

ISO/FDIS 23509-1:~~2025~~(en)

ISO/TC 60/SC 2/~~WG-13~~

~~Date: 2025-02-04~~

Secretariat: DIN

Date: 2025-02-26

Bevel and hypoid gear geometry —

Part 1: Basic methods

Géométrie des engrenages coniques et hypoides —

Partie 1: Méthodes de base

ISO/FDIS 23509-1

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Contents

| | |
|---|-----|
| Foreword..... | v |
| Introduction..... | vii |
| 1 Scope..... | 1 |
| 2 Normative references..... | 1 |
| 3 Terms, definitions and symbols | 1 |
| 3.1 Terms and definitions | 1 |
| 3.2 Symbols | 4 |
| 4 Hypoid and bevel gears nomenclature | 8 |
| 5 Design considerations..... | 16 |
| 5.1 General..... | 16 |
| 5.2 Types of bevel gears..... | 16 |
| 5.3 Ratios..... | 19 |
| 5.4 Hand of spiral | 20 |
| 5.5 Preliminary gear size | 20 |
| 6 Tooth geometry and cutting considerations..... | 20 |
| 6.1 Manufacturing considerations..... | 20 |
| 6.2 Tooth taper..... | 20 |
| 6.3 Tooth depth configurations | 23 |
| 6.4 Angle modification, q_k | 26 |
| 6.5 Cutter radius..... | 28 |
| 6.6 Mean radius of curvature..... | 28 |
| 6.7 Hypoid design..... | 29 |
| 6.8 Most general type of gearing..... | 30 |
| 6.9 Hypoid geometry..... | 30 |
| 7 Pitch cone parameters | 33 |
| 7.1 Initial data for pitch cone parameters | 33 |
| 7.2 Determination of pitch cone parameters for bevel and hypoid gears..... | 34 |
| 8 Gear dimensions..... | 51 |
| 8.1 Initial data for tooth profile parameters..... | 51 |
| 8.2 Determination of basic data..... | 54 |
| 8.3 Determination of root angles and face angles | 57 |
| 8.4 Determination of tooth depth at calculation point..... | 60 |
| 8.5 Determination of root and face apexes..... | 60 |
| 8.6 Determination of pinion facewidth, b_1 | 62 |
| 8.7 Determination of inner and outer spiral angles | 66 |
| 8.8 Determination of tooth depth | 70 |
| 8.9 Determination of tooth thickness..... | 70 |
| 8.10 Determination of remaining dimensions..... | 74 |
| 9 Undercut check..... | 76 |
| 9.1 Pinion | 76 |
| 9.2 Wheel..... | 79 |
| Annex A (informative) Structure of ISO formula set for calculation of geometry data of bevel and hypoid gears | 82 |
| Annex B (informative) Pitch cone parameters..... | 93 |
| Annex C (informative) Gear dimensions | 107 |

| | |
|--|------------|
| Annex D (informative) Analysis of forces..... | 114 |
| Annex E (informative) Machine tool data | 118 |
| Bibliography | 119 |

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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).

ISO draws attention to the possibility that the implementation of this document may involve the use of patents. ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of patents which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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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*, Subcommittee SC 2, *Gear capacity calculation*.

This first edition cancels and replaces ISO 23509:2016, which has been technically revised.

The main changes are as follows:

- ~~Clause 3~~ ~~Clause 3~~ has been rearranged, ~~Figures 1~~ ~~Figures 1~~ to ~~33~~ have been moved to a new ~~Clause 4~~ ~~Clause 4~~;
- ~~—~~ different symbols for pinion offset angles (approximate, intermediate, in pitch plane, in axial plane) for the different methods have been harmonized;
- ~~Figure 1~~ ~~Figure 1~~, keys 4, 5, 6, and 26 have been rearranged, keys 27 to 31 have been added;
- ~~subclause 5.2.6~~ ~~subclause 5.2.6~~ on skew bevel with new ~~Figure 8~~ ~~Figure 8~~ has been inserted;
- ~~—~~ indication of mean whole depth, mean addendum and mean dedendum in ~~Figure 11~~ ~~Figure 11~~ a) and ~~Figure 11~~ ~~Figure 11~~ b) have been revised;
- ~~subclause 6.4~~ ~~subclause 6.4~~ has been renamed angle modification and revised, and new ~~Figures 13~~ ~~Figures 13~~ and ~~14~~ ~~14~~ have been inserted;
- ~~—~~ keys 2 and 16 of ~~Figure 16~~ ~~Figure 16~~ have been revised;
- ~~subclause 7.2.2~~ ~~subclause 7.2.2~~, the condition to stop the iteration process for the determination of the pitch cone parameters for Method 1 has been modified;

