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Code of inspection practice —

Part 1: Measurement of cylindrical gear tooth flanks

Code pratique de réception —

Partie 1: Mesure des flancs dentaires cylindriques

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 60, *Gears*.

This second edition cancels and replaces the first edition (ISO/TR 10064-1:1992), which has been technically revised. It also incorporates the Technical Corrigendum ISO/TR 10064-1:1992/Cor. 1:2006.

The following changes have been made:

— the contents have been updated to correspond with ISO 1328-1:2013;

— additional material has been added on the proper setup and use of measuring machines, and how the measurement results can be used to determine the corrective steps needed to improve the gear tooth flank tolerance class.

A list of all parts in the ISO/TR 10064 series can be found on the ISO website.

Code of inspection practice —

Part 1:
Measurement of cylindrical gear tooth flanks

1 Scope

This document supplements ISO 1328-1:2013. It provides a code of practice dealing with measurements on flanks of individual cylindrical involute gears, i.e. with the measurement of pitch, profile, helix and tangential composite characteristics. It describes measuring equipment, provides advice for gear measuring methods and for the analysis of measurement results, and discusses the interpretation of results.

Measurements using a double flank tester are not included (see ISO/TR 10064-2). This document only applies to involute gears.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the following terms, definitions, symbols and abbreviated terms apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

NOTE The symbols and terms used throughout this document are in basic agreement with the symbols and terms given in ISO 701 and in ISO 1122-1. In all cases, the first time that each symbol is introduced, it is defined and discussed in detail. See Table 1. Abbreviated terms are given in Table 2.

Table 1 — Symbols and definitions

Symbols[a]	Definition	Units	First use
a	tip point	—	Figure 31
b	face width	mm	Figure 37
C_f	profile control point	—	Figure 31
d	reference diameter	mm	Formula (4)
d_a	tip diameter	mm	14.3.2.1
$d_{a\ eff}$	effective (measured) tip diameter	mm	Figure 29
d_b	base diameter	mm	Formula (6)
$d_{b\ eff}$	effective base diameter	mm	14.2

[a] Symbols used for deviations of individual element measurements from specified values are composed of lower case letters "f" with subscripts (exceptions include f_e, f_1 and f_2) whereas symbols used for "cumulative" or "total" deviations, which represent combinations of several individual element deviations, are composed of capital letters "F" also with subscripts. It is necessary to qualify some deviations with an algebraic sign. A deviation is positive when, for example, a dimension is larger than optimum and negative when smaller than optimum.

[b] These deviations can be + (plus) or − (minus).

Table 1 *(continued)*

Symbols[a]	Definition	Units	First use
d_M	measurement diameter	mm	6.2.3.2
d_{Nf}	start of active profile (SAP) diameter	mm	Formula (8)
d_y	individual inspection diameter (measurement diameter)	mm	Figure 29
F_a	tip form point (where tip break starts)	—	Figure 31
F_{is}	total single flank composite deviation	µm	11.1
F_p	total cumulative pitch deviation	µm	9.3.1
F_{pi}	individual total cumulative pitch deviation	µm	9.3.8
F_{pk}	sector pitch deviation over *k* pitches	µm	9.3.7
F_r	radial runout	µm	6.2.5
F_α	total profile deviation	µm	Figure 14
F_β	total helix deviation	µm	Figure 37
f_α	difference between the actual and nominal pressure angle	degrees	9.1.4
$f_{\alpha m}$	mean pressure angle deviation	degrees	14.3.1
f_b	base circle deviation (difference between the actual and nominal base diameter)	mm	9.1.4
f_{bm}	mean base diameter deviation	mm	14.3.1
f_e	eccentricity between gear axis and axis of gear teeth	µm	Figure 34
$f_{f\alpha}$	profile form deviation	µm	Figure 14
$f_{f\beta}$	helix form deviation	µm	Figure 37
$f_{f\beta T}$	helix form tolerance	µm	8.3.1
$f_{H\alpha}$	profile slope deviation[b]	µm	Figure 14
$f_{H\alpha m}$	mean profile slope deviation[b]	µm	9.1.5
$f_{H\alpha i}$	individual profile slope deviation[b]	µm	9.1.5
$f_{H\beta}$	helix slope deviation[b]	µm	6.4
$f_{H\beta i}$	individual helix slope deviation[b]	µm	9.2.5
$f_{H\beta m}$	mean helix slope deviation[b]	µm	9.2.5
$f_{H\beta mt}$	mean helix slope deviation, in the transverse plane and tangent to the measurement diameter[b]	µm	Formula (37)
f_i'	tooth-to-tooth single flank composite deviation without removal of the long term component	µm	11.2.2
f_{is}	tooth-to-tooth single flank composite deviation after removal of long term component	µm	11.1
f_l'	variance of the long period component over one revolution	µm	11.2.2
f_p	single pitch deviation[b]	µm	8.4.3
f_{pzm}	mean lead deviation[b]	mm	14.4.1
f_{pbnm}	mean normal base pitch deviation[b]	µm	14.2.1
f_{pbn}	normal base pitch deviation[b]	µm	6.2.4
f_{pbni}	individual normal base pitch deviation[b]	µm	14.1
f_{pb}	single pitch deviation[b], normal base	µm	8.4.3
f_{pbt}	single pitch deviation[b], transverse base	µm	Formula (19)

