Unit-3

Measurement of Straightness, Flatness and Surface Roughness

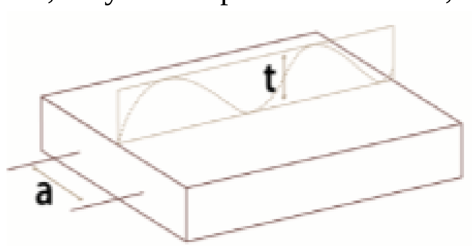
Contents: Concept of straightness and flatness, Use of straight edge, Level beam comparator and autocollimator for testing of flatness of surface plate, Principle of interferometry and application for checking flatness, Surface roughness terminology, Direction of lay, textures, symbols, Numerical assessment of surface roughness, Instruments used in surface roughness assessment.

Introduction:

The evaluation of straightness deviation is employed primarily in monitoring the form of cylindrical and conical surface parts. It can also be used to control line elements in one direction on flat surfaces.

In the mechanical area the evaluation of straightness is very important. In fact, "In machine tool guiding systems the straightness is fundamental for warranting the tolerance observation of the produced parts. In the manufacturing of hydraulics equipment parts it is also necessary to observe straightness and flatness specifications; the respect of tolerances is fundamental in aircraft wing subassembly, etc."

- The straightness tolerance is the maximum acceptable linear dimension, *t*, of the tolerance zone where the line location must be considered.
- The tolerance zone, in the considered plane, is limited by two parallel straight lines at a distance *t* from each other, only in the specified direction, at any distance *a*.



Use of Straightedge:

A straightedge is a tool with an edge free from curves, or straight, used for transcribing straight lines, or checking the straightness of lines. If it has equally spaced markings along its length, it is usually called a ruler. Straightedges are used in the automotive service and machining industry to check the flatness of machined mating surfaces. True straightness can in some cases be checked by using a laser line level as an optical straightedge: it can illuminate an accurately straight line on a flat surface such as the edge of a plank or shelf.

Fig.3.1 Straightedge

Testing of Straightness by Autocollimator:

Tests for straightness can be carried out by using spirit level or auto-collimator. The straightness of any surface could be determined by either of these instruments by measuring the relative angular positions of number of adjacent sections of the surface to be tested. So first a straight line is drawn on the surface whose straightness is to be tested. Then it is divided into a number of sections, the length of each section being equal to the length of spirit level base or the plane reflector's base in case of auto-collimator. Generally the bases of the spirit level block or reflector are fitted with two feet so that only feet have line contact with the surface and whole of the surface of base does not touch the surface to be tested. This ensures that angular deviation obtained is between the specified two points. In this case length of each section must be equal to distance between the centre lines of two feet. The spirit level can be used only for the measurement of straightness of horizontal surfaces while auto-collimator method can be used on surfaces in any plane. In case of spirit level, the block is moved along the line on the surface to be tested in steps equal to the pitch distance between the centre lines of the feet and the angular variations of the direction of block are measured by the sensitive level on it. Angular variation can be correlated in terms of the difference of height between two points by knowing the least count of level and length of the base.

In case of measurement by auto-collimator, the instrument is placed at a distance of 0.5 to 0.75 meter from the surface to be tested on any rigid support which is independent of the surface to be tested. The parallel beam from the instrument is projected along the length of the surface to be tested. A block fixed on two feet and fitted with a plane vertical reflector is placed on the surface and the reflector face is facing the instrument. The reflector and the instrument are set such that the image of the cross wires of the collimator appears nearer the centre of the field and for the complete movement of reflect or along the surface straight line, the image of cross-wires will appear in the field of eyepiece. The reflector is then moved to the other end of the surface in steps equal to the centre distance between the feet and the tilt of the reflector is noted down in seconds from the eyepiece.

Therefore, 1 sec. of arc will correspond to a rise or fall of 0.000006* I mm, where I is the distance between centres of feet in mm. The condition for initial and subsequent readings is shown in Fig. 3.2 in which the rise and fall of the surface is shown too much exaggerated.

