GOPALAN COLLEGE OF ENGINEERING AND MANAGEMENT

DEPARTMENT OF MECHANICAL ENGINEERING

MECHANICAL MEASUREMENTS AND METROLOGY LAB (15MEL47B)

IV SEMESTER (MECHANICAL)

LABORATORY MANUAL

ACADEMIC YEAR 2016-17

MECHANICAL MEASUREMENTS & METROLOGY LAB

SUB CODE: 15 MEL 47B **IA MARKS: 20**
HRS/WEEK: 03 **EXAM HRS: 03**
EXAM MARKS: 80

PART – A: MECHANICAL MEASUREMENTS

1. **Calibration of Pressure Gauge**
2. **Calibration of Thermocouple**
3. **Calibration of LVDT**
4. **Calibration of Load Cell**
5. **Determination of modulus of elasticity of a mild steel specimen using strain gauges.**

PART – B: METROLOGY

6. **Measurements using Optical Projector/Toolmaker's Microscope**
7. **Measurements of angle using Sine Centre / Sine bar / bevel protractor**
8. **Measurements of alignment using Autocollimator / roller set**
9. **Measurements of cutting tool forces using**
   a. **Lathe tool Dynamometer**
   b. **Drill tool Dynamometer**
10. **Measurements of Screw thread parameters using two wire or three-wire methods.**
11. **Measurements of surface roughness using Tally surf / mechanical comparator.**
12. **Measurements of gear tooth profile using gear tooth Vernier / gear tooth micrometer.**
13. **Calibration of micrometer using slip gauges.**
14. **Measurement using optical flats.**

Scheme of Examination:

One question from part – A	**25 marks**
One question from part – B	**40 marks**
Viva – Voce	**15 marks**
Total	**80 marks**

CONTENTS

PART – A

MECHANICAL MEASUREMENTS LAB

INTRODUCTION

Measurement: Measurement is the act or the result of a quantitative comparison between a predetermined standard and an unknown magnitude. It is essential that the procedure and apparatus employed for obtaining the comparison must be provable.

The results of measurements be meaningful and followed by all the standard which is used for comparison must be accurately known and commonly accepted.

Aims of Measurement:

i. In R & D program, measurements and correct interpretation are greater importance.
ii. In the process industries and power plants, and production industries, the aim is to achieve quality of product and have maximum efficiency.
iii. In automation or automatic controls, the measurement is based on comparison of the actual condition (known by measurement) and the desired performance (Set value).

Measurement in Design:

There are 3 methods to solve the complex problems in mechanical design.

a. The empirical method – based on previous performance
b. The rational method – is based on accepted scientific theory
c. The experimental method – based on trial and error on existing knowledge.

Classification of methods of measurement:

a. Mechanics type or Self-operated type
  - Commonly applied to experimental or developmental programs
    Ex: mercury in glass thermometer (Thermal expansion)

b. Power Type
  - Used for monitoring of operational measurement in control system.
  - Require a source of auxiliary power, such as compressed air, electric power, hydraulic supply or a mechanical source of power

c. Self-contained or remote indicating type
  - Self contained type means, all parts contained in one physical assembly.
  - In remote indicating type, the primary element is located hundreds of feet from the secondary indicating instrument.

Fundamental methods of measurement:

There are two basic methods of measurements

i. Direct method – not accurate, not sensitive
ii. Indirect method – Comparison by a standard

Factors in selection of measuring instruments:

The following factors are very essential for the proper selection of a correct instrument for any application.

a. How accurate is the measurement to be made
b. When are the final data required?
c. How expensive can the measuring process be?
d. In what form the data should be displayed.
e. Whether quality to be measured has constant value or is it a time variant?

Measurement Systems:

1. Primary sensing device
2. Transducer
3. Intermediate modifying stage
4. Terminating stage i.e. Secondary indicating instrument (recording or information)

Static Measurement:

In deals with the measurement of those quantities which remain constant.

Drift:

No drift means, the instrument reproduces same readings at different times for same variation in measured variable.

Errors in Measuring Instruments:

i. Assembly Errors – due to displaced scale, non-uniform division of the scale, bent or distorted pointer.
   - Rectified easily
ii. Environmental Errors – due to temperature, humidity, altitude etc.,
   - more trouble than assembly errors
iii. Random errors – These vary in an unacceptable, manner and it is difficult to list out all the source of errors.
   Ex: Friction, backlash, Hysteresis, vibration, parallax error etc.,

Sources of Errors:

i. Noise – signal disturbances
ii. Response time (or time constant) is defined as the time taken by the instrument to show 63.2% change is reading to a step input.
iii. Design limitations
iv. Effects of friction in the instrument movement
v. Resolving power – it is the ability of the observer to distinguish between nearly equal division.

Sensing Elements:

The sensing elements (sensors) sense the condition, state or value of the process variable and produce an output which reflects this condition, state or value. Thus sensors could be considered as transducers.

Transducers:

It transforms the energy of the process variable to an output of some other type of energy.

- Primary sensing elements – also called basic detector, transducer elements. It converts into analogous form.
- Secondary Transducers (also simply called transducer) – It converts first stage (analogues) into electrical quantity.

Ex: Pressure is measured by a Bourdon Tube which is primary sensing element. Displaying the analogous measurement into digital by Secondary transducers.

Secondary transducer may be employed to transform the output of primary sensor to still another type of energy.

1. Mechanical members as Primary detectors:

Elastic members are used to change force into displacement.

Ex: Proving Ring, Elastic Torsion member, springs, Bourdon tube, Bellows etc.

2. Mass – sensing elements:

The inertia of a concentrated mass provides another basic mechanical detector – transducer element, used in accelerometers and serves to measure the characteristics of dynamic motion, i.e., displacement, velocity, acceleration etc.,

Ex: Pendulum, manometer

3. Thermal Detectors:

Thermal detectors are the devices used to measure the temperature of solids, liquids and gases.

The following factors will affect due to temperature change:

- Change in physical state
- Change in chemical state
- Altered physical dimensions
- Change in electrical properties
- Change in radiating ability

The most commonly used thermal detectors are:

i. Glass thermometers
ii. Bimetallic Thermometers
iii. Thermocouples
iv. Resistance thermometers
v. Thermistors
vi. Pyrometers (optical, radiation, fusion)

STRAIN GAUGES:

The strain gauge is an example of a passive transducer (externally powered) that converts a mechanical displacement into a change of resistance. A strain gauge is a thin, wafer like device that can be attached (bonded) to a variety of materials to measure applied strain. Metallic strain gauges are manufactured from small diameter resistance wires such as Constantan or etched from thin foil sheets. The resistance of the wire or metal foil changes with length as the material to which the gauge is attached undergoes tension or compression. This change in resistance is proportional to the applied strain and is measured with a specially adapted ‘Wheatstone bridge’.

Gauge factor is sensitivity of strain gauge.

Gauge configuration:

i. Uniaxial
ii. Biaxial
iii. Multi directional

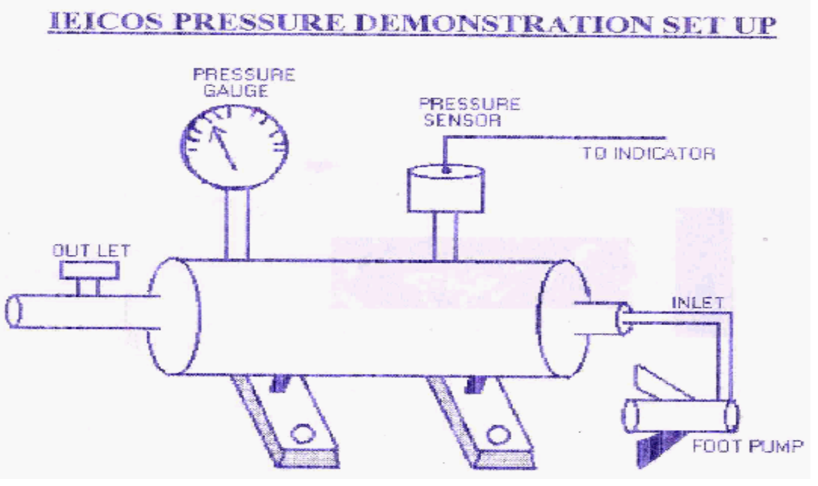
Experiment No: 1 **Date:**

CALIBRATION OF PRESSURE GAUGE

Aim: To calibrate the given pressure transducer with dead weights.

Apparatus: Dead weights, pressure transducer and digital pressure indicator.

Experimental Setup:



Functional Details of Pressure Transducer:

Power supply to Pressure Transducer	=	230 volts AC
Power supply to the Amplifier	=	± 5 volts DC
Resistance of each Strain gauge	=	300 ohms
Number of strain gauges used	=	4
Maximum range of Pressure Transducer	=	10 Kg/cm^2

Theory: Pressure is defined as force per unit area and is measured in Newton per square meter (Pascal) or in terms of an equivalent head of some standard liquid (mm of mercury or meter of water). A typical pressure gauge will measure the difference in pressure between two pressures. Thus, if a pressure gauge is connected to an air line the gauge itself stands in atmospheric pressure. The gauge reading will be the difference between the air pressure and the atmospheric pressure and is called gauge pressure. The absolute pressure (the actual pressure within the airline) is the sum of the gauge pressure and atmospheric pressure.

Pressure transducer is basically an electro mechanical device, especially manufactured and designed for wide range application in pressure measurement. The pressure transducer comprises of diaphragm and an inputs to facilitate pressure measurement. The strain gauges are bonded directly to the sensing member to provide excellent linearity, low Hysteresis and repeatability. Fluid medium whose parameter has to be measured is allowed to deflect the diaphragm (sensing member), which is a single block material and forms an integral part of the pressure transducer. It is made up non-magnetic stainless steel and thus has the advantage of avoids the yielding effects and leakage problems. The slight deflection of the diaphragms due to the pressure provided an electrical output

The materials most commonly used for manufacture of diaphragms are steel, phosphor bronze, nickel silver and beryllium copper. The deflection generally follows a linear variation with the pressure differential, when the deflection is less than one third of the diaphragm thickness.

Initial Setup:

1. Air should be released completely from air chamber
2. Pressure indicator should be set to zero.
3. Output of the gate wall should be closed.

Procedure:

1. Couple the pressure transducer to the pressure indicator.
2. Connect the pressure indicator to the main power supply and keep it in the ON position.
3. Switch on the Instrument.
4. Adjust the pressure indicator to read zero on DPM (Digital Panel Meter) using ZERO pot knob without applying any pressure.
5. Press push button switch, DPM shows range of sensor (ie., 10.0 Kg/cm^2)
6. Couple the other end of the pressure transducer to the Pressure chamber.
7. Connect the foot pump input pipe to Pressure Chamber. Close the output of gate wall, apply the pressure step by step upto 5 kg/cm^2 as shown in tabular column below.
8. Pump the air up to unknown pressure (Less than 5 kg/cm^2) and note down the reading from digital Indicator.
9. Tabulate the results and plot graphs.
10. Find the actual unknown pressure from the graph.
11. Release the air completely from air chamber.

Pre-Viva Questions:

1. What is atmospheric Pressure?
2. What is gauge Pressure?
3. What is absolute pressure?
4. What is strain gauge?

Observations:

Range of Bourdon Tube pressure gauge =
Selected range of Calibration Pressure Transducer =
Least count of bourdon pressure gauge =
Least count of Pressure Indicator (DPM) =

Sl. No.	Actual Reading ‘R_a’ (kg/cm^2)	Measured Reading ‘R_m’ (kg/cm^2)	Error ‘E’	% Error

Specimen Calculations:

1. R_a = Actual Reading (Pressure gauge reading)
2. R_m= Measured Reading (Indicator reading)

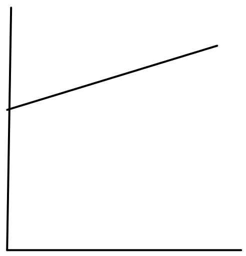
3. 'E' Error = $R_m \sim R_a$
4. % Error = $\frac{\text{Error}}{\text{Actual Reading}}$

Model Graphs: X- axis vs. Y- axis

Actual Reading (R_a) vs. Measured Reading (R_m)

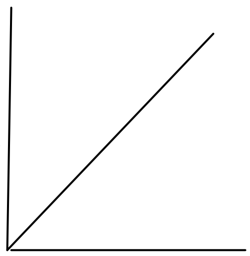
Actual Reading (R_a) vs. % Error

R_a



% error

R_a



R_m

Calculations from Graph:

Result:

Verification:

Conclusion:

Post Viva Questions:

1. What is measurement?
2. What is calibration?
3. What is least count?
4. What is one Main Scale Division?
5. What is one Vernier Scale Division?

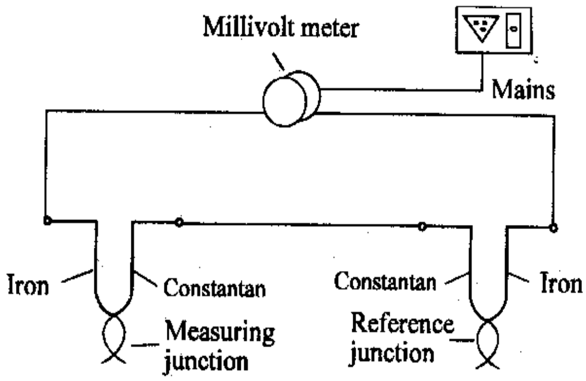
Experiment No: 2 **Date:**

CALIBRATION OF THERMOCOUPLE

Aim: To calibrate the given thermocouple at different temperatures.

Apparatus: Thermocouple, a heating coil to heat the water in the beaker, a thermometer and a digital indicator to indicate the temperature of thermocouple.

Experimental Setup:



Theory: The most common electrical method of temperature measurement uses the thermo-electric sensor, also known as thermocouple. The construction of the thermocouple consists of two wires of different metals twisted and brazed or welded together with each wire covered with insulation which may be either:

1. Mineral (Magnesium oxide)) insulation for normal duty, or
2. Ceramic insulation for heavy duty.

The basic principle of temperature measurement using a thermo-electric sensor was discovered by Seebeck in 1821. When two dissimilar metal wires are joined at both ends, and an electromotive force (e.m.f) will exist between two junctions, if the two junctions are at different temperatures. This phenomenon is called Seebeck effect. If the temperature of one junction is known then the temperature of other junction may be easily calculated using the thermoelectric properties of the materials. The known temperature is called reference temperature and is usually the temperature of ice.

