# What is the Proper Torque to Use on a Given Bolt?

By Joe Greenslade

"What torque should I use to tighten my bolts?" is a question suppliers of bolts are frequently asked by end user customers. Many times I have been asked if a chart is published on the recommended tightening torque for various bolt grades and sizes. I do not know of any. This article provides such a chart for "Initial Target Tightening Torque." See Figure 1. The formula for generating these values is explained below.

The widely recognized engineering formula, T= K x D x P (to be explained later in this article), was used to provide the chart's values, but it must be understood that every bolted joint is unique and the optimum tightening torque should be determined for each application by careful experimentation .

A properly tightened bolt is one that is stretched such that it acts like a very ridged spring pulling mating surfaces together. The rotation of a bolt (torque) at some point causes it to stretch (tension). Several factors affect how much tension occurs when a given amount of tightening torque is applied.

The first factor is the bolt's diameter. It takes more force to tighten a 3/4-10 bolt than to tighten a 3/8-16 bolt because it is larger in diameter. The second factor is the bolt's grade. It takes more force to stretch an SAE Grade 8 bolt than it does to stretch an SAE Grade 5 bolt because of the greater material strength. The third factor is the coefficient of friction, frequently referred to as the "nut factor." The value of this factor indicates that harder, smoother, and/or slicker bolting surfaces, such as threads and bearing surfaces, require less rotational force (torque) to stretch (tension) a bolt than do softer, rougher, and stickier surfaces.

The basic formula T = K x D x P stated earlier takes these factors into account and provides users with a starting point for establishing an initial target tightening torque.

- T = target tighten torque (the result of this formula is in inch pounds, dividing by 12 yields foot pounds)
- K = coefficient of friction (nut factor), always an estimation in this formula
- D = bolt's nominal diameter in inches
- P = bolt's desired tensile load in pounds (generally 75% of yield strength)

The reason all applications should be evaluated to determine the optimum tightening torque is that the K factor in this formula is always an estimate. The most commonly used bolting K factors are 0.20 for plain finished bolts, 0.22 for zinc plated bolts, and 0.10 for waxed or highly lubricated bolts.

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| Thread Size | Tensile Stress Area TSA | SAE Grade 2 75% Yield Strength (PSI) = 43000 | | | SAE Grade 5 75% Yield Strength (PSI) = 69000 | | | SAE Grade 8 75% Yield Strength (PSI) = 98000 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Plain | Zinc Plated | Waxed | Plain | Zinc Plated | Waxed | Plain | Zinc Plated | Waxed |
| | Square Inches | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. | Ft. Lb. |
| 1/4-20. | 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 |
| 5/16-18. | 0.0524 | 12 | 13 | 6 | 19 | 21 | 9 | 27 | 29 | 13 |
| 5/16-24. | 0.0580 | 13 | 14 | 6 | 21 | 23 | 10 | 30 | 33 | 15 |
| 3/8-16. | 0.0775 | 21 | 23 | 10 | 33 | 37 | 17 | 47 | 52 | 24 |
| 3/8-24. | 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 |
| 1/2-13. | 0.1419 | 51 | 56 | 25 | 82 | 90 | 41 | 116 | 127 | 58 |
| 1/2-20. | 0.1599 | 57 | 63 | 29 | 92 | 101 | 46 | 131 | 144 | 65 |
| 9/16-12. | 0.1820 | 73 | 81 | 37 | 118 | 129 | 59 | 167 | 184 | 84 |
| 9/16-18. | 0.2030 | 82 | 90 | 41 | 131 | 144 | 66 | 186 | 205 | 93 |
| 5/8-11. | 0.2260 | 101 | 111 | 51 | 162 | 179 | 81 | 231 | 254 | 115 |
| 5/8-14. | 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 |

**Figure 1.** *Initial Target Tightening Torque. (Formula: T = K x D x P)*

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## Proper Torque

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The only way to properly determine the optimum tightening torque for a given application is to simulate the exact application. This should be done with a tension indicating device of some type on the bolt in the application. The bolt is tightened until the desired P (load) is indicated by the tension indicating device. The tightening torque required to achieve the desired tension is the actual tightening torque that should be used for that given application.