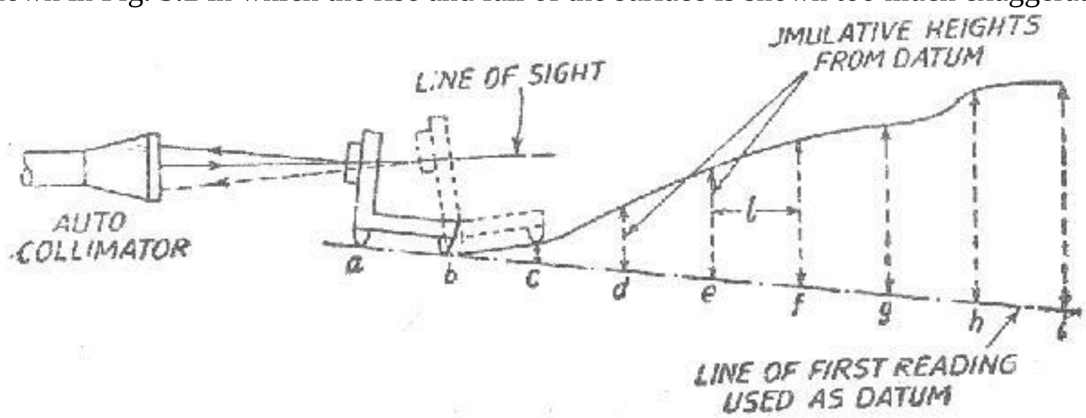


Fig.3.2 Autocollimator

With the reflector set at a- b (1st reading), the micrometer reading is noted and this line is treated as datum line. Successive readings at b-c, c-d, d-e etc. are taken till the length of the surface to be tested has been stepped along. In other to eliminate any error in previous set of readings, the second set of readings could be taken by stepping the reflector in the reverse direction and mean of two taken. This mean reading represents the angular position of the reflector in seconds relative to the optical axis or auto-collimator.

Column 1 gives the position of plane reflector at various places at intervals of ‘l’ e.g. a-b, b-c, c-d etc., column 2 gives the mean reading of auto-collimator or spirit level in seconds. In column 3, difference of each reading from the first is given in order to treat first reading as datum. These differences are then converted into the corresponding linear rise or fall in column 4 by multiplying column 3 by ‘I’. Column 5 gives the cumulative rise or fall, i.e., the heights of the support feet of the reflector above the datum line drawn through their first position. It should be noted that the values in column 4 indicate the inclinations only and are not errors from the true datum. For this the values are added cumulatively with due regard for sign. Thus it leaves a final displacement equal to L at the end of the run which of course does not represent the magnitude of error of the surface, but is merely the deviation from a straight line produced from the plane of the first reading. In column 5 each figure represents a point, therefore, an additional zero is put at the top representing the height of point ‘a’.

The errors of any surfaced may be required relative to any mean plane. If it be assumed that mean plane is one joining the end points then whole of graph must be swung round until the end point is on the axis (Fig. 3.3). This is achieved by subtracting the length L proportionately from the readings in column 5. Thus if n readings be taken, then column 6 gives the adjustments— L/n, —2L/n… etc., to bring both ends to zero. Column 7 gives the difference of columns 5 and 6 and represents errors in the surface from a straight line joining the end points. This is as if a straight edge were laid along the surface profile to be tested and touching the end points of the surface when they are in a horizontal plane and the various readings in column 7 indicate the rise and fall relative to this straight edge.

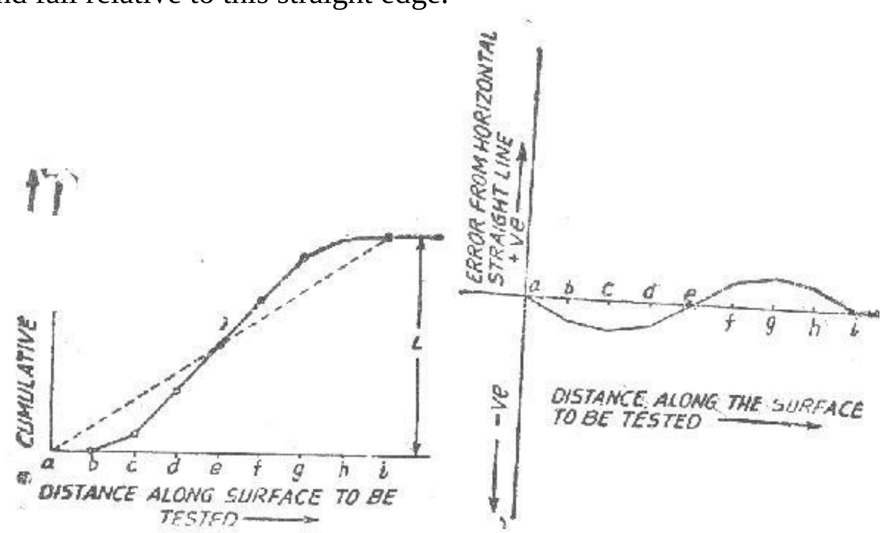


Fig.3.3 Errors in straightness measurements

Optical Flat:

Optical flat works on the principle of light interference it is made of any transparent material usually glass or quartz with 2 highly polished parallel flat surfaces as shown in fig 3.4. The yellow orange light eradicated by helium gas is most satisfactory for use with optical flat. For greater accuracy of optical flat it must be used in areas where the temperature is constant. The optical flat must be extremely clean when measurements are being made. It is advisable to use lint free paper for cleaning the optical flat and the surface of the part to be measured in order to form fringe band of normal contrast with a diffused monochromatic light, the optical flat must be close to the work but it need not actually touch.

