Manufacturing Innovation Insider Newsletter

Innovative Fastener Thread Form Can Take the Heat and Vibration of Diesel Engines

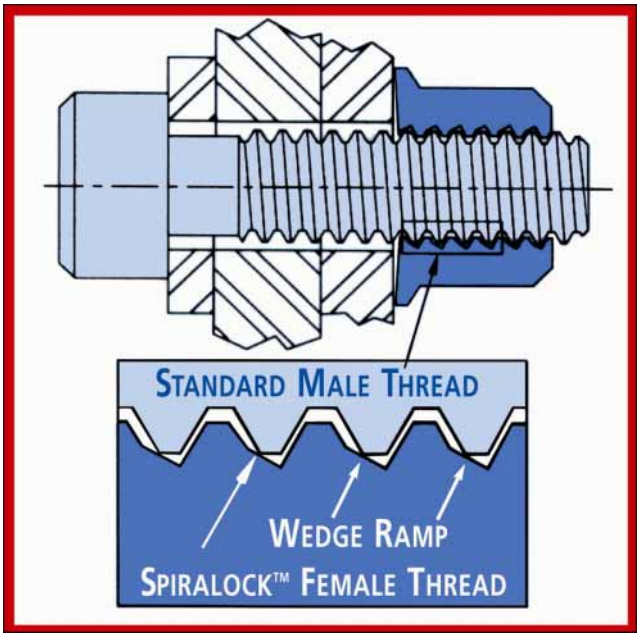
A unique internal thread form is helping domestic and international diesel-powered vehicle manufacturers combat extreme engine temperature and vibration, while minimizing thread loosening, assembly, and service costs

Imagine harnessing the heat energy of a blast furnace while keeping the vibrational equivalent of a jet fighter's acceleration in check. This is essentially what diesel engine designers worldwide must do to keep diesel trucks on the road and on schedule for thousands of operational hours. Yet for engine performance, reliability, as well as meeting emission standards, joint integrity must be maintained in critical areas such as turbocharger mounts, exhaust manifold joints and attachments, where extreme heat and vibration can weaken and shake loose standard fasteners.

"In the engine combustion process, joint fasteners may have to withstand exhaust gases up to 1300º F, components to 1000º F, and continuous vibration over thousandths of an inch, with a force of acceleration up to six times that of gravity," said Todd Werner, a design engineer for Allentown, Pennsylvania-based Mack Trucks, Inc., one of North America's largest producers of heavy trucks. "A turbocharger's vibrational acceleration, for example, can exert up to 10,000 lbs. of force on a joint."

Unfortunately, traditional methods of preventing joint loosening such as nylon rings, adhesives, and deformed threads simply don't measure up in the high temperature, high vibration diesel engine environment.

"At high engine operating temperatures, nylon coated fasteners will melt or burn, and adhesives aren't effective either," adds Sam Sutthiwan, a designer for Peoria, Ill.-based Caterpillar, a technology leader and the world's largest maker of construction and mining



Spiralock's unique 30° wedge ramp female thread securely connects standard male thread forms.

equipment, diesel and natural gas engines, and industrial gas turbines. "Split washers and standard thread type fasteners tend to yield over repeated cycles of heating and cooling and require lock tabs to prevent them from losing their fastening ability. Prevailing torque fasteners can present assembly and service challenges, especially with stainless steel."

Solving Fastening Problems with the Spiralock® Thread Design

Traditional threaded fasteners face severe limitations in diesel truck engine applications, particularly

those with high performance turbo requirements. They are susceptible to shock, vibration, loading, as well as thermal expansion and contraction.

The traditional 60° "vee" thread design was originally created to accommodate unavoidable problems such as drill, tap, and die wear; hole and thread size variation; and errors in placement, thread finish, etc. However, they are prone to self-loosening rotational movement, particularly in high vibration environments such as diesel engine applications. Stripping or shearing can also occur since 60° threads position most of the clamp load on the first and second engaged thread, permitting subsequent male threads to "float" within the female threads. Testing has found the first two threads alone often carry as much as 80% of the load, enough to cause shearing or stripping.

Friction-induced thread galling, or fusing, can also create assembly and service problems when high-resistance prevailing torque nuts are used with high-speed assembly equipment and stainless steel fasteners. Due to galling, prevailing torque nuts may "freeze" before fully tightened during assembly, causing exhaust leakage, gasket failure, reduced engine performance and a reduction in fuel economy.

