TECHNICAL REPORT

ISO/TR 10064-6

First edition
2009-02-15

Code of inspection practice —

Part 6:
Bevel gear measurement methods

Code pratique de réception —

Partie 6: Méthodes de mesure des engrenages coniques

Reference number
ISO/TR 10064-6:2009(E)

Contents

Page

Foreword ... iv
1 Scope ... 1
2 Normative references ... 1
3 Terms, definitions and symbols ... 2
3.1 Terms and definitions ... 2
3.2 Symbols ... 3
4 Bevel gear measurement ... 4
4.1 Manufacturing and purchasing considerations ... 4
4.2 Manufacturing documentation ... 5
4.3 Process control ... 5
4.4 Measurement methods ... 5
4.5 Additional considerations ... 6
4.6 Acceptance criteria ... 7
5 Measuring methods and practices ... 7
5.1 Guidelines for measurement of gear characteristics ... 7
5.2 Measuring practices ... 8
5.3 Measurement of pitch deviations ... 10
5.4 Measurement of bevel gear runout ... 16
5.5 Flank form measurement ... 18
5.6 Contact pattern checking ... 25
5.7 Single-flank composite inspection ... 30
5.8 Double-flank composite testing ... 30
5.9 Tooth thickness measurement ... 33
5.10 Manufacturing applications ... 36
6 Recommended datum surface tolerances ... 36
Bibliography ... 37

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 exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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/TR 10064-6 was prepared by Technical Committee ISO/TC 60, *Gears*.

ISO/TR 10064 consists of the following parts, under the general title *Code of inspection practice*:

— *Part 1: Inspection of corresponding flanks of gear teeth*

— *Part 2: Inspection related to radial composite deviations, runout, tooth thickness and backlash*

— *Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes*

— *Part 4: Recommendations relative to surface texture and tooth contact pattern checking*

— *Part 5: Recommendations relative to evaluation of gear measuring instruments*

— *Part 6: Bevel gear measurement methods*

Code of inspection practice —

Part 6: Bevel gear measurement methods

1 Scope

This part of ISO/TR 10064 provides information on measuring methods and practices of unassembled bevel and hypoid gears and gear pairs.

Tolerances are provided in Clause 5 of ISO 17485:2006, for calculating the maximum values allowed by the specific tolerance grade.

Measuring methods and practices are included in order to promote uniform inspection procedures (see Clause 5). These methods permit the manufacturer and purchaser to conduct measuring procedures which are accurate and repeatable to a degree compatible with the specified tolerance grade of ISO 17485.

See Clause 6 of ISO 17485:2006 for required and optional measuring methods.

This part of ISO/TR 10064 applies to bevel gear components as defined in ISO 17485. It does not apply to enclosed gear unit assemblies, including speed reducers or increasers, gear motors, shaft mounted reducers, high speed units, or other enclosed gear units which are manufactured for a given power, speed, ratio or application.

The use of the accuracy grades for the determination of gear performance requires extensive experience with specific applications. Therefore, users are cautioned against the direct application of tolerance values to a projected performance of unassembled gears when they are assembled.

Tolerance values for gears outside the limits stated in ISO 17485 are established by determining the specific application requirements. This possibly requires setting a tolerance smaller than that calculated by the formulae in ISO 17485.

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 1122-1, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 17485:2006, *Bevel gears — ISO system of accuracy*

ISO 23509, *Bevel and hypoid gear geometry*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 17485 and the following terms, definitions and symbols apply.

NOTE 1 Some of the terms, definitions and symbols contained in this Technical Report may differ from those used in other documents. Users of this Technical Report can be assured that they are using the terms, definitions and symbols in the manner indicated herein.

NOTE 2 The general wording “gear” or “bevel gear”, depending on the context, can refer to the “wheel” or the “pinion”.

NOTE 3 For other geometric, measurement and tolerance terms and definitions related to gearing, see ISO 1122-1 and ISO 23509.

