INTERNATIONAL STANDARD

ISO 4156-3

First edition
2005-10-01

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
$D_{\text{Fe max}}$	Maximum form diameter, external spline	mm
$D_{\text{Fi min}}$	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
$D_{\text{ee max}}$	Maximum major diameter, external spline	mm
$D_{\text{ee min}}$	Minimum major diameter, external spline	mm
D_{ii}	Minor diameter, internal spline	mm
$D_{\text{ii min}}$	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
$E_{\text{v max}}$	Maximum effective space width	mm
$E_{\text{v min}}$	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 α $(= \tan\alpha - \pi \times \alpha / 180°)$	—
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.

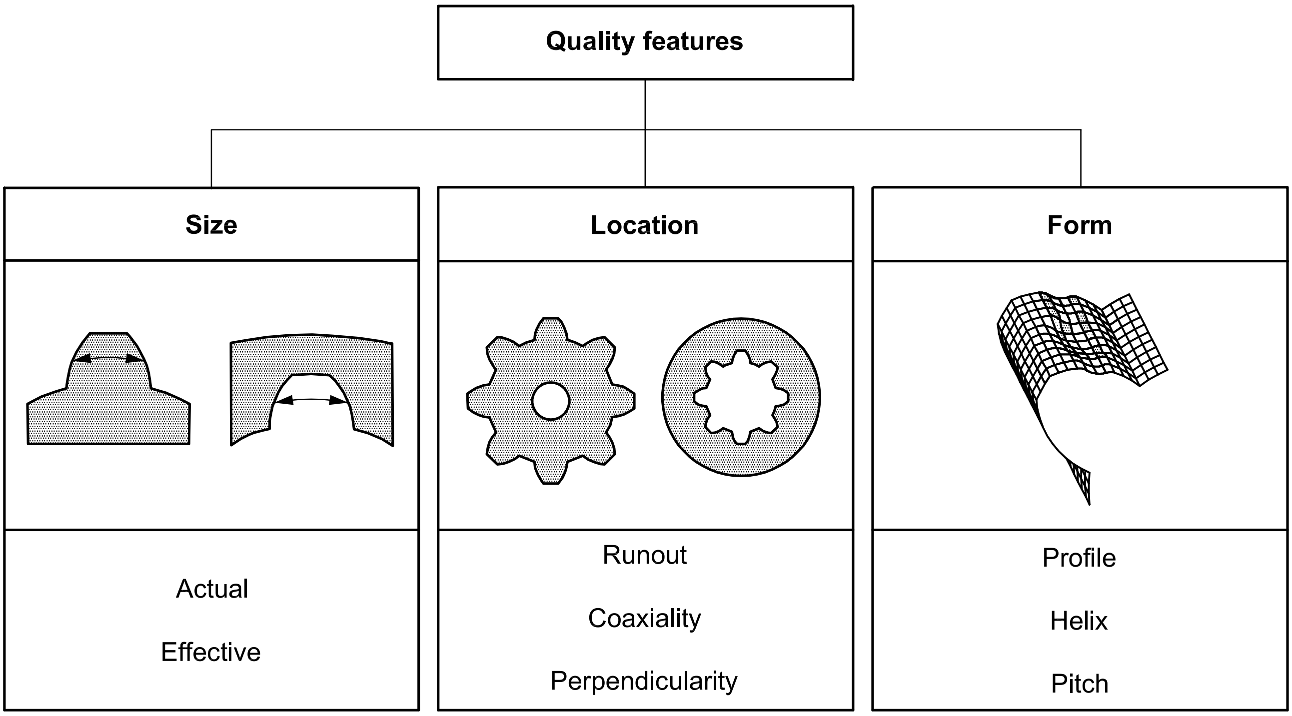


Figure 1 — Quality features

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.

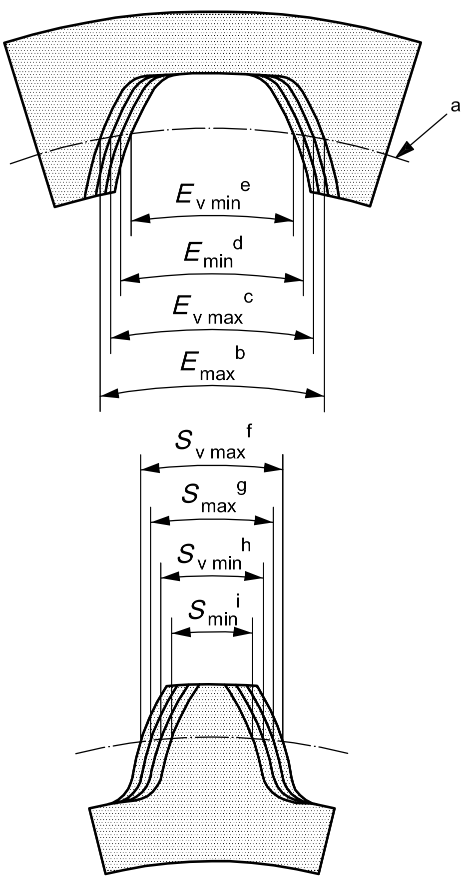
7.1.3.2 Dimensions over and between pins

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).

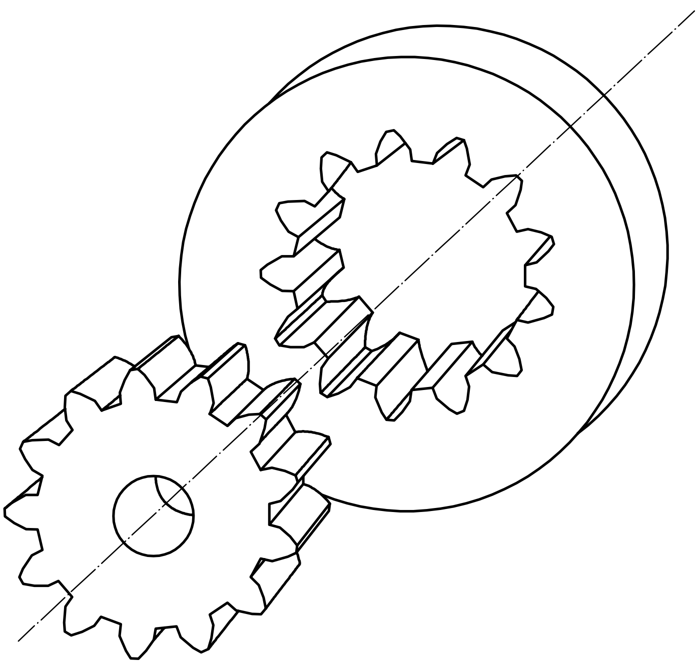
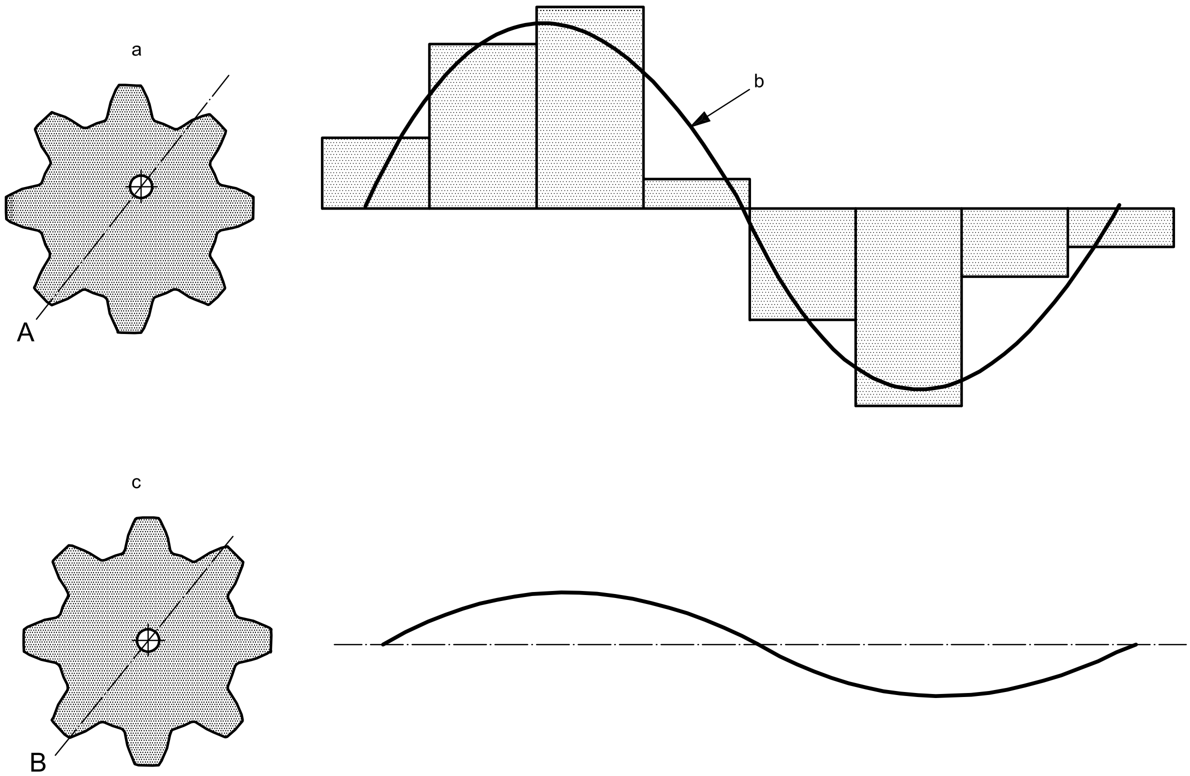


Figure 3 — Actual spline axis

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.

8.2 Selection of balls or pins

A ball or pin diameter shall be selected from the preferred number series R40 from ISO 3. Ideally, the ball or pin should contact the pitch diameter when the tooth or space is equal to S or E.

In practice it may be necessary to round the ball or pin diameter to the next greater value in the series.

In cases where it is not possible to select a size of pin or ball from ISO 4156-2, the size chosen shall satisfy the conditions of contact required for satisfactory measurements. The size to be used shall be subject to prior agreement between purchaser and manufacturer.

In some cases it will be necessary to make a flat on the pin or ball to avoid contact on the major diameter of an internal spline or minor diameter of an external spline.

The difference in geometry of measuring balls and pins influences the measuring results. Surface finish and helix deviations also have an effect.

Ball and pin accuracies are given in Table 5 with the length of the pin as a function of pin diameter.

Table 5 — Ball and pin accuracies and pin measuring length

Values in millimetres

Nominal diameter of balls or pins (D_{Ri} or D_{Re})	**Tolerances on diameter** (including all divisions)	**Pin length**
$0,3 \leqslant D_{Ri}$ or $D_{Re} \leqslant 1$	± 0,001	20 ± 5
$1 < D_{Ri}$ or $D_{Re} \leqslant 5$	± 0,001	30 ± 5
$5 < D_{Ri}$ or $D_{Re} \leqslant 15$	± 0,001 5	40 ± 5
$15 < D_{Ri}$ or $D_{Re} \leqslant 26$	± 0,001 5	50 ± 5
D_{Ri} or $D_{Re} \geqslant 26$	± 0,002	60 ± 5

8.3 Use and marking of pins

Pins shall be usable over their whole length in any area of the spline length to be checked.

They shall be marked with their nominal diameter.

8.4 Statistical actual tolerance limit STA

8.4.1 General

A number of unavoidable uncertainties exist in the inspection of the actual size of splines. The inspection result will be influenced by the

a) angular position,

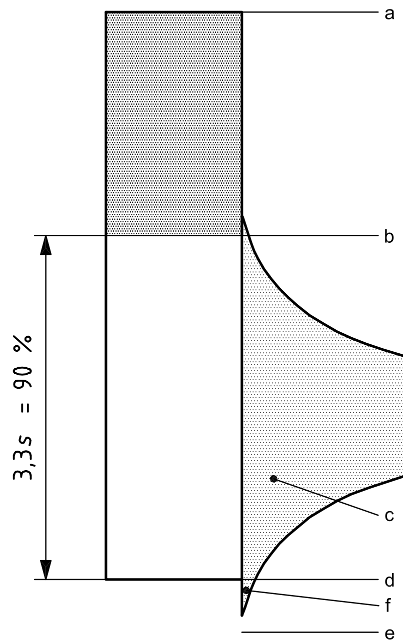
b) measuring plane, and

c) the inspection method.

These three items influence the measurement results and reduce repeatability. If not otherwise agreed by the customer and the manufacturer, the priority shall be established as follows:

All methods of inspection may be used to measure the actual size, but in case of disagreement, the measurement between or over balls shall have the highest priority in the acceptance or rejection of a part. The actual size shall be inspected in at least three equally spaced angular positions and in at least three equally spaced measuring planes. In the case of disagreement between measuring results from the same measuring method, the result which has utilised the greatest number of angular and longitudinal measuring positions shall have priority.

