Industrial Microscopes

Surface Roughness Measurement—Parameters

Profile Method

Profile Method (Linear Roughness) Parameters

Amplitude parameters (peak and valley) (ISO4287:1997)	Symbol	Equivalent areal parameters
Maximum height	Pz, Rz, Wz	Sz
Maximum profile peak height	Pp, Rp, Wp	Sp
Maximum profile valley depth	Pv, Rv, Wv	Sv
Mean height	Pc, Rc, Wc	-
Total height	Pt, Rt, Wt	-

Amplitude average parameters (ISO4287:1997)	Symbol	Equivalent areal parameters
Arithmetic mean deviation	Pa, Ra, Wa	Sa
Root mean square deviation	Pq, Rq, Wq	Sq
Skewness	Psk, Rsk, Wsk	Ssk
Kurtosis	Pku, Rku, Wku	Sku

Spacing parameters (ISO4287:1997)	Symbol	Equivalent areal parameters

Mean width	PSm, RSm, WSm	-

Hybrid parameters (ISO4287:1997)	Symbol	Equivalent areal parameters
Root mean square slope	Pdq, Rdq, Wdq	Sdq

Material ratio curves and related parameters (ISO4287:1997)	Symbol	Equivalent areal parameters
Material ratio	Pmr (c), Rmr (c), Wmr (c)	Smr (c)
Profile section height difference	Pdc, Rdc, Wdc	Sxp*
Relative material ratio	Pmr, Rmr, Wmr	-

Parameters of surface having stratified functional properties (ISO13565-2:1996)	Symbol	Equivalent areal parameters
Core roughness depth	Rk	Sk
Reduced peak height	Rpk	Spk
Reduced valley height	Rvk	Svk
Material portion	Mr1	Smr1
Material portion	Mr2	Smr2

Motif parameters (ISO12085:1996)	Symbol	Equivalent areal parameters
Mean spacing of roughness motifs	AR	-
Mean depth of roughness motifs	R	-
Maximum depth of roughness motifs	Rx	-
Mean spacing of waviness motifs	AW	-
Mean depth of waviness motifs	W	-
Maximum depth of waviness motifs	Wx	-

* Condition of calculation may differ between profile and three-dimensional methods.

Amplitude Parameters (Peak and Valley)

Maximum height (Rz)

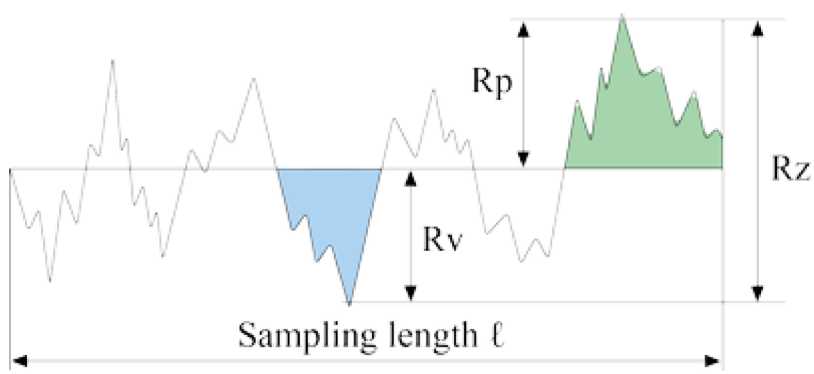
Represents the sum of the maximum peak height Zp and the maximum valley depth Zv of a profile within the reference length.

- Indicated as Ry 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

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

$$Rz = Rp + Rv$$



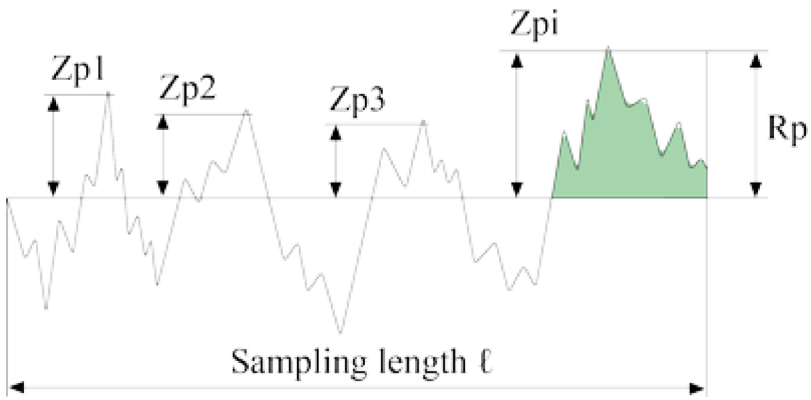
(In the case of a roughness profile)

