INTERNATIONAL STANDARD

ISO 10300-1

Third edition
2023-08

Calculation of load capacity of bevel gears —

Part 1:
Introduction and general influence factors

Calcul de la capacité de charge des engrenages coniques —

Partie 1: Introduction et facteurs généraux d'influence

Reference number
ISO 10300-1:2023(E)

Contents

Page

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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*.

This third edition cancels and replaces the second edition (ISO 10300-1:2014), which has been technically revised.

The main changes are as follows:

— Table 1 has been inserted in which only symbols and units used in this document are provided;

— Table 2 has been inserted;

— subclause 9.1 — boundary conditions for the calculation of the transverse load factors method B have been rearranged;

— Figure 3 — nomogram for the determination of the resonance speed, n_{E1}, for the mating solid steel pinion/solid wheel, with c_γ = 20 N/(mm · µm) (for bevel gears without offset only) has been removed;

— Figure 4 — dynamic factor, $K_{v\text{-}C}$, has been removed;

— Figure 5 — transverse load factors, $K_{H\alpha\text{-}B}$ and $K_{F\alpha\text{-}B}$ has been removed;

— Figure 6 — running-in allowance, y_α, of gear pairs with a tangential speed of v_{mt2} > 10 m/s has been removed;

— Figure 7 — running-in allowance, y_α, of gear pairs with a tangential speed of v_{mt2} ≤ 10 m/s has been removed;

— Figure A.6 — transverse path of contact has been newly inserted;

— Figure A.7 — general definition of length of contact lines for local geometry data has been newly inserted.

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

When ISO 10300:2001 (all parts) became due for its first revision, the opportunity was taken to include hypoid gears, since previously the series only allowed for calculating the load capacity of bevel gears without offset axes. The former structure is retained, i.e. three parts of the ISO 10300 series, together with ISO 6336-5, and it is intended to establish general principles and procedures for rating of bevel gears. Moreover, ISO 10300 (all parts) is designed to facilitate the application of future knowledge and developments, as well as the exchange of information gained from experience.

Several calculation methods, i.e. A, B and C, are specified, which stand for decreasing accuracy and reliability from A to C because of simplifications implemented in formulae and factors. The approximate methods in ISO 10300 (all parts) are used for preliminary estimates of gear capacity where the final details of the gear design are not yet known. More detailed methods are intended for the recalculation of the load capacity limits when all important gear data are given.

ISO 10300 (all parts) does not provide an upgraded calculation procedure as a method A, although it would be available, such as finite element or boundary element methods combined with sophisticated tooth contact analyses.

On the other hand, by means of such a computer program, a new calculation procedure for bevel and hypoid gears on the level of method B was developed and checked. It is part of the ISO 10300 series as submethod B1. Besides, if the hypoid offset, *a*, is zero, method B1 becomes identical to the set of proven formulae of the former version of ISO 10300:2001 (all parts).

