MEASURING SURFACE ROUGHNESS

■ Profiles and filters (DIN EN ISO 4287:1998 and DIN EN ISO 11562:1998)

The **actual surface profile** is the result of the actual surface of the workpiece intersecting with a plane that is perpendicular to this surface. The plane should run approximately vertical to the tool marks.

The **measured surface profile** is the profile after tracing the actual surface profile using a probe. The measured values are filtered due to the effect of the stylus tip radius **r** and, if applicable, due to the skid of the probe system. Surface imperfections, such as cracks, scratches and dents, are not considered roughness and should not be measured. If necessary, specify the tolerances in accordance with DIN EN ISO 8785.

The **primary profileis** the profile after low-pass filtering of the measurement values with the cutoff wavelength λs. For this, the short-wave profile segments are segregated. The parameters are identified by P and are evaluated within the individual sampling length. In this case, this is equal to the evaluation length or the length of the measured surface profile.

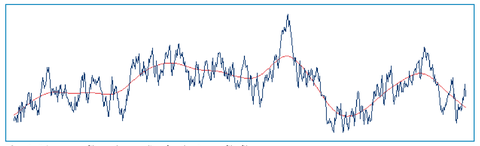


Fig. 1: Primary profile and mean line for the λs profile filter

The **roughness profile** is the result of high-pass filtering of the primary profile with the cutoff wavelength λc. For this, the long-wave profile segments are segregated. The parameters are identified by **R** and are analyzed across the evaluation length **ln**, which usually consists of five individual sampling lengths lr. The sampling length is equal to the cutoff wavelength λc of the profile filter.

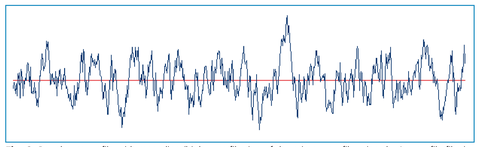


Fig. 2: Roughness profile with mean line (high-pass filtering of the primary profile using the λc- profile filter)

The **waviness profile** is the result of low-pass filtering of the primary profile with the cutoff wavelength λc and high-pass filtering with the cutoff wavelength f. The parameters are identified by **W** and are evaluated over the evaluation length **ln**, which consists of several sampling lengths **lw**. The sampling length lw corresponds to the cutoff wavelengthλf of the high-pass filter. However, the number of sampling lengths is not standardized and must therefore always be specified on the drawing. It should be between five and ten.

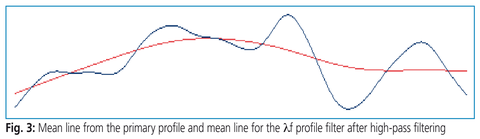


Fig. 3: Mean line from the primary profile and mean line for the λf profile filter after high-pass filtering

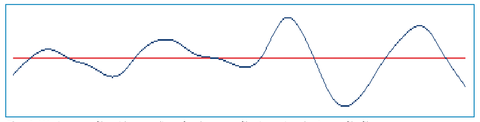


Fig. 4: Waviness profile with mean line after low-pass filtering using the λc profile filter

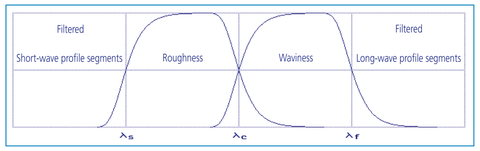
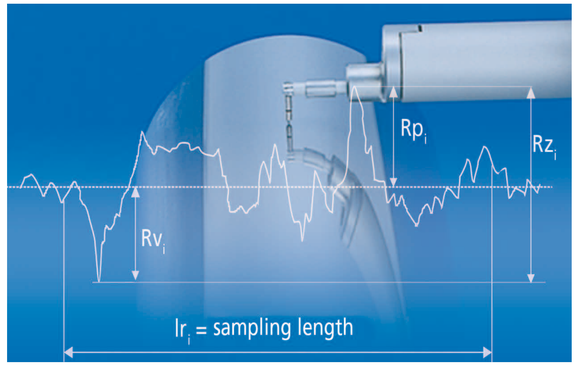


Fig. 5: Transmission characteristics of the filters for the different profiles, Gaussian filter as per DIN EN ISO 11562:1998



