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 ,which can permanently weld surfaces together. But the use of a lubricant, whether solid film, grease or oil on the threads and under the bolt head, 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:

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

where T, K, F and D represent the input torque, the "nut factor", the required preload (tension) and the bolt's diameter, respectively[1].

The nut factor, K, 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 spec be adjusted when a lubricant is used?

But in order to answer that question, we must first ask where the torque value itself came from.

"The torque spec may have been calculated by the engineering department, inscribed on a piece of equipment or it's just common knowledge within an operation," said **Chris Bunai**, Chief Engineer at **Stress Indicators Incorporated**. "But many times it is pulled from a torque chart."

Thread	Tensile Stress Area	SAE Grade 2			SAE Grade 5			SAE Grade 8		
Size	TSA	75% Yield Strength (PSI) - 43000			75% Yield Strength (PSI) - 69000			75% Yield Strength (PSI) = 98000		
		Plain	Zinc Plated	Waxed	Plain	Zinc Plated	Waxed	Plain	Zinc Plated	Waxed
	Square Inches	A. lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.	Ft.Lb.
114-20.	0.0318	6	6	3	9	10	5	13	14	6
1/4-28.	0.0364	7	7	3	10	12	5	15	16	7
5116-18.	0.0524	12	13	6	19	21	9	27	29	13
5116-24.	0.0580	13	14	6	21	23	10	30	33	15
318-16.	0.0775	21	23	10	33	37	17	47	52	24
318-24.	0.0878	24	26	12	38	42	19	54	59	27
7/16-14.	0.1063	33	37	17	53	59	27	76	83	38
7/16-24.	0.1187	37	41	19	60	66	30	85	93	42
112-13.	0.1419	51	56	25	82	90	41	116	127	58
112-20.	0,1599	57	63	29	92	101	46	131	144	65
9116-12.	0.1820	73	81	37	118	129	59	167	184	84
9116-18.	0.2030	82	90	41	131	144	66	186	205	93
5J8-11.	0.2260	101	111	51	162	179	81	231	254	115
5J8-14.	0.2560	115	126	57	184	202	92	261	287	131
3/4-10.	0.3340	180	197	90	288	317	144	409	450	205
3/4-16.	0.3730	200	221	100	322	354	161	457	503	228

Torque charts are based on several assumptions, which are often not considered when determining the torque spec for a bolted joint. (source of chart: Industrial Fasteners Institute).

Nut Factor Inconsistencies Add Uncertainty to Torque

According to Bunai[2], torque chart readings are based on several assumptions, which are often not considered when determining the torque spec 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," Bunai said. "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," Bunai said. "There are also a number of fastener coating materials that are designed to offer a more consistent nut factor."

But 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

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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," Bunai said.

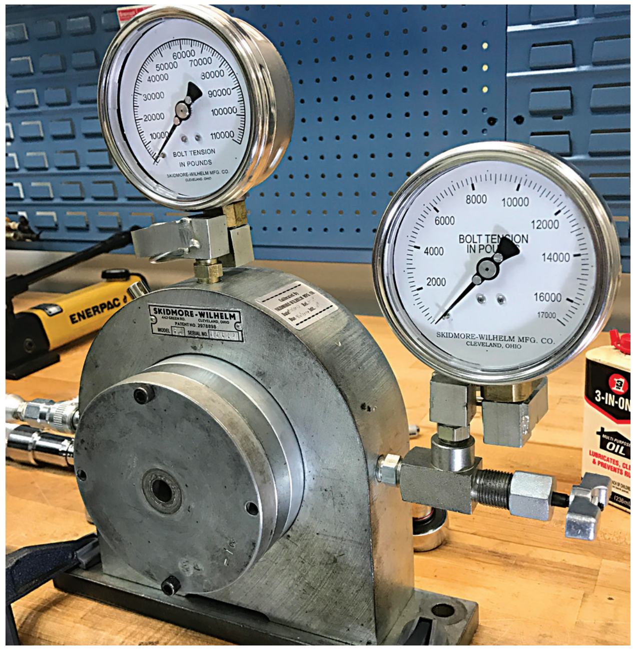
One Way to Measure Directly

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 pressurizes the hydraulic fluid in between a piston and the housing, and the pressure generated is then measured with a Bourdon tube gauge.

"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," Bunai explained. "Then using the torque formula, you can calculate and solve for the actual nut factor that will be required for all bolts utilized throughout the installation."

But 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 a varied amount of tension almost every time.

Additionally, a tightened bolt in a load cell will behave differently than it would in an actual bolted joint, because the stiffness and angle of the joint will differ,



"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," said Chris Bunai, Chief Engineer at Stress Indicators Incorporated.

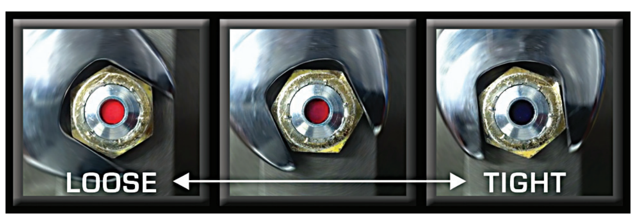
even if only to a slight amount.

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

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," Bunai said. "But an even better solution with more accuracy would be to directly measure the tension developed in the actual bolted joint."

This kind of direct tension measurement is available using SmartBolts®, that have been developed by **Stress Indicators Incorporated**, Gaithersburg, MD, USA. 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.



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

Determining the Effect of Lubrication on the Security of Bolted Joints ...continued

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.

When using SmartBolts, all of 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 the affect that the lubricant will have on bolt tightness.

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References:

[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.*

Company Profile...

Stress Indicators Incorporated is a technology and manufacturing firm based in Gaithersburg, MA, USA. The company provides industrial indication systems that increase productivity and reliability for its customers worldwide. Stress Indicators was established with the goal of innovating and developing Visual Indication systems to meet the needs of commercial and industrial users. The company's proprietary Visual Indication technology can be implemented into a wide variety of applications and products. Stress Indicators Incorporated's patented SmartBolts® allow users to simply look at their bolts at any time and know they are tight. SmartBolts are revolutionizing the way industry approaches bolting. Stress Indicators Incorporated works with companies involved in industries including power generation and distribution, manufacturing, structural, mining, factory automation and transportation.

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