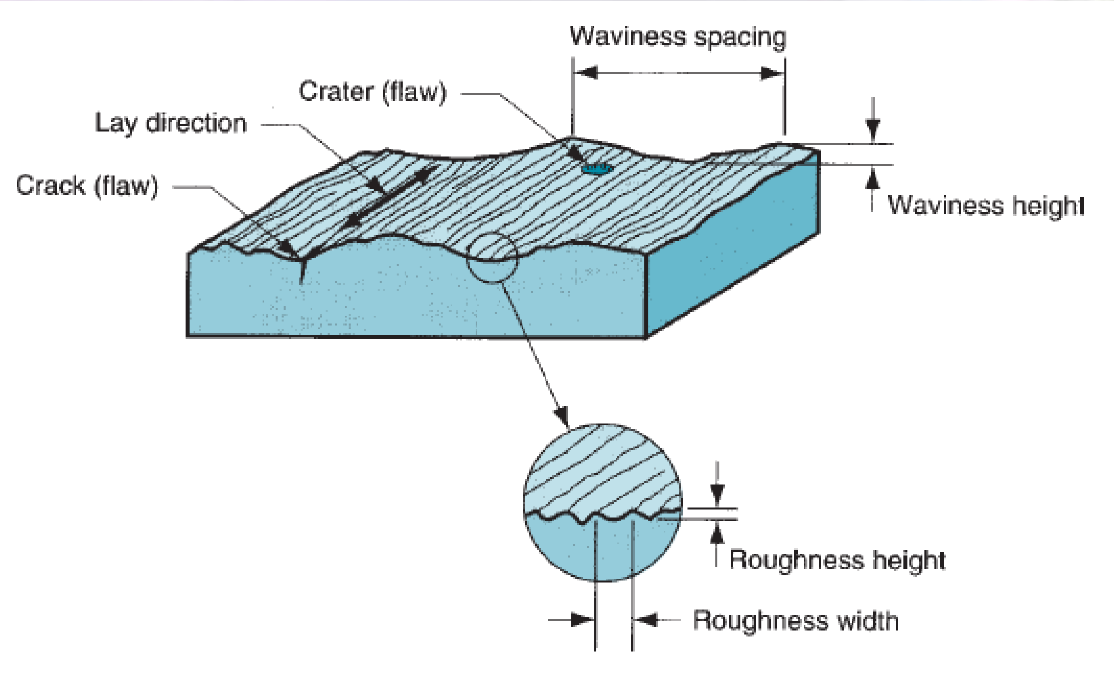
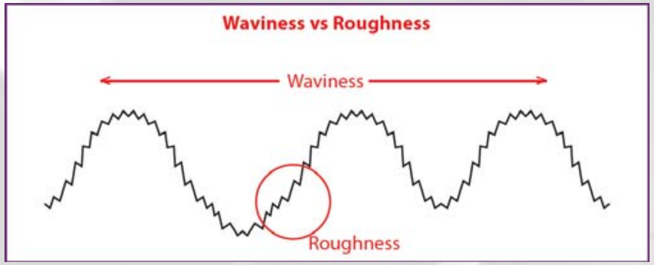
Chapter 8

Metrology of Surface Finish

Surface Metrology Concepts

✓ If one takes a look at the topology of a surface, surface irregularities are superimposed on a widely spaced component of surface texture called waviness.





Surface Irregularities

Surface irregularities arise primarily due to the following factors:

- ✓ Feed marks of cutting tools
- ✓ Chatter marks on the work-piece due to **vibrations** caused during the manufacturing operation
- ✓ Irregularities on the surface due to rupture of work-piece material during metal cutting operation
- ✓ Surface variations caused due to deformation of work-piece under the action of cutting forces
- ✓ Irregularities in the machine tool itself such as lack of straightness of guide ways

Terminology

- ✓ Roughness
- ✓ Waviness
- ✓ Lay
- ✓ Flaws
- ✓ Surface texture
- ✓ Error of Form

Terminology

Surface finish, also known a **surface texture** or surface topography, is the nature of a surface. It comprises the small local deviations of a surface from the perfectly flat ideal (a true plane).

Surface roughness, often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is **rough**; if they are small, the surface is smooth.

