Department of

Mechanical Engineering

LAB MANUAL

MMM

B.Tech–3rd Semester

KCT College of Engineering & Technology

Village Fatehgarh (Distt. Sangrur)

LIST OF EXPERIMENTS

1.Measurement with the help of vernier caliper and micrometer

2. Measurement of an angle with the help of sine bar

3. Measurement of surface roughness

4. Measurement of gear elements using profile projector

5. Three wire method to determine effective diameter of external threads

6. Measurement of thread element by Tool makers microscope

7. Calibration of a pressure guage with the help of a dead weight guage tester

8. Use of stroboscope for measurement of speed of shaft

9. Use of pilot tube to plot velocity profile of a fluid through a circular duct

10. Preparation of a thermocouple, its calibration and application for temperature measurement

EXP:1 Measurement with the help of Vernier Calliper and Micrometer.

INSTRUMENTS USED :

1. Vernier Calliper
2. Micrometer
3. Jobs

1. VERNIER CALLIPERS :

PRINCIPLE AND WORKING OF VERNIER CALIPER :

The principle of vernier calipers is based on the difference between two scales or divisions which are nearly but not exactly equal. The difference between them is utilized to determine the accuracy of measurement. It consists of two scales, Main scale which is fixed and vernier scale which moves over the main scale.

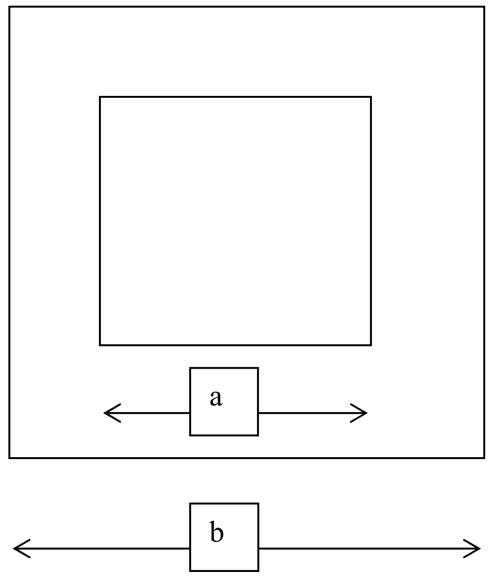
The difference between the value of main scale and vernier scale division is called least count. If the value of one small division on main scale is 0.5mm and the value of one small division on the vernier scale is 0.48mm. Then the least count of instrument is given by the difference of these two values i.e. 0.02mm.

PROCEDURE :

1. First of all, check the zero error of vernier scale by closing the two jaws. In this position, the zero of vernier scale should exactly match with zero of main scale.
2. The linear dimensions may be taken by placing the work piece between fixed and movable jaw.
3. The workpiece must be exactly perpendicular to the measuring surface.
4. The internal dimensions or internal diameter should be taken by using upper measuring jaws.
5. To obtain the reading, first count the number of divisions on main scale. The verniner scale is then examined to determine which of the divisions coincides with a division on main scale. Now calculate the value as ,

   Total Reading = Main Scale reading + (Least count x Vernier scale reading)

6. Repeat this procedure three to four times, and then calculate average value.



OBSERVATIONS :

Least count (L.C.) = ……………….

S. No.	Dimension (a)			Dimension (b)		
	Main scale reading (M.S.)	**Vernier Scale Reading (V.S.)**	**Total = [M.S. + L.C. x V.S.]**	**M.S.**	**V.S.**	**Total**
1.						
2.						
3.						

RESULT :-

The average value of dimensions is (a) = -----------------------mm
(b) = -----------------------mm

PRECAUTIONS :

1. Check the zero error of vernier before starting the experiment.
2. The parallax error must be avoided by proper positioning of observer.

EXP:2 Measurement of angles with the help of sine bar and height gauge .

APPARATUS :- **Sine bar, surface plate, height gauge, slip gauges and and dial gauge.**

THEORY: - The sine bar is one of the most widely used instrument for precision measurements of angles. It consists of a rectangular section bar of suitable grade steel having accurately ground pins of equal diameter, one at each end and lying on a line parallel to the axis of bar. The distance between the centers of these pins is arranged to be a standard, 125mm, 200mm, 250mm, 500mm etc.

The sine bar is based on the principle that in a right angled triangle the length of hypotenuse is kept constant. The sine of different angles can be obtained simply by varying the length of the perpendicular. As shown in the figure, in ΔABC, AB is the hypotenuse and if it is rotated round the point. A different length of perpendiculars BC will be obtained using the following relation:

$$\text{Sin } \theta = BC / AB = H / L$$

If AB is made 125mm the value of sine can readily be computed merely by dividing the measured height BC 125 and thus the measured height is in mm.

WORKING PRINCIPLE :- It is based on Trigonometric function Sin θ = side opposite angle / hypotenuse.

PRECAUTIONS AND CARE OF INSTRUMENT :-

(1) All the instruments should be cleaned properly.
(2) Any burrs and damage on work piece surfaces should be rectified.
(3) Zero error in any instrument likely to be checked and if so correct it.
(4) Readings should be taken carefully.
(5) In case of circular work piece sine bar should be clamped firmly with the angle plate.

SOURCES OF ERROR :-

(1) Improper cleaning of instruments or work piece.
(2) Damaged instruments and damaged work piece surface.
(3) Improper setting of instrument.
(4) Initial error in measuring instruments.
(5) Wrong observation of height gauge measuring head.
(6) Uneven pressure at two points of reading may lead to error.

OBSERVATION TABLE :-

S. No.	H1	H2	Sinθ = H2-H1/L	θ

(a)

S.NO.	H	Sinθ = H/L	θ

(b)

PROCEDURAL STEPS :-

(1) Clean the surface plate.

(2) Clean the sine bar.

(3) Clean the work piece, and ensure that there are no damages and burrs on the surfaces of work piece.

(4) If there are any burrs remove them by means of oil stone.

(5) Place the work piece on the surface plate with taper surface facing the surface plate.

(6) Place the sine bar on tapered surface of work piece with the rollers of sine bar in upward direction.

(7) Clean the base of height gauge properly.

(8) Mount the dial indicator on the height gauge.

(9) Set the dial indicator on the height point of one of the sine bar roller and put some pressure on dial indicator.

(10) Note the reading of dial indicator and height gauge scale.

(11) Set the dial indicator on second roller of sine bar.

(12) Bring the same reading on dial indicator by adjusting the height gauge.

(13) Note the reading of height gauge at the highest point of both the rollers of sine bar.

(14) Calculate the difference of two height gauge readings which will give the height (H) of one roller with respect to other.

(15) The center distance between the two rollers is known for a standard sine bar.

(16) Divide the height in step (14) by center distance between two rollers. This will give the sine of taper angle $\sin \theta = H / L$.

(17) Using sine tables or scientific calculator the value of taper angle can be calculated.

EXP:3 Measurement of surface roughness of given jobs.

INSTRUMENT REQUIRED: Surface plate, Talysurf instrument, Jobs

1.THEORY

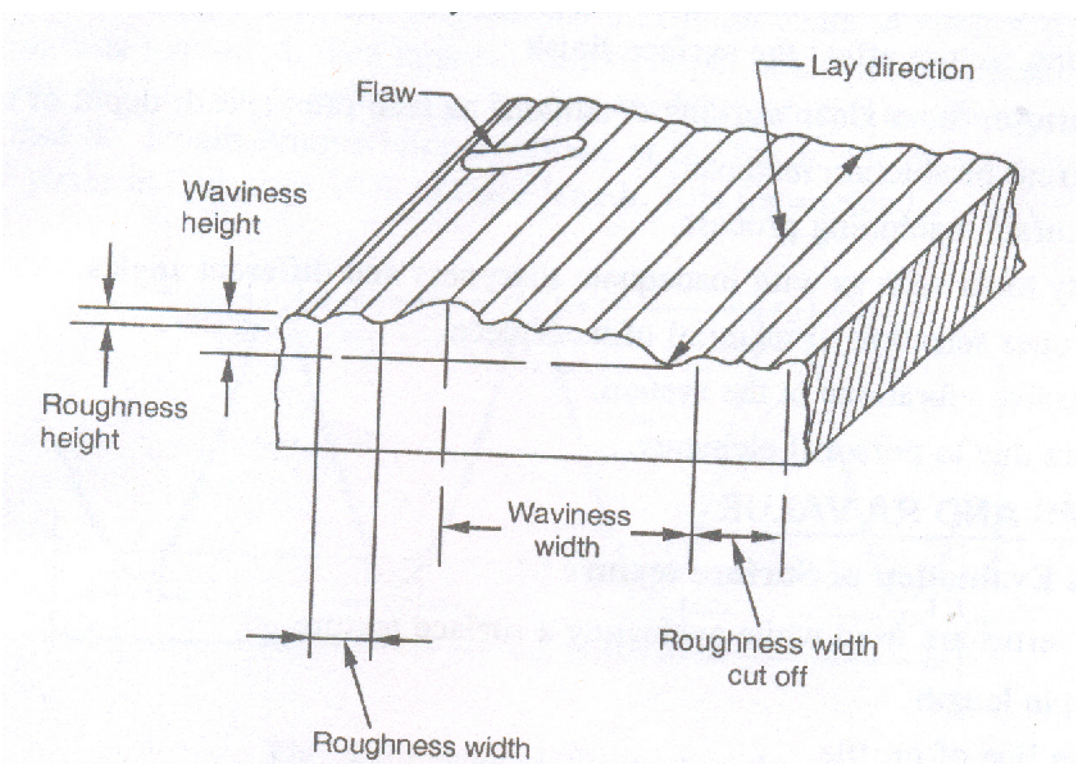
The irregularities on the surface of the part produced can be grouped into two categories:

1) Roughness and primary texture
2) Waviness and secondary texture

1) Primary surface (Roughness): The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting elements on the material i.e. cutting tool shape, tool feed rate or some other disturbances such as friction, wear and corrosion.

These are micro-geometrical errors in which the ratio lr / hr denoting the micro errors is less than 50, where lr = length along the surface and hr = deviation of surface from the ideal one.

2) Secondary texture (Waviness): The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities results due to inaccuracies of slides, wear of guides. misalignment of centers, non linear feed motion, deformation of work under the action of cutting forces, vibration of any kind etc.



These are macro-geometrical errors; the ratio of lw / hw denoting the macro-error is more than 50. Where lw = length along the surface and hw = deviation of surface from ideal one.

Thus any finished surface can be considered as the combination of two forms of wavelength superimposed upon each other. These two forms of irregularities superimposed on each other tend to form a pattern or texture of the surface.

Factors affecting surface roughness

- Vibration
- Material of the work piece
- Type of machining

- Rigidity of the system consisting of machine tool, fixture cutting tool and work
- Type, form, material and sharpness of cutting tool
- Cutting conditions; feed, speed, depth of cut
- Types of coolant used

Evaluation of surface finish

A numerical assessment of surface finish can be carried out in a number of ways. In practice, the following three methods of evaluating primary texture of a surface are used:

1) Peak to valley height method
2) The average roughness
3) Form factor or bearing curve

1) Peak to Valley height

It measures the maximum depth of the surface irregularities over a given sample length, and largest value of the depth is accepted as a measure of roughness.

