JENOPTIK

# Roughness measuring systems from Jenoptik – Surface texture parameters in practice

DAkkS
Deutsche
Akkreditierungsstelle
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# Surface texture measurement with Jenoptik

Surface texture is very important where it has a direct influence on the quality of the part. Therefore, it has to be defined as precisely as possible with the help of standardized surface texture parameters.

This leaflet gives you an overview of the most important definitions, standards, and parameters of surface texture measurement.

We manufacture a wide range of roughness measuring systems providing you with a large variety of evaluation possibilities – in the measuring lab as well as on the production line.

One particularly important aspect is the continuous monitoring of the roughness measuring systems for optimum accuracy. Our DAkkS-DKD calibration laboratory can calibrate your standards based on different surface texture parameters. For parameters not requiring accreditation, we offer an in-house calibration certificate.

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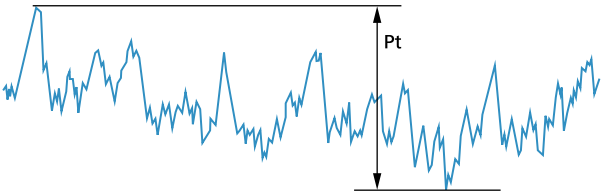
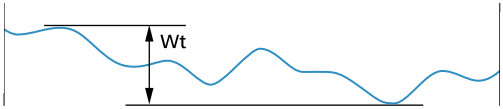
# Division of a surface

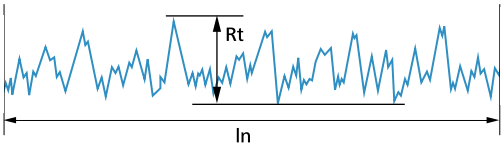
**Unfiltered P-profile**




**Filtered W-profile**




**Filtered R-profile**



# Surface profiles – total height of the profile

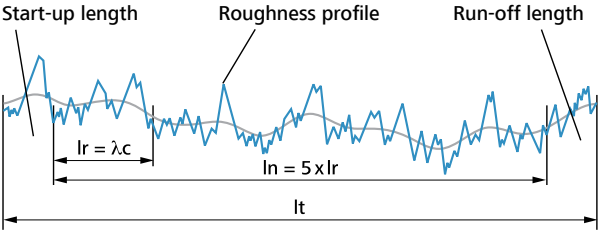
Surface profile is measured two-dimensionally using the tracing system.

The unfiltered primary profile (P-profile) is the actual measured surface profile. Filtering it in accordance with ISO 11562/ISO 16610-21 produces the waviness profile (W-profile) and the roughness profile (R-profile). The variable for determining the limit between waviness and roughness is the cut-off λc.

Following ISO 4287, all parameter definitions are valid for both the roughness profile as well as for the primary and waviness profiles. The profile type is identified by the capital letters P, R or W.

The total height Pt, Wt or Rt of the respective profile type is the maximum height between the highest peak and the deepest valley of the evaluation length profile.

# Evaluation lengths – cut-off



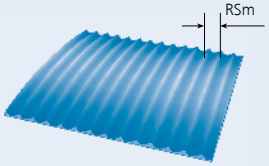

The traverse length (lt) is the total length of the probe movement during the scanning process. It must be greater than the evaluation length ln in order to be able to form the roughness profile with the profile filter. With the exception of Rt, Rmr(c) and RPc, the roughness parameters are defined within an evaluation length ln, which is determined using an average of five sampling lengths lr.

The sampling length lr corresponds to the cut-off λc.

# Selection of the cut-off (profile filter) accordi

The cut-off is selected depending on the workpiece surface either according to the valley spacing, or the expected roughness values. At the same time the total evaluation length and the corresponding traverse

**Periodic profiles**
e.g. turning, milling




| RSm (mm) |
|---|
| > 0.013 ...0.04 |
| > 0.04 ...0.13 |
| > 0.13 ...0.4 |
| > 0.4 ...1.3 |
| > 1.3 ...4 |

**Measuring conditions**

- **lr** sampling length
- **ln** evaluation length
- **lt** traverse length
- **λc** cut-off
- **λs** shortwave profile filter
- $r_{tip}$ stylus tip radius
- **ΔX** digitization distance [1)]

| λc = lr (mm) | ln (mm) |
|---|---|
| 0.08 | 0.4 |
| 0.25 | 1.25 |
| 0.8 | 4 |
| 2.5 | 12.5 |
| 8 | 40 |

Application example
In a periodic profile the mean width of the profile elements RSm is used.
With an RSm between 0.4 and 1.3 mm the following measuring conditions result:

* At Rz ≤ 2 µm the stylus tip radius is 2 µm, at Rz > 2 µm it is 5 µm. The distance between two measuring points is ≤ 0.5 µm.

