UNIT-IV

OPTICAL INTERFEROMETER & FORM MEASUREMENTS

Interferometry

- Interferometry is a precision measurement technique based on the **interference of light waves**.

Principle

- When two coherent light waves combine, they produce interference fringes.
- These fringes are formed due to **path difference** between the two waves.
- The pattern of bright and dark bands helps measure very small distances, flatness, and surface irregularities.

- Interferometry makes use of the ***principle of superposition*** to combine separate waves in a way that will cause the result of their combination to have some meaningful property that is diagnostic of the original state of the waves.

- This works because when two waves with the same frequency combine, the resulting pattern is determined by the phase difference between the two waves — waves that are in phase will undergo constructive interference while waves that are out of phase will undergo destructive interference.

- Most interferometers use light or some other form of electromagnetic wave.

- Typically a single incoming beam of coherent light will be split into two identical beams by a grating or a partial mirror.

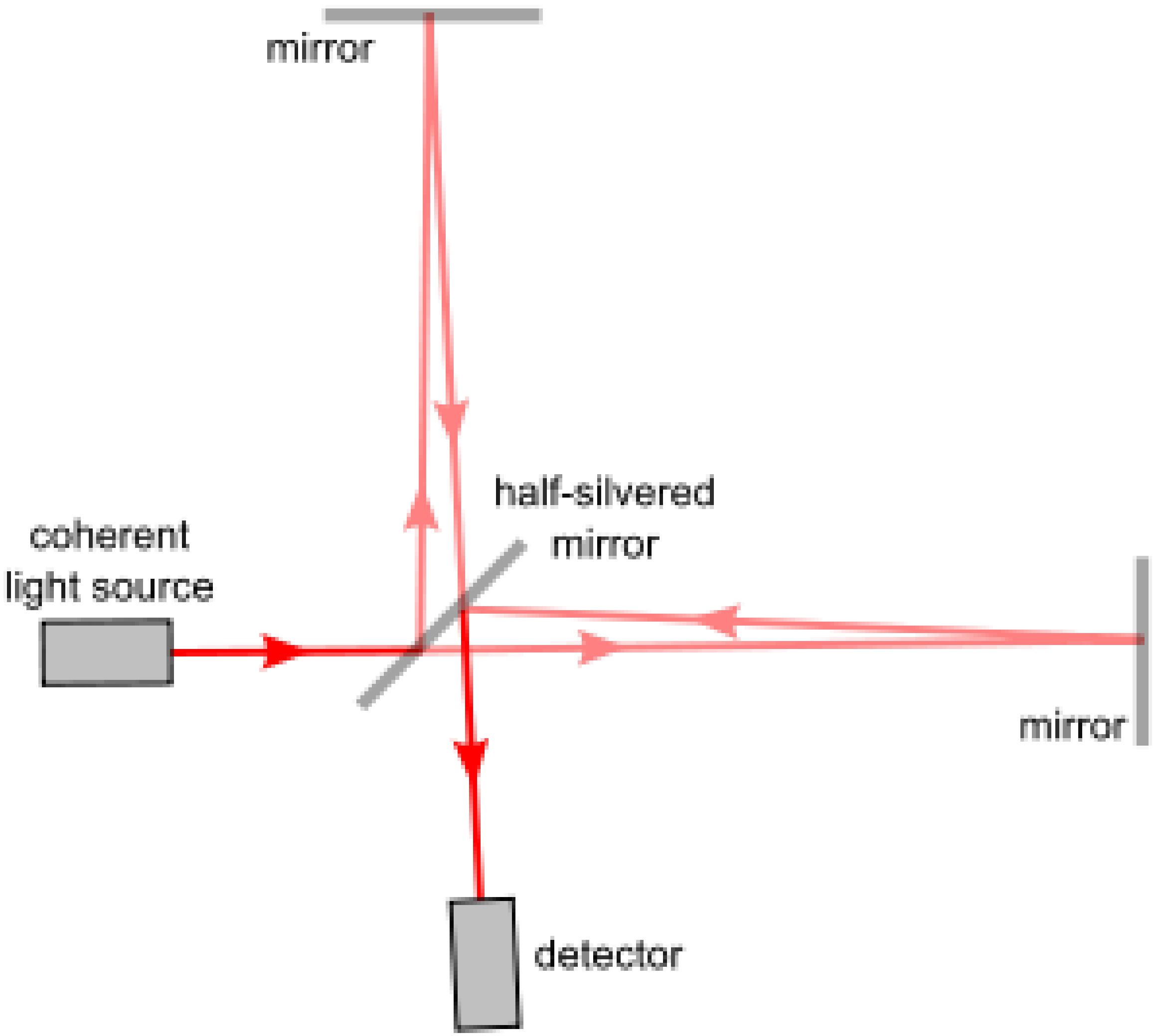
- Each of these beams will travel a different route, called a path, until they are recombined before arriving at a detector.

- The path difference, the difference in the distance traveled by each beam, creates a phase difference between them.

- It is this introduced phase difference that creates the interference pattern between the initially identical waves.

- If a single beam has been split along two paths then the phase difference is diagnostic of anything that changes the phase along the paths.

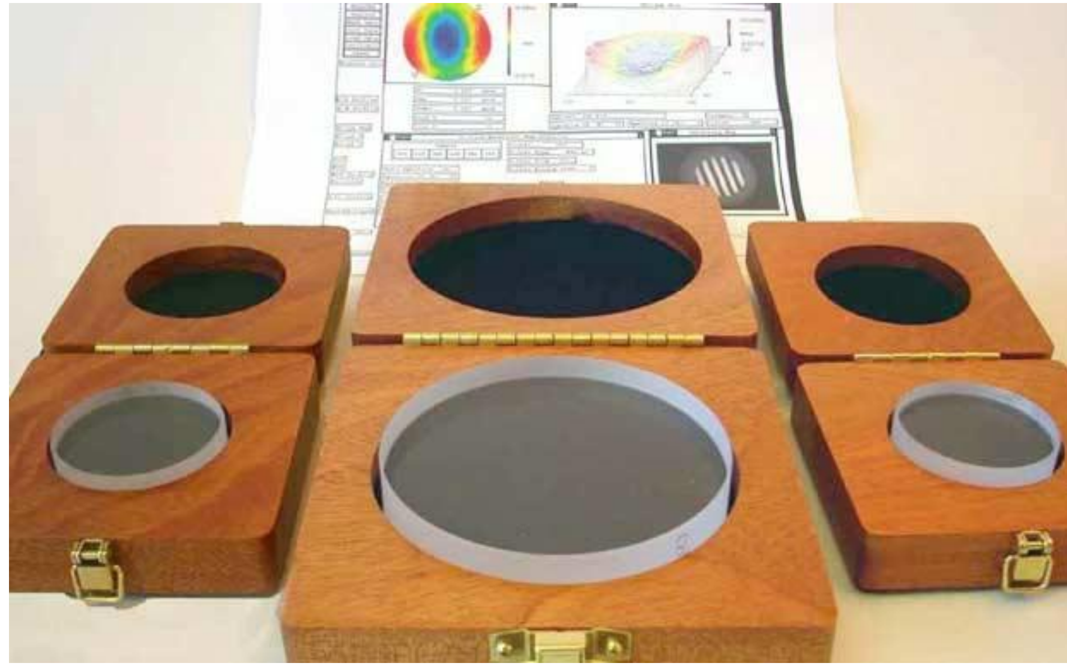
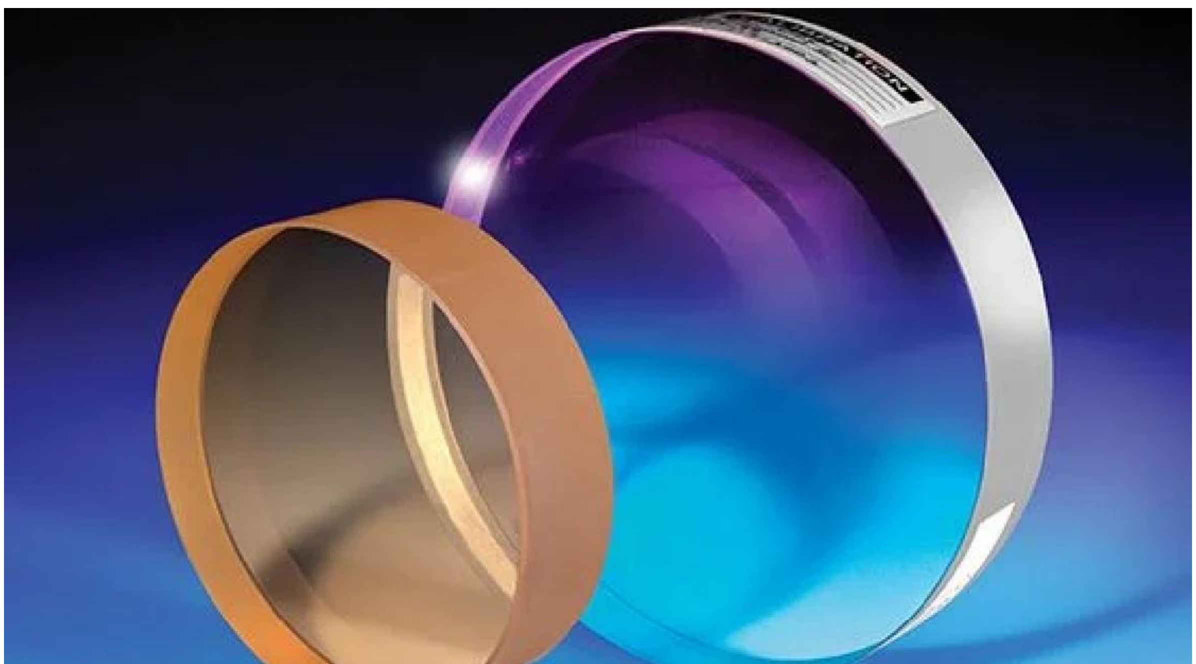
- This could be a physical change in the path length itself or a change in the refractive index along the path.



https://www.youtube.com/watch?v=3MIZGkPv1nY

OPTICAL FLAT

- The easiest and best way to test the flatness of a flat lapped or polished surface is with an optical flat.
- Such surfaces are found on micrometers, measuring machines, gage blocks, snap gages, ring seals, valve seats and precision flat lapped parts.
- They are used with a monochromatic light to determine the flatness of other optical surfaces by interference.

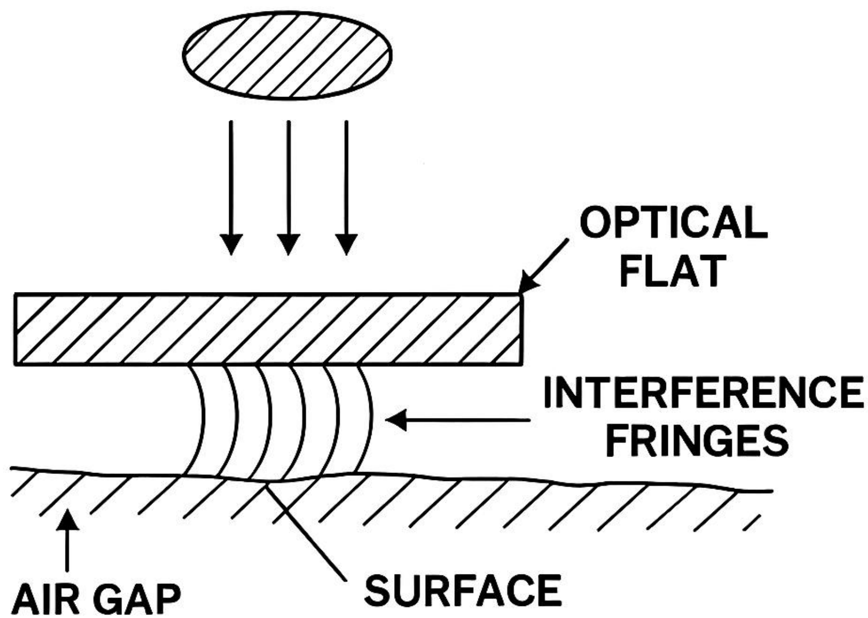




Construction

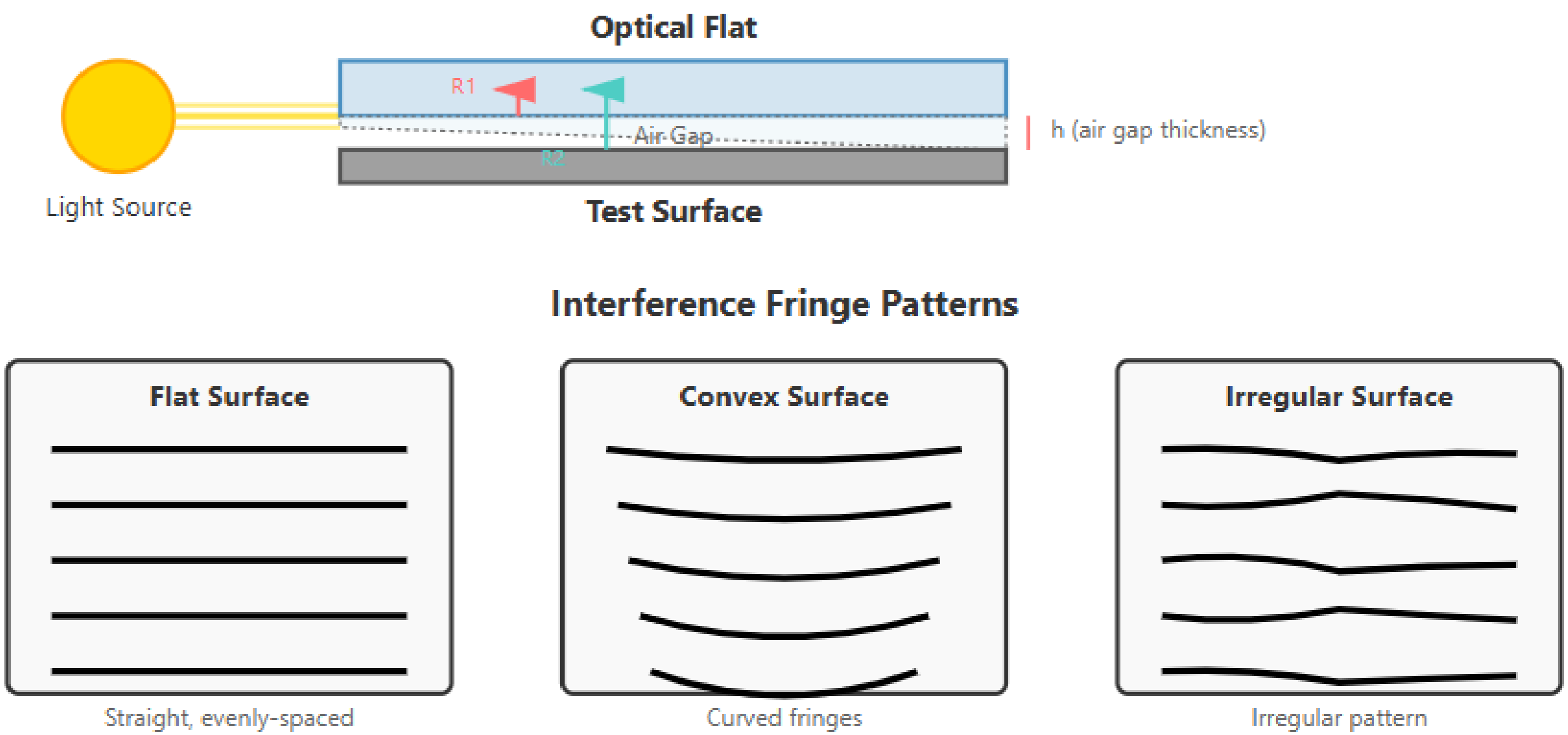
- Made of **quartz or high-grade glass**
- One surface is **optically flat** (accurate within a fraction of a wavelength)
- Used along with Monochromatic light source (usually sodium or mercury lamp)

Principle: When monochromatic light (commonly sodium light) falls on an optical flat placed over a surface, interference fringes are formed due to the air gap between them.

WORKING PRINCIPLE OF AN OPTICAL FLAT



Optical Flat - Working Principle



OPTICAL FLAT

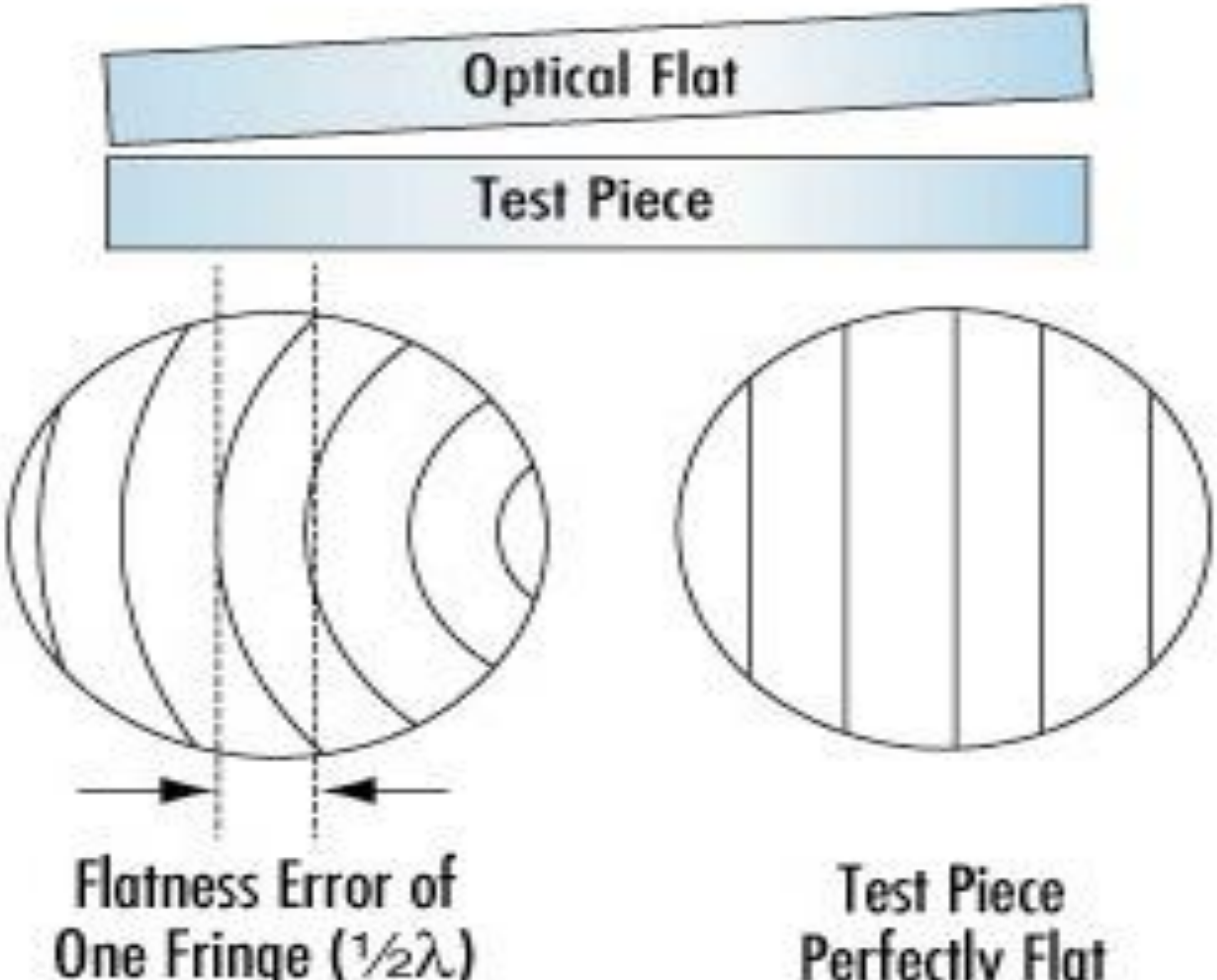
- It is a circular piece of unstressed glass or quartz usually about 5cm in diameter or more.
- The upper and lower surfaces are ground optically flat to get reference planes.
- Materials range from inexpensive glass to very expensive sapphire.
- Typically made from fused quartz, glass, or Zerodur, materials known for their low thermal expansion and high durability.

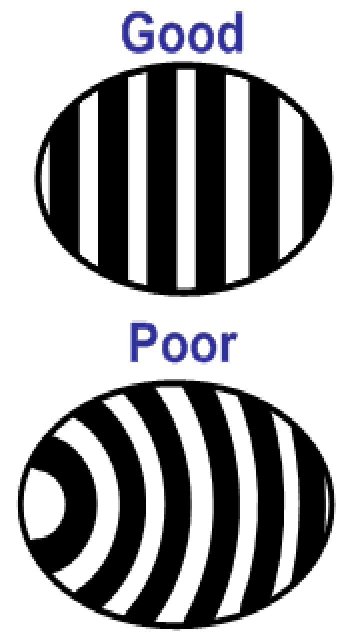
Material	Key Properties	Common Uses
Fused Quartz	• Very low thermal expansion • High optical transparency • Scratch-resistant	• High-precision interferometry setups
Glass	• Economical • Moderate thermal stability • Easy to polish	• Educational labs, basic testing
ZERODUR®	• Near-zero thermal expansion • Excellent dimensional stability • High durability	• Aerospace, high-end metrology

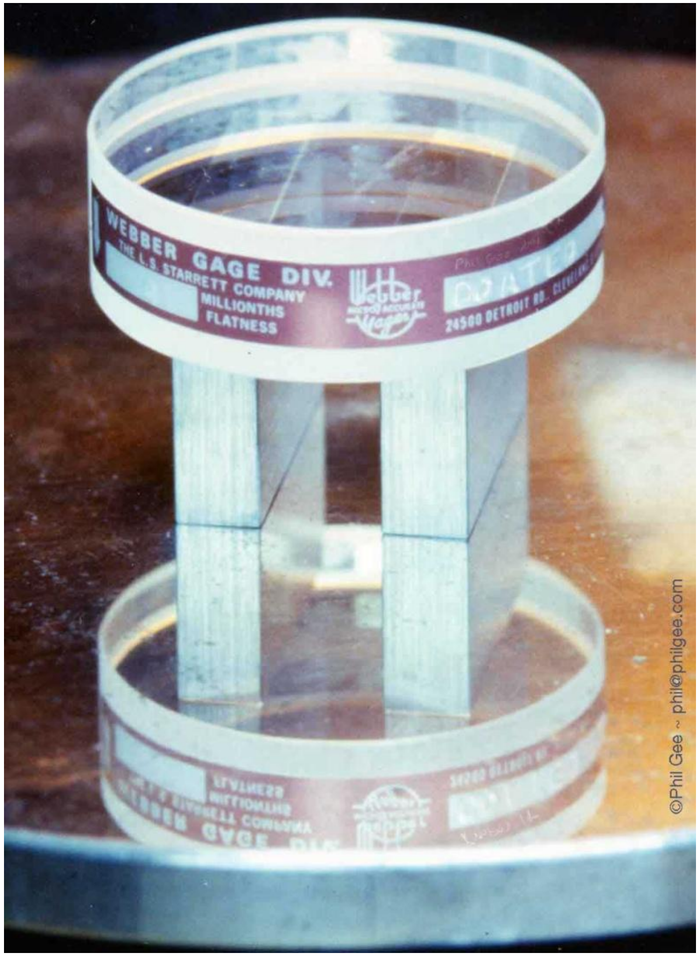
- **Type – A :** It has only one surface flat.
  - used for testing the flatness of precision measuring surface flats, slip gauges, measuring tables, etc.
- **Type – B:** It has both the surface flat and parallel.
  - used for testing the surface of micrometers, measuring anvils and similar length measuring devices for testing flatness and parallelism.

- Grade I Type A flat of diameter 250 mm is designated by: Optical flat IA 25- IS: 5440.
- **Grade I** → Used for **high-precision interferometry**.

- Grade II Type B flat of thickness 12.125 mm is designated by: Optical flat II B 12.125- IS: 5440.
- **Grade II** → Suitable for **general laboratory or workshop use**.


