Torque Control and Torque-Angle Control Tightening Methods

by Bill Eccles

Using torque to indirectly control a bolt's preload is by far the most popular controlled tightening method. This is due to its simplicity and its widespread understanding by all engineers. One of the central problems of using threaded fasteners for structural purposes is that it is difficult to maintain a consistent clamp force or preload. It is widely known that torque tightening can result in significant variability, however the structural integrity of many designs is based upon ensuring that a certain level of minimum preload is achieved and maintained.

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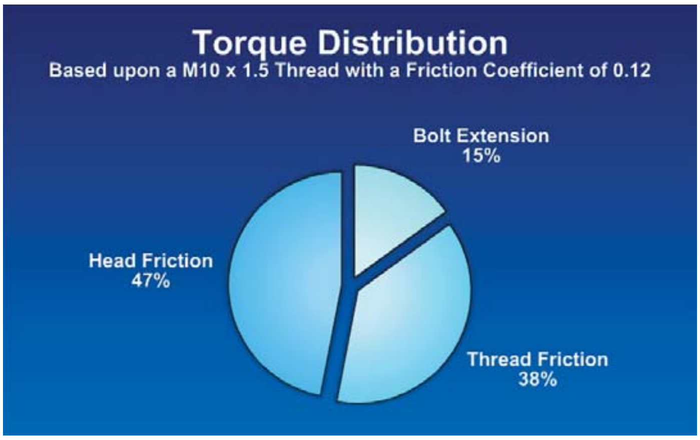
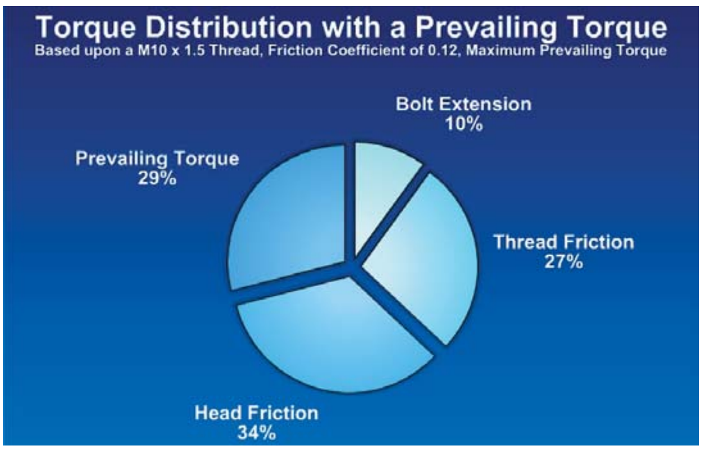


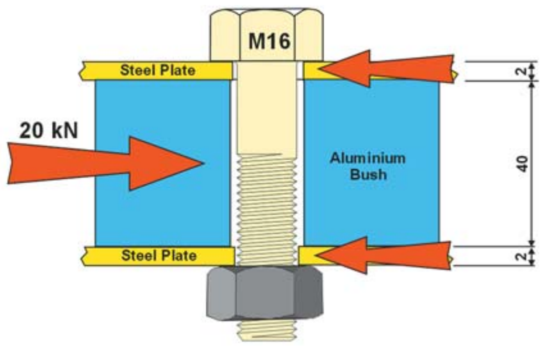
Controlling the torque that a fastener is tightened to is the most popular means of controlling preload. The nominal torque necessary to tighten the bolt to a given preload can be determined either from tables, or, by calculation using a relationship between torque and the resulting bolt tension. Friction that acts in the threads of the bolt and under the bolt head dissipates the majority of the tightening torque. For a free spinning thread, typically only about 15% of the torque is actually used to extend the fastener. The majority of the torque is used to overcome friction under the bolt head and in the threads.

When a prevailing torque nut or bolt is used (the prevailing torque is the torque needed to run a nut down a thread such as is the case when a nylon insert is used), the torque distribution is changed. With the maximum prevailing torque present the proportion of the applied torque that is actually used to extend the bolt is typically about 10%. Friction in the thread typically absorbs 29% and underhead friction 33%. Up to 29% of the torque is used to run the nut down the thread (the prevailing torque). Because of the variation in the prevailing torque, significant variation can occur in these ratios between batches of fasteners and is dependent upon the number of times the fastener is used.

