INTERNATIONAL STANDARD

ISO 1328-2

Second edition
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Cylindrical gears — ISO system of flank tolerance classification —

Part 2:
Definitions and allowable values of double flank radial composite deviations

Engrenages cylindriques — Système ISO de classification des tolérances sur flancs —

Partie 2: Définitions et valeurs admissibles des écarts composés radiaux

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Foreword

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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).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 1328-2:1997), which has been technically revised. The main changes compared to the previous edition are as follows:

— the document title of this part has been revised to correspond to that of part 1 and better reflect the contents of this part;

— the scope of applicability has been expanded to include sector gears;

— revisions have been made to the formulae which define the double flank radial composite tolerances, and the range of classification numbers has been changed to clarify the independence of this classification system from that given in part 1;

— the change in tolerance value between consecutive tolerance classes has been reduced, so two steps in the new system results in the same change as one step of the old system, but approximately the same global range of tolerance values is maintained with additional steps;

— annexes have been added to describe complementary information and examples;

— evaluation of runout, previously handled in this document, has been moved to ISO 1328-1:2013;

— advice on appropriate inspection methods has been removed; the information can be found in ISO/TR 10064-2.

A list of all parts in the ISO 1328 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Cylindrical gears — ISO system of flank tolerance classification —

Part 2: Definitions and allowable values of double flank radial composite deviations

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1 Scope

This document establishes a gear tooth classification system relevant to double flank radial composite deviations of individual cylindrical involute gears and sector gears. It specifies the appropriate definitions of gear tooth deviations, the structure of the gear tooth flank classification system, and the allowable values of the gear tooth deviations. It provides formulae to calculate tolerances for individual product gears when mated in double flank contact with a master gear. Tolerance tables are not included.

This document is applicable to gears with three or more teeth that have reference diameters of up to 600 mm.

This document does not provide guidance on gear design nor does it recommend tolerances.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 701, *International gear notation — Symbols for geometrical data*

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

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 701 and ISO 1122-1 and the following apply.

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

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

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

3.1.1
double flank test
test where a *master gear* (3.1.4) and a *product gear* (3.1.5) are rotated in tight mesh contact, i.e. held together by a spring load so there is no backlash, while measuring the changes in center distance

3.1.2
elemental deviation
deviation, such as profile and helix deviation on individual teeth or pitch deviation between teeth, generally using a single point of contact probe

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3.1.3
elemental method
method to measure *elemental deviations* (3.1.2)

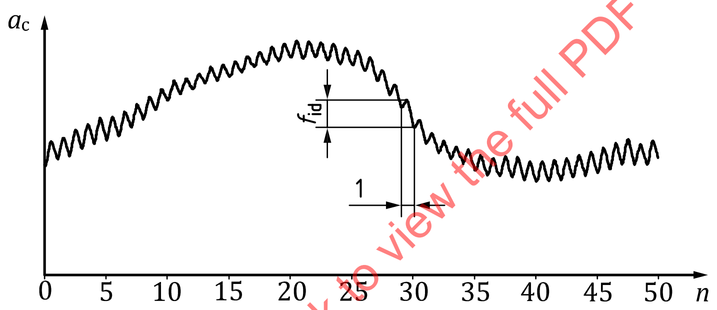
Note 1 to entry: ISO 1328-1 describes elemental methods and deviations.

3.1.4
master gear
gear with the required precision that is designed to measure double flank radial composite deviation in a double flank contact test with a *product gear* (3.1.5)

3.1.5
product gear
gear that is being measured or evaluated

3.1.6
tooth-to-tooth radial composite deviation
f_{id}
value of the greatest change in center distance within any one pitch, found after evaluating all the teeth of a *product gear* (3.1.5) in a *double flank test* (3.1.1) with a *master gear* (3.1.4)

Note 1 to entry: See Figure 1.



Key

1 single tooth pitch

n tooth number

a_c tight mesh center distance

Figure 1 — Tooth-to-tooth radial composite deviation

3.1.7
tooth-to-tooth radial composite tolerance
f_{idT}
maximum *tooth-to-tooth radial composite deviation* (3.1.6) allowable by specification

3.1.8
total radial composite deviation
F_{id}
difference between the maximum and minimum values of center distance found after evaluating all the teeth of a *product gear* (3.1.5) in a *double flank test* (3.1.1) with a *master gear* (3.1.4)

Note 1 to entry: See Figure 2.

