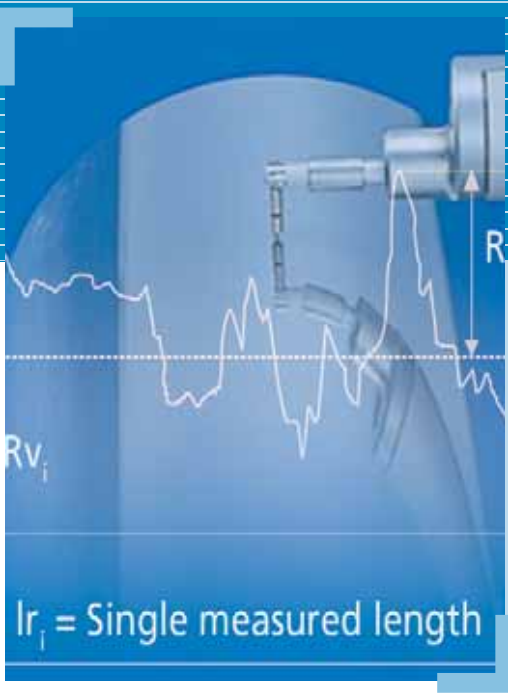
SURFACE ROUGHNESS MEASUREMENT

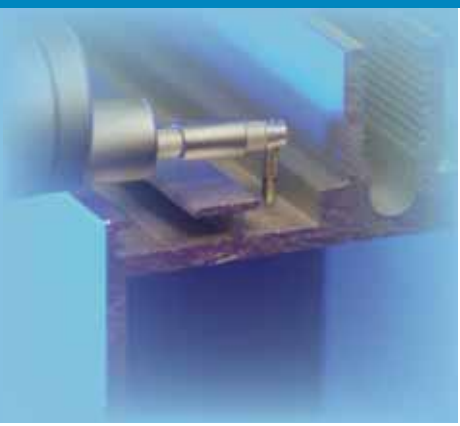
Bulletin No. 1984



Practical tips for laboratory and workshop

Mitutoyo

- **Profiles and filters**
- **Roughness parameters**
- **Preferred parameters**
- **Measuring conditions**
- **Evaluation**
- **Drawing symbols**



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

The actual surface profile results from the intersection of the actual part surface with a plane perpendicular to this surface. The plane should roughly be vertical to the machining grooves. The measured surface profile is the profile after tracing the actual surface profile using a probe. In doing so, the measured values are filtered through the effect of the stylus tip radius $\mathbf{r}_{tip}$ and - where applicable - through the sliding skid of the probe system. Imperfections of the surface, like cracks, scratches and dents do not count as roughness and should not be measured. If necessary, tolerances must be determined for this according to DIN EN ISO 8785. The primary profile is the profile after low-pass filtering the measuring values using the cutoff wavelength λ_s. In doing so, the short-wave profile parts are cutoff. The parameters are identified by P and evaluated within the sampling length (cut-off). This equals the measured length or the length of the measured surface profile.

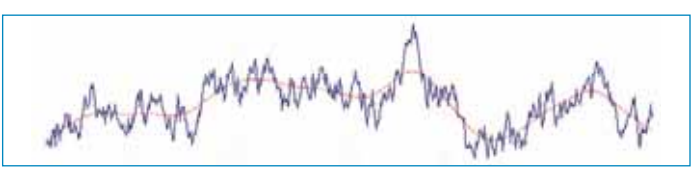


Fig. 1: Primary profile after λ_s low-pass filtering

Mitutoyo

The **roughness profile** results from high-pass filtering the primary profile with the cutoff wavelength λ_c. In doing so, the long-wave profile parts are cut-off. The parameters are identified by **R** and evaluated over the measured length **ln** which is usually composed of five single measured lengths **lr.** The single measured length corresponds to the cutoff wavelength λ_c of the profile filter.

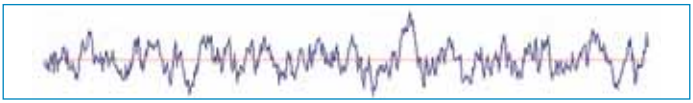


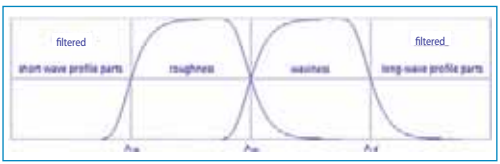
Fig. 2: Roughness profile after λ_c high-pass filtering with center line representation according to EN ISO 4287

The **waviness profile** results from low-pass filtering the primary profile with the cutoff wavelength λ_c and high-pass filtering with the cutoff wavelength λ_f. The parameters are identified by **W** and evaluated over the measured length **ln** which is composed of several sampling lengths **lw**.The single measured length **lw** corresponds to the cutoff wavelength λ_f of the high-pass filter. However, their number is not standardized and must therefore always be indicated on the drawing. It should range between five and ten. Profile filters λ_c (Fig. 3) and λ_f are applied successively. The waviness profile always results from application of both filters (Fig. 4).

