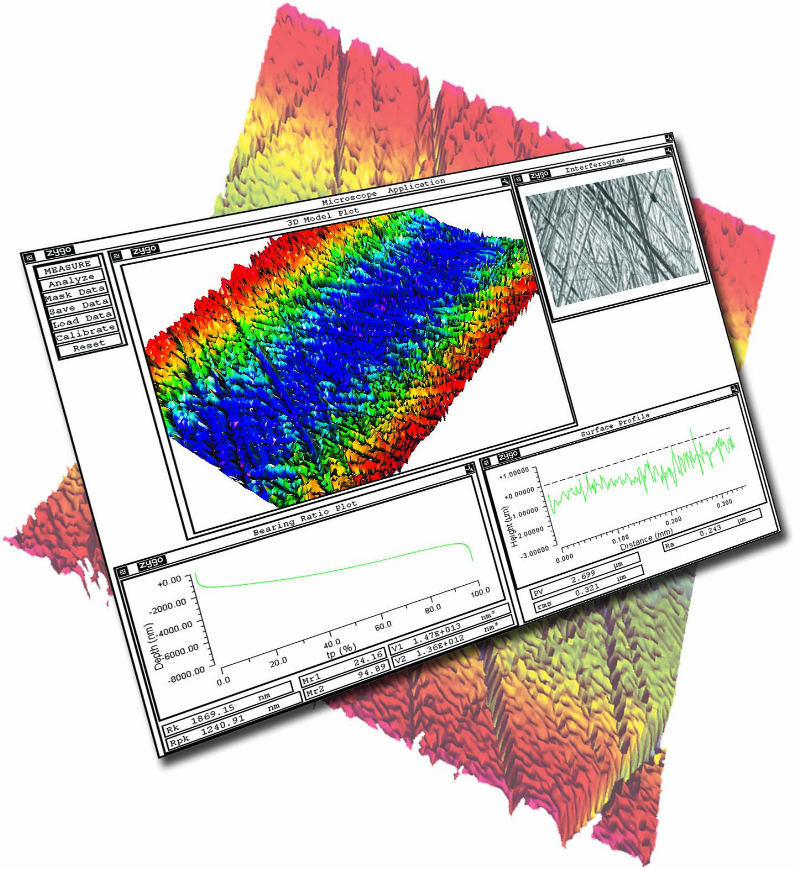
zygo®



MetroPro™ Surface Texture Parameters

Understanding Surface Texture Parameters

Every part's surface is made up of texture and roughness which varies due to manufacturing techniques and the part structure itself. To understand a component's surface and to control the manufacturing process to the degree required in today's modern world, it is necessary to quantify the surface in both two and three dimensions.

Surface texture parameters can be grouped into these basic categories: Roughness, Waviness, Spacing, and Hybrid.

Terminology

Areal- A three dimensional surface area.

Cutoff Filter- Determines the wavelength at which the surface structure is differentiated between roughness and waviness data. Proper selection of the correct filter cutoff in software is critical to measurement accuracy.

Evaluation Length- The area from which data is obtained. It is a three dimensional area that corresponds to the instrument field of view, or a two dimensional profile that corresponds to the length of the slice as defined in the filled plot.

Hybrid Parameters- These parameters are combinations of spacing and roughness parameters.

Mean Line- A straight line that is generated by calculating a weighted average for each data point resulting in equal areas above and below the line. Also known as center line.

Profile- A two dimensional slice through an area.

Roughness Parameters - The finer irregularities in the surface texture which are inherent in the production process. These are a measure of the vertical characteristics of the surface.

Sampling Length- The area selected for assessment and evaluation of the roughness parameter having the cutoff wavelength. Any surface irregularities spaced farther apart than the sampling length are considered waviness. Also known as cutoff length.

Spacing Parameters- A measure of the horizontal or lateral characteristics of the surface.

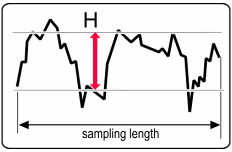
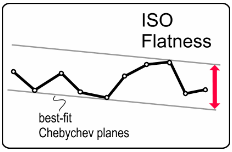
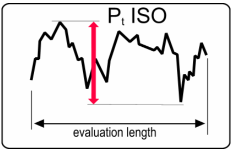
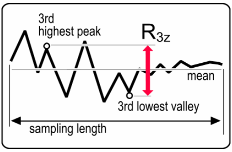
Surface Texture- The topography of a surface composed of certain deviations that are typical of the real surface. It includes roughness and waviness.

