ATTACHMENT 1

AIRWORTHINESS GROUP FACTUAL REPORT

NTSB No. DCA20LA100

Sikorsky Memorandum on the Materials Laboratory Examination of the Pedal Damper Check Valve Housing and Bolt Fractures
(14 pages)

LOCKHEED MARTIN

Memorandum

DATE: 15 November 2021

TO: C. Shin, NTSB Aviation Engineering - Helicopters

cc:

FROM: D. Blair, LM Sikorsky ASI

SUBJECT: NTSB N908CH Pedal Damper Materials Report (P/N S6165-61517-2 AN3H5A Bolts Qty 2)

LM Sikorsky Engineering Materials Lab conducted an NTSB-directed examination of two P/N S6165-61517-2 AN3H5A bolts. The pedal damper check valve housing, hydraulic servo cylinder, o-ring and two AN3H5A bolts that attach the two parts were disassembled at Sikorsky Trumbull and sent to the Materials Lab for examination (Figure 1). Bolt part markings indicated that the manufacturer was Mac Fasteners.

Examination:
SEM examination of the fractured bolt confirmed a fatigue mode originating from the root of the first engaged thread (Figure 2 ,3,5,6,7). The fracture surface was about 75% fatigue and about 25% overload. Safety wire was present on this bolt with some pink tubing and white sealant present (Figure 4). The fracture surface and impartial threads were cut off and mounted for metallographic inspection (Figure 8,9). The microstructure appeared typical for 8740 in the hardened condition. Cold worked elongated grains were not visible in the thread roots. Root radius was not measured on this bolt as the intact threads were left inside the hydraulic servo cylinder (Figure 10,11). Spectrochemical analysis shows the bolt material is 8740 conforming to one of the required specs, MIL-S-6049. Hardness ranged from 27.2 to 29.8 HRC meeting the 26 to 32 HRC requirement per MIL-B-6812. Hardness was measured with direct HRC (no conversions) in the center of the shank three times cutting off a portion of the shank with a diamond saw to get a new measurement each time.

The additional bolt from the left side lug exhibited three cracks in the first three engaged threads (Figures 12-15). Root radii were measured on a Keyence microscope to be about .005”. There is no requirement for root radius on these AN series bolts. A metallographic cross section of the threads exhibited seams in the thread crests confirming that the threads were rolled (Figure 16). The absence of grain flow in the roots and presence of seams in the crests indicates that the bolts were brought to a normalizing temperature after the threads were rolled.

The underside of the fractured and cracked bolt heads are shown in Figure 17. The bolts appeared to be the required configuration based on grip length, thread length, and major and minor diameters.

The check valve housing (also referred to as endcap gland) is shown in Figure 18 and Figure 19. Exposure of the crack surface and examination determined the mode was fatigue originating at the radius of the left side lug. A reddish oil was still present inside the crack when it was opened. There was no apparent damage or wear at the origin and paint appeared to be intact. SEM examination indicated almost the entire crack was fatigue except for a small portion of overload that was created when the lab opened the crack (Figure 20-23). The radius of the lug at the origin measured about .003”. Spectrochemical analysis shows the housing material is 7079 conforming to the AMS 4138 specification. Hardness ranged from 158 to 166 HB 10/500 meeting the requirement of 135 or greater per AMS 4138 in the T6 condition. Conductivity averaged 30.6 IACS which appears typical for 7079 in the T6 condition. Microstructure appeared typical for the material (Figure 24).

The o-ring was torn in one location and compressed at two adjacent locations likely from hydraulic pressure blowing out the side and then getting compressed between the housing and cylinder (Figure 25).

Conclusions:

1. One of the AN3H5A bolts fractured by fatigue originating in the root of the first engaged thread followed by overload. No abnormalities were present at the origin.

2. The other AN3H5A bolt exhibited multiple cracks in the first three engaged thread roots.

3. The housing crack in the lug (associated with the cracked bolt) was due to fatigue originating from a lug face edge. No abnormalities were present at the origin.

4. The bolts and housing did not exhibit any obvious features that would suggest under or over torquing.

5. Material/Dimensional Checks

a. The bolts appeared to be the required configuration based on grip length, thread length, and major and minor diameters.

b. The fractured bolt had a conforming composition and hardness. Microstructure was typical for the material.

c. The thread root radius measured 0.005 inch.

d. The housing had a conforming composition and hardness. Microstructure and conductivity were typical for the material.

e. The geometry of the edge where the housing crack initiated was a 0.003 inch radius. The requirement is to break all sharp edges .005 to .015R.

