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Geometrical product specifications (GPS) — Basic concepts —

Part 4: Geometrical characteristics for quantifying GPS deviations

Spécification géométrique des produits (GPS) — Concepts généraux —

Partie 4: Caractéristiques géométriques pour la quantification des écarts GPS

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Contents

Foreword

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This document was prepared by Technical Committee is ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification*.

A list of all parts in the ISO 17450 series can be found on the ISO website.

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). The rules and principles given in this document apply to all segments of the ISO GPS matrix which are indicated with a filled dot (•).

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 specifications made in accordance with this document, unless otherwise indicated.

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

Geometrical product specifications (GPS) — Basic concepts —

Part 4: Geometrical characteristics for quantifying GPS deviations

1 Scope

This document specifies general rules for quantifying GPS deviations for individual GPS characteristics.

NOTE GPS deviations can be local or global. A GPS characteristic defined from local GPS deviations is a parameter that transforms the set of local deviations into a global characteristic using a quantifying function (for more details, see Table 1).

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 25378, *Geometrical product specifications (GPS) — Characteristics and conditions — Definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 25378 and the following apply.

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

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

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

3.1
local geometrical deviation
$d(P), d(P)_{A_n}$

local signed distance between a point, *P*, of an input feature and a point of the reference feature

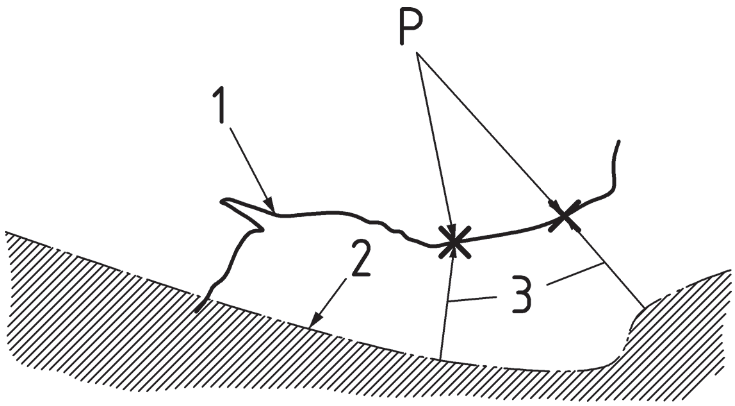
Note 1 to entry: $d(P)$ identifies any local geometrical deviation attached to any point (P) of the input feature.

Note 2 to entry: A local geometrical deviation, $d(P)_{A_n}$, can be located in an n-dimensional reference space, A_n, attached to the reference feature.

Note 3 to entry: A local geometrical deviation exists in any point of the input feature (see Figure 1). Each local geometrical deviation of a point of the input feature can be represented in a reference space, A_n, by the abscises of its corresponding point of the reference feature and by the ordinate corresponding to the local geometrical deviation.

Note 4 to entry: A local geometrical deviation can be described as an ordinate of a point of the variation curve whose abscises are defined in the reference space, A_n.

Note 5 to entry: A local geometrical deviation is equal to zero when the deviated feature crosses the reference feature.



Key

1 deviated feature (input feature)

2 reference feature

3 local geometrical deviation

P point of key 1 from which key 3 is defined

Figure 1 — Local geometrical deviation

3.2
reference space
A_n
space defined by n curvilinear axes attached to a reference feature in which for each point of an input feature a local deviation is defined

Note 1 to entry: n is equal to 1 for a reference line, or equal to 2 for a reference surface.

3.2.1
areal reference space
A_2
reference space (3.2) when the reference feature is a surface

Note 1 to entry: Reference space for a two-dimensional reference feature.

3.2.2
linear reference space
A_1
reference space (3.2) when the reference feature is a line

Note 1 to entry: Reference space for a one-dimensional reference feature.

3.2.3
two-directional reference space
combination of two *linear reference spaces* (3.2.2) of the same linear reference feature whose vectors normal to any point P of the reference feature are orthogonal

3.3
quantifying function
mathematical function using the complete set of local deviations to define a geometrical characteristic as a quantity

Note 1 to entry: A quantifying function can be a *rank-order characteristic* (3.4) (see Table 1).

