Surface Engineering and Surface Roughness

ELECTRO DISCHARGE MACHINED SURFACE 19

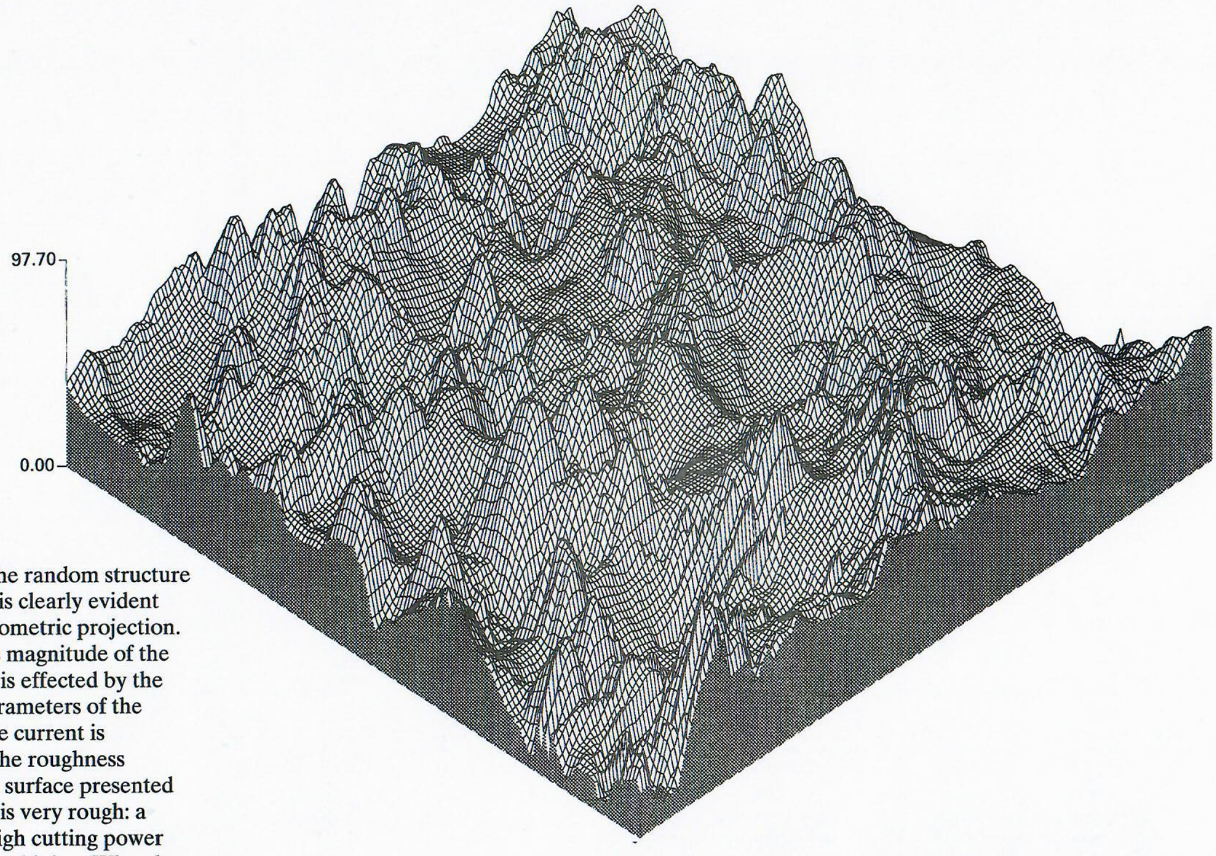
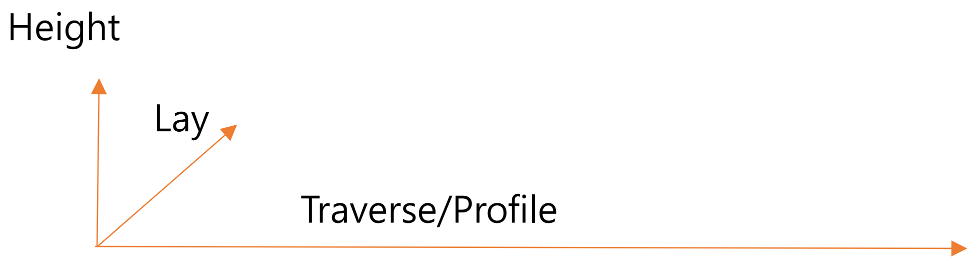
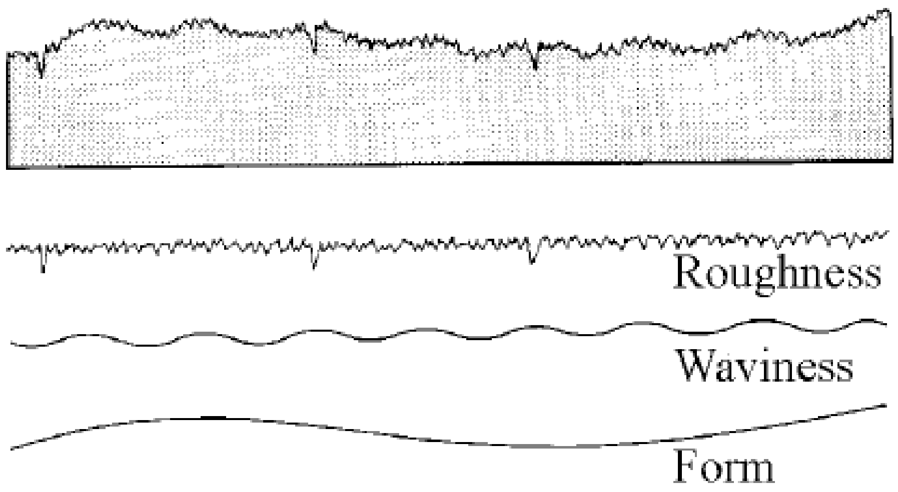


