International Standard

ISO 16610-21

Geometrical product specifications (GPS) — Filtration —

Part 21: Linear profile filters: Gaussian filters

Spécification géométrique des produits (GPS) — Filtrage —

Partie 21: Filtres de profil linéaires: Filtres gaussiens

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Foreword

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This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16610-21:2011), which has been technically revised.

The main changes are as follows:

— providing implementation details for open and closed profiles,

— providing the treatment of end effects.

A list of all parts in the ISO 16610 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain links C and E in the GPS matrix structure.

The ISO GPS matrix model given in ISO 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 the specifications made in accordance with this document, unless otherwise indicated.

For more information on the relationship of this document to the filtration matrix model, see Annex C.

For more detailed information on the relation of this document to other standards and the GPS matrix model, see Annex D.

This document develops the terminology and concepts of linear Gaussian filters for surface profiles. Linear Gaussian filters for surface profiles have a transmission of 50 % for sinusoidal surface profiles with wavelengths equal to the cut-off wavelength. It separates the large- and small-scale lateral components of surface profiles in such a way that the surface profiles can be reconstructed without altering.

Geometrical product specifications (GPS) — Filtration —

Part 21:
Linear profile filters: Gaussian filters

1 Scope

This document specifies linear Gaussian filters for the filtration of surface profiles. It defines, in particular, how to separate large- and small-scale lateral components of surface profiles.

The concept presented for closed profiles are applicable to the case of roundness filtration. Where appropriate, these concept can be extended to generalized closed profiles, especially for surface profiles with re-entrant features.

Implementation details are given in Annex A for open profiles and Annex B for closed profiles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 16610-1, *Geometrical product specifications (GPS) — Filtration — Part 1: Overview and basic concepts*

ISO 16610-20, *Geometrical product specifications (GPS) — Filtration — Part 20: Linear profile filters: Basic concepts*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16610-1, ISO 16610-20, ISO/IEC Guide 99 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
surface profile
line resulting from the intersection between a surface portion and an ideal plane

Note 1 to entry: The orientation of the ideal plane is usually perpendicular to the tangent plane of the surface portion.

Note 2 to entry: See ISO 17450-1:2011, 3.3 and 3.3.1, for the definition of an ideal plane.

[SOURCE: ISO 16610-1:2015, 3.1.2, modified — Note 2 to entry replaced.]

3.1.1
open profile
finite length *surface profile* (3.1) with two ends

Note 1 to entry: An open profile has a compact support, i.e. within a certain interval the height values of an open profile can be equal to any real number. Outside the interval, the height values of an open profile are set to zero.

[SOURCE: ISO 16610-1:2015, 3.7, modified — Note 1 to entry replaced.]

3.1.2
unbounded open profile
infinite length *surface profile* (3.1) without ends

Note 1 to entry: In this document, the term “unbounded” refers to the X-axis.

Note 2 to entry: The concept of the unbounded open profile is ideal and do not apply to real surface profiles.

3.1.3
closed profile
connected finite length *surface profile* (3.1) without ends

Note 1 to entry: A closed profile is a closed curve which is periodic with the finite period length L.

Note 2 to entry: A typical example of a closed profile is one from a roundness measurement.

[SOURCE: ISO 16610-1:2015, 3.8, modified — Note 1 to entry replaced and Note 2 to entry added.]

3.2
linear profile filter
profile filter which separates *surface profiles* (3.1) into large- and small-scale lateral components and is also a linear function

Note 1 to entry: If F is a function and X and Y are surface profiles, and if a and b are independent from X and Y, then F being a linear function implies $F(a\,X + b\,Y) = a\,F(X) + b\,F(Y)$.

[SOURCE: ISO 16610-20:2015, 3.1, modified — In definition “profiles” replaced by “surface profiles” and “long wave” and “short wave” replaced by “large-scale lateral” and “small-scale lateral”; Note 1 to entry replaced.]

3.3
weighting function
function to calculate large-scale lateral components by convolution of the surface profile heights with this function

Note 1 to entry: The convolution (see ISO 16610-20:2015, 4.1) performs a weighted moving average of the surface profile heights. The weighting function, reflected at the X-axis, defines the weighting coefficients for the averaging process.

3.4
transmission characteristic of a filter
characteristic that indicates the amount by which the amplitude of a sinusoidal surface profile is attenuated as a function of its wavelength

Note 1 to entry: The transmission characteristic is the Fourier transformation of the *weighting function* (3.3).

[SOURCE: ISO 16610-20:2015, 3.4, modified — "surface" added before "profile".]

3.5
cut-off wavelength
λ_c
wavelength of a sinusoidal surface profile of which 50 % of the amplitude is transmitted by the profile

Note 1 to entry: Linear profile filters are identified by the filter type and the cut-off wavelength value.

Note 2 to entry: The cut-off wavelength is the nesting index for linear profile filters.

[SOURCE: ISO 16610-20:2015, 3.5, modified — "surface" added before "profile", "profile filter" replaced by "profile" and in Note 2 to entry “recommended” deleted.]

3.6
undulations per revolution
UPR
integer number of sinusoidal undulations contained in a *closed profile* (3.1.3)

Note 1 to entry: In this document, UPR is a frequency and is denoted by f.

3.7
cut-off frequency in undulations per revolution
f_c
frequency in UPR of a sinusoidal *closed profile* (3.1.3) of which 50 % of the amplitude is transmitted by the profile filter

4 Characteristics of the Gaussian filter for unbounded open profiles

4.1 General

In this clause, the ideal filtration of unbounded open profiles is considered. For this purpose, the unbounded open profiles are convolved with the ideal Gaussian weighting function of infinite length. The treatment of open profiles is considered in Annex A.

