WORKSHOP

DEPARTMENT OF MECHANICAL ENGINEERING

LAB MANUAL

OF

Metrology

INDIAN INSTITUTE OF TECHNOLOGY

(INDIAN SCHOOL OF MINES), DHANBAD

OBJECTIVES

The objectives of metrology laboratory are

- ✓ To measure spur gear tooth thickness by using Gear tooth Vernier.
- ✓ To understand the principle and working of tool maker's microscope.
- ✓ Introduction to surface roughness tester.
- ✓ To study the Threads terminology and its types.
- ✓ To find the flatness of a given surface plate.
- ✓ To measure the angle between two faces of a given component using Bevel protractor.
- ✓ Introduction to direct and indirect measuring instruments like Screw pitch gauge, radius gauge, small hole gauge, Telescopic gauge and Feeler gauge.
- ✓ To measure Length, Height and Diameter of given objects by using Vernier Calipers & Micrometer.
- ✓ Introduction to laser distance measuring device

OUTCOMES

The expected outcome of metrology lab is that the students should have

- ✓ A practical hand on experience on measuring instruments.
- ✓ Understand the application and principle of measuring intruments.

TUTORIAL ASSIGNMENTS

- ✓ To measure different specimens using the measuring devices introduced in the labs.

Experiment No:

MEASUREMENT OF GEAR TOOTH THICKNESS

1 AIM: To measure spur gear tooth thickness by using Gear tooth Vernier.

2 INSTRUMENTS AND MATERIAL REQUIRED:

a) Gear tooth Vernier caliper

b) Spur gear

3 SPECIFICATIONS:

a) Gear Tooth Vernier calipers – range 0-150 mm, LC = 0.02mm

b) Spur gear size = Standard size

c) Vernier calipers - range 0-100 mm, LC = 0.02mm

4. TERMINLOGY OF GEAR TOOTH :

a) **Pitch circle diameter (P.C.D):** It is the diameter of a circle which by pure rolling action would produce the same motion as the toothed gear wheel.

b) **Module (m) :** It is defined as the length of the pitch circle diameter per tooth. Thus if P.C.D of gear be 'D' and number of teeth 'N', then module (m) = D/N. it is generally expressed in mm.

c) **Diametric pitch** : It is expressed as the number of teeth per inch of the P.C.D.

d) **Circular pitch** : It is the arc distance measured around the pitch circle from the flank of one tooth to a similar flank in the next tooth. C.P = ÏD/N = Ïm

e) **Addendum** : This is the radial distance from the pitch circle to the tip of the tooth. Its value is equal to one module.

f) **Clearance** : This is the radial distance from the tip of a tooth to the bottom of a mating tooth space when the teeth are symmetrically engaged. Its standard value is 0.157 m.

g) **Dedendum** : This is the radial distance from the pitch circle to the bottom of the tooth space.

Dedendum = Addendum + clearance = m + 0.157 m = 1.157 m.

h) **Blank diameter** : This is the diameter of the blank from which gear is cut. It is equal to P.C.D plus twice the addendum.

Blank diameter = P.C.D + 2m = mN + 2m = m (N+2)

i) **Tooth thickness** : This is the arc distance measured along the pitch circle from its intercept with on flank to its-intercept with the other flank of the same tooth.

Normally tooth thickness = 1/2 (C.P) = 1/2 (ÏM)

But thickness is usually reduced by certain amount to allow for some amount of backlash and also owing to addendum correction.

j) **Face of tooth** : It is that part of the tooth surface which is above the pitch surface.