3.1.9
total radial composite tolerance
F_{idT}
maximum *total radial composite deviation* (3.1.8) allowable by specification

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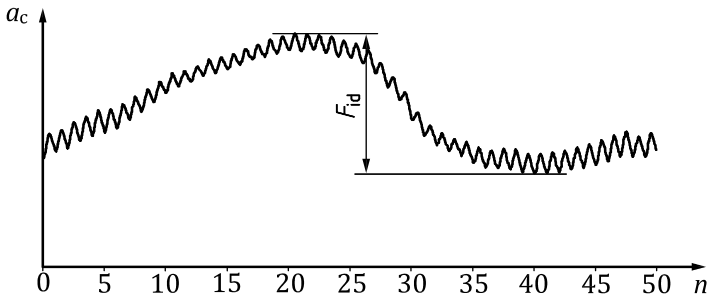

Key

n tooth number

a_c tight mesh center distance

Figure 2 — Total radial composite deviation

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3.2 Symbols

For the purposes of this document, the symbols given in Table 1 apply. The symbols are based on those given in ISO 701.

Table 1 — Symbols

Symbol	Term	Units	First used
a_c	Tight mesh center distance	mm	3.1.6
F_{id}	Total radial composite deviation	µm	3.1.8
f_{id}	Tooth-to-tooth radial composite deviation	µm	3.1.6
F_{idk}	Radial composite deviation over k teeth	µm	B.3
F_{idkT}	Radial composite tolerance over k teeth	µm	B.4
F_{idT}	Total radial composite tolerance	µm	3.1.9
f_{idT}	Tooth-to-tooth radial composite tolerance	µm	3.1.7
k_{max}	Maximum number of tooth pitches in measurement segment	—	B.4
m_n	Normal module	mm	5.3
n	Tooth number	—	3.1.6
R	Tolerance class number	—	5.3
R_x	Tolerance class modifier based on number of teeth	—	5.3
z	Number of teeth	—	5.2.1
z_c	Number of teeth for calculation	—	5.3
z_k	Number of teeth in the sector	—	5.4.2
β	Helix angle	°	5.3

4 Application of the ISO double flank radial composite tolerance classification system

4.1 General

This document provides classification tolerances and measuring methods for unassembled gears.

Surface texture is not considered in this document. For additional information on surface texture, see ISO/TR 10064-4.

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With agreement between the purchaser and manufacturer, the tolerances may be applied to other types of gears such as cylindrical worms, worm gears, racks, and bevel gears. However, in these cases, modified procedures and associated measurement processes should be considered since this standard only describes procedures for parallel axis gears. See ISO/TR 10064-2 for additional information.

Some design and application considerations may warrant measurements or documentation not normally included in standard manufacturing processes. Specific requirements shall be stated in the contractual documents.

Additional information on double flank testing is given in ISO/TR 10064-2.

NOTE 1 Tolerances for a specified class are calculated according to the formulae in Clause 5. To aid in visualizing how the tolerances change with the number of gear teeth, graphs are provided in Annex A showing tolerance values for 3 tolerance classes.

NOTE 2 There is no correlation or interrelation between the classes specified in this document and other parts or standards such as ISO 1328-1. This document uses a unique set of tolerance classes (i.e., R30 to R50) to reinforce that no correlation to other elemental or radial composite standards exists (see Annex C). However, while there is no general correlation to other standards, for a specific gear it is possible to find a tolerance class or classes according to this document that will give similar tolerances to those that were originally specified for the gear, see Annex D.

NOTE 3 The specific methods of measurement, documentation of the results, inspection frequency, and use of statistical methods are items that normally are mutually agreed upon between the manufacturer and the purchaser.

4.2 Gear tooth tolerance class

In this document, the double flank radial composite tolerance class is determined by measurement of total radial composite deviation, F_{id}, and tooth-to-tooth radial composite deviation, f_{id}. A gear that is specified to a single ISO double flank radial composite tolerance class shall meet both individual tolerance requirements.

In addition to the total and tooth-to-tooth tolerances, Annex B provides an optional specification for composite tolerance over a selected number of teeth, k.

NOTE 1 Specifying a class or measurement criteria that require more precise tolerances than required by the application can unnecessarily increase the cost.

NOTE 2 Double flank measurements, such as tight mesh center distance, can be used for control of tooth thickness and total radial composite effects simultaneously.

This document allows for the specification of separate classes for total radial composite deviation, F_{id}, and tooth-to-tooth radial composite deviation, f_{id}.

The assessment of the gear's double flank radial composite tolerance class shall be performed after the final manufacturing process. Double flank composite checks may also be performed at any step in the manufacturing process.

This document is for classes R30 to R50. It may be convenient in a specific application to use the formulae in this document by extrapolating them below R30 or beyond R50. When this is done, individual tolerances should be used on these applications as opposed to defining a class outside of the R30 to R50 range.

4.3 Specification of datum surfaces

Specification of radial composite tolerances requires the definition of datum surfaces to be used for double flank inspection. See ISO/TR 10064-3.

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4.4 Application of the ISO flank classification standard

4.4.1 Measurement equipment and master gears

When measurement according to this document is specified, the double flank equipment for the gears being measured is to be calibrated and appropriate. Unless otherwise agreed upon, the manufacturer may select the double flank equipment to be used.

