[ME 472]

Engineering Metrology & Quality Control

[CHAPTER 5]

Measurement of Surface Texture

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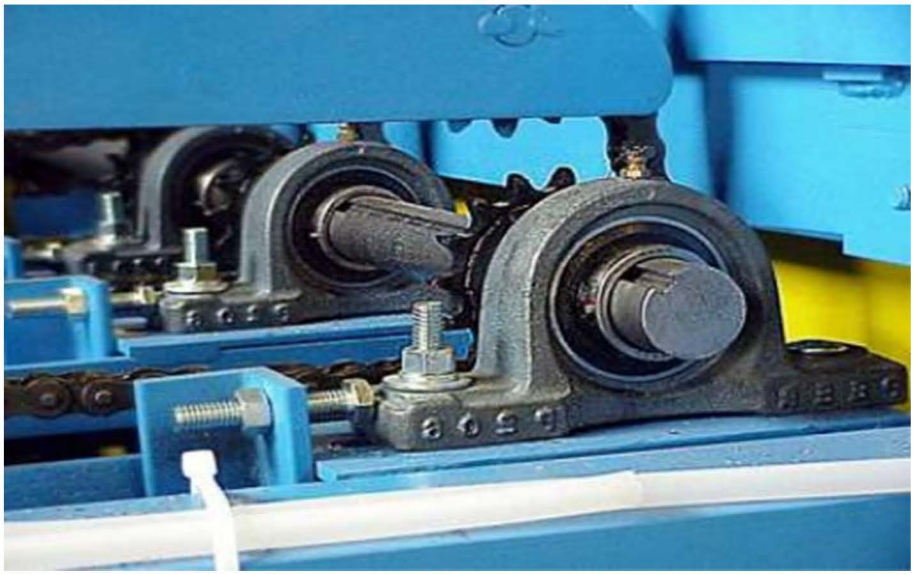
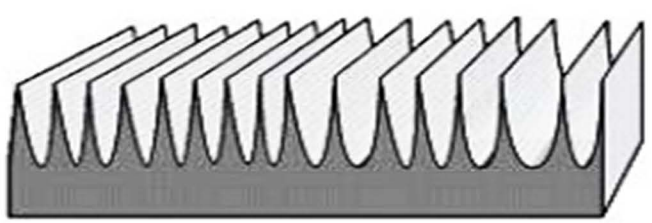
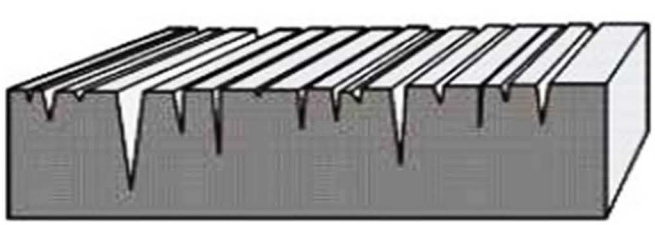
Surface Texture in Manufacturing

- Assessment of surface texture is significant for:
  - **Friction** of contact (mating) surfaces
  - **Bearing** and **lubrication** capabilities
  - **Surface protection** (coating, painting, plating, etc.)
  - Resistance to **wear** and **corrosion**
  - **Tolerancing** and **fitting**
  - **Noise reduction**