Optical Flat
Test Piece
Flatness Error of One Fringe (½λ)
Test Piece Perfectly Flat


Good
Poor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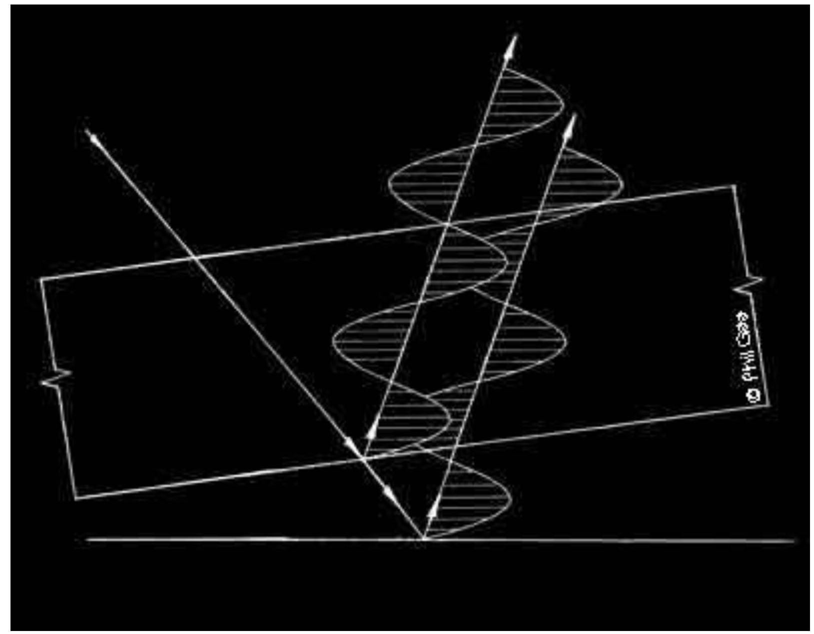
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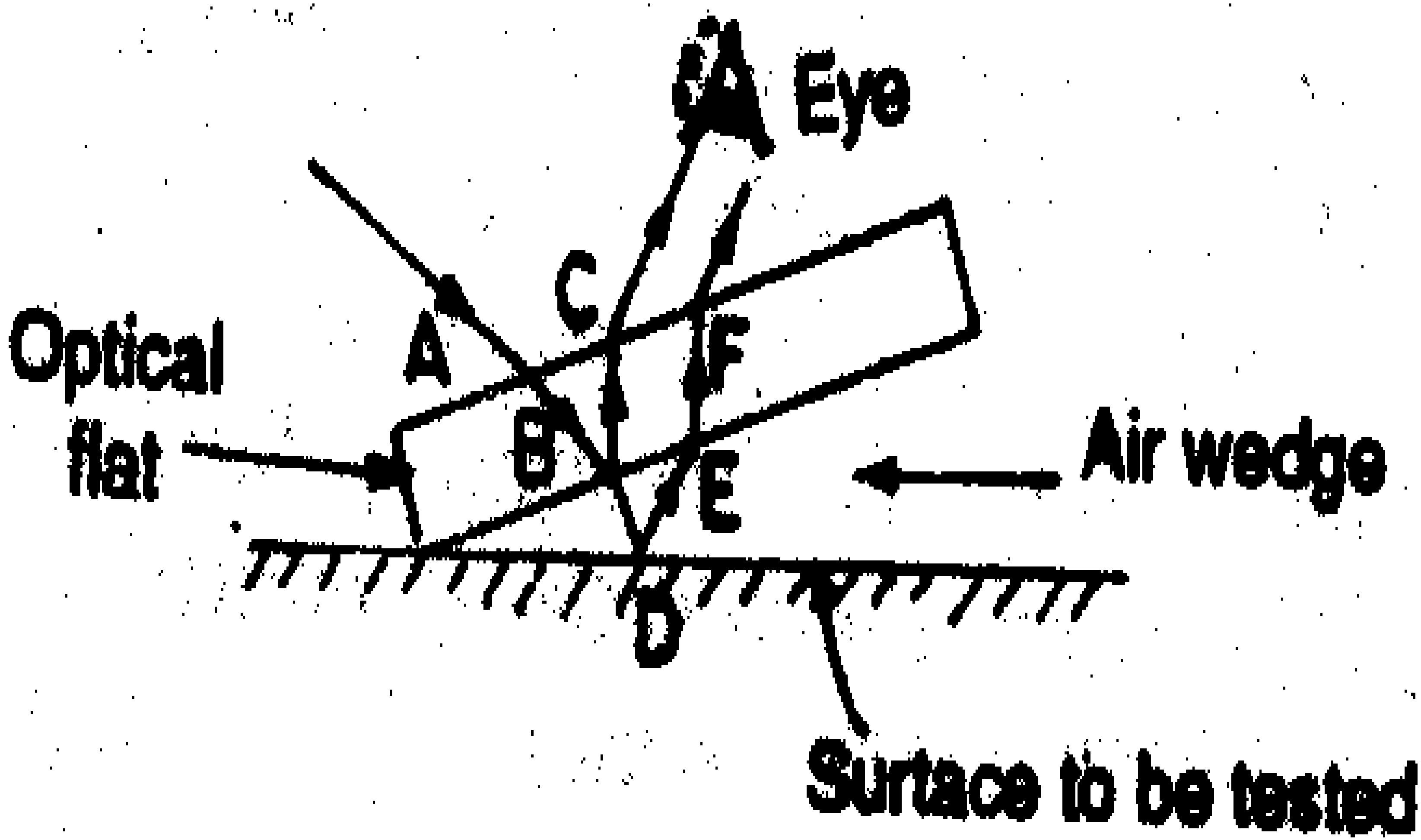

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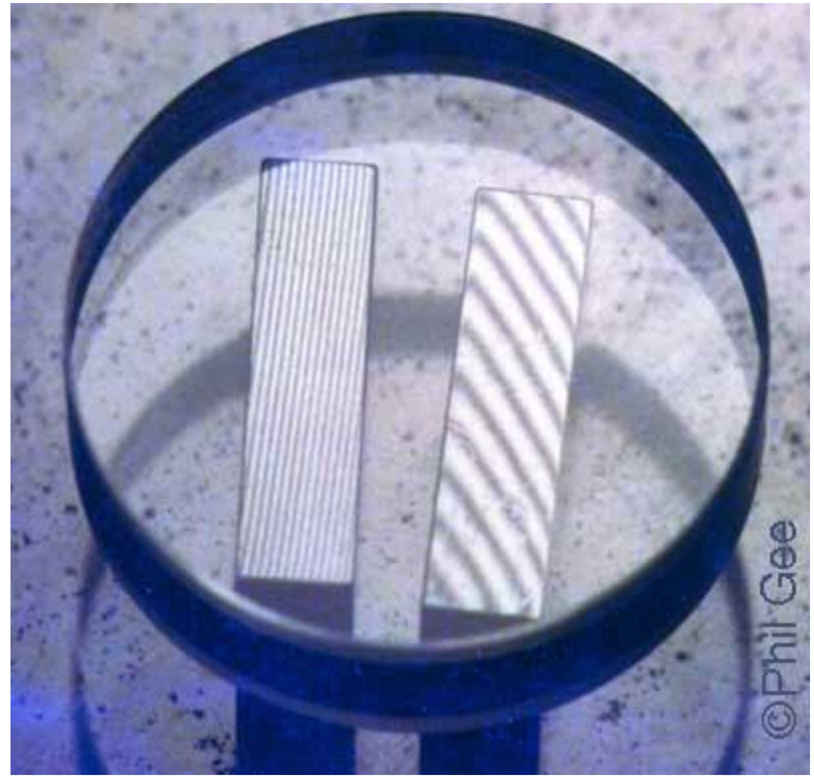


In the above example the fringes appear as a series of rings which indicate the surface under test is either concave or convex the simple way to determine which, is to apply finger pressure to the center fringe, if fringes reduce in number then the surface is concave

The two Slip Gages above are of notionally the same length, both show a series of fringes indicating there is a variation in height in the direction at right angles to the fringes

$$h = \frac{L}{l} \times N \times \frac{\lambda}{2}$$

Fringe Pattern	**Surface Condition**
Straight, parallel fringes	Flat surface
Curved fringes	Convex or concave surface
Circular fringes	Spherical surface
Uneven spacing	Surface irregularities

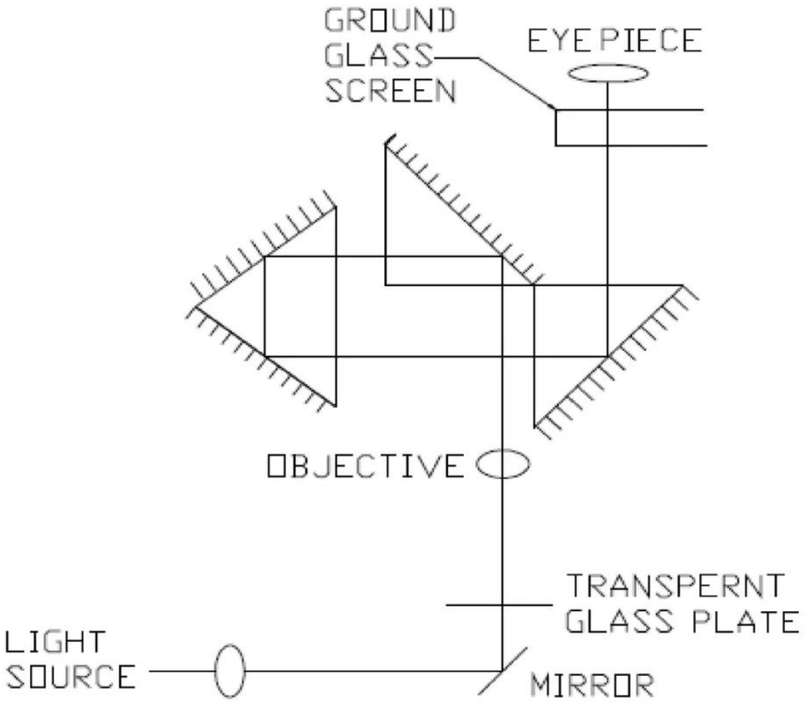
Tool makers microscope

1. Introduction

- A Tool Maker's Microscope (TMM) is a high-precision optical measuring instrument used for the measurement and inspection of small components and cutting tools.
- It is widely used in tool rooms, inspection departments, and metrology laboratories.
- It combines optical magnification with precise mechanical movements to measure linear dimensions, angles, profiles, and pitch with high accuracy.

2. Principle of Tool Maker's Microscope

- The working principle of a Tool Maker's Microscope is based on:
  - ✓ **Optical magnification** of the object using a microscope
  - ✓ **Accurate displacement measurement** using micrometer screws
  - ✓ **Alignment of cross-hair (reticle)** with the object profile
- The dimensions of the object are determined by measuring the displacement of the microscope stage required to align the cross-hair with different points of the object.



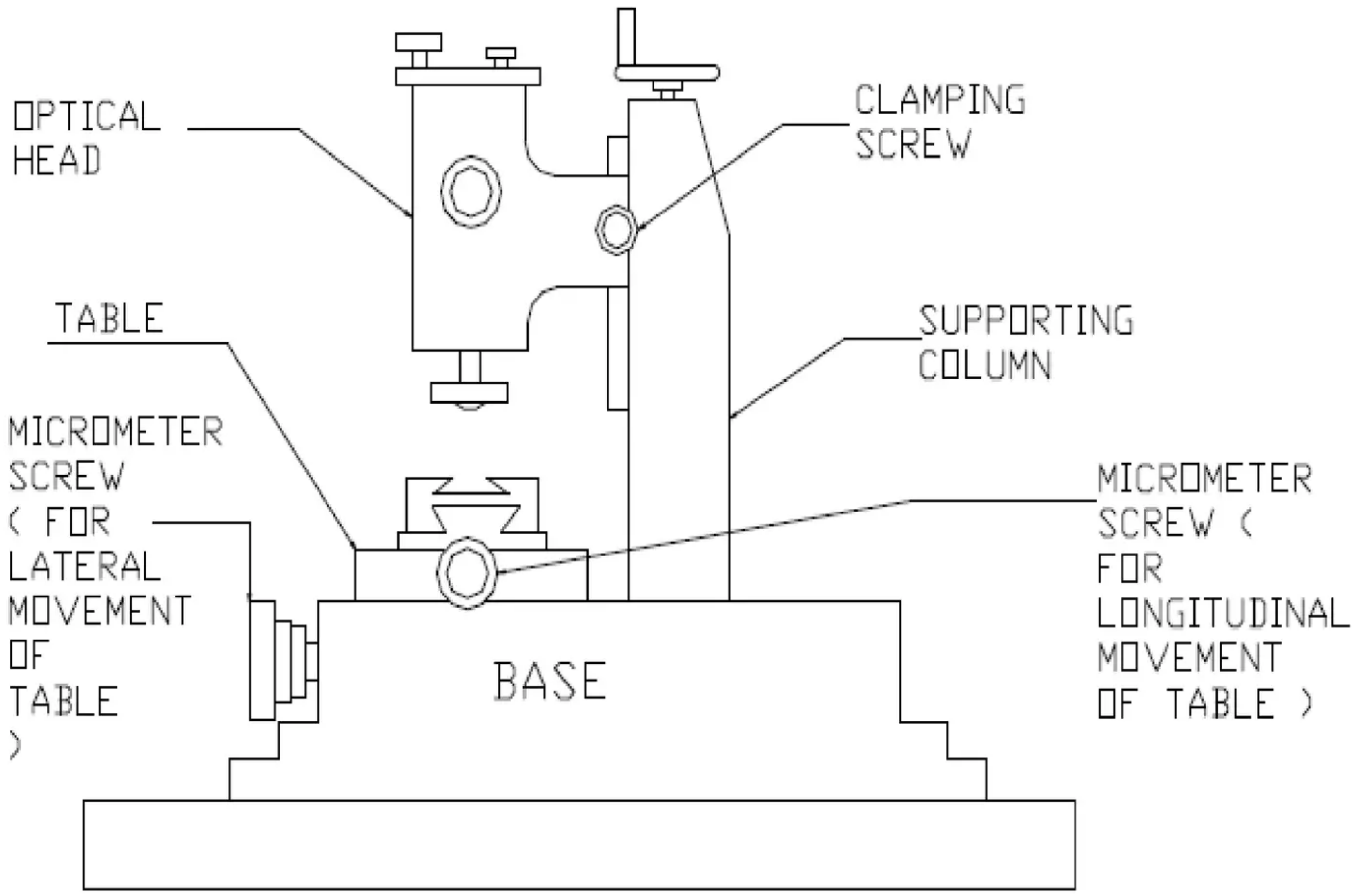
❑ Principle of Measurement

Main Components of Tool Maker's Microscope

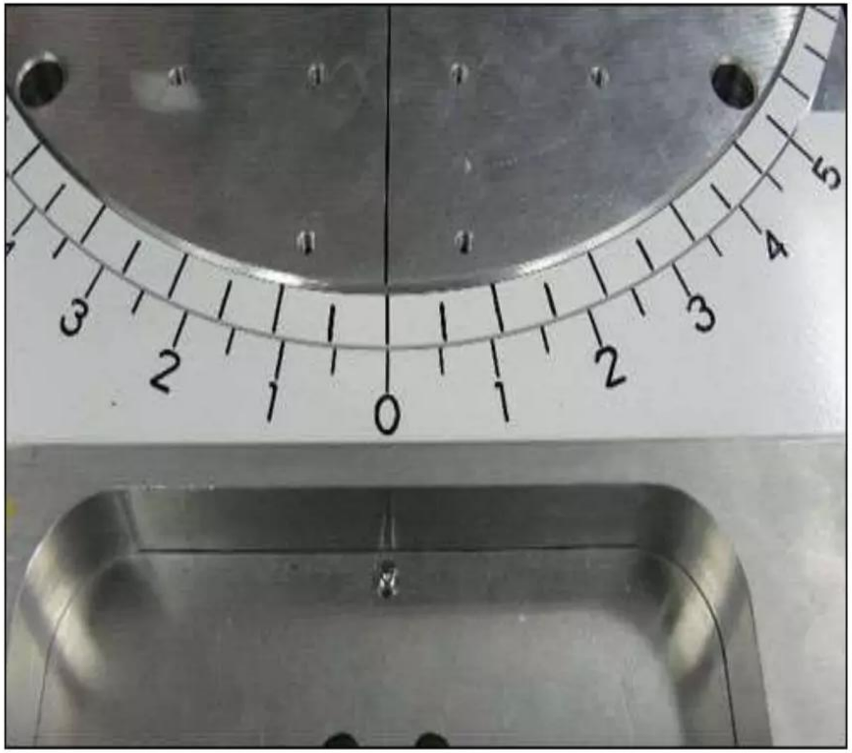
1. Rotatable Table,
2. Measuring Stage,
3. Moveable Head,
4. Ocular (Eye piece),
5. Projection Screen,
6. Micrometres,
7. Objective Lens,
8. Prism.

Construction

- ✓ TMM (toolmakers microscope) has got a robust & strong base such that it can bear & withstand sudden loads.
- ✓ A column with a track is present to carry lens, along with illuminating source in certain TMM's.
- ✓ Lens has two perpendicular straight lines marked that act as reference lines.
- ✓ Object to be measured is placed on glass table.
- ✓ Glass table is provided with 3 scales on it
- ✓ Two scales are meant for measuring in X & Y directions & the movement of table the respective direction.
- ✓ The other scale is meant for measuring rotation as well as rotation of table.



❑ Tool Maker's Microscope



- Scales On Microscope

Working

- The component being measured is illuminated by the through light method.
- A parallel beam of light illuminates the lower side of work-piece which is then received by the objective lens in its way to a prism that deflects the light rays in the direction of the measuring ocular & the projection screen.
- The direction of illumination can be tilted with respect to the work-piece by tilting the measuring head & the whole optical system.
- This inclined illumination is necessary in some cases as in screw thread measurements.

EXAMPLES

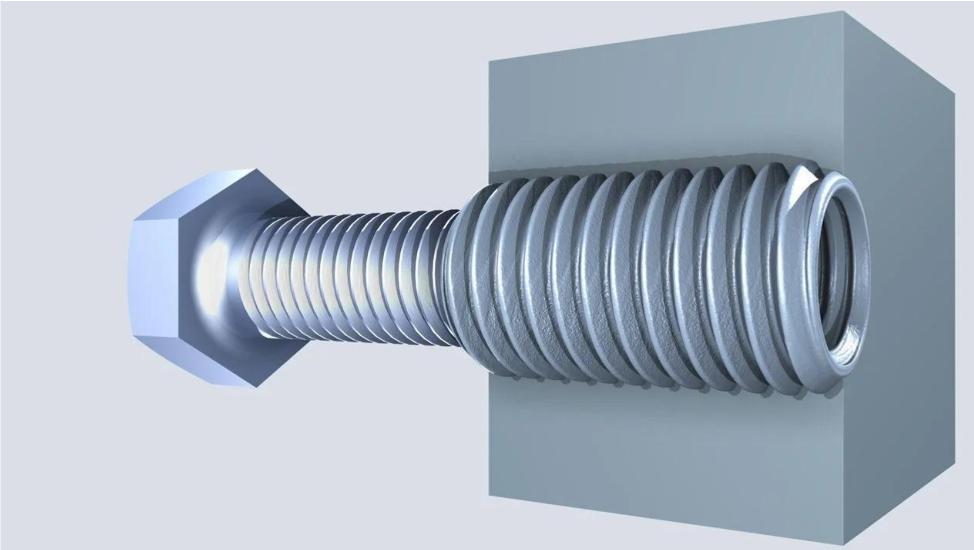
Pitch Measurement: -

- Take the hacksaw blade and mount on the moving blade of tool maker's Microscope in horizontal position.
- Focus the microscope on the blade.
- Make the cross line in the microscope coincided with one of the edge of the blade.
- Take a reading on ground glass screen, this is the initial reading.
- The table is again moved until the next edge of the blade coincides with the cross-line on the screen and the final reading takes.
- the difference between initial and final reading gives pitch of the blade.

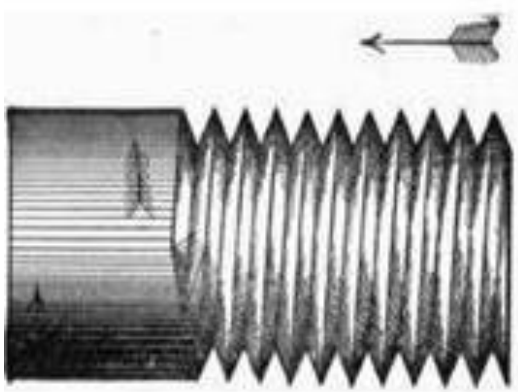
Application

- ✓ Length measurement in Cartesian & polar co-ordinates.
- ✓ Angle measurements of tools.
- ✓ Thread measurements i.e., profile major & minor diameters, height of lead, thread
- ✓ angle, profile position with respect to the thread axis & the shape of thread.
- ✓ Comparison between centers & drawn patterns & drawing of projected profiles.
- ✓ Used for measuring the shape of different components like the template, formed cutter, milling cutter, punching die, and cam

Measurements of screw threads



- External thread
- Internal thread



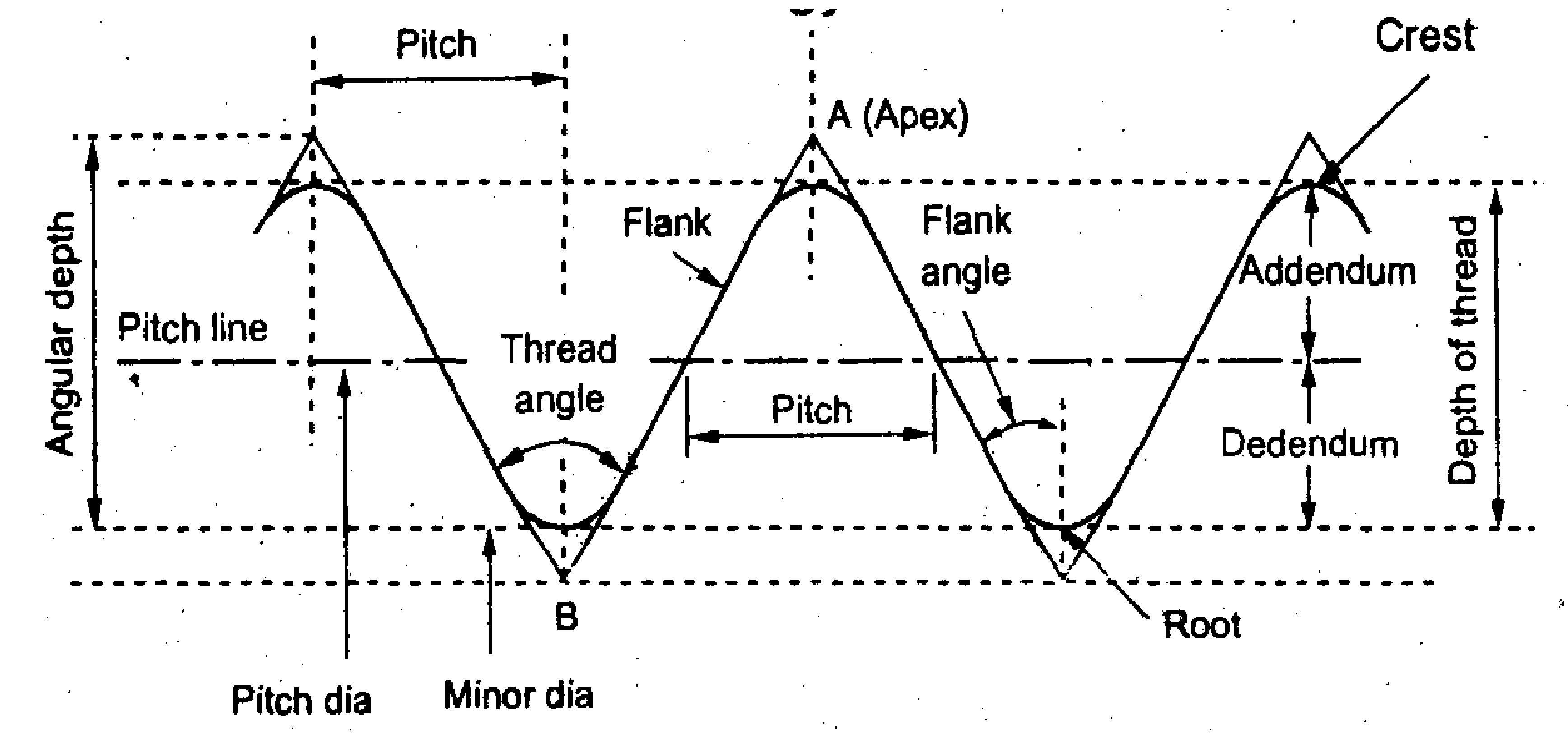
External thread.

A thread formed on the outside of a workpiece is called external thread e.g., on bolts or studs etc.

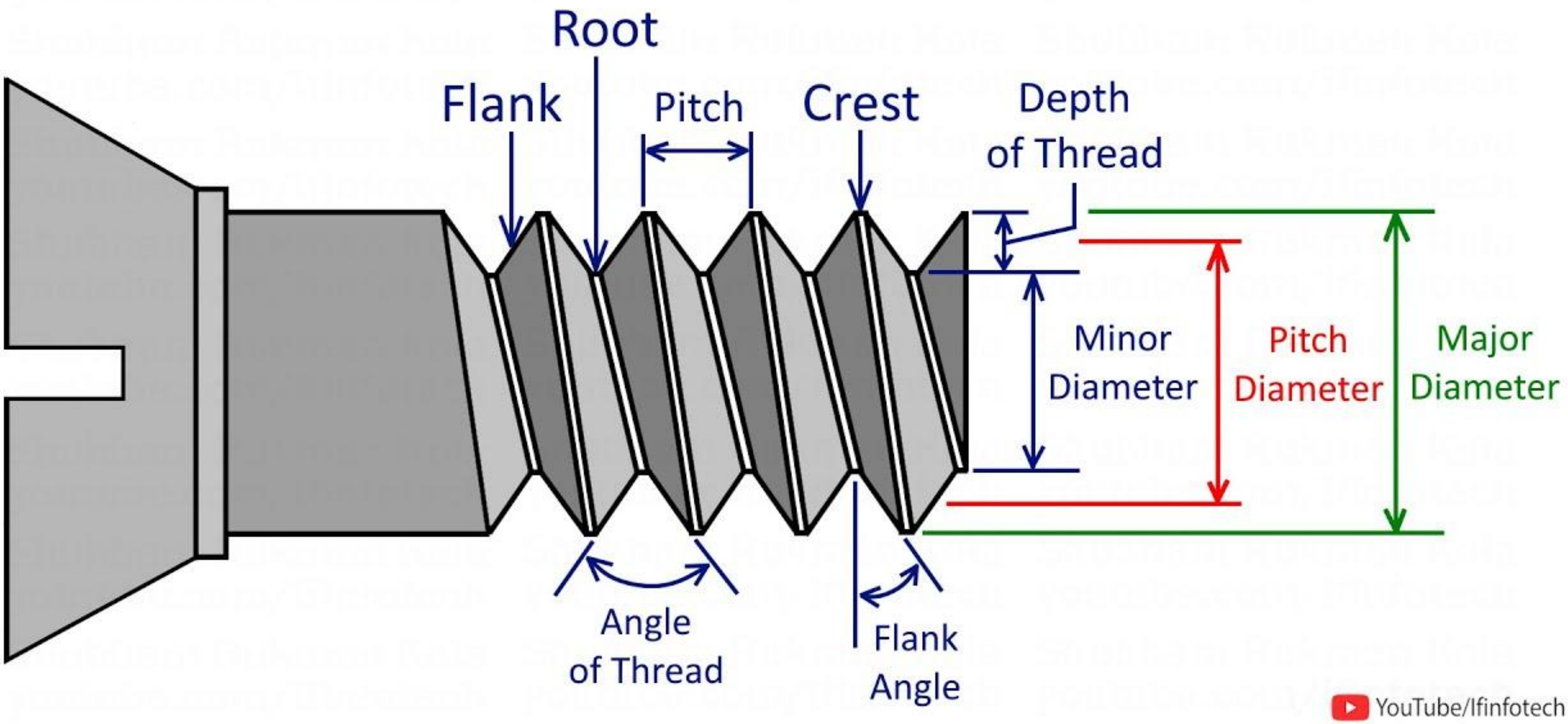
Internal thread.

