Determining the effect of lubrication on the security of bolted joints

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Lubricants provide many benefits to a bolted joint. They ease the amount of energy required to tighten the bolt; they provide better wear resistance; they make disassembly much easier; and they prevent corrosion that can permanently weld surfaces together. However, the use of a lubricant on the threads and under the bolt head – whether solid film, grease or oil – adds a layer of uncertainty to the security of the joint.

Tightening a bolt causes the threaded shank to stretch inside the joint. Like a spring, the stretched bolt has a tendency to pull back to its original shape. This tendency results in the 'preload' or tension that holds the joint together.

The traditional method for measuring and specifying bolt tightness is through the use of torque – the rotational force used when tightening a bolt. Torque is related to tension and can be calculated using a short form torque-tension equation:

$$T = K \times F \times D$$

In this equation T, K, F and D represent the input torque (T), the 'nut factor' (K), the required preload/tension (F), and the bolt's diameter (D) respectively[1]. The 'nut factor' takes into account all of the variables known to influence the torque-tension relationship, including the materials used, plating and surface finish, corrosion, thread wear, and the presence and type of lubricant.

Lubricant affects torque – but how much?

Lubrication affects the friction of the system and this in turn affects the amount of torque required to securely tighten the bolt. If too much torque is applied, the bolt may become overstressed and fail. If too little torque is applied, the joint may loosen and separate.

Because a lubricant can have a significant effect on both the torque and therefore the tension developed in a joint, the question then becomes 'how much should the torque specification be adjusted when a lubricant is used'?

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In order to answer that question, we first must ask where the torque value itself came from. "The torque specification may have been calculated by the engineering department; inscribed on a piece of equipment; or it's just common knowledge within an operation," explains Chris Bunai, chief engineer at Stress Indicators Incorporated[2]. "However, many times it is pulled from a torque chart."

'Nut factor' inconsistencies add uncertainty to torque

According to Bunai, torque chart readings are based on several assumptions, which are often not considered when determining the torque specification for a bolted joint. For example, typically a torque chart will assume a dry bolt and a 'nut factor' of K = 0.2. However, in reality, the 'nut factor' can vary even from one time to the next when tightening the same bolt.

"Each time there's relative motion between the bolt and the bolted joint, there is an opportunity for a different nut factor," explains Bunai. "We've seen that frequently in a lot of our tests."

The use of a lubricant can help provide some consistency to the 'nut factor', though only if the type, amount, and application of the lubricant, remain the same throughout the job. "Generally the fluctuation or the variability that you would see in the 'nut factor' should be narrower in a lubricated bolt than in an unlubricated bolt – with qualifications," says Bunai. "There are also a number of fastener coating materials that are designed to offer a more consistent 'nut factor'."

Even with a lubricant, according to Bunai, trying to get the 'nut factor' consistent each and every time you tighten a bolt is a losing battle. Furthermore, without knowing how much the lubricant will change the 'nut factor', the joint or bolt could be damaged by over-tightening, or the joint could be weakened by under-tightening. The problem, then, becomes how to determine the true tightness of a bolted joint when using lubrication, so that the security of the joint is assured.

"You ultimately want to look for a better method, which measures tension directly, as opposed to trying to infer it through the measurement of torque and use of the 'nut factor'," adds Bunai.

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One way to measure directly

One way to determine more directly whether a lubricated bolt will be properly tightened at a specified torque value is with a load cell, such as a Skidmore-Wilhelm. Placing the bolt in the cell and then tightening it with a torque wrench pressurises the hydraulic fluid in between a piston and the housing, and the pressure generated is then measured with a Bourdon tube gauge.

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"By applying the specified torque to the bolt in the load cell, you can mimic the bolted joint as closely as possible and see how much tension is developed," mentions Bunai. "Then, using the torque formula you can calculate and solve the actual 'nut factor' that will be required for all bolts throughout the installation."

However, as noted earlier, even using the same bolt with the same lubrication in the same bolted joint, and applying the same torque value, results in varied amount of tension almost every time. Additionally, a tightened bolt in a load cell will behave differently than in an actual bolted joint, because the stiffness and angle of the joint will differ, even if only slightly.

"Sometimes you will see that the tension developed right using torque control, and other times you find out that it didn't," points out Bunai.

Freedom from the 'nut factor'

"The current industry best practices for bolt safety, such as measuring torque in a load cell, are reliable enough in the absence of another technology," says Bunai.

An even better solution with more accuracy would be to directly measure the tension developed in the actual bolted joint, explains Bunai. This kind of direct tension measurement is available using SmartBolts, developed by Stress Indicators Incorporated. The patented visual indicator on the head of each SmartBolt, when compared with the verification guide, shows exactly how much tension has been created in the tightened bolt, based on how much the bolt has been stretched.

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The SmartBolts indicator turns from red to black when proper tension has been reached and is reusable for the life of the fastener

In this way, a SmartBolt provides the true measure of bolt tightness without the need to consider torque values or the 'nut factor'. One benefit of directly measuring tension in situ is that it takes the torque-tension relationship and the uncertain effect of lubricants completely out of the equation.

Using SmartBolts, all the benefits of lubrication – such as ease of assembly or disassembly and improved wear and corrosion resistance – can be enjoyed, without the added worry that the bolted joint will be either over-tightened so that it breaks or under-tightened and therefore too loose. Putting SmartBolts to work in a bolted joint can provide freedom from worry about how a lubricant will affect bolt tightness. +

www.smartbolts.com

1 Bickford, J.H. (1995). An introduction to the design and behavior of bolted joints (3rd ed.). New York, NY: Taylor & Francis Group
2 Bunai, C. The Torque-Tension Relationship Gets Stretched. American Fastener Journal, May/June 2012