SURFACE TEXTURE · ROUGHNESS · RA / RZ · ISO 1302 · REFERENCE DOCUMENT · PUBLIC

Surface finish reference

What surface roughness is, what each process delivers, the finish each function needs, and how to call it out on a drawing without over-specifying and paying for it.

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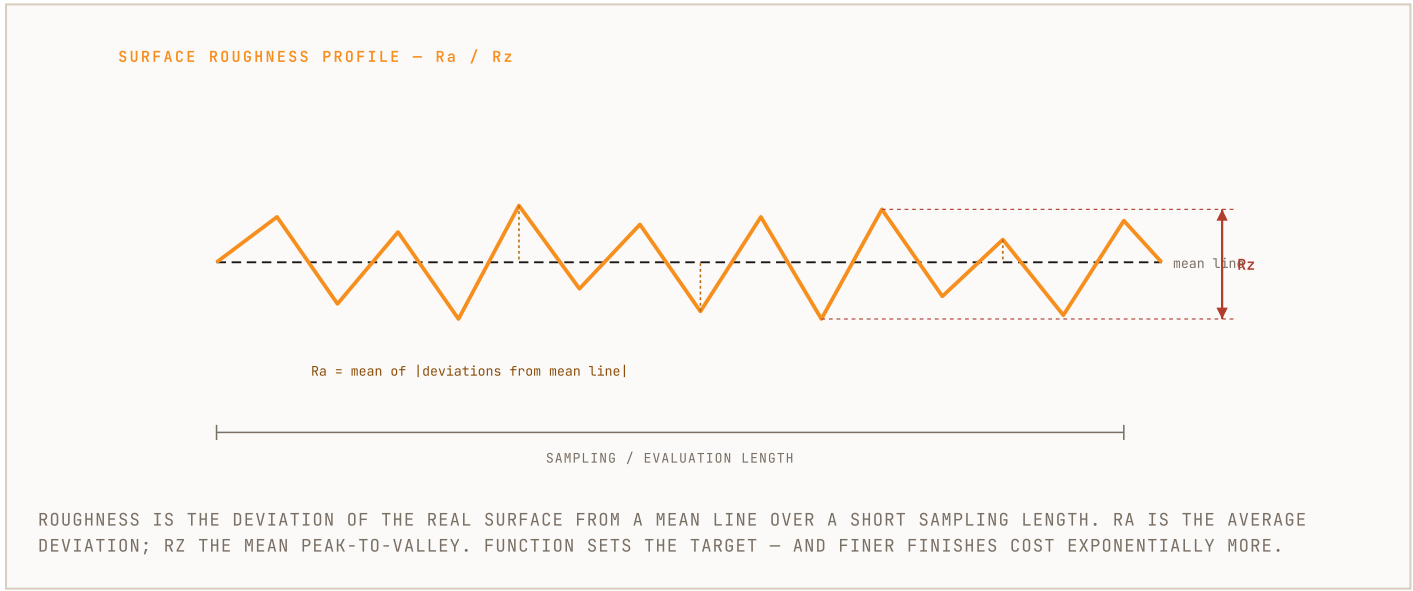
ABSTRACT

Surface finish is a real cost and performance lever, not a cosmetic afterthought. The same part is cheap at Ra 3.2 µm and expensive at Ra 0.2 µm, and the right value depends entirely on what the surface has to do — seal, slide, resist fatigue, take an interference fit, or just look right.

Section 1 defines roughness and how it's measured. Section 2 gives typical Ra by manufacturing process. Section 3 maps function to a target finish. Section 4 covers drawing call-outs (ISO 1302). Section 5 is cost and DFM. Section 6 is a conversion and N-grade quick reference.



ROUGHNESS IS THE DEVIATION OF THE REAL SURFACE FROM A MEAN LINE OVER A SHORT SAMPLING LENGTH. RA IS THE AVERAGE DEVIATION; RZ THE MEAN PEAK-TO-VALLEY. FUNCTION SETS THE TARGET — AND FINER FINISHES COST EXPONENTIALLY MORE.

CONTENTS

1. What roughness is and how it's measured

Surface texture has three scales: **form** (overall shape), **waviness** (longer-wavelength undulation), and **roughness** (the fine, closely-spaced peaks and valleys). A profilometer drags a stylus across the surface, filters out form and waviness with a cutoff (λc), and measures the remaining roughness against a **mean line** over a short **sampling length**.

