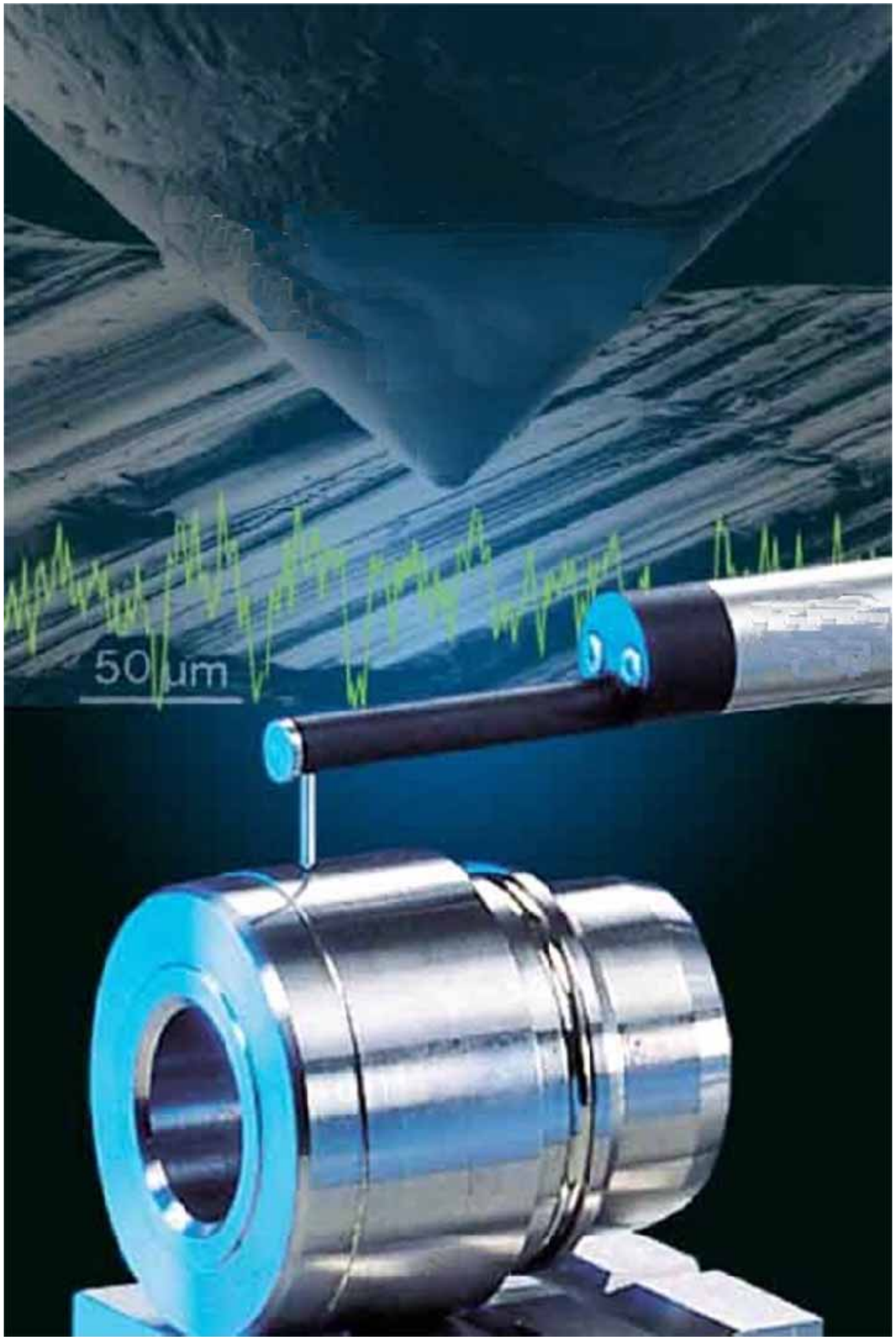

Surface Texture Measurement Fundamentals

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Mahr Federal

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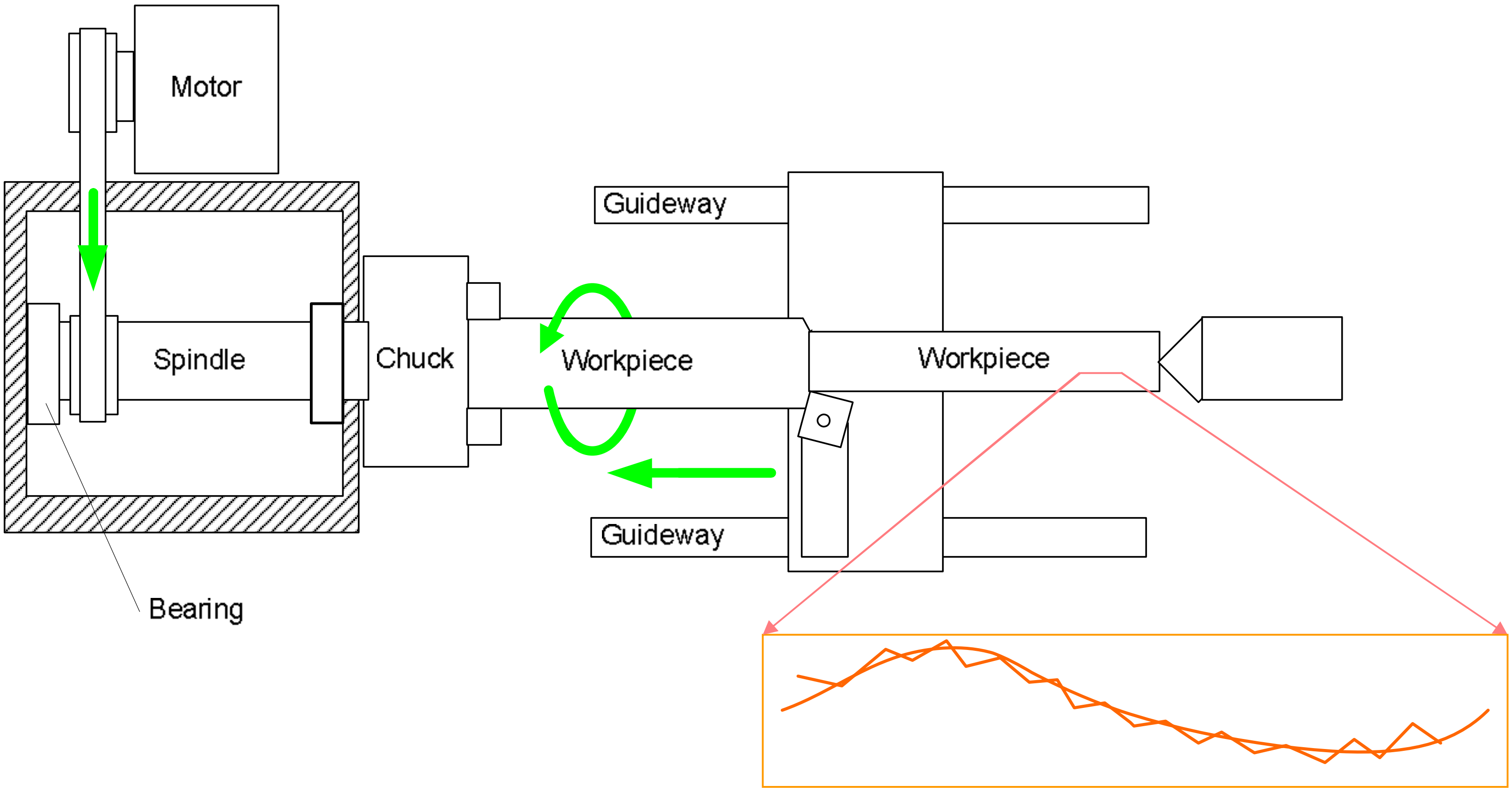
Presentation Scope

- Examples of Why We Measure Surface Texture
- Stylus Based Instruments
- Stylus Tracing Methods
- Filters and Cutoff
- Basic Parameters
- Best Practices
- Correlation Checklist
- Review and Recommendations
- References

Examples of Why We Measure Surface Texture

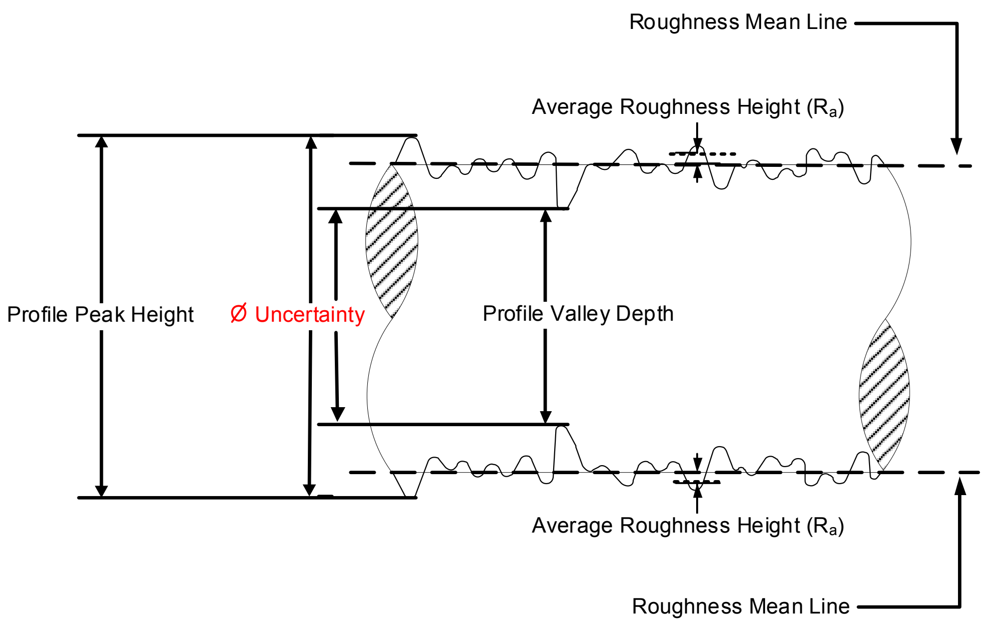
Examples of Why We Measure - for ***<u>Product Quality</u>***

Examples of Why We Measure - for ***<u>Process Control</u>***



- Surface data has different wavelengths and amplitudes

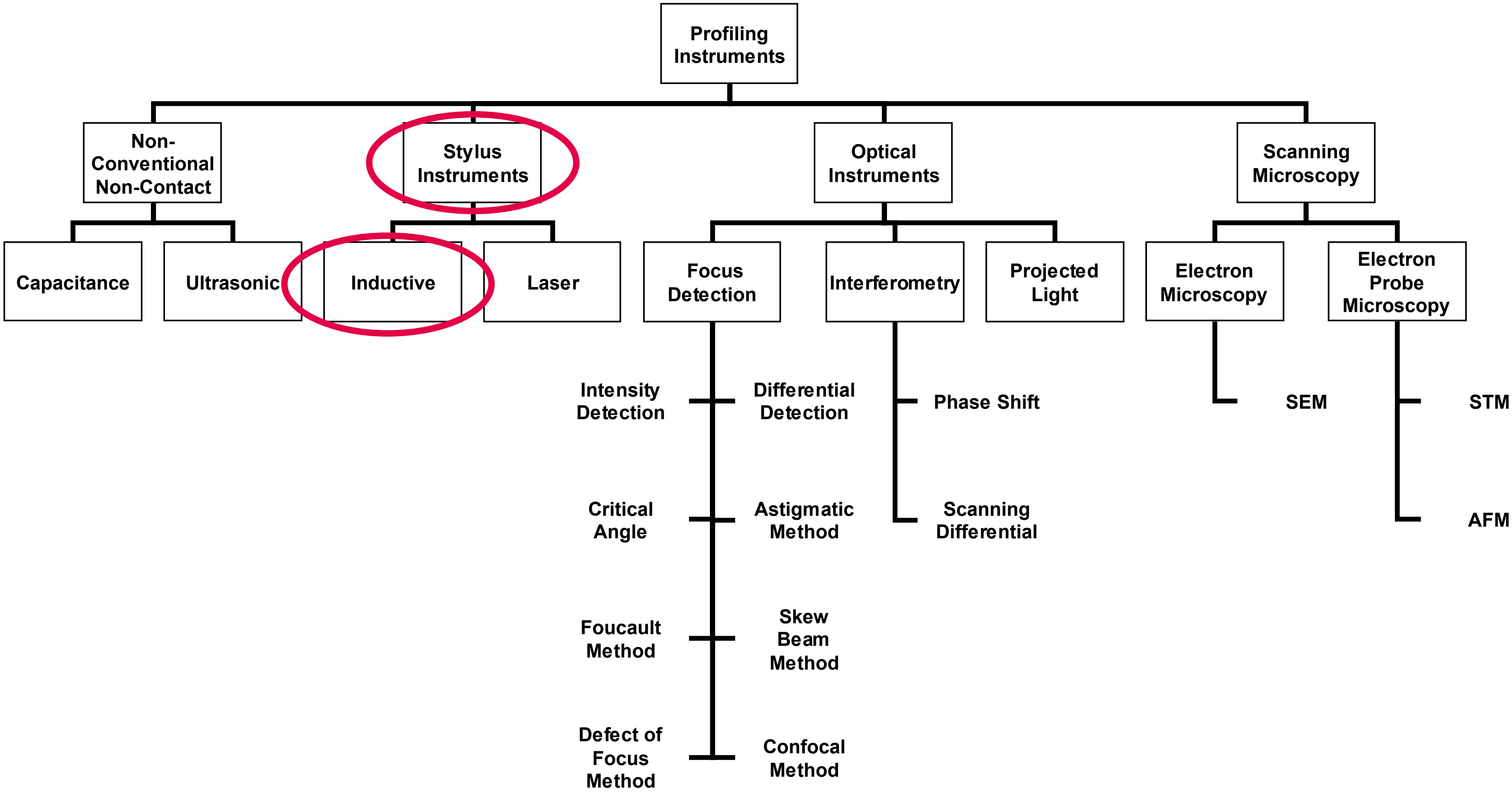
Examples of Why We Measure – for ***<u>Size Control</u>***



- Roughness peak to valley can be >4 times R_a
- Surface texture specification should be in appropriate for diameter tolerance

Surface Texture Measurement Stylus Based Instruments

Classification of Profiling Instruments



Early Analog Instrument

- Analog probe
- Analog electronics
- Paper chart recorder
- Mechanical drive, similar to present day

Early Digital Instruments

- Analog probe
- Digital conversion
- Dedicated processors
  - Digital readout
  - Later – CRT display