Potential (emf) is also obtained if the temperature gradient exists along the metal wires. This is called Thomson effect and is generally neglected in the temperature measuring process.

If two materials are connected to an external circuit in such a way that current is allowed to flow in the circuit, an emf will be produced. This is called Peltier effect. In temperature measurement, Seebeck effect is of prime concern since it is dependent on junction temperature.

The law of Intermediate metals defines the basic thermocouple loop consists of two dissimilar metals A & B. If a third wire C is introduced then three junctions are formed B – C and C – A and at the same temperature.

Thermocouple Materials:

- The choice of materials for thermocouples is governed by the following factors:
- The thermocouple material must be homogeneous.
- Ability to withstand the temperature at which they are used
- Immunity form contamination, oxidation, etc., which ensures maintenance of the precise thermo-electric properties with continuous use.
- Linearity Characteristics

It may be noted that the relationship between thermo-electric emf and the difference between hot and cold junction temperature is approximately of the parabolic form.

$$Emf = aT + bT^2$$

Thermocouples can be broadly classified in two categories.

1. Base – metal thermocouple
2. Rare – metal thermocouple

Base metal thermocouple use the combination of pure metals and alloys of iron, copper and nickel and are used for temperature up to 1450 ^{o}K. These are most commonly used in practice as they are more sensitive, cheaper and have nearly linear characteristics. Their limitation is the lower operating range because of their low melting point.

Rare metal thermocouples use a combination of pure metals and alloys of platinum for temperature up to 2000 ^{o}K and tungsten, rhodium and molybdenum for temperature up to 2900 ^{0}K.

Thermocouple Type	Thermocouple Materials	Approx. Sensitivity in mv/K	Temperature range ^{0}K	Approx. Accuracy in %
Base-metal	Copper-Constantan (Type-T)	0.05	3 – 673	±0.5 %
Base-metal	Iron – Constantan (Type-J)	0.05	63-1473	±1 %
Base-metal	Chromel – Alumel (Type-K)	0.04	3-1643	±1 %
Base-metal	Chromel–Constantan (Type-E)	0.08	3-1273	±1 %
Rare Metal	Platinum-platinum/10% rhodium	0.1	223-2033	±0.5 %
Rare Metal	Platinum-platinum/30% rhodium	0.12	223-2033	±0.5 %
Rare Metal	platinum/30% rhodium - platinum/60% rhodium	0.12	273-2093	±0.5 %

Platinum-Platinum Rhodium (type R)

Initial Setup:

1. Make sure the sensor is in water before heating the water.
2. Make sure the display reads the room temperature.
3. Make sure there are no loose connections

Procedure:

1. Connect the Temperature Transducer to the front panel of the instrument.
2. Switch ON the power to the instrument.
3. The displays read room temperature as sensed by the sensor.
4. Keep the sensor in water bath and heat the water.
5. Note the temperature of water using the glass thermometer.

6. Note the temperature of water and induced emf using the Digital Indicator.
7. Raise the temperature of water by switch on the heater and note down the reading for every 5^0 C (up to 60^0 C).
8. Rise the temperature to an unknown value (Below 60^0 C) and note down the Digital Indictor reading.
9. Tabulate the readings in the tabular column. Find the actual unknown temperature from the graph.
10. Switch of the heater and digital indicator.

Pre-Viva Questions:

1. What is Thermocouple?
2. What are the different types of Thermocouple?
3. What are the different materials used in Thermocouples?

Observations:

Materials for the thermocouples wires = Copper & Constantan
Range of Thermometer (Actual) =
Least count of Thermometer (Actual) =
Range of Thermocouple Indicator =
Least count of Thermocouple Indicator =

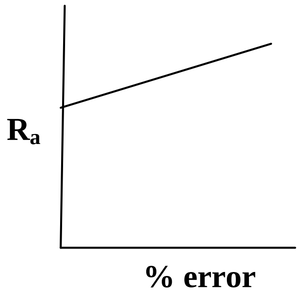
Sl. No.	Actual Reading ‘R_a’ ^{0} K	Measured Reading ‘R_m’ ^{0}K	Induced emf in mV	Error ‘E’	% Error

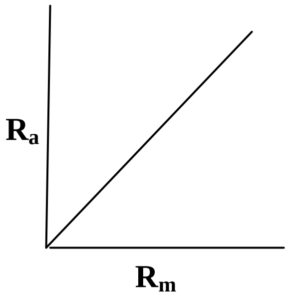
Specimen Calculations:

1. R_a = Actual Reading (Pressure gauge reading)
2. R_m= Measured Reading (Indicator reading)
3. ‘E’ Error = $R_m \sim R_a$
4. % Error = $\frac{\text{Error}}{\text{Actual Reading}}$

Graphs: on X- axis & Y- axis

Actual Reading (R_a) vs. Measured Reading (R_m)
Actual Reading (R_a) vs. % Error
Measured Reading (R_m) vs. emf induced





Calculations from Graph:

Result:

Verification:

Conclusion:

Post viva Questions:

1. What is calibration?
2. What do you mean by calibration of Thermocouple?
3. What is the range of Thermocouple?
4. What is the temperature range a thermocouple can withstand?

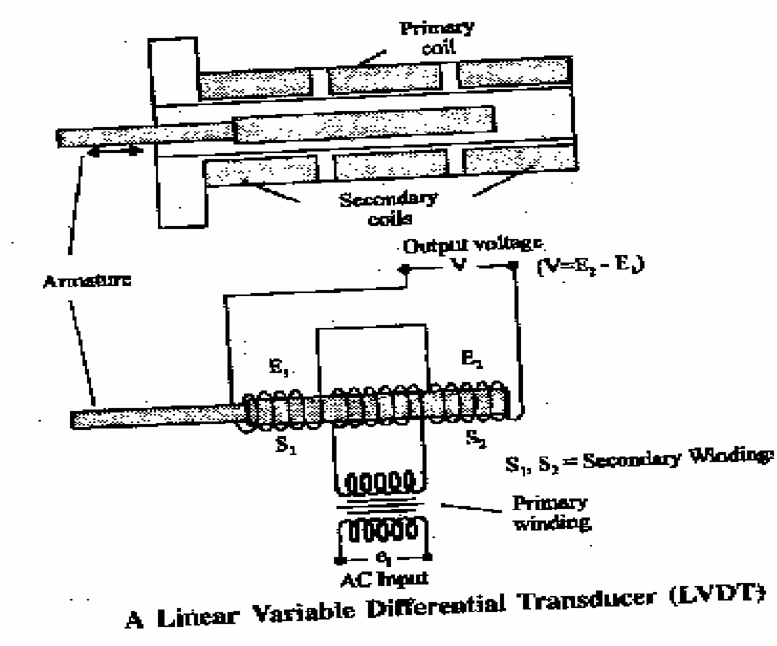
Experiment No: 3 **Date:**

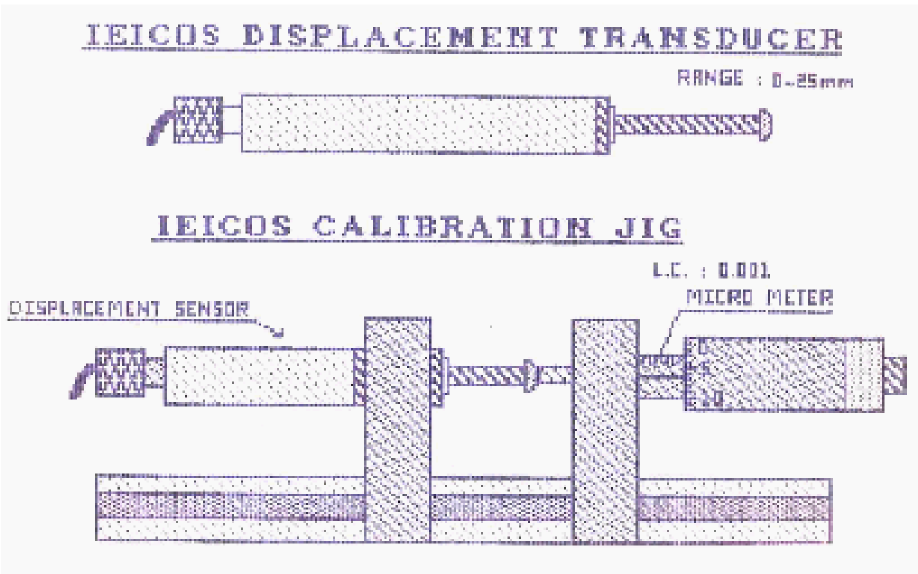
CALIBRATION OF LVDT

Aim: To calibrate Linear Variable Differential Transformer (LVDT) for the performance using Micrometer.

Apparatus: An LVDT, Digital indicator, Micrometer.

Experimental Setup:





Theory: LVDT is an inductive transducer used to translate the linear motion into electrical signal LVDT consists of a single primary winding 'P' and two secondary windings (S_1 and S_2) wound on a cylindrical Armature. An AC source is connected to the primary winding. A movable soft iron core attached with an arm placed inside the Armature.

The primary winding produces an alternating magnetic field which induces alternating voltage in the secondary windings. Single voltage is obtained by connecting the two secondary windings in series. Thus, the output voltage of the transducer is the difference of the two voltages of the secondary windings as shown in the sketch.

When the core is at null position, the flux linking with both the secondary windings is equal. Since both the secondary windings have equal number of turns, m the induced emf is same in them. The output voltage is the difference of the two emf's say E_1 and E_2. When they are equal, the voltage is zero at null position.

When the core is moved to the left side from the null position more flux links with S_1. The output voltage is $V=E_2 – E_1$, since E_1 is greater, the V value is (-)ve. Means the voltage is read in terms of mm length on the display board indicates the negative value.

When the core is moved to the right side of the null position, more flux links with S_2 induces voltage which is (+) ve. The display board indicates the (+)ve value in mm of length.

The voltage output is linear and is depending on the position of the core. Hence LVDT can be conveniently used to measure the thickness ranging from fraction of a mm to a few cm's. Normally LVDT can give better result up to 5mm.

Initial setup:

1. Make sure the indicator is set to th initial reading.
2. Make sure the display board (Meter) indicating zero at this null position

Procedure: The experiment can be carried out for both (+) ve and (-) ve sides.

1. Connect a cable from LVDT to a digital indicator. From indicator to power supply.
2. Adjust the Indicator reading to ZERO by adjusting micrometer.
3. Make sure the display board (Meter) indicating zero at this null position.
4. Note the micrometer reading as initial value and displayed reading.
5. Move the micrometer in steps of 0.5 mm (1 rotation) and note the reading of the Displacement Indicator reading.
6. Tabulate the reading as shown and plot a graph of displacement by micrometer and indicator.
7. Move the micro meter to an unknown value (with in a range).
8. Find the actual unknown value from the graph.
9. Finally set to null position.

Pre viva questions:

1. What is LVDT?
2. What is the least count of LVDT?

Observations:

Range of Micrometer =
Least count of Micrometer =
Linearity Range of LVDT =
Least count of LVDT =
Initial reading of Indicator (null position) =
Micrometer reading at null position =

Display for (+) ve side: (Backward Traverse)

Sl. No.	Actual Reading ‘R_a’ ^{0}K	Measured Reading ‘R_m’ ^{0}K	Error ‘E’	% Error

Display for (-) ve side: (Forward traverse)

Sl. No.	Actual Reading ‘R_a’ ^{0}K	Measured Reading ‘R_m’^{0}K	Error ‘E’	% Error

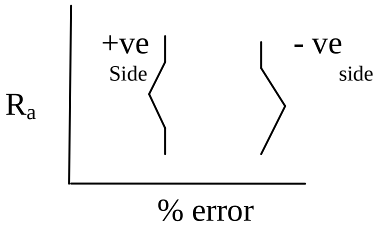
Specimen Calculations:

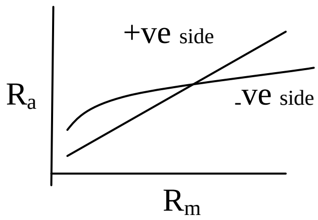
1. R_a = Actual Reading (Pressure gauge reading)
2. R_m= Measured Reading (Indicator reading)
3. ‘E’ Error = $R_m \sim R_a$
4. % Error = $\frac{\text{Error}}{\text{Actual Reading}}$

Graphs: on X- axis & Y- axis

Actual Reading (R_a) vs. Measured Reading (R_m) [for both +ve and –ve displacements]

Actual Reading (R_a) vs. % Error





Calculations from Graph:

Result:

Verification:

Conclusion:

Post viva questions:

1. Where is LVDT applicable?
2. What are the different types of Transducers?
3. Define cumulative error and total error
4. What are the categories of S.I units?

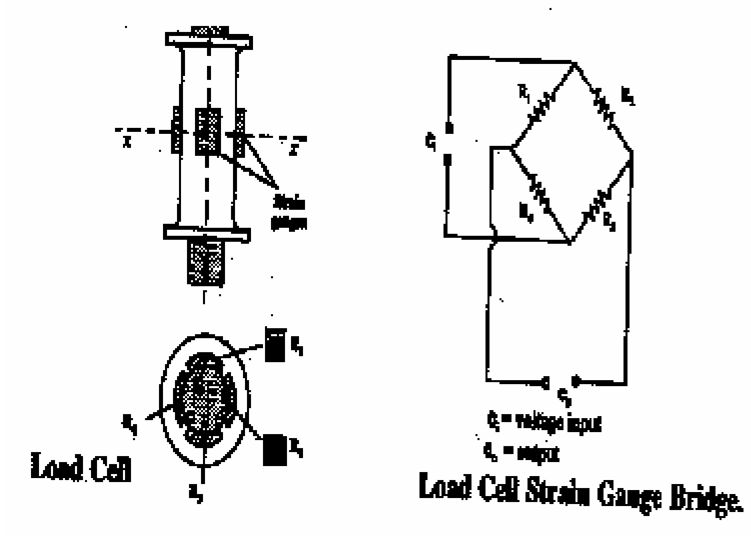
Experiment No: 4 **Date:**

CALIBRATION OF LOAD CELL

Aim: To calibrate the given load cell.

