TECHNICAL REPORT

ISO/TR 10300-32

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Calculation of load capacity of bevel gears —

Part 32:
ISO rating system for bevel and hypoid gears — Sample calculation for scuffing load capacity

Reference number
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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 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*.

A list of all parts in the ISO 10300 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

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 parts 1 to 19 cover fatigue analyses for gear rating. The procedures described in ISO 10300 parts 20 to 29 are predominantly related to the tribological behaviour of the lubricated flank surface contact. ISO 10300 parts 30 to 39 include example calculations. 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 — Parts of ISO 10300 series (status as of DATE OF PUBLICATION)

Calculation of load capacity of bevel gears	International Standard	Technical Specification	Technical Report
Part 1: Introduction and general influence factors[a]	X		
Part 2: Calculation of surface durability (pitting)[a]	X		
Part 3: Calculation of tooth root strength[a]	X		
Part 4 to 19: to be assigned			
Part 20: Calculation of scuffing load capacity — Flash temperature method		X	
Part 21 to 29: to be assigned			
Part 30: ISO rating system for bevel and hypoid gears — Sample calculations			X
Part 32: ISO rating system for bevel and hypoid gears — Sample Calculations of scuffing load capacity			X

[a] Under revision.

This document and the other parts of ISO 10300 series provide a coherent system of procedures for the calculation of the load capacity of bevel and hypoid gears. ISO 10300 series is designed to facilitate the application of future knowledge and developments, also the exchange of information gained from experience.

Calculation of load capacity of bevel gears —

Part 32:
ISO rating system for bevel and hypoid gears — Sample calculation for scuffing load capacity

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.

1 Scope

This document provides calculation examples for different bevel gear designs regarding the scuffing load capacity according to ISO/TS 10300-20. The initial geometry data of the gear necessary for these calculations are 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 formulae in this document are based on virtual cylindrical gears and restricted to bevel gears whose virtual cylindrical gears have transverse contact ratios of $\varepsilon_{v\alpha} < 2$. The results are valid within the range of the applied factors as specified in ISO 10300-1 (see ISO 6336-2). 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).

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/TS 10300-20, *Calculation of load capacity of bevel gears — Part 20: Calculation of scuffing load capacity — Flash temperature method*

3 Terms and definitions

No terms and definitions are listed in this document.

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/

4 Symbols

For the purposes of this document, the symbols and units given in ISO/TS 10300-20 apply.

5 Application

This document provides four sample calculations:

— Sample 1 is a rating of a spiral bevel gear pair without hypoid offset according to ISO/TS 10300-20 (see Annex A);

— Sample 2 is a rating of a hypoid gear set according to ISO/TS 10300-20 (see Annex B);

— Sample 3 is a rating of a hypoid gear set according to ISO/TS 10300-20 (see Annex C);

— Sample 4 is a rating of a hypoid gear set according to ISO/TS 10300-20 (see Annex D).

Annex A
(informative)

Sample 1: Rating of a spiral bevel gear pair without hypoid offset according to ISO/TS 10300-20

A.1 Initial data

Sample 1 is for a spiral bevel gear pair without hypoid offset which uses Method 0 according to ISO 23509 for calculation of gear geometry. The initial data for pitch cone parameters for this sample is shown in Table A.1 and the input data for tooth profile parameters in Table A.2.

Table A.1 — Initial data for pitch cone parameters

Symbol	Description	Method 0	Method 1	Method 2	Method 3
Σ	shaft angle	90°	X	X	X
a	hypoid offset	0 mm	X	X	X
$z_{1,2}$	number of teeth	14/39	X	X	X
d_{m2}	mean pitch diameter of wheel	—	—	X	—
d_{e2}	outer pitch diameter of wheel	176,893 mm	X	—	X
b_2	wheel face width	25,4 mm	X	X	X
β_{m1}	mean spiral angle of pinion	35°	X	—	—
β_{m2}	mean spiral angle of wheel	35°	—	X	X
r_{c0}	cutter radius	114,3 mm	X	X	X
z_0	number of blade groups (only face hobbing)	—	—	X	X

Table A.2 — Input data for tooth profile parameters

Data type I		Data type II	
Symbol	**Description**	**Symbol**	**Description**
α_{dD}	20°		
α_{dC}	20°		
$f_{\alpha lim}$	0		
x_{hm1}	—	c_{ham}	0,247 37
k_{hap}	—	k_d	2,000
k_{hfp}	—	k_c	0,125
x_{smn}	—	k_t W_{m2}	0,091 5 —
j_{et2}	0,127 mm		
θ_{a2}	2,134 2°		
θ_{f2}	6,493 4°		
ρ_{a01}	0,8 mm/0,8 mm		
ρ_{a02}	1,2 mm/1,2 mm		
$s_{pr1D,C}$	0 mm/0 mm		
$s_{pr2D,C}$	0 mm/0 mm		

Table A.3 and Table A.4 show geometry and operational data and text for explanation.