Waviness is the measurement of the more widely spaced component of surface texture. It is a broader view of roughness because it is more strictly defined as "the irregularities whose spacing is greater than the roughness sampling length"

Lay is the direction of the surface pattern ordinarily determined by the production method used.

Analysis of Surface Traces

<u>Centre Line Average (Ra) Value</u>

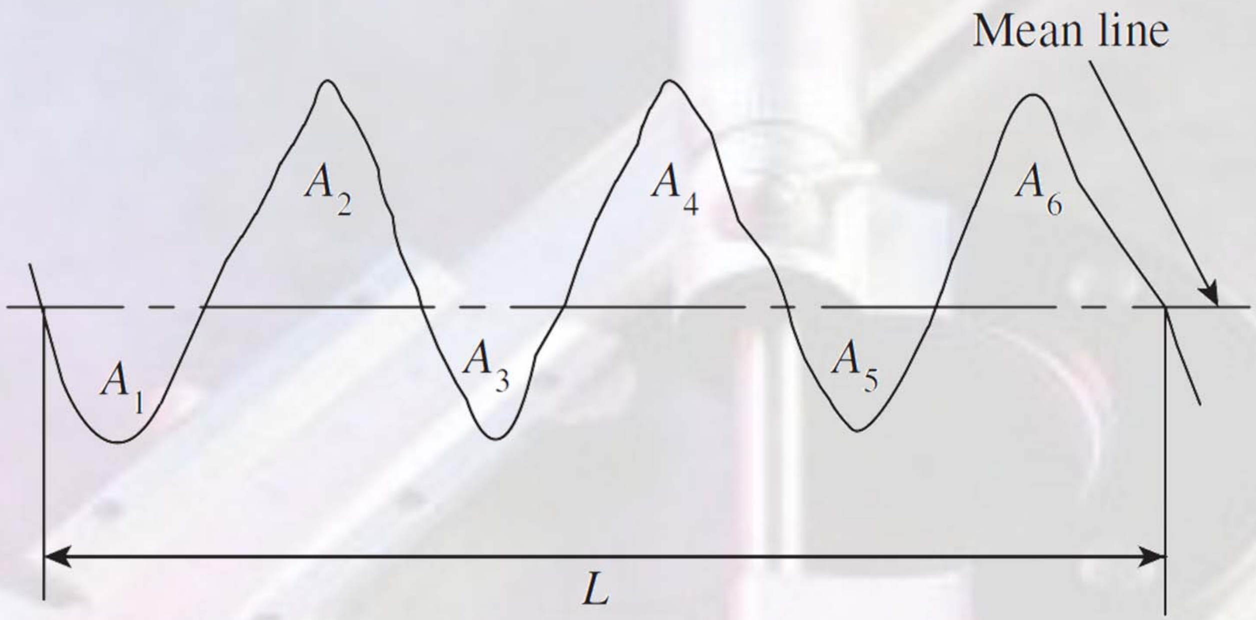


Fig. 9.4 Representation of Ra value

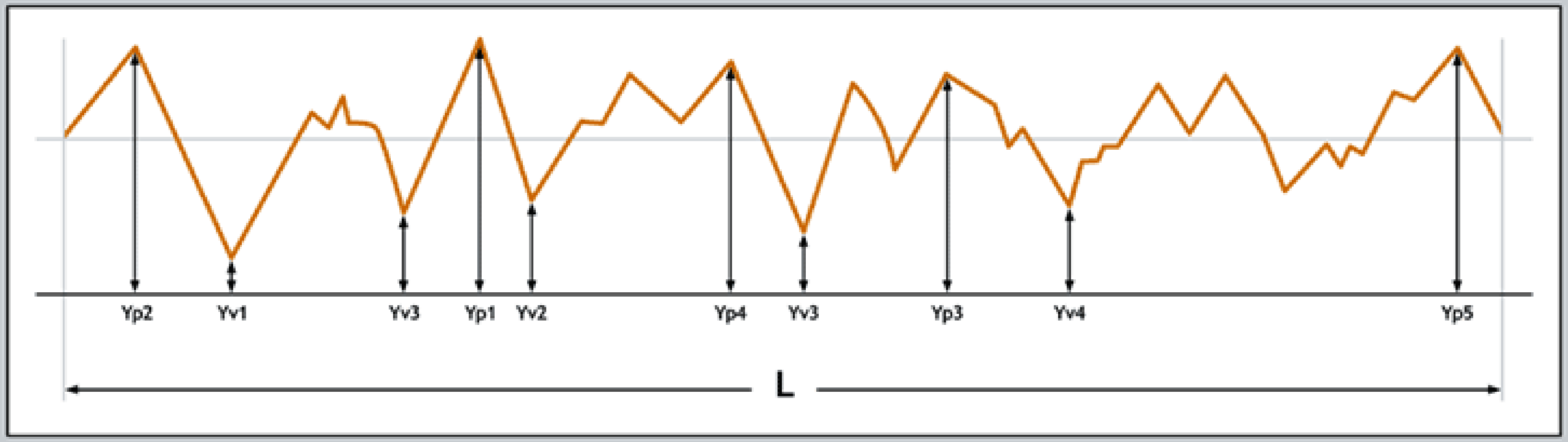
$$\text{Ra} = \frac{A_1 + A_2 + \ldots + A_N}{L}$$

