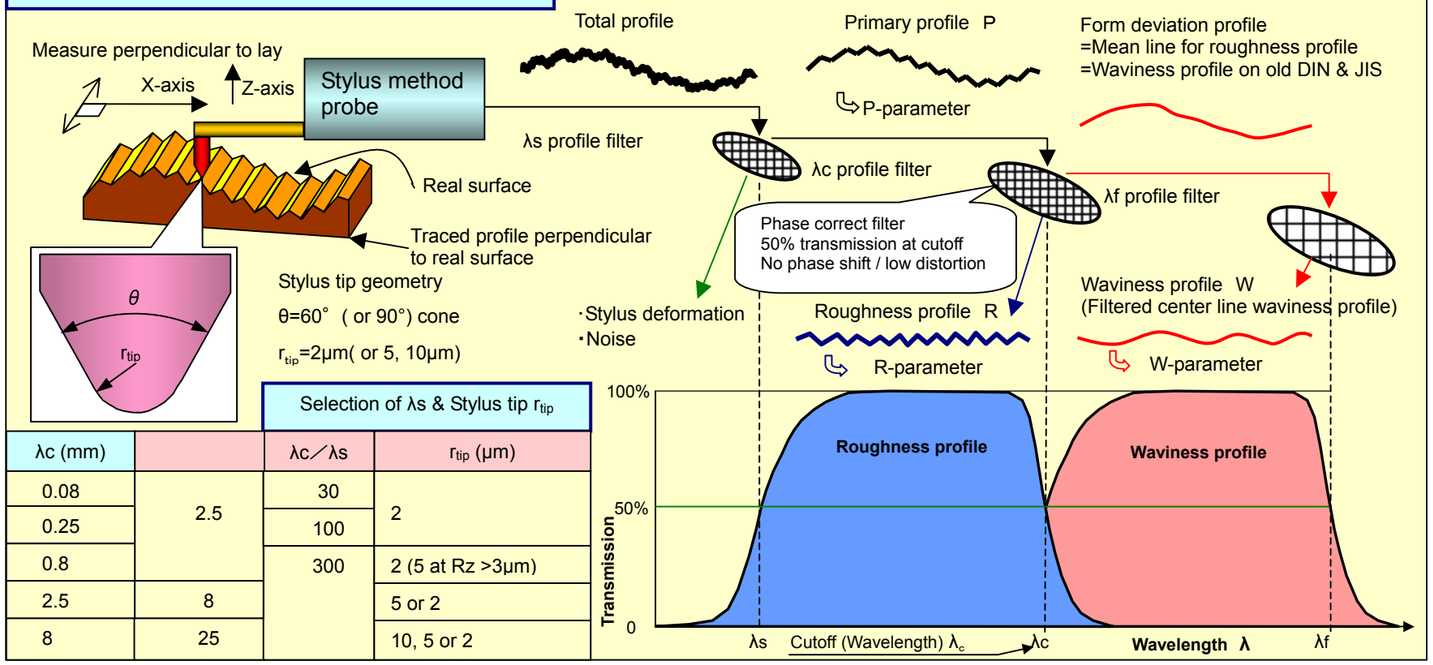
Definition of Surface texture and Stylus instrument

Confirm to ISO'02

Profile by Stylus and phase correct filter

ISO4287:'97 and ISO3274:'96

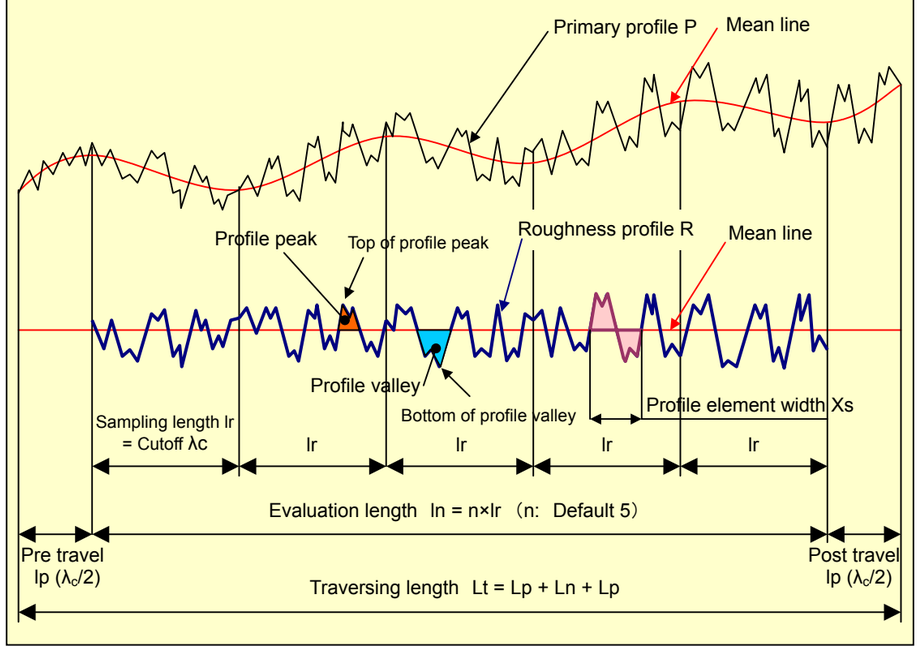


Selection of λs & Stylus tip r_{tip}

λc (mm)		λc／λs	r_{tip} (μm)
0.08	2.5	30	2
0.25		100	
0.8		300	2 (5 at Rz >3μm)
2.5	8		5 or 2
8	25		10, 5 or 2

