INTERNATIONAL STANDARD

ISO 12180-2

First edition
2011-04-01

Geometrical product specifications (GPS) — Cylindricity —

Part 2: Specification operators

Spécification géométrique des produits (GPS) — Cylindricité —

Partie 2: Opérateurs de spécification

Reference number
ISO 12180-2:2011(E)

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

Published in Switzerland

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.

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 12180-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This first edition of ISO 12180-2 cancels and replaces ISO/TS 12180-2:2003, which has been technically revised.

ISO 12180 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Cylindricity*:

— *Part 1: Vocabulary and parameters of cylindrical form*

— *Part 2: Specification operators*

Introduction

This part of ISO 12180 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 a surface (independent of a datum).

The ISO/GPS Masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this part of ISO 12180 is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this part of ISO 12180 and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this part of ISO 12180, unless otherwise indicated.

For more detailed information on the relationship of this part of ISO 12180 to other standards and the GPS matrix model, see Annex C.

This part of ISO 12180 specifies the specification operators according to ISO 17450-2 for cylindricity of integral features.

At the time of publication of this part of ISO 12180, ISO/TC 213 has not been able to reach consensus on defaults for filter undulation per revolution (UPR), probe tip radius and method of association (reference cylinder). This means that it is necessary for a cylindricity specification to explicitly state which values are intended for use with 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 cylindricity 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 state-of-the-art in International 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 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 roundness and straightness directions, can cause specification uncertainty.

This part of ISO 12180 is not intended to disallow any means of measuring cylindricity.

Geometrical product specifications (GPS) — Cylindricity —

Part 2:
Specification operators

1 Scope

This part of ISO 12180 specifies the complete specification operator for cylindricity of complete integral features only, i.e. geometrical characteristics of features of type cylinder.

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 12180-1:2011, *Geometrical product specifications (GPS) — Cylindricity — Part 1: Vocabulary and parameters of cylindrical form*

ISO 12181-1:2011, *Geometrical product specifications (GPS) — Roundness — Part 1: Vocabulary and parameters of roundness*

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 11562, ISO 12180-1, ISO 12181-1, ISO 12780-1 and ISO 17450-2 apply.

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

4 Complete specification operator

4.1 General

The complete specification operator (as defined in 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 cylindricity surface, together with an appropriate stylus tip geometry.

NOTE In practice, it is unrealistic to hope to achieve comprehensive coverage of the cylindrical feature given by the theoretical minimum density of points (see Annex B) within an acceptable time span using available technology. Therefore, more limited extraction strategies are employed that give specific, rather than general, information concerning the deviations from cylindrical form.

4.2 Probing system

4.2.1 Probing method

A contacting probing system with a stylus tip, as defined in 4.2.2, is part of the specification operator.

4.2.2 Stylus tip geometry

The theoretically exact stylus tip geometry is a sphere.

4.2.3 Probing force

The probing force is 0 N.

