MECHANICAL MEASUREMENTS
&
METROLOGY LABORATORY

(18MEL37B/47B)

DEPARTMENT OF MECHANICAL ENGINEERING

BAPUJI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DAVANGERE- 577 004

VISION OF THE INSTITUTE

To be center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

MISSION OF THE INSTITUTE

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values.

VISION OF THE DEPARTMENT

The department endeavors to be a center of excellence, to provide quality education leading the students to become professional mechanical engineers with ethics, contributing to the society through research, innovation, entrepreneurial and leadership qualities.

MISSION OF THE DEPARTMENT

l. To impart quality technical education through effective teachinglearning process leading to development of professional skills and attitude to excel in Mechanical Engineering.

2. To interact with institutes of repute, to enhance academic and research activities.

3. To inculcate creative thinking abilities among students and develop entrepreneurial skills.

4. To imbibe ethical, environmental friendly and moral values amongst students through broad based education

PROGRAM EDUCATIONAL OBJECTIVES (PEO'S)

1. Enable to understand mechanical engineering systems those are technically viable, economically feasible and socially acceptable to enhance quality of life.
2. Apply modern tools and techniques to solve problems in mechanical and allied engineering streams.
3. Communicate effectively using innovative tools, to demonstrate leadership and entrepreneurial skills.
4. Be a professional having ethical attitude with multidisciplinary approach to achieve self and organizational goals.
5. Utilize the best academic environment to create opportunity to cultivate lifelong learning skills needed to succeed in profession.

PROGRAM SPECIFIC OUTCOMES (PSO'S)

PS01:-Apply the acquired knowledge in design, thermal, manufacturing and interdisciplinary areas for solving industry and socially relevant problems.

PS02:-To enhance the abilities of students by imparting knowledge in emerging technologies to make them confident mechanical engineers.

MECHANICAL MEASUREMENTS AND METROLOGY LAB

B.E, IV Semester, Mechanical Engineering

Choice Based Credit System (CBCS) and Outcome Based Education (OBE)

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:

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

PART-A: MECHANICAL MEASUREMENTS

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

PART-B: METROLOGY

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

Course outcomes:

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

<u>Scheme of Examination:</u>

ONE question from part –A	**:**	**30 Marks**
ONE question from part –B	**:**	**50 Marks**
Viva –Voice	**:**	**20 Marks**
Total	**:**	**100 Marks**

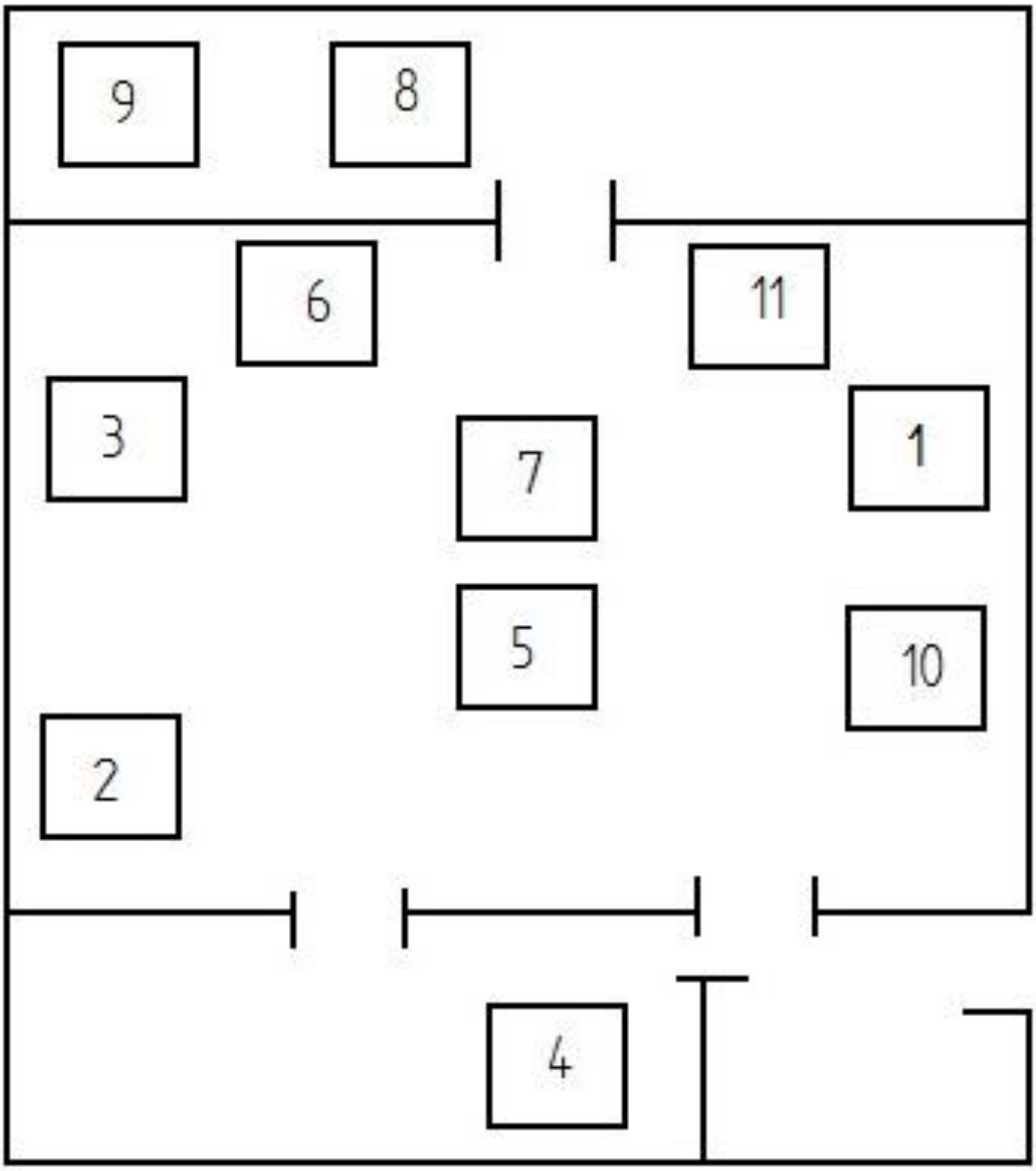
DO's

1. Students must always wear uniform and shoes before entering the lab.
2. Proper code of conduct and ethics must be followed in the lab.
3. Windows and doors to be kept open for proper ventilation and air circulation.
4. Note down the specifications of the experimental setup before performing the experiment.
5. Check for the electrical connections and inform if any discrepancy found to the attention of lecturer/lab instructor.
6. Perform the experiment under the supervision/guidance of a lecturer/lab instructor only.
7. After the observations are noted down switch off the electrical connections.
8. In case of fire use fire extinguisher/throw the sand provided in the lab.
9. In case of any physical injuries or emergencies use first aid box provided.
10. Any unsafe conditions prevailing in the lab can be brought to the notice of the lab in charge.

DONT's

1. Do not operate any experimental setup to its maximum value.
2. Do not touch/ handle the experimental setups/Test Rigs without their prior knowledge,
3. Never overcrowd the experimental setup/Test Rig, Leave sufficient space for the person to operate the equipment's.
4. Never rest your hands on the equipment or on the display board, because it has fragile measurement devices like thermometers, etc.

MECHANICAL MEASUREMENTS & METROLOGY LABORATORY
(18MEL37B/47B)



Part-A Mechanical Measurements

01. DETERMINATION OF MODULUS OF ELASTICITY USING STRAIN GAUGE
02. CALIBRATION OF THERMO COUPLE
03. CALIBRATION OF L.V.D.T
04. CALIBRATION OF PRESSURE GAUGE

Part-B Metrology Laboratory

05. CALIBRATION OF MICROMETER
06. MEASUREMENT OF TAPER ANGLE USING SINE BAR
07. MEASUREMENT OF GEAR TOOTH PROFILE
08. MEASUREMENT OF THREAD PARAMETERS USING PROFILE PROJECTOR
09. MEASUREMENT USING TOOL MAKER'S MICROSCOPE
10. MEASUREMENT OF ALIGNMENT USING AUTOCOLLIMATOR
11. MEASUREMENT OF SCREW THREAD PARAMETERS USING THREE WIRE METHOD

CONTENTS

Experiment No. 01

DETERMINATION OF MODULUS OF ELASTICITY OF MILD STEEL USING STRAIN GAUGE

Aim: Determination of Modulus of elasticity of mild steel using strain gauge by Full Bridge, Half bridge and Quarter Bridge.

Apparatus required:

1. Cantilever beam set up.
2. Strain gauges
3. Weight box

Theory:

All machine elements are standard members will deform to some extent. When subjected to external loads or force, loading relative to displacement or strain. Since the quantity straining as applied to most engineering materials is very small and it is commonly multiplied by one million, the resulting value is called Micro strain.

Strain gauge:

A strain gauge (also strain gage) is a transducer used to measure deformation or strain on an elastic member. The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the elastic member by a suitable adhesive, such as cyanoacrylate. As the elastic member is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured by using a Wheatstone bridge, is related to the strain by the quantity known as the *gauge factor*.

Resistance Strain Gauges

The resistance of an electrically conductive material changes with dimensional changes which take place when the conductor is deformed elastically. When such a material is stretched, the conductors become longer and narrower, which causes an increase in resistance. This change in resistance is then converted to an absolute voltage by a Wheatstone bridge. The resulting value is linearly related to strain by a constant called the gauge factor.

Electrical Resistance Strain gauge

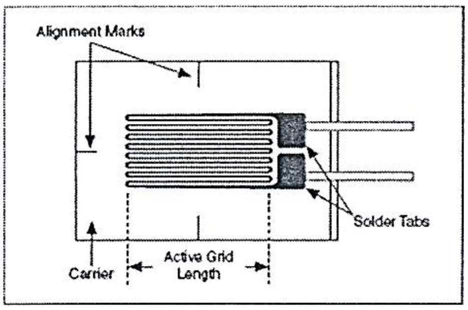
Electrical method yield advantages for dynamic measurements that no other strain gauge provides.

$R = \rho L/A$

Where R= Electrical resistance in ohms **(Ω).**

L= length in m.

ρ=specific resistance in **Ω** - m



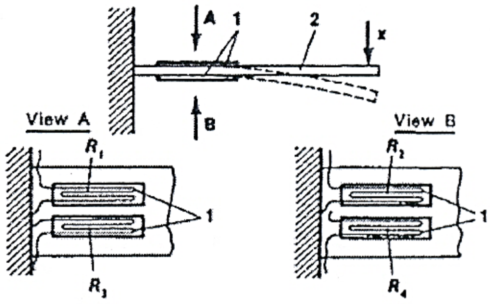
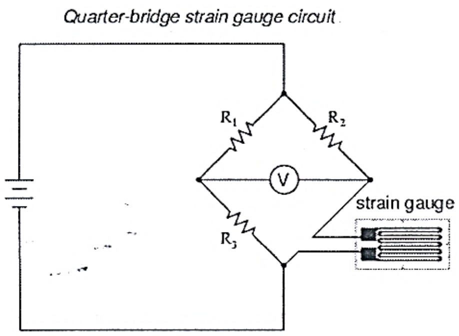


Fig.l.l a. Strain gauge

Fig.l.l b. Strain gauge attached to cantilever beam



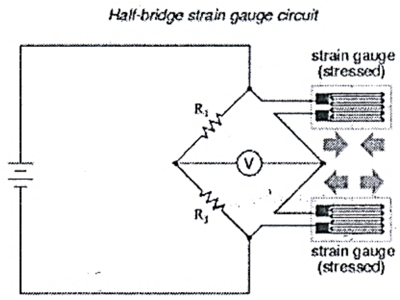
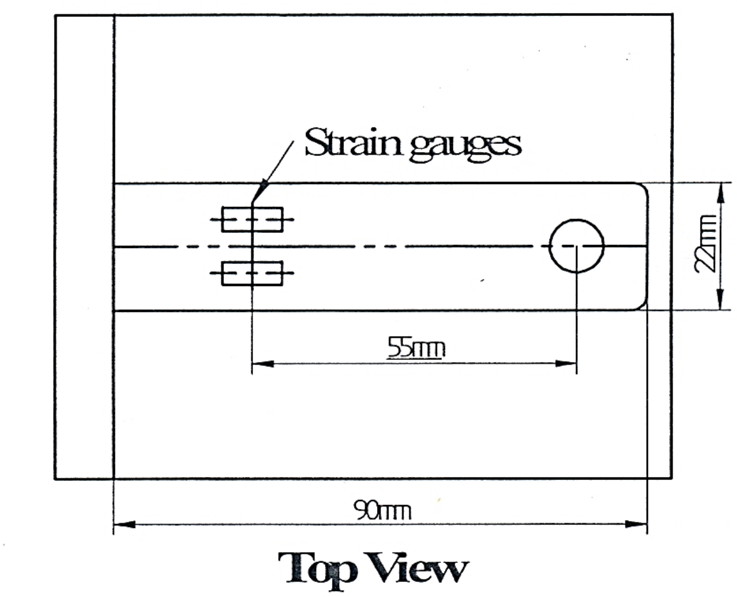


Fig.l.l c. Quarter bridge connection

Fig.l.l d. half bridge connection

Procedure:

1. Connect the coloured wire to terminal 1, 2, 3 & 4 according to the type of bridge (Quarter bridge, half bridge and full bridge) as given in the circuit connection table.
2. Adjust the strain indicator and arm selector switch to a suitable position.
3. Adjust the strain gauge indicator for zero reading. Add weights into the pan of the cantilever and note down the corresponding strain reading shown in the strain indicator for each step.
4. Strain indicator displays micro strain and the actual strain is converted for Quarter bridge, half bridge (divide the reading by 2) and full bridge (divide the reading by 4) for each load.
5. Draw the graph of stress *v/s* strain for corresponding bridge and modulus of elasticity of mild steel is found from the slope.



