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Geometrical product specifications (GPS) — Decomposition of geometrical characteristics for manufacturing control

Spécification géométrique des produits (GPS) — Décomposition des caractéristiques géométriques pour la maîtrise de la fabrication

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

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 specifications (GPS) standard and is to be regarded as a fundamental GPS standard (see ISO 14638). It influences indirectly chain link E of the chains of standards of geometrical characteristic (size, distance, form, orientation, location and run-out) in the general GPS matrix model as graphically illustrated in Table A.1. The measurement as given in chain link E is decomposed to evaluate quantity values of a geometrical characteristic, and to define manufacturing adjustment values, not to manage the conformance of a workpiece.

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.

The geometrical specification, as defined in ISO 1101, allows the evaluation of conformance or non-conformance by defining a limit value for a geometrical characteristic as a univariate characteristic (non-signed value). This evaluation alone does not provide the information necessary to adjust machine tools parameters to maintain the production of conforming workpieces. The goal of decomposition of the measurement result is to isolate parameter values that can be used to adjust the manufacturing process. This document uses simple examples to illustrate the fundamental principles.

This document defines a number of independent characteristics obtained by decomposition that are intended to assist with adjusting and evaluating the manufacturing process.

In statistical analysis the mean value and standard deviation are used to calculate capability indices. In the case of a position tolerance, for example the location of a hole, which applies in a plane perpendicular to the axis of the hole, the position characteristic is two times the radial distance between the centre of the hole and its theoretically exact location. Capability indices based on the mean value and standard deviation of this characteristic do not properly reflect the capability of a manufacturing process. Instead, the position characteristic could be decomposed according to the kinematic arrangement of the manufacturing process. If the axis of the hole is manufactured using a machine with linear X- and Y-axes, the position characteristic could be decomposed into an X-component and a Y-component and the studies of capability could be calculated based on these components so that they properly reflect the capability of the manufacturing process.

Geometrical product specifications (GPS) — Decomposition of geometrical characteristics for manufacturing control

1 Scope

This document describes principles and tools to control a manufacturing process in accordance with a GPS specification. For this purpose a set of one or more complementary, independent characteristics (size, form, orientation, and location characteristics independent to each other) that correlate to the manufacturing process parameters and to the manufacturing process coordinate system established from the manufacturing datum system are used.

This document describes the concept of decomposition of the macro-geometrical part of the GPS specification. It does not cover the micro-geometry, i.e. surface texture.

The objective of the decomposition presented in this document is to define correction values for manufacturing control or to perform a statistical analysis of the process.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
univariate characteristic
characteristic represented by a single scalar variable

EXAMPLE A global size characteristic is a univariate characteristic.

3.2
collected characteristic
C
set of a *univariate characteristic* (3.1) and the multivariate characteristic required to derive it (see 3.3)

EXAMPLE For a position specification, the median line of a hole is constrained by a cylindrical tolerance zone with a diameter of 0,4 mm. The global univariate characteristic result is 0,5 mm (out of tolerance). The decomposition of the location in two directions (X, Y) at a given height is given by the multivariate characteristic result (+0,15; +0,2). The collected characteristic combines the global result and its decomposition.

			Result of evaluation mm
Collected characteristic	Univariate characteristic		0,5
	Observed deviation		0,25
	Multivariate deviations	X	+0,15
		Y	+0,2

Note 1 to entry: A collected characteristic is a set of more than one independent variable and the final result from this set of variables, e.g. $\boldsymbol{C}$ (A, G_F, G_S, G_O, R_X, R_Y, R_Z, G_L, T_X, T_Y, T_Z). See Table 1 for an example.

Note 2 to entry: A collected characteristic is a vector.

3.3
decomposition
<manufacturing> operation establishing a multivariate characteristic from a *univariate GPS characteristic* (3.1)

Note 1 to entry: The purpose of the decomposition for manufacturing is to define a multivariate characteristic that consists of a set of variables, each of which is related to a manufacturing process parameter (See 5.2).

3.4
location point
defined point on the reference feature used to locate a geometrical feature

3.5
real orientation vector
$\boldsymbol{V}_{AO}$
unit vector defining the orientation of the extracted feature from the situation feature of the associated feature in a specified Cartesian system

3.6
nominal orientation vector
$\boldsymbol{V}_{TO}$
unit vector defined from the situation feature of the nominal feature in a specified Cartesian system

3.7
angular deviation set
$\boldsymbol{V}_{\Delta O}$
vector having components which are the angles defined in a specified Cartesian system allowing the transformation of the *real orientation vector* (3.5) into the *nominal orientation vector* (3.6)

3.8
actual location vector
$\boldsymbol{V}_{AL}$
vector defining the location of the extracted feature from the origin of a specified Cartesian system to the *location point* (3.4) of the situation feature of the associated integral feature

3.9
theoretical location vector
$\boldsymbol{V}_{TL}$
vector defined from the origin of a specified Cartesian system to a location point of a situation feature of the nominal geometrical feature (integral, or derived)

3.10
deviation location vector
$\boldsymbol{V}_{\Delta L}$
vector defined as the difference between the actual location vector (3.8) and the theoretical location vector (3.9)

Note 1 to entry: The components of the deviation location vector defined on the X-axis, Y-axis, and Z-axis of the specified Cartesian system are designated as T_X, T_Y, T_Z.

