1627/11.02

Customer Information

BÖLLHOFF

bulletin

Edition 27

Fastening technology

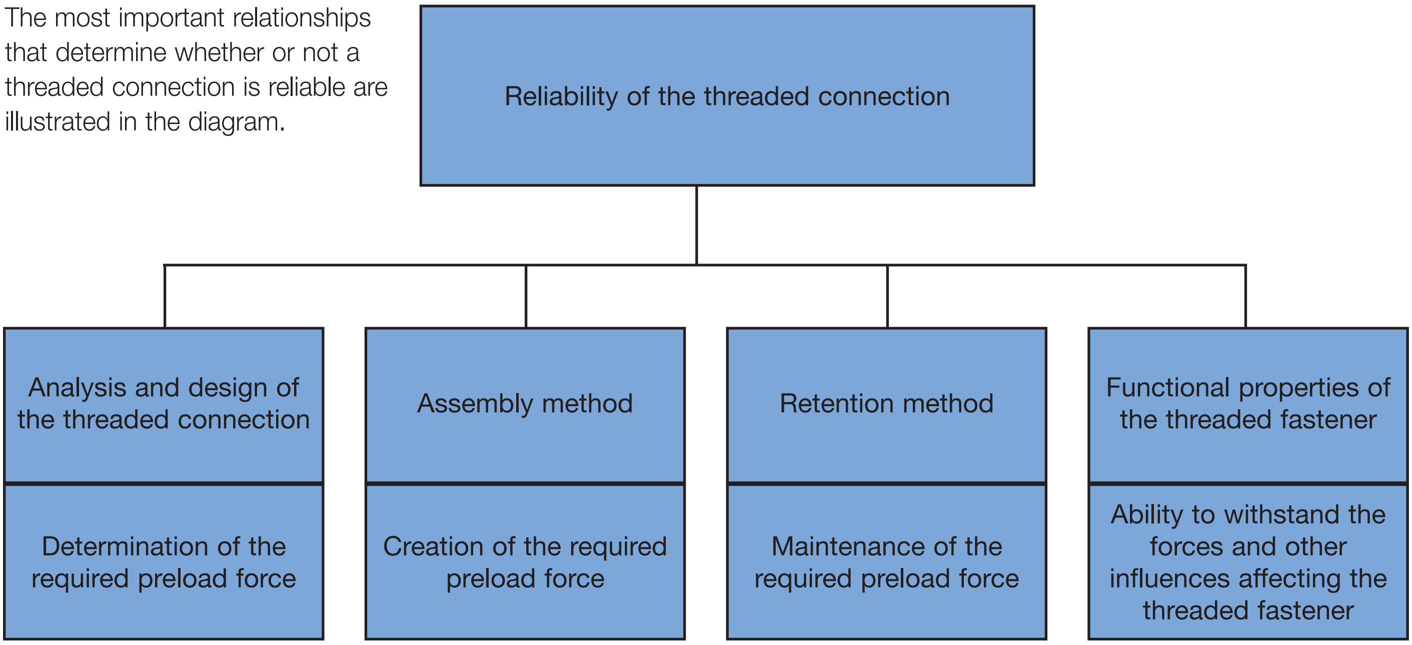
efficient, secure, safe

Securing Threaded Connections

Securing Threaded Connections

Ever since it was first invented, the threaded fastener has proven itself an irreplaceable part of the world of fastening technology. Today, threaded fasteners continue as before to be one of the most important types of releasable fastener in the fields of construction, assembly and repair. Within this category, the range of different types of fastener and the uses to which they can be put is continuously increasing. The problem of retaining these fasteners has become a hugely complex subject, which is difficult to fully comprehend. This latest issue of Böllhoff Bulletin will give you an introduction to the technical principles that underpin the subject of how to retain fasteners and provides an overview of the major types of locking system available on the market today. The following information is provided with the aim of helping you to always choose the best fastener for the job, based on technical and economic considerations. We hope we achieve our aim. Should you require any further advice on finding the right solution for your individual requirements, our applications technology engineers are always on hand to help.

The most important relationships that determine whether or not a threaded connection is reliable are illustrated in the diagram.



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

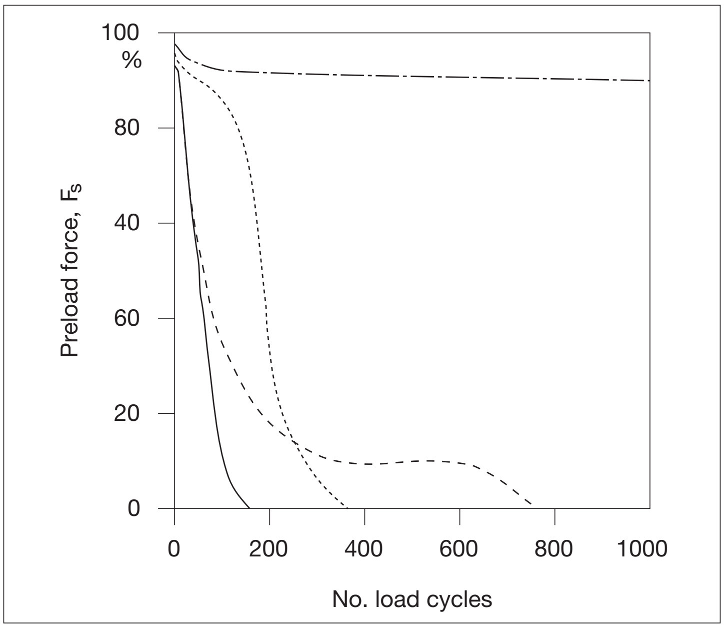
In practice, it is not always possible to achieve a sufficiently secure threaded connection through good design alone. A range of fastener locking methods is available to prevent threaded connections from loosening or falling apart in such cases.
It must however be noted that, even today, spring washers and other accessory elements are still used in their millions, despite the fact that these supposed retainers are completely ineffective in high-strength threaded connections, and the corresponding standards have long since been withdrawn by the German Institute for Standardization (DIN).
It has long been known that a properly implemented threaded connection can generate considerably higher clamping forces than could be achieved using a spring washer or tab washer.

