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ISO 1328-1

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Cylindrical gears — ISO system of accuracy —

Part 1:
Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth

Engrenages cylindriques — Système ISO de précision —
Partie 1: Définitions et valeurs admissibles des écarts pour les flancs homologues de la denture

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Contents

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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.

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.

International Standard ISO 1328-1 was prepared by Technical Committee ISO/TC 60, *Gears*.

This first edition of ISO 1328-1, together with ISO 1328-2, cancels and replaces ISO 1328:1975, which has been technically revised.

ISO 1328 consists of the following parts, under the general title *Cylindrical gears — ISO system of accuracy*:

— *Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

— *Part 2: Definitions and allowable values of deviations relevant to radial composite deviations and runout*

Annex A forms an integral part of this part of ISO 1328. Annexes B and C are for information only.

Introduction

Together with definitions and allowable values of gear element deviations, ISO 1328:1975 also provided advice on appropriate inspection methods.

In the course of revising ISO 1328:1975 and taking into account several important aspects, it was agreed that the description and advice on gear inspection methods should be published as Technical Reports and that, together with parts 1 and 2 of ISO 1328, a system of standards and technical reports (listed in clause 2 and annex C) should be established.

Cylindrical gears — ISO system of accuracy —

Part 1:
Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth

1 Scope

This part of ISO 1328 establishes a system of accuracy relevant to corresponding flanks of individual cylindrical involute gears.

It specifies appropriate definitions for gear tooth accuracy terms, the structure of the gear accuracy system and the allowable values of pitch deviations, total profile deviations and total helix deviations.

This part of ISO 1328 applies only to each element of a toothed wheel taken individually; it does not cover gear pairs as such.

It is strongly recommended that any user of this part of ISO 1328 be very familiar with the methods and procedures outlined in ISO/TR 10064-1. Use of techniques other than those of ISO/TR 10064-1 combined with the limits described in this part of ISO 1328 may not be suitable.

Annex A gives formulae for tolerances for tangential composite deviations which are also criterions of ISO quality, but are not mandatory inspection items.

Annex B provides values on profile and helix form and slope deviations which sometimes serve as useful information and evaluation values but are not mandatory inspection items.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 1328. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 1328 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/TR 10064-1:1992, *Cylindrical gears — Code of inspection practice — Part 1: Inspection of corresponding flanks of gear teeth.*

3 Definitions

For the purposes of this part of ISO 1328, the following definitions apply.

For the symbols not explained in this clause, see clause 4.

3.1 Pitch deviations

3.1.1 single pitch deviation (f_{pt})**:** Algebraic difference between the actual pitch and the corresponding theoretical pitch in the transverse plane, defined on a circle concentric with the gear axis at approximately mid-depth of the tooth. (See figure 1.)

3.1.2 cumulative pitch deviation (F_{pk})**:** Algebraic difference, over any sector of k pitches, between the actual length and the theoretical length of the relevant arc. (See figure 1.) In theory, it is equal to the algebraic sum of the single pitch deviations of the same k pitches.

NOTE 1 Unless otherwise specified, evaluation of F_{pk} is limited to sectors not larger than one-eighth of the circumference. Hence, allowable values of deviations F_{pk} apply to sectors of which the number of pitches (k) ranges from 2 to the number nearest to $z/8$. Generally, evaluation of $F_{pz/8}$ is sufficient. If for special applications (e.g. for high-speed gears) smaller sectors are also to be checked, the relevant value(s) of k should be specified.

3.1.3 total cumulative pitch deviation (F_p)**:** Maximum cumulative pitch deviation of any sector (with $k = 1$ up to $k = z$) of the corresponding flanks of a gear. It is represented by the total amplitude of the cumulative pitch deviation curve.

3.2 Profile deviations

3.2.1 profile deviation: Amount by which an actual profile deviates from the design profile. It is in the transverse plane and normal to the involute profile.

