TECHNICAL INFORMATION ON FASTENERS

1. STEEL FASTENERS FOR THE TEMPERATURE RANGE BETWEEN –50 °C AND +150 °C

1.1 Materials for fasteners

The material that is used is of decisive importance for the quality of the fasteners (screws, nuts and fittings). If there are any faults in the material used, the fastener made from it can no longer satisfy the requirements made of it.

The most important standards for screws and nuts are:

- DIN EN ISO 898-1, Mechanical properties of fasteners made of carbon steel and alloy steel, Part 1: Screws
- DIN EN 20898 Part 2 (ISO 898 Part 2), Mechanical properties of fasteners, Part 2: Nuts

These standards stipulate the material that is to be used, the marking, the properties of the finished parts and their tests and test methods.

Different materials are used for the different strength classes which are listed in the following table 1.

Strength class	Material and heat treatment	Chemical composition (molten mass analysis %)[a]					Tempering temperature
		C		P	S	B[b]	°C
		min.	max.	max.	max.	max.	min.
4.6[c, d]	Carbon steel or carbon steel with additives	–	0.55	0.050	0.060	not stipulated	–
4.8[d]							
5.6[c]		0.13	0.55	0.050	0.060		
5.8[d]		–	0.55	0.050	0.060		
6.8[d]		0.15	0.55	0.050	0.060		
8.8[f]	Carbon steel with additives (e.g. B or Mn or Cr), hardened and tempered or	0.15[e]	0.40	0.025	0.025	0.003	425
	Carbon steel, hardened and tempered or	0.25	0.55	0.025	0.025		
	Alloy steel, hardened and tempered[g]	0.20	0.55	0.025	0.025		
9.8[f]	Carbon steel with additives (e.g. B or Mn or Cr), hardened and tempered or	0.15[e]	0.40	0.025	0.025	0.003	425
	Carbon steel, hardened and tempered or	0.25	0.55	0.025	0.025		
	Alloy steel, hardened and tempered[g]	0.20	0.55	0.025	0.025		
10.9[f]	Carbon steel with additives (e.g. B or Mn or Cr), hardened and tempered or	0.20[e]	0.55	0.025	0.025	0.003	425
	Carbon steel, hardened and tempered or	0.25	0.55	0.025	0.025		
	Alloy steel, hardened and tempered[g]	0.20	0.55	0.025	0.025		

Strength class	Material and heat treatment	Chemical composition (molten mass analysis %)[a]					Tempering temperature
		C		P	S	B[b]	°C
		min.	max.	max.	max.	max.	min.
12.9[f, h, i]	Alloy steel, hardened and tempered[g]	0.30	0.50	0.025	0.025	0.003	425
<u>12.9</u>[f, h, i]	Carbon steel with additives (e.g. B or Mn or Cr or molybdenum), hardened and tempered	0.28	0.50	0.025	0.025	0.003	380

[a] In case of arbitration, the product analysis applies.
[b] The boron content may reach 0.005%, provided that the non-effective boron is controlled by additions of titanium and/or aluminium.
[c] In case of cold-formed screws in strength classes 4.6 and 5.6 heat treatment of the wire used for cold forming or the cold formed screw may be necessary to achieve the required ductility.
[d] Free-cutting steel with the following max. sulphur, phosphorous and lead shares is permissible for these strength classes: sulphur 0.34%; phosphorous 0.11%; lead 0.35%.
[e] A manganese content of not less than 0.6% for strength class 8.8 and 0.7% for strength classes 9.8 and 10.9 must be present in simple carbon steel with boron as an additive and a carbon content under 0.25% (molten mass analysis).
[f] Materials in these strength classes must be sufficiently hardenable to ensure that there is a martensite share of roughly 90% in the hardened state before tempering in the microstructure of the core in the threaded part.
[g] Alloy steel must contain at least one of the following alloying components in the given minimum amount: chromium 0.30%, nickel 0.30%, molybdenum 0.20%, vanadium 0.10%. If two, three or four elements are ascertained in combinations and have smaller alloy shares than those given above, the threshold value to be applied for the classification is 70% of the sum of the individual threshold values given above for the two, three or four elements concerned.
[h] In case of strength class 12.9/12.9 a metallographically detectable white layer enriched with phosphorous is not permissible. This must be verified with a suitable test procedure.
[i] Caution is necessary when strength class 12.9/12.9 is used. The suitability of the screw manufacturer, the assembly and the operating conditions must be taken into account. Special environmental conditions may lead to stress corrosion cracking of both uncoated and coated screws.

1.2 Mechanical properties of steel screws

This chapter provides a brief overview of the methods used to stipulate and determine the mechanical properties of screws. In this context, the most common parameters and rated quantities will be discussed.

1.2.1 Tensile test

The tensile test is used to determine important parameters for screws such as tensile strength R_m, yield point R_e, 0.2% offset yield point $R_{p0.2}$, and elongation at fracture A5 (%).

A difference is made between "tensile test with turned off specimens" and "tensile test on whole screws" (DIN EN ISO 898 Part 1).

1.2.2 Tensile strength R_m (MPa)

The tensile strength R_m indicates the tensile stress from which the screw may fracture. It results from the maximum force and the corresponding cross-section. With full strength screws the fracture may only occur in the shaft or in the thread, and not in the connection between the head and the shaft.

Tensile strength on fracture in cylindrical shaft (turned off or whole screws):

R_m = maximum tensile force/cross-section area = F/S_o [MPa]

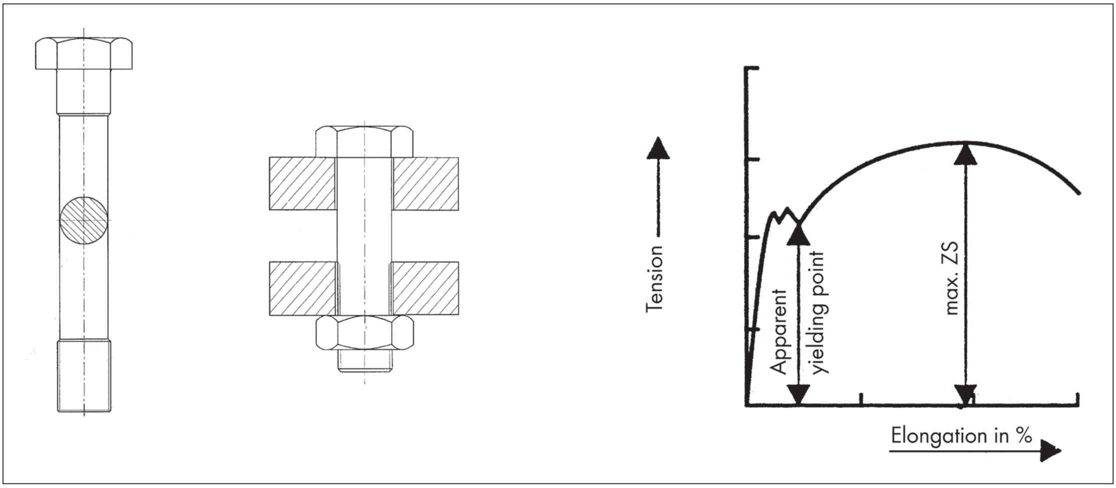
Tensile strength on fracture in thread:

R_m = maximum tensile force/tension cross-section = F/A_s [MPa]

A_s tension cross-section

1.2.3 Apparent yielding point R_e (MPa)

Under DIN EN ISO 898 Part 1 the exact yield point can only be determined on turned off specimens. The yield point is the point to which a material, under tensile load, can be elongated without permanent plastic deformation. It represents the transition from the elastic to the plastic range. Fig. C shows the qualitative curve of a 4.6 screw (ductile steel) in the stress-strain diagram.



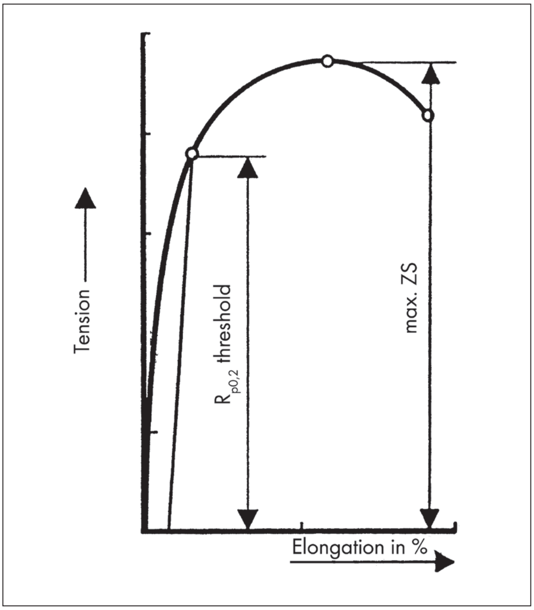
Tensile test on a turned-off screw
Fig. A

Tensile test on a whole screw
Fig. B

Stress-strain diagram of a screw with the strength class 4.6 (qualitative)
Fig. C

1.2.4 0.2% offset yield point $R_{p0.2}$ (MPa)

The offset yield point $R_{p0.2}$ is determined as a so-called substitute yield point, because most hardened and tempered steels do not show a marked transition from the elastic into the plastic range. The 0.2% offset yield point $R_{p0.2}$ represents the tension at which a permanent elongation of 0.2% is achieved. Fig. D shows the qualitative tension curve in the stress-strain diagram for a 10.9 screw.



Stress-strain diagram of a screw with strength class 10.9 (qualitative)

Fig. D

1.2.5 Tensile test on whole screws

Along with the tensile test on turned off specimens, a less complicated test of whole screws is also possible. In this test, the whole screw is clamped into the test device at the head and the thread. Because in this case the ratio of the length and the diameter of the specimen is not always the same, in deviation from the test for the proportional rod, this test can only be used to determine the tensile strength R_m, the extension to fracture A_f and the 0.004 8 d offset yield point R_{pf}.

0.004 8 d offset yield point R_{pf} (MPa) in accordance with chapter 9.3 of ISO 898-1 2009-08.

1.2.6 Strength classes

Screws are designated with strength classes, so that it is very easy to determine the tensile strength R_m and the yield point R_e (or the 0.2% offset yield point $R_{p0.2}$).

Example:

Screw 8.8

1. Determining R_m: the first number is multiplied by 100.
   → R_m = 8 x 100 = 800 Mpa
   The first number indicates 1/100 of the minimum tensile strength in MPa.
2. Determining R_e or $R_{p0.2}$:

the first number is multiplied by the second and the result is multiplied by 10; the result is the yield point R_e or 0.2% offset yield point $R_{p0.2}$. → R_e = (8 x 8) x 10 = 640 MPA.

1.2.7 Elongation at fracture A5 (%)

The elongation at fracture is an important parameter for assessing the ductility of a material and is created on the load to the screw fracturing. This is determined on turned off screws with a defined shaft range (proportional rod) (exception: rust- and acid-resistant screws, steel group A1–A5). The permanent plastic elongation is shown as a percentage and is calculated using the following equation:

$A5 = (L_u - L_o)/L_o \times 100\%$

Lo Defined length before the tensile test $L_o = 5 \times d_o$
L_u Length after fracture
d_o Shaft diameter before the tensile test

Example of a proportional rod

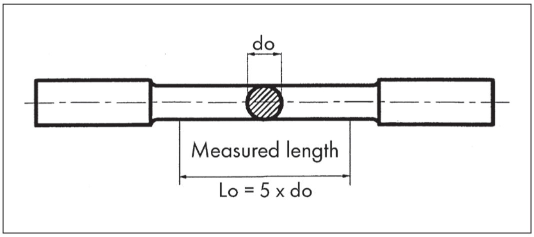


Fig. E

1.2.8 Hardness and hardness test methods

Definition:

Hardness is the resistance that a body uses to counter penetration by another, harder body.

The most important hardness test methods in practice are:

Test method	Vickers hardness HV DIN EN ISO 6507	Brinell hardness HB DIN EN ISO 6506	Rockwell hardness HRC DIN EN ISO 6508
Specimen	Pyramid	Ball	Tube

The test using the Vickers method comprises the complete hardness range for screws.

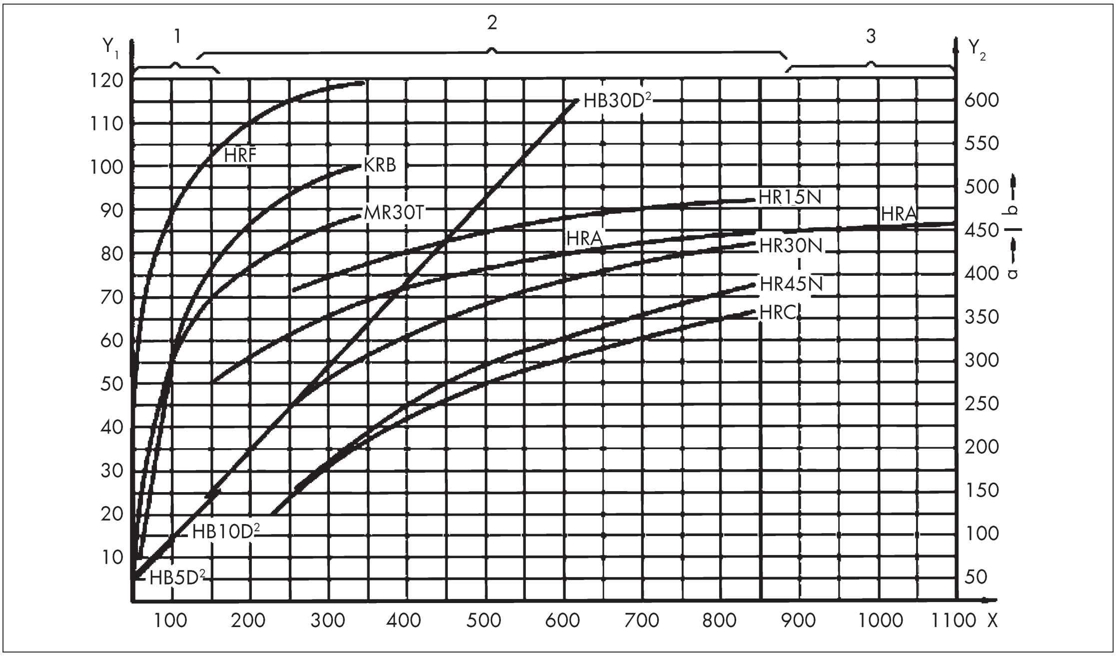
Comparison of hardness data

The following graph F applies for steels and corresponds to the hardness comparison tables in DIN EN ISO 18265. These should be used as a starting point, because an exact comparison of results is only possible with the same method and under the same conditions.

1.3 Strength classes of screws

The mechanical and physical properties of screws and nuts are described with the help of the strength classes. This is done for screws in Table 2 below by means of nine strength classes, in which each of the properties such as tensile strength, hardness, yield point, elongation at fracture, etc., are shown.

Representation of different hardness scales on the Vickers scale



Legend:
X Vickers hardness HV 30
Y_1 Rockwell hardness
Y_2 Brinell hardness

1 Hardness range for non-ferrous metals
2 Hardness range for steels
3 Hardness range for hard metals
a Brinell hardness, determined with steel ball (HBS)
b Brinell hardness, determined with hard metal tube (HBW)

Fig. F: Extract from DIN EN ISO 18265

Mechanical and physical properties of screws

			Strength class									
No.	**Mechanical or physical property**		**4.6**	**4.8**	**5.6**	**5.8**	**6.8**	**8.8**		**9.8**	**10.9**	**12.9/ 12.9**
								d ≤ 16 mm[a]	**d > 16 mm[b]**	**d ≤ 16 mm**		
1	Tensile strength, R_m, MPa	nom.[c]	400		500		600	800		900	1,000	1,200
		min.	400	420	500	520	600	800	830	900	1,040	1,220
2	Lower yield point, R_{eL}[d], MPa	nom.[c]	240	–	300	–	–	–	–	–	–	–
		min.	240	–	300	–	–	–	–	–	–	–
3	0.2% offset yield point $R_{p0.2}$, MPa	nom.[c]	–	–	–	–	–	640	640	720	900	1,080
		min.	–	–	–	–	–	640	660	720	940	1,100
4	0.0004 8 d offset yield point for whole screws R_{pf}, MPa	nom.[c]	–	320	–	400	480	–	–	–	–	–
		min.	–	340[e]	–	420[e]	480[e]	–	–	–	–	–
5	Tension under test force, S_p[f], MPa	nom.	225	310	280	380	440	580	600	650	830	970
	Test resistance ratio $S_{p,nom}/R_{eL\,min}$ or $S_{p,nom}/R_{p0,2}$ min or $S_{p,nom}/R_{pf\,min}$		0.94	0.91	0.93	0.90	0.92	0.91	0.91	0.90	0.88	0.88
6	Percentage elongation at fracture of a turned off specimen, A, %	min.	22	–	20	–	–	12	12	10	9	8
7	Percentage contraction at fracture of a turned off specimen, Z, %	min.	–					52		48	48	44
8	Extension to fracture of a whole screw, A_f (see Annex C as well)	min.	–	0,24	–	0,22	0,20	–	–	–	–	–
9	Head impact strength		No fracture									
10	Vickers hardness, HV F ≥ 98 N	min.	120	130	155	160	190	250	255	290	320	385
		max.	220[g]				250	320	335	360	380	435
11	Brinell hardness, HBW F = 30 D²	min.	114	124	147	152	181	238	242	276	304	366
		max.	209[g]				238	304	318	342	361	414
12	Rockwell hardness, HRB	min.	67	71	79	82	89	–				
		max.	95.0[g]				99,5	–				
	Rockwell hardness, HRC	min.	–					22	23	28	32	39
		max.	–					32	34	37	39	44
13	Surface hardness, HV, 0.3	max.	–					h			h,i	h,j
14	Height of non-decarburised thread zone, E, mm	min.	–					$1/2H_1$			$2/3H_1$	$3/4H_1$
	Depth of complete decarburisation in the thread, G, mm	max.	–					0,015				
15	Loss of hardness following re-tempering (hardening), HV	max.	–					20				
16	Fracture torque, M_B, Nm	min.	–					nach ISO 898-7				
17	Notch impact energy, K_V[k, l], J	min.	–		27	–		27	27	27	27	m
18	Surface condition in accordance with		ISO 6157-1[n]									ISO 6157-3

a Values do not apply to steel construction screws.
b For steel construction screws d ≥ M12.
c Nominal values are stipulated only for the designation system of the strength classes. See Annex 5.
d If the lower yield point R_{eL} cannot be determined, the 0.2% offset yield point $R_{p0.2}$ may be determined.
e The values for Rpf min are examined for strength classes 4.8, 5.8 and 6.8. The current values are shown only for the calculation of the test stress ratio. They are not test values.
f Test forces are stipulated in tables 5 and 7.
g The hardness measured at the end of a screw may not exceed max. 250 HV, 238 HB or 99.5 HRB.
h The surface hardness at the respective screw may not exceed 30 Vickers points of the measured core hardness, if both the surface hardness and the core hardness are determined with HV 0.3.
i An increase of the surface hardness to over 390 HV is not permissible.
j An increase of the surface hardness to over 435 HV is not permissible.
k The values are determined at a test temperature of −20 °C, cf. 9.14.
l Applies for d ≥ 16 mm.
m Values for KV are examined.
n ISO 6157-3 may apply instead of ISO 6157-1 by agreement between the manufacturer and the customer.

Tab. 2: Extract from DIN EN ISO 898-1, mechanical and physical properties of screws

1.3.1 Test forces

In the tensile test the test force shown in tables 3 and 4 is applied axially to the screw and held for 15 s. The test is regarded as successful if the screw length after measuring coincides with the length before the test. A tolerance of ±12.5 µm applies. The following tables are an important help for the user for choosing suitable screws.

ISO metric standard thread

Thread[a d]	Nominal tension cross-section t $A_{s, nom}$[b], mm²	Strength class								
		4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/ 12.9
		Test force, F_p ($A_{s, nom} \times S_p$), N								
M3	5.03	1,130	1,560	1,410	1,910	2,210	2,920	3,270	4,180	4,880
M3.5	6.78	1,530	2,100	1,900	2,580	2,980	3,940	4,410	5,630	6,580
M4	8.78	1,980	2,720	2,460	3,340	3,860	5,100	5,710	7,290	8,520
M5	14.2	3,200	4,400	3,980	5,400	6,250	8,230	9,230	11,800	13,800
M6	20.1	4,520	6,230	5,630	7,640	8,840	11,600	13,100	16,700	19,500
M7	28.9	6,500	8,960	8,090	11,000	12,700	16,800	18,800	24,000	28,000
M8	36.6	8,240[c]	11,400	10,200[c]	13,900	16,100	21,200[c]	23,800	30,400[c]	35,500
M10	58	13,000[c]	18,000	16,200[c]	22,000	25,500	33,700[c]	37,700	48,100[c]	56,300
M12	84.3	19,000	26,100	23,600	32,000	37,100	48,900[d]	54,800	70,000	81,800
M14	115	25,900	35,600	32,200	43,700	50,600	66,700[d]	74,800	95,500	112,000
M16	157	35,300	48,700	44,000	59,700	69,100	91,000[d]	102,000	130,000	152,000
M18	192	43,200	59,500	53,800	73,000	84,500	115,000	–	159,000	186,000
M20	245	55,100	76,000	68,600	93,100	108,000	147,000	–	203,000	238,000
M22	303	68,200	93,900	84,800	115,000	133,000	182,000	–	252,000	294,000
M24	353	79,400	109,000	98,800	134,000	155,000	212,000	–	293,000	342,000
M27	459	103,000	142,000	128,000	174,000	202,000	275,000	–	381,000	445,000
M30	561	126,000	174,000	157,000	213,000	247,000	337,000	–	466,000	544,000
M33	694	156,000	215,000	194,000	264,000	305,000	416,000	–	576,000	673,000
M36	817	184,000	253,000	229,000	310,000	359,000	490,000	–	678,000	792,000
M39	976	220,000	303,000	273,000	371,000	429,000	586,000	–	810,000	947,000

a If a thread pitch is not indicated in the thread designation, the standard thread is stipulated.
b See 9.1.6.1 for the calculation of $A_{s,nom}$.
c In accordance with ISO 10684:2004, Annex A, reduced values apply for screws with thread tolerance 6az in accordance with ISO 965-4 that are to be hot-galvanised.
d For steel construction screws 50700 N (for M12), 68800 N (for M14) and 94500 N (for M16).

Tab. 3: Extract from DIN EN ISO 898-1, Test forces for ISO metric standard thread

Metric ISO fine thread

Thread d x P	Nominal tension cross-section t $A_{s,\ nom}$ [b], mm²	Strength class								
		4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9/ 12.9
		Test force, F_p ($A_{s,\ nom}$ × S_p), N								
M8 x 1 M10 x 1.25 M10 x 1	39.2 61.2 64.5	8,820 13,800 14,500	12,200 19,000 20,000	11,000 17,100 18,100	14,900 23,300 24,500	17,200 26,900 28,400	22,700 35,500 37,400	25,500 39,800 41,900	32,500 50,800 53,500	38,000 59,400 62,700
M12 x 1.5 M12 x 1.25 M14 x 1.5	88.1 92.1 125	19,800 20,700 28,100	27,300 28,600 38,800	24,700 25,800 35,000	33,500 35,000 47,500	38,800 40,500 55,000	51,100 53,400 72,500	57,300 59,900 81,200	73,100 76,400 104,000	85,500 89,300 121,000
M16 x 1.5 M18 x 1.5 M20 x 1.5	167 216 272	37,600 48,600 61,200	51,800 67,000 84,300	46,800 60,500 76,200	63,500 82,100 103,000	73,500 95,000 120,000	96,900 130,000 163,000	109,000 - -	139,000 179,000 226,000	162,000 210,000 264,000
M22 x 1.5 M24 x 2 M27 x 2	333 384 496	74,900 86,400 112,000	103,000 119,000 154,000	93,200 108,000 139,000	126,000 146,000 188,000	146,000 169,000 218,000	200,000 230,000 298,000	- - -	276,000 319,000 412,000	323,000 372,000 481,000
M30 x 2 M33 x 2 M36 x 3	621 761 865	140,000 171,000 195,000	192,000 236,000 268,000	174,000 213,000 242,000	236,000 289,000 329,000	273,000 335,000 381,000	373,000 457,000 519,000	- - -	515,000 632,000 718,000	602,000 738,000 839,000
M39 x 3	1,030	232,000	319,000	288,000	391,000	453,000	618,000	-	855,000	999,000

a See 9.1.6.1 for the calculation of $A_{s,nom}$

Tab. 4: Extract from DIN EN ISO 898-1, Test forces for ISO metric fine thread

1.3.2 Properties of screws at increased temperatures

The values shown apply only as an indication for the reduction of the yield points in screws that are tested under increased temperatures. They are not intended for the acceptance test of screws.

Strength class	Temperature				
	+ 20 °C	+ 100 °C	+ 200 °C	+ 250 °C	+ 300 °C
	Lower yield point R_{eL} or 0.2% offset yield point $R_{p\,0.2}$ MPa				
5.6	300	250	210	190	160
8.8	640	590	540	510	480
10.9	940	875	790	745	705
12.9	1,100	1,020	925	875	825

Tab. 5: Extract from DIN EN ISO 898-1 1999-11, hot yield strength

1.4 Strength classes for nuts

With nuts, the test stress and the test forces calculated from it are usually indicated as parameters (04 to 12), because the yield point does not have to be stated. Up to the test forces shown in table 6 a tensile load on a screw is possible without problems (take note of pairing 1.5). The strength class of a nut is described through a test stress in relation to a hardened test mandrel and divided by 100.

Example:

M6, test stress 600 MPa

600/100 = 6 strength class 6

Test forces for ISO metric standard thread (nuts)

Thread	Thread pitch	Nominal stressed cross section of the test mandrel A_s	Strength class										
			04	05	4	5	6	8		9	10	12	
			Test force ($A_s \times S_p$), N										
	mm	mm²	–	–	Style 1	Style 1	Style 1	Style 1	Style 2	Style 2	Style 1	Style 1	Style 2
M3 M3.5 M4	0.5 0.6 0.7	5.03 6.78 8.78	1,910 2,580 3,340	2,500 3,400 4,400	- - -	2,600 3,550 4,550	3,000 4,050 5,250	4,000 5,400 7,000	- - -	4,500 6,100 7,900	5,200 7,050 9,150	5,700 7,700 10,000	5,800 7,800 10,100
M5 M6 M7	0.8 1 1	14.2 20.1 28.9	5,400 7,640 11,000	7,100 10,000 14,500	- - -	8,250 11,700 16,800	9,500 13,500 19,400	12,140 17,200 24,700	- - -	13,000 18,400 26,400	14,800 20,900 30,100	16,200 22,900 32,900	16,300 23,100 33,200
M8 M10 M12	1.25 1.5 1.75	36.6 58.0 84.3	13,900 22,000 32,000	18,300 29,000 42,200	- - -	21,600 34,200 51,400	24,900 39,400 59,000	31,800 50,500 74,200	- - -	34,400 54,500 80,100	38,100 60,300 88,500	41,700 66,100 98,600	42,500 67,300 100,300
M14 M16 M18	2 2 2.5	115 157 192	43,700 59,700 73,000	57,500 78,500 96,000	- - 97,900	70,200 95,800 121,000	80,500 109,900 138,200	101,200 138,200 176,600	- - 170,900	109,300 149,200 176,600	120,800 164,900 203,500	134,600 183,700 -	136,900 186,800 230,400
M20 M22 M24	2.5 2.5 3	245 303 353	93,100 115,100 134,100	122,500 151,500 176,500	125,000 154,500 180,000	154,400 190,900 222,400	176,400 218,200 254,200	225,400 278,800 324,800	218,100 269,700 314,200	225,400 278,800 324,800	259,700 321,200 374,200	- - -	294,000 363,600 423,600
M27 M30 M33	3 3.5 3.5	459 561 694	174,400 213,200 263,700	229,500 280,500 347,000	234,100 286,100 353,900	289,200 353,400 437,200	330,550 403,900 499,700	422,300 516,100 638,500	408,500 499,300 617,700	422,300 516,100 638,500	486,500 594,700 735,600	- - -	550,800 673,200 832,800
M36 M39	4 4	817 976	310,500 370,900	408,500 488,000	416,700 497,800	514,700 614,900	588,200 702,700	751,600 897,900	727,100 868,600	751,600 897,900	866,000 1,035,000	- -	980,400 1,171,000

Tab. 6: Extract from DIN EN 20898-2, Test forces for ISO metric standard thread (nuts)

The test force FP is calculated as follows with the help of the test stress Sp (DIN EN 20898 Part 2) and the nominal stressed cross section A_s: $F_p = A_s \times S_p$

The nominal tension cross-section is calculated as follows:

$$A_s = \frac{\pi}{4}\left(\frac{d_2 + d_3}{2}\right)^2$$

where:

d_2 is the flank diameter of the external thread (nominal size) d_3 is the core diameter of the production profile of the external thread (nominal size)

$$d_3 = d_1 - \frac{H}{6}$$

with

d_1 Core diameter of the base profile of the external thread

H = height of the profile triangle of the thread

1.5 Pairing of screws and nuts:

Rule:

If a screw has strength class 8.8, a nut with a strength class 8 has to be chosen as well.

To avoid the danger of stripping threads when tightening with modern assembly technology methods, screws and nuts have to be paired in accordance with the above rule. In addition, a screw assembly of this type is fully loadable.

Note:

In general nuts in the higher strength class can be used instead of nuts in the lower strength class. This is advisable for a screws-nut connection with loads above the yield point or above the test stress (expansion screws).

Pairing of screws and nuts (nominal heights ≥ 0.8 D)

Strength class of the nuts	Appropriate screw		Nuts	
			Style 1	Style 2
	Strength class	Thread range	Thread range	
4	3.6 4.6 4.8	> M16	> M16	–
5	3.6 4.6 4.8	≤ M16	≤ M39	–
	5.6 5.8	≤ M39		
6	6.8	≤ M39	≤ M39	–
8	8.8	≤ M39	≤ M39	> M16 ≤ M39
9	9.8	≤ M16	–	≤ M16
10	10.9	≤ M39	≤ M39	–
12	12.9	≤ M39	≤ M16	≤ M39

Tab. 7: Extract from DIN EN 20898 Part 2

1.5.1 Information for steel nuts

A screw in strength class 8.8 is paired with a nut in strength class 8 or higher. Thanks to this connection, the screw can be loaded to the yield point.

If nuts with a limited loadability are used – for example in strength class 04, 05; nuts with hardness details 14H, 22H – this is not the case. There are test forces for these nuts in accordance with DIN EN 20898-2.

1.5.2 Stripping resistance for nuts with a nominal height ≥ 0.5 d and < 0.8 d (in accordance with DIN EN 20898, Part 2)

If nuts are paired with screws in a higher strength class, stripping of the nut's thread can be expected.

The reference value show here for the stripping resistance refers to the strength class shown in the table.

