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**Calculation of load capacity of spur  
and helical gears —**

**Part 30:  
Calculation examples for the  
application of ISO 6336 parts 1,2,3,5**

*Calcul de la capacité de charge des engrenages cylindriques à  
dentures droite et hélicoïdale —*

*Partie 30: Exemples d'application de l'ISO 6336 parties 1, 2, 3, 5*

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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](http://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](http://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](http://www.iso.org/iso/foreword.html).

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

This second edition cancels and replaces the first edition (ISO 6336-30:2017), which has been technically revised according to ISO 6336-1:2019, ISO 6336-2:2019, ISO 6336-3:2019.

The main changes are as follows:

- introduction of tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)  $f_{ZCa}$ ;
- introduction of load distribution influence factor  $f_{\varepsilon}$ ;
- modification of the helix angle factor  $Y_{\beta}$ ;
- calculation of tooth form factor  $Y_F$  and stress correction factor  $Y_S$  generated with a shaper cutter;
- update to the qualifying comments in [4.2](#);
- update to the input variables (additional values, modified values).

A list of all parts in the ISO 6336 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](http://www.iso.org/members.html).

## Introduction

The ISO 6336 series consists of International Standards, Technical Specifications (TS) and Technical Reports (TR) under the general title *Calculation of load capacity of spur and helical 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 6336-1 to ISO 6336-19 cover fatigue analyses for gear rating. The procedures described in ISO 6336-20 to ISO 6336-29 are predominantly related to the tribological behaviour of the lubricated flank surface contact. ISO 6336-30 to ISO 6336-39 include example calculations. The ISO 6336 series allows the addition of new parts under appropriate numbers to reflect knowledge gained in the future.

Requesting standardized calculations according to ISO 6336 without referring to specific parts requires the use of only those parts that are designated as International Standards (see [Table 1](#) for listing). When requesting further calculations, the relevant part or parts of ISO 6336 need to be specified. Use of a Technical Specification as acceptance criteria for a specific design needs to be agreed in advance between manufacturer and purchaser.

**Table 1 — Overview of ISO 6336**

Calculation of load capacity of spur and helical gears	International Standard	Technical Specification	Technical Report
<i>Part 1: Basic principles, introduction and general influence factors</i>	X		
<i>Part 2: Calculation of surface durability (pitting)</i>	X		
<i>Part 3: Calculation of tooth bending strength</i>	X		
<i>Part 4: Calculation of tooth flank fracture load capacity</i>		X	
<i>Part 5: Strength and quality of materials</i>	X		
<i>Part 6: Calculation of service life under variable load</i>	X		
<i>Part 20: Calculation of scuffing load capacity — Flash temperature method</i>		X	
<i>Part 21: Calculation of scuffing load capacity — Integral temperature method</i>		X	
<i>Part 22: Calculation of micropitting load capacity (replaces: ISO/TR 15144-1)</i>		X	
<i>Part 30: Calculation examples for the application of ISO 6336-1, ISO 6336-2, ISO 6336-3 and, ISO 6336-5</i>			X
<i>Part 31: Calculation examples of micropitting load capacity (replaces: ISO/TR 15144-2)</i>			X
NOTE At the time of publication of this document, some of the parts listed here were under development. Consult the ISO website.			

This document provides worked examples for the application of the calculation procedures defined in ISO 6336-1, ISO 6336-2, ISO 6336-3 and ISO 6336-5. The example calculations cover the application to spur, helical and double helical, external and internal cylindrical involute gears for both high speed and low speed operating conditions, determining the ISO safety factors against tooth flank pitting and tooth root bending strength for each gear set. The calculation procedures used are consistent with those presented in ISO 6336-1, ISO 6336-2, ISO 6336-3 and ISO 6336-5, unless qualifying comments are provided. Where qualifying comments have been included in this document, they reflect areas of the calculation procedures presented in the current standards where points of clarification are required or editorial errors have been identified. The changes defined within the qualifying comments will be

implemented in future revisions of ISO 6336-1, ISO 6336-2, ISO 6336-3 and ISO 6336-5. No additional calculations are presented here that are outside of the referenced documents.

Eight worked examples are presented with the necessary input data for each gear set provided at the beginning of the calculation. Calculation details are presented in full for one worked example, with all following examples having summarized results data presented in tabular format.

For all calculations in this document, the flank tolerance classes according to ISO 1328-1:2013 are applied.

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# Calculation of load capacity of spur and helical gears —

## Part 30:

# Calculation examples for the application of ISO 6336 parts 1,2,3,5

## 1 Scope

This document presents worked examples that apply exclusively the approximation methods for the determination of specific influential factors, such as the dynamic factor,  $K_v$ , and the load distributions factors  $K_{H\alpha}$ ,  $K_{H\beta}$ , etc., where full analytical calculation procedures are provided within the referenced parts of ISO 6336.

Worked examples covering the more advanced analysis techniques and methods are not applicable to this document.

The example calculations presented in this document are provided for guidance on the application of ISO 6336-1:2019, ISO 6336-2:2019, ISO 6336-3:2019 and ISO 6336-5:2016. Any of the values, safety factors or the data presented do not represent recommended criteria for real gearing. Data presented within this document are for the purpose of aiding the application of the calculation procedures of ISO 6336-1, ISO 6336-2, ISO 6336-3 and ISO 6336-5.

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

ISO 6336 (all parts), *Calculation of load capacity of spur and helical gears*

## 3 Terms, definitions, symbols and units

### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1 and ISO 6336 (all parts) 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/>

### 3.2 Symbols and units

The units of length metre, millimetre and micrometre are chosen in accordance with common practice. The conversions of the units are already included in the given formulae. All symbols used in this document are given in [Table 2](#).

Table 2 — Symbols

Symbol	Description	Unit
$A$	Flank tolerance class	—
$a$	Centre distance	mm
$B_f$	Non-dimensional parameter	—
$B_K$	Non-dimensional parameter	—
$B_P$	Non-dimensional parameter	—
$B_1$	Constant	—
$B_2$	Constant	—
$b$	Facewidth (total facewidth if double helical)	mm
$b_B$	Facewidth per helical if double helical ( $b/2$ )	mm
$b_{eff}$	Contact facewidth	mm
$b_s$	Web thickness	mm
$C_a$	Tip relief	$\mu\text{m}$
$C_B$	Basic rack factor	—
$C_f$	Root relief	$\mu\text{m}$
$C_M$	Correction factor	—
$C_R$	Gear blank factor	—
$C_{v1}$	Constant	—
$C_{v2}$	Constant	—
$C_{v3}$	Constant	—
$C_{v4}$	Constant	—
$C_{v5}$	Constant	—
$C_{v6}$	Constant	—
$C_{v7}$	Constant	—
$C_{ZL}$	Lubrication film factor exponent	—
$C_{ZR}$	Roughness factor exponent	—
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth	$\text{N}/(\text{mm}\cdot\mu\text{m})$
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth	$\text{N}/(\text{mm}\cdot\mu\text{m})$
$c'$	Maximum tooth stiffness per unit facewidth of gear pair	$\text{N}/(\text{mm}\cdot\mu\text{m})$
$c'_{th}$	Theoretical single stiffness	$\text{N}/(\text{mm}\cdot\mu\text{m})$
$D_M$	Ball diameter	mm
$d$	Reference diameter	mm
$d_a$	Tip diameter	mm
$d_{an}$	Virtual tip diameter	mm
$d_b$	Base circle diameter	mm
$d_{bn}$	Virtual base diameter	mm
$d_{en}$	Virtual outer single tooth contact diameter	mm
$d_{Ff}$	Root form diameter (based on $x_E$ )	mm
$d_f$	Root diameter (based on $x_E$ )	mm
$d_m$	Mean tooth diameter	mm
$d_{Nf}$	Start of active profile diameter	mm
$d_n$	Virtual reference diameter	mm
$d_{sh}$	External shaft diameter	mm
$d_{shi}$	Internal shaft diameter	mm
$d_w$	Working pitch diameter	mm

Table 2 (continued)

Symbol	Description	Unit
$E$	Young's modulus	N/mm <sup>2</sup>
$E_{1,2}$	Auxiliary value (for form factor for pinion or wheel)	—
$F_m$	Mean transverse tangential load	N
$F_t$	Nominal tangential load at the reference cylinder	N
$F_{tH}$	Determinant tangential load	N
$F_{\beta x}$	Initial equivalent misalignment	μm
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	μm
$f_{f\alpha eff}$	Effective profile deviation after running-in	μm
$f_{f\alpha}$	Profile form deviation (see ISO 1328-1:2013)	μm
$f_{H\beta}$	Helix slope deviation (see ISO 1328-1:2013)	μm
$f_{ma}$	Mesh misalignment	μm
$f_{pb}$	Transverse base pitch deviation (the values of $f_{pT}$ may be used for calculations in accordance with the ISO 6336 series, using tolerances according to ISO 1328-1:2013)	μm
$f_{pbeff}$	Effective transverse base pitch deviation after running-in	μm
$f_{pT}$	Single pitch tolerance (see ISO 1328-1:2013, ISO 6336 refers to $f_{pT}$ as $f_{pt}$ )	μm
$f_{sh}$	Equivalent misalignment	μm
$f_{sh0}$	Shaft deformation under specific load	μm
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—
$f_{\epsilon}$	Load distribution influence factor	—
$G$	Auxiliary value (for form factor)	—
$H$	Auxiliary value (for form factor)	—
$h$	Tooth depth	mm
$h_{Fe}$	Bending moment arm	mm
$h_{fP}$	Basic rack dedendum	mm
$h_K$	Tip chamfer	mm
$K$	Constant	—
$K_A$	Application factor	—
$K_{F\alpha}$	Transverse load factor	—
$K_{F\beta}$	Face load factor	—
$K_{H\alpha}$	Transverse load factor	—
$K_{H\beta}$	Face load factor	—
$K_v$	Dynamic factor	—
$K_{\gamma}$	Mesh load factor	—
$k$	Number of teeth spanned	—
$L$	Auxiliary notch parameter	—
$l$	Bearing span	mm
$M_{dK}$	Dimension between balls	mm
$m_n$	Normal module	mm
$m_{red}$	Reduced gear pair mass per unit facewidth	kg/mm
$N$	Resonance ratio	—
$N_F$	Exponent	—
$N_L$	Number of load cycles	—
$N_M$	Number of meshes	—