[a] Symbols used for deviations of individual element measurements from specified values are composed of lower case letters "*f*" with subscripts (exceptions include f_e, f_1 and f_2) whereas symbols used for "cumulative" or "total" deviations, which represent combinations of several individual element deviations, are composed of capital letters "*F*" also with subscripts. It is necessary to qualify some deviations with an algebraic sign. A deviation is positive when, for example, a dimension is larger than optimum and negative when smaller than optimum.

[b] These deviations can be + (plus) or – (minus).

Table 1 *(continued)*

Symbols[a]	Definition	Units	First use
f_{pi}	individual single pitch deviation[b]	µm	Figure 42
f_{p2i}	individual double pitch deviation[b]	µm	9.3.8
f_{ui}	individual adjacent pitch difference[b]	µm	9.3.8
f_{u2i}	individual adjacent double pitch difference[b]	µm	9.3.8
$f_{w\alpha}$	undulation wave height in profile direction	µm	Figure 74
$f_{w\beta}$	undulation wave height in helix direction	µm	Figure 74
f_{α}	pressure angle deviation[b]	degrees	9.1.4
$f_{\alpha mn}$	mean normal pressure angle deviation[b]	degrees	14.2.1
$f_{\alpha mt}$	mean transverse pressure angle deviation[b]	degrees	14.2.1
f_{β}	helix angle deviation[b]	degrees	9.2.4
$f_{\beta m}$	mean helix angle deviation[b]	degrees	9.2.4
g_{α}	length of path of contact	mm	Figure 65
h_{cy}	chordal addendum to an individual measurement diameter	mm	Figure 29
h_{y}	radial distance from tip to an individual measurement diameter	mm	Figure 29
k	number of pitches in a sector	—	5.7
L	left flank	—	5.3
L_{α}	profile evaluation length	mm	Figure 14
$L_{\alpha c}$	functional profile length	mm	14.3.2.2
$L_{\alpha e}$	base tangent length to start of active profile	mm	Figure 14
L_{β}	helix evaluation length	mm	8.3.1
l	left hand helix	—	5.4
m_{n}	normal module	mm	Formula (1)
N	pitch number	—	5.6
N_{f}	start of active profile point on line of action	—	Figure 31
n	number of deviation values included in the mean	—	9.1.5
p_{b}	base pitch	mm	8.4.3
p_{bn}	normal base pitch	mm	Formula (1)
p_{bt}	transverse base pitch	mm	Formula (16)
p_{m}	true position pitch[b]	µm	14.1
p_{z}	lead of the helix	mm	Formula (36)
$p_{z\,eff}$	effective lead	mm	14.4.1
R	right flank	—	5.3
r	right hand helix	—	5.4
s	undulation weighting factor	mm	Figure 80
s_{cy}	chordal tooth thickness at an individual inspection diameter	mm	Figure 29
s_{n}	normal circular tooth thickness at the reference diameter	mm	Formula (12)
s_{yn}	normal circular tooth thickness at an individual inspection diameter	mm	Figure 29
z	number of teeth	—	6.2.3.2
z_{M}	number of teeth in master indexing worm wheel	—	Formula (22)

[a] Symbols used for deviations of individual element measurements from specified values are composed of lower case letters "f" with subscripts (exceptions include f_e, f_1 and f_2) whereas symbols used for "cumulative" or "total" deviations, which represent combinations of several individual element deviations, are composed of capital letters "F" also with subscripts. It is necessary to qualify some deviations with an algebraic sign. A deviation is positive when, for example, a dimension is larger than optimum and negative when smaller than optimum.