Waviness Parameters - A larger component of surface texture upon which roughness is superimposed.

When two parameter names are shown, the name in parentheses is the name used in ZYGO software.

Contents

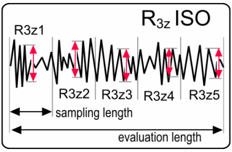
Roughness Parameters

H	Swedish height. The roughness between two predefined reference lines. The upper line exposes 5% of the data, and the lower line exposes 90%. H is less sensitive to data spikes than Rt. Available for profile and areal data.	
ISO Flatness	Areal flatness deviation. The measure of surface deviation from perfectly flat. It is the distance between two parallel planes obtained by applying a Chebychev fit to the surface data. The Chebychev fit is a mathematical technique that effectively uses two parallel planes to "squeeze" the surface data points from both inside and outside, adjusting the angle to minimize the distance between the planes.	
Pt ISO	Total peak-to-valley profile height. The distance between the highest peak and the deepest valley over the entire evaluation length. The profile data has form removed but is unfiltered.	
R_{3z}	Base roughness depth. The distance between the third highest peak and the third lowest valley. A peak is a portion of the surface above the mean line and between center line crossings. Available for profile and areal data.	

Roughness Parameters

R_{3z} ISO

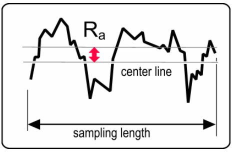
Base roughness profile depth. The height of the 3rd highest peak from the 3rd lowest valley per sampling length. The base roughness depth is found in five sampling lengths and then averaged.



R_a

Arithmetical mean deviation. The average roughness or deviation of all points from a plane fit to the test part surface. Available for profile and areal data.

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



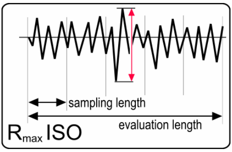
R_{ku}

Kurtosis is a measure of the randomness of heights, and of the sharpness of a surface. A perfectly random surface has a value of 3; the farther the result is from 3, the less random and more repetitive the surface is. Surfaces with spikes are higher values; bumpy surfaces are lower. Available for profile and areal data.

$$R_{ku} = \frac{1}{n(R_q)^4}\sum_{i=1}^{i=n}(Y_i)^4$$

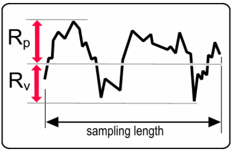
R_{max} ISO

Maximum peak-to-valley profile height. The greatest peak-to-valley distance within any one sampling length.

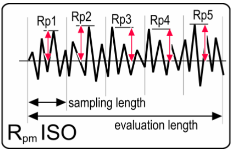
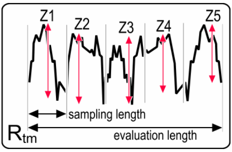
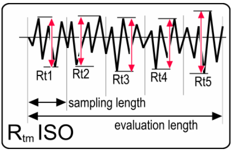


R_p (Peak)

Highest peak. The maximum distance between the mean line and the highest point within the sample. It is the maximum data point height above the mean line through the entire data set. Available for profile and areal data.



Roughness Parameters

R_{pm} ISO	Mean peak profile height. The mean peak height based on one peak per sampling length. The single highest peak is found in five sampling lengths and then averaged.	
R_q (rms)	Root-mean-square (rms) roughness. The average of the measured height deviations taken within the evaluation length or area and measured from the mean linear surface. Available for profile and areal data. Rq is the rms parameter corresponding to Ra. $R_q = \sqrt{\frac{1}{L}\int_0^L z^2(x)\,dx}$	
R_t (PV)	Maximum peak-to-valley height. The absolute value between the highest and lowest peaks. Available for profile and areal data. $R_t = R_p + R_v$	
R_{tm}	Mean peak-to-valley roughness. It is determined by the difference between the highest peak and the lowest valley within multiple samples in the evaluation area. For profile data it is based on five sample lengths. Available for profile and areal data. $R_{tm} = \frac{Z1 + Z2 ... + Zn}{n}$	
R_{tm} ISO	Mean peak-to-valley profile roughness. The mean peak-to-valley roughness based on one peak and one valley per sampling length. The single largest deviation is found in five sampling lengths and then averaged. $R_{tm}\ ISO = \frac{Rt1 + Rt2 ... + Rt5}{5}$	

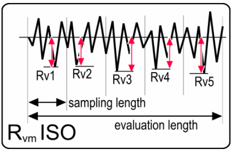
Roughness Parameters

R_v (Valley)

Lowest valley. The maximum distance between the mean line and the lowest point within the sample. It is the maximum data point height below the mean line through the entire data set. Available for profile and areal data. See Rp.

