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Worm gears — Worm profiles and gear mesh geometry

Engrenage à vis cylindriques — Géométrie des profils de vis et de l'engrènement

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 60, *Gears*, Subcommittee SC 1, *Nomenclature and wormgearing*.

This first edition of ISO 10828 cancels and replaces the second edition of ISO/TR 10828:2015.

The main changes are as follows:

— conversion from a Technical Report to an International Standard and implementation of necessary editorial changes;

— incorporation of a new Annex H on interface for geometry for involute worms defined as cylindrical gear with ISO 21771-1.

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 includes the formulation for the geometrical dimensions of the worm and worm wheel, and that for the determination of gear mesh geometry (path of contact, zone and lines of contact) with the details to determine the non-dimensional parameters used to apply load capacity calculations (radius of curvature, sliding velocities). Thread forms of the worms of worm gear pairs are commonly related to the following machining processes:

— the type of machining process (turning, milling, grinding, metal forming);

— the shapes of edges or surfaces of the cutting tools used;

— the tool position relative to an axial plane of the worm;

— where relevant, the diameters of disc type tools (grinding wheel diameter).

The calculations developed in this document are relatively complex as they involved primary and secondary derivatives of mathematical expression. In order to facilitate the writing of equations, the numerators in the left part of formulae are often omitted; this is why several formulae have special symbols and are not written in a mathematical way:

Example in Formula (B.12) $\frac{d}{dy_G}\alpha_{\mathrm{G}}\left(y_{\mathrm{G}}\right)$ is written $\mathrm{d}\alpha_{\mathrm{G}}\left(y_{\mathrm{G}}\right)$

Example in Formula (B.14) $\frac{d^2}{dy_G{}^2}\alpha_{\mathrm{G}}\left(y_{\mathrm{G}}\right)$ is written $\mathrm{d}2\alpha_{\mathrm{G}}\left(y_{\mathrm{G}}\right)$

In this document, the figures show a generic representation of worm profile types A, I, N, K, C. For the influence of different worm profile types, see Annex E.

This document introduces all the aspects concerning the gear mesh geometry to define conjugate worm wheel, path of contact, lines of contact and other associated geometrical characteristics.

Worm gears — Worm profiles and gear mesh geometry

1 Scope

This document describes the thread profiles of the five most common worm profile types and provides formulae of their axial profiles.

The five worm profile types covered in this document are designated by the letters A, C, I, K and N.

This document provides the formulae to calculate the path of contact, the conjugate profile of the worm wheel, the lines of contact, the radius of curvature and the velocities at points of contact. The application of those formulae to calculate parameters used in load capacity calculations are provided in 11.11.

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 701, *International gear notation — Symbols for geometrical data*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 701 and ISO 1122-2 and 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/obp

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

3.1
mid plane of worm wheel
plane perpendicular to its datum axis containing the centre of virtual major torus radius generating tooth flanks

Note 1 to entry: See Figure 26.

Note 2 to entry: It can be axially located by measuring the position of inflection point along the helix of the cylinder of the worm wheel defined by the measurement diameter for worm wheel. In hobbed worm wheel, the number of flutes can influence the tooth flank surface and consequently the mid plane detection.

3.2
axial plane of worm
plane containing the line of axis of the worm defined by its datum axis

Note 1 to entry: Diameters can be measured in this plane, but thread surfaces would require a theoretical sharpened edge measurement probe or correction in order to keep the contact point between the probe and the flank in this plane.

4 Symbols and abbreviated terms

Table 1 to Table 3 provide the symbols, the indices and the descriptions used in this document.

NOTE First and second derivatives symbols are not listed in Table 1 and Table 2.