Sampling length and Evaluation length

ISO4287:'97



Measuring condition: R-parameter

ISO4288:'96

Non-periodic profile				Periodic profile or RSm		Measuring condition	
Ra,Rq,Rsk,Rku or RΔq		Rz,Rv,Rp,Rc, or Rt				Sampling length : lr = Cutoff λc (mm)	Evaluation length ln (mm) = 5 × lr
Ra (μm)		Rz (μm)		RSm (mm)			
Over>	Less≤	Over>	Less≤	Over>	Less≤		
0.006	0.02	0.025	0.1	0.013	0.04	0.08	0.4
0.02	0.1	0.1	0.5	0.04	0.13	0.25	1.25
0.1	2	0.5	10	0.13	0.4	0.8	4
2	10	10	50	0.4	1.3	2.5	12.5
10	80	50	200	1.3	4	8	40

Measuring condition : P-parameter

ISO4288:'96

Stylus radius	λs	λc	No. of lp = n	S.length lp	E.length ln
2μm	2.5μm	—	1	Length of feature (Plane, Line)	Length of feature
5μm	8μm				
10μm	25μm				

Measuring condition: W-parameter

ISO1302:'02

λc	λf	No. of lw = m	S. length lw	E. length ln
λc (for roughness)	n λc (n: specified)	m: specified	λf	mλf

Evaluation procedure of roughness

ISO4288:'96

1. View the surface and decide whether profile is periodic or non-periodic.
2. When the tolerance limit is specified, use the table shown on the left for condition.
3. When the tolerance limit is not specified.
   - 3.1 Estimate roughness and measure it in corresponding condition in the table.
   - 3.2 Change condition according with above result and measure it again.
   - 3.3 Repeat "3.2" if the result does not reached the condition.
   - 3.4 When the result reaches the condition, it will be the final value.
     Check it in shorter sampling length at non-periodic and change it if it meets.
4. Compare the result toward tolerance limit in accordance with following rule,

Upper limit - the 16% rule (Default)

Measure on the most critical surface. If not more than 16% of all value based on sampling length are exceed the limit, surface is acceptable.
- The first value does not exceed 70% of the limit.
- The first three values do not exceed the limit.
- Not more than one of the first six value exceed the limit.
- Not more than two of the first twelve value exceed the limit.

or when μ+σ does not exceed the limit, the result is acceptable.

Lower limit - the 16% rule (shown as L)

Measure the surface that can be expected the lowest roughness.
If not more than 16% of all sampling length are less than the limit, or when μ-σ is not less than the limit, the result is acceptable.

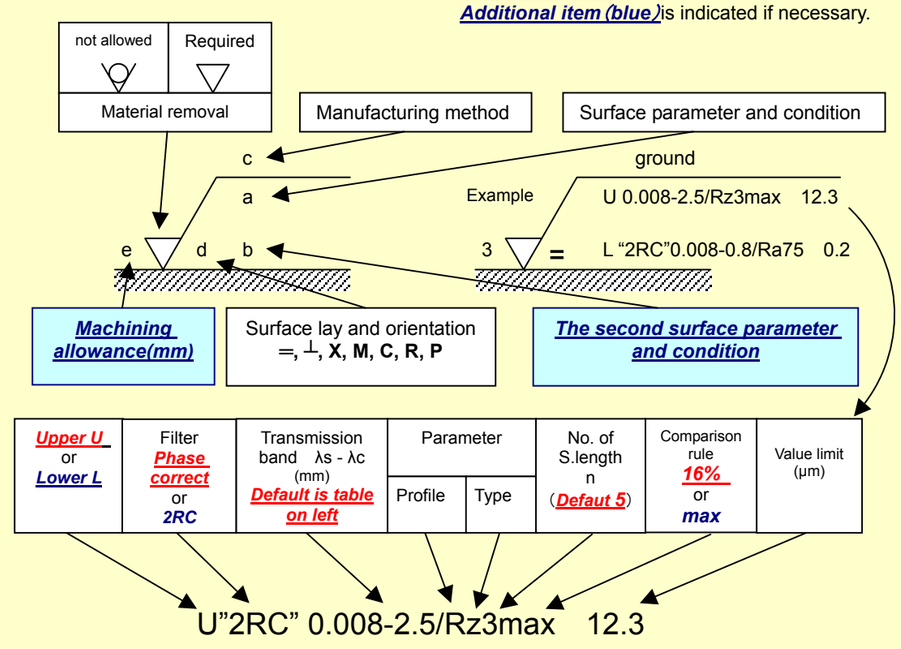
Max value - the max rule (when "max" suffix is added)

The value is acceptable when none of value in entire surface is over the limit.