It is extremely important to realize that this tightening value is valid only so long as all of the aspects of the application remain constant. Bolt suppliers sometimes have customers say that their bolts are no good because they have started breaking while being installed. Thorough investigation commonly reveals that the customer has started lubricating the bolts to make assembly easier, but maintained to same torque as was used when the were plain finished.

The table in this article shows that by using this formula a 1/2-13 Grade 5 plain bolt should be tightened to 82 foot pounds, but the same bolt that is waxed only requires 41 foot pounds to tighten the same tension. A perfect 1/2-13 Grade 5 waxed bolt will break if it is tightened to 81 foot pounds because the K factor is drastically lower. The bolts are fine, but the application changed. Suppliers need to understand this and be able to educate their customers to resolve this common customer complaint about breaking bolts.

The chart is provided for quick reference by fastener suppliers and users for selecting an initial target tightening torque. This chart was derived by using the formula shown earlier. An example of the calculation is as follows:

Product: 3/4-10 Grade 5 zinc plated bolt
Formula: T = K x D x P

- K = 0.22 (zinc plated)
- D = .750 (3/4-10 nominal diameter)
- P = 23. 046 pounds

  Note: P = 75% of yield strength (92,000 PSI) times the tensile stress area of the thread (0.3340)

T = (.022 x .750 x 23.046) / 12 = 317 foot pounds

Hopefully the chart will help suppliers with an initial answer to the customer's question, "What torque should I use to tighten my bolts?" Keep in mind this is only an estimated value. It may provide satisfactory performance, but it also may not. Every application should be evaluated on its own to determine the optimum torque value for each application. Major bolt suppliers should have tension indicating equipment necessary to help their customers determine the appropriate tightening values for their specific applications. Keep in mind that if the lubricant on a bolt and nut combination is changed, the tightening torque value must be altered to achieve the desired amount of bolt tension. ❑

# Fastener Tightening Should Be Determined by Testing

By Joe Greenslade

Fastener suppliers are frequently asked by their customers how much torque a given part should be tightened to in their specific application. This sounds like a very simple question that should have a simple answer, but many variables in an application influence the answer. Some of these factors include:

- What is the strength of the external thread member?
- What is the hardness of the mating threads?
- What is the hardness of the material the bolt is seating on?
- What is the length of thread engagement?
- What are the finishes on the mating threads?
- Is it a rigid or gasketed joint?

Fastener suppliers frequently ask me for a chart of torque values to recommend for a given type of fastener. There are a few such charts and there is a standard formula, T=KDP, but these provide a "rule of thumb" or a "guestimate" for any given application.

A major variable in any formula used in creating torque charts is the "K" or "nut" factor. This is the factor that primarily deals with the coefficient of friction in the application. In bolting, the joining of slippery bolts and nuts requires less torque to achieve proper tightness than non-slippery parts. The "K" factors vary from .1 (very slippery) to .4 (very tacky). Unfortunately, not all references list the same "K" factors for given finishes.

## Electronic Torque-Turn-Tension Method for Establishing Tightening Values:

The best method of making specific tightening suggestions to a customer for their critical applications is to perform a series of torque-turn-tension experiments. The most thorough procedure is to use sophisticated electronic test equipment using exact application components. The leading supplier of this type of joint tightening analyzing equipment is RS Technologies of Farmington Hills, Michigan.

According to years of research conducted by Ralph Shoberg, President of RS Technologies, the way to achieve the most consistent tension in critical joints is to tightened fasteners using the Torque-Turn Strategy of tightening instead of the Torque Strategy. To discover the optimum Torque-Turn Strategy for a given joint the torque at which the joint first comes into full alignment, or rigid, must first be determined. Secondly it must be determined at what amount of fastener turn, or degrees of rotation, from that alignment torque the desired joint tension is achieved. The Torque -Turn tightening method has been the required procedure for tightening structural bolts for many years. Through Mr. Shoberg's efforts it is now gaining wide acceptance in other industries, such as automotive, in critical application like engine head bolts and connecting rod bolts.

