"Staying Put"- About Keeping a Threaded Fastener In-Place

by Laurence Claus

About twenty years ago I was travelling quite often between the United States and Europe. To make sure that my luggage arrived in one piece I purchased a medium sized, hard-sided suitcase. As I unpacked the suitcase at the conclusion of every trip I would find a loose screw or two rolling around the bottom of the suitcase. To be honest, I never could figure out exactly where these screws were coming from or how so many could come loose without the suitcase falling apart, but they clearly had loosened up from the suitcase and come out during travel. I began to worry that I was only one trip away from a major catastrophe with my bag, so that today I use a different suitcase when I travel internationally.

This story illustrates a fundamental understanding about fasteners. When we purchase a product that incorporates threaded fasteners in the design, our expectation is that the fasteners holding the products together will remain intact and keep the item operating without problems. In fact, history is littered with daily occurrences of fasteners that have come loose, resulting in failure of the product or system they were tasked to hold together. Most of the time such failures represent only a nuisance to the owner or operator (such as the case with my suitcase). However, sometimes the system is a critical one and the failure of the fastened joint leads to a catastrophic and tragic outcome.

As we delve into this topic of how to keep a threaded fastener in-place, let's first refresh our understanding of a fastened joint. In all cases, whether a screw fastened into a plastic boss or a critically loaded bolted joint, the fastener is intended to generate a clamp load which holds the joint together. It is important to remember that simple loosening of the joint, which results in partial or complete loss of the clamp load, constitutes failure. In other words, when considering the subject of fastener loosening, failure occurs long before the screw or bolt actually backs out or is lost.

Therefore, the number one defense against loosening is to get the joint designed and engineered correctly, and to properly install the fastener to these parameters. Unfortunately, far too often, proper parameters are not met either during initial installation or during later servicing. The consequence on these joints is that clamp load is lost and failure is initiated.

In many cases, failure is easily discernable. Take for example an automobile, when a joint comes loose inside the interior the operator hears an annoying squeak or rattle. In fact, a number of years ago, one of the large OEM automakers acknowledged that their number one warranty issue was squeaks and rattles related to loose fastener joints. They spent millions of dollars a year addressing failed fastened joints. In another example, products that depend on a fastener to hold a sealed joint together will leak spilling fluid or lubricant where it does not belong and loose fasteners on moving components result in vibrations felt by the machine operator.

It is important to recognize the difference between joint failure and loosening of the fastener. If a screw begins to back out or completely falls out, it is because either the fastener has first lost sufficient preload or the joint has first lost sufficient clamping load to no longer be able to withstand the forces acting in service. Failure occurs as soon as the joint falls into this category and the loss of the fastener is an after event. Although failure may technically occur as soon as the preload is lost, in many cases, it is very important to not compound the problem and have the fastener actually come loose and fall out. Many systems can continue to function as long as the fastener remains intact. Falling out or coming completely loose, however, becomes the catalyst for catastrophic failure.

For this reason, many designers will incorporate a feature to keep the fastener in-place. Although these devices rarely prevent the loss of preload, they do prevent the loss of the fastener from the joint.

There are essentially two different strategies that are employed. One is to lock the part in-place with a mechanism such as a pin, wire, or adhesive. The other method is to create some "interference" between the mating threads so that "prevailing torque" (or the torque that remains between threads) is generated and resists loosening.

Whether the "locking" feature is employed on the nut, bolt/screw, or a combination of the two, one of these strategies presides. The remainder of this article will look at common solutions utilized in each of these three cases.

Nuts

Side Deflection, Prevailing Torque Type

This is a mechanical form of creating the prevailing torque feature in a nut. After the nut is formed and tapped, it undergoes a deflection process where a pin or series of pins is pushed into the side of the nut. The result is a localized deflection which results in a "bump-out" or ovalization of the nut in the center (see Figure 1). Of all the prevailing torque nut varieties, this design usually provides the least consistent results. A number of variables come into play, but ultimately small differences in the amount of deflection will result in a wide dispersion of prevailing torque performance.

Figure 1

Top Deflection, Prevailing Torque Type

This is another mechanical style of creating prevailing torque in a nut. Unlike the side deflection, however, the top is deflected in two or three places, creating an oval shaped thread at the top. As soon as the mating thread on the external fastener contacts this area, it encounters interference and generates prevailing torque. The consistency of this style tends to be an improvement over the side locking style, but there are still many variables in play so that these designs are still less consistent than some others.

Plastic Ring Insert, Prevailing Torque Type

This style of nut incorporates a plastic ring which is inserted into a channel formed into the nut (see Figure 2). The top of this channel is then crimped over, retaining the ring in the nut. These generally provide the best performance consistency because the properties and size of the plastic ring can be precisely controlled.

Figure 2

Pre-applied Adhesive Type

Although less commonly used on internal threads, a pre-applied adhesive is an option. In this case, anaerobic adhesive substances get applied into the threads. These adhesive are two part systems where small micro capsules of one adhesive component are intermixed with the second binder component. When the joint is tightened, the contact between mating threads of the external fastener will break these beads putting into motion a chemical reaction that cements the adhesive material to the threads of the nut and bolt.

Screws and Bolts

Mechanical Deflection

Like nuts, externally threaded fasteners can also have locking features that are applied during the manufacturing process and result in a mechanical locking mechanism. These designs normally include some form of "off pitch" feature integrated into the external thread (see Figure 3). Because a pitch mismatch exists between the male and female threads in localized threaded areas, minor to significant interference exists and prevailing torque is generated.


