



DEPARTMENT OF MECHANICAL ENGINEERING

Haldia, Purba Medinipur, West Bengal

HALDIA INSTITUTE OF TECHNOLOGY

PRACTICAL MANUAL

(Assessment Instrument and Instruction Items)

Course Name	Metrology and Measurement Laboratory
Course Code	PC-ME 392
Laboratory Name	Metrology and Measurement Laboratory
Programme	B. Tech in Mechanical Engineering
Semester / Year	[3 rd Semester / 2026]
Academic Session	2026–27

Faculty-in-Charge & Technical Staff

Faculty-in-Charge	Mr. Souvik Gantait
Co-Faculty (if any)	Dr. Premangshu Mukhopadhyay
Technical Staffs	Mr. Subabrata Panda

Vision

To impart quality, industry-relevant teaching-learning that blends knowledge and skill to produce industry-ready mechanical engineering graduates.

Mission Statements

M1: To create qualified and proficient technocrats having contemporary skills through outcome-based and self-learning strategies.

M2: To encourage innovation-oriented and problem-based research capabilities among young engineers through higher studies, in order to nurture the progress of society.

M3: To instill strong ethical values and good professional behaviour, enabling graduates to adopt and absorb emerging changes in the engineering profession.

Program Educational Objective

Graduates of B. Tech. Mechanical Engineering program, four years after graduation will

PEO1: Specify, design, supervise, test, and evaluate engineering skills to design, develop, and implement innovative solutions, systems, and applications in Mechanical Engineering and allied industries.

PEO2: Utilize Mechanical Engineering knowledge to address real-world and societal challenges while pursuing higher studies, research, and professional development.

PEO3: Demonstrate effective individual and collaborative capabilities in multidisciplinary professional environments, with a commitment to lifelong learning and adaptability to evolving technological, industrial, and societal requirements.

Program Specific Outcomes (PSOs)

PSO1: Design, analyze and evaluate mechanical components and systems such as thermal, fluid, manufacturing, design systems and allied engineering solutions.

PSO2: Utilize and evaluate modern engineering tools, software, and techniques to model, analyze, and solve real-world mechanical engineering problems.

PSO3: Demonstrate professional and ethical responsibility, effective communication, and the ability to work in multidisciplinary teams to address societal, industrial, and environmental challenges through sustainable mechanical engineering solutions.

PC-ME 392	Category: Professional Core courses	PCIE Marks	40
Metrology and Measurement Laboratory	Semester : Third	PSEE Marks	60
L-T-P: 0-0-3	Credit: 1.5	Total Marks	100
Pre-Requisites: Physics Lab, Engineering Drawing			
Examination (PSEE): Theory/ Drawing Assignment/ Practical/ Viva-voce/Team work/ others			

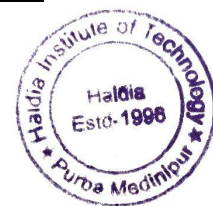
Course Content:

Experiments and instruction items are to be framed based on these units:

Unit	Topics	Hours	CO
UNIT I	Study of various vernier calipers and gear tooth vernier; determination of volume of sphere and hollow cylinder, and measurement of gear tooth thickness.	6	CO1
UNIT II	Study of various micrometers and combined slip gauges; measurement of sheet thickness, roller diameter, sphere diameter, and calibration of micrometer using slip gauges.	3	CO2
UNIT III	Measurement of external and internal taper angles using rollers, sine bar, and bevel protractor; determination of parallel bore diameter using two-ball, four-ball, and telescopic gauge methods.	9	CO3
UNIT IV	Measurement of screw thread parameters using thread micrometers, thread gauges, and optical profile projector.	6	CO4
UNIT V	Checking parallelism, cylindricity, concentricity, roundness, and flatness using dial indicators; measurements using radius, filler, drill, plug, and snap gauges.	9	CO5
UNIT V I	Measurement of surface flatness using monochromatic light interferometry and surface roughness using Talysurf.	9	CO6
Total		42	

Suggested Reference Books

- Engineering Metrology and Measurements — R.K. Jain
- Engineering Metrology — I.C. Gupta
- Metrology and Measurement — Anand K. Bewoor & Vinay A. Kulkarni



Course Outcomes:

Upon successful completion of the course, students will be able to:

CO CODES	CO Statement	Knowledge Categories	Cognitive Level
PC-ME 392.1	Determine the volume of a sphere and hollow cylinder, and gear tooth thickness, using various types of vernier calipers, within permissible least count error.	P	Ap
PC-ME 392.2	Determine the thickness of a sheet, roller diameter, and sphere diameter, and calibrate a micrometer using combined slip gauges, within instrument accuracy limits.	P	Ap
PC-ME 392.3	Measure external/internal taper angles and parallel bore diameter using rollers, sine bar, bevel protractor, balls, and telescopic gauge, within acceptable dimensional tolerance.	P	Ap
PC-ME 392.4	Measure thread parameters using screw thread micrometers, thread gauge, and optical profile projector, within standard specification tolerance.	P	Ap
PC-ME 392.5	Check parallelism, cylindricity, concentricity, roundness, flatness, and dimensions of components using dial indicator, radius/filler/drill gauge, and plug/snap gauge, within specified tolerance limits.	P	An
PC-ME 392.6	Measure surface flatness and roughness of components using monochromatic light interferometry and a Talysurf instrument, conforming to acceptable surface finish standards.	P	Ap

ALIGNING OF COS IN [CL × KC] METRIC

Knowledge Categories (KC)								
Cognitive Levels (CL)	Factual	Conceptual	Procedural	Meta-cognitive	Fundamental Design Principles	Criteria & Specifications	Practical Constraints	Design instrumentalities
Remember (R)								
Understand (U)								
Apply (Ap)			CO1, CO2, CO3, CO4, CO6					
Analyze (An)			CO5					
Evaluate (E)								
Create (C)								

Assessment Pattern and Assessment Instruments for PCIE & PSEE										
	PCIE								PSEE (60)	
	PCAI (40)				PCAII (40)					
Marks allotted	10	10	10	10	10	10	10	10	40	20
CO	EX1	EX 2	EX 3	VIVA I	EX 4	EX 5	EX 6	VIVA II	GR-A	GR-B (Viva)
CO1	10			10/3					40/6	20/6
CO2		10		10/3					40/6	20/6
CO3			10	10/3					40/6	20/6
CO4					10			10/3	40/6	20/6
CO5						10		10/3	40/6	20/6
CO6							10	10/3	40/6	20/6

CO-PO & CO-PSO Articulation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3
PC-ME 392.1	3	2	—	3	2	—	—	2	1	—	2	3	1	3
PC-ME 392.2	3	2	—	3	2	—	—	2	1	—	2	3	1	3
PC-ME 392.3	3	3	—	3	2	—	—	2	1	—	3	3	1	3
PC-ME 392.4	3	2	—	3	3	—	—	2	1	—	3	3	1	3
PC-ME 392.5	3	2	—	3	2	—	—	2	1	—	2	3	1	3
PC-ME 392.6	3	2	1	3	3	—	—	2	1	—	3	3	2	3
Average	3.0	2.2	1.0	3.0	2.3	—	—	2.0	1.0	—	2.5	3.0	1.2	3.0



METROLOGY & MEASUREMENT LABORATORY (PC-ME-392)**LIST OF ASSESSMENT ITEMS, INSTRUCTION ITEMS**

Experiment No.	Name of the experiment	Instruction Item	CO Congruence
EX1-I	Study of various types of vernier caliper and finding the volume of sphere and hollow cylinder.	II1	CO1
EX1-II	Study of measurement of gear tooth thickness by gear tooth vernier		
EX2-I	Study of various types of micrometer and determination of thickness of sheet, roller diameter, sphere diameter	II2	CO2
EX2-II	Study of combined slip gauges and calibration of micrometer using combined slip gauge as standard		
EX3-I	Measurement of external taper angle of a taper object using rollers, sine bar, and bevel protractor	II3	CO3
EX3-II	Measurement of internal taper angle of an object using balls		
EX3-III	Determination of diameter of parallel bore using two-ball method and four-ball method		
EX3-IV	Determination of diameter of parallel bore using telescopic gauge		
EX4-I	Measurement of thread parameters using screw thread micrometers, thread gauge, and optical profile projector	II4	CO4
EX5-I	Checking/measuring parallelism, cylindricity, concentricity, roundness, and flatness of components using dial indicator	II5	CO5
EX5-II	Taking measurements using: (a) radius gauge, (b) filler gauge, (c) drill gauge		
EX5-III	Checking internal diameter and thickness of given work pieces with plug gauge and snap gauge		
EX6-I	Measuring flatness with light band reading using monochromatic light source	II6	CO6
EX6-II	Measurement of surface roughness using Talysurf		

INSTRUCTION ITEM-1(II-1)			
EX1-I	Study of various types of vernier caliper and finding the volume of sphere and hollow cylinder.	II1	CO1

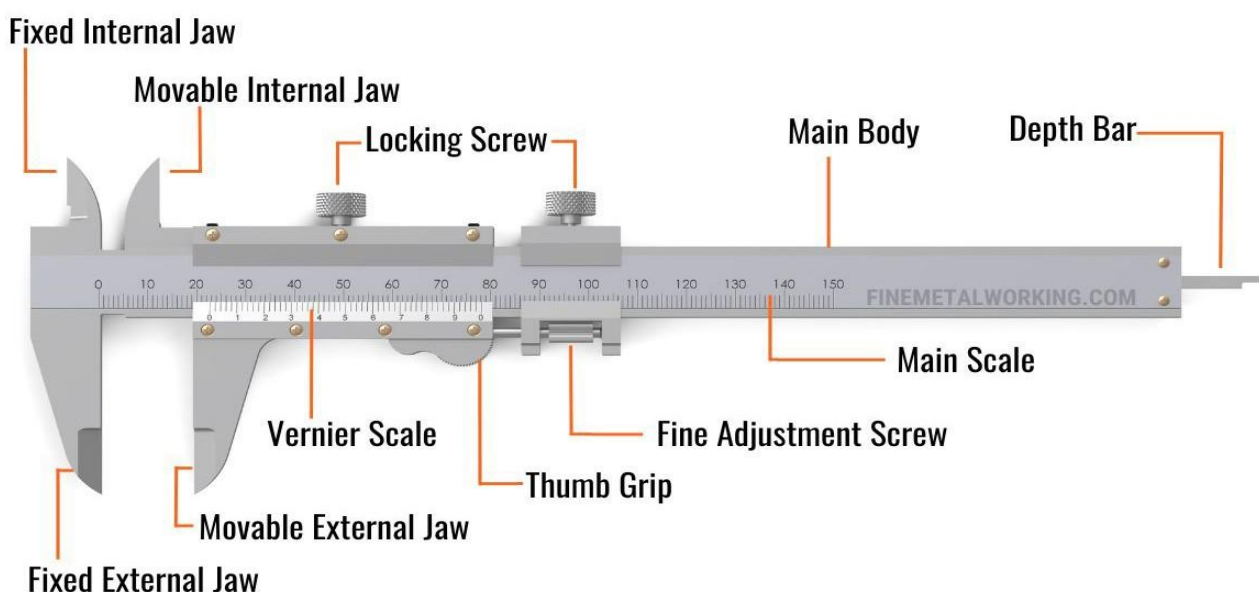
TITLE: STUDY OF VARIOUS TYPES OF VERNIER CALIPER AND FIND THE VOLUME OF SPHERE AND HOLLOW CYLINDER.

MEASURING INSTRUMENTS & TOOLS:

1. Vernier caliper
2. Spherical object
3. Hollow cylindrical object
4. Cleaning cloth
5. Slip gauge set

THEORY: Measuring instruments in usage will acquire certain errors due to wear and tear. So every instrument should be checked periodically to find out the errors and assess the accuracy. Comparing the reading of the instrument with a standard reference does this. This type of inspection is known as calibration. Depending on the type of instrument the standard reference is selected, against which the error of the instrument is evaluated. Since the error cannot be eliminated from the instrument, corresponding correction is applied to the measured reading of the instrument. Since the wear and tear of the instrument is not uniform, the error in the measured value will be different at different ranges of the instrument. To apply correction for the various readings in the range of the instrument, a calibration curve is to be drawn. Calibration curve is the curve drawn between the error and the instrument reading. The error at any stage of the instrument can be either positive or negative. The correction to be applied for a positive error is negative and vice-versa.

CONSTRUCTIONAL DETAILS & APPLICATIONS:



Method / Procedure:

1. The least count of the Vernier calipers was found.
2. The two jaws of the Vernier calipers were cleaned and vernier was checked for zero error by bringing the two jaws close at each other.
3. The given set of slip gauges, which is used as standard reference, was cleaned.
4. A slip gauge was placed in between the two jaws of Vernier calipers and was adjusted.
5. The slip gauge size and corresponding Vernier calipers reading were noted down. The difference between Vernier calipers reading and slip gauge size is the error.
6. The experiment was repeated for slip gauges of different sizes within the range of the Vernier calipers and the readings were tabulated and corresponding errors were found.
7. A graph is plotted against Vernier calipers reading and error / correction obtained.

