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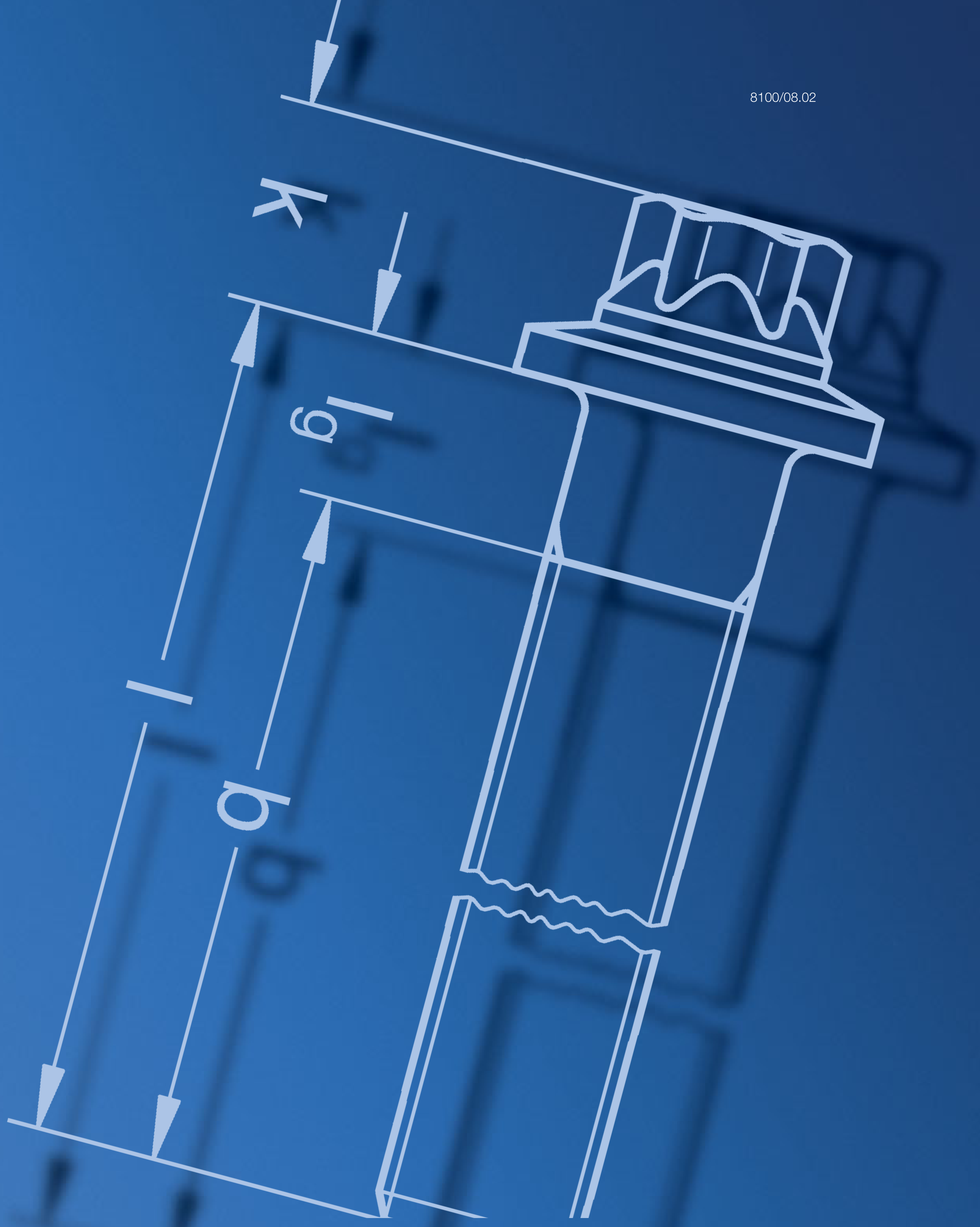


BÖLLHOFF

The Manual of Fastening Technology

5th edition

Dealing with the complex field of fastening technology every day means there are always questions to answer that go beyond the information normally provided in the standards. The aim of this manual is to provide an overview of the technology associated with threaded fasteners, in order to help users in answering these questions.

The information provided brings together details of the relationships between products and their mechanical properties, gives advice for arranging, securing and fitting fasteners, explains why these factors are significant, and outlines important aspects for everyday use.

The first edition of "The Manual of Fastening Technology" was published in 1987. The content of the third edition published in 2002, which this edition supersedes, has been comprehensively revised and updated.

Our Application Engineering team is always standing by to offer expert advice should you require any further support.

ECOTECH – **ECO**nomic **TECH**nical Engineering

Depending on requirements, a wide range of additional services are also available:

- Assembly optimisation, including on-site customer service
- Standardisation and optimisation
- Information and consulting
- Customer seminars

After defining the specific requirements for a project, our Application Engineering department works together with the customer to develop appropriate solutions, and offers design support where this is required.

Benefits of using ECOTECH

- Shorter development times
- Documented basis for decision making
- Latest fastening technology
- Reduction of storage costs
- Manufacturing process optimisation
- Optimisation of the cost of assemblies

We connect

tradition

Wilhelm Böllhoff

Josef Böllhoff

Wilhelm A. Böllhoff / Dr. Wolfgang W. Böllhoff / Michael W. Böllhoff

the future.

The Böllhoff Group's corporate identity is built in part on over 130 years of independence as a family business.

This independence will also set the pace for the future development of the company.

Experience breeds trust. Three generations of Böllhoffs have continuously built on the success of the company's founder. And our children remain the guarantee for the future.

"Our product development:

We never stand still

your advantage”

“Products and markets change at a breath-taking pace - and with them the requirements of our customers. Product development must therefore always be one step ahead. We are already thinking about tomorrow, today. It doesn't matter whether it's about developing a new product from scratch, or working hand in hand with the customer to solve a specific problem.

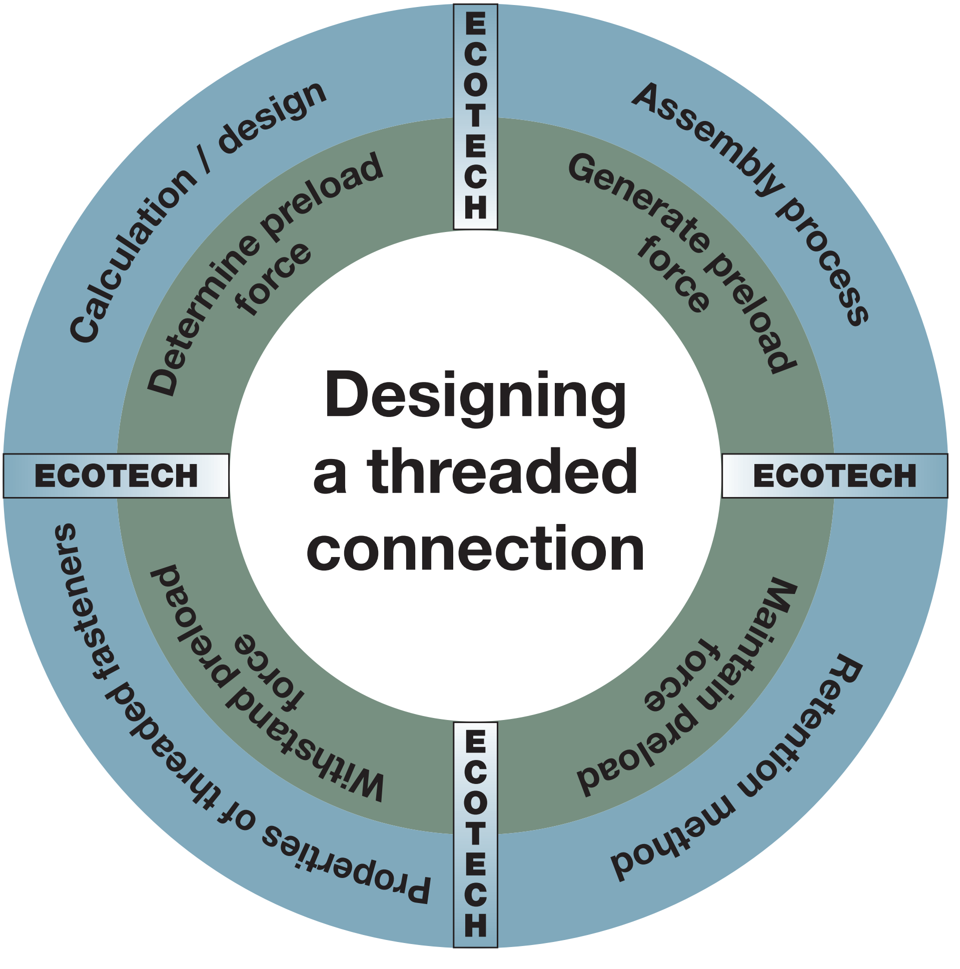
For me, every challenge is also a chance to deliver impressive performance. That's how genuine innovation is born of ideas, and new markets are born of innovation.”

The threaded fastener is one of the most universal and widely used types of fastener and is manufactured in a wide variety of shapes and sizes. Many types of design are standardised internationally and available throughout the world.

The classic threaded connection is formed by joining two or more components by means of form-fit or friction-fit fasteners. The tightening torque applied to the threaded fastener generates a preload force that clamps the components together, thereby creating a frictional connection between all the contacting surfaces.

With a properly designed threaded connection, the preload force is high enough to prevent any relative movement between the components due to the forces acting on the connection. Conversely, the preload force selected must not be so high as to cause the permissible stresses in the joined components to be exceeded during service.

The proper design of a threaded connection for a given set of components is not only dependent on positioning and the selection of an appropriate assembly method, but also, most importantly, on the quality of the design of the fastener itself. A large number of different sizes, standards, materials and property classes are available. It remains the task of the user to make the correct choice to provide the preload force required in each case.



Threaded connections should be designed in such a way that the permissible stresses in the mating components are never exceeded by the forces acting on the connection as a whole.

The tightening torque should be selected such that the preload force produced creates a purely frictional connection between the components and thus prevents them from sliding against each other or having to be supported by the shaft of the fastener (as compared to a rivet connection).

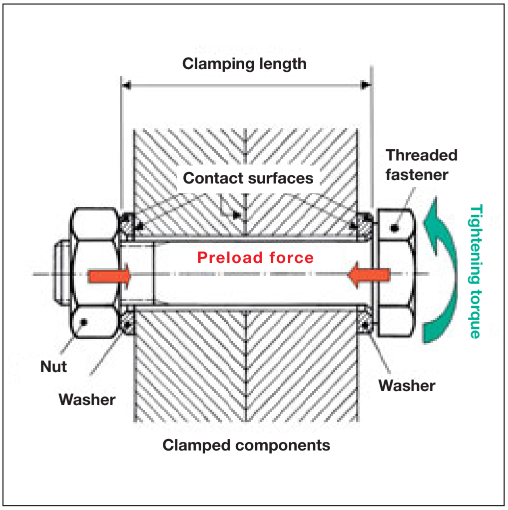
Guideline value: Preload force should be at least equal to 75% of the yield stress in the fastener.

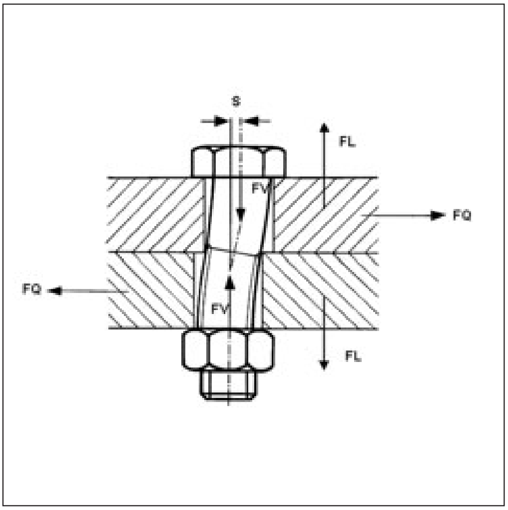
A detailed procedure for the analysis and design of threaded connections can be found in VDI Guideline 2230.

All forces that occur give rise to deformation and the possibility of displacement of the joined components. As long as the sum of all forces does not cause failure of one of the components or fasteners, the assembly acts as a unit. However, where dynamic loads are present – particularly vibration – it is possible for effects to occur that cause the threaded connection to work loose, although the permissible values are not exceeded, e.g. due to components moving relative to each other along the axis of the fastener. This effect is referred to as self-loosening.

Applying a tightening torque indirectly causes a preload force to act on the fastener, which in turn leads to elongation of the fastener and contraction of the joined components.

Forces that occur in use are distributed according to the elasticity of the mated parts. Under tensile stress, the load on the fastener is only reduced slightly, whereas the remaining clamping force decreases significantly.

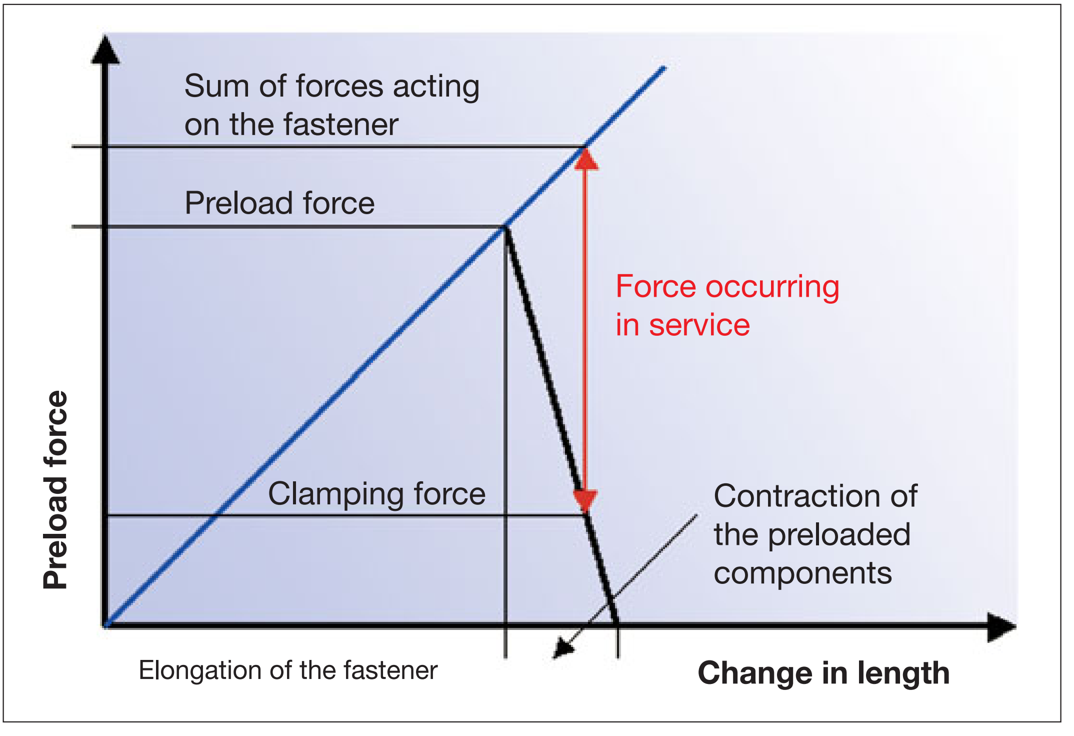




The elastic elongation of the fastener that occurs as a result of the preload force means that the frictional connection between the components remains intact under additional loading, particularly impact loading.

With a clamping length ratio of $L_k/D_{Nom} > 5$, a low number of contact surfaces and sufficient preload force, metallic components do not require additional retention measures, provided that no increased dynamic loads are likely, especially perpendicular to the axis of the fastener. In other cases, the use of additional means of fastener retention should be considered.

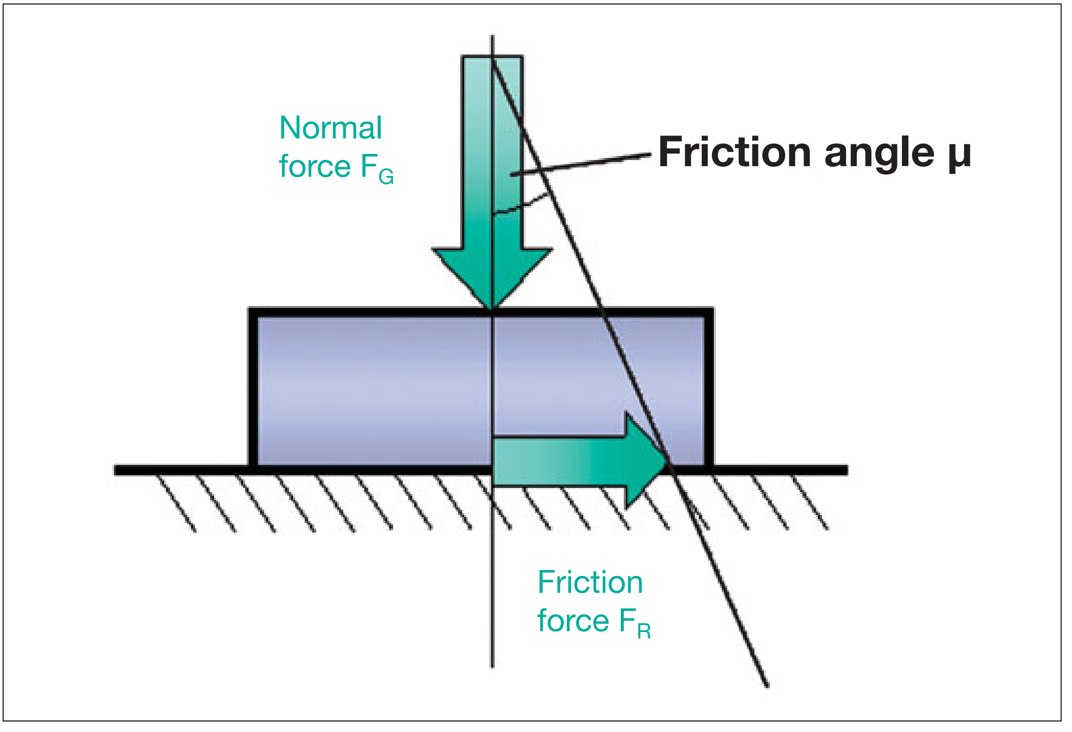
Important: Any compressible spring elements used in conjunction with the fastener will affect the load ratios.



Preload diagram

Effects of friction

During fitting of the threaded fastener, the preload force can only be regulated indirectly via the tightening torque that is applied, which means that a precise knowledge of the friction characteristics is of decisive importance. It is necessary to distinguish between the friction in the thread itself and that at the bearing surfaces.



The friction angle, µ, describes the ratio of the normal force, F_G, to the friction force, F_R, which it generates.

Taken in the context of a threaded connection, normal force and preload force can be considered equal as a first approximation.

Provided that the pitch angle, φ, of the thread is greater than the friction angle, µ, the thread will be self-locking. In order to enhance this effect, it is therefore possible to either increase the thread friction or to reduce the thread pitch.

The effect of friction at the bearing surfaces is considerably more difficult to determine. It is nonetheless possible to establish that, for a given tightening torque, an increase in friction, e.g. below the head of the fastener, on the one hand reduces the preload force, but on the other hand counteracts self-loosening of the fastener.

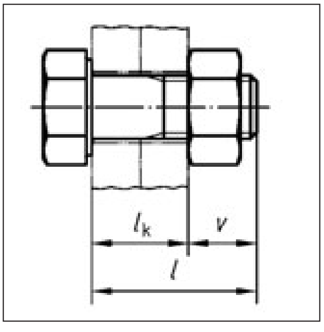
Design

The selection of the required fastener diameter and property class relies upon a precise knowledge of all loads that might occur, and is thus dependent on the specific application.

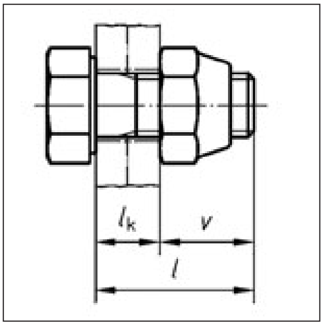
There are, however, a few generally applicable guidelines that can be followed with regard to the length of the fastener. The most important factor is that sufficient load-bearing turns of the thread are engaged to be able to withstand all forces that may occur.

It is necessary here to distinguish between connections formed using a clearance hole (bolts) and internally threaded holes (screws).

When designing through-bolted connections, the nominal length of the bolt is given by the sum of the clamping length (l_k) and the bolt end protrusion (v) (as in DIN 78 Bolt end protrusions). Compliance with the specified bolt end protrusions is of particular importance for a secure connection.

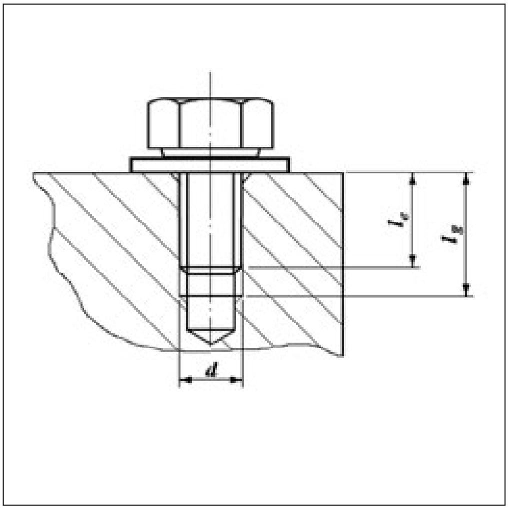


Hexagon head bolt with hexagon nut



Hexagon head bolt with lock nut

l_k: clamping length
v: bolt end protrusion
l: nominal length of the bolt



Choosing an appropriate nut is very straightforward provided the property class of the bolt is known (a bolt of property class 8.8 must be paired with a nut of property class 8 or higher). By contrast, the required length of engagement (l_e) for an internally threaded connection is a function of the material strength of the part into which the internal thread is tapped.

l_e: length of engagement
d: screw diameter
l_g: useful thread

Material of components		Length of engagement l_e [2] according to property class of screw			
		3.6 / 4.6	4.8...6.8	8.8	10.9
Steel with R_m N/mm²	≤ 400 400...600 > 600...800 > 800	0.8 · d 0.8 · d 0.8 · d 0.8 · d	1.2 · d 1.2 · d 1.2 · d 1.2 · d	– 1.2 · d 1.2 · d 1.0 · d	– – 1.2 · d 1.0 · d
Cast iron Copper alloys		1.3 · d 1.3 · d	1.5 · d 1.3 · d	1.5 · d –	– –
Light metals[1]	Cast Al alloys Pure aluminium Al alloy, hardened not hardened	1.6 · d 1.6 · d 0.8 · d 1.2 · d	2.2 · d – 1.2 · d 1.6 · d	– – 1.6 · d –	– [3] – [3] – [3] – [3]
Soft metals, plastics		2.5 · d	–	–	–

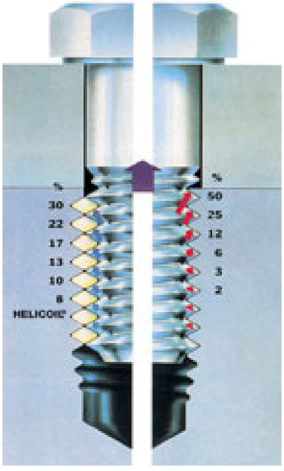
[1] For dynamic loads the specified value of l_e must be increased by approx. 20%. *Source: Roloff / Matek*
[2] Fine pitch threads require approx 25% greater lengths of engagement.
[3] For higher strength screws, the shear strength of the internal thread material as calculated in VDI 2230 must be taken into account.

When determining the nominal length of threaded fasteners, the tolerances applicable to the parts to be joined must be considered. In addition to this, the tolerances on the screw or bolt length and nut height must be taken into account.

The calculated length must – whenever possible – be rounded to the next highest nominal length, as specified in the appropriate product standard (dimensional standards).

By way of departure from the above specifications, a smaller length of engagement is permitted when using a HELICOIL® thread insert. See DIN 8140.

Example:
M 8 screw of property class 10.9 mounted in aluminium with a tensile strength of
R_m = 250 ... 270 N/mm²
and a permissible shear stress of
$T_{zul} = 0.7 \times R_m$ = 180 N/mm²
Without HELICOIL®:
Thread length min 2 x d (as in VDI 2230)
With HELICOIL®:
Thread length 1.5 x d (as in DIN 8140–1, 3.1).



Bolts, screws, studs, nuts, washers, pins, etc. are mechanical fasteners. The majority of these components is designated in accordance with standards, which specify shapes, types, dimensions, tolerances and mechanical properties.

