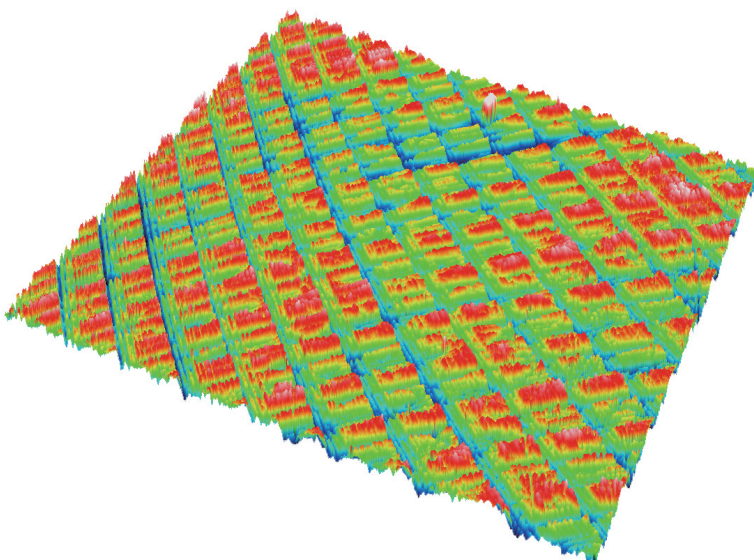


Introduction to Surface Roughness Measurement

Roughness measurement guidebook



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Introduction to Noncontact Surface Roughness Measurement

Laser Confocal Scanning Microscopes and Roughness Measurement

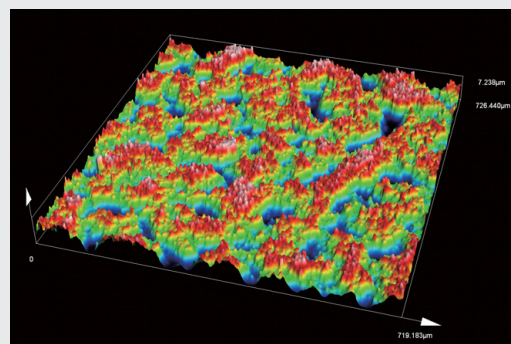
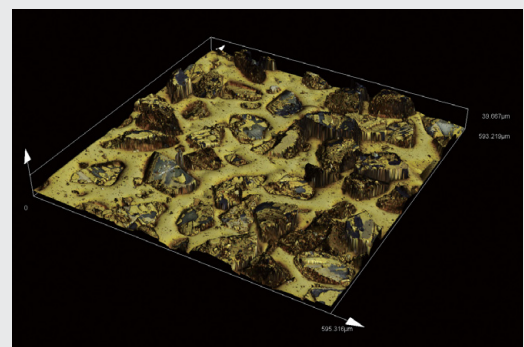
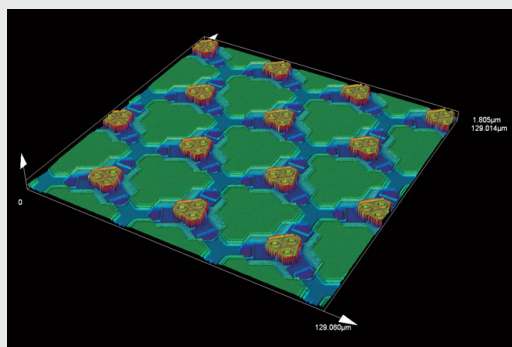
The spread of optical sensors

The transition to optical topographic measurement is important because of the proliferation of technological surfaces that cannot be measured at all or with sufficient fidelity using a conventional stylus. Many surfaces of interest, including those in fields like anthropology and archaeology, biotechnology, and engineering, require optical methods. Examples include high-pressure valve seats, battery electrodes, and even teeth. Microelectromechanical systems (MEMS) devices and other smaller parts also require optical technology.

There are differing expectations and practices for each application, and optical sensors are now the common sense choice. Even small firms are adopting optical technology, either by using other companies' equipment or buying their own. Such firms are broadening the range of applications for optical technology, such as examining teeth and surfaces made by additive manufacturing.

Trends in surface metrology and analysis

Surface metrology provides value in discovering functional correlations between roughness and performance and between processing and roughness. These discoveries depend on good measurement fidelity and resolution as well as analyzing the right geometrical features at the appropriate scales. The method of data analysis is equally important along with the data acquisition capabilities of the measurement instrument. Since three-dimensional surface texture parameters are essential for defining irregular surface features, analysis based on 3D surface texture is important.



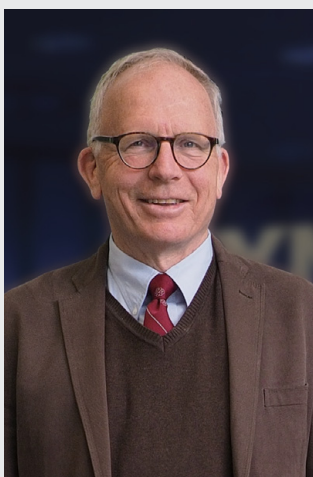
No longer dependent on Ra, Rz, and similar conventional indices of surface roughness, the science of modern surface measurement is developing innovative analytical methods acquired with high-quality measurement instruments.

The advantages of using an Olympus laser scanning microscope

Olympus' high-quality optics help eliminate many outliers before they occur. The quality of the resulting measurement is evident in multiscale analysis down to the finest scales.

The high-quality data produced by Olympus instruments minimize the problems caused by the amplification of errors in the calculation of finite approximations of derivatives for slopes and curvatures. Spike noise and other outliers that are often present in optical observations are generally eliminated by smoothing and similar filtering processes. However, such filtering processes are undesirable because they tend to eliminate correctly measured data along with the noise. Using an Olympus laser microscope, only the spike noise and other outliers are eliminated while the details of the observed data are preserved. The laser microscope's data processing capabilities are a significant advantage.

The broadness of range, fineness, and low-noise characteristics of Olympus laser microscopes deliver measurement results that are essential in the analysis of surface textures.



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A handwritten signature in black ink that reads "Christopher Brown". The signature is written in a cursive, flowing style.

October, 2017

About Surface Roughness

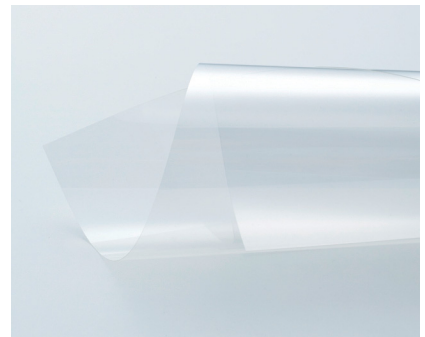
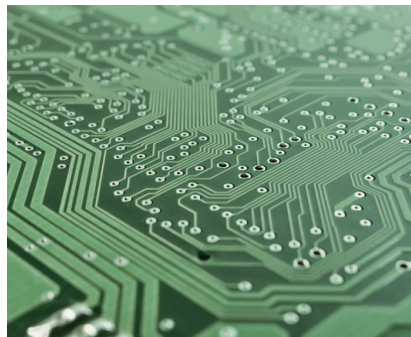
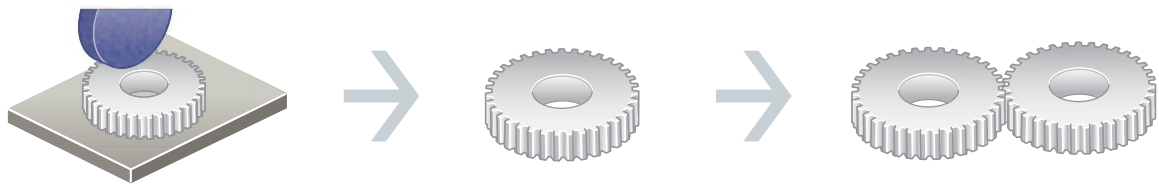
What is surface roughness?

Surface roughness indicates the condition of processed surfaces.

Surface conditions are determined by visual appearance and tactile feel and are often described using expressions such as smooth-and-shiny, matte-and-textured, mat-silver, or mirror-finish. The differences in both appearance and texture are derived from the irregularities present on the surface of the object.

Irregularities cause roughness on a surface. Surface roughness is a numerical scale of the surface condition of the shininess (or texture) that is not dependent on visual or tactile sensation. Surface roughness plays a significant role in determining the characteristics of a surface.

Facial irregularities on components and materials are either created intentionally or produced by various factors including the vibration of cutting tools, the bite of the edge used, or the physical properties of the material. Irregularities have diverse sizes and shapes and overlap in numerous layers; the concavities/convexities affect the quality and functionality of the object surface. In consequence, the irregularity impacts the performance of the resulting product in terms of friction, durability, operating noise, and air tightness. In the case of assembly components, the surface feature affects the characteristics of the final product, including friction, durability, operating noise, energy consumption, and air tightness. The surface features also influence the product's quality, such as the ink/pigment application and varnish of printing paper and panel materials.



Olympus has been participating in the Technical Committee of the International Organization for Standardization (ISO/TC213) since 2011 to promote the standardization of 3D surface texture measurement. At the same time, we have work to 3D surface texture measurement techniques to industry.

Olympus is committed to offering 3D surface texture measurement solutions that comply with international standards, thereby contributing to the development of manufacturing.

Why surface roughness needs to be measured

The size and configuration of features have a significant influence on the quality and functionality of processed surfaces and the performance of the final products. Consequently, it is important to measure the roughness of surfaces to meet high performance standards for resulting end products.

Surface irregularities measured by classifying the height/depth and intervals of surface features to evaluate their concavity/convexity. The results are then analyzed in accordance with predetermined methods, subject to a calculation based on industrial quantification (*).

The favorable or adverse influence of surface roughness is determined by the size and shape of the irregularities and the use of the product.

The level of roughness must be managed based on the desired quality and performance of the surface.

The measurement and evaluation of surface roughness is an old concept with numerous established parameters indicating various criterion of roughness. The progress of processing technology and the introduction of advanced measurement instruments enables the evaluation of diverse aspects of surface roughness.

* The industrial quantity determines the quantitative properties defined by the method of measurement (cf: roughness; hardness) instead of physical quantities, such as mass and length.

Trends in surface roughness measurement

Measuring the surface features of components and industrial products and the qualitative management of the resulting data is increasing with the evolution of nanotechnology and the higher performance demands and size-reduction of electronic devices. Conventional stylus roughness gages and other instruments designed to acquire height information through mechanical contact with the surface being measured were broadly able to measure surface height/features and the superficial condition of the surfaces. However, the increase of soft samples, like films, and surface features that are smaller than the tip of the stylus probe led to the demand for non-contact measurement techniques, from linear measurement to nondestructive/precise area measurement. To meet these demands, laser microscopes were developed as instruments capable of providing accurate, non-contact 3D measurement of the surface features of a sample within the presence of the atmosphere.



About Surface Roughness

Categories of surface texture parameters and applicable international standards

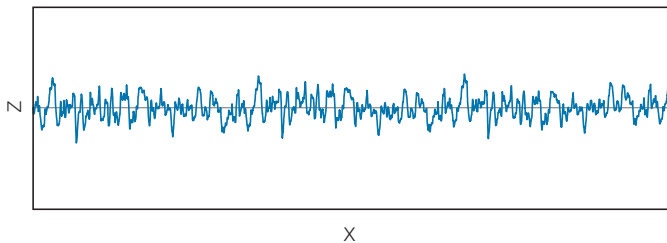
Superficial irregularities (roughness and undulation), dents, parallel grooves, and other characteristic surface features are collectively designated as “surface textures.” Converting these surface characteristics into numerical measurements is referred to as surface texture parameters.” Surface texture parameters are roughly categorized into the profile method and the areal method.

Profile method (line roughness measurement)

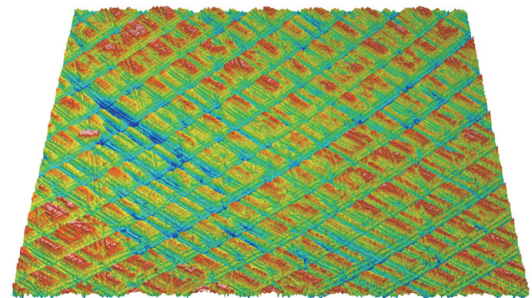
Conventionally, surface texture parameters were defined based on profile curves (curves indicated by the intersection of surfaces). The formal name for this method of measurement is the profile method, but it is also known as line roughness measurement. The surface profile is generally measured with stylus probe measurement instruments. ISO and other sets of international standards are designated for this method of measurement.

Areal method

Today, surface texture parameters are increasingly acquired through three-dimensional surface texture data with abundant areal information instead of the conventional two-dimensional contour profile curves used in profile method measurement. This is called the areal method. For the most part, the areal method involves non-contact measurement instruments based on optical observation.



Example of measurement using the profile method



Example of measurement using the areal method

Profile method versus the areal method

Measurement data acquired using the profile method is reliable since the data is obtained by directly tracing the surface with mechanical probes. Consequently, the profile method will likely remain a popular measurement technique for the foreseeable future. The disadvantages of the method are that it's not suitable for soft material since the contact probe can damage the surface being measured. In addition, since the measurement surface is evaluated based on the texture information obtained from a single section, the acquired data may not always reflect the irregularity characteristics of the overall surface area.

In contrast, most instruments based on non-contact three-dimensional measurement can work with soft materials without damaging the measurement surface. Also, three-dimensional data acquisition measures the surface characteristics over a large surface area, enabling users to characterize the orientation of parallel grooves and scratches that would be otherwise difficult to discern using the profile method. The areal method provides a lot of information and is effective at associating the required functionality of a surface, such as abrasion resistance, the adhesiveness between solids, and lubricant retention capability, with the surface parameters.

International standardization

The International Organization for Standardization (ISO) is promoting the designation of standards for areal measurement and many basic standards have already been adopted. The following table lists primary standards applicable to the profile and the areal method.

The profile method standards were created assuming the exclusive use of contact probe-based measurement instruments. The standards designated unified measurement condition requirements including evaluation length, cut off, the radius of the probe tip, etc. In the case of the areal method, various measurement instruments based on different operating principles are used, making it impossible to introduce unified measurement condition requirements. Accordingly, users are required to determine the suitable measurement conditions that correspond to the purpose of the evaluation. Hints for determining the measurement conditions are described in the section "the essentials of surface roughness evaluation using laser microscopy."

| | Profile method type | Areal method type |
|---|---------------------|-------------------|
| Surface texture parameters | ISO 4287:1997 | ISO 25178-2:2012 |
| | ISO 13565:1996 | |
| | ISO 12085:1996 | |
| Measurement conditions | ISO 4288:1996 | ISO 25178-3:2012 |
| | ISO 3274:1996 | |
| Filter | ISO 11562:1996 | ISO 16610 series |
| Categorization of measurement instruments | - | ISO 25178-6:2010 |
| Calibration of measurement instruments | ISO 12179:2000 | Under preparation |
| Standard test-pieces for calibration | ISO 5436-1:2000 | ISO 25178-70:2013 |
| Graphic method | ISO 1302:2002 | ISO 25178-1:2016 |

Primary standards of the profile and areal methods

About Surface Roughness

Various measurement instruments are capable of measuring surface roughness

Surface roughness measurement instruments can be categorized into contact-based and non-contact-based instruments. There are pros and cons to both methods, and it is important to select the most suitable instrument based on your application.

| Method | Measurement instrument | Merits | Demerits |
|-------------------------------|------------------------------------|---|---|
| Contact-based measurement | Stylus roughness instrument | <ul style="list-style-type: none"> ● Enables reliable measurement as the sample surface is physically traced with styluses ● Maintains a long track record of use | <ul style="list-style-type: none"> ● Limited to measuring a single section with a reduced quantity of acquired information ● In capable of conducting measurement of adhesive surfaces and soft samples ● Difficult to precisely position the probe ● Capable of measuring details smaller than the stylus probe tip diameter |
| | Coherence scanning interferometers | <ul style="list-style-type: none"> ● Quick measurements ● Enables measurement of smooth surfaces of sub-nm order at low magnification | <ul style="list-style-type: none"> ● Has trouble measuring rough surfaces ● Has trouble measuring samples with significant differences in brightness ● Low contrast makes it difficult to locate the areas subject to measurement ● Low XY resolution |
| Non-contact-based measurement | Laser Microscope | <ul style="list-style-type: none"> ● High angle detection sensitivity, enabling analysis of steeply inclined slopes ● High XY resolution, providing for clear, high-contrast images | <ul style="list-style-type: none"> ● Incapable of conducting sub-nanometer measurements ● Inferior height discrimination capabilities at lower magnification rates |
| | Digital microscope | <ul style="list-style-type: none"> ● Enables many kinds of observations and a simple level of measurement | <ul style="list-style-type: none"> ● Not suitable for measuring component roughness (suitable for measuring waviness) ● Incapable of measuring sub-nanometer irregularities ● Low XY resolution |
| | Scanning probe microscope (SPM) | <ul style="list-style-type: none"> ● Enables measurement of sub-nanometer surfaces ● Enables measurement of samples with relatively high aspect ratio | <ul style="list-style-type: none"> ● Difficulty in precisely positioning the probe ● Conducting the measurement takes time ● Not suitable for measuring μm irregularities |

Description of technical glossaries

Profile method glossary

Primary profile curve

The curve obtained by applying a low-pass filter with a cutoff value of λ_s to the primary profile measured. The surface texture parameter calculated from the primary profile is referred to as the primary profile parameter (P-parameter).