Observation Tables:

Least count of Vernier calipers =

Sl. No.	Vernier calipers reading, 'X' (mm)	Slip gauge reading "Y" (mm)	Error (E=X-Y)	Correction
1				
2				
3				
4				
5				
Plot a Graph C=f(X)				

Sphere			
S. No.	MSR (cm)	VSR (div)	Total Reading = MSR + (VSR × L.C.) (cm)
1			
2			
3			
Mean Diameter (D)			

Hollow Cylinder				
Quantity	MSR (cm)	VSR (div)	Total Reading (cm)	Mean
External Diameter D ₁				
Internal Diameter D ₂				
Length h				

Calculations

- Radius of sphere, $r = D/2$; $V(\text{sphere}) = (4/3)\pi r^3$
- $V(\text{hollow cylinder}) = \pi[(D_1^2 - D_2^2)/4] \times h$

Precautions

1. Handle the instrument gently; don't force the jaws.
2. Always check and account for zero error before taking readings.
3. Keep the line of sight perpendicular to the scale to avoid parallax error.
4. Take readings at different positions/orientations and use the mean value.
5. Clean the jaws and the object before measuring; ensure the object is held snugly, not over-tightened.
6. Note readings in proper units (cm), with correct significant figures.

Result

- Volume of the given sphere = ____ cm³
- Volume of the given hollow cylinder = ____ cm³

Viva Questions

1. What is the least count of a vernier caliper and how is it calculated?
2. What is zero error, and how is positive/negative zero error corrected?
3. Differentiate between the main scale and the vernier scale.
4. Why do we take multiple readings and use the mean?
5. What is the difference between a vernier caliper and a screw gauge, and when is each preferred?

INSTRUCTION ITEM-1(II-1)			
EX1-II	Study of measurement of gear tooth thickness by gear tooth vernier	II1	CO1

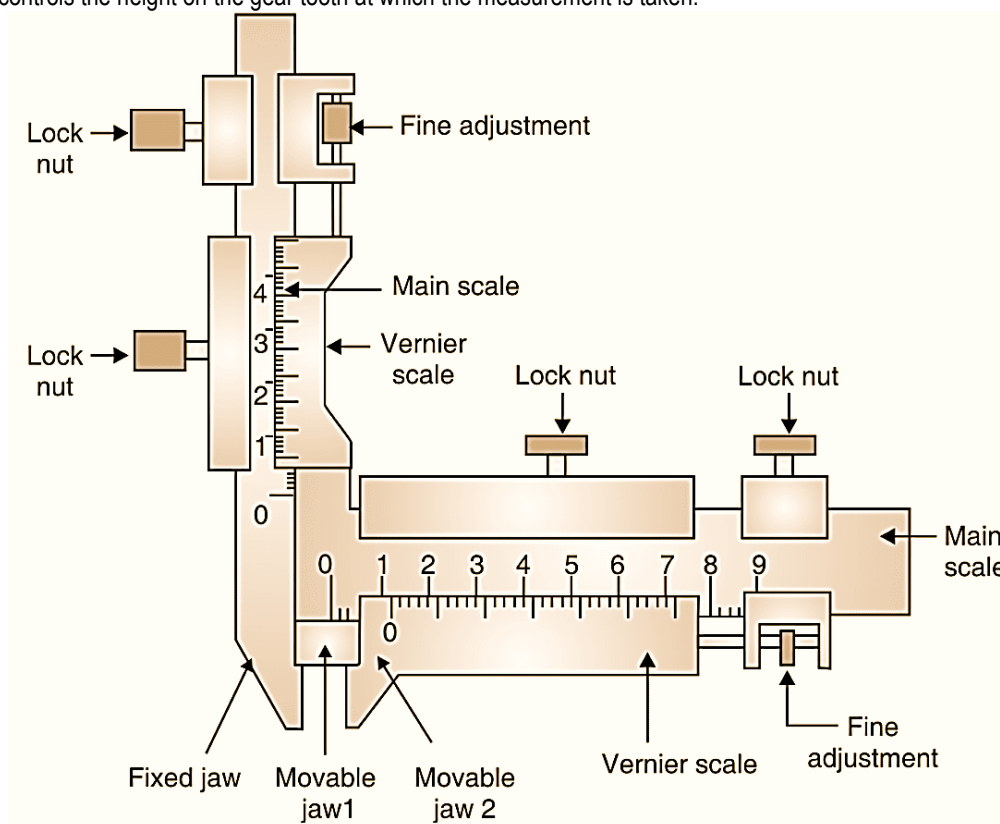
TITLE: STUDY OF MEASUREMENT OF GEAR TOOTH THICKNESS BY GEAR TOOTH VERNIER

Apparatus required:

1. Gear tooth vernier caliper
2. Spur gear
3. Vernier caliper
4. Magnifying lens

Theory:

Measurement of profile of a spur gear tooth depends on the geometrical principle of involute gear i.e., the distance between the parallel lines embracing several teeth is constant and is equal to the arc on the base circle intersected by the extreme flanks. There are various equipments by which the elements of gear tooth can be measured; one among them is gear tooth vernier caliper. It is a special type of vernier caliper with a vertical slide which controls the height on the gear tooth at which the measurement is taken.



Gear tooth vernier caliper

Description of Instrument

A gear tooth vernier caliper is a special vernier instrument used to measure the thickness of a gear tooth at the pitch line (chordal thickness) and the depth from the top of the tooth to the pitch line (chordal addendum). Unlike an ordinary vernier caliper (which has one scale), it has two separate vernier scales set at right angles to each other:

- **Vertical vernier scale (Height/Depth scale)** – set to the chordal addendum so the horizontal jaws sit exactly at the pitch line of the tooth.
- **Horizontal vernier scale (Width scale)** – measures the chordal thickness of the tooth at that pitch-line depth, using two jaws that close onto the tooth flanks.

Each scale has its own main scale, sliding vernier, and locking screw, and each has its own least count.

Relevant Gear Terminology

- **Module (m):** $m = D/T$, where D = pitch circle diameter, T = number of teeth
- **Chordal Addendum (h) – vertical scale setting:** $h = m[1 + (T/2)(1 - \cos(90^\circ/T))]$

- **Chordal Tooth Thickness (W)** – value measured on the horizontal scale: $W = m T \sin(90^\circ/T)$

Principle

Gear teeth taper from base to tip, so thickness must be measured at the pitch circle, not the top. The vertical scale is first set to the calculated chordal addendum (h), positioning the horizontal jaws exactly at the pitch-line depth. The horizontal jaws then close onto the tooth flanks and the vernier gives the actual chordal thickness.

Procedure

1. Note the number of teeth (T) and module (m) of the given gear.
2. Calculate the theoretical chordal addendum (h) from the formula above.
3. Set the vertical (depth) vernier scale to this value of h and lock it.
4. Rest the instrument's tongue/blade over the top of a gear tooth so the depth blade touches the addendum circle - positioning the horizontal jaws at the pitch line.
5. Slide the horizontal jaws inward until they gently touch both flanks of the tooth.
6. Note the main scale reading (MSR) and vernier coincidence (VSR) on the horizontal scale; calculate the actual chordal thickness.
7. Repeat on 3-5 different teeth around the gear and take the mean.
8. Compare the measured value with the theoretical chordal thickness.

Observation Table

Number of teeth, T = _____ Module, m = _____ mm Calculated chordal addendum, h = _____ mm Least Count = _____ mm

S. No.	Tooth No.	MSR (mm)	VSR (div)	Actual Chordal Thickness W = MSR + (VSR × L.C.) (mm)
1				
2				
3				
4				
5				

Mean W (actual) = _____ mm

Calculations

- Theoretical chordal thickness: $W = m T \sin(90^\circ/T)$
- Percentage error = $[(W(\text{theoretical}) - W(\text{actual})) / W(\text{theoretical})] \times 100$

$$\text{Module } m = \frac{D_o}{Z + 2} \text{ (mm)}$$

Where, D_o = Outer diameter of spur gear Z = No. of teeth

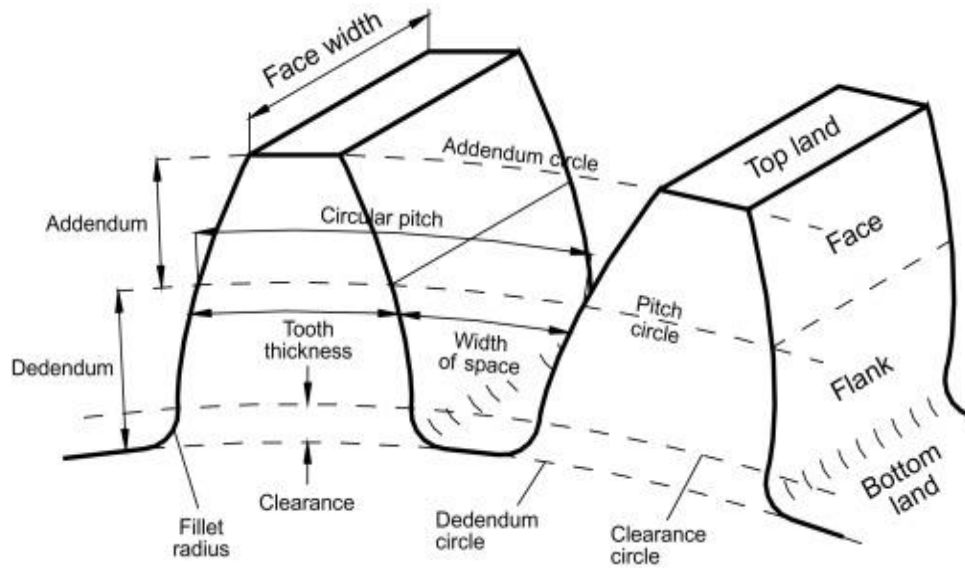
Standard preferred modules are 1, 1.25, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6, 8, 10, 12, 16 and 20

Second preferred modules are 1.75, 1.375, 1.75, 2.25, 2.75, 3.5, 4.5, 5.5, 7, 9, 11, and 14

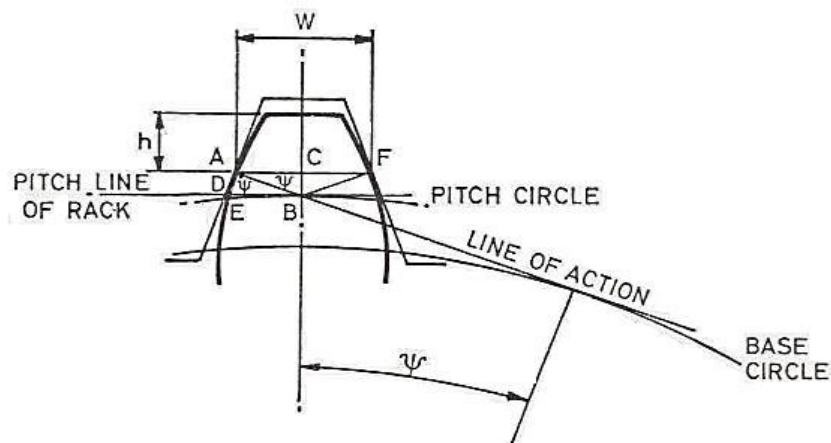
Precautions

1. Calculate and set the vertical (depth) scale accurately before measuring thickness.
2. Let the jaws just touch the tooth flanks without forcing, to avoid distorted readings or gear damage.

3. Avoid parallax error while reading the vernier scales.
4. Measure at several teeth and take the mean, to average out manufacturing errors.
5. Ensure the gear and instrument are clean and free from burrs.
6. Handle the instrument carefully; don't misalign the two vernier scales.



Spur gear tooth gear



Measurement of tooth thickness at constant chord

Result

- Theoretical chordal tooth thickness, $W = \text{_____ mm}$
- Measured (mean actual) chordal tooth thickness, $W = \text{_____ mm}$
- Percentage error = $\text{_____ \%}$

Viva Questions

1. Why must gear tooth thickness be measured at the pitch line and not at the tip?
2. What is chordal addendum, and why must it be set before measuring thickness?
3. Define module of a gear. How is it related to pitch circle diameter?
4. Why does the gear tooth vernier caliper have two vernier scales instead of one?
5. What are the possible sources of error in this measurement, and why is the reading taken on multiple teeth?