3.1 Terms and definitions

3.1.1
toe
portion of the bevel gear tooth surface at the inner end

3.1.2
heel
portion of the bevel gear tooth surface at the outer end

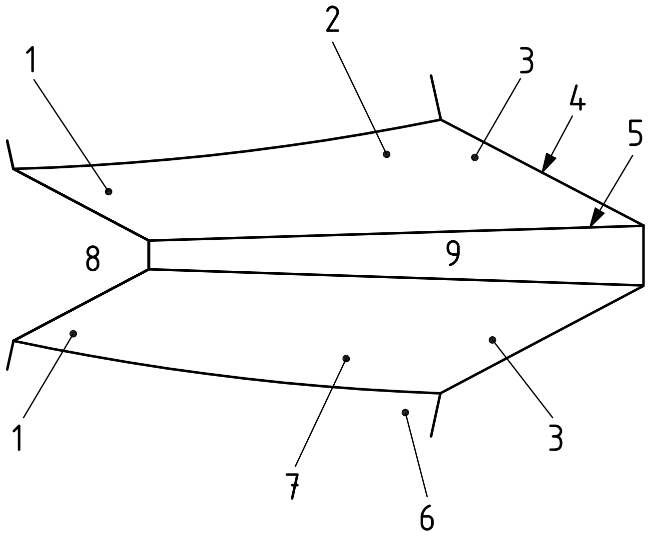
3.1.3
tip
upper edge of the gear tooth surface

3.1.4
root
lower edge of the gear tooth surface

3.1.5
topland
surface of the top of the gear tooth

3.1.6
wheel
gear with the larger number of teeth

3.1.7
pinion
gear with the smaller number of teeth



Key

1 toe
2 left side
3 heel
4 outer end of tooth
5 tip
6 root
7 right side
8 inner end of tooth
9 topland

Figure 1 — Nomenclature of bevel and hypoid gear teeth

3.2 Symbols

The symbols used in this document are listed alphabetically by term in Table 1 and alphabetically by symbol in Table 2. However, the names of several symbols have been rearranged such that the principal characteristics are grouped together.

Table 1 — Alphabetical list of terms

Symbol	Term	Where first used
R_m	Cone distance, mean	5.6.6.2
F_p	Cumulative pitch deviation, total	5.3.1
r_{c0}	Cutter radius	5.6.6.2
d_T	Diameter, tolerance	4.4
F_x	Index deviation	5.3.1
z	Number of teeth	5.3.3.1
α	Pressure angle	5.9.4
F_r	Runout deviation, total	5.4.1
f_{pt}	Single pitch deviation	5.3.1
β_m	Spiral angle, mean	5.6.6.2
f_{id}	Tooth-to-tooth deviation, double flank	5.8.4
F_{id}	Total composite deviation, double flank	5.8.4
p_m	True position pitch	5.3.4.1

Table 2 — Alphabetical list of symbols

Symbol	Term
d_T	Diameter, tolerance
F_{id}	Total composite deviation, double flank
f_{id}	Tooth-to-tooth deviation, double flank
F_p	Cumulative pitch deviation, total
f_{pt}	Single pitch deviation
F_r	Runout deviation, total
F_x	Index deviation
p_m	True position pitch
R_m	Cone distance, mean
r_{c0}	Cutter radius
z	Number of teeth
α	Pressure angle
β_m	Spiral angle, mean

4 Bevel gear measurement

4.1 Manufacturing and purchasing considerations

This clause presents considerations for control of the various phases of manufacturing, including the recommended methods of measurement control.

These methods provide the manufacturer and purchaser with recommendations for verifying the conformity of a manufactured product with the standard, as well as information relative to the interpretation of measurement data.

Some design and application considerations may warrant measuring or documentation not normally available in standard manufacturing processes.