**Table 2 (continued)**

Symbol	Description	Unit
$n_{1,2}$	Rotation speed of pinion (or wheel)	$\text{min}^{-1}$
$n_{E1}$	Resonance speed	$\text{min}^{-1}$
$p_{bn}$	Virtual base pitch	mm
$pr$	As cut basic rack undercut	mm
$q$	Material allowance for finishing	mm
$q_s$	Notch parameter	—
$q_{sT}$	Notch parameter of standard reference test piece	—
$q'$	Flexibility of pair of meshing teeth	$(\text{mm}\cdot\mu\text{m})/\text{N}$
$Ra$	Arithmetic mean roughness value, $Ra = 1/6 Rz$	$\mu\text{m}$
$Rz$	Mean peak-to-valley roughness (ISO 4287:1997 <sup>a</sup> including ISO 4287:1997/Cor 1:1998, ISO 4287:1997/Cor 2:2005, ISO 4287:1997/Amd 1:2009 and ISO 4288:1996 <sup>b</sup> )	$\mu\text{m}$
$Rz_{10}$	Mean relative peak-to-valley roughness for gear pair	$\mu\text{m}$
$S_F$	Safety factor for bending	—
$S_H$	Safety factor for surface durability	—
$s$	Bearing span offset	mm
$s_{Fn}$	Tooth root normal chord	mm
$s_{pr}$	Residual fillet undercut, $s_{pr} = pr - q$	mm
$T_{1,2}$	Nominal torque at pinion/wheel	Nm
$v$	Circumferential velocity at the reference cylinder	m/s
$v_w$	Pitch line velocity	m/s
$W_k$	Span measurement	mm
$x$	Nominal profile shift coefficient	—
$x_E$	Generating profile shift coefficient	—
$x_{E,V}$	Generating profile shift coefficient (pre-finishing)	—
$x_0$	Pinion cutter profile shift coefficient	—
$Y_B$	Rim thickness factor	—
$Y_{DT}$	Deep tooth factor	—
$Y_F$	Tooth form factor	—
$Y_N$	Life factor (tooth root stress)	—
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—
$Y_{RrelT}$	Relative surface factor	—
$Y_S$	Stress correction factor	—
$Y_{ST}$	Stress correction factor, relevant to the dimensions of the reference test gears	—
$Y_X$	Size factor	—
$Y_\beta$	Helix angle factor	—
$Y_{\delta relT}$	Relative notch sensitivity factor for reference stress	—
$y_f$	Running-in allowance	$\mu\text{m}$
$y_\alpha$	Running-in allowance	$\mu\text{m}$
$y_\beta$	Running-in allowance	$\mu\text{m}$
$Z_B$	Single pair tooth contact factor	—
$Z_D$	Single pair tooth contact factor	—
$Z_E$	Elasticity factor	$\sqrt{\text{N}/\text{mm}^2}$
$Z_H$	Zone factor	—

Table 2 (continued)

Symbol	Description	Unit
$Z_L$	Lubricant factor	—
$Z_N$	Life factor (contact stress)	—
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—
$Z_R$	Roughness factor	—
$Z_W$	Work hardening factor	—
$Z_X$	Size factor	—
$Z_v$	Velocity factor	—
$Z_\beta$	Helix angle factor	—
$Z_\varepsilon$	Contact ratio factor	—
$z$	Number of teeth	—
$z_n$	Virtual number of teeth	—
$z_0$	Pinion cutter number of teeth	—
$\alpha_n$	Normal pressure angle	°
$\alpha_{en}$	Virtual form factor pressure angle	°
$\alpha_{Fen}$	Virtual load direction angle	°
$\alpha_t$	Transverse pressure angle	°
$\alpha_{wt}$	Transverse working pressure angle	°
$\beta$	Helix angle (without subscript, at reference cylinder)	°
$\gamma$	Auxiliary angle	°
$\varepsilon_\alpha$	Transverse contact ratio	—
$\varepsilon_{\alpha n}$	Virtual contact ratio	—
$\varepsilon_\beta$	Overlap ratio	—
$\varepsilon_\gamma$	Total contact ratio	—
$\theta$	Auxiliary value (for form factor)	rad
$\nu$	Poisson's ratio	—
$\nu_{40}$	Lubrication viscosity	mm <sup>2</sup> /s
$\rho$	Material density	kg/m <sup>3</sup>
$\rho$	Radius of curvature	mm
$\rho_{aP0}$	Pinion cutter tip radius coefficient	—
$\rho_F$	Radius of root fillet	mm
$\rho_{FP}$	Root fillet radius of the basic rack for cylindrical gears	mm
$\rho_{red}$	Relative radius of curvature	mm
$\rho'$	Slip layer thickness	mm
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>
$\sigma_{F\ lim}$	Allowable stress number (bending)	N/mm <sup>2</sup>
$\sigma_{FP}$	Permissible bending stress	N/mm <sup>2</sup>
$\sigma_{FP\ long\ life}$	Permissible bending stress (long life)	N/mm <sup>2</sup>
$\sigma_{FP\ ref}$	Permissible bending stress (reference condition)	N/mm <sup>2</sup>
$\sigma_H$	Contact stress	N/mm <sup>2</sup>
$\sigma_{H\ lim}$	Allowable stress number (surface)	N/mm <sup>2</sup>
$\sigma_{H0}$	Nominal contact stress at pitch point	N/mm <sup>2</sup>
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>
$\sigma_{HP\ long\ life}$	Permissible contact stress (long life)	N/mm <sup>2</sup>

**Table 2 (continued)**

Symbol	Description	Unit
$\sigma_{HPref}$	Permissible contact stress (reference)	N/mm <sup>2</sup>
$\sigma_s$	Yield stress	N/mm <sup>2</sup>
$\sigma_{0,2}$	Proof stress	N/mm <sup>2</sup>
$\chi^*$	Relative stress gradient in root of a notch	mm <sup>-1</sup>
$\chi_P^*$	Stress gradient – smooth, polished test piece	mm <sup>-1</sup>
$\chi_T^*$	<i>Stress gradient for reference test piece</i>	mm <sup>-1</sup>
a Cancelled and replaced by ISO 21920-2:2021.		
b Cancelled and replaced by ISO 21920-3:2021.		

## 4 Worked examples

### 4.1 General

[Clause 4](#) presents examples for the calculation of the safety factor for surface durability,  $S_H$ , and safety factor for tooth breakage,  $S_F$ . For all examples, where various calculation methods are presented for the determination of specific influencing factors, the approximate methods detailed in the ISO 6336 series are applied. Where a specific method is used to calculate an influence parameter, the method used is denoted as a subscript to that factor (as defined in ISO 6336-1).

The calculations results in specific aspects of the rating procedure to highlight the influence of specific gear pair geometry, quality or application.

For example 1 in [4.3](#), the full calculation procedure is presented including the formulae. For all subsequent calculations, only the tabulated input and results data are provided.

In a number of areas, points of clarification of the procedure or specific criteria that differ slightly from the definitions provided in ISO 6336-1, ISO 6336-2 and ISO 6336-3 are incorporated within the example calculations. The points reflect the true intention of the procedures of ISO 6336-1, ISO 6336-2 and ISO 6336-3 and are defined in [4.2](#).

NOTE 1 The calculations and results presented were performed using computer-based procedures. If the calculations are performed manually, it is possible that small differences between the results appear.

NOTE 2 In the presented results, all values for  $K$  factors are presented with rounding to two decimal places (X,XX); however, for the actual calculations, the results for each factor have been used with unrounded values.

### 4.2 Qualifying comments

#### 4.2.1 Calculation of base pitch deviation, $f_{pb}$

The value calculated for  $f_{pb}$  is by means of [Formula \(1\)](#), and is applied without rounding:

$$f_{pb} = f_{pT} \cdot \cos(\alpha_t) \tag{1}$$

where  $f_{pT}$  is provided by ISO 1328-1:2013.

#### 4.2.2 Calculation of running-in allowance, $y_{\alpha}$ for the transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

The following criteria defined in ISO 6336-1:2019, 8.3.1, are applied only for the calculation of  $K_{H\alpha}$  and  $K_{F\alpha}$ :

- The base pitch deviation,  $f_{pb}$ , accounts for the total effect of all gear tooth deviations which affect the transverse load factor. If, nevertheless, the profile form deviation,  $f_{f\alpha}$  is greater than the base pitch deviation, the profile form deviation  $f_{f\alpha}$  is used instead of the base pitch deviation  $f_{pb}$ .
- If profile modifications compensate for the deflections of the teeth at the actual load level, 50 % of the base pitch deviation  $f_{pb}$  and its corresponding running-in value  $y_{\alpha}(f_{pb})$  respectively the profile form deviation  $f_{f\alpha}$  and its corresponding running-in value  $y_{\alpha}(f_{f\alpha})$  is used for the calculation of  $K_{H\alpha}$ . This reduction applies for examples 1 and 4 of this document.

The criteria listed above do not apply for determining  $f_{pb}$  and  $f_{f\alpha}$  for the calculation of  $K_v$  according to ISO 6336-1:2019, 6.5.4.

#### 4.2.3 Calculation of mesh stiffness, $c_y$

The calculation of mesh stiffness,  $c_y$ , in accordance with method B of ISO 6336-1:2019, 9.3.3, is applied for all example calculations. For all  $c_y$  calculations, the use of the nominal profile shift coefficient,  $x$ , and nominal basic rack dedendum,  $h_{fp}$ , is applied. The generating profile shift coefficient,  $x_E$ , is not used, even where  $x_E$  is used for other strength calculations associated with the tooth root. Virtual number of teeth of helical gears were calculated with Formula (16) of ISO 6336-3:2019 rather than approximate formula given in Formula (81) of ISO 6336-1:2019.

#### 4.2.4 Application of lubricant film $Z_L$ , $Z_v$ and $Z_R$ , hardness $Z_W$ and size $Z_X$ influence factors

According to the ISO 6336 series, the permissible contact stress numbers for static and reference condition, including all relevant influence factors as defined, will be calculated. For limited life, linear interpolation on a log-log scale, following the procedure of  $Z_{NT}$ , between these two values is applied. The linear interpolation on a log-log-scale for limited life leads to a value  $Z_N$ , which can be different to the value  $Z_{NT}$ .

The displayed values of  $Z_L$ ,  $Z_v$ ,  $Z_R$ ,  $Z_W$  and  $Z_X$  in the output tables of this document show the interpolated values of each Z-factor.

#### 4.2.5 Calculation of the permissible contact stress in the limited life range ( $Z_N$ and $Z_{NT}$ )

For the calculation of the permissible contact stress in the limited life range, the following procedure is considered according to ISO 6336-2:2019:

- Calculation of the permissible contact stress for static stress  $\sigma_{HP,stat}$  and for reference stress  $\sigma_{HP,ref}$  according to ISO 6336-2:2019, 5.4.3 with the use of  $Z_{NT}$ .
- Calculation of the permissible contact stress for the limited life range  $\sigma_{HP,lim}$  by applying the formulae in ISO 6336-2:2019, 5.4.4.3. The application of the formulae results in the calculation and usage of  $Z_N$  (e. g. for case hardened or through hardened material) with no pitting permissible:

$$Z_N = \left( \frac{5 \cdot 10^7}{N_L} \right)^{0,3} \cdot 705 \cdot \log \frac{\sigma_{HP,stat}}{\sigma_{HP,ref}}$$

- The obtained permissible contact stress for the limited life range  $\sigma_{HP,lim}$  is equal to the permissible contact stress  $\sigma_{HP}$ , which is subsequently used to calculate the pitting stress limit  $\sigma_{HG}$  according to ISO 6336-2:2019, 5.4.3 and eventually the safety against pitting  $S_H$  according to ISO 6336-2:2019, 5.2.

#### 4.2.6 Application of work hardening factor, $Z_W$

In example 5 in 4.7, a surface-hardened pinion is used with a through-hardened cast iron wheel. According to ISO 6336-2:2019, 13.3.2, the calculation method is only valid for through-hardened steel, not through-hardened cast iron. To be on the conservative side, the work hardening factor for the wheel is set to  $Z_{W2} = 1,0$ . For all other cases where both gears are either through-hardened or surface-hardened,  $Z_{W1,2} = 1$  for both pinion and wheel applies.

#### 4.2.7 Determination of $Rz$

The determination of  $Rz$  from the specified  $Ra$  values is determined by the approximation suggested in ISO 6336-2:2019, 12.3.2.3.1, footnote 2, where  $Rz = 6 \cdot Ra$ .

#### 4.2.8 Facewidth for calculations involving double helical gears

For calculations involving double helical gears (such as example 7), and for the application of ISO 6336-2:2019, Formula (40)  $b_B$  is used instead of  $b$ .

#### 4.2.9 Calculation of $\varepsilon_\beta$ for double helical gears

For the calculation of  $\varepsilon_\beta$  for double helical gears, the value applies for only one helix. For example, the value for facewidth,  $b$ , is replaced by  $b_B$ .

