DR. FASTENER-
SELF-LOOSENING AND PREVENTION MEASURES

WHAT IS SELF-LOOSENING?

A: From time-to-time users may discover that they have a screw or bolt that has loosened up and maybe even fallen entirely out. Most likely, this has occurred because the screws were subjected to transverse vibration and loosened up on their own. Not all experts agree on the exact mechanism that causes fasteners to do this, but everyone does agree that a fastener will not loosen unless the frictional forces between the external and internal threads are either very low or nonexistent. When the frictional forces which "bind" the external fastener with the internally threaded member are very low or nonexistent, the application of external cyclic forces, like vibrational forces, can cause the fastener to slip and loosen. In extreme cases the fastener may actually completely fall out.

UNDER WHAT KIND OF CONDITIONS ARE FASTENERS SUBJECT TO SELF-LOOSENING?

A: **The most common loading situation that results in self-loosening is from vibration, specifically transverse vibration.** Transverse vibration is where the cyclic loads are applied perpendicular to the part axis as opposed to axial vibration that is applied along the part axis. Although axial vibration may reduce clamp load by 30% to 40%, transverse vibration often causes the clamp load to go all the way to zero. Thus, transverse vibration is a much more severe loading condition than axial vibration and much more prone to result in self-loosening. In joints where the vibration may be applied in a combination of axial and transverse directions, the resulting impact on the clamp load may be to decrease it, increase it, or have no change at all. In addition to vibration, any type of cyclic loading can result in self-loosening. Other cyclic loads result from thermal cycling, flexing, and bending.

IS THERE A TEST THAT CAN PREDICT HOW WELL A JOINT WILL WITHSTAND SELF-LOOSENING?

A: The answer is yes but provided with a cautionary note. There are testing apparatuses that can apply vibration to a part while measuring the effect on clamp load. The most famous and probably common test is a Junkers test. A Junkers test apparatus applies a transverse load to the test joint. This is a very severe test and most systems that don't have exceptional "locking ability" exhibit almost immediate and sharp losses of clamp load, many losing their entire clamp load in a matter of seconds. Another test is known as the ALMA test which cycles the test joint/fastener up and down in a channel on the test apparatus. One must be careful about results though. Because there are so many factors that come into play, a test joint that does not simulate the exact joint conditions may perform very differently than the actual joint.

WHAT STRATEGIES CAN BE EMPLOYED TO RESIST SELF-LOOSENING?

A: Two criteria are necessary for self-loosening. First, the joint must be exposed to transverse cyclic loading and secondly, there must be slip between mating thread surfaces or bearing contact surfaces. To resist self-loosening, therefore, we must employ a solution that decouples or eliminates one or both factors. Therefore, **the four most common strategies employed to resist vibration and self-loosening are... >>>>>>>>>>**

1. Preserve a high enough preload to exceed any force which is trying to loosen the nut.
2. Provide some sort of mechanism to prevent slip between the mating threads or the bearing contact surfaces.
3. Reduce the thread helix angle.
4. Provide prevailing torque or locking action that counters the tendency for loosening after the friction forces have been "overwhelmed"by vibration.

WHAT IS PREVAILING TORQUE?

A: Prevailing Torque is the resistance of the fastener to turning before any clamp load is generated. A common trait of many prevailing torque fasteners is that they have some sort of deflection or added element that generates friction between either the thread or the bearing contact areas.

IS THERE ANYTHING "TRICKY" ABOUT UTILIZING PREVAILING TORQUE TO RESIST VIBRATION?

A: Yes, many of the prevailing torque fasteners rely on a deflection, protrusion, or wedge-type action to increase friction. The problem is that some of these designs can exhibit significant variation in the generated prevailing torque values. If the prevailing torque is too high, it can lead to excessive installation torque exhausting the assembler, causing torsional failure, or increasing the likelihood of galling. On the other hand, if the feature does not generate a lot of prevailing torque it may fail to accomplish its mission and supply insufficient "locking" action. To make sure that the prevailing torque is neither too high or too low and exists after the first installation and removal cycle, parts are tested against a performance standard. The most common prevailing torque performance standards are from the Industrial Fasteners Institute, IFI 100, IFI 107, IFI 124 and IFI 155. These test procedures will look at both the first and third on and off torque cycle.

WHAT IS THE MOST ECONOMICAL WAY OF COMBATING SELF-LOOSENING?

A: The simplest and most economical way to resist vibration is to develop and retain sufficient preload. Remember that that the relationship between preload and failure is first order and critical for success. Explained a slightly different way, if the preload is greater than the loads being exerted against the system, nothing should happen to the joint.