A thread formed on the inside of a workpiece is called internal thread e.g. on a nut or female screw gauge.

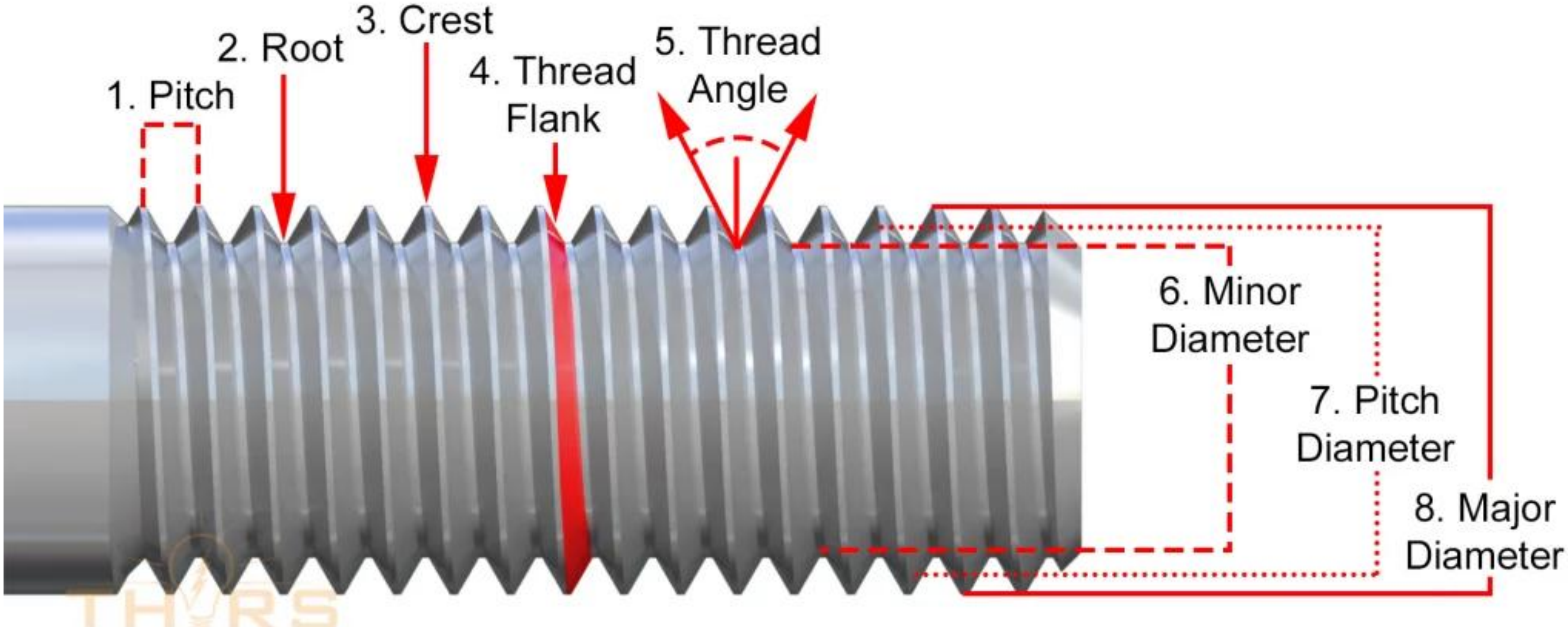
Screw thread



Screw Thread Terminology



THREAD PARTS SCHEMATIC DIAGRAM



Terminology

Crest

It is top surface joining the two sides of thread.

Flank

Surface between crest and root.

Root

The bottom of the groove between the two flanks of the thread

Contd.,

Pitch

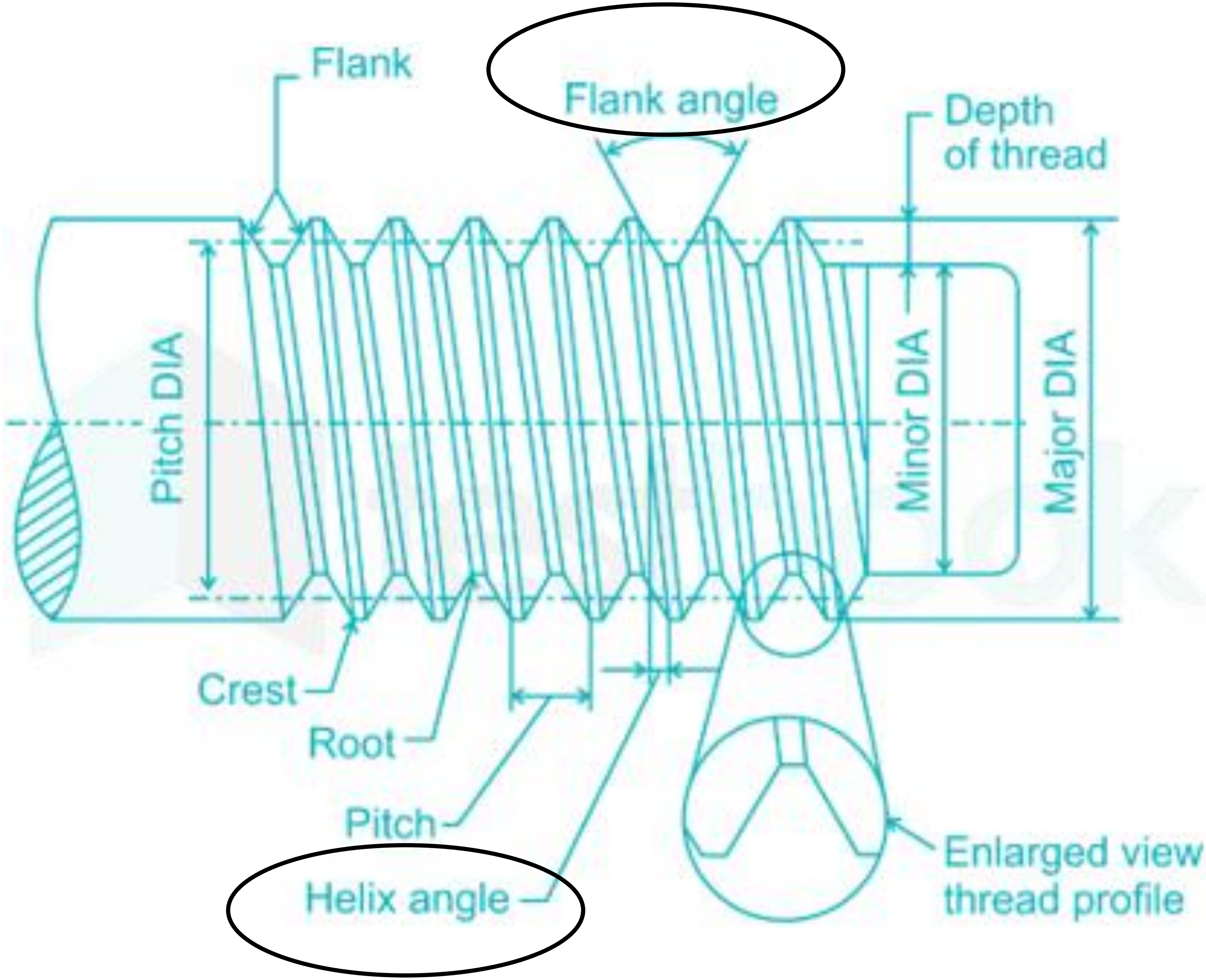
The distance measured parallel to the axis from a point on a thread to the corresponding next point.

Helix angle:

The helix is the angle made by the helix of the thread at the pitch line with the axis.

Flank angle

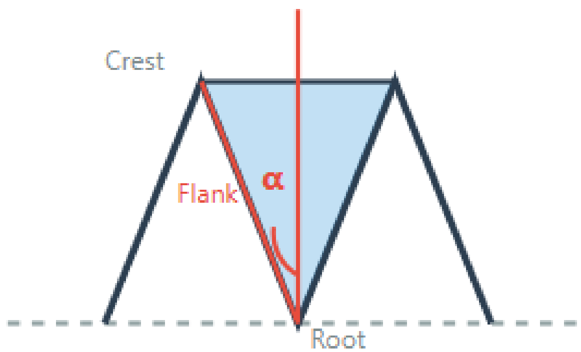
Angle made by the flank of a thread with the perpendicular to the thread axis



Flank
Flank angle
Depth
of thread
Pitch DIA
Minor DIA
Major DIA
Crest
Root
Pitch
Helix angle
Enlarged view
thread profile

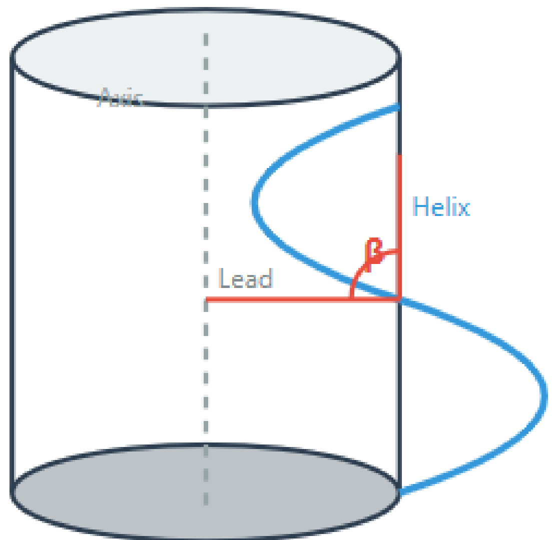
Flank and Helix Angles in Threading

Flank Angle (Profile View)



Flank Angle (α)

Helix Angle (Cylindrical View)



Helix Angle (β)

Key Definitions

Flank Angle (α):

- The angle between the thread flank and a line perpendicular to the thread axis
- Measured in the axial plane (cross-section of the thread)
- Common values: 30° for metric threads, 29° for Acme threads

Helix Angle (β):

- The angle between the helix (thread spiral) and a plane perpendicular to the axis
- Measured on the cylindrical surface of the thread

Contd.,

- **Depth of thread**

  The distance between the crest and root of the thread

- **Major diameter:**

  Diameter of an imaginary co-axial cylinder which would touch the crests of external or internal thread.

- **Minor diameter (Root diameter or Core diameter):**

  Diameter of an imaginary co-axial cylinder which would touch the roots of an external thread.

Contd.,

- **Addendum**
  - Radial distance between the major and pitch cylinders For external thread.
  - Radial distance between the minor and pitch cylinder For internal thread.
- **Dedendum**
  - Radial distance between the pitch and minor cylinder = For external thread.
  - Radial distance between the major and pitch cylinders = For internal thread

https://www.youtube.com/watch?v=vS7v0_IPMdc

Errors in Screw Thread

* Major diameter error
  * reduction in the flank contact
  * interference with the matching threads
* Minor diameter error
  * Interference
  * reduction of flank contact

Contd.,

* Effective diameter error
* Pitch error
  * the total length of thread engaged will be either too high or too small
* Flank angles error
* Crest and root error

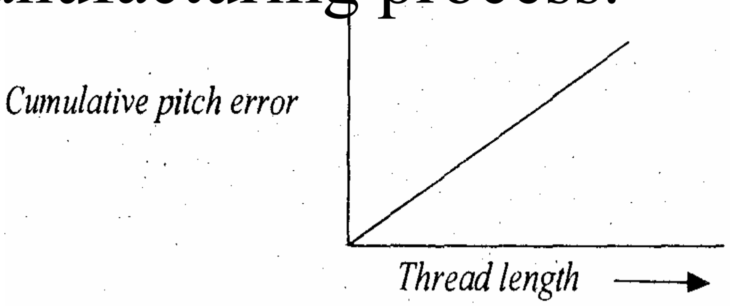
Pitch Errors Classification

- Progressive error
- Periodic error
- Drunken error
- Irregular error

Errors in Thread

1) Progressive error:

- It refers to an error or deviation that **accumulates progressively** along the length of the threaded surface.
- In other words, the error increases or decreases gradually as one moves along the thread's axis.
- This type of error can result from various factors such as tool wear, machine deflection, thermal expansion, or inaccuracies in the manufacturing process.



Cause

- Incorrect pitch of the lead screw
- Accumulated manufacturing error
- Wear of screw threads

Example

If the screw pitch is slightly larger, the error increases as measurement increases.

Correction

- Calibration using standard gauge blocks
- Error compensation chart

Contd.,

2. Periodic error

A periodic error is an error **that repeats itself at regular intervals**, usually equal to one revolution of the screw..

Causes of periodic error:

- Teeth error in gears.
- Lead screw error.
- Eccentric mounting of the gears.
- Pitch variation within one screw revolution

Example

- Error repeats every one full turn of the micrometer screw.

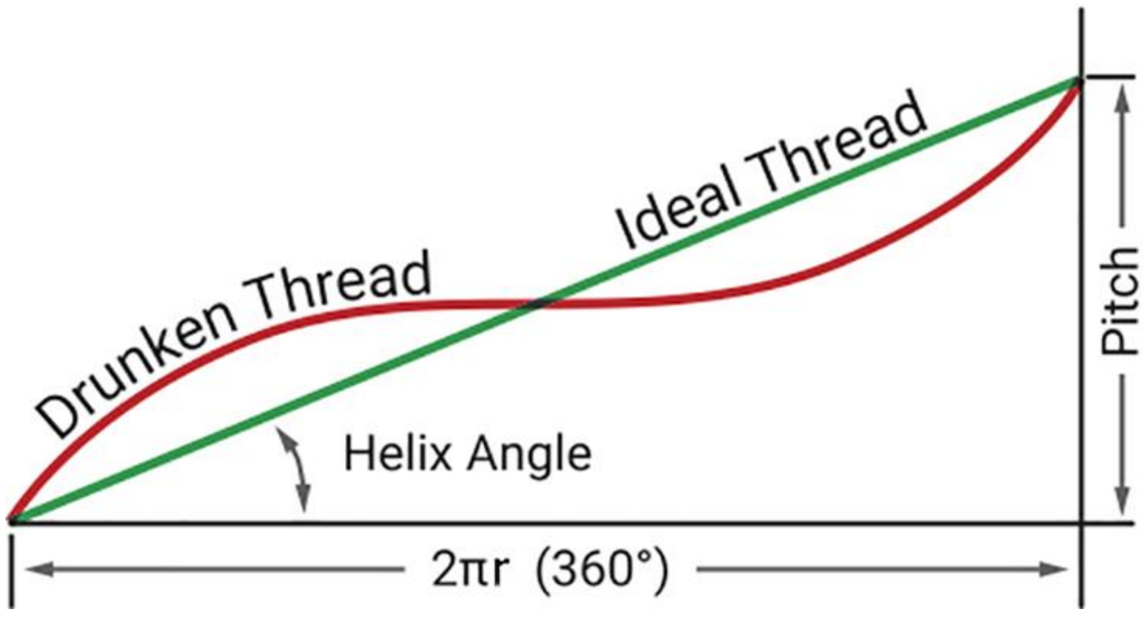
Correction

- Error mapping
- Precision grinding of screw

Contd.,

3) Drunken error:

- Drunken errors are repeated once per turn of the thread in a Drunken thread.
- In Drunken thread the pitch measured parallel to the thread axis. If the thread is not cut to the true helix the drunken thread error will form



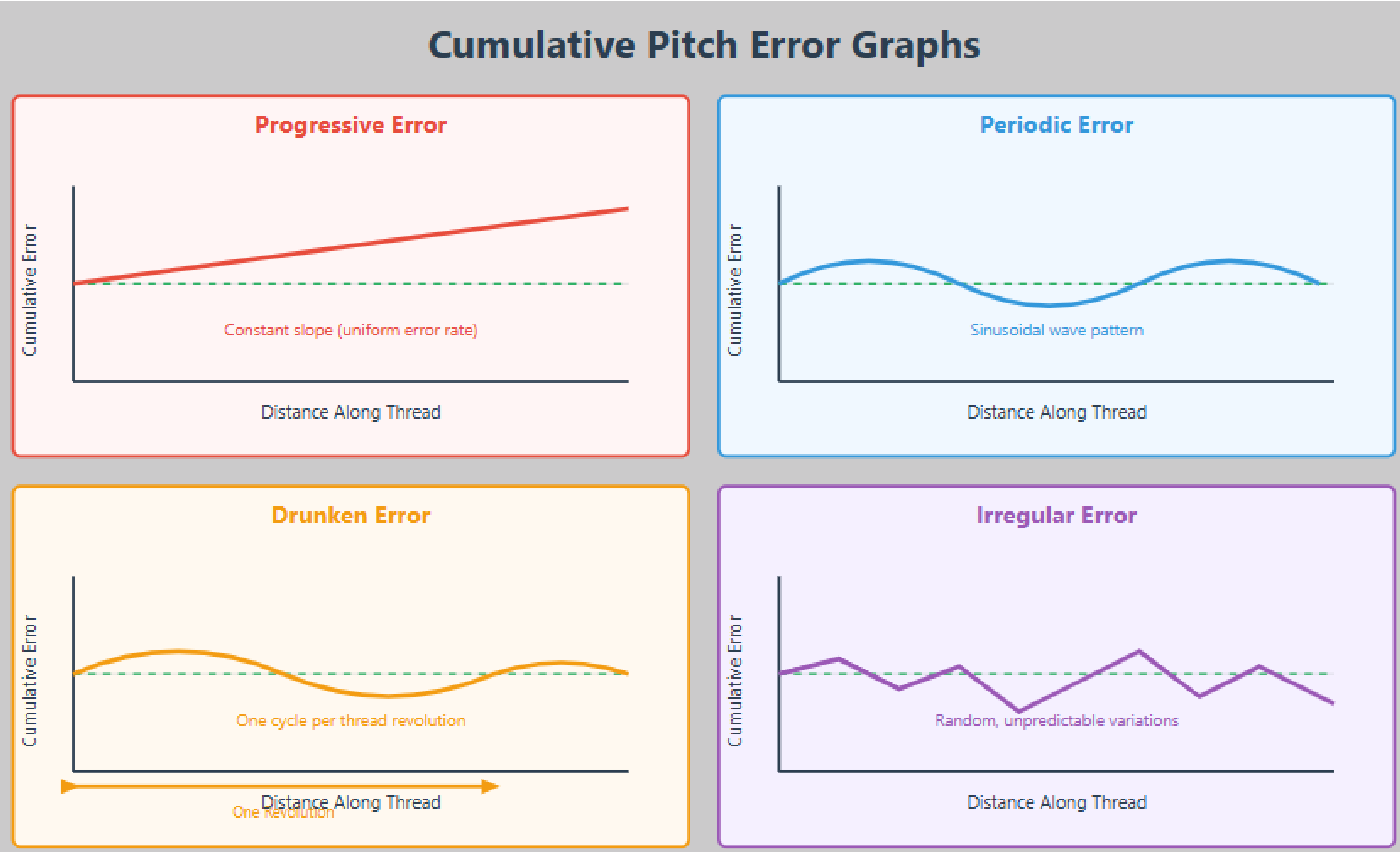
Contd.,

4) Irregular errors:

It is vary irregular manner along the length of the thread.

Irregular error causes:

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


Cumulative Pitch Error Graphs
Progressive Error
Cumulative Error
Constant slope (uniform error rate)
Distance Along Thread
Periodic Error
Cumulative Error
Sinusoidal wave pattern
Distance Along Thread
Drunken Error
Cumulative Error
One cycle per thread revolution
Distance Along Thread
One Revolution
Irregular Error
Cumulative Error
Random, unpredictable variations
Distance Along Thread

Measurement Of Various Elements Of Thread

1) Major diameter
2) Minor diameter
3) Effective or Pitch diameter
4) Pitch
5) Thread angle and form angle

Major Diameter

* Ordinary micrometer

* Bench micrometer

Ordinary micrometer

- The ordinary micrometer is quite suitable for measuring the external major diameter.
- It is first adjusted for appropriate cylindrical size (S) having the same diameter (approximately). This process is known as ‘gauge setting’.
- After taking this reading ‘ R the micrometer is set on the major diameter of the thread, and the new reading is ‘ R2

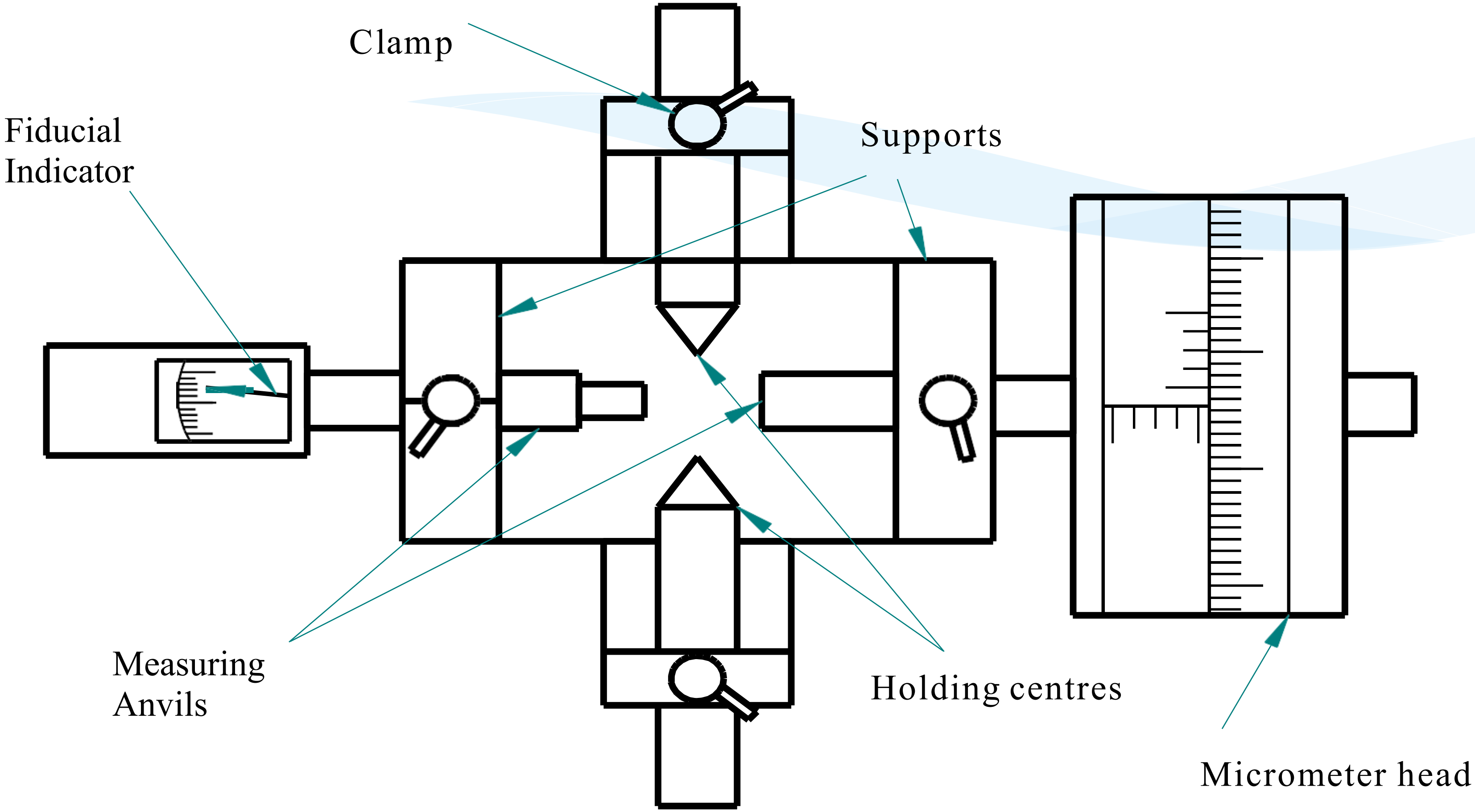
Then the major diameter, $D = S \pm (R_1 - R_2)$

S = Size of setting gauge

R_1 = Micrometer reading over setting gauge.

