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Surface Measurement Parameters for Wyko® Optical Profilers

R Parameters were originally developed for two-dimensional, stylus type profiling applications. Many of these statistics were later adapted for three-dimensional use as well, for systems such as optical profilers which are capable of true 3D measurement.

Term	Definition	Calculation	Use
R_a	*Roughness average* is the main height as calculated over the entire measured length or area. It is quoted in micrometers or micro-inches. R_a is calculated per the ANSI B46.1 standard.	Two-dimensional R_a $$R_a = \frac{1}{n}\sum_{i=1}^{n}\left\|Z_i - \bar{Z}\right\|$$ Three-dimensional R_a $$R_a = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\|Zji\right\|$$ where M and N = number of data points in X and Y, and Z is the surface height relative to the mean plane.	R_a is typically used to describe the roughness of machined surfaces. It is useful for detecting general variations in overall profile height characteristics and for monitoring an established manufacturing process.
R_q	The *Root means square* (rms) average between the height deviations and the mean line/surface, taken over the evaluation length/area The parameters "RMS" and "R_q" are equivalent in Wyko Vision®32 and are computed using the same equation.	Two-dimensional R_q $$R_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Z_i - \bar{Z}\right)^2}$$ Three-dimensional R_q $$R_q = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} Z^2(x_i, y_j)}$$	RMS roughness describes the finish of optical surfaces. It represents the standard deviation of the profile heights and is used in computations of skew and kurtosis.
R_p , R_v	*Maximum profile peak height* and *Maximum profile valley depth* are the distances from the mean line/surface to the highest/lowest point in the evaluation length/area.	Measured	Peak height provides information about friction and wear on a part. Valley depth provides information about how a part might retain a lubricant.
R_t	*Maximum height* is the vertical distance between the highest and lowest points in the evaluation length/area.	$R_t = R_p + R_v$	Maximum height describes the overall roughness of a surface.
R_z	The *Average maximum profile* of the ten greatest peak-to-valley separations in the evaluation area. Vision32 excludes an 11 x 11 region around each high (H) or low (L) point such that all peak or valley points won't emanate from one spike or hole.	$$R_z = \frac{1}{10}\left[\sum_{i=1}^{10} Hj - \sum_{j=1}^{10} Lj\right]$$	R_z is useful for evaluating surface texture on limited-access surfaces such as small valve seats and the floors and walls of grooves, particularly where the presence of high peaks or deep valleys is of functional significance.
R_{sk}	*Skewness* is a measure of the asymmetry of the profile about the mean line. Negative skew indicates a predominance of valleys, while positive skew is seen on surfaces with peaks.	$$R_{sk} = \frac{1}{nR_q^3}\sum_{i=1}^{n}\left(Z_i - \bar{Z}\right)^3$$	R_{sk} illustrates load carrying capacity, porosity, and characteristics of non-conventional machining processes. Negative skew is a criterion for a good bearing surface.
R_{ku}	*Kurtosis* is a measure of the distribution of spikes above and below the mean line. For spiky surfaces, $R_{ku} > 3$; for bumpy surfaces, $R_{ku} < 3$; perfectly random surfaces have kurtosis 3.	$$R_{ku} = \frac{1}{nR_q^4}\sum_{i=1}^{n}\left(Z_i - \bar{Z}\right)^4$$	Kurtosis describes machined surfaces and is rarely used for optical surfaces. It is sometimes specified for the control of stress fracture.

S Parameters were defined in 1991 by the attendees of the first EC Workshop on 3D Surface Measurement and Characterization. These statistics are well defined for measuring 3D data arrays, such as those generated by Wyko optical profilers. The S Parameters provide roughness, spatial and hybrid information for 3D surfaces. The parameters provide 3D equivalents to the standard 2D R-Parameters (S_a for R_a, S_{sk} for R_{sk}, etc.), as well as additional information relevant to 3D surfaces only. The S Amplitude parameters are described below.

Term	Definition	Calculation	Use
η(x,y)	*Residual Surface* - η(x,y)	The resulting data set after filtering options, if any, have been applied. Filtering may include tilt, cylinder, and/or curvature.	The residual surface is used in many of the S parameter calculations.
S_a	The *Roughness average* is the arithmetic mean of the absolute values of the surface departures from the mean plane.	$S_a = \frac{1}{MN}\sum_{j=l}^{N}\sum_{i=l}^{M}\left\|h(x_i, y_j)\right\|$ where M and N = the number of data points in X and Y.	S_a is normally used to describe the roughness of machined surfaces. It is useful for detecting variations in overall surface height and for monitoring an existing manufacturing process. A change in Sa usually signifies a change in the process.
S_q	The root mean square (RMS) roughness, obtained by squaring each height value in the dataset, then taking the square root of the mean.	$S_q = \sqrt{\frac{1}{MN}\sum_{J=l}^{N}\sum_{i=l}^{M}h^2(x_i, y_j)}$	For finish of optical surfaces. Represents the standard deviation of the profile and is used in computations of skew and kurtosis. S_q cannot detect spacing differences or the presence of infrequent high peaks or deep valleys.
S_z	The *Ten Point Average* of the absolute heights of the five highest peaks and five deepest valleys. Vision32 excludes a user-defined region around each high or low point to avoid all peak or valley points emanating from one feature.	$S_z = \frac{1}{5}\left[\sum_{i=l}^{5}\|h_{pi}\| + \sum_{i=l}^{5}\|h_{vi}\|\right]$	For evaluating surface texture on limited-access surfaces such as small valve seats or the floors and walls of grooves, particularly where the presence of high peaks or deep valleys is of functional significance. The S_z calculation reduces the effects of odd scratches or irregularities.
S_{sk}	*Skewness* measures the asymmetry of the profile about the mean plane. Negative skew indicates a predominance of valleys, while positive skew is seen on surfaces with peaks.	$S_{sk} = \frac{1}{NMS_q^3}\sum_{j=l}^{N}\sum_{i=l}^{M}h^3(x_i; y_j)$	S_{sk} can illustrate load carrying capacity, porosity, and characteristics of non-conventional machining processes. Surfaces that are smooth but are covered with particulates have positive skewness, while a surface with deep scratches/ pits will exhibit negative skewness. If S_{sk} exceeds ±1.5, you should not use average roughness alone to characterize the surface. Skewness is very sensitive to outliers in the surface data.
S_{ku}	*Kurtosis* is a measure of the "spikiness" of the surface, or the distribution of spikes above and below the mean line. For spiky surfaces, $S_{ku} > 3$; for bumpy surfaces, $S_{ku} < 3$; perfectly random surfaces have kurtosis of 3. Kurtosis is also a measure of the randomness of surface heights.	$S_{ku} = \frac{1}{NMS_q^4}\sum_{j=l}^{N}\sum_{i=l}^{M}h^4(x_i; y_j)$	Kurtosis is useful for evaluating machined surfaces and is sometimes specified for the control of stress fracture. S_{ku} is high when a high proportion of the surface falls within a narrow range of heights. If most of the surface is concentrated close to the mean surface level, S_{ku} will be different than if the height distribution contains more bumps and scratches. The farther the value is from 3, the less random (i.e., the more repetitive) is the surface.

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