



**International
Standard**

ISO 14521

**Gears — Calculation of load capacity
of worm gears**

*Engrenages — Calcul de la capacité de charge des engrenages à
vis*

**First edition
2026-09**

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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 document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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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 1, *Accuracy, nomenclature and wormgearing*.

This first edition cancels and replaces ISO/TS 14521:2020, which has been technically revised.

The main changes are as follows:

- conversion of ISO/TS 14521 to an International Standard;
- update of terminology and symbols for coherence with ISO 10828;
- "Hertzian stress" replaced with "Hertzian pressure";
- integration of Method B in [Annex B](#);
- update of [Annex C](#) formulae;
- update of [Figure D.2](#);
- update of Bibliography.

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

This document was developed for the rating and design of enclosed or open single enveloping worm gears with cylindrical worms, and cylindrical worm-gearred motors having either solid or hollow output shafts.

This document is only applicable when the flanks of the worm wheel teeth are conjugate to those of the worm threads.

The particular shapes of the rack profiles from tip to root do not affect the conjugacy when the worm and worm wheel hobs have the same profiles; thus worm wheels have proper contact with worms and the motions of worm gear pairs are uniform.

This document can apply to wormgearing with cylindrical helicoidal worms as defined in ISO 10828 having the following thread forms: A, C, I, N, K.

Other than those mentioned in the three preceding paragraphs, no restrictions are placed on the manufacturing methods used.

In order to ensure proper mating and because of the many different thread profiles in use, it is generally desirable that worms and worm wheels be supplied by the same manufacturer.

In this document, the permissible torque for a worm gear is limited by considerations of surface stresses (conveniently referred to as wear or pitting) or bending stresses (referred to as strength) in both worm threads and worm wheel teeth, worm deflection or thermal limitation.

Consequently, the load capacity of a pair of gears is determined using calculations concerned with all criteria described in the scope and [6.4](#). The permissible torque on the worm wheel is the least of the calculated values.

The choice of appropriate methods of calculation requires knowledge and experience. This document is intended for use by experienced gear designers who can make informed judgements concerning factors. It is not intended for use by engineers who lack the necessary experience. See [4.7](#).

WARNING — The geometry of worm gears is complex; therefore the user of this document is encouraged to make sure that a valid working geometry has been established.

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Gears — Calculation of load capacity of worm gears

1 Scope

This document specifies formulae for calculating the load capacity of cylindrical worm gears and covers load ratings associated with wear, pitting, worm deflection, tooth breakage and temperature. Scuffing and other failure modes are not covered by this document.

NOTE 1 The load rating and design procedures are only valid for tooth surface sliding velocities, $\bar{v}_g$, less than or equal to 25 m/s and contact ratios greater than 2,1.

NOTE 2 For wear, load rating and design procedures are only valid for tooth surface sliding velocities which are above 0,1 m/s.

NOTE 3 The rules and recommendations for the dimensioning, lubricants or materials selected by this document only apply to centre distances of 50 mm and larger. For centre distances below 50 mm, method A applies.

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 1122-2, *Vocabulary of gear terms — Part 2: Definitions related to worm gear geometry*

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

ISO 10828, *Worm gears — Worm profiles and gear mesh geometry*

3 Terms and definitions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1, ISO 1122-2 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

actual gear

worm gear set designed by this document

3.2 Symbols

This document shall be used with symbol notations in accordance with ISO 701 and geometric definitions as defined and developed in ISO 10828.

Table 1 — Symbols for worm gears

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
a	centre distance	mm	Figure 1	—
a_0, a_1, a_2	oil sump temperature coefficients determined according to Method C	—	—	(118) to (124)
a_T	centre distance of standard reference gear	mm	Figure 1	—
a_{T1}	centre distance of a gear operating or test experiences are available	mm	Table 5	—
b_{2H}	effective worm wheel facewidth	mm	—	—
$b_{2H, std}$	standard effective worm wheel facewidth	mm	—	(10)
b_{2R}	wheel rim width	mm	—	—
b_H	half of the Hertzian contact width	mm	Annex D	(D.2)
CL	Lines of contact for a relative position of the worm gear set	—	Annex B, C, D	—
c_k	coefficient for heat transition coefficient	—	—	(133)
c_{oil}	specific heat capacity of the oil (for temperature calculation with spray lubrication)	Ws/(kg°K)	—	(128)
c_α	proximity value for the viscosity pressure exponent α	m ² /N	—	(22) to (24)
d_{a1}	worm tip diameter	mm	—	(89)
d_{a2}	worm wheel tip diameter	mm	—	—
d_{e2}	worm wheel outside diameter	mm	—	—
$\overline{dF}_n$	force transmitted by a segment of a line of contact	N	Figure B.2	(B.3)
dl	length of a segment of a line of contact	mm	Figure B.1	(B.1) to (B.6)
d_{f1}	worm root diameter	mm	—	(104)
d_{f2}	worm wheel root diameter	mm	—	—
d_{m1}	worm reference diameter	mm	—	—
d_{m2}	worm wheel reference diameter	mm	—	(41) to (43)
d_{m1T}	reference diameter of the worm, from standard reference gear	mm	Table 5	(44) , (45)
d_{m2T}	reference diameter of the wheel, from standard reference gear	mm	Table 5	—
dl	length of the segment of line of contact where $\overline{dF}$ is applied	—	—	—
$\vec{e}_x$	unit vector pointing in direction of the x-axis	mm	—	(B.4)
f_h	worm wheel facewidth factor for the parameter for the mean minimum lubricant film thickness	—	—	(16)
f_p	worm wheel facewidth factor for the parameter for the mean Hertzian pressure	—	—	(13)
h_{am1}	worm tooth reference addendum in axial section	mm	—	(86)
h_{am2}	worm wheel tooth reference addendum in middle section	mm	6.4.1.4 Method C Note	—
h_{min}	minimum lubricant film thickness	µm	—	(C.1)
$h_{min m}$	mean minimum lubricant film thickness	µm	—	(21)

