# MODULE – 2
# 15 Marks

## Comparators

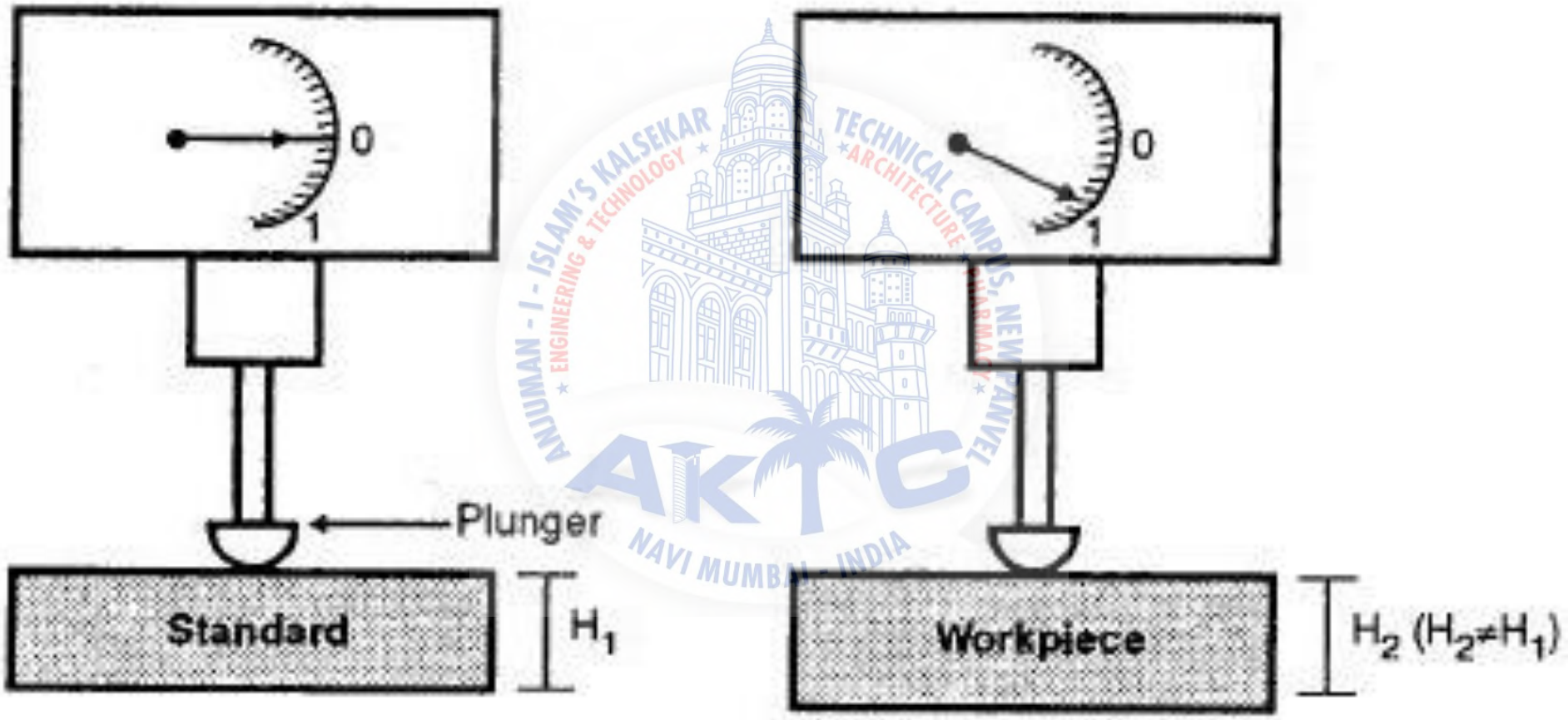
Prof. Afaqahmed

# What is This?????

# Introduction

The **general principle** of comparator **is to indicate the differences in size between the standard** and the work being measured by means of some pointer on a scale with sufficient magnification

It thus does not measure the actual dimension but indicates how much it differs from the basic dimension


0
0
Plunger
Standard
$H_1$
Workpiece
$H_2$ ($H_2 \neq H_1$)

# BRIEF

- Precise Instrument
- They are employed to find out, by how much the dimensions of the given component differ from that of a known datum?
- If the indicated difference is small, a suitable magnification device is selected to obtain the desired accuracy of measurements.
- It is an indirect type of instrument and used for linear measurement.
- If the dimension is less or greater, than the standard, then the difference will be shown on the dial.

# In short, Comparator is a device which

- (1) Picks up small variations in dimensions.
- (2) Magnifies it.
- (3) Displays it by using indicating devices, by which comparison can be made with some standard value.

# NEED FOR A COMPARATOR

**(i)** In mass production, where components are to be checked at a very fast rate.

**(ii)** As laboratory standards from which working or inspection gauges are set and correlated.

**(iii)** For inspecting newly purchased gauges.

**(iv)** Attached with some machines, comparators can be used as working gauges to prevent work spoilage and to maintain required tolerances at all stages of manufacturing.

**(v)** In selective assembly of parts, where parts are graded in three or more groups depending upon their tolerances.

# Characteristics of Good Comparators

1. Compact.
2. Easy to handle.
3. Quick response or quick result.
4. Reliable, while in use.
5. No effects of environment
6. Less weight .
7. Cost
8. Availability
9. Sensitivity
10. It should be linear in scale so that it is easy to read and get uniform response

# TYPES

1. Mechanical Comparator: It works on gears pinions, linkages, levers, springs etc.
2. Pneumatic Comparator: Pneumatic comparator works by using high pressure air, valves, back pressure etc.
3. Optical Comparator: Optical comparator works by using lens, mirrors, light source etc.
4. Electrical Comparator: Works by using step up, step down transformers.
5. Electronic Comparator: It works by using amplifier, digital signal etc
6. Combined Comparator: The combination of any two of the above types can give the best result.
7. Fluid displacement comparators
8. Projection comparators

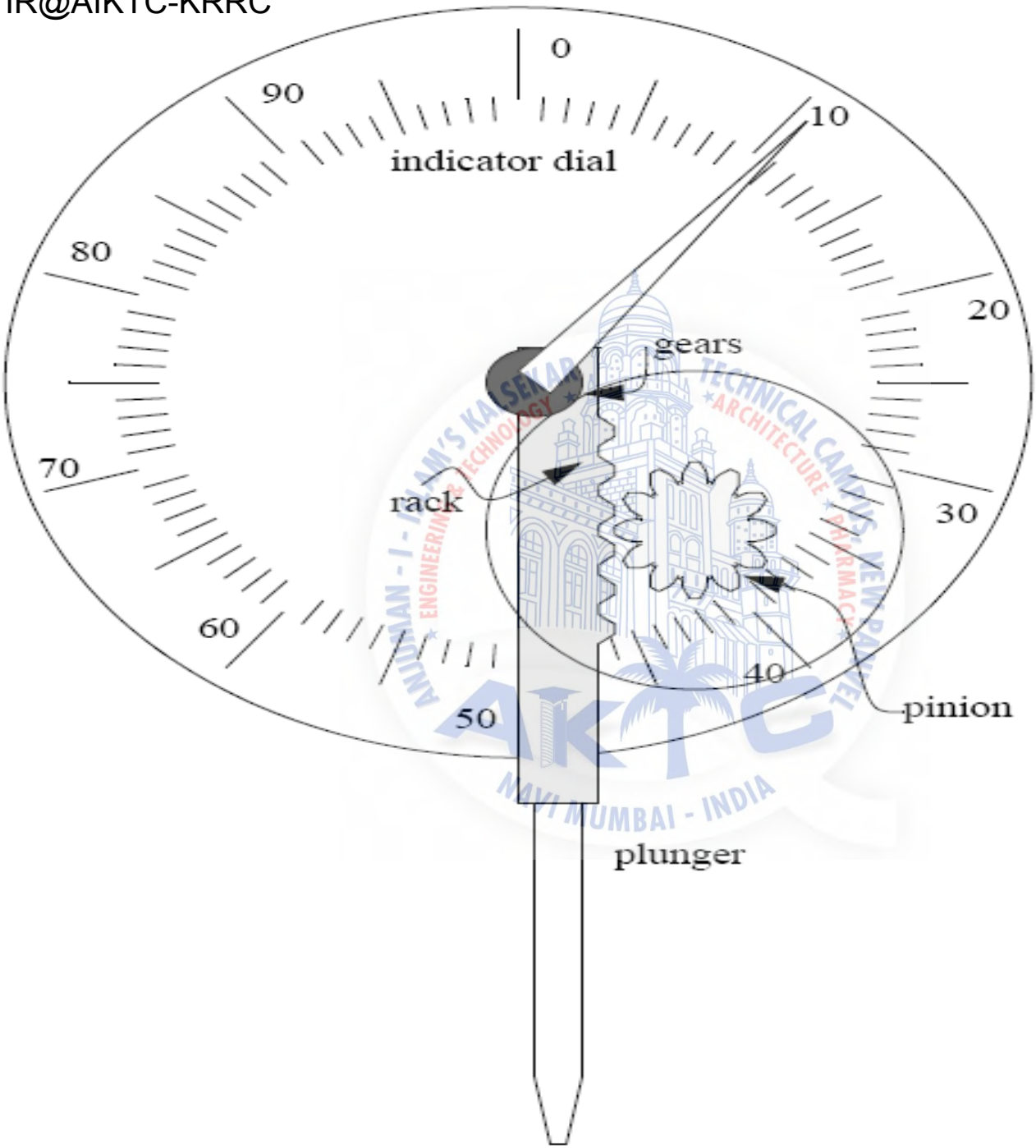
# Mechanical Type (The usual 250 to 1000 X)

- It is self controlled and no power or any other form of energy is required.
- It employs mechanical means for magnifying the small movement of the measuring stylus.
- The movement is due to the difference between the standard and the actual dimension being checked.
- The method for magnifying the small stylus movement in all the mechanical comparators is by means of levers, gear trains or combination of these.
- They are available of different make and each has it's own characteristic.

