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.

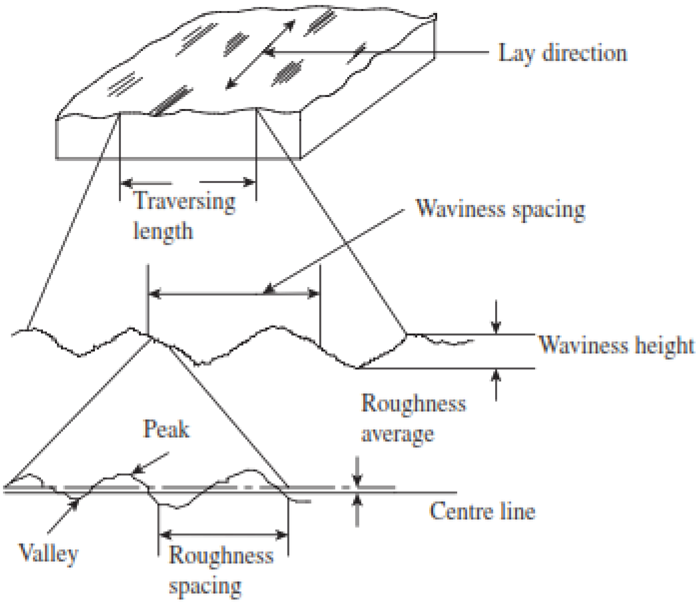

Fig. 4.34 Waviness and roughness

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 218]

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

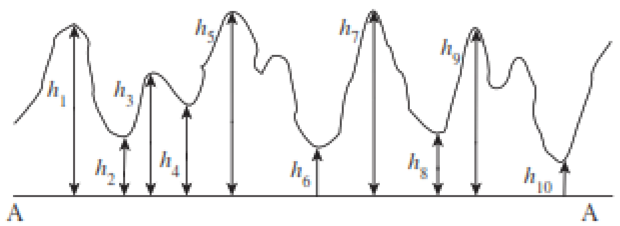

Fig. 4.35 Measurement to calculate the 10-point height average

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

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

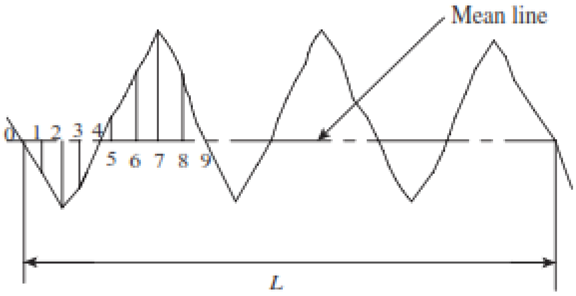

Fig. 4.36 Representation of an RMS value

[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

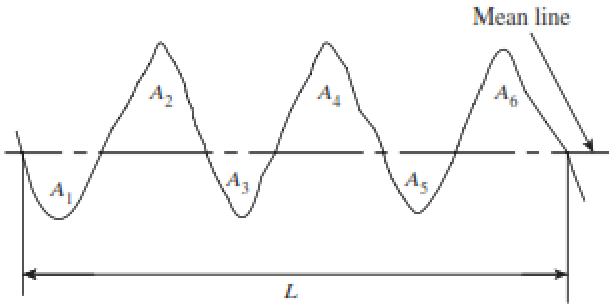

Fig. 4.37 Representation of Ra value

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 221]

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

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

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:

In this method the surface is inspected by naked eye and this measurement is limited to rough surfaces.

4.5.5.1.3. Microscopic Inspection:

In this method finished surface is placed under the microscopic and compared with the surface under inspection. The light beam also used to check the finished surface by projecting the light about 60° to the work.

4.5.5.1.4. Scratch Inspection:

The materials like lead, plastics rubbed on surface is inspected by this method. The impression of this scratches on the surface produced is then visualized.

4.5.5.1.5. Micro-Interferometer:

Optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light.

4.5.5.1.6. Surface Photographs:

Magnified photographs of the surface are taken with different types of illumination. The defects like irregularities are appear as dark spots and flat portion of the surface appears as bright.