Table 1 (continued)

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
h^*	parameter for the mean minimum lubricant film thickness	—	—	(14)/(15)
h_T^*	parameter for the mean minimum lubricant film thickness of the standard reference gear	—	Table 5	—
k	lubricant constant	1/°K	—	(27) to (29)
l_1	spacing of the worm shaft bearings	mm	—	(103)
l_{11}, l_{12}	bearing spacing of the worm shaft	mm	Figure 5	(103)
m_{x1}	axial module	mm	—	—
$\vec{n}$	normal vector	—	—	(B.5)
n_1	rotational speed of the worm shaft	min ⁻¹	—	—
p_H	Hertzian pressure	N/mm ²	—	(B.1)/(B.6)
p_{Hm}	Hertzian pressure; mean value for the total contact area	N/mm ²	—	(B.7)
p_m^*	parameter for the mean Hertzian pressure	—	—	(11)/(12)/(B.8)
p_{mT}^*	parameter for the mean Hertzian pressure of the standard reference gear	—	Table 5	—
q_1	diameter quotient	—	—	—
$\vec{r}$	radius from the axis of the worm wheel to the contact point B	mm	—	(B.4)
s_{f2}	mean tooth root thickness of the wheel teeth in the spur section	mm	—	(111)
s_{ft2}	mean tooth root thickness of the wheel teeth in the spur section	mm	—	(111)
s_{gB}	sliding path of the worm flanks within the Hertzian contact of the wheel flank per number of cycles of the wheel, around the contact point (local value)	mm	—	(D.3)/(D.5)
s_{gm}	mean sliding path	mm	—	(D.7)
s_{m2}	tooth thickness at the reference diameter of the worm wheel	mm	—	(111)
s_K	rim thickness	mm	Figure 6	—
s_{Wm}	wear path inside of the required life expectancy	mm	—	(30)/(D.1)
s_{mx1}	worm tooth thickness in axial section	mm	—	—
s_{mx1}^*	worm tooth thickness in axial section coefficient	—	—	—
s^*	parameter for the mean sliding path	—	—	(17)/(18)/(D.11)
s_T^*	parameter for the mean sliding path of the standard reference gear	—	Table 5	—
$t_{contact}$	time of contact	s	—	(D.2)
u	gear ratio	—	—	—
u_T	gear ratio of the standard reference gear	—	Table 5	—
$\vec{v}_1$	velocity of a flank point of the worm	m/s	Figure B.1	—
$\vec{v}_2$	velocity of a flank point of a worm wheel	m/s	Figure B.1	—

Table 1 (continued)