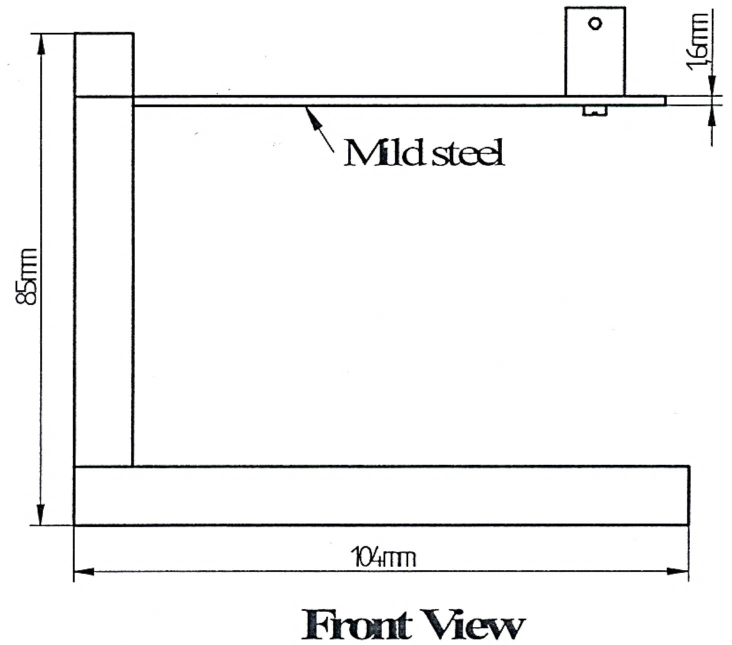


Fig.l.2. Strain gauge cantilever jig

Circuit Connections:

Connections	Arm selector		1	2	3	4
	Cantilever	Strain indicator				
Full Bridge	4	4	Yellow	Green	Red	Black
Half Bridge	2	2	---	Black	Orange	Brown
Quarter Bridge	1	2	---	White	Black	Blue

Observation:

Length of cantilever beam = 1= 55 mm

Breadth of cantilever beam = b = 22 mm

Height of cantilever beam = h = 1.6 mm

Tabular column:

Sl. No	Weight / Load		Moment M in N-m	Stress σ N/m^2	Strain (micro strain)	Actual strain	Modulus of elasticity E in GPa
	gm	Newton					
1	20						
2	40						
3	60						
4	80						
5	100						

Calculation:

1. Load in Newton = _ _ _ _ _ N
2. Moment, M = Force X Length of cantilever = _ _ _ _ _ N-m
3. Sectional Modulus $Z = bh^2/6$ = _ _ _ _ _ m^3
4. Stress $\sigma = M/Z$ = _ _ _ _ _ N/m^2

Result: Modulus of elasticity of mild steel is _ _ _ _ _ GPa

Experiment No. 02

CALIBRATION OF THERMOCOUPLE

Aim: To calibrate the given Thermocouple.

Apparatus required:

1. Thermometer range 0-110°c
2. K type thermocouple (Chromel-Alumel)
3. Milli voltmeter
4. Heater
5. Beaker with water

Thermocouple:

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. **It** produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are widely used as temperature sensors for measurement and control of temperature gradient into electricity. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self-powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (OC) can be difficult to achieve.

Thermocouples are widely used in science and industry; applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered major appliances.

Standard thermocouple types are listed below

a. **Type K** (chromel {90% nickel and 10% chromium}-alumel {95% nickel, 2% manganese, 2% aluminum and 1% silicon}) is the most common general purpose thermocouple with a sensitivity of approximately 41 µV *1°C* (chrome I positive relative to alumel when the junction temperature is higher than the reference temperature). It is inexpensive, and a wide variety of probes are available in its -200°C to +1350 °C /-330^0 F to +2460^0 F range.

b. **Type E** (chromel-constantan) has a high output (68 µV/^{0}C*)* which makes it well suited to cryogenic use. Additionally, it is non-magnetic. Wide range is -50°C to +740 °C and Narrow range is -110°C to +140 °C.

c. **Type J** (iron-constantan) has a more restricted range than type K (-40°C to +750 °C), but higher sensitivity of about 50 µ*V/°C.* The Curie point of the iron (770°C) causes a smooth change in the characteristic, which determines the upper temperature limit.

d. **Type N** (Nicrosil-Nisil) (nickel-chromium-siliconlnickel-silicon) thermocouples are suitable for use between -270 *DC* and +1300 *DC* owing to its stability and oxidation resistance. Sensitivity is about 39 IlV/DC at 900 *DC, slightly* lower compared to type K.

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 within the circuit due to the different temperatures of 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.

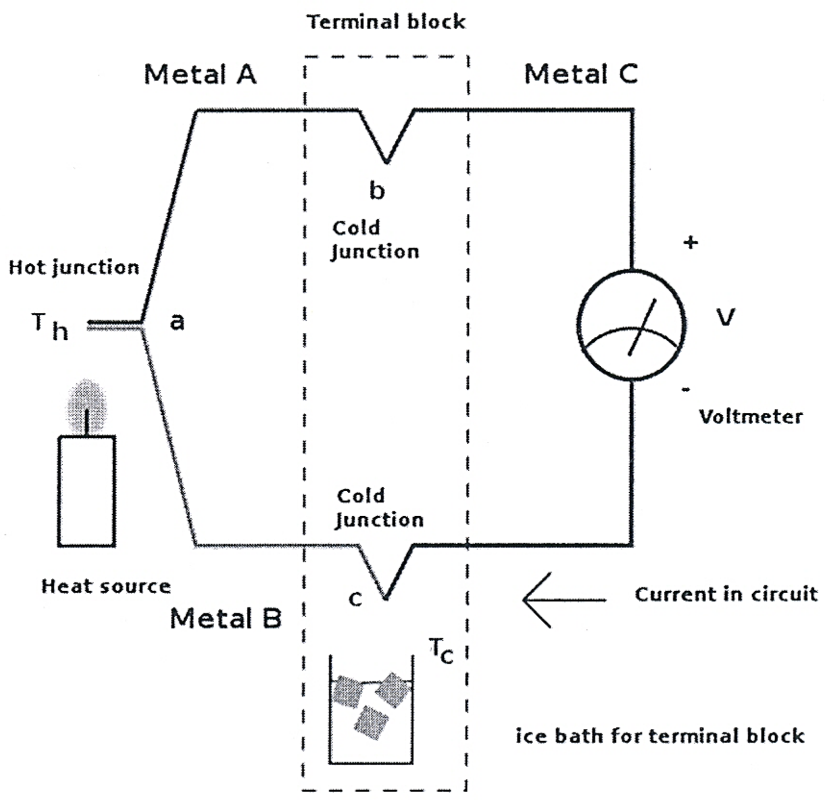


Fig. 2.1 Temperature measuring circuit using Thermocouple

Procedure:

1. Place the Thermometer and Thermocouple (K type) in a beaker containing water.
2. Thermocouple ends are connected to mill voltmeter.
3. Note down the room temperature.
4. Switch on the heater and note down the temperature in thermometer and thermocouple reading simultaneously as per the tabular column reading of milli voltmeter.
5. Convert the milli voltmeter reading to temperature using calibration chart and add room temperature to get absolute temperature.
6. Plot the graph for a. Thermocouple reading v/s Thermometer Temperature
   b. Error *vis* Thermometer Temperature

Tabular column:

Room temperature : ^{0}C

Sl. No.	Thermocouple		Thermometer Temp. in ^{0}C	Error in ^{0}C	Correction in ^{0}C
	Millivoltmeter reading in mV	Themocouple Temp. in ^{0}C			
1	0.1				
2	0.2				
3	0.3				
4	0.4				
5	0.5				
6	0.6				
7	0.7				
8	0.8				
9	0.9				
10	1.0				
11	1.1				
12	1.2				
13	1.3				
14	1.4				
15	1.5				
16	1.6				

17	1.7				
18	1.8				
19	1.9				
20	2.0				

Error = Thermocouple Temp. - Thermometer Temp.

Experiment No. 03

CALIBRATION OF L.V.D.T
(LINEAR VARIABLE DIFFERENTIAL TRANSFORMER)

Aim: To determine the characteristics of LVDT.

Apparatus required:

1. LVDT
2. Digital displacement indicator
3. Calibration jig with micrometer

LVDT

Linear Variable Differential Transformer (LVDT), is a common type of electro-mechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal.

Principle of LVDT:

LVDT works on the principle of mutual induction and the displacement is converted into an electrical signal. LVDT consists of a cylindrical former (Core) and is surrounded by one primary winding in the centre of the former and two secondary windings at the sides. The number of turns in both the secondary windings are equal, but they are opposite to each other, i.e., if the left secondary windings is in the clockwise direction, the right secondary windings will be in the anti-clockwise direction, hence the net output voltages will be the difference in voltages between the two secondary coil. The two secondary coil is represented as S1 and S2. Esteem iron core is placed in the center of the cylindrical former which can move in to and fro motion as shown in the figure 3.1. The AC excitation voltage is 5 to 12V and the operating frequency is given by 50 to 400 HZ.

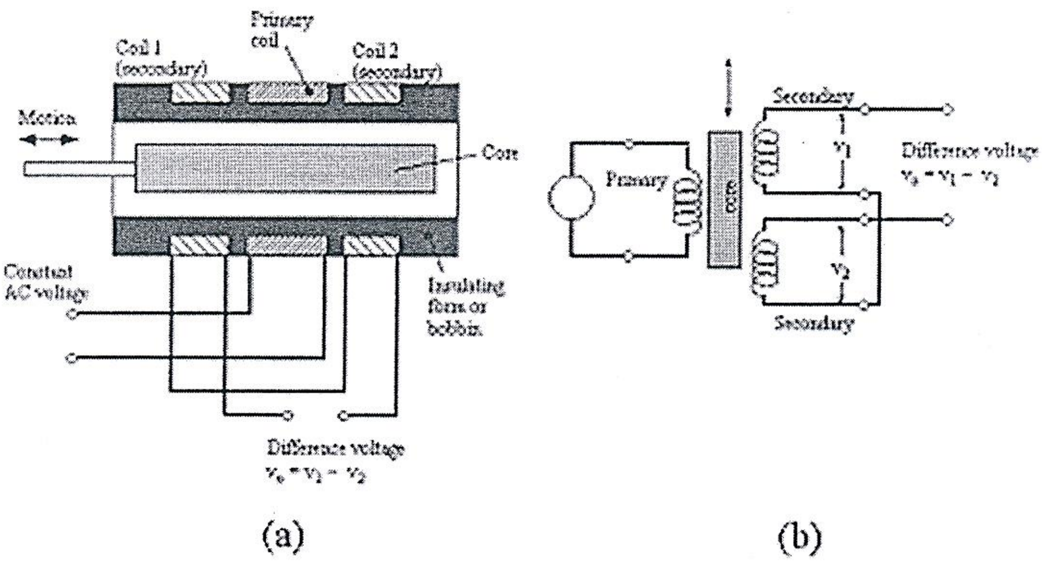


Fig.3.1. Schematic diagram of LVDT

Three different cases of LVDT based on the iron core position inside the insulated former is shown in figure 3.2.

