Surface Roughness Metrology

By

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Surface Texture

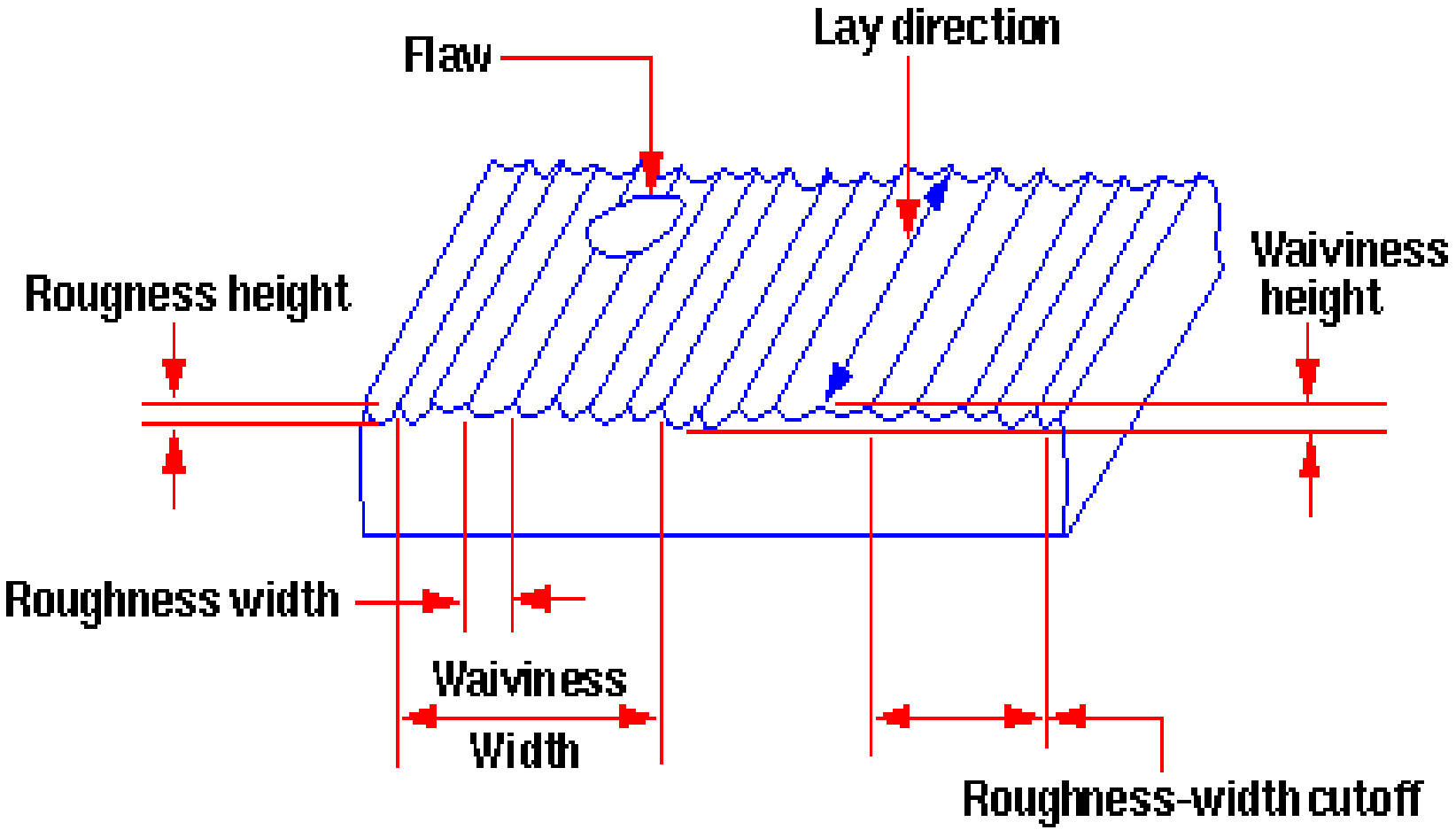
- Repetitive or random deviations from the normal surface which form the pattern of the surface. Surface texture include roughness, waviness, lay and flows.

- Every part's surface is made up of texture and roughness which varies due to manufacturing techniques and the part structure itself.

- Primary texture: lr/hr<50 (Roughness)

- Secondary texture: lw/hw>50 (Waviness)

Terms used in surface roughness measurements



Surface characteristics (Courtesy, ANSI B46.1 - 1962)

1. Roughness :

Roughness consists of **surface irregularities** which result from the **various machining process**. These irregularities combine to form surface texture.

2. Roughness Height :

It is the **height of the irregularities** with respect to a reference line. It is measured in millimeters or microns or micro inches. It is also known as the height of unevenness.

3. Roughness Width :

The roughness width is the **distance** parallel to the nominal surface **between successive peaks** or ridges which constitute the predominate pattern of the roughness. It is measured in millimeters.

4. Roughness Width Cut Off :

Roughness width cut off is the greatest spacing of respective surface irregularities to be included in the measurement of the average roughness height. It should always be greater than the roughness width in order to obtain the total roughness height rating.

5. Lay :

Lay represents the direction of predominant surface pattern produced and it reflects the machining operation used to produce it.

6. Waviness Height:

Waviness height is the peak to valley distance of the surface profile, measured in millimeters.

7. Arithmetic Average (AA):

If X is the measured value from the profilometer, then the AA value can be calculated as shown below.