3.4
rank-order characteristic
geometrical characteristic defined mathematically from a set of local geometrical deviations

Note 1 to entry: A rank-order characteristic is defined from a quantifying function. Several kinds of rank-order characteristics exist. The formulae describing them are given in Table 1.

3.4.1
maximum
characteristic maximum value of a set of local geometrical deviations

Note 1 to entry: See Table 1.

3.4.2
minimum
characteristic minimum value of a set of local geometrical deviations

Note 1 to entry: See Table 1.

3.4.3
average
characteristic average of a set of local geometrical deviations

Note 1 to entry: See Table 1.

3.4.4
median
characteristic median value of a set of local geometrical deviations

Note 1 to entry: The median value splits the population of local geometrical deviations into two equal portions (50 % above and 50 % below). Depending on the distribution of the population, the median value and the average value can be identical or different.

Note 2 to entry: See Table 1.

3.4.5
mid-range
characteristic mean of the *maximum* (3.4.1) and the *minimum* (3.4.2)

Note 1 to entry: See Table 1.

3.4.6
range
characteristic difference between the *maximum* (3.4.1) and the *minimum* (3.4.2)

Note 1 to entry: See Table 1.

3.4.7
maximum absolute deviation
characteristic maximum of absolute values of the *maximum* (3.4.1) and the *minimum* (3.4.2)

Note 1 to entry: See Table 1.

4 Geometrical characteristic

4.1 General

Several families of geometrical characteristics, as defined in ISO 25378, exist:

— intrinsic characteristic: size, form or surface texture characteristics;

— situation characteristics: location, orientation and run-out characteristics.

The specified associated feature to the input feature is the reference feature for a geometrical characteristic (see Figure 2).

NOTE 1 The reference feature is an associated feature. For more information, see ISO 5459.

NOTE 2 It is assumed that the reference feature has the extent necessary for all points on the input feature to have a corresponding point on the reference feature. In some cases, this requires a mathematical extension of the reference feature. The rules for this extension are not given in this document; they are in the standards for specific GPS characteristics.

The reference feature, to evaluate an intrinsic characteristic (size, form or surface texture characteristics), is unrelated to a datum system.

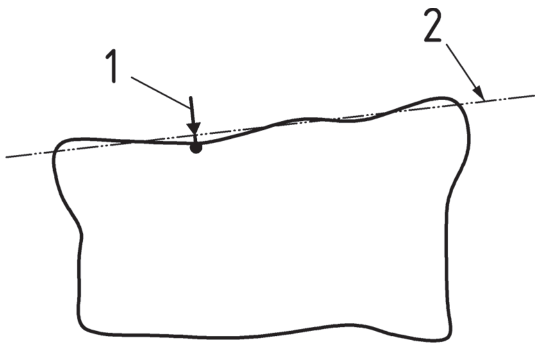
The reference feature, to evaluate a situation characteristic, is related to a datum system (defining orientation or location constraint).

The reference features can be

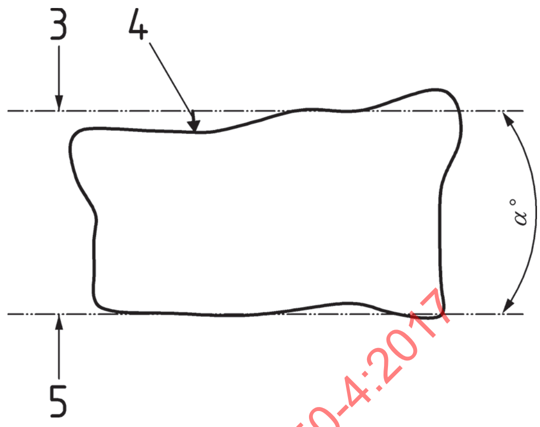
— totally constrained, where all non-redundant degrees of freedom are constrained, or

— partially constrained, where not all non-redundant degrees of freedom are constrained.

