TECHNICAL SPECIFICATION

ISO/TS 12180-2

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Geometrical Product Specifications (GPS) — Cylindricity —

Part 2: **Specification operators**

Spécification géométrique des produits (GPS) — Cylindricité —

Partie 2: Opérateurs de spécification

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Foreword

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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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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 12180-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO/TS 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/TS 12180 is a geometrical product specification (GPS) Technical Specification and is to be regarded as a general GPS document (see ISO/TR 14638). It influences chain link 3 of the chain of standards on form of a surface (independent of a datum).

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

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

At the current state of development, ISO/TC 213 has not been able to reach a consensus on defaults for filter UPR, probe tip radius and method of association (reference cylinder). This means that a cylindricity specification should 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 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 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 zero 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 roundness and straightness directions, can cause specification uncertainty.

This part of ISO/TS 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/TS 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/TS 12180-1:2003, *Geometrical Product Specifications (GPS) — Cylindricity — Part 1: Vocabulary*

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 12180, the terms and definitions given in ISO/TS 12180-1 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 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 current 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 specification

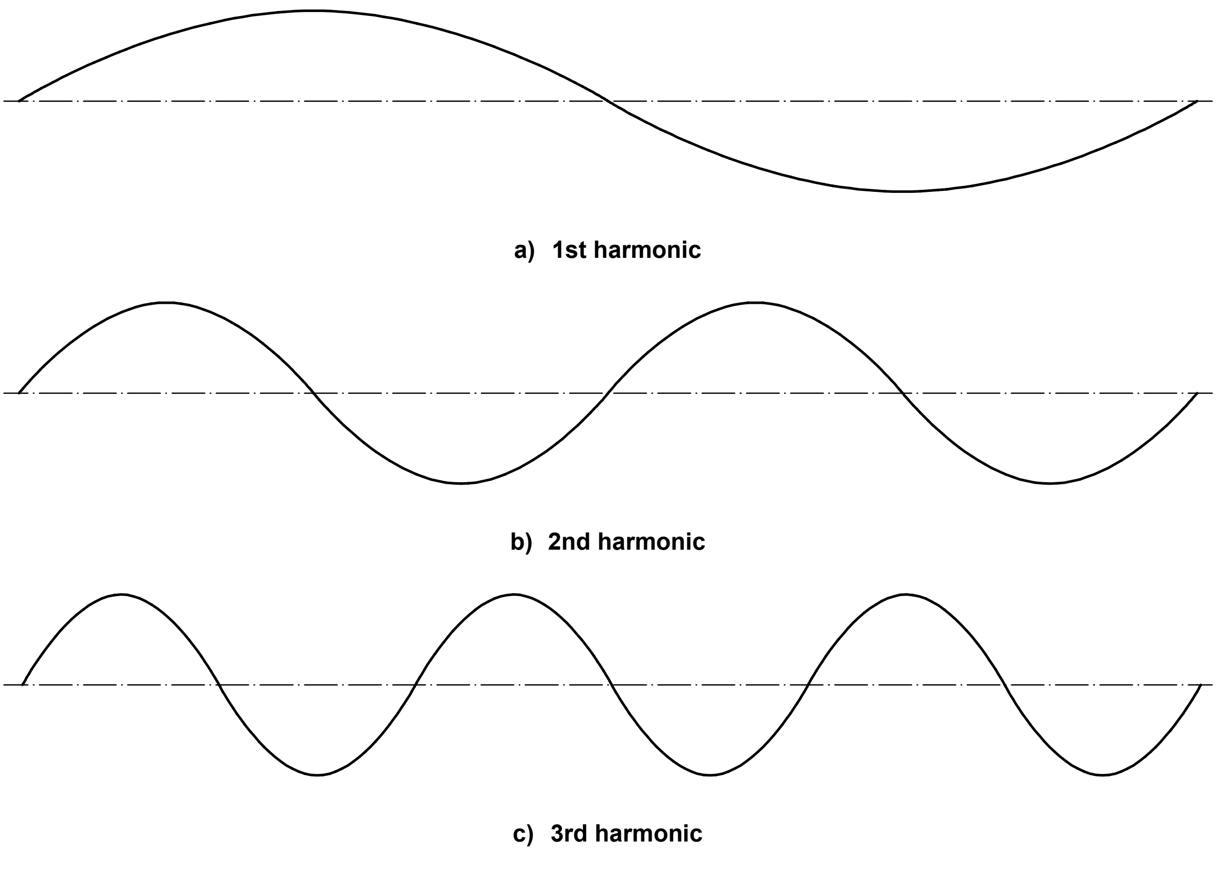
For proving conformance or non-conformance with specification, ISO 14253-1 applies.

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) 1st harmonic

b) 2nd harmonic

c) 3rd 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 2UPR, the third harmonic is the 3UPR, etc.).

All of the above 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 the 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 co-ordinate 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. 6UPR) 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) must be chosen so that the digitized signal is representative of the original signal for the method by which the signal will be analysed.

