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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

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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).

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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This 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_{ε};

— modification of the helix angle factor Y_{β};

— calculation of tooth form factor Y_F and stress correction factor Y_S generated with a shaper cutter;

— update to the qualifying comments in ~~chapter~~ 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.

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
Part 1: Basic principles, introduction and general influence factors	X		
Part 2: Calculation of surface durability (pitting)	X		
Part 3: Calculation of tooth bending strength	X		
Part 4: Calculation of tooth flank fracture load capacity		X	
Part 5: Strength and quality of materials	X		
Part 6: Calculation of service life under variable load	X		
Part 20: Calculation of scuffing load capacity — Flash temperature method		X	
Part 21: Calculation of scuffing load capacity — Integral temperature method		X	
Part 22: Calculation of micropitting load capacity (replaces: ISO/TR 15144-1)		X	
Part 30: Calculation examples for the application of ISO 6336-1, ISO 6336-2, ISO 6336-3 and, ISO 6336-5			X
Part 31: Calculation examples of micropitting load capacity (replaces: ISO/TR 15144-2)			X

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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 ~~releases~~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.

Calculation of load capacity of spur and helical gears — Part 30: Calculation examples for the application of ISO 6336-parts 1, ISO 6336-2, ISO 6336-3 and, ISO 6336-.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 outside the scope ofnot 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

There are no normative references in this document.

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) are appliedand the following 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/obphttps://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 ~~used in this document~~

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	µm
C_{B}	Basic rack factor	—
C_{f}	Root relief	µm
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	—

Symbol	Description	Unit
C_{ZR}	Roughness factor exponent	—
$c_{\gamma\alpha}$	Mean value of mesh stiffness per unit facewidth	N/(mm·µm)
$c_{\gamma\beta}$	Mean value of mesh stiffness per unit facewidth	N/(mm·µm)
c'	Maximum tooth stiffness per unit facewidth of gear pair	N/(mm·µm)
~~c'_{th}~~ c'_{th}	Theoretical single stiffness	N/(mm·µm)
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
E	Young's modulus	N/mm^2
$E_{1,2}$	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

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Symbol	Description	Unit
$f_{f\alpha}$	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~~can be used for calculations in accordance with the ISO 6336 series, using tolerances ~~complying with~~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_{ε}	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_{γ}	Mesh load factor	—
k	Number of teeth spanned	—
L	Auxiliary notch parameter	—
l	Bearing span	mm

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Symbol	Description	Unit
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	—
$n_{1,2}$	Rotation speed of pinion (or wheel)	min^{-1}
n_{E1}	Resonance speed	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	(mm·µm)/N
Ra	Arithmetic mean roughness value, Ra = 1/6 Rz	µm
Rz	Mean peak-to-valley roughness (ISO 4287:~~1997~~1997[a] including ISO 4287:1997/Cor 1:1998, ISO 4287:1997/Cor 2:2005, ISO 4287:1997/Amd 1:2009 and ISO 4288:~~1996~~1996[b])	µm
Rz_{10}	Mean relative peak-to-valley roughness for gear pair	µm
S_F	Safety factor for bending	—
S_{Fn}	Tooth root normal chord	mm
S_H	Safety factor for surface durability	—
s	Bearing span offset	mm
s_{pr}	Residual fillet undercut, ~~$s_{pr} = pr - q$~~ $s_{pr} = pr - q$	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

Symbol	Description	Unit
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_β	Helix angle factor	—
$Y_{\delta relT}$	Relative notch sensitivity factor for reference stress	—
y_f	Running-in allowance	µm
y_α	Running-in allowance	µm
y_β	Running-in allowance	µm
Z_B	Single pair tooth contact factor	—
Z_D	Single pair tooth contact factor	—
Z_E	Elasticity factor	~~$\sqrt{N/mm^2}$~~ $\sqrt{N/mm^2}$
Z_H	Zone factor	—
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	—

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Symbol	Description	Unit
Z_X	Size factor	—
Z_v	Velocity factor	—
Z_β	Helix angle factor	—
Z_ε	Contact ratio factor	—
z	Number of teeth	—
z_n	Virtual number of teeth	—
z_0	Pinion cutter number of teeth	—
α_n	Normal pressure angle	°
α_{en}	Virtual form factor pressure angle	°
α_{Fen}	Virtual load direction angle	°
α_t	Transverse pressure angle	°
α_{wt}	Transverse working pressure angle	°
β	Helix angle (without subscript, at reference cylinder)	°
γ	Auxiliary angle	°
ε_α	Transverse contact ratio	—
$\varepsilon_{\alpha n}$	Virtual contact ratio	—
ε_β	Overlap ratio	—
ε_γ	Total contact ratio	—
θ	Auxiliary value (for form factor)	rad
ν	Poisson's ratio	—
ν_{40}	Lubrication viscosity	mm^2/s
ρ	Material density	kg/m^3
ρ	Radius of curvature	mm
ρ_{aP0}	Pinion cutter tip radius coefficient	—
ρ_F	Radius of root fillet	mm
ρ_{fP}	Root fillet radius of the basic rack for cylindrical gears	mm
ρ_{red}	Relative radius of curvature	mm
ρ'	Slip layer thickness	mm

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