If measurements with a high number of measuring points are used, a statistical distribution of all measured true actual sizes at any position will exist. In theory, all local true actual sizes measured at any position have to be within the actual tolerance limit. The statistical analysis of the actual tolerance limit uses two STA (statistical tolerance analysis) tolerance limits and enables a decision to be made as to whether a part is to be accepted or rejected with regard to the actual tolerance limit. This part of ISO 4156 allows the use of the statistical actual tolerance limit STA.



[a] Max. effective tolerance limit.

[b] Reference mark, max. actual, aux.

[c] Distribution of measured sizes within one part.

[d] Min. actual tolerance limit.

[e] $STA_{absolute}$

[f] $STA_{relative}$

The statistical actual tolerance limit STA defines 2 limits:

$STA_{relative}$	$STA_{absolute}$
Number of local individual true actual sizes allowed to be outside the actual tolerance limit.	Maximum value of local individual true sizes to be allowed outside the tolerance limit.
Given in % of all measured sizes.	Given in micrograms or as a percentage of the actual tolerance value.

Figure 5 — STA

8.4.2 Acceptance of parts according to the statistical actual tolerance limit STA

The arithmetic average of all local sizes as well as compensated circles or cylinders shall always be inside the actual tolerance limit. The statistical tolerance limit actual shall only be used for local individual true sizes, and not for their average or their substituted elements. A limited number of individual true sizes may be allowed to be outside the actual tolerance limit by a limited amount.

The maximum number ($n_{allowed}$) of measured sizes allowed to be outside the tolerance limit is calculated from the number of measured sizes n and the percentage given by $STA_{relative}$:

$$n_{allowed} = \text{int}\,(n \times STA_{relative}) \tag{1}$$

The number of measured sizes shall be large enough for the STA to function with regard to $n_{allowed}$.

The maximum value allowed out of the actual tolerance limit allowed can be calculated by the percentage of the STA where $STA_{absolute} = STA_{relative}$ and the actual tolerance T:

$$a_{allowed} = T \times STA_{absolute} \tag{2}$$

If it does not fit the requirements equal to $STA_{relative} = STA_{absolute}$, the $STA_{absolute}$ value may be given separately in micrograms.

8.4.3 Examples

EXAMPLE 1

STA:	10 %	= STA relative
		= STA absolute
Number of measured values:	85	
$n_{allowed}$ =	int ($n \times STA_{relative}$)	int (85 × 10/100) = **8**
Tolerance T = 0,035		
$a_{allowed}$ =	$T \times STA_{absolute}$	0,035 × 10/100 = **0,003 5**

Maximum 8 measured values out of 85 may be out of the actual tolerance limit by maximum 0,003 5 mm and the component still has to be accepted.

EXAMPLE 2

STA relative	15 %	
STA absolute	0,005 mm	
number of measured values	28	
$n_{allowed}$ =	int ($n \times STA_{relative}$)	int (28 × 15/100) = **4**

Maximum 4 measured values out of 28 may be out of the actual tolerance limit by maximum 0,005 mm and the component still has to be accepted.

8.5 Calculation of ball or pin diameter (D_{Re} or D_{Ri})

8.5.1 External spline (see Figure 6)

S = basic tooth thickness

$$\widehat{DE}_e = p_b - (S \times \cos\alpha_D + D_b \times \mathrm{inv}\,\alpha_D) \tag{3}$$

$$\overline{BA} = \frac{D_b \times \tan\alpha_D}{2} \tag{4}$$

$$\overline{BO}_e = \frac{D_b \times \tan\left(\alpha_D + \mathrm{inv}\,\alpha_D + \dfrac{\widehat{DE}_e}{D_b}\right)}{2} \tag{5}$$

$$\text{Calculated } D_{Re} = 2(\overline{BO}_e - \overline{BA}) \tag{6}$$

Take D_{Re} as the next greater nominal diameter in the preferred number series R40.

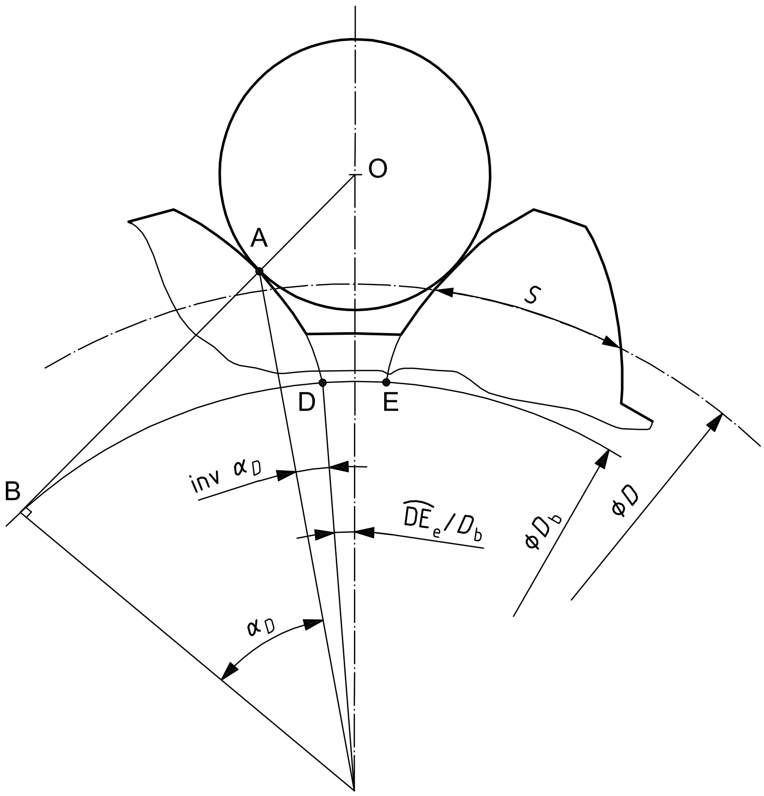


Figure 6 — External spline

8.5.2 Internal spline (see Figure 7)

The following calculation should not be used for internal splines with 30° pressure angle and a number of teeth less than 8. For these splines, use a value of E equal to the minimum actual space width of the tolerance required.

E = basic space width

$$\widehat{\mathrm{DE}}_{\mathrm{i}} = E \times \cos\alpha_D + D_{\mathrm{b}} \times \mathrm{inv}\,\alpha_D \tag{7}$$

$$\overline{\mathrm{BA}} = \frac{D_{\mathrm{b}} \times \tan\alpha_D}{2} \tag{8}$$

$$\overline{\mathrm{BO}}_{\mathrm{i}} = \frac{D_{\mathrm{b}} \times \tan\left(\alpha_D + \mathrm{inv}\,\alpha_D - \dfrac{\widehat{\mathrm{DE}}_{\mathrm{i}}}{D_{\mathrm{b}}}\right)}{2} \tag{9}$$

$$\text{Calculated } D_{\mathrm{Ri}} = 2(\overline{\mathrm{BA}} - \overline{\mathrm{BO}}_{\mathrm{i}}) \tag{10}$$

Take D_{Ri} as the next greater nominal diameter in the preferred number series R40 from ISO 3.

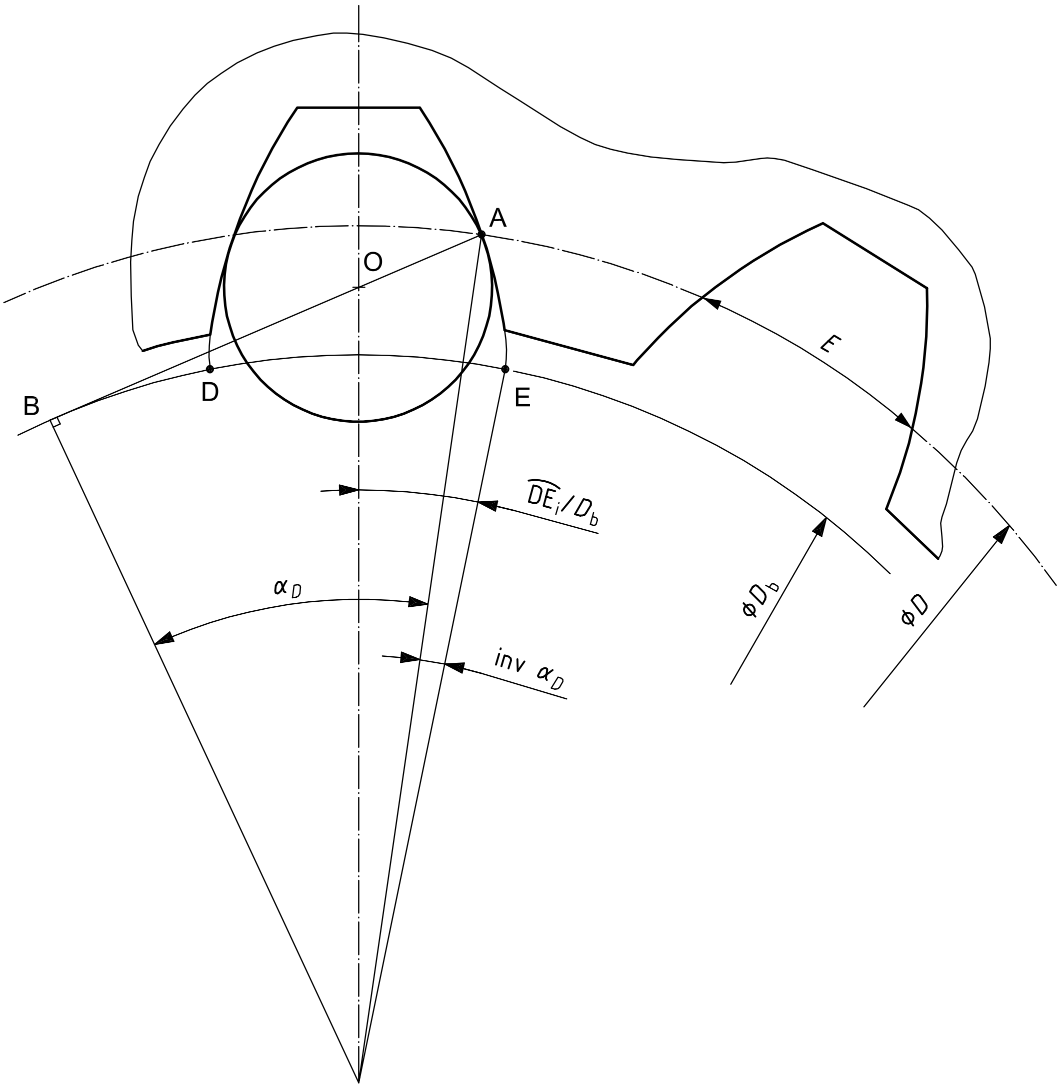


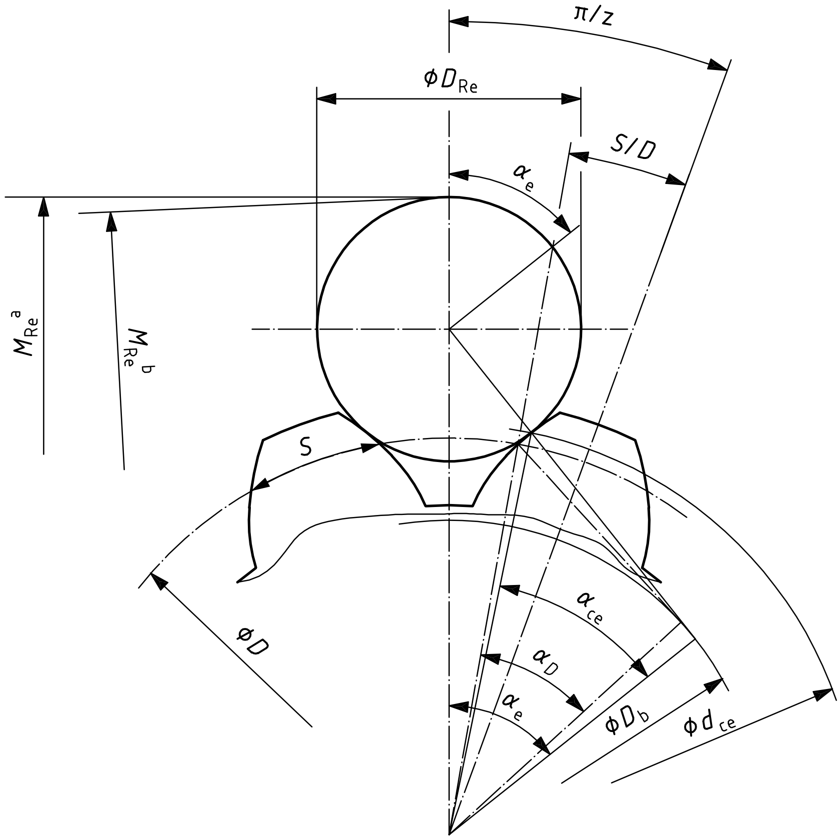
Figure 7 — Internal spline

8.6 Calculation of dimensions for ball or pin inspection (part and gauge inspection)

8.6.1 Exact calculation

8.6.1.1 Measurement over two balls or pins — External splines (M_{Re}) (see Figure 8)

S = actual circular thickness to be checked



a For z even.

b For z odd.