Fig. 3: Representation after λ_c low-pass filtering

Fig. 4: Waviness profile after λ_c low-pass filtering and λ_f high-pass filtering with center line representation according to EN ISO 4287

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



• Roughness parameters (DIN EN ISO 4287:1998)

Ra – Arithmetic mean surface roughness: Arithmetical mean of the sums of all profile values

Rmr(c) – Material proportion of the profile: Quotient from the sum of all material lengths of the profile elements at the specified section height **c** (in µm) and the measured length **ln** (specified in per cent)

RSm – Average groove width: Mean value of the width of the profile elements $\mathbf{Xs}_i$ (formerly $\mathbf{S}_m$); for the evaluation, horizontal and vertical counting thresholds are determined.

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 measured length **ln**

$\mathbf{Rz}_i$ – 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 $\mathbf{lr}_i$

Rz1max – Maximum surface roughness: Largest of the five $\mathbf{Rz}_i$-values from the five sampling lengths $\mathbf{lr}_i$ over the total measured length **ln**

Rz – Surface roughness depth: Mean value of the five $\mathbf{Rz}_i$-values from the five sampling lengths $\mathbf{lr}_i$ over the total measured length **ln**

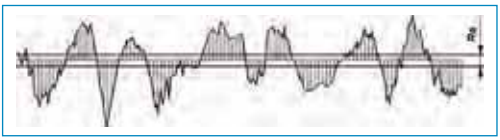


Fig. 6: Arithmetic average roughness value **Ra**

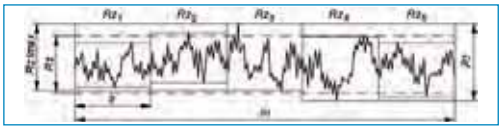
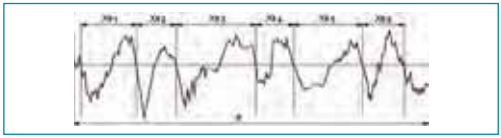


Fig. 7: Total height of the roughness profile **Rt**, surface roughness depth **Rz** and maximum surface roughness **Rz1max**



The average groove width is the mean value of the width $_i$ of the profile elements

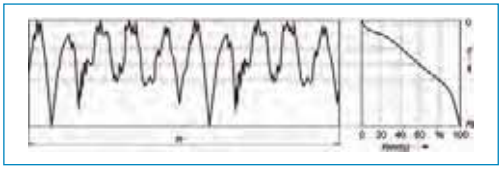


Fig. 9: The material ratio curve of the profile plots the material portion **Rmr(c)** of the profile as a function of the section height **c** (Abbott-Firestone curve)

• Preferred parameters

Maximum surface roughness Rz1max for surfaces where individual deviations heavily affect the function of the surface, e.g. sealing surfaces
Material portion of the profile Rmr(c) for guide surfaces and sealing surfaces moving against each other
Surface roughness depth Rz, as a rule, is used for all other surfaces
The arithmetic average roughness value **Ra** hardly reacts to peaks or valleys due to the mean value formation from all profile values so that its significance is rather low

• Measurement conditions for roughness measurements (DIN EN ISO 4288:1998)

Non-periodic profiles		**Periodic profiles**	**Measuring conditions according to DIN EN ISO 4288 and DIN EN ISO 3274**			
Grinding, honing, lapping, eroding ↓ or ↓		Turning, milling, planing ↓	r_{tip} Maximum stylus tip radius **lr** Single measured length **ln** Total measured length **lt** Traversed length (measured length plus start-up and trailing length)			
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.

Additionally, the measuring point distance Δx and the cutoff wavelength of the low-pass filter λ_s are standardized. However, these values have already been set in the roughness measuring instruments.

Tip for practice 1: If the space on the part surface is not sufficient for the required traversed length **lt**, the number of single measured lengths must be reduced and the reduced number be specified in the drawing.

Tip for practice 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** equals **Rt**, but is defined at the primary profile, and the measuring value is always larger.

Mitutoyo

• Evaluation of Roughness Measurements (DIN EN ISO 4288:1998)

Roughness measuring values - especially the vertical parameters (amplitude parameters) **Rt**, **Rz**, **Rz1max** and **Ra** - have a spread between -20% and +30 %. A single measuring value can therefore not provide a complete statement concerning the observance of the permissible parameter tolerances. DIN EN ISO 4288 Appendix A specifies the following procedure:

Max-rule:

All roughness parameters with the addition **"max"** as maximum value of the average value from the five single measured lengths: Measurement at least three points on the surface where the highest values are to be expected; the limit value must not be exceeded at any point.