Indication of surface texture

ISO1302:'02

Note. :
Default item (red) is not indicated.
Additional item (blue) is indicated if necessary.



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Basic surface texture parameters and curves

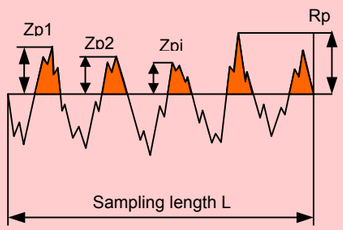
Confirm to ISO4287:'97

Amplitude parameters (peak and valley)

Rp / Pp / Wp — Maxmum profile peak height

The largest profile peak height Zp within a sampling length.

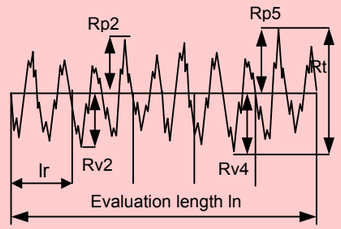
Rp, Pp, Wp = max(Z(x))



Rt / Pt / Wt — Total height of profile (Pt = Rmax at JIS'82)

Sum of height of the largest profile peak height Rp and the largest profile valley Rv within an evaluation length.

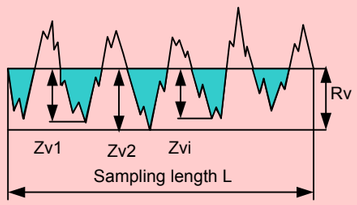
Rt, Pt, Wt = max(Rpi)+max(Rvi)



Rv / Pv / Wv — Maximum profile valley depth

The largest profile valley depth Zp within a sampling length.

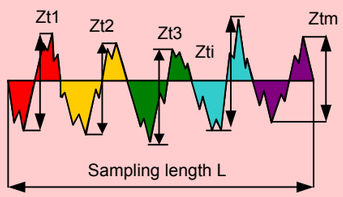
Rv, Pv, Wv = min(Z(x))



Rc / Pc / Wc — Mean height of profile elements

Mean value of the profile element heights Zt within a sampling length

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

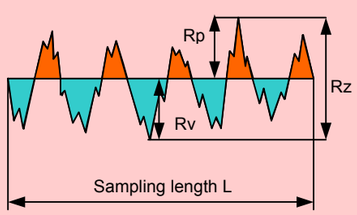


Profile element:
Profile peak & the adjacent valley

Rz / Pz / Wz — Maximum height of profile (Rz = Ry at ISO4287 '84)

Sum of height of the largest profile peak height Rp and the largest profile valley Rv within a sampling length.

Rz = Rp + Rv

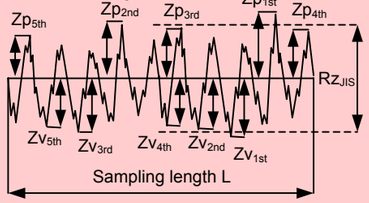


Different from Rz at old ISO,ANSI &JIS

Rz_{JIS} Ten point height of roughness profile (Rz at JIS'94)

Sum of mean value of largest peak to the fifth largest peak and mean value of largest valley to the fifth largest valley within a sampling length.

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



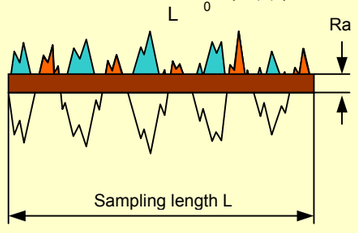
Annex of JIS only and confirm to JIS'94
Different from Rz at JIS'82

Amplitude average parameters

Ra / Pa / Wa — Arithmetical mean deviation

Arithmetic mean of the absolute ordinate values Z(x) within a sampling length.

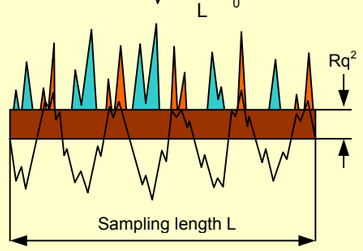
$$Ra, Pa, Wa = \frac{1}{L}\int_0^L |Z(x)|\,dx$$



Rq / Pq / Wq — Root mean square deviation

Root mean square value of the ordinate values Z(x) within a sampling length.

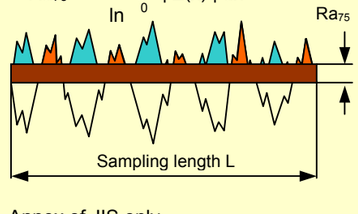
$$Rq, Pq, Wq = \sqrt{\frac{1}{L}\int_0^L Z^2(x)\,dx}$$



Ra_{75} Center line average (Old Ra,AA,CLA)

Arithmetic mean of the absolute ordinate value Z(x) in a sampling length of roughness profile with 2RC filter of 75% transmission.

$$Ra_{75} = \frac{1}{ln}\int_0^{ln} |Z(x)|\,dx$$



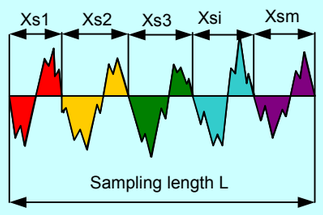
Annex of JIS only
Same as Ra at old ISO,ANSI & DIN

Spacing parameters

RSm / PSm / WSm — Mean width of the profile elements (RSm = Sm at ISO4287 '84)

Mean value of the profile element width Xs within a sampling length.

