UNIT-4

SURFACE ROUGHNESS MEASUREMENT

Introduction:-

With the more precise demands of modern engineering products, the control of surface texture together with dimensional accuracy has become more important. It has been investigated that the surface texture greatly influences the functioning of the machined parts. The properties such as appearance, corrosion resistance, wear resistance, fatigue resistance, lubrication, initial tolerance, ability 'to hold pressure, ,load carrying capacity, noise reduction in case of gears are influenced by the surface texture.

Whatever may be the manufacturing process used, it is not possible to produce perfectly smooth surface. The imperfections and irregularities are bound to occur. The manufactured surface always departs from the absolute perfection to some extent. The irregularities on the surface are in the form of succession of hills and valleys varying in height and spacing. These irregularities are usually termed as surface roughness, surface finish, surface texture or surface quality. These irregularities are responsible to a great extent for the appearance of a surface of a component and its suitability for an intended application.

Factors Affecting Surface Roughness:-

The following factors affect the surface roughness:

(1) Vibrations

(2) Material of the workpiece

(3) Type of machining.

(4) Rigidity of the system consisting of machine tool, fixture cutting tool and work

(5) Type, form, material and sharpness of cutting tool

(6) Cutting conditions i.e., feed, speed and depth of cut

(7) Type of coolant used

Reasons for Controlling Surface Texture:-

(1) To improve the service life of the components

(2) To improve the fatigue resistance

(3) To reduce initial wear of parts

(4) To have a close dimensional tolerance on the parts

(5) To reduce frictional wear

(6) To reduce corrosion by minimizing depth of irregularities

(7) For good appearance

(8) If the surface is not smooth enough, a turning shaft may act like a reamer and the piston rod like a broach.

However, as already explained perfectly smooth surface is not always required, the requirement of surface texture depends upon the specific application of the part.

<u>Orders of Geometrical Irregularities:-</u>

As we Know that the material machined by chip removal process can't be finished perfectly due to some departures from ideal conditions as specified by the designer. Due to conditions not being ideal, the surface Produced will have some irregularities, these geometrical irregularities can be classified into four categories.

First Order: The irregularities caused by inaccuracies in the machine tool itself are called as first order irregularities. These include:

(1) Irregularities caused due to lack of straightness of guide ways on which the tool most moves.

(2) Surface regularities arising due to deformation of work under the action of cutting forces, and

(3) Due to the weight of the material itself.

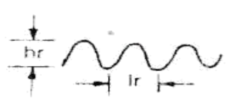
Second Order: The irregularities caused due to vibrations of any kind are called second order irregularities.

Third order: Even if the machine were perfect and completely free from vibrations some irregularities are caused by machining itself due to the characteristics of the process.

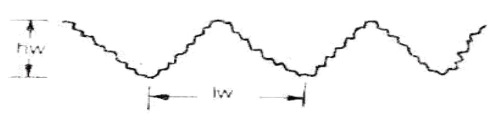
Fourth Order: The fourth order irregularities include those arising from the rupture of the material during the separation of the chip.

<u>Irregularities on the surface of the part:-</u>

The irregularities on the surface of the part produced can also be grouped into two categories:
(i) Roughness or primary texture, (ii) Waviness or secondary texture.



micro geometrical error



macro geometrical error

Micro and macro geometrical errors

(i) Primary texture (Roughness):

The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting element son the material i.e., cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion.

These include irregularities of third and fourth order and constitute the micro-geometrical errors. The ratio lr / hr denoting the micro-errors is less than 50, where Ir = length along the surface and hr = deviation of surface from the ideal one.

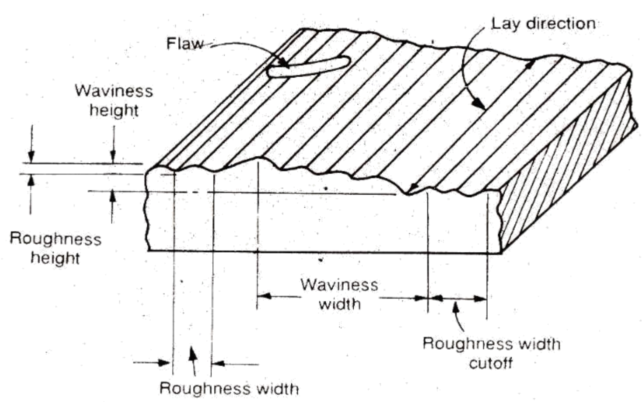
(ii) Secondary texture (Waviness):

The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind etc.

These errors include irregularities of first and second order and constitute the macro-geometrical errors. The ratio of Iw / hw denoting the macro-errors is more than 50. Where, Iw = length along the surface and kw = deviation of surface from ideal one.

Elements of Surface Texture:-

The various elements of surface texture can be defined and explained with the help of fig which shows a typical surface highly magnified.



Elements of surface texture

Surface: The surface of a part 'is confined by the boundary which separates that part from another part, substance or space. Actual surface. This refers to the surface of a part which is actually obtained after a manufacture ring process.

Nominal surface: A nominal surface is a theoretical, geometrically perfect surface which does not exist in practice, but it is an average of the irregularities that are superimposed on it.

Profile: Profile is defined as the contour of any section through a surface, Roughness. As already explained roughness refers to relatively finely spaced micro geometrical irregularities. It is also called as primary texture and constitutes third and fourth order irregularities.

Roughness Height: This is rated as the arithmetical average deviation expressed in micro-meters normal to an imaginary centre line, running through the roughness profile.

Roughness Width: Roughness width is the distance parallel , to the normal surface between successive peaks or ridges that constitutes the predominant pattern of the roughness.

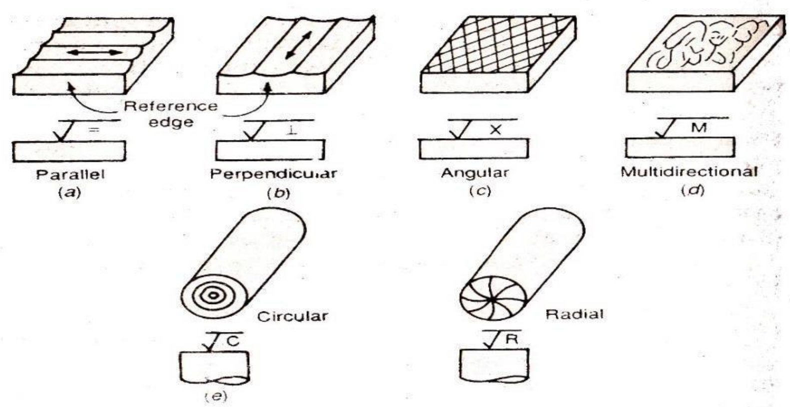
Roughness Width cutoff: This is the maximum width of surface irregularities that is included in the measurement of roughness height. This is always greater than roughness width and is rated in centimetres.

Waviness: Waviness consists of those surface irregularities which are of greater spacing than roughness and it occurs in the form of waves. These are also termed as moon geometrical errors and constitute irregularities of first and second order. These are caused `due to misalignment of centres, vibrations, machine or work deflections, warping etc.

Effective profile: It is the real canter of a surface obtained by using instrument

Laws: Flaws are surface irregularities or imperfections which occur art infrequent intervals and at random intervals. Examples are: scratches, holes, cracks, porosity etc. These may be observed directly with the aid of penetrating dye or other material which makes them visible for examination and evaluation.