4.2 Gaussian weighting function

The Gaussian weighting function with cut-off wavelength λ_c (see Figure 1) for unbounded open profiles is defined according to Formula (1):

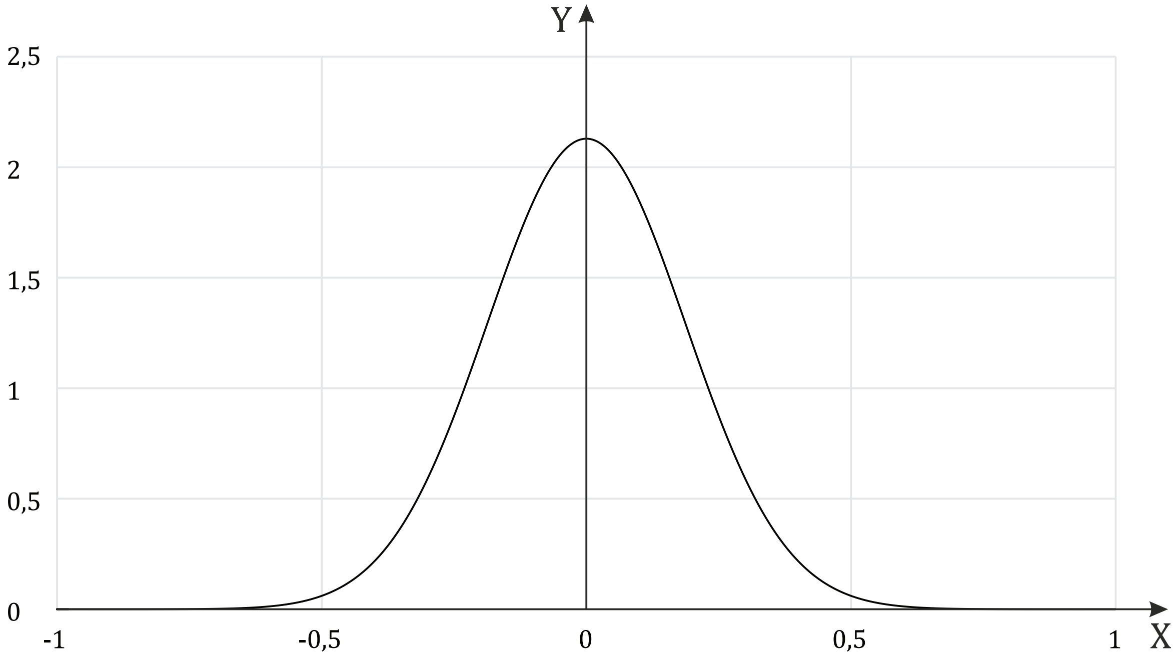
$$s(v) = \frac{1}{\alpha \lambda_c} e^{-\pi \left(\frac{v}{\alpha \lambda_c} \right)^2} \tag{1}$$

where

v	is the distance from the centre (maximum) of the Gaussian weighting function;
$s(v)$	is the Gaussian weighting function depending on v;
λ_c	is the cut-off wavelength;
α	is the constant to provide 50 % transmission characteristic at the cut-off wavelength λ_c.

The constant α is given by Formula (2):

$$\alpha = \sqrt{\frac{\ln 2}{\pi}} \approx 0{,}469\ 7 \approx \frac{318}{677} \approx \frac{31}{66} \tag{2}$$



Key

X v / λ_c

Y $s(v)\,\lambda_c$

Figure 1 — Weighting function of the Gaussian filter for unbounded open profiles

4.3 Filter equations

4.3.1 Determination of the large-scale lateral component

The large-scale lateral component of an unbounded open profile is determined by convolution of the heights of this unbounded open profile with the Gaussian weighting function according to Formula (3):

$$w(x) = \int_{-\infty}^{\infty} z(u)\, s(x-u)\, \mathrm{d}u \tag{3}$$

where

x	is the given x-coordinate;
u	is the integration variable along the X-axis of the unbounded open profile;
$z(u)$	is the unbounded open profile depending on u;
$s(x-u)$	is the Gaussian weighting function reflected at the ordinate axis at the given x-coordinate and depending on u;
$w(x)$	is the large-scale lateral component of the unbounded open profile depending on x.

4.3.2 Determination of the small-scale lateral component

The small-scale lateral component of an unbounded open profile is determined by subtracting the large-scale lateral component of this unbounded open profile, Formula (3), from this unbounded open profile according to Formula (4):

$$r(x) = z(x) - w(x) \tag{4}$$

where

x	is the given x-coordinate;
$z(x)$	is the unbounded open profile depending on x;
$w(x)$	is the large-scale lateral component of the unbounded open profile depending on x;
$r(x)$	is the small-scale lateral component of the unbounded open profile depending on x.

4.4 Transmission characteristics

4.4.1 Transmission characteristic for the large-scale lateral component

The transmission characteristic for the large-scale lateral component of an unbounded open profile (see Figure 2) is determined from the Gaussian weighting function by means of the Fourier transformation and is given by Formula (5):

$$\frac{a_1}{a_0} = \mathrm{e}^{-\pi\left(\frac{\alpha\,\lambda_c}{\lambda}\right)^2} = 2^{-\left(\frac{\lambda_c}{\lambda}\right)^2} \tag{5}$$

where

a_0	is the amplitude of a sinusoidal unbounded open profile before filtration;
a_1	is the amplitude of this sinusoidal unbounded open profile after filtration;
λ	is the wavelength of this sinusoidal unbounded open profile;
λ_c	is the cut-off wavelength;
α	is the constant to provide 50 % transmission characteristic at the cut-off wavelength λ_c and is defined according to Formula (2).