First Order. This includes the irregularities arising out of inaccuracies in the machine tool itself e.g. lack of straightness of guide-ways on which tool post is moving.

Second Order. Some irregularities are caused due to vibrations of any kind such as chatter marks and are included in second order.

Third Order. Even if the machine were perfect and completely free of vibrations, some irregularities are caused by machining itself due to characteristic of the process.

Fourth Order. This includes the irregularities arising from the rupture of the material during the separation of the chip.

Further these irregularities of four orders can be grouped under two groups:

First group includes irregularities of considerable wave-length of a periodic character resulting from mechanical disturbances in the generating set-up. These errors are termed as macro-geometrical errors and include irregularities of first and second order and are mainly due to misalignment of centres, lack of straightness of guide-ways and non-linear feed motion. These errors are also referred to as **Waviness or Secondary Texture**

Second group includes irregularities of small wavelength caused by the direct action of the cutting element on the material or by some other disturbance such as friction, wear, or corrosion. These errors are chiefly caused due to tool feed rate and due to tool chatter, i.e. it includes irregularities of third and fourth order and constitutes the micro geometrical errors. Errors in this group are referred to as **Roughness or Primary Texture**.

Terminology

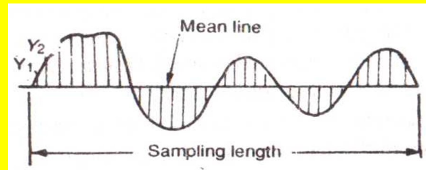
Real Surface : is the surface limiting the body and separating it from the surrounding surface.

Geometrical Surface: is the surface prescribed by the design or by the process of manufacture, neglecting the errors of form and surface roughness.

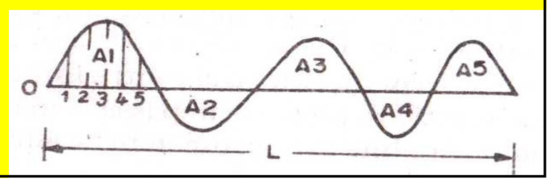
Effective Surface: is the close representation of real surface obtained by instrumental means.

Surface Texture: Repetitive or random deviations from the nominal surface which form the pattern of the surface. Surface texture includes roughness, waviness, lay and flaws.

Mean line of the profile is the line having the form of the geometrical profile and dividing the effective profile so that within the sampling length the sum of the squares of distances (Y1, y2, ... Yn) between effective points and the mean line is a minimum.



Centre line of profile is the line parallel to the general direction of the profile for which the areas embraced by the profile above and below the line are equal. When the waveform is repetitive, the mean line and the centre line are equivalent



Evaluation of surface finish

The average roughness

Peak to valley height

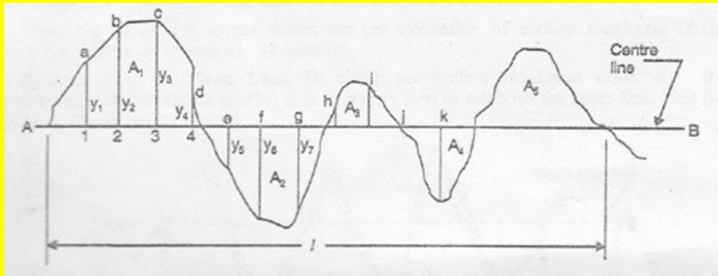
Form factor or bearing curve

Average Surface roughness

The assessment of average surface roughness follows 3 statistical criteria

a) CLA Method:

Centre line average or arithmetic average method – measured as average deviation from the nominal surface.

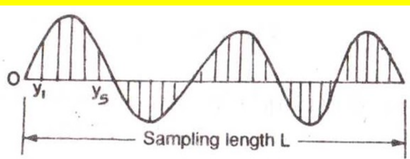


$$\text{C.L.A Value} = \frac{h_1 + h_2 + h_3 + \ldots.. h_n}{n}$$

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

$$= \frac{\Sigma A}{L}$$

b) RMS(Root Mean Square) Method



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 (y_1, y_2, y_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 y_1, y_2, y_3, ...y_n are the heights of the ordinates erected at those points.