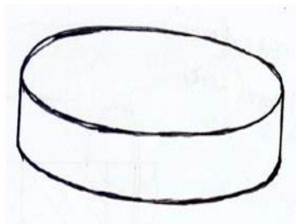


Fig.3.4 Optical Flat

Care in the use of optical flats:

1. Before using, it should be ensured that, the work piece and flat arc clean and free from dirt, dust and oil. Paper or chamois is used for polishing their surfaces.
2. Optical flats should never be slided over the work piece but lifted from it. Sliding, creeping and wringing of flat over work piece are extremely harmful and should be avoided.
3. Flats should never be wrung on work piece because it scratches readily. It should be rested carefully on the work piece.
4. If interference bands are not good, flat should be lifted and set down again, applying vertical finger pressure at various locations on the upper surface to obtain satisfactory bands.

Flatness testing:

An optical flat is considered to be placed upon a flat metal surface so that a thin wedge film of air is entrapped between them as shown in fig 3.5. This wedge is stable enough for fringe bands reading because of the presence minute dust particle or lint (friendly dirt) after grease and soil have been removed. A suitably illuminated interference fringes are visible. When the deviation from the planarity are of the order of 1mm or less.

Interference Bands by Optical Flat:

Optical flats arc blocks of glass finished to within 0.05 microns for flatness. When art optical flat is on a flat surface which is not perfectly flat then optical flat will not exactly coincide with it, but it will make an angle θ with the surface as shown in Figure3.5.

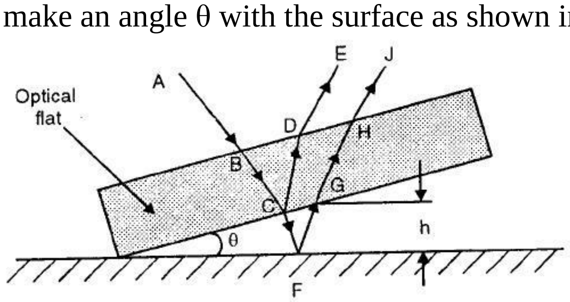
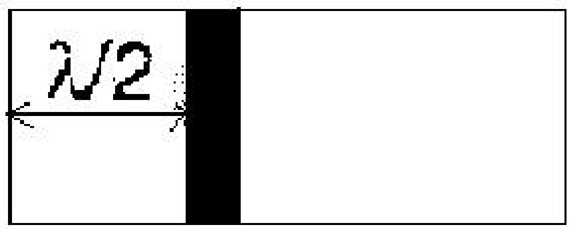


Fig. 3.5 Principle of optical flat

When a beam AB of monochromatic light falls on the optical flat, it travels further along BC. At C, part of this light is reflected by the bottom of the optical flat and goes along CDE, the remaining part goes along CF, reflected at F by the surface under test and goes further along FGHJ. The two beams DE and HJ differ in phase because of the extra distance CFG traveled by HJ. If the air gap between the bottom of the optical flat and the test surface is denoted by 'h' since θ is very small, then for vertically incident beams h = CF = FG = (λ / 4) where λ = wavelength of source and thus beam HJ will lag behind DE by 2h. When this lag is half the wavelength, the two beams DE and HJ will be in opposite phase and a state of darkness will be created. At all points where the air gap is present then darkness will be created. At all points where the air gap is present then darkness will be observed at λ / 2 distance as shown in Figure



In other words, all points with air gap h will form a dark band. As we move along the wedge to the right side, to point K, L, value of h goes on increasing and hence the phase difference between the two rays will go on increasing from λ/2 and will reach A at some point. At these points as the air gap increases, for every increase, the bright bands will be seen as shown in Figure

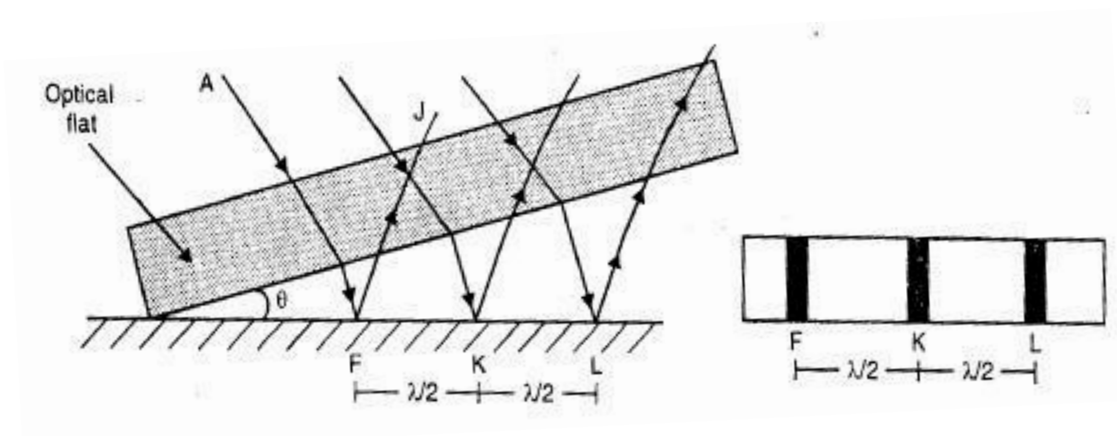


Fig. 3.6 Principle of optical flat

To check the flatness of slip gauge surface using optical flat:

The apparatus required is a monochromatic light source and optical flat. If optical flat is placed on slip gauge, it will not form an intimate contact, but will be at some angle 'θ' making an inclined plane. If the optical flat is illuminated by monochromatic light and eye if placed in proper position will observe number of bands. They are produced by interference of light rays reflected from lower plane of optical flat and top surface of slip gauge.

