LABORATORY MANUAL

18MEL37B /18MEL47B MECHANICAL MEASUREMENTS AND METROLOGY

2019-2020

DEPARTMENT OF MECHANICAL ENGINEERING
ATRIA INSTITUTE OF TECHNOLOGY
Adjacent to Bangalore Baptist Hospital
Hebbal, Bengaluru-560024

Department of Mechanical Engineering

Vision

To be a center of excellence in Mechanical Engineering education and interdisciplinary research to confrontreal world societal problems with professional ethics.

Mission

1. To push the frontiers of pedagogy amongst the students and develop new paradigms in research.

2. To develop products, processes, and technologies for the benefit of society in collaboration withindustry and commerce.

3. To mould the young minds and build a comprehensive personality by nurturing strong professionalswith human ethics through interaction with faculty, alumni, and experts from academia/industry.

PREFACE

In most of the engineering institutions, the laboratory course forms an integral form of the basic course in Mechanical Measurements & Metrology at undergraduate level. The experiments to be performed in a laboratory should ideally be designed in such a way as to reinforce the understanding of the basic principles as well as help the students to visualize the various phenomenon encountered in different applications.. The Mechanical Measurements & Metrology lab contributes to educate the undergraduate students of 4th semester B.E, VTU Belagavi in the field of Mechanical Engineering.

The objective of this laboratory is to reinforce and enhance your understanding of the fundamentals of Mechanical Measurements & Metrology. The experiments here are designed to demonstrate the applications of the basic measuring instruments, principles and to provide a more intuitive and physical understanding of the theory. The main objective is to introduce a variety of classical experimental and diagnostic techniques, and the principles behind these techniques.

This laboratory exercise also provides practice in making engineering judgments, estimates and assessing the reliability of your measurements, skills which are very important in all engineering disciplines.

I acknowledge Prof. Venkateswaran.S, head of the department for his valuable guidance and suggestions as per Revised Blooms Taxonomy in preparing the lab manual.

Anjan Kumar D
Lab Coordinator

B. E. MECHANICAL ENGINEERING Choice Based Credit System (CBCS) and Outcome Based Education (OBE) SEMESTER – III/IV			
MECHANICAL MEASUREMENTS AND METROLOGY LAB			
Course Code	**18MEL37B/47B**	CIE Marks	40
Teaching Hours/Week (L:T:P)	0:2:2	SEE Marks	60
Credits	02	Exam Hours	03

Course Learning Objectives:

- To illustrate the theoretical concepts taught in Mechanical Measurements & Metrology through experiments.
- To illustrate the use of various measuring tools & measuring techniques.
- To understand calibration techniques of various measuring devices.

Sl. No.	Experiments
	PART A
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
6	Measurements using Optical Projector / Tool makers' Microscope.
7	Measurement of angle using Sine Centre / Sine bar / Bevel Protractor.
8	Measurement of alignment using Autocollimator / Roller set.
9	Measurement of cutting tool forces using Lathe Tool Dynamometer & 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	Measurement of gear tooth profile using gear tooth Vernier/Gear tooth micrometer.
13	Calibration of Micrometer using slip gauges
14	Measurement using Optical Flats.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Understand Calibration of pressure gauge, thermocouple, LVDT, load cell, micrometer.

CO2: Apply concepts of Measurement of angle using Sine Centre/ Sine Bar/ Bevel Protractor, alignment using Autocollimator/ Roller set.

CO3: Demonstrate measurements using Optical Projector/Tool maker microscope, Optical flats.

CO4: Analyse tool forces using Lathe/Drill tool dynamometer.

CO5: Analyse Screw thread parameters using 2-Wire or 3-Wire method, gear tooth profile using gear tooth Vernier/Gear tooth micrometer.

CO6: Understand the concepts of measurement of surface roughness.

Conduct of Practical Examination:

1. All laboratory experiments are to be included for practical examination.
2. Breakup of marks and the instructions printed on the cover page of answer script to be strictly adhered by the examiners.
3. Students can pick one experiment from the questions lot prepared by the examiners.

Scheme of Examination : Total 100 Marks

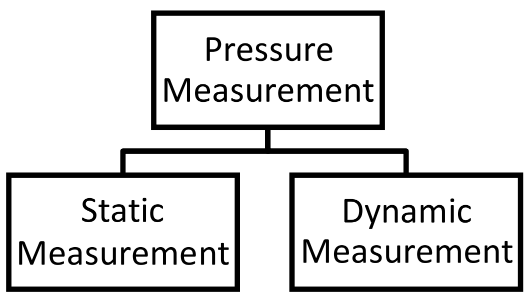
1 Q. from part - A:30 Marks	1 Q. from part -B: 50 Marks	Viva -Voice: 20 Marks

PART – A Experiment No : 1
CALIBRATION OF PRESSURE GAUGE

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

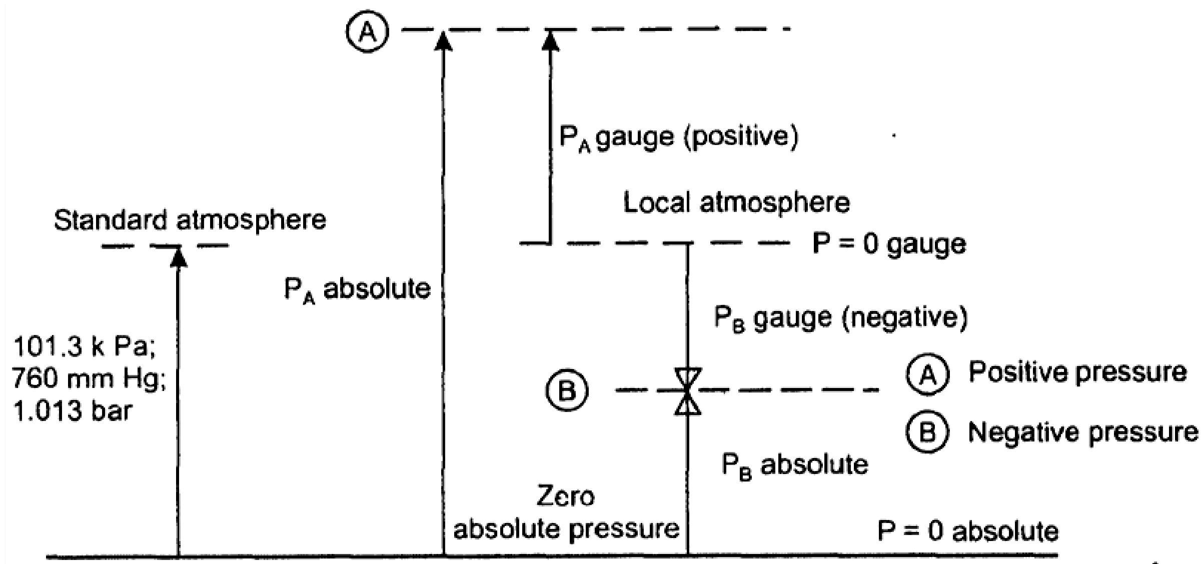
Apparatus: Pressure cell / sensor/ gauge, Dial type pressure cell indicator, Digital pressure Indicator, oil filled compression chamber.

Theory:
The pressure results from normal compressive force acting on an area.
The pressure 'P' is defined as force (F) per unit area (A).
In SI units the unit of measurement of pressure is Newton's per square meter (N/m^2) or Pascal (Pa).
Since Pascal is a small unit of measurement of pressure, the pressure is usually referred to in kilo Pascal (kPa) or even in Mega Pascal (MPa).
The standard atmospheric pressure (P_{atm}) at sea level is 101.3 kPa or 1.013 bar.



Example
Static : Car tyre, Balloon filled with air.
Dynamic : Pressure inside the pipe carrying fluid (Gas/water pipeline).

All pressure measured is a Relative term.
Pressure is measured in three ways—absolute, gauge and differential pressure.
Absolute Pressure – Relative to a zero pressure or a perfect vacuum.
Gauge Pressure – Relative to Atmospheric pressure.
Differential Pressure – Pressure difference between two point.



Absolute pressure is a pressure that is relative to the zero pressure in the empty, air-free space of the universe. This reference pressure is the ideal or absolute vacuum.

In engineering calculations, absolute pressure is used and the conversion from gauge pressure to absolute pressure is carried out using the following equation.

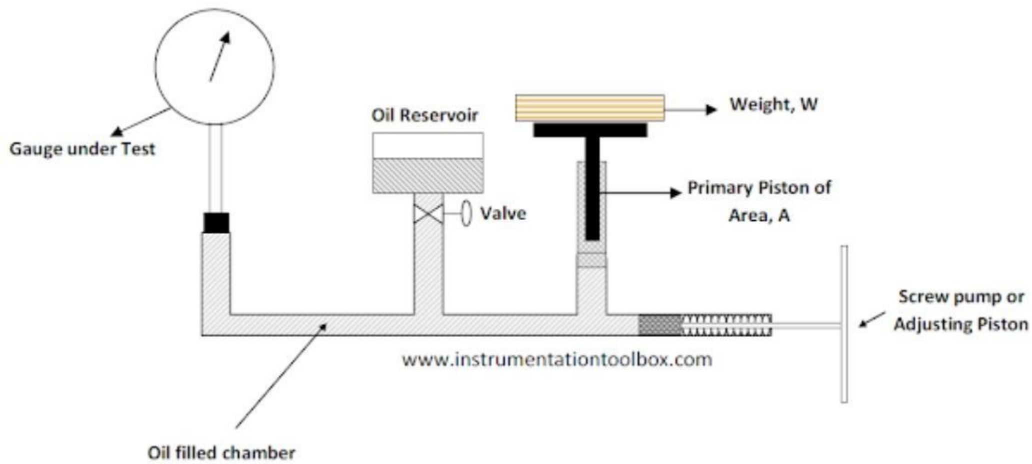
Absolute pressure = gauge pressure + atmospheric pressure

$$P_{absolute} = P_{gauge} + P_{atm}$$

'Gauge pressure' is the difference between 'absolute pressure' and 'atmospheric pressure'.
Gauge pressure is the pressure relative to atmospheric pressure.
It is also defined as the pressure which is measured with the help of pressure measuring instrument in which atmospheric pressure is taken as Datum/Reference.
Gauge pressure is positive for pressures above atmospheric pressure and negative whenever the absolute pressure is less than atmospheric pressure; it can be called as vacuum.
Instruments used to measure pressure are called pressure gauges or vacuum gauges.
Zero gauge pressure is atmospheric pressure. Also, zero absolute pressure in an ideal vacuum.

A pressure gauge is a fluid intensity measurement device.
Gauges help to ensure there are no leaks or pressure changes that could affect the operating condition of the hydraulic system.
Hydraulic gauges are often installed at or near the pump's pressure port for indication of system pressure, but can be installed anywhere on the machine where pressure needs to be monitored.
Analog gauges with custom scales are more common and digital pressure gauges with customizable firmware allow process measurement of pressure-based measurement of leaks or other parameters like torque, load, force and hardness.

A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.
Pressure sensors are used for control and monitoring in thousands of everyday applications.
Pressure sensors can alternatively be called **pressure transducers**, **pressure transmitters**, **pressure senders**, **pressure indicators**, **piezometers** and **manometers**, among other names.



Pressure Measuring Devices :
Analog Type – Barometer, Manometer & Burden tube pressure gauge.
Electro-chemical Type – unbounded resistance element type, bonded strain gauges type, inductive type, piezoelectric type.

Specifications:

Capacity : 10kg/cm^2

Procedure:

1. Connect the Pressure gauge (under test) to the test port on the dead weight tester.
2. Make sure that oil reservoir is fully filled with oil. If not, fill the oil completely and close it and then close the valve.
3. Connect the pressure transducer to the pressure digital indicator.
4. Connect the pressure indicator box to the power supply and switch ON.
5. Check the test gauge is reading zero, if not correct the zero error and ensure that gauge is reading zero before proceeding with the calibration exercise.
6. Adjust the pressure indicator to read zero on DPM (Digital Panel Meter) using ZERO pot knob without applying any pressure.
7. Select a weight and place it on the vertical piston and spin it to ensure it is floating freely.
8. Turn the handle of the adjusting piston/hand wheel to ensure that the weight and piston are supported freely by oil.
9. Allow a few minutes for the system to stabilize before taking any readings. After the system has stabilized, apply a load of 10kg and rotate the hand wheel to apply pressure on the piston. When applied pressure reaches 10 kg/cm2, piston will start moving up.

10. Now read the pressure gauge reading and adjust the cal pot of the indicator to same pressure, as the analog reading. Now the given pressure gauge is calibrated.
11. Release the pressure fully by rotating the Hand wheel.
12. Load the piston by 1 kg apply the pressure by rotating the hand wheel. At a Pressure of 1 kg /cm2, piston starts lifting up. Note down the reading.
13. Repeat the above step for increasing weights until the full range or maximum pressure is applied on the piston step by step, and then decreasing weights until the gauge reads zero pressure.
14. Note down the readings of dial gauge and pressure indicator, simultaneously in every step.
15. Calculate the percentage error and plot the graphs.

Plot the Graphs as follows:

1. Indicated Pressure **v/s** Actual Pressure.
2. Indicated Pressure **v/s** Percentage error.
3. Actual Pressure **v/s** Percentage error.

Tabular Column

(a) Upscale Readings

Sl.no	Weights (kg)	Actual Pressure (Pa) (kg/cm2)	Indicated Pressure (Pi) (kg/cm2)	Error Pi – Pa	% Error $\frac{Pi-Pa}{Pa}$ x 100

(b) Downscale Readings

Sl.no	Weights (kg)	Actual Pressure (Pa) (kg/cm2)	Indicated Pressure (Pi) (kg/cm2)	Error Pi – Pa	% Error $\frac{Pi-Pa}{Pa}$ x 100

Result :

Applications:

- Pressure gauges are used for variety of industrial and application-specific pressure monitoring applications. Their uses include visual monitoring of air & gas pressure for compressors, vacuum equipment, process lines & specialty tank applications such as medical gas cylinders & fire extinguishers.
- Fluid pressure industrial hydraulic circuits.
- Measurement of steam pressure in power plants & boilers.
- Measurement of pressure in large pumping stations/ water works/ or minor/major irrigations.

PART – A Experiment No : 2
CALIBRATION OF THERMO COUPLE

Aim: To calibrate the given thermo couple using Resistance thermometer Detector (RTD).
Apparatus: Thermocouple, RTD, Digital temperature Indicator, Water bath.