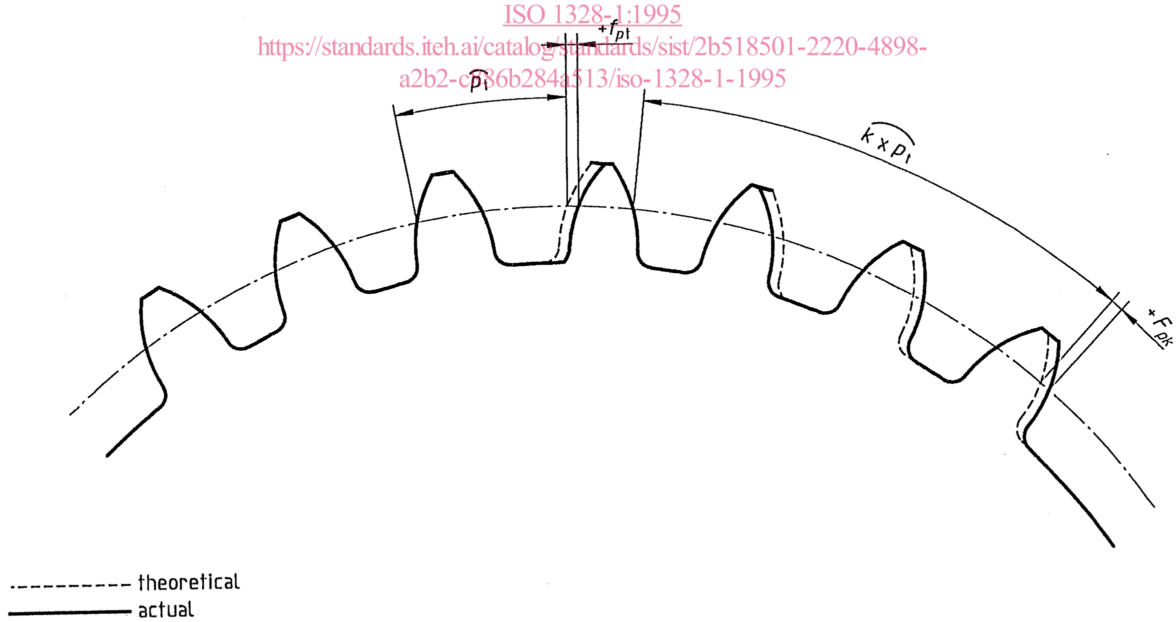
3.2.1.1 usable length (L_{AF})**:** Difference between the lengths of two transverse base tangents, of which one extends from the base circle to the outer limit and the other extends from the base circle to the inner limit of the usable profile.

Depending on the design, the usable length is limited by the tooth tip, by the start of tip chamfer or tip rounding (point A). Towards the root of the tooth, the usable length is limited either by the beginning of the root fillet or by the undercut (point F).

3.2.1.2 active length (L_{AE})**:** That part of the usable length which is related to the active profile. Towards the tooth tip, it has the same limit as the usable length (point A). Towards the root of the tooth, the active length extends to the endpoint E of the effective contact with the mating gear (start of the active profile). If the mating gear is unknown, point E is the start of the active profile of engagement with a rack having standard basic rack tooth proportions.

3.2.1.3 profile evaluation range (L_α)**:** That part of the usable length to which the tolerances of the specified accuracy grade shall apply. Unless otherwise specified, its length is equal to 92 % of the active length L_{AE}, extending from point E. (See figure 2.)

NOTE 2 It is the responsibility of the gear designer to assure that the profile evaluation range is adequate for the application.



In this example $F_{pk} = F_{p3}$

Figure 1 — Pitch deviations

For the remaining 8 % of L_{AE}, which is the zone near the tip expressed by the difference between L_{AE} and L_{α}, the following evaluation rules apply for the total profile deviation and the profile form deviation:

a) excess material (plus deviation) which increase the amount of deviation shall be taken into account;

b) unless otherwise specified, for minus deviations, the tolerance shall be three times the tolerance specified for the evaluation range L_{α}.

NOTE 3 For analysis of the profile form deviation, evaluations a) and b) are based on the mean profile trace defined in 3.2.1.5.

3.2.1.4 design profile: A profile consistent with the design specification. When not otherwise qualified, it is the profile in a transverse plane.