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

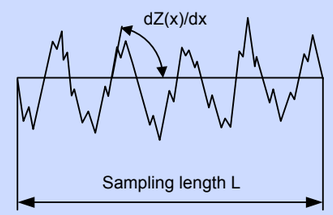


Hybrid parameters

RΔq / PΔq / WΔq — Root mean square slope

Root mean square value of the ordinate slopes dZ/dX within a sampling length.

$$R\Delta q, P\Delta q, W\Delta q = \sqrt{\frac{1}{L}\int_0^L \left[\frac{d}{dx}Z_{(x)}\right]^2 dx}$$

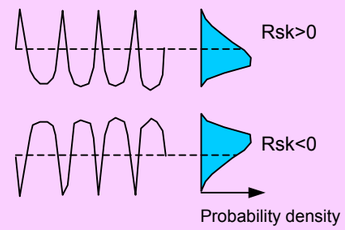


Height characteristic average parameters

Rsk / Psk / Wsk — Skewness

Quotient of mean cube value of the ordinate values Z(x) and cube Pq,Rq,Wq respectively, within a sampling length.

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



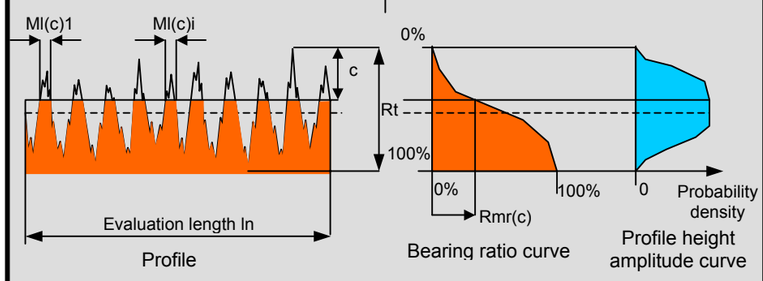
Parameter from bearing ratio curve and profile height amplitude curve

Material ratio curve of the profile (Abbott Firestone curve)

Curve representing the material ratio of the profile as a functional of level c.

Profile height amplitude curve

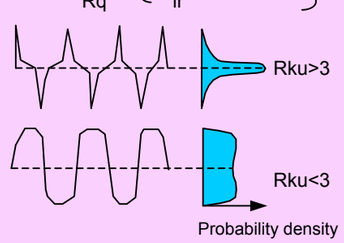
Sample probability density function of ordinate Z(x) within an evaluation length.



Rku / Pku / Wku — Kurtosis of profile

Quotient of mean quartic of the ordinate values Z(x) and 4th power of Pq,Rq,Wq respectively, within a sampling length.

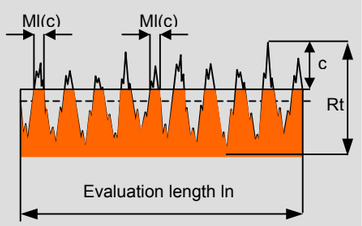
$$Rku = \frac{1}{Rq^4}\left[\frac{1}{lr}\int_0^{lr} Z^4(x)\,dx\right]$$



Rmr(c) / Pmr(c) / Wmr(c) — Material ratio of profile (Rmr(c) = ex- tp)

Ratio of the material length of the profile elements Ml(c) at a given level c to the evaluation length.

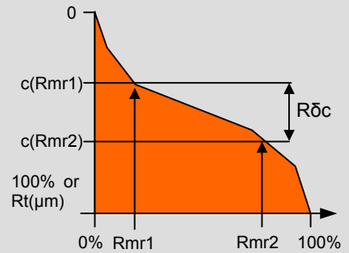
$$Rmr(c) = \frac{100}{Ln}\sum_{i=1}^{m} Ml(c)i \quad (\%)$$



Rδc / Pδc / Wδc — Profile section height difference

Vertical distance between two section levels of given material ratio.

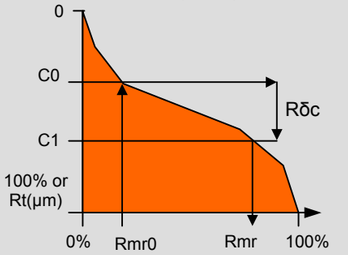
Rδc = c(Rmr1)-c(Rmr2) : Rmr1<Rmr2



Rmr / Pmr / Wmr — Relative material ratio

Material ratio determined at a profile section level Rδc, related to a reference c_0

Rmr = Rmr(c_1)
c_1= c_0- Rδc、c_0= c(Rmr0)



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Expanded surface texture parameters and curves

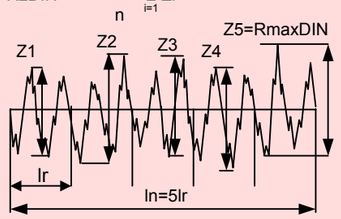
Confirm to ISO4287:'96, ISO12085:'96 & ISO13565-1:'96 / -2:'96 / -3:'98

