Why Use a Locknut?

by Thomas Doppke

The action that holds a joint together is the preload on the attachment. As long as the preload is greater than the forces acting on the joint (service loads) the joint is tight and secure. If that preload is inadequate and/or if the forces acting on the joint become cyclic and/or exceed the preload, even momentarily, vibration will loosen the joint and the parts will come apart. Sounds simple but hidden facts change the philosophy. While standard nut will work when correctly tightened, the forces that actually impact the joint may not be fully known or known exactly. Also, the external circumstances that act upon the joint may be unforeseen, for instance, hitting a pothole at 100Kmh.

The use of a locknut in a joint has always been a "belt and suspenders" solution. An extra measure of security, an "overkill", whether needed or not. However, there are some instances where a locknut has real merit. Joints are held together by the compressive forces pulling the parts together and resisting any forces tending to pull them apart. But there are attachments in which there is a compressible member (mastic, wood, plastic, cloth, etc.) or where the assembly has a component that must rotate. These joints cannot be tightened down to generate the tension and stretch necessary for preload generation but still must retain attachment security. One case is where one of the components in the joint is fragile (brittle plastic, glass, etc.). Another is in low load joints with soft bolts such as on toys and minor appliances (used as a cost savings measure as hard ones are not needed) and requires security to hold the components together but cannot exceed the low tensile/yield strength of the fastener are ideal locations for some sort of locking element.

While a locking element can be put on an external threaded fastener its use is limited to specific case applications; situations where the internal member cannot be turned (welded nut or internal tapped hole) or where the bolt is in a fixed position (a stop bolt or where it is used as a limiting device). An example of this are the seat belt bolts in automotive vehicles.

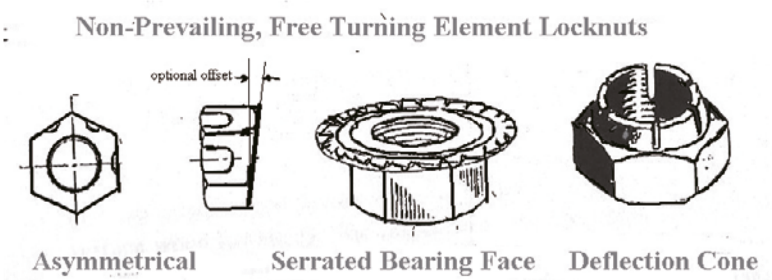
To obtain some resistance and locking ability on externally threaded parts the usual solution is to use a plastic element feature or a chemical (adhesive) application. Some thread modifications (tri-lobular, etc.) to increase prevailing torque are available but are costly, present some installation problems, and not readily available. Plant loss and misuse are also factors that make bolt locking elements less than desirable. Also, damage to the locking element because of its unprotected location (exterior) often renders them less than effective in applications. These answers have their own set of problems and concerns like the ones mentioned for nuts below.

First, a definition. The term "locking element feature" is often confused with the term "prevailing torque feature". A locking element is a feature that is designed to resist the free turning of the nut in its installed position. A prevailing torque feature prevents free turning in the uninstalled position as well. Most prevailing torque "locknuts" are locking element feature part but not all locking element nuts are prevailing torque resistant.

Let's look at what types are out there and how they work. Long ago the way to secure a joint was to use a castle nut and a lockwire, threaded through a hole and through the castellated slot. Cotter pins are still used this way occasionally. Disadvantages- hard to control torque as the slots must be aligned, regardless of the degree of tightness. The position may vary by as much as 1/6 turn (one nut face) when tightened to alignment of the holes. Also, the chances of a wire/pin being missed during assembly or falling out is always present. Lockwires are still on aircraft joints occasionally but mostly, I believe, to assure that the joint had been "looked" at.