■ Roughness measuring conditions (DIN EN ISO 4288:1998)

Non-periodic profiles		Periodic profiles	Measuring conditions as per DIN EN ISO 4288 and DIN EN ISO 3274			
Grinding, honing, lapping, eroding ↓ or ↓		Turning, milling, planing ↓	r_{tip} Maximum stylus tip radius **lr** Sampling length **ln** Evaluation length **lt** Traversing length (evaluation length plus pre-travel and post-travel lengths)			
Rt, Rz µm	**Ra** µm	**RSm** mm	r_{tip} µm	λ_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

*) For **Rz** > 3 µm or **Ra** > 0.5 µm, the stylus tip radius r_{tip} = 5 µm may be used.

In addition, the measuring point distance Δx and the cutoff wavelength λs of the low-pass filter are standardized. However, these values have already been set in the roughness measuring devices.

Practical tip 1: If there is insufficient space on the workpiece surface for the required traversing length **lt**, the number of evaluation lengths must be reduced and indicated in the drawing.

Practical tip 2: If there is still insufficient space, the total height of the primary profile **Pt** is measured over the available length instead of **Rt** or **Rz**. **Pt** is still equal to **Rt**, but defined at the primary profile, and the measurement value is always larger.

■ Evaluation of roughness measurements (DIN EN ISO 4288:1998)

Roughness measurement values, particularly the vertical parameters **Rt, Rz, Rz1max** and **Ra**, have a spread of somewhere between -20 % and +30 %. A single measurement value can therefore not provide a complete statement with regard to compliance with the permissible parameter tolerances. The following procedure is specified in the DIN EN ISO 4288 Appendix A:

Max rule

All roughness parameters with the addition of **„max"** as the maximum of the mean value from the five sampling lengths: Measure at least three points on the surface where the highest values are expected; the stated limit must not be exceeded at any point.

16% rule

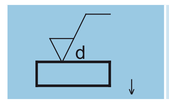
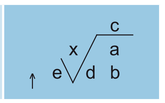
All roughness parameters without the addition of **„max"** as the mean value from the five sampling lengths:

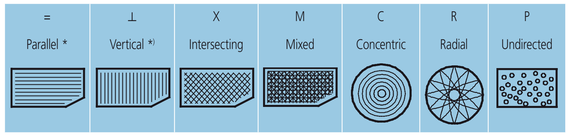
16% of the measured values may exceed the stated limit; the step-by-step procedure is as follows:

1. If the first measured value is less than 70% of the stated limit, this is considered compliant.
2. If the result is otherwise, two additional measurements are taken at other locations on the surface; if all three measured values are less than the stated limit, this considered compliant.
3. If the result is otherwise, nine additional measurements are taken at other locations on the surface; if no more than two of the measured values exceed the stated limit, this is considered compliant.

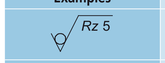
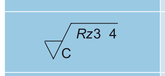
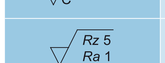
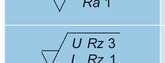
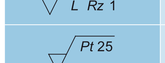
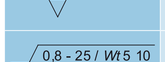
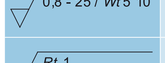
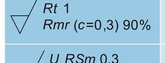
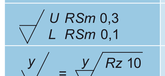
■ Drawing symbols (DIN EN ISO 1302:2002)

	Basic symbol	a b	A single surface finish requirement Additional surface requirement
	Material removal through mechanical processing required	c	Production process (e.g. turned, ground, chrome-plated)
	Material removal not permitted	d e	Symbol for direction of lay (surface grooves) Machining allowance (in mm)
	Identical texture of all surfaces	x	Letter for simplified benchmarking, if space is limited

	Symbol entries (top) Symbols for direction of lay (position d, bottom)	