8. Root Mean Square (rms)

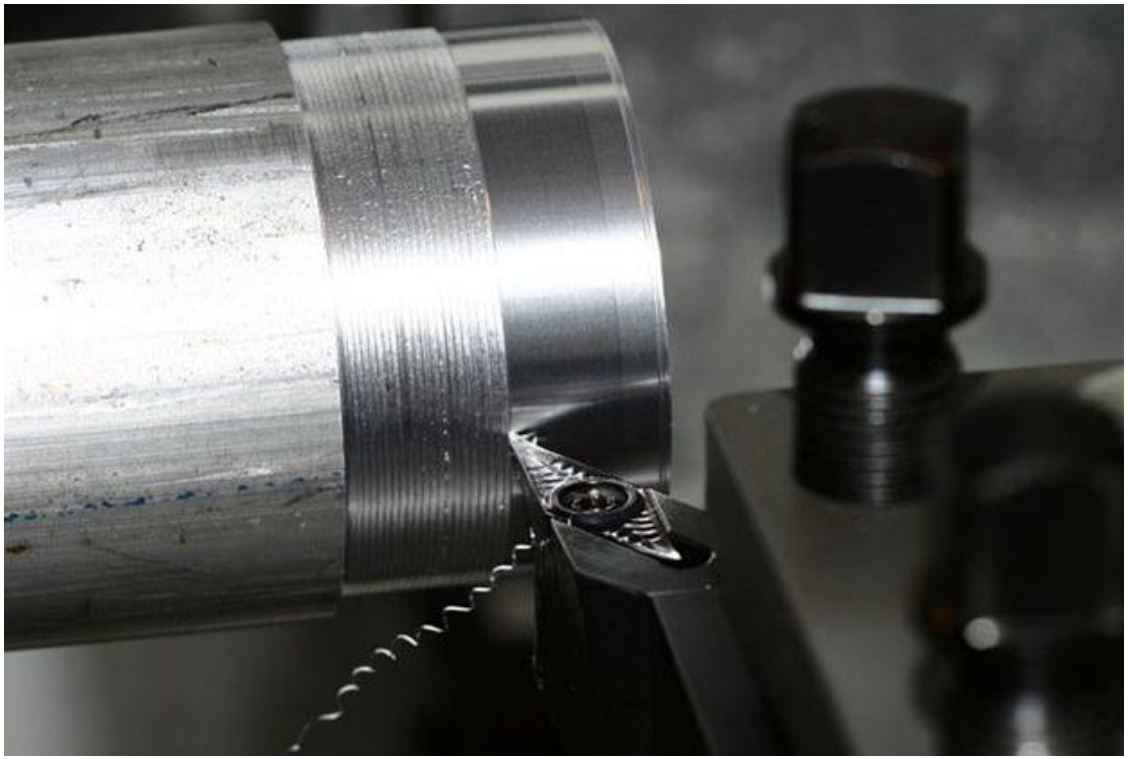
The rms value can be calculated as shown below. Its numerical value is about 11% higher than that of AA.

9. **Flaws:** Irregularity which occur at one place or widely varying intervals in surface. It include cracks, scratches etc.

X	X^2
3	9
15	225
20	400
33	1089
25	625
18	324
5	25
10	100
15	225
15	225
5	25
11	121
14	196
13	169
27	729
8	64
Total **234**	**4551**

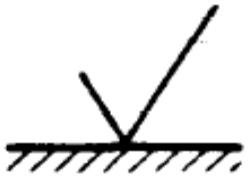
AA = 234/16 = 14.6 micro in.

RMS = (4551/16)$^{1/2}$ = 16.9 micro in.



INDICATION OF SURFACE TEXTURE

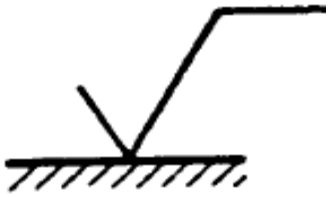
The **basic symbol** consists of two legs of **unequal** length inclined at approximately **60 degrees** to the line representing the considered surface
The symbol must be represented by thin line



If the removal of material by **machining** is required, a bar is added to the basic symbol,

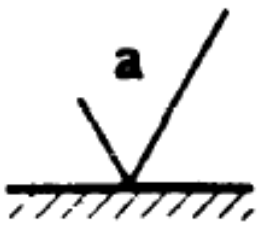
If the **removal of material is not permitted**, a circle is added to the basic symbol.

When **special surface characteristics** have to be indicated, a line is added to the longer arm of any of the above symbols,

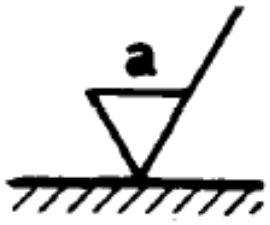


Indication of Surface Roughness

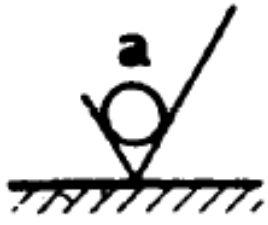
The value or **values** defining the principal criterion of **roughness** are added to the symbols



Roughness **a** obtained by any production process



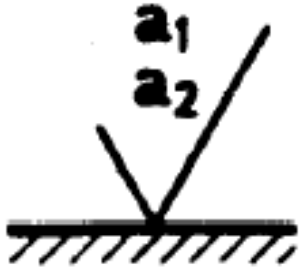
Roughness **a** obtained by removal of material by machining



Roughness **a** shall be obtained without removal of any material

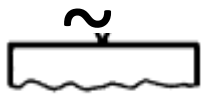
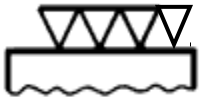
a- surface roughness value

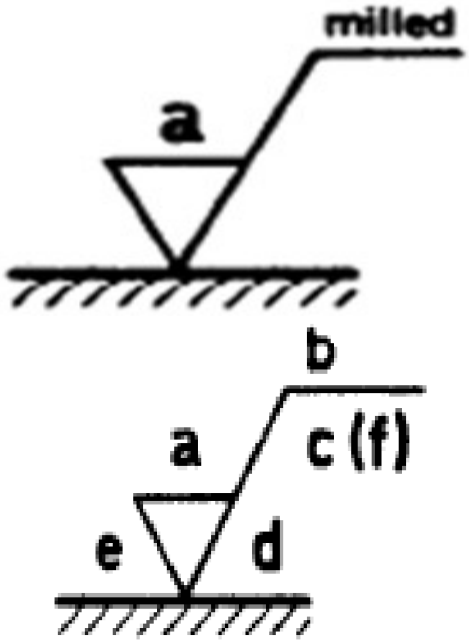
If it is necessary to impose **maximum** and **minimum limits** of the principal criterion of surface roughness, both values shall be shown



maximum limit (a_1) ;minimum limit (a_2).

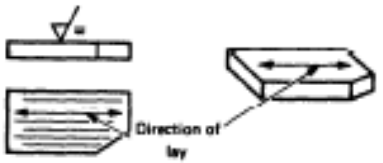
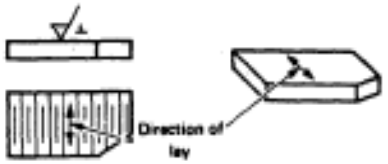
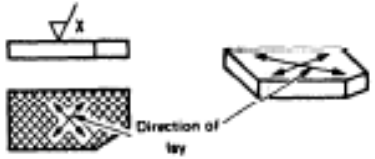
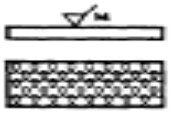
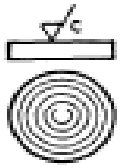
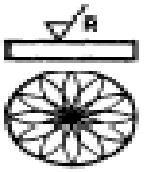
If it is required that the required **surface texture** be produced by one **particular production method**, this method shall be indicated in plain language on an extension of the longer arm of the symbol