5 Compliance with the specification

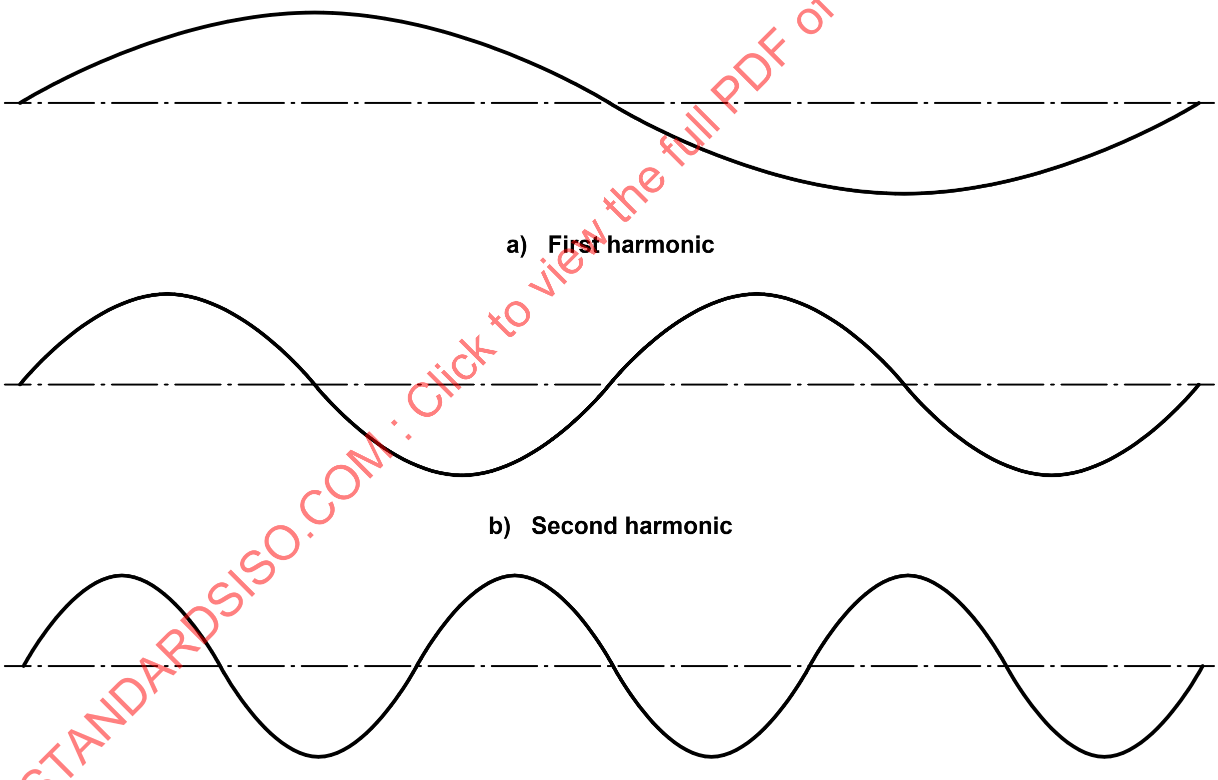
For proving conformance or non-conformance with the specification, ISO 14253-1 applies.

Annex A
(informative)

Harmonic content of nominally cylindrical workpiece and extraction strategy

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, and so on (see Figure A.1). Thus, the nth harmonic is that sinusoid whose wavelength divides into the fundamental wavelength exactly n times.



a) First harmonic

b) Second harmonic

c) Third harmonic

Figure A.1 — First three harmonics of a signal

A generatrix profile can be decomposed into its harmonic components in this manner. A roundness profile is slightly different in that the signal's start and end are joined together. Here, the fundamental wavelength of the Fourier series is the circumference of the circle or one undulation per revolution (UPR). The harmonics consist of the higher undulations per revolution (e.g. the second harmonic is the 2 UPR, the third harmonic is the 3 UPR, etc.).

All of the above-mentioned signals decomposed into Fourier series are profiles, whereas the surface of a cylinder is an area. An area can be thought of as the combination of two profiles in that the two profiles' directions can be used to establish a coordinate system for the area. In the case of a cylinder, the two profiles consist of the roundness and the generatrix profiles, with any position on the cylinder being located by giving its coordinates with respect to its distance around the circumference and distance up the generatrix from an origin.

In a similar way, an area can be decomposed into a combination of two Fourier series. Each individual component of this decomposition has two harmonic numbers: the first corresponds to the number of the harmonic in the direction of the first profile, and the second corresponds to the harmonic number in the direction of the second profile. The individual component is a combination of these two specified harmonic components.

For a cylinder, if the coordinate system is defined by the roundness and generatrix profiles, then the (6,4) harmonic consists of a term that is a combination of the sixth harmonic of the roundness profile (i.e. 6 UPR) and the fourth harmonic on the generatrix profile (i.e. four waves up the generatrix). It is important to consider which of these harmonics are present on a cylindrical feature when specifying an appropriate sampling strategy for assessment.

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.

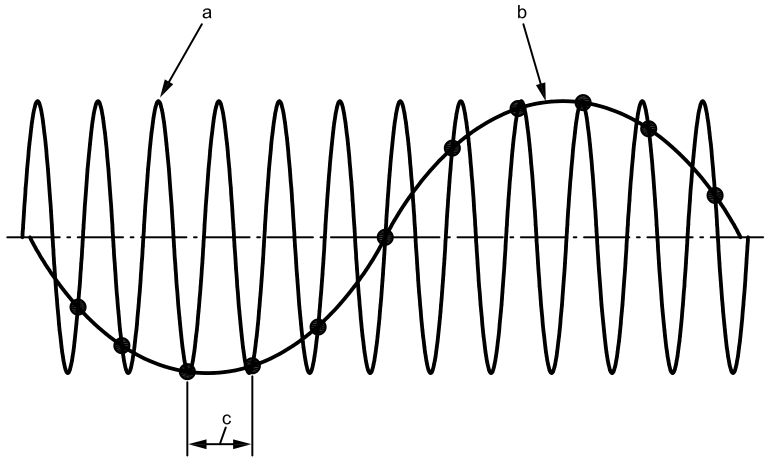
If the original signal is bandwidth limited, in that there is a shortest wavelength present (highest harmonic) in the signal, then the Nyquist theorem imposes a limitation on the maximum sampling interval possible. The Nyquist theorem states:

> *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.

