(iv) Minimum circumscribed circles:

- This is the smallest circle. Its center and radius can be found by the previous method since P = 0 there is no peak outside the circle.
- The radial distance between the minimum circumscribing circle and the maximum inscribing circle is the measure of the error circularity. The fig shows the trace produced by a recording instrument.

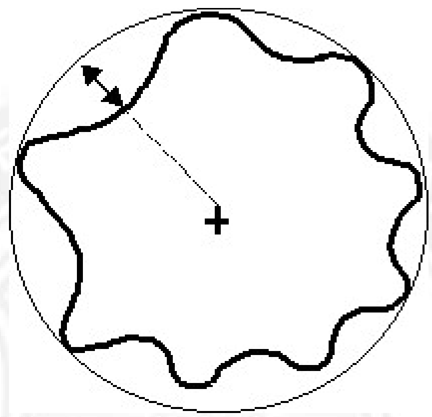

Fig. 4.22 Minimum circumscribed circles

- This trace to draw concentric circles on the polar graph which pass through the maximum and minimum points in such way that the radial distance be minimum circumscribing circle containing the trace or the n inscribing circle which can fitted into the trace is minimum.
- The radial distance between the outer and inner circle is minimum is considered for determining the circularity error.
- Assessment of roundness can be done by templates.
- The out off roundness is defined as the radial distance of the maximum peak (P) from the least square circle plus the distance of the maximum valley (V) from the least square circle.
- All roundness analysis can be performed by harmonic and slope analysis.

4.5 SURFACE FINISH MEASUREMENT

4.5.1 Introduction:

- When we are producing components by various methods of manufacturing

process it is not possible to produce perfectly smooth surface and some irregularities are formed.

- These irregularities are causes some serious difficulties in using the components.

So, it is very important to correct the surfaces before use.

- The factors which are affecting surface roughness are

1. Work piece material
2. Vibrations
3. Machining type
4. Tool, and fixtures

The geometrical irregularities can be classified as

1. First order

2.Second order

3 Third order

4.Fourth order

1. First order irregularities:

These are caused by lack of straightness of guide ways on which tool must move.

2. Second order irregularities:

These are caused by vibrations

3. Third order irregularities:

These are caused by machining.

4. Fourth order irregularities:

These are caused by improper handling machines and equipments.

4.5.2 SURFACE METROLOGY CONCEPTS

If one takes a look at the topology of a surface, one can notice that surface irregularities are superimposed on a widely spaced component of surface texture called waviness. Surface irregularities generally have a pattern and are oriented in a particular direction depending on the factors that cause these irregularities in the first place.

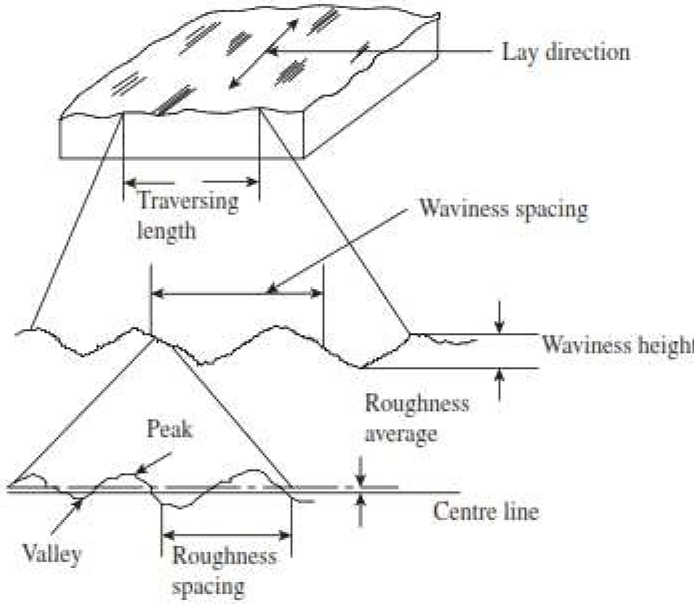

Fig. 4.23 Waviness and roughness

Surface irregularities primarily arise due to the following factors:

1. Feed marks of cutting tools

2. Chatter marks on the workpiece due to vibrations caused during the manufacturing operation

3. Irregularities on the surface due to rupture of workpiece material during the metal cutting Operation

4. Surface variations caused by the deformation of workpiece under the action of cutting forces

5. Irregularities in the machine tool itself like lack of straightness of guideways

4.5.3 TERMINOLOGY

Roughness The American Society of Tool and Manufacturing Engineers (ASTME) defines roughness as the finer irregularities in the surface texture, including those irregularities that result from an inherent action of the production process. Roughness spacing is the distance between successive peaks or ridges that constitute the predominant pattern of roughness. Roughness height is the arithmetic average deviation expressed in micrometres and measured perpendicular to the centre line.

Waviness It is the more widely spaced component of surface texture. Roughness may be considered to be superimposed on a wavy surface. Waviness is an error in form due to incorrect geometry of the tool producing the surface. On the other hand, roughness may be caused by problems such as tool chatter or traverse feed marks in a supposedly geometrically perfect machine. The spacing of waviness is the width between successive wave peaks or valleys. Waviness height is the distance from a peak to a valley.

