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Straight cylindrical involute splines — Metric module, side fit —

Part 1: Generalities

Cannelures cylindriques droites à flancs en développante — Module métrique, à centrage sur flancs —

Partie 1: Généralités

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Foreword

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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).

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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 14, *Shafts of machinery and accessories*.

This second edition cancels and replaces the first edition (ISO 4156-1:2005), which has been technically revised.

The main changes compared to the previous edition includes:

— ISO 268-1 has been removed from Clause 2;

— ISO 4156-2 and ISO 4156-3 have been moved from Clause 2 to Bibliography;

— the definitions of base diameter, major diameter, minor diameter, depth of engagement, theoretical clearance, out-of-roundness, and auxiliary dimension have been removed;

— symbols of length and arc length between two points, according to ISO 80000-3, have been adopted and used in calculation examples in Annex A;

— in Figure 8, clearance between external spline and mating part has been corrected;

— in Figure 10, measurement of space width, effective and tooth thickness, effective have been corrected;

— in Figure 11, the figure title has been changed;

— in Figure 15, the indication of form tooth height and minor tooth height has been corrected;

— in Table 11, the tolerance on D_{ii} for diameter > 80 to 120 in column H 11 has been corrected;

— the previous Tables 14 to 17 have been corrected and moved to Annex A;

— in A.4, the calculation of $M_{Re\ min}$ has been completed.

A list of all parts in the ISO 4156 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 4156 (all parts) provides the data and indications necessary for the design, manufacture and inspection of straight (non-helical) side-fitting cylindrical involute splines.

Straight cylindrical involute splines manufactured in accordance with ISO 4156 (all parts) are used for clearance, sliding and interference connections of shafts and hubs. They contain all the necessary characteristics for the assembly, transmission of torque, and economic production.

The nominal pressure angles are 30°, 37,5° and 45°. For electronic data processing purposes, the form of expression 37,5° has been adopted instead of 37°30'. ISO 4156 (all parts) establishes a specification based on the following modules:

— for pressure angles of 30° and 37,5° the module increments are:

0,5; 0,75; 1; 1,25; 1,5; 1,75; 2; 2,5; 3; 4; 5; 6; 8; 10;

— for pressure angle of 45° the module increments are:

0,25; 0,5; 0,75; 1; 1,25; 1,5; 1,75; 2; 2,5.

Straight cylindrical involute splines — Metric module, side fit —

Part 1:
Generalities

1 Scope

This document provides the data and indications necessary for the design and manufacture of straight (non-helical) side-fitting cylindrical involute splines.

Limiting dimensions, tolerances, manufacturing deviations and their effects on the fit between connecting coaxial spline elements are defined in the formulae and given in the tables. Unless otherwise specified, linear dimensions are expressed in millimetres and angular dimensions in degrees.

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 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1
spline joint
connecting, coaxial elements that transmit torque through the simultaneous engagement of equally spaced teeth situated around the periphery of a cylindrical external member with similar spaced mating spaces situated around the inner surface of the related cylindrical internal member

3.2
involute spline
member of *spline joint* (3.1) having teeth or spaces that have involute flank profiles

3.3
internal spline
spline formed on the inner surface of a cylinder

3.4
external spline
spline formed on the outer surface of a cylinder

3.5
fillet
concave surface of the tooth or space connecting the involute flank and the root circle

Note 1 to entry: For generated splines this curved surface, as generated, varies and cannot be properly specified by a radius of any given value. For splines formed directly by a tool (e.g. broached, net formed) the fillet may be specified as a true radius.

3.6
fillet root
spline having a tooth or space profile in which the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a single *fillet* (3.5)

3.7
flat root
spline having a tooth or space profile in which each of the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a *fillet* (3.5)

3.8
module
m
ratio of the *circular pitch* (3.12), expressed in millimetres, to the number π

3.9
pitch circle
reference circle to which all spline dimensions are related, and the circle on which the specified *pressure angle* (3.13) has its nominal value

3.10
pitch diameter
D
diameter of the *pitch circle* (3.9), in millimetres, equal to the number of teeth multiplied by the *module* (3.8)

3.11
pitch point
intersection of the spline tooth profile with the *pitch circle* (3.9)

3.12
circular pitch
p
length of arc of the *pitch circle* (3.9) between two consecutive *pitch points* (3.11) of left- (or right-) hand flanks, which has a value of the number π multiplied by the *module* (3.8)

3.13
pressure angle
α
acute angle between a radial line passing through any point on a tooth flank and the tangent plane to the flank at that point

3.14
standard pressure angle
α_D
pressure angle (3.13) at the specified *pitch point* (3.11)

3.15
base circle
circle from which *involute spline* (3.2) tooth profiles are generated

3.16
base pitch
p_b
arc length of the *base circle* (3.15) between two consecutive corresponding flanks

3.17
form diameter
D_F
diameter used to define the depth of involute profile control

Note 1 to entry: In the case of an *external spline* (3.4) it is located near and above the minor diameter, and on an *internal spline* (3.3) near and below the major diameter.

3.18
basic circular space width
E
for 30°, 37,5° and 45° *pressure angle* (3.13) splines, half the *circular pitch* (3.12), measured at the *pitch diameter* (3.10)

3.19
basic circular tooth thickness
S
for 30°, 37,5° and 45° *pressure angle* (3.13) splines, half the *circular pitch* (3.12), measured at the *pitch diameter* (3.10)

3.20
actual space width

practically measured circular space width, on the *pitch circle* (3.9), of any single space width within the limit values E_{max} and E_{min}

3.21
effective space width, circular
E_v
space width where an imaginary perfect *external spline* (3.4) would fit without clearance or interference, given by the size of the tooth thickness of this external spline, considering engagement of the entire axial length of the splined assembly

Note 1 to entry: The minimum effective space width ($E_{v\ min}$, always equal to E) of the *internal spline* (3.3) is always basic, as shown in Table 3.

3.22
actual tooth thickness
practically measured circular tooth thickness, on the *pitch circle* (3.9), of any single tooth within the limit values S_{max} and S_{min}

3.23
effective tooth thickness, circular
S_v
tooth thickness where an imaginary perfect *internal spline* (3.3) would fit without clearance or interference, given by the size of the space width of this internal spline, considering engagement of the entire axial length of the splined assembly

3.24
effective clearance
c_v
⟨looseness or interference⟩ *effective space width, circular* (3.21) of the *internal spline* (3.3) minus the *effective tooth thickness, circular* (3.23) of the *external spline* (3.4)

Note 1 to entry: For looseness, c_v is positive; for interference, c_v is negative.

3.25
form clearance
c_F
radial clearance between the form diameter of the *internal spline* (3.3) and the major diameter of the *external spline* (3.4), or between the minor diameter of the internal spline and the form diameter of the external spline

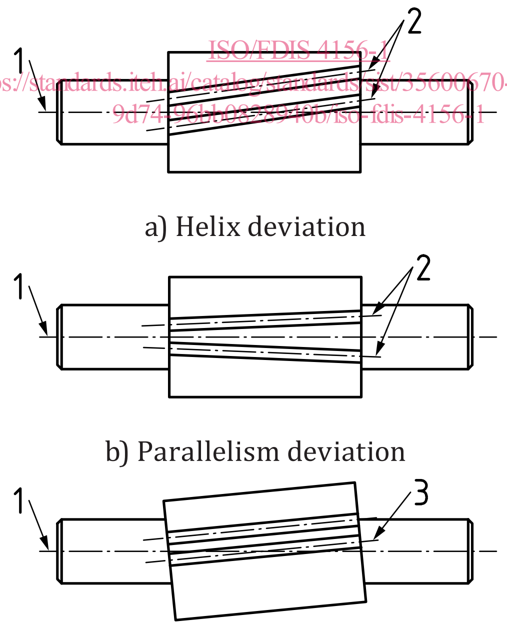
Note 1 to entry: It allows eccentricity of their respective *pitch circles* (3.9).

3.26
total pitch deviation
F_p
absolute value of the difference between the greatest positive and negative deviations from the theoretical spacing

3.27
total profile deviation
F_α
absolute value of the difference between the greatest positive and negative deviations from the theoretical tooth profile, measured normal to the flanks

3.28
total helix deviation
F_β
absolute value of the difference between the two extreme deviations from the theoretical direction parallel to the reference axis

Note 1 to entry: This includes *parallelism deviation* (3.29) and *alignment deviation* (3.30), see Figure 1.



a) Helix deviation

b) Parallelism deviation

c) Alignment deviation

Key

1 reference axis

2 centreline of teeth

3 effective spline axis

Figure 1 — Helix deviations

3.29
parallelism deviation
deviation of parallelism of a single spline tooth to any other single spline tooth

Note 1 to entry: See Figure 1 b).

3.30
alignment deviation
deviation of the effective spline axis with respect to the reference axis

Note 1 to entry: See Figure 1 c).