A master gear shall be used for double flank radial composite tests. The design of the teeth, including specified tolerances, of a master gear shall be agreed upon between the manufacturer and purchaser of the product gear. Master gears are subject to wear and damage during use and should be periodically calibrated and traceable to national standards, with a stated measurement uncertainty.

NOTE Master gear deviations can increase or decrease the measured deviations in the test gear. Therefore, parts requiring higher levels of precision normally require more precise master gears. The use of lower quality masters will increase the risk of false acceptance or rejection of a product gear.

There shall be no gear mesh interference between the product gear and the master gear. Interference between the tips and fillets at the minimum center distance during measurement should be checked. Minimum total contact ratio should be checked, and its value should be greater than 1,02 with all tolerances applied.

4.4.2 Equipment verification and uncertainty

The equipment used for the measurement of gears should be verified periodically.

The uncertainty of the measuring process should be determined, see ISO 14253-1.

4.4.3 Filtering and data density

Tooth-to-tooth radial composite deviation can be greatly influenced by runout, especially on gears with low numbers of teeth. Some double flank equipment may have the option of using filtering techniques to report tooth-to-tooth radial composite deviations after removing the effect of eccentricity. The tolerance values in this document shall be applied without the use of filtering that removes the effects of eccentricity.

Other filtering can occur due to the mechanical dynamic frequency response of the moving pieces of the tester including the effects from the mass of the gear itself, mass of the moving head, frictional resistance of the measuring system, and the spring. Slower rotation during testing reduces the effect of this filtering due to mechanical dynamic response.

When an electronic measuring device is used, a minimum of 30 data samples per tooth pitch should be taken.

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4.5 Acceptance criteria

The double flank radial composite tolerance class of a gear is determined by the larger class number measured for the tolerance parameters specified for the gear by this document.

The tolerances for double flank radial composite deviations apply to the inspection of a gear meshing with a master gear. Use of double flank radial composite tolerances on two product gears meshing together should be agreed upon between the manufacturer and the purchaser.

4.6 Correlation of double flank radial composite and element deviations

The tolerance class determined for a gear measured with the double flank radial composite methods of this document does not correlate to the class determined for that gear by the elemental methods covered in ISO 1328-1. Users are cautioned that specification to this document alone may not properly

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control deviations of index or total cumulative pitch that can occur without radial deviations. See ISO/TR 10064-1 and ISO/TR 10064-2 for more information on index deviation.

4.7 Designation of the double flank radial composite tolerance class or tolerances

Designation/specification of a double flank radial composite tolerance class in accordance with this document shall be as follows:

ISO 1328-2:2020, class Rxx

where xx designates the design double flank radial composite tolerance class.

NOTE If the year of publication is not listed and previous standard qualifier class is not listed, the latest version of ISO 1328-2 applies.

5 Tolerance values

5.1 General

The tolerance values are calculated by the formulae given in 5.3 and 5.4. In addition, the formula in B.4 may be used to calculate the optional double flank radial composite deviation over segments of k teeth.

NOTE Annex E provides tolerance calculation examples.

When the gear diameter or number of teeth is not within the specified range listed in Clause 1, use of the tolerance formulae shall be agreed upon between manufacturer and purchaser.

The double flank radial composite classification system is comprised of 21 tolerance classes for total and tooth-to-tooth radial composite deviations of which class R30 is the most accurate and class R50 is the least accurate.

5.2 Use of formulae

5.2.1 Number of teeth used to calculate tolerances

For gears with more than 200 teeth, except for sector gears, a default value of 200 shall be used for the number of teeth.

For sector gears, z is the equivalent number of teeth based on extending the sector to cover 360° around the gear's axis of rotation.

5.2.2 Rounding rules

Values calculated from Formulae (1), (4), and (5) shall be rounded to the nearest micron. If the fractional result is equal to 0,5, the value is rounded up to the next integer.

If the measuring instrument reads in inches, values calculated from Formulae (1), (4), and (5) shall be converted to ten thousandths of an inch prior to rounding and then rounded to the nearest 0,5 ten thousandths of an inch. For example, a value of 11,74 tenths would be rounded to 11,5 tenths while 11,75 tenths would be rounded to 12,0 tenths.

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5.3 Tooth-to-tooth radial composite tolerance, f_{idT}

The tooth-to-tooth radial composite tolerance, f_{idT}, shall be calculated according to Formula (1) while also using Formulae (2) and (3):

$$f_{idT} = \left(0{,}08 \frac{z_c m_n}{\cos\beta} + 64 \right) 2^{[(R - R_x - 44)/4]} = \frac{F_{idT}}{2^{(R_x/4)}} \tag{1}$$

$$z_c = \min(|z|, 200) \tag{2}$$

$$R_x = 5\left\{1 - 1{,}12^{[(1 - z_c)/1{,}12]}\right\} \tag{3}$$

5.4 Total radial composite tolerance, F_{idT}

5.4.1 Total radial composite tolerance for cylindrical gears

The total radial composite tolerance, F_{idT}, for cylindrical gears and sector gears that are greater than two-thirds of a full circle shall be calculated according to:

$$F_{idT} = \left(0{,}08 \frac{z_c m_n}{\cos\beta} + 64 \right) 2^{[(R - 44)/4]} \tag{4}$$

5.4.2 Total radial composite tolerance for sector gears

This subclause applies only to sector gears whose teeth occupy two-thirds of a full circle or less.