Figure 8 — Measurement over balls or pins

D_{Re} = pin diameter — see value in inspection dimension tables

$$\operatorname{inv}\alpha_e = \frac{S}{D} + \left(\operatorname{inv}\alpha_D + \frac{D_{Re}}{D_b} - \frac{\pi}{z}\right) \quad (11)$$

give α_e in degrees, to 5 decimal places[1)]

$$M_{Re} \text{ (for } z \text{ even)} = \frac{D_b}{\cos\alpha_e} + D_{Re} \quad (12)$$

$$M_{Re} \text{ (for } z \text{ odd)} = \frac{D_b \times \cos\frac{90^\circ}{z}}{\cos\alpha_e} + D_{Re} \quad (13)$$

$$\tan\alpha_{ce} = \tan\alpha_e - \frac{D_{Re}}{D_b} \quad (14)$$

1) Decimal degrees, for use with computers.

$$d_{ce} = \frac{D_b}{\cos \alpha_{ce}} \tag{15}$$

8.6.1.2 Measurement between two pins — Internal splines (M_{Ri})

E = actual circular space width to be checked

D_{Ri} = pin diameter — see value in inspection dimension tables

$$\text{inv } \alpha_i = \frac{E}{D} + (\text{inv } \alpha_D - \frac{D_{Ri}}{D_b}) \tag{16}$$

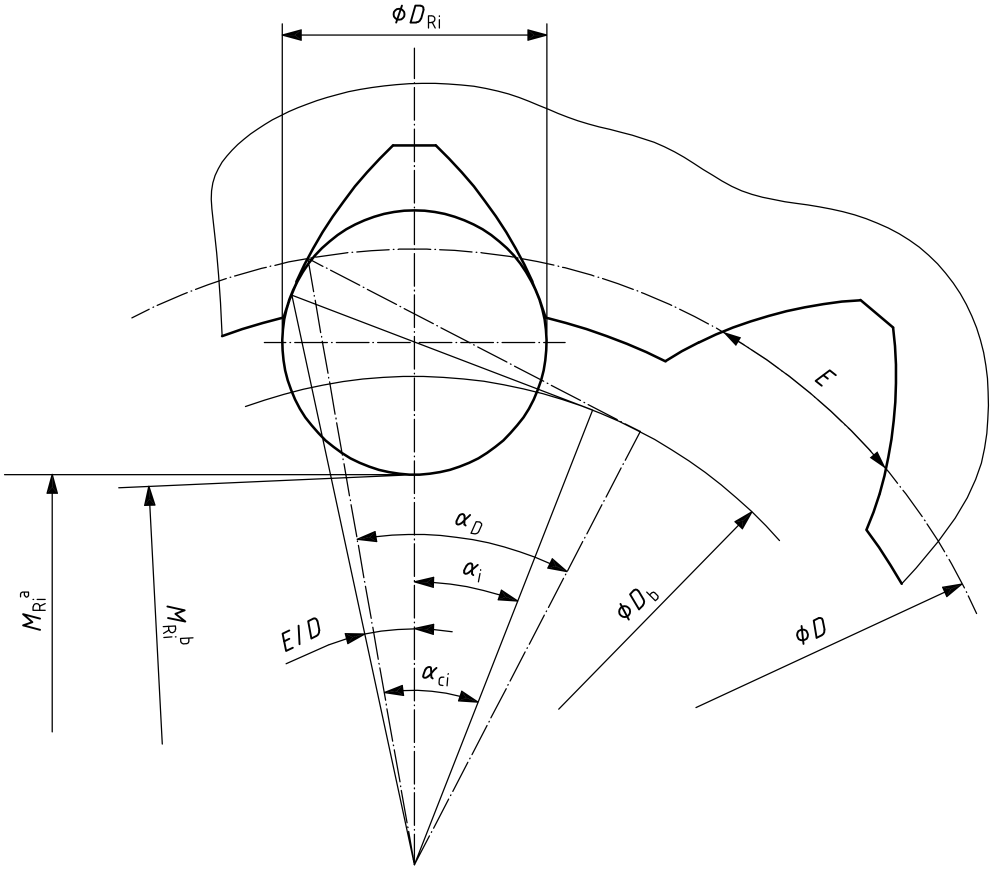
give α_i in degrees, to five decimal places[2)]

$$M_{Ri} \text{ (for } z \text{ even)} = \frac{D_b}{\cos \alpha_i} - D_{Ri} \tag{17}$$

$$M_{Ri} \text{ (for } z \text{ odd)} = \frac{D_b \cos \frac{90°}{z}}{\cos \alpha_i} - D_{Ri} \tag{18}$$

$$\tan \alpha_{ci} = \tan \alpha_i + \frac{D_{Ri}}{D_b} \tag{19}$$

$$d_{ci} = \frac{D_b}{\cos \alpha_{ci}} \tag{20}$$



a For z even.

b For z odd.

Figure 9 — Measurement between balls or pins

2) Decimal degrees, for use with computers.

8.6.2 Approximation factor

8.6.2.1 General

See ISO 4156-1.

The approximation factor (K_e for external splines, K_i for internal splines) is the variation of inspection dimensions with respect to the variation of corresponding tooth thicknesses or space widths.

The use of factors K_e or K_i leads the values of inspection dimensions, which are all the more accurate since the thickness or space width to be checked are closer to the actual thickness values (S_{min}) or the minimum actual space width values (E_{min}) of tolerance class 7 of fit considered.

8.6.2.2 Calculation of the approximation factor K_e

The parameters for the calculation of the approximation factor K_e are shown in Figure 10.

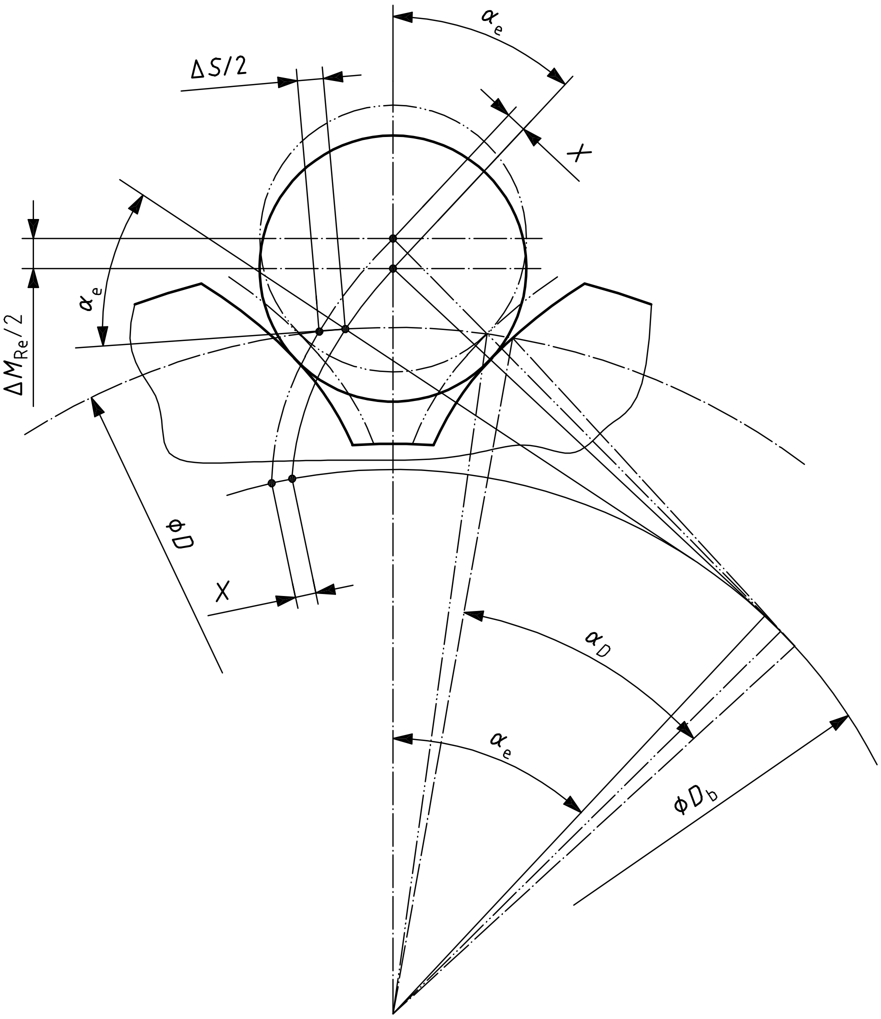


Figure 10 — Calculation of K_e

$$X \text{ (approximate)} = \frac{M_{Re}}{2} \sin \alpha_e \tag{21}$$

$$\frac{\Delta S}{2} = \frac{X}{\cos \alpha_d} = \frac{\Delta M_{Re} \sin \alpha_e}{2 \cos \alpha_D} \tag{22}$$

$$K_e = \frac{\Delta M_{Re}}{\Delta S} = \frac{\cos \alpha_D}{\sin \alpha_e} \quad \text{(for an even number of teeth)} \tag{23}$$

$$K_e = \frac{\cos \alpha_D}{\sin \alpha_e} \cos \frac{90°}{z} \quad \text{(for an odd number of teeth)} \tag{24}$$

For the calculation of α_e, see 8.6.1.1 and take S = minimum actual tooth thickness (S_{min}) of tolerance class 7 and fundamental deviation considered.

8.6.2.3 **Calculation** of the approximation factor K_i

The parameters for the calculation of the approximation factor K_i are shown in Figure 11.

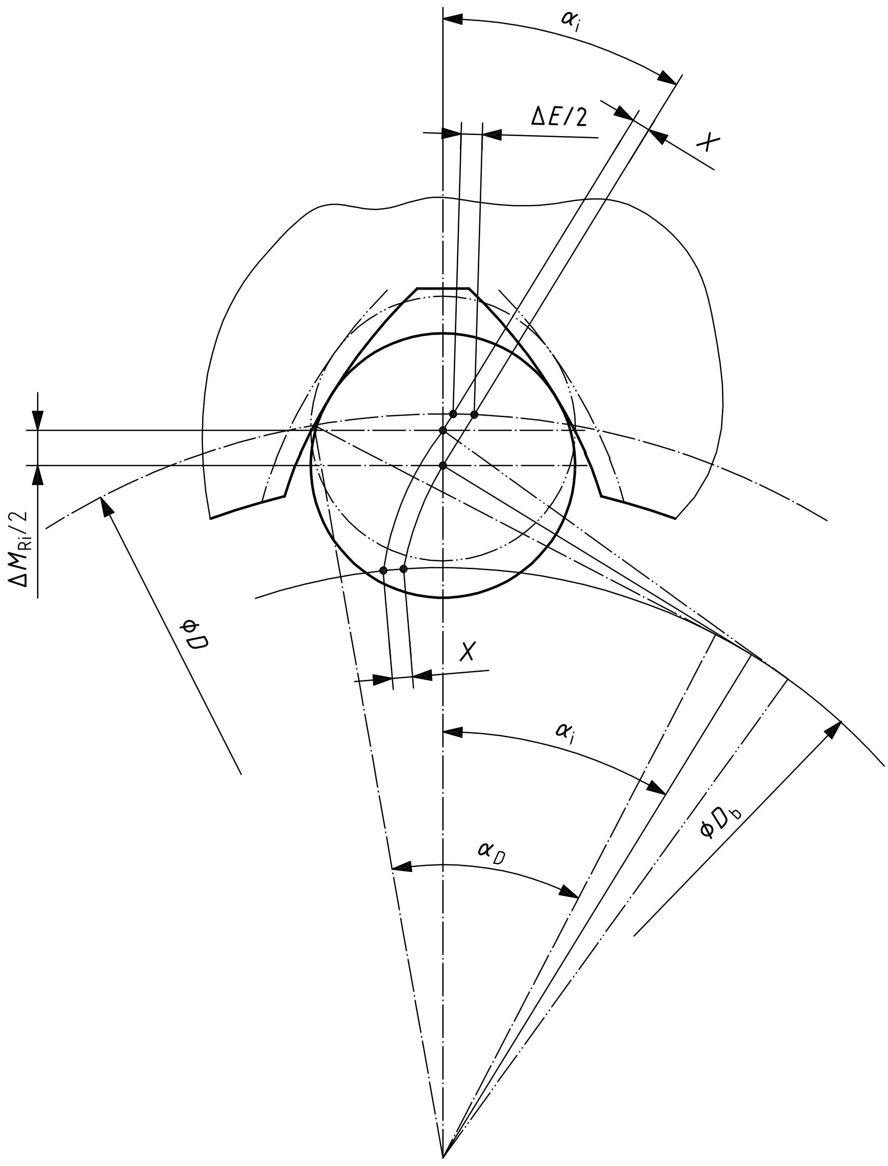


Figure 11 — Calculation of K_i

$$X \text{ (approximate)} = \frac{\Delta M_{\mathrm{Ri}}}{2} \sin\alpha_{\mathrm{i}} \tag{25}$$

$$\frac{\Delta E}{2} = \frac{X}{\cos\alpha_{\mathrm{d}}} = \frac{\Delta M_{\mathrm{Ri}} \times \sin\alpha_{\mathrm{i}}}{2 \times \cos\alpha_D} \tag{26}$$

$$K_{\mathrm{i}} = \frac{\Delta M_{\mathrm{Ri}}}{\Delta E} = \frac{\cos\alpha_D}{\sin\alpha_{\mathrm{i}}} \quad \text{(for an even number of teeth)} \tag{27}$$

$$K_{\mathrm{i}} = \frac{\cos\alpha_D}{\sin\alpha_{\mathrm{i}}} \times \cos\frac{90^\circ}{z} \quad \text{(for an odd number of teeth)} \tag{28}$$

For the calculation of α_{i}, see 8.6.1.2 and take E = basic space width.