Maximum profile peak height (Rp)

Represents the maximum peak height Zp 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

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



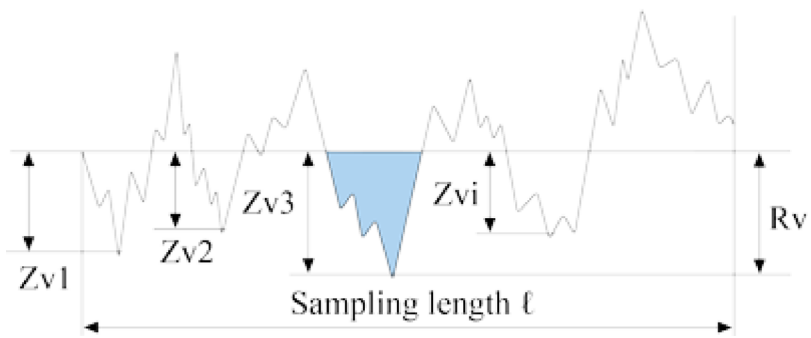
(In the case of a roughness profile)

Maximum profile valley depth (Rv)

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

Pv The maximum peak height of the primary profile
Wv The maximum peak height of the waviness profile

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



(In the case of a roughness profile)

Mean height (Rc)

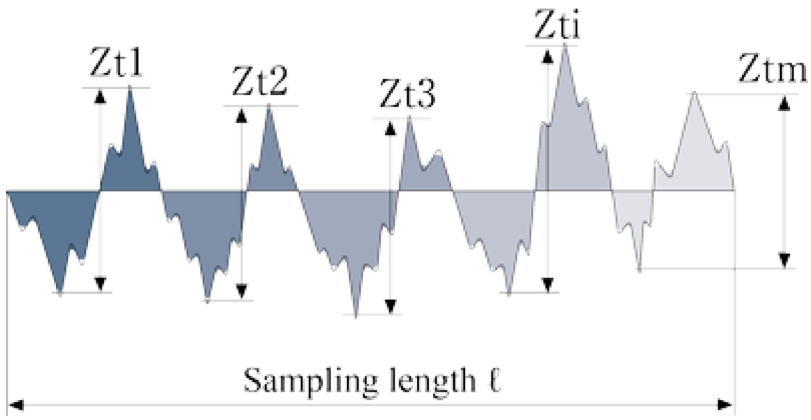
Represents the mean for the height Zt of profile elements within the sampling length.

- 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 Rz 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

$$Rc = \frac{1}{m} \sum_{i=1}^{m} Zti$$



(In the case of a roughness profile)

Total height (Rt)

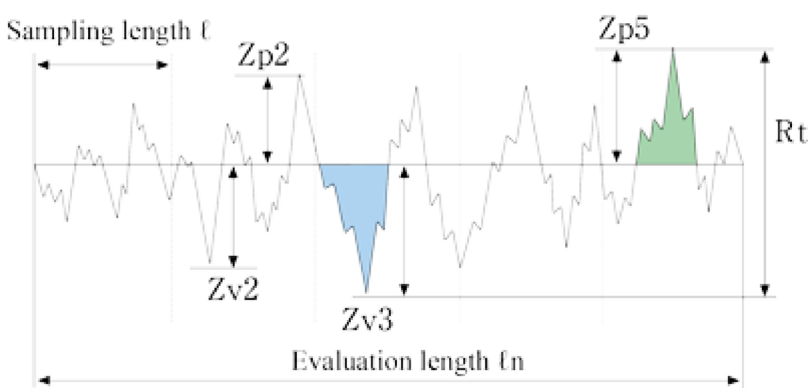
Represents the sum of the maximum peak height Zp and the maximum valley depth Zv of a profile within the evaluation length, not sampling length.

