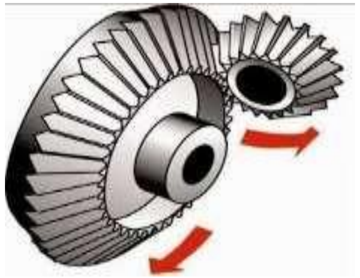
The tooth traces are straight-line generators of cone. The teeth are cut on the conical surface. It is used to connect the shafts at right angles.

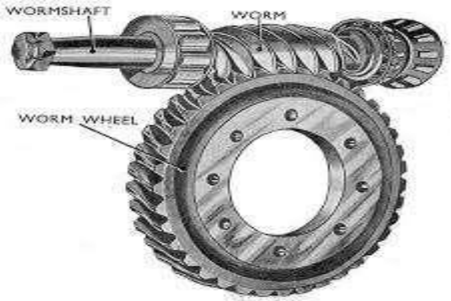
5. **Worm and Worm wheel**

It is used to connect the shafts whose axes are non-parallel and non-intersecting.

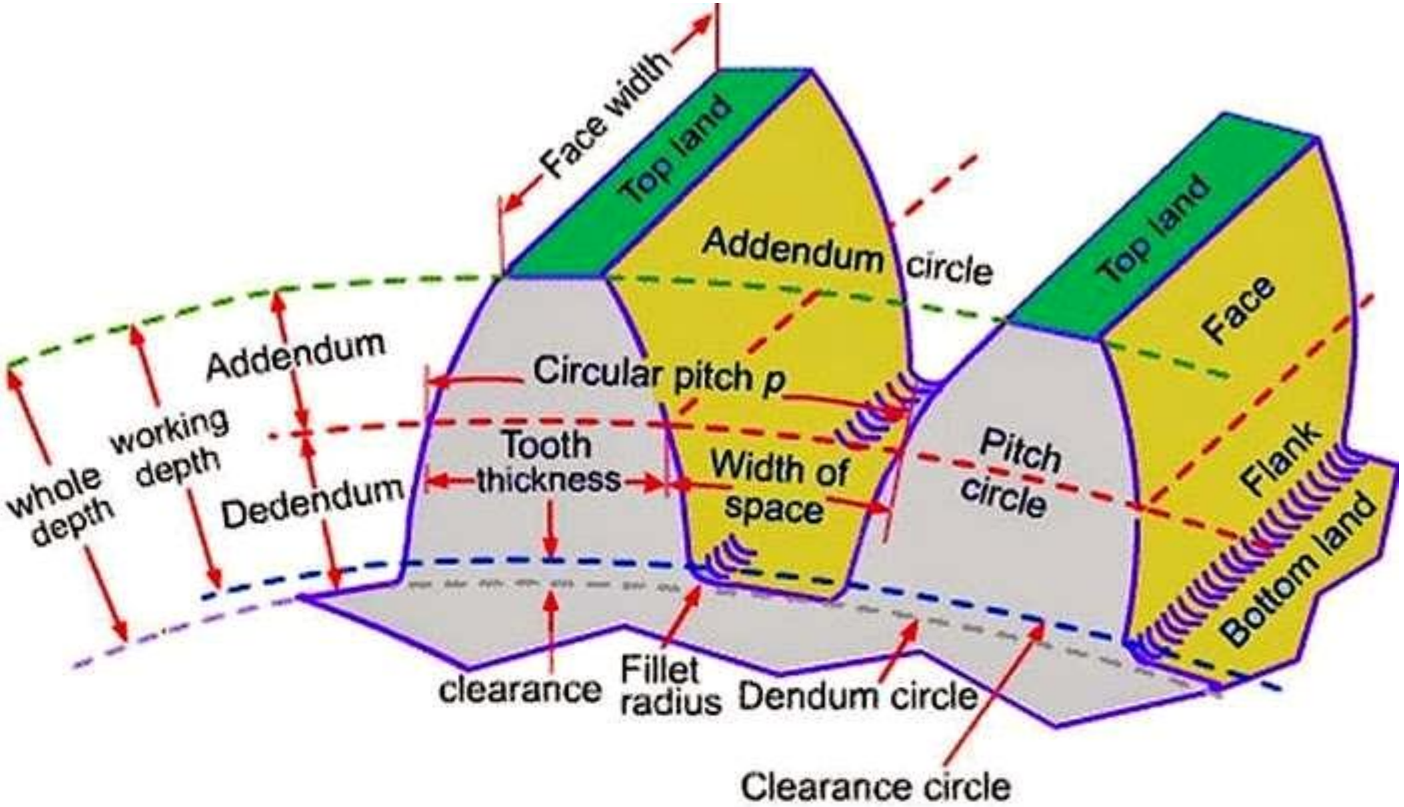
6. **Rack and Pinion**

Rack gears are straight spur gears with infinite radius.





Elements of Spur Gear



Spur Gear Terminology

1. **Tooth Profile:** It is the shape of any side of gear tooth in its cross section.
2. **Base circle:** It is the circle of gear from which the involute profile is derived. Base circle diameter = Pitch circle diameter x Cosine of pressure angle of gear
3. **Pitch circle diameter (PCD):** It is the diameter of a circle which will produce the same motion as the toothed gear wheel.
4. **Pitch circle:** It is the imaginary circle of gear that rolls without slipping over the circle of its mating gear.
5. **Addendum circle:** The circle that coincides with the crests (or) tops of teeth.
6. **Dedendum circle (or) Root circle:** This circle that coincides with the roots (or) bottom of teeth.
7. **Pressure angle (α):** It is the angle made by the line of action with the common tangent to the pitch circles of mating gears.
8. **Module (m):** It is the ratio of pitch circle diameter to the total number of teeth. m = $\frac{d}{n}$

Where, d = Pitch circle diameter, n =Number of teeth.

9. **Circular pitch:** It is the distance along the pitch circle between corresponding points of adjacent teeth.

$$P_c = \frac{\pi d}{n} = \pi m$$

10. **Diametral pitch (Pd):** Number of teeth per inch of the PCD.

$$P_d = \frac{n}{d} = \frac{1}{m}$$ Where, m = Module

11. **Addendum:** It is the radial distance between tip circle and pitch circle.

