M. E. Williams and Associates, Inc.

"Excellence in Metallurgical Engineering"

12825 385th Avenue
Waseca, MN 56093

Grade 8 Flange Head Screw Failure

By

Merlin E. Williams, P.E.

Subject

Failure analysis of a broken Grade 8 flange head screw to determine cause of failure which resulted in equipment damage. The broken screw was examined by visual examination, hardness testing, scanning electron microscopic examination, fracture mechanics, and metallographic examination.

Visual Examination

Figure 1 – Identifying Mark on Screw Head

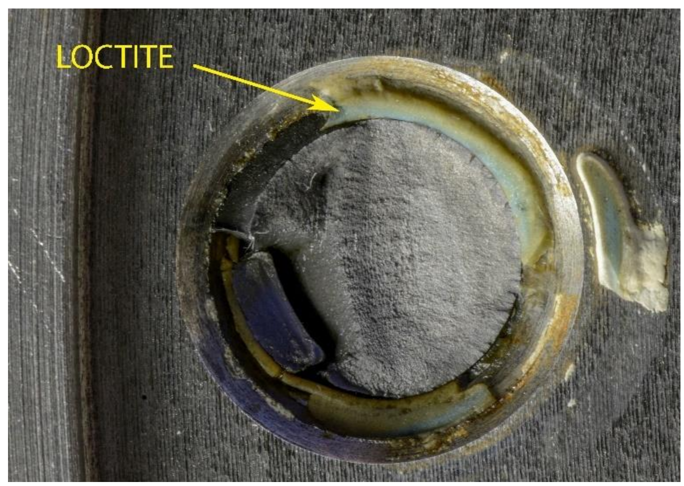

Figure 2 – Screw in Cover Plate

Figure 1 shows the screw manufacturer's identifying marks. Figure 2 shows the broken end of the screw trapped in the cover plate. The fracture surface indicates that the failure mode was fatigue. Loctite was used to prevent the flange head screw from loosening during service. Flange head screws, nuts, and bolts tend to loosen during service if they are not secured.

Hardness Test Data

The hardness testing was done according to ASTM E384, using a Vickers indenter and a 500 gram load. The results are given in the following table.

Hardness Test Data (Rockwell C Scale)						
Sample	VICKERS	STD DEV	MAX VALUE	MIN VALUE	HARDNESS	Specification
Broken Screw	323.00	3.46	328.00	320.00	32.52 RC	33 – 39 RC
Intact Screw	334.00	2.28	338.00	332.00	33.75 RC	33 - 39 RC

The hardness of the broken screw is slightly less than the minimum hardness for a Grade 8 fastener. The hardness of the Intact Screw is slightly higher than the minimum hardness for a Grade 8 fastener. The hardness of these screws is marginal for Grade 8 fasteners.

