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Laboratory Manual

Metrology and Quality Control

For

Third Year B. Tech Students

Prepared by

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Department of Mechanical Engineering

Dr. A. D. Shinde College of Engineering

Bhadgaon, Gadhinglaj.

Dr. A. D. Shinde College of Engineering

Department of Mechanical engineering

Vision of the Department

To provide best education in mechanical engineering and technology to the Aspirants and serve the nation development of innovative human asset.

Mission of the Department

M1: To make the department of mechanical engineering a preferable destination for Aspiring students

M2: To provide quality technical education using modern tools in the field of mechanical engineering.

M3: To create competent and skilled mechanical engineers who are able to handle mechanical and Allied systems

M4: Cultivate and nurture the spirit of entrepreneurship among students.

Acknowledgement

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List of Experiments

1. Study and use of linear measuring instruments.
2. Study and use of comparators.
3. Study and use of angle measuring instruments.
4. Screw thread measurement.
5. Measurement of Gear Tooth Thickness by Gear Tooth vernier caliper.
6. Study of Surfaces using optical flat.
7. Study and applications of optical profile projector.
8. Assignment on Control chart.

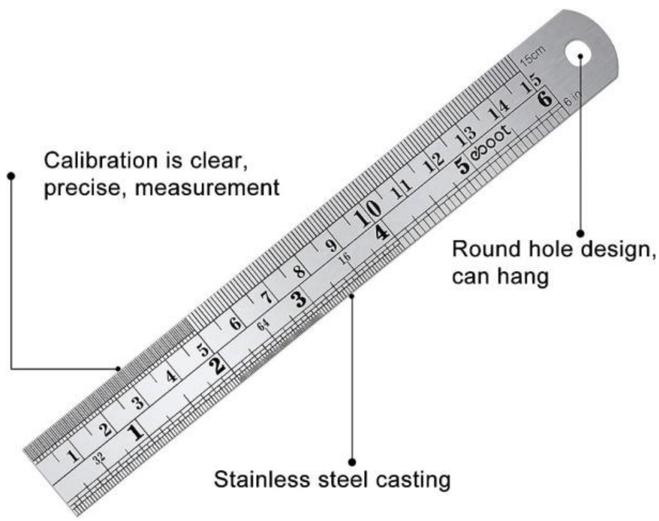
EXPERIMENT NO 1

TITLE: Study and use of linear measuring instruments.

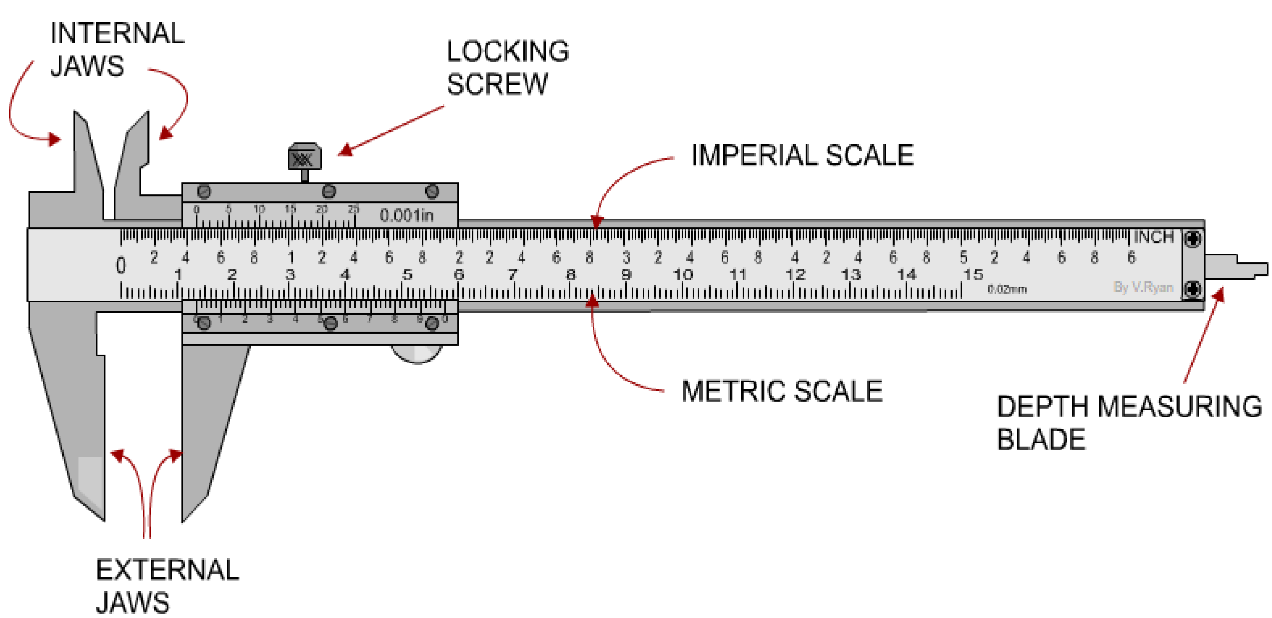
APPARATUS: Steel Rule, Vernier Caliper, Vernier Height Gauge, Micrometer, Digital Vernier Caliper, Digital Micrometer.

THEORY:

1) STEEL RULE- It is also known as scale. It is the line measuring device. It is the simplest and common measuring instrument used for inspection. It works on the basic measuring technique of company on unknown length to the one previously calibrated. It consists of a strip of hundred steel having line graduation etched engraved on internal of fraction of standard unit of length, depending upon the internal at which graduations are made. The scale can be manufactured in different sizes and styles. It may be 150 mm, 300 mm, 600 mm or 1000 mm long.



2) VERNIER CALLIPER- The principle of vernier is that when two scales or divisions slightly different in size are used, 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 slide along each other. The details are shown in fig. below



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) least country main scale division-vernier scale division.