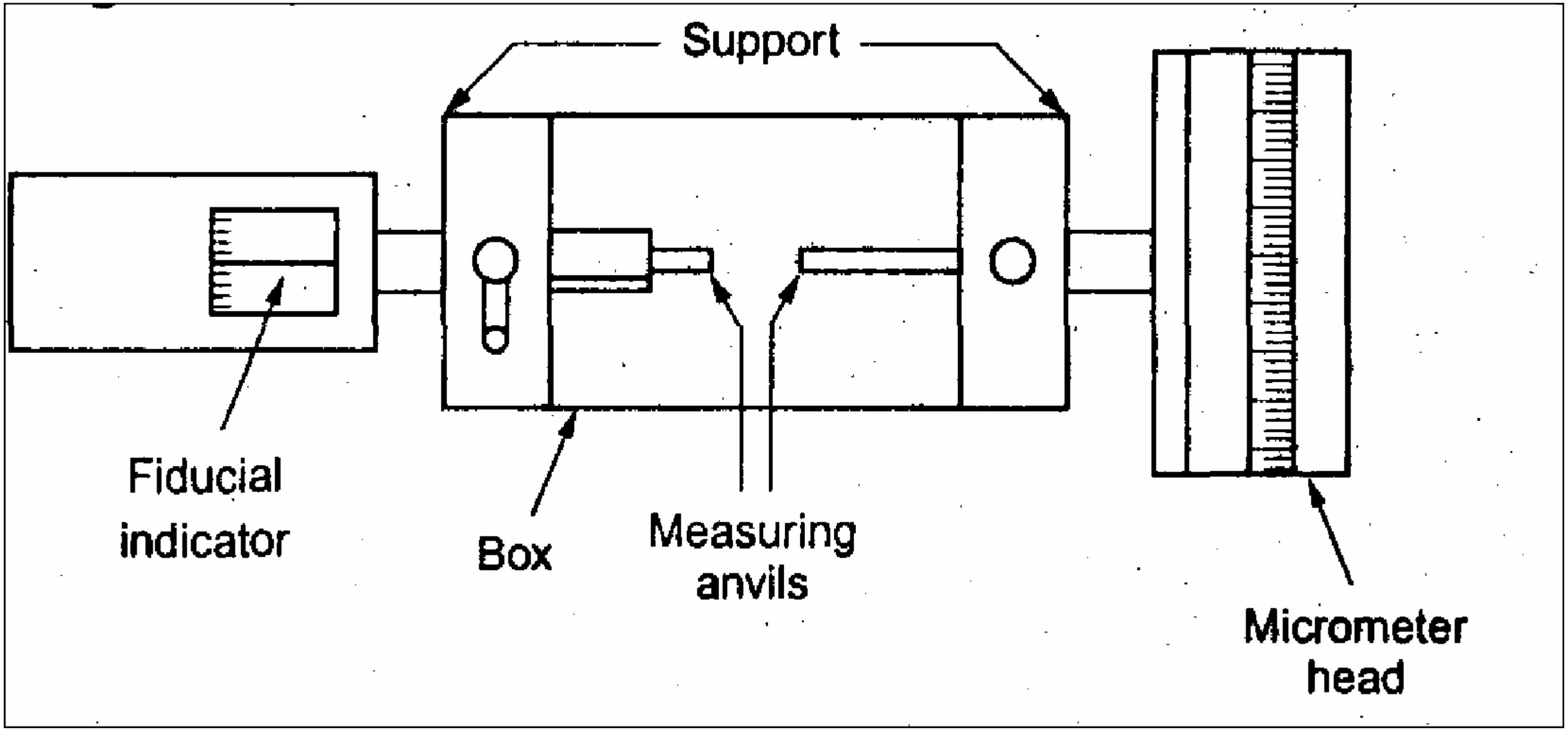
R_2 = Micrometer reading over thread.

Measurement by Bench micrometer

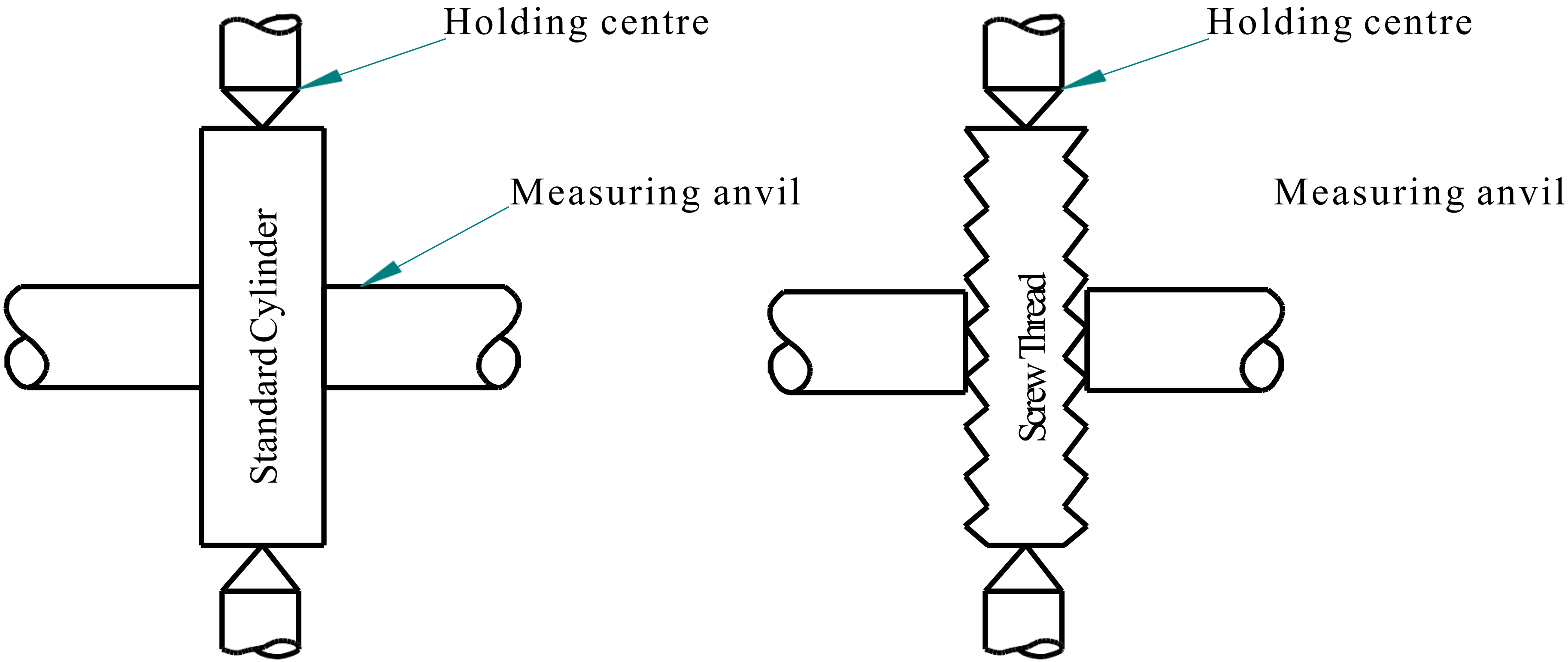


BENCH MICROMETER

Measurement by Bench micrometer:



Measurement by Bench micrometer:



Measurement of Major diameter

Measurement by Bench micrometer:

∴ The major diameter of screw thread

$$= S \pm (D_2 - D_1)$$

Where, S = Diameter of the setting cylinder.

R_2 = Micrometer Reading on screw thread

R_1 = Micrometer reading on setting cylinder.

+ or – sign is determined depending on whether the standard cylinder is smaller or larger in diameter than the thread major diameter

https://www.youtube.com/watch?v=4YViG2X67zg

Measurement of the major diameter of an Internal thread:

major diameter of internal thread is $= D \pm (R_2 - R_1)$

D = Cylindrical standard diameter

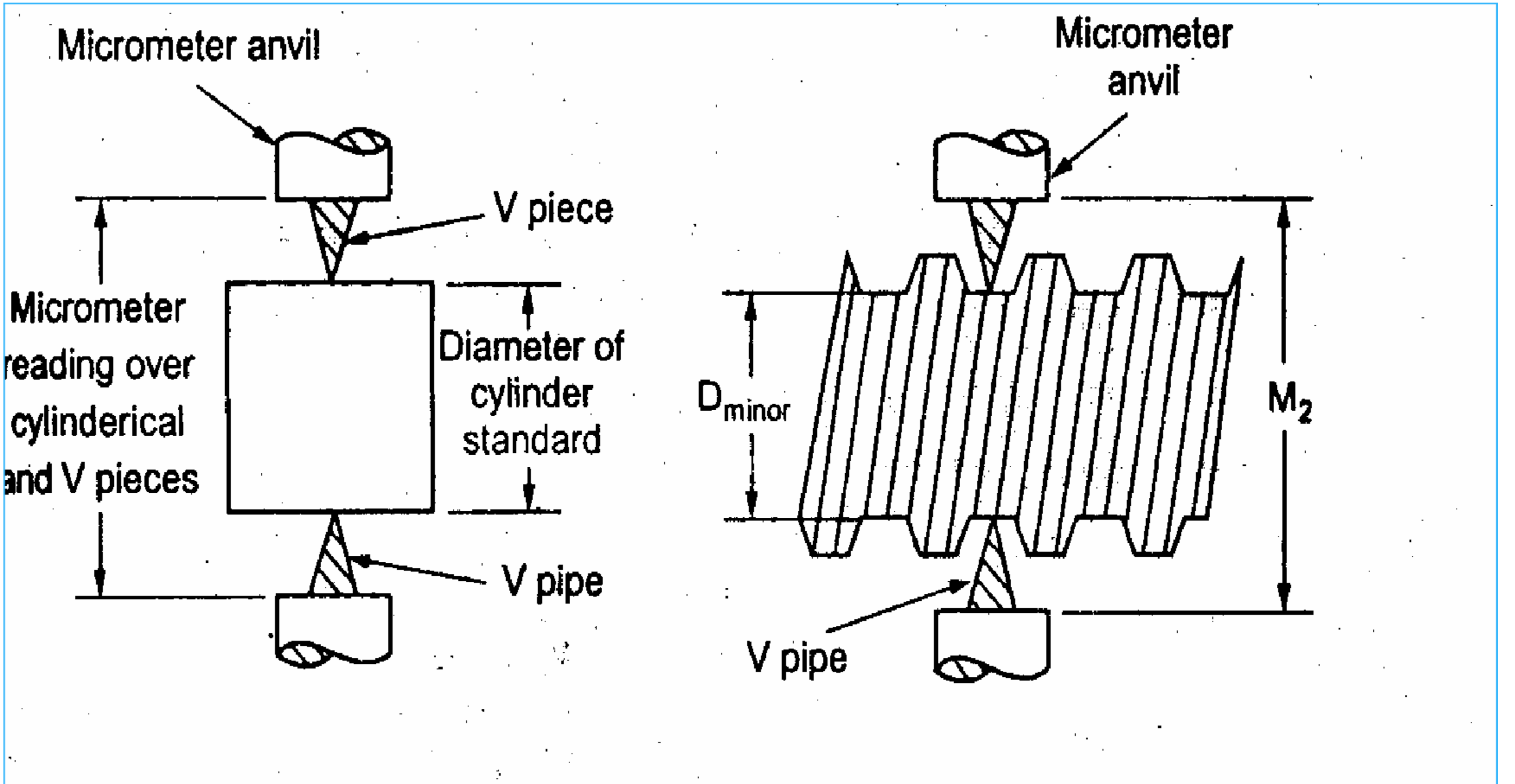
R_2 = Thread reading

R_1 = Dial Indicator reading on the standard.

Measurement of Minor diameter

- 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 of Minor diameter



Anvils being set *Thread being measured*

Measurement of Minor diameter

- The threaded work piece is mounted between the centers 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 work piece.

R_1 = Micrometer reading on cylindrical gauge.

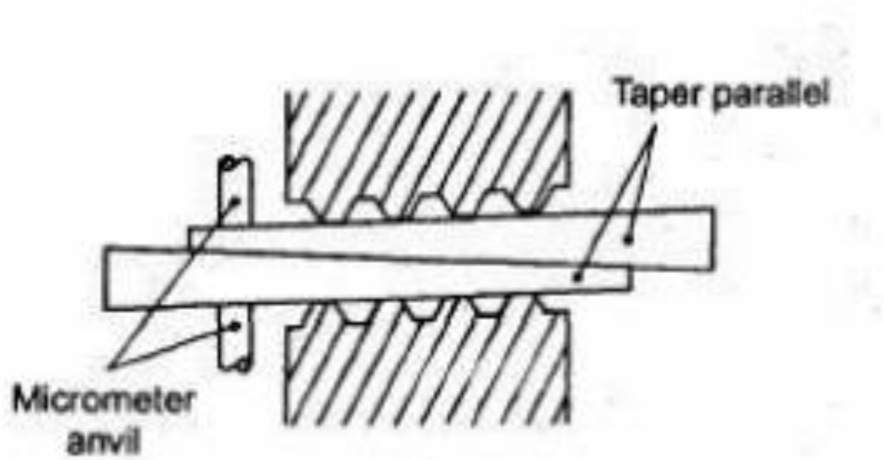
Measurement of Minor diameter of Internal threads:

The Minor diameter of Internal threads are measured by

1. Using taper parallels
2. Using Rollers.

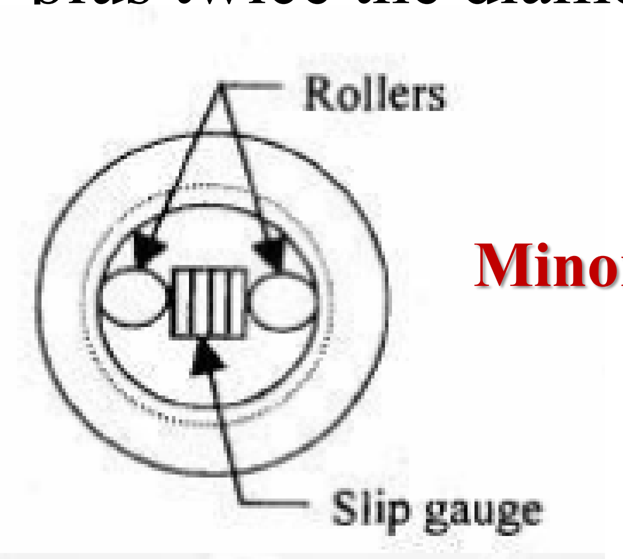
Using taper parallels

- For diameters less than 200mm the use of Taper parallels and micrometer is very common.
- The taper parallels are pairs of wedges having reduced and parallel outer edges.
- The diameter across their outer edges can be changed by sliding them over each other



Using rollers

- For more than 20mm 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.



Minor Diameter = length of slip gauges + 2 x diameter of rollers

Measurement of Effective Diameter

* One wire
* Two Wires
* Three wires method

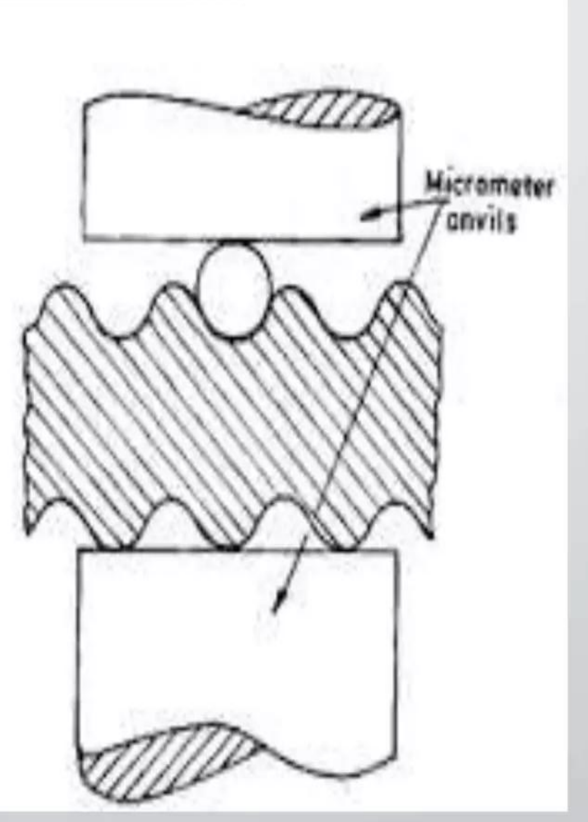
One wire method

- In this only one wire is used.
- It is placed between two threads at one side and the anvil contacts the crest on the other side.
- First the reading d_1 is noted on a standard gauge whose dimension is approx. same as that we are going to be obtained.
- Then the setting gauge is replaced by the thread that is to be measured and the reading d_2 is taken.

The effective diameter $= D \pm (d_1 \sim d_2)$

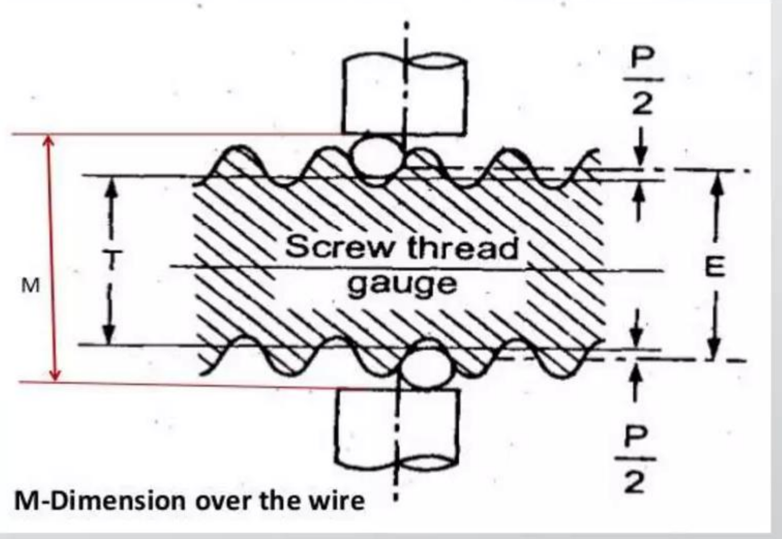
If $d_1 < d_2$ then use +ve sign

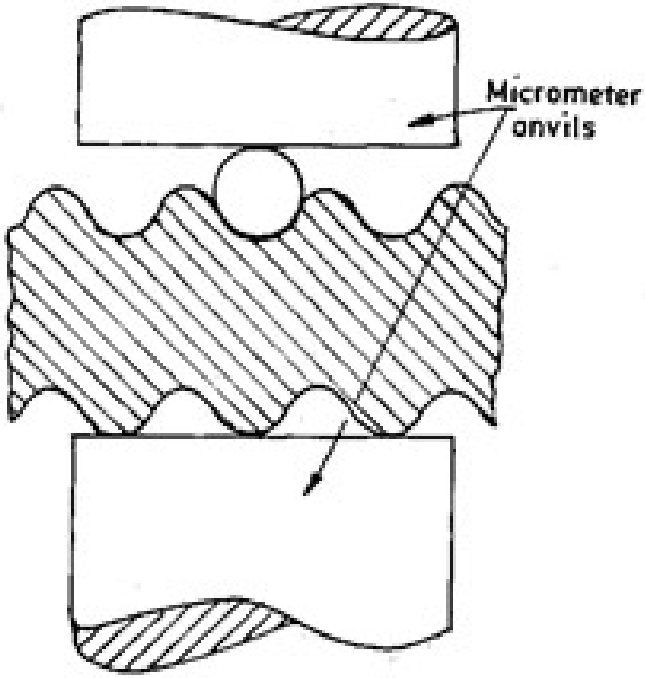
$d_1 > d_2$ then use –ve sign

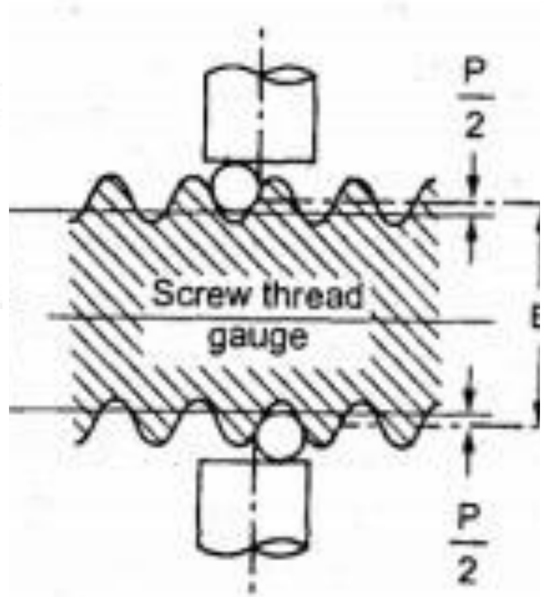


Two wire method

- In this method the two wires of identical diameter is placed between the flanks of the thread.
- In this method also first of all the reading of the standard cylinder is taken and then the actual thread that is to be measured is kept.
- The diameter of the standard = S
  The diameter under the wires = T
  The effective dimeter of screw = E
- Then E=S+P
  where T= S-(R_1-R_2).
- Where P is depended upon the diameter of wire and pitch of the thread.




Micrometer
anvils


P
2
Screw thread
gauge
P
2

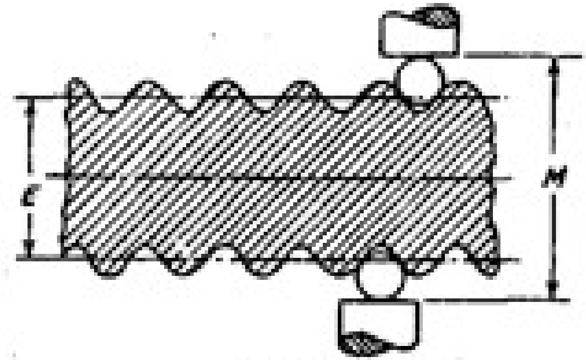
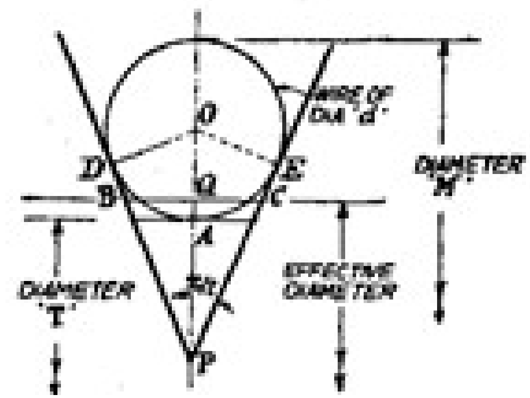
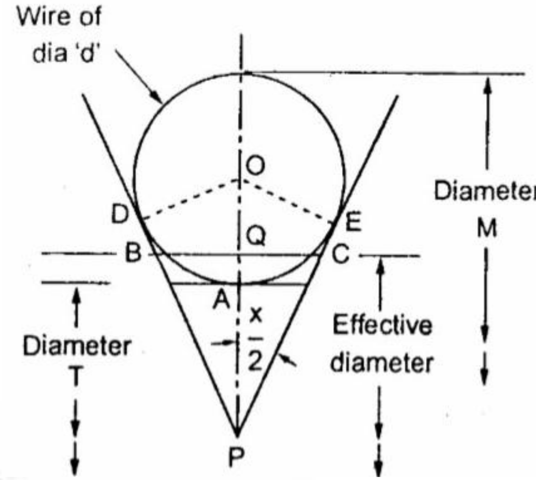

E
H

Fig. 13.15 (a)


O
D
E
Q
B
C
A
P
WIRE OF DIA 'd'
DIAMETER 'H'
DIAMETER 'T'
EFFECTIVE DIAMETER



From the above reading

The 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

If P' = Pitch of thread then

$$\boxed{P = 0.9605\,P' - 1.1657d \Rightarrow \text{Whitworth thread.}}$$

$$\boxed{P = 0.866\,P' - d \Rightarrow \text{For metric thread.}}$$

Here, P =The difference between the effective diamet
ınd the diameter under the wires.

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

$$T = S - (R_1 - R_2)$$

Where, S = The diameter of the standard.