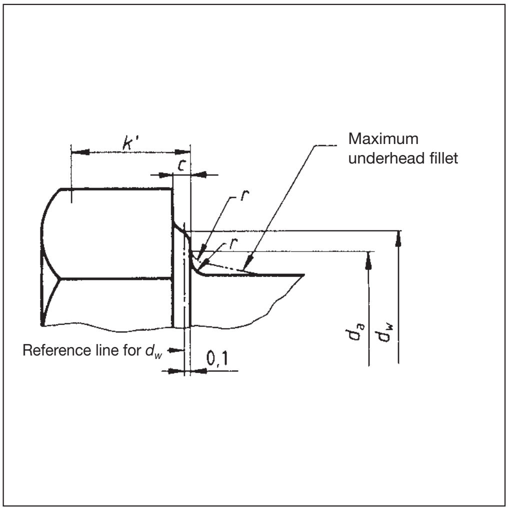
DIN EN ISO 4014 / 8.8 M 12 x 50

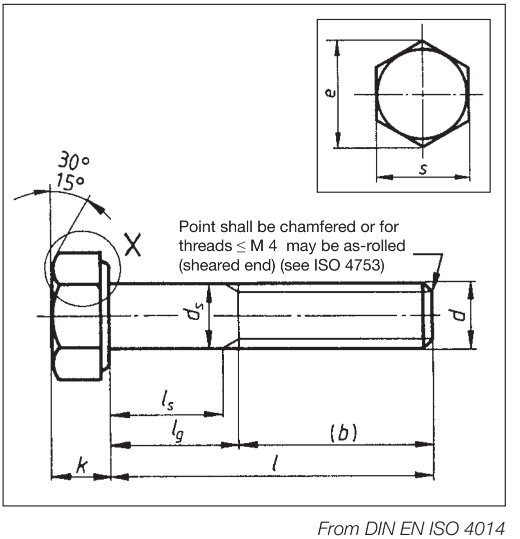
The standard designation given above includes all relevant details of the component in question. ***Product standard*** DIN EN ISO 4014, which specifies the dimensions of hexgon head bolts, was preceded by DIN EN 24014.

The above standard contains references to other standards dealing with materials, mechanical properties for individual property classes, and surface finish. Such standards are also known as ***functional standards.***

The product standards also contain references to ***basic standards,*** which specify generally applicable basic requirements. These relate for example to threads, thread run-outs, thread ends, tolerances, force application, and acceptance testing.

Product standard DIN EN ISO 4014 specifies the dimensions for hexagon head bolts. The letter symbols are explained in the table below.





From DIN EN ISO 4014

Key to dimensions

b	Thread length
c	Height of washer face
d	Major diameter (nominal diameter) of thread
d_a	Transition diameter
d_s	Diameter of unthreaded shank
d_w	Diameter of bearing surface
e	Width across corners
k	Height of head
k'	Wrenching height
l	Nominal length
l_g	Distance from last full form thread to bearing surface
l_s	Length of unthreaded shank
r	Radius of curvature under head
s	Width across flats

These symbols and designations for dimensioning are specified in DIN EN 20225.

All other dimensions in the standard are derived from the nominal diameter and the length.

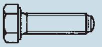
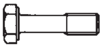
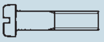
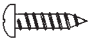
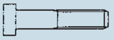
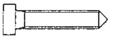
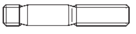
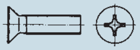
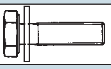
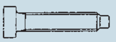
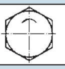
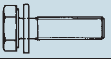
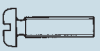
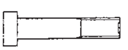
Thread d				M 12	M 16	M 20	M 24
P	*Thread pitch*			1.75	2	2.5	3
b	Reference dimension	l ≤ 125 mm		30	38	46	54
		l > 125 mm / l ≤ 200 mm		36	44	52	60
		l > 200 mm	–	49	57	65	73
c			min.	0.15	0.2	0.2	0.2
			max.	0.6	0.8	0.8	0.8
d_a			max.	13.7	17.7	22.4	26.4
d_s	max. =	Nominal dimension		12	16	20	24
	min.	Product grade	A	11.73	15.73	19.67	23.67
			B	11.57	15.57	19.48	23.48
d_w	min.	Product grade	A	16.63	22.49	28.19	33.61
			B	16.47	22	27.7	33.25
e	min.	Product grade	A	20.03	26.75	33.53	39.98
			B	19.85	26.17	32.95	39.55
l_f			max.	3	3	4	4
k		Nominal dimension		7.5	10	12.5	15
		Product grade A	min.	7.32	9.82	12.285	14.785
			max.	7.68	10.18	12.715	15.215
		Product grade B	min.	7.21	9.71	12.15	14.65
			max.	7.79	10.29	12.85	15.35
k_w	min.	Product grade	A	5.12	6.87	8.6	10.35
			B	5.05	6.8	8.51	10.26
r			min.	0.6	0.6	0.8	0.8
s	max. =	Nominal dimension		18.00	24	30	36
	min.	Product grade	A	17.73	23.67	29.67	35.38
			B	17.57	23.16	29.16	35

Extract from DIN EN ISO 4014

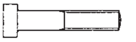
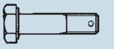
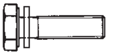
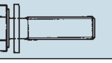
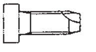
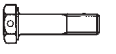
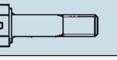
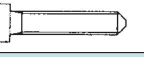
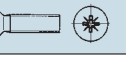
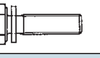
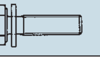
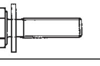
Special design features

To identify special design features in product designations, additional letter symbols are used.
Example: ISO 4014/8.8 M 12 x 50 ***S*** means “with split pin hole”.

Symbols for bolt/screw end features

Sym.	Bolt/screw end feature	Example	Figure
A	Threaded up to the head (DIN 962)	A M 6 x 40	
Ak	Rounded short dog point (DIN 962)	M 10 x 50 Ak	
B	Shank diameter ≈ pitch diameter (DIN 962)	B M 8 x 80	
C	Shank diameter ≈ thread diameter (DIN 962)	C M 12 x 90	
C	Tapping screw with cone point (DIN EN ISO 1478)	ST 3.5 x 9.5 C	
CH	Chamfered end (DIN EN ISO 4753)	M 10 x 50 CH	
CN	Cone point (DIN EN ISO 4753)	M 10 x 50 CN	
CP	Cup point (DIN EN ISO 4753)	M 10 x 50 CP	
F	Tapping screw with full dog point (DIN EN ISO 1478)	ST 3.5 x 9.5 F	
FL	Flat point (DIN EN ISO 4753)	M 10 x 50 FL	
Fo	Studs without interference fit thread (DIN 962)	M 10 Fo x 50	
H	Philips - cross recess	M 5 x 20 H	
L	Washers for screw and washer assemblies (large) (DIN EN ISO 10644)	M 10 x 50 S2-L	
LD	Long dog point (DIN EN ISO 4753)	M 10 x 50 LD	
LH	Left-hand thread (DIN 962)	M 12 LH x 75	
N	Washers for screw and washer assemblies (medium) (DIN EN ISO 10644)	M 10 x 50 S2-N	
PC	Pilot point with truncated cone (DIN EN ISO 4753)	M 10 x 50 PC	
PF	Pilot point, flat (DIN EN ISO 4753)	M 10 x 50 PF	
R	Tapping screws with rounded end (DIN EN ISO 1478)	ST 3.5 x 9.5 R	
Ri	Thread undercut (DIN 76-1)	M 10 x 50 Ri	
RL	As-rolled end (DIN EN ISO 4753)	M 10 x 50 RL	

Symbols for bolt/screw end features (continued)

Sym.	Bolt/screw end feature	Example	Figure
RN	Rounded end (DIN EN ISO 4753)	M 10 x 50 RN	
S	Split pin hole (DIN 962/DIN 34803)	M 10 x 50 S	
S	Washers for screw and washer assemblies (small) (DIN EN ISO 10644)	M 10 x 50 S2-S	
S1-S6	Various types of head for screw and washer assemblies with plain washers S, N or L (DIN EN ISO 10644)	M 10 x 50 S2-N	
SC	Scrape point (DIN EN ISO 4753)	M 10 x 50 SC	
SD	Short dog point (DIN EN ISO 4753)	M 10 x 50 SD	
Sk	Securing hole in head/wire hole (DIN 962/DIN 34803)	M 10 x 50 Sk	
Sz	Slot	M 10 x 50 Sz	
TC	Truncated cone point (DIN EN ISO 4753)	M 10 x 50 TC	
Z	Pozidriv – cross recess	M 5 x 20 Z	
Z 0	Screw and washer assembly with type S (small series) plain washer (DIN EN ISO 10644)	M 10 x 50 Z 0	
Z 1	Screw and washer assembly with type N (normal series) plain washer (DIN EN ISO 10644)	M 10 x 50 Z 1	
Z 2	Screw and washer assembly with type L (large series) plain washer (DIN EN ISO 10644)	M 10 x 50 Z 2	

Correlation of old and new symbols for bolt/screw end features

With the publication of DIN EN ISO 4753, which has to a large extent replaced DIN 78, a number of symbols designating bolt/screw end features (previously referred to as “thread ends”) have been amended. For ease of reference, the table below correlates the old symbols with those used in DIN EN ISO 4753.

Old symbol	Bolt/screw end feature	New symbol
K	Chamfered end	CH
Ka	Short dog point	SD
Ko	As-rolled end	RL
Ks	Flat point	FL
L	Rounded end	RN
Rs	Cup point	CP
Sb	Scrape point	SC
Sp	Truncated cone point	TC
Za	Long dog point	LD

Standards are technical rules

These technical rules can be referred to by everybody. The standards that are valid in Germany are published and updated by ***DIN, the German Institute for Standardization.*** The Institute is based in Berlin and administers approximately 29,500 DIN Standards, of which over 386 are applicable to mechanical fasteners.

The DIN German Institute for Standardization has around 1,745 members, drawn from trade and industry, the sciences and the service sector. Over 26,278 experts are active on behalf of DIN.

Standards are developed by working groups. The drafts of a standard are made available to all interested parties and following a consultation period, published as official standards.

In order to simplify international exchange of goods and avoid barriers to trade, national standards are being superseded by international standards.

This means that consistent terminology and definitions are available internationally, that quality standards are unified at a high level, and that products can be exchanged throughout the world.

The ISO, the "International Organization for Standardization", is headquartered in Geneva and is responsible for international standardisation. More than 157 countries are members of this organisation. Its output is published under the name ***ISO.***

Many ISO Standards are adopted as European Standards and by this means attain the status of a DIN Standard (DIN EN ISO). Other ISO Standards are adopted directly as DIN Standards (DIN ISO).

The 29 members of CEN (European Committee for Standardisation) are obliged to adopt European Standards as part of their respective national bodies of standards. Conflicting national standards must be withdrawn.

This means that there are various designations for standards.

DIN	German national Standard
ISO	International Standard
DIN ISO	German version of an unchanged ISO Standard
EN	European Standard
DIN EN	German version of a European Standard
EN ISO	European version of an unchanged ISO Standard
DIN EN ISO	German version of an EN ISO Standard

Product markings use simply DIN or ISO.

The products covered by DIN EN ISO 4014 are identified as ***ISO 4014*** in drawings, parts lists, commercial documents and on packaging.

DEUTSCHE NORM

März 2001

	Sechskantschrauben mit Schaft Produktklassen A und B (ISO 4014:1999) Deutsche Fassung EN ISO 4014:2000	DIN EN ISO 4014
ICS 21.060.10		Ersatz für DIN EN 24014:1992-02

2

Conversion from DIN to ISO

Changes that affect the various product groups as a result of the conversion are listed below:

Changes in standards applying to ***hexagon head products***

DIN	ISO	Description
931	4014	Hexagon head bolts (Product grades A and B)
601	4016	Hexagon head bolts (Product grade C)
933	4017	Hexagon head screws (Product grades A and B)
558	4018	Hexagon head screws (Product grade C)
960	8765	Hexagon head bolts with metric fine pitch thread (Product grades A and B)
961	8676	Hexagon head screws with metric fine pitch thread (Product grades A and B)
934	4032	Hexagon nuts, style 1 (Product grades A and B)
439	4035	Hexagon thin nuts (chamfered) (Product grades A and B)
934	8673	Hexagon nuts, style 1, with metric fine pitch thread (Product grades A and B)
7991	10642	Hexagon socket countersunk head screws

Changes in ***widths across flats***

Thread diameter	Small hexagon DIN 561, 564		Standard hexagon		Large hexagon HV products		Square DIN 478, 479, 480	
	DIN	ISO	DIN	ISO	DIN	ISO	DIN	ISO
M 10	–	–	17	16	–	–	–	–
M 12	17	16	19	18	22	21	–	–
M 14	–	–	22	21	–	–	–	–
M 16	19	18	–	–	–	–	17	16
M 20	–	–	–	–	32	34	22	21
M 22	–	–	32	34	–	–	–	–

Changes to heights of ***hexagon nuts***

Thread *d*	Nut height *m*					
	DIN 934			ISO 4032 Type 1		
	min.	max.	*m/d* **)	min.	max.	*m/d* **)
M 5	3.7	4	0.8	4.4	4.7	0.94
M 6	4.7	5	0.83	4.9	5.2	0.87
M 7	5.2	5.5	0.79	6.14	6.5	0.93
M 8	6.14	6.5	0.81	6.44	6.8	0.85
M 10	7.64	8	0.8	8.04	8.4	0.84
M 12	9.64	10	0.83	10.37	10.8	0.90
M 14	10.3	11	0.79	12.1	12.8	0.91
M 16	12.3	13	0.81	14.1	14.8	0.92
M 18	14.3	15	0.83	15.1	15.8	0.88
M 20	14.9	16	0.8	16.9	18	0.90
M 22	16.9	18	0.82	18.1	19.4	0.88
M 24	17.7	19	0.79	20.2	21.5	0.90
M 27	20.7	22	0.81	22.5	23.8	0.88
M 30	22.7	24	0.8	24.3	25.6	0.85
M 33	24.7	26	0.79	27.4	28.7	0.87
M 36	27.4	29	0.81	29.4	31	0.86
M 39	29.4	31	0.79	31.8	33.4	0.86

**) Note: *m/d* is the ratio of nut height to thread diameter

Changes to standards for ***threaded screws*** and ***tapping screws***

Threaded screws		**Tapping screws / self-drilling screws**	
DIN	**ISO**	**DIN**	**ISO**
84	1207	7971	1481
85	1580	7972	1482
963	2009	7973	1483
964	2010	7976	1479
965	7046	7981	7049
966	7047	7982	7050
7985	7045	7983	7051
–	–	7504	10666, 15480, 15481, 15482, 15483

Instead of DIN 7985 raised cheese head screw – ISO 7045 pan head screw with modified head dimensions.
For threaded screws and tapping screws the conversion from DIN to ISO Standards resulted in the following changes:
The countersink angle for tapping screws with countersunk and raised countersunk heads has been changed from 80° to 90°.
For tapping screws, thread size ST 3.9 has been dropped.
Head dimensions and tolerances have been changed.
The self-drilling screws covered by DIN 7504 have been specified in five separate standards.

Changes to standards for ***clevis pins, pins, slotted set screws and plain washers for clevis pins***

Product group	DIN	ISO	The most important changes
Taper pins, parallel pins	1	2339	Length l now, as to ISO, ***with*** end section (previously, as to DIN, ***excluding*** end section)
	7	2338	Length l now, as to ISO, ***with*** end section (previously, as to DIN, ***excluding*** end section) Types A, B, C (Type A/Tolerance m 6 now with end section/chamfer)
	6325	8734	New: Type A with chamfer/end section, through-hardened, (largely identical to DIN 6325) Type B with chamfer, case-hardened
	7977 7978 7979/D	8737 8736 8733/ 8735 A	No major changes DIN and ISO nearly identical
Grooved pins	1470 1471 1472 1473 1474 1475	8739 8744 8745 8740 8741 8742	Length l now, as to ISO, ***with*** end section (previously, as to DIN, ***excluding*** end section); shear force increased
	–	8743	New: Grooved pin, half-length, centre grooved
	1476 1477	8746 8747	Type A = no major changes, additional type B with pilot end
Slotted and coiled spring-type straight pins	1481 7346	8752 13337	Type A = medium duty (previously 0-12 mm) with 2 chamfers (previously 0-6 mm), additional type B = non-interlocking
	7343 7344	8750 8748	No major changes
	– –	8749 8751	New: Pins, grooved pins: shear test New: Coiled spring-type straight pins: light duty
Slotted set screws	417 438 551 553	7435 7436 4766 7434	No major changes DIN and ISO nearly identical
Clevis pins	1443 1444	2340 2341	Some nominal lengths changed Length tolerances changed
	1433 1434 1435 1436	– – – –	These standards have been withdrawn (1.94), however ISO 2340 and 2341 are comparable
Washers use with clevis pins	1440	8738	Some major diameters and thicknesses changed (in general no cause for replacement)

DIN EN ISO 10642 – DIN 7991

- Unlike DIN 7991, sizes M18, M22 and M24 are not included in DIN EN ISO 10642.
- In addition to property class 8.8, DIN EN ISO 10642 also includes higher property classes (10.9 and 12.9). These classes are not included in DIN 7991.
- While DIN EN ISO 10642 only lists steel as a material, DIN 7991 also lists stainless steel and nonferrous metal.
- The type with alternative form of socket as in DIN EN ISO 10642 tends to start at longer lengths than specified in DIN 7991.
- Dimension "w" was introduced in DIN EN ISO 10642. It measures the thickness between driving feature and bearing surface. In DIN 7991, the maximum depth of penetration "t max" is specified instead.

Further deviations, which affect thread length, head diameter and head height, can be seen in the table below:

Thread diameter (d)	Thread length (reference dimension) b		Head diameter d_k				Head height k	
			max.	min.	max.	min.	max.	
	DIN EN ISO 10642	DIN 7991	DIN EN ISO 10642		DIN 7991		DIN EN ISO 10642	DIN 7991
M 3	18	12	6.72	5.54	6.0	5.70	1.86	1.7
M 4	20	14	8.96	7.53	8.0	7.64	2.48	2.3
M 5	22	16	11.20	9.43	10.0	9.64	3.10	2.8
M 6	24	18 / 24*	13.44	11.34	12.0	11.57	3.72	3.3
M 8	28	22 / 28*	17.92	15.24	16.0	15.57	4.96	4.4
M 10	32	26 / 32 / 45*	22.40	19.22	20.0	19.48	6.20	5.5
M 12	36	30 / 36 / 49*	26.88	23.12	24.0	23.48	7.44	6.5
(M 14)	40	34 / 40 / 53*	30.80	26.52	27.0	26.48	8.40	7.0
M 16	44	38 / 44 / 57*	33.60	29.01	30.0	29.48	8.80	7.5
M 18	not listed	42 / 48 / 61*	not listed	not listed	33.0	32.38	not listed	8.0
M 20	52	46 / 52 / 65*	40.32	36.05	36.0	35.38	10.16	8.5
M 22	not listed	50 / 56 / 69*	not listed	not listed	36.0	35.38	not listed	13.1
M 24	not listed	54 / 60 / 73*	not listed	not listed	39.0	38.38	not listed	14.0

**depends on thread length*

For the user, the critical factor is the load-bearing capacity of the connecting pieces, which is determined by their mechanical properties. These properties are not only determined by the materials used, but also by the manufacturing process, which can modify the properties of the material.

The section of bar stock taken from the primary material has different properties to the finished screw once it has been cold formed and tempered.

The manufacturer shall select a material, in accordance with the specifications in the standard, that will allow the supplied finished component to possess the required properties. (Responsibility of the manufacturer/supplier)

The user shall select the property class that has the correct mechanical properties for the intended application. (Responsibility of the constructor)

Threaded fasteners made from steel

Ten different property classes are used to classify threaded fasteners.

Property classes	3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9

Property class markings on the head of a threaded fastener

The property classes are identified using two numbers.

The first number is 1/100 of the minimum tensile strength in N/mm^2.

The second number is 1/10 of the ratio of the lower yield point (or 0.2 proof stress) to the tensile strength.

Example of designation for property class 5.6:
First number: 5 x 100 = 500 N/mm² minimum tensile strength
Second number: 6 x 10 = 60 % von 500 = 300 N/mm² yield point

Designation system for property classes

Minimum elongation at break in % / Nominal tensile strength N/mm²	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
7												
8												
9				**6.8**						**12.9**		
10								**10.9**				
11												
12			**5.8**				**9.8**					
13												
14						**8.8**						
15												
16		**4.8**										
17												
18												
19												
20												
21												
22			**5.6**									
23												
24												
25		**4.6**										
26												
27												
28												
29												
30	**3.6**											

From DIN EN ISO 898-1

The property classes presented above are not valid for all types of standardised threaded fasteners. A practical selection of property classes has been made for each of the individual product standards.

3

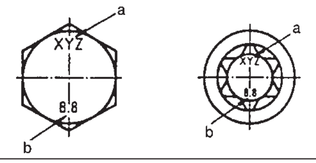
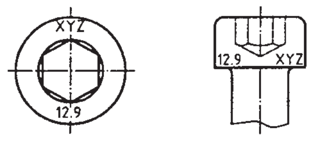
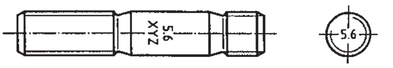
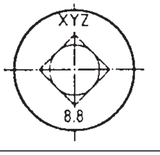
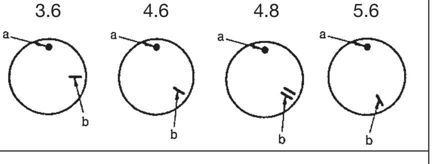
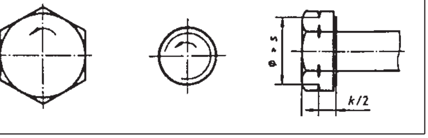
Mechanical and physical properties

Mechanical and physical properties			Property classes									
			3.6	4.6	4.8	5.6	5.8	6.8	8.8		10.9	12.9
									$d \leq$ 16 mm	$d >$ 16 mm		
Nominal tensile strength $R_{m\ Nenn}$	N/mm²		300	400		500		600	800	800	1000	1200
Minimum tensile strength $R_{m\ min}$	N/mm²		330	400	420	500	520	600	800	830	1040	1220
Vickers hardness HV $F \geq 98$ N	min.		95	120	130	155	160	190	250	255	320	385
	max.		220					250	320	335	380	435
Brinell hardness HB	min.		90	114	124	147	152	181	238	242	304	366
$F = 30\ D^2$	max.		209					238	304	318	361	414
Rockwell hardness HR	min.	HRB	52	67	71	79	82	89	–	–	–	–
		HRC	–	–	–	–	–	–	22	23	32	39
	max.	HRB	95.0					99.5	–	–	–	–
		HRC	–					–	32	34	39	44
Surface hardness HV 0,3	max.		–									
Lower yield stress R_{eL} in N/mm²	Nominal value		180	240	320	300	400	480	–	–	–	–
	min.		190	240	340	300	420	480	–	–	–	–
0.2 % proof strength $R_{p\ 0,2}$ in N/mm²	Nominal value		–						640	640	900	1080
	min.		–						640	660	940	1100
Stress under proof load	S_p/R_{eL} o. $S_p/R_{p\ 0,2}$		0.94	0.94	0.91	0.93	0.90	0.92	0.91	0.91	0.88	0.88
	S_p		180	225	310	280	380	440	580	600	830	970
Breaking torque, M_B	N m min.		–						siehe ISO 898-7			
Elongation at break, A in %	min.		25	22	–	20	–	–	12	12	9	8
Reduction of area after fracture, Z	% min.		–						52		48	44
Strength under wedge loading			The values for full-size threaded fasteners (not studs) under wedge loading must not be less than the specified minimum tensile strengths.									
Impact energy, KU	J min.		–			25	–		30	30	20	15
Head soundness			No fracture									
Minimum height of the non-decarburised thread zone E			–						$\frac{1}{2} H_1$		$\frac{2}{3} H_1$	$\frac{3}{4} H_1$
Maximum depth of complete decarburisation G	mm		–						0.015			
Hardness after retempering			–						Decrease in hardness max. 20 HV			
Surface condition			In conformance with ISO 6157-1 or ISO 6157-3, as appropriate.									

Extract from DIN EN ISO 898-1

3

Marking of bolts and screws made from steel

Hexagon head and hexalobular head bolts and screws of all property classes for thread sizes M5 and above showing manufacturer (a) and property class (b)	
Hexagon socket and hexalobular socket head bolts and screws for 8.8 and higher, for thread size M5 or higher, showing manufacturer and property class	
Studs 5.6, 8.8 and higher, of thread size M5 or higher, showing manufacturer and property class or symbol	
Cup head square neck bolts and screws 8.8 and higher, for thread size M5 or higher, showing manufacturer and property class	
Small bolts and screws and other head types Marking using clock face system 12 o'clock position shown by a dot or the manufacturer's trade mark (a). The property class is indicated by a dash (b).	
Bolts and screws with left-hand thread are marked with an arrow on the head or the end of the thread, or by notches on the hexagon flats	

Property class	5.6	8.8	9.8	10.9	12.9
Symbol	—	○	+	□	△

From DIN EN ISO 898-1

Nuts made from steel

Only one number is used to indicate the property class of a nut. This number is approximately 1/100 of the proof stress in N/mm². This corresponds to the minimum tensile strength of the bolt with which it will be paired.

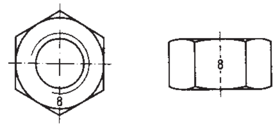
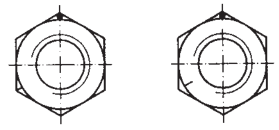
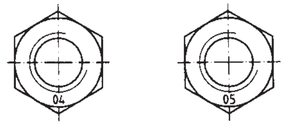
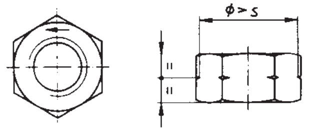
A bolt of property class 8.8 must be paired with a nut of property class 8 (or higher). Using this combination, the bolt can be loaded up to the yield point.
There are however some nuts that have a limited load-bearing capacity (see next page).