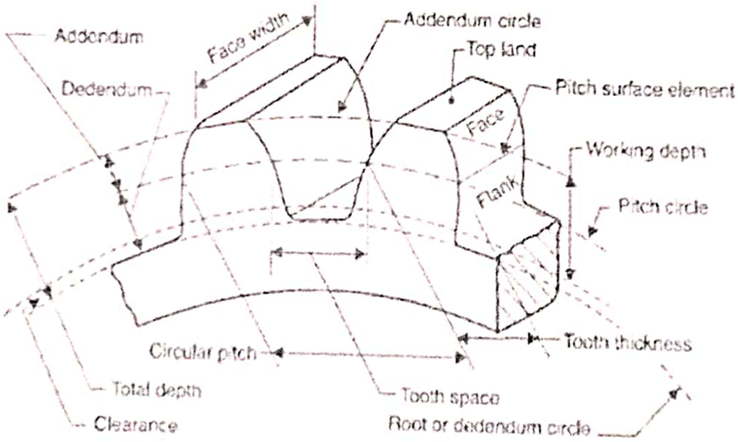
k) **Flank of tooth:** It is that part of the tooth surface which is lying below the pitch surface.

5. PRINCIPLE :

MEASUREMENT OF TOOTH THICKNESS :

The thickness measurement is the most important measurement because most of the gears manufactured may not undergo checking of all other parameters, but thickness measurement is a must for all gears.

The tooth thickness can be very conveniently measured by a gear tooth vernier. Since the gear tooth thickness varies from the tip to the base circle of the tooth, the instrument must be capable of measuring the tooth thickness at a specified position on the tooth. Further this is possible only when there is some arrangement to fix that position where the measurement is to be taken. The gear tooth vernier has two vernier scales and they are set for the width (w) of the tooth and the depth (d) from the top, at which 'w'occurs.



Considering one gear tooth, the theoretical values of 'w' and 'd' can be found which may be verified by the instrument. From fig .3.2) Chordal thickness = w = AB = 2AD
<AOD = θ = 360°/4N, where 'N' is the number of teeth.
W = 2AD = 2 x AO. Sin θ = 2R. Sin 360°/4N (R = Pitch circle radius)

Module (m) = P.C.D/Number of teeth = 2R/ N ∴R = $\frac{N.m}{2}$

Chordal thickness (w) = $2.\frac{N.m}{2} Sin\frac{360^0}{4N} = N.m.Sin\frac{90^0}{N}$

Also from fig (3.2) d = OC – OD.

But OC = OE + Addendum = R+m = [N.m/2]+m and

But OD = R Cos θ = N.m/2 Cos90^0/N. ∴ $\frac{N.m}{2} + m - \frac{Nm}{2}\cos\frac{90^0}{N}$

∴ Chordal addendum (d) = $\frac{N.m}{2}\left[1+\frac{2}{N}-Cos\left[\frac{90^0}{N}\right]\right]$

PROCEDURE:

i) Count the number of teeth (N) on the gear,

ii) Measure the outside diameter (Do) of the gear.

iii) Calculate the module from the relation, m = $D_0/(N+2)$

iv) Calculate the value of chordal addendum (d) from equation (3.1)

v) Set the gear tooth vernier caliper for depth 'd' and measure 'w' i.e., chordal thickness of tooth.

vi) Repeat the measurement on other teeth and determine an average value.

OBSERVATIONS:

Number of teeth on gear, N =

Outside diameter of gear (D_o)=

Sl No.	Chordal tooth thickness, w (in mm)

i) Chordal addendum (d) = $\frac{N.m}{2}\left[1+\frac{2}{N}-\cos\left[\frac{90^0}{N}\right]\right]$ =-------

