INTERNATIONAL STANDARD

ISO 18669-1

Second edition
2013-07-15

Internal combustion engines — Piston pins —

Part 1:
General specifications

Moteurs à combustion interne — Axes de pistons —

Partie 1: Spécifications générales

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 22, *Road vehicles*.

This second edition cancels and replaces the first edition (ISO 18669-1:2004), which has been technically revised.

ISO 18669 consists of the following parts, under the general title *Internal combustion engines — Piston pins*:

— *Part 1: General specifications*

— *Part 2: Inspection measuring principles*

Internal combustion engines — Piston pins —

Part 1:
General specifications

1 Scope

This part of ISO 18669 specifies the essential dimensional characteristics of piston pins with an outer diameter between 8 mm and 100 mm, for reciprocating internal combustion engines for road vehicles and other applications. In addition, it establishes a vocabulary, a pin-type classification, material description based on mechanical properties, common features and quality requirements.

The use of this part of ISO 18669 may require a manufacturer and customer statistical process control agreement.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1 General

2.1.1
piston pin
precision cylindrical component that connects the piston to the connecting rod and has a smooth hard peripheral surface

2.2 Geometrical and manufacturing features of piston pins

2.2.1 Bore types

2.2.1.1
cylindrical
pin having a straight cylindrical bore

2.2.1.2
centre web
pin inside diameter formed symmetrically from each end leaving a web in the pin centre

Note 1 to entry: The web is subsequently removed leaving a step as shown in Figure 3.

2.2.1.3
tapered
pin with conical-shaped inside diameter near the ends that reduces the weight of the piston pin

2.2.1.4
machined
pin with inside diameter produced solely by machining

2.2.1.5
seamless drawn tube
hollow steel product which does not contain any line junctures resulting from the method of manufacture

2.2.1.6
end web
pin inner diameter formed from one end leaving a web near the opposite end

Note 1 to entry: The web is punched out. The pin is then drawn over a mandrel and a forming line may result as shown in Figure 4.

2.2.2 Outside-edge configurations

2.2.2.1
chamfer
outside-edge bevelled feature that is sometimes used to mate with a round retainer ring

Note 1 to entry: Referred to as “locking chamfer” when a round wire retainer ring is located on the chamfer angle and used to secure the pin in the piston.

2.2.2.2
form angle δ
region of outside-edge form that provides a smooth transition to the peripheral surface to facilitate ease of assembly

2.2.2.3
form angle γ
region of outside-edge form that provides a smooth transition to the end face

2.2.2.4
drop-off
non-functional machining feature that creates a transition between the outside edge and the peripheral surface

Note 1 to entry: See Figure 12.

2.2.2.5
inside-edge chamfer
bevelled edge between the bore surface and the end faces of the piston pin

2.2.2.6
gauge point
locating point on the pin outside-edge chamfer from where the gauge diameter (d_5) and gauge length (l_5) are measured

2.2.3 Other features

2.2.3.1
volume change
change detected as a permanent outside-diameter dimensional deviation at reference temperature after being heated to a test temperature for a specified period of time

2.2.3.2
slag lines
linear flaws of non-metallic inclusions

3 Symbols

For the purposes of this part of ISO 18669, the symbols in Table 1 apply.

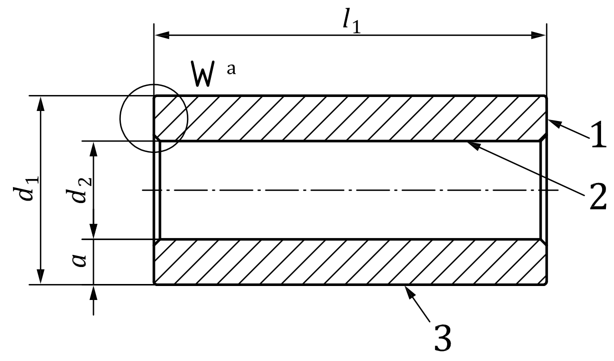
Table 1 — Symbols

Symbol abbreviation	Description
a	Wall thickness
b	Outside-edge drop-off length
c	Outside-edge drop-off height
d_1	Outside diameter
d_2	Inside diameter
d_3	Tapered bore diameter
d_4	Centre-web diameter
d_5	Gauge diameter
d_6	End face diameter
e	Tapered bore runout
f	Outside-edge length
g	Outside-edge chamfer length
H_s	Limit hardness
h_1	End face concavity
h_2	End face step
k	Tapered bore relief
l_1	Length
l_3	Tapered bore length
l_4	Centre-web length
l_5	Gauge length
r	Outside-edge radius
R_m	Core strength
s	End face runout
t_1	Inside-edge chamfer length
t_2	Outside-edge form length
α	Tapered bore angle
β	Outside-edge chamfer angle
γ	Outside-edge form angle end face
δ	Outside-edge form angle

4 Nomenclature

4.1 Outside, inside and end features

Terms commonly used to describe pins with a cylindrical bore are shown in Figure 1.



Key

1 end face

2 bore surface

3 peripheral surface

d_1 outside diameter

d_2 inside diameter

l_1 length

a wall tickness

a See Figure 2.