Proof load values for ISO 4032 nuts with coarse pitch thread

Thread	Thread pitch	Nominal stress area of the test mandrel A_S	Property class							
			4	**5**	**6**	**8**		**10**	**12**	
			Proof load (A_S x S_p), N							
	mm	mm²	Type 1	Type 1	Type 1	Type 1	Type 2	Type 1	Type 1	Type 2
M 3	0.5	5.03	–	2600	3000	4000	–	5200	5700	5800
M 3.5	0.6	6.78	–	3550	4050	5400	–	7050	7700	7800
M 4	0.7	8.78	–	4550	5250	7000	–	9150	10000	10100
M 5	0.8	14.2	–	8250	9500	12140	–	14800	16200	16300
M 6	1	20.1	–	11700	13500	17200	–	20900	22900	23100
M 7	1	28.9	–	16800	19400	24700	–	30100	32900	33200
M 8	1.25	36.6	–	21600	24900	31800	–	38100	41700	42500
M 10	1.5	58.0	–	34200	39400	50500	–	60300	66100	67300
M 12	1.75	84.3	–	51400	59000	74200	–	88500	98600	100300
M 14	2	115	–	70200	80500	101200	–	120800	134600	136900
M 16	2	157	–	95800	109900	138200	–	164900	183700	186800
M 18	2.5	192	97900	121000	138200	176600	170900	203500	–	230400
M 20	2.5	245	125000	154400	176400	225400	218100	259700	–	294000
M 22	2.5	303	154500	190900	218200	278800	269700	321200	–	363600
M 24	3	353	180000	222400	254200	324800	314200	374200	–	423600
M 27	3	459	234100	289200	330500	422300	408500	486500	–	550800
M 30	3.5	561	286100	353400	403900	516100	499300	594700	–	673200
M 33	3.5	694	353900	437200	499700	638500	617700	735600	–	832800
M 36	4	817	416700	514700	588200	751600	727100	866000	–	980400
M 39	4	976	497800	614900	702700	897900	868600	1035000	–	1171000

Extract from DIN EN 20898-2

Marking of nuts with property classes

Hexagon nuts of all property classes of thread sizes M5 and above on the bearing surface or hexagon flats	
Marking using the clock face system The 12 o'clock position is shown by a dot or the manufacturer's trade mark; the property class is shown by a dash.	
Nuts with nominal heights ≥ 0.5 D but < 0.8 D are marked with a two digit number. The load-bearing capacity of these nuts is limited.	
Nuts with left-hand thread are marked with notches or an arrow embossed on the bearing surface.	

From DIN EN ISO 20898-2

Nuts with limited load-bearing capacity

Nuts that conform to the withdrawn standard ***DIN 934*** (with nominal heights of approximately 0.8 d) cannot be loaded reliably up to the yield point of the corresponding bolt. In order to differentiate these, vertical bars are added before and after the property class marking, e.g. I8I instead of 8.

Nuts with nominal heights ≥ 0.5 D but < 0.8 D are marked with the property classes 04 and 05. DIN EN 20898-2 specifies proof load values and resistance to stripping for these flat nuts.

Property class of the nut	Proof load stress of the nut N/mm²	Minimum stress in the bolt before stripping in N/mm² when paired with bolts of the property classes below			
		6.8	8.8	10.9	12.9
04	380	260	300	330	350
05	500	290	370	410	480

From DIN EN ISO 20898-2

These nuts are marked with numbers indicating the property class, that is 04 or 05.

No proof load values are specified for ***nuts with hardness classes.*** The property classes are assigned according to the minimum hardness. The numbers indicate 1/10 of the minimum Vickers hardness HV 5.

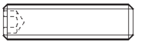
Mechanical property		Property class			
		11H	14 H	17 H	22 H
Vickers hardness HV 5	min.	110	140	170	220
	max.	185	215	245	300
Brinell hardness HB 30	min.	105	133	162	209
	max.	176	204	233	285

From DIN 267-24

Set screws

Set screws and similar threaded fasteners made of carbon steel and alloy steel which are not subject to tensile stresses are standardised in DIN EN ISO 898 Part 5. The property classes are based on the Vickers hardness scale.

Set screw with slot and chamfered end



Set screw with hexagon socket and chamfered end

Property class	**14 H**	**22 H**	**33 H**	**45 H**
Vickers hardness, HV min	**140**	**220**	**330**	**450**

From DIN EN ISO 898-5

3

A marking showing the property class is not required for these components.

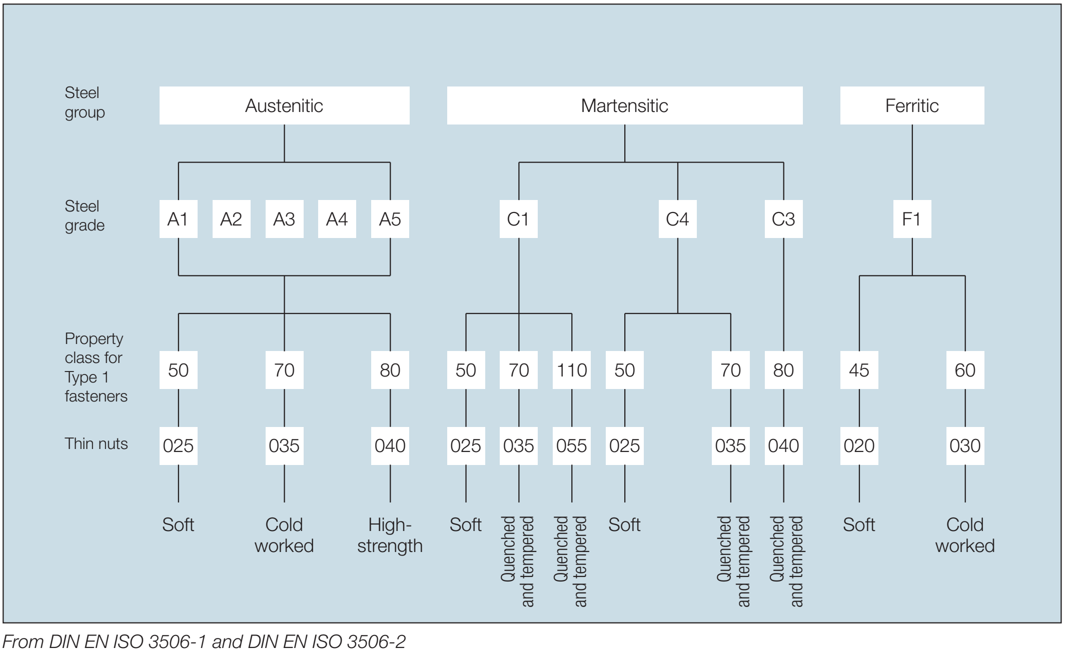
Corrosion-resistant stainless steel fasteners

In addition to the standard property classes, fasteners made from stainless steel are often used. This material has a high level of functional reliability and a long service life.

Low-alloy steels are liable to the formation of iron oxide (rust) on the surface. Steel alloys with a chromium content of 12 % or more will form a layer of chromium oxide. This compound protects the surface against corrosion. This makes the steel resistant to rusting.

Rust and acid resistant fasteners are divided into steel groups, steel grades and property classes according to DIN EN ISO 3506 Part 1.

Designation system for stainless steel grades and property classes for bolts, screws, studs and nuts



From DIN EN ISO 3506-1 and DIN EN ISO 3506-2

Ferritic steels (F1) are magnetic. Martensitic steels (C1, C3 and C4) are hardenable, but only have limited corrosion resistance.

Grades A2 and A4 austenitic steels are the most commonly used.

A stands for ***austenitic chromium-nickel steel*** with an alloying content of 15–20 % chromium and 5–15 % nickel.

A1 For machining with 2 % copper component. It is less resistant to corrosion.

A2 Frequently used steel grade with approximately 18% chromium and approximately 8 % nickel. Good resistance to corrosion. Not suitable for saltwater and chlorinated water.

A3 Properties similar to A2. Stabilised with Ti, Nb or Ta to prevent formation of chromium carbide even at high temperatures.

A4 Frequently used material Acid resistance provided by 2–3 % molybdenum, therefore also suitable for saltwater and chlorinated water.

A5 Properties similar to A4, but stabilised similarly to A3.

Fasteners made from these steel grades are divided into property classes 50, 70 and 80. These numbers indicate 1/10 of the minimum tensile strength in N/mm^2.

Mechanical properties of bolts, screws and studs made from austenitic steel

Steel group	Steel grade	Property class	Thread diameter range	Tensile strength R_m[1] N/mm^2 min.	0.2 % proof strength $R_{p\,0.2}$[1] N/mm^2 min.	Elongation at break A[2] mm min.
Austenitic	**A1, A2, A3, A4, A5**	50	≤ M 39	500	210	0.6 d
		70	≤ M 24[3]	700	450	0.4 d
		80	≤ M 24[3]	800	600	0.3 d

[1] The tensile stress is calculated with reference to the stress area.
[2] The elongation at break must be determined on the actual screw length and not on prepared test pieces. d is the nominal thread diameter.
[3] For fasteners with nominal thread diameters $d > 24$ mm, the mechanical properties must be agreed between the user and the manufacturer. They must be marked with the steel grade and the property class in accordance with this table.

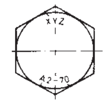
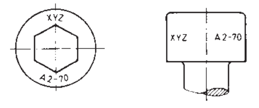
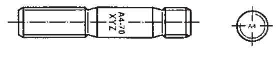
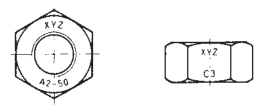
From DIN EN ISO 3506-1

Austenitic chromium-nickel steels cannot be hardened.

The higher property classes, 70 and 80, are achieved by means of the pressing force applied during cold forming. Although these steels are not magnetic, the components can become slightly magnetised as a result of the cold forming process.

Hot worked and machined components are supplied in property class 50.

Marking of corrosion-resistant stainless steel fasteners

Hexagon head bolts and screws of thread size M5 or higher show manufacturer, steel grade and property class on top of the head	
Hexagon socket head bolts and screws of thread size M5 or higher show manufacturer, steel grade and property class on the top or side of the head	
Studs M6 and above show manufacturer, steel grade and property class on the non-threaded part or show the steel grade on the chamfered end of the nut thread	
Hexagon nuts of thread size M5 and above show manufacturer, steel grade and property class	
Alternative for hexagon nuts manufactured by machining A2 has a single notch A4 has two notches	

From DIN EN ISO 3506-2

Bolts, screws and nuts made from steel with specific elevated and/or low temperature properties

DIN 267 Part 13 recommends materials suitable for making bolts, screws and nuts for use at very high and very low temperatures.

There are no property classes for these applications. The design engineer must determine which material is suitable for the operating conditions in accordance with the technical specifications.

Steels and nickel alloys for use at elevated and/or low temperatures as in DIN EN 10269

Temperature range documented in DIN EN 10269			Material				HV hardness of the fastener	
min.	Short duration [a]	Long duration [b]	Abbreviation	Number	Code	Heat treatment symbol [c]	min.	max.
- 120 °C	–	–	KB	1.5680	X12Ni5	+ NT	157	203
						+ QT	173	235
–	400 °C	500 °C	Y [d]	1.1181	C35E	+ N	150	200
–	400 °C	500 °C	YK	1.1181	C35E	+ QT	165	210
–	400 °C	–	YB	1.5511	35B2 [g]	+ QT	165	210
- 60 °C	500 °C	550 °C	KG	1.7218	25CrMo4	+ QT	195	240
- 100 °C	500 °C	–	GC	1.7225	42CrMo4	+ QT	275	337
–	500 °C	550 °C	GA	1.7709	21CrMoV5-7	+ QT	225	272
–	600 °C	550 °C	GB	1.7711	40CrMoV4-6	+ QT	272	320
–	500 °C	600 °C	V [e]	1.4923	X22CrMoV12-1	+ QT 1 [e]	256	303
–	500 °C	600 °C	VH [f]	1.4923	X22CrMoV12-1	+ QT 2 [f]	287	367
–	600 °C	600 °C	VW	1.4913	X19CrMoVNbN11-1	+ QT	287	367
–	650 °C	670 °C	S	1.4986	X7CrNiMoBNb16-16	+ WW + P	210	272
- 196 °C	650 °C	650 °C	SD	1.4980	X6NiCrTiMoVB25-15-2	+ AT + P	287	367
- 196 °C	650 °C	800 °C	SB	2.4952	NiCr20TiAl	+ AT + P	320	417

a Upper limit of temperature range with specified proof strengths and tensile strengths
b Upper limit of temperature range with specified creep strain and creep rupture strengths
c + N: normalised
+ NT: normalised and tempered
+ QT: quenched and tempered
+ WW: warm worked
+ AT: solution annealed
+ P: precipitation hardened
d Only for nuts
e Code V for material X22CrMoV12-1 as in DIN EN 10269 with 0.2% proof strength $R_{p\,0,2} \geq 600$ N/mm² (+ QT 1)
f Code VH for material X22CrMoV12-1 as in DIN EN 10269 with 0.2% proof strength $R_{p\,0,2} \geq 700$ N/mm² (+ QT 2)
g See also VdTÜV Materials Data Sheet 490

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BÖLLHOFF

The table below applies to the use of austenitic materials at low temperatures down to -200 °C. The properties must correspond to the requirements specified in DIN EN ISO 3506-1 and DIN EN ISO 3506-2 for the respective steel grades and property classes.

Austenitic materials as in DIN EN ISO 3506-1 and DIN EN ISO 3506-2 for low operating temperatures

Lower limit of the operating temperature for parts in continuous use (guideline value)	Steel grade [a]	Property class	
		Bolt/screw	Nut
- 60 °C - 200 °C	A2 A3 A4 A5	50 70	50 70 80

a Copper content ≤ 1% (limited compared to DIN EN ISO 3506-1 and -2)

Note: There are no known negative effects on serviceability above these temperatures.
For lower temperatures, an appropriate test must be carried out to assess suitability for each specific application.

3

Nonferrous metal bolts, screws and nuts

Nonferrous metals (NF) are defined as having an iron content of no more than 50%. A distinction is made between light metals and heavy metals:

Heavy metals	Copper and copper alloys, such as brass, kuprodur, etc.; nickel and nickel alloys such as Monel
Light metals	Aluminium and aluminium alloys, titanium and titanium alloys

Mechanical properties of bolts, screws and nuts made from nonferrous metals

Material			Nominal thread diameter, d	Tensile strength R_m min.	0.2%-proof strength $R_{p\,0.2}$ min.	Elongation at break A min.
Symbol	Short name	Mat. no.		N/mm²	N/mm²	%
CU1	Cu-ETP oder Cu-FRHC	2.0060	$d \leq$ M 39	240	160	14
CU2	CuZn37 (alt Ms 63)	2.0321	$d \leq$ M 6 M 6 $< d \leq$ M 39	440 370	340 250	11 19
CU3	CUZN39Pb3 (alt Ms 58)	2.0401	$d \leq$ M 6 M 6 $< d \leq$ M 39	440 370	340 250	11 19
CU4	CuSn6	2.1020	$d \leq$ M 12 M 12 $< d \leq$ M 39	470 400	340 200	22 33
CU5	CuNi1Si	2.0853	$d \leq$ M 39	590	540	12
CU6	CuZn40Mn1Pb	2.0580	M 6 $< d \leq$ M 39	440	180	18
CU7	CuAl10Ni5Fe4	2.0966	M 12 $< d \leq$ M 39	640	270	15
AL1	AlMg3	3.3535	$d \leq$ M 10 M 10 $< d \leq$ M 20	270 250	230 180	3 4
AL2	AlMg5	3.3555	$d \leq$ M 14 M 14 $< d \leq$ M 36	310 280	205 200	6 6
AL3	AlSi1MgMn	3.2315	$d \leq$ M 6 M 6 $< d \leq$ M 39	320 310	250 260	7 10
AL4	AlCu4MgSi	3.1325	$d \leq$ M 10 M 10 $< d \leq$ M 39	420 380	290 260	6 10
AL5	AlZnMgCu0,5	3.4345	$d \leq$ M 39	460	380	7
AL6	AlZn5,5MgCu	3.4365	$d \leq$ M 39	510	440	7

From DIN EN 28839

Mechanical properties

A ***tensile test*** involves applying a load to a fastener or test piece on a testing machine until it breaks. The sample is initially elongated elastically as the load is applied. When this load is removed, the part returns to its original length.

If subjected to a higher load, the sample will be elongated permanently, which is referred to as plastic deformation.

If the load is further increased, the fastener or test piece will break.

Tensile test in accredited laboratory in Bielefeld

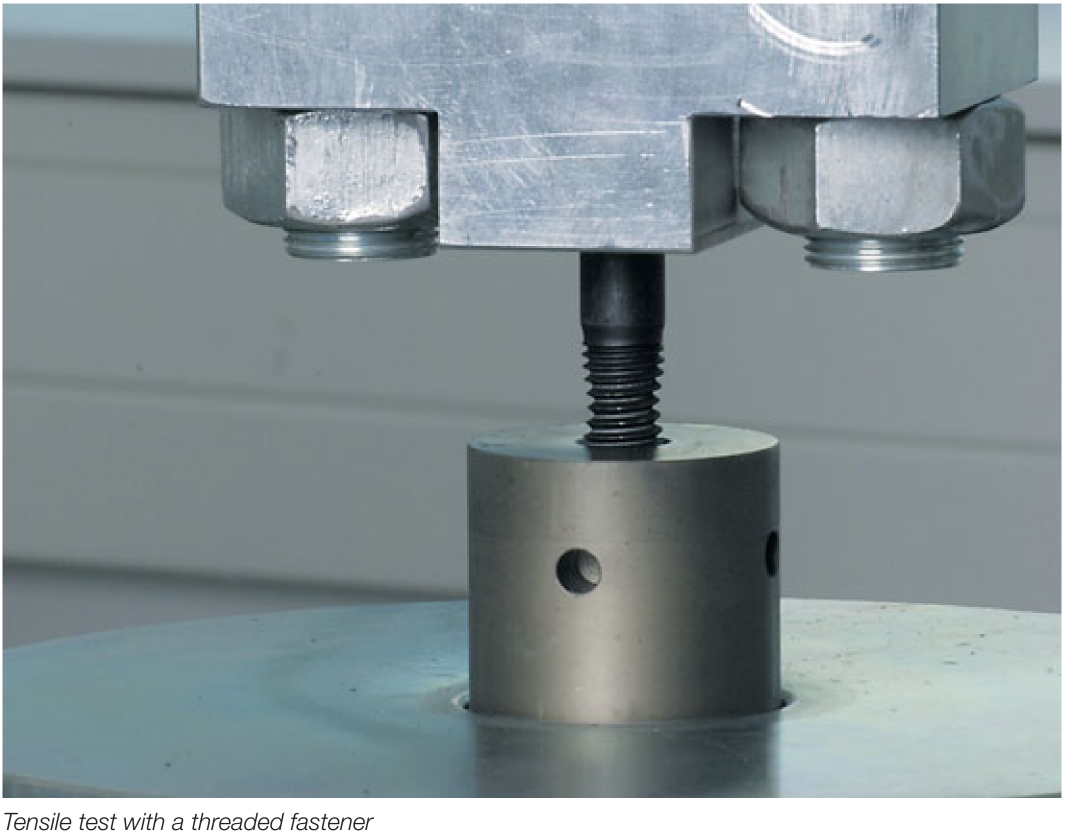
The following quantities are established during a tensile test:

Re The ***yield point*** is the point of transition from elastic to plastic deformation.
R_{eL} is the lower yield point
R_{eH} is the upper yield point

Rp 0.2 The 0.2 ***proof strength*** is measured instead of the yield point for high-strength fasteners of property class 8.8 and above.
This also represents the transition from elastic to permanent (plastic) deformation, specified by a 0.2% change in length. This value is of decisive importance for the calculation of the load capacity of the fastener.

Rm The ***tensile strength*** is the highest load that the sample is able to withstand. Beyond this value the resistance decreases and the sample splits.
For fasteners, the break must occur in the thread or the shank, not below the head.

A The ***elongation at break*** is the permanent elongation in % as compared to the initial length. The elongation at break is determined using machined test pieces.



Tensile test with a threaded fastener

Hardness testing

Hardness testing involves measuring the resistance that a material presents when an indenter is pressed against it.

HB ***Brinell*** hardness test for soft to medium-hard materials.
A hardened metal ball is pressed against the material.
The diameter of the indentation is measured.

HV ***Vickers*** hardness test for soft to hard materials.
The indentation is made using a pyramid-shaped diamond.
The indentation is measured across the diagonals.

HR ***Rockwell*** hardness test. The test measures the difference between a preliminary load and a test load. The measured values can be read directly from the measuring device. HRC and HRA are tests for hard materials using a diamond indenter. HRB and HRF are tests for soft materials using a hardened steel ball.

Hardness testing in the laboratory in Bielefeld

3

Summary of inspection documents

Designation of document type as in EN 10204		Content of the document	Document validated by:
2.1	Declaration of compliance with the order	Statement of compliance with the order	Manufacturer
2.2	Test report	Statement of compliance with the order, with indication of results of non-specific inspection	Manufacturer
3.1	Inspection certificate 3.1	Statement of compliance with the order, with indication of results of specific inspection	Manufacturer's representative, who must be independent of the manufacturing department
3.2	Inspection certificate 3.2	Statement of compliance with the order, with indication of results of specific inspection	Both the manufacturer's representative, who must be independent of the manufacturing department, and an independent inspector appointed either by the customer or an inspector designated by official regulations

The certified values are not “guaranteed properties”. Test certificates are not a substitute for goods-inwards testing.

The costs of sample parts, testing and certification are not included in the product price.

For pressure vessel applications, the Arbeitsgemeinschaft Druckbehälter (AD – German Pressure Vessel Association) publishes data sheets (Merkblätter) that are also applicable to threaded fasteners.

AD Data Sheet W 2	For austenitic steels (corrosion resistant and acid proof)
AD Data Sheet W 7	For threaded fasteners made from ferritic steels
AD Data Sheet W10	For ferrous materials for low temperatures
TRD 106	For threaded fasteners made from steel

(TRD = Technische Regeln für den Dampfkesselbau = Technical Regulations for Steam boilers)

Only prescribed materials may be used for pressure vessel applications.

Products may only originate from accredited manufacturers, whose production systems are monitored by independent certification authorities.

These manufacturers must be regularly audited to maintain their accreditation status. The names, addresses and manufacturer's trade marks are listed in the data sheets.

Which fasteners can be welded?

The suitability for welding depends on the alloying elements in the steel.

The following are suitable for welding:

- Weld nuts
- Weld-on ends
- Weld studs etc.

The functional standards for other types of fasteners do not contain any information relating to weldability.

The property classes do not specify any particular material, rather a defined framework is provided, within which the manufacturer is free to select a steel appropriate to the manufacturing method. It is therefore impossible to derive from the property class whether the material is suitable for welding.

High-strength fasteners of property class 8.8 and above are quenched and tempered. This heat treatment allows the required mechanical properties to be achieved.
If these parts are subjected to high temperatures during welding, their properties will be modified. This means that it is possible that a fastener will not retain its original property class after being welded.

There are many different welding techniques, all of which affect material properties in different ways.

Only specialist welders are qualified to decide whether a material is suitable for a particular welding technique.

Cold forming

As a general rule, threaded fasteners are manufactured by means of cold forming.This process involves causing plastic deformation at room temperature. The following materials are all suitable for cold forming: non-alloy steel, case hardening steel, quenched and tempered steel, copper, brass, aluminium alloys.
Cold forming is the most economic manufacturing method. However, this is only commercially viable for production batches with ***large numbers of parts.*** Cold forming is a method of shaping that does not require removal of material and can be used for screws, bolts and pins with ***shank diameters of 30 mm*** and ***lengths up to 300 mm.***

Careful selection of the original material is therefore the primary consideration in ensuring the quality of the final product. For fasteners, it is usually necessary to use a heat treatment process after cold forming in order to achieve the desired mechanical properties for the material. The user selects the property class that matches the requirements of the application where the threaded connection will be implemented.
It is unusual for the user to select the primary material, since although the mechanical properties do depend on the material used, these are also modified during manufacturing. This means that the properties are process dependent. The manufacturer will therefore select a material, in accordance with the specifications in the standard, that will allow the supplied, finished component to possess the required properties.
The primary material is delivered to the manufacturer in the form of bar stock with diameters ranging from 1 mm to 30 mm, wound on reels.

These reels of bar stock have a weight of approximately 1000 kg.
The reels are first pickled prior to working, then straightened and drawn to the required major diameter. Often, the bar stock is processed in the phosphated condition, which makes processing easier and minimises tool wear.

Primary reel before cold forming

Machines (presses) are used to cut off a blank from the bar stock for further processing. Cold forming processes can be split into three categories: upsetting, ironing and extrusion. These techniques can be combined with each other as appropriate.

This means that there are many different possible implementations. For certain products, these processes are combined with machining, for example trimming of hexagon head bolts and screws or producing special end features and bores.