Withdrawn standards

To date, the following standards relating to retainers have be withdrawn by DIN (Deutsches Institut für Normung e. V.):

- ***Spring washers (DIN 127, DIN 128 and DIN 6905)***
- ***Curved spring washers (DIN 137 and DIN 6904)***
- ***Toothed lock washers (DIN 6797)***
- ***Serrated lock washers (DIN 6798 and DIN 6908)***
- ***Tab washers (DIN 93, DIN 432 and DIN 463)***
- ***Safety cups (DIN 526)***
- ***Self-locking nuts (DIN 7967)***
- ***Hexagon Thin Slotted and Castle Nuts (DIN 937)***

When used with high-strength threaded fasteners, the retainers defined by these standards neither provide a locking effect, nor are they suitable as a precaution against setting.

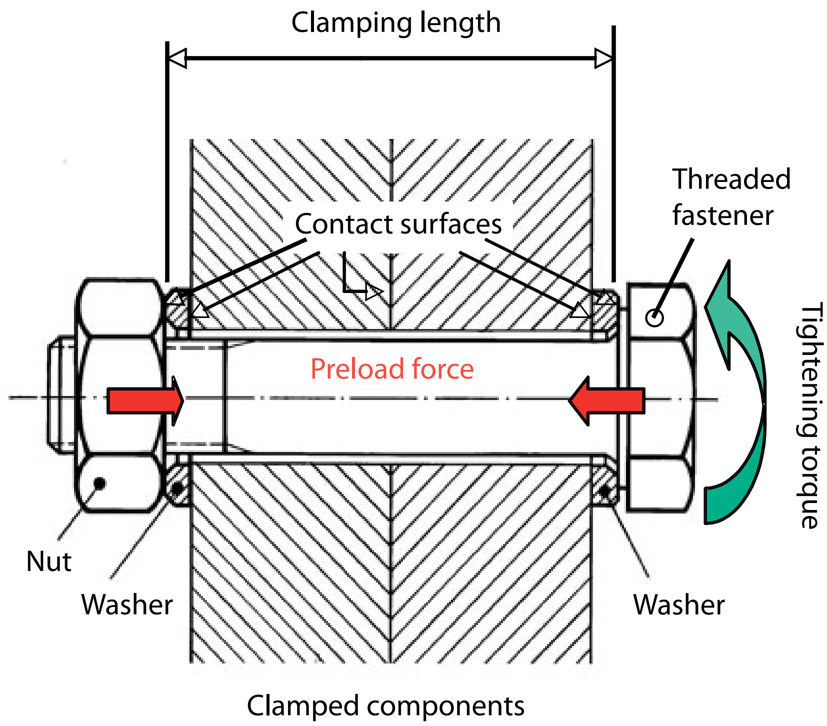


Non-retained fastener, DIN 933 – M 10 x 30-8.8	Fastener with tooth lock washer as per DIN 6797	Fastener with spring washer as per DIN 127	Serrated washer head fastener or fastener with microencapsulated adhesive

Comparison of loosening characteristics of various fastener retention methods under dynamic lateral load

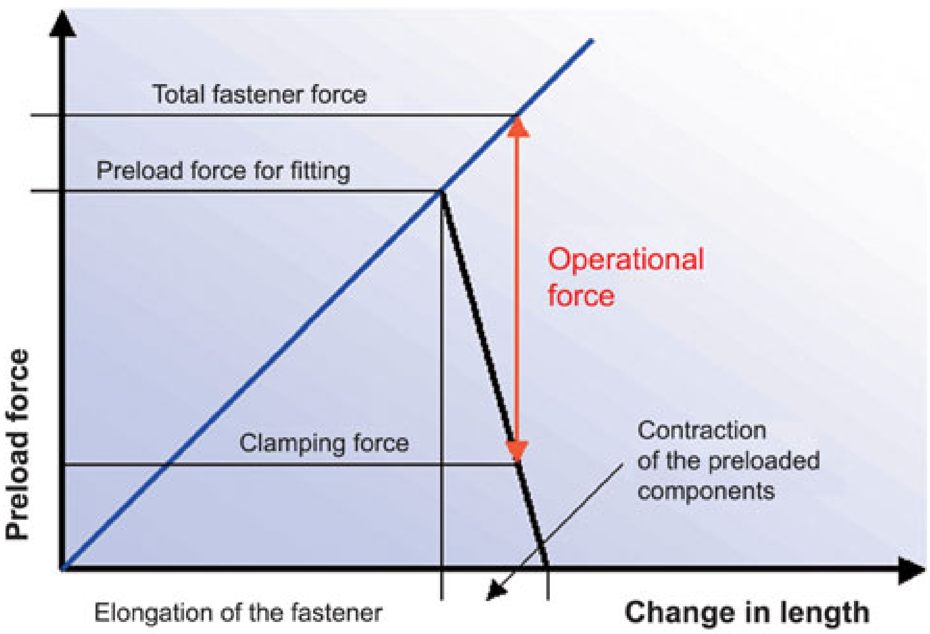
Relationships between force and deformation in preloaded threaded connections

Threaded connections should be designed in such a way that there is no way in which the maximum possible combined loads could lead to the yield point of the mated components being exceeded*.
The tightening torque must be selected so that the preload force applied results in a purely frictional connection between the components.
Guideline value: Preload force should be at least 75% of the yield strength of the threaded fastener.
With a clamping length ratio of Lk/DNom > 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 occur, particularly perpendicular to the axis of the fastener.



* Exception: Overelastic tightening – this does however require a special tightening procedure.