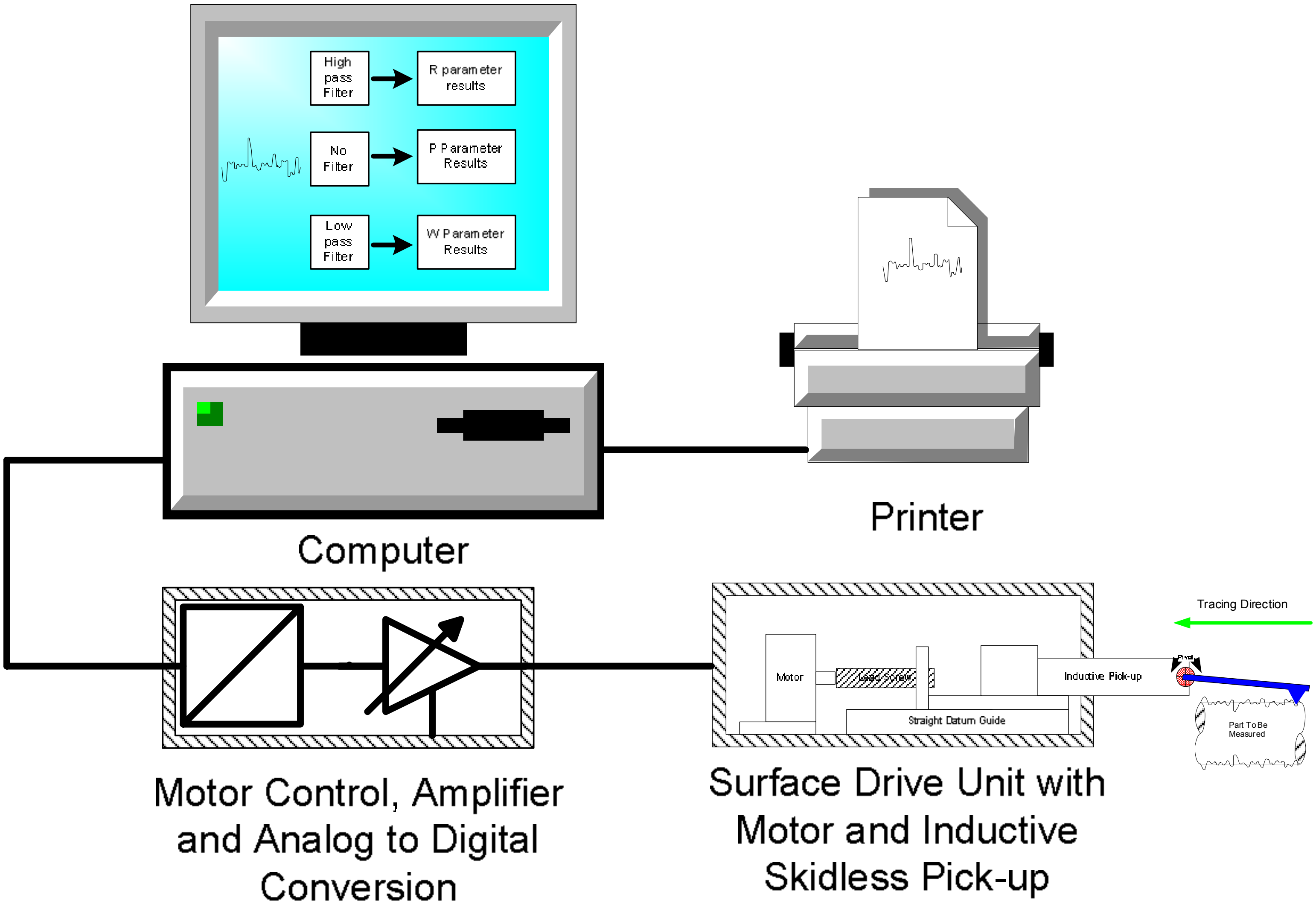
Portable Instruments

- Battery Operated
- Inductive, skidded pick-up
- Integral or Separate Drive
- LCD Display
- Printer and Output Available

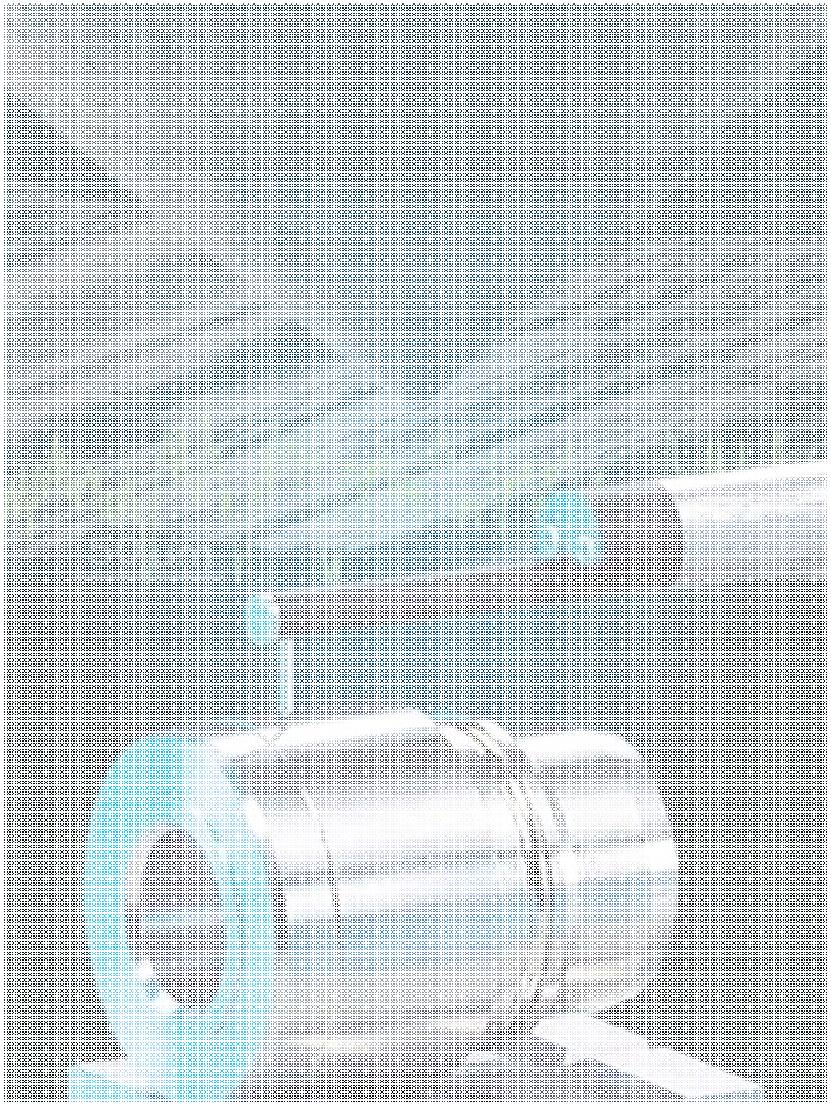
PC-Based Instrument

- Analog probe
- Digital conversion
- Windows® OS
- Surface Analysis Software

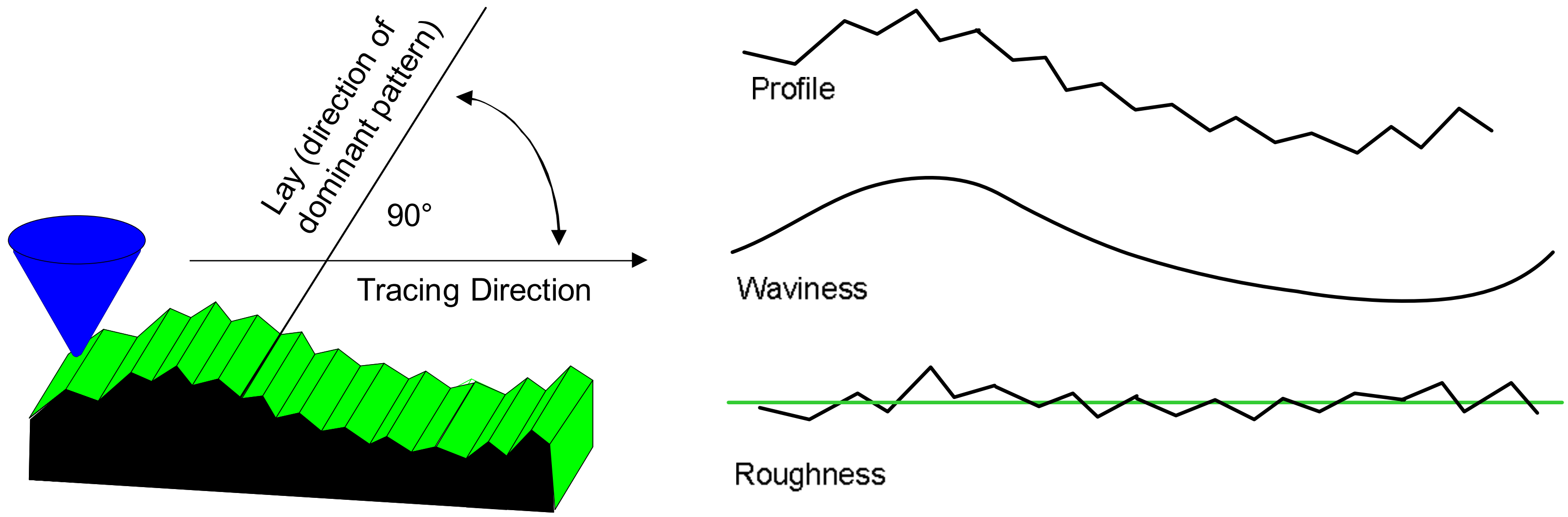
Stylus Type Instrument Schematic



Surface Texture Measurement Stylus Type Tracing Methods

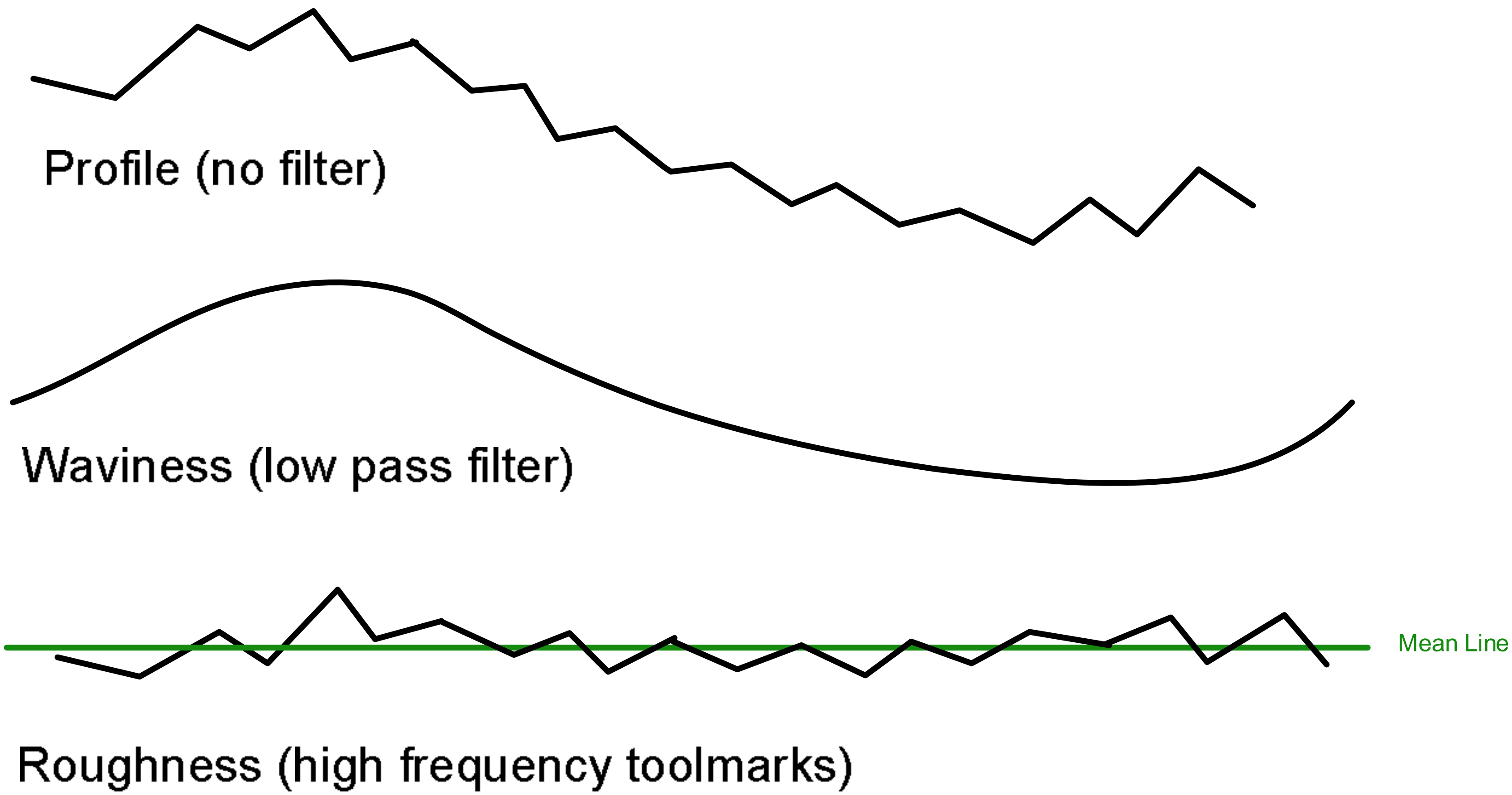


Tracing Surface Irregularities

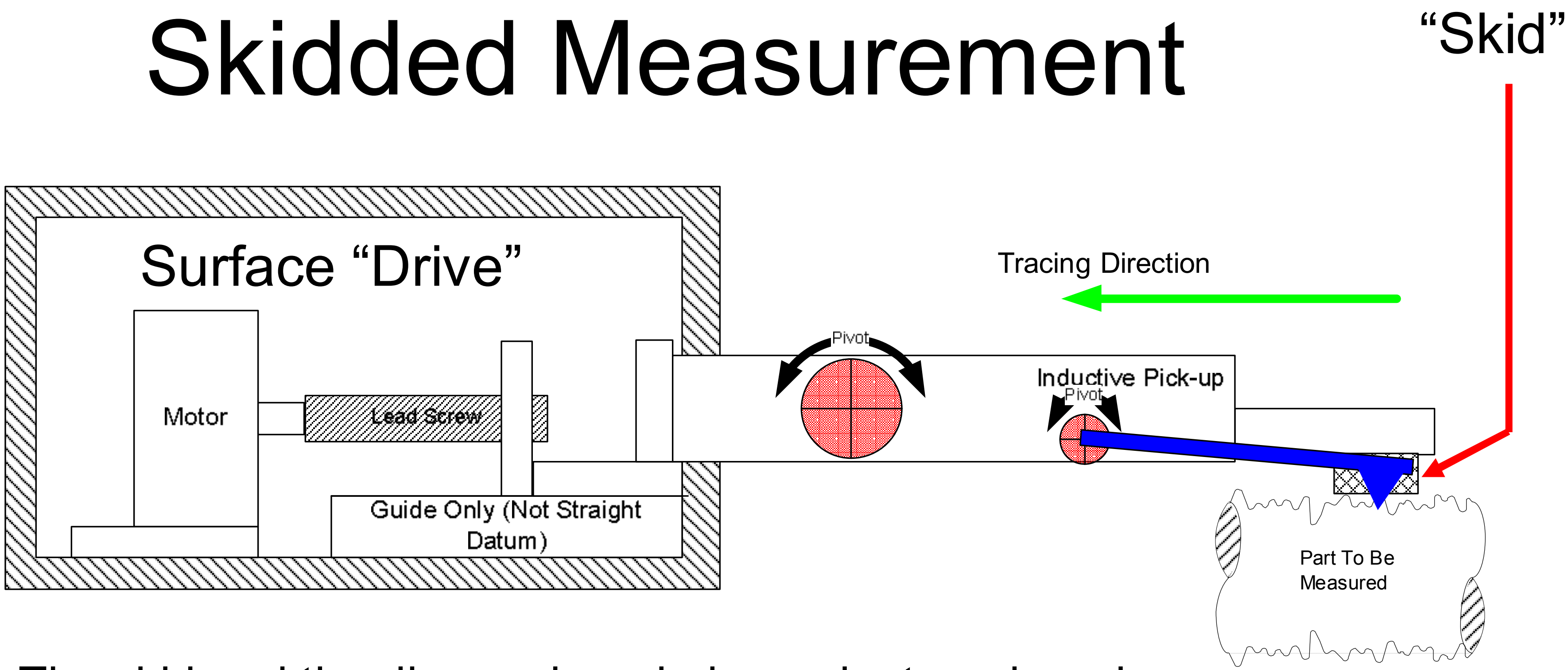


- Traces are typically done 90° to “lay,” with a conical diamond stylus
- To separate surface wavelengths, a filter is applied to the profile data

