A Laboratory Manual for

Mechanical Measurement and Metrology (3141901)

B.E. Semester 4

Lukhdhirji Engineering College, Morbi
Mechanical Engineering Department

Lukhdhirji Engineering College, Morbi

Mechanical Engineering Department

Certificate

This is to certify that Mr./Ms. ____ ___________________ Enrollment No. __________________________ of B.E. Semester _____ Mechanical Engineering of this Institute (GTU Code: 031) has satisfactorily completed the Practical / Tutorial work for the subject **Mechanical Measurement & Metrology (3141901)** for the **Academic Year ________________**.

Place: __________

Date: __________

Name and Sign of Faculty member

Head of the Department

Preface

Main motto of any laboratory/practical/field work is for enhancing required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient weightage is given to practical work. It shows importance of enhancement of skills amongst the students and it pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates an interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with competency, industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

Mechanical Measurement and Metrology involves basic linear and angular measurement. Engineering metrology deals with the applications of measurement science in manufacturing processes. It provides a means of assessing the suitability of measuring instruments, their calibration, and the quality control of manufactured components. The science of mechanical measurements has its roots in physics. It is an independent domain of knowledge dealing with the measurement of various physical quantities such as pressure, temperature, force, and flow.
Utmost care has been taken while preparing this lab manual however always there is chances of improvement. Therefore, we welcome constructive suggestions for improvement and removal of errors if any.

Practical – Course Outcome matrix

Course Outcomes (COs):

1. Summarize various methods and terms used in mechanical measurements and metrology.
2. Measure mechanical quantities like Force, Temperature, Pressure, Velocity, Acceleration, Strain and Torque.
3. Apply concepts of metrology for gears, threads and surface finish.
4. Utilize various precision machines working based on Laser technology and coordinate measuring methods.

Sr. No.	Objective(s) of Experiment	CO1	CO2	CO3	CO4
1.	Performance on linear measurements and check different characteristics of measurements.	✓			
2.	Performance on angular measurements and check different characteristics of measurements.	✓			
3.	Performance on temperature measurements and check different characteristics of measurements and also do calibration		✓		
4.	Performance on pressure measurements and check different characteristics of measurements and also do calibration.		✓		
5.	Performance on stress, strain and force measurements and check different characteristics of measurement and also do calibration.		✓		
6.	Performance on Speed/Velocity, acceleration measurements.		✓		
7.	Performance on surface measurements.			✓	
8.	Performance on measurements of gears and screw threads.			✓	

Industry Relevant Skills

The following industry relevant competency are expected to be developed in the student by undertaking the practical work of this laboratory.

1. To study procedure of specimen preparation for microscopic examination and to carry out a specimen preparation.
2. To study different heat treatment processes- annealing, normalizing, hardening and tempering.
3. To understand and perform various non-destructive tests.

Guidelines for Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the experiment to the students before starting of each practical
3. Involve all the students in performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Common Safety Instructions

1. Students are expected to carefully handle the chemicals/etchants.
2. Students must take the permission of the laboratory staffs before handling any instrument/equipment, to avoid injury.
3. Students must wear closed toe shoes while working in the laboratory.
4. Students must ensure that after completion of experiment, keep all things in appropriate manner at specific place and properly clean the instrument/equipment and your work area.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of Performance	Date of Submission	Assessment Marks	Sign. of Teacher with date	Remarks
1	Performance on linear measurements and check different characteristics of measurements						
2	Performance on angular measurements and check different characteristics of measurements						
3	Performance on temperature measurements and check different characteristics of measurements and also do calibration						
4	Performance on pressure measurements and check different characteristics of measurements and also do calibration.						
5	Performance on stress, strain and force measurements and check different characteristics of measurement and also do calibration.						
6	Performance on Speed/Velocity, acceleration measurements.						
7	Performance on surface measurements.						
8	Performance on measurements of gears and screw threads.						
Total							

Date: -

Experiment No: 1

AIM: Performance on linear measurements and check different characteristics of measurements.

Objective:

1. To familiar with linear measuring device.
2. To understand how to eliminate errors in linear measurements.
3. To study method of selection of Liner measurement instruments.

Relevant CO: Summarize various methods and terms used in mechanical measurements and metrology.

RATIONALE:

Vernier caliper is a simple arrangement using a fixed scale and sliding scale to obtain measurement of accuracy higher than that of ordinary scale. Vernier caliper is used to measure external and internal diameter, width, thickness and length of jobs.

Where two jaws of Vernier caliper are brought tougher and if zero of Vernier scale does not coincide with zero of main scale, the instruments have σ error. This σ error is due to wear and tear of the instrument.

If zero division of V.S is on right hand side of main scale zero (when two jaws are brought in contact with each other) the error is positive and if zero division is on left side of main scale zero the error is negative.

Theory:

Types of Calipers:

Vernier Calipers is caliper with a Vernier scale to enhance the ability of a caliper to measure precise dimensions. In today's market, Vernier Calipers with dial and digital read out are commonly available. Based on this let us list out the various types of calipers and Vernier calipers available.

- Inside Caliper
- Outside Caliper
- Spring Caliper
- Vernier Caliper
- Dial Vernier Caliper
- Digital Vernier Caliper

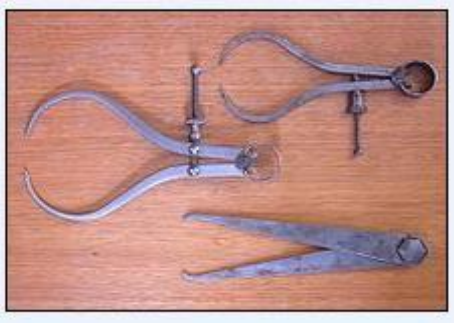
Inside Calipers

Inside Caliper:

- The inside calipers are used to measure the diameter of hole.
- The size of the caliper is specified the maximum distance which is to be measured.
- It will be effectively, if legs of the inside caliper are adjusted with micrometer.

Outside Caliper:

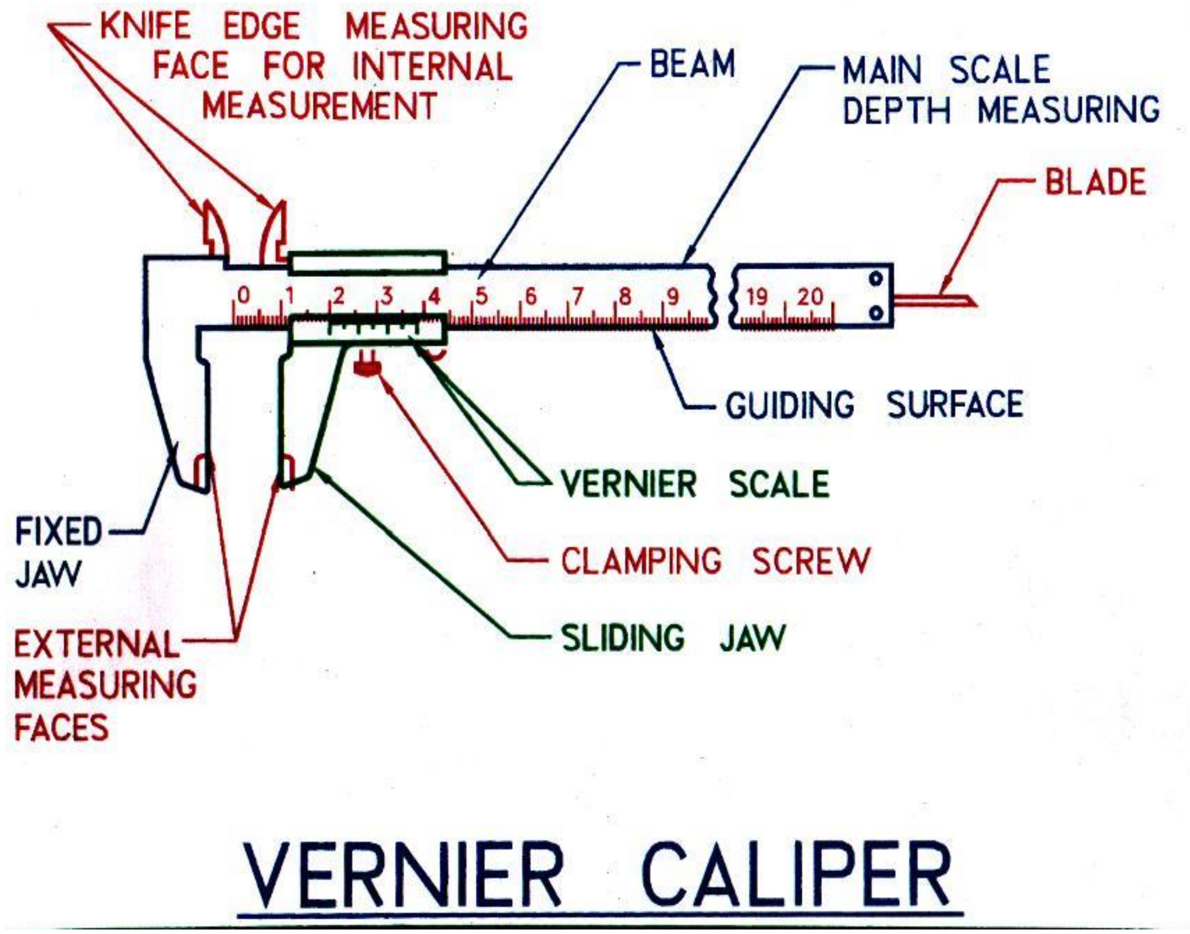
- Outside calipers are used to measure the external size of an object.
- The same observations and technique apply to this type of caliper, as for the above inside caliper.



Outside Calipers

Vernier caliper:

- Vernier caliper works on the principle of minor difference in the two scales i.e. main scale and the Vernier scale.
- Vernier calipers can measure internal dimensions (using the uppermost jaws in the picture at right), external dimensions using the pictured lower jaws, and depending on the manufacturer, depth measurements by the use of a probe that is attached to the movable head and slides along the center of the body.
- This probe is slender and can get into deep grooves that may prove difficult for other measuring tools. The Vernier scales may include both metric and inch measurements on the upper and lower part of the scale. Vernier calipers commonly used in industry provide a precision to a hundredth of a millimeter (10 micrometers), or one thousandth of an inch.

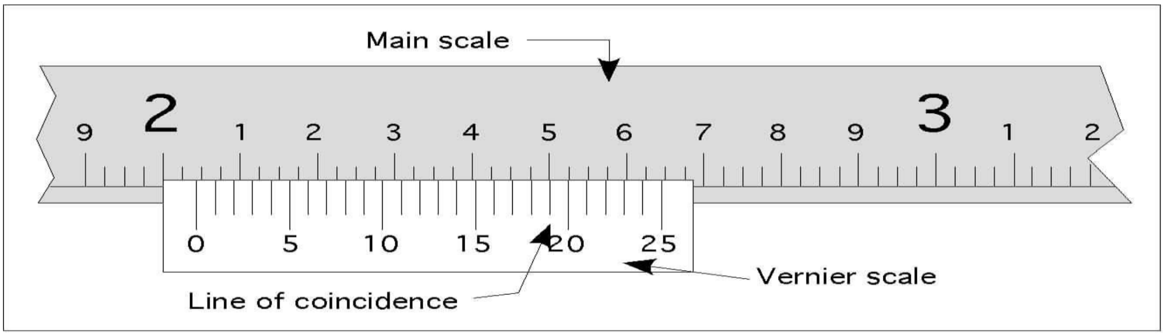


Parts of a Vernier caliper:

1. **Outside jaws:** used to measure external diameter or width of an object.
2. **Inside jaws:** used to measure internal diameter of an object.
3. **Depth probe:** used to measure depths of an object or a hole.
4. **Main scale:** gives measurements of up to one decimal place (in cm).
5. **Main scale:** gives measurements in fraction (in inch).
6. **Vernier** gives measurements up to two decimal places (in cm)
7. **Vernier** gives measurements in fraction (in inch)
8. **Retainer:** used to block movable part to allow the easy transferring a measurement

Procedure:

1. The Vernier caliper is an extremely precise measuring instrument; the reading error is 1/20 mm = 0.05 mm.
2. Close the jaws lightly on the object to be measured.
3. If you are measuring something with a round cross section, make sure that the axis of the object is perpendicular to the caliper. This is necessary to ensure that you are measuring the full diameter and not merely a chord.
4. Ignore the top scale, which is calibrated in inches.
5. Use the bottom scale, which is in metric units.
6. Notice that there is a fixed scale and a sliding scale.
7. The boldface numbers on the fixed scale are centimeters.
8. The tick marks on the fixed scale between the boldface numbers are millimeters.
9. There are ten tick marks on the sliding scale. The left-most tick mark on the sliding scale will let you read from the fixed scale the number of whole millimeters that the jaws are opened.