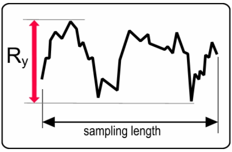
R_{vm} ISO

Mean valley profile depth. The mean valley depth based on one peak per sampling length. The single deepest valley is found in five sampling lengths and then averaged.



R_y (R_{max})

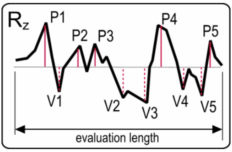
Maximum peak-to-valley roughness. The vertical distance between the top of the highest peak and the bottom of the deepest valley within the sampling length. It is the maximum of all the peak-to-valley values.



R_z

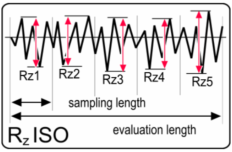
Ten-point height. The average absolute value of the five highest peaks and the five lowest valleys over the evaluation length. Available for profile and areal data.

$$R_z = \frac{(P1 + P2 ... P5) - (V1 + V2 ... V5)}{5}$$



R_z ISO

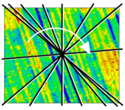
Average peak-to-valley profile roughness. The average peak-to-valley roughness based on one peak and one valley per sampling length. The single largest deviation is found in five sampling lengths and then averaged. Identical to Rtm ISO.



Roughness Parameters

For S_ ISO parameters, a surface area is analyzed by fitting a minimum enclosing rectangle and applying a 5 x 5 sampling grid, for a total of 25 sampling areas. All sampling areas together make up the evaluation area.

SP_t ISO	Total peak-to-valley areal height. The distance between the highest peak and the deepest valley over the entire evaluation area.
SR_{3z} ISO	Base roughness areal depth. The height of the 3rd highest peak from the 3rd lowest valley per sampling area. The base roughness depth is found in each sampling area and then averaged.
SR_{max} ISO	Maximum peak-to-valley height over the entire areal evaluation area.
SR_{pm} ISO	Mean peak areal height. The mean peak height based on one peak per sampling area. The single highest peak is found in each sampling area and then averaged.
SR_{tm} ISO	Mean peak-to-valley areal roughness. The mean peak-to-valley roughness based on one peak and one valley per sampling area. The single largest deviation is found in each sampling area and then averaged.
SR_{vm} ISO	Mean valley areal depth. The mean valley depth based on one peak per sampling area. The single deepest valley is found in each sampling area and then averaged.
SR_z	Average radial peak-to-valley areal roughness. The average of the largest half of many individual Rz results determined by slicing the areal data array about its center through 360 degrees. The Rz results are sorted by magnitude and SRz is calculated by averaging the largest 50% of the Rz values. A line-generation algorithm is used to determine the actual pixel-to-pixel path of each slice; there is no interpolation between pixels. SRz covers the entire array, and due to its radial generation it is lay independent.



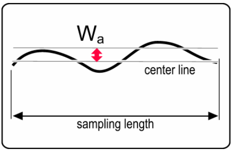
Many Rz results are analyzed by radial slicing data; the largest half are averaged

Roughness Parameters

SR_z ISO	Average peak-to-valley areal roughness. The average peak to valley roughness based on one peak and one valley per sampling area. The single largest deviation is found in each sampling area and then averaged.
SR_zX	The average of many individual Rz results, determined by slicing the data array in the x-axis. The individual Rz results are each based on a profile slice one pixel wide. SRzX is based on the entire array. See SRz.
SR_zY	The average of many individual Rz results, determined by slicing the data array in the y-axis. The individual Rz results are each based on a profile slice one pixel wide. SRzY is based on the entire array. See SRz.

Waviness Parameters

W_a The arithmetic average roughness, or average deviation, of all points from a plane fit to the waviness data.