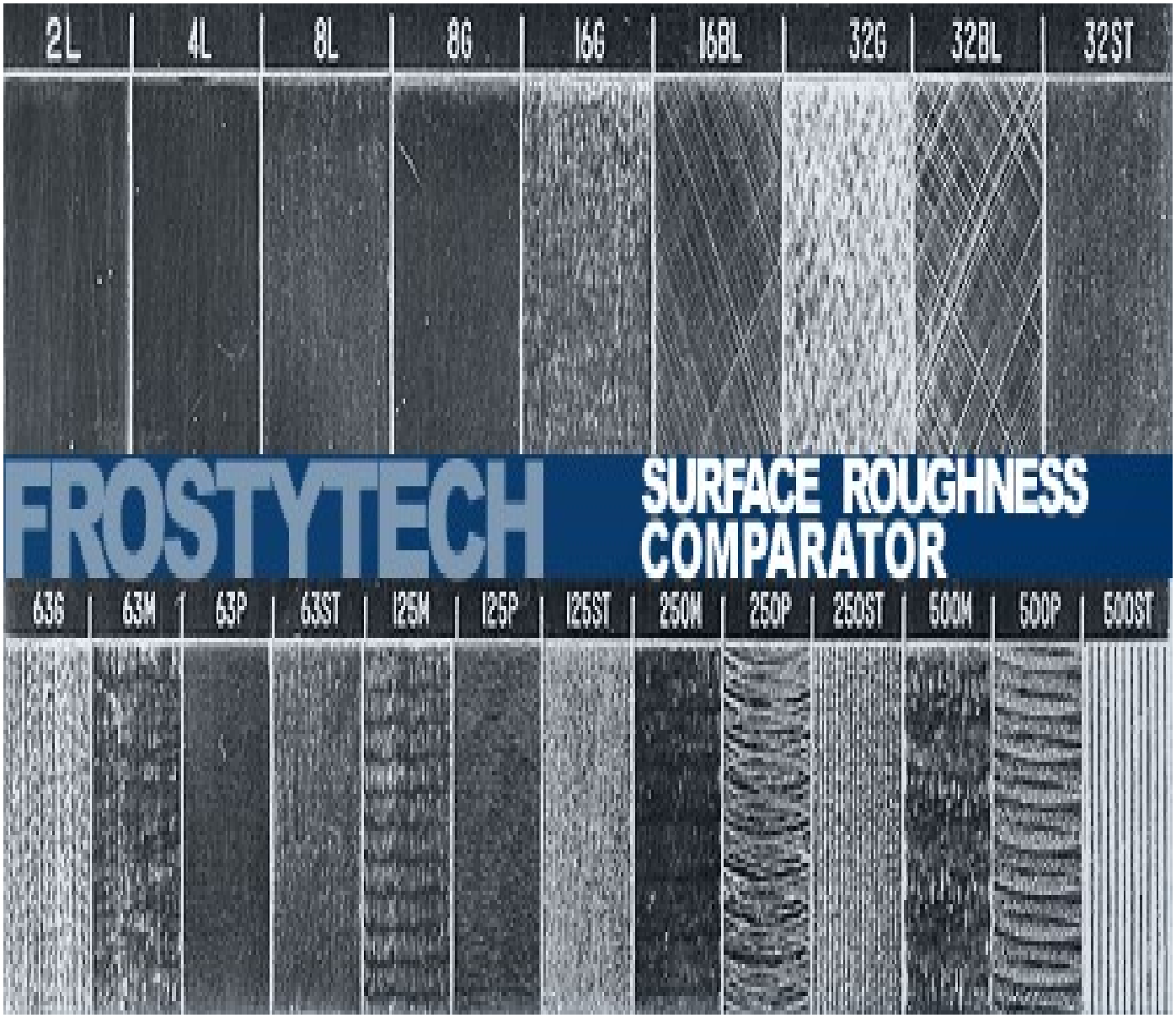
Roughness Value (Microns)	Roughness Grade	Conventional Symbol
50	N12	
25	N11	
12.5	N10	
6.3	N9	
3.2	N8	
1.6	N7	
0.8	N6	
0.4	N5	
0.2	N4	
0.1	N3	



a = Roughness value *Ra* in micrometres
or
= Roughness grade number N1 to N12.

b = Production method, treatment or coating
c = Sampling length
d = Direction of lay
e = Machining allowance
f = Other roughness values (in brackets).

Symbol of Lay	Interpretation	
=	Parallel to the plane of projection of the view in which the symbol is used	
⊥	Perpendicular to the plane of projection of the view in which the symbol is used	
X	Crossed in two slant direction relative to the plane of projection of the view in which the symbol is used	
M	Multidirectional	
C	Approximately circular relative to the centre of the surface to which the symbol is applied	
R	Approximately radial relative to the centre of the surface to which the symbol is applied	


2L
4L
8L
8G
16G
16BL
32G
32BL
32ST
FROSTYTECH
SURFACE ROUGHNESS
COMPARATOR
63G
63M
63P
63ST
125M
125P
125ST
250M
250P
250ST
500M
500P
500ST

The factors affecting surface roughness

- Type of coolant used
- Cutting parameters such as feed, speed and depth of cut
- Type of machining
- Rigidity of the system consisting of machine tool, fixture, cutting tool and work
- Vibrations
- Material of tool and work piece.

