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Gears — Evaluation of instruments for the measurement of individual gears

Engrenages — Évaluation des instruments de mesure des engrenages individuels

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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.

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 18653 was prepared by Technical Committee ISO/TC 60, *Gears*.

Gears — Evaluation of instruments for the measurement of individual gears

1 Scope

This International Standard specifies methods for the evaluation of measuring instruments used for gear measurements of involute, helix, pitch and runout. It is applicable both to instruments that measure runout directly and to those that compute it from index measurements. It also gives recommendations for the evaluation of tooth thickness measuring instruments and, of necessity, includes the estimation of measurement uncertainty with the use of calibrated gear artifacts. It does not address the calibration of artifacts by laboratories accredited in accordance with ISO/IEC 17025; nor are its requirements intended as an acceptance specification of product gears (see ISO 1328-1, ISO 1328-2, ISO/TR 10064-1 and ISO/TR 10064-2). The estimation of product gear measurement uncertainty is beyond its scope (see ISO/TR 10064-5 for recommendations).

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 1328-1, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO/TR 10064-3, *Cylindrical gears — Code of inspection practice — Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes*

ISO/TR 10064-5[1)], *Cylindrical gears — Code of inspection practice — Part 5: Recommendations relative to evaluation of gear measuring instruments*

ISO 14253-1, *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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and symbols

For the purposes of this document, the following terms, definitions and symbols (see Table 1) apply.

NOTE 1 The definitions, when applicable, conform to ISO 122-1, ISO 1328-1, ISO 1328-2 and ISO/TR 10064-1.

NOTE 2 The terms, definitions and symbols used in this document may differ from those used in other International Standards. The user needs to be certain of fully understanding them, as used here.

1) Under preparation.

3.1
accuracy
closeness of agreement between a measured value and an accepted reference (or calibrated) value

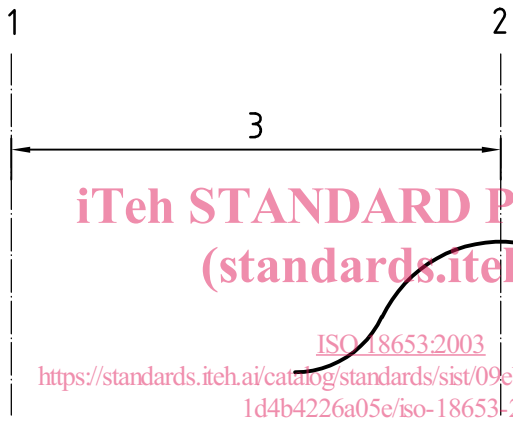
3.2
artifact
object of specific shape used to determine the accuracy of measuring devices

See Clause 7.

3.3
bias
difference between the observed average of measurements and the calibration value

See Figure 1.

NOTE Bias can be affected by systematic errors such as linearity or gain and can be different throughout the operating range of the measurement system.



Key
1 calibration value
2 observed average
3 bias

Figure 1 — Bias

3.4
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system and the corresponding values realized by standards

3.5
gain
magnification factor between the input and the output

3.6
helix artifact
artifact having a calibrated helix form

3.7
involute artifact
calibrated artifact having an involute form determined by a specific base circle

3.8
measurand
particular quantity subject to measurement

3.9
pitch and runout artifact
artifact with calibrated index features for pitch or runout or both

3.10
repeatability (of measurement results)
closeness of the agreement between results of successive measurements of the same measurand carried out under the same conditions of measurement

3.11
reproducibility (of measurement results)
closeness of the agreement between results of measurements of the same measurand carried out under changed conditions of measurement

NOTE 1 A valid statement of reproducibility requires specification of the conditions changed.

NOTE 2 The changed conditions may include

— principle of measurement,

— method of measurement,

— observer,

— measuring instrument,

— reference standard,

— location,

— conditions of use, and

— time.

NOTE 3 Reproducibility may be expressed quantitatively in terms of dispersion characteristics of the results.

3.12
uncertainty (of measurement results)
parameter associated with the result of a measurement that characterizes the dispersion of the values that could be reasonably attributed to the measurand

NOTE 1 The parameter can be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

NOTE 2 Uncertainty of measurement comprises, in general, many components. Some of these components can be evaluated from the statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. The other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

NOTE 3 It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

Table 1 — Symbols

Symbol	Definition	Unit	Where first used
E	Bias	µm	Eq. 1
k	Coverage factor	—	Eq. 1
n	Number of measurements	—	Eq. 2
U_{95}	Measuring uncertainty	µm	Eq. 1
U_{95c}	Uncertainty estimation	µm	Eq. 4
$U_{95(cal)}$	Measurement uncertainty stated in reference artifact calibration document	µm	Eq. 3
u_m	Standard uncertainty	µm	Eq. 1
u_n	Reference artifact calibration uncertainty	µm	Eq. 1
u_g	Geometry similarity influence	µm	Eq. 1
u_w	Workpiece characteristic influence	µm	Eq. 1
X_i	Individual measured value of parameter calibrated	µm	Eq. 2
$\bar{X}$	Mean of measured values	µm	Eq. 2

4 Application

4.1 General

The purpose of the tests prescribed in this standard is to estimate measurement uncertainty. It has been assumed that the gear-measuring instrument has been installed on site and a series of acceptance tests have been completed successfully. Prescribed tests may serve as interim checks to verify the measurement process.