Other devices still available but seldom used today are asymmetrical nuts. These are nuts which have either and/or off center holes or off balanced bodies. That is the body of the nut has material removed so that the nut, when tightened, eccentrically turns on. At the installation point this eccentric action wedges the nut tightly against the mating surface by the nut's attempted tilting against the mating surface and nut face. This nut is free spinning in the "on" direction until the tightening point. Also, it is free spinning "off" once the initial preload is removed. They are re-usable which is the only possible advantage that I can see. Often some additional material is removed (trimming side faces, etc.) to increase the wobble during tightening. A tried variation incorporates making the base of the nut off-perpendicular with the thread axis. The nut tightens erratically against the mating surface, generating a frictional locking action. Erratic torque and part handing confusion everywhere is common.

Another locking element nut has serrations (ridges, grooves, or formed edges) formed into the bearing face. These serration nuts are also free spinning on and lock due the action of the serrations imbedding into the mating surface. This surface must be softer than the nut to allow the embedment. The serrations must be placed so that they slid over the mating surface easily in the on direction but resist removal in the off direction. The part mars the work surface and will promote corrosion sites and cosmetic appearance issues. Again, a weak solution to locking with little advantage.



There has been some interest in a modification to the standard 60-degree thread form. The thread is angled differently on one flank (or is made with a bump or ramp-like projection at the crest). This allows the part to freely turn on but jams the threads when tightened. Another thread modification idea was to form a triangular hole in the nut blank and tap it with regular taps. When installed on a bolt they generate prevailing torque on the bolt along its length. They seat anywhere along the bolt thread length. The idea is like a "tri-lobular nut". Cost, mix-ups with standard parts and availability limit this idea, especially when compared with other solutions. Most available types of modified thread nuts are propriety and patented and require licenses for their manufacture.

The last, all metal locking element nut is the deflection or dilation nut. This nut, also free spinning on, looks like a standard nut with a coned top. The cone is slit in several places and when tightened locks onto the threads. The dilation of the nut at its base causes the thinner top section to bent inwards towards the threads and tightly jam into them. This type of nut has erratic torque characteristics and the strength of the product has been reduced by the removal of the metal for the slots. Height is also a concern in areas of limited access.

All these locking element parts have the same basic properties, both good and bad. As free spinning, they turn on easily and offer no problem with long rundowns where friction and dirt on the part would interfere with installation. They are subject to loosening if any action occurs which reduces the preload. A sharp blow would loosen the preload and the nut would begin to back off. They all are "one sided", that is, the locking element is on one side so they must be installed with the correct orientation (up-down). Being all metal they are suitable for high temperature service. Finally, the problems of handling, cost, inventory, mix-ups, and availability with today's profusion of finishes for various corrosion and cosmetic applications render any usage other than in special cases prohibitive.

The most common locknut used today is the all metal prevailing torque nut style. Made from a basic standard nut shape, the parts are crimped on an upper surface to produce an interference when the top threads come in contact with the mating external thread. The undeformed leading threads allow free starting to assist in installation. The style of crimping, the number of crimps and exact location are proprietary patents. While all perform in a similar manner (and all meet the same industry specification) the main difference appears to be the advertising. Available are parts with a side crimp (upper surface 180 degrees apart is usual), crimp on the top conical surface (2 or 3 locations with varying amounts of crimp), and a coned version which is squeezed at the upper area to deform that location). Since these types were orientation sensitive a "center punch" crimp was invented. This allows either side up installation, a useful factor in automated fastening. These PT nuts (prevailing torque nuts) are generally reusable. Although they are often re-installed and can function to a degree, most critical applications require a new nut be used for replacement. The torque decreases with each reuse, starting with the first off. Its primary advantage, besides its low cost, is its ability to maintain effective locking in high temperature situations. Since the prevailing feature is subject to opening up (loss of prevailing retention) with reuse and long rundowns, a general rule of thumb is that they should not be used on bolts (etc.). more than 2 ½ times the nut diameter. The advantage of using an all metal prevailing torque locknut is that even if the nut loosens slightly the prevailing feature prevents the complete removal of the nut and joint failure is averted, hopefully if the operator becomes aware of the increased vibrations, looseness, and/or other noise and conditions of a loose joint.

