INTERNATIONAL STANDARD

ISO 4156-3

First edition
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Straight cylindrical involute splines — Metric module, side fit —

Part 3: Inspection

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

Partie 3: Vérification

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4156-3 was prepared by Technical Committee ISO/TC 14, *Shafts for machinery and accessories*.

This first edition of ISO 4156-3, together with ISO 4156-1 and ISO 4156-2, cancels and replaces ISO 4156:1981 and ISO 4156:1981/Amd 1:1992, of which it constitutes a technical revision.

ISO 4156 consists of the following parts, under the general title *Straight cylindrical involute splines — Metric module, side fit*:

— *Part 1: Generalities*

— *Part 2: Dimensions*

— *Part 3: Inspection*

Introduction

ISO 4156 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 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 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 3:
Inspection

1 Scope

This part of ISO 4156 provides data and guidance for the inspection of straight (non-helical) side fitting cylindrical involute splines.

Limiting dimensions, tolerances, manufacturing errors and their effects on the fit between connecting coaxial spline elements are defined and tabulated. Linear dimensions are expressed in millimetres and angular dimensions in degrees.

2 Normative references

The following referenced documents are indispensable for the application 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 3, *Preferred numbers — Series of preferred numbers*

ISO 286-1, *ISO system of limits and fits — Part 1: Bases of tolerances, deviations and fits*

ISO 1101, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 1328-1, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO 1328-2, *Cylindrical gears — ISO system of accuracy — Part 2: Definitions and allowable values of deviations relevant to radial composite deviations and runout information*

ISO/R 1938-1, *ISO system of limits and fits — Part 1: Inspection of plain workpieces*

ISO 4156-1, *Straight cylindrical involute splines — Metric module, side fit — Part 1: Generalities*

ISO 4156-2, *Straight cylindrical involute splines — Metric module, side fit — Part 2: Dimensions*

ISO 5459, *Technical drawings — Geometrical tolerancing — Datums and datum-systems for geometrical tolerances*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 4156-1 apply.

4 Symbols and abbreviated terms

NOTE Some of the symbols used might have a meaning other than the one intended here. The symbols H, Z, Y and W are common for gauge tolerances in other ISO standards and could seem to conflict with symbols used in this part of ISO 4156. However, it was not thought necessary to distinguish between them, since the context will always preclude any ambiguity.

D	Pitch diameter	mm
$D_{\mathrm{Fe\,max}}$	Maximum form diameter, external spline	mm
$D_{\mathrm{Fi\,min}}$	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
$D_{\mathrm{ee\,max}}$	Maximum major diameter, external spline	mm
$D_{\mathrm{ee\,min}}$	Minimum major diameter, external spline	mm
D_{ii}	Minor diameter, internal spline	mm
$D_{\mathrm{ii\,min}}$	Minimum minor diameter, internal spline	mm
E	Basic space width	mm
E_{max}	Maximum actual space width	mm
E_{min}	Minimum actual space width	mm
E_{r}	Eccentric radial offset	mm
E_{v}	Effective space width	mm
$E_{\mathrm{v\,max}}$	Maximum effective space width	mm
$E_{\mathrm{v\,min}}$	Minimum effective space width	mm
F_p	Total cumulative pitch deviation	µm
F_α	Total profile deviation	µm
F_β	Total helix deviation	µm
K_{e}	Approximation factor for external spline	—
K_{i}	Approximation factor for internal spline	—
M_{Re}	Measurement over two balls or pins, external splines	mm
M_{Ri}	Measurement between two balls or pins, internal	mm
S	Basic tooth thickness	mm
S_{max}	Maximum actual tooth thickness	mm
S_{min}	Minimum actual tooth thickness	mm
S_{b}	Circular base thickness	mm

$S_{v\,max}$	Maximum effective tooth thickness	mm
$S_{v\,min}$	Minimum effective tooth thickness	mm
STA	Statistical tolerance limit actual	µm, %
$STA_{absolute}$	Statistical tolerance limit actual absolute	µm, %
$STA_{relative}$	Statistical tolerance limit actual relative	%
T	Machining tolerance	µm
T_v	Effective clearance tolerance	µm
W	Measurement over k teeth, external spline	mm
$a_{allowed}$	Limited max. value of distance out of the actual tolerance limit	µm
d_{ce}	Ball or pin contact diameter, external spline	mm
d_{ci}	Ball or pin contact diameter, internal spline	mm
i	Integer	
inv α	Involute $\alpha\ (= \tan\alpha - \pi \times \alpha / 180°)$	—
k	Number of measured teeth	
m	Module	mm
$n_{allowed}$	Max. allowed number of measured sizes outside tolerance limit	—
p_b	Base pitch	mm
z	Number of teeth	—
α	Pressure angle	°
α_{ce}	Pressure angle at ball or pin diameter, external spline	°
α_D	Standard pressure angle at pitch diameter	°
α_e	Pressure angle at ball or pin centre, external spline	°
α_i	Pressure angle at ball or pin centre, internal spline	°
ψ	Phase angle	°
τ	Angular pitch	°
λ	Deviation allowance	µm

