INTERNATIONAL STANDARD

ISO 6336-1

Third edition
2019-11

Calculation of load capacity of spur and helical gears —

Part 1:
Basic principles, introduction and general influence factors

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

Partie 1: Principes de base, introduction et facteurs généraux d'influence

Reference number
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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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

This third edition cancels and replaces the second edition (ISO 6336-1:2006), which has been technically revised. It also incorporates the Technical Corrigendum ISO 6336-1:2006/Cor.1:2008.

The main changes compared to the previous edition are as follows:

— incorporation of ISO/TS 6336-4, ISO/TS 6336-20, ISO/TS 6336-21 and ISO/TS 6336-22 into Clause 4 (failure mode);

— update of application factors in Clause 5;

— integration of Clause 10 "Parameters of Hertzian contact";

— integration of Clause 11 "Lubricant parameters at given temperature".

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

ISO 6336 (all parts) 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.

— Technical Specifications (TS) contain calculation methods that are still subject to further development.

— Technical Reports (TR) contain data that is informative, such as example calculations.

The procedures specified in parts 1 to 19 of the ISO 6336 series cover fatigue analyses for gear rating. The procedures described in parts 20 to 29 of the ISO 6336 series are predominantly related to the tribological behavior of the lubricated flank surface contact. Parts 30 to 39 of the ISO 6336 series 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 the ISO 6336 series without referring to specific parts requires the use of only those parts that are currently designated as International Standards (see Table 1 for listing). When requesting further calculations, the relevant part or parts of the ISO 6336 series need to be specified. Use of a Technical Specification as acceptance criteria for a specific design need to be agreed in advance between the manufacturer and the purchaser.

Table 1 — Parts of the ISO 6336 series (status as of DATE OF PUBLICATION)

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 (also applicable to bevel and hypoid gears) — Flash temperature method *(replaces: ISO/TR 13989-1)*		X	
Part 21: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Integral temperature method *(replaces: ISO/TR 13989-2)*		X	
Part 22: Calculation of micropitting load capacity *(replaces: ISO/TR 15144-1)*		X	
Part 30: Calculation examples for the application of ISO 6336 parts 1,2,3,5			X
Part 31: Calculation examples of micropitting load capacity *(replaces: ISO/TR 15144-2)*			X

This document and the other parts of the ISO 6336 series provide a coherent system of procedures for the calculation of the load capacity of cylindrical involute gears with external or internal teeth. The ISO 6336 series is designed to facilitate the application of future knowledge and developments, also the exchange of information gained from experience.

Design considerations to prevent fractures emanating from stress raisers in the tooth flank, tip chipping and failures of the gear blank through the web or hub will need to be analysed by general machine design methods.

Several methods for the calculation of load capacity, as well as for the calculation of various factors, are permitted (see 4.1.16). The directions in ISO 6336 are thus complex, but also flexible.

Included in the formulae are the major factors which are presently known to affect gear tooth damages which are covered by the ISO 6336 series. The formulae are in a form that will permit the addition of new factors to reflect knowledge gained in the future.

Calculation of load capacity of spur and helical gears —

Part 1: Basic principles, introduction and general influence factors

1 Scope

This document presents the basic principles of, an introduction to, and the general influence factors for the calculation of the load capacity of spur and helical gears. Together with the other documents in the ISO 6336 series, it provides a method by which different gear designs can be compared. It is not intended to assure the performance of assembled drive gear systems. It is not intended for 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 ISO 6336 series includes procedures based on testing and theoretical studies as referenced by each method. The methods are validated for:

— normal working pressure angle from 15° to 25°;

— reference helix angle up to 30°;

— transverse contact ratio from 1,0 to 2,5.

If this scope is exceeded, the calculated results will need to be confirmed by experience.

The formulae in the ISO 6336 series are not applicable when any of the following conditions exist:

— gears with transverse contact ratios less than 1,0;

— interference between tooth tips and root fillets;

— teeth are pointed;

— backlash is zero.

The rating formulae in the ISO 6336 series are not applicable to other types of gear tooth deterioration such as plastic deformation, case crushing and wear, and are not applicable under vibratory conditions where there can be an unpredictable profile breakdown. The ISO 6336 series does not apply to teeth finished by forging or sintering. It is not applicable to gears which have a poor contact pattern.

The influence factors presented in these methods form a method to predict the risk of damage that aligns with industry and experimental experience. It is possible that they are not entirely scientifically exact. Therefore, the calculation methods from one part of the ISO 6336 series is not applicable in another part of the ISO 6336 series unless specifically referenced.

