AVOIDING BOLT FAILURES

Bolts, fasteners, and studs are commonly used to secure rotating components, to flange two pipes together, or to join multiple structural items such as in aircraft wing skins or I-beams on a high-rise structure. Although bolts and fasteners may be the smallest items in a design, this does not minimize their importance. An accident attributed to a missing bolt occurred in 1979 when Flight 191 from Chicago’s O’Hare Airport tragically crashed 30 seconds after take-off. The NTSB concluded that the engine tore loose due to a missing pylon attach bolt. In other examples, bolt failures have resulted in fires, fatal accidents, crashes, catastrophic ruptures, foreign object damage in gas turbines, and leaks of hydrocarbon products that have exploded.

One of the most common failure mechanisms for bolts is fatigue. Fatigue is the phenomenon that occurs in bolt materials as the result of cyclic variations of the applied stress. A fatigue fracture of a bolt is shown in Figure 1. The fatigue fracture will typically have some characteristic features such as ratchet marks at the initiation location, a relatively smooth surface, and often distinct crack propagation patterns of “clam shells” or “beach marks” on the surface.

A bolt fatigue failure involves three stages of damage: 1) initial crack initiation at a thread root, radius or material defect; 2) progressive cyclic fatigue growth; and 3) final sudden failure of the remaining cross section of the bolt. Fatigue failures of bolts are often found at the first engaged threads, which have the highest stress, or at the head-to-shank fillet radius. Figures 2 and 3 show a fatigue crack that initiated at the head-to-shank radius of a bolt.
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Bolts that are torqued may fail due to fatigue in the following situations:

- The initial pre-load torque value for the bolt is too low
- The pre-load torque value is above the yield stress of the bolt
- The yield stress of the bolt material is too low
- Elevated temperatures, causing bolt relaxation
- Equipment vibrations, causing the bolt to loosen
- Higher stress amplitudes above the endurance limit

To reduce the probability of a bolt fatigue failure, each bolted-joint design should be individually evaluated and the following should be considered:

- Verify that engineering drawing torque value is appropriate for the specific bolt alloy and diameter
- Select the proper strength and toughness material for the bolt
- Use proper torque wrenches for the given application
- Use rolled threads, which induces compressive stresses, instead of cut threads
- Assure that the fastener hole is free from dirt or corrosion to avoid higher and incorrect torque readings
- Reduce operating stresses and vibrations of equipment by using additional supports
- Consider the use of a safety wire or tack welding the head in high-vibration conditions
- Check and re-torque bolts that may have become loose

Fatigue failures of bolts and fasteners can be avoided through good design practices, proper installation, and routine inspection practices.