Ra is the universally recognized parameter of roughness.

Roughness average Ra is the arithmetic average of the absolute values of the roughness profile ordinates.

Analysis of Surface Traces

<u>Ten-point height average (Rz) Value</u>

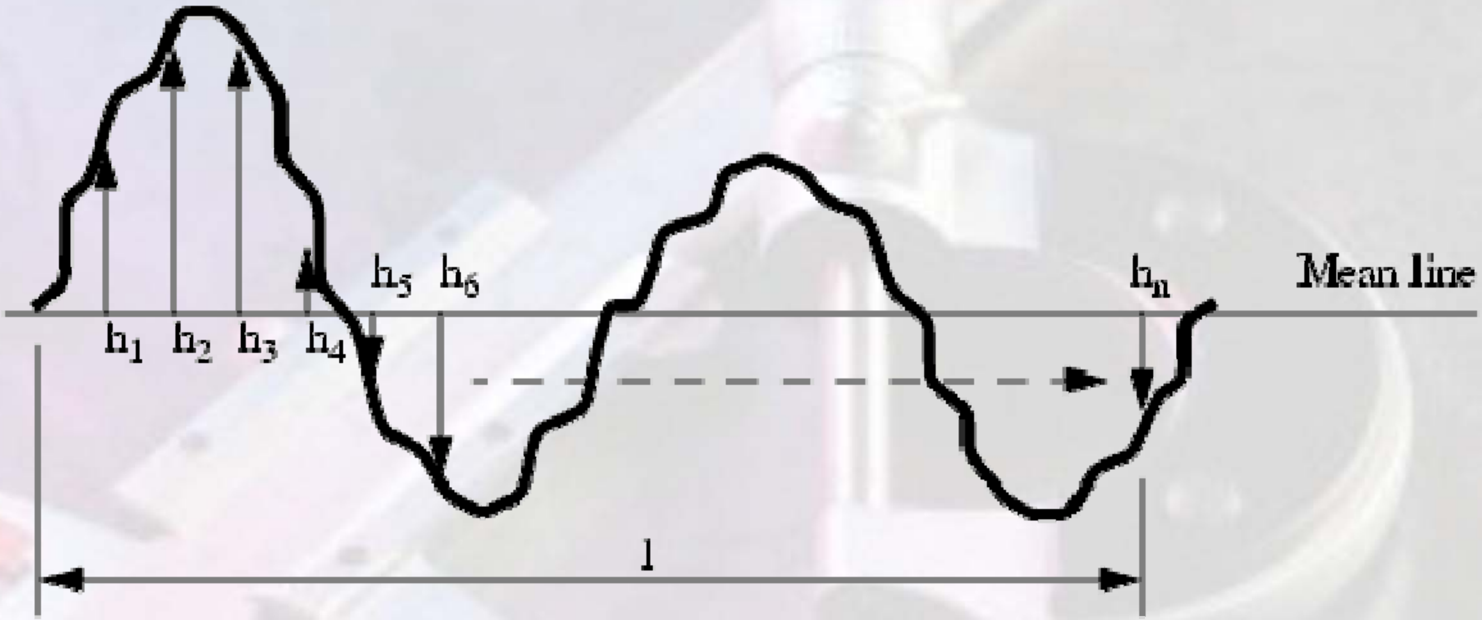


$$Rz = \frac{(Yp1 + Yp2 + Yp3 + Yp4 + Yp5) - (Yv1 + Yv2 + Yv3 + Yv4 + Yv5)}{5} = \frac{1}{5}(\Sigma\, Ypi - \Sigma\, Yvi)$$

ISO 10 POINT HEIGHT PARAMETER

Analysis of Surface Traces

Root Mean Square (R.M.S.) Value



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

Root mean square (RMS) roughness Rq is the root mean square average of the roughness profile ordinates.

