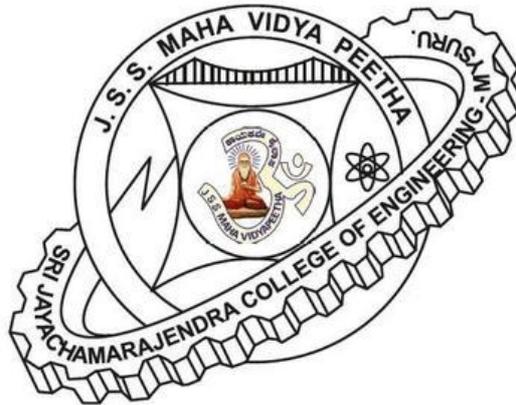


**JSS MAHA VIDYA PEETHA
JSS SCIENCE & TECHNOLOGY UNIVERSITY
(JSS&TU)
FORMERLY SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING
MYSURU-570006**

DEPARTMENT OF MECHANICAL ENGINEERING
Metrology and Measurement Laboratory Manual
IV Semester B.E. Mechanical Engineering



USN : _____
Name: _____
Roll No: _____ Sem _____ Sec _____
Course Name _____
Course Code _____

DEPARTMENT OF MECHANICAL ENGINEERING

VISION OF THE DEPARTMENT

Department of mechanical engineering is committed to prepare graduates, post graduates and research scholars by providing them the best outcome based teaching-learning experience and scholarship enriched with professional ethics.

MISSION OF THE DEPARTMENT

M-1: Prepare globally acceptable graduates, post graduates and research scholars for their lifelong learning in Mechanical Engineering, Maintenance Engineering and Engineering Management.

M-2: Develop futuristic perspective in Research towards Science, Mechanical Engineering Maintenance Engineering and Engineering Management.

M-3: Establish collaborations with Industrial and Research organizations to form strategic and meaningful partnerships.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1 Apply modern tools and skills in design and manufacturing to solve real world problems.

PSO2 Apply managerial concepts and principles of management and drive global economic growth.

PSO3 Apply thermal, fluid and materials fundamental knowledge and solve problem concerning environmental issues.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

PEO1: To apply industrial manufacturing design system tools and necessary skills in the field of mechanical engineering in solving problems of the society.

PEO2: To apply principles of management and managerial concepts to enhance global economic growth.

PEO3: To apply thermal, fluid and materials engineering concepts in solving problems concerning environmental pollution and fossil fuel depletion and work towards alternatives.

PROGRAM OUTCOMES (POS)

- PO1 Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- PO3 Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- PO4 Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- PO5 Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- PO6 The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- PO7 Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- PO8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- PO9 Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- PO10 Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- PO11 Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- PO12 Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

METROLOGY AND MEASUREMENTS LABORATORY

Subject Code	: ME46L	No. of Credits	: 0 – 0 - 1.5
No. of Practical Hours / Week	: 03	CIE Marks	: 50
Total No. of Practical Hours	: 39		

COURSE OBJECTIVES:

1. To provide students with the necessary skills for calibration and testing of different gauges and instruments.
2. To provide students with the necessary skills to collect data, perform analysis and interpret results to draw valid conclusions through standard test procedures using various metrology instruments.

COURSE CONTENT

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

1. Measurements using Optical Projector / Toolmaker Microscope.
2. Measurement of angle using Sine Center / Sine bar / bevel protractor
3. Measurement of alignment using Autocollimator / Roller set
4. Measurement of cutting tool forces using
 - a) Lathe tool Dynamometer
 - b) Drill tool Dynamometer.
5. Measurement of Screw threads Parameters using two wire or Three-wire methods.
6. Measurements of Surface roughness, Using Tally Surf/Mechanical Comparator
7. Measurement of gear tooth profile using gear tooth vernier /Gear tooth micrometer
8. Calibration of Micrometer using slip gauges
9. Measurement using Optical Flats

COURSE OUTCOMES:

Upon completion of this course, students should be able to:

- CO1** Demonstrate the necessary skills for calibration and testing of different gauges and instruments.
- CO2** Demonstrate the necessary skills to collect data, perform analysis and interpret results to draw valid conclusions through standard test procedures using various metrology instruments.

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INTRODUCTION

In science and engineering, objects of interest have to be characterized by measurement and testing. **Measurement** is the process of experimentally obtaining quantity values that can reasonably be attributed to a property of a body or substance.

- **Metrology** is the science of measurement.
- Metrology is also a fine avenue for discussing accuracy, error, and calibration.

Testing is the technical procedure consisting of the determination of characteristics of a given object or process, in accordance with a specified method

In metrology (the science of measurement), a standard is an object, system, or experiment that bears a defined relationship to a unit of measurement of a physical quantity.

Metrology is mainly concerned with the following aspects

- Unit of measurement and their standards.
- Errors of measurement.
- Changing the units in the form of standards.
- Ensuring the uniformity of measurements.
- New methods of measurement developing.
- Analyzing these new methods and their accuracy.
- Establishing uncertainty of measurement.
- Gauges designing, manufacturing and testing.
- Researching the causes of measuring errors.
- Industrial Inspection.

FUNCTIONS OF METROLOGY

- To ensure conservation of national standards.
- Guarantee their accuracy by comparison with international standards.
- To organize training in this field.
- Take part in the work of other National Organization.
- To impart proper accuracy to the secondary standards.
- Carry out Scientific and Technical work in the field of measurement.
- Regulate, supervise and control the manufacturer.
- Giving advice to repair of measuring instruments.
- To inspect and to detect guilty of measurement.

APPLICATIONS OF METROLOGY

- Industrial Measurement
- Commercial transactions
- Public health and human safety ensuring

NEED OF INSPECTION

To determine the fitness of new made materials, products or component part and to compare the materials, products to the established standard. It is summarized as

- To conforming the materials or products to the standard.
- To avoid faulty product coming out.
- To maintain the good relationship between customer and manufacturer.
- To meet the interchangeability of manufacturer.
- To maintain the good quality.
- To take decision on the defective parts.
- To purchase good quality raw materials.
- To reduce the scrap

NEED FOR MEASUREMENT

- ☐ To determine the true dimensions of a part.
- ☐ To increase our knowledge and understanding of the world.
- ☐ Needed for ensuring public health and human safety.
- ☐ To convert physical parameters into meaningful numbers.
- ☐ To test if the elements that constitute the system function as per the design.
- ☐ For evaluating the performance of a system.
- ☐ For studying some basic laws of nature.
- ☐ To ensure interchangeability with a view to promoting mass production.
- ☐ To evaluate the response of the system to a particular point.
- ☐ Check the limitations of theory in actual situation.
- ☐ To establish the validity of design and for finding new data and new designs.

METHODS OF MEASUREMENT

1. Direct comparison with Primary or Secondary Standard.
2. Indirect comparison with a standard through calibration system.
3. Comparative method.
4. Coincidence method
5. Fundamental method.
6. Contact method.
7. Transposition method.
8. Complementary method.
9. Deflection method.

1) Direct method :The value to be measured is directly obtained. Examples: Vernier calipers, Scales.

2) Indirect method:The value of quantity to be measured is obtained by measuring other quantities. Diameter measurement by using three wires.

3) Comparative method: In this method, the quantity to be measured is compared with other known value. Example: Comparators.

4) Coincidence method: The value of the quantity to be measured & determined is coincide with certain lines and signals.

5) Fundamental method: Measuring a quantity directly in related with the definition of that quantity

6) Contact method: The sensor or measuring tip of the instrument touches the area (or) diameter (or) surface to be measured. Example: Vernier caliper.

7) Transposition method: In this method, the quantity to be measured is first balanced by a known value and then it is balanced by other new known value. Example: Determination of mass by balancing methods.

8) Complementary method: The value of quantity to be measured is combined with known value of the same quantity. Example: Volume determination by liquid displacement.

9) Deflection method: The value to be measured is directly indicated by a deflection of pointer. Example: Pressure measurement

Accuracy and Error

You may have heard the expression “close enough for engineering.” It is a reference to **accuracy**— how good is the measurement (dimensional or otherwise)? More specifically, accuracy is a reference to the relative magnitude of the *error* in one or more measurements— how close is my measurement to the true value? Typically, one device (or technique, for that matter) is said to be more accurate than another because it gives measurements that have smaller errors.

Error in a measurement is classified into two types:

- **Bias errors** and
- **Precision errors.**

A measurement is accurate if both the precision error and bias error are low.

Figure 1 shows the relationship graphically. Precision error refers to the repeatability of a measurement: a group of measurements with a low precision error is always close to the same average value. However, this average value may not be the correct (i.e. true) value because of bias error. Bias error moves the average value away from the true value in a systematic (i.e. constant) way. On the other hand, a group of measurements with the correct average value,

but showing a great deal of scatter has a low bias error and a large precision error. So, precision error is a consequence of repeatability and bias error is a consequence of constant offset errors.

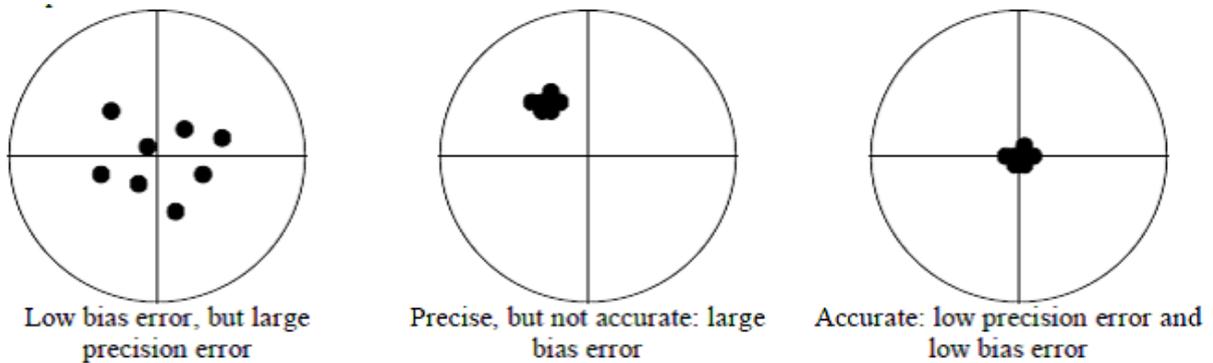


Fig1. Relationship of Accuracy, Precision Error and Bias Error

Calibration

A good measurement procedure is one which attempts to minimize these errors. An important part of this procedure is **calibration**— **the procedure of verifying the accuracy of the measurement device itself by measuring known quantities and comparing the output of the measurement instrument to the expected values.**

These “**known quantities**” are called **standards**. The **primary standard** is the internationally accepted definition of the quantity of interest, such as mass and length¹, and is maintained at a facility in France. A **mirror standard** is typically maintained in a national facility such **NIST** in the United States. **Secondary standards** are copies of the primary standard that are more accessible than the primary standard. These copies are rated, and can be certified as accurate to a certain level against the primary standard. For example, for verifying my electronic balance, I can purchase either ASTM Class 1 calibration masses, accurate to within **0.00025%** of their rated mass, or NIST Class F masses, accurate to within **0.01%**. Other than accuracy, the difference is a factor of ten in cost.