Strength class of the nuts	Test stress of the nuts	Minimum stress in the screw before stripping when paired with screws in strength classes in N/mm²			
	N/mm²	6.8	8.8	10.9	12.9
04	380	260	300	330	350
05	500	290	370	410	480

Tab. 8: Extract from DIN EN 20898 Part 2

There is limited loadability as well for nuts in accordance with DIN 934 that are marked I8I, and I4I, I5I, I6I, I9I, I10I, I12I. When a screw in strength class 8.8 and a nut in accordance with DIN 934 (nominal height approx. 0.8 x d) are used, this connection is not to be loaded with certainty to the screw's yield point. To mark and differentiate them, these nuts are marked with a bar before and after the "8" (I8I) instead of just "8".

1.6 Mechanical properties of threaded pins (in accordance with DIN EN ISO 898, Part 5)

The mechanical properties apply for threaded pins and similar threaded **parts not subject to tensile stress** that are made of alloyed and unalloyed steel.

Mechanical property		Strength class[1)]			
		14H	22 H	33 H	45H
Vickers hardness HV	min. max.	140 290	220 300	330 440	450 560
Brinell hardness HB, F = 30 D^2	min. max.	133 276	209 285	314 418	428 532
Rockwell hardness HRB	min. max.	75 105	95		
Rockwell hardness HRC	min. max.		30	33 44	45 53
Surface hardness HV 0.3			320	450	580

[1)] Strength classes 14H, 22H and 33H do not apply to threaded pins with a hexagonal socket

Tab. 9: Extract from EN ISO 898-5

1.7 Marking of screws and nuts

Marking screws with full loadability

Hexagon head screws:

Marking hexagon head screws with the manufacturer's mark and the strength class is prescribed for all strength classes and a nominal thread diameter of d ≥ 5 mm.

The screw must be marked at a point where its shape permits.

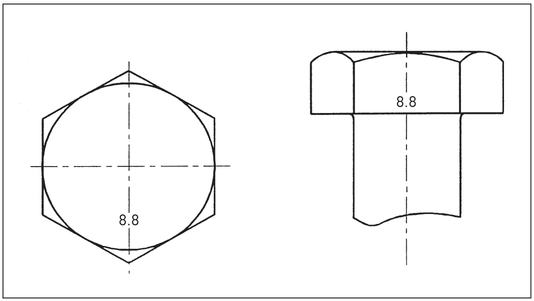


Fig. G: Example for the marking of hexagon head screws

Socket head cap screws:

Marking socket head cap screws with the manufacturer's mark and the strength class is prescribed for strength classes ≥ 8.8 and a thread diameter of d ≥ 5 mm.

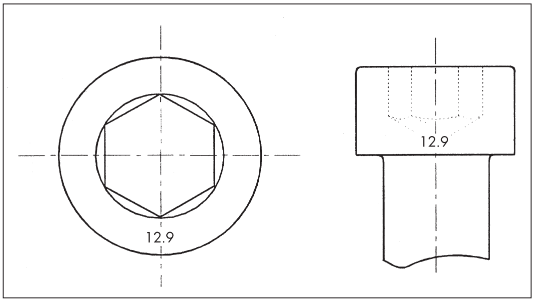


Fig. H: Example for the marking of socket head cap screws

Marking nuts

Strength class	04	05	4	5	6	8	9	10	12
Mark	04	05	4	5	6	8	9	10	12

Tab. 10: Extract from EN 20898-2

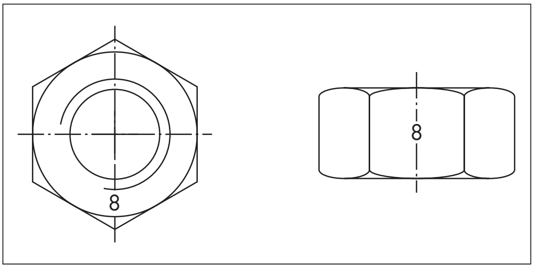


Fig. I: Example of marking with the code number of the strength class

Marking of hexagonal nuts with the manufacturer's mark and the strength class is prescribed for all strength classes and with a thread ≥ M5. Hexagonal nuts must be marked on the bearing surface or on a flat with a recessed mark or on the chamfer with a raised mark. Raised marks may not project beyond the nut's bearing surface. As an alternative to the marking with the code number of the strength class, marking can also be done with the help of the clockwise system (for more information see DIN EN 20898 Part 2).

Marking screws with reduced loadability

Screws with reduced loadability have an "0" before the strength class mark, e.g. 8.8. The point between the digits may be omitted so that the variants "08.8" and "088" are possible. This marking is possible for all strength classes.

1.8 Inch thread conversion table inch/mm

Inch	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"	1.1/4"
mm	6.3	7.9	9.5	11.1	12.7	15.9	19.1	22.2	25.4	31.8

Inch	1.1/2"	1.3/4"	2"	2.1/4"	2.1/2"	2.3/4"	3"	3.1/2"	4"	
mm	38.1	44.5	50.8	57.1	63.5	69.9	76.2	88.9	102.0	

Number of threads per 1" UNC/UNF

0-inch	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	
Thread pitch UNC	20	18	16	14	13	11	10	
Thread pitch UNF	28	24	24	20	20	18	16	

Tab. 11: Thread pitch UNC/UNF

2. RUST AND ACID-RESISTANT FASTENERS

2.1 Mechanical properties

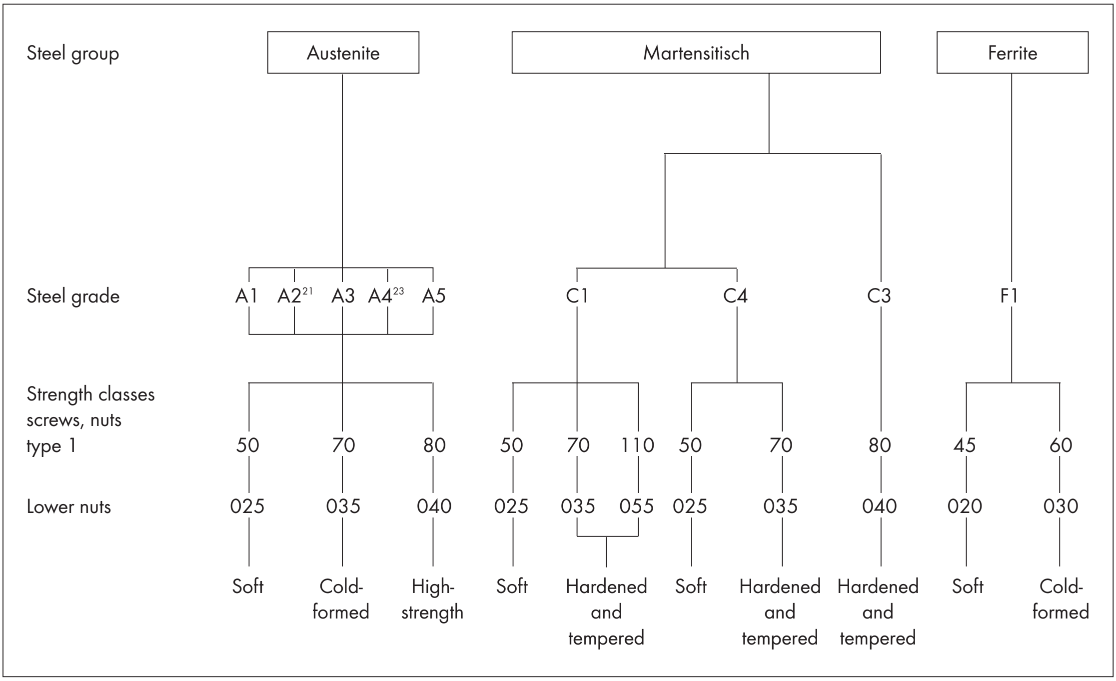
DIN EN ISO 3506 applies to screws and nuts made of stainless steel. There are a great number of stainless steels, which are classified in the three steel groups austenite, ferrite and martensite, whereby austenite steel is the most widespread.

The steel groups and the strength classes are designated with a four-character sequence of letters and digits.

Example:

A2–70

- A Austenite steel
- 2 Alloy type in group A
- 70 Tensile strength not less than 700 MPa, strain-hardened



Differentiation characteristics of austenite steel grades (in accordance with ISO 3506)

Steel group	**Chemical composition in % (maximum values, unless other details provided)**							
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Cu**
A1	0.12	1	6.5	0.2	0.15–0.35	16–19	0.7	5–10	1.75–2.25
A2	0.1	1	2	0.05	0.03	15–20	–	8–19	4
A3	0.08	1	2	0.045	0.03	17–19	–	9–12	1
A4	0.08	1	2	0.045	0.03	16–18.5	2–3	10–15	4
A5	0.08	1	2	0.045	0.03	16–18.5	2–3	10.5–14	1
A3 and A5 stabilised against intercrystalline corrosion through adding titanium, niobium or tantalum.									

Chemical composition of austenite steels (in accordance with ISO 3506)

The most important stainless steels and their composition

	Material name	Material no.	C %	Si ≤ %	Mn ≤ %	Cr %	Mo %	Ni %	Altri %
A1	X 8 Cr Ni S 18-9	1.4305	≤ 0.10	1.0	2.0	17.0 ÷ 19.0	–	8 ÷ 10	S 0.15 ÷ 0.35
A2	X 5 Cr Ni 1810	1.4301	≤ 0.07	1.0	2.0	17.0 ÷ 20.0	–	8.5 ÷ 10	–
	X 2 Cr Ni 1811	1.4306	≤ 0.03	1.0	2.0	17.0 ÷ 20.0	–	10 ÷ 12.5	–
	X 8 Cr Ni Ti 19/10	1.4303	≤ 0.07	1.0	2.0	17.0 ÷ 20.0	–	10.5 ÷ 12	–
A3	X 6 Cr Ni Ti 1811	1.4541	≤ 0.10	1.0	2.0	17.0 ÷ 19.0	–	9.0 ÷ 11.5	Ti ≥ 5 X % C
A4	X 5 Cr Ni Mo 1712	1.4401	≤ 0.07	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	10.5 ÷ 13.5	–
	X 2 Cr Ni Mo 1712	1.4404	≤ 0.03	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	11 ÷ 14	–
A5	X 6 Cr Ni Mo Ti 1712	1.4571	≤ 0.10	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	10.5 ÷ 13.5	Ti ≥ 5 X % C

Tab. 15: Common stainless steels and their chemical composition

Steel grade A1

Steel grade A1 is intended in particular for metal-cutting. Because of the high sulphur content, steels of this grade have lower corrosion resistance than corresponding steels with a normal sulphur content.

Steel grade A2

Grade A2 steels are the more commonly used stainless steels. They are used for kitchen equipment and for apparatus for the chemical industry. Steels of this steel grade are not suitable for use in non-oxidising acids and media containing chloride, e.g. in swimming pools and in sea water.

Steel grade A3

Grade A3 steels are stainless steels stabilised through the addition of titanium, possibly niobium, tantalum, with the properties of A2 steels (stabilised against intercrystalline corrosion, e.g. after welding).

Steel grade A4

Grade A4 steels are "acid-resistant steels" that are molybdenum alloyed and have much better corrosion resistance. A4 steels are used in large volumes in the cellulose industry, because this steel grade was developed for boiling sulphuric acids (which is the reason for the designation "acid-resistant"), and are suitable to a certain extent for environments containing chloride. A4 steels are also used frequently in the food industry and in ship building.

Steel grade A5

Grade A5 steels are stabilised "acid-resistant steels" with properties of grade A4 steels (see A3 as well).

2.1.1 Strength classification of stainless steel screws

DIN EN ISO 3506 puts together the steel grades that are recommended for fasteners. Austenitic steels in grade A2 are used primarily. In contrast, in case of increased corrosion loads chromium-nickel steels from steel grade A4 are used. The mechanical strength values in Table 17 below are to be used for the construction of screw assemblies made of austenitic steel.

Mechanical properties of screws in the austenitic steel groups

Steel group	Steel grade	Strength class	Diameter range	Screws		
				Tensile strength R_m [1) MPamin.	0.2% offset yield point $R_{p0.2}$ [1) MPa min.	Elongation at fracture A[2) mm min.
Austenitic	A1, A2, A3, A4 and A5	50	≤ M39	500	210	0.6 d
		70	< M24[3)	700	450	0.4 d
		80	< M24[3)	800	600	0.3 d

1) The tensile stress is calculated in relation to the tension cross-section (see annex A or DIN EN ISO 3506-1).
2) According to 6.2.4, the elongation at fracture is to be determined at the respective length of the screw and not on turned off specimens. d is the nominal diameter.
3) In case of fasteners with a nominal thread diameter d > 24 mm the mechanical properties must be agreed between the user and the manufacturer. They must be marked with the steel grade and strength class in accordance with this table.

Tab. 16: Extract from DIN EN ISO 3506-1

The yield point $R_{p0.2}$ is determined in accordance with DIN EN ISO 3506-1 in the tensile test of whole screws because the strength properties are achieved in part through cold forming.

2.1.2 Apparent yielding point loads for set screws

Austenitic chromium-nickel steels cannot be hardened. A higher yield point can only be achieved through strain hardening that arises as a consequence of cold forming (e.g. round die thread rolling). Table 17 shows apparent yielding point loads for set screws in accordance with DIN EN ISO 3506.

Nominal diameter	Apparent yielding point loads for austenitic steels in accordance with DIN EN ISO 3506 A2 and A4 in N	
Strength class	50	70
M5	2,980	6,390
M6	4,220	9,045
M8	7,685	16,470
M10	12,180	26,100
M12	17,700	37,935
M16	32,970	70,650
M20	51,450	110,250
M24	74,130	88,250
M27	96,390	114,750
M30	117,810	140,250

Tab. 17: Apparent yielding point loads for set screws in accordance with DIN EN ISO 3506

2.1.3 Reference values for tightening torques for screws, cf. chapter 6.6

2.2 Corrosion resistance of A2 and A4

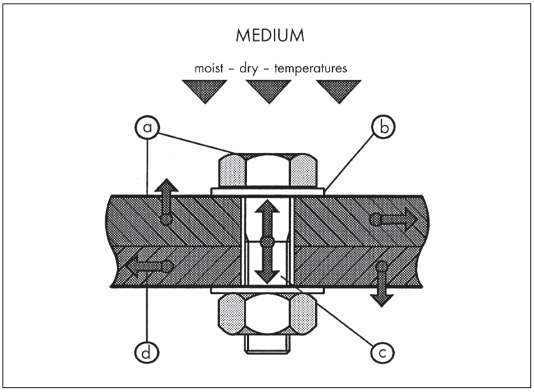
Stainless steels and acid-resistant steels such as A2 and A4 come in the category of "active" corrosion protection.

Stainless steels contain at least 16% chromium (Cr) and are resistant to aggressive oxidising media. Higher Cr contents and additional alloy components, such as nickel (Ni), molybdenum (Mo), titanium (Ti) or niobium (Nb), improve the corrosion resistance. These additives also influence the mechanical properties. Other alloy components are added only to improve the mechanical properties, e.g. nitrogen (N), or the machining capability, e.g. sulphur (S).

Fasteners made of austenitic steels are generally not magnetisable, but a certain amount of magnetisability may be present after the cold forming. However, this does not affect the corrosion resistance. Magnetisation through strain hardening can go so far that the steel part sticks to a magnet.

Under the effect of oxygen stainless steel forms a stable oxide layer (passive layer). This passive layer protects the metal from corrosion.

It should be noted that in practice there are a number of different types of corrosion. The more frequent types of corrosion involving stainless steel are shown below and in the following Fig. J as examples:



a Surface degrading corrosion, pitting
b Contact corrosion
c Stress corrosion cracking
d Mechanical effects

Fig. K: The most frequent corrosion types with screw assemblies

2.2.1 Surface and degrading corrosion

With uniform surface corrosion, also known as degrading corrosion, the surface is degraded evenly. This type of corrosion can be prevented through a careful selection of the material.

On the basis of laboratory experiments manufacturers have published resistance tables that provide information on the behaviour of the steel grades at different temperatures and concentrations in the individual media (see chapter 2.2.5).

2.2.2 Pitting

Pitting is seen through surface corrosion degrading with the additional formation of cavities and holes. The passive layer is penetrated locally here.

In case of stainless steel in contact with active media containing chloride there is also pitting by itself with pinhole notches in the material. Deposits and rust can also be the starting point for pitting. For this reason, residues and deposits must be cleaned regularly from all fasteners.

Austenitic steels such as A2 and A4 are more resistant to pitting than ferrite chromium steels.

Classification of the degree of resistance into different groups

Degree of resistance	Assessment	Weight loss in g/m^2h
A	Fully resistant	< 0.1
B	Practically resistant	0.1 – 1.0
C	Less resistant	1.0 – 10
D	Not resistant	> 10

Tab. 22

2.2.3 Contact corrosion

Contact corrosion occurs when two components with different compositions are in metallic contact with each other and there is moisture in the form of an electrolyte. The baser element is attacked and destroyed.

The following points should be observed to prevent contact corrosion:

- Insulating the metals at the contact point, e.g. through rubber, plastics or coatings, so that a contact current cannot flow.
- Where possible, avoid unequal material pairings. As an example, screws, nuts and washers should be matched to the connecting components.
- Make sure that the connection is not in contact with electrolytic active means.
  → cf. chapter 6.8 as well

2.2.4 Stress corrosion cracking

This type of corrosion usually occurs in components used in industrial atmospheres that are under heavy mechanical tensile and bending loads. Internal stresses created by welding can also lead to stress corrosion cracking.

Austenite steels in atmospheres containing chloride are particularly sensitive to stress corrosion cracking. The influence of the temperature is considerable here. The critical temperature is 50 °C.

2.2.5 A2 and A4 in combination with corrosive media

The following table provides an overview of the resistance of A2 and A4 in combination with various corrosive media. The values shown are intended only as reference points but still provide good possibilities for comparisons.

Overview of the chemical resistance of A2 and A4 screws

Corrosive agent	Concentration	Temperature in °C	Degree of resistance A2	Degree of resistance A4
Acetic acid	10%	20 boiling	A A	A A
Acetone	all	all	A	A
Ammoniac	all	20 boiling	A A	A A
Beer	–	all	A	A
Benzene, all types	–	all	A	A
Benzoic acid	all	all	A	A
Benzol	–	all	A	A
Blood	–	20	A	A
Bonderising solution	–	98	A	A
Carbon dioxide	–	–	A	A
Chloride: dry gas, damp gas	–	20 all	A D	A D
Chloroform	all	all	A	A
Chromic acid	 10% pure 50% pure	20 boiling 20 boiling	A C B D	A B B D
Citric acid	to 10% 50%	all 20 boiling	A A C	A A B
Copper acetate	–	all	A	A
Copper nitrate	–	–	A	A
Copper sulphate	all	all	A	A
Developer (photogr.)	–	20	A	A
Ethyl alcohol	all	20	A	A
Ethyl ether	–	all	A	A
Fatty acid	technical	150 180 200–235	A B C	A A A
Formic acid	10%	20 boiling	A B	A A
Fruit juices	–	all	A	A
Glycerine	conc.	all	A	A
Hydrochloric acid	0.2% 2% to 10%	20 50 20 50 20	B C D D D	B B D D D

All information is provided without guarantee or claim to completeness.

Corrosive agent	Concentration	Temperature in °C	Degree of resistance A2	Degree of resistance A4
Hydrocyanic acid	–	20	A	A
Industrial air	–	–	A	A
Lactic acid	 1.5% 10%	all 20 boiling	A A C	A A A
Lemon juice	–	20	A	A
Magnesium sulphate	approx. 26%	all	A	A
Mercury	–	to 50	A	A
Mercury nitrate	–	all	A	A
Methyl alcohol	all	all	A	A
Milk of lime	–	all	A	A
Nitric acid	to 40% 50% 90% 	all 20 boiling 20 boiling	A A B A C	A A B A C
Oils (mineral and vegetable)	–	all	A	A
Oxalic acid	10% 50%	20 boiling boiling	B C D	A C C
Petroleum	–	all	A	A
Phenol	pure	boiling	B	A
Phosphoric acid	10% 50% 80% conc. 	boiling 20 boiling 20 boiling 20 boiling	A A C B D B D	A A B A C A D
Potassium permanganate	10%	all	A	A
Salicylic acid	–	20	A	A
Seawater	–	20	A	A
Sodium carbonate	cold saturated	all	A	A
Sodium hydroxide	20% 50%	20 boiling 120	A B C	A B C
Sodium nitrate	–	all	A	A
Sodium perchlorate	10%	all	A	A
Sugar solution	–	all	A	A
Sulphur dioxide	–	100–500 900	C D	A C
Sulphuric acid. 1%	to 70% 2.5% 5% 10% 60%	B boiling to 70 boiling 20 > 70 20 70 all	A B B C B B C C D	 B A C A B B C D
Sulphurous acid	aqueous solution	20	A	A
Tannic acid	all	all	A	A

Corrosive agent	**Concentration**	**Temperature in °C**	**Degree of resistance A2**	**Degree of resistance A4**
Tar	–	hot	A	A
Tartaric acid	to 10% over 100% to 50% 75%	20 boiling 20 boiling boiling	A B A C C	A A A C C
Wine	–	20 and hot	A	A

2.2.6 Creation of extraneous rust

Extraneous rust consists of adherent particles of a carbon steel ("normal steel") on the stainless steel surface that turn into rust through the effect of oxygen. If these places are not cleaned and removed, the rust can cause electro-chemical pitting corrosion even in stainless steel.

Extraneous rust can be caused by:
- Contact of objects that rust with a stainless steel surface.
- Flying sparks during work with a right angle grinder, or grinding dust. or during welding work.
- Water containing rust dripping onto a stainless steel surface.
- Use of tools that were previously used to work on carbon steel.

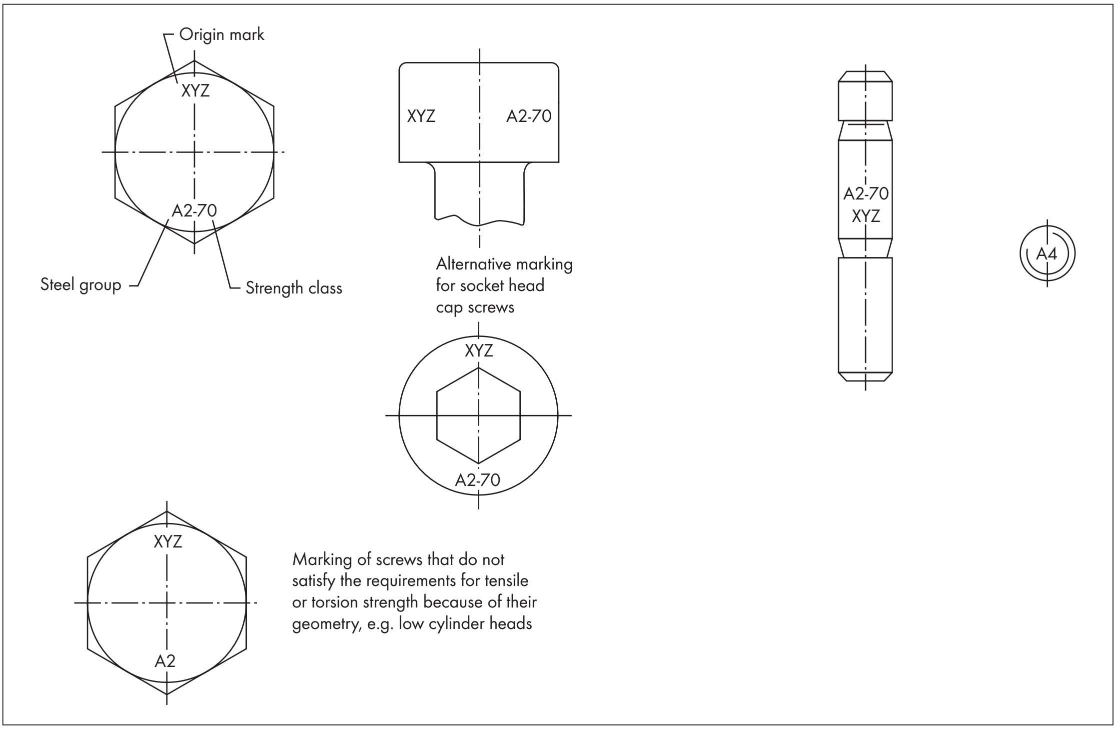


Fig. L: Extract from DIN EN ISO 3506-1

2.3 Marking corrosion-resistant screws and nuts

The marking of corrosion-resistant screws and nuts must contain the steel group, the strength class and the manufacturer's mark.

Marking screws in accordance with DIN EN ISO 3506-1

Hexagon head screws and socket head cap screws from nominal diameter M5 must be clearly marked in accordance with the classification system. Where possible, the marking should be on the screw head.

Marking nuts in accordance with DIN EN ISO 3506-2

Nuts with a nominal thread diameter from 5 mm must be clearly marked in accordance with the classification system. Marking on a single flat is permissible and may only be recessed. Marking on the flats is also permissible as an option.

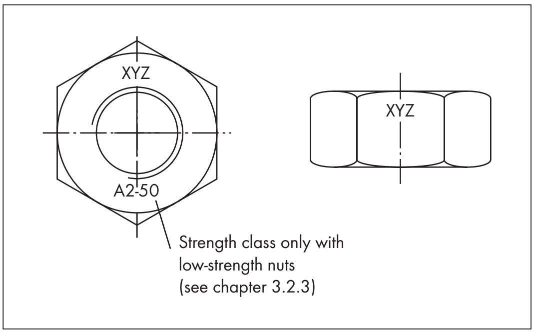


Fig. M: Extract from DIN EN ISO 3506-2

3. ISO INFORMATION ON TECHNICAL STANDARDISATION – CHANGEOVER TO ISO

3.1 Code

Technical standardisation is work of harmonisation in the technical field that is carried out jointly by all interested parties. Its aim is to stipulate, arrange and harmonise terms, products, procedures, etc., in the area of engineering. In this way, optimum solutions are found for all types of constructions, for example, whereby ordering the necessary components is considerably simplified.

This work of harmonisation in Germany was previously carried out by the Deutsches Institut für Normung e.V. (DIN) on the national level. In addition, there are European standards (EN standards), and on an international level there are the ISO standards, which are issued by the International Organisation for Standardisation.

National standards (DIN) are being or have already been largely replaced by international/European standards. There will be DIN standards only for products for which there are no ISO or EN standards.

International standards (ISO). According to the task and goal of the ISO, which was established in 1946, these are intended to serve the global harmonisation of technical rules, and thus to simplify the exchange of goods and to break down barriers to trade.

European standards (EN) aim at harmonising technical regulations and statutes in the internal European market, which was realised on 1.1.1995 (EU/EEC). In principle, existing ISO standards are to be taken over as far as possible unchanged as EN standards. The difference between ISO and EN standards is that, according to a decision of the European Council, EN standards are to be transposed and introduced without delay and without amendment as national standards in the Member States – and the corresponding national standards are to be withdrawn in the same step.

3.1.1 Product names and product changes

In many cases the introduction of the European standards is described as intransparent or even chaotic. However, a closer look reveals that this is not the case. Many DIN standards were the foundation for ISO standards. The old DIN standards were changed into new ISO standards.

If an ISO standard is taken over into national standards codes without change, the national standard is given the same title as the corresponding ISO standard. An ISO nut is thus known as an ISO 4032-M12-8 all over the world.

In many cases, a changeover from "DIN to ISO" is, strictly speaking, not correct, because in the past many DIN standards had already been taken over by ISO standards. During the harmonisation of the individual standards codes some titles are in fact being changed, but there are not many changes to the products themselves. For an interim period the number 20000 was added to the ISO number on the takeover of ISO standards into the European code (EN) (e.g. DIN EN ISO 24034). However, this naming system was abandoned some years ago and replaced by the now common form "DIN EN ISO ...".

It is certain that the changes to names are very annoying with regard to production documents or order data, because these have to be changed in the short or long term. But we have to be clear about one thing: the sooner we realise conformity to European standards, the sooner we will profit from overcoming barriers to trade or procurement within Europe.

As already stated, the contents of many DIN standards already conform to the ISO standard, because they were introduced at a time at which the "changeover to ISO" was not yet current.

Following Europeanisation there are absolutely no changes to what is certainly the most important standard for screws and nuts, ISO 898-1 "Mechanical properties of fasteners", because this standard was taken over into the German standards code from the start without any changes to the contents.

One of the most significant product changes on the harmonisation of the codes was without doubt the change of the width across flats of all hexagonal products. Screws and nuts with dimensions M10, M12 and M14 are affected (here the width across flats is reduced by 1 mm) and M22 (width across the flats is 2 mm larger).

Apart from these four dimensions, all other screw dimensions are already perfectly identical to ISO. This means, for example, that a DIN 933 M16 x 50-8.8 is dimensionally, and with regard to the technical properties, completely identical to ISO 4017 M16 x 50-8.8. All that is necessary here is a change to the name in the production documents or order files.

In contrast, following more recent technical findings the ISO has changed the height of hexagonal nuts because it was recognised that the stripping resistance can no longer be guaranteed, particularly when modern tightening methods are used. In this case, the connection would no longer be safe against failure. For this reason alone the use of nuts in accordance with ISO standards is highly recommended.