Traditional local parameters

RmaxDIN: Maximum peak to valley height
RzDIN: Average peak to valley height

Zi is the maximum Peak to valley height of a sampling length lr.
RmaxDIN is the maximum Zi of 5 adjoining sampling length lr in an evaluation length ln.
RzDIN is arithmetic mean of 5 Zi.

$$RzDIN = \frac{1}{n}\sum_{i=1}^{n} Zi$$



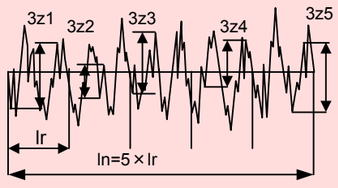
German old standard DIN4768/1:'90

R3z: Base roughness depth

3Zi is the height of the 3rd height peak from the 3rd depth valley in a sampling length lr.

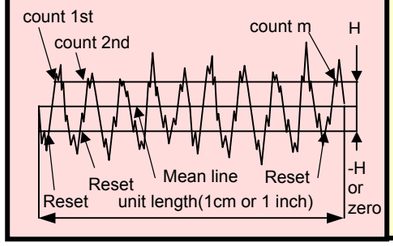
R3z is arithmetic mean of 3Zi's of 5 sampling lengths in an evaluation length ln.

$$R3z = \frac{1}{n}\sum_{i=1}^{n} 3zi$$



Pc Peak density /cm: ASME B46.1:'95
PPI Peaks per inch: SAEJ911
HSC High spot count

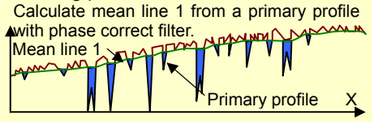
Pc is the number of peaks counted when a profile intersects a lower boundary line -H and an upper line +H per unit length 1 cm.
PPI shows Pc in 1 inch (25.4mm) unit length.
HSC shows the number of peaks when the lower boundary level is equal to zero.



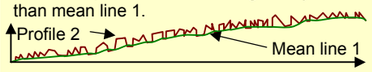
Parameters of surfaces having stratified functional properties ISO13565's

Filtering process of ISO13565-1:'96

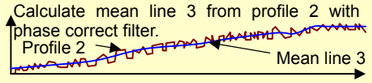
Calculate mean line 1 from a primary profile with phase correct filter.



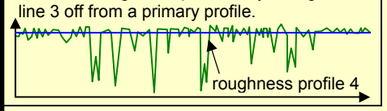
Calculate profile 2 with cutting valley lower than mean line 1.



Calculate mean line 3 from profile 2 with phase correct filter.



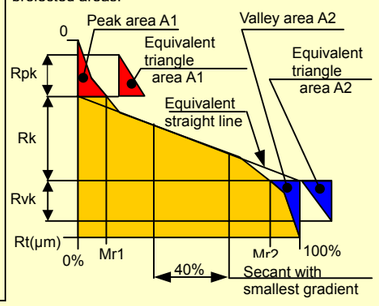
Calculate roughness profile 4 by taking mean line 3 off from a primary profile.



Measuring condition of ISO13565-1

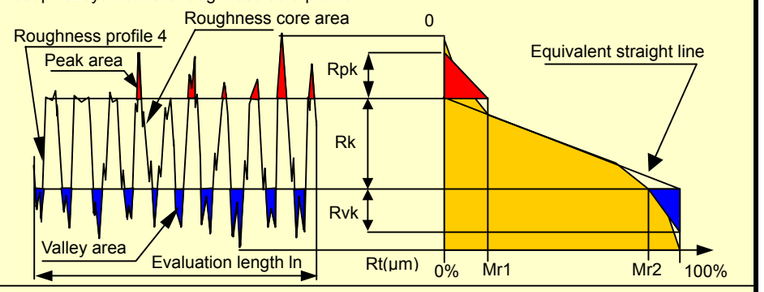
Cutoff value λc	Evaluation length ln
0.8mm	4 mm
2.5mm	12.5mm

40% length secant of smallest gradient separate the material ratio curve into core area & projected areas.
Calculate Rpk & Rvk with equivalent triangles of projected areas.



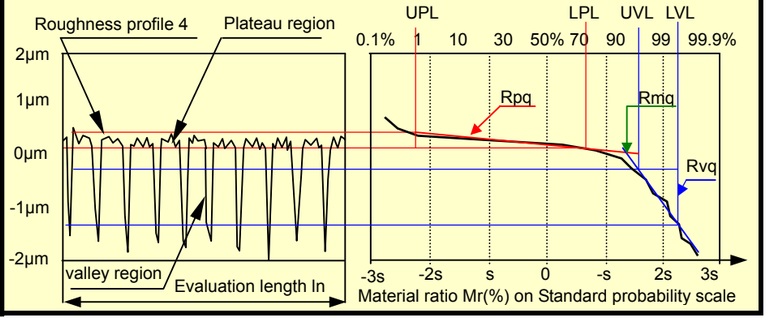
Height characterization using the linear material ratio curve ISO13565-2:'96

Rk: core roughness depth: Depth of the roughness core profile
Rpk:reduced peak height: Average height of protruding peaks above roughness core profile.
Rvk:reduced valley depths: Average depth of valleys projecting through roughness core profile.
Mr1: material portion 1: Level in %, determined for the intersection line which separates the protruding peaks from the roughness core profile.
Mr2: material portion 2: Level in %, determined for the intersection line which separates the deep valleys from the roughness core profile.



