Changes in ISO 6336:2019 — Parts 1, 2, 3, 5 and 6

Hanspeter Dinner

Introduction

ISO 6336 is the most widely used and technically advanced document for cylindrical gear strength rating. It falls under the responsibility of ISO technical committee TC 60, subcommittee 2, work group WG 6 “Gear Calculations”. Convenor of WG6 is Prof. Dr. Ing. Karsten Stahl of the FZG Munich, Germany.

The third edition of ISO 6336 has been extended and now includes the new replaced ISO/TR 13989-1 and -2 on scuffing, the now replaced ISO/TR 15144-1 and -2 on micropitting, and a new part 4 on tooth flank fracture. Calculation examples form parts 30 and 31. The different parts and classification as standard, technical specification or technical report are listed in the below table.


The purpose of this paper is to point the reader to changes in the third edition of parts 1, 2, 3, 5 and 6 compared to the previous edition (from the year 2006 for parts 1, 2, 3, 6 and from the year 2003 for part 5). The paper is limited to a more detailed introduction outside the scope of this paper.

Part 1 of ISO 6336:2019

Overview

The scope of ISO 6336-1:2019, (Ref.2) is defined as follows:

“...”

use by the general engineering public. Instead, it is intended for use by the experienced gear designer who is capable of selecting reasonable values for the factors in these formulae based on the knowledge of similar designs and the awareness of the effects of the items discussed.

The formulae in the ISO 6336 series are intended to establish a uniformly acceptable method for calculating the load capacity of cylindrical gears with straight or helical involute teeth.”

The introduction section now includes above overview of the ISO 6336 documents, Table 1, as parts 4, 20, 21, 22, 30 and 31 have been added to ISO 6336 series.

This part now includes as normative reference ISO 21771:2007, (Ref. 13), for cylindrical involute gear geometry. This standard was published in 2007 and in ISO 6336:2006, no reference to such a standard was available. ISO 6336:2019 now states that terms and definitions of ISO 21771:2007 apply, along with those from ISO 1122-1:1998 (Ref. 12). With this, the gear strength rating standards are linked to gear geometry calculation standards.

Structure of ISO 6336-1:2019, compared to previous edition

Foreword, Introduction, Sections 1, 2 and 3 maintain their structure. The
introduction now includes an overview of all the documents belonging to ISO 6336 series, see Table 1.

Section 4, specifically section 4.1, now includes those failure modes addressed in the different parts of the standard in the same sequence as they are covered in the different part numbers. These are “Surface durability (pitting),” “Tooth bending strength,” “Tooth flank fracture,” “Scuffing” and “Micropitting.” Wear and plastic yielding are still mentioned as possible failure modes but are not covered in ISO 6336. Comments on specific areas of gearing, e.g., “Vehicle final drive gears,” “Main drive for aircraft and space vehicles” or “Industrial high-speed gears” remain included.

The section on safety factors remains as well; it is now more detailed and explains differences between different safety factors, e.g., that the safety factor for bending is calculated from two stresses while e.g., the safety factor for scuffing is calculated from two temperature levels. Both 2006 and 2019 version include the most important statement that “… Recommendations concerning these minimum values (for safety factors) are made… but values are not proposed…”.

Section 5 on application factor $K_\text{A}$ retains its structure but a subsection with guide values for the application factor, method B is added, see Table 3 below. In section 6 on the dynamic factor $K_\text{D}$, a section on $K_\alpha$ for low loaded gears, $(F_t \times K_\alpha \times K_\gamma) / b < 100 \text{ N/mm}$, has been added. Otherwise, the structure of the section is the same as in 2006 edition.

The structure of section 7 on the face load factor $K_{Hfp}$, section 8 for the transverse load factors $K_{Hfa}$ and $K_{Fmu}$, section 9 for the tooth stiffness parameters, $c'$ and $c_r$ and Annex A (normative), additional methods for determination of $f_{hit}$ and $f_{max}$ is the same as in 2006 edition.

A whole new section 10, Parameter of Hertzian contact, has been added in 2019 edition of ISO 6336. It originates from ISO/TR 15144-1:2014 (there, as section 10) and ISO/TR 13989-1:2000 (there, as section 9). In section 10.1, the formulas on how to calculate the normal and transverse radius of relative curvature in the contact paint $CP$, $\rho_{\text{red,CP}}$ and $\rho_{\text{red,CP}}$ and from the transverse radius of curvature of the pinion and wheel are given (division of the product of the radii of curvature of pinion and wheel by sum of the radii of curvature of pinion and wheel). Note that the radii here are for the unmodified involute shape, not considering modifications like tip relief or similar. In a similar manner, the reduced modulus of elasticity $E_r$ is calculated from the modulus of elasticity of the pinon and the wheel as well as from the Poisson’s ratio of pinion and wheel.

