

ASME B46.1-2009
(Revision of ASME B46.1-2002)

Surface Texture (Surface Roughness, Waviness, and Lay)

AN AMERICAN NATIONAL STANDARD



ASME B46.1-2009
(Revision of ASME B46.1-2002)

Surface Texture (Surface Roughness, Waviness, and Lay)

AN AMERICAN NATIONAL STANDARD



Three Park Avenue • New York, NY • 10016 USA

Date of Issuance: August 20, 2010

This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to this edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this document. Periodically certain actions of the ASME B46 Committee may be published as Cases. Cases and interpretations are published on the ASME Web site under the Committee Pages at <http://cstools.asme.org> as they are issued.

ASME is the registered trademark of The American Society of Mechanical Engineers.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not “approve,” “rate,” or “endorse” any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

No part of this document may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

Copyright © 2010 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All rights reserved
Printed in U.S.A.

CONTENTS

Foreword	viii
Committee Roster	x
Correspondence With the B46 Committee	xi
Executive Summary	xii
Section 1 Terms Related to Surface Texture	1
1-1 General	1
1-2 Definitions Related to Surfaces	2
1-3 Definitions Related to the Measurement of Surface Texture by Profiling Methods	2
1-4 Definitions of Surface Parameters for Profiling Methods	7
1-5 Definitions Related to the Measurement of Surface Texture by Area Profiling and Area Averaging Methods	13
1-6 Definitions of Surface Parameters for Area Profiling and Area Averaging Methods	15
Section 2 Classification of Instruments for Surface Texture Measurement	19
2-1 Scope	19
2-2 Recommendation	19
2-3 Classification Scheme	19
Section 3 Terminology and Measurement Procedures for Profiling, Contact, Skidless Instruments	22
3-1 Scope	22
3-2 References	22
3-3 Terminology	22
3-4 Measurement Procedure	28
Section 4 Measurement Procedures for Contact, Skidded Instruments	29
4-1 Scope	29
4-2 References	29
4-3 Purpose	29
4-4 Instrumentation	29
Section 5 Measurement Techniques for Area Profiling	34
5-1 Scope	34
5-2 References	34
5-3 Recommendations	34
5-4 Imaging Methods	34
5-5 Scanning Methods	34
Section 6 Measurement Techniques for Area Averaging	35
6-1 Scope	35
6-2 Examples of Area Averaging Methods	35
Section 7 Nanometer Surface Texture and Step Height Measurements by Stylus Profiling Instruments	36
7-1 Scope	36
7-2 Applicable Documents	36
7-3 Definitions	36
7-4 Recommendations	36
7-5 Preparation for Measurement	38

7-6	Calibration Artifacts	39
7-7	Reports	39
Section 8	Nanometer Surface Roughness as Measured With Phase Measuring Interferometric Microscopy	41
8-1	Scope	41
8-2	Description and Definitions: Noncontact Phase Measuring Interferometer	41
8-3	Key Sources of Uncertainty	41
8-4	Noncontact Phase Measuring Interferometer Instrument Requirements	41
8-5	Test Methods	43
8-6	Measurement Procedures	43
8-7	Data Analysis and Reporting	44
8-8	References	44
Section 9	Filtering of Surface Profiles	45
9-1	Scope	45
9-2	References	45
9-3	Definitions and General Specifications	45
9-4	2RC Filter Specification for Roughness	46
9-5	Phase Correct Gaussian Filter for Roughness	48
9-6	Filtering for Waviness	50
9-7	Filtering of Surfaces With Stratified Functional Properties	53
Section 10	Terminology and Procedures for Evaluation of Surface Textures Using Fractal Geometry.....	54
10-1	General	54
10-2	Definitions Relative to Fractal Based Analyses of Surfaces	54
10-3	Reporting the Results of Fractal Analyses	56
10-4	References	59
Section 11	Specifications and Procedures for Precision Reference Specimens	61
11-1	Scope	61
11-2	References	61
11-3	Definitions	61
11-4	Reference Specimens: Profile Shape and Application	61
11-5	Physical Requirements	62
11-6	Assigned Value Calculation	62
11-7	Mechanical Requirements	62
11-8	Marking	67
11-9	Calibration Interval	67
Section 12	Specifications and Procedures for Roughness Comparison Specimens.....	68
12-1	Scope	68
12-2	References	68
12-3	Definitions	68
12-4	Roughness Comparison Specimens	68
12-5	Surface Characteristics	68
12-6	Nominal Roughness Grades	68
12-7	Specimen Size, Form, and Lay	68
12-8	Calibration of Comparison Specimens	69
12-9	Marking	69
Figures		
1-1	Schematic Diagram of Surface Characteristics	2
1-2	Measured Versus Nominal Profile	3
1-3	Stylus Profile Displayed With Two Different Aspect Ratios	4
1-4	Examples of Nominal Profiles	4
1-5	Filtering a Surface Profile	5
1-6	Profile Peak and Valley	5
1-7	Surface Profile Measurement Lengths	6