2) Average Roughness: For assessment of average roughness the following three statistical criteria are used:

a) **C.L.A. Method:** In this method, the surface roughness is measured as the average deviation from the nominal surface.
   Centre line average or arithmetic average is defined as the average values of the ordinates from the mean line, regardless of the arithmetic signs of the ordinates.
   C.L.A value = (h1+h2+h3+h4+…+hn) / n
   C.L.A = (A1+A2+A3+…….An) / n

b) **R.M.S. Method:** In this method, the roughness is measured as the average deviation from the nominal surface. Root mean square value measured is based on the least squares.
   R.M.S value is defined as the square root of the arithmetic mean of the values of the squares of the ordinates of the surface measured from a mean line. It is obtained by setting many equidistant ordinates on the mean line (y1,y2, y3,….) and then taking the root of the mean of the squared ordinates.
   Let us assume that the sample length 'L' is divided into 'n' equal parts and y1, y2, y3,………yn are the heights of the ordinates erected at these points.
   RMS average =

c) **Ten Point Height Method**: In this method, the avg. difference between the five highest peaks and five lowest valleys of surface texture within the sampling length, measured from the line parallel to the mean line and not crossing the profile is used to denote the amount of surface roughness.
   Mathematically,

   R = ten point height of irregularities
   = 1/5 [(R1 + R2 + R3 + R4 + R5) – (R6+R7+R8+R9+R10)]

   This method is relatively simple method of analysis and measures the depth of surface irregularities within the sampling length. But it does not give any sufficient information about the surface, as no account is taken of frequency of the irregularities and the profile shape.

Statement of Surface Roughness

a) Surface Roughness Value: It is expressed as Ra value in microns. If a single Ra value is stated it is understood that any Ra value from zero to that stated is acceptable.
b) Limiting values: when both minimum and maximum Ra values needed to be specified these shall be expressed as

Ra 8.0/16.0 or Ra 8.0-16.0

c) Sampling length: The sampling length is indicated in parenthesis following the roughness value as follow: Ra 8.0 (2.5)
d) Lay: It is sometimes necessary to specify the direction of lay. It is expressed in accordance with the following example

   Ra 1.5 lay parallel
e) Process: When it is necessary to limit the production of a surface to the use of one particular process, the process shall be stated.

Conventional Method of Designing Surface Finish

a) Roughness value Ra value in microns
b) Machining allowance in mm
c) Sampling length
d) Machining / Production method
e) Direction of lay in the symbol form as =,⊥

Direct Instrument Measurement: These are method of quantitative analysis. This method enables to determine the numerical value of the surface finish of any surface by using instrument of stylus probe type operating on electrical principles. In this instrument the output has to be amplified and amplified output is used to operate recording or indicating instrument.

Working of Surface Meter (Taylor-Hobson-Talysurf): Talysurf is a stylus and skid type instrument working on carrier modulating principle. The measurement of the instrument consists of simply 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 surface irregularities and the oscillatory movement of the stylus is converted into changes into electric current by the arrangement shown in fig.1. The arm-carrying stylus forms an armature, which pivots about the centrepiece of E-shaped stamping. On two legs of (outer pole pieces) the E shaped stamping there are coils carrying the a.c. current. These two coils with other two resistances form an oscillator. As the armature is pivoted about the centre leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c. current flowing in the coil is modulated. The output of the bridge thus consists of modulation only. This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

Stylus type instruments generally consists of the following units:

1) Skid or shoe
2) Finely pointed stylus or probe
3) An amplifying device for magnifying the stylus movement
4) Recording device to produce a trace
5) Means for analyzing the trace.

PROCEDURE:

1. Properly set instrument and the job over the surface plate.
2. Skid or shoe is drawn slowly over the surface by motor drive. It follows the general contours of the surface and provides a datum for measurements. The stylus moves over the surface with a skid. It moves vertically up and down to surface roughness and records the micro-geometrical form of the surface. The stylus movement may be amplified by a amplifying device and recorded to produce a trace.
3. Note down the reading in terms of Ra or Ry.

OBSERVATION:

S.No.	JOB	Ra	Rz
1			
2			
3			

PRECAUTIONS:

1. The instrument and job is to be properly set over the surface plate so that stylus could move without any problem.
2. There should not be any burr on the job.
3. The job must be cleaned from any oil, dirt or dust.
4. Surface plate should be free from any oil, dust or dirt.

VIVA VOCE

1. What is the difference between primary and secondary texture?
2. What are the different methods for surface roughness measurement?
3. What is working principle of surface tester used in your lab?
4. Name the different factors, which affect surface roughness.
5. What do you mean by sampling length?
6. What is Lay?
7. Differentiate between Ra and Rz value.
8. What is Ra value of different machining processes?

EXP:4 THREE WIRE METHOD TO DETERMINE EFFECTIVE DIAMETER OF EXTERNAL THREADS.

INSTRUMENT USED:

1. Micrometer
2. Three wires
3. Jobs (i.e. whose effective diameter is to be measured)

1.THEORY:

In this method three wires of equal and precise diameter are placed in the thread grooves at opposite sides of the screw and measuring the distance M over the outer surface of the wire with the micrometer. Out of three wires in the set two wires are placed on one side and the third on the other side. The wires are held either in hand or secured in the groove by applying grease in the thread. These wires may also be hung on through thread on a stand. This method ensures the alignment of micrometer anvil faces parallel to the thread axis. Therefore this method of measuring effective diameter is more accurate.

These wires are made of hardened steel and are lapped to sizes suitable for various pitches. For each pitch of thread there is a 'best size' wire; this is of such diameter that makes contact with the flanks of the thread on the effective diameter or pitch line.

$M = De + d\,(1 + \operatorname{cosec} \alpha/2) - p/2 \cot \alpha/2$

M = distance over the wires

De = effective diameter

R = radius of wire

d = Diameter of wire

Effective diameter:

2. PROCEDURE

1. The three wire method of measuring the effective diameter of a screw thread is shown in figure
2. Three wires of equal and precise diameter are placed on the thread grooved at opposite sides of screw thread.
3. Two wires are placed on one side and one wire at another side. This arrangement of setting wires ensures the alignment of micrometer anvils faces parallel to the thread axis.
4. Micrometer reading over wires is taken. Let it be M.
   Hence effective diameter is calculated as:
   $De = M - Q$
   Where Q is a constant, which depends upon wire diameter d and flank angle α

3. PRECAUTIONS:

1. The zero error of micrometer must be checked before using it.
2. The measuring surface of anvil and spindle must be free from dust, dirt or oil.
3. The measuring surface must be square to the measuring spindle.
4. Ensure that wire makes contact with the flanks of the thread on the effective diameter or pitch line.
5. Use ratchet to avoid error due to application of excessive diameter.

VIVA VOCE

1. What do you mean by best wire size?
2. What is the advantage of three wires method over two wires method?
3. What is the material of wires used in the measurement?
4. How three wire methods is differ from two wire method?

EXP:5 TOOL MAKER MICROSCOPE.

1.0 INTRODUCTION :

Tool maker Microscope is a highly precision and versatile microscope designed as per international standards and equipped with achromatic optical system to offer erect image of natural orientation and free from distortion for most diversified jobs in tool room workshop such as linear measurements in rectangular co-ordinates and angular measurements in complex works process such as electronic components, semi conductors chips small gauge , watch pars and micro components.

All mechanical and optical components have been ideally designed and constructed minimizing to severest tolerance to guarantee the highest degree of measuring accuracy and those operation.

2.0 SPECIFICATION :

Magnification	:	30 x (Standard)
Objective	:	2 x
Eye Piece	:	W.f. 15 x, with cross reticle
Field of View	:	8 mm, diameter
Working Distance	:	115 mm (approx)
Image	:	Erect Image
Observation Table	:	Monocular inclined at 30^0
Stand	:	Large and heavy base provide extra overall rigidity to the instruments.
Measuring Stage in each direction, micrometer mm.	:	150 x 150 mm, size travel up to 50 mm equipped with zero adjustment heads having least count 0.01
Eyepiece Protractor minutes.	:	Graduated 0 to 360^0 with adjustable vernier of least count 6
Illumination lamp and variable	:	Built in base Transmitted from Halogen incident light from two lamps with separate control on front panel.

3.0 TECHNICAL DATA :

(a) MEASURING STAGE :

Stage Dimensions	:	150mm x 150mm
Measuring range longitudinal	:	25 mm
Measuring range transverse	:	25 mm
Scale unit of measuring spindles	:	0.01 mm (10 microns)

(b) ROTATING STAGE :

Diameter of mounting surface	:	125 mm
Rotating Range	:	0-360 degree
Vernier Reading	:	6 min.
Diameter of glass insert	:	80 min.

(c) CENTER HOLDING DEVICE :

Maximum distance between centers	:	100 mm
Maximum mounting diameter	:	70 mm
Rotation ranges horizontally	:	0-360 degree
Scale unit of rotation	:	10 degree

Maximum opening of rotating chuck : 6.5 mm dia.

(d) DEPTH MEASURING GAUGE :

Measuring range in one stroke : 10 mm
Scale unit : 0.01 mm

(e) TRANSMITTED LIGHT ILLUMINATOR

Filament Lamp : 6V- 20 W

(f) INCIDENT LIGHT ILLUMINATOR

Filament Lamp : 6V-20 W

(g) OBSERVATION OPTICAL TUBE

Standard tube length : 160 mm
Maximum coarse motion travel : 200 mm

(h) OPTICS

Super wide field eye piece : 15 x
Lower Power achromatic objectives : 2 x

(i) OPTICAL COMBINATION & MAGNIFICATIONS CHART

W.F./H. Eye Piece	Achromatic Objectives
	2 x
15 X	30 x

(j) MEASURING & MICROMETER VALUES ;

Insert a micrometer eyepiece in the optical tube. Length measurements in the specimen plane can be carried out with the micrometer eye piece by first observing how many divisions of the scale visible in the eye piece correspond to the specimen length to be measured, this number is then multiplied by the micrometer value M in um (1 um=0.001 mm = 1 micron).

(k) DETERMINING THE MICROMETER VALUE :

For every accurate measurement it is advisable to determine the micrometer value by means of the stage micrometer, which is graduated in 0.01 mm.

After focusing both on the eyepiece reticle and on the graduation of the stage micrometer, the eyepiece is rotated in the microscope tube so that the two distances to be measured are exactly parallel. The stage micrometer is then moved until the zero points of the two distances concides, and the two graduations just over lap.

Now read how many divisions of the stage micrometer i.e. how many multiples of 0.01 mm correspond to 100 divisions of the eyepiece reticle. From this is very easy to calculate the micrometer value, which indicates the number of microns (um) corresponding to 1 graduation of the eyepiece scale.

(I) EXAMPLE ;

Achromatic Objective : 10x
Measuring Eye piece Micro : 5 x
Eye piece scale : Stage Micrometer
100 Div : 18 Div
1 Div : 0.01 mm = 10 um

18 Div	:	0.18 mm = 180 um
1 Div	:	18 um = M

The micrometer value (M) is therefore 18 um.

4.0 Construction of Microscope :

BASE :

The sturdy base rest on the three support two of which are adjustable for leveling the instruments. The base has built in all electrically transformers and their control panel and transmitted illuminator with green filter.

ARM :
The arm has a grove guide on which the microscope tube is vertically adjusted rack and pinion system.

FOCUSSING MECHANISM :
The course focusing movement is provided in the microscope tube separately. The coarse motion is knurled knob on both side of the tube and has the total travel of 200mm. It also lock any position by lever. This movement is characterized by its exceptionally smooth and accurate precision. The depth dial gauge can read the vertical travel or measurements up to 10 mm thickness. The thickness is being measured with the difference of two different focusing of object. The least count of gauge is 0.01.