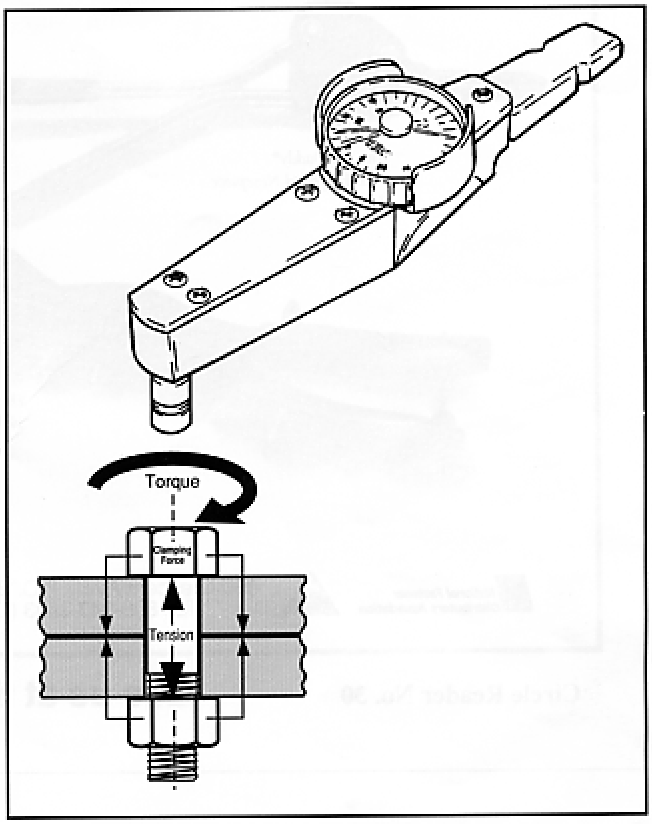


**Figure 1.** *Torque-turn tightening method.*

The testing procedure is as follows:

- The application is simulated in the machine with the exact components.
- A force measuring load cell is placed in the joint some place between the bolt head and nut, and torque is applied through an electronic torque transducer with angle encoder.
- Torque and tension values are recorded on a chart creating a torque-tension curve showing how much tension is created in the joint as progressively more torque is applied to the driven fastener.
- Turning angle and tension are recorded on another chart.
- Torque and turning angle are recorded on another chart.
- Usually the bolt or nut is driven until something in the simulated assembly fails by breaking or stripping.
- An alignment torque and turning angle

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## Fastener Tightening

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are generally recommended which corresponds to a point along the torque-tension curve where both the torque and tension are still rising together. This is before the point were the torque levels off and the tension begins to fall.

- The point at which the torque levels off, and the tension in the joint begins dropping off is the point where the components are beginning to yield or fail.
- A general rule of thumb is to tighten an assembly using an alignment torque and turning angle strategy to tighten a joint to 75% of its yield strength.

## Failure Torque Method for Establishing Seating Torque Values:

If a supplier does not have access to the kind of sophisticated test equipment described earlier, a simpler testing method can be used to establish a recommended tightening torque. This method is not as good as that described above, but it is much better than simply referring to a torque chart or formula. The procedure is as follows:

- Assemble 10 to 12 joints exactly as they are to be constructed.
- With a calibrated torque wrench, drive the fasteners in the joint to failure and record the maximum torque achieved in all joints.
- Calculate the average torque failure value for all of the tested joints.
- Multiple that average value by .6 to establish the tightening torque value for that given joint.

This method is simple to do and is illustrated to the right. The only testing equipment needed is a calibrated torque wrench with a memory needle. This method can be used for any size or type of fastener including bolts, nuts, tapping screws, and machine screws.

As stated earlier, if the sophisticated torque-turn-tension equipment is available, it should be used to gain greater insight into the dynamics of exactly what is happening in the joint at different torque levels and turning angles. If, however, this equipment is not available the simple torque wrench method is strongly recommended.

| Test # | Failure Torque (inch pounds) |
|---|---|
| 1 | 181 |
| 2 | 213 |
| 3 | 200 |
| 4 | 222 |
| 5 | 199 |
| 6 | 193 |
| 7 | 206 |
| 8 | 211 |
| 9 | 195 |
| 10 | 203 |

| | |
|---|---|
| Average Failure Torque | 202.3 inch pounds |
| Recommended Tightening Torque (203.3 x .6 =) | 120 inch pounds (rounded from 121.4 in. lbs.) |

Fastener suppliers will continue to be asked for tightening recommendations as long as fasteners are sold. Suppliers can provide a valuable service to their customers by offering to do these tests, or have them done, for their customers. Due to all of the variables effecting joint tightness in each individual application, testing by one of the methods explained above is far superior to simply pulling a number from a chart. ❑