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Geometrical product specifications (GPS) — Surface texture: Areal —

Part 6: **Classification of methods for measuring surface texture**

Spécification géométrique des produits (GPS) — État de surface: Surfacique —

Partie 6: Classification des méthodes de mesurage de l'état de surface

Reference number
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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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ISO 25178-6 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 25178 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Surface texture: Areal*:

— *Part 2: Terms, definitions and surface texture parameters*

— *Part 3: Specification operators*

— *Part 6: Classification of methods for measuring surface texture*

— *Part 7: Software measurement standards*

— *Part 601: Nominal characteristics of contact (stylus) instruments*

— *Part 602: Nominal characteristics of non-contact (confocal chromatic probe) instruments*

— *Part 603: Nominal characteristics of non-contact (phase-shifting interferometric microscopy) instruments*

— *Part 701: Calibration and measurement standards for contact (stylus) instruments*

The following parts are under preparation:

— *Part 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments*

— *Part 605: Nominal characteristics of non-contact (point autofocusing) instruments*

Introduction

This part of ISO 25178 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638[2]). It influences the chain link 5 of the chain of standards on roughness profile, waviness profile, primary profile and areal surface texture.

This part of ISO 25178 describes a classification system for methods used primarily for the measurement of surface texture. The classification system provides a context for the development of other parts of ISO 25178 that describe characteristics and measurement standards for some of the individual methods. Such a classification is also intended to aid in choosing and understanding various types of methods and in determining which standards apply to their application. The classification system is aimed to be as general as possible. However, instruments may exist that do not clearly fit within any single method class.

Geometrical product specifications (GPS) — Surface texture: Areal —

Part 6: Classification of methods for measuring surface texture

1 Scope

This part of ISO 25178 describes a classification system for methods used primarily for the measurement of surface texture. It defines three classes of methods, illustrates the relationships between the classes, and briefly describes specific methods.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 25178-2:—[1], *Geometrical product specifications (GPS) — Surface texture: Areal — Part 2: Terms, definitions and surface texture parameters*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

3.1 General terms

For the purposes of this document, the terms and definitions given in ISO 4287, ISO 25178-2, ISO/IEC Guide 99 and the following apply.

3.1.1
measurement coordinate system
system of coordinates in which surface texture parameters are measured

NOTE 1 If the nominal surface is a plane (or portion of a plane), it is usual to use a rectangular coordinate system in which the axes form a right-handed Cartesian set, the X-axis being the direction of tracing co-linear with the mean line and the Y-axis also lying on the nominal surface, and the Z-axis being in an outward direction (from the material to the surrounding medium). The rectangular coordinate system is adopted in this part of ISO 25178 except for 3.2.1, Note 3, and 3.3.3, where a cylindrical coordinate system is described.

NOTE 2 See also *specification coordinate system* [ISO 25178-2:—].

1) To be published.

3.1.2
surface profile
profile that results from the intersection of the real surface by a specified plane

NOTE In practice, it is usual to choose a plane with a normal that nominally lies parallel to the real surface and in a suitable direction.

[ISO 4287:1997, definition 3.1.4]

3.1.3
ordinate value
$z(x, y)$
height of the surface at position (x, y)

3.2 Definitions for classification of surface texture measurement methods

3.2.1
line-profiling method
surface topography measurement method that produces a two-dimensional graph or profile of the surface irregularities as measurement data, which may be represented mathematically as a height function $z(x)$

NOTE 1 By contrast, **areal-topography** (3.2.2) and **area-integrating** (3.2.3) methods are used to quantify the surface texture over a selected area of a surface instead of over single profiles.

NOTE 2 Examples of instruments that were developed specifically to measure line profiles include contact stylus scanning[1], early versions of the phase-shifting interferometer[3], and the optical differential profiler[4][5].

NOTE 3 Certain methods have rotational scanning within a cylindrical coordinate system and measure circular profiles, that is, z as a function of angle θ. One example is the circular interferometric profiler[6].

3.2.2
areal-topography method
surface measurement method that produces a topographical image of a surface, which may be represented mathematically as a height function $z(x, y)$ of two independent variables (x, y)

NOTE 1 Examples of methods that have been developed or adapted for areal-topography measurements include contact stylus scanning[7], phase-shifting interferometric microscopy[8], coherence scanning interferometry[9][10], confocal microscopy[11], confocal chromatic microscopy[12], structured light projection[13][14] (including triangulation), focus variation microscopy[15], optical differential profiler[4][5], digital holography microscopy[16], point autofocus profiling[17][18], angle-resolved scanning electron microscopy (SEM)[19][20], SEM stereoscopy[21][22], scanning tunnelling microscopy[23], and atomic force microscopy[24][25]. The areal measurement capability of these methods is often derived from a set of parallel profiles scanned sequentially or from manipulation of 2D images in microscope cameras. All of these methods may also be used to produce line-profiling results as well.

