



BSI Standards Publication

Worm gears — Worm profiles and gear mesh geometry

National foreword

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**International
Standard**

ISO 10828

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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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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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, *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 \(B.12\)](#) $\frac{d}{dy_G} \alpha_G(y_G)$ is written $d\alpha_G(y_G)$

Example in [Formula \(B.14\)](#) $\frac{d^2}{dy_G^2} \alpha_G(y_G)$ is written $d^2\alpha_G(y_G)$

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 hobbled 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
$\overline{b_D}(y_p, D)$	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
$x'_D(y_p, D), y_{1D}(y_p, D)$	coordinates of worm profile with origin at pitch point	27	90, 81, 82
$x_{1D}(y_p, D), y_{1D}(y_p, D)$	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
$x_D(y_{cusp}, D), y_D(y_{cusp}, D)$	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
$C_{eq2D}(y_p, D)$	curvature for the worm wheel at a point in an offset plane	31	111
$R_{eqD}(y_p, D)$	equivalent radius of curvature in an offset plane	—	113
$r_{a2D}(D)$	radius of worm wheel conjugate to point B, tip of the worm profile in the offset plane D	28 and 34	10.6.2
$r_{e2D}(D)$	outside radius of the worm wheel in the offset plane D	—	98
$r_{f2D}(D)$	root radius of the worm wheel in the offset plane D	—	99
$r_{wD}(D)$	radius of cylinder crossing the pitch point of in an offset plane D	—	87
$\overline{M_1}(y_p, D)$	coordinate of a point of contact for the worm	—	126
$\overline{M_2}(y_p, D)$	coordinate of a point of contact for the worm wheel	—	127 , 149
$\overline{TN1_{cont}}(y_p, D)$	tangent unit vector to conjugate profile in the offset plane D	—	134
$\overline{n_D}(y_p, D)$	normal vector to the worm and worm wheel profile in an offset plane	—	139
$\overline{NormalNxy}(y_p, D)$	normal unit vector to the lines of contact at common point of contact	—	124
$\overline{NORMAL}(y_p, D)$	normal unit vector to the lines of contact	—	122
$Req(y_p, D), Req_1(y_p, D)$	radius of curvature along the line the contact	—	143 , 141
$\overline{TD1}(y_p, D), \overline{TD2}(y_p, D)$	normalized unit vectors of the common tangent plane at point of contact between the tooth flanks	—	117 , 121
$\overline{t_D}(y_p, D)$	tangent vector to the worm and worm wheel profile in an offset plane	—	138
$\overline{V_1}(y_p, D)$	velocity of a point of the thread of the worm	—	146
$\overline{V_2}(y_p, D)$	velocity of a point of the tooth flank of the worm wheel	—	150
$V_{cDn}(y_p, D)$	velocity at the contact point along the path of contact	—	160
$V_{SUMn}(y_p, D)$	sum of velocities at the point of contact for method B in ISO/TS 14521:2020	—	163
$\delta_{DI}(D)$	angle of the projection of the pitch point of the offset plane D in the axial plane	°	88
$\Delta x_D(D)$	axial translation for the projection of the pitch point of the offset plane D in the axial plane	—	89
$\overline{\omega_1}$	angular velocity vector of the worm	—	145
$\overline{\omega_2}$	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 \(8\)](#):

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

5.1.9 Normal module

Normal module is given by [Formula \(9\)](#):

$$m_n = m_{x1} \cdot \cos \gamma_{m1} \quad (9)$$

5.1.10 Reference diameter

Reference diameter given by [Formula \(10\)](#):

$$d_{m1} = q_1 \cdot m_{x1} \quad (10)$$

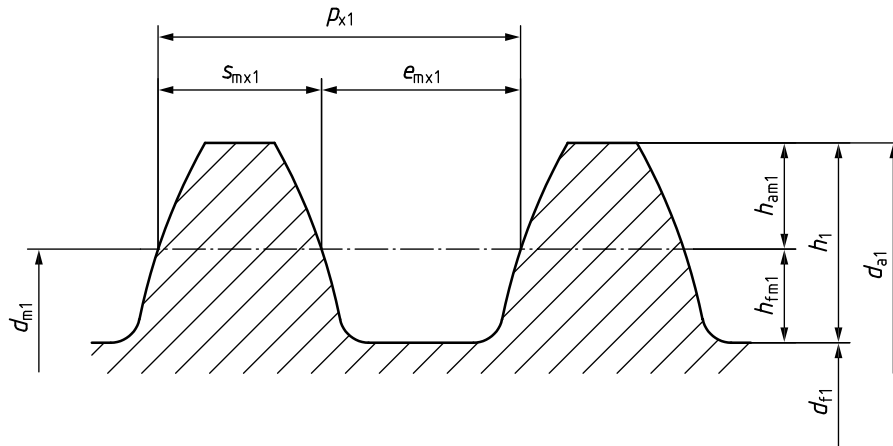


Figure 1 — Axial parameters for worm

5.1.11 Reference tooth depth

Reference tooth depth is given by [Formula \(11\)](#), (see [Figure 1](#)):

$$h_1 = h_{am1} + h_{fm1} = \frac{1}{2} \cdot (d_{a1} - d_{f1}) \quad (11)$$

5.1.12 Reference addendum

Reference addendum is given by [Formula \(12\)](#), (see [Figure 1](#)):

$$h_{am1} = h_{am1}^* \cdot m_{x1} = \frac{1}{2} \cdot (d_{a1} - d_{m1}) \quad (12)$$

where h_{am1}^* is the addendum coefficient; normally $h_{am1}^* = 1$.

5.1.13 Reference dedendum

Reference dedendum is given by [Formula \(13\)](#), (see [Figure 1](#)):

$$h_{fm1} = h_{fm1}^* \cdot m_{x1} = \frac{1}{2} \cdot (d_{m1} - d_{f1}) \quad (13)$$

where h_{fm1}^* = dedendum coefficient; generally, $1,1 < h_{fm1}^* < 1,3$, the recommended value is 1,2.

5.1.14 Tip diameter

Tip diameter is given by [Formula \(14\)](#), (see [Figure 1](#)):

$$d_{a1} = d_{m1} + 2 \cdot h_{am1} \quad (14)$$

5.1.15 Root diameter

Root diameter is given by [Formula \(15\)](#), (see [Figure 1](#)):

$$d_{f1} = d_{m1} - 2 \cdot h_{fm1} \quad (15)$$

5.1.16 Thread thickness coefficient s_{mx1}^*

A recommended value is $s_{mx1}^* = 0,5$

In general practice, this coefficient is very often less than 0,5 when there is a wish to increase the worm wheel thread thickness to extend durability against wear of worm wheel.

5.1.17 Reference thread thickness in the axial section

Reference thread thickness in the axial section is given by [Formula \(16\)](#), (see [Figure 1](#)):

$$s_{mx1} = s_{mx1}^* \cdot p_{x1} \quad (16)$$

5.1.18 Reference space width in the axial section

Reference space width in the axial section is given by [Formula \(17\)](#), (see [Figure 1](#)):

$$e_{mx1} = p_{x1} - s_{mx1} \quad (17)$$

5.1.19 Normal thread thickness

Normal thread thickness is given by [Formula \(18\)](#):

$$s_{n1} = s_{mx1} \cdot \cos \gamma_{m1} \quad (18)$$

5.1.20 Normal space width

Normal space width is given by [Formula \(19\)](#):

$$e_{n1} = e_{mx1} \cdot \cos \gamma_{m1} \quad (19)$$

5.1.21 Profile flank form

It is specified by a letter:

- A is the envelope of straight line in the axial section;
- N is the envelope of straight line in the normal section of the space width;
- I is the involute helicoid (the envelope of straight line in a plane tangent to the base cylinder);
- K is a milled helicoid by double cone form;
- C is a milled helicoid by circular convex form.

5.1.22 Normal pressure angle

For A worm profile type:

Normal pressure angle is given by [Formula \(20\)](#):

$$\tan \alpha_n = \tan \alpha_{0t} \cdot \cos \gamma_{m1} \quad (20)$$

For other worm profile types, $\alpha_n = \alpha_{0n}$ where α_{0n} is defined in [7.3](#) for I worm profile type, in [7.4](#) for N worm profile type, in [7.6](#) for K worm profile type and [7.7](#) for C worm profile type.