The surface of a cylinder is an area and so the sampling intervals both along the generatrix and around the circumference need to be specified. Again, the Nyquist criterion can be used to specify the sampling intervals in the two directions by considering the highest harmonic present in each direction.



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 combinations of these. Usually, it is a combination of all three. Once the signal has a band limitation, the Nyquist criterion may be used to impose a theoretical maximum sampling interval as the following:

> *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.*

A.3 Harmonic content of a cylindrical feature

An indication of the ability of each of the extraction strategies to assess harmonics is given in a) to d).

a) Bird-cage extraction strategy

The main characteristic of the bird-cage extraction strategy is a high density of points along both the roundness and generatrix profiles. Although this is not a full high-density coverage of the cylindrical feature, it does give the extraction strategy the ability to assess the waviness content in both the roundness and generatrix directions relative to the form content. Hence, this extraction strategy is recommended as the sampling strategy for the assessment of the total cylindrical feature.

b) Roundness profile extraction strategy

The main characteristic of the roundness profile extraction strategy is a high density of points along the circumference relative to the density of points along the generatrix. This gives the extraction strategy the ability to assess very much higher roundness harmonic information in comparison to generatrix harmonic information. Hence, this extraction strategy is recommended if roundness information is of interest.

c) Generatrix extraction strategy

The main characteristic of the generatrix extraction strategy is a high density of points along the generatrix relative to the density of points along the circumference. This gives the extraction strategy the ability to assess very much higher generatrix harmonic information in comparison to roundness harmonic information. Hence, this extraction strategy is recommended if generatrix information is of interest.

d) Points extraction strategy

The density of points is typically lower than with the other three extraction strategies listed in a) to c). This restricts the ability to assess the harmonic content of a cylindrical feature. The lower number of points also presents problems when filtering. It is for this reason that the points extraction strategy is not recommended, unless only approximate estimates of the cylinder parameters are required.

Annex B
(informative)

Extraction strategies

B.1 General

In order to obtain a reliable assessment of cylindrical form, an appropriate extraction strategy for obtaining a representative set of points on the workpiece is required. Of prime importance in determining an appropriate strategy is the harmonic content of the workpiece in both the roundness and generatrix directions. This determines the theoretical minimum density of points to cover the workpiece.

In practice, it is often difficult to achieve a complete covering of the cylindrical feature given by the theoretical minimum density of points. In these situations, more limited extraction strategies are employed that give specific rather than general information concerning the assessment of cylindrical form. These include

— bird-cage extraction strategy,

— roundness profile extraction strategy,

— generatrix extraction strategy, and

— points extraction strategy.

When extraction is made by any of the above strategies, only a small number of sample points of the cylinder are considered. For this reason and because of different instrument designs and specific implementations of the strategies, differences may occur in the measurement results unless care is taken to select a set of points which, for the purpose of the specific assessment, is adequate to represent the cylindrical feature. The harmonic content of each sampling strategy, together with some recommendations on possible use taking the harmonic content into account, are described in A.3.

B.2 Bird-cage extraction strategy

The extraction of the workpiece shall be taken in axial section planes along the generatrix within the extraction window and also in a series of parallel roundness planes, having assigned a roundness plane to the beginning and to the end of the extraction window (see Figure B.1).

B.3 Roundness profile extraction strategy

The extraction of the workpiece shall be taken in a series of parallel roundness planes, having assigned a roundness plane to the beginning and to the end of the extraction window (see Figure B.2).

B.4 Generatrix extraction strategy

The extraction of the workpiece shall be taken in generatrix planes along the generatrix within the extraction window (see Figure B.3).

B.5 Points extraction strategy

The extraction of the workpiece shall be taken as a series of points within the extraction window taken at random or patterned on the surface (see Figure B.4).

