Stop loosening of fasteners

By Michael Kaas, Bossard expert team

Everyone has experienced it – certain screws or nuts are loosening, but what is the cause? And how do you prevent it happening?

Here Michael Kass, Bossard expert team, looks at the function of a joint and how fastener threads interact. He analyses the stresses that can be introduced and lead to loosening, and which fastening solutions are available to minimise or prevent loosening.

Ref: FFT150520

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We have all experienced it. Screws or nuts are loosening – whether on a bicycle or on a pair of glasses. So what is the cause of this? And how do we prevent this?

To do so we need to know more about the function of the joint and how the fastener threads interact. We also need to analyse the stresses that are introduced to fully understand what causes the loosening. Only then can we determine the best solutions to minimise or prevent the loosening. During tightening, friction is introduced in the fastener thread and in the bearing areas. It's this friction that subsequently should prevent the tightened fasteners from loosening. So if friction should hold the joint together why is it still loosening?

The joint: In the perfect world the joint itself should withstand the dynamic forces and prevent loosening. The fasteners should be torqued to appropriate preload and bolted joints should only be stressed by tensile forces. Dynamic forces could provoke loosening. To keep the fasteners from loosening the design should prevent sliding of the assembled parts due to lateral workloads. For this, the clamp length is important. Fasteners where clamp lengths are less than 5 times the thread diameter don't necessarily react in an elastic way. They are very stiff and their vibration resistance is poor. If possible the joint design has to be modified to achieve a clamp length of 5 times the thread diameter (d). Such bolted joints react in a much more elastic way and their vibration resistance is improved. But in many applications that rule is hard to achieve.

External forces: To prevent loosening, the design engineer needs to determine the external forces. The external forces will determine if the joint friction is sustainable or if other precautions need to be taken. That can be divided into two categories – static and dynamic forces.

Dynamic forces: Dynamic force can be introduced in several ways – whether it's the equipment itself, Mother Nature or the surroundings. When introduced to dynamic forces, thread friction and bearing surface friction help to keep the joint tight. In the case of standard machine screw threads, there is friction on only one side of the threads, with a gap on the rear flank. If the forces are great enough, friction in the threads can drop dramatically leaving only the friction of the bearing area of the screw head or nut to keep the joint from loosening.

Static forces: If the joint design is only introduced to static forces, loosening is normally not an issue. But often the products are transported in ocean going cargo vessels that are exposed to constant vibration. The heavy diesel engine produces vibrations that are felt in the entire cargo hold of the ship. Fastened joints can thus become loose. Entire assemblies have fallen apart because the screws or nuts loosened, rotated loose, and eventually got lost.

Friction: Often defined as Coefficient of friction (CoF). The amount of friction introduced is dependent on the materials and coatings used. Some materials such as stainless and aluminium introduce a lot of friction, where steel typically has an additional finish that determines its friction coefficient. Often a friction modifier in coatings is used to control CoF, thereby minimising the scatter during tightening subsequently controlling the clamp load. This leaves us with a dilemma. Using friction modifier we can often insure reaching the right clamp load thereby reaching the fasteners maximum potential. But at the same time we lower the CoF thereby increasing the risk of the joint loosening during dynamic forces. When using the full potential of the fastener's clamp load, thereby introducing as much force on the thread flanks and bearing area as possible, the joint can withstand more dynamic forces. But in some cases, tightening against softer materials like plastics, aluminium, etc, this is not always obtainable. Therefore other means of securing against loosening is needed.

Head style

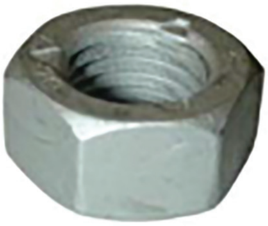
Flange/washer head: By introducing larger heads like flange head or washer heads we introduce more friction between the head and surface of the part. This will also lower the surface pressure on bearing areas thereby reducing the embedment, and creating more friction, helping to secure it more against dynamic forces.

Serrated/ribbed flange head: By introducing serrations/ribs in the bearing area of a flange head, a locking feature is introduced. During tightening, the serrations/ribs will dig into the mating surfaces leaving a high metallic locking effect. Damage to mating surfaces may be a concern with this type of locking feature, especially if painted.

If using serrations on a screw, you must also use serrations on the mating nut to ensure that you have high friction at all joint interfaces. Washers should also not be used with serrated hardware.

