R

Roughness

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Synonyms

[Surface roughness](#)

Definition

Dimensional irregularity of a surface, its deviations from a mathematical flat.

Theory and Application

Importance of Roughness for the Function of a Workpiece

Functional aspects that are affected by surface roughness can be described by 1-, 2-, and 3-body interactions.

Interaction with a Single Surface

The transmission and reflection of electromagnetic waves is determined by the surface geometry (see entry “► [Reflectivity](#)”), especially the scattering by the surface. One can look through window glass due to the fact that the surface roughness Ra (<10 nm) is much smaller than the wavelength of light (yellow light: 470 nm). The

difference between “gloss” and “mat” of, e.g., pictures or paint is determined by the surface roughness. For the final optical properties of an object also the shape is essential.

For good adhesion of coatings to a surface, a certain roughness may be needed. A simple example is the grinding of a surface before it is painted.

Chemical reactions with a surface depend on the roughness. A reflective surface of a lapped gauge has very little corrosion under normal circumstances, even if it is made from a rapidly corroding steel.

Interaction Between Two Surfaces

We give here some aspects and properties that are affected or determined by the surface roughness:

- The coefficient of friction between two bodies
- The presence/remain in a liquid film between two bodies (lubrication)
- Sealing by means of a threaded connection or a pen/hole connection
- Stiffness of a connection
- Plastic or elastic deformation at contact between two bodies
- Thermal conductivity between two bodies
- Electrical conduction between two bodies
- Wear/fatigue contact between surfaces

Interaction Between Three Surfaces

The primary example here is the bearing, the stiffness and friction on moving, the roughness

Roughness, Table 1 Typical roughness due to various machining processes

Process	Range of Ra in μm
Sandblasting	6–50
Cutting	1.6–50
Drilling	0.8–12
Spark erosion	0.8–12
Die casting	0.4–6
Milling	0.2–25
Grinding	0.02–6
Honing	0.02–1.6
Polishing	0.005–0.8
Lapping	0.005–8

of the balls, and the surfaces between which the moving occurs.

The quantification of these aspects and determine the most relevant roughness parameter is the trickiest part of a design where the roughness is important. Because this is different for each problem there are barely general guidelines.

Roughness and Manufacturing Process

Each machining process has its capabilities and limitations when it comes to reach a certain surface structure. Surfaces produced by various machining processes will look different, even though the most widely used roughness parameter Ra is equal.

Table 1 shows what surface roughness Ra is normally achieved by the machining process mentioned.

In production engineering, surface roughness is that part of the irregularities on the surface left by the shaping process, which are inherent to the material removal process itself. This contrasts with the undulations mostly due to the imperfect behavior of an individual machine. In general, the roughness depends on the basic form of the tool, especially in the case of turning and grinding, but it also depends on irregularities in the ways caused

by micro-cracks, material build-up on the tool and other causes. Although Ra is the most commonly used surface parameter, it is arguably not the most appropriate for many purposes. Many, many other surface parameters can be, and have been, defined.

Distinction Between Form Deviation, Roughness, and Waviness

In general, the deviation from the ideal shape can be distinguished in three distinct areas in which the structure of a surface is constructed, namely:

- Form deviation caused by the process by which the shape is applied, removing it may well not be machined. These are long-wavelength abnormalities, abnormalities which guide development.
- Waviness, usually caused by factors such as machine and tool deflection, vibration of machine, and machining process (chatter). Waves are predominantly periodic appearing surface deviations, with a wavelength greater than the surface roughness. The relationship between wavelength and depth is between 100:1 and 1000:1.
- Roughness caused by the shaping tool, e.g., machining grooves and the structure inside. The relationship between wavelengths and depth can be between 150:1 and 5:1.

Practically it is difficult to draw the line between these different domains of scale, especially because waviness is usually measured as part of the form deviation (Fig. 1).

The subdivision waviness/roughness is essentially deliberate, but in practice this is fixed in standards with the most common distinction is at a wavelength of 0.8 mm. More specific guidelines for this division and the related filtering are given in ISO 4288 (1996) and ISO 16610-21 (2011), respectively.

Roughness, Fig. 1 Illustration of roughness, waviness and form deviation

Cross-References

- [Bearing](#)
- [Drilling](#)
- [Grinding](#)
- [Honing](#)
- [Lapping](#)
- [Polishing](#)
- [Reflectivity](#)
- [Surface Parameter](#)
- [Wear Mechanisms](#)

References

- ISO 4288 (1996) Geometrical product specifications (GPS) – surface texture: profile method – rules and procedures for the assessment of surface texture. Beuth, Berlin
- ISO 16610-21 (2011) Geometrical product specifications (GPS) – filtration – part 21: linear profile filters: Gaussian filters. Beuth, Berlin