Surface Irregularities

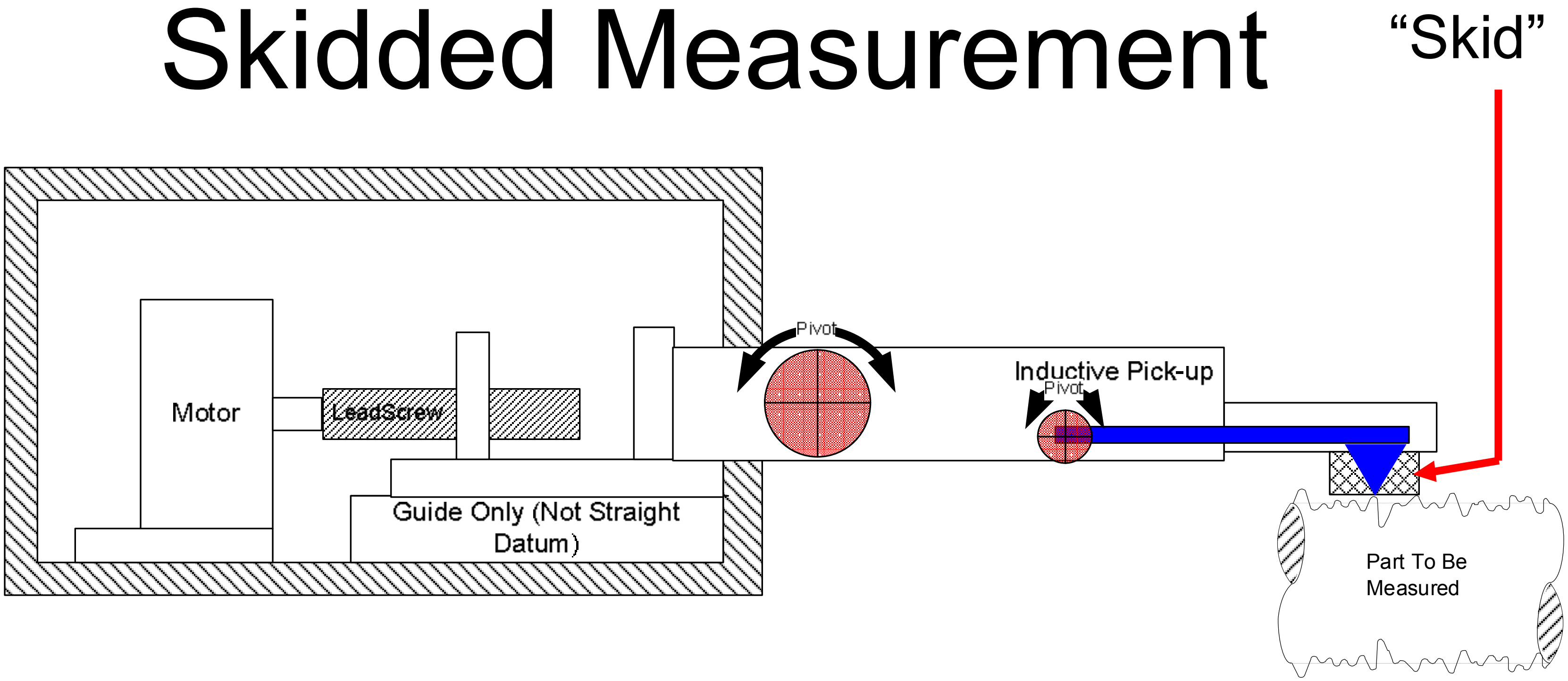


Skidded Measurement



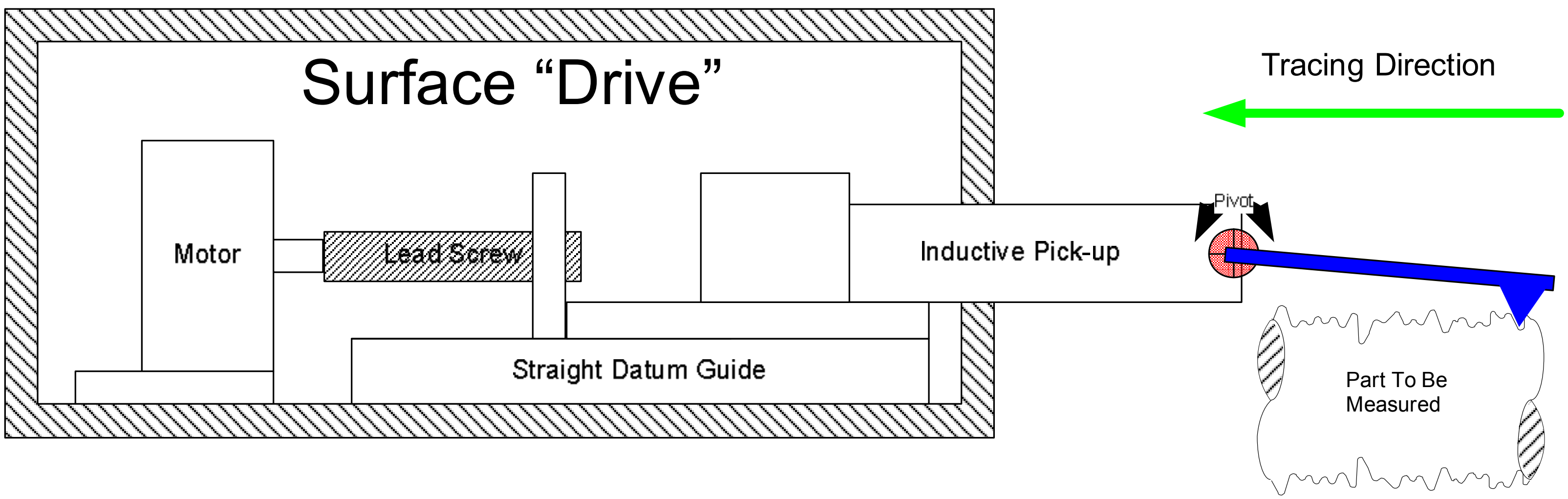
- The skid and the diamond are independent, and are in contact with the surface. The skid and diamond follow the surface during measurement.
- The surface deviations are measured by *the change in the diamond position relative to the plane of the skid.*

Skidded Measurement



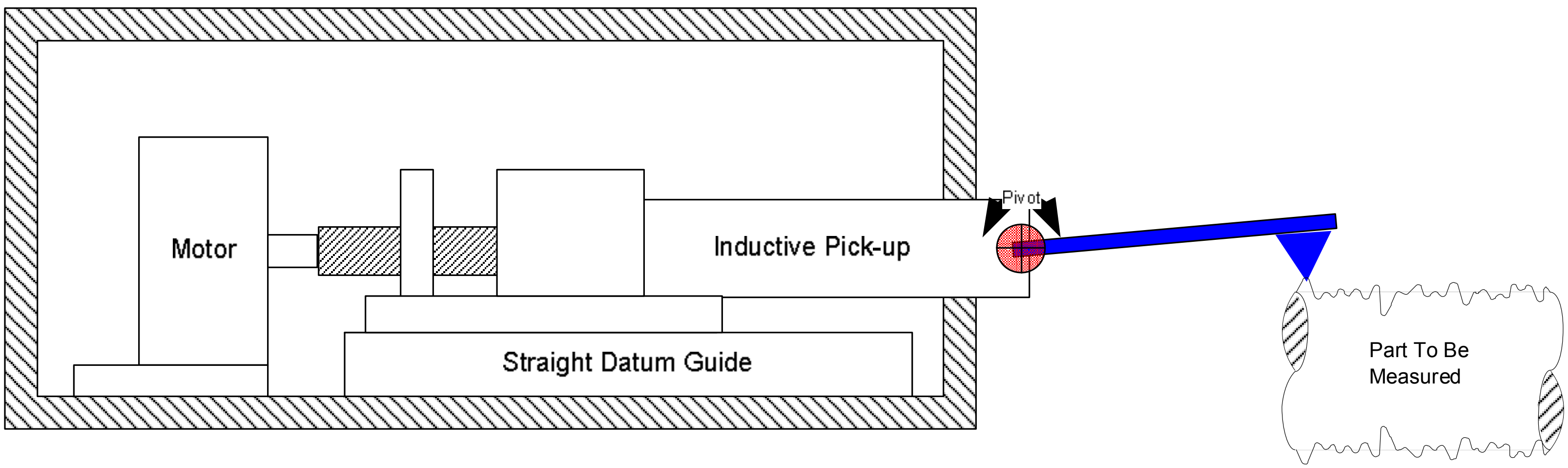
- Skidded instruments measure ***only*** Roughness parameters ($R_{...}$)
- Waviness is filtered out by the skid following the surface.
- Most portable instruments are skidded.

Skidless Measurement



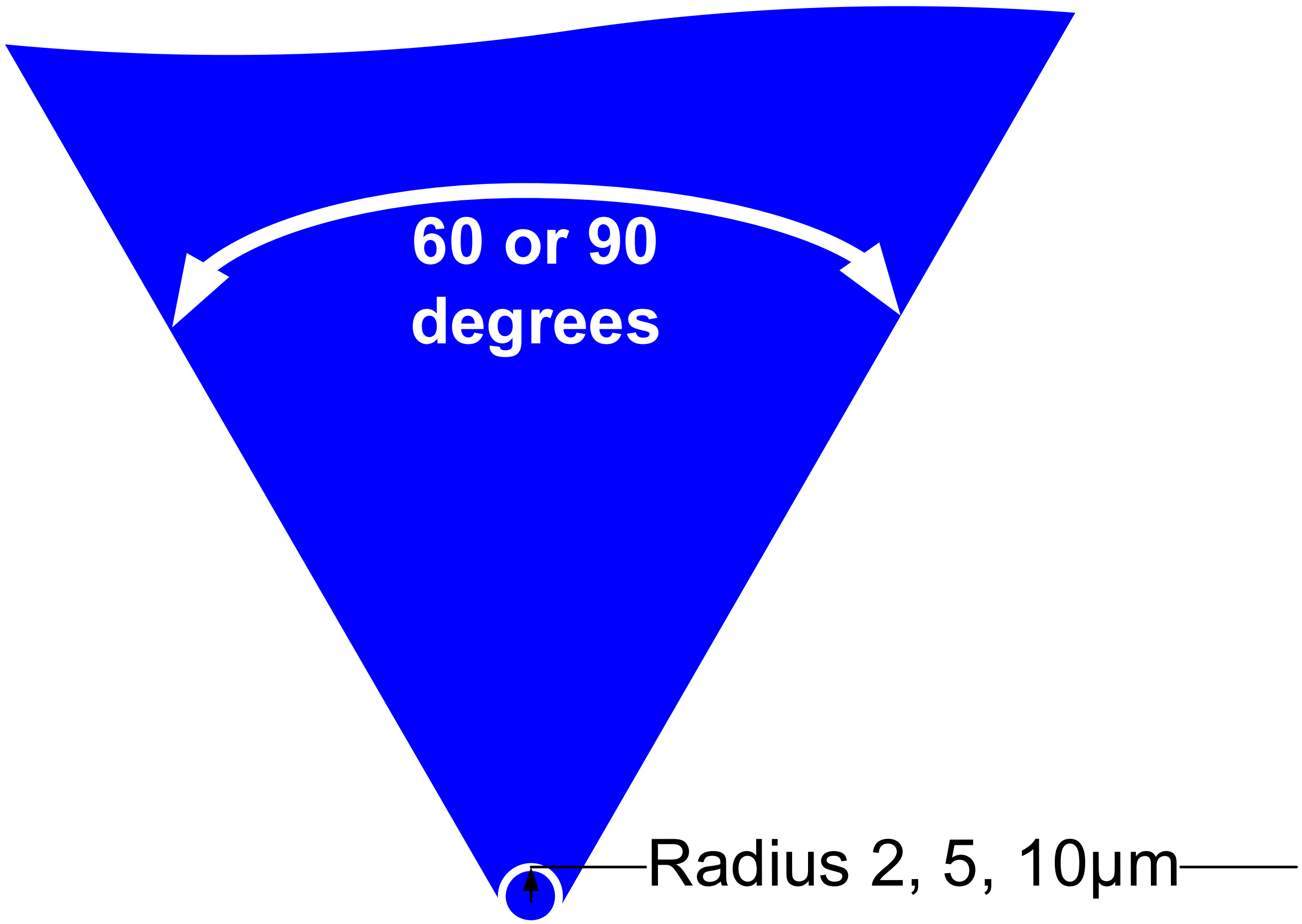
- The diamond alone follows the surface during the measurement
- Deviations are measured by *the change in the diamond position relative to the plane of the drive datum guide.*
- Skidless instruments are more expensive than skidded instruments, due to the required straight datum guide

Skidless Measurement



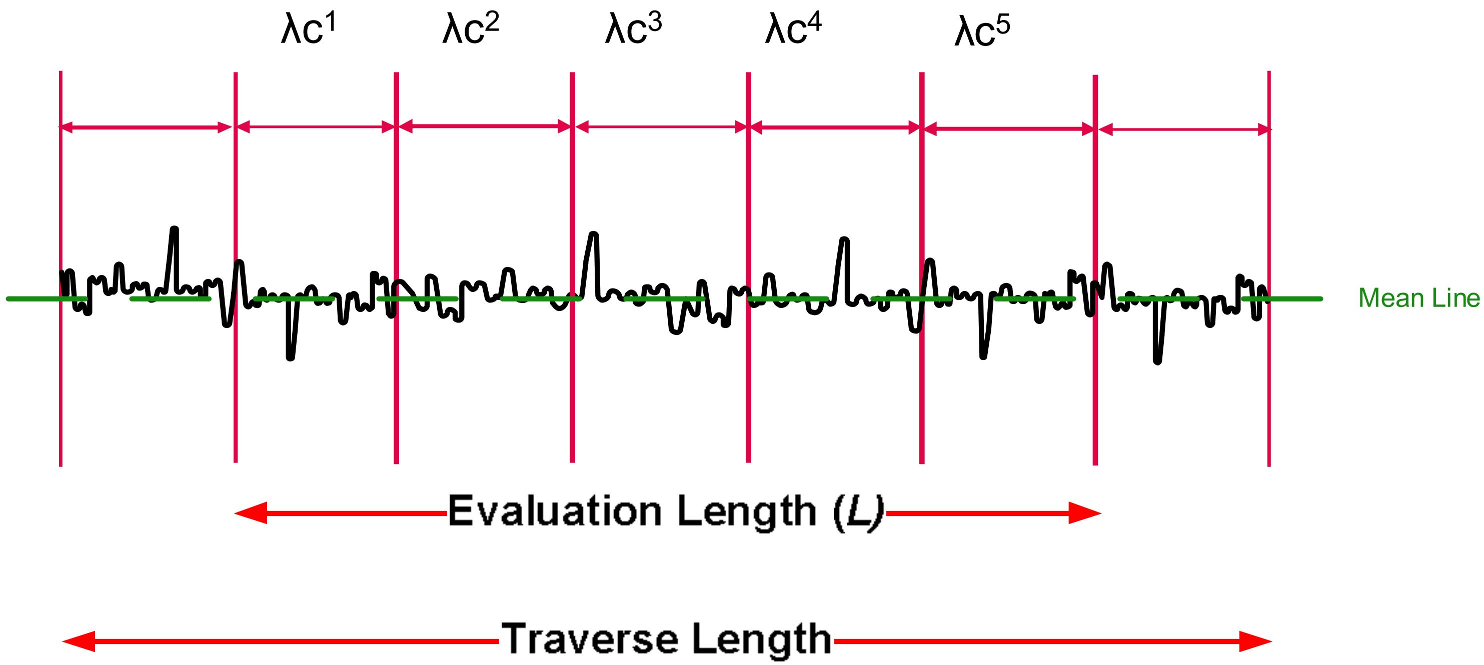
- Skidless instruments measure Roughness, Waviness and Profile
- Skidless measurements are more accurate than measurements done with a skid

Conical Diamond



Surface Texture Measurement Filters and Cutoff

Measurement Lengths



- Evaluation length of 5 cutoffs is typical for Roughness parameters

Roughness Filters

- A filter is used to isolate the roughness wavelength band
- Filters are Mechanical and Digital
  - Mechanical filters
    - Diamond Radius (valley suppression by diamond radius)
    - Skid (greater or lesser skid "bridging" effect of skid on surface valleys, dependent on skid geometry), also filters out waviness
  - Digital Filters
    - RC (Simulated old analog electrical "resistor capacitor")
    - Gaussian
- The user selects the "Cutoff" setting used by the filter to isolate the roughness wavelength band
- Filters typically have transmission curves
- Filtered data is centered around a mean line

The Role of Roughness "Cutoff" (λc)

Cutoff functions in a method similar to this screening machine – sorting mixed material via screens, into size categories

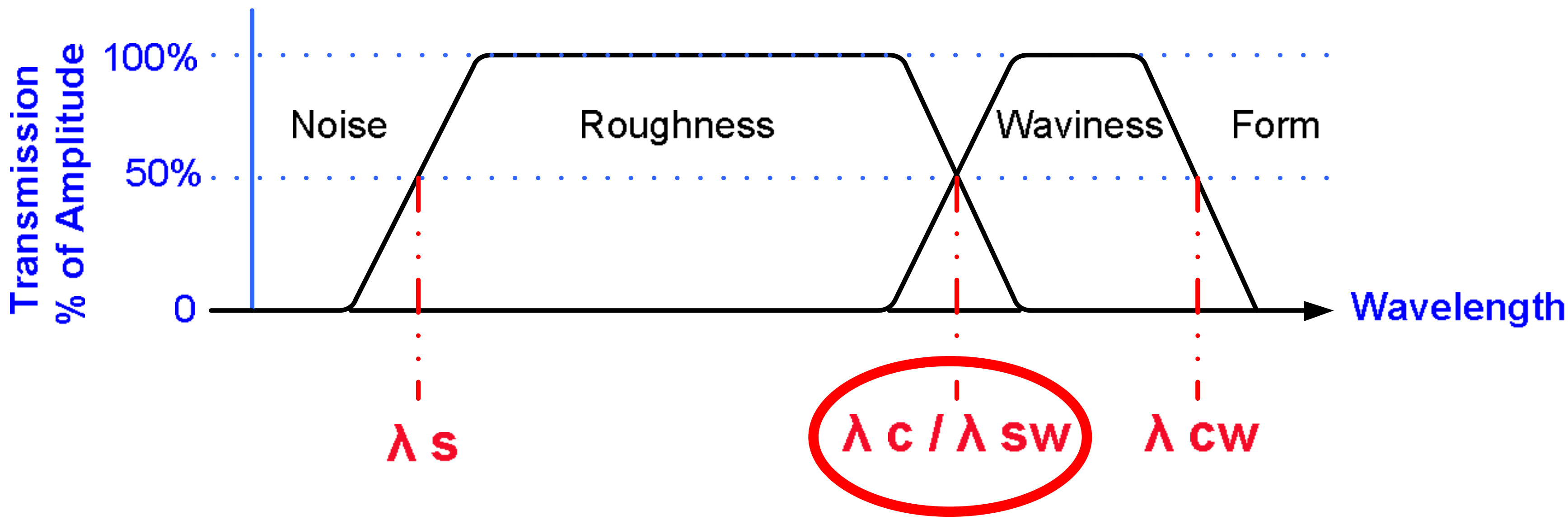
- For roughness, the cutoff value is the longest nominal wavelength to be included in roughness.
- Longer wavelengths are filtered out. Shorter wavelengths are included in roughness.
- Wavelengths longer than the roughness cutoff are usually included in waviness.

(λc) Roughness Cutoff Lengths

millimeter	inch
.08	.003
.25	.010
.80	.030
2.5	.100
8.0	.300
25.0	1.00

- The cutoff selected must be short enough to exclude long wavelengths (waviness)
- The cutoff selected must be long enough for a valid sample (at least 10 toolmarks per cutoff)
- Lengths are defined in ASME and ISO standards
- Cutoff default formerly was .8 mm, now must be defined on the drawing (ASME)

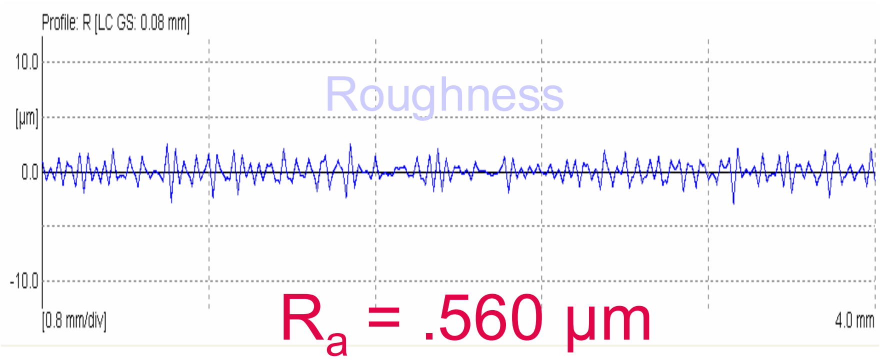
Filter Transmission and Cutoff



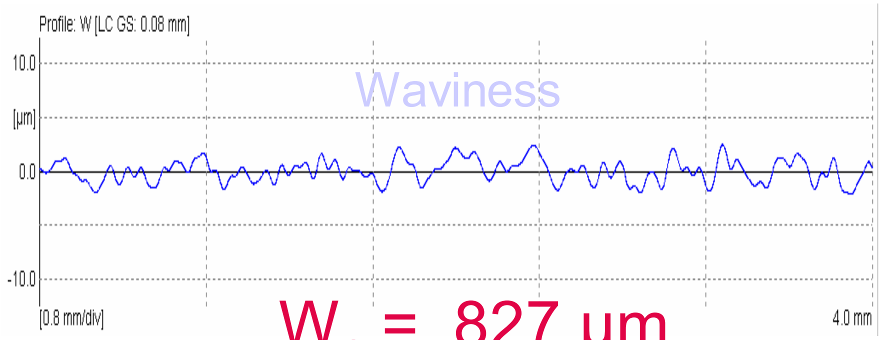
- **λ s** short wavelength cutoff for roughness
- **λ c** long wavelength cutoff for roughness
- **λ sw** short wavelength cutoff for waviness
- **λ cw** long wavelength cutoff for waviness