The local Hertzian contact stress $p_{\text{dyn,CP}}$ calculated as method A through a loaded tooth contact analysis LTCA, typically using a 3D load distribution program, is defined as the local nominal Hertzian contact stress $p_{\text{HCP,LA}}$ multiplied by the square root of $K_\alpha$, $K_\gamma$ and $K_\gamma$ (comments on these can be found above and below). For method B, no loaded tooth contact analysis is used, the load distribution is considered as additional factors (again the square root thereof) $K_{Hfa}$ (transverse load factor) and $K_{Hfp}$ (face load factor).

The formula for the local contact stress in the contact point $CP$ as per method B, $p_{\text{HCP,B}}$ then uses the relative radius of curvature (above), the reduced modulus of elasticity (above), the transverse tangential load at the reference cylinder $F_t$, the face width $b$, and the load sharing factor $X_{CP}$ and is:

$$
p_{\text{HCP,B}} = \sqrt{\frac{E_r}{2 \pi \times \rho_{\text{red,CP}}}} \times \sqrt{\frac{F_t \times X_{CP}}{b \times \rho_{\text{red,CP}} \times \cos (\alpha_r)}}
$$

In section 10.4, another very helpful formula to calculate the half of the Hertzian contact width, $b_{hit}$ is given as follows:

$$
b_{\text{HCP}} = 4 \times \rho_{\text{red,CP}} \times \frac{\rho_{\text{red,CP}}}{E_r}.
$$

Section 10.5 deals with the load sharing factor $X_{CP}$ and is complex. The factor accounts for the load sharing between succeeding pairs of meshing teeth. It is defined along the path of contact, using parameter $g_{\text{CP}}$ to describe the position of the contact. The value of $X_{CP}$ does not exceed 1.00, where 1.00 means full transverse tooth contact. The load sharing factor depends on the profile modifications and—for helical gears—is combined with the buttressing factor $X_{\text{but,CP}}$. The buttressing factor accounts for a stress increase at the start and end of the oblique contact lines on the flank in case of unmodified helical gears. Its minimum value is 1.00 and reaches a maximum of 1.30.

Section 10.5 starts with a definition of points A, AB, C, D, DE and E defined as special contact points CP, all on the path of action. If the pinion (the gear in mesh with the lower number of teeth) is driving, then, point A is the start of mesh. If the gear is driving, start of mesh is point E. It also defines the diameter of the
circles with center equal to pinion and gear center going through the contact point, \( d_{CP1} \) and \( d_{CP2} \), both as a function of the parameter \( g_{CP} \) describing the position of the contact point CP on the path of action.

In section 10.5.2, the load sharing factor is given along the path of action (from points A to E) for spur gears with unmodified profiles, spur gears with profile modifications, helical gears with \( \epsilon_p \leq 0.80 \) and unmodified profiles, helical gears with \( \epsilon_p \leq 0.80 \) and modified profiles, helical gears with \( \epsilon_p \geq 1.20 \) and unmodified profiles, helical gears with \( \epsilon_p \geq 1.20 \) and modified profiles and helical gears with \( 0.8 < \epsilon_p < 1.20 \). Only in case of a spur gear with unmodified profile, the load sharing factor is given for different quality classes \( A = 8 \) to \( A = 11 \).

Section 10.6 gives formulas on how to calculate the tangential velocities of the contact point CP on the flank of the pinon and the wheel. The two speed vectors in the contact point have the same pinion and the wheel. The two speed vectors are hence equal to the sum of the velocities of the two vectors.

Section 11, Lubricant parameters at given temperature, has been added in edition 2019 of ISO 6336-1. It is the same content as in ISO/TR 15144-1:2010 (or its second edition of 2014, both withdrawn and replaced by ISO/TS 6336-22), section 7.2. Note that the identical text can again be found in ISO/TS 6336-22:2018 on micropitting. In this new section, the procedure to calculate the dynamic viscosity at a given temperature from the kinematic viscosity is given. Also, the calculation formulae for calculation of the dynamic viscosity at a given temperature from the kinematic viscosity at 40°C and 100°C are given. Finally, the formula for the calculation of the lubricant density at a given temperature from the lubricant temperature at 15°C is given in this section.