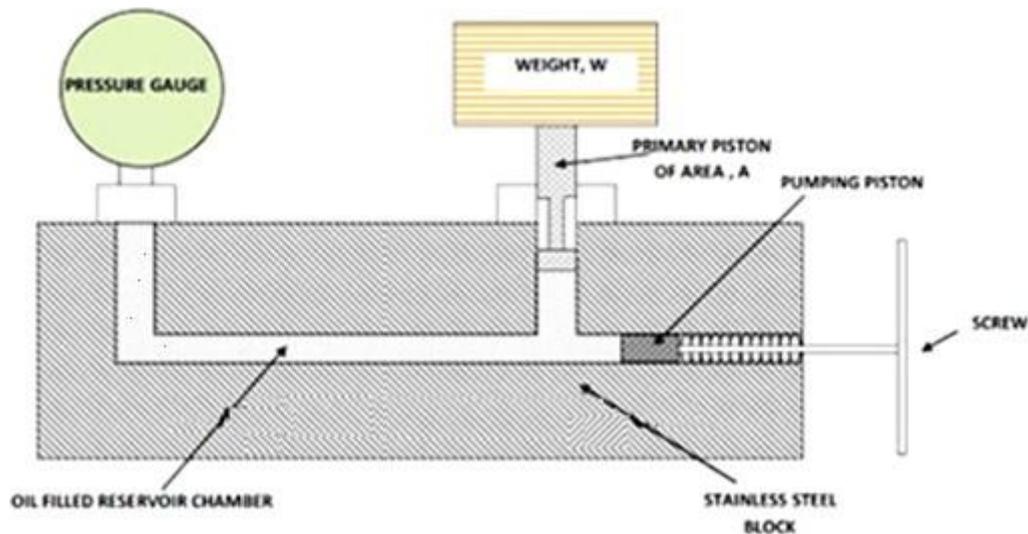
Note: Please note that this stated accuracy is an assessment of how closely these standards represent the true value relative to the primary standard.

EXPERIMENT NO.1

CALIBRATION OF PRESSURE GAUGE

Aim: To calibrate the given pressure and calculate the error

Theory: Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges.



A dead weight tester consists of a pumping piston with a screw that pressurizes the **oil** present in the cylinder which connects pressure gauge and primary piston. It works by loading the primary piston (**C/s area, A**) with the amount of **weight W**, that corresponds to the desired calibration pressure (**$P = W/A$**).

When the screw is turned, the fluid pressure increases both in the primary piston and gauge.

This pressure increase is indicated in the pressure gauge; simultaneously the primary piston raises the dead weight to the reference mark. The indicated gauge pressure is recorded and calibrated with the actual pressure acting on the primary piston with the dead weights.

Procedure:

1. The given pressure gauge is fixed in the proper position.
2. The barrel is filled with the oil.
3. The weight of the plunger and the diameter of the stem measured and the area of the cross section calculated.
4. The pressure is applied to the oil by turning the hand wheel, this is done till the certain pressure is built and the plunger is raised upto the reference mark.
5. A known weight is placed on the platform of the plunger.
6. The reading of the pressure gauge is noted and experiment is repeated by placing different weights on the plunger.
7. Actual pressure is calculated and the pressure indicated by the pressure gauge is compared.
8. Calibration curves are drawn (graph of Actual pressure v/s Indicated pressure are plotted).

Tabular Column

SL. NO	Weight on the plunger		Total weight (Wt of plunger +wt placed on the plunger) W		Actual pressure AP	Indicated pressure IP		Difference in pressure DP	% of error
	Kg	N	Kg	N	N/m ²	Kg/cm ²	N/m ²	N/m ²	

Observation:

1. Weight of the plunger, $W = \dots\dots\dots$ gms
2. Diameter of the plunger, $d = \dots\dots\dots$ mm

Calculation:

1. Area of cross section, $A = \pi d^2/4 = \dots\dots\dots$ m²
2. Actual pressure, $AP = \text{total weight} / \text{cross section area} = W/A = \dots\dots\dots$ N/m²
3. Difference in pressure, $DP = AP - IP = \dots\dots\dots$ N/m²
4. Percentage error = $DP \times 100 / AP$

Conclusion:

EXPERIMENT NO.2

CALIBRATION OF THERMOCOUPLE

Aim: To study about different Thermocouples and their calibration.

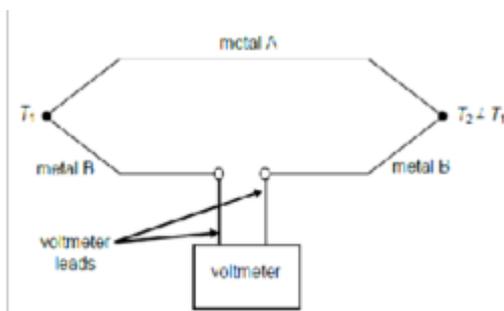
Theory:

Thermocouples, devices used to measure temperature, are composed of two dissimilar metals that produce a small voltage when joined together—one end of a thermocouple joins each metal.

The thermocouple is the most common type of temperature sensor, primarily because it is inexpensive and easy to use. Infact, it is used in many places familiar to you: in the home, it is used to control the temperature of the furnace, water heater, and the kitchen oven; in the automobile, it is used to monitor coolant and oil temperature, and even to control the air conditioner. It is not the most accurate technique available to measure temperature—typical thermocouples is accurate to around $\pm 0.5^{\circ}\text{C}$ —but for many applications this accuracy is acceptable.

Thomas Johann Seebeck (1770-1831) discovered that a circuit comprised of dissimilar metals produces a voltage (and current) when the two dissimilar junctions are exposed to different temperatures. This phenomenon, called the **Seebeck Effect**, is depicted in Figure below. The voltage produced is proportional to the temperature difference between the junctions. The voltage produced is small, on the order of millivolts, so it is not very suitable for producing power

1. But the device can easily be calibrated to measure temperature.

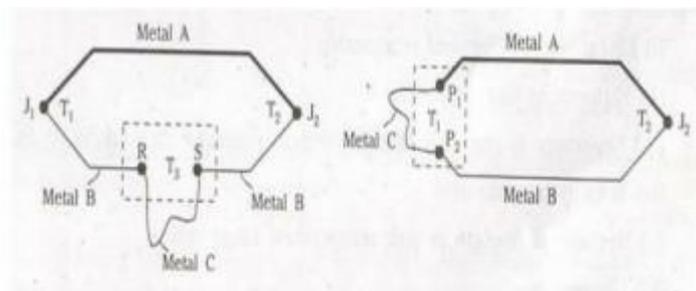


Thermocouple circuit connected to a voltmeter

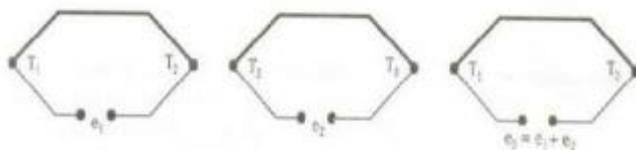
Laws of Thermocouples

The two laws governing the functioning of thermocouples are:

i) **Law of Intermediate Metals:** It states that the insertion of an intermediate metal into a thermocouple circuit will not affect the net emf, provided the two junctions introduced by the third metal are at identical temperatures. Application of this law is as shown in Fig. In Fig.(a), as shown in Fig. In Fig.(a), if the third metal C is introduced and the new junctions R and S are held at temperature T_3 , the net emf of the circuit will remain unchanged. This permits the insertion of a measuring device or circuit without affecting the temperature measurement of the thermocouple circuit. Circuits illustrating the Law of Intermediate Metals In the Fig.(b) The third metal is introduced at either a measuring or reference junction. Also junctions P1 and P2 are maintained at the same temperature T_P the net emf of the circuit will not be altered. This permits the use of joining metals, such as solder used in fabricating the thermocouples. In addition, the thermocouple may be embedded directly into the surface or interior of a conductor without affecting the thermocouple's functioning.



Circuits illustrating the Law of Intermediate Metals



Circuits illustrating the Law of Intermediate Temperatures

i) **Law of Intermediate Temperatures:**

It states that—If a simple thermocouple circuit develops an emf, e_1 when its junctions are at temperatures T_1 and T_2 , and an emf e_2 , when its junctions are at temperature T_2 and T_3 . And the same circuit will develop an emf $e_3 = e_1 + e_2$, when its junctions are at temperatures T_1 and T_3 . This is

illustrated schematically in the above Fig. This law permits the thermocouple calibration for a given temperature be used with any other reference temperature through the use of a suitable correction. Also, the extension wires having the same thermo-electric characteristics as those of the thermocouple wires can be introduced in the circuit without affecting the net emf of the thermocouple.

Classification of Thermocouples: 3 Types

1. **Nickel alloy thermocouples**

- Type E (chromel – constantan)
- Type J (iron – constantan)
- 3.1.3 Type K (chromel – alumel)
- 3.1.4 Type M (Ni/Mo 82%/18% – Ni/Co 99.2%/0.8%, by weight)
- 3.1.5 Type N (Nicrosil – Nisil)
- 3.1.6 Type T (copper – constantan)

2. **Platinum/rhodium alloy thermocouples**

- Type B
- Type R
- Type S

3. **Tungsten/rhenium alloy thermocouples**

- Type C
- Type D
- Type G

4. **Others**

Chromel – gold/iron alloy thermocouples

- Type P (noble metal alloy)
- Platinum/molybdenum alloy thermocouples
- Iridium/rhodium alloy thermocouples

Pure noble metal thermocouples Au–Pt, Pt–Pd

Applications

Steel industry

Type B, S, R and K thermocouples are used extensively in the steel and iron industries to monitor temperatures and chemistry throughout the steel making process.

Gas appliance safety

Heating appliances such as ovens and water heaters make use of a pilot flame to ignite the main gas burner when required

Thermopile radiation sensors Thermopiles are used for measuring the intensity of incident radiation, typically visible or infrared light, which heats the hot junctions,

Procedure:

1. Oil is heated in a container and temperature is measured by means of a thermometer.
2. Two set of thermocouples each containing Copper- constantan and Chromel- Alumel is located at different height.
3. For every observed readings temperature in $^{\circ}\text{C}$ or corresponding millivolt reading is noted down
4. The readings of different thermos couples are read
5. The readings are taken at intervals of $4-5^{\circ}\text{C}$
6. The experiment is repeated in opposite direction i.e. as oil cools down from high temperature to room temperature corresponding millivolt or $^{\circ}\text{C}$ readings are noted down
7. A graph of Temperature in $^{\circ}\text{C}$ (thermometer reading) versus thermos couple reading is plotted

Tabular Column:

Sl.no	Thermocouple reading (^C) T1	Thermometer reading (^C) T2	Difference in Temperature(^C) T=T1-T2	%Error T*100/T2
Heating				
Cooling				

Results: The given thermocouple is calibrated Using

EXPERIMENT NO.3
CALIBRATION OF LINEAR VARIABLE DIFFERENTIAL
TRANSFORMER (LVDT)

Aim : To calibrate the LVDT using micrometer / to study the characteristics of LVDT

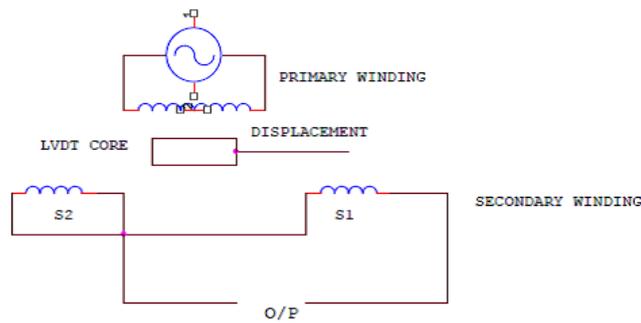
Apparatus Required : 1. LVDT, 2. Displacement micrometer

Theory : The linear variable differential transformer (LVDT) (also called differential transformer, or linear variable displacement transducer) is a type of electrical transformer used for measuring linear displacement (position).