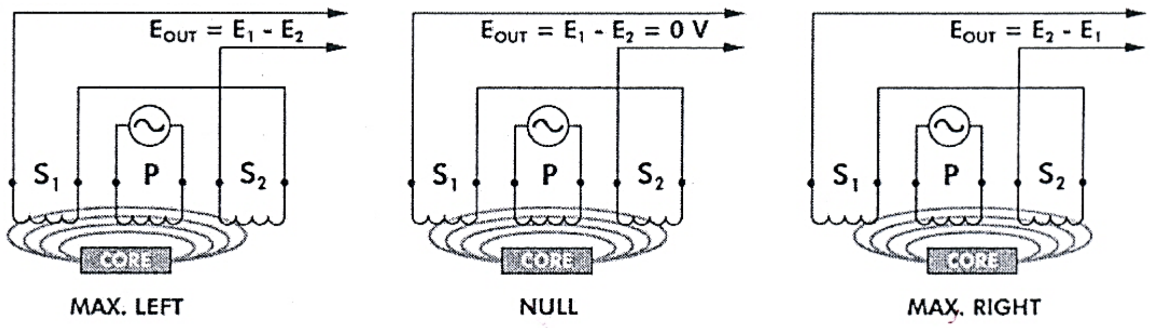


Fig.3.2. Three different cases of LVDT core position

Case 1: On applying an external force which is the displacement, if the core reminds in the null position itself without providing any movement then the voltage induced in both the secondary windings are equal which results in net output is equal to zero i.e., Esec1 – Esec2=0

Case 2: When an external force is applied and if the steel iron core tends to move in the left hand side direction then the emf voltage induced in the secondary coil is greater when compared to the emf induced in the secondary coil 2.
Therefore the net output will be Esec l-Esec2

Case 3: When an external force is applied and if the steel iron core moves in the right hand side direction then the emf induced in the secondary coil 2 is greater when compared to the emf voltage induced in the secondary coil 1. Therefore the net output voltage will be Esec2-Esec l

Procedure:

1. Plug power cable to AC mains 230V 50 Hz and switch on the instrument.
2. Place the READ/CAL switch at READ position.

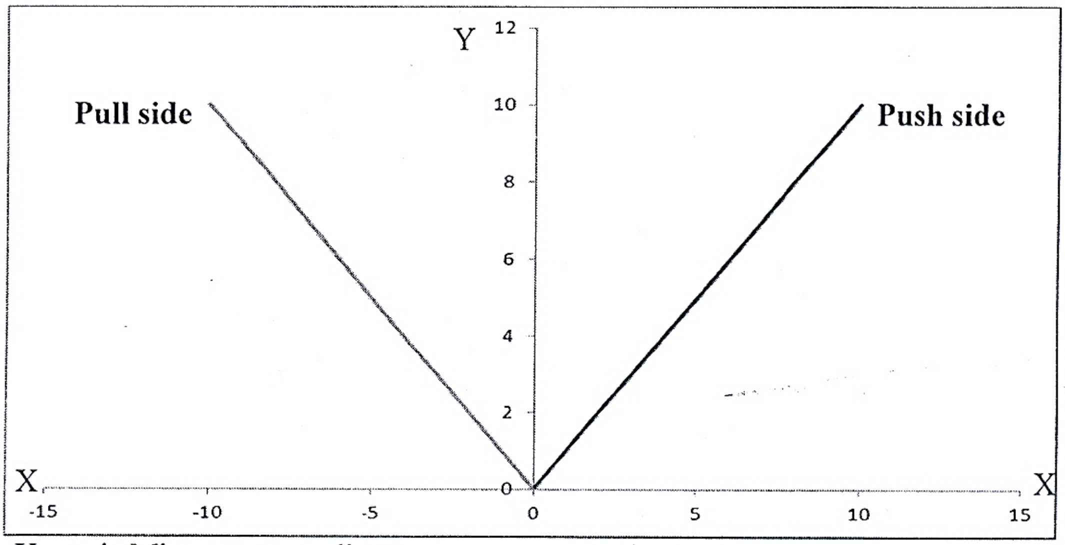
3. Balance the amplifier with the help of zero knob so that display should read zero (0.00) without connecting the LVDT to instrument.
4. Replace the READ/CAL switch at CAL position.
5. Adjust the calibration point by rotating CAL knob so display should read 10.00 i.e. maximum calibrated ranges.
6. Again keep READ/CAL switch at READ position and connect the LVDT cable to instrument.
7. Make mechanical zero by rotating the micrometer. Display will read (0.00). This is null balancing.
8. Give displacement with micrometer and observe the digital readings.
9. Plot the graph of Micrometer reading v/s Digital reading.

Tabular Column:

Sl. No.	**Push side +ve readings**			**Pull side -ve readings**		
	Micrometer reading in mm	Indicated reading in mm	Error mm	Micrometer reading in mm	Indicated reading in mm	Error mm
1	1			1		
2	2			2		
3	3			3		
4	4			4		
5	5			5		
6	6			6		
7	7			7		
8	8			8		
9	9			9		
10	10			10		

Error = Indicated reading - Micrometer reading mm

Graph: Indicated reading v/s Micrometer reading



X – axis Micrometer readings Y – axis Indicated readings

Experiment No. 04

CALIBRATION OF PRESSURE GAUGE

Aim: To calibrate the given pressure gauge using Dead weight Tester

Apparatus required:

1. Pressure gauge
2. Dead weights
3. Pressure gauge calibration test rig

Theory:

Dead weight piston pressure gauge calibrator consist of an oil chamber and a plunger, oil is filled in it, weight is applied on plunger and hand wheel of the piston is rotated till the plunger weight begins to float, i.e, both the pressure applied by the hand wheel and the weight in equilibrium.

The Bourdon pressure gauge uses the principle that a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. Although this change in cross-section may be hardly noticeable, and thus involving moderate stresses within the elastic range of easily workable materials, the strain of the material of the tube is magnified by forming the tube into a C shape or even a helix, such that the entire tube tends to straighten out or uncoil, elastically, as it is pressurized. Bourdon tubes measure gauge pressure, relative to ambient atmospheric pressure, as opposed to absolute pressure; vacuum is sensed as a reverse motion

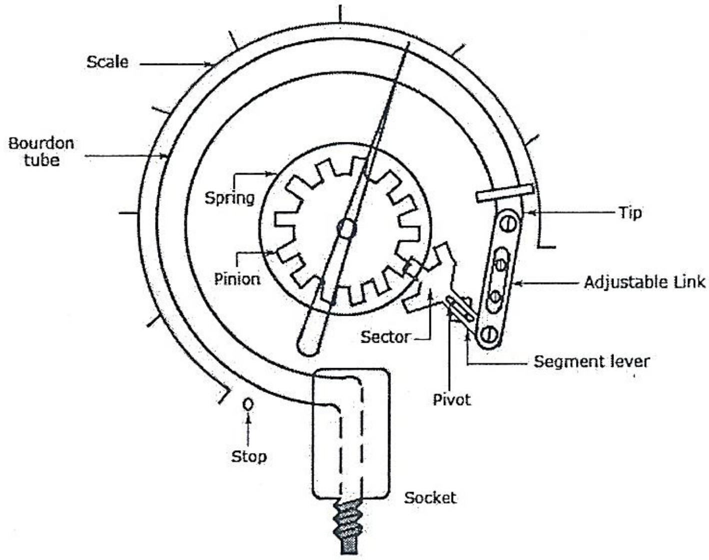


Fig 4.1. Bourdon tube pressure gauge

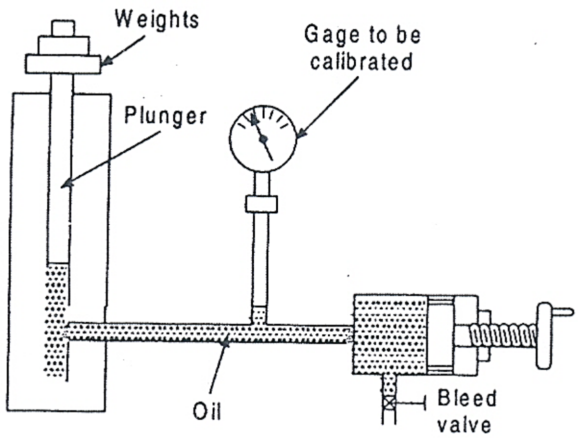


Fig4.2. Dead weight pressure gauge

Procedure:

1. Open the lid of the oil cup and fill the oil.
2. Remove the air bubble in the oil by rotating the hand lever in anticlockwise direction and the lid is closed.
3. Place the dead weight in ascending order (Known Pressure) on the plunger and the hand lever is rotated slowly in the clockwise direction until the red mark appear below the plunger and the corresponding pressure gauge reading is noted.
4. Remove the dead weight in descending order on the plunger and the hand lever is rotated slowly in the anticlockwise direction until the red mark appears below the

plunger and the corresponding pressure gauge reading is noted.

5. Corresponding error is calculated as shown in tabular column.
6. Plot the graph a. True pressure *v/s* Mean indicated pressure

   b. Error *v/s* Mean indicated pressure

Tabular column:

Sl. No.	True pressure placed on plunger, kgf/cm^2	Indicated gauge pressure in kgf/cm^2			Error in kgf/cm^2	Correction to be added in kgf/cm^2
		Ascending	Descending	Mean		
1						
2						
3						
4						
5						

Error = Mean indicated gauge pressure - True Pressure, kgf/cm^2

Experiment No. 05

CALIBRATION OF MICROMETER

Aim: To determine progressive and periodic pitch errors

Apparatus required:

1. Micrometer (0-25 mm)
2. Grade I Slip gauge set
3. Micrometer stand
4. Magnifying lens

A micrometer sometimes known as a micrometer screw gauge is a device incorporating a calibrated screw used widely for precise measurement of small distances in mechanical engineering and machining as well as most mechanical trades, along with other metrological instruments such as dial, vernier, and digital calipers.

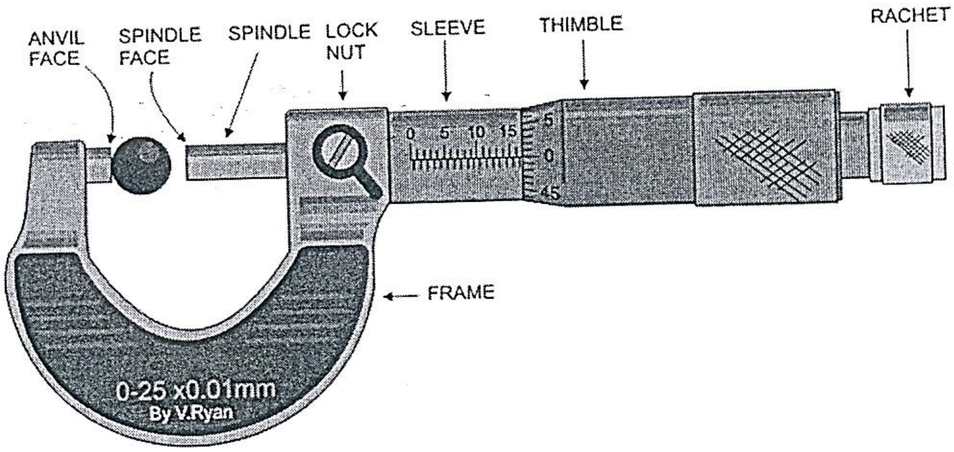
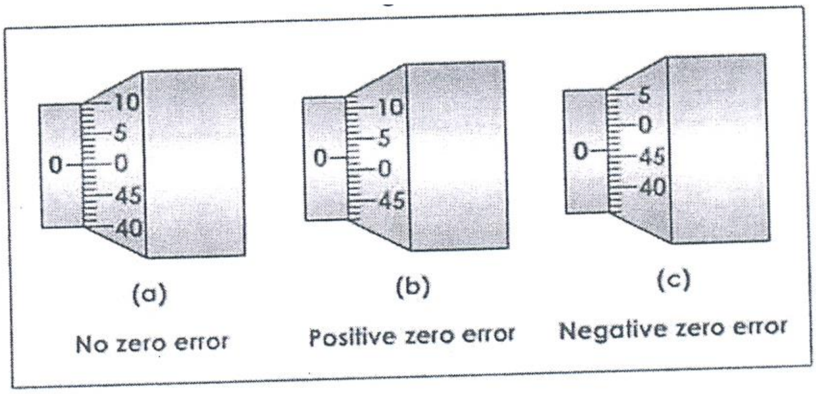


Fig.5.1 Micrometer



Types of error in micrometer screw gauge reading

Every micrometer prior to its use should be thoroughly checked for backlash error or zero error.