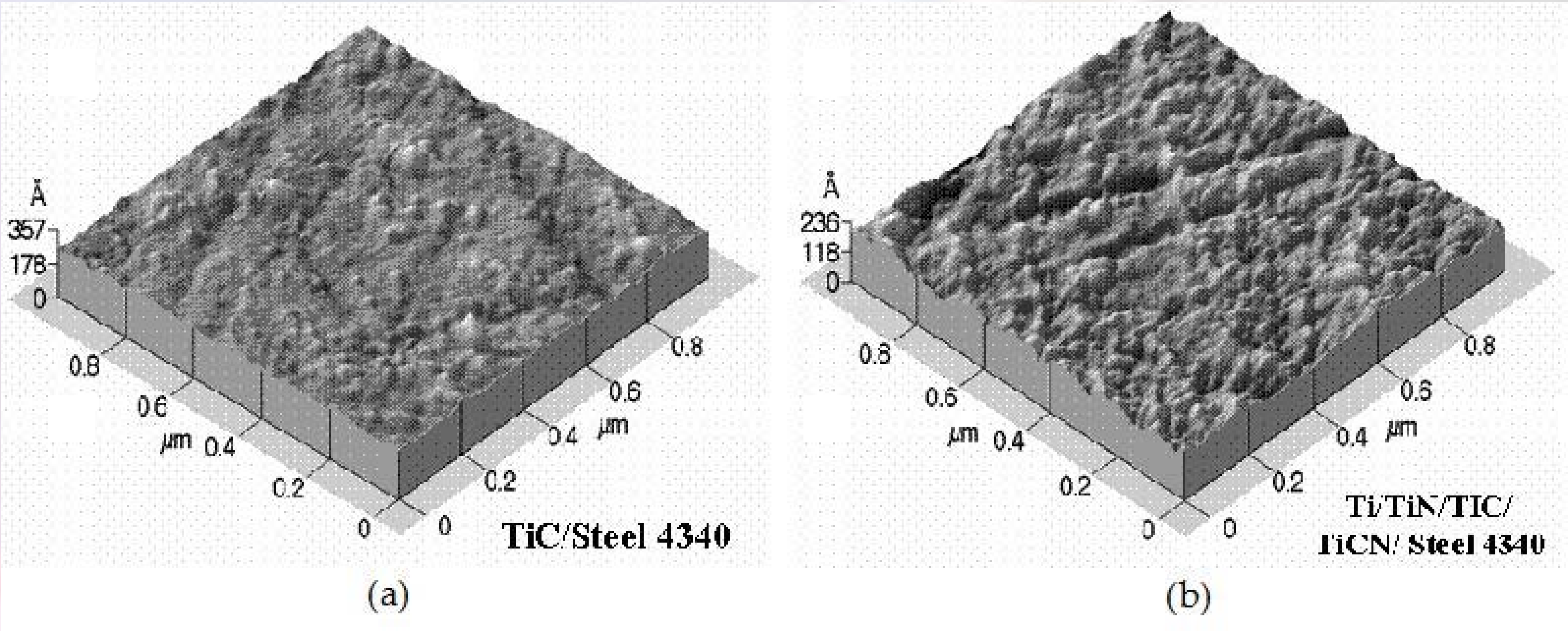
Analysis of Surface Traces

Parameters Defined in ASME B46.1-2002

R_a Arithmetic Average Deviation of the Assessed Profile
R_q Root Mean Square Deviation of the Assessed Profile
R_p Maximum Profile Peak Height
R_v Maximum Profile Valley Depth
R_t Maximum Height of the Profile
R_{pm} Average Maximum Profile Peak Height
R_z Average Maximum Height of the Profile
R_{max} Maximum Roughness Depth
S_m Mean Spacing of Profile Irregularities
P_c Peak Density