ii) Chordal thickness (w) = N.m Sin $\left\{\frac{90^0}{N}\right\}$ =------

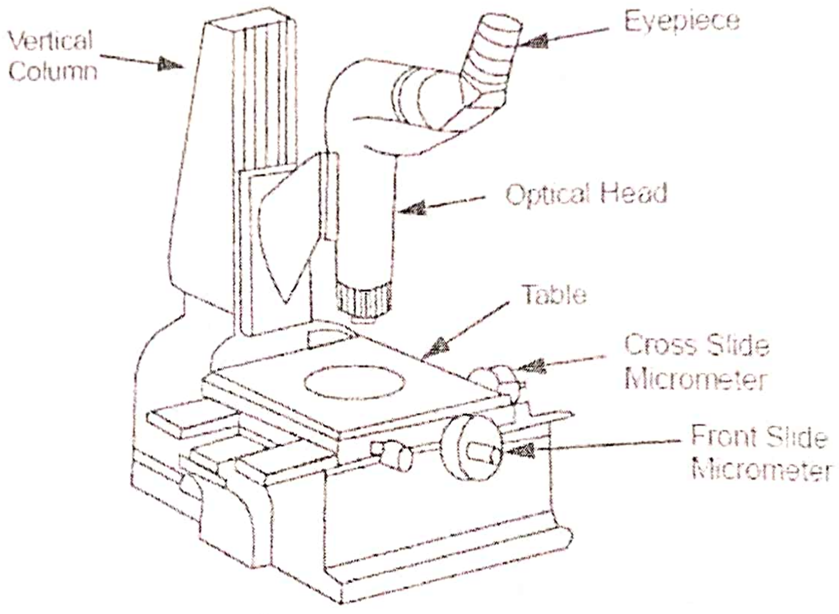
Outcome: The chordal thickness of the tooth is=……

Experiment No:

Introduction to Tool Maker's Microsocope.

Objectives: To understand the principle of working of tool maker's microscope.

Introduction:
Engineering microscopes designed to satisfy various measuring needs of tool maker's are known as toolmaker's microscopes. A plain toolmaker's microscope is primarily intended for a particular application. On the other hand, universal toolmaker's microscope is adaptable to an uncommonly wide range of measuring tasks. A toolmaker's microscope is designed for measurements of parts of complex forms, e.g. profile of external threads, tools, templates and gauges. It can also be used for measuring centre-to-centre distance of holes in any planes, as well as the co-ordinate of the outline of a complex template gauges.



Tool Makers Microscope

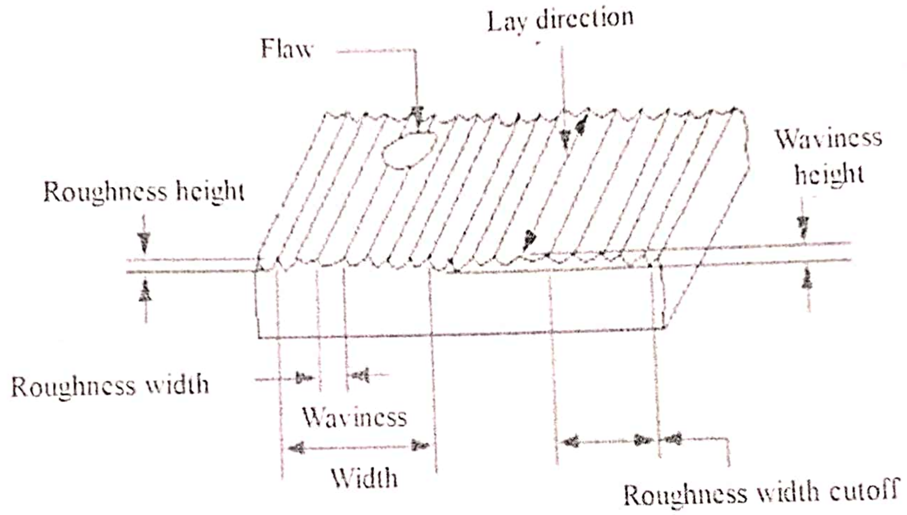
Experiment no.

SURFACE ROUGHNESS MEASUREMENT

1. AIM: Introduction to surface roughness tester.

2. MEASURING INSTRUMENTS AND MATERIAL REQUIRED :

Surface roughness tester (SJ - 201)

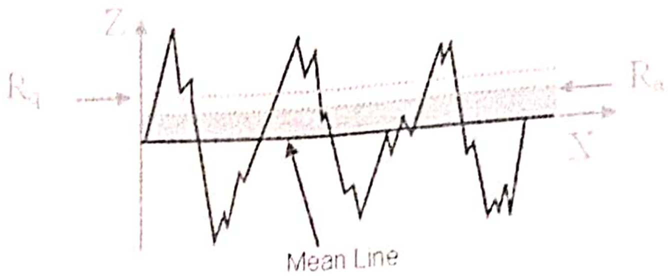


Arithmetic mean deviation of the Profile, Ra is the arithmetic average of the absolute values of the roughness profile ordinates. Ra is one of the most effective surface roughness measures commonly adopted in general engineering practice.

