TECHNICAL REPORT

# ISO/TR 10300-30

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# 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).

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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.

# 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 | — |
| $c_\gamma$ | 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 |
| $g_\eta$ | 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 | — |
| $\mathrm{r}_{vn}$ | 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 |
| $v_{\Sigma}$ | 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 |
| $y_{\alpha}$ | 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 $K_{v\text{–}B}$ | — |
| $K_v$ | 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 | — |
| $N$ | 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 | — |
| $Y_{\varepsilon}$ | 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) | — |
| $Z_{M\text{-}B}$ | 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 | — |
| $\alpha_a$ | adjusted pressure angle (Method B2) | ° |
| $\alpha_{an}$ | normal pressure angle at tooth tip | ° |
| $\alpha_{dD,C}$ | nominal design pressure angle for drive side/coast side | ° |
| $\alpha_{et}$ | effective pressure angle in transverse section | ° |
| $\alpha_{eD,C}$ | effective pressure angle for drive side/coast side | ° |
| $\alpha_f$ | limit pressure angle in wheel root coordinates (Method B2) | ° |
| $\alpha_{lim}$ | limit pressure angle | ° |
| $\alpha_{nD,C}$ | generated pressure angle for drive side/coast side | ° |
| $\alpha_{vet}$ | transverse pressure angle of virtual cylindrical gears | ° |
| $\alpha_{Fan}$ | load application angle at tooth tip of virtual cylindrical gear (Method B1) | ° |
| $\alpha_L$ | normal pressure angle at point of load application (Method B2) | ° |
| $\beta_{bm}$ | mean base spiral angle | ° |
| $\beta_m$ | mean spiral angle | ° |

| Symbol | Description or term | Unit |
|---|---|---|
| $\beta_v$ | helix angle of virtual gear (Method B1),<br>virtual spiral angle (Method B2) | ° |
| $\beta_{vb}$ | helix angle at base circle of virtual cylindrical gear | ° |
| $\beta_B$ | inclination angle of contact line | ° |
| $\gamma$ | auxiliary angle for length of contact line calculation (Method B1) | ° |
| $\gamma'$ | projected auxiliary angle for length of contact line | ° |
| $\gamma_a$ | auxiliary angle for tooth form and tooth correction factor | ° |
| $\delta$ | pitch angle of bevel gear | ° |
| $\delta_a$ | face angle | ° |
| $\delta_f$ | 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) | — |
| $\varepsilon_N$ | load sharing ratio for bending (Method B2) | — |
| $\varepsilon_{NI}$ | load sharing ratio for pitting (Method B2) | — |
| $\zeta_m$ | pinion offset angle in axial plane | ° |
| $\zeta_{mp}$ | pinion offset angle in pitch plane | ° |
| $\zeta_R$ | pinion offset angle in root plane | ° |
| $\theta$ | auxiliary quantity for tooth form and tooth correction factors | — |
| $\theta_{mp}$ | auxiliary angle for virtual face width (Method B1) | ° |
| $\theta_{a2}$ | addendum angle of wheel | ° |
| $\theta_{f2}$ | dedendum angle of wheel | ° |
| $\theta_{v2}$ | angular pitch of virtual cylindrical wheel | radiant |
| $\xi$ | assumed angle in locating weakest section | ° |
| $\xi_h$ | one half of angle subtended by normal circular tooth thickness<br>at point of load application | ° |
| $\rho$ | density of gear material | $kg/mm^3$ |
| $\rho_{a0}$ | cutter edge radius | mm |
| $\rho_F$ | fillet radius at point of contact of 30° tangent | mm |
| $\rho_{Fn}$ | fillet radius at point of contact of 30° tangent in normal section | mm |
| $\rho_{fP}$ | root fillet radius of basic rack for cylindrical gears | mm |
| $\rho_{rel}$ | radius of relative curvature vertical to contact line at<br>virtual cylindrical gears | mm |
| $\rho_t$ | radius of relative profile curvature (Method B2) | mm |
| $\rho_{va0}$ | relative edge radius of tool | — |
| $\rho'$ | slip layer thickness | mm |

| Symbol | Description or term | Unit |
|---|---|---|
| $\sigma_F$ | tooth root stress | N/mm² |
| $\sigma_{F0}$ | nominal tooth root stress | N/mm² |
| $\sigma_{F\,lim}$ | nominal stress number (bending) | N/mm² |
| $\sigma_{FE}$ | allowable stress number (bending) | N/mm² |
| $\sigma_{FP}$ | permissible tooth root stress | N/mm² |
| $\sigma_H$ | contact stress | N/mm² |
| $\sigma_{H\,lim}$ | allowable stress number for contact stress | N/mm² |
| $\sigma_{HP}$ | permissible contact stress | N/mm² |
| $\tau$ | angle between tangent of root fillet at weakest point and centreline of tooth | ° |
| $\nu$ | Poisson's ratio | — |
| $\nu_0$ | lead angle of face hobbing cutter | ° |
| $\nu_{40}$, $\nu_{50}$ | nominal kinematic viscosity of the oil at 40 °C and 50 °C, respectively | mm²/s |
| $\phi$ | auxiliary angle to determine the position of the pitch point | ° |
| $\omega$ | angular velocity | rad/s |
| $\omega_\Sigma$ | angle between the sum of velocities vector and the trace of pitch cone | ° |
| $\chi^X$ | relative stress drop in notch root | mm⁻¹ |
| $\chi_T{}^X$ | relative stress drop in notch root of standardized test gear | mm⁻¹ |
| $\Sigma$ | shaft angle | ° |



**Table 3 — Generally used subscripts in ISO 10300 (all parts)**

| 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 |