Effect of Roughness Cutoff Setting

λc .08 mm



R_a = .560 µm

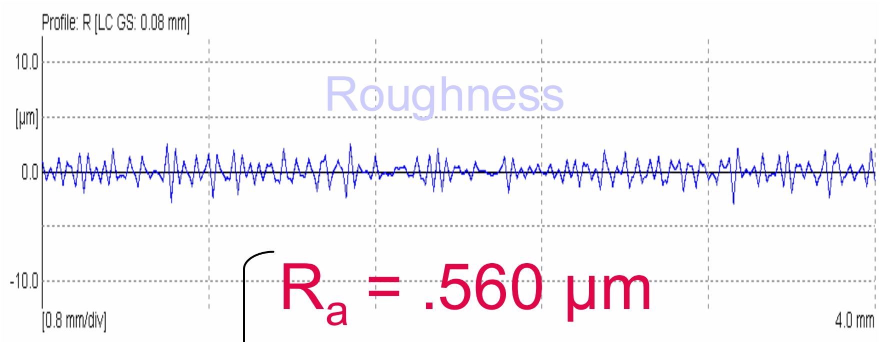


W_a = .827 µm

W_t = 4.592 µm

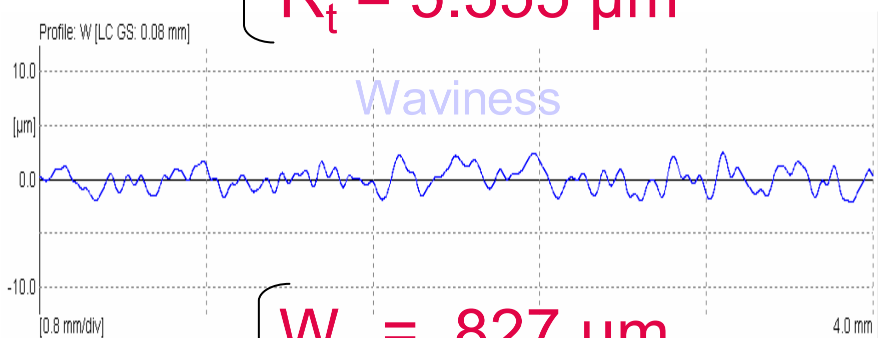
Effect of Roughness Cutoff Setting

λc .08 mm



R_a = .560 µm

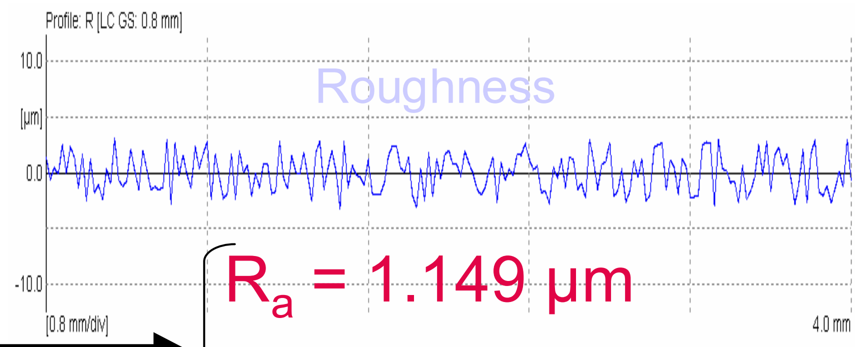
R_t = 5.555 µm



W_a = .827 µm

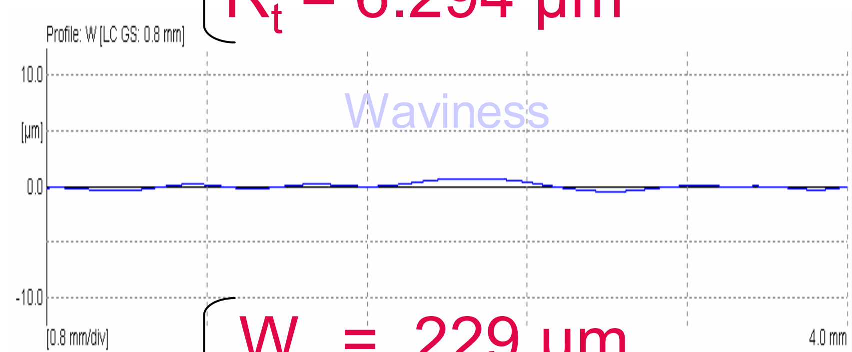
W_t = 4.592 µm

λc .80 mm



R_a = 1.149 µm

R_t = 6.294 µm

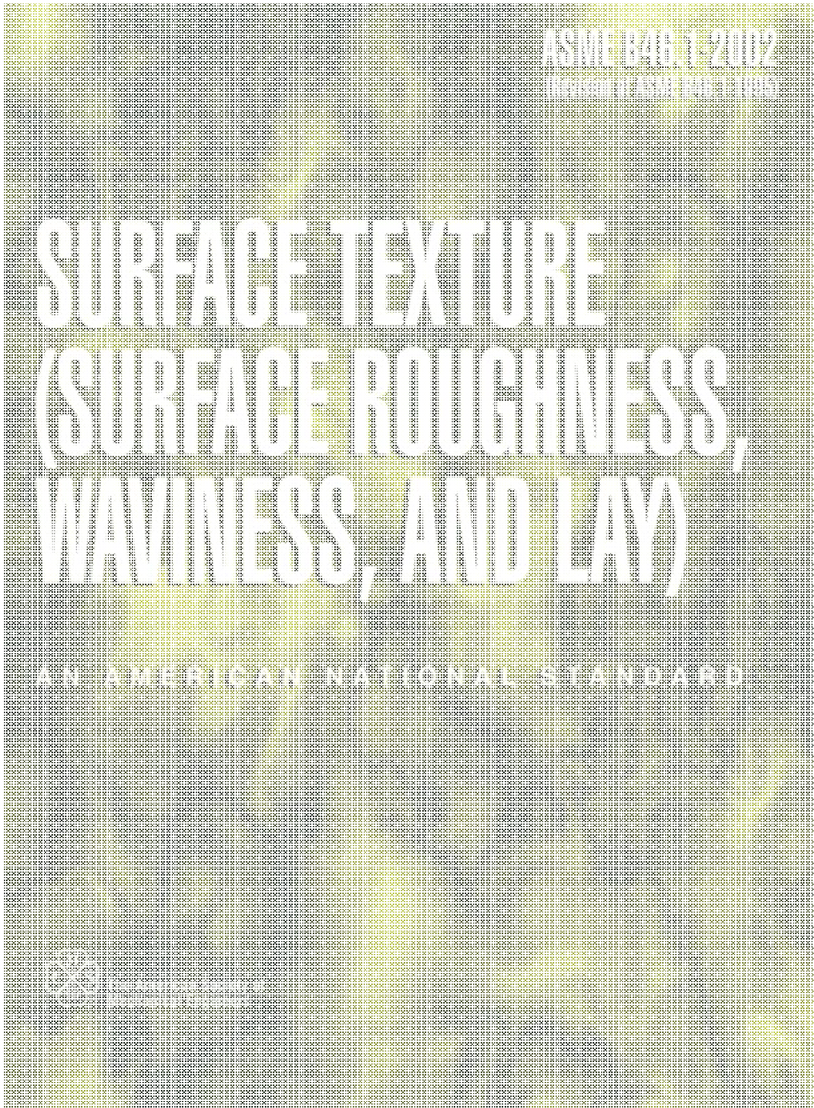


W_a = .229 µm

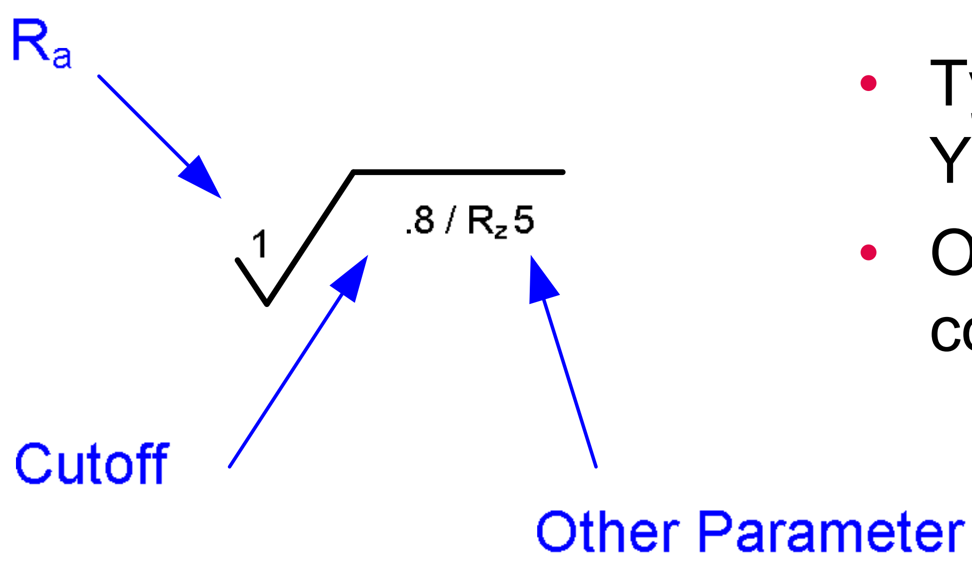
W_t = 1.187 µm

Basic Parameters

R_a R_q R_z R_{max}
R_p R_{pm} R_v R_t
W_t



Typical Surface Texture Callout



- Typical of ASME Y14.36M-1996
- Other formats are common

Roughness Average (R_a)

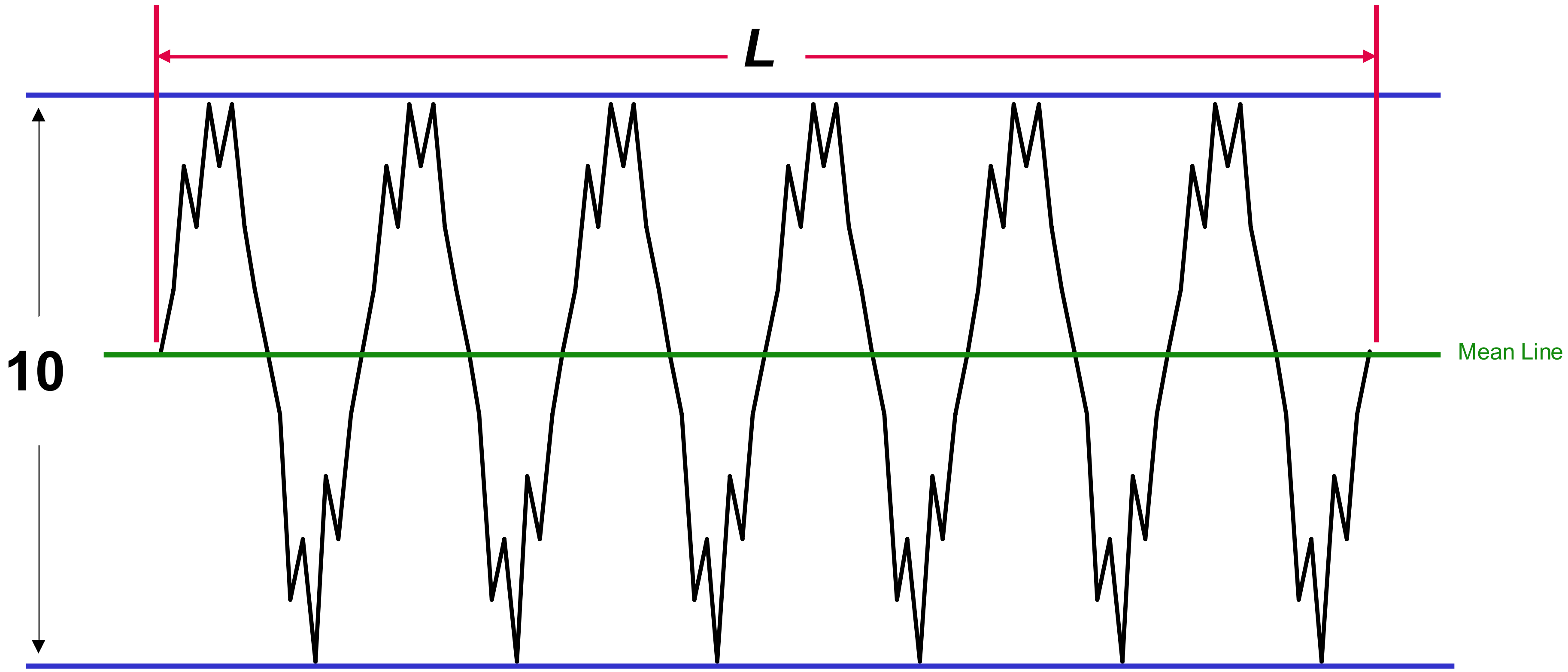
$$R_a = AA = CLA$$

$$R_a \neq RMS$$

$$R_q = RMS$$

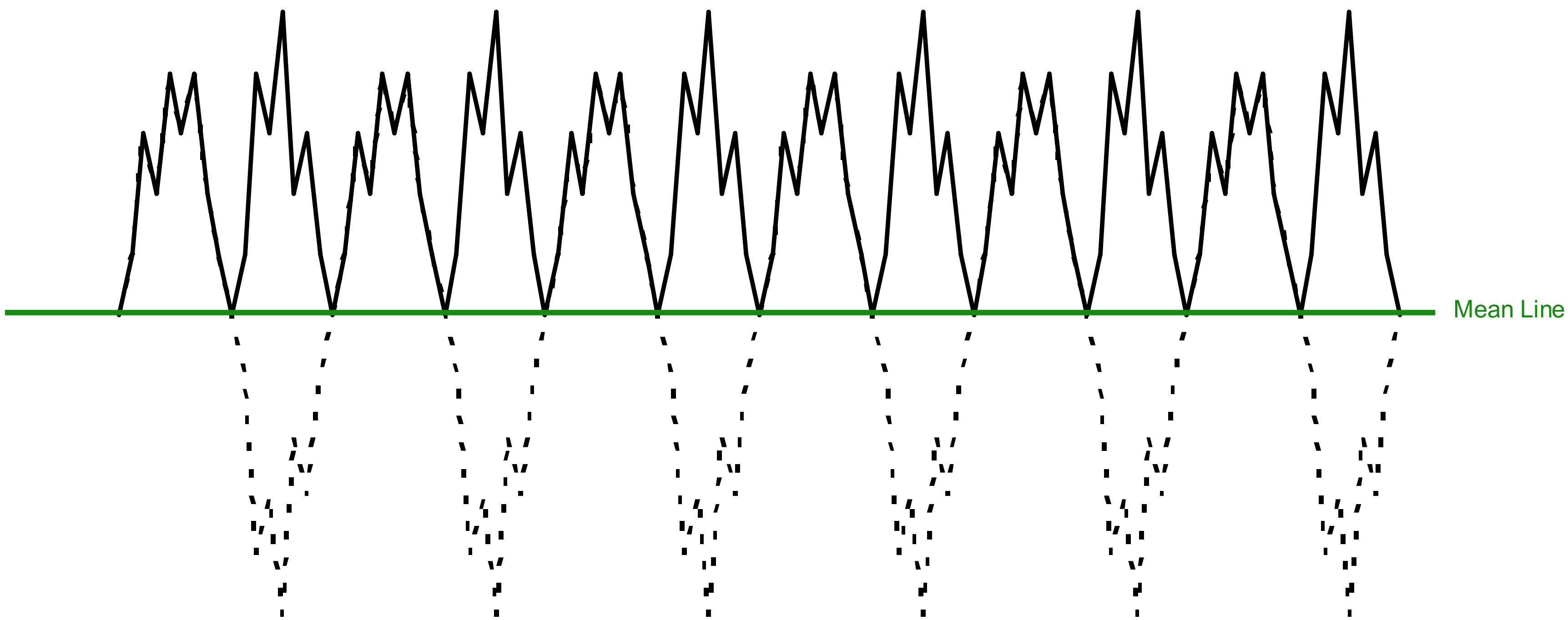
- R_a is the most commonly specified parameter in USA
- Roughness average ($R_{a)}$ is the arithmetic average of the absolute values of the roughness profile ordinates.

Step 1: Calculation of R_a



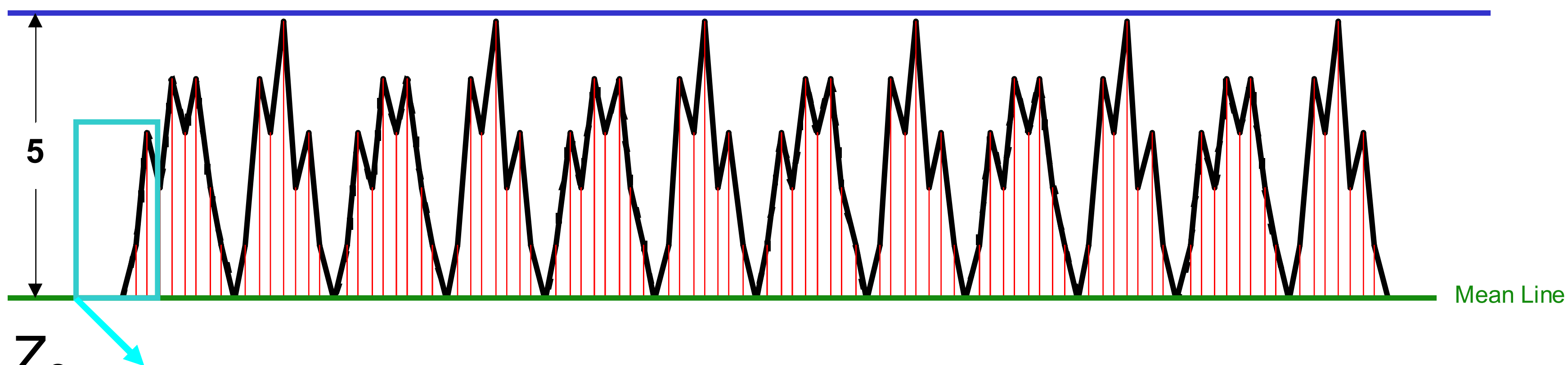
Filtered roughness profile with mean line, peak to valley is 10