### Application

The method for calculating the load capacity of cylindrical gears are in good agreement or validated for the below boundary conditions. Note the slight changes between 2006 and 2019 edition Table 2:

### Changes in formulas and factors

#### Mesh load factor \( K_f \)

Edition 2019 now specifically includes the mesh load factor \( K_f \) in the formulas where it is—like e.g., the application factor \( K_a \)—multiplied with the nominal tangential load. This is clearer than in edition 2006 where a statement was given that \( K_a \) needs to be replaced by \( K_a \times K_f \) if a gear drives two or more mating gears. Some additional comments concerning the use of \( K_f \) are given.

Note that \( K_f \) is also used in the other parts of ISO 6336 in the formulas where in previous edition, only \( K_a \) was present. This change is not further mentioned in below sections.

### Application factor \( K_a \)

The system for describing application factors has been extended. In 2006 edition, the application factor \( K_a \) could be derived along method A or method B, becoming \( K_{a,A} \) and \( K_{a,B} \) respectively. In 2019 edition, separate application factors \( K_{A,B} \) for pitting, \( K_{A,B} \) for root breakage, \( K_{A,B} \) for tooth flank fracture, \( K_{A,B} \) for scuffing, \( K_{A,B} \) for micropitting are introduced. Again, they can be determined along method A or B and the respective suffix is added. \( K_{A,B} \) for example means application factor along method B, for flank fracture calculation.

“Table 4 — Application factor, \( K_a \)” with guide values for \( K_{A,B} \) is added. Additional tables 6 and 7, with application examples, to be used in conjunction with this table, explaining the meaning of e.g., “Light shocks,” are also added in 2019 edition. With this, a practical tool to select a suitable value for \( K_{A,B} \) is available now:

### Dynamic factor \( K_v \)

In 2006 edition, a value for \( K_v > 2.00 \) was possible. This means that gear flanks could separate and in 2019 edition, the dynamic factor \( K_v \) for gears operating outside their resonance condition, shall be set \( K_{A,B} \) or \( K_{A,C} = 2.00 \) if its calculated value is higher than 2.00.

The dynamic factor in the subcritical range \( (N_s \leq N_c) \) and for main resonance range \( (N_r < N_s \leq 1.15) \) is calculated using a parameter \( B_0, B_1 \) was calculated in 2006 edition considering the tip relief \( C_o \) only.
In 2019 edition, \( B_k \) is calculated using \( \min (C_{a1} + C_{f2}, C_{a2} + C_{f1}) \), considering also root relief and being clear that the minimum value per gear shall be used.

Equations (25) and (26), for the calculation of the moment of inertia of a stationary and rotating ring gear in planetary gearboxes have changed. The correct index for the ring gear is now used and second instead of fourth power of the ring gear diameter is used in the denominator.

Edition 2019 of ISO 6336 references to ISO 1328-1:2013 (where lowest quality is grade 11), while edition 2006 references to ISO 1328-1:1995 (where lowest quality grade is 12). Quality grade 12 is no longer used for \( K_v \) calculation (see section 6.6.2 in ISO 6336-1:2019), lowest quality grade used is now 11.

Face load factors \( K_{Fβ} \) and \( K_{Hβ} \)
For calculation of \( K_{Fβ} \), in case that favorable position of contact pattern is verified, the tolerance on helix slope deviation for ISO tolerance class 5 (along ISO 1328-1:2013), \( f_{Hβ5} \) is used in edition 2019 instead of tolerance class 6 (along ISO 1328-1:1995), \( f_{Hβ6} \) in edition 2006.

Tooth stiffness parameters, \( c' \) and \( c_γ \)
In section 9.3.2.6, clarification is added that \( c_γβ \) and \( c_γα \) are defined in the transverse direction in the plane of action. This clarification was missing in 2006 edition.

**Part 2 of ISO 6336:2019**
**Overview**
The scope of ISO 6336-2:2019, (Ref. 4), is defined as follows:
“This document specifies the fundamental formulae for use in the determination of the surface load capacity of cylindrical gears with involute external or internal teeth. It includes formulae for all influences on surface durability for which quantitative assessments can be made. It applies primarily to oil lubricated transmissions, but can also be used to obtain approximate values for (slow running) grease lubricated transmissions, as long as sufficient lubricant is present in the mesh at all times.

