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Geometrical product specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)— Part 5: CMMs using single and multiple stylus contacting probing systems

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently, **JIS B 7440-5:2004** is replaced with this Standard.

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JIS B 7440 series consists of the following 9 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 linear dimensions

Part 3: CMM's with the axis of a rotary table as the fourth axis

Part 4: CMMs used in scanning measuring mode

Part 5: CMMs using single and multiple stylus contacting probing systems

Part 6: Estimation of errors in computing Gaussian associated features

Part 7: CMMs equipped with imaging probing systems (under preparation)

Part 8: CMMs with optical distance sensors (under preparation)

Part 9: CMMs with multiple probing systems (under preparation)

Geometrical product specifications (GPS)— Acceptance and reverification tests for coordinate measuring machines (CMM)— Part 5: CMMs using single and multiple stylus contacting probing systems

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **ISO 10360-5** published in 2010 without any modifications of the technical contents.

The portions with continuous sidelines or dotted underlines are the matters not given in the corresponding International Standard.

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

For more detailed information on the relation of this Standard to other standards and the GPS matrix model, see Annex E.

The acceptance and reverification tests described in this Standard are applicable to coordinate measuring machines (CMMs) that use contacting probes, with or without multiple styli or multiple articulated-probe positions, when measuring a workpiece.

Experience has shown that the multi-stylus errors calculated using this Standard are significant and, at times, the dominant errors in the CMM. Owing to the virtually infinite variety of modern CMM probing system configurations, the tests specified by this Standard have been limited to providing a testing format only. The tests are intended to provide information on the ability of a CMM to measure a feature or features, using a contacting probe and, when relevant, using multiple styli, multiple probes or multiple articulated-probe positions.

The situations to which they are applicable include

- single-stylus probing systems,
- multiple styli connected to the CMM probe (e.g. a star),
- installations using an articulating probing system (motorized or manual) that can be prequalified,
- installations using a repeatable probe-changing system,
- installations using a repeatable stylus-changing system, and
- multi-probe installations.

It is believed that the procedures given in this Standard will be helpful in identifying CMM system uncertainty components for specific measurement tasks, and that the user will be able to reduce errors by removing contributing elements such as long probe extensions and styli, then retesting the new configuration set.

The tests in this Standard are sensitive to many errors attributable to both the CMM and the probing system, and are to be performed in addition to the length-measuring tests given in **JIS B 7440-2**.

The primary objective is to determine the practical performance of the complete CMM and probing system. Therefore, the tests are designed to reveal measuring errors which are likely to occur when such a combined system is used on real workpieces, e.g. errors generated by the interaction between large probe-tip-offset lengths and uncorrected CMM rotation errors. The errors found here differ from those found in the E_{150} tests in **JIS B 7440-2**, **6.5**, because with multiple styli the net CMM travel may be very different from the measured length. See Annex C for more information.

1 Scope

This Standard specifies acceptance and periodic reverification tests of CMM performance with contacting probing systems and is only applicable to CMMs using

- any type of contacting probing system,
- a discrete point probing mode, and
- spherical or hemispherical stylus tip(s).

It complements **ISO 10360-7**, which is the module for CMMs with video probing systems, and **JIS B 7440-2**, which is universal, i.e. not probe-type specific.

NOTE 1 It is the CMM probing performance tests which are specified by the maximum permissible errors (MPEs), due to the impracticality of isolating the performance of the probing system from that of the CMM, even on a small artefact such as a test sphere.

This Standard applies to CMMs supplied with any of the following:

- single-stylus probing system;
- multi-stylus probing systems with fixed multiple styli attached to a single probe (e.g. “star” stylus);
- multiple probing systems such as those with a stylus for each of their probes;
- systems with articulating probing;
- stylus and probe changing systems;
- manual (non-driven) CMMs.

This Standard is not applicable to non-contacting probing systems, which require different testing procedures.

The terms “multi-stylus size error”, etc., should strictly be written “combined CMM and multi-stylus probing-system size error”, etc. For convenience, the wording has been truncated.

If it is desired to isolate the probing-system performance as far as is practical, the influence of the CMM can be minimized. See Annex C for more information.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows:

ISO 10360-5:2010 *Geometrical product specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)—Part 5: CMMs using single and multiple stylus contacting probing systems* (IDT)

The symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standard (including amendments) indicated below shall be applied.

JIS B 0641-1 *Geometrical Product Specifications (GPS)—Inspection by measurement of workpieces and measuring equipment—Part 1: Decision rules for proving conformance or nonconformance with specifications*

NOTE : Corresponding International Standard: 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* (IDT)

JIS B 7440-1 *Geometrical Product Specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)—Part 1: Vocabulary*

NOTE : Corresponding International Standard: ISO 10360-1:2000 *Geometrical Product Specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)—Part 1: Vocabulary* (IDT)

JIS B 7440-2 *Geometrical product specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)—Part 2: CMMs used for measuring linear dimensions*

NOTE : Corresponding International Standard: ISO 10360-2:2009 *Geometrical product specifications (GPS)—Acceptance and reverification tests for coordinate measuring machines (CMM)—Part 2: CMMs used for measuring linear dimensions* (IDT)

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

NOTE : Above Guide is publicly-available as **TS Z 0032**.