- Table 4 ~~Table 4~~ has been updated;
- Clause 8 ~~Clause 8~~ has been updated respecting new content related to angle modification in 6.4 ~~6.4~~;
- subclause 8.5 ~~subclause 8.5~~, Formulae (157), Formulae (157) and (158) ~~(158)~~ related to the determination of the pinion face and pinion root apex have been corrected;
- subclause 8.6 ~~subclause 8.6~~, Formulae (167), Formulae (167) and (168) ~~(168)~~ related to the increment along pinion axis have been corrected;
- subclause 8.9 ~~subclause 8.9~~, Formula (220), Formula (220) related to the mean chordal addendum has been corrected;
- A.4 ~~A.4~~ has been modified to distinguish between theoretical and modified tooth contour, Figures A.3 ~~Figures A.3~~ and A.5 ~~A.5~~ have been revised and new Figures A.6 ~~Figures A.6~~ and A.7 ~~A.7~~ have been inserted;
- Table C.1 ~~Table C.1~~, has been modified to introduce accuracy grades according to ISO 17485;
- C.5 ~~C.5~~, addendum and dedendum angle of wheels has been specified to non-uniform tooth depth;
- Table E.1 ~~Table E.1~~ has been updated;
- ~~Sample~~ calculations of former Annex F have been removed and are intended to be published as a separate Technical Report.

A list of all parts in the ISO 23509 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.

Introduction

For many decades, information on bevel, and especially hypoid, gear geometry has been developed and published by the gear machine manufacturers. The specific formulae for their respective geometries were developed for the mechanical generation methods of their particular machines and tools. In many cases, these formulae were not used in general for all bevel gear types. This situation changed with the introduction of universal, multi-axis, computerized numerical control (CNC)-machines, which in principle ~~are able to~~ can produce nearly all types of gearing. The manufacturers were, therefore, asked to provide CNC programs for the geometries of different bevel gear generation methods on their machines.

This document integrates straight bevel gears and the three major design generation methods for spiral bevel gears into one complete set of formulae. In only a few places, specific formulae for each method will be applied. The structure of the formulae is such that they can be programmed directly, allowing the user to compare the different designs.

The formulae of the three methods are developed for the general case of hypoid gears and to calculate the specific case of spiral bevel gears by entering zero for the hypoid offset. Additionally, the geometries correspond such that each gear set consists of a generated or non-generated wheel without offset and a pinion which is generated and provided with the total hypoid offset.

This document deals with the macro geometry of bevel gears. Some information on micro geometry and manufacturing can be found in ISO/TR 22849^[4].

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Bevel and hypoid gear geometry —

Part 1: Basic methods

1 Scope

This document specifies the macro geometry of bevel gears.

The term "bevel gears" is used to mean straight, skew, spiral, Zerol bevel and hypoid gear designs. If the text pertains to one or more, but not all, of these, the specific forms are identified.

The manufacturing process of forming the desired tooth form is not intended to imply any specific process, but rather to be general in nature and applicable to all methods of manufacture.

The geometry for the calculation of factors used in bevel gear rating, such as ISO 10300 (all parts), is also included.

This document is intended for use by an experienced gear designer capable of selecting reasonable values for the factors based on his or her knowledge and background. It is not intended for use by the engineering public at large.

[Annex A](#) provides a structure for the calculation of the methods provided in this document.

2 Normative references

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

3 Terms, definitions and symbols

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Terms and definitions

3.1.1 ~~3.1.1~~ coast side

by normal convention, convex pinion flank in mesh with the concave wheel flank

3.1.2 ~~3.1.2~~

crown gear

~~usually planar virtual crown gear whose pitch angle is $\delta_1 = 90^\circ$ and which replaces in spiral a bevel gear pair; by analogy the basic rack used to generate involute cylindrical gear is replaced by the crown gear as a usually planar virtual crown gear whose pitch angle is $\delta_1 = 90^\circ$. by analogy~~

Note 1 to entry: A figure of such crown gear can be found in [5Stadtfeld [5]] or [6Klingenberg [6]].

3.1.3 ~~3.1.3~~

cutter radius

r_{c0}
nominal radius of the face type cutter or cup-shaped grinding wheel that is used to cut or grind the spiral bevel teeth

3.1.4 ~~3.1.4~~

drive side

by normal convention, concave pinion flank in mesh with the convex wheel flank

3.1.5 ~~3.1.5~~

facewidth

b
length of the teeth measured along a pitch cone element

3.1.6 ~~3.1.6~~

mean addendum

h_{am1}, h_{am2}
height by which the gear tooth projects above the pitch cone at the mean cone distance

3.1.7 ~~3.1.7~~

mean addendum factor

C_{ham}
~~apportions~~distribution factor of the mean working depth, h_{mw} , between wheel and pinion mean addendums
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Note 1 to entry: The gear mean addendum is equal to C_{ham} times the mean working depth.