Surface Texture: Repetitive or random deviations from the nominal. Surface which forms the pattern on the surface. Surface texture includes roughness, waviness, lays and flaws.



Types of Lay

Lay: It is the direction of predominant surface pattern produced by tool marks or scratches. It is determined by the method of production used. Symbols used to indicate the direction of lay are given below:

| | = Lay parallel to the boundary line of the nominal surface that is, lay parallel to the line representing surface to which the symbol is applied e.g., parallel shaping, end view of turning and O.D grinding.

⊥= Lay perpendicular to the boundary line .of the nominal surface, that is lay perpendicular to the line representing surface to which the symbol is applied, e.g. , end view of shaping, longitudinal view of turning and O.D. grinding.

X = Lay angular in both directions to the line representing the surface to which symbol is applied, e.g. traversed end mill, side wheel grinding.

M= Lay multidirectional e.g. lapping super finishing, honing.

C= Lay approximately circular relative to the centre of the surface to which the symbol is applied e.g., facing on a lathe.

R= Lay approximately radial relative to the centre of the surface to which the symbol is applied, e.g., surface ground on a turntable, fly cut and indexed on end mill.

Sampling length: It is the length of the profile necessary for the evaluation of the irregularities to be taken into account. It is also known as cut-off length. It is measured in a direction parallelogram general direction of the profile. The sampling length should bear some relation to the type of profile.

Evaluation of Surface Finish:

A numerical assessment of surface finish can be carried out in a number of ways. These numerical values are obtained with respect to a datum. In practice, the following three methods of evaluating primary texture (roughness) of a surface are used:

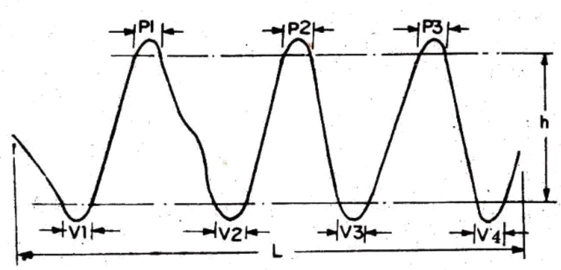
(1) Peak to valley height method

(2) The average roughness

(3) Form factor or bearing curve.

(1) Peak to valley height method:

This method is largely used in Germany and Russia. 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. The drawback of this method is that it may read the same h for two largely different texture. The value obtained would not give a representative assessment of the surface.

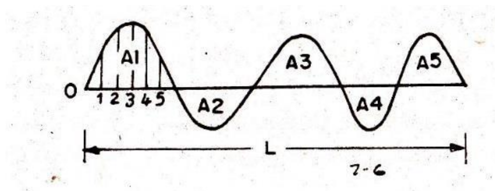


Peak to Valley height

To, overcomes this PV (Peak to Valley) height is defined as the distance between a pair of lines running parallel `to the general 'lay' of the trace positioned so that the length lying within the peaks at, the top is 5% of the trace length, and that within the valleys at the bottom is 10% of the trace length. This is represented graphically in Fig.

(2) The average roughness: For assessment off 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

$$\text{C.L.A Value} = \frac{h_1 + h_2 + h_3 + \ldots.. h_n}{n} \qquad \ldots(i)$$

Also

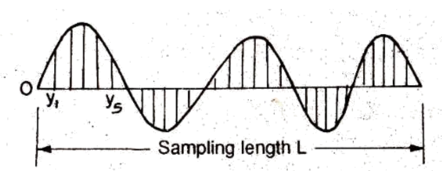
$$\text{C.L.A.} = \frac{A_1 + A_2 + A_3 + \ldots.. A_n}{L}$$

$$= \frac{\Sigma A}{L} \qquad \ldots(ii)$$

The calculation of C.L.A value using equation (ii) is facilitated by the planimeter.

CLA value measure is preferred to RMS value measure because its value can be easily determined by measuring. The areas with planimeter or graph or can be readily determined in electrical instruments by integrating the movement of the styles and displaying the result as an average.

(b) R.M.S. Method: In this method also, 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 squre 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 (1, 2, 3 ….)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 1, 2, 3 ….are the heights of the ordinates erected at those points.

Then,

$$\text{RMS average} = \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + \ldots + y_n^2}{n}}$$

$$y_{rms} = \left(\frac{1}{L} \int_0^L y^2 \, dL \right)^{1/2}$$

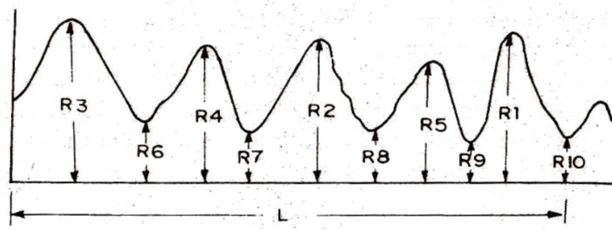
(c) Ten Point Height Method: In this method, the average difference between the five highest peaks and five lowest valleys of surface texture within the sampling length, measured from a line parallel to the mean line and not crossing the profile is used to denote the amount of surface roughness.

Mathematically,

R_2 = ten point height of irregularities

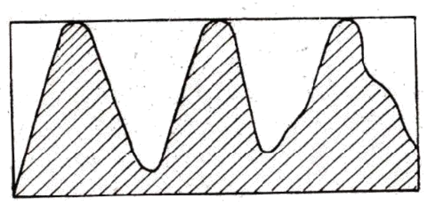
$$= \frac{1}{5}[(R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10})]$$

This method is relatively simple method of analysis and measures the total depth of surface irregularities within the sampling length. But it does not give sufficient information about the surface, as no account is taken of frequency of the irregularities and the profile shape. It is used when it is desired to control the cost of finishing for checking the rough machining.



(3) Form factor and Bearing Curves: There are certain characteristic which may be used to evaluate surface texture.

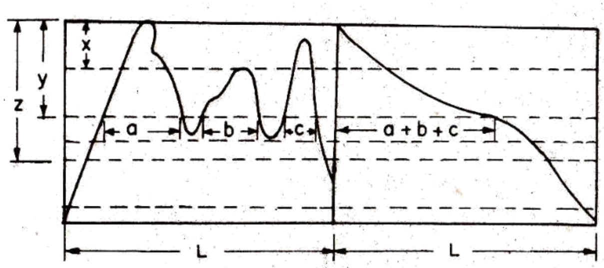
<u>Form Factor:</u> The load carrying area of every surface is often much less than might be thought. This is shown by reference to form factor. The form factor is obtained by measuring the area of material above the arbitrarily chosen base line in the section and the area of the enveloping rectangle. Then,



$$\text{Degree of fullness } (K) = \frac{\text{Area of metal}}{\text{Area of enveloping rectangle}}$$

$$\text{Degree of emptiness } = (K_p) = 1 - K$$

<u>Bearing Area Curve:</u> The bearing area curve is also called as Abbot's bearing curve. This is determined by adding the lengths a, b, c etc. at depths x, y, z etc. below the reference, line and indicates the percentage bearing area which becomes available as the crest area worn away. Fig. indicates the method of determining the bearing curve.