Theory :
Temperature is a physical property of matter that quantitatively expresses hot and cold. Temperature is measured with a thermometer.
Temperature is the manifestation of thermal energy, present in all matter, which is the source of the occurrence of heat, a flow of energy, when a body is in contact with another that, is colder.

Thermometers are calibrated in various temperature scales that historically have used various reference points and thermometric substances for definition. The most common scales are the Celsius scale (formerly called centigrade), denoted °C, the Fahrenheit scale (denoted °F), and the Kelvin scale (denoted K), the latter of which is predominantly used for scientific purposes by conventions of the International System of Units (SI).

Many physical processes are affected by temperature, such as:

- the physical properties of materials including the phase (solid, liquid, gaseous or plasma), density, solubility, vapor pressure, electrical conductivity,
- the rate and extent to which chemical reactions occur,
- the amount and properties of thermal radiation emitted from the surface of an object,
- the speed of sound which is a function of the square root of the absolute temperature.

Any of these effects may be used to measure the temperature.
Temperature Measurement by Electrical Effects, Thermo resistive Elements, Electrical Resistance Thermometers, Electrical Resistance Thermometers, Instrumentation for Resistance Thermometers and Thermocouple.

The electrical resistance of most materials varies with temperature. Resistance elements which are sensitive to temperature are made of metals and are good conductors of electricity. Examples are nickel, copper, platinum and silver. Any temperature-measuring device which uses these elements are called resistance thermometers or **resistance temperature detectors** (RTD). It is one of the accurate methods of temperature measurement. If semiconducting materials like combination of metallic oxides of cobalt, manganese
and nickel having large negative resistance co- efficient are used then such devices are called **thermistors.**

A thermocouple is comprised of at least two metals joined together to form two junctions. One is connected to the body whose temperature is to be measured; this is the hot or measuring junction. The other junction is connected to a body of known temperature; this is the cold or reference junction. Therefore the thermocouple measures unknown temperature of the body with reference to the known temperature of the other body.

Thermocouples are among the easiest temperature sensors to use and obtain and are widely used in science and industry. They are simple, need no batteries, measure over very wide temperature ranges and more. It is frequently used as the sensing element in a thermal sensor or switch.

Working Principle

The working principle of thermocouple is based on three effects, discovered by Seebeck, Peltier and Thomson. They are as follows:

1) Seebeck effect: The Seebeck effect states that when two different or unlike metals are joined together at two junctions, an electromotive force (emf) is generated at the two junctions. The amount of emf generated is different for different combinations of the metals.

2) Peltier effect: As per the Peltier effect, when two dissimilar metals are joined together to form two junctions, emf is generated due to current flow the two junctions of the circuit.

3) Thomson effect: As per the Thomson effect, when two unlike metals are joined together forming two junctions, the potential exists within the circuit due to temperature gradient along the entire length of the conductors within the circuit.

The above effects form the basis for a thermocouple which is a temperature measuring element.

In most of the cases the emf suggested by the Thomson effect is very small and it can be neglected by making proper selection of the metals. The Peltier effect plays a prominent role in the working principle of the thermocouple.

How it Works

The general circuit for the working of thermocouple is shown in the figure 1 above. It comprises of two dissimilar metals, A and B. These are joined together to form two junctions, p and q, which are maintained at the temperatures T_1 and T_2 respectively. Remember that the thermocouple cannot be formed if there are not two junctions. Since the two junctions are maintained at different temperatures the Peltier emf is generated within the circuit and it is the function of the temperatures of two junctions.

The device for measuring the current or emf is connected within the circuit of the thermocouple. It measures the amount of emf flowing through the circuit due to the two junctions of the two dissimilar metals maintained at different temperatures. In **figure** the two

junctions of the thermocouple and the device used for measurement of emf (potentiometer) are shown.
Now, the temperature of the reference junctions is already known, while the temperature of measuring junction is unknown. The output obtained from the thermocouple circuit is calibrated directly against the unknown temperature. Thus the voltage or current output obtained from thermocouple circuit gives the value of unknown temperature directly.

Thermocouple materials and Construction

Any two dissimilar metals can be used to form thermocouple, but certain metals and Combinations are better than others.

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

The desirable properties of thermocouple materials are:

i) Linear temperature-emf relationship
ii) High output emf
iii) Resistance to chemical change
iv) when in contact with working fluids
v) Stability of emf
vi) Mechanical strength in their temperature range and
vii) Cheapness.

The thermocouple materials can be divided into two types
1. Rare-metal types using platinum, rhodium, iridium etc and
2. Base-metal types.

Rare metal thermocouples use a combination of pure metals & alloys of platinum for temp. up to 2000 K and tungsten, rhodium and molybdenum for temperature up to 2900 K.
Ex- Platinum-Platinum Rhodium (type R) - Platinum-platinum/10% rhodium, Platinum-platinum/30% rhodium.

Base metal thermocouple use the combination of pure metals and alloys of iron, copper and nickel and are used for temperature up to 1450 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. Base metal thermocouples are known as Types E, J, K, T and N and comprise the most commonly used category of Thermocouple. The conductor materials in base metal thermocouples are made of common and inexpensive metals such as Nickel, Copper and Iron.

THERMOCOUPLE	Composition	Temp. Range	Applications/Characteristics
TYPE J	Composed of a positive leg which is iron and a negative leg which is approximately 45 % nickel-55% copper. (Note - Constantan is Copper-Nickel.)	0 to 750°C It has a wire color code of white and red.	Type J thermocouples can be used in vacuum, oxidizing, reducing and inert atmospheres. Due to the oxidation (rusting) problems associated with the iron leg, care must be used when using this thermocouple type in oxidizing environments above 1000°F.
TYPE K	The Type K thermocouple has a Chromel positive leg and an Alumel negative leg. Chromel {90% nickel and 10% chromium} Alumel {95% nickel, 2% manganese, 2% aluminium and 1% silicon}	−270 to 1,260°C It's wire color code is yellow and red.	It is the most common thermocouple type that provides the widest operating temperature range. Generally it will work in most applications because they are nickel based and have good corrosion resistance. Type K is recommended for use in oxidizing and completely inert environments. Because it's oxidation resistance is better than Types E, J, and T. Type K, like Type E should not be used in sulfurous atmospheres, in a vacuum or in low oxygen environments where selective oxidation will occur.
TYPE T	The Type T thermocouple has a Copper positive leg and a Constantan negative leg. (Copper / Constantan)	−200 to 350 °C It's wire color code is blue and red	Often used as a differential measurement since only copper wire touches the probes. Type T is very stable and is used in a wide variety of cryogenic and low temperature applications. For applications below 0°C, (32°F) special selection of alloys are usually required. Type T thermocouples can be used in oxidizing, reducing or inert atmospheres, except the copper leg restricts their use in air or oxidizing environments to 700°F or below.

Devices Used for Measuring EMF

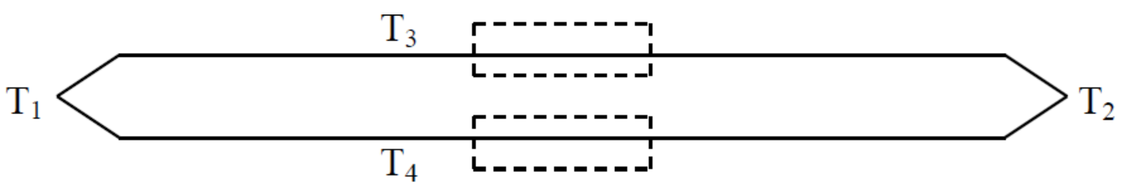
The amount of emf developed within the thermocouple circuit is very small, usually in millivolts, therefore highly sensitive instruments should be used for measuring the emf generated in the thermocouple circuit. Two devices used commonly are the ordinary galvanometer and voltage balancing potentiometer. Of those two, a manually or automatically balancing potentiometer is used most often.

Laws of Thermocouples

The following empirically derived thermocouple laws, are useful to understand, diagnose and utilise thermocouples.

a) Law of homogeneous circuits

If two thermocouple junctions are at T1 and T2, then the thermal emf generated is independent and unaffected by any temperature distribution along the wires.

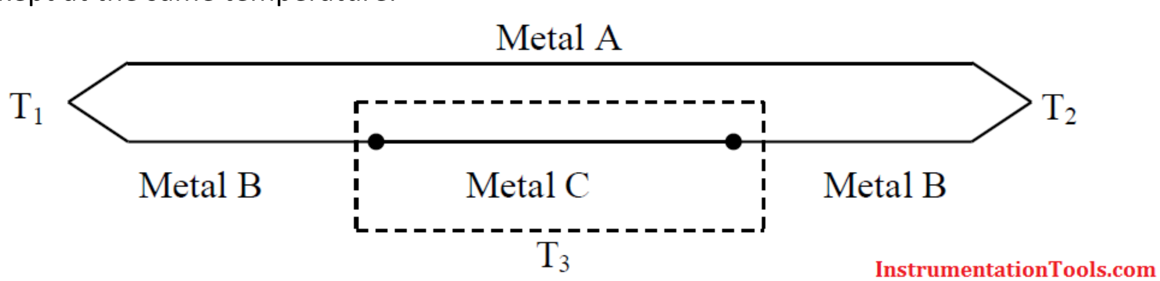


Law of homogeneous circuits

In above Figure, a thermocouple is shown with junction temperatures at T1 and T2. Along the thermocouple wires, the temperature is T3 and T4. The thermocouple emf is, however, still a function of only the temperature gradient T2 – T1.

b) Law of intermediate metals

The law of intermediate metals states that a third metal may be inserted into a thermocouple system without affecting the emf generated, if, and only if, the junctions with the third metal are kept at the same temperature.

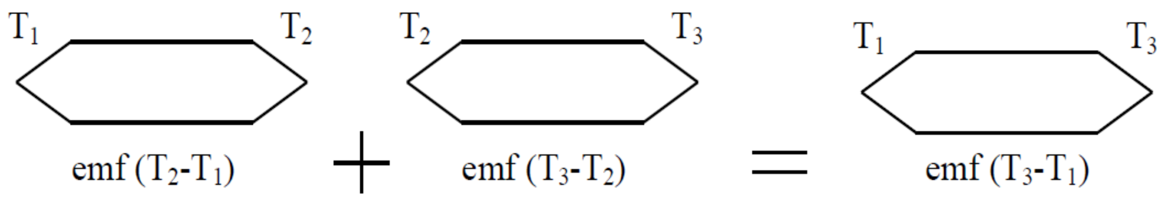


Law of Intermediate Metals

When thermocouples are used, it is usually necessary to introduce additional metals into the circuit This happens when an instrument is used to measure the emf, and when the junction is soldered or welded. It would seem that the introduction of other metals would modify the emf developed by the thermocouple and destroy its calibration. However, the law of intermediate metals states that the introduction of a third metal into the circuit will have no effect upon the emf generated so long as the junctions of the third metal are at the same temperature, as shown in Above Figure

c) Law of intermediate temperatures

The law of intermediate temperatures states that the sum of the emf developed by a thermocouple with its junctions at temperatures T1 and T2, and with its junctions at temperatures T2 and T3, will be the same as the emf developed if the thermocouple junctions are at temperatures T1 and T3.



Law of Intermediate Temperatures

This law, illustrated in above Figure, is useful in practice because it helps in giving a suitable correction in case a reference junction temperature other than 0 °C is employed. For example, if a thermocouple is calibrated for a reference junction temperature of 0 °C and used with a junction temperature of 20 °C, then the correction required for the observation would be the emf produced by the thermocouple between 0 °C and 20 °C.

Setup :

It comprises of RTD sensor as a reference & three types of Thermocouples as mentioned above, to be calibrated. All the four sensors can be placed in a hot bath where the water can be heated up to a boiling temperature through heating coil. Heater of capacity 500watts is provided which will be connected to the 230v/50Hz power supply through three-pin mains cord.

Procedure:

1. Turn & select the type of thermocouple probe (J,K &T type)
2. Connect the RTD (Resistance Temperature Detector) probe to the RTD display.
3. Connect the given thermocouple to the thermocouple temperature display.
4. Place the thermocouple hot junction and the RTD probe into a beaker containing water at room temperature.
5. Connect the power supply to the temperature indicator.
6. Record the room temperature from the RTD temperature indicator.
7. Adjust the zero setting knob of the thermocouple temperature indicator until the display shows the room temperature.
8. Connect the power supply to heating coil & heat the water in the water bath.
9. Set the temperature of thermocouple to the temperature of RTD indicator when the Water is boiling, using CAL knob.
10. Now the given thermocouple is calibrated with reference to RTD.