Nonetheless, modern technologies allow multifunctional features to be produced without the need for any machining.

Paint scraper groove/feature formed by rolling on a flat die for helping to align the thread by means of thread pitch shape

Threaded fasteners manufactured using cold forming methods can be split into two groups:

1. Relatively simple fastener geometries are manufactured on double-stroke presses. This employs an upsetting process in two stages: pre-upsetting and final upsetting.

2. Fasteners with complex forms are manufactured on transfer presses employing multiple upsetting and ironing stages.These tools consist of a die-side and a punch-side.

The press blank is repositioned using grippers after every stroke of the press, moving the part from one station to the next on the die side. This results in a sequence of stages for the cold-forming of parts. Depending on the design of the fastener, various dies and press sequences can be used here.

For a hexagon head bolt or screw, the manufacturing stages are arranged in the following order: Cutting the bar stock, pre-upsetting and ironing of the shank, upsetting a round head, trimming the head to a hexagonal shape, forming the bolt or screw end, and finally, on a separate machine, forming the screw thread by means of a flat or cylindrical die.

Stages in forming a hexagon head bolt or screw.

Advantages of cold forming:

- The material is hardened in the formed areas.
- The tensile strength and yield point are increased.
- A smooth surface is created.
- The continuity of the grain structure remains unbroken.
- Material faults are made visible by the forming process.
- Economical manufacture

Hexagon nuts are also usually cold formed. As with hexagon head bolts and screws, the primary material is bar stock with a round cross section.

Forming stages of a hexagon nut

Hot forming

Hot forming is used to a much lesser degree than cold forming. The hot forming manufacturing technique is an option when the number of parts is too low for the cold forming process, or if the deformation ratio is too high.

Hot forming or head forging is carried out after heating the primary material (fully or partially) to the forging temperature. Bar material is used in these cases.

After heating, the material is easily deformable, meaning that complicated shapes can be manufactured. Unlike cold forming, the process does not result in hardening of the material. This method allows small quantities to be manufactured more “easily” than with cold forming. The machines and dies are less complex and expensive than those used for cold forming. The surface of the part is relatively rough, a typical characteristic of hot formed objects.

Hot formed parts include:
- Large thread sizes (M30 and higher)
- Long lengths (from 300 mm)
- Complicated shapes
- Small numbers of parts (limited production or prototypes)

Due to the coarse outer texture and the large manufacturing tolerances, hot-formed parts are often finished using a machining technique.

Hot-formed part

Drop forging

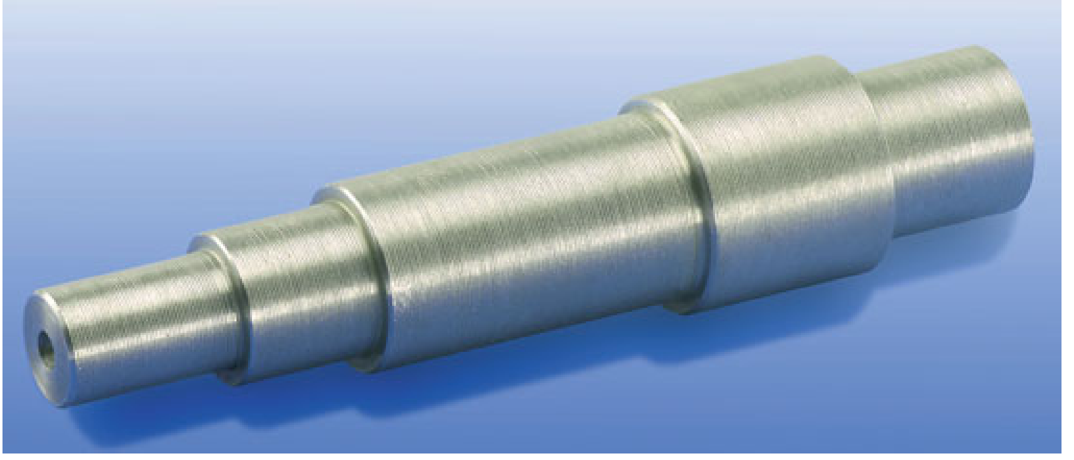
In some cases, standard parts are manufactured using a drop forging process.The dies are positioned vertically opposite to each other and together form a hollow chamber. The blank is heated up to the forging temperature and then pressed inside this hollow space to create the desired form.

Machining

Machined parts are typically characterised as turned parts. Some fasteners are also manufactured as machined parts, for example knurled thumb screws. This technique is also suitable as a manufacturing/finishing method for use with parts with special profiles, small radii or intentionally sharp edges. In addition to this, there are some special materials that cannot be formed without machining. The automatic lathes used to manufacture these parts work using rods or coils of the primary material. As a rule, the diameter of the semi-finished product is equal to the largest diameter required for the finished part. Shaping is performed by machining with the turning tool. In contrast to cold and hot forming, this has the effect of destroying the continuity of the grain structure of the primary material.

This must be taken into consideration for parts that will operate under load, such as fasteners. As a rule, no special tooling is required, and commercially available turning tools, milling cutters and drills can be used.

Machining is not only used to obtain cylindrical shapes by turning, but also implies processes such as milling of flat areas, drilling, grinding and similar fine work, e.g. to achieve a specified degree of roughness.



Turned part

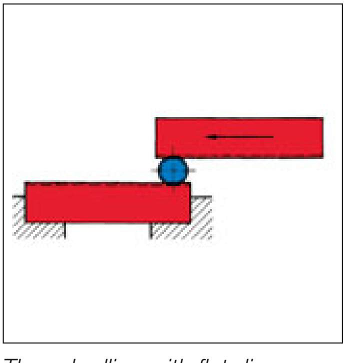
Machining process on an automatic lathe

Machining is used for:

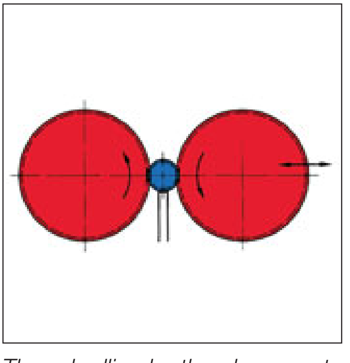
- Small numbers of parts
- Shapes and radii with tight tolerances
- Finishing
  (e.g. grinding of fit bolts)
- Special materials

Thread manufacture

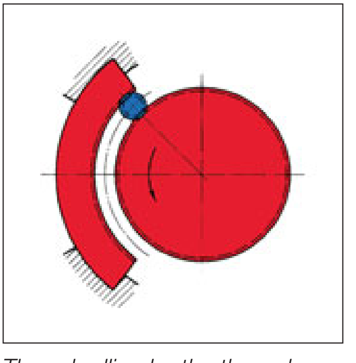
External threads on bolts and screws are usually produced by rolling with flat or cylindrical dies.The cold forming process can be carried out using flat dies, rollers or roller segments. These tools feature a negative thread profile. For threads that are rolled on a flat die, the material is extruded from its initial diameter (rolling diameter) by forcing it radially into the negative profile of the die.
With flat die rolling the thread crests are formed outwards. This makes it possible to produce screw and washer assemblies where the washer cannot be lost.
All common types of thread profiles can be formed in this way, including trapezoidal screw threads, tapping screw threads and wood screw threads.



Thread rolling with flat dies



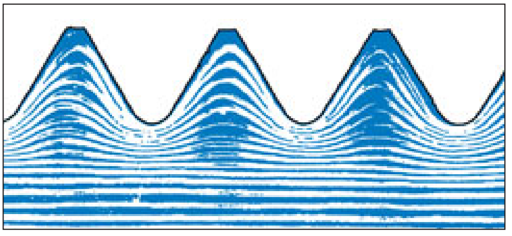
Thread rolling by the plunge-cut method



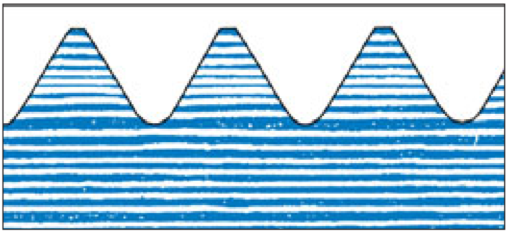
Thread rolling by the through-feed method

Thread rolling is usually carried out before quenching and tempering. This can also take place after heat treatment to meet special requirements. This is referred to as final rolling.

The schematic diagrams of the microstructure clearly shows the difference between rolled and cut threads. With rolled threads, the initial diameter is approximately the same as the pitch diameter, whereas for cut threads it is equal to the major diameter of the thread to be manufactured.

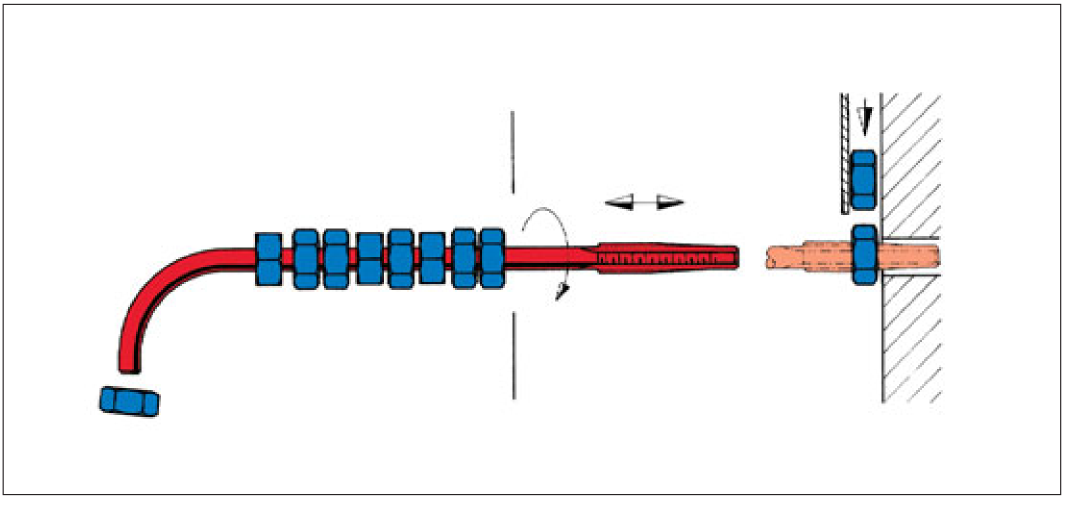


Rolled thread



Cut thread

The internal thread found on nuts is almost always machined. This is done on automatic machines fitted with reduced-shank taps. With cut threads, the surface is rougher that with rolled threads and the continuity of the grain structure is broken.



Thread cutting with reduced-shank tap

Cold-formed threads rolled with flat or cylindrical dies have the following advantages over cut threads:

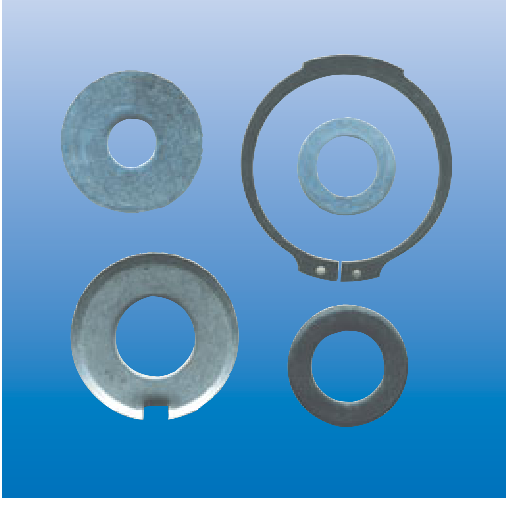
- The output quantity is high, therefore production is economical.
- No chip removal during manufacture
- Smooth surface
- Improvement of tensile strength and durability

4

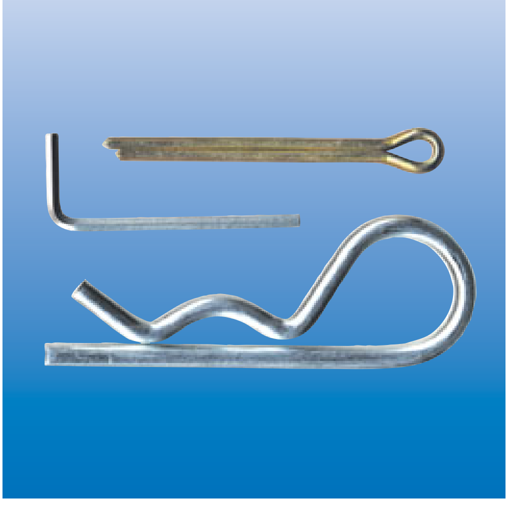
Punching and bending

Threaded connections often make use of load distribution components and other fastener fittings made from sheet or strip metal. Shaft locks and washers are also manufactured as punched parts.

The desired shape is stamped against a cutting die by a cutting punch. The term 'bent parts' refers to parts manufactured from profile wire or sheet metal that is bent into shape using appropriate tools.



Punched parts



Bent parts

Heat treatment

Specifications for the mechanical properties of fasteners mean that they usually require heat treatment. To achieve this, the manufactured product undergoes heat treatment on a quenching and tempering line.

Exception: mill finish rivets and connecting pieces/fasteners of property classes 4.8 and 5.8

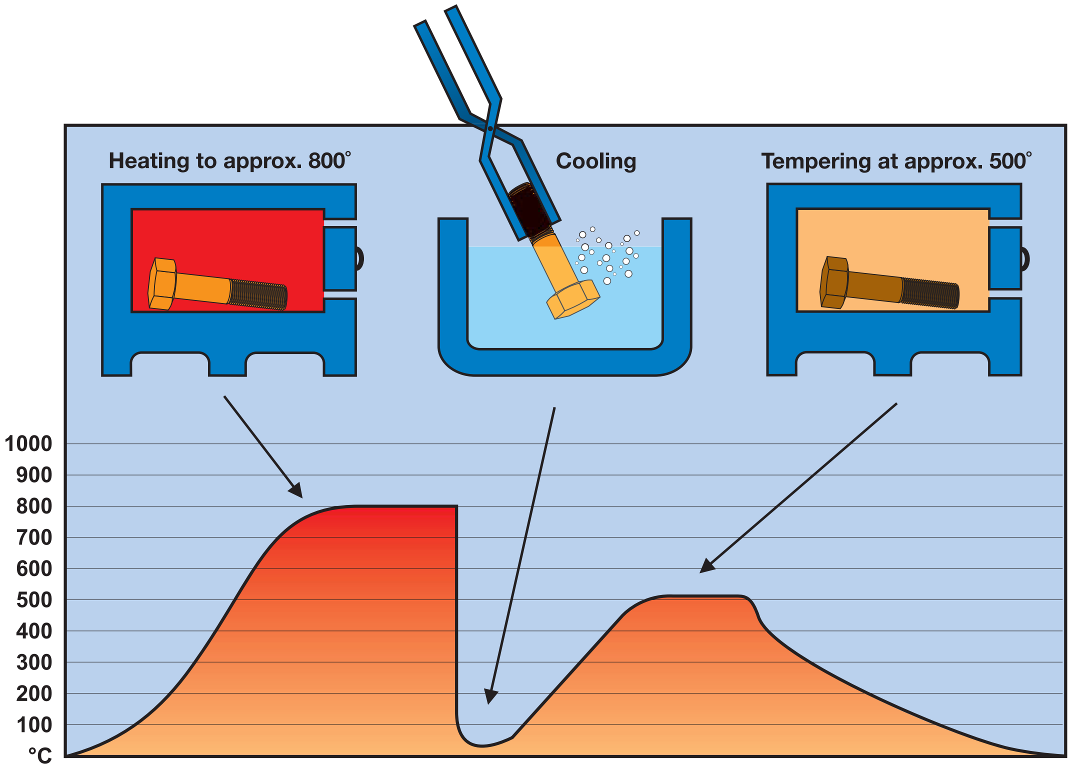
Quenching and tempering line

Heat treatment techniques are differentiated as follows:
- Annealing
- Hardening
- Quenching and tempering
- Case hardening and tempering

Annealing has the effect of reducing the stresses that are formed in the microstructure of the fastener as a result of cold forming. By heating to around 500 °C and holding the material at this temperature for a prolonged period, the internal stresses in the part become low, it loses strength, and becomes more ductile. This is important, for example, with property classes 4.6 and 5.6, since these fasteners are required to have a high elongation at break.

For hardening, the parts are heated to a temperature of around 800 °C. The absolute temperature mainly varies according to the carbon content of the steel. This heating modifies the microstructure. Subsequent quenching in oil or water causes the parts to become hard and brittle, that is they are “hardened”.

In order to achieve the properties required for proper functioning, the parts are tempered (annealed) after hardening. The minimum tempering temperature for high-strength threaded fasteners is specified in DIN EN ISO 898-1, Table 2, e.g. min. 425 °C for property class 8.8. Following this, the parts are allowed to cool slowly at room temperature, which allows them to achieve the required toughness. Hardening and subsequent tempering is known as “quenching and tempering”.



Case hardening involves heating the case-hardening steel to the hardening temperature and infusing it with carbon or nitrogen. These substances penetrate into the outermost layer of the part, thereby increasing the hardness. The surface is said to be carburised.

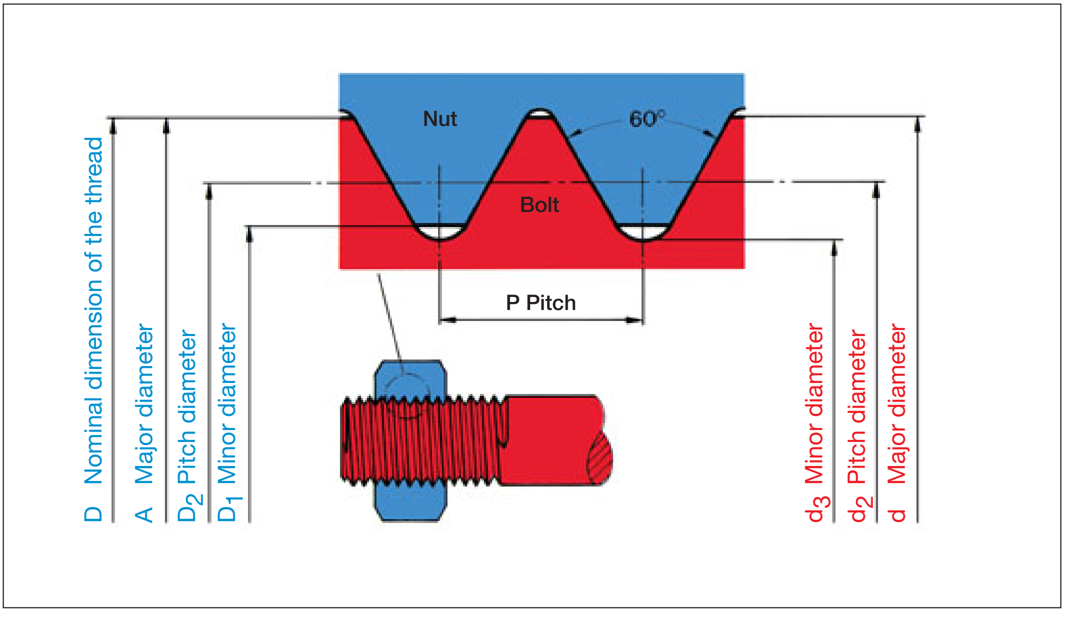
This means that the parts have a hard surface and a soft, ductile core.
These are the properties required for screws that cut or form their own threads (e.g. self-tapping screws or thread forming screws).

The thread

The threads of bolts, screws and nuts must be accurate in terms of their profile and dimensions. Only by meeting these conditions is it possible to ensure there are no problems with screwing the parts together, transferring forces as calculated, or applying a protective coating to the thread.

Threads have five dimensions that determine whether they will form a good fit:

- ***Major or nominal diameter*** is the outer diameter
- ***Minor diameter*** is the smallest diameter at the root of the thread
- ***Pitch diameter*** is the mean of the outer and minor diameters
- ***Thread pitch*** is the distance between thread crests
- ***Included angle*** is the angle formed at the thread crests



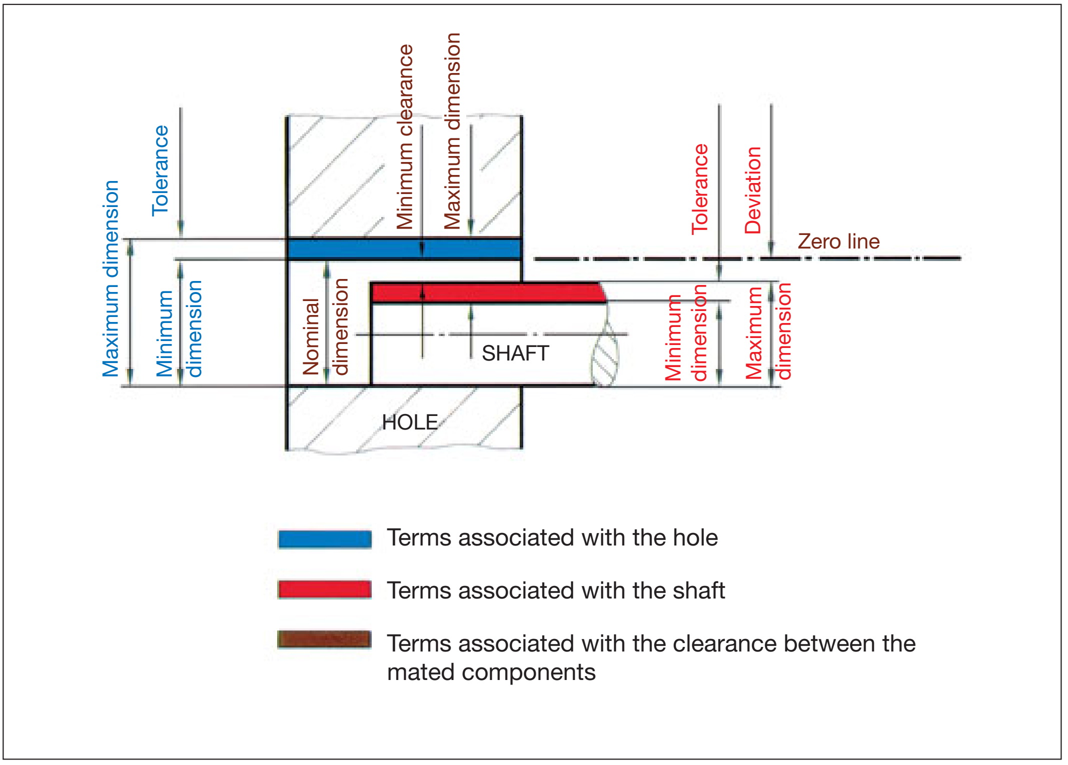
Thread profile with no clearance

The nominal dimensions, e.g. for M12 = 12 mm major diameter, lie on the zero line.

If all dimensions were manufactured exactly according to these specifications then it would be impossible to screw a part into the mating thread.

It is therefore necessary to allow some clearance between the flanks of the thread. Threads can only be manufactured within certain tolerance limits. These tolerances, that is the dimensional clearances, are very small.

The required tolerances can be seen on the diagram of a shaft passing through a hole.



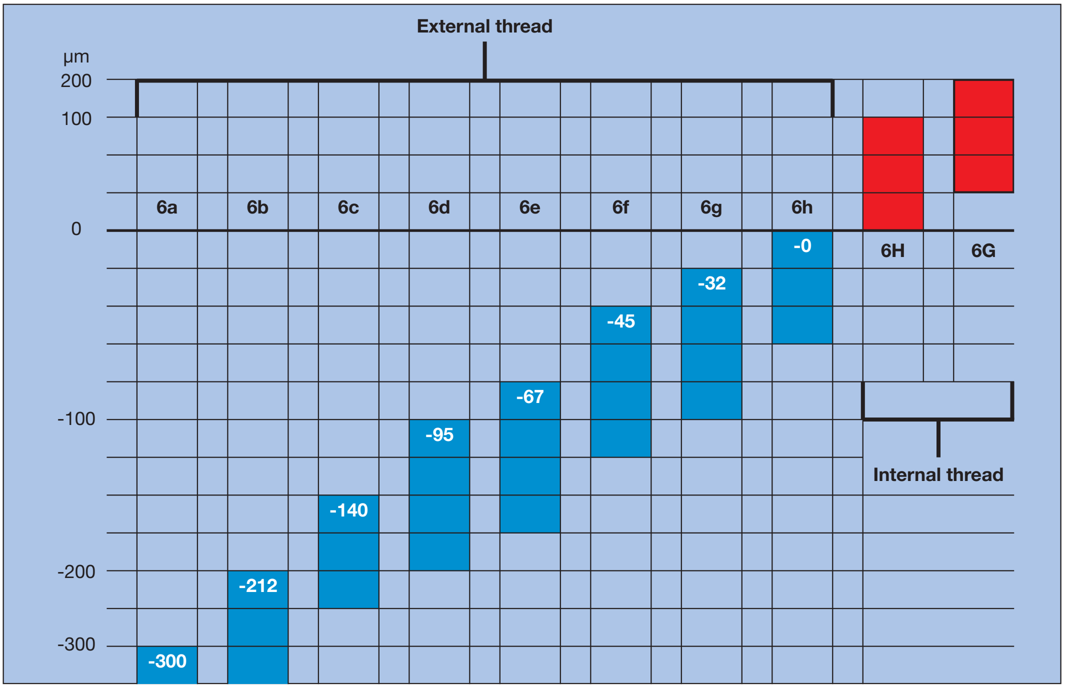
Clearance fit between shaft and hole

Even if the external thread is manufactured at the maximum dimension and the internal thread at the minimum dimension, the combination of the two must still fit together.
This means that no dimensions may transgress the zero line or the nominal dimension.

