Manufacturing Innovation Insider Newsletter

Aerospace Industry Turns to Innovative Fastener Thread to Keep the Mission from Falling Apart

Extreme shock, G-force, vibration, and temperature cycles assault every jet, rocket, and spacecraft repeatedly during thousands of hours of operational use. True mission success depends on how reliably these aerospace vehicles operate for the long haul. Whether the challenge is mounting critical aircraft avionics, clamping onboard generator cables for continuous power, or securing interplanetary satellite instrumentation, inadequate performance from conventional fasteners can diminish or even prevent mission success.

While the internal and external threads are often taken for granted, these are what primarily bind aerospace components together. However, traditional methods of preventing joint loosening such as prevailing torque nuts, deformed threads, nylon rings, and even rivets simply don't measure up in the high shock, load, and vibration of the aerospace environment, especially when reusability and ongoing resistance to thermal expansion and contraction are necessary. The heart of the problem is the 60° "vee" thread design of traditional fasteners, which is prone to self-loosening rotational movement in high load and vibration aerospace applications. Testing has found the first two threads alone often carry as much as 80% of the load, enough to cause shearing or stripping.

Fortunately, a unique thread form is helping major aerospace players - such as BAE, Boeing, Honeywell, NASA, Raytheon, Rocketdyne, Hamilton Sundstrand, and the US military - combat loading and vibration for increased safety and reliability, while minimizing thread loosening, assembly, maintenance, and service costs. The growing number of uses ranges from aircraft cockpit instruments and actuator devices to missile and Space Shuttle engines, as well as clamps for circuit boards, generator cables, and a variety of other applications.

Hamilton Sundstrand tested and adopted an alternative thread form from Spiralock on their generators that addressed not only fastener loosening and stripping under high load and vibration but also galling as well as slippage due to thermal expansion and contraction.

Striving to improve the design and manufacture of its aerospace products, Hamilton Sundstrand, a leading global aerospace supplier, examined the effectiveness of conventional prevailing torque nuts used to clamp electrical cables to the generator's terminal block in a wide range of aircraft from commercial to military. When the prevailing torque nuts were applied correctly, they worked adequately in conjunction with redundant electric generating systems plus battery power. However, Hamilton Sundstrand wanted more than adequate performance, and took action to achieve this.

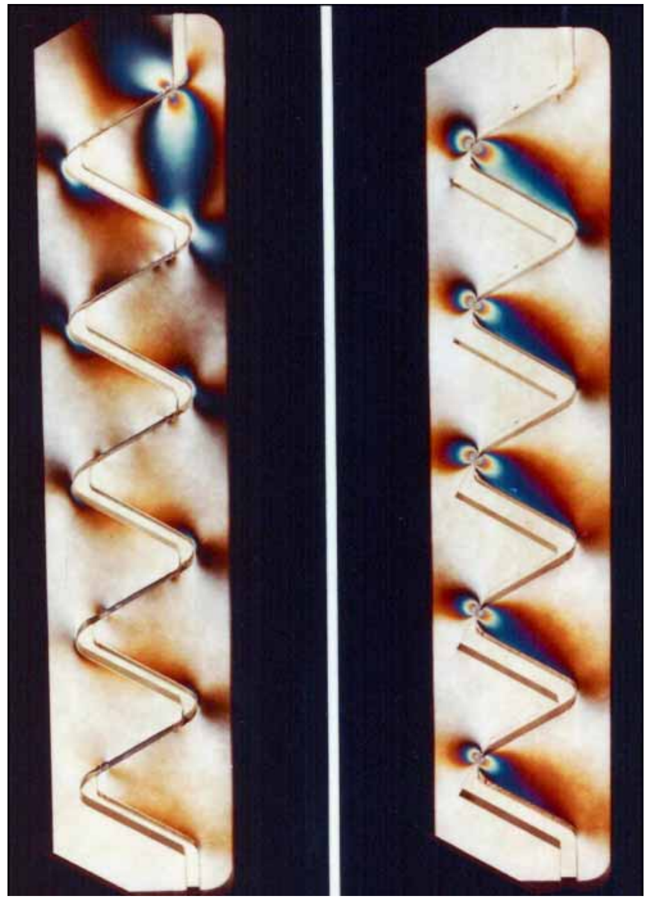
"A fastener may seem like a small thing but can make the difference between aircraft power being online or off," said Darin Morman, Hamilton Sundstrand's Manager of Generator Engineering in Rockford, Ill. "The issue was that prevailing torque nuts can gall or freeze on threaded bolts during installation, leading to intermittent power availability if the nuts' rundown torque exceeded the final torque limit before clamping."

In an effort to avoid any intermittent power disruption or maintenance under severe shock, vibration, and thermal variation prevalent in aerospace, Hamilton Sundstrand tested and adopted an alternative thread form designed to address not only fastener loosening and stripping under high load and vibration but also galling as well as slippage due to thermal expansion and contraction.

The unique thread form, offered by Madison Heights, Mich.-based Spiralock Corp., is a 30º "wedge" ramp cut at the root of the female thread—unlike a standard male bolt where the crests of the threads are drawn tightly against the wedge ramp under tension. This not only eliminates sideways motion that causes vibrational loosening but also distributes the threaded joint's load throughout all engaged threads, a claim supported by a research study conducted by the Massachusetts Institute of Technology.

Hamilton Sundstrand's field experience combined with their own tests indicated that "each Spiralock nut not only met the required clamping force when exposed to 50 Gs of vibration and 200 Gs of shock load," says Morman, "but also maintains this performance for thousands of hours of operational use and thousands of temperature cycles that can range from -65º F up to 500º F."