5.1.23 Base lead angle for profile type I

Base lead angle for profile type is given by [Formula \(21\)](#):

$$\cos \gamma_{b1} = \cos \gamma_{m1} \cdot \cos \alpha_{0n} \quad (21)$$

5.1.24 Base diameter for profile type I

Base diameter for profile type is given by [Formula \(22\)](#):

$$d_{b1} = d_{m1} \cdot \frac{\tan \gamma_{m1}}{\tan \gamma_{b1}} = \frac{m_{x1} \cdot z_1}{\tan \gamma_{b1}} \quad (22)$$

For profile type I, when the root diameter is lower than the base diameter, the diameter of start of active profile (SAP) shall be greater than d_{b1} .

5.1.25 Normal pitch on base cylinder

Normal pitch on base cylinder is given by [Formula \(23\)](#):

$$p_{bn1} = p_{x1} \cdot \cos \gamma_{b1} \quad (23)$$

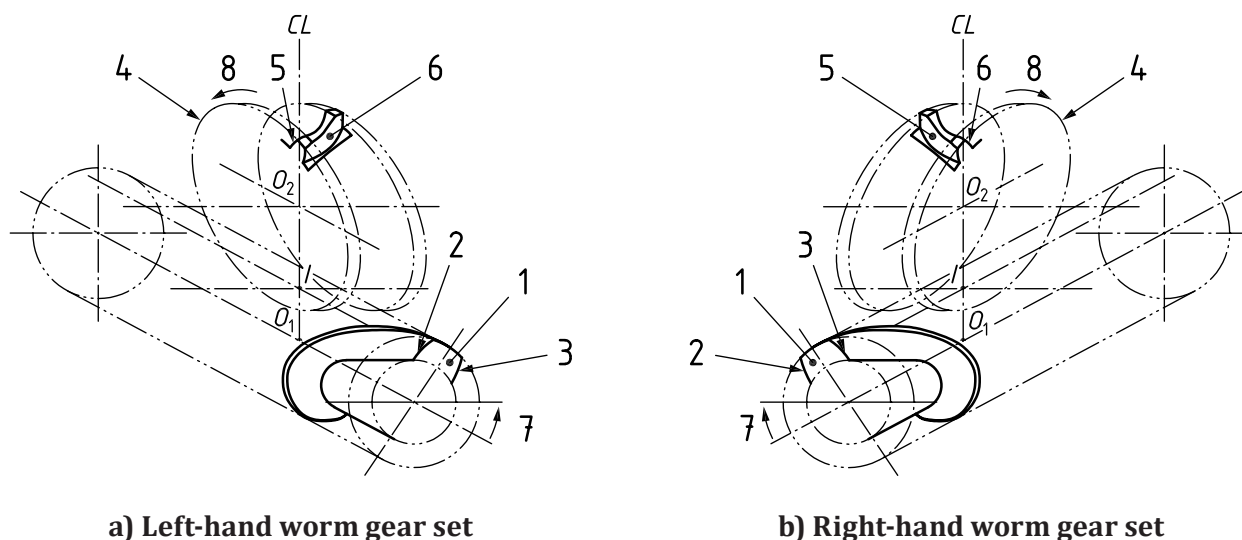
5.1.26 Worm face width

Worm face width is given by [Formula \(24\)](#):

$$b_1 \geq \sqrt{(d_{e2})^2 - (2 \cdot a - d_{a1})^2} \quad (24)$$

5.1.27 Right-hand helix and left-hand helix

The flank direction is right-handed if the flank line describes a right-hand helix and left-handed if the flank line describes a left-hand helix. See [Figure 2](#).



a) Left-hand worm gear set

b) Right-hand worm gear set

Key

1	selected reference face of worm	5	left flank (LF) of worm wheel
2	left flank (LF) of worm	6	right flank (RF) of worm wheel
3	right flank (RF) of worm	7	rotating direction of worm wheel
4	selected reference face of worm wheel	8	rotating direction of worm

Figure 2 — Direction of helix and flank conventions**5.1.28 Right flank and left flank**

The right flank (or left flank) is the tooth flank that an observer sees on the right-hand (or left-hand) side when viewing the selected reference face of a tooth when it is pointing upwards. This definition applies to both worms and worm wheels, see [Figure 2](#).

Right flank parameters are indicated by the subscript R and left flank parameters by the subscript L.

5.1.29 Flank definition

The flank direction is right-handed if the flank line describes a right-hand helix and left-handed if the flank line describes a left-hand helix. See [Figure 9](#).

5.1.30 Root form and tip form diameter for worm

The root form diameter, d_{ff1} , is the start of the portion of the worm profile (A, I, N, K, or C). For a worm, it is the diameter of the intersection of the flank with the root fillet or root radius (taking into account undercut if necessary). See [Figure 3](#).

The tip form diameter is d_{Fa1} , is the end of the portion of the worm profile (A, I, N, K, or C). For a worm, it is the diameter of the intersection of the flank with the tip chamfer or tip radius when existing.

With direct transition between the nominal helicoid profile and the top land of the tooth, the tip form diameter is equal to the tip diameter ($d_{Fa1}=d_{a1}$). In the case of tip rounding or tip chamfering, tip form diameter and tip diameter differ by double the height of chamfer or rounding h_{k1} then to study gear mesh geometry in [Clauses 10](#) and [11](#), tip diameter d_{a1} shall be replaced by form diameter d_{Fa1} .

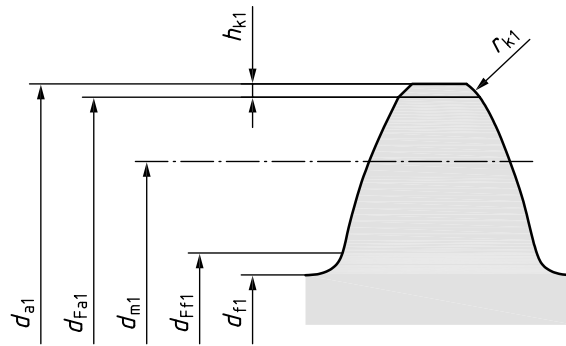


Figure 3 — Root form and tip form diameter for worm

5.2 Parameters for a worm wheel

5.2.1 General

Figure 4 shows parameters for worm wheel and Figure 7 shows pitch and reference diameters for worm gear set.

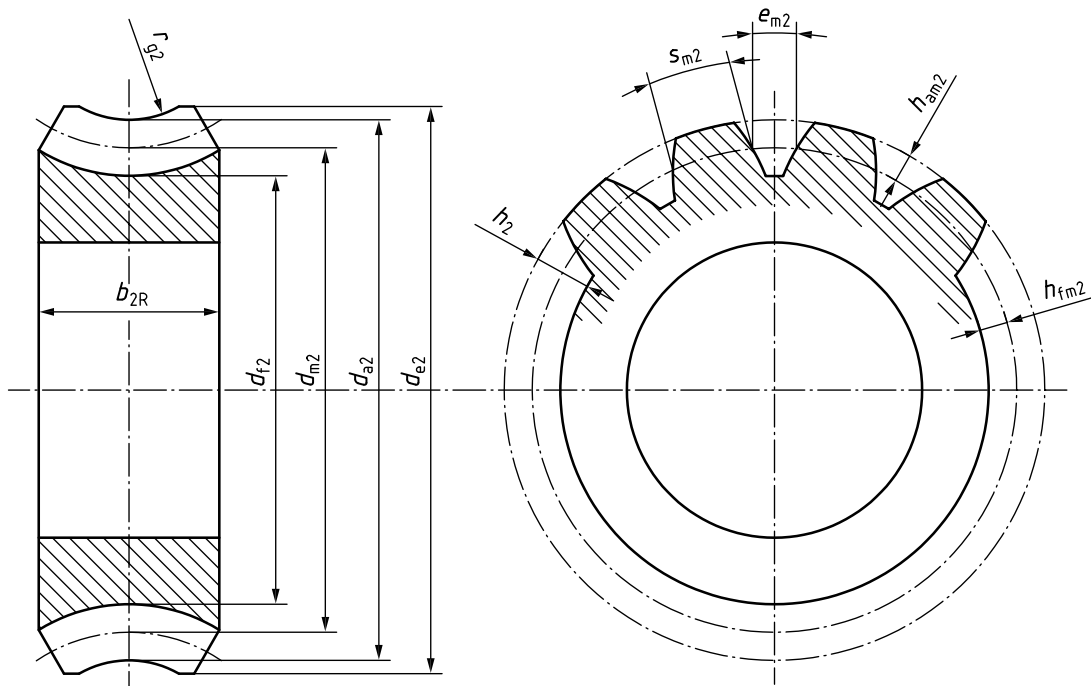


Figure 4 — Parameters for worm wheel

5.2.2 Reference diameter

Reference diameter is given by [Formulae \(25\)](#) and [\(26\)](#), (see [Figures 4](#) and [5](#)):

