Identifying Fastener Failures

by Guy Avellon

Many times customers encounter failures that we know are not always the fault of product quality. However, there are some growing concerns with product quality issues, especially from new companies, who have not made or tested fasteners before. After all, there is nothing worse than to have a salesman go into a customer's shop and have a broken fastener tossed at him with claims of poor quality. This article will help to identify some of these differences as well as providing some help you may offer your customers with their issues, since it may be difficult to obtain timely advice from distant manufacturers.

Hydrogen Embrittlement

With headed fasteners, we can usually spot a hydrogen assisted embrittlement failure within 24 hours from the head laying next to the body of the fastener. With other parts it comes as a surprise and often very quickly.

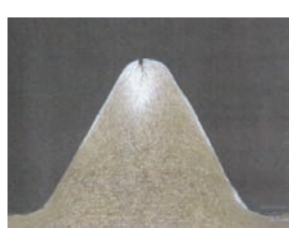
Pic. 1. Hydrogen embrittlement

The reverse side of this flat washer is stamped with a manufacturer's identification and size. This stamping alone creates residual stresses, but this washer was a high carbon steel that was heat treated to a hardness of Rc 44, then electroplated.

Platers do not know the hardness of the products they process, so without special instructions they will perform the same tasks as usual; acid pickling and electroplating without post baking. Many times the current is increased to increase productivity and quickly add thickness, but in doing so, an increase in hydrogen gas is formed and becomes trapped to release its energy at a later time.

Thread Laps

The micro photograph of picture 1 depicts a thread showing a typical crack appearing defect at the thread crest. No decarburization was observed. The light colored microstructure is the cause of the effect of etching and the defect. The etchant used was 2% Nital.



Pic. 2. Typical crack at the crest

Small lap defects on rolled threads are not uncommon and some thread laps are allowable, up to a certain depth (ASTM F788). These laps may be visible with magnification or without. If there is concern as to its depth, the sample needs to be sectioned and examined microscopically.

Pic. 3. 250μm crack

The above sample illustrates a crack at a depth of 250 μm (microns) where the ASTM F837M specifies a maximum depth of only 0.2 mm, or 200 microns. This type of defect on a socket head cap screw may lead to thread strength and shear engagement problems due to its expected high clamp load potential. This condition could be due to a combination of a thread lap and cracking resulting from the heat treatment/process control. The lot needs to be returned to the manufacturer for disposition.

Incorrect Material

Another interesting type of failure occurs when a manufacturer uses only one type of steel for all fasteners. For instance, the AISI 4140 steel is a versatile composition that can be used for many product grades; from socket head cap screws, SAE Grade 8, ISO 10.9, ASTM A193-B7 bolts and studs and even Grade 5 bolts. It became more cost effective for the manufacturer to use the higher grade of steel for all of his product manufacturing, due to high volume discounts, than to stock several types in different diameters.

However, in the following case, the 4140 steel was used for an ASTM A307B fastener.

The following depicts a head failure with an A307B fastener using a 10° wedge during tensile testing.

Pic. 4. ASTM A307B failure

The head was hot formed but the residual stresses from the forming of the steel caused the head to fail where failures are not usually expected with normally specified low carbon steel product. Several samples exhibited hardnesses of Rc 28-31 average, while others were below Rb 100.

Hot heading is performed at temperatures above 1000°F (538°C). Temperatures, time and cooling rates can change the structure of steels, since iron is an allotropic material and can exist in more than one type of lattice structure (such as a face centered cubic, f.c.c., or body centered cubic, b.c.c.). If not controlled properly, the iron can be in different phases, as evidenced from the wide range in observed hardness readings. This should be the first clue if only hardness is performed and a wedge tensile test is not done as hardness has a direct correlation on tensile strength and brittleness. The fasteners should have been stress relieved.

Look for Clues

This next photograph shows eight fractured socket head cap screws. Now, clearly these are fatigue fractures, but the patterns can be applied to other application fracture cases as well.

Pic. 5. Screws of fatigue fracture

Normally, a fastener will fracture at either the head or where the first thread is not engaged. This thread may be either the first thread at the nut which is against the joint surface, or in the case of a tapped hole, the first thread outside the grip zone. This grip zone, where the male and female threads engage to cause the fastener to stretch, depends upon the relative strength-to-hardness ratio between the fastener and the base material of the tapped hole. As with a nut of matching strength and hardness, the depth needs to be only that of the diameter of the fastener. If the material is softer, then the hole must be deeper to provide more threads to carry the load of the cap screw.