3.31
effective deviation
accumulated effect of the spline deviations on the fit with the mating part

3.32
deviation allowance
λ
permissible deviation between minimum actual and minimum *effective space width, circular* (3.21) or maximum effective and maximum *actual tooth thickness* (3.22)

3.33
machining tolerance
T
permissible deviation between maximum actual and minimum *actual space width* (3.20) or tooth thickness

3.34
effective clearance tolerance
T_v
permissible deviation between maximum effective and minimum *effective space width, circular* (3.21) or tooth thickness

3.35
total tolerance
$T + \lambda$
⟨general⟩ *machining tolerance* (3.33) plus the *deviation allowance* (3.32)

3.36
total tolerance
⟨internal spline⟩ difference between the minimum *effective space width, circular* (3.21) and the maximum *actual space width* (3.20)

3.37
total tolerance
⟨external spline⟩ difference between the maximum *effective tooth thickness, circular* (3.23) and the minimum *actual tooth thickness* (3.22)

3.38
basic dimension
numerical value to describe the theoretically exact size, shape or location of a feature

Note 1 to entry: It is the basis from which permissible deviations are established by tolerances.

4 Symbols, subscripts and abbreviated terms

4.1 General symbols

The general symbols used to designate the various spline terms and dimensions are given below.

b	Spline length	mm
c_F	Form clearance	mm
c_v	Effective clearance (looseness or interference)	µm
$c_{v\,max}$	Maximum effective clearance	µm
$c_{v\,min}$	Minimum effective clearance	µm
d_{ce}	Ball or pin contact diameter, external spline	mm
d_{ci}	Ball or pin contact diameter, internal spline	mm
D	Pitch diameter	mm
D_{Fe}	Form diameter, external spline	mm
$D_{Fe\,max}$	Maximum form diameter, external spline	mm
D_{Fi}	Form diameter, internal spline	mm
$D_{Fi\,min}$	Minimum form diameter, internal spline	mm
D_{Re}	Diameter of measuring ball or pin for external spline	mm
D_{Ri}	Diameter of measuring ball or pin for internal spline	mm
D_b	Base diameter	mm
D_{ee}	Major diameter, external spline	mm
$D_{ee\,max}$	Maximum major diameter, external spline	mm
$D_{ee\,min}$	Minimum major diameter, external spline	mm
D_{ei}	Major diameter, internal spline	mm
$D_{ei\,max}$	Maximum major diameter, internal spline	mm
$D_{ei\,min}$	Minimum major diameter, internal spline	mm
D_{ie}	Minor diameter, external spline	mm
$D_{ie\,max}$	Maximum minor diameter, external spline	mm
$D_{ie\,min}$	Minimum minor diameter, external spline	mm
D_{ii}	Minor diameter, internal spline	mm
$D_{ii\,max}$	Maximum minor diameter, internal spline	mm
$D_{ii\,min}$	Minimum minor diameter, internal spline	mm
E	Basic circular space width	mm
E_{max}	Maximum actual space width	mm
E_{min}	Minimum actual space width	mm
E_v	Effective space width, circular	mm

$E_{v\,max}$	Maximum effective space width	mm
$E_{v\,min}$	Minimum effective space width	mm
es_v	Fundamental deviation, external	µm
F_p	Total pitch deviation	µm
F_α	Total profile deviation	µm
F_β	Total helix deviation	µm
h_s	Form tooth height	mm
i	Tolerance unit	µm
inv α	Involute α $(= \tan\alpha - \pi \cdot \alpha / 180°)$	—
K_e	Approximation factor for external spline	—
K_i	Approximation factor for internal spline	—
k	Number of measured teeth	—
L	Length of the arc	mm
l_{BA}	Length between two points (e.g. point B and point A)	mm
M_{Re}	Measurement over two balls or pins, external splines	mm
M_{Ri}	Measurement between two balls or pins, internal	mm
m	Module	mm
p	Circular pitch	mm
p_b	Base pitch	mm
S	Basic circular tooth thickness	mm
S_{max}	Maximum actual tooth thickness	mm
S_{min}	Minimum actual tooth thickness	mm
S_v	Effective tooth thickness, circular	mm
$S_{v\,max}$	Maximum effective tooth thickness	mm
$S_{v\,min}$	Minimum effective tooth thickness	mm
s_{DE}	Arc length between two points (e.g. point D and point E)	mm
T	Machining tolerance	µm
T_v	Effective clearance tolerance	µm
W	Measurement over k teeth, external spline	mm
z	Number of teeth (for external and internal splines, z has a positive sign)	—
α	Pressure angle	°

α_{ce}	Pressure angle at ball or pin diameter, external spline	°
α_{ci}	Pressure angle at ball or pin diameter, internal spline	°
α_D	Standard pressure angle at pitch diameter	°
α_e	Pressure angle at ball or pin centre, external spline	°
α_{Fe}	Pressure angle at form diameter, external spline	°
α_{Fi}	Pressure angle at form diameter, internal spline	°
α_i	Pressure angle at ball or pin centre, internal spline	°
λ	Deviation allowance	µm
ρ_{Fe}	Fillet radius of the basic rack, external spline	mm
ρ_{Fi}	Fillet radius of the basic rack, internal spline	mm
φ_f	Tolerance factor	—
k; js; h; f; e; d	Fundamental deviation of the external spline	µm