NOTE 4 In a profile diagram, the profile trace of an unmodified involute generally appears as a straight line. In figure 2, the design profile traces are shown as chain-dotted lines.

3.2.1.5 mean profile of a measured flank: A trace determined by subtracting from the ordinates of the design profile trace the corresponding ordinates of a straight-line gradient. This is to be so done that, within the evaluation range, the sum of the squares of deviations of the actual profile trace from the mean profile trace is minimal. Thus, the position and the gradient of the mean profile trace is found by the "least-squares method".

NOTE 5 This profile is an aid in the determination of $f_{f\alpha}$ [figure 2 b)] and $f_{H\alpha}$ [figure 2 c)].

3.2.2 total profile deviation (F_{α})**:** Distance between two design profile traces which enclose the actual profile trace over the evaluation range L_{α}, subject to the provisions of 3.2.1.3. [See figure 2 a).]

3.2.3 profile form deviation ($f_{f\alpha}$)**:** Distance between two facsimiles of the mean profile trace, which are each placed with constant separation from the mean profile trace, so as to enclose the actual profile trace over the evaluation range L_{α}, subject to the provisions of 3.2.1.3. [See figure 2 b).]

3.2.4 profile slope deviation ($f_{H\alpha}$)**:** Distance between two design profile traces which intersect the mean profile trace at the endpoints of the evaluation range L_{α}. [See figure 2 c).]

3.3 Helix deviations

3.3.1 helix deviation: Amount, measured in the direction of the transverse base tangent, by which an actual helix deviates from the design helix.

3.3.1.1 length of trace: Length proportional to the facewidth of the gear, excluding the tooth end chamfers or roundings.

3.3.1.2 helix evaluation range (L_{β})**:** Unless otherwise specified, the "length of trace", shortened at each end by the smaller of the following two values: – 5 % of the facewidth, or the length equal to one module.

NOTE 6 It is the responsibility of the gear designer to assure that the helix evaluation range is adequate for application.

In the relevant end zones, the following evaluation rules apply for the total helix deviation and the helix form deviation:

a) excess material (plus material deviation) which increases the amount of deviation shall be taken into account;

b) unless otherwise specified, for minus material deviations, the tolerance shall be three times the tolerance specified for the evaluation range L_{β}.

NOTE 7 For the analysis of helix form deviation, evaluations a) and b) are based on the mean helix trace defined in 3.3.1.4.

3.3.1.3 design helix: A helix consistent with the design specifications.

NOTE 8 In a helix diagram, the trace of an unmodified helix generally appears as a straight line. In figure 3, the design helix traces are shown as chain-dotted lines.

3.3.1.4 mean helix of a measured flank: A trace, determined by subtracting from the ordinates of the design helix trace the corresponding ordinates of a straight-line gradient.