LVDTs are robust, absolute linear position/displacement transducers; inherently frictionless, they have a virtually infinite cycle life when properly used. As AC operated LVDTs do not contain any electronics, they can be designed to operate at cryogenic temperatures or up to 1200 °F (650 °C), in harsh environments, under high vibration and shock levels. LVDTs have been widely used in applications such as power turbines, hydraulics, automation, aircraft, satellites, nuclear reactors, and many others. These transducers have low hysteresis and excellent repeatability.

The linear variable differential transformer has three solenoidal coils placed end-to-end around a tube. The center coil is the primary, and the two outer coils are the top and bottom secondaries. A cylindrical ferromagnetic core, attached to the object whose position is to be measured, slides along the axis of the tube. An alternating current drives the primary and causes a voltage to be induced in each secondary proportional to the length of the core linking to the secondary. The frequency is usually in the range 1 to 10 kHz.

CIRCUIT DIAGRAM:



As the core moves, the primary's linkage to the two secondary coils changes and causes the induced voltages to change. The coils are connected so that the output voltage is the difference (hence "differential") between the top secondary voltage and the bottom secondary voltage. When the core is in its central position, equidistant between the two secondary, equal voltages are induced in the two secondary coils, but the two signals cancel, so the output voltage is theoretically zero. In practice minor variations in the way in which the primary is coupled to each secondary means that a small voltage is output when the core is central.

Procedure

Experiment can be carried out for both **positive** and **negative** sides.

- 1) Connect the LVDT and digital displacement together.
- 2) The Core is initially brought to null position, (exactly set the micrometer to 12.5mm **(null position)**)
- 3) Switch on the power supply.
- 4) Set the potentiometer meter to shows zero
- 5) Set the potentiometer to read full-scale reading of the calibrated range.
- 6) Now make the display to read zero by adjusting the core of the displacement transducer.
- 7) Now the indicator is ready to displacement in both directions.
- 8) Record the initial micrometer readings. (null positions)
- 9) Set the micrometer in steps of 0.5mm and record the indicator reading.
- 11) Plot the graph micrometer v/s indicator.

- 12) Set the micrometer towards the negative side in steps of 0.5mm and record the indicator reading.
- 13) Tabulate the reading and plot the graph micrometer v/s indicator.

Observation

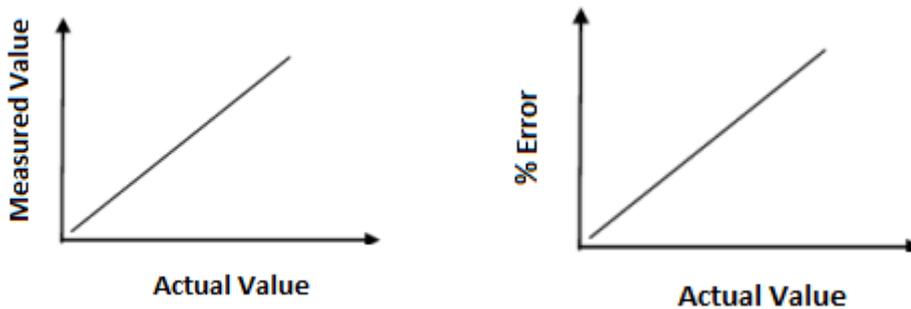
Formula

$$\% \text{ Error} = (\text{LVDT Reading} - \text{Micrometer Reading}) / \text{Micrometer Reading} * 100$$

Tabular Column:

Sl. No.	Micrometer reading mm	LVDT reading			Error	%Error
		+ve	-ve	Mean		
1						
2						
3						
4						
5						
6						

Model Graph



Results: The given LVDT is calibrated using external micrometer as standard, also LVDT is calibrated for negative and positive displacement.

EXPERIMENT NO: 4

CALIBRATION OF LOAD CELL

Aim: To calibrate the given load cell and to calculate the error.

Apparatus Required: Load cell and Weights.

Theory:

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various types of load cells include hydraulic load cells, pneumatic load cells and strain gauge load cells.

A load cell is typically a stiff and precise spring that outputs a relatively large electrical signal directly proportional to the force on the device. Applying a force to this spring produces strain that causes small deformations in the load-cell material.

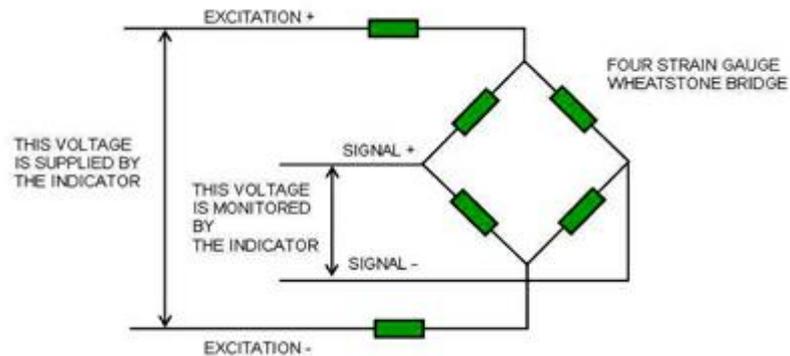
These deformations directly transfer to strain gages strategically bonded to the load cell. In turn, the dimensional change of the bonded strain gages produces a resistance change in each individual gage. The cells are typically arranged in a Wheatstone bridge configuration to produce an electrical output whose polarity depends on whether the load cell is loaded in compression or tension.

ISO17025 and ANSIZ540 dictate that the procedures used for calibration must be validated and uncertainties determined, but it is ASTM E74 that defines the specific procedure used to determine the uncertainty of calibrating a load cell.

Applications:

Load cells are designed to sense force or weight under a wide range of adverse conditions; they are the most essential part of an electronic weighing system. Load cells are used in several types of measuring instruments such as universal testing machines to accurately measure force in tension/compression.

Weighing systems both static and dynamic applications, in road and railway weigh bridges, in electrical over head travelling cranes, roll force measurement in steel plants /rolling mills, Weight bridges in conveyers & bunkers.



Procedure:

1. The given load cell is fixed to a hook suspended from the frame and lead wire is connected to the load cell indicator.
2. At one end of the load cell the load carrying pan is fixed.
3. A load indicator is first set to read zero after the pan is fixed by turning the zero setting knob.
4. A known weight is placed on the pan and indicator reading is noted.
5. Repeat the experiment by placing different weights on the pan.
6. Readings are tabulated and calibration curve is plotted (A graph of actual weight v/s indicated weight are plotted).

Tabular Column:

SL No.	Weight placed on the pan (Actual reading)		Load indicator reading (indicated reading)	Error	% of Error
	lbs	kgs	kgs	kgs	
01.					
02.					
03.					
04.					

Calculation:

01. Error = Actual reading – Indicated reading = _____ kgs.

02. %Error = (Error X 100) / Actual reading.

Result: The given load cell is calibrated using standard weight and the values are tabulated.

The load cell is calibrated in the range 1 to 6kg.

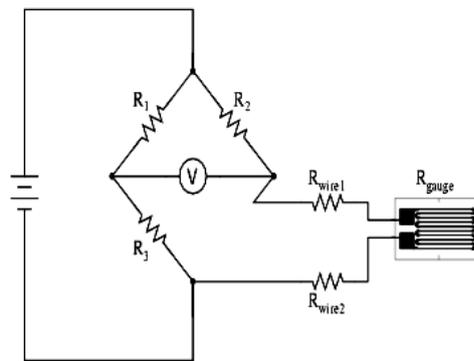
EXPERIMENT NO. 5

DETERMINATION OF MODULUS OF ELASTICITY OF A MILD STEEL SPECIMEN USING STRAIN GAUGES.

Aim : To determine the Young's modulus of a given material and to draw graphs of bending stress v/s Bending strain.

Apparatus Required: Cantilever beam with strain gauges, Micro strain indicator, loading device, Weights.

Theory:



A strain gauge is a long length of conductor arranged in a zigzag pattern on a membrane. When it is stretched, its resistance increases.

Electrical resistance of a piece of wire is directly proportional to the length and inversely to the area of the cross section. Resistance strain gage is based on that phenomenon

If a resistance strain gage is properly attached onto the surface of a structure which strain is to be measured, the strain gage wire/film will also elongate or contract with the structure, and as mentioned above, due to change in length and/or cross section, the resistance of the strain gage changes accordingly. This change of resistance is measured using a strain indicator (with the Wheatstone bridge circuitry), and the strain is displayed by properly converting the change in resistance to strain.

Every strain gage, by design, has a sensitivity factor called the **gage factor** which correlates strain and resistance as follows:

$$\text{Gage factor (F)} = (\Delta R / R) / \epsilon$$

Where: **R** = Resistance of un-deformed strain gage
R = Change in resistance of strain gage due to strain

The objective is to experimentally determine the system sensitivity and compare it to the ideal sensitivity of a strain gage measurement system. The actual system sensitivity will then be used to determine the modulus of elasticity of a cantilever beam.

When the beam is loaded, bending moment and shear forces are set up at all the sections of the beam. The bending moment tends to deflect the beam and hence internal resistance is built up. These stresses are known as bending stress and the resulting strain is called bending strain.

PROCEDURE: -

1. A flat rectangular M.S. specimen is held as cantilever
2. The strain gauge is fixed and the strain indicator is calibrated.
3. A known weight is placed at the specified distance from the fixed end.
4. Strain indicator reading is noted down.
5. The experiment is repeated for different loads and the results are tabulated.
6. The graph of stress v/s strain is plotted and young's modulus of elasticity is determined by graph.

OBSERVATION:-

Resistance of the strain gauge = _____ Ω

Length measure from the cantilever beam to the load position: L= _____ m

Width of the cantilever beam: b= _____ m

Thickness of the cantilever beam: t= _____ m

SL. no	Total weight 'F'		Bending moment M N-m	Stress σ N/m ²	Strain meter reading in Micro strain $\times 10^{-6}$ (ϵ)	Young's modulus E N/m ²
	kg	N				

CALCULATIONS:-

We know that from bending equation

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

Where

M=bending moment = F*L in N-m.

L=Length of the cantilever beam in m

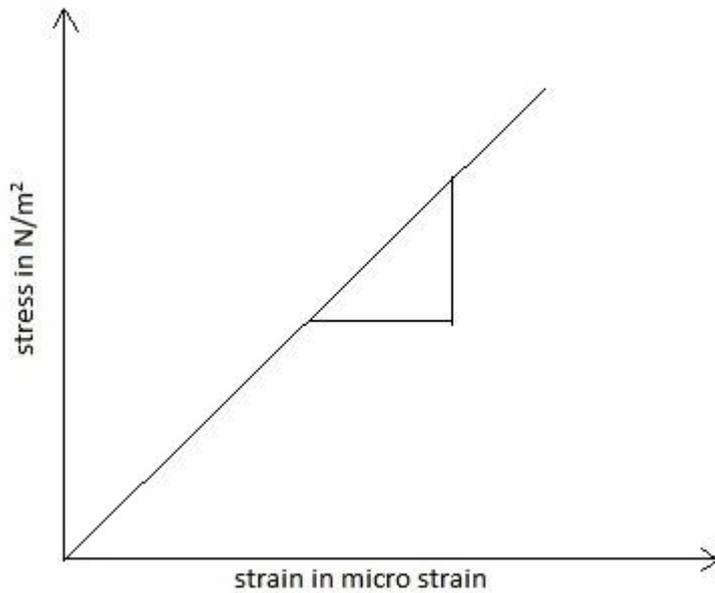
I =Moment of inertia = $bt^3/12$ in m^4

σ =bending stress in N/m^2

$Y = t/2$ in m

$$\sigma = \frac{M \times Y}{I} \quad N/m^2$$

$$\text{Young's modulus} = \frac{\sigma}{\epsilon} \quad N/m^2$$



$$E = \frac{\Delta\sigma}{\Delta\epsilon}$$

Slope: $(\Delta Y / \Delta X)$ gives Young's modulus of specimen (from graph)

Result: Using the strain gauges, Young's Modulus of the given mild steel specimen has been determined.