Table 1 — Symbols for worm gears

Symbols	Description	Units	Figure numbers	Formula numbers
A	distance from the worm axis to virtual point of the cutter (see Reference [4])	mm	A.4	—
a	centre distance	mm	5	42 and 43
a_0	refers to the worm/tool centre distance (length of the common perpendicular to the worm/tool axes)	mm	22	55
a_1 to a_4	coefficients for A, I and N profile	—		See Table 5
b_1	facewidth of worm	mm		24
b_{2H}	effective wheel facewidth	mm	5	40
b_{2R}	wheel rim width	mm	5	—
$b_{\phi 2}$	face end chamfer depth	mm	5	—
c_1,c_2	tip clearance	mm	—	47 and 48
d_{a1}	worm tip diameter	mm	1	14
d_{a2}	worm wheel tip diameter	mm	4	36
d_{b1}	base diameter of involute helicoid (for profile type I)	mm	—	22
d_{e2}	worm wheel outside diameter	mm	—	38
d_{e2max}	maximum worm wheel outside diameter	mm	—	39
d_{e2min}	minimum worm wheel outside diameter	mm	—	38
d_{f1}	worm root diameter	mm	1	15
d_{f2}	worm wheel root diameter	mm	4	35
d_{Fa1}	worm tip form diameter	mm	3	—
d_{Fa2}	worm wheel tip form diameter	mm	6	—
d_{Ff1}	worm root form diameter	mm	3	—
d_{Ff2}	worm wheel root form diameter	mm	6	—
d_{m1}	worm reference diameter	mm	1	10
d_{m2}	worm wheel reference diameter	mm	4	25
d_{Na1}	active worm tip form diameter	mm	6	—
d_{Na2}	active worm wheel tip form diameter	mm	6	—
d_{Nf1}	active worm root form diameter	mm	6	—
d_{Nf2}	active worm wheel root form diameter	mm	6	—
d_{w1}	worm pitch diameter	mm	—	45
d_{w2}	worm wheel pitch diameter	mm	7	44
e_{mx1}	worm reference tooth space width in axial section	mm	1	17
e_{n1}	worm normal tooth space width in normal section	mm	—	19
e_{m2}	worm wheel tooth space width in mid plane section	mm	—	28
h_1	worm tooth depth	mm	1	11
h_2	worm wheel tooth depth	mm	—	33
h_{am1}	worm tooth reference addendum in axial section	mm	1	12
h_{am2}	worm wheel tooth reference addendum in mid plane section	mm	5	31
h^*_{am1}	worm tooth reference addendum coefficient in axial section	—	—	31

Table 1 *(continued)*

Symbols	Description	Units	Figure numbers	Formula numbers
h^*_{am2}	worm wheel tooth reference addendum coefficient in mid plane section	—	—	32
h_{e2}	worm wheel tooth external addendum	mm	—	34
h_{fm1}	worm tooth reference dedendum in axial section	mm	1	13
h_{fm2}	worm wheel tooth reference dedendum in mid plane section	mm	—	32
h^*_{fm1}	worm tooth reference dedendum coefficient in axial section	—	1	13
h^*_{fm2}	worm wheel tooth reference dedendum coefficient in mid plane section	—	—	32
h_{k1}	radial height of chamfer (of worm)	mm	3	—
h_{k2}	radial height of chamfer (of worm wheel)	mm	7	—
j_{x}	axial backlash	mm	—	28
m_{n}	normal module	mm	—	9
m_{x1}	axial module	mm	—	2 and G.1
n_1	rotational speed of the worm	rpm	—	144
p_{bn1}	normal pitch on base cylinder (for profile type I)	mm	—	23
p_{n1}	normal pitch	mm	—	8
p_{t2}	transverse pitch	mm	—	27
p_{x1}	axial pitch	mm	1	1
p_{z1}	lead (of worm)	mm	—	3
p_{zu1}	unit lead (lead of worm per radian)	mm/rd	—	4
q_1	diameter quotient	mm	—	5
R_{Ga}	outside radius of the grinding wheel (for profile type C and K)	mm	22	—
R_{Gm}	nominal or mean radius of the grinding wheel (for profile type C and K)	mm	22	56
r_{g2}	worm wheel throat form radius	mm	5	41
r_{b1}	base radius for involute profile (for profile type I)	mm	A.4 and A.5	22
r'_{b1}	base radius of a notional base circle (for profile type N)	mm	A.4 and A.5	—
r_{k1}	tip radius (of worm)	mm	3	—
r_{k2}	tip radius (of worm wheel)	mm	7	—
r_{T}	radius at cusp	mm	34	—
s_{m2}	tooth thickness at the reference diameter of the worm wheel	mm	4	28
s_{K}	rim thickness	mm	16	—
s_{mx1}	worm thread thickness in axial section	mm	1	16
s^*_{mx1}	worm thread thickness in axial section coefficient	—	—	—
s_{n1}	normal worm thread thickness in normal section	mm	—	18
u	gear ratio	—	—	46
x_2	worm wheel profile shift coefficient	—	—	30
x_{Gm}	thickness of grinding wheel at nominal radius	mm	22 and B.2	B.9
z_1	number of threads in worm	—	—	—
z_2	number of teeth in worm wheel	—	—	—
α_{0n}	tool normal pressure angle	°		20
α_{0t}	tool transverse pressure angle for profile types A and I	°		20
α_{n}	normal pressure angle	°	—	20
β_{m1}	reference helix angle of worm	°	—	7