The measurement and evaluation procedures may be used as part of acceptance tests for a new gear-measuring instrument, with prior agreement between customer and supplier. In this situation it is recommended that a series of traceably calibrated gear artifacts be used to verify the measurement uncertainty at specific points throughout the working volume of the instrument. These measurements should include provision for testing the machine with table loads that represent the weight of product gears being tested.

4.2 Traceability

The term traceability implies an unbroken calibration chain from measurements taken on shop floor inspection instruments to the primary artifacts at a national laboratory, see Figure 2. Traceability is transferred by calibrated gear artifacts. The primary laboratory has the lowest uncertainty, and uncertainty increases at each level as the traceability chain is transferred to shop floor measuring instruments. Minimizing the steps from the primary laboratory to a shop floor measuring instrument will reduce the measurement uncertainty.

4.3 Artifacts

The gear artifacts used for these tests shall be of similar size and geometry to product gears inspected on the measuring instrument. Artifacts shall be used to evaluate the accuracy of each parameter inspected: helix (lead), profile, pitch, runout and tooth thickness. Specific artifact requirements are given in Clause 7.

4.4 Measurement uncertainty

Conventional practice recommends the uncertainty of a measurement process be less than 10 % of the parameter tolerance measured, to ensure that the reliable interpretation of the measurement results is possible. However, this is not technically achievable when inspecting high accuracy gears.

For example, in gears with tolerances better than 10 µm, the best achievable uncertainty may be only 20 to 30 %. To determine the uncertainty, see Clause 8 and ISO/TR 10064-5. Recommendations for allowable measurement uncertainty are made in ISO/TR 10064-5.

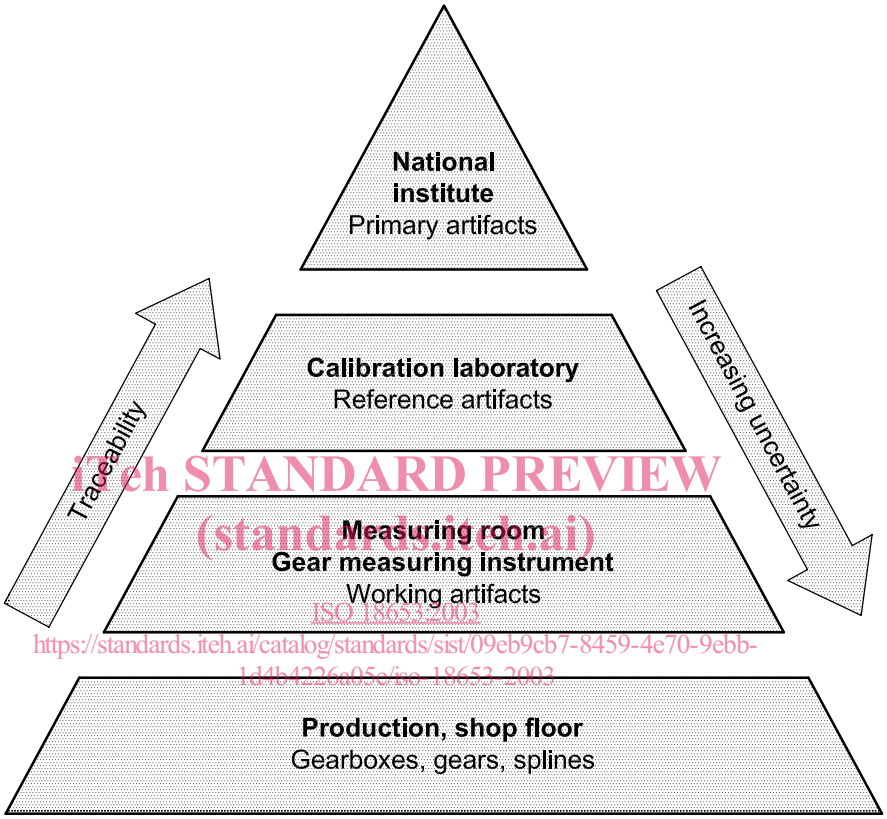


Figure 2 — Hierarchy of calibration

4.5 Sources of uncertainty

The verification of measurement uncertainty shall include, but not be limited to, the assessment of the principal contributions to uncertainty in gear measurement as follows:

— artifact data;

— calibration data;

— repeatability of the instrument;

— reproducibility of the instrument;

— probe system filtering, damping and dynamic response, and accuracy;

— environmental influence, including temperature, vibration;

— mechanical alignment;

— runout and mounting error measurement;

— servo control system;

— evaluation software;

— operator.

