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Date: 14 August 2024

Origin: International

Latest date for receipt of comments: 07 October 2024

Project No. 2022/01916

Responsible committee: MCE/5 Gears

Interested committees:

Title: Draft BS ISO 23509-1 Bevel and hypoid gear geometry. Part 1: Basic methods.

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 23509-1

Bevel and hypoid gear geometry — Part 1: Basic methods

*Géométrie des engrenages coniques et hypoïdes —
Partie 1: Principes de base*

ICS: 21.200

ISO/TC 60/SC 2

Secretariat: **DIN**

Voting begins on:
2024-08-14

Voting terminates on:
2024-11-06

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Published in Switzerland

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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).

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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 third edition cancels and replaces the second edition (ISO 23509:2016), which has been technically revised.

The main changes are as follows:

- [Clause 3](#) has been rearranged;
- Different symbols for pinion offset angles (approximate, intermediate, in pitch plane, in axial plane) for the different methods have been harmonized;
- [Figure 1](#), keys 4, 5, 6, and 26 have been rearranged;
- [Clause 4.2.6](#) on skew bevel with new [Figure 8](#) has been inserted;
- Indication of mean whole depth, mean addendum and mean dedendum in [Figure 11](#) a) Standard depth taper and [Figure 11](#) b) Constant and modified slot width have been revised;
- [Clause 5.4](#) has been renamed into angle modification, revised and new [Figures 13](#) and [14](#) were inserted;
- Keys 2 and 16 of [Figure 16](#) Hypoid geometry have been revised;
- [Clause 6.2.2](#), condition to stop the iteration process for the determination of the pitch cone parameters for Method 1 has been modified;
- [Table 3](#), Initial data for tooth profile parameters has been updated;
- [Clause 7](#) has been updated respecting new content related to angle modification in [Clause 5.4](#);
- [Clause 7.5](#), correction of formulae related to the determination of the pinion face and pinion root apex, [Formulae \(157\)](#) and [\(158\)](#);

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- [Clause 7.6](#), correction of formulae related to the increment along pinion axis, [Formulae \(167\)](#) and [\(168\)](#);
- [Clause 7.9](#), correction of [Formula \(220\)](#) related to the mean chordal addendum;
- Annex [A.4](#) has been modified by distinguishing between theoretical and modified tooth contour, [Figure A.3](#) and [A.5](#) have been revised and new [Figures A.6](#) and [A.7](#) inserted;
- [Table C.1](#), Suggested ranges for outer normal backlash modified by introducing accuracy grades according to ISO 17485;
- Annex [C.5](#), Addendum and dedendum angle of wheels has been specified to non-uniform tooth depth;
- [Table E.1](#) has been updated;
- Sample calculations of former Annex F have been moved to ISO/TR 23509-2¹⁾.

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.

1) ISO/TR 23509-2 is currently under preparation.

Introduction

For many decades, information on bevel, and especially hypoid, gear geometry has been developed and published by the gear machine manufacturers. It is clear that 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 could not be used in general for all bevel gear types. This situation changed with the introduction of universal, multi-axis, CNC-machines, which in principle are able to 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 do specific formulae for each method have to 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.

An additional objective of this document is that, on the basis of the combined bevel gear geometries, an ISO hypoid gear rating system can be established in the future.

Bevel and hypoid gear geometry —

Part 1: Basic methods

1 Scope

This document specifies the 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/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/>

NOTE 1 The symbols, terms and definitions used in this document are, wherever possible, consistent with other International Standards. It is known, because of certain limitations, that some symbols, their terms and definitions, as used in this document, are different from those used in similar literature pertaining to spur and helical gearing.

NOTE 2 Bevel gear nomenclature used throughout this document is illustrated in [Figure 1](#), the axial section of a bevel gear, and in [Figure 2](#), the mean transverse section. Hypoid nomenclature is illustrated in [Figure 3](#).

Subscript 1 refers to the pinion and subscript 2 to the wheel.

3.1 Terms and definitions

3.1.1

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

3.1.2

mean addendum

h_{am1}, h_{am2}

height by which the gear tooth projects above the pitch cone at the mean cone distance

3.1.3

outer normal backlash allowance

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.

3.1.4

coast side

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

3.1.5

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

3.1.6

sum of dedendum angles

$\Sigma\theta_f$

sum of the pinion and wheel dedendum angles

3.1.7

sum of constant slot width dedendum angles

$\Sigma\theta_{fC}$

sum of dedendum angles for constant slot width

3.1.8

sum of modified slot width dedendum angles

$\Sigma\theta_{fM}$

sum of dedendum angles for modified slot width taper

3.1.9

sum of standard depth dedendum angles

$\Sigma\theta_{fS}$

sum of dedendum angles for standard depth taper

3.1.10

sum of uniform depth dedendum angles

$\Sigma\theta_{fU}$

sum of dedendum angles for uniform depth

3.1.11

mean dedendum

h_{fm1}, h_{fm2}

depth of the tooth space below the pitch cone at the mean cone distance

3.1.12**mean whole depth** h_m

tooth depth at mean cone distance

3.1.13**mean working depth** h_{mw}

depth of engagement of two gears at mean cone distance

3.1.14**direction of rotation**

direction determined by an observer viewing the gear from the back looking towards the pitch apex

3.1.15**drive side**

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

3.1.16**facewidth** b

length of the teeth measured along a pitch cone element

3.1.17**mean addendum factor** c_{ham} apportions the mean working depth, h_{mw} , between wheel and pinion mean addendumsNote 1 to entry: The gear mean addendum is equal to c_{ham} times the mean working depth.**3.1.18****mean radius of curvature** $\rho_{m\beta}$

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

3.1.19**number of blade groups** z_0

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

3.1.20**number of teeth** z_1, z_2

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

3.1.21**number of crown gear teeth** z_p

number of teeth in the whole circumference of the crown gear

Note 1 to entry: The number may not be an integer.