Nuts

As an alternative to serrations, which add friction at the bearing surface, thread locking features can be introduced in nuts. But often these nuts are used inappropriately which can lead to loosening. 'Prevailing torque nuts with metallic or non-metallic insert'. The title itself can be misleading as these nuts are often referred to as 'lock nuts'. By introducing the nylon ring or a metallic deformation of the thread, friction loss of joint is prevented. But nuts with a jamming element in the thread are not resistant to rotational loosening. The prevailing torque element never extends over the entire height of these nuts. The jamming effect is always only in a few thread pitches at the topside of the nut while the remaining nut thread is free running.

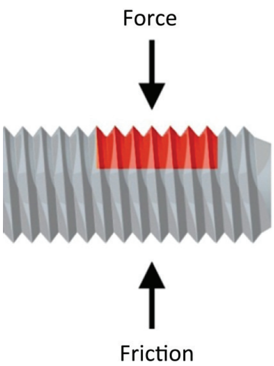


When dynamic forces are great enough to lessen the preload of the joint, the locking feature will prevent loss of the nut, but may not prevent the nut from rotating slightly and further losing preload which cannot be recovered without re-tightening. This can lead to shifting of joint members and eventual fatigue failure. Also when using prevailing torque nuts reusability needs to be taken into account, as the locking effect gradually will weaken with each re-use.

Thread locking features

Polymer patches: Non-metallic prevailing torque thread elements are made of polyamide. Polyamide is a thermoplastic resin that softens above 120°C. This is the range where the prevailing torque effect disappears. The prevailing torque thread element is normally a local polyamide coating patch that is blown on to a pre-determined, heated thread area as a fine powder.

The high temperature of the thread surface allows a layer of the powder to soften immediately and to stick to the screw thread. Finally there is a small soft polyamide patch on the screw thread that jams in the mating thread. An already loosened screw will not continue its vibration-induced self-rotation.

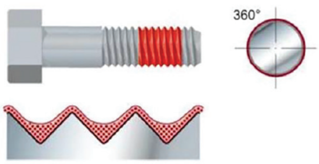


If the screw revolves when applying the coating, a 360° polyamide coating is formed. This does not only jam, but it simultaneously seals the thread – which is important in screws that are designed to seal containers. The polyamide coating can be directly applied to the area where it has to be effective, i.e. where the external/internal threads are engaged. The thickness of the coating is adjustable to a certain extent, and consequently its prevailing torque effect. In general, 2-3 thread pitches at the end of the thread are left free of coating. Thus, the screw can be started without a problem when turning it into the mating thread. The prevailing torque screw is often used as an adjusting screw.

Adhesive patches: The thread play between normal screws and nuts or internal threads can also be eliminated by using an 'adhesive patch'. During assembly these products fill in the intermediate spaces, harden, and prevent the thread flanks from sliding relative to each other.

Friction is maintained and the screws/nuts are vibration resistant. Full hardening can take up to 72 hours, but in most cases the part is already locked after a short period of time. Therefore adjusting the fasteners after assembly should be avoided as that can damage the locking effect.

For the same reason adhesive locking features can only be used once. If disassembly is necessary, the fasteners have to be discarded. As these adhesive patches are always applied 360° this will benefit as a sealing effect too.



Care should be taken as the 'adhesive strength' corresponds to the strength of the fasteners. If the patch's locked effect is 'very strong', it can result in broken hardware during disassembly.

Washers

Washers belong to the family of fasteners however don't have a direct fastening purpose. Wrong use of washers are made almost everywhere in the world, and often result in lowering the strength of the joint or increasing the risk of loosening in a dynamic joint.

Flat washers: For the objective in hand flat washers can (if chosen correctly) help reduce surface pressure on softer materials thereby minimising the loss of clamp load due to seatings. The bearing area of the washer is usually larger than the bearing area of a screw and/or nut.

The larger contact area diameter produces more frictional resistance. Thus, the bolt head will always rotate on the washer during tightening and not the washer on the clamped component. Subsequently it will protect the softer material and thereby reduce the risk of loosening due to dynamic forces. Depending on the selected fastener's property class the correct washer hardness needs to be selected. Choosing the wrong washer hardness can lead to higher risk of loosening as well if the material is too soft to support the head of the bolt without embedment.

Split lock washers: The general misunderstanding is that split lock washers are added to reduce risk of rotational loosening. In most cases that assumption is not correct.

The objective of a split lock washer is to reduce the loss of clamp load due to embedment. So if used correctly it will reduce the risk of loosening due to dynamic forces. But the strength of these types of washers is often overrated thereby resulting in much higher risk of loosening due to embedment and/or dynamic forces.

Split lock washers, as we know it, are strength wise only capable to withstand clamp forces introduced by fasteners up to property Class 5.8 (when using the fasteners full potential). When used with these fasteners split lock washers will reduce the loss of clamp load thereby reducing the risk of loosening due to dynamic forces. Also most split lock washer's edges will create a mechanical locking onto soft surfaces that will improve the locking effect.

