TECHNICAL SPECIFICATION

ISO/TS 15530-4

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Geometrical Product Specifications (GPS) — Coordinate measuring machines (CMM): Technique for determining the uncertainty of measurement —

Part 4: Evaluating task-specific measurement uncertainty using simulation

Spécification géométrique des produits (GPS) — Machines à mesurer tridimensionnelles (MMT): Technique pour la détermination de l'incertitude de mesure —

Partie 4: Évaluation de l'incertitude de mesure spécifique d'une tâche à l'aide de simulations

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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 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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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 15530-4 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification.*

ISO/TS 15530 consists of the following parts, under the general title *Geometrical Product Specifications (GPS) — Coordinate measuring machines (CMM): Technique for determining the uncertainty of measurement*:

— *Part 3: Use of calibrated workpieces or standards* [Technical Specification]

— *Part 4: Evaluating task-specific measurement uncertainty using simulation* [Technical Specification]

The following part is under preparation:

— *Part 2: Use of multiple measurements strategies in calibration artefacts* [Technical Specification]

The following part is planned:

— *Part 1: Overview and general issues*

Introduction

This part of ISO 15530 is a Geometrical Product Specification (GPS) Technical Specification and is to be regarded as a general GPS document (see ISO/TR 14638). It influences the chain link 6 of the chain 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 15530 to the GPS matrix model, see Annex H.

For coordinate measuring machines (CMMs) used to inspect tolerances according to ISO 14253-1, the task-specific uncertainties of measurement are taken into account when tests for conformity/non-conformity are carried out. While knowledge of the uncertainty of measurement is important, up to the present, there have been only a few procedures that allow the task-specific uncertainty of measurement to be stated.

For simple measuring devices, this uncertainty can be evaluated by an uncertainty budget according to the recommendations of the *Guide to the expression of uncertainty in measurement (GUM)*. However, in the case of a CMM, the formulation of a classical uncertainty budget is impractical for the majority of the measurement tasks due to the complexity of the measuring process.

Alternate methods that are consistent with the GUM can be used to determine the task-specific uncertainty of coordinate measurements. One such method that evaluates the uncertainty by numerical simulation of the measuring process allowing for uncertainty influences is described in this part of ISO 15530.

To allow CMM users to easily create uncertainty statements, CMM suppliers and other third party companies have developed uncertainty evaluating software (UES). UES is based on a computer-aided mathematical model of the measuring process. In this model, the measuring process is represented from the measurand to the measurement result, taking important influence quantities into account.

In the simulation, these influences are varied within their possible or assumed range of values (described by probability distributions), and the measuring process is repeatedly simulated, using possible combinations of the influence quantities. The uncertainty is determined from the variation of the final result.

This procedure is compatible with the fundamental principles of the internationally valid *Guide to the expression of uncertainty in measurement (GUM)*. The details of the UES are often hidden in compiled computer code making it difficult for the user to assess the reliability of the calculated uncertainty statements. This part of ISO 15530 sets forth terminology and testing procedures for both the UES supplier and the CMM user to communicate and quantify the capabilities of UES.

This part of ISO 15530 begins by considering the declaration of influence quantities. The declarations identify which influence quantities, along with their ranges of values, the UES can account for in its uncertainty evaluation. For example, some UES can include the effects of using multiple styli during a CMM measurement, while others cannot.

Similarly, some UES can include the effects of spatial temperature gradients or variations of temperature over time, while others cannot. The purpose of the declaration section is to clearly identify to the CMM user what influence quantities, and their ranges of values, the UES will consider in its uncertainty evaluation.

This will allow the user to be able to make informed decisions. Purchasing a UES product with limited capabilities that do not include some influence quantities present during the CMM measurements requires the CMM user to independently evaluate these unaccounted-for influence quantities and combine them appropriately with those that are evaluated by the UES in order to produce a GUM compliant uncertainty statement.

This part of ISO 15530 then goes on to identify four possible methods of testing, recognizing that no single method is comprehensive in a practical sense. For each method, a description is given along with its considerations, advantages and disadvantages. A descriptive example is also included for each method.