EYE PIECE PROTRACTOR :
This unique protractor head graduated 0 to 360 degree with adjustable vernier reading to 6 minute cross line incorporated in the protractor head rotating in the optical axis of the microscope. The cross line graticule is replaceable with many other measuring graticules.

MEASURING STAGE :
The stage plate is of 150x150 mm having very smooth and precise movements in both axis with special ball racers arrangement. The travel of the stage is 25 mm in both direction with precise imported Micrometer head, least count 0.01 mm.

ROTARY STAGE :
A rotating stage is fixed in T-slots of square stage plate having 360 degree graduations on its periphery with vernier reading to 6 minute and lock screw. All types of horizontal angular measurements can be done with this stage.

ILLUMINATION SYSTEMS :
Two possible ranges of illuminating systems are provided with standard equipment to meet every application, operated through 6 volts solid state variable light control built in transformer.

1. Sub state transmitted light from a bottom source providing collimated green filter. Halogen light for viewing contours and transparent objects.
2. Surface incident illuminator for shadow free lighting, for high power examination of opaque objects.

5.0 Ray Diagram Of Tool Maker Microscope :

Ray Diagram is as shown in fig.

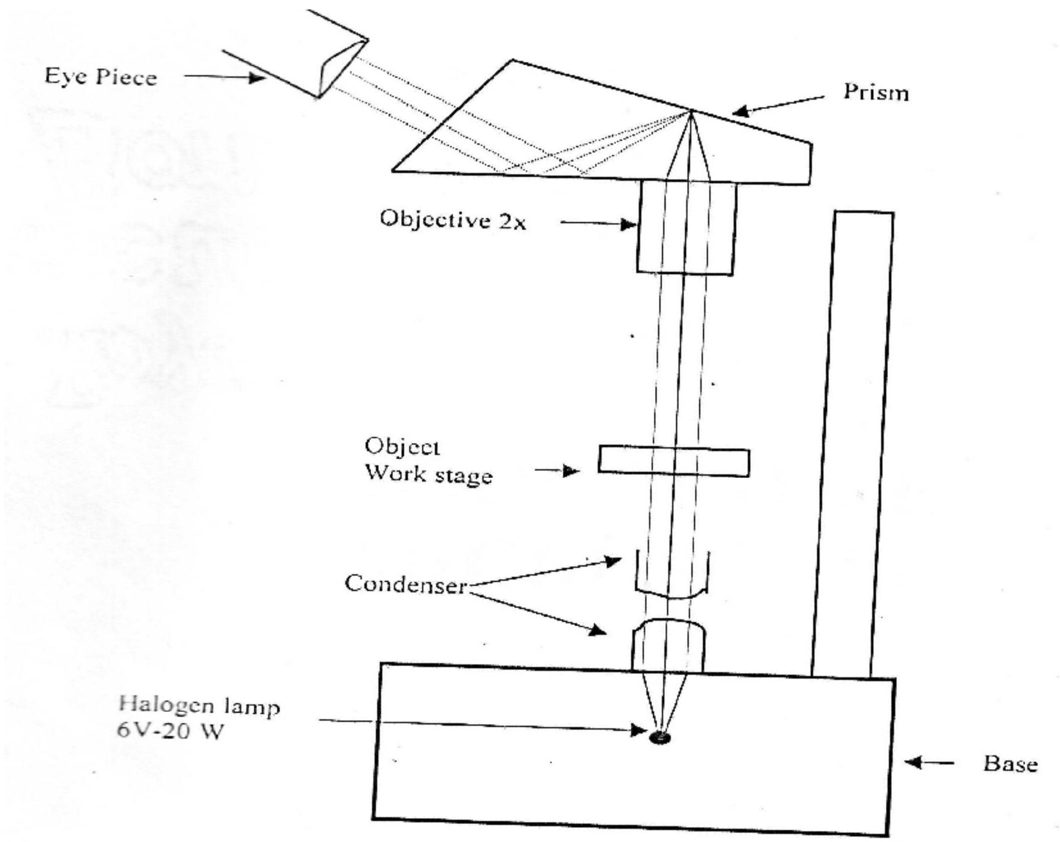


Fig 1

FORMULAE:

1. Actual time period, T_{act} = t / n

2. Actual radius of gyration, k_{act} from the equation

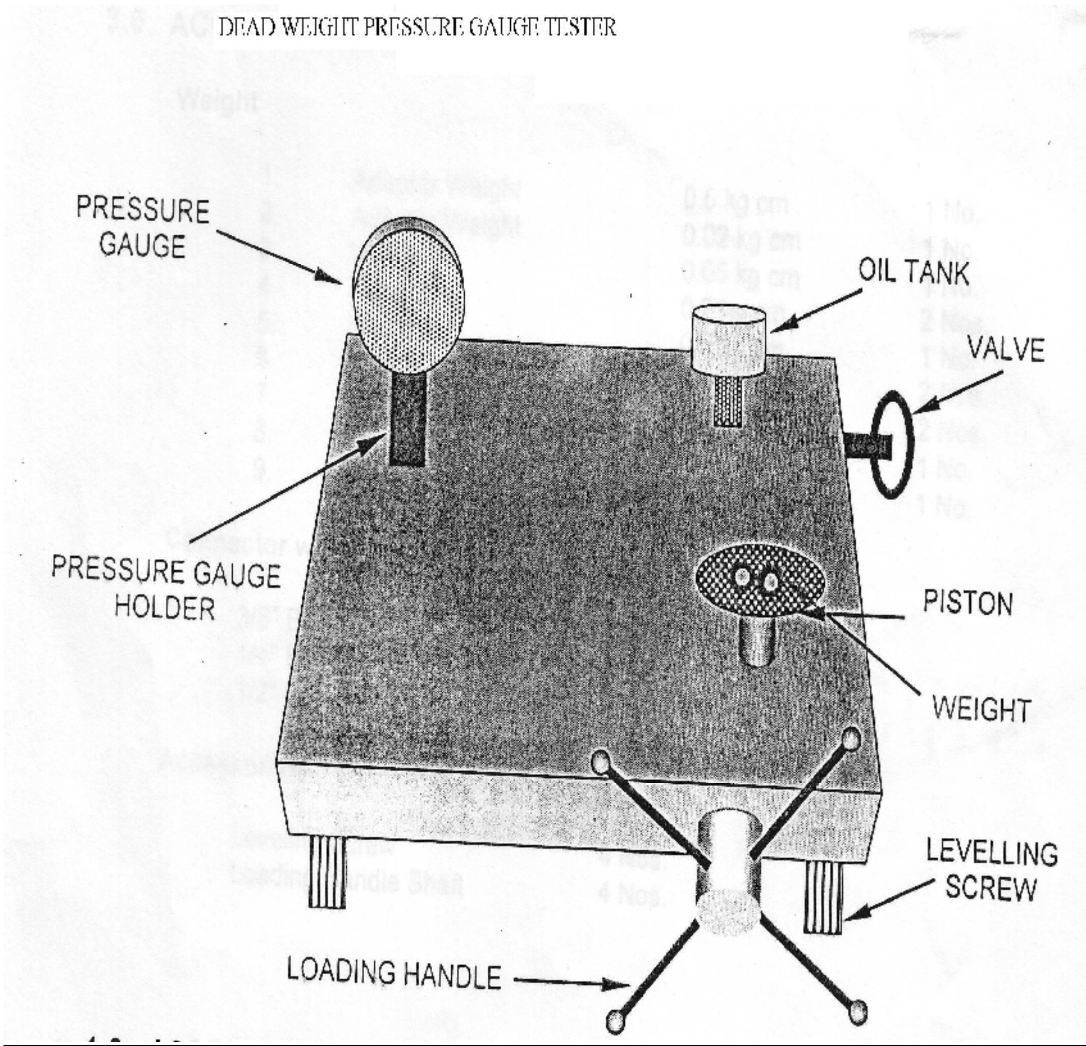
$$T = 2\pi\sqrt{\frac{k^2 + (OG)^2}{g(OG)}}$$

3. Theoretical radius of gyration, k_{Theo} = $\frac{L}{2\sqrt{3}}$

OBSERVATION & CALCULATION TABLE:

Sr. No.	L cm.	OG	No. Of Osco. N	Time for Osco.	T act.	K act.	K Theoretical
1							
2							
3							

EXP: 6 DEAD WEIGHT PRESSURE GAUGE TESTER.



1.0 ASSEMBLY:

Place the machine on the table top (vibration free environment), connect the four labeling screw as usual. Place four handle shaft on the loading handle. Open the oil tank & fill servo grade-60 oil to tank place a spirit level on top of piston than adjust the labeling screw.

2.0 TESTING PROCEDURE :

Open the locknut for pressure gauge holder than take your required adapter place the pressure gauge on it tightenly. Release the valve & wait a minute then rotate the loading handle clockwise then lock the valve. There are two type of loading adapter one for low capacity (0.1 kg cm) & another for high capacity (0.5 kg cm). Place your required loading adapter & weight on the top of piston then slowly rotate the loading handle anticlockwise & observe the reading on your pressure gauge. After completing then reset the loading handle clockwise & release the valve. Detach the pressure gauge place the locknut.

3.0 ACCESSORIES & WEIGHTS :

Weight :

1.	Adapter Weight	0.5 kg cm	1 no.
2.	Adapter Weight	0.02 kg cm	1 no.
3.	Weight	0.05 kg cm	1 no.
4.	Weight	0.2 kg cm	2 nos.
5.	Weight	0.5 kg cm	1 no.
6.	Weight	2.0 kg cm	2 nos.
7.	Weight	5.0 kg cm	2 nos.
8.	Weight	1.0 kg cm	1 no.
9.	Weight	0.1 kg cm	no.

Connector with washer :-

3/8 ’’ BSP	1 No.
1/4’’ BSP	1 No.
1/2 ’’ BSP	1 No.

Accessories :

Leveling screw	4 Nos.
Loading Handle Shaft	4 Nos.

EXP:7 **INSTRUCTIONS FOR PREPARATION AND CALIBRATION OF THERMOCOUPLE.**

Introduction :

A thermocouple is a thermoelectric device that converts thermal energy into electric energy. The Thermocouple is used as a primary transducer for measurement of temperature converting temp. Changes directly into e.m.f. It is a bimetallic device consisting of two wires. The thermocouple provided with this set up is chromel alumel.

If the junction of the thermocouple is heated then the thermoelectric e.m.f. developed across its terminals depends upon the difference in temperature between its cold and hot junction of thermocouple.

Temperature measurement has many applications. Areas include process plant, sugar mil etc.

Experimental Procedure :

Preparation of Thermocouple :

Step 1 : Select a wire of Cr Al type.

Step 2 : File the two ends of the wire nearly a ¾ '' length such that two individual wires of Cr and Al are visualize.

Step 3 : Separate the two wires.

Step 4 : Twist the both ends of the simultaneously.

Step 5 : Pour the mercury in the dish.

Step 6 : Connect one end of the copper strip (supplied with the apparatus) in the variac and other end in the mercury dish.

Step 7 : Connect one twisted end of the wire to the variac.

Step 8 : Connect the variac to mains and set the voltage to 30-50 volts.

Step 9 : Now dip the other twisted end to the mercury dish. Note that the twisted end just touches for a second. Tipped end results in a formation of a ball. If it does not then increase the voltage.

Step 10 : Thermocouple is ready.