The given formulae are valid for cylindrical gears with tooth profiles in accordance with the basic rack standardized in ISO 53. They can also be used for teeth conjugate to other basic racks where the

---

**Table 6**
| Material combinations considered for calculation of work hardening factor \( Z_W \) |
|-----------------|-------------------------------------------------|-------------------------------------------------|
| Material combinations, cases | 2006 edition, material combinations considered | 2006 edition, material combinations considered |
| Case 1 | Surface-hardened pinion with through-hardened gear | Surface-hardened steel pinion with through-hardened steel gear |
| Case 2 | Through-hardened pinion and gear | Through-hardened steel pinion with through-hardened steel gear |
| Case 3 | NA | Surface-hardened steel pinion with ductile iron gear |

**Table 7**
| Work hardening factor \( Z_W \), ISO 6336-2:2019, for combination of surface-hardened steel pinion with ductile iron gear. |
actual transverse contact ratio is less than \( \varepsilon_{an} = 2.5 \). The results are in good agreement with other methods."

**Structure of ISO 6336-2:2019, compared to previous edition**

The structure of the foreword, introduction and sections 1 to 12 and 14 remain the same.

In section 13, Work hardening factor, \( Z_W \), a new subsection 13.3.3 Surface-hardened steel pinion with ductile iron gear, is added. It describes graphical values and determination by calculation of work hardening factor \( Z_W \) for the mentioned material pairing.


**Application**

Further to the conditions for the application of ISO 6336 as found in part 1, see Table 2. These conditions apply, Table 4.

**Changes in formulas and factors**

Calculation of permissible contact stress for through hardened wrought steel, nitrided, nitro carburized steel

Formula (15) (it is the same formula in 2006 and in 2019 edition), for the calculation of the permissible contact stress of through hardened wrought steel, nitrided, nitro carburized, for the limited life stress range, has changed and now includes a different factor (0.7686 in 2019 edition vs. 0.7098 in 2006 edition).

**Calculation of zone factors \( Z_{B} \) and \( Z_{D} \) diameters**

In the formulas, the active tip diameter \( d_{Na} \) is used (in edition 2019) instead of the tip diameter \( d_{na} \) (in 2006 edition).

**Calculation of zone factors \( Z_{B} \) and \( Z_{D} \) auxiliary factor \( f_{ZCa} \)**

For helical gears with \( \varepsilon_a > 1.00 \) and \( \varepsilon_b \geq 1.00 \) (section 6.3, clause b) as well as for helical gears with \( \varepsilon_a > 1.00 \) and \( \varepsilon_b < 1.00 \) (section 6.3, clause c), a new auxiliary factor \( f_{ZCa} \) is introduced and used for the calculation of the zone factors \( Z_B \) and \( Z_D \):

For helical gears with \( \varepsilon_a > 1.00 \) and \( \varepsilon_b \geq 1.00 \), zone factors \( Z_B \) and \( Z_D \) are not \( Z_B = Z_D = 1.00 \) anymore (as in 2006 edition) but \( Z_B = Z_D = f_{ZCa} \cdot 0.5 \). Contact stress is hence increased by \( f_{ZCa} \cdot 0.5 \) or transmittable torque is reduced by \( 1/f_{ZCa} \).

**Transverse and overlap contact ratio \( \varepsilon_a \) and \( \varepsilon_b \)**

Instead of root form and tip diameters (in edition 2006), active root and active tip diameters (in edition 2019) are used for determination of contact ratios.

**Lubricant factor \( Z_L \)**

The table listing viscosity parameters (nominal viscosity \( \nu_{50} \), \( \nu_30 \), viscosity parameter \( \nu_I \) now includes the parameters for additional viscosity grades, VG10, VG15 and VG22. These values are used for determination of the lubricant factor \( Z_L \) by calculation.

**Factor \( Z_W \)**

In 2006 edition, two cases were considered for the gears in mesh material combinations whereas in 2019, a third case has been added as listed in Table 6:

**Part 3**

**Overview**

The scope of ISO 6336-3:2016, [6], is defined as follows:

“This document specifies the fundamental formulae for use in tooth bending stress calculations for involute external or internal spur and helical gears with a rim thickness \( s_R > 0.5 \) \( \) for external gears and \( s_R > 1.75 \) \( \) for internal gears. In service, internal gears can experience failure modes other than tooth bending fatigue, i.e. fractures starting at the root diameter and progressing radially outward. This document does not provide adequate safety against failure modes other than tooth bending fatigue. All load influences on the tooth root stress are included in so far as they are the result of loads transmitted by the gears and in so far as they can be evaluated quantitatively.