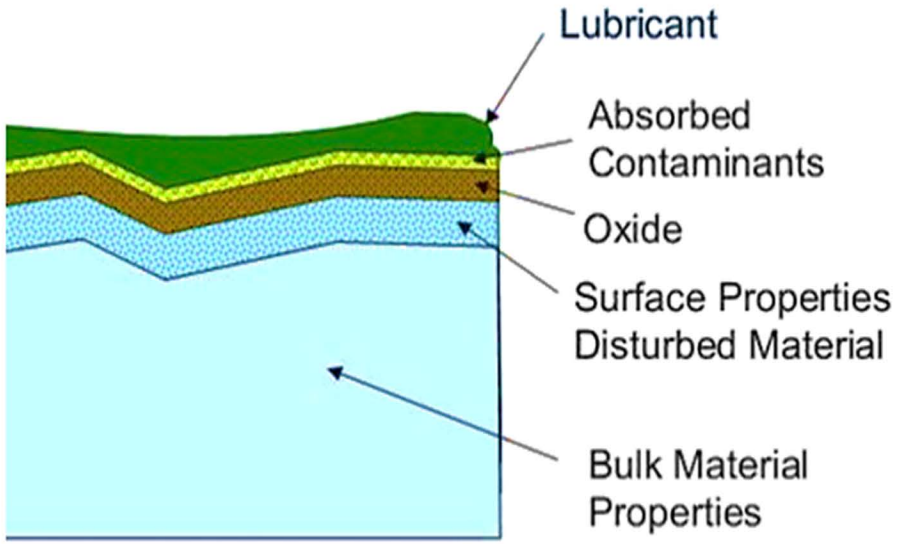




Surface with deep & regular grooves

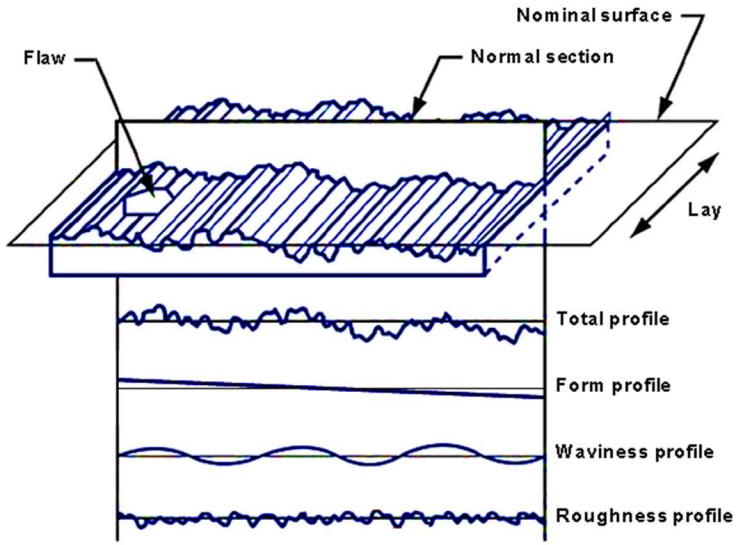


Surface with shallow & irregular grooves

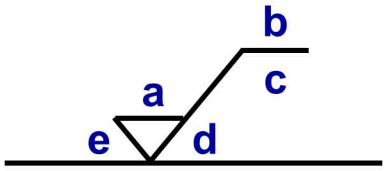


Terminology

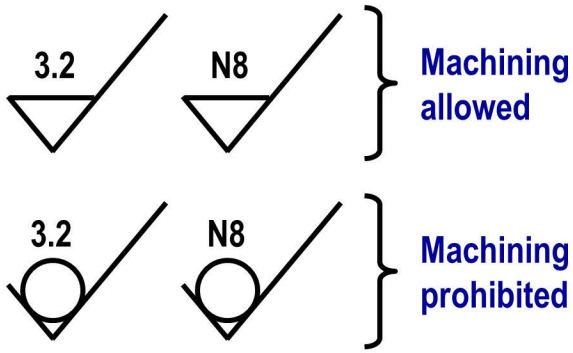
- **Surface Texture (Surface Topography):** refers to **total profile**
- **Surface Finish (Surface Quality):** refers to **roughness profile**
- **Form Error:** non-cyclic long-period deviations **(macro-scale)**
- **Waviness:** wide-spaced irregularities **(meso-scale)**
- **Roughness:** close-spaced irregularities **(micro-scale)**
- **Flaw:** **surface defects** (scratches, cracks, inclusions, etc.)
- **Lay:** **directionality** of surface pattern



R_a (µm):	50	25	12.5	6.3	3.2	1.6	0.8	0.4	0.2	0.1	0.05	0.025
Number:	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1



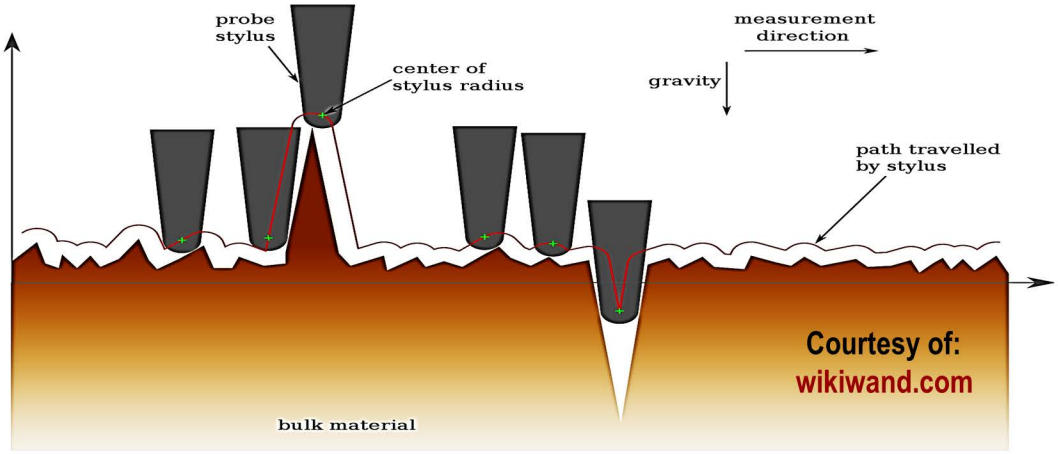
- **a** Roughness value (R_a)
- **b** Method of production
- **c** Sampling length (µm)
- **d** Direction of lay
- **e** Machining allowance



Lay symbol	Surface pattern	Description
=		Lay is parallel to line representing surface to which symbol is applied.
⊥		Lay is perpendicular to line representing surface to which symbol is applied.
X		Lay is angular in both directions to line representing surface to which symbol is applied.
M		Lay is multidirectional.
C		Lay is circular relative to center of surface to which symbol is applied.
R		Lay is approximately radial relative to the center of the surface to which symbol is applied.
P		Lay is particulate, nondirectional, or protuberant.

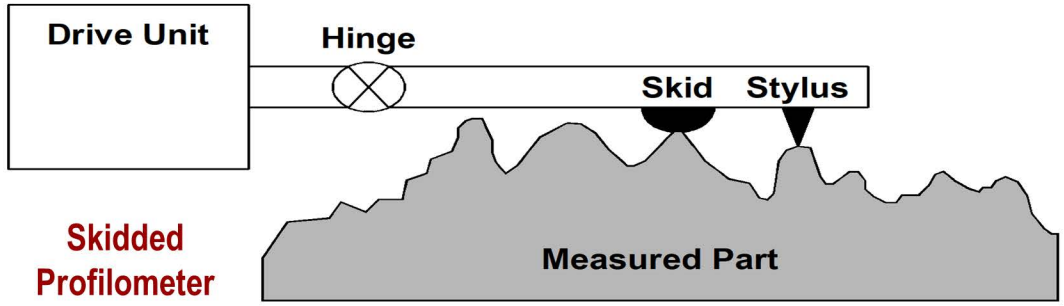
Profile Measurement

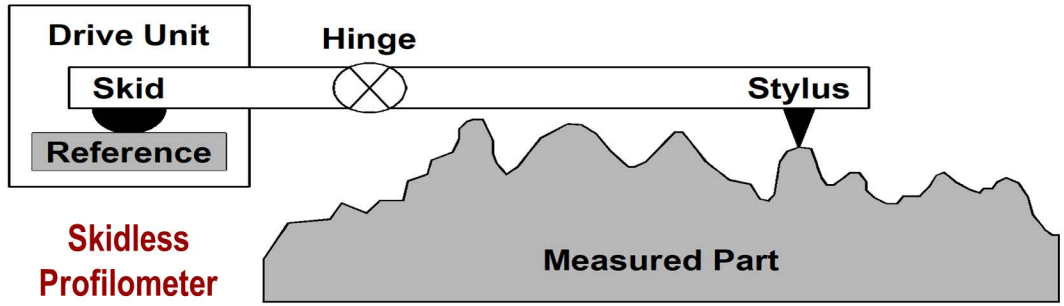
- The surface is measured using **profilometer (roughness tester)** with **stylus (tracing probe)** having perfectly sharp tip made of hard material.
- Stylus is set in such a way that its tip must have contact with surface at all times. It is moved horizontally to follow contours on the surface.
- **The path achieved by means of the stylus is always smoother than the actual path.**