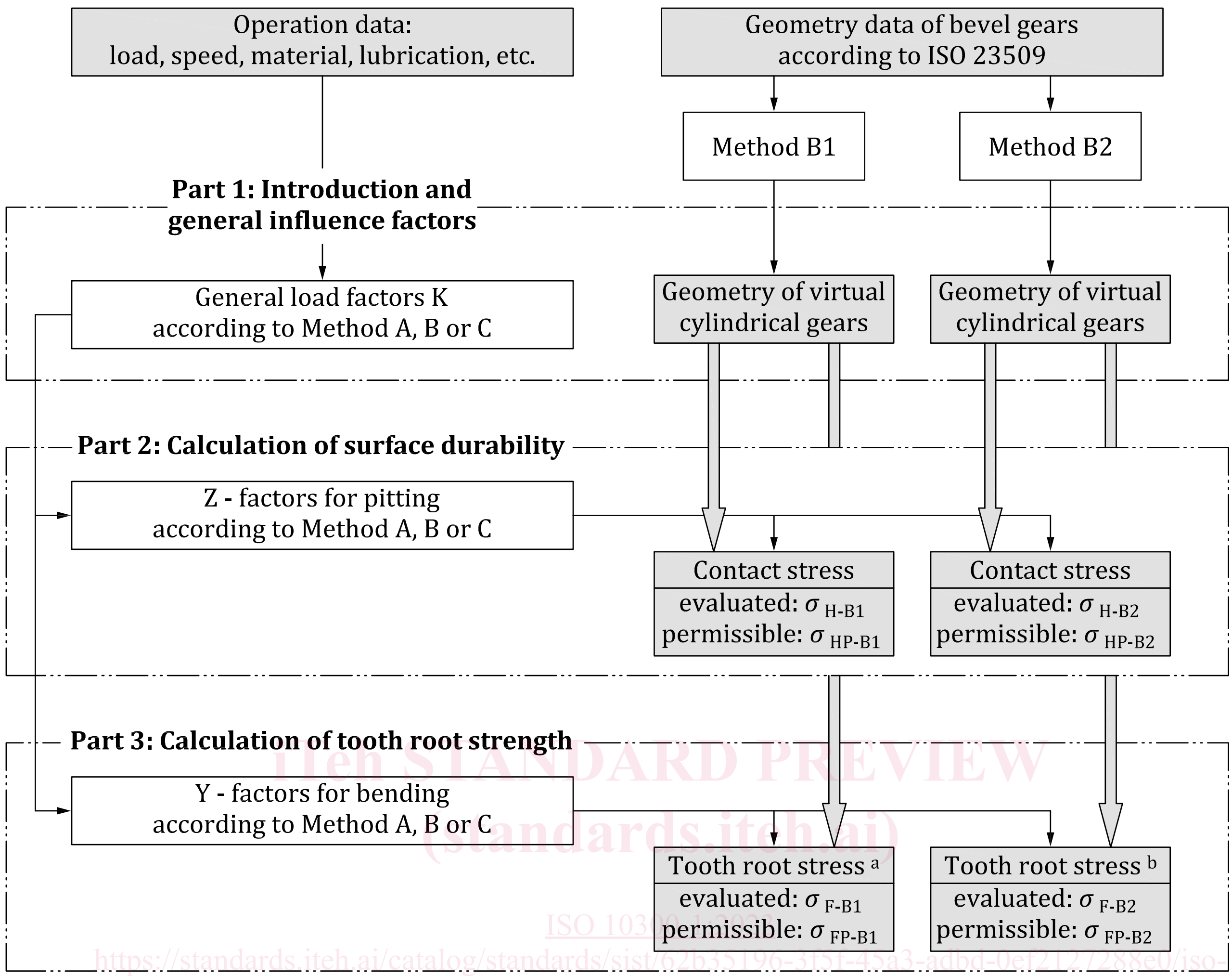
In view of the decision for ISO 10300 (all parts) to cover hypoid gears also, Annex B has been included in this document. Additionally, ISO 10300-2 is supplemented by a separate clause: “Gear flank rating formulae — Method B2”; as for ISO 10300-3, the former method B2, which uses the Lewis parabola to determine the critical section in the root and not the 30° tangent at the tooth fillet as method B1 does, is now extended by the AGMA methods for rating the strength of bevel gears and hypoid gears. It was necessary to present a new, clearer structure of the three parts, which is illustrated in Figure 1.

NOTE ISO 10300 (all parts) gives no preferences in terms of when to use method B1 and when to use method B2.

The procedures covered by ISO 10300 (all parts) are based on both testing and theoretical studies.

ISO 10300 (all parts) provides calculation procedures by which different gear designs can be compared. It is not meant to ensure the performance of assembled gear drive systems. It is intended for use by the experienced gear designer capable of selecting reasonable values for the factors in these formulae, based on knowledge of similar designs and on awareness of the effects of the items discussed.

NOTE Contrary to cylindrical gears, where the contact is usually linear, bevel gears are generally manufactured with profile and lengthwise crowning, i.e. the tooth flanks are curved on all sides and the contact develops an elliptical pressure surface. This is taken into consideration when determining the load factors by the fact that the rectangular zone of action (in the case of spur and helical gears) is replaced by an inscribed parallelogram for method B1 and an inscribed ellipse for method B2 (see Annex A for method B1 and Annex B for method B2). The conditions for bevel gears, different from cylindrical gears in their contact, are thus taken into consideration by the face and transverse load distribution factors.



a One set of formulae for both, bevel and hypoid gears.

b Separate sets of formulae for bevel and for hypoid gears.

Figure 1 — Structure of calculation methods in ISO 10300 (all parts)

Calculation of load capacity of bevel gears —

Part 1: Introduction and general influence factors

1 Scope

This document specifies the methods of calculation of the load capacity of bevel gears, the formulae and symbols used for calculation, and the general factors influencing load conditions.