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in **JIS B 7440-1**, **JIS B 0641-1**, **ISO/IEC Guide 99** and the following apply.

NOTE : This clause contains eight definitions (**3.6** to **3.13**) which supersede fourteen similar definitions **9.3**, **9.4** and **9.15** to **9.26** in **JIS B 7440-1**. Some of these revised definitions are required to avoid ambiguities which

would otherwise have been introduced with this Standard. Others effectively supersede identical definitions in **JIS B 7440-1**, because the symbols used have been revised and expanded for clarification.

3.1 inferred probing-system qualification

probing-system qualification method where the parameters for each probing system attached to an articulation system are inferred by interpolation, extrapolation, or other relevant model, for significantly different angular position(s) from parameters acquired by empirical probing-system qualification (**3.3**) at a few angular positions

3.2 angular positioning device qualification

establishment of the parameters of the angular positioning device in an articulating probing system necessary for subsequent inferred probing-system qualification (**3.1**)

3.3 empirical probing-system qualification

probing-system qualification method where the parameters for each probing system attached to an articulation system must be acquired by measurement of the reference sphere at each angular position used

3.4 effective stylus tip diameter

diameter used for the tip correction vector, for compensating measured feature size, etc.

NOTE 1 For the position of the tip correction vector, see **JIS B 7440-1**, figure 4.

NOTE 2 The effective stylus tip diameter may be a parameter established by a probing-system qualification.

3.5 probing-system pre-qualification

probing-system qualification which is separated from subsequent measurement by probe or stylus change(s), and/or articulating probing-system re-orientation(s)

3.6 multi-stylus form (measurement) error, P_{FTJ}

error of indication within which the range of Gaussian radial distances can be determined by a least-squares fit of points measured on a test sphere, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

See **JIS B 7440-1**, figure 15.

NOTE 1 The character P in P_{FTJ} indicates that the error is associated with the probing-system performance, and the subscript F indicates that it is a form error. The subscript T indicates that the probing system conforms to clause 1 of this Standard (i.e. tactile), thus enabling any alternative probing system to be clearly identified by the use of a different character at * in P_{F*j} .

NOTE 2 There are four multi-stylus form errors based on different probing systems and methods of operation. These are designated as follows:

- $j = E$, an articulating probing system using empirical qualification;
- $j = I$, an articulating probing system using inferred qualification;
- $j = M$, a fixed multi-stylus probing system;
- $j = N$, a fixed multi-probe system.

NOTE 3 All the symbols used in this Standard are listed in Annex A.

3.7 multi-stylus size error, P_{STj}

error of indication within which the diameter of a test sphere can be determined by a least-squares fit of points, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

NOTE 1 The subscript S in P_{STj} indicates that it is a size error.

NOTE 2 All the symbols used in this Standard are listed in Annex A.

3.8 multi-stylus location value, P_{LTj}

maximum of the ranges of the X, Y and Z coordinates within which the location of a test sphere can be determined by a least-squares fit of points, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

NOTE 1 The subscript L in P_{LTj} indicates that it is a location value.

NOTE 2 All the symbols used in this Standard are listed in Annex A.

NOTE 3 All values are absolute.

3.9 single-stylus form error, P_{FTU}

error of indication within which the range of radii can be determined by a least-squares fit of points measured on a test sphere, the measurements being performed by a CMM with a single stylus, using the discrete-point probing mode, with points taken on the test sphere located anywhere in the measuring volume

See **JIS B 7440-1**, figure 15.

NOTE 1 The character P in P_{FTU} indicates that the error is related primarily to the probing-system performance. The subscript U indicates use of a single (unique) stylus.

NOTE 2 See **3.6** for information on F and T.

NOTE 3 All such characters used in this Standard are listed in Annex A.

NOTE 4 P_{FTU} is identical to P in **JIS B 7440-2:2003**.

3.10 single-stylus size error, P_{STU}

error of indication of the difference between the diameter of a least-squares fit of points measured on a test sphere and its calibrated diameter, the measurements being performed by a CMM with a single stylus, using the discrete-point probing mode, with points taken on the test sphere located anywhere in the measuring volume

NOTE 1 The character P in P_{STU} indicates that the error is related primarily to the probing-system performance. The subscript U indicates use of a single (unique) stylus. The subscript S in P_{STj} indicates that it is a size error.

NOTE 2 All such characters used in this Standard are listed in Annex A.