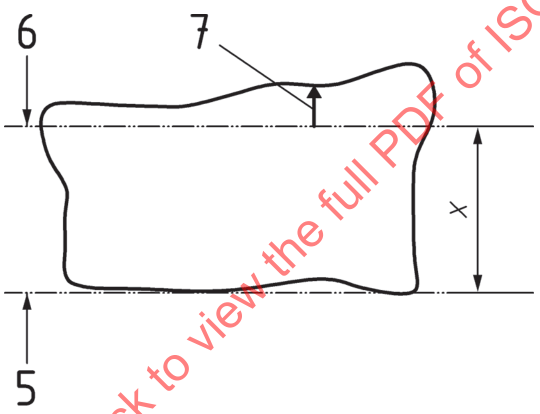
For a geometrical characteristic of form, orientation, location or run-out, the shape of the reference feature is by default the nominal shape of the toleranced feature. When the nominal shape of the toleranced feature belongs to a prismatic, or complex invariance class, then its definition is restricted to its nominal extent. To define any deviation from the reference feature, it is necessary to have a non-restricted definition of the reference feature. The extension of the reference feature compared to its nominal shape is defined by default as the continuity of the nominal shape curvature.



a) Without constraint (form deviation)



b) With orientation constraint (orientation deviation)



c) With location constraint (location deviation)

Key

1 local geometrical form deviation
2 reference feature unrelated to a datum system
3 reference feature, related to a datum system with orientation constraint (α°)
4 local geometrical orientation deviation
5 datum
6 reference feature related to a datum system with location constraint (X mm)
7 local geometrical location deviation

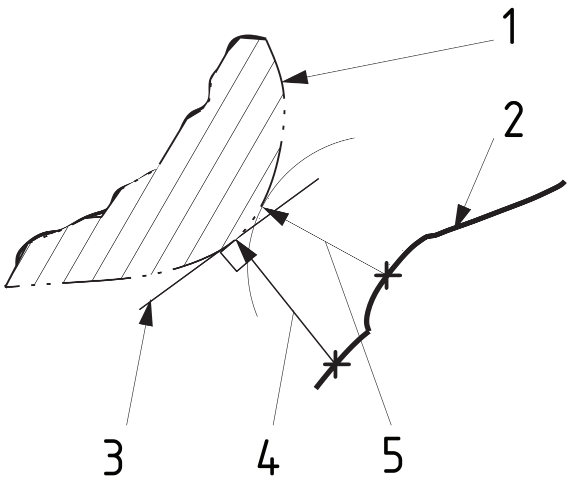
Figure 2 — Examples of reference features with different constraints for the same input feature

4.2 Types of geometrical characteristic

The local geometrical deviations are the basic elements used to establish a geometrical characteristic.

By convention, the positive direction is out of the material.

The default is defined as the minimum distance from a point of the toleranced feature to the reference feature (see Figure 3).