$$d_{m2} = d_{w2} + 2 \cdot x_2 \cdot m_{x1} \quad (25)$$

or

$$d_{m2} = 2 \cdot a - d_{m1} \quad (26)$$

5.2.3 Transverse pitch

Transverse pitch is given by [Formula \(27\)](#):

$$p_{t2} = p_{x1} \quad (27)$$

5.2.4 Transverse tooth thickness at reference diameter

This value can be calculated only for a worm wheel without profile shift from [Formula \(28\)](#), (see [Figure 4](#)):

$$s_{m2} = e_{mx1} - j_x \quad (28)$$

where j_x = axial backlash.

5.2.5 Space width at reference diameter

This value can be calculated only for a worm wheel without profile shift from [Formula \(29\)](#), (see [Figure 4](#)):

$$e_{m2} = p_{x1} - s_{m2} \quad (29)$$

5.2.6 Profile shift coefficient

Profile shift coefficient is given by [Formula \(30\)](#), (see [Figure 6](#)):

$$x_2 = \frac{2 \cdot a - d_{m1} - m_{x1} \cdot z_2}{2 \cdot m_{x1}} \quad (30)$$

5.2.7 Tooth reference addendum

Tooth reference addendum is given by [Formula \(31\)](#):

$$h_{am2} = m_{x1} \cdot h_{am2}^* = \frac{1}{2} \cdot (d_{a2} - d_{m2}) \quad (31)$$

where h_{am2}^* is the tooth reference addendum coefficient; $h_{am2}^* = 1$ (normally).

5.2.8 Tooth reference dedendum

Tooth reference dedendum is given by [Formula \(32\)](#):

$$h_{fm2} = m_{x1} \cdot h_{fm2}^* = \frac{1}{2} \cdot (d_{m2} - d_{f2}) \quad (32)$$

where h_{fm2}^* is the tooth reference dedendum coefficient; generally $1,1 < h_{fm2}^* < 1,3$, the recommended value is 1,2.

5.2.9 Tooth depth

Tooth depth is given by [Formula \(33\)](#):

$$h_2 = h_{am2} + h_{fm2} \quad (33)$$

5.2.10 Outside addendum

Outside addendum is given by [Formula \(34\)](#), (see [Figure 4](#)):

$$h_{e2} = \frac{1}{2} \cdot (d_{e2} - d_{a2}) \quad (34)$$

Generally: $0,4 \leq \frac{h_{e2}}{m_{x1}} \leq 1,5$ Normally $h_{e2} / m_{x1} = 0,5$

5.2.11 Root diameter

Root diameter is given by [Formula \(35\)](#), (see [Figure 4](#)):

$$d_{f2} = d_{m2} - 2 \cdot h_{fm2} \quad (35)$$

5.2.12 Tip diameter

Tip diameter is given by [Formula \(36\)](#), (see [Figure 4](#)):

$$d_{a2} = d_{m2} + 2 \cdot h_{am2} \quad (36)$$

5.2.13 Outside diameter

Outside diameter is given by [Formula \(37\)](#), (see [Figure 4](#)):

$$d_{e2} = d_{a2} + 2 \cdot h_{e2} \quad (37)$$

NOTE For min/max values see [5.2.14](#).

5.2.14 Minimum and maximum outside diameter

Generally, minimum and maximum outside diameters are given by [Formulae \(38\)](#) and [\(39\)](#):

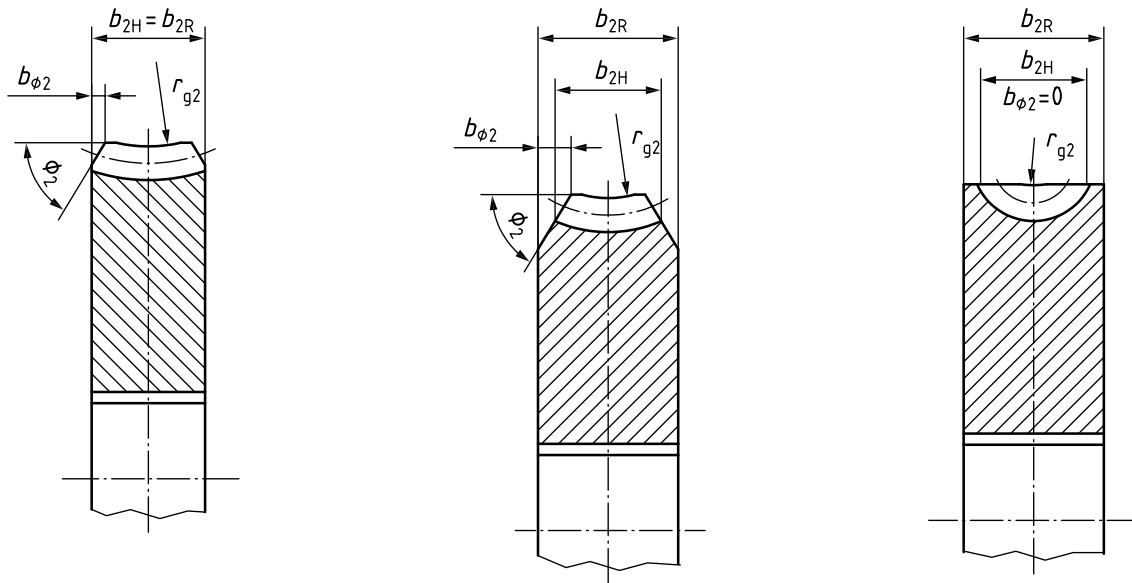
$$d_{e2min} = d_{a2} + 0,8 \cdot m_{x1} \quad (38)$$

$$d_{e2max} = d_{a2} + 3 \cdot m_{x1} \quad (39)$$

5.2.15 Worm wheel face width

Worm wheel face width is given by [Formula \(40\)](#), (see [Figures 4](#) and [6](#)):

$$b_{2H} \leq \sqrt{(2 \cdot a - d_{f2})^2 - (2 \cdot a - d_{e2})^2} \quad (40)$$



a) Worm wheel with full face width limited by face/lateral chamfers

b) Worm wheel with full face larger than tooth face width

c) Worm wheel with full face without face/lateral chamfer

NOTE c) represents the geometrical conditions where b_{2H} reaches its maximum value.

Figure 5 — Worm wheel face width

5.2.16 Throat form radius

Throat form radius is given by [Formula \(41\)](#), (see [Figure 4](#)):

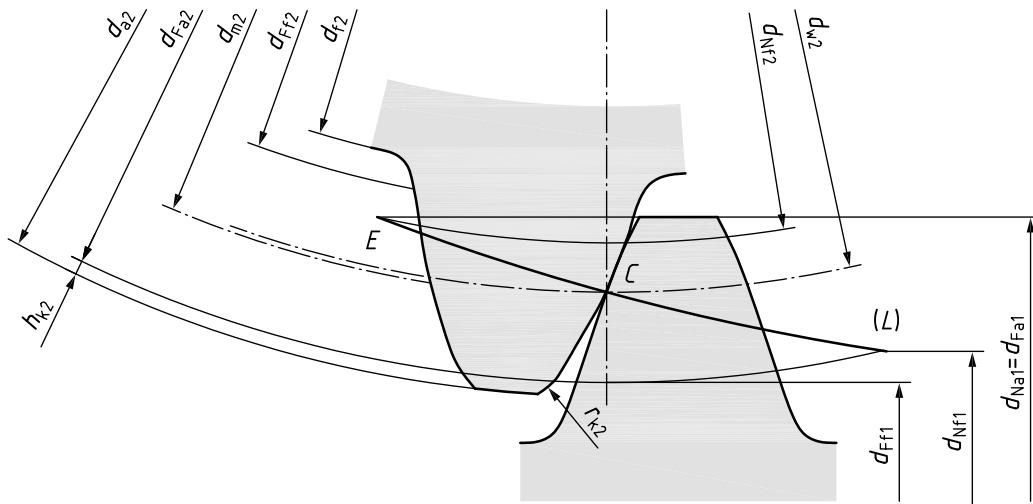
$$r_{g2} \geq a - \frac{d_{a2}}{2} \quad (41)$$

5.2.17 Root form and tip diameter for worm wheel

The root form diameter, d_{Ff2} , is the start of the portion of the worm wheel conjugate to worm profile type (A, I, N, K or C). For a worm wheel, it is the diameter of the intersection of the flank with the root fillet or trochoid (considering undercut if necessary). See [Figure 5](#).