NOTE No particular method of measurement or documentation is considered mandatory unless specifically agreed upon between manufacturer and purchaser. When applications require measurements beyond those recommended in this Technical Report, special measurement methods are negotiated prior to manufacturing the gear.

4.2 Manufacturing documentation

The manufacturing of gearing to the standard may or may not include specific measurements. When applications warrant, detailed specific measurements, data analysis and additional considerations may be necessary to establish acceptance criteria for a gear. The specific methods of measurement, documentation of accuracy grade and other geometric tolerances of a gear are normally considered items which are to be mutually agreed upon between manufacturer and purchaser.

NOTE Specifying an accuracy grade or measurement criteria that requires closer tolerances than required by the application can increase the cost unnecessarily.

4.3 Process control

Process control is defined as the method by which gear dimensional accuracy is maintained through control of each individual step of the manufacturing process. Upon completion of all manufacturing operations, a specific gear has been given an inherent level of dimensional accuracy; this level of accuracy was established during the manufacturing process and it is totally independent of any final inspection.

Process control includes elements such as manufacturing planning, maintenance of machine tools, cutting tool selection and maintenance, heat treatment control and quality assurance programmes, as needed, to achieve and maintain the necessary gear quality. When properly applied, gears manufactured by specific control techniques will be found to be of very uniform quality. Therefore, little or no final inspection may be necessary for a gear, particularly in some classification levels, assurance of the necessary accuracy having been built-in through careful manufacturing control at each step.

NOTE It is possible for documentation to be deemed unnecessary for products manufactured under process control when inspection records are not specified in the purchase contract.

With proper application of process control, relatively few measurements may be made on any one gear. For example, tooth size may be evaluated by a measurement on only two or three sections of a given gear. It is assumed that these measurements are representative of all the teeth on the gear. Gears made in mass production quantities may be inspected at various steps in their manufacturing process on a statistical basis. Thus, it is possible that a specific gear can pass through the entire production process without ever having been measured. However, based on appropriate confidence in the applied process control, the manufacturer of that gear shall be able to verify that its quality is equal to those gears that were measured.

4.4 Measurement methods

Gear geometry may be measured by a number of alternate methods as specified in Table 3 of ISO 17485:2006. The selection of the particular method depends on the magnitude of the tolerance, the size of the gear, the production quantities, equipment available, accuracy of gear blanks and measurement costs.

The manufacturer or the purchaser may wish to measure one or more of the geometric features of a gear to verify its accuracy grade. However, a gear which is specified to an accuracy grade must meet all the individual tolerance requirements applicable to the particular accuracy grade and size as noted in Tables 3 and 4 of ISO 17485:2006. Unless otherwise specified, all measurements are taken and evaluated at the tolerance diameter, d_T.

Normally the tolerances apply to both sides of the teeth unless only one side is specified as the loaded side. In some cases, the loaded side may be specified to a higher accuracy than the non-loaded or minimum-loaded side; if applicable, this information is to be specified on the gear engineering drawing.

4.5 Additional considerations

4.5.1 General aspects

When specifying the quality of a gear, there are additional or special considerations that must be reviewed. These considerations may include items such as:

— backlash allowances in tooth thickness;

— matching gears as sets;

— reference gears for composite measurement;

— replacement gearing;

— modified accuracy grade;

— mounting distance and backlash markings on wheel and pinion;

— record of tooth contact patterns by photographs or transfer tapes.

The listed items and other special considerations are to be reviewed and agreed upon by the manufacturer and purchaser.

4.5.2 Backlash

An individual gear does not have backlash. Backlash is only present when one gear mates with another. The backlash of a gear set is based on the tooth thickness of each member in mesh, as well as the mounting distances at which the gears are assembled. The functional backlash is additionally dependent on the runout of the gears, the actual variation of tooth thicknesses and tooth geometries.

The methods of determining the backlash required for individual applications are beyond the scope of this Technical Report (for additional information, see ISO 23509). See also 5.9.3.

