TECHNICAL SPECIFICATION

ISO/TS 16610-32

First edition
2009-03-15

Geometrical product specifications (GPS) — Filtration —

Part 32: Robust profile filters: Spline filters

Spécification géométrique des produits (GPS) — Filtrage —

Partie 32: Filtres de profil robustes: Filtres splines

Reference number
ISO/TS 16610-32:2009(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.

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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 16610-32 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 16610 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Filtration*:

— *Part 1: Overview and basic concepts* [Technical Specification]

— *Part 20: Linear profile filters: Basic concepts* [Technical Specification]

— *Part 21: Linear profile filters: Gaussian filters*

— *Part 22: Linear profile filters: Spline filters* [Technical Specification]

— *Part 29: Linear profile filters: Spline wavelets* [Technical Specification]

— *Part 30: Robust profile filters: Basic concepts* [Technical Specification]

— *Part 32: Robust profile filters: Spline filters* [Technical Specification]

— *Part 40: Morphological profile filters: Basic concepts* [Technical Specification]

— *Part 41: Morphological profile filters: Disk and horizontal line-segment filters* [Technical Specification]

— *Part 49: Morphological profile filters: Scale space techniques* [Technical Specification]

The following parts are under preparation:

— *Part 28: Profile filters: End effects* [Technical Specification]

— *Part 31: Robust profile filters: Gaussian regression filters* [Technical Specification]

The following parts are planned:

— *Part 26: Linear profile filters: Filtration on nominally orthogonal grid planar data sets*

— *Part 27: Linear profile filters: Filtration on nominally orthogonal grid cylindrical data sets*

— *Part 42: Morphological profile filters: Motif filters*

— *Part 60: Linear areal filters: Basic concepts*

— *Part 61: Linear areal filters: Gaussian filters*

— *Part 62: Linear areal filters: Spline filters*

— *Part 69: Linear areal filters: Spline wavelets*

— *Part 70: Robust areal filters: Basic concepts*

— *Part 71: Robust areal filters: Gaussian regression filters*

— *Part 72: Robust areal filters: Spline filters*

— *Part 80: Morphological areal filters: Basic concepts*

— *Part 81: Morphological areal filters: Sphere and horizontal planar segment filters*

— *Part 82: Morphological areal filters: Motif filters*

— *Part 89: Morphological areal filters: Scale space techniques*

Introduction

This part of ISO 16610 is a geometrical product specification (GPS) standard and is to be regarded as a global 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 part of ISO 16610 to the GPS matrix model, see Annex C.

This part of ISO 16610 develops the terminology and concepts of robust spline filters. The robust spline filter has the advantage over a conventional phase correct filter that the edges of the measured profile are still usable. This is important especially in the case of form filtering. Moreover, the robust spline filter is tolerant against outliers.

Geometrical product specifications (GPS) — Filtration —

Part 32:
Robust profile filters: Spline filters

1 Scope

This part of ISO 16610 specifies the characteristics of robust spline filters for surface profiles.

It specifies in particular how to separate the long and short wave content of a surface profile.

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

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

ISO/TS 16610-22:2006, *Geometrical product specifications (GPS) — Filtration — Part 22: Linear profile filters: Spline filters*

ISO/TS 16610-30:2009, *Geometrical product specifications (GPS) — Filtration — Part 30: Robust profile filters: Basic concepts*

ISO/IEC Guide 99:2007, *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/IEC Guide 99, ISO 4287, ISO/TS 16610-1, ISO/TS 16610-22, ISO/TS 16610-30 and the following apply.

3.1
robust spline filter
robust filter based on splines

NOTE 1 The result of the low-pass filtering (the mean line) is a spline.

NOTE 2 The degree of the spline is equal to the degree of the polynomial of highest degree used, e.g. a cubic spline is made of cubic polynomials.

NOTE 3 Robust spline filters are non-linear filters.

4 Robust spline filters

4.1 Weighting function

The weighting function of a robust spline filter does not exist because this filter is non-linear.

4.2 Filter equations

4.2.1 General

Filter equations for robust spline filters may be constructed for any degree, but only those based on cubic splines are given here.