5 Reference conditions

The standard reference temperature for industrial length measurements is 20 °C. The dimensional requirements for parts and gauges are defined at that temperature and inspection shall also normally be carried out at that same temperature.

If measurements are taken at another temperature, the results shall be corrected using the expansion coefficients of parts and gauges respectively.

Unless otherwise specified, all measurements shall be made under zero measuring load.

If measurements are made under a non-zero load, the results shall be corrected accordingly. However, such correction is not required for comparison measurements made with the same comparison means and under the same measuring load, between similar components of the same material and with the same surface condition.

6 Quality features

6.1 General

The inspection of splines is divided into three quality features, as shown in Figure 1.

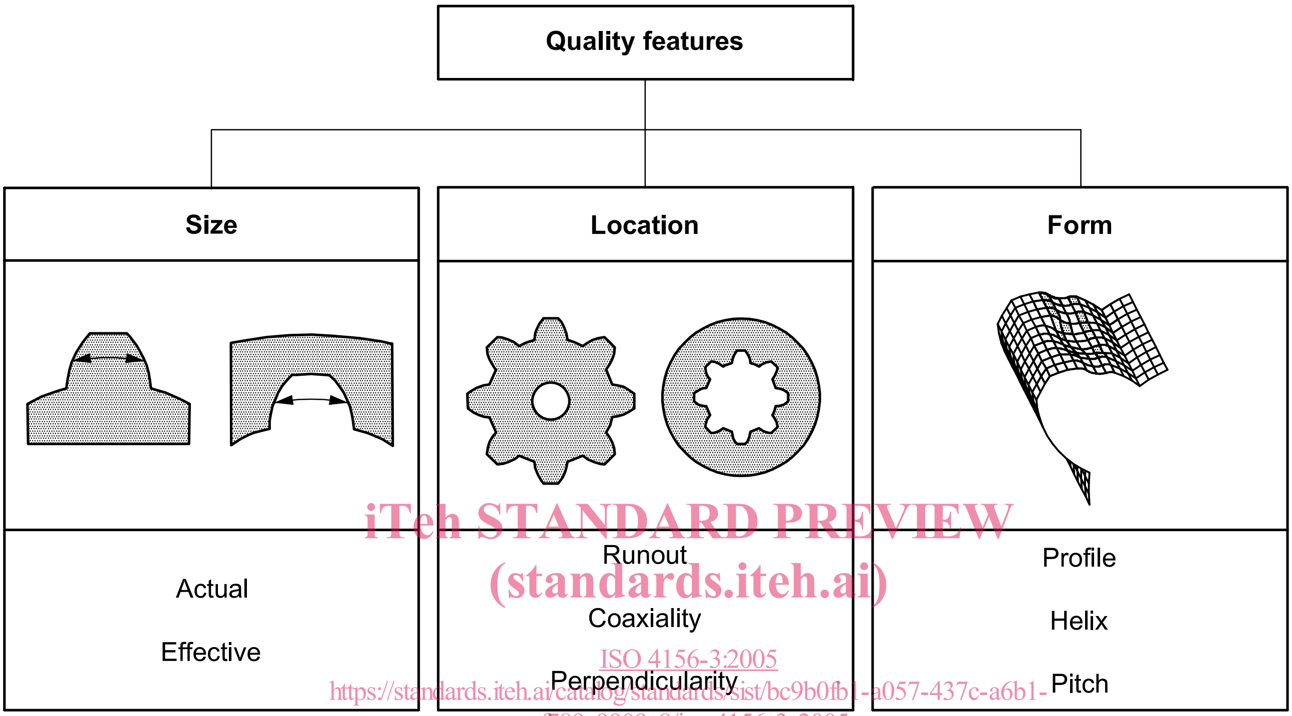


Figure 1 — Quality features

6.2 Size

6.2.1 Actual size

The actual size is

a) for external splines, the circular tooth thickness at the pitch diameter, and

b) for internal splines, the circular space width at the pitch diameter.