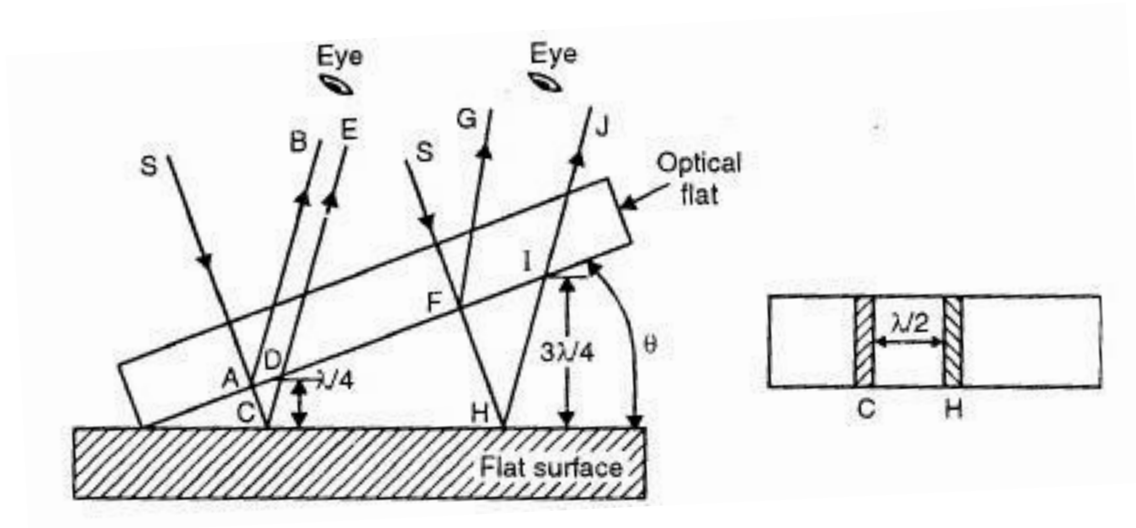
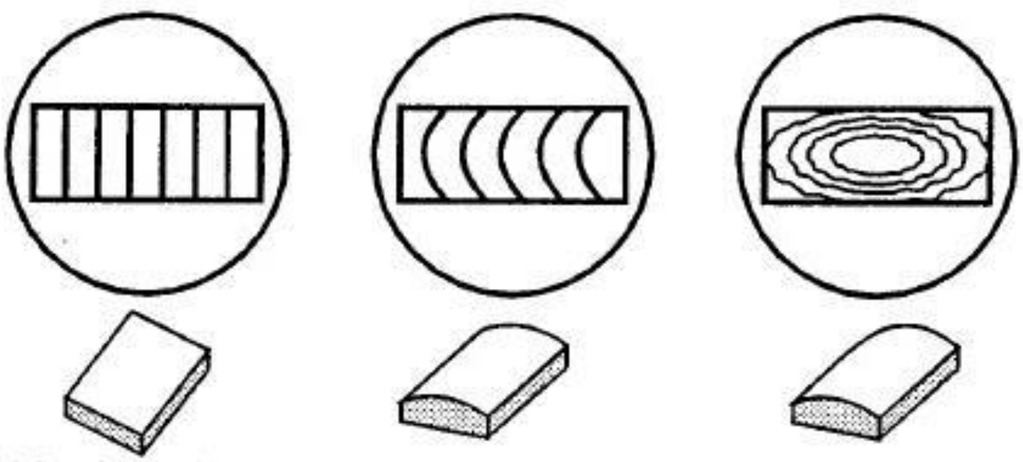