If $\left| \frac{z_k}{z} \right| > \frac{2}{3}$, Formula (4) as shown in 5.4.1 shall be used for the total radial composite tolerance, F_{idT}, of the sector gear as though it is equivalent to a full circle gear.

If $\left| \frac{z_k}{z} \right| \le \frac{2}{3}$, Formula (5) shall be used for the total radial composite tolerance, F_{idT}, of the sector gear, in order to compensate for the size of the sector [with R_x from Formula (3)]:

$$F_{idT} = \left(0{,}08 \frac{z_c m_n}{\cos\beta} + 64 \right) 2^{[(R - 44)/4]} \left[\left(1 - 1{,}5 \frac{|z_k| - 1}{|z|} \right) 2^{\left(\frac{-R_x}{4} \right)} + 1{,}5 \frac{|z_k| - 1}{|z|} \right] \tag{5}$$

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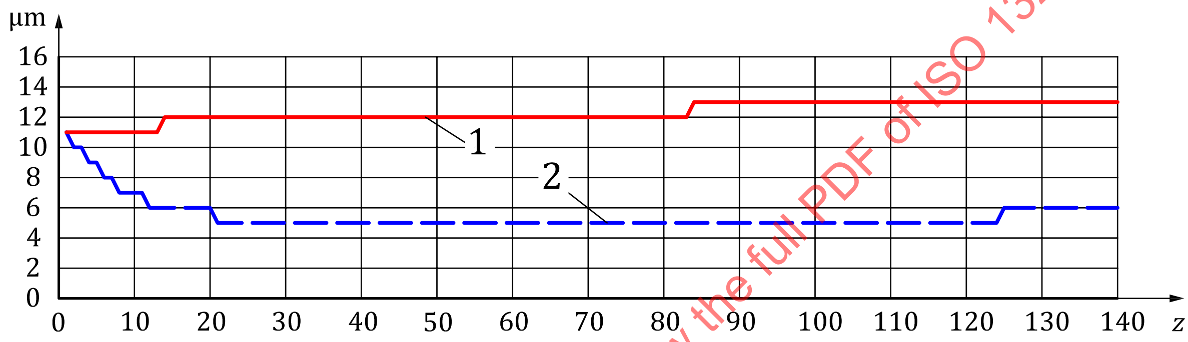
Annex A
(informative)

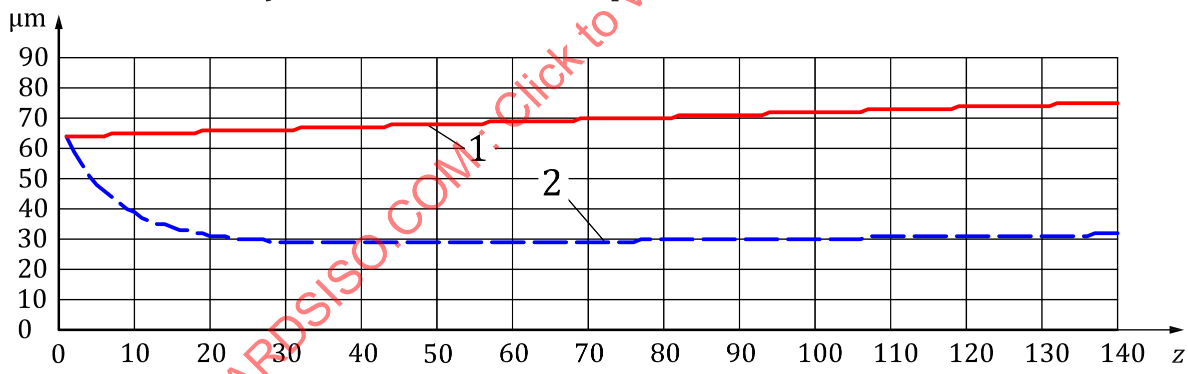
Graph of tolerance values for class R34, R44, and R50 for spur gears with module = 1,0 mm

Figure A.1 shows tolerance values for both total radial composite tolerance, F_{idT} and tooth-to-tooth radial composite tolerance, f_{idT} for module 1,0 mm class R34, R44, and R50 spur gears. These graphs plot the values from Formulae (1) and (4) rounded per 5.2.2 to assist those using this document to visualize the characteristics of the classification system formulae.

