TECHNICAL REPORT

ISO/TR 10300-30

First edition
2017-12

Calculation of load capacity of bevel gears —

Part 30:
ISO rating system for bevel and hypoid gears — Sample calculations

Calcul de la capacité de charge des engrenages coniques —

Partie 30: Système d'évaluation ISO pour engrenages conique et hypoïde - Type de calculs

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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).

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

A list of all parts in the ISO 10300 series can be found on the ISO website.

Introduction

The ISO 10300 series consists of International Standards, Technical Specifications (TS) and Technical Reports (TR) under the general title *Calculation of load capacity of bevel gears* (see Table 1).

— International Standards contain calculation methods that are based on widely accepted practices and have been validated.

— TS contain calculation methods that are still subject to further development.

— TR contain data that is informative, such as example calculations.

The procedures specified in ISO 10300-1 to ISO 10300-19 cover fatigue analyses for gear rating. The procedures described in ISO 10300-20 to ISO 10300-29 are predominantly related to the tribological behaviour of the lubricated flank surface contact. ISO 10300-30 to ISO 10300-39 include example calculations. The ISO 10300 series allows the addition of new parts under appropriate numbers to reflect knowledge gained in the future.

Requesting standardized calculations according to ISO 10300 without referring to specific parts requires the use of only those parts that are currently designated as International Standards (see Table 1 for listing). When requesting further calculations, the relevant part or parts of ISO 10300 need to be specified. Use of a Technical Specification as acceptance criteria for a specific design need to be agreed in advance between manufacturer and purchaser.

Table 1 — Overview of ISO 10300

Calculation of load capacity of bevel gears	International Standard	Technical Specification	Technical Report
Part 1: Introduction and general influence factors	X		
Part 2: Calculation of surface durability (pitting)	X		
Part 3: Calculation of tooth root strength	X		
Part 4 to 19: to be assigned			
Part 20: to be assigned for scuffing of bevel and hypoid gears			
Part 21 to 29: to be assigned			
Part 30: ISO rating system for bevel and hypoid gears — Sample calculations			X
At the time of publication of this document, some of the parts listed here were under development. Consult the ISO website.			

This document was prepared with sample calculations for different bevel gear designs. They are intended for users of the ISO 10300 series to follow a whole calculation procedure formula by formula. Practical experience has shown that this way, to get into a complex subject, is very helpful.

On the other hand, this document is not intended for use by the average engineer. Rather, it is aimed at the well-versed engineer capable of selecting reasonable values for the parameters and factors in these formulae based on knowledge of similar designs and on awareness of the effects behind these formulae.

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Calculation of load capacity of bevel gears —

Part 30: ISO rating system for bevel and hypoid gears — Sample calculations

1   Scope

This document provides sample calculations for different bevel gear designs, how the load capacity is numerically determined according to the methods and formulae of the ISO 10300 series. The initial geometric gear data necessary for these calculations in accordance with ISO 23509.

The term "bevel gear" is used to mean straight, helical (skew), spiral bevel, zerol and hypoid gear designs. Where this document pertains to one or more, but not all, 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 calculation methods of the ISO 10300 series. The fact that there are bevel gear designs with tapered teeth and others where the tooth depth remains constant along the face width (uniform depth) does not demand to apply Method B2 for the first and Method B1 for the second tooth configuration.

The rating system of the ISO 10300 series is based on virtual cylindrical gears and restricted to bevel gears whose virtual cylindrical gears have transverse contact ratios of $\varepsilon_{v\alpha} < 2$. Additionally, the given relations are valid for bevel gears of which the sum of profile shift coefficients of pinion and wheel is zero (see ISO 23509).

WARNING: The user is cautioned that when the formulae are used for large average mean spiral angles, $(\beta_{m1} + \beta_{m2})/2 > 45°$, for effective pressure angles, $\alpha_e > 30°$ and/or for large face widths, $b > 13\ m_{mn}$, the calculated results of the ISO 10300 series should be confirmed by experience.

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 10300-1:2014, *Calculation of load capacity of bevel gears — Part 1: Introduction and general influence factors*

ISO 10300-2:2014, *Calculation of load capacity of bevel gears — Part 2: Calculation of surface durability (pitting)*

ISO 10300-3:2014, *Calculation of load capacity of bevel gears — Part 3: Calculation of tooth root strength*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10300-1 and ISO 10300-2 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 https://www.electropedia.org/

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and units given in ISO 10300-1:2014, Table 1 and Table 2, as well as the abbreviated terms given in ISO 10300-2:2014, Table 1, apply.

