Precision Metrology 24- Roughness Parameters for Surface

Cut-off length(λc), or Sampling length(L_c):

Sampling length of profile to eliminate longer spacing errors such as waviness and form error from the measured profile. Mechanical filter, electrical filter, mathematical filter can attenuate the raw data measured.

Evaluation length, or Traversing length (L):

The length for roughness evaluation, or the length to be traversed for roughness measurement, typically set to $5\lambda c$.

The ISO 4288-1996 gives guidelines;

Recommended Cut-off (ISO 4288-1996)				
Periodic Profiles	Non-Periodic Profiles		Cut-off	Sampling Length/ Evaluation Length
Spacing Distance RSm (mm)	Rz (µm)	Ra (µm)	λc (mm)	λc (mm)/L
>0.013-0.04	To 0.1	To 0.02	0.08	0.08/0.4
>0.04-0.13	>0.1-0.5	>0.02-0.1	0.25	0.25/1.25
>0.13-0.4	>0.5-10	>0.1-2	0.8	0.8/4
>0.4-1.3	>10-50	>2-10	2.5	2.5/12.5
>1.3-4.0	>50	>10	8	8/40

Source: www.occonors.co.th

Surface parameters [ISO 4287, KSB0161]

Amplitude parameters: Vertical characteristics of roughness profile

Spacing parameters: Spacing of irregularity of roughness profile along a line of test

Hybrid parameters: Hybrid of Amplitude parameters and Spacing parameters, and is important in a functional view point

1. <u>Amplitude parameters</u>

Rp: Maximum Peak of roughness profile

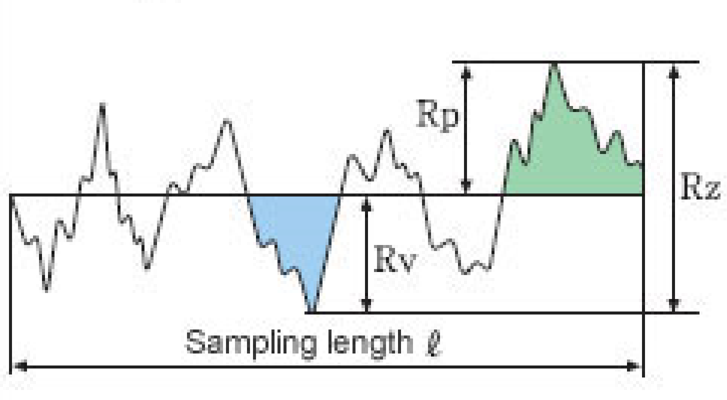
Rv: Minimum Valley of roughness profile

Rmax, Rt: Maximum Peak to Valley over the several cut-off lengths, that is Rp-Rv

Rz: Ten points Height of Irregularities

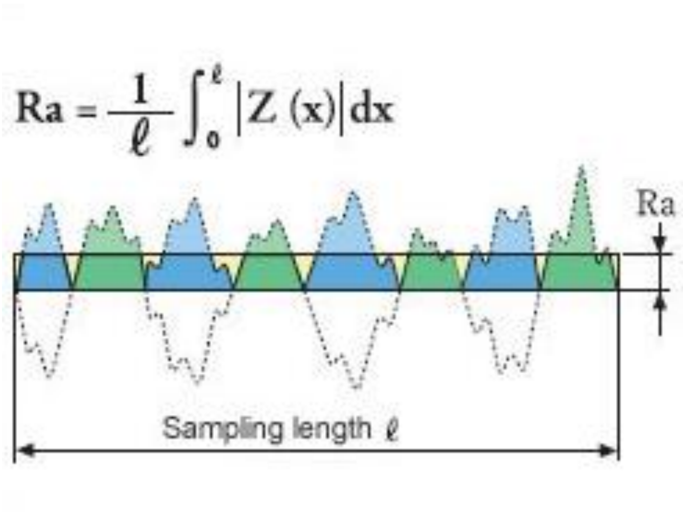
=Avg. of 5 Heights of Peaks- Avg. of 5 Lowest Valleys