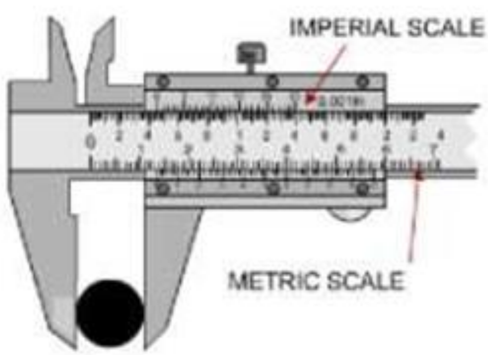
    Least count = value of 1msd/total no. Of vsd

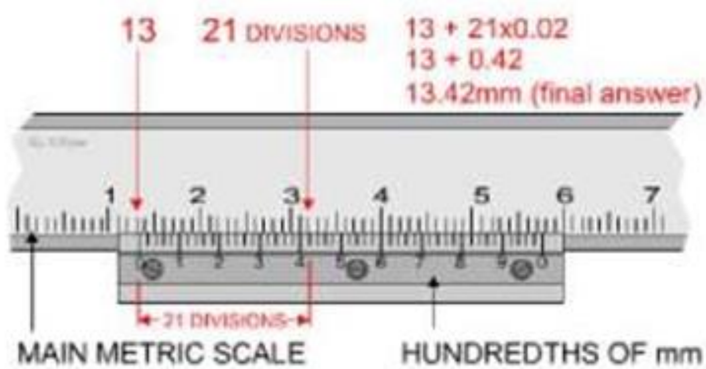
    1 msd = 0.1mm, total no. vsd = 5 therefore LC = 0.02mm

Suppose 50 vernier scale I division coincide with 49 divisions on main scale, and 1 msd=1 mm.

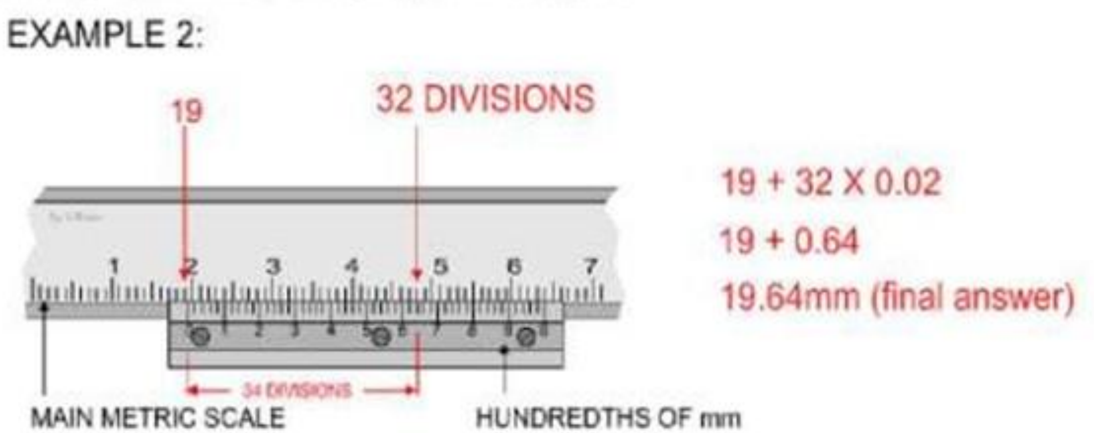
Then 1 VSD = 49/50 of MSD = 49/50 mm and LC = 1-49/50= 0.02 mm

Alternatively, it is just as easy to read the 13 on the main scale and 42 on the hundredths scale. The correct measurement being 13.42 mm.





EXAMPLE 2: (To zoom in to see the scale - right click mouse and select zoom)



3) VERNIER HEIGHT GUAGE- This is also a sort of a vernier caliper equipped with a special base back and other attachments which make the instrument suitable for height measurement. Along with the sliding jaw assembly arrangement is provided to carry a removable clamp. The upper and the lower surface of the measuring jaw are parallel to the base so that it can be used for measurement over or under the surface. The vernier height gauge is merely used to scribe lines of certain distance above surface. However, dial indicator can be attached in the clamp

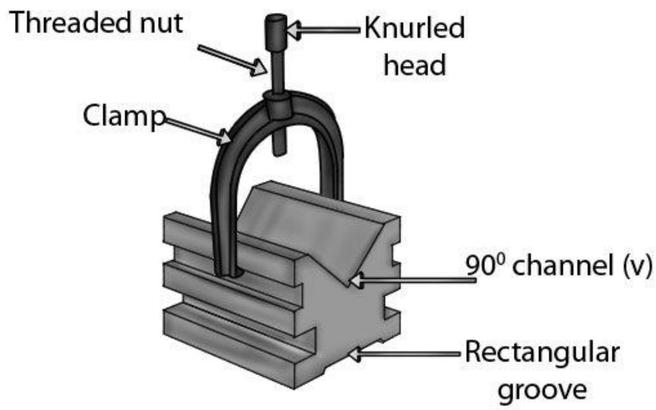
and many useful measurements can be exactly made as it exactly gives the indication when dial tip just touches the surfaces. For all these measurements, use of surface plates as datum surface is very essential.

4) MICROMETER: The micrometer essentially consists of U shaped frame. The component to be measured is held between fixed anvil and movable spindle. The spindle can be moved with the help of thimble. There are two scales on micrometer, a main scale and a circular scale. The barrel is graduated in unit of 0.5 mm whereas thimble has got 50 divisions around its periphery. One revolution of thimble moves 0.5 mm which is the lead of the screw and also the pitch.