This document includes procedures based on testing and theoretical studies such as those of Hirt, Strasser and Brossmann. The results are in good agreement with other methods. The given formulae are valid for spur and helical gears with tooth profiles in accordance with the basic rack standardized in ISO 53. They can also be used for teeth conjugate to other basic racks if the virtual contact ratio \( \varepsilon_{an} < 2.5 \).

The load capacity determined on the basis of permissible bending stress is
termed "tooth bending strength." The results are in good agreement with other methods for the range, as indicated in the scope of ISO 6336-1.

Structure of ISO 6336-3:2019, compared to previous edition
The structure of the foreword, introduction and sections 1 to 5 remain the same.

In section 6, the 2006 edition section 6.2.1 Tooth root normal chord, \(s_{fn}\), radius of root fillet, \(\rho_{fe}\), bending moment arm, \(h_{fe}\), is replaced by sections 6.2.3 Tooth root normal chord, \(s_{fn}\), radius of root fillet, \(\rho_{fe}\), bending moment arm, \(h_{fe}\) for external gears generated with a hob, 6.2.4 Tooth root normal chord, \(s_{fn}\), radius of root fillet, \(\rho_{fe}\), bending moment arm, \(h_{fe}\) for external gears generated with a shaper cutter and 6.2.5 Tooth root normal chord, \(s_{fn}\), radius of root fillet, \(\rho_{fe}\), bending moment arm, \(h_{fe}\) for internal gears generated with a shaper cutter.

Section 6.3 Derivations of determinant normal tooth load for spur gears has been moved to Annex C (informative) in 2019 edition.

The structure of sections 7 to 15 and Annex A (normative) again remain the same.

Application
Further to the conditions for the application of ISO 6336 as found in part 1, see Table 2.

Changes in formulas and factors
Load distribution influence factor \(f_{\psi}\) for the calculation of the form factor \(Y_{f}\)
Compared to 2006 edition, in 2019 edition, the formula for the calculation of \(Y_{f}\) now contains a new factor \(f_{\psi}\), the load distribution influence factor. \(Y_{f}\) as calculated in 2019 is equal to \(Y_{f}\) as calculated in 2006 edition, multiplied by \(f_{\psi}\), both for external and internal gears. The factor \(f_{\psi}\) considers the influence of load distribution between the teeth in the mesh. It improves the results accuracy for gears with contact ratios \(\varepsilon_{\alpha n} \geq 2.00\) (note that index \(n\) refers to the virtual spur gear).

Contact ratios \(\varepsilon_{\alpha n} \geq 2.00\) are reached for gears with high helix angles and or high transverse contact ratios \(\varepsilon_{\alpha}\). For gears with \(\varepsilon_{\alpha n} < 2.00\), \(f_{\psi}\) becomes \(f_{\psi} = 1.00\) and the same values for \(Y_{f}\) result in 2019 edition compared to 2006 edition (except for the influence of the tooth thickness tolerance, see there). Note that the deep tooth factor \(Y_{DF}\) for gears of high precision (ISO tolerance class \(\leq 4\)) and \(2.00 \geq \varepsilon_{\alpha n} \geq 2.50\) and with profile modifications to obtain a trapezoidal load distribution along the path of contact, does not change in 2019 edition compared to 2006 edition.

Calculation of tooth root geometry for external gears generated with a shaper cutter
The calculation of tooth root geometry for external gears generated with a shaper cutter, see Table 2. This section in 2006 edition is used for external gears generated with a hob or a shaper cutter and for internal gears generated with a virtual basic rack, with values and formulas "for external gears."

For the calculation of tooth root geometry for external gears generated with a shaper cutter (and for internal gears, see below) however, a new section 6.2.4 (and 6.2.5 for internal gears, see below) with a new set of formulas is introduced in 2019 edition. These formulas originate from VDI 2737, Calculation of the load capacity of the tooth root in internal toothings with influence of the gear rim, 2016, (Ref. 16).

The formulas introduced in section 6.2.4 of 2019 edition are formulas No. (33) to (61) resulting in the coordinates \(X\) and \(Y\) of the tangent point (with tangent angle \(\theta = 30^\circ\) for external gears and \(\theta = 60^\circ\) for internal gears, see below), the tooth root thickness \(s_{fn}\), the tooth root fillet radius \(\rho_{fe}\) and the bending moment arm \(h_{fe}\), as a function of the quantities at the shaper cutter.

