ASME B46.1 2009 Standard

The first B46.1 Standard was issued March 1940. since 1940 --- 9 revisions… 

ISO Member Bodies

You are here
Surface Texture..Why Is It Important?

Surface: “The boundary that separates an object from another object, substance, or space…”

Texture: “The composite of certain deviations that are typical of the real surface. It includes roughness and waviness…”

“Surface Roughness”. Ra is the average of the absolute value of profile heights over a given length (area).

\[
R_a = \frac{1}{L} \int_0^L |Z(x)| \, dx
\]

\[
S_a = \frac{1}{A} \iint_0^{L_y} \int_0^{L_x} |Z(x,y)| \, dx \, dy
\]
Surface Texture..Why Is It Important?

Functional / Performance Point of View........
Rolling.... Sliding....Sealing....Load Bearing....Cosmetic
Electrical Contact..Metal Forming...Lubricant Retention
Friction .... Wear .... Adhesion

Typical Applications

Mechanical: Engine cylinder bore, rings, pistons, seals, shafts, gear,
clutches, brakes, fuel delivery components, sensors
ABS components, cutting tools, coatings, bearings......

Electronics: Disk drive components, tape drive components,
MEMS, solder bumps,........

Misc: Materials (Polymer..),Printing (rolls/lithoplates/paper), Medical(Implants),
Optical (contact lens)....

What Texture do you need?
How much does it cost?

Key Discrete Parts - Value of U.S. Shipments
52% of all U.S. Manufacturing 10% of GDP
2009/$15,000,000,000,000 (GDP)

Typical Relationship of Ra to Production Time($)

Typical Relationship of Ra to Production Time($)

NIST 1992
Classification of Instruments for Surface Metrology

Instruments for Texture Measurement

Range and Resolution of Major Techniques

Fig. 3-1 Classification of Common Instruments for Measurement of Surface Texture

Source: Digital Instruments
Filtering --- Form, Waviness and ROUGHNESS

Filtering of Surface Texture Measurements - Gaussian

\( \lambda_s = \text{Short Wave Cutoff} \ldots \ 50\% \text{ Transmission} \ldots \frac{A_o}{A_i} = 0.50 \)

\( \lambda_c = \text{Long Wave Cutoff} \ldots \ 50\% \text{ Transmission} \ldots \frac{A_o}{A_i} = 0.50 \)

\( \lambda_s = 2.5 \mu m, 8 \mu m, 25 \mu m \)

\( \lambda_c = 0.08mm, 0.25mm, 0.8mm, 2.5mm, 8mm \)

\( \frac{\lambda_c}{\lambda_s} = 30, 100, 300 \)

...... Gaussian filters have minimal phase distortion......
The cutoffs, $\lambda_c$ and $\lambda_s$ should be chosen by the designer in light of the intended function of the surface. When choosing $\lambda_c$ and $\lambda_s$, one must be cognizant that the surface features not measured within the roughness cutoff bandwidth may be quite large and may affect the intended function of the surface. Thus in some cases it may be necessary to specify both surface roughness and waviness.

On all surface texture specifications as of January 1997, $\lambda_c$ and $\lambda_s$ must be stated.

When $\lambda_c$ and $\lambda_s$ are not specified, guidelines are given in section 3.3.20.1 and 3.3.20.2 of ASME B46.1 – 2009 for the metrologist to establish $\lambda_c$ and $\lambda_s$. These guidelines are intended to include the dominant features of the surface in the measurement whether these surface features are relevant to the function of the surface or not.
Surface Texture
(Surface Roughness, Waviness, and Lay)

ASME B46.1 2009 Standard
PDF/Hardcopy

Once the surface is measured, need to develop parameters for control etc.
• Probably >100, 2D parameters introduced in the literature / standards over the years
• Beginning ~1993, 3D work (Stout etal.), Identify 14+ key 3D parameters
• Standard ISO/DIS 25178-2 (3D “Areal” parameters) out for review/2010

The parameters quantify “information”:
• Height —— “Amplitude parameters” (e.g. Ra)
• Spatial —— “Spacing parameters” (e.g. Sm)
• Height & Spatial —— “Hybrid parameters” (e.g. λq)
• Function – Bearing Area (e.g. Rpk..)