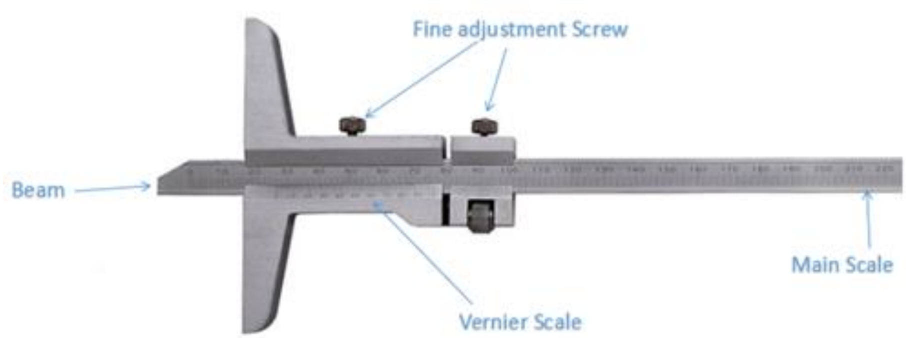
Micrometer Parts

5) Vee BLOCK: The Vee-block is essentially tool steel blocks that are very precisely 100mm square. Standard Vee-blocks come as 45 degree block, i.e. the vee-sides slope 45 degree from horizontal or vertical, the included angle of the vee being of course, 90 degrees. But blocks with different angles and shapes are also available. For special purpose

such as checking triangle effects or for taps and other three-fluted tools, 60 degree Vee-blocks are also available. The included angle of the vee then is 120 degrees. The major purpose of the Vee-blocks is to hold cylindrical pieces, or move to the point, to establish precisely the centre line or axis of a cylindrical piece. In using a vee-block, it is very essential that the cylindrical piece should rest on firmly on the sides of the vee and not on the edges of the vee.



6) VERNIER DEPTH GAUGE: This is similar to vernier height gauge. It consists of main scale, vernier scale, jaws, and lock nut fine adjustment screw like vernier caliper as shown in fig. In vernier depth gauge, graduated scale can slide through the base and vernier scale remains fixed. The vernier scale is fixed to the main body of the depth gauge and is read in the same way as vernier caliper. In vernier depth gauge, graduated scale can slide through the base and vernier scale remains fixed. The main scale provides the datum surface from which the measurements are taken. Vernier depth gauge is used to measure depth of holes, distance from a plane surface to a projection and recess



7) SURFACE PLATE -For majority of dimension measurement and establishment of geometric accuracies, a reference datum plane and flat surface is required. The instrument and jobs are kept on this surface for measurement and also the surface is used for direct comparison and acts a master for checking of flatness and other characteristics of work surface. This perfectly flat plane of reference is available on important methodicaldevice known as surface plate.

Types of surface Plate:-1) Cast Iron Surface Plate. 2) Granite Surface Plate. 3) Glass Surface Plates.

PROCEDURE:

For Vernier Calliper/Micrometer/Height gauge:

1. Check the zero of main and vernier scale to be coinciding.
2. Read the instrument for at least three random vernier positions.
3. Measure the samples at indicated places and record as per the format

OBSERVATION TABLE:

For Vernier Calliper:

S. NO.	ACTUAL READING (mm)	MEASURED READING (mm)	ERROR (mm)
1.			
2.			

For Micrometer:

S. NO.	ACTUAL READING(mm)	MEASURED READING(mm)	ERROR (mm)
1.			
2.			

For Vernier Depth Gauge:

S. NO.	ACTUAL READING	MEASURED READING	ERROR
1.			
2.			

CONCLUSION: Hence we have studied various linear measuring instruments.

EXPERIMENT NO 2

TITLE: Study and use mechanical comparators.

APPARATUS: Mechanical comparator-with Dial indicator and Work piece. Any 10 jobs of size within the range of comparator and master jobs.

THEORY: The comparator is a device which takes a dimension of standard job as reference dimension, and gives a reading to a pointer on a scale, the variation in such dimension of the job to be compared. Upper end of the vertical beam, an adjusting screw is provided for final zero setting of the scale. A new patented feature is shown at K. This is a magnetic counter balance which serves to neutralism the positive 'rate' of spring reaching on the measuring tip. In this way a constant pressure over the whole scale range is achieved. The instrument is available with vertical capacities of 6‟, 12', and 24,' and magnification of 500, 1000, 500, 3000 and 5000. The scales are graduated both in English and Metric systems. The least count is of order of 10R Inch. A work table on the base of this comparator stand is used to keep the job on. Special attachments are used for typical jobs like screw thread effective/outside diameter. Dial indicator type of mechanical comparator consists of a sensitive dial indicator mounted on a horizontal arm on a stand. The arm is capable of coarse and fine adjustment movements in the vertical direction for initial setting of the Instrument. The base is heavy so that stability and rigidity of the instrument is ensured. Different attachments are available depending upon the type or job.

PROCEDURE: (i) Clean the comparator with a flannel cloth or chastise leather.

(ii) Wipe the standard job clean of dust etc.

(iii) After lifting anvil by pressing the trigger, mount the standard jobs/slip gauges on the work table.

(iv) Adjust the screw at the top of vertical beam to zero pointer reading.

(v) Replace the standard job with sample job and record the reading on scale.

(vi)Repeat the comparisons for -eat of sample jobs. Classify the jobs into acceptable/not acceptable and give code number for selective assembly.