Apparatus: Load cell and digital strain indicator and weights.

Experimental setup:



Theory: In addition to measurement of the surface strains, electrical resistance strain gauges have important application in devices of measuring load, pressure and deflection. A load cell used for measuring the load applied to the test structure or for weighing vehicles consists of a short pillar of high tensile steel to which strain gauge elements are attached as shown in fig1. By two axial and two circumferential gauges on alternate arms of a Wheatstone bridge circuit, bending effects are eliminated and temperature compensation is provided. As long as the stress in the pillar remains within the elastic range, a linear relationship will be obtained between the load and output from the strain gauge bridge circuit. Load cell of this type can be constructed to cover a very wide range of loads, as they are compact and relatively inexpensive.

Initial setup:

1. Adjust the load indicator to zero position.
2. Wait for the equipment to get stabilised before performing the experiment.

Procedure:

1. Switch on the equipment and wait for a minute for it to stabilize.
2. Adjust the load indicator to show ZERO for no load condition.
3. Place a standard weight of 1 kg and note the reading from digital load indicator.
4. Continue increasing the load in steps of 1 kg up to 6 kg and note the corresponding indicated load.

5. Put an unknown weight (Less than 6 kg) and note the reading from digital load indicator.
6. Tabulate the results and plot graphs.
7. Find the actual unknown weight from the graph.
8. Slowly unload the weights from the load cell.

Pre viva questions:

1. What is load cell?
2. Where is load cell applicable?
3. Explain the principle of load cell?

Observations:

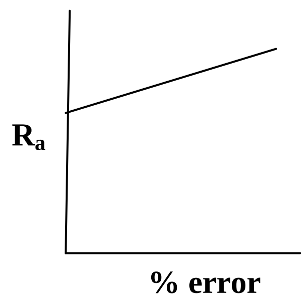
Maximum range of Load cell =
Least count of Load cell =
Increment of load =

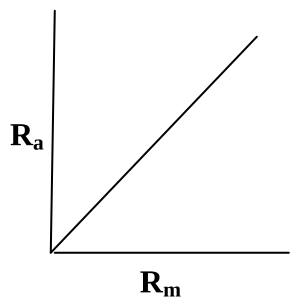
Sl. No.	Actual Reading ‘R_a’ (kg)	Measured Reading ‘R_m’ (kg)	Error ‘E’	% Error

Specimen Calculations:

1. R_a = Actual Reading
2. R_m= Measured Reading (Indicator reading)
3. ‘E’ Error = $R_m \sim R_a$
4. % Error = $\frac{\text{Error}}{\text{Actual Reading}}$

Graphs: On X- axis & Y- axis
Actual Reading (R_a) vs. Measured Reading (R_m)
Actual Reading (R_a) vs. % Error





Result:

Verification:

Conclusion:

Post viva questions:

1. What are the applications of load cell?
2. What are the standards used in calibration of load cell?
3. What is linear Measurement?

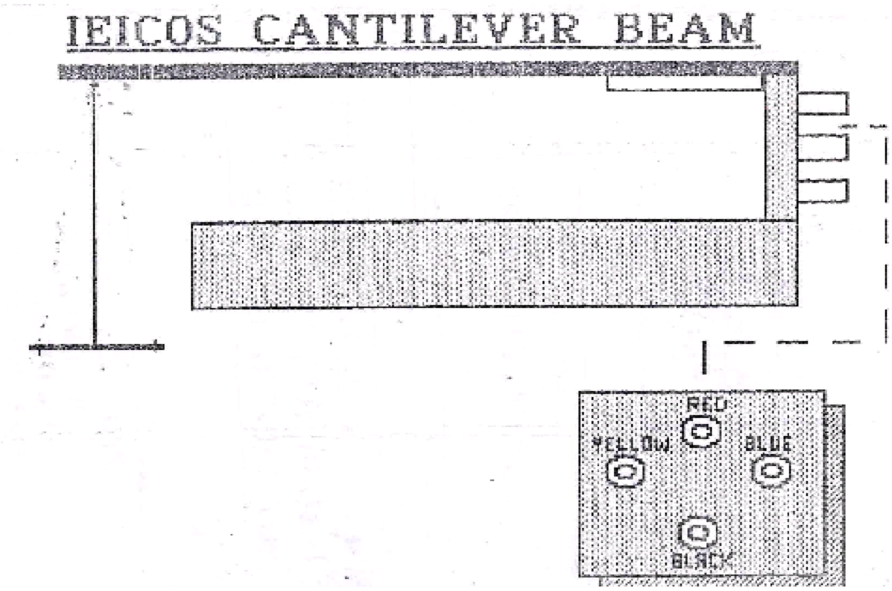
Experiment No: 5 **Date:**

ELASTIC CONSTANTS BY BENDING TEST

Aim: To determine the elastic constants (modulus of elasticity, modulus of rigidity and bulk modulus) of a cantilever beam subjected to concentrated end load by using strain gauges.

Apparatus: A cantilever beam with concentrated end load arrangement, strain gauges, weights and digital strain indicator.

Experimental setup:



Functional Details of Strain Indicator:

Maximum strain can be measured up to 20,000 micro strains with a resolution of 1 micro strain.

Power supply to the indicator = 230 Volts AC

Power supply to the amplifier = ± 8 volts DC

The most common bridge arrangements are one arm, two arms and four-arm mode.

One arm mode (one-fourth bridge): This bridge arrangement consists of a single active gauge in position R1 and three resistors are internal to the device. Temperature compensation is possible only if a self-temperature-compensating strain gauge is used.

Theory:

A body subjected to external forces is in a condition of both stress and strain. Stress cannot be directly measured but it's effect, i.e. change of shape of the body can be measured. If there is a relationship between stress and strain, the stresses occurring in a body can be computed if sufficient strain information is available. The constant connecting the stress and strain with in elastic limit is the modulus of elasticity.

The principle of electrical resistance strain gauge was discovered by lord Kelvin, when he observed that a stress applied to a metal wire, besides changing it's length and diameter, also changes it's electrical resistance.

Metallic electrical resistance strain gauges are made into two basic forms, bonded wire and bonded foil. Wire gauges are sandwiched between two sheets of thin paper and foil gauges are sandwiched between two thin sheets of epoxy.

The strain gauge is connected to the material in which it is required to measure the strain, with a thin coat of adhesive. Most common adhesive used is Eastman, Duco cement etc. As the test specimen extends or contracts under stress in the direction of windings the length and cross sectional area of the conductor alter, resulting in a corresponding increase or decrease in electrical resistance.

The usual method of measuring the change of resistance in a gauge element is by means of Wheatstone bridge circuit. It consists of galvanometer, four resistors and a battery.

Two arm mode (one half bridge): In this mode, two resistors are internal to the device, and the remaining two are strain gauges. One arm of this bridge is commonly labelled as active arm and the other as compensating arm. The bridge is temperature compensated.

Four-arm mode (full bridge): In this bridge arrangement, four active gauges are placed in the bridge with one gauge in each of the four arms. If the gauges are placed on a beam in bending as shown in figure of the elastic constant by bending test experiment, the signal from each of the four gauges will add. This bridge arrangement is temperature compensated.

The strain gauges R_1 and R_3 measure the tensile stress while the strain gauges R_2 and R_4 measure the compressive stress. The strains $\in_1$, $\in_2$, $\in_3$ and $\in_4$ are measured by the strain gauges are of equal magnitude.

Applications:

Strain is measured using resistance gauges attached to member under investigation. Stain resulting from stress (N/mm^2) can be measured by attaching strain gauges to suitable parts of machines or structures. Direct indication of strain produced is provided. Any other physical quantity can be obtained by calibration with known input. This instrument has a very wide range of application in the industrial field of construction, machinery, civil engineering, mining, spinning, ship building, aircraft and so forth.

Uses:

- Teach strain distribution at different points of a material
- Demonstrate stress concentration

- Measure of elastic constants of a material
- Evaluate Poisson's Ratio
- Calibrate strain gauges
- Verify material properties

Formulae:

Consider a cantilever beam as shown in figure.

Let W = Load applied in N.
b = width of the cantilever beam in mm.
h = Thickness of the cantilever beam in mm.
l = Length of cantilever beam in mm.
A = Cross sectional area = bh mm^2.
$\in$ = Bending strain in microstrain = $\in_i$ / i
i = Number of active gauges .
$\in_i$ = Strain indicator reading in microstrain
I = Moment of Inertia = $bh^3/12$
M = Bending Moment = W x l N-mm
c = h/2 mm
Y = Young's modulus or modulus of elasticity

The bending equation is

$$\frac{M}{I} = \frac{\sigma}{c}$$

Bending stress, σ = $\frac{Mc}{I} = \frac{Wl\,h/2}{\frac{bh^3}{12}} = \frac{6Wl}{bh^2}$

Bending strain $\in = (\in_i \times 10^{-6}) / i$ mm/mm

Modulus of elasticity, Y = $\frac{\text{Stress }(\sigma)}{\text{Strain }(\in)}$ N/mm^2

Modulus of rigidity, G = $\frac{Y}{2(1+\nu)}$

Bulk modulus, K = $\frac{Y}{3(1-2\nu)}$

Where ν = Poisson's Ratio of the given material

Initial setup:

1. Based on the type of bridge select the corresponding bridge arrangement
2. Make zero by using ZERO potentiometer provided in front panel

Procedure:

1. Connect the mains card to 230 Volts mains.
2. Switch ON the Instrument provided power ON switch in the Back Panel of Instrument.
3. To operate **Full Bridge (4-arm bridge)** select the range selection switch to 4^{th} range and connect the 4 arm connection from cantilever beam provide Red, Black and Yellow.
4. Blue Recorder and short Black and Green Recorder to back panel of Instrument.

5. Make zero by using ZERO potentiometer provided in front panel.
6. Apply weights to cantilever beam in steps of 100 grams.
7. Note down Indicator Reading vs. applied load.

8. To operate **Half Bridge (2-arm Bridge)** keep open circuit in Cantilever beam Black and Green recorder and connect Red, Black and Yellow to back panel of instrument.
9. Range selector switch select 2
10. Make zero by using ZERO potentiometer.
11. Apply load in steps of 100 grams.
12. Note down Readings
13. To operate **Single arm bridge (1-arm Bridge)** connect Red and Yellow from cantilever beam to back panel of the instrument provided Red and Yellow.
14. Select selector switch 1.
15. Make zero by using ZERO potentiometer.
16. Apply load to cantilever beam 100 gram.
17. Note down Reading.
18. Calculate Stress and Strains.
19. Draw stress and strain diagram and find the modulus of elasticity from the graph.

Pre viva questions:

1. What is strain gauge?
2. What are the applications of strain Gauge?

Observations and tabulation:

Material of Cantilever Beam		= Aluminium
b	= width of the cantilever beam in mm	= 50 mm
h	= Thickness of the cantilever beam in mm	= 6 mm
l	= Length of cantilever beam in mm.	= 275 mm
ν	= Poisson's ratio of Aluminium	= 0.330 (for cast) = 0.348 (for drawn)

Tabular Column for Full Bridge (4-arm Bridge)

(i=4)

Sl. No.	**Load W (N)**	**Strain indicator reading, $\in_i$ (Micro strain)**	**Bending Strain $\in = (\in_i \times 10^{-6}) / i$ mm/mm**	**Bending stress $6WL/bh^2$**
1				
2				
3				
4				
5				
6				

Tabular Column for Half Bridge (2-arm Bridge) (i=2)

Sl. No.	Load W (N)	Strain indicator reading, $\in_i$ (Micro strain)	Bending Strain $\in = (\in_i \times 10^{-6}) / i$ mm/mm	Bending stress $6WL/bh^2$
1				
2				
3				
4				
5				
6				

Tabular Column for Single arm Bridge (1-arm Bridge) (i=1)

Sl. No.	Load W (N)	Strain indicator reading, $\in_i$ (Micro strain)	Bending Strain $\in = (\in_i \times 10^{-6}) / i$ mm/mm	Bending stress $6WL/bh^2$
1				
2				
3				
4				
5				
6				

Graph:

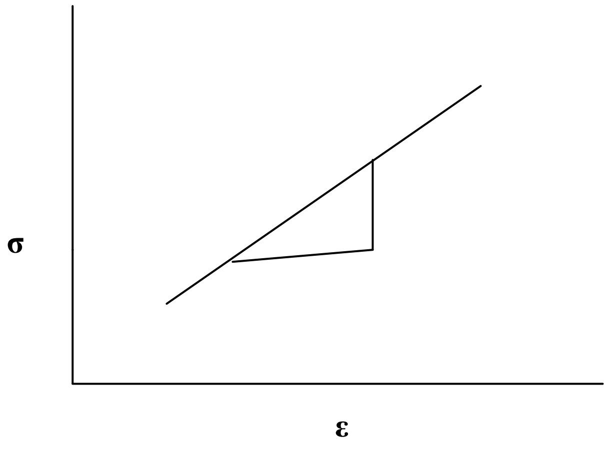
Draw the graph of σ vs ∈ (for different Bridges)

By plotting the graph ∈ as base and σ as the ordinate, a straight line is obtained from which the slope can be found.

From the graph

Modulus of elasticity $Y = \sigma / \in$ = slope of the graph.

Note: The load on the Cantilever beam should not exceed the elastic limit.



Calculations from graph:

Result:

Verification:

Conclusion

Post Viva Questions:

1. What is the difference between full bridge, half bridge and single arm bridge?
2. What is stress?
3. What is strain?
4. What is bending moment?
5. What are the different types of stresses?
6. What are the different types of strain?

PART – B

METROLOGY

INTRODUCTION

Metrology is a science of measurements and the measurement is the language of science.