The P value can be derived in terms of P (Pitch), d (Diameter of wire) and x thread angle is as follows

BC lies on the effective diameter.

$$\therefore \text{BC} = \frac{1}{2} \, Pitch = \frac{1}{2} \, P$$

$$\text{Next OP} = \frac{d \, Co\sec(x/2)}{2}$$

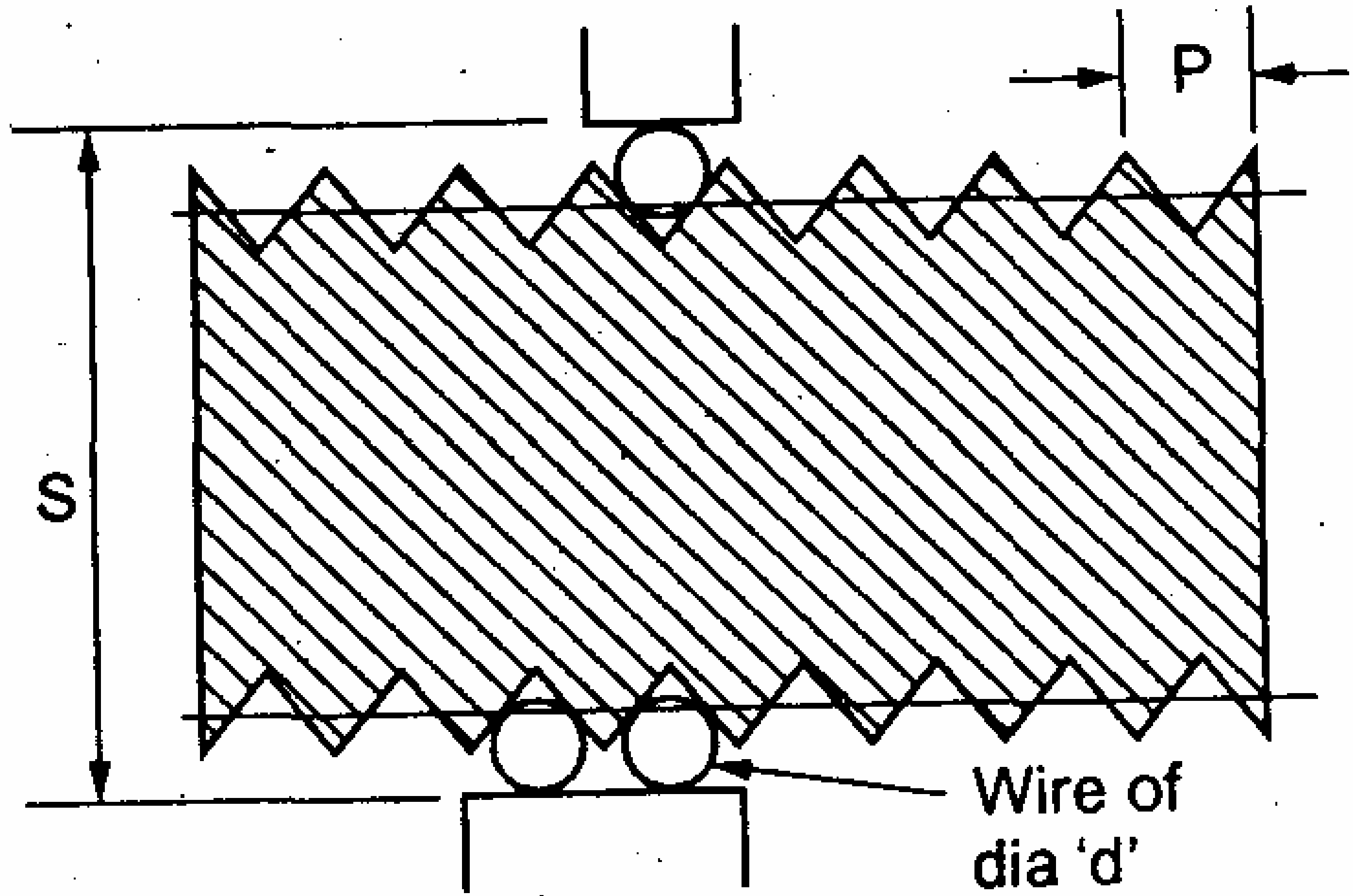
$$\text{And AQ} = \text{PQ} - \text{AP}$$

Where,

$$\text{PQ} = \text{QC} \, Cot\,(x/2) = P/4 \, Cot\,(x/2)$$

$$\boxed{\text{PQ} = \frac{P}{4} \, Cot(x/2)}$$

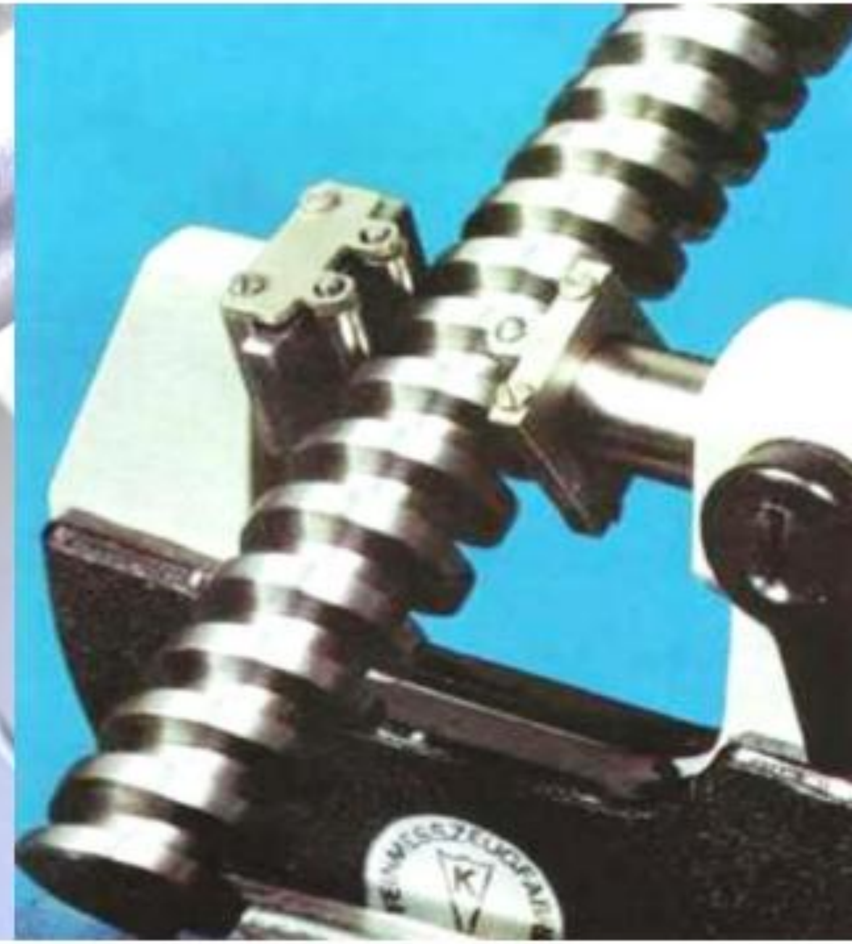
Three Wire Method



Three Wire Method

Three-wire method

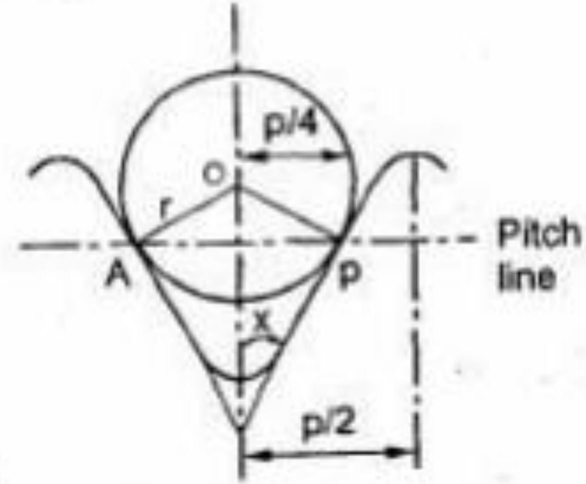
Principle of three-wire method



BEST WIRE SIZE

- Best wire diameter is that may contact with the flanks of the thread on the pitch line.
- The figure shows the wire makes contact with the flanks of the thread on the pitch.

Hence best wire diameter,



$$db = 2Ap\ secx$$

Where, db = Wire diameter

x = Included angle

$$AP = p/4$$

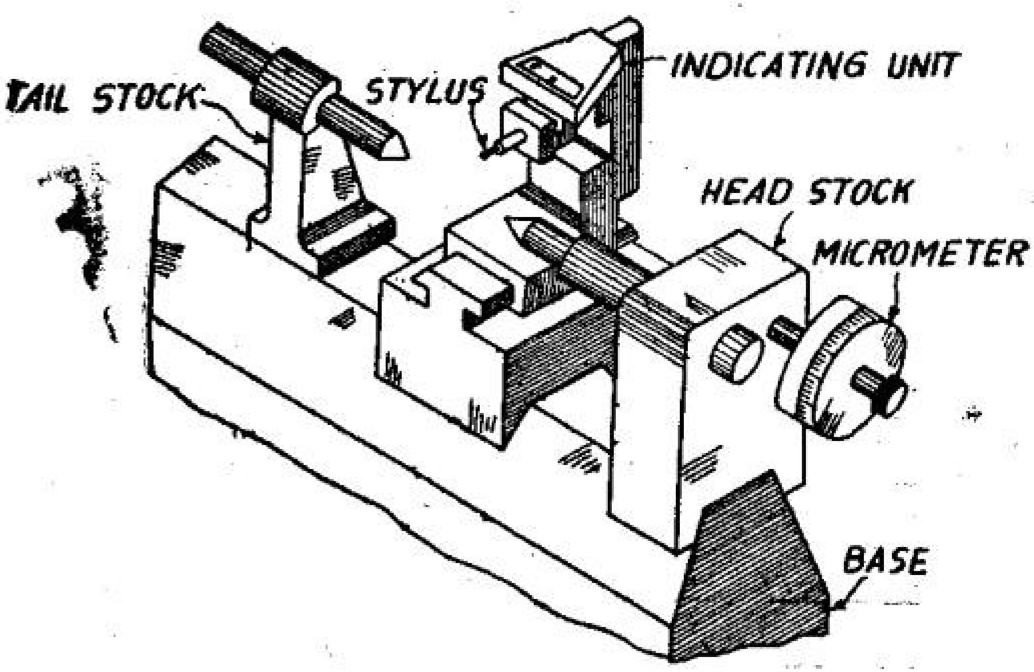
$$\therefore\ db = 2\ p/4\ sec\ x$$

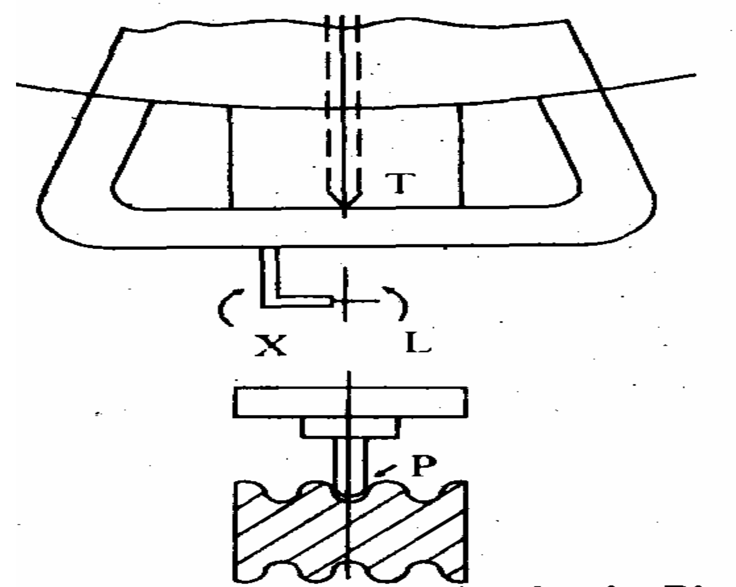
$$\boxed{db = p_2\ secx}$$

Pitch measurement

- Pitch measuring machine
- Tool makers microscope
- Screw pitch gauge

Pitch measuring machine





Screw pitch gauge

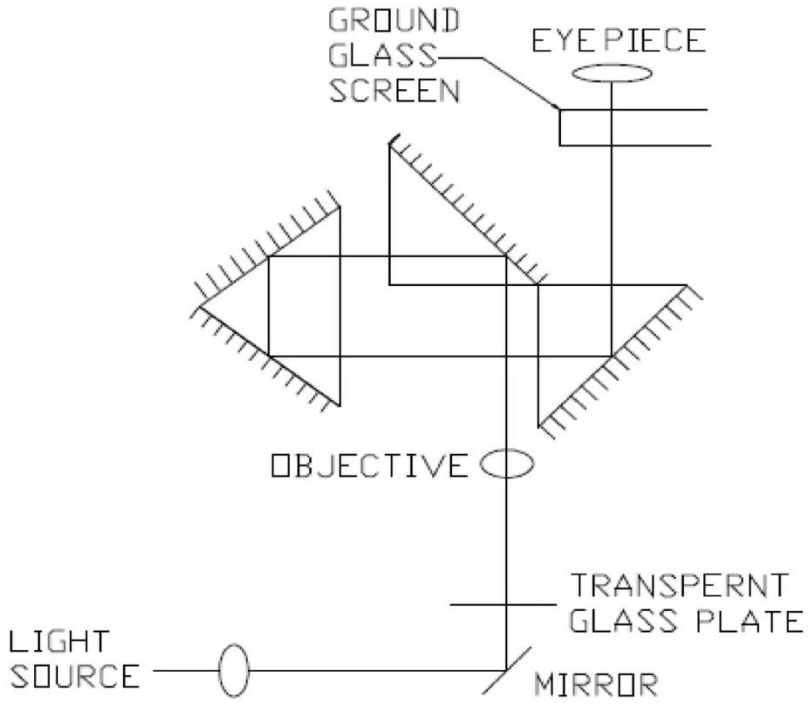
Tool makers microscope

Introduction

- ✓ The toolmaker's microscope is an optical measuring machine equipped for external & internal length measurements as well as measurements on screw threads, profiles, curvatures & angles.
- ✓ A toolmakers microscope is a measuring device that can be used to measure up to 1/100th of an mm.
- ✓ It works on the principle of a screw gauge, but a few changes were added to it to make its operation more easier.
- ✓ It needs application of optics too.
- ✓ A light focuses on the object & through lens we can see the shadow of the object, which resembles the object.
- ✓ More clear shadow would be enhance the accuracy of measurement.

Principle of Measurement

- ✓ A ray of light from a light source is reflected by a mirror through 90˚.
- ✓ It then passes through a transparent glass plate.
- ✓ A shadow image of the outline or counter of the workspaces passes through the objective of the optical head & is projected by a system of three prisms to a ground glass screen.
- ✓ Observations are made through an eyepiece.
- ✓ Measurements are made by means of cross lines engraved on the ground glass screen.
- ✓ The screen can be rotated through 360˚ the angle of rotation is read through an auxiliary eyepiece.



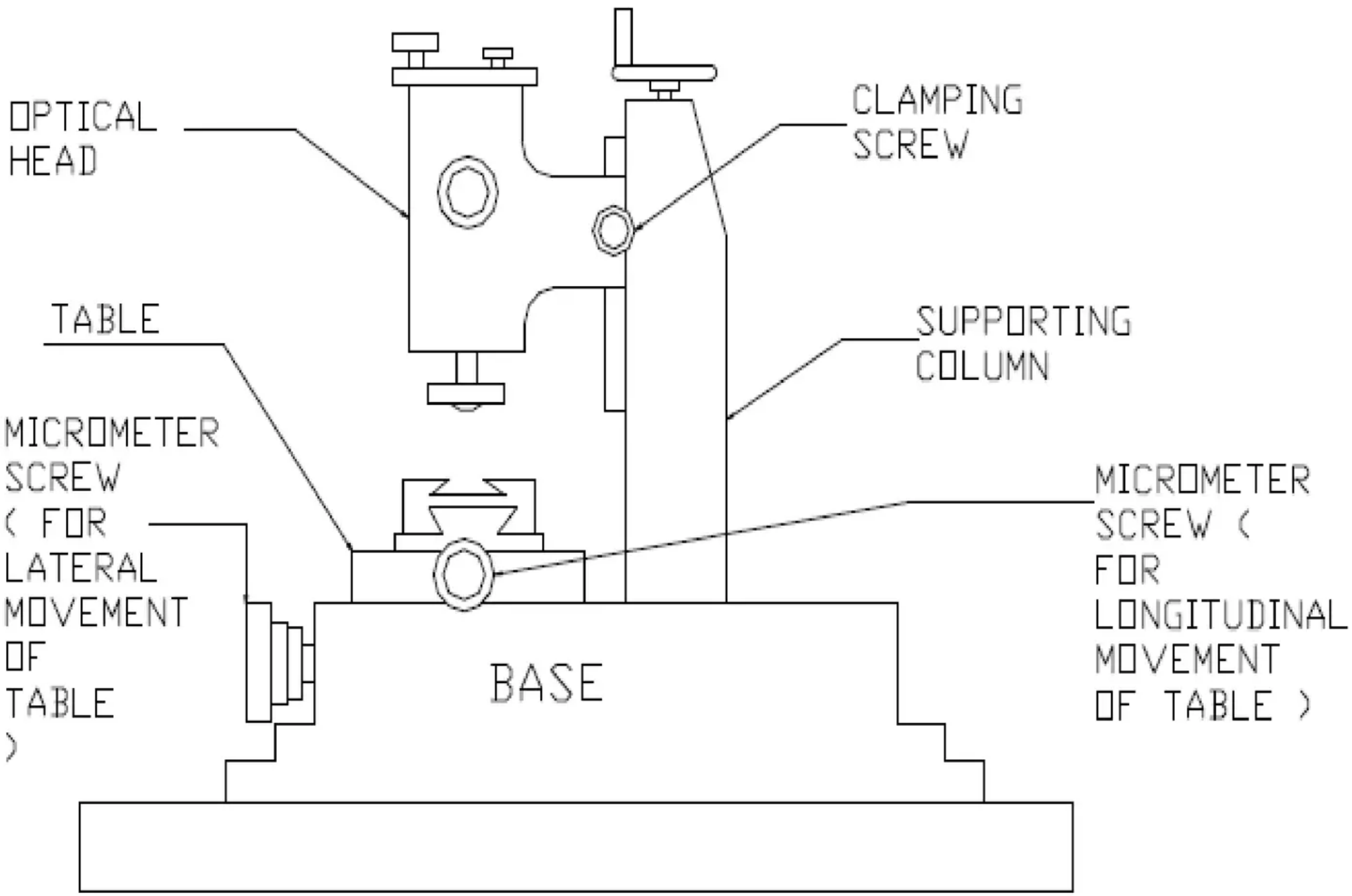
❑ Principle of Measurement

Main Components of Tool Maker’s Microscope

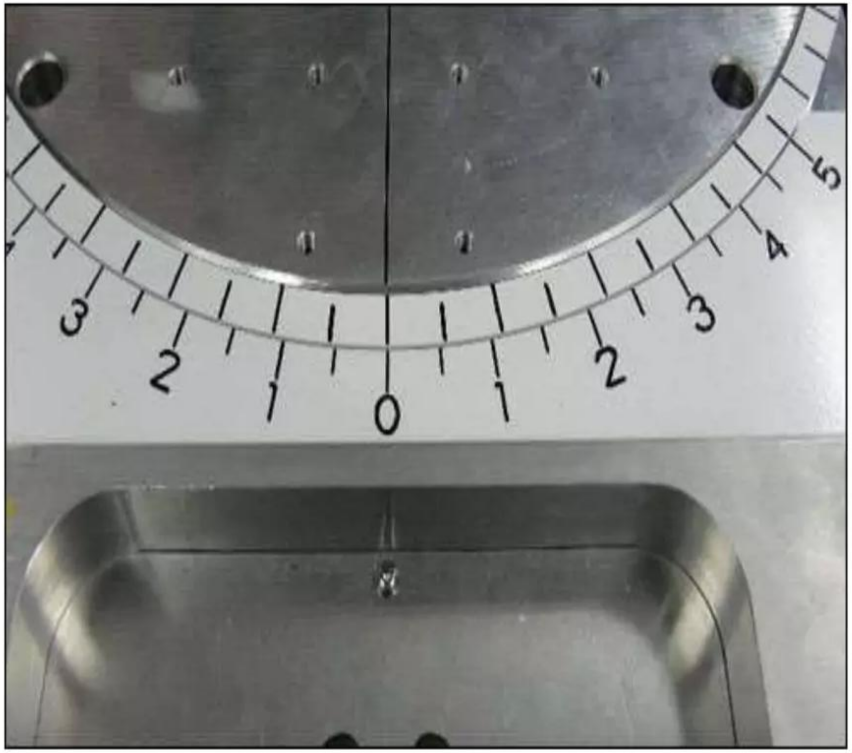
1. Rotatable Table,
2. Measuring Stage,
3. Moveable Head,
4. Ocular (Eye piece),
5. Projection Screen,
6. Micrometres,
7. Objective Lens,
8. Prism.

Construction

- ✓ TMM (toolmakers microscope) has got a robust & strong base such that it can bear & withstand sudden loads.
- ✓ A column with a track is present to carry lens, along with illuminating source in certain TMM's.
- ✓ Lens has two perpendicular straight lines marked that act as reference lines.
- ✓ Object to be measured is placed on glass table.
- ✓ Glass table is provided with 3 scales on it
- ✓ Two scales are meant for measuring in X & Y directions & the movement of table the respective direction.
- ✓ The other scale is meant for measuring rotation as well as rotation of table.



- Tool Maker's Microscope



- Scales On Microscope

Working

- The component being measured is illuminated by the through light method.
- A parallel beam of light illuminates the lower side of work-piece which is then received by the objective lens in its way to a prism that deflects the light rays in the direction of the measuring ocular & the projection screen.
- The direction of illumination can be tilted with respect to the work-piece by tilting the measuring head & the whole optical system.
- This inclined illumination is necessary in some cases as in screw thread measurements.

EXAMPLES

Pitch Measurement: -

- Take the hacksaw blade and mount on the moving blade of tool maker's Microscope in horizontal position.
- Focus the microscope on the blade.
- Make the cross line in the microscope coincided with one of the edge of the blade.
- Take a reading on ground glass screen, this is the initial reading.
- The table is again moved until the next edge of the blade coincides with the cross-line on the screen and the final reading takes.
- the difference between initial and final reading gives pitch of the blade.

Application

- ✓ Length measurement in Cartesian & polar co-ordinates.
- ✓ Angle measurements of tools.
- ✓ Thread measurements i.e., profile major & minor diameters, height of lead, thread
- ✓ angle, profile position with respect to the thread axis & the shape of thread.
- ✓ Comparison between centers & drawn patterns & drawing of projected profiles.
- ✓ Used for measuring the shape of different components like the template, formed cutter, milling cutter, punching die, and cam

Measurements of Gear tooth thickness

GEAR…..

- Power transmission is the movement of energy from its place of generation to a location where it is applied to performing useful work

- A gear is a component within a transmission device that transmits rotational force to another gear or device

TYPES OF GEARS

1. According to the position of axes of the shafts.

a. Parallel

   1. Spur Gear
   2. Helical Gear
   3. Rack and Pinion

b. Intersecting

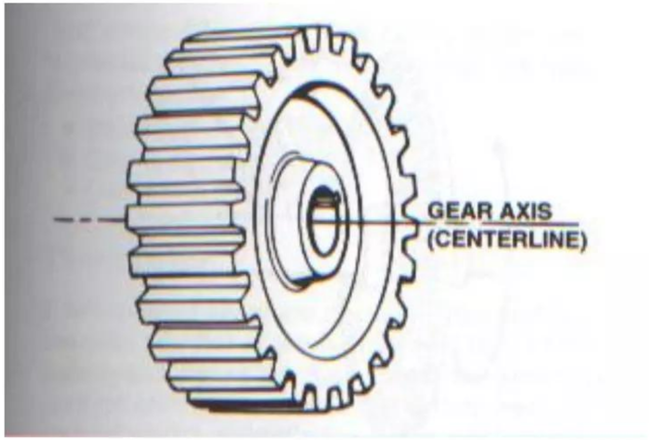
   Bevel Gear

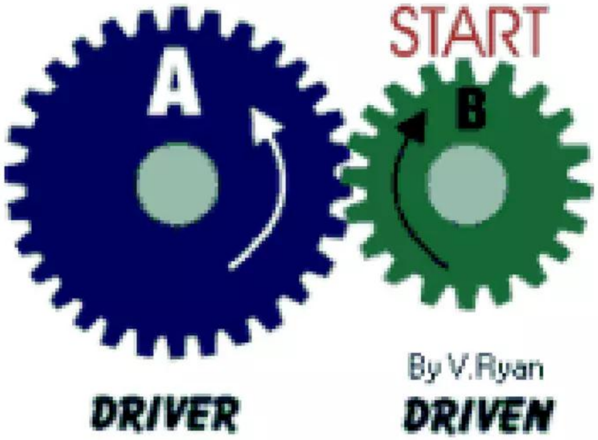
c. Non-intersecting and Non-parallel

   worm and worm gears

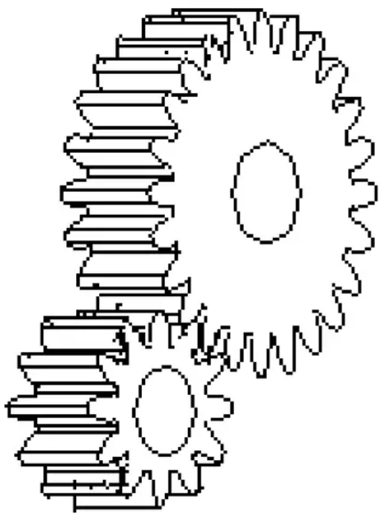
SPUR GEAR

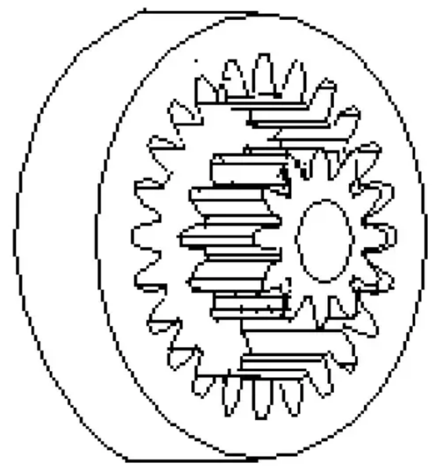
- Teeth is parallel to axis of rotation
- Transmit power from one shaft to another parallel shaft
- Used in Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer





External and Internal spur Gear…

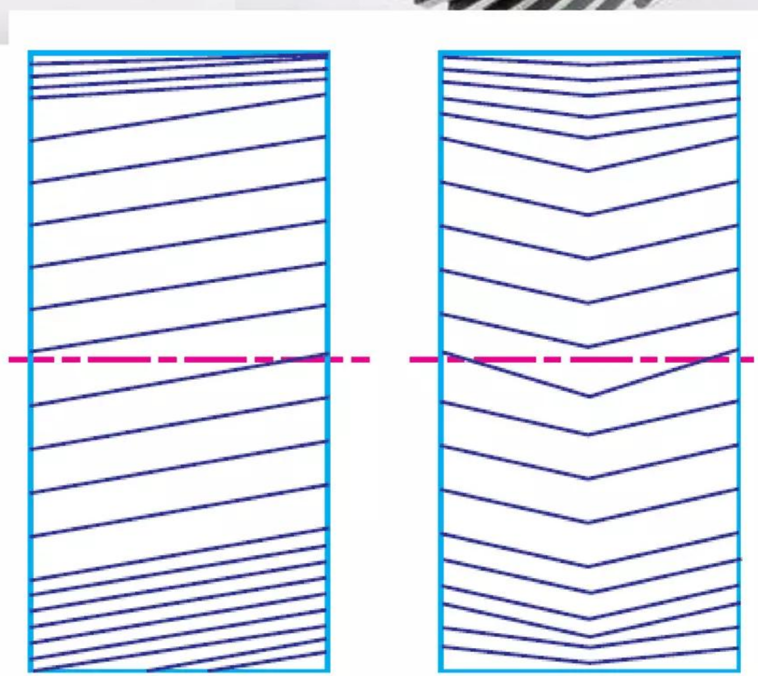




Helical Gear

- The teeth on helical gears are cut at an angle to the face of the gear
- This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears
- One interesting thing about helical gears is that if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees

Helical Gear…

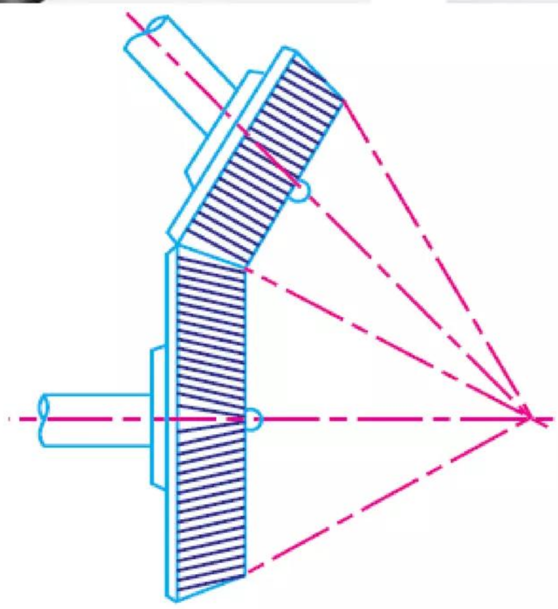


Rack and pinion

- **Rack and pinion gears** are used to convert rotation (From the pinion) into linear motion (of the rack)

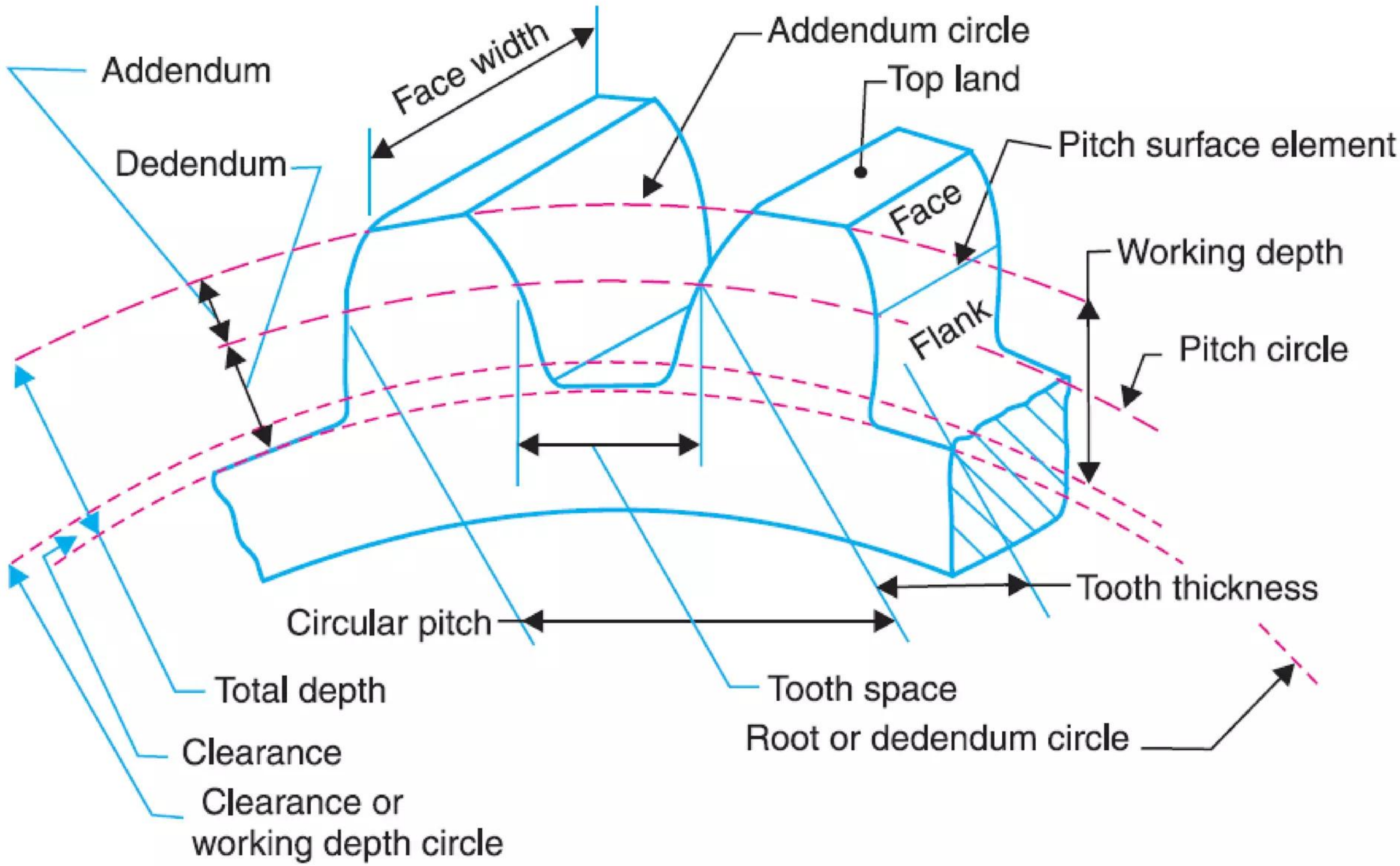
- A perfect example of this is the steering system on many cars

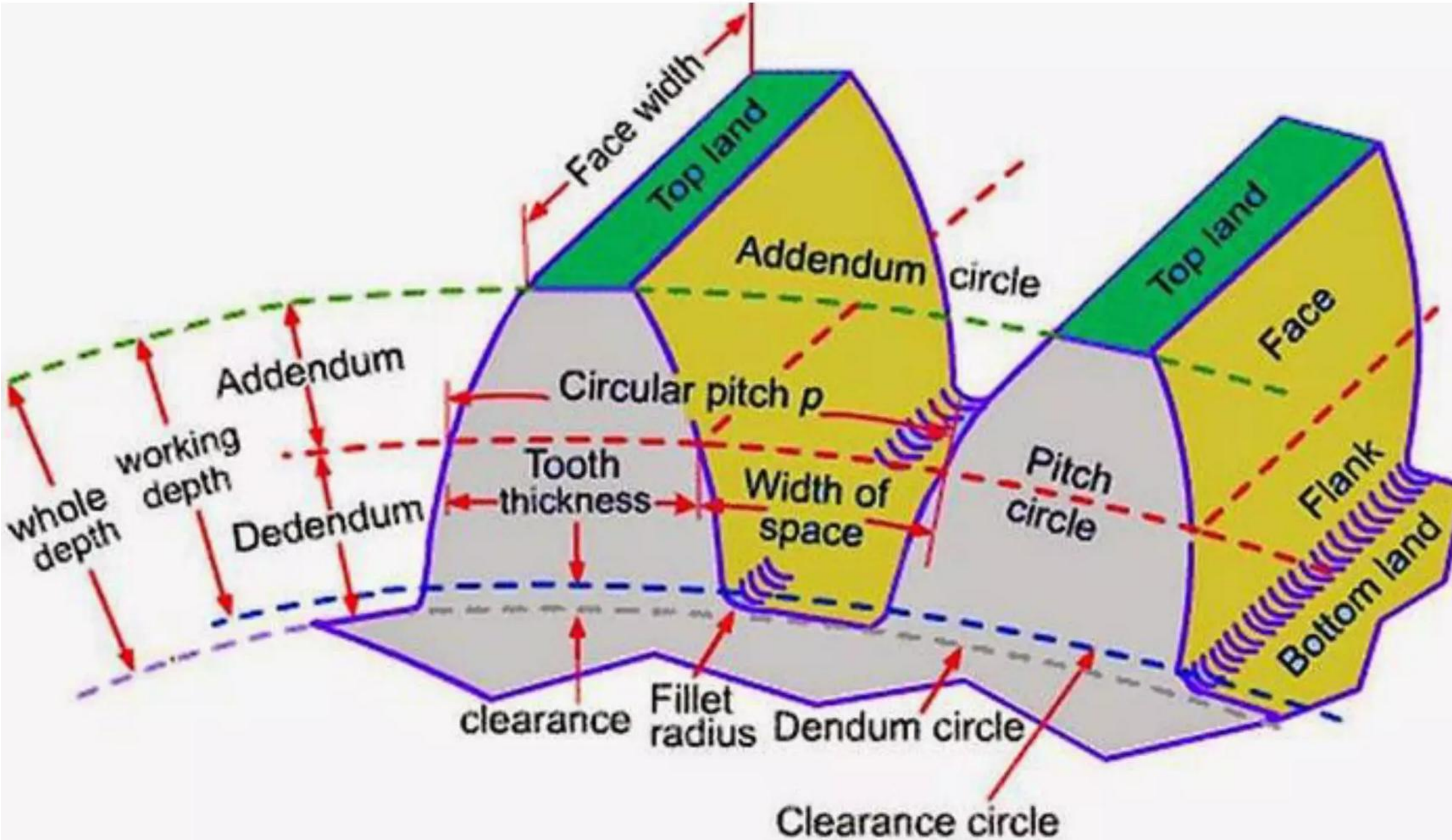
Straight and Spiral Bevel Gears

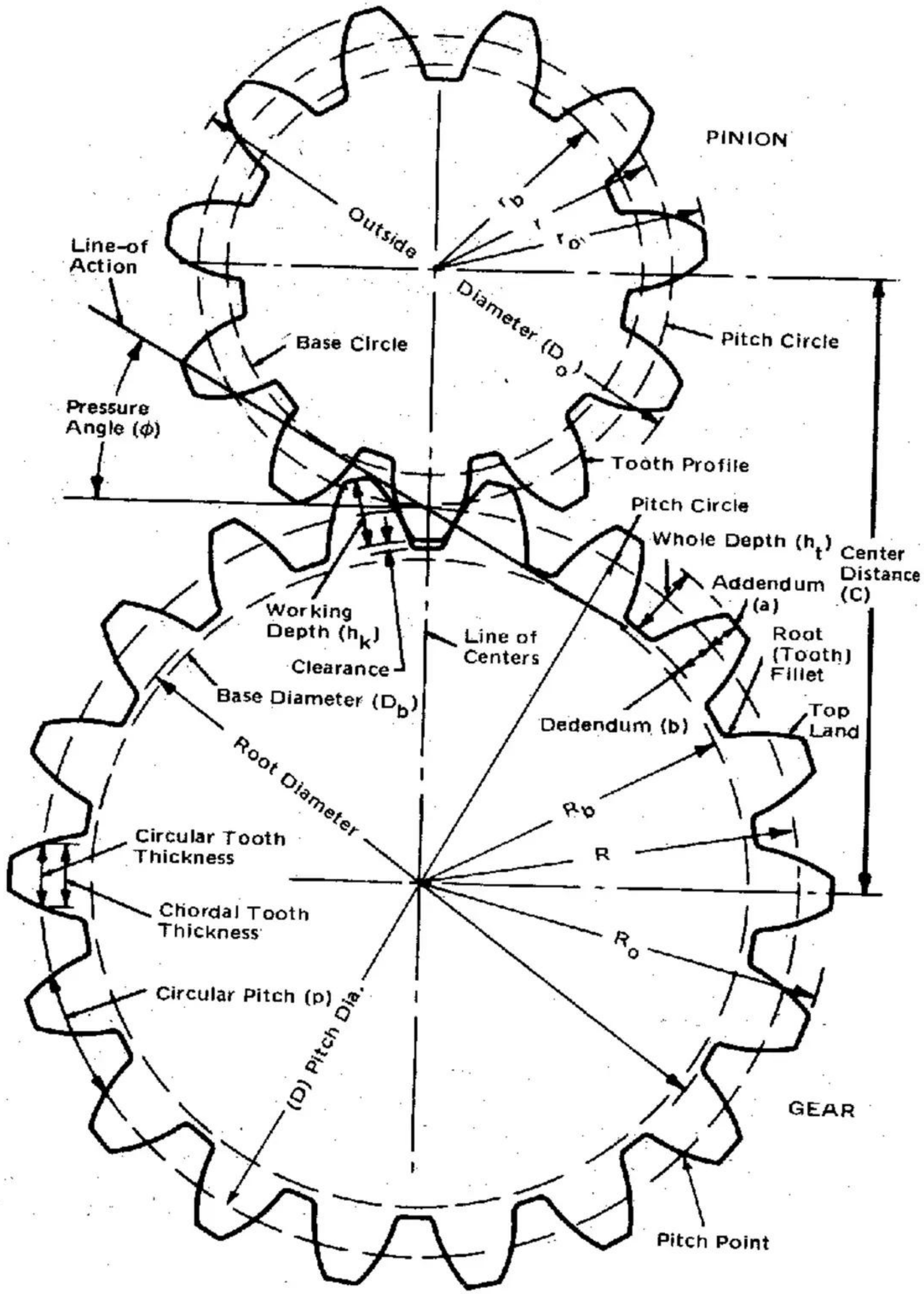


WORM AND WORM GEAR

NOMENCLATURE OF SPUR GEARS




Face width
Top land
Addendum circle
Top land
Face
Addendum
Circular pitch p
working depth
whole depth
Tooth thickness
Width of space
Pitch circle
Flank
Dedendum
Bottom land
clearance
Fillet radius
Dendum circle
Clearance circle


PINION
Line-of Action
Outside Diameter (D_o)
r_b
r
r_o
Pitch Circle
Base Circle
Pressure Angle (ϕ)
Tooth Profile
Pitch Circle
Whole Depth (h_t)
Center Distance (C)
Addendum (a)
Root (Tooth) Fillet
Working Depth (h_k)
Line of Centers
Clearance
Base Diameter (D_b)
Dedendum (b)
Top Land
Root Diameter
R_b
R
Circular Tooth Thickness
Chordal Tooth Thickness
R_o
Circular Pitch (p)
(D) Pitch Dia.
GEAR
Pitch Point

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)

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 coincides with the crests (or) tops of teeth.

6. Dedendum circle (or) Root circle

This circle coincides with the roots (or) bottom on teeth.

7. Pressure angle (a)

It is the angle making 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.
Where, d = Pitch circle diameter. n = Number f teeth.

9. Circular pitch

It is the distance along the pitch circle between corresponding points of adjacent teeth.

10. Addendum

Radial distance between tip circle and pitch circle. Addendum value = 1 module.

11. Dedendum

Radial distance between itch circle and root circle, Dedendum value = 1 .25module.

12. Face

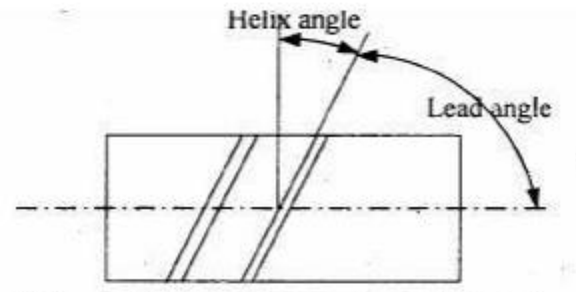
Part of the tooth in the axial plane lying between tip circle and pitch circle

13. Flank

Part of the tooth lying between pitch circle and root circle.

14. Top land

Top surface of a tooth.



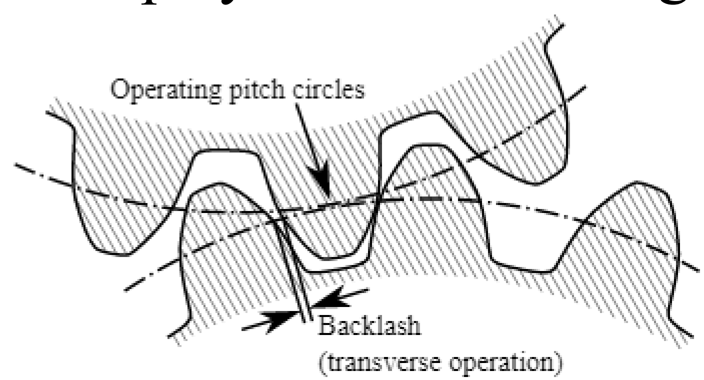
The angle between the tangents to helix angle.

15. Lead angle

The angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

16. Backlash:

Backlash in gears refers to the clearance or play between mating gear teeth when they are not engaged.



Gear errors

1. **Profile error:**

The maximum distance of any point on the tooth profile form to the design profile.

2. **Pitch error: -**

Difference between actual and design pitch

3. **Cyclic error: -**

Error occurs in each revolution of gear

4. **Run out:** - This type of error refers to the runout of the pitch circle. Runout causes vibrations and noise, and reduces the life of the gears and bearings.

5. **Eccentricity:** - Half the radial run out

6. Wobble:

Run out measured parallel to the axis of rotation at a specified distance from the axis

7. Radial run out:

Run out measured along a perpendicular to the axis of rotation.

8. Axial run out:

Run out measured parallel to the axis of rotation at a speed.

9. Periodic error:

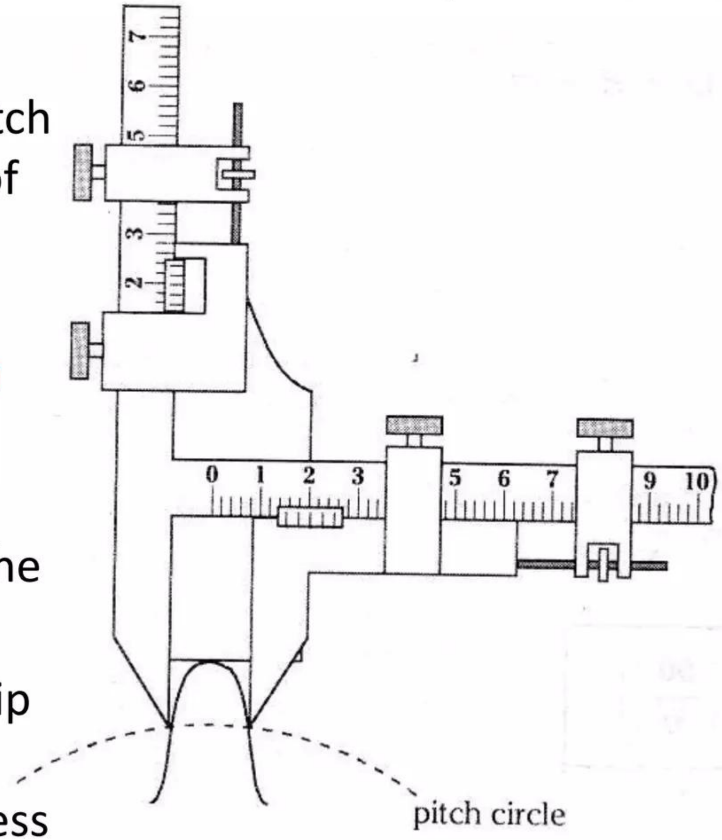
Error occurring at regular intervals.

Gear Measurement

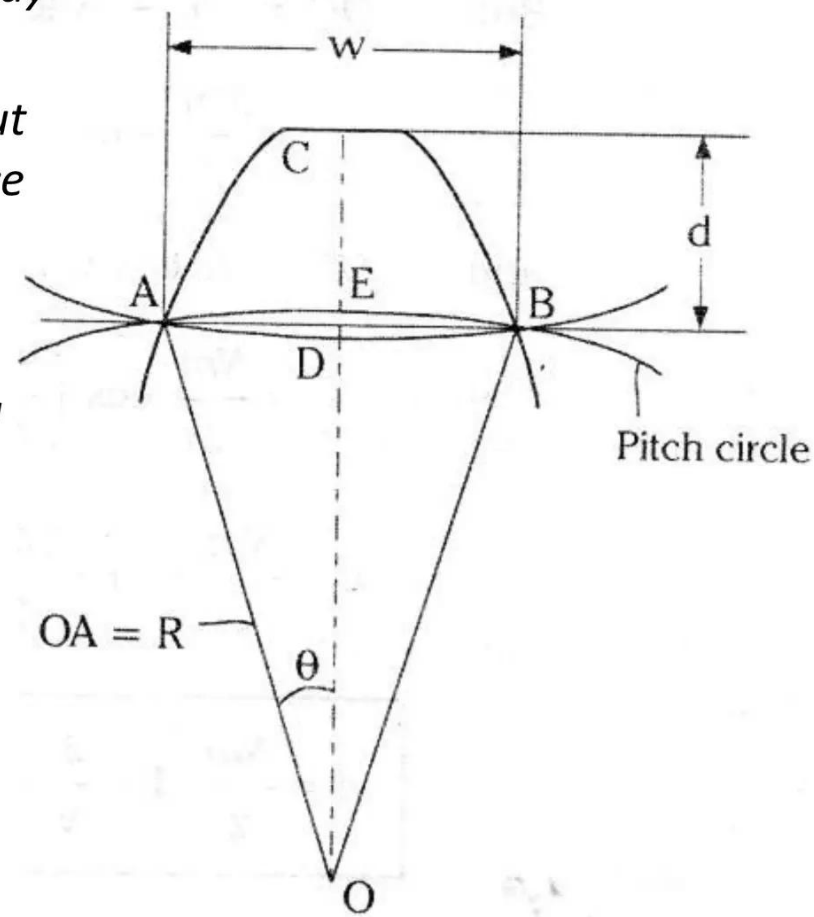
The Inspection of the gears consists of determine the following elements in which manufacturing error may be present.

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

- **Measurement of tooth thickness**
- The tooth thickness is generally measured at pitch circle and is therefore, the pitch line thickness of the tooth. Following method is used for measuring the gear tooth thickness :
- **Measurement of tooth thickness by gear tooth vernier caliper.**
- The gear tooth thickness can be conveniently measured by a gear tooth vernier as shown in the fig.
- Since the gear tooth thickness varies from the tip to the base circle of the tooth, the instrument must be capable of measuring the tooth thickness at a specified position on the tooth.
- The gear tooth vernier has two vernier scales. The vertical vernier scale is used to set the depth (d) along the pitch circle from the top surface of the tooth at which the width *(w) has to be measured. While the horizontal vernier scale is used to measure the width (w) of the teeth.*



- Considering one gear tooth, the theoretical values of *w and d can be found out which may be verified by the instrument.*
- *As shown in the figure , w is a chord ADB, but tooth thickness is specified as an arc distance AEB. Also the depth d adjusted on the instrument is slightly greater than the addendum CE", width w is therefore called chordal thickness and d is called the chordal addendum.*



W=AB=2AD

WKT, θ=360/4N,

Where N= number of teeth.

In the Δ^{le} ADO,

$$w = 2AD = 2 \times AO \sin\theta$$

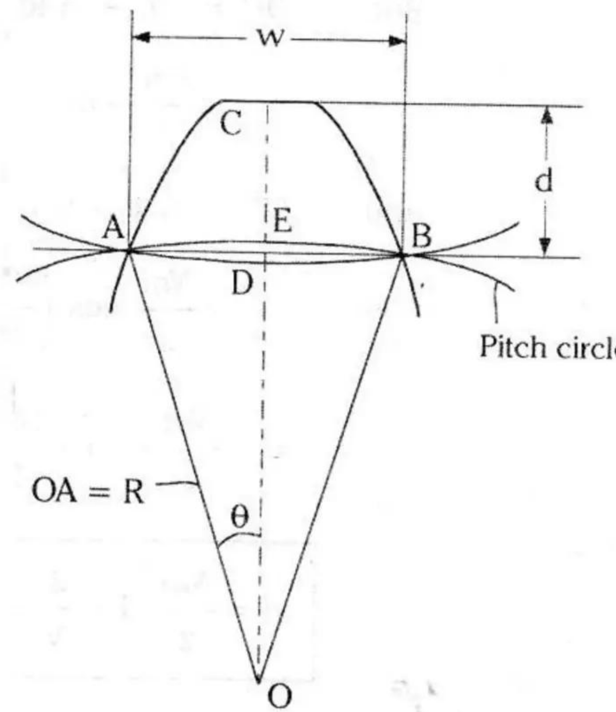
$$= 2R \sin \frac{360}{4N} \quad (; R = \text{pitch circle radius})$$

$$\text{module } m = \frac{\text{pitch circle diameter}}{\text{Number of teeth}} = \frac{2R}{N}$$

$$\therefore \quad R = \frac{N \cdot m}{2}$$

$$\therefore \quad w = 2 \cdot \frac{Nm}{2} \cdot \sin\left(\frac{360}{4N}\right)$$

$$\boxed{w = N m \sin\left(\frac{90}{N}\right)}$$



Also from the figure,

$$d = OC - OD.$$

Addendum is the radial distance from the pitch circle to the tip of the tooth. Its value is equal to one module

But $\quad OC = OE + \text{Addendum} = R + m$

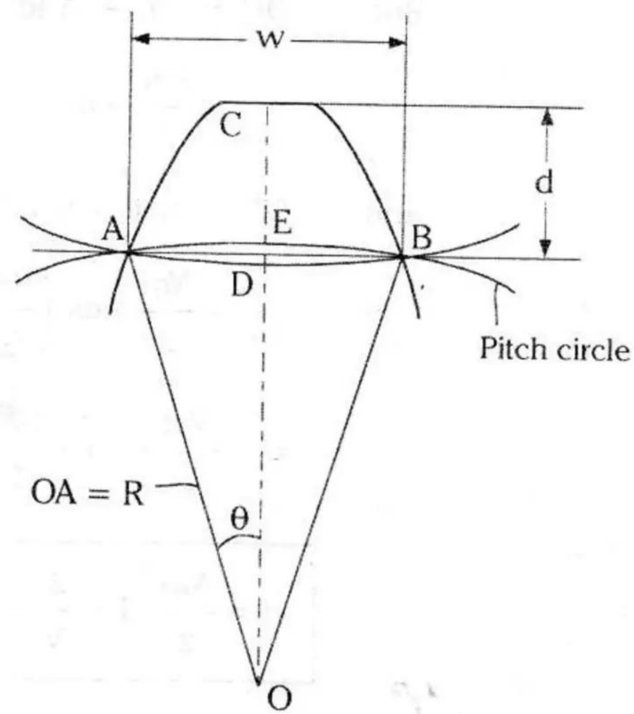
$$= \frac{Nm}{2} + m$$

and $\quad OD = R \cos \theta$

$$= \frac{Nm}{2} \cos\left(\frac{90}{N}\right)$$

$$\therefore \quad d = \frac{Nm}{2} + m - \frac{Nm}{2} \cos\left(\frac{90}{N}\right)$$

$$\boxed{\boldsymbol{d = \frac{Nm}{2}\left[1 + \frac{2}{N} - \cos\left(\frac{90}{N}\right)\right]}}$$



Measurement of surface finish

Introduction

- When we are producing components by various methods of manufacturing process it is not possible to produce perfectly smooth surface and some irregularities are formed.
- These irregularities are causes some serious difficulties in using the components.
- So it is very important to correct the surfaces before use.