Figure 2.1 The random structure of the surface is clearly evident from the axonometric projection. Obviously, the magnitude of the *Ra* parameter is effected by the controlling parameters of the process. As the current is increased, so the roughness increases. The surface presented in this section is very rough: a result of the high cutting power used during machining. When low power is used the roughness is dramatically reduced, although the general form of the surface remains approximately the same.

Source: Prof. KJ Stout etal. Atlas of Machined Surfaces, Chapman and Hall, 1990

Precision Metrology 24- Roughness Parameters for Surface





Source: P.Ettl etal. Roughness parameters and surface deformation measured by Coherence Radar

ISO 4288-1996

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

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

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, typically set to 5λc

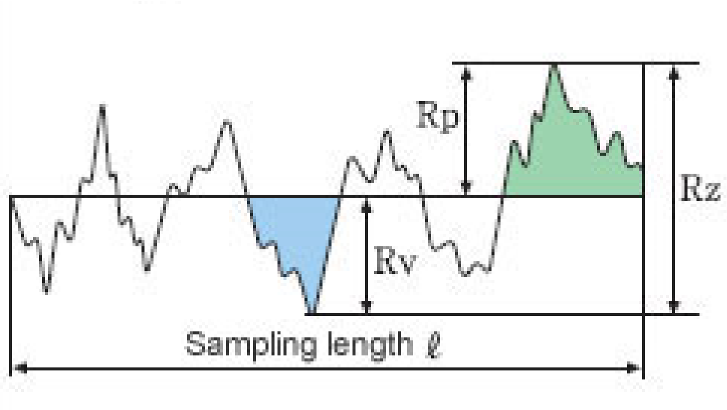
Surface parameters [ISO 4287, KSB0161]

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. Amplitude parameters



Source:www.olympus-ims.com

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

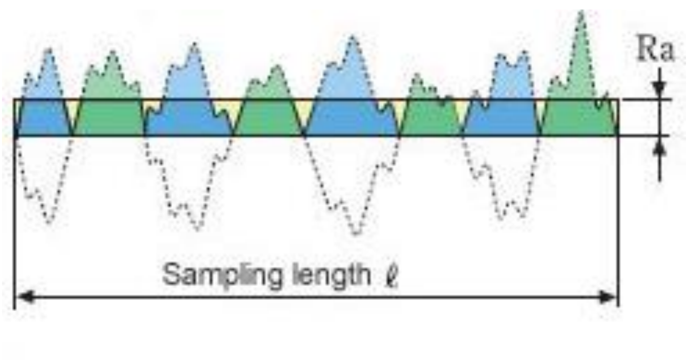
Rz: Ten points Height of Irregularities

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

=[Rp1+Rp2+Rp3+Rp4+Rp5]/5-

[Rv1+Rv2+Rv3+Rv4+Rv5]/5

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; $Ra = \Sigma | Z_i - \underline{Z} | /N$

