Improved Torque Tension

How does lubrication affect fastener torque and resultant tension?

By FSA member Dave Hageman

Many methods are used to tighten fasteners. The most common is using a hand or impact wrench and "mechanic's feel." The installer tightens the fastener until it feels tight. While this process is acceptable for non-critical applications, it is unacceptable when greater tension accuracy is required.

In more critical situations, the first thought may be to use a torque wrench. However, what torque should be used, and will the required tension be achieved? This "Sealing Sense" is intended to help end users choose the best torque to apply for their applications. It will demonstrate the importance of lubrication and describe procedures that provide the required compressive load on a gasket using torque. It will also identify other important considerations for proper assembly.

A more comprehensive discussion of the entire assembly process for bolted flange joints can be found in ASME Standard PCC-1-2010. Information provided in this "Sealing Sense" is consistent with that document's guidelines.

A word of caution, torque is not the most accurate way to tension a fastener. The amount of tension achieved from torque is affected by a number of variables. Friction is the most important, and it is difficult to control. High friction results in low tension, and low friction results in high tension. At best, torque tension results will vary in un-lubricated fasteners by +/-25 percent. Using a lubricant can improve this to about +/-15 to 20 percent.

IMPORTANT STEPS

To ensure the appropriate tightening of fasteners, certain steps should be followed:

- Determine the tension needed for each fastener.
- Choose a fastener size and grade with strength that can provide the required tension without being overloaded.
- Calculate the required torque.
- Use a calibrated torque wrench.
- Apply torque correctly to evenly load all the fasteners.
- Use only through hardened washers.

To determine the tension needed on each fastener, establish the total compressive load required for the application. Divide this by the number of fasteners to find the tension needed for each.

Next, choose the fastener size and grade. In most cases, end users already know the size since the application usually determines the required size. Keep in mind that a fine-threaded fastener of a given diameter is able to tolerate a higher load than a coarse thread of the same size. If a load is needed that is higher than a coarse-threaded fastener has the ability to provide, a fine-threaded fastener of the same grade and size can provide more tension and may be able to meet the need. Tables 2 and 3 list common grades, stress areas and maximum loads permitted using U.S. customary and International System of Units (SI) bolts. Never exceed these loads.

HOW TO CALCULATE REQUIRED TORQUE

A common method of calculating the required target torque uses the formula below:

$$T = (KDF) / 12$$

Where:

T = Torque, foot pounds

K = Nut factor (torque coefficient resulting from estimated coefficient of friction)

D = Nominal diameter of the bolt, inches

F = Tension, pounds

K Values		
	Un-Lubricated	**Lubricated**
Un-plated steel fastener	0.2	0.17
Zinc-plated fastener	0.17	0.15
Cadmium-plated fastener	0.15	0.12
Stainless steel fastener	0.3	0.2

Table 1. Nut factors for molybdenum disulfide lubricant

Dividing by 12 gives foot pounds. If inch pounds units are required, do not divide by 12.

SAMPLE TORQUE CALCULATION

This example assumes that four ⅜-16 bolts must provide a total load of 20,000 pounds. Each step for applying the correct tightening should be followed:

- **Step 1**—Tension needed for each fastener: 20,000 / 4 fasteners = 5,000 pounds needed for each fastener.
- **Step 2**—The size is ⅜-16, which is a ⅜-inch nominal diameter fastener with 16 threads per inch. Using Table 2, a ⅜-16, Grade 5 fastener has a maximum load capacity of 6,510 pounds. This fastener is appropriate for this application. For this example, assume it is an un-plated steel fastener.
- **Step 3**—Calculate the torque. This step can be tricky. Since friction variation will cause tension variation, controlling the friction as much as possible is important. Lubricants are used to do this. They must be applied to the threaded surfaces of the bolt, the nut and under the bolt head. Many lubricants are available, and they do not all work the same. Typical brush-on, thread lubricants are not always the best choice. They are intended more for facilitating fastener removal than controlling tightening friction. One of the lubricants often used (when it is permitted) is molybdenum disulfide grease with an extreme pressure (EP) additive. This lubricant is used in this example.

  Using the steps above:

  T = (K x 0.375 x 5,000)/12

Where:
D = 0.375 (⅜-inch)
F = 5,000 pounds

Only K remains an unknown. Table 1 shows the values available. Keep in mind that K values are all best approximations. For a lubricated, un-plated steel fastener, K = 0.17.