OBSERVATION TABLE:

Sr. No	Stage 1 reading	Stage 1 reading
1		
2		
3		
4		
5		
6		
7		
8		

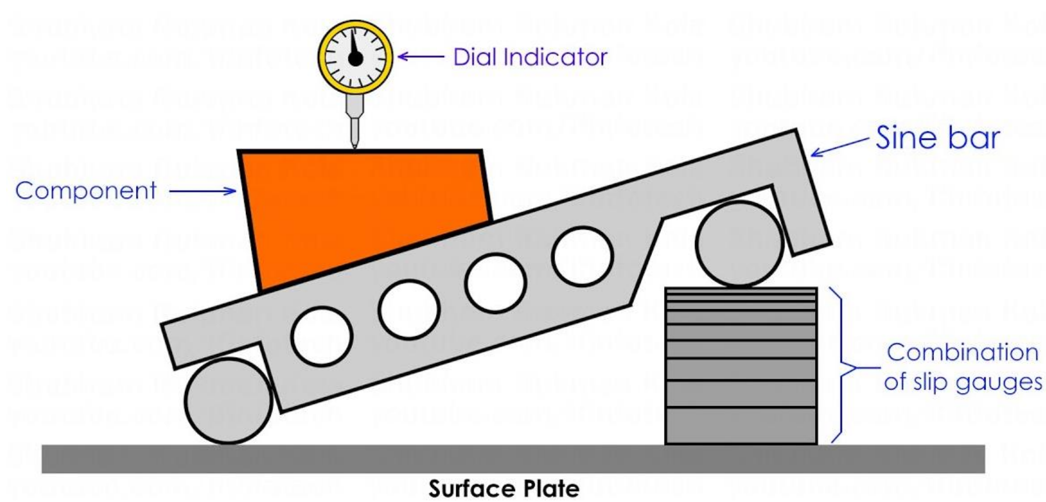
CONCLUSION: Hence we have studied use of mechanical comparator.

EXPERIMENT NO 3

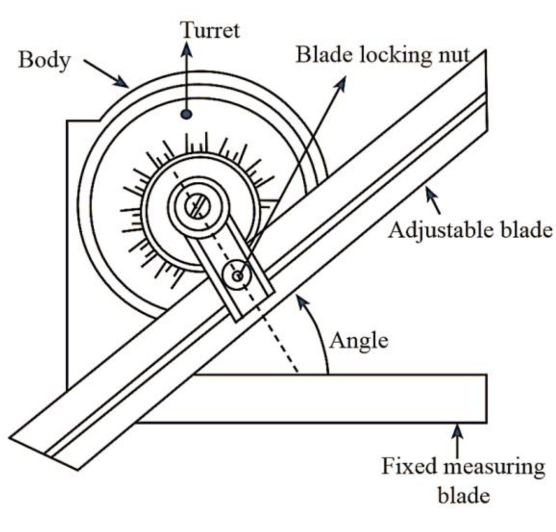
TITLE: Study and use of Angle measuring instruments.

APPARATUS: Vernier bevel protractor (0° to 360°), least count=0°-5°, Surface plate 450 x 450 mm. Holding device to suit particular job.

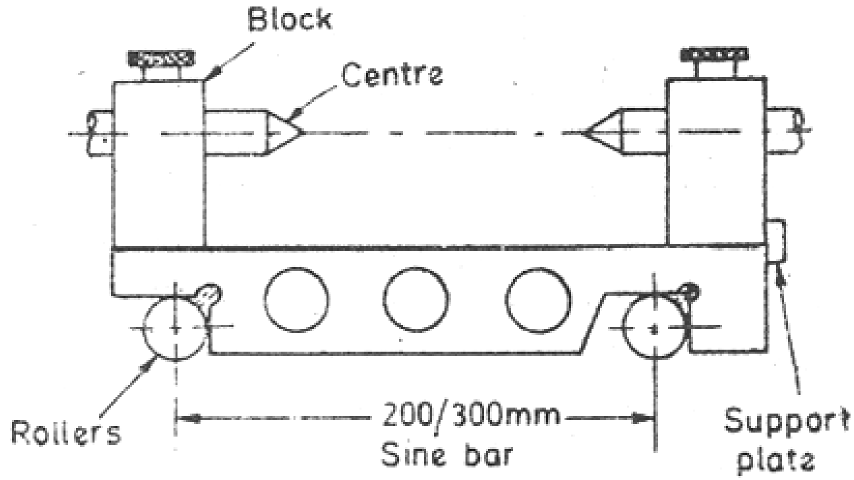
THEORY: A sine bar is a tool used to measure angles in metalworking. It consists of a hardened, precision ground body with two precision ground cylinders fixed at the ends. The distance between the centers of the cylinders is precisely controlled, and the top of the bar is parallel to a line through the centers of the two rollers as shown in Fig.



The dimension between the two rollers is chosen to be a whole number (for ease of later calculations) and forms the hypotenuse of a triangle when in use. Generally, the centre distance between two cylindrical rollers is 10 inch or 100 mm sine bar (however, in the U.S., 5 inch sine bars are the most commonly used). A Bevel Protractor, a graduated circular protractor having a pivoted arm and used for measuring or marking off angles, is shown in Fig. Sometimesvernier scales are attached to give more accurate readings.



Angles are measured using a sine bar with the help of gauge blocks and a dial gauge or a spirit level. sine of the angle of inclination of the wedge is the ratio of the height of the slip gauges used and the distance between the centers of the cylinders.



Sine Centre is a special type of sine bar, which is used for conical objects having male and female parts, as shown in Fig. It cannot measure the angle more than 45 degrees. Sine table (or sine plate) is used to measure angles of large workpieces. Compound sine table is used to measure compound angles of large work pieces. In this case, two sine tables are mounted one over the other at right angles. The tables can be twisted to get the required alignment.

PROCEDURE:

(1) Study the bevel protractor and identify its main parts.

(2) Introduce the adjustable blade in the slot of body and clamp it with the help of knob In the convenient position.

(3) Place the working edge of the stock on one surface of the job and rotate the turret holding the blade so that the working edge of the blade coincides with another surface of the job. Fix the turret and read the angle. And now measure the angles of the sample pieces with the bevel protractor and record the reading.