9 Measurement over k teeth — External splines (W)

9.1 Calculation of W

The parameters for the calculation of W are shown in Figure 12.

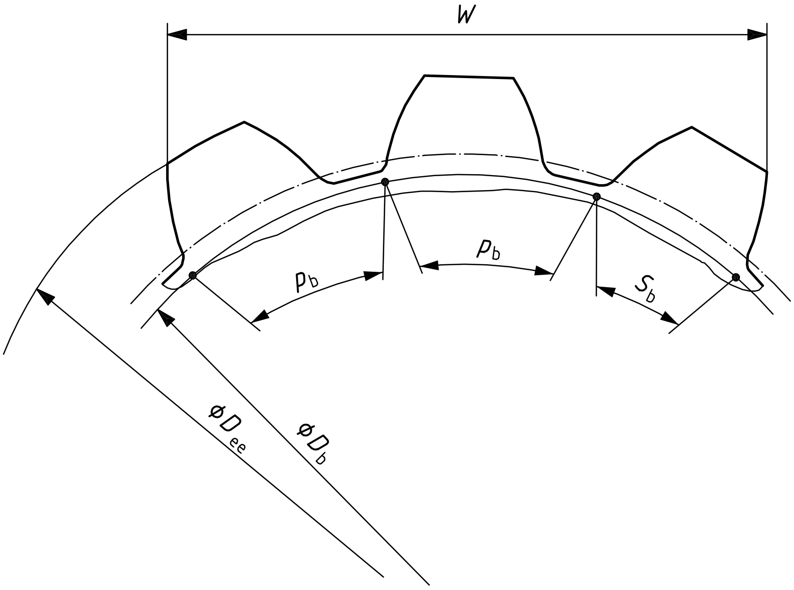


Figure 12 — Calculation of W

$$W = (k - 1)\, p_{\mathrm{b}} + S_{\mathrm{b}} \tag{29}$$

where

k is the number of teeth considered (see inspection dimension tables);

p_{b} is the base pitch $= \pi \times m \times \cos \alpha_D$;

S_{b} is the circular base thickness $= S \times \cos \alpha_D + D_{\mathrm{b}} \times \mathrm{inv}\ \alpha_D$

For the calculation of W, use S = tooth thickness of the tolerance class chosen for the fit considered.

9.2 Choice of k

For the minimum and maximum tangential dimensions shown in Figures 13 et 14, respectively, the choice of the value of k depends on the following conditions.

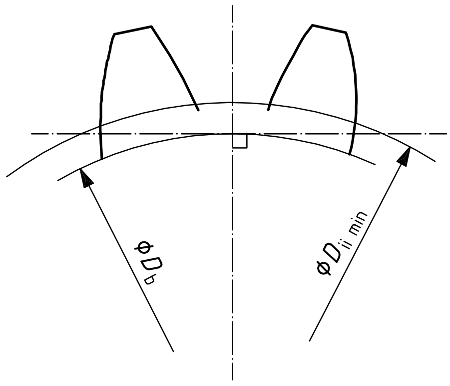


Figure 13 — Minimum tangential dimension

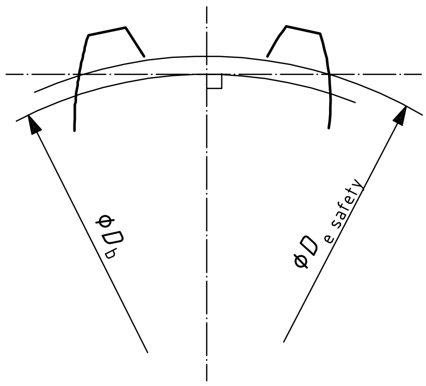


Figure 14 — Maximum tangential dimension

$$W_{\text{min}} = \sqrt{D_{\text{ii min}}^2 - D_{\text{b}}^2} \quad (30)$$

$$W_{\text{max}} = \sqrt{D_{\text{e safety}}^2 - D_{\text{b}}^2} \quad (30a)$$

Safety $= 0{,}4 \times m$ for module 0,25

$= 0{,}3 \times m$ for module 0,5 to 4

$= 0{,}2 \times m$ for module 5 to 10

$D_{\text{e safety}} = D_{\text{ee max}}$ – safety

$$\frac{W_{\text{max}} - S_{\text{b}}}{p_{\text{b}}} = k_{\text{p}} \quad (31)$$

Check that $p_b \times k_p + S_b \geqslant W_{min}$ and that $D_{ii\,min} < \sqrt{W^2 + D_b^2} < D_{ee\,max}$

If these conditions are satisfied, then $k = k_p + 1$; otherwise, it is impossible to take a dimension over k teeth (k has to be rounded to the nearest integer number). For the calculation of k_p and W_{min}, use S = minimum actual thickness (S_{min}) of tolerance class 7 of the tolerance considered.

10 Gauges

10.1 Generalities

10.1.1 Conditions of use of gauges

10.1.1.1 GO gauge

GO composite plug and ring gauges shall enter or pass over the complete spline length. Composite spline gauges shall be used without excessive force to prevent damage or distortion to the component or gauge. In case of disagreement, the composite gauge shall be accorded precedence in the acceptance or rejection of a part. If there are two gauges available and both are within the gauge tolerances, the gauge which fits the part shall be accorded precedence.

If a part is rejected by the composite GO gauge, the gauge itself cannot provide the reason. The reason can only be identified by the measurement of the actual tooth thickness or space width using pins or balls, and the analytical inspection of total pitch deviation, total profile deviation and total helix deviation.

10.1.1.2 NO GO sector gauge

NO GO gauges shall not enter or pass over the component in any angular position. Inspection shall be carried out in at least three angular positions as equally distributed as possible.

10.1.1.3 NO GO composite gauge

NO GO composite gauges shall not enter or pass over the component.

10.1.2 Limiting dimensions of use for gauges

The ease of use of gauges is limited by gauge weight and dimensions.

Parts with a pitch diameter $D \leqslant 180$ mm can normally be checked by using gauges.

Parts with a pitch diameter $D > 180$ mm can also be checked by using gauges if agreed between the customer and the supplier.

10.1.3 Handles of spline gauges

Plug gauges of pitch diameter $D < 50$ mm may be integral.

10.1.4 Number of teeth for sector NO GO gauges

The number of teeth on sector NO GO gauges is given in Table 6.

Table 6 — Number of teeth on sector NO GO gauges

Total number of product teeth, z	$6 \leqslant z \leqslant 30$	$30 < z \leqslant 44$	$44 < z \leqslant 58$	$58 < z \leqslant 72$	$72 < z \leqslant 86$	$86 < z \leqslant 100$	$z > 100$
Number of teeth in each sector	2	3	4	5	6	7	$0{,}075z$

10.2 Length of measuring part of gauges

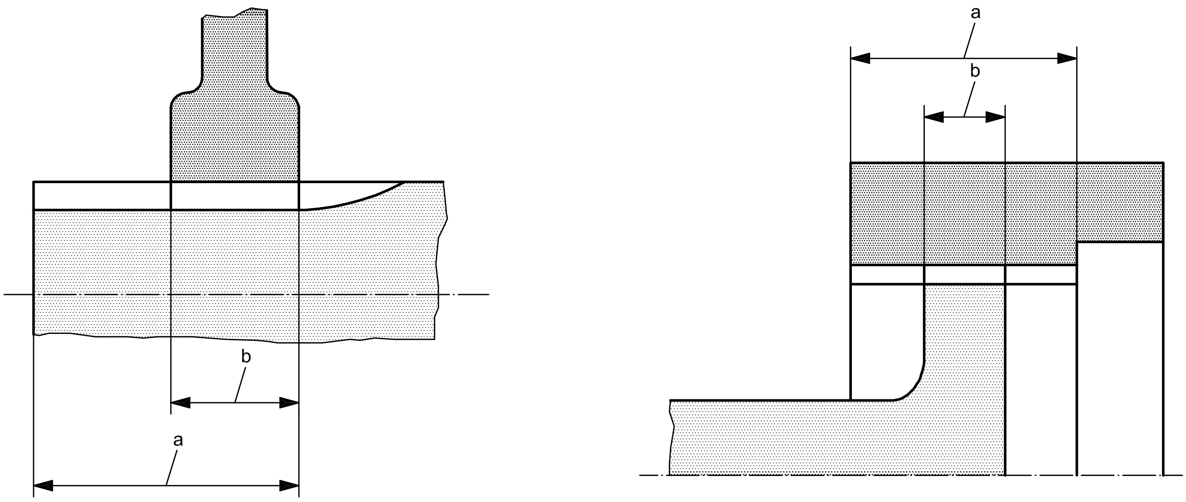
10.2.1 Influence of the active spline length and of the length of engagement

Since check gauges are often shorter than the parts to be checked, the active length and length of engagement (see Figure 15) can influence the maximum permissible alignment of splines (parallelism error of the splines with respect to the axis).

If the length of engagement is less than or equal to half the pitch diameter, and if the active length is equal to the length of engagement, alignment deviations of splines can generally, unless otherwise specified, be included in the total tolerances ($T + \lambda$) and checked simultaneously by limit gauges.

In the case where the length of engagement is greater than half the pitch diameter and the active length is greater than or equal to the length of engagement, it might be necessary to prescribe spline alignment tolerances independent of the total tolerance ($T + \lambda$): these tolerances may then have to be checked separately by analytical inspection.

If particular, if spline alignment tolerances are specified, they should generally be proportionally all the smaller since the active length or the length of engagement or both will be greater.



a) Shaft longer than hole **b) Hole longer than shaft**

a Length of engagement.

b Active spline length.

Figure 15 — Active length and length of engagement

10.2.2 GO or NO GO gauges

In the case where the length of engagement is greater than 1,5 times the value given in table 7, the active length of the GO composite splines plug or ring gauge should be increased. A gauge length of 75 % of the length of engagement is usually satisfactory. This shall be subject to prior agreement between purchaser and manufacturer.

NOTE GO and NO GO spline gauges can include a non-measuring part (plain cylindrical part or chamber) intended for making gauge entrance easier.

Table 7 — Measuring part of spline gauges — Minimum length

Dimensions in millimetres

Pitch diameter D of splines	Minimum length of spline gauges			
	GO plug	NO GO plug	GO ring	NO GO ring
$1 \leqslant D \leqslant 7$	6	4	8	6
$7 < D \leqslant 12$	8	6	10	8
$12 < D \leqslant 17$	12	8	10	8
$17 < D \leqslant 22$	16	10	16	12
$22 < D \leqslant 30$	20	12	16	12
$30 < D \leqslant 40$	25	15	20	15
$40 < D \leqslant 50$	30	18	20	15
$50 < D \leqslant 70$	30	20	25	20
$70 < D \leqslant 120$	35	25	25	20
$120 < D \leqslant 150$	40	25	30	25
$150 < D \leqslant 180$	40	25	30	25

10.2.3 Master plug gauges

All of the following elements shall be taken into account in determining the length of the measuring part of the master plug gauges:

a) a lead length corresponding to the minimum length of the measuring part of the checked ring;

b) a checking length, function of the mating side taper of the master plug gauge and of the range of the dimensional tolerance of the checked ring;

c) a wear length, function of the side taper of the master plug gauge and of the range of the wear tolerance of the checked ring.

10.2.4 Spline gauges of pitch diameters $D > 180$ mm

For spline gauges having a pitch diameter $D > 180$ mm it is advisable to choose a measuring length equal to

— 30 % of the pitch diameter for GO gauges;

— 20 % of the pitch diameter for NO GO gauges.