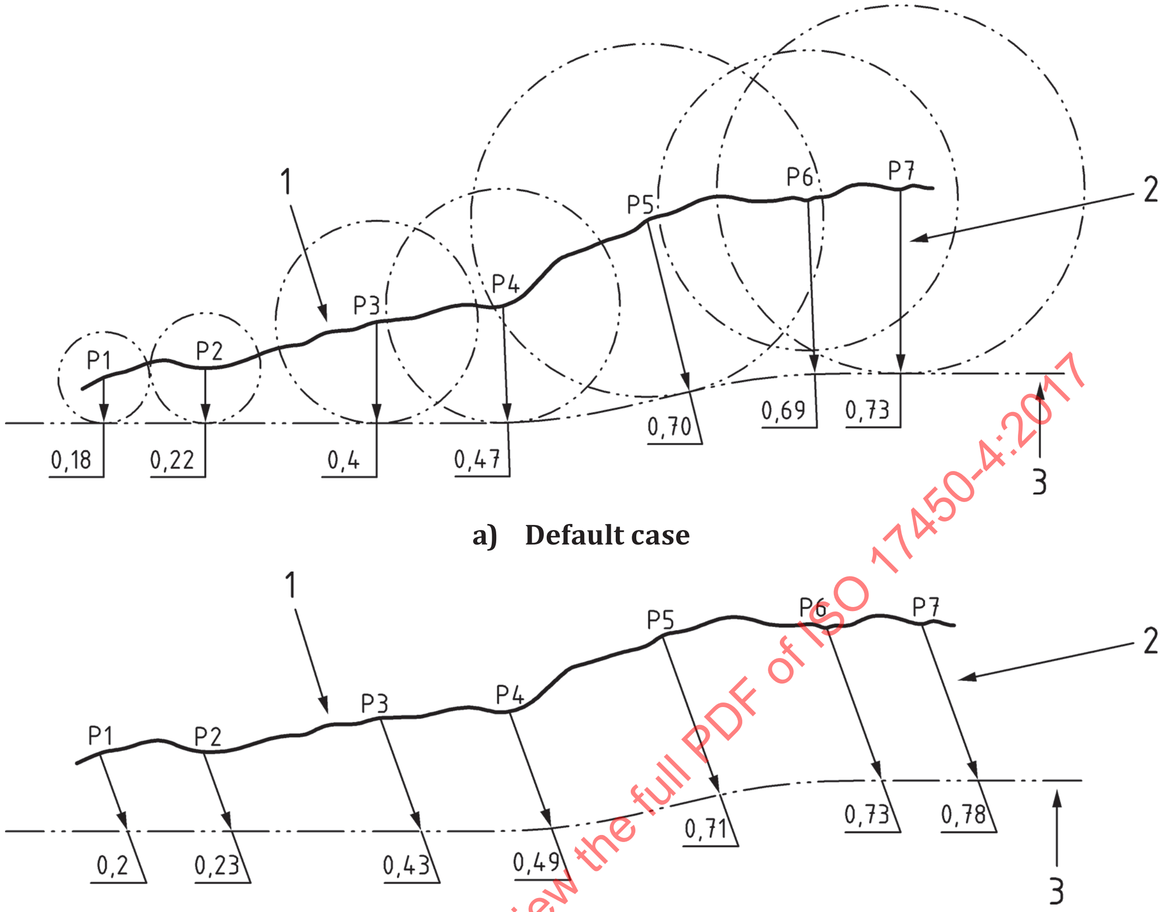
Key

1 reference feature
2 toleranced feature
3 local tangent plane to key 1
4 normal distance from key 2 to key 1
5 minimum distance (default case)

NOTE A local geometrical deviation is defined from any point on the input feature, but for the reference feature, this is not necessary the case. The set of minimal distances and the set of normal distances are not necessarily identical.

Figure 3 — Difference between normal distance and minimum distance

By default, without indication of a specified direction for local evaluation, a local geometrical deviation is defined as the minimum distance between a point, *P*, on the input feature and the reference feature [the direction of local deviations is not predefined; see Figure 4 a)]; otherwise, it is defined as the minimum distance in the specified direction from the input feature (e.g. by using a direction feature); see Figure 4 b).



a) Default case

b) With a specified direction

Key

1 real feature

2 local geometrical deviations

3 reference feature

Figure 4 — Illustrations of different types of local geometrical deviations

The input feature is an extracted feature, or a filtered feature, or a restricted associated feature.

If the input feature is an integral line, then the geometrical characteristic is a linear geometrical characteristic. If the input feature is an integral surface, then the geometrical characteristic is an areal geometrical characteristic.

If the input feature is:

— a derived surface then, the reference space is an areal reference space;

— a line belonging to an integral surface, then the reference space is a linear reference space;

— a derived line in space, then the reference space is a two-directional reference space;

— a derived point, then the reference space is a linear reference space;

— an integral point, then the reference space is linear or areal.

EXAMPLE When the input feature is a derived line (median line) of a cylinder, the areal reference space is a cylindrical space.