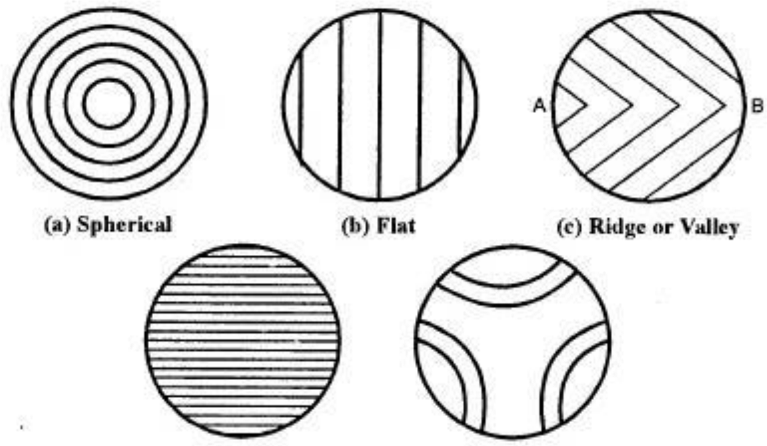
Fig. 3.7 use of optical flat

They are produced by interference of light rays reflected from lower plane of optical flat and top surface of slip gauge. As shown in Figure, if 'S' is monochromatic light source. At 'C' ray is reflected in direction CDE. The two reflected components are combined by eye, having traveled path whose wavelengths differ by an amount ACD. If path lengths differ by odd number of λ/2 then interference is said to have occurred. If surface is perfectly flat then the surface will be crossed by the pattern of alternate light and dark bands which will be straight and dark line is seen passing at C. The next line occurs at 3λ / 2 (i.e. FHI =3λ / 2) alternate dark and bright fringes are seen and variation from the straightness of the bands measure the error in the flatness of slip gauge.



(a) Perfectly flat (b) Not flat (c) Surface is 'peaked' or 'valley'

The pitch of the bands depends on the angle of the wedge and it can be easily seen that increase in this angle reduces the pitch.



(a) Spherical (b) Flat (c) Ridge or Valley

(d) Cylindrical (e) Conical

The orientation of the bands depends on the orientation of the wedge. The spherical surface can be concave or convex and a little pressure on the optical flat at the centre will spread the bands outwards in a convex way. Figure shows interference band patterns on various surfaces. This fact can be used for drawing various conclusions about the nature of the surface by applying pressure on the optical flat at various points and observing the change in the pattern of bands.

Surface roughness terminology:

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.

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.

Irregularities on the surface of the part:

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.

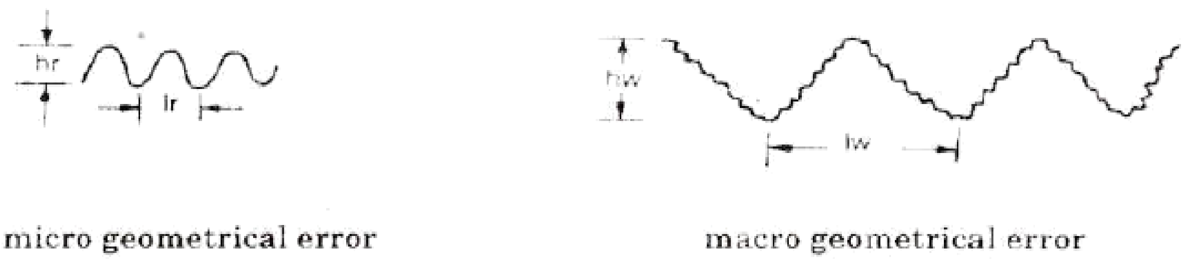


Fig. 3.8. Micro and macro geometrical errors

(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 lr = 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.

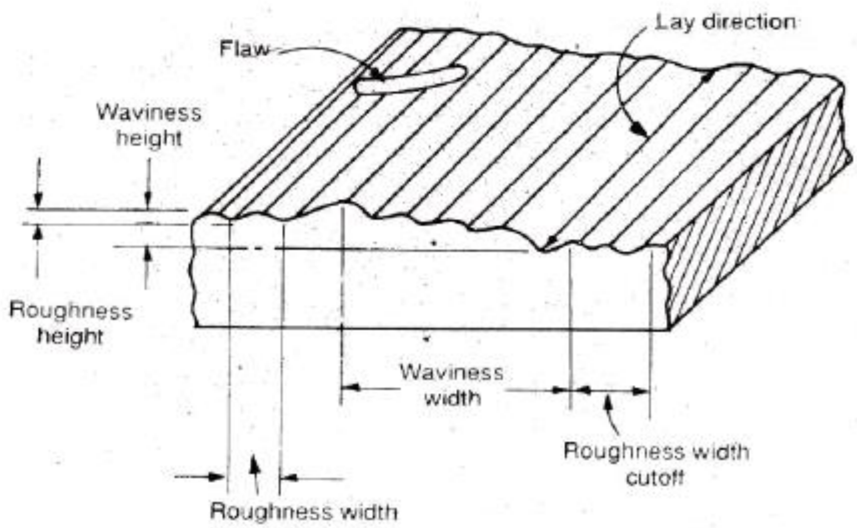


Fig. 3.9. Elements of surface texture

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 centimeters.

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

Flaws: 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.