3.2 DIN-ISO successor standards

DIN	ISO	DIN	ISO	DIN	ISO
1	2339	931	4014	6914	7412
7	2338	933	4017	6915	7414
84	1207	934	4032	6916	7416
85	1580	934	8673	6921	8102
94	1234	960	8765	6923	4161
125	7089	961	8676	6924	7040
125	7090	963	2009	6925	7042
126	7091	964	2010	7343	8750
417	7435	965	7046	7343	8751
427	2342	966	7047	7344	8748
433	7092	971-1	8673	7346	13337
438	7436	971-2	8674	7971	1481
439	4035	980	7042	7972	1482
439	4036	980	10513	7973	1483
440	7094	982	7040	7976	1479
551	4766	982	10512	7977	8737
553	7434	985	10511	7978	8736
555	4034	1440	8738	7979	8733
558	4018	1444	2341	7979	8735
601	4016	1471	8744	7981	7049
603	8677	1472	8745	7982	7050
660	1051	1473	8740	7983	7051
661	1051	1474	8741	7985	7045
911	2936	1475	8742	7991	10642
912	4762	1476	8746	9021	7093
913	4026	1477	8747	11024	7072
914	4027	1481	8752		
915	4028	6325	8734		
916	4029				

ISO-DIN previous standards ISO

ISO	DIN	ISO	DIN	ISO	DIN
1051	660/661	4036	439	8673	934
1207	84	4161	6923	8673	971
1234	94	4762	912	8674	971-2
1479	7976	4766	551	8676	961
1481	7971	7040	982	8677	603
1482	7972	7040	6924	8733	7979
1483	7973	7042	980	8734	6325
1580	85	7042	6925	8735	7979
2009	963	7045	7985	8736	7978
2010	964	7046	965	8737	7977
2338	7	7047	966	8738	1440
2339	1	7049	7981	8740	1473
2341	1434	7050	7982	8741	1474
2342	427	7051	7983	8742	1475
2936	911	7072	11024	8744	1471
4014	931	7089	125	8745	1472
4016	601	7090	125	8746	1476
4017	933	7091	126	8747	1477
4018	558	7092	433	8748	7344
4026	913	7093	9021	13337	7346
4027	914	7094	440	8750	7343
4028	915	7412	6914	8751	7343
4029	916	7414	6915	8752	1481
4032	934	7416	6916	8765	960
4034	555	7434	553	10642	7991
4035	439	7435	417	10511	985
		7436	438	10512	982
		8102	6921	10513	980

3.3 DIN-ISO changes to widths across flats

Hexagonal widths across flats	DIN	ISO
M10	17 mm	16 mm
M12	19 mm	18 mm
M14	22 mm	21 mm
M22	32 mm	34 mm

3.4 Standard changeover DIN/ISO, general changes, classified in accordance with special fields. Currently valid standards collections

3.4.1 Technical terms of delivery and basic standards

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
267 Part 20	–	DIN EN ISO 6157-2	Fasteners, surface discontinuities, nuts	Nothing noteworthy
267 Part 21	–	DIN EN ISO 10484	Widening test on nuts	Nothing noteworthy
DIN ISO 225	225	DIN EN 20225	Fasteners; bolts, screws, studs and nuts; symbols and designations of dimensioning (ISO 225:1991)	Nothing noteworthy
DIN ISO 273	273	DIN EN 20273	Mech. fasteners; clearance holes for bolts and screws (ISO 273: 1991)	Nothing noteworthy
DIN ISO 898 Part 1	898-1	DIN EN ISO 898 Part 1	Mech. properties of fasteners made of carbon steel and alloy steel (ISO 898-1: 1988)	Nothing noteworthy
267 Part 4	898-2	DIN EN 20898-2	Mech. properties of fasteners, part 2; nuts with specified proof load (ISO 898-2: 1992)	Nothing noteworthy
DIN ISO 898 Part 6	898-6	DIN EN ISO 898 Part 6	Mech. properties of fasteners, part 6; nuts with specified proof load values, fine thread (ISO 898-6: 1988)	Nothing noteworthy
267 Part 19	6157-1	DIN EN 26157 Part 1	Fasteners – Surface discontinuities – Part 1: Bolts, screws and studs for general requirements (ISO 6157-1: 1988)	Nothing noteworthy
267 Part 19	6157-3	DIN EN 26157 Part 3	Fasteners – Surface discontinuities – Part 3: Bolts, screws and studs for special requirements (ISO 6157-3: 1988)	Nothing noteworthy
DIN ISO 7721	7721	DIN EN 27721	Countersunk head screws – Head configuration and gauging (ISO 7721: 1983)	Nothing noteworthy
267 Part 9	–	DIN ISO 4042	Fasteners – Electroplated coatings	Nothing noteworthy
267 Part 1	–	DIN ISO 8992	Fasteners – General requirements for bolts, screws, studs and nuts	Nothing noteworthy
267 Part 5	–	DIN EN ISO 3269	Fasteners – acceptance inspection	Nothing noteworthy
267 Part 11	–	DIN EN ISO 3506, Part 1, 2, 3	Mechanical properties of corrosion-resistant steel fasteners – technical terms of delivery	Nothing noteworthy
267 Part 12	–	DIN EN ISO 2702	Heat-treated steel tapping screws – mechanical properties	Nothing noteworthy
267 Part 18	8839	DIN EN 28839	Mechanical properties of fasteners; nonferrous metal bolts, screws, studs and nuts (ISO 8839: 1986)	Nothing noteworthy

3.4.2 Small metric screws

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
84	1207	DIN EN 21207	Slotted cheese head screws – product grade A (ISO 1207: 1992)	Head height and diameter in places
85	1580	DIN EN 21580	Flat-headed screws with slot; product grade A	Head height and diameter in places
963	2009	DIN EN 22009	Countersunk screws with slot, shape A	Head height and diameter in places
964	2010	DIN EN 22010	Countersunk oval head screws with slot, shape A	Head height and diameter in places
965	7046-1	DIN EN 27046-1	Countersunk screws with cross recess (common head): product class A, strength class 4.8	Head height and diameter in places
965	7046-2	DIN EN 27046-2	Countersunk screws with cross recess (common head): product grade A, strength class 4.8	Head height and diameter in places
966	7047	DIN EN 27047	Countersunk oval head screws with cross recess (common head): product grade A	Head height and diameter in places
7985	7045	DIN EN 27045	Flat-headed screws with cross recess; product grade A	Head height and diameter in places

3.4.3 Pins and screws

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
1	2339	DIN EN 22339	Taper pins; unhardened (ISO 2339:1986)	Length l incl. round ends
7	2338	DIN EN 22338	Parallel pins, of unhardened steel and austenitic stainless steel (ISO 2338:1986)	Length l incl. round ends
1440	8738	DIN EN 28738	Plain washers for clevis pins – Product grade A (ISO 8738: 1986)	Outer diameter in places
1443	2340	DIN EN 22340	Clevis pins without head (ISO 2340:1986)	Nothing noteworthy
1444	2341	DIN EN 22341	Clevis pins with head (ISO 2341:1986)	Nothing noteworthy
1470	8739	DIN EN 8739	Grooved pins, full length parallel grooved pins with pilot (ISO 8739:1997)	Nothing noteworthy
1471	8744	DIN EN 8744	Grooved pins – Full-length taper grooved (ISO 8744:1997)	Nothing noteworthy
1472	8745	DIN EN 8745	Grooved pins – Half length taper grooved (ISO 8745:1997)	Nothing noteworthy
1473	8740	DIN EN 8740	Gooved pins – Full-length parallel grooved, with chamfer (ISO 8740:1997)	Nothing noteworthy
1474	8741	DIN EN 8741	Grooved pins – Half-length reverse-taper grooved (ISO 8741:1997)	Nothing noteworthy
1475	8742	DIN EN 8742	Grooved pins - one-third-length centre grooved (ISO 8742:1997)	Increased shearing forces
1476	8746	DIN EN 8746	Grooved pins with round head (ISO 8746:1997)	Nothing noteworthy
1477	8747	DIN EN 8747	Grooved pins with countersunk head (ISO 8747:1997)	Nothing noteworthy
1481	8752	DIN EN 8752	Spring-type straight pins – Slotted, heavy duty (ISO 8752:1997)	Bevel angle cancelled
6325	8734	DIN EN 8734	Parallel pins, of hardened steel and martensitic stainless steel (Dowel pins) (ISO 8734:1997)	Shape A/B cancelled

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
7977	8737	DIN EN 28737	Tapered pins with external thread; unhardened (ISO 8737:1986)	Nothing noteworthy
7978	8736	DIN EN 28736	Tapered pins with internal thread; unhardened (ISO 8736:1986)	Nothing noteworthy
7979	8733	DIN EN 8733	Parallel pins with internal thread, of unhardened steel and austenitic stainless steel (ISO 8733:1997)	Nothing noteworthy
7979	8735	DIN EN 8735	Parallel pins with internal thread, of hardened steel and martensitic stainless steel (ISO 8735:1997)	Nothing noteworthy

3.4.4 Tapping screws

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
7971	1481	DIN ISO 1481	Slotted pan head tapping screws (ISO 1481: 1983)	Head height and diameter in places
7972	1482	DIN ISO 1482	Slotted countersunk (flat) head tapping screws (common head style)	Head height and diameter in places
7973	1483	DIN ISO 1483	Slotted raised countersunk (oval) head tapping screws (common head style)	Head height and diameter in places
7976	1479	DIN ISO 1479	Hexagon head tapping screws	Head height in places
7981	7049	DIN ISO 7049	Cross recessed pan head tapping screws	Head height and diameter in places
7982	7050	DIN ISO 7050	Cross recessed countersunk (flat) head tapping screws (common head style	Head height and diameter in places
7983	7051	DIN ISO 7051	Cross recessed raised countersunk (oval) head tapping screws	Head height and diameter in places

3.4.5 Hexagon head screws and nuts

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
439 T1	4036	DIN EN 24036	Hexagon thin nuts, unchamfered (ISO 4036: 1979)	4 widths across flats
439 T2	4035	DIN EN 24035	Hexagon thin nuts, unchamfered (ISO 4035: 1986)	4 widths across flats
555	4034	DIN EN 24034	Hexagon nuts, product grade C	Nut height and 4 widths across flats
558	4018	DIN EN 24018	Hexagon head screws, product grade C	4 widths across flats
601	4016	DIN EN 24016	Hexagon head bolts, product grade C, DIN 555	4 widths across flats
931	4014	DIN EN 24014	Hexagon head bolt with shank	4 widths across flats
933	4017	DIN EN 24017	Hexagon head screw	4 widths across flats
934 ISO type 1	4032	DIN EN 24032	Hexagonal nuts, style 1	Nut height and 4 widths across flats
934 ISO type 1	8673	DIN EN 28673	Hexagon nuts, style 1, with metric fine pitch thread	Nut height and 4 widths across flats
960	8765	DIN EN 28765	Hexagon head bolts with shaft and metric fine pitch thread	4 widths across flats
961	8676	DIN EN 28676	Hexagon head screws 10.9, thread to head	4 widths across flats

3.4.6 Threaded pins

DIN (old)	ISO	DIN (new) or DIN EN	Title	Changes
417	7435	DIN EN 27435	Slotted set screws with long dog point (ISO 7431: 1983)	Head height and diameter in places
438	7436	DIN EN 27436	Slotted set screws with cup point (ISO 7436: 1983)	Head height and diameter in places
551	4766	DIN EN 24766	Slotted set screws with flat point (ISO 4766: 1983)	Head height and diameter in places
553	7434	DIN EN 27434	Slotted set screws with cone point (ISO 7431: 1983)	Head height and diameter in places
913	4026	DIN 913	Socket set screws with flat point	Head height and diameter in places
914	4027	DIN 914	Slotted set screws with cone point	Head height and diameter in places
915	4028	DIN 915	Slotted set screws with dog point	Head height and diameter in places
916	4029	DIN 916	Slotted set screws with cup point	Head height and diameter in places

3.5 Dimensional changes to hexagonal screws and nuts

Nominal size d	Width across flat s		Nut height m min. – max.			
Sizes to be avoided	DIN	ISO	DIN 555	ISO 4034 ISO type 1	DIN 934	ISO 4032 (RG) 8673 (FG) ISO type 1
M1	2.5	–	–	0.55–0.8	0.55–0.8	–
M1,2	3	–	–	–	0.75–1	–
M1,4	3	–	–	–	0.95–1.2	–
M1,6	3.2		–	–	1.05–1.3	1.05–1.3
M2	4		–	–	1.35–1.6	1.35–1.6
M2,5	5		–	–	1.75–2	1.75–2
M3	5.5		–	–	2.15–2.4	2.15–2.4
(M3,5)	6		–	–	2.55–2.8	2.55–2.8
M4	7		–	–	2.9–3.2	2.9–3.2
M5	8		3.4–4.6	4.9–5.6	3.7–4	4.4–4.7
M6	10		4.4–5.6	4.6–6.1	4.7–5	4.9–5.2
(M7)	11	–	–	–	5.2–5.5	–
M8	13		5.75–7.25	6.4–7.9	6.14–6.5	6.44–6.8
M10	17	16	7.25–8.75	8–9.5	7.64–8	8.04–8.4
M12	19	18	9.25–10.75	10.4–12.2	9.64–10	10.37–10.8
(M14)	22	21	–	12.1–13.9	10.3–11	12.1–12.8
M16	24		12.1–13.1	14.1–15.9	12.3–13	14.1–14.8
(M18)	27		–	15.1–16.9	14.3–15	15.1–15.8
M20	30		15.1–16.9	16.9–19	14.9–16	16.9–18
(M22)	32	34	17.1–18.9	18.1–20.2	16.9–18	18.1–19.4
M24	36		17.95–20.05	20.2–22.3	17.7–19	20.2–21.5
(M27)	41		20.95–23.05	22.6–24.7	20.7–22	22.5–23.8
M30	46		22.95–25.05	24.3–26.4	22.7–24	24.3–25.6

Nominal size d	Width across flat s		Nut height m min. – max.			
(M33)	50		24.95–27.05	27.4–29.5	24.7–26	27.4–28.7
M36	55		27.95–30.05	29.4–31.9	27.4–29	29.4–31
(M39)	60		29.75–32.25	31.8–34.3	29.4–31	31.8–33.4
M42	65		32.75–35.25	32.4–34.9	32.4–34	32.4–34
(M45)	70		34.75–37.25	34.4–36.9	34.4–36	34.4–36
M48	75		36.75–39.25	36.4–38.9	36.4–38	36.4–38
(M52)	80		40.75–43.25	40.4–42.9	40.4–42	40.4–42
M56	85		43.75–46.25	43.4–45.9	43.4–45	43.4–45
(M60)	90		46.75–49.25	46.4–48.9	46.4–48	46.4–48
M64	95		49.5–52.5	49.4–52.4	49.1–51	49.1–51
>M64	–		to M100*6	–	to M100*6	–/–
Nut height factor m/d approx.		≤ M4	–	–	0.8	0.8
		M5–M39	0.8	0.83–1.12		0.84–0.93
		≥ M42		~0.8		0.8
Product class			C (average)		≤ M16 = A (average) >M16 = B (average roughness)	
Thread tolerance			7 H		6 H	
Strength class Steel	Core range ~M5-39		5 M16 < d ≤ M39 = 4.5		6.8,10 (ISO 8673 = strength class 10 ≤ M16)	
	>M39		Following agreement		Following agreement	
Mechanical properties according to standard			DIN 267 Part 4	ISO 898 Part 2 (ST) d ≤ M39	DIN 267 Part 4	ISO 898 Part 2 (ST) Part 6 (FT)

ST – standard thread, FT – fine thread

4. MANUFACTURING SCREWS AND NUTS

4.1 Manufacturing processes

In principle, the following manufacturing processes are differentiated:

On the one hand there is forming without cutting and on the other, machining. With forming without cutting there is a further differentiation between cold and hot forming.

The following diagram is intended to make the production processes clearer:

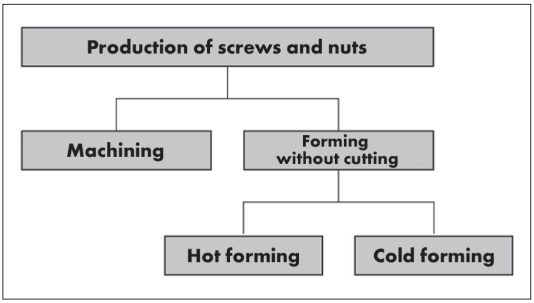


Fig. N: Overview of the various production processes

4.1.1 Cold forming (cold extrusion)

In modern fastening technology the majority of fasteners are made using the cold forming procedure. In this procedure, the fastener is formed, usually in multistage processes, by pressure forging, cold extrusion and reducing, or a combination of these procedures. The term solid or cold forming was coined for this type of production.

This procedure is usually used for large quantities, because, from an economic aspect, it is the most rational method.

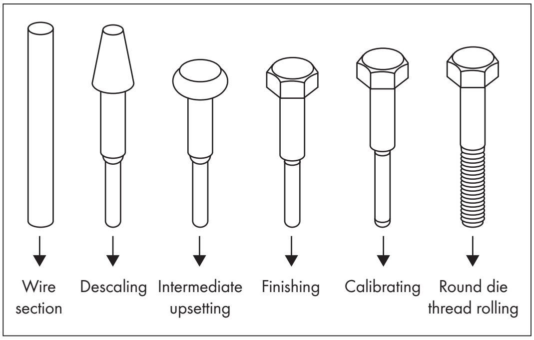
The choice of the suitable forming machine depends on the size of the fastener and on the degree of forming. The greater the degree of forming, the more forming stages are required. Sharp-edged transitions or thin profiles are unfavourable for cold forming and lead to increased tool wear.

A decisive role for the quality of the final product is played by the choice and the quality of the input material (wire). Screw manufacturers usually receive the wire coiled on rolls that often weigh over 1000 kg.

The wire is normally phosphate treated to enable the wire to be worked perfectly and to minimise tool wear.

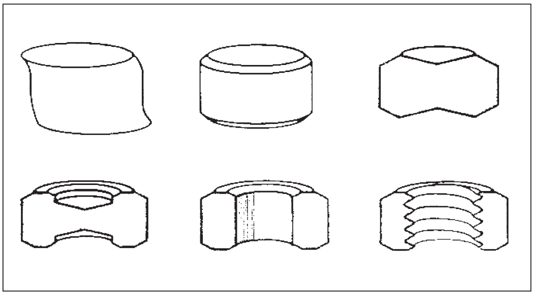
The designer of a screw or a fastener tries during development to harmonise the advantages and disadvantages of the different materials with the requirements specified for the fastener. With the materials differences are made, along with corrosion-resistant steels, between unalloyed and alloyed steels. For example, if increased strengths are required, it is absolutely essential to subject the parts after pressing to a heat treatment process in order to be able to influence the mechanical properties specifically.

Diagram of the stages for a hexagon head screw



Nuts are usually produced with the cold or hot forming procedure as well. The choice of one or the other procedure depends on the one hand on the size and on the other on the required quantities.

Diagram of the stages for a hexagonal nut



Advantages of cold forming:
- Optimal use of material
- Very high output
- High dimensional accuracy and surface quality
- Increase of strength properties through strain hardening
- Run of the chamfers in press parts in accordance with the load

4.1.2 Hot forming
This production method is used mainly to manufacture large diameters starting with approx. M27, and longer pieces starting from approx. 300 mm. In addition, parts are possible that cannot be produced using cold forming because of the very small volumes, or because of a very high degree of forming.

With this procedure, the input material (usually bars) is heated wholly or partially to forging temperature. This heating up enables even complicated geometries or very high degrees of forming to be realised. A typical feature for a hot-formed component is the raw surface structure. Strain hardening is not carried out during hot forming!

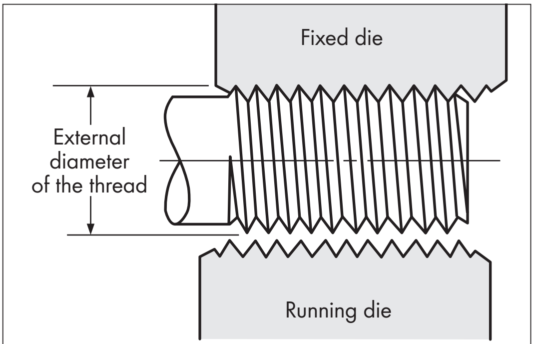
Advantages of hot forming:
- Enables production of complicated geometries
- Low production runs
- Large diameters and lengths

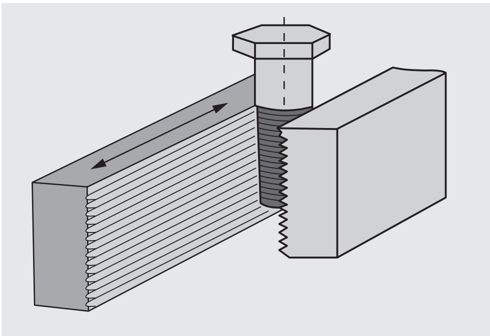
4.1.3 Machining
Machining is usually understood as processing steps such as turning, milling, grinding or reaming. The most common method with regard to fasteners is turning, but this has lost a great deal of importance because of the technical possibilities of cold pressing.

During turning, the required contour of the component is cut from the input material using a turning tool. The diameter of the input material depends on the largest diameter of the component. Usually, bars with a length of up to 6 m are used. In contrast to cold or hot forming, the chamfer course of the input material is destroyed.

This production procedure is used either if the production run is not very large or if the part geometry cannot be complied with in cold or hot forming procedures because of sharp edges, small radiuses or even nominal sizes. Surface roughnesses of Ra 0.4 or Rz 1.7 can be achieved with this production procedure without any problems. In the case of large production runs the blanks are often produced with the cold extrusion method and are then machined.

4.2 Thread production
Where screws are mass-produced, the thread is usually formed or rolled. In this procedure, the screw is rolled between two rolling dies (flat dies), one of which is fixed and the other running, and this creates the thread (see the diagram). With this type of thread production it is possible to fit several hundred screws per minute with a thread. The thread is usually applied before hardening and tempering. If special requirements mean that the thread is applied after the heat treatment process, the thread is referred to as “finally rolled”.





Other methods for making threads:

Plunge cutting

Tool rolls that are driven at the same speed rotate in the same direction. The workpiece rotates without being axially displaced. This method can be used to make threads with very high pitch accuracy.

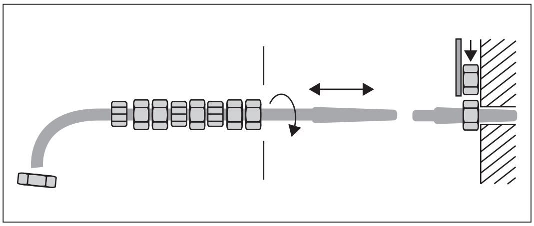
Continuous method

The thread pitch is generated by inclining the roller axes by the pitch angle. The workpiece is given an axial thrust and moves by one thread pitch in an axial direction, with a full rotation. Overlength threads can be made in this way.

Thread cutting

In this procedure the thread is made by means of a tap or a screw stock. With screws, this procedure is mainly used for very low production runs or with machined parts as well.

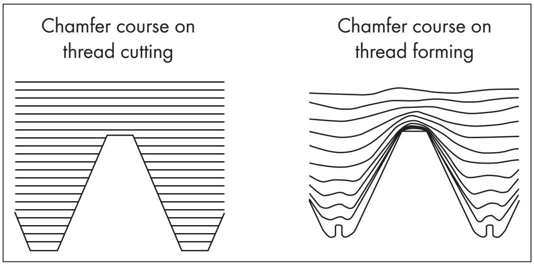
However, things are different when a female thread is made. In this case the thread is usually cut with a screw tap or taper tap.



Thread cutting on an automatic lathe with a taper tap

4.2.1 Fibre pattern

The two diagrams show very clearly the differences between a rolled and a cut thread. With thread forming the material is work hardened again in addition, and the fibre pattern is not interrupted. In this case, the original diameter of the screw is approximately the same as the flank diameter. With thread cutting, the original diameter of the screw is the same as the nominal diameter of the thread. The fibre pattern is interrupted by the cutting.



4.3 Heat treatment

4.3.1 Hardening and tempering

The combination "hardening" and subsequent "tempering" is referred to as hardening and tempering.

DIN EN ISO 898 Part 1 prescribes hardening and tempering for screws from strength class 8.8, and DIN EN 20898 Part 2 prescribes it for nuts in strength class 05 and 8 (>M16), and from strength class 10.

4.3.2 Hardening

The screw is heated to a specific temperature among other things in dependence on its carbon content and kept at this temperature for a long period. This changes the microstructure. A great increase in hardness is achieved through the subsequent quenching (water, oil, etc.).

4.3.3 Annealing
The glass-hard and therefore brittle material cannot be used in practice in this condition. The material must be heated up again to a minimum temperature specified in the standard, in order to reduce the distortions in the microstructure. It is true that this measure reduces the hardness that was reached beforehand (but this is much higher than the values of the untreated material), but greater ductility is achieved. This procedure is an important aid for manufacturers to make screws that satisfy the requirements demanded by users.

4.3.4 Case hardening
This procedure is used among other things for tapping screws, thread grooving and self-drilling screws. In this case, very hard surfaces are decisive, so that these screws are able to make their own thread automatically. The screw core, in contrast, is soft.

Steels with a carbon content of 0.05% to 0.2% are used for these types of screws. The steels are heated and kept for a long time in an atmosphere that gives off carbon (e.g. methane). The carbon diffuses into the surface zones and in this way increases the local carbon content. This process is known as carburisation. Finally, the material is quenched and in this way hardened in the surface zones. This has the advantage that the surface is very hard, but sufficient ductility remains in the core of the screw.

4.3.5 Stress relief annealing
There are a number of different annealing procedures which have different effects in each case on the microstructure and the states of stresses in the material. One very important procedure in the context of fasteners is stress relief annealing (heating to approx. 600 °C and maintaining this temperature for a long period). The strain hardening created on cold forming can be reversed by stress relief annealing. This is particularly important for screws in strength classes 4.6 and 5.6, because here there has to be a large elongation of the screw.

4.3.6 Tempering
Tempering is the thermal treatment of high strength components (strengths ≥1000 MPa or hardnesses ≥320 HV) with the aim of minimising the risk of hydrogen embrittlement. Tempering must be carried out at the latest 4 hours after the conclusion of the galvanic surface treatment. The minimum temperature depends on the strength classes or on the materials that are used.

5. SURFACE PROTECTION

5.1 Corrosion

About 4% of the gross national product of a western industrial nation is destroyed by corrosion.

About 25% of this could be avoided by applying existing knowledge.

Corrosion is the reaction of a metallic material with its environment that causes a measurable change to the material and may lead to an impairment of the function of a component or of a complete system. This reaction is usually of an electrochemical nature, but in some cases it may also be of a chemical or metal-physical nature.

We can also observe corrosion in our daily lives:

- Rust on vehicles, railings and fences
- Creeping destruction of road structures, bridges, build-ings
- Leaks in water pipelines and heating pipes made of steel

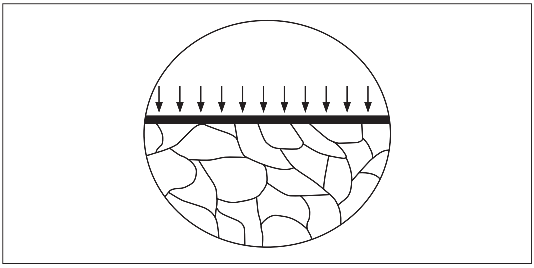
Corrosion is unavoidable – but the damage caused by corrosion can be avoided through the correct planning of suitable corrosion protection measures.

The corrosion system of a screw assembly should, under operating conditions, be at least as corrosion-resistant as the parts that are to be connected.

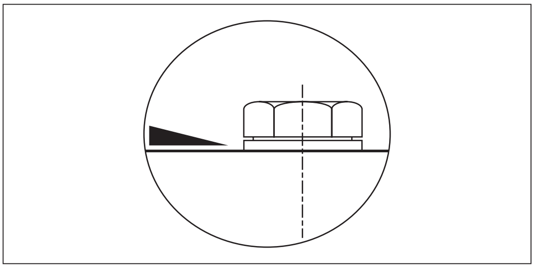
The design engineer's job is to decide on the necessary corrosion protection measures. Here, the wear reserve of a corrosion protection system and the ambient conditions have to be taken into account.

The ways in which corrosion manifests itself can vary greatly. (See DIN 50900 for corrosion types).

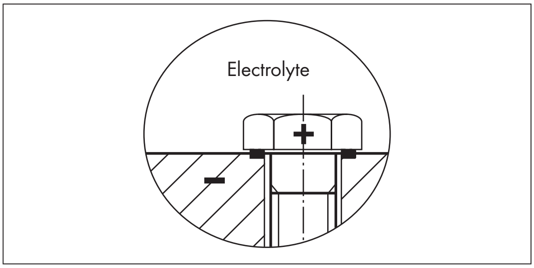
5.2 Corrosion types



Surface corrosion e.g. rust



Crevice corrosion



Contact corrosion

Corrosion rates, reference values in µm per year

Medium	Zincnon-chromated	Brass Ms 63	Copper CuNi 1.5 Si	Unalloyed steel unprotected
Country air	1–3	≤ 4	≤ 2	≤ 80
Urban air	≤ 6	≤ 4	≤ 2	≤ 270
Industrial air	6–20	≤ 8	≤ 4	≤ 170
Sea air	2–15	≤ 6	≤ 3	≤ 170

Tab. 1

5.3 Frequently used types of coatings for fasteners

5.3.1 Non-metallic coatings

Designation	Procedure	Application	Corrosion resistance
Rubbing with oil	Workpieces are immersed in oil	Bright steel parts Suitable for short-term corrosion protection e.g. during transport	Undefined
Burnishing	Workpieces are immersed in acid or alkaline solutions. Oxide layers with a (brown) black colour are created through reaction No layer development Purpose: formation of a weak protective layer on the surface No hydrogen embrittlement	Parts of weapons Gauges and measuring technology	Salt spray test approx. 0.5 h Corrosion protection oil can increase resistance
Phosphatising	Steel component in metal phosphate bath or chamber with metal phosphate solution 5–15 µm layer connected with the material Iron/manganese/nickel/zinc phosphate	Cold forming of steel Combination with corrosion protection media Reduction of wear on manganese phosphatising Primer for coat of lacquer (prevents rust creep)	Salt spray test: approx. 3 h Corrosion protection oil can increase resistance

Tab. 2

5.3.2 Metallic coatings

Designation	Procedure	Application	Corrosion resistance
Electro-galvanised	Metal deposition in the galvanic bath After treatment through passivation Optionally with sealing	In areas with low to average corrosion exposure, e.g. general mechanical engineering, electrical engineering – system-dependent thermal loadability 80°C–120°C	Corrosion resistance to 120 h against backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and dependent on the system)
Galvanic zinc alloy layer (zinc-iron) (zinc-nickel)	Metal deposition in the galvanic bath After treatment through passivation Optionally with sealing	In areas with extreme corrosion exposure – e.g. components in the engine compartment – or on brakes, where normal electro-plating is unable to cope not only because of the great heat but also because of the effect of salt in winter	Greatest cathodic corrosion protec-tion – even with layer thicknesses from 5 µm (important for fits) No voluminous corrosion products with zinc-nickel) Corrosion resistance to 720 h to backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and system-dependent)
Electro-nickel plated	Metal deposition in the galvanic bath Optionally with impregnation	In areas with very low corrosion exposure, e.g. decorative applications in interiors Component of a multilayer system e.g. copper-nickel-chromium	Because of its electrochemical properties with regard to steel nickel cannot take over the function of a reactive anode.

