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Homepage
Contact Me
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Links
Miscellaneous Info
D.I.Y. Tips
Grease 101
Technical Articles
A1 Brochure
Conversions
KLR650 FAQ
Painting Plastic
Forms
Maintenance Log
Shim Record Chart
Pictures
Corbin Saddle
Procedures in PDF
12v Waterproof Outlet

TORQUE WRENCHES & FASTENERS

This article is the answer to some to and fro about fasteners. I hope that my poor scrivenings are of use to someone. A torque wrench is the most commonly applied tool for the purpose of ensuring that screw fasteners are sufficiently tightened. While the tool is universally used, its purpose is not understood since many (most?) users believe that the torque (turning against resistance) of the fastener is what is important to the tightening process.

Torque wrenches measure the torque or turning force applied to a fastener. When tightening a threaded fastener, the turning effort acts against the threads to pull the fastener into the opposite threads. The turning effort is divided into two efforts: friction and tension. The friction of the threads is not useful to the task but must be overcome to allow tightening. The tension effort is that which applies an axial (lengthwise) pull to the fastener and it is this effort that is useful to the task. As a fastener is tightened, pressure on the threads increases, thus increasing friction and tension. What we are doing when tightening a fastener (nut, bolt, screw) is to apply a clamping force to the components that are being connected by the fasteners. In other words we are squeezing them together. In order to squeeze the components together, we apply a force which attempts to stretch the fastener. It actually does stretch the fastener in most "nut & bolt" applications. Thus, it is fastener tension that we are trying to achieve and not a twisting load (torque) to the fastener. In fact we would be better off if we could apply this force by applying a straight tension to the fasteners without any torque at all. This is the way in which rivets function. If we could avoid the need to turn the fasteners to apply tension, we could use smaller fasteners to apply the same loading and this in turn would allow for smaller, lighter assemblies.

When we are torquing a fastener, the specified torque must include the amount of expected friction as well as the amount of turning effort that will become tension. Engineers calculate these relationships and publish torque specifications based on certain assumptions. They assume that the thread friction will be within a certain range. If you lubricate when the specs specify dry threads or if you use a lubricant other than that which is specified (usually motor oil on vehicles), then you change the relationship of friction and tension that result. It can be seen from this that if the friction is reduced, the tension will go up and if the friction is increased, the tension goes down. Since we require a certain tension to hold things together, the results can be undesirable.

Did you know that industrial studies show that small fasteners tend to be over tightened and large ones under tightened?

If you look at tightening practices, you will find that there are more accurate ways of achieving the right degree to tension (tightening) than by use of a torque wrench. One method turns the fastener until its head is in contact with the work surface and then turns it a specified number of degrees of rotation. Since the angle of the threads is known and the materials in use are known, the correct clamping force due to fastener tension results.

This method, called “torque turn” in heavy equipment has been in use to my direct experience for more than 40 years and is more accurate than the torque wrench method. So why don’t we use torque turn? Answer: ? Modern automotive head bolts are usually tightened by torquing the bolts to a given torque and then use of torque turn (turning the bolts and additional number of degrees of rotation that allows the bolts to be tensioned into the beginnings of their yield range. It would be impractical to use torque for this purpose because of the number of variables involved. Rats, now I’ll have to find or rewrite the article on loading of fasteners… (VBG)

While this tome is in process, another point:
When a nut is tightened with a bolt, the force acting on the first tread is added to that of the second thread and so on. This applies an increasing tension to the bolt area that is within the nut. The result would be overloading of the first threads were it not for the fact that (for any given grade) the nut is of softer material than the bolt. This means that the tightening process deforms the nut’s threads and when reaching specified tension (due to use of specified torque), the threads will be deformed beyond their elastic range and will therefore not return to their original position. If the nut & bolt are retightened, the deformation of the threads will increase the friction component leaving less of the torque effort to be converted to tension. The result = less tension. If

Shim Value Table
SuperBrace
Swingarm Maint
Torque Values
Tube Valve Tools
Valve Adjustment
Vista-Cruise Lock
Water Pump Seals
Wheel Alignment

you repeat this for a second time (third tightening) or more, the tension that results will be very significantly less than desired. If we put a new nut onto the bolt and torque, the resulting tension will be in the normal range.
Moral - you must not re-use nuts in critical locations. If you didn't know this before, I'll bet you don't like to hear it now. Check it out, take a new nut and inspect the threads. Torque it & remove inspect again -- waadiditellya?