4 Symbols

The list of symbols is given in Table 1.

Table 1 — Symbols

Symbol	Description
$\boldsymbol{C}$	Generic symbol of a collected characteristic, which is a vector
A	Actual value of the specified GPS characteristic
O	Actual value of the orientation GPS characteristic
G_F	Independent form characteristic
G_S	Independent global size characteristic
G_O	Independent orientation characteristic, corresponding to the effect of the angular deviation (R_x, R_y, R_z) in length unit by considering the orientation deviation defined from the restricted associated feature
G_L	Independent location characteristic, corresponding to the effect of the linear deviation (T_x, T_y, T_z) considering the location deviation of the reference feature of the orientation characteristic from the theoretically exact location
$\boldsymbol{V}_{AO}$	Real orientation vector for the extracted feature in the coordinate system
$\boldsymbol{V}_{TO}$	Nominal orientation vector for the nominal feature in the coordinate system
$\boldsymbol{V}_{\Delta O}$	Angular deviation set from the theoretically exact orientation in the coordinate system
$\boldsymbol{V}_{AL}$	Actual location vector for a specific point defined from extracted feature in the coordinate system
$\boldsymbol{V}_{TL}$	Theoretical location vector for a specific point defined on the nominal feature in the coordinate system
$\boldsymbol{V}_{\Delta L}$	Deviation location vector from the theoretically exact location in the coordinate system
R_X, R_Y, R_Z	Rotation angle components around axes of the coordinate system
T_X, T_Y, T_Z	Components of $\boldsymbol{V}_{\Delta L}$ which are the translation deviations from the theoretically exact location of the location point
NOTE A geometrical GPS characteristic is defined in ISO 25378 as a "zone characteristic".	

5 Principles

5.1 General

A GPS specification is a condition (a tolerance) applied on a univariate characteristic.

In particular for a geometrical tolerance, this characteristic can include several types of independent deviations (size, form, orientation and location) and other kinds of deviation parameters (angle deviations, location deviations). To control the manufacturing process, these deviations shall be separated. This document presents a way to perform this separation for a geometrical specification, giving inputs to corrections to manufacturing process parameters. The decomposition of a GPS characteristic yields the components of the collected characteristic. These shall be measurable quantities. These components can be independent GPS characteristics (form, size, orientation and location) or components from which rotation or translation parameters reflecting the kinematics of the manufacturing process can be derived.

Typically, the univariate characteristic of a GPS specification is defined from a set of distances between an input feature (the toleranced feature) and a reference feature or a set of sizes. This definition is the primary model of decomposition for the GPS specification, having these n distances as the independent variables. Therefore if the specification is verified on a feature using for example 1 000 points on the

surface, this primary model of decomposition would result in 1 000 distances. However, these 1 000 distances cannot be used directly for manufacturing process corrections.

Three geometrical features shall be distinguished in this kind of operation: the extracted feature, its associated feature and the situation feature of the associated feature.

5.2 Decomposition process

The first step of the decomposition is to define the default form GPS characteristic of the toleranced feature (integral or derived), G_F [see Figure 2 d), Figure 3 d) and Figure 4 d)]. If the associated features are established by another association criteria than the default criteria (minimax – Chebyshev) then it shall be stated in the report of results of decomposition.

NOTE The curve variation of form deviation can itself be analysed by decomposition (e.g. by Fourier analysis or modal discrete decomposition). It is not the intent of this document to describe this process of form decomposition.

To separate the signed orientation and location parameters, a coordinate system, for example a Cartesian system or a polar system, shall be defined for manufacturing purpose from the datum system attached to the manufacturing process. If the specification datum system does not lock all degrees of freedom, it shall be complemented by a secondary datum and/or a tertiary datum defined from the workpiece interface surfaces with the manufacturing machine.

The orientation parameters (R_X, R_Y, R_Z) expressed by $V_{\Delta O}$, shall be given in angular units.

The form characteristic (G_F), the independent size characteristic (G_S), the independent orientation characteristic (G_O), the location parameters (T_X, T_Y, T_Z) and the independent location characteristic (G_L) shall be given in linear (length) unit.

The independent size characteristic, (G_S), only applies to features of size or to a non-feature of size on which an offset can be applied and which changes its nominal shape. For a feature of size, it is defined as the difference between the size of the direct associated integral feature and the nominal size. For a non-feature of size on which an offset can be applied, the size deviation parameter defines the observed offset from the nominal shape.