NOTE 2 For methods that form a surface topography image $z(x, y)$ from sequential profiles such as a set of parallel profiles $z(x)$, care should be taken to ascertain the accuracy of measurement along the slow axis $z(y)$. Although $z(x, y)$ topographic images may be displayed for an areal texture method, in some cases the method may not actually be sensitive to $z(y)$ topography changes, or the accuracy of $z(y)$ profiling may be limited by the drift of the instrument.

3.2.3
area-integrating method
surface measurement method that measures a representative area of a surface and produces numerical results that depend on area-integrated properties of the surface texture

NOTE 1 These methods do not produce line-profile data $z(x)$ or areal-topography data $z(x, y)$.

NOTE 2 Examples of instruments that have been developed as area-integrating methods include those that use the techniques of total integrated light scatter[26], angle-resolved light scatter[27], parallel-plate capacitance[28] and pneumatic (flow) measurement[29].

NOTE 3 Area-integrating methods have been used in conjunction with calibrated roughness comparison specimens or calibrated pilot specimens as comparators to distinguish the surface texture of parts manufactured by similar processes or to perform repetitive surface texture assessments.

3.3 Terms and descriptions for specific methods

3.3.1
contact stylus scanning
surface topography measurement method whereby the probing system uses a contacting stylus whose motion is converted into a signal as a function of position

NOTE See ISO 25178-601 for more information.

3.3.2
phase-shifting interferometric microscopy
PSI
surface topography measurement method whereby an optical microscope with illumination of a known effective wavelength is integrated with an interferometric attachment and produces multiple successive optical images with interferometric fringes from which the profile or areal surface topography image is calculated

NOTE 1 Bands of light and dark interferometric fringes are produced in images when two or more mutually coherent optical beams are combined.

NOTE 2 See ISO 25178-603 for more information.

3.3.3
circular interferometric profiling
surface profiling method whereby the local surface height is sensed with an interferometric probe having a scanned beam on the circumference of a circle and the reference beam at the centre, thus generating a circular profile $z(\theta)$ within a cylindrical coordinate system rather than a line profile or areal-topography image

3.3.4
optical differential profiling
surface topography measurement method whereby height differences between two closely spaced points on a surface are measured in close succession along the direction of traverse and a surface profile is obtained by integration of these local height differences

NOTE Also called “Nomarski differential profiling”.

3.3.5
coherence scanning interferometry
CSI
surface topography measurement method wherein the localization of interference fringes during a scan of optical path length provides a means to determine a surface topography map

NOTE A variation of this technique, known as optical coherence tomography[30], is widely used for three-dimensional imaging through transparent materials, particularly for medical and biological applications.

3.3.6
confocal microscopy
surface topography measurement method whereby a pinhole object illuminated by the light source is imaged by a lens onto the surface being studied and the light is reflected back through the lens to a second pinhole placed in front of a detector and acting as a spatial filter

NOTE See ISO 25178-602 for more information.

3.3.7
confocal chromatic microscopy
surface topography measurement method consisting of a confocal microscope with chromatic objective integrated with a detection device (e.g. spectrometer) whereby the surface height at a single point is sensed by the wavelength of light reflected from the surface

NOTE See ISO 25178-602 for more information.

3.3.8
structured light projection
surface topography measurement method whereby a light image with a known structure or pattern is projected on a surface and the pattern of reflected light together with knowledge of the incident structured light allows one to determine the surface topography

NOTE When the structured light is a single focused spot or a fine line, the technique may be known as triangulation.

3.3.9
focus variation microscopy
surface topography measurement method whereby the sharpness of the surface image (or another property of the reflected light at optimum focus) in an optical microscope is used to determine the surface height at each position along the surface

3.3.10
digital holography microscopy
DHM
surface topography measurement method whereby a conventional hologram resulting from the interference between a reference wave and an object wave reflected by a surface is recorded and processed digitally to reproduce the surface topography

NOTE DHM differs from carrier frequency methods[31] by the fact that DHM enables propagation of the field and yields an extended depth of field in the processed surface image. The carrier frequency method is primarily used for measurement of form rather than roughness.