The tip form diameter is d_{Fa2} , is the end of the portion of the worm wheel conjugate to worm profile type (A, I, N, K or C). For a worm wheel, it is the diameter of the intersection of the flank with the tip chamfer or tip radius when existing.

With direct transition between the worm wheel conjugate flank to worm profile type and the top land of the tooth, the tip form diameter is equal to the tip diameter ($d_{Fa2} = d_{a2}$). In the case of tip rounding or tip chamfering, tip form diameter and tip diameter differ by double the height of chamfer or rounding; h_{k2} , then to study gear mesh geometry in [Clauses 10](#) and [11](#), tip diameter d_{a2} shall be replaced by form diameter d_{Fa2} .



Key

- (L) path of contact
- C pitch point
- E end point of meshing

Figure 6 — Root form and tip form diameter for worm wheel

5.3 Meshing parameters

5.3.1 Centre distance

Centre distance is given by [Formulae \(42\)](#) or [\(43\)](#), (see [Figure 7](#)):

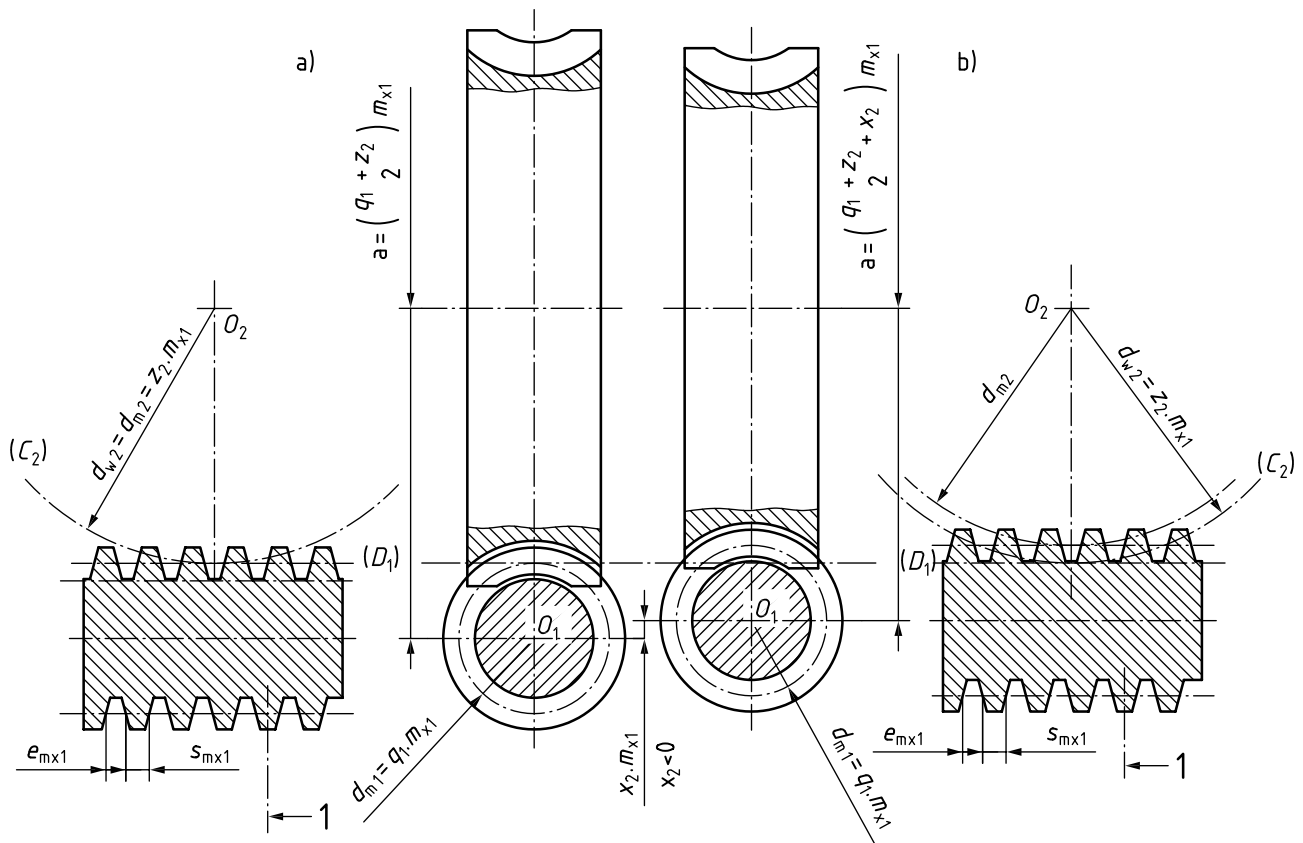
$$a = 0,5 \cdot (d_{m1} + d_{m2}) = 0,5 \cdot (d_{w1} + d_{w2}) \quad (42)$$

NOTE In case of crossed axis gear composed of two involute cylindrical helical gears with parameters defined according to ISO 21771-1:—¹⁾, [Annex H](#) provides an interface to convert those parameters with the convention used in this document.

or

$$a = m_{x1} \cdot [0,5 \cdot (q_1 + z_2) + x_2] \quad (43)$$

1) Under preparation. Stage at the time of publication: ISO/DIS 21771-1.2:2024.



Key

1 symmetrical axis of the thread

NOTE 1 The profile shift coefficient x_2 is negative.

NOTE 2 On both parts a) and b), the worm is the same. On part a) (left), the profile shift coefficient equal zero and on part b) (right) the profile shift coefficient is negative.

Figure 7 — Pitch and reference diameters for worm gear set

5.3.2 Pitch diameter of worm wheel

Pitch diameter of worm wheel is given by [Formula \(44\)](#), (see [Figure 7](#)):

$$d_{w2} = z_2 \cdot m_{x1} \quad (44)$$

5.3.3 Pitch diameter of worm

Pitch diameter of worm is given by [Formula \(45\)](#), (see [Figure 7](#)):

$$d_{w1} = 2 \cdot a - d_{w2} \quad (45)$$

5.3.4 Worm gear ratio

Worm gear ration is given by [Formula \(46\)](#):

$$u = \frac{z_2}{z_1} \quad (46)$$

5.3.5 Contact ratio

The calculation of the contact ratio is defined in [11.6](#).

5.3.6 Tip clearance

Tip clearances are given by [Formulae \(47\)](#) and [\(48\)](#):