OBSERVATION:

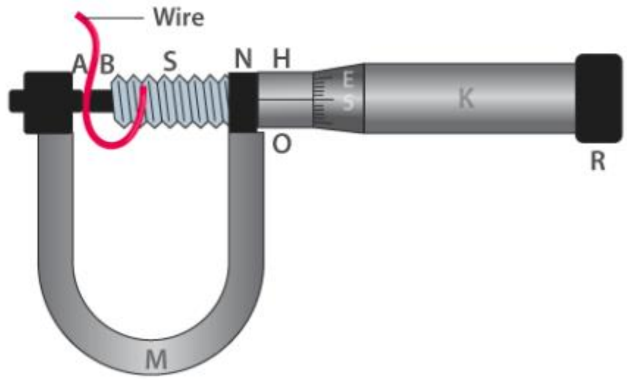
1. Length of sine bar=L= mm
2. size, h=
3. specimen angle with vernier bevel protractor=
4. centre distance=200 mm5. ø=sin-1(h/L)=
6. angle of specimen=
7. least count of dial indicator= mm

CONCLUSION: Hence we have studied various angle measuring instruments.

EXPERIMENT NO. 4

TITLE: To measure diameter of a given wire using screw gauge micrometer.

APPARATUS: Screw gauge, Wire, Half-meter scale, Magnifying glass



Screw gauge measuring diameter of the wire

PROCEDURE:

1. Find the value of one linear scale division (L.S.D).
2. Determine and record the pitch and least count of the screw gauge.
3. To find the zero error, bring the plane face B and A near. Repeat and record this for three times. Record zero error as nil if there is no error.
4. Move face B away from face A. using a ratchet head R, move the face A towards face B lengthwise and stop when R turns without moving the screw.
5. Linear scale reading (L.S.R) is recorded by noting down the no. of visible and uncovered divisions of linear scale.
6. Let n be the no. of divisions of the circular scale lying on the reference line.
7. To measure diameter in a perpendicular direction, repeat steps 5 and 6 by rotating the wire to 90°.
8. For the entire length of wire, repeat steps 4,5,6 and 7 for five different positions and record the observations.
9. Find the total reading and also zero correction.
10. Take the mean of different values of diameter.
11. Using a half-meter scale, measure the length of the wire. Repeat this step three times and record the readings.

OBSERVATIONS:

Determination of the least count of the screw gauge L.S.D = 1 mm

Number of full rotations given to screw = 4Distance moved by the screw = 4 mm

Hence, pitch p = 4 mm/4 = 1 mm

No. of divisions on circular scale = 100

Hence, the least count = 1 mm/100 = 0.01 mm = 0.001 cm

Zero error (i)… mm (ii)…. mm (iii)….. mm

Mean zero error (e) =… mm Mean zero correction (c) = …. mm

Table for diameter (D)

Sl. no	Linear scale reading (N in mm)	Circular scale reading		Total reading	
		No.of circular scale division on reference line (n)	Value [n×(L.C)] mm	Observed D_0=N+n×(L.C)mm	Corrected D=D_0+c
A ⊖ B					$D_1(a)$=
					$D_1(b)$=
A ⊖ B					$D_2(a)$=
					$D_2(b)$=
A ⊖ B					$D_3(a)$=
					$D_3(b)$=

CALCULATIONS:

Length of the wire, l = (i).....cm (ii).....cm (iii).....cm

Mean diameter of the wire,

$$D = \frac{D_1(a)+D_2(b)+\ldots..+D_3(a)+D_3(b)}{6} = \ldots.\ mm = \ldots.\ cm$$

Mean length of the wire,

$$D = \frac{l_1+l_2+l_3}{3} = \ldots.\ cm$$

Volume of the wire,

$$V = \pi(\frac{D}{2})^2 l = \ldots.\ cm$$

RESULT: The volume of the given wire is ....cm^3.

EXPERIMENT NO. 5

TITLE: Measurement of gear tooth thickness by gear tooth Vernier Calliper.

APPARATUS: Gear tooth vernier caliper, vernier caliper 12"" 300 mm, benchvice.

THEORY: Brief description of different characteristics of measuring of tooth thickness by gear truth vernier is given. It consists of a horizontal and a vertical vernier scale. It is based on the principle of vernier scale. The thickness of a tooth at pitch line and the addendum is measured by an independent tongue each of which is adjusted independently by adjusting theslide screws on graduated beams.

TERMINOLOGY OF GEAR TOOTH

(i) Pitch circle diameter (PCD) : It is the diameter of a circle which by purerolling action would produce the same motion on the toothed gear wheel.
It is equal to D = (T X OD)/(T+2)OD = outside diameter T = number of teeth

(ii) MODULE: It is defined as the length of the pitch circle diameter per truth. Module m=D/T and is expressed ih mm.

(iii) CIRCULAR PITCH (CP) : It is the arc distance measured around the pitch circle from the flank of one truth to a similar flank in the next 1.00thCP==ΠD/T=Πm.

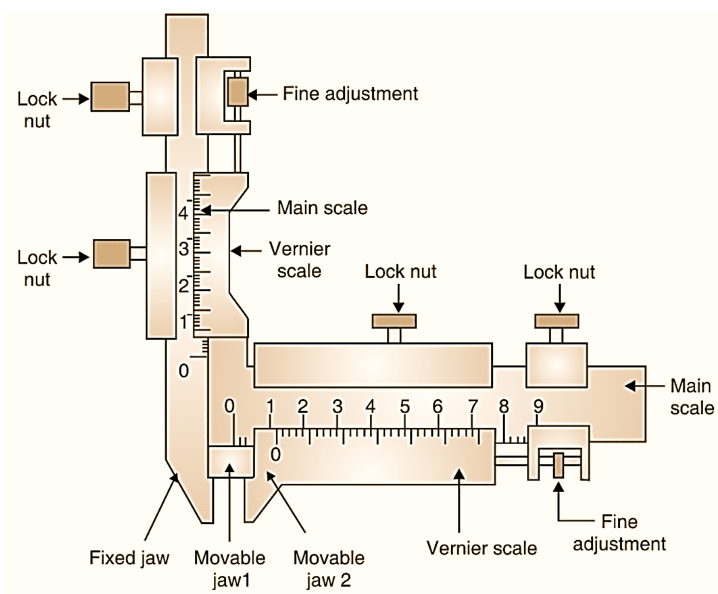
(iv) ADDENDUM: This is the radial distance from the pitch circle to the tip of the truth. It is equal to one module.