The ***tolerance position*** at the zero line is indicated by a capital H for the internal threads or a lower-case h for external threads. The letters below h, that is from g-a, indicate larger deviations from the basic size of thread.

The diameter of a thread with tolerance position e is therefore smaller than with g.

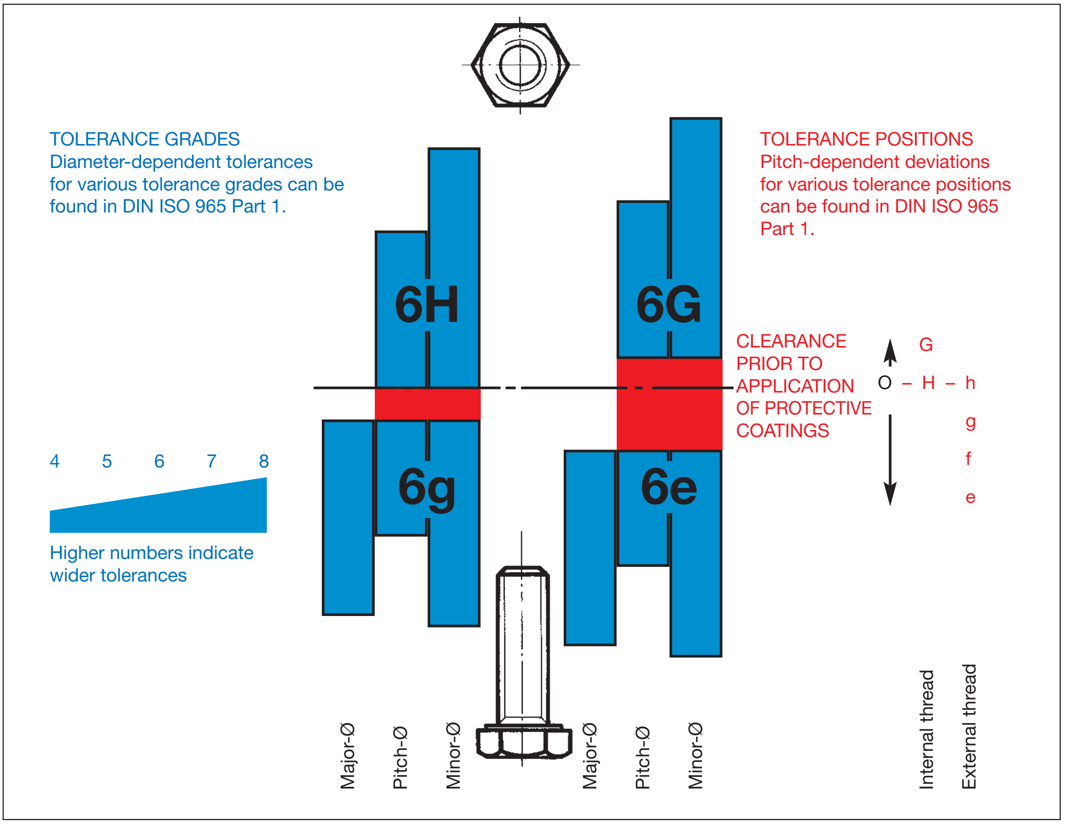
The number before the letter is referred to as the ***tolerance grade,*** e.g. ***6***g. The higher the number, the higher the tolerance zone. The dimensions of the tolerance zones also change with the nominal sizes, such that the greater the nominal dimension, the larger the tolerance zone.



Tolerance zones for bolts, screws and nuts with metric ISO thread M10

If no specific tolerance grade (size of tolerance zone) is given for a particular threaded fastener, then the part will have been manufactured to tolerance class 6g. This means that all commercially available bolts and screws have a minus allowance.

This minus allowance allows a thin electroplated coating to be subsequently applied to the surface, without the finished product exceeding the zero line for the thread. If a thicker protective layer is required, then a tolerance position with a smaller thread diameter will be necessary, e.g. 6e for thick electroplated coatings.

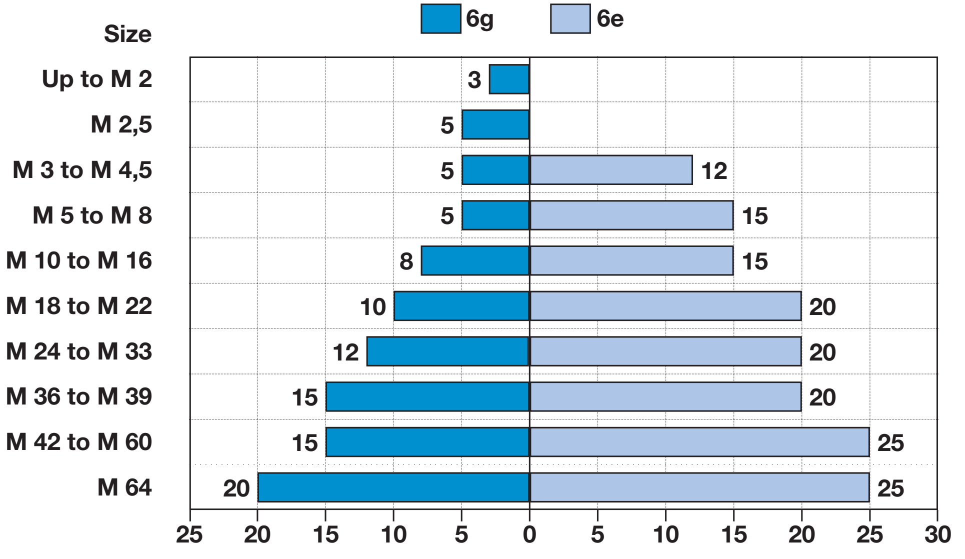


Tolerances

The various possible coating thicknesses for ISO metric coarse pitch threads of tolerance classes 6g and 6e are specified in DIN EN ISO 4042.

Allowable coating thicknesses as in DIN EN ISO 4042

ISO metric coarse pitch thread as in DIN 13 (ISO 965) of tolerance positions 6g and 6e



Coating thickness at maximum dimensions for 6g and 6e

Galvanised fasteners must not transgress the zero line at any point and will be checked for compliance with tolerance position 6h using a GO ring gauge.

The measurement positions for the protective coating on the fastener are specified by DIN EN ISO 4042. A table is provided in the section on corrosion protection.

Internal threads are usually manufactured to tolerance class 6H, but for thicker coatings the tolerance position can be greater, for example 6G.

Threads for hot-dip galvanised parts

External threads that are intended for hot-dip galvanising are manufactured to tolerance position 6a. The zinc layer is at least 40 µm thick. Threads must not be cut after hot-dip galvanising.

Due to the large minus tolerance, the diameter (stressed cross section), and therefore the load capacity, is considerably reduced (DIN EN ISO 10684).

When supplied as an assembly (nut and bolt), it is left to the manufacturer to whether the dimensional deviation occurs in the bolt thread or the nut thread

Types of thread

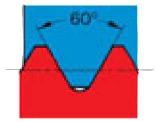
The ISO metric thread is used worldwide. Other types of thread are however also used for special purpose and replacement parts. The following table provides an overview of common thread types.

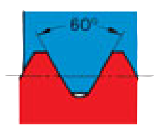
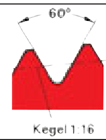
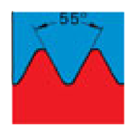
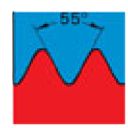
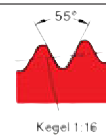
Multifunctional thread types are introduced according to manufacturer's specifications and are available commercially. These include thread forming threads for various materials and self-locking threads.

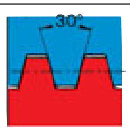
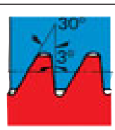
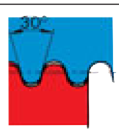
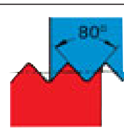
Common abbreviations for threads

M	Metric ISO thread
M..keg	Metric, tapered external thread
Tr	Metric trapezoidal thread
S	Buttress thread
Rd	Knuckle thread
Pg	Steel conduit thread
G	Pipe thread, parallel
R	Tapered pipe thread (external thread)
Rp	Parallel pipe thread where pressure-tight joints are made on the threads
St	Tapping screw thread
LH	(After the dimensional details) Left-hand thread
P	(After the thread pitch) Multi-start thread

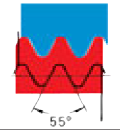
Threads

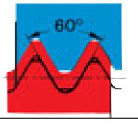
Type of thread	Metric ISO thread		Metric ISO fine pitch thread	Metric thread for interference fit	Thread with large clearance
Symbol	M	M	M x Stg	M....Sk	M....DIN......
Example of designation	M 08	M 12	M 12 x 1.5	M 12 Sk6	M 24 DIN 2510
					
Standard	DIN 14 0.3 - M 0.9 mm	DIN 13 1 - 68 mm	DIN 13 1000 mm	DIN 13 + 14	DIN 2510 12 - 180 mm
Application	Watches and precision engineering	General purpose coarse pitch thread	General purpose fine pitch thread	Threaded ends for studs	Bolted connections with waisted shank

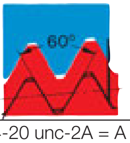
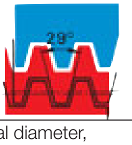
Type of thread	Metr. cyl. internal thread	Metr. tapered external thread	Parallel pipe thread	Parallel pipe thread, internal	Tapered pipe thread
Symbol	M....DIN....	M.. x P keg	G internal/external	Rp	R
Example of designation	M 24 x 2 DIN 158	M 12 x 1 keg	G 3/4 bzw. G 3/4 A	Rp 3/4	R 3/4
					
Standard	DIN 158 6 - 60 mm	DIN 158 6 - 60 mm	DIN EN ISO 228.1 1/8 bis 6 inch	DIN 2999 1/16-6 inch DIN 3858 1/8-6 inch	DIN 2999 1/16-6 inch DIN 3858 1/8-6 inch
Application	Internal threads for screw plugs	Screw plugs and lubricating nipples	Pipes and pipe joint assemblies	Pipes, fittings and pipe joint assemblies	Pipes, fittings and pipe joint assemblies

Type of thread	ISO trapezoidal thread	Buttress thread	Knuckle thread	Steel conduit thread	Left-handed thread
Symbol	Tr	S	Rd	Pg	LH
Example of designation	Tr 40 x 7	S 48 x 8	Rd 40 x 4	Pg 21	Tr 40 x 7 LH
					
Standard	DIN 103 8 x 300 mm	DIN 513 10 x 640 mm	DIN 405 DIN 20 400	DIN 40 430 Pg 7 - Pg 48	LH = Left Hand
Application	Lead-screw thread	Lead-screw thread	General purpose knuckle thread	Electrical engineering	General purpose thread

5

Type of thread	Tapping screw thread	Wood screw thread	Multi-start thread	Whitworth thread, coarse pitch	Whitworth thread, fine pitch
Symbol	–	–	P ..	BSW	BSF
Example of designation	2,9	3,5	Tr 40 x 14 P7	1/4-20 BSW	1/4-28 BSF
					
Description	DIN EN ISO 1478	DIN 7998	14 : P7 = 2 start thread	Standard BS 84	Standard BS 84
Application	Tapping screws	Wood screws	General	GB	GB

Type of thread	Unified coarse thread	Unified fine thread	Unified extra fine thread	Unified special thread	Parallel pipe thread
Symbol	UNC	UNF	UNEF	UNS	NPSM/NPSM/ NPSL/NPSH
Example of designation	1/4-20 UNC-2A	1/4-28 UNF-3A	1/4-32 UNEF-3A	1/4-27 UNS	1/2-14 NPSM
					
Description	1/4-20 unc-2A = A thread with 1/4 inch nominal diameter, 20 turns per inch				
Used in	USA/GB/Canada	USA/GB/Canada	USA/GB/Canada	USA/GB/Canada	USA

Type of thread	Standard pipe thread, tapered	Fine pipe thread, tapered	Trapezoidal thread	Stub trapezoidal thread	Buttress thread
Symbol	NPT	NPTF	ACME	Stub-ACME	Butt
Example of designation	3/-18 NPT	1/2-14 NPTF dryseal	1 3/4 4 ACME-2G	1/2-20 Stub-ACME	2,5-8 Butt-2A
					
Description	1/4-20 unc-2A = A thread with 1/4 inch nominal diameter, 20 turns per inch				Thread with ....inch N
Used in	USA	USA	USA	USA	USA

5

Inch – millimetre conversion table

Fraction	Decimal	Millimetre	Fraction	Decimal	Millimetre
1/64	.015625	.397	33/64	.515625	13.097
1/32	.03125	.794	17/32	.53125	13.494
3/64	.046875	1.191	35/64	.546875	13.890
1/16	.0625	1.587	9/16	.5625	14.287
5/64	.078125	1.984	37/64	.578125	14.684
3/32	.09375	2.381	19/32	.59375	15.081
7/64	.109375	2.778	39/64	.609375	15.478
1/8	.125	3.175	5/8	.625	15.875
9/64	.140625	3.572	41/64	.640625	16.272
5/32	.15625	3.969	21/32	.65625	16.669
11/64	.171875	4.366	43/64	.671875	17.065
3/16	.1875	4.762	11/16	.6875	17.462
13/64	.203125	5.159	45/64	.703125	17.859
7/32	.21875	5.556	23/32	.71875	18.256
15/64	.234375	5.953	47/64	.734375	18.653
1/4	.25	6.350	3/4	.75	19.050
17/64	.265625	6.747	49/64	.765625	19.447
9/32	.28125	7.144	25/32	.78125	19.844
19/64	.296875	7.541	51/64	.796875	20.240
5/16	.3125	7.937	13/16	.8125	20.637
21/64	.328125	8.334	53/64	.828125	21.034
11/32	.34375	8.731	27/32	.84375	21.431
23/64	.359375	9.128	55/64	.859375	21.828
3/8	.375	9.525	7/8	.875	22.225
25/64	.390625	9.922	57/64	.890625	22.622
13/32	.40625	10.319	29/32	.90625	23.019
27/64	.421875	10.716	59/64	.921875	23.415
7/16	.4375	11.113	15/16	.9375	23.812
29/64	.453125	11.509	61/64	.953125	24.209
15/32	.46875	11.906	31/32	.96875	24.606
31/64	.484375	12.303	63/64	.984375	25.003
1/2	.5	12.700	1	.1	25.400

Assembly of threaded connections

Threaded connections are releasable connections. In order to ensure that they fulfil their function and do not work loose or fail, connections must be selected and analysed prior to assembly for each individual application. Provided that the correct assembly technique is used, the optimal threaded connection will be obtained. The magnitude of the preload force introduced into the threaded connection cannot be measured during assembly, so the appropriate assembly technique must be selected to ensure that an optimal joint is formed.

Tightening by hand using a slugging wrench or box wrench

With this assembly method, the preload force is controlled according to the subjective experience of the person carrying out the assembly. Experience, physical constitution and the length of the tool used play a decisive role with this method. Because the variables mentioned cannot be controlled with this technique, for safety reasons it must be considered unsuitable under standard production conditions for high-strength threaded connections.

Tightening using an impact wrench

The method of operation of an impact wrench is based on the tangential rotary motion of the motor. Impact wrenches are often powered using compressed air. The creation of the required preload force is influenced by a number of different factors. These include, for example, the consistency of the operating pressure used during assembly by the compressed-air wrench. Investigations have shown that the desired tightening torque cannot be achieved with sufficiently accurate reproducibility using this technique. Impact wrenches are suitable for pre-assembly. The preload force must be applied after pre-assembly using an appropriate technique. More modern pulsed driving tools with pulse monitoring allow yield-point controlled tightening to be carried out.

Tightening using a torque wrench

This frequently used method generates the preload force indirectly through the application of torque.
It is important to understand the effects of friction when using this method. The actual preload force produced is determined by the actual coefficients of friction present. The scatter of the coefficients of friction has a direct influence on the preload force. The relationship between the tightening torque applied during assembly and the actual coefficients of friction gives the preload force.

Tightening with an angle controlled tightening tool

This tightening method determines the preload force by means of indirect measurement of the elongation of the fastener. The change in length of the fastener through the action of the thread is (theoretically) directly proportional to the described angle of rotation. Firstly, a snug torque is applied, which has the effect of pulling together all the bearing surfaces in a plastic and/or elastic manner. Final assembly is achieved by turning again through a measured angle. This procedure allows the preload force to be applied precisely by turning the bolt or nut through the predetermined angle, regardless of the coefficient of friction of the thread and bearing surfaces.
This technique is characterised by its precise reproducibility and is used when guaranteed reliability of high-strength threaded connections is required.

Tightening with a yield-point controlled tightening device

The elastic limit of the bolt or screw serves as the control parameter for the preload force during assembly using yield-point controlled tightening. Regardless of the friction, the bolt or screw is rotated until the approximate point where its yield point/proof stress is reached due to the combination of tensile and torsional stresses. Using yield-point controlled tightening, the elastic limit of the fastener is identified by measuring torque and angle of rotation during tightening and calculating their difference quotient. The difference quotient decreases at the point where plastic deformation starts. This decrease triggers a signal to switch the device off.
With yield-point tightening, the plastic elongation of the fastener is so small that there is hardly any negative effect on its reusability. This technique is characterised by its precise reproducibility and is used when guaranteed reliability of high-strength threaded connections is required.

Fully automated assembly

The degree of automation in industrial manufacture is constantly on the increase. To meet the demands of this trend, special fasteners have been developed in order to satisfying the dual requirements of suitability for automatic feeding and optimisation of force transmission geometry. Angle controlled tightening methods are generally used for fully automated assembly processes.

Fasteners with driving features particularly suited to automatic assembly

In order to ensure that a fully automated assembly process runs without problems, the customer and vendor must agree upon the most important characteristics/features of the fastener, which then form the basis for an automatic inspection process.

Automatic inspection can check for one or more features. Experience has shown that, for any one specific feature, an average residual level of non-conformities of around 10 ppm still remains after automatic inspection.

With an automatic inspection process, usually four or five characteristics are checked simultaneously. Consequently, an average of 50 ppm can be expected for these fasteners.

(Please refer to EN ISO 16426:2002 and VDI Guideline 2230 for further information).

Internal driving features for bolts and screws

Depending on the application, there may be a great number of alternatives when it comes to the selection of an internal drive system that allows economical assembly and/or provides additional features (e.g. theft prevention).

For special requirements, it is even possible to have a combination of external and internal drives (economical assembly, but oriented towards the customer with respect to servicing).

	Slotted	1
	Cross recessed H (Phillips)	2
	Combi slot	3
	Cross recessed Z (Pozidriv)	4
	Square socket (Robertson)	5
	Hexalobular socket (Torx) (DIN EN ISO 10664)	6
	Hexalobular socket, tamper resistant (Security Torx)	7
	Torx Plus	8
	Hexagon socket	9
	Hexagon socket, tamper resistant	10
	Spanner head	11
	Tri-Wing	12
	Spline socket	13
	Pentagon socket	14
	12 point socket (XZN)	15
	Triangle	16
	One-way slotted	17

Depending on the type of bolt or screw, individual driving features may only be available as custom-manufactured parts.

The following table presents a classification of friction coefficient classes for threaded connections, with guideline values for various materials/coatings and lubrication options.

Friction coefficient class	Range for μ_G and μ_K	Selected typical examples for	
		Materials/coatings	**Lubricants**
A	0.04 to 0.10	Metallic, plain Thermal black oxide Phosphated Electroplatings such as Zn, Zn/Fe, Zn/Ni Zinc flake coatings	Solid film lubricants such as MoS_2, graphite, PTFE, PA, PE, PI individual coats, as topcoats or as pastes; waxed; wax dispersions.
B	0.08 to 0.16	Metallic, plain Thermal black oxide Electroplatings such as Zn, Zn/Fe, Zn/Ni Zinc flake coatings Al and Mg alloys	Solid film lubricants such as MoS_2, graphite, PTFE, PA, PE, PI individual coats, as topcoats or as pastes; waxed; wax dispersions, greases, oils, in the as-delivered condition
		Hot-dip galvanised	MoS_2; graphite; wax dispersions
		Organic coatings	With integrated solid film lubricant or wax dispersion
		Austenitic stainless steel	Solid film lubricants or waxes; pastes
C	0.14 to 0.24	Austenitic stainless steel	Wax dispersions; pastes
		Metallic, plain Phosphated	As delivered (lightly oiled)
		Electroplatings such as Zn, Zn/Fe, Zn/Ni Zinc flake coatings Adhesive	None
D	0.20 to 0.35	Austenitic stainless steel	Oil
		Electroplatings such as Zn, Zn/Fe Hot-dip galvanised	None
E	≥ 0.30	Electroplatings such as Zn/Fe, Zn/Ni Austenitic stainless steel Al, Mg alloys	None

Source: VDI Guideline 2230

Friction coefficients should ideally be in friction coefficient class B, in order to allow the maximum possible preload force to be applied with low scatter. This does not automatically mean that the minimum value should be used, or that the friction coefficient scatter in a given situation will correspond to that used in the classification. The information given in the table is applicable to room temperature conditions.

Preload forces and tightening torques

Guideline values for metric coarse pitch threads

Size	Property class	Preload force $F_{M\,Tab}$ in kN for μ_G =					Tightening torque M_A in Nm for $\mu_K = \mu_G$ =				
		0.10	0.12	0.14	0.16	0.20	0.10	0.12	0.14	0.16	0.20
M 5	8.8	7.4	7.2	7.0	6.8	6.4	5.2	5.9	6.5	7.1	8.1
	10.9	10.8	10.6	10.3	10.0	9.4	7.6	8.6	9.5	10.4	11.9
	12.9	12.7	12.4	12.0	11.7	11.0	8.9	10.0	11.2	12.2	14.0
M 6	8.8	10.4	10.2	9.9	9.6	9.0	9.0	10.1	11.3	12.3	14.1
	10.9	15.3	14.9	14.5	14.1	13.2	13.2	14.9	16.5	18.0	20.7
	12.9	17.9	17.5	17.0	16.5	15.5	15.4	17.4	19.3	21.1	24.2
M 7	8.8	15.1	14.8	14.4	14.0	13.1	14.8	16.8	18.7	20.5	23.6
	10.9	22.5	21.7	21.1	20.5	19.3	21.7	24.7	27.5	30.1	34.7
	12.9	26.0	25.4	24.7	24.0	22.6	25.4	28.9	32.2	35.2	40.6
M 8	8.8	19.1	18.6	18.1	17.6	16.5	21.6	24.6	27.3	29.8	34.3
	10.9	28.0	27.3	26.6	25.8	24.3	31.8	36.1	40.1	43.8	50.3
	12.9	32.8	32.0	31.1	30.2	28.4	37.2	42.2	46.9	51.2	58.9
M 10	8.8	30.3	29.6	28.8	27.9	26.3	43	48	54	59	68
	10.9	44.5	43.4	42.2	41.0	38.6	63	71	79	87	100
	12.9	52.1	50.8	49.4	48.0	45.2	73	83	93	101	116
M 12	8.8	44.1	43.0	41.9	40.7	38.3	73	84	93	102	117
	10.9	64.8	63.2	61.5	59.8	56.3	108	123	137	149	172
	12.9	75.9	74.0	72.0	70.0	65.8	126	144	160	175	201
M 14	8.8	60.6	59.1	57.5	55.9	52.6	117	133	148	162	187
	10.9	88.9	86.7	84.4	82.1	77.2	172	195	218	238	274
	12.9	104.1	101.5	98.8	96.0	90.4	201	229	255	279	321
M 16	8.8	82.9	80.9	78.8	76.6	72.2	180	206	230	252	291
	10.9	121.7	118.8	115.7	112.6	106.1	264	302	338	370	428
	12.9	142.4	139.0	135.4	131.7	124.1	309	354	395	433	501
M 18	8.8	104	102	99	96	91	259	295	329	360	415
	10.9	149	145	141	137	129	369	421	469	513	592
	12.9	174	170	165	160	151	432	492	549	601	692
M 20	8.8	134	130	127	123	116	363	415	464	509	588
	10.9	190	186	181	176	166	517	592	661	725	838
	12.9	223	217	212	206	194	605	692	773	848	980
M 22	8.8	166	162	158	154	145	495	567	634	697	808
	10.9	237	231	225	219	207	704	807	904	993	1151
	12.9	277	271	264	257	242	824	945	1057	1162	1347
M 24	8.8	192	188	183	173	168	625	714	798	875	1011
	10.9	274	267	260	253	239	890	1017	1136	1246	1440
	12.9	320	313	305	296	279	1041	1190	1329	1458	1685

Source: VDI Guideline 2230

Maximum permissible tightening torques and resultant maximum preload forces for hexagon head bolts as in ISO 4014 to ISO 4018, hexagon socket head cap screws as in ISO 4762 and for threaded fasteners with analogous head strengths and bearing surfaces, of property classes 3.6 – 12.9 with 90 % utilisation of the yield point rel / 0.2 % proof strength Rp0.2 and "medium" clearance hole as in DIN EN 20273. The table shows maximum permissible values and does not include any additional safety factors.
A knowledge of the relevant guidelines and design criteria is required.