It is important to understand that the effectiveness of split lock washers is very low or nonexistent when used with heat treated fasteners of 8.8 (Grade 5) and higher. The spring rate of the washer is too low, and the edge of the washer will not dig into the hard fastener surface. When used with higher grade fasteners, they actually create greater risk as the washer may spread and break under high loads.

Serrated lock washers: The name serrated lock washers is misleading. These washers only function is to promote electrical conductivity. These are often used on grounding applications such as for car batteries. The twisted teeth of the washer may appear to be a locking feature, but the reality is that the design of the washer often can't withstand pressure applied during assembly. This will result in a higher risk of embedment and subsequently a higher risk of loosening.

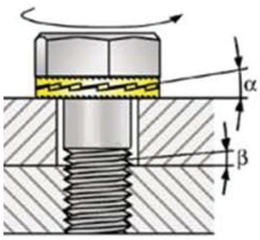
Even though the teeth should increase the friction in softer materials, most fastener's (properties Class 8.8 and above) surface hardness is too high to make this an effective metallic locking feature. In some cases, such as fasteners up to Class 6.8, some locking effect can be achieved as the surface pressure and clamp load is limited.

Ribbed lock washers: Ribbed lock washers are ridged at least on one side. Together with the friction in the thread, the friction in the bearing area prevents spontaneous rotational loosening of screws and/or nuts by considerably increasing friction between the bearing areas.

The ridges (teeth) are designed in such a way that they anchor themselves into the clamped parts as well as into the bolt or nut's bearing area thus resisting back-off. Like the conical spring washer and the split lock washer, ribbed lock washers are made to reduce the risk of embedment. As with flat washers, there are different types of ribbed lock washers, which based on their shapes have different functions. The ribbed spring lock washer has an outside diameter, which is about the same size as the bearing area diameter of the screw and/or nut. It is ribbed on both sides.

The ribbed spring lock washer type Rip-Lock® has a much larger outside diameter. It covers large clearance holes and oblong holes. The screw's head or the nut always lies on top of the ribbed side. The bottom side of this washer has no ridges. The large washer diameter produces enough friction on the clamped part to prevent the washer from turning.

Nord-Lock®: A special serrated locking washer is the Nord-Lock® washer. These always come as two washers paired together to provide the locking effect. The outer surfaces are ribbed and will bite into even the hardest materials, while the inner surfaces have precision ground ramps.



When a screw/nut is tightened, the ramps between the two lock washers remain closed and the two washers are in firm contact. If the screw is subjected to vibration and as a result tries to rotate loose, the upper washer will rotate and separate slightly from the lower one. Since, however the ramp angle (a) is larger than the thread helix angle (b), the rotational loosening of the screw is reliably prevented as the clamp load actually increases slightly during this rotation. Nord-Lock washers may be re-used many times and require slightly higher torque to achieve your required clamp load. Recommendations can be found in the Bossard catalogue.

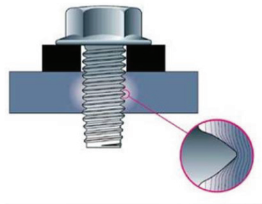
The original Nord-Lock washer doesn't prevent relaxation as the conical ribbed lock washers. But recently Nord-Lock presented a conical ribbed Nord-Lock washer that will beside the normal features also reduce the relaxations.

All mentioned ribbed lock washers:

- Have to be used both on bolt/nut side to secure locking.
- Can be used with hardened fasteners. But only the Nord-Lock washer can withstand/used with property Class 12.9.

Thread forming screws: By eliminating play in the threads, thread forming screws will not work loose under dynamic loads (vibration). Normally there is some allowance between the mating threads of screws and nuts. Thread forming screws, however, form their own mating internal thread when being driven into the work piece and do not have any thread play.

Even in the case of intense vibrations of the assembled parts, the thread flanks can't slide against each other. The existing thread friction is fully maintained, thereby eliminating additional locking devices. The vibration resistance is maintained even after disassembling and reassembling. Thread forming screws are always used without nuts either in blind hole assemblies or in through hole assemblies. Since thread forming screws are so vibration resistant they are used very successfully by design engineers in machines and equipment exposed to intense shaking and vibration.



Thread forming screws may be used in low carbon steel, light alloy metals and most plastics although different thread styles are used for each type of material. See the technical section of the Bossard catalogue for recommendations on hole size and thread engagement to ensure a good dynamic locking effect.

Summary

There's no one solution that will work in any joint design. The design engineer needs to calculate/estimate the possibility of loosening in the joint. Depending on factors like forces, materials, safety, design, reusability, and assembly, the design engineer needs to select the solution that fits the application. ■