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

The formulae in this document take into account the known major factors influencing load-carrying capacity. The rating formulae are only applicable to types of gear tooth deterioration, that are specifically addressed in the individual parts of the ISO 10300 series. Rating systems for a particular type of bevel gears can be established by selecting proper values for the factors used in the general formulae.

NOTE This document is not applicable to bevel gears which have an inadequate contact pattern under load (see Annex D).

The rating system of this document 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, for bevel gears the sum of profile shift coefficients of pinion and wheel is zero (see ISO 23509).

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 facewidths $b > 13\ m_{mn}$, the calculated results of this document 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 701, *International gear notation — Symbols for geometrical data*

ISO 1122-1, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 6336-5, *Calculation of load capacity of spur and helical gears — Part 5: Strength and quality of materials*

ISO 6336-6, *Calculation of load capacity of spur and helical gears — Part 6: Calculation of service life under variable load*

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

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

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

ISO 23509:2016, *Bevel and hypoid gear geometry*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1 and ISO 23509 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/

4 Symbols and general subscripts

For the purposes of this document, the symbols given in ISO 701, ISO 17485, ISO 23509, and the following shall apply. See Tables 1 and 2.

Table 1 — Symbols

Symbol	Description or term	Unit
A	Auxiliary factor for calculating the dynamic factor $K_{v\text{-}C}$	—
A^*	Related area for calculating the load sharing factor Z_{LS}	mm
a	Hypoid offset	mm
a_{rel}	Relative hypoid offset	—
a_v	Centre distance of virtual cylindrical gear pair	mm
a_{vn}	Relative centre distance of virtual cylindrical gear pair in normal section	—
B	Accuracy grade according to ISO 17485	—
b	Facewidth	mm
b_{ce}	Calculated effective facewidth	mm
b_{eff}	Effective facewidth (e.g. measured length of contact pattern)	mm
b_v	Facewidth of virtual cylindrical gears	mm
$b_{v,eff}$	Effective facewidth of virtual cylindrical gears	mm
$b_{v,rel}$	Relative facewidth of virtual cylindrical gear	—
C_F	Correction factor of tooth stiffness for non-average conditions	—
C_{lb}	Correction factor for the length of contact lines	—
c_v	Empirical parameter to determine the dynamic factor	—
c_γ	Mean value of mesh stiffness per unit facewidth	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
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

Table 1 *(continued)*

Symbol	Description or term	Unit
E	Modulus of elasticity, Young's modulus	N/mm^2
e_{LS}	Exponent for the load distribution along the lines of contact	—
F_{mt}	Nominal tangential force at mid-facewidth of the reference cone	N
F_{mtH}	Determinant tangential force at mid-facewidth of the reference cone	N
F_{vmt}	Nominal tangential force of virtual cylindrical gears	N
f	Distance from the centre of the zone of action to a contact line	mm
f_m	Distance of the middle contact line in the zone of action	mm
$f_{m,Y}$	Distance of the middle contact line in the zone of action for a contact point Y	mm
f_{max}	Maximum distance to middle contact line	mm
f_{maxB}	Maximum distance to middle contact line at right side of contact pattern	mm
f_{max0}	Maximum distance to middle contact line at left side of contact pattern	mm
f_{pt}	Single pitch deviation	µm
$f_{p,eff}$	Effective pitch deviation	µm
f_r	Distance of the root contact line in the zone of action	mm
$f_{r,Y}$	Distance of the root contact line in the zone of action for a contact point Y	mm
f_t	Distance of the tip contact line in the zone of action	mm
$f_{t,Y}$	Distance of the tip contact line in the zone of action for a contact point Y	mm
g_{va}	Length of path of contact	mm
$g_{v\alpha}$	Length of path of contact of virtual cylindrical gear in transverse section	mm
$g_{v\alpha n}$	Relative length of action in normal section	—
$g_{v\alpha na}$	Relative length of action from pinion tip to pitch circle in the normal section	—
$g_{v\alpha nr}$	Relative length of action from wheel tip to pitch circle in the normal section	—
g_η	Relative length of action within the contact ellipse	—
h_{am}	Mean addendum	mm
h_{fm}	Mean dedendum	mm
h_{vfm}	Relative mean virtual dedendum	—
i	Run variable	—
K	Constant; factor for calculating the dynamic factor $K_{v\text{-}B}$	—
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	—
$K_{H\beta\text{-}be}$	Mounting factor	—
k_S	Correction factor	—
k'	Contact shift factor	—
l_b	Length of contact line (method B1)	mm
l_{b0}	Theoretical length of contact line	mm
m_{et}	Outer transverse module	mm
m_{mn}	Mean normal module	mm