NOTE The steps in the curves are the result of the rounding operation.



a) Double flank radial composite tolerance class 34



b) Double flank radial composite tolerance class 44

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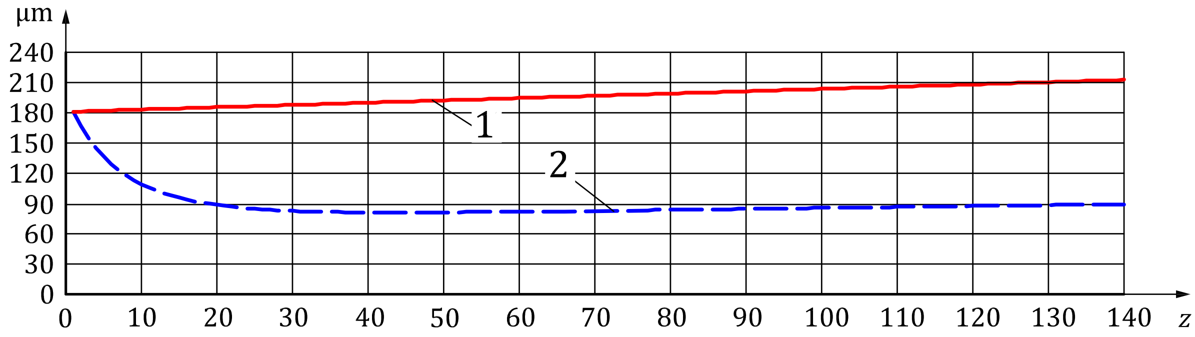

c) Double flank radial composite tolerance class 50

Key

1 total composite tolerance, F_{idT}

2 tooth to tooth tolerance, f_{idT}

Figure A.1 — Total radial composite tolerance, F_{idT} and tooth-to-tooth radial composite tolerance, f_{idT} for module = 1,0 mm full circle spur gears versus the number of teeth

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Annex B
(informative)

Double flank radial composite deviation over segments of *k* teeth

B.1 General

This annex provides the definition, measurement practices, recommended tolerances, and guidance for double flank radial composite deviation over multiple segments of *k* teeth. It may be used as an optional supplemental specification in addition to the total radial composite and tooth-to-tooth radial composite deviation specifications described in this document.

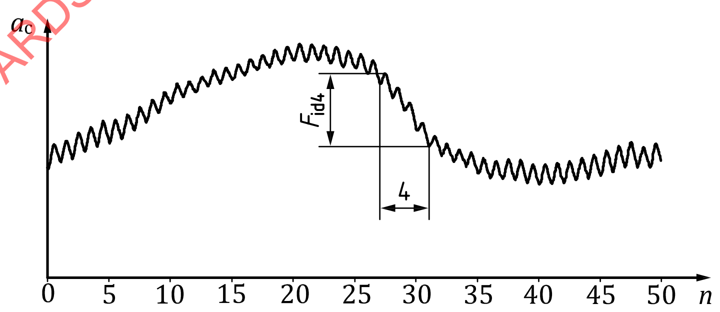
B.2 Application

A gear that has acceptable tooth-to-tooth radial composite deviations and an acceptable total radial composite deviation may still have a transmission error that is not functionally acceptable if much of the double flank radial composite deviation occurs over only a few teeth. Gears with high contact ratios, high mesh overlap, can have an anomaly on one tooth that is recorded on the double flank tester over multiple teeth. Additional defects on adjacent teeth could result in a significant functional problem due to the high mesh overlap. Use of double flank radial composite deviation testing over multiple teeth can help identify such issues.

B.3 Double flank radial composite deviation over *k* teeth, F_{idk}

The double flank radial composite deviation over *k* teeth, F_{idk}, is the value of the greatest change in center distance within any range of *k* tooth pitches found after evaluating all of the teeth of a product gear with a double flank test. An example of double flank radial composite deviation over four teeth is shown in Figure B.1. This example shows a gear where the rapid change in double flank radial composite deviation can cause operational problems, but would not be detected by single tooth-to-tooth radial composite deviation or the total radial composite deviation.

NOTE The number of tooth pitches specified appears in the symbol in place of *k*, *i.e.* if four tooth pitches are used, the symbol is F_{id4}.



Key

n tooth number

a_c tight mesh center distance

Figure B.1 — Double flank radial composite deviation over four teeth for a 50 tooth gear

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B.4 Double flank radial composite tolerance over *k* teeth, F_{idkT}

The double flank radial composite tolerance over *k* teeth is the maximum allowable double flank radial composite deviation over *k* teeth. It is calculated as:

$$F_{idkT} = \left(0{,}08\frac{z_c\, m_n}{\cos\beta} + 64\right) 2^{[(R-44)/4]} \left[\left(1 - 1{,}5\frac{k-1}{|z|}\right) 2^{\left(\frac{-R_x}{4}\right)} + 1{,}5\frac{k-1}{|z|}\right] \quad \text{(B.1)}$$

where z_c and R_x are from Formulae 2 and 3.