Any geometrical characteristic is established as a quantifying function (see examples in Table 1) of a set of local geometrical deviations.

Each quantifying function is established from

a) the variation curve of local geometrical deviations,

b) the variation curve of material ratio, or

c) the variation curve of amplitude distribution.

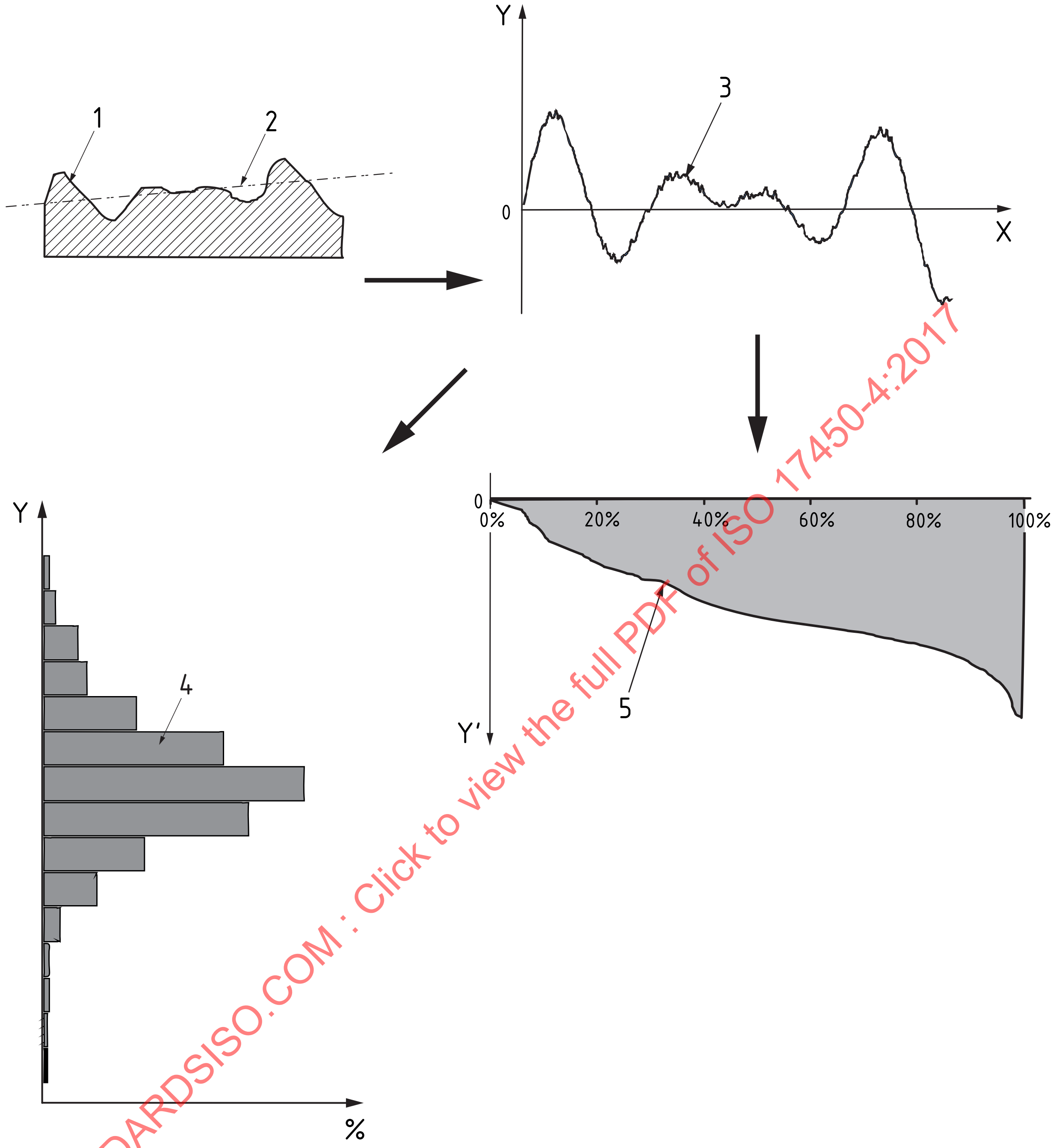
In a local coordinate system defined in a reference space, A_n, the variation curve of the local geometrical deviations is the set of the local geometrical deviations (local ordinate values), over the reference space (linear or areal). This curve can be plotted in a reference space system showing the local ordinate values directly (see Figure 5).

