Importance of Accurate Thread Gage Calibration & Product Certification

by:
Stanley P. Johnson, President
Johnson Thread-View Sytems, LLC
109B West Dudley Town Road
Bloomfield, CT 06002 USA
Tel: (888) 593-1082
www.johnsonthread-view.com

Good thread performance hinges on proper thread inspection and gage calibration as well as meeting current thread inspection standards.

In the mid 1980s, the **Department of Defense** grounded a fleet of UH-60 helicopters when spindles securing the rotor blade to the main mast continued to separate from helicopters in flight. An automotive manufacturer lost an entire day's production of engines when the threads produced to affix the engine block to the frame would not hold. A commercial airliner plunged into the ocean when its rudder failed to respond to the pilot's commands. Prior to this, there were six separate incidents when commercial aircraft made emergency landings due to in-flight engine separations. In these seemingly unrelated accidents, the underlying problem was thread failure.

From aircraft, automobiles, weapon systems and communication satellites, to skyscrapers and artificial hearts—threaded components hold the world together. Yet when improperly manufactured or not maintained to specification requirements, the very products and structures we depend upon are inherently compromised. The challenge is that threaded component characteristics are very difficult to analyze in order to ensure dimensional conformity, quality and ultimately proper fit.

In the cases above, not all of the threads broke. The link is that the threads became loose and failed. Subsequent analysis confirmed that they were all dimensionally nonconforming, and a dimensionally nonconforming thread, when torqued and subjected to an environment with stress, shock, temperature variation and/or vibration will fail. The only way to ensure proper performance of a threaded component is to confirm that the characteristics of the thread are dimensionally conforming. And to make a sound decision on the quality of the thread, the examiner needs values for the actual thread characteristics.

Sadly, the stories above are not isolated incidents. Military and commercial reports indicate that thread failure has lead to loss of life. Yet based on my review of **FAA** Air Worthiness Directives, commercial Accident/Incidence Reports and Federal Government Mishap & Accident reports, few of the studies that examine accidents attributable to thread failure consider dimensional nonconformance of the bolt/nut.[1] Hardness and material composition are examined and could be culprits, but as a pilot and a frequent traveler on our country's commercial airliners, I am alarmed about the lack of knowledge relating to the dimensional characteristics of threads and threaded components. A few statistics add some color to my concerns:

- Your company diligently completes receipt inspection on a shipment of threaded product. It was determined that the underside of the bolt head was approximately 2° out of perpendicularity to the axis of the bolt. This seemingly insignificant deviation will reduce the fatigue life of the assembly by 78%.[2]
- During first article inspection of an aerospace fastener, your company's machinist noted that a 0.6250" *18UNJ 3A/3B* bolt and nut were both acceptable, but at the minimum material limits for their respective tolerances. Therefore, he passes the lot and the threads move into assembly, for example in an engine mount bolt. True, the results are within the **ASME** and military specifications, but at the edge of the design limits, when assembled the joint only provides 67% of its static shear strength.[3]

If a dimensionally nonconforming thread passes through inspection and is torqued, problems may arise. On this out-of-tolerance thread, the yield point and the ultimate tensile strength have decreased. The assembler provides the required amount of torque (approximately 90% of yield), but has unknowingly pushed through the nonconforming yield point. At this point, the thread starts to lose its elasticity, is stretched and is permanently deformed. Pressure on the flank angle is lost and the clamping force is subject to induced relaxation.

The goal of any sound fastener is to maximize flank contact over the entire length of engagement. But this is simply not possible with a dimensionally nonconforming thread. Flank contact is lost and clamping force diminishes, and this could lead to:[4]

- Static failure of the fastener.
- Static failure of joint members.
- Vibration loosening of the nut and the bolt.
- Fatigue failure of the bolt.
- Joint separation.
- Joint slip/ leakage.

Inspection of Threaded Product & Components

There is good news. Commercial guidelines (*ASME B1.1*, *B1.2*, *B1.13M* and *B1.16M*), Military Specifications (*Mil. S 8879*C and *AS 8879C*) and Federal Standards (*Fed. Standard H28-20*) list the appropriate thread parameters to be examined and issue the proper tolerances for a given thread size. In addition, the technology has been available for decades to examine threads, but there are pros and cons to each technology.

For the inspection of threaded product there are several methods. At the turn of the last century, my grandfather invented the AGD split ring gage, which offered a quick and intuitive way to insure assembly. But designed around the birth of the **Ford** Model T, it is not suitable to assure dimensional performance. Furthermore, as the original patent states, these AGD split ring gages were not to be adjusted in the field. They were only to be adjusted by the manufacturer of the gage for final lapping procedures.

This is why European manufacturers almost exclusively use solid rings. Adjustments to the split ring mismatch the helixes and force the ring to close in on a "tri-lobing" condition. Adjustments also destroy the concentricity between the major, pitch and minor diameter cylinders. Another concern emerges if the setting plug used to calibrate the ring possesses lead and angle error. The ring will be set oversized. This is because the lead and angle error increase the effective size of the set plug and reduce the effective size of the ring gage.

In the 1950s, my father developed indicating gages. These are excellent tools for the analysis of threaded components on the production floor. But they do not have the capability to provide actual values for the individual thread characteristics of lead and angle. Rather, lead and angle errors are expressed as a percentage or a differential of the pitch diameter tolerance.