[b] These deviations can be + (plus) or − (minus).

Table 1 *(continued)*

Symbols[a]	Definition	Units	First use
z_1	number of teeth on driving gear	—	Figure 61
z_2	number of teeth on driven gear	—	Figure 61
$\alpha_{50\ \%}$	Gauss parameter	—	Formula (24)
α_{Mt}	transverse pressure angle at the measurement diameter	degrees	10.3.9
α_n	normal pressure angle	degrees	Formula (1)
$\alpha_{n\ eff}$	effective normal pressure angle	degrees	14.2.1
α_t	transverse pressure angle	degrees	Formula (5)
$\alpha_{t\ eff}$	effective transverse pressure angle	degrees	14.2.1
α_{yn}	normal pressure angle at an individual inspection diameter	degrees	8.2.3
α_{yt}	transverse pressure angle at an individual inspection diameter	degrees	Formula (11)
α_{Mt}	transverse pressure angle at measurement diameter	degrees	10.3.9
β	helix angle	degrees	Formula (4)
β_b	base helix angle	degrees	Formula (17)
β_{eff}	effective helix angle at the standard pitch diameter	degrees	14.4.1
$\beta_{M\ eff}$	effective helix angle at the measurement diameter	degrees	14.4.1
β_y	helix angle at an individual inspection diameter	degrees	Formula (10)
ε_γ	total contact ratio	—	11.3.4.2
λ_g	undulation wavelength	mm	Figure 74
λ_α	undulation wavelength in profile direction	mm	Figure 74
λ_β	undulation wavelength in helix direction	mm	Formula (22)
ξ	involute roll angle	degrees	Figure 14
ξ_a	involute roll angle to the tip diameter	radians	Formula (7)
ξ_{Nf}	involute roll angle to the start of active profile diameter	radians	Formula (8)
ξ_y	individual inspection roll angle	radians	Formula (9)
θ	angular position of gear	radians	Figure 61
$\Delta\theta$	angular gear position deviation	radians	Figure 61
I	reference face	—	5.3
II	non-reference face	—	5.3

[a] Symbols used for deviations of individual element measurements from specified values are composed of lower case letters "f" with subscripts (exceptions include f_e, f_1 and f_2) whereas symbols used for "cumulative" or "total" deviations, which represent combinations of several individual element deviations, are composed of capital letters "F" also with subscripts. It is necessary to qualify some deviations with an algebraic sign. A deviation is positive when, for example, a dimension is larger than optimum and negative when smaller than optimum.

[b] These deviations can be + (plus) or − (minus).

Table 2 — Abbreviated terms

	Definition	First use
3D	three dimensional	6.2.6
CAD	computer aided design	6.2.6
CMM	coordinate measuring machine	6.1
CNC	computer numerically controlled	6.1
CT	computer tomography	6.2.6
GCM	gear cutting machine	8.3.3
GMM	gear measuring machine	6.1

4 General considerations

4.1 Background

The purpose of this document is to provide background information that will assist with understanding the requirements, implementation and effectiveness of the gear measurements needed to establish the gear classifications defined in ISO 1328-1. This information will assist those involved in gear design and specification, gear manufacture and gear measurement processes. It includes background information and guidance on good measurement practice and addresses the interpretation of measurement results to identify common causes of gear manufacturing errors. Improved knowledge of gear measurement processes enhances the value of investments in measuring equipment.

When producing multiple identical gears in a large batch, it is rarely necessary or economical to measure all possible deviations on all the gears manufactured. Stable manufacturing processes allow a relatively small number of samples to be measured and still ensure that the required tolerance class is maintained. Certain elements may not significantly influence the function of the gear under consideration. However, some gear manufacturing processes are known to increase the risk of significant variation in tooth geometry in a single gear and thus require additional measurements to verify gear geometry parameter tolerances have been achieved. Some guidance is provided when this is necessary, but it remains the responsibility of the manufacturer of the gears to assure that the gears satisfy the specified requirements, such as those in ISO 1328-1. It is recommended that measuring plans be agreed upon between the manufacturer and the purchaser.