3.1.22**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

3.1.23**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**tooth trace**

curve of the tooth on the pitch surface

3.1.25**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.

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

3.2 Symbols

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

Table 1 — Symbols, their descriptions and units

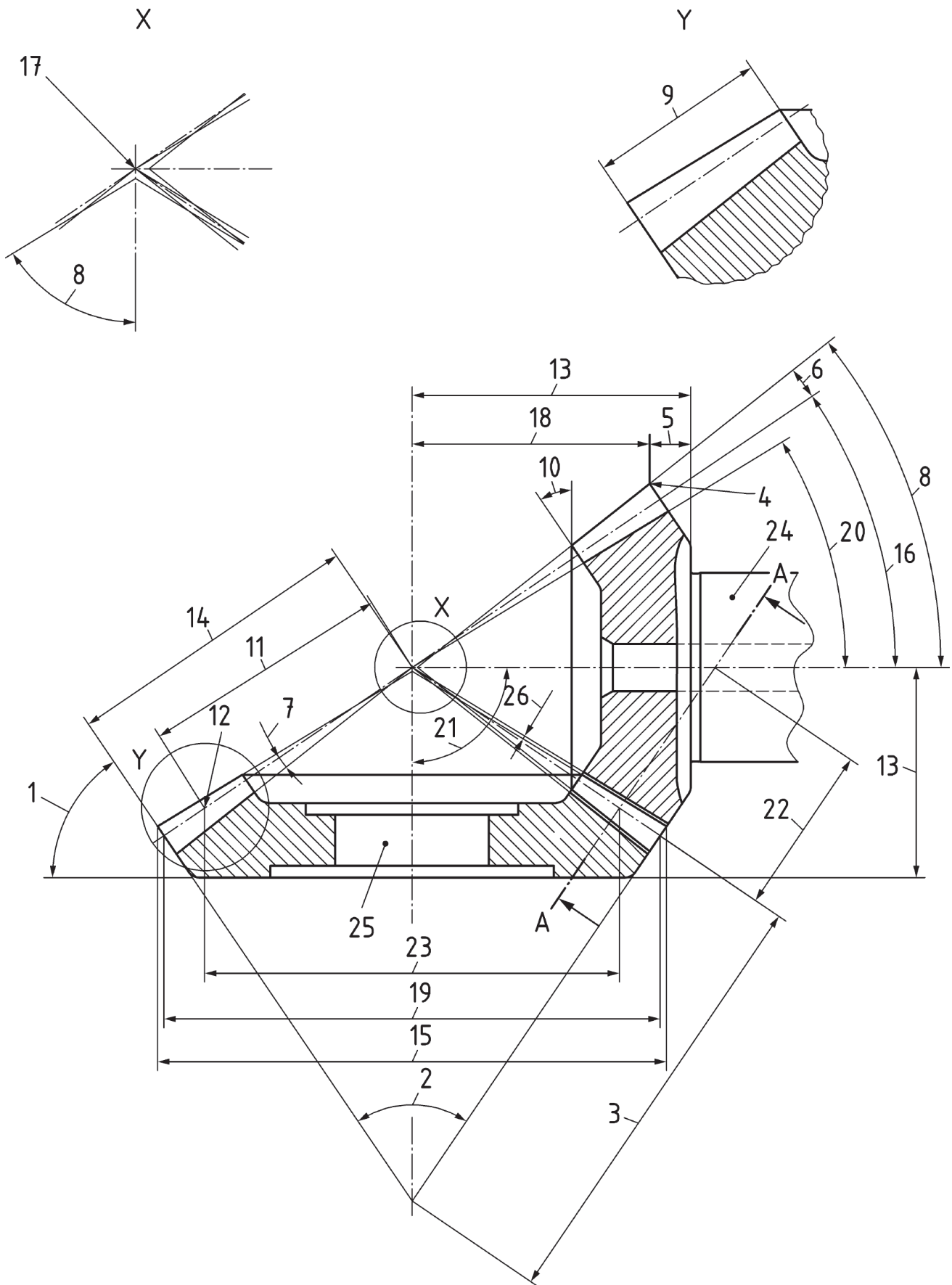
Symbol	Description	Unit
A	intermediate variable	—
a	hypoid offset	mm
b_1, b_2	facewidth	mm
b_{e1}, b_{e2}	facewidth from calculation point to outside	mm
b_{i1}, b_{i2}	facewidth from calculation point to inside	mm
c_1, c_2	clearance	mm
c_{be2}	facewidth factor	—
c_{ham}	mean addendum factor of wheel	—
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_{am1}, h_{am2}	mean addendum	mm
h_{amc1}, h_{amc2}	mean chordal addendum	mm
h_{e1}, h_{e2}	outer whole depth	mm
h_{fe1}, h_{fe2}	outer dedendum	mm
h_{fi1}, h_{fi2}	inner dedendum	mm
h_{fm1}, h_{fm2}	mean dedendum	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

Table 1 (continued)

Symbol	Description	Unit
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	°
R_{e1}, R_{e2}	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
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
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_{nD}	generated pressure angle on drive side	°
α_{nC}	generated pressure angle on coast side	°
α_{lim}	limit pressure angle	°
β_{e1}, β_{e2}	outer spiral angle	°
β_{i1}, β_{i2}	inner spiral angle	°

Table 1 (continued)