Figure 1 — Pin with cylindrical bore

Terms commonly used to describe end face concavity are shown in Figure 2a).

Terms commonly used to describe end face step are shown in Figure 2b).

a) End face concavity **b) End face step**

Key

h_1 end face concavity

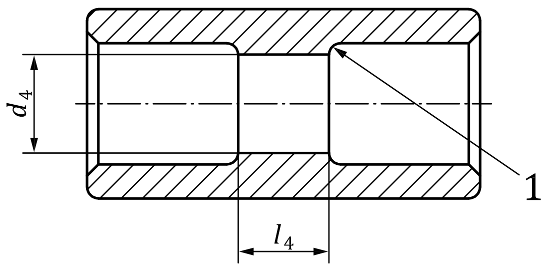
h_2 end face step

d_6 end face diameter

NOTE End face concavity and end face step not recommended for end face locking.

Figure 2 — Detail W of Figure 1

Terms commonly used to describe pins with a centre web are shown in Figure 3.



Key

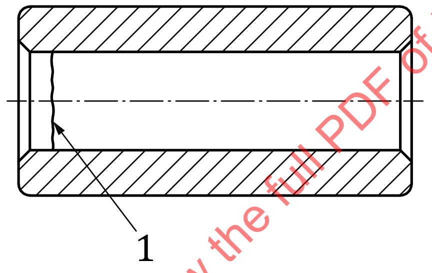
1 centre-web radius

l_4 centre-web length

d_4 centre-web diameter

Figure 3 — Pin with cold-formed centre web

Terms commonly used to describe pins with a cold-formed end-web are shown in Figure 4.

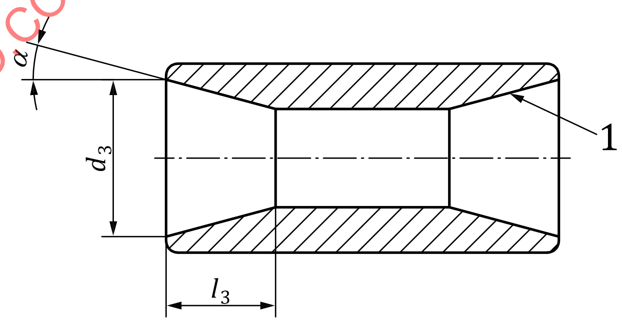


Key

1 end-web forming line

Figure 4 — Pin with cold-formed end web

Terms commonly used to describe pins with a tapered bore are shown in Figure 5.



Key

1 tapered bore surface

α tapered bore angle

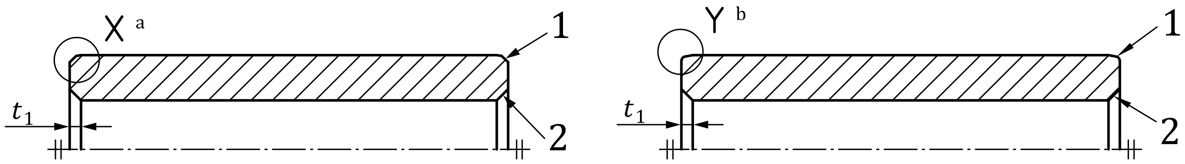
d_3 tapered bore diameter

l_3 tapered bore length

Figure 5 — Pin with tapered bore

4.2 Outside edge and inside chamfer configurations

Terms commonly used to describe the outside edge and inside chamfer configurations are shown in Figure 6.



Key

1 outside-edge chamfer or radius

2 inside-edge chamfer

t_1 inside-edge chamfer length

a See Figures 7 and 8.

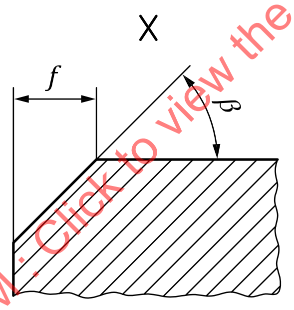
b See Figure 9.

NOTE This may be used with either a round or rectangular retainer ring.

Figure 6 — Outside-edge configuration (detail X: chamfered; detail Y: radiused)

4.2.1 Chamfered outside-edge configuration

Terms commonly used to describe the chamfered outside-edge configuration are shown in Figure 7.



Key

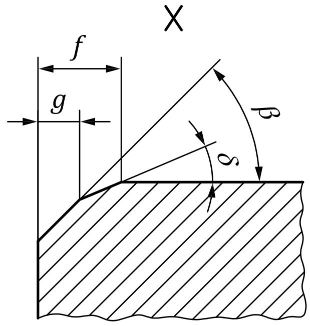
f outside-edge length

β outside-edge chamfer angle

Figure 7 — Chamfered configuration (detail X of Figure 6)

4.2.2 Double-chamfered outside-edge configuration

Terms commonly used to describe double-chamfered outside-edge configurations are shown in Figure 8. The double chamfer is for assembly improvements of the piston pin.



