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Fasteners 101

Take a few minutes to read this! It will change the way you think about fasteners and improve your equipment reliability!

Bolt Torque ft/lb									
SAE Grade 5					SAE Grade 8				
Bolt Dia.	Coarse thread		Fine thread		Coarse thread		Fine thread		Bolt Dia.
	lubed	dry	lubed	dry	lubed	dry	lubed	dry	
1/4	6	8	7	10	9	12	11	14	1/4
5/16	13	17	14	19	18	25	20	29	5/16
3/8	23	30	25	35	35	45	40	50	3/8
7/16	35	50	40	55	55	70	60	80	7/16
1/2	55	75	65	90	80	110	90	120	1/2
9/16	80	110	90	120	110	150	130	170	9/16
5/8	110	150	130	180	170	220	180	240	5/8
3/4	200	260	220	300	280	380	320	420	3/4
7/8	320	430	360	470	460	600	500	660	7/8
one inch	480	640	530	710	680	900	740	990	one inch
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Back ground information

According to a major study conducted jointly by the IISI and AISI in, the number one cause of equipment failure in the steel industry is fastener failures; lack of lubrication was number two.

The reason is that fasteners seem to be simple enough and most maintenance managers and mechanics think they understand them and take them for granted.

The fact is that fasteners are complex and few really do understand them.

For anecdotal evidence of this, did you ever notice that OEM equipment is often fine until it is taken apart and reassembled? Fasteners that are not replaced according to factory specs often start to fail after first time equipment is disassembled.

The purpose of this document is to provide a first level practical understanding of the theory and application of fasteners. This information is derived from my experience in the steel industry and racing over the past 40 or so years.

For more in depth information or assistance with special applications, contact me at www.allangoldconsulting.com

Fastener trap # 1 Lock washers

The first step in reducing fastener failures is a trip to your bolt bin to scrap all of your lock washers that are larger than 3/8".

Lock washers may help in a soft application such as a blind hole tapped into aluminum or a muffler clamp, otherwise they are pretty much a gimmick and people use them because it makes them feel good.

For proof of this, try to find one on your car or any other piece of precision machinery.

If you really want to use them, make sure they are grade 8 lock washers. At best they are redundant if the connection is torqued properly; at worse they soften the connection and reduce its integrity.

To use fasteners effectively you first need to understand some basic fastener theory.

Torquing Theory 101

The effectiveness of a torqued joint depends on the strain energy created in the fastener during the torquing process. This strain or pre-load imparts a stress in the bolt or cap screw. This stress creates a clamping force between mated parts.

Think of it as a preloaded spring.

Strain means stretch measured in .000" inch/inch. That's right; the bolt actually stretches when it is torqued properly. The longer the bolt the more stretch for an equal amount of stress.

For example, in a properly bolted torque coupling, the friction that is created by this pre-load between the coupling faces will carry all of the rotational torque, and the bolts are not in shear. There are some exceptions, keep reading.

The standard stress/strain curve relationship applies during the torquing process. The higher the strength of the steel, the more torque is required to stretch it. Conversely, more strain energy is imparted into higher strength bolts for an equal amount of stretch.

Because of this higher strength fasteners require more torque to work properly. Conversely, if they are not torqued they won't work much better than regular fasteners

In a properly torqued joint the stress (in PSI) imparted in the fastener is about 75% of the material yield point. This stress acts like a preloaded spring to maintain pressure on the joint.

When a fastener is torqued, about 90% of the torque is used up by friction between the threads and the interface at the washer and head of the fastener. The remaining 10% stretches the bolt or cap screw.

The amount of stretch is important. On critical applications such as connecting rod bolts of a race car motor, the stretch is actually measured with a micrometer. Knowing the exact amount of stretch (strain) provides the ability to accurately measure the stress. This method eliminates all of the variables related to friction.

Action steps to eliminating fastener failures.