• **Backlash error:** Sometimes due to wear and tear of the screw threads, it is observed that reversing the direction of rotation of the thimble, the tip of the screw does not start moving in the opposite direction immediately, but remains stationary for a part of rotation. This is called back lash error.
• **Zero error:** If on bringing the flat end of the screw in contact with the stud, the zero mark of the circular scale coincides with the zero mark on base line of the main scale, the instrument is said to be free from zero error. Otherwise an error is said to be there. This can be both positive and negative zero error.
• **The Periodic error** is the error existing in one revolution of the micrometer and is usually caused by drunkenness of the thread or eccentricity of thimble or its graduations.
• **The Progressive error** is the cumulative error over the total range of the micrometer

Procedure:

1. Clean the micrometer faces with clean moistened petrol, benzene, carbon tetrachloride or other suitable solvent. Wipe with a clean dry, soft cloth or chamois leather.
2. Check the feel of the micrometer by operating it over the complete range and if necessary adjust for backlash and zero error.
3. Clamp the micrometer horizontally in the stand with the anvils uppermost. Take care to see that the thimble is perfectly free.
4. If it is desired to use the ratchet, advance the spindle slowly to the anvil and take the reading as soon as the ratchet has slipped rapid rotation of the ratchet or friction drive will give false readings.
5. Set the micrometer reading i.e 1, 1.5, 2.5 up to 25mm and combination of slip gauges are made using wringing procedure to check the gap between anvil faces, corresponding error is noted.
6. Experiment is conducted to determine the progressive and periodic pitch error of the micrometer.

Observation:

$$\text{Pitch} = \frac{\text{Distance moved by thimble of linear scale}}{\text{No. of rotation given to thimble}} = \_\_\_\_ \text{ mm}$$

$$\text{L.C. for micrometer} = \frac{\text{Pitch}}{\text{Total No. of division on thimble}} = \_\_\_\_ \text{ mm}$$

Tabular column for Progressive Error:

Sl. No.	Micrometer reading (mm)	Slip gauge reading (mm)	Combination of slip gauges mm	Error in mm	Cumulative error in µ
1	1.00				
2	1.50				
3	2.00				
4	2.50				
5	3.00				
6	3.50				
7	4.00				

8	4.50				
9	5.00				
10	5.50				
11	6.00				
12	6.50				
13	7.00				
14	7.50				
16	Upto 25 mm				

Tabular column for Periodic Error:

Sl. No.	Micrometer reading (mm)	Slip gauge reading (mm)	Combination of slip gauges mm	Error in mm
1	6.05			
2	6.10			
3	6.15			
4	6.20			
5	6.25			
6	6.30			
7	6.35			
8	6.40			
9	6.45			
10	6.50			

Result: Periodic and Progressive Error of the micrometer is shown graphically

Experiment No. 06

MEASUREMENT OF TAPER ANGLE USING SINE BAR

Aim: To measure the taper angle of dead centre using side bar

Apparatus required:

1. Dead centre
2. Sine Bar
3. Set of Slip gauge
4. Surface Plate
5. Angle Plate
6. Magnetic stand

Theory:

Sine bar is used to measure or set accurate angles. It consists of a bar to which two rollers of equal diameter are attached. The distance between the axes of rollers is fixed to a high degree of accuracy. When the rollers are brought in contact with a flat surface, the top of the sine bar is parallel to the flat surface.

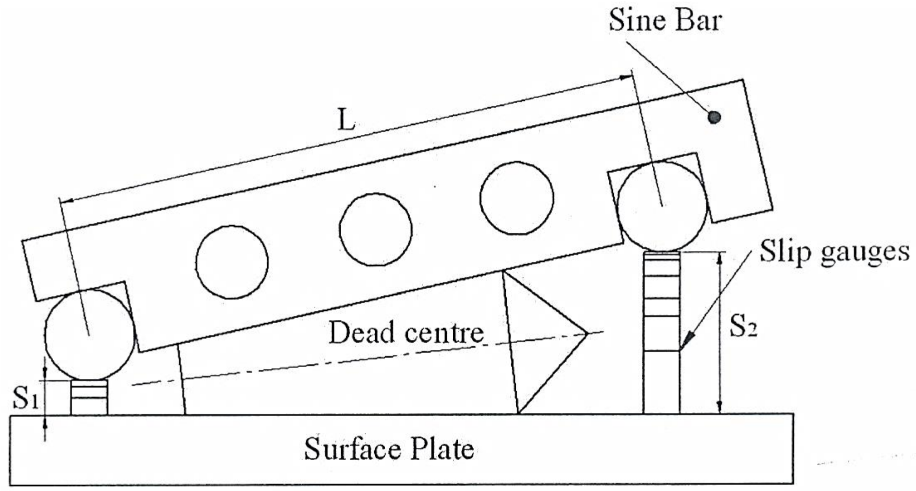


Fig.6.1. Experimental setup to measure taper angle using Sine bar

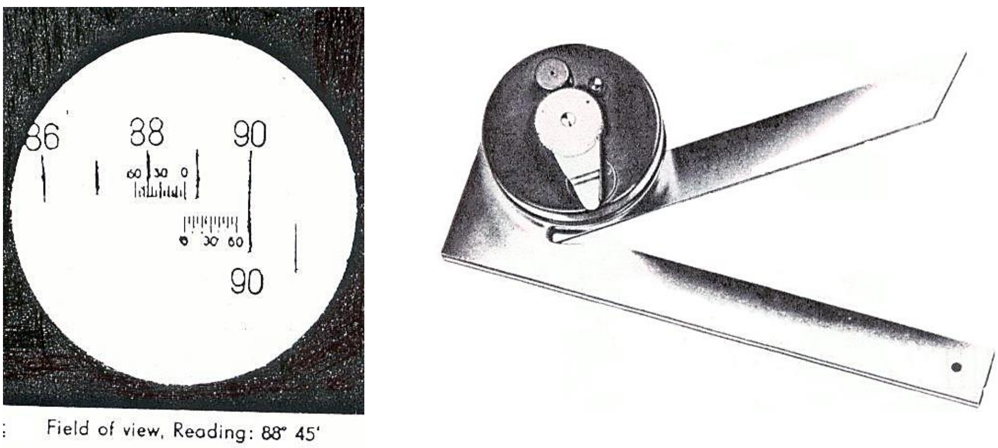


Fig.6.2. Optical bevel protractor

Procedure:

1. Clean the protective grease from the slip gauge, the sine bar with a clean cloth or acetone or carbon tetrachloride or other suitable solvent. Wipe the surface plate with a clean, dry soft cloth.
2. Place the dead centre with one of its generators resting on the surface Plate as shown in the figure 6.1.
3. Rest the sine bar on the top surface of the dead centre ensuring a line contact

throughout.

4. Adjust the position of the sine bar such that the rollers are free to take supports.
5. Bridge the gap between rollers and the surface plate with a pile of slip gauges S1 and S2, such that the roller make a positive line contact over the slip gauge surfaces.
6. Then by several trails obtain slip gauge heights S1 and S2 so as to have the height in three decimals.
7. Taper angle of the dead centre is calculated and cross checked using optical bevel protractor.

Observation:

Length of Sine bar, L = _ _ _ _ _ rnm

Height of Slip gauge, S1 = _ _ _ _ _ rnm

Height of Slip gauge, S2 = _ _ _ _ _ rnm

Then $\sin\theta = \frac{S2-S1}{L}$

$$\theta = \sin^{-1}\frac{S2-S1}{L}$$

Then Taper angle = $\frac{\theta}{2}$ = _ _ _ _

Taper angle cross checked by optical bevel protractor = 90^0 - _ _ _ =

Result:

1. Taper angle of dead centre using sine bar is _ _ _
2. Taper angle of dead centre using optical bevel protractor is _ _ _

Experiment No. 07

MEASURMENT OF GEAR TOOTH PROFILE

Aim: To measure the gear tooth thickness of spur gear using gear tooth vernier caliper

Apparatus required:

1. Gear tooth vernier caliper
2. Spur gear

3. Vernier caliper
4. Magnifying lens

Theory:

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

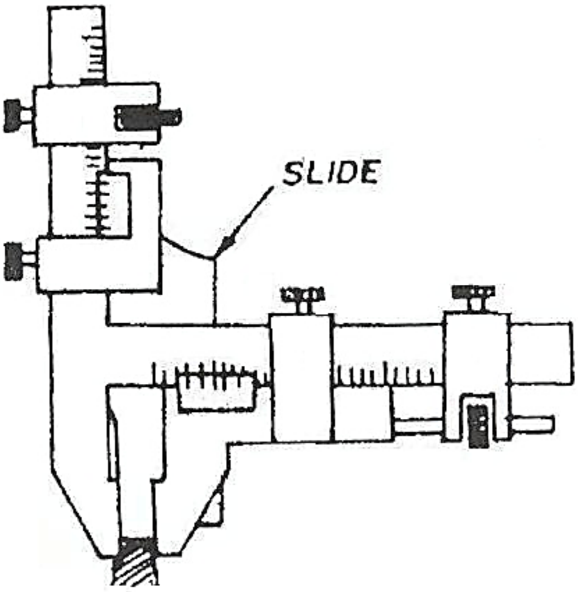


Fig. 7.1. Gear tooth vernier caliper

Procedure:

1. Measure the outside diameter of the spur gear using vernier caliper.
2. Calculate the module, height (h) and thickness/width (w) of the spur gear.
3. Using gear tooth vernier caliper fix the theoretical height (h) and measure the width (w).
4. Then by several trails measure the value of width (w) and take its average.

Calculation:

Module, $m = \frac{D_0}{Z+2}$ rnrn

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

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

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

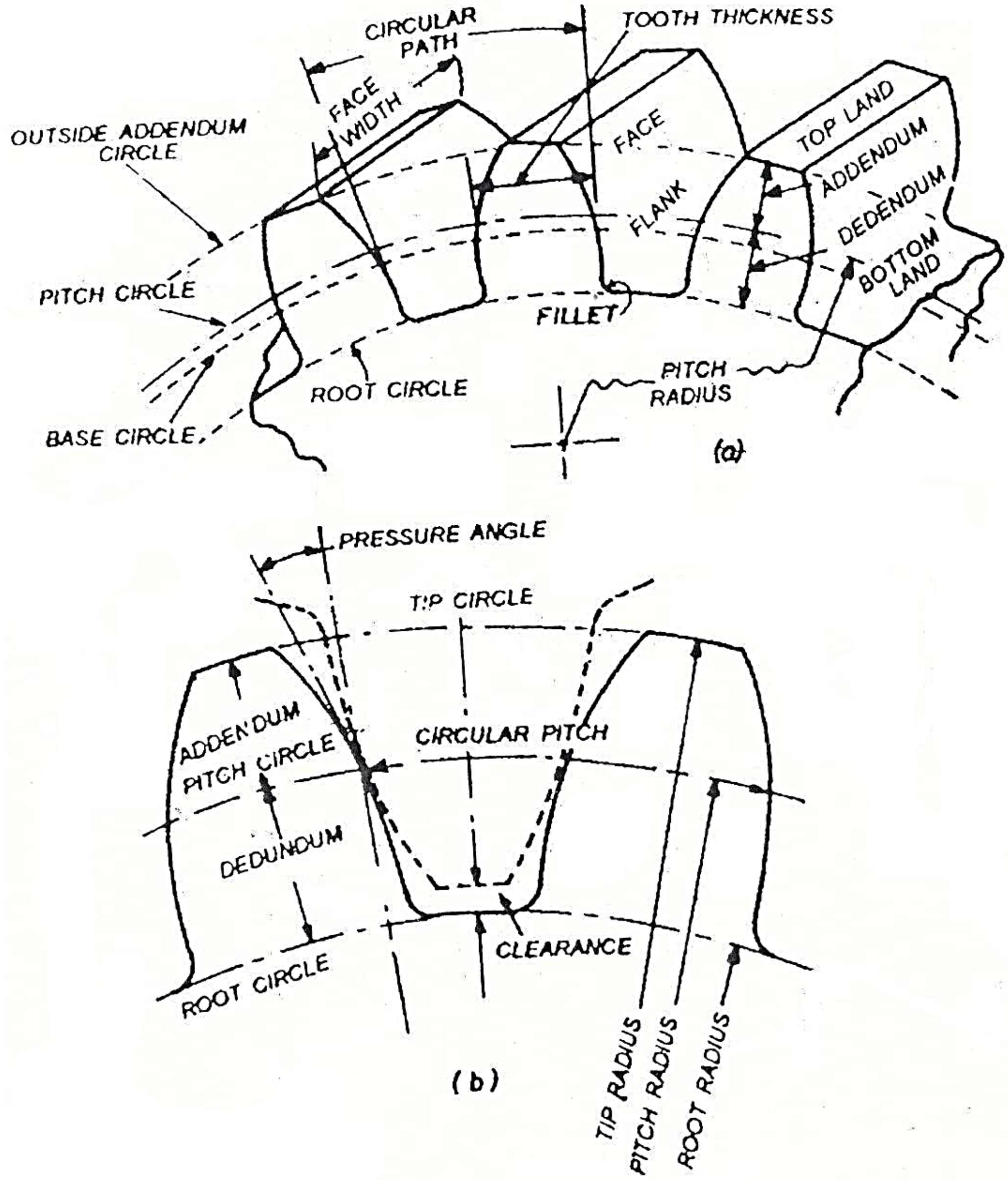


Fig.7.2. Spur gear tooth gear

1. Measurement of tooth width/thickness at Pitch circle diameter

Height $h = \left(\frac{mz}{2}\right)\left[\left(1 + \frac{2}{z}\right) - \left(\cos\frac{90^0}{z}\right)\right]$ mm