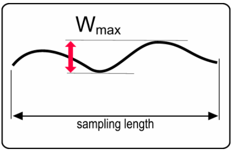


$$W_a = \frac{1}{L}\int_0^L |z(x)|dx$$

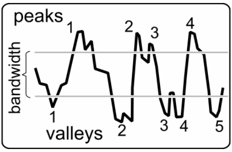
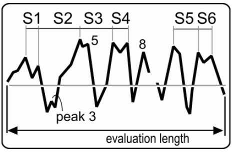
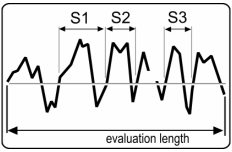
W_q The root-mean-square (rms) roughness of all points from a plane fit to the waviness data.

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

W_y (W_{max}) The maximum height of the waviness data.



Spacing Parameters

P_c (Peaks)	Peak count or the number of peaks included in the analysis. A peak is defined as a data point whose height is above a software selected bandwidth.	
Peak Density	The number of peaks per unit area.	
Peak Spacing	The average distance between peaks.	
S	The average spacing between local peaks over the evaluation length. A local peak is the highest point between two adjacent minima. The average spacing for the example shown is calculated by: $S = \frac{S1 + S2 ... + S6}{6}$	
S_m	The average spacing between peaks at the mean line over the evaluation length. A peak is the highest point between an upwards and downwards crossing of the mean line. It is calculated by summing all the peak spacing and dividing by the number of spaces.	
Summits	The number of summits included in the analysis. A summit is a point that is higher than the four nearest data points as determined by a software threshold value. The higher the threshold, the fewer and steeper the summits.	
Summit Density	The number of summits per unit area.	
Summit Spacing	The average distance between summits.	

Spacing Parameters

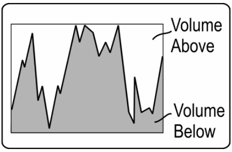
Valleys	The number of valleys included in the analysis. A valley is defined as a data point whose height is below a software selected bandwidth. See Pc.
Valley Density	The number of valleys per unit area.
Valley Spacing	The average distance between valleys.

Hybrid Parameters

Δ_a (Slope $_{Ra}$)	The arithmetic average surface slope of the entire data matrix. Slopes are directly related to the reflective properties of the surface. They are useful for controlling cosmetic appearances of surfaces, as well as in controlling reflective surfaces. Results are available for overall slopes and in just the x or y axes. In mathematical symbols: $\Delta_a = \frac{1}{L}\int_0^L \left\lvert \frac{dy}{dx} \right\rvert dx$
Δ_q (Slope $_{rms}$)	The geometric average slope of the entire data matrix. This result is similar to Δ_a except that individual slopes are averaged by the rms method rather than arithmetically, emphasizing more extreme slopes. Results are available for overall slopes and in just the x or y axes.
Δ_{tm} (Slope $_{Rtm}$)	The average peak-to-valley slope of nine sample areas on the entire data matrix. Results are available for overall slopes and in just the x or y axes.
I_a	The average surface height, or average deviation, of all points from a plane fit to the input data. Input data is the data obtained by the instrument; it includes roughness and waviness information.
I_q	The root-mean-square deviation of all points from a plane fit to the input data. Input data includes roughness and waviness information.
I_y (I_{max})	The maximum height of the input data. Input data includes roughness and waviness information.

Hybrid Parameters

R_{volume} — The volume of the roughness data as specified by software as above or below the surface.



$R_{SurfAreaRatio}$ — The ratio of roughness surface area to the planar area occupied by the data.

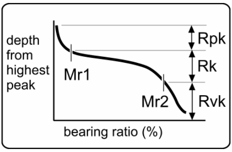
$W_{SurfAreaRatio}$ — The ratio of waviness surface area to the planar area occupied by the data.

$I_{SurfAreaRatio}$ — The ratio of input surface area to the planar area occupied by the data.

Bearing Ratio Parameters

Bearing Ratio (T_p) — Bearing ratio is the ratio (expressed as a percentage) of the length of the bearing surface at any specified depth in the evaluation area. It simulates the effect of wear on a bearing surface. Bearing Ratio results are available for profile data (tp) and surface area (Stp).

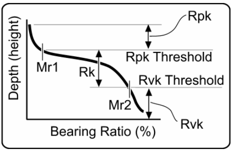
R_k — Core Roughness Depth - The long term running surface which will influence the performance and life of the bearing surface.



R_k Midpoint — The middle point of the R_k region; it is an absolute height.

R_{pk} — Reduced Peak Height - The top portion of the surface that will be worn away in the run-in period.

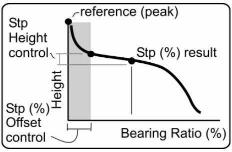
R_{pk} Threshold — The threshold between the R_{pk} and R_k regions; it is an absolute height.



