Dr. Fasteners- How to Analyze Fastener Failures

Procedures

When a fastener fails there are always questions of 'what caused the failure'. Of course, a customer is always concerned about the quality of the products he purchased; however, with the strict quality controls in typical modern manufacturing facilities the quality of products is not an issue, so we must determine the root cause of the failure. To begin an investigation, we must gather as much information as possible. There are certain questions to ask about the application of the fastener. To serve as a guide, the following is a list of questions to ask.

1. How was it installed?

a. By hand wrench
b. Pneumatic tool
c. Impact wrench
d. Torque wrench

Knowing how the fastener was installed will give clues to if the fastener was possibly overtightened or not sufficiently tightened.

2. What type, if any, of ancillary components were used?

a. Flat washer
- Hardened
- Plain steel
- SAE
- USS

b. Was a nut used?
- Grade
- Type
- Locking
- Standard hex
- Finish
    1. Plain
    2. Coated
        a. Zinc
        b. Cadmium
        c. Dip and Spin

3. Type of loads exerted on the joint?

a. Heavy impacting
b. Vibrating
c. Rotational
d. Static
e. Axial, transverse, shear

4. Approximate amount of expected loads?

Knowing the applied loads will provide an idea if the fastener strength grade was sufficient and if the installation method resulted in sufficient clamp load for the joint.

5. Environment type?

a. Heat
b. Cold
c. Wet
- Chlorinated
- Salt

d. Other

6. Number of other fasteners in the joint

7. How were the multiple fasteners tightened?

a. Cross-pattern
b. Incremental loading
c. One after the other

Knowing how the tightening procedure was applied will give an indication if the loads were applied evenly or there was a chance that some fasteners were not tightened as sufficiently as others.

8. Where were the fasteners tightened?

a. On the bolt head
b. By the nut
c. Alternating

Knowing how the fastener was tightened will indicate if the procedure was consistent. Tightening the nut to a certain specified torque will produce lower clamp loads than tightening the bolt head due to torsional twist and unloading.

9. Do you know the speed of the assembly?

a. Power driven
- Controlled output
- No control

b. Hand

Knowing the speed will also indicate if the applied loads were consistent. Fast speeds will produce an elastic rebound of the joint surface that will produce higher than expected clamp loads. If there is no control over the speed, the applied loads will vary.

10. What is the condition of the joint?

a. Rusty
b. Painted surface
c. Rough
d. Smooth
e. Greasy
f. Hard material
g. Soft material
h. Any signs of embedment of the fastener?

11. What is the condition of the failed parts?

a. Rusty
b. Greasy or lubricated
c. Heat scorched
d. Stripped threads
e. Bent
f. Wrench pads damaged

12. Where is the location of the fracture?

a. At the head of the bolt
b. At the thread run-out
c. First thread outside the nut
d. External cracking evidence

13. What is the condition of the fracture surface?

a. Smooth with conchoidal lines
b. Dull or darkish with dimples
c. Shiny
d. Rusty

14. Did all of the bolts fracture at the same location?

15. Did the fastener fail during installation or had it been in service for a while?

16. Were the fasteners ever removed and replaced?

Investigation

This is the time when we categorize the data we collected. Sometimes we can tell by the appearance of the samples and fracture surface what may have happened. This will narrow the questions and failure possibilities.

For instance, a ductile fracture will exhibit dimples with an inclusion, or a cups and cones appearance with a dull colored surface. It will also show some type of distortion, as the material will deform plastically before ultimate failure. However, if the load is applied very rapidly, as in a shock or impact load even while tightening, a ductile material may have the appearance of a brittle fracture and the surface will be darker. This can happen when using unregulated pneumatic installation tools.

When possible, check the threads of the bolt to determine if there is a change in thread pitch. This will indicate if the bolt was stretched into yield either by service loads or during installation.


Fig. 1. Metal fatigue fracture of a wheel stud


Fig. 2. Lock nut


Fig. 3. The inside of the lock nut

A brittle fracture may be flat, similar to metal fatigue but is more shiny, exposing grain boundary cracking, or grain boundary cleaving. Brittle fractures will not show visible signs of distortion. Some fractures may have the characteristic markings of chevron or waterfall patterns, which point to origin of stress initiation.

Metal fatigue will display the conchoidal or 'beach marks' striations across the fracture surface. These will be a series of bands which may be dark, light or both. The darker bands signifying low frequency impacts or vibration, while the lighter bands are indicative of a higher frequency or more rapid impact loads.

Fig. 1 is of a metal fatigue fracture of a wheel stud. It exhibits both light and dark conchoidal bands. There are several initiation points in the fracture zone which suggests the wheel stud experienced a rotational load and a bending load in a loose condition.

Typically, fatigue fractures initiate either at the last thread run-out or at the first unengaged thread protruding from the nut.

Coatings can make a difference in environments with elevated temperatures. If there is an all-metal lock nut (**Fig. 2**) that came off a turbocharger, exhaust manifold or boiler vessel, the inside will look like **Fig. 3**. The gold colored nuts are cadmium plated and will fail from Liquid Metal Embrittlement at temperatures exceeding 400°F or 204°C. LME is time dependent so failure will take longer at lower temperatures than higher. Zinc plating will also cause LME but at much higher temperatures.

The next installment will deal with the analysis of the failure. ■