Symbol	Description	Unit
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 (Figure 15)	°
θ_{a1}, θ_{a2}	addendum angle	°
θ_{f1}, θ_{f2}	dedendum angle	°
ϑ	auxiliary angle	°
λ	first auxiliary angle (Figure 15)	°
ν	lead angle of cutter	°
ξ	auxiliary angle	°
ρ_b	epicycloid base circle radius	mm
ρ_{lim}	limit curvature radius	mm
ρ_{P0}	crown gear to cutter centre distance	mm
Σ	shaft angle	°
$\Sigma \theta_f$	sum of dedendum angles	°
$\Sigma \theta_{fC}$	sum of dedendum angles for constant slot width taper	°
$\Sigma \theta_{fS}$	sum of dedendum angles for standard taper	°
$\Sigma \theta_{fM}$	sum of dedendum angles for modified slot width taper	°
$\Sigma \theta_{fU}$	sum of dedendum angles for uniform depth taper	°
ζ_o	pinion offset angle in face plane	°
$\zeta_{m,M1}, \zeta_{m,M2}, \zeta_{m,M3}$	pinion offset angle in axial plane (Method 1, Method 2, or Method 3)	°
$\zeta_{mi,M2}$	approximate pinion offset angle in axial plane (Method 2)	°
$\zeta_{mp,M1}, \zeta_{mp,M2}, \zeta_{mp,M3}$	pinion offset angle in pitch plane (Method 1, Method 2, or Method 3)	°
$\zeta_{mpi,M1}$	approximate pinion offset angle in pitch plane (Method 1)	°
$\zeta'_{m,M1}, \zeta'_{m,M2}$	intermediate pinion offset angle in axial plane (Method 1, Method 2)	°
$\zeta'_{mp,M1}, \zeta'_{mp,M2}$	intermediate pinion offset angle in pitch plane (Method 1, Method 2)	°
ζ_R	pinion offset angle in root plane	°
φ	Intermediate or auxiliary angle	°



Key

1 back angle

10 front angle

19 outer pitch diameter, d_{e2} (d_{e1})

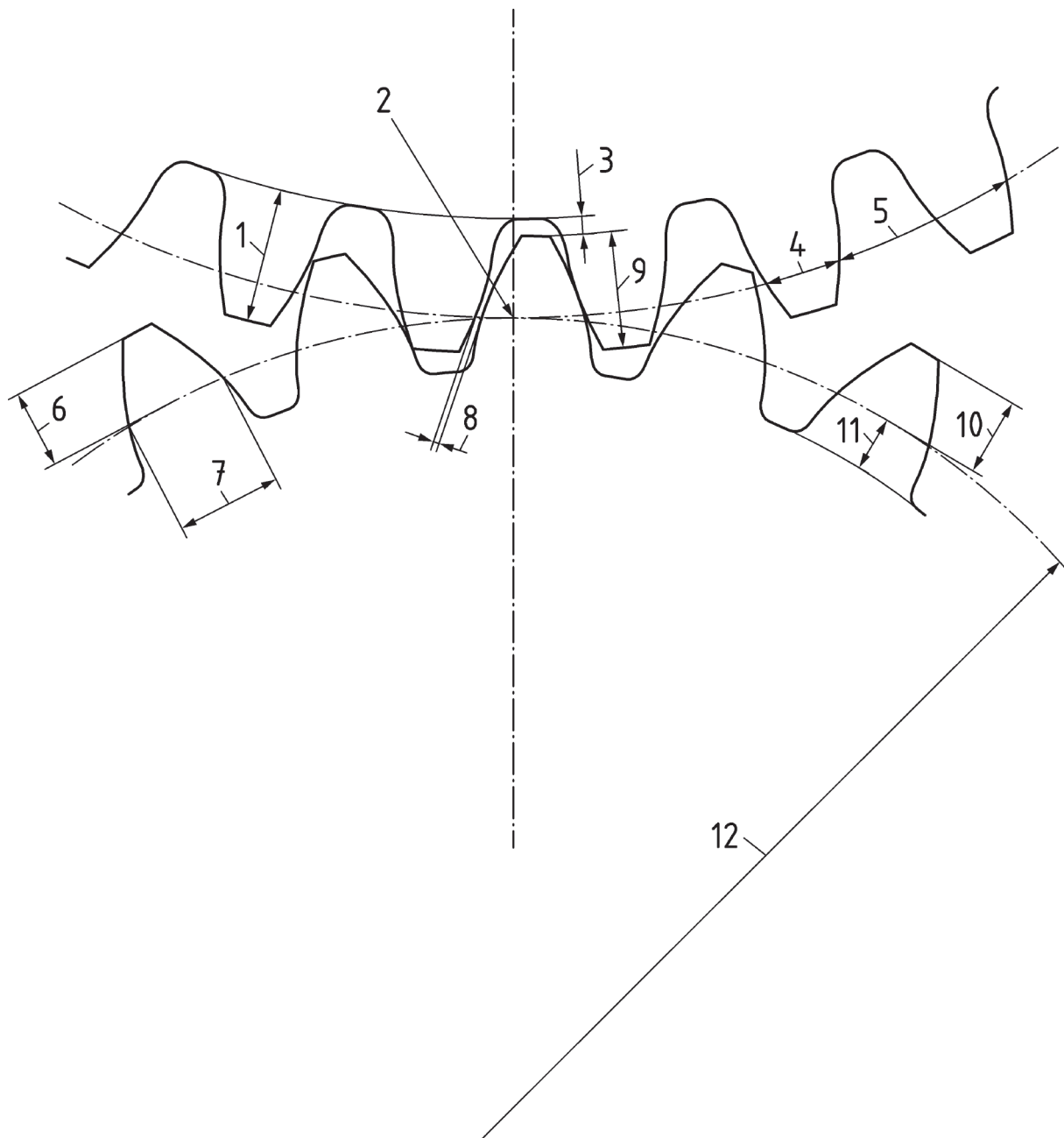
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2	back cone angle	11	mean cone distance, R_{m2} (R_{m1})	20	root angle, δ_{f1} (δ_{f2})
3	back cone distance	12	mean point P	21	shaft angle, Σ
4	crown point	13	mounting distance	22	equivalent pitch radius
5	crown to back	14	outer cone distance, R_{e2} (R_{e1})	23	mean pitch diameter, d_{m2} (d_{m1})
6	addendum angle, θ_{a1} (θ_{a2})	15	outside diameter, d_{ae2} (d_{ae1})	24	pinion
7	dedendum angle, θ_{f2} , (θ_{f1})	16	pitch angle, δ_1 (δ_2)	25	wheel
8	face angle δ_{a1} (δ_{a2})	17	pitch cone apex	26	clearance, c_2 (c_1)
9	facewidth, b_2 (b_1)	18	outer crown to crossing point, t_{xo1} (t_{xo2})		

NOTE 1 See [Figure 2](#) for mean transverse section, A-A.

