Locking Fasteners Part 2

by Guy Avellon

The previous article discussed two types of methods to achieve a locking effect on a fastener; the use of nylon inserts and chemicals. Both methods are uniquely different, but then again, we have so many variables within our applications that we need a variety to help keep the parts together.

In Part 2, we will discuss the advantages and concerns of all-metal prevailing torque type lock nuts and the proper use and application for Belleville washers.

All-Metal Prevailing-Torque (PT) Nuts

A prevailing-torque type nut is not completely free spinning. It will allow the first few threads to become engaged, then it will encounter resistance which will then require the use of a wrench and exertion of torque energy to complete the assembly.

There are many different designs with variations among each. Earlier locking nuts featured a slotted, castle like top that was deflected inwards to produce drag interference against the threads of the bolt. Other designs incorporated springs on the top of the nut or metal inserts into the nut. The more common and popular designs incorporate some type of thread deflection or deformation of the nut.

Figure 1 is a variation of the first type of P-T nut, called a Stover lock nut, where two sides of the nut were crimped inwards towards the top, to provide thread deformation and thread interference for the locking effect. This method produces a distinct elongated oval exit.

Figure 1 depicts a metric Class 10 flange lock nut. Prevailing-Torque nuts that are inch series are designated as Grades A, B and C for matching the fastener strength grades of SAE 2, 5 and 8, respectively. The Grades F and G are to designate flange nuts for grades 5 and 8, respectively.

The Stover style of crimping the nut on two sides includes placing the crimp in the center of the nut, so it does not matter how the nut is oriented for assembly and crimped near the top, as shown in ***Figure 2.***


Fig 1


Fig 2

The drawback with a two-point deformation is its reusability. Major interference and galling can occur if the coating or plating on either or both the nut and bolt have thicknesses at or exceeding their tolerances.

The all-metal P-T nut in ***Figure 3*** illustrates the three-point top thread deflection. There are also P-T nuts with two-point top thread deflections as well. By deflecting the top few threads inwards and slightly downwards, the interference is more on the non-pressured thread flanks than the contact side. Thread distortion and galling of the male threads is minimal.

Here is where coatings are extremely important. The IFI (Industrial Fasteners Institute) 100/107 specifies requirements for reusing the P-T nuts up to five times. The only way to accomplish this without galling is to have the nuts plated with cadmium, then dip them in a wax coating. Depending upon the wax, the reduction in assembly torque was between 40-50%.

Since RoHS (Restriction of Hazardous Substances Directive), cadmium has been banned from commerce. Typically, to identify cadmium plating, parts were also treated in a hexavalent chromium conversion coating prior to the wax immersion, which gave the products an iridescent yellow/gold color. Hexavalent chromium has also been banned. However, there is still residual stock on shelves of the cadmium plated product.

The current market substitute is zinc plating. Zinc has always had a clear chromate post treatment for visual identification, but some producers may use the trivalent chromium for identification purposes, due to its yellow/gold color.

If the P-T nuts are not coated with a lubricating wax, there may be chances for thread galling; if not when threading on, then during removal. Non-coated nuts will not be temperature limited. Cadmium plated nuts had the tendency to crack at temperatures over 450° (232° C) from liquid metal embrittlement. The zinc plated nuts will withstand higher temperatures, but be aware, the wax will melt and will not be effective.

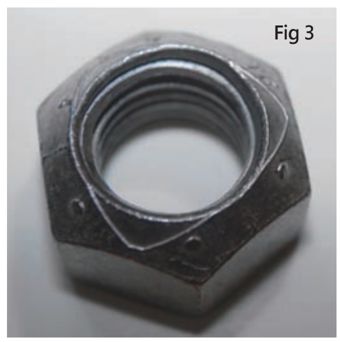


Fig 3

These P-T nuts may not be suitable for mass assembly with power tools, especially for long runs, which may cause heating and galling from friction as well as melting the wax. In this case, the nylon nuts are more suitable. Power tools will have high RPM speeds and with the low coefficient of friction provided from the wax coating, there is little friction to stop the nut from rotating after it contacts the joint surface. The result will be overtightening the bolt into yield with UNC threads, or stripping SAE threads.

Prevailing-torque nuts will definitely stay on if the joint loses clamp load. However, joints that relax from severe shock or temperature changes may promote metal fatigue of the fastener, which brings us to another device: the Belleville washer.