Key

f outside-edge length

g outside-edge chamfer length

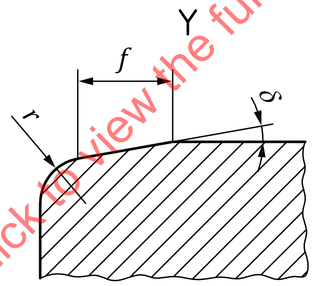
δ outside-edge form angle

β outside-edge chamfer angle

Figure 8 — Double-chamfered configuration (detail X of Figure 6)

4.2.3 Radiused outside-edge configuration

Terms commonly used to describe radiused outside-edge configurations are shown in Figure 9.



Key

r outside-edge radius

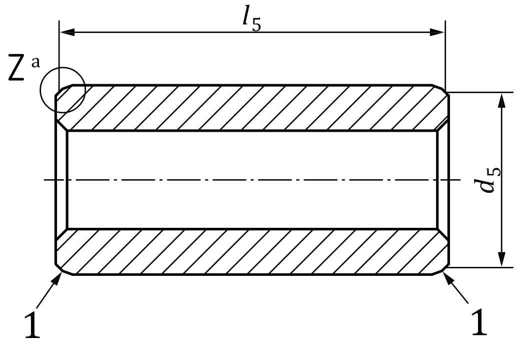
f outside-edge length

δ outside-edge form angle

Figure 9 — Radiused configuration (detail Y of Figure 6)

4.2.4 Chamfer-locking outside-edge configuration

Terms commonly used to describe chamfer-locking outside-edge configurations are shown in Figures 10 and 11.



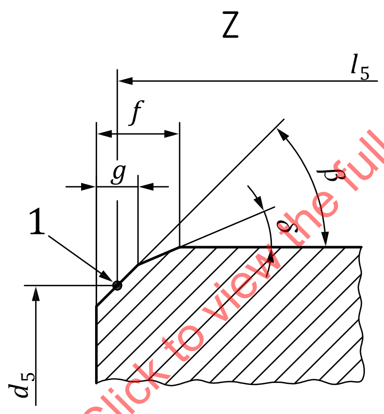
Key

1 gauge points

l_5 gauge length

d_5 gauge diameter

Figure 10 — Chamfer-locking outside-edge for round retainer ring



Key

1 gauge point

g outside-edge chamfer length

f outside-edge length

l_5 gauge length

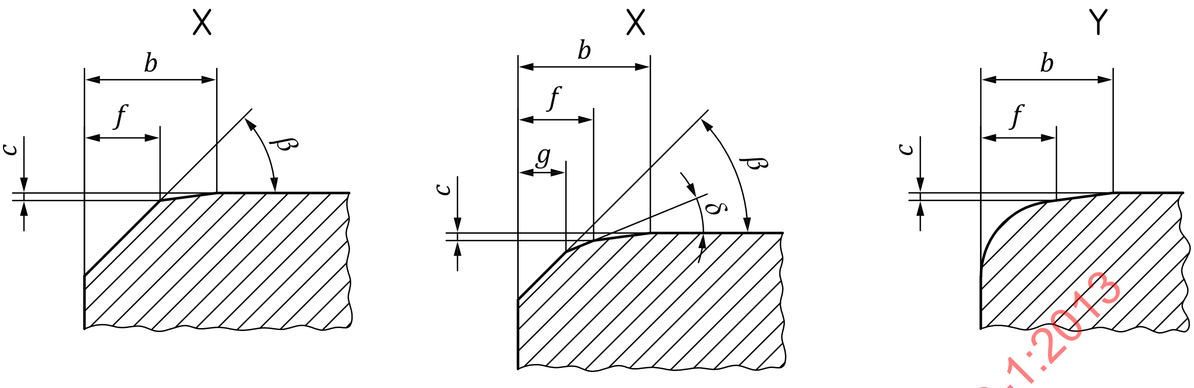
d_5 gauge diameter

Figure 11 — Detail Z of Figure 10

4.3 Outside-edge drop-off configuration

Terms commonly used to describe outside-edge drop-off configurations are shown in Figure 12a), 12b) and 12c).

The outside-edge drop-off is for manufacturing purposes and is therefore a chamfer that is very small in height but long in length.



a) Chamfered edge and drop-off **b) Double-chamfered edge and drop-off** **c) Radiused edge and drop-off**

Key

b outside-edge drop-off length

c outside-edge drop-off height

g outside-edge chamfer length

f outside-edge length

δ outside-edge form angle

β outside-edge chamfer angle

Figure 12 — Drop-off configurations (detail X and Y of Figure 6)

5 Codes

Codes used for piston pins shall be as given in Table 2 with their explanatory descriptions.

Table 2 — Codes and descriptions

Code	Description	Relevant sub-clause of this part of ISO 18669
P1...P6	Pin-type classification according to manufacturing method of the pin centre hole	7.1
X	Piston pins in combination with needle bearing	8.3
F1, F2, F3	Outside-edge configuration tolerance class	7.2.4
K	Carburising steel class K	8.1 / 8.2
S	Carburising steel class S	8.1 / 8.2
L	Carburising steel class L	8.1 / 8.2
M	Carburising steel class M	8.1 / 8.2
N	Nitriding steel class N	8.1 / 8.2
V	Piston pins with limited volume change	8.3 / 8.4 / 8.5
H1, H2	Surface hardness class	8.4
R1, R2	Peripheral surface roughness class	9.1.1
G	Chamfer-locking outside-edge configuration (gauge point)	6.2 / 7.2.4
R	Outside-edge radiused	7.2.4 / 6.1.2
C1	Outside-edge chamfered	7.2.4
C2	Outside-edge double chamfered	7.2.4
LA, LB	Length tolerance class	7.2.3
MM	Manufacturer's mark	9.2
TC	Piston pins with bore surface cold formed	7.2.6

6 Designation of piston pins

6.1 Designation elements and order

To designate piston pins, the following details shall be given, in the order shown below. The codes given in Table 2 shall be used.