Scanning Electron Microscopic Examination

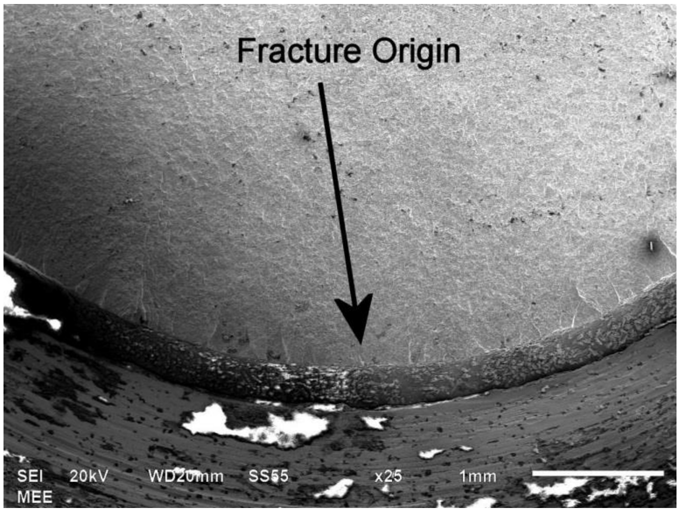

Figure 3 – 25X Fracture Origin, Broken Screw

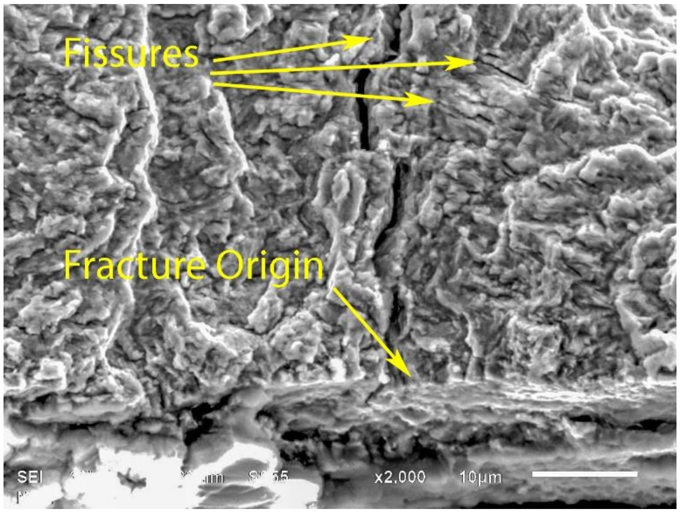

Figure 4 – 2000X Fracture Origin, Broken Screw

Figure 3 shows the location of the fracture origin. Figure 4 shows the fracture origin. The failure mode at the fracture origin is a mixture of low and very low cycle fatigue, plus a large secondary crack. The fatigue striation spacing for the low cycle fatigue was 16.2 X 10^{-6} inches. The very low cycle fatigue is indicated by fissure cracking that is parallel to the fatigue striations, and is an indication that the broken screw was periodically loaded beyond its tensile strength. The spacing of the very low cycle fatigue was 73.3 X 10^{-6} inches.

The scanning electron microscopic examination showed that the broken screw failed by a combination of low cycle and very low cycle fatigue.

Fracture Mechanics

Fracture mechanics can be used to estimate the stress levels that were on the parts at the time of fracture. Knowing the location and spacing of the fatigue striations permits the estimation of the cyclic fatigue stress by the following equation: $\Delta\sigma = \dfrac{E\sqrt{\dfrac{spacing}{6}}}{Y\sqrt{a}}$. The terms are defined below:

$\Delta\sigma$	The applied cyclic stress.
E	The modulus of elasticity equal to 30,000,000 psi for steel alloys.
a	The distance the fatigue striations progressed from the fracture origin.
Y	A constant equal to 2.1. It is defined by the shape of the crack.

“a” is equal to 0.096 inches for this screw failure.

The estimated low cycle fatigue stress was 76 ksi. The estimated cyclic stress is very near the endurance limit of 80 ksi for quenched and tempered steel.

The estimated very low cycle fatigue stress was 166 ksi, which exceeds the minimum tensile strength of a Grade 8 screw as shown by the fissure fracturing in Figure 4.

Fracture mechanics indicates that the load on the broken screw was excessively high. The right hand side of Figure 2 shows that Loctite was used to secure the screw flange, and that the flange had Brinelled the housing cover.

Metallographic Examination

The magnification shown for the photo is the magnification at which the photos were taken. The photos shown in this report may be smaller or larger in size than the originals.

Figures 5 and 6, show a fatigue crack in a thread root of the broken bolt. The crack is originating from a defect that was caused by thread rolling. The crack that caused the screw to break, Figures 2 and 3, did not appear to originate from a defect in the thread root, but could have.

Figure 7 shows the flank of one of the threads of the broken screw. The flank was free of decarburization or other heat treating related defects. The microstructure of this screw and of the Intact Screw was a very fine grained tempered martensite.

Figure 8 shows a thread root of the Intact Screw. There is a thread rolling defect present, and a small crack has been initiated.

