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Surface Texture
(Surface Roughness, Waviness, and Lay)

AN INTERNATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers

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FOREWORD

The first standard on surface texture was issued in March 1940. The dates for the subsequent changes are as follows:

Revision — February 1947
Revision — January 1955
Revision — September 1962
Revision — August 1971
Revision — March 1978
Revision — March 1985
Revision — June 1995
Revision — October 2002
Revision — October 2009

The current revision is the culmination of a major effort by the ASME B46 Committee on the Classification and Designation of Surface Qualities. A considerable amount of new material has been added, particularly to reflect the increasing number of surface measurement techniques and surface parameters in practical use. Overall, the vision for ASME B46.1 is twofold as follows:

(a) to keep it abreast of the latest developments in the regime of contact profiling techniques where the degree of measurement control is highly advanced

(b) to encompass a large range of other techniques that present valid and useful descriptions of surface texture

Technical drawings referring to a specific edition of ASME B46.1 (e.g., ASME B46.1-2009) refer to the rules and definitions given in that edition of the surface texture standard as indicated. For technical drawings that do not indicate a specific edition of the ASME B46.1 surface texture standard, the rules and definitions given in the ASME B46.1 revision in effect at the release date of the drawing shall be used.

The ASME B46 Committee contributes to international standardization activities related to surface texture measurement and analysis as referenced in ISO/TR 14368:1995, Geometrical Product Specification (GPS) — Masterplan.

The present Standard includes 12 Sections as follows:

Section 1, Terms Related to Surface Texture, contains a number of definitions that are used in other Sections of the Standard. A large number of surface parameters are defined in addition to roughness average, *Ra*. These include rms roughness *Rq*, waviness height *Wt*, the mean spacing of profile elements *RSm*, and several statistical functions, as well as surface parameters for area profiling techniques.

Section 2, Classification of Instruments for Surface Texture Measurement, defines six types of surface texture measuring instruments including several types of profiling instruments, scanned probe microscopy, and area averaging instruments. With this classification scheme, future Sections may provide for the specification on drawings of the type of instrument to be used for a particular surface texture measurement.

Section 3, Terminology and Measurement Procedures for Profiling, Contact, Skidless Instruments, is based on proposals by ISO Technical Committee 57 to define the characteristics of instruments that directly measure surface profiles, which then can serve as input data to the calculations of surface texture parameters.

Section 4, Measurement Procedures for Contact, Skidded Instruments, contains much of the information that was previously contained in ASME B46.1-1985 for specification of instruments primarily intended for measurement of averaging parameters such as the roughness average *Ra*.

Section 5, Measurement Techniques for Area Profiling, lists a number of techniques, many of them developed since the mid-1980s, for three-dimensional surface mapping. Because of the diversity of techniques, very few recommendations can be given in Section 5 at this time to facilitate uniformity of results between different techniques. However, this Section does allow for the measurement of the area profiling parameters, *Sa* and *Sq*, as alternatives to the traditional profiling parameters.

Section 6, Measurement Techniques for Area Averaging, discusses the use of area averaging techniques as comparators to distinguish the surface texture of parts manufactured by similar processes. In later Sections, surface parameters based directly on these techniques may be defined or surface specifications may be proposed that call for measurements by these types of instruments.

Section 7, Nanometer Surface Texture and Step Height Measurements by Stylus Profiling Instruments, addresses the use of contacting profilometry in the measurement of surface texture features whose height dimensions are typically measured within the scale of nanometers. Section 7 may be applicable to such industries as semiconductor, data storage, and microelectromechanical systems (MEMS) manufacturers.

Section 8, Nanometer Surface Roughness as Measured With Phase Measuring Interferometric Microscopy, addresses the use of optical noncontact techniques for measuring highly polished surfaces. Section 8 may be applied to the measurement of such items as polished silicon wafers, optical components, and precision mechanical components.

Section 9, Filtering of Surface Profiles, carries on with the traditional specifications of the 2RC cutoff filter and introduces the phase corrected Gaussian filter as well as band-pass roughness concepts.

Section 10, Terminology and Procedures for Evaluation of Surface Textures Using Fractal Geometry, introduces the field of fractal analysis as applied to measuring surface texture. Introductions of various techniques and terms are included to allow for lateral scale specific interpretation of surface texture.