INSTRUCTION ITEM-1(II-2)			
EX2-I	Study of various types of micrometer and determination of thickness of sheet, roller diameter, sphere diameter	II2	CO2

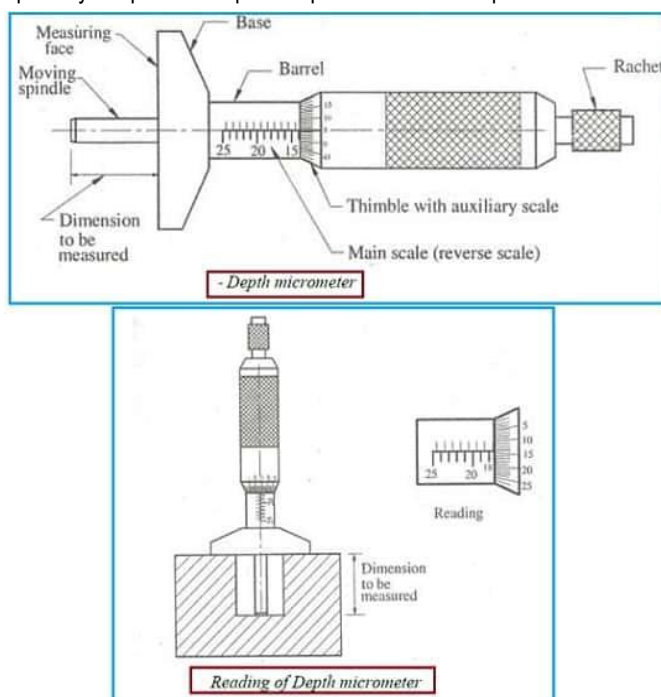
TITLE: STUDY OF VARIOUS TYPES OF MICROMETER AND DETERMINATION OF THICKNESS OF SHEET, ROLLER DIAMETER, SPHERE DIAMETER.

Apparatus

Micrometer screw gauge, given metal sheet, given roller (cylindrical rod), given sphere.

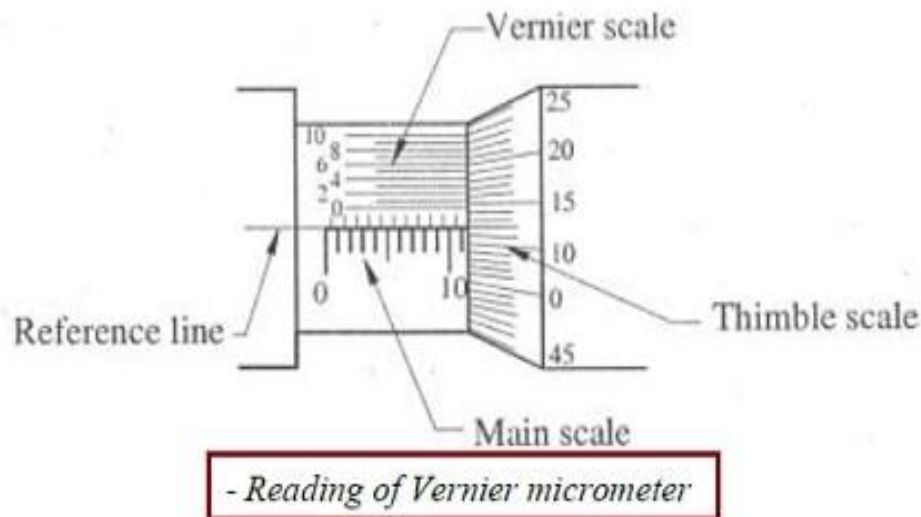
Types of Micrometer

- **Outside (external) micrometer** – measures outer dimensions (thickness, diameter, length) between the anvil and spindle.
- **Inside micrometer** – measures internal dimensions such as the diameter of a hole or width of a groove.
- **Depth micrometer** – measures depth of holes, slots or steps; has a flat base with the spindle projecting through it.
- **Digital micrometer** – gives a direct LCD readout, eliminating manual reading and reducing reading error.
- **Vernier micrometer** – has an additional vernier scale on the sleeve, allowing readings finer than the circular scale alone.
- **Screw thread micrometer** – has specially shaped anvil/spindle tips to measure the pitch diameter of screw threads.



Scales on a Micrometer

- 1. Main scale (Pitch / Sleeve scale):** Engraved lengthwise on the sleeve (barrel), graduated in mm and often half-mm. As the thimble rotates, its edge reveals the main scale reading in whole and half millimetres.
- 2. Circular scale (Thimble scale):** Engraved around the bevelled edge of the thimble, usually with 50 (sometimes 100) divisions. One full rotation advances the spindle by one pitch (commonly 0.5 mm). The division aligned with the datum line on the sleeve gives the circular scale reading (CSR).
- 3. Vernier scale (vernier micrometers only):** Extra graduations on the sleeve, parallel to the main scale, typically 10 divisions covering 9 divisions of the circular scale. The vernier division that coincides exactly with a circular scale division gives the extra digit of the reading.



Principle / Least Count

A micrometer works on the screw-nut principle: one full rotation of the thimble advances the spindle by a distance equal to the pitch of the screw. The circular scale subdivides the pitch into fine divisions, and the vernier scale (where fitted) subdivides it further.

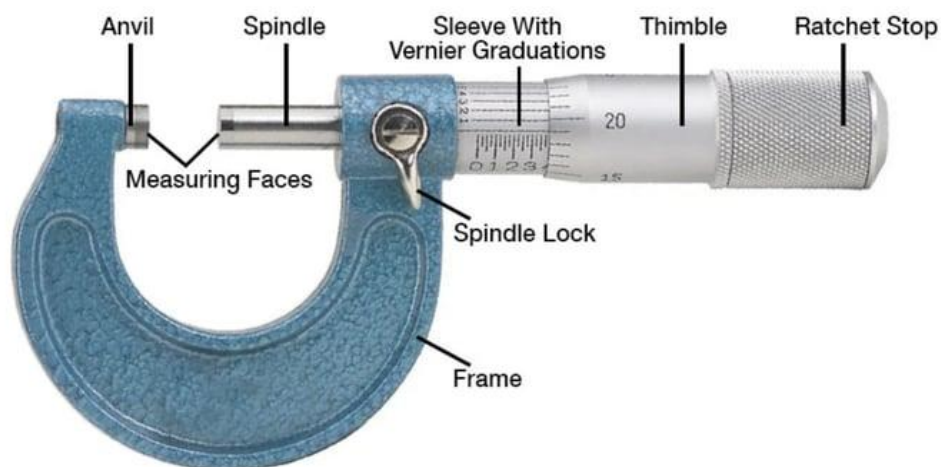
Least Count (ordinary micrometer) = Pitch of screw / Number of divisions on circular scale

For pitch = 0.5 mm and 50 divisions: L.C. = $0.5 / 50 = 0.01$ mm

Least Count (vernier micrometer) = L.C. of circular scale / Number of vernier divisions = $0.01 / 10 = 0.001$ mm

Total Reading = MSR + (CSR $\times$ L.C.) + (VSR $\times$ L.C. vernier) – Zero Error

(The vernier term applies only if the instrument has a vernier scale.)



Procedure

A. Zero error

Bring the anvil and spindle into contact using the ratchet (2–3 clicks only). Note whether the zero of the circular scale coincides with the reference line on the main scale. If not, note the zero error (positive or negative) and correct every subsequent reading.

B. Thickness of the sheet

1. Place the sheet gently between the anvil and spindle; close using the ratchet.
2. Note MSR, CSR (and VSR if applicable) and calculate the total reading.
3. Repeat at 3–5 different points on the sheet and take the mean.

C. Diameter of the roller

1. Place the roller between the anvil and spindle, perpendicular to the spindle axis.
2. Take readings at different positions along its length, two in mutually perpendicular directions at each position.
3. Take the mean of all readings.

D. Diameter of the sphere

1. Place the sphere between the anvil and spindle.

2. Take readings along three mutually perpendicular directions.
3. Take the mean diameter.

Observation Tables

Pitch of screw = _____ mm No. of circular scale divisions = _____ Least Count = _____ mm

Zero Error

Observation	Reading
Zero error (if any)	
Correction	

Thickness of Sheet

S. No.	MSR (mm)	CSR (div)	VSR (div)	Total Reading (mm)
1				
2				
3				

Mean thickness = _____ mm

Diameter of Roller

S. No.	Position	MSR (mm)	CSR (div)	VSR (div)	Total Reading (mm)
1					
2					
3					

Mean diameter = _____ mm

Diameter of Sphere

S. No.	MSR (mm)	CSR (div)	VSR (div)	Total Reading (mm)
1				
2				
3				

Mean diameter = _____ mm

(Omit the VSR column if the instrument has no vernier scale.)

Calculations

- Mean thickness of sheet = (sum of readings) / n
- Mean diameter of roller = (sum of readings) / n
- Mean diameter of sphere = (sum of readings) / n

Precautions

1. Always use the ratchet, not the thimble, to bring the spindle into contact, avoiding excess pressure on the screw thread.
2. Check and apply zero error correction before taking readings.
3. Avoid parallax error while reading the main, circular and vernier scales.
4. Take readings at multiple points/positions and use the mean.
5. Clean the anvil, spindle faces and object before measurement.
6. Handle the instrument gently; do not drop it or force the screw beyond the ratchet's click.

Result

- Mean thickness of the given sheet = _____ mm
- Mean diameter of the given roller = _____ mm
- Mean diameter of the given sphere = _____ mm

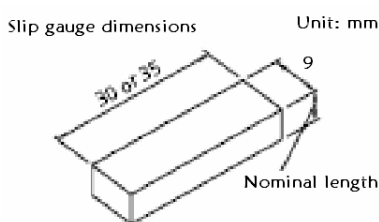
Viva Questions

1. What are the main scale, circular scale and vernier scale of a micrometer, and what role does each play?
2. How is the least count of a micrometer calculated, and how does a vernier scale improve it?
3. What is backlash error, and how does it differ from zero error?
4. Why is the ratchet used instead of the thimble to close the jaws?
5. Compare the precision of a micrometer with a vernier caliper.

INSTRUCTION ITEM-1(II-2)			
EX2-II	Study of combined slip gauges and calibration of micrometer using combined slip gauge as standard	II2	CO2

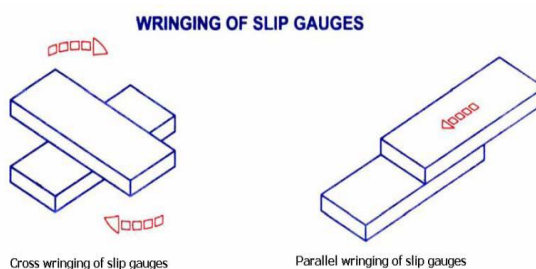
TITLE: STUDY OF COMBINED SLIP GAUGES AND CALIBRATION OF MICROMETER USING COMBINED SLIP GAUGE AS STANDARD.

Theory: Slip gauges are end standards used in linear measurements. They are used in workshop for work where a tolerance as low as 0.001mm is needed. Slip gauges were invented by Swedish engineer, C.E. Johnson, so they are also called Johnson gauges. Slip gauges are rectangular blocks, made of high grade steel, having cross section about 30mm X10mm. These blocks are made into required sizes and hardened to resist wear and allowed to stabilize so as to relieve internal stresses. This prevents occurrence of size and shape variations. After hardening the blocks, measuring faces are carefully finished to fine degree of surface finish, flatness and accuracy. This high grade surface finish is obtained by super finishing process known as lapping.



RECTANGULAR GAUGE BLOCK

Wringing of slip gauges:



The measuring face of the gauges is flat and it possesses high surface finish. If two slip gauges are forced against each other on measuring faces, because of contact pressure, gauges stick together and considerable force is required to separate these blocks. This is known as wringing of slip gauges. Thus, wringing refers to condition of intimate and complete contact and of permanent adhesion between measuring faces. Slip gauges are wrung to build desired dimension. Slip gauges are wrung together by hand and no other external means. Figure shows 1) Parallel wringing of slip gauges and 2) Cross wringing of slip gauges. In cross wringing – the two slip gauges are first cleaned to remove dirt, then they are placed together at right angles in the form of cross and then rotated through 90°, while being pressed together. This method causes less rubbing of surfaces. Almost any dimension may be built by suitable combination of gauges. Wringing phenomenon is purely due to surface contact and molecular adhesion of metal of blocks. Hence, “**wringing is defined** as the property of measuring faces of gauge blocks of adhering, by sliding or pressing the gauge against measuring faces of other gauge blocks or reference faces or datum surfaces without the use of external means.”

Uses of slip gauges:

1. as a reference standard.
2. for verification and calibration of measuring apparatus.
3. for adjustment of indicating devices.
4. for direct measurement.
5. for setting of various types of comparators.

M87 is a special set of slip gauges.

Range (mm)	Steps	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	0
1.005	-	1

Procedure of performing experiment:

- (1) Clean the fixed vice and micrometer
- (2) Clamp the micrometer in vice putting cushioning material between micrometer and jaws of vice to protect the micrometer from probable damage due to clamping force.
- (3) Make pile of gauge blocks and insert between two anvils of the micrometer and take reading.
- (4) Increase the value of gauge blocks pile and take next few readings.
- (5) Then decrease the value of gauge blocks pile and take same readings in decreasing order.
- (6) Tabulate the readings
- (7) After cleaning the place the gauge blocks should be placed in their respective places.