Belleville Washers

The Belleville washer is a spring washer. Its existence is often forgotten, except in some industries, but it is very advantageous when multiple factors are involved; such as with thermal expansion, softer materials, dissimilar metals, gasketed joints and with multiple bolts. Depending on materials and strength, they may be used in critical and non-critical applications.

Producing a tight connection is difficult enough when the main objective is to keep everything tight. From prior discussions, we know that a fastener will lose between 10-15% of its initial preload just from normal relaxation soon after it is tightened. In a multiple bolting connection, adjacent fasteners can lose over 50% on solid joints and over 75% with a gasketed connection due to an elastic interaction between the fasteners, even if criss-cross torqueing is used.

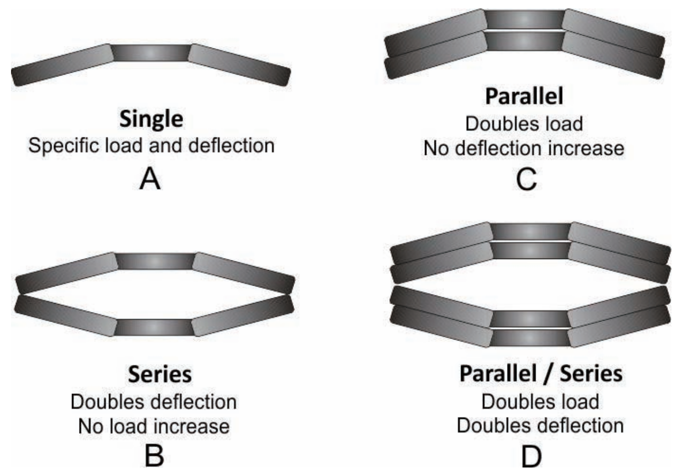
A solid joint surface can be fully tightened by employing the criss-cross method with incremental torque increases to allow for the joint relaxation to settle. Gaskets are never fully compressed. When the flange around the gasket heats, the flange expands slightly and compresses the gasket a little more. When the parts cool, the gasket may not regain its prior thickness which will lead to leaking problems when under pressure.

Thermal expansion and contraction in joints are a problem with many applications; steam generators, hot fluids or gases through pipes and flanges, electrical connections and bus bars, etc. Not only do the conveyances of the heat expand and contract, so do the fasteners from creep: all at different rates of expansion and contraction.

Ferrous fasteners expand and contract much slower than the common heat conductors of copper and aluminum. Therefore, embedment is likely to occur, followed by joint relaxation and a loose connection. Then, there is the galvanic reaction between steel and aluminum that must be avoided, which will require fasteners made of silicon bronze, nickel alloys, stainless, or other expensive non-ferrous material. Most of these non-ferrous materials are not supplied in the form of a locking nut unless they are specially made.

The Belleville spring washer is available in a multitude of materials; from 1075, 6150 and H-13 steels, 301 and 17-7PH stainless and X-750 and 718 Inconel, as well as other materials. The material choices are available for compatibility with the application requirements, operating temperatures and environment.

Why use a spring washer? Because of its conical shape, it is capable of producing high loads that are consistent during periods of joint relaxation that keep the joint together.



One of the unique properties of these spring washers is their ability to produce different loads and / or deflection by how they are arranged; single, series, parallel or stacked.

As an example; let us examine one spring washer (A) with a flat load of 500 pounds producing a deflection of 0.020”. Two of the same spring washers stacked in series (B) would also have a flat load of 500 pounds, but would have a deflection of 0.040”. Therefore, if the thermal expansion was significant, the greater deflection rate would compensate and keep the load constant on the joint.

Stacking two spring washers in parallel (C) would increase the flat rate load to 1,000 pounds but maintain a smaller deflection rate of 0.020”.

Stacking four Belleville spring washers together in parallel and series would produce the same 1,000 pound flat load and increase the deflection to 0.040”.

When tightened, the spring washers should become flat. This will not damage the spring properties of the washer. Typically, the spring washer is installed under the nut with the ID against the nut’s bearing surface. It can also be installed under the bolt head or both, if required. If the materials are relatively soft or thin, a flat washer may be used against the joint surface, allowing the edge of the spring washer to slide against it, rather than gouge the soft joint surface.