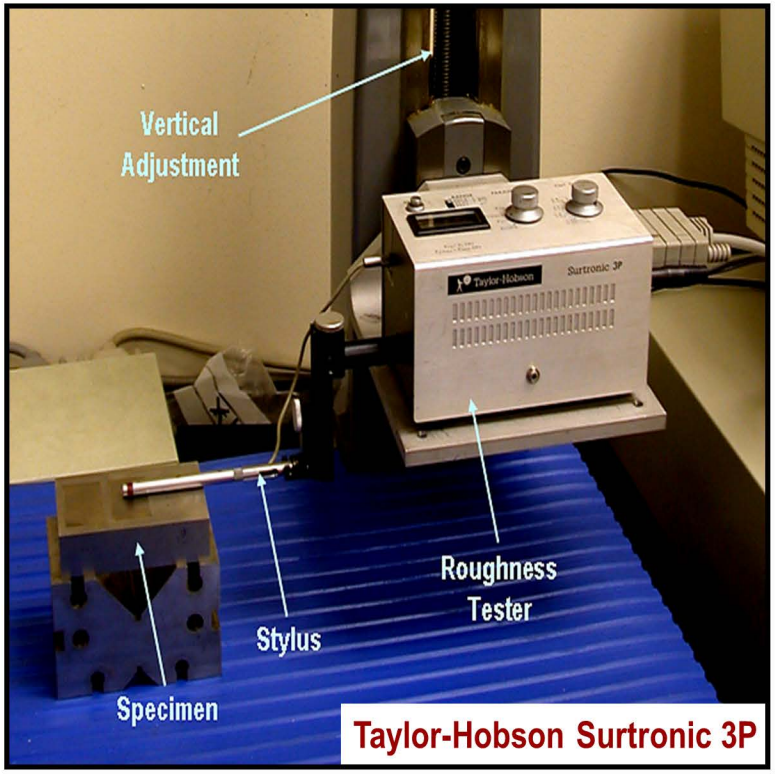


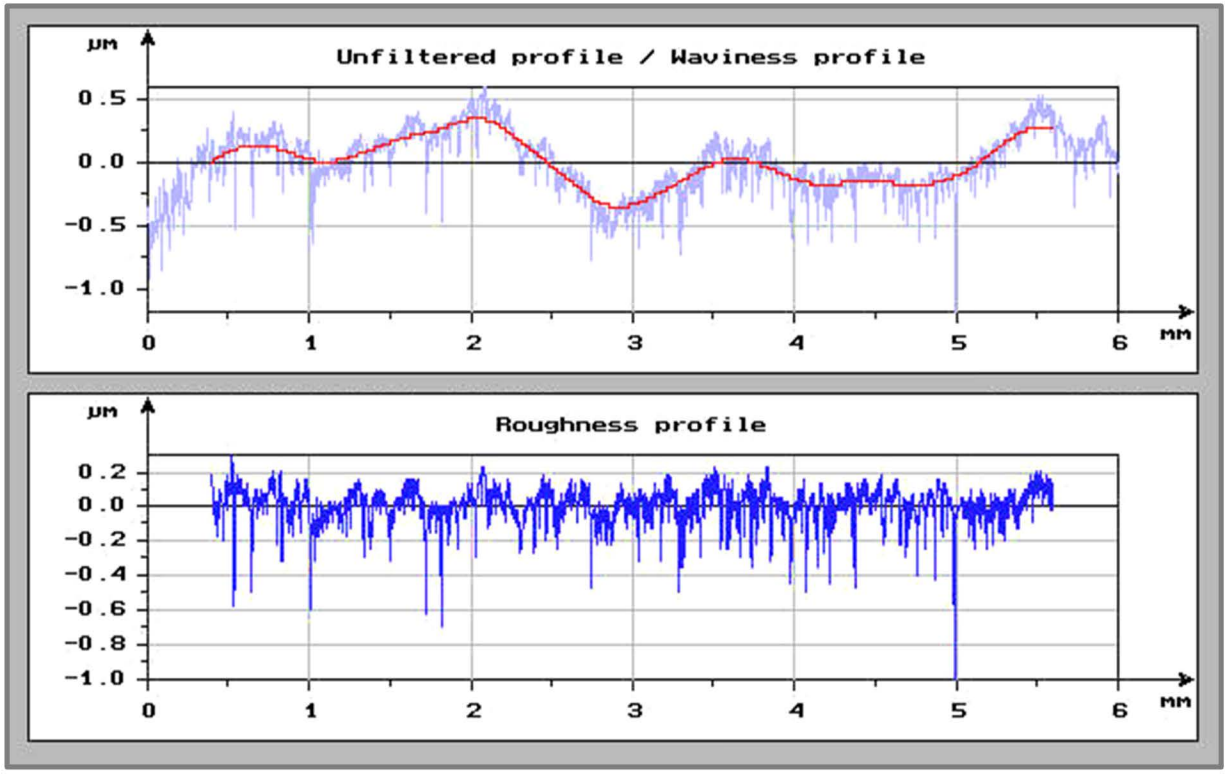
Profilometers (Roughness Testers)

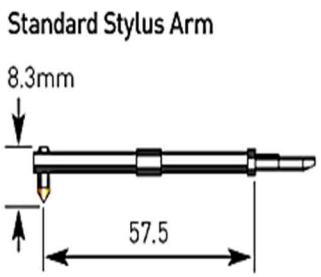
- **Skidded Profilometer:** The probe has stylus with a skid (a gauge). Part surface is taken as the datum. **Only roughness can be measured**.
- **Skidless Profilometer:** An internal reference surface located inside the profilometer is taken as the datum. **Roughness, waviness and form can be measured.**