Designation	Procedure	Application	Corrosion resistance
Electro-chrome plated	Metal deposition in the galvanic bath Usually as a coating on a nickel-plated surface Thickness of the chromium layer usually between 0.2 µm and 0.5 µm	In areas with very low corrosion exposure, e.g. decorative applications in interiors Component of a multilayer system e.g. copper-nickel-chromium	Because of its electrochemical properties with regard to steel chromium cannot take over the function of a reactive anode.
Mechanically galvanised	Metal powder is hammered onto the components, glass beads are used as "impact material". Coating is carried out by means of a chemical medium, electricity is not used. Coating is carried out at room temperature.	Retaining washers, high-strength spring-mounted components (no risk of hydrogen induction during the coating process)	Corrosion resistance to 144 h against backing metal corrosion (red rust) in the salt spray test in accordance with DIN 50021 SS (ISO 9227) (layer thicknesses and system-dependent)
Hot-dip galvanising	Immersion in molten metal bath Min. layer thicknesses approx. 40 µm Process temperature approx. 450 °C Greater corrosion protection Not suitable for small screws Cathodic corrosion protection	Fasteners for steel construction. For example, HV kits. Applicable for fasteners ≥ M12	Corrosion resistance between 5 and 25 years depending on the environmental conditions

Tab. 3

5.3.3 Other coatings

Procedure	Explanations	Maximum application temperature
Veralising	Special hard nickel-plating.	
Brass coating	Brass coatings are used mainly for decorative purposes. Apart from this, steel parts are coated with brass to improve the adherence of rubber on steel.	
Copperplating	If necessary, as an intermediate layer before nickel-plating, chrome-plating and silver-plating. As a cover layer for decorative purposes.	
Silver-plating	Silver coatings are used for decorative and technical purposes.	
Tinning	Tinning is used mainly to achieve or improve soldering capability (soft solder). Serves at the same time as corrosion protection. Thermal after-treatment not possible.	
Anodising	A protective layer is generated in aluminium through anodic oxidation that works as corrosion protection and prevents staining. Nearly all colour shades can be achieved for decorative purposes.	
Ruspert	High-grade zinc-aluminium flake coating, can be produced in extremely different colours. Depending on the layer thickness 500 h or 1000 h in fog test (DIN 50021).	
Burnishing (blackening)	Chemical procedure. Bath temperature approx. 140 °C with subsequent oiling. For decorative purposes. Only slight corrosion protection.	
Blackening (stainless)	Chemical procedure. The corrosion resistance of A1 – A5 can be impaired by this. For decorative purposes. Not suitable for external application.	70 °C
Polyseal	Following a conventional immersion procedure a zinc-phosphate layer is applied at first. An organic protective layer is then applied that is precipitation-hardened at approx. 200 °C. Following this, a rust-protection oil is applied as well. This protective coating can be carried out in different colours (layer thickness approx. 12 µm).	
Impregnating	With nickel-plated parts above all, the micropores can be sealed with wax through after-treatment in dewatering fluid with added wax. Significant improvement of corrosion resistance. The wax film is dry, invisible.	

Tab. 4

5.4 Standardisation of galvanic corrosion protection systems

5.4.1 Designation system in accordance with DIN EN ISO 4042

The most common system for the abbreviated designation of galvanic surfaces on fasteners is the standard DIN EN ISO 4042. In the first place, this standard stipulates the dimensional requirements for fasteners made of steel and copper alloys that are to be given a galvanic coating. It stipulates layer thicknesses and provides recommendations for reducing the risk of hydrogen embrittlement in high-strength or very hard fasteners, or with surface-hardened fasteners.

DIN EN ISO 4042 does not differentiate between surface coatings containing chromium (VI) and those without chromium (VI).

Designation example

A surface designation must always consist of the code letter table A + code number table B + code letter table C

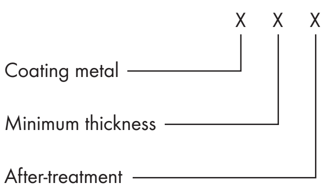


Table A Coating metal/alloy

Coating metal/alloy		Code letter
Abbreviation	**Element**	
Zn	Zinc	A
Cd	Cadmium	B
Cu	Copper	C
CuZn	Copper-zinc	D
Ni b	Nickel	E
Ni b Cr r	Nickel-chromium	F
CuNi b	Copper-nickel	G
CuNi b Cr r	Copper-nickel-chromium	H
Sn	Tin	J
CuSn	Copper-tin	K
Ag	Silver	L
CuAg	Copper-silver	N
ZnNi	Zinc-nickel	P
ZnCo	Zinc-cobalt	O
ZnFe	Zinc-iron	R

Tab. 5: Extract from ISO 4042

Table B layer thickness

Layer thickness in µm		Code no
One coating metal	**Two coating metals**	
No layer thickness prescribed	–	0
3	–	1
5	2+3	2
8	3+5	3
10	4+6	9
12	4+8	4
15	5+10	5
20	8+12	6
25	10+15	7
30	12+18	8

Tab. 6: Extract from ISO 4042

Table C Passivation/chromating

Gloss level	Passivation through chromating	Code letter
Matte	No colour	A
	Bluish to bluish iridescent	B
	Yellowish shimmering to yellow-brown iridescent	C
	Olive green to olive brown	D
Bright	No colour	E
	Bluish to bluish iridescent	F
	Yellowish shimmering to yellow-brown iridescent	G
	Olive green to olive brown	H
Glossy	No colour	J
	Bluish to bluish iridescent	K
	Yellowish shimmering to yellow-brown iridescent	L
	Olive green to olive brown	M

Gloss level	Passivation through chromating	Code letter
High gloss	No colour	N
Any	As B, C or D	P
Matte	Brown-Black to black	R
Bright	Brown-Black to black	S
Glossy	Brown-Black to black	T
All gloss levels	Without chromating	U

Tab. 7: Extract from ISO 4042

5.4.2 Reference values for corrosion resistances in the salt spray test DIN 50021 SS (ISO 9227)

Procedure group	Chromating designation	Inherent colour of the chromate layer	Designation in accordance with ISO 4042	Nominal layer thickness	White rust h	Red rust h
Passivation colourless	A	Transparent	A1A, A1E, A1J	3	2	12
			A2A, A2E, A2J	5	6	24
			A3A, A3E, A3J	8	6	48
Passivation blue	B	Blue iridescent	A1B, A1F, A1K	3	6	12
			A2B, A2F, A2K	5	12	36
			A3B, A3F, A3K	8	24	72
Chromating yellow	C	Yellow iridescent	A1C, A1G, A1L	3	24	24
			A2C, A2G, A2L	5	48	72
			A3C, A3G, A3L	8	72	120
Chromating olive	D	Olive green	A1D, A1H, A1M	3	24	24
			A2D, A2H, A2M	5	72	96
			A3D, A3H, A3M	8	96	144
Chromating black	BK	Sooty to black	A1R, A1S, A1T	3	12	36
			A2R, A2S, A2T	5	12	72
				8	24	96

Tab. 8

5.4.3 Designation system in accordance with DIN 50979

This standard applies to electroplated and Cr(VI)-free passivated zinc and zinc alloy coatings on ferrous materials. The zinc alloy coatings contain nickel or iron (zinc/nickel, zinc/iron) as the alloy components.

The main purpose of the coatings or coating systems is the corrosion protection of components made of ferrous materials.

This standard defines the designations for the coating systems that are shown below and stipulates minimum corrosion resistances in the described test procedures as well as the minimum layer thicknesses required for this.

5.4.4 Designation of the galvanic coatings

The galvanic coatings consist of zinc or zinc alloys

Abbreviation	Definition
Zn	Zinc coating without added alloy partner
ZnFe	Zinc alloy coating with a mass share of 0.3% to 1.0% iron
ZnNi	Zinc alloy coating with a mass share of 12% to 16% nickel

Tab. 9: Extract from DIN 50979

5.4.5 Passivation

Passivating means making conversion layers by treating with suitable Cr(VI) free solutions in order to improve the corrosion resistance of the coatings. Colouring is possible.

Passivation or procedure group	Abbreviation	Appearance of the surface	Notes
Transparent passivated	An	Colourless to coloured, iridescent	Frequently referred to as thin layer passivation
Iridescent passivated	Cn	Coloured iridescent	Frequently referred to as thick layer passivation
Black passivated	Fn	Black	

Tab. 10: Extract from DIN 50979

5.4.6 Sealings

Sealings increase corrosion resistance and usually have a layer thickness up to 2 µm. Sealings consist of Cr(VI)-free organic and/or inorganic compounds.

Products that can be removed with cold cleaners, e.g. on an oil, grease, wax basis, are not considered as sealings in the context of this standard. The influence of sealings on the functional properties of the component, such as, for example, transition resistance, weldability, compatibility with fuels, glued joints, is to be assessed on the basis of the component. In case of the special requirements for the surface functionality the use of the sealing and the type of sealant have to be agreed, because the band width of the possible surface modifications through sealings is large.

In most cases the sealings also eliminate the interference colours (iridescences) formed by passivating.

Abbreviation	Description
T0	Without sealing
T2	With sealing

Tab. 11: Extract from DIN 50979

5.4.7 Minimum layer thicknesses and test duration

Type of surface protective layer	Execution type	Procedure type	Without coating corrosion	Minimum test duration in h Without base material corrosion (in dependence on the Zn or Zn alloy layer thickness)		
				5 µm	8 µm	12 µm
Galv. zinc coating, transparent passivated	Zn//An//T0	Drum	8	48	72	96
		Frame	16	72	96	120
Galv. zinc coating, iridescent passivated	Zn//Cn//T0	Drum	72	144	216	288
		Frame	120	192	264	336
Galv. zinc coating, iridescent passivated and sealed	Zn//Cn//T2	Drum	120	192	264	360
		Frame	168	264	360	480
Galv. zinc iron alloy coating, iridescent passivated	ZnFe//Cn//T0	Drum	96	168	240	312
		Frame	168	240	312	384
Galv. zinc iron alloy coating, iridescent passivated and sealed	ZnFe//Cn//T2	Drum	144	216	288	384
		Frame	216	312	408	528
Galv. zinc nickel alloy coating, iridescent passivated	ZnNi//Cn//T0	Drum	120	480	720	720
		Frame	192	600	720	720
Galv. zinc nickel alloy coating, iridescent passivated and sealed	ZnNi//Cn//T2	Drum	168	600	720	720
		Frame	360	720	720	720
Galv. zinc iron alloy coating, black passivated and sealed	ZnFe//Fn//T2	Drum	120	192	264	360
		Frame	168	264	360	480
Galv. zinc nickel alloy coating, black passivated and sealed	ZnNi//Fn//T2	Drum	168	480	720	720
		Frame	240	600	720	720
Galv. zinc nickel alloy coating, black passivated	ZnNi//Fn//T0	Drum	48	480	720	720
		Frame	72	600	720	720

Tab. 12: Extract from DIN 50979

Designation examples:
Zinc/nickel alloy coating on a component made of steel (Fe), a thinnest local layer thickness of 8 µm (8) and iridescent passivated (Cn), without sealing (T0) Fe//ZnNi8//Cn//T0

Zinc/iron alloy coating on a component made of steel (Fe), a thinnest local layer thickness of 5 µm (5) and black passivated (Fn), with sealing (T2) Fe//ZnFe5//Fn//T2

5.5 Standardisation of non-electrolytically applied corrosion protection systems

5.5.1 Zinc flake systems

The parts that are to be coated are placed in a centrifuge basket and immersed in the coating medium. Part of the coating substance is thrown off through centrifugation. In this way a largely even layer is created. The coating is then burnt in a continuous furnace at 150 °C–300 °C (depends on the system). To obtain an even and covering layer it is necessary that the parts to be coated pass through two coating passes. Larger parts can also be coated by spraying the coating medium on.

This procedure is unsuitable for threaded parts ≤M6 and for fasteners with small internal drives or fine contours. Here, threads that are not true to gauge size and unusable internal drives must be reckoned with.

Zinc flake systems are suitable for coating high-strength components. If suitable cleaning procedures are used hydrogen inducement in the coating process is ruled out.

5.5.2 Standardisation of non-electrolytically applied corrosion protection systems

Designations in accordance with DIN EN ISO 10683

- **flZn-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, e.g. ZFSH, Geomet 500A, Geomet 321A, Dacromet 320A, Delta Tone/Seal
- **flZnL-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with integrated lubricant, e.g. Geomet 500A, Dacromet 500A
- **flZn-480h-TL** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with integrated lubricant in the top layer e.g. ZFSHL, Geomet 321A+VL, Dacromet 320A+VL
- **flZnnc-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, without chromate, e.g. ZFSH, Geomet 321A, Delta Protect, Delta Tone/Seal
- **flZnyc-480h** = zinc flake coating (flZn), corrosion resistance to RR 480 hours, with chromate, e.g. Dacromet 500A, Dacromet 320A

5.6 Standardisation of the hot-dip galvanising of screws in accordance with DIN EN ISO 10684

5.6.1 Procedure and area of application

Hot dip galvanising is a procedure in which the fasteners are immersed in a molten bath after suitable pre-treatment. Excessive zinc is then thrown off in a centrifuge in order to set the zinc layer thickness required for corrosion protection. Following this, the fasteners are usually cooled down in a water bath.

Hot dip galvanising is permissible to strength class 10.9. DIN EN ISO 10684 provides information for pre-treatment and galvanising processes that minimise the risk of brittle fractures. Further specifications, which are described in the technical guidelines of the Gemeinschaftsausschusses Verzinken e.V. (GAV) and of the Deutscher Schraubenverband e.V. (DSV), are required, in particular with screws in strength class 10.9. Only normal temperature galvanising should be applied above the thread size M24.

Corrosion resistances in accordance with DIN 50021 SS (ISO 9227) in dependence on the layer thickness

	Minimum values for the local layer thickness (if specified by buyer)	
Test duration in hours (salt spray test)	**Coating with chromate (flZnyc) µm**	**Coating without chromate (flZnnc) µm**
240	4	6
480	5	8
720	8	10
960	9	12
If the layer weight per unit of area in g/m² is specified by the buyer, it can be converted as follows into the layer thickness: • Coating with chromate: 4.5 g/m² corresponds to a thickness of 1 µm • Coating without chromate: 3.8 g/m² corresponds to a thickness of 1 µm		
The buyer may specify whether he wants to have a coating with chromate (flZnyc) or without chromate (flZnnc); in other cases the abbreviation flZn applies.		

Tab. 13: Extract from DIN EN ISO 10683

With female thread parts such as nuts, the thread is not cut until after galvanising.

The load bearing capacity of the paired threads can be reduced with thread sizes less than M12, because the zinc coating, with its thickness of at least 50 µm on average, leads to a reduction of thread overlapping.

5.6.2 Thread tolerances and designation system

Two different ways of proceeding have proved their worth for creating sufficient space for the quite thick coating when screws and nuts are paired. Starting from the zero line of the thread tolerance system, the space for the coating is placed either in the screw or in the nut thread. These methods may not be mixed. It is therefore very advisable to obtain hot-dip galvanised fasteners in a set. In the building industry this is in fact prescribed in standards.

Mixing the procedures 1 and 2 shown in table 15 leads either to a reduction of the connection's load bearing capability or to assembly problems .

5.7 Restriction on the use of hazardous substances

5.7.1 RoHS

Electrical and electronic equipment brought onto the market from 1 July 2006 may not contain any lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl (PBB) or polybrominated diphenyl ethers (PBDE).

Exceptions (among others)

- Lead as alloy element in steel up to 0.35% by weight
- Lead as alloy element in aluminium up to 0.4% by weight
- Lead as alloy element in copper alloys up to 4.0% by weight

Up to 0.1% by weight of the above-mentioned substances (cadmium 0.01% by weight) per homogeneous material is permissible.

	Nut thread tolerance	**Screw thread tolerance before galvanising**
Procedure 1	6AZ/6AX	6g/6h
Special marking	„Z" or „X"	None
Procedure 2	6H/6G	6az
Special marking	None	„U"

Tab. 14: Tolerance systems on pairing hot-dip galvanised screws and nuts

The special marking is to be applied after the strength class marking. In the order designation, the hot-dip galvanising is expressed by the notation "tZn".

Example:
Hexagon head screw ISO 4014 M12x80 - 8.8U – tZn

This concerns:
- Large and small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electric and electronic tools, with the exception of large-scale stationary industrial tools
- Toys
- Sports and leisure equipment
- Medical devices
- Monitoring and control instruments
- Automatic dispensers

5.7.2 ELV
End-of life vehicles directive
(up to 3.5 t gross vehicle weight)

Materials and components for vehicles brought onto the market from 1 July 2007 may not contain any lead, mercury, cadmium or hexavalent chromium.

Exceptions include
- Lead as alloy element in steel up to 0.35% by weight
- Hexavalent chromium in corrosion protection layers (to 01 July 2007)
- Lead as alloy element in copper alloys up to 4.0% by weight

Up to 0.1% by weight of the above-mentioned substances (cadmium 0.01% by weight) per homogeneous material is permissible, insofar as they are not added intentionally.

This concerns:
All vehicles with a gross vehicle weight not exceeding 3.5 t

5.8 Hydrogen embrittlement

With galvanically coated steel components with tensile strengths Rm ≥1000 Mpa or hardness ≥320 HV that are subject to tensile stress there is a risk of a hydrogen-induced brittle fracture.

Tempering the components immediately after the coating process contributes to minimising the risk. However, a complete elimination of the risk of brittle fractures cannot be guaranteed under the current state of the art. If the risk of a hydrogen-induced brittle fracture has to be reduced, alternative coating systems should be preferred.

Corrosion protection and coating systems should be selected for safety components that exclude the possibility of hydrogen inducement during coating through the procedure, e.g. mechanical galvanising and zinc flake coatings.

Users of fasteners are familiar with the respective purposes and the resulting requirements and must select the most suitable surface system themselves.

6. DIMENSIONING METRIC SCREW ASSEMBLIES

VDI guideline 2230, published in 2003, provides fundamental information on dimensioning, in particular of high-strength screw assemblies in engineering.

The calculation of a screw assembly starts from the operating force F_B that works on the joint from the outside. This operating force and the elastic deformations of the components that it causes bring about an axial operating force F_A, a shear force F_Q, a bending moment M_b and where applicable a torque M_T at the individual screw position.

When the necessary screw dimension is calculated mathematically, it must be taken into account, starting from the known load ratios, that a loss of preload force can occur through setting processes and temperature changes.

It must also be taken into account that, depending on the chosen assembly method and on the frictional conditions, the assembly preload force F_M can disperse in more or less wide limits.

An approximate dimensioning is often sufficient for an initial selection of the suitable screw dimension. Depending on the application, further criteria are then to be checked in accordance with VDI 2230.

6.1 Approximate calculation of the dimension or the strength classes of screws (in accordance with VDI 2230)

On the basis of the above-mentioned findings, the preselection of the screw is carried out in the first step in accordance with the following table.

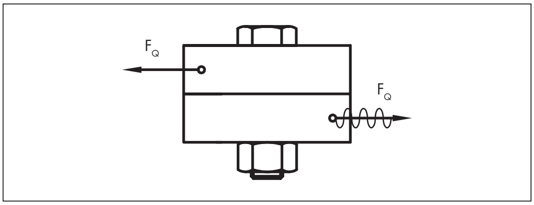
1	2	3	4
Force in N	**Nominal diameter in mm**		
	Strength class		
	12.9	**10.9**	**8.8**
250			
400			
630			
1.000	M3	M3	M3
1.600	M3	M3	M3
2.500	M3	M3	M4
4.000	M4	M4	M5
6.300	M4	M5	M6
10.000	M5	M6	M8
16.000	M6	M8	M10
25.000	M8	M10	M12
40.000	M10	M12	M14
63.000	M12	M14	M16
100.000	M16	M18	M20
160.000	M20	M22	M24
250.000	M24	M27	M30
400.000	M30	M33	M36
630.000	M36	M39	

Tab. 1

A From column 1 choose the next higher force to the one that acts on the joint. If the combined load (lengthwise and shear forces $F_{Amax} < F_{Qmax}/\mu_{Tmin}$) apply, only F_{Qmax} is to be used.

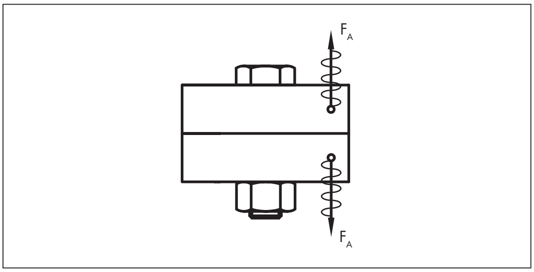
B The necessary minimum preload force F_{Mmin} is found by proceeding as follows from this figure:

B1 If the design has to use F_{Qmax}: four steps for static or dynamic shear force



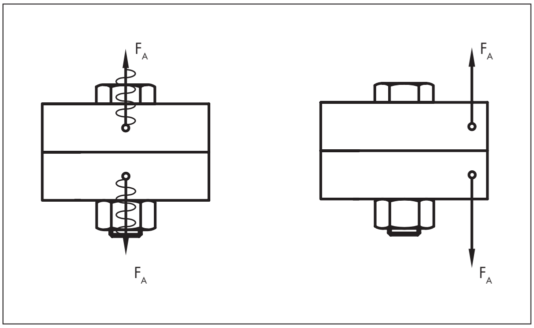
B2 If the design has to use F_{Amax}: 2 steps for dynamic and eccentric axial force

or



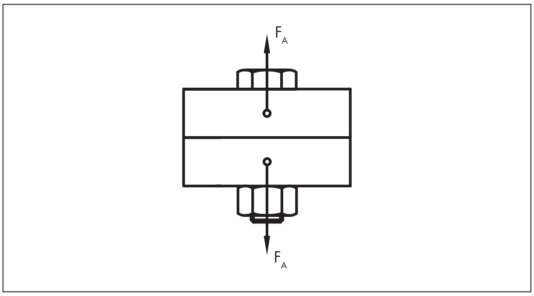
or

1 step for dynamic and concentric or static and eccentric axial force



or

0 steps for static and concentric axial force



C The required maximum preload force FMmax is found by proceeding from force FMmin with:
2 steps for tightening the screw with a simple screw-driver which is set for a tightening torque

or

1 step for tightening with a torque wrench or precision screwdriver, which is set by means of the dynamic torque measurement or elongation of the screw

or

0 steps for tightening by angle control in the plastic range or by computerised yield point control

D Next to the number that is found, the required screw dimension in mm for the appropriate strength class for the screw is found in columns 2 to 4.

Example:
A joint is subjected dynamically and eccentrically to an axial force of 9000 N (F_A).
The strength class was stipulated previously as strength class 10.9.
The installation is carried out using a torque wrench.
A 10.000 N is the next higher force in column 1 for the force F_A
B 2 additional steps because of eccentric and dynamic axial force
Reading: 25,000 N (= F_{Mmin})
C 1 additional step because of the tightening method using a torque wrench
Reading: 40,000 N (= F_{Mmax})
D The screw size M12 is now read in column 3 for strength class 10.9.

6.2 Choosing the tightening method and the mode of procedure

Tightening factor α_A (taking the tightening uncertainty into account)

All tightening methods are more or less accurate. This is caused by:

- the large range of distribution of the friction that actually occurs during installation (friction figures can only be estimated roughly for the calculation)
- differences in the manipulation with the torque wrench (e.g. fast or slow tightening of the screw)

Depending on whether the influences referred to above can be controlled. the tightening factor aA has to be selected.

A calculation is therefore made taking account of the tightening and setting method, as well as the coefficients of friction classes in accordance with the following table.

Reference values for the tightening factor α_A

<table>
<tr><th>Tightening factor α_A</th><th>Distribution</th><th>Tightening method</th><th>Setting method</th><th colspan="2">Notes</th></tr>
<tr><td>1.05 to 1.2</td><td>±2% to ±10%</td><td>Elongation-controlled tightening with ultrasound</td><td>Sound transmission time</td><td colspan="2">• Calibration values required
• With $l_K/d<2$ progressive fault increase to be noted
• Smaller fault with direct mechanical coupling, greater fault with indirect coupling</td></tr>
<tr><td>1.1 to 1.5</td><td>±5% to ±20%</td><td>Mechanical length measuring</td><td>Setting by means of elongation measurement</td><td colspan="2">• The exact determination of the screw's axial elastic flexibility is necessary. The distribution depends essentially on the accuracy of the measuring method.
• With $l_K/d<2$ progressive fault increase to be noted</td></tr>
<tr><td>1.2 to 1.4</td><td>±9% to ±17%</td><td>Yield strength controlled tightening, power-operated or manual</td><td>Input of the relative torque – angle of rotation coefficients</td><td colspan="2" rowspan="2">The preload force distribution is determined basically through the distribution of the yield point in the installed screw batch. The screws are dimensioned here for F_{Mmin}. A construction of the screws for F_{Mmax} with the tightening factor α_A is therefore not applicable for these tightening methods.</td></tr>
<tr><td>1.2 to 1.4</td><td>±9% to ±17%</td><td>Rotation angle controlled tightening, power-operated or manual</td><td>Experimental determination of preliminary torque and angle of rotation (stages)</td></tr>
<tr><td>1.2 to 1.6</td><td>±9% to ±23%</td><td>Hydraulic tightening</td><td>Setting by means of length or pressure measuring</td><td colspan="2">• Lower values for long screws ($l_K/d\geq5$)
• Higher values for short screws ($l_K/d\leq2$)</td></tr>
<tr><td>1.4 to 1.6</td><td>±17% to ±23%</td><td>Torque controlled tightening with torque wrench, torque signalling wrench or mechanical screw driver with dynamic torque measuring</td><td>Experimental determination of target torques at the original screw part, e.g. by means of elongation measurements of the screw</td><td>Lower values: large number of setting or control tests necessary (e.g. 20). Low distribution of the given torque (e.g. ±5%) necessary.</td><td rowspan="3">Lower values for:
low angle of rotation, i.e. relatively stiff connections
relatively low hardness of the counter-surface
Counter-surfaces that do not tend to “seize”, e.g. phosphated or with sufficient lubrication.
Higher values for:
large angle of rotation, i.e. relatively resilient connections and fine threads
Very hard counter-surfaces in combination with rough surface.</td></tr>
<tr><td>1.6 to 2.0 (coefficient of friction class B)</td><td>±23% to ±33%</td><td rowspan="2">Torque controlled tightening with torque wrench, torque signalling wrench or mechanical screw driver with dynamic torque measuring</td><td rowspan="2">Determining the target torques by estimating the coefficient of friction (surface- and lubrication ratios)</td><td rowspan="2">Lower values for:
measuring torque wrench on even tightening and for precision torque wrenches
Higher values for:
signalling or collapsing torque wrench</td></tr>
<tr><td>1.7 to 2.5 (coefficient of friction class A)</td><td>±26% to ±43%</td></tr>
<tr><td>2.5 to 4</td><td>±43% to ±60%</td><td>Tightening with impact or impulse screw driver</td><td>Setting the screws by means of the retightening torque, which comprises the target tightening torque (for the estimated coefficient of friction) and a supplement</td><td colspan="2">Lower values for:
• large number of setting tests (retightening torque)
• on the horizontal branch of the screw driver characteristics
• impulse transmission without play</td></tr>
</table>

Tab. 2

A different coefficient of friction "μ" has to be selected, depending on the surface and lubrication condition of the screws or nut coat. With the great number of surface and lubrication conditions it is often difficult to ascertain the correct coefficient of friction. If the coefficient of friction is not known exactly, the lowest probable coefficient of friction is to be reckoned with so that the screw is not overloaded.

6.3 Allocation of friction coefficients with reference values to different materials/surfaces and lubrication conditions in screw assemblies (in accordance with VDI 2230)

Coefficient of friction class	Range for μ_G and μ_K	Selection of typical examples for	
		Material/surface	**Lubricants**
A	0.04 to 0.10	Bright metal Black annealed Phosphate Galv. coatings such as Zn, Zn/Fe, Zn/Ni, zinc flake coatings	Solid lubricants such as MoS2, graphite, PTFE, PA, PE, PI in solid film lubricants, as top coats or in pastes; liquefied wax; wax dispersions
B	0.08 to 0.16	Bright metal Black annealed Phosphate Galv. coatings such as Zn, Zn/Fe, Zn/Ni, zinc flake coatings, Al and Mg alloys	Solid lubricants such as MoS2, graphite, PTFE, PA, PE, PI in solid film lubricants, as top coats or in pastes; liquefied wax; wax dispersions; greases, oils, delivery condition
		Hot dip galvanised	MoS_2; graphite; wax dispersions
		Organic coating	With integrated solid lubricant or wax dispersion
		Austenitic steel	Solid lubricants, waxes, pastes
C	0.14 to 0.24	Austenitic steel	Wax dispersions, pastes
		Bright metal, Phosphate	Delivery condition (lightly oiled)
		Galv. coatings such as Zn, Zn/Fe, Zn/Ni, zinc flake coatings, adhesive	None
D	0.20 to 0.35	Austenitic steel	Oil
		Galv. coatings such as Zn, Zn/Fe, hot-dip galvanised	None
E	≥ 0.30	Galv. coatings such as Zn/Fe, Zn/Ni, austenitic steel, Al, Mg alloys	None

Tab. 3

Coefficient of friction class B should be aimed for, so that the highest possible preload force with simultaneous low distribution can be applied. (The table applies to room temperature.)