#### 4.2.10 Calculation of $f_{H\beta 5}$ and $f_{H\beta}$

The calculation of  $f_{H\beta 5}$  for use in the determination of the initial equivalent misalignment,  $F_{\beta x}$ , in ISO 6336-1:2019, 7.5.3.4 is performed in accordance with ISO 1328-1:2013 for flank tolerance class 5 with the as required rounding applied.

#### 4.2.11 Helix tolerance $f_{H\beta 5}$ and $f_{H\beta}$ for double helical gears

When calculating the helix tolerance value  $f_{H\beta 5}$  and  $f_{H\beta}$  for double helical gears, the facewidth of one helix is used, i.e.  $b_B$ .

#### 4.2.12 Calculation of root diameter, $d_f$

For all calculations presented within this document, the calculation of the root diameter,  $d_f$ , is performed with the generating profile shift coefficient,  $x_E$ , and not the nominal profile shift coefficient,  $x$  (see also 4.2.16).

#### 4.2.13 Calculations for internal gears

For all calculations involving internal gears (example 6), the input data uses negative values for diameters as defined in the ISO 6336 series.

#### 4.2.14 Rounding of values

The calculations within this document have been conducted with unrounded values. The values documented in the table are rounded.

#### 4.2.15 Deviations of values

Numeric calculations and different programming of calculation programs can lead to slight deviations of the values when recalculating. The calculated values documented in this document were achieved by different calculation programs. Deviations were accepted in a defined range, as the basic statement of

the calculation remains. The range of acceptable deviations for the calculations in this document was defined as the following:

- Absolute deviation: 0,01.
- Relative deviation: 0,5 %.

Values for the calculations were within the absolute and relative deviation range.

#### **4.2.16 Nominal and generated values**

The values were calculated with nominal values if not otherwise stated in this document (e.g. in [4.2.12](#)) or the corresponding standard (e.g. bending geometry according to ISO 6336-3:2019).

#### **4.2.17 ISO 1328-1:2013**

ISO 1328-1:2013 was used for the calculation of the allowable values of deviations.

#### **4.2.18 Values for reference only**

Values in the input table (e.g. nominal profile shift coefficient  $x$ ) are put in parenthesis when they are calculated and for reference only.

### **4.3 Example 1: Single helical case carburized gear pair**

For example 1, input values and output values are given in [Tables 3](#) and [4](#), respectively.

A full calculation description is provided in [Annex A](#).

Table 3 — Example 1 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	17	103
	Normal module	mm	$m_n$	8,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	15,80	
	Hand of helix	—	—	Left	Right
	Facewidth (total)	mm	$b$	100,00	100,00
	Gap width	mm	—	0	0
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	100,00	
	Centre distance	mm	$a$	500,000	
	Span measurement	mm	$W_k$	38,196	307,943
	Number of teeth spanned	—	$k$	2	13
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	(0,145)	0,000
	Tip diameter	mm	$d_a$	159,66	872,35
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,400	1,400
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,39	0,39
	As cut basic rack undercut	mm	$pr$	0,00	0,00
	Material allowance for finishing	mm	$q$	0,00	0,00
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,00	0,00
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
	Tip relief	µm	$C_a$	70	70
	Root relief	µm	$C_f$	0	0
Profile modification compensate for the deflections	—	—	Yes		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	based on 3D load distribution program		
Quality	Flank tolerance class	—	$A$	5	5
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	8,5	9,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	9,5	9,5
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	8,0	9,0
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	1,0 (6,0)	1,0 (6,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 3 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	Eh	Eh
	Material quality	—	—	MQ	MQ
	Case hardness	—	—	60 HRC	60 HRC
	Core hardness	—	—	30 HRC	30 HRC
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	—	—
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{AA}$	1,00	
	Mesh load factor	—	$K_Y$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	125,00	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	100,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00		
Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	320		
Load	Torque	kNm	$T_1$	9,000	
	Speed	min <sup>-1</sup>	$n_1$	360,0	
	Required life	h	—	50 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 4 — Example 1 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	141,34	856,35
$d_a$	Tip diameter	mm	159,66	872,35
$d_b$	Base circle diameter	mm	132,20	800,97
$x_E$	Generating profile shift coefficient	—	0,117 8	- 0,027 5
$d_f$	Root diameter (based on $x_E$ )	mm	120,82	833,52
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	132,25	839,08
$d_{Nf}$	Start of active profile diameter	mm	132,92	845,23
$d_w$	Working pitch diameter	mm	141,67	858,33
$F_t$	Nominal tangential load at the reference cylinder	N	127 352	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,00	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,13	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,00	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,16	
$K_{v-B}$	Dynamic factor	—	1,00	
$S_F$	Tooth root breakage safety factor	—	2,09	2,25
$S_H$	Pitting safety factor	—	1,03	1,09
$v_w$	Pitch line velocity	m/s	2,67	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,26	1,07
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,89	0,92
$Y_N$	Life factor (tooth root stress)	—	0,89	0,92
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	1,79	2,05
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,97	0,97
$Y_\beta$	Helix angle factor	—	0,97	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,99	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,00	
$Z_\beta$	Helix angle factor (pitting)	—	1,02	
$Z_D$	Single pair tooth contact factor, wheel	—	1,00	
$Z_E$	Elasticity factor	$\sqrt{N/mm^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,80	
$Z_H$	Zone factor	—	2,40	
$Z_L$	Lubricant factor	—	1,05	1,05
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	0,91	0,96
$Z_N$	Life factor (contact stress)	—	0,91	0,96
$Z_R$	Roughness factor	—	0,97	0,97
$Z_v$	Velocity factor	—	0,97	0,97
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,55	
$\epsilon_\beta$	Overlap ratio	—	1,08	

Table 4 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\gamma$	Total contact ratio	—	2,63	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	350	339
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	395	382
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	500	500
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	824	860
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	1 299	1 299
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	1 500	1 500
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	1 207	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	1 338	1 415
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·µm)	17,5	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·µm)	12,4	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,067	
$N$	Resonance ratio	—	0,04	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·µm)	14,8	
$f_{sh0}$	Shaft deformation under specific load	µm	0,012	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	µm	31,6	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	µm	26,9	
$y_\alpha$	Running-in allowance for a gear pair for the calculation of $K_{H\alpha}$ (calculated with 50 % of $\max(f_{pb}, f_{f\alpha})$ )	µm	0,356	
$y_\beta$	Running-in allowance (equivalent misalignment)	µm	4,7	
$f_{pb}$	Transverse base pitch deviation	µm	8,4	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	µm	9,0	
$f_{sh}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	µm	14,7	
$f_{ma}$	Mesh misalignment due to manufacturing deviations	µm	12,0	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	1,00	
$f_\varepsilon$	Load distribution influence factor	—	0,78	

4.4 Example 2: Single helical through-hardened gear pair

For example 2, input values are given in Tables 5 and 6.

Table 5 — Example 2 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	17	103
	Normal module	mm	$m_n$	8,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	15,80	
	Hand of helix	—	—	Left	Right
	Facewidth (total)	mm	$b$	100,00	100,00
	Gap width	mm	—	—	—
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	100,00	
	Centre distance	mm	$a$	500,000	
	Span measurement	mm	$W_k$	38,196	307,943
	Number of teeth spanned	—	$k$	2	13
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	(0,145)	0,000
	Tip diameter	mm	$d_a$	159,66	872,35
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,250	1,250
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,39	0,39
	As cut basic rack undercut	mm	$pr$	0,00	0,00
	Material allowance for finishing	mm	$q$	0,00	0,00
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,00	0,00
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
	Tip relief	µm	$C_a$	70	70
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	No modification		
Quality	Flank tolerance class	—	$A$	8	6
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	24,0	13,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	27,0	13,0
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	23,0	13,0
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 5 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	V (alloy steel)	V (alloy steel)
	Material quality	—	—	MQ	MQ
	Case hardness	—	—	310 HV	260 HV
	Core hardness	—	—	—	—
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	500,0	500,0
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{A-A}$	1,00	
	Mesh load factor	—	$K_\gamma$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	125,00	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	100,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	15,0	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	5,0	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
	Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00	
	Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	320	
Load	Torque	kNm	$T_1$	1,000	
	Speed	min <sup>-1</sup>	$n_1$	360,0	
	Required life	h	—	100 00	
	Life factor for contact stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 6 — Example 2 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	141,34	856,35
$d_a$	Tip diameter	mm	159,66	872,35
$d_b$	Base circle diameter	mm	132,20	800,97
$x_E$	Generating profile shift coefficient	—	0,117 8	- 0,027 5
$d_f$	Root diameter (based on $x_E$ )	mm	123,22	835,92
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	132,61	841,13
$d_{Nf}$	Start of active profile diameter	mm	132,92	845,23
$d_w$	Working pitch diameter	mm	141,67	858,33
$F_t$	Nominal tangential load at the reference cylinder	N	14 150	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,58	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,61	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,58	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,78	
$K_{v-B}$	Dynamic factor	—	1,04	
$S_F$	Tooth root breakage safety factor	—	5,57	5,42
$S_H$	Pitting safety factor	—	0,80	0,79
$v_w$	Pitch line velocity	m/s	2,67	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,11	1,02
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,92	0,95
$Y_N$	Life factor (tooth root stress)	—	0,92	0,95
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	1,93	2,12
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,98	0,98
$Y_\beta$	Helix angle factor	—	0,97	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,98	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,10	
$Z_\beta$	Helix angle factor (pitting)	—	1,02	
$Z_D$	Single pair tooth contact factor, wheel	—	1,10	
$Z_E$	Elasticity factor	$\sqrt{N / \text{mm}^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,80	
$Z_H$	Zone factor	—	2,40	
$Z_L$	Lubricant factor	—	1,09	1,08
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	0,96	1,03
$Z_N$	Life factor (contact stress)	—	0,96	1,04
$Z_R$	Roughness factor	—	0,79	0,80
$Z_v$	Velocity factor	—	0,93	0,94
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,55	
$\epsilon_\beta$	Overlap ratio	—	1,08	

Table 6 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\gamma$	Total contact ratio	—	2,63	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	37	37
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	98	99
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	319	298
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	544	535
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	754	754
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	780	714
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	402	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	603	600
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·μm)	18,9	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·μm)	13,4	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,069	
$N$	Resonance ratio	—	0,04	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·μm)	16,1	
$f_{sh0}$	Shaft deformation under specific load	μm	0,102	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	μm	25,0	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	μm	14,2	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{f\alpha})$ )	μm	5,793	
$y_\beta$	Running-in allowance (equivalent misalignment)	μm	10,7	
$f_{pb}$	Transverse base pitch deviation	μm	22,4	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	μm	9,0	
$f_{sh}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	μm	15,0	
$f_{ma}$	Mesh misalignment due to manufacturing deviations	μm	5,0	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	1,20	
$f_\varepsilon$	Load distribution influence factor	—	0,78	

4.5 Example 3: Spur through-hardened gear pair

For example 3, input values and output values are given in [Tables 7](#) and [8](#), respectively.