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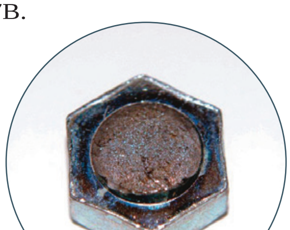
In the above photograph, the fastener with the head still attached was the last to fail. It broke in tension at the threads in the grip zone. The others failed at the head as the application was supporting a die ring that was under high pressure that cycled. The head on this fastener would have failed also but the others had weakened the connection clamp load so much that this lone fastener was carrying the majority of the load until it failed in tensile.

The progression of the fatigue fracture across the surface of the steel will indicate how long the microcrack had been propagating before the tensile failure occurred. For example, the fourth from the left was the first to begin failing. This is because the fatigue fracture had propagated nearly completely across the cross section of the cap screw. As one begins to lose clamping load, the stresses are moved to another fastener, usually the adjacent fasteners, who begins to develop their own stress cracks. Their crack propagation is a little less than the first. And the cycle progresses to the other fasteners in the connection; each one has a little less progression than the previous cap screw.

In this case, the cap screws were not torqued evenly, in a criss-cross pattern nor in a sequence.

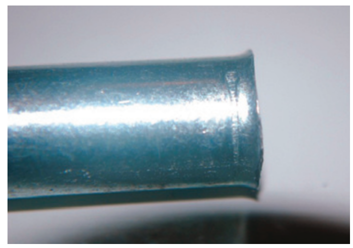
Other failure clues will involve assembly abuse. By looking at all of the parts, we can piece together the details of what happened.

The following is a head failure which occurred during installation of an A307A fastener. Again, it is unusual for these low carbon steel fasteners to fail but this was of the correct steel composition, unlike the A307B.



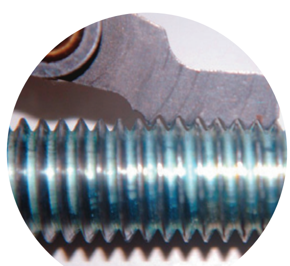
Pic. 6. A307A head failure

The head fracture was completely ductile, as evidenced by the 'cups and cones' appearance of the fracture surface. The hardness was also within specification. By looking at the shank of the bolt, a small gouge can be observed. This was due to the fastener spinning, which was then caught by a burr from the hole which caused the deeper impression.



Pic. 7. Small gouge on bolt shank

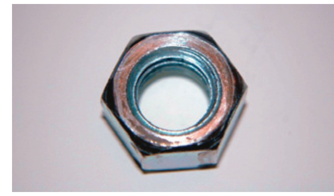
The next step is to check the thread pitch to determine if the fastener had been tensioned into yield. This is done by placing a thread gauge along the threads nearest the head, not the end of the fastener. The threads closest to the head are the threads that stretch and will remain stretched if into yield, not the threads inside the nut, or grip zone.



Pic. 8. Thread pitch check via thread gauge

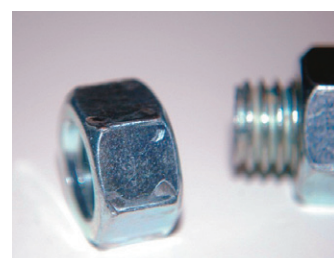
Picture 8 shows an air gap between the threads indicating the fastener experienced yield. If you do not have a thread gauge, another method would be to take a new fastener of the same diameter and thread pitch and lay the threads along the entire thread length of the two fasteners. If they do not match, the fastener in question has been stretched beyond its yield point.

From examining the nut we can observe that one side of the nut is normal, while the obverse was the side against the joint. This side is severely swiped, more so than when just using a hand wrench. The only clear assembly method used here was a power wrench that caused the high speed spinning marks.



Pic. 9. Swiped part of the nut

When taking a closer look at the wrenching corners of the nut, it is clearly evident that a power wrench was used for assembly. There are indentation markings on the corners of the nut in the 'on' position. There was some back-lash of the wrench that caused the mark on the opposite corner (top) of the nut.



Pic. 10. Indentation markings on the nut

The back-lash is also caused by a high assembly speed; the faster the speed the greater the compression of the joint which rebounds in relation to the compression relaxation. In this case, the fastener was being tightened against a metal plate and wood, which increased the compressibility and rebound.

Although not mandatory by the ASTM A307 standard, the manufacturer can stress relieve the fasteners, which would minimize any potential damage to the head during installation. The installer could be less aggressive with the speed wrench and watch for any accidental lubricants on the threads. Lubricants will greatly reduce any assembly friction and cause more tension than torsion. ■