Addendum value = 1 module.

11. **Dedendum:** It is the radial distance between pitch circle and root circle.

Dedendum value=1.25 module.

13. **Clearance(c):** The distance covered by the tip of one gear with the root of mating gear.

Clearance = Difference between Dedendum and addendum values.

14. **Blank diameter:** It is the diameter of the blank upto outer periphery.

Blank diameter = PCD+2m

9. **Face:** It is the part of the tooth in the axial plane lying between tip circle and pitch circle.

10. **Flank:** It is the part of the tooth lying between pitch circle and root circle.

11. **Helix angle:** It is the angle between the tangents to helix angle.

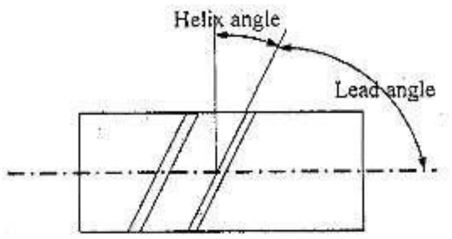
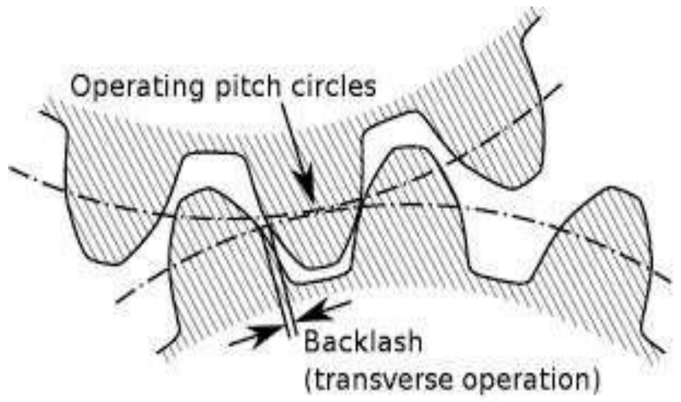


Fig. 3.27 (a). Helix angle

12. **Top land:** Top surface of a tooth is called as top land.

13. **Lead angle:** It is the angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

14. **Backlash:** It is the difference between the tooth thickness and the space into which it meshes. If we assume the tooth thickness as 't_1' and width 't_2' then



$$\text{Back lash} = t_2 - t_1$$

Errors in Gear

1. **Profile error:** The maximum distance is at any point on the tooth profile form to the design profile.
2. **Pitch error:** It is the difference between actual and design pitch.
3. **Cyclic error:** Error occurs in each revolution of gear.
4. **Run out:** Total range of a fixed indicator with, the contact points applied to a surface rotated, without axial movement, about a fixed axis.
5. **Eccentricity:** It is the half radial run out.
6. **Wobble:** Run out is measured parallel to the axis of rotation at a specified distance from the axis.
7. **Radial run out:** Run out is measured along a perpendicular to the axis of rotation.
8. **Undulation:** It is the periodical departure of the actual tooth surface from the design surface.
9. **Axial run out:** Run out is measured parallel to the axis of rotation at a speed.
10. **Periodic error:** Error occurs at regular intervals.

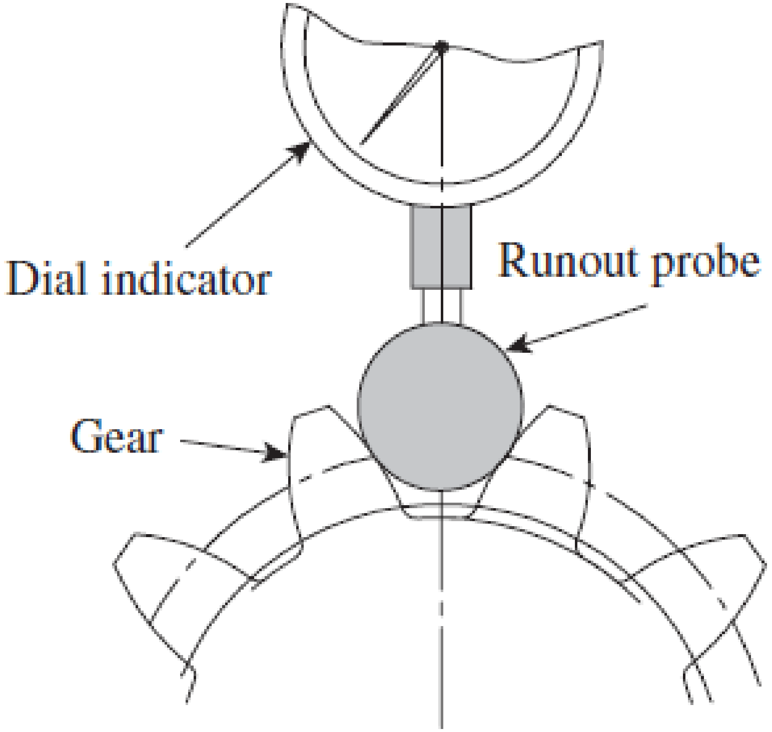
Spur Gear Measurement

The inspection of the gears consists of the following elements in which manufacturing **error** may be present.

1. **Runout**
2. **Pitch**
3. **Profile**
4. **Lead**
5. **Backlash**
6. **Tooth thickness**

1. Measurement of Runout

- the run out is an amount a gear moves **in and out away** from it true centre as it is rotated.
- If runout is excessive, the **gear wobbles** as it rotates. Runout is also the eccentricity in the pitch circle of gear.
- Gears that are eccentric tend to have **vibration** per revolution.
- It may cause an abrupt gear failure.
- The gear is held on a mandrel in the centers and the dial indicator of the tester holds a special tip descending upon the module of gear being tested.
- The tip is inserted between the tooth spaces and dial indicator reading is noted.
- The gear is rotated tooth by tooth and dial readings are recorded the maximum variation is noted from the dial indicator reading and that gives the run out of the gear



2. Measurement of Pitch

Pitch is the distance between **corresponding points** on equally spaced and adjacent teeth. Pitch error is the difference in distance between equally spaced adjacent teeth and the measured distance between any two adjacent teeth.