11. Record the RTD and thermocouple temperature indicator reading simultaneously at Regular intervals.

RTD Type : J - Type

Sl.no	Temp of Water by RTD ta (°C)	Temp of Water by Thermocouple tm (°C)	Error tm – ta	% Error $\frac{tm - ta}{ta}$ x 100
1				
2				
3				
4				
5				

RTD Type : K - Type

Sl.no	Temp of Water by RTD ta (°C)	Temp of Water by Thermocouple tm (°C)	Error tm – ta	% Error $\frac{tm - ta}{ta}$ x 100
1				
2				
3				
4				
5				

RTD Type : T - Type

Sl.no	Temp of Water by RTD ta (°C)	Temp of Water by Thermocouple tm (°C)	Error tm – ta	% Error $\frac{tm - ta}{ta}$ x 100
1				
2				
3				
4				
5				

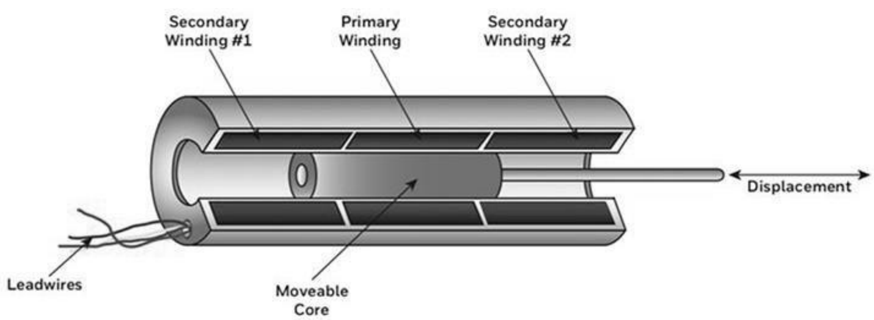
Result :

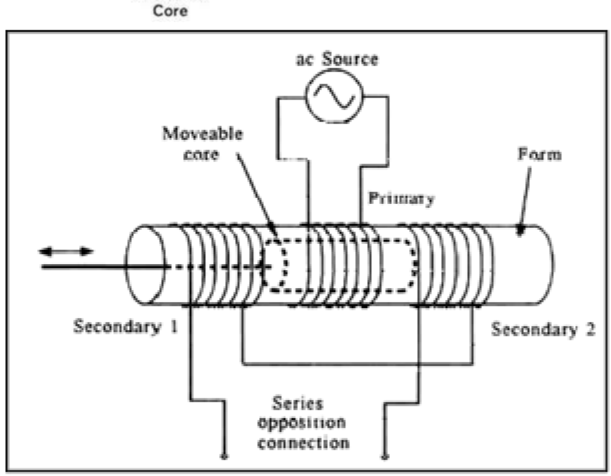
PART – A Experiment No : 3

CALIBRATION OF LVDT

Aim: To calibrate Linear Variable Differential Transformer (LVDT) for the performance using Micrometer.
Apparatus: LVDT, Digital display indicator, Micrometer**.**

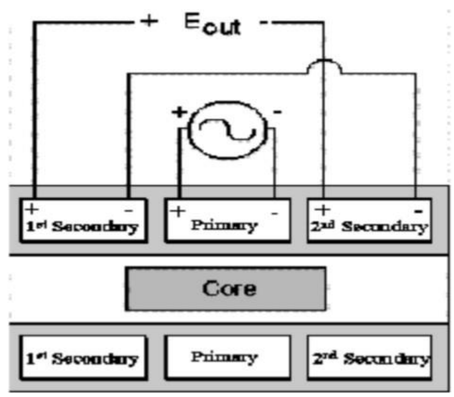
Theory:
The most widely used inductive transducer to translate the linear motion into electrical signals is the linear variable differential transformer (LVDT). The basic construction of LVDT is shown in fig: Soft iron, core Arm, Secondary winding, Primary winding. The transformer consists of a single primary P and two secondary windings S1 and S2 wound on a cylindrical former. The secondary windings have equal number of turns and are identically placed on either side. A moveable soft iron core is placed inside the transformer. The displacement to be measured is applied to the arm attached to the soft iron core. In practice the arm is made of highly permeability, nickel iron which is hydrogen annealed. This gives low harmonics low null voltage and high sensitivity. This is slotted longitudinally to reduce eddy current losses. The assembly is placed in stainless steel housing and the end leads provides electrostatic and electromagnetic shielding. 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.



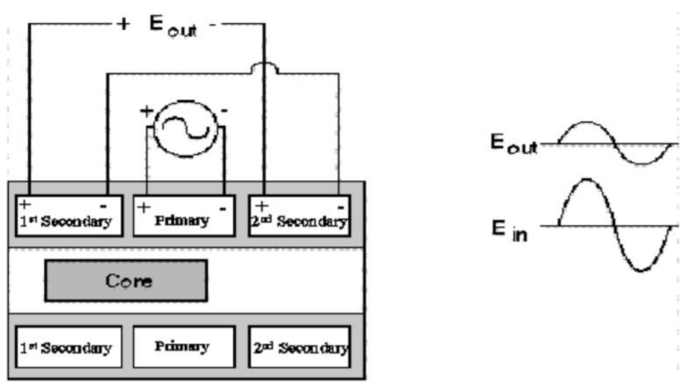


The frequency of AC applied to primary windings may be between 50 Hz to 20 kHz. Since the primary winding is excited by an alternating source, it produces an alternating magnetic field which in turn induces alternating current voltage in the two secondary windings.

Figure 3 depicts a cross-sectional view of an LVDT. The core causes the magnetic field generated by the primary winding to be coupled to the secondaries. When the core is centered perfectly between both secondary's and the primary (null position), the flux linking with both the secondary windings is equal as shown, the voltage induced in each secondary is equal in amplitude and 180 deg out of phase. The output voltage is the difference of the two emf's say E1 and E2. Thus the LVDT output (for the series-opposed connection shown in this case) is zero at null position because the voltage cancels each other. E0 = Es1 - Es2 = 0

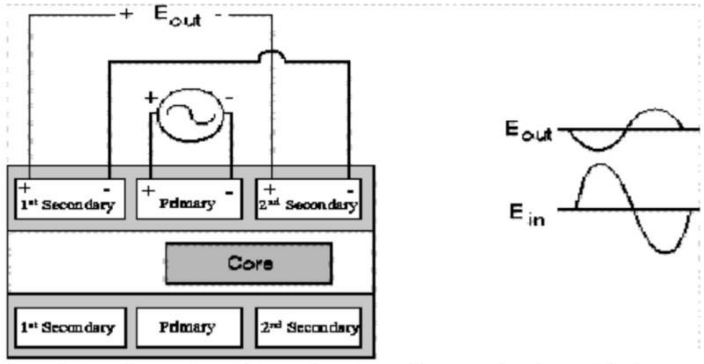


Cross-sectional View ofLVDT Core & Windings



Coupling to 1st secondary caused by associated Core displacement

Displacing the core to the left (Figure 4) causes the first secondary to be more strongly coupled to the primary than the second secondary. The resulting higher voltage of the first secondary in relation to the second secondary causes an output voltage that is in phase with the primary voltage. The output voltage is V=E2 – E1, since E1 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.



Coupling to 2nd secondary caused by associated Core displacement

Likewise, displacing the core to the right causes the second secondary to be more strongly coupled to the primary than the first secondary. The greater voltage of the second secondary causes an output voltage which is (+) ve and to be out of phase with the primary voltage. 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 cms. Normally LVDT can give better result up to 5mm.

Transformer :

The basic transformer formula, which states that the voltage is proportional to the number of coil windings, is the backbone of the LVDT. The equation is as follows

$$\frac{E_{out}}{E_{in}} = \frac{N_{out}}{N_{in}}$$

Setup :

LVDT, a displacement sensor used here has a primary and secondary coil winded and covered by an aluminum body. Five core cable is connected to the primary coil (Input Supply) and the secondary coil (output of the sensor). An Iron core is placed so as to move inside the coil, which will be supposed by the spring for an easy to and fro movement. This sensor has been mounted on the aluminum bracket. Screw gauge is fixed with the help of bracket, in line with the core, for linear measurement of core movement.

Procedure:

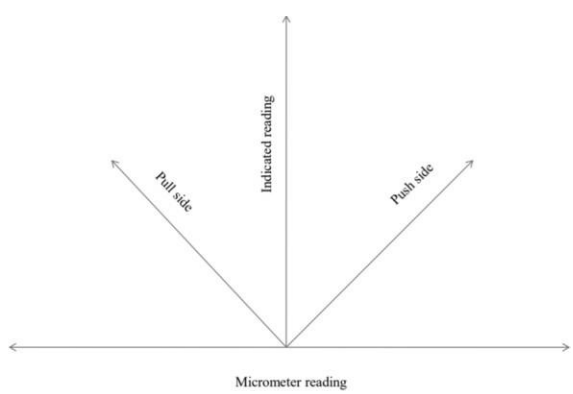
The experiment can be carried out for both (+) ve and (-) ve sides.

1. Connect the five core cable from LVDT to a digital indicator with 5 pin socket at sensor end and respective color connectors at the other end.
2. Connect Digital indicator to power supply and switch ON.
3. Place the READ/CAL switch at READ position.
4. Adjust the zero knob of the indicator to indicate 0000.
5. Rotate the Micrometer knob to clockwise direction, to bring the LVDT core to NULL position of the sensor where there is no induced emf. At this position indicator will read "00.00". Note down the micrometer reading. This is initial reading of Micrometer.
6. Now move the core to any one side of the null position by slowly rotating the screw gauge knob to clockwise or anti-clockwise direction until it reads + or – 10mm in the micrometer.
7. Replace the READ/CAL switch at CAL position. Note down the reading & adjust the calibration knob of the instrument to read "10.00" mm in the indicator.
8. Repeat the above operation (5^{th} - 7^{th} step) once again. Now the given LVDT sensor is calibrated.
9. Note the micrometer reading as actual value and displayed reading as indicated value.
10. Now bring the LVDT to null position, rotate micrometer to clockwise by 0.55mm or 1 mm and note down the readings in the micrometer as well as of displacement indicator. Note down the micrometer reading.
11. Repeat the experiment for different position of the core and note down the readings of the screw gauge and displacement indicator, simultaneously in every step.
12. Tabulate the reading as shown and plot a graph of displacement by micrometer and indicator.
13. Plot the graph of micrometer reading v/s digital reading
14. Calculate the error and error %.
15. Finally set to null position.

Tabular Column :

Sl. No	Core Position	Digital Displacement Reading (Si)(mm) Indicated Value	Micrometer Reading (Sa)(mm) Actual Valve	Error Si – Sa	% Error $\frac{Si - Sa}{Sa}$ x 100
1	Left of Null Position				
2					
3					
4					
5					
6					
1	Right of Null Position				
2					
3					
4					
5					
6					

Graphs :
Micrometer reading V/s Indicated reading.
% Error V/s Micrometer reading.



Result :
Thus the displacement is calibrated by using LVDT

PART – A Experiment No : 4

CALIBRATION OF LOAD CELL

Aim: To calibrate given load cell by actual load.

Apparatus: Load cell of (10 kg capacity), dead weights and digital load indicator.

Theory:

Weighing load/force using spring deflection is widely accepted one. But the deflection of spring reading mechanically is very tedious and time consuming. One of the most effective & accurate method is using strain gauge based load cells. Using the principle of deflection of high tensile strength material when load is applied on it and converting it into proportional electrical signal by using strain gauges will give accurate way of measuring load. **Strain gauge**s are bonded on the columns of corrosion resistance super tough alloy of high tensile strength steel that deforms very minutely under load. This deformation is converted to electrical signal through strain gauges bonded on the column and connected to form a wheat stone bridge. This electrical output is proportional to the load acting on the columns. The output of the load cell is calibrated with reference to some standard i.e., primary standard i.e. dead weights.

Load cell is designed for tensile-compressive (universal type). It consists of a steel cylinder which has four identical strain gauges of equal resistance (350Ω). Mounted upon it, the gauges R1 and R4 are along the direction of applied load and the gauges R2 and R3 are attached circumferentially at right angles to gauges R1 and R4. These four gauges are connected electrically to the four limbs of a Wheatstone bridge circuit. Excitation to the bridge is supplied from load indicator i.e., regulated DC 12V, output of the load cell I is feeding to the highly sophisticated amplifier to the cable corresponding to the force applied on the cell. Amplified output is then converting in analog to digital. This digital output is calibrated to read directly in terms of kgs with respect to amplified force.

Operation of strain gauge Load cell

Case 1 : When there is no load (force) on the steel cylinder, all the four gauges will have the same resistance. As the terminals N and P are at the same potential, the wheat stone bridge is balanced and hence the output voltage will be zero.

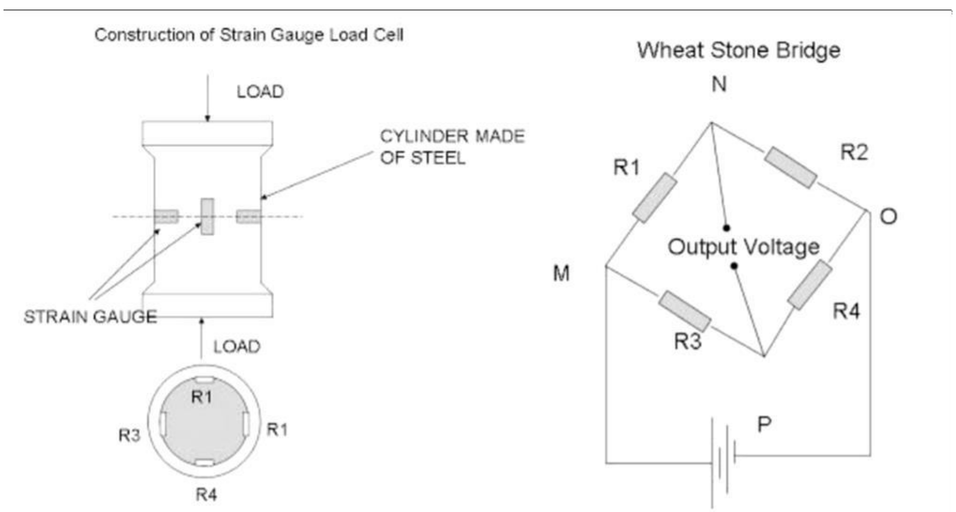
Case 2 : Now the load (force) to be measured (say compression force) is applied on the steel cylinder. Due to this, the vertical gauges R1 and R4 will undergo compression and hence there will be a decrease in resistance. At the same time, the horizontal gauges R2 and R3 will undergo tension and there will be an increase in resistance. Thus when strained, the resistance of the various gauges change. Now the terminal N and P will be at different potential and the change in output voltage due to the applied load (force) becomes a measure of the applied load force when calibrated.

Setup :

Load cell sensor used here is a stain less steel material fitted on bottom frame. Stainless steel pipe has been bonded with strain gauges to form a wheat stones bridge, and the output is taken out through five-pin connector. This sensor can be used as tensile or compressive load cell (i.e., universal type). Here to use this as compressive top of the sensor is fixed with metal frame with stainless steel cover, upon which dead weights can be loaded.

Procedure :

1. Connect the load cell to digital indicator by inserting the corresponding color codes.
2. Connect the digital indicator to mains, power supply and switch ON the indicator.
3. Connect the sensor to the sensor socket provided at the front panel.
4. Switch ON the instrument.
5. Put the READ/CAL switch in READ position and set the zero pot to 00.00(i.e. balance the bridge).
6. Select a weight (say 8kg) and load it on load cell.
7. Put the READ/CAL switch in CAL position and check calibration point that is 78.48 N. i.e.(8 x 9.81N). If not, adjust with the help of CAL pot.
8. Remove the weight from the load cell.
9. Set the zero knob to zero position.
10. Wait for the equipment to get stabilized before performing the experiment.
11. Now instrument is ready for measurement, again put the READ/CAL switch in READ position and apply the load on the sensor one by one and take down the indicator reading.
12. Plot the graph for applied voltage vs. Indicator Reading.
13. Calculate the correction, error and % error.



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

Specification :

Type :	Strain Gauge based.
Range :	10kg
Gauge Resistance :	350ohms
Maximum Excitation :	12 Volt DC
Insulation Resistance :	1000 mega ohms at 25 degrees measured at 30 volt DC
Operating Temperature :	0° - 50° C
Safe Load :	10% of the rated Load.

Tabular Column :

Sl. No	Actual Load (La)		Indicated Load (Li)		Error (Li-La)	Error % $\frac{Li - La}{La}$ x 100
	Kg	N	kg	N		
1						
2						
3						
4						
5						

Uses of Strain Gauge Load Cell.