Conventional Method for Designing Surface finigh:

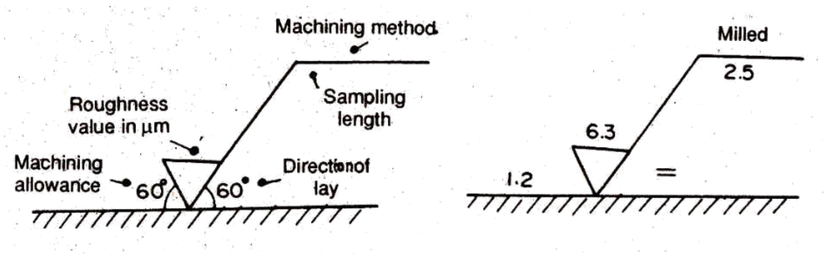
As per IS: 696 surface texture specified by indicating the following

(a) Roughness value i.e., Ra value in mm

(b) Machining allowance in mm.

(c) Sampling length or instrument cut-off length in mm.

(d) Machining production method, and
(e) Direction of lay in the symbol form as = ⊥, X, M, C, R



Measurement of surface finish surfaces texture:

The methods used for ensuring the surface finish can be classified broadly into two groups.

1. Inspection by comparison.

2. Direct instrument measurement

1. Inspection by comparison methods. In these methods, the surface texture is assessed by observation of the surface. These are the methods of qualitative analysis of the surface texture. The texture, e of the surface W be tested is compared with that of a specimen of known roughness ~value and `finished by similar machining processes. Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with\the surface produced by similar techniques. The various methods available for comparison are:

(i) Visual Inspection

(ii) Touch Inspection

(iii) Scratch Inspection

(iv) Microscopicc Inspection

(v) Surface photographs

(vi) Micro-Interferometer

(vii) Wallace surface Dynomometer

(viii) Reflected Light Intensity.

(i) Visual Inspection: In this method the surface is inspected by naked eye. This method is always likely to be misleading particularly when surfaces with high degree of finish are inspected. It is therefore limited to rougher surfaces.

(ii) Touch Inspection: This method can simply assess which surface is more rough, it cannot give the degree of surface roughness. Secondly, the minute flaws can't be detected. In this method, the finger tip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.0125 mm can be detected. In modified method a tennis ball is rubbed over the surface and surface roughness is judged thereby.

(iii) Scratch Inspection: In this method a softer material like lead, babbit, or plastic is rubbed over the surface to be inspected. The impression of the scratches on the surface produced is then visualised.

(iv) Microscopic Inspection: This is probably the best method for examining the surface texture by comparison. But since, only a small surface can be inspected at a time several readings are required to get an average value. In this method, a master finished surface is placed under the microscope and compared with the surface under inspection. Alternatively, a straight edge is placed on the surface to be inspected and a beam of light projected at about 600 to the work. Thus the shadow is cast into the surface, the scratches are magnified and the surface irregularities can be studied.

(v) Surface photographs: In this method magnified photographs of the surface are taken with different types of illumination to reveal the irregularities.

If the vertical illumination is used then defects like irregularities and scratches appear as dark spots and flat portion of the surface appears as bright area. In case of 'oblique illumination, reverse is the case. Photographs with different illumination are compared and the result is assessed.

(vi) Micro Interferometer: In this method, an optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light. Interference bands are studied through a microscope. The scratches in the surface appear as interference lines extending from the dark bands into the bright bands. The depth of the defect is measured in terms of the fraction of the interference bands.

(vii) Wallace Surface Dynamometer: It is a sort of friction meter. It consists of a pendulum in which the testing shoes are damped to a bearing surface and a predetermined spring pressure can be applied. The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested. If the surface is smooth, then there will be less friction and pendulum swings for a longer period. Thus, the time of swing is a direct measure of surface texture.

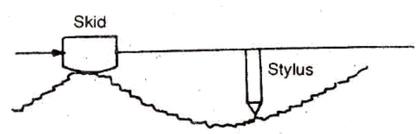
(viii)Reflected Light Intensity: In this method a beam of light of known quantity is projected upon the surface. This light is reflected in several directions as beams of lesser intensity and the change in light intensity in different directions is measured by a photocell. The measured intensity changes are already calibrated by means of reading taken from surface of known roughness by some other suitable method.

2. Direct Instrument Measurement:

These are the methods of quantitative analysis. These methods enable to determine the numerical value of the surface finish of any surface by using instruments of stylus probe type operating on electrical principles. In these instruments the output has to be amplified and the amplified output is used to operate recording or indicating instrument.

Principle, constructive and operation of stylus Probe type surface texture measuring instruments:

If a finely pointed Probe or stylus be moved over the surface of a workpiece, the vertical movement of the stylus caused due to the irregularities in the surface texture can be used to assess the surface finish of the workpiece.



Stylus which is a fine point made of diamond or any such hard material is drawn over the surface to be tested. The movements of the stylus are used to modulate a high frequency carrier current or to generate a voltage signal. The output is then amplified by suitable means and used to operate a recording or indicating instrument.

Stylus type instruments generally consist of the following units:

(i) Skid or shoe

(ii) Finely pointed stylus or probe

(iii) An amplifying device for magnifying the stylus movement and indicator

(iv) Recording device to produce a trace and ~

(v) Means for analyzing the trace.

Advantages:

The main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore, the stylus type instruments are widely used for surface texture measurements inspite of the following disadvantages.

Disadvantages:

(i) These instruments are bulky and complex.

(ii) They are relatively fragile.

(iii) Initial cost is high.

(iv) Measurements are limited to a section of a surface.

(v) Needs skilled operators for measurements.

(vi) Distance between stylus and skid and the shape of the skid introduce errors in measurement for wavy surfaces.

The stylus probe instruments currently in use for surface finish measurement.

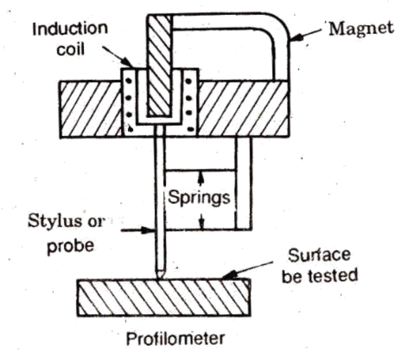
(a) Profilometer

(b) The Tomlinson surface meter.

(c) The Taylor Hobson Talysurf

(d) Profilograph.

(a) Profilometer:

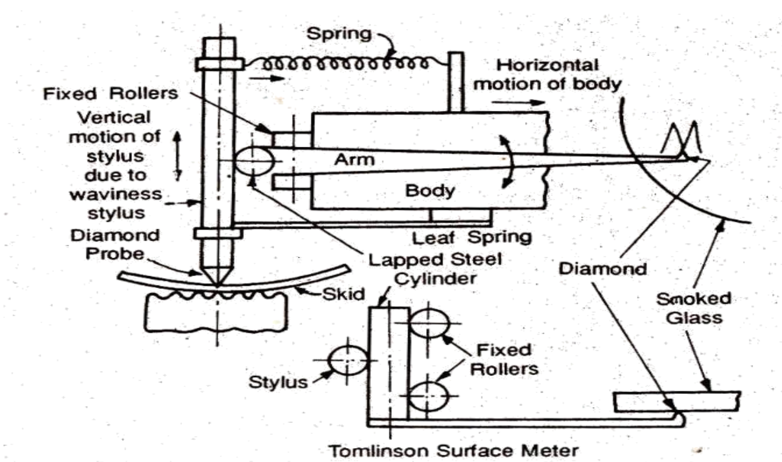


Profilometer is an indicating and recording instrument used to measure roughness in microns. The principle of the instrument is similar to gramophone pick up. It consists of two principal units: a tracer and an amplifier. Tracer is a finely pointed stylus. It is mounted in the pick up unit which consists of an induction coil located in the field of a permanent magnet. When the tracer is moved across the surface to be tested, it is displaced vertically up and down due to the surface irregularities. This causes the induction coil to move in the field of the permanent magnet and induces a voltage. The induced voltage is amplified and recorded.