For a sinusoidal profile with amplitude A,

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

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

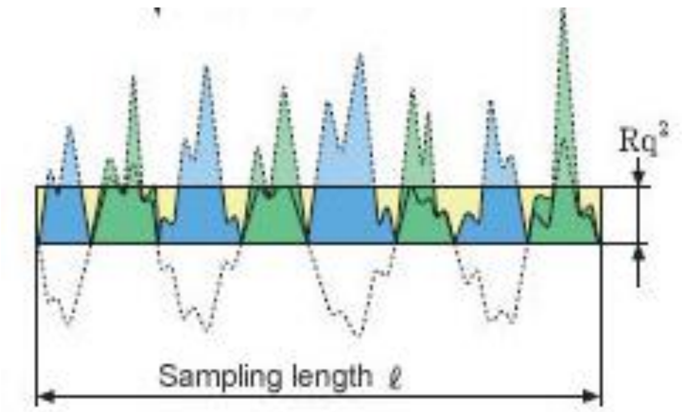
Rmax≒(4-7) Ra for normal machining,

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

Rq: RMS(Root Mean Square) average roughness



Source:www.olympus-ims.com

$Rq = \sqrt{\int [Z(x) - \underline{Z}]^2 dx / L} \fallingdotseq \sqrt{\Sigma (Z_i - \underline{Z})^2 / N}$;

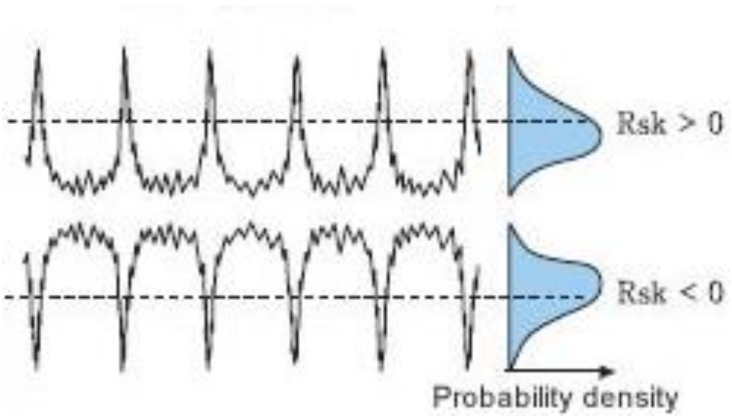
where $\underline{Z}$ is the CLA

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

Rsk: Skewness

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

$$= \Sigma (Z_i-\underline{Z})^3/Rq^3/N \text{ (in digital form)}$$



Source:www.olympus-ims.com

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

Symmetric profile if Rsk=0

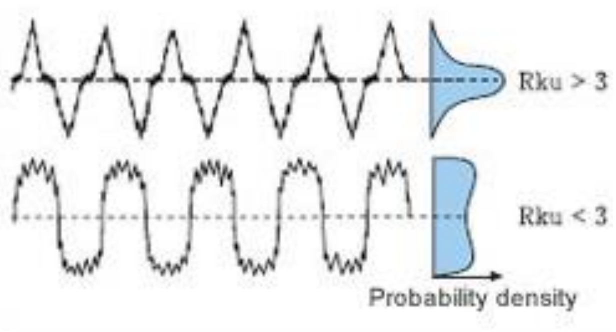
Less wear and better load capacity if Rsk<0

More wear and less load capacity if Rsk>0

Rku: Kurtosis

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

$= \Sigma(Z_i-\underline{Z})^4/Rq^4/N$ (in digital form)