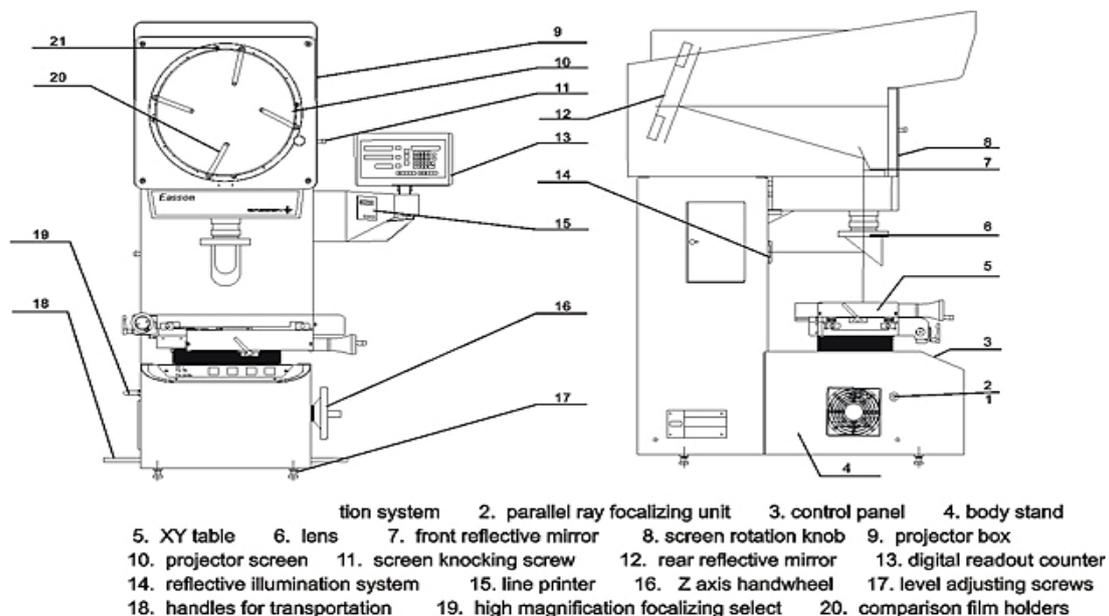
EXPERIMENT NO.6

MEASUREMENTS USING PROFILE PROJECTOR

Aim: To measure the thread parameter of given screw thread using profile projector.

Operators Required: Profile projector, thread specimen, gear.

Theory: The optical comparator is a device that applies the principle of optics for the inspection of manufactured parts. The profile projector is basically an optical instrument which makes use of enlarged instruments. The purpose of the optical projector is to compare the shape or profile of relatively small engineering compound with an accurate standard or drawing. The projector magnifies the profile of specimen and shows this on the built in projection screen. From this screen there is usually grid that could be rotated 360 degrees. Therefore the XY axis of the screen could be aligned correctly using straight edge of machine part to analyze or measure. Dimension can be directly measured on the screen or compared to the standard reference.



Procedure:

1. Calculate the least count of micrometer of the projector.
2. Fix the given test specimen under the magnifying lens on the fixture provided.
3. Select a suitable magnification.
4. Switch on the projector and focus to obtain the clear image of the object on screen.
5. Adjust the reference axis (core wire) to a point of element by adjusting the micrometer and angular disc.
6. Note down the initial reading of micrometer.

Thread parameters found using profile projector.

- Major diameter = _____ mm
- Minor diameter = _____ mm
- Pitch of screw = _____ mm
- Depth of thread = _____ mm
- Angle of thread = _____ degree

Observation:**Reading from the profile projector.**

MR₁=

MR₂=

MR₃=

MR₄=

MR₅=

MR₆=

MR₇=

MR₈=

MR₉ =

N=number of thread between two end points

Major diameter= MR₁-MR₄

Minor diameter=MR₂-MR₃

Pitch diameter=MR₂-MR₄

A)depth of thread =MR₁-MR₂

B)depth of thread =MR₃-MR₄

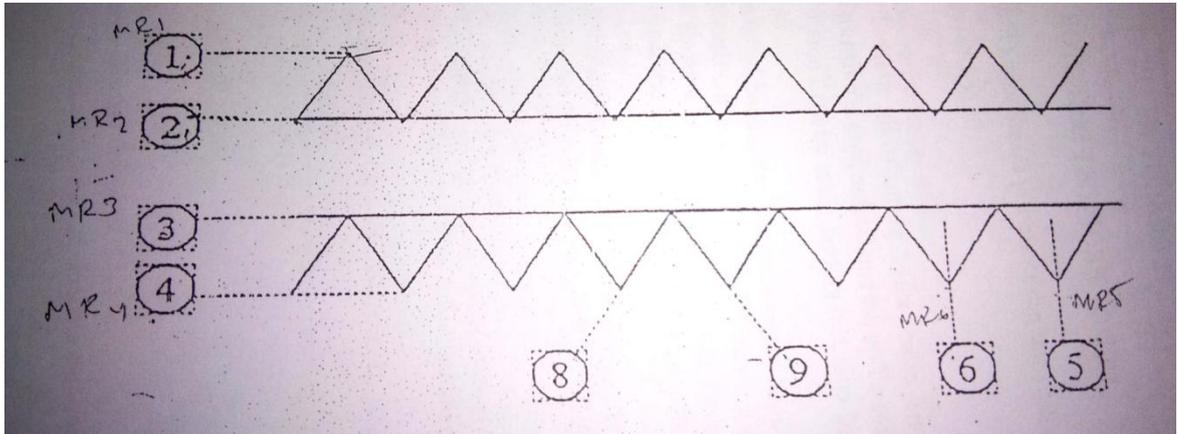
Average depth =(A+B)/2

Pitch= $MR_5 - MR_6$

Average pitch= $(MR_5 - MR_7) / 2$

Angle of thread= $MR_8 - MR_9$

Flank angle= $(MR_8 - MR_9) / 2$



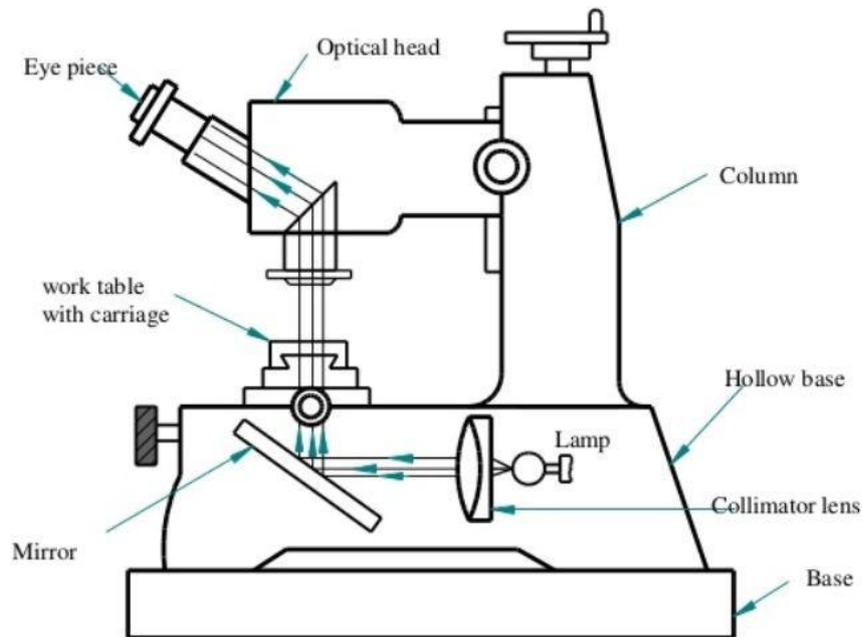
Results:

EXPERIMENT NO: 07

USE OF TOOL MAKER'S MICROSCOPE

AIM: To determine the various thread parameters using a tool maker's microscope.

APPARATUS REQUIRED: 1. Anvil Micrometer 2. Pointed Micrometer
3. Pitch gauge 4. Tool Maker's microscope.



PROCEDURE:

Before measuring different thread parameters on Tool maker's microscope, measure the major diameter, pitch diameter, the pitch of the thread using V-anvil micrometer, pointed micrometer and pitch gauge respectively. Then the different thread parameters like, major diameter, minor diameter, pitch diameter, pitch, average pitch and helix angle of the thread are determined by positioning the cross-wires at different positions as shown in the fig.1. Then different reading are taken at respective positions using the cross-wire and longitudinal micrometer. The angular readings are obtained with the help of the circular scale provided in the geometric head. The readings at different positions are tabulated as follows:

READINGS FROM MICROSCOPE.

(MR-Microscope Reading in mm)

MR1=

MR2=

MR3=

MR4=

MR5=

MR6=

MR7=

MR8=

MR9=

N=No. of threads between two end points.

Major diameter = MR1~MR4.

Minor diameter = MR2~MR3.

Pitch diameter = MR2~MR4 or MR1~MR3.

A) Depth of the Thread =MR1~MR2.

B) Depth of thread = MR3~MR4.

Average Depth = (A+B)/2.

Pitch = MR5~MR6.

Average pitch = (MR5~MR7)/2.

Angle of Thread =MR8~MR9.

Flank angle =(MR8~MR9)/2.

Reading of the Vernier caliper/depth gauge is given by the expression,

$$T.R= MSR+CVSD*LC$$

Where,

TR= Total reading.

MSR=Main scale reading.

CVSD=Coinciding Vernier scale division.

LC= Least count.

Observation:

Instrument:

Make:

Range:

L.C :

Measurement using micrometer:

For taking the measurement, using micrometer place the specimen between the anvils of the micrometer and rotate the thimble till the spacing between the anvils is slightly more than the dimension to be measured. Then rotate the ratchet screw till the jaws have proper contact with the specimen. The necessary pressure to be applied can be recognized from the ratchet arrangement. Sufficient pressure is obtained. Now lock the spindle and note down the micrometer reading.

L.C of the micro meter can be determined using the expression,

$$L.C = \text{Pitch} / (\text{No. of HSD})$$

Pitch scale reading (PSR)=

Least count(L.C)=

No. of head scale divisions(HSD)=

$\text{Total reading (TR)} = \text{PSR} + \text{HSD} * \text{LC}$

Results: The pitch and angle of the given object is measured with toolmakers microscope are tabulated

EXPERIMENT NO : 8

USE OF SLIP GAUGES, SINE BARS AND SINE CENTERS

AIM: To set the required angle using slip gauges and sine bar and to measure the taper angle of the given specimen using sine center and slip gauges.