# The various types of mechanical comparators are

1. Dial indicator,
2. Rack and pinion,
3. Sigma comparator,
4. Johansson Mikrokator.

# 1. Dial indicator / Dial Gauge



0
10
20
30
40
50
60
70
80
90
indicator dial
gears
rack
pinion
plunger

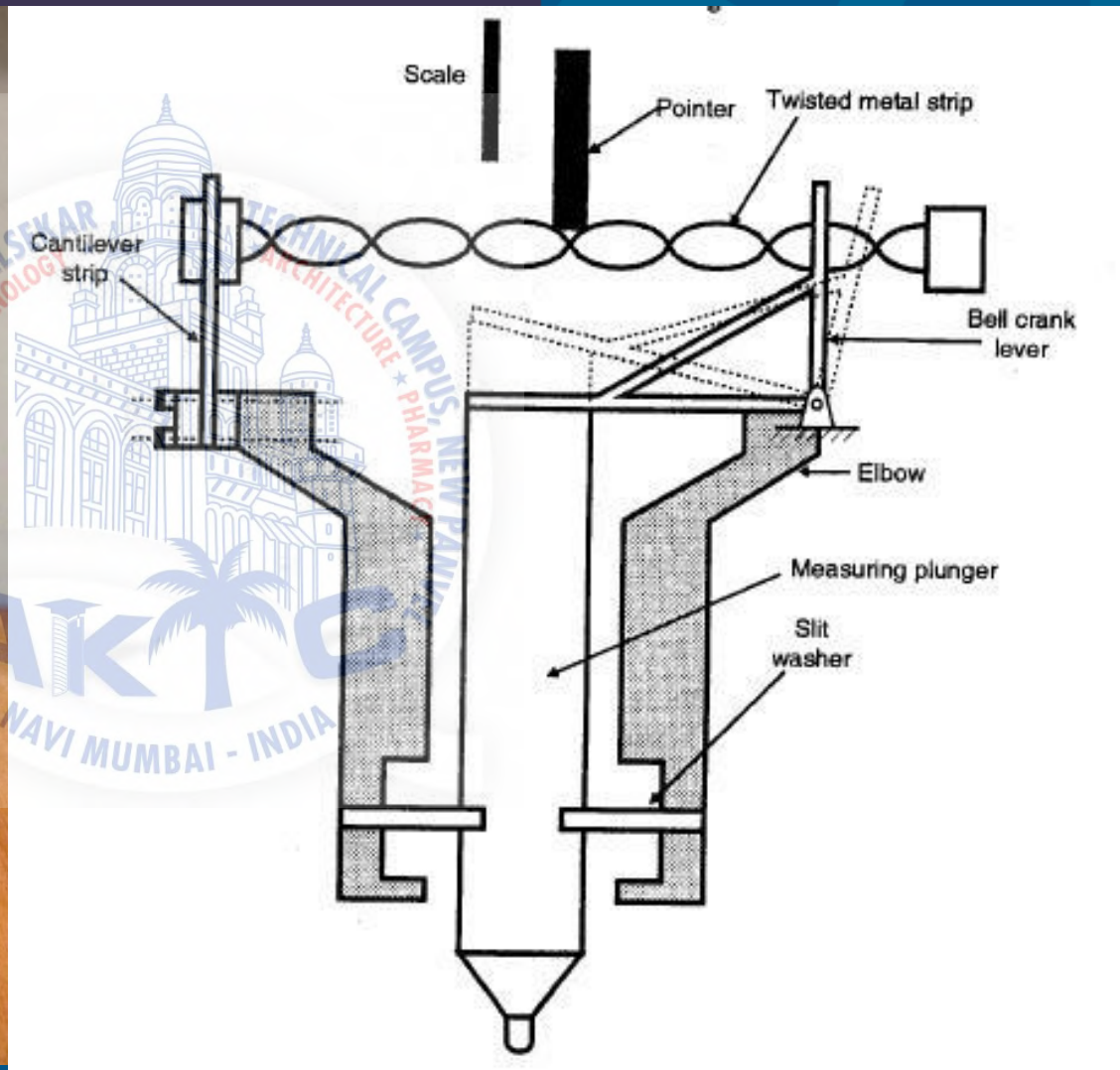
# Working

- It operates on the principle, that a very slight upward pressure on the spindle at the contact point is multiplied through a system of gears and levers.
- It is indicated on the face of the dial by a dial finger.
- Dial indicators basically consists of a body with a round graduated dial and a contact point connected with a spiral or gear train so that hand on the dial face indicates the amount of movement of the contact point.
- They are designed for use on a wide range of standard measuring devices such as dial box gauges, portal dial, hand gauges, dial depth gauges, diameter gauges and dial indicator snap gauge

# Application

1. Comparing two heights or distances between narrow limits.
2. To determine the errors in geometrical form such as ovality, roundness and taper.
3. For taking accurate measurement of deformation such as tension and compression.
4. To determine positional errors of surfaces such as parallelism, squareness and alignment.
5. To check the alignment of lathe centers by using suitable accurate bar between the centers.
6. To check trueness of milling machine arbours and to check the parallelism of shaper arm with table surface or vice.
7. Checking of components with a tolerance of $\pm$ 0.005 mm

# Johansson Mikrokator



# Working Principle

- A very thin metal strip at the centre carries a light pointer made up of glass .
- One end of the strip is connected to the adjustable cantilever strip and the other end is to the spring elbow, in turn connected to the plunger.
- The slight movements of the plunger will make the bell crank lever to rotate.
- This rotation will create tension in the strip and causes the strip to rotate thereby the strip start to untwist resulting in the movement of the point
- Magnification up to 5000X can be obtained by this comparator

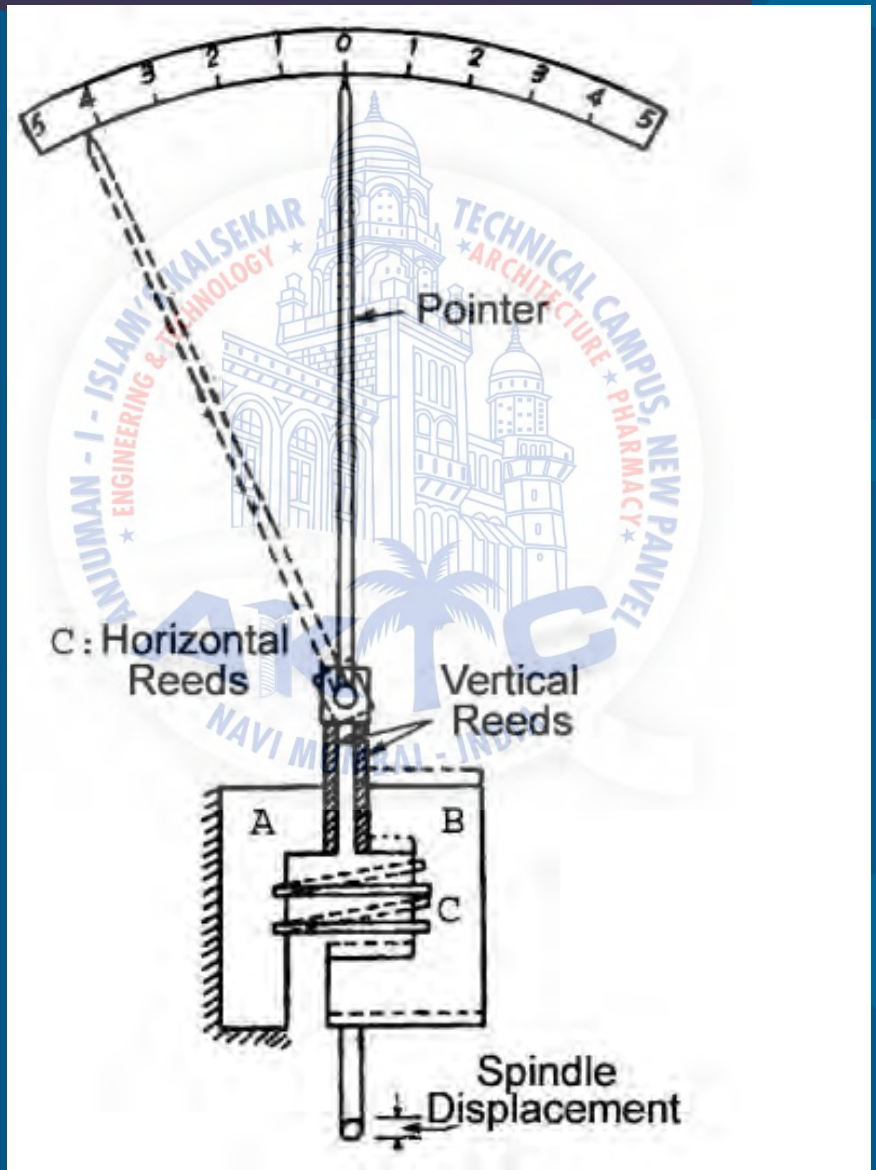
# PROS

1. They do not require any external source of energy.
2. These are cheaper and portable.
3. These are of robust construction and compact design.
4. The simple linear scales are easy to read.
5. These are unaffected by variations due to external source of energy such air, electricity etc.

# Cons (LIMITATIONS)

1. Range is limited as the pointer moves over a fixed scale.
2. Pointer scale system used can cause parallax error.
3. There are number of moving parts which create problems due to friction, and ultimately the accuracy is less.
4. The instrument may become sensitive to vibration due to high inertia.

# REED TYPE


Pointer
C : Horizontal Reeds
Vertical Reeds
A
B
C
Spindle Displacement

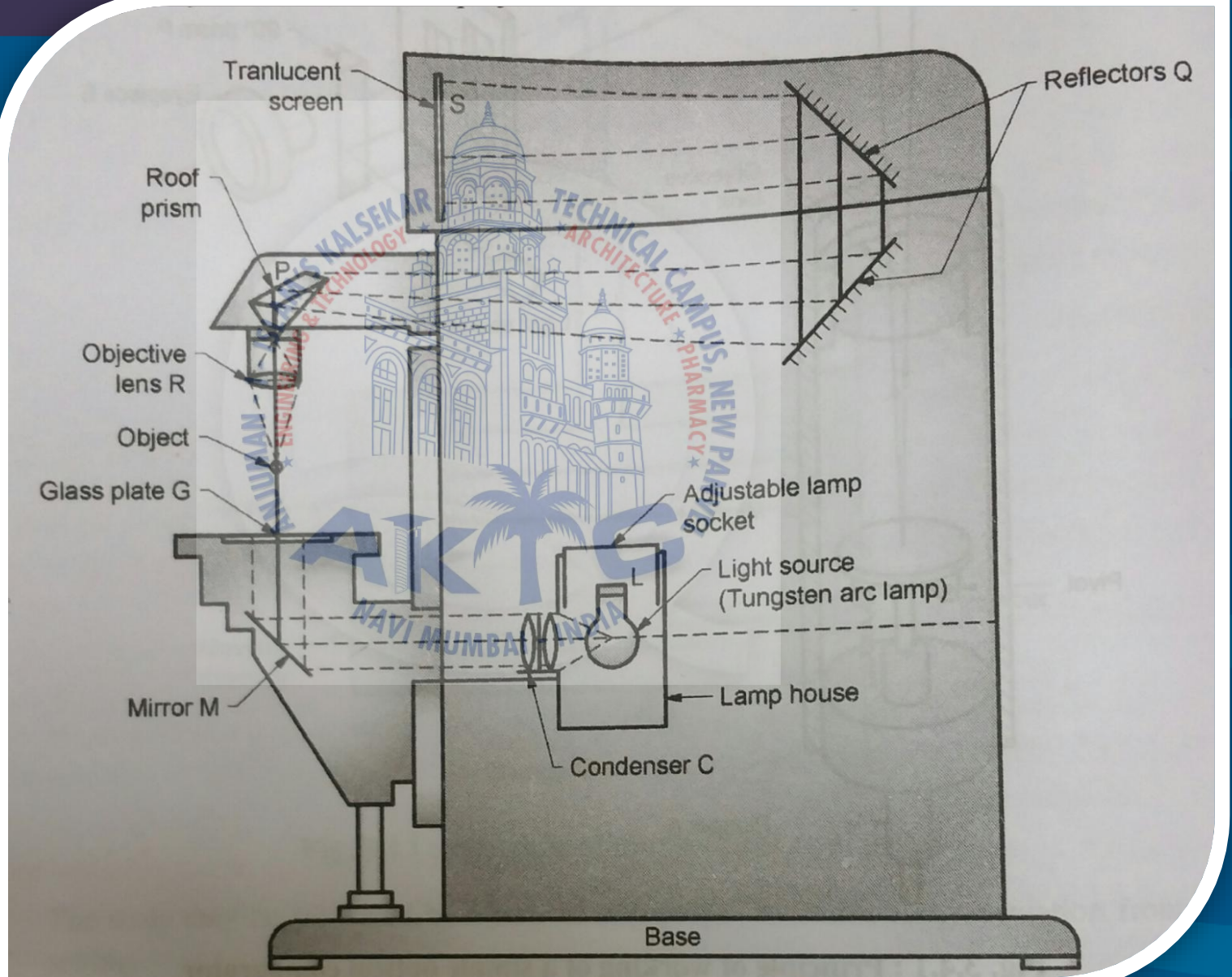
# Working Principle

- The reed mechanism is device for magnifying small motions of spindle
- It consists of a fixed block A which is rigidly fastened to the gauge head case. The floating block B carries the gauging spindle and is connected horizontally to the fixed block by reeds C
- A linear motion of the spindle moves the free block vertically causing the vertical reed to slide
- This movement causes the pointer or target to swing through an arc over the scale proportional to the distance travelled by the spindle and of course very much magnified.