Table 1 *(continued)*

Symbols	Description	Units	Figure numbers	Formula numbers
γ_{m1}	reference lead angle of worm	°	—	6
γ_{b1}	base lead angle of worm thread (for profile type I)	°	A.1	21
γ'_{b1}	base lead angle of the notional base helix (for profile type N)	°	A.4 and A.5	—
ϕ_2	face end chamfer angle	°	5	—
ρ_{Gm}	radius of curvature of grinding wheel (for profile type C)	—	—	—
ω_{w1}	angular velocity of the worm	rad/s	—	144
ω_{w2}	angular velocity of the worm wheel	rad/s	—	146

In calculation, when a radius is derived, the symbol d for diameter shall be replaced by r for radius.

Table 2 — Subscripts for worm gears

Symbols	Description
0	cutting tool
1	worm
2	wheel
G	grinding wheel

Table 3 — Coordinate of remarkable points (units are mm for length and degrees for angles)

Symbols	Description	Figure numbers	Formula numbers
$\overrightarrow{b_D}(y_p, D)$	normal vector to an offset plane	—	140
c_1, $c_2(y_G)$, $c_3(y_G)$, $\varepsilon(y_G)$	parameters to determine generated point by the grinding wheel	—	59 to 62
$x_G(y_G)$, y_G, $\alpha_G(y_G)$	coordinates of a point on the tool flank when the origin is at the point of intersection of the tool axis and the tool median plane, with the x-axis as the tool spindle axis and the abscissa on the trace of the median plane for profile C and K	22	Table 8
$x_x(y_r)$, $y_x(y_r)$, $\alpha_x(y_r)$	coordinates of axial profile and axial pressure angle for A, I, N worm profiles	25	49, 50, 54
$x_x(y_G)$, $y_x(y_G)$, $\alpha_x(y_G)$	coordinates of axial profile and axial pressure angle for K and C worm profiles	25	67, 68, 78
$x_D(y_p, D)$, $y_D(y_p, D)$, $\alpha_D(y_p, D)$, $\delta_D(y_p, D)$	coordinates of worm profile and pressure angle of worm profile in an offset plane, projection angle from axial profile	27	80, 81, 82, 86
$x'_D(y_p, D)$, $y_{lD}(y_p, D)$	coordinates of worm profile with origin at pitch point	27	90, 81, 82
$x_{lD}(y_p, D)$, $y_{lD}(y_p, D)$	coordinates of path of contact in an offset plane with origin on pitch axis	27	91, 92
$xR_D(y_p, D)$, $yR_D(y_p, D)$ $r_{M2D}(y_p, D)$, $\vartheta_D(y_p, D)$	coordinates of conjugate worm wheel profile of the worm in an offset plane with origin on worm wheel axis and polar coordinates	29	96, 97
$xT_D(r_{t2D}, D)$, $yT_D(r_{t2D}, D)$	coordinates of trochoid profile of the worm wheel profile in an offset plane with origin on worm wheel axis	30	101, 102
$x_D(ycusp, D)$, $y_D(ycusp, D)$	coordinates of cusp point in an offset plane with origin on pitch axis	—	—
$C_{eq1D}(y_p, D)$	curvature for the worm at a point in an offset plane	—	103, 110