=[Rp1+Rp2+Rp3+Rp4+Rp5]/5-[Rv1+Rv2+Rv3+Rv4+Rv5]/5



Source:www.olympus-ims.com

Ra: Average roughness



Source:www.olympus-ims.com

$Ra = \int | Z(x) - \underline{Z} | dx / L$

where $\underline{Z} = \int Z(x)dx/L$ =CLA(Centre Line Average)

In digital form; $Ra = [| Z_1 | + | Z_2 | + \ldots + | Z_n |]/N$

For a sinusoidal profile with amplitude A,

$Ra = 2A/\pi \fallingdotseq 0.636A$,

:The most popular parameters for surface roughness together with Rmax;

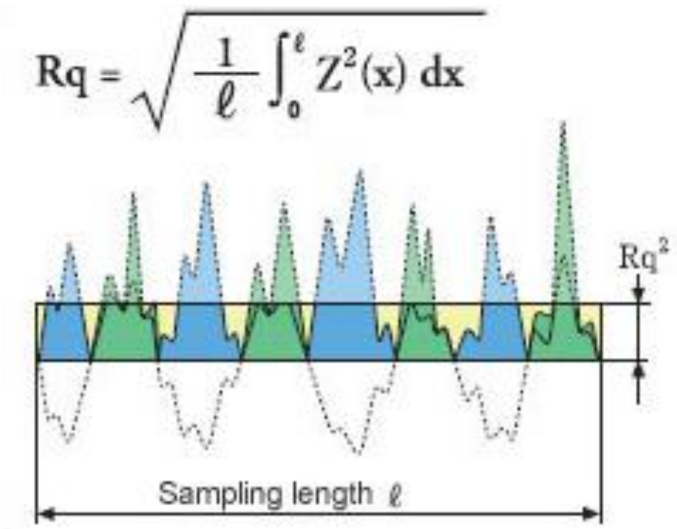
Rmax≒(4-7) Ra for normal machining,

Rmax≒(7-14) Ra for grinding and lapping

:Representative parameter for surface roughness, otherwise specified

:Peak, Valley are considered with the same significance, while the peak may be more significant for practical cases

<u>Rq: RMS(Root Mean Square) average roughness</u>



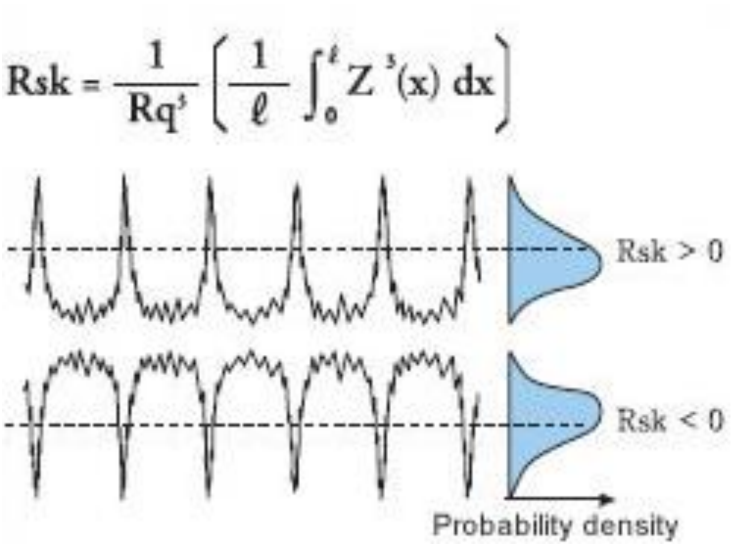
Source:www.olympus-ims.com

$Rq=\sqrt{\int[Z(x)-\underline{Z}]^2dx/L} \fallingdotseq \sqrt{[Z_1^2+Z_2^2+\ldots X_n^2]/N}$;

where $\underline{Z}$ is the CLA

$Rq= A/\sqrt{2}$ for a sinusoidal profile with amplitude A;