Width $w = mz\ \sin\frac{90^0}{z}$ mm

1. Module of the gear, m = _ _ _ _ mm
2. No. of teeth on gear, z = _ _ _ _
3. Theoretical value of height, h = _ _ _ _ mm
4. Theoretical value of width/thickness, w = _ _ _ _ mm

5. Measured values of width/thickness, w =

a) _ _ _ _ _ _ _ _ _ d) _ _ _ _ _ _ _ _ _

b) _ _ _ _ _ _ _ _ _ e) _ _ _ _ _ _ _ _ _

c) _ _ _ _ _ _ _ _ _ f) _ _ _ _ _ _ _ _ _

6. Average value of width/thickness w = _ _ _ _ _ mm

7. Error in tooth thickness = _ _ _ _ _ mm

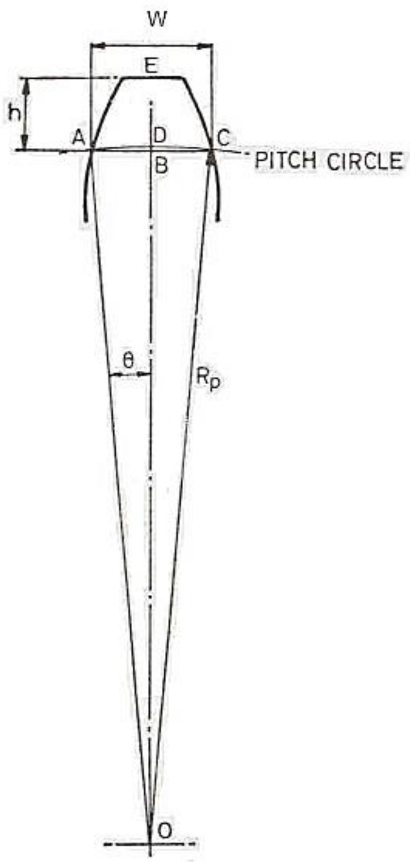


Fig.7.3. Measurement of tooth thickness at pitch circle diameter

2. Measurement of tooth width/thickness at Constant Chord

Height $h = m\left(1 - \frac{\pi}{4}\cos\varphi\sin\varphi\right)$ mm

Width $w = 2AC = \frac{\pi}{2} m \cos^2\varphi$ mm

1. Module of the gear, m = _ _ _ _ mm
2. No. of teeth on gear, z = _ _ _ _
3. Theoretical value of height, h = _ _ _ _ mm
4. Theoretical value of width/thickness, w = _ _ _ _ mm
5. Measured values of width/thickness, w =

a) _ _ _ _ _ _ _ _ _   d) _ _ _ _ _ _ _ _ _

b) _ _ _ _ _ _ _ _ _   e) _ _ _ _ _ _ _ _ _

c) _ _ _ _ _ _ _ _ _   f) _ _ _ _ _ _ _ _ _

6. Average value of width/thickness w = _ _ _ _ _ mm

7. Error in tooth thickness = _ _ _ _ _ mm

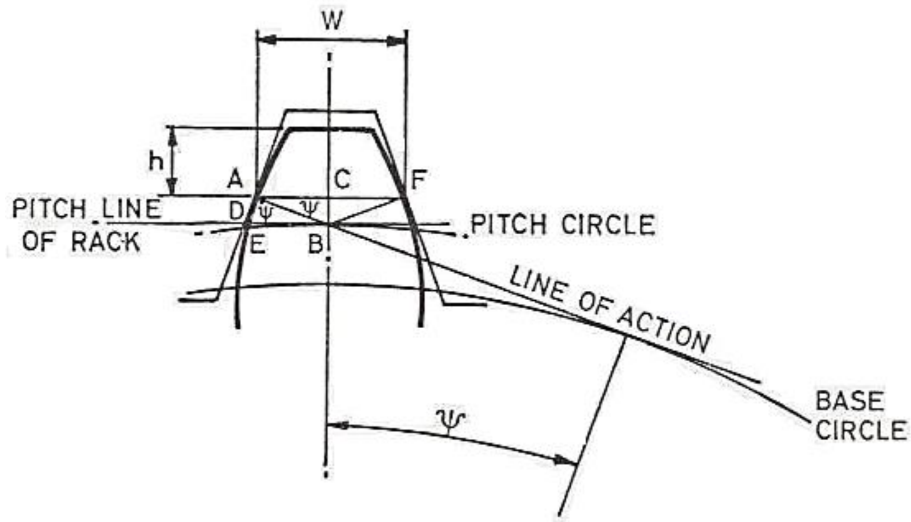


Fig.7.4. Measurement of tooth thickness at constant chord

Result: 1. Width/Thickness of spur gear tooth at pitch circle diameter (w) = _ _ _ _ mm

2. Width/Thickness of spur gear tooth at Constant Chord (w) = _ _ _ _ rnrn

Experiment No. 8

MEASUREMENT OF THREAD PARAMETERS USING PROFILE PROJECTOR

Aim: To Measure the thread parameters using profile projector.

Apparatus required:
1. Profile projector
2. Screw thread (Metric)
3. Pitch gauge (Metric)
4. Micrometer

Theory:
Profile projector is a precision measuring device that provides fast, simple and reliable quality control. Profile projector projects the profiles at desired magnification. Profile projector consists of a lens system, measuring system and a screen. The lens system consists of a light source, magnification lens system, a focus control threaded tube for profile and

surface illumination. The measuring system consists of an X- Y table each with a micrometer and a protractor scale on the screen. The projection screen is made of thick ground glass to give uniform distribution of light. There is a radial graduated vernier scale for angular measurement. It also has cross wires for reference during linear measurement. The drawing of the profile drawn to same magnification as the projected image can also be fixed on the screen and compared. The application of profile projectors are tracing of profiles on tracing paper, to measure terminology of screw threads, gears ,control of square ness and parallelism etc.

Observation:

1. Pitch of the thread measured using pitch gauge, P = _ _ _ _ mm

2. Major diameter of the thread measured using micrometer D_1 = _ _ _ _ mm

Procedure:

1. Place the specimen on the table and clamp it.
2. Adjust the magnification lens for required magnification.
3. The magnified image of thread is seen on the screen.
4. Adjust the Y-axis to the lower position of threads.
5. Reset the reading display.
6. Make the axis to the opposite ends of the threads and note down the readings which gives outside diameter of thread
7. Similarly pitch is measured by operating on X-axis.
8. Angle of the thread can be found by adjusting the scale line to the flanks of the threads by swiveling the screen and reading angle directly.

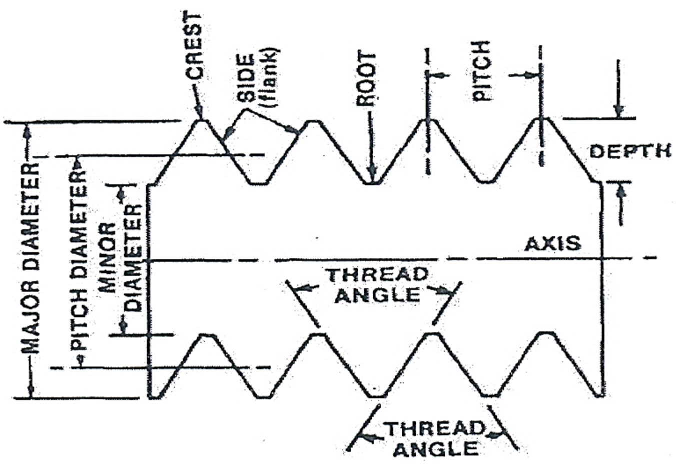


Fig.8.l. Screw Thread profile / parameters

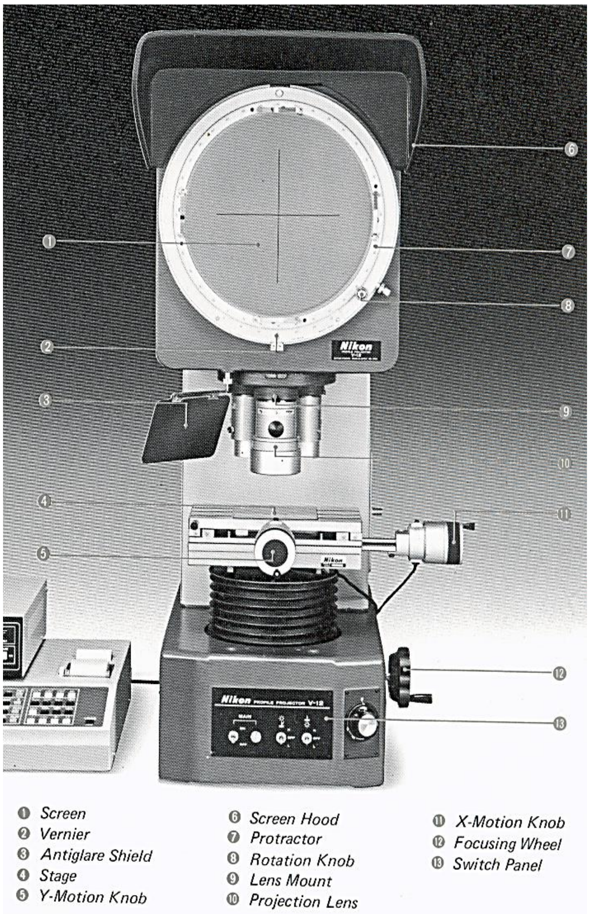


Fig.8.2. Profile Projector

Result:

1. The pitch of screw thread, P = _ _ _ _ mm
2. Major diameter of screw thread, D_1 = _ _ _ _ mm
3. Minor diameter of screw thread, D_2 = _ _ _ _ mm
4. Angle of thread, θ = _ _ _ _ degrees

Experiment No. 09

MEASURMENT USING TOOL MAKER'S MICROSCOPE

Aim: To measure pitch and diameter of the Nozzle of Inkjet printer cartridge using tool maker's microscope.

Apparatus required:

1. Tool maker's microscope.
2. Inkjet printer cartridge

Theory:

Tool maker’s microscope is used for measuring complex profiles. It consists of a work table, an objective and an eye piece. The illumination system consists of surface illumination and profile illumination. Surface illumination is used to study surface of the component and profile illumination for profile of the component. The profile of threads and gears, the nose radius of tools can be easily compared and measured by using corresponding reticles which have standard profiles on them. Angles can be measured by using angle dial which is in the eye piece assembly. The linear measurements are made using two micrometers fixed to the X -Y work table perpendicular to each other. A cross- wire reticle has two lines engraved perpendicular to each other. This cross-wire reticle is used for measurements.

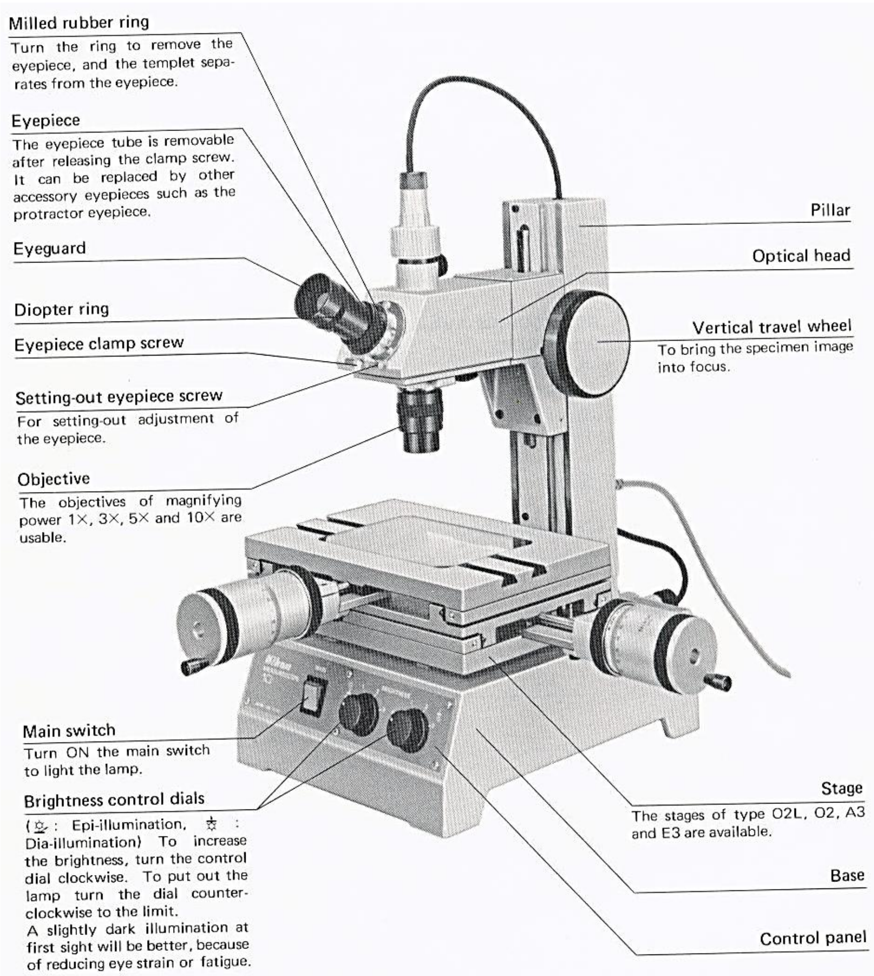


Fig.9.1 Tool maker’s microscope (Measuroscope)

Observation:

Magnification of Eyepiece used = 3x objective.

