DIN 5480-1

ICS 21.120.10

Supersedes
DIN 5480-1:1991-10 and
DIN 5480-14:1986-03

Involute splines based on reference diameters – Part 1: General

Passverzahnungen mit Evolventenflanken und Bezugsdurchmesser –
Teil 1: Grundlagen

Document comprises 24 pages

Translation by DIN-Sprachendienst.
In case of doubt, the German-language original should be consulted as the authoritative text.

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See foreword for relationship to the ISO 4156 series of standards published by the International Organization for Standardization (ISO).

Validity

This standard is valid from 2006-03-01.

Foreword

This series of standards deals with involute splines and spline joints within a module range of 0,5 to 10, having a number of teeth ranging from 6 to 82 and with a pressure angle of 30°. The DIN 5480 series of standards is limited to splines with a pressure angle of 30°, since pressure angles of 37,5° and 45° are covered by ISO 4156.

Involute splines in accordance with ISO 4156 are based on module series. These are not interchangeable with involute splines conforming to the DIN 5480 series of standards.

The DIN 5480 series of standards is based on reference diameters that are independent of the module, allowing an optimal fit to standard ball and roller bearing diameters and reducing the number of different tools required for manufacturing. This series of standards has been revised by Technical Committee 2.1 *Passverzahnungen* ("Involute splines") of the *Normenauschuss Maschinenbau* (Mechanical Engineering Standards Committee). The revision was considered necessary since a review of the DIN 5480 series of standards in accordance with DIN 820-4 had shown that the series had structural and editorial weaknesses. The object of the revision was to combine the individual parts of this standard in a practical, sensible manner.

The entire series of standards now consists of only four parts instead of the previous sixteen.

DIN 5480 *Involute splines based on reference diameters* now comprises:

— *Part 1: General*

— *Part 2: Nominal and inspection dimensions*

— *Part 15: Inspection*

— *Part 16: Tools*

The new edition of DIN 5480-1 deals with fundamental principles, the same as its predecessor, but now also includes fit dimensions and tolerances, these being formerly contained in DIN 5480-14:1986-03. The calculation formulae, tolerances and deviations contained in Part 1 also apply to the other parts of this series of standards. DIN 5480-2 now contains the nominal dimensions and inspection dimensions for the range of items stated above, and incorporates the contents of the former editions of DIN 5480-2 to DIN 5480-13.

DIN 5480-15 covers quality inspections of spline joints.

DIN 5480-16 defines the design features of tools for manufacturing involute splines.

Amendments

This standard differs from DIN 5480-1:1991-10 and DIN 5480-14:1986-03 as follows:

a) The title has been changed to "Involute splines based on reference diameters".

b) The full root radius has been included for shafts.

c) Cold-rolling has been included as a manufacturing process for shafts.

d) The standard has been editorially revised.

e) The entire contents of DIN 5480-14:1986-03 have been integrated into DIN 5480-1.

Previous editions

DIN 5480-1: 1966-12, 1974-09, 1986-03, 1991-10

DIN 5480-14: 1966-12, 1974-09, 1986-03

1 Scope

This standard applies to involute splines and spline joints based on reference diameters for connecting hubs and shafts either with a removable connection, a sliding fit or a permanent fit. It lays down the following general characteristics for splines as in this standard:

a) They have a standard pressure angle of 30°.

b) The basic rack profile is the same for all pitches, therefore applying a uniform design rule to all profiles.

c) They have a side fit profile (a diameter fit is permitted in some cases).

d) Addendum modification is used in order to achieve specific reference diameters.

e) The fit system includes tolerances for effective form deviations so that the effect of such deviations on backlash is taken into account. The specified range of fundamental deviations and tolerance classes takes due consideration of all requirements.

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.

DIN 323-1, *Preferred numbers and series of preferred numbers — Basic values, calculated values, rounded values*

DIN 780-1, *Series of modules for gears — Modules for spur gears*

DIN 3960, *Definitions, parameters and equations for involute cylindrical gears and gear pairs*

DIN 5466-1, *Splined joints, calculation of load capacity — Part 1: General*

DIN 5480-2, *Involute splines based on reference diameters — Part 2: Nominal dimensions and inspection dimensions*

DIN 5480-15, *Involute splines based on reference diameters — Part 15: Quality inspection*

DIN 5480-16, *Involute splines based on reference diameters — Part 16: Tools*

DIN ISO 6413, *Technical drawings — Representation of splines and serrations*

3 Symbols, designations and units

Symbol	Designation	Unit
c	bottom clearance	mm
c_F	form clearance	mm
c_{FP}	form clearance of basic rack profile	mm
$c_{F\,min}$	minimum form clearance	mm
d	pitch diameter	mm
d_a	tip diameter	mm
d_{a1}	tip diameter of shaft	mm
d_{a2}	tip diameter of hub	mm
d_b	base diameter	mm
d_f	root diameter	mm
d_{f1}	root diameter of shaft	mm
d_{f2}	root diameter of hub	mm
d_B	reference diameter	mm
d_{Ff1}	root form circle diameter of shaft	mm
d_{Ff2}	root form circle diameter of hub	mm
d_{Nf}	effective root diameter	mm
e	space width on hub	mm
e_2	nominal space width on hub	mm
e_{max}	maximum actual space width	mm
e_{min}	minimum actual reference space width	mm
e_{vmin}	minimum effective space width	mm
f_p	individual pitch deviation	µm
h	tooth height	mm
h_{aP}	addendum of basic rack profile	mm
h_{aP0}	addendum of tool basic rack profile	mm
h_{fP}	dedendum of basic rack profile	mm
h_K	radial height of tip chamfer or rounding	mm
h_P	tooth height of basic rack profile	mm
k	number of teeth measured for face width measurement	
m	module	mm
p	pitch	mm
s	shaft tooth thickness	mm
s_1	nominal shaft tooth thickness	mm
s_{max}	maximum actual reference tooth thickness	mm
s_{min}	minimum actual tooth thickness	mm
$s_{v\,max}$	maximum effective tooth thickness	mm