Calibration of Thermocouple :

Step 1 : Now disconnect the two ends of the thermocouple wire (which is connected to the variac) and connect them to the digital temperature indicator. First end connected is of Cr wire while second end is of Al wire.

Step 2 : now fill the ice in the beaker provided.

Step 3 : Now dip the ball end of the thermocouple in the beaker. Also dip a thermometer. Check that the thermometer and temperature indicator reads the same reading. Temperature indicator must indicate the 0^0C or as shown by the thermometer.

Step 4 : now place the immersion rod in the beaker and start the heating till the boiling of water.

Step 5 : Now dip the ball end of the thermocouple in the beaker. Also dip a thermometer. Check that the thermometer and temperature indicator reads the same reading. Temperature indicator must indicate the 100^0C or as shown by the thermometer.

Step 6 : This is the calibration of thermocouple.

Note :-

If the indicator does not indicate the readings of 0^0C and 100^0C then check the connections and as well as the ball end of the thermocouple.

Also check that the ball end must not touch the bottom of the beaker.

Thermocouple must also not touch the immersion rod.

Compare the results obtained with a standard thermometer.

EXP:8 PITOT TUBE APPARATUS.

APPARATUS: **Pitot tube apparatus with inclined 'U' tube differential manometer, vernier caliper, stop watch etc.**

THEORY:

The flow rate in a pipeline running full and under pressure can be computed by measuring the velocity of flow at a number of points in the cross section. Pitot tube is such an instrument used to determine the velocity of flow at a point in a pipe or a stream. Pitot static tube can be installed in a pipeline in such away that it can be traversed across the section and a series of flow velocity measurement taken. Pitot static tube in its simplest form is bent through 90^0 as shown in Fig. 1

The tube senses the stagnation pressure at its top or head and the static fluid pressure around its periphery. These two pressures are transmitted to the limbs of a manometer.

The total head of fluid can be represented by

$$p/\rho g + V^2/2g$$

i.e. the pressure head and the velocity head.

The peripheral static tapping can be represented by

$$p/\rho g$$

Where, p = Pressure intensity

V= Velocity of liquid flow.

ρ = Density of fluid

g = Acceleration due to gravety.

As these are opposed on the manometer, the differential reading is equal to the $V^2/2g$, thus enabling the velocity to be calculated. The difference in pressure is called dynamic pressure or velocity head. Generally velocity of liquid flow V, can be measured by

$$V = C\sqrt{2gh}$$

Where 'C' takes into account the various form of losses and 'h' is the difference of pressure head.

DESCRIPTION :

The experimental set up consist of a circuit through which the fluid is circulated continuously having a pitot tube on the downstream side of the pipe. A regulating valve is provided on the downstream side of the circuit to regulate the flow. The pipe has a provision for fixing the pitot tube with gauge to fix the pitot tube at different positions across the diameter. The pitot tube is provided with two tappings one each for stagnation pressure and static pressure. These are further connected to two limbs of 'U' tube manometer. An inclined 'U' tube manometer is provided to measure the pressure difference between two sections. A collecting tank is used to find the actual discharge through the circuit, by direct measurement of volume collected and time taken.

STANDARD DATA :

Diameter of pipe, cm	= 5cm
Area of cross section of pipe, cm^2	= $19.6375 cm^2$
Inclination of the manometer, θ	= 15^0
Slope of inclined manometer, $\sin 15^0$	= 0.2588
Area of collecting tank (upper)	= $40 \times 40\ cm^2$
Diameter of pitot static tube, 'D', cm	= 0.65cm

Reading of pitot static gauge while touching bottom of conduit, h_0 = (from experiment)

Reading of pitot static gauge take on different position, h_f = (from experiment)

COEFFICIENT OF PITOT TUBE

Discharge Measurement					Manometer Reading				
S. No.	*Initial water level* *(cm)*	*Final water level* (cm)	*Time* *(sec)*	*Discharge, Q,* *(cm^3/sec)*	Left limb h_2 *(cm)*	Right limb h_2 (cm)	*Difference of head on vertical scale* $h = (h_1 - h_2) \sin\theta$ (cm)	$V = \frac{Q}{A}$	$C = \frac{V}{\sqrt{2gh}}$

VELOCITY DISTRIBUTION PROFILE

S. No.	Reading of pitot static gauge h_f (cm)	$Y = h_f - h_0 + D/2$ (cm)	Manometer reading		Difference of head on vertical scale $h = (h_1 - h_2) \sin\theta$ d(cm)	$V = C\sqrt{2gh}$
			Left limb h_1 (cm)	Right limb h_2 (cm)		

PRECAUTIONS :

- Apparatus should be in levelled condition.
- Holes of pitot static tube must be free from dust and be kept open.
- There should not be any air bubble in the manometer.
- Reading must be taken in steady conditions.
- Position of pitot static tube should be varied in uniform small steps.

PROCEDURE :

1. Note down the relevant dimensions as internal diameter of pipeline, outer dia of pitot tube and inclination of manometer, volume of collecting tank.
2. Connect pressure tapping of pitot tube to the manometer by means of flexible tubes.
3. Set the flow to full position by maintaining this amount of steady flow in the pipe circuit, there establishes a steady and uniform flow in the conduit. Time is allowed to stabilize the levels in the manometer tube.
4. The discharge flowing in the circuit is recorded together with the water level in left and right limbs of manometer tube.

5. From the reading taken above calculate discharge, velocity, coefficient of pitot tube and plot the velocity profile.
6. Change flow control valve is set at ¾ open position. Take all the readings for different position of pitot tube again and repeat the procedure in step no. 5.
7. Repeat the experiment and get results for other discharge value like ½ & ¼ open positions.
8. Now observe the difference between the velocity profile curves.

RESULTS :

1. Draw the velocity profile i.e. plot between radial distance and velocity of flow i.e. 'Y' v/s 'V' on a simple graph paper.
2. 'C' lies between 0.9 to 1.0 as result of the small energy loss.
3. First reading of tube position is not velocity at the wall of the pipe, but at a distance of D/2 from the wall.

EXP:9 To Design A Limit Gauge.

Theory:

To a greater or lesser extent, every gauge is a copy of the part which mates with the part for which the gauge is designed. For example, a bushing is made which is to mate with a shaft; in this case, the shift is the opposed (mating part) part. The bushing is checked by a plug gauge, which in so far as the form of its surface and its size is concerned, is a copy of the opposed part (shaft).

If a gauge is designed as an exact copy of the opposed part in so far as the dimension to be checked is concerned, it is called a 'Standard Gauge'.

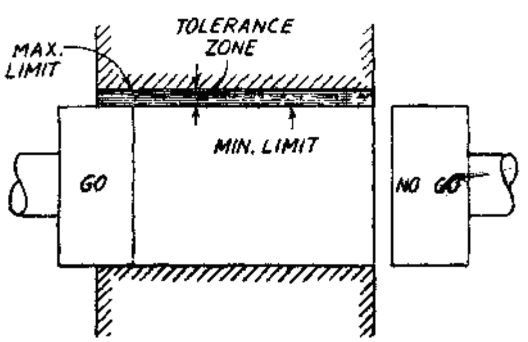
In design of a gauge, simplicity should be the main aim as simple gauges can take measurements continuously and accurately.

1. **Taylor's Principle.** According to Taylor, 'Go' and 'No go' gauges should be designed to check maximum and minimum material limits which are checked as below.

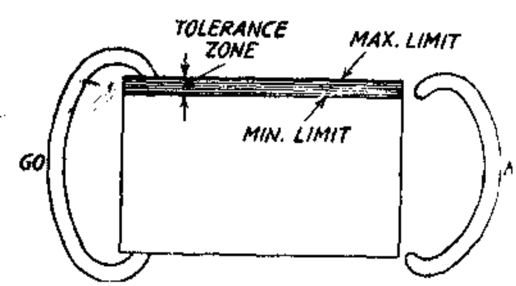
'Go' Limit. This designation is applied to that limit of the two limits of size which corresponds to the maximum material limit considerations,. i.e. upper limit of a shaft and lower limit of a hole. The form of the 'go' gauge should be such that it can check one feature of the component in one pass.

'No Go' Limit. This designation is appliled to that limit of the two limits of size which corresponds to the minimum material condition, i.e. the lower limit of a shaft and the upper limit of a hole.

'No Go' gauge should check only one part or feature of the component at a time, so that specific discrepancies in shape or size can be detected. Thus a separate 'No go' gauge is required for each different individual dimension.



Plug gauge.



Snap gauge.

The 'go' plug gauge is the size of the minimum limit of the hole, while the 'No go' plug gauge corresponds to the maximum limit.

The 'Go' snap gauge on the other hand, is of a size corresponding to the maximum limit of the shaft, while the 'No go' snap gauge corresponds to the minimum limit. Gauging faces of a normal snap or gap gauge must be parallel and square to each other and the gauging points of contact with the work should be in the same plane. The difference in size between the 'Go' and 'No Go' snap gauges, as well as the difference in size between the 'Go' and 'No Go' plug gauges, is approximately equal to the tolerance of the tested hole or shaft in case of Standard Gauges, Rigidity and robustness of snap gauges are important features so that gauges function adequately and maintain size. Gauging diameters of components that are slightly larger than the gap setting can produce high wielding action which may lead to gauge distortion and wrong interpretation of reading. Therefore, larger gap gauges should, preferably, be forged in a deep p[I-section, ensuring maximum rigidity in the plane of gauge and sufficient rigidity in lateral direction.

Taylor's principle states that the 'Go' gauges should check all the possible elements of dimensions at a time (roundness, size, location etc.) and the 'No go' gauge should check only one element of the dimension at a time.

To 'Go' plug gauge must be of corresponding section and preferably full length of hole so that straightness of hole can also be checked. Thus it not only controls diameter in any given section but also ensures bore alignability. However it cannot check the degree of ovality.

The 'No Go' plug is relatively short and its function is dependent not only on the diameter but also on the circularity of the hole. Thus to some extent, variation of hole shape can be measured

2. **Wear Allowance consideration on Gauge Maker's Tolerance**. Since the gauge maker can't dace absolutely accurately gauges, permissible deviation in accuracy must be assigned for gauge manufacture. Furthermore, the measuring surfaces of 'go' gauges which constantly rub against the surfaces of parts in inspection are consequently subject to wear and lose their initial size. Thus due to wear, the size of 'go' plug gauges is reduced, while that of 'Go' snap gauges is increased. It is of course desirable to prolong the service life of a gauges and, therefore, a special allowance of metal, the wear allowance is added in a direction opposite to the wear. For this reason new 'go' plug gauges are made with two positive deviations and 'Go' snap gauges with two negative deviations from the nominal size.(The nominal size on which limits of gauges are based are the limits of the parts to be checked.) .

3. **Important Points for Design**.

(1) The form of 'go' gauges should exactly coincide with the form of the opposed (mating) parts.

(2) 'go' gauges are complex gauges which enable several related dimensions to be checked simultaneously.

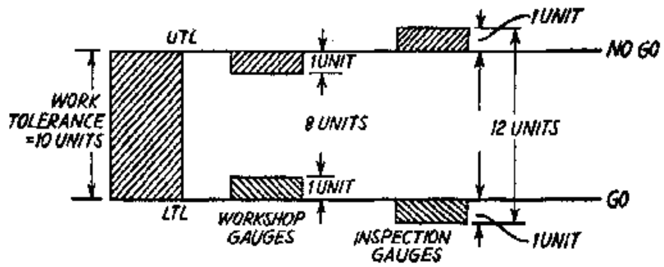
(3) In inspection, 'Go' gauges must always be put into conditions of maximum impassability.