# Working Principle

- The amount of target swing is proportional to the distance the floating block has moved but of course very much magnified.
- The scale may be calibrated by means of gauge block (slip gauges) to indicate any deviation from an initial setting.
- Sensitivities of the order of 0.25 micron per scale division.
- The mechanical amplification is usually less than 100, but it is multiplied by the optical lens system.
- It is available in amplifications ranging from x 500 to x 1000.

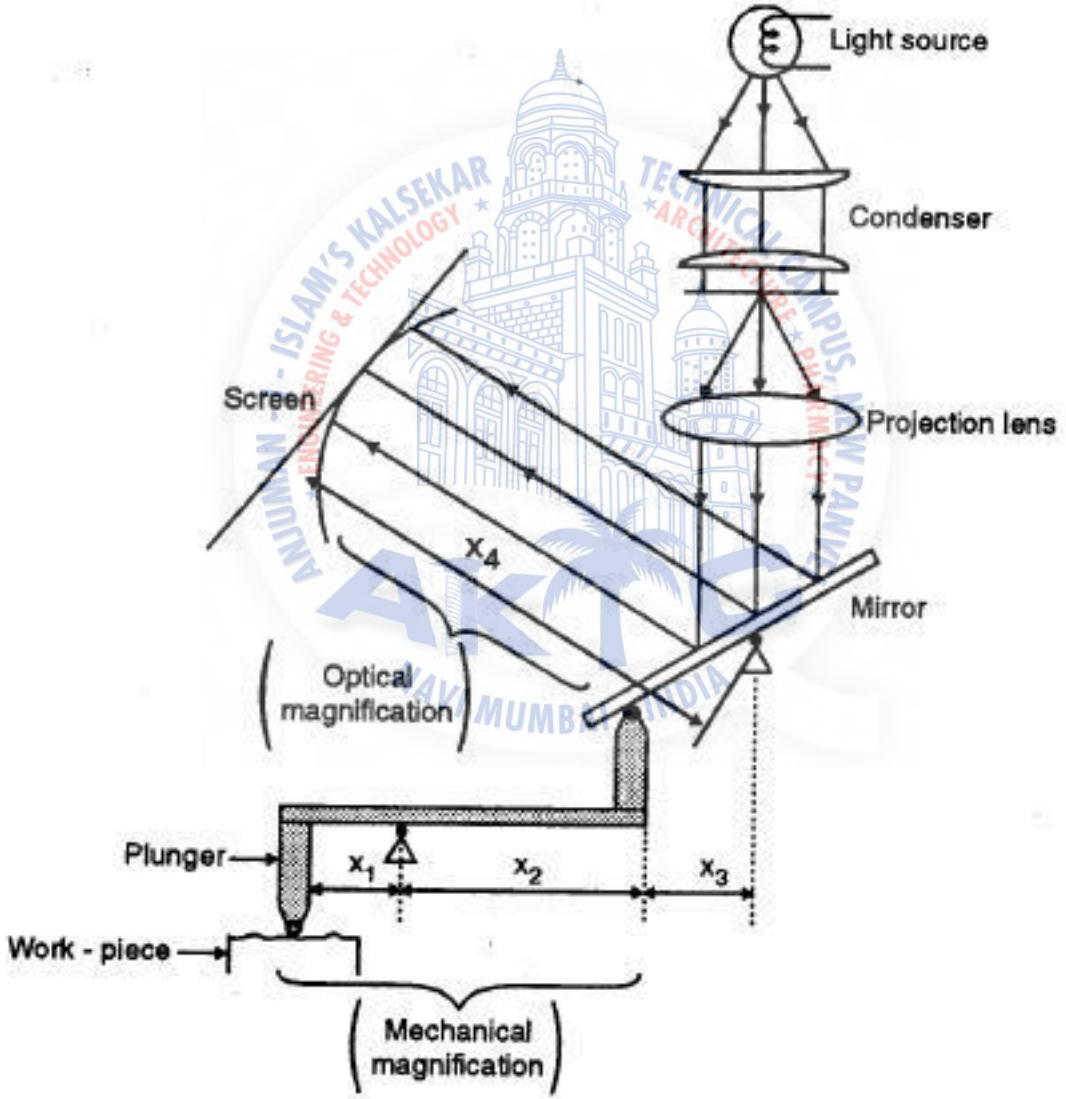
# Profile Projector



It Projects magnified image of an object being measured onto the screen and compare it with the master piece.

It is useful to check small components which are too small and complicated.

# Mechanical - Optical



# Working Principle

- In mechanical optical comparator, small variation in the plunger movement is magnified: first by mechanical system and then by optical system.
- In mechanical optical comparators small displacements of the measuring plunger are amplified first by a mechanical system consisting of pivoted levers.
- The amplified mechanical movement is further amplified by a simple optical system involving the projection of an image.

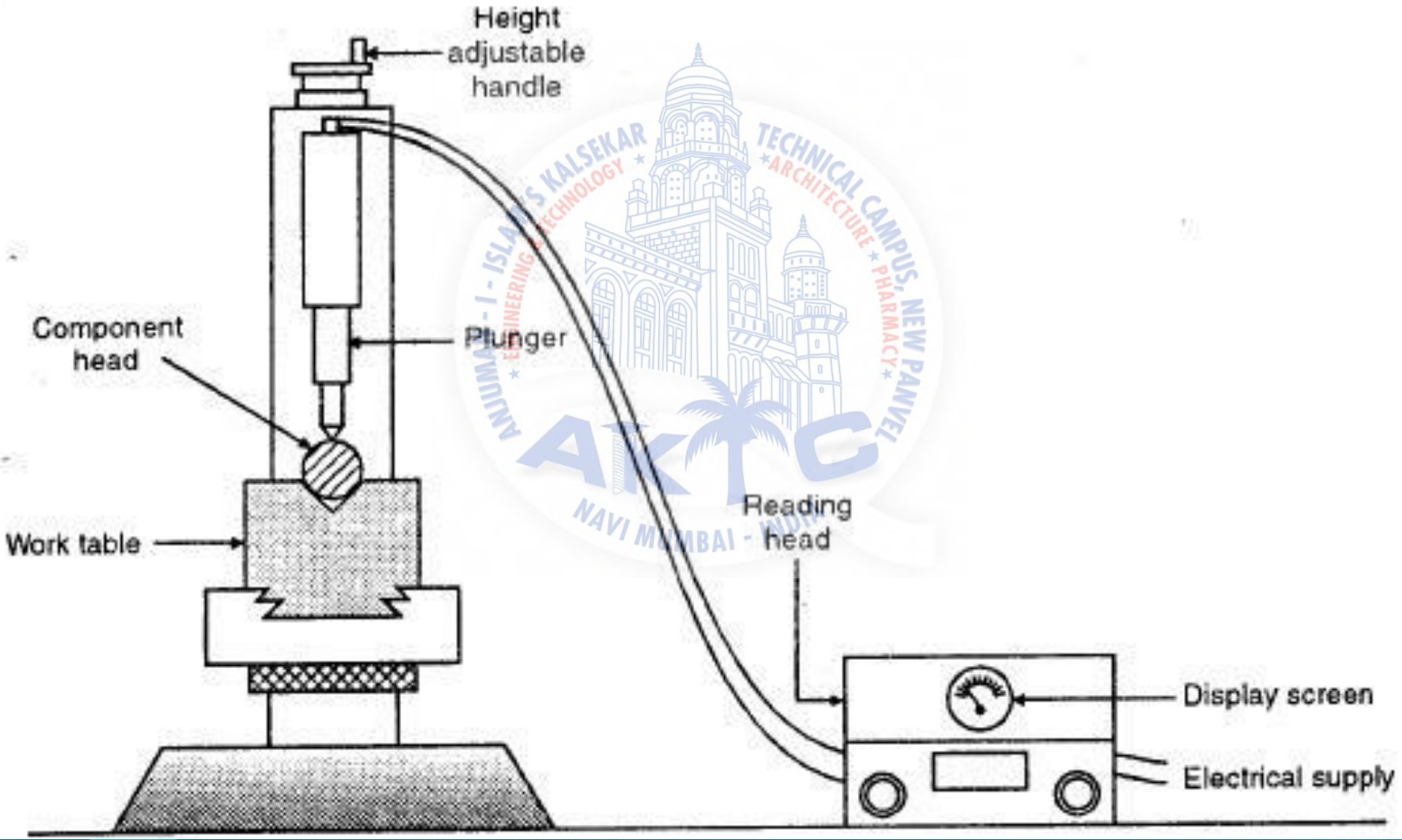
# PROS

1. These Comparators are almost weightless and have less number of moving parts, due to this there is less wear and hence less friction.
2. Higher range even at high magnification is possible as the scale moves past the index.
3. The scale can be made to move past a datum line and without having any parallax errors.
4. They are used to magnify parts of very small size and of complex configuration such as intricate grooves, radii or steps.

# Cons

1. The accuracy of measurement is limited to 0.001 mm
2. They have their own built in illuminating device which tends to heat the instrument.
3. Electrical supply is required.
4. Eyepiece type instrument may cause strain on the operator.
5. Projection type instruments occupy large space and they are expensive.
6. When the scale is projected on a screen, then it is essential to take the instrument to a dark room in order to take the readings easily.

# ELECTRICAL TYPE



# Working Principle

- In electrical comparators, the movement of the measuring contact is converted into an electrical signal.
- The electrical signal is recorded by an instrument which can be calibrated in terms of plunger movement.
- For this an AC wheatstone bridge circuit incorporating a galvanometer is used. It can rather be said that all the electronic comparators work on the principle of wheatstone bridge.
- Electrical comparators have no moving parts. Thus a high degree of reliability is expected from these instruments.

# Pros:

1. Measuring units can be remote from indicating units.
2. Variable sensitivity which can be adjusted as per requirement.
3. No moving parts, hence it can retain accuracy over long periods.
4. Higher magnification is possible as compared to mechanical comparator.
5. Compact sizes of probes arc available.