Calculation of tooth root geometry for internal gears
In 2006 edition, for internal gears, a virtual basic rack profile is used which differs from the basic rack profile in the tooth root radius \(r_{p}\). Formulas in section 6.2.1. “for internal gears” apply. In 2019 edition, for internal gears, only the shaper

Figure 4  Left: Quantities at the shaper cutter, (Ref. 6). Right: External gear in mesh with shaper cutter, coordinates X and Y of tangent point, tangent angle \(\theta\) and tooth thickness \(s_{fn}\). Tooth root fillet radius \(\rho_{fe}\) and the bending moment arm \(h_{fe}\) not shown explicitly.
cutter data is used. The calculation of the tooth root geometry (tooth root normal chord \( s_{n0} \), radius of root fillet \( \delta_r \) and bending moment arm \( h_{(r)} \)) to derive form factor \( Y_f \) and stress correction factor \( Y_s \), follows the same formula as used for external gears generated with a shaper cutter. However, negative signs are used for all diameters, and the manufacturing center distance \( a_n \) is used. Furthermore, the tangential angle \( \theta \) is \( \theta = 60^\circ \).

**Influence of tooth thickness tolerances**

In 2006 edition, form factor \( Y_f \) and stress correction factor \( Y_s \) are calculated from the nominal tooth form with the theoretical profile shift coefficient \( x \). If the tooth thickness deviation near the root results in a thickness reduction of more than \( 0.05 \times m_n \) this shall be considered, by taking the generated profile, \( x_{(g)} \), relative to rack shift amount \( m_n \) instead of the nominal profile. In 2019 edition, when the manufactured geometry is measured, it should be used. If not, then, based on the tooth thickness tolerance, the smallest generating profile shift, \( x_{(g)} \), should be used to determine \( Y_f \) and \( Y_s \).

**Helix angle factor \( Y_{h(\alpha)} \)**

The tooth root stress of a virtual spur gear, calculated as a preliminary value, is converted by means of the helix factor, \( Y_{h(\alpha)} \), to that of the corresponding helical gear. In 2019 edition, the formula to calculate \( Y_{h(\alpha)} \) has changed compared to 2006 edition, resulting in the values shown in Figure 5. Note that the value 1.0 is substituted for \( \epsilon_{(h)} \) when \( \epsilon_{(h)}>1.00 \) and \( 30^\circ \) is substituted for \( \beta \) when \( \beta > 30^\circ \). Helix factors \( Y_{h(\alpha)} \) for \( \beta > 25^\circ \) shall be confirmed by experience.

### Relative notch sensitivity factor \( Y_{relT} \) for static stress

The relative notch sensitivity factor \( Y_{relT} \) was defined in 2006 edition for normalized base steel (St), case-hardened wrought steel (Eh), flame or induction hardened wrought special steel (IF), nitrided wrought steel and nitriding steel (NT), through-hardened wrought steel, nitrided, nitrocarburized (NV), grey cast iron (GG) and modular cast iron (GGG). In 2019 edition, formulas to calculate the relative notch sensitivity factor for black malleable cast iron (GTS) are added in section 13.3.2.2, clause e).

### Table 8 Range of validity and limitations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Use with</td>
<td>Application standards for industrial, high-speed and marine gears</td>
<td>Application standards for industrial, high-speed and marine gears</td>
</tr>
<tr>
<td>Applicable also</td>
<td>For rating of bevel gears along ISO 10300 series</td>
<td>For rating of bevel gears along ISO 10300 series</td>
</tr>
<tr>
<td>Limitations</td>
<td>Applicable to all gearing, basic rack profiles, profile dimensions, design, etc.</td>
<td>Applicable to all gearing, basic rack profiles, profile dimensions, design, etc.</td>
</tr>
<tr>
<td>Scope</td>
<td>Range indicated for scope of ISO 6336-1 and ISO 10300-1</td>
<td>Range indicated for scope of ISO 6336-1 and ISO 10300-1</td>
</tr>
</tbody>
</table>

### Figure 5 Helix angle factor \( Y_{h(\alpha)} \), ISO 6336-3:2006

- \( \phi = 0.00 \) to \( \phi = 1.00 \)

### Figure 5 Helix angle factor \( Y_{h(\alpha)} \), ISO 6336-3:2019

- \( \phi = 0.10 \) to \( \phi = 1.00 \)

**Structure of ISO 6336-5:2019, compared to previous edition**

The structure of ISO 6336-5:2016, (Ref.8) is — with below exceptions — the same as in ISO 6336-5:2003, (Ref. 7). Additional subsections have been introduced in 2016 edition:

- Section 4.4 on method Br for determination of allowable stress numbers.
- Annex A was normative in 2003 edition whereas it is informative in 2016 edition.