1-8	Illustration for the Calculation of Roughness Average Ra	7
1-9	Rt , Rp , and Rv Parameters	8
1-10	Surface Profile Containing Two Sampling Lengths, l_1 and l_2 , Also Showing the Rp_i and Rt_i Parameters	8
1-11	The Rt and $Rmax$ Parameters	9
1-12	The Waviness Height, Wt	9
1-13	The Mean Spacing of Profile Irregularities, RSm	10
1-14	The Peak Count Level, Used for Calculating Peak Density	10
1-15	Amplitude Density Function— $ADF(z)$ or $p(z)$	11
1-16	The Profile Bearing Length	11
1-17	The Bearing Area Curve and Related Parameters	12
1-18	Three Surface Profiles With Different Skewness	12
1-19	Three Surface Profiles With Different Kurtosis	13
1-20	Topographic Map Obtained by an Area Profiling Method	14
1-21	Area Peaks (Left) and Area Valleys (Right)	14
1-22	Comparison of Profiles Measured in Two Directions on a Uniaxial Periodic Surface Showing the Difference in Peak Spacing as a Function of Direction	16
1-23	Indication of Surface Lay	18
2-1	Classification of Common Instruments for Measurement of Surface Texture	20
3-1	Profile Coordinate System	23
3-2	Conical Stylus Tip	23
3-3	Other Stylus Tip Geometries	24
3-4	Aliasing	26
4-1	Schematic Diagrams of a Typical Stylus Probe and Fringe-Field Capacitance Probe	30
4-2	Effects of Various Cutoff Values	31
4-3	Examples of Profile Distortion Due to Skid Motion	33
4-4	Examples of Profile Distortion	33
7-1	The Radius of Curvature for a Surface Sine Wave	37
7-2	Stylus Tip Touching Bottom and Shoulders of Groove	38
7-3	The Stylus Tip Contact Distance, x	38
8-1	A Typical Phase Measuring Interferometer System	42
8-2	Demonstration of the Detector Array With Element Spacing Δ and the Measurement of the Longest Spatial Wavelength, λL Covering the Total Number (N) Pixels	42
8-3	Demonstration of the Detector Array With Element Spacing Δ and the Measurement of the Smallest Spatial Wavelength, λR Covering Five Pixels	43
9-1	Wavelength Transmission Characteristics for the 2RC Filter System	46
9-2	Gaussian Transmission Characteristics Together With the Uncertain Nominal Transmission Characteristic of a 2 μm Stylus Radius	47
9-3	Weighting Function of the Gaussian Profile Filter	47
9-4	Gaussian Transmission Characteristic for the Waviness Short-Wavelength Cutoff (λ_{sw}) or for Deriving the Roughness Mean Line Having Cutoff Wavelengths (λ_c) of 0.08 mm, 0.25 mm, 0.8 mm, 2.5 mm, and 8.0 mm	50
9-5	Gaussian Transmission Characteristic for the Roughness Long- Wavelength Cutoff Having Cutoff Wavelengths $\lambda_c = 0.08$ mm, 0.25 mm, 0.8 mm, 2.5 mm, and 8.0 mm	51
9-6	Example of a Deviation Curve of an Implemented Filter From the Ideal Gaussian Filter as a Function of Spatial Wavelength	51
10-1	Self-Similarity Illustrated on a Simulated Profile	54
10-2	An Idealized Log-Log Plot of Relative Length (of a Profile) or Relative Area (of a Surface) Versus the Scale of Observation	54