# Cons

- The accuracy of working of these comparators is likely to be affect due to temperature and humidity.
- It is not a self contained unit; it needs stabilized power supply for its operation.
- Heating of coils can cause zero drifts and it may alter calibration.
- It is more expensive than mechanical comparator

# Pneumatic Comparators

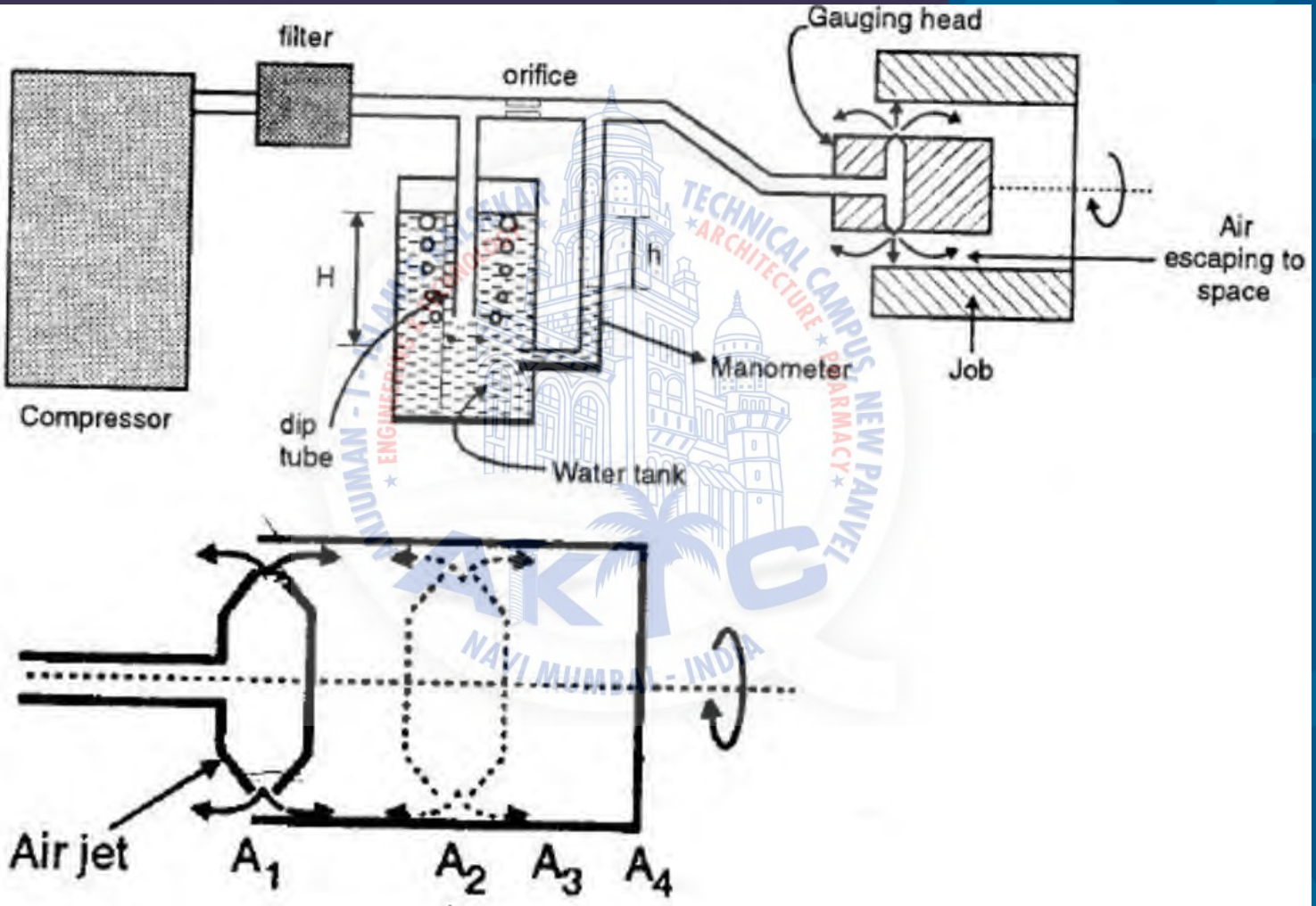



Figure (b)

# Working Principle

- It works on the principle of pressure difference generated by the air flow.
- Air is supplied at constant pressure through the orifice and the air escapes in the form of jets through a restricted space which exerts a back pressure.
- The variation in the back pressure is then used to find the dimensions of a component.

The air is compressed in the compressor at high pressure which is equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, at A1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1. Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1 corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore

# PROS

1. It is cheaper, simple to operate and the cost is low.
2. It is free from mechanical hysteresis and wear.
3. The magnification can be obtained as high as 10,000 X.
4. The gauging member is not in direct contact with the work.
5. Indicating and measuring is done at two different places.
6. Tapers and ovality can be easily detected.
7. The method is self cleaning due to continuous flow of air through the jets and this makes the method ideal to be used on shop floor for online controls.

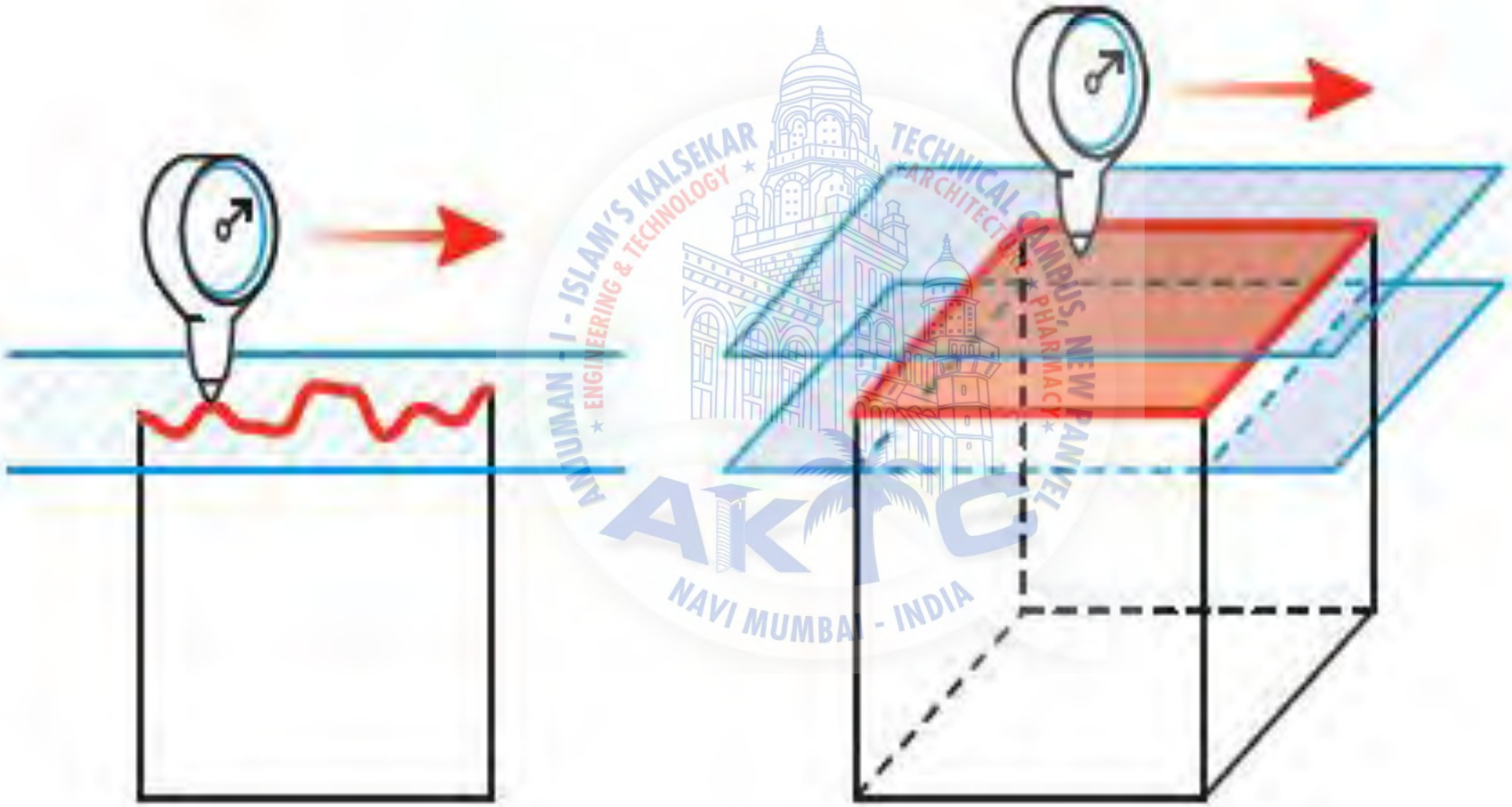
# CONS

1. They are very sensitive to temperature and humidity changes.
2. The accuracy may be influenced by the surface roughness of the component being checked.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipments such as air filters, pressure gauges and regulators are needed.
5. Non-uniformity of scale is a peculiar aspect of air gauging as the variation of back pressure is linear, over only a small range of the orifice size variation


# FLATNESS MEASUREMENT

Prof. Afaqahmed

# **Flatness** is an important geometric condition for workpiece and tools



# Introduction

- It is min. distance between two planes which cover all the irregularities of surface.

Methods of Measurement –

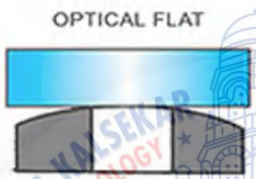
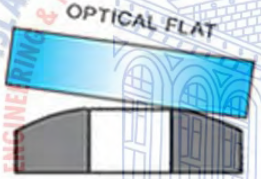
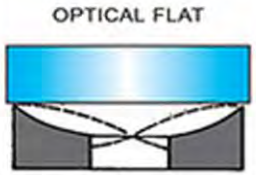
- Using Dial Gauge
- Spirit Level
- Autocollimator
- Optical Flat
- Interference method

- In the manufacturing of precision parts and assemblies, especially where parts will be required to be connected across a surface area in an air-tight or liquid-tight manner, flatness is a critical quality of the manufactured surfaces.

- Such surfaces are usually machined or ground to achieve the required degree of flatness.