APPARATUS REQUIRED:

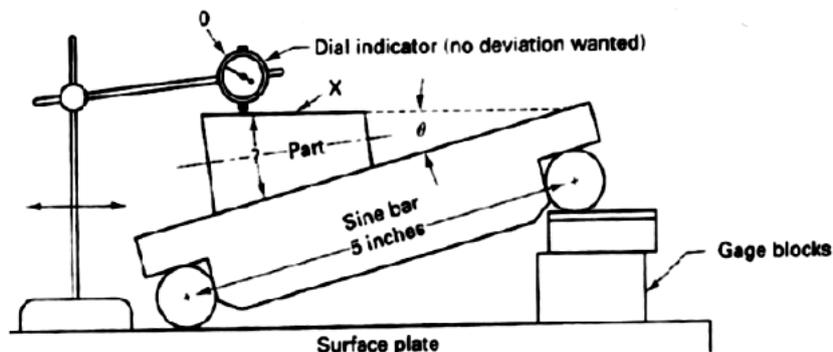
1.Surface plate. 2.slip gauges. 3.Sine bar. 4.Bevel protractor combination square. 5.sine center. 6.Dial indicator. 7.Vernier caliper. 8.Magnetic Stand/height gauge.

THEORY:

Theory: Sine bar is based upon laws of trigonometry. To set a given angle one roller of the bar is placed on the surface plate and the combination of slip gauges is inserted under the second roller as shown in the figure. If **h** is the height of the combination of the slip gauges, **l** is the distance between roller centers,

Therefore, $\theta = \sin^{-1} (h/L)$

Then the angle can be measured as a function of sine. Thus, it is called **Sine bar**.



Requirements of a Sine bar:

- The axes of the roller must be parallel to each other and the center distance **L** must be known.
- The top surface of the bar must have a **high degree of flatness**.
- The **roller must be of identical diameters** and round within a close tolerance.

Depending upon the accuracy of the center distance, sine bars are graded as of **A grade or B grade**. **B grade** - Sine bars are guaranteed accurately **up to 0.02 mm /meter of length** and **A grade sine bars** are more accurate and guaranteed **up to 0.01 mm/meter of length**.

Procedure:

1. The sine bar is made to rest on surface plate with rollers contacting the datum.
2. Place the component on sine bar and lock it in position.
3. Lift one end of the roller of sine bar and place a pack of slip gauge, underneath the roller.

Height of the slip gauges (h) should be selected such that the top surface of component is parallel to the datum plate.

4. Record the final height of the slip gauge combination for achieving parallelism.

5. **Calculate inclination $\theta = \sin^{-1} (h/L)$**

Setting the given sine bar to the given angle:

Take note of the given angle for which the top surface of the sine bar is to be set.

1. Theoretically calculate the height of the slip gauge required to lift one end of sine bar such that top surface of the sine bar make the required slope.

Approximate height of slip gauge used= $H_{app.}$

$$H_{app.} = \frac{dh \times L}{\sqrt{dh^2 + l^2}} \text{----- mm}$$

2. Insert the selected combination of slip gauge under one end of the sine bar.
3. Use dial gauge with stand and traverse the plunger of the dial gauge over a known length and check the slope of the sine bar

Limitations:

1. Sine bar is reliable for angles less than **15°**, and the angle above **45°**.
2. Slightly errors of the sine bar cause larger angular errors.
3. Size of the parts which can be impacted by sine bar is limited.

PROCEDURE:

To set the required angle using slip gauges and sine bar.

1. Measure the length of sine bar (Distance between the centers of two rollers)
2. Calculate the height of the slip gauges required for setting the required angle using the formula, $H=L \times \text{Sine} \theta$
3. Select and clean the required sizes of slip gauges and wring them together to get the required dimension.
4. Place the pile of slip gauges below the roller of the sine bar carefully.
5. Check the setup angle using either a bevel protractor or combination square (While using combination square ensure that the air bubbles lies in the mid position).
6. If found incorrect, change the slip gauge combination suitably and correct it to the required angle.

OBSERVATION:

Length of the sine bar, L=

Angle to be set =

Slip gauge combination used =

To measure the angle of taper of a given tapered specimen using slip gauges and sine center

PROCEDURE:

1. First, the length of the tapered section, major and minor diameter of the given specimen are measured using Vernier caliper/micrometer and the approximate half taper angle is calculated using the formula.

$$\theta = \tan^{-1} \left(\frac{D - d}{2l} \right)$$

2. The taper specimen is mounted in between the centers of sine center and is placed over the surface plate. A Vernier height gauge/magnetic stand fitted with dial indicator is also placed on the surface plate.
3. Using the calculated value of taper angle, the required height of slip gauges is calculated using the formula, $H=L \cdot \sin \theta$ and the combination is built

up. One end of the sine center is lifted up and one of its roller is placed carefully on the pile of slip gauges.

4. Now to verify the angle, bring the height gauge near the work piece and make the tip of the dial indicator touch the diameter of the taper at one and make the dial indicator reading zero.

5. Now the height gauge or magnetic stand fitted with dial indicator is moved parallel to the work piece axis and the pointer is made to rest on the other end of the tapered length. If no deflection is observed in the indicator, the angle calculated is correct. Otherwise, the height of the slip gauges is to be corrected till we get the same reading on the dial indicator at both the taper end. The height to be corrected can be determined using the relation.

$$H = y * \frac{L}{L1}$$

The correct taper angle can be calculated using the corrected height of the slip gauge as follows:

$$\theta = \sin^{-1} \left(\frac{H \pm h}{L1} \right)$$

OBSERVATION:

- 1. Length of the sine center =L=
- 2. Length of the tapered portion =L1=
- 3. Major diameter =D=
- 4. Minor diameter =d=
- 5. Height of slip gauge =H=
- 6. Corrected height of slip gauge =h=
- 7. Half tapered angle =
- 8. Reading in dial indicator =y=

Sl.no	ANGLE	SLIP GAUGE COMBINATON

EXPERIMENT NO.9

USE OF AUTO COLLIMATOR

AIM: To determine the parallelity, perpendicularity of given specimen using Auto collimator.

APPARATUS REQUIRED :

1.Auto collimator 2.Surface plate 3.Highly polished mirror 4.Try square.

THEORY:

Auto-collimator is basically a telescope permanently focused for infinity. This is a sensitive extremely accurate optical instrument which is used in workshops for inspecting straightness, squareness and parallelism. The instrument uses the basic principle of reflection.

A plane parallel beam of light projected on to a plane reflecting surface placed normal to the beam is reflected back along the same path. When the surface is slightly tilted the reflected beam returns but in deviated path. The angle of direction is taken as a measure to check the straightness.

PRINCIPLE OF MEASUREMENT:

The optical arrangement adopted for autocollimator is as shown in fig. Light rays from the light source will be reflected partially in to the optical axis by half-reflecting layer in the prism. Then, passing through the objective the light rays become parallel and reach the mirror 'M' placed at a distance in front of the objective. The light beam thus, reflected back by the mirror surface will pass through the objective again and further through the half-reflecting layer in the prism, forming an image S1 of the cross-hair S on the rectile.

If the mirror is tilted by a minute angle of θ° from position A to B, the reflected light beam, being inclined at $2\theta^\circ$, will re-enter the objective, causing a displacement of 'd' to the image of the cross-hair. This interrelation can be expressed by the formula,

$$d = f * \tan(2\theta) = 2f * \theta$$

where,

'f' is the focal length of the objective. By reading the value of 'd' with the scale provided on the article the tilt angle of the mirror can be determined.

In the auto collimator Model-6D, two vertical and horizontal scales are engraved at right angles on the reticle with one division of 1' and the fractional value of 1' can be read down to 0.6" by moving the reticle precisely with the micrometer.

INITIAL SET UP:

1. Set the compensator ring to 100.
2. Set the reading of the micrometer to 'zero'.
3. Place the reflecting mirror on the work piece to be tested at a distance between 0.9 to 1.4 meters.
4. Approximately align the collimator such that the green light is visible in the reflecting mirror when viewed from one side of the collimator tube.
5. Get the cross wire in the field of view by swinging the collimator tube along vertical and horizontal axis.

NOTE: While swinging the collimator tube, at most care must be taken, as these are chances of collimator tube hitting the surface plate and may cause damage. After getting the cross wires in the field of view lock all the locking knobs firmly.

6. Using the fine adjustment knobs provided at the bottom of the collimator bracket, bring the cross wires to align at the center of the scale. Then the measurements are made as explained below.

READING AND CALCULATIONS: (For Straightness Measurements)

1. Set the successive measuring points at some interval and call such points as C, D in the order from the autocollimator.
2. Move the mirror across various distances and make autocollimations at respective points in the tabular column, with the help of the autocollimator scale and the micrometer. This represents the differences in 'θ' from the zero position with '±' sign according to the moving direction of the cross wire from the zero position.
3. Find the amount of linear variation corresponding to the angular values using the relation,

$$h = L \sin \theta$$

where,

h = Difference in height between two successive points.

L = Length of successive measuring points.

θ = Angle noted between two successive points.

Then tabulate the reading of 'h' in the tabular column.

4. Write the accumulated values in the next row and draw a graph with successive lengths on X-axis and the accumulated reading at different points on Y-axis.
5. Join the end points by a straight line and tilt this line such that it becomes parallel to the X-axis. Now transfer the perpendicular heights from this line to get the total deviation p present on the component. The height between the peak points on the positive and negative coordinates will indicate the error of straightness.

TABULATION:

SL. NO.	DETAILS	MEASURING POINTS				
		A	B	C	D	E
1.	Read out angles by auto collimator (difference from the read out angle)					
2.	(Deviations for each 100 mm)					
3.	Accumulated values					

PRINCIPLE OF AUTOCOLLIMATOR:

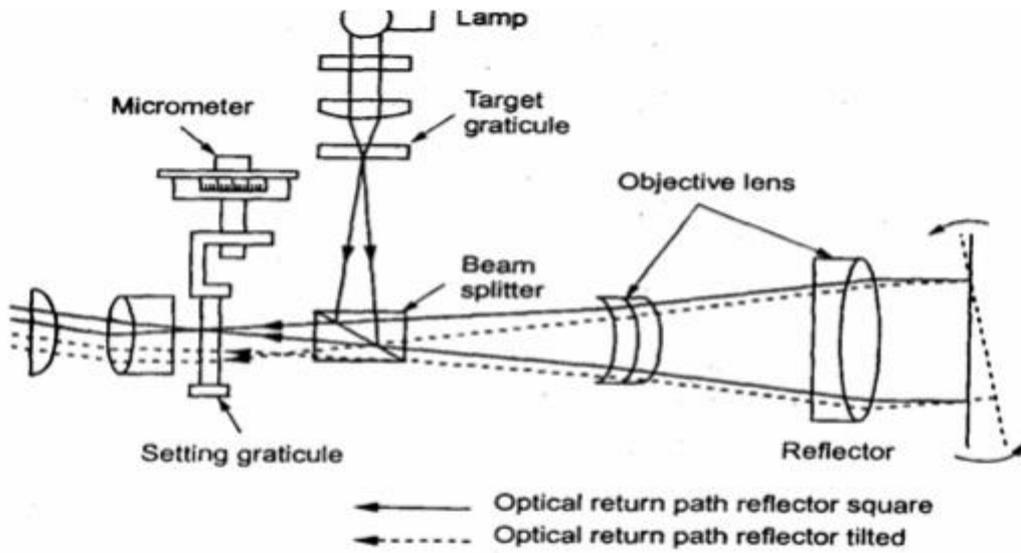


Fig 2.26 Line diagram of an injected graticule auto-collimator

Results: Measured the Straightness and Flatness of the given specimen using Auto Collimator

EXPERIMENT NO. 10
LATHE TOOL DYNAMOMETERS

AIM: To determine cutting force and power absorbed in turning process on lathe.