Strain gauge load cells are used when the load is not steady.
Strain gauge load cells are used in vehicle weigh bridges, and tool force dynamometers.
The use of four identical strain gauges each arm of the bridge provides full temperature compensation and also increases the bridge sensitivity 2(1+μ) times. The strain gauge load cells are excellent force measuring devices, particularly when the force is not steady. They are generally stable, accurate and find extensive use in industrial applications such as draw-bar and tool-force dynamometers, crane load monitoring, and road vehicle weighing device etc.

Plot the Graphs:

1. Indicated Load **v/s** Actual Load.
2. Indicated Load **v/s** % Error.
3. Actual Load v/s Error.

Result : Thus the force cell is calibrated by using digital force cell indicator.

PART A – Experiment No 5
Determination of modulus of elasticity of a mild steel specimen using Strain Gauges

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

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

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.

$$\text{i.e., } E=\sigma/\varepsilon$$

Why is Strain Measured?
Most commonly, strain is measured to determine the level of stress on the material – Experimental Stress Analysis. The absolute value and direction of the mechanical stress is determined from the measured strain and known properties of the material (modulus of elasticity and Poisson's ratio). These calculations are based on Hooke's Law. In its simplest form, Hooke's Law determines the direct proportionality of the strain ε [m/m] and the stress σ [N/mm2] of a certain material using its elasticity or Young's modulus E [N/mm2].

$$\sigma = \varepsilon \cdot E$$

The principle of the electrical resistance strain gauge was discovered by Lord Kelvin, when he observed that a stress applied to a metal wire, besides changing its length and diameter, also changes its electrical resistance. Metallic electrical strain gauges are made in to two basic forms, bonded wire and bonded foil. Wire gauges are sand witched between two sheets thin paper and foil gauges are sand witched between two thin sheets of epoxy. The resistance **R** of a metal depends on its electrical resistivity ρ, its area **A** and the length **L** according to the equation.

$$R= \rho L/A$$

Thus to obtain a high resistance gauge occupying a small area the metal chosen has a high resistivity, a large number of grid loops and a very small cross sectional area. The most common material for strain gauges is a copper- nickel alloy.

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 are 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 gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the **gauge factor.**

Gauge Factor or Strain Sensitivity

For a given amount of unit strain (ΔL/L), the gauge will undergo a corresponding change in resistance (ΔR/R). The ratio of the unit change in the resistance to the unit change in the length is known as gauge factor. Where *R* is the nominal resistance of the gauge

$$G = \frac{dR/R}{dL/L}$$

Conventional foil gauges have standardized nominal resistance values of 120 & 350 ohms & typically exhibit gauge factors between 1.5 & 3.5 in typical transducer applications, they are subjected to full scale design strain levels ranging from 500 to 2000 micro strain.

A strain gauge takes advantage of the physical property of electrical conductance and its dependence on the conductor's geometry. When an electrical conductor is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer, changes that increase its electrical resistance end-to-end. Conversely, when a conductor is compressed such that it does not buckle, it will broaden and shorten changes that decrease its electrical resistance end-to-end. From the measured electrical resistance of the strain gauge, the amount of applied stress may be inferred. A typical strain gauge arranges a long, thin conductive strip in a zigzag pattern of parallel lines such that a small amount of stress in the direction of the orientation of the parallel lines results in a multiplicatively larger strain measurement over the effective length of the conductor surfaces in the array of conductive lines and hence a multiplicatively larger change in resistance than would be observed with a single straight-line conductive wire.

A **Wheatstone bridge** is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. Its operation is similar to the original potentiometer. It was invented by Samuel Hunter Christie in 1833 and improved and popularized by Sir Charles Wheatstone in 1843.

One of the Wheatstone bridge's initial uses was for the purpose of soils analysis and comparison. In the figure, Rx is the unknown resistance to be measured; R1, R2 & R3 are resistors of known resistance and the resistance of R2 is adjustable.

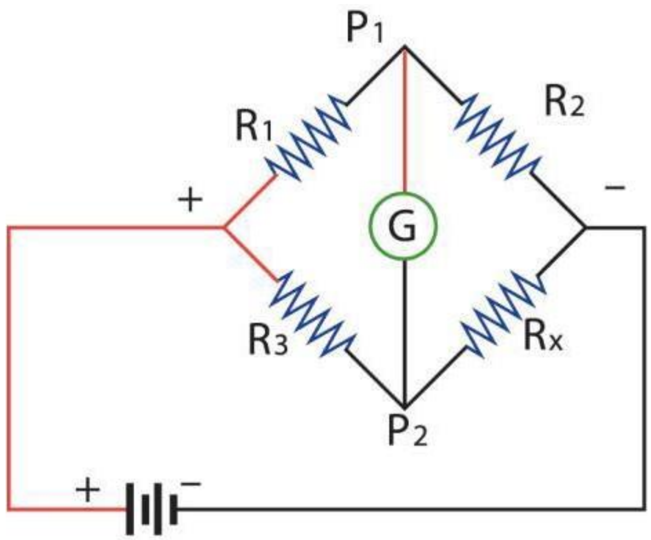
If the ratio of the two resistances in the known leg (R2/R1) is equal to the ratio of the two in the unknown leg (Rx/R3) then the voltage between the two midpoints (**B** and **D**) will be zero and no current will flow through the galvanometer Vg. If the bridge is unbalanced, the direction of the current indicates whether R2 is too high or too low. R2 is varied until there is no current through the galvanometer, which then reads zero. Detecting zero current with a galvanometer can be done to extremely high accuracy.

Therefore, if R1, R2 and R3 are known to high precision, then Rx can be measured to high precision. Very small changes in Rx disrupt the balance and are readily detected. At the point of balance, the ratio of

$$\frac{R2}{R1} = \frac{Rx}{R3}$$

$$Rx = \frac{R2}{R1}\ R3$$

Let us assume that the resistance have been adjusted so that the bridge is balanced.



i.e., $V_G = 0$.
Thus for initial balance, R1 x Rx = R2 x R3
Rx = (R2 x R3) / R1

If the structural member, to which the strain gauage is bonded, is to be loaded and strained, there would be a resultant change in the resistance R1.

Alternatively, if R1, R2 & R3 are known, but R2 is not adjustable, the voltage difference across or current flow through the meter can be used to calculate the value of Rx, using Kirchhoff's (also known as Kirchhoff's rules). This setup is frequently used in strain gauge and resistance thermometer measurements, as it is usually faster to read a voltage level off a meter than to adjust a resistance to zero the voltage.

The most common bridge arrangements are single 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.

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 labeled 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.

Consider a cantilever beam as shown in figure,

Let W= Load applied on the beam in N.

L = Distance between the centre of the gauges to the point of application of Load.

b = Width of the beam in mm.

h = thickness of the beam in mm.

Mb = Bending Moment, WL in Nmm.

I = Moment of Inertia = $bh^3/12$ mm^4

c = h/2 mm.

The Bending equation is $\frac{Mb}{I} = \frac{\sigma}{C}$

Bending Stress, $\sigma = \frac{Mb}{I} \times c$

$$Wl \times \frac{h}{2} \times \frac{12}{bh^3} = \frac{6WL}{bh^2}$$

Let ε = strain indicator reading in micro strain.

i = Number of active gauges.

$$\text{Measured strain, } (\varepsilon_m) = \frac{(si)(10^{-5})}{i}$$

$$\text{Modulus of Elasticity, } E = \sigma / \varepsilon_m$$

$$= \frac{6WL}{bh^2} \varepsilon_m$$

The strain gauges R1 and R3 measure the tensile stress while the strain gauges R2 and R4 measure the compressive stress. The strains ε1, ε2, ε3 and ε4 are measured by the strain gauges are of equal magnitude. The bridge in this arrangement is said to be working as full bridge and sensitivity (output) is 4 times that achievable with a single active gauge.

Setup :

The setup comprises of cantilever beam made up of mild steel material. Square pipe with opening at the top at one end and the other end Land for fixing the table. A loading pan is provided to load the sensor. Weights up to 1kg in steps of 10gms will be provided with the setup. Specimen with strain gauges of 120 ohms are bonded on the material and connected in the form of wheat stones bridge and the terminals are brought out through a connector.

Characteristics of Strain Gauges

For a satisfactory operation a strain gauge should have the following characteristics:

- It should have a high value of gauge factor. With the high value of the gauge factor, we can get a high sensitivity of the system.
- It should have a high value of resistance as it minimizes the effect of unwanted variations of resistance in the measurement circuit.
- It should have low resistance temperature coefficient. It is very necessary to minimize errors due to temperature variations.
- It should not have any hysteresis effects.
- It should have linear characteristics. variations in resistance should always be proportional to the variations in the strain.

Significance:

The Wheatstone bridge illustrates the concept of a difference measurement, which can be extremely accurate. Variations on the Wheatstone bridge can be used to measure capacitance, inductance, impedance and other quantities, such as the amount of combustible gases in a sample, with an explosimeter. The Kelvin Bridge was specially adapted from the Wheatstone bridge for measuring very low resistances. In many cases, the significance of measuring the unknown resistance is related to measuring the impact of some physical phenomenon (such as force, temperature, pressure, etc.) which thereby allows the use of Wheatstone bridge in measuring those elements indirectly. The concept was extended to alternating current measurements by James Clerk Maxwell in 1865 and further improved by Alan Blumlein around 1926.

Specification of Cantilever Beam setup :

Capacity : 1kg
Type : Strain Gauge based
Strain gauge: Foil type, 120 ohms
Guage Factor : 2
Weights : 100 gms – 10 Numbers
Beam Material : Mild Steel
Length in mm L = 250 mm (Distance between gauge centers to the point application of load)
Width of beam, b in mm = 41 mm.
Thickness of beam, h in mm = 2.83 mm.

I. Strain Measurement in Four Arm Modes (Full bridge)

Procedure:

1. Switch on the instrument and leave 15 minutes to warm up.
2. Connect the respective color wires of sensors to terminals in the indicator panel.
3. Keep the arm selector switch on 4 (i=4)
4. Keep the function switch to gauge factor and adjust the gauge factor pot, to read 500 in display.
5. Select the function switch to cal and adjust the cal pot to read 1000.
6. Keep the function switch to read and adjust the display to read zero.
7. Apply load 100 gms step by step and note the readings.
8. Calculate the Young's Modulus and compare the value with theoretical value.

Tabular Column (Full Bridge) :

Sl.no	Load Applied W in (N)		Strain Indicator Reading εi micro strain	Measured strain $S_m = \frac{(si)(10^{-5})}{i}$	Bending Stress (N/mm²) $\sigma = \frac{6WL}{bh^2}$	Modulus of Elasticity $E = \sigma / \varepsilon_m$ (N/mm²)
	gms	N				
1	200					
2	400					
3	600					
4	800					
5	1000					

Calculation:

Load Applied, W = 0.2 x 9.81 (200g / 1000) = 1.962 N

Bending Stress, = $6WL / bh^2$ = (6 x 1.962 x 250) / (42 x 3^2) = 7.78 N/mm²

For Four arm modes, (Full Bridge)

Measured Strain, $\varepsilon = \frac{(si)(10^{-6})}{4} =$

Young's Modulus, E = σ / εm =

Results:

Using the strain gauges, Young's Modulus of the given mild steel specimen has been determined for full bridge.

II. Strain Measurement in Two Arm Modes (Half bridge)

Procedure:

1. Switch on the instrument and leave 15 minutes to warm up.
2. Connect the respective color wires of sensors to terminals in the indicator Panel.
3. Remove the center pin in the sensor part and green pin in the indicator panel.
4. Keep the arm selector switch on 2.(i=2)
5. Keep the function to gauge factor and adjust the gauge factor pot to read 500 in display.
6. Select the function switch to cal and adjust the cal pot to read 1000.
7. Keep the function switch to read and adjust the display to read zero.
8. Apply load of 100 gms gradually and note down the reading.
9. Calculate the Young's Modulus and compare the value with theoretical value.

Tabular column (For Half Bridge)

Sl.no	Load Applied W in (N)		Strain Indicator Reading εi micro strain	Measured strain $S_m = \frac{(si)(10^{-5})}{i}$	Bending Stress (N/mm²) $\sigma = \frac{6WL}{bh^2}$	Modulus of Elasticity $E = \sigma / \varepsilon_m$ (N/mm²)
	gms	N				
1	200					
2	400					
3	600					
4	800					
5	1000					

III. Strain Measurement in one Arm Modes (Quarter Bridge)

Procedure: Remove the center pin in the sensor part and black pin in the indicator panel. Remaining is same as half bridge.

1. Switch on the instrument and leave 15 minutes to warm up.
2. Connect the respective color wires of sensors to terminals in the indicator Panel.
3. Remove the center pin in the sensor part and yellow & black pin in the indicator panel.
4. Keep the arm selector switch on 1.(i=1)
5. Keep the function to gauge factor and adjust the gauge factor pot to read 500 in display.
6. Select the function switch to cal and adjust the cal pot to read 1000.
7. Keep the function switch to read and adjust the display to read zero.
8. Apply load of 100 gms gradually and note down the readings.
9. Calculate the Young's Modulus and compare the value with theoretical value.

Sl.no	Load Applied W in (N)		Strain Indicator Reading εi micro strain	Measured strain $S_m = \frac{(si)(10^{-5})}{i}$	Bending Stress (N/mm²) $\sigma = \frac{6WL}{bh^2}$	Modulus of Elasticity $E = \sigma / \varepsilon_m$ (N/mm²)
	gms	N				
1	200					
2	400					
3	600					
4	800					
5	1000					

Applications:

1. Wherever load cells are using there is a strain gauge embedded in it.
2. Estimation of structural strength in steel & concrete structures, bridges & hydraulic structures.
3. In large machineries, pipelines & pressure vessels.
4. Estimation of remaining life of old & huge structures like civil engineering structures, rail bridges & electrical towers.
5. Strain gauges are used for the stress analysis without any experiments.
6. Strain gauges are also used in measuring the stress developed in the moving parts of the engine. Ex: piston.

Strain is measured using resistance gauges attached to member under investigation. Stain resulting from stress (N/mm2) 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.

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

Graphs:

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

Modulus of elasticity E = slope of the line

Results:

Using the strain gauges, Young's Modulus of the given mild steel specimen has been determined for half and quarter bridges.

PART – B Experiment No : 6

OPTICAL PROFILE PROJECTOR

Aim : To measure the screw thread parameters of a given specimen using Optical Profile projector.