Roughness profile

The profile derived from the primary profile by suppressing the long wave component using the high-pass filter with a cutoff value of λ_c . The surface texture parameter calculated from the roughness profile is referred to as the roughness profile parameter (R-parameter).

Waviness profile

The profile obtained by sequential application of profile filters with cutoff values of λ_f and λ_c to the primary profile. λ_f cuts off the long wave component while the short wave component is cut off with filter λ_c . The surface texture parameter calculated from the waviness profile is referred to as the waviness profile parameter (W-parameter).

Profile filter

The filter for the isolation of the long and short wave components contained in the profile. Three types of filters are defined:

λ_s filter: Filter designating the threshold between the roughness component and shorter wave components

λ_c filter: Filter designating the threshold between the roughness component and waviness components

λ_f filter: Filter designating the threshold between the waviness component and longer wave components

Cut-off wavelength

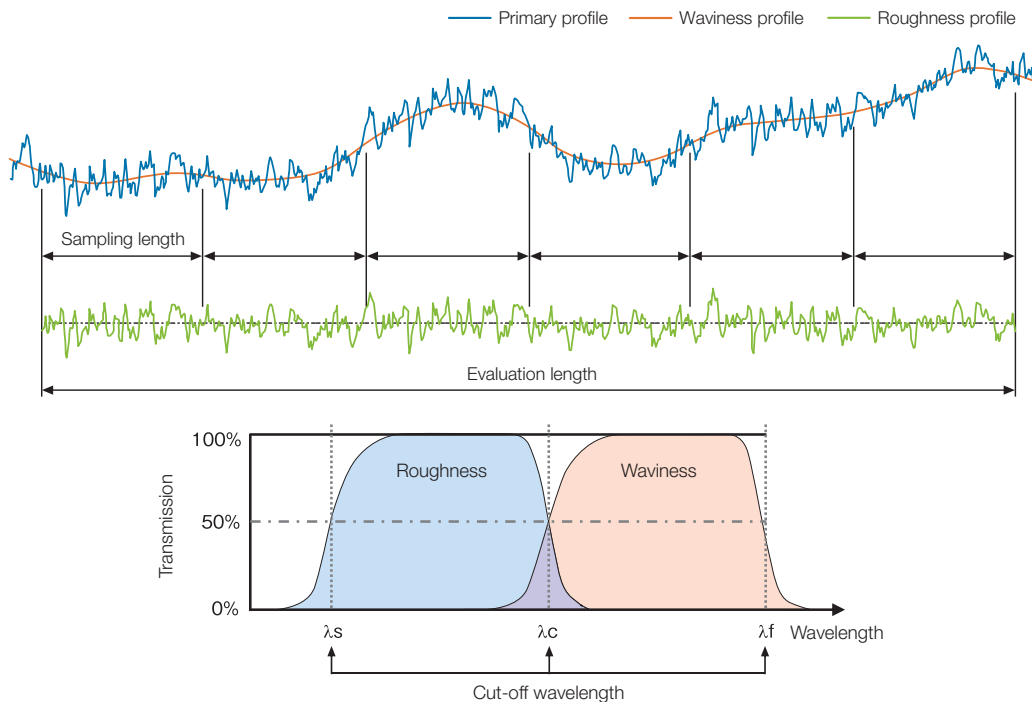
Threshold wavelength for profile filters. Wavelength indicating 50% transmission factor for a given amplitude.

Sampling length

The length in the direction of the X-axis used for the determination of profile characteristics.

Evaluation length

Length in the direction of the X-axis used for assessing the profile under evaluation.



Conceptual drawing of Profile method

About Surface Roughness

Description of technical glossaries

Areal method glossary

Scale limited surface

The surface data are serving as the basis for the calculation of areal surface texture parameters. S-F surface or S-L surface. Sometimes simply referred to as 'surface.'

Areal filter

The filter for the separation of the long and short wave components contained in the scale-limited surfaces. Three types of filters are defined according to function:

S filter: Filter eliminates small wavelength components from scale-limited surfaces

L filter: Filter eliminates large wavelength components from scale-limited surfaces

F operation: Association or filter for the elimination of specific forms (spheres, cylinders, etc.)

NOTE) Gaussian filters are generally applied as S and L filters, and the total least square association is applied for the F operation.

Gaussian filter

A type of areal filter normally used in areal measurement. Filtration is applied by convolution based on weighting functions derived from a Gaussian function. The value of the nesting index is the wavelength of a sinusoidal profile for which 50% of the amplitude is transmitted.

Spline filter

A type of areal filter with smaller distortion in the peripheral edge when compared to the Gaussian filter.

Nesting index

The index representing the threshold wavelength for areal filters. The nesting index for the application of areal Gaussian filters are designated in terms of units of length and equivalent to the cutoff value in the profile method.

S-F surface

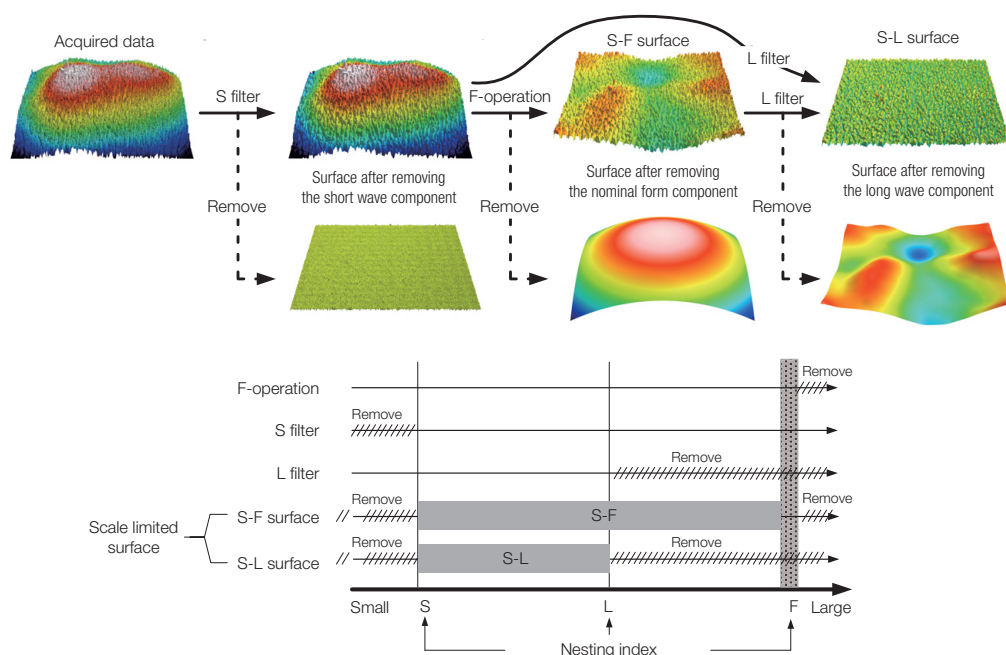
The surface obtained by eliminating small wavelength components using the S filter and then processed by removing certain form components using the F operation.

S-L surface

The surface obtained by eliminating small wavelength components using the S filter and then eliminating large wavelength components using L filtration.

Evaluation area

A rectangular portion of the surface designated for characteristic evaluation. The evaluation area shall be a square (if not otherwise specified).



Conceptual drawing of the areal method

Essentials of surface roughness evaluation using laser microscopy

Point 1 Guide to selecting objective lenses

- 1) From the items listed below, select the appropriate objective lenses (◎, ○) based on the item to be measured (roughness, waviness, or unevenness). Be sure that the working distance (W.D.) value exceeds the clearance between the sample and the lens.
- 2) If there are multiple objective lenses candidates, make a final selection. The size of the field of the measurement is typically chosen to be five times the scale of the coarsest structure of interest.

— In case multiple candidates are available, select the objective lens with the largest possible numerical aperture (N.A.).

— If no suitable lens is available, either return to candidate selection and include objective lenses marked as △ or consider expanding the area of measurement using the stitching function.

| Objectives | Specification | | | | Measurement item | | |
|-----------------|---------------------------|-------------------------------------|-------------------------------------|------------------------------------|------------------|----------|----------------|
| | Numerical Aperture (N.A.) | Working Distance (W.D.) (Units: mm) | Focusing spot diameter* (Units: μm) | Field of measurement** (Units: μm) | Roughness | Waviness | Unevenness (Z) |
| MPLFLN2.5x | 0.08 | 10.7 | 6.2 | 5120×5120 | × | × | × |
| MPLFLN5x | 0.15 | 20 | 3.3 | 2560×2560 | × | × | × |
| MPLFLN10xLEXT | 0.3 | 10.4 | 1.6 | 1280×1280 | × | ○ | △ |
| MPLAPON20xLEXT | 0.6 | 1 | 0.82 | 640×640 | △ | ○ | ○ |
| MPLAPON50xLEXT | 0.95 | 0.35 | 0.52 | 256×256 | ◎ | ○ | ◎ |
| MPLAPON100xLEXT | 0.95 | 0.35 | 0.52 | 128×128 | ◎ | ○ | ◎ |
| LMPLFLN20xLEXT | 0.45 | 6.5 | 1.1 | 640×640 | △ | ○ | ○ |
| LMPLFLN50xLEXT | 0.6 | 5 | 0.82 | 256×256 | △ | ○ | ○ |
| LMPLFLN100xLEXT | 0.8 | 3.4 | 0.62 | 128×128 | ○ | ○ | ◎ |
| SLMPLN20x | 0.25 | 25 | 2 | 640×640 | × | ○ | △ |
| SLMPLN50x | 0.35 | 18 | 1.4 | 256×256 | × | ○ | △ |
| SLMPLN100x | 0.6 | 7.6 | 0.82 | 128×128 | △ | ○ | ○ |
| LCPLFLN20xLCD | 0.45 | 7.4-8.3 | 1.1 | 640×640 | △ | ○ | ○ |
| LCPLFLN50xLCD | 0.7 | 3.0-2.2 | 0.71 | 256×256 | ○ | ○ | ○ |
| LCPLFLN100xLCD | 0.85 | 1.0-0.9 | 0.58 | 128×128 | ○ | ○ | ◎ |

*: Theoretical value.

** : Standard value when using OLS5000.

◎: Most suitable.

○: Suitable.

△: Acceptable depending on usage.

×: Not suitable.

Essentials of surface roughness evaluation using laser microscopy

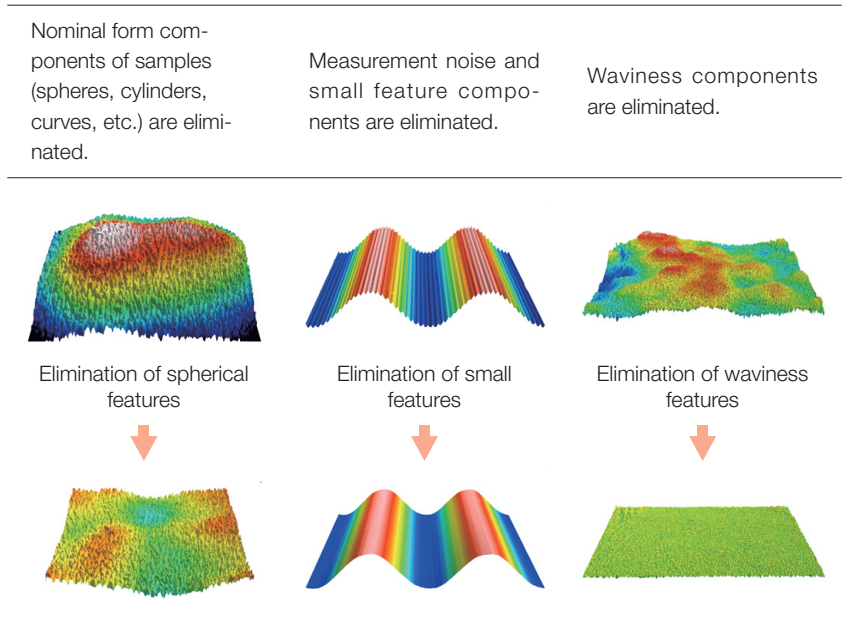
Point 2 Method of filter application

The functionality of the respective filters, the combination of filters, and the size of the filters used in surface feature analysis are as described below:

The filtering conditions are determined in accordance with the objectives of the analysis.

Filter functionality

In conducting surface feature parametric analysis, the application of three types of filters (F operation, S filter, and L filter) should be considered for the surface texture data acquired in accordance with the objectives of the measurement.



Combination of filters

A total of eight combinations are available for the three filters (F operation, S filter, and L filter). Select the combination of filters to be applied referencing the list of measurement objectives indicated in the following table.

—: Non-application ○: Application

| Intended purpose | When analyzing raw acquired data | When eliminating waviness component | When eliminating spheres, curves and other form components | When eliminating spheres, curves and other form components in addition to the waviness component | When eliminating small roughness components and noises | When eliminating small roughness components, noises and waviness components | When eliminating spheres, curves and other form components along with small roughness components and noises | When eliminating small roughness components and noises, spheres, curves and other feature components in addition to the waviness component |
|------------------|----------------------------------|-------------------------------------|--|--|--|---|---|--|
| F-operation | - | - | ○ | ○ | - | - | ○ | ○ |
| S filter | - | - | - | - | ○ | ○ | ○ | ○ |
| L filter | - | ○ | - | ○ | - | ○ | - | ○ |

Filter size (nesting indices)

- Filtering strength (separating capabilities) is referred to as nesting indices (L filters are alternately called cutoffs.)
 - The S filter eliminates increasingly more detailed feature components the larger the nesting index value is.
 - The L filter eliminates increasingly more waviness feature components the smaller the nesting index value is.
- Although the use of numerical values (0.5, 0.8, 1, 2, 2.5, 5, 8, 10, 20) are recommended when defining nesting index values, the following restrictions apply:
 - The nesting index value for S filters needs to be specified to exceed the optical resolution (\approx focusing spot diameter) and at least three times the value of the data sampling interval.
 - The nesting index for the L filter needs to be set to a value smaller than the area of measurement (length of the narrow side of the rectangular area).

