Causes of Torque and Tension Variables

扭力与张力变数的成因

The past several articles have dealt with the theory and application of torque to various industries for achieving the proper preload and bolt tension in joints. However, as we well know, results are not always consistent as there are variables involved that will cause assembly errors; some are human, others are not.

There are two major factors which affect joint preload and tension:

Torque, which is a function of friction, because anytime there is a change in rotational friction within the joint during assembly, preload and tension will be lost or drastically changed.

Embedment will cause an initial decrease in clamp load, then a gradual decrease over time. It will also cause an increase in rotational friction during assembly.

Other joint factors include:

Materials/Grade:

This would include all components of the assembly; nut, bolt, washer and joint material. Are all components compatible? Is the bolt grade the proper strength for the joint material and does it match the other bolts in the connection?

Having the incorrect joint material would mean that the bolting components would embed themselves into the material and lose clamp load during installation and continuing with repetitious service loads on the joint.

The strength of the nut must be able to support the load of the bolt. Nuts come in many different grades and dimensions to provide the support to the bolt. If the nut cannot support the load of the bolt, the internal threads of the nut will deflect and the nut will dilate against the joint surface causing an increase in thread friction and weakness of the threads.

Flat washers may or not always be used on some applications but it is advisable to use at least one, if not two, washers when tightening the nut or bolt; one under the nut and the other under the bolt head. For one, the washer provides a smooth and consistent surface for the bolt or nut to rotate against while tightening. Washers should not be stacked unless it is a specially designed washer, as this will lead to joint relaxation.

Washers are made in different grades and sizes. Using a smaller washer than its recommended inside diameter for the bolt diameter will cause a stress load on the bolt head from contacting the fillet radius of the bolt head, which could later cause the bolt head to separate. The SAE flat washer provides the proper inside diameter to fully support the washer face, or bearing surface, of the bolt, whereas the inside diameter of the USS washer is too wide and will not provide full contact with the washer face.

Structural washers (F436) are graded as to their hardness and capability of supporting high strength bolts without embedment. Most 'standard' commercial washers are made from low carbon steel which will quickly compress under the load of a heat treated bolt. Check the hardness, it should be heat treated to 38 – 45 HRC and be used with grade 5 (8.8) and stronger bolts.

The manufacturing of bolts has been fairly error proof with in-process inspections as well as final inspections and other quality measures to monitor heat treatment and check for gouges, bursts, surface roughness and perpendicularity. Therefore, a bolt that has an interference fit with the hole in the joint is a human error who did not make the correct size hole.

There is always the chance for threads to nick. This will be the result of how the bolts are transferred from one area to another. Many 'green' bolts are dumped into containers, then loaded into hoppers for the heat treating conveyor belts. From there they continue to the quenching operation to another container where they may go out for surface treatments.

Plating, Coatings:

If the bolt is electroplated, the thread crests will have a greater amount of deposited material than any other part of the bolt due to the "Christmas tree" effect. The nut is also affected by this phenomenon as the first lead thread will receive more plating deposit than the rest of the threads. This leads to a situation where a small thread nick on the bolt could prevent the nut from being threaded onto the bolt when you factor both areas of build-up.

Consider the type of coatings and keep them consistent on all parts. Electrodeposited coatings include zinc, zinc alloy, nickel and cadmium. Zinc phosphate is by immersion or spraying and provides some minimal level of corrosion resistance. Hot dip galvanizing is done by immersion of the parts into a molten zinc bath which coats the parts as they are dragged through the bath. Due to the temperatures of the molten zinc, the hardness of the product subjected to the molten zinc is limited to prevent annealing of any hardened parts. The heavy hot dip coating provides maximum outdoor service against normal atmospheric corrosion. Mechanical zinc coating is a slightly thinner coating and is performed by immersion of the parts in a slurry of zinc metal flakes which are impinged onto the parts by glass or ceramic beads.

Organic or zinc-rich dip-spin coatings are available in various thicknesses according to the type of corrosion resistance required. Many will exceed 1,000 hours of salt spray resistance. The increased resistance is provided from a variety of top coatings. Therefore, a product may have several coating thicknesses which need to be considered when mating it with certain thread types. Sometimes nuts may have to be overtapped or tapped after coating.

Every different type of surface finish will provide a unique 'k' factor. This is what determines the friction variables in the torque output. The 'k' will vary from 0.05 to 30.0, depending upon the type of oil used, wax coatings, top coats, heat treat scale, thickness, etc.

Upper and Lower Surfaces:

The joint material must be able to withstand the type and strength of fasteners used. Naturally, if the materials are too soft or too thin to support the preload of the fasteners, embedment will occur that can lead to fatigue failure of the fasteners.

For new joint assemblies; are the materials compatible to avoid galvanic reactions? Will the design of the joint allow for complete drainage to avoid standing water? Are the materials flat? Have the materials been painted or coated which may affect joint slippage and shear factors?

When a bolt replacement or joint repair is necessary, inspect the joint for corrosion. Is there any corrosion or other compressible material between the joint that will affect clamp load? **Keep the area under the bolt head and nut clean and free from surface contaminants.**

Tapped and Hole Clearance:

Is the entrance to the bolt hole clean and free from burrs, metal shavings and other debris? Is there cutting or tapping fluid present that may affect torque? Too much cutting fluid left inside a tapped hole will prevent a cap screw from being properly tightened. The end of the cap screw will be tightened against the oil and not the joint.

If a cap screw has broken inside a tapped hole, check for thread deformity or other damage from the breakage. It is always a good idea to retap the threads.

Lubricants:

This would include any viscous material or chemical locking compound on or around the fasteners. All oils are lubricants; their viscosities will determine their 'k' number for torque. All locking chemicals are lubricants. This includes the ones purchased with dry chemicals already applied to the threads and to the liquid chemicals which are to be applied by the user. The viscosity of the liquid locking chemicals change by how fast they set up, which affects the torque output as they are being tightened.

Depending upon the torque applied and size of the bolt, the amount of an applied lubricant can affect the torque. Lubricants should be placed only on the threads. Too much under the bolt head or against the nut and washer will affect the torque.

Temperature:

An increase in operating temperature for most lubricants will decrease their effectiveness. In this case, metallic based lubricants are the most effective because if the carrier evaporates, there are enough metal particles left to keep the part lubricated for easy disassembly and to keep it from 'freezing' in place within highly corrosive environments. Molecules expand with heat and contract with a cold ambient temperature. If the temperatures are different from installation to operating, make the proper adjustments. Each material, from the bolt to the joint, has its own coefficient of thermal expansion rate.

Contaminants:

Corrosion products, excessive sealants, locking compounds, dirt, debris, and metal shavings (tapped holes), will all increase or decrease friction. **Keep the components clean and free of contaminants.**

Be Consistent:

As with any assembly, consistency with all factors will yield favorable and repeatable results.

There are more variables to discuss that have to deal with how the bolts are installed. That will be for the next article.