Apparatus : Optical Profile Projector, screw thread.

Theory:

The optical comparator is a device that applies the principle of optics for the inspection of manufactured parts. Profile projector is a optical 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 renders geometrically accurate & bright image on a ground glass serving as a screen.

The system consists of a projection lens in combination with a condenser unit, micro stage and grounded glass as viewing screen as shown in figure. The illuminating system consists of a light source and a collimating optics, which are free from spherical aberration. The micro control stage below the condenser unit was provided with X and Y displacements to an accuracy of ten microns. The projection lens fixed below the micro stage has 20X magnification and is designed for distortion free image. Moving the stage up and down will do focusing of the object placed on the stage. The clear image of the object will be seen on the projection screen with the help of a front-coated reflecting glass provided in the projection system.

The screen is generally translucent so that the image can be viewed from the opposite side.

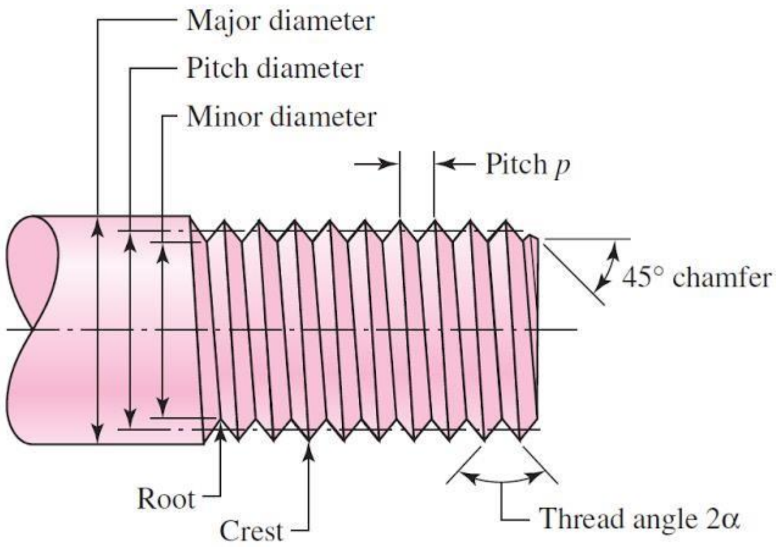
The function of the roof prism is to direct the beam of light horizontally towards the back of the projector to assist in the projection of the image. There are three types of projectors. Those are Horizontal projector, vertical projector, cabinet projector.

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.

Screw threads are employed basically for two purposes:

(i) To fasten two components with the help of nuts, bolts and studs.

(ii) To transmit the power, as in case of lathe machine lead screw.



Terminology of Screw Threads

Screw thread is a continuous helical groove of specified cross-section produced on the external or internal surface. A screw thread formed on a cylinder is known as straight or parallel screw thread, while screw thread formed on a cone or frustum is known as the tapered screw thread.

Axis of a thread: This is an imaginary line running longitudinally through the center of the screw.

Crest: *Crest of the thread* is the top most surface joining the two sides.

Root: *Root of the thread* is the bottom of the groove between the two flanks.

Flank: *Flank of thread* are straight edges which connect the crest with the root of the thread.

Pitch: Pitch of a thread is the distance measured parallel to the axis from a point on a thread to the corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis.

Depth of thread: Depth of a thread is the distance between the crest and root of the thread.

Major diameter: It is an imaginary largest diameter of the thread which would touch the crests of an internal or external thread.

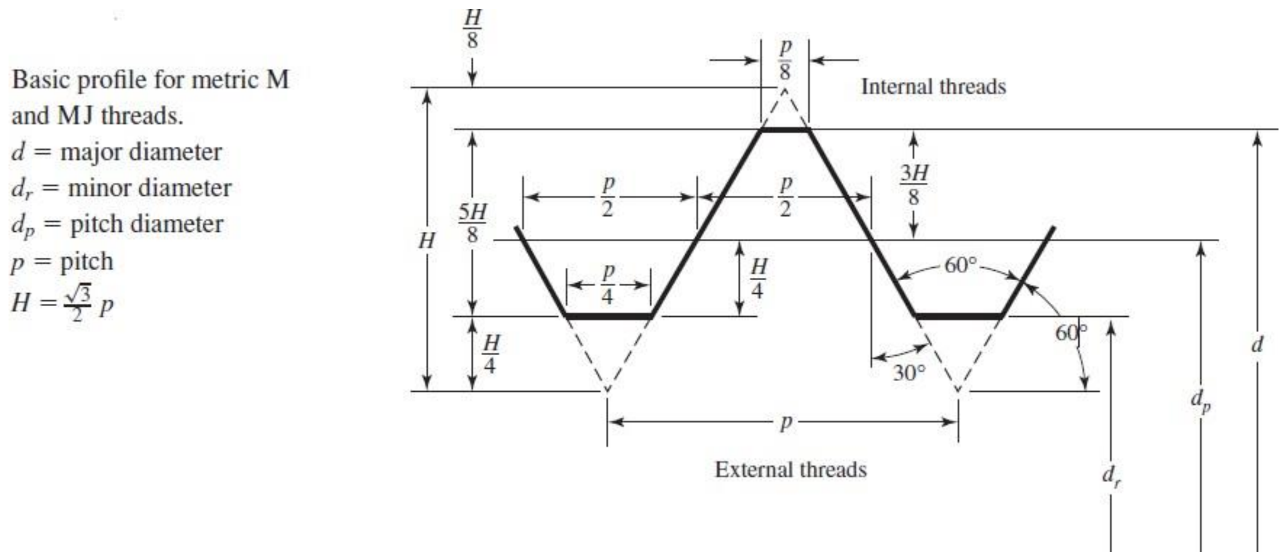
Minor diameter: It is an imaginary smallest diameter of the thread which would touch the roots of an external thread.

Pitch diameter: It is a theoretical diameter between the major and minor diameter of screw threads.

Helix angle: On the straight thread, It is the angle made by the helix of the thread at the pitch line with the axis.

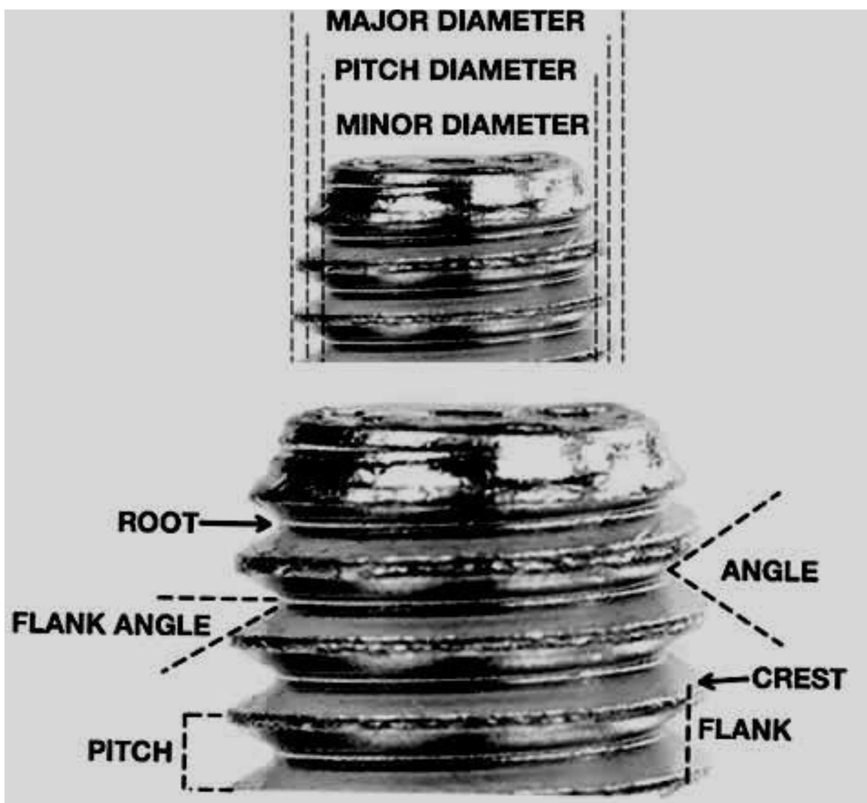
Lead angle: On the straight thread, It is the angle made by the helix of the thread at the pitch line with a plane perpendicular to the axis. Lead angle is measured in an axial plane.

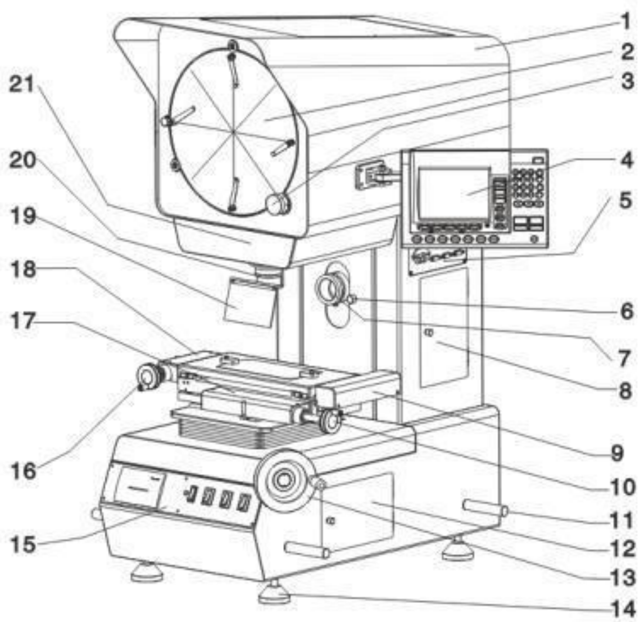
Flank angle: Flank angle is the angle made by the flank of a thread with the perpendicular to the axis of a thread.



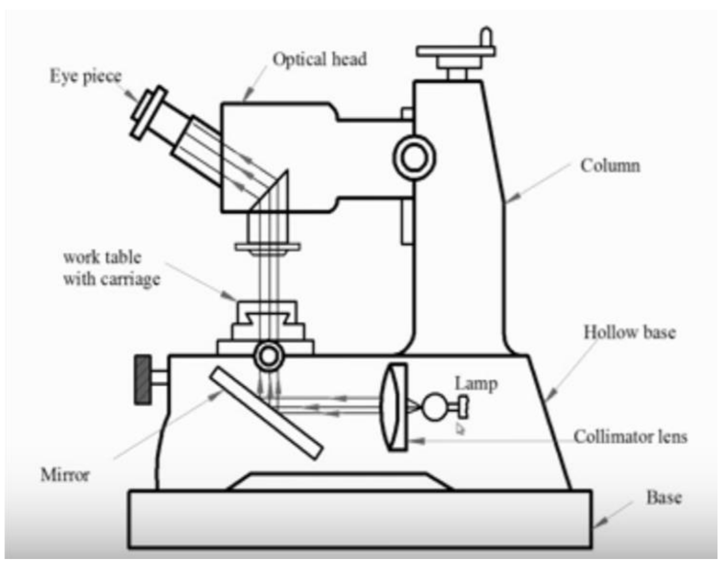
Included angle: Included angle is the angle between the flanks or slope of the thread measured in an axial plane.

The lead: It is the distance the nut moves parallel to the screw axis when the nut is given one turn. For a single thread as shown in the figure above, the lead is the same as the pitch of the screw thread.





1.Projector Box 2.Projection Screen 3.Projection screen rotating fine-turning band wheel 4.Digital Display Box 5.Signal Line adapter Board 6.Reflective Lighting adjustment handle 7.Reflective Lighting condenser 8.Wicket 9.Y-axis Grating ruler 10.X-asis hand wheel 11.Carrying bolts 12.Wicket 13.Lifting hand wheel 14.Foot 15.Operation panel 16.Y-axis hand wheel 17.X-drive group 18.Y-drive group 19.Shading plate 20.Objective lens 21.Instrument signs.



The purpose of the optical projector is to compare the shape or profile of relatively small engineering compound with an accurate standard or drawing.

Profile projector Specification:
Screen diameter = 300 mm
Magnification = 20X
Table travel = 25 x 25 mm
Screen rotation L.C = 2 min

PROCEDURE:
1. The power supply to the profile projector was switched on.
2. The micro stage was made free from dust and the given grub screw was placed on it.
3. The height of the micro stage was adjusted to focus the object to get clear and sharp image on the projection screen.
4. The micrometer heads of the stage were adjusted to have the image at the center of the projection screen.
5. The screw thread parameters are found by adjusting the micrometer heads provided for the table movement and the protractor fitted to the projection screen.
6. The image on the screen was traced on a tracing paper or graph sheet.
7. Knowing the magnification, the parameters, pitch, thread angle, root diameter and major diameter were found from the drawing.
8. Both the readings are compared and noted down.

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. The specimen should be cleaned before placing
2. The specimen axis should be parallel to stage surface
3. The tracing paper should be fixed securely on the screen
4. On the sharp image after proper focusing should be traced.
5. Do not disturb the original setting of the mirror.
6. Never touch the surface of the mirror with bare hands

PART – B Experiment No : 7
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 (900), which is defined as the angle between two lines which interest so as to make the adjacent angle equals (four equal parts). 10 = 60" (60 equal parts), 1''=60" (60 equal parts).
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

PART – B Experiment No : 7(i)

Angle Measurement Using Sine – Bar

Aim: To determine the taper angle of the given work piece and compare it with theoretical value by using sine bar.

Apparatus: Surface plate, sine bar, slip gauge sets, Vernier calliper, cleaning agent, tapered work piece, clean dry soft cloth, clamping devices etc.

Theory:

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

Use of Sine bar: The work piece whose angle is to be measured is placed on sine bar. Below one roller of sine bar, slip gauges are placed. Slip gauges are added till the work piece surface is straight. Dial indicator is moved from one end of work piece till another end. Slip gauges are added till dial pointer does not move from zero position. The use of sine bar is based on the laws of trigonometry. When sine bar set up is made for the purpose of angle measurement, sine bar itself forms hypotenuse of right angle triangle and slip gauges form the side opposite to the required angle**.** Sin θ= (h/L), Therefore θ= sin-1(h/L), Angle θ is determined by an indirect method as a function of sine so this device is called as sine bar. Sine bar is always used in conjunction with slip gauge and dial indicator for the measurement of angle.

The angle is defined as the opening between the two lines or planes, which meet at a point. So angle is a thing which can be generated very easily requiring no absolute standard. Sine bars are used in junction with slip gauges constitute a very good device for the precision measurement of angles. Since sine bars are used either to measure angle very accurately or for locating any work to a given angle within very close limit. Sine bars are used only for measuring and setting any angle of the object having flat surface. Sine bars are also used to measure or set angle of the object not larger than the 450, if higher accuracy is demanded.