Table 7 — Example 3 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	17	108
	Normal module	mm	$m_n$	8,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	0,00	
	Hand of helix	—	—	Left	Right
	Facewidth (total)	mm	$b$	100,00	100,00
	Gap width	mm	—	0,00	0,00
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	100,00	
	Centre distance	mm	$a$	500,000	
	Span measurement	mm	$W_k$	37,728	283,000
	Number of teeth spanned	—	$k$	2	12
	Dimension between balls	mm	$M_{dk}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	0,100	(-0,100)
	Tip diameter	mm	$d_a$	153,60	878,40
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,250	1,250
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,45	0,40
	As cut basic rack undercut	mm	$pr$	0,000	0,000
	Material allowance for finishing	mm	$q$	0,000	0,000
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,000	0,000
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
Tip relief	µm	$C_a$	70	70	
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	—		
Quality	Flank tolerance class	—	$A$	8	6
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	24,0	13,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	27,0	13,0
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	23,0	13,0
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 7 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	V (alloy steel)	V (alloy steel)
	Material quality	—	—	MQ	MQ
	Case hardness	—	—	310 HV	260 HV
	Core hardness	—	—	—	—
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	500,0	500,0
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{A-A}$	1,000	
	Mesh load factor	—	$K_\gamma$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	100,0	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	100,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H \min}$	1,00	
	Minimum safety factor tooth breakage	—	$S_{F \min}$	1,00	
	Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	320	
Load	Torque	kNm	$T_1$	1,000	
	Speed	min <sup>-1</sup>	$n_1$	360,0	
	Required life	h	—	10 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 8 — Example 3 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	136,00	864,00
$d_a$	Tip diameter	mm	153,60	878,40
$d_b$	Base circle diameter	mm	127,80	811,89
$x_E$	Generating profile shift coefficient	—	0,072 7	- 0,127 3
$d_f$	Root diameter (based on $x_E$ )	mm	117,16	841,96
$d_{Ff}$	Root form diameter (based on $x_E$ )	mm	127,91	847,59
$d_{Nf}$	Start of active profile diameter	mm	127,98	851,54
$d_w$	Working pitch diameter	mm	136,00	864,00
$F_t$	Nominal tangential load at the reference cylinder	N	14 706	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,23	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,71	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,23	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,92	
$K_{v-B}$	Dynamic factor	—	1,05	
$S_F$	Tooth root breakage safety factor	—	4,91	4,80
$S_H$	Pitting safety factor	—	0,75	0,82
$v$	Pitch line velocity	m/s	2,56	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,50	1,33
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,92	0,95
$Y_N$	Life factor (tooth root stress)	—	0,92	0,95
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	1,82	2,06
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,98	0,98
$Y_\beta$	Helix angle factor	—	1,00	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,98	0,99
$Z_B$	Single pair tooth contact factor, pinion	—	1,09	
$Z_\beta$	Helix angle factor (pitting)	—	1,00	
$Z_D$	Single pair tooth contact factor, wheel	—	1,00	
$Z_E$	Elasticity factor	$\sqrt{N/mm^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,88	
$Z_H$	Zone factor	—	2,49	
$Z_L$	Lubricant factor	—	1,09	1,08
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	0,96	1,03
$Z_N$	Life factor (contact stress)	—	0,96	1,04
$Z_R$	Roughness factor	—	0,79	0,80
$Z_v$	Velocity factor	—	0,93	0,94
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,66	
$\epsilon_\beta$	Overlap ratio	—	0,00	

Table 8 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\gamma$	Total contact ratio	—	1,66	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	50	50
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	110	111
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	319	298
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	540	533
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	802	735
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	780	714
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	468	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	600	599
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·µm)	20,1	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·µm)	13,5	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,062	
$N$	Resonance ratio	—	0,04	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·µm)	17,1	
$f_{sh0}$	Shaft deformation under specific load	µm	0,012	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	µm	29,0	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	µm	16,5	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{f\alpha})$ )	µm	5,793	
$y_\beta$	Running-in allowance (equivalent misalignment)	µm	12,4	
$f_{pb}$	Transverse base pitch deviation	µm	22,6	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	µm	9,0	
$f_{sh}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	µm	1,9	
$f_{ma}$	Mesh misalignment due to manufacturing deviations	µm	26,4	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	—	
$f_\varepsilon$	Load distribution influence factor	—	1,00	

4.6 Example 4: Spur case carburized gear pair

For example 4, input values and output values are given in [Tables 9](#) and [10](#), respectively.

Table 9 — Example 4 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	17	108
	Normal module	mm	$m_n$	8,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	0,00	
	Hand of helix	—	—	Left	Right
	Facewidth (total)	mm	$b$	100,00	100,00
	Gap width	mm	—	0,00	0,00
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	100,00	
	Centre distance	mm	$a$	500,000	
	Span measurement	mm	$W_k$	37,728	283,000
	Number of teeth spanned	—	$k$	2	12
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	0,100	(-0,100)
	Tip diameter	mm	$d_a$	154,60	878,40
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,400	1,400
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,39	0,39
	As cut basic rack undercut	mm	$pr$	0,000	0,000
	Material allowance for finishing	mm	$q$	0,000	0,000
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,000	0,000
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
	Tip relief	µm	$C_a$	70	70
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	Yes		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	—		
Quality	Flank tolerance class	—	$A$	5	5
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	8,5	9,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	9,5	9,5
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	8,0	9,0
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	1,0 (6,0)	1,0 (6,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 9 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	Eh	Eh
	Material quality	—	—	MQ	MQ
	Case hardness	—	—	60 HRC	60 HRC
	Core hardness	—	—	30 HRC	30 HRC
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	—	—
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{AA}$	1,000	
	Mesh load factor	—	$K_Y$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	100,0	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	100,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00		
Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	320		
Load	Torque	kNm	$T_1$	9,000	
	Speed	min <sup>-1</sup>	$n_1$	360,0	
	Required life	h	—	50 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 10 — Example 4 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	136,00	864,00
$d_a$	Tip diameter	mm	154,60	878,40
$d_b$	Base circle diameter	mm	127,80	811,89
$x_E$	Generating profile shift coefficient	—	0,072 7	- 0,127 3
$d_f$	Root diameter (based on $x_E$ )	mm	114,76	839,56
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	127,81	845,52
$d_{Nf}$	Start of active profile diameter	mm	127,98	851,00
$d_w$	Working pitch diameter	mm	136,00	864,00
$F_t$	Nominal tangential load at the reference cylinder	N	132 353	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,00	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,14	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,00	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,18	
$K_{v-B}$	Dynamic factor	—	1,00	
$S_F$	Tooth root breakage safety factor	—	1,43	1,66
$S_H$	Pitting safety factor	—	0,83	0,93
$v_w$	Pitch line velocity	m/s	2,56	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,77	1,36
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,89	0,92
$Y_N$	Life factor (tooth root stress)	—	0,89	0,92
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	1,72	2,01
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,97	0,97
$Y_\beta$	Helix angle factor	—	1,00	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,99	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,07	
$Z_\beta$	Helix angle factor (pitting)	—	1,00	
$Z_D$	Single pair tooth contact factor, wheel	—	1,00	
$Z_E$	Elasticity factor	$\sqrt{N/mm^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,88	
$Z_H$	Zone factor	—	2,49	
$Z_L$	Lubricant factor	—	1,05	1,05
$Z_{NT}$	Life factor for test reference conditions (contact stress)	—	0,91	0,96
$Z_N$	Life factor (contact stress)	—	0,91	0,96
$Z_R$	Roughness factor	—	0,96	0,96
$Z_v$	Velocity factor	—	0,97	0,97
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,70	
$\epsilon_\beta$	Overlap ratio	—	0,00	

Table 10 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\gamma$	Total contact ratio	—	1,70	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	502	452
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	574	518
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	500	500
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	823	860
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	1 617	1 512
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	1 500	1 500
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	1 392	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	1 335	1 412
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·μm)	18,9	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·μm)	12,4	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,061	
$N$	Resonance ratio	—	0,04	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·μm)	16,1	
$f_{sh0}$	Shaft deformation under specific load	μm	0,012	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	μm	34,0	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	μm	28,9	
$y_\alpha$	Running-in allowance for a gear pair for the calculation of $K_{H\alpha}$ (calculated with 50 % of $\max(f_{pb}, f_{f\alpha})$ )	μm	0,356	
$y_\beta$	Running-in allowance (equivalent misalignment)	μm	5,1	
$f_{pb}$	Transverse base pitch deviation	μm	8,5	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	μm	9,0	
$f_{sh}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	μm	16,5	
$f_{ma}$	Mesh misalignment due to manufacturing deviations	μm	12,0	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	—	
$f_\varepsilon$	Load distribution influence factor	—	1,00	

4.7 Example 5: Spur gear pair with an induction hardened pinion and through-hardened cast gear

For example 5, input values and output values are given in Tables 11 and 12, respectively.

Table 11 — Example 5 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	27	192
	Normal module	mm	$m_n$	32,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	0,00	
	Hand of helix	—	—	—	—
	Facewidth (total)	mm	$b$	500,00	500,00
	Gap width	mm	—	0,00	0,00
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	500,00	
	Centre distance	mm	$a$	3 504,000	
	Span measurement	mm	$W_k$	247,771	2 022,148
	Number of teeth spanned	—	$k$	3	21
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	0,000	(0,000)
	Tip diameter	mm	$d_a$	928,00	6 208,00
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,250	1,250
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,39	0,39
	As cut basic rack undercut	mm	$pr$	0,000	0,000
	Material allowance for finishing	mm	$q$	0,000	0,000
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,000	0,000
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
Tip relief	µm	$C_a$	0	0	
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	—		
Quality	Flank tolerance class	—	$A$	6	9
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	26,0	96,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	32,0	90,0
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	19,0	63,0
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	2,5 (15,0)	3,0 (18,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 11 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	IF	St (cast)
	Material quality	—	—	ML	MQ
	Case hardness	—	—	550 HV	200 HBW
	Core hardness	—	—	166 HV	
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	202 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_s/\sigma_{0,2}$		400,0
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{AA}$	1,00	
	Mesh load factor	—	$K_M$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	1 000,00	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	400,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00		
Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	160		
Load	Torque	kNm	$T_1$	120,000	
	Speed	min <sup>-1</sup>	$n_1$	200,0	
	Required life	h	—	25 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 12 — Example 5 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	864,00	6 144,00
$d_a$	Tip diameter	mm	928,00	6 208,00
$d_b$	Base circle diameter	mm	811,89	5 773,47
$x_E$	Generating profile shift coefficient	—	- 0,022 9	-0,022 9
$d_f$	Root diameter (based on $x_E$ )	mm	782,54	6 062,54
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	818,70	6 081,59
$d_{Nf}$	Start of active profile diameter	mm	820,02	6 093,06
$d_w$	Working pitch diameter	mm	864,00	6 144,00
$F_t$	Nominal tangential load at the reference cylinder	N	275 778	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,33	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,39	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,33	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,47	
$K_{v-B}$	Dynamic factor	—	1,26	
$S_F$	Tooth root breakage safety factor	—	3,27	1,85
$S_H$	Pitting safety factor	—	1,44	0,53
$v_w$	Pitch line velocity	m/s	9,05	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,33	1,15
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,91	0,95
$Y_N$	Life factor (tooth root stress)	—	0,91	0,95
$Y_{RrelT}$	Relative surface factor	—	0,96	0,98
$Y_S$	Stress correction factor	—	1,94	2,30
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,80	0,85
$Y_\beta$	Helix angle factor	—	1,00	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,99	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,06	
$Z_\beta$	Helix angle factor (pitting)	—	1,00	
$Z_D$	Single pair tooth contact factor, wheel	—	1,00	
$Z_E$	Elasticity factor	$\sqrt{N / \text{mm}^2}$	188,88	
$Z_\epsilon$	Contact ratio factor	—	0,86	
$Z_H$	Zone factor	—	2,49	
$Z_L$	Lubricant factor	—	0,99	0,99
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	0,95	1,01
$Z_N$	Life factor (contact stress)	—	0,95	1,01
$Z_R$	Roughness factor	—	0,88	0,88
$Z_v$	Velocity factor	—	0,99	0,99
$Z_W$	Work hardening factor (only applicable for through hardened steel, not cast iron)	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,77	
$\epsilon_\beta$	Overlap ratio	—	0,00	

Table 12 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\gamma$	Total contact ratio	—	1,77	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	45	46
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	104	107
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	244	125
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	340	197
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	577	546
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	1 009	328
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	348	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	830	290
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·µm)	22,4	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·µm)	14,2	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	2,457	
$N$	Resonance ratio	—	0,19	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·µm)	19,1	
$f_{sh0}$	Shaft deformation under specific load	µm	0,008	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	µm	73,0	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	µm	34,4	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{f\alpha})$ )	µm	21,0	
$y_\beta$	Running-in allowance (equivalent misalignment)	µm	38,6	
$f_{pb}$	Transverse base pitch deviation	µm	90,2	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	µm	16,0	
$f_{sh}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	µm	5,4	
$f_{ma}$	Mesh misalignment due to manufacturing deviations	µm	65,8	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	—	
$f_\varepsilon$	Load distribution influence factor	—	1,00	

4.8 Example 6: Spur internal through-hardened gear pair

For example 6, input values and output values are given in Tables 13 and 14, respectively.