4.5.3 Matching gears as sets

Matched sets can be provided, usually at extra cost, and are required in many applications. In such a case, the purchaser must agree on the details of the additional specifications concerning how the matching is to be performed and verified. Applications requiring high accuracy gearing may necessitate the matching, or modifying, of pinion and gear profiles and spiral angles such that the matched set is satisfactory for the application.

NOTE ISO 17485 provides tolerances for unassembled gears only. The inspection of gearing mated in an assembly for a specific application is beyond the scope of this Technical Report. The matching process for such gears sold as pairs assumes greater importance than the individual absolute measurements.

4.5.4 Reference gears for composite action tests

When a composite check is specified, a reference gear becomes necessary. The design, accuracy grade validation procedure and cost of a reference gear must be negotiated between the manufacturer and purchaser. A specific reference gear is required for each different production gear design.

4.6 Acceptance criteria

The tolerances, methods and definitions specified in ISO 17485 prevail unless contractual agreements between the manufacturer and purchaser contain specific exceptions. See ISO/TR 10064-5 for discussion on measurement uncertainty.

The overall accuracy grade of a gear is determined by the largest accuracy grade number measured for any tolerance parameter specified for the gear by ISO 17485.

5 Measuring methods and practices

5.1 Guidelines for measurement of gear characteristics

This clause describes the recommended methods and practices used for the measurement of bevel gears. The practices and measurement methods included are recognized and accepted throughout the gear industry as being reliable.

These methods can provide measurements of the particular accuracy grade when correctly applied. Unless otherwise specified, all measurements are taken and evaluated at the tolerance diameter, d_T, as specified in ISO 17485:2006, 3.1.8. Experienced personnel, using calibrated instruments in a suitable environment, are required.

Bevel gear practice is different from spur and helical gear practice regarding the measurement of tooth shape. Formerly the method was to inspect the tooth shape with contact pattern testing. The measurement of geometrical tooth shape or flank form is now possible. There are two different measuring methods. The grid point method uses a series of discrete points distributed along the tooth flank with the graphic output representing the topography of the tooth surface in three dimensions. The tooth trace method involves traces along the tooth flank both parallel and perpendicular to the pitch angle, similar to helix and profile measurement on spur and helical gears. Both of these methods may also output numerical data suitable for non-subjective pass/fail decisions and statistical methods for process control, which were not possible with contact pattern testing.

Guidelines for measurement options are as follows.

a) Individual gears:

- single pitch and total cumulative pitch deviation;
- runout;
- measured by tooth thickness: gear tooth calipers, CMM (coordinate measuring machine) or CNC (computer numerically controlled) gear measuring instrument;
- measured by flank form: grid point or tooth trace method.

b) Matched gear pairs (normally lapped):

- measurements described in a) as individual gears;
- tooth contact pattern;
- backlash check;
- composite single flank.

c) Individual gears matched to reference mating gears:

- measurements described in a) as individual gears;
- tooth contact pattern;

- tooth thickness by backlash;
- single-flank composite testing, all pitches;
- double-flank composite testing, modules less than 1 only.

NOTE No particular method of measurement or documentation is considered mandatory unless specifically agreed upon between manufacturer and purchaser. When applications require measurements beyond those recommended in ISO 17485, special methods are negotiated prior to the manufacture of the gear.

5.2 Measuring practices

When measurement of bevel gears is specified, it may be done with a number of alternate methods.

5.2.1 Statistical sampling

Production quantities, available equipment, labour and measurement costs may influence the choice toward statistical sampling methods. If measurement by statistical sampling is chosen, the particular sampling plan shall be negotiated between manufacturer and purchaser. For further information, see ANSI/ASQ Z1.4.

NOTE Statistical sampling involves careful planning for the specific method of measurement (what is to be measured and on which equipment), how the measurement results are to be recorded, how many samples are to be taken (measurement frequency) and how the resulting data is to be analysed.