Least Count:

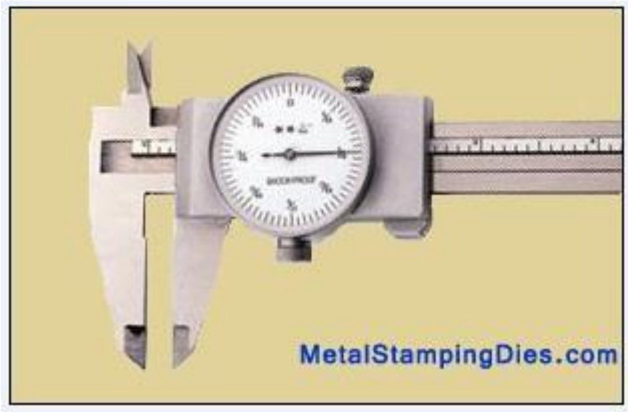
- Least count of measuring instrument is defined a smaller measurement which can be done by measuring instrument is called is least count.

$$L.C = \frac{\text{Value of smallest division on main scale}}{\text{Total no of division on Vernier scale}} = \_\_\_\_\_\_\_\_ \text{ mm}$$

Error of Vernier = ______________________________

Dial Vernier Calipers:

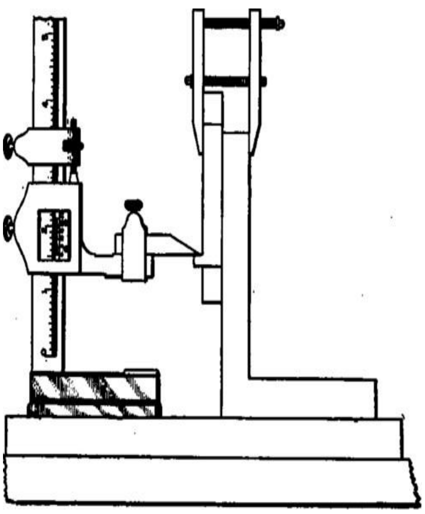
- Dial Calipers is an advanced version of Vernier calipers.
- In dial calipers, Vernier scale is replaced with a dial with a needle rotating in 360 degrees as you move the movable jaw of the dial caliper.
- The motion of the dial needle is achieved accurately by using precisely manufactured rack and pinion mechanism.
- The dial caliper eliminated the difficulty in reading the Vernier scale especially one with small least count.
- Dial caliper also eliminated the parallax error, which can occur from reading normal Vernier calipers with Vernier scale.

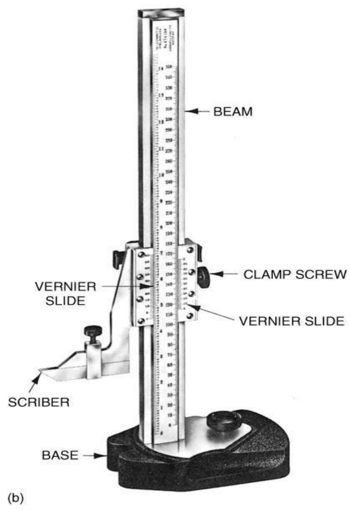


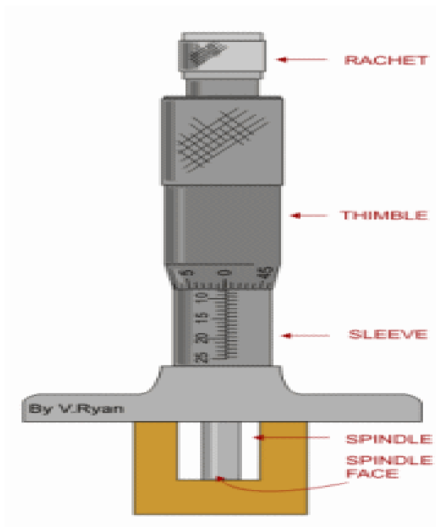
Dial Caliper

Vernier Height & Depth Gauge:

- It is used to measure a Height, width or thickness of work pieces.
- It is also used for inspection of parts and layout work.
- Vernier depth gauge measures the depth and the Vernier height gauge measures the height of the component.







Vernier Height Gauge **Vernier Depth Gauge**

OBSERVATION TABLE:

Sr. No	Instrument/Object	Main Scale Reading (M.S.R) (mm)	Vernier Scale coincide	V.S.C X L.C	Total Length (mm) = M.S.R+ (V.S.C X L.C) ± (error)
1					
2					
3					
4					
5					

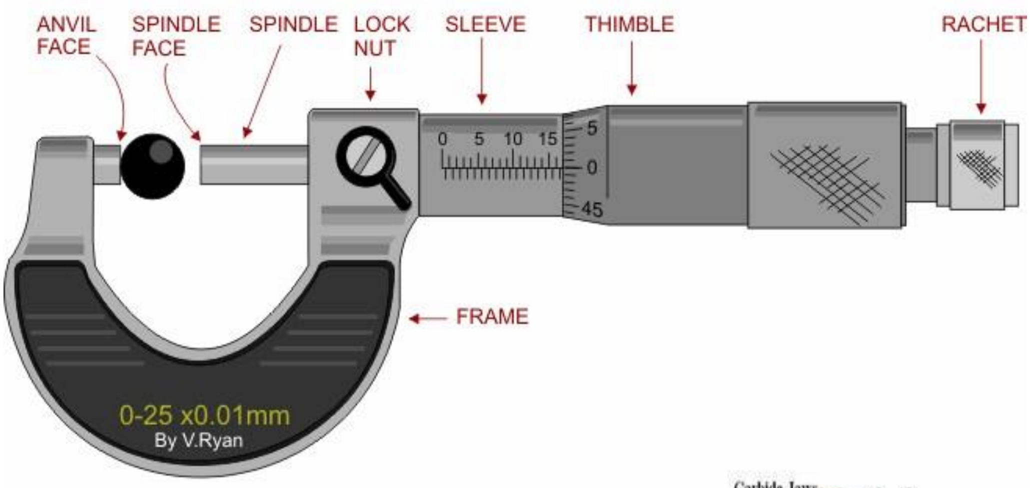
CALCULATION:

MICROMETERS

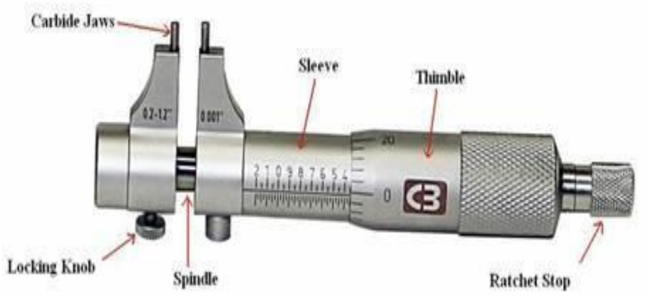
Micrometer is operating on the principle of screw and nut. Micrometer and Vernier caliper are the end standards. Micrometer is one of the most common & most popular forms of measuring instruments for precise measurement with 0.01 mm accuracy. Micrometer with 0.001 mm accuracy is also available.

PARTS OF MICROMETER:

- C-frame
- Anvil
- Barrel
- Thimble
- Ratchet screw
- Lock nut



Micrometer



Inside Micrometer:

- The inside calipers are used to measure the diameter of hole.
- Used for measuring cylinder bores, housing bores.

Inside Micrometer

Outside Micrometer:

- Outside micrometer is used to measure the outer dimension.

Outside Micrometer

Least count of Micrometer:

Least count is the minimum distance that can be measured accurately by the instrument. The micrometers have a screw of 0.5 mm pitch, with a thimble graduated in divisions to provide a direct reading of (pitch / n) = 0.50 / 50 = 0.01 mm.

$$\text{Least Count} = \frac{\text{Value of smallest division on main scale or Pitch}}{\text{Total number of divisions on thimble scale}}$$

PROCEDURE:

1. Study the given Outside micrometer and Inside micrometer critically and recognize their various parts.
2. Calculate the L.C. and note the range of measurement of the instrument.
3. Read any three positions of the main and circular scale.

OBSERVATION TABLE:

S No	Instrument/Object	Main Scale Reading (M.S.R) (mm)	Thimble Scale coincide	T.S.C X L.C	Total Length (mm) = M.S.R+ (T.S.C X L.C) ± (error)
1					
2					
3					
4					
5					

CALCULATION:

Questions

1. Define:
   i. Least count:

   ii. Error:

2. Write name of instruments used for linear measurement.

3. Write function of:
   a. Vernier caliper –

   b. Micrometer –

   c. Dial indicator –

d. Telescopic gauge -

Suggested Reference:

1) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
2) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 2

AIM: Performance on Angular measurements and check different characteristics of measurements.

Objective:

1. To familiar with Angular measuring device.
2. Find out Angle of work piece.
3. To study method of selection of Angular measurement instruments.

Relevant CO: Summarize various methods and terms used in mechanical measurements and metrology.

Equipment And Materials:

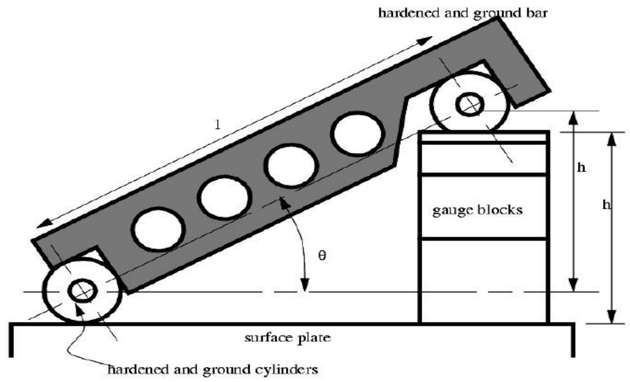
(1) Sine bar, (2) Bevel protector (3) Slip gauges (4) Work piece (5) Surface plate (6) Dial indicator
(7) Clamps and angle plates

Rationale:

Sine bar is an indirect precision angular measuring instrument. It is used in connection with slip gauges. Sine bars are used either to measure angle very accurately or for locating any work piece to given angle within very close limits.

Theory:

The Angle is defined as the opening between two lines, which meet at a point. Sine bar is used for the accurate angle measurement and to locate the work to a given angle. Sine bar is reliable for angle less than 15^o and it becomes in accurate as the angle increases. It is impractical to use sine bar for angle above 45^{o}Angle gauges are used to measure the angle to the accuracy of 3". To locate the work to a given angle within very close limits. It consists of steel bar & two rollers. It is made of high carbon, high chromium corrosion resistant steel, hardened. The rollers are of accurate & equal diameters. They are attaché to the bar at each end. The axes of these rollers are parallel to each other. The normal distance between the axes of the rollers is exactly 100 mm, 200 mm or 300 mm. It has two grade A & B. A Grade sine bar is made with accuracy of 0.01 mm/m of length. B Grade sine bar with accuracy of 0.02 mm/m of length.



Sine Bar

Granite Surface Plate

Where,
L = distance between centers of ground cylinder (typically 5’’ or 10’’)
H = height of the gauge blocks Θ =the angle of the plane
Θ = asin (h/ L)

Precautions:

(1) Before using a given sine bar, ensure its accuracy requirement and tolerances as per I.S.
(2) Take all precautions require for handling & using slip gauges.
(3) Place the light job on the upper surface of the sine bar or place the upper surface of the sine baron the heavy job.
(4) As far as possible use, longer sine bar.
(5) Do not use sine bar for angle greater than 60º.
(6) Correctly place the work piece on sine bar (i.e. clamp work and sine bar).