Table 13 — Example 6 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	15	-99
	Normal module	mm	$m_n$	12,00	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	0,00	
	Hand of helix	—	—	—	—
	Facewidth (total)	mm	$b$	125,00	125,00
	Gap width	mm	—	0,00	0,00
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	125,00	
	Centre distance	mm	$a$	-500,000	
	Span measurement	mm	$W_k$	58,161	—
	Number of teeth spanned	—	$k$	2	—
	Dimension between balls	mm	$M_{dK}$	—	1 154,900
	Ball diameter	mm	$D_M$	—	21,60
	Nominal profile shift coefficient	—	$x$	(0,323)	0,000
	Tip diameter	mm	$d_a$	211,75	-1 166,00
	Basic rack dedendum coefficient	—	$h_{fP}/m_n$	1,250	1,250
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fP}/m_n$	0,39	—
	As cut basic rack undercut	mm	$pr$	0,000	0,000
	Material allowance for finishing	mm	$q$	0,000	0,000
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,000	0,000
	Pinion cutter number of teeth	—	$z_0$	—	20
	Pinion cutter profile shift (ref)	—	$x_0$	—	0,00
	Pinion cutter tip radius coefficient	—	$\rho_{aP0}$	—	0,001
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
	Tip relief	µm	$C_a$	70	70
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	—		
Quality	Flank tolerance class	—	$A$	6	8
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	14,0	31,0
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	16,0	33,0
	Helix slope deviation according to ISO 1328-1:2013	µm	$f_{H\beta}$	12,0	27,0
	Surface roughness – flank $R_a$ ( $R_z$ )	µm	—	1,0 (6,0)	3,0 (18,0)
	Surface roughness – fillet $R_a$ ( $R_z$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 13 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	V	V
	Material quality	—	—	MQ	MQ
	Case hardness	various	—	310 HV	260 HV
	Core hardness	various	—	—	—
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	500,0	500,0
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{AA}$	1,300	
	Mesh load factor	—	$K_M$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	No	No
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	200,0	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	100,00	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00		
Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	320		
Load	Torque	kNm	$T_1$	1,000	
	Speed	min <sup>-1</sup>	$n_1$	360,0	
	Required life	h	—	10 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 14 — Example 6 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	180,00	-1 188,00
$d_a$	Tip diameter	mm	211,75	-1 166,00
$d_b$	Base circle diameter	mm	169,14	-1 116,35
$x_E$	Generating profile shift coefficient	—	0,304 8	-0,018 2
$d_f$	Root diameter (based on $x_E$ )	mm	157,31	-1 218,44
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	169,66	-1 212,79
$d_{Nf}$	Start of active profile diameter	mm	169,90	-1 202,89
$d_w$	Working pitch diameter	mm	178,57	-1 178,57
$F_t$	Nominal tangential load at the reference cylinder	N	11 111	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,31	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,89	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,24	
$K_{H\beta-C}$	Face load factor (contact stress)	—	2,24	
$K_{v-B}$	Dynamic factor	—	1,10	
$S_F$	Tooth root breakage safety factor	—	7,40	5,66
$S_H$	Pitting safety factor	—	1,16	1,16
$v_w$	Pitch line velocity	m/s	3,37	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,35	1,14
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,92	0,95
$Y_N$	Life factor (tooth root stress)	—	0,92	0,95
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	2,04	3,42
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	0,96	0,96
$Y_\beta$	Helix angle factor	—	1,00	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	0,99	1,10
$Z_B$	Single pair tooth contact factor, pinion	—	1,01	
$Z_\beta$	Helix angle factor (pitting)	—	1,00	
$Z_D$	Single pair tooth contact factor, wheel	—	1,00	
$Z_E$	Elasticity factor	$\sqrt{N/mm^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,90	
$Z_H$	Zone factor	—	2,59	
$Z_L$	Lubricant factor	—	1,09	1,08
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	0,96	1,03
$Z_N$	Life factor (contact stress)	—	0,96	1,04
$Z_R$	Roughness factor	—	0,86	0,87
$Z_v$	Velocity factor	—	0,94	0,95
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00

Table 14 (continued)

Symbol	Description	Unit	Pinion	Gear
$\varepsilon_\alpha$	Transverse contact ratio	—	1,57	
$\varepsilon_\beta$	Overlap ratio	—	0,00	
$\varepsilon_\gamma$	Total contact ratio	—	1,57	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	20	29
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	72	102
$\sigma_{F\text{ lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	319	298
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	534	578
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	572	568
$\sigma_{H\text{ lim}}$	Limiting contact stress	N/mm <sup>2</sup>	780	714
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	286	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	662	660
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit face-width (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·µm)	20,8	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·µm)	14,6	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,123	
$N$	Resonance ratio	—	0,04	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit face-width (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·µm)	17,7	
$f_{\text{sh}0}$	Shaft deformation under specific load	µm	0,011	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	µm	31,4	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	µm	17,9	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{f\alpha})$ )	µm	7,080	
$y_\beta$	Running-in allowance (equivalent misalignment)	µm	13,5	
$f_{pb}$	Transverse base pitch deviation	µm	29,1	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	µm	9,5	
$f_{\text{sh}}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	µm	1,4	
$f_{\text{ma}}$	Mesh misalignment due to manufacturing deviations	µm	29,5	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	—	
$f_\varepsilon$	Load distribution influence factor	—	1,00	

4.9 Example 7: Double helical through-hardened wrought gear pair

For example 7, input values and output values are given in Tables 15 and 16, respectively.

Table 15 — Example 7 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	86	429
	Normal module	mm	$m_n$	1,693 333 3 (15 DP)	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	18,31	
	Hand of helix	—	—	Double helical	
	Facewidth (total)	mm	$b$	165,1 (82,55 × 2)	165,1 (82,55 × 2)
	Gap width	mm	—	50,80	50,80
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	—	165,1 (82,55 × 2)	
	Centre distance	mm	$a$	460,375	
	Span measurement	mm	$W_k$	60,068	289,367
	Number of teeth spanned	—	$k$	12	56
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	0,361 5	(0,286 3)
	Tip diameter	mm	$d_a$	157,99	769,52
	Basic rack dedendum coefficient	—	$h_{fp}/m_n$	1,250	1,250
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,38	0,38
	As cut basic rack undercut	mm	$pr$	0,000	0,000
	Material allowance for finishing	mm	$q$	0,000	0,000
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,000	0,000
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	As cut	As cut
	Root finishing process	—	—	As cut	As cut
	Tip relief	µm	$C_a$	13	13
Root relief	µm	$C_f$	0	0	
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	manufacturers experience		
Quality	Flank tolerance class	—	$A$	5	5
	Single pitch tolerance according to ISO 1328-1:2013	µm	$f_{pT}$	6,0	6,5
	Profile form deviation according to ISO 1328-1:2013	µm	$f_{f\alpha}$	6,0	6,0
	Helix slope deviation	µm	$f_{H\beta}$	8,0	8,5
	Surface roughness – flank $Ra$ ( $Rz$ )	µm	—	1,0 (6,0)	1,0 (6,0)
	Surface roughness – fillet $Ra$ ( $Rz$ )	µm	—	3,0 (18,0)	3,0 (18,0)

Table 15 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Material	Material	—	—	V (alloy steel)	V (alloy steel)
	Material quality	—	—	ML	ML
	Case hardness	—	—	342 HB	300 HB
	Core hardness	—	—	—	—
	Young's modulus	N/mm <sup>2</sup>	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	N/mm <sup>2</sup>	$\sigma_S/\sigma_{0,2}$	1 000,0	1 000,0
	Material density	kg/m <sup>3</sup>	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	Yes	Yes
Application	Application factor	—	$K_{A-A}$	1,000	
	Mesh load factor	—	$K_Y$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	Yes	Yes
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	None (No. 1)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	mm	$b_s$	—	—
	Inside diameter	mm	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	a	
	Bearing span	mm	$l$	355,600	—
	Bearing span offset	mm	$s$	0,00	—
	External shaft diameter	mm	$d_{sh}$	63,50	—
	Internal shaft diameter	mm	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00		
Lubrication viscosity	mm <sup>2</sup> /s	$\nu_{40}$	25		
Load	Torque	kNm	$T_1$	0,528	
	Speed	min <sup>-1</sup>	$n_1$	5 400,0	
	Required life	h	—	30 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	0,85	0,85

Table 16 — Example 7 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	153,39	765,18
$d_a$	Tip diameter	mm	157,988	769,518
$d_b$	Base circle diameter	mm	143,23	714,47
$x_E$	Generating profile shift coefficient	—	0,185 7	0,110 4
$d_f$	Root diameter (based on $x_E$ )	mm	149,79	761,32
$d_{FF}$	Root form diameter (based on $x_E$ )	mm	150,81	762,21
$d_{Nf}$	Start of active profile diameter	mm	151,39	763,15
$d_w$	Working pitch diameter	mm	153,76	766,99
$F_t$	nominal tangential load at the reference cylinder	N	6 884	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,37	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,36	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,37	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,38	
$K_{v-B}$	Dynamic factor	—	1,68	
$S_F$	Tooth root breakage safety factor	—	2,79	2,50
$S_H$	Pitting safety factor	—	1,30	1,33
$v_w$	Pitch line velocity	m/s	43,47	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	0,86	0,89
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	0,85	0,88
$Y_N$	Life factor (tooth root stress)	—	0,85	0,88
$Y_{RrelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	2,30	2,36
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	1,00	1,00
$Y_\beta$	Helix angle factor	—	0,99	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	1,00	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,03	
$Z_\beta$	Helix angle factor (pitting)	—	1,03	
$Z_D$	Single pair tooth contact factor, wheel	—	1,03	
$Z_E$	Elasticity factor	—	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,77	
$Z_H$	Zone factor	—	2,37	
$Z_L$	Lubricant factor	—	0,85	0,85
$Z_{NT}$	Life factor for test reference conditions (contact stress)	—	0,85	0,95
$Z_N$	Life factor (contact stress)	—	0,85	0,95
$Z_R$	Roughness factor	—	0,94	0,94
$Z_v$	Velocity factor	—	1,09	1,09
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio	—	1,68	
$\epsilon_\beta$	Overlap ratio	—	4,87	
$\epsilon_\gamma$	Total contact ratio	—	6,56	

Table 16 (continued)

Symbol	Description	Unit	Pinion	Gear
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	48	51
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	151	161
$\sigma_{F\text{lim}}$	Limiting tooth root stress (input data)	N/mm <sup>2</sup>	256	238
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	421	404
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	375	375
$\sigma_{H\text{lim}}$	Limiting contact stress (input data)	N/mm <sup>2</sup>	661	603
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	203	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	489	499
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{y\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm· $\mu\text{m}$ )	19,3	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm· $\mu\text{m}$ )	12,7	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,081	
$N$	Resonance ratio	—	3,16	
$K_{H\beta-C}$ intermediate calculation values				
$c_{y\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm· $\mu\text{m}$ )	16,4	
$f_{\text{sh}0}$	Shaft deformation under specific load	$\mu\text{m}$	0,010	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	$\mu\text{m}$	6,6	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	$\mu\text{m}$	3,3	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{td})$ )	$\mu\text{m}$	1,540	
$y_\beta$	Running-in allowance (equivalent misalignment)	$\mu\text{m}$	3,4	
$f_{pb}$	Transverse base pitch deviation	$\mu\text{m}$	6,1	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	$\mu\text{m}$	8,5	
$f_{\text{sh}}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	$\mu\text{m}$	1,4	
$f_{\text{ma}}$	Mesh misalignment due to manufacturing deviations	$\mu\text{m}$	11,7	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	1,07	
$f_\epsilon$	Load distribution influence factor	—	0,74	

4.10 Example 8: Single helical case carburized gear pair

NOTE Example 8 is the application of residual protuberance,  $pr$ .