6.1.1 Mandatory elements

The following mandatory elements shall constitute the designation of a piston pin:

— designation, i.e. piston pin;

— number of International Standard: ISO 18669;

— type of piston pin, e.g. P1;

— hyphen;

— size of piston pin, $d_1 \times d_2 \times l_1$ or d_1 / $d_3 - \alpha \times d_2 \times l_1$ for a pin with tapered bore;

— hyphen;

— material code, e.g. L.

6.1.2 Additional elements

The following optional elements may be added to the designation of a piston pin; in this case they shall be separated from the mandatory elements by a slash (/):

— code for outside-edge configuration, e.g. R, C1, C2, G;

— size of chamfer-locking gauge dimensions, $d_5 \times l_5 \times \beta$ when code G is specified;

— code for limited volume change, V;

— code for surface hardness, H1, H2;

— code for surface roughness, R1, R2.

6.2 Designation examples

The following are examples of piston pin designation in accordance with this part of ISO 18669.

EXAMPLE 1 Designation of a piston pin complying with the requirements of ISO 18669-1, manufacturing type P5 (P5) of outside diameter d_1 = 20 mm (20), inside diameter d_2 = 11 mm (11) and length l_1 = 50 mm (50) made of carburising steel, class L (L) with double chamfered outside-edge configuration (C2), selected chamfer-locking outside-edge configuration (G) of gauge diameter d_5 = 18,9 mm (18,9), gauge length l_5 = 49 mm (49) and outside-edge chamfer angle β = 45° (45), limited volume change (V), class 2 surface hardness (H2) and class 1 roughness on peripheral surface (R1). Parameters in parenthesis are used in the ISO piston pin designation:

Piston pin ISO 18669-P5, 20 × 11 × 50-L / C2 G-18,9 × 49 × 45 V H2 R1

EXAMPLE 2 Designation of a piston pin complying with the requirements of ISO 18669-1, manufacturing type P2 (P2) of outside diameter d_1 = 22 mm (22), tapered bore diameter d_3 = 18 mm (18), tapered bore angle α = 20º (20), inside diameter d_2 = 12 mm (12) and length l_1 = 60 mm (60) made of nitriding steel, class (N). Parameters in parenthesis are used in the ISO piston pin designation:

Piston pin ISO 18669-P2, 22/18-20 × 12 × 60-N

7 Piston pin types, dimensions and tolerances

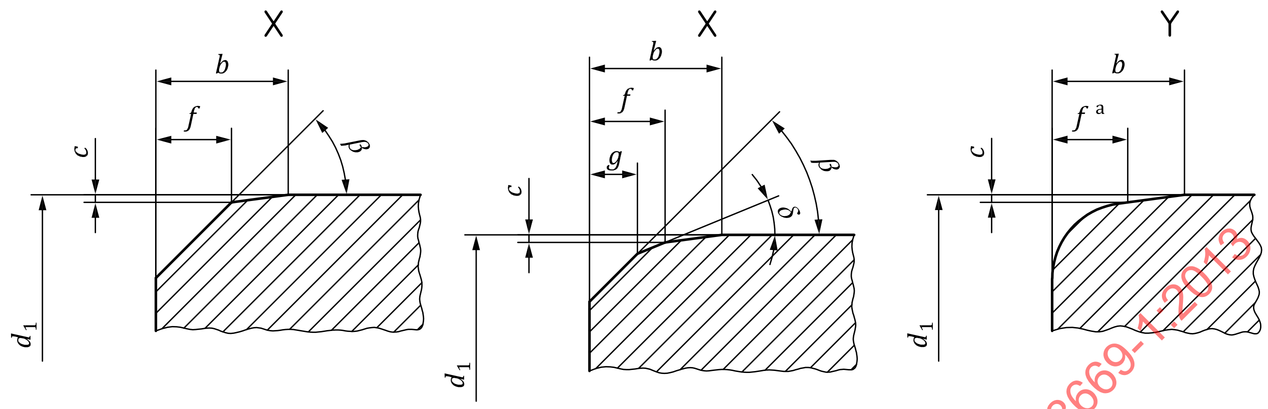
7.1 Manufacturing types

Table 3 — Piston pin manufacturing types

Manufacturing code	Permissible manufacturing methods			
	machined	cold-formed	cold-formed centre web	seamless drawn tube
P1	x	x	x	x
P2	x	x	x	no
P3	no	x	x	no
P4	x	x	no	no
P5	no	x	no	no
P6	x	no	no	no

7.2 Dimensions and tolerances

7.2.1 Outside diameter and form and location tolerances



a) Chamfered edge and drop-off b) Double-chamfered edge and drop-off c) Radiused edge and drop-off

Key

b outside-edge drop-off length
c outside-edge drop-off height
f outside-edge length
g outside-edge chamfer length
δ outside-edge form angle
β outside-edge chamfer angle
[a] See Figure 14.