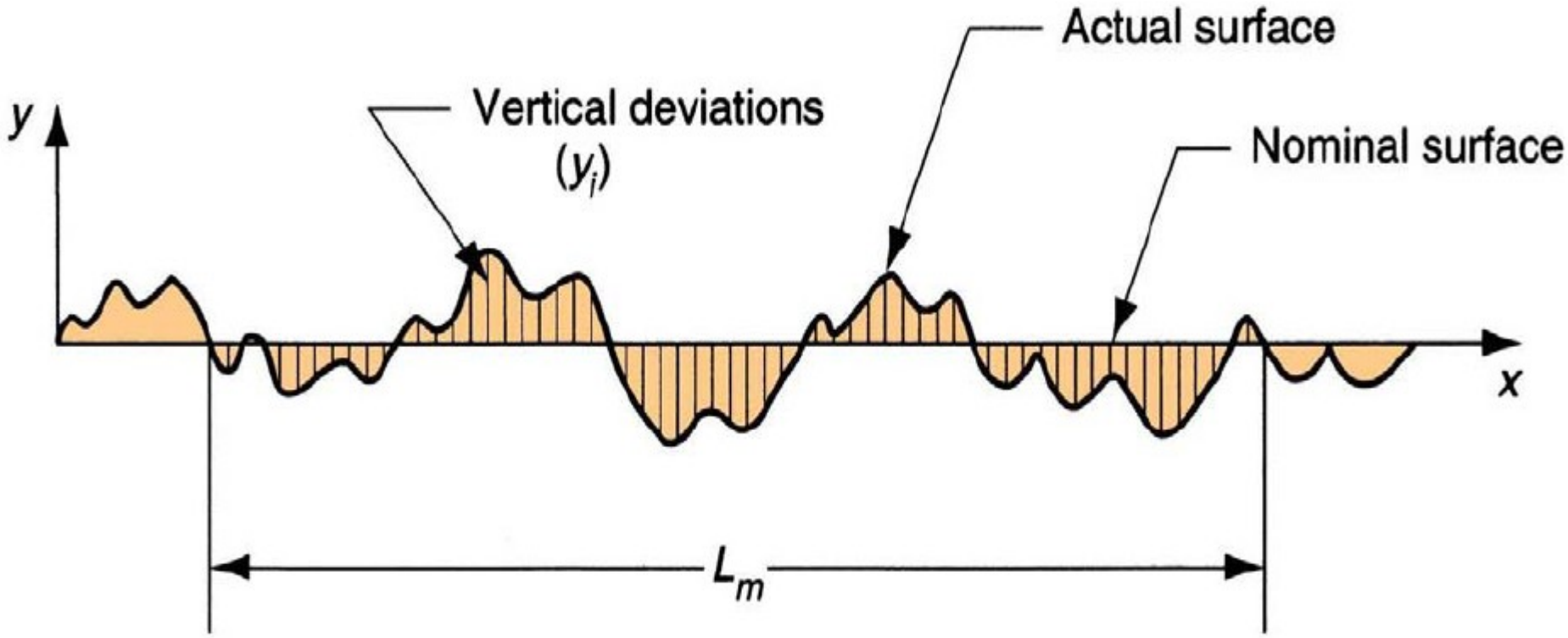
Orders of Geometrical irregularities

Any material being machined by conventional machining process cannot be finished perfectly. The surface generated will have some irregularities and these geometrical irregularities could be classified as follows:

- **First Order:** It includes the irregularities developed due to the inaccuracies in the machine tool such as lack of straightness of guide ways, on which tool post is moving.
- **Second Order:** It includes tile irregularities developed due to the vibrations and rigidity of machine tools.
- **Third Order:** It includes the irregularities due to the cutting parameters such as cutting speed, feed and depth of cut.
- **Fourth Order:** It includes the irregularities developed due to the rupture of the material during the separation of the chip from the already finished surface of the work piece.

Surface Roughness

Average of vertical deviations from nominal surface over a specified length surface.



Sampling Length: It is the length of Profile necessary for the evaluation of irregularities to be taken in account. Also called as "Cut-off" length.

It is measured Parallel to direction of profile.

Mean line of the Profile: It is the line that divides the effective profile such that, within sampling length the sum of squares of vertical ordinates (y1,y2,...) between effective profile points & mean line is minimum or Zero.

Center line of the Profile: It is the line that divides the effective profile such that, the area contained by the profile above & below the line are equal.

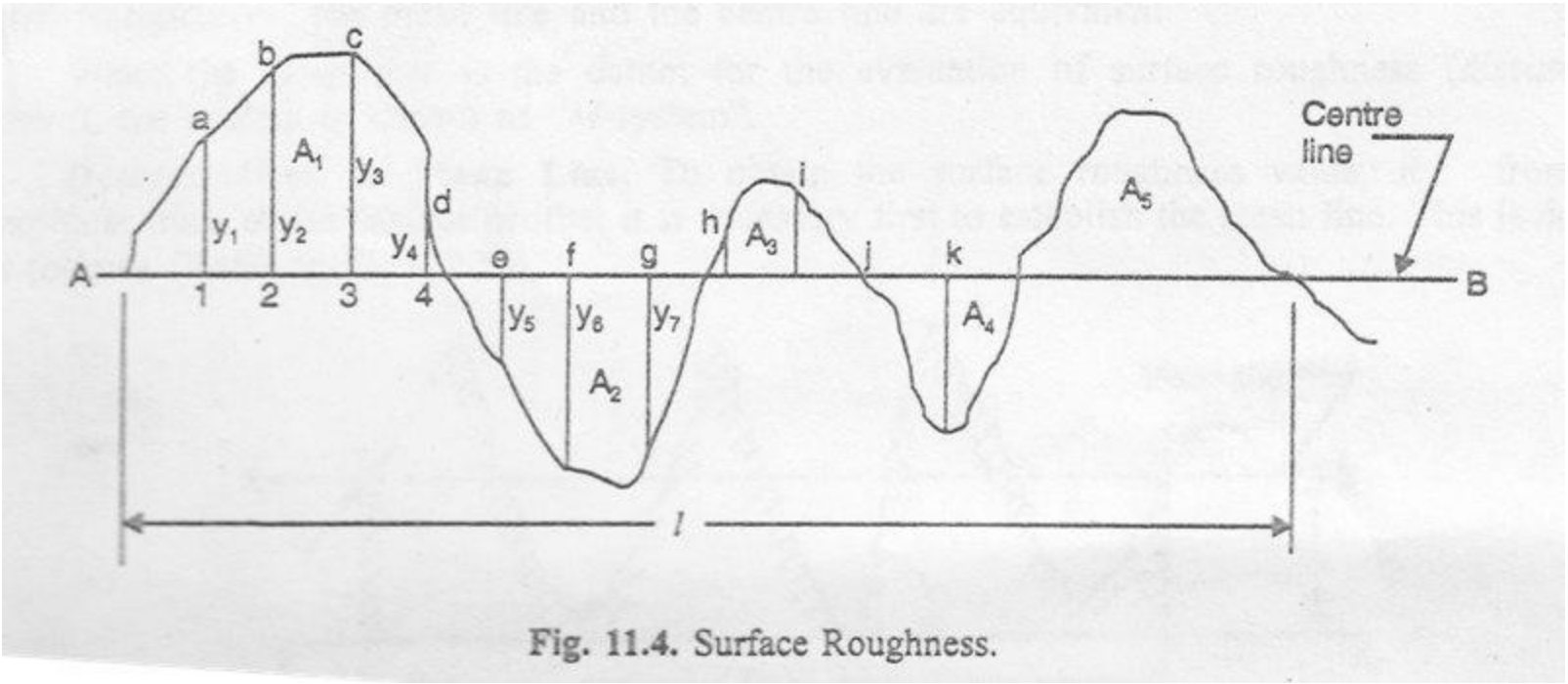
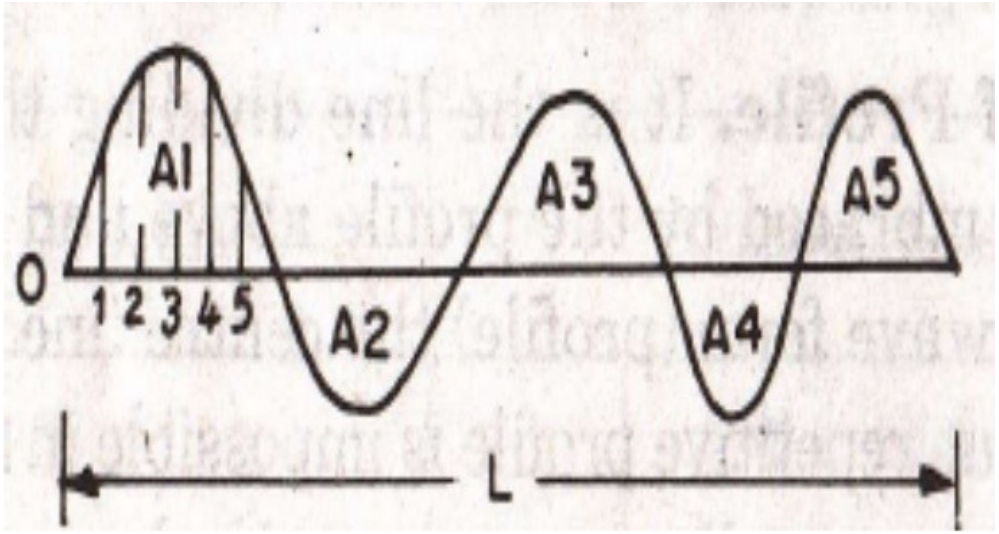