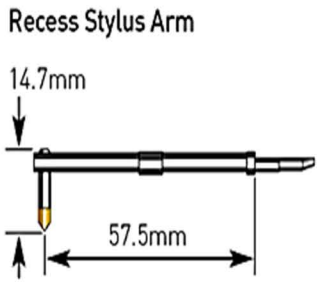


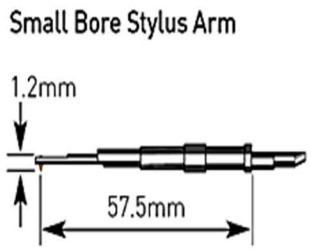


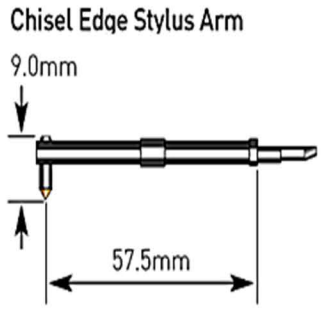

Vertical Adjustment
Roughness Tester
Stylus
Specimen
Taylor-Hobson Surtronic 3P

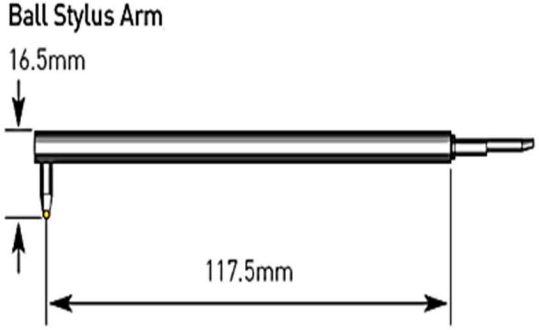

Unfiltered profile / Waviness profile
µm
0.5
0.0
-0.5
-1.0
0
1
2
3
4
5
6
mm
Roughness profile
µm
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0
1
2
3
4
5
6
mm


Standard Stylus Arm
8.3mm
57.5


Recess Stylus Arm
14.7mm
57.5mm


Small Bore Stylus Arm
1.2mm
57.5mm


Chisel Edge Stylus Arm
9.0mm
57.5mm


Ball Stylus Arm
16.5mm
117.5mm

Surface Texture Parameters

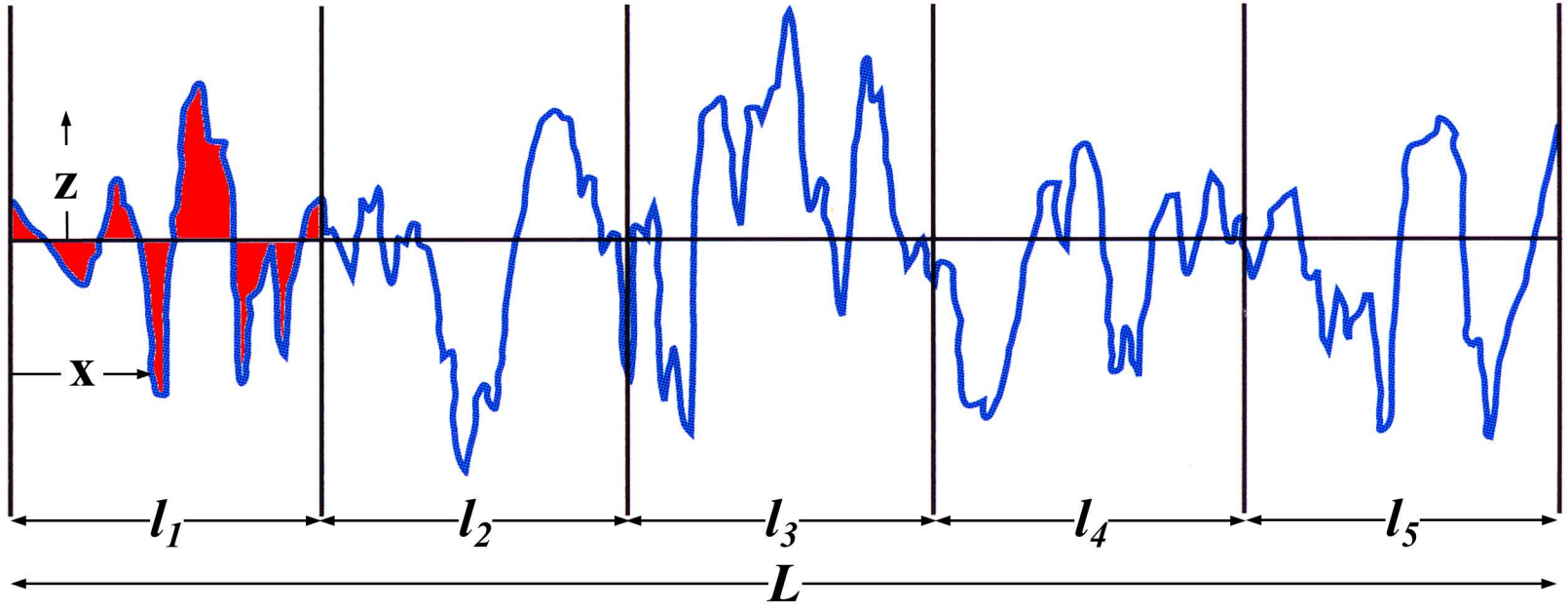
Category	Explanation	Primary	Waviness	Roughness
Amplitude Parameters	Vertical characteristics of surface deviations	Pa, Pq, Pv, Pp, Pt, Psk, Pku, Pz	Wa, Wq, Wv, Wp, Wt, Wsk, Wku, Wz	Ra, Rq, Rv, Rp, Rt, Rsk, Rku, Rz, R_{3z}
Spacing Parameters	Horizontal characteristics of surface deviations	Psm	Wsm	Rsm, RHSC, RPc
Hybrid Parameters	Combination of vertical & horizontal characteristics of surface deviations	PΔq, Pλq	WΔq, Wλq	RΔq, Rλq, Rmr, Rpk, Rk, Rvk, Mr_1 & Mr_2

Only roughness parameters will be explained in this chapter.
For others, refer to related standards given at the last slide.