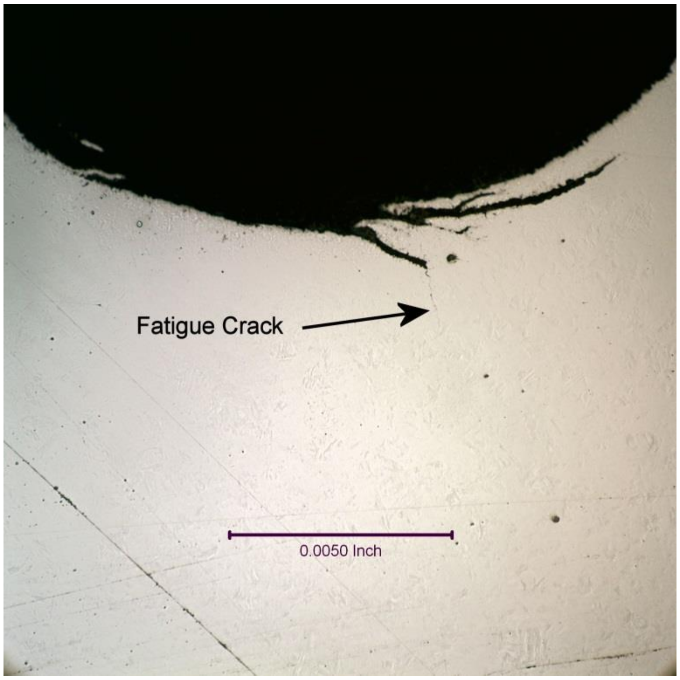

Figure 5 – 400X Thread Root, Broken Screw

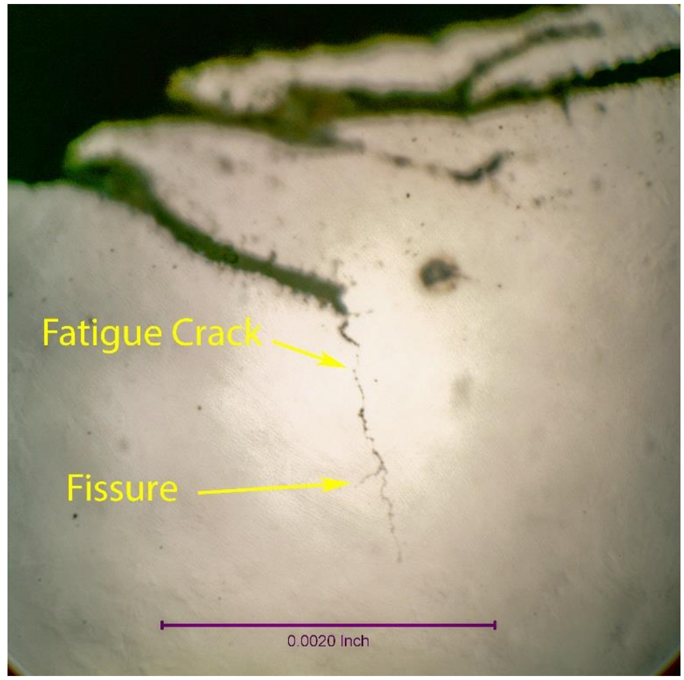

Figure 6 – 1500X Thread Root, Broken Screw

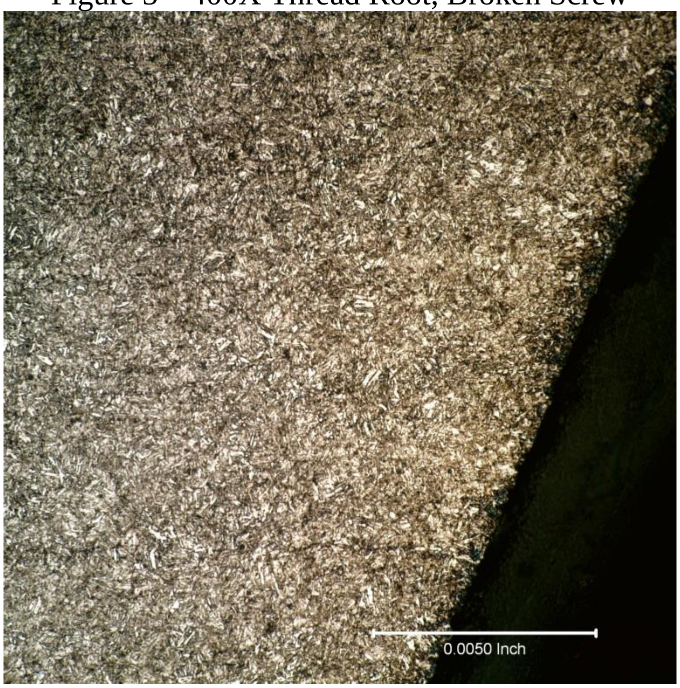

Figure 7 – 400X Thread Flank, Broken Screw

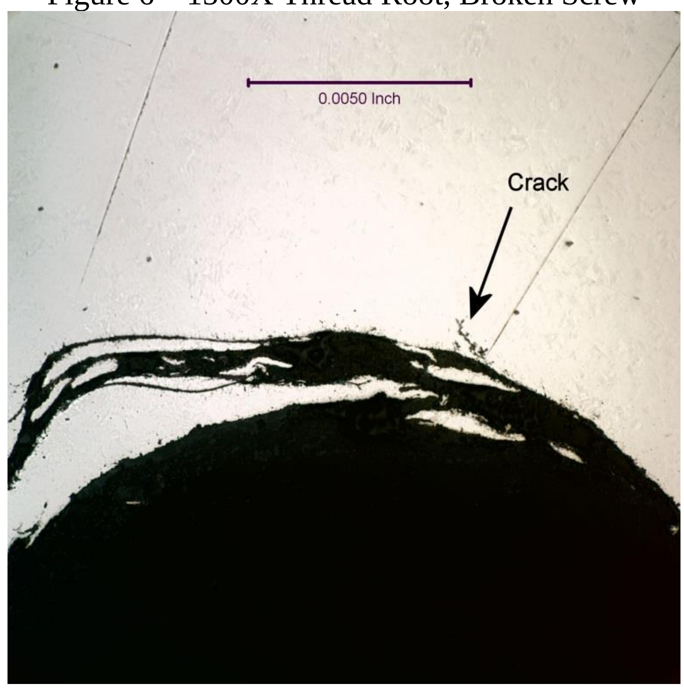

Figure 8 – 400X Thread Root, Intact Screw

Conclusion

The screw failed because of high cyclic stress. The normal cyclic stress was at or near the endurance limit of the screw. There was cyclic loading present that exceeded the tensile strength of the steel used for the screw. The quality of the thread rolling was very poor, but did not contribute to the failure of this screw.