3.1.8 ~~3.1.8~~

mean chordal addendum

h_{amc1}, h_{amc2}
height from the top of the gear tooth to the chord subtending the circular thickness arc at the mean cone distance in a plane normal to the tooth face

3.1.9 ~~3.1.9~~

mean dedendum

h_{fm1}, h_{fm2}
depth of the tooth space below the pitch cone at the mean cone distance

3.1.10 ~~3.1.10~~

mean normal chordal tooth thickness

S_{mnc1}, S_{mnc2}
chordal thickness of the gear tooth at the mean cone distance in a plane normal to the *tooth trace* (3.1.24)

3.1.11 ~~3.1.11~~

mean normal circular tooth thickness

S_{mn1}, S_{mn2}
length of arc on the pitch cone between the two sides of the gear tooth at the mean cone distance in the plane normal to the *tooth trace* (3.1.24)

3.1.12 ~~3.1.12~~**mean point**

point where the calculation of basic geometry is executed

Note 1 to entry: Mean point does not necessarily coincide with middle point of *facewidth* (3.1.5.).

Note 2 to entry: In all the methods listed in this document, the term “mean point” refers to “calculation point”. See A.3A.3 for calculation points.

3.1.13 ~~3.1.13~~**mean radius of curvature**

$\rho_{m\beta}$

radius of curvature of the tooth surface in the lengthwise direction at the mean cone distance

3.1.14 ~~3.1.14~~**mean whole depth**

h_m

tooth depth at mean cone distance

3.1.15 ~~3.1.15~~**mean working depth**

h_{mw}

depth of engagement of two gears at mean cone distance

3.1.16 ~~3.1.16~~**number of blade groups**

Z_0

number of blade groups contained in the circumference of the cutting tool

3.1.17 ~~3.1.17~~**number of crown gear teeth**

Z_p

number of teeth in the whole circumference of the *crown gear* (3.1.2)

Note 1 to entry: The number will not become necessarily an integer.

3.1.18 ~~3.1.18~~**number of teeth**

Z_1, Z_2

number of teeth contained in the whole circumference of the pitch cone

3.1.19 ~~3.1.19~~**outer normal backlash**

j_{en}

amount by which the tooth thicknesses are reduced to provide the necessary backlash in assembly

Note 1 to entry: It is specified at the outer cone distance.

3.1.20 ~~3.1.20~~**sum of dedendum angles for constant slot width**

$\Sigma\theta_{fc}$

sum of the pinion and wheel dedendum angles for constant slot width

3.1.21 ~~3.1.21~~**sum of dedendum angles**

$\Sigma\theta_f$

sum of the pinion and wheel dedendum angles

3.1.22 3.1.22**sum of dedendum angles for modified slot width taper** $\Sigma\theta_{\text{FM}}$

sum of the pinion and wheel dedendum angles for modified slot width taper

3.1.23 3.1.23**sum of dedendum angles for standard depth taper** $\Sigma\theta_{\text{FS}}$

sum of the pinion and wheel dedendum angles for standard depth taper

3.1.24 3.1.24**tooth trace**

curve of the tooth on the pitch surface

3.2 Symbols

For the purpose of this document, the symbols and general subscripts given in [Table 1](#) [Table 1](#) and [Table 2](#) [Table 2](#) apply.

Table 1 — Symbols, their descriptions and units

| Symbol | Description | Unit |
|----------------------|---|------|
| A | intermediate variable | — |
| a | hypoid offset | mm |
| b_1, b_2 | facewidth | mm |
| b_{e1}, b_{e2} | facewidth from calculation point to outside | mm |
| b_{i1}, b_{i2} | facewidth from calculation point to inside | mm |
| c_1, c_2 | clearance | mm |
| C_{be2} | facewidth factor | — |
| $Cham$ | mean addendum factor of wheel | — |
| d_{ae1}, d_{ae2} | outside diameter | mm |
| d_{ai1}, d_{ai2} | inner outside diameter | mm |
| d_{e1}, d_{e2} | outer pitch diameter | mm |
| d_{fe1}, d_{fe2} | outer root diameter | mm |
| d_{fi1}, d_{fi2} | inner root diameter | mm |
| d_{m1}, d_{m2} | mean pitch diameter | mm |
| F_{ax} | axial force | N |
| F_{mt1}, F_{mt2} | tangential force at mean diameter | N |
| F_{rad} | radial force | N |
| f_{alim} | influence factor of limit pressure angle | — |
| h_{ae1}, h_{ae2} | outer addendum | mm |
| h_{ai1}, h_{ai2} | inner addendum | mm |
| h_{am1}, h_{am2} | mean addendum | mm |
| h_{amc1}, h_{amc2} | mean chordal addendum | mm |
| h_{e1}, h_{e2} | outer whole depth | mm |