Symbol	Designation	Unit
x	addendum modification coefficient	
$x \cdot m$	addendum modification	mm
z	number of teeth	
A	deviation	mm
A_{df1}	deviation of shaft root diameter	mm
A_{df2}	deviation of hub root diameter	mm
A_{e}	space width deviation	mm
A_{s}	tooth thickness deviation	mm
A_{M1}	deviation of inspection dimension M_1	mm
A_{M2}	deviation of inspection dimension M_2	mm
A_{Wk}	deviation of base tangent length W_{k}	mm
A^*_{M1}	deviation factor for inspection dimension M_1	
A^*_{M2}	deviation factor for inspection dimension M_2	
A^*_{Wk}	deviation factor for base tangent length W_{k}	
D_{M}	measuring circle diameter (diameter of ball or pin)	mm
F_{α}	total profile deviation	µm
F_{β}	total helix deviation	µm
F_{p}	total cumulative pitch deviation	µm
F_{r}	(radial) runout	µm
M_1	dimension over measuring circles (balls or pins)	mm
M_2	dimension between measuring circles (balls or pins)	mm
N	hub	
NA	hub centred on major diameter	
NI	hub centred on minor diameter	
R_{S}	tooth thickness variation	mm
T_{act}	actual tooth thickness (or space width) tolerance	mm
T_{eff}	effective tooth thickness (or space width) tolerance	mm
T_{G}	total tooth thickness (or space width) tolerance	mm
W	shaft	
WA	shaft centred on major diameter	
WI	shaft centred on minor diameter	
W_{k}	base tangent length over k teeth	mm
α	pressure angle	°
α_{v}	pressure angle at the v-cylinder	°
ρ_{fP}	root fillet radius of basic rack profile	mm

Subscript	Refers to	Subscript	Refers to	Subscript	Refers to
a	tooth tip	G	total	0	tool
e	space width	K	tip chamfer	1	shaft
f	root of tooth	N	effective diameter	2	hub
s	tooth thickness	P	basic rack profile	*	deviation factor
v	effective tolerance limit	act	actual		
F	form diameter	eff	effective		

4 Structure

The tooth interlock of a splined joint is determined by the basic rack profile, the reference diameter, the module and the number of teeth. The selection of nominal dimensions is essentially determined by the following condition: The shaft cross-section remaining available for transmitting torques shall not be reduced more than is necessary to permit easy slip-fitting of components such as, for instance, ball or roller bearings. In joints centred on any pitch diameter, this condition is met by making the reference diameter equal to the bore of the bearing and then modifying the profiles of the teeth of the hub and the shaft accordingly.

The number of teeth shall be selected in such a way that the addendum modification necessitated by the reference diameter is kept within the range $x_1 \cdot m$ = –0,05 · m to +0,45 · m. The mean pressure angle on the v-cylinder ranges from 30° to more than 40°.

Even numbers of teeth are given preference in Tables 1 and 2. The reasons for this are explained in subclause 7.2.

Values of –0,05 · m and +0,45 · m are specified as limits for the nominal addendum modification of shafts; the limits for the nominal addendum modification of hubs are specified as +0,05 · m and –0,45 · m. Exceptions (x_1 >+ 0,45) have been permitted for some larger numbers of teeth ($z_1 \geq 60$) in order to enable even numbers of teeth to be produced and to avoid using prime numbers, since the effect of the addendum modifications on the pressure angle on the v-cylinder α_v decreases as the number of teeth increases.

Depending on the reference diameter, calculations for the number of teeth for Tables 1 and 2 using the formulae given in Table 3 will result either in a number teeth with an addendum modification that is within the specified limits or in two consecutive numbers of teeth with equal limit values x_1 = –0,05 and +0,45, since this addendum modification range of 0,5 · m corresponds to a difference of one tooth. In such cases, the maximum value of the addendum modification (x_1 = +0,45) is taken for splines where z < 10, and the even number of teeth is taken where $z \geq 10$ to facilitate the production of double teeth on shafts or hubs, which means that the addendum modification can also assume the minimum value (x_1 = –0,05). Figure 1 shows a major diameter fit shaft with splines. The double spaces of the associated hub or of a minor diameter fit shaft cannot be measured using balls or pins; rather, GO and NO GO gauges are required.

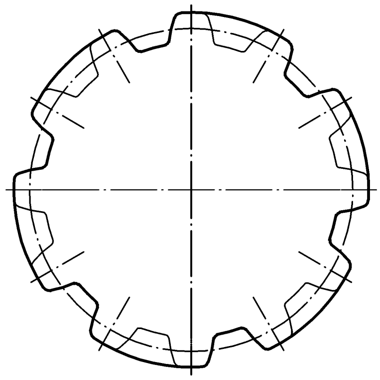


Figure 1 — Double teeth

If the number of spaces which can be measured using pins is an odd number, then the measurements given in the Tables can be converted.

$$M_{1,2} = (M_{1,2\text{Tabelle}} - D_\text{M}) \cdot \cos(\pi/(2 \cdot z)) + D_\text{M} \tag{1}$$

$$A^*_{\text{M}1,2} = A^*_{\text{M}1,2\text{Tabelle}} \cdot \cos(\pi/(2 \cdot z)) \tag{2}$$

(π is the angle in radians)

In keeping with the rule defined in DIN 3960, M_2 must be a negative value. The symbol z then represents the new odd number of spaces.

A number of teeth expressed as 6 (12) indicates six double teeth out of a total of 12:

EXAMPLE DIN 5480 – WA 17 × 1,25 × 6 (12) × h6 × 9e

5 Preferred series of modules, reference diameters and number of teeth

This standard provides for a large selection of splines. The module series correspond to the module series I and II as defined in DIN 780-1 and the metric module series as defined in ISO 54:1977.

