INTERNATIONAL STANDARD

ISO 12780-2

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Geometrical product specifications (GPS) — Straightness —

Part 2: Specification operators

Spécification géométrique des produits (GPS) — Rectitude —

Partie 2: Opérateurs de spécification

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12780-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This first edition of ISO 12780-2 cancels and replaces ISO/TS 12780-2:2003, which has been technically revised.

ISO 12780 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Straightness*:

— *Part 1: Vocabulary and parameters of straightness*

— *Part 2: Specification operators*

Introduction

This part of ISO 12780 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 3 of the chain of standards on form of line independent of datum.

The ISO/GPS Masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

For more detailed information on the relationship of this part of ISO 12780 to other standards and the GPS matrix model, see Annex B.

This part of ISO 12780 specifies the specification operators according to ISO 17450-2 for straightness of integral features.

This part of ISO 12780 does not specify defaults for filter cut-off, probe tip radius and method of association (reference line). This means that it is necessary for a straightness specification to explicitly state which values are to be used for these specification operations in order for it to be unique.

Consequently, if a specification does not explicitly state which values are to be used for one or more of these operators, the specification is ambiguous (see ISO 17450-2) and a supplier can use any value for the operator(s) not specified when proving conformance.

Extracting data always involves applying a certain filtering process. An additional filtering of the extracted data might or might not be applied. This additional filter can be a mean line filter (Gaussian, spline, wavelet, etc.) or a non-linear filter (e.g. morphological filter). The type of filtering influences the definition of straightness and the specification operators and, therefore, needs to be stated unambiguously.

NOTE 1 Stylus filtering is not sufficient on its own to smooth a profile. In certain circumstances, it can create spurious high-frequency content, thus giving incorrect values. To correct this, a longwave-pass filter can be employed. A Gaussian filter is used, since this is the state-of-the-art. This filter has some shortcomings, e.g. it can distort rather than eliminate some roughness features and it can distort rather than transmit correctly some waviness features. It is envisioned that new filters under development within ISO provide better solutions for several of these issues.

NOTE 2 If a smaller tip radius than the one specified is used for a given cut-off length, the resulting measured value is generally higher. This effect is usually insignificant. If a larger tip radius is used, the resulting measured value is generally lower. The amount of change is heavily dependent on the surface measured.

NOTE 3 The measuring force of 0 N is chosen to eliminate effects of elastic deformation of the workpiece from the specification operator. On metal surfaces with adequate thickness, the effect of normally occurring measuring forces is negligible.

NOTE 4 Aliasing and other problems during extraction (see Annex A), due to the higher harmonic content of the skin model, in the straightness directions, can cause specification uncertainty.

This part of ISO 12780 is not intended to disallow any means of measuring straightness.

Geometrical product specifications (GPS) — Straightness —

Part 2:
Specification operators

1 Scope

This part of ISO 12780 specifies the complete specification operator for straightness of integral features only and covers complete straightness profiles only, i.e. geometrical characteristics of features of type line.

NOTE Straightness of an extracted median line of a cylinder is defined in ISO 12180-1.

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 11562:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters*

ISO 12780-1:2011, *Geometrical product specifications (GPS) — Straightness — Part 1: Vocabulary and parameters of straightness*

ISO 14253-1:1998, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications*

ISO 17450-2:—[1)], *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators and uncertainties*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12780-1 and ISO 17450-2 apply.