NOTE 2 To enhance clarity, terms occurring at both pinion and wheel are displayed only once. The corresponding term, which is not displayed, is provided in parentheses

Figure 1 — Bevel gear nomenclature — Axial plane

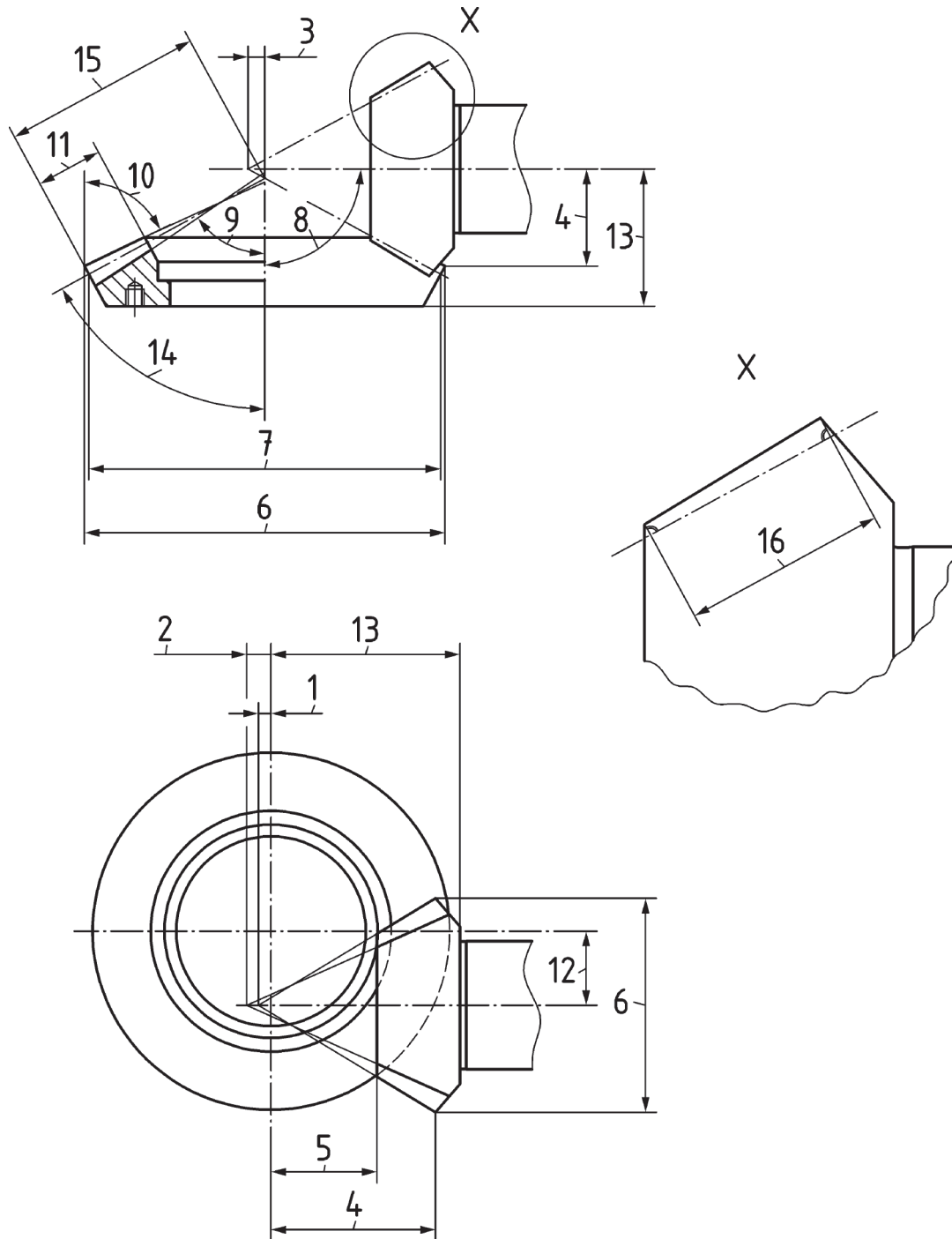


Key

- | | | | |
|---|--------------------|----|-------------------------|
| 1 | whole depth, h_m | 7 | chordal thickness |
| 2 | pitch point | 8 | backlash |
| 3 | clearance, c | 9 | working depth, h_{mw} |
| 4 | circular thickness | 10 | addendum, h_{am} |
| 5 | circular pitch | 11 | dedendum, h_{fm} |
| 6 | chordal addendum | 12 | equivalent pitch radius |

NOTE See A-A in [Figure 1](#).

Figure 2 — Bevel gear nomenclature — Mean transverse section



Key

- | | | | |
|---|--|----|--|
| 1 | face apex beyond crossing point, t_{zF1} | 9 | root angle, δ_{f2} (δ_{f1}) |
| 2 | root apex beyond crossing point, t_{zR1} | 10 | face angle of blank, δ_{a2} (δ_{a1}) |
| 3 | pitch apex beyond crossing point, t_{z1} | 11 | Wheel facewidth, b_2 |
| 4 | outer crown to crossing point, t_{x01} (t_{x02}) | 12 | hypoid offset, a |
| 5 | inner crown to crossing point, t_{xi1} | 13 | mounting distance |
| 6 | outside diameter, d_{ae2} (d_{ae1}) | 14 | pitch angle, δ_2 (δ_1) |
| 7 | outer pitch diameter, d_{e2} (d_{e1}) | 15 | outer cone distance, R_{e2} (R_{e1}) |
| 8 | shaft angle, Σ | 16 | pinion facewidth, b_1 |

NOTE 1 Apex beyond crossing point values are positive when crossing point lies inside the respective cone.