This instrument is best suited for measuring surface finish of deep bores.

(b) The Tomlinson surface meter:

The Tomlinson surface meter is a comparatively cheap and reliable instrument. It was originally designed by Dr. Tomlinson.

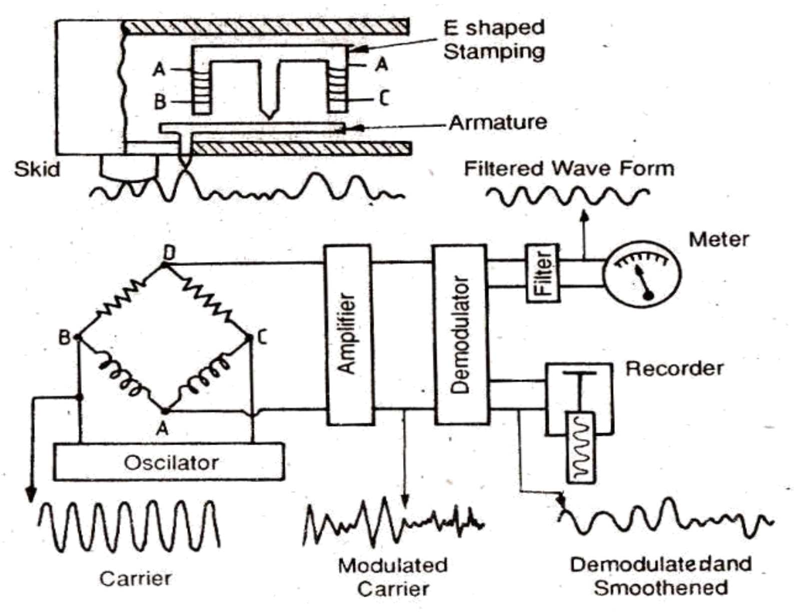


Tomlinson Surface Meter

It consists of a diamond probe (stylus) held by spring pressure against the surface of a lapped steel cylinder and is attached to the body of the instrument by a leaf spring. The lapped cylinder is supported on one side by the probe and on the either side by fixed rollers. Alight spring steel arm is attached to the lapped cylinder. It carries at its tip a diamond scriber which rests against a smoked glass. The motions of the stylus in all the directions except the vertical one are prevented by the forces exerted by the two springs.

For measuring surface finish the body of the instrument is moved across the surface by screw rotated by asynchronous motor. The vertical movement of the probe caused by surface irregularities makes the horizontal lapped cylinder to roll. This causes the movement of the arm attached to the lapped cylinder. A magnified vertical movement of the diamond scriber on smoked glass is obtained by the movement of the arm. This vertical movement of the scriber together with horizontal movement produces a trace on the smoked glass plate. This trace is further magnified at X 50 or X 100 by an optical projector for examination.

(c) The Taylor Hobson Talysurf:



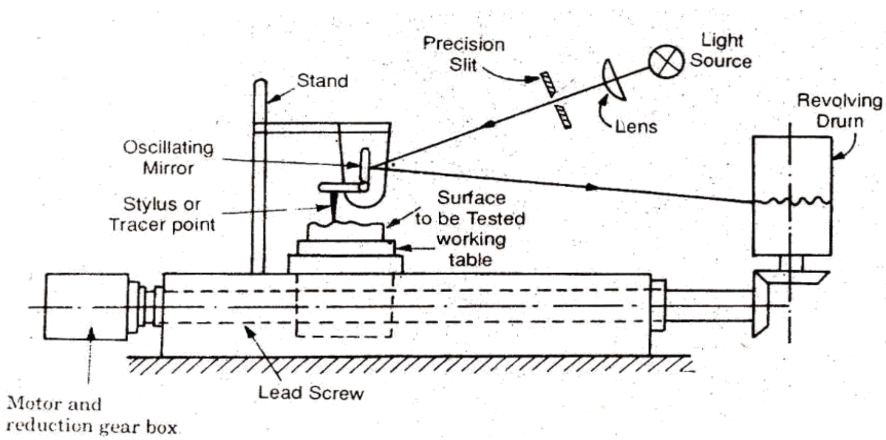
Talyor-Hobson-Talysurf

Taylor-Hobson Talysurf is a stylus and skid type of instrument working on carrier modulating principle. Its response is more rapid and accurate as comparred to Temlinson Surface Meter. The measuring head of this instrument consists of a sharply pointed diamond stylus of about 0.002 mm tip radius and skid or shoe which is drawn across the surface by means of a motorised driving unit. In this instrument the stylus is made to trace the profile of the surface irregularities, and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as shown in Fig. The arm carrying the stylus forms an armature which pivots about the centre piece of E-shaped stamping. On two legs of (outer pole pieces)'the E-shaped stamping there are coils carrying an a.c. current. These two coils with other two resistances form an oscillator. As the armature is pivoted about the central leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c. current flowing in the coils is modulated. The output of the bridge thus consists of modulation only as shown in

Fig. This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

(d) Profilograph:

(i) Proyilograph : The principle of Working of a tracer type profilograph is shown in Fig. The work to be tested is placed on the table of the instrument. The work and the table are traversed with the help of a lead screw.



The stylus which is pivoted to a mirror moves over the tested surface. Oscillations of the tracer point are transmitted to the mirror. A light source sends a beam of light through lens and a precision slit to the oscillating mirror. The reflected beam is directed to a revolving drum, upon which a sensitised film is arranged. This drum is rotated through two bevel gears from the same lead screw that moves the table of the instrument. A profilogram will be obtained from the sensitised film, that may be sub-sequently analysed to determine the value of the surface roughness.

Problems:

Problem 3. *What do you mean by Ra and Rz values ?*

Sol. The Roughness average (R_a) is a quantitative measure of surface roughness. It is the arithmetical mean deviation of the surface profile from the mean line. Thus *Ra* values are numerical assessment of the average heights of irregularities of surface texture and are usually expressed in microns where one microns $= 10^{-3}$ mm. Fig. 7.21 shows a graph of machined surface. To obtain *Ra* value, a sampling length is chosen and a return line is drawn so that the sum of the area $(A_2 + A_4 + A_6)$ enclosed above the line is equal to the sum of the shaded areas $(A_1 + A_2 + A_3)$ enclosed below it. The *Ra* value is given by, $Ra(CLA) = \frac{\Sigma A}{L}$.

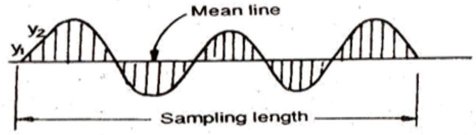


Fig. 7.21

R_2 Value : It is ten point height of irregularities and is defined as the average difference between the five height peaks and five lowest valleys on.

the surface profile within the sampling length from a line parallel to the mean line and not crossing the profile. Mathematically,

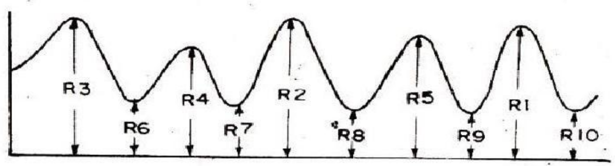


Fig. 7.22.

$$R_2 = \frac{1}{5}\left[(R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10})\right]$$

where, $R_1, R_2 \ldots R_5$ are five highest peaks

and $R_6, R_7 \ldots R_{10}$ are five lowest valleys.