Then,

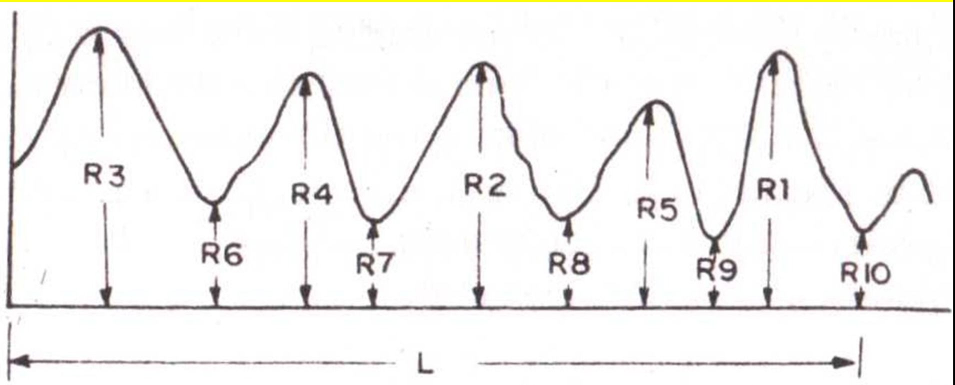
$$\text{RMS average} = \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + \ldots + y_n^2}{n}}$$

or

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

c) Ten point height method

It is the average difference between the five highest peaks and five lowest valleys of the surface within sampling length



R_z = ten point height of irregularities

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

...components.

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 mm^2 and 95, 65, 170, 150 mm^2 respectively.

Sol. $$\text{C.L.A.} = \frac{\Sigma A}{L} \times \frac{1}{\text{vertical scale}} \times \frac{1}{\text{horizontal scale}} \times 1000$$

$$= \frac{(160 + 95 + 90 + 65 + 180 + 170 + 50 + 150)}{0.8} \times 15000 \times 100 \quad \frac{1}{} \ \frac{1}{} \times 100$$

$= 0.8\ \mu m$.

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.

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

$= 29.35$

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

$= 930.96$

Methods of Measuring Surface Finish

There are two methods used for measuring the finish of machined part :

1. **Surface Inspection by Comparison Methods**.

(i)Touch Inspection,
(ii) Visual Inspection,
(iii) Scratch Inspection,
(iv) Microscopic Inspection,
(v) Surface Photographs,
(vi) Micro-Interferometer,
(vii) Reflected Light Intensity

2. Direct Instrument Measurements

(i) Profilometer
(ii) Tomlinson surface meter
(iii) Taylor Hobson talysurf

Touch Inspection

This method can simply tell which surface is more rough. 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 0.01 mm can be easily detected.

A modification of it is possible by using a table tennis ball, which is rubbed over the surface and vibrations from the ball transmitted to hand and surface roughness judged thereby

Visual Inspection

Visual inspection by naked eye is always likely to be misleading particularly when surfaces having high degree of finish are inspected. The method is, therefore, limited to rougher surfaces and results vary from person to person. More accurate inspection can be done by using illuminated magnifiers.

Scratch Inspection

In this method, a softer material like lead babbit or plastic is rubbed over the surface to be inspected. By doing so it carries the impression of the scratches on the surfaces which can be easily visualised.

Microscopic Inspection

In this method, a master finished surface is placed under the microscope and compared with the surface under inspection.

This is probably the best method for examining the surface finish but suffers due to limitation that only a small portion of the surface can be inspected at a time. Thus several readings are required to get an average value.

Surface Photographs

In this method magnified photographs of the surface are taken with different types of illumination.

In case we use vertical illumination, 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 results assessed.

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.

Defects, i.e. 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 band.

Reflected light intensity

In this method a beam of light of know 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.

Direct Instrument Measurements

These methods enable to determine a numerical value of the surface finish of any surface. Nearly all instruments used are stylus probe type of instruments Stylus probe Instrument

(i) Profilometer
(ii) Tomlinson surface meter
(iii) Taylor Hobson talysurf

Stylus probe Instrument

Skid

A skid or shoe which is drawn slowly over the surface either by hand or by motor drive. The skid when moved over the surface, follows its general contours and provides a datum for the measurements.