6.4 Assembly preload forces F_{MTab} and tightening torques M_A with 90% utilisation of the screw yield strength R_{el} or 0.2% offset yield point $R_{p0.2}$ for set screws with metric standard thread in accordance with DIN ISO 262; head sizes of hexagon head screws in accordance with DIN EN ISO 4014 to 4018, screws with external hexalobular drive in accordance with DIN 34800 or socket cap screws in accordance with DIN EN ISO 4762 and "medium" bore in accordance with DIN EN 20 273 (in accordance with VDI 2230)

Standard thread

Size	Strength class	Assembly preload forces F_{MTab} in kN for μ_G =							Tightening torques M_A in Nm for $\mu_K = \mu_G$ =						
		0.08	0.10	0.12	0.14	0.16	0.20	0.24	0.08	0.10	0.12	0.14	0.16	0.20	0.24
M4	8.8	4.6	4.5	4.4	4.3	4.2	3.9	3.7	2.3	2.6	3.0	3.3	3.6	4.1	4.5
	10.9	6.8	6.7	6.5	6.3	6.1	5.7	5.4	3.3	3.9	4.6	4.8	5.3	6.0	6.6
	12.9	8.0	7.8	7.6	7.4	7.1	6.7	6.3	3.9	4.5	5.1	5.6	6.2	7.0	7.8
M5	8.8	7.6	7.4	7.2	7.0	6.8	6.4	6.0	4.4	5.2	5.9	6.5	7.1	8.1	9.0
	10.9	11.1	10.8	10.6	10.3	10.0	9.4	8.8	6.5	7.6	8.6	9.5	10.4	11.9	13.2
	12.9	13.0	12.7	12.4	12.0	11.7	11.0	10.3	7.6	8.9	10.0	11.2	12.2	14.0	15.5
M6	8.8	10.7	10.4	10.2	9.9	9.6	9.0	8.4	7.7	9.0	10.1	11.3	12.3	14.1	15.6
	10.9	15.7	15.3	14.9	14.5	14.1	13.2	12.4	11.3	13.2	14.9	16.5	18.0	20.7	22.9
	12.9	18.4	17.9	17.5	17.0	16.5	15.5	14.5	13.2	15.4	17.4	19.3	21.1	24.2	26.8
M7	8.8	15.5	15.1	14.8	14.4	14.0	13.1	12.3	12.6	14.8	16.8	18.7	20.5	23.6	26.2
	10.9	22.7	22.5	21.7	21.1	20.5	19.3	18.1	18.5	21.7	24.7	27.5	30.1	34.7	38.5
	12.9	26.6	26.0	25.4	24.7	24.0	22.6	21.2	21.6	25.4	28.9	32.2	35.2	40.6	45.1
M8	8.8	19.5	19.1	18.6	18.1	17.6	16.5	15.5	18.5	21.6	24.6	27.3	29.8	34.3	38.0
	10.9	28.7	28.0	27.3	26.6	25.8	24.3	22.7	27.2	31.8	36.1	40.1	43.8	50.3	55.8
	12.9	33.6	32.8	32.0	31.1	30.2	28.4	26.6	31.8	37.2	42.2	46.9	51.2	58.9	65.3
M10	8.8	31.0	30.3	29.6	28.8	27.9	26.3	24.7	36	43	48	54	59	68	75
	10.9	45.6	44.5	43.4	42.2	41.0	38.6	36.2	53	63	71	79	87	100	110
	12.9	53.3	52.1	50.8	49.4	48.0	45.2	42.4	62	73	83	93	101	116	129
M12	8.8	45.2	44.1	43.0	41.9	40.7	38.3	35.9	63	73	84	93	102	117	130
	10.9	66.3	64.8	63.2	61.5	59.8	56.3	52.8	92	108	123	137	149	172	191
	12.9	77.6	75.9	74.0	72.0	70.0	65.8	61.8	108	126	144	160	175	201	223
M14	8.8	62.0	60.6	59.1	57.5	55.9	52.6	49.3	100	117	133	148	162	187	207
	10.9	91.0	88.9	86.7	84.4	82.1	77.2	72.5	146	172	195	218	238	274	304
	12.9	106.5	104.1	101.5	98.8	96.0	90.4	84.8	171	201	229	255	279	321	356
M16	8.8	84.7	82.9	80.9	78.8	76.6	72.2	67.8	153	180	206	230	252	291	325
	10.9	124.4	121.7	118.8	115.7	112.6	106.1	99.6	224	264	302	338	370	428	477
	12.9	145.5	142.4	139.0	135.4	131.7	124.1	116.6	262	309	354	395	433	501	558
M18	8.8	107	104	102	99	96	91	85	220	259	295	329	360	415	462
	10.9	152	149	145	141	137	129	121	314	369	421	469	513	592	657
	12.9	178	174	170	165	160	151	142	367	432	492	549	601	692	769
M20	8.8	136	134	130	127	123	116	109	308	363	415	464	509	588	655
	10.9	194	190	186	181	176	166	156	438	517	592	661	725	838	933
	12.9	227	223	217	212	206	194	182	513	605	692	773	848	980	1,092
M22	8.8	170	166	162	158	154	145	137	417	495	567	634	697	808	901
	10.9	242	237	231	225	219	207	194	595	704	807	904	993	1,151	1,284
	12.9	283	277	271	264	257	242	228	696	824	945	1,057	1,162	1,347	1,502
M24	8.8	196	192	188	183	178	168	157	529	625	714	798	875	1,011	1,126
	10.9	280	274	267	260	253	239	224	754	890	1,017	1,136	1,246	1,440	1,604
	12.9	327	320	313	305	296	279	262	882	1,041	1,190	1,329	1,458	1,685	1,877
M27	8.8	257	252	246	240	234	220	207	772	915	1,050	1,176	1,292	1,498	1,672
	10.9	367	359	351	342	333	314	295	1,100	1,304	1,496	1,674	1,840	2,134	2,381
	12.9	429	420	410	400	389	367	345	1,287	1,526	1,750	1,959	2,153	2,497	2,787
M30	8.8	313	307	300	292	284	268	252	1,053	1,246	1,428	1,597	1,754	2,931	2,265
	10.9	446	437	427	416	405	382	359	1,500	1,775	2,033	2,274	2,498	2,893	3,226
	12.9	522	511	499	487	474	447	420	1,755	2,077	2,380	2,662	2,923	3,386	3,775
M33	8.8	389	381	373	363	354	334	314	1,415	1,679	1,928	2,161	2,377	2,759	3,081
	10.9	554	543	531	517	504	475	447	2,015	2,322	2,747	3,078	3,385	3,930	4,388
	12.9	649	635	621	605	589	556	523	2,358	2,799	3,214	3,601	3,961	4,598	5,135
M36	8.8	458	448	438	427	415	392	368	1,825	2,164	2,482	2,778	3,054	3,541	3,951
	10.9	652	638	623	608	591	558	524	2,600	3,082	3,535	3,957	4,349	5,043	5,627
	12.9	763	747	729	711	692	653	614	3,042	3,607	4,136	4,631	5,089	5,902	6,585
M39	8.8	548	537	525	512	498	470	443	2,348	2,791	3,208	3,597	3,958	4,598	5,137
	10.9	781	765	748	729	710	670	630	3,345	3,975	4,569	5,123	5,637	6,549	7,317
	12.9	914	895	875	853	831	784	738	3,914	4,652	5,346	5,994	6,596	7,664	8,562

Tab. 5

WÜRTH

Assembly preload forces F_{MTab} and tightening torques M_A with 90% utilisation of the screw yield strength R_{el} or 0.2% offset yield point $R_{p0.2}$ for **set screws** with **metric fine thread** in accordance with DIN ISO 262; head sizes of hexagon head screws in accordance with DIN EN ISO 4014 to 4018, screws with external hexalobular drive in accordance with DIN 34800 or socket cap screws in accordance with DIN EN ISO 4762 and "medium" bore in accordance with DIN EN 20 273 (in accordance with VDI 2230)

Fine thread

Size	Strength class	Assembly preload forces F_{MTab} in kN for μ_G =							Tightening torques M_A in Nm for $\mu_K = \mu_G$ =						
		0.08	**0.10**	**0.12**	**0.14**	**0.16**	**0.20**	**0.24**	**0.08**	**0.10**	**0.12**	**0.14**	**0.16**	**0.20**	**0.24**
M8 x 1	8.8	21.2	20.7	20.2	19.7	19.2	18.1	17.0	19.3	22.8	26.1	29.2	32.0	37.0	41.2
	10.9	31.1	30.4	29.7	28.9	28.1	26.5	24.9	28.4	33.5	38.3	42.8	47.0	54.3	60.5
	12.9	36.4	35.6	34.7	33.9	32.9	31.0	29.1	33.2	39.2	44.9	50.1	55.0	63.6	70.8
M9 x 1	8.8	27.7	27.2	26.5	25.9	25.2	23.7	22.3	28.0	33.2	38.1	42.6	46.9	54.4	60.7
	10.9	40.7	39.9	39.0	38.0	37.0	34.9	32.8	41.1	48.8	55.9	62.6	68.8	79.8	89.1
	12.9	47.7	46.7	45.6	44.4	43.3	40.8	38.4	48.1	57.0	65.4	73.3	80.6	93.4	104.3
M10 x 1	8.8	35.2	34.5	33.7	32.9	32.0	30.2	28.4	39	46	53	60	66	76	85
	10.9	51.7	50.6	49.5	48.3	47.0	44.4	41.7	57	68	78	88	97	112	125
	12.9	60.4	59.2	57.9	56.5	55.0	51.9	48.8	67	80	91	103	113	131	147
M10 x 1,25	8.8	33.1	32.4	31.6	30.8	29.9	28.2	26.5	38	44	51	57	62	72	80
	10.9	48.6	47.5	46.4	45.2	44.0	41.4	38.9	55	65	75	83	92	106	118
	12.9	56.8	55.6	54.3	52.9	51.4	48.5	45.5	65	76	87	98	107	124	138
M12 x 1,25	8.8	50.1	49.1	48.0	46.8	45.6	43.0	40.4	66	79	90	101	111	129	145
	10.9	73.6	72.1	70.5	68.7	66.9	63.2	59.4	97	116	133	149	164	190	212
	12.9	86.2	84.4	82.5	80.4	78.3	73.9	69.5	114	135	155	174	192	222	249
M12 x 1,5	8.8	47.6	46.6	45.5	44.3	43.1	40.6	38.2	64	76	87	97	107	123	137
	10.9	70.0	68.5	66.8	65.1	63.3	59.7	56.0	95	112	128	143	157	181	202
	12.9	81.9	80.1	78.2	76.2	74.1	69.8	65.6	111	131	150	167	183	212	236
M14 x 1,5	8.8	67.8	66.4	64.8	63.2	61.5	58.1	45.6	104	124	142	159	175	203	227
	10.9	99.5	97.5	95.2	92.9	90.4	85.3	80.2	153	182	209	234	257	299	333
	12.9	116.5	114.1	111.4	108.7	105.8	99.8	93.9	179	213	244	274	301	349	390
M16 x 1,5	8.8	91.4	89.6	87.6	85.5	83.2	78.6	74.0	159	189	218	244	269	314	351
	10.9	134.2	131.6	128.7	125.5	122.3	155.5	108.7	233	278	320	359	396	461	515
	12.9	157.1	154.0	150.6	146.9	143.1	135.1	127.2	273	325	374	420	463	539	603
M18 x 1,5	8.8	122	120	117	115	112	105	99	237	283	327	368	406	473	530
	10.9	174	171	167	163	159	150	141	337	403	465	523	578	674	755
	12.9	204	200	196	191	186	176	166	394	472	544	613	676	789	884
M18 x 2	8.8	114	112	109	107	104	98	92	229	271	311	348	383	444	495
	10.9	163	160	156	152	148	139	131	326	386	443	496	545	632	706
	12.9	191	187	182	178	173	163	153	381	452	519	581	638	740	826
M20 x 1,5	8.8	154	151	148	144	141	133	125	327	392	454	511	565	660	741
	10.9	219	215	211	206	200	190	179	466	558	646	728	804	940	1,055
	12.9	257	252	246	241	234	222	209	545	653	756	852	941	1,100	1,234
M22 x 1,5	8.8	189	186	182	178	173	164	154	440	529	613	692	765	896	1,006
	10.9	269	264	259	253	247	233	220	627	754	873	985	1,090	1,276	1,433
	12.9	315	309	303	296	289	273	257	734	882	1,022	1,153	1,275	1,493	1,677
M24 x 1,5	8.8	228	224	219	214	209	198	187	570	686	796	899	995	1,166	1,311
	10.9	325	319	312	305	298	282	266	811	977	1,133	1,280	1,417	1,661	1,867
	12.9	380	373	366	357	347	330	311	949	1,143	1,326	1,498	1,658	1,943	2,185
M24 x 2	8.8	217	213	209	204	198	187	177	557	666	769	865	955	1,114	1,248
	10.9	310	304	297	290	282	267	251	793	949	1,095	1,232	1,360	1,586	1,777
	12.9	362	355	348	339	331	312	294	928	1,110	1,282	1,442	1,591	1,856	2,080
M27 x 1,5	8.8	293	288	282	276	269	255	240	822	992	1,153	1,304	1,445	1,697	1,910
	10.9	418	410	402	393	383	363	342	1,171	1,413	1,643	1,858	2,059	2,417	2,720
	12.9	489	480	470	460	448	425	401	1,370	1,654	1,922	2,174	2,409	2,828	3,183

Size	Strength class	Assembly preload forces F_{MTab} in kN for μ_G =							Tightening torques M_A in Nm for $\mu_K = \mu_G$ =						
		0.08	0.10	0.12	0.14	0.16	0.20	0.24	0.08	0.10	0.12	0.14	0.16	0.20	0.24
M27 x 2	8.8	281	276	270	264	257	243	229	806	967	1,119	1,262	1,394	1,630	1,829
	10.9	400	393	384	375	366	346	326	1,149	1,378	1,594	1,797	1,986	2,322	2,605
	12.9	468	460	450	439	428	405	382	1,344	1,612	1,866	2,103	2,324	2,717	3,049
M30 x 2	8.8	353	347	339	331	323	306	288	1,116	1,343	1,556	1,756	1,943	2,276	2,557
	10.9	503	494	483	472	460	436	411	1,590	1,912	2,216	2,502	2,767	3,241	3,641
	12.9	588	578	565	552	539	510	481	1,861	2,238	2,594	2,927	3,238	3,793	4,261
M33 x 2	8.8	433	425	416	407	397	376	354	1,489	1,794	2,082	2,352	2,605	3,054	3,435
	10.9	617	606	593	580	565	535	505	2,120	2,555	2,965	3,350	3,710	4,350	4,892
	12.9	722	709	694	678	662	626	591	2,481	2,989	3,470	3,921	4,341	5,090	5,725
M36 x 2	8.8	521	512	502	490	478	453	427	1,943	2,345	2,725	3,082	3,415	4,010	4,513
	10.9	742	729	714	698	681	645	609	2,767	3,340	3,882	4,390	4,864	5,711	6,428
	12.9	869	853	836	817	797	755	712	3,238	3,908	4,542	5,137	5,692	6,683	7,522
M39 x 2	8.8	618	607	595	581	567	537	507	2,483	3,002	3,493	3,953	4,383	5,151	5,801
	10.9	880	864	847	828	808	765	722	3,537	4,276	4,974	5,631	6,243	7,336	8,263
	12.9	1,030	1,011	991	969	945	896	845	4,139	5,003	5,821	6,589	7,306	8,585	9,669

Tab. 6

6.5 Tightening torque and preload force of

- Safety screws with nuts
- Flange screws with nuts

With 90% utilisation of the screws' yield strength R_{el} or 0.2% offset yield point $R_{p0.2}$ (according to manufacturer's data)

	Counter material	Preload forces F_{Vmax} (N)							Tightening torque M_A (Nm)						
		M5	M6	M8	M10	M12	M14	M16	M5	M6	M8	M10	M12	M14	M16
Locking screws strength class 100 and nuts strength class 10	Steel Rm < 800 MPa	9,000	12,600	23,200	37,000	54,000	74,000	102,000	11	19	42	85	130	230	330
	Steel Rm = 800–1,100 MPa	9,000	12,600	23,200	37,000	54,000	74,000	102,000	10	18	37	80	120	215	310
	Gray cast iron	9,000	12,600	23,200	37,000	54,000	74,000	102,000	9	16	35	75	115	200	300

Reference values

6.6 Reference values for tightening torques for austenite screws in accordance with DIN EN ISO 3506

The following table shows the tightening torque required for an individual case in dependence on the nominal diameter, the coefficient of friction and the strength class (SC) as a reference value.

Coefficient of friction μ_{ges} 0.10

	Preload forces $F_{Vmax.}$ [KN]			Tightening torque M_A [Nm]		
	FK 50	FK 70	FK 80	FK 50	FK 70	FK80
M3	0.90	1.00	1.20	0.85	1.00	1.30
M4	1.08	2.97	3.96	0.80	1.70	2.30
M5	2.26	4.85	6.47	1.60	3.40	4.60
M6	3.2	6.85	9.13	2.80	5.90	8.00
M8	5.86	12.6	16.7	6.80	14.5	19.3
M10	9.32	20.0	26.6	13.7	30.0	39.4
M12	13.6	29.1	38.8	23.6	50.0	67.0
M14	18.7	40.0	53.3	37.1	79.0	106.0
M16	25.7	55.0	73.3	56.0	121.0	161.0
M18	32.2	69.0	92.0	81.0	174.0	232.0
M20	41.3	88.6	118.1	114.0	224.0	325.0
M22	50.0	107.0	143.0	148.0	318.0	424.0
M24	58.0	142.0	165.0	187.0	400.0	534.0
M27	75.0			275.0		
M30	91.0			374.0		
M33	114.0			506.0		
M36	135.0			651.0		
M39	162.0			842.0		

Coefficient of friction μ_{ges} 0.20

	Preload forces $F_{Vmax.}$ [KN]			Tightening torque M_A [Nm]		
	FK 50	FK 70	FK 80	FK 50	FK 70	FK 80
M3	0.60	0.65	0.95	1.00	1.10	1.60
M4	1.12	2.40	3.20	1.30	2.60	3.50
M5	1.83	3.93	5.24	2.40	5.10	6.90
M6	2.59	5.54	7.39	4.10	8.80	11.8
M8	4.75	10.2	13.6	10.1	21.4	28.7
M10	7.58	16.2	21.7	20.3	44.0	58.0
M12	11.1	23.7	31.6	34.8	74.0	100.0
M14	15.2	32.6	43.4	56.0	119.0	159.0
M16	20.9	44.9	59.8	86.0	183.0	245.0
M18	26.2	56.2	74.9	122.0	260.0	346.0
M20	33.8	72.4	96.5	173.0	370.0	494.0
M22	41.0	88.0	118.0	227.0	488.0	650.0
M24	47.0	101.0	135.0	284.0	608.0	810.0
M27	61.0			421.0		
M30	75.0			571.0		
M33	94.0			779.0		
M36	110.0			998.0		
M39	133.0			1.300		

Coefficient of friction μ_{ges} 0.30

	Preload forces $F_{Vmax.}$ [KN]			Tightening torque M_A [Nm]		
	FK 50	FK 70	FK 80	FK 50	FK 70	FK80
M3	0.40	0.45	0.70	1.25	1.35	1.85
M4	0.90	1.94	2.59	1.50	3.00	4.10
M5	1.49	3.19	4.25	2.80	6.10	8.00
M6	2.09	4.49	5.98	4.80	10.4	13.9
M8	3.85	8.85	11.0	11.9	25.5	33.9
M10	6.14	13.1	17.5	24.0	51.0	69.0
M12	9.00	19.2	25.6	41.0	88.0	117.0
M14	12.3	26.4	35.2	66.0	141.0	188.0
M16	17.0	36.4	48.6	102.0	218.0	291.0
M18	21.1	45.5	60.7	144.0	308.0	411.0
M20	27.4	58.7	78.3	205.0	439.0	586.0
M22	34.0	72.0	96.0	272.0	582.0	776.0
M24	39.0	83.0	110.0	338.0	724.0	966.0
M27	50.0			503.0		
M30	61.0			680.0		
M33	76.0			929.0		
M36	89.0			1.189		
M39	108.0			1.553		

Tab. 8

6.7 How to use the tables for preload forces and tightening torques!

The procedure is as follows:

A) Determining the total coefficient of friction $\mu_{ges.}$:

Different coefficients of friction "μ" have to be reckoned with, depending on the surface or lubrication condition of the screws or nuts. Table 3 in chapter 6 is used to make the selection.

Example:

Selecting the screw and nut with surface condition zinc galvanised transparent passivation, without lubricant:

μ_{ges} **= 0.14**

(Note: the lowest probable coefficient of friction is to be reckoned with for the dimensioning of the screw so that it is not overloaded)

B) Tightening torque M_A max.

The maximum tightening torque is found with 90% utilisation of the 0.2% offset yield point ($R_{p0.2}$) or of the yield point (R_{el}).

Example:

Hexagon head screw DIN 933, M12 x 50, strength class 8.8, galvanised, blue passivation:

In Table 5 in chapter 6 look in the column for $\mu_G = 0.14$ for the line for M12 with strength class 8.8.

Now read off the desired value

$M_{A\,max}$ **= 93 Nm**

from the section "Tightening torque MA [Nm]".

C) Tightening factor α_A (taking the tightening uncertainty into account)

All tightening methods are more or less accurate. This is caused by:

- The large range of distribution of the friction that actually occurs during installation (if friction figures can only be estimated roughly for the calculation)
- Differences in the manipulation with the torque wrench (e.g. fast or slow tightening of the screw)
- The distribution of the torque wrench itself.

Depending on how the above-mentioned influences are controlled, the tightening factor aA must be selected.

Example:

If a commercially available torque wrench with an electronic display is used, a tightening factor $\alpha_A = 1.4 – 1.6$ must be reckoned with.

The selection is:

$\alpha_A = 1.\ 4$ (see Table 2 in chapter 6 "Reference values for the tightening factor ...")

D) Preload force F_{Vmin}

Example:

In Table 5 in chapter 6 in column $\mu_G = 0.14$, line M12 and strength class 8.8 read off the value for the maximum preload force $F_{Vmax} = 41.9$ KN in the area "Assembly preload forces".

The minimum preload force F_{Vmin} is obtained by dividing F_{Vmax} by the tightening factor α_A.

$$\textbf{Preload force } F_{Vmin} = \frac{41.9 \text{ KN}}{1.4}$$

$$F_{Vmin} = 29.92 \text{ KN}$$

E) Control of the results

You should ask yourself the following questions!

- Is the residual clamping power sufficient?
- Is the minimum probable preload force F_{Vmin} sufficient for the maximum forces that occur in practice?

6.8 Pairing different element/contact corrosion

The following rule applies for preventing contact corrosion:

In each case fasteners must have at least the same corrosion resistance as the parts that are to be connected. If fasteners of equal value cannot be selected, they must be of higher value than the parts to be connected.

Pairing different fasteners/component materials with regard to contact corrosion

Fastener material/surface \ Component material/surface*	Stainless steel A2/A4	Aluminium	Copper	Brass	Steel, galvanised, black pass.	Steel, galvanised, yellow chromated	Steel, galvanised, blue pass.	Steel, bright
Stainless steel A2/A4	+++	+++	++	++	++	++	++	++
Aluminium	++	+++	++	++	+	+	+	+
Copper	+	+	+++	++	+	+	+	+
Brass	+	+	++	+++	+	+	+	+
Steel, galvanised, black passivated	–	–	–	–	+++	++	++	+
Steel, galvanised, yellow chromated	– –	– –	– –	– –	+	+++	++	+
Steel, galvanised, blue passivated	– –	– –	– –	– –	+	+	+++	+
Steel, bright	– – –	– – –	– – –	– – –	– –	– –	– –	+++

+++ Highly recommended pairing
++ Recommended pairing
+ Moderately recommended pairing
– Less recommended pairing
– – Not recommended pairing
– – – Pairing not recommended under any circumstances
* This assumption applies with a surface ratio (component ratio of fastener to the part to be connected) between 1:10 and 1:40.

Tab. 9

6.9 Static shearing forces for slotted spring pin connections

Slotted spring pins, heavy duty in accordance with ISO 8752 (DIN 1481)

Up to 8 mm nominal diameter

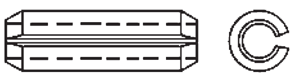


Fig. AU

Up to 10 mm nominal diameter

Fig. AV

Material:
Spring steel hardened from 420 to 560 HV

Nominal diameter [mm]		**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**6**	**8**	**10**	**12**	**13**	**14**	**16**	**18**	**20**
Shearing force min. [kN]	Single-shear	0.35	0.79	1.41	2.19	3.16	4.53	5.62	7.68	8.77	13	21.3	35	52	57.5	72.3	85.5	111.2	140.3
	Two-shear	0.7	1.58	2.82	4.38	6.32	9.06	11.2	15.4	17.5	26	42.7	70.1	104.1	115.1	144.1	171	222.5	280.6

Tab. 10

Spring-type straight pins, standard design in accordance with ISO 8750 (DIN 7343)

Fig. AW

Material:
Spring steel hardened
from 420 to 520 HV

Nominal diameter [mm]		**0.8**	**1**	**1.2**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**5**	**6**	**8**	**10**	**12**	**14**	**16**
Shearing force min. [kN]	Single-shear	0.21	0.3	0.45	0.73	1.29	1.94	2.76	3.77	4.93	7.64	11.05	19.6	31.12	44.85	61.62	76.02
	Two-shear	0.40	0.6	0.90	1.46	2.58	3.88	5.52	7.54	9.86	15.28	22.1	39.2	62.24	89.7	123.2	152

Tab. 11

Spring-type straight pins, coiled, heavy duty in accordance with ISO 8748 (DIN 7344)

Fig. AX

Material:
Spring steel hardened
from 420 to 520 HV

Nominal diameter [mm]		**1.5**	**2**	**2.5**	**3**	**4**	**5**	**6**
Shearing force min. [kN]	Single-shear	0.91	1.57	2.37	3.43	6.14	9.46	13.5
	Two-shear	1.82	3.14	4.74	6.86	12.2	18.9	27

Tab. 12

Spring-type straight pins, slotted, light duty in accordance with ISO 13337 (DIN 7346)

Up 8 mm nominal diameter

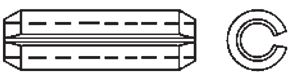


Fig. AY

Up to 10 mm nominal diameter

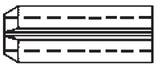


Fig. AZ

Material:
Spring steel hardened
from 420 to 560 HV

Nominal diameter [mm]		**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**6**	**7**	**8**	**10**	**11**	**12**	**13**	**14**	**16**	**18**	**20**
Shearing force min. [kN]	Single-shear	0.75	1.2	1.75	2.3	4	4.4	5.2	9	10.5	12	20	22	24	33	42	49	63	79
	Two-shear	1.5	2.4	3.5	4.6	8	8.8	10.4	18	21	24	40	44	48	66	84	98	126	158

Tab. 13

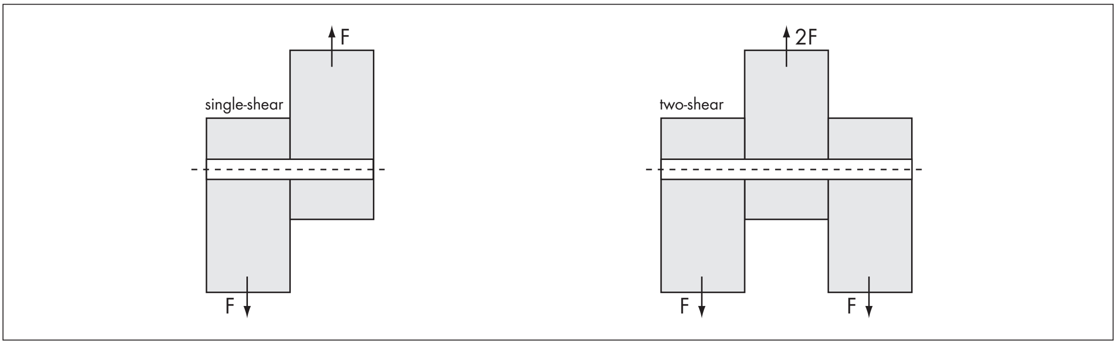


Fig. BA

6.10 Design recommendations for internal drives for screws

Technical progress and financial considerations are leading worldwide to an almost complete replacement of straight slot screws by internal drives.

AW drive

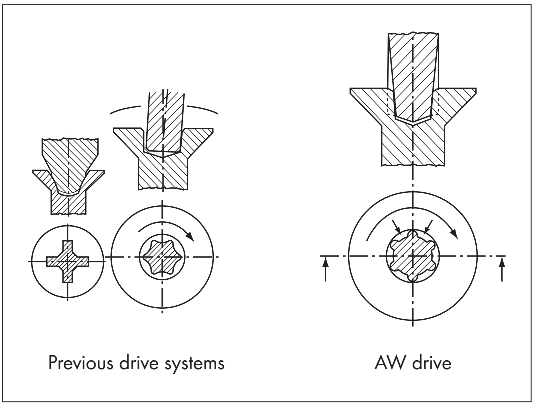


Fig. AR

AW drive system

Advantages with regard to previous drive systems:

- Improved force transmission by means of the conical multipoint head.
- Longer service life through optimal fit.
- Optimum centring through the conical course of the bit.
- Greatest possible bearing surface of the bit in the screw drive → comeout.
- Comeout = zero. The even force distribution prevents damage to the surface protective layer and thus guarantees greater corrosion resistance.

Hexagonal socket

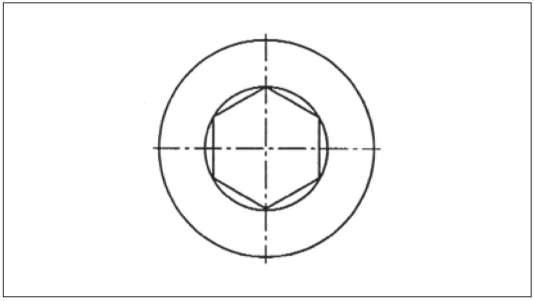


Fig. AS

Good force transmission through several points of application of force. Hexagonal socket-screws have smaller widths across flats than hexagon head screws, which also means more economic designs because of smaller dimensions.

Cross recess Z (pozi drive) in accordance with ISO 4757

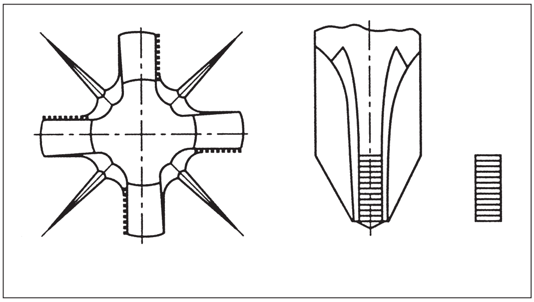


Fig. AT

The four "tightening walls" in the cross recess, with which the screwdriver is in contact when the screw is being screwed in, are vertical. The remaining walls and ribs are slanted. This can improve ease of assembly if the cross recesses are made optimally. Pozi drive screwdrivers have rectangular blade ends.

Cross recess H (Phillips) in accordance with ISO 4757

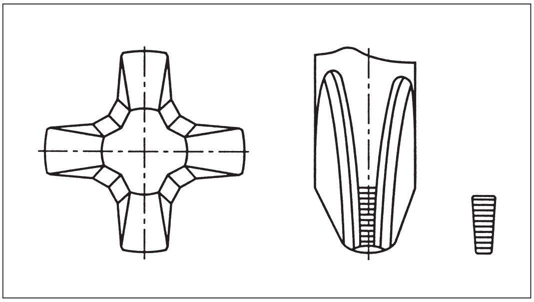


Fig. AU

Normal cross recess in which all walls and ribs are slanted, whereby the screwdriver has trapezoid blade ends.

6.11 Assembly

Torque method

The required preload force is generated by the measurable torque MV. The tightening appliance that is used (e.g. a torque wrench) must have uncertainty of less than 5%.

Angular momentum method

The connections are tightened with the help of an impulse or impact driver with an uncertainty of less than 5%. The tightening appliances are to be adjusted as far as possible to the original screw assembly in a suitable manner (e.g. retightening method or length measuring method).

Retightening method: the connection is tightened first of all with the screwdriver and then retightened/checked with a precision torque wrench. Length measuring method: the resulting lengthening of the screw is checked (measuring calliper), whereby the lengthening of the screw has to be calibrated beforehand on a screw test stand.

Angle of rotation method

Prerequisite is that the parts to be joined rest largely flat on each other. The pre-tightening torque is applied with one of the two methods described above. Mark the position of the nut relative to the screw shaft and component clearly and permanently, so that the subsequently applied further tightening angle of the nut can be determined easily. The required further tightening angle must be determined by means of a method test at the respective original screwed connections (e.g. by means of screw lengthening).