6.2.2 Effective size

The effective tooth thickness or space width is the maximum material condition resulting from the actual size and the accumulation of form deviations.

6.3 Location

The location of a spline is the location of the central axis in relation to any other geometrical element found by actual or effective inspection methods.

6.4 Form

The form deviations of a spline are the deviations to the true geometrical form of profile, helix and pitch.

7 Methods of inspection

7.1 Size

7.1.1 General methods

Three general methods of inspection are provided in Table 1. If not otherwise specified, the standard method shall be used. If the alternative methods A or B are required, this shall be stated in the part data table. For the consequence of general methods, see Table 2.

Table 1 — Relationship between parameters and control method

	Minimum material	**Minimum effective clearance**	**Maximum effective clearance**
Parameter	S_{min}/E_{max}	$S_{v\ max}/E_{v\ min}$	$S_{v\ min}/E_{v\ max}$
Standard method	X	X	—
Method A	X	X	X
Method B	—	X	X

Table 2 — Consequence of general methods

Inspection method	**Theoretical maximum clearance between mating parts (zero form deviation)**	**Maximum deviation of form in each part (zero clearance)**
Standard	$2\ (T + \lambda)$	$T + \lambda$
Alternative A	$2T_v$	$T + \lambda$
Alternative B	$2T_v$	Undetermined
NOTE The theoretical maximum clearance between mating parts in this table is for parts in their new condition. The clearance will increase when wear occurs.		

7.1.2 Choice of measuring instrument

The choice of measuring instrument shall be made according to the design requirements (see ISO 4156 part 1). See Table 3 and Figure 2.

7.1.3 Actual size

7.1.3.1 Dimensions over and between balls

The dimension over or between balls facilitates the calculation of the theoretical actual circular tooth thickness or space width at the pitch circle diameter based on the actual tooth thickness or space width where the balls contact through one normal plane. The size measured over or between balls is a true size at 2 particular gaps and in one particular plane.

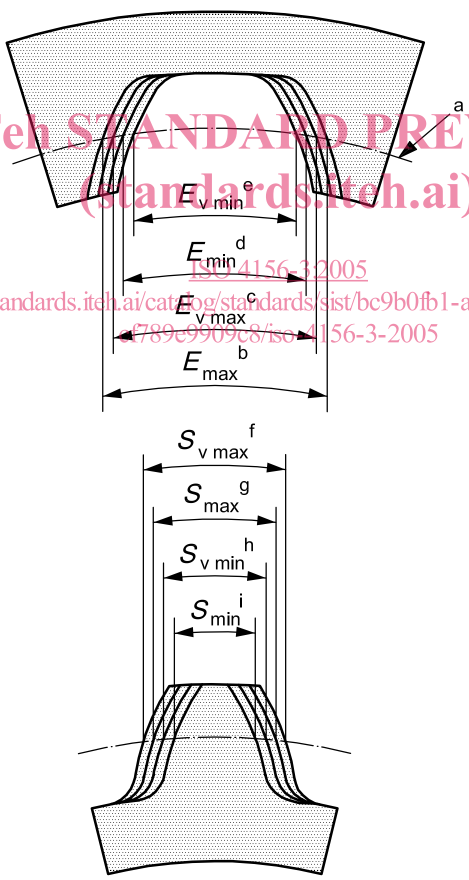
7.1.3.2 Dimensions over and between pins

The dimension over or between pins facilitates the calculation of the theoretical actual circular tooth thickness or space width at the pitch circle diameter based on the actual tooth thickness or space width where the pins have a line contact.

Table 3 — Size Inspection measuring instruments, methods and priorities

Priority	Parameter			
	S_{min}/E_{max}	$S_{v\ max}/E_{v\ min}$	$S_{v\ min}/E_{v\ max}$	S_{max}/E_{min}
	Method			
Highest	Measurement over and between balls	GO composite gauge	NO GO composite gauge	Measurement over and between balls
Lower ↓	Measurement over and between pins NO GO sector gauge Variable sector gauge Span size	Variable composite gauge Analysis calculations using size and form deviations	Variable composite gauge	Measurement over and between pins Variable sector gauge

Internal space width



External tooth thickness

[a] Pitch circle.
[b] NO GO sector plug gauge or max. measurement between balls or pins.
[c] NO GO composite plug gauge.
[d] Min. measurement between balls or pins, aux.
[e] GO composite plug gauge.
[f] GO composite ring gauge.
[g] Max. measurement over balls or pins, aux.
[h] NO GO composite ring gauge.
[i] NO GO sector ring gauge or min. measurement over balls or pins.