You can check this out in another way if you have access to a hollow centre hydraulic cylinder. Screw a pressure gauge into the cylinder and bleed out as much air as possible. Put an adapter plate on either side to allow a nut and bolt to bear against the piston on one side and the body of the cylinder on the other. Tighten the nut & bolt to the specified torque. Read the resulting pressure (calculate bolt tension if you want). Loosen the nut and re-torque to the same spec. The pressure is significantly less isn't it? Repeat - the pressure resulting is really down isn't it?

If you’re doing this, read the next lines very carefully! Do not, (repeat) DO NOT, tighten the fastener until it breaks! The tension will result in stretch of the fastener and compression of the metal of the nut and hydraulic cylinder. IN addition, it will result in the compression of the hydraulic fluid (if you were told that fluids don’t compress then you were lied to, same with Santa, Easter Bunny and honest lawyer. Sorry! VBG) The resulting storage of potential energy may result in a lethal projection of the fastener ends when it breaks. Translation: the two pieces may come out like bullets!

Now the icing on the cake, so to speak:
If there is insufficient clamping force to prevent leakage (i.e. cylinder head or oil pump) you will have a leak. No big deal. There's usually enough surplus clamping force built in to the design. With newer designs this isn't always the case. Ford require replacement of head bolts when reinstalling the cylinder head on some engines due to the change in thread friction and the degree of tension used.

PROBLEMS occur when you have a reciprocating or varying load on a fastener. If the load on the fastener is less than the tension on the fastener, the load will cause the fastener to stretch. If the load varies, the fastener with stretch and relax over and over. If the amount of cycling of the fastener is sufficient, the fastener will "metal fatigue" and break. General Motors did some testing with under tightened connecting rod bolts and had breakage due to "fatigue”. The more under tightened, the sooner they broke. Most often when a con rod bolt breaks, the person doing the repair will state that it was likely a faulty bolt or they may say that the bolt was over tightened. Think about the physics of the loading- if the bolt were over tightened it will break right away while under tightened will break later due to gradual fatigue. I don't like to reuse nuts when reinstalling critical items such as steering, suspension or brakes. See why?

Some more points:

1) Nuts, bolts and cap screws (a capscrew is called a bolt if it is used with a nut) are rated by Grade.

2) American and ISO (metric) grade systems both use numbers but you had better not confuse a metric grade with a US grade. (i.e. Metric Grade 8.8 is closer to a US grade 5 in strength than it is to a US Grade 8)

3) Always use the same grade nut and bolt together.

4) If you mix nuts and bolts of different grades you will have to go by the specs for the lower grade component.

5) Learn how to read nut and bolt grades and keep a reference sheet around if you don't work with them a lot.

6) Make sure that you use hardened flat washers. If you use a soft washer, particularly with Grade 8 (Metric 9.6) or up, the washer may/will compress over time removing the clamping force. This = loose bolt.

7) Don't use split lock washers (these are the kind which are a ring with the ends of the split spread in opposite directions. They work by biting into the nut or bolt head and are not reliable with Grade US 5/ Metric Grade 8.8 (the minimum you should use) or above, because they aren't able to bite into the material. They have a tendency to break and fall out. Auto Manufacturers stopped using them 30 years ago.

8) If you stop turning a fastener while torquing in the top 20% of the torque range, back it off and start over. This is because the torque (twisting force) necessary to start it moving is a lot more than is required to keep it turning.

9) Use the lubrication (or none) specified.

10) Recheck your torque wrench every few years and don't leave the tension on "click" type torque wrenches because it will weaken the spring. How would you like to have the head off of a bulldozer out in the bush several times due to blown head gaskets and have me suggest

your torque wrench might be at fault? Yes.

11) Just because "and I haven't gotten killed yet!" hasn't happened YET doesn't mean that you were right, maybe just lucky. If you had gotten killed, we wouldn't be doing this!