- Relationship Rt≧Rz applies for all profiles

Pt The maximum total height of the profile (Rmax in the case of JIS'82)
Wt The maximum total height of the waviness

Note
Rt is a stricter standard than Rz 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.

$$Rt = \max(Zpi) + \max(Zvi)$$



(In the case of a roughness profile)

Ten-point mean roughness (Rzjis)

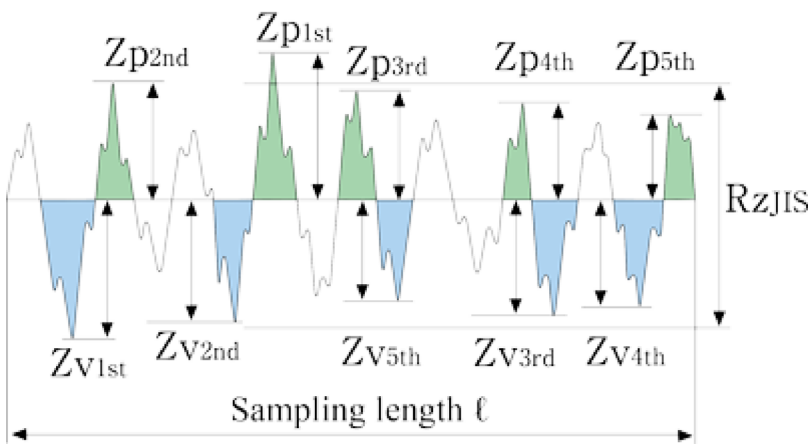
Represents the sum of the mean value for the height of the five tallest peaks and the mean of the depth of the five deepest valleys of a profile within the sampling length.

- Indicated as Rz within JIS'94

Note

Rzjis is equivalent to the parameter Rz 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 the parameter Rzjis.

$$Rzjis = \frac{1}{5}\sum_{j=1}^{5}(Zpj + Zvj)$$



(In the case of a 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

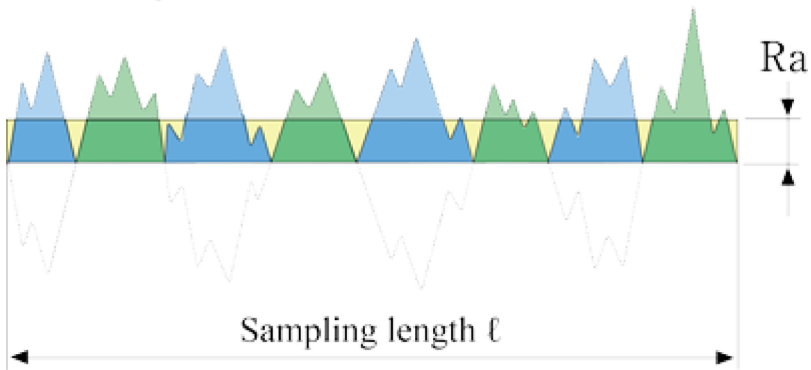
Wa The arithmetic mean waviness

Note

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 a roughness profile)

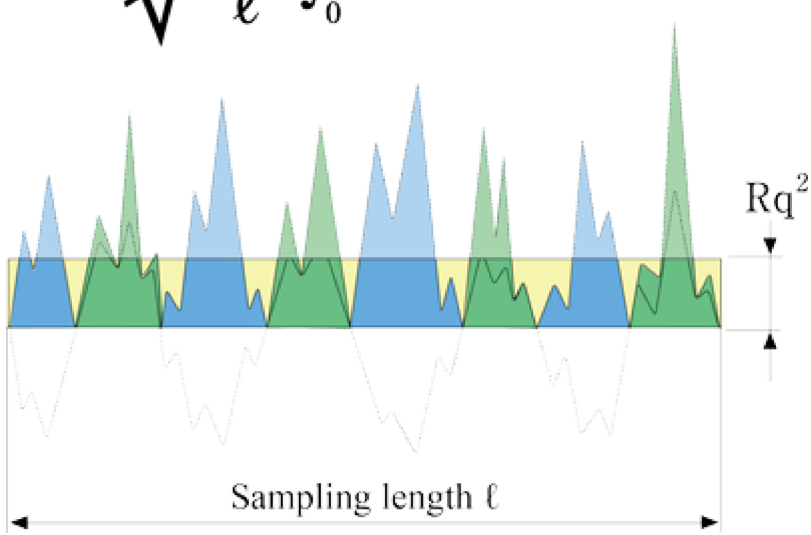
Root mean square deviation (Rq)