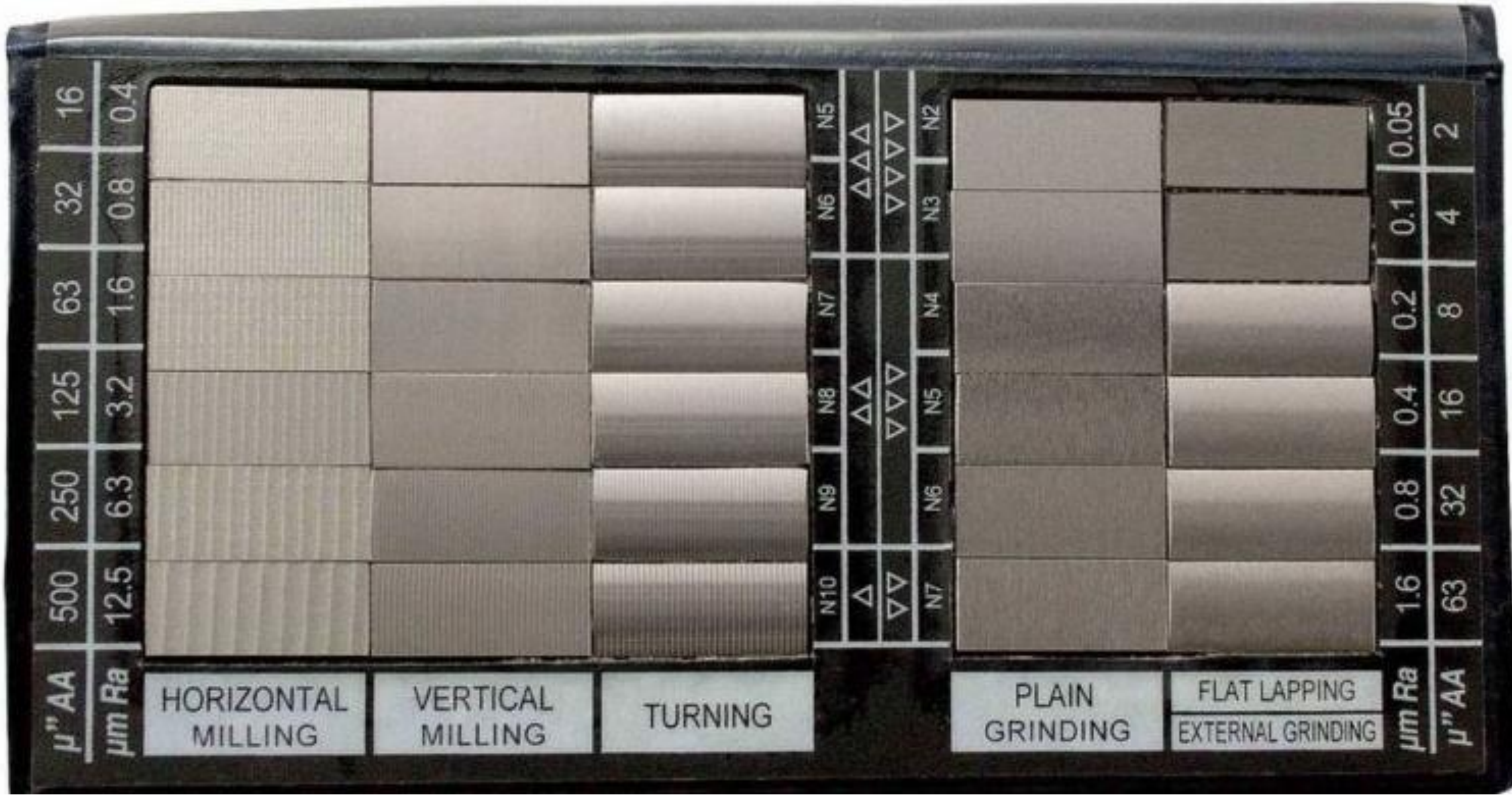
The factors which are affecting surface roughness are

1. Work piece material

2. Vibrations

3. Machining type

4. Tool and fixtures


μ" AA
μm Ra
16 32 63 125 250 500
0.4 0.8 1.6 3.2 6.3 12.5
N5 N6 N7 N8 N9 N10
N2 N3 N4 N5 N6 N7
HORIZONTAL MILLING
VERTICAL MILLING
TURNING
PLAIN GRINDING
FLAT LAPPING
EXTERNAL GRINDING
0.05 0.1 0.2 0.4 0.8 1.6
2 4 8 16 32 63
μm Ra
μ" AA

The geometrical irregularities can be classified as

1. First order
2. Second order
3. Third order
4. Fourth order

1. First order irregularities

These are caused by lack of straightness of guide ways on which tool must move.

2. Second order irregularities

These are caused by vibrations

3. Third order irregularities

These are caused by machining.

4. Fourth order irregularities

These are caused by improper handling machines and equipment.

Analysis of surface finish

The analyses of surface finish being carried out by

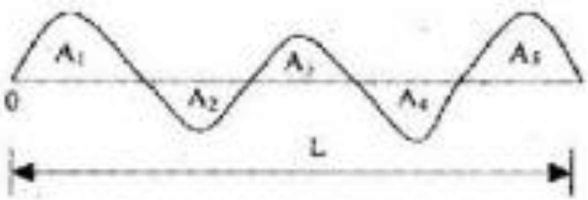
1. **The average roughness method.**
2. **Peak to valley height method**
3. **From factor**

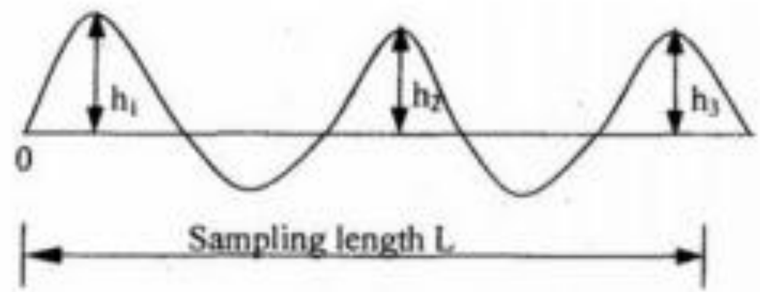
1. Average roughness measurement

- The assessment of average roughness is carried out by
  - a Centre line average (CLA)
  - b Root mean square (RMS)
  - c Ten point method

Centre line average (CLA)

- The surface roughness is measured as the average deviation from the nominal surface.





$$\text{C. L. A. Value} = \frac{A_1 + A_2 + A_3 + \ldots A_n}{L}$$

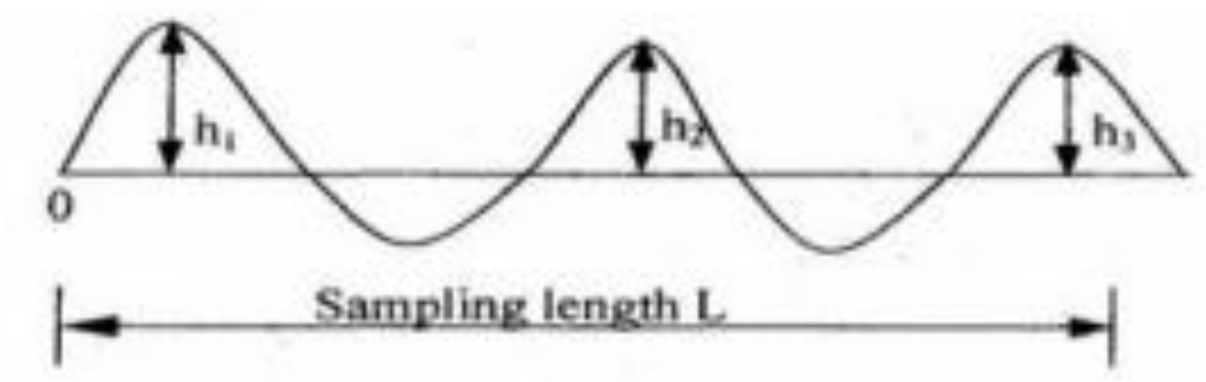
$$\boxed{\text{C. L. A.} = \frac{\sum A}{L}}$$

Where, $\sum A$ = Average area

L = Total length

Root mean square (RMS)

- The roughness is measured as the average deviation from the nominal surface.
- Let, h1,h2, ... are the heights of the ordinates and L is the sampling length

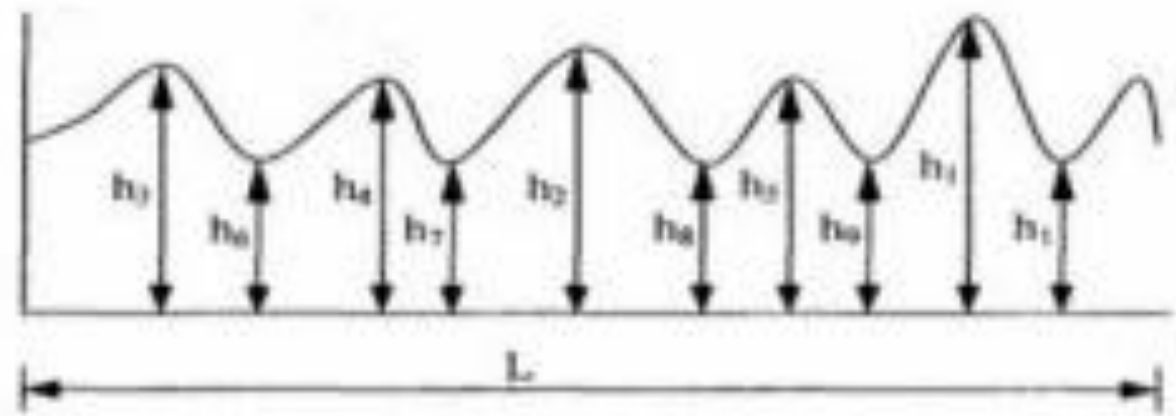


$$\text{R.M.S. average} = \frac{\sqrt{h_1^2 + h_2^2 + h_3^2 + \ldots + h_n^2}}{n}$$

Ten point method

- The average difference between five highest peaks and five lowest valleys of surface is taken and irregularities are calculated by

$$S_2 = \frac{1}{5}\left(h_1 + h_2 + h_3 + h_4 + h_5\right) - \left(h_6 + h_7 + h_8 + h_9 + h_{10}\right)$$



Methods of measuring surface finish

- The methods used for measuring the surface finish is classified into
- 1. Inspection by comparison
- 2. Direct Instrument Measurements

Inspection by comparison methods

- In these methods the surface texture is assessed by observation of the surface.
- The surface to be tested is compared with known value of roughness specimen and finished by similar machining process.

The various methods which are used for comparison are

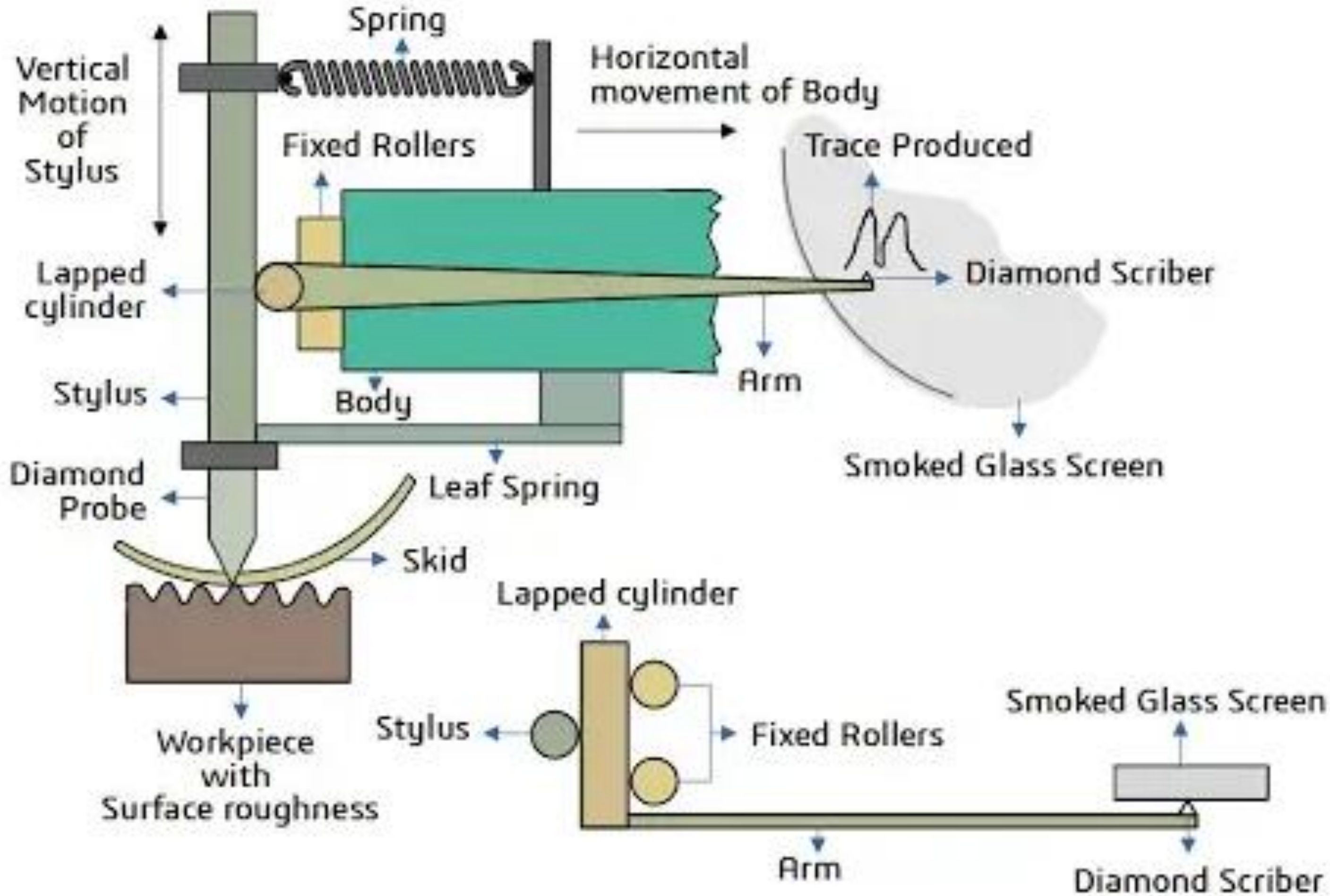
- 1. Touch Inspection.
- 2. Visual Inspection.
- 3. Microscopic Inspection.
- 4. Scratch Inspection.
- 5. Micro Interferometer.
- 6. Surface photographs.
- 7. Reflected Light Intensity.
- 8. Wallace surface Dynamometer.

Direct instrument measurements

- Some of the direct measurement instruments are
- 1. Stylus probe instruments.
- 2. ***Tomlinson surface meter.***
- 3. Profilometer.
- 4. Taylor-Hobson Talysurf

Tomlinson Surface Meter.

This instrument uses mechanical-cum-optical means for magnification.



Construction

- In this the diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped cylinder.
- The lapped cylinder is supported one side by probe and other side by rollers.
- The stylus is also attached to the body of the instrument by a leaf spring and its height is adjustable to enable the diamond to be positioned and the light spring steel arm is attached to the lapped cylinder.
- The spring arm has a diamond scriber at the end and smoked glass is rest on the arm

Working

- When measuring surface finish the body of the instrument is moved across the surface by a screw rotation.
- The vertical movement of the probe caused by the surface irregularities makes the horizontal lapped cylinder to roll.
- This rolling of lapped cylinder causes the movement of the arm.
- So this movement is induces the diamond scriber on smoked glass.
- Finally the movement of scriber together with horizontal movement produces a trace on the smoked glass plate and this trace is magnified by an optical projector.

Straightness Measurement

Introduction

- A line is said to be straight over a given length, if the variation of the distance of its from two planes perpendicular to each other and parallel to the general direction of the line remains within the specified tolerance limits.
- The tolerance on the straightness of a line is defined as the maximum deviation in relation to the reference straight line joining the two extremities of the line to be checked.

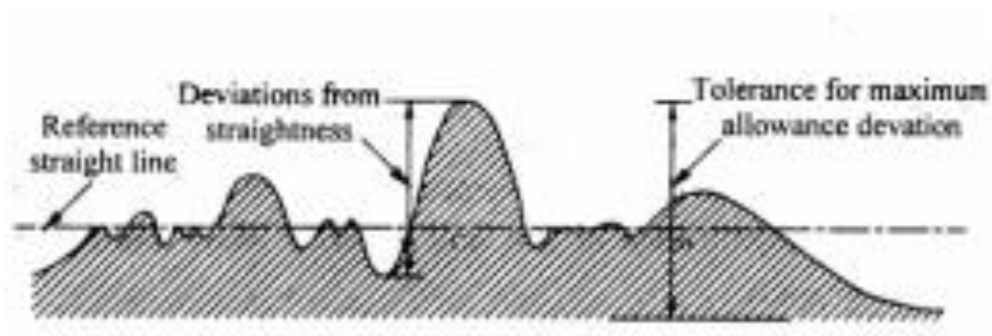


Fig 3.27 Straightness Measurement

Test for straightness by using spirit level

Autocollimator

Operating Principle of the Autocollimator

- The operating principle of an autocollimator combines collimator and telescope functions in a single instrument.

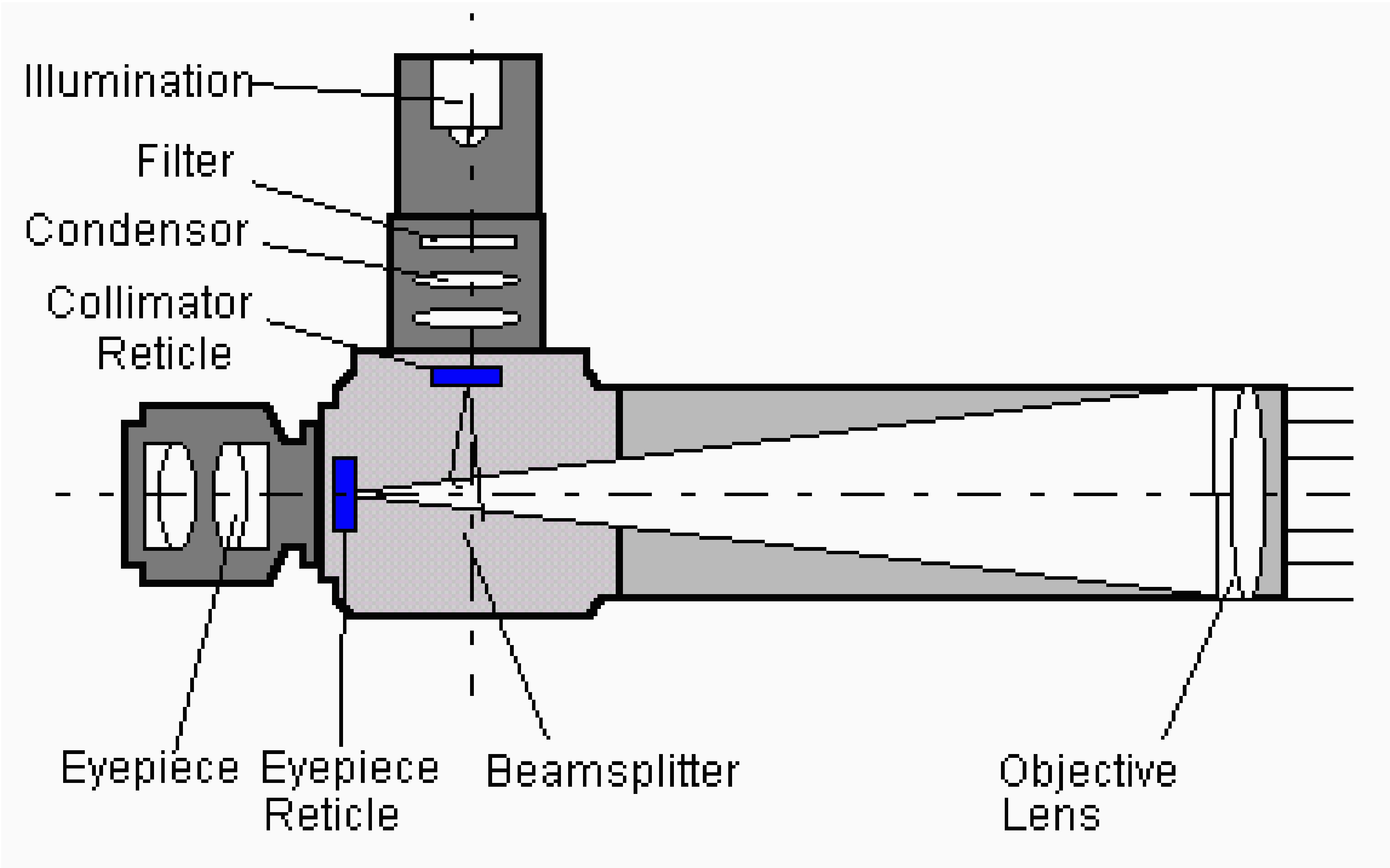
- An illuminated reticle is projected to infinity at the collimator section and at the telescope section the image is reflected at a mirror surface and then received back.

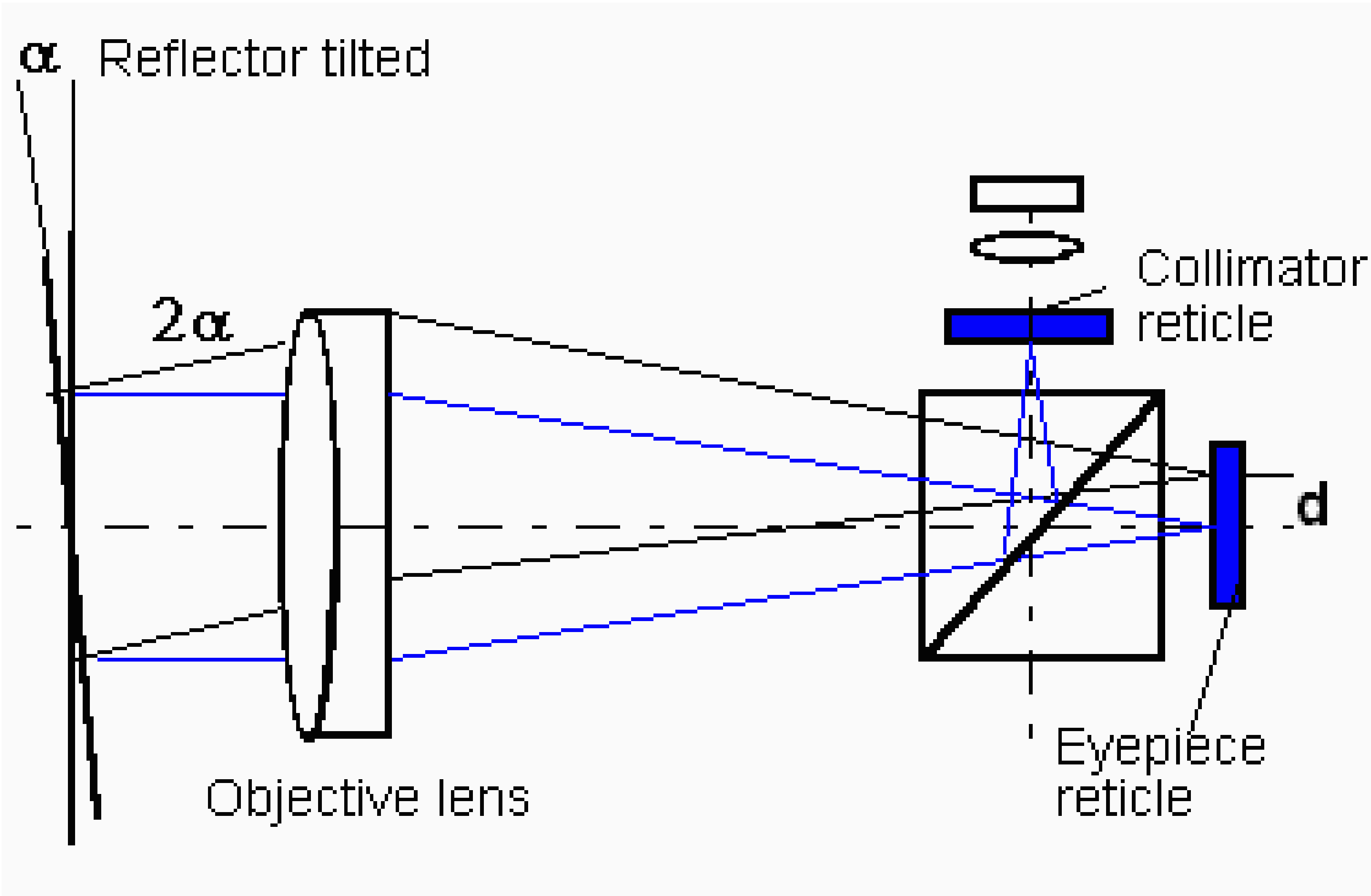
- A beam splitter separates the optical paths.

- The image obtained is focused at the objective lens in which the Charge Couple Device of an electronic camera or any other position sensor is present.

- In this arrangement, the illuminated reticle and the CCD plane are conjugate.

- When the collimated beam falls on a mirror which is at an angle of nearly 90° to the beam axis, the crosshair image will be positioned nearby the CCD center.