Figure 13 — Drop-off configurations (detail X and Y of Figure 6)

Table 4 shows the outside diameter tolerances and the permissible cylindricity, circularity and edge drop-off.

Table 4 — Outside diameter (d_1) and form and location tolerances

Dimensions in millimetres

Outside diameter		Cylindricity	Circularity	Edge drop-off	
d_1	tolerance	max.	max.	b max.	c max.
8 to ≤ 16	0 to − 0,004	0,0015	0,001	0,12 × d_1	0,001
> 16 to ≤ 30	0 to − 0,005	0,002	0,0015		
> 30 to ≤ 60	0 to − 0,006	0,0025	0,002		
> 60 to ≤ 100	0 to − 0,008	0,003	0,0025	0,08 × d_1	0,0015

7.2.2 Inside diameter tolerance

The tolerances of inside diameter (d_2) and concentricity (permissible wall difference) are shown in Table 5.

Table 5 — Inside diameter tolerance and concentricity at wall thickness (a)

Dimensions in millimetres

Inside diameter		Concentricity		
d_2	tolerance	$a \le 3$ max.	$3 < a \le 5$ max.	$a > 5$ max.
≤ 30	+ 0,1 / − 0,2	0,3	0,4	0,5 / 0,6 [a]
> 30	+ 0,2 / − 0,4	—		

[a] Only when piston pins are manufactured from seamless tube.

7.2.3 Length (l_1) and gauge length (l_5) tolerances

Table 6 shows the length tolerances and the permissible runout for end face.

Table 6 — Length tolerances and runout end face

Dimensions in millimetres

Outside diameter d_1	Length l_1 tolerance		Gauge length l_5 tolerance	End face runout s [b] max.	
	class 1 code: LA	class 2 [a] code: LB		class 1 code: LA	class 2 [a] code: LB
8 to ≤ 16	0 to − 0,25	0 to − 0,45	± 0,125	0,12	0,20
> 16 to ≤ 35	0 to − 0,3	0 to − 0,5	± 0,15	0,15	0,25
> 35 to ≤ 60	0 to − 0,4	0 to − 0,6	± 0,2	0,15	0,40
> 60 to ≤ 100	0 to − 0,5	–	± 0,25	0,25	-

[a] Not recommended for end face locking.

[b] Reference: ISO 18669-2:2004, Figure 7.

The end face concavity and end face step are shown in Table 7.

Table 7 — End face concavity and end face step for code LB pins

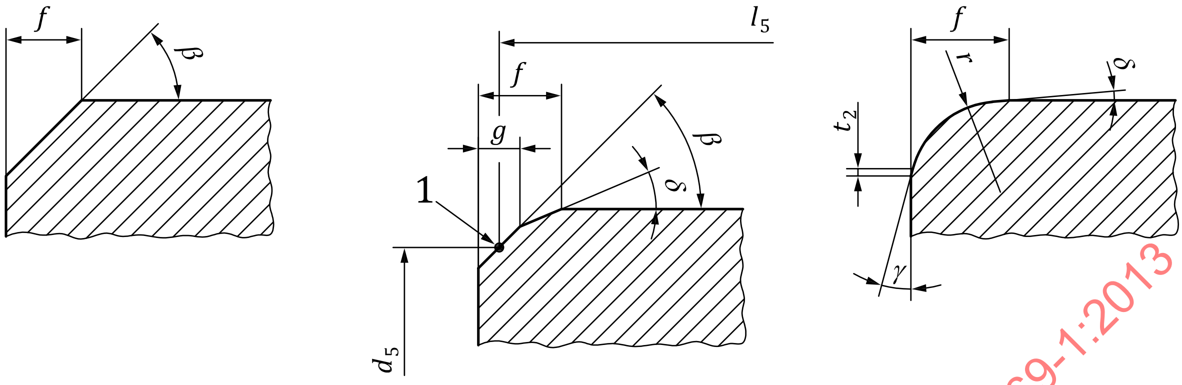
Dimensions in millimetres

Outside diameter d_1	End face concavity h_1 max. [a]	End face step h_2 max. [a]	Diameter for h_1 and h_2 determination d_6 max.
8 to ≤ 16	0,7	0,3	d_1 − 1,8
> 16 to ≤ 25	0,8		d_1 − 2,0
> 25 to ≤ 32	0,9	0,4	d_1 − 2,2
> 32 to ≤ 60	1,0		d_1 − 2.4

[a] Not recommended for end face locking

7.2.4 Outside-edge form

The outside-edge configuration is shown in Figure 14.



a) Chamfered
Code: C1

b) Double-chamfered
Code: C2

c) Radiused
Code: R

Key

1 gauge point

t_2 Outside-edge form length

γ outside-edge form angle end face

δ outside-edge form angle

NOTE Chamfer-locking outside-edge configurations (gauge point, code: G) are possible with a chamfered or double-chamfered outside edge. The values for the gauge point l_5 and d_5 and for the angles β and δ shall be given in the designation of the piston pins.

