

Roughness measurements of stainless steel surfaces

Introduction

Surface roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are great, the surface is rough, if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. In practice, it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for purpose [1].

Ra value

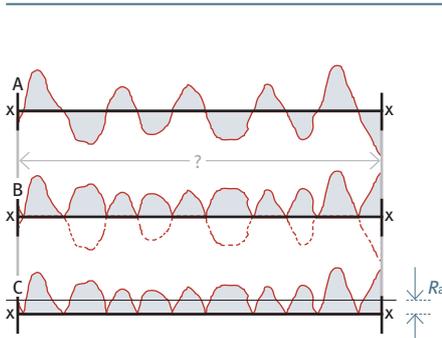


Figure 1. The principle of measuring average roughness (R_a) [3]

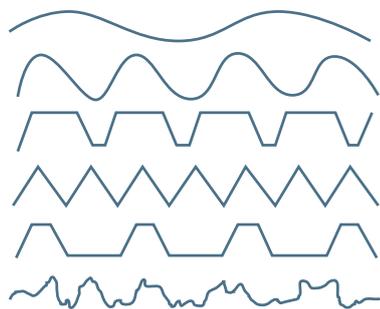


Figure 2. Various surface profiles having the same R_a value [4]

The roughness of a surface has most commonly been measured by an instrument in which a stylus travels across the surface, the movement of the stylus is amplified and the signal recorded. The result is generally expressed as R_a or average roughness and is the arithmetic average value of the deviation of the trace above and below the centre line. The value of R_a is normally measured in micrometres. ISO standards use the term CLA (Centre Line Average). Both are interpreted identically [2].

Although R_a is a useful average, it does not differentiate between peaks and valleys. Very different profiles can have the same R_a value. In technical specifications, the upper limit or maximum value of the parameter is often found during inspection. For requirements specified by the upper limit (e.g. $R_a \leq 0.6 \mu\text{m}$) of a parameter, the surface is considered acceptable if not more than 16 % of all measured values of the selected parameter (based on an evaluation length) exceed the value specified in the drawings or the technical product documentation. To designate the upper limit of the parameter, the symbol of the parameter is used without the “max” index. For requirements specified by the maximum value (e.g. $R_a \text{ max. } 0.6 \mu\text{m}$) of the parameter during inspection, none of the measured values of the parameter, over the entire surface under inspection, should exceed the value specified in the drawings or in the technical product documentation. To designate the maximum permissible value of the parameter, the “max” index has to be added to the symbol of the parameter (for example $R_a \text{ max.}$). Control of surface roughness

can be performed quickly and easily using the simplified procedure for roughness inspection given in Annex A, EN ISO 4288 [5], [6]. Only the upper limit of roughness is usually established – not a lower limit. An exception is cylinder bores where oil is retained in the surface profile and a minimum roughness is required.

Rz value

An alternative measure of surface roughness is the R_z value. ISO 4287-1:1997 [8] defines R_z as the maximum height of profile. Older documents and surface roughness measuring instruments may still refer to R_z according to the 1984 version of this standard, which indicated the “ten point height of irregularities”. Typographical detail is important: “ R_z ” refers to the current, “ R_z ” to the obsolete version of the standard.

Rq value

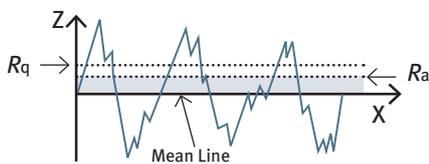


Figure 3. The principle of measuring root-mean-square roughness (R_q) [8]

Another factor for the description of surface roughness, R_q (sometimes also RMS) measures the root-mean-square deviation of a profile. The terms, definitions and parameters for determination of surface roughness are again provided in EN ISO 4287 [7].

Table 1. Surface roughness for different stainless steel finishes [9], [10], [11], [12]

Surface finish EN 10088-2	Type of process route	Surface roughness as in EN 10088-2	Notes
1D	Hot rolled, heat treated, (shot blasted) and pickled. Rough and dull.		Ra typically in the 3.50-7.50 µm range
2D	Cold rolled, heat treated, pickled. Smooth.		
2B	Cold rolled, heat treated, pickled, skin passed. Smoother than 2D.		Ra typically in the 0.30-0.50 µm range
2G	Ground Grade of grit or surface roughness can be specified. Unidirectional texture, not very reflective.		
2R	Bright annealed Cold rolled, bright annealed. Smooth, bright, reflective.		
2J	Brushed or dull polished Grade of brush or polishing belt or surface roughness can be specified. Unidirectional texture, not very reflective.		
2K	Satin polish	Transverse Ra < 0.5 µm	
2P	Bright polished The finish is achieved by mechanical polishing. The process of surface roughness can be specified. It is a non-directional finish, reflective, with a high degree of image clarity.		