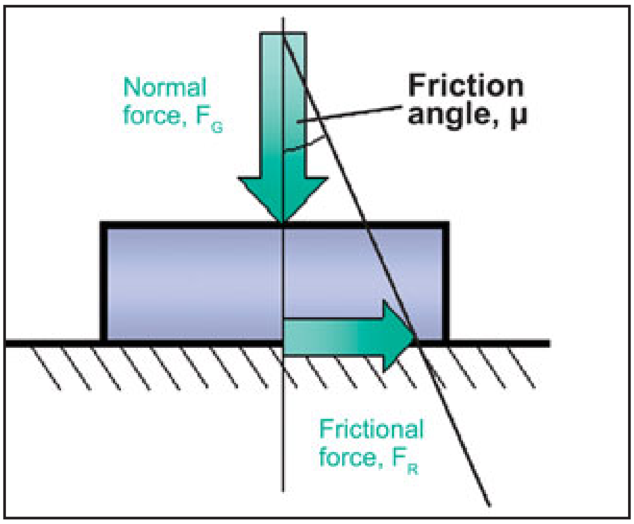
Preload diagram

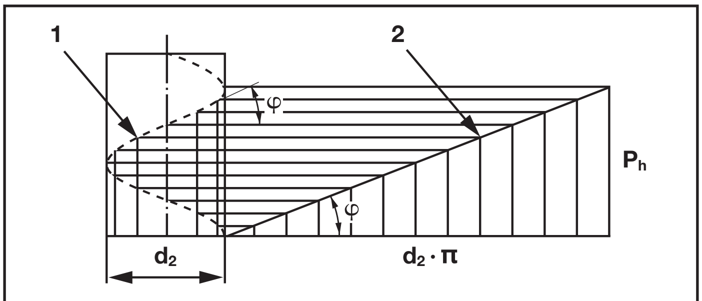


Applying a tightening torque to create a connection indirectly causes a preload force to act on the fastener, which in turn leads to lengthening of the fastener and a contraction of the components. Any forces that occur in use are distributed according the elasticity of the mated parts. Under tensile stress, the load on the fastener is only reduced slightly, however the remaining clamping force is decreased significantly.
Important: Any compressible spring components used in conjunction with the fastener will affect the load ratios.

Effect of preload force and thread pitch

The friction angle, μ, describes the ratio of the normal force, F_G, to the frictional force, F_R that it generates. Taken in the context of a threaded connection, the normal force and the preload force can be considered equal as a first approximation.
Provided that the pitch angle, φ, of the thread is smaller than the friction angle, μ, the thread will be self-locking.

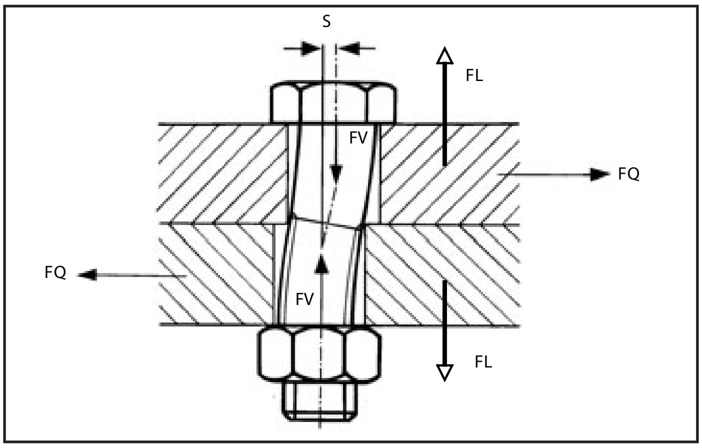




1 Helix
2 Uncoiled helix

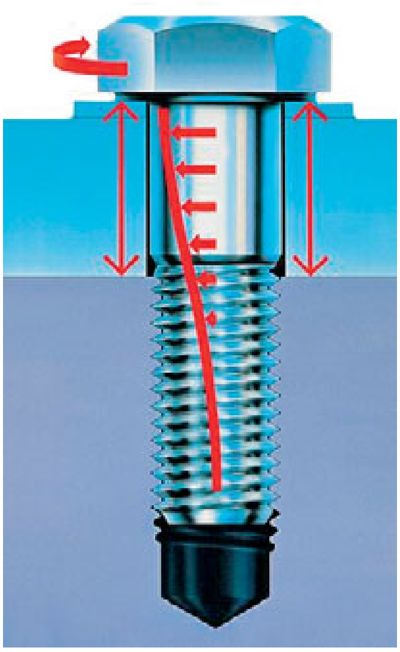
Static and dynamic load cases

Forces acting on the system that give rise to deformation may cause a displacement of the component. When dynamic loads (vibrations) are present, it is possible for effects to occur that cause the threaded connection to work loose, despite the fact that permissible values were not exceeded, e.g. due to parts oscillating in opposition to each other.
This effect is referred to as self-loosening. In such cases, the dynamic lateral forces, FQ, acting on the connection are of sufficient magnitude to cause the joined parts to move against each other in opposite directions (relative motion between the contact surfaces of the clamped parts).



How self-loosening occurs

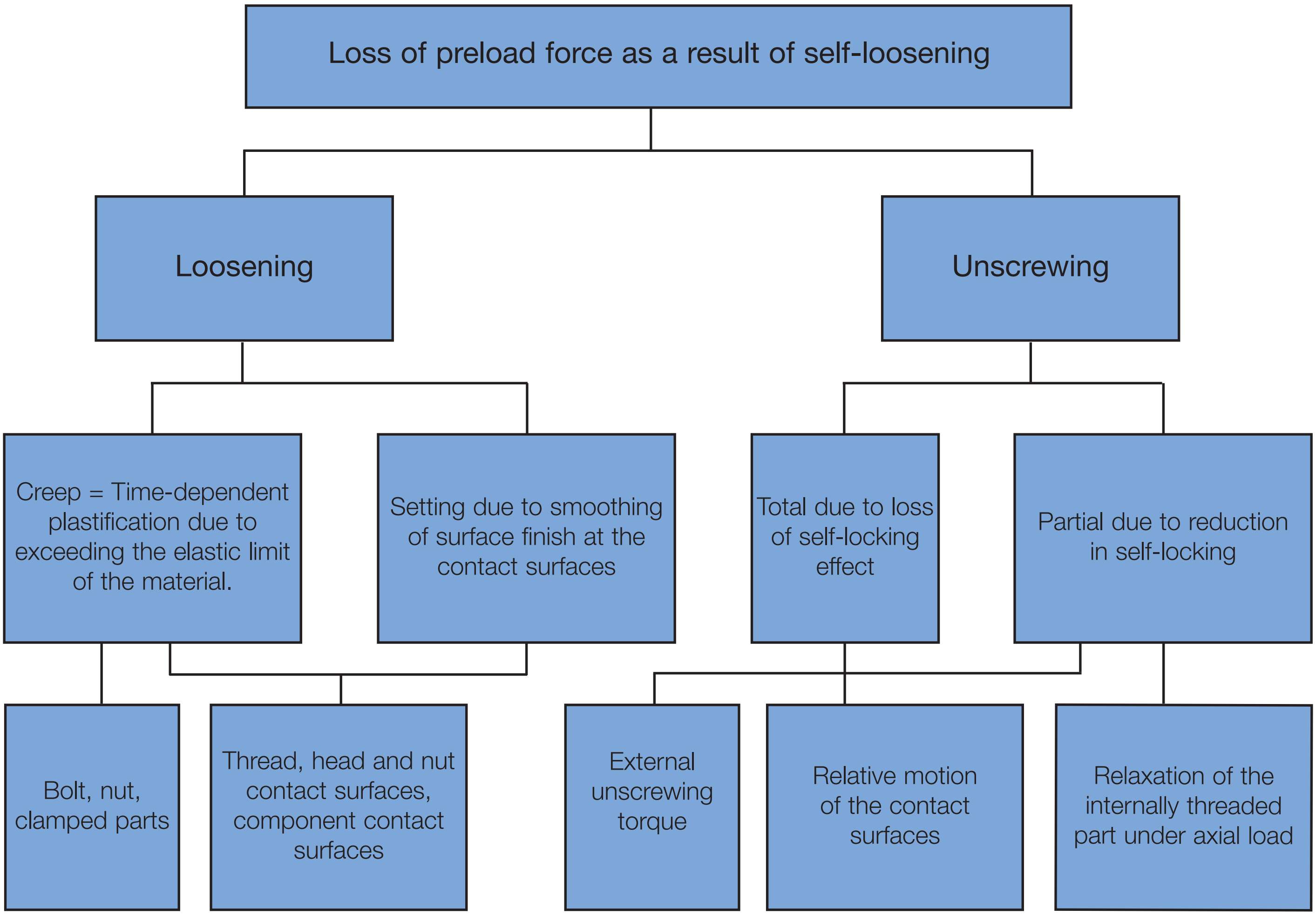
It is not uncommon for threaded connections to fail due to self-loosening when subjected to dynamic loads, particularly where the forces act perpendicularly to the axis of the connection.
This can result in defects and damage caused by the partial or complete loss of preload force in the form of fatigue cracks or unscrewing of connections.
Connections unscrew because of the internal unscrewing torque within the connection, which occurs when forces act to overcome the frictional connection between the head of the fastener and the part and/or between the fastener and the internal thread.
Connections formed using a clearance through-hole (nut and bolt) are particularly at risk of this type of failure as there is more potential for the fastener to work loose.