= l0x eyepiece.

Illumination used: Vertical episcope illumination.

Least count LC = 0.001 mm

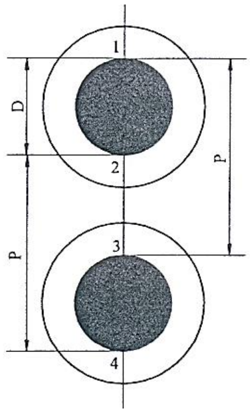


Fig.9.2. Inkjet nozzle parameters

Measured values of nozzle diameter, D =

a) _ _ _ _ _ _ _ _ _ _ _ b) _ _ _ _ _ _ _ _ _ _ _ c) _ _ _ _ _ _ _ _ _ _ _

Average value of nozzle diameter, D = _ _ _ _ mm

Measured values of nozzle pitch, P = _ _ _ _ mm

a) _ _ _ _ _ _ _ _ _ _ _ b) _ _ _ _ _ _ _ _ _ _ _ c) _ _ _ _ _ _ _ _ _ _ _

Average value of nozzle pitch, P = _ _ _ _ mm

Procedure:

1. Place the Inkjet printer cartridge on the stage in such a position that its sectional or contour surface plane is perpendicular to the optical axis of the objective. If this is not exactly attained, no uniform focusing will be obtained over the entire area of the template.
2. Adjust the cross wire at point 1 of the nozzle and note down the initial reading on Y-axis and further move the cross wire till point 2 on the nozzle diameter, note the final reading as shown in the figure 2. The difference initial and final reading will give the diameter of nozzle.
3. Similarly the pitch of the nozzle is measured by setting the cross wire on point 1 and 3 or 2 and 4.
4. Then by several trails measure the value of diameter (D) and pitch (P) and average value is computed

Result: Measured value of diameter, D = _ _ _ _ mm

Measured value of pitch of the nozzle, P = _ _ _ _ mm

Experiment No. 10

MEASUREMENT OF ALIGNMENT USING AUTOCOLLIMATOR

Aim: To check the correctness of the angles marked on a circular indexing table, using 8 faced mirror reflector and autocollimator

Apparatus required:

1. Auto collimator

2. 8 Faced mirror reflector
3. Circular indexing table

Theory:

It is an instrument used for angle measurement. It incorporates a collimating lens which is designed to transmit a parallel beam of light radiating from a source of its principal focus. A plane reflector placed in the path of the beam and normal to the geometrical axis of the lens will reflect the light along the transmission path to be refocused at the source. If the reflector is inclined at a small angle Su to the normal, the beam is reflected at an angle equal to 28u from its transmission path.

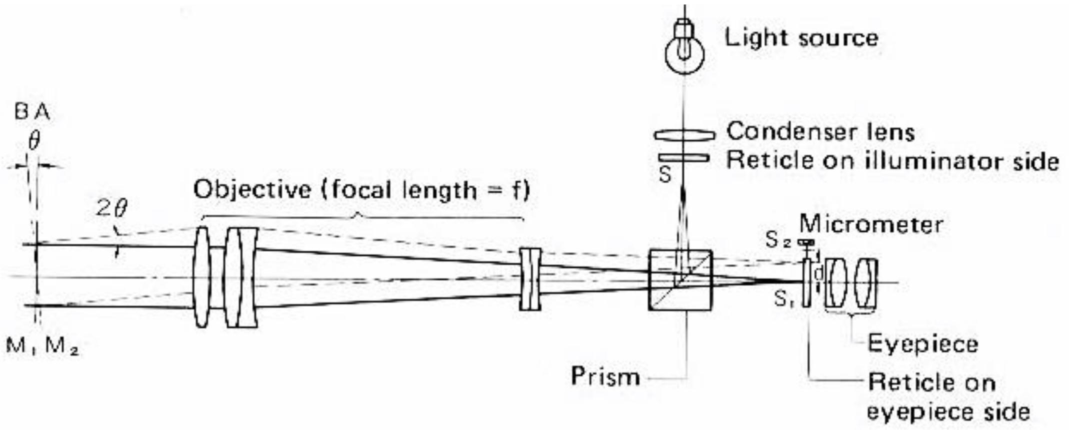


Fig.10.1. Working principle of Autocollimator

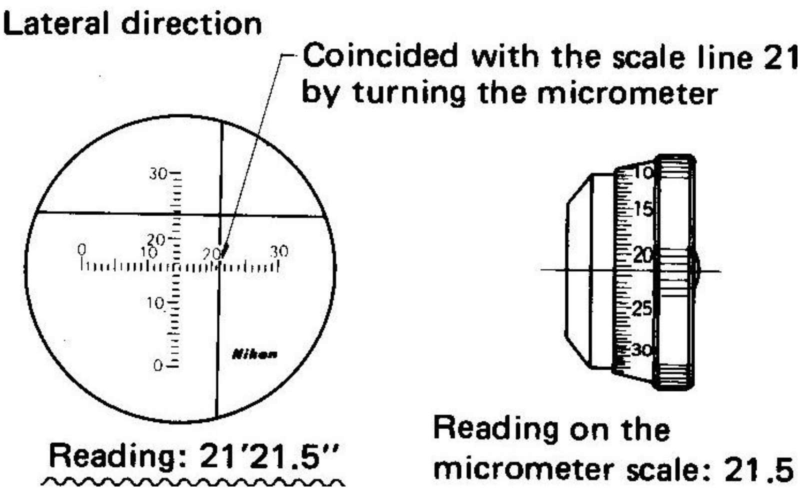


Fig.10.2. Micrometer scale

Procedure:

1. The mirror polygon of an 8 faces is mounted on the indexing table to be calibrated. Initially the Indexing table is, fixed at 0°. The Auto collimator is now set to receive the reflection from the side of polygon corresponding to *0°*, and the cross wires are set at 15' on the auto collimator scale. (Which is taken as reference) The micrometer reading is also set at 0".
2. Now the indexing table is rotated and fixed at *45°* so that the polygon is also shows 45° at this point. Now the Auto collimator scale is observed and the

movement of the vertical cross Wire on horizontal scale (Which gives the angularity) is noted down, with Reference to 15' on auto collimator scale. Now the Cross wire is coincided on to the nearest value. (When the cross wire is in between the values) by using micrometer Screw and the value of Micrometer readings in seconds are noted down.

3. The procedure is repeated for the angles 90°, 135°, 225°, 180°, 270°, 315° and the values are tabulated.
4. The correction factor (Error of each polygon face nominal Value) is given by the manufacturer and the true value of error the marking of indexing table IS obtained by True value of error = (Measured value) --- (Correction factor)

Tabular Column:

Sl. No.	Setting of indexing table	Autocollimator reading in minutes and seconds measured value	Correction factor in seconds	True value = Measured value – Correction factor
1	00^0			
2	45^0			
3	90^0			
4	135^0			
5	180^0			
6	225^0			
7	270^0			
8	315^0			

Nikon 8面鏡成績表

8 sided Polygon Mirror Inspection Certificate

No. 9239 87 . 9 . 1 .

呼称角度値 Nominal Angle	器差 Correction Factor
0 degrees	0 second
45	1.9
90	-0.1
135	-0.5
180	0.4
225	2.4
270	-1.6
315	0.5

実測に基づく器差の値を表記致します。
真値は、これを補正量として、真値＝測定値－器差にて計算し、求めることが出来ます。

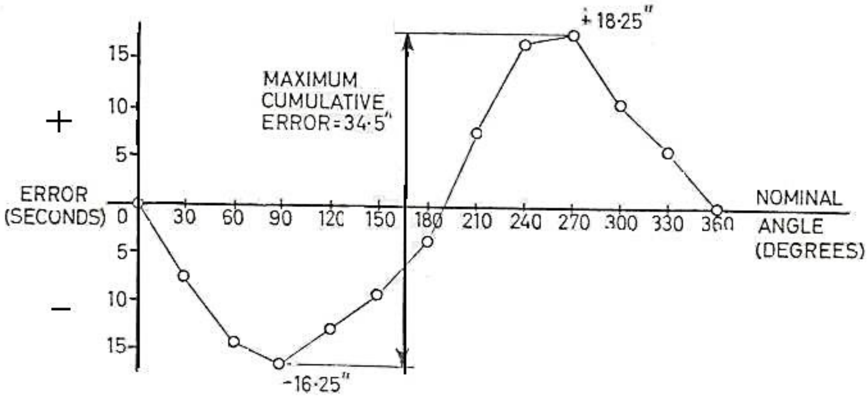
To obtain the true value for a measurement taken with the 8 sided Polygon Mirror, you must use the correction factor table provided above.

True value = Measured value − Correction factor

Correction Factor Table

Calibrating Circular Divided Scales and Indexing Equipment

The simplest means of calibrating an indexing device, such as a dividing head, is to refer it to a precision polygon.



Graph of indexing errors from an indexing device having an eccentric mounting.

MEASUREMENT OF SCREW THREAD PARAMETERS USING THREE WIRE METHOD

Aim: To determine the effective diameter by using three wire method

Apparatus required:

1. Micrometer stand
2. Screw thread
3. Set of standard three wires
4. Micrometer.

Theory:

This method of measuring the effective diameter is an accurate. In this, three wires or rods of known diameter are used. One on one side and two on the other side, which ensures the alignment of wires. Micrometer with anvil faced parallel to the thread axis is used, where the wire may be held in hand or hung from a stand so as to ensure freedom to wires to adjust them under micrometer pressure.

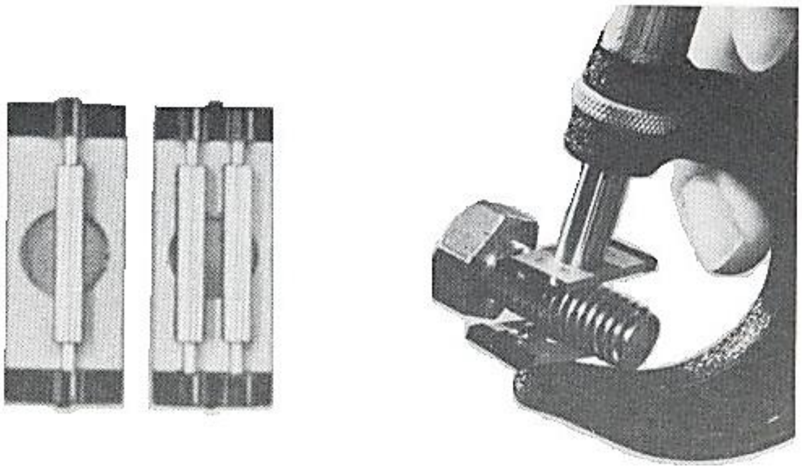


Fig.11.1. Set-up for measuring effective diameter using three

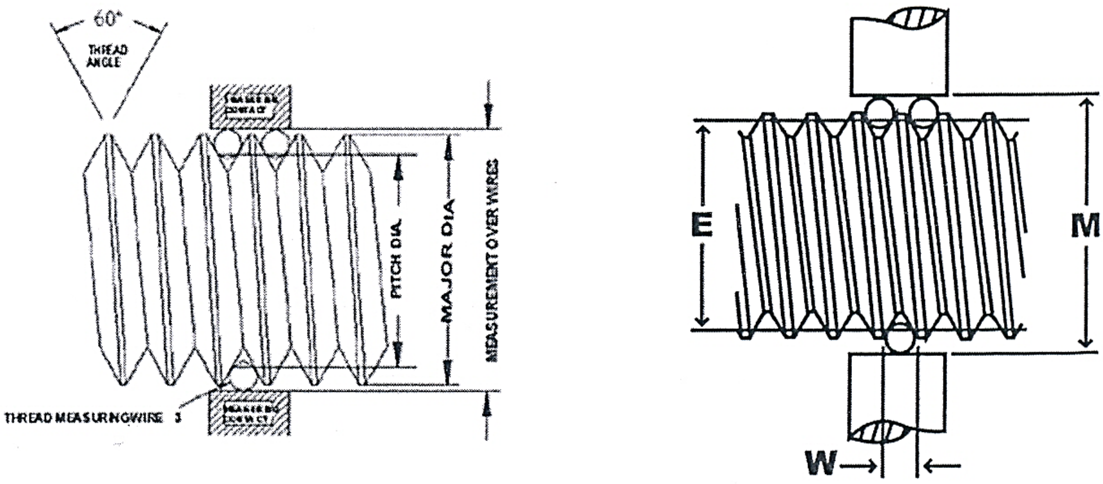


Fig. 11.2. Screw thread parameters

Procedure:

1. Screw thread parameters such as pitch and angle of the given thread are used to calculate the wire size or diameter.
2. The best size wire (dw) is selected from the standard series, which is nearer to the

calculated value of wire diameter.

