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Bevel and hypoid gear geometry —

Part 1:
Basic methods

Géométrie des engrenages coniques et hypoïdes —

Partie 1: Méthodes de base

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Foreword

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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 has been rearranged, Figures 1 to 3 have been moved to a new 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, keys 4, 5, 6, and 26 have been rearranged, keys 27 to 31 have been added;

— subclause 5.2.6 on skew bevel with new Figure 8 has been inserted;

— indication of mean whole depth, mean addendum and mean dedendum in Figure 11 a) and Figure 11 b) have been revised;

— subclause 6.4 has been renamed angle modification and revised, and new Figures 13 and 14 have been inserted;

— keys 2 and 16 of Figure 16 have been revised;

— 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 has been updated;

— Clause 8 has been updated respecting new content related to angle modification in 6.4;

— subclause 8.5, Formulae (157) and (158) related to the determination of the pinion face and pinion root apex have been corrected;

— subclause 8.6, Formulae (167) and (168) related to the increment along pinion axis have been corrected;

— subclause 8.9, Formula (220) related to the mean chordal addendum has been corrected;

— A.4 has been modified to distinguish between theoretical and modified tooth contour, Figures A.3 and A.5 have been revised and new Figures A.6 and A.7 have been inserted;

— Table C.1, has been modified to introduce accuracy grades according to ISO 17485;

— 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 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 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].

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

3.1.2
crown gear
usually planar virtual crown gear whose pitch angle is $\delta 1 = 90°$ and which replaces in a bevel gear pair the basic rack used to generate involute cylindrical gear by analogy

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

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

3.1.5
facewidth
b
length of the teeth measured along a pitch cone element

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
mean addendum factor
c_{ham}
distribution factor of the mean working depth, h_{mw}, between wheel and pinion mean addendums

Note 1 to entry: The gear mean addendum is equal to c_{ham} times the mean working depth.

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

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
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
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.3 for calculation points.

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
mean whole depth
h_m
tooth depth at mean cone distance

3.1.15
mean working depth
h_{mw}
depth of engagement of two gears at mean cone distance

3.1.16
number of blade groups
z_0
number of blade groups contained in the circumference of the cutting tool

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
number of teeth
z_1, z_2
number of teeth contained in the whole circumference of the pitch cone

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
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
sum of dedendum angles
$\Sigma\theta_f$
sum of the pinion and wheel dedendum angles

3.1.22
sum of dedendum angles for modified slot width taper
$\Sigma\theta_{fM}$
sum of the pinion and wheel dedendum angles for modified slot width taper

3.1.23
sum of dedendum angles for standard depth taper
$\Sigma\theta_{fS}$
sum of the pinion and wheel dedendum angles for standard depth taper

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 and 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	—
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
$f_{\alpha lim}$	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
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	—

Table 1 *(continued)*

Symbol	Description	Unit
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
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
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

Table 1 *(continued)*

Symbol	Description	Unit
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
ρ_{lim}	limit curvature radius	mm
$\rho_{m\beta}$	lengthwise tooth mean radius of curvature	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 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	°

Table 2 — General subscripts

Subscript	Description
a	addendum
b	base
C	coast side
D	drive side
d	nominal design