It is divided depending upon the quantity like metrology of length, metrology of time etc.,. Also, it is divided depending upon the field of application as Industrial metrology, Medical metrology etc.,

Metrology is mainly concerned with

1. Establishing the units of measurements, reproducing these units in the form of standards and ensuring the uniformity of measurement.
2. Developing methods of measurement
3. Analyzing the accuracy of methods of measurement, reaching into the causes of measuring errors and eliminating these.
4. design, manufacturing and testing of gauges of all kinds
5. measuring instruments and devices

Dynamic Metrology: It is concerned with measuring small variations of continuous nature: Ex: Temp, pressure

Legal Metrology: It is concerned with units of measurement, methods of measurement and the measuring instruments, in relation to the statutory technical and legal requirements. It is directed by National Organization is called National Service of Legal Metrology (NSLM). Its object is to maintain uniformity of measurement throughout the world.

Function of Legal Metrology are – to ensure conservation of national standards, to guarantee their accuracy by comparison with international standards, to impart proper accuracy to the secondary standards of the country by comparison with national standards and to carryout technical and scientific works.

Deterministic Metrology: This is a new philosophy is which, part measurement is replaced by process measurement. In deterministic metrology, full advantage is taken of the deterministic nature of production machines and all of the manufacturing sub-systems are optimized to maintain deterministic performance within acceptable quality levels.

Passive Metrology: Checking the components by using gauges is Passive metrology.

Active Metrology: Checking the gauges with instruments is Active metrology.

Need of Inspection:

Inspection can be defined as the process of checking the materials, whether they satisfy design standards. The need of inspection can be summarized as:

- to ensure that the part confirms to the established standard
- to meet the interchange ability of manufacture
- To maintain customer relation by ensuring that no faulty product reaches the customers.

- Helps purchase of good quality raw materials, tools, equipment etc.,
- It gives necessary steps, so as to produce acceptable parts and reduce scrap.

Physical Measurements: It is defined as the act of deriving quantitative information about a physical object or action by comparison with a reference.

There are 3 important elements of measurement:

i. Measurand – physical quantity or property like length, angle etc., being measure
ii. Comparison (or) Comparator – the means of comparing measured with some reference to render a judgment
iii. Reference: The physical quantity or property to which quantitative comparisons made.

Ex: Surface Table (Measurand), Scale or steel rule (Reference), Comparison by eye (Comparator)

Measuring System: A measuring system is made of five basic elements (SWIPE). These are

Standard	-	S
Work piece	-	W
Instrument	-	I
Person	-	P
Environment	-	E

Measuring Instruments: These are measuring devices that transform the measured quantity or a related quantity into an indication or information. It can indicate either directly the value of the measured quantity or only indicated its equality to a known measure of the same quantity (equal arm balance, or null detecting galvanometer).

CHARACTERISTICS OF MEASURING INSTRUMENTS (DEFINITIONS):

Measuring Range: It is the range of values of the measured quantity. The error does not exceed the maximum permissible error. It is limited by the maximum capacity (upper limit) and minimum capacity (minimum limit). It may or may not coincide with the range of scale indication.

Scale Interval: It is the difference between two successive scale marks in units of the measured quantity. It is an important parameter that determines the ability of the instrument to give accurate indication of the value of the measured quantity.

Discrimination: It is the ability of the measuring instrument to react to small changes of the measured quantity.

Hysteresis: It is the difference between the indications of a measuring instrument when the same value of the measured quantity is reached by increasing or by decreasing that quantity. It is due to the presence of dry friction as well as to the properties of elastic elements. It results in the loading and unloading curves of the instrument being separated by a difference called the Hysteresis error. Hysteresis results in the pointer not returning completely to zero when the load is removed. Hysteresis in materials is due to presence of internal stresses. It reduced by proper heat treatment.

Response Time: It is the time which elapses after a sudden change in the measured quantity until the instrument gives an indication differing from the true value by an amount less than a given permissible error. It is an exponential curve. It the inertia forces are not negligible, we get second order response. There are 3 possibilities. Those are Over damped system, under damped system and critically damped.

Bias: It is the characteristics of a measure or a measuring instrument to give indications of the value of a measured quantity whose average differs from the true value of that quantity.

Inaccuracy: It is the total error of a measure or measuring instrument under specified conditions of use and including bias and repeatability errors. This inaccuracy is called the "Uncertainty of measurement".

Accuracy Class: Measuring instruments are classified into accuracy classes according to their metrological properties. There are two methods for classifying instruments into accuracy classes.

i. Expressed by a class ordinal number that gives an idea but no direct indication of the accuracy. (Ex: block gauges 0, 1, 2, etc.)
ii. Expressed by a number stating the maximum permissible inaccuracy as % of the highest indication given by the instrument. (Ex: ±0.2 ie., 0.2 for 0 – 100)

Precision: It is the repeatability of the measuring process. It refers to the group of measurements for the same characteristics taken under identical conditions. If the instrument is not precise it will give different results for the same dimension when measure again and again.

Accuracy: It is the agreement of the result of measurement with the true value of the measured quantity. For good accuracy avoid errors in manufacture and in measuring those errors during inspection. Highly accurate instrument possesses both great sensitivity and consistency. But the instrument which is sensitive and consistence need not necessarily be accurate. Higher the accuracy, higher will be the cost.

According to the thumb rule, the instrument accuracy is more than component accuracy. In calibration, accuracy of master instrument is more than instrument accuracy (approximately by 10 times).

Error: Error is the difference between true value and the measured value. It the error is less, accuracy will be more.

Repeatability: It is the ability of the measuring instrument to give the same value every time the measurement of a given quantity is repeated, when the measurement are carried out - by the same observer, with the same instrument, under the same conditions, without any change in location, without change in method of measurement. And the measurements are carried out in short intervals.

Sensitivity: Sensitivity refers to the ability of measuring device to detect small differences in quantity being measured. It is ratio of the scale spacing to the scale division value. It is also called amplification factor or gearing ratio. It may by constant (linear scale) or variable (non-linear scale) along the scale.

High sensitivity instruments may lead to drifts due to thermal or other effects and less repeatable or less precise.

Readability: Readability refers to the ease with which the reading of a measuring instrument can read. It is the susceptibility of a measuring device to have its indications converted into meaningful number. Fine and widely spaced graduation lines improve the readability. By using magnifying devices, the readability improves.

Magnification: Magnification means increasing the magnitude of output signal of measuring instrument many times to make it more readable. The magnification is possible on mechanical, pneumatic, optical, electrical principles or combination of these.

Reproducibility: Reproducibility is the consistency of pattern of variation in measurement i.e., closeness of the agreement between the result of measurement of the same quantity, when by different observers, by different methods, using different instruments, under different conditions, locations, times etc.,,

Calibration: The calibration of any measuring system is very important to get meaningful results. It measures the quantity in terms of standards unit. It is carried out by making adjustments such that readout device produces zero output for zero measured input. It should display an output equivalent to the known measured input near the full scale input value.

Accuracy of the instrument depends upon the calibration. Calibration depends upon the severity of use, environmental conditions and accuracy of measurement required etc.,

Traceability: Concept of establishing a valid calibration of a measuring instrument of measurement standard by step by step comparing with better standards up to acceptable specified standards.

Uncertainty: Uncertainty is a parameter to quantify the reliability of mesurand. Uncertainty of measurement determines the measurement capability of a laboratory.

OBJECTIVES OF METROLOGY:

The objective of a measurement is to provide the required accuracy at minimum cost.

The objectives of metrology are:

i. To evaluate, newly developed products, to ensure that components designed are within the process and measuring instrument capabilities available in the plant.
ii. To determine the process capabilities and ensure that these are better than the relevant component tolerance.
iii. To determine the measuring instrument capabilities and ensure that these are adequate for their respective measurements.
iv. To minimize the cost of inspection by effective and efficient use of available facilities and to reduce the cost of rejects and rework.
v. Standardization of measuring methods.
vi. Maintenance of the accuracies of measurements
vii. Solution of problems arising on the shop floor
viii. Preparation of designs for all gauges and special inspection fixtures.

STANDARD:

A standard is defined as something that is setup and established by authority as rule for measurement of quantity, weight, extent, value or quality etc., any system of measurement must be related to known standard otherwise the measurement has no meaning. The role of standards is to support the system which makes uniform measurement throughout the world and helps to maintain interchangeability in mass production.

Sub-Division of Standards:

Primary Standards
↑
Secondary Standards — IBWM (England), BIPM (Paris)
↑
Tertiary Standards
(**National Reference Standards, NPL (India, UK), NIST (USA), DIB (Germany))**
↑
Working Standards
(CMTI, FCRI, ETDC, NABL, RTC, CPRI)
↑
Plants/Lab Reference Standards
(Slip gauges OO, CMM)
↑
Plants/Lab Working Standards
(Slip Gauges 2, 1)
↑
Shop floor Standards
(Vernier Caliper, Micrometer, Dial guage etc.,)

Work shops (Plants/Lab Reference Standards, Plants/Lab Working Standards, Shop floor Standards)

Measurement: In industries, various quantities like length, width and other parameters are expressed in meaningful numbers by comparing them with standards. This result of quantitative comparison of unknown magnitude with the pre-determined standard is called measurement.

Gauging: Gauging is the method of checking the dimensions of manufactured parts and it does not indicate the actual value of the inspected dimension on the work and also used for determining as to whether the inspected parts are made within the specified limits.

CLASSIFICATION OF METHODS OF MEASUREMENTS:

In precision measurements various methods of measurements are followed depending upon the accuracy required and the amount of permissible error.

The different methods are as follows:

1. Direct method of measurement
2. Indirect method of measurement
3. Fundamental method of measurement
4. Substitution method of measurement
5. Comparison method of measurement
6. Transposition method of measurement
7. Differential method of measurement
8. Coincidence method of measurement
9. Null method of measurement
10. Deflection method of measurement.
11. Interpolation method of measurement.
12. Extrapolation method of measurement.

13. Complementary method of measurement.
14. Composite method of measurement.
15. Element method of measurement.
16. Contact and Contact less method of measurement.

Classification of Measuring Instruments:

According to the functions, the measuring instruments are classified as:

i. Length Measuring instruments
ii. Angle Measuring instruments
iii. Instruments for checking deviations from geometrical forms
iv. Instruments for determining the quality of surface finish.

According to the accuracy of measurement, the measuring instruments are classified as follows:

i. Most Accurate Instruments: Ex: Light interference instruments
ii. Second group consists of less accurate instruments such as tool room microscopes, comparators, optical instruments etc.,
iii. The third group comprises still less accurate instruments. Ex: Dial indicators, Vernier calipers and rules with vernier scales.

SOURCES OF ERRORS:

Error is the difference between the actual value and the indicated value of the measured quantity.

Errors may be classified in the following ways:

I. a) Static Errors – result from the physical nature of various components of the measuring system Ex: Internal imperfections, environmental effects, calibration effects, reading erros etc.,

b) Dynamic Errors – result by time variations in the measurand like inertia, clamping friction or other physical constraints in the measuring system.

II. Controllable or systematic or fixed errors:

i. Calibration erros
ii. Ambient conditions
iii. Stylus pressure
iv. Random or accidental errors

III. Illegitimate Errors:

i. Blunders or mistakes
ii. Computational errors
iii. Chaotic errors

GENERAL CARE OF EQUIPMENT:

i. As far as possible highly finished surfaces should not be touched by hand because the natural acids on the skin are likely to corrode the surfaces and also the temperature of the body may upset the dimensions of precision instruments.
ii. It is better to wash hands thoroughly and coat them with a thin film of pure petroleum jelly, before handling the instruments
iii. Very precise equipments like slip gauges should be handled by using a piece of chamois leather or tons made from of strip of Perspex
iv. When the equipment is not in use it should be protected from atmospheric corrosion. The highly finished surfaces should be wiped to remove finger marks and then coat them with mixtures of heated petroleum jelly and petrol.
v. For very precise measurements, the work piece and instruments should be allowed to attain 20^oC before use and the handling should be as little as possible.

Experiment No: 6 **Date:**

TOOL MAKER'S MICROSCOPE

Aim: To measure the screw thread parameters of a given specimen using Tool Maker's Microscope.

Apparatus: Tool room microscope, screw thread.