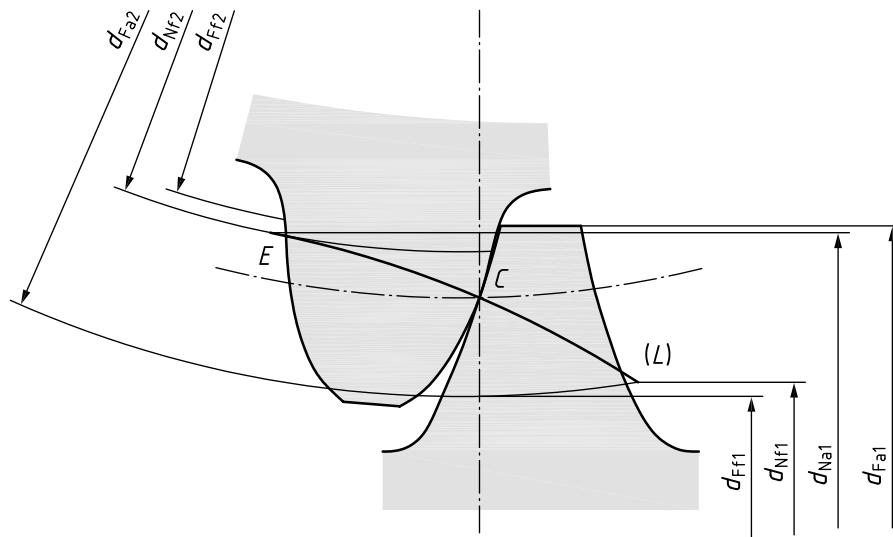
$$c_1 = a - 0,5 \cdot (d_{a2} + d_{f1}) \quad (47)$$

$$c_2 = a - 0,5 \cdot (d_{a1} + d_{f2}) \quad (48)$$

5.3.7 Start of active profile (SAP) and end of active profile (EAP) diameters for worm and worm wheel

In a defined gear pair, the active tip diameter, d_{Na} , of a gear can be governed either by its tip form diameter, d_{Fa} or by the start of conjugate profile of its mate (i.e. d_{Nf} or d_{Ff}). The SAP, (active root) diameter, d_{Nf} , can be governed either by the diameter of start of the portion of the worm profile type (A, I, N, K or C) or by the tip form diameter of its mate. The active area of the flank extends from the active tip diameter to the active root diameter and so is dependent on the characteristics of both gears and the centre distance. See [Figure 8](#).

NOTE In some cases (e.g. low-pressure angle) the conjugate action of profiles can be limited by a cusp (see point E in [Figure 8](#)). In such case, the active lengths of profile are shortened; the EAP is below the tip form diameter of the worm and the SAP on the worm wheel is above the usual one (see [Figure 8](#) and [10.6.3](#)).



Key

- (L) path of contact
- C pitch point
- E end point of meshing

Figure 8 — Diameters and worm wheel evaluation height for profile in mid plane

6 Generalities on worm profile types

6.1 Worm profile types, see [Table 4](#)

Table 4 — Worm profile types

Profile type	Description
A Profile type	straight sided axial profile
C Profile type	concave axial profile formed by machining with a convex circular profile disc type cutter or grinding wheel
I Profile type	involute helicoid, straight generatrix in base tangent planes
N Profile type	straight profiles in normal plane of thread space width helix
K Profile type	milled helicoid generated by biconical grinding wheel or milling cutter, convex profiles in axial planes

6.2 Conventions relative to the formulae of this document

6.2.1 The worm threads are right-handed.

The formulae in this document define the coordinates of the flank of the axial profile of worm, located on the left when looking in the plane XOY of [Figure 9](#). This is the right flank of the worm according to [Figure 2](#).

A symmetric profile to the right flank relative to a perpendicular axis to the worm axis shall be drawn to obtain the left flank.

6.2.2 The worm and wheel pairs operate as speed reducing gears with directions of rotation as shown in [Figure 9](#), thus the worm thread right flanks contact the wheel tooth left flanks. These are the flanks studied in this report.

6.2.3 The worm wheel is above the worm.

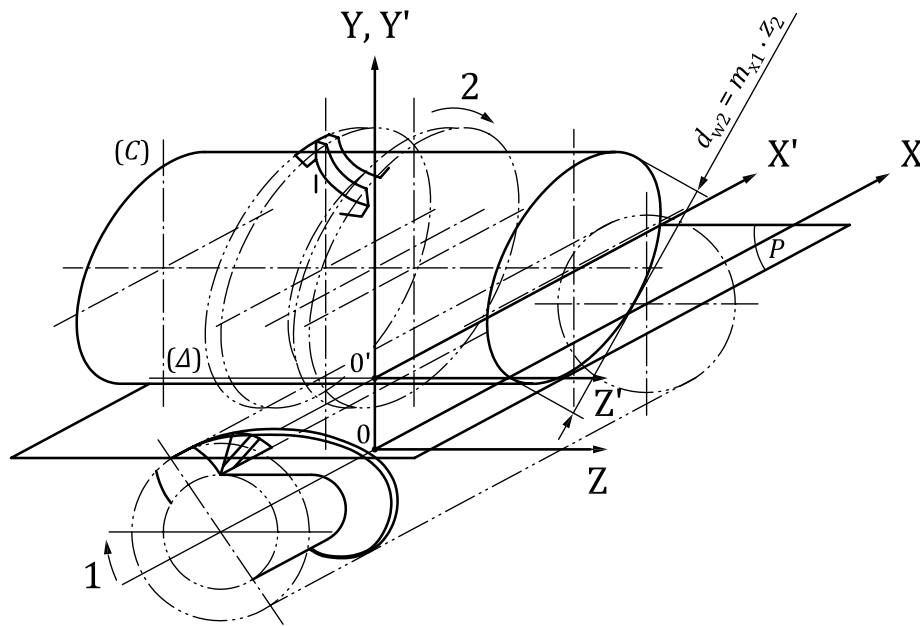
6.2.4 With the origin O, the reference axes X Y Z, are mutually perpendicular (see [Figure 9](#)):

- OX the worm axis coincides with the X axis;
- OY the common perpendicular to the worm and wheel axes coincides with the Y axis;
- OZ to complete the direct coordinate system.

A point is defined by its x, y, z coordinates. The following subscripts are used:

- x refers to the X-Y axial plane;
- D refers to an offset plane;
- n refers to the normal plane;
- t refers to a transverse plane.

6.2.5 If the worm is driving, the worm gear set is a reducer. If the worm wheel is driving, the worm gear set is an increaser.



Key

- | | | | |
|-----|---|-----|--|
| 1 | direction of rotation of the worm | (C) | pitch cylinder of the worm wheel – diameter d_{w2} |
| 2 | direction of rotation of the worm wheel | P | pitch plane of the worm – distance from the axis of the worm equal to $d_{w1}/2$ |
| (Δ) | pitch axis – common tangent between pitch surfaces of worm and worm wheel | | |

NOTE For the clarity of drawing, only one thread for worm is represented.

Figure 9 — Conventions used in formulae

7 Definition of profile types

7.1 General

There are two kinds of worm profile types:

- Profile types A, I, N are generated by a helical movement of a straight line in the space. The formulae of the axial profile are a direct function according to the radius of the worm. In that case, gear mesh in an offset plane uses two parameters: y_r which is the radius of the worm and D which is the distance of the offset plane
- Profile types K and C are generated by a helical movement of a grinding wheel with a certain profile (see [Figure 22](#)) in the space. The generated flanks on the worm are the envelope of the grinding wheel. Each point of the worm profile is generated by a point of the grinding wheel. The formulae of the axial profile are not a direct function according to the radius of the grinding wheel profile. In that case, gear mesh in an offset plane uses two parameters: y_r which is the radius of the grinding wheel and D which is the distance of the offset plane. In those cases, the calculations are more complex.

The differences between these five profile types are shown in [Annex D](#). In complement, [Annex G](#) provides an informative calculation method to link the main geometric parameters of the gear set with the tooling parameters.

7.2 A worm profile type

7.2.1 Geometrical definition

The worm flanks with A profile type are generated as envelopes of straight lines in axial planes which are inclined at a constant angle: $\frac{\hat{A}}{2} - \alpha_{ot}$ to the axis (see [Figure 10](#)). This line as it is moved with simultaneous rotation about and translation along the axis X, defines the worm thread flank (see [Figure 10](#)). The form of which is commonly described as an Archimedean helix.