Point 3 Selecting the roughness parameter

Depending on the purpose of the evaluation, the analysis conducted based on the following parameters are considered to be effective:

| Example of purpose | Parameter, or method of analysis | Page |
|--|----------------------------------|------|
| (1) Evaluating the unevenness | Sq, Sa, Sz, Sp, Sv | P.13 |
| (2) Evaluating the height distribution | Ssk, Sku, Histogram analysis | P.14 |
| (3) Evaluating the fineness | Sal, Sdq, Sdr | P.15 |
| (4) Evaluating the direction | Std, Str, directional plotting | P.16 |
| (5) Evaluating the periodicity | PSD | P.17 |
| (6) Evaluating the dominant feature component | PSD | P.18 |
| (7) Evaluating the quantity and tip configuration of protrusions | Spd, Spc | P.19 |
| (8) Evaluating the variation before/after abrasion | Sk, Spk, Svk | P.20 |

Detailed explanations of items (1) to (8) are provided in the next section using specific examples.

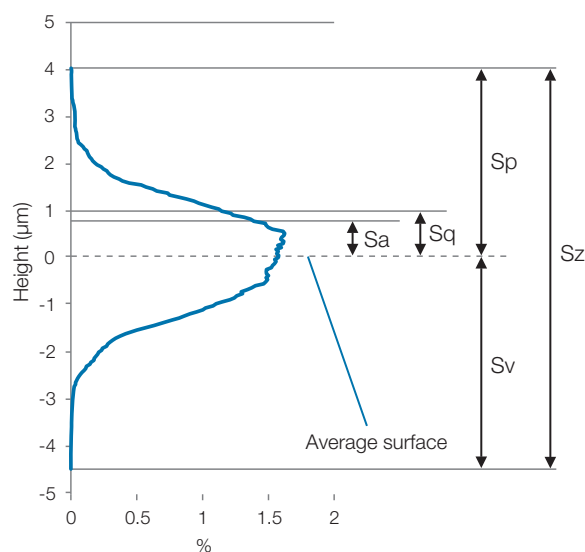
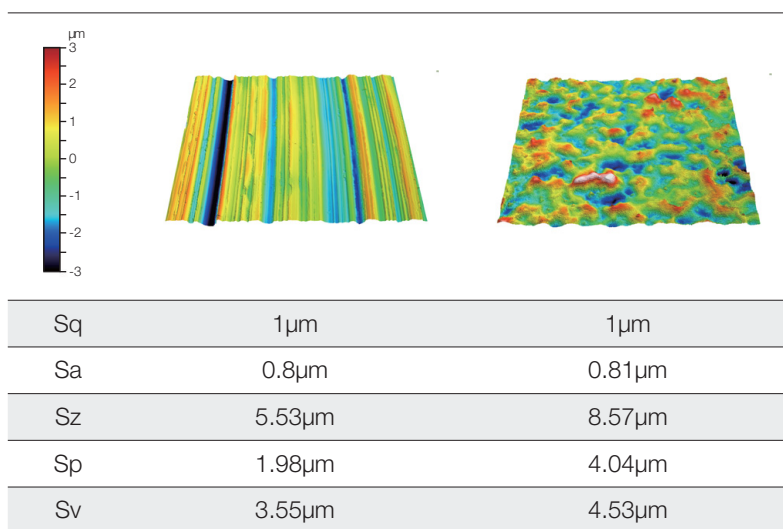
Selecting the roughness parameter

Evaluating the unevenness

(Sq, Sa, Sz, Sp, Sv)

The unevenness can be evaluated using the height parameter (Sq, Sa, Sz, Sp, and Sv). Within the histogram, height parameters have a relationship as indicated below.

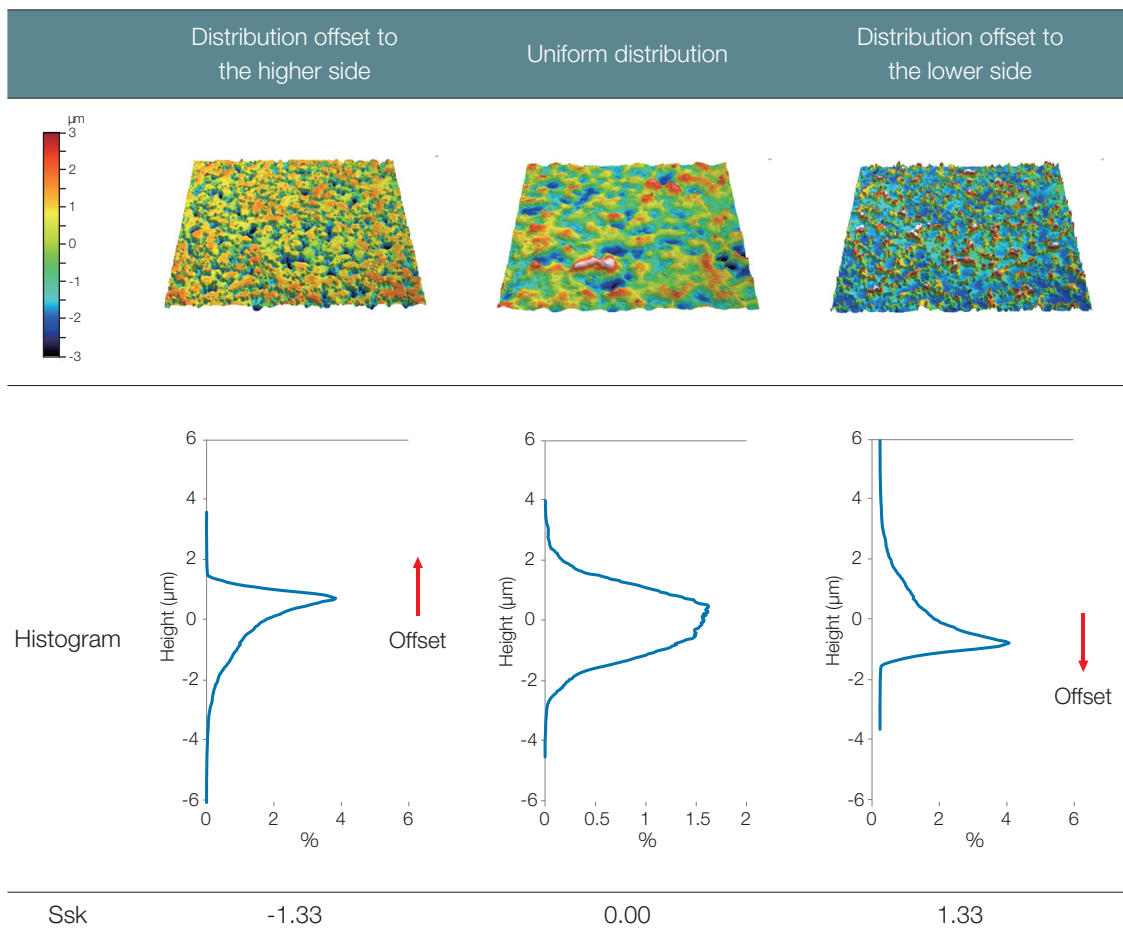
Sq (squared mean height) is equivalent to the standard deviation of height distribution and is an easy-to-handle statistical parameter. Sa (arithmetic mean height) is the mean difference in height from the mean plane. When the height distribution is normal, the relationship between the parameters Sq and Sa becomes $Sa \approx 0.8 \cdot Sq$. As parameters Sz, Sq, and Sv utilize maximum and minimum height values, the stability of the results may be adversely affected by measurement noise. Height parameter is a parameter determined solely by the distribution of height information. Accordingly, the characteristics of horizontal features are not reflected in these parameters.



Evaluating the height distribution (Ssk, Sku, histogram)

The height distribution is generally evaluated in the form of histogram charts. Ssk is a parameter used in the evaluation of the degree of asymmetry in the graphic representation (distribution) of the histogram chart.

Ssk = 0 signifies that the difference in height is distributed uniformly, while minus values of the parameter indicate a deviation to the higher side and plus indicates a deviation to the lower side. In samples with the higher features whittled away due to sliding abrasion, Ssk values tend to indicate negative values. Because of this, the parameter is sometimes used as an evaluation index for the extent of sliding abrasion.



Selecting the roughness parameter

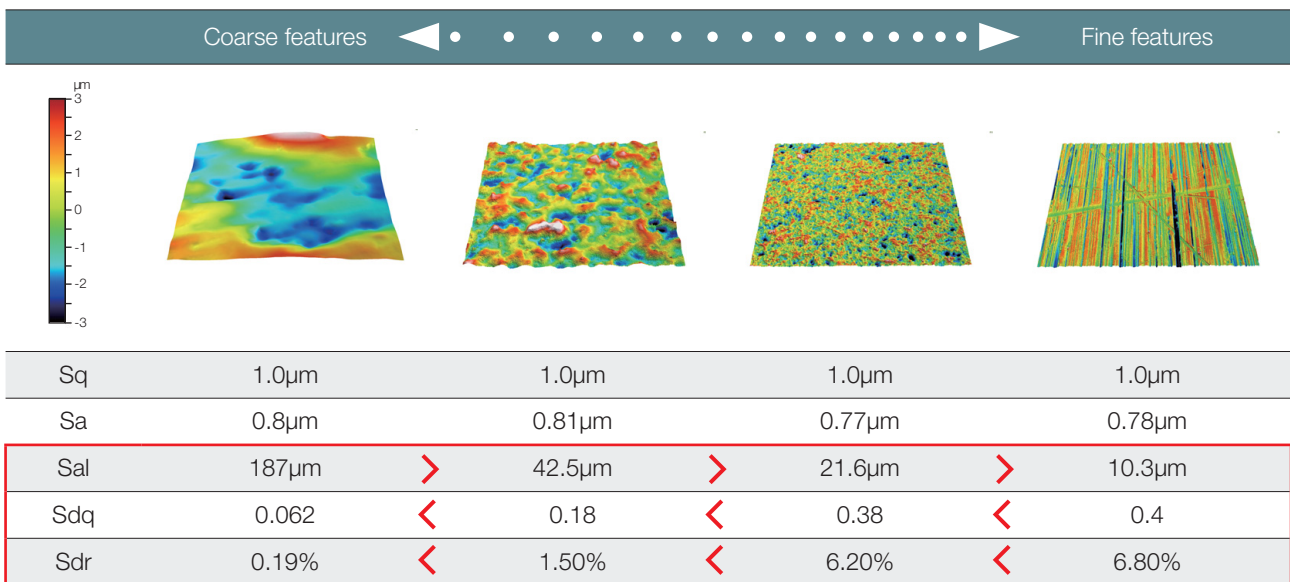
Selecting the roughness parameter

Evaluating the fineness

(Sa, Sdq, Sdr)

The Sa parameter provides a numerical index of the density of similar structures in units of length. Features become finer as the value gets smaller.

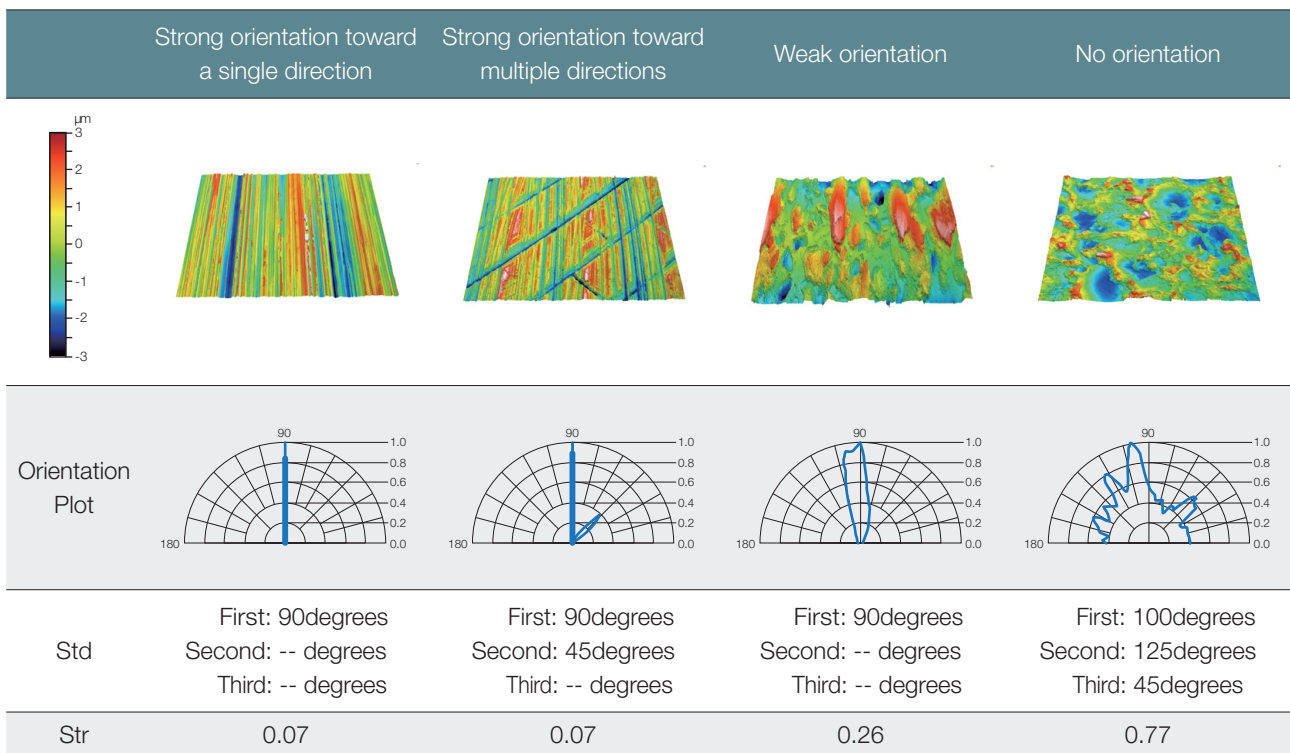
Indirect indices representing the fineness of features include local gradients and the superficial area. Sdq is the mean value of local gradients present on the surface, while Sdr is a parameter indicating the rate of growth in the superficial area. If height parameters such as Sa and Sq are on a comparable level, the degree of fineness becomes finer as parameters Sdq (gradient) and Sdr (superficial area) become larger.



Evaluating the orientation (Std, Str, directional plotting)

The orientation plot represents the directional properties of surface features as an angular chart. Plotted peaks become sharper as the orientation becomes pronounced. The strength of orientation is normalized, so the strongest peak is in contact with the outermost circle. Within an orientation plot, the Std parameter indicates the angle of peaks sequentially from the largest peak.

The Str parameter is a numerical representation of the strength of orientation. $Str < 0.3$ signifies a (directional) anisotropic surface, while $Str > 0.5$ represents an isotropic surface.