Observation Table:

Instrument: Sine Bar

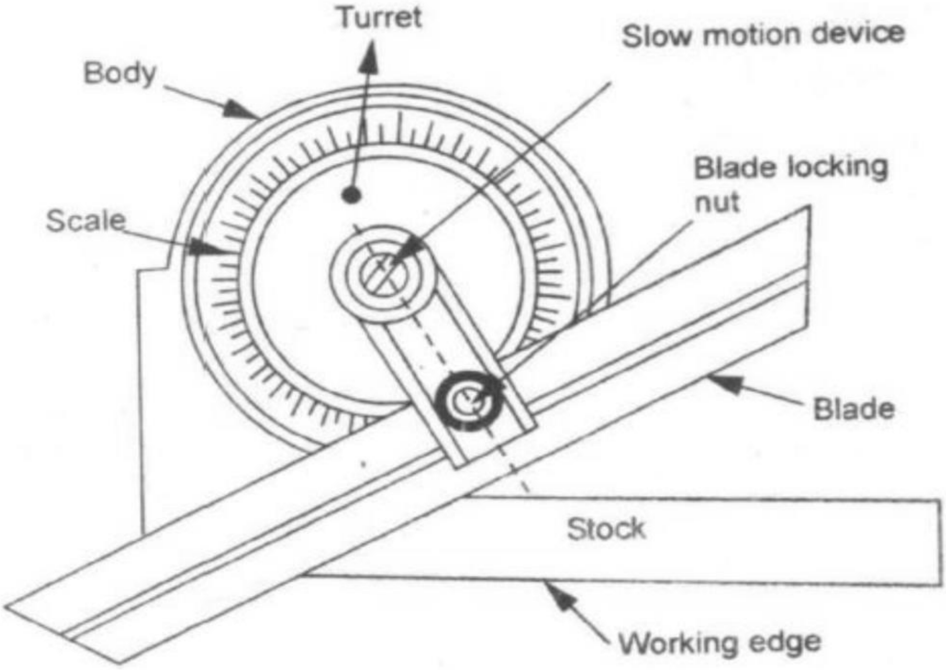
Sr. No.	Length of sine bar (mm)	Height of Slip Gauge (mm)		Difference in Height $\Delta h = h_1 - h_2$ (mm)	Angle (θ)= asin(h/L)
		Length h1	Height h2		
1					
2					
3					
4					
5					

Calculation: -

Bevel protector

Equipment /Materials:

- Bevel protectors.
- Work piece.
- Surface plate
- Holding devices to suit particular job



Theory: -

Main parts of bevel protractor are:
1. Fixed base blade and a circular body 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 angles accurately and precisely within 5 minutes. The protractor dial is slotted to hold a blade which can be rotated with the dial to the required angle and also independently adjusted to any desired length. The blade can be locked in any position. It is the simplest instrument for measuring the angle between two faces of component. It consists of base plate attached to the main body and an adjustable blade which is attached to a circular plate containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale engraved on the body of the instrument and can be locked in any position. It is capable of measuring from 0 to 3600. The vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus, the least count of the instrument is 5′. This instrument is commonly used in workshop for angular measurements.

Reading: -

To 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 the bevel protractor as shown in figure. Once the reading is fixed, blade clamp fixes the reading. Blades are about 150 mm long or 300 mm long, 13 mm wide and 2 mm thick. Its ends are bevelled at angles of 45ºand 60º. 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 360º. There are 12 graduations of vernier scale starting from 0 to 60ºon both sides of 0 of vernier scale.

Least count of vernier bevel protractor = $\frac{\text{Smallest division on main scale}}{\text{Total no. of division on vernier scale}}$

= 1° (equal to 60′) i.e. 60/12

= 5′ (5 minutes)

Observations: -

Least count of bevel protractor is __________ minutes.

Procedure: -

1. Note down the least count of the bevel protractor.
2. Keep the workpiece 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 center, after matching both the faces and note down the reading.
6. Repeat the experiment for different faces.

Observation Table: -

Sr. No.	Angles	Readings									Average Angle (Avg. T.R)
		1			2			3			
		M.S.R	V.S.R	T.R	M.S.R	V.S.R	T.R	M.S.R	V.S.R	T.R	
1	θ_1										
2	θ_2										
3	θ_3										

Calculation: -

Questions: -

1. List out the various instruments used for angle measurement according to their accuracy.

2. Why is it not preferable to use sine bar for measuring angle more than 45^0 ?

3. Explain the principle of sine bar.

4. Differentiate between sine bar and vernier bevel protractor in terms of accuracy.

Suggested Reference:

1) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
2) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 3

AIM: Performance on temperature measurements and check different characteristics of measurements and also do calibration

Objective:

1. To familiar with various Temperature measuring instruments.
2. To know about the temperature measuring instrument used in industries.

Relevant CO: Measure mechanical quantities like Force, Temperature, Pressure, Velocity, Acceleration, Strain and Torque.

Equipment And Materials:

Use chart, models and actual devices which are available in your laboratory. Thermo-couple is widely used for temperature measurement in furnace in industries, so it is important to know the working, its use and range of this instrument

Rationale:

(1) The principal on which temperature measuring devices works is shown below.

Sr. no	**Principal**	**Devices**
1	Principal of expansion	thermometer
2	Principal of Electrical resistance	resistance thermometer
3	Change in physical state	Bio metallic thermometer
4	Change in chemical state	thermistor
5	Change in Radiation	Pyrometer

(2) The principal on which temperature measuring devices and range of temperature.

Sr. no	**Devices**	**Range ˚ C**
1	Thermometer (1) Alcohol type (2) Mercury type (3) Perfect gas type	 35˚ C to 132˚ C -39˚ C to 404˚ C -129˚ C to 538˚ C
2	Resistance type	-240˚ C to 982˚ C
3	Thermocouple (Base metal type)	-184˚ C to 1093˚ C
4	Bimetal type	-73˚ C to 538˚ C
5	Thermistor	-101˚ C to 260˚ C
6	Radiation Pyrometer	-18˚ C to 5760˚ C

Theory:

(1) Bimetallic thermometer:

Description:

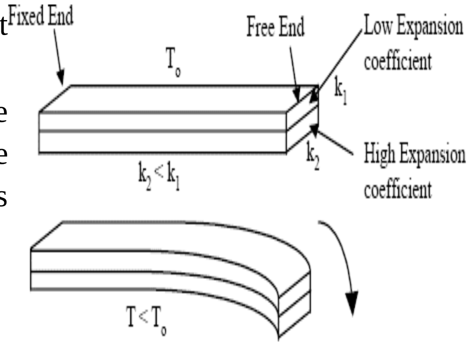
- This series of thermometers is universally suitable for Machine building, refrigeration and air- conditioning industry.
- Expansion thermometers can be installed in or mounted at nearly all locations. Versions with capillaries are used in locations which are not easily accessible and where long distances have to be bridged.

Case, capillary, stem and process connection are made from stainless steel. Various insertion lengths and process connections are available to match the requirements of each measuring location optimally.

Working Principle: -

These thermometers use the following two principles:

- All metals change in dimension, that is expand or contract when there is a change in temperature.
- The rate at which this expansion or contraction takes place depend on the temperature co-efficient of expansion of the metal and this temperature coefficient of expansion is different for different metals.



Standard Version Measuring Principle

Bourdon tube system

Nominal size in mm: 63, 100, 160 Design of connection:

(1) Plain stem (without thread)
(2) Male nut
(3) Union nut
(4) Compression fitting (sliding on stem)
(5) Union nut with fitting
(6) Compression fitting (sliding on capillary)

Working temperature range:

- Low temperature: -30°C to 220°C
- High temperature: 0°C to 550°C

Advantages:

- Simple and not easily broken
- Relatively less costly
- Easily installed & maintained
- Good accuracy relative to lab instruments.

Disadvantages:

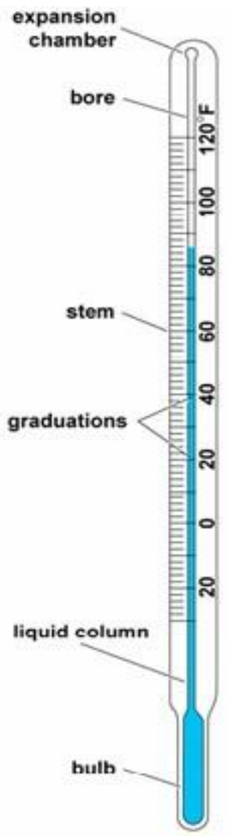
- Accuracy is not high as mercury in glass thermometer.
- It is to be mounted at the point of temperature measurement.
- Remote indication cannot be obtained.
- Possibility of calibration change due to handling.

Applications:
- General-purpose temperature measuring instruments for Gaseous, liquid and highly-viscous process media in harsh
- Working environments:- (i) Refrigeration industry & (ii) Machine building

(2). Liquid in glass thermometer

- It works based on expansion of liquid, expansion of liquid causes the liquid to rise in the tube and the rise in height of liquid is used as measure of the temperature. It consists of a glass steam having fine uniform bore capillary, after filling capillary open end of the capillary is sealed off under vacuum such that no air is left in the capillary. Sometimes the top of capillary tube having the bulb to provide safety against the breakage of thermometer.
- Fore temperature measurement the bulb of thermometer is immersed in the system whose temperature to be measured. The heat from the system is transferred to the mercury. Due to heating of mercury, it expands. Since the volumetric capacity of capillary is smaller than that of bulb, hence expansion of mercury level inside capillary. The level of mercury in the capillary indicates the temperature of calibrated scale on glass steam.

Range of glass liquid thermometer: -



Liquid	**Range (°C)**
Mercury	-35 to 510
Alcohol	-80 to 70
Pentene	-200 to 30
Toluene	-80 to 100

Advantages of liquid in glass thermometer:
- Low cost and portable as well as simple to use.
- No auxiliary power required to use.
- Less space is required.

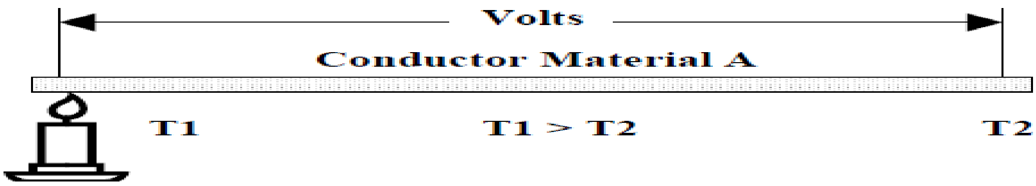
Disadvantages of liquid in glass thermometer:
- Range limited to 600.
- Difficult to read.
- Poor response against variation in temperature.
- Glass is very easy to break.
- Accuracy of temperature measurement depends upon position of thermometer and amount of immersion.
- The scale of thermometer is not exactly in linear because of expansion of glass envelope.

Application:

It is used for temperature measurement in open tank containing liquids, molten metal etc.

(3). Thermocouple:

Thermocouple is a sensing element which is sensible at temperature. For higher temp above 650˚c thermocouple is use.



Thermo electric effects: -

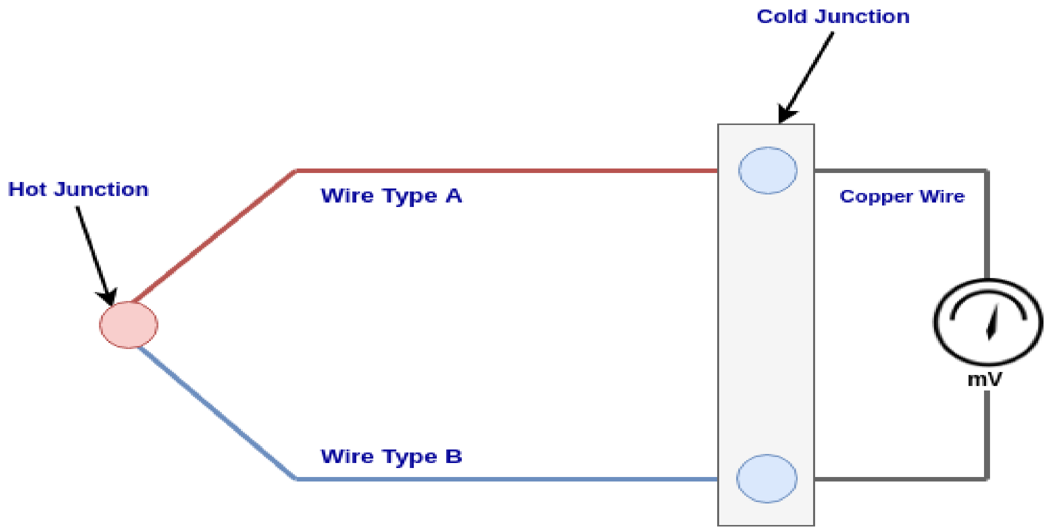
1. **See–back effect:** When the junctions of pure metals are maintained at different temperature then emf is generated. Then emf is = (α_{a}- α_{b}) ΔT.

2. **Peltier effect:** If direct current passed through a pair of dissimilar metals, there is heating at one junction and cooling at other junction, means heat absorbed or generated. So, dq=I x a x dt.

3. **Thomson effect:** If homogeneous electrical conductor is subjected to a temperature gradient then corresponding voltage gradient generated in to the conductors and current flow from cold region to hot region.

Laws of Thermo-electric circuit:-

1. **Law of Homogeneous Materials: -** It states that the thermoelectric current cannot be to exist in a circuit of a single homogeneous material by application of heat alone. In short, two different materials are required for any thermocouple circuit.