4.2.2 Filter equation of the robust spline filter for open profiles

The filter equation is given by

$$\left[\beta\alpha^2 P + (1-\beta)\alpha^4 Q\right] w = \frac{\operatorname{sgn}(z-w)}{\sum\left|(z-w)\right|} \tag{1}$$

with the matrix

$$P = \begin{pmatrix} 1 & -1 & & & & & \\ -1 & 2 & -1 & & & & \\ & -1 & 2 & -1 & & & \\ & & \ddots & \ddots & \ddots & & \\ & & -1 & 2 & -1 & & \\ & & & -1 & 2 & -1 & \\ & & & & -1 & 1 \end{pmatrix} \quad Q = \begin{pmatrix} 1 & -2 & 1 & & & & \\ -2 & 5 & -4 & 1 & & & \\ 1 & -4 & 6 & -4 & 1 & & \\ & \ddots & \ddots & \ddots & \ddots & \ddots & \\ & & 1 & -4 & 6 & -4 & 1 \\ & & & 1 & -4 & 5 & -2 \\ & & & & 1 & -2 & 1 \end{pmatrix} \tag{2}$$

with n rows and n columns and the parameters

$$\alpha = \frac{1}{2\sin\dfrac{\pi\Delta x}{\lambda_c}} \quad \text{and} \quad 0 \leqslant \beta \leqslant 1 \tag{3}$$

where

n is the number of measured values of the profile;

z is the vector of dimension n of the profile values before filtering;

w is the vector of dimension n of this profile's values in the reference line;

λ_c is the limiting wavelength of the profile filter;

Δx is the sampling interval

$$\operatorname{sgn}(t) = \begin{cases} +1 & \text{if } t \geqslant 0 \\ -1 & \text{if } t < 0 \end{cases}$$

NOTE 1 The vector w gives the profile values of the long wave component (reference line). The short wave component, r, may be obtained by the difference vector $r = z - w$, i.e. by subtracting the mean line values obtained by the filtering process from the measured profile values.

NOTE 2 The β value of 0,625 242… gets the spline filter as close as possible to the Gaussian filter.

4.2.3 Filter equation of the robust spline filter for closed profiles

The filter equation is given by

$$\left[\beta\alpha^2\tilde{P} + (1-\beta)\alpha^4\tilde{Q}\right]\tilde{w} = \frac{\operatorname{sgn}(\tilde{z}-\tilde{w})}{\sum\left|(\tilde{z}-\tilde{w})\right|} \tag{4}$$

with the matrix

$$\tilde{P} = \begin{pmatrix} 2 & -1 & & & & & -1 \\ -1 & 2 & -1 & & & & \\ & -1 & 2 & -1 & & & \\ & & \ddots & \ddots & \ddots & & \\ & & & -1 & 2 & -1 & \\ & & & & -1 & 2 & -1 \\ -1 & & & & & -1 & 2 \end{pmatrix} \quad \tilde{Q} = \begin{pmatrix} 6 & -4 & 1 & & & 1 & -4 \\ -4 & 6 & -4 & 1 & & & 1 \\ 1 & -4 & 6 & -4 & 1 & & \\ & \ddots & \ddots & \ddots & \ddots & \ddots & \\ & & 1 & -4 & 6 & -4 & 1 \\ 1 & & & 1 & -4 & 6 & -4 \\ -4 & 1 & & & 1 & -4 & 6 \end{pmatrix} \tag{5}$$

with n rows and n columns and the parameters

$$\alpha = \frac{1}{2\sin\dfrac{\pi\Delta x}{\lambda_c}} \text{ and } 0 \leqslant \beta \leqslant 1 \tag{6}$$

where

n is the number of measured values of the profile;

$\tilde{z}$ is the vector of dimension n of the profile values before filtering;

$\tilde{w}$ is the vector of dimension n of this profile's values in the mean line;

λ_c is the limiting wavelength of the profile filter;

Δx is the sampling interval.

NOTE The vector $\tilde{z}$ gives the profile values of the long wave component (mean line). The short wave component, $\tilde{r}$, may be obtained by the difference vector $\tilde{r} = \tilde{z} - \tilde{w}$, i.e. by subtracting the mean line values obtained by the filtering process from the measured profile values.

4.3 Transmission characteristic

The transmission characteristic of a robust spline filter does not exist because this filter is non-linear, i.e. no weighting function exists.

NOTE The transmission characteristic of a linear filter is given as the Fourier transformation of the weighting function. This is not possible with non-linear filters.

5 Recommendations

5.1 Nesting index (cut-off value λ_c)

It is recommended that the nesting index (the cut-off value λ_c) be chosen from a logarithmic series (constant ratio) of values. Experience has shown that a constant ratio of around the square root of ten between successive scale values is optimal. The nesting index should be chosen from the following series of values:

... 2,5 µm; 8 µm; 25 µm; 80 µm; 250 µm; 0,8 mm; 2,5 mm; 8 mm; 25 mm; ...

5.2 Tension parameter (β)

If not otherwise specified, the tension parameter, β, takes the value zero.

5.3 Implementation

It is strongly recommended that the matrix equations given in 4.2.2 and 4.2.3 be used to implement the spline filter.

5.4 Filter designation

Spline filters in accordance with this part of ISO 16610 are designated

FPRS

See also ISO/TS 16610-1:2006, Clause 5.

Annex A
(informative)

Examples

Examples for the application of the robust spline filter and the Gaussian filter are given for information purposes.