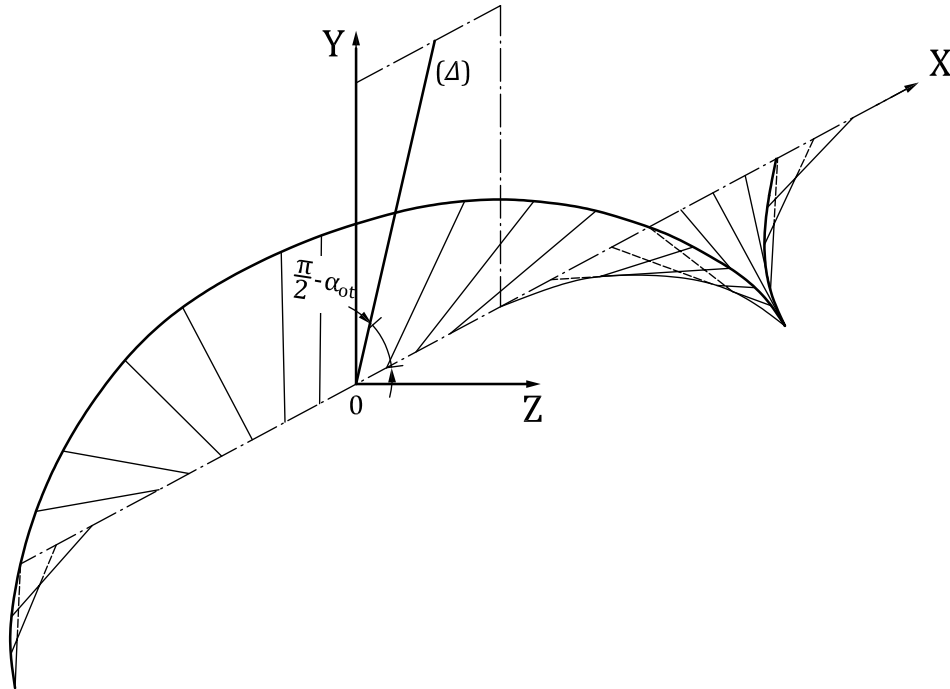


Figure 10 — A Profile type - Theoretical generation

7.2.2 Machining methods

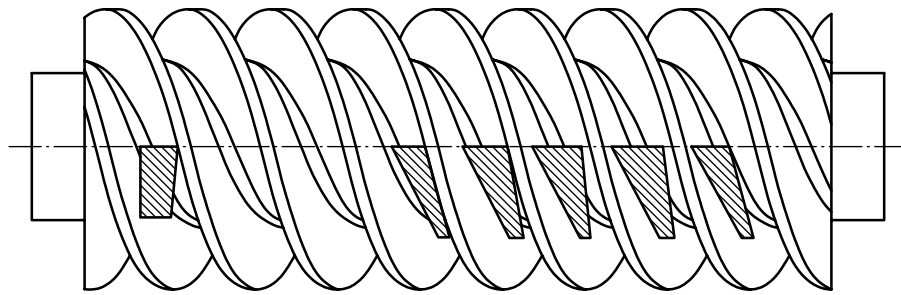
The straight generatrix is always crossing the worm axis; the flank of thread in an axial plane is always a straight line; so machining methods should ensure to generate this straight axial flank.

The threads can be cut on a lathe with a tool having straight edges, the cutting plane of which lies in an axial plane of the worm [see [Figure 11 a](#)].

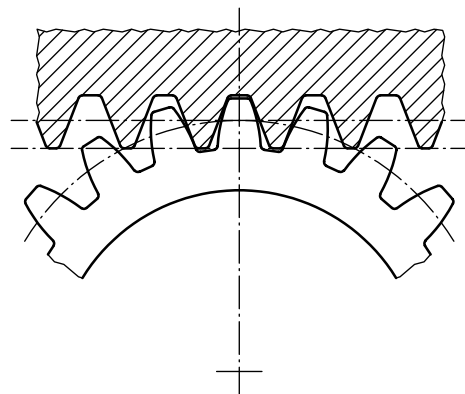
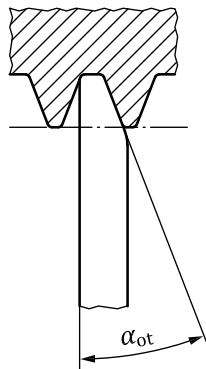
Both flanks of a thread space can be machined simultaneously by using a tool of trapezoidal form.

Another method, which is an inversion of the process of cutting a helical gear with a rack cutter, involves the use of an involute shaper to produce the desired rectilinear rack profile in an axial plane of the worm. The cutting face shall lie in that axial plane [see [Figure 11 b](#)].

The pitch circle of the shaper shall roll without slip on the datum line of the rack profile. This coincides with a straight line generatrix of the worm pitch cylinder.



a) Profile type A generation by two methods



b) Partial projection view in axial plane of the worm of tool of trapezoidal form

c) Partial projection view in axial plane of the worm of involute shaper

Figure 11 — A Profile type - Machining methods

An A Profile type is equivalent to a straight line in an axial plane.

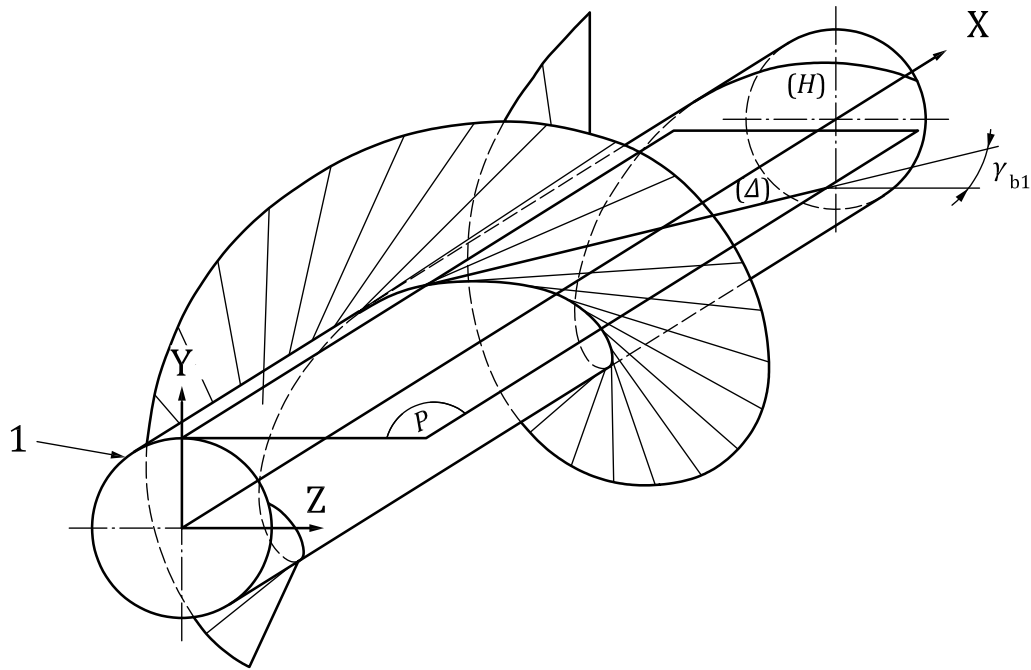
The development of the formulae for the axial profile of A worm profile type is shown in [Annex A, A.2](#).

7.3 I worm profile type

7.3.1 Geometrical definition

The worm flank with I profile type is an involute helicoidal surface. The form of which can be generated by a line (Δ) which is tangent to the base helix (H) lying on the base cylinder of the worm, and is moving along (H). (H) is concentric with the worm axis (see [Figure 12](#)).

A transverse profile (in a normal plane to the worm axis) of a flank is an involute to a circle.

**Key**

1 base cylinder of the worm

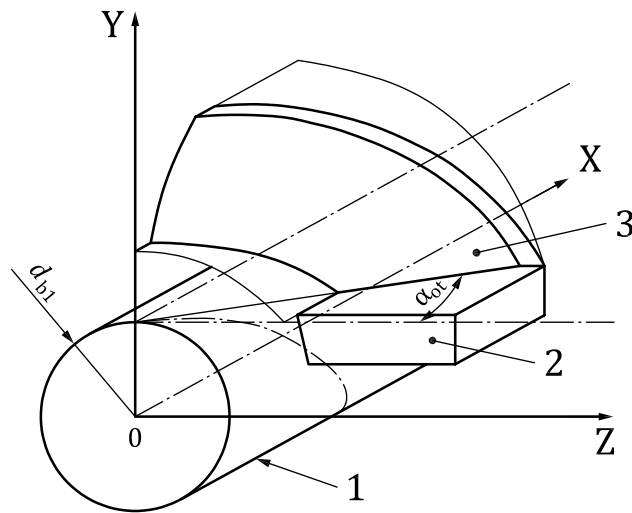
Figure 12 — I Profile type - Theoretical generation

7.3.2 Machining methods

The straight generatrix is always tangential to the base helix in a plane which is tangential to the base cylinder, so the flank of the worm is a straight line in an offset plane which is tangential to the base cylinder. Machining methods should ensure this straight offset profile.

The involute helicoidal flanks of the threads can be generated by turning on a lathe using a knife tool with its straight edge aligned with the base tangent generatrix in a plane tangential to the base cylinder.