The calculated value is subject to the same rounding rules as outlined in 5.2.2.

The maximum number of tooth pitches k_{max} for all gears other than sector gears is:

$$k_{max} = \frac{z_c}{1{,}5} \quad \text{(B.2)}$$

while in the case of sector gears, k_{max} is:

$$k_{max} = \text{minimum}\left(\frac{|z|}{1{,}5}, |z_k|\right) \quad \text{(B.3)}$$

Selection of a value for *k* beyond k_{max} will result in a tolerance which will exceed the total radial composite tolerance. Generally, *k* is in the range of 3 to $z/8$ tooth pitches, however values of *k* are not limited by this range.

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Annex C
(informative)

Reasons for changing double flank composite tolerances

C.1 General

This edition of this document has new tolerance formulae. The reason for the change is:

— the large increase in total composite tolerances with size does not correlate well with either the difficulty in manufacturing or the needs of typical gear applications;

— a $\sqrt{2}$ step factor from one class to the next is excessive for large tolerances;

— provision is needed for specification of composite tolerance over a limited number of teeth;

— sector gears were not explicitly covered;

— the old formulae for tooth-to-tooth composite tolerances do not correspond well to those given for total composite tolerances, particularly when the number of teeth is low.

C.2 Sector gears

The formulae in ISO 1328-2:1997 are not suitable for sector gears, and, in particular, sector gears with few teeth in comparison to a full circle gear. The new formula accounts for sector gears, and so allows the scope to be expanded to include them.

C.3 Tooth to tooth tolerances

The proposed tooth-to-tooth tolerances are aligned with the proposed total composite tolerances in a practical way. The new tolerance formulae also result in a one tooth helical gear having the same tolerance for total composite and tooth-to-tooth deviation.

C.4 Step factor

For double flank testing of gears with large tolerances, a factor of square root of two, which gives a 41,4 % jump in tolerance, is too large both for economical manufacturing and for proper functioning of the product. This is particularly important for lower quality gears.

By way of illustration, consider a gear that with a $\sqrt{2}$ step factor can have a total composite tolerance of 100 µm or 141 µm. If the process used has a manufacturing capability of 110 µm total composite tolerance, one class cannot be achieved while the other results in an excessive tolerance. The new step size of 1,19 results in a 119 µm tolerance being available, which is reasonable.

C.5 Composite tolerance over k teeth

Annex B provides an optional specification for composite tolerance for a selected number of teeth, *k*. This is similar in concept to the sector pitch deviation tolerance given in ISO 1328-1:2013, Annex D. Some designers may choose to use this optional specification, especially in applications where excessive deviations in one portion of a gear may cause functional problems even if they are within the total composite tolerance of the whole gear. This tolerance is often specified for applications that are sensitive to noise and vibration.

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Annex D
(informative)

Conversion from another double flank composite tolerance specification

D.1 General method

To convert a double flank composite tolerance specification to a tolerance class according to this edition of this document, the actual tolerances should be found. Then the new tolerances classes can be found from:

For total composite tolerance:

$$R = 4\left[\frac{\ln \dfrac{F_{\mathrm{idT}}}{\left(0{,}08\dfrac{z_c\, m_n}{\cos\beta}+64\right)}}{\ln 2}\right]+44 \qquad \text{(D.1)}$$

For tooth-to-tooth tolerance:

$$R = 4\left[\frac{\ln \dfrac{f_{\mathrm{idT}}}{\left(0{,}08\dfrac{z_c\, m_n}{\cos\beta}+64\right)}}{\ln 2}\right]+44+R_x \qquad \text{(D.2)}$$

where

z_c is from Formula (2) and

R_x is from Formula (3).

NOTE 1 In some prior standards, the total radial composite tolerance F_{idT} used the symbol F_i'' and the tooth to tooth radial composite tolerance f_{idT} used the symbol f_i''.

NOTE 2 When the total and tooth-to-tooth tolerance values from another standard are calculated for a tolerance class, the designer can choose to round the values per the rounding rules or to just use the results directly. Usually the choice does not affect the final result. In example E.6, the values are not rounded.

D.2 Choices

The designer needs to decide if it is appropriate to pick a single tolerance class, or if separate classes should be specified for each tolerance. The designer also needs to choose between rounding the calculated tolerance class to the nearest integer and rounding it to the next higher integer.

In some cases, it can be appropriate to just use the new total composite tolerance class and accept the new tooth to tooth tolerance resulting from that.