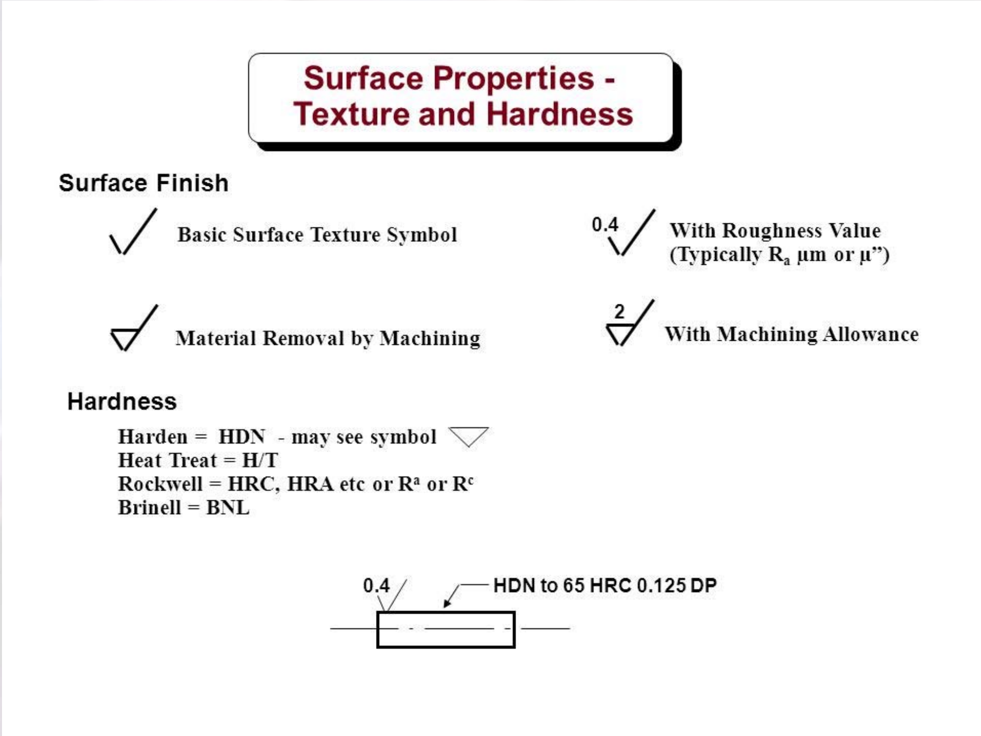
1. Root-Means-Square roughness (R_a or RMS)
   - Closely related to the roughness average (Ra)
   - Square the distances, average them, and determine the square root of the result
   - The resulting value is the index for surface texture comparison
   - Usually 11% higher than the Ra value
2. Maximum Peak-Valley Roughness (R_{max} or R_t)
   - Determine the distance between the lines that contact the extreme outer and inner point of the profile
   - Second most popular method in industry
   - See figure A
3. Ten-Point Height (R_z)
   - Averages the distance between the five peaks and five deepest valleys within the sampling length
   - See figure B