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

Note
This is one of the most widely used parameters and is also referred to as the RMS value. The parameter Rq 7 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 a roughness profile)

Skewness (Rsk)

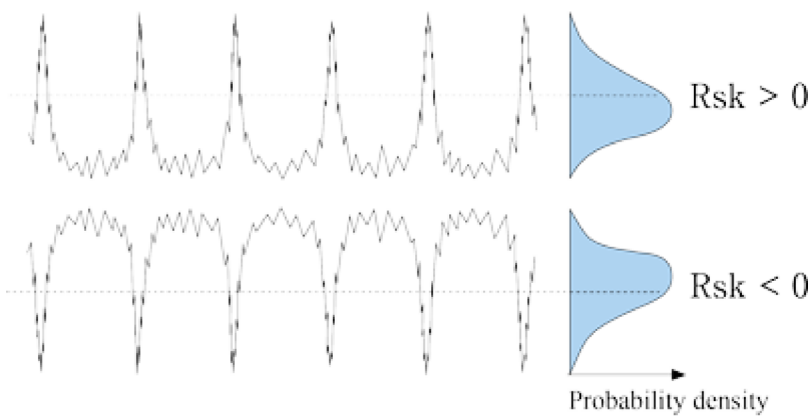
The quotient of the mean cube value of Z (x) and the cube of R8 within a sampling length.

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

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

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



(In the case of a roughness profile)

Kurtosis (Rku)

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

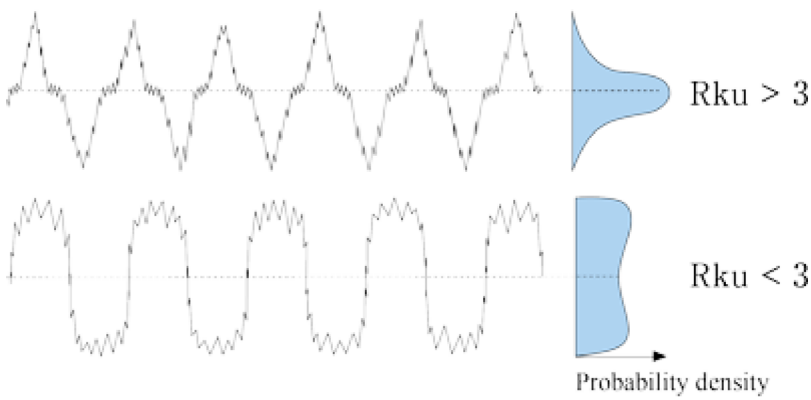
Rku=3: Normal distribution
Rku>3: The height distribution is sharp
Rku<3: The height distribution is even

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

Note

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

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



(In the case of a roughness profile)

Spacing Parameters

Mean width (RSm)

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

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

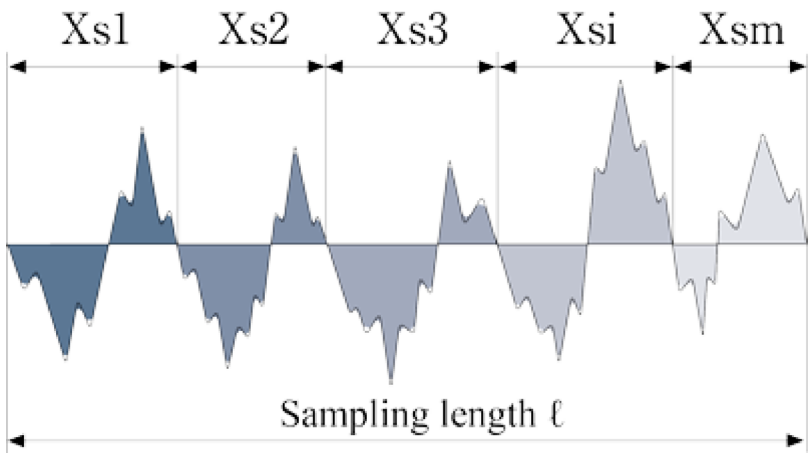
  Minimum height discrimination: 10% of the Rz value
  Minimum length discrimination: 1% of the reference length