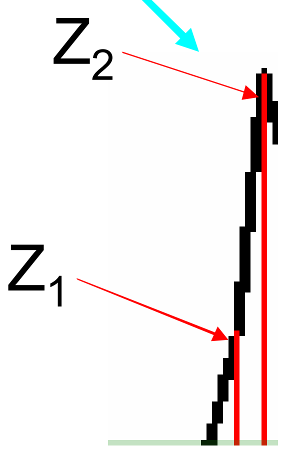
Step 2: Calculation of R_a



Absolute value is applied to the profile data

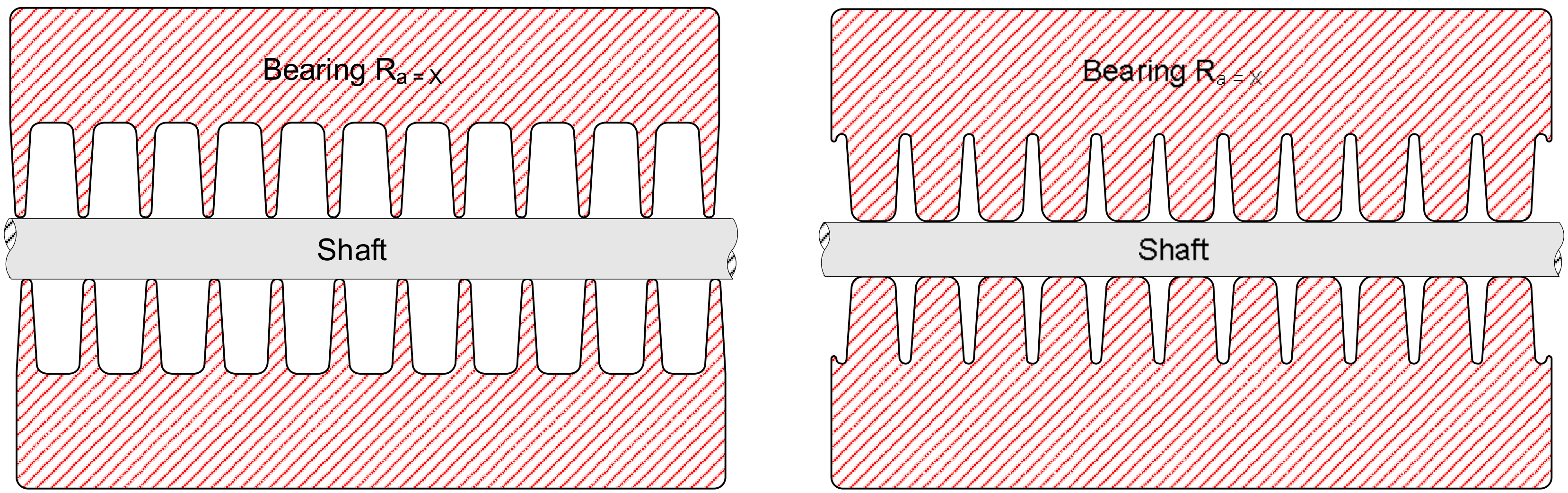
Step 3: Calculation of R_a





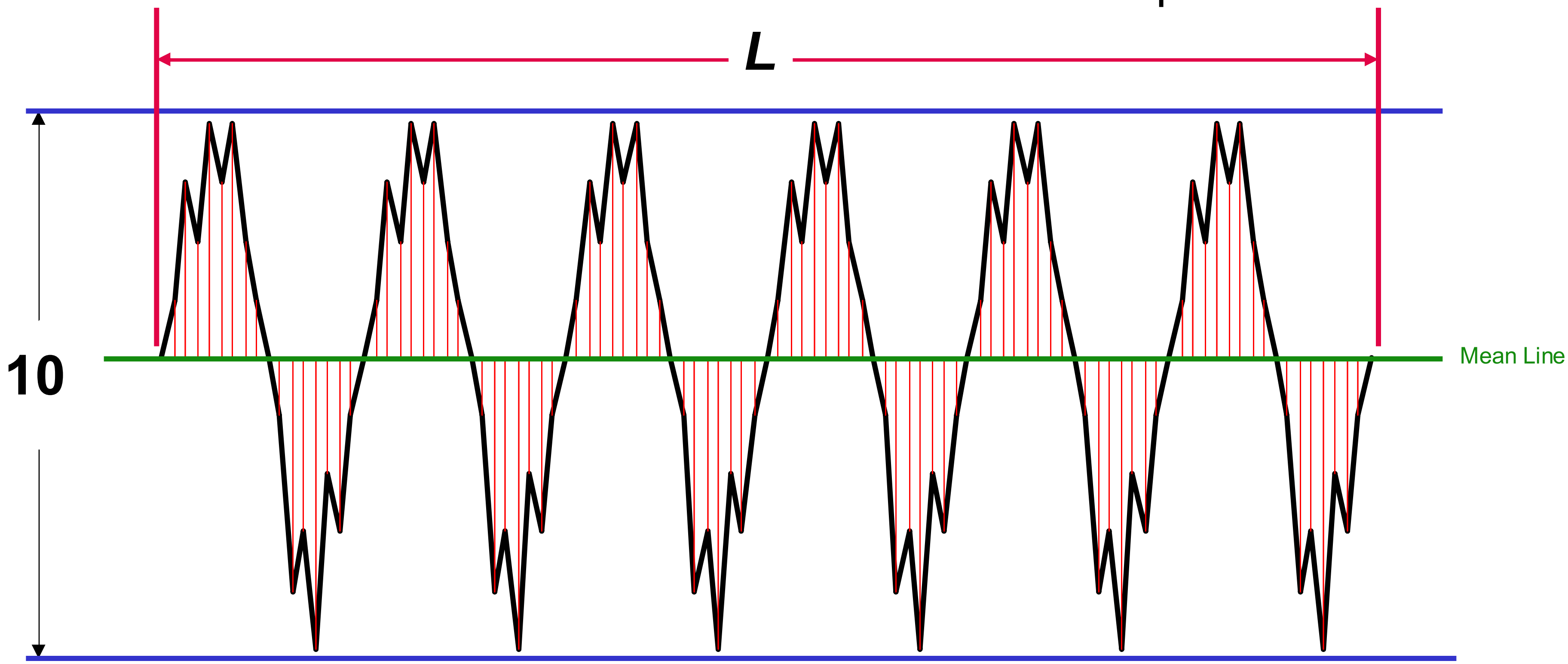
$$R_a \approx \left(\frac{|Z_1| + |Z_2| + \ldots + |Z_n|}{n} \right)$$

Different Surfaces, ***<u>Same</u>*** R_a



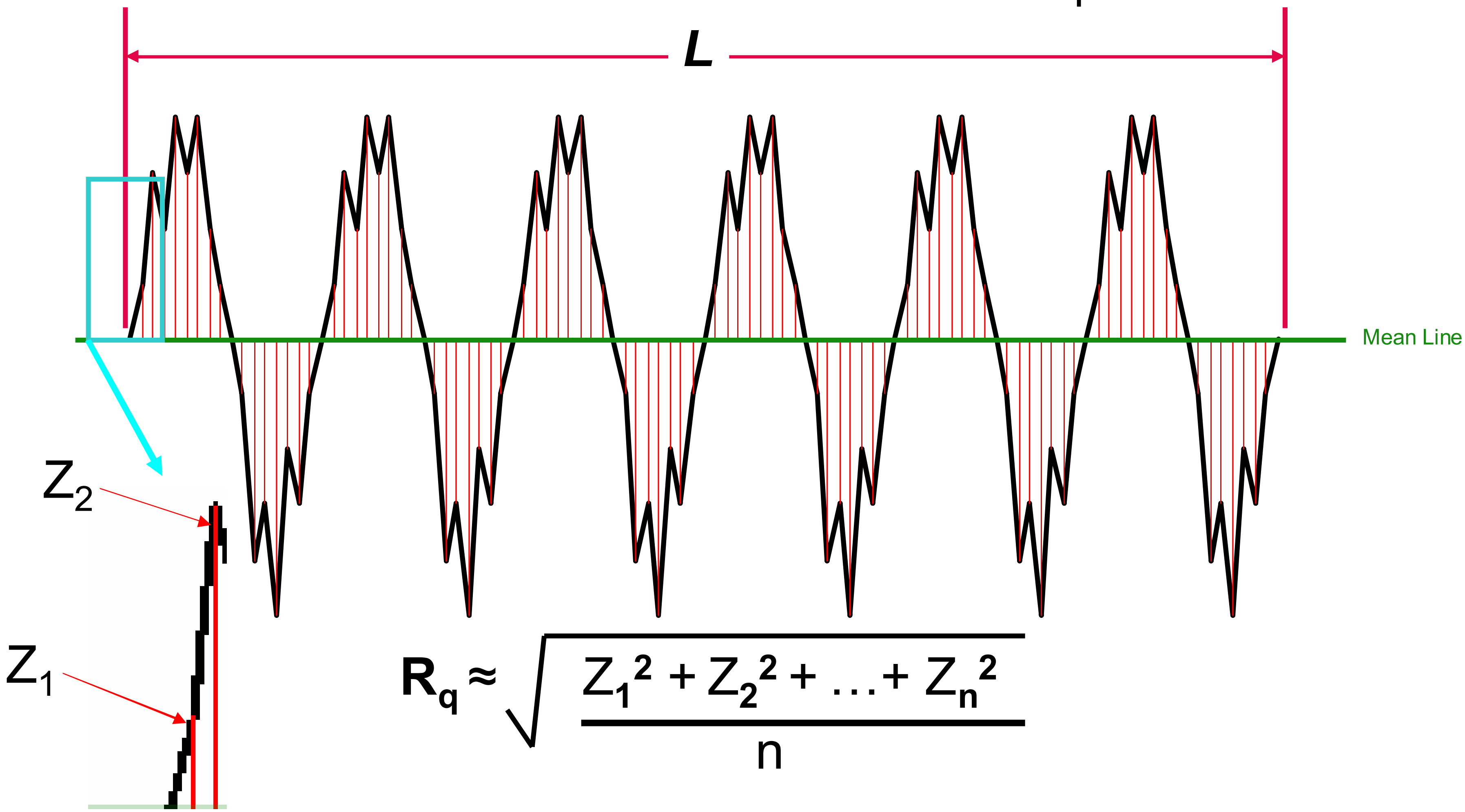
- Surface performance is different due to bearing contact
- R_a is often specified and is valuable for monitoring process stability, other parameters may be needed to monitor for surface function

Step 1: Calculation of R_q



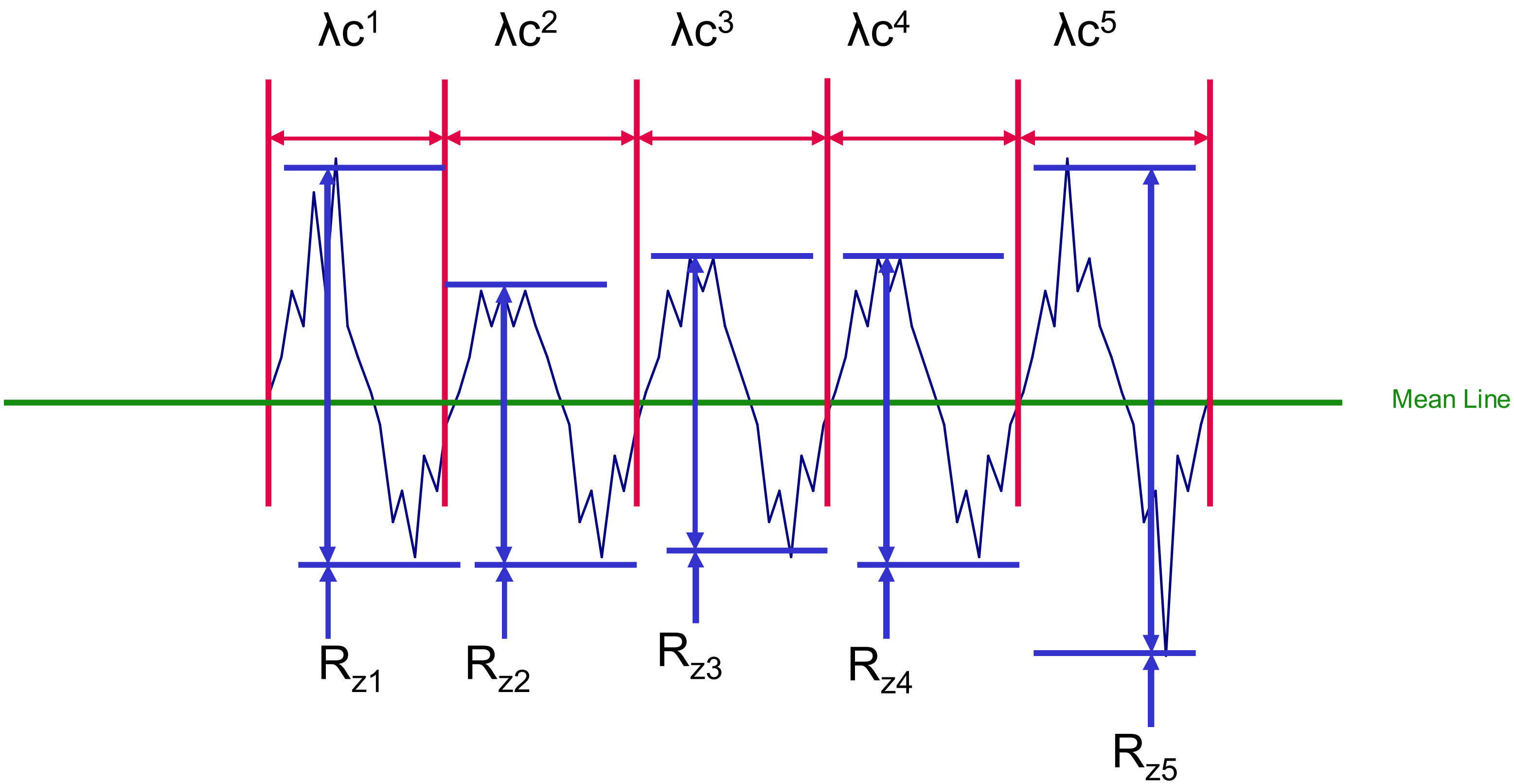
Filtered roughness profile with mean line, peak to valley is 10

Step 2: Calculation of R_q



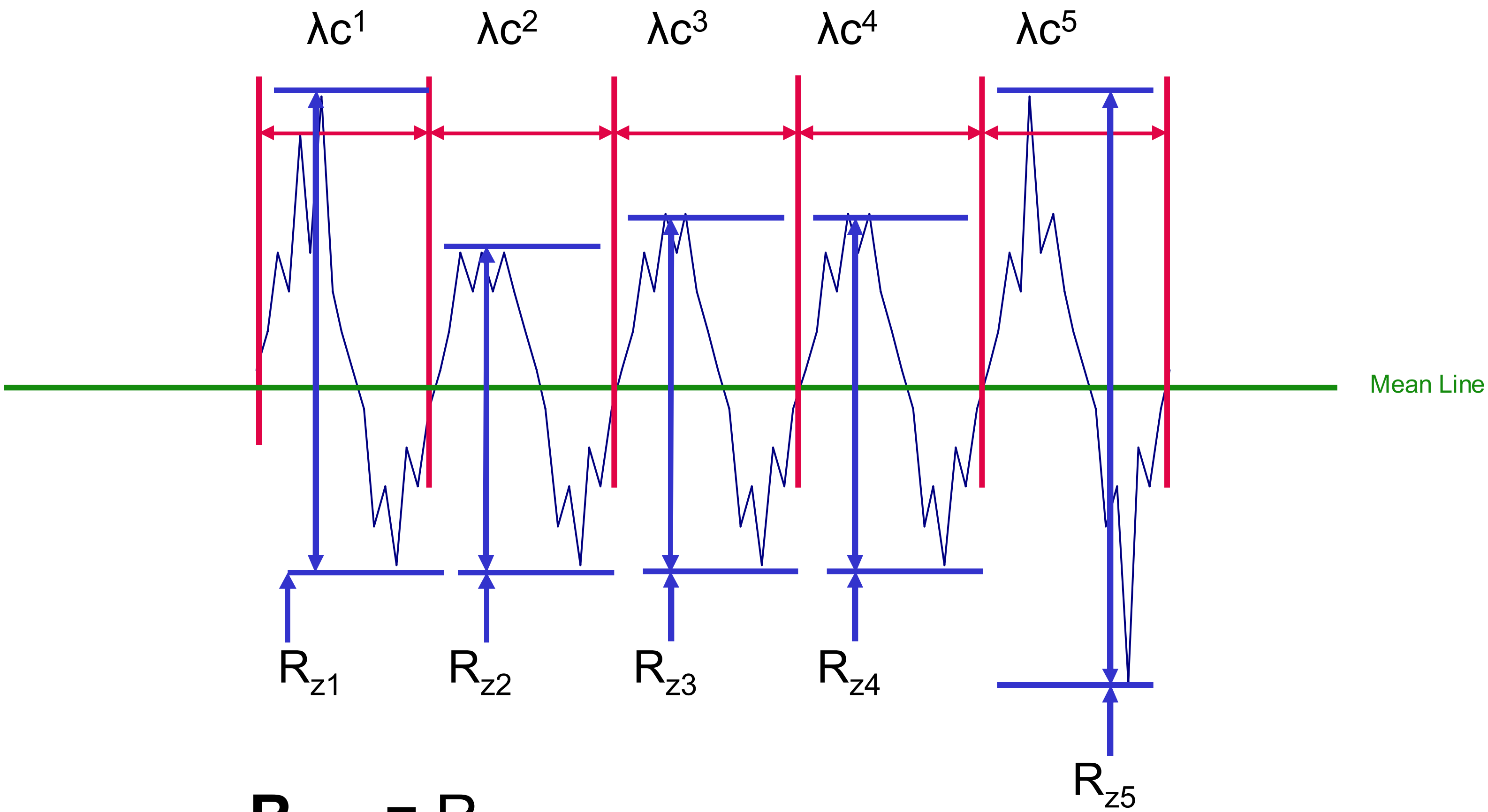
$$R_q \approx \sqrt{\frac{Z_1^2 + Z_2^2 + \ldots + Z_n^2}{n}}$$

Calculation of R_z (DIN, ASME)