(4) 'No Go' gauges are gauges for checking a single element of feature.

(5) In inspection, 'No Go' gauges must always be put into conditions of maximum passability.

4. **Gauge maker's Tolerance**. Keeping all above main points for gauge design in view there are three methods of giving tolerances on gauges (snap and plug gauges).

a) First System. Workshop and Inspection Gauges. In this method workshop and inspection gauges are made separately and their tolerance zones are different. This was evolved many years ago in the development stage of limit gauges.



UTL—Upper Tolerance Limit
LTL—Lower Tolerance Limit

Disposition of tolerances on workship and inspection gauges.

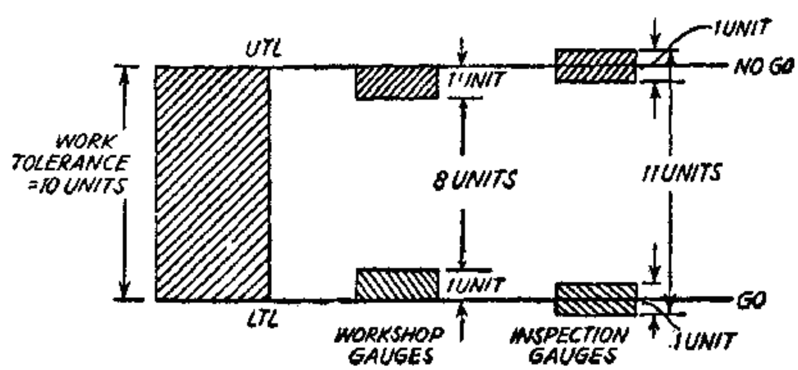
According to this system the tolerances on the workshop gauge are arranged to fall inside the work tolerance while the inspection gauge tolerances fall outside the work tolerance. Further in workshop gauges, 'Go' gauge should eat away 10% of work tolerance and similarly the tolerances on 'No Go' gauges should be one-tenth of work tolerance, so if work tolerance is 10 units then only 8 units will be left as the difference between the minimum of 'No Go' and maximum of 'Go'; the tolerance on 'Go'; as well as 'No Go' gauges individually being 1 unit each.

In Inspection Gauges, gauges are kept beyond work tolerance by 10% of its value.

Disadvantages of Workshop and Inspection Gauges.

(1) Some of the components which are in work tolerance limits may be rejected under workshop gauges. So they are again checked by inspection gauges and may be accepted after that.
(2) Some components which are not in work tolerance limits may be accepted when tested by inspection gauges.
(3) The workshop and inspection gauges are to be made separately as their tolerance zones are different.

b) Second System (Revised Gauge Limits). Under this system the disadvantages of inspection gauges are reduced by reducing the tolerance zone of inspection gauge, and the workshop gauge tolerance remains the same.



Modified tolerances on inspection gauge.

For 'Go' and 'No Go' inspection gauges in this system, the 110% of the range of work tolerance is covered instead of 120% in the first system

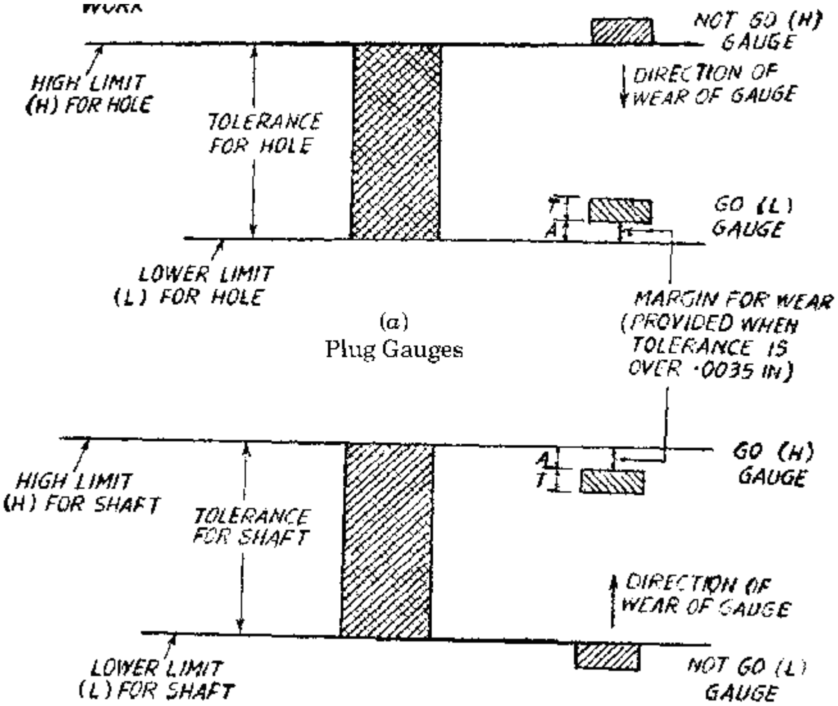
c) Third System (present British System). In new system, following principles are followed along with Taylor's principle.

i) Tolerance should be as wide as is consistent with satisfactory functioning, economical production and inspection.
ii) No work system dispenses with workshop and inspection gauges and we give the same tolerance limits on workshop and inspection gauges and the same gauges can be used for both purposes.

Thus modern system dispenses with workshop and inspection gauges and we give the same tolerance limits on workshop and inspection gauges and the same gauges can be used for both purposes.

The tolerance zone for the 'Go' gauges should placed inside the work-limits and tolerance for the 'No Go' gauges outside the work-limits. Provision for wear of 'Go' gauges is made by introduction of a margin between the tolerance zone for the gauge and maximum metal limit of the work. Wear should not be permitted beyond the maximum metal limit of the work, when the limit is of critical importance. Its magnitude is one-tenth of the gauge tolerance. Thus when work tolerance is less than 0.09 mm there is no need of giving allowance for wear. If work tolerance is more than 0.09mm then 10% gauge tolerance is given allowance for wear.

The disposition of various tolerances and allowances on gauges according to this system is shown in Figure and further clarified by the following example.

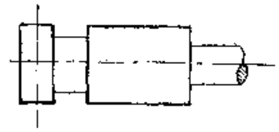


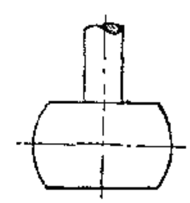
(a)
Plug Gauges

(b)
Gap and Ring Gauges
Provision of margin for wear on GO gauges.

Limit Gauges. The various types of limit gauges used for gauging internal diameters or holes are "

(1) ***Full form cylindrical plug gauge***. The gauging surface is in the form of an external cylinder. Generally a small circumferential groove is cut near the leading end of the gauge and the remaining short cylindrical surface is slightly reduced in order to act as a pilot. The method of attaching gauge to the handle should be such as not to affect the size and form of the gauge by producing undesirable stresses.

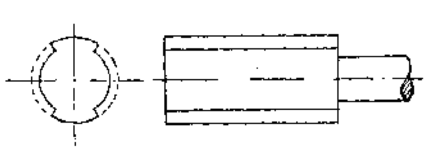

Full form cylinderical plug gauge.


Full form disc gauge.

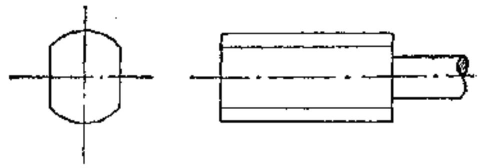
(2) ***Full form spherical plug or disc gauge***. This has gauging surface in the form of a sphere from which two equal segments are cut off by planes normal to the axis of the handle.

(3) ***Segmental cylindrical bar gauge.*** It has gauging surface in one of the following two forms: (i) External cylindrical form from which two axial segments are made by lowering down surface at other places. (ii) External cylindrical form in which segments are formed by removing remaining material.

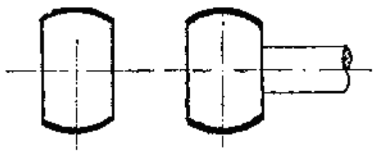
(4) ***Segmental spherical plug gauge.*** It is similar to full form spherical plug or disc gauge but has two equal segments cut off by planes parallel to the axis of the handle in addition to the segments cut off by planes normal to the axis of the handle.



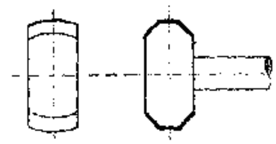
Segmental cylindrical bar gauge.



Segmental cylindrical bar gauge.



Segmental spherical gauge.



Segmental cylindrical bar gauge.

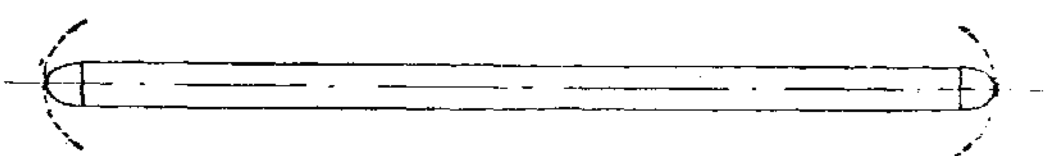
(5) ***Segmental cylindrical bar gauge with reduced measuring faces***. It is similar to segmental cylindrical bar gauge but has reduced measuring faces in a plane parallel to the axis of the handle.

(6) ***Rod gauge with spherical ends.*** It has spherical end surfaces which form part of one single sphere.

The standard limit gauges used for gauging external diameters or shafts are:

(i) Full form cylindrical ring gauge, which has gauging surface, in the form of an internal cylinder and whose wall is thick enough to avo9id deformation under normal conditions of use.

(ii) Gap gauge. It generally has one flat surface and one cylindrical surface, the axis of the two surfaces being parallel to the axis of the shaft being checked. The surfaces constituting the working size may both be flat or both cylindrical also.



Rod gauge with spherical ends.

EXP:10 To measure Flatness, Squareness, and Roundness of a machined surface.
Theory:

Flatness Testing

Like straightness testing, the simplest form of flatness testing is possible by comparing the surface with an accurate surface. One of the surfaces is marked with Prussian blue and the other surface rubbed over it. The distribution of colour over the other surface gives a rough idea of high and low points on the surface. This method is usually suitable for small plates and not for large surfaces.

Mathematically, flatness error of a surface states that the departure from flatness is the minimum separation of a pair of parallel planes which will just contain all points on the surface. The deviation of a large surface such as surface table or machine table from the true plane may be determined by the use of either a spirit level or an auto-collimator. The principle of the method is same, whether the apparatus used is auto-collimator or spirit level.

According to IS : 2063—1962, a surface is deemed to be flat within a given range of measurement when the variation of the perpendicular distance of its points from a geometrical plane (this plane should be exterior to the surface to be tested) parallel to the general trajectory of the plane to be tested remains below a given value. The geometrical plane may be represented either by means of a surface plane or a family of straight lines obtained by the displacement of a straight edge or a spirit level or a light beam :

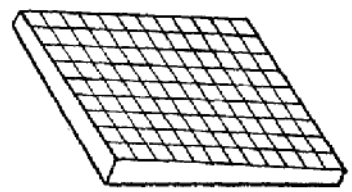
Flatness deviations (errors of flatness) are indicated as follows :

(*i*) ... μ or mm per metre when convexities are allowed as well as concavities ;

(*ii*) concave to ... μ or mm, when, between the ends, only concave surfaces are allowed ; and

(*iii*) convex to ... μ or mm, when, between the ends, only convex surfaces are allowed.