Psm Mean width of the primary profile element
Wc Mean width of the waviness element

Note

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

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



(In the case of a roughness profile)

Hybrid Parameters

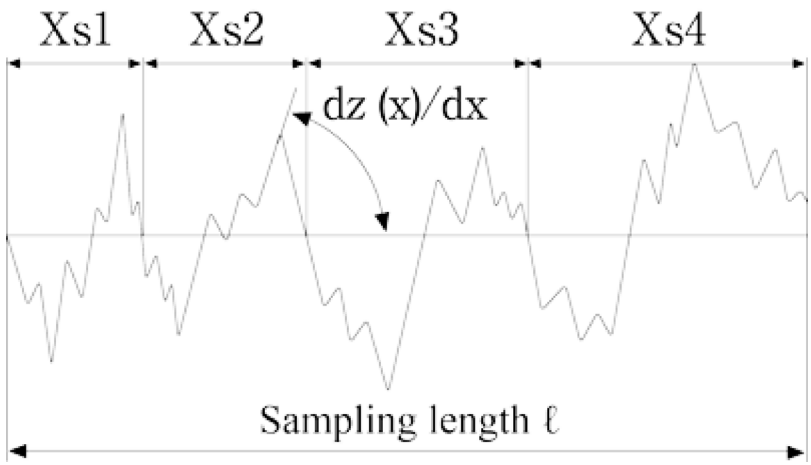
Root mean square slope (Rdq)

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

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

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

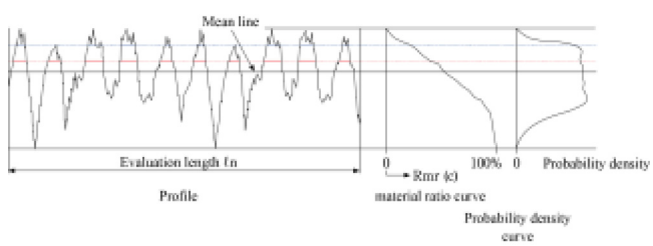


(In the case of a roughness profile)

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 Zx. The parameter is equivalent to the height distribution histogram.



(In the case of a roughness profile)

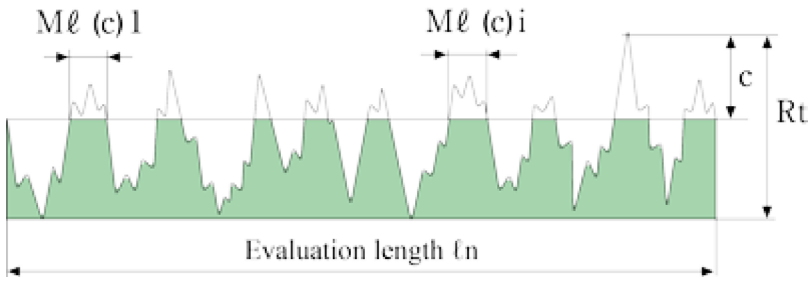
Material ratio (Rmr(c))

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

$$Rmr\ (c) = \frac{1}{\ell n} \sum_{i=1}^{m} M\ell\ (c)\ i$$



(In the case of a roughness profile)