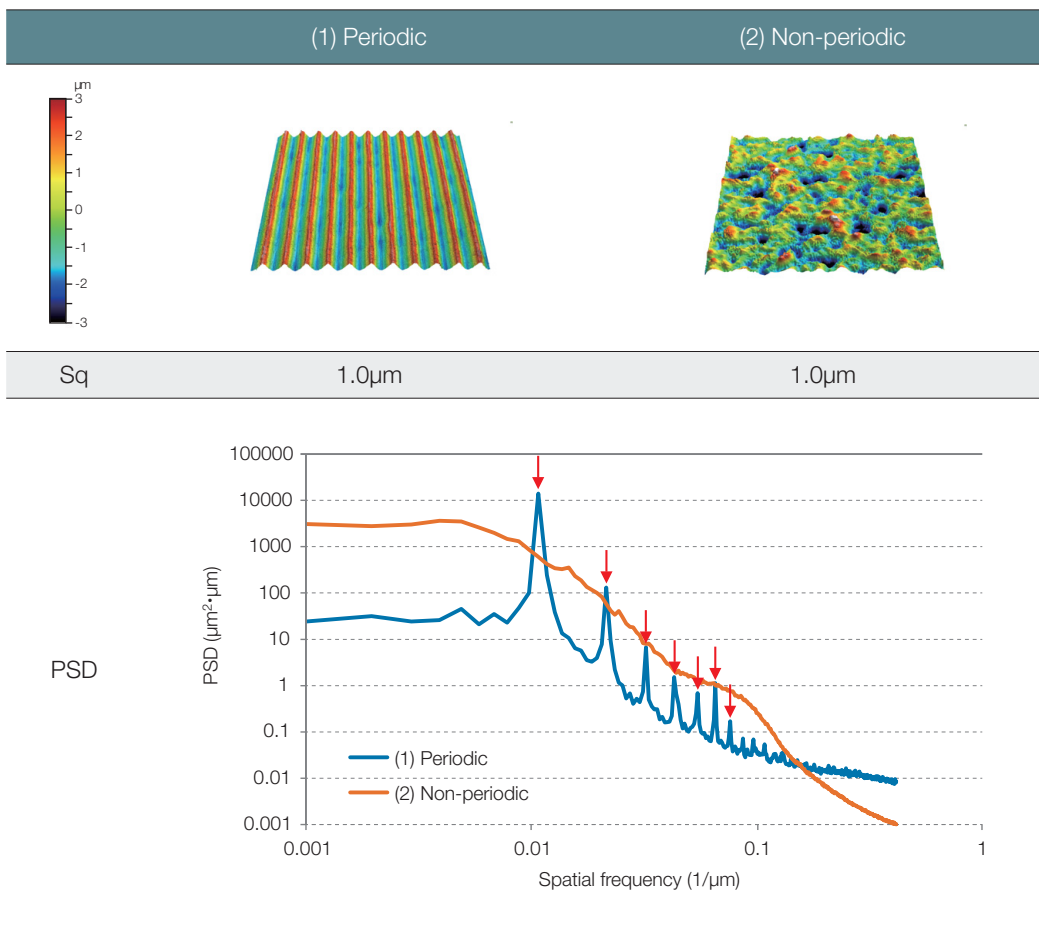


Selecting the roughness parameter

Evaluating the periodicity (PSD)

Power spectral density (PSD) represents the magnitude of surface unevenness for the respective spatial frequency. In samples with periodicity, peaks (arrows) are present in the PSD chart. The frequency of the periodicity (inverse number of the cycle) can be obtained by determining the horizontal axis of the peak.

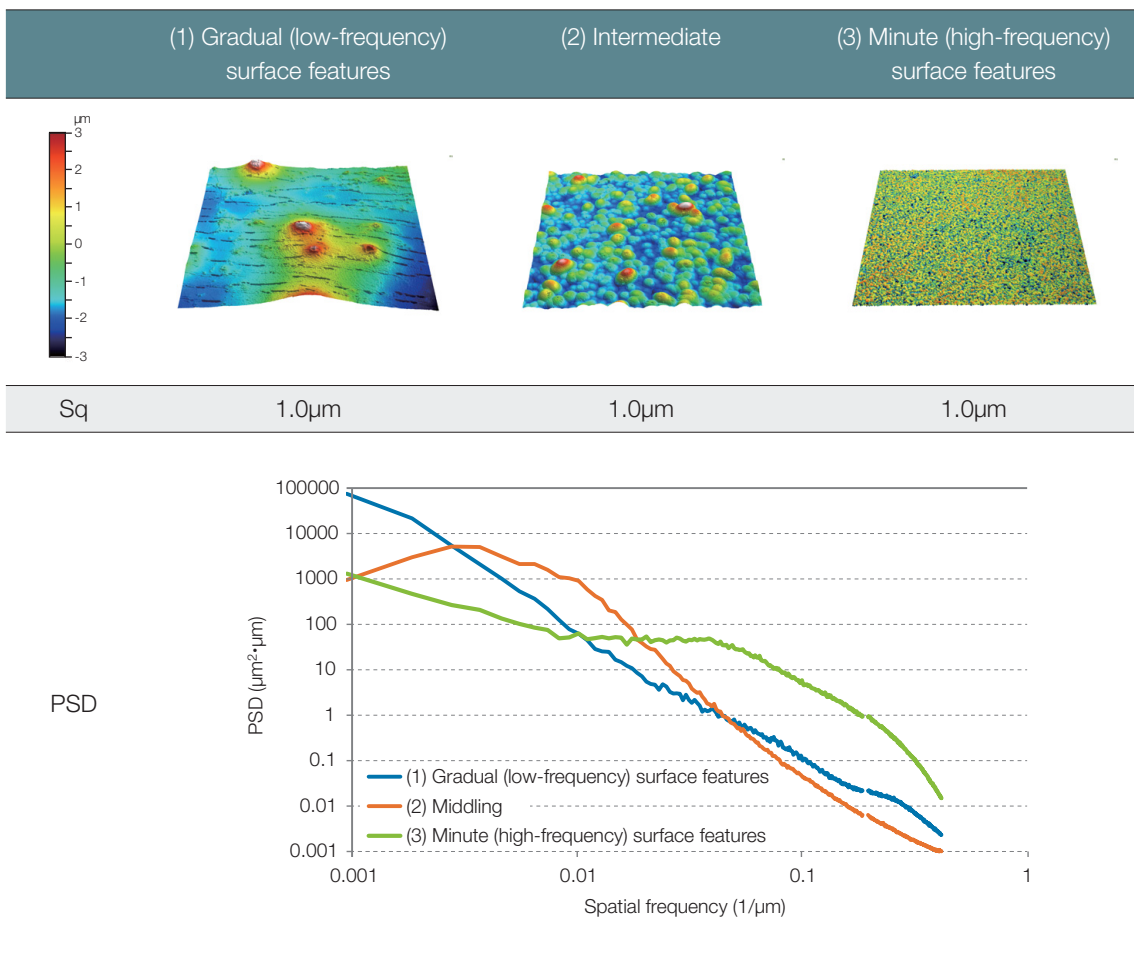
The chart shows a general decline to the right if no periodicity is present.



Evaluating the dominant feature component (PSD)

Power spectral density (PSD) represents the magnitude of surface unevenness for respective spatial frequency “Gradual,” “minute,” and similar feature characteristics are reflected in the PSD charts.

In gradual surface features, the values on the low-frequency end (left side of the chart) tend to be larger. In minute surface features, the values on the high-frequency end (right side of the chart) tend to be larger.



Selecting the roughness parameter

Selecting the roughness parameter

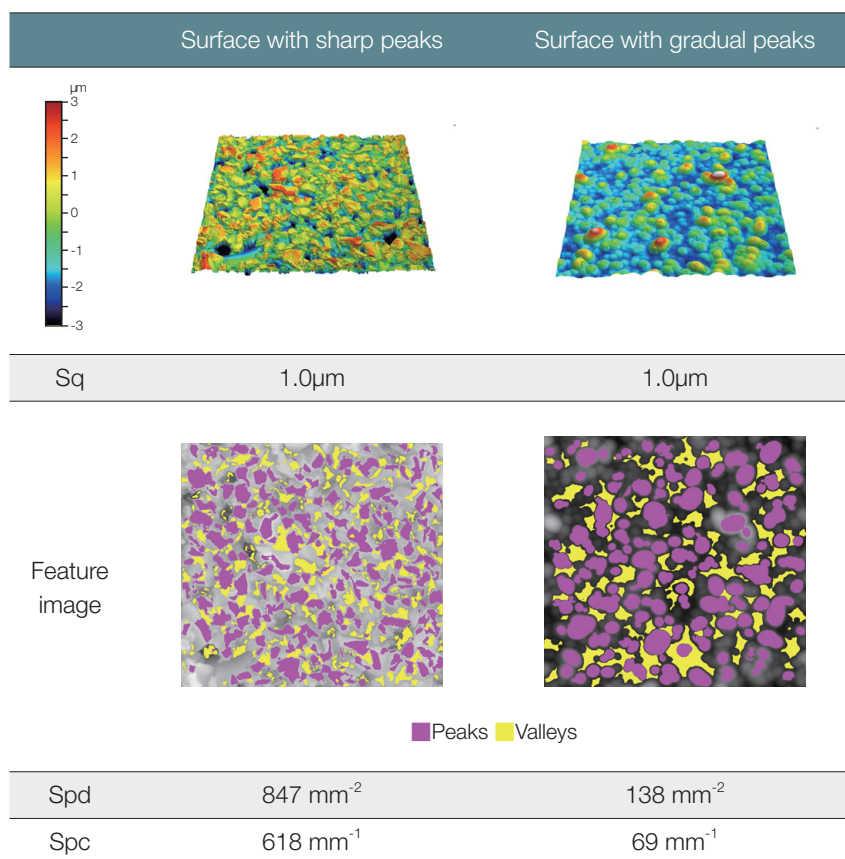
Evaluating the quantity and tip configuration of peaks (Spd, Spc)

Peaks present on the surface relate to the osculation of objects, friction, abrasion, and similar phenomena.

The feature image indicates the categorized topographical characteristics (peaks, valleys, ridge lines, and channel lines) of the surfaces. The Spd parameter represents the density (number of features per unit area) of surface features categorized into peaks (colored pink) within the feature image.

The Spc parameter represents the mean curvature radius of peaks for surface features categorized into peaks within the feature image.

As the Spc value becomes larger, the curvature of peaks grow smaller (sharper), and the curvature increases (obtuse) as the value gets smaller.

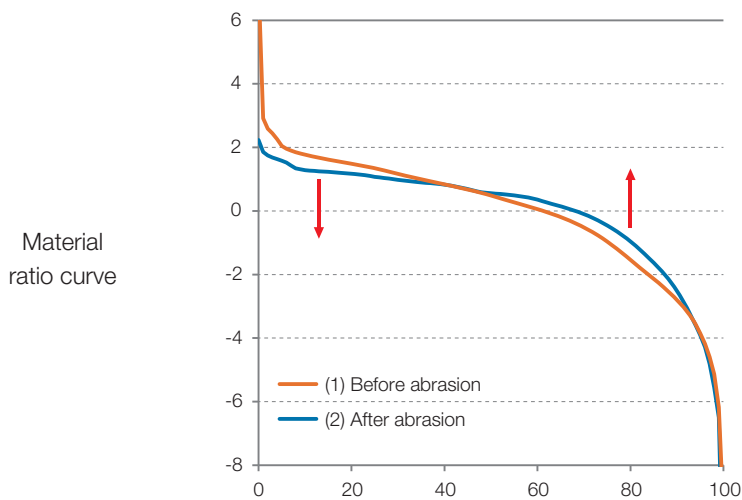
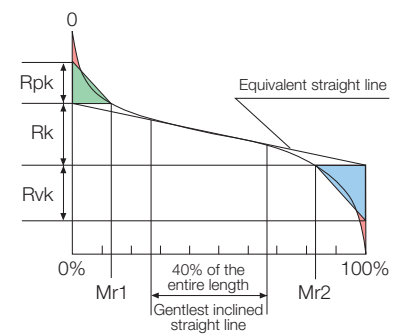
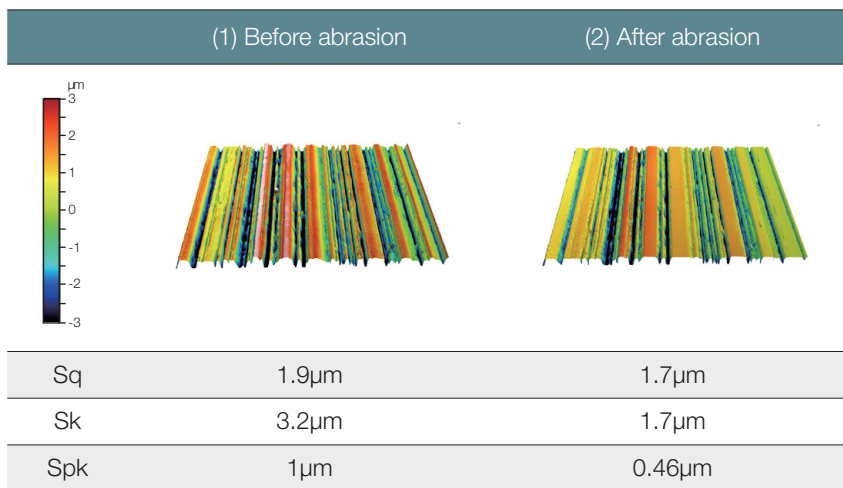


Evaluating the variation before/after abrasion (Sk, Spk, Sv_k)

Generally, abrasion progresses from the surface's highest position. The use of height distribution based parameters is effective in the evaluation of abrasion status.

With the progress of abrasion, the curve in the higher portion of the material ratio curve moves downward, while the curve on the lower portion shifts upward.

The values for the parameters Sk and Spk decline in correspondence with the progress of abrasion.



Profile method (linear roughness)

| Amplitude parameters (peak and valley) (ISO4287:1997) | Symbol | Equivalent areal parameters | Page |
|--|---------------------------|--|-------------|
| Maximum height | Pz, Rz, Wz | Sz | P.22 |
| Maximum profile peak height | Pp, Rp, Wp | Sp | P.22 |
| Maximum profile valley depth | Pv, Rv, Wv | Sv | P.22 |
| Mean height | Pc, Rc, Wc | - | P.23 |
| Total height | Pt, Rt, Wt | - | P.23 |
| Amplitude average parameters (ISO4287:1997) | | | |
| Arithmetic mean deviation | Pa, Ra, Wa | Sa | P.24 |
| Root mean square deviation | Pq, Rq, Wq | Sq | P.24 |
| Skewness | Psk, Rsk, Wsk | Ssk | P.24 |
| Kurtosis | Pku, Rku, Wku | Sku | P.25 |
| Spacing parameters (ISO4287:1997) | | | |
| Mean width | PSm, RSm, WSm | - | P.25 |
| Hybrid parameters (ISO4287:1997) | | | |
| Root mean square slope | Pdq, Rdq, Wdq | Sdq | P.25 |
| Material ratio curves and related parameters (ISO4287:1997) | | | |
| Material ratio | Pmr (c), Rmr (c), Wmr (c) | Smr (c) | P.26 |
| Profile Section height difference | Pdc, Rdc, Wdc | Sxp NOTE1) | P.26 |
| Relative material ratio | Pmr, Rmr, Wmr | - | P.26 |
| Parameters of surface having stratified functional properties (ISO13565-2:1996) | | | |
| Core roughness depth | Rk | Sk | P.27 |
| Reduced peak height | Rpk | Spk | P.27 |
| Reduced valley height | Rvk | Svk | P.27 |
| Material portion | Mr1 | Smr1 | P.27 |
| Material portion | Mr2 | Smr2 | P.27 |
| Motif parameters (ISO12085:1996) | | | |
| Mean spacing of roughness motifs | AR | - | P.27 |
| Mean depth of roughness motifs | R | - | P.27 |
| Maximum depth of roughness motifs | Rx | - | P.27 |
| Mean spacing of waviness motifs | AW | - | P.27 |
| Mean depth of waviness motifs | W | - | P.27 |
| Maximum depth of waviness motifs | Wx | - | P.27 |

NOTE 1) Condition of calculation may differ between profile and three-dimensional methods.

Amplitude parameters (peak and valley)

Maximum height (R_z)

Represents the sum of the maximum peak height Z_p and the maximum valley depth Z_v of a profile within the reference length.