10-3	An Idealized Log-Log Plot of Relative Length or Area Versus the Scale of Observation (Length-Scale or Area-Scale Plot), Showing Multi-Fractal Characteristics and Crossover Scales	55
10-4	Three Stepping Exercises From a Length-Scale Analysis on a Simulated Profile	57
10-5	Four Tiling Exercises From an Area-Scale Analysis	57
10-6	An Area-Scale Plot Including the Results of the Tiling Series in Fig. 10-5	58
11-1	Type A1 Groove	61
11-2	Type A2 Groove	61
11-3	Allowable Waviness Height Wt for Roughness Calibration Specimens	62
11-4	Assessment of Calibrated Values for Type A1	63
11-5	Type B1 Grooves: Set of Four Grooves	64
11-6	Type B2 or C2 Specimens With Multiple Grooves	64
11-7	Use of Type B3 Specimen	65
11-8	Type C1 Grooves	65
11-9	Type C3 Grooves	66
11-10	Type C4 Grooves	66
11-11	Unidirectional Irregular Groove Specimen Having Profile Repetition at $5\lambda_c$ Intervals (Type D1 With $\lambda_c = 0.8$ mm)	67

Tables

3-1	Cutoff Values for Periodic Profiles Using RSm	27
3-2	Cutoff Values for Nonperiodic Profiles Using Ra	28
4-1	Measurement Cutoffs and Traversing Lengths for Continuously Averaging Instruments Using Analog Meter Readouts	30
4-2	Measurement Cutoffs and Minimum Evaluation Lengths for Instruments Measuring Integrated Roughness Values Over a Fixed Evaluation Length	30
9-1	Limits for the Transmission Characteristics for 2RC Long-Wavelength Cutoff Filters	49
9-2	Typical Cutoffs for Gaussian Filters and Associated Cutoff Ratios	52
9-3	Typical Values for the Waviness Long-Wavelength Cutoff (λ_{cw}) and Recommended Minimum Values for the Waviness Traversing Length	52
10-1	Example of a Report on Fractal Analysis	58
11-1	Nominal Values of Depth or Height and Examples of Width for Type A1	62
11-2	Nominal Values of Depth and Radius for Type A2	63
11-3	Tolerances and Uncertainties for Types A1 and A2	63
11-4	Tip Size Estimation From the Profile Graph for Type B1	64
11-5	Typical Ra and RSm Values for Type C1	65
11-6	Tolerances and Uncertainties for Types C1 Through C4	65
11-7	Typical Values of Ra and RSm for Type C2	66
11-8	Typical Values of Ra for Type C4	66
11-9	Tolerances and Uncertainties for Types D1 and D2	67
12-1	Nominal Roughness Grades (Ra) for Roughness Comparison Specimens	68
12-2	Form and Lay of Roughness Comparison Specimens Representing Various Types of Machined Surfaces	69
12-3	Examples of Sampling Lengths for Calibration of Comparison Specimens, mm	70

Nonmandatory Appendices

A	General Notes on Use and Interpretation of Data Produced by Stylus Instruments	71
B	Control and Production of Surface Texture	73
C	A Review of Additional Surface Measurement Methods	76
D	Additional Parameters for Surface Characterization	83
E	Characteristics of Certain Area Profiling Methods	86

F	Descriptions of Area Averaging Methods	93
G	Observations on the Filtering of Surface Profiles	96
H	Reference Subroutines	97
I	A Comparison of ASME and ISO Surface Texture Parameters	105
J	Functional Standards	107