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TORQUE VALUES - A GUIDE TO SPECIFYING TORQUE VALUES FOR FASTENERS

Introduction

The following notes are given as a guide only. It is recommended that torque values derived from formulae should not be used without comparison to figures obtained using practical tests.

Generally, the reliability of the joint is dependent upon the bolt's ability to clamp the parts together. Adequate clamping prevents relative motion between parts of the joint and leakage from joints containing gaskets. Measuring a bolt's clamp force is difficult, especially under production assembly conditions. The preload generated by a bolt can be indirectly controlled by regulating the applied torque. This method, known as torque control, is by far the most popular method of controlling a bolt's preload. There is a relationship between the torque applied to a bolt and the resulting preload. A problem exists in that friction has a large influence on how much torque is converted into preload. Besides the torque required to stretch the bolt, torque is also required to overcome friction in the threads and under the nut face. Typically, only 10% to 15% of the torque is used to stretch the bolt. Of the remaining torque, typically 30% is dissipated in the threads and 50% to 55% under the nut face. Because friction is such an important factor in the relationship between torque and preload, variations in friction have a significant influence on the bolt's preload. Different bolt surface finishes have different friction values.

The torque required for a socket headed screw will not be the same as that required for the same size standard hexagon head bolt. The larger bearing face of the standard hexagon bolt will result in an increased torque being required compared to a socket headed screw. This is because more torque is being dissipated between the nut face and the joint surface.

Stresses induced into a bolt

When a bolt is tightened the shank and thread sustain a direct (tensile) stress due to it being stretched.

In order to effectively utilise the strength of the bolt, yet leave some margin for any loading the bolt would sustain in service, an equivalent stress of 90% of the yield stress is commonly used.

Background

The following information is provided to assist Engineers wishing to establish the theoretical torque value for a particular fastener. Caution should be exercised when using theoretical values because the preload and torque is dependent upon the friction values selected.

Terms used in the formulae below

Care should be taken to use consistent units throughout.

T Tightening torque to be applied to the fastener.

F The preload (or clamp force) in the fastener.

σ_E Equivalent stress (combined tensile and torsional stress) in the bolt thread. A figure of 90%

of the yield or proof stress of the fastener is usual.

σ_T Tensile stress in the fastener.

d2 Pitch diameter of the thread.

d3 Minor (or root) diameterof the thread.

P Pitch of the thread.

μ_T Thread friction coefficient.

μ_H Underhead coefficient of friction.

D_f The effective friction diameter of the bolt head or nut.

D_o Outside diameter of the nut bearing surface.

D_i Inside diameter of the nut bearing surface.

Calculation Procedure
The formulae used are applicable to metric and uinified thread forms which have a thread flank angle of 60°. The calculation procedure distinguishes between thread and underhead friction as well as differences which can be caused by bearing face diameter variations. The procedure comprises the following steps:

Step 1
Fastener Details. Dimensions and strength grades are specified in various standards (see download PDF - mechanical properties of fasteners below) Table 1 presents information on strength grades of bolts; the most common grade for metric fasteners is grade 8.8. Estimating the appropriate friction coefficient can be problematical. Tables 2 and 3 may be used as a guide when other information is not available. Tables 4 and 5 provide relevant information relating to thread dimensions.

Step 2
Establish the preload. The preload F is related to the direct tensile stress σT by:

$$F = A_S \times \sigma_T$$

The stress area of the thread AS represents the effective section of the thread. It is based upon the mean of the thread pitch and minor diameters. It can be obtained from tables or calculated using the formula:

$$A_S = \frac{\pi \times (d_3 + {}_2d)^2}{16}$$

Step 3
To determine the tensile stress in the fastener, first establish what proportion of the fasteners yield strength you wish to use. Normally a figure of 90% of the yield strength is acceptable but may be varied to suit the application.

The following formula can be used to determine the tensile stress in the fastener.

$$\sigma_T = \frac{\sigma_E}{\sqrt{\left[1 + 3 \times \left\{\left(\frac{4 \times d_2}{d_2 + d_3}\right) \times \left(\left[\frac{P}{\pi \times d_2}\right] + \left[1.155 \times \mu_T\right]\right)\right\}^2\right]}}$$

Step 4
As can be seen from tables 2 and 3, upper and lower limits to friction values are stated. Traditionally a mean value of friction is used when calculating the tightening torque and preload value. Be aware however, that for other conditions remaining constant, the higher the value of friction - higher is the required tightening torque and lower is the resulting preload. Determine the tightening torque. The relationship between tightening torque T and bolt preload F is:

$$T = F \times \left[(0.159 \times P) + (0.577 \times d_2 \times \mu_T) + \left(D_f \times \frac{\mu_H}{2} \right) \right]$$

If units of Newtons and millimeters are being used, T will be in N.mm. To convert to N.m, divide the value by 1000.The effective friction diameter Df can be determined using the following formula:

$$D_f = \frac{(D_o + D_i)}{2}$$

For a standard hexagon headed nut, Do is usually taken as the across flats dimension and Di as the diameter of the bolt's clearance hole.

Example calculation

As an example, the above formulae will be used to determine the preload and tightening torque for a grade 8.8 M16 hexagon headed bolt.

Step 1.

Establishing the dimensions and friction conditions. The data Establishing the dimensions and friction conditions. The data below is to be used

d_2 = 14.701mm d_3 = 13.546mm P = 2mm
μ_T Taken as 0.11 μ_H Taken as 0.16

Step 2.

Taking the stress area as 157mm^2, gives the bolt preload F to be 77087N.

Step 3.

Calculating the tensile stress in the fastener. Using 90% of 640N/mm2 gives σ_E=576N/mm2, substituting values into the formula gives σ_T = 491N/mm^2.

Step 4.

Determination of the tightening torque T

i) The effective friction diameter. Taking Do = 24mm and Di = 17.27mm gives Df = 20.6mm.

ii) Using the values calculated gives a tightening torque T of 350437Nmm, that is 350Nm.