All self-tapping fasteners are thread forming fasteners, which form their own threads when screwed into core holes; some screw types can also create their own core holes.

In contrast to this, screws with metric thread require either a mating thread to be manufactured or an extra internally threaded component to be used.

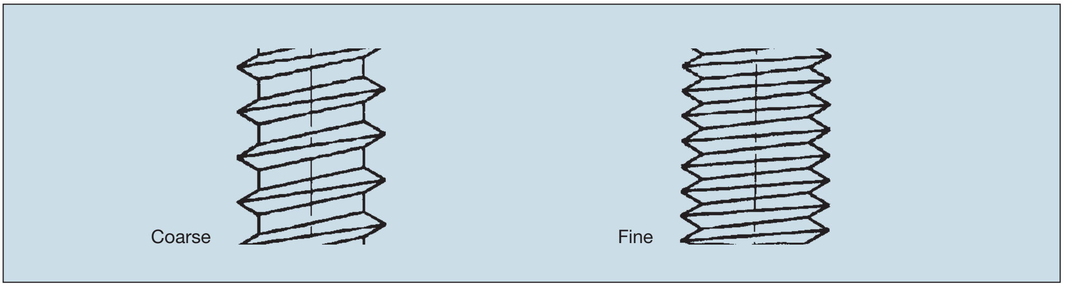
Using self-tapping fasteners increases productivity during assembly and reduces the cost of connections.

The female thread is formed by the screw thread. Generally this is achieved by rolling. The prerequisites for this are that the screw thread is harder than the workpiece and that the material is sufficiently ductile to allow the thread to be formed.

Which screw for which purpose?

The type of screw that can be considered depends on the material of the workpiece.

The basic rule is:
Coarse pitch threads for soft materials – fine pitch threads for hard materials.

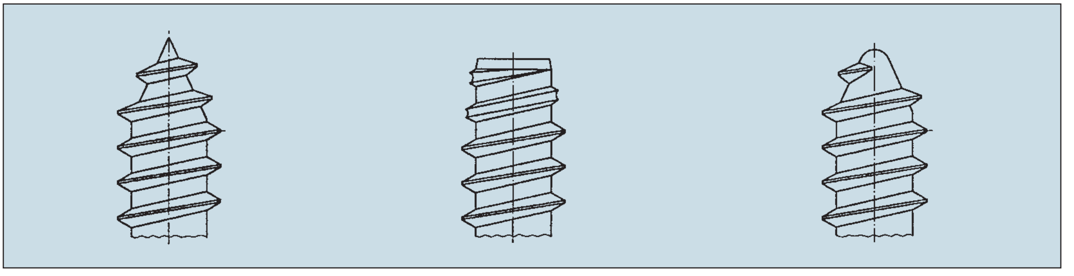


Thread pitch

Tapping screws

The threads of self-tapping screws are identified using the abbreviation ST e.g. ST 3.5.
The self-tapping thread is standardised in DIN EN ISO 1478. The included angle of the thread is the same as for metric threads, i.e. 60°.
The thread has a coarser pitch, however. This acts as a forming tool when the screw is screwed in, deforming the material without wastage.

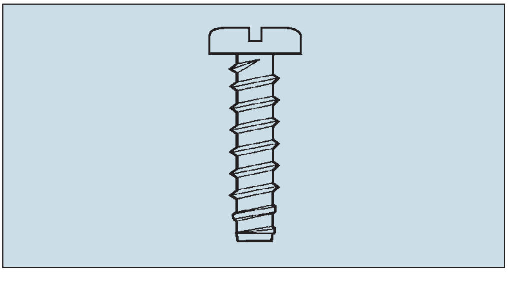
DIN EN ISO 1478 differentiates between three thread ends:



C (B) Cone end **F (BZ)** Flat end **R** Rounded end

1. Tapping screws

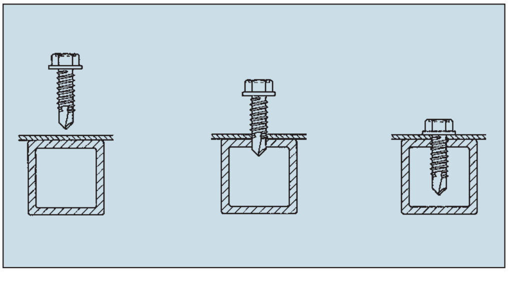
Tapping screws for use with steel materials are case hardened and tempered. This means that the screws have high surface hardness with a ductile core.



2. Tapping screws with drill tips

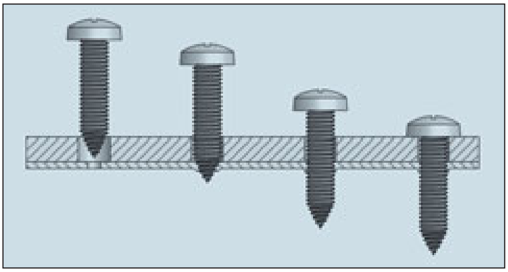
Threads correspond to those of tapping screws with additional drill tips.

Advantages of self-drilling screws
- No core hole
- No hole mismatch
- No tolerance problems
- No centre punching



3. Sheet metal screws

If the part to be screwed (sheet) is thinner than the thread pitch of the tapping screw as in DIN EN ISO 1478 (wobble limit), then it is necessary to use additional joining elements, since otherwise it is not possible to form a solid direct connection between the screw and the sheet. An economical alternative is offered by thin sheet screws.
These produce a through hole in the sheet and then form a metric thread. This means that the locating hole gains a more favourable mounting height at the point where the screw passes through. The thread pitch is also finer, thereby providing sufficient contact surface at the flanks of the metric thread produced.



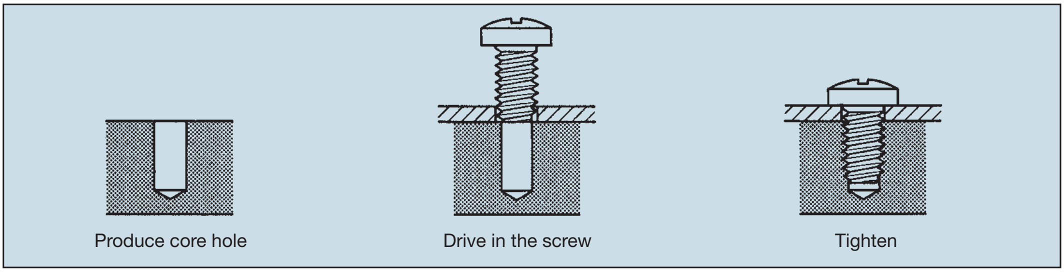
Threaded connection with thin sheet screw

Applications that do not require a core hole are also possible. Use of additional internally threaded components is not necessary.

4. Thread rolling screws as in DIN 7500, Duo type

Thread rolling screws are designed to be driven into predrilled core holes in solid metal parts. The diameter of the hole is between the minor diameter and the pitch diameter of the thread.* The thread end of the screw is tapered to make it easier to start the thread forming process. The mating thread is pressed into the core hole by means of the non-circular (lobulated) shape of the screw.

Various types of thread rolling screws are standardised in DIN 7500. In addition to the Duo type screw shown here, there are various other designs for the thread forming part of the screw – different principles may be exploited by different manufacturers. The screw thread itself has a positive tolerance.



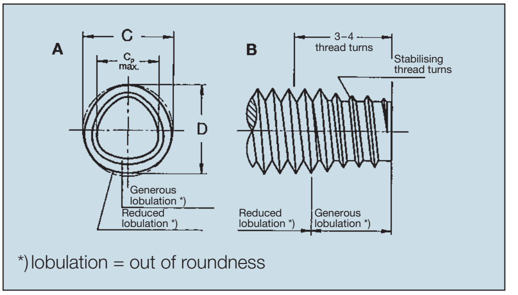
A few of the materials suitable for use with thread rolling screws are:
- Steel with tensile strength up to 450 N/mm^2
- Aluminium
- Copper alloys
- Die-cast zinc

Thread rolling screws roll their mating thread without cutting action. The rolled thread is hardened and is compatible with ISO metric external threads. This means, for example, that a standard metric screw can be used in case a repair is required.

**Design notes can be found in the "Blue Pages" and/or the product standards.*

Advantages of thread rolling screws in metallic materials

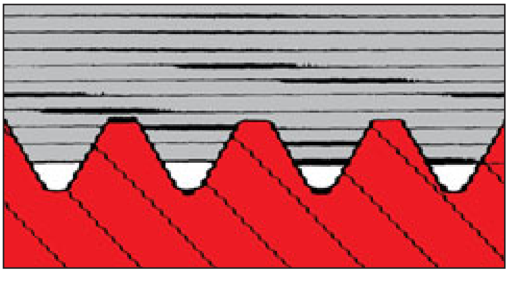
- No thread cutting / no chips
- No retention mechanism required
- Good resistance to vibrational loosening
- High pull-out resistance



Thread rolling screw as in DIN 7500, Duo type

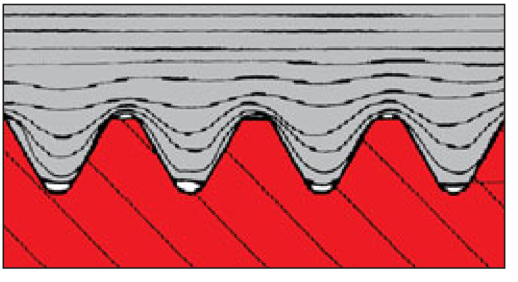
Cut thread

- Reduced contact surface area at flanks
- Cuts through grain structure
- Chips
- Flank clearance



Rolled thread

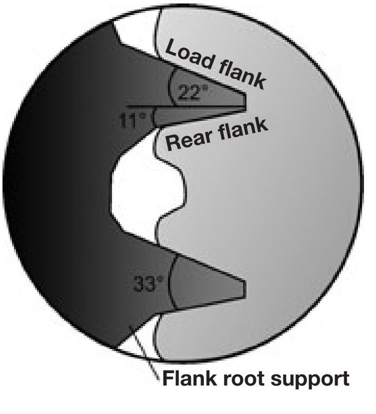
- High flank contact surface area
- Unbroken grain structure
- Hardened surfaces
- No chips

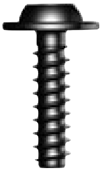


5. Thread rolling screws according to special designs and company standards

In addition to the screws covered by DIN 7500, various screws with optimised flank geometries specially designed for use with light metals are available.

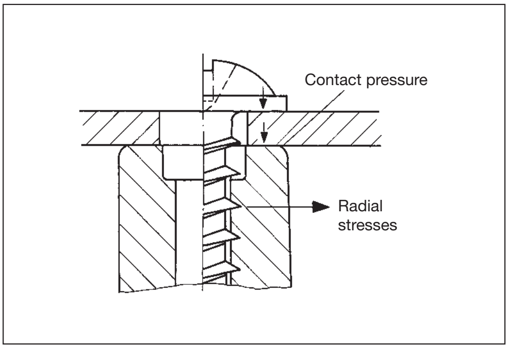
Example: ALtracs®

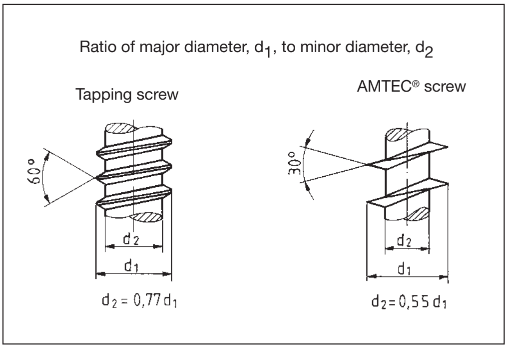




6. Thread rolling screws for plastics

Self-tapping screws for thermoplastic synthetic materials must be constructed so as to provide low driving torques, high stripping torques and high pull-out forces. AMTEC® screws from Böllhoff, Standard B 52004 et seq. with 30° flank angle have a proven track record. These have a relatively large pitch and a small minor diameter. The threaded connection has self-locking properties and can be reused up to ten times.





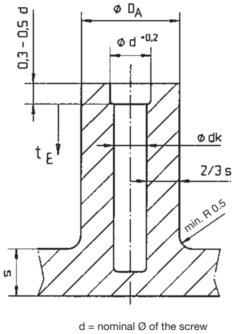
This process is particularly economical because metric threads generally require an additional internally threaded component to be embedded. It is, however, very important to follow the design notes* to ensure that no problems occur in the use of this fastener.

*See product brochure or "Blue Pages"

7

Recommended core hole diameters for AMTEC® screws

Materials	Hole diameter d_k	Major diameter D_a	Screw-in depth t_E
ABS	0.80 x d	2.00 x d	2.00 x d
ABS PC Blend	0.80 x d	2.00 x d	2.00 x d
ASA	0.78 x d	2.00 x d	2.00 x d
PA 4.6	0.73 x d	1.85 x d	1.80 x d
PA 4.6 GF 3.0	0.75 x d	1.85 x d	1.80 x d
PV 6	0.75 x d	1.85 x d	1.70 x d
PA 6 GF 30	0.80 x d	2.00 x d	1.90 x d
PA 6.6	0.75 x d	1.85 x d	1.70 x d
PA 6.6 GF 30	0.82 x d	2.00 x d	1.80 x d
PRT	0.75 x d	1.85 x d	1.70 x d
PRT GF 30	0.80 x d	1.80 x d	1.70 x d
PC*	0.85 x d	2.50 x d	2.20 x d
PC GF 30*	0.85 x d	2.30 x d	2.00 x d
ID PE (soft)	0.70 x d	2.00 x d	2.00 x d
ID PE (hard)	0.75 x d	1.80 x d	1.80 x d
PET	0.75 x d	1.85 x d	1.70 x d
PET GF 30	0.80 x d	1.80 x d	1.70 x d
PMMA	0.85 x d	2.00 x d	2.00 x d
POM	0.75 x d	1.95 x d	2.00 x d
PP	0.70 x d	2.00 x d	2.00 x d
PP TV 20	0.72 x d	2.00 x d	2.00 x d
PPO*	0.85 x d	2.50 x d	2.30 x d
PS	0.80 x d	2.00 x d	2.00 x d
PVC (hard)	0.80 x d	2.00 x d	2.00 x d
SAN	0.77 x d	2.00 x d	1.90 x d



d = nominal Ø of the screw

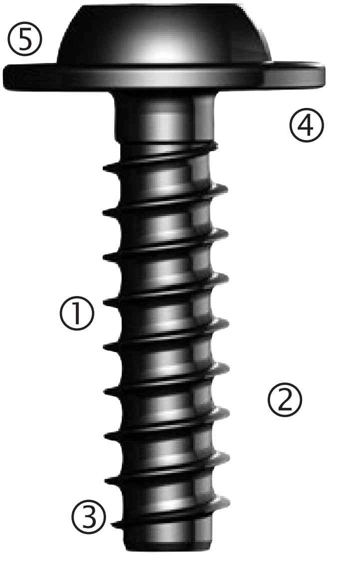
The Delta PT screw is an advanced fastener for use in thermoplastic and highly-reinforced synthetic materials.

Features

① Advanced flank geometry
② Increased minor diameter
③ Smaller pitch
④ Stronger head geometry
⑤ High quality screw material

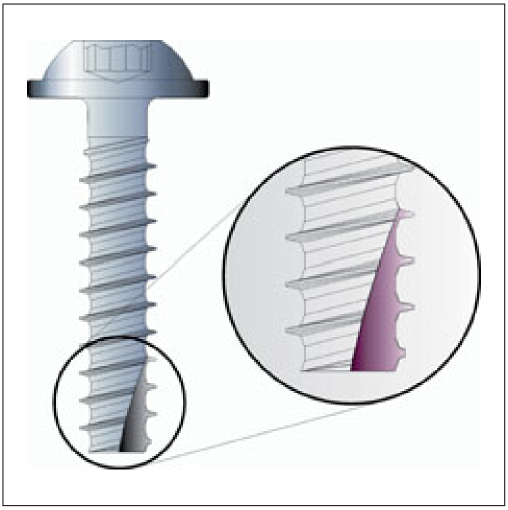
Performance

- High torsional and tensile strength
- High dynamic safety
- Good heat dissipation
- Low radial expansion
- Low contact pressure



Duroplast applications using the Delta PT screw with cutting edge

- Duroplastic components cannot be plastically deformed
- Very brittle materials with low ductility require a cutting aid

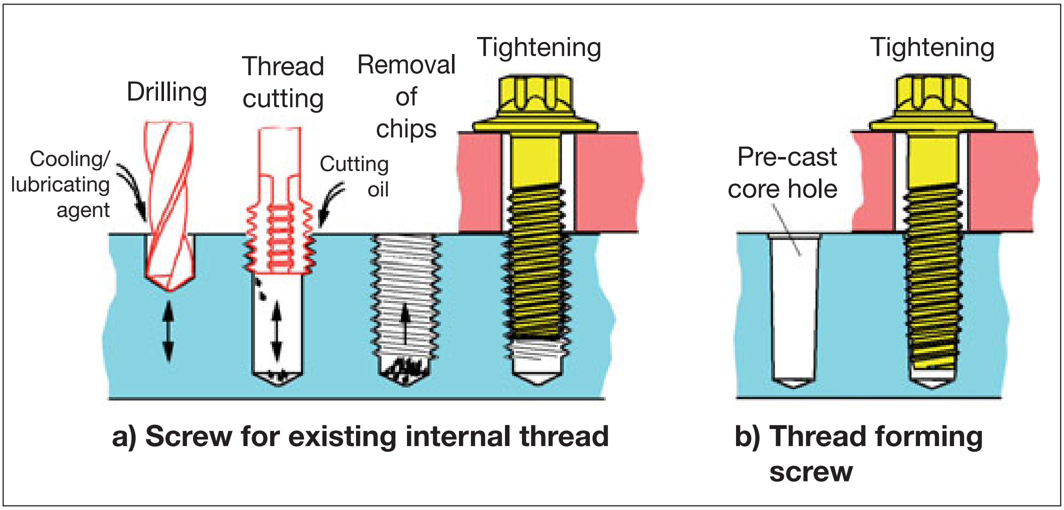


Cutting edge

- ¼ circle removed by milling
- Length: 3–4 turns of thread

Technical and commercial advantages of self-tapping fasteners

- Internal threads with high load bearing capacity due to cold working during insertion of metal self-tapping fastener
- Lower costs and better process reliability due to reduced number of operations
- Highly resistant to loosening due to interference fit thread

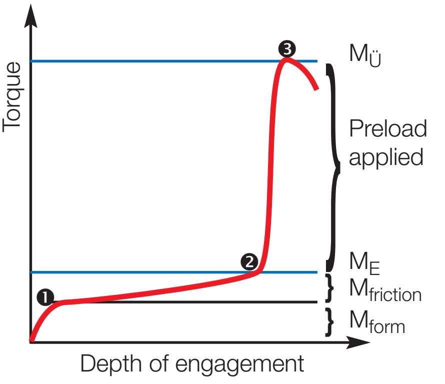


7

Important technical note

The optimal self-tapping screw connection can only be achieved by following the necessary design notes and assembly guidelines. Correctly matching the component, the type of screw and the assembly process is extremely important.
It is recommended that assembly tests with original parts are carried out and assembly parameters established and checked before starting series production.

Böllhoff Application Engineering will be pleased to assist you in determining the correct fastener characteristics for your application.



Self-tapping fasteners

Due to the increased volumes of lightweight, cost-effective materials being processed, the use of self-tapping fasteners is set to increase further.

When are thread rolling screws not an option?

- When the materials used for the screw and the component are of similar hardness.
- When the material is too brittle.
- When very high preload forces are required.

Securing threaded connections

By definition, a threaded connection is a connection that can be released multiple times and which, by means of the preload force created during assembly, joins together two or more components.
This assembly must consistently behave as a single part, even under the influence of external operating forces.
To this end, the preload force created by the tightening torque applied during assembly, which produces the frictional connection between the components, must remain unchanged as far as possible. If this is not achieved, components may gape apart, fasteners may become loose, and shear stresses will not act on the fasteners as intended.

If a threaded connection is properly designed, the frictional resistance in the thread and below the head will be sufficiently large to prevent self-loosening under oscillating loads. In such cases, the connection is described as self-locking
Self-loosening of a threaded connection always starts with an unintended reduction of the preload force, which is particularly likely under dynamic loads. The loss of preload force may be either partial or complete.
The relationships that determine whether a threaded connection is reliable are illustrated in the diagram below.

Main factors determining the reliability of a threaded connection

Analysis and design of the threaded connection	Assembly method	Retention method	Functional properties of the threaded fastener
Determination of the required preload force	Creation of the required preload force	Maintenance of the required preload force	Ability to withstand the forces and other influences affecting the threaded fastener

From Data Sheet 302*): A well designed threaded connection, tightened under controlled conditions, should not usually require additional retention measures!

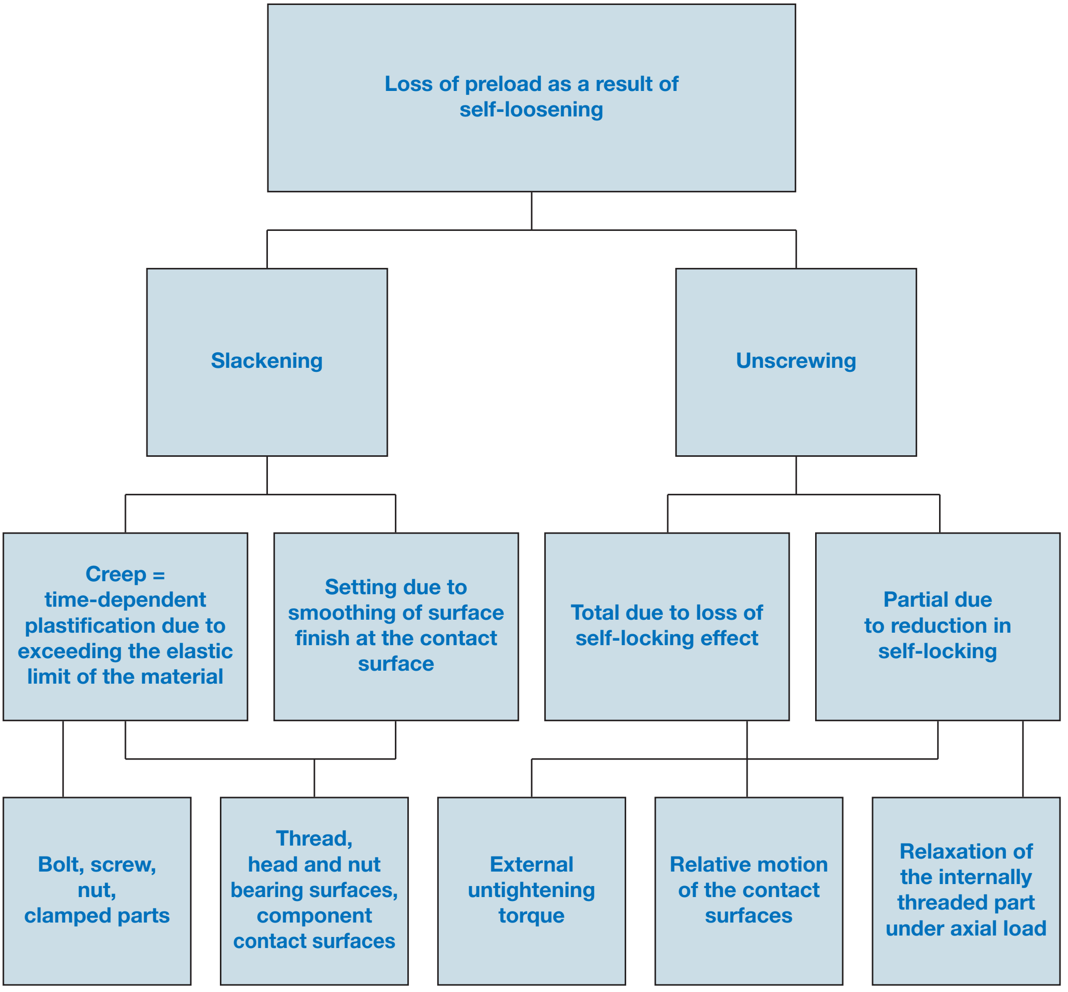
In practice, it is not always possible to achieve a sufficiently secure threaded connection through the use of good design alone. In such cases it is necessary to use fastener retention components, in order to prevent threaded connections working loose or falling out completely. The various retention means available are divided into the following groups, according to their mode of operation:

• Retaining elements
• Loss prevention elements
• Unscrewing prevention elements

The table shows possible causes of loosening and the mechanisms by which this can be prevented.