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Annex E
(informative)

Calculation examples

E.1 Example 1 — Spur gear

14 tooth spur gear

3,0 mm normal module

Class R48

Step 1. Calculation of the tooth-to-tooth radial composite tolerance

From Formulae (1), (2), and (3):

$$\begin{aligned} z_c &= \min(|z|, 200) \\ &= \min(|14|, 200) \\ &= 14 \end{aligned}$$

$$\begin{aligned} R_x &= 5\left\{1 - 1{,}12^{[(1-z_c)/1{,}12]}\right\} \\ &= 5\left\{1 - 1{,}12^{[(1-14)/1{,}12]}\right\} \\ &= 3{,}658 \end{aligned}$$

$$\begin{aligned} f_{idT} &= \left(0{,}08\frac{z_c\, m_n}{\cos\beta} + 64\right) 2^{[(R-R_x-44)/4]} \\ &= \left(0{,}08\frac{14\times 3}{\cos 0} + 64\right) 2^{[(48-3{,}658-44)/4]} \\ &= 71{,}470\ \mu\text{m} \end{aligned}$$

Based on the rounding rules in 5.2.2, this value is rounded to the nearest micron.

$f_{idT} = 71\ \mu\text{m}$

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Step 2. Calculation of the total radial composite tolerance

From Formula (4):

$$\begin{aligned} F_{idT} &= \left(0{,}08\frac{z_c\, m_n}{\cos\beta} + 64\right) 2^{[(R-44)/4]} \\ &= \left(0{,}08\frac{14\times 3}{\cos 0} + 64\right) 2^{[(48-44)/4]} \\ &= 134{,}720\mu\text{m} \end{aligned}$$

Based on the rounding rules, this value is rounded to the nearest micron.

$F_{idT} = 135\ \mu\text{m}$

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E.2 Example 2 — Helical gear including tolerance over segments of $z/8$ teeth

40 tooth helical gear

0,7 mm normal module

25° helix angle

Class R44

Also calculate $F_{\text{id}z/8\text{T}}$.

Step 1. Calculation of the tooth-to-tooth radial composite tolerance

From Formulae (1), (2), and (3):

$$z_c = \min(|z|, 200)$$

$$z_c = \min(|40|, 200)$$

$$= 40$$

$$R_x = 5\left\{1 - 1{,}12^{[(1-z_c)/1{,}12]}\right\}$$

$$= 5\left\{1 - 1{,}12^{[(1-40)/1{,}12]}\right\}$$

$$= 4{,}903$$

$$f_{\text{idT}} = \left(0{,}08\frac{z_c m_n}{\cos\beta} + 64\right)2^{[(R-R_x-44)/4]}$$

$$= \left(0{,}08\frac{40\times 0{,}7}{\cos 25} + 64\right)2^{[(44-4{,}903-44)/4]}$$

$$= 28{,}420\ \mu\text{m}$$

Based on the rounding rules in 5.2.2, this value is rounded to the nearest micron.

$f_{\text{idT}} = 28\ \mu\text{m}$

Step 2. Calculation of the total radial composite tolerance

From Formula (4):

$$F_{\text{idT}} = \left(0{,}08\frac{z_c m_n}{\cos\beta} + 64\right)2^{[(R-44)/4]}$$

$$= \left(0{,}08\frac{40\times 0{,}7}{\cos 25} + 64\right)2^{[(44-44)/4]}$$

$$= 66{,}472\ \mu\text{m}$$

Based on the rounding rules, this value is rounded to the nearest micron.

$F_{\text{idT}} = 66\ \mu\text{m}$

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Step 3. Calculation of the double flank radial composite tolerance over $z/8$ teeth

Determine the number of tooth pitches:

$k = |z|/8 = 40/8 = 5$

From Formula (B.1), calculate the double flank radial composite tolerance over five teeth:

$$F_{\text{idkT}} = \left(0{,}08\frac{z_\text{c}\,m_n}{\cos\beta}+64\right)2^{[(R-44)/4]}\left[\left(1-1{,}5\frac{k-1}{|z|}\right)2^{\left(\frac{-R_x}{4}\right)}+1{,}5\frac{k-1}{|z|}\right]$$

$$F_{\text{id5T}} = \left(0{,}08\frac{40\times 0{,}7}{\cos 25}+64\right)2^{[(44-44)/4]}\left[\left(1-1{,}5\frac{5-1}{40}\right)2^{\left(\frac{-4{,}903}{4}\right)}+1{,}5\frac{5-1}{40}\right]$$

$$=34{,}128\ \mu\text{m}$$

Based on the rounding rules, this value is rounded to the nearest micron.

$F_{\text{id5T}} = 34\ \mu\text{m}$

E.3 Example 3 — Helical gear with over 200 teeth

324 tooth helical gear

0,8 mm normal module

15° helix angle

Class R41

Since the number of teeth exceeds the maximum threshold value of 200 teeth per 5.2.1, the tolerances are calculated based on a gear with 200 teeth in all formulae.