4.2 Subscripts

The following subscripts are used as part of the above general symbols to designate relative conditions or locations:

b	at the base
c	at contact point
D	standard
d	tolerance based on pitch diameter (*D*)
E	tolerance based on basic circular space width (*E*) or basic circular tooth thickness (*S*)
e	major or external (in the last case in the last position)
F	pertaining to form diameter
f	factor
i	minor or internal (in the last case in the last position)
R	pertaining to gauge
v	effective

NOTE In electronic data processing (EDP), it is not always possible to present symbols in their theoretically correct form because of limitations of connected printing equipment. For this reason, some alternative symbols for EDP usage are given in Table 1 (for example, the symbol for D_b for base diameter can be printed as DB).

4.3 Formulae for dimensions and tolerances for all fit classes

The formulae for dimensions and tolerances for all fit classes are given in Table 1.

Table 1 — Formulae for dimensions and tolerances for all fit classes

Term	Symbol	Formula	EDP representation
Pitch diameter	D	$m \cdot z$	D
Base diameter	D_b	$m \cdot z \cdot \cos\alpha_D$	DB
Circular pitch	p	$m \cdot \pi$	P
Base pitch	p_b	$m \cdot \pi \cdot \cos\alpha_D$	PB
Fundamental deviation, external	es_v	Resulting from fundamental deviation k, js, h, f, e and d	ESV
Minimum major diameter, internal:			
30°, flat root	$D_{ei\ min}$	$m \cdot (z+1{,}5)$	DEIMIN
30°, fillet root	$D_{ei\ min}$	$m \cdot (z+1{,}8)$	DEIMIN
37,5°, fillet root	$D_{ei\ min}$	$m \cdot (z+1{,}4)$	DEIMIN
45°, fillet root	$D_{ei\ min}$	$m \cdot (z+1{,}2)$	DEIMIN
Maximum major diameter, internal	$D_{ei\ max}$	$D_{ei\ min} + (T+\lambda) / \tan\alpha_D$ [a]	DEIMAX
Minimum form diameter, internal:			
30° flat root and fillet root	$D_{Fi\ min}$	$m \cdot (z+1) + 2 \cdot c_F$	DFIMIN
37,5° fillet root	$D_{Fi\ min}$	$m \cdot (z+0{,}9) + 2 \cdot c_F$	DFIMIN
45° fillet root	$D_{Fi\ min}$	$m \cdot (z+0{,}8) + 2 \cdot c_F$	DFIMIN
Minimum minor diameter, internal	$D_{ii\ min}$	$D_{Fe\ max} + 2 \cdot c_F$ [b]	DIIMIN
Maximum minor diameter, internal:			
$m \leq 0{,}75$	$D_{ii\ max}$	$D_{ii\ min} + \text{IT } 10$	DIIMAX
$0{,}75 < m < 2$	$D_{ii\ max}$	$D_{ii\ min} + \text{IT } 11$	DIIMAX
$m \geq 2$	$D_{ii\ max}$	$D_{ii\ min} + \text{IT } 12$	DIIMAX
Basic circular space width	E	$0{,}5 \cdot \pi \cdot m$	E
Minimum effective space width	$E_{v\ min}$	$0{,}5 \cdot \pi \cdot m$	EVMIN
Maximum actual space width:			
class 4 to class 7	E_{max}	$E_{v\ min} + (T+\lambda)$ [c]	EMAX
Minimum actual space width	E_{min}	$E_{v\ min} + \lambda$	EMIN
Maximum effective space width	$E_{v\ max}$	$E_{v\ min} + T_v$	EVMAX
Maximum major diameter, external:			
30°, flat root and fillet root	$D_{ee\ max}$	$m \cdot (z+1) + es_v / \tan\alpha_D$ [d]	DEEMAX
37,5°, fillet root	$D_{ee\ max}$	$m \cdot (z+0{,}9) + es_v / \tan\alpha_D$ [d]	DEEMAX
45°, fillet root	$D_{ee\ max}$	$m \cdot (z+0{,}8) + es_v / \tan\alpha_D$ [d]	DEEMAX

[a] $(T+\lambda)$ for class 7 – see 9.1.

[b] For all classes of fit, always take the $D_{Fe\ max}$ value corresponding to the H/h fit.

[c] See Clauses 8, 9 and ISO 4156-2.

[d] Take $es_v = 0$ for fundamental deviation js and k.

[e] For h_s, see Figure 15 and Table 2.

[f] See 9.1.

[g] See ISO 4156-3 concerning the choice of balls or pins.