1.1 Terms

`Ra`	Arithmetic mean of the absolute deviations from the mean line — the default, most-quoted parameter
`Rz`	Mean peak-to-valley height over the sampling lengths — more sensitive to single defects than Ra
`Rt / Rmax`	Largest single peak-to-valley in the evaluation length — worst-case
`Mean line`	The reference line that splits the profile into equal areas above and below
`Cutoff (λc)`	The filter wavelength that separates roughness from waviness (commonly 0.8 mm)
`Lay`	The dominant direction of the surface pattern (e.g. parallel, perpendicular, circular)

Ra alone can hide problems. Two surfaces with the same Ra can behave very differently — one with a few deep scratches (high Rz, bad for sealing/fatigue) and one uniformly fine. For sealing and fatigue, constrain Rz (or Rmax) as well as Ra.

2. Typical roughness by process

PROCESS	TYPICAL RA (MM)
Sand casting	6.3 – 25
Die casting	0.8 – 3.2
Hot rolling / forging	3.2 – 12.5
Flame / plasma / laser cut edge	3.2 – 25
Milling	0.8 – 6.3
Turning / boring	0.4 – 6.3
Drilling	1.6 – 6.3
Reaming	0.4 – 1.6
Grinding	0.1 – 1.6
Honing	0.05 – 0.4
Lapping / superfinishing	0.012 – 0.1
Polishing	0.025 – 0.2
EDM	0.4 – 6.3
Injection moulding (SPI A–D)	0.05 – 3.2+
FDM 3D print (layer lines)	6 – 25
SLA / SLS / MJF 3D print	1.6 – 6.3

A surface finer than the base process allows needs a **secondary operation** (grind, hone, lap, polish) — extra setups and cost.

3. Choosing the finish by function

Specify the **loosest finish that works** for the job the surface does:

FUNCTION	TARGET RA (MM)
Dynamic seal / O-ring sliding face	0.1 – 0.4
Static seal / O-ring groove (face & bottom)	≤ 0.8 / ≤ 1.6
Sliding or journal bearing surface	0.2 – 0.8
Fatigue-critical surface	≤ 0.4 (smoother → higher endurance limit)
Press / interference fit	0.4 – 1.6
Mating / clamping / gasket faces	1.6 – 3.2
General machined, non-critical	1.6 – 6.3
Paint / adhesive adhesion	1.6 – 6.3 (some tooth helps)

Notes: rough surfaces lose effective interference in press fits (asperities flatten), so a fit specced from nominal sizes over-predicts holding force if the finish is coarse. Smoother surfaces raise the fatigue endurance limit because scratches are stress raisers — which is why fatigue-critical parts are ground or polished.

4. Drawing call-outs (ISO 1302 / ASME Y14.36)

The surface-texture symbol is a check-mark on the surface or its extension line:

- **Basic symbol (✓)**
  surface; add a bar for
  material removal required
  , or a circle for
  removal prohibited
  (leave as-cast/moulded).
- **Value placement**
  Ra value at upper-left (e.g. `Ra 1.6`). A single value is the **maximum** (16%-rule); a range uses upper and lower limits.
- **Other parameters**
  call Rz/Rmax explicitly when they matter (`Rz 6.3`), alongside or instead of Ra.
- **Lay**
  add the lay symbol (`=` parallel, `⊥` perpendicular, `X` crossed, `M` multidirectional, `C` circular, `R` radial) when direction matters for sealing or sliding.
- **All-around / general**
  a circle on the symbol means all surfaces of the outline; a general note (e.g. "Ra 3.2 unless otherwise stated") covers the rest.

State the **direction of measurement / lay** for sealing and sliding surfaces — a groove machined with the wrong lay leaks even at the right Ra.

5. Cost and DFM

- Finer finish costs exponentially. Each step down (3.2 → 1.6 → 0.8 → 0.4 µm) typically adds setups, slower feeds, or a whole secondary process. Don't tighten a finish "to be safe."
- Specify per surface, not per part. Put the tight finish only on the faces that need it; leave everything else at the general note.
- Match finish to process. Asking for Ra 0.4 on an as-milled face forces grinding; design the feature so the base process delivers it where possible.
- Coatings change it. Plating and painting alter the final texture; specify before- or after-coating and account for build-up on fits.

6. Conversion and grade quick reference

RA (MM)	RA (MIN)	ISO N-GRADE	~RZ (MM)
0.025	1	N1	~0.15
0.05	2	N2	~0.3
0.1	4	N3	~0.5
0.2	8	N4	~1
0.4	16	N5	~2
0.8	32	N6	~4
1.6	63	N7	~8
3.2	125	N8	~16
6.3	250	N9	~25
12.5	500	N10	~50

Rules of thumb: **1 µm Ra ≈ 39.4 µin**; for typical machined surfaces **Rz ≈ 4–7 × Ra** (use a measured ratio when Rz is critical). N-grades (ISO 1302) are a shorthand some drawings still use — prefer an explicit Ra value.