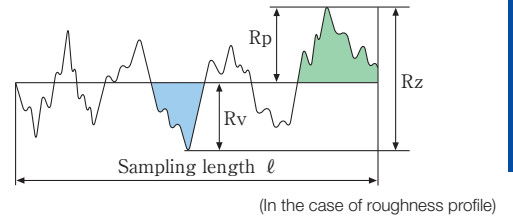
- * Indicated as R_y within JIS' 94
- * Profile peak: Portion above (from the object) the mean profile line (X-axis)
- * Profile valley: Portion below (from the surrounding space) the mean profile line (X-axis)

- **Pz** Maximum height of the primary profile
- **Wz** Maximum height of the waviness

POINT

Although frequently used, max height is significantly influenced by scratches, contamination, and measurement noise due to its reliance on peak values.

$$R_z = R_p + R_v$$

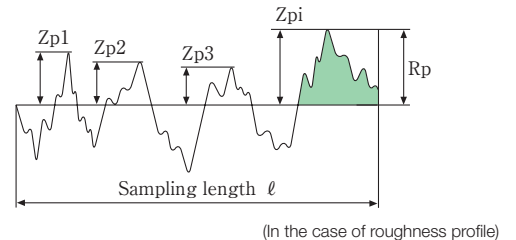


Maximum profile peak height (R_p)

Represents the maximum peak height Z_p of a profile within the sampling length.

- **Pp** The maximum peak height of the primary profile
- **Wp** The maximum peak height of the waviness profile

$$R_p = \max(Z(x))$$

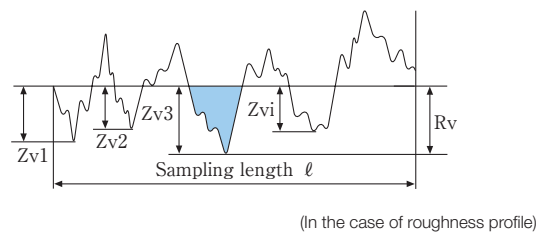


Maximum profile valley depth (R_v)

Represents the maximum valley depth Z_v of a profile within the sampling length.

- **Pv** The maximum valley depth of the primary profile
- **Wv** The maximum valley depth of the waviness profile

$$R_v = \min(Z(x))$$



Profile method (linear roughness) parameters

Amplitude parameters (peak and valley)

Mean height (Rc)

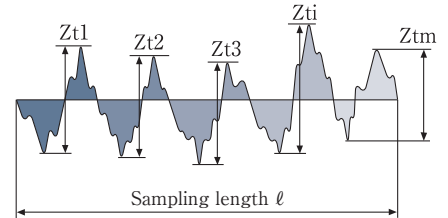
Represents the mean for the height Z_t of profile elements within the sampling length.

- * Profile element: A set of adjacent peaks and valleys
- * Minimum height and minimum length to be discriminated from the peaks (valleys).

Minimum height discrimination: 10% of the R_z value
 Minimum length discrimination: 1% of the reference length

- **Pc** The mean height of the primary profile element
- **Wc** The mean height of the waviness element

$$R_c = \frac{1}{m} \sum_{i=1}^m Z_{ti}$$



(In the case of roughness profile)

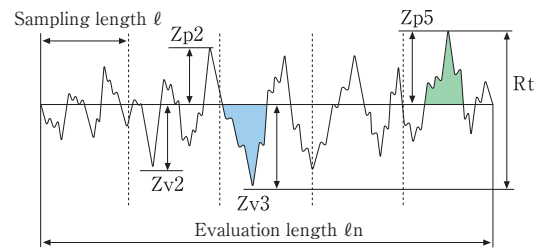
Total height (Rt)

Represents the sum of the maximum peak height Z_p and the maximum valley depth Z_v of a profile within the evaluation length, not sampling length.

- * Relationship $R_t \geq R_z$ applies for all profiles.

- **Pt** The maximum total height of the profile (R_{max} in the case of JIS'82)
- **Wt** The maximum total height of the waviness

$$R_t = \max(Z_{pi}) + \max(Z_{vi})$$



(In the case of roughness profile)

POINT

R_t is a stricter standard than R_z in that the measurement is conducted against the evaluation length. It should be noted that the parameter is significantly influenced by scratches, contamination, and measurement noise due to its utilization of peak values.

Ten-point mean roughness (Rzjis)

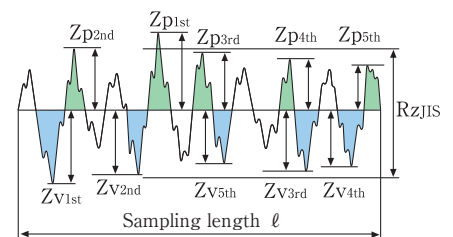
Represents the sum of the mean value for the height of the five highest peaks and the mean of the depth of the five deepest valleys of a profile within the sampling length.

- * Indicated as R_z within JIS'94

POINT

R_{zjis} is equivalent to the parameter R_z of the obsolete JIS standard B0601:1994. Although ten-point mean roughness was deleted from current ISO standards, it was popularly used in Japan and was retained within the JIS standard as parameter R_{zjis} .

$$R_{zjis} = \frac{1}{5} \sum_{j=1}^5 (Z_{pj} + Z_{vj})$$



(In the case of roughness profile)

Amplitude average parameters

Arithmetic mean deviation (Ra)

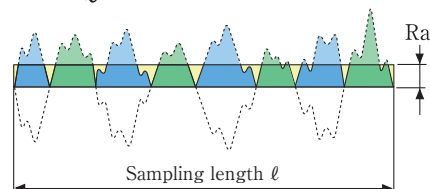
Represents the arithmetic mean of the absolute ordinate $Z(x)$ within the sampling length.

- **Pa** The arithmetic mean height of the primary profile
- **Wa** The arithmetic mean waviness

POINT

One of the most widely used parameters is the mean of the average height difference for the average surface. It provides for stable results as the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$Ra = \frac{1}{\ell} \int_0^{\ell} |Z(x)| dx$$



(In the case of roughness profile)

Root mean square deviation (Rq)

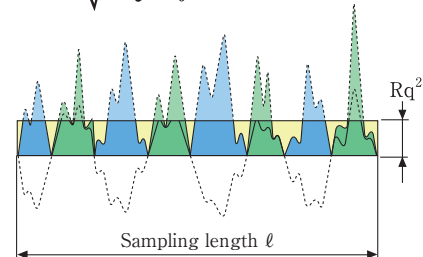
Represents the root mean square for $Z(x)$ within the sampling length.

- **Pq** The root mean square height for the primary profile
- **Wq** Root mean square waviness

POINT

This is one of the most widely used parameters and is also referred to as the RMS value. The parameter Rq corresponds to the standard deviation of the height distribution. The parameter provides for easy statistical handling and enables stable results as the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$Rq = \sqrt{\frac{1}{\ell} \int_0^{\ell} Z^2(x) dx}$$



(In the case of roughness profile)

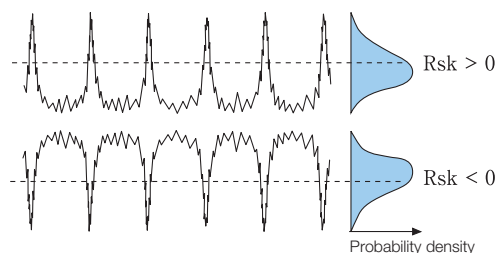
Skewness (Rsk)

The quotient of the mean cube value of $Z(x)$ and the cube of Rq within a sampling length.

- $Rsk=0$: Symmetric against the mean line (normal distribution)
- $Rsk>0$: Deviation beneath the mean line
- $Rsk<0$: Deviation above the mean line

- **Psk** The skewness of the primary profile
- **Wsk** The skewness of the waviness profile

$$Rsk = \frac{1}{Rq^3} \left[\frac{1}{\ell} \int_0^{\ell} Z^3(x) dx \right]$$



(In the case of roughness profile)

POINT

This parameter concerns height distribution. It is suitable for evaluating the abrasion and oil sump of lubricants for slide planes.

Profile method (linear roughness) parameters

Amplitude average parameters

Kurtosis (Rku)

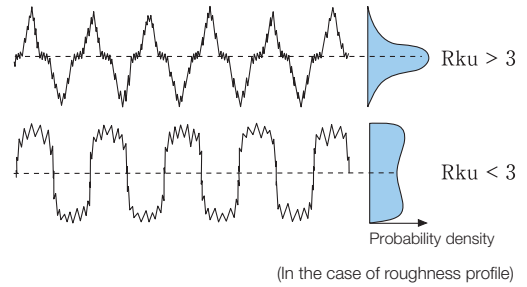
The quotient of the mean quadratic value of $Z(x)$ and the fourth power of Rq within a sampling length.

- Rku=3: Normal distribution
- Rku>3: The height distribution is sharp
- Rku<3: The height distribution is even

- **Pku** The Kurtosis of the primary profile
- **Wku** The Kurtosis of the waviness profile

POINT This parameter relates to the tip geometry of peaks and valleys and is suitable for analyzing the degree of contact between two objects.

$$Rku = \frac{1}{Rq^4} \left[\frac{1}{\ell} \int_0^{\ell} Z^4(x) dx \right]$$



Spacing parameters

Mean width (RSm)

Represents the mean for the length Xs of profile elements within the sampling length.

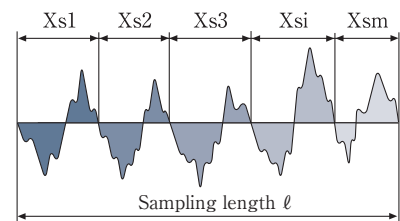
- * Indicated as S_m within JIS'94
- * Minimum height and minimum length to be discriminated from peaks (valleys).

Minimum height discrimination: 10% of the Rz value
 Minimum length discrimination: 1% of the reference length

- **PSm** Mean width of the primary profile element
- **Wc** Mean width of the waviness element

POINT This parameter is used to evaluate the horizontal size of parallel grooves and grains instead of the height parameters.

$$RSm = \frac{1}{m} \sum_{i=1}^m Xsi$$



Hybrid parameters

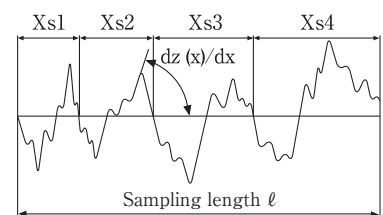
Root mean square slope (Rdq)

Represents the root mean square for the local slope dz/dx within the sampling length.

- **Pdq** The root mean square slope for the primary profile
- **Wdq** The root mean square slope for the waviness

POINT The steepness of the surface can be numerically represented with this parameter.

$$Rdq = \sqrt{\frac{1}{\ell} \int_0^{\ell} \left[\frac{d}{dx} Z(x) \right]^2 dx}$$

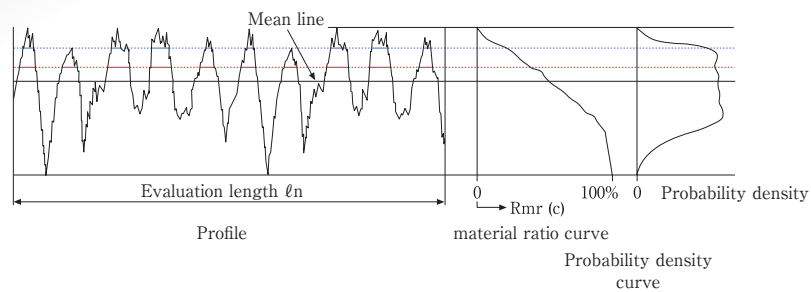


Material ratio curves and related parameters

Material ratio curve and probability density curves

Material ratio curves signify the ratio of materiality derived as a mathematical function of parameter c , where c represents the height of severance for a specific sample. This is also referred to as the bearing curve (BAC) or Abbott curve.

Probability density curves signify the probability of occurrence for height Z_x . The parameter is equivalent to the height distribution histogram.



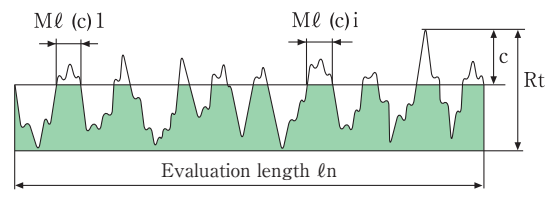
(In the case of roughness profile)

Material ratio (Rmr(c))

Indicates the ratio of the material length $Ml(c)$ of the profile element to the evaluation length for the section height level c (% or μm).

- **Pmr(c)** The material length rate of the primary profile (formerly tp)
- **Wmr(c)** The material length rate of the waviness

$$Rmr(c) = \frac{1}{l_n} \sum_{i=1}^m Ml(c)_i$$



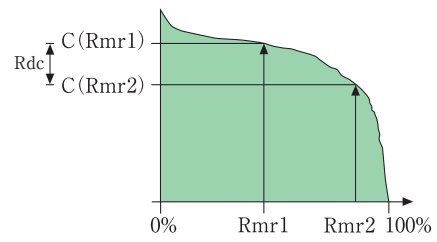
(In the case of roughness profile)

Profile section height difference (Rdc)

Rdc signifies the height difference in section height level c , matching the two material ratios.

- **Pdc** The section height level difference for the primary profile
- **Wdc** The section height level difference for the waviness profile

$$Rdc = c(Rmr1) - c(Rmr2) : Rmr1 < Rmr2$$



(In the case of roughness profile)

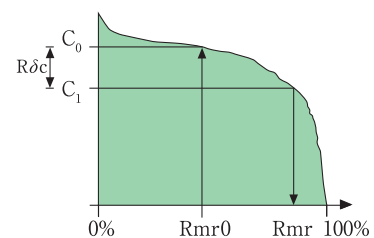
Relative material ratio (Rmr)

Rmr indicates the material ratio determined by the difference $R\delta c$ between the referential section height level C_0 and the profile section height level.

- **Pmr** The relative material length rate of the primary profile
- **Wmr** The relative material length rate of the waviness profile

$$Rmr = Rmr(c_1)$$

Where $C_1 = C_0 - R\delta c$, $C_0 = C(Rmr0)$



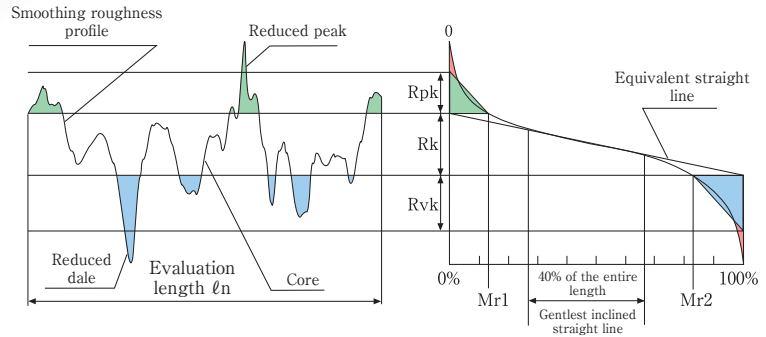
(In the case of roughness profile)

Profile method (linear roughness) parameters

Parameters of surface having stratified functional properties

R_k , Mr_1 , and Mr_2 values are calculated from the linear curve (equivalent linear curve) minimizing the sectional inclination corresponding to 40% of the material ratio curve.

Draw a triangle with the area equivalent to the protrusion of the material ratio curve segmented by the breadth of the parameter R_k and calculate parameters R_{pk} and R_{vk} .



- **R_k** Core roughness depth
- **R_{pk}** Reduced peak height
- **R_{vk}** Reduced valley depth
- **Mr_1, Mr_2** Material portion

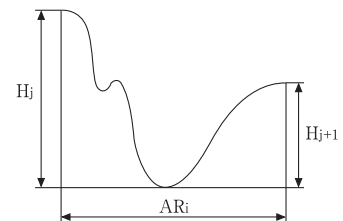
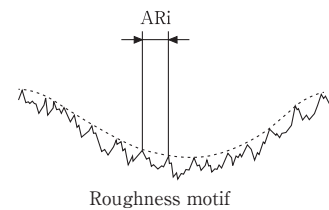
POINT

This function is used to evaluate friction and abrasion. It is also used to evaluate the lubricity of engine cylinder surfaces.

Motif parameters

Motif parameters are used for the evaluation of surface contact status based on the enveloped features of the sample surface.