Section 11, Specifications and Procedures for Precision Reference Specimens, describes different types of specimens useful in the calibration and testing of surface profiling instruments. It is based on ISO 5436, Part 1, Material Measures, and contains new information as well.

Section 12, Specifications and Procedures for Roughness Comparison Specimens, describes specimens that are useful for the testing and characterization of area averaging instruments.

ASME B46.1-2019 was approved by the American National Standards Institute on October 22, 2019.

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Classification and Designation of Surface Qualities

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Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

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Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a “yes” or “no” reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of “Yes” or “No,” with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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EXECUTIVE SUMMARY

1 GENERAL

In cases of disagreement regarding the interpretation of surface texture measurements, it is recommended that measurements with skidless stylus–based instruments with Gaussian filtering be used as the basis for interpretation. The following key measurement parameters must be established for proper surface texture specification and measurement.

2 FILTERING

The spatial wavelengths to be included in a surface texture measurement are generally limited by digital band-pass filtering. For measurement of roughness, short-wavelength cutoff, λs, specifies the short spatial wavelength limit and is defined as the wavelength where the Gaussian filter will attenuate the true profile by 50%. Spatial wavelengths less than λs are severely attenuated and minimally contribute to the roughness measurement.

The roughness long-wavelength cutoff, λc, specifies the long spatial wavelength limit and is defined as the wavelength where the Gaussian filter will attenuate the true profile by 50%. Spatial wavelengths greater than λc are severely attenuated and minimally contribute to the roughness measurement.

The ratio of λc to λs (λc:λs) is the bandwidth of the measurement. Some instruments allow the selection of λc and λs individually and/or the selection of a bandwidth, typically 100:1 or 300:1. The spatial wavelengths comprising the texture between λs and λc are minimally attenuated by the Gaussian filter.

The cutoffs, λc and λs, should be chosen by the designer in light of the intended function of the surface. When choosing λc and λs, 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.

When surface waviness control is important, digital band-pass filtering is applied similarly as it is for roughness filtering. For waviness, the waviness short-wavelength cutoff, λsw, and waviness long-wavelength cutoff, λcw, are applied to obtain the waviness profile. An important consideration is the correspondence of the roughness long-wavelength cutoff and the waviness short-wavelength cutoff. When these respective cutoff values are not equal, the discrimination of the roughness and waviness features of a given surface can become confounded.

On all surface texture specifications as of January 1997, λc and λs must be stated. When λc and λs are not specified, guidelines are given in paras. 3-3.20.1 and 3-3.20.2 for the metrologist to establish λc and λs. 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.

3 STYLUS TIP RADIUS

The stylus tip radius may be chosen by the designer or metrologist based on the value of λs (i.e., the short-wavelength cutoff). For λs equal to 2.5 μm, the tip radius should typically be 2 μm or less. For λs equal to 8 μm, the tip radius should typically be 5 μm or less. For λs equal to 25 μm, the tip radius should typically be 10 μm or less.

4 STYLUS FORCE

The maximum static measuring force is determined by the radius of the stylus and is chosen to assure minimal damage to the surface and that constant contact is maintained with the surface. Specific recommendations for stylus force may be found in para. 3-3.5.2.

5 MEASUREMENT PARAMETERS

Many surface finish height parameters are in use throughout the world. From the simplest specification of a single roughness parameter to multiple roughness and waviness parameter specifications of a given surface, product designers have many options for specifying surface texture to control surface function. Between these extremes, designers should consider the need to control roughness height (e.g., *Ra* or *Rz*), roughness height consistency (e.g., *Rmax*), and waviness height (e.g., *Wt*). Waviness is a secondary longer wavelength feature that is only of concern for particular surface functions and finishing processes. A complete description of the various texture parameters may be found in Section 1.

6 SURFACE TEXTURE SYMBOLS

Once the various key measurement parameters are established, ISO 1302:2002 may be used to establish the proper indication on the relevant engineering drawings.

ASME B46.1-2019
SUMMARY OF CHANGES

Following approval by the ASME B46 Committee and ASME, and after public review, ASME B46.1-2019 was approved by the American National Standards Institute on October 22, 2019.

In ASME B46.1-2019, the figures and tables have been redesignated based on their parent paragraph, and the cross-references have been updated accordingly. ASME B46.1-2019 includes the following additional changes identified by a margin note, **(19)**.