3.3.11
point autofocus profiling
surface topography measurement method whereby the local surface height is measured by automatically centring a focused light beam reflected from the sample on a position sensitive detector as a function of surface height

3.3.12
angle-resolved scanning electron microscopy
SEM
surface topography measurement method whereby local gradients of a surface are determined by angular distributions of reflection or secondary electron emission intensity and an areal-topography image is obtained by integration of these local gradients

3.3.13
SEM stereoscopy
surface topography measurement method whereby two (or sometimes more) scanning electron microscopy (SEM) images are taken of a surface oriented at slightly different angles and the comparison of the two images yields a stereo effect, which allows the determination of surface topography

3.3.14
scanning tunnelling microscopy
STM
surface topography measurement method whereby the determination of surface height arises from the height-related variations in the electrical tunnelling current produced between a conducting surface and a conducting tip placed very close to it, with a constant voltage maintained between them

3.3.15
atomic force microscopy
AFM
scanning force microscopy
SFM
surface topography measurement method whereby the surface height is sensed from the mechanical force of attraction or repulsion between a probe tip and a surface

NOTE STM and AFM (or SFM) are two methods that can also be classified as methods of scanned probe microscopy (SPM). SPM also encompasses near-field scanning optical microscopy (NSOM/SNOM), scanning capacitance microscopy (SCM) and others. The development of certain standards related to these techniques falls under the scope of ISO TC 201, SC 9, *Scanning probe microscopy*.

3.3.16
total integrated scatter
surface area-integrating method whereby the light scattered from the surface is collected over a wide range of angles and used to calculate rms (root-mean-square) surface roughness

3.3.17
angle-resolved scatter
surface area-integrating method whereby the light scattered from the surface is collected as a function of incident angle or scattered angle or both and the measured function may be used to calculate rms (root-mean-square) roughness, power spectral density and other roughness parameters

3.3.18
parallel-plate capacitance method
surface area-integrating method whereby a capacitance plate rests on a conducting surface with insulating material between them and the resulting capacitance between the two elements is used to calculate a roughness-dependent parameter

3.3.19
pneumatic measuring system
surface area-integrating method whereby gas is made to flow over a rough surface and the resistance to the flow (or a related quantity) is used to calculate a roughness-dependent parameter