Therefore:
T = (0.17 x 0.375 x 5000) / 12 = 27 foot pounds

SIZE	DIA.	Threads Per Inch	STRESS AREA	Grade 2	300 SS	Grade 5	B7	Grade 8	Socket Head Cap Screws
				Max	Max	Max	Max	Max	Max
	INCHES		SQ INCH	LOAD LBS	LOAD LBS	LOAD LBS	LOAD LBS	LOAD LBS	LOAD LBS
1/4	0.2500	28	0.0364	1886	1638	3058	3185	3822	4586
	0.2500	20	0.0318	1647	1431	2671	2783	3339	4007
5/16	0.3125	24	0.0580	3004	2610	4872	5075	6090	7308
	0.3125	18	0.0524	2714	2358	4402	4585	5502	6602
3/8	0.3750	24	0.0878	4548	3951	7375	7683	9219	11063
	0.3750	16	0.0775	4015	3488	6510	6781	8138	9765
7/16	0.4375	20	0.1187	6149	5342	9971	10386	12464	14956
	0.4375	14	0.1063	5506	4784	8929	9301	11162	13394
1/2	0.5000	20	0.1599	8283	7196	13432	13991	16790	20147
	0.5000	13	0.1419	7350	6386	11920	12416	14900	17879
9/16	0.5625	18	0.2030	10515	9135	17052	17763	21315	24157
	0.5625	12	0.1820	9428	8190	15288	15925	19110	21658
5/8	0.6250	18	0.2560	13261	11520	21504	22400	26880	30464
	0.6250	11	0.2260	11707	10170	18984	19775	23730	26894
3/4	0.7500	16	0.3730	19321	16785	31332	32638	39165	44387
	0.7500	10	0.3340	17301	15030	28056	29225	35070	39746
7/8	0.8750	14	0.5090	26366	22905	42756	44538	53445	60571
	0.8750	9	0.4620	23932	20790	38808	40425	48510	54978
1	1.0000	14	0.6800	35224	30600	57120	59500	71400	80920
	1.0000	12	0.6630	34343	29835	55692	58013	69615	78897
	1.0000	8	0.6060	31391	27270	50904	53025	63630	72114
1 1/8	1.1250	12	0.8560	44341	38520	71904	74900	89880	101864
	1.1250	7	0.7630	39523	34335	64092	66763	80115	90797
1 1/4	1.2500	12	1.0730	55581	48285	90132	93888	112665	127687
	1.2500	7	0.9690	50194	43605	81396	84788	101745	115311
Chart calculated based on industry standards (ISO, IFI, ASTM etc.)									

Table 2. Bolt specifications – U.S. customary units

OTHER CONSIDERATIONS

Using the methods described so far, end users will know how much torque to apply, but they have more to consider. As they tighten the fasteners, each fastener's load affects the others as each is tightened. To help ensure uniform loading on all the fasteners, they must be brought up evenly by tightening in stages and in a staggered manner.

Historically, the star pattern has been used for the tightening sequence. ASME PCC-1-2010 describes this procedure in detail as the Legacy Tightening Sequence/Pattern.

As a brief overview, take each fastener to 25 percent, 50 percent, 75 percent and finally 100 percent of the required torque. In the example using the lubricated, un-plated fastener, the end users would take each fastener to 7 (6.75 calculated), 14 (13.7 calculated), 20 (20.25 calculated) and finally, to 27 foot pounds.

CONCLUSIONS

Proper fastener loading depends on friction control. For torque to provide predictable and repeatable loading, friction must also be predictable and repeatable. Fastener lubrication is one of the most effective ways to accomplish this. Keep in mind that other factors can affect friction—such as corrosion and re-used components. The best practice for critical applications is to use only new, clean and lubricated fasteners and to calculate the torque using the information and formulas described in this article and described in more detail in ASME Standard PCC-1-2010. **P&S**

NEXT MONTH:

What should I do about flange face damage: accept, repair or replace?

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Metric Course

NOMINAL SIZE AND THREAD	DEC.	PITCH	STRESS AREA	METRIC 5.8	METRIC 8.8	METRIC 9.8	METRIC 10.9
				Max	Max	Max	Max
	EQUIV.		SQ INCH	Load Lbs	Load Lbs	Load Lbs	Load Lbs
M5	0.197	0.75	0.022	4634	7394	8021	9268
M5	0.197	0.5	0.025	4090	6526	7080	8181
M6	0.236	1.00	0.031	6265	9996	10843	12530
M6	0.236	0.75	0.035	5611	8952	9711	11221
M8	0.315	1.25	0.057	8440	13465	14607	16879
M8	0.315	1.00	0.061	7489	11949	12963	14979
M10	0.394	1.5	0.09	10714	17095	18544	21429
M10	0.394	1.25	0.095	9606	15326	16626	19212
M12	0.472	1.75	0.131	13512	21558	23386	27023
M12	0.472	1.25	0.143	11928	19031	20645	23857
M14	0.551	2.0	0.178	19687	31410	34074	39374
M14	0.551	1.5	0.194	17629	28126	30511	35257
M16	0.63	2.0	0.243	26865	42863	46497	53730
M16	0.63	1.5	0.259	24384	38905	42204	48769
M20	0.787	2.5	0.38	35890	57263	62118	71781
M20	0.787	1.5	0.422	34993	55831	60565	69986
M22	0.8661	2.5	0.447	31985	51031	55358	63969
M24	0.945	3.0	0.547	45180	72084	78196	90359
M24	0.945	2.0	0.595	40271	64252	69700	80542
M27	1.063	3.0	0.711	56633	90357	98019	113266
M30	1.1811	3.5	0.87	51144	81599	88518	102288

Chart calculated based on industry standards (ISO, IFI, ASTM etc.)

Table 3. Bolt specifications – SI units

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