Geometrical Product Specifications (GPS) — Coordinate measuring machines (CMM): Technique for determining the uncertainty of measurement —

Part 4: Evaluating task-specific measurement uncertainty using simulation

1 Scope

This part of ISO 15530 specifies requirements (for the manufacturer and the user) for the application of (simulation-based) uncertainty evaluating software (UES) to measurements made with CMMs, and gives informative descriptions of simulation techniques used for evaluating task-specific measurement uncertainty.

Furthermore, it describes testing methods for such simulation software, along with advantages and disadvantages of various testing methods.

Finally, it describes various testing procedures for the evaluation of task specific uncertainty determination by simulation for specific measurement tasks carried out on CMMs, taking into account the measuring device, the environment, the measurement strategy and the object. This document describes the general procedures without restricting the possibilities of the technical realization. Guidelines for verification and evaluation of the simulation package are included.

The document is not aimed at defining new parameters for the general evaluation of the accuracy of CMM measurements.

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

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

Guide to the expression of uncertainty in measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1st edition, 1993, corrected and reprinted in 1995

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 10360-1, VIM and GUM apply.

4 Abbreviations

CVE Computer-aided Verification and Evaluation

UES Uncertainty Evaluating Software

NOTE Definitions beyond the words of these abbreviations are not given. The abbreviations and their associated phrases should be meaningful in the contexts of their use in this document.

5 Requirements concerning uncertainty evaluating software (UES)

5.1 Specification of the claimed scope of the UES

The manufacturer of the UES shall explicitly declare the claimed scope of the software. This declaration shall include specifying:

— the types of CMMs for which the software is applicable;

— any CMM accessories allowed;

— which CMM errors are accounted for;

— the considered environmental conditions of both CMM and workpiece;

— the applicable probe types and accessories;

— the associated features included;

— the geometric tolerancing allowed;

— the measuring procedures and strategies covered;

— the operator effects covered;

— any other influence factors affecting the uncertainty of measurement covered by the UES.

In particular, the manufacturer shall specify, by means of the checklist (see Annex A), which uncertainty contributors the software claims to take into account.

NOTE 1 It is expected that the UES account for only some of the influence factors listed here and in Annex A.

NOTE 2 The checklist in Annex A includes the categories listed above.

EXAMPLE 1 An example of UES might take into account:

— the geometrical deviations of the CMM;

— deviations of the probing system;

— influences of temporal and spatial temperature gradients on the workpiece and CMM.

For each influence factor claimed on the checklist of Annex A, the manufacturer shall specify the ranges of validity when applicable. The ranges to be specified include (when claimed) but are not limited to:

a) permissible part spectrum (e.g. exclusion of flexible sheet-metal parts, a minimum arc length for circles, maximum cone apex angles, etc.);

b) permissible task spectrum (e.g. exclusion of scanning or form measurement);

c) permissible temperature range;

d) permissible temporal temperature gradients dT/dt;

e) permissible spatial temperature gradients dT/dx;

f) other permissible environmental conditions.

EXAMPLE 2 If “non 20 °C temperature” is claimed on the checklist, the range of validity might be defined as: Homogenous temperature in space and time, within the limits of 15 °C to 30 °C. This range might also vary depending on the CMM.

5.2 Specification of input to the UES

The UES manufacturer shall specify in detail (or reference appropriate documents that do the same) what input quantities are required to characterize the measurement system and how these quantities are obtained.

NOTE 1 These are the values that are used by the UES to characterize the CMM, the environment, operator effects, etc.

EXAMPLE 1 For example, a requirement of the UES might be to first measure calibrated artefacts in certain positions. The software can then use this information to characterize some of the CMM behaviour.

EXAMPLE 2 Another example of how UES could characterize some of the CMM behaviour could include requiring certain specified MPE values.

EXAMPLE 3 An example of how operator effects might be assessed is from gauge repeatability and reproducibility studies (i.e. GR&R), analysis of variance (i.e. ANOVA), and/or from expert judgment (i.e. “type B evaluation”).

NOTE 2 Any other required information (e.g. the CMM type) is included in this specification requirement.