Step 1. Calculation of the tooth-to-tooth radial composite tolerance

From Formulae (1), (2), and (3):

$$z_\text{c} = \min(|z|, 200)$$

$$z_\text{c} = \min(|324|, 200)$$

$$=200$$

$$R_x = 5\left\{1-1{,}12^{[(1-z_\text{c})/1{,}12]}\right\}$$

$$=5\left\{1-1{,}12^{[(1-200)/1{,}12]}\right\}$$

$$=5{,}00$$

$$f_{\text{idT}} = \left(0{,}08\frac{z_\text{c}\,m_n}{\cos\beta}+64\right)2^{[(R-R_\text{x}-44)/4]}$$

$$=\left(0{,}08\frac{200\times 0{,}8}{\cos 15}+64\right)2^{[(41-5-44)/4]}$$

$$=19{,}313\ \mu\text{m}$$

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Based on the rounding rules in 5.2.2, this value is rounded to the nearest micron.

f_{idT} = 19 µm

Step 2. Calculation of the total radial composite tolerance

From Formula (4):

$$F_{idT} = \left(0,08\frac{z_c\, m_n}{\cos\beta} + 64\right) 2^{[(R-44)/4]}$$
$$= \left(0,08\frac{200\times 0,8}{\cos 15} + 64\right) 2^{[(41-44)/4]}$$
$$= 45,934 \text{ µm}$$

Based on the rounding rules, this value is rounded to the nearest micron.

F_{idT} = 46 µm

E.4 Example 4 — Sector gear

16 tooth sector from 50 tooth helical gear

1,5 mm normal module

5° helix angle

Class R45

Also calculate $F_{idz/8T}$.

Step 1. Calculation of the tooth-to-tooth radial composite tolerance

From Formulae (1), (2), and (3):

$$z_c = \min(|z|, 200)$$
$$z_c = \min(|50|, 200)$$
$$= 50$$
$$R_x = 5\left\{1 - 1,12^{[(1-z_c)/1,12]}\right\}$$
$$= 5\left\{1 - 1,12^{[(1-50)/1,12]}\right\}$$
$$= 4,965$$
$$f_{idT} = \left(0,08\frac{z_c\, m_n}{\cos\beta} + 64\right) 2^{[(R-R_x-44)/4]}$$
$$= \left(0,08\frac{50\times 1,5}{\cos 5} + 64\right) 2^{[(45-4,965-44)/4]}$$
$$= 35,225 \text{ µm}$$

Based on the rounding rules in 5.2.2, this value is rounded to the nearest micron.

f_{idT} = 35 µm

Step 2. Calculation of the total radial composite tolerance

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Formula (5) applies since $\left|\frac{z_k}{z}\right| = \frac{16}{50} = 0{,}32 \le \frac{2}{3}$.

From Formula (5):

$$F_{idT} = \left(0{,}08\frac{z_c\, m_n}{\cos\beta} + 64\right)2^{[(R-44)/4]}\left[\left(1 - 1{,}5\frac{z_k - 1}{|z|}\right)2^{\left(\frac{-R_x}{4}\right)} + 1{,}5\frac{z_k - 1}{|z|}\right]$$

$$= \left(0{,}08\frac{50\times 1{,}5}{\cos 5} + 64\right)2^{[(45-44)/4]}\left[\left(1 - 1{,}5\frac{16-1}{50}\right)2^{\left(\frac{-4{,}965}{4}\right)} + 1{,}5\frac{16-1}{50}\right]$$

$$= 56{,}846\ \mu\text{m}$$

Based on the rounding rules, this value is rounded to the nearest micron.

F_{idT} = 57 µm

Step 3. Calculation of the double flank radial composite tolerance over z/8 teeth

Determine the number of tooth pitches:

$k = |z|/8 = 50/8 = 6{,}25$

This is rounded to an integer:

$k = 6$

From Formula (B.1), calculate the double flank radial composite tolerance over six teeth:

$$F_{idkT} = \left(0{,}08\frac{z_c\, m_n}{\cos\beta} + 64\right)2^{[(R-44)/4]}\left[\left(1 - 1{,}5\frac{k-1}{|z|}\right)2^{\left(\frac{-R_x}{4}\right)} + 1{,}5\frac{k-1}{|z|}\right]$$

$$F_{id6T} = \left(0{,}08\frac{50\times 1{,}5}{\cos 5} + 64\right)2^{[(45-44)/4]}\left[\left(1 - 1{,}5\frac{6-1}{50}\right)2^{\left(\frac{-4{,}965}{4}\right)} + 1{,}5\frac{6-1}{50}\right]$$

$$= 42{,}432\ \mu\text{m}$$

Based on the rounding rules, this value is rounded to the nearest micron.

F_{id6T} = 42 µm

E.5 Example 5 — Helical gear specified with diametral pitch

45 tooth helical gear

12 in^{-1} normal diametral pitch

17° helix angle

Class R48

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