Guideline

Connections are usually sufficiently secure simply as a result of the combination of frictional resistance and the clamping force between the nut/fastener and the clamped parts.
Provided that the clamping length is appropriate (guideline value > 5d), threaded fasteners do not generally require additional retention measures, even when subject to dynamic load.
If loads occur that create a situation where design measures alone are insufficient to maintain a connection, then additional retainers must be used.

Causes of self-loosening of a threaded connection



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

Precautions against self-loosening

Spring retainer

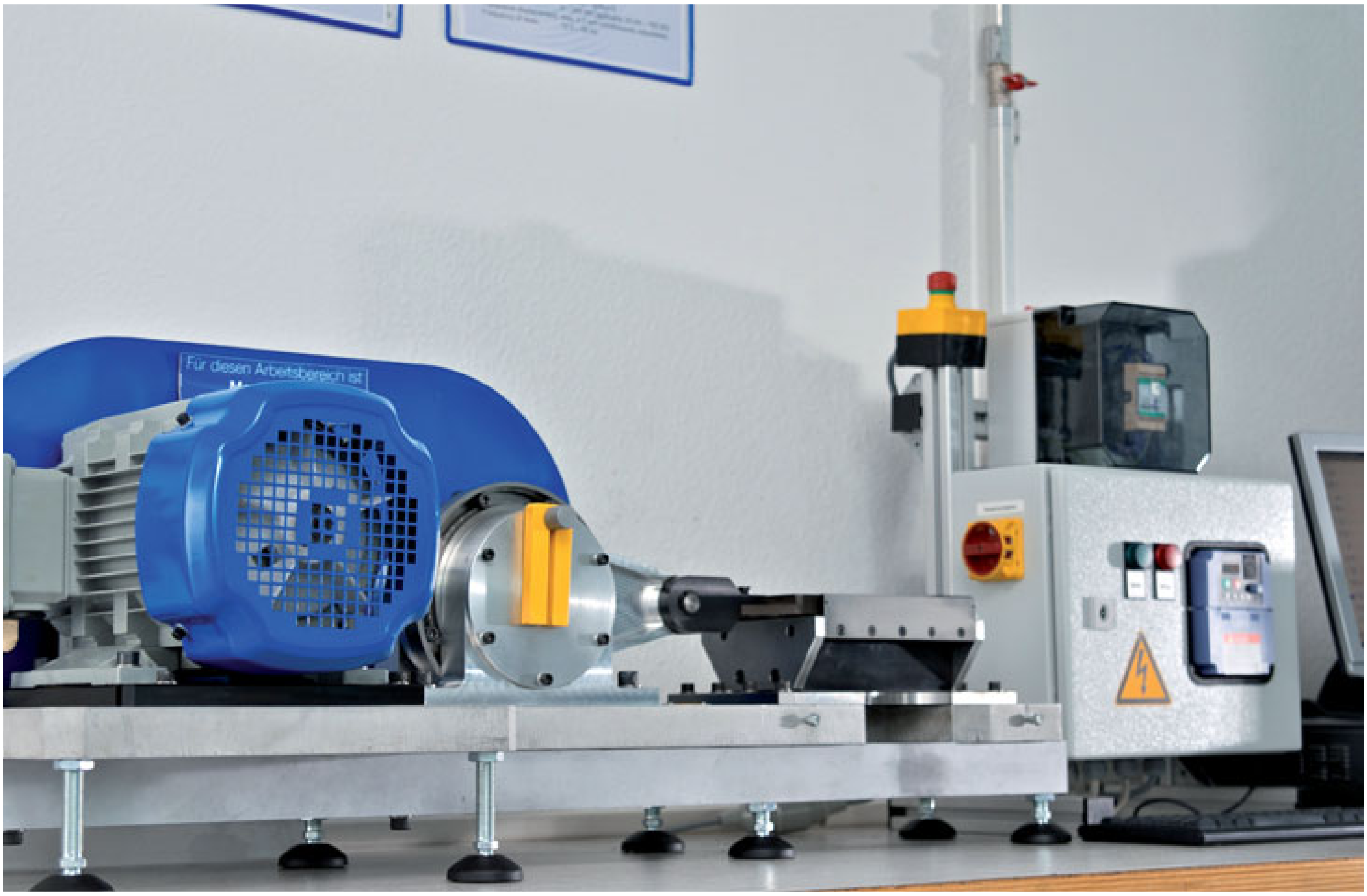
These retainers compensate for the effects of creep, setting and the elasticity of the parts. They generally act in a similar way to a return spring. Caution: Many compressible components still in common use are ineffective, e.g. spring washers.