Problem 4. *State how surface finish is designated on drawings.*

Sol. The surface roughness is represented as shown in Fig. 7.23.

The following information is furnished with the symbol ∇.

(1) Surface roughness value in *Ra* value in microns μm

(2) Machining allowance in mm.

(3) Sampling length in mm.

(4) Method of machining such as milled, ground turned, tapped, shaped etc.

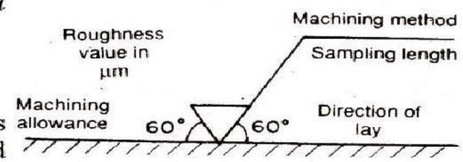


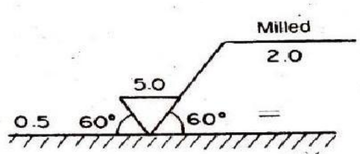
Fig. 7.23.

(5) Direction of lay in the symbol form as :

=, ⊥ ,X, M, C, R

Problem 5. *The surface finish on the milled surface is not to exceed 5 μm Ra with a cut-off length 2 mm, machining allowance 0.5 mm. and direction of lay parallel. How will you represent it on a drawing ?*

Sol.



Problem 7. *In the measurement of surface roughness, heights of successive 10 peaks and troughs were measured from a datum and were 33, 25, 30, 19, 22, 18, 27, 29 and 20 microns. If these measurements were obtained on 10 mm length, determine CLA and RMS values of surface roughness.*

Sol. CLA value or *Ra* value $= \dfrac{y_1 + y_2 + y_3 + \ldots + y_n}{n}$

$$= \frac{33 + 25 + 30 + 19 + 22 + 18 + 27 + 29 + 20}{10}$$

$= 25.5$ microns

RMS value $= \sqrt{\dfrac{y_1^2 + y_2^2 + y_3^2 + \ldots y_n^2}{n}}$

$$= \sqrt{\frac{33^2 + 25^2 + 30^2 + 19^2 + 22^2 + 18^2 + 27^2 + 28^2 + 20^2}{10}}$$

$= 26.03$ microns

Problem 10. *Calculate the C.L.A. value of a surface for the following data :*

The sampling length is 0.8 mm, the graph is drawn to a vertical magnification of 15,000 and horizontal magnification of 100 and the areas above and below the datum line are 160, 90, 180, 50 mm² and 95, 65, 170, 150 mm² respectively.

Sol. $\text{C.L.A.} = \frac{\Sigma A}{L} \times \frac{1}{\text{vertical scale}} \times \frac{1}{\text{horizontal scale}}$

$$= \frac{(160 \times 95 + 90 + 65 + 180 + 170 + 50 + 150)}{0.8} \times 15000 \times 100$$

$$= 0.8\ \mu\text{m}.$$

Problem 11. *In the measurement of surface roughness, heights of 20 successive peaks and valleys measured from a datum are as follows :*

45, 25, 40, 25, 35, 16, 40, 22, 25, 34, 25, 40, 20, 36, 28, 18, 20, 25, 30, 38

If these measurements were made over a length of 20 mm, determine the C.L.A and RMS values of the surface.

Sol.

$$\text{C.L.A.value} = \frac{45 + 25 + 40 + 25 + 35 + 16 + 40 + 22 + 25 + 34 + 25 + 40 + 20 + 36 + 28 + 18 + 20 + 30 + 38}{20}$$

$$= 29.35$$

$$\text{RMS Value} = \sqrt{\frac{45^2 + 25^2 + 40^2 + 25^2 + 35^2 + 16^2 + 40^2 + 22^2 + 25^2 + 34^2 + 25^2 + 40^2 + 20^2 + 36^2 + 28^2 + 18^2 + 20^2 + 25^2 + 30^2 + 38^2}{20}}$$

$$= 930.96$$

ISI Symbols for Indication of surface Finish

The surface roughness is represented in figure. If the matching method is milling, .sampling length is 2.5 mm, direction of lay is parallel to the surface, machining allowance is 3 mm and the representative will be as shown in figure,

Representation of Surface Roughness:

(i) The limits of surface roughness can be represented as,

$R^{8.0}_{a_{16.0}}$ or $R_a^{8.0-16.0}$

(ii) The surface roughness and sampling length can be represented as,

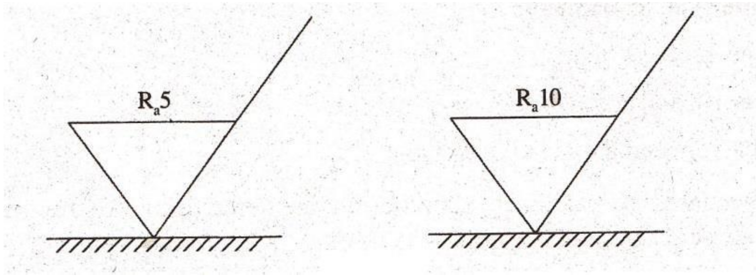
$R_a 8.0\,(2.5)$

Here surface sampling length is 2.5 mm p

(iii) The surface roughness and lay can be stated as,

R_a 1.6 lay Circular

However, in most cases, one single piece of information is sufficient which is indicated as follows,



The I.S.O has recommended as series of preferred roughness values and corresponding roughness grade numbers to be used when specifying surface roughness on drawings.

The roughness symbols indicate the practice followed in the industry.

Roughness Values (R_a) (µm)	Roughness Grade Number	IS Roughness Symbol
50	N 12	~
25	N 11	∇
12.5	N 10	
6.3	N 9	
3.2	N 8	∇∇
1.6	N 7	
0.8	N 6	
0.4	N 5	∇∇∇
0.2	N 4	
0.1	N 3	
0.05	N 2	∇∇∇∇
0.025	N 1	

Comparators

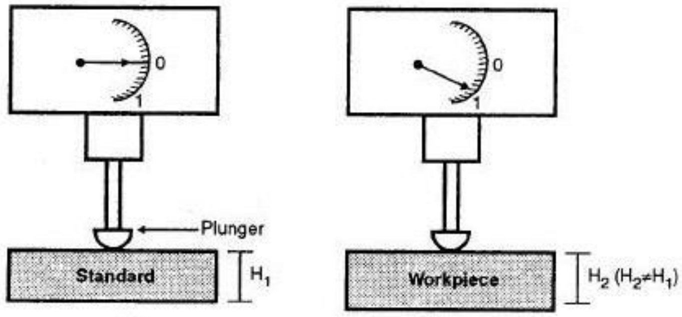
Comparators
- Introduction to comparators
- Characteristics
- Uses of Comparators
- Classification of comparators
- Mechanical comparators
  - Dial indicator
  - Johnson Mikrokator
  - Sigma comparators

Optical comparators
- Principles,
- Zeiss ultra optimeter,

Electric and electronic comparators principles,
- LVDT,

Pneumatic comparators,
- Back pressure gauges,
- Solex comparators.

