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Overloaded & Underloaded Fasteners

There are many ways a fastener can fail but the majority of failures investigated have been due to installation or application errors. Less than 1% was the cause of a material defect. Therefore, it is imperative that a dialogue begins with the customer to determine the conditions of how the fasteners were used.

The following outlines the causes and effects of various installation errors. The most common failures come from fasteners being overloaded or underloaded but there are many ways to get there.

OVERLOADED:

The term 'overloaded' means that the bolt or cap screw has been stretched past its yield strength. This type of failure can be identified visually by a 'dog bone' appearance of the threaded portion, much like taffy when pulled (**Photo 1**).

Photo 1

An overloaded fastener will also cause a loose connection. If the service loads exceed the proof load or yield strength, the fastener does become slightly longer, but remains in the connection. When the external service loads are removed, the joint returns to a relaxed condition but the bolt remains slightly longer and appears to be loose. The bolt may not have a 'dog bone' appearance but will have a change in thread pitch.

It is always best to check the thread pitch of the fasteners as the thread deformation may not always be visually apparent. Checking the thread pitch of a questionable fastener is done with a thread pitch gauge. However, when one is not readily available, the thread pitch may always be compared using a new bolt of the same diameter and thread pitch. Simply place the entire length of the new bolt on top of the entire length of the questionable bolt.

It is very important to check the entire length of the threads because there will be no thread pitch change of the threads where the nut held the bolt or the first five or so threads of a cap screw in a tapped hole. This is because all of the stretching in tension and thread deformation occurs between the nut and bolt head.

Causes:

- Improper Fastener Grades
  - Here, the bolt is not strong enough for the applied loads and will yield.
  - The bolt may fail or be loose when the external loads are removed.
  - If the nut does not match the grade of the bolt, the nut will fail.
- Incorrect Torque
  - This could mean that no measuring method was used and/or a lubricant was present.
  - This could also mean that the proper torque was not applied for the conditions of the application; environmental, temperature, surface finish, lubricants, etc.
- Lubrication
  - All torque charts cite values for 'as received' product, which is mostly 'dry'.
  - There are numerous lubricants on the market of which some are more efficient than others. Therefore, torque values must be adjusted for each type of lubricant.
  - Lubricants reduce the friction between the mating threads as the bolt is torsionally tightened. Therefore, torque values are generally reduced to much lower values than on torque charts.
  - Using a 'dry' torque value, or no torque at all, with a lubricated fastener will generally cause the fastener to be stretched into its plastic region well past its yield point.
- Power Wrenches
  - Pneumatic or hydraulic power all rely on pressure. Unless regulated, there is no accurate method of applying torque.
  - Air wrenches are much faster than hydraulic wrenches, but all seek friction to cause the wrench to stall. If a lubricant is present, there is little friction present to cause the wrench to stall. Therefore, the wrench continues to impact or turn until the fastener is beyond its yield point.
  - As an example, an ordinary shop ½" unregulated impact gun has an initial impact of 425 lb-ft of torque. This will cause a ¾"-7/8" Grade 8 lubricated bolt to yield.
  - Impact wrench abuse can be noted by the damage to the hex corners of the nut as the socket slams repeatedly into the nut corners causing visible deformation (**Photo 2**).

Photo 2

- Speed of Applied Torque
  - Even a matching strength grade nut will strip its threads in the presence of intentional or accidental lubricant if the applied torque is too fast.

- The bolt is more likely to be stretched into yield, or fractured, if the speed of assembly is high as the speed also reduces friction until contact with the surface.
- Speed also causes an elastic rebound effect, which in some circumstances could cause the fastener to be stretched into yield as the joint material regains its shape from compression.

• Elevated Temperatures

- Joint materials expand with heat.
- If the fastener was tightened very tight in the connection, the joint expansion could cause the fastener to be stretched into yield.
- This will cause a loose bolt in the joint when it cools. Again, check the thread pitch.

UNDERLOADED:

If the cap screw is not tightened sufficiently to produce a clamping force greater than the load that will be applied to it, the fastener will fail from a phenomenon known as metal fatigue.