Figure 2 — Space widths and tooth thicknesses

7.1.3.3 NO GO sector gauge

The NO GO sector gauge is used to inspect the specified actual tolerance limit of the circular tooth thickness or space width at the minimum material condition of the part, where the gauge contacts only at the ends.

7.1.3.4 Span size over k teeth

The span measurement facilitates the calculation of the theoretical actual circular tooth thickness of external splines at the pitch circle diameter based on the measurement over a block of teeth. Before using this method, suitability should be checked.

7.1.3.5 Variable sector gauge

The variable sector gauge measures the actual circular tooth thickness or space width. The actual measurement is achieved using radially locking left and right hand flanks and comparison to a master having a known tooth thickness or space width.

7.1.4 Effective size

7.1.4.1 GO composite gauge

GO composite gauges are used to check

a) that the specified effective limits of tooth thickness or space width are not exceeded at the maximum material condition of the part,

b) the specified form diameter of the part, thus ensuring that the required tolerances are controlled for the full involute depth, and

c) the specified length of engagement, thus ensuring that the spline maximum material limit has not been exceeded.

7.1.4.2 Variable composite gauge

The variable composite measures the effective size of tooth thickness or space width. The actual measurement is achieved using the radially locking left and right hand flanks and comparison to a master having a known tooth thickness of space width.

7.1.4.3 NO GO composite gauge

The NO GO composite gauge is used to check the specified effective limit of minimum tooth thickness or maximum space width, where the gauge contacts only at the ends.

7.1.4.4 Inspection of diameter at tooth tip (D_{ii} or D_{ee})

All these inspection methods require measuring the tooth tip (internal minor diameter, D_{ii}, or external major diameter, D_{ee}) using GO and NO GO plain (plug or ring) gauges or other acceptable measuring devices.

7.2 Location

7.2.1 General

Splines have an actual and effective true size of space width or tooth thickness, and hence also an actual and effective axis.

The tolerances concerning location (i.e. runout, total runout, concentricity, and coaxiality tolerances) shall be specified on the component drawing. Where the spline is used as a datum axis, other geometry features have to be toleranced to the spline axis. Because of the inherent form deviations, difficulties arise in the reproducibility and repeatability of the spline profile if the form deviations and cylindricity errors are numerous.

7.2.2 Choice of the method of inspection of location

The methods of inspection of location are given in Table 4.

Table 4 — Location inspection methods and priorities

Priority	Method
Highest	Effective axis using perfectly fitting mating part without form deviations
Lower ↓	Actual pitch cylinder axis Calculation with Fourier analysis Spline clamping systems

7.2.3 Effective axis using mating part

The location of the effective spline axis is defined by the axis of a perfect (without form deviations) mating spline fitting without clearance or looseness. As this is difficult in practice, spline clamping systems or mathematic calculation methods using the individual form deviations derived from analytical inspection may be used.

7.2.4 Actual pitch cylinder axis

The location of the actual spline axis (see Figure 3) is defined by the mean centre line of all measured points on the tooth flanks. This axis represents the position at which all deviations are minimum (least-square condition).