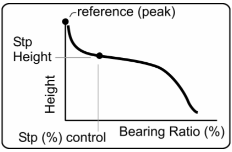
R_{vk} — Reduced Valley Depth - The lowest part of the surface that retains lubricant.

R_{vk} Threshold — The threshold between the R_k and R_{vk} regions; it is an absolute height.

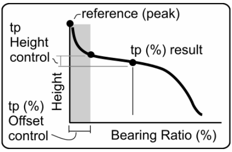
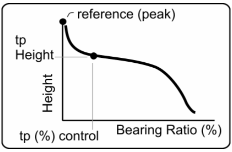
Hybrid Parameters

M_{r1}	Peak Material Component - The material ratio at which R_{pk} and R_k meet. It represents the upper limit of the core roughness profile. This parameter is derived from the bearing ratio plot.
M_{r2}	Valley Material Component - The material ratio at which R_{vk} and R_k meet. It represents the lower limit of the core roughness profile. This parameter is derived from the bearing ratio plot.
V_1	Volume 1 - the volume of the material that will be removed during the run-in period. Part of the bearing ratio analysis.
V_2	Volume 2 - The potential volume of retained lubricant. Part of the bearing ratio analysis.
Stp1 (%)	The areal bearing ratio (expressed as a percentage) at the height specified by the Stp1 Height control, relative to the selected Stp Reference location and Stp1 (%) Offset value. 
Stp2 (%)	The areal bearing ratio (expressed as a percentage) at the height specified by the Stp2 Height control, relative to the selected Stp Reference location and Stp2 (%) Offset value.
Stp3 (%)	The areal bearing ratio (expressed as a percentage) at the height specified by the Stp3 Height control, relative to the selected Stp Reference location and Stp3 (%) Offset value.
Upper Stp (%)	The areal bearing ratio (expressed as a percentage) at the location specified by the Upper Stp Height control, relative to the selected Stp Reference location.
Lower Stp (%)	The areal bearing ratio (expressed as a percentage) at the location specified by the Lower Stp Height control, relative to the selected Stp Reference location.

Hybrid Parameters

Delta Stp (%)	The difference in the areal bearing ratio (expressed as a percentage) between the Upper and Lower Stp (%) values.
Stp1 Height	The height of the areal bearing ratio curve where it intersects the percentage specified by the Stp1 (%) control, relative to the selected Stp Reference location. 
Stp2 Height	The height of the areal bearing ratio curve where it intersects the percentage specified by the Stp2 (%) control, relative to the selected Stp Reference location.
Stp3 Height	The height of the areal bearing ratio curve where it intersects the percentage specified by the Stp3 (%) control, relative to the selected Stp Reference location.
Upper Stp Height	The height of the areal bearing ratio curve at the location specified by the Upper Stp (%) control, relative to the selected Stp Reference location
Lower Stp Height	The height of the areal bearing ratio curve at the location specified by the Lower Stp (%) control, relative to the selected Stp Reference location.
SH_{tp}	Height between two points on the areal bearing ratio curve as specified by the Upper Stp (%) and Lower Stp (%) controls. It is used to help determine material removal over multiple processes.
Mean SHtp	The average of all the height values between the two points on the areal bearing ratio curve specified by the Upper Stp (%) and Lower Stp (%) controls.

Hybrid Parameters

tp1 (%)	The profile bearing ratio (expressed as a percentage) at the height specified by the tp1 Height control, relative to the selected tp Reference location and the tp1 (%) Offset control value. 
tp2 (%)	The profile bearing ratio (expressed as a percentage) at the height specified by the tp2 Height control, relative to the selected tp Reference location and the tp2 (%) Offset control value.
tp3 (%)	The profile bearing ratio (expressed as a percentage) at the height specified by the tp3 Height control, relative to the selected tp Reference location and the tp3 (%) Offset control value.
Upper tp (%)	The profile bearing ratio (expressed as a percentage) at the location specified by the Upper tp Height control, relative to the selected tp Reference location.
Lower tp (%)	The profile bearing ratio (expressed as a percentage) at the location specified by the Lower tp Height control, relative to the selected tp Reference location.
Delta tp (%)	The difference in the profile bearing ratio (expressed as a percentage) between the Upper and Lower tp (%) values.
tp1 Height	The height of the profile bearing ratio curve where it intersects the percentage specified by the tp1 (%) control, relative to the selected tp Reference location. 
tp2 Height	The height of the profile bearing ratio curve where it intersects the percentage specified by the tp2 (%) control, relative to the selected tp Reference location.
tp3 Height	The height of the profile bearing ratio curve where it intersects the percentage specified by the tp3 (%) control, relative to the selected tp Reference location.