5.3 Additional UES documentation

The following requirements provide a level of transparency in the fundamental nature of the UES. The manufacturer of the UES shall provide:

— documentation describing how the influence quantities are varied (as a rule, the probability distribution should be documented);

— documentation describing how the uncertainties are derived from the simulated samples;

— documentation describing the essential features of the model.

Transparency of the model increases the user's confidence in the statement of the uncertainty. Documentation of the model and procedure should be sufficient to enable the user to furnish proof of a statement of uncertainty in compliance with this requirement. This is important in particular in connection with ISO 9000, which requires documentation of the procedure used for the uncertainty determination.

5.4 GUM compliance

The manufacturer shall ensure that the statement of the uncertainty complies with the internationally valid principles of the expression of uncertainty (GUM). This includes the statement of a confidence level or a coverage factor.

The combined standard uncertainty may be indicated in addition to the expanded uncertainty.

5.5 Use of results from UES

An uncertainty reported from UES is applicable only as consistent with the scope of the software (5.1). In particular, when using UES, the uncertainty of a measurement shall be composed of the uncertainty evaluated by the UES and the uncertainties from the other influence quantities that have not been taken into account in the UES, which have been evaluated by other appropriate means. These uncertainties shall be combined in a GUM compliant manner.

NOTE Some informative content dealing with this matter appears in Annex B.

Annex A
(normative)

Checklist — Declaration of influence quantities

No reasonable checklist can be comprehensive. However, this checklist should serve to identify several key influence factors in identifying the scope of uncertainty evaluating software. Varied listings are also included in ISO 15530-1 [1)] and ISO 14253-1. The CMM types listed below are extracted from ISO 10360-1.

Check box	Influence factor	Additional information
	CMM types (see ISO 10360-1)	
	moving bridge	
	fixed bridge	
	column	
	moving table cantilever	
	fixed table cantilever	
	moving ram horizontal arm	
	moving table horizontal arm	
	fixed table horizontal arm	
	L-shaped bridge	
	gantry	
	dual ram	
	CMM accessories	
	rotary table	
	CMM errors	
	rigid-body errors	
	static, nonrigid-body geometry errors	
	dynamic machine geometry errors	
	part loading effects	
	CMM environmental conditions	
	non 20° C temperature	Range:
	thermal compensation applied to CMM	Range:
	spatial gradients	Up to:
	thermal variations in time	Up to:
	algorithm software accuracy	
	hysteresis	
	Probing system accessories	
	multiple styli	Maximum lengths:
	multiple probe	
	articulated probing system	
	styli changing	
	probe changing	

1) Planned.

Check box	Influence factor	Additional information
	Geometric tolerancing	
	datum reference frames	
	form	
	size	
	location	
	orientation	
	orientation with maximum/least material condition	
	position with maximum/least material condition	
	Workpiece environment and conditions	
	non 20° C temperature (same as CMM)	
	non 20° C temperature (independent of CMM)	Range:
	thermal compensation applied to workpiece	
	spatial thermal gradients (e.g. up to 2°C/m)	Up to:
	thermal variations in time (e.g. up to 1°C/hr)	Up to:
	contamination	
	vibration effects	Up to:
	surface roughness	Up to:
	surface waviness	Up to:
	form	Up to:
	fixturing	
	material composition (CTE, etc.)	
	Measuring procedure and strategy	
	sampling strategies	
	number of points	Range:
	location of points on the workpiece coordinate system	Restrictions:
	workpiece location and orientation in the machine coordinate system	
	filtration / outlier removal	
	probing speed	
	probing acceleration	
	Operator effects	
	operator effects (specify)	
	Other effects	
	(specify)	

Probe types (check boxes):			
	Discrete point sampling	**Offline scanning**	**Online scanning**
contact touch trigger			
contact analog			
noncontact			

Associated features (check boxes):				
	Least-squares	**Minimum-zone**	**Maximum-inscribed**	**Minimum-circumscribed**
lines				
circles				
planes				
spheres				
cylinders				
cones				
tori				
splines (specify)				
other (specify)				