Observation table:

Range:

Least count:

Make:

Sr. No	Slip gauges in combination	Micrometer reading in mm				
		Increasing	Decreasing	Average	Error	Correction
1						
2						
3						
4						
5						
6						

Following graphs are to be drawn:

- (1) Slip gauges combination – Micrometer average
- (2) Slip gauges combination – Error
- (3) Micrometer average reading – correction

Conclusion: By this experiment, we can easily measure the dimension of combined slip gauge.

Frequently asked questions during Interviews

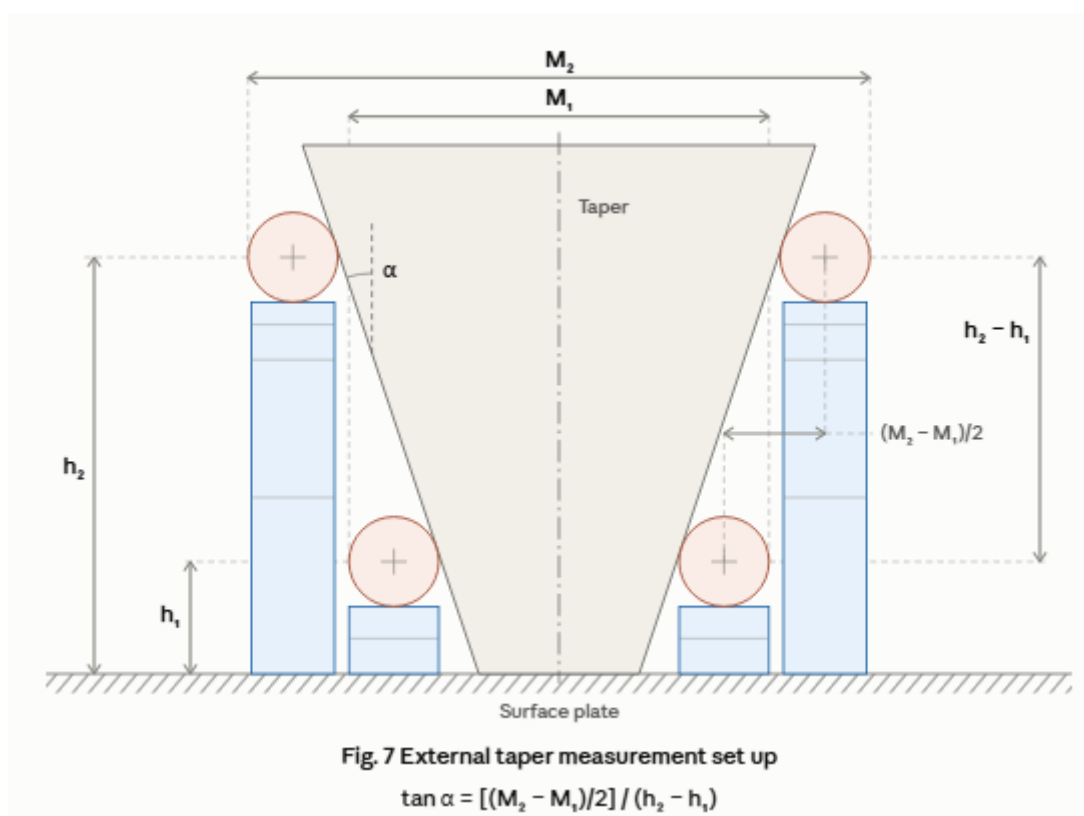
1. What are slip gauges?
2. What is wringing?
3. What is calibration?
4. Define an error
5. Define least count.

INSTRUCTION ITEM-1(II-3)			
EX3-I	Measurement of external taper angle of a taper object using rollers, sine bar, and bevel protractor	II3	CO3

TITLE: MEASUREMENT OF EXTERNAL TAPER ANGLE OF A TAPER OBJECT USING ROLLERS

Apparatus Required: A set of slip gauges of M 87 Grade 1, two rollers of equal diameters, height gauges and surface table.

Description: The object with external taper angle is placed directly on the surface plate or on a slip gauge of known height h_2 mounted on the surface plate and is located as shown in figure. The angle of taper can be determined from measurement over two equal rollers mounted on the slip gauges at each side of the object at two arbitrary heights, one near the smaller end and the other near the larger end of the object.



Where, M_1 = Distance between two rollers at lower position
 M_2 = Distance between two rollers at upper position
 h_1 = Slip gauge combination height at lower position
 h_2 = Slip gauge combination height at upper position
 α = Half taper angle

Procedure:

1. Locate the tapered object on a slip gauge of known height or directly on the surface plate in a stable position.
2. Choose two suitable rollers of equal diameter.
3. Select the suitable combination of slip gauges and place the rollers on the slip gauges to obtain the heights h_1 and h_2
4. h_1 and h_2 can be measured with the help of height gauge by measuring the diameter of the rollers and height of the slip gauges.
5. Measure D_1 and D_2 by means of a micrometer.
6. Repeat the steps from 1 to 5 with different combination of slip gauges for the variation of h_1 and h_2 to obtain different D_1 and D_2 .
7. Evaluate the taper angle for each repetition and calculate the average taper angle.

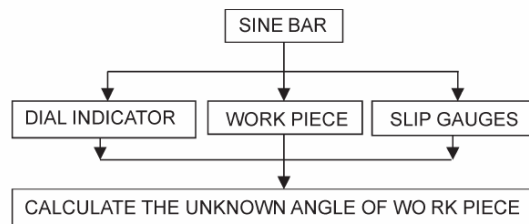
Conclusion: By this experiment, we came to know about the process of measuring the taper angle of taper object with the help of a micrometer.

Frequently asked questions during Interviews

1. What is the least count of Vernier caliper?
2. Name some linear measuring devices?
3. What is the difference between micrometer and Vernier caliper?
4. Write the applications of Vernier height gauge?

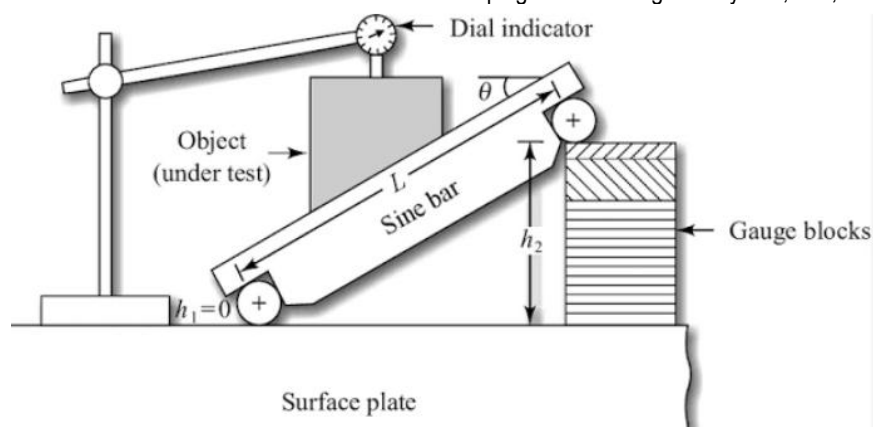
TITLE: MEASUREMENT OF EXTERNAL TAPER ANGLE OF A TAPER OBJECT USING SIN BAR

Concept Structure:



SINE BAR:

Sine bar is a precision instrument used along with slip gauges for accurate angle measurements or angle setting. Sine bar consists of an accurate straight bar in which two accurately lapped cylindrical plugs or rollers are located with extreme position. The straight bar are made of high carbon, high chromium, corrosion resistant steel and the surfaces are hardened, grounded and lapped. Ends of the straight bar are stepped so that the plugs can be screwed at each step. Plugs are the two rollers of same diameter fixed at a distance L between them and is called as length of the bar. This distance L is the centre to centre distance of plugs is which is generally 100, 200, 300 mm and so on.



Principle:

The use of sine bar is based on the laws of trigonometry. When sine bar set up is made for the purpose of angle measurement as shown below, sine bar itself forms hypotenuse of right angle triangle and slip gauges form the side opposite to the required angle. $\sin \theta = (h/L)$
Therefore $\theta = \sin^{-1}(h/L)$

Angle θ is determined by an indirect method as a function of sine so this device is called as sine bar. Sine bar is always used in conjunction with slip gauge and dial indicator for the measurement of angle.

Stepwise Procedure: -

1. Note the length of sine bar $L = \dots\dots\dots$ mm
2. Find the approximate angle of the component by using bevel protractor or any other suitable device. Let this angle be θ .
3. Calculate height of slip gauges (h) required from relation $\sin \theta = h/L$, where L is the length of sine bar. $h = L \sin \theta$
4. Select & bring together the required slip gauges for dimension ' h ' mm.
5. Place the work piece on sine bar & clamp to the angle plate if necessary as shown.
6. Dial indicator is clamped firmly in dial indicator stand and slight pressure applied so that plunger just touches one end of workpiece.
7. To check the parallelism of upper surface of workpiece, a dial indicator along with the stand is moved from one end of the work and moved to other end.
8. Note the deviation ' h '. This deviation may be noticed by taking two readings of dial indicator at two ends of work piece top edge.
9. Add / subtract the slip gauges of height ' dh '. Where $dh = h * L / l$ 'l' is length of workpiece.
10. Adjust the slip gauges so that deviation of dial indicator is zero from one end to other end.
11. Calculate the height of slip gauges. Unknown angle $= \sin^{-1}(\text{Height of slip gauges/Length of sine bar}) = \sin^{-1}(h/L) = \dots\dots$

Observation and Calculations:

L = Distance between axes of supporting roller of sine bar = _____ mm

h = height of slip gauge = _____ mm

Frequently asked questions during Interviews

1. What is a sine bar?
2. What are the limitations of sine bar?
3. What are slip gauges and why do we use them?

4. What are the modifications of sine bar?

TITLE: MEASUREMENT OF EXTERNAL TAPER ANGLE OF A TAPER OBJECT USING BEVEL PROTRACTOR

Apparatus: Surface Plate, Bevel Protractor, Tapered work piece.

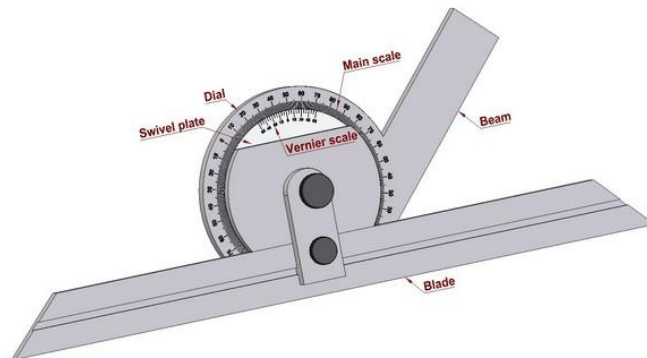
Theory:

Main parts of bevel protractor are

1. Fixed Base blade and a circular body is attached to it.
2. Adjustable blade.
3. Blade clamp.
4. Scale magnifier lens.
5. Acute angle attachment.

Bevel protractor is used for measuring and laying out of angles accurately and precisely within 5 minutes. The protractor dial is slotted to hold a blade which can be rotated with the dial to the required angle and also independently adjusted to any desired length. The blade can be locked in any position. It is the simplest instrument for measuring the angle between two faces of component. It consists of base plate attached to the main body and an adjustable blade which is attached to a circular plate containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale engraved on the body of the instrument and can be locked in the any position. It is capable of measuring from zero to 360°. The vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus the least count of the instrument is 5'. This instrument is most commonly used in work shop for angular measurements.

Note the reading, magnifying lens has been provided for easy reading of the instrument. Main scale is circular and is graduated in degrees on the circular body. Main scale graduations are all around the circular body which is attached to fixed base blade. Fixed base blade also called as stock is attached to circular body of bevel protractor as shown in figure. Once the reading is fixed, blade clamp fixes the reading. Blades are about 150 mm long or 300mm long, 13mm wide and 2mm thick. Its ends are bevelled at angles of 45 degree and 60 degree. Vernier scale is also marked on turret which can rotate all over the fixed body. Adjustable blade can pass through the slot provided in turret. So as the turret rotates, adjustable blade also rotates full 360 degrees. There are 12 graduations of Vernier scale starting from 0 to 60° on both sides of zero of Vernier scale as shown in figure.



Least count of Vernier bevel protractor = (smallest division on main scale) / (Total no of divisions on Vernier scale) = 1° (equal to 60') i.e. $60 / 12 = 5$ minutes (written as 5')

Observations:

Least count of the bevel protractor _____ minutes.

SL No.	Faces/Sides	Angles
1		
2		
3		
4		

Applications:

1. To measure the acute & obtuse angles in case of flat & circular objects with large radius.
2. In machining processes like production of flat surfaces.
3. For checking the V'block, it is used.

Procedure:

1. Note down the least count of the Bevel Protractor.
2. Keep the work piece on the surface plate.

3. Fix the slide of Bevel Protractor to the Turret.
4. Keep one of the surfaces of the specimen on the working edge and rotate the turret. Remove the slide on to the other surface.
5. Fix the centre, after matching the both the faces and note down the reading.
6. Repeat the experiment for different faces

Results:

By using the bevel protractor, the taper angle of the given specimen is calculated.

