ASME
SETTING THE STANDARD

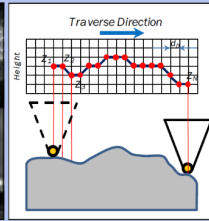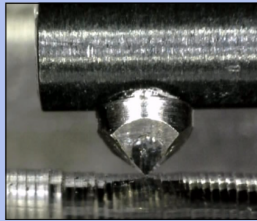# B46.1 - 2019 : Surface Roughness, Waviness, and Lay
## Basic Terms

Measurement of Surfaces

Stylus instruments are commonly used to measure surface roughness and waviness. A stylus of a known tip radius is moved across a surface at a fixed speed. As the stylus follows the irregularities in the surface, height data (Z_1, Z_2, Z_3, ...Z_N) is recorded at a given sampling interval, d_0. The height data can then be filtered to level the profile, remove the underlying form, and separate short wavelengths (roughness) from longer wavelengths (waviness).

Aspect Ratio — Section 1-3.1.1

In displays of surface profiles generated by instruments, heights are usually magnified many times more than the distances along the profile. The sharp peaks, valleys, and the steep slopes seen on such profile representations of surfaces are thus greatly distorted images of the relatively gentle slopes characteristic of actual measured profiles.
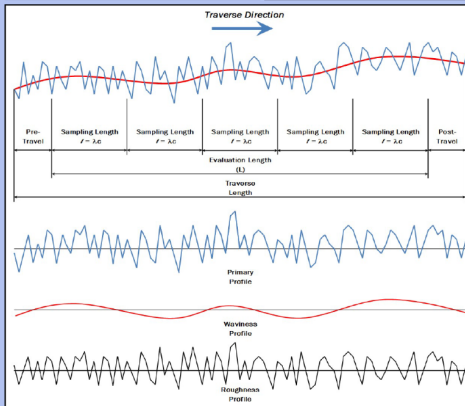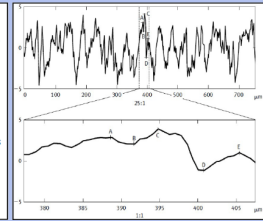
Definitions — Sections 1-2.1, 1-2.2, 1-3.1, & 1-3.5

Surface: The boundary that separates an object from another object, substance, or space.

Error of Form: Widely spaced deviations of the real surface from the nominal surface which are not included in surface texture.

Form Suppressed Profile: A modified profile obtained by various techniques to attenuate dominant form such as curvature or tilt.

Waviness: The more widely spaced component of the surface texture. The *waviness profile* is the modified profile obtained by filtering to attenuate the shorter spatial wavelengths associated with roughness and the longer spatial wavelengths associated with form.

Roughness: The finer spaced irregularities of the surface texture that usually result from the inherent action of the production process or material condition. The *roughness profile* is the modified profile obtained by filtering to attenuate the longer spatial wavelengths associated with waviness.
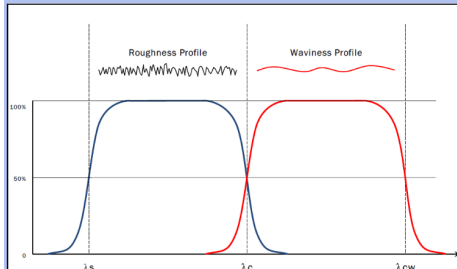
Lay: The predominant direction of the surface pattern, ordinarily determined by the production method used.

Profiling instruments sample surface height data over a specific distance, consisting of several different lengths:

- Traverse Length: This is the total length of travel of the instrument on the surface. Due to end effects, the traversing length must be longer than the evaluation length.
- Evaluation Length (L): Length used to evaluate the profile, after discarding a given distance at the beginning and end of the profile to account for end effects.
- Sampling Length (ℓ): Length in the direction of the X-axis used for identifying the widest irregularities that are of interest for the profile. When an electrical or digital filter is used, the roughness long wavelength cutoff value determines and is equal to the roughness sampling length (i.e. ℓr = λc).

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Filtering, Ra, and Wt

Section 1-3.5 Measurement and Analysis Lengths

Filtering is required to separate long wavelengths (waviness) from short wavelengths (roughness).

- Roughness Long Wavelength Cutoff (λc) : Attenuates longer wavelengths to yield the roughness profile.
- Roughness Short Wavelength Cutoff (λs) : Shorter wavelengths are attenuated to remove fine asperities or noise from the roughness profile.
- Waviness Long Wavelength Cutoff (λcw) : Attenuates longer wavelengths to separate waviness from form.
- Waviness Short Wavelength Cutoff (λsw) : Shorter wavelengths are attenuated to separate waviness from roughness. Generally set equal in value to the corresponding roughness long wavelength cutoff (λsw = λc).

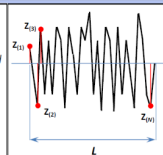*How do filter settings affect roughness parameters?*

Changing the filter settings shifts profile height data from the roughness to the waviness domain, depending on what is of interest to the user. If the filter settings are not given on the drawing, guidelines are provided in section 3-3.20 of B46.1-2019.

The charts below show how changing the filter cutoff changes what is considered roughness (represented by the black line) and waviness (represented by the red line). As λc is reduced, the height deviations considered roughness become smaller and the Ra is reduced while the waviness (Wt) increases. Filter settings *can significantly impact roughness and waviness values* and it is critical that the user understand the requirements of the surface and how it should be measured and analyzed.

Cutoff Values for Nonperiodic Profiles Using Rsm (ref. Table 3-3.20.2-1 B46.1-2019)			
Ra [µm] Over	Ra [µm] Up To	Cutoff Length - λc [mm]	Evaluation Length - L [mm]
***	0.02	0.08	0.40
0.02	0.10	0.25	1.25
0.10	2.0	0.80	4.0
2.0	10.0	2.5	12.5
10.0	***	8.0	40.0

Cutoff Values for Periodic Profiles Using Ra (ref. Table 3-3.20.1-1 B46.1-2019)			
Rsm [mm] Over	Rsm [mm] Up To	Cutoff Length - λc [mm]	Evaluation Length - L [mm]
0.01	0.04	0.08	0.40
0.04	0.13	0.25	1.25
0.13	0.40	0.80	4.0
0.40	1.3	2.5	12.5
1.3	4.0	8.0	40.0

Note: Values given are guidelines for cases where the roughness filter cutoff length is not specified on the drawing.

Ra - Roughness Average - Section 1-4.1.1

Ra is the average of the absolute values profile height deviations recorded within the evaluation length, L, and measured from the mean line.
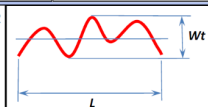
For digital instruments Ra is obtained by:

$$Ra = (|Z_1| + |Z_2| + |Z_3| ... |Z_N|) / N$$

Wt - Waviness Height - Section 1-4.1.2

The peak-to-valley height of the modified profile from which roughness and part form have been removed by filtering, smoothing, or other means.

Primary Profile — no filter

λc = 0.8 [mm], Ra = 0.057 [µm], Wt = 0.092 [µm]

λc = 0.25 [mm], Ra = 0.044 [µm], Wt = 0.204 [µm]

λc = 0.08 [mm], Ra = 0.028 [µm], Wt = 0.325 [µm]