SAE International®

SURFACE VEHICLE INFORMATION REPORT

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Torque-Tension Tightening for Inch Series Fasteners

RATIONALE

J1701 has been reaffirmed to comply with the SAE five-year review policy.

Foreword—Fundamentally, threaded fasteners are required to create a clamping force or load on the assembled joint to prevent loosening. To accomplish this, a tensile loading is applied onto a bolt or screw by itself or by a nut tightened on the bolt or screw.

The axial stress in them produces a clamping force equal to the product of the proof-load stress, reduced by a design factor, and the core area of the bolt or screw.

Although clamping or tension load can be measured by load cells and strain gauges, these methods are impractical on the production line. The most practical methods of achieving control of joint clamp load involve torque control, tightening angle control, or combinations of torque and angle. In some cases, a torque versus angle yield method is utilized, particularly when tightening 5/8 in and larger fastener sizes. But measurement and assembly equipment is sensitive. Therefore, it becomes very important to understand the relationship between torque and tension.

1. Scope—This SAE Information Report is provided as an advisory guide. Individual application discretion is recommended. The content has been presented as accurately as possible, but responsibility for its application lies with the user. The document covers the variables in the torque-tension relationship: friction, materials, temperature, humidity, fastener and mating part finishes, surfaces, and the kind of wrenching employed.

Also described in this document is the torque management required to achieve correct fastener joint tightening.

The thread fit of fasteners must be in accordance with Class 2A for external and 2B for internal inch threads.

2. References

2.1 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J174—Torque-Tension Test Procedures
SAE J995—Mechanical and Material Requirements for Steel Nuts
SAE J1648—Protective Coatings for Fasteners

3. *Explanation of Tightening Terms*

3.1 Torque is the product of force x lever arm length. It is the moment resistance of the fastener and its components to tightening, expressed in in-oz, in-lb, and ft-lb.

3.2 Turn Screw or Bolt and Turn Nut Terms describe which mating part is tightened. For turn screw, the head of the screw or bolt is turned against a panel into either a panel with a tapped thread or separate nut component.

For turn nut, the nut is threaded onto a screw or bolt and is tightened against the panel surface.

3.3 Clamping Load occurs when the screw or bolt is stretched when the fastener is tightened. It is equal and opposite to the tensile force developed in the screw or bolt and is expressed as pounds (lb).

3.4 Inertia is the tendency of a body to continue in motion after being subjected to a force in a specific direction until acted upon by an outside force. In tightening, friction between mating parts and bearing against panel or part surfaces is the major contributing outside force and has to be overcome. Inertia of the rotating power tool is another factor which must be considered.

4. *Variables in the Relationship of Clamping Load to Applied Torque*

4.1 Friction—The friction resistance torque is the most important of all of the variables. It has two components, the friction resistance of the applied nut fastener with respect to mating part threads, and the bearing surface against joint members. Increasing the clamping tension force on the screw or bolt increases the resistance to turning.

4.2 Fastener Materials—Characteristic properties of hardness and surface condition can contribute to friction variability thus affecting tightening torque to obtain the same clamping load.

4.2.1 Nonheat-treatable low-carbon stainless steels and other soft alloys cause increased friction resistance resulting in higher tightening torque for a given clamp load.

4.2.2 Hardened steel or hard alloy fasteners have a harder slippery surface reducing friction and thereby requiring lower tightening torque.

4.2.3 Special materials, rubber, plastics, etc., either as fabricated fasteners or attached to them, also affect torque if they contact the rubbing surfaces during the tightening.

4.3 Surface Conditions, such as coatings or effects of the environment applied to fasteners and bearing surfaces will affect tightening torque requirements for a given clamp load.

4.3.1 The roughness, coarseness, or abrasiveness of coatings will increase required torque.

4.3.2 Decreased friction due to the nature of the coating including oil, wax, teflon, or other lubricants will reduce required torque.

4.3.3 Interferences due to dirt, rust, burrs and galling, or seizing caused by soft coatings (zinc is an example) on fasteners, mating parts, and panels increases required torque.

4.3.4 Hardness of the fastener, its mating part, or the joint material will reduce required torque.

4.3.5 Temperature contraction, especially if the assembly tightening was made while warm, will reduce clamping load. If the fastener is at a higher temperature than the assembly, then the clamping load increases upon cooling. Adjustments to assembly torque must accommodate these conditions.