Experimental setup:

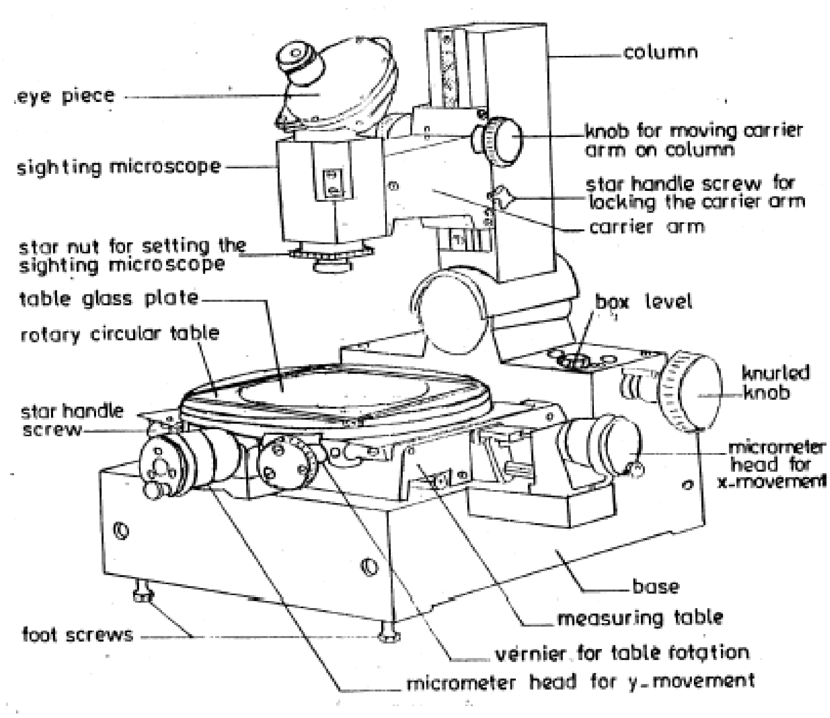
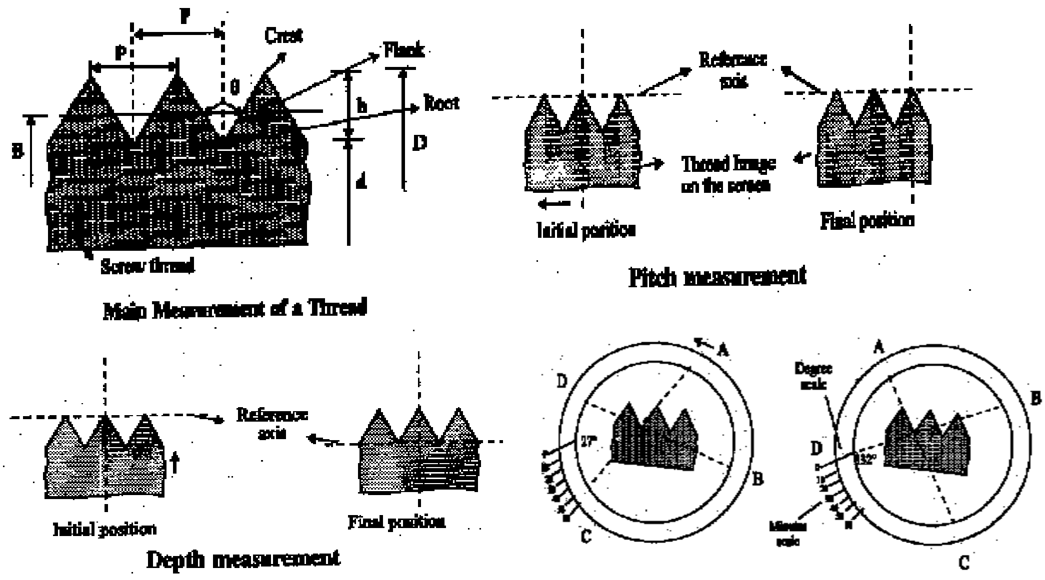


Fig. 1 Tool Makers Microscope



Theory:

The large Tool Maker's Microscope (TMM) essentially consists of the cast base, the main lighting unit, the upright with carrying arm and the sighting microscope. The rigid cast base is resting on three foots screws by means of which the equipment can be leveled with reference to the build-in box level. The base carries the co-ordinate measuring table, consists of two measuring slides; one each for directions X and Y and a rotary circular table provided with the glass plate (Fig.1). The slides are running on precision balls in hardened guide ways warranting reliable travel. Two micrometer screws each of them measuring range of 0 to 25 mm permit the measuring table to be displaced in the directions X and Y. The range of movements of the carriage can be widened up to 150 mm in the X direction and up to 50mm in the Y direction with the use of gage blocks.

The rotary table has been provided with 360 degrees graduation and with a three minute vernier. The rotary motion is initiated by activation of knurled knob and locked with star handle screw. Slots in the rotary table serve for fastening different accessories and completing elements.

The sighting microscope has been fastened with a carrier arm to column. The carrier arm can be adjusted in height by means of a rack and locked with star handle screw. Thread measuring according to the shadow image permits the column to be tilted in X direction to either side about an axis on centre plane level. The corresponding swivel can be adjusted with a knurled knob with a graduation cellar. The main lighting unit has been arranged in the rear of the cast base and equipped with projection lamp where rays are directed via stationary mounted mirror through table glass plate into the sighting microscope.

Measuring principle

The work piece to be checked is arranged in the path of the rays of the lighting equipment. It produces a shadow image, which is viewed with the microscope eyepiece having either a suitable mark for aiming at the next points of the objects or in case of often occurring profiles. e.g. Threads or rounding – standard line pattern for comparison with the shadow image of the text object is projected to a ground glass screen. The text object is shifted or turned on the measuring in addition to the comparison of shapes.

The addition to this method (shadow image method), measuring operations are also possible by use of the axial reaction method, which can be recommended especially for thread measuring. This involves approached measuring knife edges and measurement in axial section of thread according to definition. This method permits higher precision than shadow image method for special measuring operations.

Applications

The large tool maker's microscope is suitable for the following fields of applications;

Length measurement in Cartesian and polar co-ordinates.

Angle measurements of tools; threading tool punches and gauges, templates etc.

Thread measurements i.e., profile major and minor diameters, height of lead, thread angle, profile position with respect to the thread axis and the shape of thread. (rounding, flattering, straightness of flanks)

Angle Measurement

Procedure:

1. Calculate the Least counts of thimble scale and vernier scale of micrometer and Least count of angular scale.
2. Keep the given specimen on the table.
3. Adjust the horizontal line of the eyepiece so that it touches the tip of the image formed. Note this as the initial reading for major diameter (R_1).
4. Move the horizontal wire till it touches the root of the screw and tabulate the reading (R_2).
5. Move the horizontal wire till it touches the root on the other side of the screw and tabulate the reading (R_3).
6. Move the horizontal wire till it touches the tip of the image on the other side and note down the reading (R_4).
7. Make one vertical line coincide through the center of any crest or root. Note Reading (R_5).
8. Move the specimen such that the vertical wire passes through the center of the next crest or root (R_6). This gives the final value of pitch.
9. Using the cross wires adjusting it along the flank center of the root find out angle of the screw. (R_7 and R_8)

Pre viva questions:

1. What is least count?
2. What is the least count of microscope?
3. Different types of microscopes?

Observations and Tabulations:

Least count of micrometer as follows:

$$\text{Pitch} = \frac{\text{No. of divisions moved on the main scale}}{\text{No. of rotations given to thimble}} =$$

$$\text{Least count of thimble scale} = \frac{\text{Pitch}}{\text{No. of divisions on the thimble}} =$$

$$\text{Least count of vernier Scale} = \frac{\text{T.S.D}}{\text{Number of Vernier divisions}} =$$

Total Reading of micrometer = MSR + (TSR x LC of thimble scale) + (VC x LC of vernier scale)

$$\text{Least count of Angular scale} = \frac{\text{1MSD}}{\text{Number of division of vernier}}$$

Tabular Column:

Engraved line Position	MSR	TSR	VSR	Total Reading
R_1				
R_2				
R_3				
R_4				
R_5				
R_6				
R_7				
R_8				

1. Major diameter = R1~R4
2. Root diameter = R2~R3
3. Depth of the thread = R1~R2 or R3~R4
4. Pitch of the thread = R5~R6
5. Angle of the thread = R7~R8

Results:

Verification:

Conclusions:

Post viva questions:

1. What is major diameter?
2. What is minor diameter?
3. What is precision?
4. What is accuracy?
5. What is effective diameter?

Experiment No: 7 **Date:**

OPTICAL PROFILE PROJECTOR

Aim: a. To measure the screw thread parameters of a given specimen using Optical Profile projector.
b. To determine the diameter of the holes drilled in a plate and to measure the center distance between them

Apparatus: Profile projector, screw, specimen with drilled holes etc.

Theory: Optical profile projector is a measuring instrument which projects an enlarged shadow of the part being measured on a screen, where it is compared to a master drawing. By these devices, complicated shaped parts can be easily checked. In any projection system, there are four essential elements viz., source of light, collimating lens, projection lens and screen. The purpose of collimating lens is to render the beam of light from point source to the parallel. The projection lens form a real image on the screen of an object placed between it and collimator. The screen is generally translucent so that the image can be viewed from the opposite side.

The function of the roof prism is to direct the beam of light horizontally towards the back of the projector to assist in the projection of the image. There are three types of projectors. Those are Horizontal projector, vertical projector, cabinet projector

Advantages of Optical projector:

- Compares all the elements of the thread with an accurate gauge
- Checking of dimensions from parts and lines.
- Locating centres of holes, the intersections of two straight lines.
- Checking of profiles which can't be projected.
- Locate the radius centre of a fillet.

Precautions:

1. Do not disturb the original setting of the mirror.
2. Never touch the surface of the mirror with bare hands

Procedure (to measure screw thread parameters):

1. Calculate the Least counts of thimble scale and vernier scale of micrometer and Least count of angular scale.
2. Keep the given specimen on the table.
3. Adjust the horizontal line of the eyepiece so that it touches the tip of the image formed. Note this as the initial reading for major diameter (R_1).
4. Move the horizontal wire till it touches the root of the screw and tabulate the reading (R_2).
5. Move the horizontal wire till it touches the root on the other side of the screw and tabulate the reading (R_3).
6. Move the horizontal wire till it touches the tip of the image on the other side and note down the reading (R_4).
7. Make one vertical line coincide through the center of any crest or root. Note Reading (R_5).

8. Move the specimen such that the vertical wire passes through the center of the next crest or root (R_6). This gives the final value of pitch.
9. Using the cross wires adjusting it along the flank center of the root find out angle of the screw. (R_7 and R_8)

Observations and Tabulations:

Least count of micrometer as follows:

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$$\text{Least count of vernier Scale} = \frac{\text{T.S.D}}{\text{Number of Vernier divisions}} =$$

Total Reading of micrometer = MSR + (TSR x LC of thimble scale) + (VC x LC of vernier scale)

$$\text{Least count of Angular scale} = \frac{\text{1MSD}}{\text{Number of division of vernier}}$$

Tabular Column:

Engraved line Position	MSR	TSR	VSR	Total Reading
R_1				
R_2				
R_3				
R_4				
R_5				
R_6				
R_7				
R_8				

Specimen calculations:

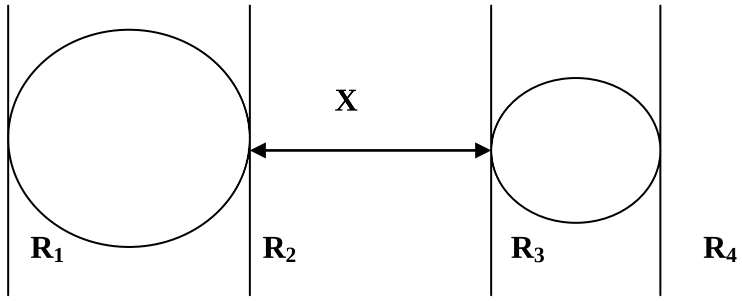
1. Major diameter = R1~R4
2. Root diameter = R2~R3
3. Depth of the thread = R1~R2 or R3~R4
4. Pitch of the thread = R5~R6
5. Angle of the thread = R7~R8

Procedure: (To determine the centre distance between two holes.)

1. Go through the operations and inspection manual of profile projector.
2. Remove the projector lens cap.
3. Switch on the mains and the lens cap.
4. Keep the object on the stage fitted with two micrometers and with the help of the focusing system see that the profile is properly focused on the screen.
5. Move the two micrometers in X and Y direction (after initial setting) to measure the center distance between the two holes chosen.
6. By adjusting the circular scale determine the included angle of the notch.
7. For finding the radius of the specimen, find the value of r and d using X-Y micrometers.

Precautions:

1. Do not disturb the original setting of the mirror.
2. Never touch the surface of the mirror with bare hands.



Pre viva Questions:

1. What is one main scale division?
2. What is one vernier scale division?
3. What is the least count?

Observations &Tabular Column:

Engraved line Position	MSR	TSR	VSR	Total Reading
R_1				
R_2				
R_3				
R_4				

Sample Calculations:

1. Diameter of the first hole = $D_1 = R_1 \sim R_2$.
2. Diameter of the second hole = $D_2 = R_3 \sim R_4$.
3. Distance $X = R_3 \sim R_2$
4. Centre distance between the two holes = $D_1/2 + D_2/2 + X =$

Result:

Verification:

Conclusion:

Post viva Questions:

1. What is the thread and explain different types of threads?
2. What is addendum?
3. What is dedendum?

Experiment No: 8 **Date:**

MEASUREMENT OF ANGLE

Aim: To determine the angle of the given specimen using sine bar/sine center/bevel protractor.

Apparatus: Specimen, sine bar/sine centre/bevel protractor.

Theory:

The angle is defined as the opening between two lines which meet at a point. The basic unit in angular measurement is the right angle (90^0), which is defined as the angle between two lines which interest so as to make the adjacent angle equals (four equal parts). 1^0 = 60' (60 equal parts), 1'=60" (60 equal parts).

Before 1,000 BC, the degree, minutes and seconds referred as 'Sexagecimal System'.

The difference between angular and linear division, is that in angular division no reference is necessary to an arbitrary standard (Like wave length of light in linear division) to establish angular units and that the calibration of angular subdivision is a self-checking process.

Alternative method for angular units is radian. This is the relationship between the radius and arc of a circle. Radian is defined as the angle subtended at the center by an arc of a circle of length equal to its radius.

2π radians = 360 degrees

The degrees system is used for engineering purposes; the radian system is used for mathematical investigations.

Linear units, such as 1 in 30 or mm/m are often used for specifying tapers.

Angular measurement may be broadly be classified as follows:

1. Measurement of angular features on components or gauges.
2. Measurement of the angular rotation of a divided circle.

Angle Standards:

1. End standard takes the form of either angle gauges or polygon.
2. Line standards takes the form of uniformly defined circles with the lines engraved at regular intervals of say one degree.

Instruments for Angular Measurements:

The selection of an instrument depends upon the component and the accuracy of measurement required.

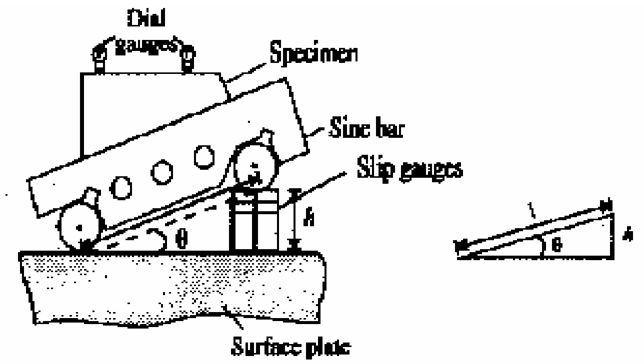
1. Bevel protractors (Vernier, optical, universal) (Accuracy : 2 ½ min, 2 min)
2. Sine Bar (Seconds) and Sine center
3. Angle gauges (3 seconds)
4. Clinometers
5. Angle dekkor
6. Autocollimator

a. Angle Measurement Using Sine – Bar

Aim: To find out the unknown angle of the given specimen-using sine – bar and slip gauges.