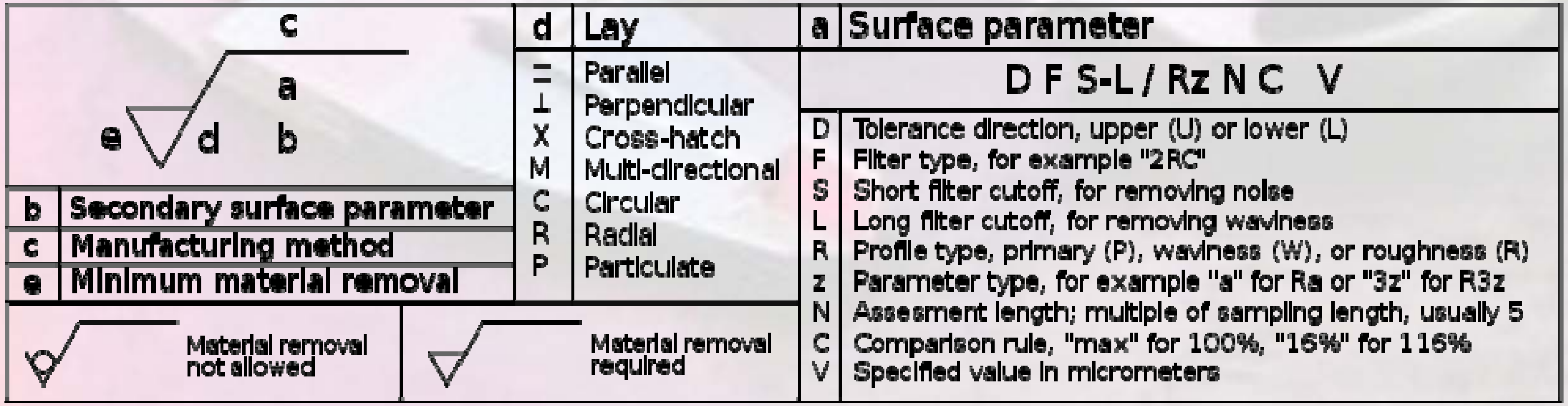
Analysis of Surface Traces



AFM Micrographs of surface structure of multilayers grown steel.

Symbols of Surface Texture





Methods of Measuring Surface Finish

- ✓ There are basically two approaches for the measurement of surface finish, namely, by comparison and direct measurement.

- ✓ The former is the simpler of the two, but is more subjective in nature. The comparative method advocates assessment of surface texture by observation or feel of the surface.

- ✓ Direct measurement enables a numerical value to be assigned to the surface finish.

Stylus System of Measurement

- ✓ A skid or shoe drawn over the work-piece surface such that it follows the general contours of the surface as accurately as possible. The skid also provides the datum for the stylus
- ✓ A stylus which moves over the surface along with the skid, such that its motion vertically is relative to the skid. This factor enables the stylus to capture the contours of surface roughness independent of surface waviness.

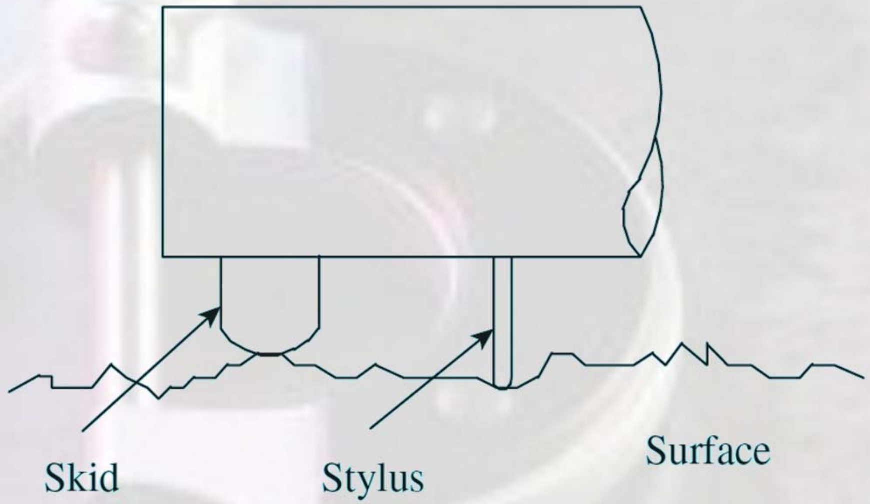


Fig. 9.8 Skid and stylus type

- ✓ An amplifying device for magnifying the stylus movements
- ✓ A recording device to produce a trace or record of the surface profile

Tomilson Surface Meter

- ✓ This is a mechanical-optical instrument designed by Dr Tomlinson of the National Physical laboratory of U.K.