3. Three wires of equal and precise diameter (dw) are placed in thread grooves on opposite sides of the screw.
4. Out of the three wires in the set, two wires are placed on one side and third on the other side. These wires are also hung through threads on a stand. However they must ensure freedom to the wires to adjust them under the micrometer pressure.
5. Measure the distance over the outer surface of the wires M with the micrometer.
6. Then by several trails measure the value of M and take its average, and calculate the effective diameter, E using the formulae.
7. Effective diameter E of the screw thread is verified using thread micrometer and error is noted.

Observation:

1. Pitch of the screw thread, P = _ _ _ _ mm
2. Angle of thread, θ = _ _ _ _

Where,

P = Nominal pitch of the thread in mm

θ = Angle of thread = 60° for metric thread

Calculation:

Best wire size, $$dw = \frac{P}{2}\sec\frac{\theta}{2} \text{ mm}$$

dw = _ _ _ _ mm

Measurement over wire, M = 1. _ _ _ _ _ 2. _ _ _ _ _ 3. _ _ _ _ _ mm

Average value of measurement over wire, M = _ _ _ _ _ mm

Effective diameter E, as shown in fig.11.2 is calculated as follows

E = M - 2dw + X

Where, $$X = \frac{P}{2}\cot\frac{\theta}{2} - dw\left(\operatorname{cosec}\frac{\theta}{2} - 1\right)$$

Now substitute the value of X in the expression, and calculate the simple effective diameter,

E = M - 2dw + X

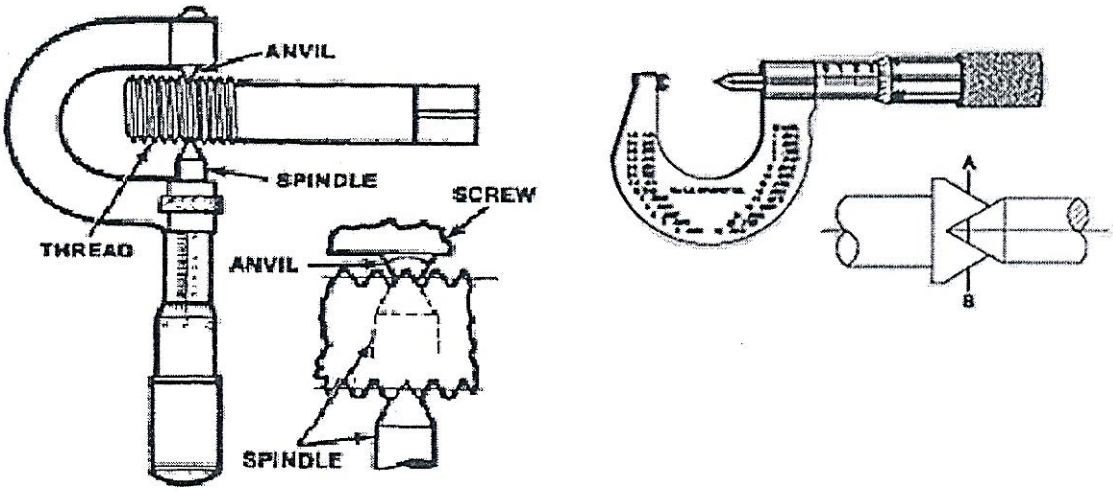


Fig.11.3. Screw thread micrometer

Cross verified by using thread micrometer as show in fig.11.3.

E = 1. _ _ _ _ _ 2. _ _ _ _ _ 3. _ _ _ _ _ mm

Average value of effective diameter, E = _ _ _ _ mm

Result:

Effective diameter measured by three wire method E = _ _ _ _ mm

Effective diameter measured by screw thread micrometer E = _ _ _ _ mm

MEASUREMENT OF CUTTING TOOL FORCES USING LATHE TOOL DYNAMOMETER

Aim: To measure cutting tool forces using lathe tool dynamometer

Apparatus required:

1. Lathe
2. Lathe tool dynamometer
3. HSS Single point cutting tool

Theory:

To investigate the performance of cutting tools during metal cutting, the measurement of cutting forces is essential. This helps the analysis of metal cutting as below:
1. Effects of speeds and feeds on the action of cutting tool.
2. Effect of mechanical properties of work material on cutting forces.
3. Values of forces exerted on machine components, on jigs and fixtures, and effect of those forces on the geometrical accuracies of the work pieces.

In short, the tool force measurement i.e. tool-dynamometry is an essential device to analyses the process of metal cutting. Further, the test results are used to solve shop floor problems such as tool performance, load exerted on the machines, or on the jigs and fixtures.

In orthogonal cutting, the force components Fv and Fh are named as vertical force component and horizontal force component. The Lathe tool dynamometer is used to measure Fv and Fh at different cutting conditions and further makes it possible to construct the merchant circle diagram. This dynamometer consists of a tool holder held rigidly in dynamometer body.

Procedure:

1. Fix the lathe tool dynamometer rigidly on the lathe machine.
2. Take the mild steel specimen and hold it by chuck. The distance between specimen and lathe chuck should not exceed 100 mrn.
3. The specimen should not have any eccentricity.
4. Give the proper connection between lathe tool dynamometer and digital multi component force indicator.
5. Switch ON the power supply.
6. Keep the toggle switch (READ-CAL switch) in 'READ' position. Make all X, Y, and Z - forces Zero and adjust 'CAL' depending on the suitable range (lao kg).
7. By keeping the READ-CAL switch in read position observe that all forces are ZERO and switch ON the lathe machine.
8. Give the depth of cut in steps of 0.2 mm till 1 mm (depending on specimen) and measure the cutting force values in X, Y and Z direction.

Note: X - Force - Feed force towards the job

Y - Force - Cutting force.

Z - Force - Thrust force

Observation:

Machine tool :

Cutting Tool : High speed steel

Work piece material : Mild steel

Tabular Column:

Sl. No	Cutting condition			Chip thickness ratio			Shear angle υ tanυ = r cosα/(1-rsinα)	Feed force Ff 'X' Kgf	Cutting force Fc 'Y' Kgf	Thrust force Ft 'Z' Kgf
	Speed N r/min	Depth of cut d mm	Feed 'f' mm/rev	Uncut chip thickness 't' mm	Cut chip thickness 'tc' mm	Ratio rc= t/tc				
1										
2										
3										
4										

Back rack angle of tool (α) = 0°
Fc: (Y) - Cutting Force. Kgf
Ff: (X) - Feed force. Kgf
Ft: (Z) - Thrust Force. Kgf

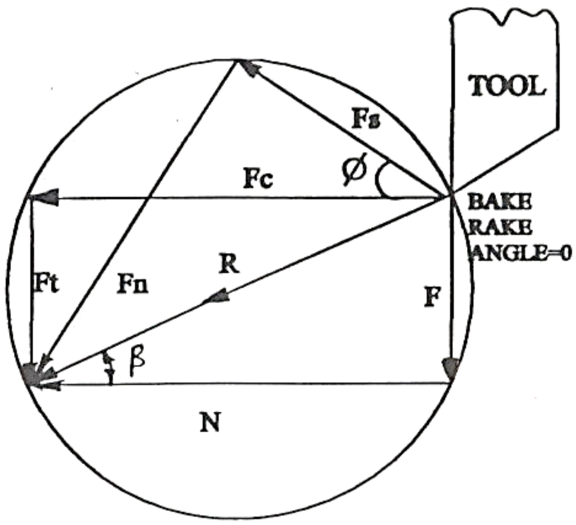


Fig.12.1 Merchant's Circle diagram

Result: from the merchant's circle diagram, the following force components are noted

Fs = Shear force.
F = Frictional force
υ = Shear angle.
Fn = Normal force on Rake Face.
β = Friction angle.

MEASUREMENT USING OPTICAL FLATS

Aim: To measure the flatness using optical flat and comparing with a standard.

Apparatus required:

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

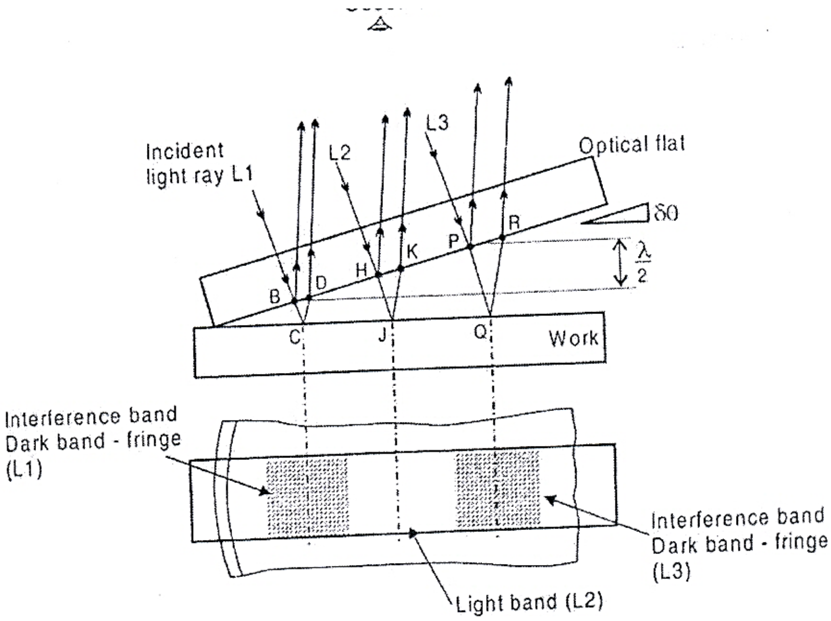
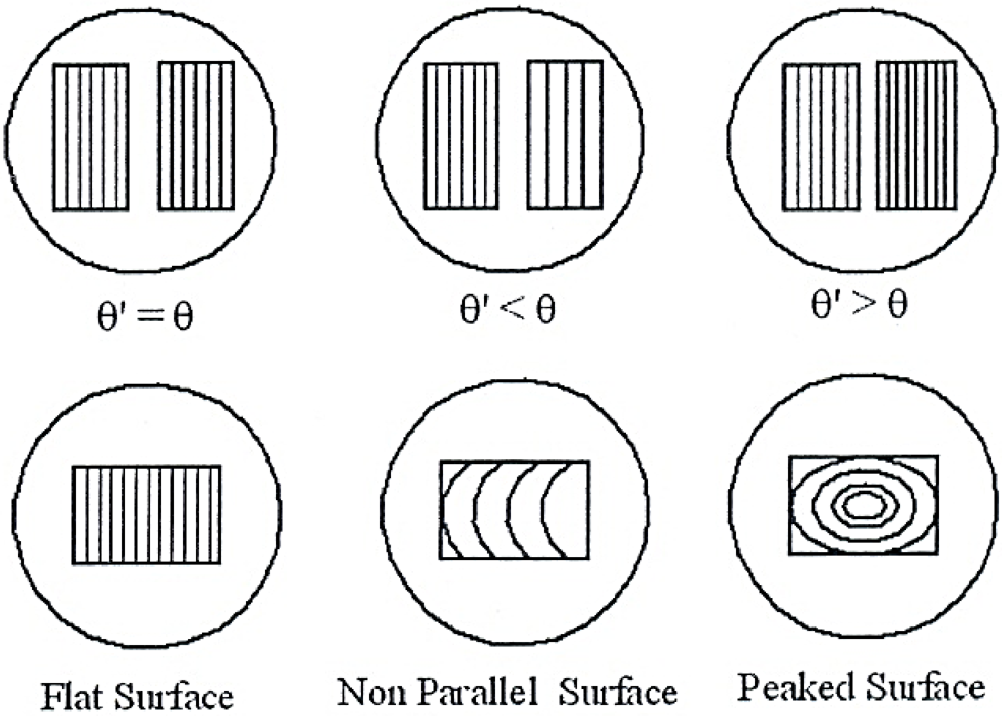


Fig.13.1. Fringe generation by interference



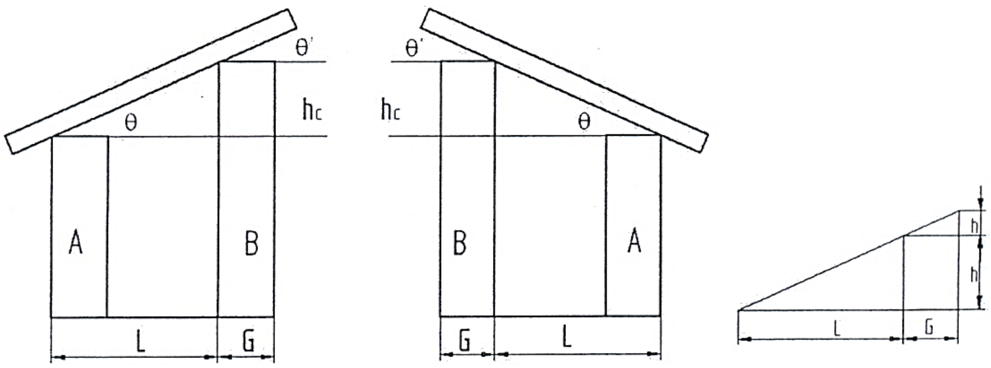
Theory:

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

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

The deformations in the surface must not be large with respect to the wavelength of light being used. The incident light passing through the optical flat is either reflected off the rear surface of the flat or transmitted through the air gap between the flat and the test piece (refer figure). Some of the transmitted light is then reflected of the surface of the test piece. The amount of light reflected from the test piece needs to be similar to the light reflected from the back surface of the optical flat.

