



Engineering Bulletin 024

RE: Use Turn-of-Nut for Accurate Pre-Loading of Bolted Joints

Don't Fall Apart on Me

There are two kinds of bolted joints used in the assembly of metal structures: a tension joint where the applied load works to pull apart the layers being bolted and shear joint where the applied force is across the bolt, working to slide the layers along one another. For both joint types, knowing how much to tighten the fastener is critical to meet the design goals for the structure. There are several methods that people use to estimate how tight is tight enough, but the gold-standard method is called “turn-of-nut”, and it turns out to be the only practical, reliable method to ensure that the bolted joint will perform as intended.

Secure Bolted Joints Depend on Accurate Preload

In many bolted joints, the load that is applied to the joint fluctuates: on a tension joint, think of the wind on a tall steel lamppost that is bolted to a concrete pier, and for a shear joint, think of the joint that holds the wings on an airplane responding to the changing loads in flight. These unstable loads cause a fluctuating stress on the bolt in the joint, and this in turn can lead to fatigue failure of the bolt. For several reasons, fatigue failure is a difficult condition to include in a design but fortunately the amount of fluctuating stress on the bolt (and hence the high fatigue environment) can be significantly reduced by “preloading” the joint. The joint is preloaded when the nut is turned so much that the bolt is literally stretched (lengthened) and the layers of material being bolted are compressed between the bolt head and nut. The counter-intuitive attribute about a preloaded joint is that the applied fluctuating load is balanced (or “taken up”) mostly by the compressive force in the layers of material in the joint, rather than only by the bolt. In fact, when the material stiffness of the layers is much stiffer than the bolt material, the fluctuating stress on the bolt can be a small fraction of the preload stress – and thus the risk of fatigue failure in the bolt is greatly reduced. When there is no preload (the joint is loose), the bolt carries the entire fluctuating load on the structure and the risk of failure at the bolt is high.

The minimum preload of a bolted joint is 75% of the bolt's rated strength. In many cases the bolt preload can be as high as 90% or even high enough to cause plastic deformation of the bolt! For this reason, an accurate method for an assembler to gauge the preload is critical. Since a threaded bolt is an inclined plane wrapped around a rod, and a nut being turned on the thread is climbing the inclined plane, it's a matter of simple geometry to design for the forces on the bolt and on the layers of material being squeezed between the bolt head and nut. It is for this reason that

observing how far the nut is turned after the joint is snug-tight is the best way to be assured of a correct joint preload.

How to Properly Ensure Bolt Preload

The Turn-of-Nut method to ensure bolt preload is as follows:

- First snug the joint by tightening each bolt of the joint in small increments to draw the plies into firm contact with each other. This is called the snug-tight condition.
- To guide the assembler to meet the proper amount of preload, the nuts and bolts must be match-marked. Using a suitable marking tool, start at the center of the bolt and draw a line across the end of the bolt, down the thread, and across the nut. This shows where the nut started at the snug-tight condition.
- Follow assembly instructions or refer to the table below to find the appropriate fraction of a full turn the nut needs to be tightened.
- Turn the nut to meet the specification. It is allowable to inadvertently turn the nut too far, but not allowable to loosen it. If the joint requires rework, the fastener assembly must be replaced.

Bolt Length	Disposition of Outer Faces of Bolted Parts		
	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis, Other Sloped Not More Than 1:20	Both Faces Sloped Not More Than 1:20 from Normal to Bolt Axis
Not more than $4d_b$	$\frac{1}{3}$ turn	$\frac{1}{2}$ turn	$\frac{2}{3}$ turn
More than $4d_b$ but not more than $8d_b$	$\frac{1}{2}$ turn	$\frac{2}{3}$ turn	$\frac{5}{8}$ turn
More than $8d_b$ but not more than $12d_b$	$\frac{2}{3}$ turn	$\frac{5}{8}$ turn	1 turn

What If My Snug-tight Is Different From Someone Else's?

Using the Turn-of-Nut method to accurately assemble a joint with the proper preload depends on what level of tightness the assembler refers to as “zero”, beyond which the nut is turned the required amount to reach the specified preload. The Building Code specifies “snug-tight” as follows:

The joint condition in which the plies have been brought into firm contact and each bolting assembly has at least the tightness attained with either a few impacts of an impact wrench, resistance to a suitable non-impacting wrench, or the full effort of an ironworker using an ordinary spud wrench.

However, the difference in tension on the bolt between various people's "snug-tight" is a small fraction of the preload, so the person-to-person variation in snug-tight shouldn't concern the assembler.

Why Shouldn't I Use a Torque Wrench to Determine Preload?

To some, it might seem as though a torque wrench would also be a good way to determine the preload – but for several reasons it isn't. A torque wrench measures only the amount of torque that is applied to the bolt head or nut, and many factors other than the stretching of the bolt can affect how much torque is needed to drive the nut up the inclined plane of the bolt thread. The friction between the sliding surfaces of the nut and the bolt can be affected by lubricant, any plating on the bolt or nut, any grit on the bolt or nut, and even a relative temperature difference between the two could change how much torque is needed to advance the nut up the thread of the bolt. Clearly then, a torque wrench does not give an assembler much of an accurate indication of the preload – or put another way, how far the nut has turned on the bolt. In fact, measurements of the accuracy of various methods for obtaining a target preload shows torque wrenches to be the worst – as bad as an error of $\pm 35\%$!

The Dangers of Using an Impact Wrench

Impact wrenches are great tools to loosen a bolt or nut and to create the snug-tight condition when used carefully. However, these tools provide a wildly variable amount of torque and so like a torque wrench, do not give the installer accurate feedback about the preload on the joint. These tools are not an acceptable way to preload a bolted joint.

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