NOTE 1 Since a local geometrical deviation is defined from any point of an input feature, then there are three possibilities for any coordinate in the reference space: no attached local geometrical deviation, one attached local geometrical deviation and more than one attached local geometrical deviation (when the reference feature is less locally smooth than the input feature).

The material ratio curve is a transformation of the variation curve of local geometrical deviations. The material ratio is defined as the percentage of material seen for any value of the geometrical characteristic between its minimum value and its maximum value.

NOTE 2 The material ratio curve can be interpreted as the cumulative probability function along a reference space.

A variation curve of amplitude distribution is a transformation of the variation curve of the local geometrical deviations curve. The variation curve of amplitude distribution is defined as the derivative of the material ratio curve, indicating the probability over the reference space that a local geometrical deviation level has a certain value.



Key

1 extracted integral feature

2 reference feature

3 variation curve of local geometrical deviations

4 amplitude distribution variation curve

5 variation curve of material ratio

X abscisse in reference space

Y amplitude of local geometrical deviation

Y′ amplitude of local geometrical deviation below the highest point in key 3

Figure 5 — Illustration of the process establishing a variation curve

A geometrical characteristic is defined by a quantifying function which is a mathematical operator. The quantifying functions given in Table 1 are applied over the variation curve of local geometrical deviations (see ISO 25378).

Other mathematical operators can be defined when a geometrical characteristic results from the variation curves of material ratio or of amplitude distribution.

NOTE 3 The mathematical operators can be applied over a portion of the geometrical feature, taken anywhere along the extracted (integral or derived) feature. Mathematical operators can be applied first in one direction in the reference space, and subsequently in the other direction, or directly in the two directions of the reference space. This process can be repeated until the geometrical characteristic becomes a global characteristic.

Table 1 — Simple quantifying functions defined on the variation curve of local geometrical deviation

Name of the quantifying function	Rank-order operator	Mathematical description of a quantifying function[a]	
		On a continuous model [from $d(P)_{A_n}$]	On a discontinuous model[b] [from $d(P) = d_i$]
Maximum	Yes	$\max\left[d(P)_{A_n}\right]$	$\max\left[d(P)\right]$
Minimum	Yes	$\min\left[d(P)_{A_n}\right]$	$\min\left[d(P)\right]$
Maximum absolute deviation	Yes	$\max\left\{\left\|\max\left[d(P)_{A_n}\right]\right\|;\left\|\min\left[d(P)_{A_n}\right]\right\|\right\}$	$\max\left\{\left\|\max\left[d(P)\right]\right\|;\left\|\min\left[d(P)\right]\right\|\right\}$
Median	Yes	$d(P)_{50\,\%} = d_{50\,\%}$	$\tilde{d}$
Range	Yes	$\max\left[d(P)_{A_n}\right]-\min\left[d(P)_{A_n}\right]$	$\max\left[d(P)\right]-\min\left[d(P)\right]$
Mid-range	Yes	$\frac{1}{2}\left\{\max\left[d(P)_{A_n}\right]+\min\left[d(P)_{A_n}\right]\right\}$	$\frac{1}{2}\left\{\max\left[d(P)\right]+\min\left[d(P)\right]\right\}$
Peak height	Yes	$\left\|\max\left[d(P)_{A_n}\right]\right\|$	$\left\|\max\left[d(P)\right]\right\|$
Valley depth	Yes	$\left\|\min\left[d(P)_{A_n}\right]\right\|$	$\left\|\min\left[d(P)\right]\right\|$
Doubled maximum deviation[d]	Yes	$2\cdot\max\left\{\left\|\min\left[d(P)_{A_n}\right]\right\|;\left\|\max\left[d(P)_{A_n}\right]\right\|\right\}$	$2\cdot\max\left\{\left\|\min\left[d(P)\right]\right\|;\left\|\max\left[d(P)\right]\right\|\right\}$
Average	No	$\mu = \frac{1}{\int_{A_n} dA_n}\cdot\int_{A_n} d(P)_{A_n}\cdot dA_n$	$\bar{d} = \frac{\sum_{i=1}^{m} w_i \cdot d_i}{\sum_{i=1}^{m} w_i}$