**Application**

The conditions and limitations for application of ISO 6336-5 remain basically the same and are summarized in the table for the two editions, Table 8:

- Minor changes in the normative references include:
- Some additional references are added (e.g., ISO 642, ISO 683-2, EN 10204 Metallic products — Types of inspection documents).

---

```
**Table 8 Range of validity and limitations**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Use with</td>
<td>Application standards for industrial, high-speed and marine gears</td>
<td>Application standards for industrial, high-speed and marine gears</td>
</tr>
<tr>
<td>Applicable also</td>
<td>For rating of bevel gears along ISO 10300 series</td>
<td>For rating of bevel gears along ISO 10300 series</td>
</tr>
<tr>
<td>Limitations</td>
<td>Applicable to all gearing, basic rack profiles, profile dimensions, design, etc.</td>
<td>Applicable to all gearing, basic rack profiles, profile dimensions, design, etc.</td>
</tr>
<tr>
<td>Scope</td>
<td>Range indicated for scope of ISO 6336-1 and ISO 10300-1</td>
<td>Range indicated for scope of ISO 6336-1 and ISO 10300-1</td>
</tr>
</tbody>
</table>
```
Changes in formulas and factors

In the new section 4.4, Method Br for methods for the determination of allowable stress numbers, the user is cautioned that “…contact stress numbers derived from rolling contact fatigue testing have to be used with caution since they tend to overestimate allowable contact stress numbers…”

There are several minor changes and additions, but the permissible values typically used in gear rating are not changed. Changes include:

- Figure 5: Warning added for ME material grade for alloy steels “…relies heavily on the experience of the manufacturer…”
- Figure 14: Notes added with additional information on embrittlement due to white layer and aluminum containing nitriding steels.
- Figure 17+18, term “CHD” is used instead of “Eht” and “NHD” instead of “Nht”.
- Figure 18: Maximum recommended NHD of 0.8mm is introduced. Values to determine hardness coefficient are moved to appendix B.2. A note is added regarding the use of heavier case depths for general designs.
- Table 3, item 3.1: some changes in the required cleanliness, conditions about calcium and oxygen content is moved to new items 3.2 and 3.3, item 4: requirements on grain size are now more specific, item 5.1: requirements on UT are now more specific, item 6: requirements for area reduction ratio now more specific, item 3: requirements on grain size are now more specific.
- Table 5, item 3.1: some changes in the required cleanliness, conditions about calcium and oxygen content is moved to new items 3.2 and 3.3, item 4: requirements on grain size are now more specific, item 10.4: permissible retained austenite level increased from 25% to 30%, magnetic particle inspection information removed.
- Table 8, item 7: “dwell time” removed, information on NHD added.
- Section 6.5: representative test bar size changed.
- Section 6.7.1: standards for control of shot peening process added.
- Section 6.7.3: use of shot peening as a salvage operation, section added.

Part 6

Overview

The scope of ISO 6336-6:2016, (Ref. 10), is defined as follows:

“This document specifies the information and standardized conditions necessary for the calculation of the service life (or safety factors for a required life) of gears subject to variable loading for only pitting and tooth root bending strength.”

It is noteworthy that this part 6 does not apply for other rating methods covered in ISO 6336 series, namely tooth flank fracture, scuffing and micropitting. Refer to the respective documents to find guideline on how to consider variable loads for these rating procedures.

Structure of ISO 6336-6:2019, compared to previous edition

Section 4.1 and Annex B (informative) with guide values for the application factor K, in ISO 6336-6:2006 has been removed in 2019 edition. They are now given in part 1, see Table 3 above. Otherwise, the structure of the document remains the same with edition 2019 as it was in edition 2006.