<u>Rsk: Skewness</u>



Source:www.olympus-ims.com

$Rsk=\int[\{Z(x)-\underline{Z}\}/Rq]^3dx/L$

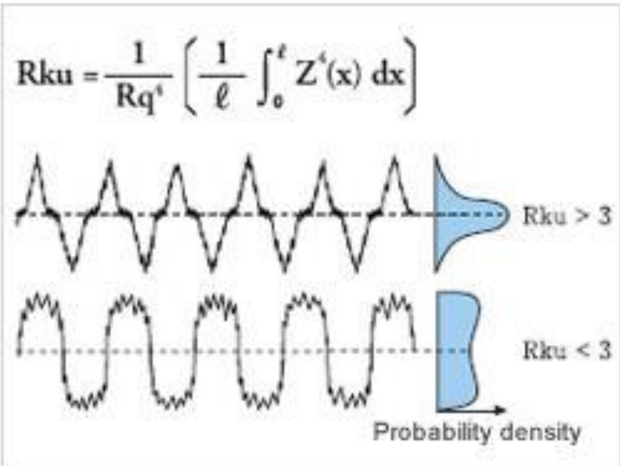
$=[Z_1^3+Z_2^3+\ldots+Z_n^3]/Rq^3/N$

Typically, $-3\leq Rsk\leq 3$, and

Symmetric profile if Rsk=0

Less wear and better load capacity if Rsk<0

<u>Rku: Kurtosis</u>



Source:www.olympus-ims.com

$$Rku=\int[\{Z(x)-\underline{Z}\}/Rq]^4dx/L$$

$$=[Z_1^4+Z_2^4+\ldots+Z_n^4]/Rq^4/N$$

Normal surface (Normal distribution) if Rku=3

Sharp surface if Rku>3

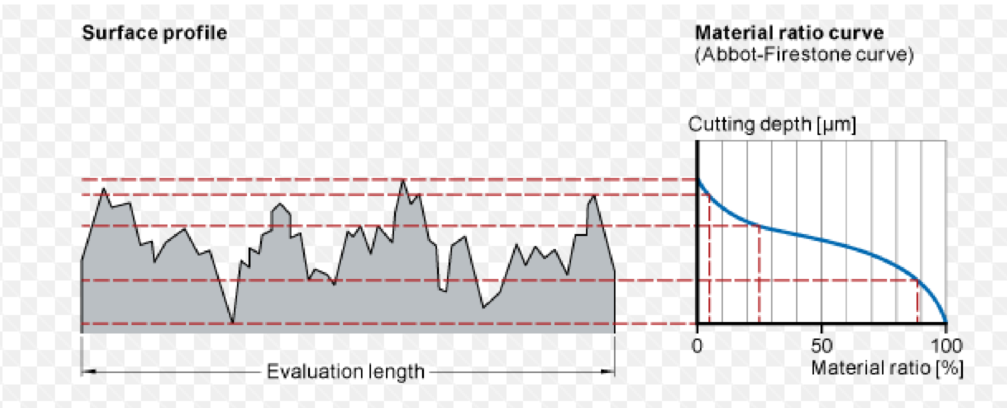
Dull surface if Rku<3

Bearing ratio, Material ratio, or Abbott Firestone Curve

:H vs Tp plot

Where, $Tp=[b_1+b_2+..+b_n] / L \times 100$ (%)

And b_n is the length of the n'th profile over the certain height, H



Source:www.skf.com

Straight line: Normal surface

Convex Curve: Less wear, Better load capacity

Concave Curve: More wear, Less load capacity

2. Spacing parameters

HSC: High Spot Count

Number of High Spots over the reference height during the evaluation length. Higher HSC surface with the same Ra give more dense profile.