There are two ways for measuring the pitch.

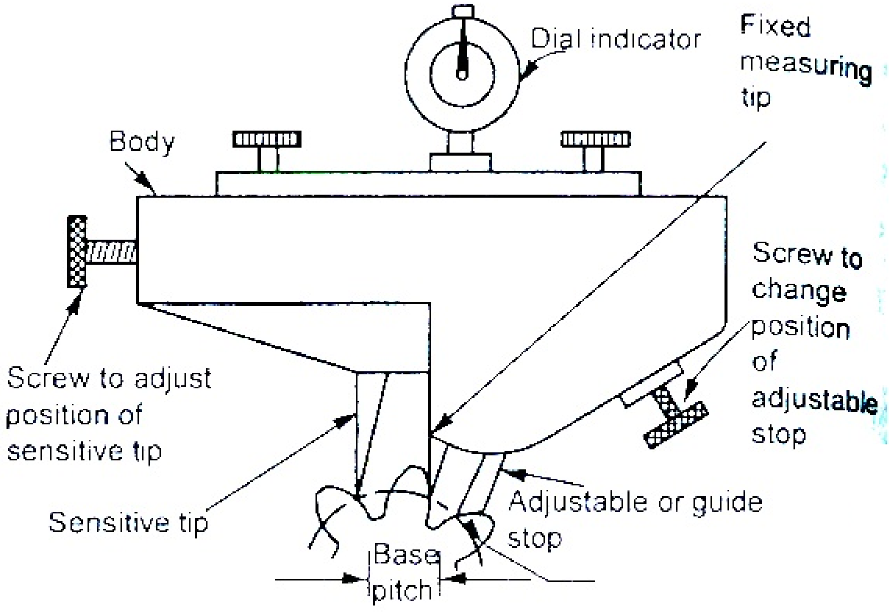
a) **Point to point measurement (i.e. One tooth point to next tooth point)**

b) **Direct angular measurement**

2. Measurement of Pitch

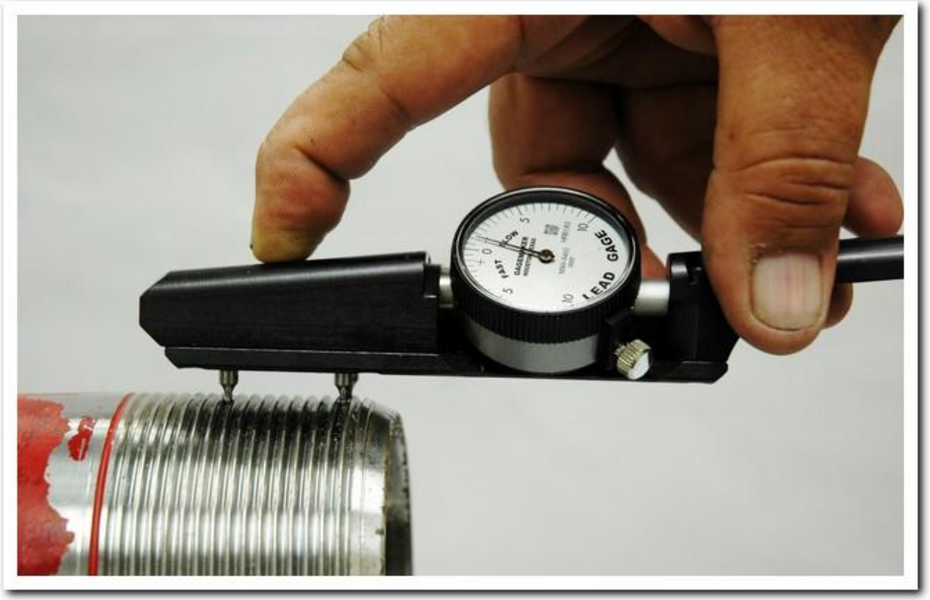
a) Tooth to Tooth measurement:

The instrument has three tips. One is fixed measuring tip and the second is sensitive tip, whose position can be adjusted by a screw and the third tip is adjustable or guide stop. The distance between the fixed and sensitive tip is equivalent to base pitch of the gear. All the three tips are made in contact with the tooth by setting the instrument and the reading on the dial indicator is the error in the base pitch.



b) Direct Angular Measurement:

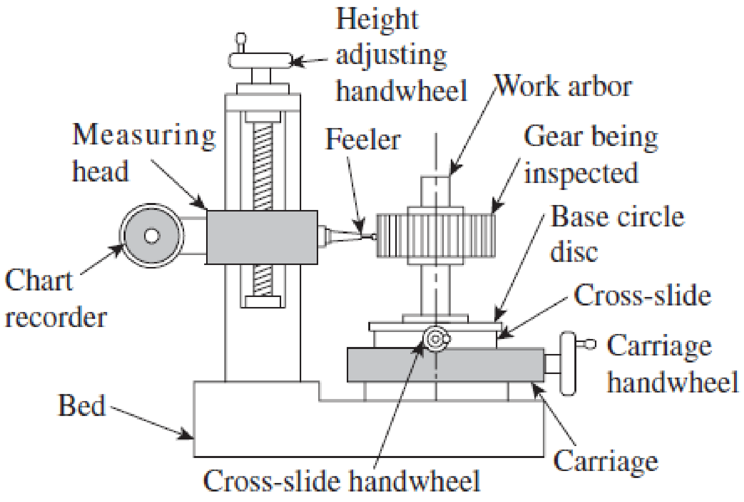
It is the simplest method for measuring the error by using set dial gauge against a tooth. In this method, the position of a suitable point on a tooth is measured after the gear has been indexed by a suitable angle. If the gear is not indexed through the angular pitch the reading differs from the original reading. This difference is the cumulative pitch error.