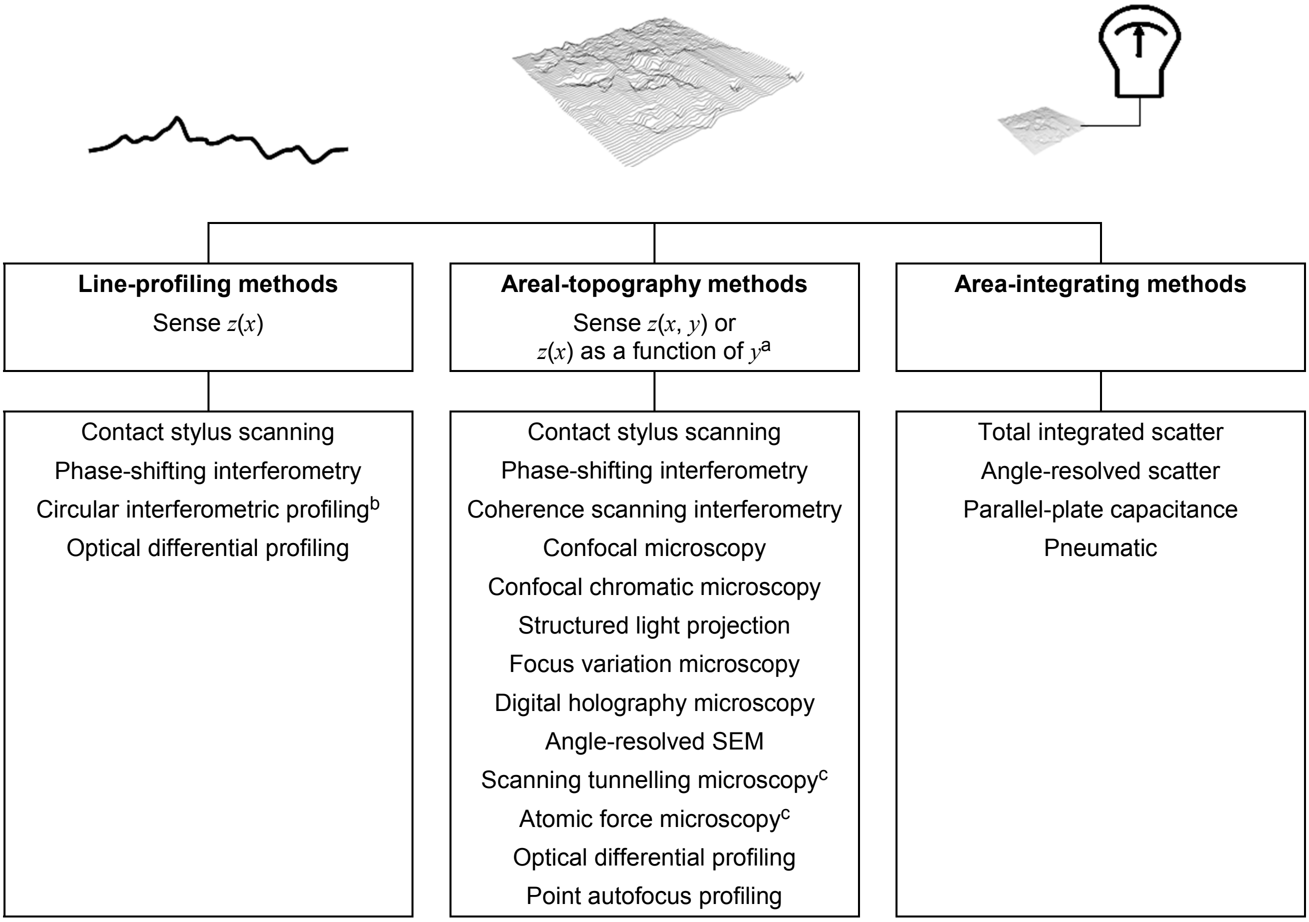
4 Classification scheme

As shown in Figure 1, methods for measuring surface texture may be divided into three general classes: line-profiling methods, areal-topography methods and area-integrating methods.

Line-profiling methods produce topographic profiles $z(x)$. Areal-topography methods produce topographic images $z(x, y)$. Often, the height function $z(x, y)$ is developed by juxtaposing a set of parallel profiles (see Figure 2). The height function customarily represents the point-by-point deviations between the measured topography and the mean surface.

The topography data can be used to calculate a variety of surface texture parameters. However, the measured values of parameters depend on details of the method used for the measurement. Areal-topography methods may be used to measure surface parameters provided that the spatial resolution and the sampling length in each direction (or alternatively the sampling area) are indicated for each measurement. In addition, it is important to determine the uncertainty of the measured coordinates x, y and z. One important issue is whether the instrument detects height differences between profiles spaced along the Y-direction and, if so, whether it routinely filters away those differences (see also 3.2.2, Note 2). Another issue is the accuracy of any lateral scanning system and the resulting accuracy of the X- or Y-coordinates.

Surface metrology methods are subject to a number of limitations, which the user should be aware of. Some important limitations are described in Annex A.



[a] The accuracy of $z(y)$ profiling depends on the method and should be ascertained for each method.

[b] This technique relies on circular scanning to produce a $z(\theta)$ profile.

[c] STM and AFM are methods that are often classified as scanned probe microscopies (SPM). Other SPM techniques, such as near-field scanning optical microscopy (NSOM/SNOM) or scanning capacitance microscopy (SCM), might also be developed or adapted to surface topography measurement.

The icons illustrate the types of data produced by each class of method.