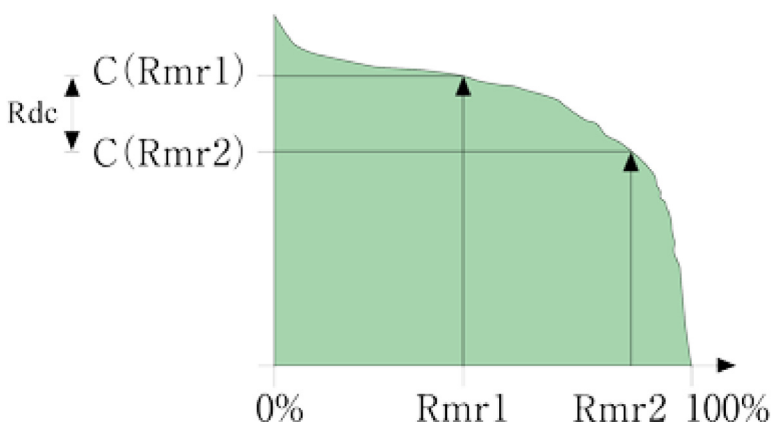
Profile section height difference (Rdc)

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 a roughness profile)

Relative material ratio (Rmr)

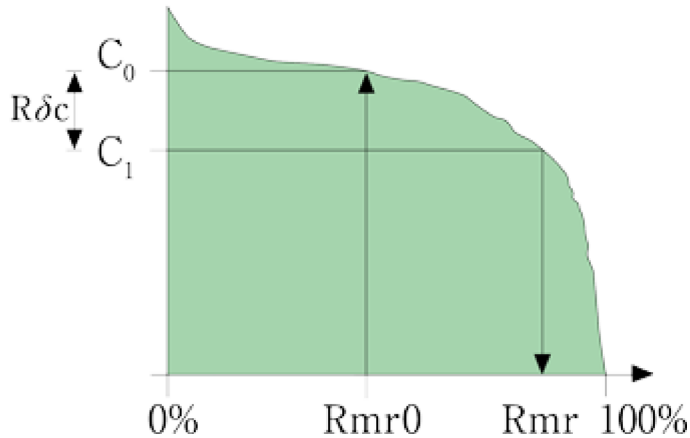
Rmr indicates the material ratio determined by the difference Rδc between the referential section height level C_0 and the profile section height level.

Pmr The relative material length rate of the primary profile

Wmr The relative material length rate of the waviness profile

$$Rmr = Rmr(c_1)$$

$$\text{Where} \quad C_1 = C_0 - R\delta c, \; C_0 = C(Rmr0)$$



(In the case of a roughness profile)

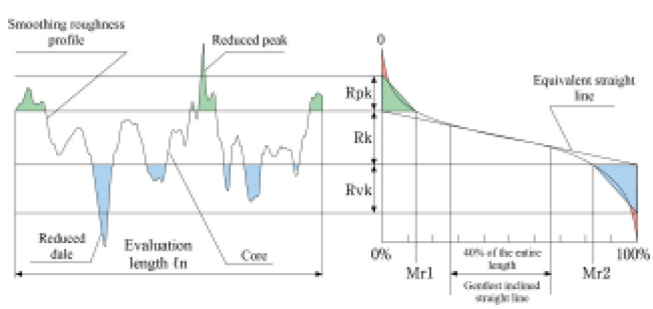
Parameters of a Surface with Stratified Functional Properties

Parameters of a surface with stratified functional properties

Rk, Mr1, and Mr2 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 Rk and calculate parameters Rpk and Rvk.

Rk Core roughness depth
Rpk Reduced peak height
Rvk Reduced valley depth
Mr1, Mr2 Material portion