# Measurement conditions for Motif paramet

| A* (mm) | B* (mm) | Traverse length (mm) |
|---|---|---|
| 0.02 | 0.1 | 0.64 |
| 0.1 | 0.5 | 3.2 |
| 0.5 | 2.5 | 16 |
| 2.5 | 12.5 | 80 |

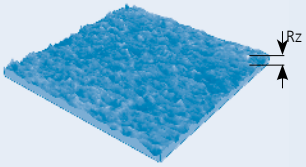
* If not otherwise specified, the default values are A = 0.5 mm and B = 2.5 mm, respectively.

# ng to ISO 4288:1998 and ISO 3274:1998

1) The digitization distance is also standardized. This is set automatically by most roughness measuring instruments.

| lt (mm) | $r_{tip}$ (µm) | λs (µm) |
|---|---|---|
| 0.48 | 2 | 2.5 |
| 1.5 | 2 | 2.5 |
| 4.8 | 2 or 5 * | 2.5 |
| 15 | 5 | 8 |
| 48 | 10 | 25 |

**Aperiodic profiles**
e.g. grinding, eroding




| Ra (µm) | | Rz (µm) | |
|---|---|---|---|
| > (0.006) | …0.02 | > (0.025) | …0.1 |
| > 0.02 | …0.1 | > 0.1 | …0.5 |
| > 0.1 | …2 | > 0.5 | …10 |
| > 2 | …10 | > 10 | …50 |
| > 10 | …80 | > 50 | …200 |

λc = 2.5 mm / ln = 12.5 mm / lt = 15 mm / $r_{tip}$ = 5 µm / λs = 8 µm.

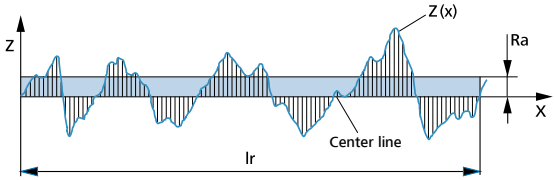
Shortened standard evaluation length

If the actual possible traverse length on the workpiece surface is not enough for lt, the number of sampling lengths is reduced accordingly and specified in the drawing.
If the actually available traverse length is less than a sampling length, the total height of profile Pt of the primary profile is evaluated instead of Rt or Rz.

# ters according to ISO 12085

| Evaluation length (mm) | λs (µm) | Maximum stylus tip radius (µm) |
|---|---|---|
| 0.64 | 2.5 | 2 ± 0.5 |
| 3.2 | 2.5 | 2 ± 0.5 |
| 16 | 8 | 5 ± 1 |
| 80 | 25 | 10 ± 2 |

# **Ra** according to ISO 4287

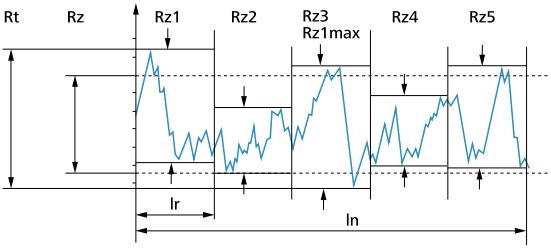



## Ra – arithmetical mean deviation

Ra is the arithmetic mean roughness value from the amounts of all profile values. Ra does not differentiate between peaks and valleys and has therefore a relatively weak information character.

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

# **Rz, Rz1max, Rt** according to ISO 4287




## Rz – maximum height of profile

Average value of the five Rz values.

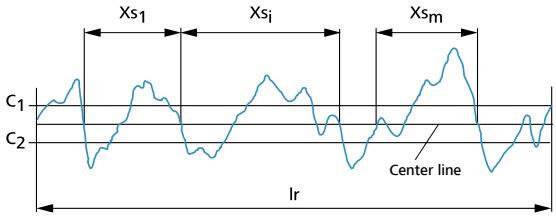
## Rz1max – maximum height of profile (ISO 4287:1997)

Greatest Rz value from the five sampling lengths lr.

## Rt – total height of profile

Rt is the distance between the highest peak and the deepest valley of the profile of the total evaluation length ln.

# **RSm** according to ISO 4287

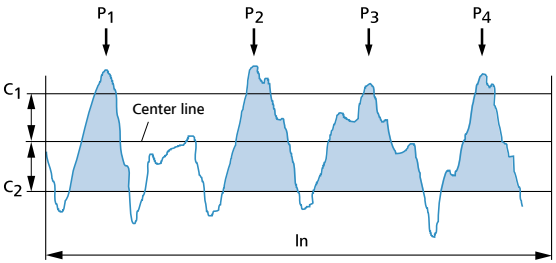



## RSm – mean width of the profile elements

RSm is the arithmetic mean value of the width of the roughness profile elements within the sampling length and requires the definition of height discriminations (c1, c2) matching the function of the surface. If not specified otherwise, the sum of the height discriminations should add up to 10 % of Rz.

$$RSm = \frac{1}{m}\sum_{i=1}^{m} Xs_i$$

# **RPc** according to EN 10049/ISO 4287




## RPc – standardized number of peaks

RPc corresponds to the number of local peaks, which successively exceed an upper section line c1 and a lower section line c2. The number of peaks is related to a length of 10 mm irrespective of the evaluation length selected.