The procedures in the ISO 6336 series provide rating formulae for the calculation of load capacity with regard to different failure modes such as pitting, tooth root breakage, tooth flank fracture, scuffing and micropitting. At pitch line velocities below 1 m/s the gear load capacity is often limited by abrasive wear (see other literature such as References [23] and [22] for further information on such calculation).

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 53:1998, *Cylindrical gears for general and heavy engineering — Standard basic rack tooth profile*

ISO 1122-1:1998, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 1328-1:2013, *Cylindrical gears — ISO system of flank tolerance classification — Part 1: Definitions and allowable values of deviations relevant to flanks of gear teeth*

ISO 21771:2007, *Gears — Cylindrical involute gears and gear pairs — Concepts and geometry*

ISO 6336-2, *Calculation of load capacity of spur and helical gears — Part 2: Calculation of surface durability (pitting)*

ISO 6336-3, *Calculation of load capacity of spur and helical gears — Part 3: Calculation of tooth bending strength*

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

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

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1:1998 and ISO 21771:2007 apply.

ISO and IEC maintain terminological databases for use in standardization at following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.2 Symbols and abbreviated terms

For the purpose of this document, the symbols and abbreviated terms given in ISO 1122-1:1998, ISO 21771:2007 and Table 2 apply. Further general symbols and abbreviated terms used for the calculation of load capacity of spur and helical gears can be found in Annex F.

NOTE Symbols are based on, and are extensions of, the symbols given in ISO 701 and ISO 1328-1:2013. Only symbols for quantities used for the calculation of the particular factors treated in the ISO 6336 series are given, together with the preferred units.

Table 2 — Abbreviated terms and symbols used in this document

Abbreviated terms	
Terms	**Description**
A, B, C, D, E	points on path of contact (pinion root to pinion tip, regardless of whether pinion or wheel drives, only for geometrical considerations)
CP	contact point
EAP	end of active profile (for driving pinion: contact point E, for driving wheel: contact point A)
Eh	material designation for case-hardened wrought steel
GG	material designation for grey cast iron
GGG	material designation for nodular cast iron (perlitic, bainitic, ferritic structure)
GTS	material designation for black malleable cast iron (perlitic structure)
IF	material designation for flame or induction hardened wrought special steel
NT	material designation for nitrided wrought steel, nitriding steel
NV	material designation for through-hardened wrought steel, nitrided, nitrocarburized
SAP	start of active profile (for driving pinion: contact point A, for driving wheel: contact point E)
St	material designation for normalized base steel (σ_B < 800 N/mm^2)
V	material designation for through-hardened wrought steel, alloy or carbon ($\sigma_B \geq$ 800 N/mm^2)

Symbols		
Symbol	**Description**	**Unit**
B	total face width of double helical gear including gap width	mm
B_f	non-dimensional parameter taking into account the effect of profile form deviations on the dynamic load	—
B_k	non-dimensional parameter taking into account the effect of tip and root reliefs on the dynamic load	—
B_p	non-dimensional parameter taking into account the effect of transverse base pitch deviations on the dynamic load	—
B^*	constant (see formulae in Clause 7)	—
b	face width	mm
b_{cal}	calculated face width	mm
b_{c0}	length of tooth bearing pattern at low load (contact marking)	mm
b_H	half of the Hertzian contact width	mm
b_{red}	reduced face width (face width minus end reliefs)	mm
b_s	web thickness	mm

[a] For external gears a, d, d_a, z_1 and z_2 are positive; for internal gearing, a, d, d_a and z_2 have a negative sign, z_1 has a positive sign. All calculated diameters have a negative sign for internal gearing.

[b] The components in the plane of action are determinant.