| Symbol | Description | Unit |
|--------------------------|---|-------------------|
| h_{fe1}, h_{fe2} | outer dedendum | mm |
| h_{fi1}, h_{fi2} | inner dedendum | mm |
| h_{fm1}, h_{fm2} | mean dedendum | mm |
| $h_{i1,2}$ | inner whole depth | mm |
| h_m | mean whole depth | mm |
| h_{mw} | mean working depth | mm |
| h_{t1} | pinion whole depth | mm |
| j_{en} | outer normal backlash | mm |
| j_{et} | outer transverse backlash | mm |
| j_{mn} | mean normal backlash | mm |
| j_{mt} | mean transverse backlash | mm |
| K_{M1}, K_{M2}, K_{M3} | approximate hypoid dimension factor (subscript indicates the method used) | — |
| k_c | clearance factor | — |
| k_d | depth factor | — |
| k_{hap} | basic crown gear addendum factor (related to m_{mn}) | — |
| k_{hfp} | basic crown gear dedendum factor (related to m_{mn}) | — |
| k_t | circular thickness factor | — |
| m_{et} | outer transverse module | mm |
| m_{mn} | mean normal module | mm |
| n_1 | pinion speed | min ⁻¹ |
| P | power | kW |
| q_k | angle modification | ° |
| $Re1, Re2$ | outer cone distance | mm |
| R_{i1}, R_{i2} | inner cone distance | mm |
| R_{m1}, R_{m2} | mean cone distance | mm |
| r_{c0} | cutter radius | mm |
| s_{mn1}, s_{mn2} | mean normal circular tooth thickness | mm |
| s_{mnc1}, s_{mnc2} | mean normal chordal tooth thickness | mm |
| s_{mt1}, s_{mt2} | mean transverse circular tooth thickness | mm |
| T_1 | pinion torque | Nm |
| t_{xi1}, t_{xi2} | inner crown to crossing point | mm |
| t_{xo1}, t_{xo2} | outer crown to crossing point | mm |
| t_{z1}, t_{z2} | pitch apex beyond crossing point | mm |
| t_{zF1}, t_{zF2} | face apex beyond crossing point | mm |
| t_{zm1}, t_{zm2} | crossing point to mean point along axis | mm |
| t_{zR1}, t_{zR2} | root apex beyond crossing point | mm |

| Symbol | Description | Unit |
|----------------------------|---|------|
| u | gear ratio | — |
| u_a | equivalent ratio | — |
| W_{m2} | wheel mean slot width | mm |
| x_{hm1} | profile shift coefficient | — |
| x_{sm1}, x_{sm2} | thickness modification coefficient (backlash included) | — |
| x_{smn} | thickness modification coefficient (theoretical) | — |
| z_0 | number of blade groups | — |
| z_1, z_2 | number of teeth | — |
| z_p | number of crown gear teeth | — |
| α_{dC} | nominal design pressure angle on coast side | ° |
| α_{dD} | nominal design pressure angle on drive side | ° |
| α_{eC} | effective pressure angle on coast side | ° |
| α_{eD} | effective pressure angle on drive side | ° |
| α_{nC} | generated pressure angle on coast side | ° |
| α_{nD} | generated pressure angle on drive side | ° |
| α_{lim} | limit pressure angle | ° |
| β_{e1}, β_{e2} | outer spiral angle | ° |
| β_{i1}, β_{i2} | inner spiral angle | ° |
| β_{m1}, β_{m2} | mean spiral angle | ° |
| Δb_{x1} | pinion facewidth increment | mm |
| Δg_{xi} | increment along pinion axis from calculation point to inside | mm |
| Δg_{xe} | increment along pinion axis from calculation point to outside | mm |
| ΔK | increment in hypoid dimension factor | — |
| $\Delta \Sigma$ | shaft angle departure from 90° | ° |
| δ_{a1}, δ_{a2} | face angle | ° |
| δ_{f1}, δ_{f2} | root angle | ° |
| δ_1, δ_2 | pitch angle | ° |
| ε_β | face contact ratio | — |
| η | wheel offset angle in axial plane | ° |
| η_1 | second auxiliary angle (see Figure 15) | ° |
| θ_{a1}, θ_{a2} | addendum angle | ° |
| θ_{f1}, θ_{f2} | dedendum angle | ° |
| ϑ | auxiliary angle | ° |
| λ | first auxiliary angle (see Figure 15) | ° |
| ν | lead angle of cutter | ° |
| ξ | auxiliary angle | ° |
| ρ_b | epicycloid base circle radius | mm |