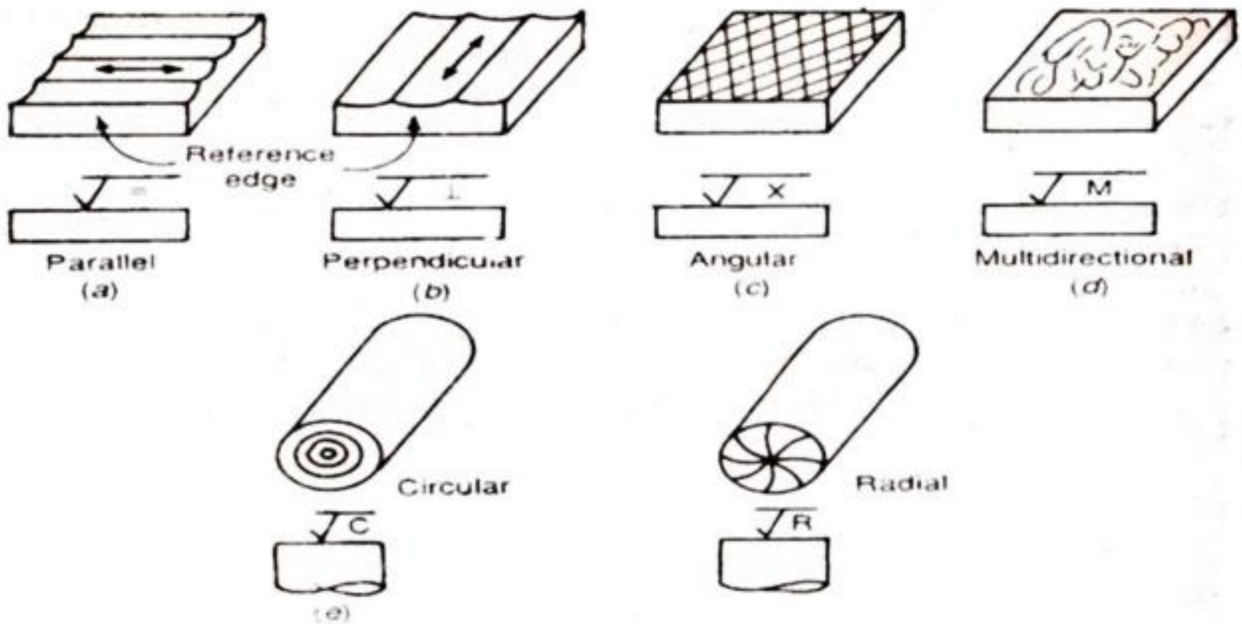


Fig. 3.10 Types of lays

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 methods of evaluating primary texture (roughness) of a surface are used:

(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.

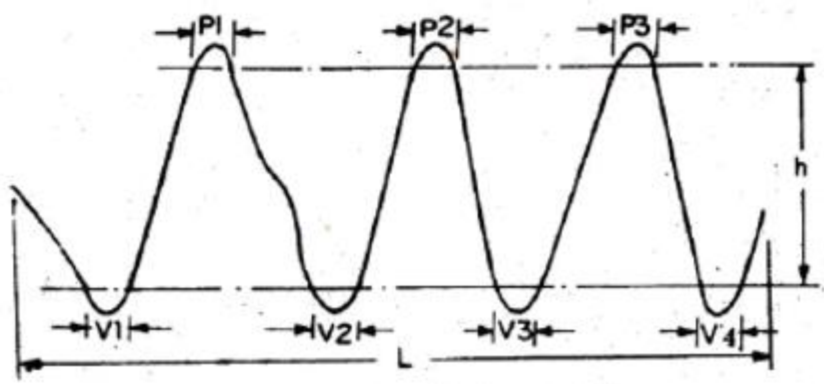


Fig.3.11 Peak to valley height method

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 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.

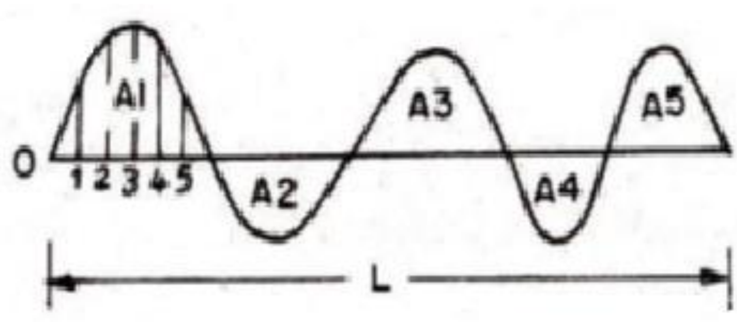


Fig. 3.12 CLA Method

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.

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

Also

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

$$= \frac{\Sigma A}{L} \quad ...(ii)$$

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.

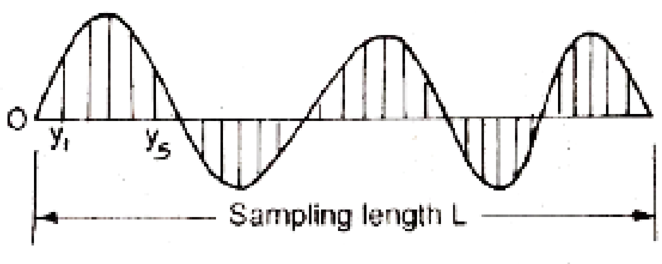


Fig.3.13 R.M.S. Method

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 (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

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

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.

