Hanging by a Thread

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Related Content

Maintenance shops get their nuts and bolts from many sources — some of which are OK, some of which may not be OK! Have you ever taken a good look at the nuts and bolts used to put an aircraft together? Have you ever considered that, in many cases, lives may be hanging by a thread? How can we protect ourselves from sub-standard hardware? One way is to educate ourselves about standard hardware so that we can at least make thoughtful determinations as to the integrity and quality of the fasteners we are buying.

Fastener Strength

The strength of mating threads depends upon the depth and length of the thread engagement. The depth of the engagement is based upon the overlap of the threads determined by the major diameter of the bolt thread and the minor diameter of the nut thread. The length of engagement depends upon the thread length which supports the load.

Bolt stress and the transfer of loading through the threads into another component is a complex engineering problem which takes into consideration things such as the elasticity and plasticity of materials. As materials become less plastic due to heat treating and other processes, the need for quality and adherence to dimensions and specifications becomes increasingly critical.

Thread Categories

Threads generally fall into "fit" categories such as Class 1, Class 2, and Class 3. Class 1 is a sloppy fit and is hardly ever used on aircraft. Class 2 is sometimes used on aircraft, but is mostly used in automotive applications. Class 3 is mostly aircraft and, more than any other, approaches a "perfect fit" condition. There is very little tolerance between the high limit of the bolt and the low limit of the nut. They fit together, or should fit together, without any "play."
Most fasteners used on aircraft are generated by the military or large commercial manufacturers. They will be found in the Military Standard (MS), Air Force/Navy (AN), National Aerospace Standard (NAS) or Aerospace Standard (AS) documents. (These can be ordered free for the most part from the Department of the Navy, Publications Center, Tabor Avenue, Philadelphia, PA.)

All Class 3 threads are generated from the basic size of the "maximum material" condition of both the internal and external thread. (The internal thread is described as a Class 3B while the external thread is described as a Class 3A). There are then small tolerances of a few thousandths applied to each. The limits of size of Class 3 threads are exact and must be maintained to ensure the integrity of the joint.

**Preload**

Fasteners work through a condition termed preload. For a joint to do the job for which it was intended it must be torqued to a proper value. This preloads the assembly and transfers the load to the tightened assembly. Obviously, if the nut comes loose from the bolt, the load must be transferred elsewhere and will cause failure. Incorrect preloading can cause static failure of the fastener, static failure of the joint, vibration loosening of the nut, fatigue failure of the bolt, joint separation, joint slip, etc.

Factors affecting proper preloading could be tool accuracy, operator accuracy, external loads, preload relaxation, or the basic quality of the parts! Correct preloading can not be achieved unless the parts are the right size, are hardened properly and are in good condition. If bolts are soft then they can not be preloaded to the correct torque, and relaxation of the joint will be even worse.

Out-of-tolerance bolts can have catastrophic effects. What seems ridiculous is that it is really easy to inspect for hardware imperfections. Only a few elements that can be gauged will tell us what kind of a part we have. We need to know just a little bit about basic thread geometry though.

**Thread Geometry**

All aircraft threads used in the United States are called "unified" and they all should have a 60-degree "included angle." The outside of the external thread is called the "major diameter" as is the unseen large diameter of the internal thread. The "minor diameter" is the root diameter at the base of the external thread while it is the visible hole in the internal thread. Again, the "pitch diameter" is that distance measured equally between the major and minor diameters. (The pitch diameter indicates the "minimum material" condition of the thread.)

A number of things can produce a thread oversize condition. Should the 60-degree angle vary, an oversize pitch diameter, a warped thread or an imperfect "lead" will do. On the
other hand, an undersize pitch will produce an undersize thread condition. Either is bad because an undersize thread will not preload properly and an oversize thread will not mate with the internal thread flanks properly and therefore will not transfer loads as needed.

For threads to be correct they must meet two criteria: minimum material condition (pitch diameter) and functional size. Functional size is defined as the size which includes the cumulative effect of variations in lead, uniformity of helix, flank angle, taper, straightness and roundness. Pitch diameter is defined as the diameter of the cylinder that passes through the thread profile of either an internal thread product or external screw thread in such a manner as to make the widths of thread ridge and thread groove equal on both sides of the thread and parallel to the axis. The pitch diameter is the measured value of the minimum material limit of size of either an internal or external thread.

If you are using threads that are classified as "J Form" such as a UNJF-3A, you can have further problems! (Most aircraft threads today are J Form by the way.) While the minor diameter of most threads is either truncated (flattened) or sharp, J Form threads have a radius at the "root" or minor diameter. This radius is 1/16 on a side and was designed into the thread to specifically preclude "preload relaxation" (loosening) of the assembly. Many old style fasteners are floating around out there which were either "surplused" by the military or just could not be sold after the change took place.