Through the geometry and physics of the thread itself, Madison Heights, Mich.-based Spiralock Corp. offers an alternative thread form designed to address fastener loosening, and stripping under high temperature and vibration. Instead of the traditional 60º "vee" thread design, the Spiralock thread form is a 30º "wedge" ramp cut at the root of the female thread. Under clamp load, the crests of the threads on any standard male bolt are drawn tightly against the wedge ramp. Since the Spiralock thread form is a mechanical solution to the loosening problem, it's more tolerant of cyclic temperature changes than 60° threads using nylon or adhesives. It allows for both thermal expansion and contraction without slippage.

The 30º wedge ramp 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. 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. Using this thread design, bolts spin freely until clamped to a final torque-retaining position, which eliminates galling during assembly and needed service repair.

When Mack found that a mechanical crimp nut wasn't meeting its stringent installation and service requirements in mounting a turbocharger to the exhaust manifold in a heavy truck model, it rigorously tested the Spiralock thread form.

"During a particular engine durability test, the fasteners were exposed to temperatures as high as 1300º F, which is hotter than normal operating temperatures. The engine was then rapidly cooled every twelve minutes for 3,000 hours," says Werner of Mack. "Upon inspection every 250 hours, the Spiralock fasteners maintained joint integrity without losing torque for 15,000 cycles."

"After their adoption, none have failed in the field to my knowledge," says Werner. "They're not only self-locking but also re-usable during service without damage to the nut or stud. The Spiralock fasteners are now used on every Mack turbocharger mount across our vocational truck line and on the EGR valve mount on our highway truck line."

Caterpillar has also adopted Spiralock fasteners for diesel engine applications such as turbocharger mounts, exhaust manifold joints and attachments, after thorough testing by its technical center.

"The Spiralock fasteners stay put under engine vibration, and withstand high temperature," says designer Sam Sutthiwan of Caterpillar. "This improves reliability, upholds our reputation with customers, and lowers the need for service repair."

The international market is turning to the Spiralock thread form as well. Recently Shanghai Diesel Engine, one of the largest engine manufacturers in China, found deformed thread nuts unsatisfactory for their turbocharger outlet clamp assembly and tur-

bocharger mount to exhaust manifold for use in trucks, buses, and other applications.

"The deformed thread nuts were costly, difficult to assemble, and often damaged bolt threads during assembly," said Jessie Zhang, a senior engineer at Shanghai Diesel Engine. "Damaged bolt threads meant the clamp assembly couldn't be used because the bolt was welded to other parts. Without the clamp assembly, the engine wouldn't properly connect to the exhaust pipeline, which could hurt engine performance, damage the gasket, and cause injury."

While Zhang was looking for a better machining process for the deformed thread nuts, Spiralock of China contacted her. Zhang was swayed by the unique thread form's design, use by NASA, and performance in a 500-hour durability engine test at full load and speed conducted by her company.

"The design works like using a wedge to keep a door open," says Zhang. "The thread form offers locking performance and vibration resistance in high temperature. It protects the bolt threads and clamped assembly from damage during assembly or service. In the past few years, we've produced tens of thousands of diesel engines with the Spiralock thread form, with very good results for the Chinese and international markets."

Gary Svidron, a design engineer for International Truck and Engine Corporation, a Warrenville, Ill.-based manufacturer of trucks, buses, and diesel engines, also sought fastener resistance to vibration and shock. He faced a design challenge in securely fastening a turbocharger to an exhaust manifold on a six-cylinder diesel engine used in trucks and buses, where fasteners had to retain clamping power at high temperatures.

During pre-production testing, standard nuts and other traditional fasteners came loose due to sustained road vibration, and adhesives simply didn't work because engine-operating temperatures were too high.

"Joint integrity on the turbocharger/exhaust manifold was critical to prevent gasket leaks, warranty costs, and exhaust leakage, which can cause particular problems in states like California with strict emissions standards," said Svidron. "Moreover, truckers and bus drivers can't tolerate downtime, since staying on the road is their livelihood. To keep them on the road and warranty costs down, we needed fasteners that quickly and securely clamped in place for the life of the engine. This would make it easy for our dealers' service technicians who have to keep our customers on the road."

After pre-production dynamometer and field testing, International Truck replaced standard flange nuts with stainless steel Spiralock fasteners. "We've not only solved the joint integrity problem, but also avoided potential assembly issues with prevailing-torque-style fasteners and improved assembly production," says Svidron. "Since the Spiralock fasteners spin freely until it's time to tighten them, they take significantly less time to tighten than resistance-heavy locking methods such as prevailing torque nuts."

"With four fasteners per assembly on volume of many thousands of engines per year, we're saving a large amount of assembly time," adds Svidron.

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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