10.3 Manufacturing tolerances for spline gauges (see Tables 8, 9 and 10)

The practical use and the relationship of manufacturing tolerances to wear tolerances have shown the necessity to slightly change the tolerances in this part of ISO 4156 in a way which does not affect the compatibility with gauges according to ISO 4156:1981. Wear tolerance limits for NO GO gauges having half of the wear allowance of GO gauges have been added to this part of ISO 4156.

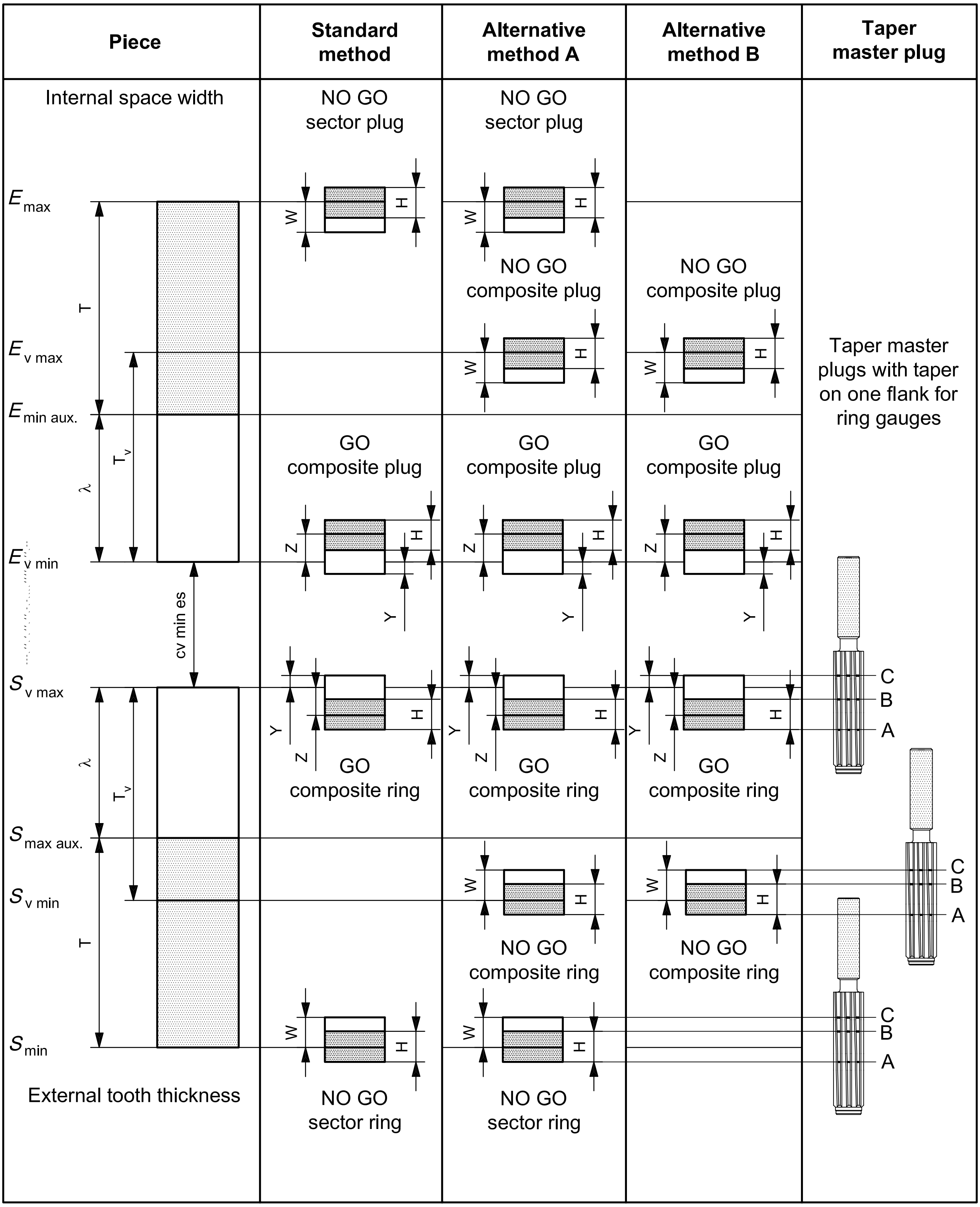
Table 8 — Gauge positions and tolerances

Calibre	Position	Tolerance	Wear limit
NO GO sector plug gauge	E_{max}	± H/2	E_{max} − W
NO GO composite plug gauge	$E_{v\ max}$	± H/2	$E_{v\ max}$ − W
GO composite plug gauge	$E_{v\ min}$ + Z	± H/2	$E_{v\ min}$ − Y
GO composite ring gauge	$S_{v\ max}$ − Z	± H/2	$S_{v\ max}$ + Y
NO GO composite ring gauge	$S_{v\ min}$	± H/2	$S_{v\ min}$ + W
NO GO sector ring gauge	S_{min}	± H/2	S_{min} + W

Table 9 — Values of gauge tolerances

Pitch diameter D mm	Tol.	Plug gauges Tooth thickness S mm				Rings Space width E mm			
		$S \leqslant 3$	$3 < S \leqslant 6$	$6 < S \leqslant 10$	$10 < S \leqslant 18$	$E \leqslant 3$	$3 < E \leqslant 6$	$6 < E \leqslant 10$	$10 < E \leqslant 18$
		Tolerance values µm							
$D \leqslant 3$	H Z Y W	2 4 1 3				2 4 1,5 3			
$3 < D \leqslant 10$	H Z Y W	2,5 4 1,25 3				2,5 4 2 4			
$10 < D \leqslant 18$	H Z Y W	3 4 1,5 4	3 5 1,5 4			3 4 2,5 4	3 5 2,5 5		
$18 < D \leqslant 30$	H Z Y W	4 4 2 4	4 5 2 5	4 6 2 5		4 4 3 5	4 5 3 5	4 6 3 6	
$30 < D \leqslant 50$	H Z Y W	4 4 2 4	4 5 2 5	4 6 2 5	4 8 2 6	4 4 3,5 5	4 5 3,5 5	4 6 3,5 6	4 8 3,5 7
$50 < D \leqslant 80$	H Z Y W	5 4 2,5 4	5 5 2,5 5	5 6 2,5 6	5 8 2,5 7	5 4 4 5	5 5 4 6	5 6 4 6	5 8 4 7
$80 < D \leqslant 120$	H Z Y W	6 4 3 5	6 5 3 6	6 6 3 6	6 8 3 7	6 4 5 6	6 5 5 7	6 6 5 7	6 8 5 8
$120 < D \leqslant 180$	H Z Y W	8 4 4 6	8 5 4 7	8 6 4 7	8 8 4 8	8 4 6 7	8 5 6 8	8 6 6 8	8 8 6 9
Spline gauges with a pitch diameter > 180 mm shall be created in steps similar to those above.									

Table 10 — Positions of gauge tolerances



10.4 Values of deviation allowances of spline gauges

The deviations of form checked for spline gauges, see Table 11, are the same as those checked on corresponding parts, i.e:

- total pitch deviation;
- total profile deviation;
- total helix deviation.

NOTE GO spline gauges may have a plain cylindrical diameter to facilitate the inspection of form deviations. The runout of this cylinder to the pitch diameter is shown in Table 11. These values are also valid for the runout of the major diameter of plug gauges and the minor diameter of ring gauges to the pitch diameter.

Table 11 — Deviation allowances for spline gauges

Pitch diameter D	Total profile deviation F_α	Total pitch variation F_p	Total helix deviation for a measuring length of part F_β		Radial run-out	
			$F_\beta \leqslant 25$ mm	$F_\beta > 25$ mm	Ring	Plug
mm	µm					
$1 \leqslant D \leqslant 100$	5	5	3	5	10	7
$100 < D \leqslant 150$	5	8	3	5	15	10
$150 < D \leqslant 180$	5	10	—	5	15	10
Spline gauges with a pitch diameter > 180 mm shall be created in steps similar to those above.						

10.5 Inspection of gauges

10.5.1 Damage

Inspection method: visual inspection of all spline flanks and important diameters. Damage and rust is not allowed.

10.5.2 Marking

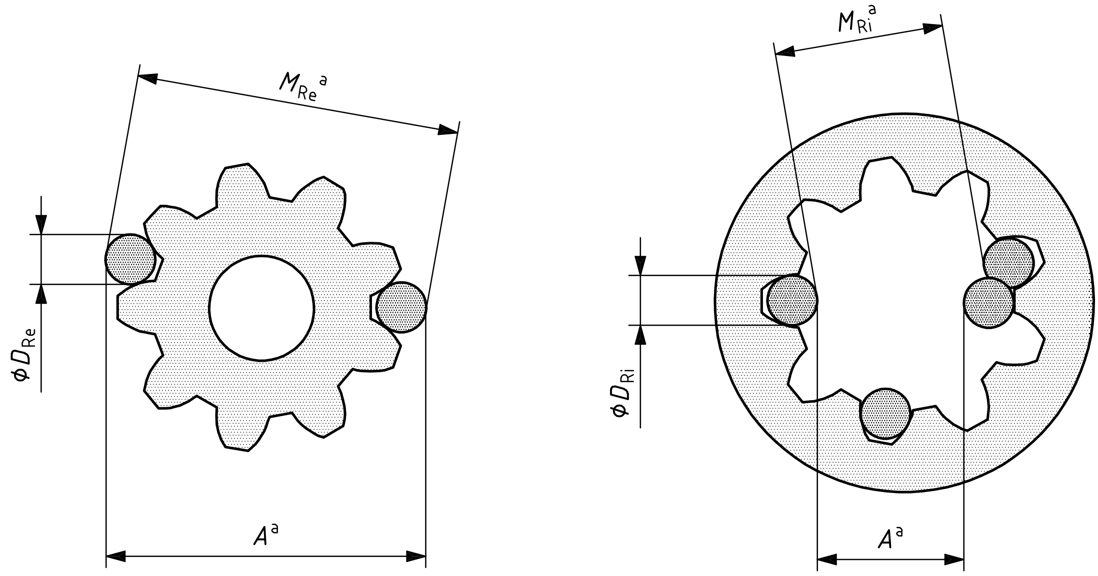
Inspection method: visual inspection. The marking shall be durable, complete and correct (see 10.6.4).

10.5.3 Major diameter of plug gauges and minor diameter of ring gauges

Inspection method: 2-point measurement for even numbers of teeth, radial measurements for odd numbers of teeth as shown in Figure 16.

NOTE 1 In the case of external and internal splines, it is desirable that one of the balls/pins be in a common space for both measurements.

NOTE 2 If several measurements are taken in various positions, then due to manufacturing variations a variable result will be obtained.



a Measured.

Figure 16 — Inspection of major diameter (plug gauges) and minor diameter (ring gauges)

Major diameter:

$$D_{ee} = 2\left[A - \left(\frac{0{,}5\left(M_{Re} - D_{Re}\right)}{\cos\dfrac{90°}{z}} + \frac{D_{Re}}{2}\right)\right] \quad (32)$$

Minor diameter:

$$D_{ii} = 2\left[A + D_{Ri} - \left(\frac{0{,}5\left(M_{Ri} + D_{Ri}\right)}{\cos\dfrac{90°}{z}} - \frac{D_{Ri}}{2}\right)\right] \quad (33)$$

10.5.4 Form diameter

Inspection method: involute inspection machine.

10.5.5 Tooth thickness of plug gauges

Inspection methods: measurement over 2 pins. Measurements shall be taken at 0° and 90° at each end and in the middle of the pin length. Pins need to be rubbed in order to avoid friction and microdirt. Measuring pins have a tolerance (see Table 5) which can affect the measurement over pins. To allow for this, the true calibrated pin diameter shall be used.

10.5.6 Space width of ring gauges

For ring gauges, the requirements of 10.5.5 are applicable. Ring gauges are inspected with pins and gauge blocks. The true size of a ring gauge is achieved when the gauge block can be moved axially with minimum resistance and has no radial movement.

Taper master plugs for ring gauges may also be used for size inspection. Due to the combined form deviations of ring and master plug, when ring gauges are fitted to taper masters, they are larger than those manufactured to a dimension between pins. Master plug gauges are tapered on one side of all teeth and can be checked by measurement over pins in well defined planes.

10.5.7 Form deviations

Inspection methods: gear-testing machines. The profile and helix deviation shall be measured in at least 3 equally spaced angular positions on left and right flanks. For composite gauges, the total pitch deviation and the pitch diameter runout shall also be inspected.

10.5.8 Gauge wear inspection

An inspection period shall be chosen to guarantee that gauges remain within their wear limit. A spline gauge is considered to be worn out when the space width or tooth thickness exceeds the specified wear limit, or one of the form deviations exceeds 1,5 times the allowed tolerance.