It is well known that a surface can be considered to be composed of an infinitely large number of lines. The surface will be truly flat only if all the lines are straight and they lie in the same plane. Let us study the case of rectangular table. From Fig. it is obvious that all the generators (lines) are straight and parallel to the sides of the rectangle in both the perpendicular directions. Even then it is not truly flat, but concave and convex along two diagonals. Thus for the verification of a surface to be truly flat, it is essential to measure the straightness of diagonals in addition to the lines parallel to the sides. Thus the whole of the surface is divided by straight lines as shown in Fig. 7.5. The end lines *AB* and *AD* etc., are drawn away from the edges as the edges of the surface are not flat but get worn out by use and can fall off little in accuracy. The straightness of all these lines is determined and then those lines are related with each other in order to verify whether they lie in the same plane or not. In above setting of the lines, it should be kept in mind that the lines are whole multiples of the length of base of spirit level or reflector stand and the centre of the diagonals. I must be one of the contact points of the feet of the block.



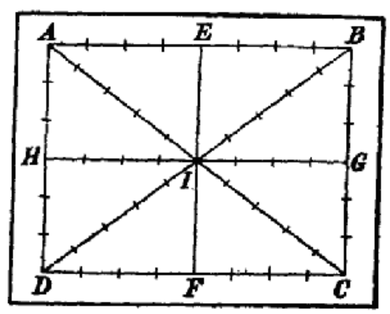
Testing flatness.

Procedure for determining flatness The procedure for determining flatness is as follows :

(1) Carry out the straightness test already described on all the lines *AB*, *BC*, *AC* etc. and tabulate the readings upto the cumulative error column.

(2) Let a plane passing through the points *A*, *B* and *D* be assumed to be an arbitrary plane, relative to which the heights of all other points may be determined. For it, the ends of lines *AB*, *AD* and *BD* are corrected to zero and thus the height of points *A*, *B* and *D* are zero.

(3) The height of point *I* is determined relative to the arbitrary plane *ABD* = 000. As *I* is the mid-point of line *AC* also, all the points on *AC* can be fixed relative to the arbitrary plane by assuming *A* = 0 and correcting *I* on *AC* to coincide with the mid-point *I* on *BD*. In this way, all points on *AC* are corrected by amounts proportionate to the movement of its mid-point. *A* hint could be taken here that *C* is twice as far from *A* as the mid-point, the correction for *C* will be double that of *I*.



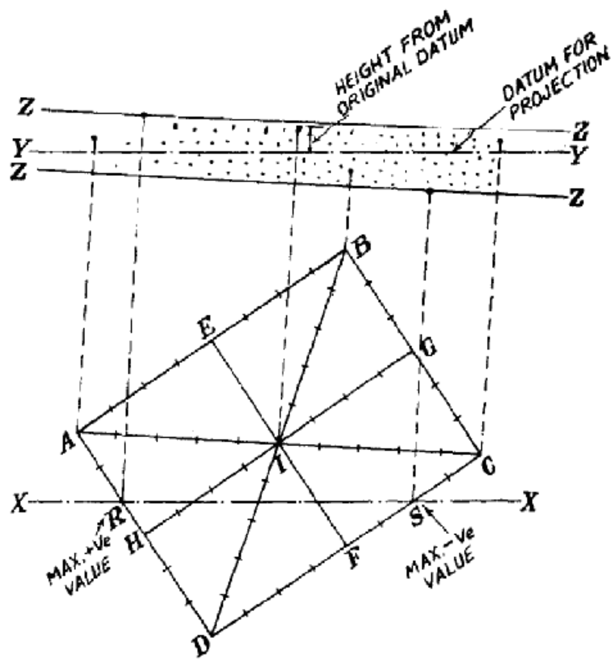
Flatness testing procedure.

(4) Point *C* is now fixed relative to the arbitrary plane and points *B* and *D* are set at zero, all intermediate points on *BC* and *DC* can be corrected accordingly.

(5) The positions of *H* and *G*, *E* and *F* are known, so it is now possible to fit in lines *HG* and *EF*. This also provides a check on previous evaluation since the mid-point of these lines should coincide with the known position of mid-point *I*.

In this way, the height of all the points on the surface relative to the arbitrary plane *ABD* are known.

One thing to be noted here is that according to definition of flatness error, departure from flatness is determined by the *minimum* separation of a pair of parallel planes which will just contain all the points on the surface. Here it is possible to determine two points at either extreme of the reference plane to define the separation but the reference plane chosen may not be the best plane. Therefore, in order to determine the minimum separation some correction has to be made. The calculation for a final correction to determine the minimum separation of a pair of parallel planes which just contain all the points on the surface is made by graphical method as given below.



Minimum separation of parallel planes containing all points on surface.

The various points on the surface have been determined with reference to *ABD* as reference plane as described previously. Two points on opposite sides having maximum positive and maximum negative values are selected and jointed together by a line *XX*. Let these points in Fig. be *R* and *S*. Draw a line *YY* parallel to *XX* to represent the plane *ABD* as shown in Fig. Set off to scale the height of all points relative to *YY* by taking projections from all the points on the surface.

In Fig. projections from all points have not been shown for the sake of clarity. Next by inspection, draw a closest pair of parallel lines *ZZ* and *ZZ*, which will contain all of the points. It may be noted that one line will have two points on it, and the other line, one point only. The distance between these two lines is a measure of the error in flatness. Although it is not exact value but for practical purpose it gives sufficiently accurate results.

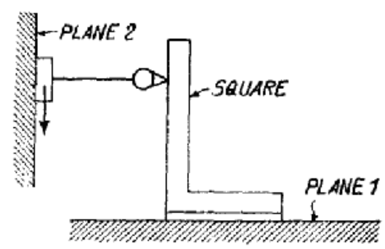
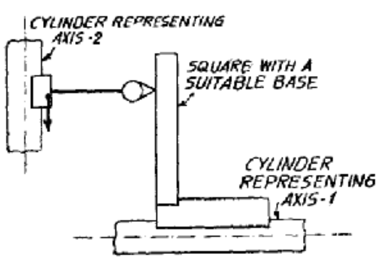
The optical flatness testing method for very flat and polished surface has already been discussed in the chapter of Interferometry.

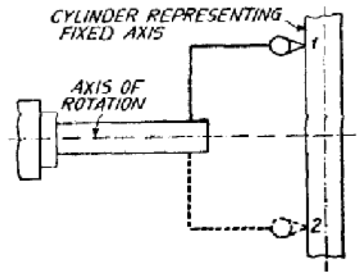
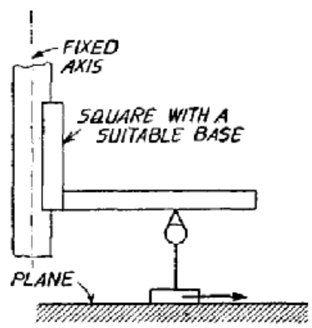
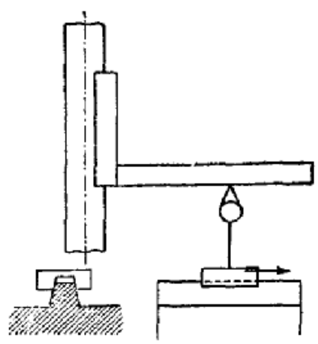
Squareness Testing. The angle of 90° is probably the most important angle in gineering applications. It is assigned several names as square, normal, right angle and it is presented for most practical purposes by squares, rectangular blocks etc. Probably the nievement of modern sciences would have not reached the present state of advancement if ;ht angle was unattainable to within a close degree of accuracy. Its importance is realised m the following applications. The cross slide of lathe must move exactly at 90° to the spindle is in order to produce a flat face during facing operation. The spindle of depth micrometer ıst be square to the locating face in order to avoid any errors in measurement. The column d table of milling machine must be at 90° to each other.

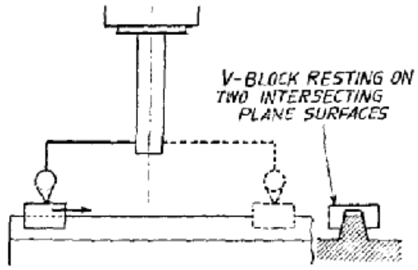
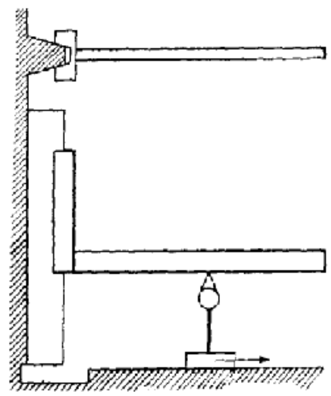
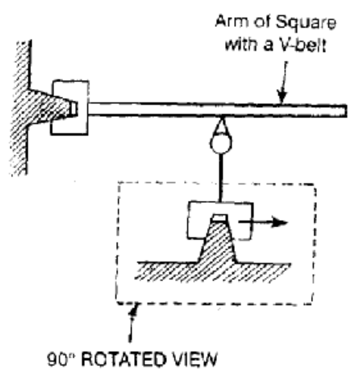
For most of the purposes where high degree of accuracy is not desired, the workpiece ı be tested against an engineer's square or square block. It simply shows whether the two rfaces of a workpiece are at right angle or not and judgement is purely based on eye. In order know the amount of error and for checking squares and square blocks, the following methods ı be used.

Indicator Method. This method is particularly suitable for checking the ıareness of a block whose opposite faces are supposed to be parallel. It is assumed that the ıareness of the block has already been assured to a reasonable accuracy by the use of square :., as otherwise the full sensitivity of the method can't be obtained. The instrument for this rpose is designed by N.P.L. and is very suitable for checking squareness while manufactur- ; a square block. The instrument consists of parallel strip (framework) and a flat base. A ife edge and some form of indicator is mounted on the framework as shown in Fig.

The other tests of squareness of lines and planes are given below in the tabular form.

Condition	*Test set up*	*Method in brief*
Two planes (1 and 2) 90° to each other		Squareness of two planes 1 and 2 is checked by placing the square on one plane and then checking the parallelism of 2nd plane with the free arm of the square by sliding the dial indicator (mounted on a base) along 2nd plane and its feeler moving against free arm of the square.
) Two axes at 90° to ch other) Both axes fixed		—do—

(*b*) One axis being axis of rotation and other fixed.		The dial gauge mounted on arm and fixed on the mandrel is brought into contact with the cylinder representing fixed axis at two points 1 and 2, 180° apart and deviation expressed in relation to distance between 1 and 2.
(*c*) Both the axes being axes of rotation.		The test is conducted in the same way as (*ii*)-(*b*) but the cylinder representing 2nd axis of rotation is brought into the mean position of the run out in the plane of measurement.
(*iii*) An axis at 90° to a plane. (*a*) axis is fixed.		Test set up is self explanatory, but the test is carried out in two perpendicular directions.
(*b*) Axis being the axis of rotation.		This test has already been described.
(*iv*) An axis at 90° to the intersection of two planes. (*a*) Axis is fixed.		The test set up is self explanatory.

(*b*) Axis being the axis of rotation.		First reading is taken by making the feeler of the dial indicator to touch on a V-block resting on two intersecting plane surfaces. (The dial indicator is mounted on the spindle). The second reading is noted by rotating the spindle along with dial by 180° and moving the V-block so as to bring the feeler into contact with the same point on the block.
(*v*) Intersection of two planes is at 90° to another plane.		In this test, either the square or the dial indicator fitted with a suitable base is allowed to rest on the intersecting planes and the dial indicator is moved with its feeler resting against the arms of dial gauge. The test is made in two perpendicular planes.
(*vi*) Two straight lines, each formed by the intersection of two planes, are at 90° to each other.		Test is self explanatory.