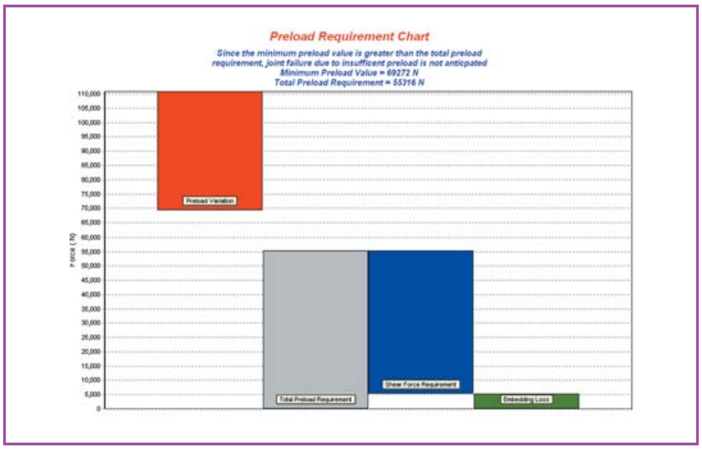


When the preload is below that required by the joint, it is frequently other elements in the assembly that apparently fail. Examples of this are when gaskets leak because of insufficient clamp load to maintain a seal, or when brackets fail because of the load transfer that can occur when bolts come loose.

Case studies are often useful in assisting understanding. The engine mounting support shown used a M16 bolt to transmit the engine loads into the structure. The loading was 20 kN and this is sustained in double shear by the steel plate supports. Torque controlled tightening was used and an analysis completed to assess if the preload provided by the bolt was sufficient to prevent the bush moving when the 20 kN load was applied.



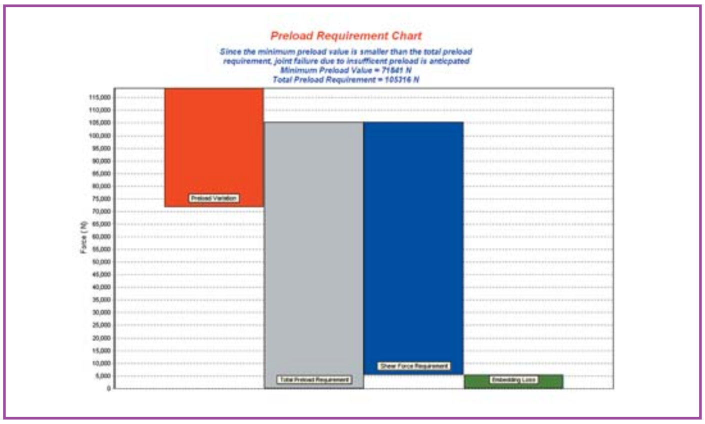
The preload requirement chart shows the variability that was expected in the bolt's preload, assuming that the torque tightening method was being used. The preload requirement inthis case consisted of two elements. Firstly, a small amount of preload was anticipated being lost as a result of embedding.



Embedding or settlement occurs in joints as the surface irregularities are flattened by the high surface stresses. Some degree of embedding is inevitable, to a greater or lesser extent, on all bolted joints. The other preload requirement was that sufficient preload should be applied so that the grip provided by friction between the plates and the bush would be sufficient to prevent any joint movement. As can be seen from the chart, the minimum anticipated preload is greater than the preload requirement. What this means is that it is anticipated that even under the worst conditions, no joint movement and hence, no failures are predicted.