# Optical Flat

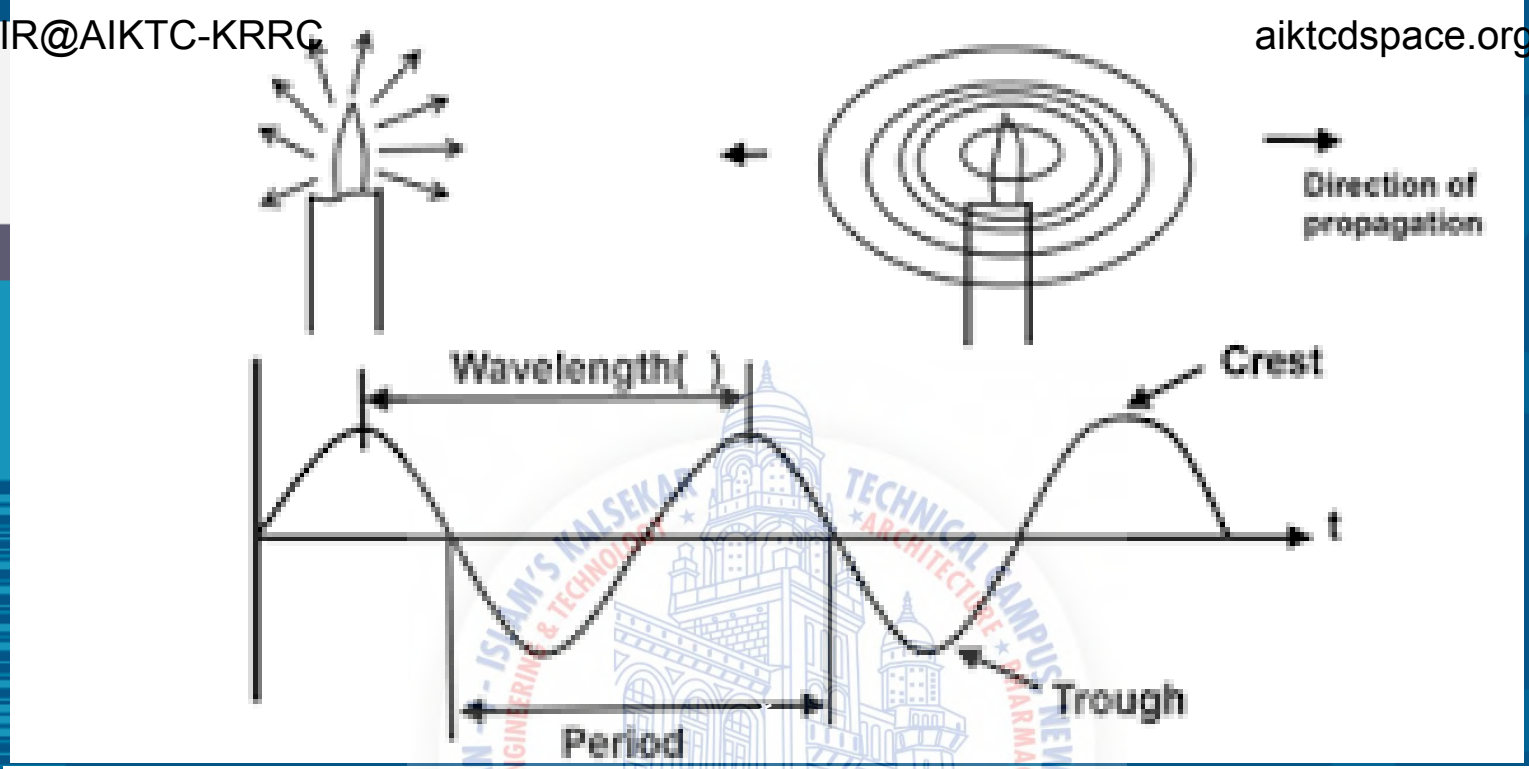
- The easiest and best way to test the flatness of a flat lapped or polished surface is with an optical flat.
- Such surfaces are found on micrometers, measuring machines, gauge blocks, snap gages, ring seals, valve seats and precision flat lapped parts.
- They are used with a monochromatic light to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

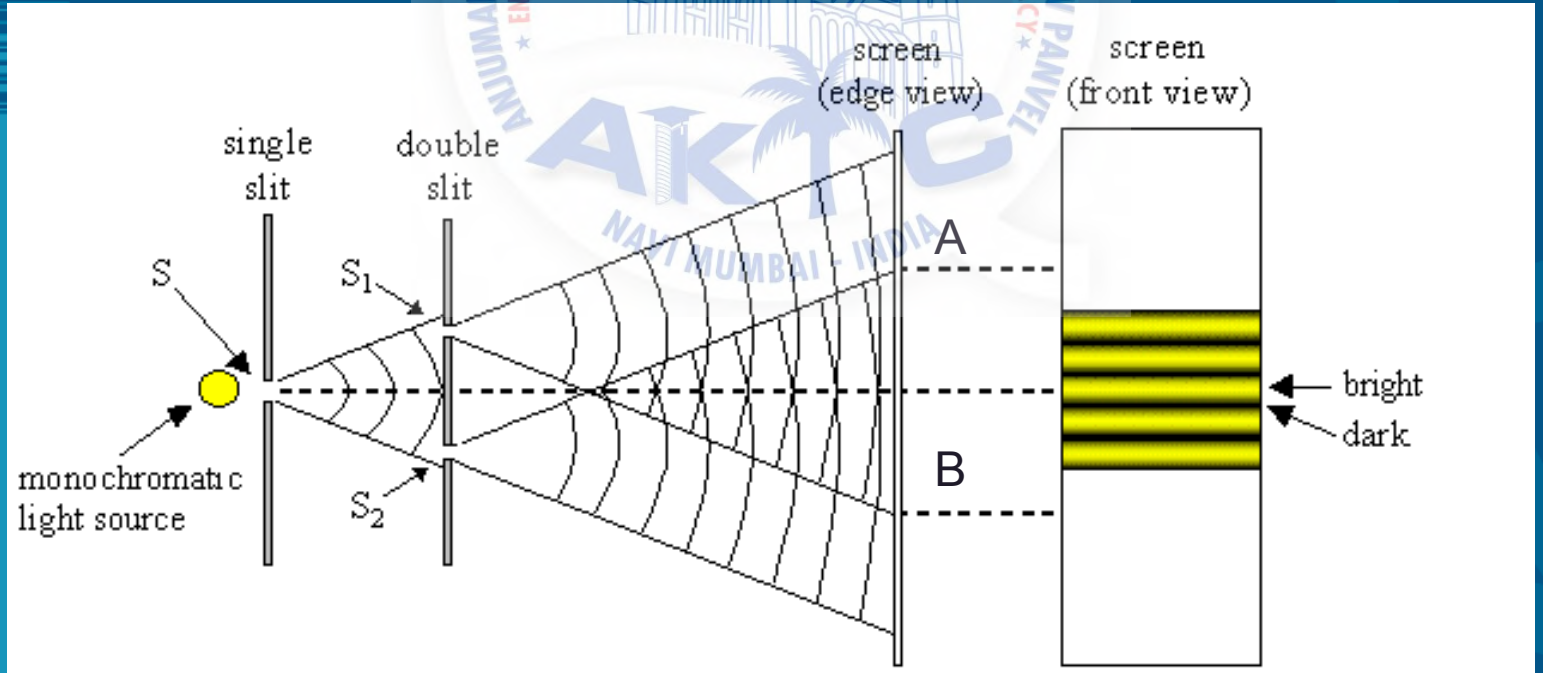
| Surface geometry | | 1 Light band 0.00029mm | 2 Light bands 0.00058mm | 3 Light bands 0.00087mm | 9 Light bands 0.00261mm |
|---|---|---|---|---|---|
| Convex or Concave<br>Surface parallel to flat<br>**Symmetrical Pattern** |  |  |  |  |  |
| Convex<br>With concave surface band will curve in opposite direction<br>**Non-Symmetrical Pattern** |  |  |  |  |  |
| Cylindrical<br>Convex or Concave<br>**Symmetrical Pattern** |  |  |  |  |  |
| Saddle Shaped<br>**Symmetrical Pattern** |  |  |  |  |  |

When an optical flat is placed on another surface and illuminated, the light waves reflect off both the bottom surface of the flat and the surface it is resting on. This causes a phenomenon similar to thin-film interference. The reflected waves interfere, creating a pattern of interference fringes visible as light and dark bands. The spacing between the fringes is smaller where the gap is changing more rapidly, indicating a departure from flatness in one of the two surfaces, in a similar way to the contour lines on a map. A flat surface is indicated by a pattern of straight, parallel fringes with equal spacing, while other patterns indicate uneven surfaces.

# Interferometry

- Light is considered as wave motion propagated in each other (Huygen Theory)
- Light is electromagnetic sinusoidal waves
- High side is crest and low side is trough
- The distance between two consecutive crest or trough is called wavelength ƛ.
- The coinciding point between S1-A and S2B reflect light bright and rest is dark


Direction of propagation
Wavelength( )
Crest
t
Trough
Period

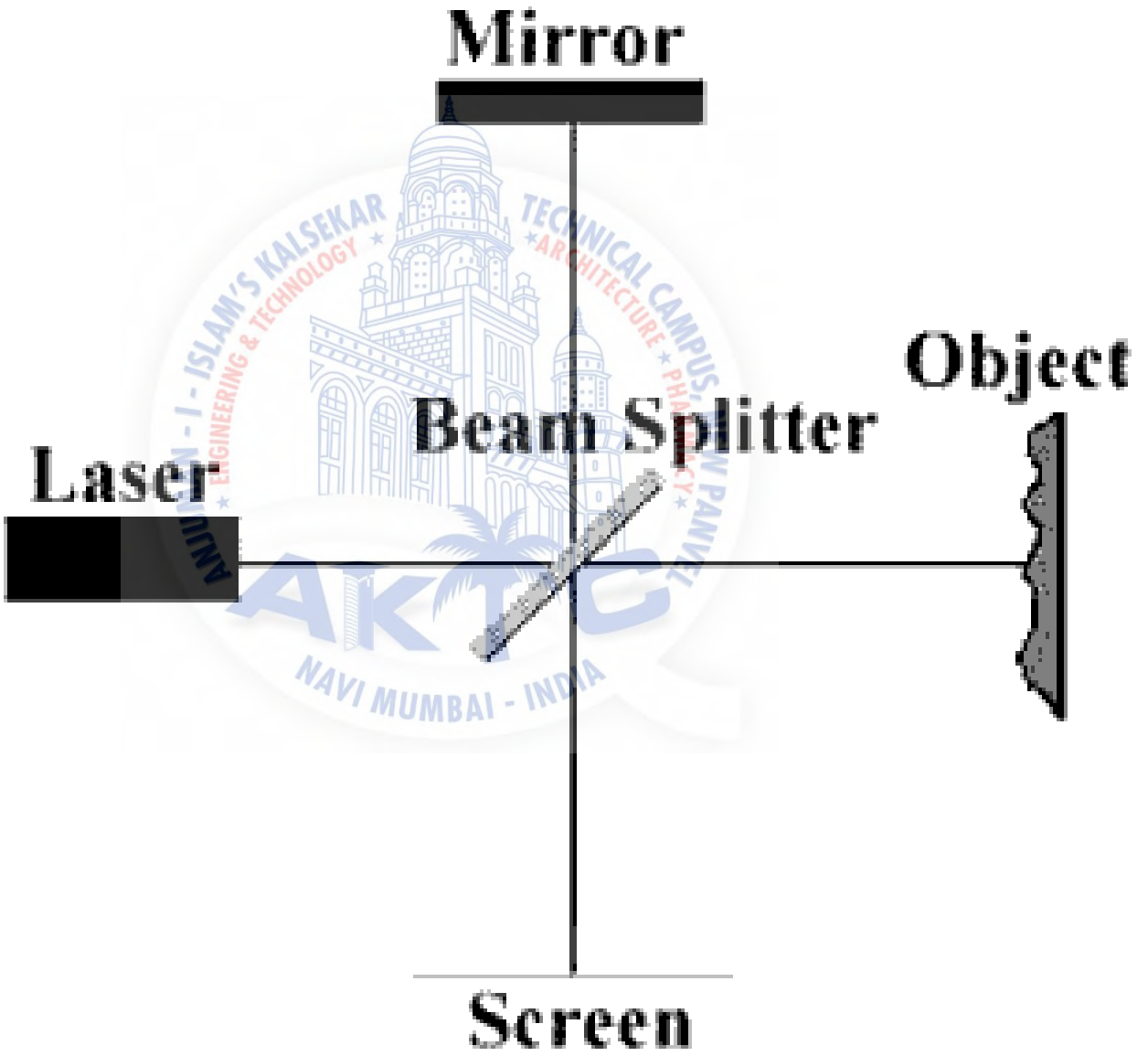

screen (edge view)
screen (front view)
single slit
double slit
S
$S_1$
$S_2$
monochromatic light source
A
B
bright
dark