APPARATUS REQUIRED: Lathe tool Dynamometer.

APPARATUS DESCRIPTION: The instrument comprises of digital display calibrated to read 3 forces at a time along X, Y, Z directions. It has been built in excitation supply with independent null balancing for respective strain gauge bridge. Within the given range, the display is calibrated for respective force.

SPECIFICATION:

Range of force: 500kgf in X,Y,Z directions.

Bridge Resistance: 350Ω

Bridge Voltage: J2V Max.

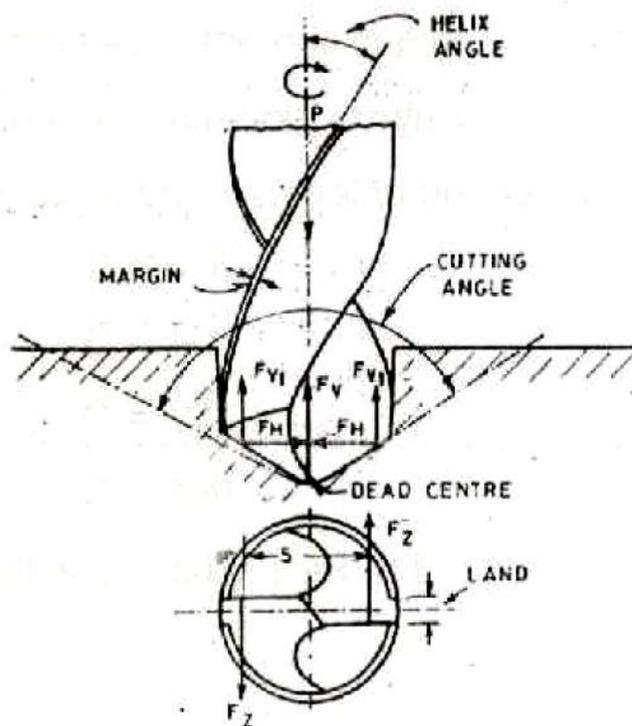
THEORY :

In machining or metal cutting operation the device used for determination of cutting forces is known as a Tool Dynamometer or Force Dynamometer. Majority of dynamometers used for measuring the tool forces use the deflections or strains caused in the components, supporting the tool in metal cutting, as the basis for determining these forces. In order that a dynamometer gives satisfactory results it should possess the following important characteristics:

- It should be sufficiently rigid to prevent vibrations.
- At the same time, it should be sensitive enough to record deflections and strains appreciably.
- Its design should be such that it can be assembled and disassembled easily.
- A simpler design is always preferable because it can be used easily.
- It should possess substantial stability against variations in time, temperature, humidity etc.
- It should be perfectly reliable.
- The metal cutting process should not be disturbed by it, i.e. no obstruction
- should be provided by it in the path of chip flow or tool travel.

PROCEDURE:

1. Fix the lathe tool dynamometer in the tool post, using the central hole provided on the dynamometer. Ensure that the object being turned as a smooth surface and the tool tip exact at center height.
2. Plug the Power cable to the main supply.
3. Connect one end of the interconnecting cables to X,Y,Z output socket of the dynamometer and the other end to the sensor socket on the front panel of the instrument.
4. Set the RED-CAL switch at READ position.
5. Switch on the instrument by placing the power on switch ON position.
6. Adjust the potentiometer such that the display reads zero.
7. Turn on the RED-CAL switch to CAL. Adjust the CAL-Potentiometer until the display reads the range of force. This operation is to be conducted when dynamometer is not having any load applied on it.
8. Turn back the READ-CAL switch to READ position. Now the instrument is calibrated to read force value upto calibrated capacity of the dynamometer in respective X,Y,Z axis.
9. If a recording oscilloscope or oscilloscope is to be used to connect them to the recorder output terminals.
10. The forces applied on dynamometer are to be read on analogmeter. Connect the 6-core cable provided with the instrument from back panel of the multifore indicator to the back panel of analog display.



Force system in Drilling.

OBSERVATION:

1. Initial diameter of the specimen(D)=_____mm
2. Speed(N)=_____RPM
3. Depth of cut/pass=_____mm

TABULAR COLUMN:

SL NO.	FORCE IN kgf			DEPTH OF CUT (mm)	DIAMETER (mm)	RESULTANT FORCE(F _R)		CUTTING SPEED V _C (m/s)	POWER (WATTS)
	F _X	F _Y	F _Z			kg	N		

CALCULATIONS:

Diameter=Initial diameter-(2*Depth of cut) mm.

$$\text{cutting speed } (V_C) = \frac{\pi DN}{1000 * 60} \quad \frac{m}{s}$$

Where D =Diameter of Work Piece in mm.

N =RPM.

Power= $P=Fr \times V_C$ watts.

Where Fr =Resultant Force = $\sqrt{F_x^2 + F_y^2 + F_z^2}$ N

V_C =Cutting Speed (m/s).

RESULTS: The resultant forces are found out for different speeds (V) by lathe tool dynamometer

EXPERIMENT NO.11

TWO WIRE AND THREE WIRE METHOD OF EFFECTIVE DIAMETER MEASUREMENT USING FLOATING CARRIAGE MICROMETER.

AIM: To determine the major and effective diameter of the given threaded component.

APPARATUS REQUIRED:

1. Floating carriage machine
2. Standard wires
3. Standard cylinder.

THEORY:

1. Two wire and three method of effective diameter measurement.
2. Care to be taken while handling Floating Carriage Diameter Measuring Machine.
3. Best size of wires.

Floating Carriage Micrometer (FCM):

Effective Diameter Measuring Micrometer (EDMM) is also commonly known as FCM or Floating Carriage Micrometer. This instrument is used for accurate measurement of 'Thread Plug Gauges'. Gauge dimensions such as Outside diameter, Pitch diameter, and Root diameter are measured with the help of this instrument. In order to ensure the manufacture of screw threads to the specified limits laid down in the appropriate standard it is essential to provide some means of inspecting the final product. For measurement of internal threads thread plug gauge is used and to check these plug gauges Floating Carriage Micrometer is used for measuring Major, Minor and Effective diameter.

The pitch diameter is the diameter of an imaginary cylinder which passes through the thread profile at such points as to make the widths of thread groove and thread ridge equal. The correct pitch diameter assures that the threaded product or thread gage is within required limits in producing interchange ability and strength. Periodic measurement of the pitch diameter is recommended to determine whether a thread gage is worn below tolerance.

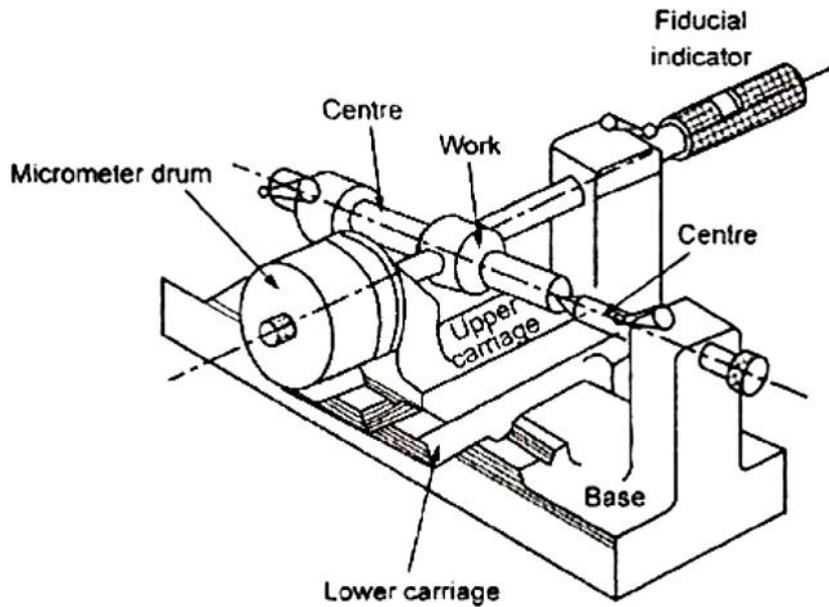
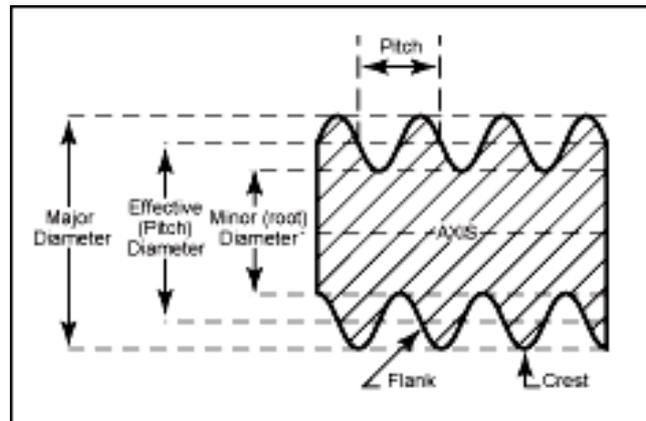
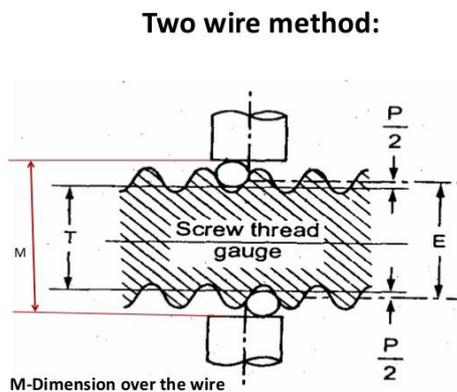


Fig. Floating Carriage Micrometer
Two-wire method



- The effective diameter cannot be measured directly but can be calculated from the measurements made.
- Wires of exactly known diameters are chosen such that they contact the flanks at their straight portions
- If the size of the wire is such that it contacts the flanks at the pitch line, it is called the best size of wire which can be determined by the geometry of screw thread.

The screw thread is mounted between the centers and wires are placed in the grooves and reading is taken.

PROCEDURE:

PRINCIPLE OF MEASUREMENT:

The floating carriage diameter measuring machine is primarily used for measuring, major, and effective diameters of thread gauges and precision threaded components. The instrument has a meaning accuracy of 0.0002mm. It consists of a sturdy cast-iron base, two accurately aligned and adjustable centers. At right angles to the axis of centers, there is a freely moving measuring carriage mounted on 'v'-ways and carrying a micrometer and highly sensitive fiducial indicator. This carriage permits measurements to be taken along the center line and at right angles to the work. All measurements are made relative to a reference master gauge or plain cylinder standard. The diameter of the standard should be within 2.5mm of the effective diameter of the work to be measured. The reading is taken on the diameter over the standard with cylinders/prisms in position depending upon the thread element to be measured. The standard is then replaced by the workpiece and the measurements are taken.

MAJOR DIAMETER MEASUREMENT:

The instrument is first present using a suitable cylindrical standard and the reading (R) of the micrometer is noted. The standard is then replaced by the workpiece and second reading is taken. The major diameter of the given specimen can be determined using the expression.

$$F = D \pm (R \sim R1)$$

where, F = Major diameter.

D = Diameter of the cylindrical standard used.

± = is determined by the relative size of the standard workpiece.

EFFECTIVE DIAMETER MEASUREMENT:

To determine the effective diameter of the thread, measurements are taken over the thread measuring wires which will be selected depending upon the size and form of thread by referring to the tables supplied.