Table A.3 — Geometry data from calculation according to ISO 23509

Symbol	Description	Values	Symbol	Description	Value
$d_{m1,2}$	mean pitch diameter of pinion/wheel	54,918 mm/ 152,987 mm	ζ_{mp}	offset angle on pitch plane	0°
$h_{am1,2}$	mean addendum of pinion/ wheel	4,836 mm/ 1,591 mm	ζ_R	pinion offset angle on root plane	0°
$h_{fm1,2}$	mean dedendum of pinion/ wheel	2,394 mm/ 5,639 mm	$R_{e1,2}$	outer cone distance on pinion/wheel	93,973 mm
$\alpha_{eD,C}$	effective pressure angle for drive side/coast side	20°/20°	$R_{m1,2}$	mean cone distance on pinion/wheel	81,273 mm
$\alpha_{nD,C}$	generated pressure angle for drive side/coast side	20°/20°	$\delta_{1,2}$	pitch angle on pinion/wheel	19,747°/ 70,253°
α_{lim}	limit pressure angle	0°	$\delta_{a1,2}$	face angle on pinion/wheel	26,240°/ 72,387°
m_{mn}	mean normal module	3,213 mm	$\delta_{f1,2}$	root angle on pinion/wheel	17,613°/ 63,760°
k_{hfp}	basic crown gear dedendum factor	1,25	$x_{sm1,2}$	thickness modification coefficient on pinion/ wheel	0,037/ -0,055
ζ_m	pinion offset angle on axial plane	0,000°	m_{et2}	outer transverse module	4,536 mm
$s_{mn1,2}$	mean normal circular tooth thickness of pinion/wheel	6,465 mm/ 3,511 mm			

Table A.4 — Operation parameters and additional considerations

Symbol	Description	Value
Additional data		
	wheel profile	generated
	roughing/finishing method	face milling (ground)
b_{2eff}	effective face width on wheel	$0{,}85 \cdot b_2$
	profile crowning	low
	verification of contact pattern	checked under light test load for each gear
	mounting conditions of pinion and wheel	one member cantilever–mounted
Operation parameters		
T_1	pinion torque	300 Nm
n_1	pinion rotational speed	1 200 min^{-1}
K_A	application factor	1,1
	active flank	drive
	Run-In-Status	Run-In
Material data for pinion and wheel (case hardened steel)		
E	modulus of elasticity	210 000 N/mm^2
ν	Poisson's ratio	0,3
$\sigma_{H\,lim}$	allowable stress number (contact)	1 500 N/mm^2
$\sigma_{F\,lim}$	nominal stress number (bending)	480 N/mm^2
ρ_M	densitiy of pinion / wheel	7 800 kg/m^3 (according to ISO/TS 10300-20:2021, Table 5)

Table A.4 *(continued)*

Symbol	Description	Value
c_M	specific heat per unit mass of pinion / wheel	440 J/(kgK) (according to ISO/TS 10300-20:2021, Table 5)
λ_M	specific heat conductivity of pinion / wheel	45 W/(mK) (according to ISO/TS 10300-20:2021, Table 5)
surface hardness		same for pinion and wheel
Quality parameters		
Rz	flank roughness on pinion/wheel	8 µm/8 µm
Ra	flank roughness on pinion/wheel	1,33 µm/1,33 µm
Rz	tooth root roughness on pinion/wheel	16 µm/16 µm
f_{pt}	single pitch deviation on pinion/wheel	12 µm/26 µm
Lubrication parameters		
oil type		ISO-VG-150
θ_{Oil}	oil temperature	90 °C
$\theta_{Oil,Ref}$	reference oil temperature	90 °C
e_d	immersion depth	35,379 mm
T_{1T}	pinion torque of achieved load stage (load stage 12)	534,5 Nm (A/8,3/90 according to ISO 14635-1)
ν_{40}	kinematic viscosity at temperature 40 °C	150 mm^2/s
ν_{100}	kinematic viscosity at temperature 100 °C	15 mm^2/s
ρ_{15}	density at temperature 15 °C	890 kg/m^3

A.2 Calculation of scuffing load capacity of Sample 1

The calculation results of the virtual cylindrical gear are listed in Table A.5, of stresses, velocities and coefficient of friction in Table A.6. Results of the calculation of the occurring contact temperature are shown in Table A.7, the permissible contact temperature in Table A.8. The results of the calculated safety factor can be found in Table A.9.