Nonconforming Hardware

In 1977 a letter was written by the Chief of the Mechanics Division of the National Bureau of Standards in Washington, D.C., (the custodian of all calibration reference standards) to the head of the Metrology Laboratory at Portsmouth Naval Shipyard. This letter stated emphatically that threaded parts accepted using inspection gauges such as thread rings and threaded plugs might easily be out-of-tolerance! It went on to state that thread rings and plugs do not check for the thread angle, taper, out-of-round or lead. Further, "Tests at NBS have shown that product inspected by not GO gauging and passed as conforming to Handbook H28 upon proper measurement proved to be nonconforming to the product dimensions specified."

In 1987, 10 years later, the Air Force finally accepted the fact that rings and plugs were not sufficient and ordered that all aircraft Class 3 threads be gaged and inspected for the thread elements. The Air Force went on to identify some 360 individual parts that were classified as, "safety critical" requiring specific element gaging. All "other" aircraft threads could be checked just for maximum material, pitch diameter, minor diameter, root radius for J Form and major diameter.

Discovering Defects

How can we discover defective parts? There are generally three ways: failure, visually detecting a problem and quantitative measurement of dimensions. Obviously, quantitative measurement is the most desirable of the three.
Unless you want to invest in some $5,000 worth of inspection equipment, you can try to follow some of these guidelines:

1. Whenever you purchase hardware that is the subject of AN, MS, NAS or AS specifications, ask the seller the origin. If he says that he bought it as military or commercial "surplus," walk away! It is untraceable material and you buy it at your own risk! No bargain is worth a life! If purchasing from a legitimate distributor, ask them to supply a copy of the original manufacturer's invoice. That invoice will contain, or should contain, a "certificate of compliance" on it attesting that the parts were produced properly. You can then contact the manufacturer and request a copy of the material certifications, process certifications, etc., that went into that part. You would be surprised what the manufacturer might give you.

2. Send a letter to the Naval Publications Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099 and get a free copy of thread specification MIL-S-8879. Read it carefully and you will find out all those elements that must be present in a proper aircraft quality thread. It will tell you about tensile strength values, plating, gauging, dimensional limitations, etc. It will not make an expert thread inspector out of you but it will tell you what to ask the manufacturer or distributor when buying nuts and bolts. (You may be surprised to find that you know more than most of the people with whom you speak!)

3. When you have developed your list of fasteners needed, write again to the Naval Publications Center and request free copies of the standards you are going to use. Again, these will be AN and MS type documents. These are also mostly available on the Internet; Google "MIL-SPECs".

4. Invest in an inexpensive pair of dial calipers. Get someone knowledgeable to show you how to inspect nuts and bolts for basic dimensions. You may be surprised what you can find out with a simple set of calipers!

5. In critical cases you can enlist the services of any reputable inspection company. Many are listed in the phone book under "Inspection Services." I recommend that your wing attach bolts be X-rayed and verified to the specification with respect to hardness and plating before you use or reuse them. This is really an economical inspection at about $50. In many instances these inspection companies can also perform a thorough thread inspection as well. They will document and certify the results.

Remember that you do not always get what you pay for! If you doubt the integrity of threaded fasteners you are probably correct! Start asking questions. If the seller keeps getting off the track, walk away! No bargain is worth a life.

In April 1988 the Defense Industrial Supply Center, the government's agency for purchasing all threaded fasteners, issued an "Alert" which brought to the military's
attention the fact that an inspection of its inventory showed that 40 percent of its Class 3
fasteners were defective. "Pitch diameters and functional diameters, especially, were
found to be nonconforming." As a result of this investigation, DISC will now perform
complete source inspection of all Class 3 fasteners at the manufacturer's facility."

The Johnson Gage Company, at the request of the military, performed a like inspection of
the inventories at Tinker AFB, Kelly AFB and Hill AFB. The results were a defective
rate of 60 percent on internal threads and 40 percent on external threads! The value of
this inventory was about $4,000,000,000! What do you think is going to happen to these
defective nuts and bolts? Much of this inventory will either be returned to the
manufacturer or "surplused" by the government. If surplused, it will be sold "as is, where
is" without any warranty whatsoever! It certainly can wind up on the open market before
long and then on to some aircraft! You will buy this stuff from unwitting distributors, at
fly-ins from stall vendors and from manufacturers who reserve it for unsuspecting buyers.
(This last case is certainly fraud rather than blatant stupidity!)