Cause of loosening	**Grouping of retainer types by:**		
	Function	**Operating principle**	**Example**
Slackening due to setting or creep	Retaining	Reduction of contact pressure	Screw and washer assemblies, e.g. DIN EN ISO 10644 Hexagon bolts with flange, DIN EN 1665
		Compressible spring elements	Disc springs, DIN 2093 Conical spring washers, DIN 6796 and B 53072 Screw and washer assemblies, DIN 6900-5 Nuts with captive washers, B 53010
Unscrewing due to loss of self-locking	Loss prevention	Positive-locking	Hexagon slotted and castle nuts, DIN 935 and DIN 979 Fasteners with split pin hole, DIN 962 Wire retainers Tab washers
		Self-locking	Prevailing torque type all-metal nuts, e.g. DIN 6927 Prevailing torque type hex nuts with non-metallic insert, e.g. DIN 6926 Threaded fasteners with plastic coating in thread, e.g. B 53081, Thread rolling screws DIN 7500, HELICOIL® screwlock B 62000
	Unscrewing prevention	Locking components	Serrated washer head screws and nuts, e.g. B 158
		Locking, tensioning components	Wedge-locking washers, B 53074
		Adhesive components	“Microencapsulated fasteners”, e.g. B 53084

A distinction can be made between two basic mechanisms for self-loosening – slackening and unscrewing. Slackening is caused by dynamic or static loads, particularly in the axial direction, that lead to stresses in excess of the allowable limits, thereby inducing setting and creep processes. This reduces the remaining clamping length, which in turn causes a reduction in the preload force applied.
Conversely, unscrewing is caused by dynamic loads that act radially to the axis of the fastener, which causes the clamped components to slip with respect to each other. When the resultant lateral forces present are greater than the static friction produced between the components by the preload force, then the “slip limit” is said to have been exceeded; this can induce a gyratory motion around the axis of the fastener. This relative motion produces an internal untightening torque, which can lead to the preload force being lost completely, and can even result in connected components falling apart completely.



*) Data Sheet 302: “Sicherungen für Schraubverbindungen”, O. Strelow, Beratungsstelle für Stahlverwendung, Düsseldorf, Germany

Methods to prevent slackening

In order to keep the effects of loosening of threaded fasteners to a minimum, the connections must be accurately calculated and correctly assembled. The use of large head diameters reduces the contact pressure and thus the tendency for setting and creep at the bearing surfaces. Screw and washer assemblies and flanged fasteners have become established as suitable fastener types for this purpose. In order to minimise the loss of preload force as a result of setting and creep processes, a "compressible spring element" can be used. For some applications, stiff conical spring washers or disc springs are suitable options. Spring washers and serrated lock washers do not provide a sufficiently strong spring action and are therefore not suitable for use as retainers. The corresponding standards were withdrawn in 2003.

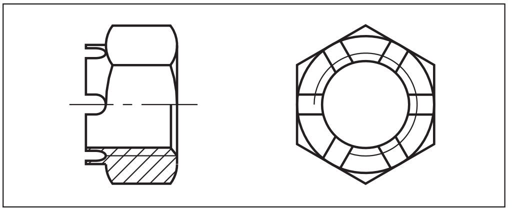
Methods to prevent unscrewing

As has always been the case, the best method of preventing unintentional unscrewing is still good design. The basic rule here is to prevent relative movement at the contact surfaces between the joined components and at the threads. To this end, the components being joined should be as rigid as possible; by contrast, the associated fasteners should be as elastic as possible. This is achieved by use of high-strength threaded fasteners with high flexibility, large clamping lengths and small shank diameters. As an additional measure, self-locking components can be used for loss prevention, or locking/adhesive means for unscrewing prevention. Whereas loss prevention elements simply prevent the loss of the fastener, unscrewing prevention elements are designed to prevent a significant reduction in preload force.

Retainers

Loss prevention elements allow partial slackening or unscrewing of the threaded connection to occur, but prevent the assembly from falling apart completely. Such elements should therefore not be placed on a par with effective fastener retainers, which prevent any loosening of the joint. Loss prevention elements include locking components such as nuts with plastic insert, screws with plastic coating in the thread, and prevailing torque type all-metal nuts with special flank geometries.

Among the most well known types of retainer, which are not to be recommended, are positive-locking components such as hexagon slotted and castle nuts, fasteners with a split pin hole, and wire retainers.



BÖLLHOFF

Whereas loss prevention elements prevent the loss of loose fasteners, unscrewing prevention elements are designed to prevent loosening of the assembly.

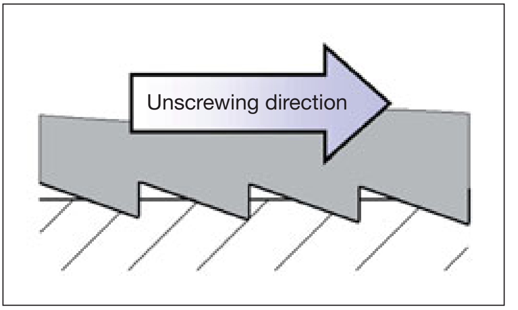
These include, but are not limited to, retainers with shaped profiles on the bearing surface.

Serrated components

The way in which this retention method works is based on the teeth embossed onto the fastener head, which are usually asymmetrical and arranged in such a way that the steeper flanks are aligned towards the direction of unscrewing. These formed elements are embedded into the component when the fastener is tightened and produce a positive locking effect that must be overcome before loosening can occur (see diagram). The functionality is largely dependent on the characteristics of the surfaces and the strength of the clamping parts.

Components with locking ribs

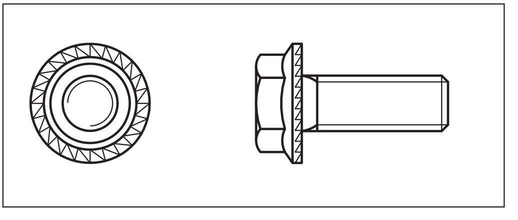
For sensitive surfaces a ribbed profile may be a suitable option. Plastic deformation and hardening of the bearing surface increase the torque required to unscrew the fastener.



Bolts, screws and nuts with locking profile from our range

The advantage of this retention method is that it is integrated into the screw or nut and can therefore not be forgotten. To date, these fasteners have not been standardised. The following Böllhoff standards are available from stock:

B53085 Hexagon head self-locking fasteners
B53012 Self-locking nuts with flange
B151 and B196 Verbus Tensilock
B158 and B193 Verbus Ripp

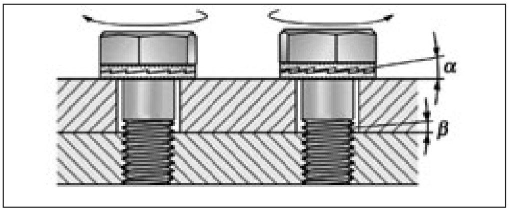


8

Nordlock wedge-locking washers®

This system uses a pair of bonded washers with radial teeth, which are placed under the head of the bolt or screw and/or nut. This means that standard bolts, screws and nuts can still be used. When the screw and/or nut is tightened, the radial teeth of the washer pair are pressed into the mating faces, creating a positive locking effect.

The diagram below shows what happens if the fastener is loosened:



Böllhoff part no. B53074

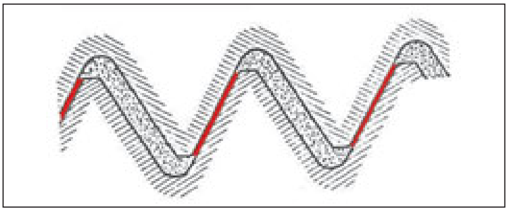
The washer pair is firmly seated in position and movement is only possible between the cam faces. Even the smallest rotation in the unscrewing direction results in an increase in the clamping force due to the effect of the cams – the fastener locks itself. Wedge-locking washers provide effective locking against unscrewing of threaded connections that are subject to lateral, oscillatory and vibrational loads.

Chemical fastener retention

Chemical thread retention methods (adhesive – locking – sealing). These products are offered either as liquid adhesive coatings (anaerobically hardening) or as pre-coatings. The latter has the advantage that the coating no longer has to be applied manually during assembly, but rather can be applied using a reproducible process before the fastener is supplied. This is also possible with bulk quantities.

Description

To ensure reproducible processes (no omissions or uneven application of the product), chemical thread retention in the form of a pre-coating is the best option. Pre-coatings are categorised as either adhesive or locking types:



DIN 267-27 – Adhesive coating

Microencapsulated adhesive: the pressure and/or shear forces produced as the fastener is tightened cause the micro-capsules to rupture. This releases the adhesive contained within the capsules. Combined with the hardener, this creates a chemical reaction (polymerisation) that hardens the adhesive (adhesive bonding), thereby producing the desired locking effect. The assembly process should be completed within five minutes (hardening). Different hardening times may be applicable depending on the product. (Effectiveness of the adhesive retention).

DIN 267-28 – Locking coating

Locking thread retention agent: this technique involves applying a polyamide to a section of the thread. A locking effect is produced when the fastener is screwed in. The axial clearance between the external and internal threads is filled in by the coating, which results in increased contact pressure on the flanks of the opposite, uncoated thread. This creates the desired locking effect. Loss prevention elements can not prevent partial unscrewing, but are certainly able to prevent the threaded connection falling apart completely.

Adhesive and locking retention treatments

Unless defined otherwise, all coatings must comply with the requirements of DIN 267-27 and DIN 267-28.

Length: 1.5 d +/- 2P for P < 1
1.5 d +/- P for $P \geq 1$
measured from the thread end.

The first two to three turns of the thread should be largely free from coating material in order to facilitate bolting. The thread retention material can be applied as an internal coating (nuts) or an external coating (bolts). Depending on the product, it may be possible to use the coating on different materials and surface finishes. Consideration must be given to the varying temperature resistance of different products. Chemical thread coatings can also provide a sealing function. Where this property is used, attention should be paid to ensuring that the coating is applied over the whole circumference of the fastener and that any additional requirements have been defined.

Overview of various chemical fastener retention materials; all information subject to change

Material	Effect	Standard	Thread friction	Hardening	Colour
Polyamide, spot (Plasbolt)	Locking	DIN 267-28	Effect due to clamping action	None – can be used immediately	Red (standard), others also available
Polyamide, continuous (Plasbolt continuous)	Locking, sealing	DIN 267-28	Effect due to clamping action	None – can be used immediately	Red (standard), others also available
Precote 30	Medium strength, adhesive, sealing	DIN 267-27	μ 0.10 – 0.15	3 hours	Yellow
Precote 80	Very high strength adhesive, sealing	DIN 267-27	μ 0.25 – 0.28	3 hours	Red
Precote 85	High strength adhesive, sealing	DIN 267-27	μ 0.10 – 0.15	6 hours	Turquoise
3M scotch grip 2353	High strength adhesive, sealing	DIN 267-27	μ 0.14 – 0.18	24 hours	Blue
3M scotch grip 2510	High strength adhesive, sealing	DIN 267-27	μ 0.16 – 0.20	72 hours	Orange

Retention of threaded connections

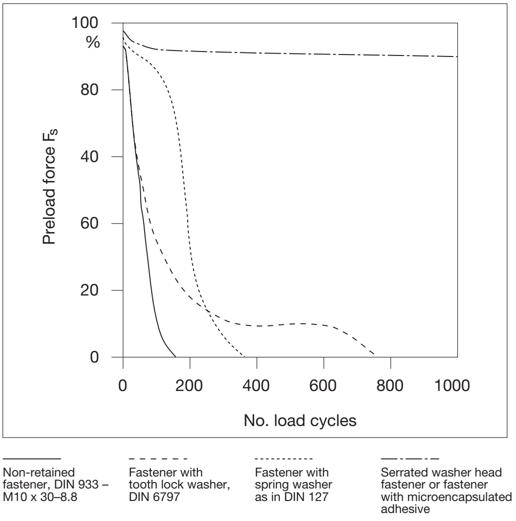
This remains an important topic since it has become necessary to take account of more stringent product liability and safety requirements and it is often not possible to make allowance for all influencing parameters in the design of the connection. On the other hand, any thread retention mechanisms used will have an effect on the properties of the threaded connection and this must be considered during assembly planning. Decisive factors in the selection of an appropriate retention component include: reusability, temperature effects, material combinations, specific locking properties and additional characteristics. Another critical issue to consider is that of multiple usability.

Unsuitable fastener retention methods

Some unsuitable fastener retention methods are still widely-used today, even though they no longer comply with the state of the art. The relevant product standards have been withdrawn. Such components have been incorrectly categorised as “unscrewing prevention devices” and “retaining devices”. The compressible spring elements are ineffective for high strength threaded connections with high preload and, under unfavourable circumstances, may even promote setting and corresponding loss of preload force. This applies in particular to:

- Spring lock washers as in DIN 127 (already withdrawn in 1993), DIN 128 and DIN 6905
- Curved spring washers as in DIN 137 and DIN 6904
- Serrated lock washers as in DIN 6798 and DIN 6907
- Toothed lock washers as in DIN 6797
- Tab washers as in DIN 93, DIN 432 and DIN 463
- Safety cups as in DIN 526
- Self-locking nuts as in DIN 7967

In these cases, it has been demonstrated that the intended retention effect is not achieved. This may be, for example, because the washers are already fully compressed even at relatively low preload forces and no spring action is produced, or because the mechanical function anticipated for these products cannot be realised.



Unscrewing curves for various threaded fasteners under dynamic lateral load

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Corrosion protection

DIN 50900-1 describes corrosion as “the reaction of a metallic material with its environment, which produces measurable change in the material and can impair the function of a metal component or a complete system”.

Most damage to fasteners is caused by corrosion. But corrosion is unavoidable. Corrosion protection should therefore be understood as a measure that controls and delays the development of corrosion.

Of the numerous different types of corrosion, the following are of particular relevance to fasteners:

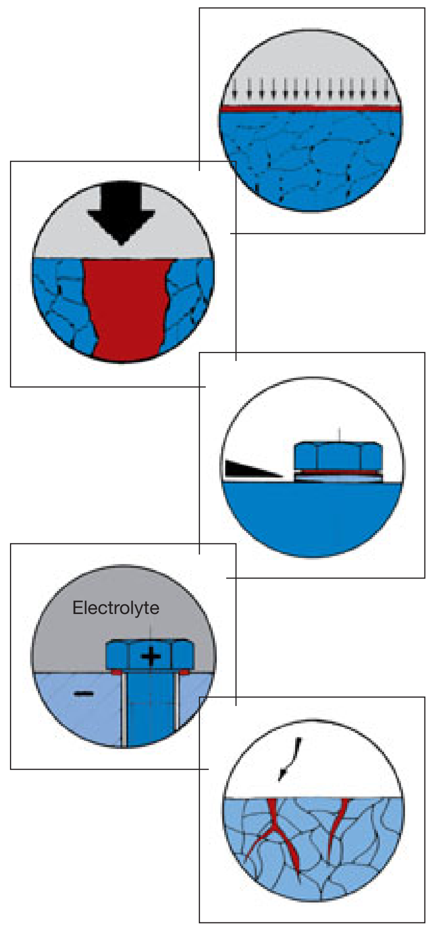
Surface corrosion is a virtually uniform attack over the complete surface.

Pitting corrosion only on small areas of the surface, e.g. as a result of protective coatings being damaged.

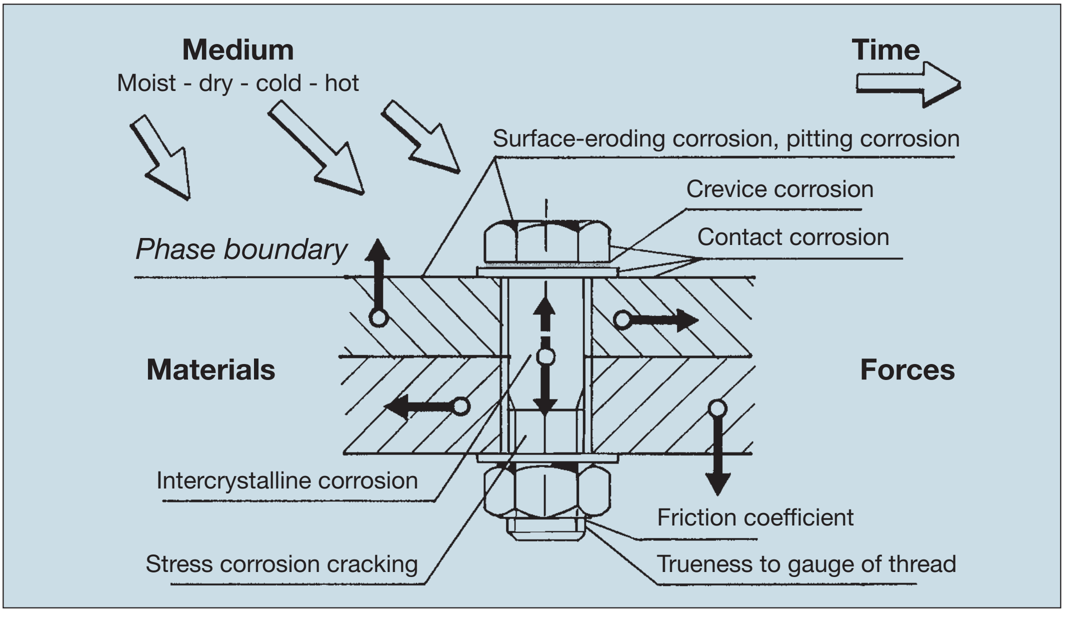
Crevice corrosion occurs in crevices in the material or between connected components.

Contact corrosion occurs as a result of differing metals coming into contact with an electrolyte.

Stress corrosion cracking occurs as a result of the action of a corrosive medium in the presence of mechanical stress.



Fasteners form part of a larger corrosion system that must be considered as a complete entity by the user.



Threaded connection corrosion system

A differentiation is made between active and passive corrosion protection.

If the fasteners used are made from a material that is, broadly speaking, resistant to corrosion then this is referred to as ***active protection***. This includes, for example, stainless steels, corrosion resistant steels and nonferrous metals.

If steel fasteners are provided with a protective coating, this is known as ***passive corrosion protection***. This should be understood to include all types of surface treatment.

A few examples of common types of surface coatings for fasteners are presented on the following pages.

Common surface coatings

Inorganic	Metallic				Organic
	Electroplated	**Thin film**	**Hot-dipped**	**Mechanical**	
Phosphating	Zinc	Dacromet	Zinc	Zinc	Delta-Seal
Black finishing	Copper	Geomet	Tin	Zinc-tin	Polyseal
Passivating	Brass	Delta Protekt		Zinc-aluminium	
Sealing	Nickel				
	Nickel/chromium				

Metallic protective coatings are subdivided into:

- ***Anodic*** coatings, e.g. zinc
- ***Cathodic*** coatings, e.g. nickel and chromium

Zinc is very commonly used in various types of coatings. Zinc has the property of being less noble than the steel of the fastener. If a part of the zinc coating is damaged, then the area affected will be resealed due to the reaction of the zinc.

This is explained by the anodic effect, whereby the zinc reacts before the base metal, hence “sacrificing” itself for the steel component.

This reaction is also utilised for subterranean pipelines and ships hulls made from steel by attaching a sacrificial anode. This also applies to the plain threads on hot-dip galvanised nuts, which are protected by the zinc layer on the external thread of the fastener.

The most common surface coating techniques are electroplating and galvanising. The designation systems for electroplated coatings are specified in DIN EN ISO 4042.

Surfaces for fasteners

The surface treatment on a fastener is not just for corrosion protection, rather it is a system with multifunctional properties that has to do a lot more that "just" protection against corrosion!

This notwithstanding, particular attention must be paid to the protection of fasteners against corrosion. A proportionally small number of cases of real-word failures are caused by mechanical loads; very many more are due to destruction through corrosion. In this respect, it is particularly important to give thought to the fact that the fastener used with a component must not be associated with any weak points. Combined with other design requirements, the need to choose a suitable anti-corrosion coating means that a complex approach is necessary (see diagram).

In addition to this, it is also necessary to consider the latest market developments, in order that the surface protection systems used for new products meet the following requirements:
a) Up-to-date, future-proof
b) Long-term availability
c) Economical
Why? Because every change to an existing product already in standard production costs a lot of money and can lead to bottlenecks and quality problems.

One such market development is the introduction of a ban on chromium (VI) in the key automotive and electronics sectors, to which suppliers and electroplating technology has had to adapt.

According to the VDA and DIN 50993, the limit of detection for Cr(VI) is 0.1 µg/cm².

The following figures from the VDA can be considered as a guide to the chromium (VI) content of various coatings:

Yellow chromated	Olive chromated	Black chromated	Zinc flake coatings as in DIN EN ISO 10683, FlZnyc (e.g. Dacromet)
Approx. content in µg/cm² 10	Approx. content in µg/cm² 15	Approx. content in µg/cm² 16	Approx. content in µg/cm² 20

The various systems all have advantages and disadvantages when compared to each other. Some chromium(VI)-free systems require additional surface sealing due to the absence of the self-healing effect. In the medium term, however, all users and sectors will be unable to avoid converting to environmentally-friendly chromium(VI)-free coatings.

Our recommendations for the selection of a surface coating are based on the modern “non-poisonous” systems.

Reference surface containing Cr(VI) As in DIN EN ISO 4042 (minimum coating thickness of 8 µm)	Zinc corrosion [h]	Base metal corrosion [h]	Designation
Zn, yellow chromated	72	120	A3C
ZnFe, black chromated	72	360	R3R

The figures in the above table are calculated guideline values for barrel plated fasteners.
The degree of corrosion protection varies according to dimensions and geometry.
Requirements for other functional properties and the means of assembly must also be assessed.

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Corrosion resistance of Cr(VI)-free surfaces in salt spray tests

Coating	Coating thickness [µm]	DIN EN ISO 9227 SS white rust [h]	DIN EN ISO 9227 SS red rust [h]	Böllhoff surface
Zn (thin film) passivated, **no** surface sealing	5	12	36	C1
	8	24	72	C2
Zn (thin film) passivated, **with** surface sealing	5	72	96	V1
	8	72	120	V2
Zn (thick film) passivated, **no** surface sealing	5	48	72	C5
	8	72	120	C6
Zn (thick film) passivated, **with** surface sealing	5	96	168	V5
	8	96	240	V6
ZnFe black, **with** surface sealing	5	120	168	E8
	8	120	360	E9
ZnFe transparent, **no** surface sealing	5	72	168	E1
	8	72	360	E2
ZnFe transparent, **with** surface sealing	5	120	240	E3
	8	120	360	E4
ZnNi transparent, no surface sealing	5	120	360	N0
	8	120	600	N1
ZnNi transparent, with surface sealing	5	144	480	N3
	8	144	720	N4
ZnNi black passivated, no surface sealing	8*	24	360	N7
ZnNi black, with surface sealing	5	120	480	N8
	8	120	720	N9
Zn, black passivated, with surface sealing	8*	12	72	C9
Zinc flake coating, e.g. DIN EN ISO 10683 - flZnnc-480 h	~ 8	–	480	Examples: G1 = Geomet 321 A, L0 = Delta Protekt KL 100, L8 = Magni Flake
Zinc flake coating DIN EN ISO 10683 - flZnnc-720 h-L	~ 10	–	720	Examples: G7 = Geomet 321 B + VL, L1 = Delta Protekt KL 100 + VH 301 GZ
Zinc flake coating DIN EN ISO 10683 - flZnncL-480 h	~ 10	–	480	Example: G9 = Geomet 500 A
Zinc flake coating DIN EN ISO 10683 - flZnnc-480 h black	~ 8	120	480	Examples: L4 = Delta-Protekt KL 100 B + Delta Seal, L9 = Zintek 300 + Techseal SL

The values given are guideline values for barrel plated products tested immediately after coating.
* Recommended minimum coating thickness.

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Designation of electroplated coatings as in DIN EN ISO 4042

Coating metal/alloy Short name	Element	Letter symbol
Zn	Zinc	A
Cd[1]	Cadmium	B
Cu	Copper	C
CuZn	Copper-zinc	D
Ni	Nickel	E
Ni Cr[2]	Nickel-chromium	F
CuNi	Copper-nickel	G
CuNi Cr[2]	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	Q
ZnFe	Zinc-iron	R

[1] For environmental reasons, the use of cadmium is partially restricted.
[2] Thickness of the chromium layer = 0.3 µm

Coating thickness (total deposit thickness) in µm Single coating metal	Two coating metals[1]	Code number
No coating thickness specified	–	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

[1] The thicknesses specified for the first and second coating metals apply for all combinations of coatings, with the exception that if chromium is the topmost layer it always has a thickness of 0.3 µm.

Finish	Passivation by chromating[1] Colour	Letter symbol
Dull	No colour	A
Dull	Bluish to bluish iridescent	B
Dull	Yellowish to yellowish-brown, iridescent	C
Dull	Olive green to olive brown	D
Semi-bright	No colour	E
Semi-bright	Bluish to bluish iridescent	F
Semi-bright	Yellowish glistening to yellowish-brown, iridescent	G
Semi-bright	Olive green to olive brown	H
Bright	No colour	J
Bright	Bluish to bluish iridescent	K
Bright	Yellowish glistening to yellowish-brown, iridescent	L
Bright	Olive green to olive brown	M
High-bright	No colour	N
Optional	As B, C or D	P
Dull	Brownish black to black	R
Semi-bright	Brownish black to black	S
Bright	Brownish black to black	T
All finishes	No chromate treatment[c]	U

Passivating is used for zinc, zinc alloy and cadmium coatings. Some colours are only available for zinc coatings.
[1] Cr(VI)-free passivation is not yet covered by standards. Therefore these coatings must be specially identified and specially ordered, e.g. Cr(VI)-free, thin or thick film passivation. See overview on page 89.