NOTE 2 To enhance clarity, terms occurring at both pinion and wheel are displayed only once. The corresponding term, which is not displayed, is provided in parentheses.

Figure 3 — Hypoid nomenclature

4 Design considerations

4.1 General

Loading, speed, accuracy requirements, space limitations and special operating conditions influence the design. For details, see ISO 10300 (all parts), Annex B and handbooks of gear manufacturing companies.

“Precision finish”, as used in this document, refers to a machine finishing operation which includes grinding, skiving and hard cut finishing. However, the common form of finishing known as “lapping” is specifically excluded as a form of precision finishing.

Users should determine the cutting methods available from their gear manufacturer prior to proceeding. Cutting systems used by bevel gear manufacturers are heavily dependent upon the type of machine tool that will be used.

4.2 Types of bevel gears

4.2.1 General

Bevel gears are suitable for transmitting power between shafts at practically any angle or speed. However, the particular type of gear best suited for a specific application is dependent upon the mountings, available space and operating conditions.

4.2.2 Straight bevels

Straight bevel gears (see [Figure 4](#)) are the simplest form of bevel gears. Contact on the driven gear begins at the top of the tooth and progresses towards the root. They have teeth which are straight and tapered which, if extended inward, generally intersect in a common point at the axis.

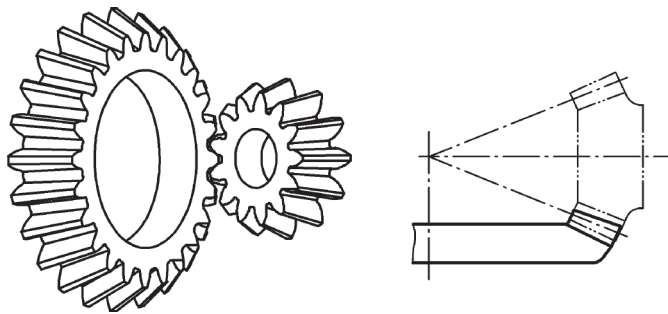


Figure 4 — Straight bevel gears

4.2.3 Spiral bevels

Spiral bevel gears (see [Figure 5](#)) have curved oblique teeth on which contact begins at one end of the tooth and progresses smoothly to the other end. They mesh with contact similar to straight bevels but as the result of additional overlapping tooth action, the motion will be transmitted more smoothly than by straight bevel or zerol bevel gears. This reduces noise and vibration especially noticeable at high speeds. Spiral bevel gears can also have their tooth surfaces precision-finished.

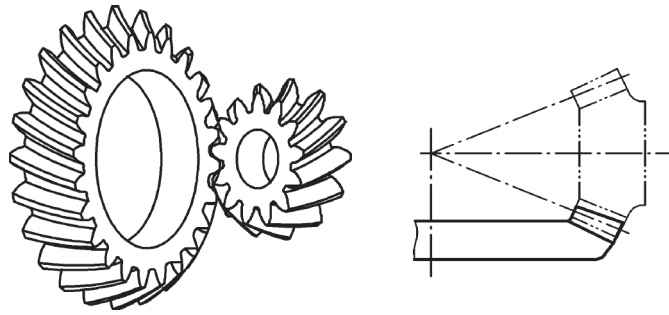


Figure 5 — Spiral bevel gears

4.2.4 Zerol bevels

Zerol bevel gears (see [Figure 6](#)), as well as other spiral bevel gears, with zero spiral angle have curved teeth which are in the same general direction as straight bevel teeth. They produce the same thrust loads on the bearings, can be used in the same mounting, have smooth operating characteristics and are manufactured on the same machines as spiral bevel gears. Zerol bevels can also have their tooth surfaces precision-finished. Gears with spiral angles less than 10° are sometimes referred to by the name “zerol”.

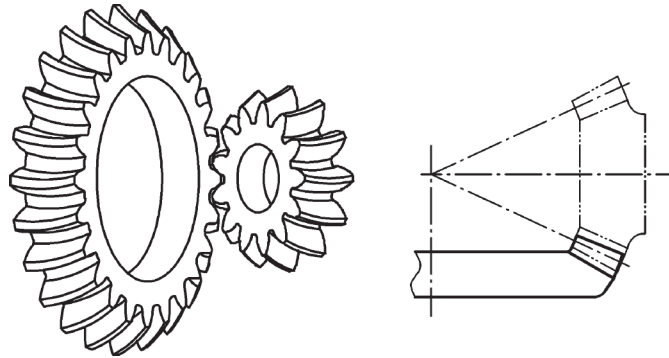


Figure 6 — Zerol bevel gears

4.2.5 Hypoids

Hypoid gears (see [Figure 7](#)) are similar to spiral bevel gears except that the pinion axis is offset above or below the wheel axis; see [B.3](#). If there is sufficient offset, the shafts may pass one another and a compact straddle mounting can be used on the wheel and pinion. Hypoid gears can also have their tooth surfaces precision-finished.