Apparatus: A surface plate, Sine Bar, Slip gauges, Specimen. Dial gauge.

Experimental Setup:



Theory: Sine bar is common and most precise way of getting the angle or finding the angle. The angle is found out by knowing the ratio of the length of two sides of a right angle. The angle to be measured or determined by indirect method as a function of sine, for this reason, the device is called a 'Sine bar'. Angles are measured accurately by sine bars with the help of other auxiliary instruments such as slip gauges, indicating devices etc.

The sine bar consists of a steel bar and two rollers. It is made from high carbon, high chromium corrosion resistant steel, suitably hardened, precision ground and stabilized. Rollers or cylinders are of accurate and equal diameters.

The sine principle uses the ratio of the length of two sides of a right triangle in deriving a given angle. It may be noted that devices operating on sine principle are capable of "self generation." The measurement is usually limited to 45^0 from loss of accuracy point of view.

Precautions in use of Sine bars:

1. Sine bar not used for angle greater than 45^0 (impractical) fairly reliable for angles less than 15^0.
2. Longer sine bars should be used, since many errors are used by using longer sine bar.

Formula:

$$\sin\theta = \frac{h}{l}$$

$$\theta = \sin^{-1}\left(\frac{h}{l}\right)$$

$$l = 150$$

Procedure:

1. Fix up the work specimen on the sine bar for which the angle is to be measured.
2. One of the cylinders or rollers of sine bar is placed on the surface plate and other roller is placed on the slip gauges of height 'h'.

3. The height ‘h’ is to be adjusted by introducing the slip gauges in such a way that the dial gauges show zero reading on both the ends. Now the top surface of the work is parallel to the surface plate.
4. This height ‘h’ is obtained by trial and error method. After obtaining zero deflection on both ends, note down the slip gauge height ‘h’.
5. Find out the angle using the formula,
   Sin θ = h / l

Note: First calculate the approximate angle (θ_1) of the given specimen using bevel protractor, then calculate the approximate height of slip gauges for the length of sine bar (h_1).

Pre viva questions:

1. What is the difference between slip gauge and pitch gauge
2. Explain how you measure minor and effective diameter

Specimen calculations:

1. l = Length of the sine bar = Distance between two centers of cylinders.
   =
2. h = Height of the slip gauge. =
3. The angle ‘θ’ of the given specimen,

$$\sin\theta = \frac{h}{l} =$$

$$\theta = \sin^{-1}\left(\frac{h}{l}\right) =$$

Results:

Verification:

Conclusion:

Post Viva Questions:

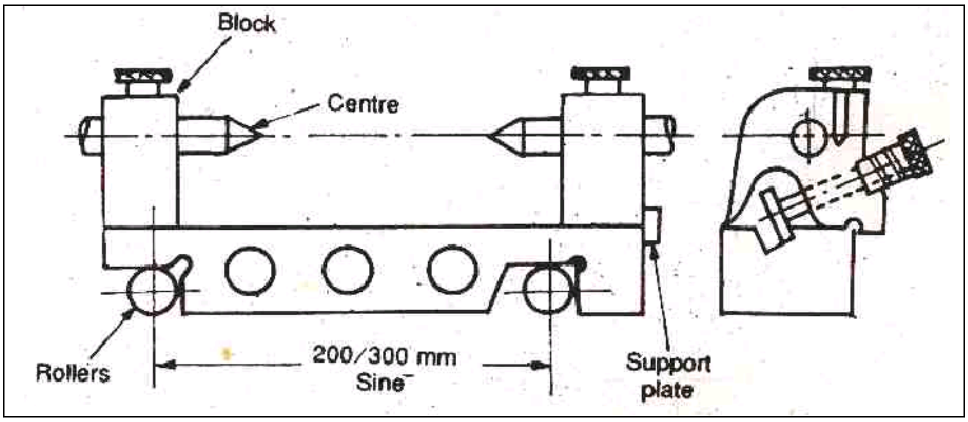
1. Which is instrument used to find the effective diameter very accurately
2. Name the instrument used to find the screw thread parameters
3. What is error?
4. Mention the two important requirements of measurements
5. Why we use Sine bars to find angles?
6. What are the sources of errors in sine bars?

b. Angle Measurement Using Sine Centre

Aim: To find out the unknown angle of the given specimen-using sine centre and slip gauges.

Apparatus: A surface plate, Sine centre, Slip gauges, Specimen. Dial gauge.

Experimental setup for Sine center:



Theory: Due to difficulty of mounting conical work easily on a conventional sine bar, sine centres are used. Two blocks as shown in figure are mounted on the top of sine bar. These blocks accommodate centres and can be clamped at any position on the sine bar. The centres can also be adjusted depending on the length of the conical work-piece, to be held between centres. Sine centres are extremely useful for the testing of conical work, since the centres ensure correct alignment of the work-piece.

Procedure:

The procedure for its setting is the same as that for sine bar.

Formula:

$$\sin\frac{\theta}{2} = \frac{h}{l}$$

$$\theta = 2\sin^{-1}\left(\frac{h}{l}\right)$$

Note: First calculate the approximate angle (θ_1) of the given specimen using bevel protractor, then calculate the approximate height of slip gauges for the length of sine bar (h_1).

Specimen calculations:

1. l = Length of the sine bar = Distance between two centres of cylinders.
   =
2. h = Height of the slip gauge=
3. The angle ‘θ’ of the given specimen =

Results:

Verification:

Conclusion:

Post viva Questions:

1. What is the major difference between Sine bar, Bevel protractor & Clinometers?
2. Explain the use of Sine Center?
3. Define: i) Major Dia ii) Effective Dia iii) Pitch iv) Angle of Thread.
4. Explain the three uses of sine bars
5. What are the major errors in screw thread?
6. Types of screw thread?
7. What are the types of pitch errors found in screws?

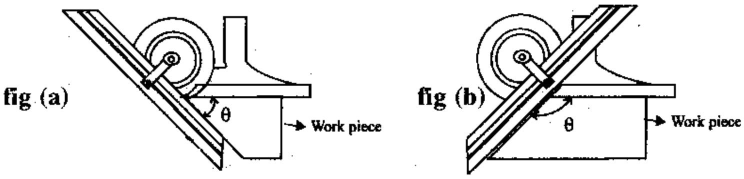
c. Angle Measurement Using Universal Bevel Protractor:

Aim: To find the angle of the given specimen using Universal Bevel Protractor.

Apparatus: Surface plate, Bevel protractor, and specimen whose angle is to be measured.

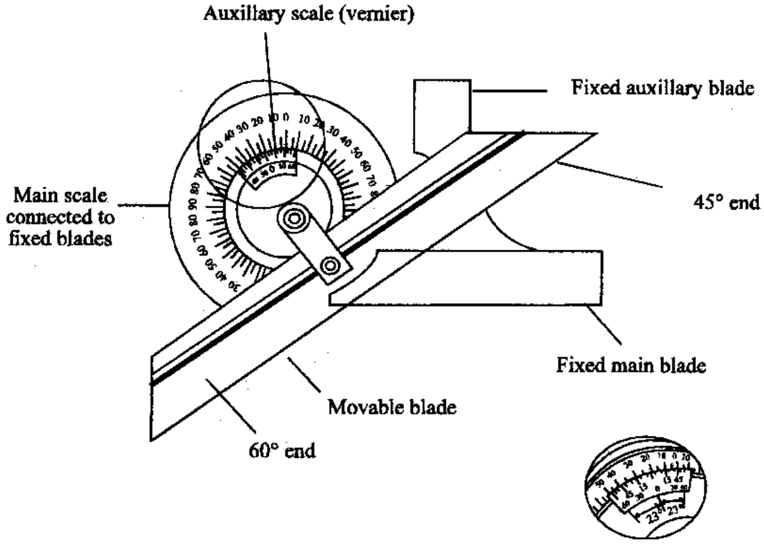
Theory: The bevel protractor is simplest instrument for measuring the angles between two faces of a component. It consists of important parts such as stock, blade, body, vernier, scale etc., Back of the instrument is flat and there are no projections beyond its back. The blade has 150mm to 300mm long, 13mm wide and 2mm thick. Its ends are beveled at angles of 45^0 and 60^0. These are hardened and tempered to reduce wear.

It is used for measuring and lying 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 capable of measuring any angle from 0^0 to 360^0. This is widely used in workshops for angular measurement. The acute angle attachment enables very small angles to be measured.



Measuring an acute angle   Measuring an obtuse angle

Universal Bevel Protractor :



Procedure:

1. The blade is clamped to the body of the bevel protractor.
2. Base plate is held against one of the plane surface which forms an angle.
3. The adjustable plate is survived with respect to the base plate and the angular position is adjusted and locked.

4. The angle between the two surfaces is determined by referring the position of the pointer.
5. Also the sides of the given components are measured suing vernier calipers.

Calculation of Least count of Bevel Protractor:

The main scale is graduated in degrees of arc, which are grouped into four 90^0 quadrants. The degrees are numbered to read either way: from zero to 90, then back to zero which is opposite the zero you started at.

The vernier scale is divided into 24 spaces, 12 on each side of zero, numbered 60-0-60. 12 division occupy the space of 23 degrees on the main scale.

Therefore, each division of the vernier =1/12 or 23^0 or $1\frac{11^\circ}{23}$

Since two divisions on the main scale equals 2 degrees of arc, the difference between two divisions on the main scale equals 2^0 of arc, the difference between two divisions on the main scale and on division on the vernier scale is

$$2^\circ - 1\frac{11^\circ}{12} = \frac{1^\circ}{12} \quad or \quad 5 \min utes\, of\ arc$$

The reading of bevel protractor equals

a) The largest 'whole' degree on the main scale indicated by the vernier zero division, plus

b) The reading on the vernier scale in line with a main scale division.

Tabular Column:

SL. NO	Component shape	Angle measurement at each corner	Result

Results:

1. Angle using Sine Bar =
2. Angle using Sine center =
3. Angle using Universal Bevel Protractor =

Verification:

Conclusions:

Post Vive Questions:

1. Write down the applications of bevel protractor
2. What is the major difference between Sine bar, Bevel protractor & Clinometers?
3. Explain the principle of Wheatstone bridge

AUTOCOLLIMATOR

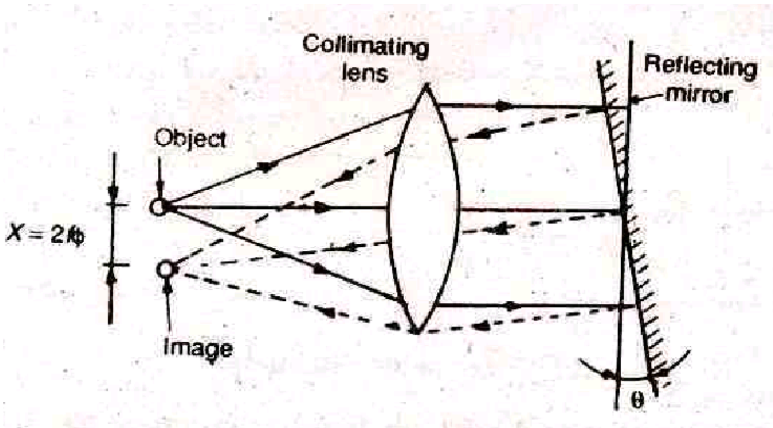
Experiment No: 9 **Date:**

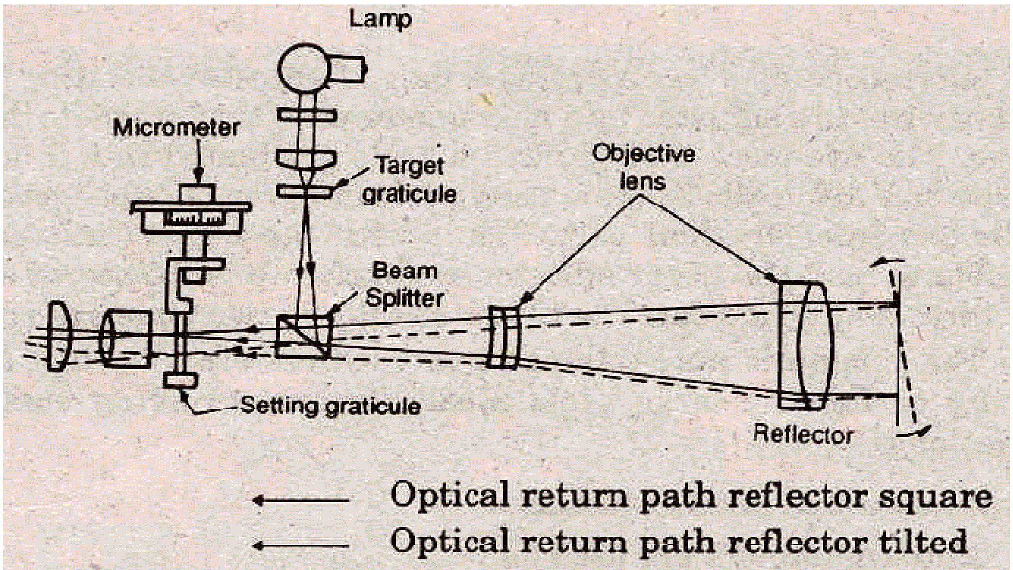
Aim: a). To measure the level difference between two points on a surface of the given surface plate.

b). To find the straightness of the surface of the given surface plate.

Apparatus: Autocollimator, Surface plate, Mirror, straight edge

Experimental Setup:





Line diagram of an injected graticule autocollimator

Functional Details of Autocollimator

Type of Measurement Axis	:	Dual Axis
Accuracy of Autocollimator	:	1 second
Power source	:	230 Volts AC
Range of Measurement	:	10 min
Reflector Size (Mirror)(base x Width)	:	100 mm x 75 mm
Reflector Flatness Accuracy	:	0.08 microns
Yellow Filter		
Focal length	:	430 mm
Eye piece	:	10 X WF
Readout Means	:	Micrometer
No. of Division on Micrometer Drum	:	120

Theory:

It is an optical instrument used for the measurement of small angular differences (level differences), accurately. It is essentially an infinity telescope and a collimator combined into one instrument. The general principle on which this instrument works is shown in the following figure.

