TECHNICAL SPECIFICATION

ISO/TS 10300-20

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Calculation of load capacity of bevel gears —

Part 20: Calculation of scuffing load capacity — Flash temperature method

Calcul de la capacité de charge des engrenages coniques —

Partie 20: Calcul de la capacité de charge au grippage — Méthode de la température-éclair

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).

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

Design considerations to prevent fractures emanating from stress raisers in the tooth flank, tip chipping and failures of the gear blank through the web or hub will need to be analysed by general machine design methods.

Several methods for the calculation of load capacity, as well as for the calculation of various factors, are permitted. The directions in the ISO 10300 series are thus complex, but also flexible.

Scuffing is a localized damage caused by solid-phase welding between sliding surfaces. It is accompanied by transfer of metal from one surface to another due to welding and tearing. Scuffing can occur in gear flanks that operate in the boundary-lubrication regime where the lubricant film is insufficient to separate tooth surfaces and contact breaks through the oxide layers that normally protect the surfaces and enables bare metal surfaces to weld together. Blok[4] hypothesized that scuffing occurs when the maximum surface temperature in the contact reaches a critical value. The maximum contact temperature is determined by the sum of the gear tooth bulk temperature and the local, instantaneous flash temperature. Scuffing risk is determined by comparing the maximum contact temperature to the critical temperature. The critical temperature is not only a function of the lubricant-metal-atmosphere combination; but it depends also upon operating conditions and surface characteristics. Consequently, the most reliable critical temperatures are determined from tests performed on actual gears, under actual service loads, and in actual service environments.

Calculation of load capacity of bevel gears —

Part 20: Calculation of scuffing load capacity — Flash temperature method

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 a calculation method for bevel and hypoid gears regarding scuffing based on experimental and theoretical investigation[7]. This calculation method is a flash temperature method.

The formulae in this document are intended to establish uniformly acceptable methods for calculating scuffing resistance of straight, helical (skew), spiral bevel, Zerol and hypoid gears made of steel. They are applicable equally to tapered depth and uniform depth teeth. Hereinafter, the term “bevel gear” refers to all of these gear types; if not the case, the specific forms are identified.

A calculation method of the scuffing load capacity of bevel and hypoid gears based on an integral temperature method is not available when this document is published.

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

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

ISO 14635-1, *Gears — FZG test procedures — Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*

ISO 17485, *Bevel gears — ISO system of accuracy*

ISO 23509, *Bevel and hypoid gear geometry*

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 10300-1, ISO 23509 and Table 2 apply. Table 3 lists the generally used subscripts.

Table 2 — Symbols and units

Symbol	Description or term	Unit
A^*_Y	related area for calculating the load sharing factor X_{LS} at contact point Y	mm
a	auxiliary value	mm
a_{ref}	reference centre distance	mm
B	accuracy grade (ISO 17485 shall apply)	—
B_M	thermal contact coefficient	N/(ms^{0,5}K)
b_H	half of the Hertzian contact width	mm
b_Y	auxiliary value	1/mm
C_A	tip relief	µm
C_{eff}	effective tip relief	µm
$C_{lb,Y}$	correction factor for the length of contact lines at contact point Y	—
C_{RS}	surface roughness structure factor	—
C_{th}	gradient of the permissible temperature function for $X_T > 1{,}0$	K
$C_{th,Y}$	thermal correction factor at contact point Y	—
C_{tn}	gradient of the permissible temperature function for $X_T \leq 1{,}0$	K
$C_{\lambda,Y}$	lubricating film thickness factor at contact point Y	—
c_M	specific heat per unit mass of pinion / wheel	J/(kgK)
D	rotating direction factor	—
E'	reduced modulus of elasticity	N/mm^2
e	exponent (ISO 10300-2 shall apply)	—
e_d	immersion depth	mm
F_n	nominal normal force at mean point P (ISO 10300-2 shall apply)	N
F_{vmt}	nominal tangential force of virtual cylindrical gears	N
$f_{m,Y}$	meshing coordinate of middle contact line at contact point Y	mm
$f_{r,Y}$	meshing coordinate of root contact line at contact point Y	mm
$f_{t,Y}$	meshing coordinate of tip contact line at contact point Y	mm
G	material parameter	—
g_{va}	length of tip path of contact of virtual cylindrical gear	mm
g_Y	coordinate for transverse path of contact at contact point Y	mm
$h_{0,Y}$	lubricating film thickness at contact point Y	µm
$h'_{0,Y}$	lubricating film thickness according to Ertl/Grubin[5], [6] at contact point Y	µm
i	number of calculation points along the path of contact	—
$K_{H\beta,Y}$	face load factor for contact stress at contact point Y	—
L_Y	thermal load factor	—
$l_{b,Y}$	length of contact line (Method B1) at contact point Y	mm
$l_{b0,Y}$	theoretical length of contact line at contact point Y	mm
M_Y	centre of path of contact	—
P_{VZP}	load dependent power losses	kW