# Interference

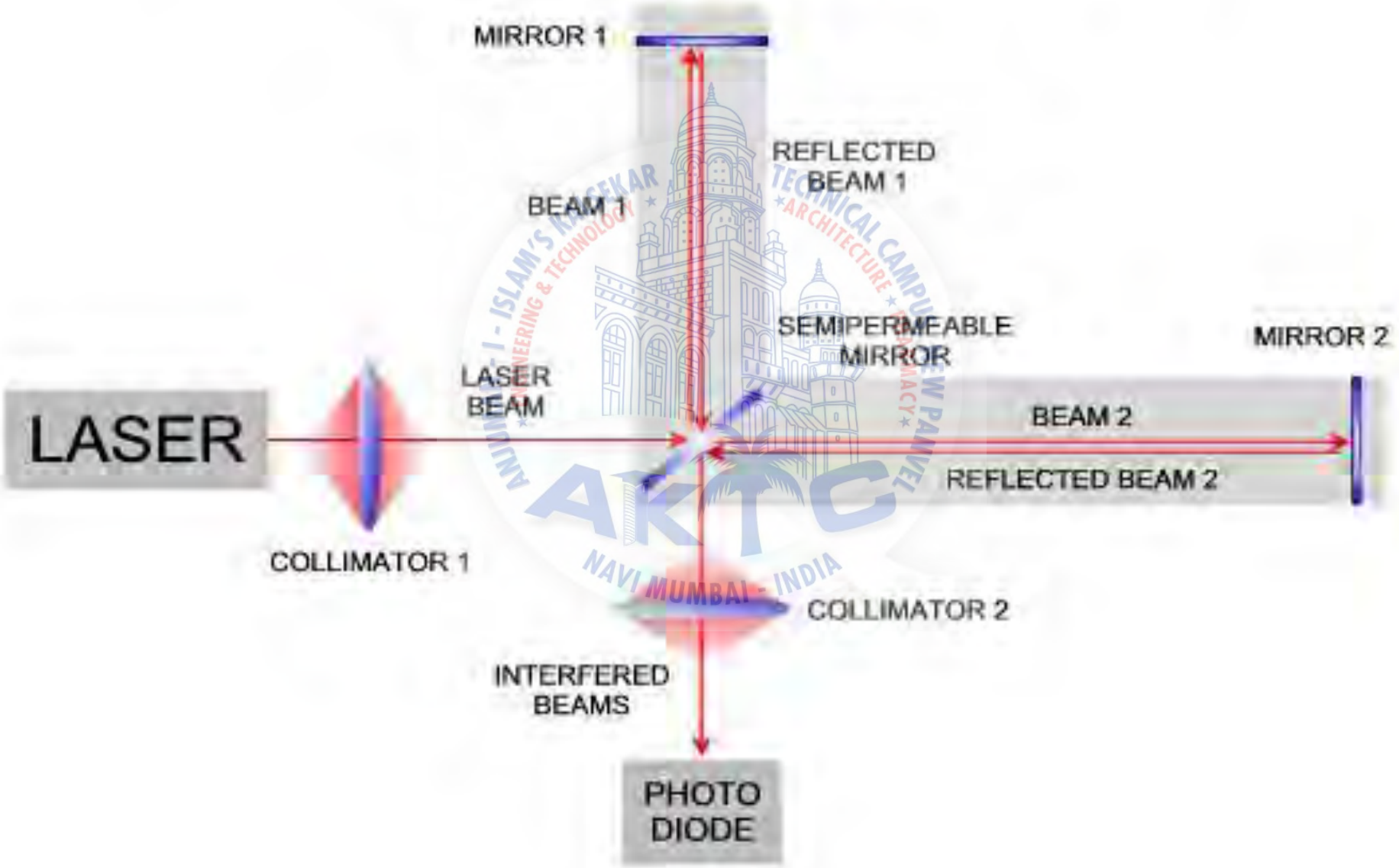
It is a phenomenon in which two waves superpose to form a resultant wave of greater or lower amplitude. Interference usually refers to the interaction of waves that are correlated with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves or matter waves.

# What's a Laser Interferometer ??

- Laser Interferometer:
  - the instrument used for high precision measurements (distance, angles…. etc.)
  - it uses interferometry as the basis for measurement.
  - it uses the very small, stable and accurately defined wavelength of laser as a unit of measure.


Mirror
Object
Beam Splitter
Laser
Screen

# MICHELSON INTERFEROMETER



# Working Principle

- Light beam from monochromatic falls on splitter and hence two mirrors which are right angles to each other. Where mirror 1 is fixed and other is movable.
- They reunite at the same point from where they are transmitted and back to detector / photo diode.
- Reflected ray from M1 serves as reference beam. M2 is attached to object / sample
- Observer see bright spot when mirrors are at same distance
- It will create darkness if mirror 1 shift from position
- Each cycle intensity is ƛ / 2 and total across the workpiece is multiplied by “n”


# SURFACE TEXTURE MEASUREMENT


1. Good Surface
2. Bad Surface

# SURFACE TEXTURE:

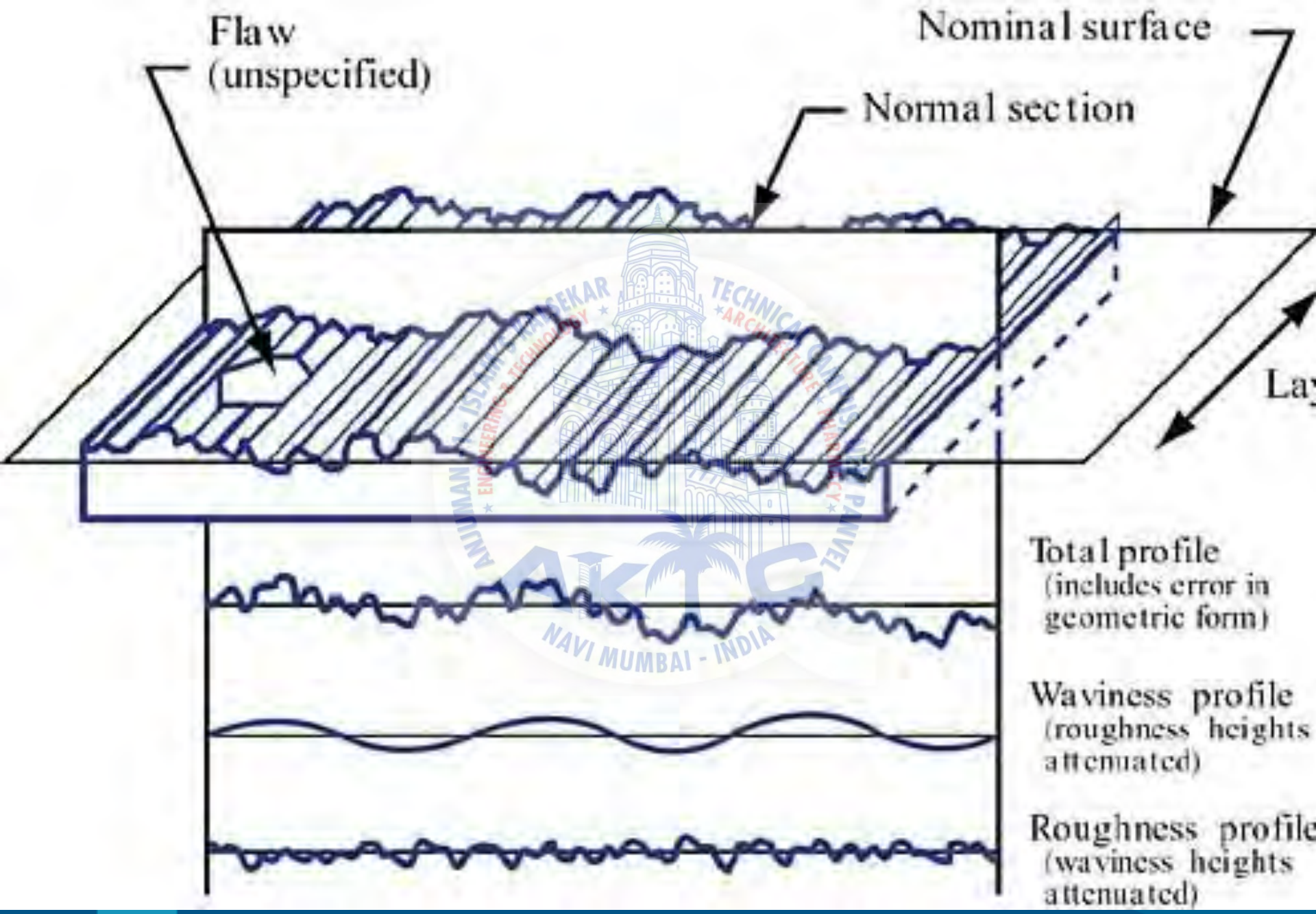
" The characteristics of an actual surface due to small departures from its general geometrical form which, occurring at regular or irregular intervals, tend to form a pattern or texture on the surface"

# SURFACE TEXTURE

- It is possible for two or more kind of irregularity to be combined in the complete texture of a surface in such a way that they are not readily distinguishable individually by eye or touch
- Surface texture varies according to the machining processes used in producing it (eg. Metal machining)
- Difference in surface texture are apparent by visual examination & can be felt readily by passing a finger nail over the surface
- The texture of surfaces can be regular or non-regular in character

# Importance

- Greater strength and Bearing Load
- Causes fatigue if improper surface texture
- Better strength in repeated loads



# Waviness

- **Surface Waviness → Waviness** is the measurement of the more widely spaced component of surface texture. It is a broader view of roughness because it is more strictly defined as "the irregularities whose spacing is greater than the roughness sampling length". It can occur from machine or work deflections, chatter (Tool Vibration), residual stress, vibrations, or heat treatment Waviness should also be distinguished from flatness, both by its shorter spacing and its characteristic of being typically periodic in nature.

# Roughness

- **Surface roughness** often shortened to **roughness**, is a component of **surface** texture. It is quantified by the deviations in the direction of the normal vector of a real **surface** from its ideal form. If these deviations are large, the **surface** is rough; if they are small, the **surface** is smooth.