In tests each nut was installed and removed up to 50 times retaining the initial clamping force, with virtually zero rundown torque. "This prevents galling and thread damage, thereby minimizing maintenance and part replacement over the life of each aircraft generator," says Morman. "The Spiralock thread form is now used in virtually all Hamilton Sundstrand aircraft generator applications."



Photoelastic comparison of Spiralock's 30º wedge ramp (right) shows distributed threaded joint's load throughout all engaged threads. The first two threads on the conventional thread (left) often carry as much as 80% of the load, enough to cause shearing or stripping.

Other studies show the load percentage on the first engaged thread with a Spiralock thread form is significantly lower, which further reduces possible bolt failure and improves product performance. With the thread design, bolts spin freely until clamped to a final tension-retaining position, which streamlines assembly and maintenance. The thread form allows for both thermal expansion and contraction without slippage, an important consideration for extreme engine and environmental conditions.

Engineers at Rockwell International's Rocketdyne Division in Canoga Park, Cal. applied the Spiralock thread form on the Space Shuttle Main Engine (SSME) and Peacekeeper Missile Attitude Control Engines, based on a series of demanding tests. The thread form is used on pressure joints, brackets and tube clamps on the SSME and on injector clamps and bushings in the Peacekeeper. Benefits include certification for 50 loaded cycles of operation versus three to five loaded cycles for prevailing torque fasteners used previously, substantial reduction in assembly and maintenance time, and ability to identify poor-quality male threads through binding during assembly, which are explained later in the article.

A four-year testing program preceded application of Spiralock at Rocketdyne. In initial functional testing, a Spiralock nut was used to replace one nut on a variety of joint flanges. In subsequent testing, all the nuts on a variety of flanges were replaced with Spiralock nuts. During the tests, each mounted nut was marked with black paint to determine whether it moved. Additional inspection assured there was no loss in preload. During 50 research test firings totaling 8,000 seconds, not a single fastener moved.

Spiralock nuts and tapped holes were also used in the initial design of the Peacekeeper missile. Testing on the Peacekeeper has involved static firing and simulated launches. To date, not a single Spiralock fastener has lost a measurable amount of clamp load.

Aside from outstanding vibration resistance, the Spiralock thread form has demonstrated three key advantages for Rocketdyne over the prevailing torque fasteners used before: reusability, reduced teardown and assembly time, and the ability to locate galling or male thread damage during assembly.

Previously, crimped nuts could be reused, but locking torque and breakaway torque had to be checked after each cycle. Usually locking torque and breakaway torque fell outside specifications after three to five loaded cycles. Tests showed the Spiralock nuts, however, will last the full 55-mission life of the shuttle engines. This reusability contributes significantly to the overall reusability of the engine. Unlike earlier rocket engines which were used just once, the SSME is designed for 7-1/2 hours of operation. When amortized over 55 missions, the three SSME's used on each orbiter cost just a third of the non-reusable Delta engine system, saving $500,000 per payload.

Rocketdyne estimates saving an additional 20 hours whenever an engine is torn down and reassembled because Spiralock nuts spin on prior to torquing, eliminating the time required for crimped nuts that need to be forcibly thread until they seat.

The ability to locate galling or male thread damage during assembly is another advantage. With a traditional torque fastener, it's difficult to distinguish between binding caused by locking and that caused by thread damage. Previously, problems weren't uncovered until the nut or bolt was removed. With the free-spinning Spiralock thread form, however, any resistance prior to seating is immediately identifiable as thread damage and can be remedied.

NASA was among the first to appreciate the advantages of the Spiralock thread, when designing the main engines of the Shuttle orbiter. Each of the three main engines develops 400,000 lb. of thrust and terrific vibration. But the Space Agency also wanted a 15-cycle reuse capability per fastener. Under its own test, NASA determined the fasteners in Spiralock-threaded holes did not back off or loosen when subjected to ten times shuttle-specified vibrations, and they stayed that way ten times longer than called for. NASA tests found the Spiralock-thread fasteners delivered 50 uses with no loss of clamping power. To this day, every shuttle engine carries no fewer than 757 Spiralock fasteners.

For the current Cassini-Huygens mission across 750 million miles of space, NASA used the Spiralock thread form to resist vibration and temperature-induced thread loosening on mass spectrometer instrumentation used for atmospheric measurement of Saturn and

Titan. Together in the Cassini orbiter and Huygens probe, several hundred fasteners had to maintain vacuum-tight sealed cavities from final assembly and testing through launch, until the end of the seven-year mission.

"To survive the vibration and high temperatures of launch, we required the most reliable locking engagement thread," said Dan Harpold, a NASA scientist who worked on the project. "Screws had to remain tight without opportunity for retightening. With conventional threading, however, screws loosened up and backed out under testing."

Among the tests carried out were a series of about 12 high temperature "bake outs," where screws and their matching internal thread forms were heated from room temperature to 300° C to simulate temperature-induced thread loosening.

"The Spiralock thread form retained a tight seal at 300° C," says Harpold. "Once torqued down properly, the screws stayed put in the threads, which helped us meet our flight schedule. Not one has come loose that I'm aware of."

For more info on Spiralock Corp. technology and products, visit www.spiralock.com; email slinfo@spiralock.com; call (800) 521-2688; fax (248) 543-1403; or write to them at Madison Tech Center, PO Box 71629, Madison Heights, MI 48071.

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