

Mitutoyo

SURFACE ROUGHNESS

QUICK GUIDE TO SURFACE ROUGHNESS MEASUREMENT

Reference guide for laboratory and workshop



Surface profiles and filters

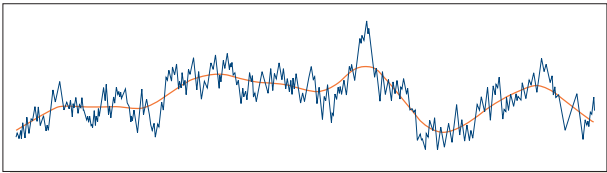
(EN ISO 4287 and EN ISO 16610-21)

1

The **actual profile** is the profile resulting from the intersection of the workpiece surface and a plane normal to that surface and in a direction that maximizes the surface roughness value, normally at right angles to the lay of the machining marks.

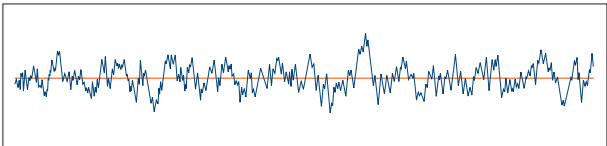
The **measured profile** is the profile resulting from scanning the actual profile with a probe which mechanically filters this profile due to the probe tip radius r_{tip} and, if fitted, by the skid of the probe system. Surface imperfections, such as cracks, scratches and dents are not part of the profile and should not be included in the recording. If necessary, tolerances according to DIN EN ISO 8785 can be set for them.

The **primary profile (P-profile)** is the profile resulting from electronic low-pass filtering of the measured profile with a cut-off wavelength λ_s . This process removes the shortest wavelength components that are judged not relevant to a roughness measurement. The parameters are designated **P** and evaluated within the sampling lengths. In Figure 1 this is equal to the evaluation length l_n (the total length of the surface profile recorded).



> **Figure 1:** The primary profile and mean line for the primary profile (λ_s cut-off) filter

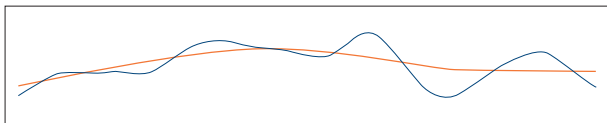
The **roughness profile (R-profile)** is the profile resulting from electronic high-pass filtering of the primary profile with a cut-off wavelength λ_c . This process removes the longer wavelength components as shown in Figure 2. The parameters are designated **R** and evaluated within the evaluation length l_n , which generally consists of five sampling lengths l_r . The sampling length corresponds to the cut-off wavelength λ_c of the profile filter.



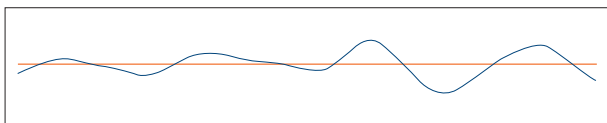
> **Figure 2:** The roughness profile with its mean line (high-pass filtering of the primary profile with a cut-off wavelength of λ_c)

The **waviness profile (W-profile)** is the profile resulting from electronic low-pass filtering of the primary profile with the cut-off wavelength λ_c (Figure 3) followed

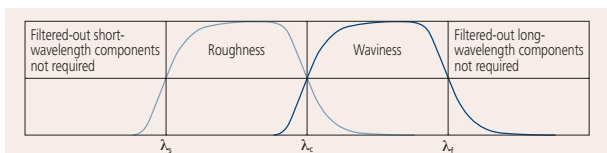
by high-pass filtering with the cut-off wavelength λ_f as shown in Figure 4. The parameters are designated **W** and evaluated over the evaluation length l_n , consisting of several sampling lengths l_w . The sampling length l_w corresponds to the cut-off wavelength λ_f of the high-pass filter. However, this quantity is not standardized and must be stipulated on the drawing. It should lie between five and ten times λ_f .



> **Figure 3:** Low-pass filtered mean line from the primary profile and mean line for the λ_f profile filter



> **Figure 4:** Waviness profile with mean line after high-pass filtering with the λ_c profile filter



> **Figure 5:** Transmission parameters of the filters used to separate roughness and waviness characteristics. Filter response is Gaussian according to DIN EN ISO 11562:1998

Roughness parameters

(EN ISO 4287)

Ra – arithmetical mean roughness value: The arithmetical mean of the absolute values of the profile deviations (Z_i) from the mean line of the roughness profile (Figure 6).