(v) Clearance: This is the radial distance from the tip of a tooth to thebottom of the mating tooth space when the teeth are symmetrically engaged. Its standard value is 0.157m or 0.25m.

(vi) DEDENDUM: This is the radial distance from the pitch circle to the bottom of tooth space.

Dedendum = Addendum +Clearance = m +0.157m =1

(vii)TOOTH THICKNESS: This is the arc distance measured along the pitch from the intercepts with one flank to the intercepts with the other flank ofthe same tooth.



PROCEDURE:

For finding PCD, module, addendum, dedendum and clearance:

1. First find the blank diameter, OD by a vernier caliper and also count the number of teeth T of the spur gear.
2. Next calculate pitch circle diameter D=(TxOD)/(T+2)
3. Find addendum, clearance, pitch, module and dedendum as per theformulae given in the theory.

FOR CHORDAL TOOTH THICKNESS (using gear tooth calliper):

1. Set the chordal depth (addendum) on the vertical slide of the geartooth vernier and then insert the jaws of the instrument on the tooth tobe measured.
2. Adjust the horizontal vernier slide by the fine adjusting screw so thatthe jaws just touch the tooth.
3. Read the horizontal vernier slide and note the reading. It gives thechordal thickness of tooth.
   Repeat the observations for the different teeth.
4. Compare the values of different characteristics with the standard value and set the percentage error.

OBSERVATION:

Least count of caliper= 0.02mm

Number of teeth= 40

TABLE FOR SETTING GEAR TOOTH CALLIPER FOR SPUR GEAR NO. OF TEETH

	30	32	34	36	38	40	42
CHORDAL THICKNESS							
HEIGHT OF TOOTH							

CHORDAL THICKNESS:

S NO	M.S.R	V.S.R	CHORDAL THICKNESS (M.S.R+V.S.R*L.C)	VERIFICATION (VERNIER CALIPER)
1.				
2.				

HEIGHT OF THE TOOTH:

S NO	M.S.R	V.S.R	CHORDAL THICKNESS (M.S.R+V.S.R*L.C)	VERIFICATION (VERNIER CALIPER)
1.				
2.				

CALCULATIONS:

1. Pitch circle diameter, D= (TxOD)/(T+2)=
2. module, m=D/T mm=
3. Addendum=m=
4. Dedendum=m+0.157m=

CONCLUSION: Hence we have various gear parameters of gear using verniergear caliper.

EXPERIMENT NO. 6

TITLE: Study of optical surfaces using optical flat interferometer.

APPARATUS: Optical Flat, Mercury lamp etc.

THEORY: Light can be considered as an electromagnetic wave of sinusoidal form. High point and low point of the wave are called as crest and trough resp. the distance between a consecutive crest and a trough is called as wavelength λ. Maximum displacement of the wave is called as "amplitude". Velocity of transmission is λ\T where T is the time provided. Wavelength has a precise value and form.

INTERFFERANCE OF TWO RAYS:

Let us consider effect of combining two monochromatic rays of light ofintensity having amplitude A1 and An.

1. If they have combined with each other, the resultant effect is production of maximum illuminator and the resultant amplitude of addition af A1 and An.
2. If they combine in such a way that the crest of one and trough of otherare simultaneous then they are said to out of phase by λ/p or 180°.

LIGHT SOURCE INTERFEROMETER

For simple applications like testing of surfaces, it is used. However satisfactory operation requires use of light sources such as mercury, Krypton, Thallium, Helium and gases in this sources discharge lamp is charged with one particularly element excited elastically so that they radiate at a certain wavelength.

INTERFEROMETER APPLIED TO FLATNESS TESTING:

The essential equipment is monochromatic light source and a set of optical flats having its 2 plane surfaces flat and parallel and surfaces are finished to an optical. The importance of optical flat is operation in light wave measurement because all inspection operation are performed with referenceto the surface of optical flat.

If an optical flat is placed upon another optical flat facing the reflecting surface, it will not form an important contacting but will lie at some angle making and if optical flat now be illuminated by monochromatic surface of light, eye placed in proper position will observe number of bonds produced by interference of light wave reflected from lower surface of other flat through thin layer of air between two flats is monochromatic light of surface of wave of incident beam from 5 is particularly reflected thus recommended by the eye having traveled path whose length will differ by an amount ACD.

OPTICAL FLAT: They are cylindrical in form with working surfaces and are of twotypes

Type A: Only one surface flat.

Type B: Both surfaces flat and parallel to each other.

