A case study in torque-angle tightening

Bill Eccles – Bolt Science

Because of space restraints, a manufacturer of construction equipment found that it was not possible to achieve the performance requirements for a high performance joint by using torque tightening. The joint shown in figure 1, consists of two steel outer members sandwiching an aluminium beam that are clamped together with a M12 flanged headed nut and bolt.

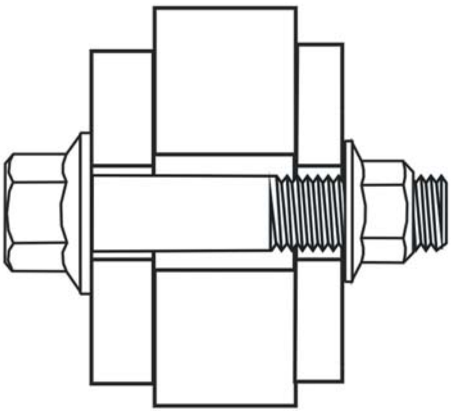


Figure 1 - Section through the joint

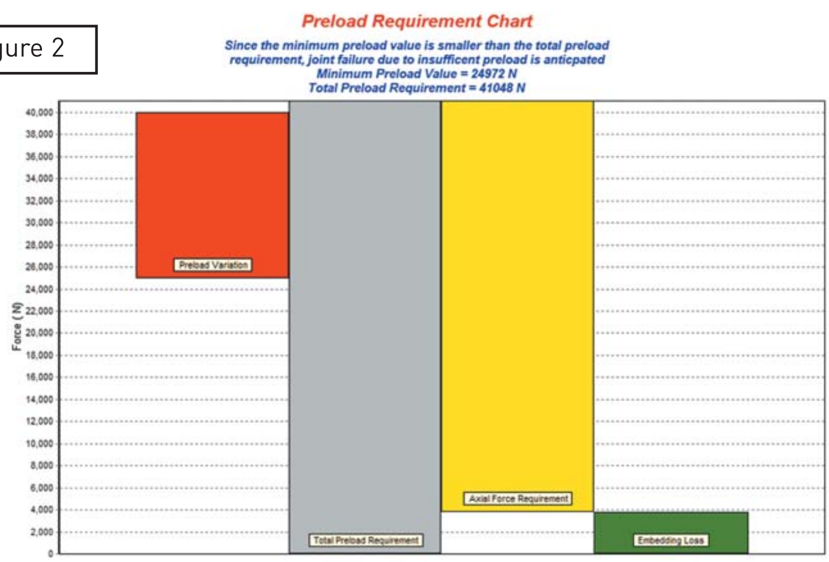
Based upon an analysis of the forces acting on the joint, an axial force of 40 kN was acting which, when embedding loss was accounted for, meant that at least 41 kN clamp force was required. A minimum clamp force requirement for the joint was 50 kN to provide a safety factor. Following a series of tests it was established that the clamp force scatter achieved by torque tightening was between 25 kN and 40 kN. A chart illustrating this is shown in figure 2 below.

To the manufacturer it was essential that the assembly could be tightened without the need for exotic tightening control tooling since servicing would be performed using standard garage equipment. Based upon advice, the manufacturer decided to investigate if the torque-angle tightening method could meet the requirements. With the torque-angle tightening method an initial tightening torque is specified, known as a snug torque (whose purpose is to pull - or 'snug' - the plates of the joint into metal to metal contact). An angle of turn is then specified for the bolt/nut to be rotated through. The angle of rotation should be such that yield is induced into the bolt virtually eliminating the clamp force scatter as a result of friction. A standard torque wrench can be used to apply the snug torque and a simple angle meter on the wrench used to measure the angle of turn of the nut.

A series of tests were conducted to investigate the torque angle properties of the joint. A typical set of results from 5 bolts is shown in figure 3. What can be surprising, at first sight, is how much stretch you can get from a typical bolt before it breaks.

In order to decide what the torque-angle specification should be a torque-angle graph is usually needed. A typical graph from the study is shown in figure 4. The point at which the graph goes away from the straight line is an indicator that yield has occurred. In the particular case shown in the graph, it indicates that yield occurred at about 200 degrees of rotation. Because unevenness of the plates can affect the angle of rotation, the snug torque is needed to pull the plates together. Using information provided by the graphs, it was decided to specify that 15 Nm snug torque was required followed by a nut rotation of 180 degrees. Specifying 180 degrees of rotation should make it easier when being assembled in a

Figure 2



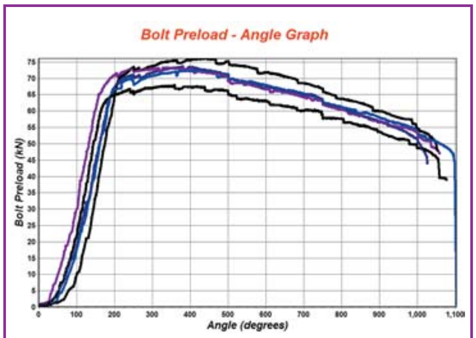


Figure 3

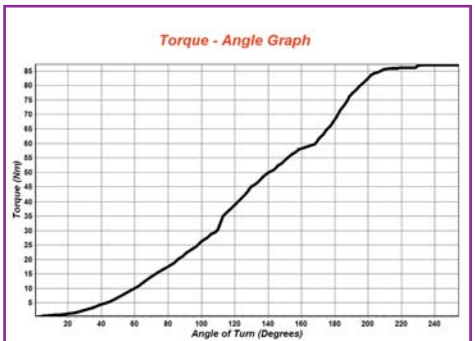


Figure 4

garage, i.e. 15 Nm then half a turn of the nut.