Fig. 11.4. Surface Roughness.

Analysis of Surface Traces(surface finish)

1. Centre line Average (C.L.A. Method)



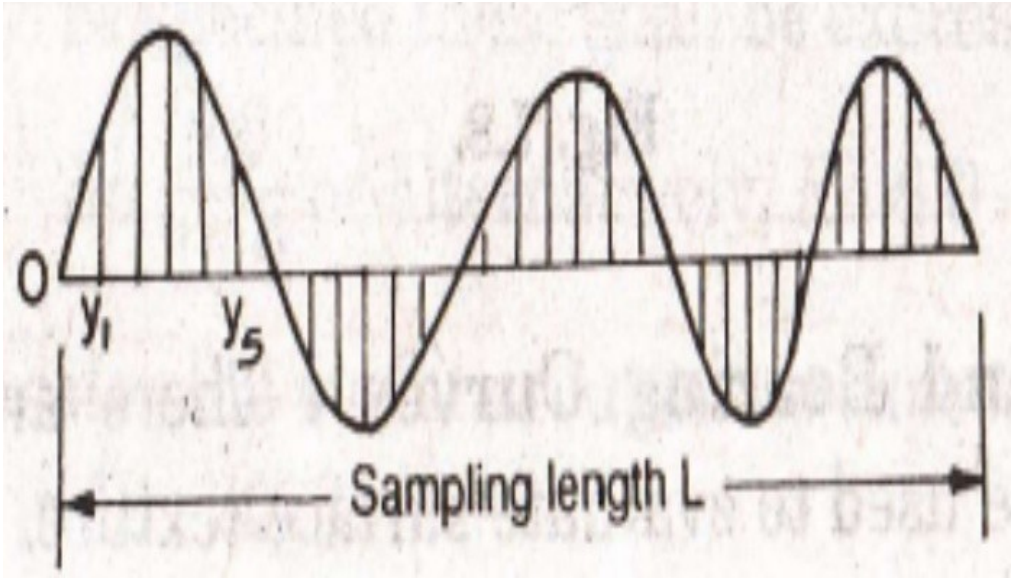
- Surface roughness is measured as the average deviation from nominal surface.
- It is defined as average value of the ordinates from mean line, regardless of the arithmetic sign of ordinates.

$$C.L.A.Value = \frac{h1 + h2 + h3 + \cdots . + hn}{n} \quad (1)$$

Calⁿ of CLA Value by equation 2 is carried out by *Planimeter* .

$$C.L.A.Value = \frac{A1 + A2 + A3 + \cdots . + An}{L} = \frac{\sum A}{L} \quad (2)$$

2. Root Mean Square (R.M.S. Method)

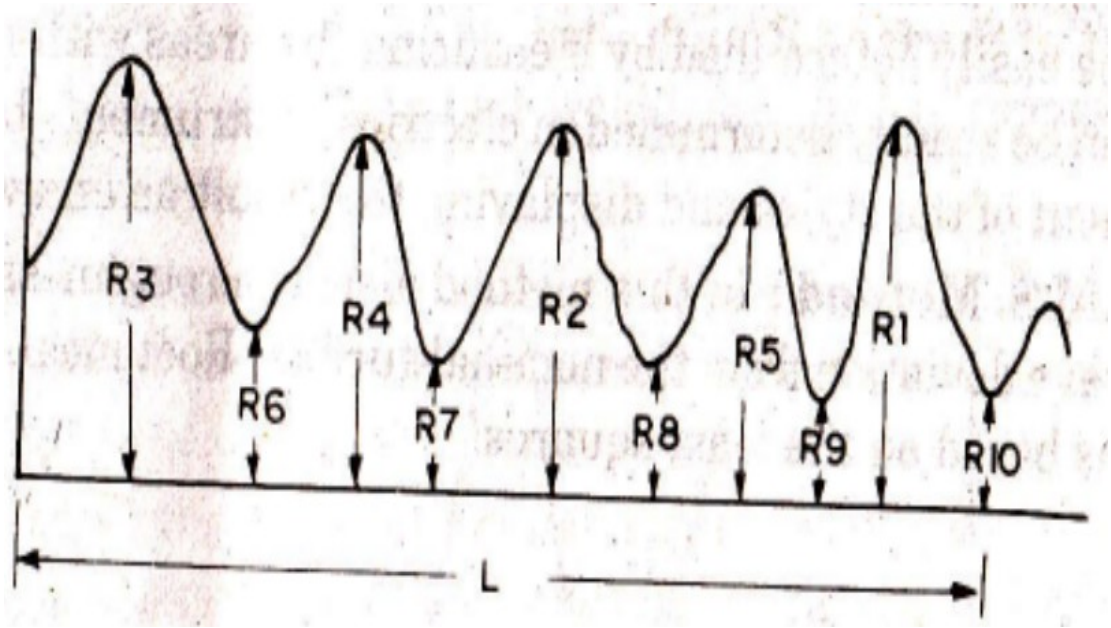


- Surface roughness is measured as the average deviation from nominal surface.
- It is defined as square root of arithmetic mean of values of square of ordinates of the surfaces measured from mean line.

$$R.M.S.Avg. = \sqrt{\frac{y_1^2 + y_2^2 + \cdots . + y_n^2}{n}}$$

$$y_{rms} = \sqrt{\left[\int_0^L y^2 dl\right]}$$

3. Ten Point Height Method



In this method avg. difference between five height peaks & five lowest valleys of surface texture within sampling length measured from a line parallel to mean line & not crossing the profile.