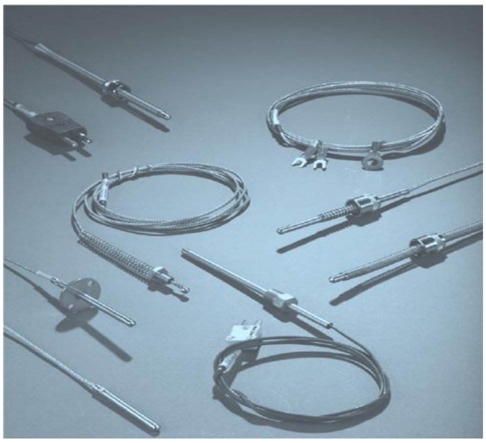


2. **Law of Intermediate temperature: -** This law is important because it allows the

calculation of a measuring junction temperature using standard calibration relations (generally developed for 0°C) when the reference temperature junction is not at 0°C.

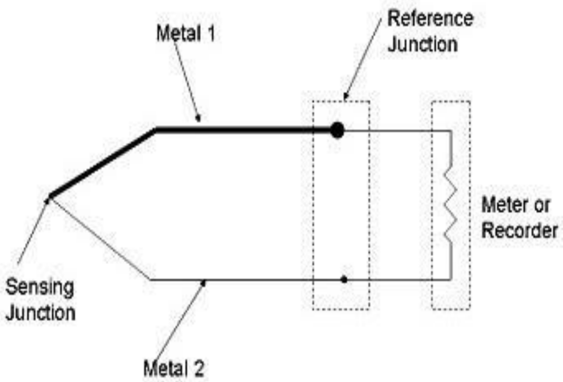
3. **Law of intermediate metals: -** The introduction of third metals the thermocouple circuit will have no effect on the emf generated as they have are at same temperature. Metals A & B junction at T1&T2 temperature. Therefore, the total emf is E1+E2.

Thermocouple construction:



1. Two metals are jointed by welding, soldering.
2. Compensating cable should be faxible.
3. Then jointed with it end to end.
4. Measurements measure the temperature with help of potentiometer. To increase the efficiency of thermocouple we connect thermopile in a series.

Applications:



1. Plastic injection molding machine
2. Chemical plants.
3. Industrial heat Control plants.
4. Medical plants.

Advantages:

1. They are comparatively cheap temperature transducers.
2. Calibration checks can be done easily.
3. Thermocouples offer good reproducibility.
4. Speed of response is high compared to filled system thermometers.

Limitations:

1. They emf-Vs-temperature characteristics may be nonlinear.
2. They require expensive accessories for many control applications.
3. In many applications, need of amplification of the signal exists.

(4). PYROMETER:

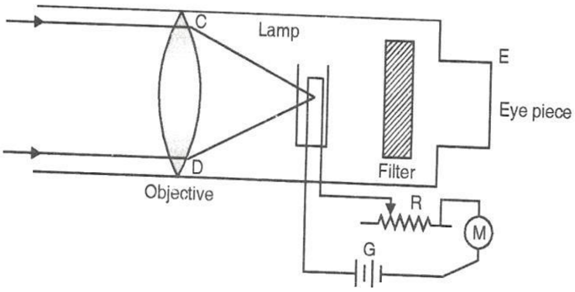
"Any instrument used for measuring high temperatures by means of the radiation emitted by a hot object" OR "A thermometer designed to measure high temperatures" OR "A device measuring the temperature of an object by means of the quantity and character of the energy which it radiates"

There are two types of pyrometers, 1. Optical pyrometer 2. Radiation pyrometer

Introduction of Optical pyrometer:

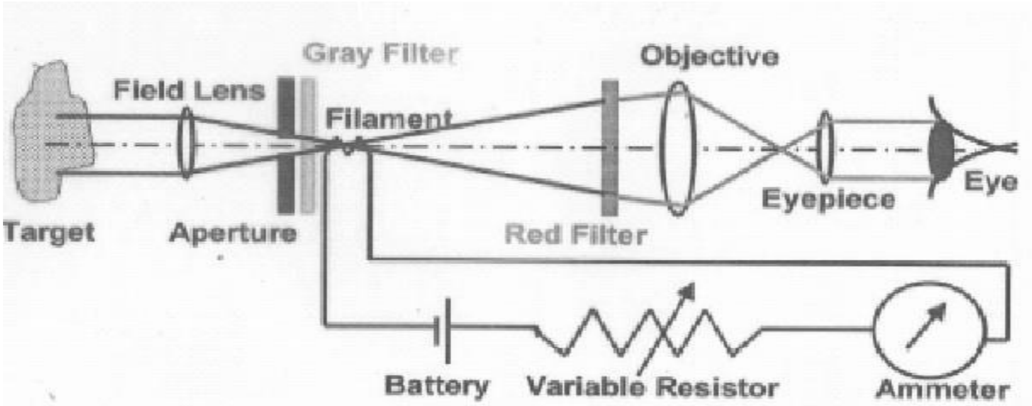
- 1892 introduced by Lechatelier, which it measured radiation from dull red to white hot-Used for measuring kiln and furnace temperature. Today an optical pyrometer is used in which the color of an electrically heated filament is matched visually to that of the emitted radiation.

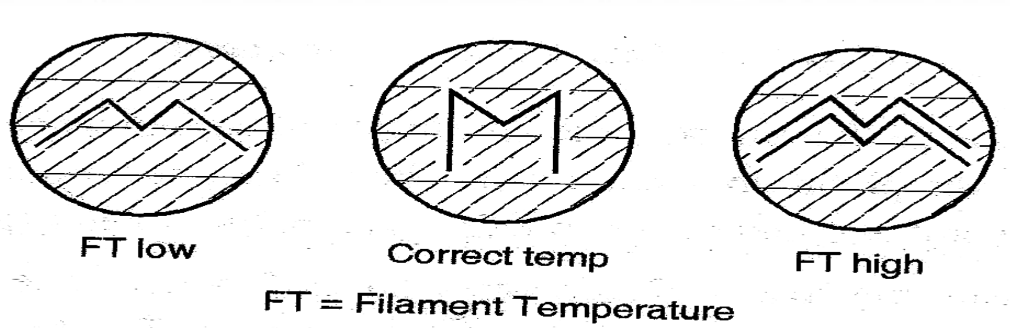
- Based on the principle of using the human eye to match the brightness of the hot object to that calibrated inside the instrument.



Construction & working:

- The radiant energy have wavelengths in the optical part of the spectrum. This fact is used in case of optical pyrometers. A single wavelength or a narrow band of wavelength or a narrow band of wavelengths is used for the measurement of temperature of a heated body.
- The radiation source is viewed through a telescope system consisting of an objective lens CD and eyepiece E as shown in fig. A. Inside telescope is a small lamp heated by battery G. The current through E is adjustable by resistant R millimeter is connected in the heating circuit. A red optical filter is interposed between the eyepiece & lamp.
- On looking through the eyepiece, the source is seen as a bright circle, square or other shape and in the Centre of it, is the image of the filament of the lamp.(See fig. B) The resistant R adjusted until the brightness of the filament is equal to that of the radiation.





- At this point the filament image appears to merge into the source image. The arrangement avoids personal error. The current through E is directly proportional to the temperature of filament. Thus on calibration millimeter, measurement of temperature is possible.
- These pyrometer are suitable for a range of 800°C to 2000°C.This range depend on

the material used for filament. Tungsten provides maximum range.

Applications:

- Moving Objects like (i) Rollers (ii) Moving Machinery (iii) Conveyer Belt Nursing Homes and Hospitals.

OBSERVATION TABLE:

Sr. No.	Object	Instrument	Reading (°C)			Avg. (°C)
			1	2	3	

CONCLUSION:

Questions

1. Write classification of temperature measuring instrument.

2. Distinguish between RTD and Thermistor.

3. Describe the principle of thermocouples.

Suggested Reference:

1) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
2) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 4

AIM: Calibration of Bourdon Tube pressure gauge

Objective:

1. To Calibrate given Bourdon Tube pressure gauge.

Relevant CO: Measure mechanical quantities like Force, Temperature, Pressure, Velocity, Acceleration, Strain and Torque.

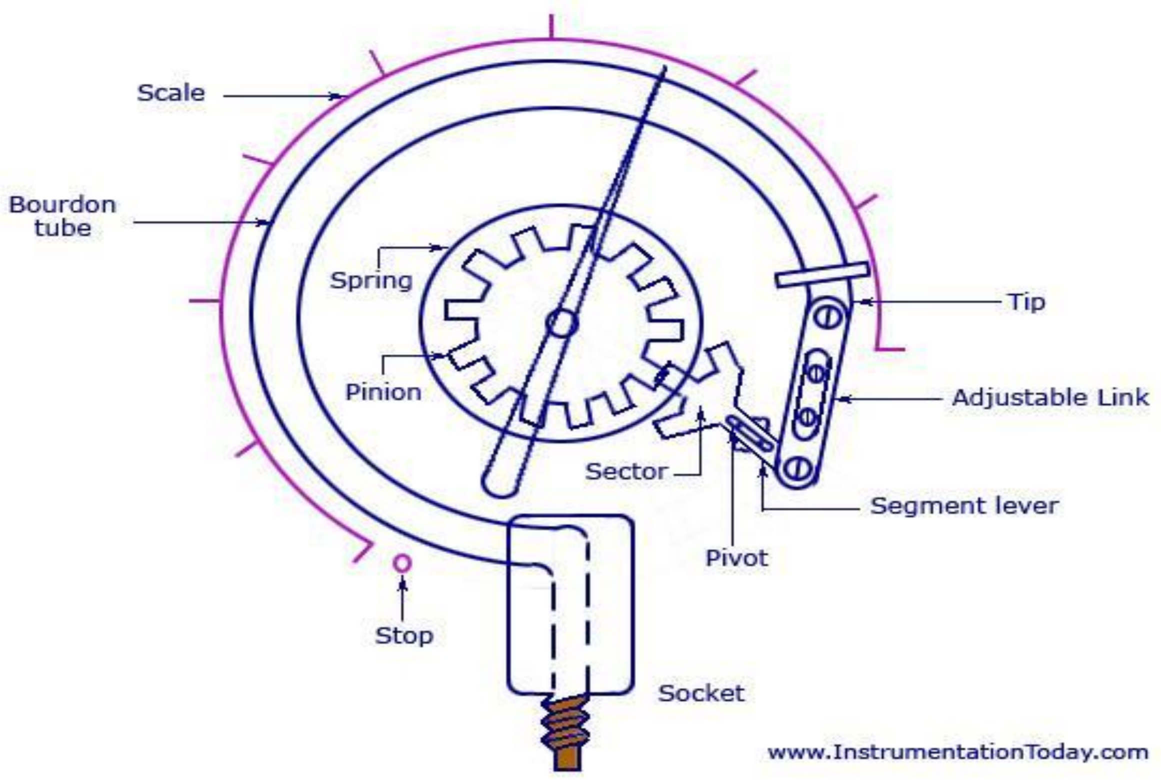
Equipment And Materials:

Bourdon tube pressure gauge, Dead weights, Pressure gauge calibration test ring.

Rationale: Bourdon Tubes are known for its very high range of differential pressure measurement in the range of almost 100,000 psi (700 MPa). It is an elastic type pressure transducer. The device was invented by Eugene Bourdon in the year 1849. The basic idea behind the device is that, cross-sectional tubing when deformed in any way will tend to regain its circular form under the action of pressure.

Theory:

The bourdon pressure gauges used today have a slight elliptical cross-section and the tube is generally bent into a C-shape or arc length of about 27 degrees. The detailed diagram of the bourdon tube is shown below.



Bourdon Tube Pressure Gauge

As seen in the figure, the pressure input is given to a socket which is soldered to the tube at the base. The other end or free end of the device is sealed by a tip. This tip is connected to a segmental lever through an adjustable length link. The lever length may also be adjustable. The segmental lever is suitably pivoted and the spindle holds the pointer as shown in the figure. A hair spring is sometimes used to fasten the spindle of the frame of the instrument to provide necessary tension for proper meshing of the gear teeth and thereby freeing the system from the backlash. Any error due to friction in the spindle bearings is known as lost motion. The mechanical construction has to be highly accurate in the case of a Bourdon Tube Gauge. If we consider a cross-section of the tube, its outer edge will have a larger surface than the inner portion. The tube walls will have a thickness between 0.01 and 0.05 inches.