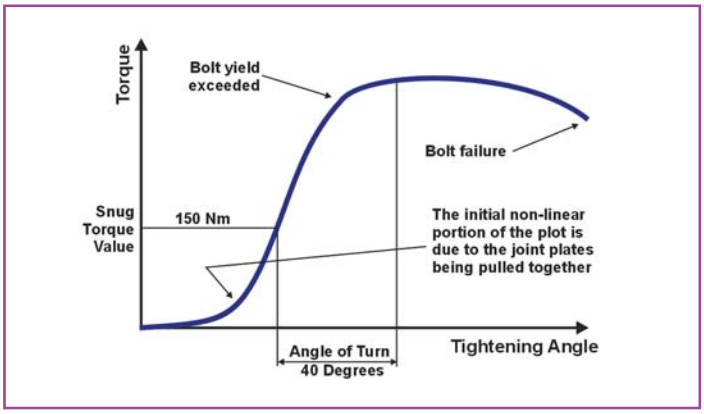
If the bush was allowed to move relative to the plates, when loading was applied or it changed, it is likely that the nut would self-loosen. Even if a reliable locking means was used, fretting of the surfaces that occurs under such relative movement would lead to preload loss and the bolt sustaining bending that would likely lead to fatigue failure. Hence the strong desirability that even under the worse anticipated conditions, there would be sufficient preload present from the bolt to prevent any joint movement.

Subsequent to the joint design being finalised, a decision was taken to increase the engine performance and make other changes that resulted in the loading that was being applied to the bush doubling from 20 kN to 40 kN. The preload requirement chart for this condition, using torque tightening, is shown. As can be seen, in this new case the preload requirement exceeds the minimum preload condition. What this means is that a proportion of the product would be anticipated to fail since the bolt would not provide, in all situations, sufficient friction grip to prevent the bush from moving. It is known that transverse

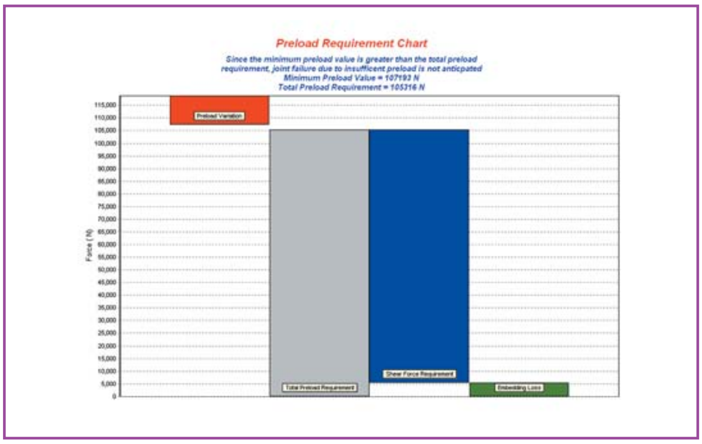


movement of the joint is the major cause of self-loosening of fasteners. Even if the nut was locked onto the thread using a chemical adhesive, the movement would result in the bolt bending leading to fatigue problems.

A re-design in such a situation would normally be done to increase the size of the bolt. However in this case, space constraints restricted such a design change. To reduce the large scatter that is present due to the tightening process, another tightening method was assessed. The torque-angle tightening method is known to give a consistently high preload but does involve more care and consideration on the tightening process



With the torque-angle tightening method an initial tightening torque is specified that is typically about 50% of the torque that would induce yield into the thread. This torque is called the snug torque and its purpose is to pull (or 'snug') the plates of the joint into metal to metal contact. Because the flatness of plates vary, if just a tightening angle is specified then it has been found that the process is less accurate. In the case of the M16 assembly, a snug torque of 150 Nm was specified followed by an angle of turn of 40 degrees. Specifying an angle of turn is equivalent to specifying an extension or stretch of the bolt (since one turn is equivalent to extending the bolt a complete thread pitch). In this application, the 40 degree equates to extending the bolt 0.22 mm. The angle of turn was determined so that the bolt would go into yield but not break. By pushing the bolt into yield the large variation in preload that occurs as a result of friction variation is largely eliminated.



The preload requirement chart with the torque-angle tightening method specified indicates that the minimum preload is now greater than that which is required to prevent joint movement. Hence a satisfactory life is anticipated from the joint without having to increase the size or strength of the bolt. If torque controlled tightening was used in this application and allowance was made from the preload variation from friction scatter, then a M20 bolt would have been required. It is for this reason that the torque-angle tightening method is becoming more popular amongst OEM companies.