Source:www.olympus-ims.com

Normal surface (Normal distribution) if Rku=3

Sharp surface if Rku>3

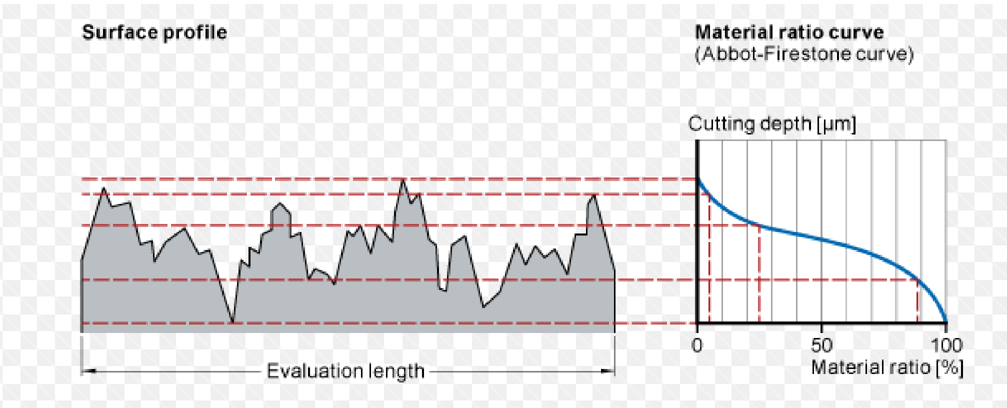
Dull surface if Rku<3

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

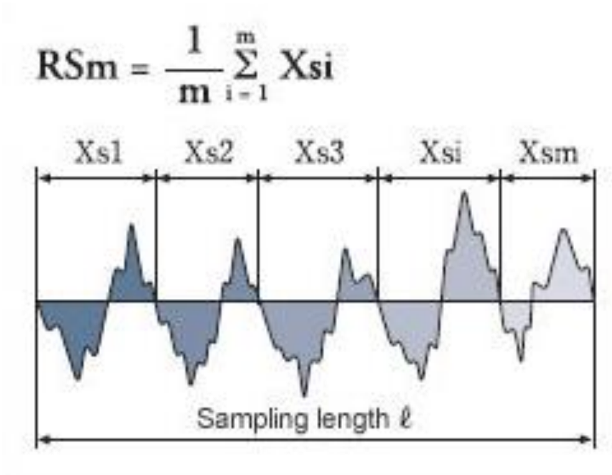
Convex Curve: Less wear, Better load capacity

Concave Curve: More wear, Less load capacity

2. Spacing parameters

Sm or RSm: Average spacing between profiles

Average spacing of profile irregularities over length L



Source:www.olympus-ims.com

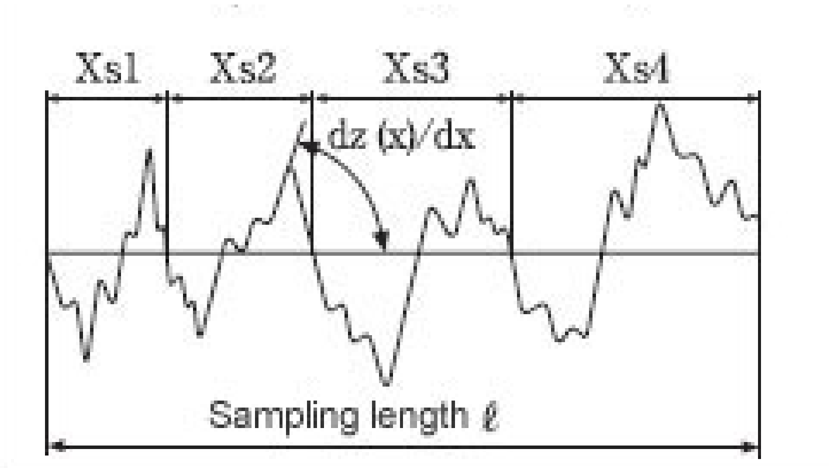
HSC: High Spot Count

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.

3. Hybrid Parameters



Source:www.olympus-ims.com

<u>Average slope of profiles, Δa and Δq</u>

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

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

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

Lr: Ratio of profile length to the nominal length

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

In digital form, $Lr = \Sigma\sqrt{[1+(\delta z/\delta x)_i^2]}/N$

Application: painting, plating, coating

Comparison with ∇ and Ra

∇∇∇∇ ⇒ 0.025-0.2 Ra

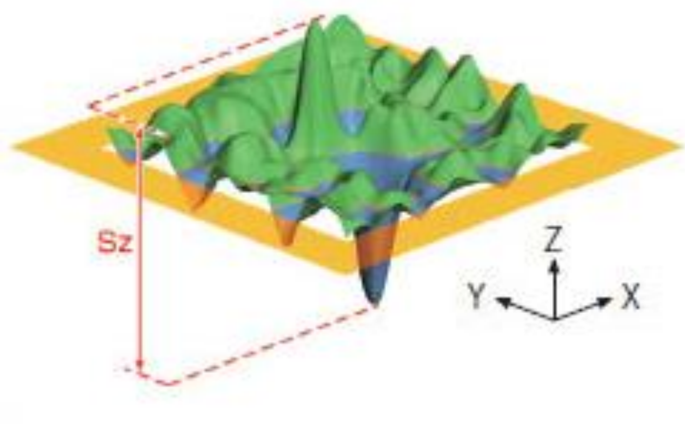
∇∇∇⇒ 0.4-1.6 Ra

∇∇⇒ 3.2-6.3 Ra

∇⇒ 12.5-25 Ra

3D Surface Parameters

:To define 3D roughness parameters in terms of ISO 25178; 3D version of 2D parameters



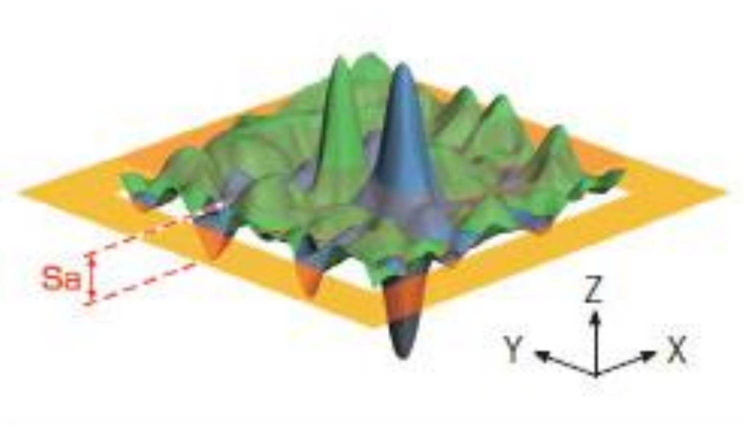
Source:www.olympus-ims.com

Sp, Sv: Maximum peak, Valley over the surface

Sz or Smax: Maximum peak to valley over the surface

Sz or Smax = Sp-Sv

Sa: Average 3D surface roughness



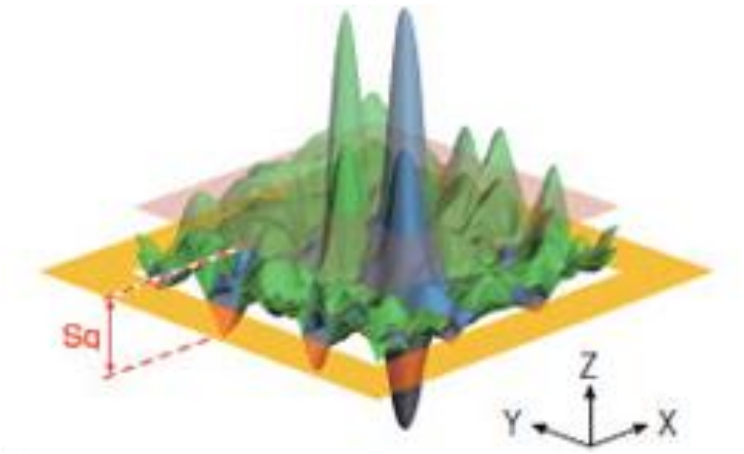
Source:www.olympus-ims.com

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

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

In digital form, $Sa = \Sigma | Z_i - \underline{Z} | / N$, where $\underline{Z} = \Sigma Z_i / N$

Sq:Average RMS 3D suface roughness



Source:www.olympus-ims.com

$$Sq=\sqrt{\left[\iint (Z(x,y)-\underline{Z})^2 dxdy/A\right]}$$

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

In digital from $Sq=\sqrt{[\Sigma(Z_i-\underline{Z})^2/N]}$

3D Skewness, Ssk

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

$= \Sigma (Z_i - \underline{Z})^3 / Sq^3 / N$ (in digital form)

3D Kurtosis, Sku

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

$= \Sigma (Z_i - \underline{Z})^4 / Sq^4 / N$ (in digital form)

Sr: Area Ratio of 3D surface to the nominal surface

$Sr = \int\int \sqrt{[1 + (dz/dx)^2 + (dz/dy)^2]} dxdy / A$

In digital form, $Sr = \Sigma \sqrt{[1 + (\delta z/\delta x)_i^2 + (\delta z/\delta y)_i^2]} / N$

Metrology

I often say that when you can measure what you are speaking about and express it in numbers, you know something about it.

But when you can not measure it, or when you can not express it in numbers, your knowledge is of a meagre and unsatisfactory kind.

Lord Kelvin