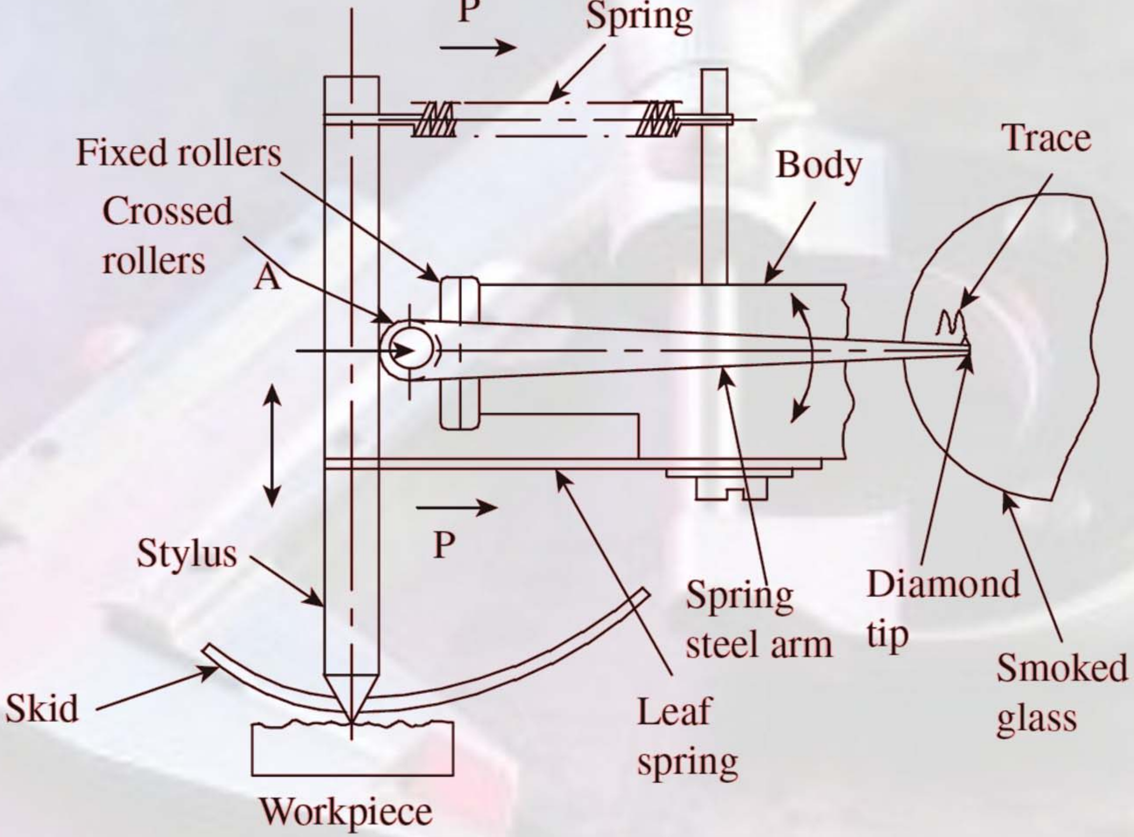


Fig. 9.9 Tomlinson surface meter

Tomilson Surface Meter

- ✓ The sensing element is the stylus, which moves up and down depending upon the irregularities of the work-piece 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.
- ✓ A diamond tip traces the profile of the work-piece on a smoked glass sheet.

Taylor Hobson Talysurf

- ✓ A 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 pre-determined 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.

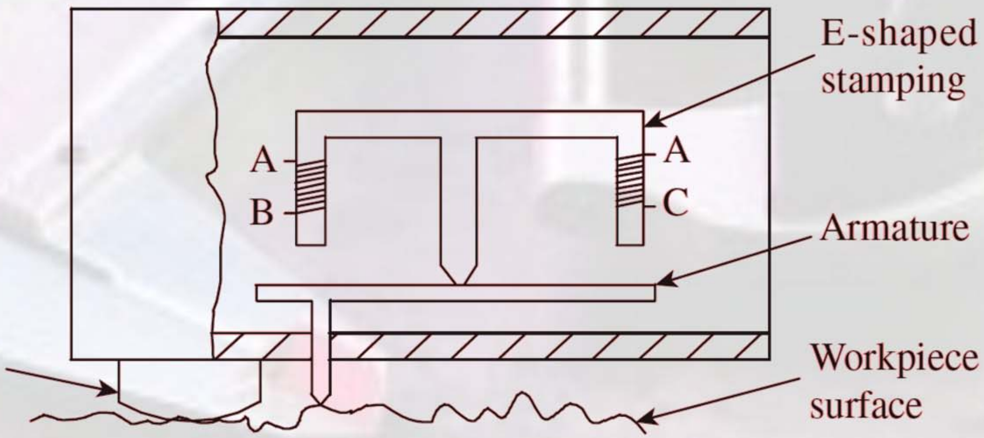


Fig. 9.10 Taylor–Hobson talysurf

Taylor Hobson Talysurf

- ✓ As the stylus moves up and down due to surface irregularities, the armature is also displaced. This causes variation in the air gap and causes an imbalance in the bridge circuit.

- ✓ The resulting bridge circuit output consists of modulation only. This is fed to an amplifier and caused to operate a pen recorder to produce a permanent record.