Table 3 *(continued)*

Symbols	Description	Figure numbers	Formula numbers
$C_{\mathrm{eq2D}}\left(y_{\mathrm{p}},D\right)$	curvature for the worm wheel at a point in an offset plane	31	111
$R_{\mathrm{eqD}}\left(y_{\mathrm{p}},D\right)$	equivalent radius of curvature in an offset plane	—	113
$r_{\mathrm{a2D}}(D)$	radius of worm wheel conjugate to point B, tip of the worm profile in the offset plane D	28 and 34	10.6.2
$r_{\mathrm{e2D}}(D)$	outside radius of the worm wheel in the offset plane D	—	98
$r_{\mathrm{f2D}}(D)$	root radius of the worm wheel in the offset plane D	—	99
$r_{\mathrm{wD}}(D)$	radius of cylinder crossing the pitch point of in an offset plane D	—	87
$\overrightarrow{M_1\left(y_{\mathrm{p}},D\right)}$	coordinate of a point of contact for the worm	—	126
$\overrightarrow{M_2\left(y_{\mathrm{p}},D\right)}$	coordinate of a point of contact for the worm wheel	—	127, 149
$\overrightarrow{TN1_{\mathrm{cont}}\left(y_{\mathrm{p}},D\right)}$	tangent unit vector to conjugate profile in the offset plane D	—	134
$\overrightarrow{n_D}\left(y_{\mathrm{p}},D\right)$	normal vector to the worm and worm wheel profile in an offset plane	—	139
$\overrightarrow{\mathrm{Normal}Nxy\left(y_{\mathrm{p}},D\right)}$	normal unit vector to the lines of contact at common point of contact	—	124
$\overrightarrow{\mathrm{NORMAL}\left(y_{\mathrm{p}},D\right)}$	normal unit vector to the lines of contact	—	122
$\mathrm{Req}\left(y_{\mathrm{p}},D\right)$, $\mathrm{Req}_1\left(y_{\mathrm{p}},D\right)$	radius of curvature along the line the contact	—	143, 141
$\overrightarrow{TD1\left(y_{\mathrm{p}},D\right)}$, $\overrightarrow{TD2\left(y_{\mathrm{p}},D\right)}$	normalized unit vectors of the common tangent plane at point of contact between the tooth flanks	—	117, 121
$\overrightarrow{t_D\left(y_{\mathrm{p}},D\right)}$	tangent vector to the worm and worm wheel profile in an offset plane	—	138
$\overrightarrow{V_1\left(y_{\mathrm{p}},D\right)}$	velocity of a point of the thread of the worm	—	146
$\overrightarrow{V_2\left(y_{\mathrm{p}},D\right)}$	velocity of a point of the tooth flank of the worm wheel	—	150
$V_{\mathrm{cDn}}\left(y_{\mathrm{p}},D\right)$	velocity at the contact point along the path of contact	—	160
$V_{\mathrm{SUMn}}\left(y_{\mathrm{p}},D\right)$	sum of velocities at the point of contact for method B in ISO/TS 14521:2020	—	163
$\delta_{\mathrm{Dl}}(D)$	angle of the projection of the pitch point of the offset plane D in the axial plane	°	88
$\Delta x_{\mathrm{D}}(D)$	axial translation for the projection of the pitch point of the offset plane D in the axial plane	—	89
$\overrightarrow{\omega_1}$	angular velocity vector of the worm	—	145
$\overrightarrow{\omega_2}$	angular velocity vector of the worm wheel	—	148

5 Formulae for calculation of dimensions

5.1 Parameters for a cylindrical worm

5.1.1 Axial pitch

Axial pitch is given by Formula (1), (see Figure 1):

$$p_{x1} = \pi \cdot m_{x1} \quad (1)$$

5.1.2 Axial module

Axial module is given by Formula (2):

$$m_{x1} = \frac{p_{x1}}{\pi} \quad (2)$$

5.1.3 Lead

Lead is given by Formula (3), (see Figure 1):

$$p_{z1} = z_1 \cdot p_{x1} \quad (3)$$

5.1.4 Unit lead

Unit lead is given by Formula (4):

$$p_{zu1} = \frac{p_{z1}}{2 \cdot \pi} \quad (4)$$

5.1.5 Diameter quotient

Diameter quotient is given by Formula (5):

$$q_1 = \frac{d_{m1}}{m_{x1}} \quad (5)$$

5.1.6 Reference lead angle

Reference angle is given by Formula (6):

$$\tan \gamma_{m1} = \frac{m_{x1} \cdot z_1}{d_{m1}} = \frac{z_1}{q_1} \quad (6)$$

5.1.7 Reference helix angle

Reference helix angle is given by Formula (7):

$$\beta_{m1} = 90^\circ - \gamma_{m1} \quad (7)$$

5.1.8 Normal pitch on reference cylinder

Normal pitch on reference cylinder is given by Formula (8):

$$p_{n1} = p_{x1} \cdot \cos \gamma_{m1} \quad (8)$$