4.5.5.1.7. Reflected light Intensity:

A beam of light is projected on the surface to be inspected and the light intensity variation on the surface is measured by a photocell and this measured value is calibrated

4.5.5.1.8. Wallace surface Dynamometer:

It consists of a pendulum in which the testing shoes are clamped to a bearing surface and a pre-determined spring pressure can be applied and then, the pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested.

4.5.6 DIRECT INSTRUMENT MEASUREMENTS

- Direct methods enable to determine a numerical value of the surface finish of any surface.
- These methods are quantitative analysis methods and the output is used to operate recording or indicating instrument.
- Direct Instruments are operated by electrical principles. These instruments are classified into two types according to the operating principle.
- In this is operated by carrier-modulating principle and the other is operated by voltage-generating principle, and in the both types the output is amplified.
- Some of the direct measurement instruments are

    1. Stylus probe instruments.
    2. Tomlinson surface meter.
    3. Profilometer.
    4. Taylor-Hobson Talysurf

4.5.6.1 Stylus probe instruments.

There are two types of stylus instruments: true datum and surface datum, which are also known as skidless and skid type, respectively. In the skidless instrument, the stylus is drawn across the surface by a mechanical movement that results in a precise path. The path is the datum from which the assessment is made. In the skid-type instrument, the stylus pickup unit is supported by a member that rests on the surface and slides along with it. This additional member is the skid or the shoe.

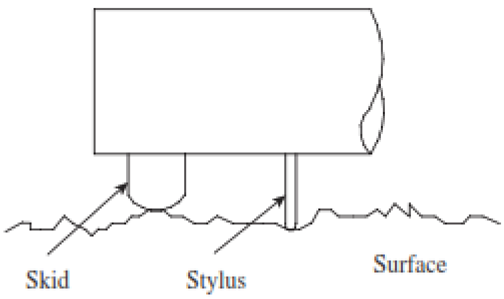

Fig. 4.38 Skid and stylus type

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 224]

Skids are rounded at the bottom and fixed to the pickup unit. They may be located in front of or behind the stylus. Some instruments use a shoe as a supporting slide instead of a skid. Shoes are flat pads with swivel mountings in the head. The datum created by a skid or a shoe is the locus of its centre of curvature as it slides along the surface.

The stylus is typically a diamond having a cone angle of 90° and a spherical tip radius of 1–5 μm or even less. The stylus tip radius should be small enough to follow the details of the surface irregularities, but should also have the strength to resist wear and shocks. Stylus load should also be controlled so that it does not leave additional scratch marks on the component being inspected.

In order to capture the complete picture of surface irregularities, it is necessary to investigate waviness (secondary texture) in addition to roughness (primary texture). Waviness may occur with the same lay as the primary texture. While a pointed stylus is used to measure roughness, a blunt stylus is required to plot the waviness.

Advantage:

Any desired roughness parameter can be recorded.

Disadvantages:

1. Fragile material cannot be measured.

2. High Initial cost.

3. Skilled operators are needed to operate.

4.5.6.2 Tomlinson Surface Meter.

The sensing element is the stylus, which moves up and down depending on the irregularities of the workpiece surface. The stylus is constrained to move only in the vertical direction because of a leaf spring and a coil spring. The tension in the coil spring P causes a similar tension in the leaf spring. These two combined forces hold a cross-roller in position between the stylus and a pair of parallel fixed rollers. A shoe is attached to the body of the instrument to provide the required datum for the measurement of surface roughness.