Table 2 — Symbols and units used in ISO 10300 (all parts)

Symbol	Description or term	Unit
a	hypoid offset	mm
a_{rel}	relative hypoid offset	—
a_v	centre distance of virtual cylindrical gear pair	mm
a_{vn}	centre distance of virtual cylindrical gear pair in normal section	mm
b	face width	mm
b_b	related base face width	—
b_{ce}	calculated effective face width	mm
b_{eff}	effective face width (e.g. measured length of contact pattern)	mm
b_v	face width of virtual cylindrical gears	mm
$b_{v\,eff}$	effective face width of virtual cylindrical gears	mm
c_{ham}	mean addendum factor of wheel	—
c_v	empirical parameter to determine the dynamic factor	—
c_γ	mean value of mesh stiffness per unit face width	N/(mm · μm)
$c_{\gamma 0}$	mesh stiffness for average conditions	N/(mm · μm)
c'	single stiffness	N/(mm · μm)
c_0'	single stiffness for average conditions	N/(mm · μm)
d_e	outer pitch diameter	mm
d_m	mean pitch diameter	mm
d_T	tolerance diameter according to ISO 17485	mm
d_v	reference diameter of virtual cylindrical gear	mm
d_{va}	tip diameter of virtual cylindrical gear	mm
d_{van}	tip diameter of virtual cylindrical gear in normal section	mm
d_{vb}	base diameter of virtual cylindrical gear	mm

Symbol	Description or term	Unit
d_{vbn}	base diameter of virtual cylindrical gear in normal section	mm
d_{vf}	root diameter of virtual cylindrical gear	mm
d_{vn}	reference diameter of virtual cylindrical gear in normal section	mm
e	exponent for the distribution of the load peaks along the lines of contact	—
f	distance from the centre of the zone of action to a contact line	mm
f_{max}	maximum distance to middle contact line	mm
f_{maxB}	maximum distance to middle contact line at right side of the contact pattern	mm
f_{max0}	maximum distance to middle contact line at left side of the contact pattern	mm
f_{pt}	single pitch deviation	μm
$f_{p\,eff}$	effective pitch deviation	μm
$f_{\alpha lim}$	Influence factor of limit pressure angle	
g_c	length of contact line (Method B2)	mm
$g_{v\alpha}$	length of path of contact of virtual cylindrical gear in transverse section	mm
$g_{v\alpha n}$	related length of action in normal section	—
g_J	length of action from mean point to point of load application (Method B2)	mm
g_η	relative length of action within the contact ellipse	mm
h_{am}	mean addendum	mm
h_{a0}	tool addendum	mm
h_{fm}	mean dedendum	mm
h_{fP}	dedendum of the basic rack profile	mm
h_m	mean whole depth used for bevel spiral angle factor	mm
h_{vfm}	relative mean virtual dedendum	—
h_{Fa}	bending moment arm for tooth root stress (load application at tooth tip)	mm
h_N	load height from critical section (Method B2)	mm
j_{en}	outer normal backlash	mm
k'	contact shift factor	—
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	—
l_b	length of contact line (Method B1)	mm

Symbol	Description or term	Unit
l_{b0}	theoretical length of contact line	mm
l_{bm}	theoretical length of middle contact line	mm
m_{et}	outer transverse module	mm
m_{mn}	mean normal module	mm
m_{mt}	mean transverse module	mm
m_{red}	mass per unit face width reduced to the line of action of dynamically equivalent cylindrical gears	kg/mm
m^*	related individual gear mass per unit face width referred to the line of action	kg/mm
n	rotational speed	min^{-1}
n_{E1}	resonance speed of pinion	min^{-1}
p	peak load	N/mm
p_{et}	transverse base pitch (Method B2)	mm
p_{max}	maximum peak load	N/mm
p^*	related peak load for calculating the load sharing factor (Method B1)	—
p_{mn}	relative mean normal pitch	—
p_{nb}	relative mean normal base pitch	—
p_{vet}	transverse base pitch of virtual cylindrical gear (Method B1)	mm
q	exponent in the formula for lengthwise curvature factor	—
q_s	notch parameter	—
r_{c0}	cutter radius	mm
r_{mf}	tooth fillet radius at the root in mean section	mm
r_{mpt}	mean pitch radius	mm
$r_{my\,0}$	mean transverse radius to point of load application (Method B2)	mm
r_{va}	relative mean virtual tip radius	—
r_{vn}	relative mean virtual pitch radius	—
s_{mn}	mean normal circular thickness	mm
s_{pr}	amount of protuberance at the tool	mm
s_{Fn}	tooth root chord in calculation section	mm
s_N	one-half tooth thickness at critical section (Method B2)	mm
u	gear ratio of bevel gear	—
u_v	gear ratio of virtual cylindrical gear	—
v_{et}	tangential speed at outer end (heel) of the reference cone	m/s
$v_{et\,max}$	maximum pitch line velocity at operating pitch diameter	m/s
v_g	sliding velocity in the mean point P	m/s
$v_{g\,par}$	sliding velocity parallel to the contact line	m/s
$v_{g\,vert}$	sliding velocity vertical to the contact line	m/s