Table 2 *(continued)*

Symbol	Description or term	Unit
p_{H}	Hertzian stress	N/mm^2
p^*_{Y}	related peak load for calculating the load sharing factor (Method B1) at contact point Y	—
$S_{\mathrm{S,Y}}$	local safety factor regarding scuffing at contact point Y	—
$s_{\mathrm{x,Y}}$	local sliding-rolling-ratio at contact point Y	—
T_{1T}	pinion torque of the test load stage	Nm
t_{C}	contact exposure time	s
U_{Y}	local velocity parameter at contact point Y	—
v_{gs}	sliding velocity in tooth lengthwise direction at the mean point	m/s
$v_{\mathrm{g,Y}}$	sliding velocity at contact point Y	m/s
$v_{\mathrm{gh,Y}}$	sliding velocity in profile direction at contact point Y	m/s
$v_{\Sigma\mathrm{,Y}}$	sum of velocities at contact point Y	m/s
$v_{\Sigma\mathrm{h,Y}}$	sum of velocities in profile direction at contact point Y	m/s
$v_{\Sigma\mathrm{s}}$	sum of velocities in lengthwise direction	m/s
$v_{\Sigma\,\mathrm{vert,Y}}$	sum of velocities vertical to the contact line at contact point Y	m/s
W_{Y}	local load parameter at contact point Y	—
w_{max}	maximum line load along path of contact	N/mm
w_{tvert}	surface velocity vertical to the contact line	m/s
$w_{\mathrm{t1,2,h,Y}}$	local surface velocity in profile direction at contact point Y	m/s
$w_{\mathrm{t1,2s}}$	surface velocity in lengthwise direction	m/s
$w_{\mathrm{t1,2,Y}}$	local surface velocity	m/s
X_{CA}	tip relief factor	—
X_{E}	running-in factor	—
X_{L}	lubricant factor	—
$X_{\mathrm{LS,Y}}$	local load sharing factor at contact point Y	—
X_{Q}	driving direction factor	—
X_{S}	lubrication factor	—
X_{T}	temperature factor	—
X_{WrelT}	relative material structure factor	—
X_{Y}	curvature factor at contact point Y	—
$x_{\mathrm{1,2,Y}}$	coordinates of the ends of the contact line at contact point Y	mm
$y_{\mathrm{1,2,Y}}$	coordinates of the ends of the contact line at contact point Y	mm
Z_{E}	elasticity factor (ISO 10300-2 shall apply)	(N/mm^2)$^{1/2}$
z_{Y}	auxiliary value at contact point Y	mm
$\alpha_{\mathrm{p},\theta}$	pressure-viscosity coefficient	m^2/N
α_{th}	temperature coefficient of the dynamic viscosity	1/K
ε_{a}	tip contact ratio	—
ε_{f}	root contact ratio	—
ε_{v}	virtual addendum contact ratio	—
$\varepsilon_{\mathrm{vf}}$	root transverse contact ratio of virtual cylindrical gears	—
$\varepsilon_{\mathrm{vmax}}$	virtual maximum addendum contact ratio	—
η_{M}	dynamic viscosity at bulk temperature	N s/m^2
$\eta_{\theta 1,2}$	dynamic viscosity at bulk temperature $\theta_{1,2}$	N s/m^2
$\theta_{\mathrm{C,Y}}$	local contact temperature at contact point Y	°C