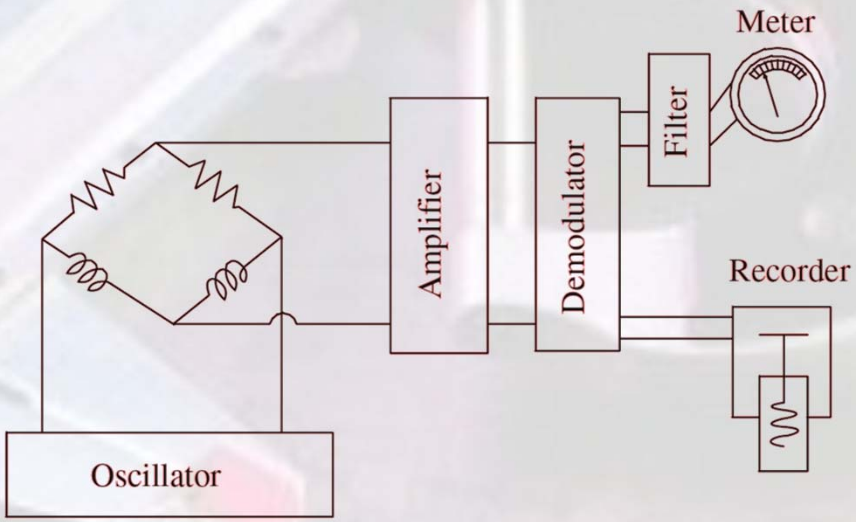


Fig. 9.11 Bridge circuit and electronics

Wavelength, Frequency and Cutoff

- ✓ Skids simplify surface assessment while using stylus instruments. However, there is distortion because of phase relationship between the stylus and the skid.
- ✓ In case A, the stylus and the skid are in phase. Therefore, roughness (the primary texture) will be relatively undistorted.
- ✓ In case B, the two are out of phase. In this situation, waviness superimposes in the roughness reading and is misleading.

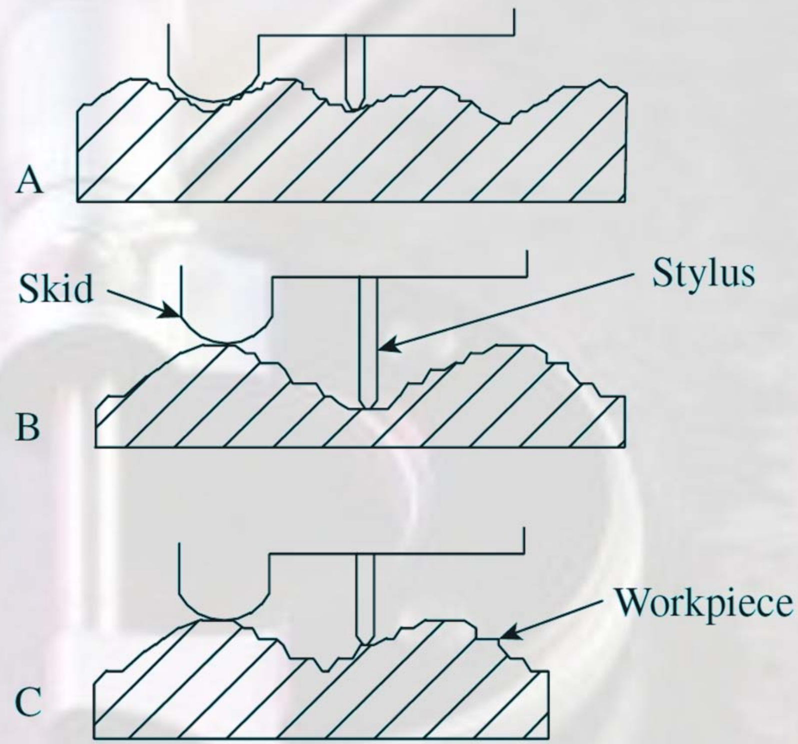


Fig. 9.12 Phase relationship between the skid and stylus

- ✓ In case C also the stylus and skid are out of phase, resulting in unrealistic interpretation of roughness value

Other methods for measuring Surface Roughness

- ✓ Pneumatic Method
- ✓ Light Interference Microscopes
- ✓ The Mecrin Instrument