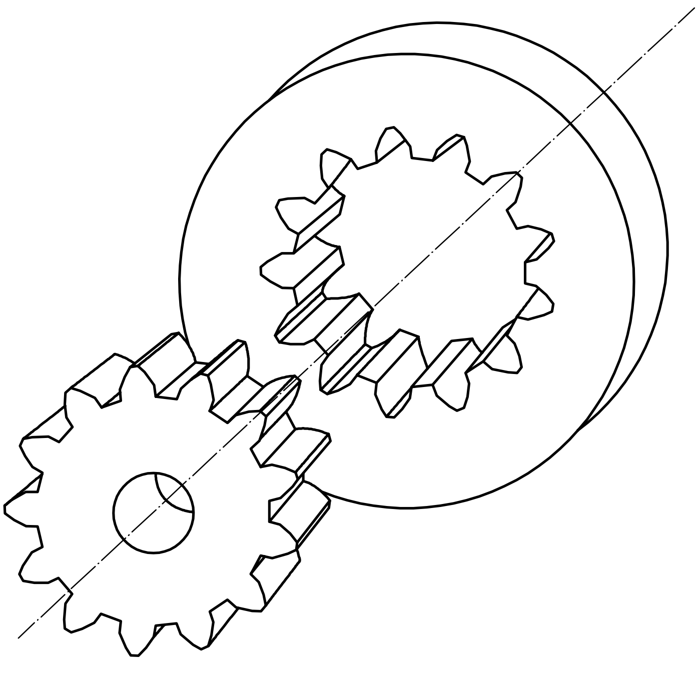
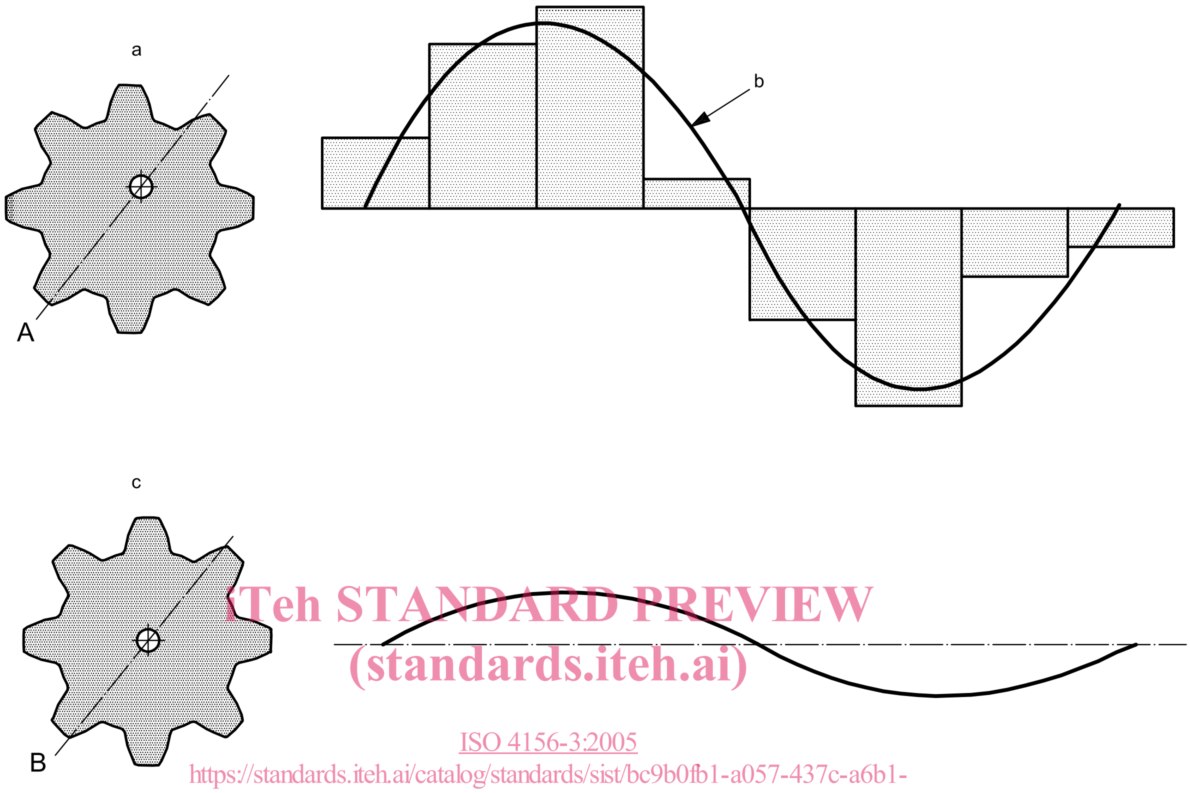


Figure 3 — Actual spline axis

7.2.5 Calculation with Fourier analysis

This can be carried out by the measurement and analysis of pitch deviation, profile deviation and helix deviation. This axis found by this method represents the axis where pitch, profile and helix deviations have their smallest values.



[a] Pitch errors to axis A.
[b] Found by Fourier analysis.
[c] Pitch errors to axis B with min. value.

Figure 4 — Axis found by Fourier analysis of pitch deviation

7.2.6 Spline clamping system

In practice it is very difficult to manufacture a perfect (without form deviations) mating spline that fits without looseness or clearance. As an alternative, a splined clamping system can be used. These clamp the parts on the tooth flanks. A variety of different systems are available, but they are a compromise in comparison to the perfect mating spline.

7.3 Form

A more comprehensive explanation of form deviations exists in ISO 1328 and ISO/TR 10064-1. The datum for form deviations is the effective pitch cylinder.

8 Measurements with balls or pins

8.1 General

The theoretical actual space width or tooth thickness can be calculated from the measurement over or between balls or pins.

The following concepts and formulae apply when using ball or pins.