2D Surface Texture Parameters

Traversing Length
Evaluation Length
Sampling Length
2D Surface Texture Parameters

Ra ... Average Roughness. (e.g. WYKO – Stylus X Ra)

Why Ra?..."Standard" ......Limits of technology..circa 1930...

Why Not Ra?.....
No spatial structure information
No difference between peaks/valleys

Amplitude Parameters .. Rq, Rsk, Rku

Rq=3, Rsk = 0, Rku=3, Gaussian Surface
Rq=12, Rsk = -1, Rku=8, Negatively Skewed
Rq=12, Rsk = 1, Rku=8, Positively Skewed
Rq=4, Rsk = 0, Rku=1.5, Slowly Varying
Rq=4, Rsk = 0, Rku=10, Extreme Peak/Valley
### 2D Surface Texture Parameters

**Peaks/Valleys**.. Rp, Rv, Rt, Rz, Pc... (e.g. WYKO Stylus X Rp)

- **Rp** = Highest Point from Mean Line
- **Rv** = Lowest Point from Mean Line
- **Rt** = Rp - Rv = Peak to Valley

**Rpi** = Highest Peak from mean line in “ith” sampling length

**Rpm** = Average of all Rpi

**Rti** = Highest - Lowest points from mean line in “ith” Sampling length “Peak to Valley”

**Rmax** = Maximum Rt over evaluation length

| Rz (ASME B46.1) = Average of all Rti (i.e. over all sample lengths) |
| Rz (DIN) = Average Rti over 5 sample lengths |
| Rz (ISO) = “Rt” (That’s right - peak to valley in one cutoff!) |
| For ISO – must specify number of sample lengths |
| ISO – Default – 5 cutoffs for Rz – Rz5 |

**Rz (ASME B46.1)**

- Average of all Rti (i.e. over all sample lengths)

**Rz (DIN)**

- Average Rti over 5 sample lengths

**Rz (ISO)**

- “Rt” (That’s right - peak to valley in one cutoff!)
  - For ISO – must specify number of sample lengths
  - ISO – Default – 5 cutoffs for Rz – Rz5

**PCL = Peak Count Level...Threshold**

- “Peak” = When profile intersects lower and upper PCL

**Rpc = Peak Density...peaks/unit length**

### Spacing Parameters

**Rsm, PCL** (e.g. WYKO Stylus Rsm)

- **Rsm** = The Average of all Smi
- Height Threshold -10% of Rz
- Spacing > 1% of sampling length

**PCL** = Peak Count Level...Threshold

- “Peak” = When profile intersects lower and upper PCL

**Rpc = Peak Density...peaks/unit length**

- **PCL-via B46**
- Check your software...
- factors of 2 exist!

### Why Sm, Pc...?

- Sealing, Appearance, Adhesion
- Sheet Steel...Forming release v.s. appearance

### Why Not Sm, Pc...?

- No height information
2D Surface Texture Parameters

Hybrid Parameters...Slope, $\Delta q$, $\lambda q$ (e.g. WYKO Stylus $X\Delta q$)

Slope – 2D Profile

$$\Delta q = \sqrt{\frac{1}{L} \int_0^L \left[ \frac{dZ(x)}{dx} \right]^2 \, dx}$$

“Average Wavelength Weighted By Amplitude”

$$\lambda q = \frac{2\pi Rq}{\Delta q}$$

---

2D Surface Texture Parameters

Functional Parameters...

Bearing Area $Rpk$, $Rk$ $Rvk$...

DIN 4776 – ISO 13565-2

$Rpk$ = “Peak Height”.. First Region of contact
$Rk$ = “Core Height”... “working” Region ..“Base”
$Rvk$ = “Valley Depth”... “Lubricant Retention Region”

$Rpk/Rk$, $Rvk/Rk$ and $Rpk/Rvk$ – Normalized parameters

$Mr1$ = “1st Material Ratio”... “Peak Material”
$Mr2$ = “2nd Material Ratio” ... “Valley Material”
$V_0 = Rvk(100-Mr2)/200$......“Retention Volume”
2D Surface Texture Parameters

Functional Parameters

Bearing Area Rpk, Rk Rvk...

Talk about Bearing area Offsets

3D Surface Texture Metrology

History....