Roughness Profile

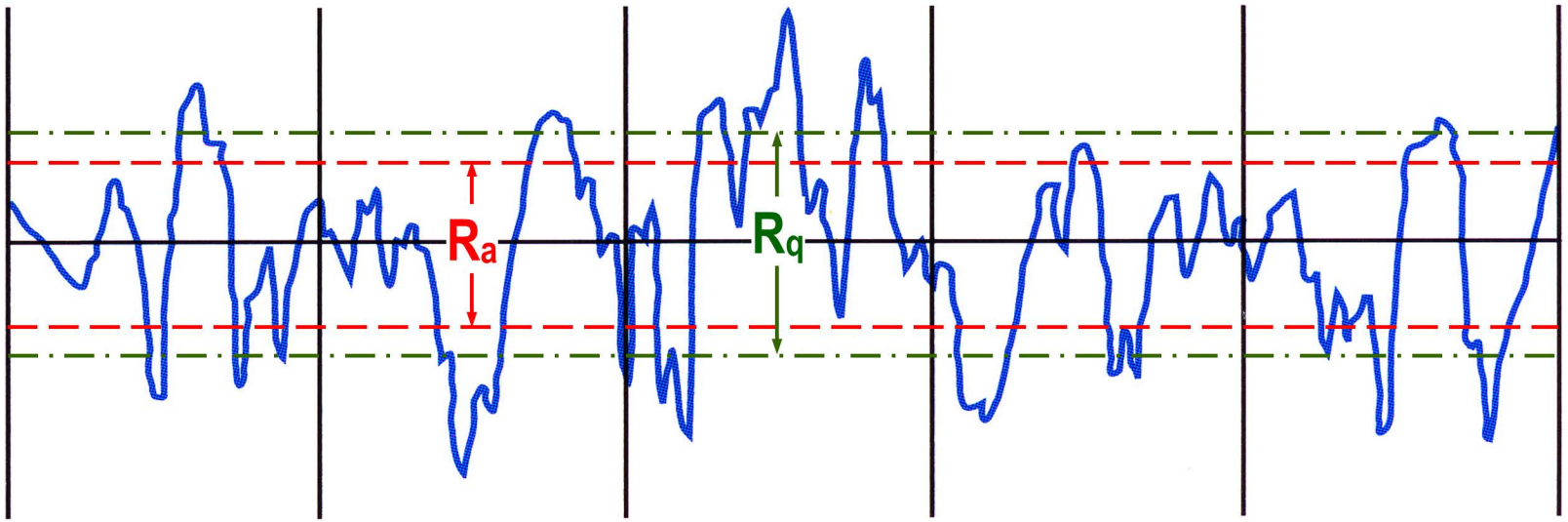
- Typical 2D roughness profile is shown below:
  - **Assessment (Evaluation) Length [L]:** This is **the length of profile** to be assessed.
  - **Sampling Length [l]:** The length of profile is divided into **five equal sampling lengths** (from l_1 to l_5).
  - **Cut-off Length [λ_C]:** It is **a filter** to remove/reduce unwanted data in assesment region.

    In fact, cut-off length is **the same as sampling length**.



Common Roughness Parameters:

- **Roughness Average [R_a]:** Also known as Center Line Average (CLA) or Arithmetic Average (AA). Universally recognized and commonly used parameter, which is **the arithmetic mean** of departures from the mean line.
- **Root Mean Square (RMS) Roughness [R_q]:** It is **RMS average** of profile ordinates.
- R_a is useful for random (irregular) surfaces. However, it cannot provide distinction between peaks and valleys.
- R_q is more sensitive to peaks and valleys since the amplitudes are squared.