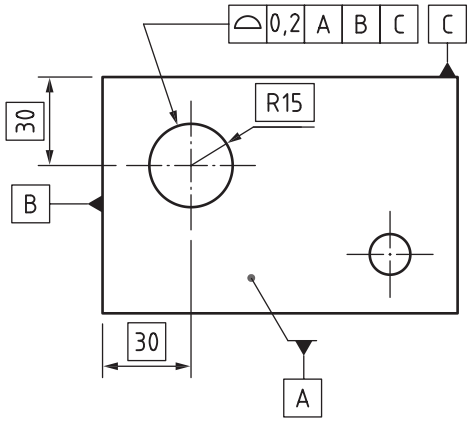
The direction vector of the form reference feature allows establishing the transfer angles (R_X, R_Y, R_Z) from the geometrical specification Cartesian system. The relation between the manufacturing Cartesian system and the geometrical specification Cartesian system is used to define the correction to the manufacturing process. To evaluate the independent characteristic, the restricted associated feature shall be established by projecting the extracted feature onto the form reference feature.

The orientation reference feature is defined from the restricted associated feature. The independent orientation characteristic, (G_O), is evaluated as an orientation characteristic established from the restricted associated feature (corresponding to the extracted feature, see Figure 2 e), Figure 3 e), and Figure 4 e). The independent orientation characteristic can be decomposed in three angles (R_X, R_Y, R_Z).

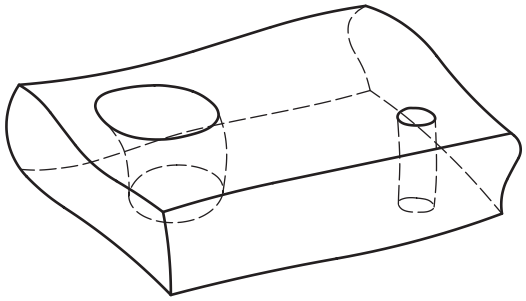
The independent location characteristic, (G_L), is the signed distance between the location reference feature and the orientation reference feature, at the location point (considered on the location reference feature). The independent location characteristic shall be described in the manufacturing Cartesian system. By default, it is the distance between the location point (belonging to the orientation reference feature) and its theoretical exact location (see Figure 4 f).

The independent location characteristic can be decomposed in three linear components (T_X, T_Y, T_Z).

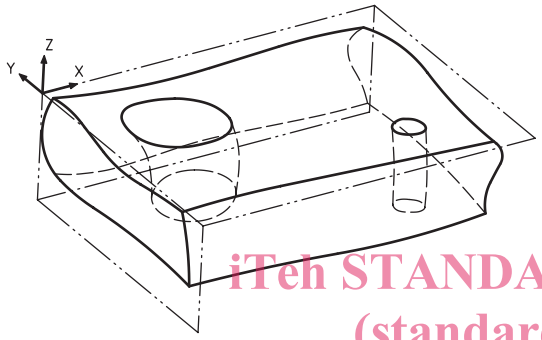
Figure 1 a) presents a geometrical specification with datum system where the manufacturing datum system is considered identical to the specified datum system. Figure 1 b) illustrates the manufacturing result: the workpiece. Figures 1 c) to f) illustrate steps of the decomposition process of a specified geometrical characteristic.



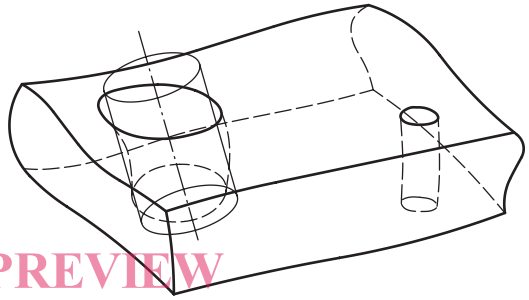
a) GPS specification



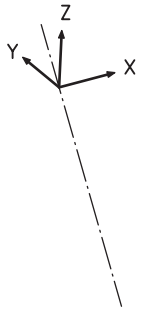
b) Workpiece



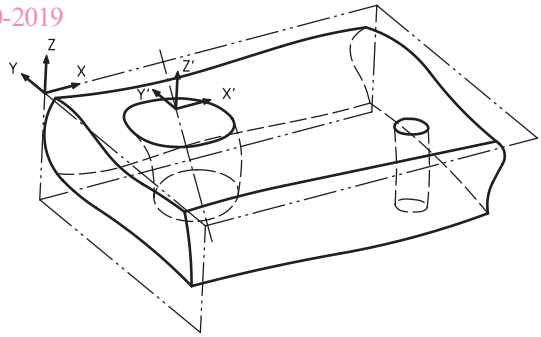
c) Step 1: datum system and Cartesian system (see Note 1)



d) Step 2: independent form and size characteristics (see Note 2)



e) Step 3: independent orientation characteristic (see Note 3)



f) Step 4: independent location characteristic (see Note 4)

NOTE 1 To determine the collected characteristic (see Table 4):

— the univariate characteristic is the result of the evaluation of GPS location specification.

— the multivariate characteristic is the result of the decomposition, i.e. the set of independent size, form, orientation, and location characteristic evaluations.

NOTE 2 After a first association, the evaluation of the size deviation parameter and of the form deviation is considered independently.

NOTE 3 The evaluation of the angular deviations is established from the situation feature of the previous associated feature from the datum A.