Our global presence.

## Our service range

**Metrology**
Tactile metrology
Pneumatic metrology
Optical metrology

**Product range**
Roughness measurement
Contour measurement
Form measurement
Optical shaft measurement
Dimensional measurement
Optical surface inspection

**Inspection process**
In-process
Post-process
PLC
Final inspection
Measuring room

**Service**
System solutions
DAkkS-DKD calibration service
Consulting, training and service

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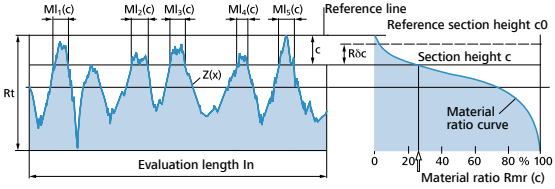
# **Rmr(c)** according to ISO 4287

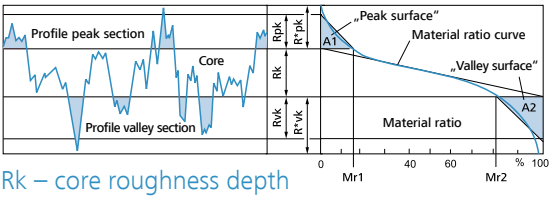



## Rmr(c) – material ratio of the profile

Rmr indicates what ratio the totaled length in the material has assumed relative to the evaluation length (in %). The comparison is made in the specified section height c and the total evaluation length ln. The material ratio curve indicates the material ratio as a function of the section height.

$$Rmr(c) = \frac{100}{ln} \sum_{i=1}^{n} Ml_i(c) = \frac{Ml(c)}{ln} \; [\%]$$

# **Rk, Rpk, Rvk, Mr1, Mr2** according to ISO 13565-2




## Rk – core roughness depth

Depth of the roughness core profile.

## Rpk – reduced peak height

Mean height of the peaks protruding from the roughness profile.

## Rpk* – highest profile peak height (not ISO 13565-2)

## Rvk – reduced valley depth

Mean depth of the valleys reaching into the material from the core.

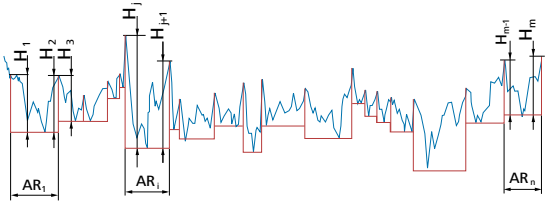
## Rvk* – deepest profile valley depth (not ISO 13565-2)

## Mr1, Mr2 – material ratio

Smallest (Mr1) and greatest (Mr2) material ratio (in %) at the limits of the roughness core area.

# **Motif** standard according to ISO 12085

The principle of the Motif standard consists of looking for local peaks and valleys in the primary profile, and associating one valley with the closest preceding and following peaks in order to create a Motif. Several iterative combinations of two Motifs each assure that the most important Motifs, the width of which fall below the limit A, are considered. If not otherwise specified, the default value is A = 0.5 mm (see measurement conditions page 4/5). The limit A has a similar function as the cut-off in the Gaußian filtering. The 16 % rule generally applies.




## The most important Motif parameters:

### R – Mean depth of roughness Motifs

R is the arithmetic mean value of the depths Hj of the roughness Motifs within the evaluation length.

### AR – Mean spacing of roughness Motifs

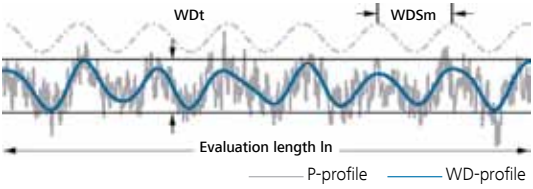
AR is the arithmetic mean value of the lengths ARi of the roughness Motifs within the evaluation length.

### Rx – Maximum depth of profile irregularity

The deepest depth Hj within the evaluation length.

# **WDSm, WDt, WDc** – Dominant waviness according to VDA 2007

The primary profile is checked for none, one or two dominant wavinesses. Narrow band filtering of the primary profile with the waviness creates the WD-profile that is used for calculating the parameters. The evaluation length ln is chosen either according to ISO 4288 (as for surface roughness measurements) or on the basis of the drawing entry. Period lengths are checked for dominant wavinesses in the range of 0.02 mm ≤ WDSm ≤ ln/5. To catch dominant wavinesses at WDSm > ln/5, it is necessary to enlarge the evaluation length.