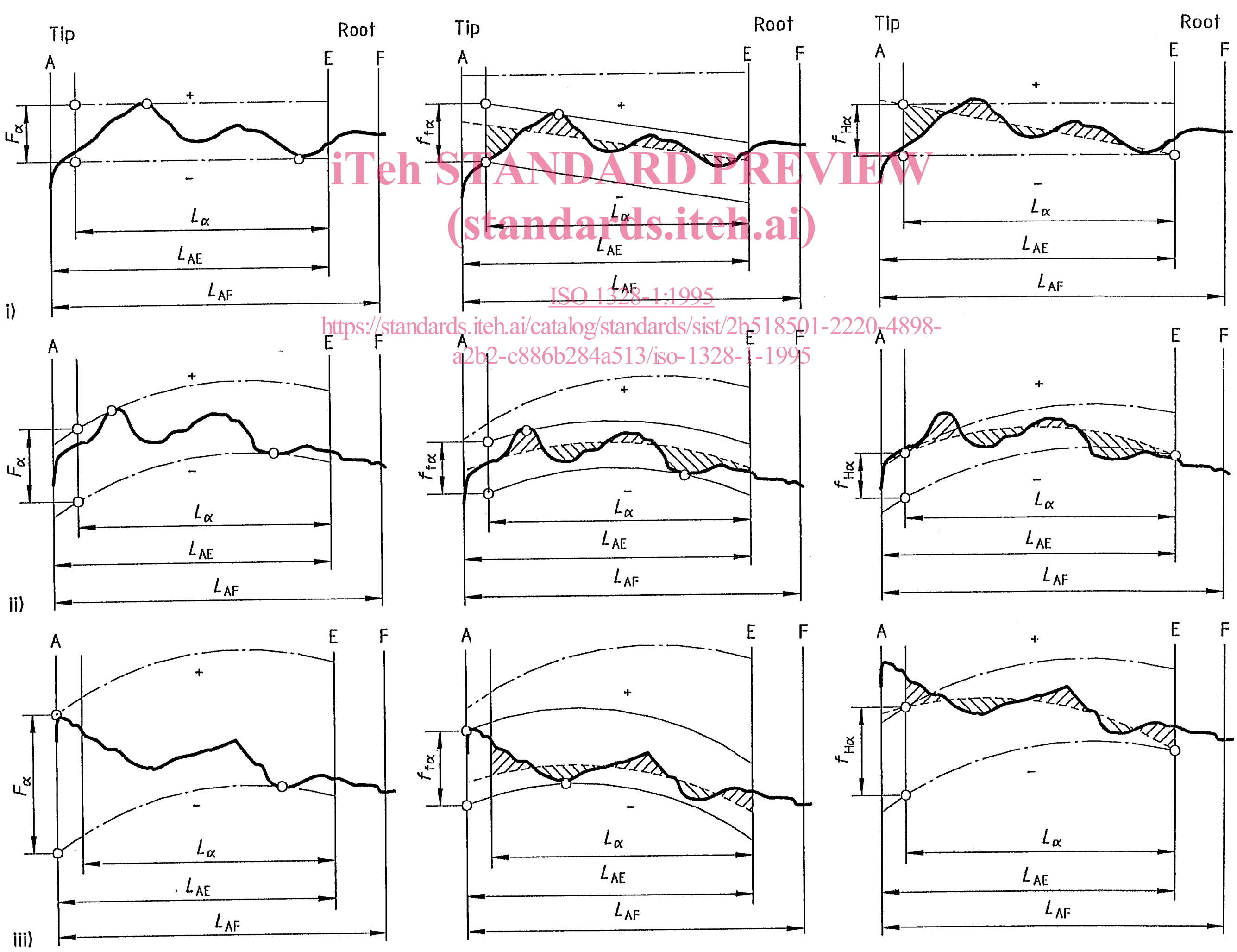
This is to be so done that, within the evaluation range, the sum of the squares of the deviations of the actual helix trace from the mean helix trace is minimal. Thus, the position and the gradient of the mean helix is found by the "least-squares method".

NOTE 9 This helix is an aid in the determination of the deviations $f_{f\beta}$ [figure 3 b)] and $f_{H\beta}$ [figure 3 c)].

Key

: Design profile   : Actual profile   : Mean profile

i)	Design profile:	unmodified involute
	Actual profile:	with minus material deviations in the reduction zone
ii)	Design profile:	modified involute (example)
	Actual profile:	with minus material deviations in the reduction zone
iii)	Design profile:	modified involute (example)
	Actual profile:	with excess of material in the reduction zone