Table 1 — Preferred series, reference diameters d_B from 6 mm to 58 mm

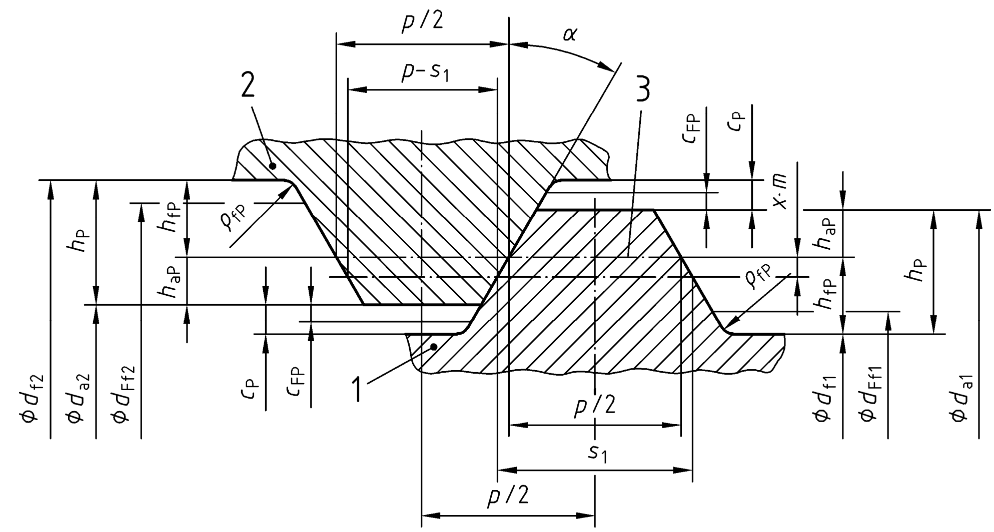
d_B mm	Number of teeth z for module m													
	0,5	**0,6**	**0,75**	**0,8**	**1**	**1,25**	**1,5**	**1,75**	**2**	**2,5**	**3**	**4**	**5**	**6**
6	10	8	6	6										
7	12	10	8	7										
8	14	12	9	8	6									
9	16	13	10	10	7									
10	18	15	12	11	8	6								
11	20	17	13	12	9	7								
12	22	18	14	13	10	8	6							
13	24	20	16	15	11	9	7	6						
14	26	22	17	16	12	10	8	6						
15	28	23	18	17	13	10	8	7	6					
16	30	25	20	18	14	11	9	8	6					
17	32	27	21	20	15	12	10	8	7					
18	34	28	22	21	16	13	10	9	7					
19	36	30	24	22	17	14	11	9						
20	38	32	25	23,24	18	14	12	10	8	6				
21	40	34	26	25	19	15	12	10						
22	42	35	28	26	20	16	13	11	9	7	6			
23	44	37	29	27	22	17	14	12						
24	46	38	30	28	22	18	14	12						
25	48	40	32	30	24	18	15	13	11	8	7			
26	50	42	33	31	24	19	16	13						
27	52	44	34	32	26	20	16	14						
28	54	45	36	34	26	21	17	14	12	10	8			
29	56	47	37	35	28	22	18	15						
30	58	48	38	36	28	22	18	16	13,14	10	8			
31	60	50	40	37	30	23	19	16						
32	62	52	41	38	30	24	20	17	14	11	9	6		
33	64	54	42	40	32	25	20	17						
34	66	55	44	41	32	26	21	18						
35	68	57	45	42	34	26	22	18	16	12	10	7		
36	70	58	46	44	34	27	22	19						
37	72	60	48	45	36	28	23	20	17	13	11	8		
38	74	62	49	46	36	29	24	20	18	14	11	8		
39	76	64	50	47	38	30	24	21						
40	78	64	52	48	38	30	25	21	18	14	12	8	6	
42		68	54	51	40	32	26	22	20	15	12	9	7	
45		74	58	55	44	34	28	24	21	16	13,14	10	7	
47		76	60	57	46	36	30	25	22	17	14	10	8	
48		78	62	58	46	37	30	26	22	18	14	10	8	6
50			64	60	48	38	32	27	24	18	15	11	9	7
52			68	64	50	40	33	28	24	19	16	11	9	7
55			72	66	54	42	35	30	26	20	17	12	9	8
58				70	56	45	37	32	28	22	18	13	10	8

Table 2 — Preferred series, reference diameters d_B from 60 mm to 500 mm

d_B mm	Number of teeth z for module m												
	0,8	**1**	**1,25**	**1,5**	**1,75**	**2**	**2,5**	**3**	**4**	**5**	**6**	**8**	**10**
60	74	58	46	38	33	28	22	18	13,14	10	8	6	
62			48	40	34	30	23	19	14	11	9		
65			50	42	36	31	24	20	15	11	9	7	
68			53	44	37	32	26	21	15,16	12	10		
70			54	45	38	34	26	22	16	12	10	7	
72			56	46	40	34	27	22	16	13	10		
75			58	48	41	36	28	24	17	13,14	11	8	
78			60	50	43	38	30	24	18	14	11,12		
80			62	52	44	38	30	25	18	14	12	8	6
82				53	45	40	31	26	19	15	12		
85				55	47	41	32	27	20	15,16	13	9	7
88				57	49	42	34	28	20	16	13		
90				58	50	44	34	28	21	16	13,14	10	7
92				60	51	44	35	29	22	17	14		
95				62	53	46	36	30	22	18	14	10	8
98				64	54	48	38	31	23	18	15		
100				64	56	48	38	32	24	18	15	11	8
105				68	58	51	40	34	25	20	16	12	9
110				72	60,61	54	42	35	26	20	17	12	9
120					66,67	58	46	38	28	22	18	13,14	10
130						64	50	42	31	24	20	15	11,12
140						68	54	45	34	26	22	16	12
150						74	58	48	36	28	24	17	13,14
160								52	38	30	25	18	14
170								55	41	32	27	20	15,16
180								58	44	34	28	21	16
190								62	46	36	30	22	17,18
200								65	48	38	32	24	18
210								68,69	51	40	34	25	20
220										42	35	26	20
240										46	38	28	22
250										48	40	30	24
260										50	42	31	24
280										54	45	34	26
300										58	48	36	28
320										62	52	38	30
340											55	41	32
360											58	44	34
380											62	46	36
400											65	48	38
420											68	51	40
440											72	54	42
450											74	55	44
460											75	56	44
480											78	58	46
500											82	61	48

6 Basic rack profile

Figure 2 shows the basic rack profile. The corresponding descriptive parameters, tooth interlock data and calculation formulae are given in Table 3.