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
v_{1n}	worm velocity component normal to the line of contact	m/s	Figure B.2	—
v_{2n}	wheel velocity component normal to the contact line	m/s	Figure B.2	(D.2)
$\overline{v_{gB}}$	sliding velocity normal to the line of contact in flank direction	m/s	—	(D.3)/(D.5)/(D.6)
v_g	sliding velocity at reference diameter	m/s	—	(9)/(49)/(50)/(51)/(H.2)/(H.3)/(H.5)
v_{ref}	reference sliding velocity	m/s	—	(H.2) to (H.5)
x_2	worm wheel profile shift coefficient	—	—	—
z_1	number of threads in worm	—	—	—
z_2	number of teeth in worm wheel	—	—	—
A	coefficient for kinematic viscosity	—	—	(33)
A_{fl}	total flank surface of the worm wheel	mm ²	—	(89)
A_R	dominant cooled surface of the gear set	m ²	—	(132)
B	coefficient for kinematic viscosity	—	—	(34)
B	coefficient for h^*	mm	—	(14)
E_1	modulus of elasticity of the worm	N/mm ²	—	—
E_2	modulus of elasticity of the worm wheel	N/mm ²	—	—
E_{red}	reduced modulus of elasticity	N/mm ²	Table 5	(20)
F_{xm1}	axial force to the worm shaft	N	—	(4)/(7)
F_{xm2}	axial force to the worm wheel	N	—	(3)/(6)
F_{rm1}	radial force to the worm shaft	N	—	(5)
F_{rm2}	radial force to the worm wheel	N	—	(11)
F_{tm1}	circumferential or tangential force to the worm shaft	N	—	(3)/(6)/(8)
F_{tm2}	circumferential or tangential force to the worm wheel	N	—	(4)/(7)
dF/dl	specific loading	N/mm	—	(C.5)
J_{OT}	reference wear intensity	—	Figure 4	(69) to (79)
$J_{OI}, J_{OII}, J_{OIII}$	reference wear intensity for stage I, II, III	—	—	(H.6) to (H.7)
J_W	wear intensity	—	—	(68)
J_{WP}	wear intensity	—	—	(H.6)
K_n	rotational speed factor/wheel bulk temperature	—	—	(135)
$K_{H\alpha}$	transverse load distribution factor	—	—	6.2.3
$K_{H\beta}$	longitudinal load distribution factor	—	—	6.2.3
K_S	size factor for wheel bulk temperature	—	—	(137)
K_A	application factor	—	—	6.2.1
K_v	dynamic factor	—	—	6.2.2
K_W	lubricant film thickness parameter	—	—	(80)
K_v	viscosity factor/wheel bulk temperature	—	—	(136)
K_1	factor	—	—	(G.5)
L_h	life time	h	—	—
N_L	number of stress cycles of the worm wheel	—	—	(31)

Table 1 (continued)

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
$N_{LI}, N_{LII}, N_{LIII}$	number of stress cycles of the worm wheel for stage I to III	—	—	(H.1)
N_S	number of starts per hour	—	—	(70)
P_1	input power to the worm shaft	W	—	—
P_2	output power from the worm wheel shaft	W	—	—
P_K	cooling capacity of the oil with spray lubrication	W	—	(127)(125)
P_V	total power loss of the worm gear unit	W	—	(37)
P_{V0}	idle running power loss	W	—	(38)/(39)/(G.1)
P_{Vz1-2}	meshing power loss in reducer	W	—	(63)
P_{Vz2-1}	meshing power loss in increaser	W	—	(64)
P_{VD}	sealing power loss	W	—	(44)/(45)
P_{VLP}	bearing power loss through loading	W	—	(40) to (43)
Q_{oil}	spray quantity	m ³ /s	—	(127)
Ra_1	arithmetic mean roughness for worm	µm	Table 5	—
Ra_T	arithmetic mean roughness for reference gear	µm	—	(62)
Rz_1	mean roughness depth	µm	—	7.4.6
S_F	tooth breakage safety factor	—	—	(106)
S_{Fmin}	minimum tooth breakage safety factor	—	—	(107)
S_H	pitting safety factor	—	—	(91)
S_{Hmin}	minimum pitting safety factor	—	—	(92)
S_T	temperature safety factor	—	—	(115)/(125)
S_{Tmin}	minimum temperature safety factor	—	—	(116)/(126)
S_W	wear safety factor	—	—	(65)
S_{Wmin}	minimum wear safety factor	—	—	(66)
S_δ	worm deflection safety factor	—	—	(101)
$S_{\delta min}$	minimum worm deflection safety factor	—	—	(102)
T_1	input torque to the worm shaft	Nm	—	(1)
T_{1N}	nominal input torque to the worm shaft	Nm	—	(1)
T_2	output torque from the worm wheel	Nm	—	(2)/(B.4)/(B.5)
T_{2N}	nominal output torque from the worm wheel	Nm	—	(2)
V_{SUMn}	sum of velocities at contact point	—	—	(C.1)
W_H	pressure factor	—	—	(84)/(85)
W_{ML}	material — lubricant factor	—	Table 8	—
W_{NS}	start factor	—	—	(83)
W_P	damage factor	—	—	(H.8)
W_S	lubricant structure factor	—	—	(81)/(82)
Y_F	form factor for tooth breakage	—	—	(110)
Y_G	geometry factor for coefficient of friction	—	—	(59)/(60)
Y_K	rim thickness factor for tooth breakage	—	—	(113)
Y_{NL}	life factor for tooth breakage	—	Figure 7 a)/b)	Table 12
Y_R	roughness factor for coefficient of friction	—	—	(61)/(62)
Y_S	size factor for coefficient of friction	—	—	(57)/(58)

Table 1 (continued)