Frequently asked questions during Interviews

1. What is the least count of Vernier bevel protractor?
2. What are the limitations of Vernier bevel protractor?

INSTRUCTION ITEM-1(II-3)

EX3-II

Measurement of internal taper angle of an object using balls

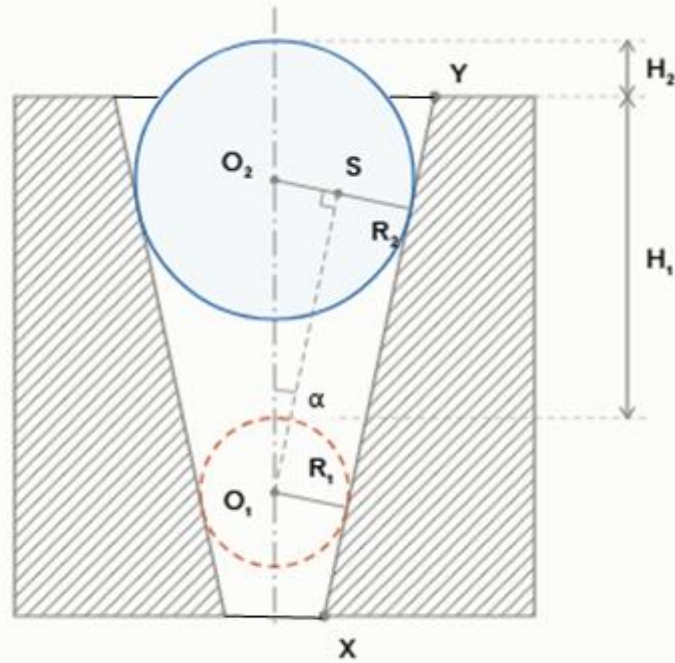
II3

CO3

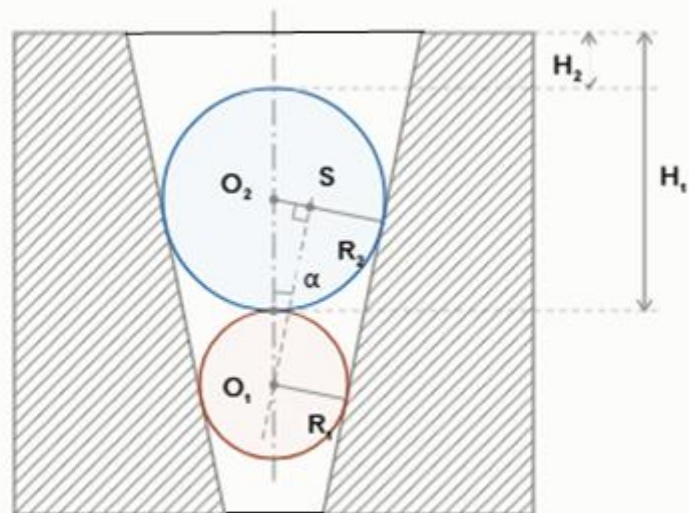
TITLE: MEASUREMENT OF INTERNAL TAPER ANGLE OF AN OBJECT USING BALLS

Apparatus Required: A set of slip gauges of M 87 Grade 1, micrometer depth gauge, height gauges, two balls and surface table.

Description: An object with internal taper is placed directly on the surface plate and located in positions as shown in figure



(a)



(b)



The internal taper angle can be determined from the measurement over two balls of different sizes inserted in the tapered separately. If the smaller balls lie inside the hole and the bigger ball is partially inserted into the taper hole, the angle of taper can be determined as

$$\alpha = 2\sin^{-1} \left\{ \frac{0.5 (D_2 - D_1)}{(H_2 + H_1) + 0.5 (D_1 - D_2)} \right\}$$

If both the balls are fully inserted into the hole as shown in the figure, then the angle of taper can be determined as

$$\alpha = 2\sin^{-1} \left\{ \frac{0.5 (D_2 - D_1)}{(H_1 + D_1/2) - (H_2 + D_2/2)} \right\}$$

where H_1, H_2 = heights over the balls, D_1, D_2 = diameters of the balls

Procedure:

1. Locate the object on the surface plate the stable position.
2. Choose the balls of suitable diameters
3. Measures the diameters and the heights and thickness of the slip gauges in case of very small taper angle.

Observation Table

Obs. No.	Height (H_1) mm	Height (H_2) mm	Diameter of smaller ball (D_1) mm	Diameter of bigger ball (D_2) mm	Average α

Conclusion:

By this experiment, we came to know about the process of measuring the internal taper angle of taper object with the help of a micrometer.

You report should contain the followings

1. Sketch and specification of Vernier height gauge and micrometer depth gauges
2. Derive with sequential steps for the determination of taper angle
3. What precaution should be taken in the experiment?

Frequently asked questions during Interviews

1. Which one is smaller M.S div or V.S. div?
2. How the LC of a micrometer is determined?
3. Write the applications of Vernier depth gauge?



INSTRUCTION ITEM-1(II-3)

EX3-III

Determination of diameter of parallel bore using two-ball method and four-ball method

II3

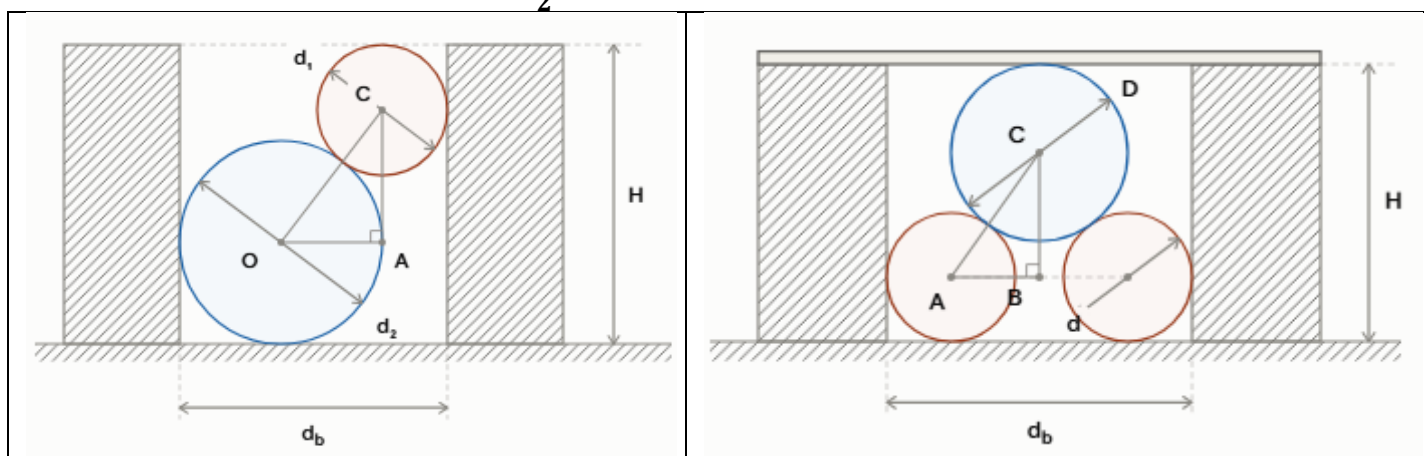
CO3

TITLE: DETERMINATION OF DIAMETER OF PARALLEL BORE USING TWO-BALL METHOD AND FOUR-BALL METHOD.

Description:

The parallel bore is placed directly on the surface plate keeping its axis perpendicular to the surface plate and located in stable position as shown in the figure. Two balls of known diameter are inserted in the hole one over another. For this case the sum of D_1 and D_2 should be greater than the diameter of the bore. The measurement of the height over the upper ball from the surface plate is measured with the help of slip gauges and dial indicator or height gauge and micrometer depth gauge. The diameter of the parallel bore can be determined using the following equation

$$D_b = \frac{1}{2} (D_1 + D_2) + \{H (D_1 + D_2) - H^2\}^{1/2}$$



If the balls of equal diameter D_1 less than the radius of the bore diameter and the fourth ball of any diameter D_2 but less than 0.75 of the bore diameter are used as depicted in the figure, the diameter of the parallel bore can be determined using the following equation

$$D_b = D_1 + 2\{H (D_1 + D_2) - H^2\}^{1/2}$$

Apparatus Required: A set of slip gauges of M 87 Grade 1, micrometer depth gauge, height gauges, steel balls and surface table.

Observation Table

Obs. No.	Height (H) mm	Diameter of smaller ball (D_1) mm	Diameter of bigger ball (D_2) mm	Average D_b

Conclusion:

By this experiment, we came to know about the process of measuring the diameter of a parallel bore.

Frequently asked questions during Interviews

1. What is the least count of Vernier caliper?
2. Name some angular measuring devices?
3. What is the difference between micrometer and Vernier caliper?
4. Write the applications of Vernier depth gauge?



INSTRUCTION ITEM-1(II-3)

EX3-IV

Determination of diameter of parallel bore using telescopic gauge

II3

CO3

TITLE: DETERMINATION OF DIAMETER OF PARALLEL BORE USING TELESCOPIC GAUGE

Apparatus

Telescopic gauge set, outside micrometer (0–25 mm or as required), given component with a parallel bore, cleaning cloth.

Description of the Instrument

A telescopic gauge is a transfer-type instrument: it does not display a reading itself, but captures the size of the bore, which is then measured with a micrometer. It consists of:

- **T-handle**, held by the operator.
- **Two spring-loaded telescoping plungers (measuring anvils)** at the head, which spring outward and contact opposite walls of the bore.
- **Locking screw** (knurled knob at the end of the handle) that clamps the plungers at the captured size.

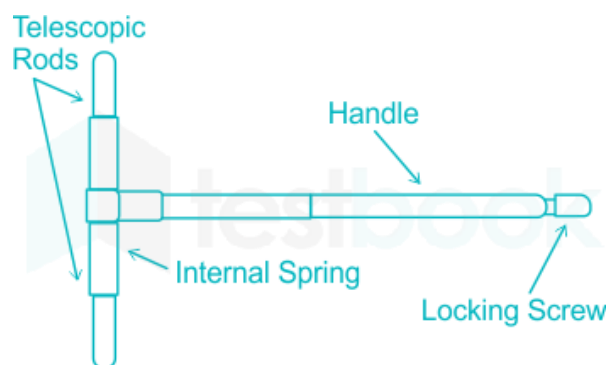
Telescopic gauges come in a set of sizes (for example 8–13 mm, 13–19 mm, 19–32 mm), so the gauge whose range covers the bore size must be selected.

Principle

The spring-loaded plungers expand to touch the bore walls, and locking them fixes the bore diameter into the gauge. The distance across the plunger tips is then measured with a micrometer, giving the bore diameter. Since a bore may not be perfectly parallel or round, readings are taken at several depths and in different directions.

Procedure

1. Clean the bore and the gauge tips, and estimate the bore size to select the correct gauge from the set.
2. Loosen the locking screw so the plungers move freely, and compress them slightly.
3. Insert the gauge head into the bore at an angle, then release the plungers so they spring out against the bore walls.
4. Gently rock the handle back and forth about the bore axis so the plungers find the true diameter (the maximum position across the axis, not along a chord).
5. In this position, tighten the locking screw to lock the plungers.
6. Carefully withdraw the gauge from the bore, tilting it to avoid disturbing the locked setting.
7. Measure the distance across the plunger tips with an outside micrometer using a light, steady touch, and note the reading ($MSR + CSR \times L.C.$).
8. Repeat at three depths (mouth, middle, and bottom) and in two mutually perpendicular directions at each depth.
9. Calculate the mean diameter. Compare readings at different depths to check for taper, and readings in perpendicular directions to check for ovality.





Observation Table

Least count of micrometer = _____ mm Zero error = _____ mm Range of telescopic gauge used = _____ mm

S. No.	Position (depth)	Direction	MSR (mm)	CSR (div)	Diameter = MSR + (CSR × L.C.) (mm)
1	Mouth	A-A			
2	Mouth	B-B (⊥)			
3	Middle	A-A			
4	Middle	B-B (⊥)			
5	Bottom	A-A			
6	Bottom	B-B (⊥)			
				Mean diameter	

Calculations

- Mean diameter of bore, $D = (\text{sum of all readings}) / 6$
- Taper = $D(\text{mouth}) - D(\text{bottom})$
- Ovality = difference between A-A and B-B readings at the same depth

Precautions

1. Select the gauge whose range fits the bore size; never use a gauge outside its range.
2. Rock the gauge properly to find the true diameter before locking; a slanted or off-centre position gives an incorrect reading.
3. Lock the screw firmly before withdrawing the gauge, and do not disturb the plungers while removing it.
4. Use a light, consistent touch when measuring across the plungers with the micrometer, as excess pressure compresses the springs and gives a false reading.
5. Check and correct the micrometer for zero error before taking readings.
6. Clean the bore and gauge tips to remove dirt or oil.
7. Take readings at different depths and directions, and use the mean.

