

## Bolts and Tightening

There is a lot of confusion amongst bolt suppliers and those using them as to what the different grades mean. In actual fact grades are used to define imperial bolts and metric bolts come in classes. The confusion is not helped by the NZ steel code also getting it wrong. The table below compares four commonly available bolt types in NZ.

<b>Metric</b>	<b>Imperial</b>	<b>Proof load PSI</b>	<b>Proof load MPa</b>
Class 4.6	Grade 2	32600	225
Class 8.8	Grade 5	87000	600
Class 10.9	Grade 8	120400	830
Class 12.9	High Strength	140700	970

**Bolt Class and Grades**

The proof load is the maximum working load of the bolt which is at an acceptable level below the yield point, for a class 12.9 it normally 90% of yield and for 10.9 and under a figure of 60% of yield is normally used.

The class numbers tell you the strength of the bolt in question. A 12.9 has an ultimate tensile strength of 1200MPa and a yield strength 90% of ultimate.

It's easy to see where the confusion comes from as the numbers don't match between metric and imperial. An aircraft bolt is equivalent to a Class 10.9 or Grade 8. Grade 8 is not to be confused with class 8.8, this bolt is clearly not as strong. Aircraft bolts are made to a very high standard and must be able to bend 180 degrees around a radius equal to their diameter.

Metric bolts are supposed to be made to a high standard but it is much harder to track their pedigree as they are mostly made in China. I have been told that if you ask for a bolt to be made and marked 8.8 that is what you will get, i.e. a bolt "marked" 8.8, but the material may not be 8.8 so it may be necessary to test a bolt before use. Of course if you asked for a bolt to be made to 8.8 standard you should get just that. Cap screws are almost always class 12.9 or grade high strength but not always so care needs to be taken when acquiring them.

Another misconception is that commercial bolts have their threads cut as opposed to rolled in aircraft bolts, in fact all bolts have their threads rolled. The reason for this is it is quicker to roll threads than to cut them, it also reduces waste and so makes them cheaper to make. A by product of rolled threads is the grain follows the surface of the threads and so makes the thread more resistant to shearing under load.

The next problem with bolts is how to torque them to the correct tension. A bolt used in any situation where the bolt is under tension to hold two components together must be tensioned correctly. (eg flange joint) A bolt in this situation must have the proper preload applied, if not it may come loose and if it is to hold a shear load will break under cyclic loading, in fact cyclic loading well below the fracture threshold stress may result in the propagation of flaws, leading to fracture. Class 12.9 or grade high strength bolts should never be used in any situation where they are exposed to bending loads as this will also cause them to fail well below published stresses. The preload is attained by the bolt stretching to a point below its yield point, once the bolt yields its length will be permanently changed. MIL-HDBK-5J states that the maximum any metal can be stretched or compressed before permanent deformation occurs is .002"/inch, this is the yield stress. A joint length to bolt diameter of four or greater is recommended to attain proper preload; through bolts, far side tapped holes, spacers and washers are methods used to improve this ratio. In fact the longer the bolt the better as this will give greater tolerance to joint relaxation due to local yielding, local high spots, rough surface finish and even thread deformation. Local relaxation can result in up to 10% loss of preload and retightening after several minutes to several days may be required.

There are many ways to check the preload of a bolt including using a micrometer to measure the elongation of the bolt. The two most common are with a torque wrench or the part turn method. The table below shows the accuracy of the various methods.

Operator Judgment	± 35%
Torque Wrench	± 25%
Turn of Nut	± 15%
Bolt elongation	± 5%
Strain Gauge	± 1%

**Tightening Accuracy**

So it seems that our trusty torque wrench is not that flash and the greater the accuracy required the greater the cost in time or machinery. The reason the torque wrench is so inaccurate is due to friction in the threads and under the bolt or nut head, these can vary depending on the amount of lubrication on the bolt and the plating material. The table below gives correction factors for using a torque wrench which should help to improve its accuracy. If a bolt is installed heavily greased then it may be possible to take it beyond yield and still not achieve the desired torque, conversely if a bolt is degreased then it is unlikely to achieve the required preload. Published torque figures are normally based on bolts which are blacked and lightly machine oiled, their correction factor is x1.

Galvanised Degreased	x 2.1
Galvanised Lightly Oiled	x 1.1
Zinc Plated As Supplied	x 1.0
Zinc Plated Lightly Oiled	x 0.9
Heavily Greased	x 0.7

**Torque Correction Factors**

The coefficient of friction for a zinc plated bolt or nut is 0.17 and for a cadmium plated bolt (aircraft) 0.12 The milspec MIL-HDBK-60 has a detailed formula for calculating torque based on various friction coefficients.

It will also become obvious that if the part turn method is to be used then the longer the bolt the greater the turn of the nut and so the greater the accuracy.

If one is required to work out the proper tension for a bolted application you will need to refer to MIL-HDBK-60 and the other milspecs included in this resource.

This report has been based on the milspecs MIL-HDBK-60 “Threaded Fasteners - Tightening to proper Tension”, MIL-HDBK-5J “Metallic Materials and Elements for Aerospace Vehicle Structures” and Steelmasters news letters.

## How a bolt breaks under cyclic stress.



It is easy to see how the initial fracture has started at the base of the thread.



The growth rings are very evident. The fracture has progressed through the bolt until the stress area has reduced to such a small size the bolt has failed under tension.



The fact that the thread is bent in the direction of axial load is evidence the bolt ultimately failed under tension.

The surface of the bolt in the area of the fracture rings also shows signs of corrosion. This is probably an excellent example of “stress corrosion cracking” where corrosion in the initial flaw helps to propagate the crack deeper into the bolt.