Table 2 *(continued)*

Symbols		
Symbol	**Description**	**Unit**
b_B	face width of one helix on a double helical gear	mm
$b_{I(II)}$	length of end relief	mm
C	constant, coefficient	—
	relief of tooth flank	µm
C_a	tip relief	µm
C_{ay}	tip relief by running-in	µm
C_B	basic rack factor (same rack for pinion and wheel)	—
C_{B1}	basic rack factor (pinion)	—
C_{B2}	basic rack factor (wheel)	—
C_f	root relief	µm
C_M	correction factor (see Clause 9)	—
C_R	gear blank factor (see Clause 9)	—
C_β	crowning height	µm
$C_{I(II)}$	end relief	µm
c	constant	—
c_γ	mean value of mesh stiffness per unit face width	N/(mm·µm)
$c_{\gamma\alpha}$	mean value of mesh stiffness per unit face width (used for K_v, $K_{H\alpha}$, $K_{F\alpha}$)	N/(mm·µm)
$c_{\gamma\beta}$	mean value of mesh stiffness per unit face width (used for $K_{H\beta}$, $K_{F\beta}$)	N/(mm·µm)
c'	maximum tooth stiffness per unit face width (single stiffness) of a tooth pair	N/(mm·µm)
c'_{th}	theoretical single stiffness	N/(mm·µm)
D	diameter (design)	mm
D_I	deflection increment	µm
d	diameter (without subscript, reference diameter)[a]	mm
	effective twist diameter (Annex E)	mm
d_a	tip diameter[a]	mm
d_b	base diameter	mm
d_f	root diameter	mm
d_{in}	inside shaft diameter (Annex E)	mm
d_m	mean diameter for calculating reduced gear pair mass	mm
d_{Na}	active tip diameter of pinion or wheel	mm

[a] For external gears a, d, d_a, z_1 and z_2 are positive; for internal gearing, a, d, d_a and z_2 have a negative sign, z_1 has a positive sign. All calculated diameters have a negative sign for internal gearing.

[b] The components in the plane of action are determinant.

Table 2 *(continued)*

Symbols		
Symbol	**Description**	**Unit**
d_{sh}	external diameter of shaft, nominal for bending deflection	mm
d_{shi}	internal diameter of a hollow shaft	mm
d_w	pitch diameter	mm
$d_{1,2}$	reference diameter of pinion (or wheel)	mm
E	modulus of elasticity	N/mm^2
E_r	reduced modulus of elasticity	N/mm^2
F	composite and cumulative deviations	µm
	force or load	N
F_{bt}	nominal transverse load in plane of action (base tangent plane)	N
$F_{bt\ eff}$	total load in the plane of action	N
F_g	total load on the gearset	N
F_m	mean transverse tangential load at the reference circle relevant to mesh calculations, $F_m = F_t K_A K_\gamma K_v$	N
$F_{m\ T}$	mean transverse tangential part load at reference circle	N
F_{max}	maximum tangential tooth load for the mesh calculated	N
F_t	(nominal) transverse tangential load at reference cylinder per mesh	N
F_{tH}	determinant tangential load in a transverse plane for $K_{H\alpha}$ and $K_{F\alpha}$, $F_{tH} = F_t K_A K_\gamma K_v K_{H\beta}$	N
$F_{\beta x}$	initial equivalent misalignment (before running-in)	µm
$F_{\beta x\ cv}$	initial equivalent misalignment for the determination of the crowning height (estimate)	µm
$F_{\beta x\ T}$	equivalent misalignment measured under a partial load	µm
$F_{\beta y}$	effective equivalent misalignment (after running-in)	µm
f	deviation, tooth deformation	µm
f_{be}	component of equivalent misalignment [b] due to bearing deformation	µm
f_{ca}	component of equivalent misalignment [b] due to case deformation	µm
f_F	load correction factor	—
$f_{f\alpha}$	profile form deviation (the value for the total profile deviation F_α may be used alternatively for this, if tolerances complying with ISO 1328-1:2013 are used)	µm
$f_{f\alpha\ eff}$	effective profile form deviation after running-in	µm
f_{ma}	mesh misalignment[b] due to manufacturing deviations	µm

[a] For external gears a, d, d_a, z_1 and z_2 are positive; for internal gearing, a, d, d_a and z_2 have a negative sign, z_1 has a positive sign. All calculated diameters have a negative sign for internal gearing.

[b] The components in the plane of action are determinant.