5.2.2 First piece measurement

On small quantities of parts, first piece measurement with process control for subsequent parts may be applied to reduce measurement costs and assure a given level of dimensional accuracy.

5.2.3 Measurement data references

5.2.3.1 Reference surfaces

To facilitate the machining, measurement and assembly of a gear, the radial and axial reference surfaces need to be clearly indicated on the manufacturing drawings (see Figure 2). This includes the mounting distance (MD), which is the distance between the axial reference surface and the crossing point of hypoid gears. In the case of bevel gears, this is the intersection point of the axes.

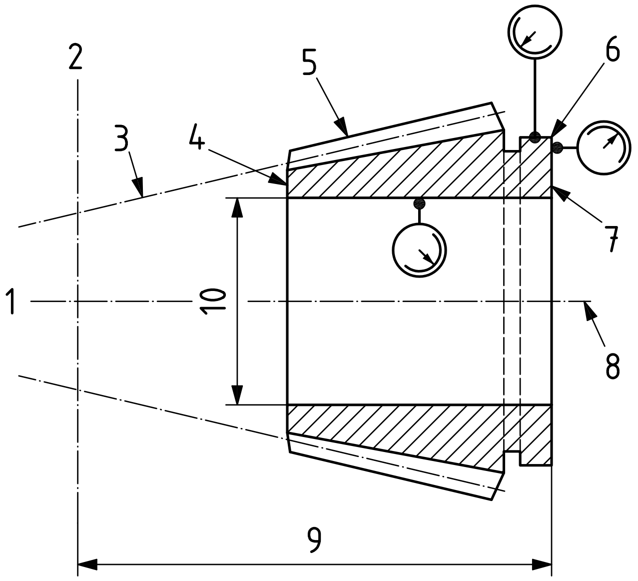
5.2.3.2 Datum axis of rotation

The bevel gear datum axis of rotation is defined by the centres of its datum surfaces. It is the axis to which the gear tooth details, such as pitch and flank measurements, are defined.

Ideally the surfaces used to determine the datum axis of rotation for measurement, the surfaces used to locate the gear for manufacturing and the functional surfaces that define the gear axis of rotation in its final assembly should all be the same. In practice, this is often not the case. When the manufacturing, measurement and functional datum surfaces or centres are different, the datum axis of rotation should be established so as to ensure that the geometry of the gear is adequately represented during measurement.

The datum axis of rotation for a gear with a bore shall be the datum axis of rotation established relative to the bore. The datum axis of rotation for a gear with a shaft shall be the datum axis of rotation established by the bearing support surfaces of the shaft. In addition to the datum axis of rotation, an axial feature, from which the mounting distance is dimensioned, should also be defined.

Care shall be taken to assure that the mounting of the part for measurement has minimum deviation with the instrument's axis of rotation. Computer-controlled measuring instruments, such as CNC and CMM, can be programmed to mathematically correct the errors resulting from an off-axis mounting condition.



Key

1 crossing point
2 centreline of mating gear
3 pitch cone
4 apex end
5 face cone
6 radial reference surface
7 axial reference surface
8 datum axis of rotation
9 mounting distance
10 bore diameter (reference surface)

Figure 2 — Example reference surfaces

5.2.3.3 Reference identification of tooth data

When viewing the gear from the apex end (see Figure 2), the teeth shall be numbered for identification in a clockwise direction from a datum tooth ($k = 1, 2, 3$ ... etc.). The terms right or left flank are the surfaces bounding a tooth when this tooth is viewed with its tip above its root (see Figure 3).

5.2.3.4 Hand of spiral

A right-hand spiral bevel gear is one in which the outer half of a tooth is inclined in the clockwise direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear.

A left-hand spiral bevel gear is one in which the outer half of a tooth is inclined in the anticlockwise (counterclockwise) direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear.