Lay It is the direction of the predominant surface pattern, ordinarily determined by the production process used for manufacturing the component. Symbols are used to represent lays of surface pattern

Flaws These are the irregularities that occur in isolation or infrequently because of specific causes such as scratches, cracks, and blemishes.

Surface texture It is generally understood as the repetitive or random deviations from the nominal surface that form the pattern of the surface. Surface texture encompasses roughness, waviness, lay, and flaws.

Errors of form These are the widely spaced repetitive irregularities occurring over the full length of the work surface. Common types of errors of form include bow, snaking, and lobbing.

4.5.4 ANALYSIS OF SURFACE TRACES

It is required to assign a numerical value to surface roughness in order to measure its degree. This will enable the analyst to assess whether the surface quality meets the functional requirements of a component. Various methodologies are employed to arrive at a representative parameter of surface roughness. Some of these are 10-point height average (Rz), root mean square (RMS) value, and the centre line average height (Ra), which are explained in the following paragraphs.

4.5.4.1 Ten-point Height Average Value

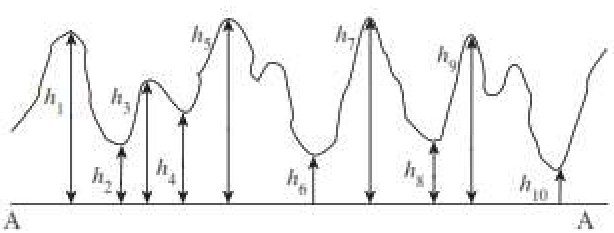

Fig. 4.24 Measurement to calculate the 10-point height average

It is also referred to as the peak-to-valley height. In this case, we basically consider the average height encompassing a number of successive peaks and valleys of the asperities. As can be seen in Fig., a line AA parallel to the general lay of the trace is drawn. The heights of five consecutive peaks and valleys from the line AA are noted down.

The average peak-to-valley height Rz is given by the following expression:

$$Rz = \frac{(h_1 + h_3 + h_5 + h_7 + h_9) - (h_2 + h_4 + h_6 + h_8 + h_{10})}{5} \times \frac{1000}{\text{Vertical magnification}}\ \mu m$$

4.5.4.2 Root Mean Square Value

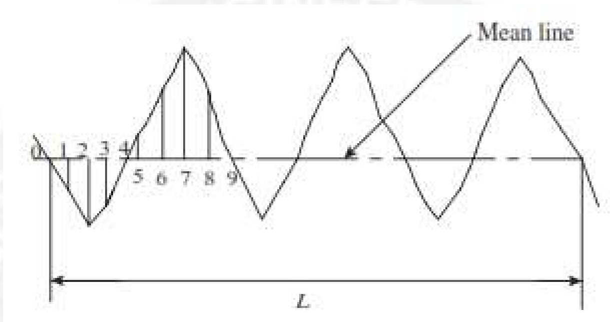

Fig. 4.25 Representation of an RMS value

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 220]

Until recently, RMS value was a popular choice for quantifying surface roughness; however, this has been superseded by the centre line average value. The RMS value is defined as the square root of the mean of squares of the ordinates of the surface measured from a mean line.

Figure illustrates the graphical procedure for arriving at an RMS value. With reference to this figure, if h_1, h_2, ..., h_n are equally spaced ordinates at points 1, 2, ..., n, then

$$h_{RMS} = \frac{\sqrt{(h_1^2 + h_2^2 + \ldots + h_n^2)}}{n}$$

4.5.4.3 Centre Line Average Value

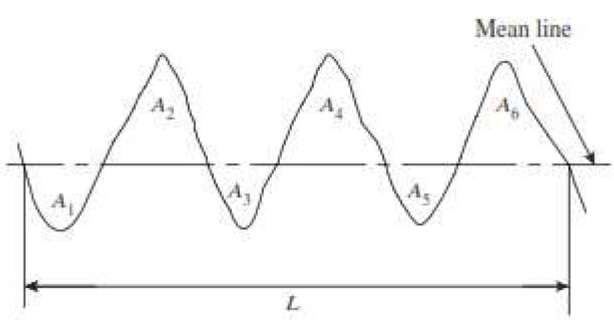

Fig. 4.26 Representation of Ra value

The Ra value is the prevalent standard for measuring surface roughness. It is defined as the average height from a mean line of all ordinates of the surface, regardless of sign. With reference to Fig., it can be shown that

$$\text{Ra} = \frac{A_1 + A_2 + \ldots + A_N}{L}$$
$$= \Sigma A / L$$

4.5.5 Methods of measuring surface finish

The methods used for measuring the surface finish is classified into

1. Inspection by comparison
2. Direct Instrument Measurements

4.5.5.1. Inspection by comparison methods:

- In these methods the surface texture is assessed by observation of the surface.
- The surface to be tested is compared with known value of roughness specimen and finished by similar machining process.
- The various methods which are used for comparison are

1. Touch Inspection.
2. Visual Inspection.
3. Microscopic Inspection.
4. Scratch Inspection.
5. Micro Interferometer.
6. Surface photographs.
7. Reflected Light Intensity.
8. Wallace surface Dynamometer.

4.5.5.1.1. Touch Inspection

It is used when surface roughness is very high and in this method the fingertip is moved along the surface at a speed of 25mm/second and the irregularities as up to 0.0 125mm can be detected.

4.5.5.1.2. Visual Inspection: