INTERNATIONAL STANDARD

ISO 10360-6

First edition
2001-12-15

Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 6: Estimation of errors in computing Gaussian associated features

Spécification géométrique des produits (GPS) — Essai de réception et de vérification périodique des machines à mesurer tridimensionnelles (MMT)
Partie 6: Estimation des erreurs dans le calcul des éléments associés gaussiens

Reference number
ISO 10360-6:2001(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 10360 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10360-6 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 10360 consists of the following parts, under the general title *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM)*:

— *Part 1: Vocabulary*

— *Part 2: CMMs used for measuring size*

— *Part 3: CMMs with the axis of a rotary table as the fourth axis*

— *Part 4: CMMs used in scanning measuring mode*

— *Part 5: CMMs using multiple-stylus probing systems*

— *Part 6: Estimation of errors in computing Gaussian associated features*

Annex A forms a normative part of this part of ISO 10360. Annex B is for information only.

Introduction

This part of ISO 10360 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences link 5 of the chains of standards on size, distance, radius, angle, form, orientation, location, run-out and datums.

For more detailed information of the relation of this part of ISO 10360 to other standards and the GPS matrix model see annex B.

Coordinate measurement technology is widely used in industrial metrology to assess features of a workpiece. A common requirement is to fit an associated feature to a data set consisting of coordinate measurements of a real feature. This fitting is carried out by software.

Software for calculating an associated feature provides values of parameters of the associated feature that are descriptive of the size, shape, location and orientation of the feature. These parameters are useful

— for the purpose of carrying out calculations involving the feature, often in conjunction with other associated features and other information, and

— in determining the extent to which a workpiece satisfies dimensional and positional specifications.

The reliability of information about features that is determined from associated features is influenced by the quality of the software for computing these features.

The tests defined in this part of ISO 10360 are concerned with assessing the correctness of the parameters of computed associated features as measured by a coordinate measuring machine (CMM) or other coordinate measuring system. Although different criteria may be used to compute associated features, for example, by minimizing the Euclidean or Chebyshev norm of residuals, this test is applicable for software designed for unconstrained Gaussian (least-squares) features.

In the case of reverification tests of CMMs, the software test of this part of ISO 10360 usually does not provide new or different information in comparison with that obtained by an acceptance test, since software is supposed to be stable over time. However, a reverification test of the software may be useful following possible corruption or alteration of the software under test.

For software already in existence, the evaluation of the performance may not be obtained only by fulfilling the requirements of this part of ISO 10360. However, such cases do not necessarily exclude the ability of the software to perform correct computation of measurements.

This part of ISO 10360 is applicable to software submitted for test in respect of the values it provides for the parameters of an associated feature. The test procedure is based on applying the software under test to reference data sets, and comparing the results obtained with reference results.

Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 6: Estimation of errors in computing Gaussian associated features

1 Scope

This part of ISO 10360 specifies a method for testing software used for computing associated features from coordinate measurements. The features of concern are the line (in two and three dimensions), the plane, the circle (in two and three dimensions), the sphere, the cylinder, the cone and the torus.

One or more separate tests are required for each feature claimed to be covered by the software.

The test is of the software alone and therefore independent of the coordinate measuring system.

NOTE 1 If the result of the test indicates that the performance values for linear size parameters of the associated feature are significant compared with the error of indication of a CMM for size measurement (see ISO 10360-2), as provided by the CMM manufacturer, the software is inadequate for application on that measuring system. However, small performance values, obtained as a result of this test, do not provide complete assurance that the software is totally suitable for computing associated features.

This part of ISO 10360 is concerned with complete features and non-extremely partial features; however, the test for complete features and that for partial features are separate, and software may be submitted for either or both tests.

Cones with very large apex angles are not covered by the test.

NOTE 2 Associated cones with very large angles are unusual in practice and the software for their stable computation is not widely available.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10360. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10360 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 10360-1:2000, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 10360-2:2001, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 2: CMMs used for measuring size*

ISO 14253-1:1998, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications*

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

ISO 14660-2:1999, *Geometrical product specifications (GPS) — Geometrical features — Part 2: Extracted median line of a cylinder and a cone, extracted median surface, local size of an extracted feature*

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM, IFCC, IEC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993

3 Terms and definitions

For the purposes of this part of ISO 10360, the terms and definitions given in ISO 10360-1, ISO 14660-1, ISO 14660-2 and VIM apply.

4 Basic requirements

The following basic requirements shall be met by the software supplier.

a) The software under test shall have an unambiguous and unique identification (e.g. a release number).

   Improper applications of the test result to other versions of the software under test are forbidden. The testing body is allowed to satisfy the request by an owner of (a license of) the software under test and its test certificate to re-run the test based on the reference data sets identified by the release number reported in the test certificate.

b) The software under test shall provide a means of

   1) direct input of a reference data set and output of test parameter values to adequate numerical precision (see clause 8), bypassing the measurement and software correction parts of the system, and

   2) inputting 2D coordinates to the software under test for computing 2D associated features (line and circle in two dimensions); if this is not available, it is tolerated to add a dummy null z coordinate to each point in the reference data sets, thus projecting the feature onto the xy coordinate plane.

   NOTE 1 The input and output procedures associated with some measuring systems may be limited in terms of the numerical precision of the values transmitted. This limitation may disadvantage the software under test in terms of the test results obtained.

c) The method of input to, and output from, the processor is to be agreed with the testing body.

   NOTE 2 It may be convenient to use a standard computer-readable medium in a standard format (e.g. ASCII on a 3,5" disk).

d) Corresponding to each feature for which the software under test is to be tested, a statement of the parametrization of the feature used by the software under test shall be provided.

   NOTE 3 Reference parametrizations are given in Table 3.

e) Corresponding to each feature for which the software under test is to be tested and to the test type (see Table 2), a statement of the maximum permissible errors, MPEq, of the relevant parameter classes (see 9.3) shall be provided.

5 Reference data sets and reference parameter values

5.1 General

The reference data sets and the corresponding reference parameter values used for the purposes of testing the software under test shall be generated according to the procedure specified in annex A. The reference data sets are designed to simulate a range of sizes, shapes, locations, orientations and sampling of features. They are also designed to simulate typical CMM errors of measurement, including probing errors, and feature form deviations.

The reference data sets and the reference parameter values generated according to annex A shall be used only once for verification of any software under test (see A.1).

5.2 Initial estimates of parameter values

Software under test may require that a subset of the points input to the software, usually the first ones in the set, has a predefined sampling pattern. This subset is used to determine the initial estimates of the parameter values. When this requirement is written in the operating instructions of the software under test, and upon request of the software supplier, the testing body shall generate additional points consistent with the predefined sampling pattern. These additional points form the subset added to the data as generated according to annex A to form a reference data set. These circumstances shall be noted on the test certificate [see clause 11, e)].

NOTE 1 The software under test typically employs iterative methods of calculation for determining the values of the parameters of the associated feature. For this purpose, identification of a subset of points may be required, from which initial estimates of these values can be computed.

NOTE 2 A Gaussian associated cylinder can be used for purposes of illustration: the first six points in a reference data set could be identified as a subset for initial-estimation purposes. For instance, the line joining the centres of the circles defined by the first three points and the second three points could be used as an approximation to the axis of the associated cylinder, and the radii of these circles could be used as approximations to the radius of the associated cylinder.

NOTE 3 Software under test which does not require initial estimates of the parameter values is more robust, being self-contained, and does not impose an operating procedure for measuring real features.

6 Test parameter values and converted test parameter values

Since different software suppliers may use different parametrizations, for the purposes of the test, the test parameter values produced by the software under test shall be modified, if necessary, by applying a conversion rule to produce converted test parameter values. The converted test parameter values so derived correspond to the same parametrization as the reference parameter values and can meaningfully be compared with them.

For this purpose, the software supplier shall provide full details of the test parametrization.

When necessary, the testing body shall implement and apply the appropriate conversion rule.

It is recommended that the software supplier provide test parameter values to adequate numerical resolution (see clause 8), in order that uncertainty may not be unnecessarily added in producing converted test parameter values.

Software under test may fail to produce results for some reference data sets.

NOTE Failure to produce results may be due to, for example:

a) the software under test indicating that the data set cannot be processed because it is beyond its domain of application (e.g. it contains too many data points or the data points are unsuitably distributed), or

b) lack of convergence of an iterative algorithm, or

c) a fatal error that has arisen during execution of the software (e.g. a floating-point overflow or an attempt to take the square root of a negative number).

7 Units

The units specified in Table 1 shall be used.

Table 1 — Units

	Reference data sets	Reference parameter values
Point coordinates	millimetres	—
Location parameters	—	millimetres
Size parameters	—	millimetres
Angle parameters	—	radians
Orientation parameters	—	(dimensionless) [a]
Submultiples, for example, micrometres and microradians, may be used on the test certificate for quoting differences between the converted test parameter values and corresponding reference parameter values and their uncertainties.		
[a] The orientation parameters are expressed as direction cosines.		

8 Numerical uncertainty

It is the responsibility of the testing body to evaluate any numerical uncertainty introduced by the finite number of digits used to transfer information and to represent numerical values computationally. This numerical uncertainty shall be included in the uncertainty statement reported in the test certificate (see clause 10).

NOTE 1 Information transferred includes point coordinates in reference data sets and reference parameter values (controlled by the testing body), as well as test parameter values (submitted by the software supplier).

NOTE 2 The computational representation affects the calculation of reference parameter values from reference data sets (in the case of reference software, see Figure 2) or reference data sets from reference parameter values (in the case of data generators, see Figure 3), in applying conversion rules and in calculating q values [see 9.3, d)].

NOTE 3 The numerical uncertainty also depends on how well a Gaussian associated feature is defined by a reference data set or, equivalently, the numerical condition of the fitting problem (a measure of the perturbation in the reference parameter values relative to a small perturbation in the coordinate values in a reference data set). The condition is influenced by the type of feature, and by the number and locations of points in the reference data set.

NOTE 4 The numerical uncertainty can be estimated by simulation if an analytical evaluation is not straightforward.

Depending on the manner in which the information is produced, the testing body may regard either the reference data sets or the reference parameter values as exact, provided the appropriate uncertainty is determined in the other.

9 Application of the test method

9.1 Principle

The principle underlying the method of test is that of comparing converted test parameter values with reference parameter values (see Figure 1). The converted test parameter values are obtained by applying the software under test to the reference data sets to obtain test parameter values, and by applying a conversion rule to these test parameter values. Each reference data set and the corresponding reference parameter values are regarded as a reference pair for testing purposes.

NOTE 1 The testing body will provide reference pairs using, for example, reference software or a data generator, as illustrated in Figures 2 and 3.

Different software under test may be intended, and regularly used, for different applications (e.g. for calculating complete or partial features), or with measurement points affected by small or large noise or form deviations or both. To tailor the test accordingly, four types of tests are possible, as summarized in Table 2; simplified tests are subsets of the corresponding regular tests, and are intended for software not designed for severe applications. The software supplier may choose the test or tests to which to submit the software under test; the test or tests chosen shall be reported in the test certificate.

NOTE 2 Since no partial features can be defined for lines in two and three dimensions and planes, tests are not available for these features in tests of the following types: partial feature, simplified test; partial feature, regular test.

A separate test shall be carried out for each feature and each test type (see Table 2).

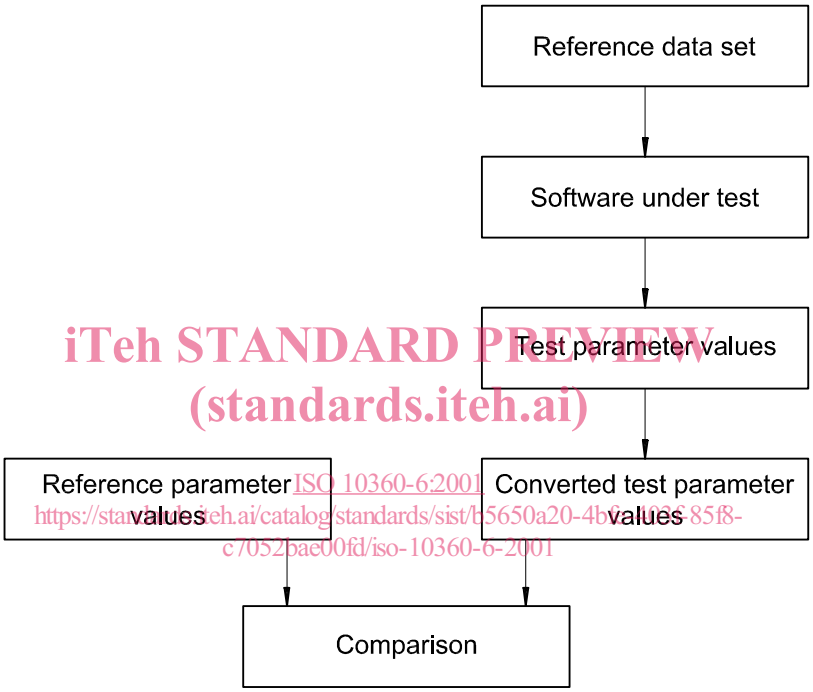

Figure 1 — Principle of test method

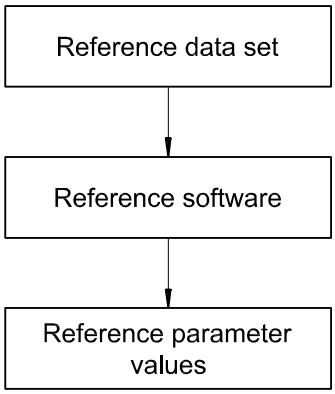

Figure 2 — Use of reference software for producing reference pairs