In an autocollimator there are three parts viz. micrometer microscope, lighting unit and collimating lens. A line diagram of a modern auto-collimator (injected graticule auto-collimator) is shown in the following figure.

Applications of autocollimator:

- The measurement of straightness and flatness of surfaces.
- Precise angular indexing in conjunction with polygons
- Comparative measurement using master angles
- Assessment of squarenss and parallelism of components
- The measurement of small linear dimensions, and
- For machine tool adjustment setting etc.,

Pre viva questions:

1. Differentiate between Progressive error and Periodic error
2. Define briefly about interchangeability and its types.

Procedure:

1. Place the autocollimator with the stand on a surface plate to be inspected.
2. Place the reflector along the axis of the autocollimator
3. Connect the autocollimator illumination leads to the power supply. Switch on and turn the brightness to the maximum.
4. Adjust the stand, so that the autocollimator appears to be pointing straight at the flat reflective surface.
5. View through the Eyepiece and try to locate the cross line image of the target Graticule.

6. Check that the returned cross line image is in the field of the view.
7. Observe through eyepiece and adjust the micrometer so that the eyepiece Graticule horizontal line made to coincide with the horizontal line of image of the target Graticule.
8. Note the readings on the micrometer drum. This reading is the reference for all subsequent observations (Position A).
9. Move the reflector to position B say by 100 mm away along the same axis from the earlier position A.
10. Observe through the eyepiece. If the surface plate flatness is good you will see the two horizontal lines coincide. If there is a level difference between the position A & B then you will observer a gap between the two horizontal lines.
11. By means of the micrometer move the horizontal line to coincide again.
12. Note the micrometer readings of position B
13. The difference in reading for Position A & B refers to the angular tilt at Position B.
14. Repeat the above observation for various positions along a straight line.

a. Level difference between two points:

Aim: To find level different between two points with specified length on the given surface Plate.

Apparatus: Autocollimator, Surface Plate, Reflector Mount

Procedure:

Procedure for the measurement of level difference between two points is same as above. (Tabulate the readings by using Y-axis micrometer).

Observations and Tabular Column:

Least count of the Autocollimator =
Deviation for the length, L =
Least count of the Main Scale =
Least count of the Vernier Scale (X-axis) =
Least count of the Vernier Scale (Y-axis) =

Initial Reading			Final Reading			Deviation , θ= Final - Initial	Linear Deviation, X= L X tanθ in mm
Main Scale	Vernier Scale	Total Reading	Main Scale	Vernier Scale	Total Reading		

Specimen Calculations:

Initial Reading =
Final Reading =
Deviation, θ = Final Reading – Initial Reading
Tan θ = X/L
Linear Deviation, X = L x Tan θ

Result:

Verification:

Conclusion:

b. To find the straightness of a surface of the given Surface Plate:
Aim: To find the straightness of the given surface Plate.

Apparatus: Autocollimator, Surface Plate, Reflector Mount

Procedure:
Procedure for the measurement of straightness of the given surface plate is same as above. (Tabulate the readings by using Y-axis micrometer).
Take readings for every 100 mm base length.
Draw the Graph

Observations and Tabular Column:

Least count of the Autocollimator =
Deviation for the length, L =
Least count of the Main Scale =
Least count of the Vernier Scale (X-axis) =
Least count of the Vernier Scale (Y-axis) =

Sl. No.	Alignment over given sample length, L	Initial Reading			Final Reading		
		Main Scale	Vernier Scale	Total Reading	Main Scale	Vernier Scale	Total Reading
	100 mm						
	200 mm						
	300 mm						
	400 mm						
	500 mm						
	600 mm						
	700 mm						

Deviation , θ= Final - Initial	Linear Deviation, X = L X tanθ in mm

Specimen Calculations:

Initial Reading =

Final Reading =

Deviation, θ = Final Reading – Initial Reading

$\tan\theta = X/L$

Linear Deviation, X = L x Tan θ

Graph:

Draw graph between Length of Base (X-axis) to the Linear Deviation (Y-axis) and find the mean straightness error.

Results:

Verification:

Conclusion:

Post viva Questions:

1. What are the applications of Autocollimator?
2. What is Comparator?

Experiment No: 10 **Date:**

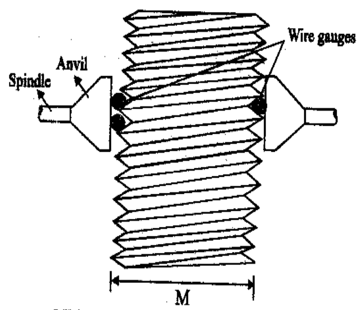
MEASUREMENT OF EFFECTIVE DIAMETER OF SCREW THREAD USING THREE WIRE METHOD

Aim: To find the effective diameter of a given screw thread by three wire method.

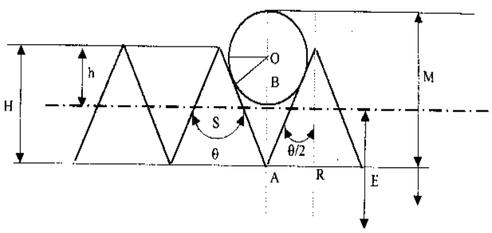
Apparatus: Three wires of same diameter, flanged micrometer, thread specimen.

Theory: This method of measuring the effective diameter is an accurate method. In this three wires or rods of known diameter are used: one on one side and two on the other side. This method ensures the alignment of micrometer anvil faces parallel to the thread axis.

Best size wire: Best size wire has a diameter which makes contact with the flanks of the thread on pitch line, since effective diameter wire which makes contact on the true flank of the thread.



Measurement of Effective Diameter by three wire method.



Procedure:

1. Find out the pitch of the given thread specimen.
2. Select the suitable wire. The diameter of the wire depends upon the pitch. (Refer table – 1 3 – wire unit gauges 313 series)
3. Note down the diameter of the wire.
4. Keep one wire on one side and the other two wires on the opposite side of the flange between the two flanks of micrometer as shown in the sketch.
5. Find out the dimension over the wires.
6. Find out the dimension under the wires using the formula.
7. Find the effective diameter of the wire using the formula.

Specimen Calculations:

1. d = diameter of the wire
r = radius of the wire.
p = pitch of the thread.
M = Measurement over the wire.

E = Effective diameter

D = Outside diameter of the thread specimen.

2. $$E = M - d\left(1 + \operatorname{cosec}\frac{\theta}{2}\right) + \left(\frac{p}{2}\right)\cot\frac{\theta}{2} \quad \text{mm}$$

Where θ = Thread angle.

In case of Whit Worth thread

$\theta = 55^0$

In case of Metric thread

$\theta = 60^0$

Diameter of best size wire is given by

$$d = \frac{p}{2\cos\left(\frac{\theta}{2}\right)}$$

Result:

Effective diameter of the given thread =

Verification:

Conclusions:

Experiment No: 11 **Date:**

MEASUREMENT OF EFFECTIVE DIAMETER OF SCREW THREAD USING TWO WIRE METHOD

Title :

To Measure the effective diameter of external screw threads using floating carriage micrometer.

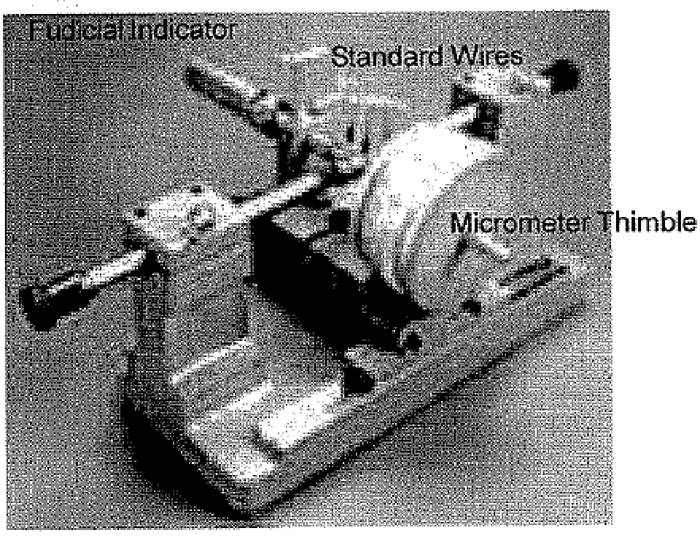
Prior Concepts:

- Working and use of micrometer, terminology of screw thread (Pitch, major diameter, minor diameter, lead etc) Types of threads..

New Concepts:

Proposition 1 : Floating carriage micrometer.

It is an precision measuring equipment, primarily used for measurement of major, minor and effective diameters of thread gauges and precision threaded components.



Learning Objectives :

Intellectual Skills :

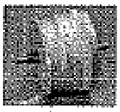
- To understand the Principle of floating carriage micrometer..
- To Select the proper sized wires for effective diameter measurement.

Motor Skills :

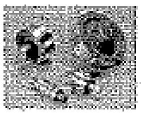
- Ability to operate floating carriage micrometer.
- Ability to observe and record the readings.

Apparatus :

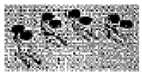
Floating carriage micrometer, set of standard wires and cylinders, thread plug gauge, threaded component :



Micrometer Thimble

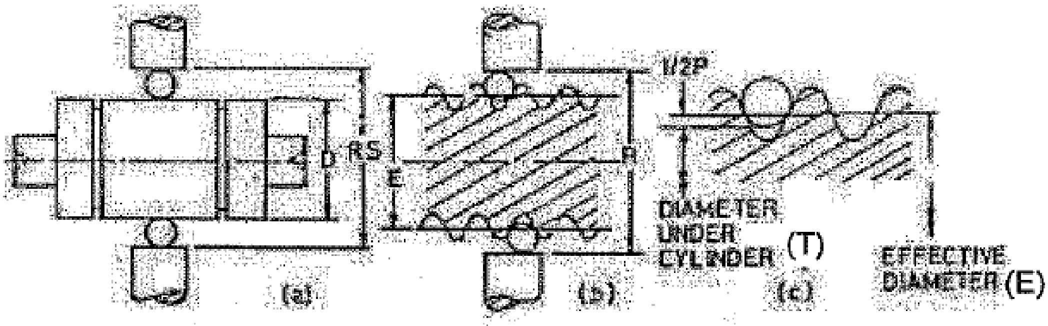


Setting cylinders



Standard wires

Diagram :



Setting cylinder with wires

Threaded compenent with wires

Effective Diameter

Stepwise Procedure :

1. Select a plain setting cylinder of a size nearer to workpiece under test.
2. Select a set of standard wires by refering chart 'A'.
3. Hold the selected setting cylinder between centers.
4. Calculate best wire size and hang the standard wires so that they can contact setting cylinder on both sides.
5. Set the floating carriage at right angles to axis of center so that anvils of microme ter head and fiducial indicator contanct the hanging wires as shown in figure (a)
6. Apply the spring pressure by rotating the thimble screw so that fiducial indica tor is set to zero. Zero error in setting is avoided by rotating the setting cylinder so that it rolls over the wires.
7. Note the micrometer reading Rs.
8. Replace the setting cylinder by a threaded component which is to be chekced.
9. Insert the standard wires in root of the thread on each side of component.
10. Apply spring pressure as stated in earlier step above.

• Note the micrometer reading R as shown in figure (b)

• Note the various observations and calculate effective diameter.

Observation :

• Diamter of setting cylinder (D) = ... mm

• Micrometer reading over wire on setting cylinder (Rs) = ... mm.

• Micrometer reading over wire on threaded component (R) = ... mm.

• Diamter of wires used (d) = ... mm

• Pitch of thread (p) = ... mm.

Calculation :

1. Diameter under wire (T)

$$T = D - (Rs - R)$$

∴ T = ... mm

2. P_{value} (P)

P = (0.86602 * p) - d for metric thread

P = (0.9605 * p) - (1.1657 * d) for with worth thread

∴ P = ... mm

3. Effective diameter (E)

$$E = T + P$$

∴ E = ... mm

Result :

Effective diameter of a threaded component is found to be (E) = ... mm

Conclusion :

• Floating carriage micrometer can be used to measure effective diameter of .... (internal / external) threads.

• The significance of P_{value} is ....

CHART - A (For selection of standard wire)

Wire size (d) mm	Pitch (p) mm	P_{value} (for reference only)
0.17	0.25	0.047
0.22	0.35	0.083
0.53	0.9	0.246
0.62	1.0	0.249
0.725	1.25	0.358
0.895	1.5	0.404
1.1	1.75	0.416
1.35	2.0	

Verification :

Post viva questions:

1. What is interferometry & how you get interference bands
2. Define hole basis and shaft basis.
3. What is roughness and define Ra, Rz values?
4. What is plug gauge and thread gauge?
5. What is a cosine error?
6. Types of fits.
7. Type of comparators.
8. What is the thread and explain different types of threads?

Experiment No. 12 **Date:**

MEASUREMENT OF SURFACE ROUGHNESS

Title :

To measure surface roughness of component using surface roughness measuring instrument and compare with standard specimen.

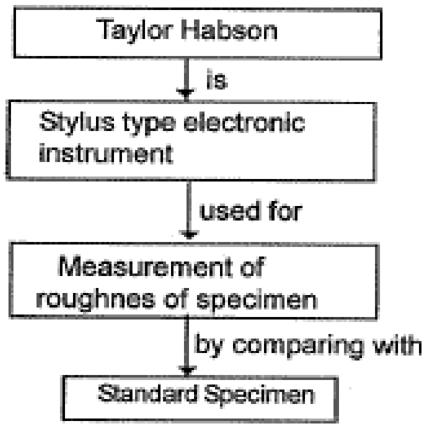
Prior Concepts:

Surface roughness, calculation of Ra, CLA (center line average) and RMS (Root mean square) Value.

New Concepts:

Proposition 1 : Surface roughness measuring instrument.

Taylor Hobson Tallysurf is stylus type electonic instrument used to measure surface roughness of a given sample.