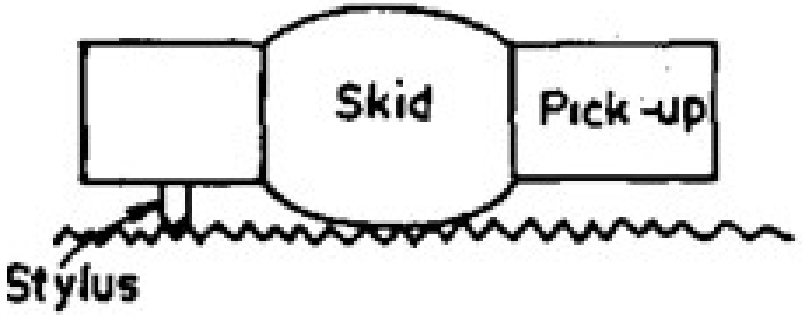
It is simple method to measure total depth of surface irregularities, but it does not give sufficient information about surface, as no account is taken of frequency of the irregularities.

If R = Ten point height of irregularities then,

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

Measurement of Surface finish

1) Stylus Probe Instrument (Contact type)



- These methods enable to determine a numerical value of the surface finish of any surface.
- 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.

- A stylus or probe which moves over the surface with the skid. The stylus should be cone shaped with a spherical tip. This records the micro-geometrical form of the surface. It moves vertically up and down relative to skid movement due to roughness of the surface.
- As the stylus tracks the surface peaks and valleys, its vertical motion is converted to a time varying electrical signal that represent surface profile.
- Generally it is desired that if the skid is moving up then the stylus must also be moving up.

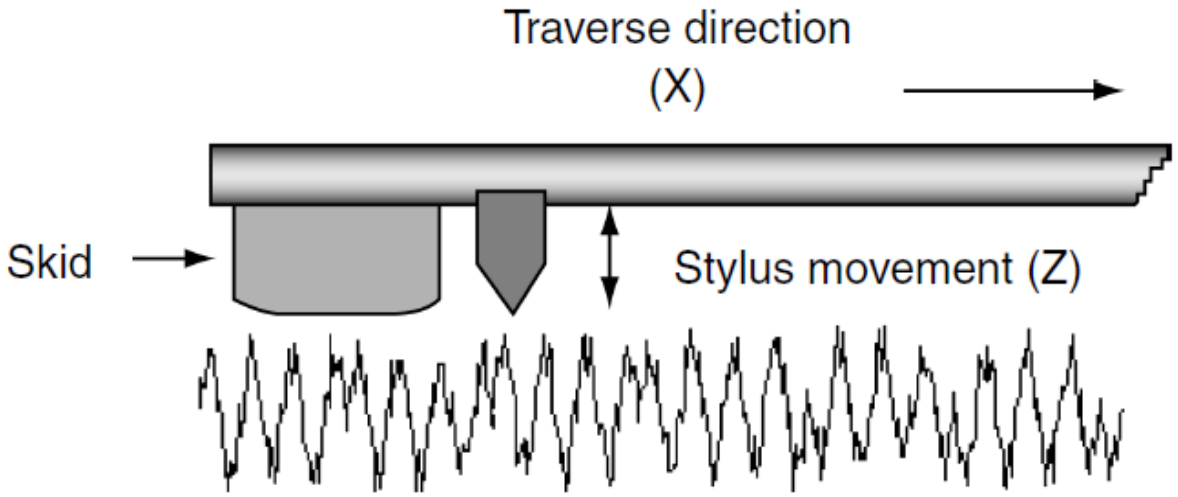
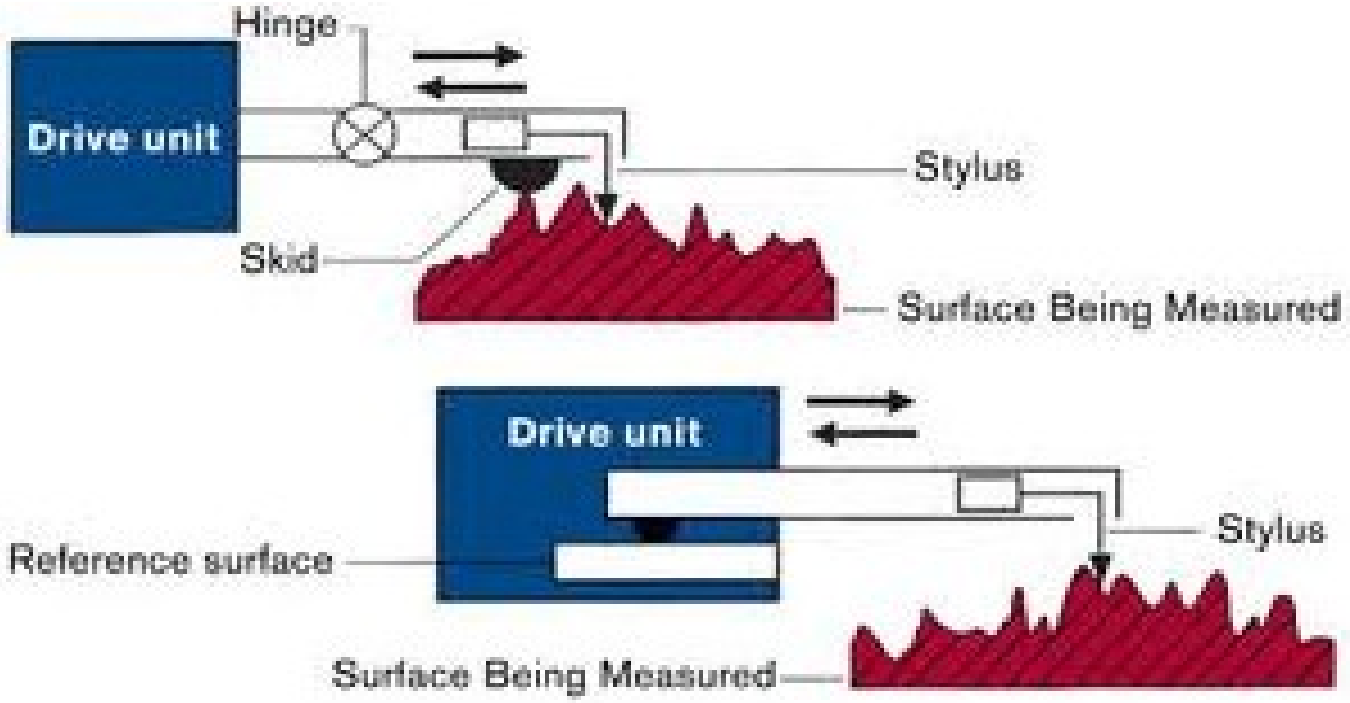
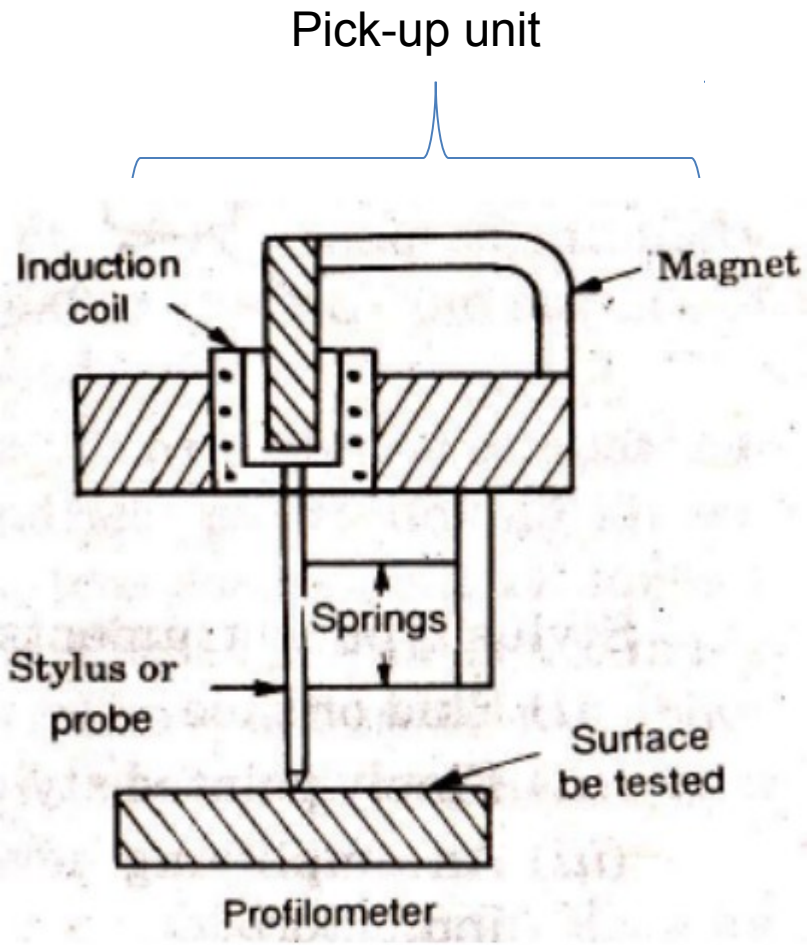