4.2 Required inspection information

All necessary information should be provided to the operator(s) of the measuring equipment. The information required will vary depending on the type of measurement(s). Most measurement processes require basic gear and blank data, such as number of teeth, pressure angle, helix angle, module, tip diameter, root diameter, face width, design profile, design helix, etc. Certain measuring tasks require additional information. For example, to measure profile, the profile control diameter and start of tip break must be provided. Minimum requirements are defined in ISO 1328-1 but it is the responsibility of the gear designer to ensure the specification provides sufficient information for the manufacturer to develop a measurement strategy that is suitable for the subject gears.

4.3 Measurement selection

4.3.1 Substitution of measurement methods

Inspection may be carried out using a number of methods. In some cases, some measurements may be substituted for others. For example, single flank composite measurement may be substituted for pitch measurement, or radial composite measurement may replace radial runout measurement. However, such substitutions may only be done with agreement between the manufacturer and the purchaser. See ISO 1328-1:2013, Table 4.

A number of factors should be considered when selecting the measurements, including the tolerance class required, size of the gear, manufacturing cost, and most important, the application of the product gear.

4.3.2 First piece inspection

It may be possible to verify that the manufacturing process is correct by inspecting only the first piece of a batch, allowing the inherent accuracy of the process to assure subsequent parts meet the required tolerance class.

4.3.3 Sampling and statistical process control

The deviations from the design shape of the gear that result from the manufacturing process are dependent on the production process used. When the process is proven capable of producing the required tolerance class (e.g. when using statistical methods), sampling inspection may be utilized. Many factors may influence the sample size and frequency; foremost among these should be the assurance that the required tolerance class of the parts is met.

The variability of the measuring process contributes to the perceived variability of the manufacturing process. For more information, see ISO 22514-7.

To achieve statistical compliance, the manufacturing deviations must be smaller than the specified tolerance. In some cases, for very accurate gears, the use of statistical process control is not possible due to the uncertainty in the measurements.

5 Conventions and measurement positions

5.1 General

When measuring gear teeth, specific reference is made to right flanks, left flanks, pitches, teeth or combinations of these.

5.2 Datum axis

Specification of the design profile, design helix, and design pitch requires definition of an appropriate reference axis of rotation, called the datum axis. It is defined by specification of datum surfaces. See ISO/TR 10064-3.

The datum axis is the reference for measurements and associated tolerances. The location and orientation of the measurement diameter circle are determined by this axis.

Ideally, the surfaces used to construct the datum axis, the surfaces used to locate the gear for manufacturing, and the functional surfaces that define the gear axis of rotation in its final assembly will all be the same. In practice, this is often not the case. For example, shaft type parts are often manufactured and inspected using centres to define the datum axis. In cases where the inspection, manufacturing, and/or functional datum surfaces are different, these surfaces should be coincident with each other to a level of accuracy sufficient to assure the final positioning of the gear is adequately represented during measurement.

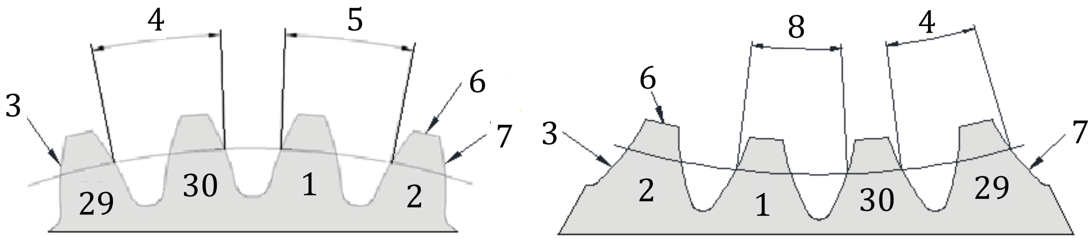
When a rotary table is used, the gear being measured should be oriented so that its datum axis is coincident with the axis of rotation of the measuring instrument. In the case of mounting the gear between centres, care should be taken to assure that the mounting arbor, if used, is in good condition, and the centres are clean and concentric with the datum surfaces of the gear. In the case of computer controlled measuring instruments, if the measuring program is capable of mathematically correcting the errors resulting from off axis mounting condition, then it may be possible to mount the gear with some deviation to the instrument's axis of rotation.