# FACTORS PRODUCING SURFACE IRREGULARITY:

- Faulty tools
- Inherent imperfections in the m/c tools
- Errors due to personal element

# Surface metrology

- Surface metrology or surface topology refers to the geometry and texture of surfaces
- The condition of surface is defined by its characteristics:
  - Surface texture (finish)
  - Roundness (a function of geometry)
  - Material
  - Hardness
  - Surface metallurgy

# Surface metrology (cont')

- Three forms of asperity
  1. Roughness
  2. Waviness
  3. Error of form

  Vary according to the length of spacing or wavelength

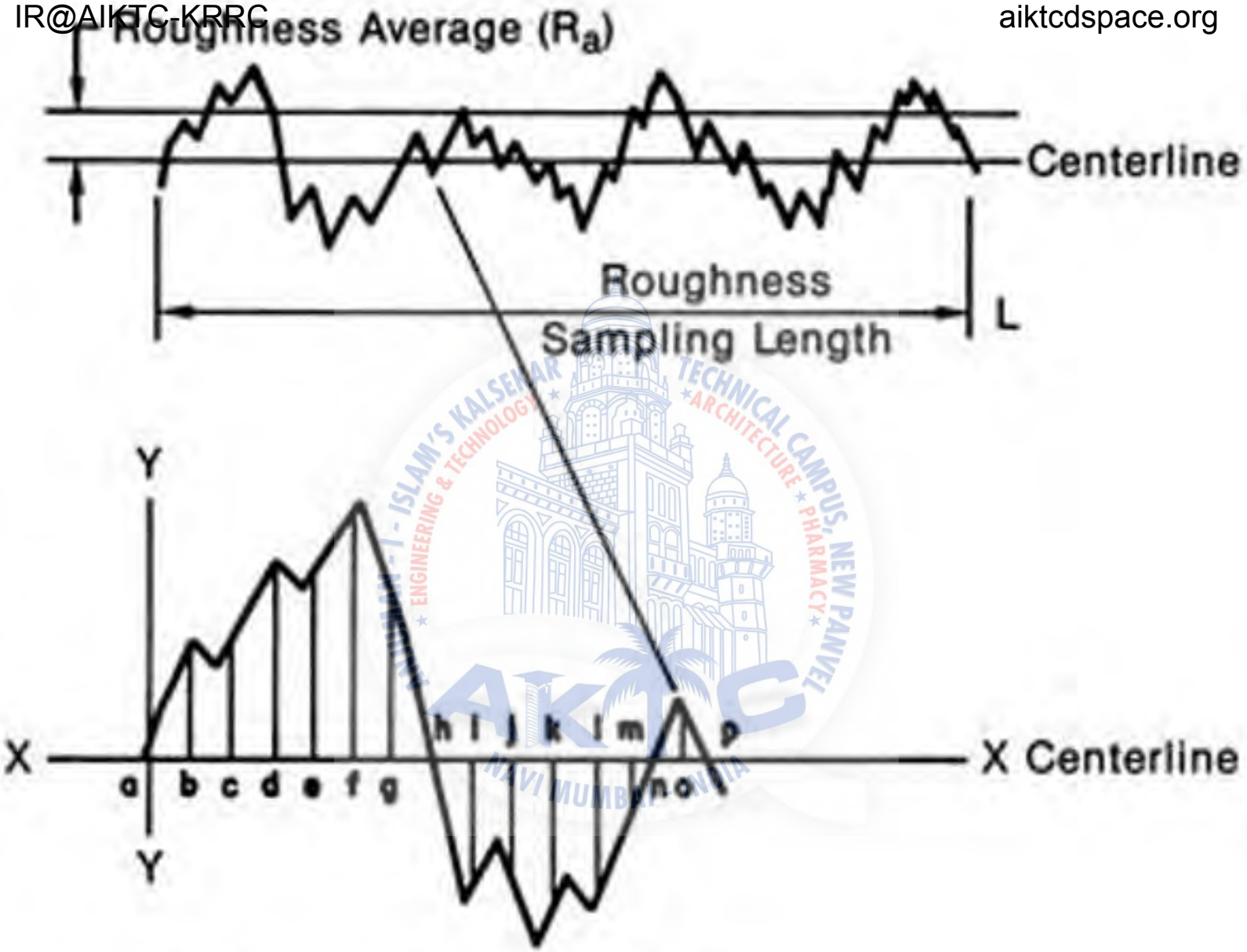
- The fourth asperity is not distinguish by wavelength; it is flaw

- Lay is the direction of the asperities in which most cases means that roughness and waviness are perpendicular to each other

# Ra / RMS

1. **Root-Means-Square roughness ($R_a$ or RMS)**

Closely related to the roughness average (Ra)Square the distances, average them, and determine the square root of the result The resulting value is the index for surface texture comparison. Usually 11% higher than the Ra value




$$R_a = \frac{y_a + y_b + y_c \cdots\cdots + y_n}{n}$$

# Root Mean Square (rms)

| X | $X^2$ |
|---|---|
| 3 | 9 |
| 15 | 225 |
| 20 | 400 |
| 33 | 1089 |
| 25 | 625 |
| 18 | 324 |
| 5 | 25 |
| 10 | 100 |
| 15 | 225 |
| 15 | 225 |
| 5 | 25 |
| 11 | 121 |
| 14 | 196 |
| 13 | 169 |
| 27 | 729 |
| 8 | 64 |
| Total 234 | 4551 |

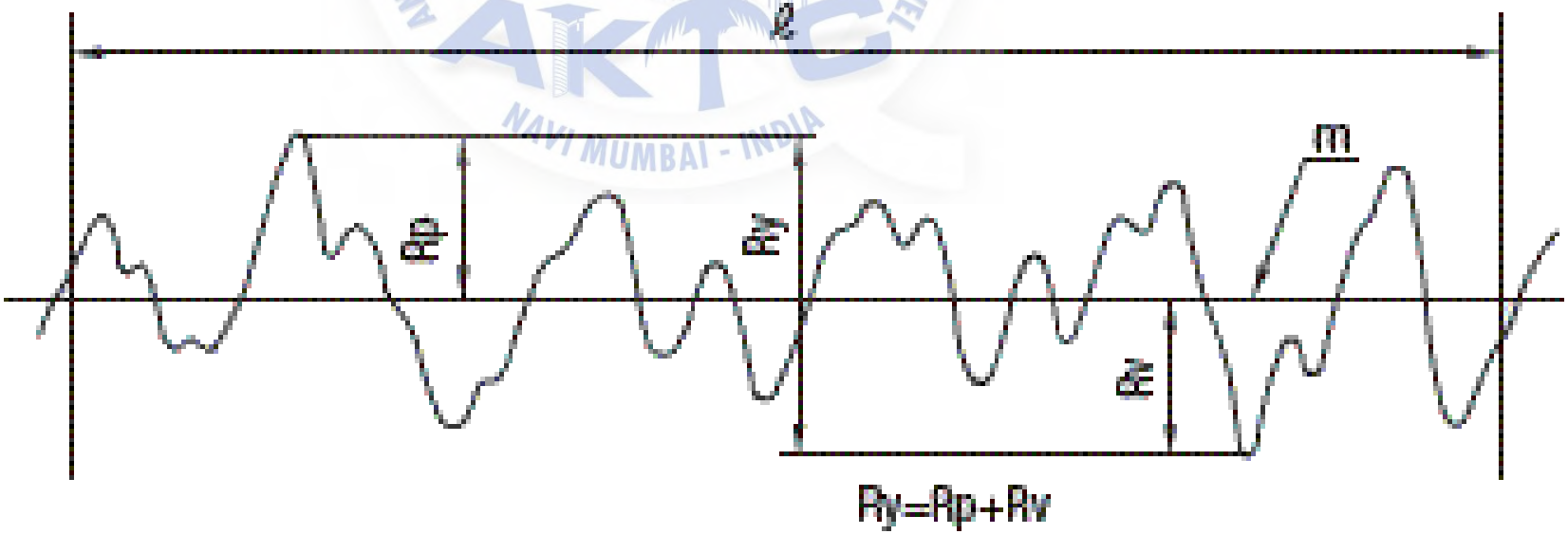
AA = 234/16 = 14.6 micro in.

RMS = $(4551/16)^{1/2}$ = 16.9 micro in.

# Ry

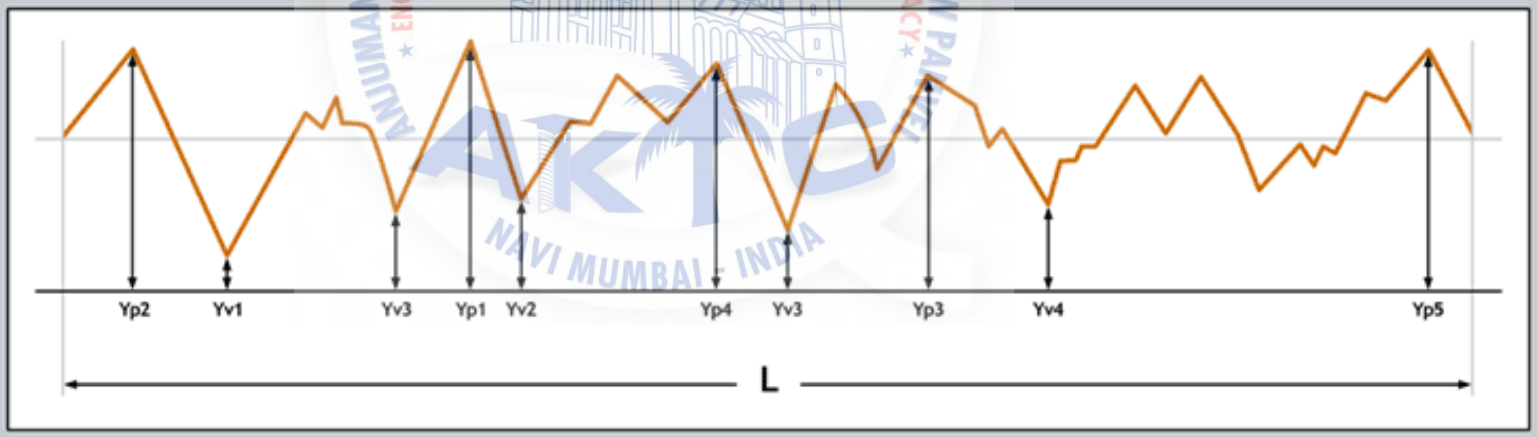
- **Ry -->**

A section of standard length is sampled from the mean line on the roughness chart. The distance between the peaks and valleys of the sampled line is measured in the y direction. The value is expressed in micron (µm).



# Rz

Ten point height of irregularities (Rz) is defined as the average difference between the five highest peaks and the five deepest valleys within the sampling length measured from a line, parallel to the mean line and not crossing the profile.




$$Rz = \frac{(Yp1 + Yp2 + Yp3 + Yp4 + Yp5) - (Yv1 + Yv2 + Yv3 + Yv4 + Yv5)}{5} = \frac{1}{5}(\Sigma Ypi - \Sigma Yvi)$$

ISO 10 POINT HEIGHT PARAMETER

# Methods of Measuring Surface Finish

There are two methods used for measuring the finish of machined part :

1. Surface Inspection by Comparison Methods.

(i)Touch Inspection, *(ii) Visual Inspection, (iii) Scratch Inspection, (iv) Microscopic Inspection, (v)* Surface Photographs, *(vi) Micro-Interferometer, (vii) Reflected* Light Intensity

# Touch Inspection

- This method can simply tell which surface is more rough. In this method, the finger-tip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.01 mm can be easily detected.

- A modification of it is possible by using a table tennis ball, which is rubbed over the surface and vibrations from the ball transmitted to hand and surface roughness judged thereby.

# Visual Inspection

- Visual inspection by naked eye is always likely to be misleading particularly when surfaces having high degree of finish are inspected. The method is, therefore, limited to rougher surfaces and results vary from person to person. More accurate inspection can be done by using illuminated magnifiers.

# Scratch Inspection

- In this method, a softer material like lead, Babbitt or plastic is rubbed over the surface to be inspected. By doing so it carries the impression of the scratches on the surfaces which can be easily visualised.

# Direct Instrument Measurements

These methods enable to determine a numerical value of the surface finish of any surface. Nearly all instruments used are stylus probe type of instruments.