3. Measurement of Profile

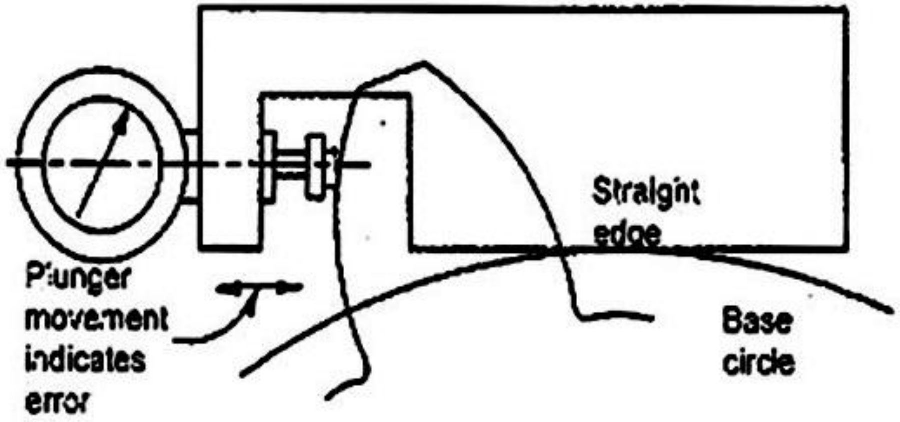
i. Optical projection method:

The profile of the gear is projected on the screen by optical lens and then the projected value is compared with master profile.



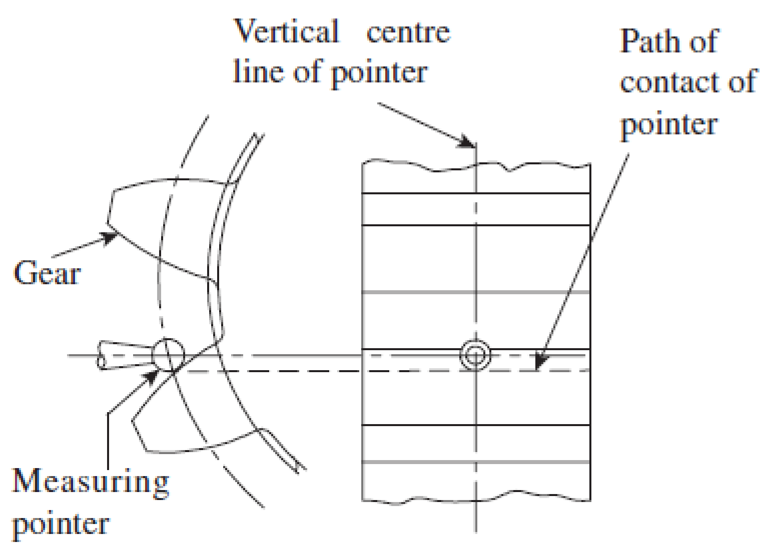
ii. Involute measuring machine:

In this method, the gear is held on a mandrel and circular disc of same diameter as the base circle of gear for the measurement is fixed on the mandrel. After fixing the gear on the mandrel, the straight edge of the instrument is brought in contact with the base circle of the disc. Now, the gear and disc are rotated and the edge moves over the disc without slip. The stylus moves over the tooth profile and the error is indicated on the dial gauge.



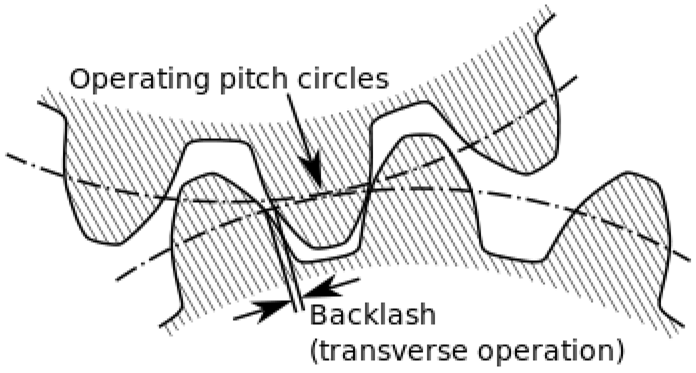
4. Measurement of Lead

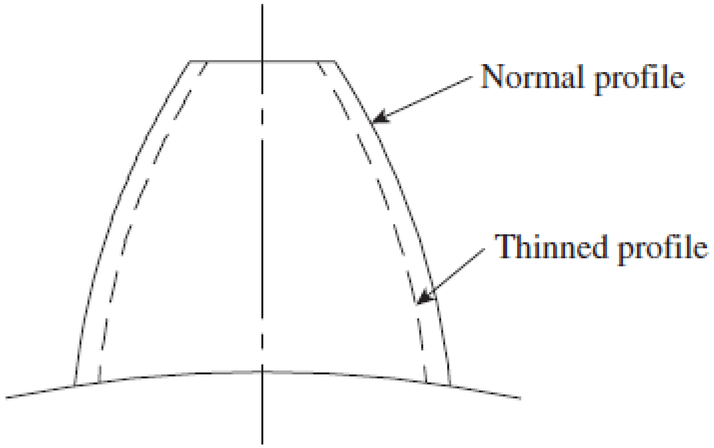
- Actually, lead is the **axial advance** of a helix for one complete turn.
- A measuring pointer traces the tooth surface at the pitch circle and parallel to the axis of the gear.
- The measuring pointer is mounted on a slide, which travels parallel to the centre on which the gear is held. The measuring pointer is connected to a dial gauge or any other suitable comparator, which continuously indicates the deviation.
- The total deviation shown by the dial indicator over the distance measured indicates the amount of displacement of the gear tooth in the face width traversed.
- Measurement of lead is more important in helical and worm gears. Interested readers are advised to refer to a gear handbook to learn more about the same.



5. Measurement of Backlash

- The **play** between the mating tooth surfaces is called a backlash.
- We can define backlash as the amount by which a tooth space exceeds the thickness of an engaging tooth.
- Backlash should be measured at the tightest point of mesh on the pitch circle, in a direction normal to the tooth surface when the gears are mounted at their specified position.
- Backlash value can be described as the shortest or normal distance between the trailing flanks when the driving flank and the driven flank are in contact.
- A dial gauge is usually employed to measure the backlash. Holding the driver gear firmly, the driven gear can be rocked back and forth.
- This movement is registered by a dial indicator having its pointer positioned along the tangent to the pitch circle of the driven gear.