Procedure:

1. Set the sine bar on the surface plate.
2. Measure the distance between rollers of center of sine bar.
3. Mark the position of the rollers on the surface plate which is advantage if the position of sine bar is changed.
4. The axial length of taper under test is noted by use of vernier calliper.
5. The work piece whose taper is required to be known is fixed on the upper surface of the sine bar by means of clamp and so positioned that easily access whole length of the taper to the dial gauge.

6. The dial gauge is fixed on its stand which in term is fixed on the slide way.
7. Note down the least count of the dial gauge used.
8. Adjust the slip gauge height on the taper to be measure in such a way that it easily takes slip on the smaller end and note down dial gauge reading at the entry end.
9. By sliding the dial gauge across the work piece length take reading of the dial gauge on other end.
10. Calculate approximate height of slip gauge required at smaller dimension end in order to become an upper surface of the work piece parallel to the reference plane.
11. Without altering the position of the roller place the slip gauge pile under the roller of small size end of the sine bar set up to equal approximate height.
12. Then test with dial gauge for null deflection. If there is any slight deflection in dial gauge then alter slip gauges pile until getting null deflection.
13. With the help of formulas given in, calculate the actual angle and theoretical angle of taper and error in taper.

Observations:

1. Least count of vernier calliper =_____________mm
2. Least count of dial gauge =_____________ mm
3. Distance between the centre of rollers & side bar L = 200 mm
4. Length of specimen (taper length), l =_____________mm

Sl. no	Taper length of the specimen 'l' mm	Height for one side of the work piece 'h1' mm	Height for another side of the work piece 'h2' mm	Diff. of height dh = (h2 - h1)	App. Ht. of slip gauge Read. Happ	Actual Ht. of slip gauge Read. Hact	Theoretical Taper angle, θth	Actual taper angle, θact	Error
1									
2									

Calculations:

1) Height for one side of the work piece 'h1' = -------------mm
2) Height for another side of the work piece 'h2' =--------------mm
3) Difference in height dh = (h2- h1) = -------------- mm.

4) Approximate height of slip gauge used = Happ.

$$Happ. = \frac{dh \times L}{\sqrt{(dh^2 + l^2)}} \text{------------------------} mm$$

5)Theoretical taper angle, θth = tan-($\frac{D-d}{2l}$)= --------------Degrees.

6)Actual taper angle, θact = $\sin^{-1}$ (Hact/l) = ----------- Degrees.

7)Error θact - θthe = ----------------Degrees.

Precautions in use of Sine bars:

1. Sine bar not used for angle greater than 450 (impractical) fairly reliable for angles less than 150.
2. Longer sine bars should be used, since many errors are used by using longer sine bar.

Applications:

1. To measure and/ or set the angle accurately using a sine bar, the main requirement is that it must be accurate.
2. To check the flat surfaces in industry machine tools like lathe beds, milling machines columns, tables, apron & also saddle in lathe.
3. Rolling mills housing can be checked by sine bars.

Results: For a given component/ plug gauge , we found the theoretical taper angle is ________ degrees & also actual taper angle is___________degrees.

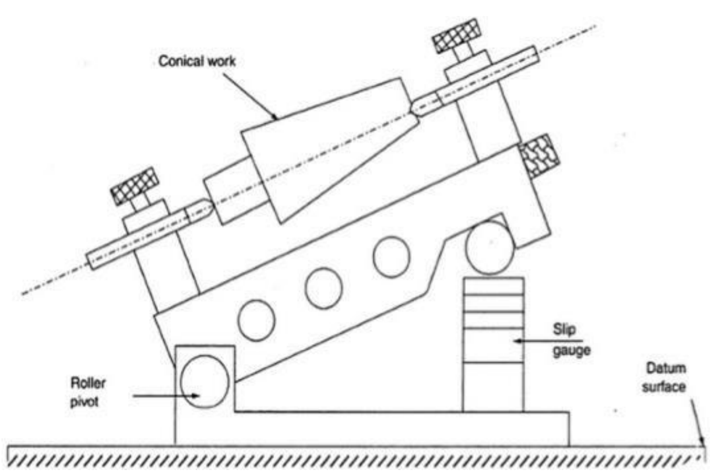
PART – B Experiment No : 7(ii)

Angle Measurement Using Sine Centre

Aim: To determine the taper angle of a given taper plug gauge/component by using sine centre.

Apparatus: Sine centre, Plug gauge, slips gauge, Surface Plate, Comparator with arrangement & cleaning agent with cotton.

Theory:



Theory:
The sine centres are used to measure the angles very accurately or for locating any work to a given angle within much closed limits. Sine centre are made from High Carbon, High Chromium corrosion resistant steel, hardened, ground and stabilized.
A special type of sine bar is sine centre which is used for conical objects. It cannot measure the angle more than 45 degrees. Two cylinders of equal diameter are attached at the ends, the axis of these two cylinders are mutually parallel to each other and also parallel to and equal distance from the upper surface of the sine center. The distance between the axes of the two cylinders is exactly 50 or 100 in British system and 100, 200, 300, mm in Metric system.
Some holes are drilled in the body of the bar to reduce the weight and to facilitate handling. Sine centre itself is not a complete measuring instrument. Another datum such as surface plate is used as well as auxiliary equipment notably slips gauges. Sine centre is basically a sine bar with block holding centres which can be adjusted and rigidly clamped in any position. These are used for inspection of conical objects between centres. These are used up to inclination of 60°. Rollers are clamped firmly to the body without any play. This is a very useful device for testing the conical work cantered at each end. The principle of setting is same as of sine table.

Procedure:
1. Note down the least count of the vernier calliper and dial gauge.
2. Measure the minimum, maximum diameter and axial length of taper plug gauge usingVernier calliper.
3. Calculate approximate height of slip gauge using formula.
4. Build up the height using M-87 set of cleaning the surface of slip gauge using acetone liquid and use wringing technique to build the height.
5. Place the slips below one of the cylinder of sine centre which is placed above the surface plate.
6. Keep the plug gauge in between the sin centre.
7. Use the dial gauge with assembling to check the deviation from one end to other end of plug gauge and note down the deviations.
8. Add or subtract the value of the deviation to difference in dial gauge Reading (dh) and repeat the step 7 until zero reading occur in dial gauge and rebuilt the slips repeatedly.
9. Calculate the actual angle of taper plug gauge using actual slip heights.

Sl. no	Taper length of the specimen 'l' mm	Height for one side of the work piece 'h1' mm	Height for another side of the work piece 'h2' mm	Diff. of height dh = (h2 - h1)	App. Ht. of slip gauge Read. Happ	Actual Ht. of slip gauge Read. Hact	Theoretical Taper angle, θth	Actual taper angle, θact	Error
1									
2									

Applications:
1. In workshops, assembly shops, precision machining.
2. Checking of existing machine components.
3. Precision machining in aerospace industries & quality control departments.
4. These are used in situations where it is difficult to mount the component on the sine bar.

Calculations:
1) Height for one side of the work piece 'h1' = --------------- mm
2) Height for another side of the work piece 'h2' = --------------- mm
3) Difference in height dh = (h2- h1) = --------------- mm.
4) Approximate height of slip gauge used = Happ.

$$\text{Happ.} = \frac{dh \times L}{\sqrt{(dh^2 + l^2)}}\text{-----------------------}\text{mm}$$

5)Theoretical taper angle, θth = $\tan^{-1}\left(\frac{D - d}{2l}\right)$= -------------- Degrees.

6)Actual taper angle, θact = $\sin^{-1}$ (Hact/l) = ----------- Degrees.

7)Error θact - θthe = ---------------- Degrees.

Result:
For a given component/ plug gauge , we found the theoretical taper angle is________degrees & also actual taper angle is___________degrees.

PART – B Experiment No : 7(iii)

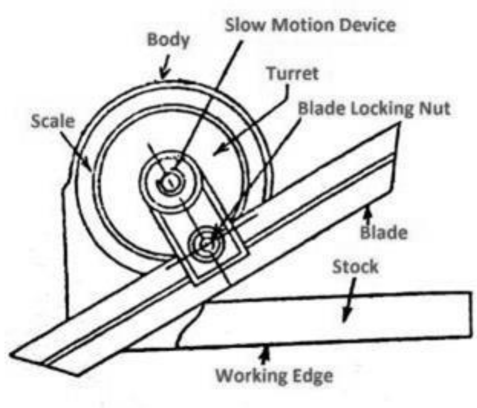
Angle Measurement Using Bevel Protractor

Aim: To find out the taper angle of given work piece by using Bevel Protractor.
Apparatus: Surface Plate, Bevel Protractor, Tapered work piece.
Objectives:
Students will be able to know

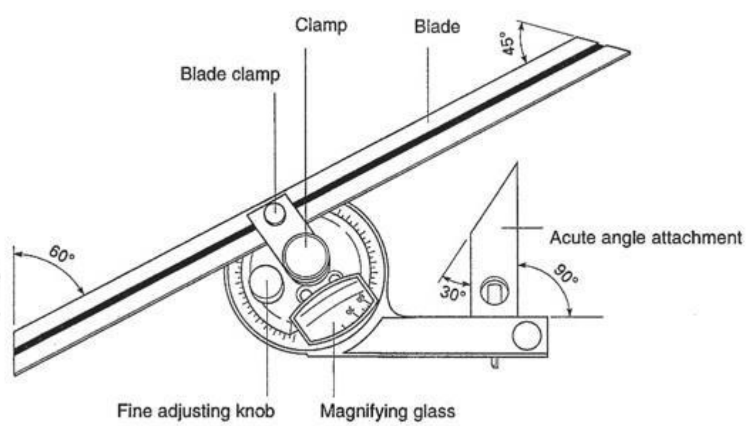
- Understand different parts of vernier bevel protractor,
- Know the use and working of bevel protractor,
- Understand the use of vernier bevel protractor.

Theory:
Main parts of bevel protractor are
1. Fixed Base blade and a circular body is attached to it.
2. Adjustable blade.
3. Blade clamp.
4. Scale magnifier lens.
5. Acute angle attachment.

Bevel protractor is used for measuring and 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.



Mechanical Bevel Protractor Without Vernier & Acute Angle Attahment



It is the simplest instrument for measuring the angle between two faces of component. It consists of base plate attached to the main body and an adjustable blade which is attached to a circular plate containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale engraved on the body of the instrument and can be locked in the any position. It is capable of measuring from zero to 3600. The vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus the least count of the instrument is 51. This instrument is most commonly used in work shop for angular measurements.

Note the reading, magnifying lens has been provided for easy reading of the instrument. Main scale is circular and is graduated in degrees on the circular body. Main scale graduations are all around the circular body which is attached to fixed base blade. Fixed base blade also called as stock is attached to circular body of bevel protractor as shown in figure. Once the reading is fixed, blade clamp fixes the reading. Blades are about 150 mm long or 300mm long, 13mm wide and 2mm thick. Its ends are bevelled at angles of 45 degree and 60 degree.

Vernier scale is also marked on turret which can rotate all over the fixed body. Adjustable blade can pass through the slot provided in turret. So as the turret rotates, adjustable blade also rotates full 360 degrees. There are 12 graduations of Vernier scale starting from 0 to 60° on both sides of zero of Vernier scale as shown in figure.

L.C of Vernier bevel protractor $= \frac{Smallest\ Division\ on\ main\ scale}{Total\ no\ of\ divisions\ on\ vernier\ scale} = 1° \,(60^{'}) = 5^{'}(minutes)$

Procedure:

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

Observations:

Least count of the Bevel Protractor__________________minutes.

Tabular Column:

SL No.	Faces/Sides	Angles
1		
2		
3		
4		

Applications:

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

Results:

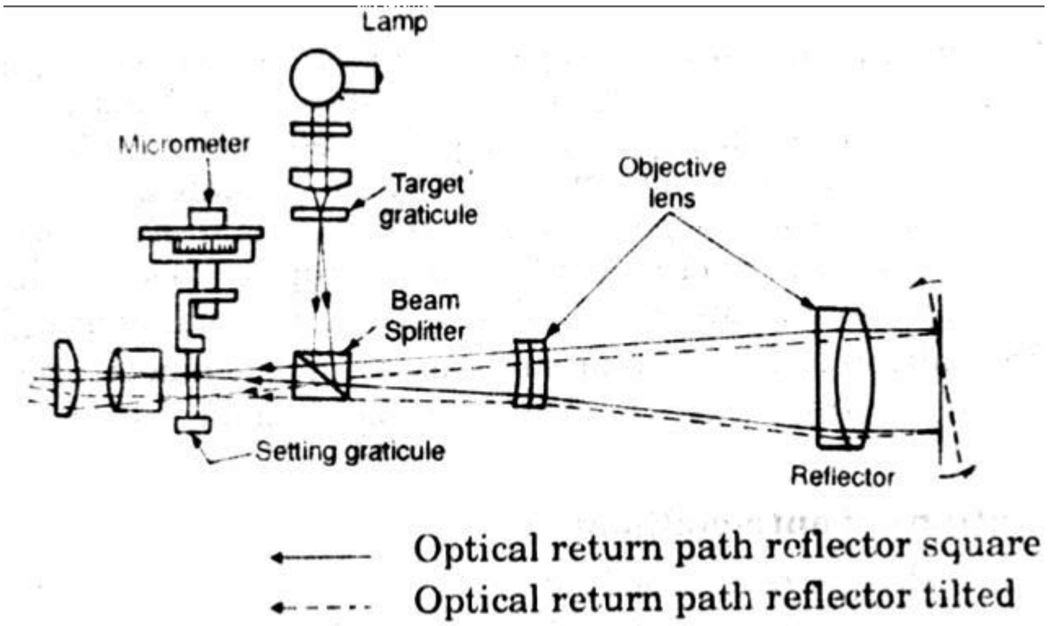
By using the bevel protractor, the taper angle of the given specimen is calculated.