Fatigue failure occurs in heat treated metals and is most frequently encountered in heavy dynamic and fluctuating load assemblies where maximum loading does not occur during installation but later, when the equipment has been placed into service and when a heavy initial load impacts the joint. In this case, a cap screw may fail even though its tensile strength is much greater than the service loads it experiences.

The mechanism for this type of failure is similar to the repeated bending of a coat hanger wire. The metal becomes 'tired' or fatigues due to this repeated movement. A certain amount of 'cold working' occurs and the metal develops a stress rupture. This ruptured stress raiser continues to propagate through the grain boundaries of the metal until there is very little cross-sectional area left to support the service load or next impact, and then it suddenly fractures. Such is the case when a cap screw is not tightened sufficiently to produce a clamp load greater than what it is being subjected to by the service loads.

Stresses can also initiate at other points which are voids (abrupt changes in size or shape), imperfections, scratches or discontinuities elsewhere on the metal surface. Once a crack initiates, it propagates through the core of the bolt with every additional shock or impact load, until the area of metal which is left can no longer support the next impact, at which point total fracture occurs instantly.

Photo 3

Typically, fatigue stress raisers develop at the last thread run-out or at the first unengaged thread outside the nut. If the fillet radius under the bolt head becomes scratched or damaged, stress raisers develop and the bolt head separates in a dramatic manner.

A metal fatigue pattern consists of conchoidal markings or 'beach marks' as seen in **Photo 3.**

The fracture in Photo 3 initiated at the 7 o'clock position and continued through the body of the bolt until final fracture occurred at the heavy darkened area. The variance in dark to light bands indicate the frequency and intensity of the service loads.

Some fractures may have multiple stress initiation points as seen in **Photo 4**.

Photo 4

Causes:

• Non-Matching Fastener Components

- Check the grade markings on the nut and bolt to determine compatibility.
- A Grade 2 nut on a Grade 8 bolt only produces a Grade 2 connection.

• Embedment

- If the imprint of the bolt head and/or nut is visible in the joint surface or flat washer, clamp load has been lost.
- It only takes 0.001" of bolt relaxation, per inch of loaded length, to lose 30,000 psi of clamp load.
- Continued load impacts will cause further embedment and loss of clamp load.

• Debris in Threads or Tapped Hole

- Any amount of thread interference will increase thread friction, provide false torque readings and decrease clamp load.

• Burrs

- A burr is an uneven surface and may not allow the joint surfaces to lay flat and parallel.
- The extra metal will compress further during service and cause joint relaxation.
- The edge of the burr can dig into the fillet radius at the head of the cap screw causing a stress raiser or notch effect for metal fatigue.

- Inadequate Torque
  - Too much torque will cause the fastener to yield. The fastener is now weakened and subject to higher service loads and increased thread stress.
  - Too little torque will cause immediate stress in the threads.
  - Heavy dynamic loads require the fasteners to be retorqued after experiencing the service loads. The service loads will settle the joint and cause some relaxation.
- Incorrect Torque Pattern
  - Applying full torque to all fasteners, even in a criss-cross pattern, will cause some bolts to be tighter as well as loosen others.
  - Proper procedure is to tighten the fasteners in increments in a criss-cross pattern.
- Reusing the Nut
  - Nuts are softer than the bolts to which they mate so the threads can plastically flow to carry the load of the expanding threads of the bolt. This produces thread distortion and causes an increase in thread friction.
  - Torque is a function of friction. Therefore, any increase in thread friction will decrease the amount of applied torque to the nut and bolt.
  - The nut will continue to produce more thread friction and less clamp load each time it is reused, even when torqued at the same torque value.
  - The exception is with using lubrication.
- Mixed Fastener Grades in the Same Connection
  - The joint will produce less clamping force than that of the lower bolt grade.
  - If the higher bolt grade is torqued the same as the lower bolt grade, the resultant clamp load will be less than that produced by the lower bolt grade. This is due to the strength of materials and torsion, not axial tension.
- Joint Relaxation
  - All of the above.

There are 'other' less common reasons for fastener failures but none the less cause of dramatic failures, which we will explain in the next issue. ■