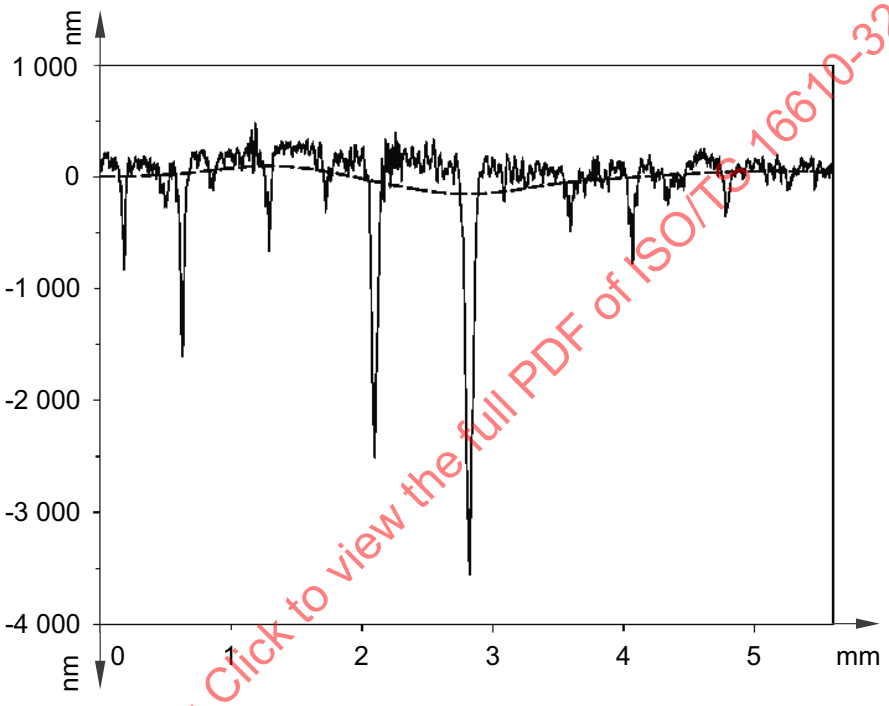

Figure A.1 — Gaussian filter with λ_c = 2,5 mm according to ISO 11562

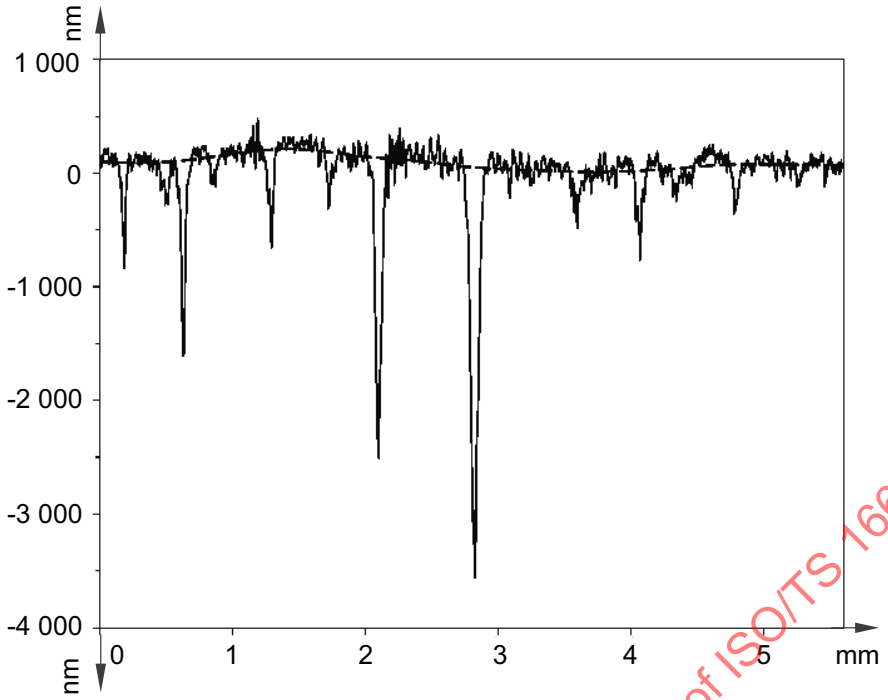

Figure A.2 — Robust spline filter with λ_c = 2,5 mm

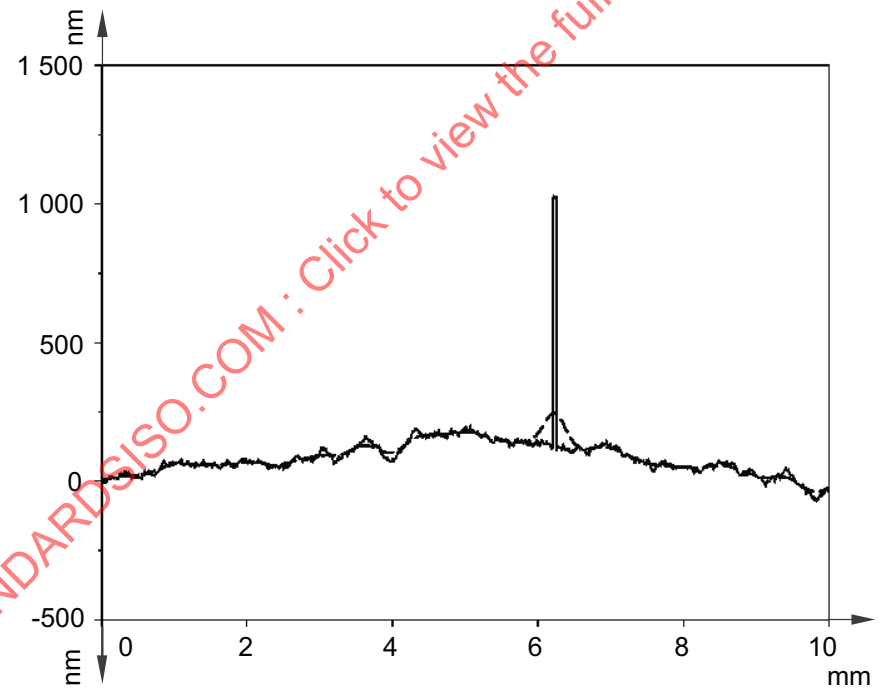

Figure A.3 — Gaussian filter with λ_c = 0,8 mm according to ISO 11562

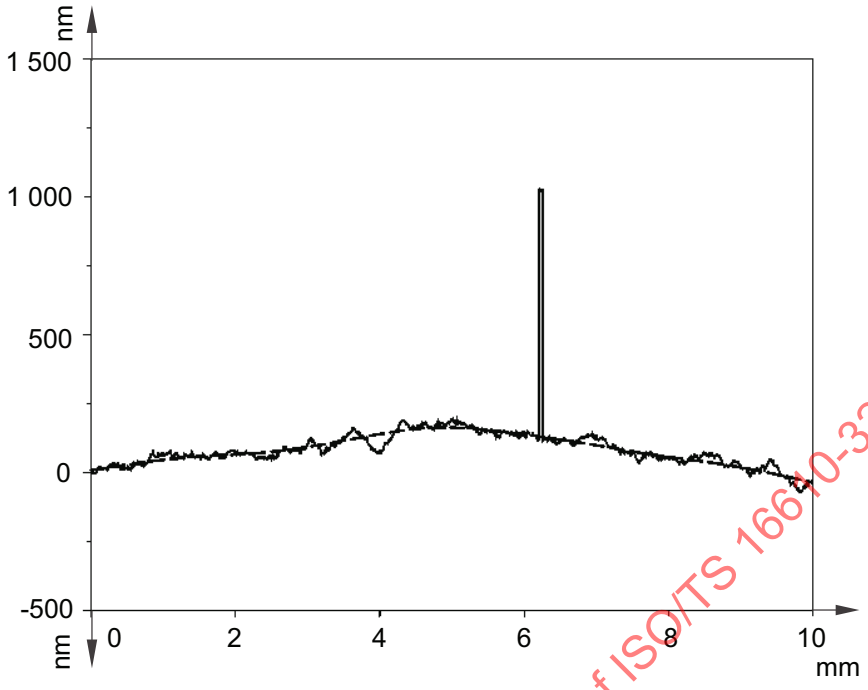

Figure A.4 — Robust spline filter with $\lambda_c = 0{,}8$ mm

Annex B
(informative)

Relationship to the filtration matrix model

B.1 General

For full details about the filtration matrix model, see ISO/TR 16610-1.

B.2 Position in the filtration matrix model

This part of ISO 16610 is a document that influences particular filters in the column "Profile filters, Robust" (see Figure B.1).

General	**Filters: ISO 16610 series**					
	Part 1					
Fundamental	**Profile filters**			**Areal filters**		
	Part 11[a]			Part 12[a]		
	Linear	**Robust**	**Morphological**	**Linear**	**Robust**	**Morphological**
Basic concepts	Part 20	Part 30	Part 40	Part 60	Part 70	Part 80
Particular filters	Parts 21-25	Parts 31-35	Parts 41-45	Parts 61-65	Parts 71-75	Parts 81-85
How to filter	Parts 26-28	Parts 36-38	Parts 46-48	Parts 66-68	Parts 76-78	Parts 86-88
Multiresolution	Part 29	Part 39	Part 49	Part 69	Part 79	Part 89

[a] At present included in Part 1.

Figure B.1 — Relationship to the filtration matrix model