The dead-weight tester is a device used for balancing a fluid pressure with a known weight. It acts as a source of static pressure. Typically, it is a device, which is used for static calibration of pressure gauges. It can also be employed for measurement of pressure. Here we will use it as a calibration device. It consists of following parts.

Needle Valves: -

There are two needle valves. One at right and at left side. Oil cup is fitted on the top of one of the valves. Pressure gauge to be tested, can be fitted to the other valve by means of adapters. Different types of adapters have been provided to fix the gauges with 3/8” , ½” BSP threading. Both the valves are connected by means of metallic adapters to the main block.

Main Block: -

Besides the above adapters main block houses floating plunger and screw pump assembly.

Screw Pump: -

Screw pump consists of main cylinder, screw and nut support. Rotation of the handle causes the screw to move into the cylinder. By operating the pump and valve, sufficient quantity of oil can be taken in. screw pump also develops sufficient pressure to lift the floating plunger.

Floating Plunger: -

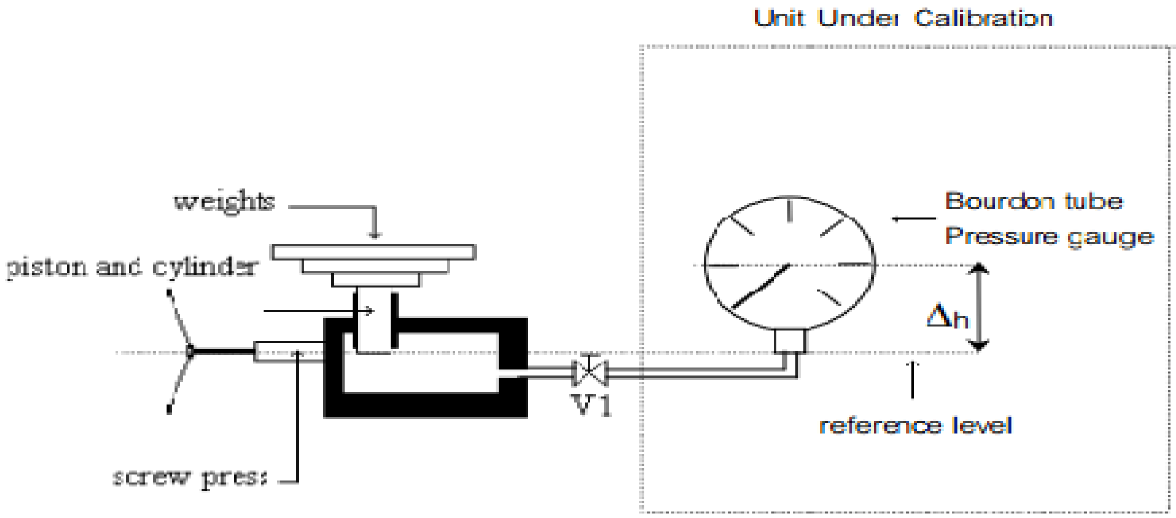
Fluid pressure developed by screw pump acts on the bottom of the plunger and the pushes the plunger up along with the weight-carrier and weights. Effect of friction is eliminated by rotating the plunger along with weights.

Set of Weights: -

Each weight is marked in terms of the pressure equivalent of its weights.

PRECAUTION: -

Floating plunger is most important part of the tester and must be limited to its travel length. If the handle is rotated continuously, the floating plunger may get damaged and locked. Hence care should be taken to limit the displacement of plunger to above value.



Schematic Diagram for practical set up of bourdon tube gauge.

PROCEDURE: -

It is essential that floating plunger is vertical during operation. This could be accomplished by leveling the top face of the weight carrier.

OIL FILLING: -

- Fix the oil to one of the valves. In fig. No. 1 it is fitted to the right-side valve.
- Open this valve and close the other valve.
- Fill clean HYDRAULIC MINERAL OIL to nearly top of the oil cup. SAE NO. 20 or 30 are suitable. It is necessary that oil is clean.
- Turn the screw pump handle clockwise. This will expel some air from the system which will bubble out in the oil cup.
- Turn the pump handle anticlockwise. Oil will be sucked into the instrument.
- Repeat this clockwise and anticlockwise turning, until no air bubble appears in the oil cup.
- Open the other valve and rotate the screw pump handle for oil to come out of this valve.
- Close this valve and draw more oil in the instrument.

PRESSURE GAUGE TESTER: -

- Ensure that air has been expelled from the system as per the oil filling procedure given above.
- Place a spirit level on top of the weight carrier and adjust level by means of the leveling screws in the standard way. The tester is now ready for use.
- Installation pressure gauge to be tested as shown in the illustration. Use an adapter if necessary.
- Open valve under the pressure gauge (i.e. left valve) and close valve under the oil cup (i.e. right valve).
- Place a weight on the weight-carrier and slowly turn the screw pump clockwise. This increases the pressure in the system which will be shown on the pressure gauge.
- Rotate the weight to reduce the effect of the friction in the free piston. Keep turning the handle until the weight carrier and weights rise by about 3 to 4mm. If the weight-carrier is

lifted beyond the above limit, the piston is exposed and may suffer damage.

- Take reading of the pressure gauge while the weights are rotating. Write it down against the value of pressure which is the sum of pressure markings on the weights and weight-carrier.
- Progressively add weights and take reading as above.
- When the maximum reading has been taken reduce the pressure by turning the handle anticlockwise and reducing the weights progressively.
- Consider the average of the value for increasing and decreasing pressures.
- In case two pressure gauge are desired to be tested simultaneously, the oil cup may be removed and second gauge installed, on the other valve.
- The valve under the gauge should also be opened.

NOTE: - Care should be taken while operating the instrument that the weight carrier dose not rise too much as otherwise the free piston may be damaged.

CLOSING UP: -

- After the work is over, turn screw pump handle anticlockwise so that- There is no pressure in the system and
- Maximum oil is drawn in.
- Reinstall the oil cup if it had been removed and open the valve under it. This will ensure that (a) there is no residual pressure in the system and (b) prevent pressure build-up by accidental turning of the screw pump handle.
- Place dust cover on the instrument and stack weights properly.

OBSERVATION TABLE

Sr.No.	Pressure Applied (kgf/cm^2) p_a	Pressure Indicated (kgf/cm^2) p_i	Error (kgf/cm^2) $E_p = p_i - p_a$
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

GRAPH: -
Applied Pressure vs. Indicated Pressure.

CONCLUSION: -

Questions

1. What is Bourdon Pressure gauge?

2. How does Bourdon pressure gauge work? Explain with necessary diagram.?

3. What are the advantages and disadvantages of using Bourdon pressure gauge?

Suggested Reference:

3) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
4) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 5

AIM: Calibration of LVDT & Strain gauge.

Objective:

1. To calibrate a L.V.D.T. for displacement measurement & Strain gauge.

Relevant CO: Measure mechanical quantities like Force, Temperature, Pressure, Velocity, Acceleration, Strain and Torque.

Equipment And Materials:

LVDT & Strain gauge.

PART- 1 To calibrate a L.V.D.T. for displacement measurement.

Rationale:

One of the most useful variable inductance transducers is the differential transformer, which provides an A.C. voltage output proportional to the displacement of core passing through the windings. It is a mutual inductance device making use of three coils arranged generally on a single

Theory:

LVDT:

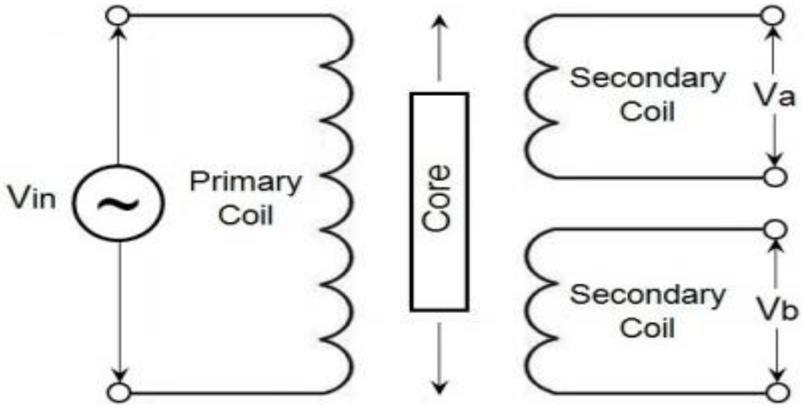
cylindrical concentric nonmagnetic form. The center coil is energized from an external power source and the two coils connected in series oppositions to each other, are used as pick up coils. Output amplitude and phase depend on the relative coupling between the two pick up coils and the power coil. Relative coupling in them is dependent on the position of the core. Theoretically there should be core position for which the voltage induced in each of the pickup coil or secondaries will of the same magnitude and the resulting output should be zero.

Within limits on the either side of the position (Null) core displacement results in a proportional output. While the output voltage magnitudes are ideally the same for equal core displacement results on either side of null balance, but phase relation existing between power source and output changes 180 degrees through null. It is therefore possible through phase sensitive detector to distinguish between outputs resulting from displacements on each side of null.

L.V.D.T. is a very widely used transducer for conversion of mechanical displacement into proportional electrical voltage. The displacement into proportional electrical voltage range extends for new microns to few tens of inches. It is free from temp. effects.

Principles of operation: When the primary coil is excited with a sine wave voltage (Vin), this voltage produces a current in the LVDT primary windings, function of the input impedance. In turn, this variable current generates a variable magnetic flux which, channeled by the high-permeability ferromagnetic core, induces the secondary sine wave voltages Va and Vb. While the secondary windings are designed so that the amplitude of the differential output voltage (Va-Vb) is proportional to the core position, the phase of (VaVb) with reference to the excitation, called

Phase Shift (close to 0 or 180 degrees) determines the direction away from the zero position. The zero, called Null Position, is defined as the core position where the phase shift of the (Va-Vb) differential output is 90 degrees.



Schematic Diagram of L.V.D.T.

The differential output between the two secondary outputs (Va-Vb) when the core is at null position is called the Null Voltage; as the phase shift at null position is 90 degrees, the null voltage is a “quadrature” voltage. This residual voltage is low. It is due to the complex nature of the LVDT electrical model, which includes the parasitic capacitances of the windings. This complexity also explains why the phase shift of (Va-Vb) is not exactly 0 or 180 degrees when the core is away from the null position. The phase shift is very important as most signal conditioning electronics employ synchronous demodulation to provide a DC output that is proportional to the following transfer function: RMS voltage (Va-Vb) multiplied by the cosine of phase shift. This is the best way to provide an accurate and linear (especially around the null) position signal in a measuring system using an LVDT. It is also the method that allows the minimum numbers of electrical connections to the LVDT, as only 4 are needed (2 for the excitation and 2 for the differential output; the secondary windings being connected in series opposing at the LVDT). One drawback of this technique is that the phase shift has to be low enough to avoid affecting the noise level in the demodulator, and to prevent a too large signal drop (due to the cosine in the transfer function). To avoid these adverse effects, MEAS offers instrumentation that includes phase compensation electronic circuitry to bring the phase shift back to zero (or 180 degrees). In some cases it is beneficial to use the secondary sum, (Va+Vb) as the reference for the phase shift of (Va-Vb). However, one must ensure that the LVDT is designed with windings that provide a fairly constant sum along the stroke to be measured. The advantage of this method is that the phase shift between the differential and the sum is very low and therefore there is no need to adjust it. However, only 5 or 6 wire LVDTs must be used

PRECAUTIONS: -

1. While connecting lead wire from panel to transducer, make proper connections. Avoid shorting of the excitation source terminals.
2. Move the core with a gentle fashion.

PROCEDURE: -

- Connect the terminals marked 'PRIMARY', on the front panel of the instrument to the terminals marked 'PRIMARY', on the transducer itself, with the help of the flexible wires provided.
- Identically establish connection from terminals "SECONDARY".
- Keep pot marked "MAX" in most anticlockwise position.
- The magnetic core may be displaced and the pointer may be brought to zero position. If the DPM is not indicating zero use potentiometer marked "MIN", to get a zero on DPM at zero mechanical position. If the core is displaced in both directions, the meter must show indications with appropriate polarity. Now displace the core to 19mm position in one of the directions. Adjust the 'MAX', pot to get an indication of 19.00 on the DPM under these conditions. Now the set up is ready for experimentation. You may again check for zero position also.
- Now the core can be displaced by a known amount in the range +19 and –19mm and the meter readings can be entered in the table given below. It may be noted that by interchanging the secondary terminals or the primary terminals the polarity of the meter indication can be reserved for a given direction of input displacement.
- Plot the graph of input displacement and the output indications on the X and Y axis respectively.