PART – B Experiment No : 8

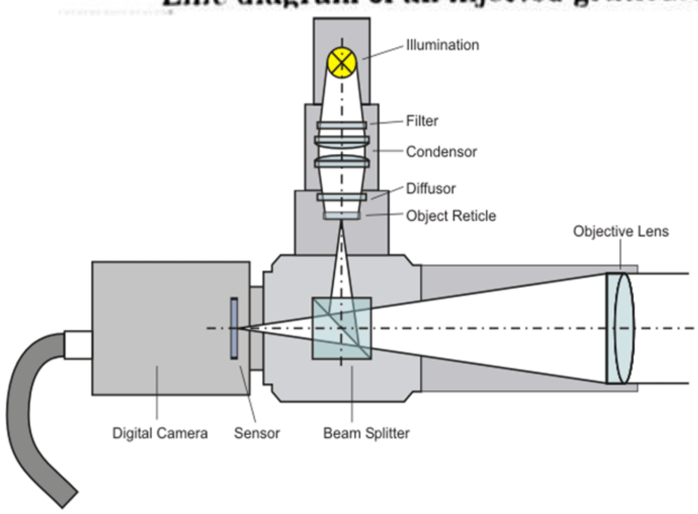
Measurement of Alignment Using Autocollimator

Aim: To check the Straightness & flatness of the given component by using Autocollimator.
Apparatus: Autocollimator, work piece/ object to be tested.

Theory:
Definition of straightness-a plane is to be said straight over a given length. If the variation or distance of its point from two planes perpendicular to each other and parallel to the generation direction at of the line remain within specified tolerance limits. The reference planes being so chosen that there intersection is parallel to the straight line joining two points suitably located on the line to be tested and two points being close ends of the length to be measured.



Line diagram of an injected graticule autocollimator



Principle of the Autocollimator: A cross line 'target' graticule is positioned at the focal plane of a telescope objective system with the intersection of the cross line on the optical axis, i.e. at the principal focus. When the target graticule is illuminated, rays of light diverging from the intersection point reach the objective via a beam splitter and are projected from the objective as parallel pencils of light. In this mode the optical system is operating as a **'collimator'**

A **flat reflector** placed in front of the objective and exactly normal to the optical axis reflects the parallel pencils of light back along their original paths. They are then brought to focus in the plane of the target graticule and exactor coincident with its intersection. A proportion of the returned light passes straight through the beam splitter and the return image of the target cross line is therefore visible through the eyepiece. In this mode, the optical system is operating as a telescope focused at infinity.

If the reflector is tilted through a small angle the reflected pencils of light will be deflected by twice the angle of tilt (principle of reflection) & will be brought to focus in the plane of target graticule but linearly displaced from the actual target cross lines by an amount $2\theta * f$.

An optical system of an auto collimator consists of a light source, condensers, semi reflectors, target wire, collimating lens and reflector apart from microscope eyepiece. A target wire takes place of the light source into the focal plane of the collimator lenses. Both the target wire and the reflected image are seen through a microscope eyepiece. The eyepiece incorporates a scale graduated in 0.05mm interval and a pair of parallel setting wires which can be adjusted. Movements of wires are effected through a micrometer, one rotation of the drum equals to one scale division movement of the wires. The instrument is designed to be rotated through 90 degrees about its longitudinal axis so that the angles in both horizontal & vertical planes are measured.

SL No	Bridge Length (Base length of the reflector)	Cumulative Bridge length (Position of the reflector)	Micrometer final reading (Autocollimator)	Difference from previous position (X in seconds)	Deviation for each 100mm (Ɵ in degrees)
1					
2					
3					
4					

Calculation:

Tan θ= X / 100

X = (100 x **Tan** θ) x 1000 in Microns

Where X = Level at position B with respect to position A

θ = Angle/Deviation in degrees/ Seconds (1 Degree = 60 Minutes, 1 Minute = 60 Seconds).

Autocollimators: It is an instrument designed to measure small angular deflections & may be used in conjunction with a plane mirror or other reflecting surface. An automator is essentially

an infinity telescope & a collimator combined into one instrument. This is an optical instrument used for the measurement of small angular differences. For small angular measurements, autocollimator provides a very sensitive and accurate approach. Autocollimator is essentially an infinity telescope and a collimator combined into one instrument.
The principle on which this instrument works is given below. O is a point source of light placed at the principal focus of a collimating lens. The rays of light from O incident on the lens will now travel as a parallel beam of light. If this beam now strikes a plane reflector which is normal to the optical axis, it will be reflected back along its own path and refocused at the same point O. If the plane reflector be now tilted through a small angle 0, then parallel beam will be deflected through twice this angle, and will be brought to focus at O' in the same plane at a distance x from O. Obviously $OO' = x = 2\theta . f$, where *f* is the focal length of the lens.

Applications:
1. To find the control line & alignment of circular & flat surfaces in machining.
2. Alignment of beams & columns in construction buildings / industries, steel structures.
3. In measuring the straightness, flatness and parallelism, these can be used.

Procedure:
(1) Make the distance of 100mm internal on the work piece.
(2) Set the cross wire so that two cross will coincide.
(3) Set the mirror so that the cross wire will be visible
(4) Move the reflector on next 100mm mark and adjust it to see reflection of cross wire.
(5) Take the reading of reflected crosswire deviated or moved up or down. Measure the distance between two crosswire.

Result:
The values are analyzed and necessary modification of the surface may be recommended based on the accuracy required on flatness. If the values observed from the micrometer are varying linearly then straightness/flatness can be judged.

PART – B Experiment No : 9
Measurement Of Cutting Tool Forces By Using Lathe Tool Dynamometer

Aim: To measure the cutting tool forces by using lathe Tool Dynamometer.
Apparatus: Lathe tool dynamometer, digital force indicator, work piece of any material and lathe machine tool.

Specifications:

Capacity : X, Y, Z - Force 500 Kg
Excitation : 10v Dc
Linearity : 2%
Accuracy : 2%
Cross-Sensitivity : 5%
Max. Over Load : 150 %

Theory: The dynamometers being commonly used now-a-days for measuring machining forces desirably accurately and precisely (both static and dynamic characteristics) are either a strain gauge type or a piezoelectric type. Strain gauge type dynamometers are inexpensive but less accurate and consistent, whereas, the piezoelectric type are highly accurate, reliable and consistent but very expensive for high material cost and stringent construction.

Turning/Lathe Dynamometer: Turning dynamometers may be strain gauge or piezoelectric type and may be of one, two or three dimensions capable to monitor all of PX, PY and PZ. For ease of manufacture and low cost, strain gauge type turning dynamometers are widely used and preferably of 2 – D (dimension) for simpler construction, lower cost and ability to provide almost all the desired force values. Pictorially shows use of 3 – D turning dynamometer having piezoelectric transducers inside.

Procedure: Lathe Tool Dynamometer is a cutting force measuring instrument used to measure the cutting forces coming on the tool tip on the Lathe Machine. The sensor is designed in such a way that it can be rigidly mounted on the tool post, and the cutting tool can be fixed to the sensor directly. This feature will help to measure the forces accurately without lose of the force. The sensor is made of single element with three different wheat stones strain gauge bridge. Provision is made to fix 1/2" size Tool bit at the front side of the sensor. The tool tip of the tool bit can be grind to any angle required. Forces in X - Y – Z directions will be shown individually & simultaneously in three digital Indicators Supplied.

Applications:
1. To determine the cutting forces in all the directions in cutting tools mounted on a machine like lathe, milling etc.
2. In metal forming operations, like to find out the forces on punch press tools.

Sl.No	**RPM of the motor**	**Speed V = πDN**	**Forces in Kg-f**			**Resultant force**	
	N	**mm/min**	**FX**	**FY**	**FZ**	**Kg**	**N**
1							
2							
3							

Tabular Column:
Material used: __________________ Depth of Cut:_________________mm

Calculation:
Diameter of the specimen (D) = MSR + (CVD x LC) mm
1. For___________RPM Fr =___________Kg

2. For___________RPM Fr =___________Kg

3. For___________RPM Fr =___________Kg

4. For___________RPM Fr =___________Kg

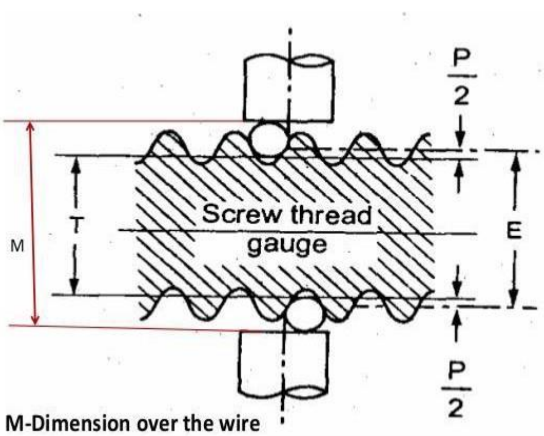
Result:
The resultant forces are found out for different speeds (V) by lathe tool dynamometer.

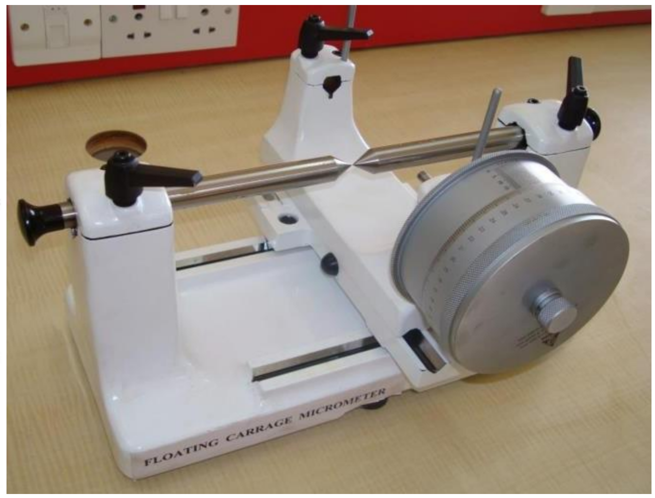
PART – B Experiment No : 10

Measurement of Screw Thread Parameters Using Two Wire Method / By Floating Carriage Micrometer

Aim: To measure the screw thread parameters using two wire method by Floating carriage micrometer.

Apparatus: Micrometer, micrometer stand, a set of two wires, pitch gauge and Screw thread specimen.



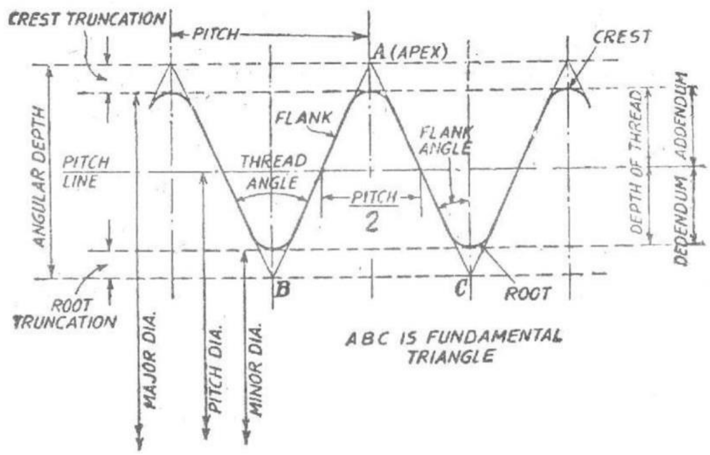


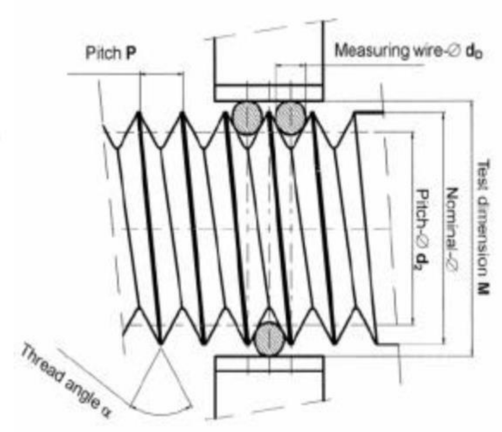
Procedure:

1. Fix the given screw thread specimen to the arrangement block.
2. Measure the pitch of the given thread using pitch gauges and also note down the angle of the thread based on Metric or With Worth.
3. Measure the maximum diameter of the screw thread using micrometer.
4. Calculate the best wire to be used by using the given equation.
5. Consider the available wires and fix the two wires to one end on micrometer Anvil and one wire towards another anvil.
6. Measure the distance over the wire properly by using micrometer.
7. Calculate the effective diameter of the screw thread.
8. Find out the error in effective diameter of the screw thread.

Observations:

1. Least Count of the Micrometer =______________mm.
2. Initial error in the micrometer =______________mm.
3. Pitch of the thread p =______________mm.
4. Best size of the wire used d =_____________mm.





Screw Threads Terminology:

1. **Screw thread.** A screw thread is the helical ridge produced by forming a continuous helical groove of uniform section on the external or internal surface of a cylinder or cone. A screw thread formed on a cylinder is known as straight or parallel screw thread, while the one formed on a cone or frustum of a cone is known as tapered screw thread.
2. **External thread**. A thread formed on the outside of a work piece is called external thread. e.g., on bolts or studs etc.
3. **Internal thread**. A thread formed on the inside of a work piece is called internal thread e.g. on a nut or female screw gauge.
4. 4. **Multiple-start screw thread**. This is produced by forming two or more helical grooves, equally spaced and similarly formed in an axial section on a cylinder. This gives a ‗quick traverse‘ without sacrificing core strength.
5. **Axis of a thread.** This is imaginary line running longitudinally through the centre of the screw.
6. **Hand (Right or left hand threads).** Suppose a screw is held such that the observer is looking along the axis. If a point moves along the thread in clockwise direction and thus moves away from the observer, the thread is right hand; and if it moves towards the observer, the thread is left hand.
7. **Form, of thread.** This is the shape of the contour of one- complete thread as seen in axial section.
8. **Crest of thread**. This is defined as the prominent part of thread, whether it is external or internal.
9. **Root of thread**. This is defined as the bottom of the groove between the two flanks of the thread, whether it be external or internal.
10. **Flanks of thread.** These are straight edges which connect the crest with the root.
11. **Angle of thread {Included angle).** This is the angle between the flanks or slope of the thread measured in an axial plane.
12. **Flank angle.** The flank angles are the angles between individual flanks and the perpendicular to the axis of the thread which passes through the vertex of the fundamental triangle. The flank angle of a symmetrical thread is commonly termed as the half- angle of thread.