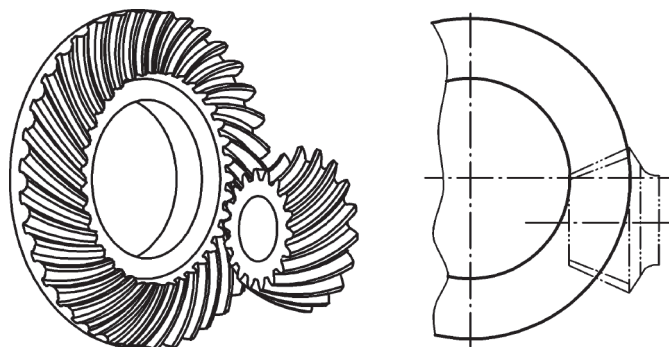


Figure 7 — Hypoid gears

4.2.6 Skew Bevels

Skew bevel gears (see [Figure 8](#)) have teeth that are oblique with straight-line elements that if extended would not intersect the gear axis. They generally operate at a 90° shaft angle. Skew hypoid bevel gears are not covered in this document.

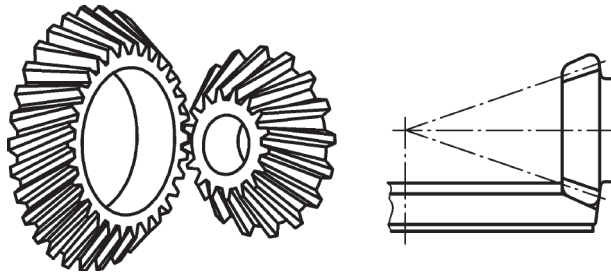


Figure 8 — Skew bevel gears

4.3 Ratios

Bevel gears may be used for both speed-reducing and speed-increasing drives. The required ratio shall be determined by the designer from the given input speed and required output speed. For power drives, the ratio in bevel and hypoid gears may be as low as 1, but should not exceed approximately 10. High-ratio hypoids from 10 to approximately 20 have found considerable usage in machine tool design where precision gears are required. In speed-increasing applications, the ratio should not exceed 5.

4.4 Hand of spiral

The hand of spiral should be selected to give an axial thrust that tends to move both the wheel and pinion out of mesh when operating in the predominant working direction.

Often, the mounting conditions will dictate the hand of spiral to be selected. For spiral bevel and hypoid gears, both members should be held against axial movement in both directions.

A *right-hand spiral bevel gear* is one in which the outer half of a tooth is inclined in the clockwise direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear. [Figure 5](#) shows a right-hand wheel.

A *left-hand spiral bevel gear* is one in which the outer half of a tooth is inclined in the anticlockwise (counterclockwise) direction from the axial plane through the midpoint of the tooth as viewed by an observer looking at the face of the gear. [Figure 5](#) shows a left-hand pinion.

To avoid the loss of backlash, the hand of spiral should be selected to give an axial thrust that tends to move the pinion out of mesh. See [Annex D](#).

For relation of the hand of spiral and the direction of hypoid offset, see [B.3](#).

4.5 Preliminary gear size

Once the preliminary gear size is determined (see [B.4.3](#)), the tooth proportions of the gears should be established and the resulting design should be checked for bending strength and pitting resistance. See ISO 10300 (all parts).

5 Tooth geometry and cutting considerations

5.1 Manufacturing considerations

This clause presents tooth dimensions for bevel and hypoid gears in which the teeth are machined by a face mill cutter, face hob cutter, a planing tool or a cup-shaped grinding wheel. The gear geometry is a

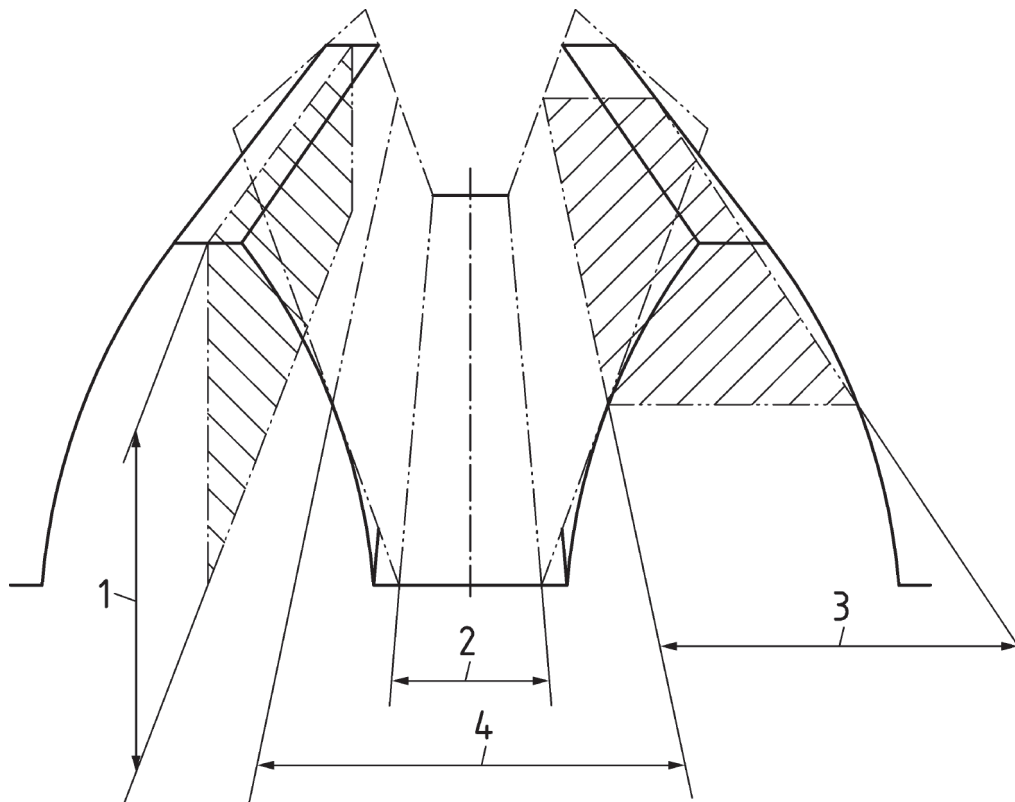
function of the cutting method used. For this reason, it is important that the user is familiar with the cutting methods used by the gear manufacturer. The following section is provided to familiarize the user with this interdependence.