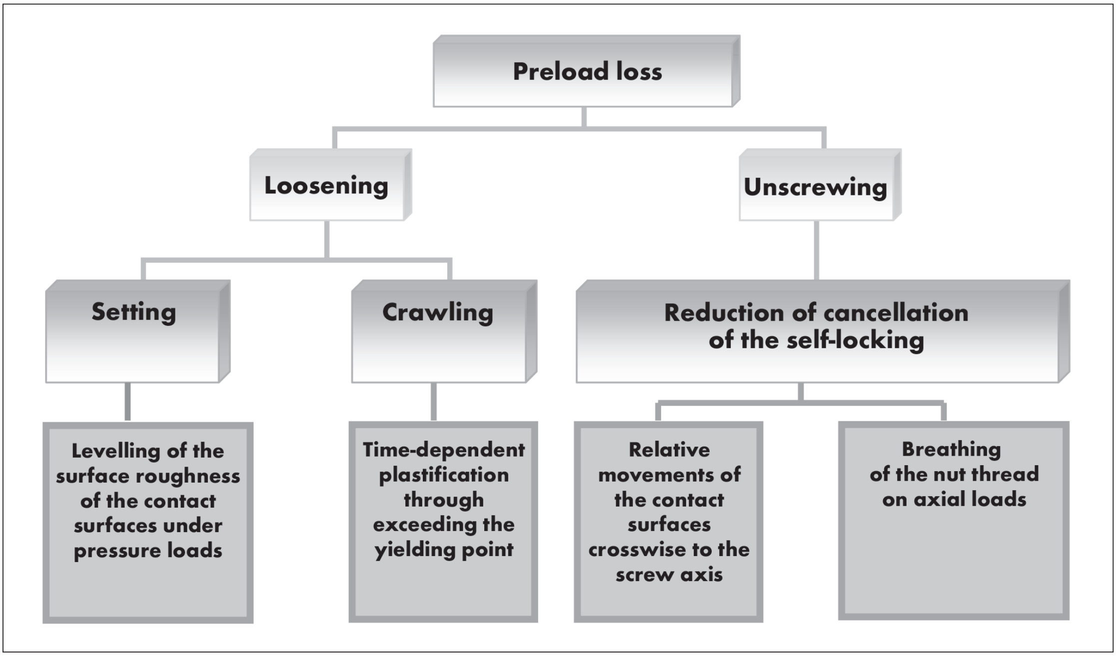
Fig. W

7. SECURING ELEMENTS

7.1 General

To select the right securing element it is necessary to consider the screw assembly as a whole. In particular, the hardness of the materials that are to be braced and any dynamic loads that may have an effect on the screw assembly must be considered when choosing a securing element.

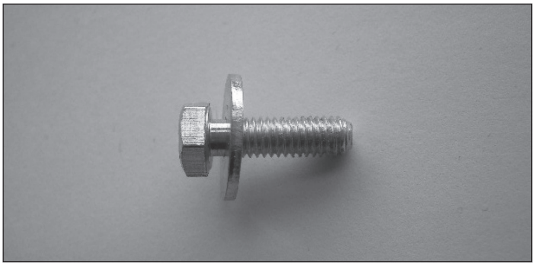
7.2 Causes of preload force loss



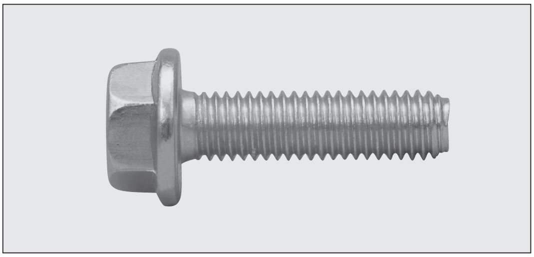
7.3 Methods of functioning

7.3.1 Securing against loosening

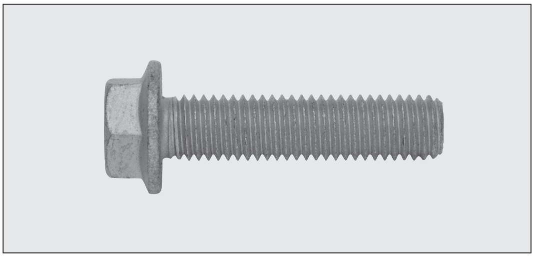
Screw assemblies can be prevented from loosening by means of suitable construction measures. This may mean using expansion screws or long screws, or increasing the preload force through screws with greater strength. In the latter case in particular, attention must be paid to the surface pressing on the support. A flanged screw, or moulding a suitable hard washer to the head, or using such a washer, reduces the surface pressure and prevents loosening.



Sems screw

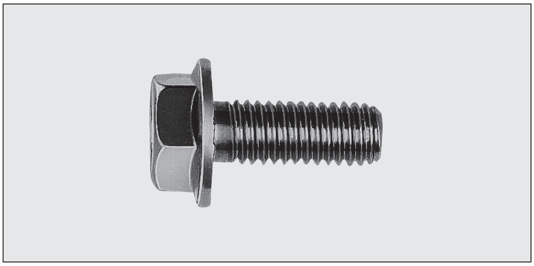


Flange screw



Lock screw

Ribbed washer



Self-locking screw with serrated bearing

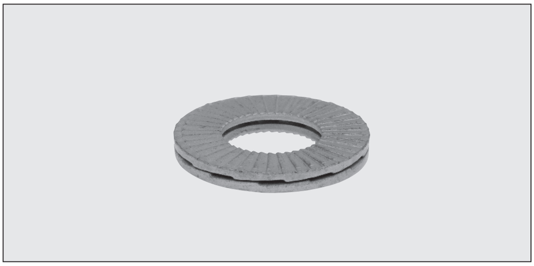
7.3.2 Securing against loosening

Loose-proof fasteners effectively prevent automatic unscrewing under the heaviest dynamic loads. With the exception of slight unavoidable setting amounts the preload force in the connection is retained. Retention methods to prevent unscrewing are divided into

- locking at the bearing
- bonding in the thread

Locking at the bearing takes place by means of the locking teeth that embed into the bearing material in the direction of unscrewing by means of tapered edges, or by means of symmetrical securing ribs that retain the preload force effectively on hard and soft materials.

With bonding in the thread it is possible to work with anaerobically bonding liquid plastic retention devices, or to use screws with micro-encapsulated adhesives. Screws with micro-encapsulated precoating are standardised in accordance with DIN 267/Part 27.



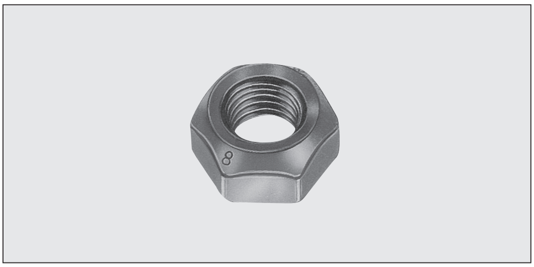
Disc-lock washer

Micro-encapsulation

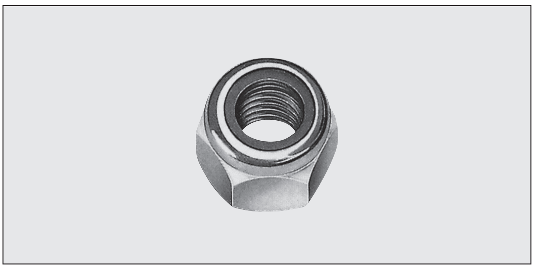
Liquid adhesives

7.3.3 Securing against loss

This group of securing devices comprises products that initially are unable to prevent automatic loosening, but after a more or less large preload force loss prevent complete unscrewing, so that the connection does not fall apart.



All-metal lock nut

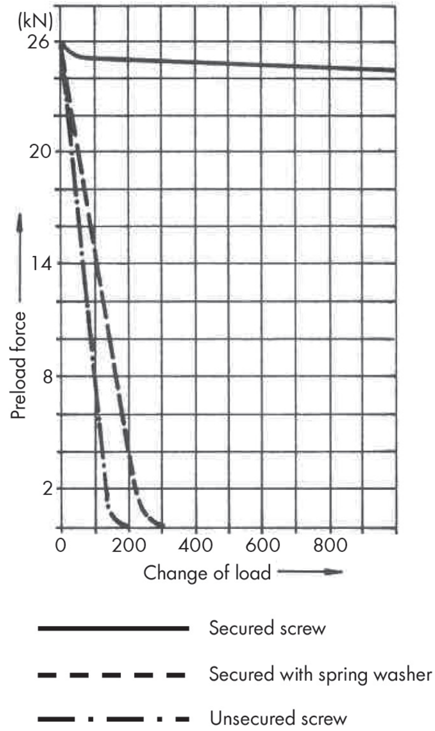


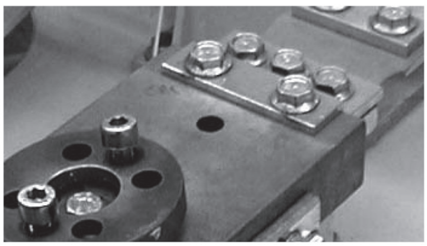
Lock nut with plastic ring

Optisert insert

7.4 How securing elements work

The action of a securing element can be tested on a vibration test stand (Junker test).





The test results in three categories.

7.4.1 Ineffective securing elements

The products listed below have no securing effect whatsoever, either with regard to loosening, or with regard to unscrewing. Use with screws in strength class ≥ 8.8 is not advised.

- Spring washers DIN 127, DIN 128, DIN 6905, DIN 7980
- Wave washers DIN 137, DIN 6904
- Toothed washers DIN 6797, DIN 6906
- Serrated lock washers DIN 6798, DIN 6907
- Tab washers with external tab or two tabs DIN 432, DIN 463
- Hex castle nuts DIN 935, DIN 937 with cotter pins DIN 94

7.4.2 Loss-proof fasteners

The category of loss-proof fasteners comprises products that initially are unable to prevent automatic loosening, but after an unspecified large preload force loss prevent complete unscrewing, so that the connection does not fall apart. This category includes, for example, nuts with a polyamide ring insert (lock nuts), all-metal lock nuts or screws with a thread clamping insert in accordance with DIN 267/Part 28.

7.4.3 Loose-proof fasteners

Loose-proof fasteners effectively prevent automatic unscrewing under the heaviest dynamic loads. With the exception of slight unavoidable setting amounts, the preload force in the connection is retained. Retention methods to prevent unscrewing are divided into

- locking at the bearing
- bonding in the thread

Locking at the bearing takes place by means of the locking teeth that embed into the bearing material in the direction of unscrewing by means of tapered edges, or by means of symmetrical securing ribs that retain the preload force effectively on hard and soft materials.

With bonding in the thread it is possible to work with anaerobically bonding liquid plastic retention devices, or to use screws with micro-encapsulated adhesives. Screws with micro-encapsulated pre-coating are standardised in accordance with DIN 267/Part 27.

7.5 Measures for securing screws

7.5.1 Loosening

Securing type	Functional principle	Securing element	Information on application		
Loose-proof			**Screws/nuts**	**Washers**	
			Strength class	**Hardness class**	
				200 HV	**300 HV**
	Reduce the surface pressure if braced together	Washer in accordance with DIN EN ISO 7089 DIN EN ISO 7090 DIN 7349 DIN EN ISO 7092 DIN EN ISO 7093-1	8.8/8 10.9/10 A2-70/A2-70	Yes No Yes	Yes Yes No
	Elastic if braced together	Heavy-duty locking washer in accordance with DIN 6796, profiled locking washer serrated contact washer	To reduce setting max. 20 µm elastic force has to be aligned to the preload force.		

Thread grooving screws also belong to the group of loss-proof fasteners.

7.5.2 Automatic unscrewing

Securing type	Functional principle	Securing element	Information on application
Unscrewing-proof	Blocking, in part braced together	Lock screw, lock nuts Profiled locking washers Tapered washer pair Ribbed washer Profile ring (material A2)	To be used where screw connections with high preload forces are exposed to changing transverse loads. Not on hardened surfaces. Hardness of the contact surface must be lower than that of the contact surface of the screw and nut and of the elements that are tightened. Securing elements are only effective if they are arranged directly under the screw head and the nut. For electrical applications.
	Adhesive	Micro-encapsulated adhesive in accordance with DIN 267-27	To be used where screw connections with high preload forces are exposed to changing transverse loads and hardened surfaces do not permit the use of locking fasteners. Temperature-dependent. Use with electrical applications not recommended. If adhesives are used the threads must not be lubricated.
		Liquid adhesive	The temperature limits for the adhesives that are used must be observed. Use with electrical applications not recommended. If adhesives are used the threads must not be lubricated.
Loss-proof	Clamping	Nuts with clamp DIN EN ISO 7040, DIN EN ISO 7042, Inserts DIN 8140 Screws with plastic coating in the thread in accordance with DIN 267-28	To be used where the primary aim of the screw assemblies is to retain a residual preload force and to secure the connection against falling apart. The temperature dependency must be noted for nuts and screws with a plastic insert. With electrical applications there may not be any chip formation through all-metal nuts.

8. STEEL STRUCTURES

8.1 HV connections for steel structures

„HV" is the marking of a screw assembly in steel constructions with high-strength screws in strength class 10.9. „H" stands here for high-strength, corresponding to the requirements for strength class 10.9 and „V" for „preloaded", i.e. the possibility to bring the connection to a defined preload force with standardised methods.

While it is true that in over 90% of steel construction connections preloading is not necessary for technical reasons, because the connections are not designed with friction grip, in such cases it is often usual and practical to pre-stress the connections, in order to close gaps, to increase the resistance against dynamic loads on parts or to limit the deformation of the total construction.

HV connections are therefore suitable without restriction for implementing all the following standard connections in steel construction.

Shear bearing connections (SL) transfer the force applied from the outside transverse to the screw axis through direct force transmission from the inner wall of the drill hole to the shaft of the screw (Fig. 1) The components affect the screw shaft like the blades of scissors. This type of connection can be preloaded (SLV) or implemented with dowel screws (SLP) or both (SLVP). Preloading the connection is necessary in particular with dynamic loads in the screw's lengthways axis.

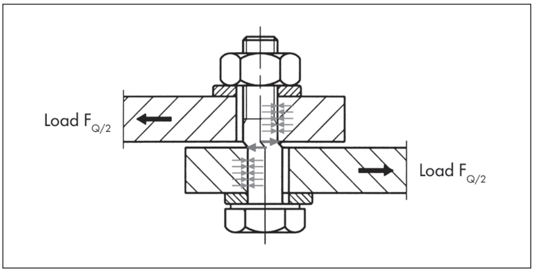


Fig. 1

The principle of operation of friction-grip preloaded connections (GV), which are used in individual cases, such as bridge building, including with screws with short threaded portions (GVP), is fundamentally different. Force transmission here takes place through friction between the contact surfaces of the preloaded components. For this purpose, the contact surfaces have to be made friction grip by blasting or by means of approved friction grip coatings. When the screw is tightened, the operating forces are transmitted vertically to the screw axis, as shown in Fig. 2.

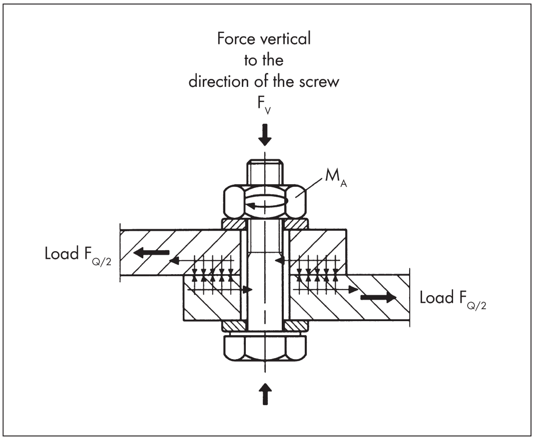


Fig. 2

Operating forces in the screw's lengthwise axis are of course permissible in all standard connections in steel construction and are accessible for verification of the strength by means of appropriate calculation formulae, for example, DIN 18800-1.

Würth HV sets have good, high-grade corrosion protection through hot-dip galvanising with a zinc layer thickness of 60–80 µm. In this way, long-term corrosion protection is achieved even in aggressive atmospheres. (Fig. 3).

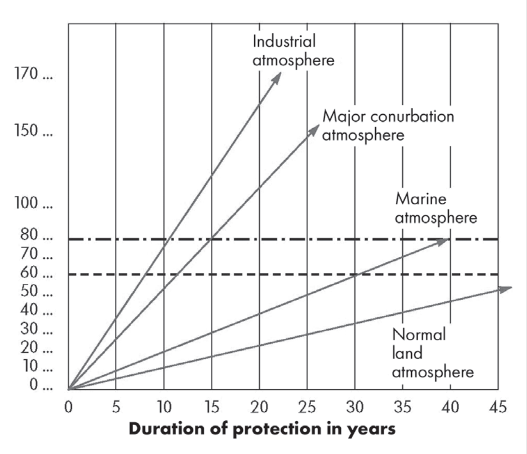


Fig. 3

The galvanising is carried out accordance with DIN EN ISO 10684, taking account of additional stipulations that conform to the state of the art on manufacturing hot-dip galvanised screws. The cutting of the nut thread and the lubrication of the nuts under process conditions are carried out after hot-dip galvanising, in order to ensure the thread's fit and to guarantee uniform tightening behaviour through special lubrication. The then unplated nut thread is corrosion protected after assembly by the zinc coating of the screw through cathodic corrosion protection. For this reason, only complete assemblies (screw, nut and washer) from **a single** manufacturer are to be used.

8.2 HV screws, nuts and washers

In the course of the changeover to the European Construction Products Directive, harmonised European standards were drawn up for fasteners in steel and metal construction that have replaced the previous German DIN standards to a great extent. The German standards have been retained only for ancillary products, such as HV square taper washers in accordance with DIN 6917 and DIN 6918. The procedure for verifying compliance in accordance with Building Rules List A continues to apply, i.e. the products are marketable with the so-called "Ü" sign (conformity sign). Table 1 provides an overview of the changeover of the standards.

	DIN	**DIN EN**
Calculation design	DIN 18 800-1	DIN EN 1993-1-8 DIN EN 1993-1-9
Execution	DIN 18 800-7	DIN EN 1090-2
Products	DIN 7968, DIN 7969 DIN 7990 DIN EN ISO 4014/4017 DIN 6914, DIN 6915, DIN 6916 DIN 7999	DIN EN 15048-1/-2 + tech. product specs. (DIN EN ISO 4014) DIN EN 14399-1/-2 DIN EN 14399-4 DIN EN 14399-6 DIN EN 14399-8

Tab. 1: Changeover to European standards

In future, DIN EN 1993-1-8 will apply to the calculation and design of joints, and DIN EN 1993-1-9 for the verification of fatigue, whereby the former DIN standards will continue to be applied during a transition period. DIN EN 1090-2 will apply in future to the execution, and there are transition periods here as well. The European standard DIN EN 15048 was created for non-preloaded, low-strength screwing assemblies and describes the procedure and the requirements for acquiring the CE mark. The appropriate technical descriptions for this may be, for example, the already existing standards for hexagon head screws such as DIN EN ISO 4014.

The harmonised standard DIN EN 14399 was drawn up for high-strength structural screwing assemblies. In Parts 1 and 2, this standard also describes the requirements and the procedure for acquiring the CE mark. In Europe, trade barriers may not exist or be established for products displaying the CE mark. The HV screws that are commonly used in Germany, and the appropriate nuts and washers, and HV fitting screws are found in Parts 4, 6, and 8 of this standard. The DIN pro-ducts were taken over to a great extent, so that there are only a few changes, and these will be discussed separately below.

- Under the European standard, HV nuts are always treated with a special lubricant, irrespective of the applied corrosion protection. Where the joints are preloaded in accordance with DIN 18800-7 with the help of the torque method, the same tightening torques are always applicable, which represents a simplification in comparison with the previous status.
- The screw grip lengths table contained in the standard defines the screw grip length **including the washers used** (Table 2a and 2b). In addition, the criteria

for calculating the screw grip length in accordance with the special requirements of DIN EN 1993-1-8 have been changed slightly, so that there are further minor differences. However, if a structure in accordance with DIN 18800 was planned, the planned DIN HV assemblies can be replaced by others with the same nominal length in accordance with the DIN EN standards without the necessity of a realignment of the screwed positions. The reason for this is the fact that DIN 18800 does not contain the above-mentioned special requirement in DIN EN 1993-1-8.

	Sizes for HV and HVP screws[1)]								
Nominal size		**M12**	**M16**	**M20**	**M22**	**M24**	**M27**	**M30**	**M36**
P[1)]		1.75	2	2.5	2.5	3	3	3.5	4
c	min.	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	max.	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8
d_a	max.	15.2	19.2	24	26	28	32	35	41
d_s	nom.	12	16	20	22	24	27	30	36
	min.	11.3	15.3	19.16	21.16	23.16	26.16	29.16	35
	max.	12.7	16.7	20.84	22.84	24.84	27.84	30	37
d_w[2)]	min.	20.1	24.9	29.5	33.3	38.0	42.8	46.6	55.9
e	min.	23.91	29.56	35.03	39.55	45.20	50.85	55.37	66.44
k	nom.	8	10	13	14	15	17	19	23
	min.	7.55	9.25	12.1	13.1	14.1	16.1	17.95	21.95
	max.	8.45	10.75	13.9	14.9	15.9	17.9	20.05	24.05
k_w	min.	5.28	6.47	8.47	9.17	9.87	11.27	12.56	15.36
r	min.	1.2	1.2	1.5	1.5	1.5	2	2	2
s	max.	22	27	32	36	41	46	50	60
	min.	21.16	26.16	31	35	40	45	49	58.8
h	nom.	3	4	4	4	4	5	5	6
	min.	2.7	3.7	3.7	3.7	3.7	4.4	4.4	5.4
	max.	3.3	4.3	4.3	4.3	4.3	5.6	5.6	6.6
m	nom. = max.	10	13	16	18	20	22	24	29
	min.	9.64	12.3	14.9	16.9	18.7	20.7	22.7	27.7

Note: sizes before galvanising apply for hot-dip galvanised screws, washers and nuts
1) P = thread pitch (standard thread)
2) $d_{w,max.} = s_{ist}$

Tab. 2a

	Screw grip length $\Sigma t_{min.}$ and $\Sigma t_{max.}$ for HV and HVP screws[1)]							
Nominal length l	**M12**	**M16**	**M20**	**M22**	**M24**	**M27**	**M30**	**M36**
30	11– 16							
35	16– 21	12– 17						
40	21– 26	17– 22						
45	26– 31	22– 27	18– 23					
50	31– 36	27– 32	23– 28	22– 27				
55	36– 41	32– 37	28– 33	27– 32				
60	41– 46	37– 42	33– 38	32– 37	29– 34			
65	46– 51	42– 47	38– 43	37– 42	34– 39			
70	51– 56	47– 52	43– 48	42– 47	39– 44	36– 41		
75	56– 61	52– 57	48– 53	47– 52	44– 49	41– 46	39– 44	
80	61– 66	57– 62	53– 58	52– 57	49– 54	46– 51	44– 49	
85	66– 71	62– 67	58– 63	57– 62	54– 59	51– 56	49– 54	43– 48
90	71– 76	67– 72	63– 68	62– 67	59– 64	56– 61	54– 59	48– 53
95	76– 81	72– 77	68– 73	67– 72	64– 69	61– 66	59– 64	53– 58
100	81– 86	77– 82	73– 78	72– 77	69– 74	66– 71	64– 69	58– 63
105	86– 91	82– 87	78– 83	77– 82	74– 79	71– 76	69– 74	63– 68
110	91– 96	87– 92	83– 88	82– 87	79– 84	76– 81	74– 79	68– 73
115	96–101	92– 97	88– 93	87– 92	84– 89	81– 86	79– 84	73– 78
120	101–106	97–102	93– 98	92– 97	89– 94	86– 91	84– 89	78– 83
125	106–111	102–107	98–103	97–102	94– 99	91– 96	89– 94	83– 88
130	111–116	107–112	103- 108	102–107	99–104	96–101	94– 99	88– 93
135	116–121	112–117	108–113	107–112	104–109	101–106	99–104	93– 98
140	121–126	117–122	113–118	112–117	109–114	106–111	104–109	98–103
145	126–131	122–127	118–123	117–122	114–119	111–116	109–114	103- 108
150	131–136	127–132	123–128	122–127	119–124	116–121	114–119	108–113
155	136–141	132–137	128–133	127–132	124–129	121–126	119–124	113–118
160	141–146	137–142	133–138	132–137	129–134	126–131	124–129	118–123
165	146–151	142–147	138–143	137–142	134–139	131–136	129–134	123–128
170	151–156	147–152	143–148	142–147	139–144	136–141	134–139	128–133
175	156–161	152–157	148–153	147–152	144–149	141–146	139–144	133–138
180	161–166	157–162	153–158	152–157	149–154	146–151	144–149	138–143
185			158–163	157–162	154–159	151–156	149–154	143–148
190			163–168	162–167	159–164	156–161	154–159	148–153
195			168–173	167–172	164–169	161–166	159–164	153–158
200			173–178	172–177	169–174	166–171	164–169	158–163
210			183–188	182–187	179–184	176–181	174–179	168–173
220			193–198	192–197	189–194	186–191	184–189	178–183
230			203–208	202–207	199–204	196–201	194–199	188–193
240			213–218	212–217	209–214	206–211	204–209	198–203
250			223–228	222–227	219–224	216–221	214–219	208–213
260			233–238	232–237	229–234	226–231	224–229	218–223

[1)] The screw grip length Σ_t comprises the two washers as well

Tab. 2b

All information is provided without guarantee or claim to completeness.

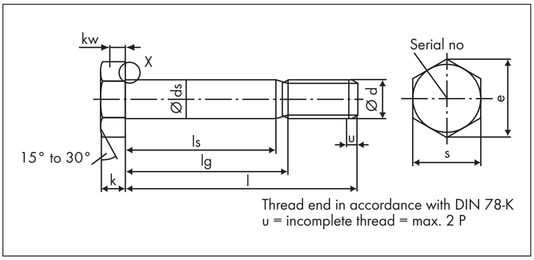


Fig. 4

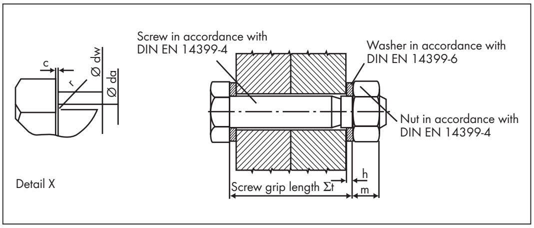


Fig. 5

8.3 Construction information and verifications for HV joints accordance with DIN 18800-1 and DIN EN 1993-1-8.

8.3.1 HV joints in accordance with DIN 18800-1 (2008)

The calculation values for the shearing stress V_a may not exceed the limit shear forces $V_{a,R,d}$ in accordance with DIN 18800-1:2008-11.

$\frac{V_a}{V_{a,R,d}} \leq 1$ The limit shear force $V_{a,R,d}$ is

$$V_{a,R,d} = A \cdot \tau_{a,R,d} = A \cdot \alpha_a \cdot \frac{f_{u,b,k}}{\gamma_M}$$

A Shaft cross-section A_{sch}, when the smooth shaft is in the shear joint.
Tension cross-section A_{Sp}, when the threaded part of the shaft is in the shear joint.

α_a 0.55 for HV screws in strength class 10.9, when the smooth shaft is in the shear joint.
0.44 for HV screws in strength class 10.9, when the threaded part of the shaft is in the shear joint.

$f_{u,b,k}$ Characteristic tensile strength of the screw material, for HV screws:
1000 N/mm²

γ_M = 1.1 part safety coefficient for the resistance

In accordance with DIN 18800-1:2008-11 the calculation values for the hole face loads V_l may not exceed the limit hole face forces $V_{l,R,d}$.

$$\frac{V_l}{V_{l,R,d}} \leq 1$$

The limit hole face force $V_{l,R,d}$ is

$$V_{l,R,d} = t \cdot d_{Sch} \cdot \sigma_{l,R,d}$$

$$= t \cdot d_{Sch} \cdot \alpha_l \cdot \frac{f_{z,k}}{\gamma_M}$$

With t thickness of the component

d_{Sch} Shaft diameter of the screw

α_l Factor for determining the hole face endurance, depending on the hole pattern

$f_{y,k}$ Characteristic yield point of the component material

γ_M = 1.1 part safety coefficient for the resistance

Factor α_l depends here on the geometry of the completed screwed connection, in particular on the distances of the screws from the edges of the components and from each other. Tables or appropriate software are usually available for calculation purposes.

DIN 18800-1 differentiates cases for the calculation of the limit tensile force under the pure tensile load on the screws. Because of the yield point ratios of strength class 10.9, the failure in the thread is decisive for HV screws. The limit tensile force is therefore calculated as:

$$N_{R,d} = \frac{A_{Sp} \cdot f_{u,b,k}}{1.25 \cdot \gamma_M}$$

A_{Sp} Tension cross-section

$f_{u,b,k}$ for FK 10.9 = 1,000 N/mm²

1.25 = Coefficient for the increased security against tensile strength

γ_M = 1.1

If a tensile force and a shear force affect a screw simultaneously, interaction verification has to be carried out in accordance with the requirements of DIN 18800-1.

With friction-grip connections (GV and GVP), the loads V_g may not exceed the boundary sliding forces $V_{g,R,d}$ in the boundary state of usability

$$\frac{V_g}{V_{g,R,d}} \leq 1$$

8.3.2 HV joints in accordance with DIN EN 1993-1-8

The European standard classifies the screw assemblies in accordance with Table 3 and makes a fundamental difference depending on the direction of the external force.

Shear/bearing resistant and friction-grip connections			
Category	**Remarks**	**Compared with DIN 18800-1**	
		GdG	**GdT**
A Shear/bearing connection	No preloading necessary, but in most cases an advantage, strength classes 4.6 to 10.9	SL or SLP	SL or SLP
B Friction-grip connection (GdG)	High-strength screws SC 8.8 or 10.9 preloaded	GV or GVP	SL or SLP
C Friction-grip connection (GdT)	High-strength screws SC 8.8 or 10.9 preloaded.	GV or GVP	GV or GVP (net)
Tensile loaded connections			
Category	**Remarks**	**Compared with DIN 18800-1**	
D Not preloaded	No preloading necessary, strength classes 4.6 to 10.9	Not classified, but verification criterion indicated	
E Preloaded	High-strength screws SC 8.8 or 10.9		

Tab. 3

The boundary sliding force $V_{g,R,d}$ is

$$V_{g,R,d} = \frac{\mu \cdot F_v}{(1.15 \cdot \gamma_M)},$$ if no external tensile force acts on the HV screw,

$$V_{g,R,d} = \frac{\mu \cdot F_v \cdot (1 - \frac{N}{F_v})}{(1.15 \cdot \gamma_M)},$$ if an external tensile force acts on the HV screw,

whereby:

μ is the coefficient of friction after pre-treatment of the friction surfaces in accordance with DIN 18800-7

F_v is the preload force in accordance with DIN 18800-7

N is the tensile force falling pro rate on the screw

$\gamma_M = 1.0$

In addition, interaction verification has to be carried out for GV and GVP connections in the same way as for SL and SLP connections.

The verification of bearing stress differs here in the approach from the procedure in accordance with DIN 18800-1 so that transmission of calculation results or table values is not possible. In this case, recalculation in accordance with the requirements of DIN EN 1993-1-8 is necessary. In many cases, the stress resistance in accordance with EN is greater than in accordance with DIN.

Verification of shearing off of the screws in accordance with EN differs only slightly and has a similar structure from the theoretical aspect. If the shaft is in the shear joint the stress resistances are approximately the same. If the thread is in the shear joint they are the same.

In the case of HV screws under tensile load in the screw's lengthwise axis the calculation approach hardly differs at all from that in the DIN standard and the results are approximately the same.

In the simple case of friction-grip connections without external tensile load the approaches in accordance with DIN and EN are also similar; however, a significant difference has to be mentioned at this point that also has effects on the applicable preloading method.

DIN EN 1993-1-8 stipulates a higher preload force level for friction-grip connections (and only for these) than is usual for preloaded HV joints in accordance with DIN 18800-7. The preload force should amount to 70% of the tensile strength of the screw:

$F_{p,C} = 0.7\ f_{ub}\ A_S$

Because of friction distributions, this preload force level is no longer reliably achievable with the torque method, so that alternative methods have to be applied that reduce the influence of the friction.