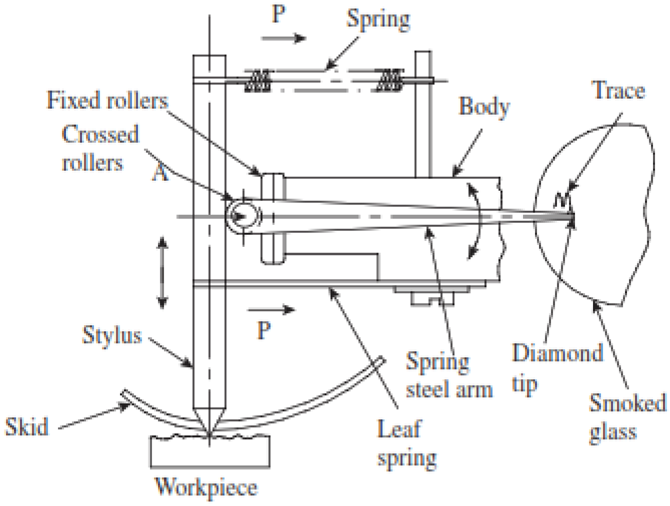

Fig. 4.39 Tomlinson surface meter

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 224]

A light spring steel arm is P Spring attached to the cross-roller and carries a diamond tip. The translatory motion of the stylus causes rotation of the cross roller about the point A, which in turn is converted to a magnified motion of the diamond point. The diamond tip traces the profile of the workpiece on a smoked glass sheet. The glass sheet is transferred to an optical projector and magnified further. Typically, a magnification of the order of 50–100 is easily achieved in this instrument.

In order to get a trace of the surface irregularities, a relative motion needs to be generated between the stylus and the workpiece surface. Usually, this requirement is met by moving the body of the instrument slowly with a screw driven by an electric motor at a very slow speed. Anti-friction guide-ways are used to provide friction-free movement in a straight path.

4.5.6.3. Taylor–Hobson Talysurf.

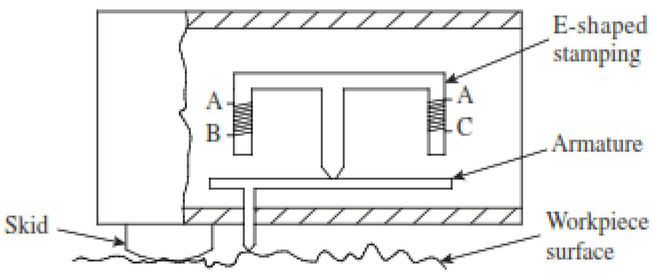

Fig. 4.40 Taylor–Hobson Talysurf

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 225]

The Taylor–Hobson talysurf works on the same principle as that of the Tomlinson surface meter. However, unlike the surface meter, which is purely a mechanical instrument, the talysurf is an electronic instrument. This factor makes the talysurf a more versatile instrument and can be used in any condition, be it a metrology laboratory or the factory shop floor.

The stylus is attached to an armature, which pivots about the centre of piece of an E-shaped stamping. The outer legs of the E-shaped stamping are wound with electrical coils. A predetermined value of alternating current (excitation current) is supplied to the coils. The coils form part of a bridge circuit. A skid or shoe provides the datum to plot surface roughness. The measuring head can be traversed in a linear path by an electric motor. The motor, which may be of a variable speed type or provided with a gear box, provides the required speed for the movement of the measuring head.

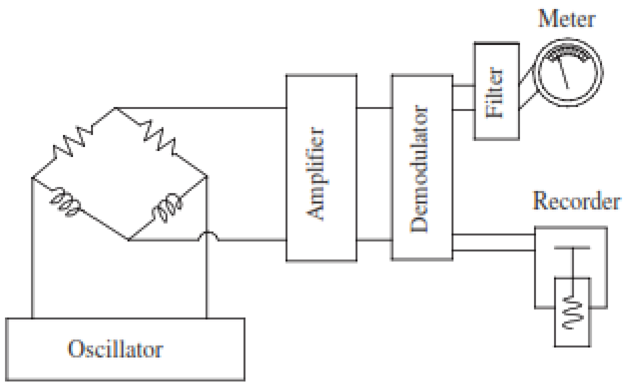

Fig. 4.41 Bridge circuit and electronics

[source: Engineering Metrology and Measurements, N.V. Raghavendra, Pg. No 225]

As the stylus moves up and down due to surface irregularities, the armature is also displaced. This causes variation in the air gap, leading to an imbalance in the bridge circuit. The resulting bridge circuit output consists of only modulation. This is fed to an amplifier and a pen recorder is used to make a permanent record. The instrument has the capability to calculate and display the roughness value according to a standard formula.