10.5.9 Inspection certificates

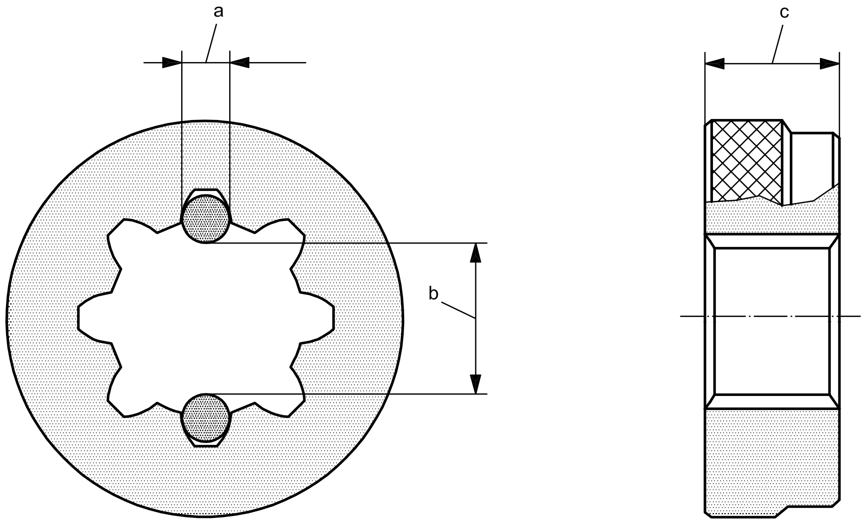
When inspection certificates for spline gauges are required, such certificates shall only be accepted when graphs of the form deviations are provided. Graphs of involute profile shall indicate the form diameter.

10.6 Dimensions, designation and marking of gauges

10.6.1 Inspection of external splines

10.6.1.1 GO composite ring gauge

The external splines are inspected using a GO composite ring gauge as shown in Figure 17, with dimensions as given in Table 12.



[a] Pin diameter.

[b] Size between pins.

[c] Gauge length.

Figure 17 — GO composite ring gauge

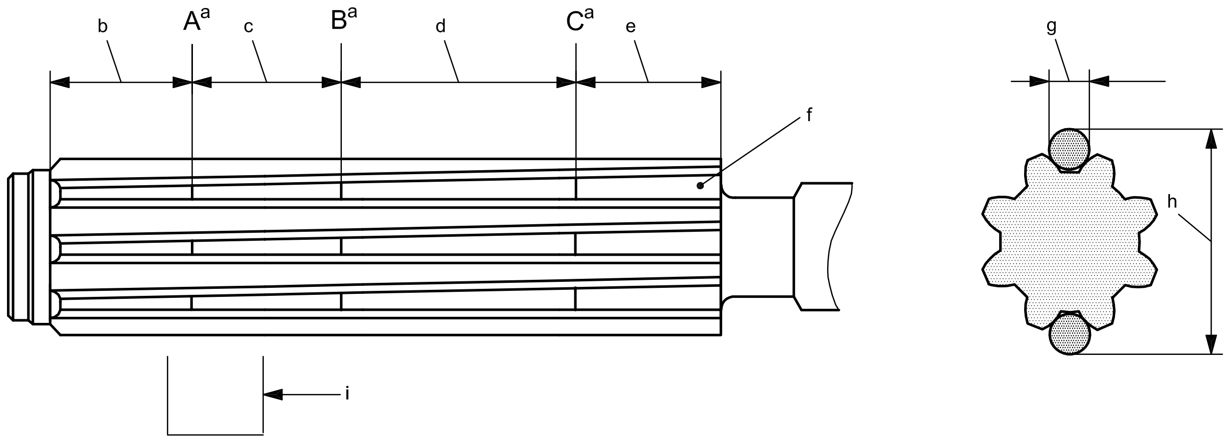
Table 12 — Dimensions and tolerances for GO composite ring gauges

Gauge dimension	Formula	Tolerance	Where fitted to taper master
Number of teeth	xx		
Module	xx		
Pressure angle	xx		
Pitch diameter	xx.xxxx		
Base diameter	xx.xxxx		
Major diameter	$D_{\text{ee max}} + 0{,}3m$	min.	
Form diameter	$D_{\text{ee max}} + 0{,}2m$	min.	
Minor diameter	$D_{\text{Fe max}}$	K7 [a]	
Space width new	$S_{\text{v max}} - \text{Z}$	± H/2	($S_{\text{v max}} - \text{Z}$) ref.
Space width wear limit	$S_{\text{v max}} + \text{Y}$		($S_{\text{v max}} + \text{Y}$) ref.
Pin diameter	See 8.5.2		
Size between pins new	See 8.6.1.2		Refer to taper master
Size between pins wear limit	See 8.6.1.2		Refer to taper master
Form deviations	See Table 11		

[a] See ISO 286.

10.6.1.2 Tapered tooth master plug gauge for GO composite ring gauge

A tapered tooth master plug gauge for a GO composite ring gauge is shown in Figure 18 and its dimensions are given in Table 13.



[a] Lines marked at major diameter (position to be determined by calibration).
[b] Lead length/ring gauge length.
[c] Manufacturing tolerance of ring.
[d] Ring wear tolerance.
[e] Oversize zone.
[f] Taper on one flank of all teeth.
[g] Pin diameter.
[h] Size over pins.
[i] Front face of new ring gauge.

Figure 18 — Tapered tooth master plug gauge for GO composite ring gauge

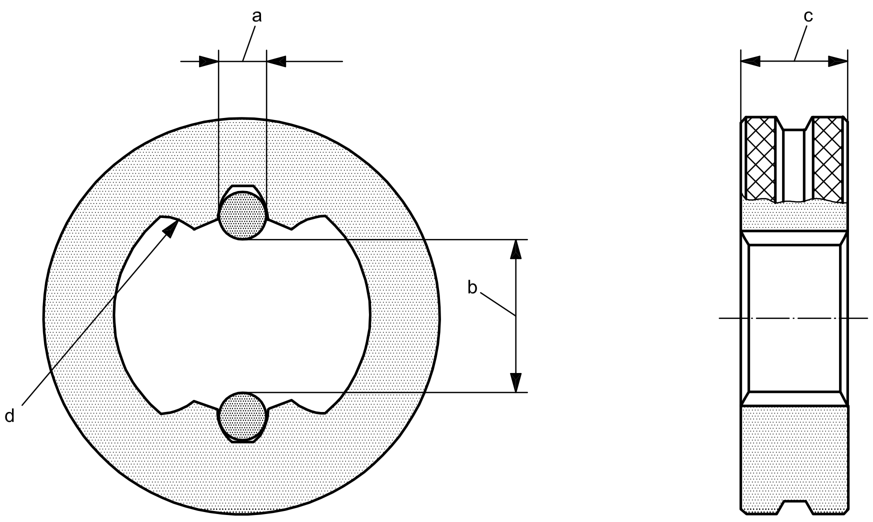
Table 13 — Dimensions and tolerances for master plug gauges for GO composite ring gauges

Gauge dimension	Formula	Tolerance
Number of teeth	xx	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$D_{\text{ee min}} - 0{,}2m$	h8 [a]
Form diameter	$D_{\text{Fe max}} - 0{,}1m$	max.
Minor diameter	$D_{\text{Fe max}} - 0{,}2m$	max.
Tooth thickness A	$S_{\text{v max}} - Z - H/2$	
Tooth thickness B	$S_{\text{v max}} - Z + H/2$	
Tooth thickness C	$S_{\text{v max}} + Y$	
Taper on one flank	0,02 %	min.
Pin diameter	See 8.5.1	
Size over pins A	See 8.6.1.1	
Size over pins B	See 8.6.1.1	
Size over pins C	See 8.6.1.1	
Form deviations	See Table 11	

[a] See ISO 286.

10.6.1.3 NO GO sector ring gauge

The external splines are inspected using a NO GO sector ring gauge as shown in Figure 19, with dimensions as given in Table 14.



a Pin diameter.
b Size between pins.
c Gauge length.
d Relieved outer surface.

Figure 19 — NO GO sector ring gauge

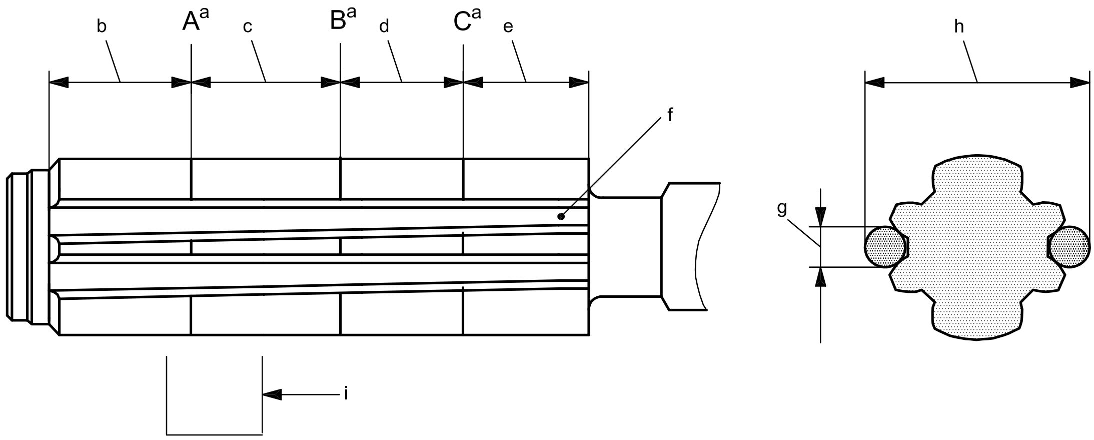
Table 14 — Dimensions and tolerances for NO GO sector ring gauges

Gauge dimension	Formula	Tolerance	Where fitted to taper master
Number of teeth	(z) x+x see Table 6		
Module	xx		
Pressure angle	xx		
Pitch diameter	xx.xxxx		
Base diameter	xx.xxxx		
Major diameter	$D_{\text{ee max}} + 0{,}3m$	min.	
Form diameter	$D_{\text{ee max}} + 0{,}2m$	min.	
Minor diameter	$(D + 2D_{\text{Fe max}})/3$	JS8 [a]	
Space width new	S_{min}	± H/2	(S_{min} − Z) ref.
Space width wear limit	S_{min} + W		($S_{\text{v max}}$ + W) ref.
Pin diameter	See 8.5.2		
Size between pins new	See 8.6.1.2		Refer to taper master
Size between pins wear limit	See 8.6.1.2		Refer to taper master
Form deviations	See Table 11		

a See ISO 286.

10.6.1.4 Tapered tooth master plug gauge for NO GO sector ring gauge

A tapered tooth master plug gauge for a NO GO sector ring gauge is shown in Figure 20 and its dimensions are given in Table 15.



[a] Lines marked at major diameter (position to be determined by calibration).
[b] Lead length/ring gauge length.
[c] Manufacturing tolerance of ring.
[d] Ring wear tolerance.
[e] Oversize zone.
[f] Taper on one flank of all teeth.
[g] Pin diameter.
[h] Size over pins.
[i] Front face of new ring gauge.

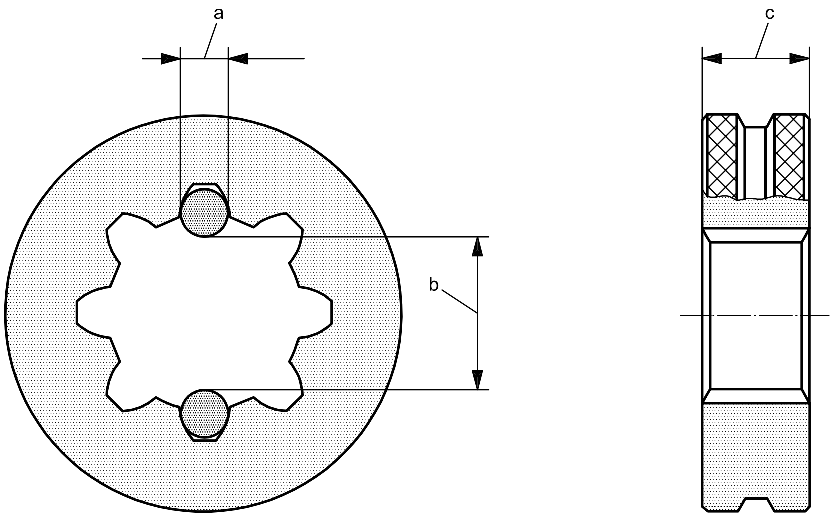
Figure 20 — Tapered tooth master plug gauge for NO GO two-sector ring gauge

Table 15 — Dimensions and tolerances for master plug gauges for NO GO sector ring gauges

Gauge dimension	Formula	Tolerance
Number of teeth	(z) x+x see Table 6	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$D_{ee\ min} - 0{,}2m$	h8 [a]
Form diameter	$(D + 2D_{Fe\ max})/3 - 0{,}1m$	max.
Minor diameter	$(D + 2D_{Fe\ max})/3 - 0{,}2m$	max.
Tooth thickness A	$S_{min} - H/2$	
Tooth thickness B	$S_{min} + H/2$	
Tooth thickness C	$S_{min} + W$	
Taper on one flank	0,02 %	min.
Pin diameter	See 8.5.1	
Size over pins A	See 8.6.1.1	
Size over pins B	See 8.6.1.1	
Size over pins C	See 8.6.1.1	
Form deviations	See Table 11	
[a] See ISO 286.		