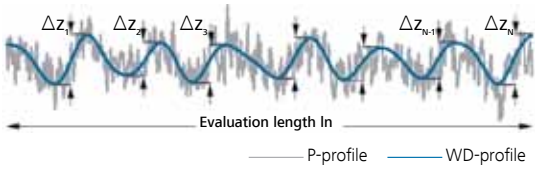



## WDSm

Mean horizontal value of the profile elements, calculated from the amplitude spectrum (mean periodic length of the dominant waviness).

## WDt

Vertical difference between the highest and the deepest point of the WD-profile within the evaluation length.




## WDc

Mean value of the peaks of the profile elements within the evaluation length.

$$WDc = \frac{1}{N}\sum_{i=1}^{N} \Delta z_i$$

# Evaluation of measurement results

According to ISO 4288 the surface measurement should be made where the highest values are to be expected (visual determination).

## Maximum value rule

The surface is considered good when the measured values of a parameter do not exceed the fixed maximum value. In this case, the parameter is identified by the suffix „max“, e.g. Rz1max.

## 16 % rule

If the suffix „max“ is not specified, the 16 % rule applies, which states that the surface is considered “good” if not more than 16 % of the measured parameter values exceed the fixed maximum value. You will find further information about this rule in the standard ISO 4288:1997.

## Special rule VDA

The 16 % rule is not used. VDA 2006 assumes that the dispersion of the parameters is taken into account in the definition of the limit values.

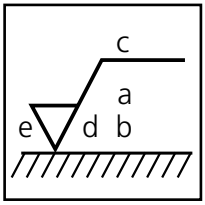
The maximum value rule applies generally even without the „max“ index in the designation.

The use of the λs filter is prohibited.

At Rz ≤ 2 µm the stylus tip radius is 2 µm, at Rz > 2 µm it is 5 µm. The distance between two measuring points is ≤ 0.5 µm.

The cone angle is either 60° or 90°. If not otherwise specified, the cone angle is 90°.

# Drawing entries according to ISO 1302:2002




Specifications for requirements

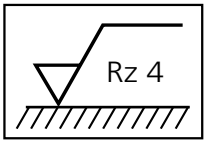
a surface parameter with numeric value in µm

b second requirement (surface parameter in µm)

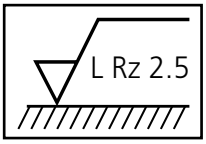
c production method

d specification of valley direction

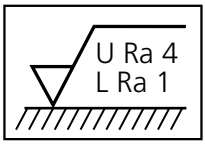
e machining allowance in mm



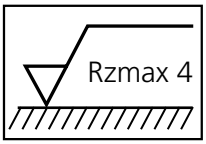

Material removing machining;
Rz = max. 4 µm



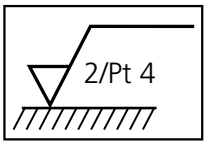

Material removing machining; lower limit value for Rz demanded;
Rz = min. 2.5 µm



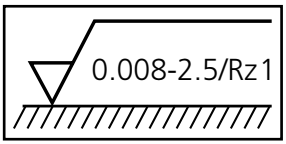

Material removing machining; upper and lower limit value for Ra demanded; Ra = min. 1 µm and max. 4 µm




Material removing machining; Rz = max. 4 µm; the maximum value rule applies



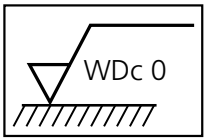

Material removing machining; P-profile, traverse length = 2 mm;
Pt = max. 4 µm




Material removing machining; transmission characteristic does not comply with standard case (cf. table)
Rz = max. 1 µm; filter selection
λs = 0.008 mm and λc = 2.5 mm

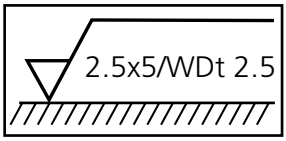
# Drawing entries according to VDA 2007 – dominant waviness

## Case 1: No dominant waviness allowed



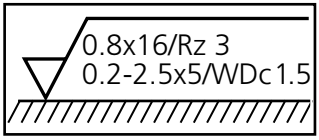

Material removing machining; WDc 0 or WDt 0: no dominant waviness allowed

## Case 2: Dominant wavinesses are allowed up to an upper limit




Material removing machining;
in the period range up to 2.5 mm,
WDt = max. 2.5 µm applies

## Case 3: Dominant wavinesses are allowed in a period length with an upper or an upper and lower limit




Material removing machining;
Rz: the evaluation length is 12.5 mm and
λc = 0.8 mm, Rz = max. 3 µm;
WDc: in the period range of 0.2 to 2.5 mm,
WDc = max. 1.5 µm applies