Table 1 *(continued)*

Symbol	Description or term	Unit
m_{red}	Mass per unit facewidth reduced to the line of action of dynamically equivalent cylindrical gear pairs	kg/mm
m_{vt}	Transverse module	mm
m^*	Relative individual gear mass per unit facewidth referred to line of action	kg/mm
N	Reference speed related to resonance speed n_{E1}	—
n	Rotational speed	min^{-1}
n_{E1}	Resonance speed of pinion	min^{-1}
P	Nominal power	kW
p	Peak load	N/mm
p^*	Relative peak load for calculating the load sharing factor (method B1)	—
p_{mn}	Relative mean normal pitch	—
p_{vet}	Transverse base pitch of virtual cylindrical gear (method B1)	mm
q	Exponent in the Formula for lengthwise curvature factor	—
R_m	Mean cone distance	mm
R_{mpt}	Relative mean back cone distance	—
r_{c0}	Cutter radius	mm
r_{va}	Relative mean virtual tip radius	—
r_{vbn}	Relative mean virtual base radius	—
r_{vn}	Relative mean virtual pitch radius	—
s_{mn}	Mean normal circular thickness	mm
s_{vmn}	Relative virtual tooth thickness	—
$T_{1,2}$	Nominal torque of pinion and wheel	Nm
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_{mt}	Tangential speed at mid-facewidth of the reference cone	m/s
X_Y	Curvature factor	—
x	Coordinates of the ends of the contact line	mm
Y_{FS}	Combined tooth form factor for generated gears	—
Y_{LS}	Load sharing factor (bending)	—
y_p	Running-in allowance for pitch deviation related to the polished test piece	µm
y_α	Running-in allowance for pitch deviation	µm
Z_{LS}	Load sharing factor (method B1)	—
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_Y	Auxiliary value	mm
z_0	Number of blade groups of the cutter	—
α_a	Adjusted pressure angle (method B2)	°
$\alpha_{eD,C}$	Effective pressure angle for drive side/coast side	°
α_{et}	Effective pressure angle in transverse section	°
α_{lim}	Limit pressure angle	°
$\alpha_{nD,C}$	Generated pressure angle for drive side/coast side	°

Table 1 *(continued)*

Symbol	Description or term	Unit
α_{vet}	Effective pressure angle of virtual cylindrical gears calculated for the active flank	°
β_B	Inclination angle of contact line	°
β_m	Mean spiral angle	°
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	°
γ	Auxiliary angle for length of contact line calculation (method B1)	°
γ'	Projected auxiliary angle for length of contact line	°
δ	Pitch angle of bevel gear	°
δ_a	Face angle	°
δ_f	Root angle	°
ε_N	Load sharing ratio for bending (method B2)	—
$\varepsilon_{v\alpha}$	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)	—
η	Auxiliary angle	°
ζ_R	Pinion offset angle in root plane	°
ζ_m	Pinion offset angle in axial plane	°
ζ_{mp}	Pinion offset angle in pitch plane	°
θ_{v2}	Angular pitch of virtual cylindrical wheel	rad
ϑ_{mp}	Auxiliary angle for virtual facewidth (method B1)	°
λ	Adjustment angle for contact angle of hypoid gears (method B2)	°
λ_r	Adjustment angle for virtual spiral angle of hypoid gears (method B2)	°
ρ	Density of gear material	kg/mm^3
ρ_{a0}	Cutter edge radius	mm
$\rho_{m\beta}$	Lengthwise tooth mean radius of curvature	mm
ρ_{rel}	Local equivalent radius of curvature vertical to the contact line	mm
ρ_t	Relative radius of profile curvature between pinion and wheel (method B2)	—
ρ_{va0}	Relative edge radius of tool	—
ρ'	Slip layer thickness	mm
$\sigma_{H,lim}$	Allowable stress number for contact stress	N/mm^2
ν_0	Lead angle of face hobbing cutter	°
φ	Auxiliary angle to determine the position of the pitch point	°
ω	Angular velocity	rad/s
Σ	Shaft angle	°

Table 2 — General 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
C	Coast flank
T	Relative to standardized test gear dimensions
(1), (2)	Trials of interpolation

5 Application

5.1 Calculation methods

5.1.1 General

ISO 10300 (all parts) provides the procedures to predict load capacity of bevel gears. The most valid method is full-scale and full-load testing of a specific gear set design. However, at the design stage or in certain fields of application, some calculation methods are needed to predict load capacity. Therefore, methods A, B and C are used in this document, while method A, if its accuracy and reliability are proven, is preferred over method B, which in turn is preferred over method C.