Anti-unscrewing

Retainers for preventing relative movement between fastening elements. (Locking teeth, locking ribs, micro-encapsulated adhesives). Specification: Min. 80% of preload force must be maintained.

Anti-loss

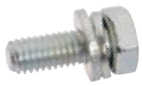
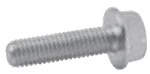
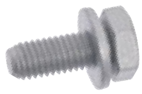
Retainers for preventing connections from completely falling apart. The principle underlying these retainers is usually an increase in friction/ clamping force in the thread or underside of the head. Less than 80% of preload force is maintained.

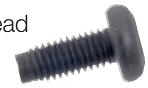
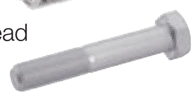
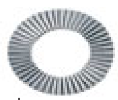
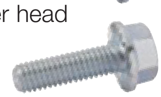


Vibration test rig in Böllhoff laboratory

Overview of retainers in tabular form

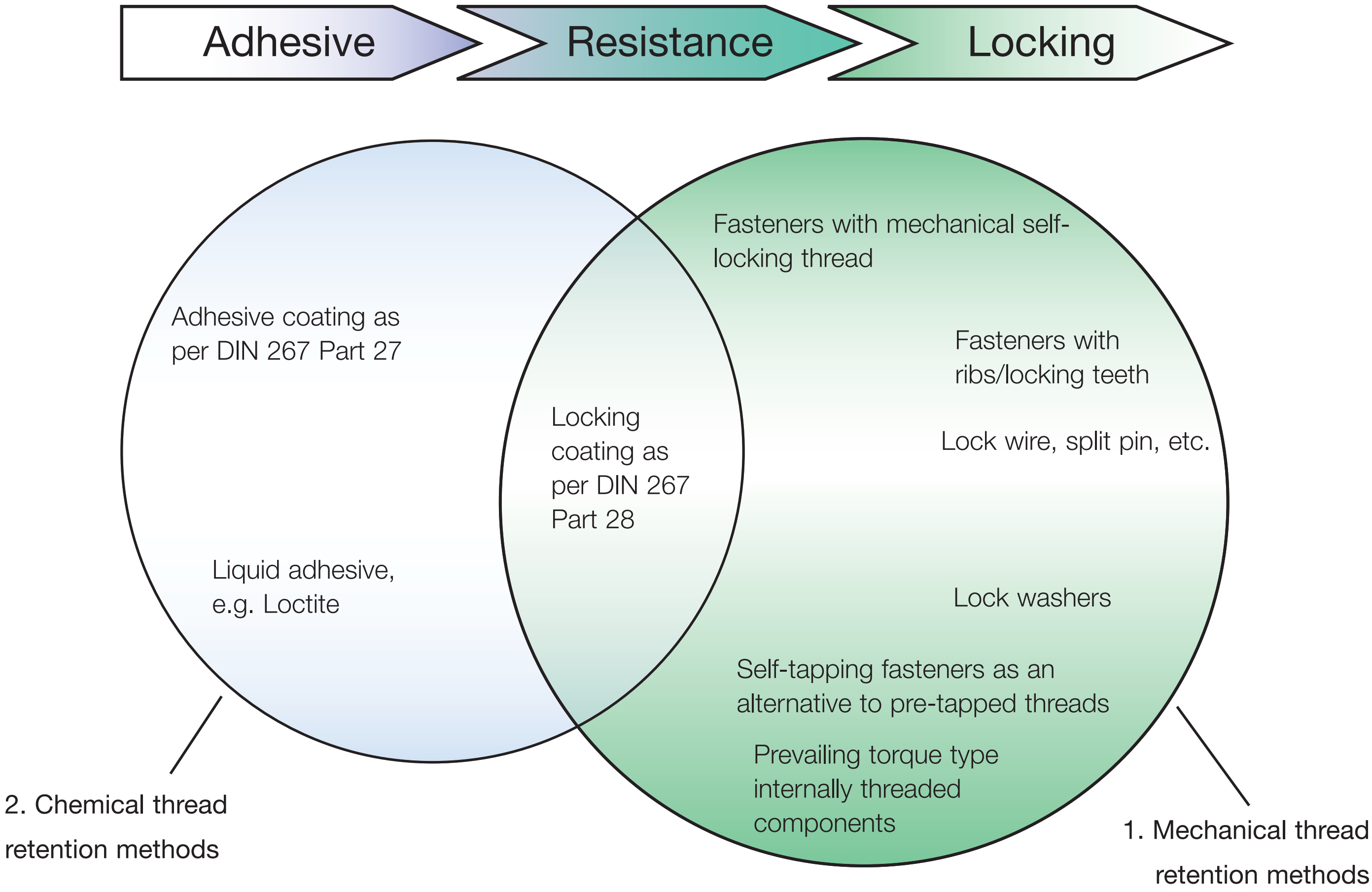
Suitability for specialist requirements

Type	Operating principle	Designation		Standard	Retention effect	Ease of integration into existing design	Thermal stability	Multiple use	Corrosion protection	Additional benefit
Cause of loosening: loosening due to setting										
Spring retainer	Compressible spring components	Disc springs		DIN 2093	o	o	+	+	o	
		Conical spring washer		DIN 6796 and B 53072	o	o	+	o	o	
		Screw and washer assemblies		DIN 6900	o	o	+	+	o	
		Nuts with captive washers		B 53010	o	o	+	+	o	
		Lock washers		B 53070	+	o	+	o	o	
	Reduction of surface pressure	Hexagon bolts with flange		DIN EN 1665	-	o	+	+	+	
		Screw and washer assemblies		DIN EN ISO 10644	-	o	+	+	+	
		Flanged nuts		DIN 6923	-	o	+	+	+	
		Washers		e.g. ISO 7089	-	o	+	+	+	
Cause of loosening: unscrewing due to forces too great for anti-loss retainer										
Anti-loss	Positive locking	hex. castle nut		e.g. DIN 935	o	-	+	o	o	
		Fasteners with split pin hole		DIN 962	-	-	+	o	o	
	Prevailing torque components	Prevailing torque type all-metal nuts		e.g. DIN 6927	o	+	+	o	o	
		Self-locking hex flange nuts: non metallic insert		e.g. DIN 6926	o	o	-	o	+	
		Plastic coating in thread		B 53081	o	+	-	o	+	