4 Complete specification operator

4.1 General

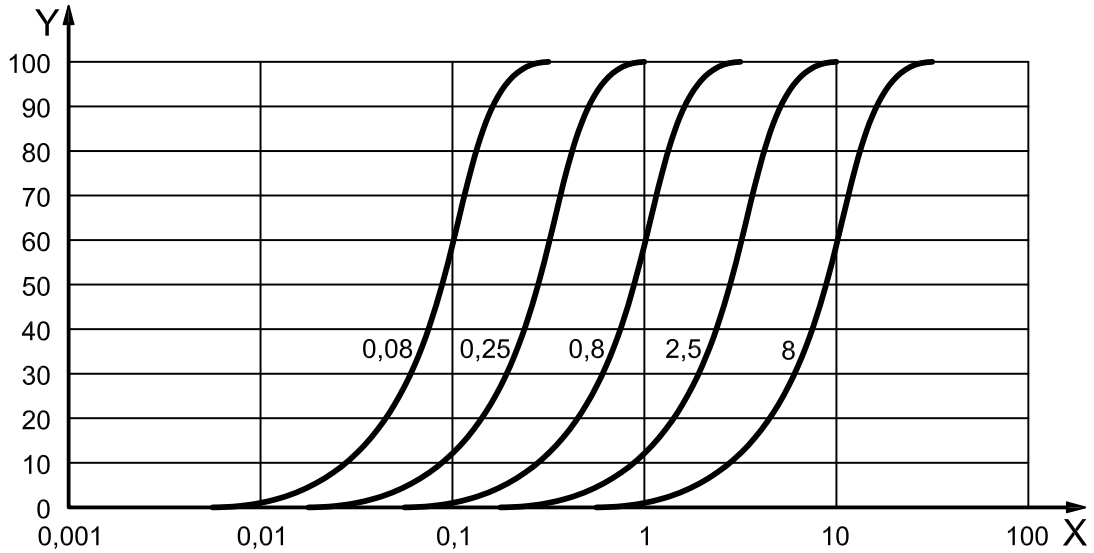
The complete specification operator (see ISO 17450-2) is a full ordered set of unambiguous specification operations in a well-defined order. The complete specification operator defines the transmission band for the straightness profile, together with an appropriate stylus tip geometry.

1) To be published. (Revision of ISO/TS 17450-2:2002)

4.2 Transmission band

4.2.1 Longwave-pass filter

The longwave-pass filter shall be a phase correct filter (according to ISO 11562) transmitting waves of infinite length and attenuating profile undulations progressively in the undulation region around the cut-off length (see Figure 1).



Key

X wavelength, in millimetres

Y transmission, as a percentage

NOTE Other filter values than those shown in this figure can be used, if necessary for the application.

Figure 1 — Transmission characteristic for longwave-pass filter having cut-off lengths
λ_c = 0,08 mm; 0,25 mm; 0,8 mm; 2,5 mm; 8 mm

The attenuation function is given by:

$$\frac{a_1}{a_0} = e^{-\pi\left(\frac{\alpha\times\lambda_c}{\lambda}\right)^2}$$

where

$$\alpha = \sqrt{\frac{\ln(2)}{\pi}} = 0{,}469\,7$$

a_0 is the amplitude of sine wave undulation before filtering;

a_1 is the amplitude of this sine wave undulation after filtering;

λ_c is the cut-off length of the longwave-pass filter;

λ is the wavelength of the sine wave.

4.2.2 Cut-off wavelengths

The profile filter determines the range of periodic sinusoidal undulations of the feature included in the straightness assessment. The range is terminated by values taken from Table 1. Table 1 also gives the maximum sample point spacing that shall be used for the extracted line and the stylus tip radius needed to avoid distortion of the straightness profile from the influence of the stylus tip.

Table 1 — Cut-off values

Dimensions in millimetres

Longwave-pass filters		
Filter transmitting from infinite wavelength down to	**Maximum sample point spacing**	**Maximum stylus tip radius**[a] R
8	1,14	5
2,5	0,357	1,5
0,8	0,114	0,5
0,25	0,035 7	0,15
0,08	0,011 4	0,05

[a] When the maximum stylus tip radius requirement is fulfilled, the radius of the stylus tip is of comparable size to the wavelength of the shortest undulations transmitted by the profile filter. This is consistent with the stylus tip radius requirements for surface texture measuring instruments (see ISO 3274).

NOTE 1 The required number of points corresponds to seven sample points for each cut-off, which is the minimum number of points to be assessed.

NOTE 2 If a longer or shorter cut-off value than those given in Table 1 is used, then the applicable maximum sample point spacing and maximum stylus tip radius can be calculated from the ratios in Table 1.

4.3 Probing system

4.3.1 Probing method

A contacting probing system with a stylus tip, as defined in 4.3.2, is part of the specification operator.