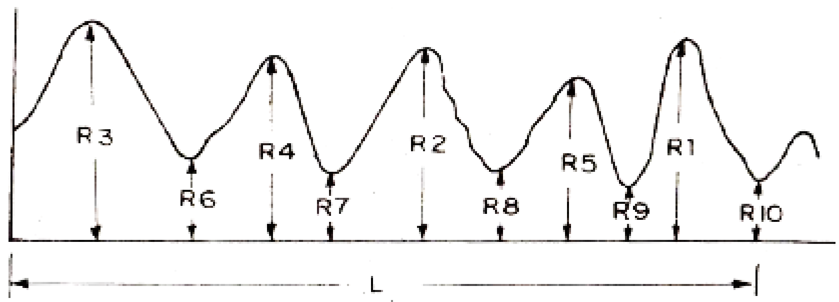


Fig.3.14 Ten Point Method

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: 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 visualized.

(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.

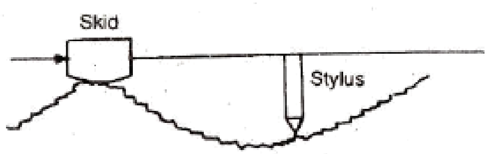


Fig.3.15 Direct instrument method of surface finish measurement

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:

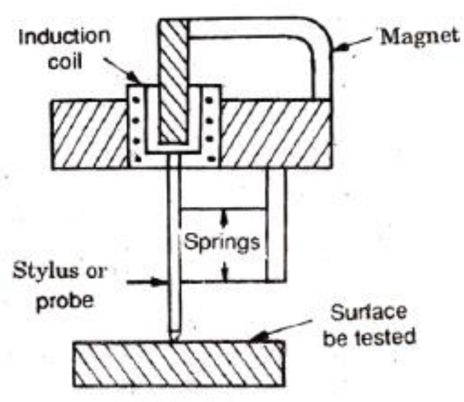


Fig.3.16 Profilometer

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.

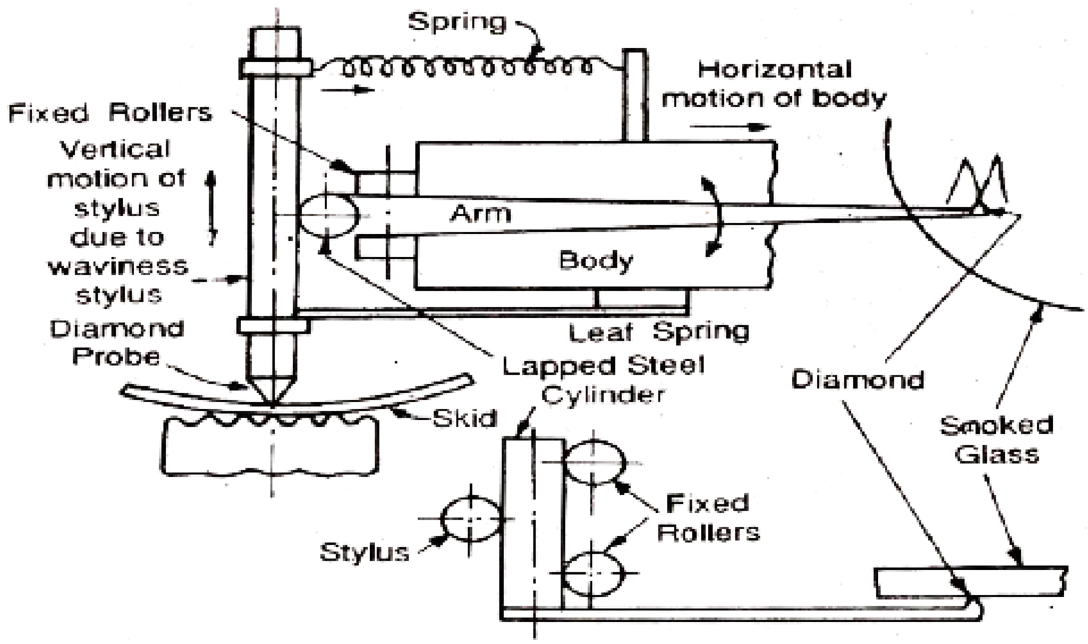


Fig.3.17. Tomlinson surface meter:

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:

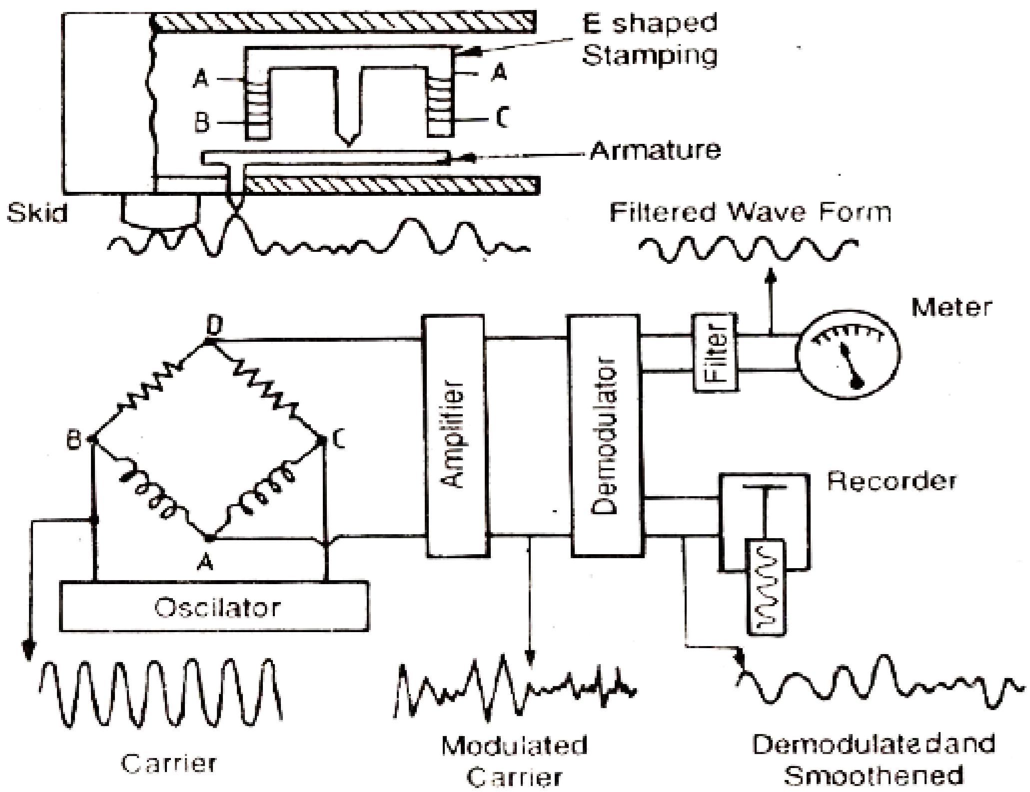


Fig.3.18. Taylor Hobson Talysurf

Taylor-Hobson Talysurf is a stylus and skid type of instrument working on carrier modulating principle. Its response is more rapid and accurate as compared 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 motorized driving unit. In this instrument the stylus is made to trace the profile of the surface irregularities, and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as 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) Profilograph: 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.

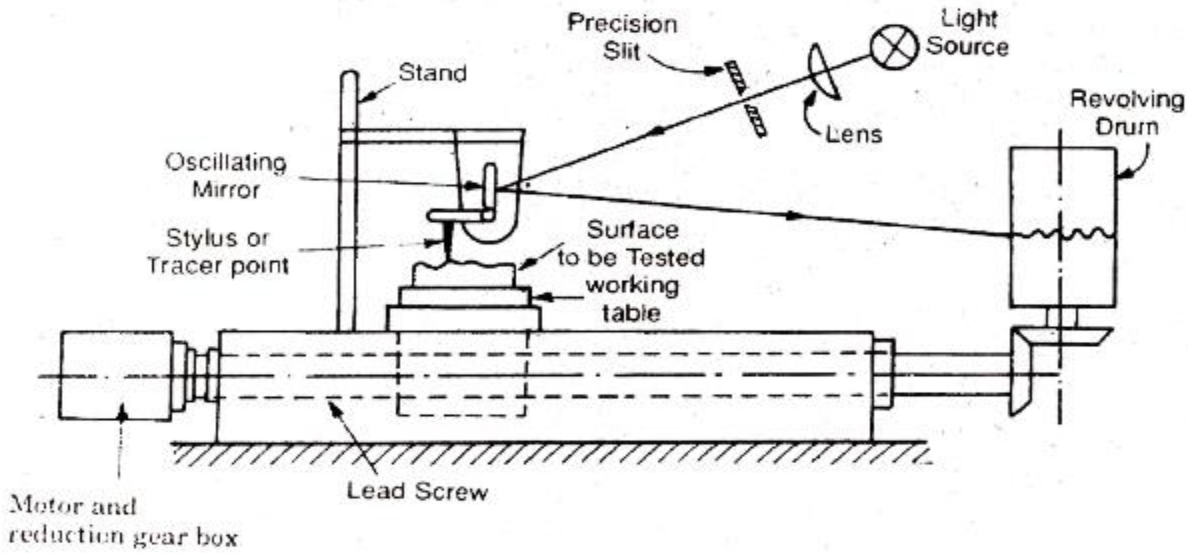


Fig. 3.19. Profilograph

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 sensitized 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 sensitized film that may be sub-sequently analyzed to determine the value of the surface roughness.

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.

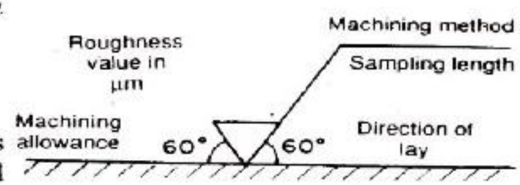


Fig. 7.23.

(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.