Torque Applied in Manufacturing

The function of any threaded fastener is to provide sufficient clamping force onto a joint that when properly tightened will achieve and maintain the desired clamp load for its intended application. Any type of joint movement must be overcome to prevent joint failure. This clamp load is achieved by means of torquing a fastener.

In a bolted joint, torque is measured in two different planes that are perpendicular to one another. Torque is a combined relationship between force, times distance and tension. Torque measures the reaction of rotational movement of the fastener, while tension measures the longitudinal movement of the same fastener.

The longitudinal movement (tension) is constrained by the joint members between the first engaged threads and the bearing surfaces of the bolt and nut. A portion of the rotational energy (torsion) is used to stretch (tension) the bolt while, at the same time, causes the joint members to compress.

The amount of energy that is applied to the bolt from rotation to create tension is determined by the energy losses due to the friction between the surfaces of the rotating parts and the joint. The relationship between the applied torque and the tension generated in the joint is the torque-tension relationship.

While torque may seem universal in use, the torque-tension relationship is applied differently to three specific industries; mass assembly, structural assembly and in maintenance and repair.

The mass assembly of products includes the automotive, truck and bus industries to name a few, excluding the electronics industries because vehicles experience heavy loading, vibration and shock. Also, because vehicles can become very dangerous to life and property if something breaks or loosens.

Recently Rivian Automotive has recalled approximately 13,000 of its vehicles for a loose steering assembly. It was reported that the fastener connecting the front upper control arm and steering knuckle "may not have been sufficiently torqued."

The question to be asked is, why wasn't there sufficient torque applied? How was the assembly tightened? Is there a calibration issue? Was the output data not interpreted correctly?

Automotive assembly lines use a variety of programmable, digital power tools for assembly that many will transmit data, such as torque and angle, to the data processor for error-proofing. The torque-angle measurement is a most accurate tool used for solid and stiff joints. In most cases the turn will negate friction variables, which is why a pre-torque is first applied to establish a hard base without any further joint compression.

However, in some cases it will not always mean that the preload has been achieved. This depends upon how the data is monitored. If the torque and angle have been achieved within a certain per cent window, then the joint is good.

However, if the angle goes significantly beyond the expected tolerance window to achieve the proper torque, this means the joint was not solid and there was interference between the joint, such as a burr, unexpected lubrication or even a non-conforming part that produced compression or resistance. If the torque becomes high and the angle was not reached, then this could mean debris in the threads, cross threading or something else that needs to be investigated. If none of these anomalies are noticed and the operator just inputs on torque alone, then there are problems later on, which is why there are recalls.

Automotive manufacturers are basically just assemblers of pre made and assembled parts from other manufacturers. They also use a variety of fasteners and special fasteners besides the common bolt and nut. Many stampings will have extrusions where threads are tapped which will accommodate a threaded fastener and there are times where several stampings will be stacked together, some of which are designed to move about the fastener.

When several manufacturers are producing parts that are to be assembled together, tolerances and torque accuracy become paramount. Because movement of the assembled parts is involved, a thread locking chemical is used to help with vibrational loosening.

Loosening occurs in the presence of transverse and cyclic loads. It is subject to the relative slip between the threads and the joint surfaces. Since threads are a helix angle, which is nothing more than an inclined plane, there is a natural tendency for threads to relax and rotate in the downward or counter clockwise "off" position, which will cause joint loosening under cyclic, vibration or impacts to the joint.

To overcome any external forces of transverse loads, bending, vibration and tensile loads, the joint must develop and maintain a clamp load in excess of any of these external loads. Any significant amount of loss of clamp load will cause the joint to become loose.

For example, let's assume one of the extrusions has a burr that is just slightly over tolerance. In this case, a burr that is only 0.43 mm (0.0169") over tolerance can be most significant. The most important reason for loss of clamp load is not being able to maintain the required clamp load due to embedment during tightening and further embedment under service loads. These losses cause joint relaxation and looseness.

During assembly, torque has been applied by use of a positioning electronic torque wrench. It has a preset torque value which the results are stored for reference and error-proofing. There is no fault with the assembly method. However, once the torque is applied, the joint may still relax and lose clamp load.

The electronic torque wrench also measures rotation angle. Parameters were set for the amount of torque required to achieve a certain preload with respect to the viscosity of the thread locking material on the threads of the screw and with the amount of torque angle that should be achieved.

The assembly torque data is monitored to the extent that if the required assembly torque is not reached upon the second time, that bolt is discarded. However, the mistake here is not relating to the torque angle for potential problems.

For example, if the required torque was 25 lb-ft and took only 35 degrees of angular rotation to achieve clamp load, acceptable tolerances would be ± 5 lb-ft and ± 10 degrees rotation. However, suppose the torque was achieved at 24 lb-ft but at 90 degrees rotation or more. This should be an immediate red flag to the operator.

Unfortunately, in this case, the operators failed to observe the torque angle as a significant component of the entire assembly. The excessive rotation resulted in a loss of clamp load from embedment and weakened threads which permitted transverse loading. Adhesives are good at resisting rotational movement and cyclic tensile impacts, not lateral impacts. Therefore, the fastener becomes loose and joint failure occurs.

Error-proofing does not mean fool-proof. There are still variables that can cause errors. ■

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