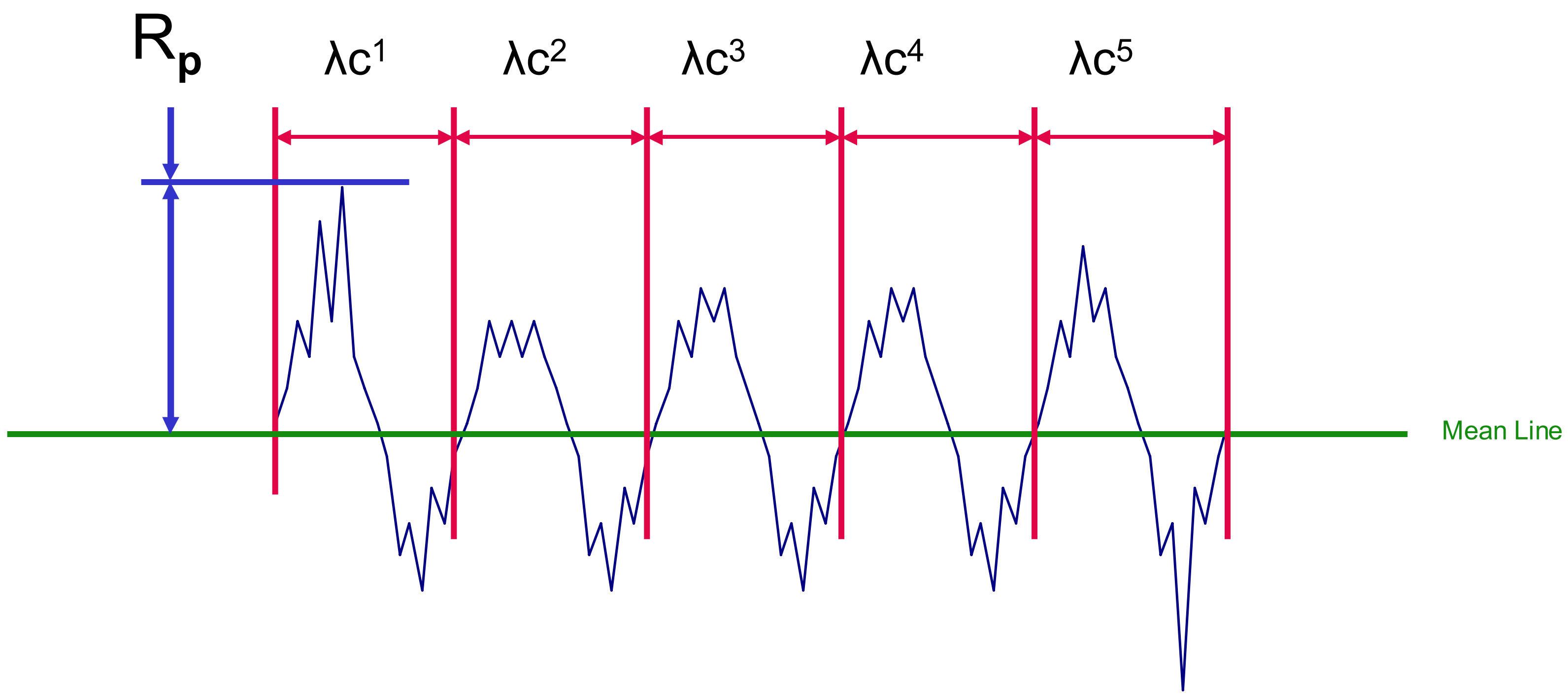
$$\mathbf{R_z} = \frac{(R_{z1} + R_{z2} + \ldots)}{5}$$