6. Measurement of Tooth Thickness

Tooth thickness is generally measured at pitch circle and also in most cases the chordal thickness measurement is carried out .i.e. the chord joining the intersection of the tooth profile with the pitch circle. The methods which are used for measuring.

The gear tooth thickness are

a) Gear tooth Vernier caliper method

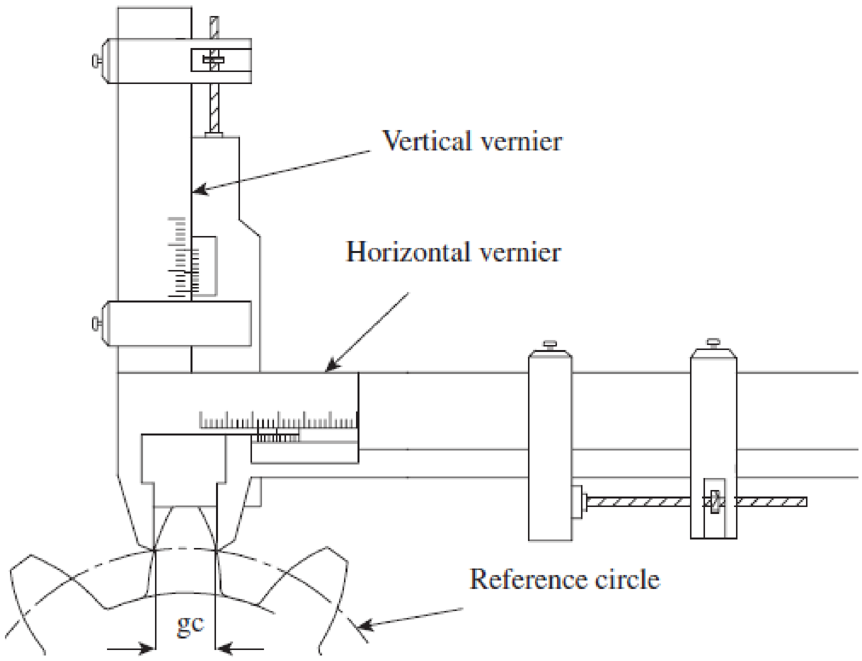
b)Constant chord method

c)Base tangent method

d) Measurement over pins or ball

Gear tooth Thickness – Gear Tooth Vernier

- It is used to measure the thickness of gear teeth at the pitch line or chordal thickness of teeth and the distance from the top of a tooth to the chord.
- The tooth vernier caliper consists of vernier scale and two perpendicular arms. In the two perpendicular arms one arm is used to measure the thickness and other arm is used to measure the depth.
- Horizontal vernier scale reading gives chordal thickness (W) and vertical vernier scale gives the chordal addendum. Finally the two values compared.
- This method is simple and inexpensive.

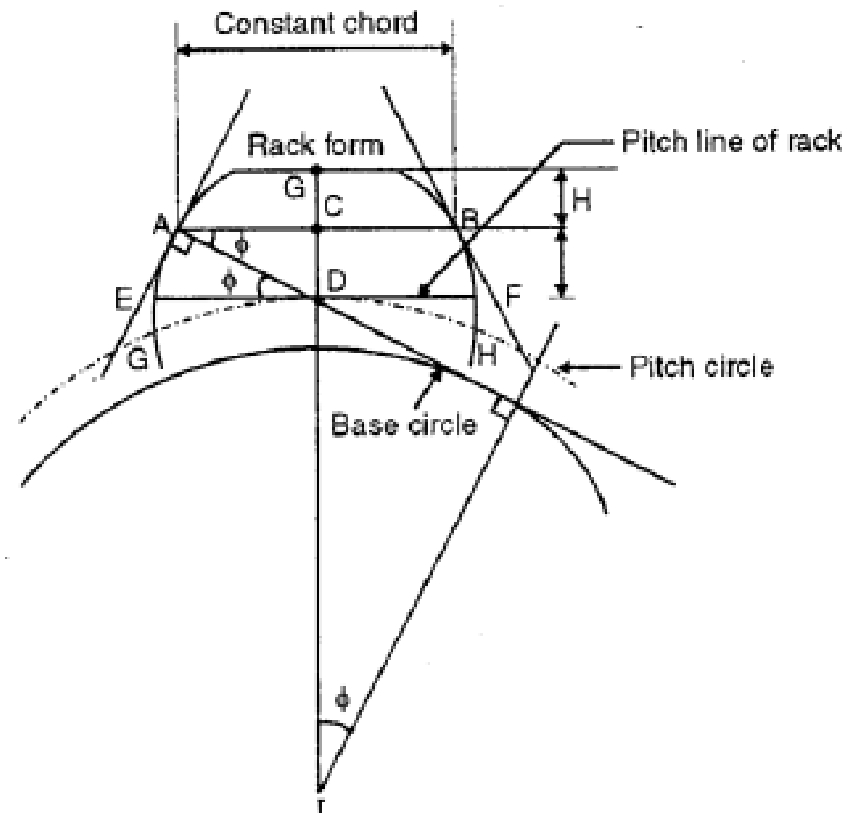


Disadvantages of Gear Tooth Vernier method:

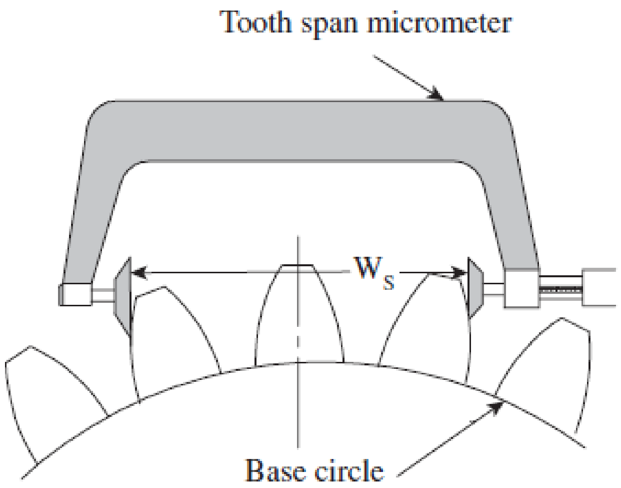
1. Not closer to 0.05mm.
2. Two Vernier readings are required.
3. Measurement is done by edge of measuring jaw and not by face.