5.2 Tooth taper

Bevel gear tooth design involves some consideration of tooth taper because the amount of taper affects the final tooth proportions and the size and shape of the blank.

It is advisable to define the following interrelated basic types of tapers (these are illustrated in [Figure 9](#), in which straight bevel teeth are shown for simplicity).

- Depth taper refers to the change in tooth depth along the face measured perpendicular to the pitch cone.
- Slot width taper refers to the change in the point width formed by a V-shaped cutting tool of nominal pressure angle, whose sides are tangent to the two sides of the tooth space and whose top is tangent to the root cone, along the face.
- Space width taper refers to the change in the space width along the face. It is generally measured in the pitch plane.
- Thickness taper refers to the change in tooth thickness along the face. It is generally measured in the pitch plane.



Key

- 1 depth
- 2 slot width
- 3 thickness
- 4 space width

Figure 9 — Bevel gear tooth tapers

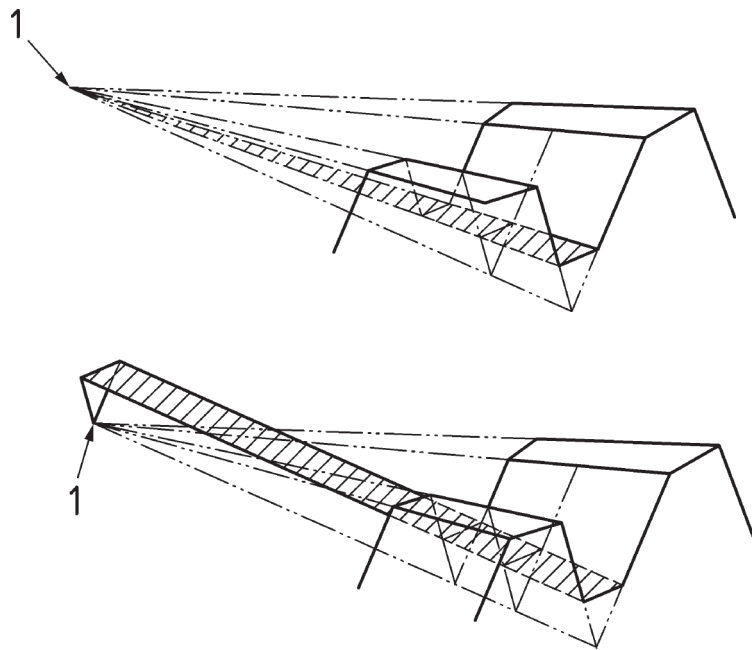
The taper of primary consideration for production is the slot width taper. The width of the slot at its narrowest point determines the point width of the cutting tool and limits the edge radius that can be placed on the cutter blade.

The taper which directly affects the blank is the depth taper through its effect on the dedendum angle, which is used in the calculation of the face angle of the mating member.

The slot width taper depends upon the lengthwise curvature and the dedendum angle. It can be changed by varying the depth taper, i.e. by tilting the root line as shown in [Figure 10](#), in which the concept is simplified by illustrating straight bevel teeth. In spiral bevel and hypoid gears, the amount by which the root line is tilted is further dependent upon a number of geometric characteristics including the cutter radius.

This relationship is discussed more thoroughly in [5.3](#).

The root line is generally rotated about the mid-section at the pitch line in order to maintain the desired working depth at the mean section of the tooth.



Key

1 pitch cone apex

Figure 10 — Root line tilt

5.3 Tooth depth configurations

5.3.1 Taper depth

5.3.1.1 Standard depth

Standard depth pertains to the configuration where the depth changes in proportion to the cone distance at any particular section of the tooth. If the root line of such a tooth is extended, it intersects the axis at the pitch cone apex, as illustrated in [Figure 11](#), but the face cone apex does not. The sum of the dedendum angles of pinion and wheel for standard depth taper, $\Sigma\theta_{fs}$, does not depend on cutter radius. Most straight bevel gears are designed with standard depth taper.

5.3.1.2 Constant slot width

This taper represents a tilt of the root line such that the slot width is constant while maintaining the proper space width taper. The slot width taper is zero on both members.

The formula for the sum of the dedendum angles is given in [C.5.1](#).

Formula (C.4), for the sum of the dedendum angles, indicates that the cutter radius, r_{c0} , has a significant effect on the amount by which the root line is tilted. For a given design, the following tendencies should be noted.

- A large cutter radius increases the sum of the dedendum angles. If the radius is too large, the resultant depthwise taper could adversely affect the depth of the teeth at either end, i.e. too shallow at inner end for proper tooth contact, and too deep at the outer end, which can cause undercut and narrow toplands. Therefore, the cutter radius should not be too large and an upper limit of r_{c0} approximately equal to R_{m2} is suggested.
- A small cutter radius decreases the sum of the dedendum angles. In fact, if r_{c0} equals $R_{m2} \sin \beta_{m2}$, the sum of the dedendum angles becomes zero, which results in uniform depth teeth. If r_{c0} is less than $R_{m2} \sin \beta_{m2}$, reverse depthwise taper would exist and the teeth would be deeper at the inner end than at the outer. In order to avoid excessive depth (undercut and narrow toplands) at the inner end, a minimum value of r_{c0} , equal to $1,1 R_{m2} \sin \beta_{m2}$, is suggested.

NOTE For gears cut with a planing tool, the cutter centre is considered to be at infinity and root lines are not tilted. Standard taper is the norm for gears produced in this manner.

5.3.1.3 Modified slot width

This taper is an intermediate one in which the root line is tilted about the mean point. In this case, the slot width of the gear member is constant along the tooth length and any slot width taper is on the pinion member.