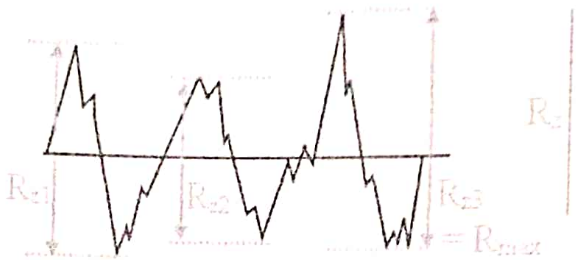
$$R_a = \frac{1}{l}\int_0^l |Z(x)|\,dx$$

Root-mean-square deviation of the Profile, Rq

Rq is the square root of the arithmetic mean of the squares of profile deviations (Yi) from the mean line.



Maximum height of the Profile, Rz is the arithmetic mean value of the single roughness depths of consecutive sampling lengths.



MEASUREMENT OF SURFACE ROUGHNESS:

Surface roughness measurement with the surf test SJ-201 includes

i) Mounting/dismounting the drive unit/detector, and cable connection, etc. according to he feature of the work piece to be measured,

ii) Selection of power supply i.e., either the AC adapter or built-in battery,

iii) Modifying the measurement conditions as necessary,

iv) Calibrating surf test SJ-201 to adjust the detector gain for correct measurements,

v) Measuring the roughness specimen and display the result,

OBSERVATIONS:

S.No.	Ra [µm]	Rq [µm]	Rz[µm]

OUTCOME:

The surface roughness of the specimen is :

Experiment No:

THREAD NOMENCLATURE

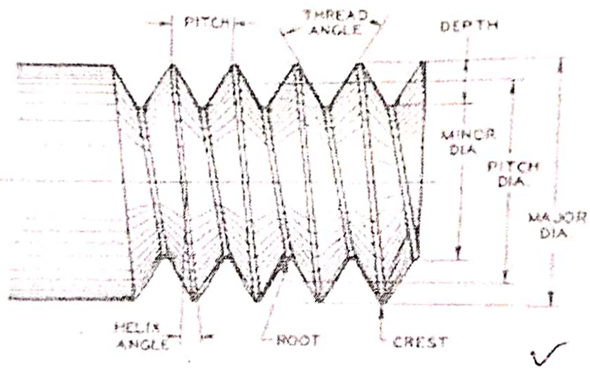
Aim: To study the Threads Terminology and its types

Thread terminology:

1. **Pitch:** The pitch is the distance from the crest of one thread to the next.

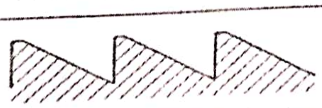
2. **Crest and Root:** The outer most part of the thread is called crest and the inner most part of the thread is called the root.

3. **Diameter:** The major diameter is determined by the thread tips and the minor diameter is determined by the groove of the thread. The pitch diameter is the distance between the two opposite flanks or the distance of the centerline of the profile.



4. **Flank angle:** The flank angle is the angle between the flank of a screw thread and the perpendicular to the axis of the screw.

Types of thread:

Thread Form	Figure	Uses
Metric		General use.
Square		Ideal thread for power transmission
ACME		Stronger than the square thread
Buttress		Designed to handle heavy forces in one direction (e.g truck jack)

Experiment No:

FLATNESS TEST

AIM: To find the flatness of a given surface plate

APPARATUS: Surface plate and precision spirit level

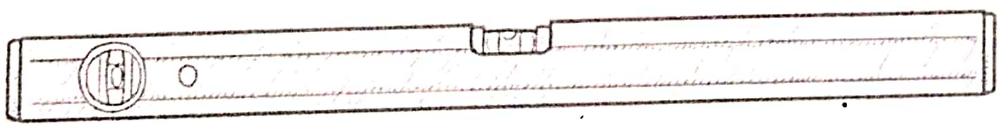
THEORY:

The simplest form of flatness testing is possible by comparing the surface with an accurate surface. Spirit level is used in special cases and called Clinometers, precision micro-optic clinometers utilizes bubble unit with a prismatic coincidence reader which presents both ends of the bubble an adjacent images in a spirit field.