However, a lower preload force level Fp,C* is permissible for all screw assemblies that are not friction-grip calculated and are to be preloaded for other reasons, for example to increase the fatigue resistance. For example, this can be the preload force level in accordance with DIN 18800-7.

$F_{p,C}{}^* = 0.7\ f_{yb}\ A_S$

That is, the preload force amounts to 70% of the screw yield point. This means that all preloaded screw assemblies in accordance with DIN EN 1993-1-8 that are not friction-grip preloaded may be preloaded with the standard torque method for screw assemblies. The assembly values may be taken from DIN 18800-7 and are shown in chapter 8.4.

8.4 Assembly

8.4.1 Assembly and test in accordance with DIN 18 800-7

The torque method is to be used preferably for preloading. The standard preload force in accordance with Table 4 corresponds to 70% of the screw yield point and is therefore generated by applying a tightening torque M_A.

The tightening torque is the same here for all surface conditions of the fasteners.

Screw assemblies that were preloaded with the help of the torque method are accessible very easily for a check by applying a test torque that is 10% greater than the tightening torque.

Dimensions		**Standard preload force F_V [kN] (corresponds to $F_{p,C}{}^* = 0.7 \times f_{yb} \cdot A_S$)**	**Torque method**
			Applicable tightening torque M_A for achieving the standard preload force F_V [Nm]
			Surface condition: hot-dip galvanised and lubricated[a] and as manufactured and lubricated[a]
1	M12	50	100
2	M16	100	250
3	M20	160	450
4	M22	190	650
5	M24	220	800
6	M27	290	1250
7	M30	350	1650
8	M36	510	2800

[a] Nuts treated in the delivery condition by the manufacturer with molybdenum sulphide or similar lubricant. In contrast to earlier rules, the tightening torque is always the same irrespective of the delivery condition.

Tab. 4: Preloading through torque

Measures for checking are not required for connections that are not systematically preloaded. In the case of connections that are preloaded systematically at least 10% of the assemblies for the connection are tested in the case of connections that are not mainly loaded at rest, and at least 5% of the assemblies for the connection with connections that are mainly loaded at rest (with connections with less than 20 screws at least 2 connections, or 1 connection). The assembly is to be checked after the marking (situation of the nut relative to the screw shaft) from the side from which tightening took place.

The procedure in Table 5 that is used depends on the further rotation angles that occur during the test. If an unequivocal test is not possible (other methods used), the operation must be monitored for at least 10% of the connections. If deviations from the defaults specified in the respective method test are found, following corrections the complete execution of the whole connection must be monitored.

Checking the preload force with standard preload forces

Further angle of rotation	Evaluation	Measure
< 30°	Preload force was sufficient	None
30° to 60°	Preload force was conditionally sufficient	Leave the assembly and test two adjoining connections in the same joint
> 60°	Preload force was not sufficient	Change the assembly[1] and test two adjoining connections in the same joint
[1] These checked fasteners may only be left in the construction with SLV or SLVP connections that are loaded mainly at rest without additional tensile loads.		

Tab. 5

Other methods referred to in the standard are the momentum method, the angle of rotation method and a combined method, which are only mentioned here because they are seldom used. If necessary, the wording of the standard is to be used.

8.4.2 Assembly in accordance with DIN EN 1090-2

With all preloaded connections that are not designed friction-proof the preload force is 70% of the screw yield point and thus the torque method in accordance with DIN 18800-7 is applicable in conformity with the EN without restriction. In the cases in which the connection is designed friction-proof, a preload force to:

$F_{p,C} = 0.7\ f_{ub}\ A_S$

is stipulated in accordance with DIN EN 1993-1-8. This makes it necessary to apply other methods, whereby the combined method appears practicable here. The connections are tightened here with a pre-tightening torque that is recommended by the screw manufacturer or can be estimated with

$M_{r,1} = 0.13\ d\ F_{p,C}$

if there is no recommendation from the manufacturer. After this the connections are then tightened by the further angle of rotation stipulated in the standard. Table 6 indicates the tightening parameters for the combined method in accordance with DIN EN 1090-2.

8.5 Special information for using HV assemblies

- When stored, HV screws, nuts and washers must be protected from corrosion and dirt.
- If preloading is carried out by turning the screw head, a suitable lubricant must be applied to the head and a method test carried out.
- If a preloaded assembly is unscrewed subsequently it must be dismantled and replaced with a new one.
- After tightening, the screw thread should usually project over the nut by a complete turn of a thread.
- Up to 3 washers with a total thickness of 12 mm are permissible on the side of the assembly that is not turned to compensate for the screw grip length.

Combined method									
Dimensions		M12	M16	M20	M22	M24	M27	M30	M36
Preload force $F_{p,C} = 0.7 \cdot f_{ub} \cdot A_S$ [kN]		59	110	172	212	247	321	393	572
Pretightening torque M_A [Nm][1)]		75	190	340	490	600	940	1240	2100
	Further angle of rotation or revolution dimension for screw grip length Σt								
	Total nominal thickness "t" of the parts to be joined (including all lining plates and washers) d = screw diameter			Further angle of rotation			Further revolution dimension		
1	t < 2d			60			1/6		
2	2d ≤ t ≤ 6d			90			1/4		
3	6d ≤ t ≤ 10d			120			1/3		

Note: If the surface under the screw head or the nut (taking account of any square taper washers that are used as well) is not vertical to the screw axis, the necessary further angle of rotation should be determined in experiments.

[1)] Example of manufacturer's recommendation

Tab. 6: Preloading with the combined method

9. DIRECT SCREWING INTO PLASTICS AND METAL

9.1 Direct screwing into plastics

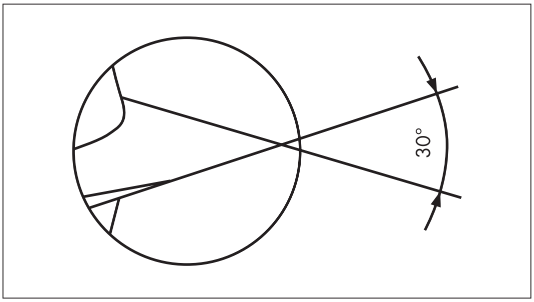
The use of plastics is gaining in importance through new application possibilities.

Advantages here are found among other things in the fields of weight reduction, increased chemical resistance and in recycling components.

The direct screwing into plastics with thread-forming metal screws offers advantages over other connection methods through its economic assembly possibilities, the ability to be unscrewed and low-cost procurement. Fasteners constructed for screwing into plastics in particular enable greater process security in comparison to other screw types through their lower flank angle and greater thread pitch.

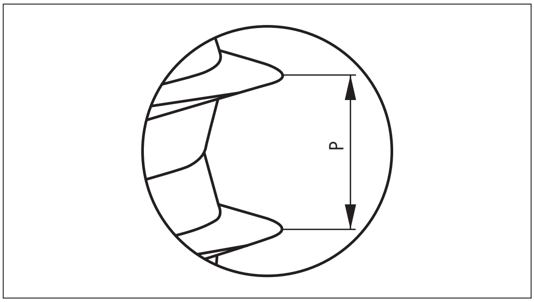
With its WÜPLAST® product line the Würth Industrie Service GmbH & Co. KG offers its customers an in-stock range of thread-forming metal screws for the application in plastics. Over 150 different dimensions are manufactured according to standards of the automotive industry.

Thread geometry
30° angle



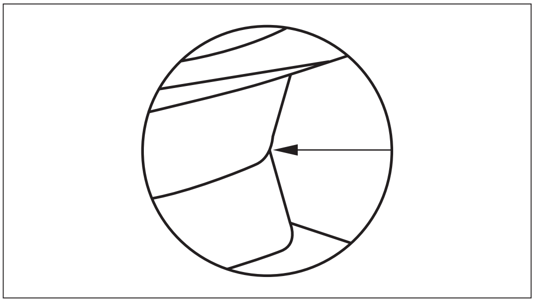
- Reduction of radial tensions
  Construction of thinner walls, possibly savings of costs and weight
  No damage to the screw dome
- Greater overlapping between the thread flanks and material greater pull-out forces increase the process security.

Optimised thread pitch



- Highly self-locking
  Independent loosening of the connection is less likely
- Material protection
  Greater loadability of the screw assembly

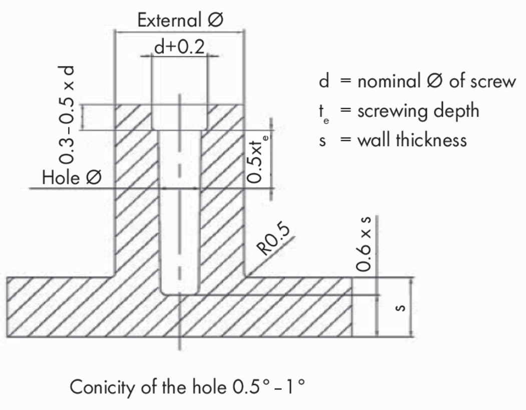
Optimised core diameter



- No material jam/improved material flow
  No damage to the material and therefore enhanced assembly security
- Lower tightening torques
  Secure connection because of the greater difference between screwing torque and thread stripping torque

The reliable multiple connections of WÜPLAST® products is secured through the combination of these features.

Tube design:



Construction:

The properties of WÜPLAST® screws enable the tube to be constructed with thin walls and flat.

Relief hole:
The relief hole at the upper end of the drilled hole reduces tension overlapping and thus prevents the tube from bursting.
At the same time it serves to guide the screw during assembly.

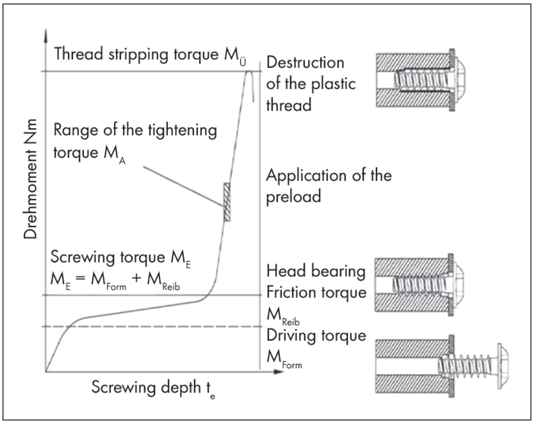
The tube geometry is to be adjusted to the different materials.

Material		**Hole Ø mm**	**External Ø mm**	**Recommended screwing depth mm e**
ABS	Acrylonitrile/butadiene/styrene	0.8x d	2x d	2x d
ASA	Acrylonitrile/styrene/acrylic ester	0.78x d	2x d	2x d
PA 4.6	Polyamide	0.73x d	1.85x d	1.8x d
PA 4.6-GF30	Polyamide	0.78x d	1.85x d	1.8x d
PA 6	Polyamide	0.75x d	1.85x d	1.7x d
PA 6-GF30	Polyamide	0.8x d	2x d	1.8x d
PA 6.6	Polyamide	0.75x d	1.85x d	1.7x d
PA 6.6-GF30	Polyamide	0.82x d	2x d	1.8x d
PA 30GV	Polyamide	0.8x d	1.8x d	1.7x d
PBT	Polybuteneterephthalate	0.75x d	1.85x d	1.7x d
PBT-GF30	Polybuteneterephthalate	0.8x d	1.8x d	1.7x d
PC	Polycarbonate	0.85x d	2.5x d	2.2x d*
PC-GF30	Polycarbonate	0.85x d	2.2x d	2.2x d*
PE (weich)	Polyethylene	0.7x d	2x d	2x d
PE (hart)	Polyethylene	0.75x d	1.8x d	1.8x d
PET	Polyethylene terephtalate	0.75x d	1.85x d	1.7x d
PET-GF30	Polyethylene terephtalate	0.8x d	1.8x d	1.7x d
PETP	Polyethylene terephtalate	0.75x d	1.85x d	1.7x d
PETP 30GV	Polyethylene terephtalate	0.8x d	1.8x d	1.7x d
PMMA	Polymethylmethacrylate	0.85x d	2x d	2x d
POM	Polyoxymethylene	0.75x d	1.95x d	2x d
PP	Polypropylene	0.7x d	2x d	2x d
PP-TV20	Polypropylene	0.72x d	2x d	2x d
PPO	Polyphenylenoxide	0.85x d	2.5x d	2.2x d**
PS	Polystyrene	0.8x d	2x d	2x d
PVC (hart)	Polyvinyl chloride	0.8x d	2x d	2x d
SAN	Styrene/acrylonitrile	0.77x d	2x d	1.9x d

* TnP test
** TnBP test materials sensitive to tension cracking

Assembly instructions

Schematic curve of the tightening process



Tightening torque:

Necessary for a reliable screwed joint is a great difference between the screwing and the thread-stripping torques.

The required tightening torque can be determined theoretically with the following equation:
MA = ME + 1/3 ... 1/2 (MÜ – ME)

The screwing and the thread-stripping torques are to be determined in experiments.

A secure directly screwed plastic joint can only be made with torque-controlled and rotation-angle controlled assembly equipment. The screwing speed is to be selected between 300 rpm and 800 rpm.

Because of the heat effect, greater speeds lead to damage to the plastic and to a disproportionate reduction of the preload force.

Both the tube design and the tightening torque are to be checked in practice on the components.

9.2 Direct screwing into metals

Thread forming screws for metals are grooving screws with metric threads and tapping screws. These screws groove the counterthread themselves without cutting. They can be used in ductile metals such as, e.g., steel, or in lightweight construction materials up to 140 HV10 or in accordance with a tensile strength of 450 MPa.

9.2.1 Metric thread grooving screws

These screws are used in clearance holes and very frequently in tapping holes (aluminium or zinc diecasting).

The DIN 7500 screw is the oldest and most widespread design here and defines the thread and the technical delivery conditions. However, screws such as Taptite, Duo-Taptite or Taptite 2000 are frequently found on the market today.

When driven in, the screws form a normal nut thread without cutting into which a conventional screw can be screwed.

These screws are usually case-hardened, which means that the surface is extremely hard and the core is very ductile.

To make thread grooving easier the screw cross-sections are specially formed (trilobular) over the whole length or at the screw end only.

For placing in the core removing hole the screw thread is conical over max. 4 x P thread pitch in accordance with DIN 7500.

The thread pitch, which is smaller in comparison with tapping screws, and the high thread engagement give the screws a certain amount of security against independent loosening.

9.2.2 Screw assemblies for thread-grooving screws in accordance with DIN 7500 (Gefu-1 and Gefu-2)

The ideal drilling diameter for the tapping holes is to be determined through experiments. The following two tables provide good points of reference.

Gefu-1: Recommended tapping holes for cold malleable materials in dependence on the screwing length

Thread d	**M3**			**M4**			**M5**			**M6**		
Material thickness of the screwing length	**Recommended tolerance field**											
	St	**Al**	**Cu**	**St**	**Al**	**Cu**	**St**	**Al**	**Cu**	**St**	**Al**	**Cu**
1.0		2.7										
1.2		2.7										
1.5		2.7			3.6			4.5				
1.6		2.7			3.6			4.5				
1.7		2.7			3.6			4.5				
1.8	2.75	2.7			3.6			4.5				
2.0	2.75	2.7	2.7		3.6			4.5			5.4	
2.2		2.75			3.6			4.5			5.4	
2.5		2.75		3.65	3.6	3.6		4.5			5.4	
3.0		2.75		3.65	3.6	3.6		4.5			5.45	
3.2		2.75		3.65	3.6	3.6	4.55	4.5	4.5		5.45	
3.5		2.75			3.6			4.55			5.45	
4.0		2.75			3.6			4.55		5.5	5.45	5.45
5.0		2.75		3.7	3.65	3.65		4.6		5.5	5.45	5.45
5.5		2.75		3.7	3.65	3.65		4.6			5.5	
6.0		2.75		3.7	3.65	3.65		4.6			5.5	
6.3		2.75						4.65			5.5	
6.5		2.75						4.65			5.5	
7.0		2.75						4.65		5.55	5.5	5.5
7.5								4.65		5.55	5.5	5.5
8 to ≤ 10								4.65			5.55	
>10 to ≤ 12												
>12 to ≤ 15												

Gefu-2: Recommended tapping holes for ductile materials

Thread d	**M5**			**M6**			**M8**		
Material thickness of the screwing length	**Recommended tolerance field**								
	St	**Al**	**Cu**	**St**	**Al**	**Cu**	**St**	**Al**	**Cu**
1.0									
1.2									
1.5	4.5	4.5	4.5						
1.6	4.5	4.5	4.5						
1.7	4.5	4.5	4.5						
1.8	4.5	4.5	4.5						
2.0	4.5	4.5	4.5	5.4	5.4	5.4			
2.2	4.5	4.5	4.5	5.4	5.4	5.4	7.25	7.25	7.25
2.5	4.5	4.5	4.5	5.4	5.4	5.4	7.25	7.25	7.25
3.0	4.5	4.5	4.5	5.45	5.45	5.45	7.25	7.25	7.25
3.2	4.55	4.5	4.5	5.45	5.45	5.45	7.25	7.25	7.25
3.5	4.55	4.55	4.55	5.45	5.45	5.45	7.25	7.25	7.25

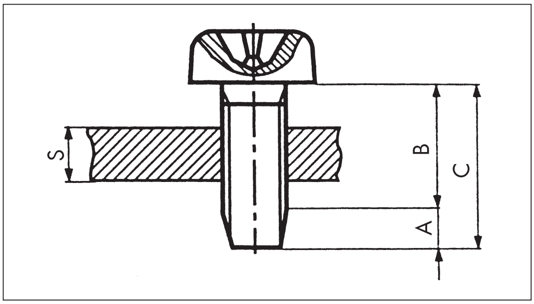
Thread d	M5			M6			M8		
Material thickness of the screwing length	Recommended tolerance field								
	St	Al	Cu	St	Al	Cu	St	Al	Cu
4.0	4.55	4.55	4.55	5.5	5.45	5.45	7.3	7.3	7.3
5.0	4.6	4.6	4.6	5.5	5.45	5.45	7.4	7.3	7.3
5.5	4.6	4.6	4.6	5.5	5.5	5.5	7.4	7.3	7.3
6.0	4.6	4.6	4.6	5.5	5.5	5.5	7.4	7.3	7.3
6.3	4.65	4.65	4.65	5.5	5.5	5.5	7.4	7.35	7.35
6.5	4.65	4.65	4.65	5.5	5.5	5.5	7.4	7.35	7.35
7.0	4.65	4.65	4.65	5.55	5.5	5.5	7.5	7.4	7.4
7.5	4.65	4.65	4.65	5.55	5.5	5.5	7.5	7.4	7.4
8 to <= 10	4.65	4.65	4.65	5.55	5.55	5.55	7.5	7.4	7.4
>10 to <=12							7.5	7.5	7.5
>12 to <=15							7.5	7.5	7.5

9.2.3 Direct screwing into metals with thread-grooving screws in accordance with DIN 7500

When they are driven in, DIN 7500 screws form their own counterthread without cutting through plastic deformation of the base material (steel, HB max. 135, light metal, nonferrous heavy metal). A2 screws can normally only be driven into lightweight metal.

Strength properties, tapping hole geometry

When the screw length is selected, the length of the non-bearing conical screw end has to be taken into account! With harder materials the hole diameters are to be determined in experiments.



A = Max. 4 P
B = Possible bearing thread length
C = Total length, tolerance js 16
s = Material thickness

Fig. AB

Technical data	Thread nominal diameter						
	M2	M2.5	M3	M3.5	M4	M5	M6	M8
Thread pitch P [mm]	0.4	0.45	0.5	0.6	0.7	0.8	1	1.25
Tightening torque max.	approx. 80% of the fracture torque							
Fracture torque min. [Nm]	0.5	1	1.5	2.3	3.4	7.1	12	29
Tensile force min. [kN]	1.7	2.7	4	5.4	7	11.4	16	29
Material strength s [mm]	**Tapping hole diameter d – H11 for steel. HB max. 135; drilled and stamped**							
2 and less	1.8	2.25	2.7	3.15	3.6	4.5	5.4	7.25
4.0	1.85	2.3	2.75	3.2	3.65	4.5	5.45	7.3
6.0		2.35	2.8	3.25	3.7	4.6	5.5	7.35
8.0				3.3	3.75	4.65	5.55	7.4
10.0						4.7	5.6	7.45
12.0							5.65	7.5
14.0								7.5
16.0								7.55

Tapping holes for diecasting

All recommendations must be checked by means of practical assembly experiments.

General

t_1 [mm]: Upper hole range, with increased conicity for roundings advantageous for casting, strengthening of the mandrel, screw centring, prevention of material bucking, and adaptation to low-cost standard screw lengths.
t_2/t_3 [mm]: Bearing tapping hole range, max. tightening angle 1 °

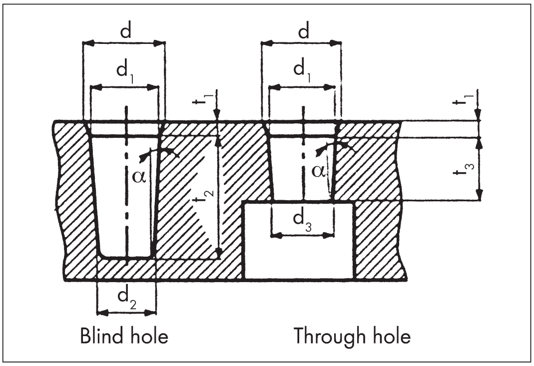


Fig. AC

Thread nominal diameter	M2.5	M3	M3.5	M4	M5	M6	M8
dH12 [mm]	2.7	3.2	3.7	4.3	5.3	6.4	8.4
d_1 [mm]	2.36	2.86	3.32	3.78	4.77	5.69	7.63
d_2 [mm]	2.2	2.67	3.11	3.54	4.5	5.37	7.24
d_3 [mm]	2.27	2.76	3.23	3.64	4.6	5.48	7.35
Tolerances for d_1, d_2, d_3 in [mm]	+0	+0	+0	+0	+0	+0	+0
	-0.06	-0.06	-0.075	-0.075	-0.075	-0.075	-0.09
t_1 [mm]	Variable, minimum 1x thread pitch P						
t_2 [mm]	5.3	6	6.9	7.8	9.2	11	14
Tolerances for t_2 in [mm]	+0.2	+0.2	+0.6	+0.5	+0.5	+0.5	+0.5
	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
t_3 [mm]	2.5	3	3.5	4	5	6	8

All information is provided without guarantee or claim to completeness.

9.3 Tapping screws

9.3.1 Tapping screw assemblies

The following examples for screw assemblies apply for tapping screws with threads in accordance to DIN EN ISO 1478. Tapping screws with form C with a point (also known as a pilot point) are used preferably. This applies in particular when several plates are screwed together and hole misalignment must be expected.

Minimum value for the total thickness of the plates to be screwed together

The plate thicknesses of the parts that are to be screwed together must be greater than the increase in the thread of the selected screw, because otherwise sufficient tightening torque cannot be applied because of the thread run-out under the screw head. If this condition is fulfilled, tapping screw assemblies as shown in Figs. 3 to 6 can be used.

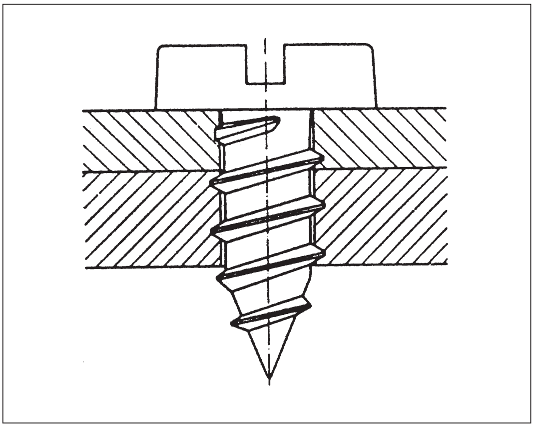


Fig. 1: Simple screwed joint (two tapping holes)

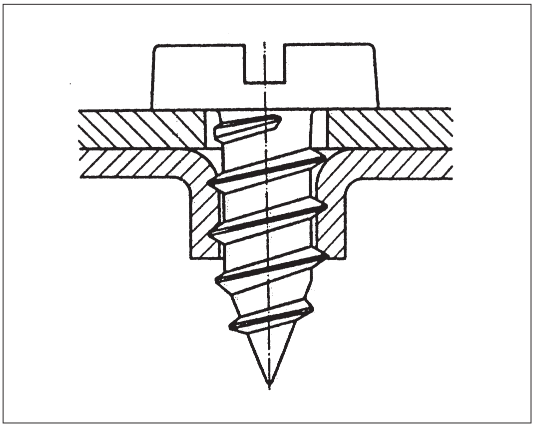


Fig. 4: Tapping hole drawn through (thin plates)

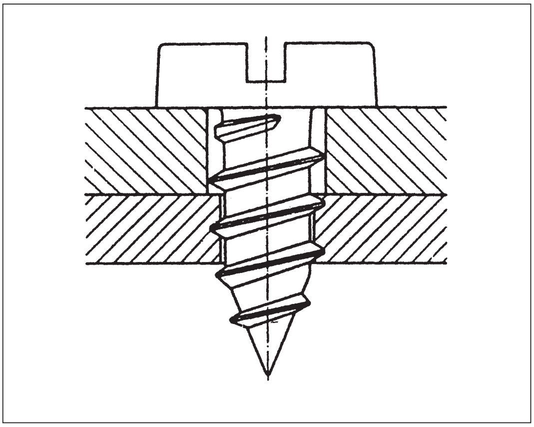


Fig. 2: Simple screwed joint with through hole

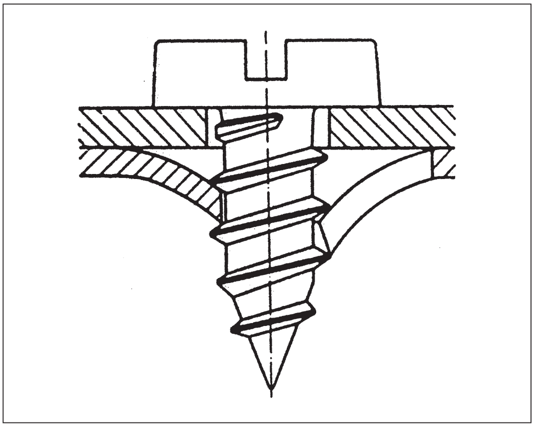


Fig. 5: Prestole screwed joint

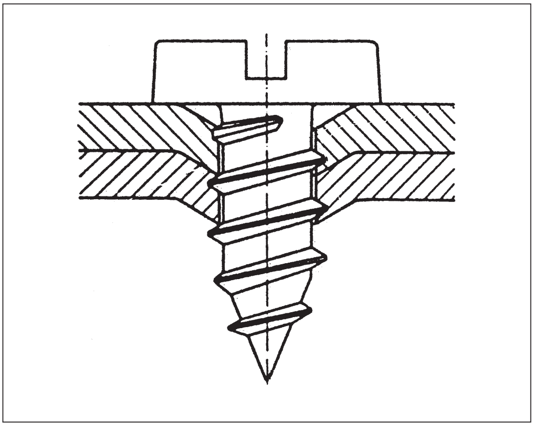


Fig. 3: Tapping hole, widened (thin plates)

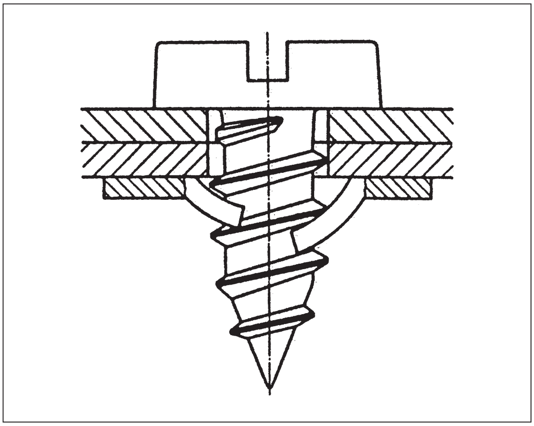


Fig. 6: Screwed joint with tightening nut

Tapping hole diameters

The tapping hole diameters shown in the following tables apply subject to the following preconditions:

- Simple tapping screw assembly in accordance with Fig. Z
- Tapping hole drilled
- Tapping screw case-hardened and uncoated
- Screwing torque ≤ 0.5 x minimum fracture torque
- Screwed joint in direction of stamping only
- Select stamped holes possibly 0.1 – 0.3 mm larger

Internal preliminary tests should be carried out with other screws or plate materials.