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
Y_W	material factor for coefficient of friction	—	—	—
Y_ε	contact factor for tooth breakage	—	—	(109)
Y_γ	lead factor for tooth breakage	—	—	(112)
Z_h	life factor for pitting	—	—	(94)
Z_{oil}	lubricant factor for pitting	—	—	(100)
Z_S	size factor for pitting	—	—	(96)/(97)
Z_u	gear ratio factor	—	—	(98)/(99)
Z_v	velocity factor for pitting	—	—	(95)
α_L	heat transition coefficient for immersed wheel teeth	W/(m ² °K)	—	(133)
α_n	normal pressure angle	°	—	(5), (86)
Δf	relative deviation between a quantity of the gear concerned and a reference gear	—	Figure 1	—
Δf_T	relative deviation between the centre distance of the gear concerned and the standard reference gear	—	Figure 1	—
Δf_{T1}	relative deviation between the centre distance of the gear concerned and a gear operating or test experiences are available	—	Figure 1	—
Δm_{lim}	material loss limit	mg	—	(88)
Δs	tooth thickness loss	mm	—	(111)
Δs_{lim}	allowable tooth thickness loss	mm	—	(87)/(111)
γ_{m1}	reference lead angle of worm	°	—	(86)
δ_{lim}	limiting value of the worm deflection	mm	—	(105)
δ_m	worm deflection – Method C	mm	—	(103)/(104)
δ_{Wn}	flank loss from wheel through abrasive wear in the normal section	mm	—	(67)
$\delta_{W lim n}$	limiting value of the flank loss in the normal section	mm	—	(86) to (88) + (90)
η_{ges1-2}	total efficiency worm driving wheel	—	—	(35)
η_{ges2-1}	total efficiency wheel driving worm	—	—	(36)
η'_{ges}	total efficiency in increaser	—	—	(36)
η_{z1-2}	gear efficiency in reducer	—	—	(46)
η_{z2-1}	gear efficiency in increaser	—	—	(47)
η_{0M}	dynamic viscosity of lubricant at ambient pressure and wheel bulk temperature	Ns/m ²	—	(25)/(C.1)
θ	temperature	°C	—	—
$\Delta\theta$	temperature difference between oil sump and worm wheel bulk temperature	°C	—	(131)
θ_{in}	oil entrance temperature	°C	—	(129)
θ_0	ambient temperature	°C	—	—
θ_{oil}	spray temperature	°C	—	(129)
$\Delta\theta_{oil}$	oil temperature difference between input and output cooling system	°C	—	(129)
θ_M	wheel bulk temperature	°C	—	(130)/(134)
θ_S	oil sump temperature	°C	—	(117)

Table 1 (continued)

Symbols	Description	Unit	Figure/ Table/ Annex	Formula
$\theta_{S \text{ lim}}$	limiting value of the oil sump temperature	°C	—	(115)
μ_{0T}	base coefficient of friction	—	—	(49) to (56)
μ_{zm}	mean tooth coefficient of friction	—	—	(48)
ν_1	Poisson's ratio of the worm	—	—	—
ν_2	Poisson's ratio for the worm wheel	—	—	—
ν_θ	kinematic viscosity at oil temperature θ	mm ² /s	—	—
ν_{40}	kinematic viscosity at 40 °C	mm ² /s	—	—
ν_{100}	kinematic viscosity at 100 °C	mm ² /s	—	—
ν_M	kinematic viscosity at wheel bulk temperature	mm ² /s	—	(25)
ρ_1, ρ_2	local radius of curvature	mm	—	(B.2)
ρ_{oil}	lubricant density	kg/dm ³	—	(127)
ρ_{oil15}	lubricant density at 15 °C	kg/dm ³	—	(25)
ρ_{oilM}	lubricant density at wheel bulk temperature	kg/dm ³	—	(26)
ρ_{red}	equivalent radius of curvature	mm	—	(B.2)
ρ_z	friction angle for the tooth coefficient of friction	—	—	(5)
ρ_{Rad}	material density of the wheel	mg/mm ³	Table 9	(88)
$\sigma_{H \text{ lim T}}$	pitting resistance for contact stress	N/mm ²	Table 10	—
σ_{Hm}	mean contact stress	N/mm ²	—	(19)
σ_{HG}	limiting value of the mean contact stress	N/mm ²	—	(93)
τ_F	nominal shear stress at tooth root	N/mm ²	—	(108)
$\tau_{F \text{ lim T}}$	shear stress endurance limit	N/mm ²	Table 11	—
τ_{FG}	limiting value of the shear stress at tooth root	N/mm ²	—	(114)

4 General consideration

4.1 Worm gear load capacity rating criteria

The load capacity of a worm gear corresponds to the torque (or the power) which can be transmitted without the occurrence of tooth breakage or the appearance of excessive damage on the active flanks of the teeth during the design life of the gearing.

Conditions shown in Table 2 can limit the rated load capacity.