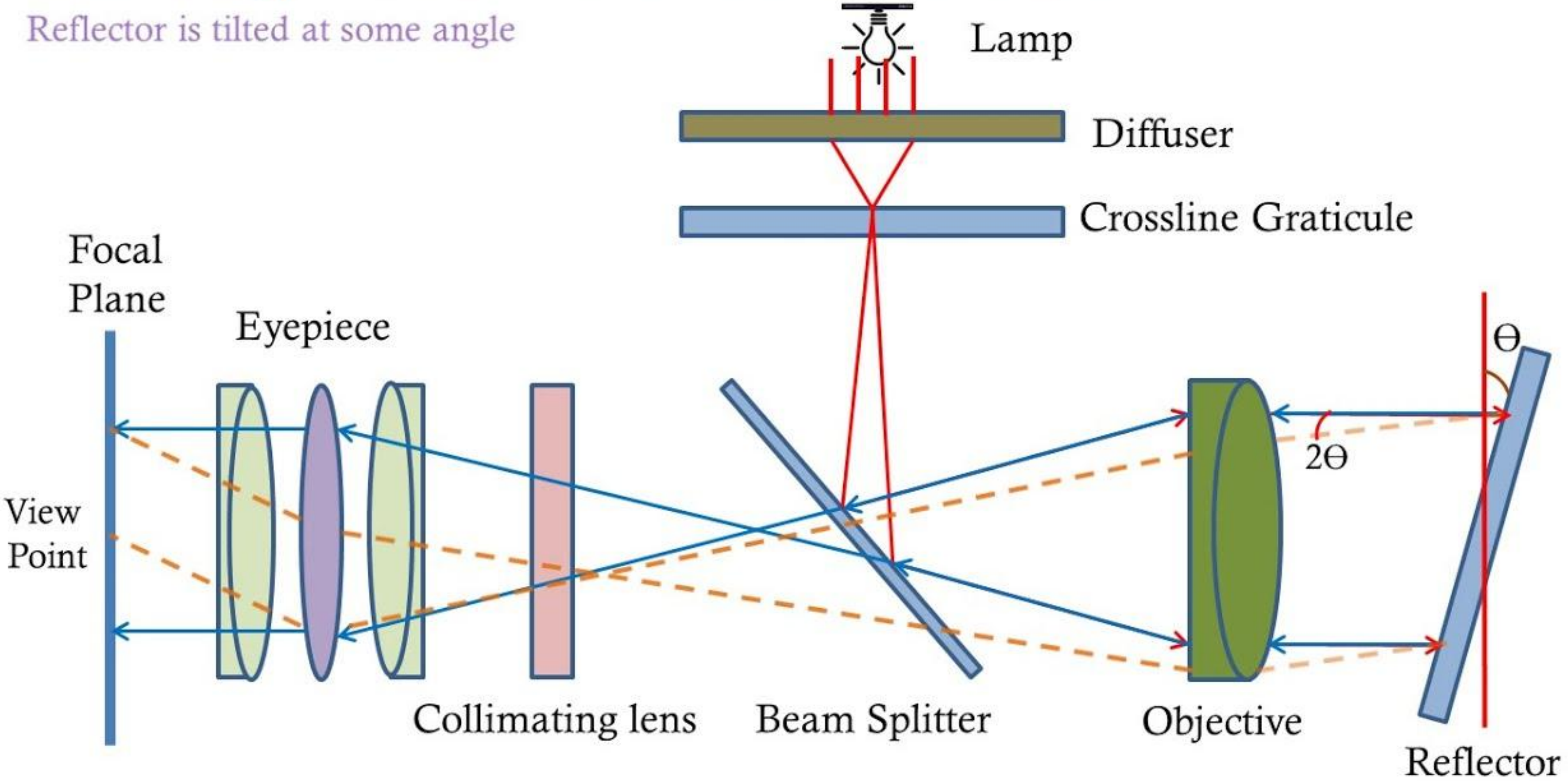

Illumination
Filter
Condensor
Collimator
Reticle
Eyepiece
Eyepiece
Reticle
Beamsplitter
Objective
Lens



Principle of autocollimator

Working Process of Autocollimator

Reflector is tilted at some angle



When the reflector is tilted by an angle α the reflected image will be displaced laterally by an amount d with respect to the original position.

This displacement d is a function of the tilt angle α and the focal length f of the objective lens and is obtained by Equation 1:

$$d = 2 \times \alpha \times f \qquad (1)$$

When the displacement d is measured on the CCD, the tilt angle α of the mirror is determined by Equation 2.

$$\alpha = d/2f \qquad (2)$$

https://www.youtube.com/watch?v=XHEywuzl9sA

Straightness measurement using autocollimator

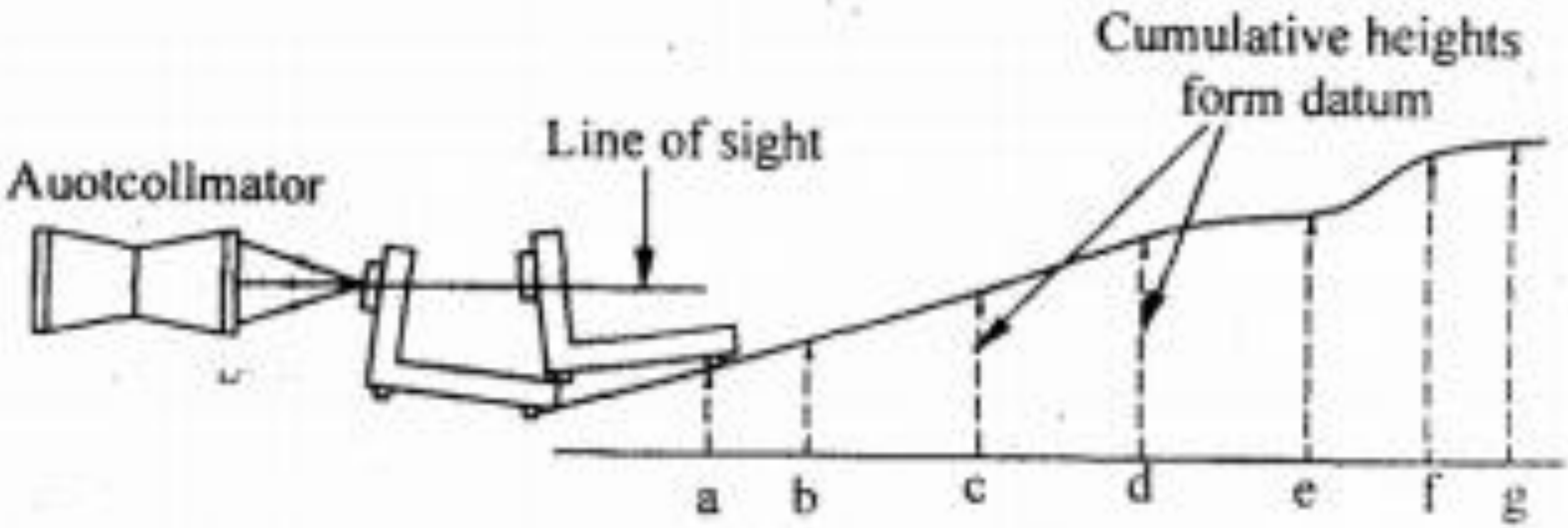
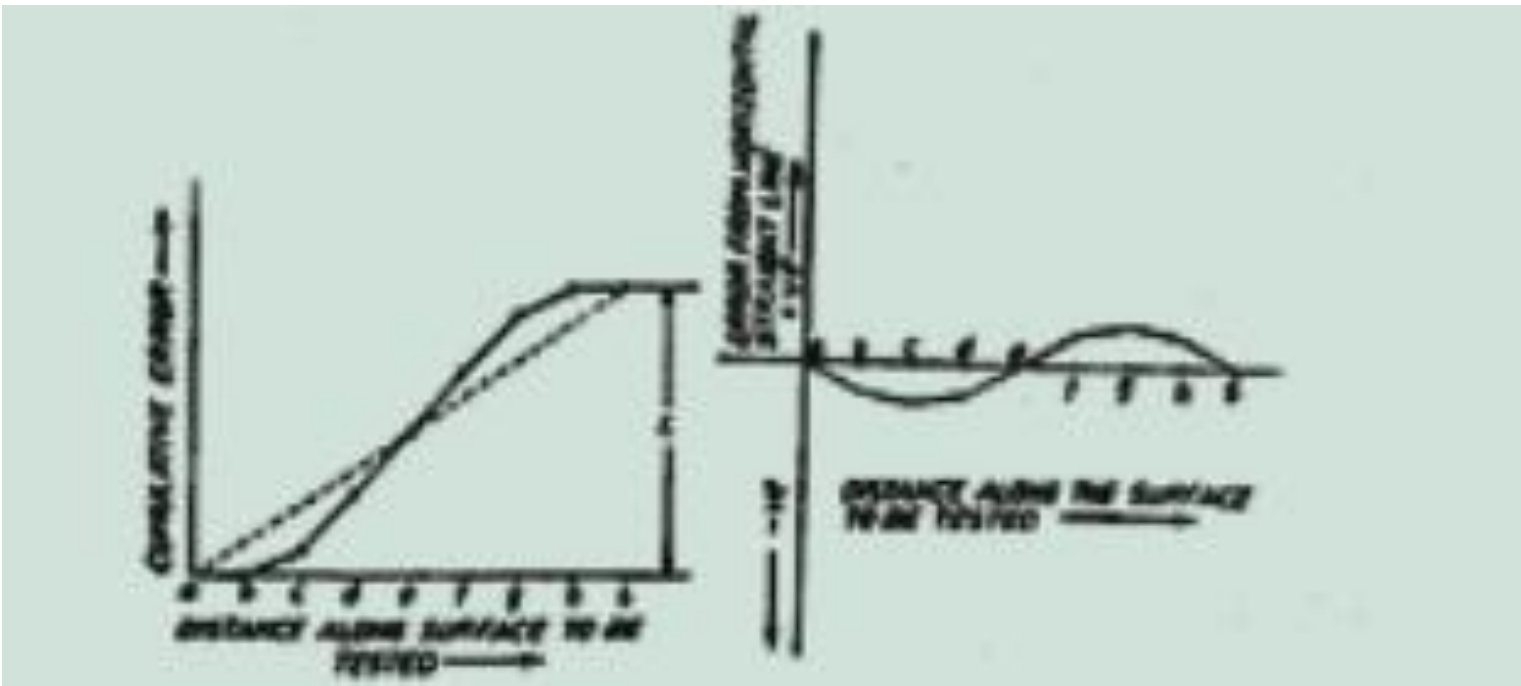
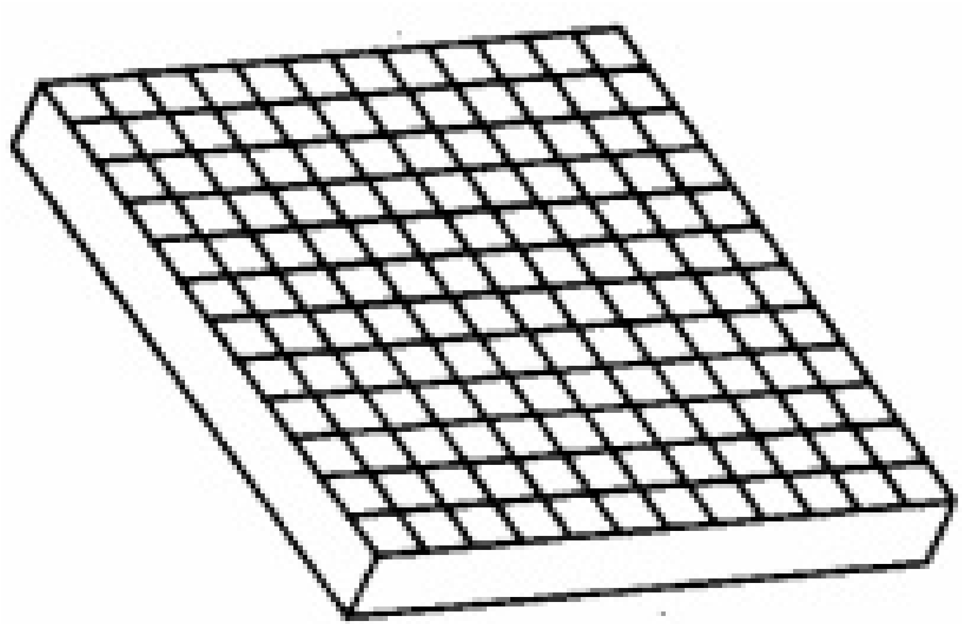


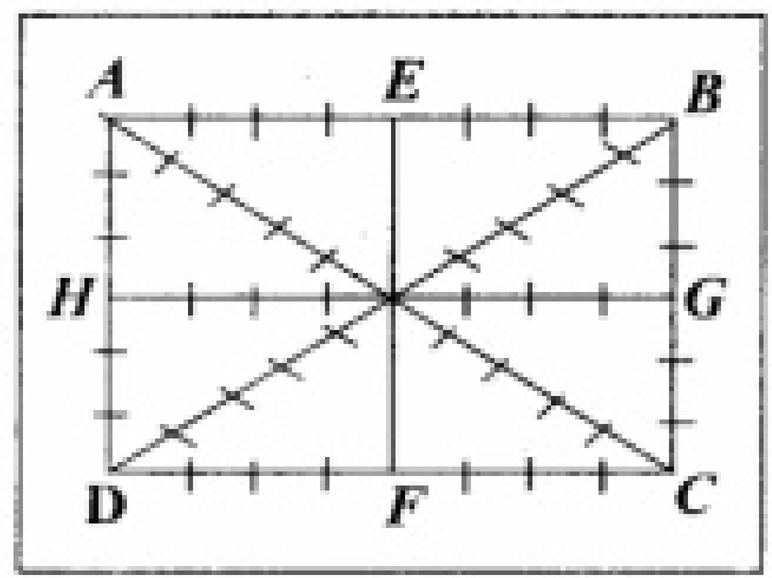
Fig 3.28 Straightness using Auto-Collimator

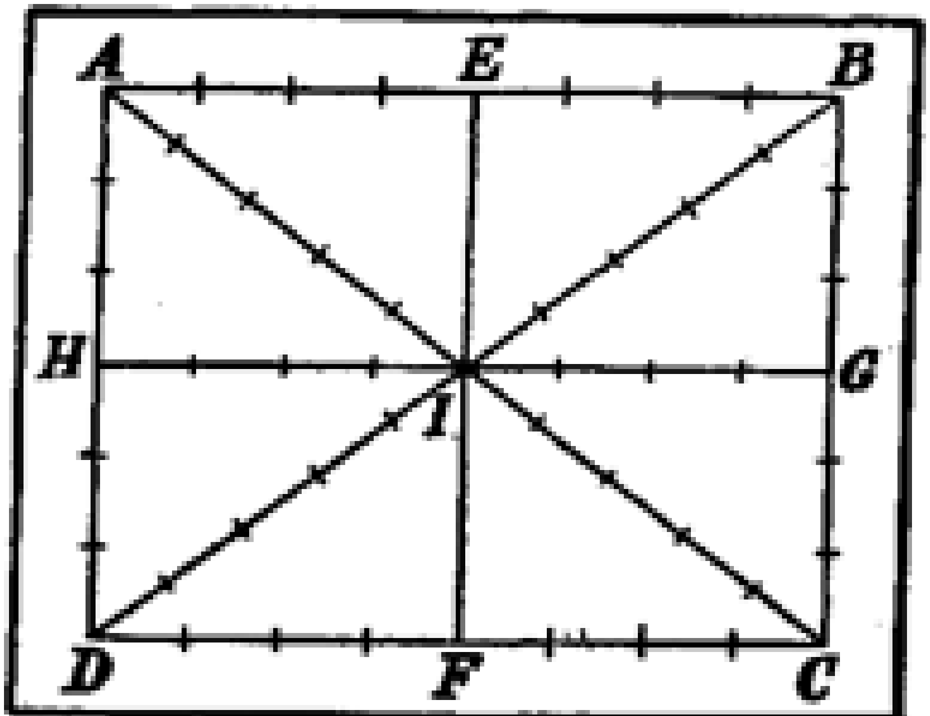

CUMULATIVE ERROR
DISTANCE ALONG SURFACE TO BE TESTED
DISTANCE ALONG THE SURFACE TO BE TESTED

Flatness Measurement

Flatness measurement using autocollimator






A
E
B
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G
I
D
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C

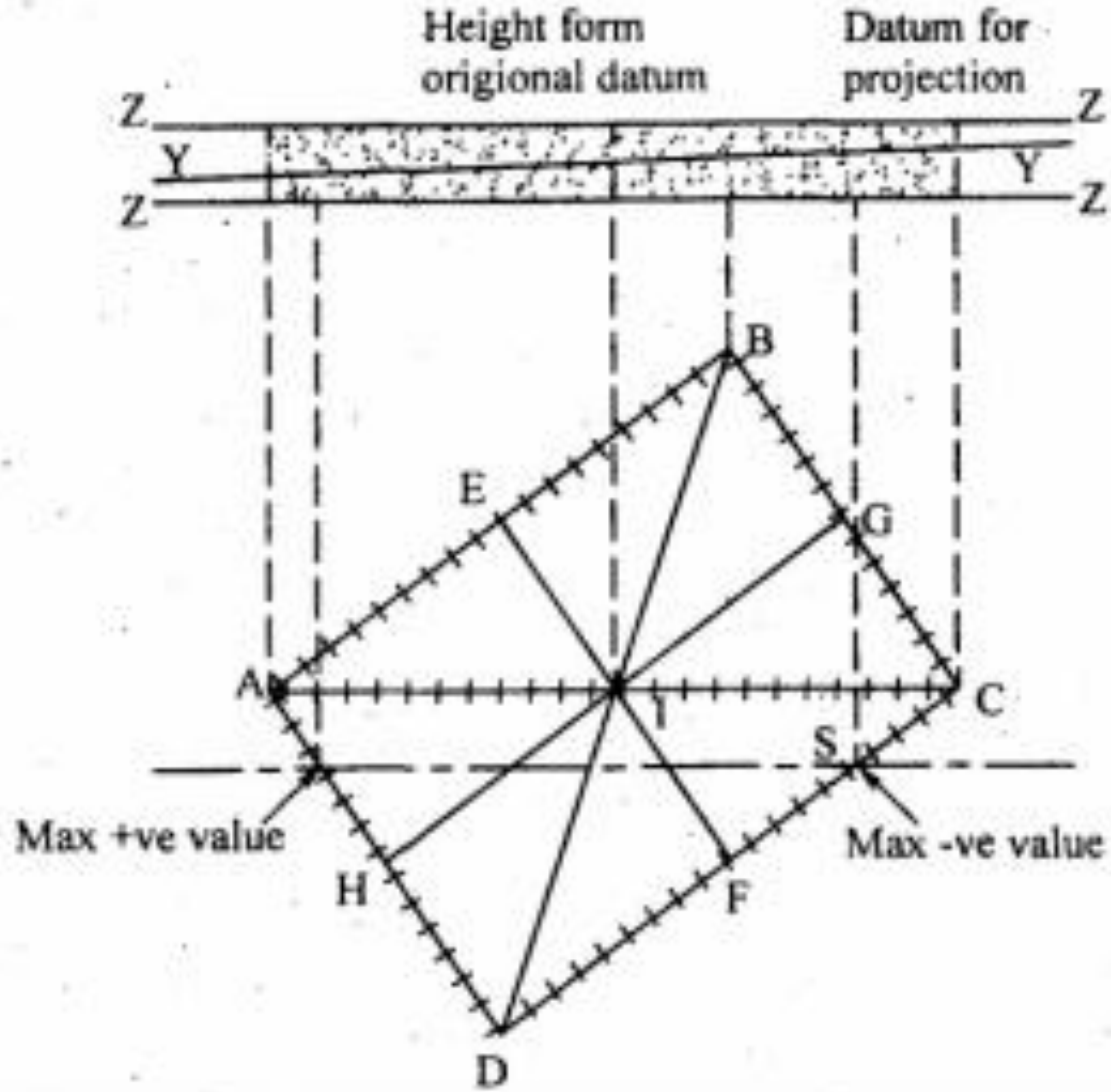

Fig 3.29 Flatness Testing

Roundness Measurement

Roundness Measurements

- Roundness is defined as a condition of a surface of revolution.
- Where all points of the surface intersected by any plane perpendicular to a common axis in case of cylinder and cone.

Devices used for measurement of roundness

1. Diametral gauge.
2. Circumferential conferring
3. Rotating on center
4. V-Block
5. Three-point probe.
6. Accurate spindle.

Circumferential confining gauge

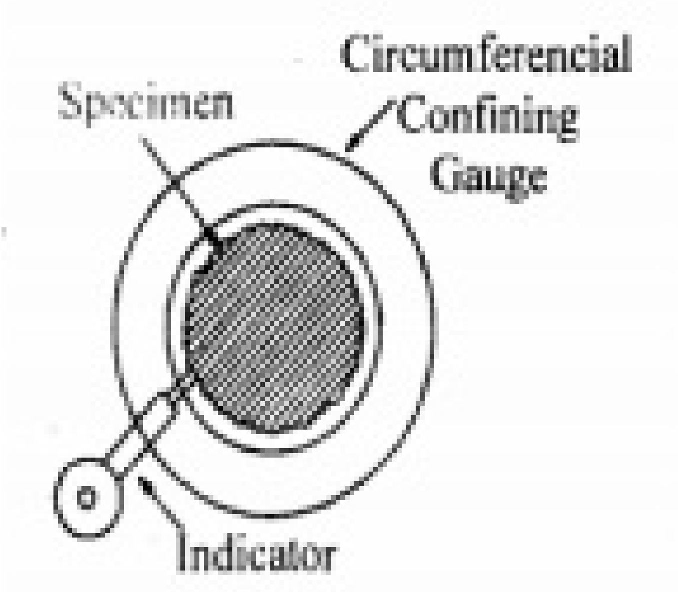

Fig 3.30 Confining Gauge

V-Block

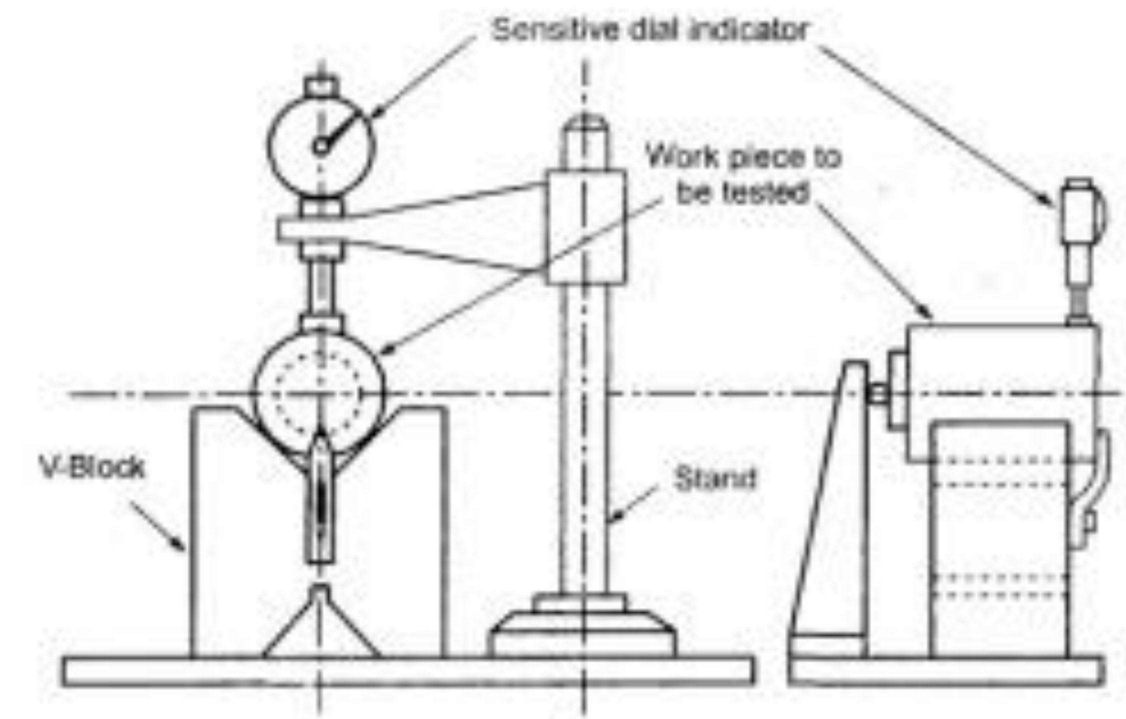

Fig 3.31 V-Block

Three point probe

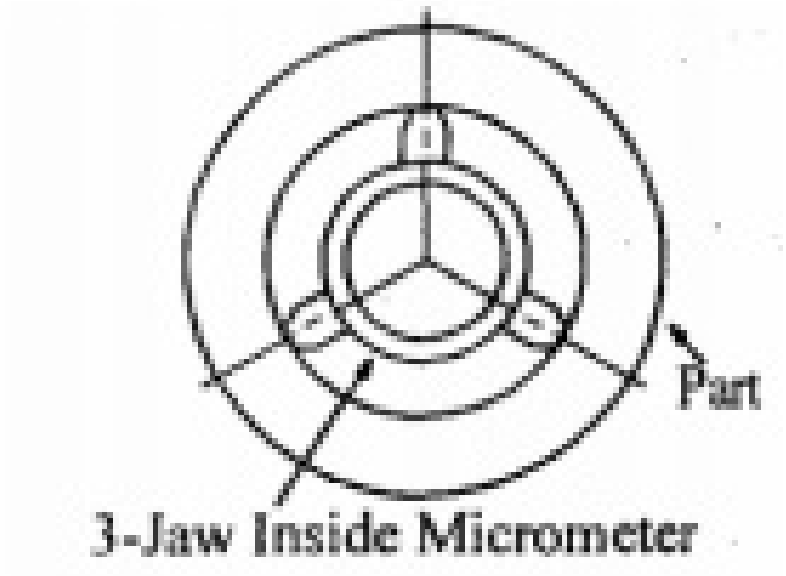

Fig 3.32 Three Point Probe

Thank You