Key

1 Shaft
2 Hub
3 Profile reference line

Figure 2 — Basic rack profile

Table 3 — Basic rack profile

Parameter		Sym-bol	Spline data and calculation formulae
Module		m	0,5-0,6-0,75-0,8-1,0-1,25-1,5-1,75-2-2,5-3-4-5-6-8-10
Pressure angle		α	30°
Pitch		p	$m \cdot \pi$
Number of teeth	shaft	z_1	z_1
	hub	z_2	$-z_1$
Addendum modification	shaft	$x_1 \cdot m$	$-0{,}05 \cdot m$ to $+ 0{,}45 \cdot m$ (exceptions up to $+0{,}879 \cdot m$)
(nominal value)	hub	$x_2 \cdot m$	$-x_1 \cdot m = +0{,}05 \cdot m$ to $-0{,}45 \cdot m$ (exceptions up to $-0{,}879 \cdot m$)
Addendum of basic rack profile		h_{aP}	$0{,}45 \cdot m$
Dedendum of basic rack profile		h_{fP}	$0{,}55 \cdot m$ $0{,}60 \cdot m$ $0{,}65 \cdot m$ $0{,}84 \cdot m$
= addendum of tool basic rack profile		$= h_{aP0}$	broaching hobbing gear shaping cold rolling
Tooth height of basic rack profile		h_P	$h_{aP} + h_{fP}$
Bottom clearance of basic rack profile		c_P	$h_{fP} - h_{aP}$
Root fillet radius of basic rack profile		ρ_{fP}	$0{,}16 \cdot m$ chip-removal machining $0{,}54 \cdot m$ cold rolling
Pitch diameter		d	$m \cdot z$
Base diameter		d_b	$m \cdot z \cdot \cos\alpha$
Reference diameter		d_B	$m \cdot z_1 + 2 \cdot x_1 \cdot m + 1{,}1 \cdot m$, diameters with standard numbers in accordance with DIN 323-1 and ball/roller bearing diameters, integer values with increments of one for the range $d_B < 40$ mm and $m \leq 1{,}75$ mm.
Tip diameter of hub		d_{a2}	$m \cdot z_2 + 2 \cdot x_2 \cdot m + 0{,}9 \cdot m$
Root diameter of hub		d_{f2}	$m \cdot z_2 + 2 \cdot x_2 \cdot m - 2 \cdot h_{fP}$ (see 7.1)
Root form circle diameter of hub		d_{Ff2}	$\leq -(d_{a1} + 2 \cdot c_{Fmin})$
Tip diameter of shaft		d_{a1}	$m \cdot z_1 + 2 \cdot x_1 \cdot m + 0{,}9 \cdot m$
Root diameter of shaft		d_{f1}	$m \cdot z_1 + 2 \cdot x_1 \cdot m - 2 \cdot h_{fP}$ (see 7.1)
Base form circle diameter of shaft		d_{Ff1}	$\leq \lvert d_{a2} \rvert - 2 \cdot c_{Fmin}$
Form clearance of basic rack profile		c_{FP}	$0{,}02 \cdot m$ $0{,}07 \cdot m$ $0{,}12 \cdot m$ $0{,}12 \cdot m$ broaching hobbing gear shaping cold rolling
Minimum form clearance		c_{Fmin}	see Table 4
Nominal space width of hub		e_2	$e_2 = s_1$
Nominal tooth thickness of shaft		s_1	$m \cdot \pi/2 + 2 \cdot x_1 \cdot m \cdot \tan\alpha$

In the formulae given in Table 3, the signs for the number of teeth and addendum modification coefficients of internal gear splines as defined in DIN 3960 have been introduced in order to facilitate the use of computers when designing splines. These lead to negative signs for all hub diameters and dimensions (see DIN 3960). In the Tables of dimensions given in DIN 5480-2, only the absolute values of diameters and inspection dimensions are given, i.e. the values are to be understood as absolute values in order to avoid any misunderstanding.

The form clearance c_F is the distance between the effective root diameter used by the mating part and the root form circle diameter created by the tool. The minimum form clearance c_{Fmin} values given in Table 4 provide an adequate excess length of the root involute so that disturbance-free contact between the involute flanks of the hub and shaft is ensured even when there are eccentricities in the motion of the interacting tip circle.

Table 4 — Minimum form clearance

d_B mm	Minimum form clearance c_{Fmin} µm		
	Module 0,5 to 1,5	**Module 1,75 to 4**	**Module 5 to 10**
up to and including 12	25	–	–
over 12 up to 25	28	30	–
over 25 up to 50	30	35	40
over 50 up to 100	35	40	45
over 100 up to 200	40	45	50
over 200 up to 400	–	50	55
over 400	–	–	65

7 Diameters

The DIN 5480 series of standards applies to side-fit splines. The flanks of the teeth are used both for transmitting the torque and for centring the hub and shaft relative to one another. This standard can also be applied, however, to design splines with a diameter fit.

7.1 Diameters for side-fit splines

In side-fit spline joints the flanks of the teeth serve to transmit the forces as well as to centre the parts. The tip and root diameters of the shaft differ from the respective diameters of the hub by at least the bottom clearance c (see Figure 3).

The fit and centring accuracy are determined by deviation in space width and tooth thickness, and by the tolerances achieved or specified. For limits of centring accuracy, see DIN 5466-1. The definitive fit parameter is that for the flanks, the backlash. Refer to clause 10 for the relationship between space width tolerance and tooth thickness tolerance, measurement methods, spline mesh quality and backlash.

The nominal dimension for the root diameter of side-fit splines is the “theoretical root diameter” calculated using $h_{fP} = 0{,}55 \cdot m$. The deviations applicable to chip-cutting manufacturing methods cover the associated maximum possible dedendum $h_{fP} = 0{,}65 \cdot m$ and the root diameter deviations, which correspond to the space width/tooth thickness tolerance fields 9H and 11a. These determine the design dimension of the spline diameters where the chip-cutting manufacturing method is not yet known and the tool run-out spaces are free. The root diameters of shafts are dependent on the machining method used: When created by hobbing they can be calculated by subtracting $0{,}1 \cdot m$; those of hubs with teeth made by shaping are calculated by adding $0{,}2 \cdot m$, while those of shafts made by shaping are determined by subtracting $0{,}2 \cdot m$ from the theoretical root diameter. Correspondingly, the absolute values of the deviation must then be reduced by $0{,}1 \cdot m$ or $0{,}2 \cdot m$, respectively. The deviations applicable to cold-rolled splines for shaft splines cover the associated dedendum $h_{fP} = 0{,}84 \cdot m$ and the root deviations which would be needed to implement fully-rounded roots at a tolerance 11 and fundamental deviation *a*. They determine the design value of the connection diameter. Root diameters of shafts with cold-rolled splines are calculated by subtracting $0{,}58 \cdot m$ from the theoretical root diameter. Refer to Table 5 for recommended tolerance fields and deviations for the root and tip diameters.

The exact root diameters of hubs and shafts for splines created by rolling are calculated using the formulae given in DIN 5480-16, taking into account the particular features of the respective rolling method used, the deviations of the space widths and tooth thicknesses and, where necessary, a machining allowance. DIN 5480-16 also contains formulae for calculating the exact root diameters of shafts with cold-rolled splines.

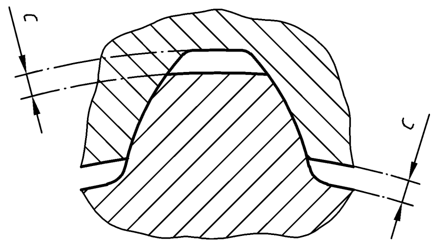


Figure 3 — Bottom clearance of side-fit splines

7.2 Diameters for diameter fit splines

7.2.1 General

Diameter fit splines are centred either on the major diameter (hub root diameter and shaft tip diameter = major diameter fit) or on the minor diameter (hub tip diameter and shaft root diameter = minor diameter fit). The teeth merely serve to transmit the forces. Such spline joints shall always be given enough backlash in order to prevent over-determination of the centring (see Figures 4 and 5).