Table 2 *(continued)*

Symbols		
Symbol	**Description**	**Unit**
$f_{pb\ eff}$	transverse effective base pitch deviation after running-in	µm
f_{pt}	transverse single pitch deviation	µm
$f_{par\ act}$	non-parallelism of pinion and wheel axes (manufacturing deviation)[b]	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 complying with ISO 1328-1:2013)	µm
f_{sh}	component of equivalent misalignment [b] due to deformations of pinion and wheel shafts	µm
f_{shT}	component of misalignment due to shaft and pinion deformation measured at a partial load	µm
$f_{\Sigma\beta}$	shaft parallelism out-of-plane deviation according to ISO/TR 10064-3:1996	—
$f_{H\beta}$	helix slope deviation (the value for the total helix deviation F_β may be used alternatively for this, if tolerances complying with ISO 1328-1:2013 are used)	µm
$f_{\alpha\ eff}$	effective single profile deviation	µm
f_δ	torsional deflection	µm
$f_{H\beta 5}$	tolerance on helix slope deviation for ISO tolerance class 5	µm
G	shear modulus	N/mm^2
g	path of contact	mm
g_α	length of path of contact	mm
h	tooth depth (without subscript, root circle to tip circle)	mm
h_{aP}	addendum of basic rack of cylindrical gears	mm
h_{fP}	dedendum of basic rack of cylindrical gears	mm
h_t	tooth height	mm
I	moment of inertia	mm^4
I_{CS}	integration constant	µm
J^*	moment of inertia per unit face width	kg·mm^2/mm
K	constant, factors concerning tooth load	—
K'	constant of the pinion offset	—
K_A	application factor	—
$K_{A\text{-}A}$	application factor (Method A)	—
$K_{A\text{-}B}$	application factor (Method B)	—
$K_{FA\text{-}A}$	application factor for tooth root breakage along ISO 6336-3 (Method A)	—

[a] For external gears a, d, d_a, z_1 and z_2 are positive; for internal gearing, a, d, d_a and z_2 have a negative sign, z_1 has a positive sign. All calculated diameters have a negative sign for internal gearing.

[b] The components in the plane of action are determinant.

Table 2 *(continued)*

Symbols		
Symbol	**Description**	**Unit**
$K_{\text{FA-B}}$	application factor for tooth root breakage along ISO 6336-3 (Method B)	—
$K_{\text{F}\alpha}$	transverse load factor (root stress)	—
$K_{\text{F}\alpha\text{-A}}$	transverse load factor (root stress) (Method A)	—
$K_{\text{F}\alpha\text{-B}}$	transverse load factor (root stress) (Method B)	—
$K_{\text{FFA-A}}$	application factor for tooth flank fracture along ISO/TS 6336-4 (Method A)	—
$K_{\text{FFA-B}}$	application factor for tooth flank fracture along ISO/TS 6336-4 (Method B)	—
$K_{\text{F}\beta}$	face load factor (root stress)	—
$K_{\text{F}\beta\text{-A}}$	face load factor (root stress) (Method A)	—
$K_{\text{F}\beta\text{-B}}$	face load factor (root stress) (Method B)	—
$K_{\text{F}\beta\text{-C}}$	face load factor (root stress) (Method C)	—
$K_{\text{H}\alpha}$	transverse load factor (contact stress)	—
$K_{\text{H}\alpha\text{–A}}$	transverse load factor (contact stress) (Method A)	—
$K_{\text{H}\alpha\text{–B}}$	transverse load factor (contact stress) (Method B)	—
$K_{\text{H}\beta}$	face load factor (contact stress)	—
$K_{\text{H}\beta\text{-A}}$	face load factor (contact stress) (Method A)	—
$K_{\text{H}\beta\text{-B}}$	face load factor (contact stress) (Method B)	—
$K_{\text{H}\beta\text{-C}}$	face load factor (contact stress) (Method C)	—
K_{v}	dynamic factor	—
$K_{\text{v-A}}$	dynamic factor (Method A)	—
$K_{\text{v-B}}$	dynamic factor (Method B)	—
$K_{\text{v-C}}$	dynamic factor (Method C)	—
K_{γ}	mesh load factor (takes into account the uneven distribution of the load between meshes for multiple transmission paths)	—
K_{λ}	application factor for micropitting along ISO/TS 6336-22	—
$K_{\lambda\text{A-A}}$	application factor for micropitting along ISO/TS 6336-22 (Method A)	—
$K_{\lambda\text{A-B}}$	application factor for micropitting along ISO/TS 6336-22 (Method B)	—
K_{ϑ}	application factor for scuffing along ISO/TS 6336-20/ISO/TS 6336-21	—
$K_{\vartheta\text{A-A}}$	application factor for scuffing along ISO/TS 6336-20/ISO/TS 6336-21 (Method A)	—
$K_{\vartheta\text{A-B}}$	application factor for scuffing along ISO/TS 6336-20/ISO/TS 6336-21 (Method B)	—

[a] For external gears a, d, d_a, z_1 and z_2 are positive; for internal gearing, a, d, d_a and z_2 have a negative sign, z_1 has a positive sign. All calculated diameters have a negative sign for internal gearing.

[b] The components in the plane of action are determinant.