5.3 Left or right flank

It is convenient to choose one face of the gear as the reference face and to denote it with the letter "*I*". The other non-reference face might be termed face "*II*".

For an observer looking at the reference face, so that the tooth is seen with its tip uppermost, the right flank is on the right and the left flank is on the left.

Right and left flanks are denoted by the letters "R" and "L", respectively. See Figure 1.



a) External gear **b) Internal gear**

Key

1	Tooth 1	6	tip
2	Tooth 2	7	right flank
3	left flank	8	1L = pitch number 1, left flank
4	30R = pitch number 30, right flank	29	Tooth 29
5	2L = pitch number 2, left flank	30	Tooth 30

Figure 1 — Notation and numbering for external and internal gears

5.4 Left hand or right hand helical gears

The helix of an external or internal helical gear is referred to as being right hand or left hand. The hand of helix is denoted by the letters “r” and “l”, respectively.

The helix is right hand (left hand) if, when looking from one face, the transverse profiles show successive clockwise (counter-clockwise) displacement with increasing distance from an observer. See Figure 2.

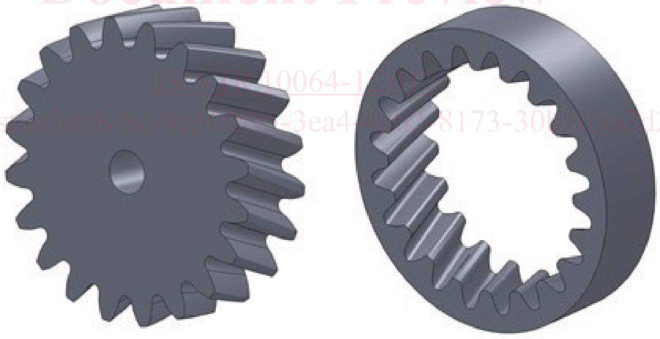


Figure 2 — Right hand gears, external and internal

5.5 Numbering of teeth and flanks

Looking at the reference face of a gear, the teeth are numbered sequentially in the clockwise direction. The tooth number is followed by the letter R or L, indicating whether it is a right or a left flank. For example, “Flank 30 R”. See Figure 1.

5.6 Numbering of pitches

The numbering of individual pitches is related to tooth numbering as follows: pitch number "*N*" lies between the corresponding flanks of teeth numbers "*N*-1" and "*N*"; with a letter R or L, it is indicated whether the pitch lies between right or left flanks. For example, "Pitch 30 R" (see Figure 1).

NOTE Pitch 1 lies between the last and first tooth. Therefore, sector gears have no pitch 1; they start with pitch number 2.

5.7 Number of pitches "*k*" in a deviation symbol subscript

The subscript "*k*" in a deviation symbol denotes the number of consecutive pitches to which the deviation applies.

In practice, a number is substituted for "*k*", for example, F_{p3} indicates that a given cumulative pitch deviation refers to three pitches.

6 Types of measuring equipment and principle

6.1 General

The analytical measurement of gears, also known as individual or elemental measurement, includes the measurement of helix, profile, pitch, radial runout and tooth thickness deviations. Measurements are made by positioning a contacting probe at the theoretical position where the gear flank should be relative to the datum axis and measuring any deviation. This can be performed by a number of different types of measuring devices including:

— coordinate measuring machines (CMM, with appropriate software), illustrated in Figures 3 and 4;

— traditional mechanical gear measuring machine (GMM), illustrated in Figure 5;

— computer numerically controlled (CNC) gear measuring machines (GMM), illustrated in Figure 6 and 7;

— in-process CNC measuring stations mounted on a machine tool, illustrated in Figure 8;

— portable measuring devices, illustrated in Figures 9, 17 and 18;

— portable gear measuring machines which can be mounted on machine tools or rotary tables to measure pitch and radial runout of the tooth space on large gears, as illustrated in Figures 10 and 11.

NOTE Portable measuring arms typically cannot achieve the same level of uncertainty as can be achieved by other measuring devices.

These methods generally involve scanning the probe over the tooth flank in a continuous manner.