Rmr(c) – material component of the profile: The fraction of a line, which, in sectioning a profile, cuts through material at a stipulated height **c** above the mean line (in μm). Stated as a percentage.

RSm – mean peak width: Mean value of the width of the profile elements Xs_i , (previously S_m); horizontal and vertical counting thresholds are stipulated for this evaluation (Figure 8).

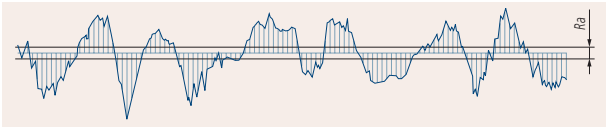
Roughness parameters (cont.)

Rt – total height of the roughness profile: Difference between height **Zp** of the highest peak and depth **Zv** of the deepest valley within the evaluation length l_n (Figure 7).

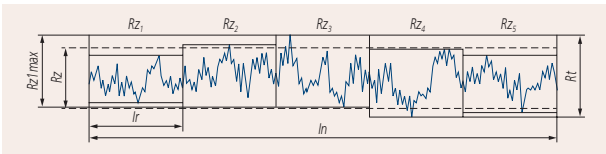
Rz_i – greatest height of the roughness profile: Sum of the height of the highest profile peak and the depth of the deepest profile valley, relative to the mean line, within a sampling length l_r .

Rz1max – maximum roughness depth: Largest of the five **Rz_i** values from the five sampling lengths l_r within the evaluation length l_n .

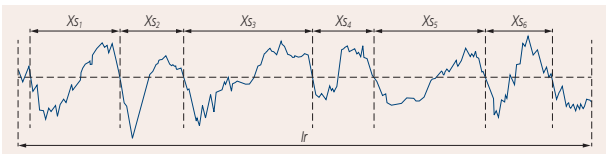
Rz – mean roughness depth: Mean value of the five **Rz_i** values from the five sampling lengths l_r within the evaluation length l_n .



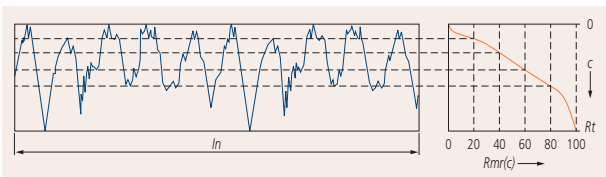
> **Figure 6:** Arithmetical mean roughness value R_a



> **Figure 7:** Total height of the roughness profile R_t , mean roughness depth R_z and maximum roughness depth R_{z1max}



> **Figure 8:** The mean groove spacing R_{Sm} is the mean value of the spacing X_{s_i} of the profile elements



> **Figure 9:** The material component curve of the profile depicts the material component $R_{mr}(c)$ of the profile as a function of the section height c (Abbott-Firestone curve)

Maximum roughness depth $Rz1max$ for surfaces in which individual deviations have a significant influence on the function of the surface, e.g. sealing surfaces.

Material component of the profile $Rmr(c)$ for guide surfaces and sealing surfaces moving against one another.

Mean roughness depth Rz as a rule for all other surfaces.

The arithmetical mean roughness value Ra is hardly affected by individual peaks or valleys because it is the mean value of the whole profile. It is, therefore, only of minor importance.

Setups for roughness measurement (EN ISO 4288)

Non-periodic profiles		Periodic profiles	Measuring conditions according to DIN EN ISO 4288 and DIN EN ISO 3274			
Grinding, honing, lapping, EDM		Turning, milling, planing	r_{tip} Maximum probe tip radius lr Sampling length ln Evaluation length lt Stylus travel (evaluation length plus start and finish lengths)			
Rt, Rz μm	Ra μm	RSm mm	r_{tip} μm	$\lambda_c = lr$ mm	ln mm	lt mm
> 0.025...0.1	> 0.006...0.02	> 0.013...0.04	2	0.08	0.4	0.48
> 0.1...0.5	> 0.02...0.1	> 0.04...0.13	2	0.25	1.25	1.5
> 0.5...10	> 0.1...2	> 0.13...0.4	2*	0.8	4	4.8
> 10...50	> 2...10	> 0.4...1.3	5	2.5	12.5	15
> 50...200	> 10...80	> 1.3...4	10	8	40	48

* When $Rz > 3 \mu m$ or $Ra > 0.5 \mu m$ a probe tip radius (r_{tip}) = $5 \mu m$ may be used.