10.6.1.5 NO GO composite ring gauge

The external splines are inspected using a NO GO composite ring gauge as shown in Figure 21, with dimensions as given in Table 16.



a Pin diameter.
b Size between pins.
c Gauge length.

Figure 21 — NO GO composite ring gauge

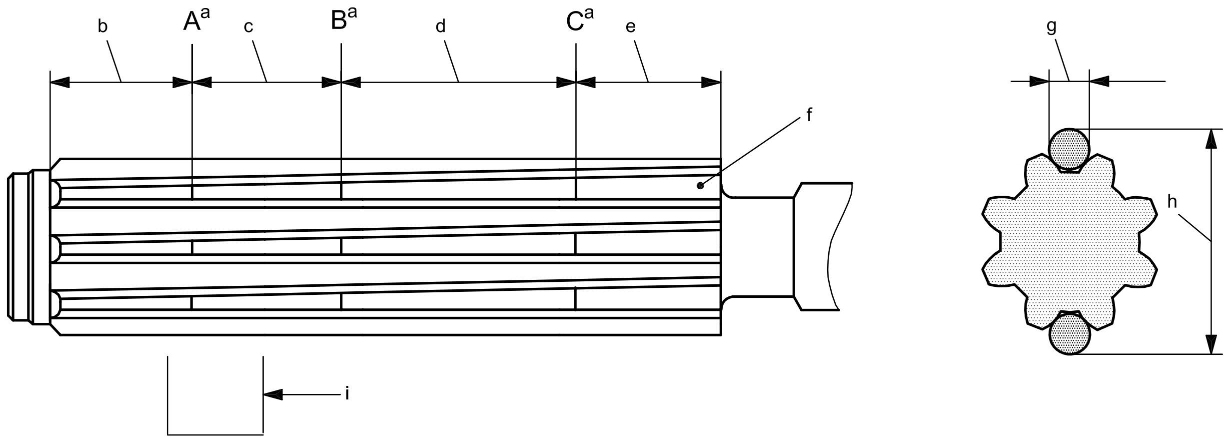
Table 16 — Dimensions and tolerances for NO GO composite ring gauges

Gauge dimension	Formula	Tolerance	Where fitted to taper master
Number of teeth	xx		
Module	xx		
Pressure angle	xx		
Pitch diameter	xx.xxxx		
Base diameter	xx.xxxx		
Major diameter	$D_{ee\ max} + 0{,}3m$	min.	
Form diameter	$D_{ee\ max} + 0{,}2m$	min.	
Minor diameter	$(D + 2D_{Fe\ max})/3$	JS8 [a]	
Space width new	$S_{v\ min}$	± H/2	$(S_{v\ min})$ ref.
Space width wear limit	$S_{v\ min}$ + W		$(S_{min}$ + W) ref.
Pin diameter	See 8.5.2		
Size between pins new	See 8.6.1.2		Refer to taper master
Size between pins wear limit	See 8.6.1.2		Refer to taper master
Form deviations	See Table 11		

a See ISO 286.

10.6.1.6 Tapered tooth master plug gauge for NO GO composite ring gauge

A tapered tooth master plug gauge for a NO GO composite ring gauge is shown in Figure 22 and its dimensions are given in Table 17.



[a] Lines marked at major diameter (position to be determined by calibration).
[b] Lead length/ring gauge length.
[c] Manufacturing tolerance of ring.
[d] Ring wear tolerance.
[e] Oversize zone.
[f] Taper on one flank of all teeth.
[g] Pin diameter.
[h] Size over pins.
[i] Front face of new ring gauge.

Figure 22 — Tapered tooth master plug gauge for NO GO composite ring gauge

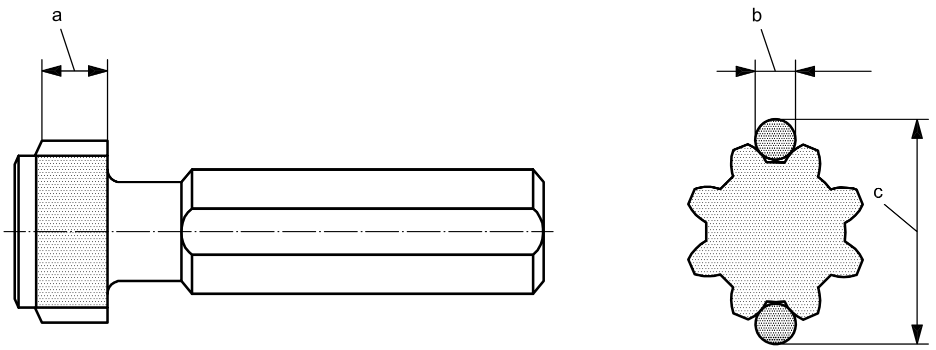
Table 17 — Dimensions and tolerances for master plug gauges for NO GO composite ring gauges

Gauge dimension	Formula	Tolerance
Number of teeth	xx	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$D_{ee\ min} - 0{,}2m$	h8 [a]
Form diameter	$(D + 2D_{Fe\ max})/3 - 0{,}1m$	max.
Minor diameter	$(D + 2D_{Fe\ max})/3 - 0{,}2m$	max.
Tooth thickness A	$S_{v\ min}$ − H/2	
Tooth thickness B	$S_{v\ min}$ + H/2	
Tooth thickness C	$S_{v\ min}$ + W	
Taper on one flank	0,02 %	min.
Pin diameter	See 8.5.1	
Size over pins A	See 8.6.1.1	
Size over pins B	See 8.6.1.1	
Size over pins C	See 8.6.1.1	
Form deviations	See Table 11	
[a] See ISO 286.		

10.6.2 Inspection of internal splines

10.6.2.1 GO composite plug gauge

The internal splines are inspected using a GO composite plug gauge as shown in Figure 23, with dimensions as given in Table 18.



[a] Gauge length.

[b] Pin diameter.

[c] Size over pins.

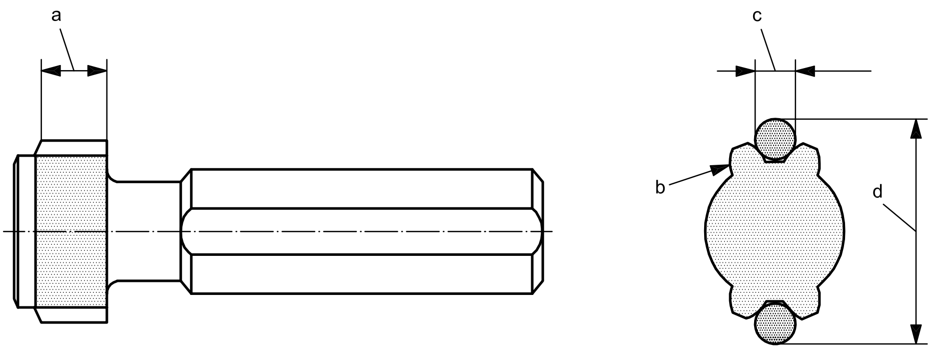
Figure 23 — GO composite plug gauge

Table 18 — Dimensions and tolerances for GO composite plug gauges

Gauge dimension	Formula	Tolerance
Number of teeth	xx	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$D_{\text{Fi min}}$	k7 [a]
Form diameter	$D_{\text{ii min}} - 0{,}2m$	max.
Minor diameter	$D_{\text{ii min}} - 0{,}3m$	max.
Tooth thickness new	$E_{\text{v min}} + \text{Z}$	± H/2
Tooth thickness wear limit	$E_{\text{v min}} - \text{Y}$	
Pin diameter	See 8.5.1	
Size over pins new	See 8.6.1.1	
Size over pins wear limit	See 8.6.1.1	
Form deviations	See Table 11	
[a] See ISO 286.		

10.6.2.2 NO GO sector plug gauge

The internal splines are inspected using a NO GO sector plug gauge as shown in Figure 24, with dimensions as given in Table 19.



a Gauge length.

b Relieved outer surface.

c Pin diameter.

d Size over pins.

Figure 24 — NO GO sector plug gauge

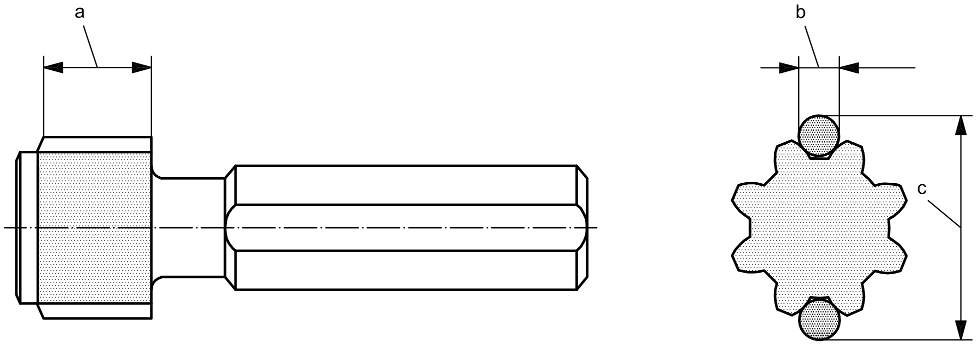
Table 19 — Dimensions and tolerances for NO GO sector plug gauges

Gauge dimension	Formula	Tolerance
Number of teeth	(z) x+x see Table 6	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$(D + 2D_{\text{Fi min}})/3$	js8 [a]
Form diameter	$D_{\text{ii min}} - 0{,}2m$	max.
Minor diameter	$D_{\text{ii min}} - 0{,}3m$	max.
Tooth thickness new	E_{max}	± H/2
Wear limit	$E_{\text{max}} - \text{W}$	
Pin diameter	See 8.5.1	
Size over pins new	See 8.6.1.1	
Size over pins wear limit	See 8.6.1.1	
Form deviations	See Table 11	

a See ISO 286.

10.6.2.3 NO GO composite plug gauge

The internal splines are inspected using a NO GO composite plug gauge as shown in Figure 25, with dimensions as given in Table 20.



[a] Gauge length.

[b] Pin diameter.

[c] Size over pins.

Figure 25 — NO GO composite plug gauge

Table 20 — Dimensions and tolerances for NO GO composite plug gauges

Gauge dimension	Formula	Tolerance
Number of teeth	xx	
Module	xx	
Pressure angle	xx	
Pitch diameter	xx.xxxx	
Base diameter	xx.xxxx	
Major diameter	$(D + 2D_{\text{Fi min}})/3$	js8 [a]
Form diameter	$D_{\text{ii min}} - 0{,}2m$	max.
Minor diameter	$D_{\text{ii min}} - 0{,}3m$	max.
Tooth thickness new	$E_{\text{v max}}$	± H/2
Tooth thickness wear limit	$E_{\text{v max}} - \text{W}$	
Pin diameter	See 8.5.1	
Size over pins new	See 8.6.1.1	
Size over pins wear limit	See 8.6.1.1	
Form deviations	See Table 11	
[a] See ISO 286.		

10.6.3 Inspection with plain gauges for internal and external splines

10.6.3.1 General

Gauge tolerances should be taken from ISO R 1938 inspection of plain parts.

10.6.3.2 Inspection of minor diameter — Internal spline

A double plain gauge is used for toleranced minor diameter (D_{ii}) inspection of internal splines. See Figure 26.

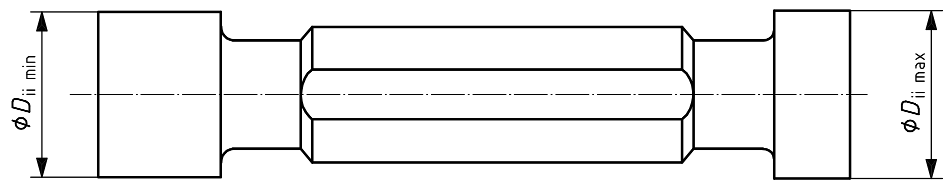
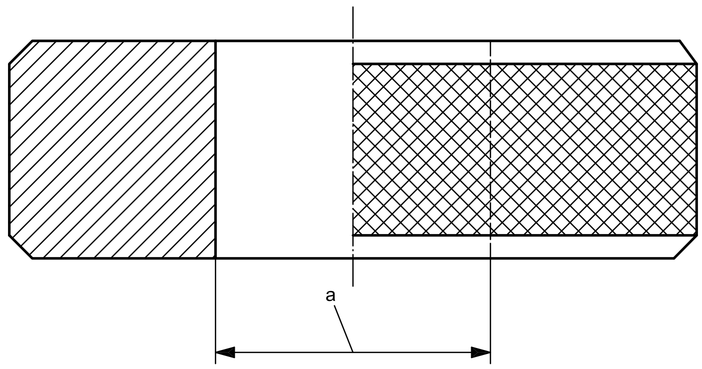


Figure 26 — Double-ended plain gauge

10.6.3.3 Inspection of major diameter — External spline

A GO plain ring or NO GO plain ring is used for toleranced major (D_{ee}) diameter inspection of external splines. See Figure 27.



a $D_{ee\ max}$ or $D_{ee\ min}$.