Leveling helps in the coincidence of the 2 images, making it very easy to see when the bubble is exactly centered without reference to any graduations. The special features to precision micro-optic clinometers are direct reading over range 0-360°, optically reading system, main coarse setting, slow motion screw to fine setting. The least count of precision spirit level is 0.01 mm.

PROCEDURE:

1. Place the spirit level on the surface plate and adjust it's into suitable reference point.
2. Divide the plate (surface) into no. of sections and note the reading.
3. Thus a number of readings w.r.t to surface plate reference is found.
4. A plot is done on the performance.



OBSERVATIONS:

Experiment No:

ANGULAR MEASUREMENT WITH BEVEL PROTACTOR

AIM: To measure the angle between two faces of a given component using Bevel protractor

INSTRUMENTS AND MATERIALS REQUIRED:

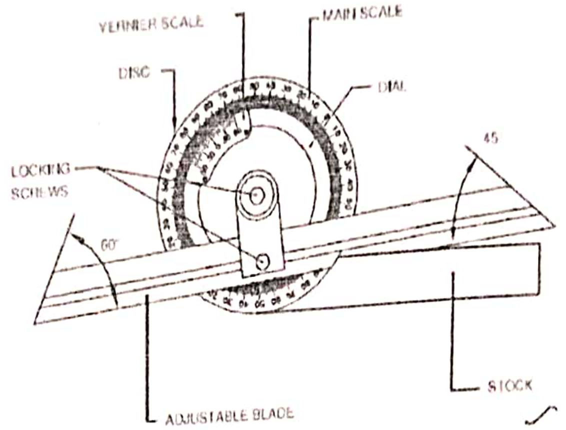
1. Bevel protractor with vernier and acute angle attachment (150/300 mm blades)
2. Surface plate
3. Slip gauges
4. Dial gauge (0.01 mm least count)
5. Slotted angle plate

THEORY AND DESCRIPTION :

Bevel Protractor:

It is the simplest instrument for measuring angle between two faces of component. It consists of a base plate attached to the main body and an adjustable blade which is attached to a circular plate called turret containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale (graduated around a complete circle from 0° to 90°, 90° to 0° and 0° to 90°, 90° to 0°) engraved on the body of the instrument and can be locked in any position. An acute angle attachment is provided at the top as shown in fig (4.1) to measure acute angles. The base of the base plate is made flat so that it could be laid flat upon the work and any type of angle measured. It is capable of measuring from 0° to 360°.

The vernier scale has 24 divisions coinciding with 46 main scale divisions (23 on either side) as shown in fig (4.2) The vernier scale is graduated to the right and left of zero upto 60 minutes, each of the 12 graduations representing 5 minutes. Since both the protractor dial and vernier scale have graduations in both directions from zero, any angle can be measured, but it should be remembered that the vernier must be read in the same direction from zero as the protractor either left or right. If the zero graduation on the vernier scale coincides with a graduation on the protractor dial, the reading is in exact degrees, but if some other graduation on the vernier scale coincides with a protractor graduation, the number of vernier graduations multiplied by 5 minutes, must be added to the number of degrees read between the zeros on the protractor dial and vernier scale. Magnified view of main scale is shown in fig (4.2a)



PROCEDURE:

i) The base plate of the Bevel protractor is placed on the top horizontal surface of the component,

ii) Blade locking nut is loosened and by rotating the blade about the centre of the main scale, the working edge of the blade is made to coincide with the inclined surface of the component,

iii) Blade is locked in that position by tightening the nut.

iv) Vernier scale division coinciding with main scale division is noted.