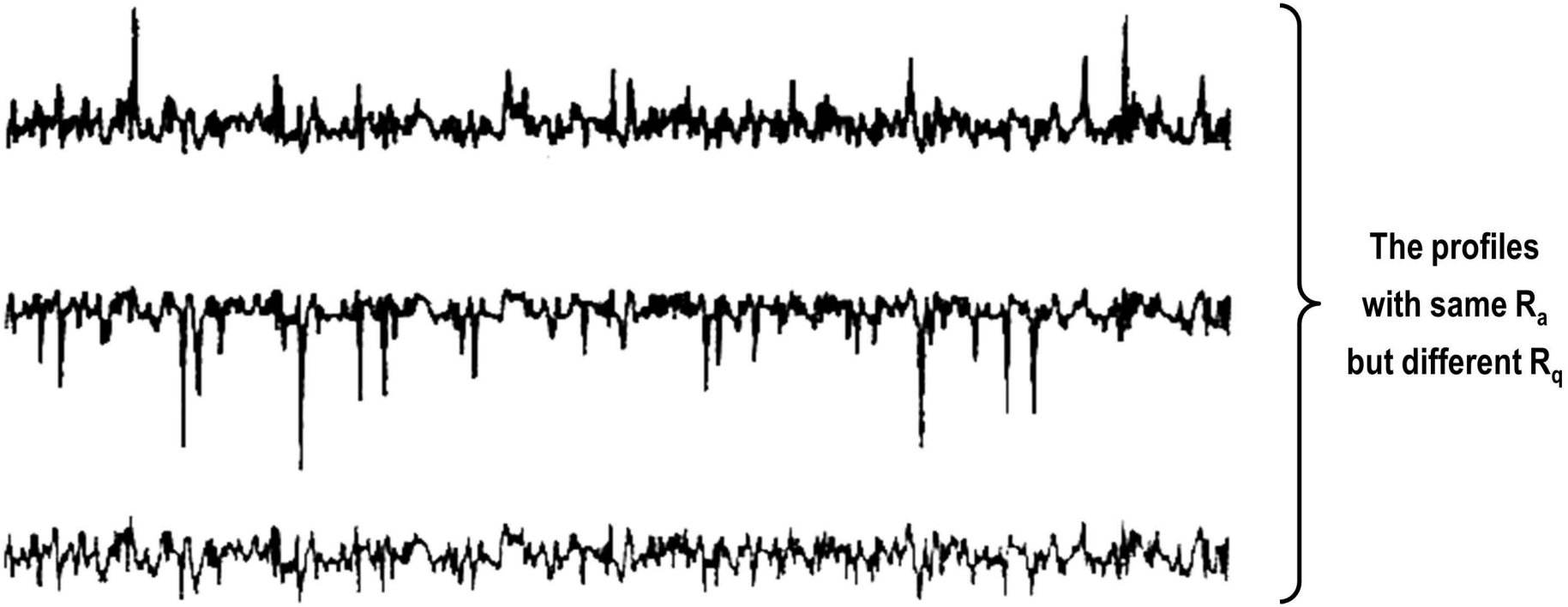


$$R_a = \frac{1}{L}\int_0^L |z(x)|\,dx$$

$$R_q = \sqrt{\frac{1}{L}\int_0^L [z(x)]^2\,dx}$$

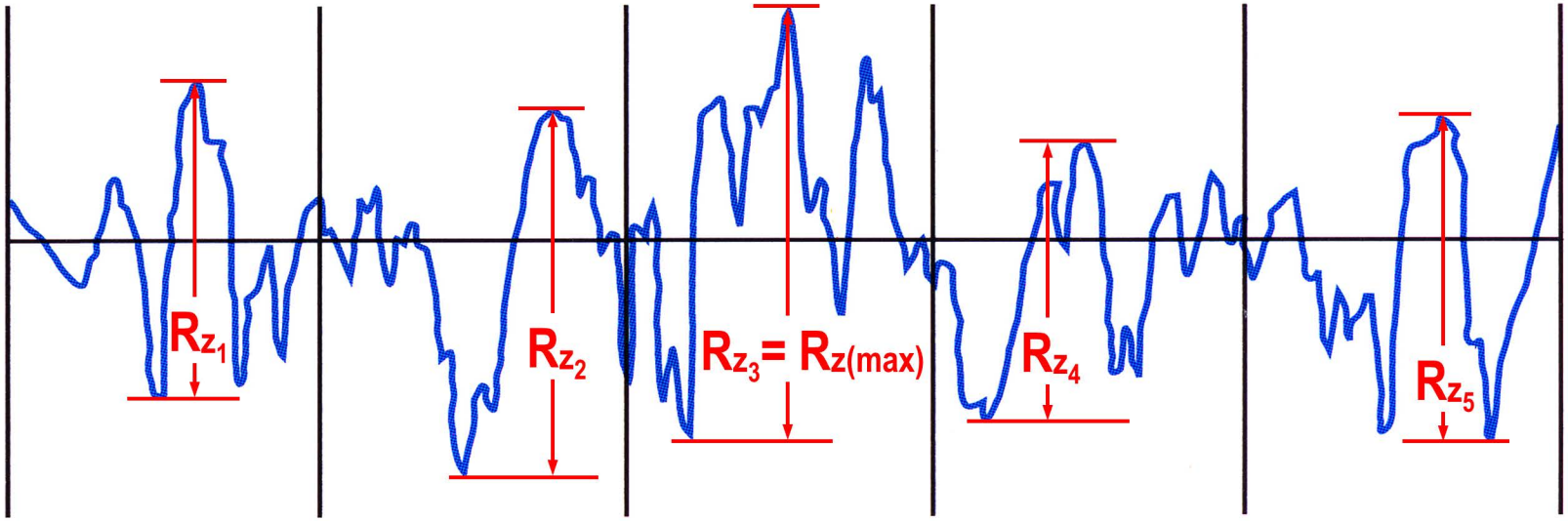
Misinterpretation of Roughness:

- As said before, it is not possible to make a distinction between peaks and valleys based on R_a parameter.
- The profiles below have the same R_a value, and hence using only R_a will cause inaccurate conclusions.
- So, there is need for more specific and sensitive parameters so that reliable assessment can be made.



Other Roughness Parameters:

- **Mean Roughness Height/Depth [R_z]: The mean** of heights and depths at each sample length.
- **Maximum Roughness [$R_{z(max)}$]: The largest** of five heights and depths at each sample length.
- R_z is more sensitive than R_a to changes on the surface since the maximum of profile heights are examined.
- $R_{z(max)}$ is useful when a single defect is not permissible (e.g. seal with a scratch).
- R_z and $R_{z(max)}$ are used together to monitor the variations of surface finish. Similar values of them indicate consistent surface finish while significant difference between them indicates a defect on consistent surface.
- **R_z to R_a conversion** (based on **BS 1134/1-1972**): $4 < R_z / R_a < 7$ (depending on profile)