Reference values for the tapping hole diameter

Plate thickness s	Tapping hole diameter d_b for thread size ST 2.2								
	Material strength R_m N/mm²								
	100	150	200	250	300	350	400	450	500
0.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
0.9	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
1.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8
1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8
1.2	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8
1.3	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8
1.4	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.9
1.5	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.9	1.9
1.6	1.7	1.7	1.7	1.8	1.8	1.8	1.9	1.9	1.9
1.7	1.7	1.7	1.7	1.8	1.8	1.9	1.9	1.9	1.9
1.8	1.7	1.7	1.8	1.8	1.8	1.9	1.9	1.9	1.9

Plate thickness s	Tapping hole diameter d_b for thread size ST 2.9								
	Material strength R_m N/mm²								
	100	150	200	250	300	350	400	450	500
1.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
1.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.3
1.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.3
1.4	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.4
1.5	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.4	2.4
1.6	2.2	2.2	2.2	2.2	2.3	2.3	2.4	2.4	2.4
1.7	2.2	2.2	2.2	2.2	2.3	2.4	2.4	2.4	2.4
1.8	2.2	2.2	2.2	2.3	2.3	2.4	2.4	2.4	2.5
1.9	2.2	2.2	2.2	2.3	2.4	2.4	2.4	2.5	2.5
2.0	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.5
2.2	2.2	2.2	2.3	2.4	2.4	2.5	2.5	2.5	2.5

Plate thickness s	Tapping hole diameter d_b for thread size ST 3.5								
	Material strength R_m N/mm²								
	100	150	200	250	300	350	400	450	500
1.3	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.8
1.4	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8
1.5	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.9
1.6	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.9	2.9
1.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.9	2.9
1.8	2.7	2.7	2.7	2.7	2.8	2.8	2.9	2.9	2.9
1.9	2.7	2.7	2.7	2.7	2.8	2.9	2.9	2.9	3.0
2.0	2.7	2.7	2.7	2.8	2.9	2.9	2.9	3.0	3.0
2.2	2.7	2.7	2.8	2.8	2.9	3.0	3.0	3.0	3.0
2.5	2.7	2.7	2.9	2.9	3.0	3.0	3.0	3.1	3.1
2.8	2.7	2.8	2.9	3.0	3.0	3.0	3.1	3.1	3.1

Plate thickness s	Tapping hole diameter d_b for thread size ST 3.9								
	Material strength R_m N/mm²								
	100	150	200	250	300	350	400	450	500
1.3	2.9	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.1
1.4	2.9	2.9	2.9	2.9	2.9	3.0	3.1	3.1	3.1
1.5	3.0	3.0	3.0	3.0	3.0	3.0	3.1	3.1	3.2
1.6	3.0	3.0	3.0	3.0	3.0	3.1	3.1	3.2	3.2
1.7	3.0	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.3
1.8	3.0	3.0	3.0	3.0	3.1	3.2	3.2	3.3	3.3
1.9	3.0	3.0	3.0	3.1	3.2	3.2	3.3	3.3	3.3
2.0	3.0	3.0	3.0	3.1	3.2	3.2	3.3	3.3	3.3
2.2	3.0	3.0	3.1	3.2	3.2	3.3	3.3	3.3	3.4
2.5	3.0	3.0	3.2	3.3	3.3	3.3	3.4	3.4	3.4
2.8	3.0	3.2	3.3	3.3	3.4	3.4	3.4	3.4	3.4
3.0	3.0	3.2	3.3	3.3	3.4	3.4	3.4	3.4	3.5

Plate thickness s	Tapping hole diameter d_b for thread size ST 4.2								
	Material strength R_m N/mm²								
	100	150	200	250	300	350	400	450	500
1.4	3.1	3.1	3.1	3.1	3.1	3.1	3.2	3.3	3.4
1.5	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.3	3.4
1.6	3.2	3.2	3.2	3.2	3.2	3.2	3.3	3.4	3.4
1.7	3.2	3.2	3.2	3.2	3.2	3.3	3.3	3.4	3.4
1.8	3.2	3.2	3.2	3.2	3.3	3.3	3.4	3.4	3.5
1.9	3.2	3.2	3.2	3.2	3.3	3.4	3.4	3.4	3.5
2.0	3.2	3.2	3.2	3.3	3.4	3.4	3.5	3.5	3.5
2.2	3.2	3.2	3.2	3.3	3.4	3.5	3.5	3.5	3.6
2.5	3.2	3.2	3.4	3.4	3.5	3.5	3.6	3.6	3.6
2.8	3.2	3.3	3.4	3.5	3.6	3.6	3.6	3.6	3.6
3.0	3.2	3.4	3.5	3.5	3.6	3.6	3.6	3.6	3.7
3.5	3.3	3.5	3.6	3.6	3.7	3.7	3.7	3.7	3.7

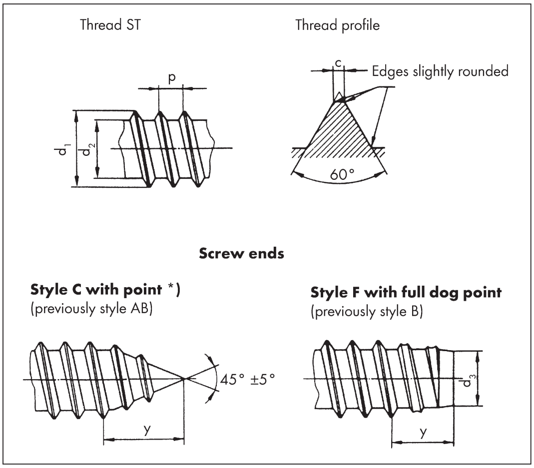
Plate thickness s	Tapping hole diameter d_b for thread size ST 4.8								
	Material strength R_m N/mm²								
	100	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
1.6	3.6	3.6	3.6	3.6	3.6	3.7	3.8	3.9	3.9
1.7	3.6	3.6	3.6	3.6	3.7	3.8	3.9	3.9	4.0
1.8	3.6	3.6	3.6	3.6	3.8	3.8	3.9	4.0	4.0
1.9	3.6	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0
2.0	3.6	3.6	3.6	3.8	3.9	3.9	4.0	4.0	4.1
2.2	3.6	3.6	3.7	3.9	3.9	4.0	4.0	4.1	4.1
2.5	3.6	3.7	3.9	4.0	4.0	4.1	4.1	4.1	4.2
2.8	3.6	3.8	4.0	4.0	4.1	4.1	4.2	4.2	4.2
3.0	3.7	3.9	4.0	4.1	4.1	4.2	4.2	4.2	4.2
3.5	3.8	4.0	4.1	4.2	4.2	4.2	4.2	4.2	4.2
4.0	4.0	4.1	4.2	4.2	4.2	4.2	4.3	4.3	4.3

Plate thickness s	Tapping hole diameter d_b for thread size ST 5.5								
	Material strength R_m N/mm²								
	100	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
1.8	4.2	4.2	4.2	4.2	4.3	4.4	4.5	4.6	4.6
1.9	4.2	4.2	4.2	4.2	4.4	4.5	4.6	4.6	4.7
2.0	4.2	4.2	4.2	4.3	4.4	4.5	4.6	4.6	4.7
2.2	4.2	4.2	4.3	4.4	4.5	4.6	4.7	4.7	4.8
2.5	4.2	4.2	4.4	4.6	4.7	4.7	4.8	4.8	4.8
2.8	4.2	4.4	4.6	4.7	4.7	4.8	4.8	4.8	4.9
3.0	4.2	4.5	4.6	4.7	4.8	4.8	4.8	4.9	4.9
3.5	4.4	4.6	4.7	4.8	4.8	4.9	4.9	4.9	4.9
4.0	4.6	4.7	4.8	4.9	4.9	4.9	4.9	5.0	5.0
4.5	4.7	4.8	4.9	4.9	4.9	4.9	5.0	5.0	5.0

Plate thickness s	Tapping hole diameter d_b for thread size ST 6.3								
	Material strength R_m N/mm²								
	100	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
1.8	4.9	4.9	4.9	4.9	5.0	5.2	5.3	5.3	5.4
1.9	4.9	4.9	4.9	5.0	5.1	5.2	5.3	5.4	5.4
2.0	4.9	4.9	4.9	5.1	5.2	5.3	5.4	5.4	5.5
2.2	4.9	4.9	5.0	5.2	5.3	5.4	5.5	5.5	5.6
2.5	4.9	5.0	5.2	5.4	5.4	5.5	5.6	5.6	5.6
2.8	4.9	5.2	5.3	5.5	5.5	5.6	5.6	5.7	5.7
3.0	4.9	5.3	5.4	5.5	5.6	5.7	5.7	5.7	5.7
3.5	5.2	5.4	5.5	5.6	5.7	5.7	5.7	5.7	5.8
4.0	5.3	5.5	5.6	5.7	5.7	5.7	5.8	5.8	5.8
4.5	5.5	5.6	5.7	5.7	5.8	5.8	5.8	5.8	5.8
5.0	5.5	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8

Plate thickness s	Tapping hole diameter d_b for thread size ST 8								
	Material strength R_m N/mm²								
	100	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
2.1	6.3	6.3	6.3	6.3	6.5	6.6	6.7	6.8	6.9
2.2	6.3	6.3	6.3	6.5	6.6	6.8	6.8	6.9	7.0
2.5	6.3	6.3	6.5	6.7	6.8	6.9	7.0	7.0	7.1
2.8	6.3	6.4	6.7	6.8	6.9	7.0	7.1	7.1	7.2
3.0	6.3	6.5	6.8	6.9	7.0	7.1	7.1	7.2	7.2
3.5	6.4	6.8	7.0	7.1	7.1	7.2	7.2	7.3	7.3
4.0	6.7	6.9	7.1	7.2	7.2	7.3	7.3	7.3	7.3
4.5	6.8	7.1	7.2	7.2	7.3	7.3	7.3	7.3	7.4
5.0	7.0	7.1	7.2	7.3	7.3	7.3	7.4	7.4	7.4
5.5	7.1	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.4
6.0	7.1	7.2	7.3	7.3	7.4	7.4	7.4	7.4	7.4
6.5	7.2	7.3	7.3	7.4	7.4	7.4	7.4	7.4	7.4

9.3.2 Thread for tapping screws



The dimensions for tapping screws such as pitch and diameter are shown in table 48 for ST 1.5 to ST 9.5.

Thread size		**ST 1.5**	**ST 1.9**	**ST 2.2**	**ST 2.6**	**ST 2.9**	**ST 3.3**	**ST 3.5**
P	≈	0.5	0.6	0.8	0.9	1.1	1.3	1.3
d^1	max.	1.52	1.90	2.24	2.57	2.90	3.30	3.53
	min.	1.38	1.76	2.1	2.43	2.76	3.12	3.35
d_2	max.	0.91	1.24	1.63	1.90	2.18	2.39	2.64
	min.	0.84	1.17	1.52	1.80	2.08	2.29	2.51
d_3	max.	0.79	1.12	1.47	1.73	2.01	2.21	2.41
	min.	0.69	1.02	1.37	1.60	1.88	2.08	2.26
c	max.	0.1	0.1	0.1	0.1	0.1	0.1	0.1
y	Style C	1.4	1.6	2	2.3	2.6	3	3.2
Aux. dimension	Style F	1.1	1.2	1.6	1.8	2.1	2.5	2.5
Number		0	1	2	3	4	5	6

Thread size		**ST 3.9**	**ST 4.2**	**ST 4.8**	**ST 5.5**	**ST 6.3**	**ST 8**	**ST 9.5**
P	≈	1.3	1.4	1.6	1.8	1.8	2.1	2.1
d^1	max.	3.91	4.22	4.8	5.46	6.25	8	9.65
	min.	3.73	4.04	4.62	5.28	6.03	7.78	9.43
d_2	max.	2.92	3.10	3.58	4.17	4.88	6.20	7.85
	min.	2.77	2.95	3.43	3.99	4.70	5.99	7.59
d_3	max.	2.67	2.84	3.30	3.86	4.55	5.84	7.44
	min.	2.51	2.69	3.12	3.68	4.34	5.64	7.24
c	max.	0.1	0.1	0.15	0.15	0.15	0.15	0.15
y	Style C	3.5	3.7	4.3	5	6	6.5	8
Aux. dimension	Style F	2.7	2.8	3.2	3.6	3.6	4.2	4.2
Number		7	8	10	12	14	16	20

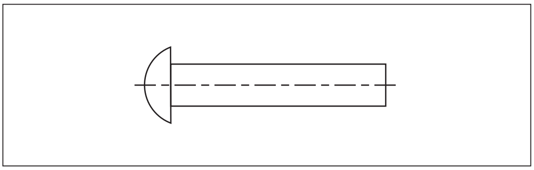
10. RIVETING

10.1 Rivet types

10.1.1 Solid rivets

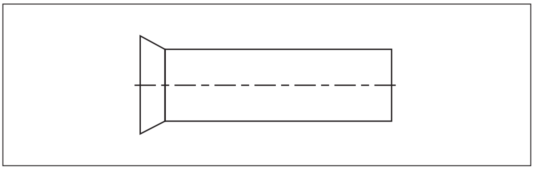
Solid rivets are used less and less. They have been replaced in many cases by welding or bonding.

The most common head form is the round head rivet (DIN 660 (to 8 mm), DIN 124 (from 10 mm)), which is still used occasionally in steel constructions. However, riveting is being replaced here as well by joining with HV fasteners.



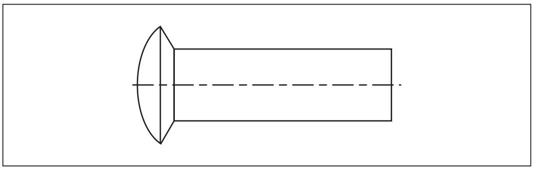
Round head rivet

Countersunk head rivets (DIN 661 (to 8 mm), DIN 302 (from 10 mm)) are used wherever the rivet head must not project. However, the connection can only support lower loads.



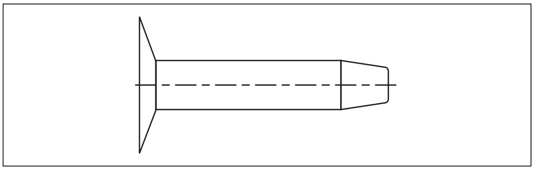
Countersunk head

Oval head rivets (DIN 662) are still used in many cases for stairs, treads and catwalks where the surface has to be non-slip and safe to walk on without risk of an accident.



Raised countersunk head

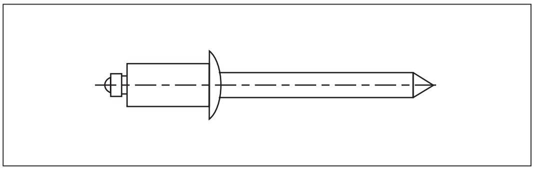
Because of the large countersinking angle of 140° flat countersunk head rivets (DIN 675) are very often used to join soft materials such as leather, felt, rubber (no tearing).



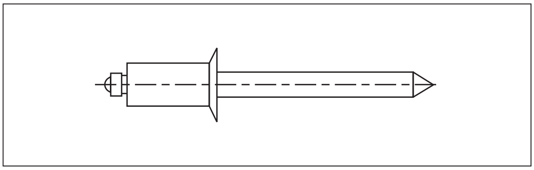
Countersunk head rivet

10.1.2 Hollow rivets

In contrast to solid rivets, hollow rivets are still in demand. Over the last ten years blind rivets above all have experienced an enormous boom because they are relatively easy to work with.



Blind rivet, round head



Blind rivet, countersunk head

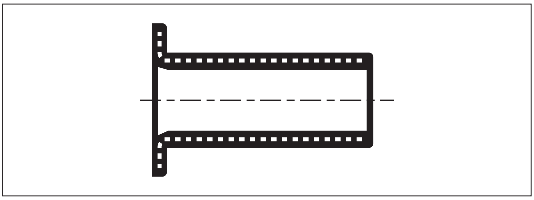
Rivet pins are simple cylindrical steel pins who's end face is either countersunk to 120° or has a short bore hole. The end faces are only slightly flared to secure the pins from falling out. For this reason only a load causing shear stress is permissible.

10.1.3 Tubular rivets

Tubular rivets (DIN 7339 (made from strip), 7340 (made from tube)) are cylindrical sleeves that have a flat edge at one end. A special tool is used to flange the other end during processing. This type of rivet is frequently used to join metal parts with sensitive materials (leather, cardboard, plastics) in electrical engineering and in the

All information is provided without guarantee or claim to completeness.

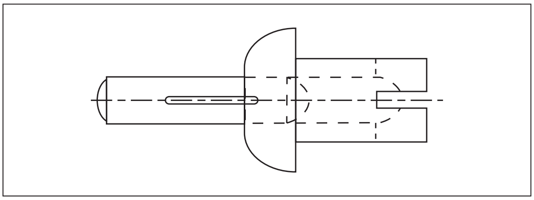
toy industry. A further advantage of these tubular rivets: cables can be led through the very clean hollow part.



Hollow rivet, one-piece

10.1.4 Expanding rivets

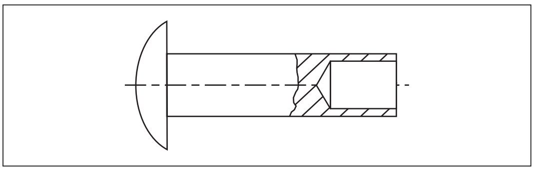
Expanding rivets (hammer drive rivets). No special tools are required for these rivets. A hammer is used to drive a pressed slotted pin or a grooved expanding mandrel into the hollow part. This creates a firm riveted connection with good properties against vibrations.



Expanding rivet

10.1.5 Semi-tubular pan head rivets

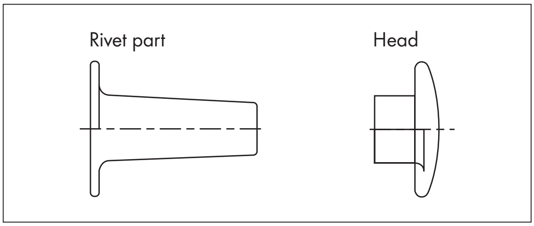
This rivet type (DIN 6791 and DIN 6792) is characterised by the fact that only the rivet end has to be processed. Same uses as for rivet pins.



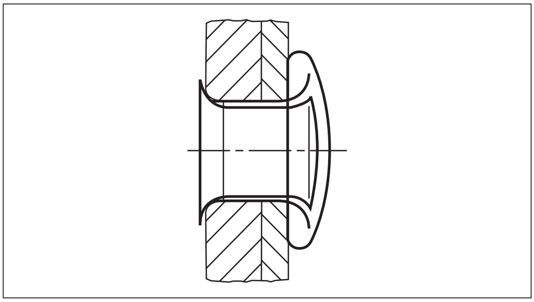
Round head
Semi-tubular pan head rivet

10.1.6 Two-piece hollow rivet

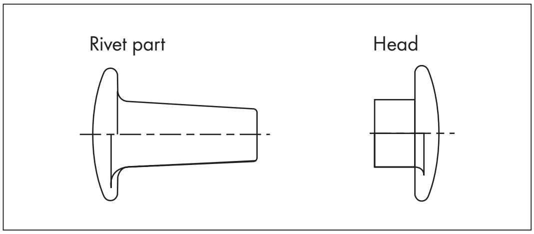
This type of rivet is used very frequently for subordinate purposes. It is differentiated in accordance with the type of the rivet part:



Style A, rivet part open



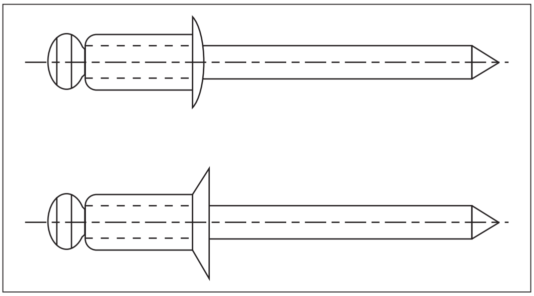
In place



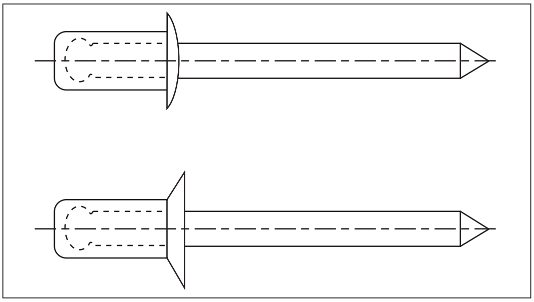
Style B rivet part closed

10.1.7 Blind rivets

This type of rivet has gained greatly in importance, in particular for joining thin-walled plates or in hollow profile construction. In addition, the great advantage is that the rivet can be inserted from one side, i.e. it is fitted blind. The rivet consists of the rivet sleeve and a mandrel. Two types are differentiated as follows: closed blind rivets (cup-type blind rivets) are suitable for making splash-proof connections.



Blind rivet, open (standard type)

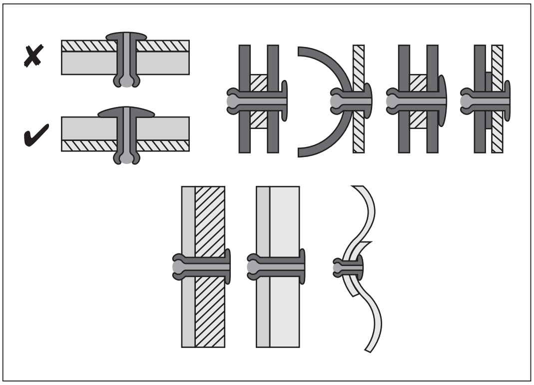


Blind rivet, closed (cup-type blind rivet)

10.2 Instructions for use

10.2.1 Joining hard to soft materials

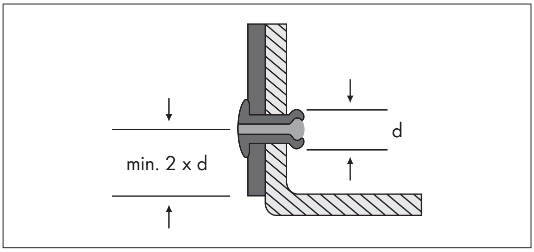
Soft and hard parts are often fastened with the help of an additional washer at the sleeve head that is pressed against the soft material. A much better method is to use a rivet with a large mushroom head and to place the sleeve head against the hard material.



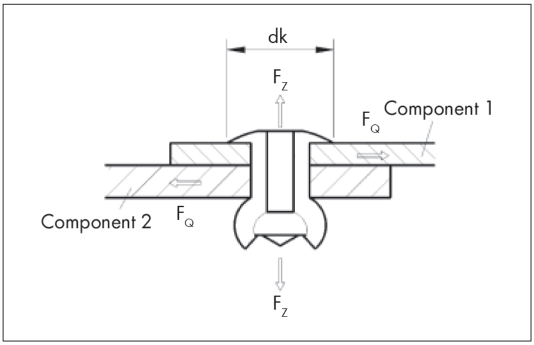
Soft claw blind rivets, blind rivets with a grooved rivet shaft, all-purpose rivets (press clip rivets) are recommended for this application.

10.2.2 Corner clearances for connections:

To enable the greatest possible joint strength, the clearance from the centre axis of the rivet to the edge of the workpiece should not be less than twice the diameter of the sleeve.

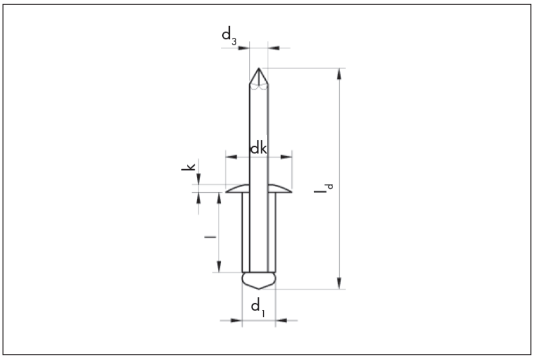


10.3 Definitions and mechanical parameters



d_k Head diameter
F_Z Tensile force affecting the sleeve
F_Q Shearing force affecting the sleeve

Splice plate joint



d_1 Sleeve diameter
d_3 Mandrel diameter
d_k Head diameter
l Sleeve length
l_d Mandrel length
k Head height

10.4 Using blind rivets

The rivet is placed with the rivet mandrel into the opening of the rivet tool and into the bore hole with the rivet sleeve. When the tool is operated, the clamping jaws grip the mandrel and pull it back. (Fig. 1)

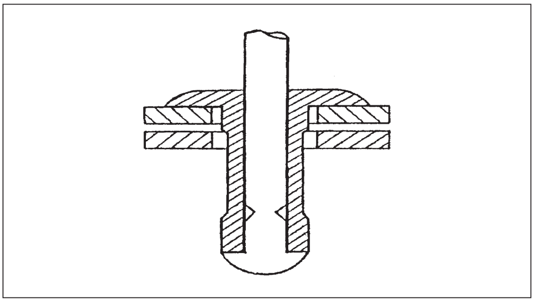


Fig. 1

The pulling movement causes the rivet head to deform the sleeve and this leads the two workpieces to be pressed firmly together. (Fig. 2)

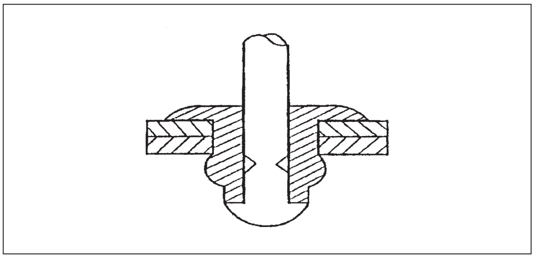


Fig. 2

The sleeve is pressed against the hole wall inside the material bore hole and at the same time is shaped from the "blind" side to the closing head. The mandrel breaks off at the predefined rupture joint, while the remainder of the mandrel in the rivet sleeve is sealed tight by the rivet sleeve. (Fig. 2)

The rivet connection is complete and does not require any more step to finish. (Fig. 3)

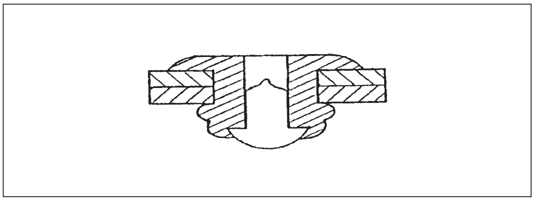
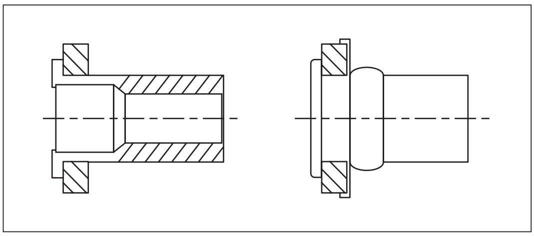


Fig. 3

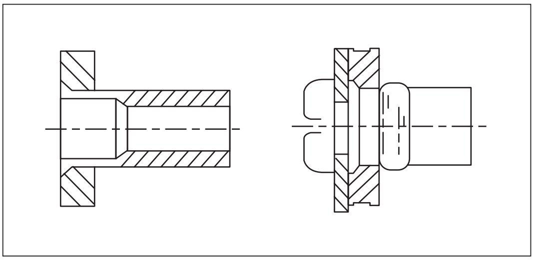
10.5 Rivet nuts

These nuts are mainly used with hollow bodies, because they can only be set from one side (blind assembly). The very universal range is for material thicknesses of 0.5–7.5 mm.



Blind rivet nut, flat head

Rivet nuts combine two fastening types: blind riveting and an additional screw assembly.



Blind rivet nut, countersunk head

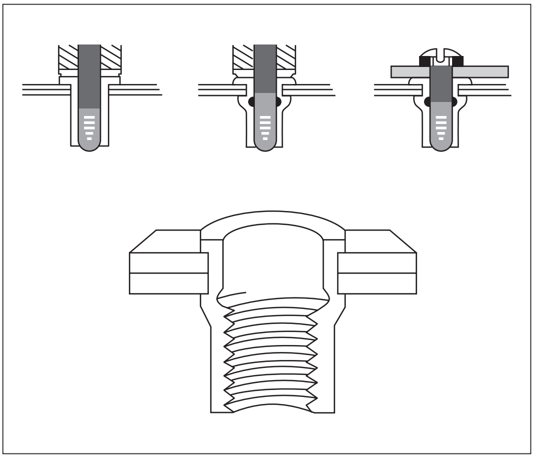
This makes it possible above all to use screw assemblies in relatively thin-walled construction elements.

10.5.1 Using rivet nuts

The blind rivet nuts are used in a similar way to blind rivets.

The blind rivet nut is screwed onto the threaded mandrel of the rivet tool.

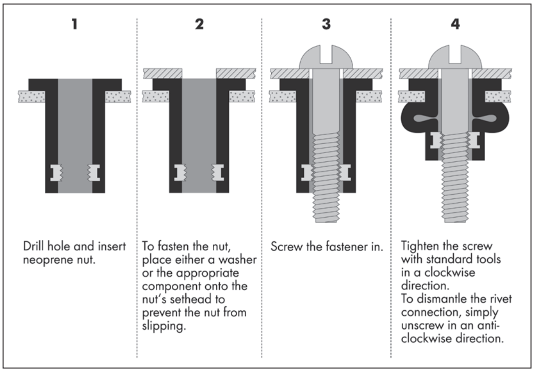
The nut is then placed into the prepared bore hole. When the tool is operated the threaded mandrel is withdrawn. The pulling movement causes the rivet head to deform the sleeve and this leads the two workpieces to be pressed firmly together.



10.5.2 Special types of rivet nuts

Neoprene rivet nuts

Detachable, electrically insulating rivet connection with oscillation and noise-restricting function for fastening metal and plastic connections.



Method of use

Design: mushroom head.
Material: rivet body made of neoprene (EPDM) with brass insert.
Hardness: 60 Shore.
Advantages: can be used in blind or pocket holes.
Double function as thread carrier or fastener. Air-tight and moisture-proof connection. Ideal for various materials.
Possible operating temperatures: –30 °C to +80 °C.
Ozone-resistant.

Areas of application:

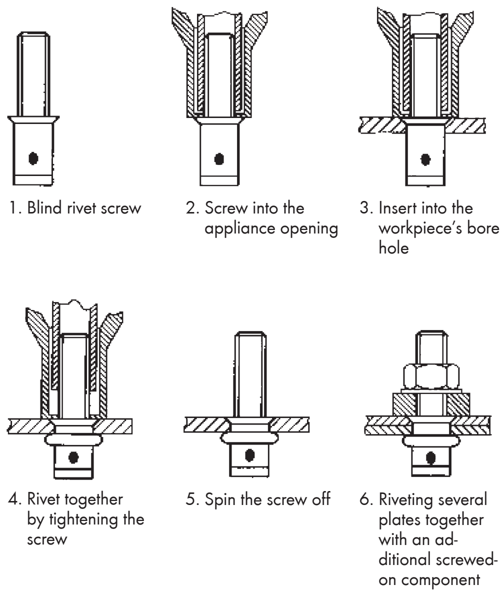
Electronics construction, vehicle construction, trailer construction, sign making, plant engineering, air-conditioning and refrigeration engineering, agricultural engineering

10.6 Rivet screws

Rivet screws are used analogously to rivet nuts. The rivet screw is screwed into the threaded sleeve of the rivet tool and the rivet sleeve is then inserted into the prepared bore hole.

When the tool is operated the threaded sleeve is withdrawn. The pulling movement causes the threaded mandrel to deform the sleeve and this leads the two workpieces to be pressed firmly together.

This type of connection results in a high-strength screw thread in thin-walled materials.



Procedure for use

10.7 Trouble shooting

10.7.1 Selected grip range too large:

- The mandrel does not break off at the rupture joint so that it may still project from the drawn sleeve after processing.
- The connection has insufficient or no tensile or shearing strengths.

10.7.2 Grip range too small:

- The connection has weak points in the area of tensile and shearing strength.
- The rivet mandrel breaks off at the rupture joint but still projects from the sleeve.

10.7.3 Bore hole too big:

- The rivet can be inserted but there is no high connection strength because the sleeve material is insufficient to fill the bore hole.

10.7.4 Bore hole too small:

- The rivet sleeve cannot be inserted into the material because the rivet sleeve diameter is greater than the bore hole.

Other assembly faults can occur through the choice of the incorrect grip or riveting tool.

10.8 Explanation of terms

10.8.1 Cup-type blind rivet:

Also known as sealed rivet. Its blind rivet sleeve is connected to the head in the shape of a cup and in comparison with open blind rivets is proof against splashed water.

10.8.2 Grip range:

The range in which a blind rivet with a given rivet sleeve length fulfils its riveting task perfectly.

The grip range of the components is the total of all components that are to be connected.

10.8.3 Multi-range blind rivet:

Blind rivet that unites several grip ranges in a single rivet (grip range to 20 mm possible).

10.8.4 Rivet sleeve diameter:

The external diameter of the rivet sleeve. Frequently also referred to as well as the shaft diameter.

10.8.5 Rivet sleeve length:

With blind rivets with mushroom heads the rivet sleeve length is measured to the start of the mushroom head.

With the countersunk head design the rivet sleeve length is the total length including the countersunk head and the sleeve.

10.8.6 Closing head:

The part of the blind rivet sleeve that is shaped by the head of the rivet mandrel after setting.

10.8.7 Setting head:

The factory-shaped head at the blind rivet sleeve that is not deformed. Designed as a round or countersunk head.

10.8.8 Rupture joint:

Mandrels have notches at which they break off on the maximum deformation of the rivet sleeve.