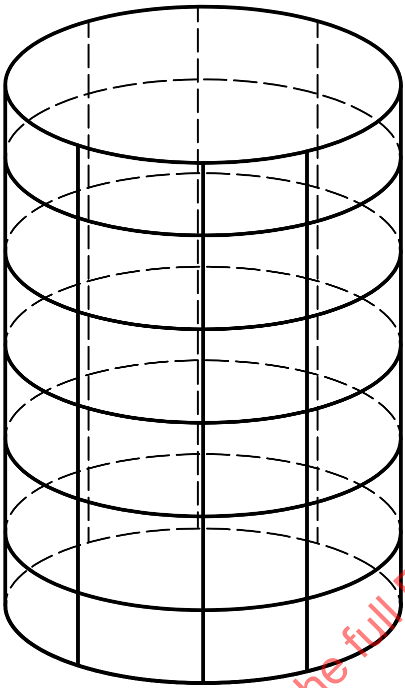


Figure B.1 — Bird-cage extraction strategy

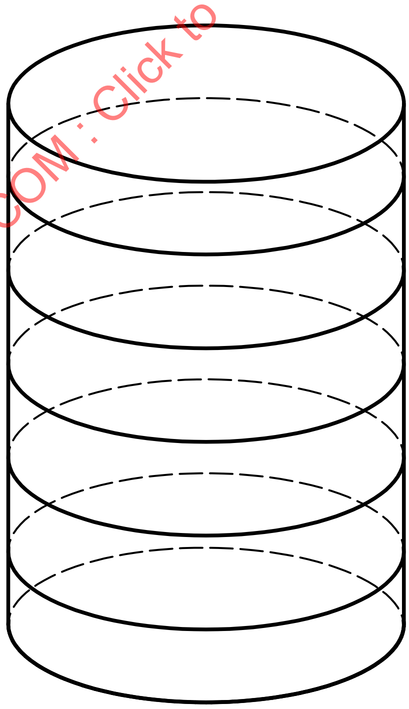


Figure B.2 — Roundness profile extraction strategy

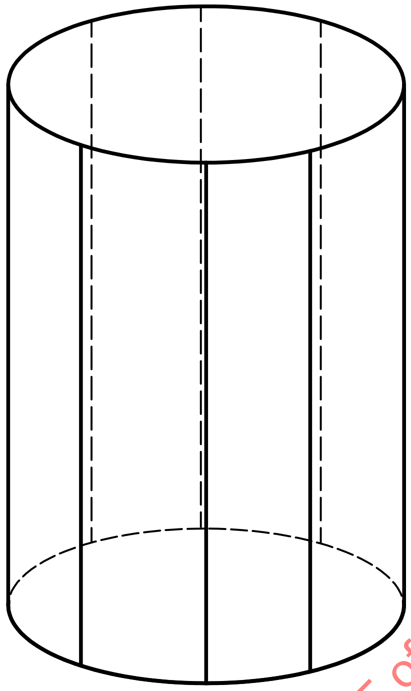


Figure B.3 — Generatrix extraction strategy

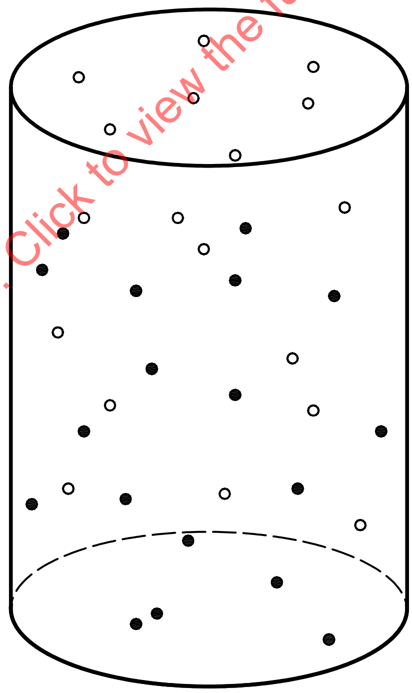


Figure B.4 — Points extraction strategy

Annex C
(informative)

Relationship to the GPS matrix model

C.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 part of ISO 12180 is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this part of ISO 12180 and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this part of ISO 12180, unless otherwise indicated.

C.2 Information about this part of ISO 12180 and its use

This part of ISO 12180 specifies the complete specification operator for cylindricity, i.e. geometrical characteristics of features of type cylinder.

C.3 Position in the GPS matrix model

This part of ISO 12180 is a general GPS standard, which influences chain link 3 of the chain of standards on form of surface independent of datum in the general GPS matrix, as graphically illustrated in Figure C.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 C.1 — Position in the GPS matrix model