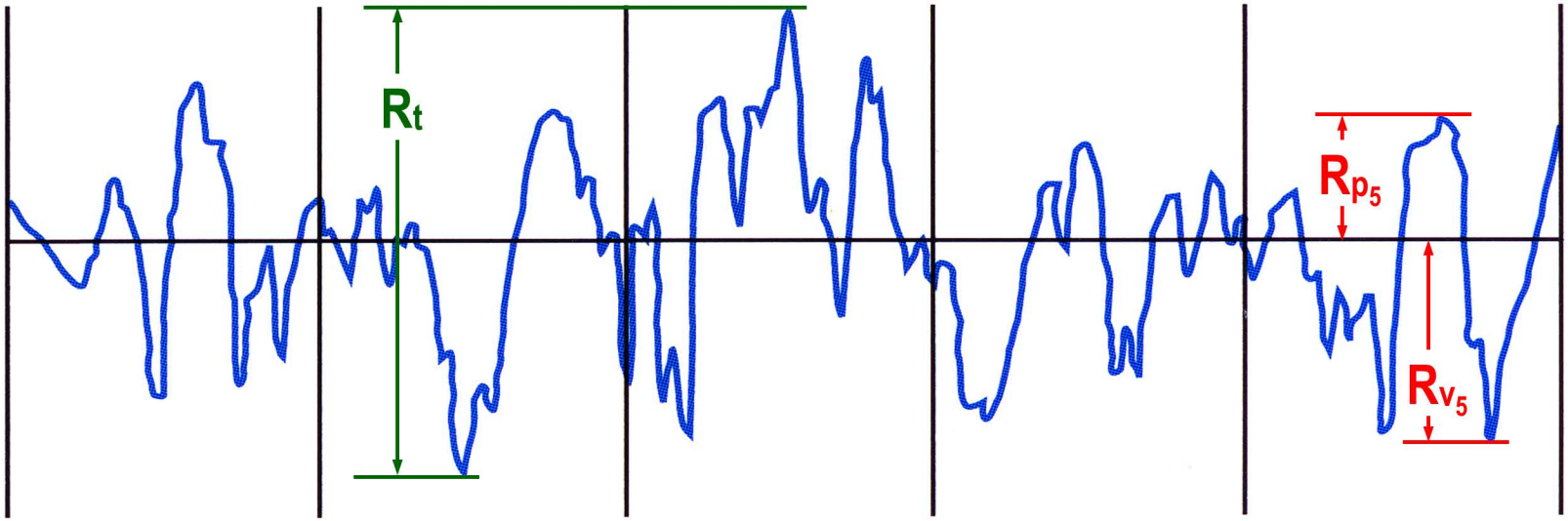


$$R_z = \frac{1}{n}\sum_{i=1}^{n} R_{z_i}$$

$$R_{z(max)} = (R_{z_i})_{max}$$

Other Roughness Parameters:

- **Maximum Height [R_p]: The maximum height (peak)** within each sampling length.
- **Maximum Depth [R_v]: The maximum depth (valley)** within each sampling length.
- **Mean Levelling [R_{p_m} & R_{v_m}]: The mean** of five consecutive peaks/valleys.
- **Peak-to-Valley Roughness [R_t]: The largest peak-to-valley** in the entire profile.
- R_v is used where stress is a major factor. However, R_p is used to assess coating quality.
- R_{p_m} is for bearing and sliding surfaces and surface substrates prior to coating.
- A low value of R_{p_m} together with a large value of R_z indicates a plateau surface.
- The ratio of R_{p_m} / R_z quantifies the asymmetry of profile.



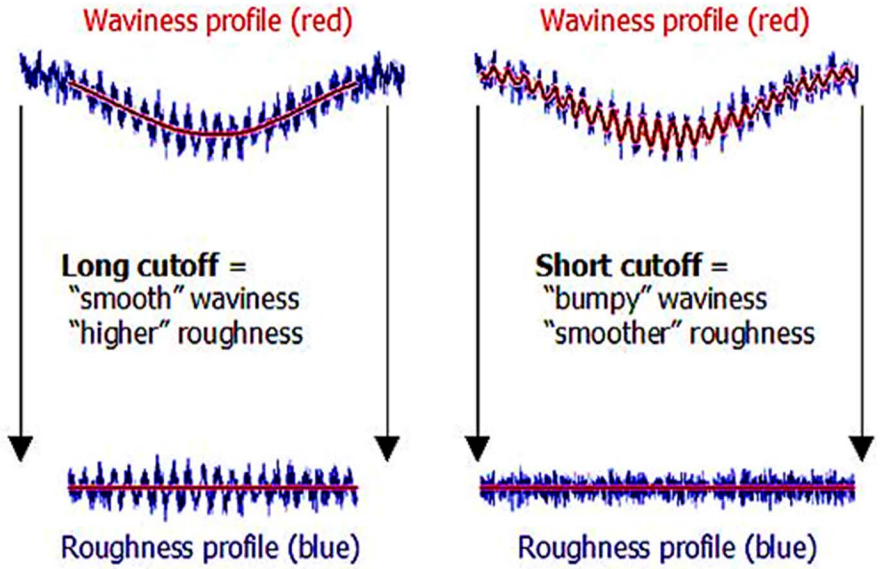
$$R_p = (R_{p_i})_{max}$$

$$R_v = (R_{v_i})_{max}$$

$$R_t = R_p + R_v$$

Selection of Cut-off Value:

- Changing cut-off value (i.e. changing amount of "averaging" and "smoothing") affects roughness and waviness.
- Using smaller cut-off gives smaller roughness & bigger waviness (although the real surface could be very rough).
- There are **recommended cut-off values (given in table below)** according to **ISO 4288-1996**.

