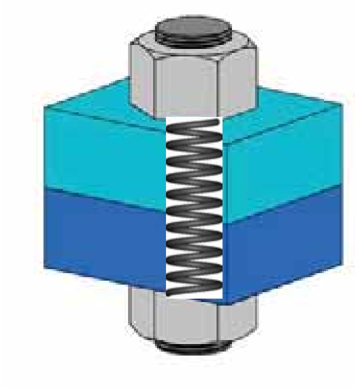
GREAT LAKES HYDRAULICS LLC
PNEUMATIC AND HYDRAULIC BOLTING EQUIPMENT

Understanding Torque and Tension

- ## The Basics of a Bolted Joint

- **A Bolt is a mechanism for creating clamping force on a joint**
- **This clamping force is used to overcome separation forces on the joint (e.g. from pressure or axial loads)**
- **The clamping force is created by placing the bolt in tension**



- **A bolt effectively behaves as a spring**
- **This is explained by Hooke's Law**
- **Force is proportional to extension**
- **We can express this relationship in terms of applied stress and strain**
- **The ratio of stress and strain is a constant for a given material**
- **This constant is known as Young's Modulus**

$$YoungsModulus = \frac{Stress}{Strain}$$

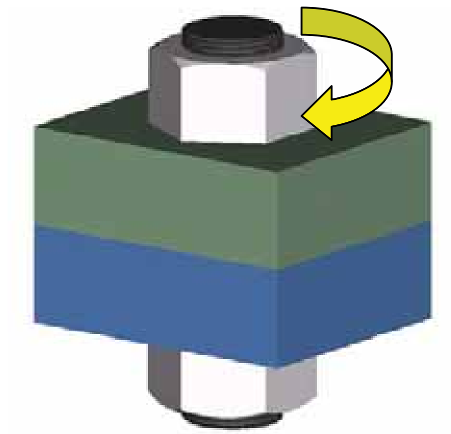
- **Therefore stretching a bolt by a known a amount will induce a known amount of load in the bolt and thus a known clamping force**

FORCE = Young's Modulus x Area x Strain

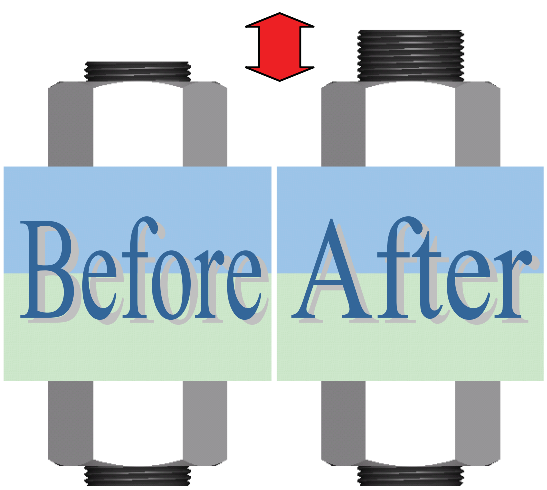
920-452-0095
708-205-1907

GREAT LAKES HYDRAULICS LLC
PNEUMATIC AND HYDRAULIC BOLTING EQUIPMENT

- **What happens when torque is applied to a nut?**



- **When torque is applied to a nut it is turned down against the flange face**
- **As the nut is continued to be turned, the stud or bolt then starts to stretch or elongate**
- **As we have seen this stretch equates to a bolt load**
- **Therefore we TURN the nut in order to STRETCH the bolt**
- **When torque is applied to a nut, frictional forces must be overcome between the mating thread, and between the flange and face of the nut**



- **Overcoming these frictional forces will typically account for 90% of the work done on the nut**
- **So from the torque that is applied only a small percentage is transferred into useful, required bolt load**
- **Since so much of the applied torque is lost due to friction it can be seen that small differences in the coefficient of friction will have massive effects on the actual obtained bolt load**

920-452-0095
708-205-1907

GREAT LAKES HYDRAULICS LLC
PNEUMATIC AND HYDRAULIC BOLTING EQUIPMENT

• Calculating Load and Applied Torque

- **A number of equations have been derived to explain the relationship between Torque and Load. Here is a common one used:**