Depends on preload force	Suitable for thread lubrication	Effort required to install	Hardness of counter surface	Cost of component	Additional space required	Effect on connection	Shelf life	Type	Operating principle	Designation
								Cause of loosening: unscrewing due to forces too great for anti-		
o	+	o	o	+	o	Clamping length	Unlimited	**Anti-loss**	Other method	Thread forming screw 
o	+	o	o	+	o	Clamping length	Unlimited			Self-locking thread 
o	+	+	o	o	o	Clamping length	Unlimited			HELICOIL® screwlock 
o	+	+	o	o	o	Clamping length	Unlimited			Lock nut 
o	+	o	o	o	o	Clamping length	Unlimited			Fine pitch thread 
+	+	+	+	o	+	Neutral	Unlimited	**Anti-unscrewing**	Locking components	RIPP LOCK® lock washers 
+	+	+	+	o	o	Clamping length	Unlimited			Ribbed fastener/nut 
+	+	+	+	+	+	Neutral	Unlimited			Serrated washer head screws/nuts 
+	+	o	+	+	o	Clamping length	Unlimited			Profiled washer 
+	+	-	+	-	-	Various	Unlimited		Adhesive components	Microencapsulated adhesive 
+	+	-	+	-	-	Negative	Unlimited			Liquid adhesive 
+	o	+	+	o	o	Tightening torque	Unlimited		Wedge locking method	NORD-LOCK® Paired wedge-locking washers 
+	o	+	+	o	o	Almost none	Unlimited			
+	o	+	+	-	o	Almost none	Unlimited			

			Suitability for specialist requirements											
Standard	Retention effect	Ease of integration into existing design	Thermal stability	Multiple use	Corrosion protection	Additional benefit	Depends on preload force	Suitable for thread lubrication	Effort required to install	Hardness of counter surface	Cost of component	Additional space required	Effect on connection	Shelf life
-loss retainer														
e.g. DIN 7500	o	-	+	o	o	Stream-lined	+	+	+	o	+	+	Flank clearance	Unlimited
No standard	o	+	+	o	o		+	+	+	o	o	+	Tightening torque	Unlimited
B 62000	o	-	+	+	+	Increases strength	+	o	-	+	-	+	Almost none	Unlimited
No standard	-	-	+	+	+		-	o	-	+	+	-	Additional clamping	Unlimited
DIN 13 Part 2 et seq.	-	-	+	+	+		o	o	+	+	o	+	Tightening torque	Unlimited
B 53065	+	o	+	+	+		o	+	o	o	o	o	Clamping length	Unlimited
B 158	+	o	+	o	o		-	o	+	-	o	+	Almost none	Unlimited
B 53085, B 151	+	o	+	o	-		-	o	+	-	o	+	Almost none	Unlimited
e.g. B 53072	+	o	+	o	o		-	o	o	-	o	o	Clamping length	Unlimited
DIN 267 Part 27	+	+	o	-	+	Sealing	+	-	+	+	-	+	Almost none	Approx. 4 years
No standard	o	+	-	-	+	Sealing	+	-	-	+	-	+	Almost none	Approx. 1 year
B 53074	+	o	+	+	+		o	+	o	o	-	o	Clamping length	Unlimited

Differentiation of retention types

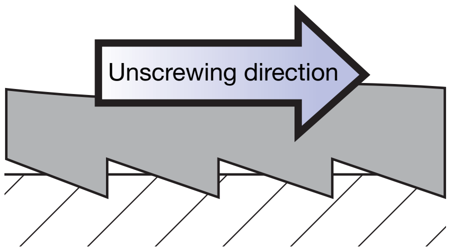


1. Mechanical thread retention methods

Prevailing torque	Mostly internally threaded components, e.g. prevailing torque type nuts (DIN 6927, DIN 6926, DIN 985), Fujilok nut (B 53030), Vargal (B 53040), etc.
Locking	Serrated washer head fasteners (B 53085, B 151 and B 158), serrated washer head nuts (B 196, B 193 and B 53012), lock washers (e.g. RIPP LOCK®).
Sprung	e.g. 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), etc.
Lock nut	Any type of nut that is clamped by an additional internally-threaded component – these are not true retainers.
Positive locking	Hexagon slotted nuts and castle nuts (DIN 935 and DIN 979), fasteners with split pin hole (DIN 962).
Thread forming	Thread retention as added benefit

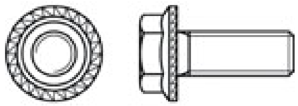
There are also numerous types of retainer that combine two or more different types of mechanical retention (e.g. RIPP LOCK® lock washers, NORD-LOCK® washers).

1.1 Retainers with locking teeth/profiled surfaces



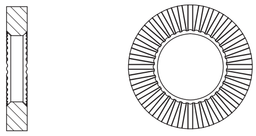
This retention method works using embossed teeth, which are usually asymmetrical, arranged in such a way that the steeper flanks are aligned towards the direction of unscrewing. These formed elements are embedded into the component when the fastener is tightened and produce a positive locking effect that must be overcome before loosening can occur. The functionality is highly dependent on the characteristics of the surfaces and the strength of the parts that provide the prevailing torque. There are two major subdivisions within this category:

Fasteners and nuts with teeth/profiling underneath the head



e.g.
B 53085 Hexagonal self-locking fasteners
B 53012 Self-locking nuts with flange
B 151 and B 196 ZAHN self-locking fasteners
B 158 and B 193 RIPP self-locking fasteners

Toothed, profiled washers



e.g.
B 53065 RIPP LOCK® lock washers
B 53070 lock washers (Schnorr washers)
B 53072 Spring-lock washers (contact washers)

1.2.1 RIPP LOCK® lock washers

RIPP LOCK® lock washers feature radial ribs on both sides. During fitting, the radial ribs are pressed into the mating face and the underside of the fastener head, forming a positive locking connection.