Table 2 *(continued)*

Symbol	Description or term	Unit
$\theta_{fl,Y}$	flash temperature at contact point Y	°C
θ_M	bulk temperature	°C
$\theta_{S,DIN}$	limit temperature according to standard scuffing tests	°C
θ_S	permissible scuffing temperature	°C
$\theta_{S,C}$	permissible temperature considering the influence of the contact temperature	°C
θ_{Oil}	oil temperature	°C
$\theta_{Oil,Ref}$	reference oil temperature	°C
λ	specific heat conductivity of the oil	W/(mK)
λ_M	specific heat conductivity of material	W/(mK)
$\lambda_{z,Y}$	local relative lubricating film thickness at contact point Y	—
μ_Y	local coefficient of friction at contact point Y	—
ρ_M	density of material	kg/m^3
$\rho_{rel,C}$	local equivalent radius of curvature vertical to the contact line at point C	mm
$\rho_{rel,Y}$	local equivalent radius of curvature vertical to the contact line at contact point Y	mm
ρ_t	radius of relative profile curvature (Method B2)	mm
$\sigma_{H,Y}$	contact stress at contact point Y	N/mm^2
$\sigma_{H,mod,Y}$	modified contact stress at contact point Y	N/mm^2
$\omega_{wt1,2,Y}$	angle between the surface velocities in lengthwise and tooth profile direction at contact point Y	°

Table 3 — Generally used subscripts

Subscripts	Description
0	tool
1	pinion
2	wheel
A, B, B1, B2, C	value according to Method A, B, B1, B2 or C
D	drive flank /drive side
C	coast flank / coast side
T	relative to standardized test gear dimensions
(1), (2)	trials of interpolation
Y	contact point variable

5 Virtual cylindrical gear

5.1 General

The calculation method in this document uses virtual cylindrical gears to determine relevant parameters, see ISO 10300-1.

5.2 Local geometry parameters

5.2.1 Transverse path of contact

For local calculation of the flash temperature, $\theta_{fl,Y}$, along the transverse path of contact, the coordinate g_Y is introduced with its origin in the pitch point C, i.e. g_Y(C)=0, as shown in Figure 1.

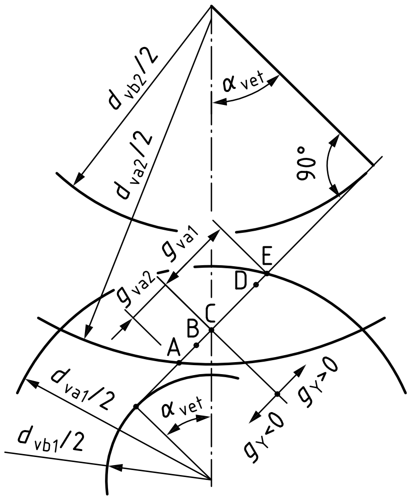

Figure 1 — Transverse path of contact

Towards the pinion tip g_Y is defined as positive and towards the pinion root it is defined as negative. In the boundary points A and E on the transverse path of contact g_Y is determined by Formulae (1) and (2).

$$g_Y\,(\mathrm{A}) = -g_{va2} \tag{1}$$

$$g_Y\,(\mathrm{E}) = g_{va1} \tag{2}$$

where

$$g_{v\alpha} = g_{va1} + g_{va2} = \frac{1}{2}\left[\left(\sqrt{d_{va1}^2 - d_{vb1}^2} - d_{v1}\sin\alpha_{vet}\right) + \left(\sqrt{d_{va2}^2 - d_{vb2}^2} - d_{v2}\sin\alpha_{vet}\right)\right] \tag{3}$$

$g_{v\alpha}$ is the length of path of contact of virtual cylindrical gear in transverse section;

g_{va} is the length of tip path of contact;

α_{vet} is the transverse pressure angle of virtual cylindrical gear;

d_v is the reference diameter of virtual cylindrical gear;

d_{va} is the tip diameter of virtual cylindrical gear;

d_{vb} is the base diameter of virtual cylindrical gear.