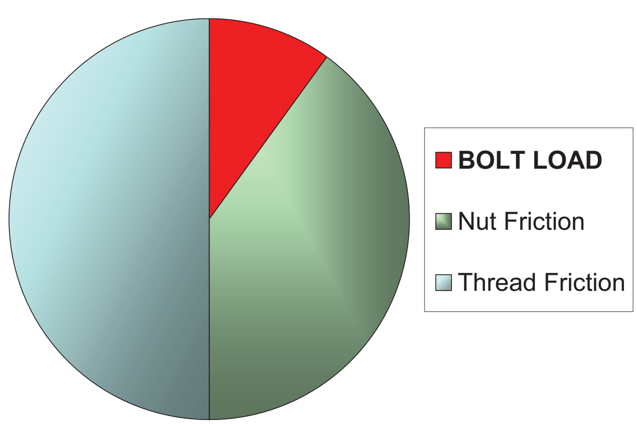
$$T_{in} = F_P\left(\frac{P}{2\pi} + \frac{\mu_r r_t}{\cos\beta} + \mu_n r_n\right)$$

where: T_{in} = torque supplied to the fastener
F_P = load created in the fastener
P = thread pitch
μ_t = coefficient of friction between nut and bolt threads
r_t = effective contact radius of the threads
β = half angle of the threads
μ_n = coefficient of friction between the face of the nut and the joint surface
r_n = effective radius of contact between the nut and joint surface

- **It can be seen that the input torque is broken down into three reaction torques**

$F_P \frac{P}{2\pi}$	**This is produced by the reaction on the angled plane of the nut and bolt threads. This is the torque component of useful bolt load**
$F_P \frac{\mu_r r_t}{\cos\beta}$	**This component is a reaction torque due to friction between bolt and nut threads**
$F_P \mu_n r_n$	**This is the reaction torque due to friction between nut and joint face**

- **Most of the input torque is lost in frictional effects**



920-452-0095
708-205-1907

GREAT LAKES HYDRAULICS LLC
PNEUMATIC AND HYDRAULIC BOLTING EQUIPMENT

- **The Inaccuracy of Using Torque**

- **As we have seen only a small proportion of the input torque is retained as useful bolt load.**

- **This in itself would not appear to matter as long as the correct bolt load is reached, regardless of what frictional losses occur**

- **But that is the problem – ensuring the correct bolt load is reached**

- **The frictional reactions from the input torque are much more significant than the bolt load, therefore small changes in the frictional effects have a much larger percentage effect on the retained bolt load**

An Example - Consider a typical bolted assembly

When the nut is tightened frictional effects take approximately 90% of the applied torque, 10% is retained as bolt load.

The same bolt is tightened, perhaps this time the bolt is older and the surface finish has deteriorated, perhaps a different amount of lubricant was applied. The end result is the same – the coefficient of friction has changed.

This time more of the applied torque is therefore taken by frictional effects.

Even if this change is small, say 4%, then the percentage change on retained bolt load is proportionally larger.

Frictional Effects:	**90%**	⇒	**94%**
Bolt Load:	**10%**	⇒	**6%**

Percentage difference in bolt load = 40%

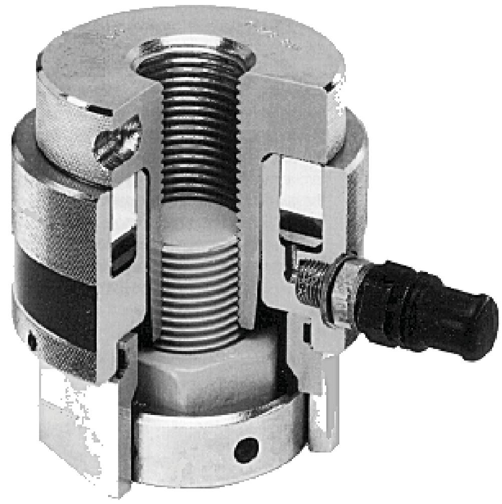
- **With careful control of many aspects of a bolted assembly the variation in bolt load through torqueing can be reduced**