Changes in formulas and factors

In 2019 edition of this part 6, at the end of section 4.3 on the Palmgren-Miner rule, a sentence is added as follows: “…Other damage accumulation (including non-linear) hypotheses in addition to the herein described method and permissible damage sums other than one may be used upon agreement of the purchaser and the gear box manufacturer…” This now allows for the use of a permissible total damage different (typically smaller) than unity, or modified Miner’s rule, e.g., using Haibach modification and total permissible damage D = 0.50 as shown in (Ref. 16) to match experiments.

Formulas and the calculation process in section 5 of edition 2019 have not changed compared to 2006 edition. However, the graphics have been extended and improved. For each step in the calculation process, a separate graphic is now available, explaining the calculation step by step.

An additional figure for the case where the life factor ZNT or YNT is less than unity in the range of long life is also included as Figure 5 of the 2019 edition of this part, not shown here.

Figure 6  Load and stress spectrum. Figure 2 in ISO 6336-6:2019. The figure explains how the load (torque) spectrum, represented by the torque levels $T_i$ associated with a speed level $n_i$ each, is converted to a stress spectrum with stress levels $\sigma_i$ (for speed levels $n_i$), using the methods given in ISO 6336-2 and -3. Above and below figures were combined in one figure in 2006 edition, lacking some clarity.
Conclusion

The members of ISO TC 60/SC 2/WG 6 have contributed their expertise and time to advance ISO 6336. Industry experts and researchers have contributed new methods, run calculation examples with newly developed software and discussed how to improve the wording and structure of the document. The result is an even broader, more complex, practical and accurate tool aiming at increased gearbox power density, lowered risk of failures and deepened understanding of mechanisms governing the load capacity of cylindrical gears. Work does not stop here, under the guidance of the convenor, WG 6 is already working on the next edition of the documents.

The above changes will result in different load ratings, some of the differences are substantial, e.g., for internal gears or for helical gears without modifications. Users of ISO 6336 are advised to run extensive comparisons and gain experience using the third edition of ISO 6336. Further papers discussing the pros and cons of the changes or the implications on gear design are desirable. The influence of the changes on application standards and guidelines in specific industries is currently being discussed. This paper may help the engineers responsible for application standards and guidelines in adjusting e.g., K factors or required safety factors listed there.

While care has been taken to list all changes, the complexity of the document will have resulted in some changes having been overlooked. If so, readers’ comments will be appreciated, thank you.

Figure 8 Cumulated stress spectrum and fatigue curve limit when there is an endurance limit, Figure 4 in ISO 6336-6:2019. The figure explains how to represent the total accumulated damage $U$ for the given load spectrum as the ratio $n_{eq}/N_i$ ($i=3$ in this example) where $n_{eq}$ is the lowest stress level still higher than the endurance limit. Note that the bins are shifted by drawing a line of the same slope than the S-N curve from the extremity of the stress bin $\sigma_i$ to the stress level $\sigma_{eq}$. This figure is new in edition 2016, adding clarity.

Figure 7 Stress spectrum and S-N curve, Figure 3 in ISO 6336-6:2019. The figure explains how for a given stress level $\sigma_i$, an allowable number of load cycles $N_i$ can be determined using the S-N curve(s) determined along ISO 6336-2 and -3. Note that the value $\sigma_2$ is either $\sigma_{HG}$ or $\sigma_{FG}$. Above two figures were combined in one figure in 2006 edition, lacking some clarity.
Hanspeter Dinner

studied mechanical engineering at the Swiss Federal Institute of Technology, Zürich, Switzerland and the National University of Singapore. He first worked as FEM engineer with a Swiss consultancy and as lead stress engineer with a roller coaster developer. He joined KISSsoft AG as software support and project engineer. In 2008, he started the consultancy company EES KISSsoft GmbH, representing the KISSsoft company in China, Japan, Korea, Taiwan and India. He has conducted about a hundred FEM, gear, bearings and transmission projects serving the wind, tractor, industrial gearbox and fine pitch gear industry. Since August 2018, he has been working in the function of Director Global Sales with KISSsoft – A Gleason Company.

ISO 6336

For Related Articles Search at www.geartechnology.com

Figure 9 Accumulation of damage, shown here for the first three bins (following bins are below endurance limit in this example). Accumulated damage $U$ is $U = \frac{n_{eq}}{N_3}$. Lines b and c are corresponding to line a (S-N curve determined along ISO 6336-2 or -3) but for higher probability of failure. This figure is the same in both editions.

References

17. VDI 2737, Calculation of the load capacity of the tooth root in internal toothings with influence of the gear rim, 2016.