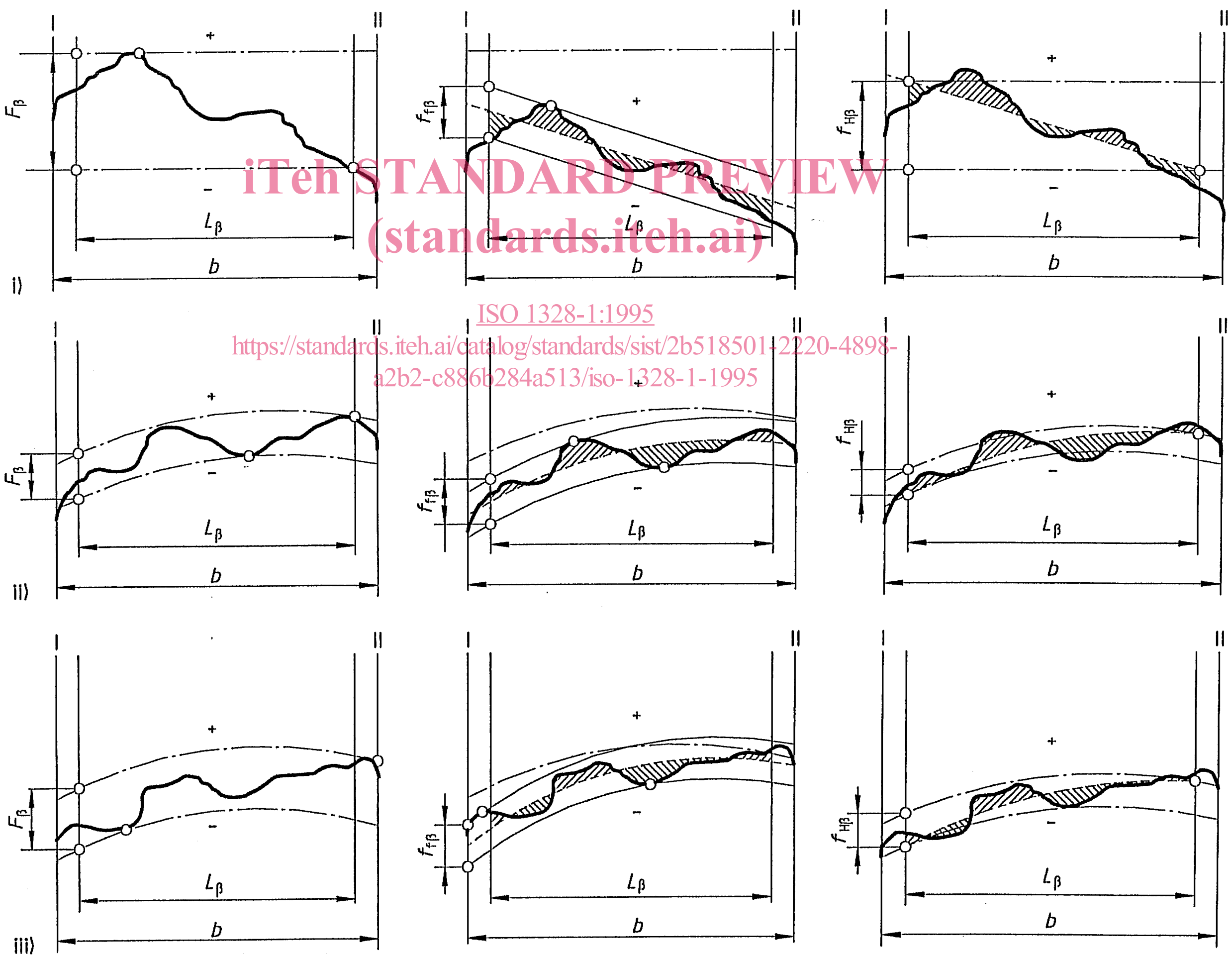
a) Total profile deviation   b) Profile form deviation   c) Profile slope deviation

Figure 2 — Profile deviations

Key

—·—·—·—· : Design helix  : Actual helix - - - - - - - - - : Mean helix

i)	Design helix: Actual helix:	unmodified helix with minus material deviations in the reduction zone
ii)	Design helix: Actual helix:	modified helix (example) with minus material deviations in the reduction zone
iii)	Design helix: Actual helix:	modified helix (example) with excess of material in the reduction zone



a) Total helix deviation b) Helix form deviation c) Helix slope deviation

Figure 3 — Helix deviations

3.3.2 total helix deviation (F_β): Distance between two design helix traces which enclose the actual helix trace over the evaluation range L_β, subject to the provisions of 3.3.1.2. [See figure 3 a).]

3.3.3 helix form deviation ($f_{f\beta}$): Distance between two facsimiles of the mean helix trace, which are each placed with constant separation from the mean helix trace, so as to enclose the actual helix trace over the evaluation range L_β, subject to the provisions of 3.3.1.2. [See figure 3 b).]