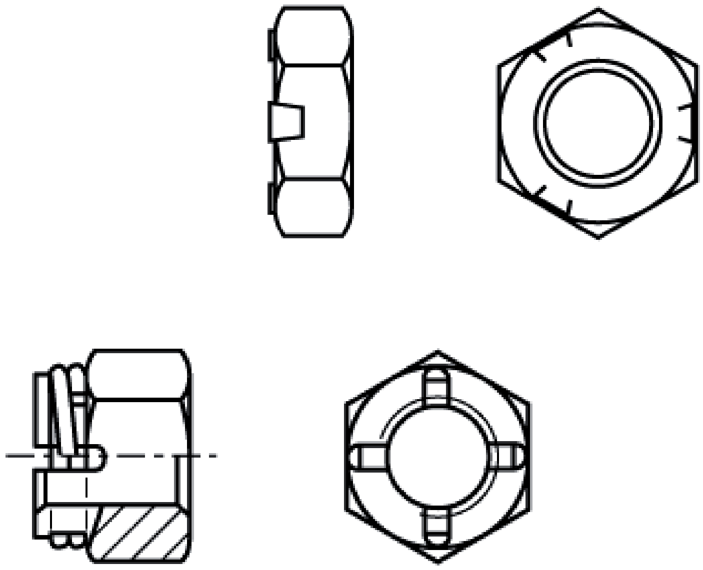
- Reliable and economical fastener retention for universal use
- Also suitable for use under extreme vibration and high dynamic loads
- Simple fitting and removal, multiple reuse

1.2.2 NORD-LOCK® lock washers

The NORD-LOCK® fastener locking system makes use of a difference in angle between the cam faces and the thread pitch to ensure effective locking of threaded connections in critical applications. This offers the following benefits:

- Maximum security for locking of threaded connections up to property class 12.9
- Prevents unscrewing under oscillatory and dynamic load
- Effective even with low preload forces

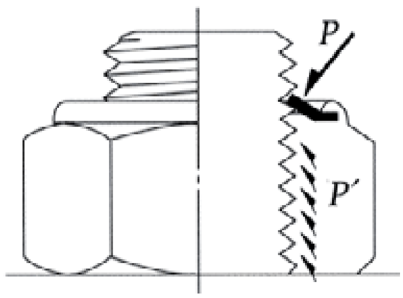
1.3.1 Prevailing torque type nuts, DIN EN ISO 2320



Self-locking nuts as defined by this standard incorporate an integral resistance piece that ensures the externally threaded part cannot move freely within the nut and that provides resistance against turning (prevailing torque) independently of the clamping or compressive forces. The design of the resistance insert is usually at the discretion of the manufacturer.

Different types:

- With non-metallic insert, ISO 10511, ISO 7040
- With metallic insert, e.g. B 53030 “Fujilok”, B 53040 “Vargal”
- All-metal type, e.g. ISO 7042
- Triple compressed, based on DIN 934, e.g. B 53001, B 53002



1.3.2 HELICOIL® *lock nuts*

HELICOIL® screwlock lock nuts combine the benefits of a high-strength nut with a HELICOIL® screwlock thread insert. In a HELICOIL® screwlock lock nut, the retaining effect is generated by the elastic action of the coiled wire of the HELICOIL® screwlock. These high-quality nuts provide enormous structural benefits.

Benefits:

- Heat resistant up to 600°C and above
- Anti-loss action even with frequent, repeated fastening
- Improved load distribution in thread for threaded connections subject to high dynamic loading
- Low, constant thread friction ensures high, uniform preload force
- Application-specific coating on HELICOIL® does not depend on coating used on nut

1.4 Self-tapping fasteners as an alternative to pre-tapped threads

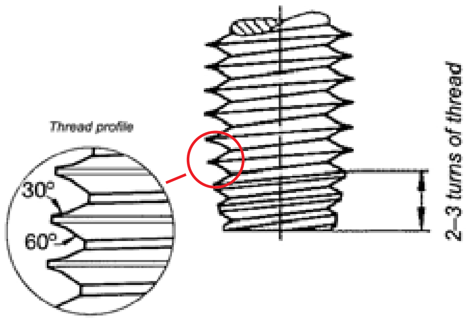
Metric ISO standard thread as per DIN 13 in pre-cut internal thread

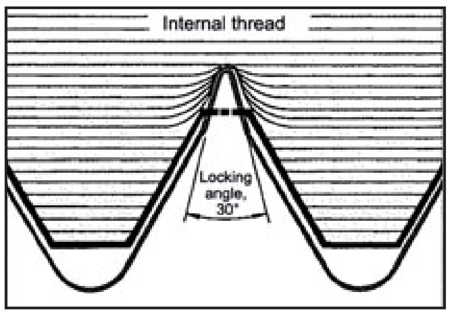
Thread forming fastener in self-tapped internal thread

Where a pre-cut internal thread is used, the flank clearance means that the fastener only makes contact with the internal thread on the load flank once tightened. This means that frictional properties of this type of connection offer less resistance to self-loosening than would be the case with a self-tapped connection, which ideally should have zero flank clearance. A proportion of the tightening torque applied when forming a self-tapped connection is spent in forming the thread. The optimum torque must therefore be established by means of testing.

1.5 Fasteners with mechanical self-locking thread

Threaded fasteners described as having an integral "thread brake" are self-locking fasteners with special threads. The fasteners are simply screwed into an existing metric ISO thread (tolerance zone 6H).
This category includes, for example, fasteners that have small additional flanks at 30° rolled onto the regular 60° flanks of thread, which protrude beyond the nominal diameter of the external thread.
These 30° tips are forced into the mating thread as the fastener is tightened, thereby creating a self-locking effect that helps the fastener remain firmly seated even when subjected to oscillation and vibration. The deformation of the internal thread is largely confined to the elastic region. This ensures that the locking effect is maintained for up to five repeated fastenings.

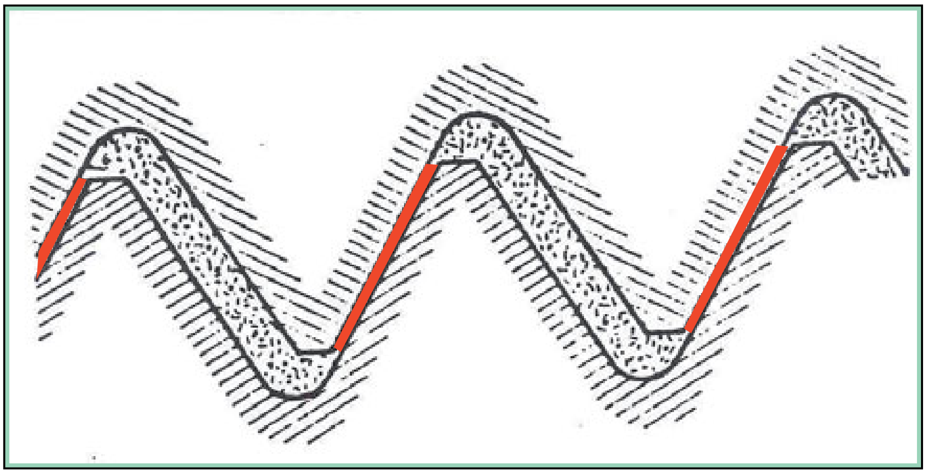




2. Chemical fastener retention

Chemical thread retention methods (adhesive - locking - sealing)

Chemical thread retention methods play a very important role in providing secure fastenings in the modern world. 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 it can be applied using a reproducible process before the fastener is supplied. This is also possible with bulk quantities.