Figure 3

Often these areas of interference are localized to small sections of the external thread. This means that the roll dies are modified in small sections, often by adding a small insert to the roll die, which protrudes into a thread groove or two and deflects a section of the resulting thread. Although simple in concept, the actual results are often very inconsistent. For the external locking variants this variability makes mechanical locking mechanisms normally the least consistent of all the options.

Patches

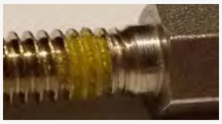
Figure 4

Another "mechanical" locking mechanism is a plastic patch. Patches consist of spraying a small spritz of powderized thermoplastic onto a heated fastener. The thermoplastic powder melts when it strikes the heated surface of the fastener resulting in a localized accumulation of plastic on one side of the threaded area of the fastener (see Figure 4). This "patch" performs two separate functions. First the accumulation of plastic in the threads creates some interference between mating threads, which provides prevailing torque. Secondly, and perhaps more importantly, the plastic in the threads fills up the natural clearance void between the external and internal threads. Since the patch is only on one side, this causes the threads to "tilt", generating a wedge-like clamping action on the side opposite the patch. This results in increased thread friction and because it is a continuous force, the generation of prevailing torque.

Pre-Applied Adhesives

Similar but slightly different in appearance to a patch are thread adhesives. While patches are only on one side of the thread and result in a mechanical locking mechanism, adhesives are applied completely around the entire periphery and utilize a chemical locking mechanism (see Figure 5). Like patches, however, they may only extend over a limited number of thread pitches. An adhesive is very different from a patch, as it uses a chemical bond to lock it into place. Essentially, most of these types of locking mechanisms rely on being anaerobic in nature. This means they do not require oxygen to fuel the chemical reactions required to cure them.


Figure 5

The principle in how they work is pretty simple. They are normally a two part system, like an epoxy. The predominant component is the one you see on the part and is a colored binder. Impregnated in that binder are many little microspheres of the second component. When the external fastener is driven into the internal one, the fit between the two threads results in many of the microspheres being crushed, releasing their encapsulated chemical to react with that in the binder. Chemical reactions take place and over some determined amount of time, the joint cures and cements the externally threaded part into place.

The "bond" created by the adhesive is a function of its service level. In other words, there are adhesive systems that provide a very minor bond and can be easily disassembled and there are those that provide a very secure bond that can only be broken by adding heat to the joint.

For users who decide to employ this method, most applications have a variety of different colors which distinguish the level of bond they will receive. Additionally, these types of adhesives can be applied during assembly from a bottle or tube. Preapplying them onto the fastener eliminates a great deal of operation time, variability, and mess. Therefore, preapplied versions are normally significantly advantageous to application during assembly.

Plastic Insert

An effective, but rarely used, method of mechanical locking on external threads are plastic inserts. These can be small, round inserts which fit into predrilled holes or rectangular inserts that fit into grooves (see Figure 6). Conceptually, this mechanism is identical to inserts placed in locknuts. These are generally very predictable in behavior and can be tailored to different user needs. They are utilized more infrequently than patches and adhesives because of the higher process costs required for installation.


Figure 6

Other Locking Mechanisms and Combination Mechanisms

Cotter Pin

In a combination mechanism a slotted nut, screw with a hole drilled through the threaded shank, and a cotter pin are used. In this method, the nut is tightened until the drilled hole in the threaded shank is exposed between tab openings in the slotted nut. A cotter pin is then inserted and bent around the tabs to prevent any unintended disassembly.

Lock Wires

Lock wires can be employed in a number of different ways. They can be employed in a similar fashion to the cotter pin assembly described immediately above. More commonly, however, lock wires are inserted into holes drilled through the heads of external fasteners, twisted, and set. In the same way that a cotter pin assembly will prevent any unintended disassembly, so will lock wires.

Serrations and Opposing Wedges

Figure 7


Head serrations located on both the bearing surface of screws and nuts are intended to prevent the fastener from turning backwards (see Figure 7). This method generally tears up the surface it is bearing against, which may be problematic for applications against painted surfaces or where the customer might see them. The serrations are wedge shaped and once embedded into the clamped material will resist the fastener turning backwards. In a more sophisticated embodiment of this principle are fastener systems with two opposing wedge-like features, which, when engaged result in a ratchet-like mechanism that opposes rotation in the opposite direction. These systems tend to be quite effective and in some instances are able to retain clamping load.

Lock Washers

Split lock washers and external tooth lock washers have long been employed as a way of preventing loosening. External tooth lock washers act like serrated heads, by digging into the clamped material and resisting backward rotation (see Figure 8). Split lock washers have long been debated as to whether they are an effective means of locking or not. Some experts contend they provide locking ability while others contend they are a complete waste. Regardless of which side of the debate one might land on, likely there are other options that will perform better or more reliably.


Figure 8

Conclusion

There are many different methods that can be employed to lock a fastener in-place. Designers should understand their needs so that they may choose the method that most closely meets all of their design needs. It is important to remember, however, that employing a locking feature may guarantee that a fastener remains intact, but in most cases, it does not guarantee that the joint retains its clamp load. Therefore, astute fastener engineers will do their best to understand all the parameters of the joint and design the right installation parameters in addition to any extra insurance afforded by the locking feature. ■