Calculation of R_{max}

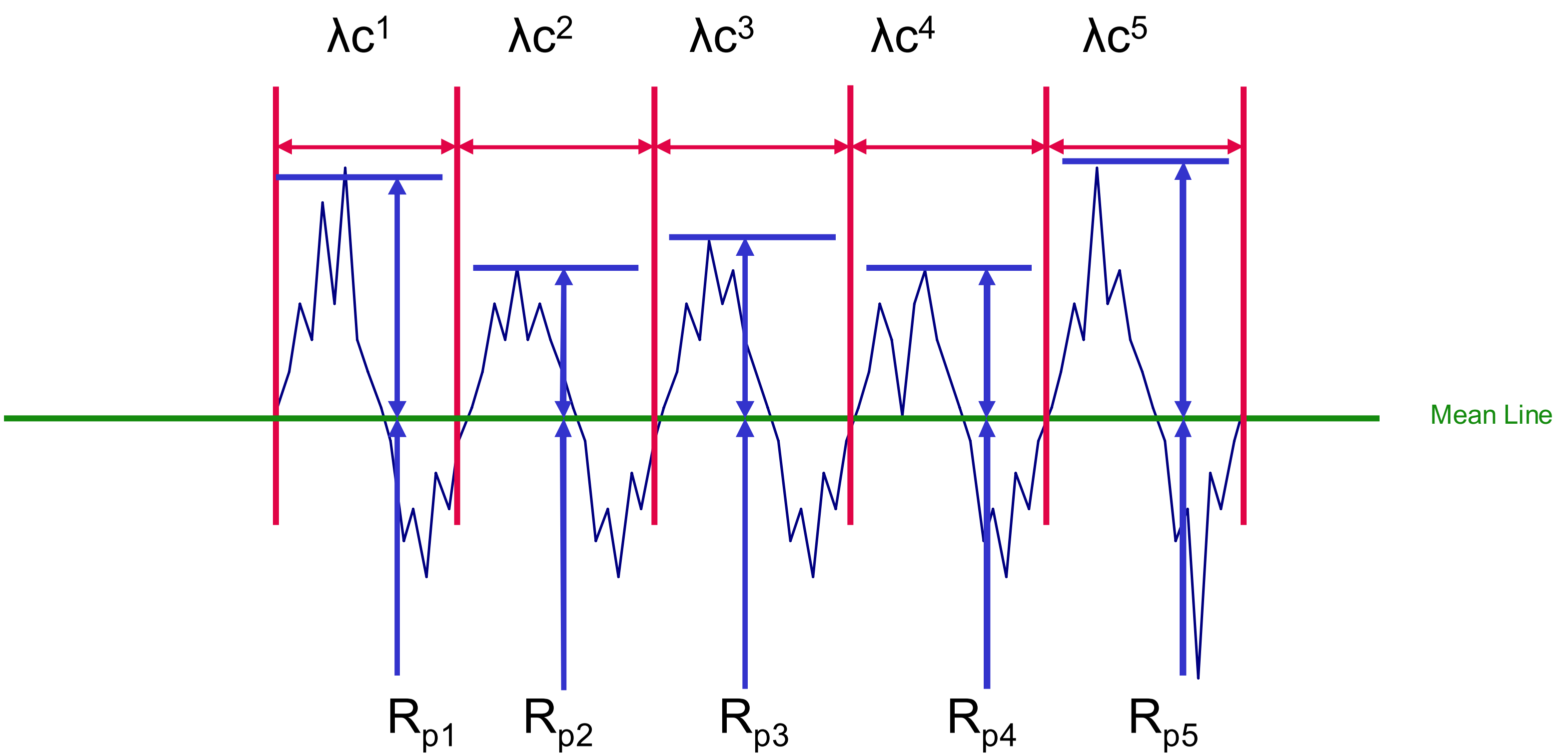


$\mathbf{R_{max}} = R_{\mathbf{z5}}$

Calculation of R_p

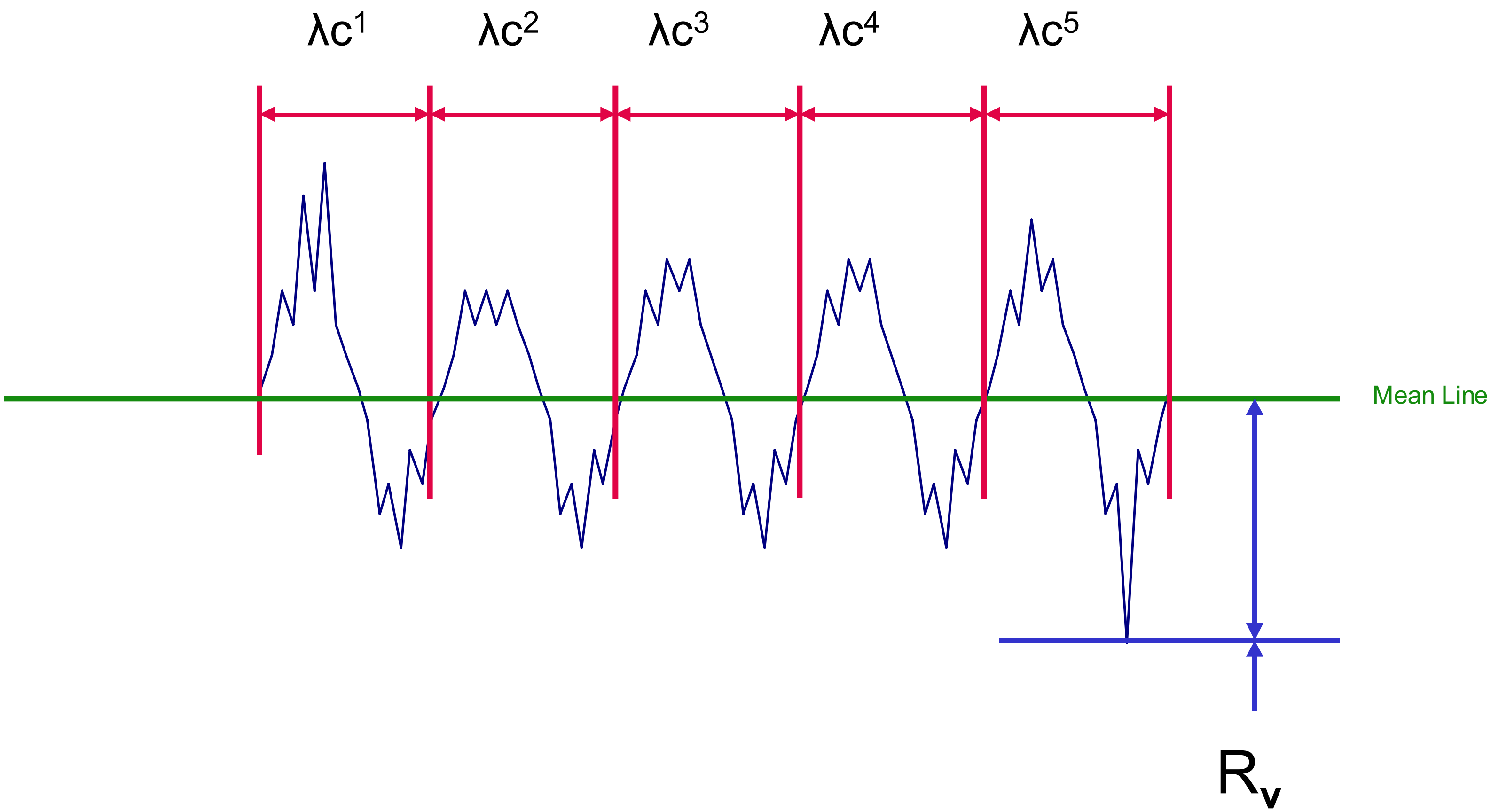


Calculation of R_{pm}

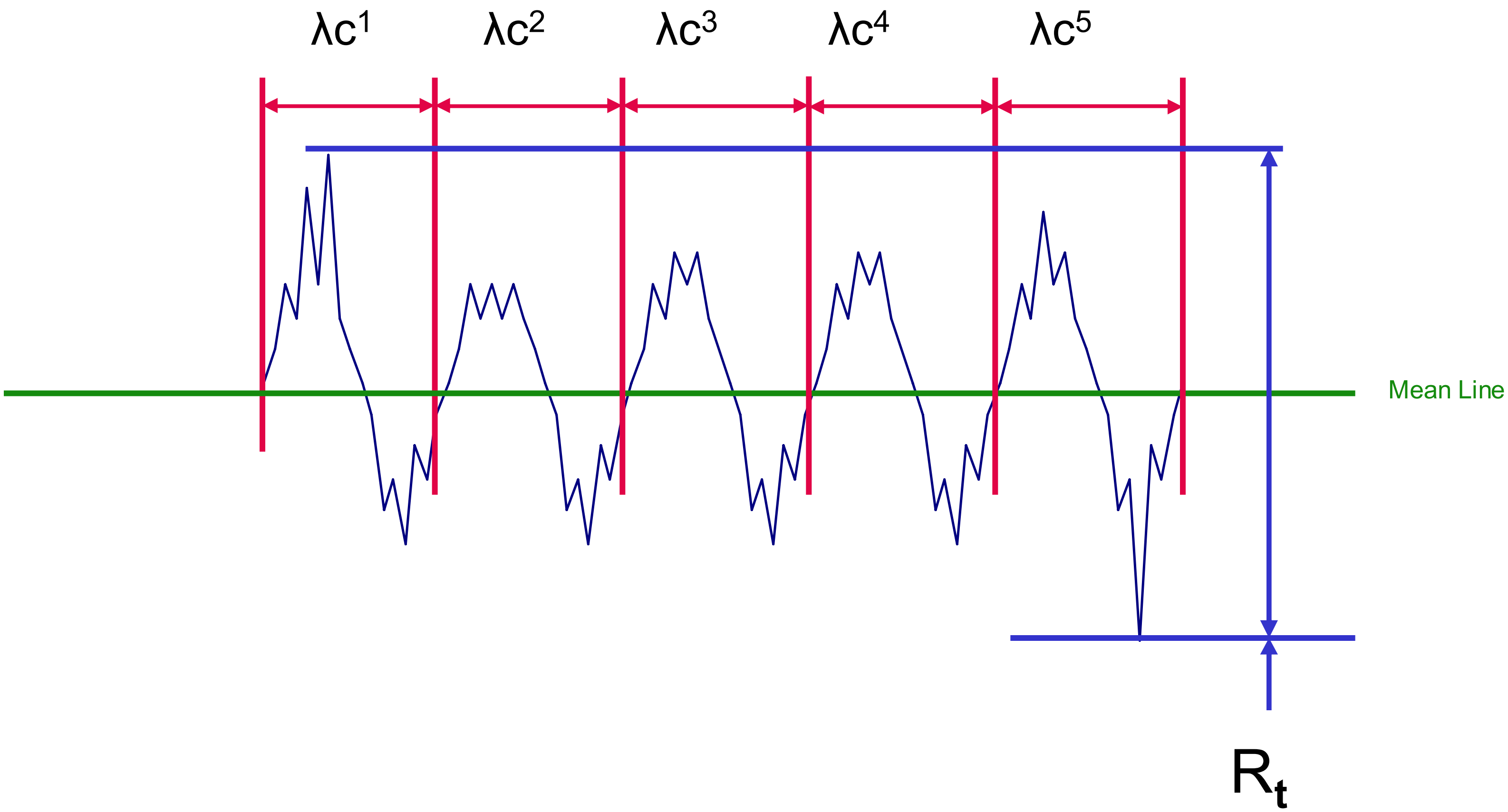


$$\mathbf{R_{pm}} = \frac{(R_{\mathbf{p1}} + R_{\mathbf{p2}} + \ldots)}{5}$$

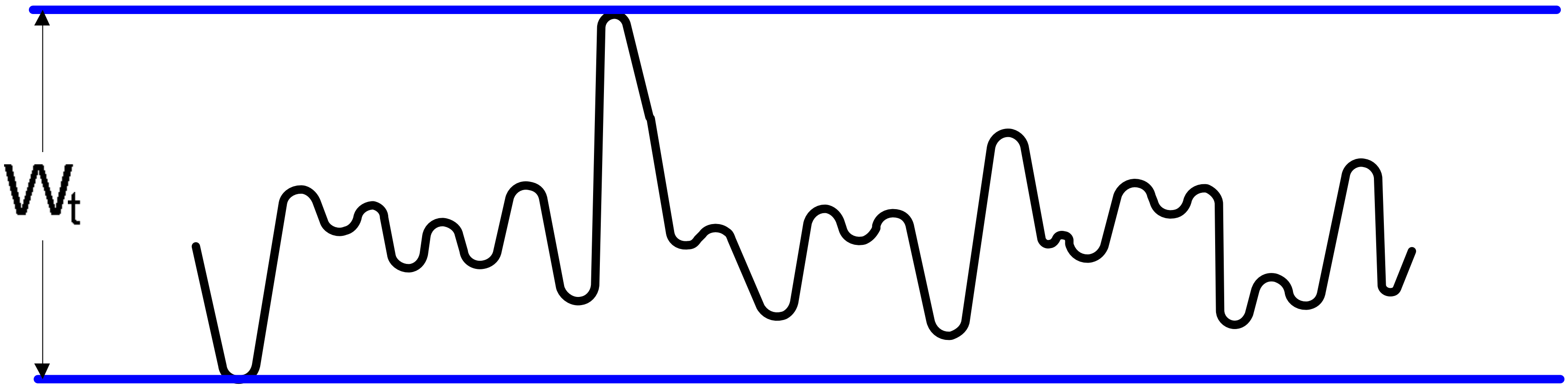
Calculation of R_v



Calculation of R_t

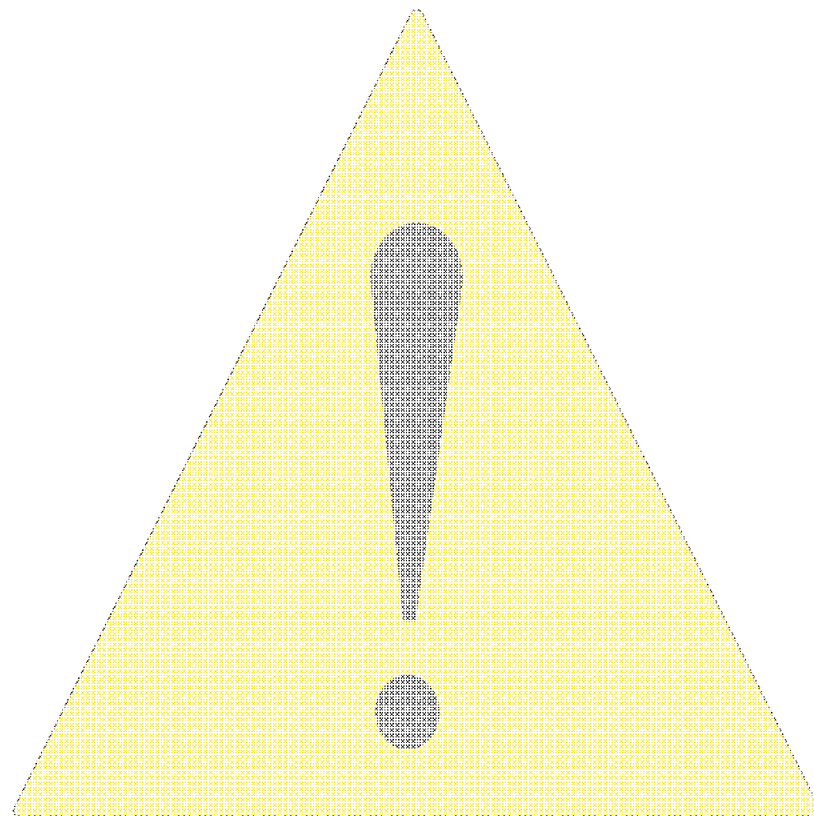


Calculation of Waviness Height W_t



Generally, a maximum peak-to-valley measurement of waviness (roughness has been filtered out)

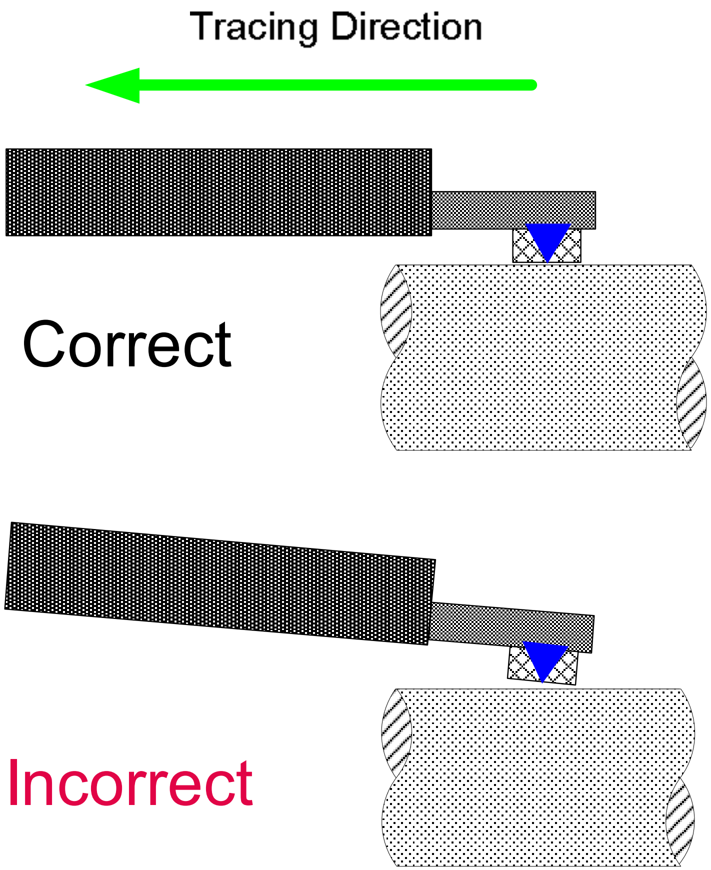
Best Practices and Correlation



Best Practices - Mechanical

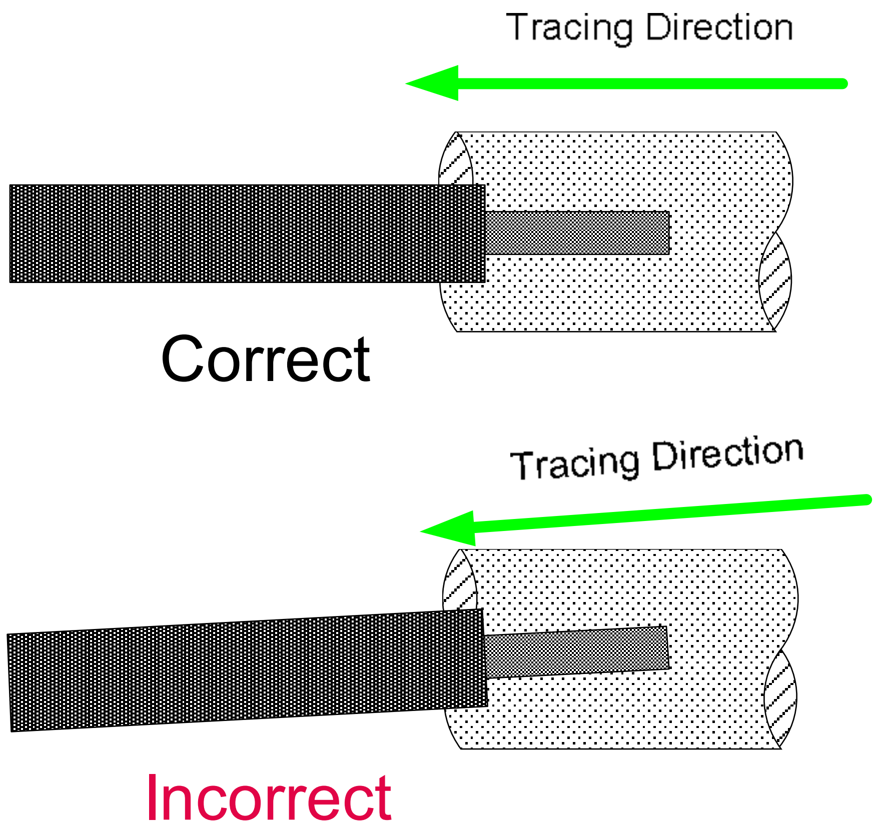
- Check the following:
  - ❑ Skid flush and parallel with surface being measured
  - ❑ Skidless drive datum level to surface being measured
  - ❑ Drive X axis parallel with part axis
  - ❑ Measurement on OD top dead center or bottom of bore
  - ❑ Tracing arm assembled properly (set screw or other method)
  - ❑ Part held in rigid mount
  - ❑ Drive stable and set up free from ambient vibration
  - ❑ Surface to be measured clean
  - ❑ Measurement 90 degrees to “lay” unless otherwise specified

Best Practices - Mechanical



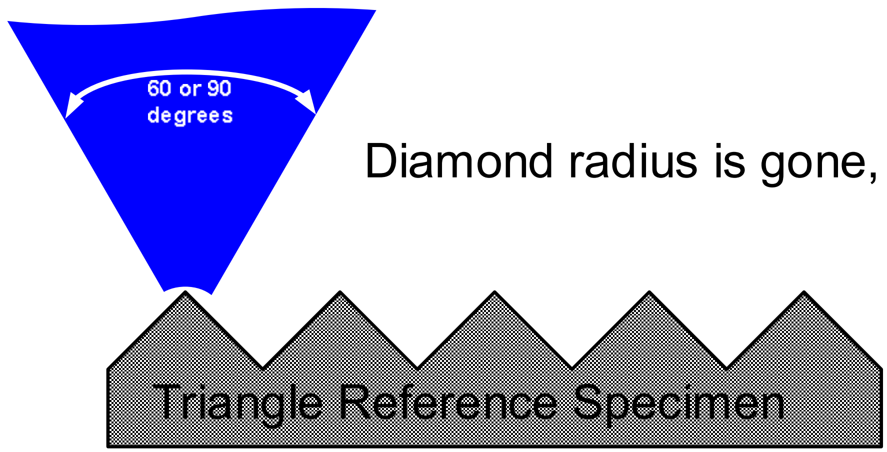
- Skid or pickup parallel or level to the surface being measured

Best Practices - Mechanical



- Skid or pickup on “top dead center”
- Alignment parallel with part centerline

Diamond Condition



Diamond radius is gone, now a "crater"

Trace of reference specimen indicates diamond is damaged

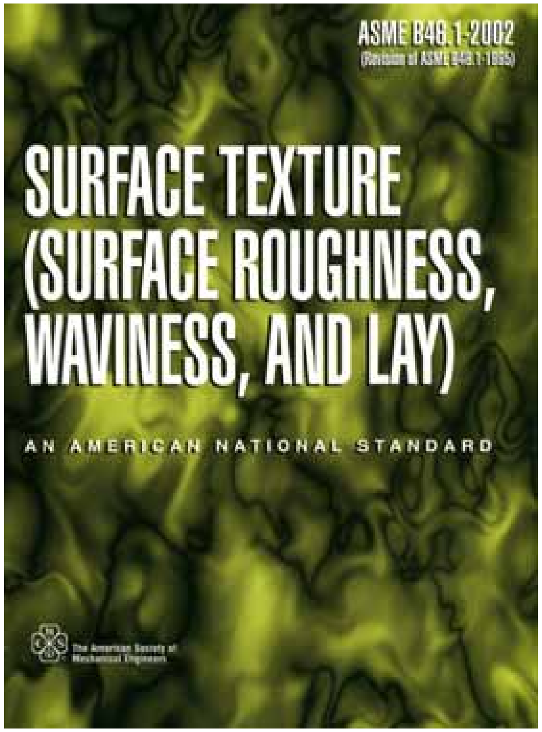
Correlation Checklist

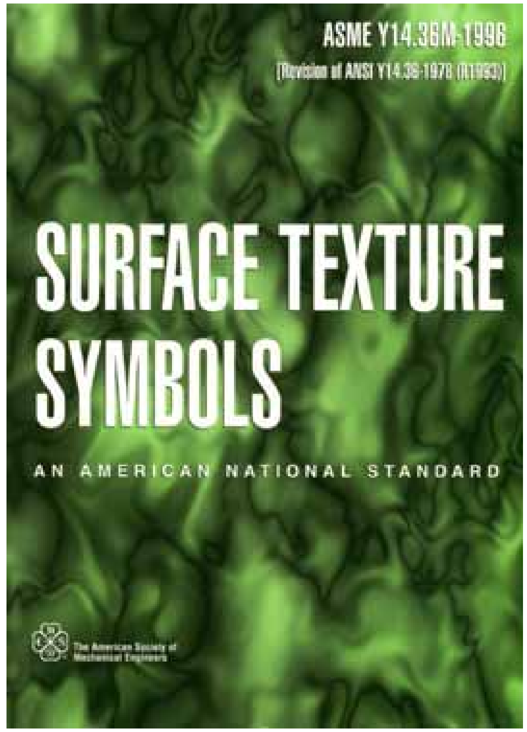
- If you have a correlation problem on surface finish measurement here are some things to check:
  - ❑ Instrument calibration to manufacturer's method
  - ❑ Parameter (R_a…) and Standard (ISO, JIS, ASME…)
  - ❑ Filter (Gaussian, RC)
  - ❑ Cutoff
  - ❑ Diamond Radius and included angle
  - ❑ Diamond condition
  - ❑ Stylus force
  - ❑ Skidded or Skidless
  - ❑ Part alignment/stability
  - ❑ Ambient vibration
  - ❑ Data density (X and Z)
  - ❑ Measurement location and orientation to lay

Review and Recommendations

- To study surface texture, we filter surface data into wavelength bands.
- The wavelength bands are called Roughness and Waviness
- Skidded stylus instruments measure ***only*** Roughness parameters ($R_{...}$). Most portable instruments are skidded.
- Skidless stylus instruments measure Roughness, Waviness and Profile
- Cutoff default formerly was .8 mm, now must be defined on the drawing.
- Use the same cutoff, number of cutoffs, diamond radius, filter type (Gaussian or RC), and parameter(s) that your customer uses and specifies.
- Be aware of standard authority (JIS, ISO, DIN, ASME). Do not assume that parameters are the same!
- Routinely check calibration ***and*** diamond condition

American National Standards





- ASME B46.1-2002 is the current USA standard for Surface Texture
- ASME Y14.36M-1996 (reaffirmed) contains the USA standard for Surface Texture Symbols used on drawings

References

1. Tabenkin, A., : Surface Finish: A Machinist's Tool, A Design Necessity, *Modern Machine Shop.* April 1996
2. Tabenkin, A., : Surface Finish Measurement Basics, *Quality Magazine.* September 2004
3. Tabenkin, A., : Where do we go wrong in surface finish gaging?, *Quality in Manufacturing.* November/December 1998.
4. Sander, M.: A Practical Guide to the Assessment of Surface Texture, *Feinpruf GmbH, Goettingen* 1989
5. ANSI/ASME B46.1 - 2002 Surface Texture, Surface Roughness, Waviness and Lay, *American Society of Mechanical Engineers* , 2002
6. ANSI/ASME Y14.36M-1996(R2002) Surface Texture Symbols - Metric version, *American Society of Mechanical Engineers,* 1996
7. Nugent, P., MacKenzie D., Developments in Surface (and Form) Measurement Technology (Presentation for Caterpillar), October 2006.
8. Vorburger, T., Raja, J., Surface Finish Metrology Tutorial (NISTIR 89-4088), U.S. Department of Commerce, National Institute of Standards and Technology, June 1990.

Note: Parameter calculations in this presentation are shown for discussion and purposes of illustration only. Refer to the ANSI/ASME B46.1 - 2002 Surface Texture, Surface Roughness, Waviness and Lay for actual calculations and methods of evaluation