Comparators can give precision measurements, with consistent accuracy by eliminating human error. They are employed to find out, by how much the dimensions of the given component differ from that of a known datum. If the indicated difference is small, a suitable magnification device is selected to obtain the desired accuracy of measurements. It is an indirect type of instrument and used for linear measurement. If the dimension is less or greater, than the standard, then the difference will be shown on the dial. It gives only the difference between actual and standard dimension of the workpiece. To check the height of the job H2 ,with the standard job of height H1



(a) (b)

Initially, the comparator is adjusted to zero on its dial with a standard job in position as shown in Figure(a). The reading H1is taken with the help of a plunger. Then the standard job is replaced by the work-piece to be checked and the reading H2 is taken. If H1and H2 are different, then the change i~ the dimension will be shown on the dial of the comparator. Thus difference is then magnified 1000 to 3000 X to get the clear variation in the standard and actual job.

In short, Comparator is a device which
(1) Picks up small variations in dimensions.
(2) Magnifies it.
(3) Displays it by using indicating devices, by which comparison can be made with some standard value.

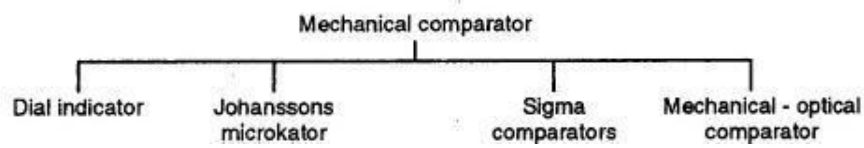
Classification:
1. Mechanical Comparator: It works on gears pinions, linkages, levers, springs etc.
2. Pneumatic Comparator: Pneumatic comparator works by using high pressure air, valves, back pressure etc.
3. Optical Comparator: Optical comparator works by using lens, mirrors, light source etc.
4. Electrical Comparator: Works by using step up, step down transformers.
5. Electronic Comparator: It works by using amplifier, digital signal etc.
6. Combined Comparator: The combination of any two of the above types can give the best result.

Characteristics of Good Comparators:
1. It should be compact.
2. It should be easy to handle.
3. It should give quick response or quick result.
4. It should be reliable, while in use.
5. There should be no effects of environment on the comparator.
6. Its weight must be less.
7. It must be cheaper.
8. It must be easily available in the market.
9. It should be sensitive as per the requirement.
10. The design should be robust.
11. It should be linear in scale so that it is easy to read and get uniform response.

12. It should have less maintenance.
13. It should have hard contact point, with long life.
14. It should be free from backlash and wear.

Mechanical Comparator:

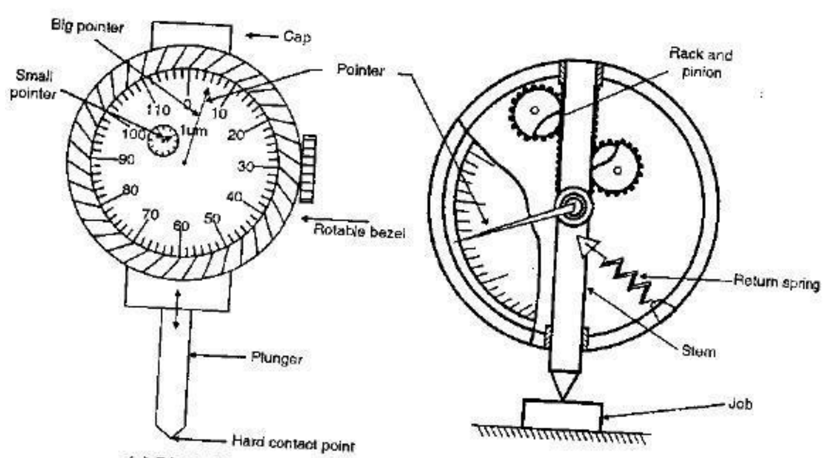
It is self controlled and no power or any other form of energy is required. It employs mechanical means for magnifying the small movement of the measuring stylus. The movement is due to the difference between the standard and the actual dimension being checked



The method for magnifying the small stylus movement in all the mechanical comparators is by means of levers, gear trains or combination of these. They are available of different make and each has it's own characteristic. The various types of mechanical comparators are dial indicator, rack and pinion, sigma comparator, Johansson mikrokator.

a. Dial Indicator:

It operates on the principle, that a very slight upward pressure on the spindle at the contact point is multiplied through a system of gears and levers. It is indicated on the face of the dial by a dial finger. Dial indicators basically consists of a body with a round graduated dial and a contact point connected with a spiral or gear train so that hand on the dial face indicates the amount of movement of the contact point. They are designed for use on a wide range of standard measuring devices such as dial box gauges, portal dial, hand gauges, dial depth gauges, diameter gauges and dial indicator snap gauge.



(a) Dial indicator

(b) Mechanism of dial indicator

Corresponds to a spindle movement of 1 mm. The movement mechanism of the instrument is housed in a metal case for it's protection. The large dial scale is graduated into 100 divisions. The indicator is set to zero by the use of slip gauges representing the basic size of part.

Requirements of Good Dial Indicator:

1. It should give trouble free and dependable readings over a long period.
2. The pressure required on measuring head to obtain zero reading must remain constant over the whole range.
3. The pointer should indicate the direction of movement of the measuring plunger.
4. The accuracy of the readings should be within close limits of the various sizes and ranges
5. The movement of the measuring plunger should be in either direction without affecting the accuracy.
6. The pointer movement should be damped, so that it will not oscillate when the readings are being taken.

Applications:

1. Comparing two heights or distances between narrow limits.
2. To determine the errors in geometrical form such as ovality, roundness and taper.
3. For taking accurate measurement of deformation such as intension and compression.
4. To determine positional errors of surfaces such as parallelism, squareness and alignment.
5. To check the alignment of lathe centers by using suitable accurate bar between the centers.
6. To check trueness of milling machine arbours and to check the parallelism of shaper arm with table surface or vice.

b) Johansson Mikrokator :

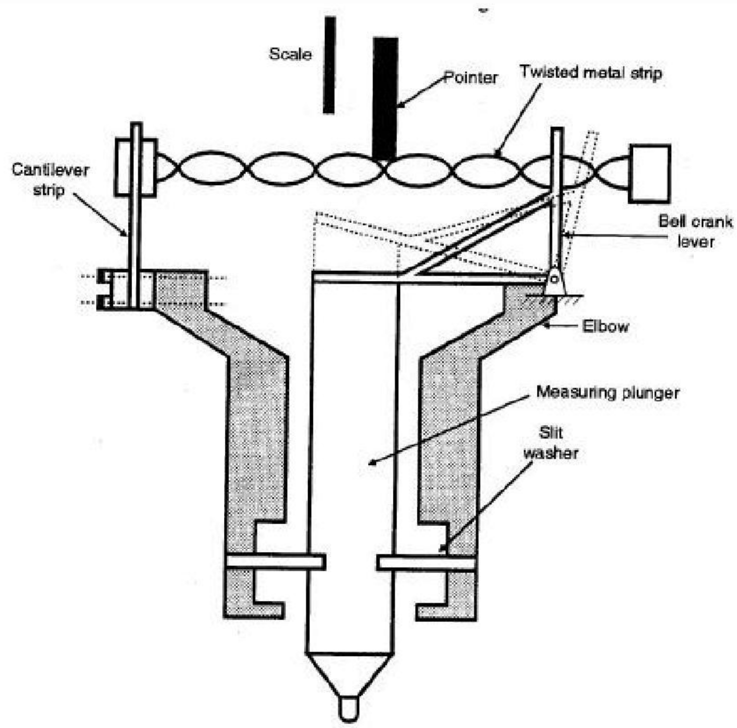
This comparator was developed by C.F. Johansson.