For example 8, input values and output values are given in Tables 17 and 18, respectively.

Table 17 — Example 8 input values

Type	Description	Unit	Symbol	Pinion	Wheel
Geometry	Number of teeth	—	$z$	15	63
	Normal module	mm	$m_n$	4,50	
	Normal pressure angle	°	$\alpha_n$	20,00	
	Helix angle	°	$\beta$	11,00	
	Hand of helix	—	—	Left	Right
	Facewidth (total)	mm	$b$	78,74	76,20
	Gap width	mm	—	0,00	0,00
	Edge chamfer	mm	—	0,00	0,00
	Contact facewidth (total)	mm	$b_{eff}$	76,20	
	Centre distance	mm	$a$	182,880	
	Span measurement	mm	$W_k$	35,706	118,358
	Number of teeth spanned	—	$k$	3	9
	Dimension between balls	mm	$M_{dK}$	—	—
	Ball diameter	mm	$D_M$	—	—
	Nominal profile shift coefficient	—	$x$	0,541 3	(0,439 3)
	Tip diameter	mm	$d_a$	82,19	301,55
	Basic rack dedendum coefficient (pre-finishing)	—	$h_{fp}/m_n$	1,516	1,516
	Basic rack dedendum coefficient (finishing)	—	$h_{fp}/m_n$	1,373	1,373
	Tip chamfer	mm	$h_K$	0,00	0,00
	Basic rack fillet root radius coefficient	—	$\rho_{fp}/m_n$	0,40	0,40
	As cut (pre-finishing) basic rack undercut	mm	$pr$	0,267	0,267
	Material allowance for grinding (finishing)	mm	$q$	0,220	0,220
	Residual fillet undercut, $s_{pr} = pr - q$	mm	$s_{pr}$	0,047	0,047
	Cutting tool protuberance angle	—	—	10°	10°
	Pinion cutter number of teeth	—	$z_0$	—	—
	Pinion cutter profile shift (ref)	—	$x_0$	—	—
	Flank finishing process	—	—	Cut (pre-finishing) and ground (finishing)	Cut (pre-finishing) and ground (finishing)
	Root finishing process	—	—	As cut (pre-finishing)	As cut (pre-finishing)
	Tip relief	µm	$C_a$	13	13
	Root relief	µm	$C_f$	0	0
Profile modification compensate for the deflections	—	—	No		
Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	$f_{ZCa}$	manufacturers experience		

Table 17 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Quality	Flank tolerance class	—	$A$	6	6
	Single pitch tolerance according to ISO 1328-1:2013	$\mu\text{m}$	$f_{pT}$	9,5	10,0
	Profile form deviation according to ISO 1328-1:2013	$\mu\text{m}$	$f_{f\alpha}$	11,0	11,0
	Helix slope deviation	$\mu\text{m}$	$f_{H\beta}$	11,0	11,0
	Surface roughness – flank $Ra$ ( $Rz$ )	$\mu\text{m}$	—	0,38 (2,3)	0,38 (2,3)
	Surface roughness – fillet $Ra$ ( $Rz$ )	$\mu\text{m}$	—	3,0 (18,0)	3,0 (18,0)
Material	Material	—	—	Eh	Eh
	Material quality	—	—	MQ	MQ
	Case hardness	—	—	58 HRC	58 HRC
	Core hardness	—	—	30 HRC	30 HRC
	Young's modulus	$\text{N/mm}^2$	$E$	206 000	206 000
	Poisson's ratio	—	$\nu$	0,3	0,3
	Yield/proof stress	$\text{N/mm}^2$	$\sigma_S/\sigma_{0,2}$	689,5	689,5
	Material density	$\text{kg/m}^3$	$\rho$	7 830	7 830
	Shot peen	—	—	No	No
	Limited pitting allowable	—	—	No	No
Application	Application factor	—	$K_{A-A}$	1,000	
	Mesh load factor	—	$K_Y$	1,00	
	Reverse bending	—	—	No	No
	Favourable contact position	—	—	Yes	Yes
	Helix modification (ISO 6336-1:2019, Table 12)	—	—	Helix + Crowning (No. 5)	
	Dynamic factor, $K_v$ , calculation method	—	—	Method B	
	Face load distribution factor, $K_{H\beta}$ and $K_{F\beta}$ , calculation method	—	—	Method C	
	Number of meshes	—	$N_M$	1	1
	Gear blank type	—	—	Solid	Solid
	Web thickness	$\text{mm}$	$b_s$	—	—
	Inside diameter	$\text{mm}$	—	—	—
	Number of webs	—	—	—	—
	Arrangement (ISO 6336-1:2019, Figure 13)	—	—	b	
	Bearing span	$\text{mm}$	$l$	331,724	—
	Bearing span offset	$\text{mm}$	$s$	67,56	—
	External shaft diameter	$\text{mm}$	$d_{sh}$	63,50	—
	Internal shaft diameter	$\text{mm}$	$d_{shi}$	0,00	—
	Equivalent misalignment	$\mu\text{m}$	$f_{sh}$	As <a href="#">Formula (59)</a>	
	Mesh misalignment	$\mu\text{m}$	$f_{ma}$	As <a href="#">Formula (66)</a>	
	Minimum safety factor pitting	—	$S_{H\min}$	1,00	
	Minimum safety factor tooth breakage	—	$S_{F\min}$	1,00	
	Lubrication viscosity	$\text{mm}^2/\text{s}$	$\nu_{40}$	220	

Table 17 (continued)

Type	Description	Unit	Symbol	Pinion	Wheel
Load	Torque	kNm	$T_1$	1,494	
	Speed	min <sup>-1</sup>	$n_1$	1 430,0	
	Required life	h	—	10 000	
	Life factor for contact stress, $Z_{NT}$ , at 10 <sup>10</sup> cycles	—	—	1,00	1,00
	Life factor for tooth root stress, $Y_{NT}$ , at 10 <sup>10</sup> cycles	—	—	1,00	1,00

Table 18 — Example 8 output values

Symbol	Description	Unit	Pinion	Gear
$d$	Reference diameter	mm	68,76	288,81
$d_a$	Tip diameter	mm	82,19	301,55
$d_b$	Base circle diameter	mm	64,47	270,79
$x_{E,V}$	Generating profile shift coefficient (pre-finishing)	—	0,629 5	0,549 9
$x_E$	Generating profile shift coefficient	—	0,486 6	0,406 9
$d_f$	Root diameter (based on $x_{E,V}$ — pre-finishing)	mm	60,79	280,11
$d_{Ff}$	Root form diameter (based on $x_E$ — finishing)	mm	65,87	284,03
$d_{Nf}$	Start of active profile diameter	mm	65,88	287,05
$d_w$	Working pitch diameter	mm	70,34	295,42
$F_t$	Nominal tangential load at the reference cylinder	N	43 453	
$K_{F\alpha-B}$	Transverse load factor (root stress)	—	1,03	
$K_{F\beta-C}$	Face load factor (root stress)	—	1,05	
$K_{H\alpha-B}$	Transverse load factor (contact stress)	—	1,03	
$K_{H\beta-C}$	Face load factor (contact stress)	—	1,06	
$K_{V-B}$	Dynamic factor	—	1,02	
$S_F$	Tooth root breakage safety factor	—	3,01	2,78
$S_H$	Pitting safety factor	—	1,20	1,20
$v_w$	Pitch line velocity	m/s	5,27	
$Y_B$	Rim thickness factor	—	1,00	1,00
$Y_{DT}$	Deep tooth factor	—	1,00	
$Y_F$	Tooth form factor	—	1,25	1,28
$Y_{NT}$	Life factor for reference test conditions (tooth root stress)	—	1,00	1,00
$Y_N$	Life factor (tooth root stress)	—	1,00	1,00
$Y_{RelT}$	Relative surface factor	—	0,96	0,96
$Y_S$	Stress correction factor	—	1,98	2,03
$Y_{ST}$	Stress correction factor for reference gears	—	2,00	
$Y_X$	Size factor	—	1,00	1,00
$Y_\beta$	Helix angle factor	—	0,96	
$Y_{\delta relT}$	Relative notch sensitivity factor	—	1,00	1,00
$Z_B$	Single pair tooth contact factor, pinion	—	1,03	
$Z_\beta$	Helix angle factor (pitting)	—	1,01	
$Z_D$	Single pair tooth contact factor, wheel	—	1,03	

Table 18 (continued)

Symbol	Description	Unit	Pinion	Gear
$Z_E$	Elasticity factor	$\sqrt{N/mm^2}$	189,81	
$Z_\epsilon$	Contact ratio factor	—	0,85	
$Z_H$	Zone factor	—	2,27	
$Z_L$	Lubricant factor	—	1,02	1,02
$Z_{NT}$	Life factor for reference test conditions (contact stress)	—	1,00	1,00
$Z_N$	Life factor (contact stress)	—	1,00	1,00
$Z_R$	Roughness factor	—	1,02	1,02
$Z_v$	Velocity factor	—	0,98	0,98
$Z_W$	Work hardening factor	—	1,00	1,00
$Z_X$	Size factor	—	1,00	1,00
$\epsilon_\alpha$	Transverse contact ratio		1,39	
$\epsilon_\beta$	Overlap ratio	—	1,03	
$\epsilon_\gamma$	Total contact ratio	—	2,41	
$\sigma_{F0}$	Nominal tooth root stress	N/mm <sup>2</sup>	291	317
$\sigma_F$	Tooth root stress	N/mm <sup>2</sup>	320	347
$\sigma_{F\text{lim}}$	Limiting tooth root stress	N/mm <sup>2</sup>	500	500
$\sigma_{FP}$	Permissible tooth root stress	N/mm <sup>2</sup>	962	965
$\sigma_H$	Contact stress	N/mm <sup>2</sup>	1 285	1 285
$\sigma_{H\text{lim}}$	Limiting contact stress	N/mm <sup>2</sup>	1 500	1 500
$\sigma_{H0}$	Nominal contact stress	N/mm <sup>2</sup>	1 181	
$\sigma_{HP}$	Permissible contact stress	N/mm <sup>2</sup>	1 541	1 541
Intermediate calculation values				
$K_{v-B}$ intermediate calculation values				
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth (used for $K_{v-B}$ , $K_{H\alpha-B}$ , $K_{F\alpha-B}$ )	N/(mm·µm)	17,5	
$c'$	Maximum tooth stiffness per unit facewidth (single stiffness) of a tooth pair	N/(mm·µm)	13,5	
$m_{\text{red}}$	Reduced gear pair mass per unit facewidth referenced to the line of action	kg/mm	0,018	
$N$	Resonance ratio	—	0,07	
$K_{H\beta-C}$ intermediate calculation values				
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth (used for $K_{H\beta-C}$ , $K_{F\beta-C}$ )	N/(mm·µm)	14,8	
$f_{\text{sh}0}$	Shaft deformation under specific load	µm	0,136	
$F_{\beta x}$	Initial equivalent misalignment (before running-in)	µm	5,5	
$F_{\beta y}$	Effective equivalent misalignment (after running-in)	µm	4,7	
$y_\alpha$	Running-in allowance for a gear pair (calculated with $\max(f_{pb}, f_{fa})$ )	µm	0,825	
$y_\beta$	Running-in allowance (equivalent misalignment)	µm	0,8	
$f_{pb}$	Transverse base pitch deviation	µm	9,4	
$f_{H\beta 5}$	Tolerance on helix slope deviation for flank tolerance class 5	µm	8,0	
$f_{\text{sh}}$	Component of equivalent misalignment due to deformations of pinion and wheel shafts	µm	78,9	

