TECHNICAL SPECIFICATION

ISO/TS 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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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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

ISO/TS 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/TS 12780 is a geometrical product specification (GPS) Technical Specification 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.

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

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

At the current state of development, ISO/TC 213 has not been able to reach a consensus on defaults for filter cut-off, probe tip radius and method of association (reference line). This means that a straightness specification must 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 uncertain (see ISO/TS 17450-2) and a supplier can use any value for the operator(s) not specified when proving conformance.

Extracting data will always involve applying a certain filtering process. An additional filtering of the extracted data may or may 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 will influence 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 is employed. A Gaussian filter is used, since this is the current state-of-the-art in ISO standards. 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 will 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 will generally be higher. This effect is usually insignificant. If a larger tip radius is used, the resulting measured value will generally be 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 will be 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/TS 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/TS 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/TS 12180-1 and ISO/TS 12180-2.

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/TS 12780-1:2003, *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/TS 17450-2:2002, *Geometrical Product Specifications (GPS) — General concepts — Part 2: Basic tenets, specifications operators and uncertainties*

3 Terms and definitions

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

4 Complete specification operator

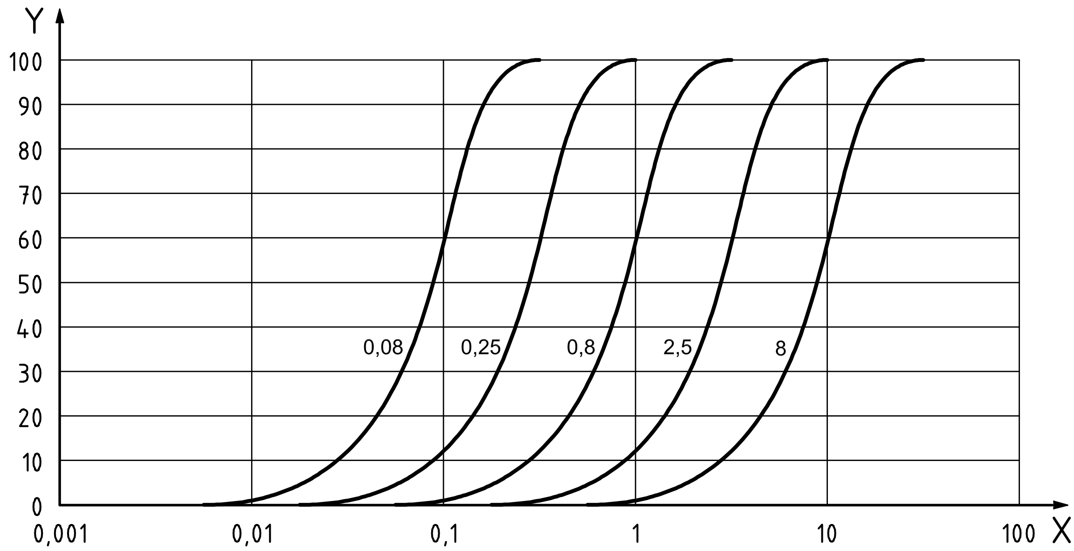
4.1 General

The complete specification operator (see ISO/TS 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.

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, mm

Y transmission, %

NOTE Other filter values than those shown in Figure 1 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 = amplitude of sine wave undulation before filtering;

a_1 = amplitude of this sine wave undulation after filtering;

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

λ = 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 to 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 The required number of points corresponds to 7 sample points for each cut-off, which is the minimum number of points to be assessed.

4.3 Probing system

4.3.1 Probing method

A contacting probing system with a stylus tip 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