Between the two boundary points the length of the transverse path of contact can be subdivided in a number of sections *i* which are specified by the user. For bevel gears with mean spiral angle zero (β_m = 0) calculations are not performed at the tip and root boundary points to avoid infinity values in some of the following formulae. Formula (4) is used to calculate the coordinate g_Y(Y) of a contact point

Y on the transvers path of contact using auxiliary variable k_s to exclude tip and root boundary points for bevel gears with mean spiral angle zero ($\beta_m = 0$).

$$g_Y(Y) = (g_Y(A) + k_s g_{v\alpha}) + Y \cdot \frac{(1-2k_s) g_{v\alpha}}{i} \qquad \text{with } Y = 0 \dots i \tag{4}$$

where

$k_s = 0$ for bevel gears with $\beta_{vb} > 0$;

$k_s = 0{,}001$ for bevel gears with $\beta_{vb} = 0$.

NOTE In all following formulae, g_Y is a function of Y ($g_Y = g_Y(Y)$).

5.2.2 Length of contact lines

A general definition of the length of contact lines is shown in Figure 2.

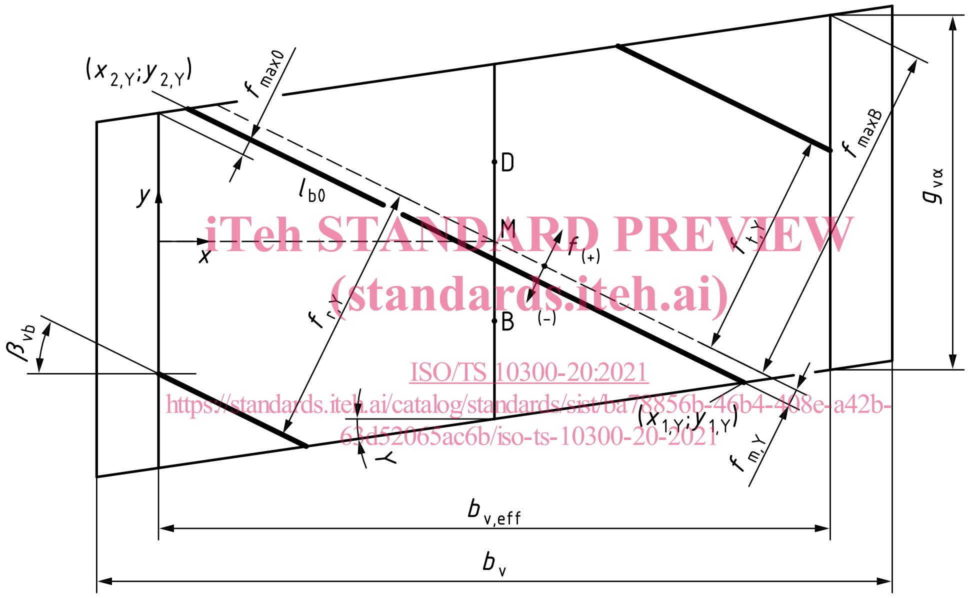

Figure 2 — General definition of length of contact lines

Distance of the tip, $f_{t,Y}$, middle, $f_{m,Y}$,and root, $f_{r,Y}$, contact line in the zone of action can be calculated by using Formulae (5) to (7).

$$f_{m,Y} = (g_{va2} - g_{v\alpha}/2 + g_Y) \cdot \cos\beta_{vb} \tag{5}$$

$$f_{t,Y} = f_{m,Y} + p_{vet} \cdot \cos\beta_{vb} \tag{6}$$

$$f_{r,Y} = f_{m,Y} - p_{vet} \cdot \cos\beta_{vb} \tag{7}$$

where

β_{vb} is the helix angle at base circle;

p_{vet} is the transverse base pitch.