Figure 14 — Outside-edge configuration

The radiused outside-edge dimensions are given in Table 8.

Table 8 — Radiused outside-edge dimensions

Dimensions in millimetres

Outside diameter, d_1	Outside-edge form angle		Outside-edge form length	class 1 [a] code: F1		class 2 code: F2		class 3 code: F3	
	δ	γ	t_2	r	f	r	f	r	f **max.**
8 to ≤ 16				0,15 to 0,3	0,15 to 0,3	0,15 to 0,3	0,15 to 0,6	0,9 to 1,4	2,2
> 16 to ≤ 25				0,2 to 0,5	0,2 to 0,5	0,2 to 0,5	0,2 to 0,8	1,2 to 1,7	2,5
> 25 to ≤ 32	20° max.	30° max.	1 max.	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,9	1,5 to 2,0	2,8
> 32 to ≤ 60				0,4 to 0,8	0,4 to 0,8	0,4 to 0,8	0,4 to 1,1	-	-
> 60 to ≤ 100				0,5 to 1,0	0,5 to 1,0	0,5 to 1,0	0,5 to 1,3	-	-

[a] See subclause 1.2.

The chamfered outside-edge dimensions are given in Table 9.

Table 9 — Chamfered outside-edge dimensions

Dimensions in millimetres

Outside diameter d_1	Chamfered C1			Double chamfered C2	
	f class 1 [b] code: F1	f class 2 [c] code: F2	f class 3 code: F3	g [a]	f [a]
8 to ≤ 16	0,15 to 0,3	0,15 to 0,6	0,35 to 1,05	0,35 to 1,05	1,25 to 2,15
> 16 to ≤ 25	0,2 to 0,5	0,2 to 0,8			
> 25 to ≤ 32	0,3 to 0,6	0,3 to 0,9	0,5 to 1,2	0,5 to 1,2	1,25 to 2,4
> 32 to ≤ 60	0,4 to 0,8	0,4 to 1,1			
> 60 to ≤ 100	0,5 to 1,0	0,5 to 1,3	0,8 to 1,5	0,8 to 1,5	—

[a] $g \leq f - 0{,}25$.

[b] See subclause 1.2.

[c] Tolerance may be reduced for large β angle.

7.2.5 Inside-edge profile

The inside chamfer configuration is shown in Figure 15.

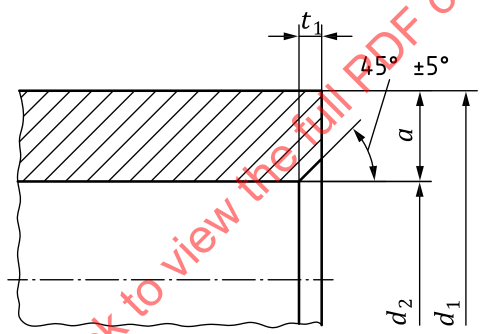


Figure 15 — Inside chamfer configuration

The inside chamfer dimensions are given in Table 10.

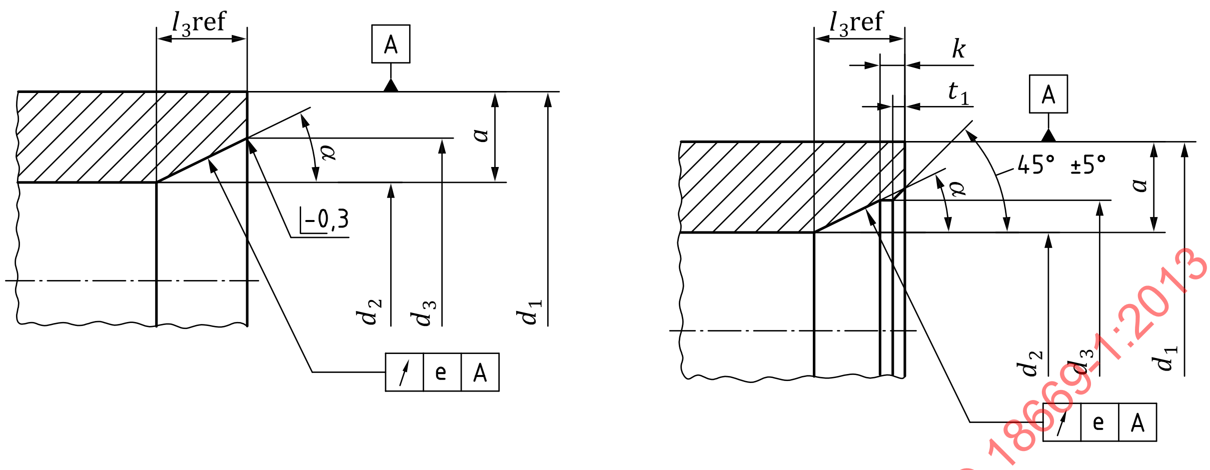
Table 10 — Inside chamfer dimensions

Dimensions in millimetres

Wall thickness a	Inside-edge chamfer length t_1
1,5 to ≤ 3	0,1 to 0,5
> 3 to ≤ 5	0,3 to 0,8
> 5 to ≤ 8	0,3 to 1,3
> 8 to ≤ 12	0,5 to 2
> 12	1 to 3

7.2.6 Tapered bore dimensions

Figure 16 shows the tapered bore configurations.



a) Taper bore without relief

b) Taper bore with relief

Figure 16 — Tapered bore configurations

Table 11 gives the tolerances on tapered bore angle and diameter.