4.3.2 Stylus tip geometry

The theoretically exact stylus tip geometry is a sphere.

4.3.3 Probing force

The probing force is 0 N.

5 Compliance with specification

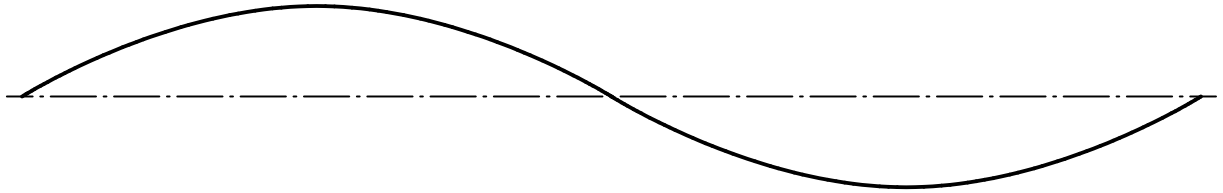
For proving conformance or non-conformance with specification, ISO 14253-1 applies.

Annex A
(informative)

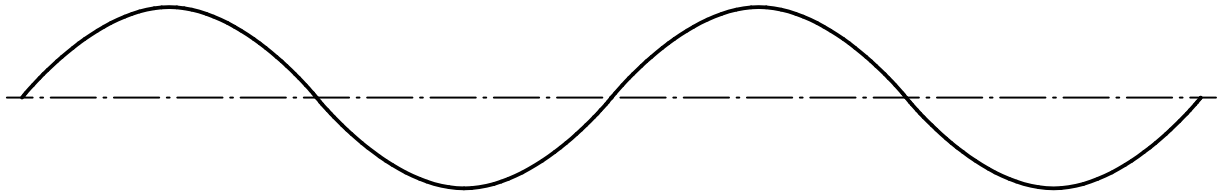
Harmonic content of a nominally straight workpiece

A.1 Harmonic content

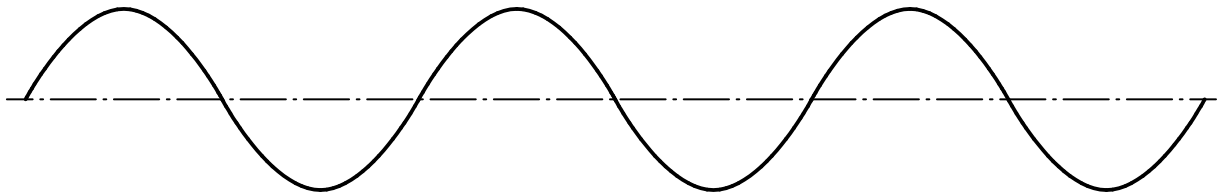
A finite length signal can be decomposed into a number of sinusoidal components called a Fourier series. A Fourier series consists of a fundamental sinusoid whose wavelength is the length of the signal and harmonic sinusoids, whose wavelengths divide into the fundamental wavelength a whole number of times. The fundamental sinusoid is called the first harmonic of the signal. The sinusoid whose wavelength is half the fundamental wavelength is called the second harmonic. The sinusoid whose wavelength is one third the fundamental wavelength is called the third harmonic, etc. (see Figure A.1). Thus, the nth harmonic is that sinusoid whose wavelength divides into the fundamental wavelength exactly n times. A straightness profile can be decomposed into its harmonic components in this manner.