Refer to ISO/TS 14253-2 for further information on this subject.

4.6 Evaluation interval

The user shall establish the interval for evaluation of the measurement process. It is also recommended that interim tests be performed on a designated artifact. Data produced by the interim tests on calibrated gear artifacts can be used for measurement uncertainty.

5 Condition of the measurement system

5.1 System characteristics

Several characteristics of the measuring instrument and readout system should be checked or verified before proceeding with artifact measurement.

5.2 Suitability for calibration

The instrument should be suitable for calibration and representative of the normal operating conditions.

5.2.1 Instrument alignment

When the instrument manufacturer provides procedural checks for verification of alignments, these checks shall be made on a regular basis. Instrument alignment includes such things as runout of centres, whether the centres are coaxial, parallelism of centre axis to instrument ways, squareness of ways, etc. See ISO/TR 10064-5.

5.2.2 Readout condition

Meter movements and chart recorders should be checked to the manufacturer's specifications such as magnification, linearity, lost motion, and frequency response. See ISO/TR 10064-5.

5.3 Table load considerations

Instruments that are used to check very large gears (above 1 m) may deflect or change shape under the weight of the part being tested. This will cause deviations in measurement. Such instruments should be calibrated with a simulated load on the table. Gears with significant inertial mass can also cause measurement deviations. The effects of driving methods such as centre size, friction characteristics, live or dead centres, etc. should be considered.

5.4 Tooling and gauges

Any tooling or gauges used in the set up or calibration of a measuring instrument shall be calibrated at suitable intervals.

6 Environment

The stability of the environment will affect accuracy of the calibration process and measurement of production parts. The required environment specified by the instrument manufacturer shall be met during its evaluation and use. Calibration requires an environment controlled to the extent necessary to assure continued measurements of required accuracy considering temperature, humidity, vibration, cleanliness and other controllable factors affecting precision measurement.

In particular, an adequate thermal equilibrium of the reference artifact and the instrument should exist. If measurements of the reference artifact are taken with an ambient temperature other than that of its calibration (normally 20 °C), either the calibrated value shall be adjusted to the actual operating temperature or the measured values shall be corrected to the calibration temperature. This procedure will add significant sources of uncertainty to the calibration process. See ISO/TR 10064-5 for details.

7 Artifacts

7.1 Artifact size and geometry

This clause describes artifacts for estimating measurement uncertainty. Artifacts are required for verifying every parameter measured by an instrument, namely helix (lead), involute, pitch, runout and tooth thickness. Artifacts may be work-piece-like, such as an accurate gear.

The specific requirements are prescribed in the following sections. Further recommendations, supporting information and artifact design details are presented in ISO/TR 10064-5.

The minimum requirement is that the artifact size shall be selected as near as practical to the centre of the measurement range over which the instrument is used.

Ideally, the geometry of the artifacts should represent the tooth number, module, helix angle, facewidth and weight of the product gear range. The artifacts should have left and right flank features. Single flank artifacts may be used inverted to simulate the opposite flank.

It is recommended that internal artifacts be used to verify instrument uncertainty where internal work pieces are measured.

A key characteristic of reference artifacts is their geometric stability. Adequate stability is an inherent requirement of the comparator method of measurement uncertainty determination. Since it is very difficult to detect stability problems in reference artifacts during usage, it is important to confirm that their design, manufacture and handling are carried out so as to minimize instability. Use of multiple artifacts is recommended to assist with detection of artifact instability. See ISO/TR 10064-5 for additional guidance.

7.1.1 Artifact calibration frequency

The user shall establish the artifact calibration interval. It is recommended that the interval be 3 years — or less, depending on the amount of usage and artifact material stability.

7.1.2 Artifact calibration certificates

Artifacts used for evaluation purposes shall have a valid traceable calibration certificate that has been issued by a laboratory and which complies with the requirements specified in ISO/IEC 17025.

The calibration certificate shall contain sufficient information to enable a comparison of calibration data and measurement data from the instrument being evaluated. Specific details regarding the calibration method and the interpretation of results shall be unambiguously reported. Annex A contains a list of the specific requirements.