In order to machine both flanks of a thread simultaneously, one left hand tool in one plane and one right hand tool in another plane as described in [Figure 13](#) shall be set.



Key

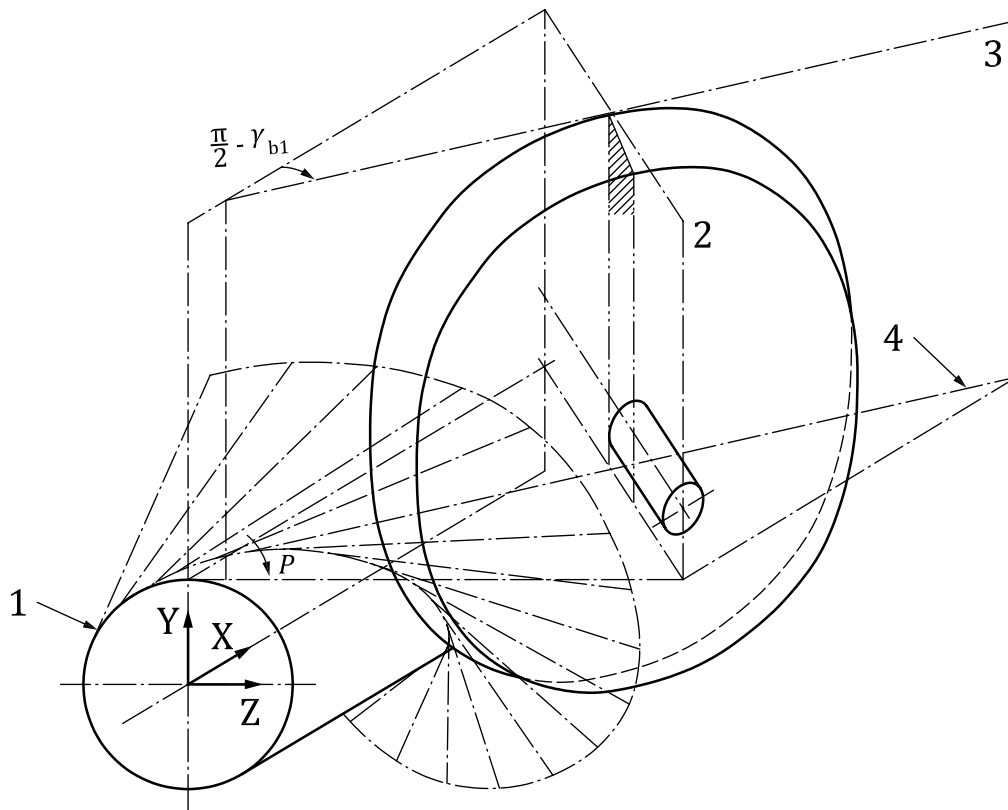
- 1 base cylinder
- 2 cutting tool
- 3 generatrix

NOTE $\alpha_{0t} = \gamma_{b1}$

Figure 13 — I Profile type - Machining method with a lathe

The worm flanks can be machined by milling or grinding using the plane side face of a disc type milling cutter or grinding wheel. The cutting face shall be aligned either

- with its axis parallel to the X-Z plane and the base tangent generatrix of the flank in the cutting face (see [Figure 14](#)), or
- with the reference helix of the worm and in a plane perpendicular to the reference helix set to the normal pressure angle α_{0n} (see [Figure 15](#)).

**Key**

- 1 base cylinder
- 2 grinding wheel (with flat active face)
- 3 action plane of the grinding wheel
- 4 generatrix
- P plane tangent to the base circle containing the generatrix

Figure 14 — I Profile type - Machining method by grinding (solution 1)

In the set-up of alignment in [Figure 15](#), the cutting face has the advantage to extend near the thread root.

In the set-up of method of [Figure 14](#), the cutter/grinding-wheel spindle shall be raised so that the cutter/wheel periphery is tangent to the point of intersection of the base tangent generatrix with the root cylinder of the worm.

Both methods require that the mounting of the worm in the milling/grinding machine be reversed between machining right and left flanks.

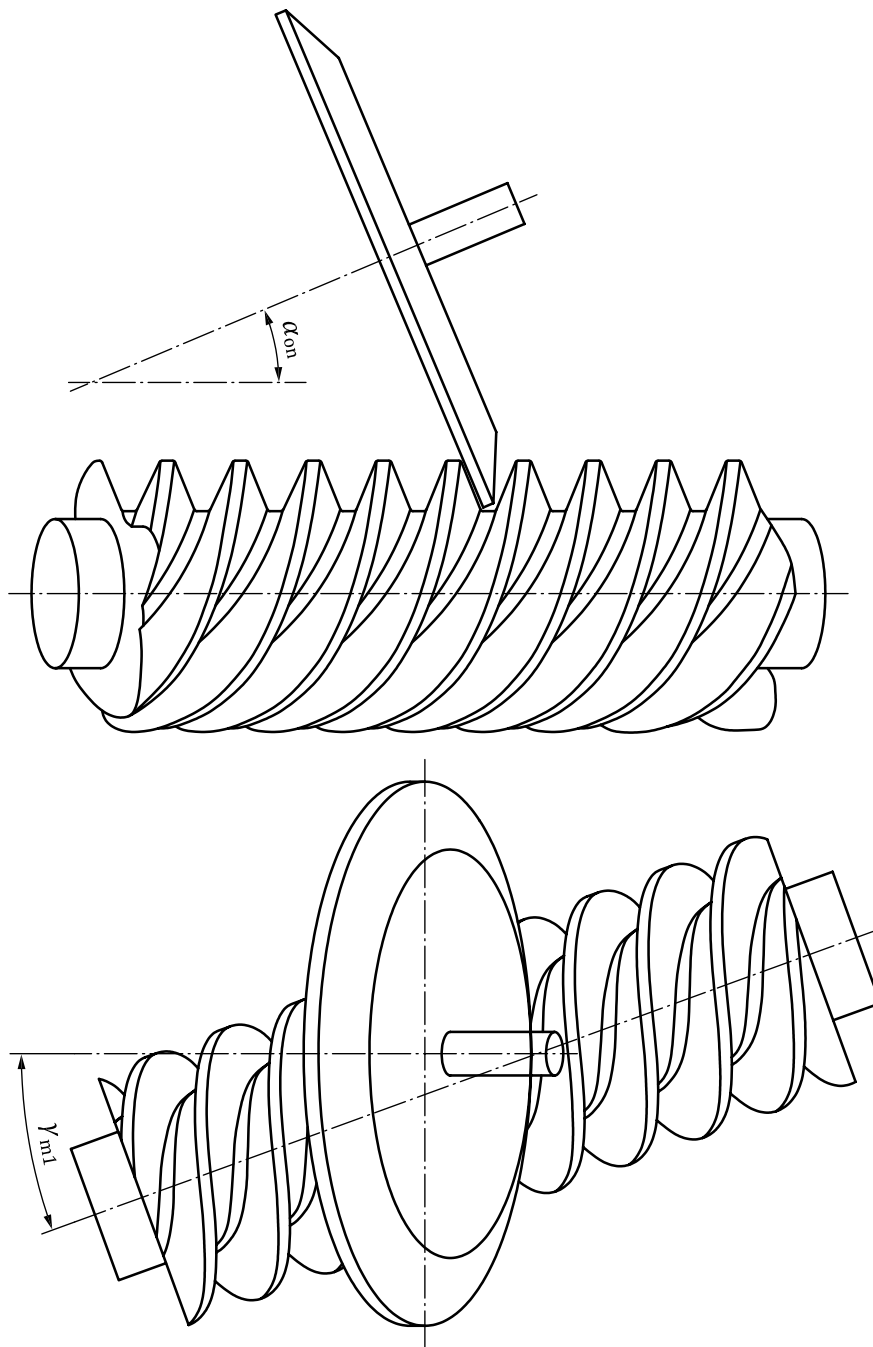


Figure 15 — I Profile type - Machining method by grinding (solution 2)

I profile type is slightly convex in an axial plane.

The development of the formulae for the axial profile of I worm profile type is shown in [Annex A, A.3](#).