OBSERVATION TABLE: -

Sr. No.	Input Displacement (mm)	Output Indication (mm)
1		
2		
3		
4		
5		
6		
7		
8		
9		

CONCLUSION: -

Questions

1. Explain with suitable waveforms, working of LVDT

2. Explain how LVDT can be used with DC supply to measure displacement.

3. Explain the concept of Residual voltage and its effect on measurement.

4. What are the limitations of LVDT

5. What Phase sensitive detector (PSD) is necessary of at the output side of LVDT?

PART-2 To calibrate a Strain Gauge.

OBJECTIVE: - To calibrate a Strain Gauge Sensor.

INTRODUCTION:-

Electrical resistance of a piece of wire is directly proportional to the length and inversely to the area of the cross section. Resistance strain gage is based on that phenomenon (see Sec.11.3 Resistance Strain Gauges, Text p.488-494 or similar reference). If a resistance strain gage is properly attached onto the surface of a structure which strain is to be measured, the strain gage wire/film will also elongate or contract with the structure, and as mentioned above, due to change in length and/or cross section, the resistance of the strain gage changes accordingly. This change of resistance is measured using a strain indicator (with the Wheatstone bridge circuitry), and the strain is displayed by properly converting the change in resistance to strain. Every strain gage, by design, has a sensitivity factor called the gage factor which correlates strain and resistance as follows:

Gage factor (F) = (D R / R)/ e

Where: R = Resistance of un-deformed strain gage

D R = Change in resistance of strain gage due to strain

e = Strain

As specified by the manufacturer of strain indicator, we set the initial gage factor (as 2.005 for example) and take the measurements. In our experiment, we will also assume that we do not know the gage factor of the strain gage in order to calibrate it. We may do so by calculating the theoretical strain using the appropriate formula and adjust the gage factor setting so that we get the theoretical strain value on the display of the indicator. The set gage factor for which the display coincides with the theoretical strain is the calibrated gage factor of our strain gage as applied on a particular structure (a beam in our case).

Procedure:

1. Attach the strain gage to the bar (beam) surface using five basic steps: i.e. degreasing, surface abrading, burnishing, conditioning and neutralizing.
2. Set the specimen bar (beam) to the bar holder so that the bar acts as a cantilever beam. Measure the span (L), breadth (b) and thickness (t, see NOTE 1) of the bar.
3. Balance the instrument by moving the ten turn pot in gentle fashion and then come down to most sensitive range.
4. Additional pots are provided to get the finer balance.
5. Now apply a gentle pressure by a weight on the cantilever beam. The digital indication will show some change in value. If upward force is applied the meter pointer shall show opposite deflection.

PRECAUTION: -

a. Make connections to the binding posts & terminals very carefully.

b. Ensure that the cantilever arrangement is securely fixed to the table.

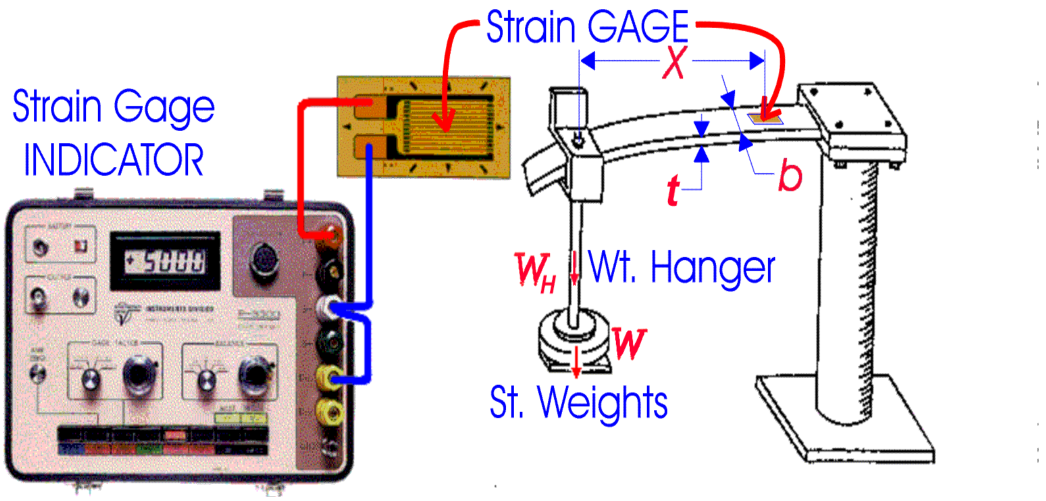


Figure: - Cantilever strain gauge arrangement

After doing the experiment one can check-up the meter output with the help of following formula:-

$$E\ Out = \frac{Exc.\ X\ \Delta R}{R}$$

$$\frac{\Delta R}{R} = \text{Gauge factor x Strain}$$

$$= 1.9 \text{ x Strain}$$

$$\text{Strain} = \frac{\text{Stress}}{2 \times 10^6}$$ (Modulus of Elasticity = 2 x 106 Kg/cm2) for mild-steel.

$$\text{Stress} = f = \frac{M}{Z}$$ Where z = Moment of Cross Section

Z = 1/6 bt2 (b = width of cantilever & t = thickness of beam)

M = Length x Applied Load.

OBSERVATION TABLE:-

- G.F. = Gauge factor = 1.9
- Rg = 350 Ω
- L=Length of cantilever = 17.5 cm
- b= Width of cantilever = 2.42 cm
- t= Thickness of cant. = .4555 cm
- Exc= Excitation source voltage = 5 Volts
- Y= Young modulus of elasticity = 2 x 106 Kgf/cm2

OBSERVATION TABLE for strain gauge Measurement

Sr. No.	Output of Bridge $(E_{out})_{gauge}$, m	Applied Moment M, Kgf-cm	Stress f = m/z Kgf / cm^2	Strain = $\frac{f}{y}$	$\frac{\Delta R}{R}$	$(E_{out})_{th}$ mV

	Full Bridge				= G.F. X strain	Full Bridge
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

SAMPLE CALCULATION; -

Z = 1/6 bt^2 = , cm^3

M = Length (cm) x Applied load (kgf) = Kgf-cm

Stress = f = $\frac{M}{Z}$ = , Kgf/cm^2

Strain = $\frac{Stress}{Y}$ =

$\frac{\Delta R}{R}$ = Gauge factor x strain

$(E_{out})_{th}$ = Exc X $\frac{\Delta R}{R}$ (for full bridge or 4 arm bridge)

= $\frac{Exc}{2}$ X $\frac{\Delta R}{R}$ (for half bridge or 2 arm bridge)

GRAPH:-

$(E_{out})_{gauge}$ vs $(E_{out})_{th}$ full bridge

CONCLUSION: -

Questions

1. What is the strain gauge?

2. Explain principle of working of strain gauge.

3. What are the materials used for strain gauge.

4. Application of strain gauge.

Suggested Reference:

1) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
2) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 6

AIM: Performance on Speed/Velocity, acceleration measurements.

Objective:

2. To familiar with various velocity as well as acceleration measuring instruments.
3. To know about the working of instruments such as Tachometer and accelerometers.

Relevant CO: Measure mechanical quantities like Force, Temperature, Pressure, Velocity, Acceleration, Strain and Torque.

Equipment And Materials:

Measuring instruments that will give the calculation of velocity/speed and acceleration. Instruments needed are various tachometers and accelerometers.

Rationale:

(1) **Classification of tachometers:**

Mechanical tachometer
Electrical tachometer
Contactless electrical tachometers

(2) **Classification of Accelerometers:**

Piezo-electric type
Seismic type
Strain gauge accelerometer

Theory:

Tachometer

A **tachometer** (revolution-counter, tach, rev-counter, RPM gauge) is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common

Mechanical type of tachometer is nothing but a linkage of shafts, gears and rotating weights. When the input shaft which is seen horizontal rotates the vertical shaft it also rotates the weights attached to it which are hinged and free to move inward and outwards. The movement of these flyweights rotates a pointer which is calibrated to give the speed in desired units such as RPM.

Two main drawbacks of this are that the mechanical weights have inertia and hence not very accurate and secondly it does not give an indication of the direction of rotation.

Fig: Digital tachometer **Fig: Mechanical tachometer**

Accelerometers

An accelerometer measures proper acceleration, which is the acceleration it experiences relative to freefall and is the acceleration felt by people and objects.

Conceptually, an accelerometer behaves as a damped mass on a spring. When the accelerometer experiences an acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration.

Piezoelectric accelerometers rely on piezo ceramics or single crystals. Piezo resistive accelerometers are preferred in high shock applications. Capacitive accelerometers typically use a silicon micro-machined sensing element. Their performance is superior in the low frequency range and they can be operated in servo mode to achieve high stability and linearity.

Fig: Accelerometer

Accelerometers can be used to measure vehicle acceleration. Accelerometers can be used to measure vibration on cars, machines, buildings, process control systems and safety installations. They can also be used to measure seismic activity, inclination, machine vibration, dynamic distance and speed with or without the influence of gravity

Stroboscope: -

A stroboscope, also known as a strobe, is an instrument used to make a cyclically moving object appear to be slow moving, or stationary. The principle is used for the study of rotating, reciprocating, oscillating or vibrating objects. Machine parts and vibrating strings are common examples.

A Stroboscopic light source provides high intensity flashes of light, which can be caused to occur at a precise frequency. When this light source is made to fall on an object with periodic motion then it appears that the motion is slowed down or stopped when both frequencies bear a definite relationship. Stroboscopes use this effect for measurement of rotational speed.

Types of stroboscopes

Mechanical

In its simplest mechanical form, a rotating cylinder (or bowl with a raised edge) with evenly spaced holes or slots placed in the line of sight between the observer and the moving object. The observer looks through the holes/slots on the near and far side at the same time, with the slots/holes moving in opposite directions. When the holes/slots are aligned on opposite sides, the object is visible to the observer.

Alternately, a single moving hole or slot can be used with a fixed/stationary hole or slot. The stationary hole or slot limits the light to a single viewing path and reduces glare from light passing through other parts of the moving hole/slot. Viewing through a single line of holes/slots does not work, since the holes/slots appear to just sweep across the object without a strobe effect.

The rotational speed is adjusted so that it becomes synchronized with the movement of the observed system, which seems to slow and stop. The illusion is caused by temporal aliasing, commonly known as the stroboscopic effect.

Fig. Stroboscope

In electronic versions, the perforated disc is replaced by a lamp capable of emitting brief and rapid flashes of light. Typically, a gas-discharge or solid-state lamp is used, because they are capable of emitting light nearly instantly when power is applied, and extinguishing just as fast when the power is removed.

By comparison, incandescent lamps have a brief warm-up when energized, followed by a cool-down period when power is removed. These delays result in smearing and blurring of detail of objects partially illuminated during the warm-up and cool-down periods.

The frequency of the flash is adjusted so that it is an equal to, or a unit fraction of the object's cyclic speed, at which point the object is seen to be either stationary or moving slowly backward or forward, depending on the flash frequency.

Neon lamps or light emitting diodes are commonly used for low-intensity strobe applications, Neon lamps were more common before the development of solid-state electronics, but are being replaced by LEDs in most low-intensity strobe applications.

Xenon flash lamps are used for medium- and high-intensity strobe applications. Sufficiently rapid or bright flashing may require active cooling such as forced-air or water-cooling to prevent the xenon flash lamp from melting.

Application:

Stroboscopes play an important role in the study of stresses on machinery in motion, and in many other forms of research. They are also used as measuring instruments for determining cyclic speed.

Medicine: In medicine, stroboscopes are used to view the vocal cords for diagnosis of conditions that have produced dysphonic (hoarseness). The patient hums or speaks into a microphone, which in turn activates the stroboscope at either the same or a slightly different frequency. The light source and a camera are positioned by endoscopy.

Observation table:

Sr. No.	**Object**	**Instrument**	**Reading (rpm)**			**Avg. (rpm)**
			1	**2**	**3**	

CONCLUSION:

Questions

1. List out speed measurement devices.

2. What is tachometer, list out its application?

3. Explain working of Stroboscope.

Suggested Reference:

3) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
4) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 7

AIM: To Study of surface roughness measuring instruments.

Objective:

1. To know about the surface measurement instrument.

Relevant CO: Apply concepts of metrology for gears, threads and surface finish.

Equipment:
Surface roughness tester.