Inclination of the surface with respect to horizontal is calculated as follows: Angular reading = (Vernier scale division x 5minutes) + Main scale division in degrees

OBSERVATION

Main Scale Reading	Vernier Scale Reading	Total angular Reading

CONCLUSIONS

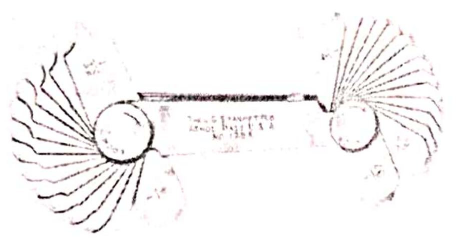
Experiment No. **TYPES OF GAUGE**

AIM: Introduction to direct and indirect measuring instruments like Screw pitch gauge, radius gauge, small hole gauge, Telescopic gauge and Feeler gauge

THEORY

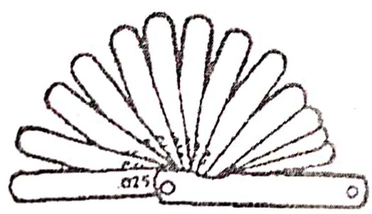
(a) RADIUS GAUGE

Radius gauges are employed for checking external and internal radii on a curved surface. Radius gauges consists of set of blades. Corresponding radius is permanently marked on each blade. The set of blades with internal radius on one side and external radius on the other so that it may be suitable for checking fillets as well as radius. The passage of light between the gauge and the work allows the radius to be checked properly.



(b) FEELER GAUGE:

Feeler gauge is used to measure the clearance between the two mating parts. For example, it can be used in gauging of the clearance between the piston and cylinder and also for adjusting the spark plug between the distributor points of an automobile. The feeler gauge set consists of narrow strips of sheet steel of different thickness assembled together in holder. A set of feeler gauge consists of series of blades of thickness varying from 0.03mm to 1mm. The width of blade is 12 mm at heal and tapered for outer part of their length so that the width of tip is 6mm.

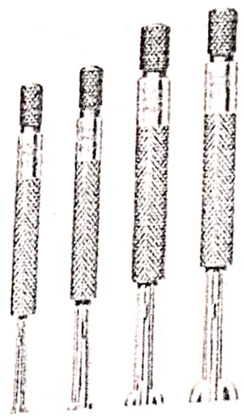


(c) SCREW PITCH GAUGE:

Screw pitch gauge is used to check the pitch of screw thread. They quickly determine the pitch of thread by matching the teeth on the strips with the teeth on the work.

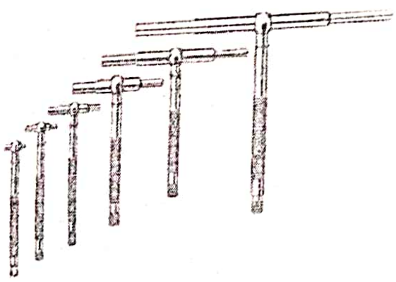
(d) SMALL HOLE GAUGE:

Small hole gauges are used to measure the diameter of holes of smaller size and they are used specially when holes are drilled in the inside area of workpiece and measurement is not possible by the used of direct instruments like vernier caliper and micro meters.



(e) TELESCOPIC GAUGE:

Telescopic gauges are indirect and non- graduated instruments used for linear measurement. They are used in the situations where other instruments like Vernier caliper and micrometer cannot approach the contours of workpiece whose dimension is to be measured. For example for T slot measurement, intermediate bore diameter.



OBSERVATIONS:

Experiment No.

MEASUREMENT THROUGH VERNIER AND MICROMETER

AIM: To measure Length, Height and Diameter of given objects by using Vernier Calipers & Micrometer.

INSTRUMENT USED: Vernier Calipers, Outside Micrometer, Height gauge & Objects

PRINCIPLE OF VERNIER :

The principle of Vernier is based on the difference between two scales or divisions, which are nearly, but not quite alike for obtaining small difference. It enables to enhance the accuracy of measurement.