The instrument is first present over a suitable cylindrical standard and selected thread measuring wires. The reading (Rs) of micrometer is noted.

Then the standard is replaced by the workpiece along with the wires introduced in the thread form as shown in fig. The second reading (R_w) of the micrometer is noted.

The effective diameter can be determined using the relation,

$$E = D \pm [(R_s - P) \sim R_w]$$

where, E = The effective diameter.

D = Diameter of the standard cylinder.

P = A constant which is dependent on the diameter of cylinders and the form of thread to be measured. It is also defined as the difference between the effective diameter and the diameter under the standard wires.

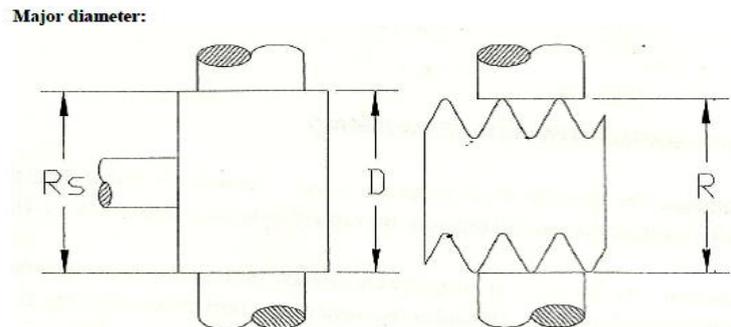
The value of 'p' can be calculated using the expression,

$$P = [(0.86602 * p) - d]$$

where, p = pitch of the threaded component.

d = mean diameter of the wires used.

1. Measurement of major diameter:



R_s = Micrometer reading over setting Master/Standard.

R_w = micrometer reading over threaded work piece.

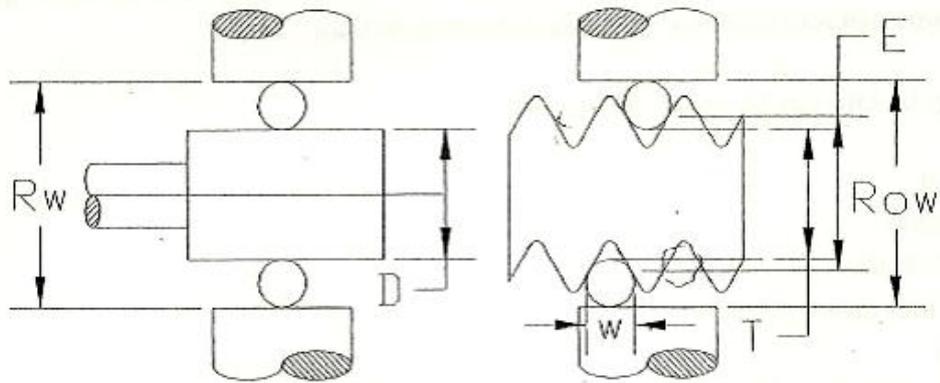
D = Standard cylinder diameter

$$R_s = MSR + (HSR \times LC) + (CVD \times LC)$$

$$R_w = MSR + (HSR \times LC) + (CVD \times LC)$$

2. Measurement of effective diameter:

Effective diameter:



RESULTS:

Major Diameter = _____ mm

Minor Diameter = _____ mm

Effective Diameter = _____ mm

EXPERIMENT NO.12
USE OF COMPARATORS

AIM: To compare the dimensions of given specimens with appropriate standards using mechanical, electrical and pneumatic comparators.

APPARATUS REQUIRED:

1. Dial indicator
2. Dial mounting stand with fine adjustments
3. Electrical comparator with probe and work table
4. Pneumatic comparator with measuring gauges
5. Vernier caliper
6. Micrometer

TO FIND:

1. Average size of the component.
2. To plot the graph of variations.
3. To determine the variation with respect to given tolerance value.
4. To segregate the component under heading oversize, undersize and correct size.

PROCEDURE:

FOR USING MECHANICAL AND ELECTRICAL COMPARATOR:

1. First measure the dimension of given specimen using micro meter/Vernier caliper.
2. Select the appropriate standard/buildup the slip gauges to required height and place it below the plunger.
3. Set the reading of the dial indicator to zero. Thus the standard dimension is set on the dial indicator.
4. The standard component/pile of slip gauges is removed and the given specimen is introduced below plunger in place of the standard. Take the reading of the dial indicator at different point on the surface of the specimen. Then the average of all deviations is calculated and the correct size of the specimen is determined.

5.A graph is plotted with the number of components in X-axis and the deviation on Y-axis.

USE OF PNEUMATIC COMPATOR;

1.Before measurement make certain that the compressed air is passed through the system and freely escapes from the gauge head nozzles.

2.Use masterpiece and zero adjuster set the tolerance limits and initial reference reading in the indicator.

3.Now the standard gauge is introduced in the bore of the component to be compared and the reading are tabulated.

The average size of component=standard size+- Average deviation

Result: The given specimen is tested for roughness using Talysurf and the different roughness parameters R_a , R_q , R_y , & R_z are tabulated in the tabular column.

TABULAR COLUMN FOR USE OF COMPARATORS

Sl. No.	Deviations					Average Deviation	Average size	Deviation from Given Tol. Value		Given Tolerance Value		
	1	2	3	4	5			+ve	-ve	Over size	Correct size	Under size
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

EXPERIMENT NO. 13

MEASUREMENT OF GEAR ELEMENTS

Aim: To measure the gear tooth profile for the given spur gear using Vernier gear tooth caliper.

Apparatus required:

1) Gear tooth vernier caliper 2) Disc micrometer 3) Outside micrometer 4) Mandrel 5) Dial indicator

Theory:

Gear tooth Vernier is used to measure the depth and thickness of the tooth in a same operation. The thickness of a tooth along the pitch line is measured by an adjustable tongue. Each of these is adjusted independently by screws on the graduated bars.

- The caliper consists of two adjustable Vernier's that reference two dimensions on the gear and provide a measurement
- Vertical scale: Measures the depth of the teeth from the top of the pitch line.
- Horizontal Scale: This is used to measure the Chordal Thickness of the gear tooth.

PROCEDURE:

To start with the following data is noted about the given spur gear.

Number of teeth, N=

(This is determined by number stamped on the side of the gear or alternatively by actual counting)

Pressure angle $\theta =$

The pressure angle is taken as 14.5 or 20 degrees.

Module m=

The value of m can be find out by measuring the outside diameter or tip diameter 'd_o' and using relation

$$d_o = m(N + 2)$$

1). MEASUREMENT OF TOOTH THICKNESS USING GEAR TOOTH VERNIER CALIPER:

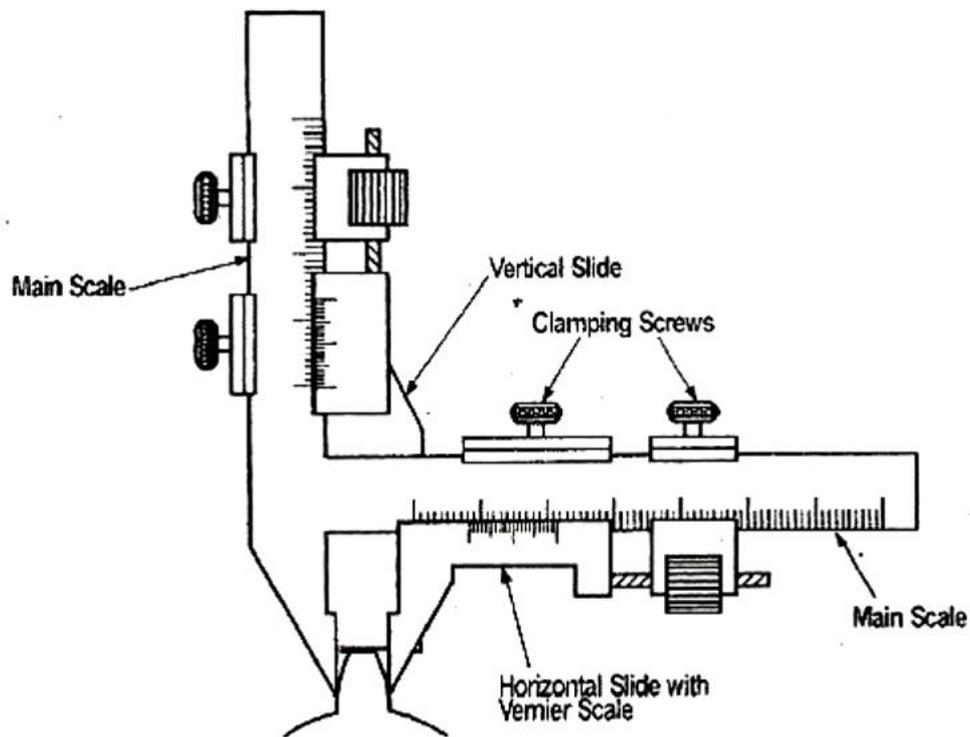
The gear tooth vernier measures chordal thickness or thickness at pitch line of gear tooth. The vertical slide is set to depth (d) by means of its vernier plate, so that when it rests on top of the gear tooth, the caliper jaws will be correctly position to measure across the pitch line of the gear tooth. The horizontal slide is then used to obtain the chordal thickness of gear tooth by means of its vernier plate.

Chordal addendum or depth to be set on the vertical side of the gear tooth vernier caliper is obtain using the expression

$$d_{theoretical} = \left(\frac{Nm}{2}\right) \left\{1 + \left(\frac{2}{N}\right) - \cos\left(\frac{90}{N}\right)\right\}$$

Sl No.	W (Theoretical) in mm	W (Actual) in mm	Error (mm)

Sl No.	Mt (Theoretical) in mm	Mt (Actual) in mm	Error (mm)



Chordal thickness, $W_{theoretical} = N m \sin (90/N)$

2. MEASUREMENT OF TOOTH SPAN BY DISC MICROMETRE:

In this method, the span of a convenient number of teeth is measured (The number of teeth is so chosen. Such that the measurement is made approximately at the pitch circle of the gear.)

$$\text{Tooth span } M_t = Nm \cos \theta \left[\tan \theta - \phi - \left(\frac{\pi}{2N} \right) + \left(\frac{\pi S}{N} \right) \right]$$

Where,

$$\phi = \frac{\pi}{180}$$

N=Number of teeth on the gear.

m=module in mm.

θ =Pressure angle.

s=Number of teeth spanned.

The actual and the theoretical values are compared.

3. MEASUREMENT OF RUN OUT:

The given gear is mounted on a mandrel and support between two centers. A dial indicator or test indicator, mounted on a stand is kept near the gear and the tip of the indicator is made to touch the tip of the tooth. The reading is set to zero. Then the gear is rotated tooth by tooth and deviations are noted. The maximum variation indicates the run out in the gear.

$$\text{Eccentricity} = \text{Runout} / 2.$$

Hence eccentricity is found out.

Results: The actual and theoretical tooth thickness of a gear is calculated by using Gear tooth vernier.