4.3.6 Humidity will cause reduced friction reducing required torque.

4.3.7 Joint relaxation can occur if joint material can deform under load and/or time. In such cases, special torque sequencing may be required.

4.4 Wrenching—The method of tightening has a profound influence on required torque.

4.4.1 The slow deliberate turning by hand wrenching allows the assembly to settle somewhat during tightening thus negating some of the effects of joint relaxation.

4.4.2 High air pressure or electric power tool fastener tightening involving rotation contribute to lower torque. The use of inertia lessens the affect of static friction, but can increase torsional loading of bolts or screws.

***5. Torque Management*—**To determine how much hand or power tool torque should be applied to a fastener assembly or how much turn-of-the-nut tightening is required, consideration must be directed to the development of these methods.

5.1 Theoretical Calculations to Obtain Torque Guide

5.1.1 Empirical Equation

$$T = KDW \quad \text{(Eq. 1)}$$

where:

T= Torque (in-lb, ft-lb)
D= Screw or bolt nominal size (in)
W= Screw or bolt tension (lb-oz)
K= Torque factor

5.1.2 The tension of the screw or bolt is calculated by multiplying the usable screw or bolt tensile strength by the tensile-stress core area of the screw or bolt. The nominal clamp load stress is assumed as 75% of proof load.

5.1.3 The torque factor is the critical parameter in Equation 1 influenced primarily by the frictional conditions along the thread flank and at the bearing surfaces.

The other influence on "K" is the relative resiliency of the fastener and joint material.

a. Therefore:

$$K = K_1 + K_2 + K_3 \quad \text{(Eq. 2)}$$

where:

K_1 represents the torque factor wasted by friction on the bearing surface of the nut or bolt, approximately 50% of the total torque factor.

K_2 factor represents the wasted friction on the contact flanks of the threads, about 40% of the total "K".

K_3 factor represents the useful torque producing the bolt tension, about 10% of the total "K".

b. K is 0.15/0.20 when bolts, nuts, and washers of the fastener joint are clean and coated with a thin film of protective oil. When dirt, rust, and other defects of field storage and environmental exposure are present, K can be 0.25/0.40. Refer to Table 1 for torque K factors for other conditions.

TABLE 1—TORQUE FACTORS FOR SURFACE CONDITIONS OF MATING FASTENERS

Mating Parts	K
Dry, clean with thin film of oil	0.15/0.20
Additional lubricating coatings of oil, wax, or dissimilar plating or hard washer	0.10/0.15
Thread and head bearing surfaces covered with high-performance lubricants or with anti-seize compounds	can be as low as 0.05
Combinations of certain materials such as Austenite stainless steel screws/bolts and parts not lubricated or coated	can be as high as 0.35

5.2 Clamp load and torque calculations based on the aforementioned formula for dry and lubricated conditions are tabulated in Table 2.

5.3 Turn-of-the-Nut Method—The previous sections dwelled on tightening torque to produce clamping tension. The turn-of-the-nut method can produce satisfactory clamping when the joint is completely closed prior to the turn movement.

Since the basis for tightening threaded fasteners is screw or bolt tension, stretching the bolt by turning the nut a number of degrees clockwise after finger or snug tight will accomplish this. The bolt stretch is the degrees turned portion of the 360 degree pitch dimension. The number of degrees turned depends upon the strength of the bolt and the joint thickness.

This document has not elaborated on the method because it is not effective unless the joint is closed under the screw/bolt head or nut. Nevertheless, turn-of-the-nut is the most practical for 5/8 in and larger sizes.

5.4 Check procedure for correct tightening torque because assembly conditions such as mismatching components and pull-up tightening occur. The calculated guide torques previously discussed may overpower the fastener or its mating part causing failure to each other or both. Therefore, the following procedure on assimilated assemblies can be a practical method of establishing installation torque.

5.4.1 First determine the torque at which any of twelve or statistically determined number of fasteners selected from the same lot or their mating parts fail when they are applied by either hand or power tool wrenching to be used in production.

5.4.2 Average the twelve individual torques. Then apply 85% safety factor and repeat the previous with a new set of twelve fasteners until no failures occur.

5.4.3 Retest a new set of fasteners on the assemblies utilizing the design factor established torque to confirm installation is satisfactory or make minor adjustments until it is so.