3.3.4 helix slope deviation ($f_{H\beta}$): Distance between two design helix traces which intersect the mean helix trace at the endpoints of the evaluation range L_β. [See figure 3 c).]

3.4 Tangential composite deviations

3.4.1 total tangential composite deviation (F'_i): Maximum difference between the effective and theoretical circumferential displacements at the reference circle of the gear under inspection, when meshing with a master gear, the tested product gear being turned through one complete revolution.

NOTE 10 During the inspection process, contact takes place on only one set of corresponding flanks (figure 4).

3.4.2 tooth-to-tooth tangential composite deviation (f'_i): Value of the tangential composite deviation over a displacement of one pitch. (See figure 4.)

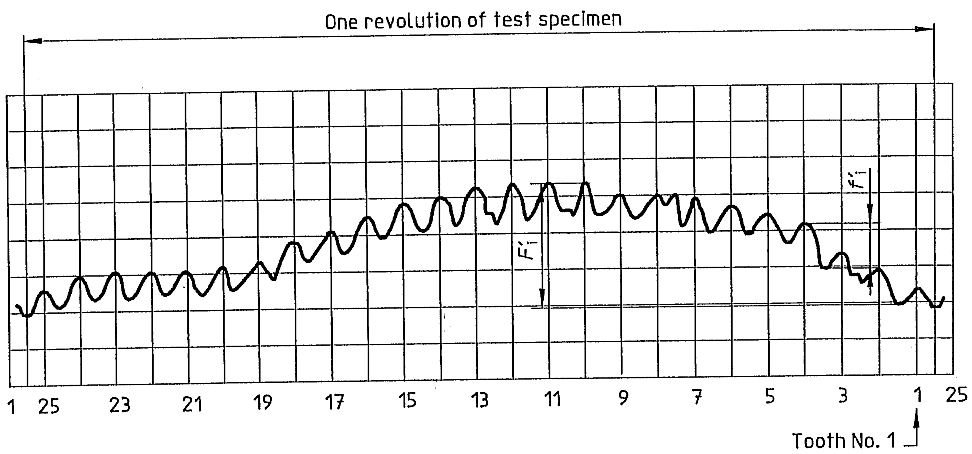


Figure 4 — Tangential composite deviations

4 Symbols and abbreviations

4.1 Gear data and gear terms (lengths in millimetres)

b Facewidth

d Reference diameter

k Number of successive pitches

m Module

p_t Transverse pitch

z Number of teeth

A Beginning point of chamfer or tip rounding

E Start of active profile

F Start of usable profile

L_{AE} Active length (of base tangent)

L_{AF} Usable length (of base tangent)

L_α Profile evaluation range

L_β Helix evaluation range

Q Accuracy grade

ε_γ Total contact ratio

I Reference face

II Non-reference face

4.2 Gear deviations (in micrometres)

$f_{f\alpha}$ Profile form deviation

$f_{f\beta}$ Helix form deviation

$f_{H\alpha}$ [1] Profile slope deviation

$f_{H\beta}$ [1] Helix slope deviation

f'_i Tooth-to-tooth tangential composite deviation

f_{pt} [1] Single pitch deviation

F'_i Total tangential composite deviation

F_p Total cumulative pitch deviation

F_{pk} [1] Cumulative pitch deviation

F_α Total profile deviation

F_β Total helix deviation

5 Structure of the system of accuracy for gears

5.1 ISO system of accuracy

The ISO system of accuracy comprises 13 accuracy grades of which grade 0 is the highest and grade 12 is the lowest degree of accuracy.

When a statement concerning required accuracy is made in documents, reference to ISO 1328-1 or ISO 1328-2, as appropriate, shall be included.

5.2 Allowable values for deviations

The accuracy grade of a gear is evaluated by comparing measured deviations against the numerical values given in tables 1 to 4. These values are calculated with the formulae given in clause 6, which apply for accuracy grade 5. The step factor between two consecutive grades is equal to $\sqrt{2}$; i.e. values of each next higher (lower) grade are determined by multiplying (dividing) by $\sqrt{2}$. The required value for any accuracy grade can be determined by multiplying the unrounded calculated value for accuracy grade 5 by $2^{0,5\,(Q-5)}$, where Q is the accuracy grade number of the required value.