Least Count:

Least count is the minimum distance which can be measured accurately by the Instrument.

Least Count of Vernier Caliper is the difference between the value of main scale division and Vernier Scale Division.

(i) in mm scale

Value of one smallest main scale division = 1 MSD = 1mm

We have 49 MSD = 50 VSD =49mm

1 VSD = 49/50 mm =0.98 mm

(1 MSD > 1 VSD)

Least Count = (Value of Smallest Division on Main Scale)-(Value of Smallest Division on Vernier Scale)

= 1-49/50 = 0.02 mm.

Observation Table for mm scale (length measurement)

Main Scale Reading	Vernier Scale Reading	Total Reading

Average of reading =

Height measurement of V-block

Main Scale Reading	Vernier Scale Reading	Total Reading

(ii) inch scale

40 MSD = 1"

1 MSD = 1/40" = 0.025"

We have 49 MSD = 25 VSD =49/40"

1 VSD=49/(40×25)=0.049"

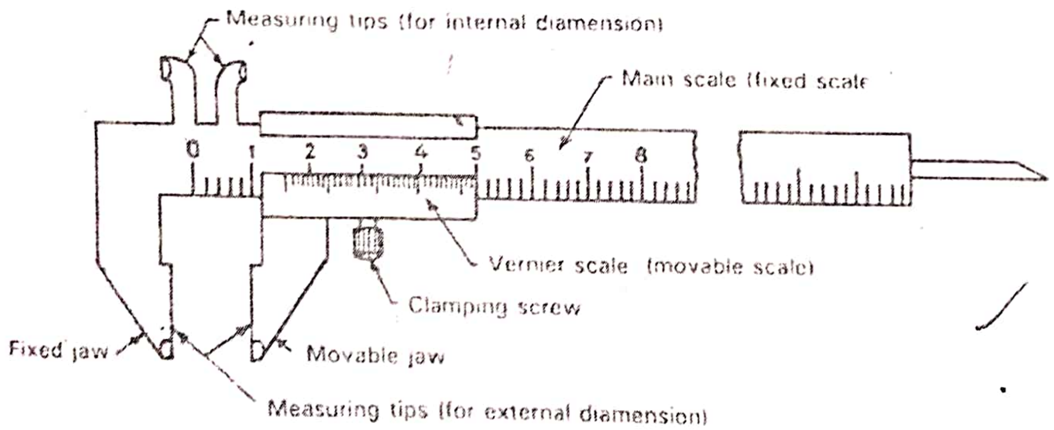
1MSD<1VSD so take 2MSD=1TMSD=0.05"

(TMSD= two main scale division)

24.5"×2MSD=49 MSD= 25 VSD = 24.5 TMSD (1TMSD=1VSD)

Hence, LC=1TMSD – 1VSD = 0.050" -0.049" =0.001"

1 Thou =0.001" =25.4μm



Total reading = [Main scale reading] + [No. of divisions with a division on Main Scale] X Least Count.

For inch scale:

LC=0.001 inch = 1 thou =25.4μm (since 0.001 mm=1μm)

Observation table for inch scale

Main Scale Reading	Vernier Scale Reading	Total Reading

Average of reading =

OUTSIDE MICROMETER :

Micrometers are designated according to screw and nut principle where a calibrated screw thread and a circular scale divisions are used to indicate the principle practical part of main scale divisions. The semi circular frame caries a fixed anvil at one extremely and cylindrical barrel at the other end. A fine accurately cut screw of uniform pitch is machined on a spindle. The spindle passes through the barrel and its left hand side constitutes the movable anvil. A sleeve fits on the screw and caries on its inner edge a circular scale divided into desired no. of divisions. The spindle with its screw and thimble are in one piece and sleeve forms the nut. The thimble scale serves to measure the friction of its circular rotations. The number of complete rotations is read from main scale, which is graduated in 'mm' on nut parallel to axis of screw.