One solution to joints that will never have to be serviced is to run down a standard nut to the proper torque and then crush them onto the external member. Severe to be sure but it does show up occasionally!! Ouch!

One of the first designs to gain popularity was the nylon insert locknut. A plastic (nylon usually) ring was affixed onto the top of a nut. When installed onto a bolt, threads were formed in the plastic, generating a prevailing torque. The nut is reusable, does not adversely affect the bolt threads (jamming, scarfing, galling) and has a fairly constant although slightly decreasing torque over several reuses. Because of the installed ring and retention features, the nut height is taller than standard parts and is, of course, a "one side up" orientation part. The type has excellent vibration resistance. One drawback is the plastic. Nylon softens and melts at about 250 degrees F although new compounds with melt temperatures of about 400F are being used in some applications currently. Instead of frictionally grabbing the mating part like PT nuts, the nylon threads of the insert type formed during installation effectively dampen vibration and form a 100% contact with the bolt threads (no side to side vibrational wiggle. See below.)

As has been mentioned many times in many articles, the nemesis of tightness in a joint is vibration. Threads, contrary to popular belief, do not fit face to face. To enable mating to occur there is an interface, a slight clearance between the internal and external members. Installed threads are jammed against one side of the mating joint, hopefully tightly enough to prevent movement (loosening). Vibration produces movement in the loosening direction which reduces the jamming (preload) which again allows further loosening, and so on. Locking elements are designed to prevent this loosening by either increasing the amount of force resisting the loosening through friction on the mated threads or other surfaces. The nylon insert type mentioned above, works by filling in this interface with 100% nylon contact.

A quick summary of the advantages and disadvantages of locknuts and their use is tabled below.

	Asym-metrical	Serrated Face	Mod'd Thread	Deflec-tion	Top Crimp	Side Crimp	Top Cone	Crush	Nylon Insert	Nylon Patch	Glue Patch
Reuse	G	G	G-F	G-F	F	P	F	N/A	G	G	N/R
Heat Area	G	G	G	G	G	G	G	G	N/R	N/R	N/R
P.T.1st On	N	N	N	N	Y	Y	Y	N	Y	Y	N
Free Spinning	Y	Y	Y	Y	N	N	N	Y	N	N	Y
Breakaway	F	G	F	F	F	F	F	G	G-F	F	G
Long Run Downs	G	G	G	G	P	P	F	G	G-F	F	N/R
Height*	NC	NC	NC	H	F	F	H	NC	H	NC	NC
Limited Space Needed	P	F	NC	P	F	F	F	P	P	G	G
Up-Down Assembly	Y	Y	N/A	Y	Y	N	Y	Y	Y	N	N
Total Cost*	5	2	3	H+	1.3	1.3	1.5	4	3	2	2

G = GOOD F = FAIR P = POOR N/A NOT APPLICABLE N/R NOT RECOMMENDED
Y = YES N = NO H= HIGH L = LOW F = FAIR NC = NO CHANGE
* = AS COMPARED TO A STANDARD NUT WITHOUT THE FEATURE AS 1. (Includes tooling, labor, etc).

Is there any other way to make a locking nut? How about we address the thread interface vibrational loosing phenomenon? Non-metallic locknuts are solutions to specific problems. There are two basic types- a plastic insert/patch and an adhesive. Early bolts were manufactured with a nylon pellet, later a strip, which was pressed into a formed hole/slot (early seat belt bolts come to mind). The problem was that these often fell out or were damaged in various ways. The obvious solution was to put the nylon feature inside the nut, safe from harm. The nylon ring insert nut was very costly, and the height required additional bolt length and clearance at backside of the joint. The pellet/strip type was manufactured from standard parts. They ae reusable, chemically inert to many compounds routinely encountered in service, and do not require installation orientation. The parts worked by pushing the nut threads against the opposite (from the nylon feature) against the mating threads with a firm pressure from the nylon which acted like a mini shock absorber.