a) First harmonic



b) Second harmonic



c) Third harmonic

Figure A.1 — First three harmonics of a signal

A.2 Aliasing and the Nyquist criterion

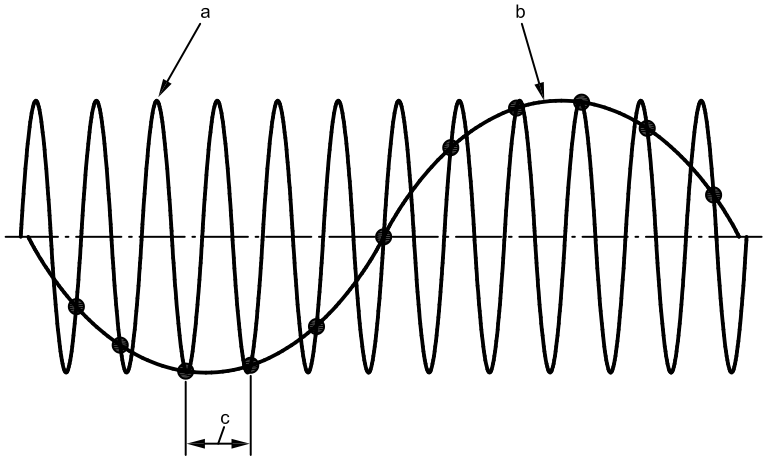
Recording digital data from a signal involves sampling that signal. The separation of the sampling points (the sampling interval) shall be chosen such that the digitized signal is representative of the original signal for the method by which the signal is being analysed.

If the original signal is bandwidth limited, in that there is a shortest wavelength present (highest harmonic) in the signal, then the Nyquist theorem imposes a limitation on the maximum sampling interval possible. The Nyquist theorem states:

> *If it is known that an infinitely long signal contains no wavelengths shorter than a specified wavelength, then the signal can be reconstructed from the values of the signal at regularly spaced intervals provided that the interval is smaller than half of the specified wavelength.*

In principle, the Nyquist theorem only applies to infinitely long signals. In practice, the Nyquist criterion of sampling less than half of the shortest wavelength present is still useful even though signals are finite in length.

If a longer sampling interval than the Nyquist criterion is specified, the digitized signal suffers from aliasing distortion. Aliasing is when a short wavelength sinusoid appears to be a longer wave sinusoid due to the sampling interval being too large to define the true shape of the signal (see Figure A.2). Thus, if too large a sampling interval is chosen, the higher harmonics appear to be lower harmonics and distort any subsequent analysis.



a True signal.

b Alias signal.

c Sampling interval.

NOTE The sampling interval is too large to define the true shape of the signal.

Figure A.2 — Aliasing

In practice, many measuring instruments impose an artificial band limitation on the signal to overcome the problem of aliasing. There are many ways to achieve this artificial band limitation. Three common approaches are using the “natural” band limitation of the probe, analogue filters and digital filters or any combination of these. Usually, it is a combination of all three. Once the signal has a band limitation, the Nyquist criterion can be used to impose a theoretical maximum sampling interval as follows:

> *Assuming all wavelengths less than the 0,02 % point of the Gaussian filter transmission curve can be ignored, then by applying the Nyquist theorem, at least seven sampling points per cut-off are required. This represents the theoretical minimum number of sampling points per cut-off.*

Annex B
(informative)

Relationship to the GPS matrix model

B.1 General

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

The ISO/GPS Masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

B.2 Information about this part of ISO 12780 and its use

This part of ISO 12780 specifies the complete specification operator for straightness, i.e. geometrical characteristics of features of type line.

B.3 Position in the GPS matrix model

This part of ISO 12780 is a general GPS standard, which influences chain link 3 of the chain of standards on form of line independent of datum in the general GPS matrix, as graphically 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 line independent of datum						
	Form of line dependent on datum						
	Form of surface independent of datum						
	Form of surface dependent on datum						
	Orientation						
	Location						
	Circular run-out						
	Total run-out						
	Datums						
	Roughness profile						
	Waviness profile						
	Primary profile						
	Surface defects						
	Edges						

Figure B.1 — Position in the GPS matrix model

B.4 Related International Standards

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

Bibliography

[1] ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

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

[3] ISO 4288, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

[4] ISO 8015, *Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules*

[5] ISO 10360-1, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

[6] ISO 12180-1, *Geometrical product specifications (GPS) — Cylindricity — Part 1: Vocabulary and parameters of cylindrical form*

[7] ISO 12180-2, *Geometrical product specifications (GPS) — Cylindricity — Part 2: Specification operators*

[8] ISO/TR 14638, *Geometrical product specifications (GPS) — Masterplan*

[9] ISO 14660-1, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

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