- **AR** Mean spacing of roughness motifs: the arithmetic mean of roughness motifs AR_i calculated from the evaluation length
- **R** Mean depth of roughness motifs: the arithmetic mean of the roughness motif depth H_j calculated from the evaluation length
- **R_x** Maximum depth of roughness motifs: the maximum value of the H_j calculated from the evaluation length
- **AW** Mean spacing of waviness motifs: the arithmetic mean of the waviness motif AW_i calculated from the evaluation length
- **W** Mean depth of waviness motifs: the arithmetic mean of the waviness motif depth HW_j calculated from the evaluation length
- **W_x** Maximum depth of waviness motifs: the maximum value of the HW_j calculated from the evaluation length



POINT

These parameters are suited to evaluating the slippage of lubrication mechanisms and contact surfaces, such as gaskets.

Areal Method Parameters

| Height Parameters (ISO25178-2:2012) | Symbol | Units (Default) | Page |
|---|---------------|---|-------------|
| Maximum height | Sz | μm | P.29 |
| Maximum peak height | Sp | μm | P.29 |
| Maximum pit depth | Sv | μm | P.29 |
| Arithmetical mean height | Sa | μm | P.30 |
| Root mean square height | Sq | μm | P.30 |
| Skewness | Ssk | (Unitless) | P.31 |
| Kurtosis | Sku | (Unitless) | P.31 |
| Spacial parameters (ISO25178-2:2012) | | | |
| Autocorrelation length | Sal | μm | P.32 |
| Texture aspect ratio | Str | (Unitless) | P.32 |
| Hybrid parameters (ISO25178-2:2012) | | | |
| Root mean square gradient | Sdq | (Unitless) | P.32 |
| Developed interfacial area ratio | Sdr | % | P.32 |
| Functions and related parameters (ISO25178-2:2012) | | | |
| Core height | Sk | μm | P.33 |
| Reduced peak height | Spk | μm | P.33 |
| Reduced valley height | Svk | μm | P.33 |
| Material ratio | Smr1 | % | P.33 |
| Material ratio | Smr2 | % | P.33 |
| Peak extreme height | Sxp | μm | P.34 |
| Dale void volume | Vv | ml m ⁻² (=μm ³ /μm ²) | P.34 |
| Core void volume | Vvc | ml m ⁻² (=μm ³ /μm ²) | P.34 |
| Peak material volume | Vmp | ml m ⁻² (=μm ³ /μm ²) | P.34 |
| Core material volume | Vmc | ml m ⁻² (=μm ³ /μm ²) | P.34 |
| Miscellaneous parameter (ISO25178-2:2012) | | | |
| Texture direction | Std | degrees | P.35 |
| Feature parameters (ISO25178-2:2012) | | | |
| Density of peaks | Spd | mm ⁻² | P.35 |
| Arithmetic mean peak curvature | Spc | mm ⁻¹ | P.35 |
| Ten-point height of surface | S10z | μm | P.36 |
| Five-point peak height | S5p | μm | P.36 |
| Five-point pit height | S5v | μm | P.36 |

Areal Method Parameters

Height parameters

Maximum height (Sz)

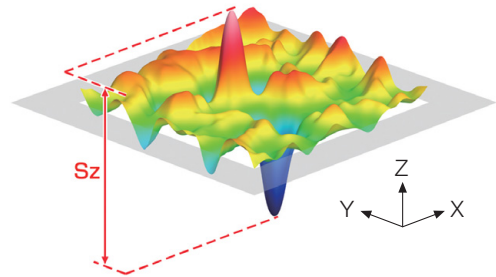
This parameter expands the profile (line roughness) parameter Rz three dimensionally.

The maximum height Sz is equivalent to the sum of the maximum peak height Sp and maximum valley depth Sv.

POINT

Although frequently used, this parameter is significantly influenced by scratches, contamination, and measurement noise due to its utilization of peak values.

$$S_z = S_p + S_v$$

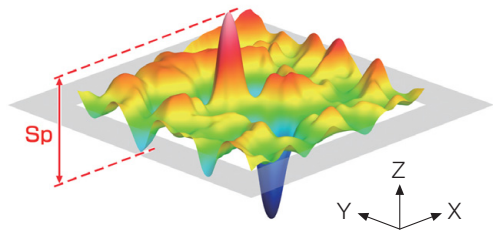


Maximum peak height (Sp)

This parameter expands the profile (line roughness) parameter Rp three dimensionally.

It is the maximum value for peak height.

$$S_p = \max (Z(x,y))$$

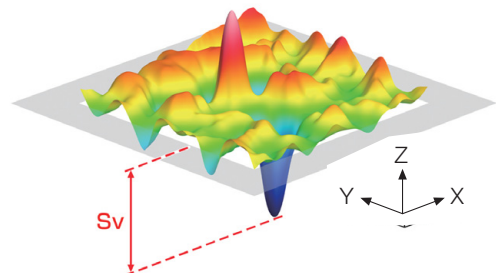


Maximum pit depth (Sv)

This parameter expands the profile (line roughness) parameter Rv three dimensionally.

It is the maximum value for the valley's depth.

$$S_v = | \min (Z(x,y)) |$$



Arithmetical mean height (Sa)

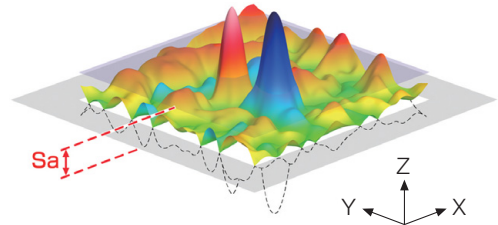
This parameter expands the profile (line roughness) parameter Ra three dimensionally.

It represents the arithmetic mean of the absolute ordinate $Z(x, y)$ within the evaluation area.

POINT

This is one of the most widely used parameters and is the mean of the average height difference for the average plane. It provides stable results since the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$S_a = \frac{1}{A} \iint_A |Z(x,y)| dx dy$$



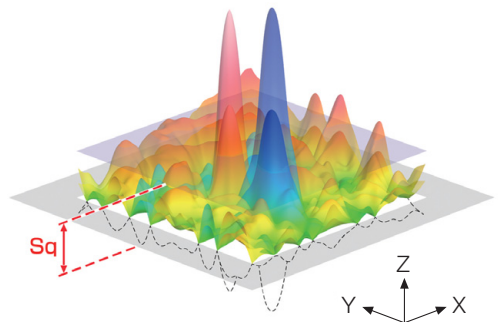
Root mean square height (Sq)

This parameter expands the profile (line roughness) parameter Rq three dimensionally. It represents the root mean square for $Z(x, y)$ within the evaluation area.

POINT

This is one of the most widely used parameters and is also referred to as the RMS value. The parameter Rq corresponds to the standard deviation of the height distribution. The parameter generates good statistics and enables stable results since the parameter is not significantly influenced by scratches, contamination, and measurement noise.

$$S_q = \sqrt{\frac{1}{A} \iint_A Z^2(x,y) dx dy}$$



Areal Method Parameters

Height Parameters

Skewness (Ssk)

This parameter expands the profile (line roughness) parameter Rsk three dimensionally; parameter Rsk, is used to evaluate deviations in the height distribution.

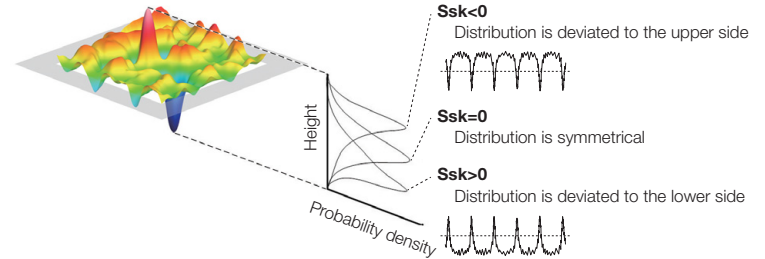
- Ssk=0: Symmetric against the mean line
- Ssk>0: Deviation beneath the mean line
- Ssk<0: Deviation above the mean line

POINT

This parameter concerns the height distribution and is suitable for evaluating the abrasion and oil sump of lubricants for slide planes.

$$Ssk = \frac{1}{Sq^3} \left(\frac{1}{A} \iint_A Z^3(x,y) dx dy \right)$$

Scale-limited surface



Kurtosis (Sku)

This parameter expands the profile (line roughness) parameter Rku three dimensionally; Rku, is used to evaluate sharpness in the height distribution.

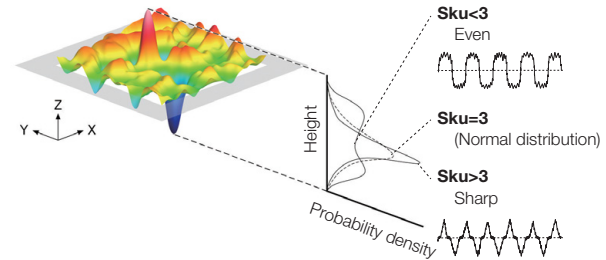
- Sku=3: Normal distribution
- Sku>3: Height distribution is sharp
- Sku<3: Height distribution is even

POINT

This parameter relates to the tip geometry of peaks and valleys and is suited to analyzing the contact between two objects.

$$Sku = \frac{1}{Sq^4} \left(\frac{1}{A} \iint_A Z^4(x,y) dx dy \right)$$

Scale-limited surface



Spatial parameters

Autocorrelation length (Sal)

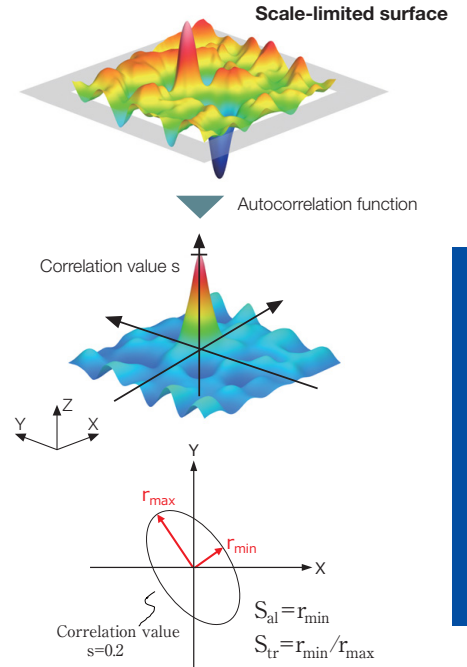
The horizontal distance of the autocorrelation function that has the fastest decay to a specified value s ($0 \leq s < 1$). Unless otherwise specified, the parameter is specified as $s = 0.2$.

Texture aspect ratio (Str)

This parameter is defined as the ratio of the horizontal distance of the autocorrelation function that has the fastest decay to a specified value s to the horizontal distance of the autocorrelation function that has the slowest decay to s ($0 \leq s < 1$) and indicates the isotropic/anisotropic strength of the surface. The Str value ranges from 0 to 1; normally $Str > 0.5$ indicates a strong isotropy while $Str < 0.3$ is strongly anisotropic.

POINT

These parameters are used to evaluate the horizontal size and complexity of parallel grooves and grains instead of the height parameters.



Hybrid parameters

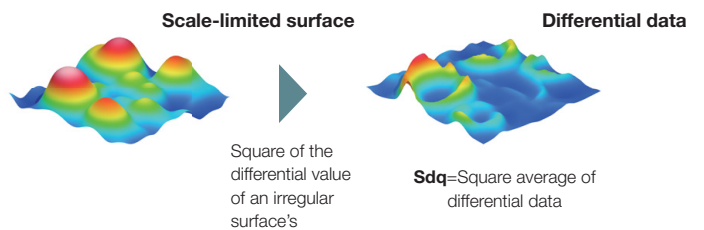
Root mean square gradient (Sdq)

This parameter expands the profile (line roughness) parameter Rdq three dimensionally. It indicates the mean magnitude of the local gradient (slope) of the surface. The surface is more steeply inclined as the value of the parameter Sdq becomes larger.

POINT

The steepness of the surface can be numerically represented in this parameter.

$$Sdq = \sqrt{\frac{1}{A} \iint_A \left[\left(\frac{\partial z(x,y)}{\partial x} \right)^2 + \left(\frac{\partial z(x,y)}{\partial y} \right)^2 \right] dx dy}$$



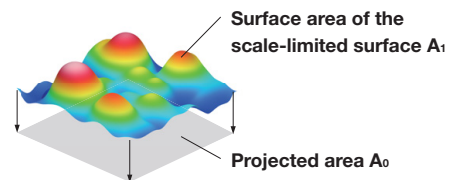
Developed interfacial area ratio (Sdr)

This signifies the rate of an increase in the surface area. The increase rate is calculated from the surface area A_1 derived by the projected area A_0 .

POINT

Sdr values increase as the surface texture becomes fine and rough.

$$Sdr = \frac{1}{A} \left[\iint_A \left(\sqrt{1 + \left(\frac{\partial z(x,y)}{\partial x} \right)^2 + \left(\frac{\partial z(x,y)}{\partial y} \right)^2} - 1 \right) dx dy \right]$$



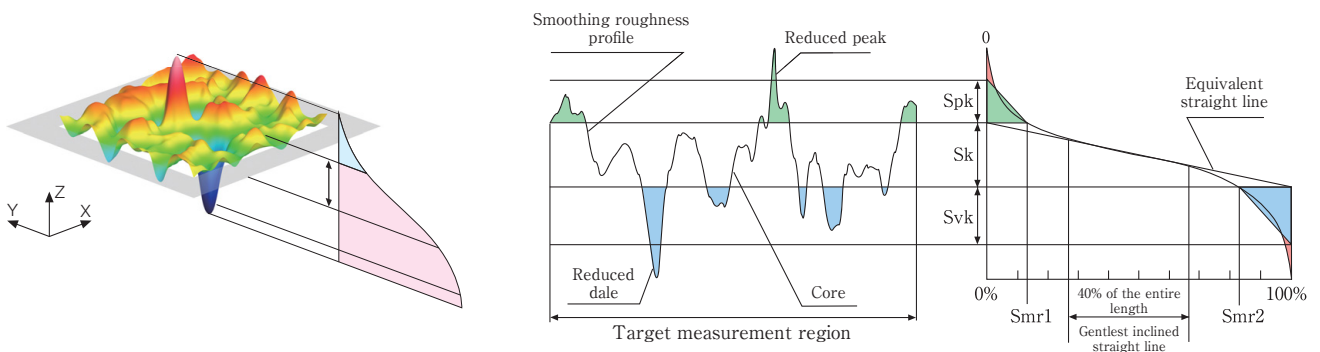
$$Sdr = (A_1/A_0 - 1) \times 100(\%)$$

Areal Method Parameters

Function and related parameters

This parameter expands the material ratio curve parameters (R_k , R_{pk} , R_{vk} , $Mr1$, and $Mr2$) of the profile parameter three dimensionally.

- **S_k** Core height: the difference between the upper and lower levels of the core
- **S_{pk}** Reduced peak height: the mean height of the protruding peaks above the core
- **S_{vk}** Reduced valley height: the mean height of the protruding dales beneath the core
- **$Smr1$** The areal material ratio segmenting protruding peaks from the core (indicated as a percentage)
- **$Smr2$** Areal material ratio segmenting protruding valleys from the core (indicated as a percentage)

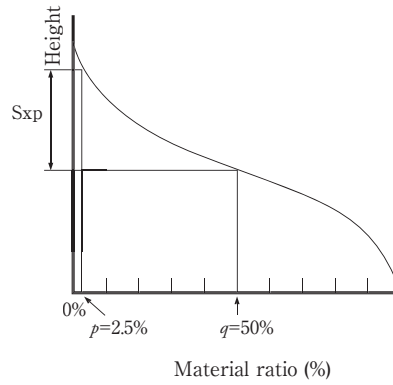
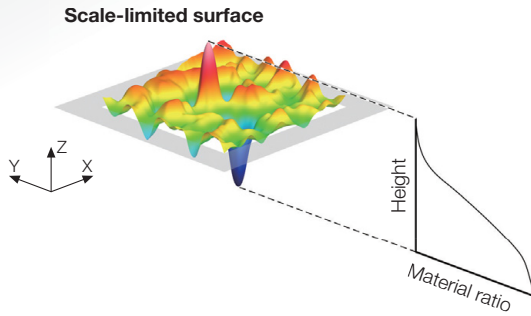


POINT

This parameter is suitable for evaluating friction and abrasion. It is also used to evaluate lubricity for engine cylinder surfaces.