For the case where the root line is tilted to permit finishing the gear in one operation, the amount of tilt is somewhat arbitrary, but should fall within the following guidelines (see [Table C.4](#)):

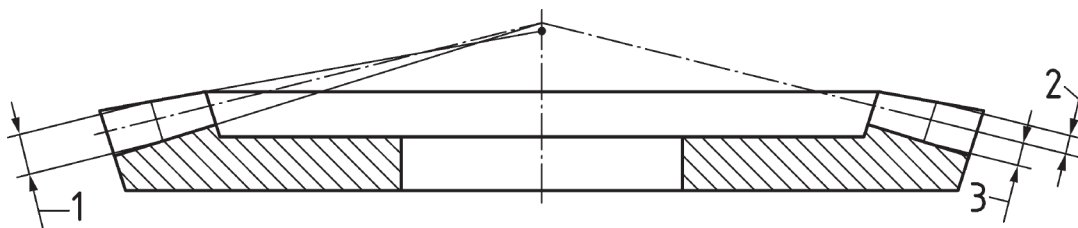
- the sum of the pinion and wheel dedendum angles for modified slot width taper, $\Sigma\theta_{fM}$, should not exceed 1,3 times the sum of the dedendum angles for standard depth taper, $\Sigma\theta_{fS}$, nor should it exceed the sum of the dedendum angles for constant slot width taper, $\Sigma\theta_{fC}$;
- in practice, the smaller of the values, $1,3 \Sigma\theta_{fS}$ or $\Sigma\theta_{fC}$, is used.

5.3.2 Uniform depth

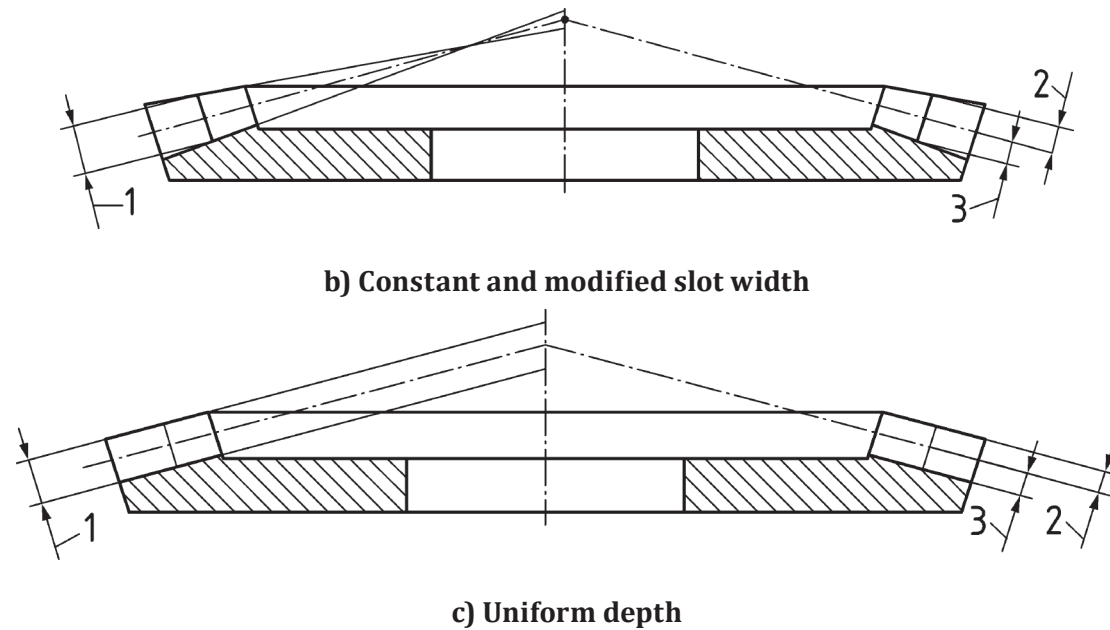
Uniform depth is the configuration where the tooth depth remains constant along the facewidth regardless of cutter radius. In this case, the root line is parallel to an element of the face cone, as illustrated in [Figure 11](#). The sum of the dedendum angles of pinion and wheel for uniform depth, $\Sigma\theta_{fU}$, equals zero.

For the uniform depth tooth, the cutter radius, r_{c0} , should be greater than $R_{m2} \sin \beta_{m2}$, but not more than 1,5 times this value. This approximation of lengthwise involute curvature, in conjunction with the uniform depth, holds the variation along the facewidth in normal circular thickness on the pinion and wheel to a minimum.

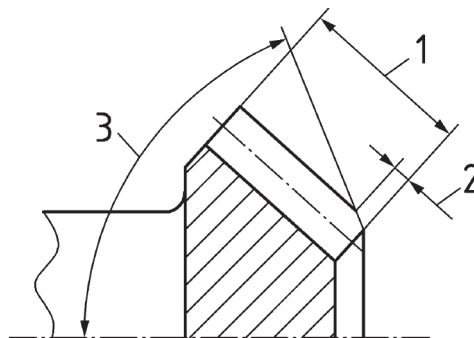
If narrow inner toplands occur on the pinion, a small tooth tip chamfer may be provided (see [Figure 12](#)).



a) Standard depth taper

**Key**

- 1 mean whole depth
- 2 mean addendum
- 3 mean dedendum

Figure 11 — Bevel gear depthwise tapers**Key**

- 1 facewidth, b_1
- 2 length of chamfer
- 3 angle of chamfer

Figure 12 — Tooth tip chamfering on the pinion**5.4 Angle modification, q_k**

Angle modifications may be necessary for design or manufacturing reasons. This prevents interference between the tool and the blank or shaft contour in toe or heel area of pinion or wheel. In this case, the entire tooth is rotated by a small angular amount q_k around the mean point (see [Figure 13](#)). This modification is applicable exclusively for gears with constant tooth depth and affects both gearing partners with different signs, but with slightly different amounts for hypoid gears. The parameter q_k is always specified for the pinion and relevant angle for the wheel is calculated. A positive angle modification q_k reduces tip and root angle for the pinion and increases the respective angles for the wheel.