Result

- Mean diameter of the given parallel bore = _____ mm
- Taper (if any) = _____ mm
- Ovality (if any) = _____ mm

Viva Questions

1. Why a telescopic gauge is called a "transfer" instrument?
2. Why must the gauge be rocked before locking the plungers?
3. How do you check a bore for taper and ovality?
4. What are the advantages and limitations of a telescopic gauge compared with an inside micrometer or a bore gauge?
5. Why is the gauge locked before it is withdrawn from the bore?

out-of-roundness (ovality).



INSTRUCTION ITEM-1(II-4)

EX4-I

Measurement of thread parameters using screw thread micrometers, thread gauge, and optical profile projector

II4

CO4

TITLE: MEASUREMENT OF THREAD PARAMETERS USING SCREW THREAD MICROMETERS, THREAD GAUGE, AND OPTICAL PROFILE PROJECTOR

Apparatus: Tool maker's microscope, profile projector threading job

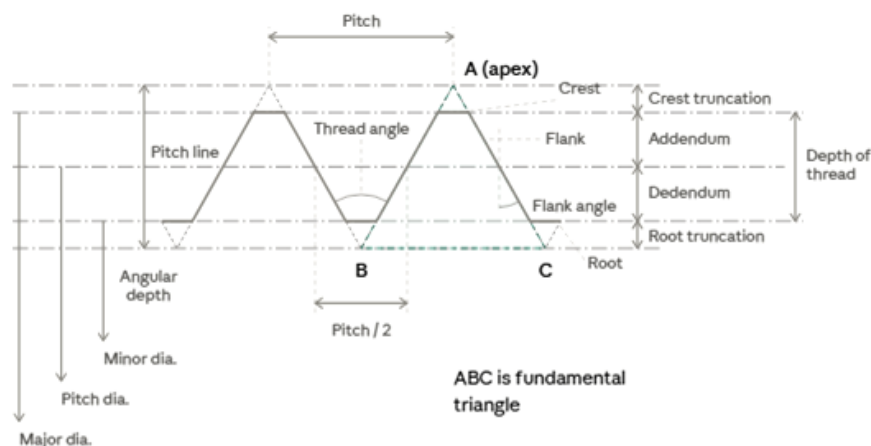
THEORY:

By using lenses and beams of light, profiles of small shapes can be magnified. The enlarged image can be compared with accurate magnified drawing made to the scale of magnification. Such a comparison can reveal any deviations in the sizes and contours of the objects and to get a numerical assessment of such deviations, measurements can be made on the enlarged shadow. The measured dimensions on the shadow will then have to be divided by the multiplication factor. The projection apparatus used for this purpose is termed as an optical profile projector. The essential features of a profile projector are that, it should be accurately as stated and that there should be maximum latitude in holding and adjusting the work piece and examining the projected shadow.

Parameters to be measured:

- Major and minor diameter of screw
- Depth of screw
- Pitch of screw
- Thread angle

Common Screw Thread Terminology



Major diameter: In case of a straight thread, this is the diameter of the major cylinder (imaginary cylinder, co-axial with the screw, which just touches the crests of an external thread or the root of an internal thread). It is often referred to as the outside diameter, crest diameter or full diameter of external threads.

Minor diameter: In case of straight thread, this is the diameter of the minor cylinder (an imaginary cylinder, co- axial with the screw which just touches the roots of an external thread or the crest of an internal thread). It is often referred to as root diameter or cone diameter of external threads.

Pitch: The pitch of a thread is the distance, measured parallel to the axis of the thread, between corresponding points on adjacent thread forms in the same axial plane and on the same side of axis. The basic pitch is equal to the lead divided by the number of thread starts. On drawings of



thread sections, the pitch is shown as the distance from the centre of one thread crest to the centre of the next, and this representation is correct for single start as well as multi-start threads

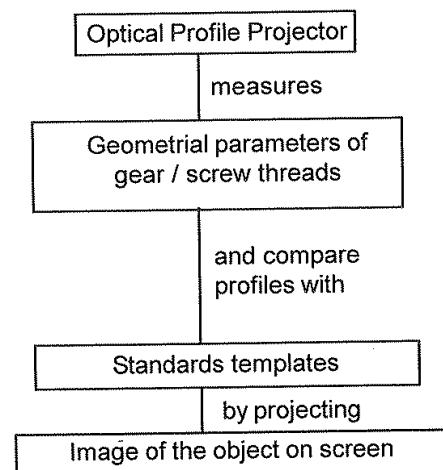
Effective diameter or pitch diameter: In case of straight thread, this is the diameter of the pitch cylinder (the imaginary cylinder which is co-axial with the axis of the screw, and intersects the flank of the threads in such a way as to make the width of threads and width of the spaces between the threads equal). If the pitch cylinder be imagined as generated by a straight line parallel to the axis of screw, that straight line is then referred to as the pitch line. Along the pitch line, the widths of the threads and the widths of the spaces are equal on a perfect thread. This is the most important dimension as it decides the quality of the fit between the screw and the nut.

Angle of thread: This is the angle between the flanks or slope of the thread measured in an axial plane.

Depth of thread: This is the distance from the crest or tip of the thread to the root of the thread measured perpendicular to the longitudinal axis or this could be defined as the distance measured radially between the major and minor cylinders.

Errors in Threads: In the case of plain shafts and holes, there is only one dimension which has to be considered (i.e. diameter), and errors on this dimension if exceed the permissible tolerance, will justify the rejection of part. While in the case of screw threads there are at least five important elements which require consideration and error in any one of these can cause rejection of the thread. Errors on the major and minor diameters will cause interference with the mating thread. Due to errors in these elements, the root section and wall thickness will be less, also the flank contact will be reduced and ultimately the component will be weak in strength. Errors on the effective diameter will also result in weakening of the assembly due to interference between the flanks. Similarly pitch and angle errors are also not desirable as they cause a progressive tightening and interference on assembly. These two errors have a special significance as they can be precisely related to the effective diameter.

Operating Principle Of A Profile Projector: A Profile Projector (often simply called a optical comparator in context) is a device that applies the principles of optics to the inspection of manufactured parts. In a comparator, the magnified silhouette of a part is projected upon the screen, and The dimensions and geometry of the part are measured against prescribed limits. The inspection operation and dimensional measurement that can be carried out with optical projector are similar to engineering microscope in many ways. However, there are still differences between these two families of optical measuring instruments. Microscopes are intended primarily for tool room and gage room applications and require certain degree of skill in operation. On the other hand, projectors are basically production-oriented instruments in shop floor by machine tool operators. Optical projectors are not adaptable to various types of special accessories designed for microscope. But they provide application advantages in many other respects in comparison to the capabilities of engineering microscopes.





The need of observing a magnified image of an object from a convenient distance has given rise to the construction of projectors. Unlike microscope where observation and measurement of objects with the aid of optical magnification are limited to viewing through an ocular, projector uses project magnified image of the object on a glass screen. As a result visual impressions become a physical reality insofar as the dimensions and forms can be directly compared to the physical master components.

The primary purpose of a projector is to produce undistorted magnified shadow image or reflected image of an object on a screen. To accomplish this, any projector should comprise the following basic elements.

Source of Light

Light source is usually a powerful lamp up to 1000 watts or more. Generally, tungsten filament lamp is used for illumination. However, it is replaced by high-pressure mercury lamp when specific measurement has to be made. It produces steady light without flickering. The light source has to be designed with consideration of several factors to avoid harmful heat transfer to the optical system and operating elements of the projector. Therefore, the lamp house is usually mounted externally with a powerful blower fan. It also has special heat absorbing glass filters to keep back the heat rays that might affect the dimensional stability of the object. Two types of light source systems are commonly employed.

Shadow Projection Light Source System

In this system, light rays originating from the light source hit the object, whose physical body creates a shadow bounded by the actual contour of the object when viewed in the direction of light rays. This shadow is then magnified by the lens system and projected on the viewing screen. Figure shows a schematic diagram of such type of system. In this particular system, an auxiliary element, a relay lens is used to transfer the shadow on the projecting lenses.

Reflection Projection Light Source System

In this system, light source illuminate the front side of the object, which faces the lens system. The lens system receives reflected light, which is magnified and projected on the screen as the object image.

Modern optical projectors are equipped with light switches with a provision to regulate the light intensity. This enables the production of best level of illumination for any particular magnification.

Collimating or Condensing Lens

These lenses are the parts of a projector, which refract the light into a beam with parallel rays of almost uniform intensity on the entire area of object illumination. They are fixed in the lens housing and are situated nearest to the light source. Therefore, the glass used for collimating lens must be heat resistant. For special applications of projectors, like photo-elastic stress analysis provisions are made in the collimators to mounting of polarizing filters.

Projection Lens

The projection lens system magnifies and transmits the object contour or image resulting from the collimated parallel light rays. The image formed on the screen should be erect and unreversed. Different types of lens arrangement are possible according to need and application. For plainer type of optical projectors, the magnifying lens system is interchangeable lens system. For complicated application like in measuring machine, the lens system consists of several lenses with different magnification. They can be adjusted manually or with power drives. The lens system must be capable of giving clear definition of the object. Therefore it is coated for extra light transmission.

Screen

The projected image of the object appears and is displayed on the screen for inspection. It is made of ground glass, with finely grained texture, to provide a bright, glare-free image. The screen must present an image easy to measure with accuracy without causing fatigue to the operator. The brightness of the image must be uniform over the full area of the screen. It must permit observation of the image without distortion, when viewed by a group at different angles. Depending on the design of the optical system, the position of the screen may be exactly horizontal, vertical or tilted at certain angle.



Magnification of a Projector

The magnification of a projector is defined by the following formulae:

Lens magnification (m) = Screen Diameter / Field Diameter

The most frequently available magnifications in optical projectors are 5X, 10X, 20X, 25X, 30 X, 31.25X, 50X, 62.5X, 100X, and 125X. Since different magnification is required depending on the object, projectors are built with optical system that permits interchanging the lenses. The two aspects that must be noted in magnifying an image are

The higher the magnification, the more is the intricate details of the object, and

The lower is the magnification; the larger will be the area that can be projected on the screen.

APPARATUS & SPECIMEN REQUIRED:

- Optical profile projector
- Standard templates
- Threaded specimen
- Trace paper & pencil

PROCEDURE:

- Switch on the optical profile projector.
- Place the clean work piece on the glass of the table
- Focus it properly by moving focusing wheel and moving the work table to obtain correct magnified image of the object.
- Horizontal (X-axis) measurement can be taken by right hand side micrometer and the vertical measurement can be taken from the front side micrometer.
- To measure pitch take the distance between two similar points on adjacent flank or crest to crest or root to root on adjacent threads, parallel to the axis of the screw thread. For achieving this adjust the reference line on the projector to the corresponding points and note the micrometer readings between these points.
- Adopt similar procedure for measurement of the other linear parameters of the thread.
- For measurement of thread angle match the reference line between flanks and note down the angle.

Observation Tables

Parameters to be measured	Reference point reading 1	Reference point reading 2	Measured Parameter (Difference of reading 1 & 2)
Major Diameter			
Minor Diameter			
Pitch			
Pitch Diameter			
Depth of Thread			
Angle of Thread			

SAFETY:

- Use the projector under the supervision of some experienced person
- Place the work piece properly on the table on the path of source light

Frequently asked questions during Interviews

1. What is effective diameter of thread?
2. What is minor diameter of thread?
3. Define pitch.
4. Explain the principle of optical profile projector?



INSTRUCTION ITEM-1(II-5)

EX5-I	Checking/measuring parallelism, cylindricity, concentricity, roundness, and flatness of components using dial indicator	II5	CO5
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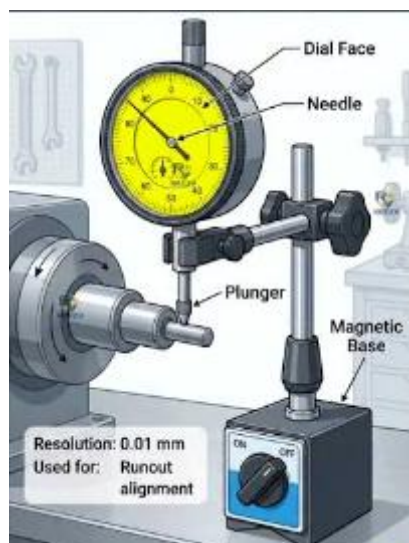
TITLE: CHECKING / MEASURING PARALLELISM, CYLINDRICITY, CONCENTRICITY, ROUNDNESS AND FLATNESS OF COMPONENTS USING DIAL INDICATOR

MEASURING INSTRUMENTS & TOOLS:

1. Mechanical comparator
2. Slip gauge set
3. Comparator stand
4. Surface plate

THEORY: Measuring instruments in usage will acquire certain errors due to wear and tear. So every instrument should be checked periodically to find out the errors and assess the accuracy. Comparing the reading of the instrument with a standard reference does this. This type of inspection is known as calibration. Depending on the type of instrument the standard reference is selected, against which the error of the instrument is evaluated. Since the error cannot be eliminated from the instrument, corresponding correction is applied to the measured reading of the instrument. Since the wear and tear of the instrument is not uniform, the error in the measured value will be different at different ranges of the instrument. To apply correction for the various readings in the range of the instrument, a calibration curve is to be drawn. Calibration curve is the curve drawn between the error and the instrument reading. The error at any stage of the instrument can be either positive or negative. The correction to be applied for a positive error is negative and vice – versa.