Gear tooth Thickness – Constant Chord Method

- A 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 center line of the tooth lies on the line of the gear centers.
- Constant chord of a gear is measured where the tooth flanks touch the flanks of the basic rack.
- The teeth of the **rack** are straight and inclined to their centre lines at the pressure angle.
- Also the pitch line of the rack is tangential to the pitch circle of the gear, the tooth thickness of the rack along this line is equal to the arc tooth thickness of the gear round its pitch circle.
- Now, since the gear tooth and rack space are in contact in the symmetrical position at the points of contact of the flanks, the chord is constant at this position irrespective of the gear of the system in mesh with the rack.



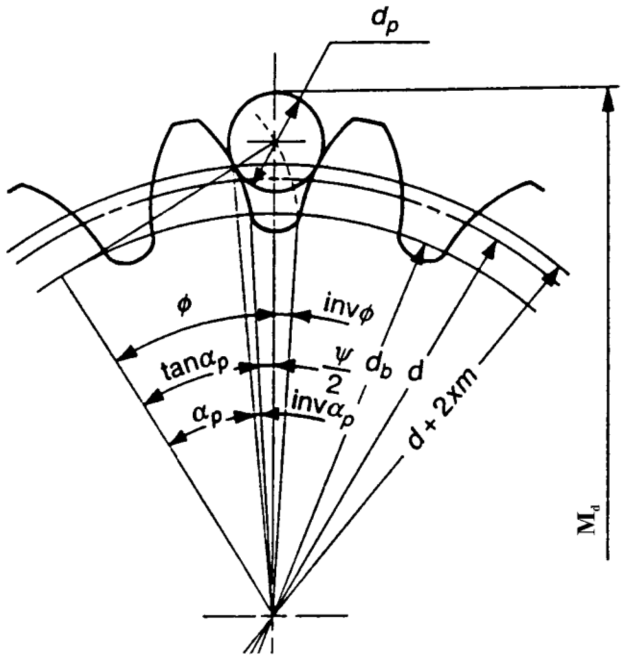
Gear tooth Thickness – Base Tangent Method



- It is the most commonly used method for checking the tooth thickness of gear.
- The advantage of this method is that, it depends only on one vernier reading unlike gear tooth vernier Caliper where we require two vernier readings.
- The base tangent length is **the distance between the two parallel planes which are tangential to the opposing tooth flanks.**
- The measurements made across these opposed involutes by span gauging will be constant and equal to the arc length of the base circle between the origins of involutes.
- The value of the distance between two opposed involutes, or the dimension over parallel faces is equal to the distance round the base circle between the points where the corresponding tooth flanks.

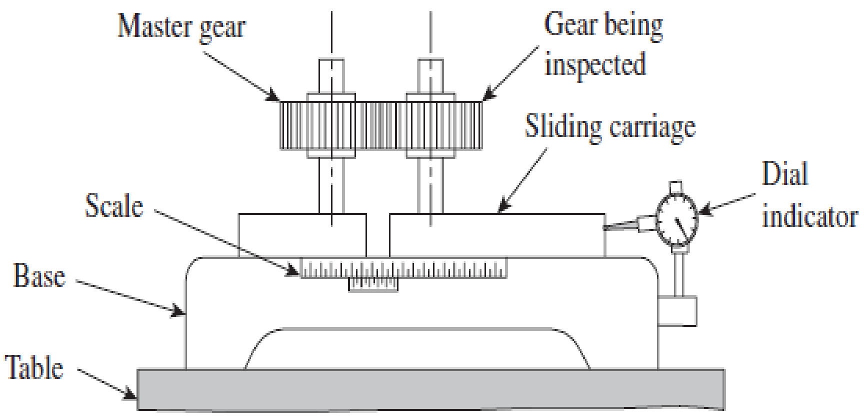
Gear tooth Thickness – Measurement over Rolls or balls

- A very good and convenient method is for measuring thickness of gear.
- In this method, two or three different size rollers are used to check the vibrations at different places on the tooth.
- Measurement over the rollers placed in the space between a pair of gear teeth gives a convenient method for checking **tooth spacing and the pitch diameter**.
- The special case of the roller with its centre on the pitch circle simplifies the problem.
- It is, therefore, considered desirable to find the diameter on the roller whose centre will lie on the pitch circle and to derive an expression for the distance over the rollers placed in opposite teeth spaces with the centers of rollers lying on the pitch circle.