Symbol	Description or term	Unit
v_{mt}	tangential speed at mid face width of the reference cone	m/s
v_Σ	sum of velocities in the mean point P	m/s
$v_{\Sigma h}$	sum of velocities in profile direction	m/s
$v_{\Sigma l}$	sum of velocities in lengthwise direction	m/s
$v_{\Sigma\,vert}$	sum of velocities vertical to the contact line	m/s
w	angle of contact line relative to the root cone	°
x_{hm}	profile shift coefficient	—
x_{sm}	thickness modification coefficient (backlash included)	—
x_{smn}	thickness modification coefficient (theoretical)	—
x_N	tooth strength factor (Method B2)	mm
x_{oo}	distance from mean section to point of load application	mm
y_p	running-in allowance for pitch deviation related to the polished test piece	μm
y_J	location of point of load application for maximum bending stress on path of action (Method B2)	mm
y_3	location of point of load application on path of action for maximum root stress	mm
y_α	running-in allowance for pitch error	μm
z	number of teeth	—
z_v	number of teeth of virtual cylindrical gear	—
z_{vn}	number of teeth of virtual cylindrical gear in normal section	—
z_0	number of blade groups of the cutter	—
A	auxiliary factor for calculating the dynamic factor $K_v - _C$	—
A^*	related area for calculating the load sharing factor Z_{LS}	mm
A_{sne}	outer tooth thickness allowance	mm
B	accuracy grade according to ISO 17485	—
C_F	correction factor of tooth stiffness for non-average conditions	—
C_{lb}	correction factor for the length of contact lines	—
C_{ZL}, C_{ZR}, C_{ZV}	constants for determining lubricant film factors	—
E	modulus of elasticity, Young's modulus	N/mm²
E, G, H	auxiliary variables for tooth form factor (Method B1)	—
F	auxiliary variable for mid-zone factor	—
F_{mt}	nominal tangential force at mid face width of the reference cone	N
F_{mtH}	determinant tangential force at mid face width of the reference cone	N
F_n	nominal normal force	N
F_{vmt}	nominal tangential force of virtual cylindrical gears	N
HB	Brinell hardness	—

Symbol	Description or term	Unit
K	constant; factor for calculating the dynamic factor K_{v-B}	—
K_v	dynamic factor	—
$K_v{}^*$	preliminary dynamic factor for non-hypoid gears	—
K_A	application factor	—
K_{F0}	lengthwise curvature factor for bending stress	—
$K_{F\alpha}$	transverse load factor for bending stress	—
$K_{F\beta}$	face load factor for bending stress	—
$K_{H\alpha}$	transverse load factor for contact stress	—
$K_{H\alpha}{}^*$	preliminary transverse load factor for contact stress for non-hypoid gears	—
$K_{H\beta}$	face load factor for contact stress	—
$K_{H\beta-be}$	mounting factor	—
N	reference speed related to resonance speed n_{E1}	—
N_L	number of load cycles	—
P	nominal power	kW
Ra	= CLA = AA arithmetic average roughness	µm
R_e	outer cone distance	mm
R_m	mean cone distance	mm
R_{mpt}	relative mean back cone distance	—
Rz	mean roughness	µm
Rz_{10}	mean roughness for gear pairs with relative curvature radius $\rho_{rel} = 10$ mm	µm
S_F	safety factor for bending stress (against breakage)	—
$S_{F\,min}$	minimum safety factor for bending stress	—
S_H	safety factor for contact stress (against pitting)	—
$S_{H\,min}$	minimum safety factor for contact stress	—
$T_{1,2}$	nominal torque of pinion and wheel	Nm
W_{m2}	wheel mean slot width	mm
$Y_{1,2}$	tooth form factor of pinion and wheel (Method B2)	—
Y_f	stress concentration and stress correction factor (Method B2)	—
Y_i	inertia factor (bending)	—
Y_A	root stress adjustment factor (Method B2)	—
Y_{BS}	bevel spiral angle factor	—
Y_{Fa}	tooth form factor for load application at the tooth tip (Method B1)	—
Y_{FS}	combined tooth form factor for generated gears	—
Y_J	bending strength geometry factor (Method B2)	—
Y_{LS}	load sharing factor (bending)	—