CONSTRUCTIONAL DETAILS & APPLICATIONS:



PROCEDURE:

1. The comparator was mounted securely in the stand and the base of the stand is cleaned.
2. Free movement of the comparator plunger was ensured.
3. The slip gauge set was degreased and an initial reading is set by selecting a suitable slip gauge and so that the plunger of the comparator just slides on the top surface and the comparator reads zero.
4. A small increment was given to the initial size of the slip gauge and the corresponding comparator reading was noted down.
5. The procedure was repeated for various slip gauge sizes within the range of the comparator so as to have the deflection on either side of zero reading.
6. The reading was tabulated and corresponding errors were found.
7. A graph is plotted against the comparator reading and error obtained.

PRECAUTIONS:

1. The slip gauge set should be degreased properly before use.
2. The initial setting of the comparator should be done carefully so as to have zero reading.
3. Slip gauges should be increased in size with regular increments within the range on either side of zero reading.
4. Slip gauges should be wringing properly for various combinations.



OBSERVATIONS:

Least count of Mechanical comparator =

Sl. No	Mechanical comparator reading X (mm)	Slip gauge reading Y (mm)	Error E = X - Y
Draw E vs. X plot			

VIVA QUESTIONS

1. Explain about Linear measurement?
2. What is difference between accuracy and repeat which?
3. What is the use of comparator?
4. Classify comparators?
5. Explain tolerance?
6. Explain limits?
7. What is surface plate?
8. Comparators are used in which type of production?



INSTRUCTION ITEM-1(II-5)

EX5-II

Taking measurements using: (a) radius gauge, (b) filler gauge, (c) drill gauge

II5

CO5

TITLE: TAKING MEASUREMENTS USING: (A) RADIUS GAUGE, (B) FILLER GAUGE, (C) DRILL GAUGE

Apparatus

Radius (fillet) gauge set, feeler gauge set, drill gauge (drill size plate), given components with rounded edges/fillets, a pair of mating parts with a small gap, and a set of twist drills.

Description of the Gauges

(a) Radius gauge (fillet gauge): A set of thin steel leaves, each having a convex profile at one end and a concave profile at the other, marked with the radius (for example 1 mm to 7 mm in steps of 0.5 mm). It is used to check the radius of external corners (convex) and internal fillets (concave) by comparison.

(b) Feeler gauge (thickness gauge): A set of thin steel blades, each of accurately known thickness (for example 0.05 mm to 1.00 mm), hinged together at one end like a folding knife. It is used to measure small gaps or clearances between two mating surfaces, such as valve tappet clearance, spark plug gap and the gap between a bracket and a face.

(c) Drill gauge: A flat steel plate with a series of accurately drilled holes of graded sizes (metric, fractional, number or letter series), each marked with its size. It is used to identify the size of a twist drill, especially when the marking has worn off.

Principle

All three are fixed (limit-type) comparison gauges. They do not have a scale; the size is obtained by finding the leaf, blade or hole that just matches the feature being measured. The radius gauge works by fit and light gap, the feeler gauge by a slight drag when the blade slides in the gap, and the drill gauge by the drill fitting freely in a hole of known size.

Procedure

A. Radius gauge

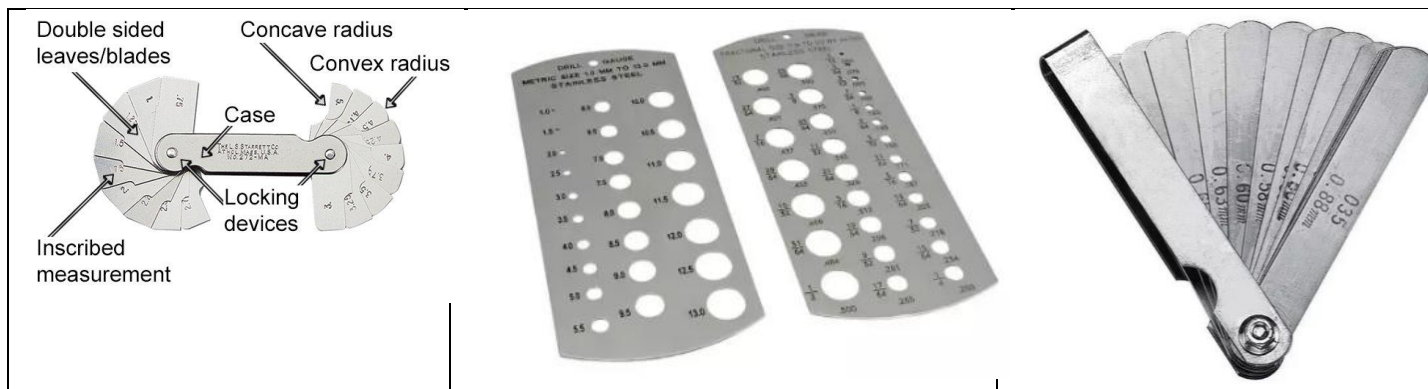
1. Clean the component and the gauge leaves.
2. Select a leaf that appears close to the radius of the edge or fillet, using the convex end for a concave surface and the concave end for a convex surface.
3. Hold the leaf square to the surface and against the profile, and view the joint against a light source.
4. Try leaves in succession until the one with no visible light gap is found.
5. Note the radius marked on that leaf. If two adjacent leaves are near, record the value as lying between them.

B. Feeler gauge

1. Clean the mating surfaces and the blades.
2. Select a blade that appears close to the gap and insert it into the gap.
3. Slide it in and out; a correct blade enters with a slight drag or resistance, without being forced.
4. If the blade is loose, try a thicker one; if it does not enter, try a thinner one.
5. Where no single blade fits, combine two or more blades (total thickness = sum of the marked thicknesses) and note the value.

C. Drill gauge

1. Clean the drill and hold it by the fluted body, not the worn cutting tip.
2. Try the drill in the holes of the plate, starting from a hole that is clearly smaller.
3. Find the smallest hole through which the drill passes freely but without noticeable play.
4. Read the size marked beside that hole; this is the drill size.
5. Compare with the size marked on the drill, if any, and note any difference due to wear.



Observation Tables

(a) Radius gauge

S. No.	Component / feature	Type (convex / concave)	Leaf that fits (mm)	Radius (mm)
1				
2				
3				

(b) Feeler gauge

S. No.	Gap measured between	Blade(s) used (mm)	Total thickness = gap (mm)
1			
2			
3			

(c) Drill gauge

S. No.	Drill No.	Marked size on drill (mm)	Hole size on gauge that fits (mm)	Remarks (wear)
1				
2				
3				



Precautions

1. Clean the gauges and the surfaces before use, as dust and oil affect the fit.
2. Do not force a feeler blade into a gap or bend it; a bent blade gives false readings and damages the gauge.
3. Hold the radius gauge square to the surface, and view against light to judge the gap correctly.
4. Avoid using a feeler blade on hot or rough surfaces, and do not use worn or rusted blades.
5. Measure a drill on the fluted body, not on a worn tip, to avoid a wrong size.
6. Store the gauges in their case after wiping with a light coat of oil to prevent rust.

Result

- Radius of the given edge/fillet = _____ mm
- Gap between the given mating surfaces = _____ mm
- Size of the given drill = _____ mm

Viva Questions

1. What is a radius gauge and how do you use it for concave and convex surfaces?
2. How is a gap measured using a feeler gauge, and how is the correct fit judged?
3. What are the uses of a feeler gauge in an automobile engine?
4. Why are these gauges called fixed comparison gauges, and what is their limitation compared with a vernier caliper?
5. How can the size of a drill with a worn marking be found using a drill gauge?



INSTRUCTION ITEM-1(II-5)

Ex5-III	Checking internal diameter and thickness of given work pieces with plug gauge and snap gauge	II5	CO5
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TITLE: CHECKING INTERNAL DIAMETER AND THICKNESS OF GIVEN WORK PIECES WITH PLUG GAUGE AND SNAP GAUGE

Apparatus

GO / NO GO plug gauge, GO / NO GO snap gauge (adjustable or fixed), work pieces with bores, work pieces (plates or shafts) for thickness check, cleaning cloth.

Theory

A limit gauge does not give the actual size of a component. It only checks whether the dimension lies within the permitted tolerance, that is, between the upper (high) limit and the lower (low) limit. Every limit gauge has two ends:

- **GO end:** checks the dimension at its maximum material condition. It must pass (enter or go over) the work piece.
- **NO GO (NOT GO) end:** checks the dimension at its minimum material condition. It must not pass the work piece.

A component is accepted only if the GO end passes and the NO GO end does not pass.

Plug gauge (for holes/bores): A cylindrical gauge, usually double-ended. The GO plug is made to the low limit (minimum size) of the hole and the NO GO plug to the high limit (maximum size). The GO plug is longer than the NO GO plug, because a GO plug must check the full length of the bore, while a NO GO plug checks only the diameter at one position. A NO GO plug is often marked with a red band and made shorter to tell them apart.

Snap gauge (for shafts/thicknesses): A C-shaped or U-shaped gauge with two pairs of anvils (gap openings), used for external dimensions such as shaft diameter and plate thickness. The GO gap is set to the high limit (maximum size) and the NO GO gap to the low limit (minimum size). The work piece should pass through the GO gap and should not pass through the NO GO gap.

Conditions of Acceptance

GO end	NO GO end	Decision
Passes	Does not pass	Accepted (within limits)
Does not pass	Does not pass	Rejected (hole undersize / shaft oversize) - can be reworked
Passes	Passes	Rejected (hole oversize / shaft undersize) - scrap

Note: the rejection cases above are written for a hole checked with a plug gauge; for a shaft/thickness checked with a snap gauge, the undersize/oversize wording is reversed.

Procedure

A. Internal diameter with plug gauge

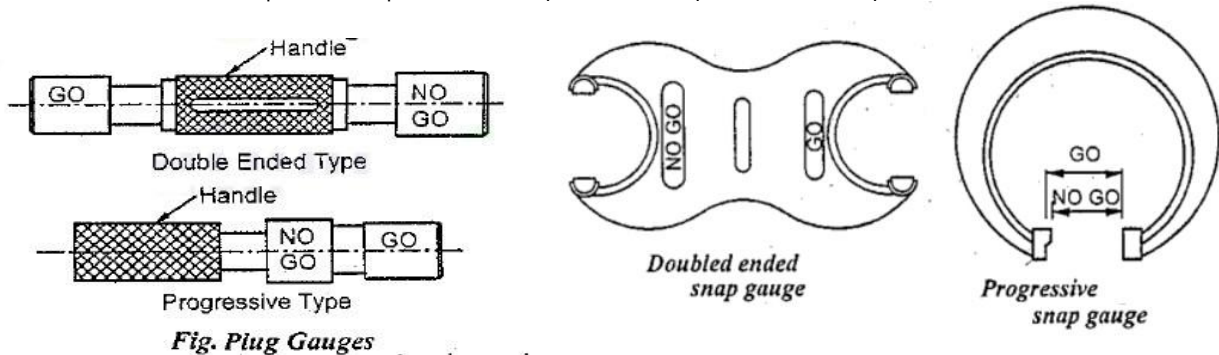
1. Note the specified diameter and tolerance of the bore, and calculate the high and low limits.
2. Clean the bore and the plug gauge.
3. Hold the GO end square to the bore and try to insert it under its own weight or with light hand pressure, without forcing. It should enter the full length of the bore.
4. Now try the NO GO end in the same way. It should not enter (it may start but must not go in).
5. Note the result and decide as per the acceptance table. Repeat at more than one position and in different directions for each work piece.

B. Thickness with snap gauge

1. Note the specified thickness and tolerance, and calculate the high and low limits.



2. Check that the gap openings of the snap gauge are set to the high limit (GO) and low limit (NO GO); adjust if it is an adjustable gauge, using slip gauges or a micrometer.
3. Clean the work piece and the gauge anvils.
4. Pass the GO gap over the work piece with light pressure; it should pass freely under its own weight.
5. Try the NO GO gap in the same way; it should not pass.
6. Note the result and decide as per the acceptance table. Repeat at several points of the work piece.



Observation Tables

(a) Internal diameter - plug gauge

W.P. No.	Specified size and tolerance (mm)	Low limit (mm)	High limit (mm)	GO end (pass / not pass)	NO GO end (pass / not pass)	Decision
1						
2						
3						

(b) Thickness - snap gauge

W.P. No.	Specified size and tolerance (mm)	Low limit (mm)	High limit (mm)	GO gap (pass / not pass)	NO GO gap (pass / not pass)	Decision
1						
2						
3						

Precautions

1. Clean the gauge and the work piece; dirt or burrs give false results.
2. Never force a gauge into the bore or over the work piece; use only light pressure or the gauge's own weight.
3. Hold the plug gauge square to the bore axis and avoid tilting.
4. Work pieces and gauges should be at the same (room) temperature; a warm work piece expands and gives errors.
5. Check the gauge itself for wear at regular intervals, as worn gauges give wrong decisions.
6. Handle the gauges carefully and store them with a thin coat of oil to prevent rust.