The fit and accuracy of concentricity are determined by the selected ISO tolerance field of the centring diameters.

The nominal dimension of the centring diameters for diameter fit splines is the reference diameter in the case of major diameter fits and the hub tip diameter for minor diameter fits.

Where the teeth number is divisible, the centring surfaces can be widened by providing multiple teeth on the shaft and multiple spaces in the hub, for instance in order to make, with primarily lateral loading (see DIN 5466-1), diameter fit spline joints stronger or to allow diameter fits for splines with a small module (see Figure 1).

Diameter fit splines require greater manufacturing effort due to the small tolerances of the centring diameters and the measures required to limit the offsets between the centring diameter centre and the centre of the tooth circle. These should therefore only be used in a few exceptional cases.

See Table 5 for recommended tolerance fields for the root circle and tip diameters.

7.2.2 Major diameter fit splines

The fit parameters for major diameter fit splines are as follows:

— the clearance between the hub root diameter and the shaft tip diameter, which are both assigned the same nominal dimension d_B, i.e. d_{f2} and d_{a1} are both equal to d_B;

— the flank backlash which, because of the centring action of the flank fit, must always be positive and large enough to prevent overdetermination of the centring.

The edges of tooth tips on major diameter fit shafts shall be chamfered (a minimum value of $h_K = 0{,}1 \cdot m$ is recommended) in order to prevent interference with the fillets of the roots of the hub teeth, see Figure 4. Refer to Table 5 for recommended tolerance fields for the root and tip diameters.

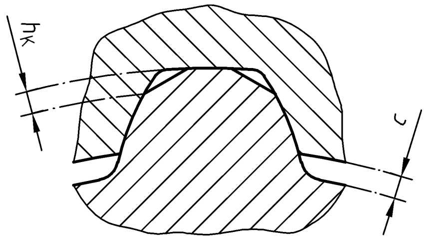


Figure 4 — Major diameter fit

7.2.3 Minor diameter fit splines

The fit parameters for minor diameter fit splines are as follows:

- the clearance between the tip diameter d_{a2} of the hub and the root diameter d_{f1} of the shaft (which is the centring diameter in this case), both of which are assigned the same nominal diameter here;
- the flank backlash which, because of the centring action of the flank fit, must always be positive and large enough to prevent overdetermination of the centring.

The edges of tooth tips on minor diameter fit shafts shall be chamfered (a minimum value of $h_K = 0{,}1 \cdot m$ is recommended) in order to prevent interference with the fillets of the roots of the hub teeth, see Figure 5. Refer to Table 5 for recommended tolerance fields for the root and tip diameters.

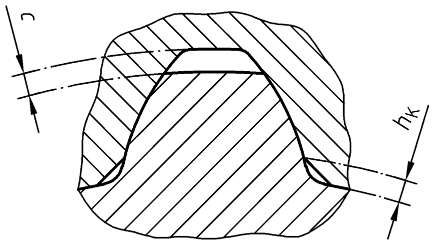


Figure 5 — Minor diameter fit

Table 5 — Recommended tolerances and deviations for tip and root diameters

	Side fit	Diameter fit	
		Major[c]	Minor[c]
Tip diameter of hub, d_{a2}	H11	H11	H7
Tip diameter of shaft, d_{a1}	h11	h6	h11
Deviation for the hub root diameter d_{f2}	$A_{df2} = (0{,}2 \cdot m + 1{,}73 \cdot (A_e + T_G))$[a]	H7	H14
Deviation for the shaft root diameter d_{f1}	Chip-removal machining: $A_{df1} = -(0{,}2 \cdot m + 1{,}73 \cdot (-A_s + T_G))$[b] Cold rolling: $A_{df1} = -0{,}76 \cdot m$ (max.)	h14	h6

[a] A_e and T_G in series 9H (see 7.1).
[b] A_s and T_G in series a11 (see 7.1).
[c] For side fit: 9H/9e.

8 Designation

Splines as in this standard shall be designated by the main standard number (i.e. DIN 5480), an N for a hub or W for a shaft, followed by an A for major diameter fit or an I for minor diameter fit (only in the case of diameter fitting), then by the reference diameter, the module, the number of teeth, the tolerance class and the fundamental deviation. For diameter fit splines, the tolerance class and fundamental deviation shall be placed in front of the respective data of the tooth flanks.

EXAMPLE 1

Designation of a side fit spline joint

Reference diameter	d_B	120 mm
Module	m	3 mm
Number of teeth	z	38
Side fit		9H 8f

Spline joint	DIN 5480 – 120 × 3 × 38 × 9H 8f
Hub	DIN 5480 – N 120 x 3 × 38 × 9H
Shaft	DIN 5480 – W 120 × 3 × 38 × 8f

EXAMPLE 2

Designation of a major diameter fit spline joint

Reference diameter	d_B	120 mm
Module	m	3 mm
Number of teeth	z	38
Side fit		9H 9e
Diameter fit		H7 h6

Spline joint	DIN 5480 – A 120 × 3 × 38 × H7 h6 × 9H 9e
Hub	DIN 5480 – NA 120 × 3 × 38 × H7 × 9H
Shaft	DIN 5480 – WA 120 × 3 × 38 × h6 × 9e

EXAMPLE 3

Designation of a major diameter fit spline joint with double teeth on the shaft

Reference diameter	d_B	120 mm
Module	m	3 mm
Number of teeth	z	38
Side fit		9H 9e
Diameter fit		H7 h6

Spline joint	DIN 5480 – A 120 × 3 × 19 (38) × H7 h6 × 9H 9e
Hub	DIN 5480 – NA 120 × 3 × 19 (38) × H7 × 9H
Shaft	DIN 5480 – WA 120 × 3 × 19 (38) × h6 × 9e

EXAMPLE 4

Designation of a minor diameter fit spline joint

Reference diameter	d_B	120 mm
Module	m	3 mm
Number of teeth	z	38
Side fit		9H 9e
Diameter fit		H7 h6

Spline joint	DIN 5480 – I 120 × 3 × 38 × H7 h6 × 9H 9e
Hub	DIN 5480 – NI 120 × 3 × 38 × H7 × 9H
Shaft	DIN 5480 – WI 120 × 3 × 38 × h6 × 9e

9 Data to be shown on drawings

9.1 Data field

The geometrical data for the teeth are too extensive to be written directly in the drawings as dimensions. It is therefore recommended that these be indicated in the form of a data field, see Figure 6.