Peak extreme height (Sxp)

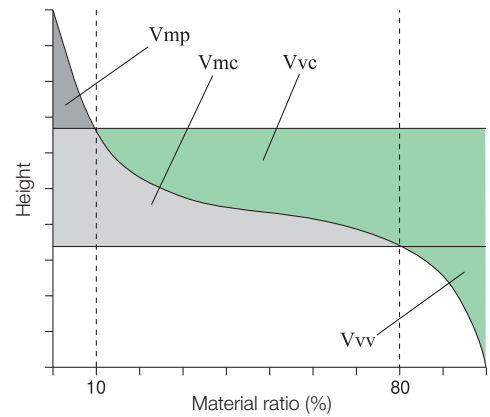
The difference in height between the p and q material ratio.
 Unless specified otherwise, the values $p=2.5\%$, $q=50\%$ shall be applied.



The material volume and void volume are calculated from a material ratio curve as indicated in the diagram. The position that corresponds to a material ratio of 10% and 80% is regarded as the threshold segmenting the peak, core, and dale.

- **V_{vv}** Dale void volume
- **V_{vc}** Core void volume
- **V_{mp}** Peak material volume
- **V_{mc}** Core material volume

POINT This parameter is often used to evaluate abrasion and lubricant retention.



Areal Method Parameters

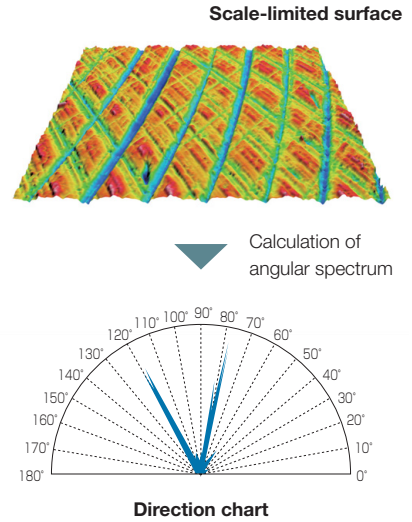
Miscellaneous parameters

Texture direction (Std)

This parameter indicates the direction angle of the texture (parallel groove orientation, etc.). It is derived from the angle maximizing the angle spectrum of two-dimensional Fourier transformation images.

POINT

Std represents the angle for the strongest orientation, although the second and third strongest angles can also be defined on the directional chart.



Feature parameters

Density of peaks (Spd)

This is the number of peaks per unit area. Only peaks that exceed a designated size are counted.

Unless otherwise specified, the designated size is determined to be 5% of the maximum height S_z .

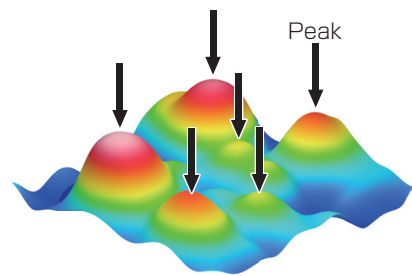
The parameter is calculated from the number of peaks divided by the projected area.

Arithmetic mean peak curvature (Spc)

Spc indicates the mean principle curvature (average sharpness) of the peaks. Only peaks that exceed a designated curvature are taken into consideration.

Unless otherwise specified, the designated size is determined to be 5% of the maximum height S_z .

The parameter is derived from the arithmetic mean curvatures of peaks within the evaluation area.



POINT

This parameter is suited for analyzing the contact between two objects.

Ten-point height of surface

The average value of the heights of the five peaks with the largest global peak height added to the average value of the heights of the five pits with the largest global pit height.

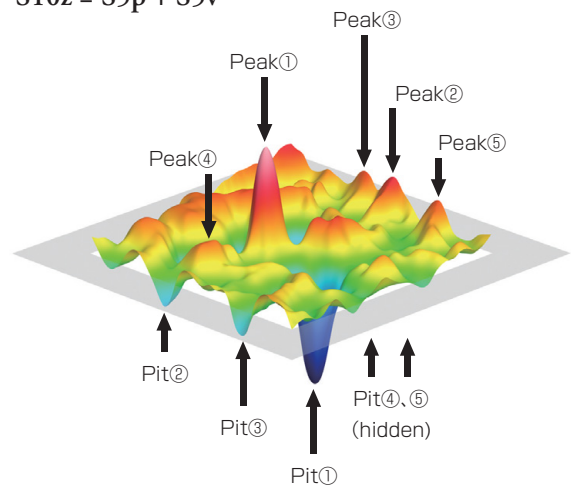
Five-point peak height (S5p)

The average value of the heights of the five peaks with the largest global peak height.

Five-point pit height (S5v)

The average value of the heights of the five pits with the largest global pit height.

$$S_{10z} = S_{5p} + S_{5v}$$



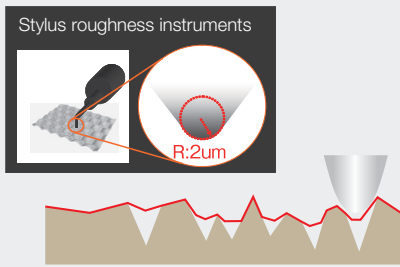
Laser microscope solution

Advantages over conventional stylus roughness measurement instruments

Finer roughness measurements

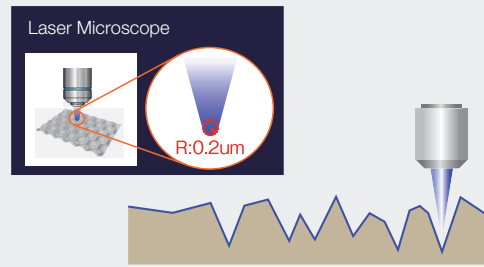
Issues

The tip radius of ordinary stylus probes is 2 to 10 μm , making it difficult to capture micro-roughness.



Solutions

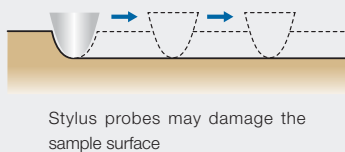
The tip radius of laser microscopes is much smaller (only 0.2 μm) and enables surface roughness measurement of fine irregularities that are unreachable using stylus probes.



Non-contact roughness measurement

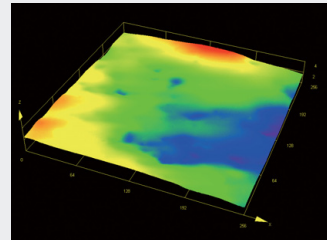
Issues

Stylus instruments require direct contact between the probe and sample surface. This may cause the probes to scrape soft sample features or strain samples that have adhesive properties, making it difficult to obtain accurate data.



Solutions

Laser microscopes acquire information without touching the sample, making them capable of taking accurate roughness measurements regardless of the sample's surface.

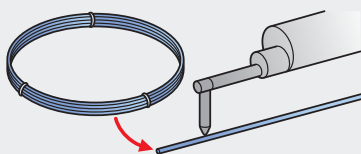


Laser microscope observation image
Sample: Adhesive tape
256 \times 256 μm

Local region roughness measurement

Issues

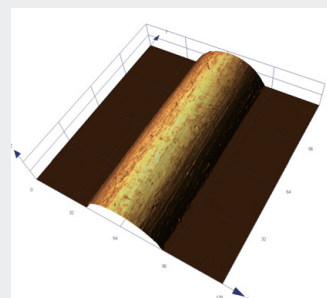
A contact stylus is not good at taking measurements from restricted areas, such as very small wires.



Lowering stylus probes onto the surface of wires several dozen microns across is extremely difficult to accomplish

Solutions

Laser microscopes function on a planar basis, and the image-based precision positioning capability enables easy roughness measurement of minute targeted areas.



Observation image obtained with laser microscopes
Sample: Extra fine wire ϕ 50 μm

Advantages over coherence scanning interferometers

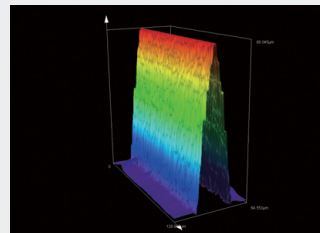
Steep slope detection performance

Issues

Although whiteness interferometers maintain subnano level detection sensitivity for smooth surfaces, the congestion of interference patterns prevents accurate measurement of steeply inclined surfaces (rough surfaces).

Solutions

With high NA dedicated objective lenses and 405 nm lasers, the laser microscope provides accurate measurements of samples with steep, angled surfaces.



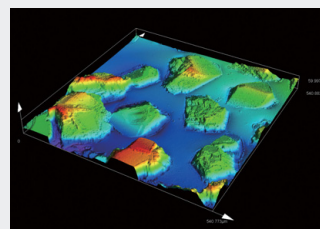
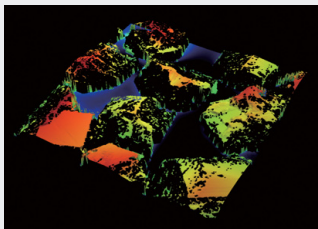
Capable of measuring low-reflection surfaces

Issues

CCD and other types of imaging sensors in whiteness interferometers tend to pass over weak signals depending on the condition of the sample's surface, making it difficult to take accurate measurements.

Solutions

The high sensitivity light detectors (photo multipliers) used in a laser microscope maintain a high S/N ratio, providing accurate measurements of sample surfaces with low-reflectivity.



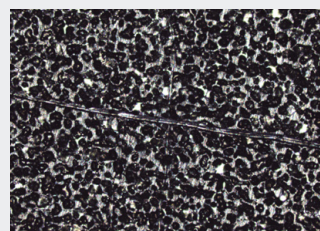
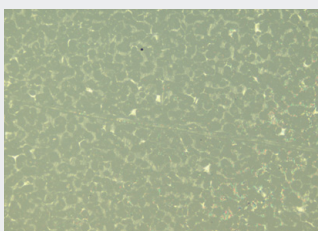
High horizontal resolution

Issues

The NA of the interference objective lens on whiteness interferometers is smaller than that used on optical microscopes and has lower horizontal resolution. Unlike optical microscopes, clear, live sample observation is difficult for interferometers.

Solutions

Laser microscopes are equipped with both color optics and laser confocal optics, offering clear, high resolution images to observe microscopic scratches and fine positioning.



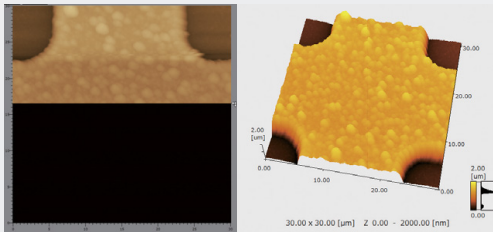
Laser microscope solution

Advantages over scanning probe microscopes (SPM)

Fast, precise 3D measurement

Issues

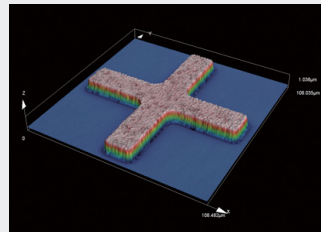
Although SPMs are capable of sub-nano level feature measurement, the cantilever-based scanning of the sample surface is a time-consuming process.



About 850 seconds

Solutions

The high-speed horizontal laser scanning of laser microscopes enables sub-micron level feature data to be acquired quickly.

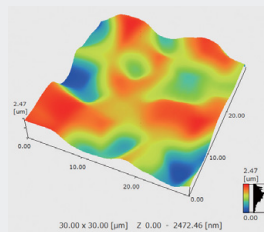


About 15 seconds

Wide field measurement

Issues

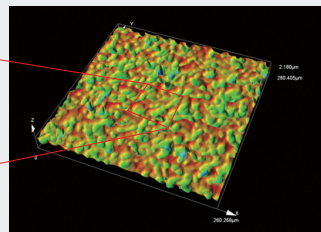
The scan area for SPMs is confined to small areas of about 100 micrometers and is not suitable for measuring large features and low magnification observation.



Scanning probe microscope

Solutions

Laser microscopes are capable of observing sub-micron irregularities using a field of view much broader than SPMs. The horizontal stitching capabilities further expand the area of analysis.



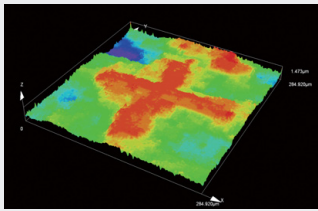
Laser microscope

Advantages over digital microscopes

Accurate, precise 3D measurement

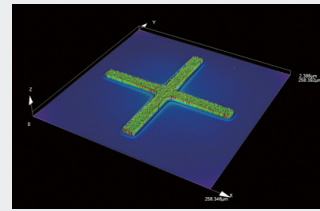
Issues

Digital microscopes are not suitable for acquiring information of delicate sub-micron surface features.



Solutions

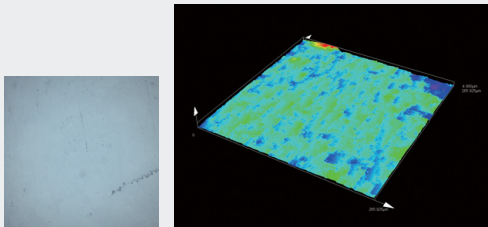
The laser-based scanning of the sample surface enables laser microscopes to accurately acquire delicate surface features.



Capable of measurement regardless of the sample (this could be clearer)

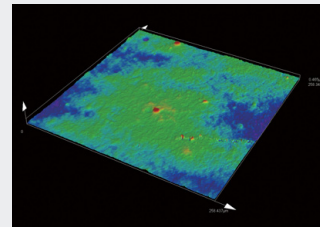
Issues

Digital microscopes construct the configuration data using the contrast information acquired from the sample surface. Because of this, they are not suitable for observing low-contrast polished surfaces and smooth films.



Solutions

The confocal optics incorporated in laser microscopes accurately capture surface features without being influenced by the sample's surface condition.



Advantages of the OLS5000 3D laser scanning confocal microscope for surface roughness measurement

OLS5000 microscope characteristics

Characteristics 1 Non-contact, nondestructive, and fast

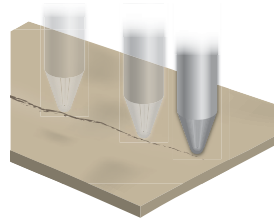
No preliminary preparation required. Simply place the sample on the stage and begin measurement.