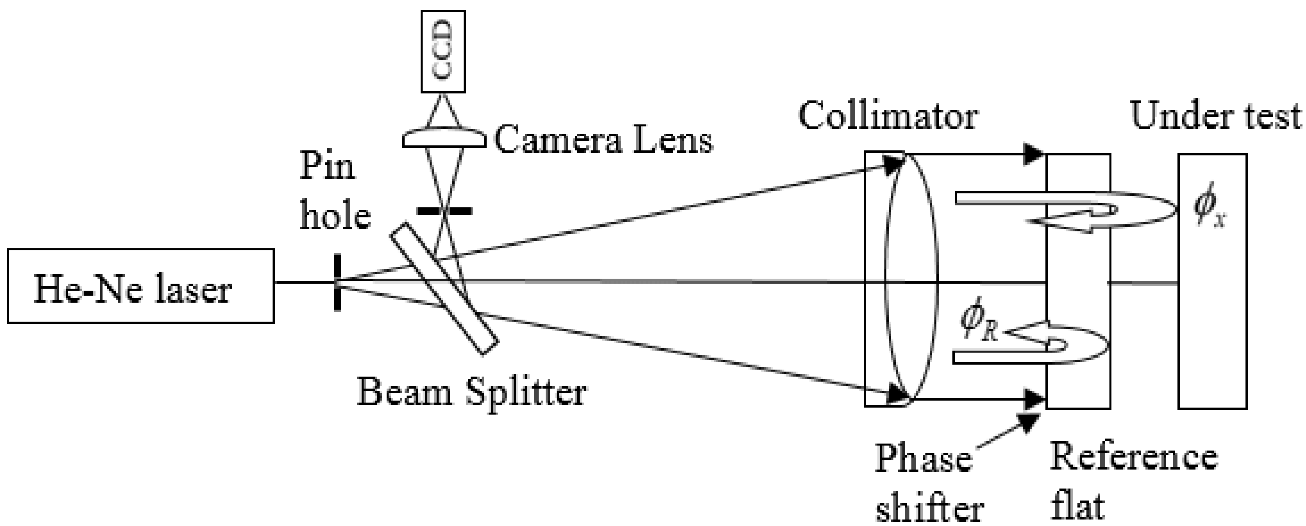
PROCEDURE:

FLATNESS TEST:

Light from the mercury lamp is focused on to an operating piece. In eyepiece, particularly reflected light collimating lens which collimates through it. Further leveling arrangement is provided on a table.

PARALLEL TEST:

Light from the mercury vapor lamp is focused on the eyepiece and particularly reflected by a beam splitter. The reflected light strikes illuminated lens which collimates it and through it further on optical flat under test. The flat under test is placed on the table provided with leaving arrangement.



CONCLUSION: Hence we have studied about surface flatness using optical flat for different surfaces we got different patterns as follows: Flat surface: Straight lines, Concave surface: Concentric circles moving away from center.

EXPERIMENT NO. 7

TITLE: Study and applications of optical profile projector.

APPARATUS: optical Profile Projector

THEORY: By using lenses and beams of light, profiles of small shapes can be magnified. The enlarged image can be compared with accurate drawing made tothe scale of magnification. Such a comparison can reveal any deviations in the sizes and contours of the objects and to get a numerical assessment of such deviations, measurements can be made on the enlarged shadow. The measured dimensions on the shadow will then have to be divided by the multiplication factor. The projection apparatus used for this purpose is termed as an optical profile projector. The essential features of a profile projector are that, it should beaccurately as stated and that there should be maximum latitude in holdingand adjusting the work piece and examining the projected shadow.

OBSERVATION TABLE:

S NO	PARAMETER	INITIAL READING (MM)	FINAL READING (MM)	ACTUAL READING (MM)
1.	Major Diameter			
2.	Bore Diameter			
3.	Thickness of Slot			
4.	Length of Slot			

S NO	PARAMETER	INITIAL READING (MM)	FINAL READING (MM)	ACTUAL READING (MM)
1.	MAJOR DIAMETER			
2.	MINOR DIAMETER			
3.	PITCH			
4.	ANGLE			

CONCLUSION: Thus diameter of given component, thread pitch of thecomponent is measured by profile projector.

EXPERIMENT NO. 8

TITLE: Assignment on Control charts.

INTRODUCTION:

What are Control Charts?

Control charts are graphic representations of a collection of data points from a particular process over a period of time. They contain a centerline representing the process average or expected performance, as well as, upper and lower control limits that set bounds for an acceptable area of deviation from the centerline.

How are Control Charts Used?

After a sufficient amount of data points have been plotted, it can be determined if a process is "in control" as shown in Fig. 1 or "out of control" as shown in Fig. 2 and 3.