Table 18 (continued)

Symbol	Description	Unit	Pinion	Gear
$f_{ma}$	Mesh misalignment due to manufacturing deviations	$\mu\text{m}$	15,6	
Auxiliary values				
$f_{ZCa}$	Tooth flank correction factor (auxiliary factor, see ISO 6336-2:2019)	—	1,07	
$f_{\epsilon}$	Load distribution influence factor	—	0,84	

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## Annex A (informative)

### Example 1 detailed calculation

#### A.1 General

This annex contains the detailed calculation example 1. The formulae are numbered according to the respective referenced document.

#### A.2 Defined data

The defined data are shown in [Tables A.1](#), [A.2](#) and [A.3](#).

**Table A.1 — Gear geometry**

Description	Pinion	Wheel
Number of teeth	$z_1 = 17$	$z_2 = 103$
Normal module	$m_n = 8$	
Normal pressure angle	$\alpha_n = 20,00^\circ$	
Helix angle	$\beta = 15,8^\circ$	
Hand of helix	Left	Right
Facewidth	$b_1 = 100 \text{ mm}$	$b_2 = 100 \text{ mm}$
Contact facewidth	$b = 100 \text{ mm}$	
Centre distance	$a = 500 \text{ mm}$	
Nominal addendum correction factor	$x_1 = (0,145\ 22)$	$x_2 = 0$
Span measurement	$W_{k1} = 38,196 \text{ mm}$	$W_{k2} = 307,943 \text{ mm}$
Number of teeth spanned	$k_1 = 2$	$k_2 = 13$
Tip diameter	$d_{a1} = 159,66 \text{ mm}$	$d_{a2} = 872,35 \text{ mm}$
Basic rack dedendum	$h_{fP1} = 1,4 m_n \text{ mm}$	$h_{fP2} = 1,4 m_n = 11,2 \text{ mm}$
Basic rack fillet root radius	$\rho_{fP1} = 0,39 m_n \text{ mm}$	$\rho_{fP2} = 0,39 m_n = 3,12 \text{ mm}$
residual fillet undercut	$s_{pr1} = 0,00 \text{ mm}$	$s_{pr2} = 0,00 \text{ mm}$
Material allowance for finishing	$q_1 = 0,00 \text{ mm}$	$q_2 = 0,00 \text{ mm}$
Tip relief	$C_a = 70 \mu\text{m}$	
Root relief	$C_f = 0 \mu\text{m}$	
Profile modification compensate for the deflections	Yes	

**Table A.2 — Gear quality**

Description	Pinion	Wheel
Flank tolerance class	$A = 5$	$A = 5$
Single pitch tolerance	$f_{pT1} = 8,5 \mu\text{m}$	$f_{pT2} = 9,0 \mu\text{m}$
Profile form deviation	$f_{fa1} = 9,5 \mu\text{m}$	$f_{fa2} = 9,5 \mu\text{m}$
Helix slope deviation	$f_{H\beta1} = 8,0 \mu\text{m}$	$f_{H\beta2} = 9,0 \mu\text{m}$
Surface roughness ( $Ra$ )	$Ra_{H1} = 1,0 \mu\text{m}$	$Ra_{H2} = 1,0 \mu\text{m}$
Fillet roughness ( $Ra$ )	$Ra_{F1} = 3,0 \mu\text{m}$	$Ra_{F2} = 3,0 \mu\text{m}$

**Table A.3 — Material data**

Description	Pinion	Wheel
Material type	Eh	Eh
Material quality	MQ	MQ
Case hardness (HRC)	60	60
Core hardness (HRC)	30	30
Young's modulus	$E_1 = 206\,000\text{ N/mm}^2$	$E_2 = 206\,000\text{ N/mm}^2$
Poisson's ratio	$\nu_1 = 0,3$	$\nu_2 = 0,3$
Yield/proof stress	$\sigma_{S1} = 500\text{ N/mm}^2$	$\sigma_{S2} = 500\text{ N/mm}^2$
Material density	$\rho_1 = 7\,830\text{ kg/m}^3$	$\rho_2 = 7\,830\text{ kg/m}^3$
Shot peen	No	No
Limited pitting allowable	No	No

**A.3 ISO 6336-5:2016 — Allowable stress values for contact and bending**

**5.5 Allowable contact stress number,  $\sigma_{H\text{ lim}}$**

For material Eh with MQ quality (see ISO 6336-5:2016, Table 1),

$$\sigma_{H\text{ lim}} = 1\,500\text{ N/mm}^2$$

Minimum required safety value for contact,  $S_{H\text{ min}} = 1,00$

**Allowable stress number (bending),  $\sigma_{F\text{ lim}}$**

For material Eh, material quality MQ with core hardness  $\geq 30$  HRC (see ISO 6336-5:2016, Figure 10),

$$\sigma_{F\text{ lim}} = 500\text{ N/mm}^2$$

Minimum safety value for bending,  $S_{F\text{ min}} = 1,00$

**A.4 Application data**

See [Table A.4](#).

**Table A.4 — Application data**

Description	Pinion	Wheel
Application factor	$K_A = 1,00$	
Mesh load factor	$K_\gamma = 1,00$	
Reverse bending	No	No
Favourable contact position	No	No
Helix modification	No	No
Profile modifications compensate for the deflections	Yes	Yes
Number of mesh contacts	$N_{M1} = 1$	$N_{M2} = 1$
Gear blank type	Solid	Solid
Bearing span offset	$s_1 = 0,00\text{ mm}$	
Equivalent misalignment	$f_{sh} = 14,705\text{ }\mu\text{m}$	
Mesh misalignment	$f_{ma} = 12,042\text{ }\mu\text{m}$	
Lubrication viscosity	$\nu_{40} = 320\text{ mm}^2/\text{s}$	

## A.5 Load data

See [Table A.5](#).

**Table A.5 — Load data**

Description	Pinion	Wheel
Pinion torque	$T_1 = 9\,000\text{ Nm}$	—
Pinion speed	$n_1 = 360\text{ min}^{-1}$	—
Required life	$L_h = 50\,000\text{ h}$	—

## A.6 Supplementary calculations

Gear ratio  $u = \frac{z_2}{z_1} = 6,058\,82$

Transverse module  $m_t = \frac{m_n}{\cos(\beta)} = 8,314\,12\text{ mm}$

Reference diameter  $d_1 = z_1 \cdot m_t = 141,340\text{ mm}$   
 $d_2 = z_2 \cdot m_t = 856,355\text{ mm}$

Involute normal pressure angle  $\text{inv}\alpha_n = \tan(\alpha_n) - \alpha_n = 0,014\,90\text{ rad}$

Transverse pressure angle  $\alpha_t = \text{atan}\left[\frac{\tan(\alpha_n)}{\cos(\beta)}\right] = 20,720^\circ$   
 $\text{inv}\alpha_t = \tan(\alpha_t) - \alpha_t = 0,016\,63\text{ rad}$

Transverse working pressure angle  $\alpha_{wt} = \text{acos}\left\{z_1 + z_2 \left[\frac{m_n \cdot \cos(\alpha_t)}{2a_w \cdot \cos(\beta)}\right]\right\} = 21,066^\circ$

Generating profile shift coefficient  $x_{E1} = \frac{W_{k1} - \{m_n \cdot \cos(\alpha_n) [\pi(k_1 - 0,5) + z_1 \cdot \text{inv}\alpha_t]\}}{2 \cdot m_n \cdot \sin(\alpha_n)} = 0,117\,79$   
 $x_{E2} = \frac{W_{k2} - \{m_n \cdot \cos(\alpha_n) [\pi(k_2 - 0,5) + z_2 \cdot \text{inv}\alpha_t]\}}{2 \cdot m_n \cdot \sin(\alpha_n)} = -0,027\,48$

Root diameter  $d_{f1} = d_1 - 2[h_{fp1} - (x_{E1}m_n)] = 120,825\text{ mm}$

(based on generating profile shift coefficient,  $x_E$ )  $d_{f2} = d_2 - 2[h_{fp2} - (x_{E2}m_n)] = 833,515\text{ mm}$

Root form diameter (based on generated profile shift coefficient,  $x_E$ ; in this case there is no undercut or protuberance, so the following formula can be applied)

$$d_{Ff1} = \sqrt{\left\{d_1 \sin(\alpha_t) - \frac{2[h_{aP0} - x_{E1}m_n - \rho_{aP0}(1 - \sin(\alpha_n))]}{\sin(\alpha_t)}\right\}^2 + d_{b1}^2} = 132,248\text{ mm}$$

$$d_{Ff2} = \sqrt{\left\{d_2 \sin(\alpha_t) - \frac{2[h_{aP0} - x_{E2}m_n - \rho_{aP0}(1 - \sin(\alpha_n))]}{\sin(\alpha_t)}\right\}^2 + d_{b2}^2} = 839,084\text{ mm}$$

Base diameter  $d_{b1} = d_1 \cos(\alpha_t) = 132,199\text{ mm}$

$$d_{b2} = d_2 \cos(\alpha_t) = 800,968\text{ mm}$$

Base helix angle  $\beta_b = \tan^{-1}[\tan(\beta) \cos(\alpha_t)] = 14,825^\circ$

Working pitch diameter  $d_{w1} = \frac{d_{b1}}{\cos(\alpha_{wt})} = 141,667 \text{ mm}$

$$d_{w2} = \frac{d_{b2}}{\cos(\alpha_{wt})} = 858,333 \text{ mm}$$

Normal pitch  $p_n = \pi \cdot m_n = 25,133 \text{ mm}$

Transverse pitch  $p_t = \pi \cdot m_t = 26,120 \text{ mm}$

Transverse base pitch  $p_{bt} = p_t \cdot \cos(\alpha_t) = 24,430 \text{ mm}$

Transverse base pitch on the path of contact  $p_{et} = p_{bt} = 24,430 \text{ mm}$

Length of line of contact  $g_\alpha = \frac{1}{2} \left[ \sqrt{d_{Na1}^2 - d_{b1}^2} + \frac{z_2}{|z_2|} \left( \sqrt{d_{Na2}^2 - d_{b2}^2} - 2 a_w \sin \alpha_{wt} \right) \right] = 37,845 \text{ mm}$