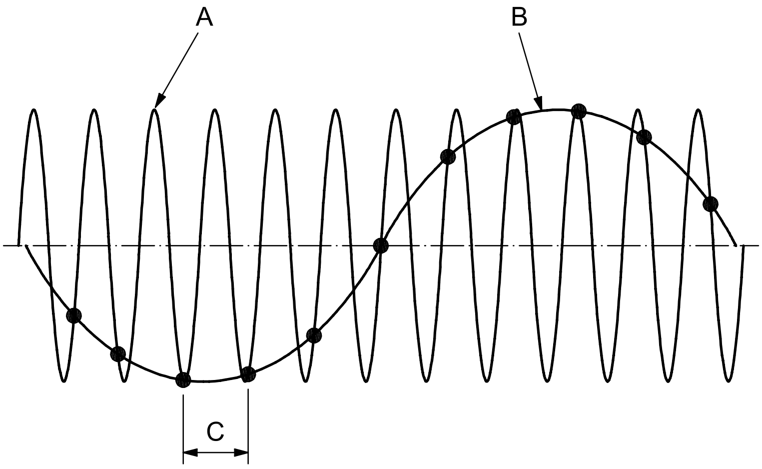
If the original signal is bandwidth limited, in that there is a shortest wavelength present (highest harmonic) in the signal, then the Nyquist theorem imposes a limitation on the maximum sampling interval possible. The Nyquist theorem states:

> *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 digitised 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.

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.



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, 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 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 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 as follows.

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 above. 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 will determine 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. In A.3 is described the harmonic content of each sampling strategy together with some recommendations on possible use taking the harmonic content into account.

B.2 Bird-cage extraction strategy

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

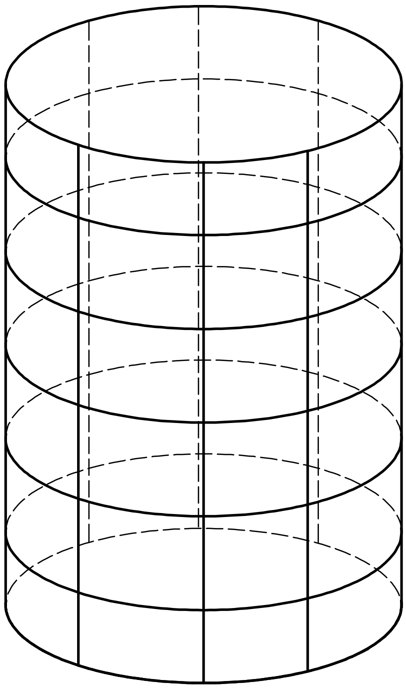


Figure B.1 — Bird-cage extraction strategy

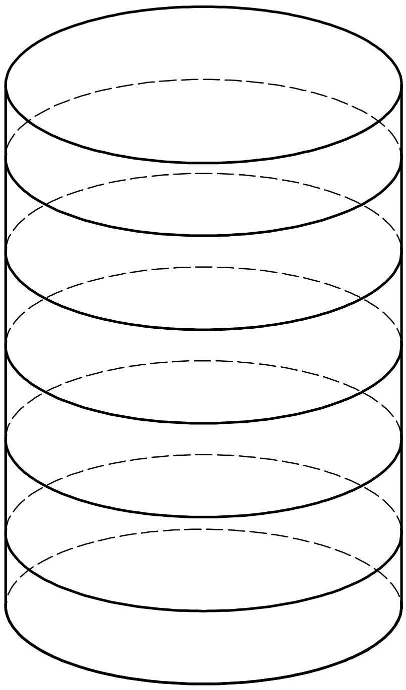


Figure B.2 — Roundness profile extraction strategy

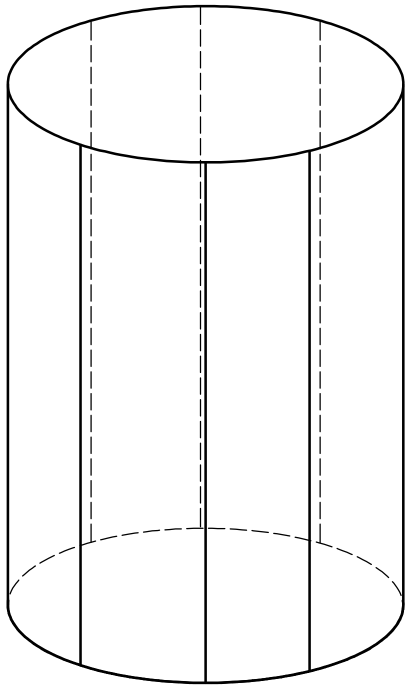


Figure B.3 — Generatrix extraction strategy

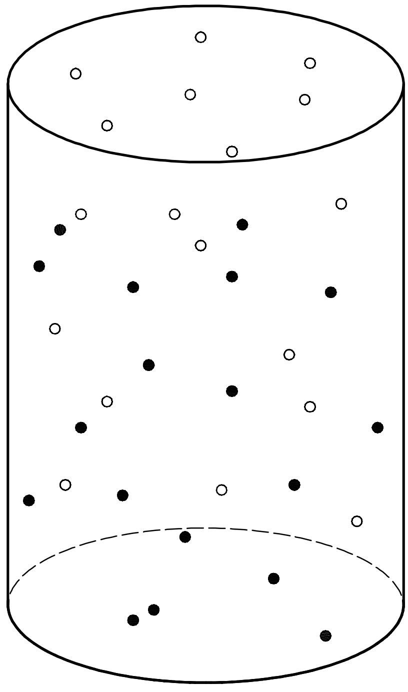


Figure B.4 — Points extraction strategy

Annex C
(informative)

Relation to the GPS matrix model

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

C.1 Information about this part of ISO/TS 12180 and its use

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

C.2 Position in the GPS matrix model

This part of ISO/TS 12180 is a general GPS document, 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 imperfections						
Edges						

Figure C.1

C.3 Related International Standards

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

Bibliography

[1] ISO 11562:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characterization of phase correct filters*

[2] ISO/TS 12181-2:2003, *Geometrical Product Specifications (GPS) — Roundness — Part 2: Specification operators*

[3] ISO/TS 12780-1:2003, *Geometrical Product Specifications (GPS) — Straightness — Part 1: Vocabulary and parameters of straightness*

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

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