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

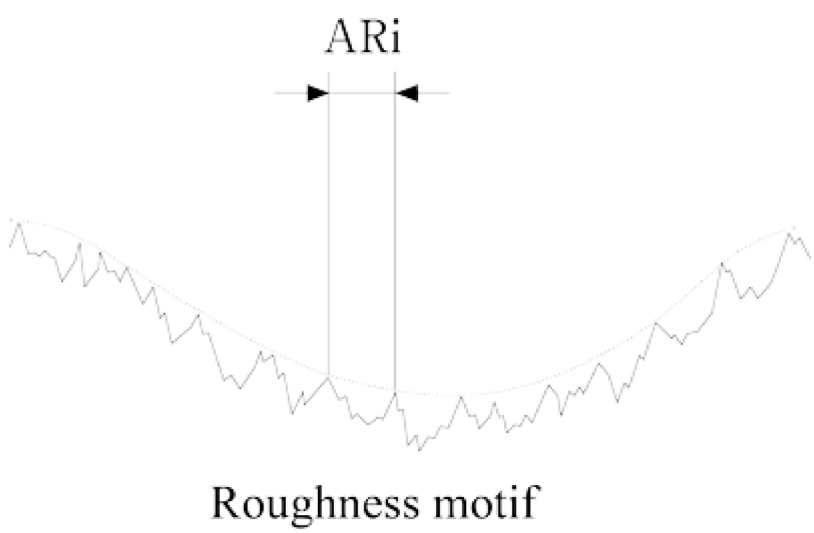


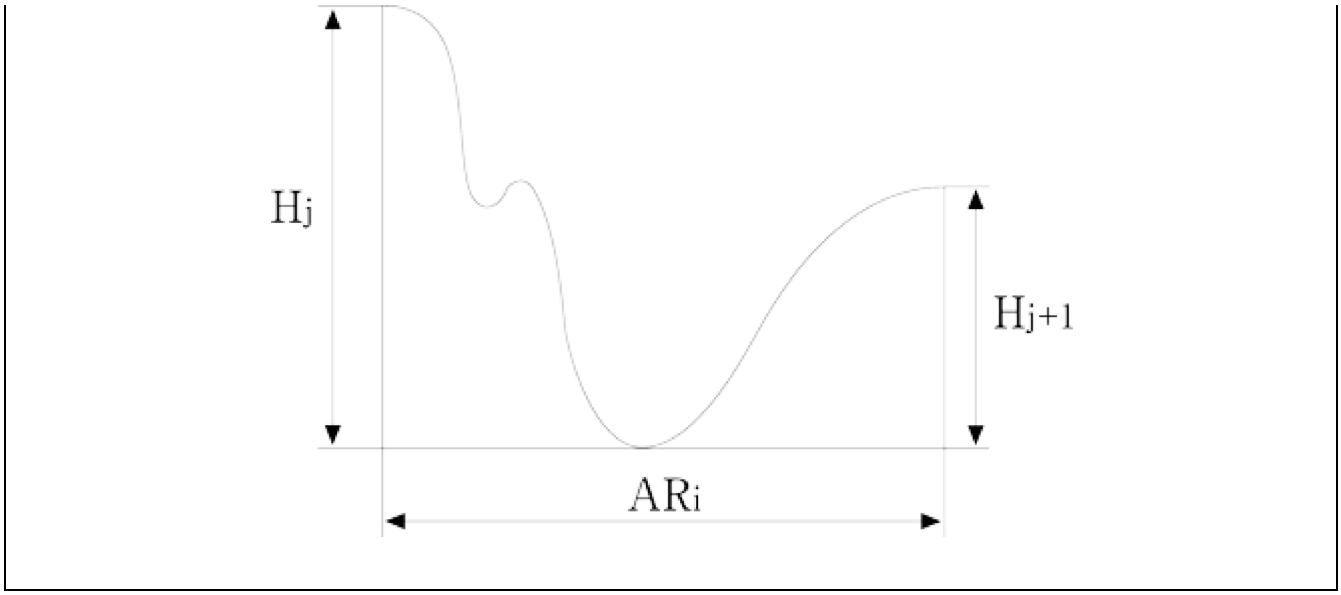
Motif parameters

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 ARi calculated from the evaluation length
R Mean depth of roughness motifs: the arithmetic mean of the roughness motif depth Hj calculated from the evaluation length
Rx Maximum depth of roughness motifs: the maximum value of the Hj calculated from the evaluation length
AW Mean spacing of waviness motifs: the arithmetic mean of the waviness motif AWi calculated from the evaluation length
W Mean depth of waviness motifs: the arithmetic mean of the waviness motif depth HWj calculated from the evaluation length
Wx Maximum depth of waviness motifs: the maximum value of the HWj calculated from the evaluation length

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





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