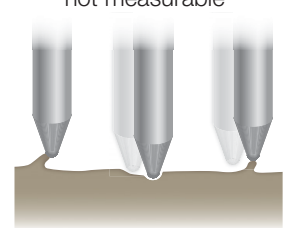
Roughness gage



Sample damage

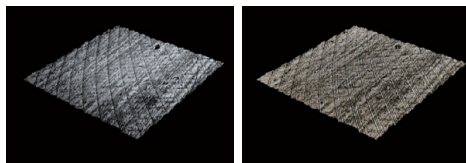


Adhesive samples are not measurable



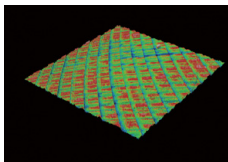
Characteristics 2 Comprehensive sample information

Three types of information are acquired simultaneously



Laser image

Color image

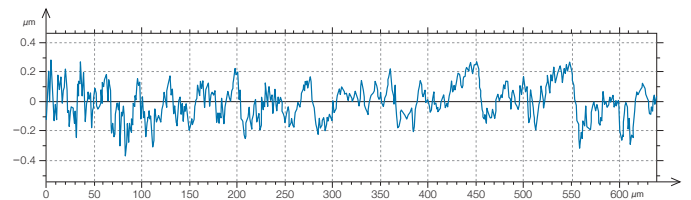


3D feature data

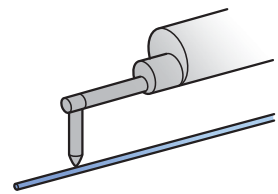
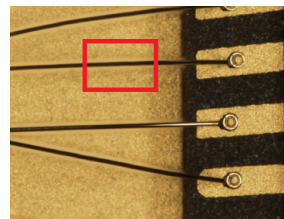
Roughness gage



Observation for a single profile only

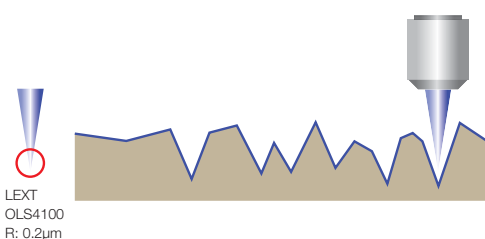


Difficult to precisely position



Characteristics 3 Captures fine irregularities

The 405 nm / 0.4 µm diameter laser beam scans fine features without distortion.



LEXT OLS4100
R: 0.2µm

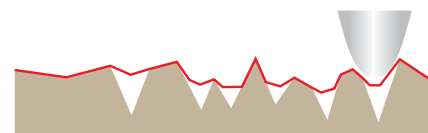
Roughness gage



The stylus cannot measure features smaller than the tip of the probe



Contact Surface
Roughness
Measuring Machine
R: 2µm



Advantages of the OLS5000 3D laser scanning confocal microscope for surface roughness measurement

OLS5000
Example of
measurement

1

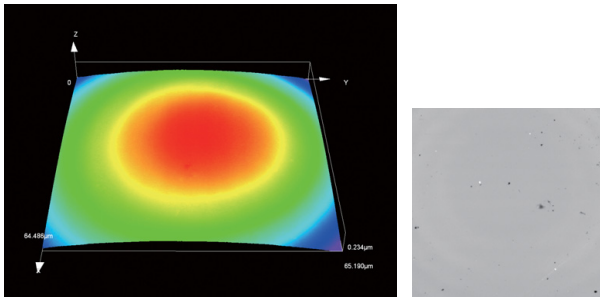
Measuring the tip of burnishing tools

Burnish processing is a method to create smooth mirror-finish surfaces by moving hemispheric burnishing tools (diamond turning tools) along the metal surface. The tip of the burnishing tool wears out over time, influencing the smoothness of the surface being processed. It is important to manage the damage and evaluate surface roughness of the tool tips.



A comparison of the roughness of diamond tool tips from new and used tools

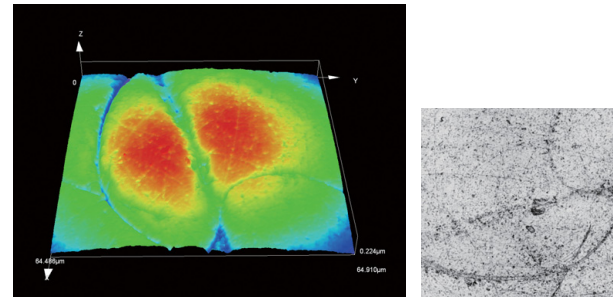
Before use



Analysis parameters

| | | | |
|-----|-------------------------|-----|-------------------------|
| Sq | 0.019 [μm] | Ssk | 0.883 |
| Sku | 5.473 | Sp | 0.110 [μm] |
| Sv | 0.047 [μm] | Sz | 0.157 [μm] |
| Sa | 0.014 [μm] | | |

After use

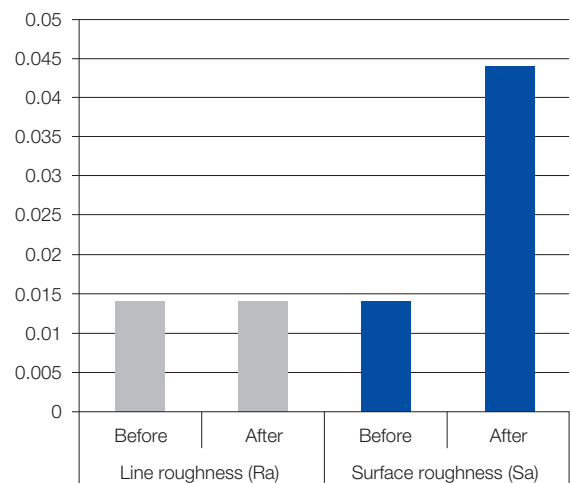


Analysis parameters

| | | | |
|-----|-------------------------|-----|-------------------------|
| Sq | 0.065 [μm] | Ssk | -1.753 |
| Sku | 6.976 | Sp | 0.153 [μm] |
| Sv | 0.386 [μm] | Sz | 0.539 [μm] |
| Sa | 0.044 [μm] | | |

Applying stylus probes from conventional roughness gages onto the $\phi 3$ mm tip of burnishing tools is difficult. Furthermore, slight wear of the tool tips cannot be captured using conventional instruments. When comparing new and used burnishing tools using the linear roughness parameter Ra, distinctive differences may be overlooked depending on the line of measurement, leading to potential errors in the determining the condition of abrasion.

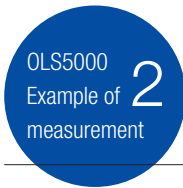
By contrast, the OLS5000 confocal laser microscope bases its numerical conversion on the areal roughness parameter Sa and is capable of capturing fine irregularities on a broader scope to identify the difference between pre- and post-usage. This enables a more accurate judgment.



OLS5000 Solutions

Able to measure the surface roughness of the target area easily while observing the magnified high resolution image in a wide area.

Advantages of the OLS5000 3D laser scanning confocal microscope for surface roughness measurement



Evaluating the roughness of the receiving seat of a ball placed at the tip of a ballpoint pen

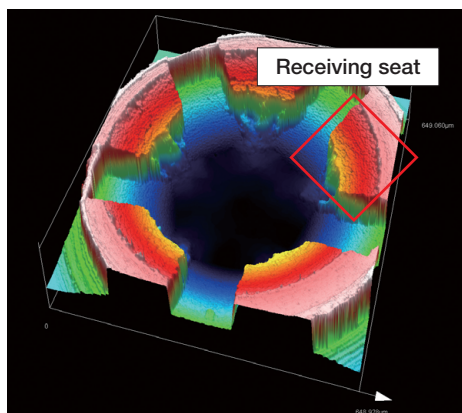
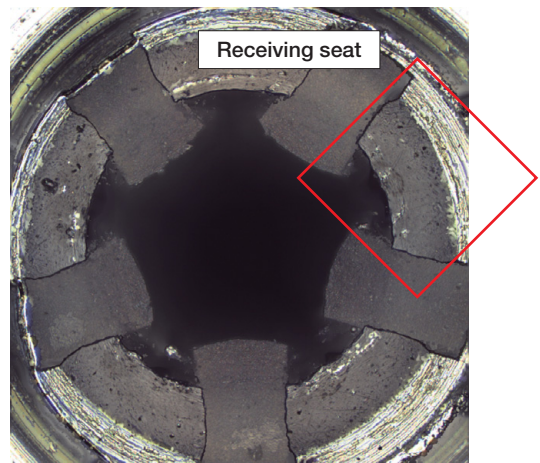
Widely used in daily activities, the condition of ballpoint pens are determined how well the ball slides while writing, the feel of the handheld pen, and the ease of operation. The surface roughness of the receiving seats holding the rotating tips are directly linked to the friction (resistance) and are, therefore, an important aspect of ballpoint pens.



Evaluating the roughness of the ball receiving seat of a ballpoint pen

Due to the small size and complex shape of receiving seats, conventional roughness gages have difficulty probing and tracing the features.

The non-contact measurement of OLS5000 microscope easily acquires fine details from the recessed portions of the seat. Contrary to single profile-based roughness gages, the large amount of data acquired from a broad area makes it possible to focus the target region for localized roughness measurement on components with complex forms. Multiple target areas can be designated, and their surface roughness and mean roughness can be easily quantified.



The roughness of the receiving seat

| | | | |
|-----|-------------|----|-------------|
| Sq | 6.698 [μm] | Sv | 23.792 [μm] |
| Sku | 3.316 | Sz | 45.475 [μm] |
| Ssk | -0.408 | Sa | 5.087 [μm] |
| Sp | 21.683 [μm] | | |



OLS5000 Solutions

Non-contact measurement enables surface roughness measurement in recessed portions of the sample that are difficult to measure using conventional roughness gages

Quantitative evaluation of the difference in skin texture

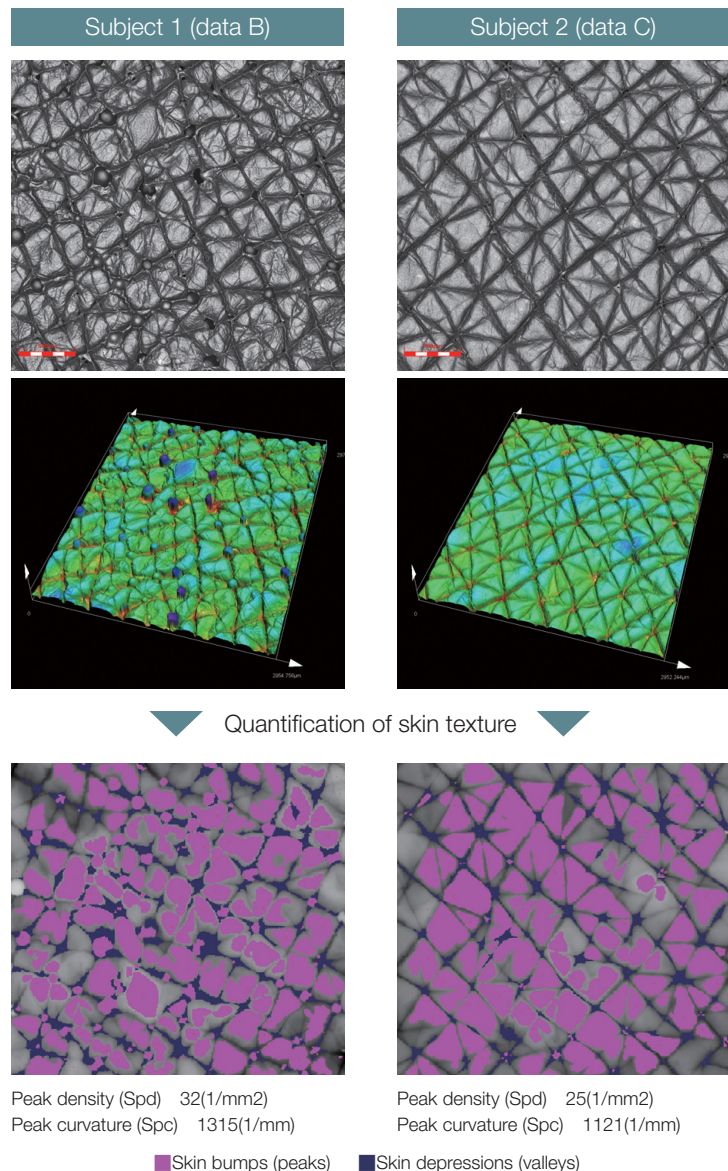
Industrial products can be enhanced in various ways. Improving the texture to impart a high-quality feel in the interior of automobiles and architectural materials are two applications where these enhancements are common. Another example is cosmetic companies, who have analyzed the texture of human skin to understand the impact cosmetics have on how the skin feels.

Quantification of skin texture

Skin texture differs among individuals. Accordingly, it is important to quantify the texture of the skin's surface.

Since conventional roughness gages evaluate texture based on a linear measurement, it is difficult to determine the overall condition of the skin. The stylus may also cause damage.

The OLS5000 microscope bases its data acquisition on planar roughness parameters like Spc and Spd (ISO25178-2), facilitating the quantification of skin texture topography including the quantity of skin bumps per unit area, the average height of skin bumps (or depth of skin depressions), and the curvature of skin bump peaks. In addition, the non-contact scanning does not harm the sample.



* Observation sample image uses an inverted replica.

* Provided by Laboratory of Department of Fashion Technology, Faculty of Fashion Science, BUNKA GAKUEN UNIVERSITY

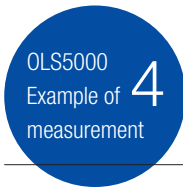
Advantages of the OLS5000 3D laser scanning confocal microscope for surface roughness measurement



OLS5000 Solutions

Non-contact and capable of surface roughness measurements regardless of the sample

Advantages of the OLS5000 3D laser scanning confocal microscope for surface roughness measurement



4 Measuring the roughness of a painted surface under a clear coating

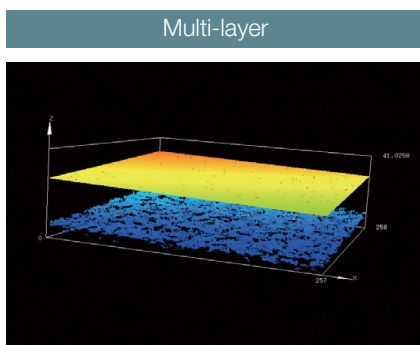
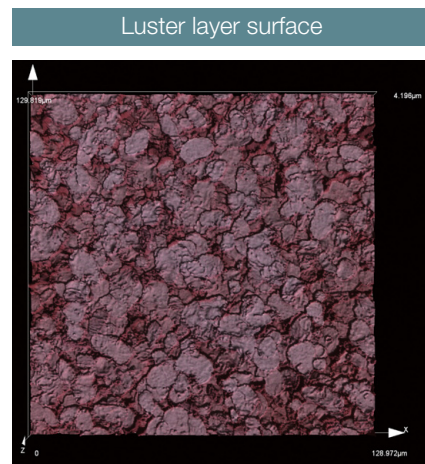
Smart phones, automobiles, and mobile electronic devices and industrial products are painted in various colors and lusters and many have a clear coating. The surface condition of the luster undercoating layer beneath the superficial coating significantly influences the texture of the product.



Feature measurement of a coating under transparent films

Conventional roughness gages were only capable measuring the top layer of the coating. Additionally, the stylus probe could damage the surface of the soft layer of clear coating.

Because the laser permeates the transparent layer of a clear coating, the OLS5000 microscope is capable of capturing the features of the luster coating layer without destroying/disrupting the top layer. The OLS5000 microscope can measure the film thickness of the clear coating layer as well as the surface roughness by using the multilayer scanning function. The non-contact scanning is harmless to the sample.



The roughness of a painted surface

| | | | |
|-----|------------|----|-------------|
| Sq | 1.159 [µm] | Sv | 5.535 [µm] |
| Sku | 4.337 | Sz | 11.052 [µm] |
| Ssk | -0.559 | Sa | 0.881 [µm] |
| Sp | 5.516 [µm] | | |



OLS5000 Solutions

Non-contact measurement enables the analysis of surface roughness for previously impossible undercoats beneath the clear coating

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–Surface texture: Profile method type -- Glossary, definition, and surface texture parameters

JIS B0671(2013)Geometric Product characteristic Specifications (GPS)

–Surface texture: Profile method type -- Characteristics evaluation of scale-limited stratified functional surfaces

JIS B0631 (2000) Geometric Product characteristic Specifications (GPS)

–Surface texture: Profile method type -- Motif parameter

JIS B0632 (2001) Geometric Product characteristic Specifications (GPS)

–Surface texture: Profile method type -- Phase correct filter characteristics

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