Symbol	Description or term	Unit
Y_{NT}	life factor (bending)	—
$Y_{R\,rel\,T}$	relative surface condition factor	—
Y_{Sa}	stress correction factor for load application at the tooth tip	—
Y_{ST}	stress correction factor for dimensions of the standard test gear	—
Y_X	size factor for tooth root stress	—
$Y_{\delta\,rel\,T}$	relative notch sensitivity factor	—
Y_ε	contact ratio factor for bending (Method B1)	—
Z_i	inertia factor (pitting)	—
Z_v	speed factor	—
Z_A	contact stress adjustment factor (Method B2)	—
Z_E	elasticity factor	—
Z_{FW}	face width factor	—
Z_{Hyp}	hypoid factor	—
Z_I	pitting resistance geometry factor (Method B2)	—
Z_K	bevel gear factor (Method B1)	—
Z_L	lubricant factor	—
Z_{LS}	load sharing factor (Method B1)	—
Z_{M-B}	mid zone factor	—
Z_{NT}	life factor (pitting)	—
Z_R	roughness factor for contact stress	—
Z_S	bevel slip factor	—
Z_W	work hardening factor	—
Z_X	size factor	—
α_a	adjusted pressure angle (Method B2)	°
α_{an}	normal pressure angle at tooth tip	°
$\alpha_{dD,C}$	nominal design pressure angle for drive side/coast side	°
α_{et}	effective pressure angle in transverse section	°
$\alpha_{eD,C}$	effective pressure angle for drive side/coast side	°
α_f	limit pressure angle in wheel root coordinates (Method B2)	°
α_{lim}	limit pressure angle	°
$\alpha_{nD,C}$	generated pressure angle for drive side/coast side	°
α_{vet}	transverse pressure angle of virtual cylindrical gears	°
α_{Fan}	load application angle at tooth tip of virtual cylindrical gear (Method B1)	°
α_L	normal pressure angle at point of load application (Method B2)	°
β_{bm}	mean base spiral angle	°
β_m	mean spiral angle	°

Symbol	Description or term	Unit
β_v	helix angle of virtual gear (Method B1), virtual spiral angle (Method B2)	°
β_{vb}	helix angle at base circle of virtual cylindrical gear	°
β_B	inclination angle of contact line	°
γ	auxiliary angle for length of contact line calculation (Method B1)	°
γ'	projected auxiliary angle for length of contact line	°
γ_a	auxiliary angle for tooth form and tooth correction factor	°
δ	pitch angle of bevel gear	°
δ_a	face angle	°
δ_f	root angle	°
$\varepsilon_{v\alpha}$	transverse contact ratio of virtual cylindrical gears	—
$\varepsilon_{v\alpha n}$	transverse contact ratio of virtual cylindrical gears in normal section	—
$\varepsilon_{v\beta}$	face contact ratio of virtual cylindrical gears	—
$\varepsilon_{v\gamma}$	virtual contact ratio (Method B1), modified contact ratio (Method B2)	—
ε_N	load sharing ratio for bending (Method B2)	—
ε_{NI}	load sharing ratio for pitting (Method B2)	—
ζ_m	pinion offset angle in axial plane	°
ζ_{mp}	pinion offset angle in pitch plane	°
ζ_R	pinion offset angle in root plane	°
θ	auxiliary quantity for tooth form and tooth correction factors	—
θ_{mp}	auxiliary angle for virtual face width (Method B1)	°
θ_{a2}	addendum angle of wheel	°
θ_{f2}	dedendum angle of wheel	°
θ_{v2}	angular pitch of virtual cylindrical wheel	radiant
ξ	assumed angle in locating weakest section	°
ξ_h	one half of angle subtended by normal circular tooth thickness at point of load application	°
ρ	density of gear material	kg/mm³
ρ_{a0}	cutter edge radius	mm
ρ_F	fillet radius at point of contact of 30° tangent	mm
ρ_{Fn}	fillet radius at point of contact of 30° tangent in normal section	mm
ρ_{fP}	root fillet radius of basic rack for cylindrical gears	mm
ρ_{rel}	radius of relative curvature vertical to contact line at virtual cylindrical gears	mm
ρ_t	radius of relative profile curvature (Method B2)	mm
ρ_{va0}	relative edge radius of tool	—
ρ'	slip layer thickness	mm