Hub DIN 5480 – N120 × 3 × 38 × 9H			**Shaft DIN 5480 – W120 × 3 × 38 × 8f**		
Number of teeth	z	38	Number of teeth	z	38
Module	m	3	Module	m	3
Pressure angle	α	30°	Pressure angle	α	30°
Root diameter	d_{f2}	120 + 0,76	Tip diameter	d_{a1}	119,40 h11
Root form circle diameter	d_{Ff2}	119,49 min.	Root form circle diameter	d_{Ff1}	113,91 max.
Tip diameter	d_{a2}	114 H11	Root diameter, cold-rolled	d_{f1}	113,4 – 1,74
Maximum actual space width	e_{max}	6,361	Max. effective tooth thickness	s_{vmax}	6,243
Minimum actual reference space width	e_{min}	6,305	Maximum actual reference tooth thickness	s_{max}	6,220
Minimum effective space width	e_{vmin}	6,271	Minimum actual tooth thickness	s_{min}	6,180
Measuring circle diameter (ball or pin diameter)	D_M	5,250	Measuring circle diameter (ball or pin diameter)	D_M	6,000
Max. dist. betw. measuring circles (balls or pins)	M_{2max}	109,266	Max. ref. dimension over measuring circles (balls or pins)	M_{1max} Ref.	(126,017)
Min. ref. dist. betw. measuring circles (balls or pins)	M_{2min} Ref.	(109,169)	Min. dimension over measuring circles (balls or pins)	M_{1min}	125,956

Figure 6 — Example of a data field in a drawing

If the method of measurement has to be specified, it is also possible to state a measuring ball or measuring pin diameter instead of the measuring circle diameter. The dimension over or between measuring circles is then stated either as the dimension over or between balls or pins, accordingly. The designations given in DIN 3960 for gear teeth are also permitted.

9.2 Indication of individual deviations

Guide values for individual deviations can also be entered directly in the data field. However, in this case a note shall be added stating that the GO gauge has priority. This means that the respective workpieces may not be rejected because of individual deviations. If, in special cases, it is necessary to state permissible individual deviations as a tolerance, this shall be identified as such by the supplementary note “max.”.

9.3 Statistical actual tolerance limit (STA)

When a dimension is checked over and between measurement balls or pins, the actual measurement will depend very strongly on the angular position and the measuring plane. If very many measurements are taken in different angular positions and measuring planes, it may be useful to apply statistical concepts when evaluating the actual tolerance limit. This avoids excessive reject rates, which would not occur if fewer measurements were to be taken. The statistical actual tolerance limit permits a certain number of measurements to exceed the tolerance limits by a specific value. For details, see DIN 5480-15, 5.3.6. Where necessary, the data for the statistical actual tolerance limit STA are to be entered at the bottom of the data field.

9.4 Representation in drawings

DIN ISO 6413 specifies how splines are to be represented in drawings.

10 Fit system for space width / tooth thickness

10.1 General

The tooth flanks of splines are used both for transmitting the torque and for centring the hub and shaft relative to one another. The difference between the space width and the tooth thickness determines the rotational backlash. This standard specifies deviation series and tolerances for space widths of hubs and tooth thicknesses of shafts, which are based on the nominal dimensions, see Figure 7. The deviation series permits the definition of fit types (interference, transition, clearance). The tolerance classes define the manufacturing tolerances.

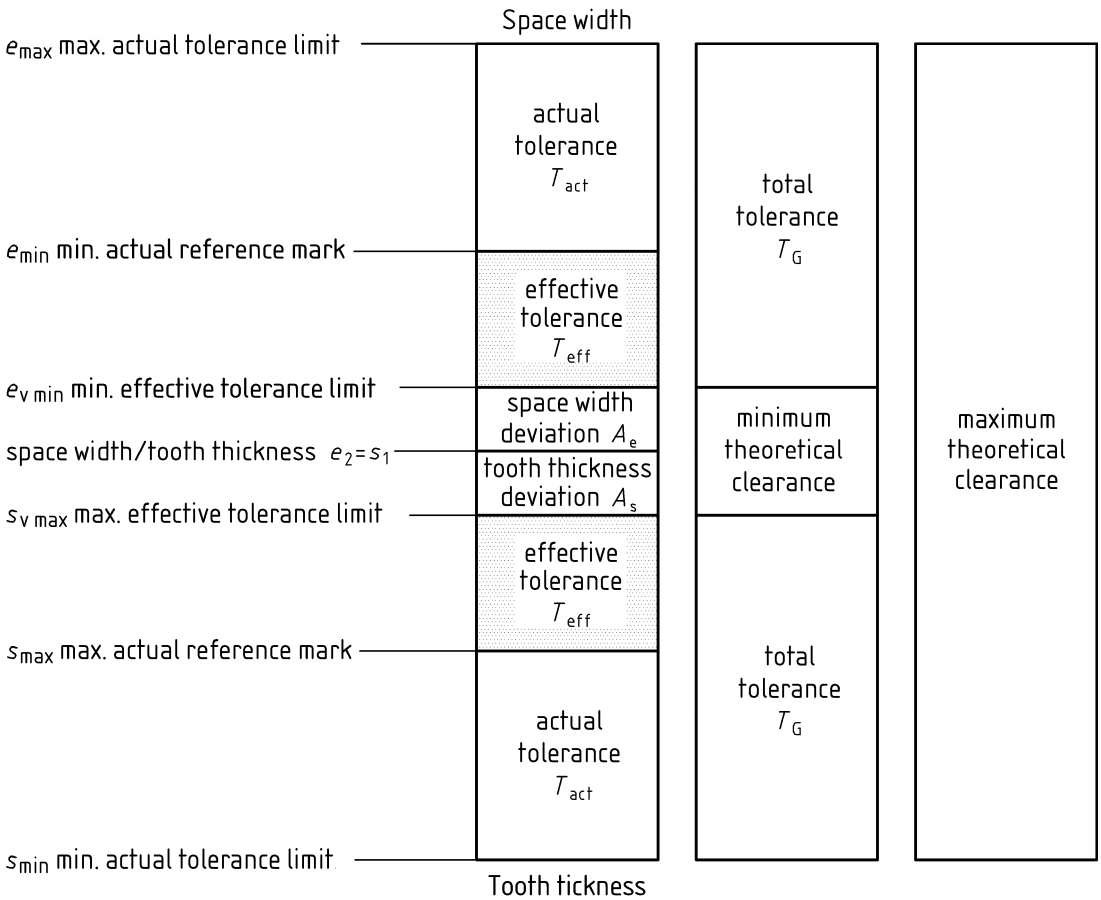


Figure 7 — Schematic diagram of space width / tooth thickness fit

10.2 Structure of the tolerance system

The tolerance system for splines as in this standard is based on the minimum theoretical clearance. A design clearance of zero ensures that the hub can be fitted on the shaft. For a minimum clearance of zero, it is better to set the effective tolerance limits to the dimension of the nominal space width e_2 and the nominal tooth thickness s_1.