Inspection of Threaded Masters

Technology has been relatively static since the invention of the optical comparator and the development of the three wire method of measurement (M.O.W.). These technologies are pervasive, but industry should be cognizant of the shortcomings of these antiquated methods.

Few know that the M.O.W. does not measure pitch diameter—it measures thread groove diameter. These two measurements are distinctly different if lead or angle error is present. Other problems might also develop with the M.O.W. measurement. The technician must ensure that he has the required spindle pressure on the thread under examination as too much will generate deformation of the thread setting or work plug. He or she must be confident that the anvils are parallel before measurement. Finally, the technician must be careful with math/transcription errors as subtraction of the wire constant and application of the "General Formula" is required to derive a proxy for the pitch diameter.

But the greatest problem is lack of conformity. For inspection of Master Thread Setting and Work Plugs, it is common practice to examine only two thread characteristics (pitch and major diameters). This is not acceptable. Only the long form certification requiring examination of 12 thread characteristics is supported by the commercial and military standards. Not meeting the full certifications exposes industry to undue risk.

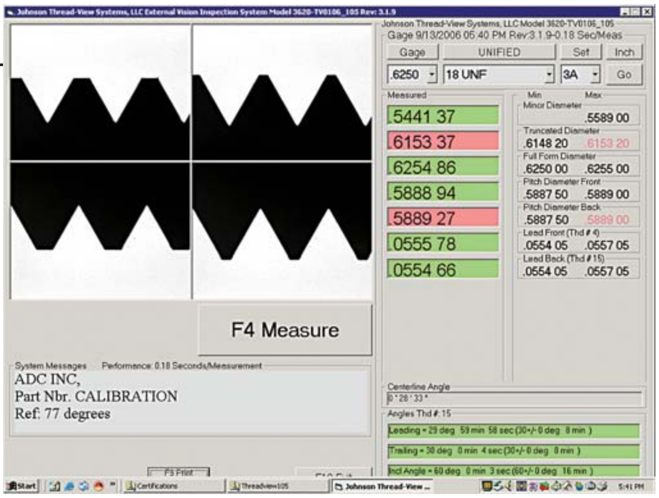
In summary, standards are not being met and current technology depends heavily on the operator's skill and experience. I think that due to the importance of the human element, it is difficult to replicate results on current metrology equipment.

New Technology

Finally, technology has advanced to the point that with vision inspection we are able to overcome the limitations of current inspection equipment. Our latest technology, the Johnson Thread-View System Model 3620 will provide a full form certification for Set Plugs and Work Plugs in approximately two minutes, and in three minutes will provide the same data for the certification of threaded product. And as a vision system, it works independent of the skill or experience of the technician.

With product or master thread setting/work plugs, verifying the dimensional conformance of a thread is straight forward. See the accompanying photograph for an example of the information provided by the Thread-View System.

Thread-View also provides companies with a competitive advantage. Verifying the dimensional conformance with exact values for each thread characteristic can be accomplished for a fraction of current costs. Thread-View requires less up-front investment, training is minimal and its quick cycle time offers tremendous savings. I developed the Thread-View System so that when master thread setting/work plugs are within stated tolerances and threaded components meet design specifications, industry can greatly reduce thread failure in the field.



Sample screen from the Thread-View System.

Conclusions

For 37 years, I have preached the merits of thread inspection. Through my companies, I have sought to bolster thread standards, improve quality of manufactured items and reduce costs attributable to thread performance. Today the solution to ensuring proper thread performance is no different than when I came to work for my father four decades ago. It is a two step process: 1. Educate industry regarding proper thread inspection and gage calibration; 2. Meet current thread inspection standards.

I believe that with the recent advancements in technology, it is easier and far more affordable to meet thread inspection requirements. Dimensionally nonconforming characteristics can be immediately recognized and when dimensional characteristics are concerned, the "witchcraft" and the mystery as to the root cause of failure is no longer an issue.

Do your part. Manufacturers and users of threaded fasteners and thread gages should insist upon a full form certification.

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Footnotes:

1. *A GAO report, "Military Fasteners, Changes to Specifications Justified (Report No. GAO/NSIAD-91-309)" did indicate that dimensional nonconformance was a contributing factor to threaded component failure.*
2. *Bickford, John,* ***An Introduction to the Design and Behavior of Bolted Joints, 2nd Edition****, 1990, pg. 486.*
3. *Bickford, John, pg. 426,*
4. *Bickford, John, pg. 128.*

Author & Company Profiles...

Stanley P. Johnson *is the President of* ***Johnson Thread-View Systems, LLC****. For the past 35 years, his companies have developed gaging to verify the dimensional conformance of internal and external threaded components to inch and metric specifications. In the summer of 2001, he sought to leverage recent advancements in vision inspection and optics to create a noncontact thread inspection system, the Thread-View Model 3620 System. Over the course of his career, Johnson has published several articles relating to thread failure and has presented multiple seminars to the* ***Department of Defense****, the* ***Department of Energy****, the* ***National Transportation Safety Board****, the* ***Federal Aviation Administration*** *and the* ***National Institute of Standards and Technology*** *related to threaded product and measurement. He has also been called to serve as an expert witness in South Carolina and California relating to thread failure. Also, he was a past member of the* **ASME** *B1 committee, which set threaded product and gage standards for the industry.*

In addition to the Thread-View System, Johnson Thread-View Systems, LLC offers a complete screw thread technology seminar that includes a thorough discussion regarding gage calibration and product certification requirements.
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