Principle:

It works on the principle of a Button spring, spinning on a loop of string like in the case of Children's toys.

Construction:

The method of mechanical magnification is shown in Figure. It employs a twisted metal strip. Any pull on the strip causes the centre of the strip to rotate. A very light pointer made of glass tube is attached to the centre of the twisted metal strip. The measuring plunger is on the slit washer and transmits its motion through the bell crank lever to the twisted metal strip. The other end of the twisted metal strip is fastened to the cantilever strip. The overhanging length of the cantilever strip can be varied to adjust the magnification of the instrument. The longer the length of the cantilever, the more it will deflect under the pull of the twisted metal strip and less rotation of the pointer is obtained.



When the plunger moves by a small distance in upward direction the bell crank lever turns to the right hand side. This exerts a force on the twisted strip and it causes a change in its length by making it further twist or untwist. Hence the pointer at the centre rotates by some amount. Magnification up to 5000X can be obtained by this comparator

Advantages of Mechanical Comparator:

1. They do not require any external source of energy.
2. These are cheaper and portable.
3. These are of robust construction and compact design.
4. The simple linear scales are easy to read.
5. These are unaffected by variations due to external source of energy such air, electricity etc.

Disadvantages:

(vi) Range is limited as the pointer moves over a fixed scale.
(vii) Pointer scale system used can cause parallax error.
(viii) There are number of moving parts which create problems due to friction, and ultimately the accuracy is less.
(ix) The instrument may become sensitive to vibration due to high inertia.

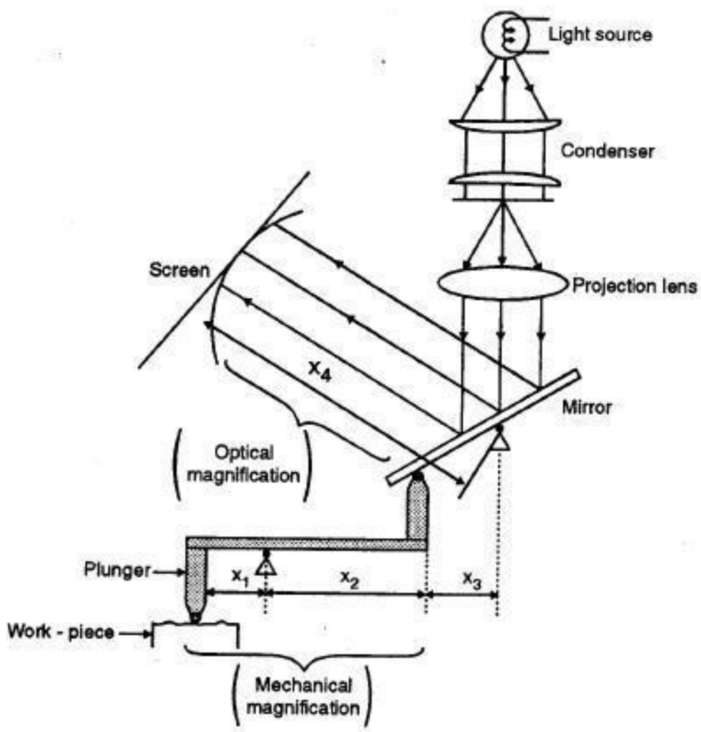
c) Mechanical - Optical Comparator:

Principle:

In mechanical optical comparator, small variation in the plunger movement is magnified: first by mechanical system and then by optical system.

Construction:

The movement of the plunger is magnified by the mechanical system using a pivoted lever. From the Figure the mechanical magnification = x2 / x1. High optical magnification is possible with a small movement of the mirror. The important factor is that the mirror used is of front reflection type only.



The back reflection type mirror will give two reflected images as shown in Figure, hence the exact reflected image cannot be identified.

Advantages:

(viii) These Comparators are almost weightless and have less number of moving parts, due to this there is less wear and hence lessfriction.70

(ix) Higher range even at high magnification is possible as the scale moves past the index.

(x) The scale can be made to move past a datum line and without having any parallax errors.

(xi) They are used to magnify parts of very small size and of complex configuration such as intricate grooves, radii or steps.

Disadvantages:

(iv) The accuracy of measurement is limited to 0.001 mm

(v) They have their own built in illuminating device which tends to heat the instrument.

(vi) Electrical supply is required.

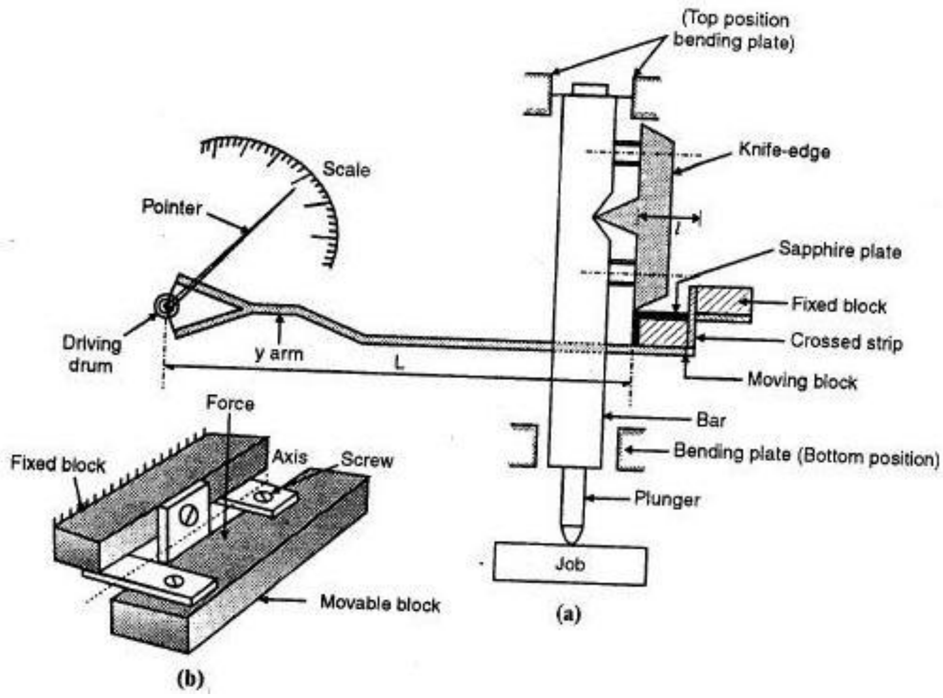
(vii) Eyepiece type instrument may cause strain on the operator.

(viii) Projection type instruments occupy large space and they are expensive.