Allowable values for the cumulative pitch deviation F_{pk} for which no tables with numerical values are provided are to be calculated on the basis of 3.1.2, 5.2 to 5.4, 6.1 and 6.2.

With reference to the formulae in clause 6 and tables 1 to 4, module m and facewidth b are, if not otherwise specified, understood to be nominal values, without taking into account tooth tip and tooth end chamfers.

5.3 Ranges of parameters

The lower and upper range limits areas follows (values are in millimetres):

a) **for the reference diameter,** d

5/20/50/125/280/560/1 000/1 600/2 500/
4 000/6 000/8 000/10 000

1) These deviations can be plus or minus.

b) **for the module (normal module),** m

0,5/2/3,5/6/10/16/25/40/70

c) **for the facewidth,** b

4/10/20/40/80/160/250/400/650/1 000

When applying the formulae given in clause 6, the parameters m, d and b are to be introduced as the geometrical mean values of the relevant range limits and not as the actual values. If, for example, the actual module is 7, the range limits are $m = 6$ and $m = 10$, and allowable deviations are calculated with

$$m = \sqrt{6 \times 10} = 7{,}746$$

When gear data are not within the specified ranges or when agreed between purchaser and supplier, actual gear data may be substituted in the formulae.

5.4 Rounding rules

Values given in tables 1 to 4 are rounded versions of values calculated using the formulae in clause 6. If greater than 10 µm, they are rounded to the nearest integer number. If less than 10 µm, they are rounded to the nearest 0,5 µm value or integer number. If less than 5 µm, they are rounded to the nearest 0,1 µm value or integer number.

5.5 Validity

When in procurement documents the required gear accuracy grade corresponding ISO 1328-1 is stated without other indication, that grade applies to deviations of all elements in accordance with 6.1 to 6.5 of this part of ISO 1328. However, by agreement, working and non-working flanks of different accuracy grades may be specified and/or different accuracy grades may be specified for different deviations. Alternatively, the required accuracy grade may be specified for the working flanks only.

Unless otherwise specified, measurements are carried out at approximately mid-tooth depth and/or mid-facewidth, as appropriate. When tolerance values are small, particularly when less than 5 µm, the measuring equipment shall be of sufficient accuracy to insure that the measurements of size can be repeated with the required accuracy.

Unless otherwise specified, profile and helix deviations are to be evaluated on both flanks of a minimum of three teeth approximately equally spaced around the gear. Measurements of the single pitch deviation, f_{pt}, are required on both flanks of all teeth.

6 Formulae for allowable values of gear deviations of accuracy grade 5

NOTE 11 Symbols are as defined in clause 4.

6.1 Single pitch deviation, f_{pt}, is calculated from

$$f_{pt} = 0{,}3\left(m + 0{,}4\sqrt{d}\right) + 4$$

6.2 Cumulative pitch deviation, F_{pk}, is calculated from

$$F_{pk} = f_{pt} + 1{,}6\sqrt{(k-1)m}$$

6.3 Total cumulative pitch deviation, F_p, is calculated from

$$F_p = 0{,}3m + 1{,}25\sqrt{d} + 7$$

6.4 Total profile deviation, F_α, is calculated from

$$F_\alpha = 3{,}2\sqrt{m} + 0{,}22\sqrt{d} + 0{,}7$$

6.5 Total helix deviation, F_β, is calculated from

$$F_\beta = 0{,}1\sqrt{d} + 0{,}63\sqrt{b} + 4{,}2$$

6.6 Parameters m, d and b are introduced into the formulae as geometrical mean values of relevant range limits as defined in 5.3 and 5.4.

Formulae for tolerances for tangential composite deviations, and for recommended tolerances for profile and helix form and slope deviations, are given in annexes A and B respectively.

7 Allowable values of gear deviations relevant to corresponding flanks

See tables 1 to 4.