Learning Objectives:

Intellectual Skills:

- To understand the concept of reading Ra value by using Taylor Hobson Talysurf.

Motor Skills:

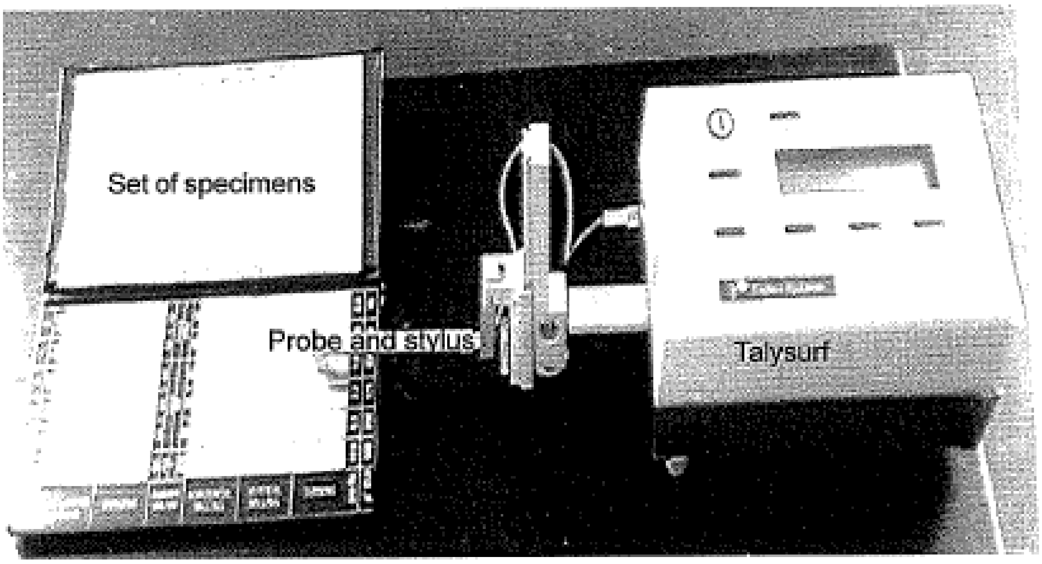
- Ability to set sampling length.
- Ability to handle and set given instrument
- Ability to compare measured Ra value with standard specimen.

Apparatus :

Talylor Hobson Tallysurf is an instrument used to measure surface roughness of work pieces finished by different manufacturing processes, standard set of different finished workpieces with known surface roghness value. It is an electonic stylus probe type instrument working on carrier modulating principle. Measuring head of this instrument consists of a diamond stylus of about 0.002 mm tip radius and skid or screw which is drawn accross the surface by means of a motirised gearbox.

Arm carying the stylus focus an armature which pivots around the centre piece of 'E' shaped stamping. On two legs of E shaped stamping there are two coils carrying an a.c. current. These two coils with the other two resistances form an oscillator. Movement of the stylus causes the air gap to vary and amplitude of the original a.c. current flowing in the coil is modulated. The output i.e. modulation is demodulated so that current flowing is directly proportional to vertical displacement of the stylus.

Diagram :



Experimental Setup

Stepwise procedure :

1. Collect sample work pieces manufactured by different methods.
2. Clean the surface whose roughness value is to be meausred, keep it on the surface plate.
3. Keep the Tallysurf so that its stylus touches the workpiece and adjust proper sampling length.
4. Press the start button of Talysurf.
5. Measure the Ra value of given workpiece.
6. Measure Ra value of different samples.
7. Compare the measured Ra value with the standard value.
8. CLA values of different samples can be measured in a similar manner.

Observations :

S.N	Mfg. process	Indicated Ra value (µm)	Measured Ra value (µm)	Compared with standard specimen (µm)
1	Turning/Milling	0.32 to 25		
2	Drilling	1.6 to 20		
3	Grinding	0.063 to 5		
4	Lapping	0.01 to 0.16		
5				
6				

Result:

Verification:

Conclusion:

Post viva Questions:

1. What do you mean by surface roughness?
2. What are the instruments used for measuring surface roughness?
3. What are the different operations where you can find out surface roughness?

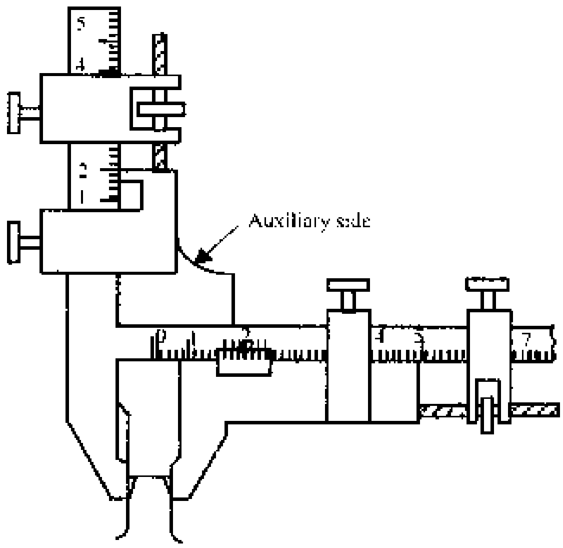
Experiment No: 13 **Date:**

GEAR TOOTH VERNIER CALIPER

Aim: a. To Measure the tooth thickness of the given gear using Gear Tooth Vernier Caliper.

Apparatus: A gear tooth vernier caliper, gear specimen.

Experimental setup:



Theory: The gear tooth vernier caliper can be conveniently used to measure the tooth thickness at a specified position on the teeth. The tooth thickness is measured at the pitch circle and is therefore referred to as the pitch line thickness of the tooth. This caliper has two vernier scales and they are set for width (‘w’) of the tooth and depth (‘d’) from the top at which (‘w’) is measured.

Gear Tooth Vernier Caliper

Procedure: (To measure the gear tooth thickness)

1. Find out the least count of the caliper.
2. Calculate the diametral pitch, pitch circle diameter and module.
3. Find out the theoretical thickness ‘W_t’ and Chordal depth (h).
4. Set the vernier depth gauge (y-axis) of the vernier gear tooth caliper for the dimension of chorda depth (h).
5. Measure the gear tooth thickness (W_m) using the gear tooth vernier caliper.
6. Repeat the procedure for different teeth (at least for three teeth) and note down the reading.
7. Compare the actual measurement with calculated readings and find out the errors.

Formulas:

$$\text{Module, m} = \frac{d}{N} = \frac{1}{d_p}$$

Where d = Pitch Circle Diameter (pcd)
N = Number of teeth on given gear
d_p = Diametral Pitch

$$\text{Diametral Pitch, } d_p = \frac{N}{d} = \frac{(N+2)}{D}$$

Where D = Outside Diameter of Gear

$$\text{Theoretical Thickness, } W_t = N\,m\,\sin\left(\frac{90}{N}\right)$$

$$\text{Chordal Height or depth, } h = \frac{N\,m}{2}\left[1+\frac{2}{N}-\cos\left(\frac{90}{N}\right)\right]$$

$$\%\ \text{Error} = (W_t - W_m)/W_t \times 100$$

Observations:

Least count of gear tooth vernier caliper
X – axis =
Y – axis =
Number of teeth on the given gear , N =
Outside Diameter of the Gear, D =
(Take minimum three trials)

Tabular Column:

Sl. No.	**Measured Thickness “W_m”**
Average =	

Results:

Tooth thickness
Theoretical Thickness of the given gear =
Measured Thickness of the given gear =
% Error =

Verification:

Conclusions:

Post viva Questions:

1. Define GO and NO GO gauges.
2. Name the types of gauges.
3. How will you measure the major diameter & minor diameter of internal thread?
4. What are the major errors in screw thread?
5. What are the major errors in gear tooth?

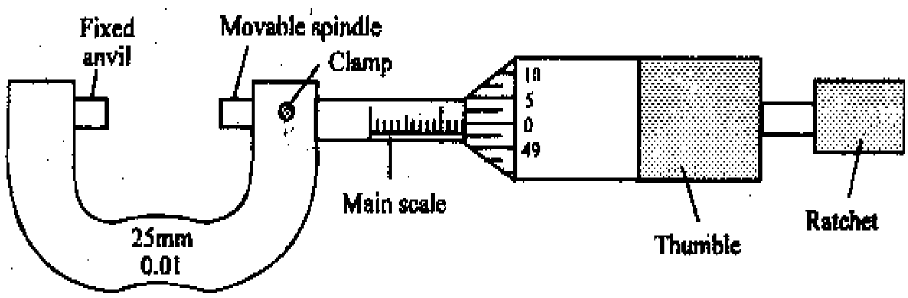
Experiment No: 14 **Date:**

CALIBRATION OF MICROMETER

Aim: To calibrate the given micrometer and to draw the calibration curve.

Apparatus: micrometer, slip gauges

Experimental setup:



External Micrometer

Theory: The micrometer screw is fitted with a threaded spindle as the movable part for measuring length. The micrometer collar is generally marked with a scale containing 50 intervals. The pitch is 0.5 mm with one rotation of the collar. Therefore the measuring pin advances by 0.5 mm. One interval of the collar scale therefore equals 0.5 mm. 50 = 0.01 mm. Whole millimeters and half millimeters are read off the main scale.

Procedure:

1. **Find out the least count of the micrometer.**
2. Select slip gauges of different sizes, which are to be measured.
3. Find out the thickness of each slip gauge and note down the reading.
4. Calculate the error.
5. Calculate the % error.
6. Plot the graph of error vs actual reading.

Specimen Calculations:

1. $$\text{Pitch} = \frac{\text{No. of divisions moved on the main scale}}{\text{No. of rotations given to thimble}}$$

$$\text{L.C.} = \frac{\text{Pitch}}{\text{No. of divisions on the thimble}}$$

Reading = (Main scale reading) + (Coinciding vernier x L.C.)

2. Error, E = $R_m - R_a$

Where R_M=Measured Reading
R_A=Actual Reading

3. % Error = (Error/Actual reading) x 100

= (E/R_a) x 100.

Tabular Column :

Sl.No.	Actual Reading (R_A)	Measured Reading (R_M)	Error R_M-R_A	% of Error

Results:

Verification:

Conclusions:

Post viva Questions:

1. What is slip gauge?
2. Explain the different grades of slip gauges.
3. What is meant by wringing process?

Experiment No: 15 **Date:**

FLATNESS TEST

Aim: To test the flatness of the given specimen using optical flats.

Apparatus: Monochromatic light source, optical flats, and specimen.

Theory: Optical flats are cylindrical in form with the working surfaces flat. There are type A and type B flats. The type A has only one surface flat and type B has both the surfaces flat and parallel to each other.

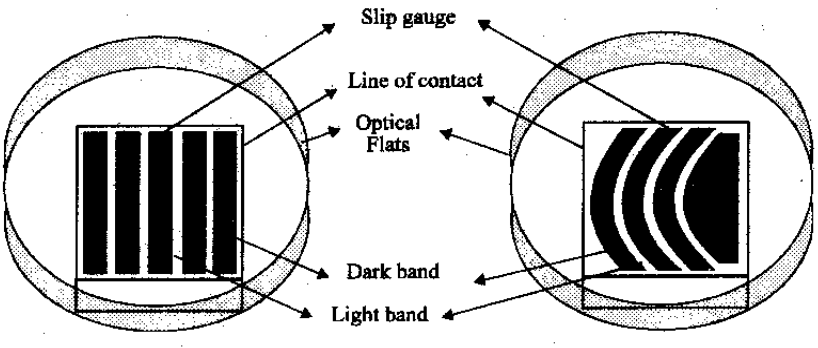
Testing procedure:

1. Ensure that the flat and work piece is clean and free from dirt and even from finge prints.
2. Select type A flats, which are normally used for testing the flatness of slip gauges, measuring tables. The type B flats are used for testing measuring anvils, measuring surfaces of micrometers and measuring devices for testing flatness and parallelism.
3. Keep the specimen on the flat table under the monochromatic light source.
4. Keep the optical flat on the specimen. Thus in case of a perfectly flat surface, an alternate light and dark straight lines on the surface can be observed as shown in the sketch.
5. Any deviation from this pattern will be a measure of the error in the flatness of the surface being inspected.

Checking the Flatness of Rectangular Pieces (Gauges):

Source of light = Monochromatic light source
Wavelength of light = ‘λ’ = 23.2 millionths of an inch.
Pitch = Distance between any two fringes (dark and bright)
= λ/2 = 11.6 millionths of an inch.
λ/2 = 0.0002794 mm or 0.0000116″
Straight, parallel and equally spaced bands show that, surface is perfectly flat within one millionth of an inch.

Reflected tangent line intersects one full band or 0.0002794 mm (or 0.0000116″).



Flatness test of Rectangular pieces :

Result:

Verification:

Conclusion:

Post viva Questions:

1. What do you mean by flatness?
2. What are optical flats?
3. What is the material with which optical flats are made?

Experiment No:16 **Date:**

Measurement of Cutting Forces Using Lathe Tool/Drill Tool Dynamometer

Aim: To determine the various cutting forces and power required in turning.
Apparatus: Lathe, Specimen, Tool, Dynamometer, etc.

Procedure:

1. Fix the work piece between the canters of the lathe and cutting tool along with the dynamometer in place of the tool post.
2. Select the cutting parameters speed, feed and depth of cut.
3. Make the necessary electrical connections and switch on the lathe.
4. Measure the various cutting forces, i.e. feed force – F_x, thrust force – F_y and the main cutting force F_z using dynamometer for various cutting conditions.
5. Determine the cutting speed V in m/s by knowing the diameter of the work-piece and then find the power required.

Tabulation:

Sl. No.	Speed N, rpm	Feed f, mm/rev	Depth of cut, mm	Feed force F_x, N	Thrust Force F_y, N	Main cutting force F_z, N	Cutting speed V, m/s	Power in Watts

Calculations:

Cutting speed V = πdN/60000 m/s, where d is the diameter of the work piece in mm.
Power required = F_x * V Watts.

Results:

Verification:

Conclusions:

Post viva questions:

1. Explain bilateral tolerance.
2. Explain unilateral tolerance
3. What is dynamometer?
4. Types of dynamometers?