ISO 10300 (all parts) allows the use of mixed factor rating methods within method B1 or method B2. For example, method B for dynamic factor $K_{\text{v-B}}$ may be used with method C face load factor $K_{\text{H}\beta\text{-C}}$.

For the calculation of the virtual cylindrical gear geometry, Annex A shall apply for method B1 and Annex B shall apply for method B2.

5.1.2 Method A

Where sufficient experience from the operation of other, similar designs is available, satisfactory guidance can be obtained by the extrapolation of the associated test results or field data. The factors involved in this extrapolation may be evaluated by the precise measurement and comprehensive mathematical analysis of the transmission system under consideration, or from field experience. All gear and load data shall be known for the use of this method, which shall be clearly described and presented with all mathematical and test premises, boundary conditions and any specific characteristics of the method that influence the result. The accuracy and the reliability of the method shall be demonstrated. Precision, for example, shall be demonstrated through comparison with other, acknowledged gear measurements. The method should be approved by both the customer and the supplier.

5.1.3 Method B

Method B provides the calculation formulae to predict load capacity of bevel gears for which the essential data are known. However, sufficient experience from the operation of other, similar designs is needed in the evaluation of certain factors even in this method. The validity of these evaluations for the given operating conditions shall be checked.

5.1.4 Method C

Where suitable test results or field experience from similar designs are unavailable for use in the evaluation of certain factors, a further simplified calculation method, method C, should be used.

5.2 Safety factors

The allowable probability of failure shall be carefully weighed when choosing a safety factor, in balancing reliability against cost. If the performance of the gears can be accurately appraised by testing the unit itself under actual load conditions, lower safety factors are allowed. The safety factors shall be determined by dividing the calculated permissible stress by the specific evaluated operating stress.

In addition to this general requirement and the special requirements relating to surface durability (macropitting) and tooth root strength (see ISO 10300-2 and ISO 10300-3, respectively), safety factors shall be determined only after careful consideration of the reliability of the material data and of the load values used for calculation. The allowable stress numbers used for calculation are valid for a given probability of failure, or damage (the material values in ISO 6336-5, for example, are valid for a 1 % probability of damage), the risk of damage being reduced as the safety factors are increased, and vice versa. If loads, or the response of the system to vibration, are estimated rather than measured, a larger factor of safety should be used.

The following deviations shall also be taken into consideration in the determination of a safety factor:

— deviations in gear geometry due to manufacturing;

— deviations in alignment of gear members;

— variations in material due to process variations in chemistry, cleanliness and microstructure (material quality and heat treatment);

— variations in lubrication and its maintenance over the service life of the gears.

The appropriateness of the safety factors will thus depend on the reliability of the assumptions, such as those related to load, on which the calculations are based, as well as on the reliability required of the gears themselves, in respect of the possible consequences of any damage that can occur in the case of failure.

Supplied gears or assembled gear drives should have a minimum safety factor for contact stress $S_{H,min}$ of 1,0. The minimum bending stress value $S_{F,min}$ should be 1,3 for spiral bevel including hypoid gears, and 1,5 for straight bevel gears or those with $\beta_m \leq 5°$.

The minimum safety factors against macropitting damage and tooth breakage should be agreed between the supplier and customer.

5.3 Rating factors

5.3.1 Testing

The most effective overall approach to gear system performance management is through the full-scale, full-load testing of a proposed new design. Alternatively, where sufficient experience of similar designs exists and results are available, a satisfactory solution may be obtained through extrapolation from such data. On the other hand, where suitable test results or field data are not available, rating factor values should be chosen conservatively.

5.3.2 Manufacturing tolerances

Rating factors should be evaluated based on the acceptable quality limits of the expected variation of parts in the manufacturing process. The accuracy grade, B, shall be determined, preferably as specified in ISO 17485, e.g. single pitch deviation for calculating the dynamic factor $K_{v\text{-}B}$.