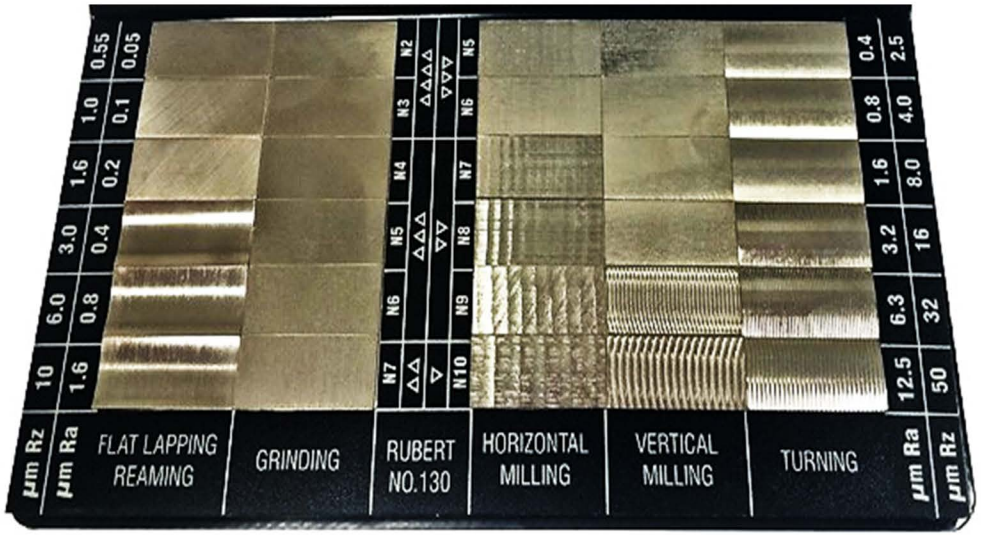


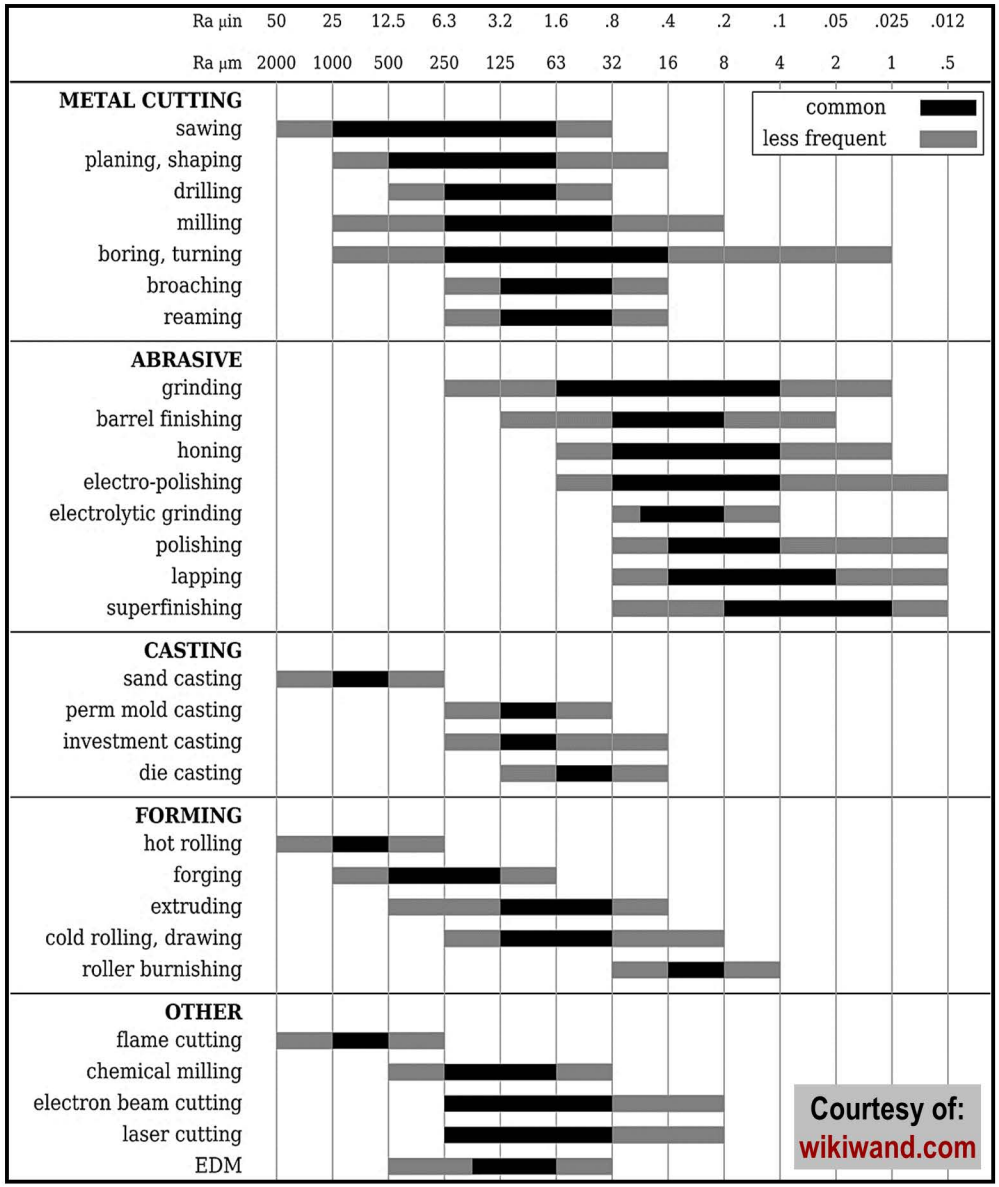
Courtesy of: renishaw.com

RECOMMENDED CUT-OFF VALUES (ISO 4288-1996)			
Roughness Values		Cut-off	Profile Length
R_z (µm)	R_a (µm)	λ_c (mm)	L (mm)
(0.025) to 0.1	(0.006) to 0.02	0.08	0.4
>0.1 to 0.5	>0.02 to 0.1	0.25	1.25
>0.5 to 10	>0.1 to 2	0.8	4
>10 to 50	>2 to 10	2.5	12.5
>50 to 200	>10 to 80	8	40

Surface Finish in Manufacturing:

- Surface finish (usually expressed with R_a) is strictly dependent on manufacturing process to be applied.
- Some processes give rough surfaces (sand casting, sawing, etc.) whereas finishing processes provide relatively smoother surfaces (like reaming, lapping, burnishing, so on).
- Therefore, it is crucial to have **process planning for desired surface quality**.





Common Standards on Assessment of Surface Texture

ISO 1302 - 2001	Indication of Surface Texture
ISO 3274 - 1996	Nominal Characteristics of Contact (Stylus) Instruments
ISO 4287 - 1997	Terms, Definitions and Surface Texture Parameters
ISO 4288 - 1996	Rules and Procedures for Assessment of Surface Texture
ISO 5436-1 - 2000	Calibration (Measurement Standards)
ISO 5436-2 - 2000	Calibration (Soft Gages)
ISO 8785 - 1999	Surface Imperfections (Terms, Definitions and Parameters)
ISO 11562 - 1996	Metrological Characteristics of Phase Correct Filters
ISO 12085 - 1996	Motif Parameters
ISO 12179 - 2000	Calibration of Contact (Stylus) Instruments
ISO 13565 - 1996	Characterization of Surfaces Having Stratified Functional Properties

More information on Surface Texture Measurement: www.taylor-hobson.com