4.5.6.4. Profilometer.

A profilometer is a compact device that can be used for the direct measurement of surface texture. A finely pointed stylus will be in contact with the workpiece surface. An electrical pickup attached to the stylus amplifies the signal and feeds it to either an indicating unit or a recording unit. The stylus may be moved either by hand or by a motorized mechanism.

The profilometer is capable of measuring roughness together with waviness and any other surface flaws. It provides a quick-fix means of conducting an initial investigation before attempting a major investigation of surface quality.

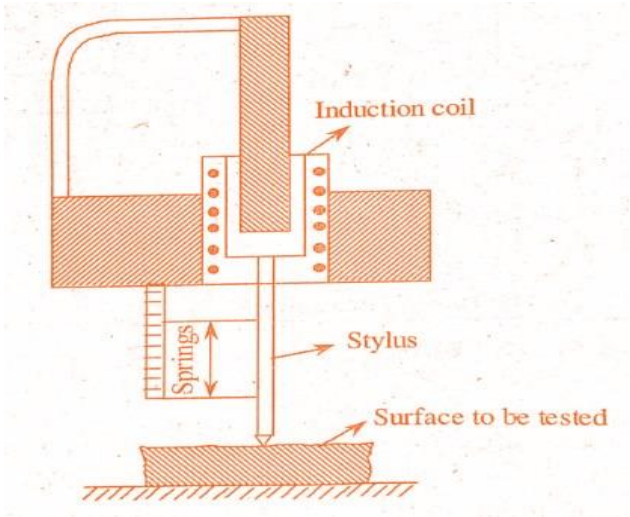

Fig. 4.42 Profilometer

[source: http://www.mechanicaleducation.com/2018/10/what-is-profilometer-and-uses-of-profilometer.html]