Theory: -

Elements of Surface Roughness:

Roughness:
Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered the high frequency, short wavelength component of a measured surface.
Roughness height:
It is defined as the arithmetical average deviation expressed in micrometers normal to an imaginary centerline, running through the roughness profile.
Roughness width:
The distance parallel to the nominal surface between successive peaks or ridges which constitute the predominant pattern of the roughness.
Roughness-width cutoff:
The maximum width of surface irregularities that is included in the measurement of average roughness height. Roughness-width cutoff is rated in inches. Roughness-width cutoff must always be greater than the roughness width in order to obtain the total roughness height rating. Standard tables list roughness-width cutoff values of 0.003, 0.010.
Waviness:
Waviness is the measure of the more widely spaced component of surface texture. It is a broader view of roughness because it is more strictly defined as "the irregularities whose spacing is greater than the roughness “sampling length".
Lay:
It is the direction of predominant surface pattern produced by tool marks or scratches. It is determined by the method of production used.
Flaws:
They are Irregularities, which occur at one place or at relatively infrequent or widely varying intervals in a surface
The factors affecting surface roughness are:

- Type of coolant used.

- Cutting parameters such as feed, speed and depth of cut.
- Type of machining.
- Rigidity of the system, consisting of machine tool, fixture, cutting tool and work.
- Vibrations.
- Material of tool and work piece.

The surface roughness has been experienced and understood by the sense of light and touch. Any material being machined by conventional machining process cannot be finished perfectly.

The surface generated will have some irregularities and these geometrical irregularities could be classified as follows.

(i) **First order:** It includes the irregularities developed due to the inaccuracies in the machine tool such as lack of straightness of guide ways, on which tool post is moving.

(ii) **Second order:** It includes the irregularities developed due to the vibrations and rigidity of the machine tools.

(iii) **Third order:** It includes the irregularities developed due to the cutting parameters such as cutting speed, feed and depth of cut.

(iv) **Fourth order:** It includes the irregularities developed due to the rupture of the material during the separation of the chip from the already finished surface of the work piece.

Methods of Measuring Surface Finish:

There are two methods used for measuring the finish of machined part:

1. Surface Inspection by Comparison Methods.
2. Direct Instrument Measurements.

In comparative methods, the surface texture is assessed by observation of the surface. However, these methods are not reliable as they can be misleading if comparison is not made with surfaces produced by same techniques.

The various methods available under comparison methods are:

(i) Touch Inspection & Visual inspection.
(ii) Scratch Inspection.
(iii) Microscopic Inspection.
(iv) Surface Photographs.

Direct Instrument Measurements:

These methods enable to determine a numerical value of the surface finish of any surface.

(i) Tomlinson Meter
(ii) Taly-surf Meter

Conventional method for designing surface finish:

As per TS-696, surface texture specified by indicating the following main characteristics in the symbols.

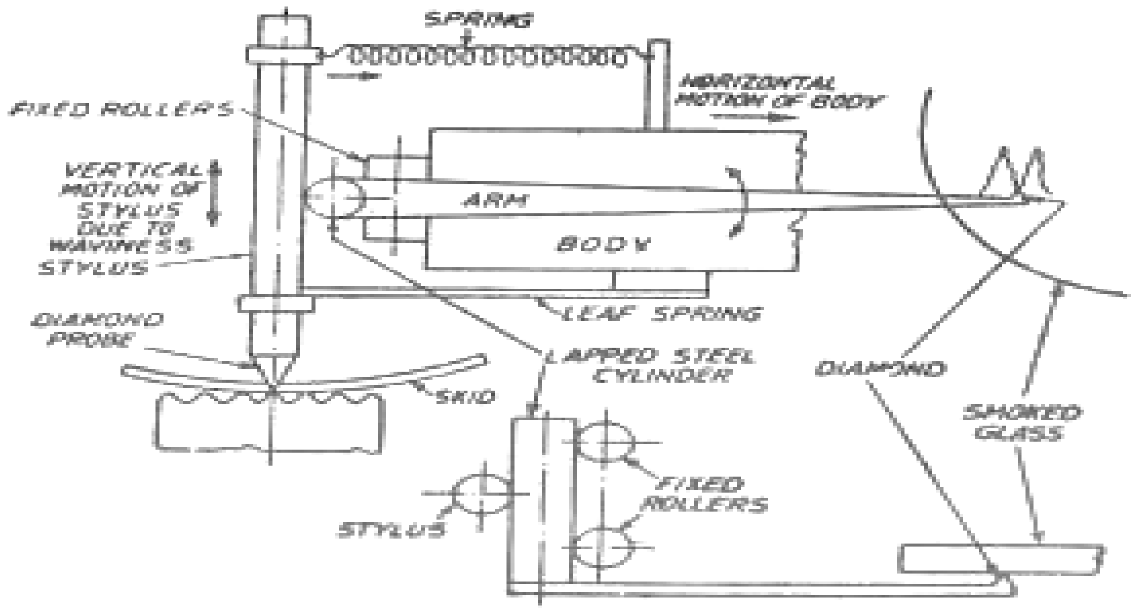
a) Roughness value i.e. Ra value in µm.
b) Machining allowance in mm.
c) Sampling length or instrument cut-off length in mm.
d) Machining/production method, and
e) Direction of lay in the symbol form as (//, ⊥, ×, M, C, R.)

For example, a milled surface with 1.2 mm machining allowance having Ra value 6.3 µm, with cut-off length 2.5 mm and direction of lay parallel will be represented.

The Tomlinson Surface Meter:

Inventor: Dr. Thomas Tomlinson In 1999

Principal: “The stylus movement is restricted in vertical direction only with the help of coil and leaf spring. The variation in the surface is sensed by probe and is magnified on a smoked glass.”



Construction:

The diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped steel cylinder. The stylus is also attached to the body of the instrument by a leaf spring and its height is adjustable to enable the diamond to be positioned conveniently. The lapped cylinder is supported on one side by the stylus and on the other side by two fixed rollers as shown in Fig. The stylus is restrained from all motion except the vertical one by the tensions in coil and leaf spring. The tensile forces in these two springs also keep the lapped steel cylinder in position between the stylus and it carries at its tip a diamond scriber, which bears against a smoked glass.

Working:

When measuring surface finish, body is traversed across the surface by a screw rotated by a synchronous motor. Any vertical movement of the stylus caused by the surface irregularities causes the magnified movement on a smoked glass plate. This vertical movement coupled with the horizontal in horizontal direction. The smoked glass trace is then, further projected at × 50 or × 100 magnifications for examination by an optical projector. This instrument is comparatively cheap one and gives reliable results.

Advantages:

- It is simple.
- It has low cost.
- It gives reliable results.

Disadvantages:

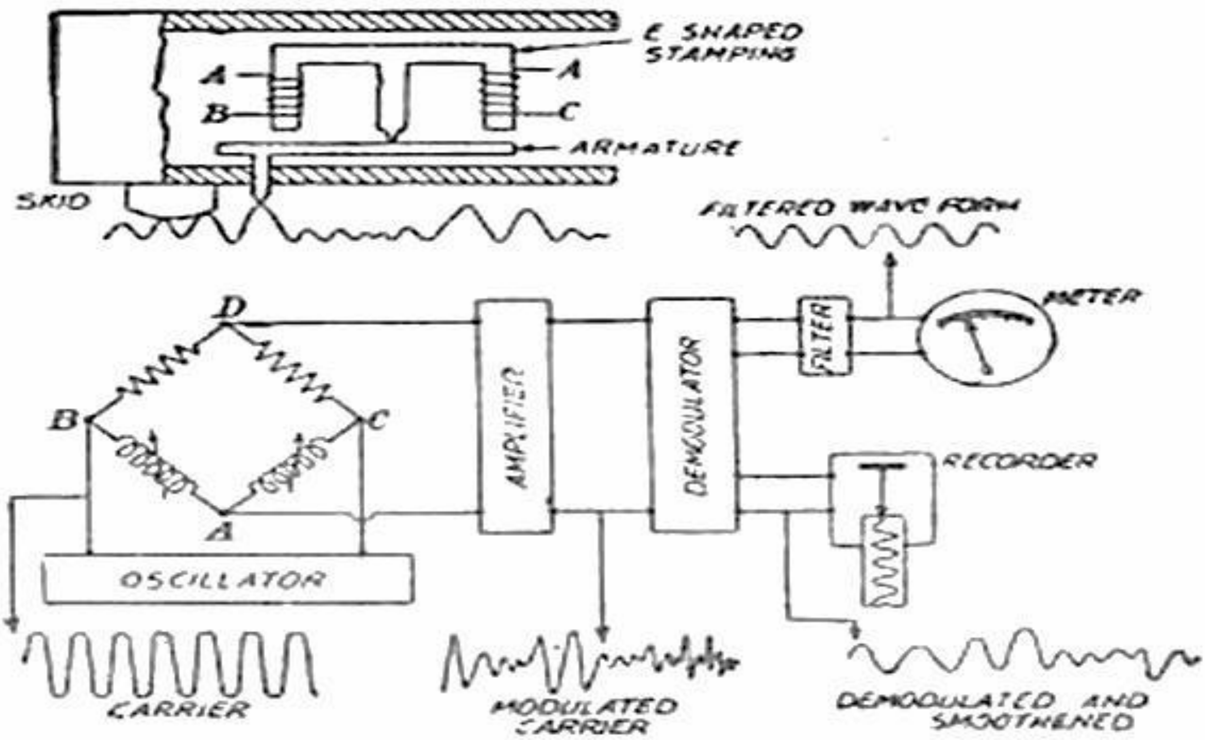
- It is delicate and requires great care.
- It is slow in operation.
- It is not suitable for rapid and continues use on the shop floor.

The Taylor-Hobson Taly-surf meter

Taylor-Hobson Taly-surf is a stylus and skid type of instrument working on carrier modulating principle.

Principle: It working on the carrier modulating & the variation in the surface profile is sensed by the probe, which is attached to the armature.

Its response is more rapid and accurate as compare to Tomlinson is more rapid and accurate as compared to Tomlinson surface meter.



Schematic layout of Taly-surf meter

Construction:

The measuring head of this instrument consists of a sharply pointed diamond stylus of about 0.002 mm tip radius and skid or shoe, which is drawn across the surface by means of a motorized driving unit. In this instrument, the stylus is made to trace the profile of the surface irregularities and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as in figure.

The arm carrying the stylus forms an armature, which pivots about the centerpiece of E-shaped stamping on two legs the E-shaped stamping there are coils carrying an AC current. These two coils with two resistances from an oscillator. As the armature is pivoted about the central leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original AC current flowing in the coils is modulated.

Working:

A downward movement of the stylus results in decreasing the air gap at the secondary coil. Thus, the amplitude of the original A.C. current flowing in the coils is modulated. The output of the bridge thus consists of modulation only as shown in fig. This is further demodulated so that the current is now directly proportional to the vertical displacement of the stylus only. The demodulated output is caused to operate a pen recorder to produce a permanent record & the meter to give a numerical assessment directly.

Application:

The talysurf meter can be used to measure etch depths, deposited film thickness and surface roughness.





CONCLUSION:

Questions

1. Define term: (i) Primary texture, (ii) Secondary texture.

2. Define the following elements of surface texture: (i) Roughness (ii) Flaws (iii) Lay (iv) Waviness (iv) mean line profile (vi) Sampling length.

3. Define the following with reference to surface texture: (i) Peak to valley height, (ii) C.L.A (iii) R.M.S

Suggested Reference:

1) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
2) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Date: -

Experiment No: 8

AIM: Performance on measurements of gears and screw threads.

Objective:

1. To measure the dimensions of a gear tooth using gear tooth Vernier caliper
2. To measure the dimensions of a threads using screw thread micrometer caliper
3. To get module m by base tangent methods & other parameter such as Pitch circle dia., addendum circle diameter, dedendum circle dia., depth of tooth.

Relevant CO: Apply concepts of metrology for gears, threads and surface finish.

Equipment And Materials:

Spur gear, gear tooth Vernier caliper, flange micrometer, Micrometer, three wire set box

Theory:

Measurement of Screw Threads.

Three wire method: it is the most accurate method for checking the pitch diameter. This method consists of placing three small diameter cylinders (three wires of equal and precise diameter) in the thread grooves at opposite sides of screw and measuring the distance W over the outer surfaces of the wires with an ordinary outside micrometer having flat measuring faces on the micrometer. The pitch or effective diameter is calculated from the value W in the following manner

W =P + 2AC + 2 x (d/2) ------------- (1)

Where P= pitch or effective diameter

D = wire size

Now AC = AD- CD

= (d/2) cosec (α/2) – (p/4) cot (α/2)

Where α= thread angle

P = pitch of threads

After simplification,

W = P + d (1+ cosec α/2) – p/2 cot α/2 ------- (2)

In the case of I.SO. Metric threads, α = 60°

W = P + 3d – 0.866p

P = W – 3d + 0.866p ------- (3)

Here the pitch diameter lines 0.328P inside the crest of the thread that is,

P = D – 0.6496p --------- (4)

Where D = outside diameter, from equations (3) and (4) it is

D = W – 3d + 1.5156p -------- (5)

Where d = wire diameter in mm

P =thread pitch in mm

W = distance over wire in mm.