Table 11 — Tolerances on tapered bore angle (α) and diameter (d_3)

Dimensions in millimetres

Tapered bore angle α			Tolerance d_3	
α degrees	Tolerance			
	class 1	class 2 code: TC	class 1	class 2 code: TC
< 8	± 15′	± 1°	± 0,10	± 0,20
≥ 8 to < 25	± 30′		± 0,15	± 0,25
≥ 25 to < 45	± 1°	± 2°	± 0,25	± 0,30
≥ 45 to ≤ 60			± 0,30	± 0,35

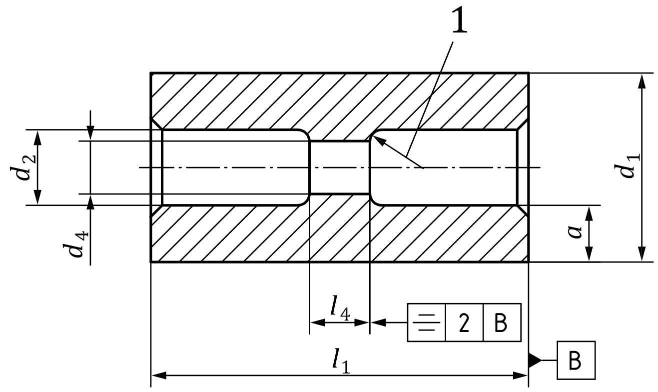
Table 12 gives the tapered bore runout tolerance (e) and the tapered bore relief (k).

Table 12 — Tapered bore runout tolerance (e) and the tapered bore relief (k)

Dimensions in millimetres

Outside diameter d_1	Runout e max.		Tapered bore relief k max.
	class 1	class 2 code: TC	
8 to ≤ 16	0,2	0,3	1,5
> 16 to ≤ 25	0,3	0,4	1,7
> 25 to ≤ 32	0,4	0,5	2,0
> 32 to ≤ 100	0,5	0,6	2,5

7.2.7 Centre-web dimensions (see Figure 17)



Key

1 radiused

Figure 17 — Centre-web dimensions

7.2.7.1 Centre-web length (l_4)

Centre-web length (l_4) can be determined using the formula:

$$l_4 = 1{,}3 \times a + 2{,}5 \text{ mm}$$

The common tolerance for the centre-web length (l_4) is ± 1 mm.

7.2.7.2 Centre-web diameter (d_4)

Centre-web diameter (d_4) can be determined using the formula:

$$d_4 = 0{,}94 \times d_2 - 0{,}7 \text{ mm}$$

The common tolerance for the centre-web diameter (d_4) is ± 0,5 mm.

8 Material and heat treatment

8.1 Type of material

See Table 13. Materials from different regions shown below are examples. Other materials can be used as well as long as they fit into the specifications of the classes.

Table 13 — Chemical composition, mechanical and physical properties

Feature	**Material**				
Chemical composition (% by weight)	**Class K carburising steel** **code: K**	**Class S carburising steel** **code: S**	**Class L carburising steel** **code: L**	**Class M carburising steel** **code: M**	**Class N nitriding steel** **code: N**
C	0,13 to 0,20	0,13 to 0,25	0,12 to 0,24	0,14 to 0,19	0,26 to 0,34
Si	—	0,15 to 0,35	≤ 0,40	≤ 0,40	0,15 to 0,35
Mn	0,60 to 1,00	0,60 to 0,95	0,50 to 0,90	1,00 to 1,30	0,40 to 0,70
P	≤ 0,040	≤ 0,035	≤ 0,035	≤ 0,035	≤ 0,025
S	≤ 0,050	≤ 0,040	≤ 0,040	≤ 0,035	≤ 0,025
Cr	—	0,35 to 0,65	0,70 to 1,25	0,80 to 1,10	2,3 to 2,7
Mo	—	0,15 to 0,30	—	—	0,15 to 0,25
V	—	—	—	—	0,10 to 0,20
Ni	—	0,35 to 0,75	—	—	—
Modulus of Elasticity MPa or N/mm^2	195 000	206 000	210 000	210 000	210 000
Examples	SAE 1016[d]	SAE 8620[e] SNCM 220H[a]	SAE 5120[e] 17Cr3[b] SCr 415H[a] 20Cr[f]	16MnCr5[b] 16CrMnH[g]	31CrMoV9[c]
NOTE Only for calculation: specific gravity 7,8 g/cm^3.					

[a] Material designation as specified in JIS G 4052 (see Bibliography).
[b] Material designation as specified in EN 10084 (see Bibliography).
[c] Material designation as specified in EN 10085 (see Bibliography).
[d] Material designation as specified in SAE J403 (see Bibliography).
[e] Material designation as specified in SAE J404 (see Bibliography).
[f] Material designation as specified in GB/T 3077 (see Bibliography).
[g] Material designation as specified in GB/T 5216 (see Bibliography).