13. **Pitch.** The pitch of a thread is the distance, measured parallel to the axis of the thread, between corresponding points on adjacent thread forms in the same axial plane and on the same side of axis. The basic pitch is equal to the lead divided by the number of thread starts. On drawings of thread sections, the pitch is shown as the distance from the centre of one thread crest to the centre of the next, and this representation is correct for single start as well as multi-start threads.
14. **Lead.** Lead is the axial distance moved by the threaded part, when it is given one\ complete revolution about its axis with respect to a fixed mating thread. It is necessary to distinguish between measurements of lead from measurement of pitch, as uniformity of pitch measurement does not assure uniformity of lead. Variations in either lead or pitch cause the functional or virtual diameter of thread to differ from the pitch diameter.
15. **Thread per inch.** This is the reciprocal of the pitch in inches.
16. **Lead angle**. On a straight thread, lead angle is the angle made by the helix of the thread at the pitch line with plane perpendicular to the axis. The angle is measured in an axial plane.
17. **Helix angle.** On straight thread, the helix angle is the angle made by the helix of the thread at the pitch line with the axis. The angle is measured in an axial plane.
18. **Depth of thread**. This is the distance from the crest or tip of the thread to the root of the thread measured perpendicular to the longitudinal axis or this could be defined as the distance measured radially between the major and minor cylinders.
19. **Axial thickness.** This is the distance between the opposite faces of the same thread measured on the pitch cylinder in a direction parallel to the axis of thread.
20. **Fundamental triangle**. This is found by extending the flanks and joining the points B and C. Thus in Fig. 13.2, triangle ABC is referred to as fundamental triangle. Here BC=pitch and the vertical height of the triangle is called the angular or theoretical depth. The point A is the apex of the triangle ABC.
21. **Truncation.** A thread is sometimes truncated at the crest or at the root or at both crest and root. The truncation at the crest is the radial distance from the crest to the nearest apex of the fundamental triangle. Similarly the truncation at the root is the radial distance from the root to the nearest apex.
22. **Addendum.** For an external thread, this is defined as the radial distance between the major and pitch cylinders. For an internal thread this is the radial distance between the minor and pitch cylinders.
23. **Dedendum.** This is the radial distance between the pitch and minor cylinder for external thread, and for internal thread, this is the radial distance between the major and pitch cylinders.
24. **Major diameter.** In case of a straight thread, this is the diameter of the major cylinder (imaginary cylinder, co-axial with the screw, which just touches the crests of an external thread or the root of an internal thread). It is often referred to as the outside diameter, crest diameter or full diameter of external threads.
25. **Minor diameter.** In case of straight thread, this is the diameter of the minor cylinder (an imaginary cylinder, co-axial with the screw which just touches the roots of an external

thread or the crest of an internal thread). It is often referred to as the root diameter or cone diameter of external threads.

26. **Effective diameter or pitch diameter.** In case of straight thread, this is the diameter of the pitch cylinder (the imaginary‘ cylinder which is co-axial with the axis of the screw, and intersects the flank of the threads in such a way as to make the width of threads and width of the spaces between the threads equal). If the pitch cylinder be imagined as generated by a straight line parallel to the axis of screw, that straight line is then referred to as the pitch line. Along the pitch line, the widths of the threads and the widths of the spaces are equal on a perfect thread. This is the most important dimension at it decides the quality of the fit between the screw and the nut.
27. **Functional (virtual) diameter.** For an external or internal thread, this is the pitch diameter of the enveloping thread of perfect pitch, lead and flank angles having full depth of engagement but clear at crests and roots. This is defined over a specified length of thread. This may be greater than the simple effective diameter by an amount due to errors in pitch and angle of thread. The virtual diameter being the modified effective diameter by pitches and angle errors, is the most important single dimension of a screw thread gauge. In the case of taper screw thread, the cone angle of taper, for measurement of effective diameter, and whether pitch is measured along the axis or along the pitch cone generator also need to be specified.

Theory:
Effective diameter of screw thread is the diameter of pitch cylinder which is coaxial with the axis of the screw and intersects the flanges of the thread in such way as to make width of thread and the width of spaces between the threads equal. This is the most important dimension as it decides the quality of the fit between screw thread micrometer and two and three wire method.

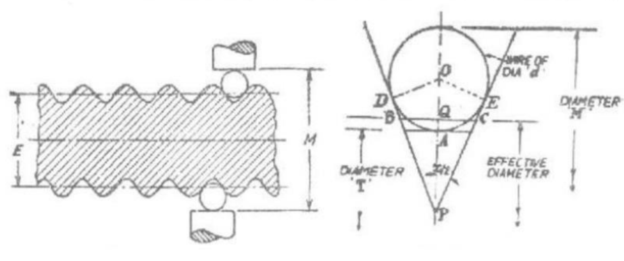
Two Wire Method.
The effective diameter of a screw thread may be ascertained by placing two wires or rods of identical diameter between the flanks of the thread, as shown in Fig. 13.15, and measuring the distance over the outside of these wires. The effective diameter E I s then calculated as E=T+P, Where T= Dimension under the wires = M—2d, M=dimension over the wires, d= diameter of each wire.

$E = T + P$

Where T = Dimension under the wires

$= M - 2d$

M = dimension over the wires, d = diameter of each wire



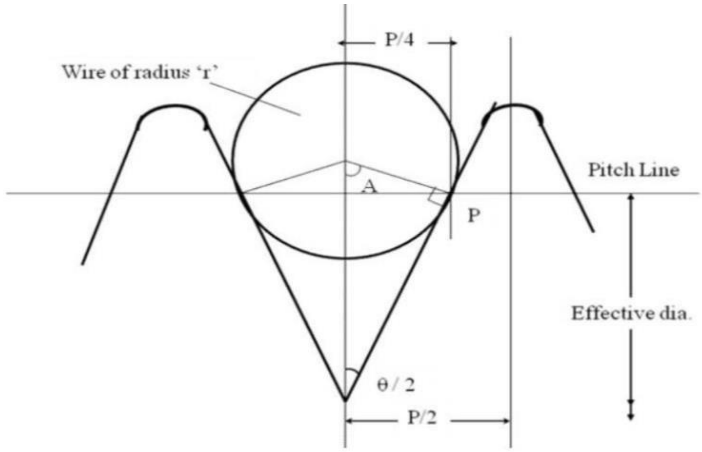
The wires used are made of hardened steel to sustain the wear and tear in use. These are given a high degree of accuracy and finish by lapping to suit different pitches. Dimension T can also be determined by placing wires over a standard cylinder of diameter greater than the diameter under the wires and noting the reading R1 and then taking reading with over the gauge, say R2. Then T=S—(R1—R2).
P=It is a value which depends upon the diameter of wire and pitch of the thread.
If P= pitch of the thread, then
P= 0.9605p−1.1657d (for Whitworth thread).
P= 0.866p—d (for metric thread).

Actually P is a constant Value which has to be added to the diameter under the wires to give the effective diameter. The expression for the value of P in terms of p (pitch), d (diameter of wire) and x (thread angle) can be derived as follows:
In Fig.13.15 (b), since BC lies on the effective diameter line

BC= ½ pitch=½ p
OP=d cosec x/2⁄2
PA=d (cosecx⁄2−1)⁄2
PQ=QC cot x⁄2=p⁄4 cot x⁄2
AQ=PQ−AP=p cot x⁄2⁄4 – d (cosec x⁄2 −1)⁄2
AQ is half the value of P
Therefore P value=2AQ =p⁄2 cot x⁄2 −d (cosecx⁄2−1)

Two wire method can be carried out only on the diameter measuring machine described for measuring the minor diameter, because alignment is not possible by 2 wires and can be provided only by the floating carriage machine. In the case of three wire method, 2 wire, on one side help in aligning the micrometer square to the thread while the third placed on the other side permits taking of readings.

Best size wire Method:
This wire is of such diameter that it makes contact with the flanks of the thread on the effective diameter or pitch line. The effective diameter can be measured with any diameter wire which makes contact on the true flank of the thread, but the values so obtained will differ from those obtained with ‗best size' wires if there is any error in angle or form of thread. t is recommended that for measuring the effective diameter, always the best size wire should be used and for this condition the wire touches the flank at mean diameter line within ±1/5 of flank length



Let the thread angle be $\frac{\theta}{2}$

Then in Triangle, sin POA = $\frac{AP}{OP}$

Sin (90° - $\frac{\theta}{2}$) = $\frac{AP}{OP}$

OP = $\frac{AP}{\sin(90° - \frac{\theta}{2})} = \frac{AP}{\cos\frac{\theta}{2}} =$ AP sec $\frac{\theta}{2}$

Since, OP = r = AP sec $\frac{\theta}{2}$

And wire diameter = Db = 2r = 2AP sec $\frac{\theta}{2}$

Since AP lies on the pitch line

AP = p/4 where, p is the pitch of the thread

Therefore, Db= $\frac{2P}{4} sec\frac{\theta}{2}$

Db= $\frac{P}{2}\ sec\frac{\theta}{2}$

Results:

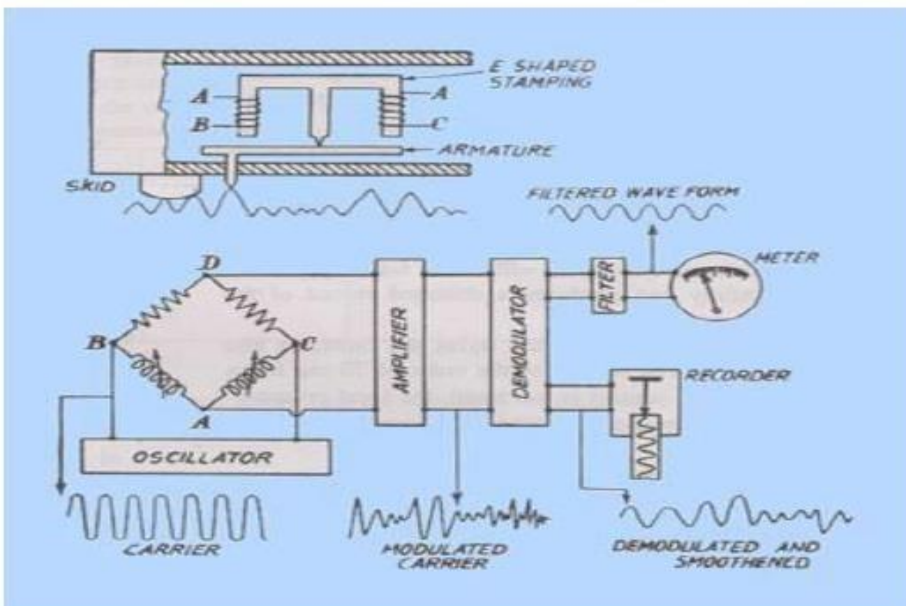
The following parameters are found as follows;

1. Major Diameter =________________mm
2. Minor Diameter =________________mm
3. Effective Diameter =________________mm.

PART – B Experiment No : 11(i)
Measurement of Surface Roughness (Tally Surf)

Aim: To measure surface roughness parameter as per ISO Standards
Apparatus: Mitituyo make surface roughness tester, Calibrated specimen, Surface plate, Specimen
Procedure:
1. Connect Ac adopter to the measuring instrument & Switch on the power supply
2. Attach the drive detector unit & connect to all the cable connection as shown when mounting the
detector to the drive unit, take care not to apply excessive force to the drive unit.
3. Adjust or modify the measurement condition such as sample length, number samples, Standard
required for the measurement
4. Calibrate the instrument using standard calibration piece
5. Carefully place the detector on the work piece. Care should be taken to see that work piece &
detector are aligned properly
6. Press the start button to measure the work piece & result are displaced on the console
7. Press print button to take the print out.

Applications:
1. Taly surf is the dynamic electronic instrument used on the factory floor as well as in the laboratory.
2. To find out the surface roughness of the machines & components.
3. To check the accuracy of the cast iron, granites used in workshops for checking the surface finish & flatness.



Tabular column:

Sl. no	Specimen	Ra value	Rz value	Rq value
1				
2				
3				
4				

Results: Surface roughness checked for different specimens by Tally surf.

PART – B Experiment No : 11(i)

Measurement of Surface Roughness (Using Mechanical Comparator)

Aim: To measure the surface roughness of the components by using mechanical comparator (dial gauge) & also Acceptance/Rejections of the specimen test will be conducted.
To compare the dimensions of given mass produced product with designed tolerance standard by using mechanical comparator.
Apparatus: 20 No's of product to be tested, Mechanical comparator with dial gauge and slip gauges for setting standard.
Theory:
Comparator is the instrument used to compare the unknown dimension with one of the reference standard known as designed specification. The purpose of comparator is to detect and
display the small difference between the unknown and the standard. The deviation in size is detected as the displacement of sensing device. The important and essential function of the instatement is to magnify the small input to displacement. The magnification required is greater than 1000: 1. The relationship between the input and output affected by the readings in the direction of input and this reveals that the movement should not have any backlash. The major disadvantage of mechanical comparator is that, it is very difficult to recompute the arrangement for the adjustment of magnification.
Dial gauge is one of the Mechanical components which are used in laboratories. It has contact tip, graduated circular scale, plunger and clamp. Dial gauge works on the
rack and pinion principle.

Procedure

1. Clean the sensors of the comparator and the surface table of the comparator.
2. Note down the actual measurement of each product by micrometer.
3. Slip gauge of specified basic size is placed on the surfaces of comparator table and here slip gauge
serves as a setting standard have specified size.
4. Adjust the tolerance read needles to the specified size on either side of the zero reading by using
screw knobs provided on the comparator.
5. Adjust the comparator needle, which is reading actual dimension to zero reading by using Corresponding knobs (vertical movement)
7. After initial adjustment of comparator remove the setting standard.
8. Place the given product for test in-between the sensors and surface of Comparator table.
9. Note down the readings of dial indicator provided in comparator. If the readings are within the
tolerance needles the product can be accepted if it lies outside the tolerance Needle the product can be
rejected.

10. The product following within certain tolerance ranges are grouped together according to Sequence of test and tabulated in the tabular column.
11. The above procedure is repeated for all products.

Observations:
1. Name of the product to be tested = -----------------------------------
2. No of product to be tested = -----------------------------------
3. Size of standard slip gauge used = ------------------------------------mm
4. Least count of the comparator =------------------------------------mm.
5. Specified designed dimensions with tolerance = ------------------------ mm ⍰ ------ ⍰
6. No. of components rejected during the test = -------------------------
7. No. of components accepted during the test = -------------------------

Sl.No.	Error Frequency		Rejected	Accepted
	Positive	Negative		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Applications:

1. Mechanical comparators are most widely used tools of dimensional measurements in metal – working production.
2. These are instruments for comparative measurements where the linear movement of a precision spindle is amplified and displayed on a dial or digital display.
3. Measurements of heights & levels by using combination of surface plate & dial gauges. Use of measurement by accurate slip gauges
4. In mechanical industries, acceptance & rejections of the components will be checked by the mechanical comparators.

Results:

The given components are tested by mechanical comparator or a dial gauge by using slip gauges as standards.