10.3 Deviations

Both positive and negative minimum clearances can be designed using the space width deviation A_e and the tooth thickness deviation A_s. The deviations for hubs are designated by upper case letters and those for shafts are designated by lower case letters; see Table 9. There are six deviations, from F to M for hubs and 18 deviations from v to a for shafts.

10.4 Total tolerance T_G

The maximum theoretical clearance is determined by adding the deviations and the tolerance values of the total tolerances T_G for the hub and the shaft. The total tolerance combines the actual tolerance and the effective tolerance. Eight tolerance grades are specified for hubs and shafts, determining the total tolerance as well as the actual and effective individual tolerances. These have a predefined interrelationship. In practice, the size of the actual tolerance T_{act} in relationship to the effective tolerance T_{eff} within the total tolerance T_G varies greatly. A ratio of $T_G/T_{act} \approx 1{,}6$ has been chosen in this standard as this seemed to be most suitable. If it is necessary to change the size ratio, then the actual tolerances and the effective tolerances as stated in this standard can be selected separately from the different tolerance grades and will, when added, lead to a total tolerance deviating from this standard.

10.5 Actual tolerance T_{act}

The actual tolerance allows for the effects of wear on tool dimensions, the infeed accuracy of machine tools and dimensional deviations due to heat treatment. In the data field of the workpiece drawing, it is given as the actual tolerance limit and as the reference mark actual Ref. Since it is difficult to measure tooth thickness and space widths directly, they shall be converted to dimensions across and between measuring circles and are entered in this form into the data field. In practice, measuring balls or measuring pins are used as measuring circles. The manufacturing tolerance should be at least twice the expected tooth thickness variation R_s.

10.6 Effective tolerance T_{eff}

The effective tolerance is specified separately for splines as in this standard. This is necessary because the fit is generated over all left and right flanks of all teeth. The flanks of the teeth are subject to individual deviations due to the profile, the helix and the pitch. These deviations reduce the clearance of spline joints so severely that provision must be made for this effect. In hubs, the superposition of all individual deviations leads to an effective space width that is smaller than the actual space that can be measured. In shafts, the superposition of all individual deviations lead to an effective tooth thickness that is greater than the actual thickness which can be measured.

10.7 Design specifications

When designing splines as in this standard, the maximum and minimum permissible clearance are to be defined in the technical specifications. Given these values, it is the designer's task to select the deviations and tolerance classes. A certain amount of experience is needed in selecting deviations and tolerances suitable for practical applications.

10.8 Calculation of tolerance limits

Tolerance limits are to be calculated on the basis of the nominal space width e_2 of the hub and the tooth thickness s_1 of the shaft, using the formulae given in Table 6. The deviations A_e and A_s as well as the tolerances T_{act} and T_{eff} for the relevant tolerance grade are to be taken from Table 7.

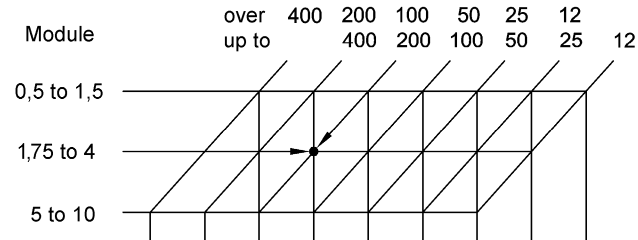
Table 6 — Calculation of tolerance limits

Space width	max. actual	$e_{max} = e_2 + A_e + T_G = e_2 + A_e + T_{act} + T_{eff}$
Space width	min. actual Ref.	$e_{min} = e_2 + A_e + T_{eff}$
Space width	min. effective	$e_{vmin} = e_2 + A_e$
Tooth thickness	max. effective	$s_{vmax} = s_1 + A_s$
Tooth thickness	max. actual Ref.	$s_{max} = s_1 + A_s - T_{eff}$
Tooth thickness	min. actual	$s_{min} = s_1 + A_s - T_G = s_1 + A_s - T_{act} - T_{eff}$

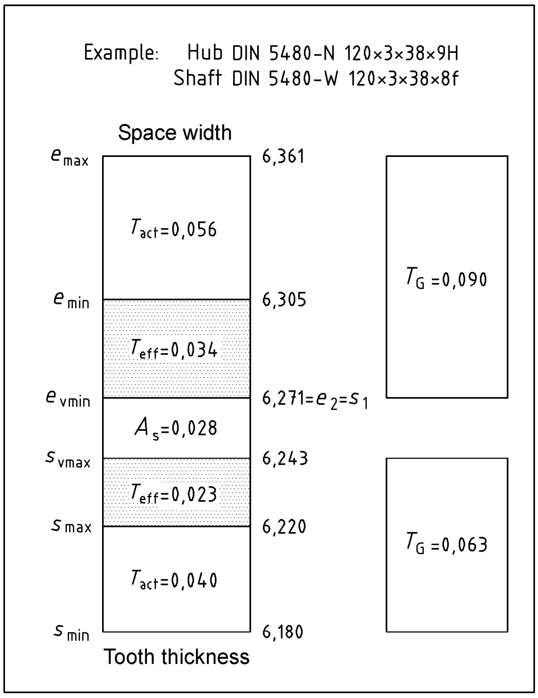
In addition to showing the actual and effective tolerances, Table 7 also gives guide values for individual deviations F_p, f_p and F_α, F_β. These values do not constitute a tolerance, but can be used to determine the cause of nonconformities in cases where GO gauges will not fit. If a GO gauge does fit, this will in effect ensure adherence to the tolerance limit.