Result

- Bore of work piece no. ____ : ACCEPTED / REJECTED (GO end ____, NO GO end ____)
- Thickness of work piece no. ____ : ACCEPTED / REJECTED (GO gap ____, NO GO gap ____)

Viva Questions

1. What is a limit gauge, and what does it check?
2. Why is the GO plug gauge longer than the NO GO plug gauge?
3. What is Taylor's principle of gauge design?
4. What is the difference between a plug gauge and a snap gauge, and where is each used?
5. What are the advantages and limitations of limit gauges compared with a vernier caliper or micrometer?



INSTRUCTION ITEM-1(II-6)

EX6-I

Measuring flatness with light band reading using monochromatic light source

II6

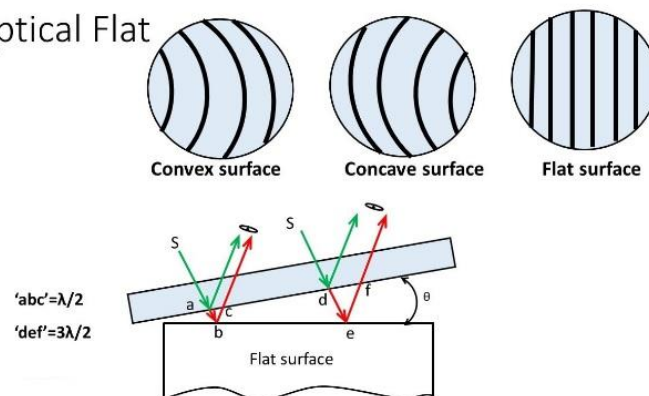
CO6

TITLE: MEASURING FLATNESS WITH LIGHT BAND READING BY USING MONOCHROMATIC LIGHT SOURCE

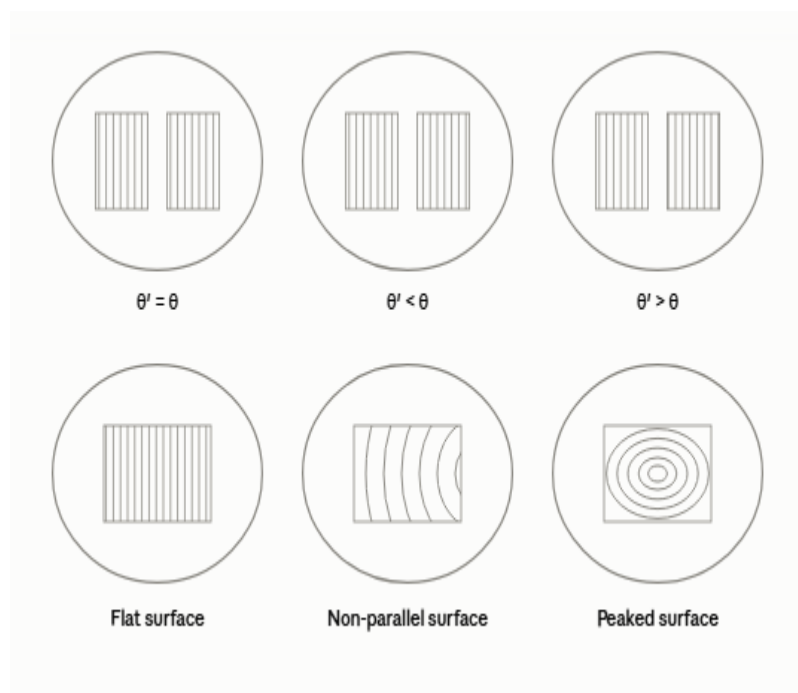
Apparatus required:

1. Slip gauges.
2. Optical flat.
3. Interferometer.
4. Magnifying lens.

Optical Flat



Fringe generation by interference



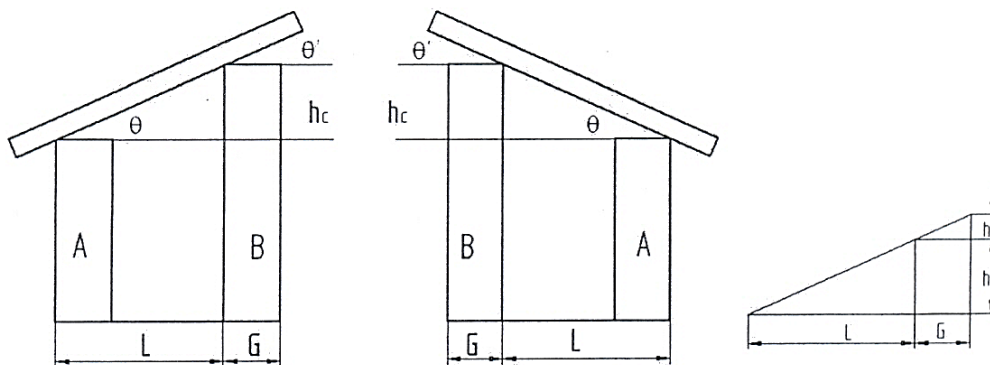


Theory:

The essential equipment for measurement of flatness by light wave interference is a monochromatic light source and a set of optical flats. Optical Flats can be used to measure the form of a surface. Optical flats use the principles of interferometer to make measurements of the surface. An optical flat is a circular piece of optical glass or fused quartz having its two plane faces flat and parallel and the surfaces are finished to an optical degree of flatness.

Optical flats vary in size from 25 mm diameter to about 300 mm diameters. If an optical flat is placed upon another flat reflecting surface without applying pressure it will not form an intimate contact, but it will lie at some angle ϵ making an inclined plane. If the optical flat is now illuminated by monochromatic source of light, the eye if placed in proper position, will observe a number of bands. These bands are produced by interference of the light rays reflected from lower surface of the top flat and the top surface of lower flat through a very thin layer of air between the flats, the optical flat is a precision tool and great care should be taken when handling it. One side of the glass is guaranteed to be flat to better than a quarter of a wavelength (wavelength is nominally 600nm). the faces of the flat must be kept clean.

The deformations in the surface must not be large with respect to the wavelength of light being used. The incident light passing through the optical flat is either reflected off the rear surface of the flat or transmitted through the air gap between the flat and the test piece (refer figure). Some of the transmitted light is then reflected of the surface of the test piece. The amount of light reflected from the test piece needs to be similar to the light reflected from the back surface of the optical flat. When ϵ is considered small the difference in the path length for the two reflected beams is measured as $2d$. This is twice the distance of the gap between the optical flat and the test piece.



A is the standard reference gauge. B is the gauge block under test. The distances L between the two gauges are to be measured very accurately. In case A and B are perfectly flat but different in height then there will be equal wedge shaped air layers between A and B and the optical flat and hence equal number of fringes will be seen. In case the surfaces are not parallel the angles formed by the surfaces of two gauges with optical flat will be different. Let the angle be ϵ and ϵ' respectively. If the width of the gauge block G is same for both, then the number of fringes per unit width will be different. Once it is assured that the surface of the two gauges are flat and parallel to each other, then it is possible to check the height of the gauges.

Procedure:

1. Clean the slip gauges and keep the slip gauges side by side over the table.
2. The slip gauges are to be separated by a known distance.
3. Place the optical flat on two slip gauges of different height.
4. Adjust the monochromatic light and optical flat to get clear fringes.
5. Note down the number of fringes on the calibration grade.
6. Calculate the difference in height 'hc'

Observation:

Distance between two adjacent slip gauges, $L = \text{--- mm}$
Width of the slip gauge, $G = \text{--- mm}$
Difference in height, $d = \text{--- mm}$
Wavelength of the monochromatic light $\lambda = \text{--- mm}$
Number of fringes on reference slip gauge, $N = \text{---}$

Calculation:

Difference in height h_c is calculated as $h_c = (L / G) \times N \times (\lambda / 2) \text{ mm}$



INSTRUCTION ITEM-1(II-6)			
EX6-II	Measurement of surface roughness using Talysurf	II6	CO6

TITLE: MEASUREMENT OF SURFACE ROUGHNESS USING TALLYSURF.

APPARATUS: Talysurf (stylus-type profilometer), given work pieces with machined surfaces, cleaning cloth, anti-vibration table/mounting.

Principle

The diamond stylus is drawn across the surface at a constant speed. Its vertical displacement, following the surface irregularities, is converted into a proportional electrical signal. This signal is filtered to separate short-wavelength roughness from long-wavelength waviness, and is then processed electronically to compute R_a (and other parameters) directly, or is plotted as a magnified profile.

Theory

No machined surface is perfectly smooth; it has irregularities left by the cutting tool, tool feed, vibration and material behaviour. Surface texture is described by:

- **Roughness:** closely spaced, fine irregularities caused directly by the cutting action (tool marks, feed marks).
- **Waviness:** the more widely spaced component, usually caused by machine or work deflection, vibration, or chatter.
- **Lay:** the direction of the predominant surface pattern produced by the machining process.

The most common parameter used to specify roughness is the centre line average, R_a , defined as the arithmetic mean of the absolute values of the profile deviations from the mean line over the sampling length:

$$R_a = (1/L) \int_0^L |y| dx \quad (\text{or, discretely, } R_a = (1/n) \sum |y_i|)$$

Other parameters that may be reported are R_q (root mean square roughness), R_z (average of the five highest peaks and five deepest valleys), and R_t (total peak-to-valley height within the sampling length).

Description of Talysurf

Talysurf is a stylus-type electronic surface roughness measuring instrument. It consists of:

- **Pick-up (stylus unit):** a fine diamond stylus, of tip radius about 2 micrometers, mounted on an arm that traces the surface. As the stylus moves over the irregularities, its vertical movement is converted to an electrical signal by an inductive (or piezoelectric) transducer inside the pick-up.
- **Drive unit:** moves the pick-up over the surface at a constant, controlled speed along the sampling length.
- **Amplifier and meter/recorder:** amplifies the transducer signal and processes it electronically (through a filter that separates roughness from waviness) to give a direct digital readout of R_a (and other parameters), and may also plot the surface profile on a chart.
- **Base and leveling table:** supports the work piece and allows it to be leveled so that the stylus travels along a true datum.



Procedure

1. Clean the work piece surface to be tested, removing dirt, oil and loose particles.
2. Mount the work piece securely on the leveling table, and adjust it so the stylus traverse direction is perpendicular to the machining lay (tool marks), which gives the true roughness value.
3. Select the appropriate cut-off (sampling) length and traverse length on the instrument, based on the expected roughness and the relevant standard.
4. Bring the stylus gently into contact with the surface using the pick-up positioning control; ensure the stylus is not damaged and the surface is not scratched.
5. Switch on the drive unit so the pick-up traverses the surface at constant speed.
6. Note the Ra value (and Rz, RMS if displayed) directly from the meter/display, or study the recorded profile chart.
7. Repeat the measurement at 3 different locations on the surface (and, if required, in a direction along the lay for comparison) and take the mean.
8. Repeat the whole procedure for each given work piece.

Precautions

1. Clean the surface thoroughly before measurement; dust or oil particles are picked up by the stylus and give a false reading.
2. Handle the stylus with great care; never touch its tip or drag it across the surface by hand, as it is extremely delicate and easily damaged.
3. Mount the work piece firmly and free of vibration; use an anti-vibration table if available.
4. Keep the direction of the stylus traverse perpendicular to the lay (tool marks) unless a different direction is specifically required.
5. Select the correct cut-off length for the expected roughness, as an unsuitable cut-off gives an incorrect Ra.
6. Take readings at more than one location and use the mean, since roughness varies over a surface.
7. Switch off and lift the pick-up before removing or repositioning the work piece.

Observation Table

Cut-off length used = _____ mm Traverse length = _____ mm Stylus tip radius = _____ μm

W.P. No.	Trial No.	Machining process	Ra (μm)	Rz (μm)	RMS (μm)	
1						
2						
3						
4						

Mean Ra for each work piece = _____ μm



Sl. NO.	Specimen	Ra	Average (μm)	Ry (μm)	Average (μm)	Rz (μm)	Average (μm)
1							
2							
3							
4							
5							

RESULT:

The surface roughness (Ra) of the given work piece(s), measured using the Talysurf, is as follows:

- Work piece 1: Ra = _____ μm
- Work piece 2: Ra = _____ μm

Viva Questions

1. What is meant by surface roughness, and how is it different from waviness?
2. Define Ra (centre line average) and explain how it is calculated.
3. Why must the stylus traverse be perpendicular to the lay of the surface?
4. What is a cut-off (sampling) length, and why is it important?
5. Name other roughness parameters besides Ra, and state what each represents.