Table A.5 — Virtual cylindrical gear

Description	Formula	Result	References to ISO/TS 10300-20:2021
Length of path of contact in transverse section	$g_{v\alpha} = g_{va1} + g_{va2} = \frac{1}{2}\left[\left(\sqrt{d_{va1}^2 - d_{vb1}^2} - d_{v1}\sin\alpha_{vet}\right) + \left(\sqrt{d_{va2}^2 - d_{vb2}^2} - d_{v2}\sin\alpha_{vet}\right)\right]$	13,121 mm	Formula (3)
Point A on the transverse path of contact	$g_Y(A) = -g_{va2}$	-3,851 mm	Formula (1)
Point E on the transverse path of contact	$g_Y(E) = g_{va1}$	9,27 mm	Formula (2)
Contact point Y on the transverse path of contact	$g_Y(Y) = (g_Y(A) + k_s g_{v\alpha}) + Y \cdot \frac{(1-2k_s)g_{v\alpha}}{i}$ with Y = 0...i; i = 10 NOTE In all following formulae, g_Y is a function of Y($g_Y = g_Y(Y)$)	-3,851 mm -2,539 mm -1,227 mm 0,085 mm 1,397 mm 2,709 mm 4,021 mm 5,334 mm 6,646 mm 7,958 mm 9,27 mm	Formula (4)

Table A.5 *(continued)*

Description	Formula	Result	References to ISO/TS 10300-20:2021
Distance of the middle contact line in the zone of action	$f_{m,Y} = (g_{va2} - g_{v\alpha} / 2 + g_Y) \cdot \cos \beta_{vb}$	-5,526 mm -4,421 mm -3,316 mm -2,21 mm -1,105 mm 0 mm 1,105 mm 2,210 mm 3,316 mm 4,421 mm 5,526 mm	Formula (5)
Coordinates of the ends of the contact line	$x_{1,Y} = \dfrac{f_Y \cos \beta_{vb} + \tan \beta_{vb} \left(f_Y \sin \beta_{vb} + \dfrac{b_{v,eff}}{2} \right) + \dfrac{1}{2} (g_{v\alpha} + b_{v,eff} \tan \gamma)}{\tan \gamma + \tan \beta_{vb}} \geq 0$	10,795 mm 12,846 mm 14,896 mm 16,947 mm 18,997 mm 21,048 mm 21,59 mm 21,59 mm 21,59 mm 21,59 mm 21,59 mm	Formula (10)

Table A.5 *(continued)*

Description	Formula	Result	References to ISO/TS 10300-20:2021
Coordinates of the ends of the contact line	$x_{2,\mathrm{Y}} = \dfrac{f_\mathrm{Y} \cos\beta_\mathrm{vb} + \tan\beta_\mathrm{vb}\left(f_\mathrm{Y} \sin\beta_\mathrm{vb} + \dfrac{b_\mathrm{v,eff}}{2}\right) - \dfrac{1}{2}\left(g_{\mathrm{v}\alpha} - b_\mathrm{v,eff} \tan\gamma\right)}{\tan\gamma + \tan\beta_\mathrm{vb}} \le b_\mathrm{v,eff}$	0 mm 0 mm 0 mm 0 mm 0 mm 0,542 mm 2,593 mm 4,643 mm 6,694 mm 8,744 mm 10,795 mm	Formula (11)
Coordinates of the ends of the contact line	$y_{1,\mathrm{Y}} = -x_{1,\mathrm{Y}} \tan\beta_\mathrm{vb} + f_\mathrm{Y} \cos\beta_\mathrm{vb} + \tan\beta_\mathrm{vb}\left(f_\mathrm{Y} \sin\beta_\mathrm{vb} + \dfrac{b_\mathrm{v,eff}}{2}\right)$	-6,561 mm -6,561 mm -6,561 mm -6,561 mm -6,561 mm -6,561 mm -5,595 mm -4,283 mm -2,971 mm -1,659 mm -0,347 mm	Formula (12)

Table A.5 *(continued)*

Description	Formula	Result	References to ISO/TS 10300-20:2021
Coordinates of the ends of the contact line	$y_{2,Y} = -x_{2,Y} \tan\beta_{vb} + f_Y \cos\beta_{vb} + \tan\beta_{vb}\left(f_Y \sin\beta_{vb} + \frac{b_{v,eff}}{2}\right)$	0,347 mm 1,659 mm 2,971 mm 4,283 mm 5,595 mm 6,561 mm 6,561 mm 6,561 mm 6,561 mm 6,561 mm 6,561 mm	Formula (12)
Correction factor for the length of contact lines	$C_{lb,Y} = \sqrt{\left(1-\left(\frac{f_Y}{f_{max}}\right)^2\right)\left(1-\sqrt{\frac{b_{v,eff}}{b_v}}\right)^2}$	0,068 0,072 0,075 0,077 0,078 0,078 0,078 0,077 0,075 0,072 0,068	Formula (15)