16%-rule

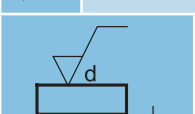
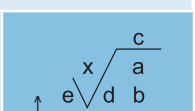
All roughness parameters without the addition **"max"** as mean value from the five single measured lengths:

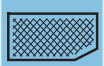
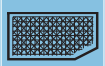
16% of the measuring values may exceed the limit value; step-by-step procedure:

1. If the first measuring value is smaller than 70% of the limit value the latter is considered to be observed.
2. Otherwise two further measurements at other points on the surface; if all three measuring values are smaller than the limit value, the latter is considered to be observed.
3. Otherwise nine further measurements at other points on the surface; if no more than two measuring values exceed the limit value, the latter is considered to be observed.

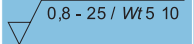
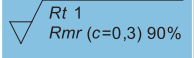
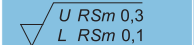
• Drawing symbols (DIN EN ISO 1302:2002)

	Basic symbol	a Single surface finish requirement b Further surface requirement
	Material removal through mechanical machining required	c Machining process (e.g. turned, ground, chrome-plated)
	Material removal not permissible	d Symbol for the directon of the surface grooves e Machining allowance (in mm)
	Identical texture for all surfaces	x Letter for ease of benchmarking if space is limited

	Entry at symbol (top) Symbol for the direction of the surface groove (position d, bottom)	

=	⊥	X	M	C	R	P
Parallel*	Vertical*)	Crossed	Mixed	Concentric	Radial	Undirected Undirected
						

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

Examples	Explanation
	No chip removing process permissible, rule transmission characteristic, **R**-profile, 16%-rule, surface roughness depth 5 µm (upper limit value)
	Chip removing process, rule transmission characteristic, **R**-profile, max-rule, maximum surface roughness 3 µm (upper limit value); machining allowance 0.2 mm
	Chip removing process, rule transmission characteristic, **R**-profile, measuring path from 3 single measured lengths, 16%-rule, surface roughness depth 4 µm (upper limit value); concentric surface grooves
	Chip removing process, rule transmission characteristic, **R**-profile, 16%-rule, surface roughness depth 5 µm, arithmetic average roughness value 1 µm (upper limit values)
	Chip removing process, rule transmission characteristic, **R**-profile, 16%-rule, surface roughness depth between 1 µm (lower limit value) and 3 µm (upper limit value)
	Chip removing process, rule transmission characteristic for λ_s, no λ_c filter, **P**-profile, measuring path equals part length, 16%-rule, total height of primary profile 25 µm (upper limit value)
	Chip removing process, rule transmission characteristic 0.8 (=λ_c) - 25 (=λ_f=**lw**) mm, **W**-profile, measured length from 5 single measured lengths (**ln**=5***lw**=125 mm), 16%-rule, total height of profile 10 µm (upper limit value)
	Chip removing process, rule transmission characteristic , **R**-profile, 16%-rule, total height of roughness profile 1 µm (upper limit value); material portion of the profile 90% in the cutting height **c**=0,3µm (lower limit value)
	Chip removing process, rule transmission characteristic, **R**-profile, mean groove width between 0.1 mm (lower limit value) and 0.3 mm (upper limit value)
	Explanation of the meaning (right) of simplified benchmarking (left) if space is limited.

- Coordinate Measuring Machines
- Vision Measuring Systems
- Form Measurement
- Optical Measuring
- Sensor Systems
- Testing Equipment and Seismometer
- Digital Scale and DRO Systems
- Small Tool Instruments and Data Management

Mitutoyo America Corporation
www.mitutoyo.com

One Number to Serve You Better
1-888-MITUTOYO (1-888-648-8869)

M² Solution Centers
Aurora, Illinois
(Corporate Headquarters)
Westford, Massachusetts
Huntersville, North Carolina
Mason, Ohio
Plymouth, Michigan
City of Industry, California

Note: All information regarding our products, and in particular the illustrations, drawings, dimensional and performance data contained in this printed matter as well as other technical data are to be regarded as approximate average values. We therefore reserve the right to make changes to the corresponding designs. The stated standards, similar technical regulations, descriptions and illustrations of the products were valid at the time of printing. In addition, the latest applicable version of our General Trading Conditions will apply. Only quotations submitted by ourselves may be regarded as definitive.

Mitutoyo products are subject to US Export Administration Regulations (EAR). Re-export or relocation of Mitutoyo products may require prior approval by an appropriate governing authority.

Trademarks and Registrations
Designations used by companies to distinguish their products are often claimed as trademarks. In all instances where Mitutoyo America Corporation is aware of a claim, the product names appear in initial capital or all capital letters. The appropriate companies should be contacted for more complete trademark and registration information.

We reserve the right to change specifications and prices without notice.

1109-05 • Printed in USA • Dec. 2009

Mitutoyo
Precision is our Profession