When e is considered small the difference in the path length for the two reflected beams s measured as 2d. This is twice the distance of the gap between the optical flat and the test piece.



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

Procedure:

1. Clean the slip gauges and keep the slip gauges side by side over the table.
2. The slip gauges are to be separated by a known distance.
3. Place the optical flat on two slip gauges of different height.
4. Adjust the monochromatic light and optical flat to get clear fringes.

5. Note down the number of fringes on the calibration grade.
6. Calculate the difference in height 'hc'

Observation:

Distance between two adjacent slip gauges, L = _ _ _ _ mm

Width of the slip gauge, G = _ _ _ _ mm

Difference in height, d = _ _ _ _ mm

Wavelength of the monochromatic light λ = _ _ _ _ mm

Number of fringes on reference slip gauge, N = _ _ _ _

Calculation:

Difference in height h_c is calculated $$h_c = \frac{L}{G} N \frac{\lambda}{2} \text{ mm}$$

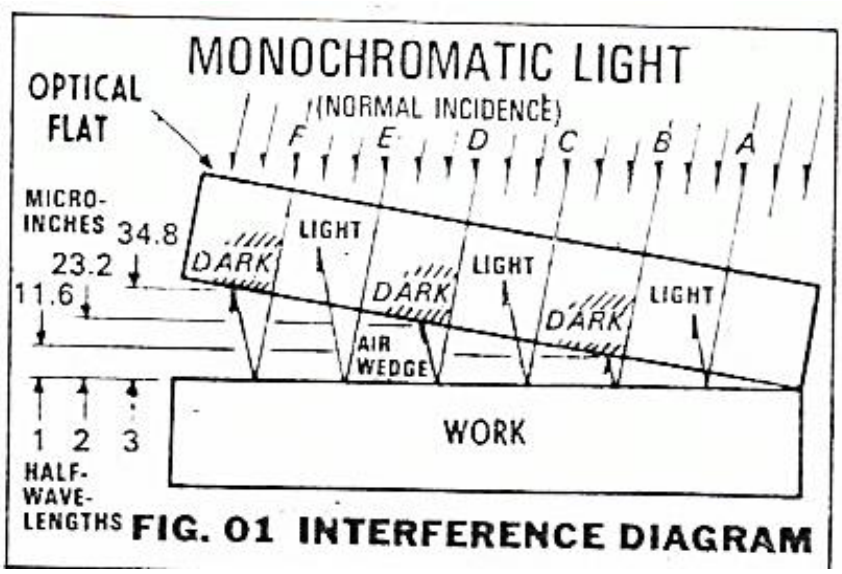


FIG. 01 INTERFERENCE DIAGRAM

FIG. 1 FLAT — AIR WEDGE

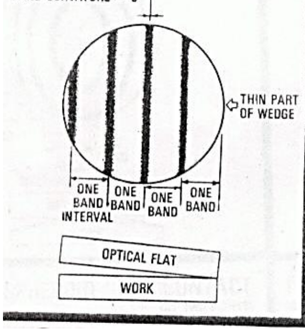


FIG. 2 CYLINDER — AIR WEDGE

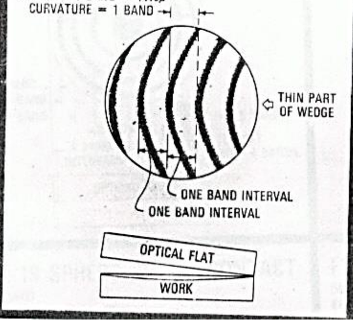
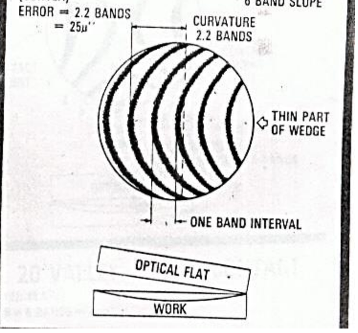
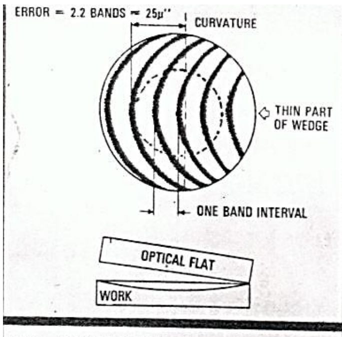


FIG. 3 CYLINDER — AIR WEDGE





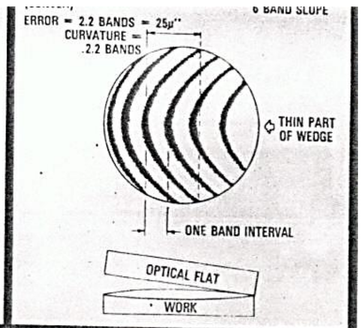


FIG. 9 CYLINDER — CONTACT

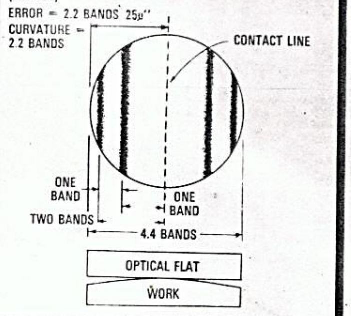


FIG. 10 SPHEROID — CONTACT

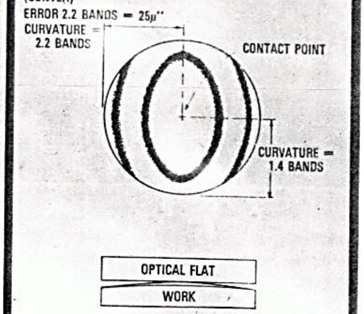


FIG. 13 CYLINDER — CONTACT

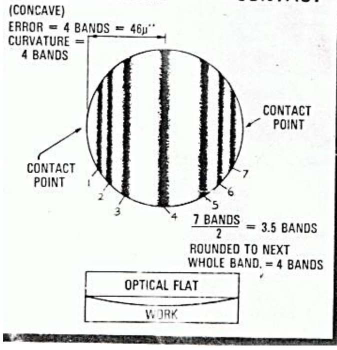
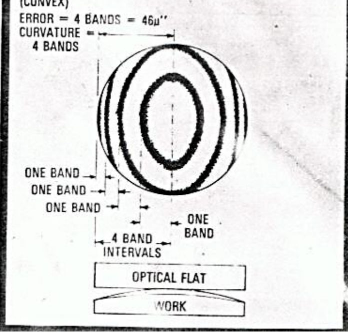


FIG. 14 SPHEROID — CONTACT



;. 6 SPHEROID — AIR WEDGE

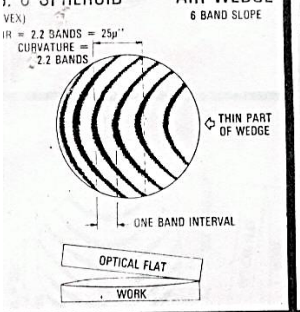


FIG. 7 SPHERE — AIR WEDGE

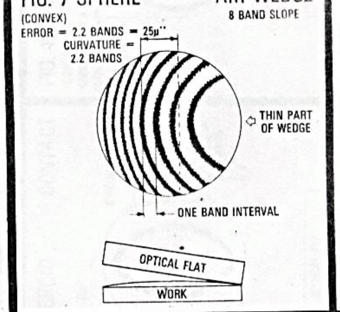
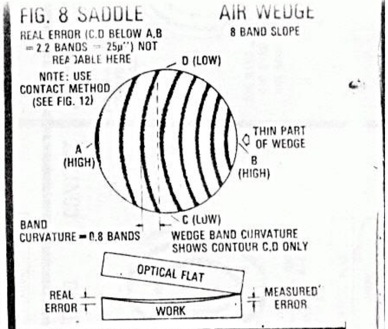


FIG. 8 SADDLE — AIR WEDGE



G. 10 SPHEROID — CONTACT

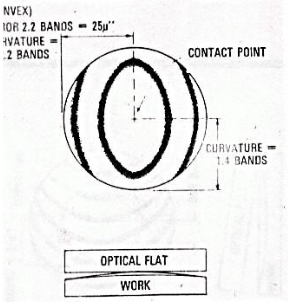


FIG. 11 SPHERE — CONTACT

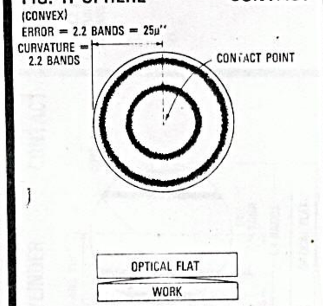
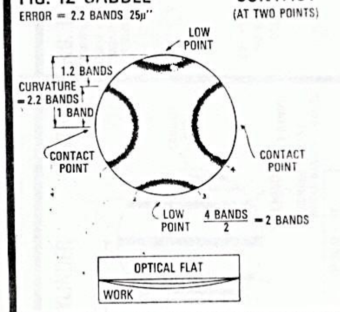


FIG. 12 SADDLE — CONTACT (AT TWO POINTS)



IG. 14 SPHEROID — CONTACT

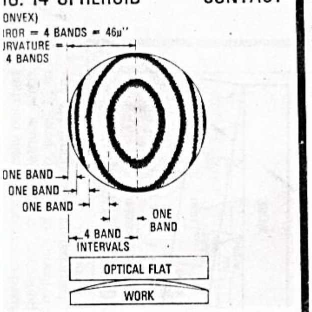


FIG. 15 SPHERE — CONTACT

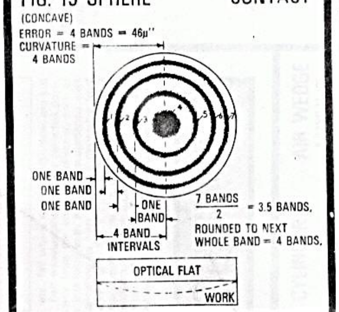
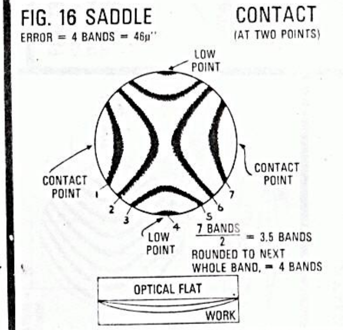


FIG. 16 SADDLE — CONTACT (AT TWO POINTS)



IG. 18 SPHEROID — CONTACT (AT TWO POINTS)

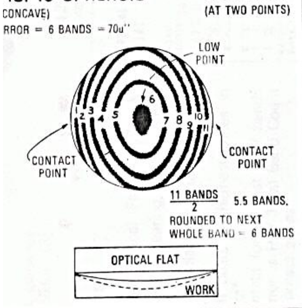


FIG. 19 SPHERE — CONTACT

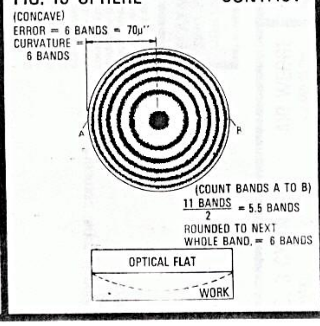


FIG. 20 VALLEY — CONTACT