Parkinson Gear Tester – Gear profile inspection

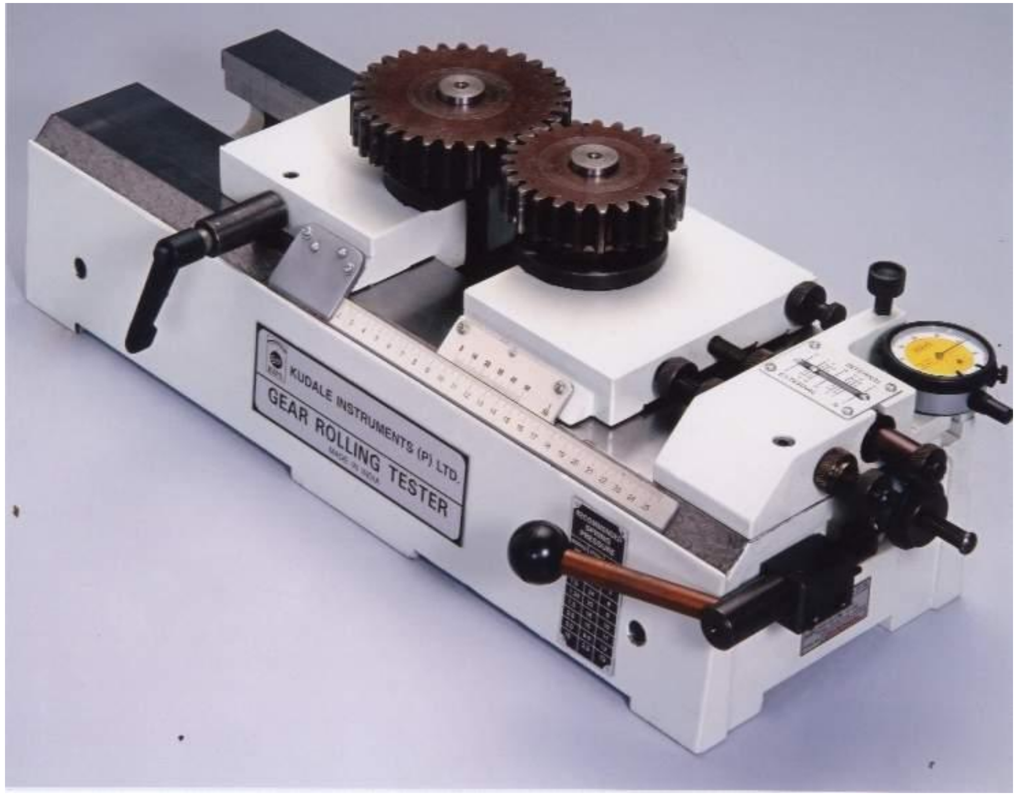
- The master gear is fixed on vertical spindle and the gear to be tested is fixed on similar spindle which is mounted on a carriage.
- The carriage which can slide both side and these gears are maintained in mesh by spring pressure.
- When the gears are rotated, the movement of sliding carriage is indicated by a dial indicator and these variations are the measure of any irregularities in the gear under test.
- The variation's recorded in a recorder which is fitted in the form of a waxed circular chart.
- In fig, the gears are fitted on the mandrels and are free to rotate without clearance.
- Left mandrel moves along the table and the right mandrel moves along the spring-loaded carriage.
- The two spindles can be adjusted so that the axial distance is equal and a scale is attached to one side and vernier to the other, this enables center distance to be measured to with in 0.025mm.



- If errors occur in the tooth form when gears will be in closer mesh, pitch or concentricity of pitch line will cause a variation in center distance from this movement of carriage as indicated to the dial gauge will show the errors in the gear test.
- The recorder is also fitted in the form of circular or rectangular chart and the errors are recorded.

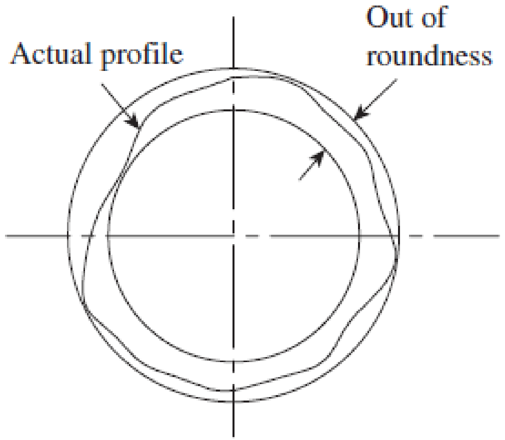
Limitations of Parkinson gear tester:

1. Accuracy ±0.001mm
2. Maximum gear diameter is 300mm
3. Errors are not clearly identified.
4. Measurement is dependent upon the master gear.
5. Low friction in the movement of the floating carriage.



Roundness Measurement

- By definition, roundness or circularity is the **radial uniformity of work surface** measured from the **center line of the workpiece**.
- Circularity is specified by circularity tolerance. For example, if it is specified that circularity of a feature is to be 0.1mm, than it means that the circumference of each cross section of the feature should be contained between two coplanar concentric circles that are 0.1mm apart.



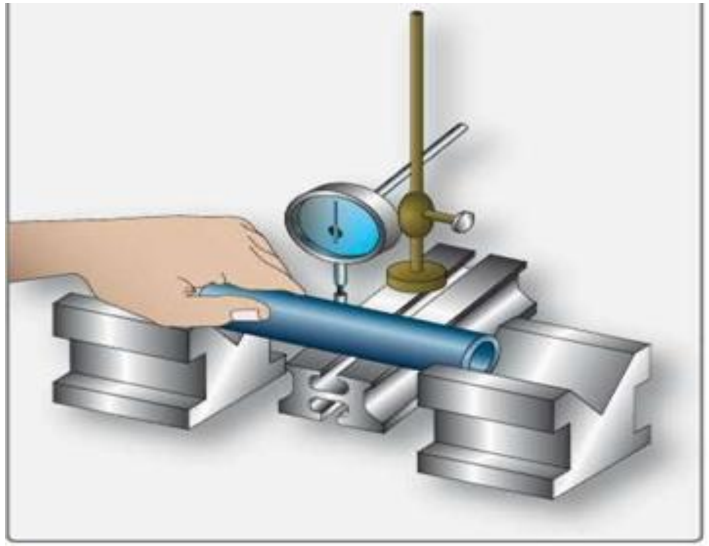
- Error in roundness is defined as the radial distance between the minimum inscribing circle and maximum inscribing circle, that contain the actual profile of the surface at a section perpendicular to the axis of rotation.