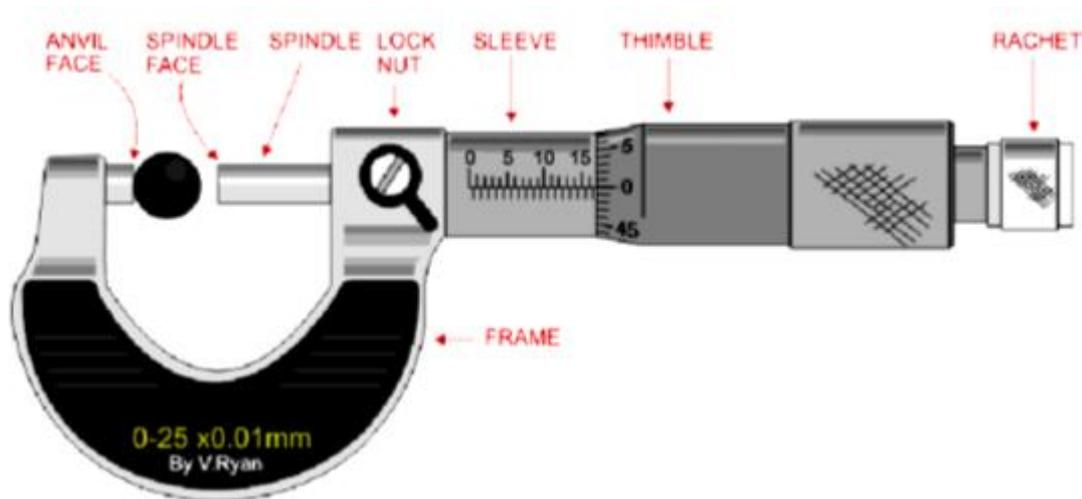
CALIBRATION OF MICROMETER

Aim: To calibrate the given micrometer over the entire range.

Apparatus Required:

1. Micrometer
2. Micrometer Stand
3. Slip Gauge Box

Theory:



It is one of the most common & most popular forms of measuring instrument for precise measurement with **0.01 mm** accuracy. In addition, Micrometer screw gauges are available with **0.001 mm** accuracy.

It is classified as Outside Micrometer, Inside Micrometer, Screw thread Micrometer, Depth gauge Micrometer.

Principle of Micrometer: The Micrometer works on the principle of—**screw & nut**. We know that when a screw is turned through one revolution it advances by one pitch distance i.e. – one revolution of screw corresponds to a linear movement of a distance equal to the pitch of the thread.

Procedure:

1. The method of testing the accuracy of the micrometer involves, setting a known dimension across the measuring face of the micrometer and noting the reading. The known dimension is built up using a combination of slip gauges.
2. The sizes of these gauges are chosen in such a way as to test the micrometer not only at complete turns of its thimble but also

intermediate portions. This is required as a check on the accuracy of the graduation on the thimble.

3. Starting from 'zero' the prescribed combination of slip gauges is built and introduced between the measuring faces of the micrometer and the reading is taken,
4. This is repeated till the range of the micrometer is covered. The readings are tabulated in the tabular column and a graph of the actual readings (on X-axis) and cumulative error (on Y-axis) is plotted.

Total Error = Distance between the ordinates of the highest and lowest points on the graph.

Observation:

Range of the Micrometer:

Value of 1 HSD = Pitch/Total No. of HSD

Least count of the Micrometer = LC = 1HSD – 1 VSD

Total Reading = PSR + (CHSD * Value of 1 HSD) + (Dial Reading * LC)

TABULAR COLUMN

Sl. No (1)	Actual Reading (Slip Gauge) (2)	Micrometer Reading PSR + (CHSD * Value of 1 HSD) + (Dial Reading * LC) (3)	ERROR (3)-(2)	Cumulative Error

Result:

Thus, the micrometer was calibrated using slip gauges.

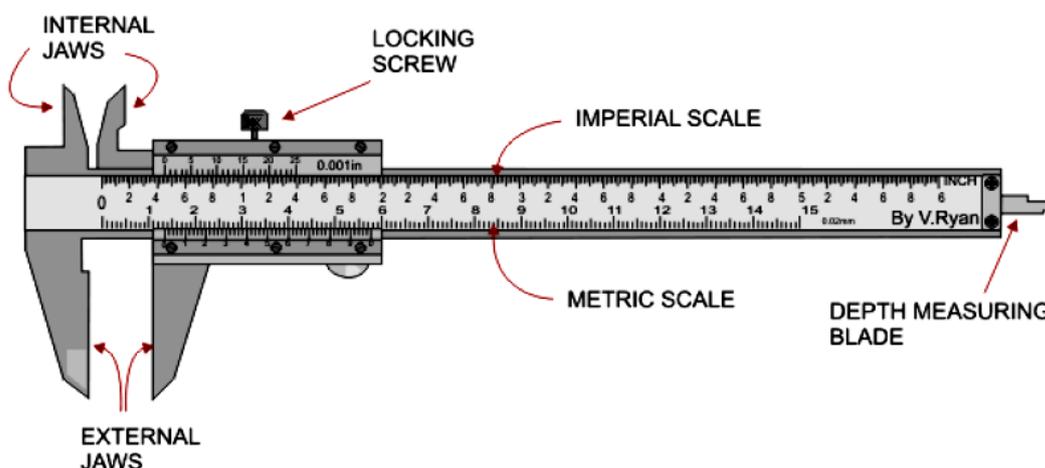
CONTENT BEYOND SYLLABUS

CALIBRATION OF VERNIER CALIPER USING SLIP GAUGE

Aim: To calibrate the given Vernier Caliper using Slip Gauge

Apparatus Required: 1. Surface Plate, 2. Vernier scale, 3. Slip Gauge.

Theory:



Construction: The Vernier caliper consists of two scales: One is fixed while other is movable. The fixed scale called main scale is calibrated on L shaped frame and carries a fixed jaw. The movable scale called Vernier scale slides over the main scale and carries a movable jaw. In addition, an arrangement is provided to lock the sliding scale on the fixed main scale. For the precise setting of movable jaw, an adjustment screw is provided. The least count of Vernier caliper is 0.02mm

Principle: Vernier Caliper is the most commonly used instrument for measuring outer and inner diameters. It works on the principle of Vernier Scale which is some fixed units of length (e.g. 49mm) divided into 1 less or 1 more parts of the unit (e.g. 49mm are divided into 50 parts). The exact measurement with up to 0.02mm accuracy can be determined by the coinciding line between Main Scale and Vernier Scale. Total Reading = M.S.R + L.C X V.C

Procedure for Calibration

1. The measuring instrument is placed on the surface plate and set for zero
2. Clean the Vernier caliper fixed and movable jaws and slip gauges to be measured with cloth

3. Vernier is checked for zero error
4. Slip gauge is clamped between the jaws and the Vernier scale is tightened by screws
5. Main scale and Vernier scale coincidence are noted for 5 different slip gauges
6. Calculate the error and percentage error
7. Plot the graph between

(i) Slip gauge reading vs Total reading (Vernier caliper)

(ii) Slip gauge reading vs Error

Result

Thus the Vernier caliper was calibrated using slip gauges

Error range = _____ mm

Specification

Formulae:

Least Count = 1 Main Scale Division – 1 Vernier Scale Division

Vernier Scale Reading = Vernier Scale Coincidence X Least Count

Total Reading = Main Scale Reading + Vernier Scale Reading

Error = Slip gauge reading - Verniercaliper Reading

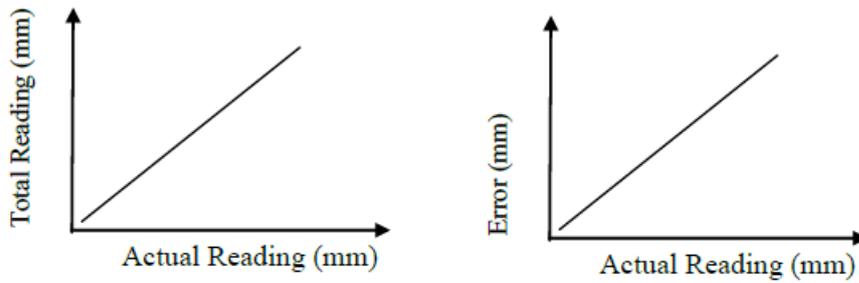
$$\% \text{ Error} = \frac{\text{Error}}{\text{Actual reading}} \times 100$$

Tabular column:

Sl. No.	Slip Gauge Reading, mm	Verniercaliper Reading MSR+(VSD x LC), mm	Error	%Error
1				
2				
3				
4				
5				

1. Error = Slip gauge reading - Total reading = $1.8 - 1.8 = 0$
2. % Error = (Slip gauge reading - Total reading) / Slip gauge reading
= $(1.8 - 1.8) / 1.8 = 0$

Model Graphs:



Results :

Thus the VerniercaliperReading was calibrated using slip gauges.

$$\text{Error range} = 0 - 0.16 \text{ mm}$$

VIVA-VOCE Questions

INTRODUCTION TO METROLOGY AND MEASUREMENTS

1. What is measurement? Give its type.
2. Mention the two important requirements of measurements.
3. Define primary sensing elements.
4. What are the categories of S.I units?
5. Define the term standard.
6. Define precision and accuracy.
7. Define systematic error.
8. What are the sources of errors?
9. Define the term repeatability.
10. Define the term calibration.
11. Method of measurements, with examples.
12. Give the structure of generalized measuring system.
13. Fundamental and derived units.
14. Define:(i) International standard, (ii) Fundamental units,(iii) Secondary measurements.
(iv) Working standard.
15. List various types of measuring instruments
16. Distinguish between accuracy and precision with example.
17. Describe the different types of errors in measurement and their causes.
18. Differentiate between systematic error and random error.
19. Define: (i) Instrumental error, (ii) Environmental error

LINEAR AND ANGULAR MEASUREMENTS

1. Define metrology.
2. List the various linear measurements. What are the various types of linear measuring instruments used in metrology?
3. Define backlash in micrometer.
4. Define cumulative error and total error.
5. What are the slip gauge accessories?
6. List the applications of limit gauges.
7. What are the advantages of electrical and electronic comparator?
8. What are the sources of errors in sine bars?
9. List the applications of bevel protractor.
10. What is the Principle of an autocollimator?
11. How Vernier height gauge is specified? Label the parts of a Vernier height gauge?
12. Difference between the dial type and reed type of mechanical comparator.
13. Mechanism of dial type mechanical comparator.
14. Principle of Sine bar.
15. Principle optical bevel protractor.
16. (i) Limitations of sine bars, (ii) Applications of bevel protractor, (iii) Angle gauges, (iv) Rollers

SCREW THREAD AND GEAR FORM MEASUREMENTS

1. Define the effective diameter of thread.
2. Give the names of the various methods of measuring the minor diameter.
3. What are the types of pitch errors found in screws?
4. What is the effect of flank angle error?
5. What are the applications of toolmaker's microscope?
6. Name the types of gears.
7. Define addendum and dedendum.
8. Define module.
9. Name the gear errors.
10. What are the types of profile checking method?

11. Discuss briefly about errors in threads with neat sketch.
12. Explain the measurement of effective diameter of a screw thread using two wires.
13. Principle of (i) Tool maker's microscope, (ii) Floating carriage micrometer.
14. Explain the principle of measuring gear tooth thickness by gear tooth Vernier caliper and derive the mathematical formula.

POWER AND TEMPERATURE MEASUREMENTS

1. Define force.
2. Give the list of devices used to measure the force.
3. Define the working of load cells.
4. Name the instrument used for measurement of torque.
5. Give the basic principle of mechanical torsion meter.
6. Classify the types of strain gauges.
7. Mention the types of dynamometer.
8. Define thermocouple.
9. What are the different types of bi-metallic sensors?
10. Discuss briefly about the torque measurements using strain gauge.
11. Explain the temperature measurement using thermocouple.