# INTERNATIONAL STANDARD

# ISO 14406

First edition
2010-12-15

## Geometrical product specifications (GPS) — Extraction

*Spécification géométrique des produits (GPS) — Extraction*



Reference number
ISO 14406:2010(E)

## 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 14406 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.



 

## Introduction

This International Standard is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences the chain links 3 and 5 of all chains of standards.

For more detailed information of the relation of this International Standard to the GPS matrix model, see Annex B.

This International Standard develops the terminology and concepts for GPS extraction. It introduces the concept of sampling and reconstruction for extraction (see ISO 17450-1).

# Geometrical product specifications (GPS) — Extraction

## 1 Scope

This International Standard specifies the basic terminology for GPS extraction. It defines a framework for the fundamental operations used in GPS extraction and introduces the concepts of sampling and reconstruction for extraction, together with some principal sampling schemes on several basic geometries.

## 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 14660-1:1999, *Geometrical product specifications (GPS) — Geometrical features — Part 1: General terms and definitions*



ISO/TS 16610-1:2006, *Geometrical product specifications (GPS) — Filtration — Part 1: Overview and basic concepts*

ISO/TS 16610-40:2006, *Geometrical product specifications (GPS) — Filtration — Part 40: Morphological profile filters: Basic concepts*



ISO 17450-1:—[1)], *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

ISO 17450-2:—[2)], *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 14660-1, ISO/TS 16610-1, ISO/TS 16610-40, ISO 17450-1, ISO 17450-2 and the following apply.

**3.1**
**non-ideal surface model (of a workpiece)**
**skin model (of a workpiece)**
model of the physical interface of the workpiece with its environment

[ISO 17450-1:—, 3.27]

1) To be published. (Revision of ISO/TS 17450-1:2005)

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

 

**3.1.1**
**mechanical surface**
boundary of the erosion, by a sphere of radius $r$, of the locus of the centre of an ideal tactile sphere, also with radius $r$, rolled over the **skin model of a workpiece** (3.1)

NOTE 1 Erosion is a morphological operation (see ISO/TS 16610-40).

NOTE 2 The mechanical surface is an essential characteristic of a skin model of a workpiece.

**3.1.2**
**electromagnetic surface**
surface obtained by the electromagnetic interaction with the **skin model of a workpiece** (3.1)

NOTE 1 Different wavelengths give different surfaces.

NOTE 2 The electromagnetic surface is an essential characteristic of a skin model of a workpiece.

NOTE 3 Examples of electromagnetic surface include optical surfaces from coherence-scanning interferometers, optical stylus instruments and scanning confocal microscopes.

**3.2**
**real surface of a workpiece**
set of features which physically exist and separate the entire workpiece from the surrounding medium

[ISO 14660-1:1999, 2.4.1]



NOTE Real surfaces of workpieces have many potential functional uses, from bearing surfaces in roller bearings to visual appearance in car body panels. At the atomic level, these different functions define different real surfaces, depending on the nature of the functional interaction with the surface. Since nanoscale measurement is becoming increasingly important economically, there is a requirement to differentiate between these different functional surfaces. The mechanical surface and the electromagnetic surface, defined below, are two commonly used functional surfaces.



**3.2.1**
**real mechanical surface**
boundary of the erosion, by a sphere of radius $r$, of the locus of the centre of an ideal tactile sphere, also with radius $r$, rolled over the **real surface of a workpiece** (3.2)

NOTE 1 Erosion is a morphological operation (see ISO/TS 16610- 40).

NOTE 2 The real mechanical surface is a specific type of real surface of a workpiece.

**3.2.2**
**real electromagnetic surface**
surface obtained by the electromagnetic interaction with the **real surface of a workpiece** (3.2)

NOTE 1 The locus of the effective ideal reflection point can be affected by both the topographical surface and the material properties of the workpiece.

NOTE 2 Different wavelengths give different surfaces.

NOTE 3 The real electromagnetic surface is a specific type of real surface of a workpiece.

**3.3**
**integral feature**
surface or line on a surface

NOTE An integral feature is intrinsically defined.

[ISO 14660-1:1999, 2.1.1]

 

**3.3.1**
**real (integral) feature**
**integral feature** (3.3) part of a **real surface of a workpiece** (3.2) limited by the adjacent real (integral) features

[ISO 14660-1:1999, 2.4.1]

**3.3.2**
**surface portion**
portion of a partitioned integral surface

[ISO/TS 16610-1:2006, 3.1.1]

NOTE In practice, the integral surface will be either an **integral feature** (3.3) or a **real (integral) feature** (3.3.1).

**3.4**
**primary mathematical model**
set of nested mathematical representations of the **surface portion** (3.3.2), wherein each representation in the set can be described by a finite number of parameters

[ISO/TS 16610-1:2006, 3.2]

**3.4.1**
**nesting index**
NI
number, or set of numbers, indicating the relative level of nesting for a particular **primary mathematical model** (3.4)



NOTE 1 Given a particular nesting index, models with lower indices contain more surface information, whereas models with higher nesting indices contain less surface information.

NOTE 2 By convention, as the nesting index approaches zero (or a series of all zeros), there exists a primary mathematical model that approximates the real surface of a workpiece to within any given measure of closeness.