7.4 N worm profile type

7.4.1 Geometrical definition

The worm flank with N profile type is formed by a straight line generatrix (Δ) which lies in a plane normal to the reference helix (H_1); crossing (M) which is a common point of intersection of a vector radius, the generatrix (Δ) and the reference helix H. The angle α between (Δ) and the radius vector at M point is constant.

The flank envelope is formed by the generatrix (Δ), due to the helicoidal movement of the vector radius carrying the point M which describes the reference helix (see [Figure 12](#)).

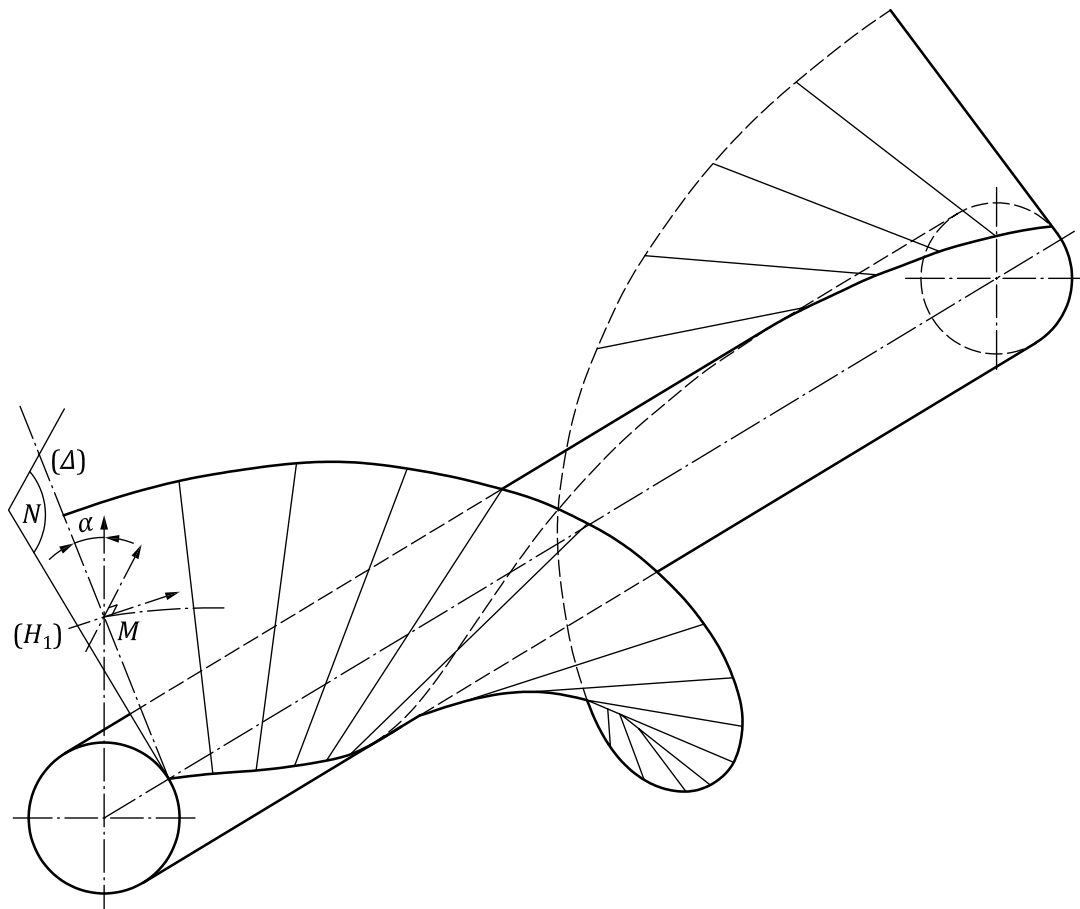


Figure 16 — N Profile type - Theoretical generation

7.4.2 Machining methods

The threads can be cut in a lathe with a tool having trapezoidal form having edges in the cutting plane which match the profile of the thread space in a plane normal to the reference helix of the thread space.

This is equivalent to placing the tool as for threads with A profile type, then to rotate it around an axis matching its symmetrical axis up to an angle equal to the reference lead angle γ_{m1} (see [Figure 17](#)).

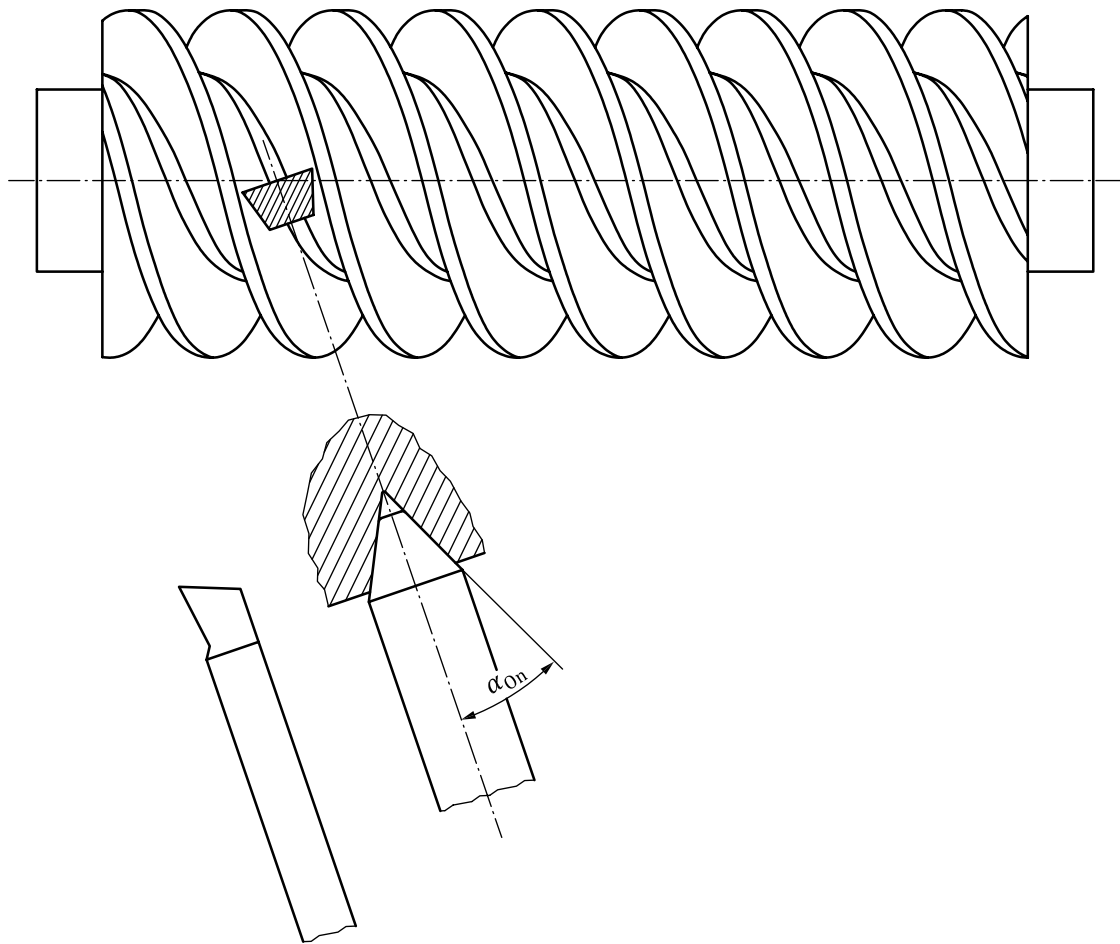


Figure 17 — N Profile type - Machining methods

Type N profiles are slightly concave in an axial plane.

The development of the formulae for the axial profile of N worm profile type is shown in [Annex A, A.4](#).

7.5 General formulae for A, I and N profile types

[Formulae \(49\)](#) to [\(54\)](#) shall be used to obtain the axial profile for A, I, N profile types.

The general formula of the axial profile of the worm for A, I, N profiles can be given by [Formula \(49\)](#) and [Formula \(50\)](#) with x_x as the axial abscissa of the axial profile point function of the radius of the circle y_r at this point:

$$x_x(y_r) = a_1 \cdot \arctan\left(\frac{\sqrt{y_r^2 - a_2^2}}{a_2}\right) + a_3 \cdot \sqrt{y_r^2 - a_2^2} + a_4 \quad (49)$$

$$y_x(y_r) = y_r \quad (50)$$

The values for the coefficients are given in [Table 5](#).