Figure 27 — GO or NO GO plain ring gauge

10.6.4 Marking of gauges

Gauges for splines conforming to ISO 4156 shall be marked with the following:

a) type of gauge;

b) designation;

c) dated reference to ISO 4156, i.e. ISO 4156:2005;

d) date of manufacture (DD.MM.YYYY).

EXAMPLE GO 24z × 2,5m × 30R × 5f ISO 4156:2005 01.01.2006

11 Measurement of spline deviations

11.1 General

The effect of these deviations is dealt with in ISO 4156-1.

11.2 Total profile deviation F_α

The total profile deviation is the sum of the absolute values of the greatest positive and negative profile deviations.

It shall be measured from the form diameter to the major diameter in the case of external splines, and from the form diameter to the minor diameter in the case of internal splines.

The machines for checking the involute profile are currently based on these principles.

11.3 Total cumulative pitch deviation F_p

Pitch deviations are the deviations in the spacing of all corresponding tooth profiles from theoretical spacing with respect to the arbitrarily selected tooth flank.

The total pitch deviation is the sum of the absolute values of the two greatest deviations of opposite sign (this value of total pitch deviation includes eccentricity) (see ISO 4156-1).

The total pitch deviation may be measured directly or obtained indirectly by measuring circular pitch deviations, which are the deviations from the theoretical pitch positions.

The measurement of circular pitch deviations is of little value for splines unless converted to total pitch deviation.

11.4 Total helix deviation F_β

The total helix deviation is the sum of the absolute values of the greatest positive and negative deviations in spline side direction with respect to the theoretical direction (see ISO 4156-1).

The total helix deviation is determined by recording the positive or negative deviations of side direction at the control circle level over the whole spline length.

The machines for checking the actual helix deviation are currently based on these principles.

The “negative” or “positive” direction of recorded deviations shall be defined by agreement between the purchaser and the supplier and indicated in the inspection report, if any.

Annex A
(informative)

Influences of eccentricity and pitch deviation as explained in ISO 4156:1981

A.1 This annex presents the influences of eccentricity and pitch deviation as these were explained in ISO 4156:1981, and is given for information only.

A.2 Pitch deviation of tooth profiles is not identical with that of the centrelines of spaces or teeth. Measurement of either deviation is acceptable, since only a percentage of the total cumulative pitch deviation is assumed to be reflected in the fit. Where readings must be repeatable, it is necessary to describe in detail the manner of inspection. Measurements taken on the centreline of internal spaces and external teeth may be more suitable for determining the effective deviation, since they are not influenced by space width and tooth thickness deviations. Furthermore, determination of the spacing of tooth profiles permits contact analysis and separate inspection of drive and coast sides. Pitch deviation is usually measured normal to the tooth surface. This practice yields readings smaller than the deviation at the pitch circle but is generally accepted.

A.3 The total cumulative pitch deviation may be inspected directly by means of precision indexing devices. Readings may be recorded as shown in Table A.1 and Figure A.1. However, the readings may be affected by eccentricity. It is therefore useful to dissociate pitch deviation from eccentricity of the splines as a whole and for this a method is proposed below.

When recordings are taken on perfect splines rotated about an axis offset from their true axis, the apparent error due to the eccentricity is given by

$$E_\mathrm{r} \times \cos\left(i \times \tau + \psi\right) \tag{A.1}$$

where

E_r is the eccentric radial offset;

i is an integer defining the tooth considered and has values 0, 1, 2, ..., z – 1;

ψ is the phase angle relating the inclination of the offset E_r and the position of the first tooth measured;

τ is the angular pitch.

$$\tau = \frac{360°}{z}\left(= \frac{2\pi}{z}\left[\mathrm{rad}\right]\right) \tag{A.2}$$

For an actual group of splines, the most probable values of E_r and ψ can be determined by a harmonic analysis of the measured deviation curve.

Such an analysis will yield the values of the coefficients of a Fourier series; the general form can be written as

$$f_\mathrm{n}(i) = A_0 + A_1 \cos\,(i\tau) + B_1 \sin\,(i\tau) + A_2 \cos\,(2i\tau)\,B_2 \sin\,(2i\tau) + \ldots \tag{A.3}$$

Only A_0, A_1 et B_1 are needed to separate pitch and eccentricity deviations, given by

$$\tan\psi = \frac{-B_1}{A_1} \tag{A.4}$$

$$E_r = \frac{A_1}{\cos\psi} = \frac{-B_1}{\sin\psi} = \sqrt{A_1^2 + B_1^2} \tag{A.5}$$

(Some computer harmonic analysis programs may give E_r and ψ directly.)

A_0 is the mean height of the measured deviation curve and shall be subtracted from each measurement for direct comparison with the eccentricity effect as indicated in the following example.

EXAMPLE 12-teeth splines with measured pitch deviation

$\tau = 360°/12 = 30°$

From a harmonic analysis it follows that

$A_0 = 2$

$A_1 = 2{,}805\ 4$

$B_1 = 5{,}011\ 2$

hence

$\tan\psi = 1{,}786\ 27$

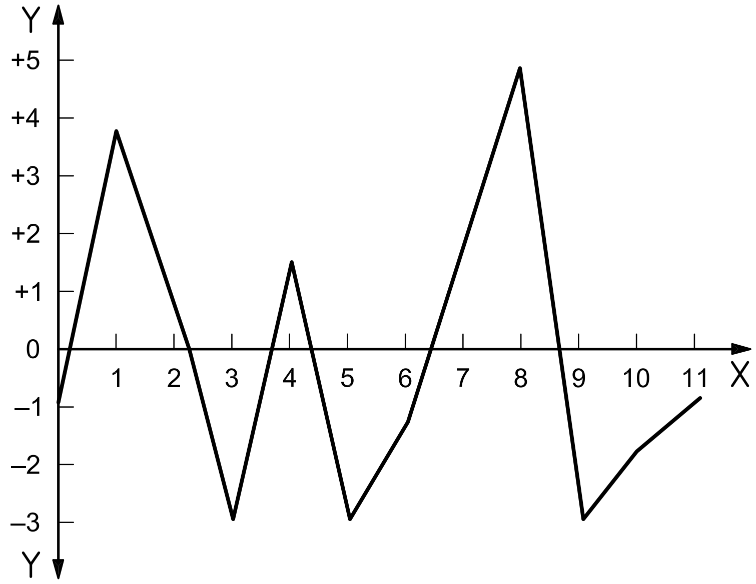
$E_r = 5{,}713$

$\psi = 60{,}758\ 8°$

and Table A.1 can then be drawn up. See also Figures A.1, A.2 and A.3 and Table A.2.

Table A.1 — Measurement results

Number of teeth	Measured deviation	Measured deviation in relation to A_0	Influence of eccentricity $E_r \cos(i\tau + \psi)$ measured from mean height	Residual pitch deviation
0	+ 4	+ 2	+ 2,80	− 0,80
1	+ 6	+ 4	− 0,08	+ 4,08
2	0	− 2	− 2,94	+ 0,94
3	− 6	− 8	− 5,01	− 2,99
4	− 2	− 4	− 5,74	+ 1,74
5	− 6	− 8	− 4,94	− 3,06
6	− 2	− 4	− 2,81	− 1,19
7	+ 4	+ 2	+ 0,08	+ 1,92
8	+ 10	+ 8	+ 2,94	+ 5,06
9	+ 4	+ 2	+ 5,01	− 3,01
10	+ 6	+ 4	+ 5,74	− 1,74
11	+ 6	+ 4	+ 4,94	− 0,94



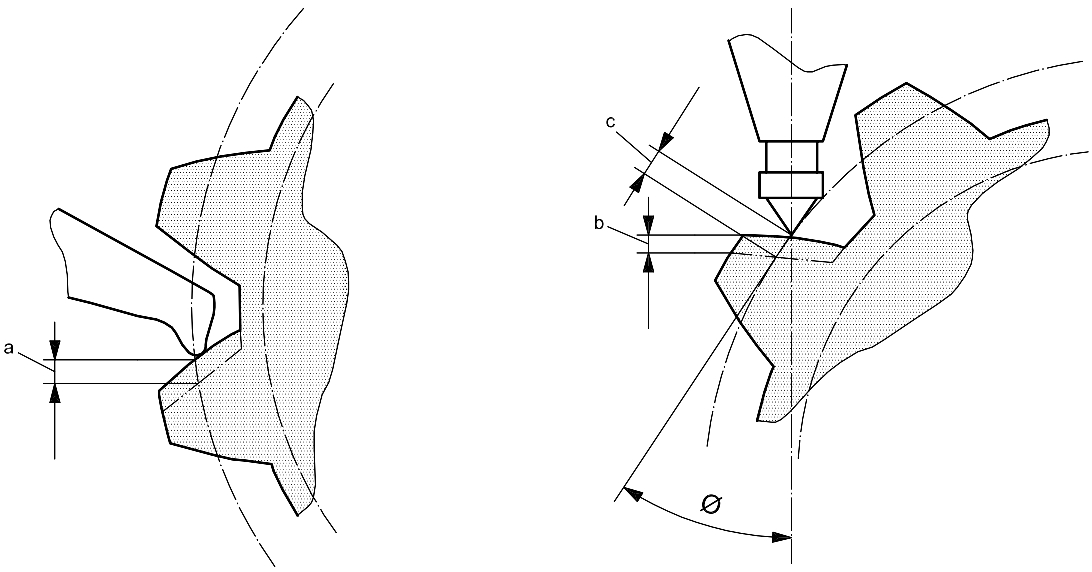
X *i*

Y Residual pitch deviation, µm

Figure A.1 — Graph of residual deviation

Table A.2 — Results of inspection

Eccentricity	5,743
Maximum residual deviation, positive	5,06
Maximum residual deviation, negative	− 3,06
Maximum deviation	8,12



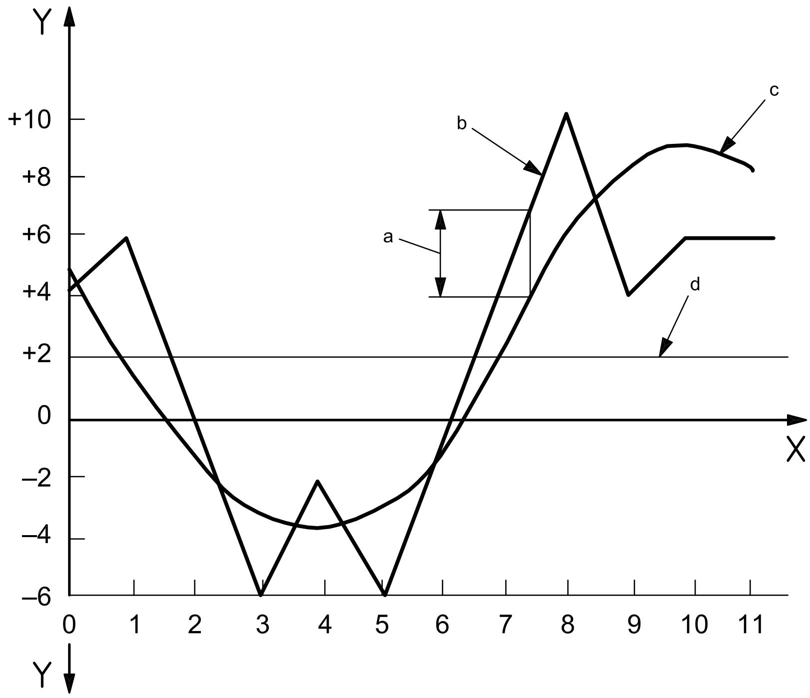
a) Deviation at the pitch circle **b) Pitch deviation**

[a] Tangential indication.

[b] Normal deviation.

[c] Tangential deviation.

Figure A.2 — Measuring method



X i, tooth no. 1

Y Residual pitch deviation, µm

[a] Residual pitch variation.

[b] Measured deviation.

[c] Most probable eccentricity effect.

[d] A_0, mean height of measured deviator.

Figure A.3 — Measuring results

A.4 The total cumulative pitch deviation can be determined indirectly by measuring the actual circular pitches on the control circles and recording their deviations with respect to the theoretical control circular pitch.

The theoretical control circular pitch is the arithmetical mean of all actual circular pitches measured on the control circle.

The total cumulative pitch deviation examined indirectly according to the above method in fact determines an "apparent" pitch deviation that includes other deviations as well.

ICS 21.120

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