Height characterization using the material probability curve of ISO13565-3

Draw a material ratio curve on normal probability paper from the roughness profile 4 (primary profile) of an evaluation length.
Separate the material probability curve to 2 area, upper plateau area and lower valley area.
Rpq (Ppq) parameter: slope of a linear regression performed through the plateau region.
Rvq (Pvq) parameter: slope of a linear regression performed through the valley region.
Rmq (Pmq) parameter: relative material ratio at the plateau to valley intersection.

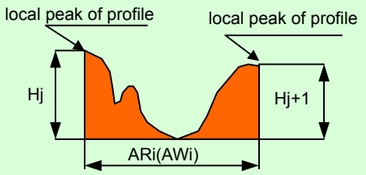


Motif parameters of ISO12085:'96

Motif: A portion of the primary profile between the highest points of two local peaks of the profile, which are not necessarily adjacent.

Motif depths H_j & H_{j+1}: Depth measured perpendicular to the general direction of the primary profile.

Motif length Ari or AWi: Length measured parallel to the general direction of the profile.



Measuring condition

Default A=0.5mm、B=2.5mm, ln=16mm

A(mm)	B(mm)	ln (mm)	λs (μm)
0.02	0.1	0.64	2.5
0.1	0.5	3.2	
0.5	**2.5**	**16**	**8**
2.5	12.5	80	25

Indication of ISO1302:'02

Roughness motif

√ λs – A / ln / R parameter limit value

Waviness motif

√ A – B / ln / W parameter limit value

(default value need not to be indicated)

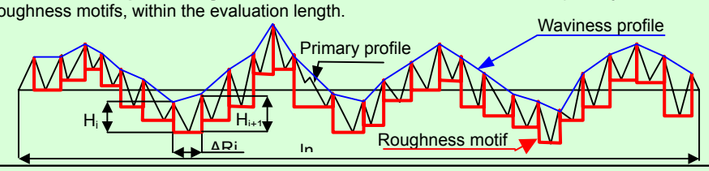
Roughness motif: Motif derived by using the ideal operator with limit value A.
Limit value A: Maximum length of roughness motif to separate waviness motif.
Upper envelope line of the primary profile (Waviness profile): Straight lines joining the highest points of peaks of the primary profile, after conventional discrimination of peaks.
AR: Mean spacing of roughness motifs: The arithmetical mean value of the lengths AR_i of roughness motifs, within the evaluation length, i.e.

$$AR = \frac{1}{n}\sum_{i=1}^{n} AR_i \quad (n: \text{Total number of roughness motifs})$$

R: Mean depth of roughness motifs: The arithmetical mean value of the depths H_j of roughness motifs, within the evaluation length, i.e.

$$R = \frac{1}{m}\sum_{j=1}^{m} H_j \quad m=2n$$

Rx: Maximum depth of roughness motifs: The maximum value of the depths Hj of roughness motifs, within the evaluation length.



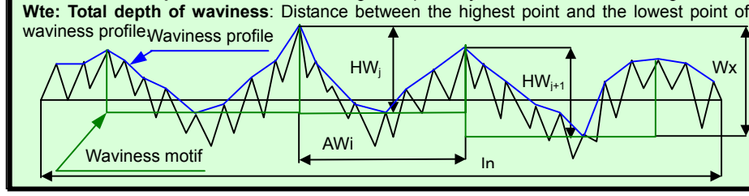
Waviness motif: Motif derived on upper envelope line by using ideal operator with limit value B
Limit value B: Maximum length of waviness motif
AW: Mean spacing of waviness motifs: The arithmetical mean value of the lengths Awi of waviness motifs, within the evaluation length, i.e.

$$AW = \frac{1}{n}\sum_{i=1}^{n} Awi \quad (n: \text{Total number of waviness motifs})$$

W: mean depth of waviness motifs: The arithmetical mean value of the depths HWj of waviness motifs, within the evaluation length, i.e.

$$W = \frac{1}{m}\sum_{j=1}^{m} HWj \quad m=2n$$

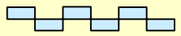
Wx: Maximum depth of waviness: The largest depth HWj, within the evaluation length.
Wte: Total depth of waviness: Distance between the highest point and the lowest point of waviness profile.



Hint of surface texture measurement

Roughness parameter conversion
The parameter ratio Ra／Rz (Rmax,Ry)=0.25 is applicable only to triangle profile.
Actual profiles have different parameter ratios according to the form of profile.