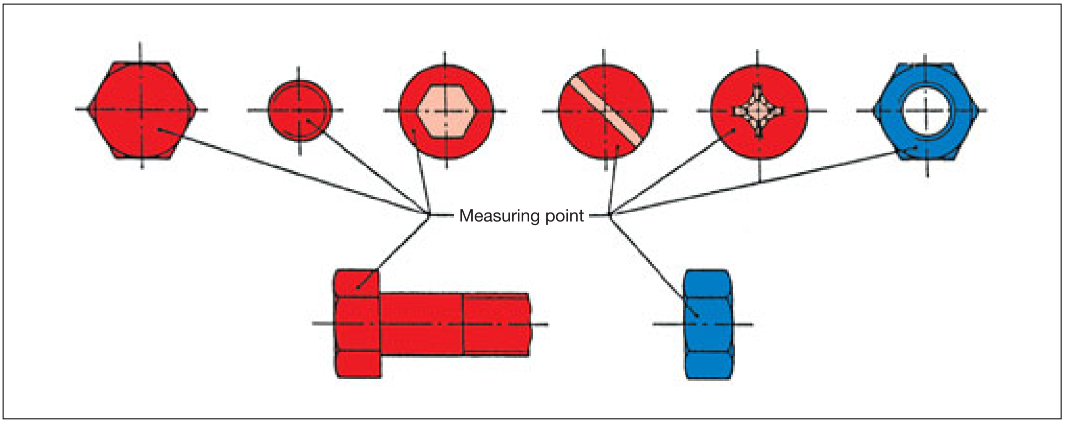
Example of designation of a 5 µm zinc-coated, bluish, dull, passivated fastener: A 2 B

Electroplating

Fasteners are degreased and pickled before being electrolytically coated with the coating metal in an electrolyte bath. For fasteners and small components, this is predominantly carried out using barrel plating systems. Large fasteners and bulky components are rack plated in order to avoid damage being caused by the high self-weight of the compent.

The metal is not deposited on the surface of the steel evenly when this method is used. Protruding areas are coated more thickly, while recessed areas and notches are more thinly coated.

Specific measurement points are therefore provided for the evaluation of coating thickness.



Measuring points for local coating thickness measurement

For long, thin fasteners, electroplating can cause problems with trueness to gauge due to the unevenness of the coating.

Various metals can be deposited using electroplating. The most common coating metals are zinc, nickel, chromium, copper, brass and tin.

Zinc

Zinc is well suited for electroplated surface coatings due to its anodic effect.

Thanks to Faraday's Law, it is possible to regulate the quantity of zinc deposited on the fastener (and therefore the coating thickness) as required by varying the electrical current and electroplating time.

Fasteners are usually coated and passivated with a 5–7 µm thick zinc coating.

Zinc alloy coatings

This process is characterised by the use of coatings based on alloys of zinc with other elements. A final transparent or black passivation treatment can be applied.

ZnFe contains 0.3 % to 1 % iron. ZnNi 8 % to 15 % nickel.

Due to the low levels of corrosion products formed by alloy coatings, zinc alloy coatings are increasingly gaining in importance.

Nickel and chromium

In contrast to the non-noble metals such as zinc, nickel and chromium provide protection by forming a hard layer. The metals are more noble than steel. If the surface is damaged, then rust creep will occur below the coating metal, causing it to break away.

Both metals are used for decorative purposes.

Chromium surfaces are particularly hard, durable to abrasion, and do not tarnish.

Usually, chromium surfaces are not applied directly onto the steel surface. First the steel is plated with copper, then with nickel and only then is the chromium applied.

The electroplated chromium coating is usually applied using a rack coating technique.

Copper

Copper surfaces serve as intermediate layers for nickel and chromium surfaces and also have high electrical conductivity.

Brass

Fasteners with electroplated brass coatings are predominantly used for decorative purposes.

Tin

Parts with a tin surface are easier to solder.

Barrel plating

Post-treatment of electrolytically applied zinc coatings

Electrolytically deposited coatings are commonly post-treated to improve their corrosion resistance.

Passivation

A conversion layer is created by a reaction with a post-dip solution. This layer has a specific technical purpose and increases the corrosion resistance. Passivations are applied chemically and completely cover the electroplated protective coating, meaning that pores at the surface of the zinc are closed.
Thin-film passivation. Is available in Cr(VI)-free versions and is the standard post-treatment for Zn, ZnFe and ZnNi. Additional protection against the susceptibility to corrosion of the zinc coating can be provided by
Thick-film passivation. This can also be Cr(III)-based and is therefore in compliance with legal requirements for the absence of Cr(VI).
Passivation layers have an iridescent appearance with blue-silver-rainbow colours and can also be additionally coloured.
Chromating[1)]. Passivation layer containing Cr(VI). Yellowish moving to black with increasing Cr(VI) content.Yellow chromated surfaces offer good corrosion protection, however chromating is only thermally stable up to approximately 70° C.

Gradual delamination of the more conservative blue chromating, which is applied by thin-film passivation, should be expected. The corrosion protection values are comparable.

Topcoats

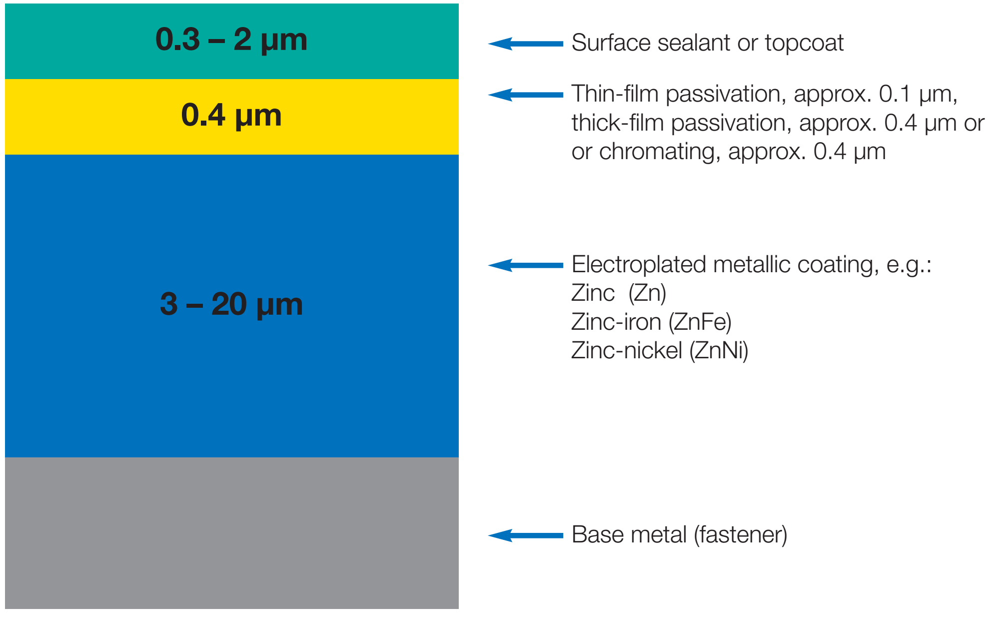
In general, these are additional film-forming layers intended to increase the level of corrosion protection or to add colour.

Surface sealants

Surface sealing is generally provided by substances containing silicates that bond with the passivation layer. Surface sealants heighten the visual effect of passivation coatings and can be used to adjust the coefficient of friction.

[1)] The previously most common method of chromating is now no longer permissible due to EU regulations relating to the protection of human health and the environment. This also means that it is necessary for fasteners to use an alternative treatment or coating system. Cr(VI)-free passivations, with or without surface sealing, are an option here.

Example of surface structure



Hydrogen embrittlement

Manufacturers and users forming the Mechanical Fasteners Standards Committee (FMV) have agreed on important wording relating to this complicated technical process, which has been incorporated into DIN EN ISO 4042.

Hydrogen induced cracking
This is the failure of components due to the interaction of atomically diffused hydrogen and internal tensile stresses and/or tensile load induced stresses.

Risks from hydrogen embrittlement
With the processes in use today for the deposition of metal coatings from aqueous solutions (applied in compliance with the requirements for steel fasteners relating to minimum alloying components and minimum tempering temperatures, as specified in DIN EN ISO 898-1), it is not possible to exclude with certainty the possibility of hydrogen induced delayed cracking. This applies to steel components with tensile strengths R_m > 1000 N/mm², corresponding to 300 HV. This phenomenon can generally be avoided by selecting a material that is particularly well suited to the application of electroplated surface protection, in conjunction with the use of modern surface treatment processes, including appropriate post-treatment.

There is an increased risk of brittle fracture in sprung accessory components with hardnesses greater than 400 HV. Special precautions must therefore be taken with regard to material selection, heat treatment and surface treatment.

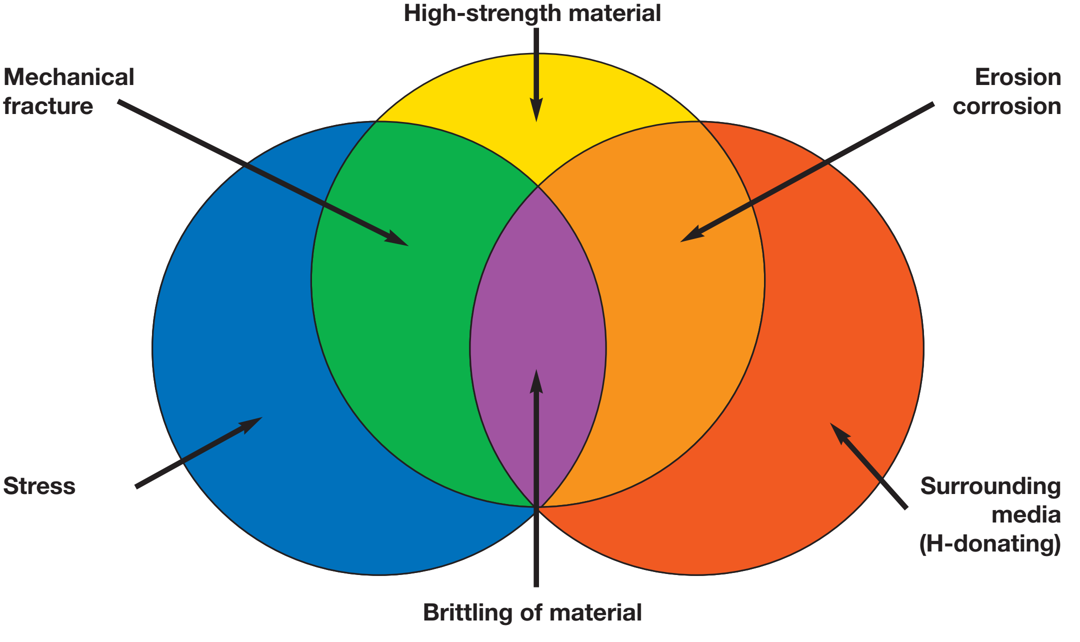
Other mechanical fasteners should be checked on a case-by-case basis with regard to the circumstances under which hydrogen induced embrittlement might occur. Should a corresponding risk be identified, appropriate measures should be taken to avoid hydrogen induced embrittlement.

How does the hydrogen get into the steel?
The harmful hydrogen may be diffused into the steel during pickling or electroplating, or may be a side-effect of corrosion.

The sensitivity of a material to hydrogen induced embrittlement increases with increasing strength of the steel. Susceptibility to brittle fracture can be largely avoided by choosing a sufficiently ductile material with a minimum tempering temperature of +500° C and also by using a suitable surface treatment process plus suitable post-treatment. (Suitable post-treatment should be understood to mean heating to between +190 and +200° C with a holding time from two to four hours...).

This means that there is a certain risk associated with subsequently applying an electroplated surface treatment to fasteners that only meet the minimum requirements with regard to material and tempering temperature for property classes 10.9 and 12.9, as specified in DIN EN ISO 898-1.

Interaction of the conditions that lead to hydrogen induced delayed cracking*)



**) K. Kayser: VDI-Z Vol. 126 No. 20*

Zinc flake coatings

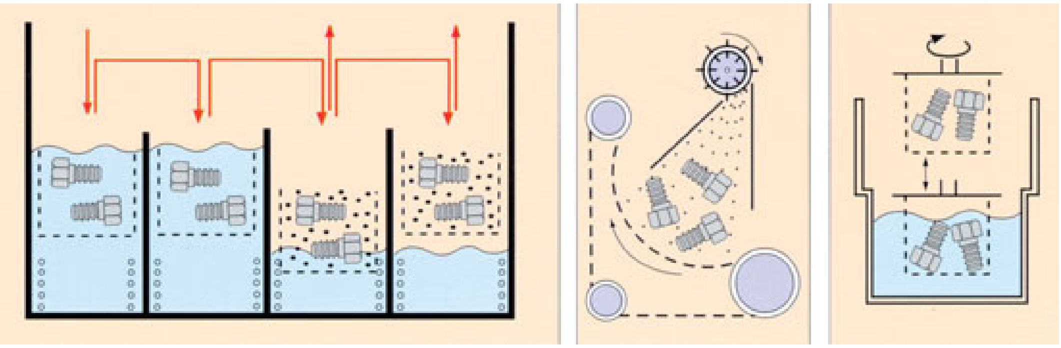
After cleaning and degreasing the surface, the parts are dipped into an aqueous or solvent-based, dispersive solution containing a mixture of zinc and aluminium flakes.

The parts are then spun to remove any excess coating metal.

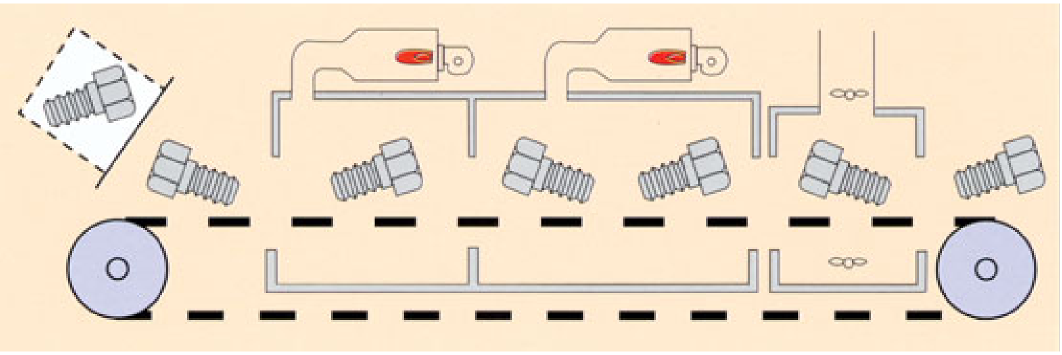
Large and bulky parts are treated by spraying.

Once the coating has been applied it is cured at 180 °C or 300 °C.

Degreasing | Blast-cleaning | Dipping/spinning



Curing



Coating process

After one cycle the coating thickness is approximately 4 µm. At least two layers are applied, meaning that the coating is 8-10 µm in total; this technique is therefore unsuitable for use on fasteners with a small thread diameter.

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Parts treated with this type of dispersion coating are dull grey in appearance and have a high degree of corrosion protection, which is far greater than that achieved by electroplated zinc coatings.

Surface sealants and ***topcoats*** can also be subsequently applied. Lubricants can be integrated into a coating or applied in a final post-treatment. Friction coefficients can be adjusted with a relatively high degree of accuracy.

When using this coating technique there is no risk of ***hydrogen embrittlement.***

Zinc flake coatings are commonly known as thin coatings or ***dispersion coatings,*** and sold under the trade names Dacromet, Geomet and Delta Protekt, among others.

DIN EN ISO 10683 describes these coatings as non-electrolytically applied ***zinc flake coatings.***

The standard designation is ***flZn***. The required duration of salt spray test, in hours, is also given. The parts must not show any signs of rust after these periods.

flZn – 480 h	Zinc flake coating with a test duration of 480 h
flZnL – 240 h	Zinc flake coating with a test duration of 240 h and an integral lubricant
flZn – 720 h – L	Zinc flake coating with a test duration of 720 h and a subsequently applied lubricant
flZnnc – 240 h	Zinc flake coating with a test duration of 240 h, Cr(VI)-free
flZnyc – 480 h	Zinc flake coating with a test duration of 480 h, with Cr(VI)

The thickness of coating can be inferred from the test duration indicated. A part that withstands 480 hours in the salt spray test will require a coating (flZn) of 5 µm with Cr(VI), or 8 µm without Cr(VI).

Where subsequent coatings are applied to stock parts, the thread tolerances and the possible coating thicknesses must be taken into account.

Thin paint film (topcoat)

This refers to topcoats based on an organic compound that is applied in the liquid state. The fasteners are either dipped or have the topcoat sprayed on; they are then heated to 200 °C. This causes the paint film to harden.

The protective layer can be applied on top of another surface coating in many different colours. Lubricants can be incorporated into this protective layer, thereby giving the thread a favourable, consistent coefficient of friction.

This process is known by the trade names "Delta Seal" and "Polyseal".

Hot-dip galvanising

Hot zinc plating (tZn) is carried out in a bath containing molten zinc at a temperature of around 500° C. Due to the high temperature, zinc and iron react to form a layer of zinc-iron alloy. This layer is not damaged during the treatment.

After dipping, excess zinc is removed from the fasteners by spinning. External threads must not be cut after galvanising.

DIN EN ISO 10684 specifies a minimum coating thickness of 40 µm. The thickness of the protective coating and the zinc-iron layer underneath provide a very high level of corrosion protection.

The thick coating must be considered in the design of the thread to ensure that the fastener can still be screwed in once it has been zinc plated. The thread must therefore be manufactured with a large minus allowance to accommodate the zinc plating.

This also has the effect of reducing the stressed cross section and the contact surface at the flanks. For this reason, different proof forces are specified for hot-dip galvanised fasteners and fasteners with electroplated coatings (DIN EN ISO 10684).

For the same reasons, it is not advisable to use hot-dip galvanising for bolts and screws of sizes below M10. Internal threads are only cut after the hot-dip galvanising process and therefore do not have a zinc coating. The internal thread is protected indirectly by the zinc present on the external thread.

For hot-dip galvanised HV connections, DIN EN 14399 should also be followed (until September 2007 also DIN 18800).

Phosphating and bonding

This dark-grey to black coloured surface protection is produced by dipping into a zinc phosphate solution. The phosphate coating provides good adhesion for paint coats and lubricants. Phosphating is also commonly used to achieve better frictional characteristics prior to cold forming.

Phosphate coatings only provide a low level of corrosion protection

Black finishing

Black finishing involves dipping parts of plain ferrous materials into an oxidising solution at 140° C. This produces a brownish-black iron oxide film on the surface. The black finished parts are then oiled or waxed.

The degree of corrosion protection is very low.

Blackening

Blackening of high-strength threaded fasteners is produced during heat treatment by cooling the parts in an oil emulsion after tempering. The oil penetrates into the hot surface and gives the part a black colour.

This treatment provides a simple method of corrosion protection prior to storage or transportation.

Chemical nickel plating

Coating is carried out without any electrical current in a nickel salt solution. This allows a very even thickness of coating to be achieved at the microscopic level, even at corners and inside holes.

This type of coating is therefore suitable for use on small, complicated components. The surface hardness is high because nickel is used as the coating metal.

Mechanical coatings

The fasteners are placed in a drum with a glass bead mixture which, through the motion of the drum, causes metallic particles to be deposited (plated). The mixture of glass beads varies depending on the size and shape of the parts.

This process is also referred to as “Mechanical plating” or “3M zinc plating”.

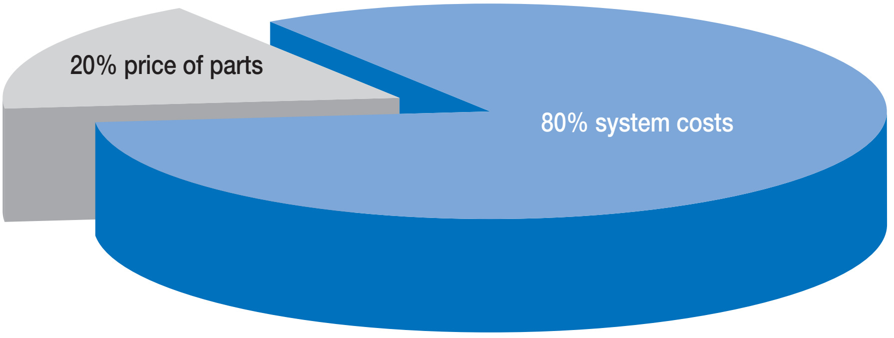
Guideline values for the service life of surface treatments

Service life in years until formation of red rust for various corrosive atmospheres				Surface protection	Coating thickness
Countryside climate	City climate	Industrial climate	Ocean climate		
3 – 8 5 – 12 10 – 20	1 – 4 2 – 6 5 – 10	unter 1 1 – 2 2 – 3	1 – 3 1 – 4 2 – 5	Zinc coated, passivated	5 – 8 µm 12 µm 20 µm
5 – 13 8 – 20 17 – 34	1 – 7 3 – 10 8 – 17	1 1 – 3 3 – 5	1 – 5 1 – 7 3 – 8	Zinc coated, yellow chromated thick-film passivated	5 – 8 µm 12 µm 20 µm
50	25	5	7	Hot-dip galvanised, M6 and above	60 µm

ECOTECH – Application technology consulting at Böllhoff (**ECO**nomic **TECH**nical Engineering)

Whatever the type of fastening technology, its main purpose is to fulfil its intended function. The focus of economical fastening technology is to fulfil this function with minimum complexity at the lowest possible cost.

This results in the necessity to be clearly aware of how the total cost of a connection is distributed. Investigations around this subject repeatedly show that the price of the fastener itself only has a small influence on the commercial assessment of cost. Of much greater significance are the system costs.



The term 'system costs' encompasses outlay for procurement, storage, quality assurance, assembly, administration, internal transportation, and so on. This opens up many possible approaches to cost reduction, in contrast to those relating to the cost of the product itself. The table illustrates a few possible options and strategies.

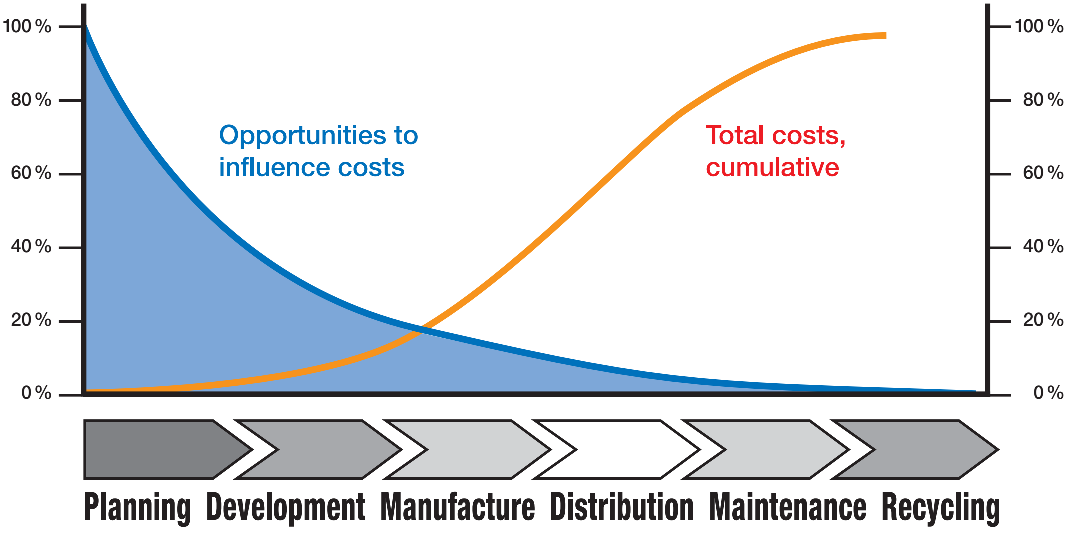
Rationalisation of fastener functionality	E.g. multi-functional fasteners, self-tapping fasteners
Standardisation of the range of products	Drive types, dimensions, surfaces, property classes, etc.
Simplified assembly	Select drive types that make assembly easier Reduce movements during assembly Use combination parts Aim to use automated solutions
Select lower cost fastener types	Snap connections Clips
Supplier and logistics management	Reduce transportation routes Minimise sources of supply Utilise distribution systems
Design modifications	Reduce the number of directions in which parts connect; think sandwich construction Make it easy to join parts (lead-in chamfers, locating pins, etc.) Improve accessibility Reduce number of contact surfaces

Even by itself, the selection and validation of a suitable fastener from the wide range of standardised parts can cost a lot of time during the design phase, bringing with it associated costs. These costs can be reduced by engaging the services of an experienced partner company. In addition to this, it is often the case that the user does not possess relevant design experience or sufficient knowledge of possible alternatives.

Special requirements often demand customised solutions, and this is where the greatest potential for savings is to be found – in establishing the ideal solution to a fastening technology problem, whatever form it might take.

In fact, the commercially and technically ideal solution is often to be found outside the range of standardised components.

Fastening technology is often taken into consideration relatively late in the design process. Unfortunately, the opportunities to influence costs decrease the later this is postponed. It is therefore advisable to consult an expert in fastening technology right at the start of product development.



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