In this method, means are also available to produce and measure parallel surfaces by some form of grinder and a comparator respectively. The height of the indicator is adjusted such that it makes contact near the top of the side of the square block. The block is then placed against the knife edge as shown in Fig. 7.21 (*a*) and a reading is noted on the indicator. The block is then turned so that now the opposite side is facing the knife edge [Fig. 7.21 (*b*)] and again a reading is noted on the indicator. If two sides *AD* and *BC* are truly parallel then the two readings will be same for true right angle. In case the faces are not exactly at right angles,

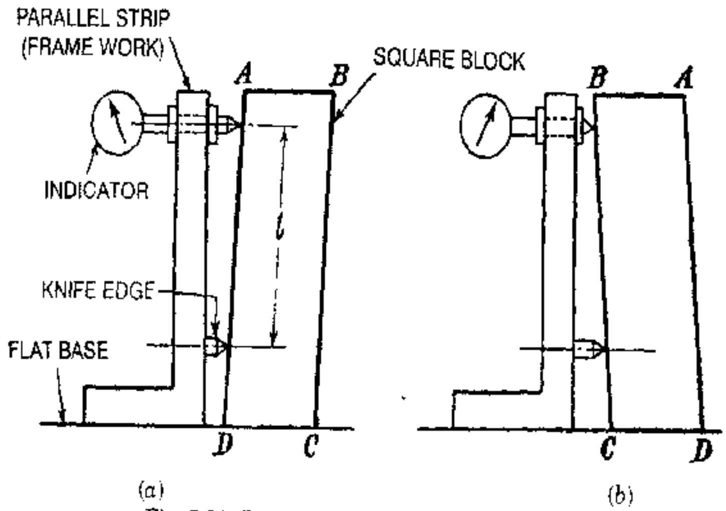


Fig. 7.21. Squareness testing by indicator method.

then the two readings will be equally above and below the reading for a true right angle. Thus the differences of two readings is double the error in squareness of work over the length '*l*' between the two contact marks.

Roundness and circularity. Often the terms roundness and circularity are used interchangeability. Roundness is defined as a condition of a surface of revolution (like cylinder, cone or sphere) where all points of the surface intersected by any plane perpendicular to a common axis in case of cylinder and cone (or passing through a common centre in case of sphere) are equidistant from the axis (or centre). Since the axis and centre do not exist physically, measurements have to be made with reference to surfaces of the figures of revolution only. Whatever is measured by referring to the surface of revolution is the circular contour. It may be understood that while roundness expresses a particular geometric form of a body of revolution in all the three dimensions, the circular contour is the characteristic form of the entire periphery of a plane figure. For measuring roundness, it is only the circularity of the contour which is determined.

Devices for measurement of roundness. The most commonly used devices for measurement of roundness are :

(1) Diametral. (2) Circumferential confining gauge—a shaft is confined in a ring gauge and rotated against a set indicator probe. (3) Rotating on centres. (4) V-Block.

Piece rotating against a set probe (*a*) of fixed angle, (*b*) of adjustable angle.

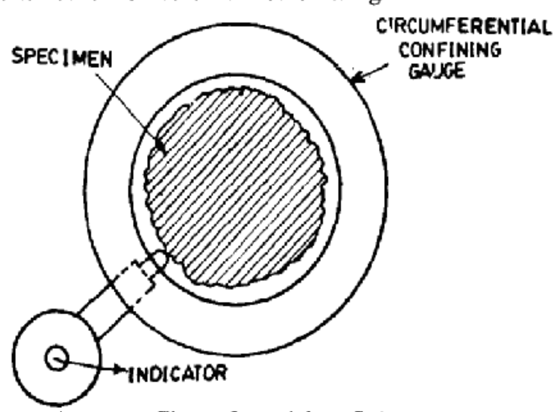
(5) Three-point probe (120° spacing).

(6) Accurate spindle.

(*a*) part fixed, exterior spindle with probe rotates, (*b*) probe fixed, part rotates with spindle.

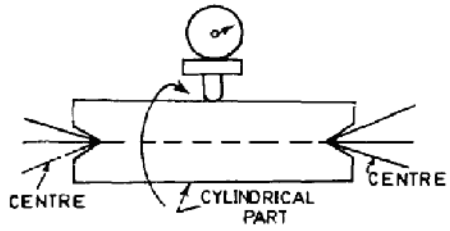
Diametral Method. In this method, the measuring plungers are located 180° apart and the diameter is measured at several places. This method is suitable only when the specimen is elliptical or has an even number of lobes. Diametral check does not necessarily disclose effective size or roundness. This method is unreliable in determining roundness.

Circumferential Confining Gauge. Fig. shows the principle of this method. It is useful for inspection of roundness in production. However, this method requires a separate highly accurate master for each size part to be measured. The clearance between part and gauge is critical to reliability. This technique does not allow for the measurement of other related geometric characteristics, such as concentricity, flatness of shoulders, etc. The values obtained are dependent on the shape of the specimen.



Circumferential confining gauge.

Rotating on centres. (Refer Fig. 7.36). Some parts, (such as shafts) may be inspected for roundness while mounted on centres. In this case, reliability is dependent on many factors like angles of centres, alignment of centres, roundness and surface condition of the centres and centre holes, and runout of piece. Out-of-straightness of the part will cause a doubling runout effect and appear to be roundness error.

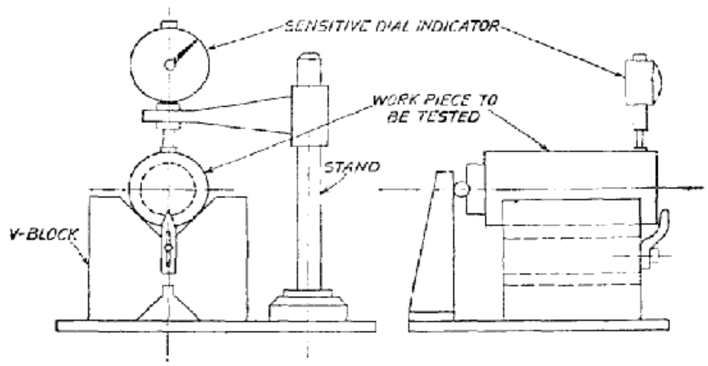


Inspecting shaft for roundness.

Any or all of these factors may combine, creating a high degree of uncertainty as to exact nature of the error.

For workshop purpose, the V-block method is quite accurate as it is capable of indicating normal requirements of accuracy. However for very precise job where more reliable and more accurate results are desired, the second method is recommended which is quicker and also eliminates the effects of angle of the block and the number of lobes on part, but of course, is a very costly one.

Assessment using a V-block. The set up employed for assessing the circularity error (lobing) by using a V-block is shown in Fig. 7.37, *i.e.*, the vee-block is placed on a surface plate and the work to be checked is placed upon it. A sensitive dial indicator is firmly fixed in a stand and its feeler made to rest against the surface of the work. The work is rotated to measure the rise and fall of the work-piece. For determining the number of lobes on the work-piece, the work-piece is first tested in a 60° V-block and then in a 90° V-block. The number of lobes is then equal to the number of times the indicator pointer deflects during rotation of the workpiece through 360°. The idea of testing the work-piece in two V-blocks is that when an elliptically shaped part is rotated on a V-block is that when an elliptically shaped part is rotated on a V-block of angle 60°, no change in reading is indicated, whereas if the same part is rotated on a 90° angle Vee-block, two maximum and two minimum readings are indicated on the indicator.



Assessing circularity using a V-block.

The method of determination of the circularity error by V-block has certain limitations and, therefore, the following points should be born in mind.

(*a*) The error of circularity measured on a V-block is greatly affected by the following factors :

(*i*) Angle of V-block very much influences in the determination of circularity error, *i.e.* if the circularity error is say Δe, then it is possible that the indicator shows no variation, or same as Δe, or twice Δe, or thrice Δe, or some other value for each position of the instrument when V-blocks of different angles are used. This is because of the fact that as the angle of V changes the place where the work-piece rests also changes. Ultimately it will be noted that the same work-piece rests at higher place in V-Block of smaller angle and at lower place in V-block of larger angle and thus the indicator will show different readings for same work-piece kept in same position on different angle V-blocks.

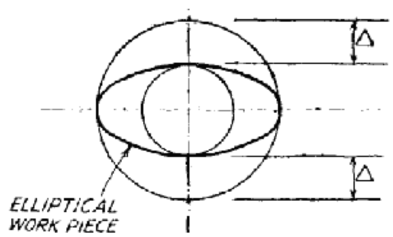
(*ii*) Position of the instrument, *i.e.* whether measured from top or bottom.

(*iii*) Number of lobes on the rotating part (*e.g.*, elliptical, triangular, quadrilateral, pentagonal etc.)

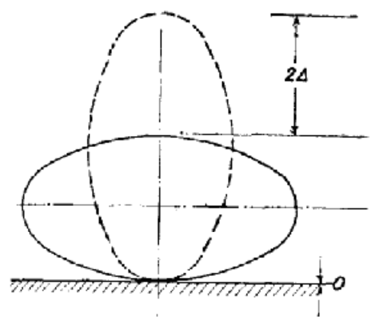
(*b*) The instrument's position should be in the same vertical plane as the point of contact of the part with the V-block. If the error is measured at a point far from the V-block, the error of circularity will be influenced by the radial run out of the part.

(*c*) A leaf spring should always be kept below the indicator plunger and the surface of the part, otherwise readings are likely to be affected by minute undulations of the surface, such as surface roughness.

It is obvious that with different angle of V-blocks, dial indicator shows different readings for the same work-piece placed in the same position. If this problem is studied further by analysing an elliptical workpiece on different angle V-blocks, it will be found that some solution can be arrived at. Let us consider an elliptical work-piece whose major axis is 2Δ more than the minor axis as shown in Fig. 7.38.



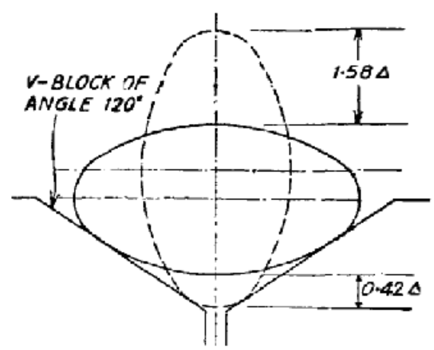
Major axis 2Δ more than minor axis.



2Δ error revealed when elliptical object is placed on flat surface.

We will place this work-piece on different angle V-blocks first with major axis placed along the direction of dial movement and then with minor axis along the direction of dial-movement. This is so because the work-piece has two number of lobes.

It may be noted that it is possible to take dial readings both from top as well as bottom. Consider the case when work-piece is placed at flat surface in two positions as shown in Fig. 7.39. It will be noted that the error of circularity when measured from top = 2Δ and when measured from bottom = 0, whereas the actual error of circularity in the work-piece = Δ.



Elliptical workpiece tested on V-block of 120°.

Similarly, if the work-piece is placed on a V-block of angle 120°, it will be found by calculation or otherwise that the error of circularity in this case when measured from top = 1.58Δ, whereas if measured from bottom = 0.42 Δ.