Rectangle: Ra/Rz=0.5



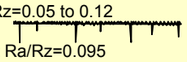
Sinusoidal: Ra/Rz=0.32

Triangle: Ra/Rz=0.25

Lathed, Milled: Ra/Rz=0.16 to 0.26

Ground, Sand blasted: Ra/Rz=0.10 to 0.17

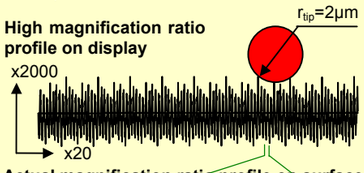
Honing, Lapped: Ra/Rz=0.05 to 0.12



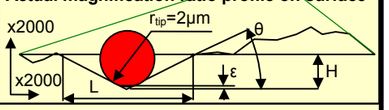
Pulse (Duty ratio 5%): Ra/Rz=0.095

Display aspect ratio & Stylus fall depth in valley
Roughness profile usually displayed as much magnified height deviations than wavelength.
Displayed valley looks sharp but actually wide. Stylus can contact to bottom of valley.
Depth error ε with stylus unable to contact on triangle valley is; $\varepsilon = r_{tip}(1/\cos\theta - 1)$
θ<15˚, or H/L=0.1-0.01 on machined surface.

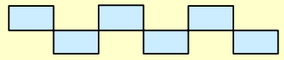
High magnification ratio profile on display



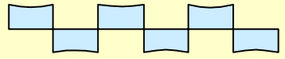
Actual magnification ratio profile on surface



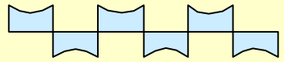
Profile distortion with cutoff
Roughness profile will have bigger profile distortion & smaller amplitude when cutoff λc is short.
Primary profile P



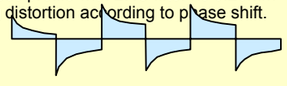
Roughness profile R phase correct λc 0.8mm



Roughness profile R phase correct λc 0.25mm



Roughness profile with 2RC filter λc 0.25mm have big distortion according to phase shift.



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Comparison of national standards of surface texture measurement