4.5.7 Other methods for measuring surface roughness

4.5.7.1 Profilograph

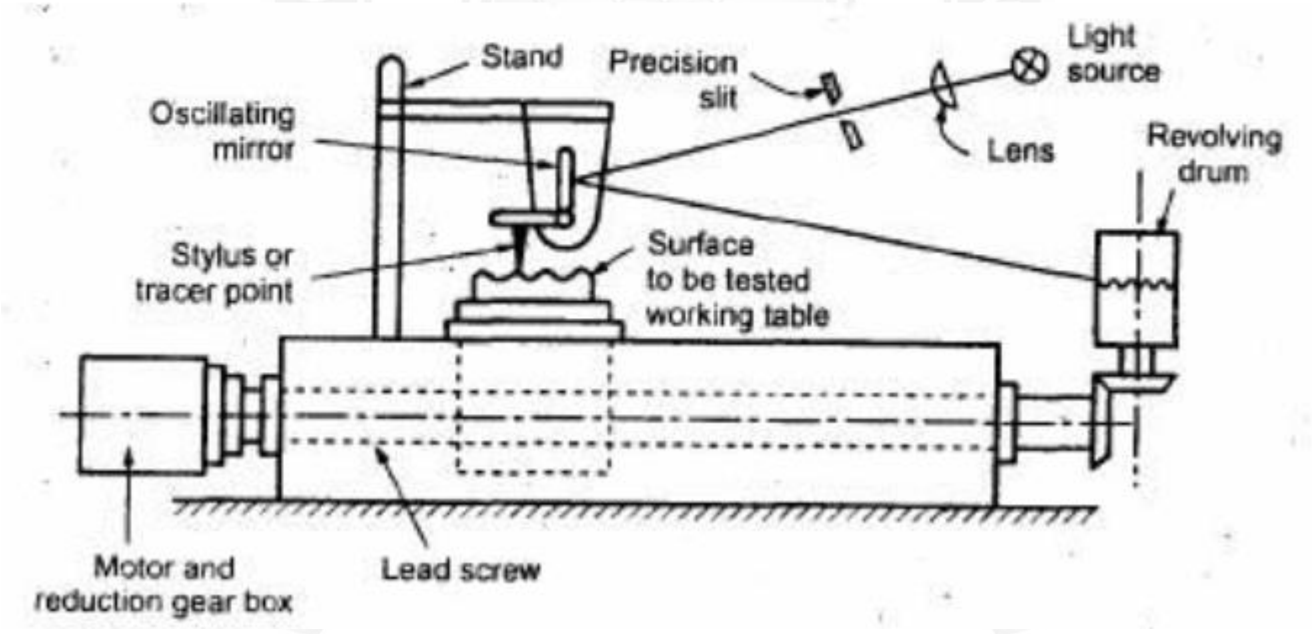

Fig. 4.43 Profilograph

[source: https://www.slideshare.net/navroznavodia/surface-finish-measurement-mechanical-measurement-and-metrology]

- ❖ The surface finish to be checked work piece is placed on the table.
- ❖ The table can move either side by lead screw and the stylus is pivoted over the tested surface, so the oscillation in the stylus due to surface irregularities are transmitted to the mirror.
- ❖ A light source sends a beam of light through lens and a precision slit to the mirror, and the reflected beam is directed to revolving drum.

- ❖ Upon the revolving drum a sensitive film is attached. The revolving drum can be rotated by two bevel gears and the gears are attached to the same lead screw.
- ❖ Finally, the profilogram will be obtained from the sensitive film and it is analysed.

4.5.7.2 Double microscope

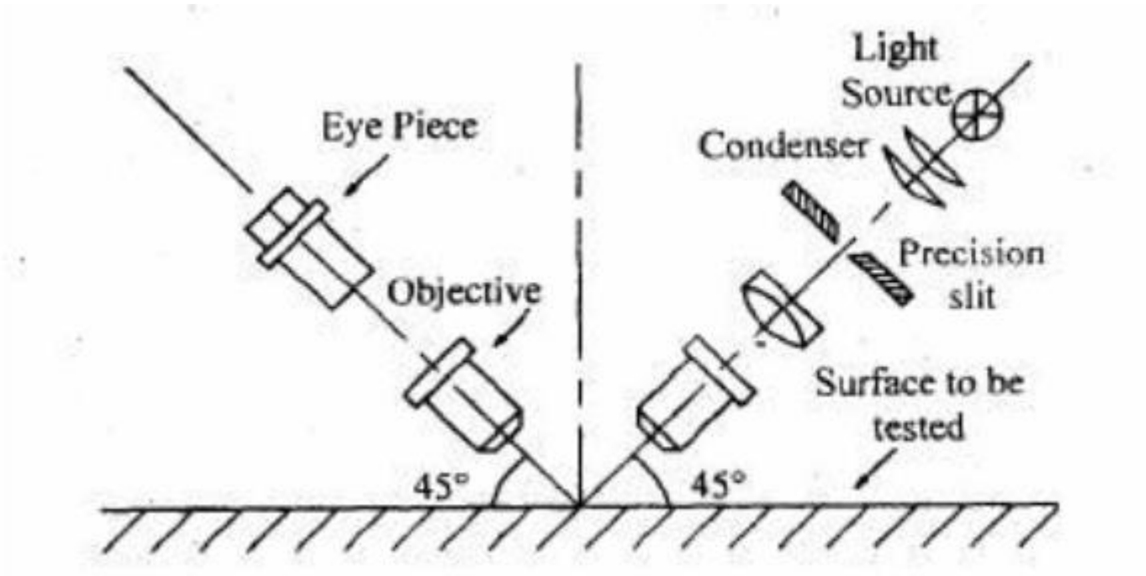

Fig. 4.44 Profilograph

[source: https://www.slideshare.net/navroznavodia/surface-finish-measurement-mechanical-measurement-and-metrology]

- ❖ It is an optical method for measuring the surface roughness, working principle is a thin film of light strikes the surface to be tested by an angle of 45° through the condenser and precision slit and the observing microscope is also inclined at an angle. of 45° to the tested surface.
- ❖ The surface is illuminated by a projection tube and it is observed by an eyepiece through the microscope.
- ❖ The eyepiece contains an eyepiece micrometer and it is used to measure the irregularities.