1MSD =0.5mm

50CSD (circular scale division) =0.5mm

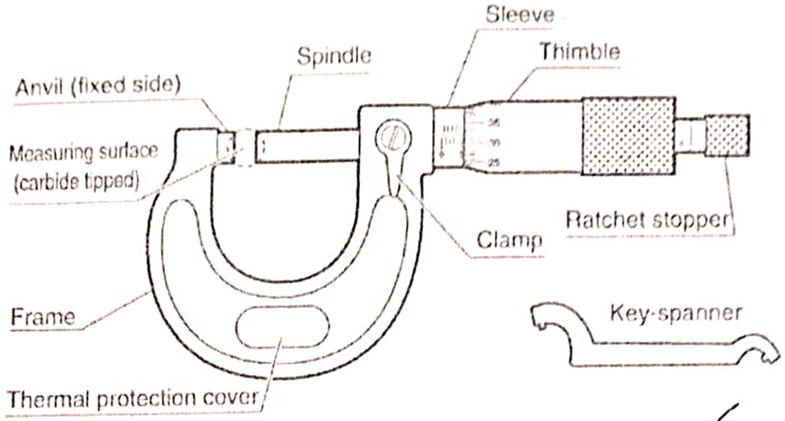
1CSD=0.5/50 = 0.01 mm

We have 9CSD = 10VSD =9×0.01 =0.09mm

1VSD= 0.09/10 =0.009 mm

Hence, LC= 1CSD- 1VSD= 0.01mm – 0.009 mm = 0.001 mm = 1μm

Total reading = main scale reading + circular scale reading + vernier (or linear) scale reading



Observation table for micrometer

Main Scale Reading	Circular Scale Reading	Vernier Scale reading	Total Reading

Experiment No.

LASER DISTANCE MEASUREMENT

AIM: Introduction to laser distance measuring device

INSTRUMENT REQUIRED: LASER distance measuring device

PRINCIPLE:

Laser distance measurer works on the basic principle of distance traveled by light in a given time. It projects a laser pulse on a solid opaque target object, the pulse then bounces back towards the device which records the time taken for the pulse to travel to-and-back from the target object. Based on these calculations the laser measuring tool then gives you the distance measured.

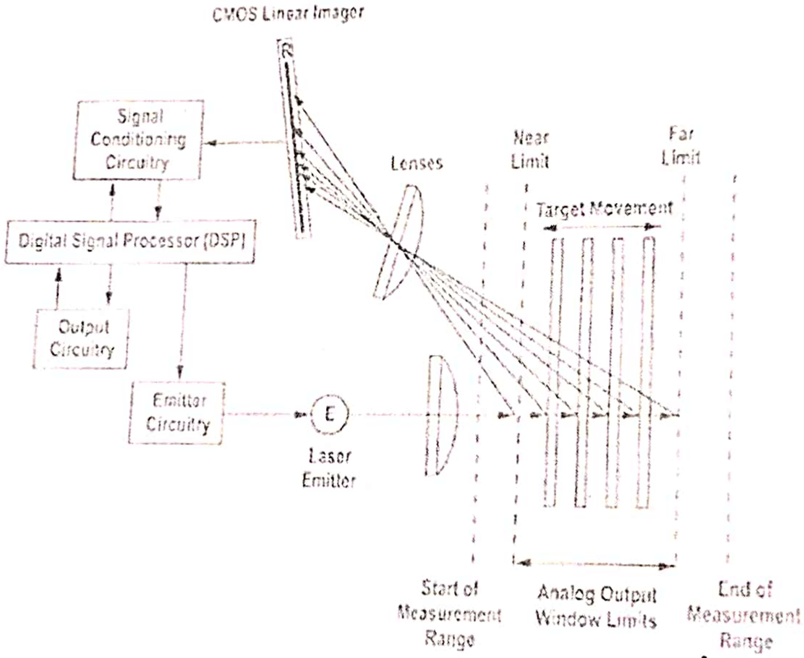


Figure 1. Optical Triangulation Sensing System Overview