Specification \ ID. of national standard / country		JIS B0601-'82 JIS B0031-'82 former Japan	ANSI B46.1-'85 former U.S.A.	NF E05-015('84) NF E05-016('78) NF E05-017('72) former France	ISO468-'82 ISO4287/1-'84 ISO4288-'85 ISO1302-'78 former ISO	BS1134 part 1-'88 BS1134 part 2-'90 former U.K.	DIN4768-'90 DIN4771-'77 DIN4775-'82 DIN4776-'90 DIN4777-'90 former Germany	JIS B0601-'94 JIS B0031-'94 former Japan	ASME B46.1-'95 U.S.A.	ISO4287:'97 (JISB0601:'01) ISO4288:'96 (JISB0633:'01) ISO12085:'96 (JISB0631:'00) ISO13565's, (JISB0671's) ISO1302:'02 EU, U.K. & Japan
Primary profile P	Profile format	Analog signal without filtering	Analog signal with low pass filtering	Analog signal without filtering	Analog signal without filtering	Analog signal without filtering	Digital data without filtering	Digital data without filtering	Digital data with λs filter	Digital data with λs filter
	Evaluation length	1 sampling length 0.25,0.8,2.5,8,&25	———	not defined	———	———	0,5, 1,5, 5, 15 & 50mm	———	———	= 1 sampling length = Length of the measured feature
P profile parameter	Maximum height	Rmax(**S** indication)	———	Pt	———	———	Pt	———	———	Pt, Pz(=Pt)
	Ten point height	Rz (**Z** indication)	———	———	———	———	———	———	———	———
	Other P parameters	———	———	Pp, Pa, (Tp)c,	———	———	———	———	———	Pp,Pv,Pc,Pa,Pq,Psk,Pku,PSm, PΔq,Pmr(c),Pδc,Pmr,Ppq,Pvq,Pmq
	Motif parameters	———	———	R, AR, Kr, W, W'max, W't, AW, Kw	———	———	———	———	———	R, AR, Rx, W, AW, Wx, Wte
	Indication of maximum height <1.5μm	Rmax=1.6 Rmax=0.8	———	Pt 0.8 - 1.6	———	———	15 / Pt 1,6	———	———	U 0.008- / Pt 1.5
Roughness profile R	Unit of height	μm	μm or μin.	μm	μm	μm (μin)	μm	μm	μm (or μin.)	μm
	Unit of length	mm	mm or in.	mm	mm	mm(inch)	mm	mm	mm (or in.)	mm
	Filter	2RC	2RC	2RC	2RC	2RC	Phase correct	Phase correct	Phase correct(or 2RC)	Phase correct
	Long cutoff	λc	λ_B	λc	λc	λ_B	λc	λc	λc	λc
	Short cutoff	———	cutoff value 2.5μm	———	———	———	———	———	λs	λs
	Sampling length	L=3 x λc or over	L:1.3-5mm@λ_B 0.25 L:2.4-8mm@λ_B0.8 L:5-15mm @λ_B2.5	l	l	lr	lc	lr	Cutoff length : l	lr
	Evaluation length	TL=L=3 x λc or over		L = n x l	ln = n x l	le = 5 x lr	5 x lc	le = 5 x lr	L = 5 x l	le = 5 x lr Calculate for each sampling length lr
R profile Height parameter	Maximum height	———	Peak-to-Valley Height (Rmax,Ry)	Ry	Ry	———	Rt	Maximum height Ry in 1 lr	Rt	Maximum height Rz in 1 lr or total height Rt in 1 le
	Maximum peak to valley height	———	———	Rmax	Rymax	Ry	Maximum two point height Rmax	———	Rmax	Rz max
	Ten point height	———	(Rz)	Rz	Rz	Rz	———	Ten point height Rz	———	———
	Average peak to valley height	———	———	———	Ry5	———	Ten point height Rz	Maximum height Ry	Rz	Average method Rz
	Other peak height parameters	———	(Rp)	Rp	Rp, Rpmax, Rp5, Rm, Rc	———	———	———	Rp, Rpm, Rv	Rp, Rv, Rc
lr & λc for peak height parameter	0.25mm	R_{max}, Rz ≤ 0.8μm	———	not defined	0,1<Rz,Ry ≤0,5μm	0,1< Rz ≤ 0,5μm	0,1< Rz ≤ 0,5μm	0.1<Rz,Ry≤ 0.5μm	0.02< Ra ≤ 0.1μm	0.1< Rz ≤ 0.5μm
	0.8mm	0.8<R_{max} ,Rz ≤6.3μm	———	not defined	0,5<Rz,Ry ≤10μm	0,5< Rz ≤10μm	0,5< Rz ≤10μm	0.5<Rz,Ry≤10μm	0.1 < Ra ≤ 2μm	0.5< Rz ≤ 10μm
	2.5mm	6.3<R_{max} ,Rz ≤25μm	———	not defined	10<Rz,Ry≤50μm	10< Rz ≤50μm	10< Rz ≤50μm	10<Rz,Ry≤50μm	2 < Ra ≤ 10μm	10 < Rz ≤ 50μm
Indication of Maximum height in case of Rz<1.5μm		———	———	Rmax 1.6	Ry =1.6	Ry =1.6	Rmax = 1,6	Ry1.6~0.8 λc 0.25	Rmax = 1.6	U 0.008-2.5/Rz 1.5 L -0.25/Rz 0.7
R profile averaging parameter	Arithmetic average	Ra (**a** indication)	Ra	Ra	Ra	Ra	Ra	Ra	Ra	Ra
	root mean square	———	(Rq)	Rq	Rq	———	———	———	Rq	Rq
	Skewness, kurtosis	———	(Skewness,Kurtosis)	Sk, Ek	Sk	———	———	———	Rsk, Rku	Rsk, Rku
lr & λc for Ra on non-periodic profile	0.25mm	optional	0.0063<Sm≤0.05μm	not defined	0,02< Ra ≤ 0,1μm	0,02< Ra ≤ 0,1μm	0,02< Ra ≤ 0,1μm	0.02< Ra ≤ 0.1μm	0.02 < Ra ≤ 0.1μm	0.02 < Ra ≤ 0.1μm
	0.8mm	Ra ≤ 12.5μm	0.02 <Sm≤0.16μm	not defined	0,1< Ra ≤ 2μm	0,1< Ra ≤ 2μm	0,1< Ra ≤ 2μm	0.1< Ra ≤ 2μm	0.1 < Ra ≤ 2μm	0.1 < Ra ≤ 2μm
	2.5mm	12.5<Ra≤100μm	0.063<Sm≤ 0.5μm	not defined	2 < Ra ≤ 10μm	2 < Ra ≤ 10μm	2 < Ra ≤ 10μm	2 < Ra ≤ 10μm	2 < Ra ≤ 10μm	2 < Ra ≤ 10μm
Indication of Ra in case of 1.5<Ra<3.1μm		3.2 1.6	125 63	Ra 1.6 - 3.2	3.2 1.6 N8 N7	3.2 1.6 N8 N7	3,2 1.6	1.6~3.2	3.2 1.6	U"2RC" -0.8/Ra75 3.1 L"2RC" -0.8/Ra75 1.5
R profile other parameter	Mean spacing	———	Roughness spacing	Sm	Sm	Sm	———	Sm	Sm	RSm
	RMS slope	———	———	Δq	Δq	———	———	———	Δq	RΔq
	material ratio	———	(tp)	———	tp	tp	———	tp	tp	Rmr(c)
	Other parameters	———	(Peak count Pc)	S, Δa, λa, λq	S, Δa, λa, λq, Lo, D	S	———	S	Htp, Δa, SAE Peak PPI, Peak density Pc	Rδc, Rmr, Rpk, Rvk, Rk, Mr1, Mr2, Rpq, Rvq, Rmq
Comparison rule of measured value with tolerance limits	Average	average value of all sampling lengths	average value of all sampling lengths	not defined	———	———	———	average value of all sampling lengths	not defined	average value of all sampling lengths
	16% rule	———	———	not defined	16% rule default	16% rule	16% rule for Ra, Rz	———	not defined	16% rule default
	Maximum rule	———	———	not defined	Max rule for parameter with suffix "max"	Max rule for parameter with suffix "max"	Max rule for Rmax	———	not defined	Max rule for parameter with suffix "max"

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