Traverse direction
(X)
Skid
Stylus movement (Z)

Fig. 10.7 *Skid*


Hinge
Drive unit
Stylus
Skid
Surface Being Measured
Drive unit
Stylus
Reference surface
Surface Being Measured

2) Profilometer (Contact type)



- It is indicating & recording instrument used to measure roughness in microns.

- It consist of two units Tracer & amplifier.
- Tracer is finely pointed stylus mounted in pick-up unit which consist of induction coil located in field of Permanent magnet.
- When tracer(stylus) is moved across the surface to be tested, it is displaced vertically up & down due to surface irregularities.
- This causes induction coil to move in the field of Permanent magnet & induces the voltage.
- The induced voltage is amplified & recorded.

2) Tomlinson Surface Meter (Contact type)

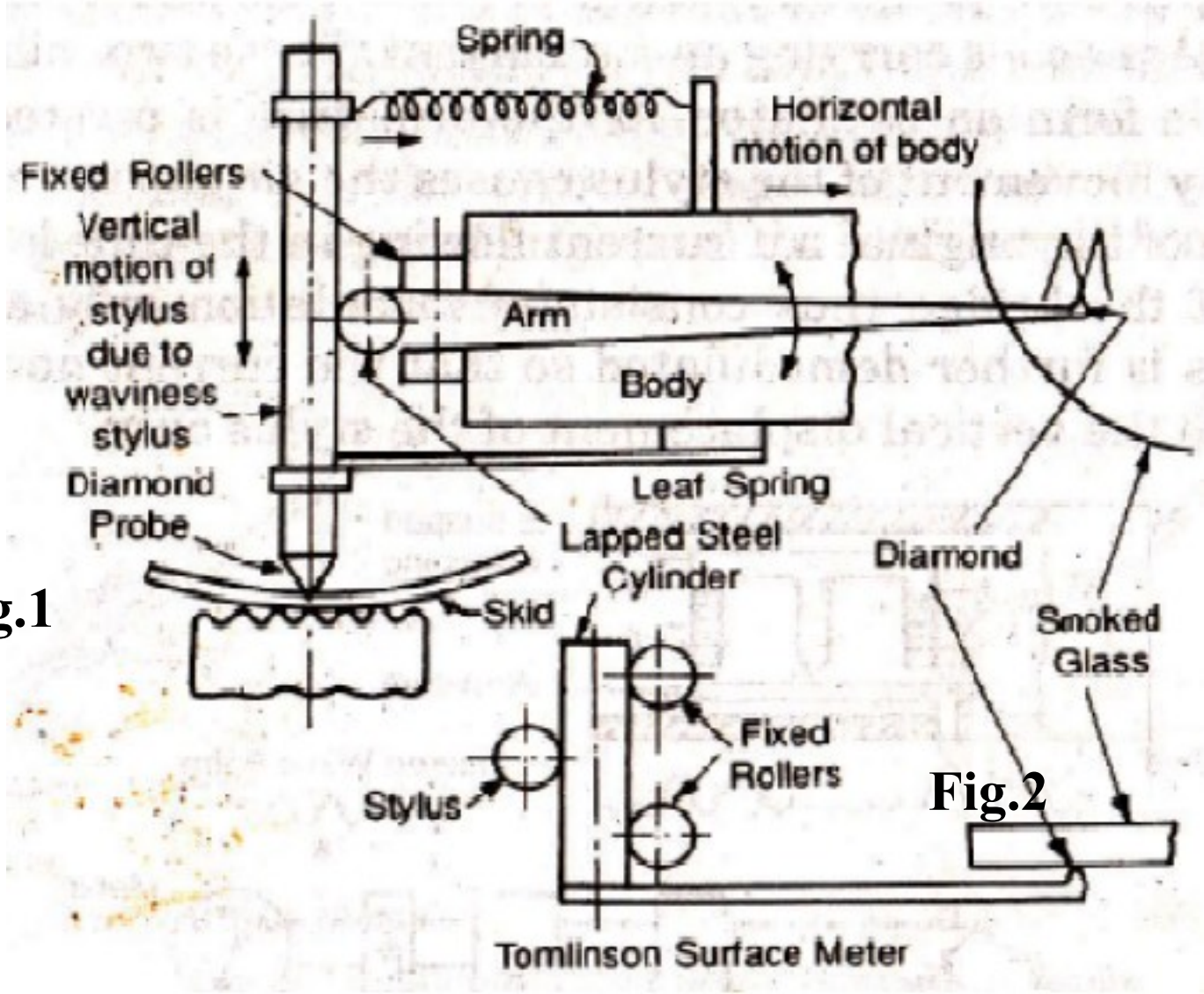


Fig.1

Fig.2

This instrument was designed by Dr. Tomlinson.

Construction:- 1) The diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped steel cylinder.

2) 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.

3) The lapped cylinder is supported on one side by the stylus and on the other side by two fixed rollers as shown in Fig.2.

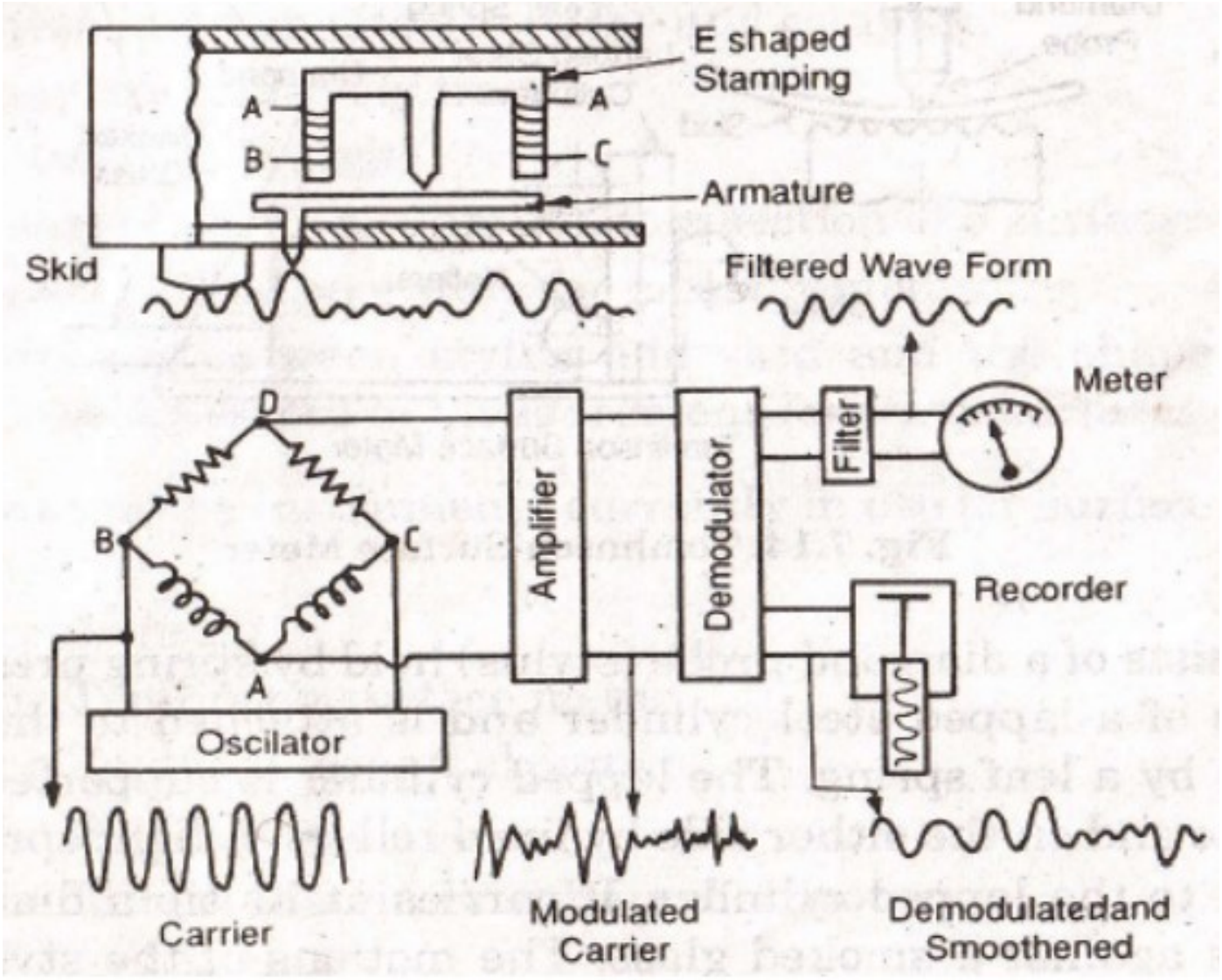
3) The stylus is restrained from all motions except the vertical one by the tensions in coil and leaf spring.

4)The tensile forces in these two Springs also keep the lapped steel cylinder in position between the stylus and a pair of fixed rollers.

5) 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:-**
- 1) Any vertical movement of the stylus caused by the surface irregularities causes the horizontal lapped steel cylinder to roll.
- 2) By its rolling, the light arm attached to its end provides a magnified movement on a smoked glass plate.
- 3) The smoked glass trace is then, further projected at x50 or x100 magnification for examination. This instrument is comparatively cheap one and gives reliable results.

2) The Taylor-Hobson Talysurf (Contact type)



This instrument also gives the same information as the previous instrument, but much more rapidly and accurately.

Construction:- 1) The measuring head of this instrument consists of a 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.

2) The arm carrying stylus forms an armature which pivots about centre piece of E-shaped stamping.

3) 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.

Working:- 1) 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.

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

3) The Demodulated output is caused to operate a pen recorder to produced a permanent record & meter gives numerical assessment directly.

References:

1. Engineering Metrology by M.Mahajan, Dhanpatrai and Company Pvt. Ltd.
2. Engineering Metrology, Author-R. K. Jain, Publisher, Khanna