It is worth keeping in mind that incorrect surface treatment can result in irreversible damage. As an example, there is no repair procedure for a process tank delivered with a cold-rolled, bright finish (2B finish, ASTM A 480/A 480M) that exceeds a specified maximum Ra value [6].

Surface finish ASTM A 480/480 M	Description	Notes
3	A linearly textured finish that can be produced by either mechanical polishing or rolling. A skilled operator can generally blend this finish.	Average Ra may generally be up to 1 µm*
4	A linearly textured finish that may be produced by either mechanical polishing or rolling. A skilled operator can generally blend this finish.	Average Ra may generally be up to 0.6 µm*
5	Architectural finishes. These are a separate category and can be negotiated between buyer and seller, as there are many techniques and finish variations available throughout the world.*	Transverse Ra value should not exceed 0.5 µm
6	This finish has a soft, satin appearance, typically produced by Tampico brushing of a No. 4 finish.	
8	This is a highly reflective, smooth finish, typically produced by polishing with successively finer grit abrasives, then buffing. Typically, very faint buffing or polishing lines may still be visible on the final product. Blending after assembly may be done by buffing.	

* Surface roughness measurements differ with different instruments, laboratories and operators. There may also be overlap on measurements of surface roughness for both No. 3 and No. 4 finishes.

Surface finish in fabrication	Average Ra µm
Bead blasted	1.00-6.00
Bored, turned	0.40-6.00
Electropolished	0.10-0.80

It should be noted that the values in the table are for orientation only and that they vary between different producers and typical surface finish. It is suggested that, as concerns surface roughness requirements, a possible Ra acceptance criterion should be explicitly stated, since surface finish as defined by the standards only defines the process route (such as cold rolled, heat treated, pickled, skin passed for 2B) and surface roughness can vary from one producer to another.

Table 2. Comparison of grit size and surface roughness – approximate values [13]

Grit size	R_q μm	R_a μm
80	2.02	1.80
120	1.47	1.32
150	1.20	1.06
180	0.86	0.76
240	0.43	0.38
320	0.36	0.30
500	0.20	0.18
600	0.15	0.13

Summary

Although R_a values are commonly used to describe surfaces, the limits of this indicator should not be forgotten. Also the notation is important: “ $R_a \leq 0.5 \mu\text{m}$ ”, for instance, does not have the same meaning as “ $R_a \text{ max } 0.5 \mu\text{m}$ ”. Surface designations such as “2B” according to EN or “No 4 finish” according to ASTM encompass relatively large ranges of surface roughness. Products which have identical designations but come from different batches or different suppliers may have noticeably different roughness characteristics. In architectural applications where surface appearance is of great importance roughness values alone are insufficient to characterise a surface. In this case, it is recommended that samples should be exchanged between the customer and the supplier and made part of purchase orders, to avoid later disagreement.

Relevant standards

ISO 1302:2002	Geometrical Product Specifications (GPS) – Indication of surface texture in technical product documentation (ISO 1302:2002)
EN ISO 3274:1997	Geometrical product specifications (GPS) – Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments (ISO 3274:1996)
EN ISO 4287:1998/AC:2008	Geometrical product specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters (ISO 4287:1997/Cor 1:1998/Cor 2:2005)

EN ISO 4288:1997	Geometrical product specifications (GPS) – Surface texture: Profile method – Rules and procedures for the assessment of surface texture (ISO 4288:1996)
EN ISO 5436-1:2000	Geometrical Product Specifications (GPS) – Surface texture: Profile method; Measurement standards – Part 1: Material measures (ISO 5436-1:2000)
EN ISO 5436-2:2012	Geometrical product specifications (GPS) – Surface texture: Profile method; Measurement standards – Part 2: Software measurement standards (ISO 5436-2:2012)
EN ISO 12085:1997/AC:2008	Geometrical product specification (GPS) – Surface texture: Profile method – Motif parameters (ISO 12085:1996/Cor 1:1998)
EN ISO 12179:2000/AC:2008	Geometrical Product Specifications (GPS) – Surface texture: Profile method – Calibration of contact (stylus) instruments (ISO 12179:2000/Cor 1:2003)
EN ISO 13565-1:1997	Geometrical product specifications (GPS) – Surface texture: Profile method; surfaces having stratified functional properties – Part 1: Filtering and general measurement conditions (ISO 13565-1:1996)
EN ISO 13565-2:1997	Geometrical product specifications (GPS) – Surface texture: Profile method; surfaces having stratified functional properties – Part 2: Height characterization using the linear material ratio curve (ISO 13565-2:1996)
EN ISO 13565-3:2000	Geometrical Product Specifications (GPS) – Surface texture: Profile method; surfaces having stratified functional properties – Part 3: Height characterization using the material probability curve (ISO 13565-3:1998)
ISO 16610-21:2011	Geometrical product specifications (GPS) – Filtration – Part 21: Linear profile filters: Gaussian filters

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