In the same way, it will be found that when work-piece is tested on the 108° V-block, the circularity error measurement when measured from top = 1.38Δ and 0.62Δ if measured from bottom. The corresponding values for 90° and 60° V-block will be Δ, Δ and 0, 2Δ respectively.

Thus for an elliptical work-piece which has got 2 number of lobes, the ratio of circularity error measurement by dial indicator on different V-blocks and the actual error is as given below :

Angle of V-block	*Measurement from top*	*Measurement from bottom*
60°	0.00	2.00
90°	1.00	1.00
108°	1.38	0.62
120°	1.58	0.42

$$\text{Such values of the constant } K = \frac{\text{Measured value of error of circularity}}{\text{Actual value of error of circularity}}$$

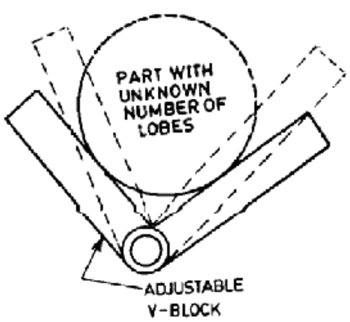
can be determined for different shapes of work-pieces, *i.e.* having different number of lobes.

V-Block. (*a*) *Fixed Angle.* Depending on the number of lobes on a part, the following angles of V-blocks are recommended for measurement of correct roundness by V-block method.

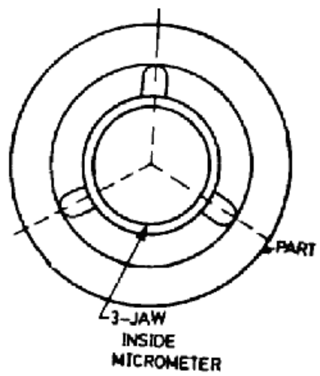
Lobes	**Angle of V-block**
Three-point out of roundness	60°
Five-lobed part	108°
Seven-lobed part	128° 34′

(*b*) **Adjustable V-Block.** It is usually difficult to ascertain the number of lobes of a part and have large number of fixed angle V- blocks. V-block which can be adjusted to correct angle to show out-of-roundness is better choice.

V-Block method is limited in the determination of roundness of parts because it is suitable only when the number of lobes is known and is uniformly arranged, which is never the case.



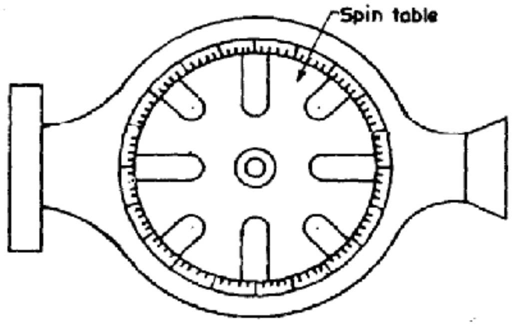
Adjustable V-block.



Three point probe.

Three-Point Probe. The three-probe with 120° spacing is very useful for determining effective size in cases of doubtful geometry of part. They perform like a 60° V-block. Like 60° V-block, it will show no error for 5 and 7 lobes, magnify the error for 3-lobed parts, show partial error for randomly spaced lobes.

Accurate spindle. None of .he five methods discussed above are satis- 'actory for measuring roundness absolute- y. Accurate spindle method is a method to ›rovide a definitive value for calibration of ·oundness. There are innumerable types of ;pindle designs available for generation ınd inspection of round shapes. Various lesigns are : ball bearings, roller bearings, ›lain ball spindles, plain bearings (journal .ype), metered oil flow and fluid-bearing gas bearing and oil-bearing). These ;pindles are available in a wide range of .olerances (down to a fraction of a micron).



Accurate spindle.

Spin Table. It is a highly precise spindle. It is a rotating table-type of spindle, ıseful for generating cylindrical, conical and spherical shapes when mounted on the jig grinder. 't is designed for the generation of essentially round shapes. When the spin table is mounted ›n the Micro-Sine Table, tapers and conical shapes are ground and to an exact included angle. 'f the spin table is placed on the jig grinder so that its spindle is horizontal, either by mounting t on an angle iron or on the Sine Table.

The conventional design for this type of spindle includes the use of balls. For maximum ·igidity and for minimising the danger of brivelling, the Spin Table instead uses precision ·ollers under stiff radial and axial preload. Trueness of rotation of the Spin Table is held to).0001 mm (Total Indicator Reading) and 0.0005 mm maximum axial deviation, including the ›ffects of camming, flatness and parallelism. In rotation, these accurate spindles describe a ›erfect circle to which the part may be compared at all its radial ordinates.

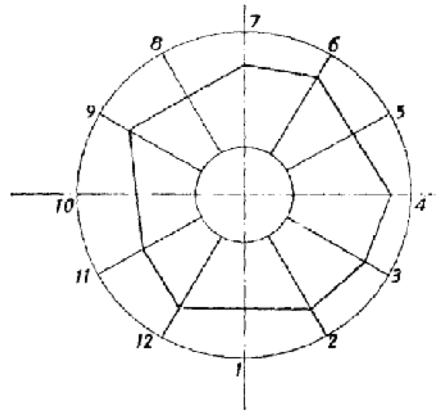
Out-of-roundness is shown by the movement of high-magnification comparators. It often ;uffices to merely observe and note indicator readings. These are usually equipped with means ›f recording the (linear or polar) results. The polar recorder is an auxiliary device having ;everal rotational speeds, synchronous to those of the measuring spindle. Deviations from true ·oundness registering on an indicator are traced on circular graph paper at magnifications ıpto 20,000 to provide a permanent physical record. By overlaying a special transparent emplate where there are concentric circles representing calibrated value (such as 1 line = 0.00025 mm) to the graph, deviations from roundness may be easily understood and analysed. Րhis can be accomplished even without exact alignment of the part with the spindle.

Roundness Measurement by Plotting Polar Graph. The idea of the actual ;hape of the work-piece can be had by actually plotting the polar graph, which is explained ater. Once the shape is known, the value of the constant can be noted from the table given on ıext page corresponding to that very shape and the actual error of circularity determined.

The procedure to be adopted for the measurement and drawing of the polar graph and herefrom the error of circularity is given below :

First of all 12 markings equally space at angles of 30° are made on the face of the vork-piece to be measured. The work-piece after properly cleaning is then placed on the V-block ıgainst a rigid block with a steel ball in between as shown in Fig. The dial indicator is ›laced just above the work-piece so that it is touching the work-piece nearly at the centre of he V-block. The work-piece is then rotated such that the marking on the work-piece is below he indicator plunger. A small strip (leaf spring) is fixed between the indicator plunger and the surface of the part. The readings of the dial indicator are noted down for all the markings. This is repeated three times to take the average value.

For plotting the polar graph, a suitable scale is chosen depending on the maximum value of the reading. Then a circle of diameter nearly 4 times the maximum reading of the dial indicator is drawn and is divided into 12 number of angular divisions as shown in Fig. Inside the outer circle, another concentric circle of suitable diameter is drawn. Actually there are standard diameters drawn on polar graphs. Then the values of the indicator are plotted in radial direction taking the smaller circle as the reference circle in order that both the positive and negative readings are plotted within the prepared graph.



Measuring roundness by plotting polar graph.

Table for determining the value of K different shapes of work-pieces

Shape of the Work-piece	*Angle of vee-block*							
	60°		*90°*		*108°*		*120°*	
	Measurement made from top	*Measurement made from bottom*	*Measurement made from top*	*Measurement made from bottom*	*Measurement made from top*	*Measurement made from bottom*	*Measurement made from top*	*Measurement made from bottom*
Elliptical	0.00*	2.00	1.00	1.00	1.38	0.62*	1.58	0.42
Equilateral Triangle	3.02	3.02	2.05	2.05	1.44	1.44	1.00	1.00
Quadrilateral	0.10*	2.00	0.415	2.40	1.01*	2.01	0.38	1.00
Pentagonal	0.5*	0.5*	2.07	2.07	2.24	2.24	2.03	2.03
Hexagonal	3.00	1.00	1.00	1.00	0.08*	2.00	0.16*	2.11
Heptagonal	0.10*	1.10*	0.02*	0.02*	1.40	1.40	2.04	2.04

*Out of experience it has been found out that the angles of vee-blocks corresponding to values of K indicated with aesterisk mark should not be used.

Individual points are then joined by straight lines, thus obtaining the actual profile of the measured work-piece. The error is measured as the radial distance between the minimum circumscribing circle and the maximum inscribing circle for the profile obtained. This is done by hit and trial method such that this distance is minimum.

The actual value of error of circularity is given by,

$$\text{Error} = \frac{\text{Measured error from polar graph}}{K}$$

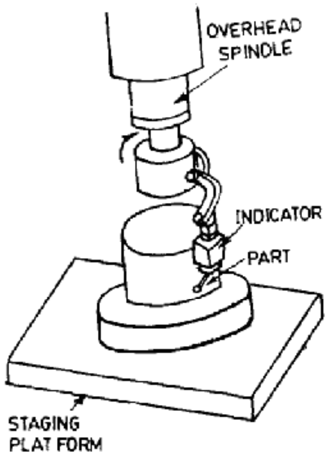
where K is a constant, value of which depends upon shape of work-piece and angle of V-block.

Roundness Measuring Spindles. Roundness measuring spindles are of two kinds :

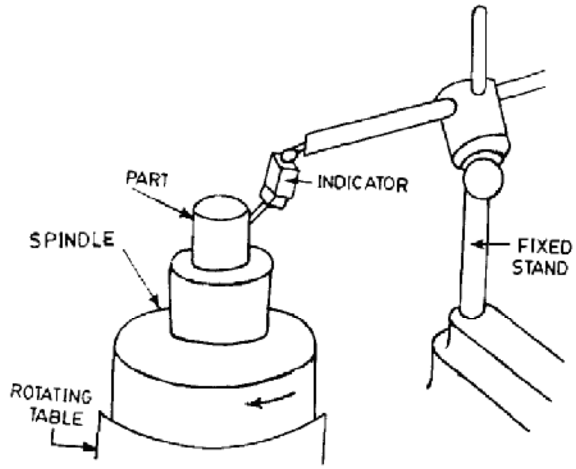
(*i*) Overhead spindle in which the part is fixed on a staging platform and the overhead spindle carrying the comparator rotates separately from the part

It can determine roundness as well as camming (circular flatness). The concentricity can be checked by extending the indicator from the spindle and thus the range of this check is limited. Flatness and squareness can be inspected by physically sliding the workpiece past the indicator as is done on a surface plate. Height of the work-piece is limited by the location of overhead spindle.

Since the workpiece is stationary and separate from the spindle, the spindle is not affected by load of workpiece.



Roundness measuring spindle-overhead spindle.



Roundness measuring spindle-rotating table.

(*ii*) Rotating table—in which the spindle is integral with the table and rotates alongwith it. The part is placed over the spindle and rotates past a fixed comparator It can determine more geometric characteristics without having to move the part.

The rotating table spindle can measure roundness, concentricity and camming (circular flatness). This design allows the inspection of concentricity over a great range along the part axis. Squareness inspection requires sliding the indicator and stand, or an auxiliary horizontal movement. The height of workpiece is no limitation. However, weight of workpiece may result in inaccuracy since it has to be supported on the rotating spindle. Spindle accuracy may be deteriorated due to eccentrically mounted load. There is also the danger of damaging the spindle during mounting of workpiece. With small parts such as bearings, ring gauges etc. no loss of accuracy may be there.