3.11 maximum permissible multi-stylus form error, $P_{FTj, MPE}$

extreme value of the multi-stylus form error (3.6), P_{FTj} , permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible value of the multi-stylus form error, $P_{FTj, MPE}$, can be expressed in one of three forms (see Annex D):

- a) $P_{FTj, MPE} = \text{minimum of } (A + L_p/K) \text{ and } B$; or
- b) $P_{FTj, MPE} = (A + L_p/K)$; or
- c) $P_{FTj, MPE} = B$

where

- A : a positive constant, expressed in micrometres and supplied by the manufacturer;
- K : a dimensionless positive constant supplied by the manufacturer;
- L_p : the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;
- B : the maximum permissible error $P_{FTj, MPE}$, in micrometres, as stated by the manufacturer.

These forms are shown in figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible error (MPE) as opposed to a maximum permissible limit (MPL) specification is used when the test measurements determine errors; hence, testing an MPE specification requires the use of calibrated artefacts.

NOTE 3 $P_{FTj, MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

3.12 maximum permissible multi-stylus size error, $P_{STj, MPE}$

extreme value of the multi-stylus size error (3.7), P_{STj} , permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible value of the multi-stylus size error, $P_{STj, MPE}$, can be expressed in one of three forms (see Annex D):

- a) $P_{STj, MPE} = \text{minimum of } (A + L_p/K) \text{ and } B$; or
- b) $P_{STj, MPE} = (A + L_p/K)$; or
- c) $P_{STj, MPE} = B$

where

- A : a positive constant, expressed in micrometres and supplied by the manufacturer;

- K : a dimensionless positive constant supplied by the manufacturer;
- L_p : the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;
- B : the maximum permissible error $P_{STj, MPE}$, in micrometres, as stated by the manufacturer.

These forms are shown in figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible error (MPE) as opposed to a maximum permissible limit (MPL) specification is used when the test measurements determine errors; hence, testing an MPE specification requires the use of calibrated artefacts.

NOTE 3 $P_{STj, MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

3.13 maximum permissible limit of the multi-stylus location value, $P_{LTj, MPL}$
extreme value of the multi-stylus location value (3.8), P_{LTj} , permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible limit of the multi-stylus location value, $P_{LTj, MPL}$, can be expressed in one of three forms:

- a) $P_{LTj, MPL} = \text{minimum of } (A + L_p/K) \text{ and } B$; or
- b) $P_{LTj, MPL} = (A + L_p/K)$; or
- c) $P_{LTj, MPL} = B$

where

- A : a positive constant, expressed in micrometres and supplied by the manufacturer;
- K : a dimensionless positive constant supplied by the manufacturer;
- L_p : the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;
- B : the maximum permissible limit $P_{LTj, MPL}$, in micrometres, as stated by the manufacturer.

These forms are shown in figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible limit (MPL) as opposed to a maximum permissible error (MPE) specification is used when the test measurements are not errors; hence, testing an MPL specification does not require the use of artefacts with a relevant calibration.

NOTE 3 $P_{LTj, MPL}$ can be specified by the probe-tip-offset length or by the stylus system description.

3.14 maximum permissible single-stylus form error, $P_{FTU, MPE}$

extreme value of the single-stylus form error (3.9), P_{FTU} , permitted by specifications, regulations, etc. for a CMM

See **JIS B 7440-1**, figure 15.

NOTE 1 $P_{FTU, MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

NOTE 2 $P_{FTU, MPE}$ is identical to MPE_p in **JIS B 7440-2:2003**.

4 Symbols

For the purpose of this Standard, the symbols of table 1 apply (see table 2).

Table 1 Symbols

Symbol	Meaning
A	Positive constant, expressed in micrometres and supplied by the manufacturer, used to express a maximum permissible limit or error
K	Dimensionless positive constant supplied by the manufacturer, used to express a maximum permissible limit or error
L_p	Distance in 3D between the centres of the reference sphere and the test sphere, in millimetres
B	Maximum permissible error (e.g. $P_{FTj, MPE}$) or limit (e.g. $P_{LTj, MPL}$), in micrometres, as stated by the manufacturer
R	Gaussian radial distance
l	Fixed multi-stylus probing-system stylus length
l_U	Single-stylus length
l_O	Fixed multi-probe-tip-offset length
l_A	Articulating probing-system probe-tip-offset length
X, Y, Z	Centre coordinates
E_0	Length measurement error with minimal probe-tip-offset length (See JIS B 7440-2)
$E_{0, MPE}$	Maximum permissible error of length measurement with minimal probe-tip-offset length (See JIS B 7440-2)
E_L	Length measurement error with probe-tip-offset length L (See JIS B 7440-2)
$E_{L, MPE}$	Maximum permissible error of length measurement (See JIS B 7440-2)
$j = E$	Articulating probing system using empirical qualification
$j = I$	Articulating probing system using inferred qualification
$j = M$	Fixed multi-stylus probing system
$j = N$	Fixed multi-probe system
P_{FTE}	Multi-stylus form error, P_{FTj}
P_{FTI}	
P_{FTM}	
P_{FTN}	
P_{STE}	Multi-stylus size error, P_{STj}
P_{STI}	
P_{STM}	
P_{STN}	