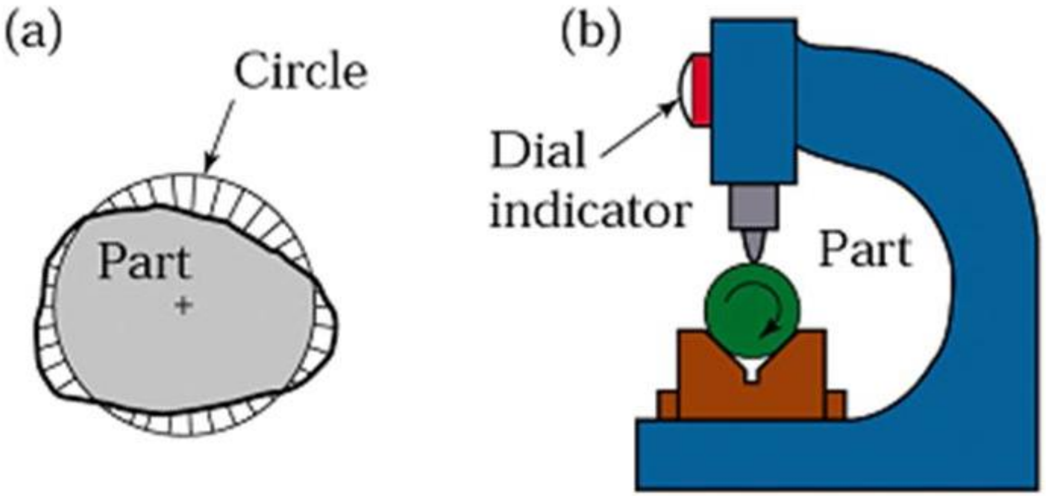
- **Methods for Measuring Roundness:**

  a) V-block and dial indicator method **b) Roundness Measuring Machine**

V-block and dial indicator method:

- The arrangement consists of a V-block that is placed on the surface plate. The workpiece to be tested is placed in the V-groove of the V-block as shown in the figure.
- The feeler of a sensitive dial indicator (held firmly by a stand) is made to rest on the workpiece.
- Now the workpiece is rotated about the diameter to be checked. The dial indicator will indicate variations in the dimensions caused due to out of roundness.





- **Plotting a Polar Graph:** An idea of the actual shape of the workpiece can be obtained by plotting a polar graph. 12 equispaced markings at an angle of 30° are made in the face of the workpiece to be measured. The workpiece is placed on the V-block.
- The dial indicator is made to touch the workpiece at its center. Now when the workpiece is rotated and when the marking comes exactly under the plunger of the dial indicator, the reading is noted.
- Hence 12 readings will be obtained. The procedure is repeated thrice to get average values for each marking. Now for plotting the polar graph, a proper scale is selected.
- A circle of diameter equal to four times the maximum reading of the dial indicator is drawn. Another concentric circle is drawn in this circle. The values of the dial indicator are plotted in radial direction by taking the smallest circle as the reference circle. The individual points are joined by straight lines to get the actual profile of the workpiece.
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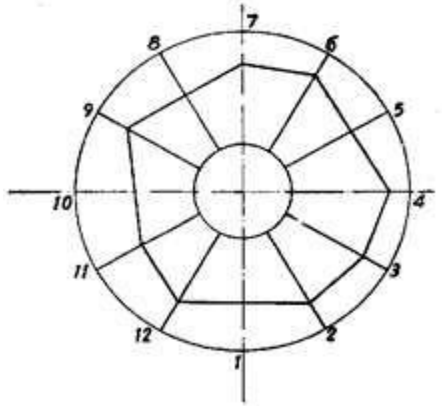


- Error is measured as the radial distance between the maximum and minimum inscribing circle for the profile obtained.

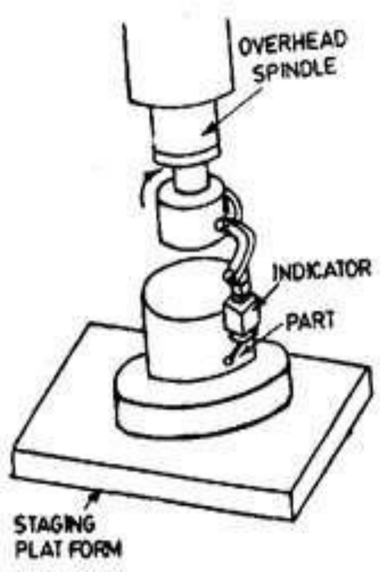
Roundness error = $\frac{Measured\ error\ from\ polar\ graph}{K}$

Where, K is a constant (This constant depends on the shape of the workpiece and angle of V-block)

- The position of the indicating instrument, the number of lobes on the workpiece and the angle of the V-block have an influence on the determination of roundness error.

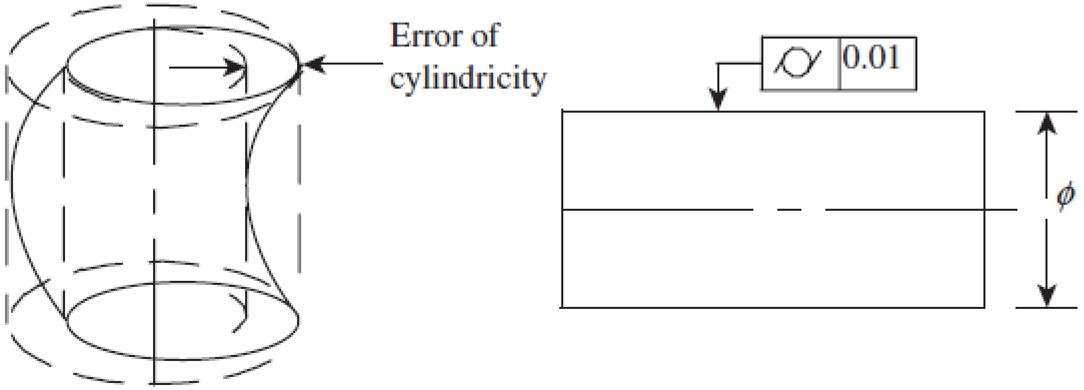
Roundness Measuring Machine:

- The machine is also called as Taly-round Instrument or precision spindle method.
- The main parts of the instrument are a truly running spindle that is mounted on precision ball bearing and micron indicator.
- The indicating pointer is rotated around the workpiece about an accurately stable axis. The indicator shows deviations from roundness. As the output of the indicator is connected to an amplifier unit and pen recorder, a polar graph of the out line of the workpiece is obtained.
- This is an accurate method. Automatic recording of the exact profile of the workpiece is obtained. Waviness also is superimposed on the profile of the workpiece.



Cylindricity

A cylinder is an envelope of a **rectangle rotated about an axis**. It is bound between two circular and parallel planes.



Runout

Runout is a measure of the **trueness of the running of a body** about its own axis.