SAP diameter  $d_{Nf1} = \sqrt{\left( 2|a| \sin \alpha_{wt} - \sqrt{d_{Fa2}^2 - d_{b2}^2} \right)^2 + d_{b1}^2} = 132,921 \text{ mm}$

$$d_{Nf2} = \frac{z_2}{|z_2|} \sqrt{\left( 2a \sin \alpha_{wt} - \sqrt{d_{Fa1}^2 - d_{b1}^2} \right)^2 + d_{b2}^2} = 845,225 \text{ mm}$$

Transverse contact ratio  $\varepsilon_\alpha = \frac{g_\alpha}{p_{et}} = 1,549 09$

Overlap ratio  $\varepsilon_\beta = \frac{b \cdot \sin(\beta)}{m_n \cdot \pi} = 1,083 37$

Total contact ratio  $\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta = 2,632 46$

Transverse base pitch deviation  $f_{pb1} = f_{pT1} \cdot \cos(\alpha_t) = 7,950 24 \mu\text{m}$

$$f_{pb2} = f_{pT2} \cdot \cos(\alpha_t) = 8,417 90 \mu\text{m}$$

Pitch line velocity  $v_w = \frac{d_{w1} \cdot \pi \cdot n_1}{60 \cdot 10^3} = 2,670 35 \frac{\text{m}}{\text{s}}$

Circumferential velocity at the reference circle  $v = \frac{d_1 \cdot \pi \cdot n_1}{60 \cdot 10^3} = 2,664 20 \frac{\text{m}}{\text{s}}$

(see ISO 6336-1:2019, 4.2.2)

## A.7 ISO 6336-2:2019 — Contact ratio factor

### 8.2.2 Contact ratio factor, $Z_\varepsilon$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} = 0,803 46 \tag{31}$$

## A.8 ISO 6336-1:2019 — Basic principles, introduction and general influence factors

### A.8.1 Determination of dynamic factor, $K_v$

#### 4.2.2 Nominal tangential load, $F_t$

$$F_t = \frac{2\,000 T_1}{d_1} = 127\,352,381 \text{ N} \quad (1)$$

### 9.3 Determination of tooth stiffness parameters, $c'$ and $c_\gamma$

Virtual number of teeth,  $z_n$

$$z_{n1} = \frac{z_1}{\cos(\beta_b)^2 \cos(\beta)} = 18,905$$

$$z_{n2} = \frac{z_2}{\cos(\beta_b)^2 \cos(\beta)} = 114,543$$

#### 9.3.2.2 Theoretical single stiffness, $c'_{th}$

Coefficients:  $C_1 = 0,047\,23$

$$C_2 = 0,155\,51$$

$$C_3 = 0,257\,91$$

$$C_4 = -0,006\,35$$

$$C_5 = -0,116\,54$$

$$C_6 = -0,001\,93$$

$$C_7 = -0,241\,88$$

$$C_8 = 0,005\,29$$

$$C_9 = 0,001\,82$$

Minimum value for the flexibility of gear pair,  $q'$

$$q' = C_1 + \frac{C_2}{z_{n1}} + \frac{C_3}{z_{n2}} + C_4 x_1 + \frac{C_5 x_1}{z_{n1}} + C_6 x_2 + \frac{C_7 x_2}{z_{n2}} + C_8 x_1^2 + C_9 x_2^2 = 0,056\,00 \text{ (mm} \cdot \mu\text{m)}/\text{N} \quad (84)$$

$$c'_{th} = \frac{1}{q'} = 17,857 \text{ N}/(\text{mm} \cdot \mu\text{m}) \quad (83)$$

#### 9.3.2.3 Correction factor, $C_M$

$$C_M = 0,8 \quad (85)$$

#### 9.3.2.4 Gear blank factor, $C_R$

$$C_R = 1,0 \text{ (for solid gears)} \quad (86)$$

**9.3.2.5 Basic rack factor,  $C_B$**

Normal pressure angle of basic rack,  $\alpha_{Pn} = \alpha_n$

Basic rack dedendum for pinion and gear are the same, therefore,

$$C_{B1} = \left[ 1,0 + 0,5 \left( 1,2 - \frac{h_{FP1}}{m_n} \right) \right] [1,0 - 0,02 \cdot (20^\circ - \alpha_{Pn})] = 0,900\ 00 \quad (88)$$

$$C_{B2} = \left[ 1,0 + 0,5 \left( 1,2 - \frac{h_{FP2}}{m_n} \right) \right] [1,0 - 0,02 \cdot (20^\circ - \alpha_{Pn})] = 0,900\ 00$$

$$C_B = 0,5 \cdot (C_{B1} + C_{B2}) = 0,900\ 00 \quad (89)$$

**9.3.2 Single stiffness,  $c'$**

$$c' = c'_{th} \cdot C_M \cdot C_R \cdot C_B \cos(\beta) = 12,371\ \text{N} / (\text{mm} \cdot \mu\text{m}) \quad (82)$$

**9.3.3.1 Mesh stiffness,  $c_{\gamma\alpha}$**

$$c_{\gamma\alpha} = c' \cdot (0,75 \varepsilon_\alpha + 0,25) = 17,466\ \text{N} / (\text{mm} \cdot \mu\text{m}) \quad (93)$$

**9.3.3.2 Mesh stiffness,  $c_{\gamma\beta}$**

$$c_{\gamma\beta} = 0,85 c_{\gamma\alpha} = 14,846\ \text{N} / (\text{mm} \cdot \mu\text{m}) \quad (94)$$

**6.5.3 Calculation of reduced mass of gear pair with external teeth,  $m_{red}$**

Mean tooth diameter,  $d_m$

$$d_{m1} = \frac{d_{a1} + d_{f1}}{2} = 140,462\ \text{mm} \quad d_{m2} = \frac{d_{a2} + d_{f2}}{2} = 853,152\ \text{mm} \quad (31)$$

Given density  $\rho_1 = 7\ 830\ \text{kg}/\text{m}^3$   $\rho_2 = 7\ 830\ \text{kg}/\text{m}^3$

$$m_1^* = \frac{J_1^*}{r_{b1}^2} = 0,068\ 486\ \text{kg} / \text{mm} \quad m_2^* = \frac{J_2^*}{r_{b2}^2} = 2,539\ 206\ \text{kg} / \text{mm} \quad (8)$$

$$m_{red} = \frac{m_1^* \cdot m_2^*}{m_1^* + m_2^*} = 0,066\ 69\ \text{kg} / \text{mm} \quad (7)$$

NOTE Quantity  $(1 - q_1^4) = (1 - q_2^4) = 1$  for solid pinion and wheel (33)

**6.5.3 Determination of resonance running speed,  $n_{E1}$** 

$$n_{E1} = \frac{30\,000}{\pi z_1} \sqrt{\frac{c_{\gamma\alpha}}{m_{\text{red}}}} = 9\,090,605 \text{ min}^{-1} \quad (6)$$

**Resonance ratio,  $N$** 

$$N = \frac{n_1}{n_{E1}} = 0,039\,60 \quad (9)$$

**Lower limit of resonance ratio,  $N_S$** 

$$\frac{F_t K_A}{b} > 100, \text{ therefore, } N_S = 0,85 \quad (12)$$

**6.5.4 Dynamic factor in subcritical range, ( $N \leq N_S$ )**

$\varepsilon_\gamma > 2$  (see ISO 6336-1:2019, Table 8), therefore,

$$C_{v1} = 0,320\,00 \quad C_{v4} = \frac{0,57 - 0,05 \varepsilon_\gamma}{\varepsilon_\gamma - 1,44} = 0,367\,62$$

$$C_{v2} = \frac{0,57}{\varepsilon_\gamma - 0,3} = 0,244\,38 \quad C_{v5} = 0,47 = 0,470\,00$$

$$C_{v3} = \frac{0,096}{\varepsilon_\gamma - 1,56} = 0,089\,51 \quad C_{v6} = \frac{0,12}{\varepsilon_\gamma - 1,74} = 0,134\,46$$

$$\varepsilon_\gamma > 2,5 \quad C_{v7} = 1$$

$$C_{ay} = \frac{1}{18} \left( \frac{\sigma_{H \text{ lim}}}{97} - 18,45 \right)^2 + 1,5 = 1,995\,37 \mu\text{m}$$

Base pitch deviation,  $f_{pb} = \max(f_{pb1}, f_{pb2}) = 8,417\,90 \mu\text{m}$  (see note in ISO 6336-1:2019, 8.3.2)

Profile form deviation,  $f_{f\alpha} = \max(f_{f\alpha1}, f_{f\alpha2}) = 9,5 \mu\text{m}$ , Running-in allowance (see ISO 6336-1:2019, 8.3.6)

As materials are the same and for Eh material, then,

$$y_\alpha = 0,075 f_{pb} = 0,631\,34 \mu\text{m} \quad (79)$$

NOTE The application of 50 % of the values  $f_{pb}$  or  $f_{f\alpha}$  (due to profile modification compensation of deflections) is only valid for the calculation of  $K_{H\beta}$ , but not for the calculation of  $K_v$ .

Comparison with the allowable limit for material Eh of  $3 \mu\text{m}$ .

Estimated running-in allowance (pitch deviation) (see note in ISO 6336-1:2019, 6.5.4)

$$y_p = y_\alpha = 0,631\ 34\ \mu\text{m}$$

Estimated running-in allowance (flank deviation) (see ISO 6336-1:2019, 6.5.4)

$$y_f = 0,075\ f_{f\alpha} = 0,712\ 50\ \mu\text{m}$$

Comparison with the allowable limit for material Eh of 3  $\mu\text{m}$ .

$$f_{\text{pbeff}} = f_{\text{pb}} - y_p = 7,786\ 56\ \mu\text{m} \quad (18)$$

$$f_{\text{f\alpha eff}} = f_{f\alpha} - y_f = 8,787\ 50\ \mu\text{m} \quad (19)$$

$$B_p = \frac{c' \cdot f_{\text{pbeff}}}{K_A \cdot K_\gamma \cdot \left(\frac{F_t}{b}\right)} = 0,075\ 64 \quad (15)$$

$$B_f = \frac{c' \cdot f_{\text{f\alpha eff}}}{K_A \cdot K_\gamma \cdot \left(\frac{F_t}{b}\right)} = 0,085\ 36 \quad (16)$$

As lowest flank tolerance class  $\leq$  Flank tolerance class 5, then,

$$B_k = \left| 1 - \frac{c' \cdot \min(C_{a1} + C_{f2}, C_{a2} + C_{f1})}{K_A \cdot K_\gamma \cdot \left(\frac{F_t}{b}\right)} \right| = 0,320\ 02 \quad (17)$$

$$K = (C_{v1} \cdot B_p) + (C_{v2} \cdot B_f) + (C_{v3} \cdot B_k) = 0,073\ 71 \quad (14)$$

As  $N \leq N_S$ , (see ISO 6336-1:2019, 6.5.4), then,

$$K_v = N \cdot K + 1 = 1,002\ 92 \quad (13)$$

### A.8.2 Determination of face load factors, $K_{H\beta}$ and $K_{F\beta}$

Mean transverse tangential load (see 7.2)

$$F_m = F_t \cdot K_A \cdot K_\gamma \cdot K_v = 127\ 724,130\ \text{N}$$

#### 7.5.3.5.2 Approximate calculation of equivalent misalignment, $f_{\text{sh}}$

Pinion offset  $s_1 = 0$ , therefore,

$$f_{\text{sh}} = \frac{F_m}{b} 0,023 [(1+0-0,3)+0,3] \left(\frac{b}{d_1}\right)^2 = 14,705\ \mu\text{m} \quad (59)$$

#### 7.5.4.4 Mesh misalignment, $f_{\text{ma}}$

$$f_{\text{ma}} = \sqrt{f_{H\beta 1}^2 + f_{H\beta 2}^2} = 12,042\ \mu\text{m} \quad (66)$$