Figure 1 — A classification of surface texture measurement methods with examples

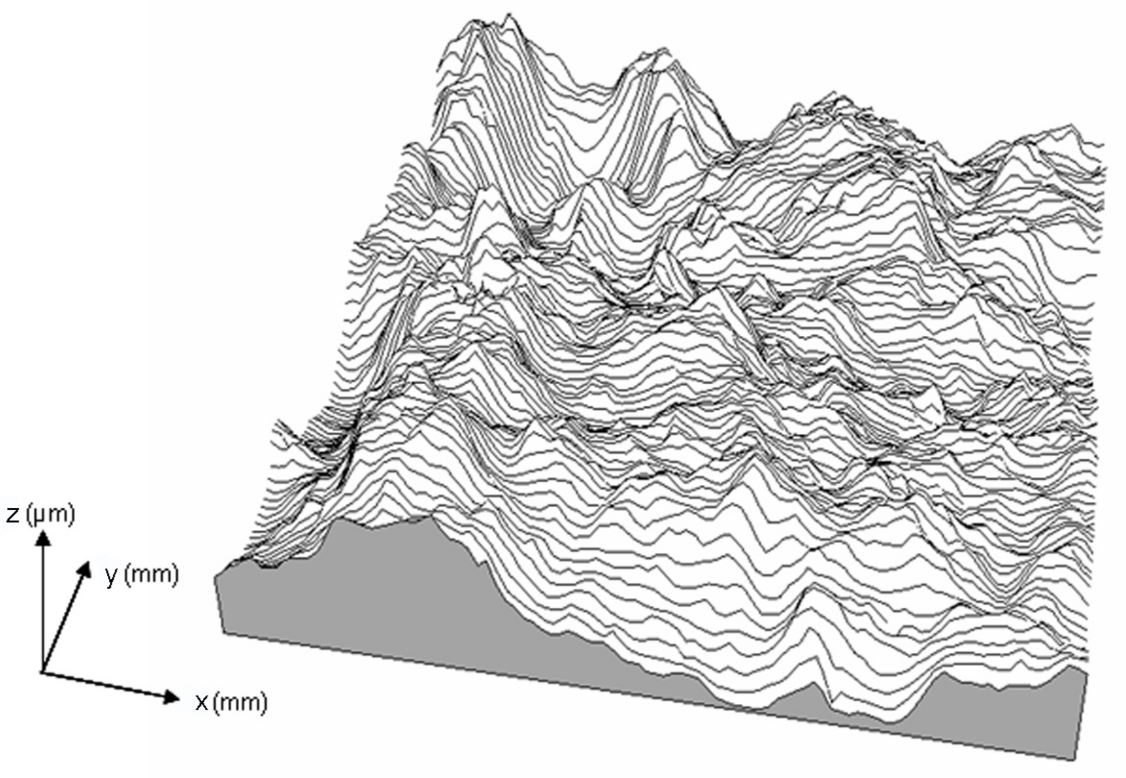


Figure 2 — Example of a topographic image obtained by an areal-topography method, plotted as a series of parallel profiles $z(x)$

Annex A
(informative)

Metrological limitations

A.1 Surface homogeneity

Each method described in 3.3 involves an interaction between a probe and the surface and therefore relies on the homogeneity of the sensed surface property in order to provide an accurate measurement of surface topography. Otherwise, variations in the surface material properties can lead to false, apparent variations in the measured surface topography. Optical methods may be affected by variations in optical properties over the surface; contacting methods, such as the stylus and the atomic force microscope, may be affected by variations in elasticity; and the scanning tunnelling microscope may be affected by variations in electrical conductivity. Therefore, it is important to take these properties into account when performing surface topography measurements with any method.

A.2 Range and resolution

Each method described in 3.3 has limitations of range and resolution in both the lateral and vertical directions. It is important for the user to understand the range and resolution limitations of the instrument being used. These quantities should be described in the manufacturer’s manuals and literature.

In general,

— the lateral (spatial) resolution is usually limited by the spatial resolution of the sensor, such as the diffraction limit of an optical microscope or the size of a probe tip on a contact mechanical profiler, or sometimes by the short wavelength cut-off or nesting index of a smoothing filter, applied in topography analysis according to accepted specifications, such as ISO 16610[32];

— the lateral range is limited by the length of profile or size of area measured;

— the vertical resolution is often limited by the noise of the measuring instrument [see *discrimination threshold* (ISO/IEC Guide 99:2007, 4.16)];

— the vertical range is often limited by the length of travel in the vertical direction.

Therefore, both resolution limits are often determined by the quality of the interaction sensor, whereas both ranges are often determined by the quality of the displacement devices used to perform vertical and lateral displacement of the probe. Range and resolution are important characteristics for areal-topography instruments and are reviewed in a number of places[33][34][35].

A.3 Slope measurement

Surface texture methods often have limits for measuring steeply sloped surfaces. Stylus methods and atomic force microscopes, for example, are limited by the shank angle of the probe tip. For several types of optical microscopes, the limits for measurement of steep slopes are related to the numerical aperture of the objective.

Annex B
(informative)

Relation to the GPS matrix model

B.1 General

For full details about the GPS matrix model, see ISO/TR 14638.

B.2 Position in the GPS matrix model

This part of ISO 25178 is a general GPS standard, which influences chain link 5 of the chains of standards on areal surface texture in the general GPS matrix, as illustrated in Figure B.1.

Fundamental GPS standards

Global GPS standards

General GPS standards						
Chain link number	**1**	**2**	**3**	**4**	**5**	**6**
Size						
Distance						
Radius						
Angle						
Form of a line independent of datum						
Form of a line dependent on datum						
Form of a surface independent of datum						
Form of a surface dependent on datum						
Orientation						
Location						
Circular run-out						
Total run-out						
Datums						
Roughness profile					X	
Waviness profile					X	
Primary profile					X	
Surface imperfections						
Edges						
Areal surface texture					X	

Figure B.1 — Position in the GPS matrix model

B.3 Related International Standards

The related International Standards are those of the chains of standards indicated in Figure B.1.

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[2] ISO/TR 14638, *Geometrical product specification (GPS) — Masterplan*

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