The joint needed to be untightened for servicing reasons typically on an annual basis. It was requested that checks be made to investigate what the effects of re-using the bolt would have on the joint's performance. Figure 5 shows the same bolt

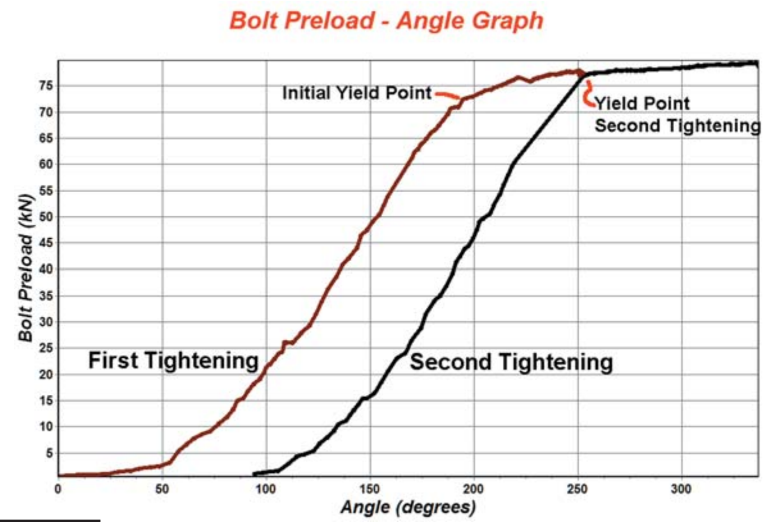


Figure 5

tightened twice to the torque-angle specification. The second curve has been moved along the x axis for illustration purposes. The chart shows an interesting characteristic of re-tightening bolts into the plastic zone. The yield strength on the second tightening is higher than that on the first tightening. Stressing a ductile material past its yield point in tension will raise the yield strength in the next cycle. This phenomenum is know as the Bauschinger effect and it is one of the reasons why a bolt tightened past its yield point will act elastically when loading is subsequently applied to the joint. Upon the completion of the tightening process some relaxation will occur (from embedding and the reduction in the torque locked in the bolt shank) reducing the stress present in the bolt. When loading is applied to the joint, the small stress increase in the bolt will typically be lower than the new yield point formed due to the Bauschinger effect when it was tightened.

In this application, a test was completed in which the same bolt was tightened several times to the torque-angle specification i.e. 15 Nm followed by 180 degrees rotation. Figure 6 illustrates the results of this test. The bolt failed at the end of the tenth application of the angle of turn. In this graph the curves have been successively moved along the x axis so that each can be compared with its predecessor. As can be seen, the ten graphs together are similar in shape to the torque-angle curve shown in figure 3.

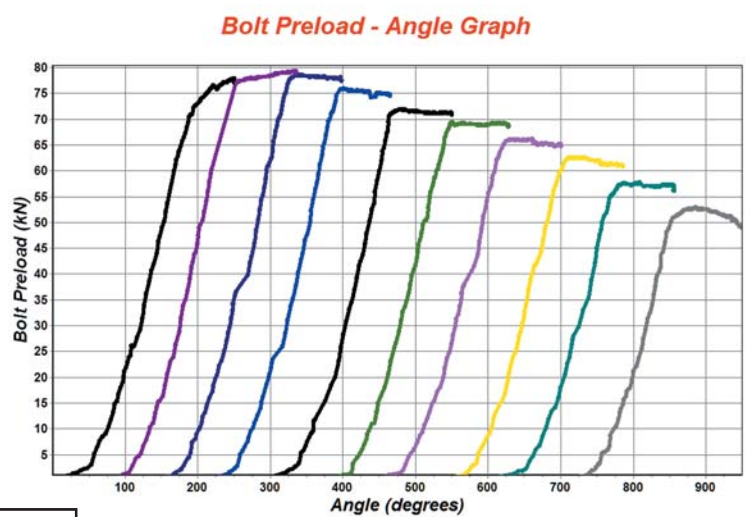


Figure 6

Since it was necessary to have at least 50 kN present in the bolt for this application it was obviously undesireable to allow the bolt to be re-tightened 10 times. To provide some reserve on the elongation, it was decided that the bolt could be used for up to 5 re-tightenings. Based upon this test a minimum of 70 kN clamp force would be provided by the torque-angle method, which, even when allowing for scatter in the material strength, is significantly higher than the 50 kN required in this application.

For critical applications, the torque-angle method of tightening bolts provides a way of achieving the maximum clamp force in a joint and is often the way forward when torque control proves to be inadequate.

If you have any questions on torque-angle tightening, Bill can be contacted via email at bill@boltscience.com or by phone on 01257 411503.

Bill Eccles is a Chartered Engineer and formed his company Bolt Science some 12 years ago to specialise in bolting technology. The company writes and markets bolted joint analysis software together with completing consultancy assignments and training courses. Further information is available from Bill via email (bill@boltscience.com) or from the website at www.boltscience.co.uk.