[ISO/TS 16610-1:2006, 3.2.1]

**3.4.2**
**degrees of freedom**
⟨primary mathematical model⟩ number of independent parameters required to fully describe a particular **primary mathematical model** (3.4)

[ISO/TS 16610-1:2006, 3.2.2]

**3.5**
**primary surface**
PS
**surface portion** (3.3.2) obtained when the latter is represented as a specified **primary mathematical model** (3.4) with specified **nesting index** (3.4.1)

[ISO/TS 16610-1:2006, 3.3]

**3.6**
**primary mapping**
PM( | NI)
mapping indexed by the **nesting index** (3.4.1), used to identify a particular **primary surface** (3.5) with the specified nesting index, in order to represent a **surface portion** (3.3.2) that satisfies the sieve and projection criteria

NOTE The primary mapping is defined in terms of mathematical mappings as

PS = PM(SP | NI)

where

PS is the primary surface;

SP is the surface portion.

[ISO/TS 16610-1:2006, 3.4]

**3.7**
**primary extracted surface**
finite set of data points sampled from the **primary surface** (3.5)

NOTE 1 The primary extracted surface represents the basis for digital processing by means of surface filters and the calculation of characterization parameters.

NOTE 2 Here, "extracted" is used only for objects containing a finite number of data points. Thus the primary surface is still a continuous surface and the primary extracted surface contains a finite number of data points sampled from the primary surface.

**3.7.1**
**reconstruction**
method of choosing a particular **primary mathematical model** (3.4), of a fixed **nesting index** (3.4.1), that passes exactly through the **primary extracted surface** (3.7)

NOTE 1 The concept of "exact reconstruction" is described in 4.2.

NOTE 2 With many primary mathematical models, if the number of sampled points is greater than or equal to the number of degrees of freedom, there exists a sampling scheme by which the primary surface can be reconstructed without any loss of information from the primary extracted surface (this generalizes the Nyquist criterion).



**3.7.2**
**sampling aliasing**
two or more **primary mathematical models** (3.4), of a fixed **nesting index** (3.4.1), passing exactly through the **primary extracted surface** (3.7)

NOTE 1 This can cause real problems if the two or more primary mathematical models are very different from each other.

NOTE 2 The aliasing is the incorrect reconstruction of a signal due to the overlap of the transfer functions of the filter in a filter bank.

**3.8**
**extraction**
specification operation that results in a **primary extracted surface** (3.7) as an approximate representation of the **skin model of a workpiece** (3.1)

**3.9**
**physical extraction**
verification operation that results in a **primary extracted surface** (3.7) as an approximate representation of the **real surface of a workpiece** (3.2)

 

# 4 Sampling and reconstruction for extraction

## 4.1 General

The primary surface shall, if possible, be reconstructed without loss of information from the primary extracted surface, the reason being to attempt to generalize the Nyquist theorem[4], which 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.*

For linear primary mappings (wavelets, etc.), there are exact reconstruction theorems equivalent to the Nyquist theorem. For other types of primary mappings (e.g. morphological filters), there are reconstruction theorems that are not exact but that limit the amount of information lost (for example through a zone of possible reconstructions). The following two sections give an example of both types of reconstruction theorems: one for wavelets and the other for morphological filters. Both examples are for profile filters for ease of explanation; areal reconstruction theorems do exist but are much more complex and require deeper explanations than can be given in an International Standard.

## 4.2 Wavelets: exact reconstruction

Wavelets for which the multi-resolution algorithm applies (see ISO/TS 16610-29), have an equivalent theorem to the Nyquist theorem[4] and the number of sampling points shall be greater or equal to the number of degrees of freedom in the particular order of the nested mathematical model.

This theorem shall be used to determine the theoretical maximum equidistant sampling interval of the primary extracted profile without loss of information. This means that the primary profile can be fully reconstructed from the primary extracted profile if and only if the equidistant sampling interval is shorter than the theoretical maximum (this reconstruction is also discussed in Reference [5]).



NOTE 1 If a larger sampling interval is used, there will be information loss, and exact reconstruction of the primary profile is not possible (e.g. aliasing problems, etc.).

NOTE 2 Second generation wavelets allow many sampling strategies, including equidistant, non-equidistant and random[6][7].

## 4.3 Morphological filters: zone of possible reconstruction

### 4.3.1 General

There is no theorem for morphological filters (see ISO/TS 16610-40) equivalent to the Nyquist theorem in which a universal equidistant sampling scheme can be found which has no loss of information. Instead, there are a number of morphological sampling theorems[8] to limit the amount of information that is lost. The following is a sampling and reconstruction theorem for alternating sequence filters (see ISO/TS 16610-49).

**Assumption**: $Z(x)$ is a profile which remains unchanged after the application of a closing and opening of that profile by a particular structuring element of a given size, i.e.

$$C\left[Z(x),\mathrm{SE}\right]=Z(x)=O\left[Z(x),\mathrm{SE}\right]$$

**Theorem 4.1**: if $Z(x)$ satisfies the above assumption with the particular structuring element SE, and is sampled with a sampling interval always strictly less than the size of SE, then:

$$C\left[Z_s(x),\mathrm{SE}\right]\leqslant Z(x)\leqslant O\left[\overline{Z_s(x),\hat{\mathrm{SE}}}\right]$$

 