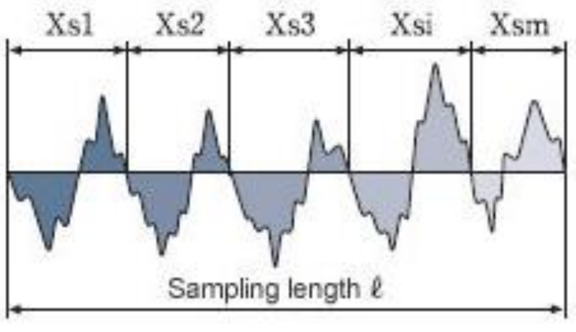
PC: Peak Count

Number of Peaks and Valleys exceeding the bandwidth from the reference height.

Sm or RSm: Average spacing between profiles

Average spacing of profile irregularities over length L

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



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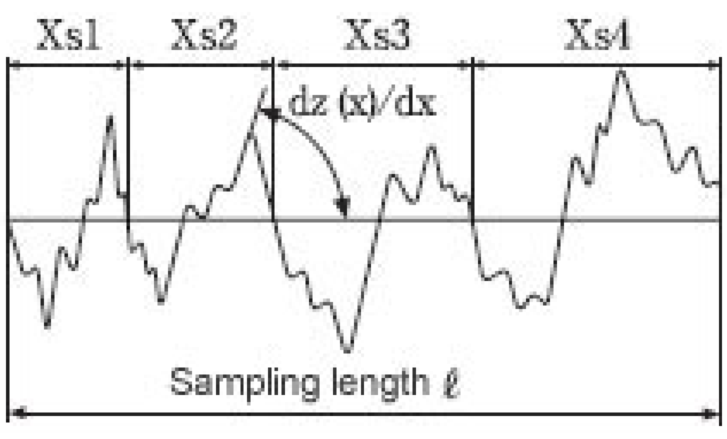
3. Hybrid Parameters



Source:www.olympus-ims.com

Lr: Ratio of profile length to the nominal length

$Lr = \int \sqrt{[1+\{dz/dx\}^2]} / L \leq 1.01$, typically

Application: painting, plating, coating

Average slope of profiles, Δa and Δq

$\Delta a = \int | dz/dx | dx / L \fallingdotseq \Sigma | \delta z/\delta x | / N$

$\Delta q = \sqrt{\int (dz/dx)^2 dx/L} \fallingdotseq \sqrt{[\Sigma(\delta z/\delta x)^2/N]}$

Generally, the average slope is less than 8 deg.

Application:

Mechanical->Good interfacial strength and Hertz stress with lower slope; Lower friction and adhesion with lower slope

Optical->Better reflectivity with lower slope

Average wavelength, λa, λq

$\lambda a = 2\pi Ra/\Delta a$

$\lambda q = 2\pi Rq/\Delta q$

Application: Larger wavelength profile will give less wear for the similar average roughness

<u>Comparison with ∇ and Ra</u>

∇∇∇∇ ⇒ 0.025-0.2 Ra

∇∇∇⇒ 0.4-1.6 Ra

∇∇⇒ 3.2-6.3 Ra

∇⇒ 12.5-25 Ra

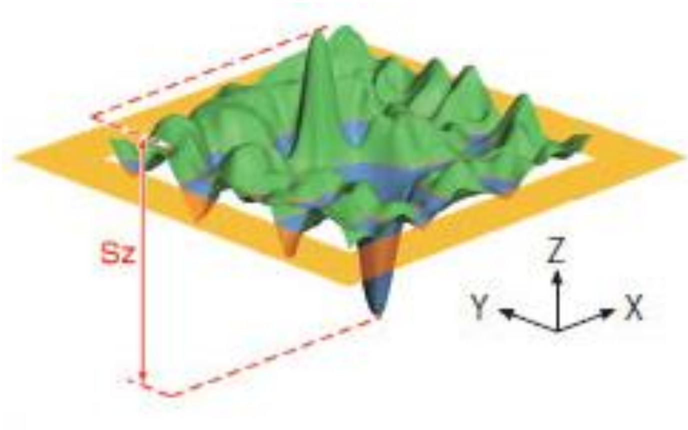
<u>3D Surface Parameters</u>

:To define 3D roughness parameters in terms of ISO 25178, that is 3D version of 2D parameters