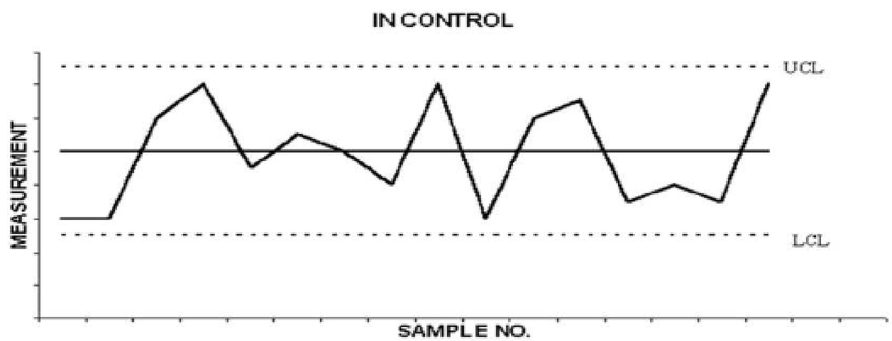


Fig.1

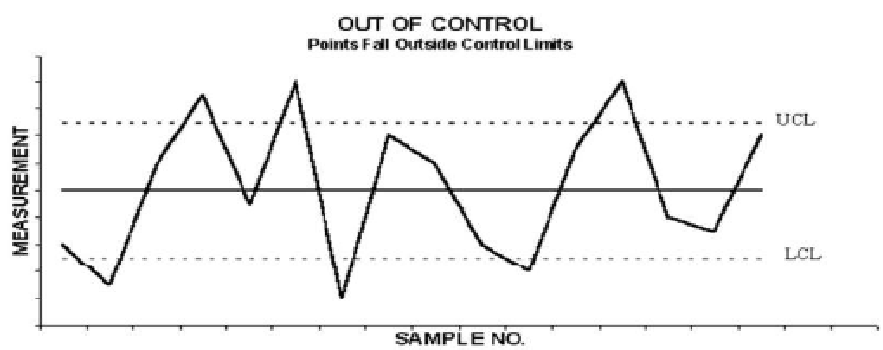


Fig.2

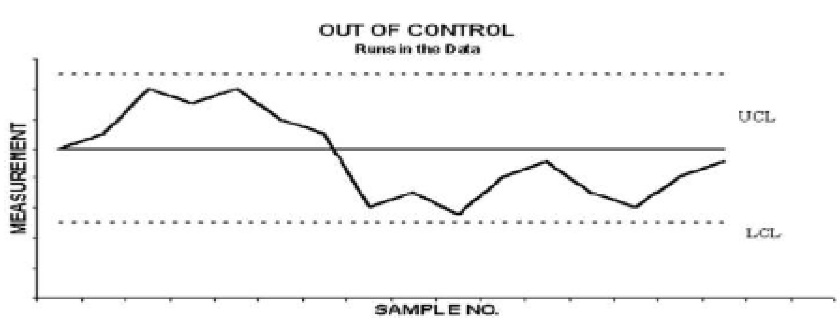


Fig.3

Data points falling outside the upper and lower control limits, as in Figure 2, would be investigated to determine the root cause for the deviation. As these causes are understood, corrective actions can be taken to prevent future "out of control" data points. While the data points in Figure 3 are all within the tolerance levels, the long running periods above or below the centerline indicate a change or shift in the process has occurred. The point at which the shift occurred should be investigated, so corrective action can be taken to bring the process back into control. Control charts are commonly used in manufacturing and industrial processes, but they can also be applied to any process where there is a need to monitor and control variation. Some common applications of control charts include.

Quality control: Control charts are often used in manufacturing to monitor the quality of products being produced. By tracking key process variables over time, such as the size or weight of a product, manufacturers can identify when a process is operating outside of its expected range of variation and take corrective action. 2. Process improvement: Control charts can also be used to identify areas where a process can be improved. By analyzing the data collected on a control chart, process engineers can identify sources of variation and develop strategies to reduce that variation and improve the process. 3. Healthcare: Control charts are also used in healthcare settings to monitor patient outcomes and identify areas for improvement. For example, a control chart could be used to track the number of patients who develop infections after surgery. If the number of infections exceeds the expected range of variation, healthcare providers can investigate the cause and implement corrective actions. 4. Financial services: Control charts can be used in financial services to monitor financial processes and identify unusual transactions or patterns of behavior. For example, a control chart could be used to monitor the number of customer complaints received by a bank. If the number of complaints exceeds the expected range of variation, the bank can investigate and address the underlying issues.

P and C charts are two types of control charts that are used in statistical process control to monitor and control the proportion of nonconforming items or defects in a process. P Charts: A P chart, also known as a proportion chart, is used to monitor the proportion of nonconforming items or defects in a process. It is a type of control chart that is used when the sample size is constant, and the number of nonconforming items or defects can be counted. P charts are used to detect if the process is stable or if there is a significant change in the proportion of nonconforming items or defects.

C Charts: A C chart, also known as a count chart, is used to monitor the number of defects in a process when the sample size is not constant. It is a type of control chart that is used when the number of nonconforming items or defects is not counted, but instead, the total number of defects is counted. C charts are used to detect if the process is stable or if there is a significant change in the number of defects.

In both P and C charts, the data is collected in subgroups over time, and the sample statistics are plotted on the control chart. The control chart includes upper and lower control limits, which are calculated based on the historical data, and a centerline, which represents the average proportion of nonconforming items or defects.

Methodology: **-** The methodology of P and C charts involves the following steps:

1. Define the process: The first step is to define the process being monitored and determine what constitutes a nonconforming item or defect.

2. Determine the sample size: For P charts, the sample size is constant, while for C charts, the sample size may vary. The sample size should be selected based on the process and the level of precision desired.
3. Collect data: Data is collected in subgroups over time, with each subgroup containing the sample size. 4. Calculate the sample statistics: The proportion of nonconforming items or defects is calculated for each subgroup for P charts, and the total number of defects is calculated for each subgroup for C charts. 5. Calculate the control limits: The upper and lower control limits are calculated based on the historical data using statistical techniques such as the binomial distribution. P-charts display the fraction of outcomes of a process which do not, or do obey some rules. The lower and upper control limits are again set in a way that the probability of a fraction falling outside these limits is quite low (i.e. <1 %). The lower control limit may often fall below zero, which does not make any sense in connection with fractions; in this case the lower control limit is set to zero. The control limits are usually set by the following equations:

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

and

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

With being the mean of n proportions considered. Note that the band of tolerance is given by +/- 3 standard deviations of the distribution of proportions (binomial distribution). A c-chart is quite similar to the p-chart, except that in this case the special outcomes (like defects) of a process are counted. The control limits are given by

$$LCL = \bar{c} - 3\sqrt{\bar{c}}$$

and

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$

Again forming a band of +/- 3 standard deviations of an assumed Poisson distribution. Plot the data on the control chart: The sample statistics are plotted on the control chart, with the centerline representing the average proportion of nonconforming items or defects. 7. Analyze the results: If the data points on the control chart fall within the control limits, the process is considered stable, and no further action is required. However, if the data points fall outside the control limits, the process is considered out of control, and corrective action must be taken to identify and eliminate the source of variation. 8. Take corrective action: If the process is out of control, the cause of the variation must be identified and eliminated to bring the process back into control.

Example 1: ABC Manufacturing produces thousands of tubes every day. A Quality inspector randomly draws samples for 20 days and reports the defective tubes for each sample size. Based on the given data, prepare the control chart for the fraction defective and determine the process in statistical control.

Example 2: Mobile charger supplier drawn randomly constant sample size of 500 chargers every day for quality control test. Defects in each charger are recorded during testing. Based on the given data, draw the appropriate control chart and comment on the state of control.