- **But, as shown, large differences will always be present**

920-452-0095
708-205-1907

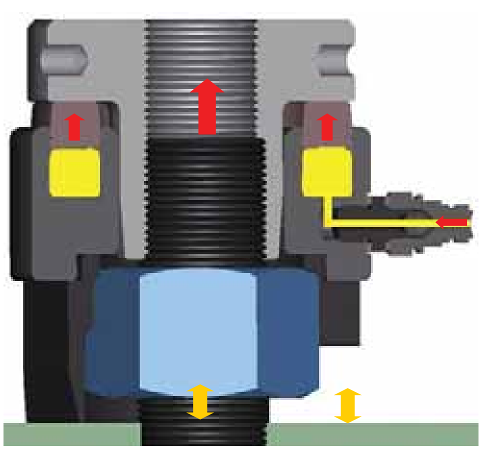
- The Torque method is fundamentally inaccurate

The Hydraulic Tensioner

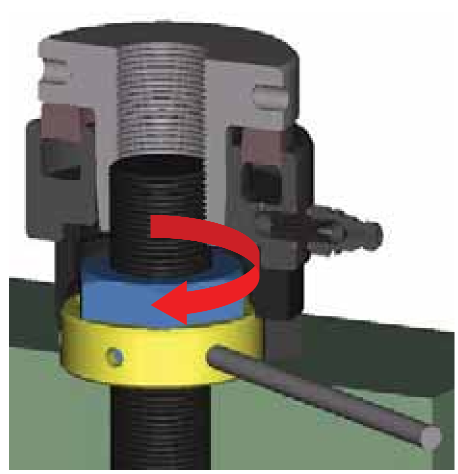


- The principle and operation of a hydraulic tensioner is simple
- A Tensioner is basically a hydraulic jack, with a threaded insert to attach to the bolt
- High pressure hydraulic are used to axially stretch the bolt by the exact amount required
- The nut will now be clear of the flange surface (by however much the bolt has been stretched by)
- An access window allows the nut to be turned down manually (normally a socket is placed around the nut, and this is turned using a metal pin)
- The pressure is then released from the tensioner. Because the nut has been turned down back onto the joint surface the stretch in the bolt is retained

1. STRETCH THE BOLT



2. TURN DOWN THE NUT



- **Tensioning Accuracy**

- **As we have seen when we tighten bolts what we are actually doing is stretching the bolt. We are putting TENSION in the bolt**

- **The disadvantage and inacuracy of traditional torque tightening is that the useful tension is achieved indirectly, after overcoming large and variable frictional effects**

- **With the tensioning method the immediate advatage is that we use TENSION directly to stretch the bolt. When the nut is turned down to retain the load, it is done so in an unloaded condition, therefore we do not need to fight against friction**

- **The applied load onto the bolt will be directly proportional to the pressure applied to the hydraulic bolt tensioner. Therefore the load is controlled very accurately**

- **When the pressure is released from the tensioner, the load is transferred to the nut. When this happens some of the applied load is taken by bending effects between the now loaded threads of the nut and stud interface**

- **Unlike the losses caused by friction in the torque method, the load transfer factor in the tensioning method is a much smaller proportion (typically 20% or less)**

- **The load transfer factor is calculable, allowing the factor to be built in to the initial applied load to give the correct residual load**

- **So the tensioning method is considerably more accurate than the torque method**

- **Not only is it more accurate it is also more repeatable. Since a much smaller amount of losses are incurred in the tensioning method (20% compared to 90%), any variations in conditions between different joint assemblies will have a much smaller percentage effect on retained load**

- ## Other Benefits Of Bolt Tensioning

- **Besides being the most accurate and repeatable method for bolt tightening the are several other advantages:**

  1. **Torque tightening can lead to galling problems. This is not a problem with tensioning as the nut is turned down in an unloaded condition**

  2. **Bolt tensioning is proving to be the fastest method of tightening, particularly with the improved accuracy reducing time required to retighten incorrectly loaded bolts**

  3. **Several tensioners can be linked together on the same hydraulic harness, allowing simultaneous tightening of a number of bolts. This offers the advantage of saving time, and also giving a better, more uniform joint**

  4. **The bolt tensioning method used in conjunction with modern elongation measurement techniques (e.g. ultrasonics) offers unparrelled load accuracy, speed and opportunities for automated, 'intelligent' tightening systems**

920-452-0095
708-205-1907