2.1 Liquid anaerobic adhesives

The liquid adhesive is applied immediately before fitting the fastener. This is commonly done either by the fitter applying adhesive from a plastic bottle or, in standard production, by using an automatic metering and application system. The adhesive is characterised by having the property that it hardens on contact with metal and in the absence of air (anaerobically).

2.2 Description of pre-coating systems

Standard DIN 267 predefines the coating zone as 1.5 d measured from the thread end.
The first 2–3 turns of the thread should be kept free of coating material in order to make it easier to screw the fastener in. Also contained in the standard is a comparison of tightening torques with breakaway torques/clamping torques. This ensures that testing procedures are systematic.

a) DIN 267 Part 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 and hardener contained within the capsules. A chemical reaction (polymerisation) then occurs that hardens the adhesive (adhesive bonding), thereby producing the desired locking effect. Bonding the internally and externally threaded components in this manner is a reliable way to prevent self-unscrewing of the threaded connection. Apart from any loss of force due to the effects of setting, the connection retains the full preload force applied during fitting (unscrewing prevention). Depending on the product, the fitting process should be completed within five minutes (hardening). The time taken for the adhesive to become fully effective varies between 1 and 24 hours according to the type used.

b) DIN 267 Part 28, locking coating

Locking thread retention agent: this technique involves applying a polyamide to a section of the thread. A prevailing torque effect is produced when the fastener is screwed in.

Reason for thread precoating = built-in retention with existing components

Fasteners according to customer specifications

The axial clearance between the external and internal threads is filled in by the coating, which results in high surface pressure (positive locking) between the coated thread and the flanks of the uncoated mating thread. This creates the desired locking effect. Loss-prevention methods can not prevent partial unscrewing, but are certainly able to prevent the threaded connection falling apart completely. Multiple use is possible here, however the clamping forces are reduced with each fastening.

Benefits of chemical thread locking applied as precoating as per DIN 267 Parts 27/28:

- **Impossible to forget to fit the retainer**
- **Economical – time-consuming fitting of additional mechanical fasteners not required**
- **Good reliability compared to many other so-called "retainers" such as circlips, washers and wire retainers**
- **Does not damage surface of component**
- **No adhesive metering problems**
- **Activated at exactly the right time during tightening**
- **Possible to match fastener properties to the requirements of a specific application**

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 continuously around the fastener or nut and that any additional requirements have been defined.

Material	Effect		Coating
Polyamide, spot	Locking	1	Red, blue or green
Polyamide, all round	Locking, sealing	2	Red, blue or green
Polyamide, spot, heat res.	Locking (heat resistant)	3	Brown
Polyamide, all round, heat res.	Locking, sealing (heat resistant)	4	Brown
Precote 30	Med. strength adhesive, thread μ 0.10–0.15	5	Yellow
Precote 80	V. high strength adhesive, sealing, thread μ 0.25 0.28	6	Red
Precote 85	High strength adhesive, sealing, thread μ 0.10–0.15	7	Turquoise
Precote 85-8	Adhesive, sealing, thread μ 0.10–0.15	8	Turquoise
Scotch Grip 2353	High strength adhesive, sealing, thread μ 0.13–0.18	9	Blue
Scotch Grip 2510	High strength adhesive, sealing, thread μ 0.12–0.15	0	Orange

Looking ahead

Securing threaded connections will become an increasingly important issue in future because designers either do not or cannot always take full account of the full range of parameters affecting threaded connections. At the same time, product liability and safety requirements are becoming ever more stringent.
Thread retention systems that do not require an additional retainer component offer higher process security overall and will dominate this market. Particularly important in this respect are chemical thread retention methods, fasteners and nuts with locking teeth, self-tapping fasteners and, to a limited extent, self-locking nuts as defined by DIN EN ISO 2320.
Specialist retainers that provide additional beneficial properties for the connection beyond the retention effect (e.g. NORD-LOCK® washers, HELICOIL® screwlock) will increasingly be used.
Retainers that work by generating a positive fit (castle nut with split pin, etc.) and those for which the respective standards have been withdrawn (spring washers, toothed lock washers, etc.) should be avoided wherever possible.
Modern mechanical systems are often not standardised and/or are subject to patents, utility models and other protective rights.

ECOTECH –

ECOnomic TECHnical Engineering

We are pleased to offer the following services according to individual requirements:

- Assembly optimisation, including on-site work at the customer
- Standardisation and optimisation
- Information and consultancy
- Customer seminars

After defining the specific requirements of a project, our Application Engineering department works together with the customer to develop recommended solutions, and provides design support where 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

Böllhoff International with companies in:

Argentina
Austria
Brazil
Canada
China
Czech Republic
France
Germany
Hungary
India
Italy
Japan
Mexico
Poland
Romania
Russia
Slovakia
Spain
Turkey
United Kingdom
USA

Apart from these 21 countries, Böllhoff supports its international customers in other important industrial markets in close partnership with agents and dealers.

Important

We reserve the right to make technical modifications.
Reproduction in whole or in part without express permission is prohibited.
Protection notices for restricting the use of documents and products apply in accordance with DIN ISO 16016.

The information in this brochure draws on general technical regulations and on Böllhoff's own laboratory experiments and experience.
Our aim in presenting this information is to document a certain level of knowledge in a specialist subject.
Actual physical behaviour and results may vary between applications depending on the circumstances and conditions of each individual case.
It is the responsibility of the user to ensure the suitability of each individual component for each specific application as part of their design process.
Böllhoff accepts no responsibility whatsoever for damages that may occur.

Böllhoff Groupe
Please find your local contact on **www.boellhoff.com**
or contact us under **dlv@boellhoff.com**