CAN YOU PROVIDE EXAMPLES OF PREVAILING TORQUE FASTENERS?

A: Prevailing torque fasteners are probably the most commonly employed of the "locking" fasteners and systems. They come in both internal and externally threaded versions. On the externally threaded side they fall into all metal, nylon patch, and plastic insert varieties. The all-metal versions usually rely on some sort of thread deflection or feature that causes interference with the normal internal thread. A patched fastener is one where a bead of Nylon has been applied to just one side of the externally threaded fastener. When it is installed, this section wedges the other side of the fastener into the internal threads resulting in increased frictional contact and increased prevailing torque. A round plastic insert or plastic strip effectively does the same thing. For internally threaded nuts there are also essentially three main types, side, top, and insert locking nuts. In the Side Locking variety, a pin is pushed into one or more of the hex flats. This indented punch effectively creates a protrusion inside the threaded section of the nut which generates interference and increased fiction when assembled onto an externally threaded fastener. A Top Locking Nut has either two or three indentations at the top which effectively deflect the top threads or ovalize the nut at the top. Both conditions have the effect of creating interference and friction when mated with the externally threaded fastener. Finally, Nylon Insert Lock Nuts have a round Nylon ring whose ID is smaller than the externally threaded fastener OD inserted into the top of the nut. When the two components are assembled, the smaller diameter ring creates interference and friction with the externally threaded fastener, generating prevailing torque.

IS THERE A DIFFERENCE BETWEEN A PATCHED PART AND ONE WITH PRE-APPLIED ADHESIVE?

A: Yes, a patched part generates friction through mechanical wedging action of the imbalance of having the patch on one side of the thread. Adhesives are applied 360 degrees around the external thread and rely on chemical action to bond or cement the fastener in-place. Whereas a patched part is expected to perform over several assembly and disassembly cycles, an adhesive is usually designed for a single application. Different strengths of chemical bonds exist so that fasteners can be designed to provide only moderate adhesion, so that they can be easily disassembled or very strong bonds that are nearly impossible to break without damaging the fastener or joint.

ARE THERE LOCKING SYSTEMS THAT WILL GUARANTEE A FASTENER CAN NOT COMPLETELY DISASSEMBLE AND BE LOST?

A: Within reason, yes. There are instances where losing clamp load is bad but losing the fastener is catastrophic. An example might be the fasteners used to hold a suspension link together. Losing clamp load may cause the link to be loose and cause vibration in the system, but if the link comes apart because the fastener falls out, a driver could lose complete control of the vehicle resulting in a car crash. To address these sorts of situations there are three methods that are commonly utilized; 1. Locking wires- where wires are inserted through holes in the head and braided to prevent the fastener from moving or being lost if it should break. 2. Cotter Pin and Slotted Nut- where a hole is drilled through the external threaded component, a slotted nut is installed, and the cotter pin is inserted through the hole and the protruding end wrapped around the lugs of the slotted nut. 3. Tab Washers- special washers that have folding tabs or hex cut outs that are intended to keep the nut from rotating or the system from coming apart.

DO HELICAL SPRING LOCK WASHERS WORK?

A: If you put ten experts in a room and asked this question you are bound to get about seven or eight that answer no and two or three that answer yes. This author is in the camp that they do not provide enough benefit to justify the cost of the extra component. However, there are some studies which suggest that under certain circumstances these washers may provide some benefit.

HOW DOES A RAMPED WEDGE WASHER WORK?

A: These washers are found on the market under several different brand names. They work as a matched pair with one face of each having ridged serrations and the opposing faces being an interlocking pair of ramped wedge features. The serrated side of the washer goes against the bearing face of the bolt or nut and the contact surface of the clamped material. The serrations "dig into" the contacted surface and prevent the washer from spinning. The other face interlocks and as the system is tightened these wedges cam over one another until locking into place when the fastener achieves its preloaded position.

The cam angle on these wedge features is greater than the lead angle of the threads so that once locked in-place it is impossible for the wedge to disassemble on their own. This locks the system in place. This system is one of the few that actually retains the clamp load after assembling. This makes them a powerful option for critical joints where the designer needs to ensure that clamp load is retained.

WRAP-UP

There are many other special fasteners or methods that can supply resistance to vibration and self-loosening. They are not, however, all the same and some may provide better performance than others under certain application scenarios. For example, a top locking all metal locknut usually provides more consistent prevailing torque than its side locking cousin. However, if space constraints limit the number of full threads that can extend beyond the top of the nut, a top locking nut may be ineffective and the side locking version a better choice. The moral of the story, therefore, is that designers should understand what they need to accomplish and seek to find the best solution amongst this crowded field of options. ■

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