*)... to projection plane of view in which the symbol is entered

Examples	Explanation
	No material removal allowed, default transmission band, **R** profile, 16% rule, mean roughness depth 5 µm (upper limit)
	Material removal allowed, default transmission band, **R** profile, max rule, maximum roughness depth 3 µm (upper limit); machining allowance 0.2 mm
	Material removal permitted, default transmission band, **R** profile, evaluation length of 3 sampling lengths, 16% rule, mean roughness depth 4 µm (upper limit); concentric surface grooves
	Material removal allowed, default transmission band, **R** profile, 16% rule, mean roughness depth 5 µm; arithmetic average roughness value 1 µm (upper limit)
	Material removal allowed, default transmission band, **R** profile, 16% rule, mean roughness depth between 1 µm (lower limit) and 3 µm (upper limit)
	Material removal allowed, default transmission band for λs, no λc filter, **P** profile, evaluation length equals workpiece length, 16% rule, total height of primary profile 25 µm (upper limit)
	Material removal allowed, default transmission band 0.8 (=λc) 25 (=λf=**lw**) mm, W profile, evaluation length of 5 sampling lengths **ln**=5*lw= 125 mm), 16% rule, total height of profile 10 µm (upper limit)
	Material removal allowed, default transmission band, **R** profile, 16% rule, total height of roughness profile 1 µm (upper limit); material portion of profile is 90% in cutting height c =0.3 µm (lower limit)
	Material removal allowed, default transmission band, **R** profile, mean groove width between 0.1 mm (lower limit) and 0.3 mm (upper limit)
	Explanation of the meaning (right) of simplified benchmarking (left), if space is limited.

■ Roughness parameters (DIN EN ISO 4287:1998)

Ra – Arithmetic average roughness value: arithmetic mean of the sums of all profile values

Rmr(c) – Material portion of profile: quotient from the sum of the material lengths of the profile elements at the specified section height c (in µm) and of the evaluation length **ln** (specified as a percentage)

RSm – Mean groove width: mean value of the width of the profile elements **Xsi** (previously Sm); horizontal and vertical counting thresholds have been defined for the evaluation

Rt – Total height of the roughness profile: Sum from the height **Zp** of the highest profile peak and the depth **Zv** of the lowest profile valley within the evaluation length **ln**

Rz_i – Maximum height of the roughness profile: Sum from the height of the highest profile peak and the depth of the lowest profile valley within a sampling length **lr_i**

Rz1max – Maximum roughness depth: Largest of the five Rzi values from the five sampling lengths lri within the evaluation length **ln**

Rz – Mean roughness depth: mean value of the five **Rz_i** values from the five sampling lengths **lr_i** within the evaluation lengthln

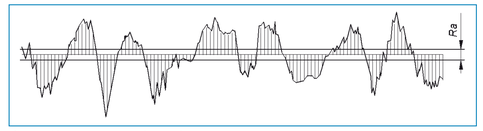


Fig. 6: Arithmetic average roughness value **Ra**

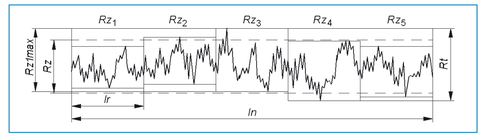


Fig. 7: Total height of the roughness profile **Rt**, mean roughness depth **Rz** and maximum roughness depth **Rz1max**

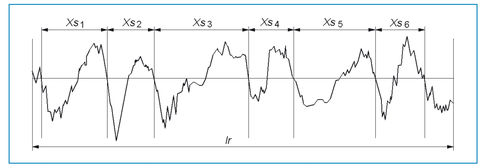


Fig. 8: The mean groove width **RSm** is the mean value of the width **Xs** of the profile elements

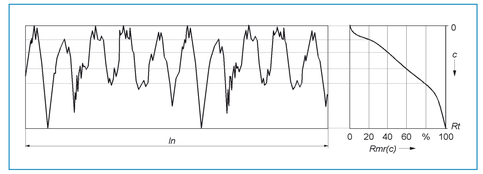


Fig. 9: The material ratio curve of the profile represents the material portion **Rmr(c)** of the profile as a function of the section height c (Abbott-Firestone curve)

■ Preferred parameters

Maximum roughness depth Rz1max for surfaces where individual deviations strongly affect the function of the surface, e.g. sealing surfaces.

Material portion of the profile Rmr(c) for guide surfaces and opposing sealing surfaces

Mean roughness depth Rz usually applies to all other surfaces.
The arithmetic mean roughness value **Ra** hardly reacts to individual peaks or valleys due to the mean value formed from all profile values; its significance is therefore rather low.

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