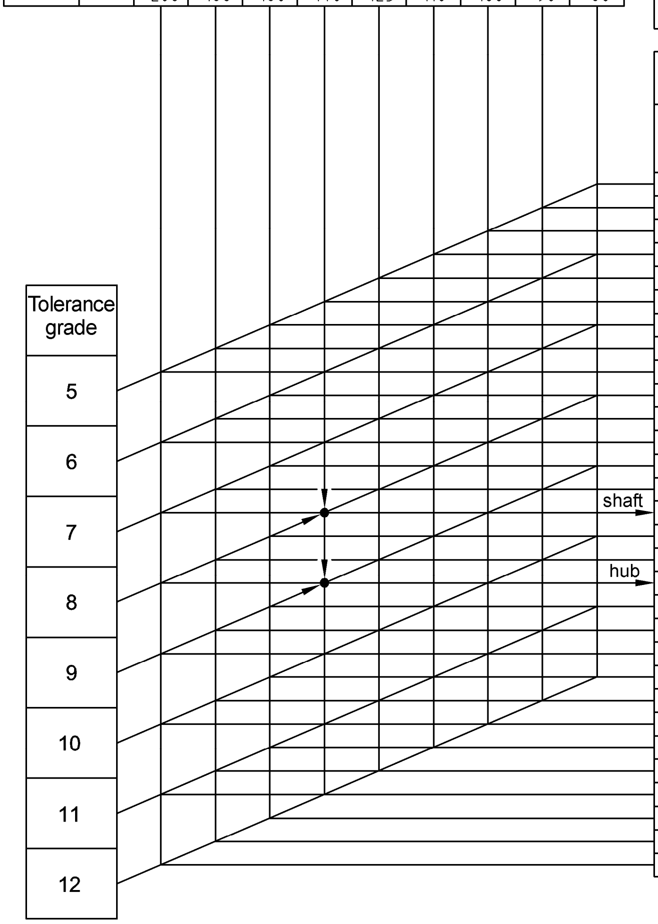
10.9 Deviations and tolerances

Table 7 — Deviations and tolerances



Deviation		Deviations: space width A_e and tooth thickness A_s in µm								
	v	200	180	160	140	125	110	100	90	80
	u	180	162	144	126	112	99	90	81	72
	t	160	144	128	112	100	88	80	72	64
	s	140	126	112	98	88	77	70	63	56
	r	120	108	96	84	75	66	60	54	48
	p	100	90	80	70	62	55	50	45	40
	n	80	72	64	56	50	44	40	36	32
	m	60	54	48	42	37	33	30	27	24
F	k	40	36	32	28	25	22	20	18	16
G	j	20	18	16	14	12	11	10	9	8
H	h	0								
J	g	−20	−18	−16	−14	−12	−11	−10	−9	−8
K	f	−40	−36	−32	−28	−25	−22	−20	−18	−16
M	e	−60	−54	−48	−42	−37	−33	−30	−27	−24
	d	−80	−72	−64	−56	−50	−44	−40	−36	−32
	c	−120	−108	−96	−84	−75	−66	−60	−54	−48
	b	−160	−144	−128	−112	−100	−88	−80	−72	−64
	a	−200	−180	−160	−140	−125	−110	−100	−90	−80





Tolerances in µm			Guide values for individual deviations in µm					
T_G	$T_{act.}$	$T_{eff.}$	f_p	F_p	F_α	F_β up to length (mm) 50	100	200
12	8	4	3,5	8	5	5	8	10
14	9	5	4	9	5,5	5	8	10
16	10	6	4,5	10	6	5	8	11
18	11	7	5	11	6	6	9	11
20	12	8	5,5	12	7	6	9	12
22	14	8	6	14	8	6	9	13
25	16	9	7	16	9	7	10	13
28	18	10	8	18	10	7	10	14
32	20	12	9	20	11	8	11	14
36	22	14	10	22	12	8	11	15
40	25	15	11	25	13	9	12	16
45	28	17	12	28	15	9	12	17
50	32	18	13	32	17	10	13	18
56	36	20	15	36	19	10	13	19
63	40	23	17	40	21	11	14	20
71	45	26	19	45	23	12	15	21
80	50	30	21	50	25	13	16	22
90	56	34	24	56	28	14	17	23
100	63	37	27	63	31	15	18	24
112	71	41	30	71	34	16	19	25
125	80	45	34	80	37	17	20	26
140	90	50	38	90	41	18	21	27
160	100	60	43	100	45	19	22	28
180	112	68	48	112	49	20	23	29
200	125	75	53	125	53	21	24	30
224	140	84	60	140	58	22	25	31
250	160	90	68	160	63	23	26	32
280	175	105	75	175	68	24	27	33
320	200	120	85	200	73	25	28	34
360	225	135	96	225	78	26	29	35

10.10 Guide values for radial runout

As radial runout is largely a deviation of position and is specified relative to other geometrical elements, it is not possible to specify guide values for this parameter. Table 8 gives guideline values for the radial runout of the pitch diameter of external splines relative to a reference axis.

Table 8 — Guideline values for radial runout

Pitch diameter d mm	**Radial runout** F_r µm
< 18	20
18 to < 30	30
30 to < 50	40
50 to < 100	50
100 to < 200	60
200 to < 500	80

10.11 Fit types

The deviations and tolerances given in Table 9 can be used to achieve a specific fit tpye (interference, transition or clearance).

Table 9 — Fit types

Fit type	**Deviations/tolerances**							
	Hub			**Shaft**				
Rough interference fit			9H	9v				
Precision interference fit	7H	8H		7p	8s			
Rough transition fit			9H	9p				
Precision transition fit	7H	8H		7m	8n			
Rough clearance fit			9H	9g	9e	9d	10c	11a
Precision clearance fit	7H	8H		7h	7g	8f		

10.12 Quality assurance

Quality assurance is described in DIN 5480-15. Compliance with the effective tolerance limit is to be checked using a composite GO gauge. Actual tolerance limits shall be checked with the aid of the auxiliary dimensions over and between measuring circles (using measuring balls or pins), or alternatively using sector NO GO gauges. The method of calculating the inspection dimensions over and between measuring circles from the dimensions of the space widths and the tooth thicknesses is described in DIN 5480-15, 5.2.4.3. As an alternative, this can also be done using the deviation factors as described in DIN 5480-2.

Deviation of the measurements between/over measuring circles:

$$A_{M2} = A_e \times A^*_{M2} \tag{3}$$

$$A_{M1} = A_s \times A^*_{M1} \tag{4}$$

Bibliography

DIN 3961, *Tolerances for cylindrical gear teeth — Principles*

DIN 3977:1981-02, *Measuring element diameters for the radial or diametral dimension for testing tooth thickness of cylindrical gears*

DIN ISO 6413:1990-03, *Technical drawings — Representation of splines and serrations (ISO 6413:1988)*

ISO 54:1996, *Cylindrical gears for general engineering and for heavy engineering — Modules*

ISO 4156 series, *Straight cylindrical involute splines — Metric module, side fit*