WIRE SIZE:

Wire of any diameter can be used to measure the pitch diameter, provided it makes contact on the true flank of the thread and provided the thread angle is correct. A wire of best size is the one that makes contact with the help of any wire touching the true flank of the thread will differ from that obtained by using a wire of best size if any there is an error in the angle or from of the thread. In the case of best size wire of best size wire, the point B at which the wire touches the flank of the thread lies on the pitch line, that is , BC lies on the pitch line and that AB is perpendicular to the flank position of the thread. If there is a possibility of the thread angle being Incorrect, the wire of best size should be used to determine effective diameter, science such wires will be independent of any error in thread angles.

Now BC=p/4

From triangle ABC, AB = d/2 =BC sec α/2 =p/4 sec α/2

Best wire size, d= p/2 sec α/2

For I.S.O. metric tread,

d = p/2 sec 30 = 0.5774p

Procedure:

1. Measure the outside diameter of the given thread component by means of outside micrometre, which is equal to major diameter.
2. Measure the pitch of the given threaded component by using the pitch gauge.
3. Measure the root diameter of the component by using a vernier calliper, which is equal to minor diameter.
4. To find the pitch or effective diameter, keep the three wires made of hardened steel between the flanks of the thread as shown in fig.
5. Take the diameter over the wires with the help of outside micrometre, which is held with micrometre holder on the anvil and spindle of the micrometre. Now calculate the pitch or effective diameter as per the formula explained in the theory.

OBSERVATIONS AND CALCULATIONS:

THREE WIRE METHOD:

1. the major diameter (D1) = _____________
2. the minor diameter (D2) = _____________
3. pitch (p) =____________
4. pitch of effective diameter (P) = __________

P=W-d (1+ cosec α/2) +p/2 cot α/2

Where,

W= Distance over the three wires

d= diameter of wire = 1.10mm.

p= pitch of thread

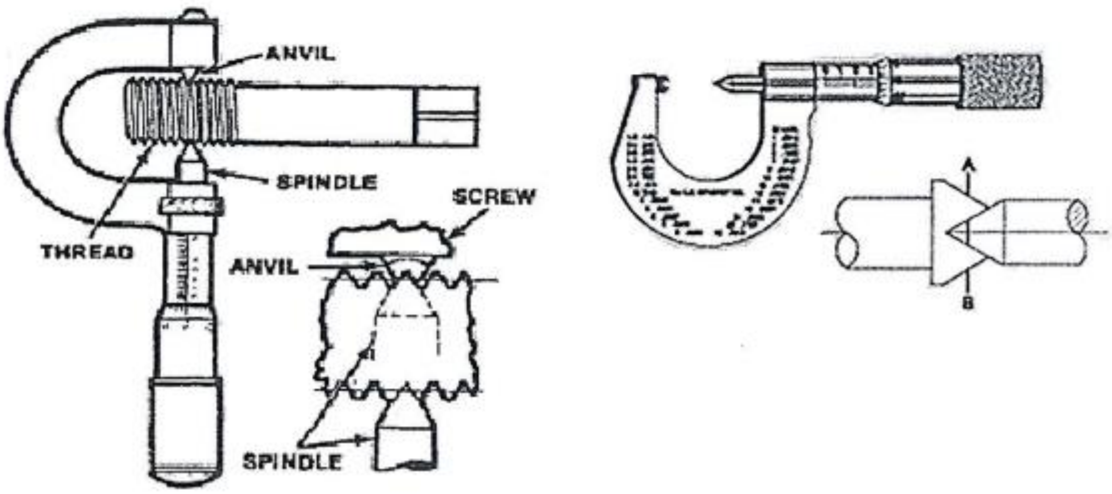
α = thread angle = 60

RESULT:

1. the major diameter (D1) = ___________
2. the minor diameter (D2) = ___________

3. pitch (p) = __________

4. pitch of effective diameter (P) = __________



Screw thread micrometer

Cross verified by using thread micrometer

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

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

CONCLUSION:

Questions

1. What is pitch?

2. What is major diameter?

3. What is minor diameter?

4. What is root and crest?

5. Give classification of screw threads.

6. List the various types of pitch errors

Measurements of gears threads

Gear tooth vernier calliper: Range a) vertical beam: 0-80 mm
b) Horizontal beam: 0-100 mm
Least count: 0.02 mm

WORKING PRINCIPLE
GEAR TOOTH VERNIER CALIPER:

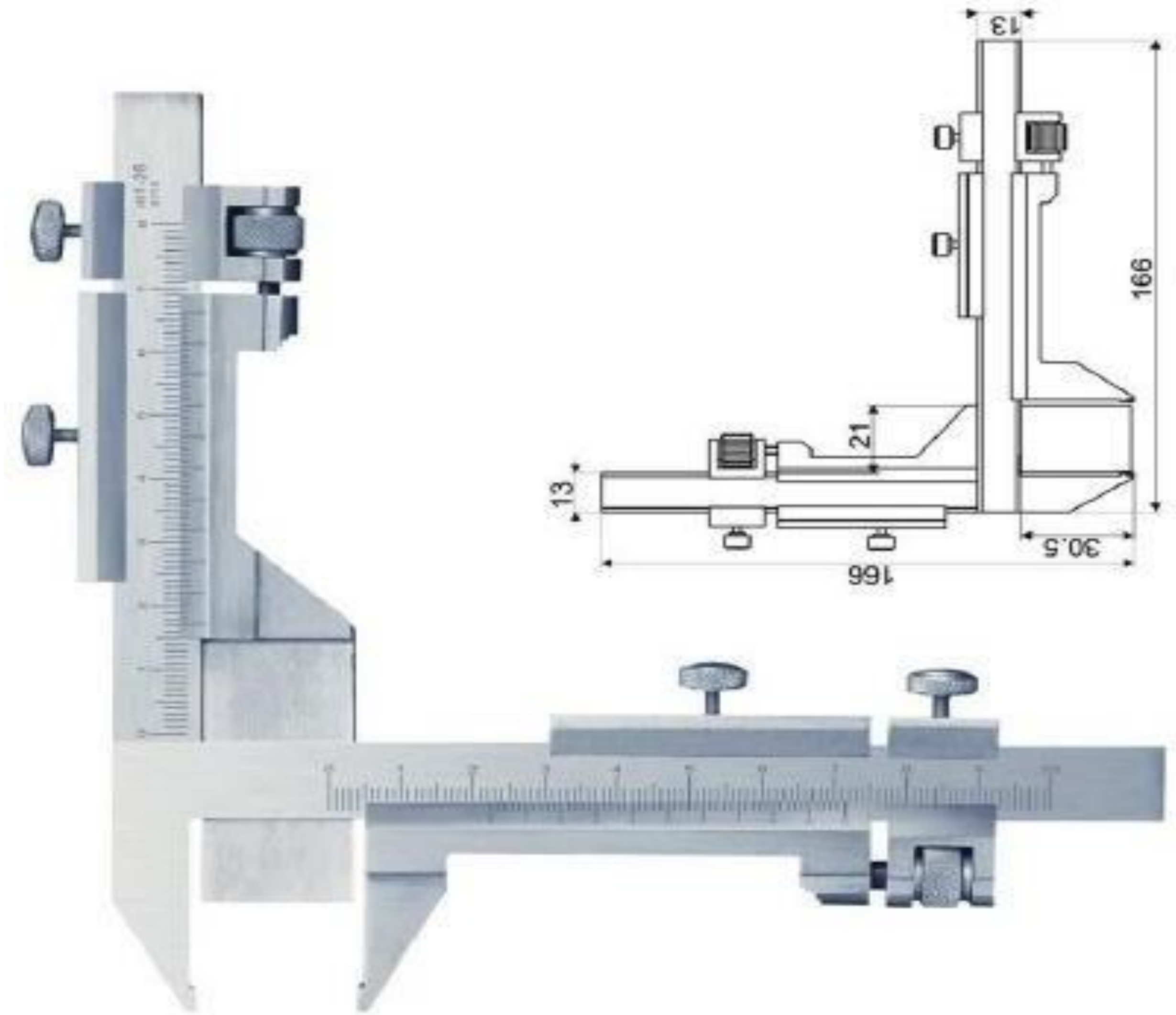
The principle of vernier is that when two scales slightly different in length are placed on below the other, the difference between them can be utilized to enhance the accuracy of measurement. The vernier caliper essentially consists of two steel rules and these can be slide along each other. One of the scales, i.e. the main scale is engraved in mm and partly in 1mm. The sliding scale, called the vernier scale consists of 50 divisions engraved on a length of 49 mm. hence the least count which is the minimum significant value that can be measured further to the main scale reading is (1-49/50) = 0.02 mm . the graduation divisions and the L.C . May vary from the type of vernier to another based on the range of measurement. Further, gear tooth vernier works on the principle that when the jaws are set to the chordal thickness then the vertical scale should measure the chordal height (or chordal addendum) when its moving blade (tongue) touches the tooth outer surface.

Theory:-
GEAR TOOTH VERNIER CALIPER:

Gear tooth vernier caliper is used to measure the chordal thickness of the gear tooth at the pitch line or chordal thickness of the tooth and the chordal addendum is. The chordal thickness of a tooth at pitch line and chordel addedum is measured by an adjustable touge, each of which is adjusted independently by adjusting screw on graduated bars. The effect of zero error should be taken into considerations. This method is simple and inexpensive. However it needs different setting for every change in the number of teeth for a given pitch and accuracy is limited by the least count of instrument. Since the wear during use is concentred on the two jaws, the caliper has to be calibrated at regular intervals to maintain the accuracy of measurement.

Where, w- chordel thickness or width, d- chordel addendum
Directly the value of w can be found out the formula.
w- Nm sin (90/N), Where N-total no of teeth of the given gear
m- Module (which is given or determined)

Once this value is known then directly we can find the value of chordel addendum with the help of gear tooth vernier caliper (by setting the value of w in the caliper).
The formula to find out theoretical chordel addendum is
D= Nm /2 {1+2/N-COS (90/N)}



PROCIDURE:

1. When two measuring tip surfaces are in contact with each other, check for zero error.

2. Count the number of teeth on gear wheel.

3. The chordel thickness or width of the gear is calculated by using the formula for w. module ‘m’ is to be obtained either by design specification or by trial and error. Bear in mind that module will be usually a whole integer 3 to 10 or at most 0.5 more than a whole number. To arrive at correct ‘m’ first approximately measure w at about the pitch circle and calculate ‘m’ using the formula for w. now round off the value for ‘m’ and recalculate ‘w’ with this new ‘m’.

4. The value of chordel thickness is set on caliper (on horizontal beam) and chordel addendum is measured by using gear tooth vernier (on vertical beam).

5. Thus the chordal addenda of several teeth are measured and their average is taken as the actual value of the chordel addendum for the gear along with the σ for the variation of the average.

6. If any error in the instrument is found then it is added to the obtained value accordingly.

7. The measured value is compared with the calculated value. if the difference is within limits the chordel addendum is accepted.

8. Where thickness correction has been indicated in the design this should be considered when calculating ‘m’ by using the actual value of ‘w’.

Observation & Tabulation:

Least count of gear tooth vernier caliper =__________mm

Number of teeth on the spur gear (N) =

Diameter of gear blank (d) =____________.mm

Modulus (m) = d / (N+2)

Chordal thickness (W) = N m sin (90 / N) =______________mm

Chordal depth= Nm /2 {1+2/N-COS (90/N)}=_____________mm

Sr. No.	No. of teeth (Z)	Outer dia. Of gear (d)	Modulus (m)	Chordal thickness (W) (Theo) (mm)	Chordal thickness (W) (Exp.) (mm)	Chordal depth (D) (Theo) mm	Chordal depth (D) (Exp.) mm

CONCLUSION:

Questions

1. Give comparison between involute and cycloidal gears.

2. Discuss the gear tooth terminology with neat sketch.

Suggested Reference:

3) Mechanical Measurement and Metrology, R K Jain, Khanna Publisher
4) Mechanical Measurement and Metrology, Er. R K Rajput, Kataria Publication.

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**Total**
Marks					

Signature of faculty: ___________________

Rubric wise marks obtained:

Criteria	%	10	9-8	7-6	5
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *______		
Quality of report	20		0.2*______		
Participation	30		0.3*______		
Punctuality	20		0.2*_______		
			Total Marks		