Page	*Location*	*Change*
1	1-1.4	Address of ISO updated
3	1-3.3	Definitions of *profile element*, *profile peak*, *profile peak height*, *profile valley*, and *profile valley depth* revised
7	Figure 1-3.3-1	Former Figure 1-6 revised
9	1-4.2	Definitions of *mean spacing of profile elements*, *peak density*, *SAE peak*, and *spacing parameter* revised
10	Figure 1-4.2-1	Former Figure 1-13 revised
13	1-4.4	In first equation, symbol between *dZ* and *dx* corrected to division symbol
20	Figure 1-6.5-1	Former Figure 1-23 revised
24	3-2	Address of ISO updated
29	Table 3-3.20.1-1	Former Table 3-1 editorially revised
29	Table 3-3.20.2-1	Former Table 3-2 editorially revised
31	4-2	Address of ISO updated
36	5-2	Address of ISO updated
38	7-2	Address of ISO updated
47	9-2	Address of ISO updated
51	Table 9-4.3.2-1	Former Table 9-1 editorially revised
63	11-2	Address of ISO updated
71	Table 11-7.3-1	Former Table 11-5 revised
72	Table 11-7.3-3	Former Table 11-7 revised
73	Table 11-7.3-4	Former Table 11-8 revised
75	12-2	Address of ISO updated
82	Nonmandatory Appendix B, B-5	Added
91	Nonmandatory Appendix D	D-1 added and subsequent sections redesignated
94	Nonmandatory Appendix E	E-1 added and subsequent sections redesignated
104	Nonmandatory Appendix G	Section headings G-1 and G-2 editorially added
117	Nonmandatory Appendix J	Updated
118	Nonmandatory Appendix K	Added

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Section 1
Terms Related to Surface Texture

1-1 GENERAL

1-1.1 Scope

This Standard is concerned with the geometric irregularities of surfaces. It defines surface texture and its constituents: roughness, waviness, and lay. It also defines parameters for specifying surface texture.

The terms and ratings in this Standard relate to surfaces produced by such means as abrading, casting, coating, cutting, etching, plastic deformation, sintering, wear, and erosion.

1-1.2 Limitations

This Standard is not concerned with error of form and flaws, but discusses these two factors to distinguish them from surface texture.

This Standard is not concerned with luster, appearance, color, corrosion resistance, wear resistance, hardness, subsurface microstructure, surface integrity, and many other characteristics that may govern functional considerations in specific applications.

This Section does not recommend specific surface roughness, waviness, or type of lay suitable for specific purposes, nor does it specify the means by which these irregularities may be obtained or produced. Criteria for selection of surface qualities and information on instrument techniques and methods of producing, controlling, and inspecting surfaces are included in the other Sections and in the Appendices.

Surface texture designations as delineated in this Standard may not provide a sufficient set of indices for describing performance. Other characteristics of engineering components such as dimensional and geometrical characteristics, material, metallurgy, and stress must also be controlled.

1-1.3 SI Values

Values of quantities stated in the SI[1] (metric) system are to be regarded as standard. Approximate nonmetric equivalents are shown for reference.

1-1.4 References (19)

Unless otherwise specified on the engineering drawing or other relevant documents, this Standard is to be used in conjunction with ISO 1302:2002, which prescribes engineering drawing and other related documentation practices for specifying surface texture. Relevant standards that may be used in design and measurement are the following:

ASME B89.6.2-1973 (R2003), Temperature and Humidity Environment for Dimensional Measurement

ASME Y14.5M-1994 (R2004), Dimensioning and Tolerancing, Engineering Drawings and Related Documentation Practices

Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ISO 1302:2002, Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation

Publisher: International Organization for Standardization (ISO), Central Secretariat, Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland (www.iso.org)

Nonmandatory Appendix J, Table J-1 is a partial list of specific industry standards that reference surface texture specifications. Users are encouraged to submit additional industry standards to be considered as references in Nonmandatory Appendix J.

References to other useful works are included as footnotes.

1-1.5 Cleanliness

Normally, surfaces to be measured should be free of any foreign material that would interfere with the measurement.

1-2 DEFINITIONS RELATED TO SURFACES

1-2.1 Surfaces

measured surface: a representation of the real surface obtained by the use of a measuring instrument.

[1] Le Système International d'Unités.