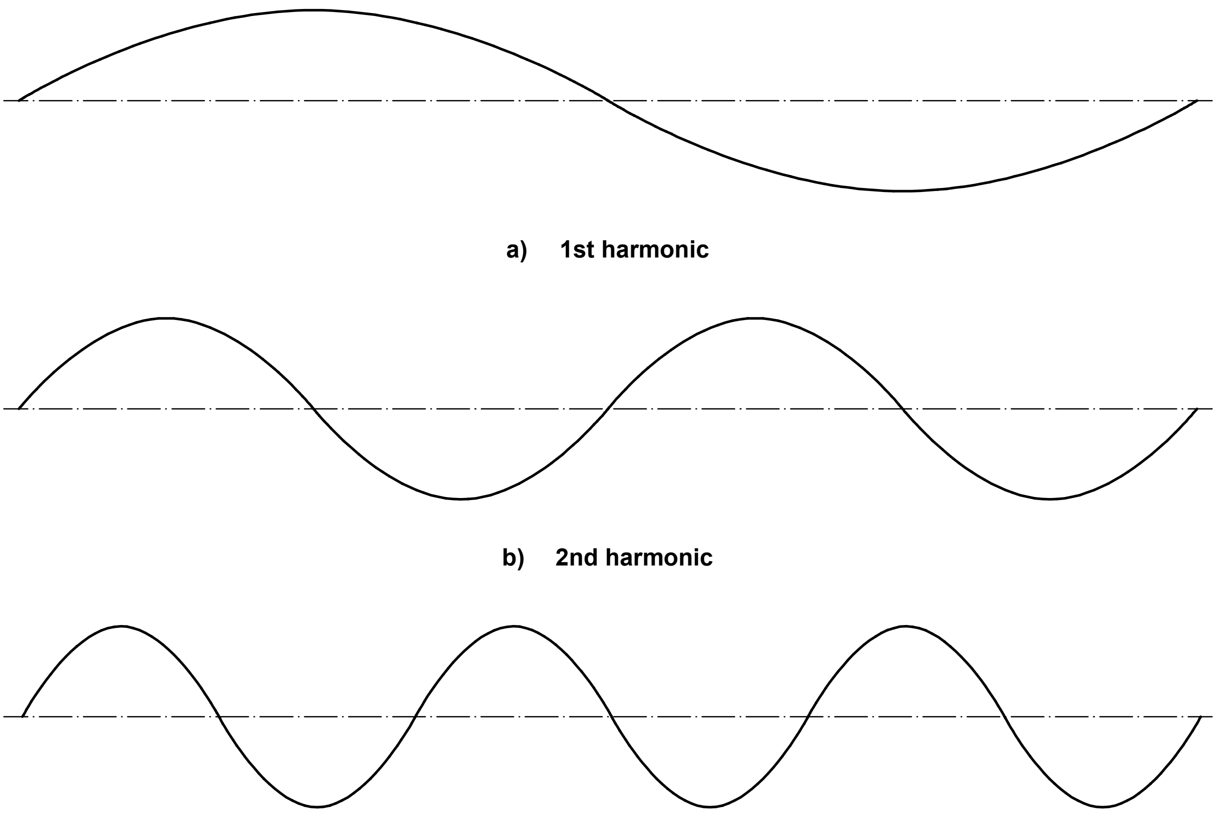
For proving conformance or non-conformance with specification, ISO 14253-1 applies.

Annex A
(informative)

Harmonic content of 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) 1st harmonic

b) 2nd harmonic

c) 3rd harmonic

Figure A.1 —First three harmonics of a signal

A.2 Aliasing and the Nyquist criterion

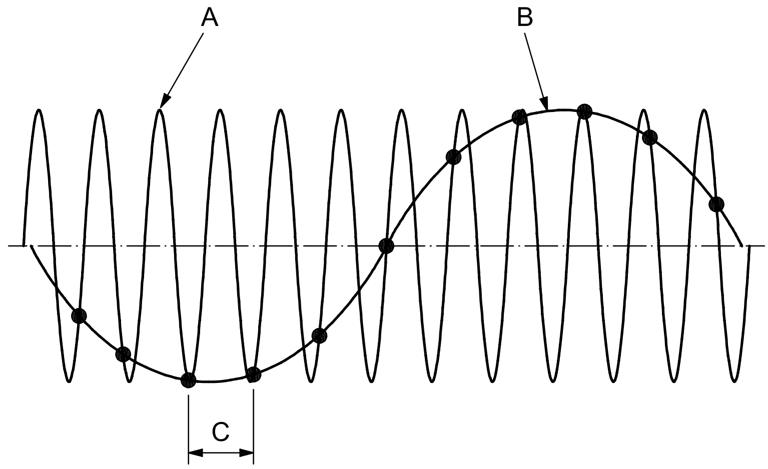
Recording digital data from a signal involves sampling that signal. The separation of the sampling points (the sampling interval) must be chosen so that the digitized signal is representative of the original signal for the method by which the signal will be analysed.

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.*

Strictly, 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 will suffer 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.



Key

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, analog filters and digital filters or any combinations 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:

> *Assume all wavelengths less than the 0,02 % point of the Gaussian filter transmission curve can be ignored, by applying the Nyquist theorem, means at least 7 sampling points per cut-off are required. This represents the theoretical minimum number of sampling points per cut-off.*

Annex B
(informative)

Relation to the GPS matrix model

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

B.1 Information about this part of ISO/TS 12780 and its use

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

B.2 Position in the GPS matrix model

This part of ISO/TS 12780 is a general GPS document, 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 imperfections						
Edges						

Figure B.1

B.3 Related International Standards

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

Bibliography

[1] ISO 3274:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

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

[3] ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the measurement of surface texture*

[4] ISO 10360-1:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

[5] ISO/TS 12180-1:2003, *Geometrical Product Specifications (GPS) — Cylindricity — Part 1: Vocabulary and parameters of cylindrical form*

[6] ISO/TS 12180-2:2003, *Geometrical Product Specifications (GPS) — Cylindricity — Part 2: Specification operators*

[7] ISO/TR 14638:1995, *Geometrical Product Specifications (GPS) — Masterplan*

[8] ISO 14660-1:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

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