Sp, Sv: Maximum peak, Valley over the surface

Sz, or Smax: Maximum peak to valley over the surface,

Sz=Sp-Sv



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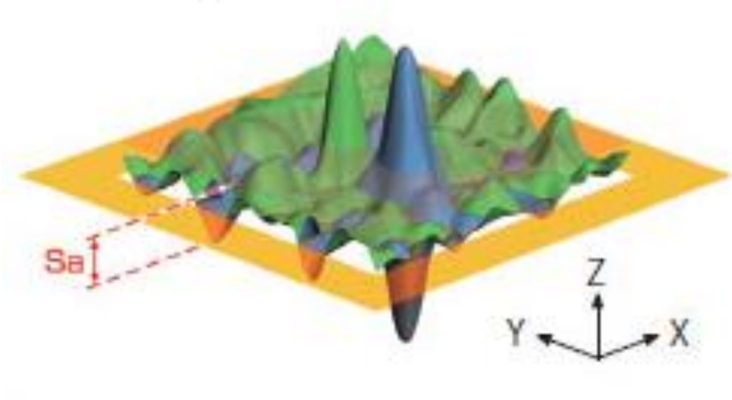
Sa: Average 3D surface roughness

$$Sa = \frac{1}{A}\iint_A |Z(x,y)|dxdy$$

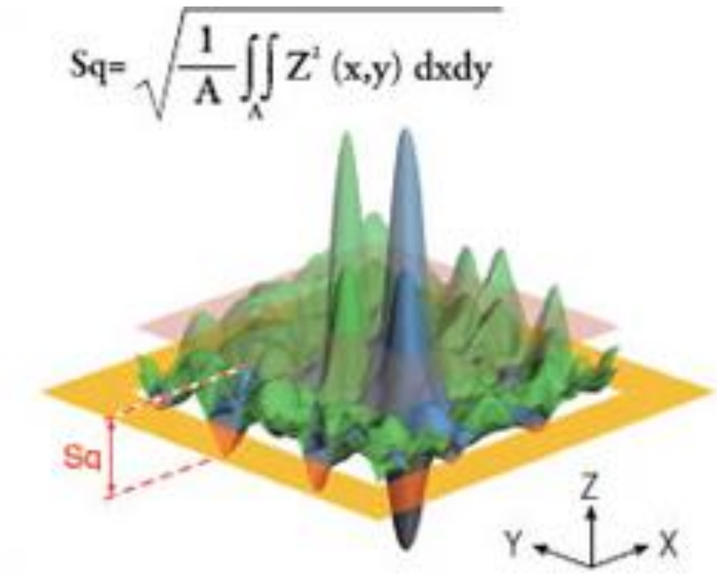


Source:www.olympus-ims.com

Sa=$\int\int$ | Z(x,y)-$\underline{Z}$ | dxdy / A,

where $\underline{Z}$=$\int\int$ | Z(x,y) | dxdy / A = mean surface height

<u>Sq:Average RMS 3D suface roughness</u>



Source:www.olympus-ims.com

Sq=$\sqrt{}\int\int(Z(x,y)-\underline{Z})^2$dxdy/A

where $\underline{Z}$ = mean surface height

Similarly, other 3D parameters can be defined;

3D Skewness, Ssk=$\int\int[Z(x,y)-\underline{Z}]^3/Sq^3$dxdy/A

3D Kurtosis, Sku=$\int\int[Z(x,y)-\underline{Z}]^4$ /Sq^4dxdy/A