1. Get rid of your lock washers over 3/8”
2. Fasteners are graded by SAE, Society of Automotive Engineers. Use a minimum of grade 5 fasteners. Grade five fasteners are about 120,000 psi yield. These fasteners will usually have three radial lines on the head of the bolt or cap screw. Cap screws without any lines should not be used nor should stamped flat garden variety washers
3. Use grade 8 fasteners for critical or marginal applications. Grade 8 fasteners are about 150,000 psi yield. Grade 8 bolts usually have five or more radial lines on the head. Grade 8 washers and nuts also have lines on them. The washers are also thicker and all of the Grade 8 components have a superior finish compared to grade 5.
4. Most fastener makers also produce a premium “Grade 9 fasteners” These fasteners are more than 150,000 psi yield and are available in a variety of finishes. They are very expensive and should be used only when necessary, i.e. connecting rod bolts
5. Socket head or Allen Head cap screws are an example of a premium fastener. They are 160,000 PSI yield.
6. Where possible, always use fasteners as a matched set. A set includes the cap screw, nut and **two** flat hardened washers, one under the head of the cap screw and one under the nut. Two washers are important to seat the caps screw properly and distribute the load. A soft washer will gall and create friction, this reducing the torque that goes into stretching the bolt.
7. Use the torque charts included in this document for the size and type of fastener you are using
8. Use a micrometer dial type torque wrench and torque every fastener to the prescribed torque, then torque it again just to be sure.
9. Some torque charts provide a recommended torque for lubricated and not lubricated applications. Use the lubricated application if you have a choice. Fastener threads should be lightly oiled to be sure that the torque goes into stretching the cap screw and not into friction.
10. You may need more than one size of torque wrench to cover the range of fasteners. For example a one inch bolt requires over 600 ft /lb of torque. You will require a 48” micrometer dial torque wrench and sometimes a torque multiplier to get it tight.
11. If space restrictions prevent the use of s torque wrench, tighten the nut until all clearance is taken out, i.e. it is tight but not torqued, mark it with a sharpie then tighten it 90 degrees from this point. It will be pretty close. This is called the “**turn of the nut method”.**
12. If you prefer using an impact wrench, use the “turn of the nut” method or snug the nuts up with the impact then finish with a torque wrench.

13. Verify the integrity of the joint. The seating area under the cap screw and nut must be machined flat, square to the bolt and smooth. Faces between the couplings should be machined smooth and bolt holes should be in good condition. Clearance between the bolt and bolt hole should be minimal.
14. Fitted bolts are required in special applications where the bolts are intended to be in shear, i.e. mill motor drive couplings.
15. Cap screws can be reused provided they have not been over torqued. As long as the fastener is not torqued beyond the yield point it will return to the original length when the stress is removed. If it does not return to the original length it should be replaced.
16. Nuts distort on torquing. This distortion will result in more of the torque being absorbed by friction on the next use. They should be replaced after one or two uses. In critical applications always use new fasteners if you can.
17. Never re-use steel self locking nuts. Nylock nuts may be re-used with caution.
18. Do not use Nylock nuts in hot applications.
19. Replace OEM fasteners with the exact same kind unless they have failed in some way. In other words if you don't have a problem, don't fix it. If you do the application should be re-engineered.
20. If they have failed, apply these guidelines to the next application. Even some OEM's don't understand fasteners.

Special Applications

1. Structural members on steel erection, this application normally uses an A-325 structural fastener with two hard washers. These fasteners are about 120,000 psi yield and are torqued to the yield point on installation. They are not intended to be removed and should be replaced if they are.

2. In special or critical applications such as fitted or reamed couplings, special procedures should be used. Couplings and bolts should be match marked and fasteners always returned to the same hole they came from. If bolts are replaced they must be machined to the exact size of bolt that they replace.

3. Mechanical torque multipliers may be required to achieve torques over 600ft/lb. reference www.futek.com

4. Special hydraulic torque wrenches are also available for applications requiring 10,000 ft/lb or more.

5. The 90 degree "**turn of the nut method"** may also be used with hammer wrenches to torque larger bolts where the torque can not be measured.

6. "Super Nuts" can be used in special applications. Super nuts use many smaller nuts to torque a larger one. These are expensive but are the best solution in some special applications.

7. In critical applications that are not accessible to be checked after first assembly, aircraft style cap screws with drilled holes can be wired together with aircraft quality wire rope and a special application tool to ensure they do not loosen.

8. Another tool to use when you want both a belt and suspenders is Loc-tite. It is not a substitute for torquing except where torquing is not possible. There are a variety of products, some are permanent and some are removable. Follow the instructions carefully.

9. In applications such as automotive wheel bearings high torques are not desirable because they would damage the bearing. In these applications tabbed washers are used to lock the nut in place.

10. Fastener failures in coupling bolts are common. Again, if the bolts are torqued properly the friction induced between the flanges should carry the rotational torque. If the coupling is too small for the application it is best to replace it with the proper size coupling. If this is not possible you can increase the torque capacity by using oversized bolts or double drilling the coupling flanges.

11. Increasing the effective length of the fastener will increase the amount of strain achieved with the same stress and impart more strain energy. That is why taller main bearing caps are used on race motors.

12. In critical applications the diameter of the body of the fastener is less than the thread area to ensure that the threads do not distort under high torque.

There is a lot more to fasteners and I will add to this from time to time, I hope that this will give you something to think about and help you in some way.

If you require torque calculations or assistance for special applications, please contact me.
I also welcome your feedback!

Post the attached torque charts in your shop and use them often.

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