(ix) When the scale is projected on a screen, then it is essential to take the instrument to a dark room in order to take the readings easily.

d) Sigma Comparator:

The plunger is attached to a bar which is supported between the bending plates at the top and bottom portion as shown in Figure (a)

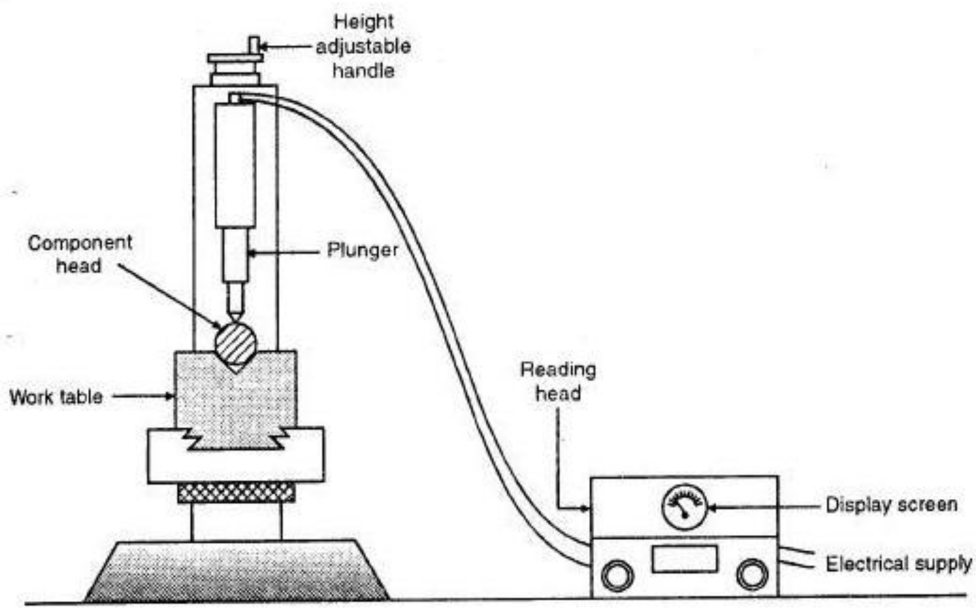


The bar is restricted to move in the vertical direction. A knife edge is fixed to the bar. The knife edge is attached to the sapphire plate which is attached to the moving block. The knife edge extorts a force on the moving block through sapphire plate. Moving block is attached to the fixed block with the help of crossed strips as shown in Figure (b). When the force is applied on the moving block, it will give an angular deflection. A Y-arm which is attached to the moving block transmits the rotary motion to the driving drum of radius r. This deflects the pointer and then the reading is noted.

If l = Distance from hinge pivot to the knife edge
L = Length of y-arm
R = Driving drum radius
D Length of the pointer
Then the total magnification = (L/l) *(D/R)

Electrical Comparators:

Electrical comparators give a wide range of advantages. As we know, components like levers, gears, racks and pinions, activate mechanical devices. The accuracy and life of the instruments are affected as they are subjected to wear and friction



Electrical comparators have no moving parts. Thus a high degree of reliability is expected from these instruments. Generally there are two important applications of electrical comparators:1. Used as measuring heads2. Used for electrical gauging heads, to provide usual indication to check the dimensions within the limits laid down. The first application is very important when there is a requirement for precise measurement for e.g. Checking or comparison of workshop slip gauges against inspection slip gauges. The second application is used to indicate with a green light if a dimension is within the limits. A red lamp indicates an undersize dimension; a yellow lamp indicates an oversize dimension. So the operator is not required to be aware of the actual tolerances on the dimension. After setting the instrument correctly, all that needs to be done is to place the component under the plunger of the gauging head. The signal lamps provide in standard positive indication of the acceptability of the dimension under test

Advantages:

(vii) Measuring units can be remote from indicating units.
(viii) Variable sensitivity which can be adjusted as per requirement.
(ix) No moving parts, hence it can retain accuracy over long periods.
(x) Higher magnification is possible as compared to mechanical comparator.
(xi) Compact sizes of probes arc available.

Disadvantages:

(e) The accuracy of working of these comparators is likely to be affect due to temperature and humidity.
(f) It is not a self contained unit; it needs stabilized power supply for its operation.
(g) Heating of coils can cause zero drifts and it may alter calibration.
(h) It is more expensive than mechanical comparator

Pneumatic Comparators (Solex Gauge):

Principle:

It works on the principle of pressure difference generated by the air flow. Air is supplied at constant pressure through the orifice and the air escapes in the form of jets through a restricted space which exerts a back pressure. The variation in the back pressure is then used to find the dimensions of a component.

Working:

As shown in Figure (a) the air is compressed in the compressor at high pressure which is equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, at A1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1.

Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1 corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore

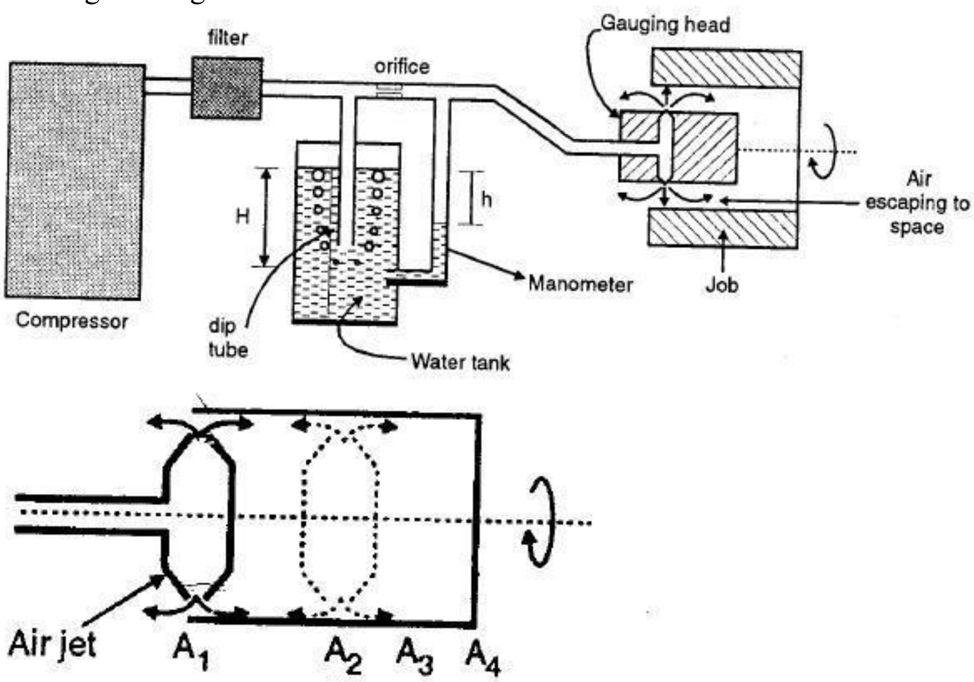


Figure (b)

Any variation in the dimension changes the value of h, e.g. Change in dimension of 0.002 mm changes the value of h from 3 to 20 mm. Moderate and constant supply pressure is required to have the high sensitivity of the instrument.

Advantages:

(ii) It is cheaper, simple to operate and the cost is low.
(iii) It is free from mechanical hysteresis and wear.
(iv) The magnification can be obtained as high as 10,000 X.
(v) The gauging member is not in direct contact with the work.
(vi) Indicating and measuring is done at two different places.
(vii) Tapers and ovality can be easily detected.
(viii) The method is self cleaning due to continuous flow of air through the jets and this makes the method ideal to be used on shop floor for online controls.

Disadvantages:

1. They are very sensitive to temperature and humidity changes.
2. The accuracy may be influenced by the surface roughness of the component being checked.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipments such as air filters, pressure gauges and regulators are needed.
5. Non-uniformity of scale is a peculiar aspect of air gauging as the variation of back pressure is linear, over only a small range of the orifice size variation.