1930’s – First “2D” instruments for texture – analogue, charts etc.
1960’s – Digital Computers – parameter development – 3D machines
1979 – 1st of Triennial International Conferences
1990’s – Workshops – indicating a need to standardize 3D parameters
3D Texture Parameters

Sa: Roughness average
Sq: Root-mean-square deviation of the surface
Sp: Maximum peak height
Sv: Maximum valley depth
Sz: Maximum height of the surface
Ssk: Skewness of surface height distribution
Sku: Kurtosis of surface height distribution

Sal: Fastest Decay Autocorrelation Length
St: Texture Aspect Ratio
Std: Texture Direction of Surface

Sdq: Root-Mean Square Surface Slope
Sdr: Developed Surface Area Ratio
Sds: Density of Summits*
Ssc: Mean Summit Curvature*

Smr(c): Areal Material Ratio
Sdc(mr): Inverse Areal Material Ratio
Sxp(p,q),Spk, Sv, SMr1,SMr2, Spk/Sk, Svk/Sk, Spk/Svk – Bearing Area Related Parameters
Vv(mr),Vvv(p),Vvc(p,q): Areal Material Ratio – Void Volume Parameters
Vm(mr), Vvp(p), Vmc(p,q): Areal Material Ratio – Material Volume Parameters
Sbi, Sc, Svi: Functional Index Parameters*

*not in ISO 25178-2

Michigan Metrology, LLC
Future Direction
Features ... Wolf Pruning, Fractals
New “Tribology” parameters – reservoirs- flow connectivity
Contact Mechanics – asperity shape unloaded/loaded
  saddle points, ridges, valleys, peaks etc.

If you flatten Vermont
will it be larger than Texas?

Chris Brown
http://www.me.wpi.edu/research/SurfMet/

Surface Texture Parameters
From $R_a$...
to amplitude parameters ($R_q$, $R_{sk}$....)
to bearing area ($R_{pk}$, $R_{vk}$....)
  spacing ($S_m$....)
  Hybrid... ($\lambda q$....)
  S parameters........

Which one(s) do I use?

• Guided by “physics” (e.g. bearing? Sealing? Appearance?)...choose a set of parameters..
• Functional Correlation?
• Is measurement Gage Capable?
Specifying Surface Finish


Basic Symbology

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) √</td>
<td>Basic Surface Texture Symbol. Surface may be produced by any method except when the bar or circle (Symbol b or d) is specified.</td>
</tr>
<tr>
<td>(b) √</td>
<td>Material Removal By Machining is Required. The horizontal bar indicates material removal by machining is required to produce the surface and material must be provided for that purpose.</td>
</tr>
<tr>
<td>(c) x √</td>
<td>Material Removal Allowance. Value in millimeters for &quot;X&quot; defines the minimum material removal requirement.</td>
</tr>
<tr>
<td>(d) √</td>
<td>Material Removal Prohibited. The circle in the bar indicates the surface must be produced by processes such as casting, forging, hot finishing, cold finishing, die casting, powder-metallurgy or injection molding without subsequent removal of material.</td>
</tr>
<tr>
<td>(e) √</td>
<td>Surface Texture Symbol. To be used when any surface texture values, production method, treatment, coating or other characteristics are not to be specified or understood. Surface may be produced by any method except when bar or circle (Symbol b or d) is specified or when the method is specified above the horizontal line.</td>
</tr>
</tbody>
</table>

Michigan Metrology, LLC
Key Measurement Concepts

• Texture parameter specified is max value along the direction that gives the max value (i.e. across the lay) .. must locate at region of expected max roughness. Can also indicate bilateral spec.

• Cutoff Length MUST be specified after “1995”

• Unless specified, parameters are averaged over 5 cutoff lengths
Specifying Surface Finish
ISO 1302-2002

Key Measurement Concepts
- Texture parameter may be unilateral max, min, 16% or bilateral – (see next slides)
- Cutoff Length/ bandwidth MUST BE SPECIFIED
- Unless specified, parameter are averaged over 5 cutoff lengths.

Future Webinar Topics:
ASME B46.1-2009

- Instrumentation?
- Filtering?
- Parameters – 2D/3D?
- Functional Correlation?
- Advanced Analysis – Fractals, Pruning, etc.
- Gage Calibration/Capability?
- ISO Harmonization?
- Surface Metrology – Friction?
- Surface Metrology – Wear?
- Surface Metrology – Application Case Studies
- 
- 
- 

Michigan Metrology, LLC