[a] For information, see ISO 3534-1.

[b] m extracted points, each one having a weighting w_i. The weighting of each point is equal to 1 when the extracted points of the toleranced feature are uniformly distributed.

[c] For geometrical specifications, the target value, τ, is considered equal to zero.

[d] In the case of the minimax criterion (Chebyshev without material constraint) used to establish the reference feature, there is no difference between the results obtained on a discontinuous model from the functions “doubled maximum deviation” or “range”.

Table 1 *(continued)*

Name of the quantifying function	Rank-order operator	Mathematical description of a quantifying function[a] On a continuous model [from $d(P)_{A_n}$]	On a discontinuous model[b] [from $d(P) = d_i$]
Standard deviation	No	$\sigma = \sqrt{\frac{1}{\int_{A_n} dA_n} \cdot \int_{A_n} \left[d(P)_{A_n} - \mu \right]^2 \cdot dA_n}$	$s = \sqrt{\frac{\sum_{i=1}^{m} w_i \cdot \left(d_i - \bar{d}\right)^2}{\left(\sum_{i=1}^{m} w_i\right) - 1}}$
Inertia	No	$\sqrt{(\mu - \tau)^2 + \sigma^2}$ [c]	$\sqrt{\left(\bar{d} - \tau\right)^2 + s^2}$ [c]
Average of absolute values	No	$\frac{1}{\int_{A_n} dA_n} \cdot \int_{A_n} \left\| d(P)_{A_n} \right\| \cdot dA_n$	$\overline{\|d\|} = \frac{\sum_{i=1}^{m} w_i \cdot \|d_i\|}{\sum_{i=1}^{m} w_i}$
Skewness	No	$\frac{1}{\sigma^3} \cdot \left[\frac{1}{\int_{A_n} dA_n} \cdot \int_{A_n} \left[d(P)_{A_n} - \mu \right]^3 \cdot dA_n \right]$	$\gamma_1 = \frac{n}{(n-1) \cdot (n-2)} \times \sum_{i=1}^{m} \left(\frac{d_i - \bar{d}}{s} \right)^3$
Kurtosis	No	$\frac{1}{\sigma^4} \cdot \left[\frac{1}{\int_{A_n} dA_n} \cdot \int_{A_n} \left[d(P)_{A_n} - \mu \right]^4 \cdot dA_n \right]$	$\beta_2 = \frac{n \cdot (n+1)}{(n-1) \cdot (n-2)(n-3)} \cdot \sum_{i=1}^{m} \left(\frac{d_i - \bar{d}}{s} \right)^4 - \frac{3 \cdot (n-1)^2}{(n-2)(n-3)}$

a For information, see ISO 3534-1.

b *m* extracted points, each one having a weighting w_i. The weighting of each point is equal to 1 when the extracted points of the toleranced feature are uniformly distributed.

c For geometrical specifications, the target value, *τ*, is considered equal to zero.

d In the case of the minimax criterion (Chebyshev without material constraint) used to establish the reference feature, there is no difference between the results obtained on a discontinuous model from the functions "doubled maximum deviation" or "range".

One of these quantifying functions is used in a geometrical specification to define the geometrical characteristic.

Figure 6 shows a set of the local geometrical deviations defined as signed distances between an extracted integral feature and a reference feature, which is a circle with fixed size, located from a datum system. These local distances define the variation curve.