In later cost reduction designs the pellet/strip feature was replaced with a plastic sprayed on to the threads. Partial to full 360-degree spray patches allowed varying degrees of torque to be generated. Nylon patch locknuts have a relatively high torque first time on with a lower breakaway and prevailing torque off. The torque decreases with each subsequent reuse. It is also heat sensitive although newer types are using plastics which exceed nylon's 250-degree softening point.

The fault of nylon patch nuts was the fact that they had high torques and, especially, breakaway torques were too low for many designs. Many joints required that the attachment be very secure but could not be twisted severely with an all metal nut. Small and soft bolts, little items such as jewelry, non-serviceable components whose life did not need adjustment and replacement require one time installation fastening. Adhesives work by filling in the thread interfaces with a compound that hardens, preventing the space from vibrational movement.

Adhesives are best handled as a pre-applied material. While they may be applied “on-line”, the process is messy to operators and surrounding surfaces. The compounds today can be doctored to meet the application’s conditions of breakaway, holding, cure time, and so forth. Many compounds cure in minutes and some are not hardened for as much as 24 hours (a condition that makes them unusable on fast assembly lines). They have low torques but exhibit very high breakaway torques after fully cured. However, once broken free they have little prevailing torque. A major plant problem is the fact that adhesives cannot be quality control checked for proper torque as they harden slowly and checking later breaks the adhesive bond of the joint. Summation of the good and bad about these locking elements is tabled below:

	Plastic Patch	Adhesive Patch
Installation Torque	No	Low
Breakloose Torque	Low	High
Resist Vibration	Good	Poor
Reuseable	Yes	No
Inspectionable	Yes	No
Heat Area Usable (250F+)	No	Yes (some)
Time to Partial Cure	N/A	1-4 minutes
Time to Full Cure		24-72 hours

Why use a locknut? The answer seems to be that the extra measure of security is worth the extra cost. The forces that a product sees in service are unknown and unexpected despite the best guess and testing of engineering. The costs of repair, replacement and legal complications outweigh any immediate monetary advantages. Th overall impact of adding a locking feature can be lessened with the selection of the right type to fit the application.

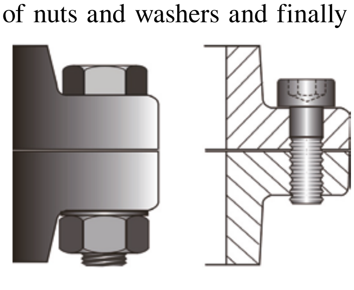
The Steels for Screws and Nuts Production and Their Heat Treatment

by *Jozef Dominik*

Introduction

Steels and their heat treatment determine decisively the final mechanical, physical and chemical characteristics of bolted joints such as their hardness, strength, tenacity, weldability and resistance to corrosion, etc. In the past, the strength of constructions was realised by their increased dimension. Thanks to the development of new alloy structures, the strengths from 800 to 1200 MPa are nowadays commonly reached by heat treatment. The advantages of the application of the screws at higher strength follow from Fig. 1. From this figure, it is clear that the replacement of the unhardened hexagonal screw DIN 931 at the strength 5.6 for the screw of DIN 912 in strength class 10.9 enables to reduce its size from M18 to M10. Logically, the size of the flange is smaller, with the saving of nuts and washers and finally the simplification of the assembly and logistics.

Fig. 1



1. Heat Treatment Procedure

There are various kinds of heat treatment. The most important operation is hardening, i.e. quenching and tempering to a certain temperature (Fig. 2).

The principle lies in the heating of steel parts at hardening temperature ca 870°C (1600°F) in continuous furnaces with the protective atmosphere with sequential immediate cooling down in oil bath and tempering at ca 370°C (700°F) for two hours. During this process the phase shift $\gamma \rightarrow \alpha$ occurs

Fig. 2