In addition, the measuring point pitch Δx and the cut-off wavelength λ_s of the low-pass filter are standardized. These values are, however, preset in roughness measurement devices.

Practical tip 1: If there is insufficient space on the surface of the workpiece for the required stylus travel lt , the number of sampling lengths must be reduced and recorded on the drawing.

Practical tip 2: If there is still insufficient space, instead of Rt or Rz the total height of the primary profile Pt is measured over the available length. It is, however, defined on the primary profile similarly to Rt and the measured value is always greater.

Evaluation of roughness measurements

(EN ISO 4288)

5

Roughness measurement values, particularly the vertical parameters R_t , R_z , $R_{z1\max}$ and R_a , vary in the approximate range of -20% to +30%. A single measurement may, therefore, not give a complete picture of compliance with the toleranced parameters. In DIN EN ISO 4288 Annex A the following procedure is stipulated:

Max rule

All roughness parameters with the suffix "max" represent the maximum mean value measured within the five sampling lengths. Measurement should be made at three positions, at least, on the surface where the greatest values can be expected; at no position should the limit be exceeded.

16% rule

All roughness parameters without the "max" suffix represent the mean value measured within the five sampling lengths:

16% of the measured values may exceed the limit.

Step-by-step method:








1. If the first measured value is below 70% of the limit, this is considered to comply.
2. Failing this, take two additional measurements at other points on the surface; if all three measured values are below the limit, this is considered to comply.
3. Failing this, take nine additional measurements at other points on the surface; if a total of not more than two measured values are greater than the limit, this is considered to comply.

Drawing symbols

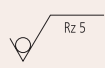

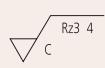
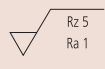
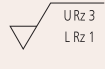
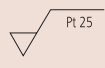
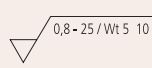
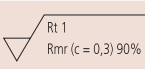

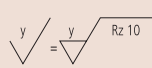
(EN ISO 1302)

	Basic symbol	a Surface roughness value required b Other surface requirement
	Material removal by machining required	c Production process (e.g. turning, grinding, chrome plating)
	Material removal not permitted	d Symbol defining the direction of the machining lay e Processing allowance (in mm)
	The same finish for all surfaces	x Letter for simplified reference if space is limited

	Entries on the symbol (top) Symbols defining the direction of the machining lay (position d, bottom)	
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=	⊥	X	M	C	R	P
Parallel*	Across*	Crossed	Different	Concentric	Radial	Non-directional
						

* For the projection level of the view in which the symbol is entered.

Examples	Explanatory notes
	No material-removal processing is permitted, rule-transfer characteristic, R-profile, 16% rule, mean roughness depth 5 μm (upper limit)
	Material-removal process, rule-transfer characteristic, R-profile, max rule, maximum mean roughness depth 3 μm (upper limit); processing allowance 0.2 mm
	Material-removal process, rule-transfer characteristic, R-profile, evaluation length consists of 3 sampling lengths, 16% rule, mean roughness depth 4 μm (upper limit); surface grooves concentric
	Material-removal process, rule-transfer characteristic, R-profile, 16% rule, mean roughness depth 5 μm , arithmetical mean roughness value 1 μm (upper limit)
	Material-removal process, rule-transfer characteristic, R-profile, 16% rule, mean roughness depth between 1 μm (lower limit) and 3 μm (upper limit)
	Material-removal process, rule-transfer characteristic for λ_s , no λ_c filter, P-profile, trace length equal to workpiece length, 16% rule, total height of the primary profile 25 μm (upper limit)
	Material-removal process, filter characteristics 0.8 (λ_c) - 25 ($\lambda_f = l_w$) mm, W-profile, evaluation length consists of 5 sampling lengths $l_n = 5 \times l_r$ $l_w = 125$ mm, 16% rule, total height of profile 10 μm (upper limit)
	Material-removal process, rule-transfer characteristic, R-profile, 16% rule, total height of roughness profile 1 μm (upper limit); material component of the profile 90% within the section height $c = 0.3$ μm (lower limit)
	Material-removal process, rule-transfer characteristic, R-profile, mean groove width between 0.1 mm (lower limit) and 0.3 mm (upper limit)
	Explanation of the meaning (right) of simplified reference (left), when space is insufficient for a full definition.