8.2 Core hardness / core strength

See Table 14.

Table 14 — Core hardness

<table>
<tr><th rowspan="2">Wall thickness
a
mm</th><th colspan="5">Core hardness Vickers HV 30
(Core strength, N/mm²) [a]</th></tr>
<tr><th>Class K</th><th>Class S</th><th>Class L</th><th>Class M</th><th>Class N</th></tr>
<tr><td>1,5 to ≤ 2</td><td rowspan="4">240 to 450
(780 to 1450)</td><td>—</td><td>310 to 515
(1000 to 1650)</td><td rowspan="2">310 to 470
(1000 to 1500)</td><td rowspan="6">310 to 470
(1000 to 1500)</td></tr>
<tr><td>> 2 to ≤ 5</td><td rowspan="2">270 to 485
(870 to 1575)</td><td>280 to 485
(900 to 1575)</td></tr>
<tr><td>> 5 to ≤ 10</td><td>270 to 470
(850 to 1500)</td><td rowspan="3">280 to 470
(900 to 1500)</td></tr>
<tr><td>> 10 to ≤ 15</td><td rowspan="3">240 to 450
(780 to 1450)</td><td>250 to 470
(800 to 1500)</td></tr>
<tr><td>> 15 to ≤ 25</td><td rowspan="2">—</td><td rowspan="2">235 to 470
(750 to 1500)</td></tr>
<tr><td>> 25</td><td>250 to 435
(800 to 1400)</td></tr>
<tr><td colspan="6">[a] Core strength values R_m are given for reference only and are determined from the core hardness HV by conversion with factor 3,2.</td></tr>
</table>

8.3 Carburised and nitrided case depth

See Table 15.

Table 15 — Case depth

Dimensions in millimetres

<table>
<tr><th rowspan="3">Wall thick-
ness, *a*</th><th colspan="5">Carburised depth</th><th colspan="2">Nitrided depth</th></tr>
<tr><th colspan="2">outside</th><th rowspan="2">inside min.</th><th colspan="2">outside and inside together</th><th rowspan="2">outside min.</th><th rowspan="2">inside min.</th></tr>
<tr><th>min.</th><th>code: X min.</th><th>max.</th><th>code: X max.</th></tr>
<tr><td>1,5 to < 2</td><td>—</td><td>0,4</td><td rowspan="2">0,1</td><td rowspan="2">0,65 × *a*</td><td rowspan="2">0,80 × *a*</td><td rowspan="5">0,3</td><td rowspan="5">0,2</td></tr>
<tr><td>≥ 2 to ≤ 3</td><td>0,3</td><td>0,5</td></tr>
<tr><td>> 3 to ≤ 5</td><td>0,4</td><td>0,6</td><td>0,2</td><td>0,50 × *a*</td><td>0,65 × *a*</td></tr>
<tr><td>> 5 to ≤ 15</td><td>0,6</td><td>—</td><td>0,4</td><td>0,35 × *a*</td><td>—</td></tr>
<tr><td>> 15</td><td>0,8</td><td>—</td><td>0,6</td><td>0,35 × *a*</td><td>—</td></tr>
<tr><td colspan="8">NOTE 1 For determination of the case depth, the limit hardness H_s is 550 HV.
NOTE 2 For piston pins with limited volume change code V, the limit hardness H_s is 500 HV.</td></tr>
</table>

8.4 Surface hardness

See Table 16.

Table 16 — Surface hardness

Hardness-measuring method	Surface hardness				
	carburised steel				nitrided steel
	non-limited volume change		limited volume change code: V		
	class 1 [c] code: H1	class 2 code: H2	class 1 [c] code: H1	class 2 code: H2	
Vickers HV 10	675 min.	654 min.	635 min.	615 min.	690 min.
Rockwell HRC [a]	59 min.	58 min.	57 min.	56 min.	—
Rockwell HRA [b]	80,7 min.	80 min.	79,6 min.	79 min.	—

[a] Case depth min. 0,9 mm.

[b] Case depth 0,4 mm - 0,9 mm.

[c] See subclause 1.2.

8.5 Volume change

See Table 17.

Table 17 — Outside diameter change Δd_1 after thermal stability test

Dimensions in millimetres

Test conditions	Outside diameter, d_1	Max.increase Δd_1 [a]		
		carburised steel		nitrided steel
		non-limited volume change	limited volume change code: V	
after 4 h at 180 °C	≤ 50	+ 0,006	0	0
	> 50 to ≤ 60	+ 0,008	0	
	> 60 to ≤ 100	+ 0,012	0	
after 4 h at 220 °C	≤ 50	—	+ 0,006	
	> 50 to ≤ 60	—	+ 0,008	
	> 60 to ≤ 100	—	+ 0,012	

[a] These values exclude gauge uncertainty which allows up to 0,001 per individual Δd_1 reading.

9 Common features

9.1 Roughness of surfaces

9.1.1 Roughness of machined surfaces

See Table 18.