Hybrid Parameters

Upper tp Height

The height of the profile bearing ratio curve where it intersects the percentage specified by the Upper tp (%) control, relative to the selected tp Reference location.

Lower tp Height

The height of the profile bearing ratio curve where it intersects the percentage specified by the Lower tp (%) control, relative to the selected tp Reference location.

H_{tp}

Height between two points on the profile bearing ratio curve as specified by the Upper tp (%) and Lower tp (%) controls.

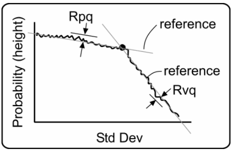
Mean H_{tp}

The average of all the height values between the two points on the profile bearing ratio curve specified by the Upper tp (%) and Lower tp (%) controls.

Material Probability Parameters

R_{pq}

The root-mean-square average of the height deviations in the peak or plateau portion of the Material Probability plot.

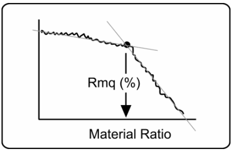


R_{vq}

The root-mean-square average of the height deviations in the valley portion of the Material Probability plot. This result is useful as a predictor of original surface roughness before the removal of more material in subsequent processes. See Rpq.

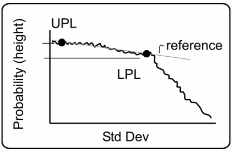
R_{mq} (%)

The material ratio (expressed as a percentage) at the peak-to-valley transition.

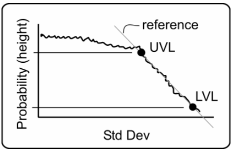
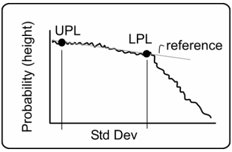
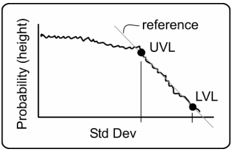


Height UPL

The height at the upper peak or plateau limit. UPL is set with inspectors in the Material Probability plot.



Hybrid Parameters

Height LPL	The height at the lower peak or plateau limit as located by the software in the Material Probability analysis.
Height UVL	The height at the upper valley limit, as located by the software in the Material Probability analysis.
Height LVL	The height at the lower valley limit. LVL is set with inspectors in the Material Probability plot. 
Std UPL	The standard deviation at the upper peak or plateau limit. UPL is set with inspectors in the Material Probability plot. 
Std LPL	The standard deviation at the lower peak or plateau limit, as located by the software in the Material Probability analysis.
Std UVL	The standard deviation at the upper valley limit, as located by the software in the Material Probability analysis.
Std LVL	The standard deviation at the lower valley limit. LVL is set with inspectors in the Material Probability plot. 

Hybrid Parameters

Other Hybrid Parameters

R_{sk}

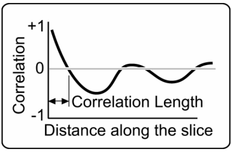
Skewness. A measure of symmetry of the profile about the mean line. Negative skew indicates a predominance of valleys, while positive skew indicates a "peaky" surface. Bearing surfaces should have negative skew.

$$R_{sk} = \frac{1}{n(R_q)^3} \sum_{\iota=1}^{i=n} (Y_i)^3$$

ACF

(Auto-covariance)

Autocorrelation function or Autocovariance. Used to determine the periodicity of a surface; it shows the dominant spatial frequencies along a cross section of the test surface. ACF is a measure of "self-similarity" of a profile - the extent to which a surface waveform pattern repeats. If the surface is random, the plot drops rapidly to zero. If the plot oscillates around zero in a periodic manner, then the surface has a dominant spatial frequency. Correlation Length is the length along the x-axis where the Autocovariance function first crosses zero.



$$ACF = \sum_{i=1}^{N-m} Y_i \, Y_i + m$$

Compliance with International Standards

ZYGO is an industrial leader in surface texture metrology and complies with numerous international standards for surface texture parameters, including:

- ANSI The American National Standards Institute
- ISO International Standards Organization
- JIS Japanese Industry Standard

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