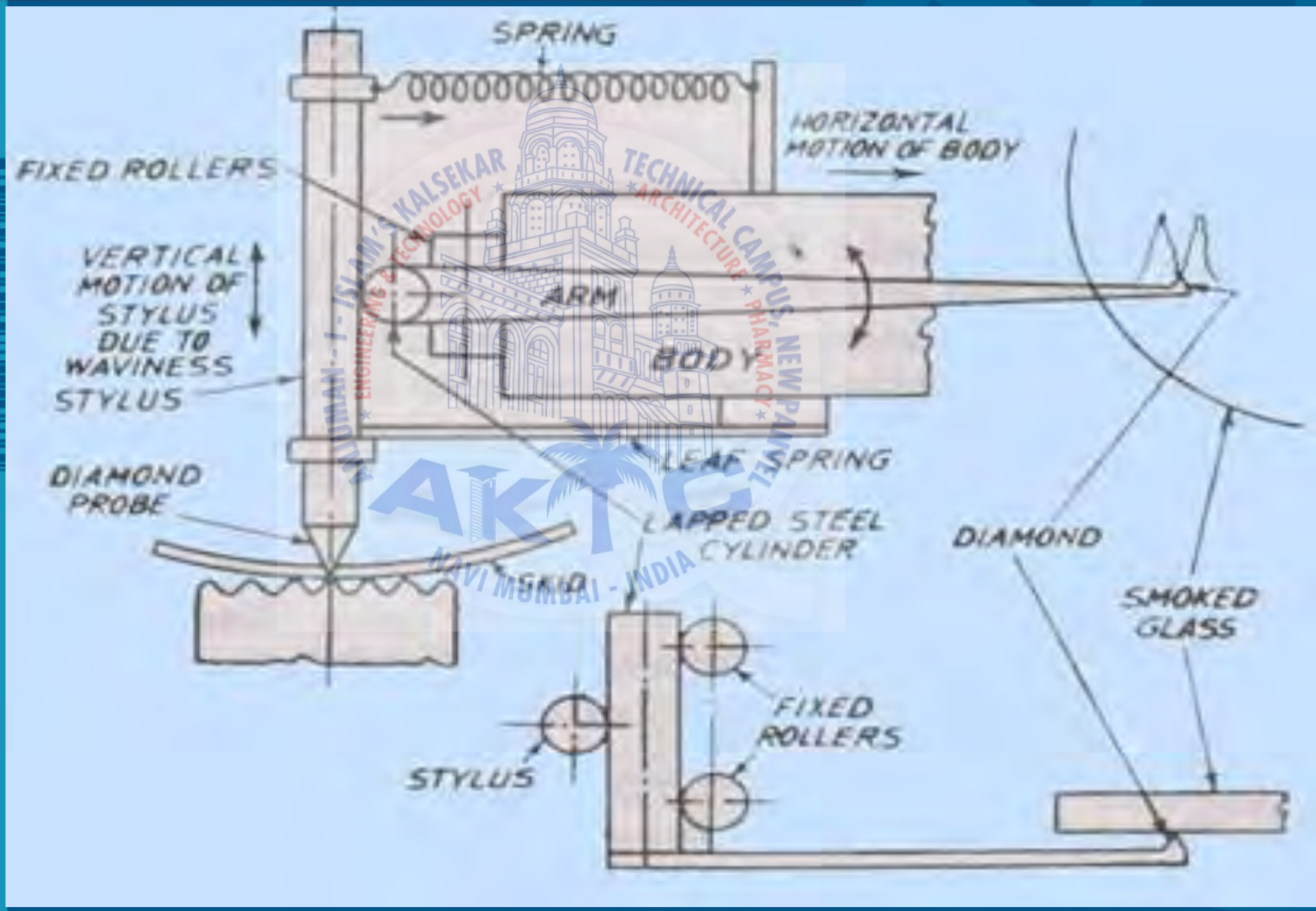
*Stylus probe Instruments*

*(i)Profilometer*

*(ii)Tomlinson surface meter*

*(iii)Taylor Hobson Talysurf*

# Tomlinson Surface meter



# Description

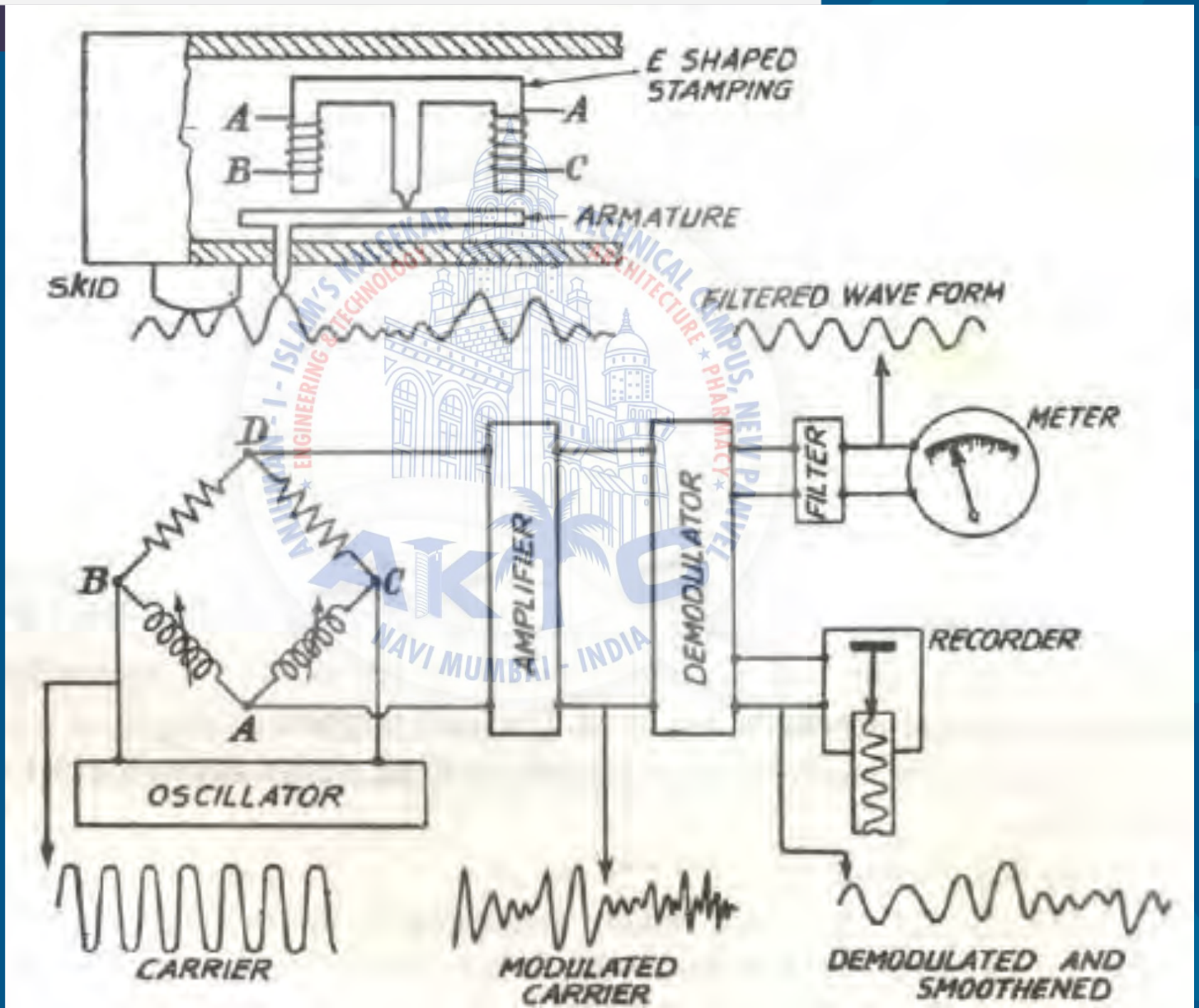
- This instrument was designed by Dr. Tomlinson. This instrument uses mechanical-cum-optical means for magnification

- The diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped steel cylinder.

- 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 conveniently.

- The lapped cylinder is supported on one side by the stylus and on the other side by two fixed rollers as shown in Fig.
- The stylus is restrained from all motion except the vertical one by the tensions in coil and leaf spring.
- The tensile forces in these two springs also keep the lapped steel cylinder in position between the stylus and it carries at its tip a diamond scriber which bears against a smoked glass.

# Taylor-Hobson Talysurf

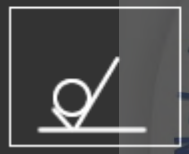


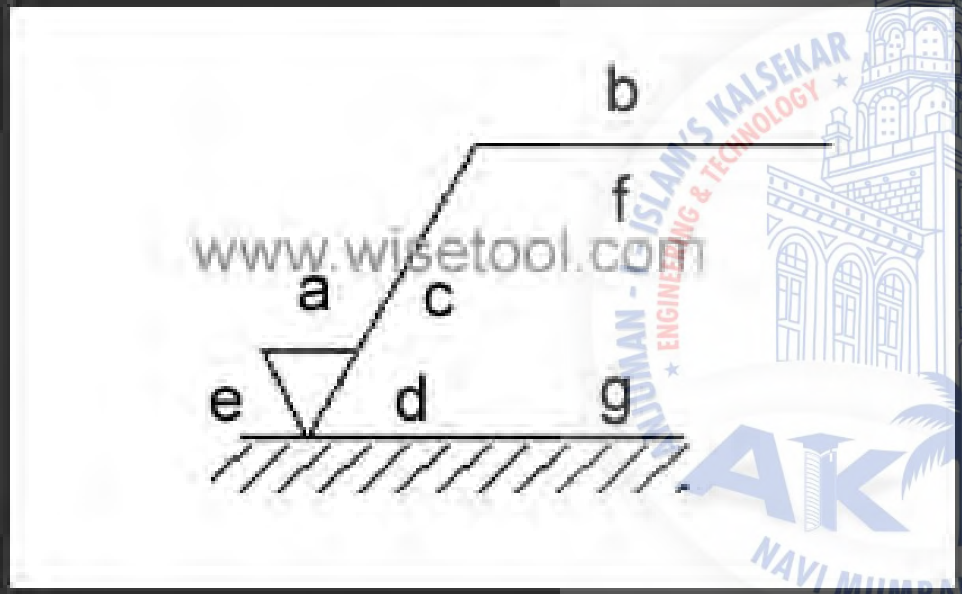
# Description

- The measuring head of this instrument consists of a diamond stylus of about 0.002 mm tip radius and skid or shoe which is drawn across the surface by means of a motorised driving unit.
- A neutral position in which the pick-up can be traversed manually is also provided.
- The arm carrying the stylus forms an armature which pivots about the centre piece of E-shaped stamping. On two legs of (outer pole pieces) the E-shaped stamping there are coils carrying an a.c. current.

- These two coils with other two resistances form an oscillator.
- The amplitude of the original a.c. current flowing in the coils is modulated because of air gap between the armature and E-shaped stamping.
- This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

# Symbols

| Symbol | Meaning |
| --- | --- |
|  | Surface Symbol |
|  | Removal od material by machining is required |
|  | Removal of material is prohibited |
|   | Upper limit of Ra Value |
|  | Grain direction |
|   | Machining Method |
|   | Upper and lower limit of Ra value |






a = Ra Value
b = Machining method
c = Cut off value, length
d = Grain direction
e = Parameter
f = Parameter other than Ra value
g = Surface undulation