Stylus probe

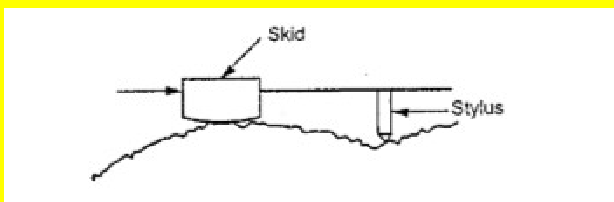
A stylus or probe which moves over the surface with the skid. The stylus for Ra measurement should be cone shaped with a spherical tip.

Amplifying

An amplifying device for magnifying the stylus movement and an indicator. Electronic or optical magnification is employed.

Recording

A recording device to produce a trace or record of the surface profile. Usually the vertical movement is magnified more in comparison to horizontal movement, thus the record will not Stylus give the actual picture of surface roughness but a distorted trace obtained.



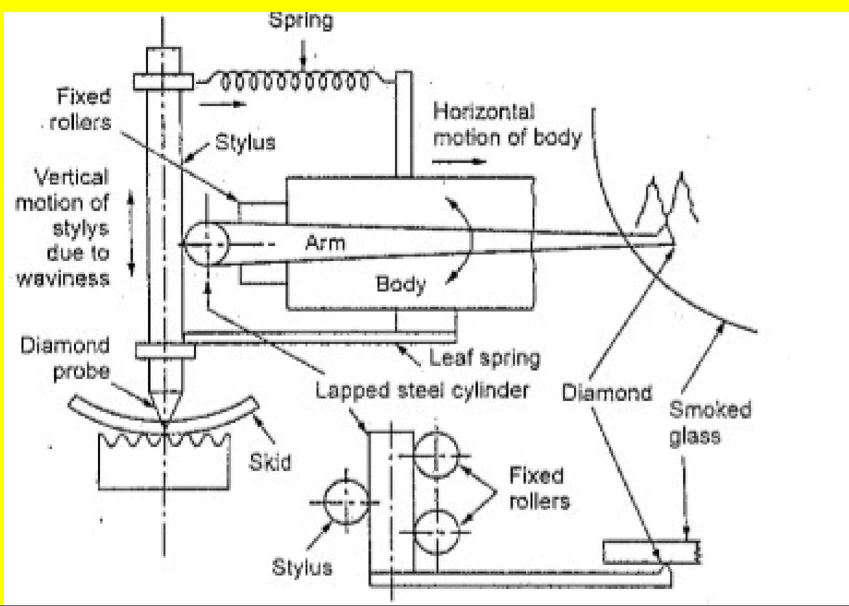
Principle
When the stylus is moved over the surface ,the irregularities in the surface texture are measured and it is used to assess the surface finish of the work piece.

Working
This consists of skid, stylus, amplifying device and recording device. The skid is slowly moved over the surface by hand or by motor drive. The skid follows the irregularities of surface and stylus moves along the skid. When the stylus moves vertically up and down, the movements are magnified, amplified and recorded to get a trace. The trace is then analyzed by an automatic device.

Advantages
Any desired roughness parameter can be recorded.

Disadvantages
Can not be used for fragile material .
High initial cost.
Skilled operators are needed.

Tomlinson Surface meter



Construction

The diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped steel cylinder. The stylus is also attached to the body of the instrument by a leaf spring and its height is adjustable to enable the diamond to be positioned conveniently. The stylus is restrained from all motions except the vertical one by the tensions in coil and leaf spring. A light spring steel arm is attached to the horizontal lapped steel cylinder and it carries at its tip a diamond scriber which bears against a smoked glass.

Working

When measuring surface finish, body is traversed across the surface by a screw rotated by a synchronous motor. Any vertical movement of the stylus caused by the surface irregularities, causes the horizontal lapped steel cylinder to roll.

By its rolling, the light arm attached to its end provides a magnified movement on a smoked glass plate and this trace is magnified by an optical projector