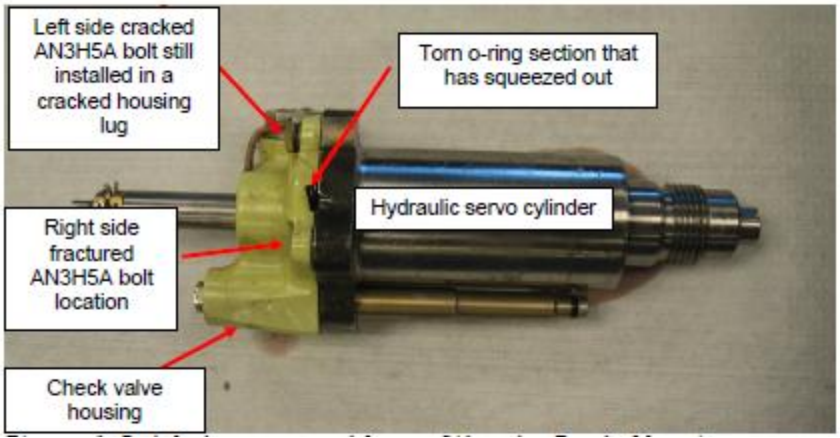

Figure 1 Pedal damper assembly at Sikorsky Trumbull prior to disassembly. The cylinder, bolts, housing, and o-ring were sent to the Materials Lab.

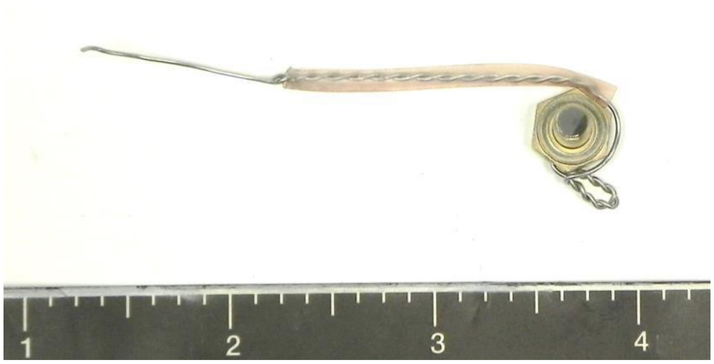

Figure 2 Fractured bolt.

Figure 3 Fractured bolt isotropic view.

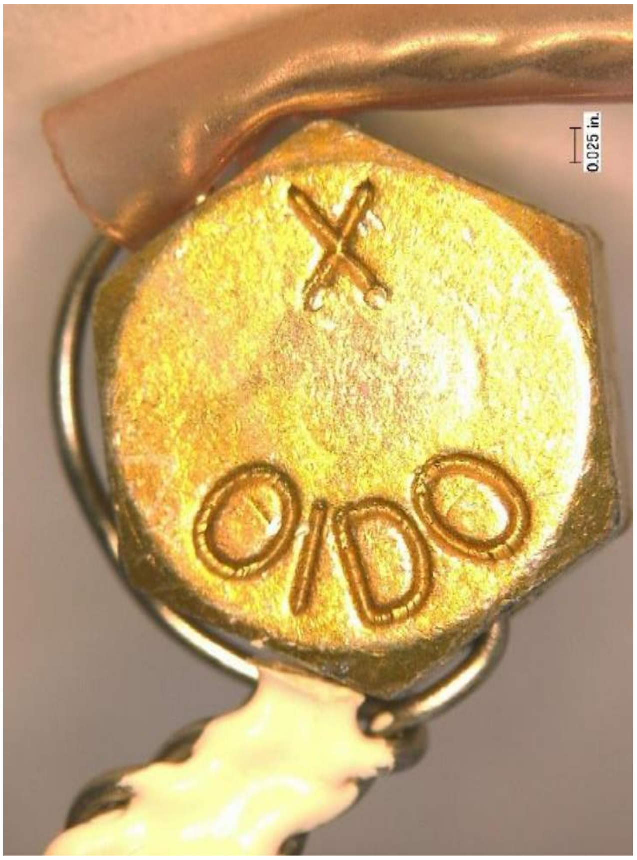

Figure 4 Fractured bolt part markings indicate that the manufacturer was Mac Fasteners. (Cracked bolt had identical markings)

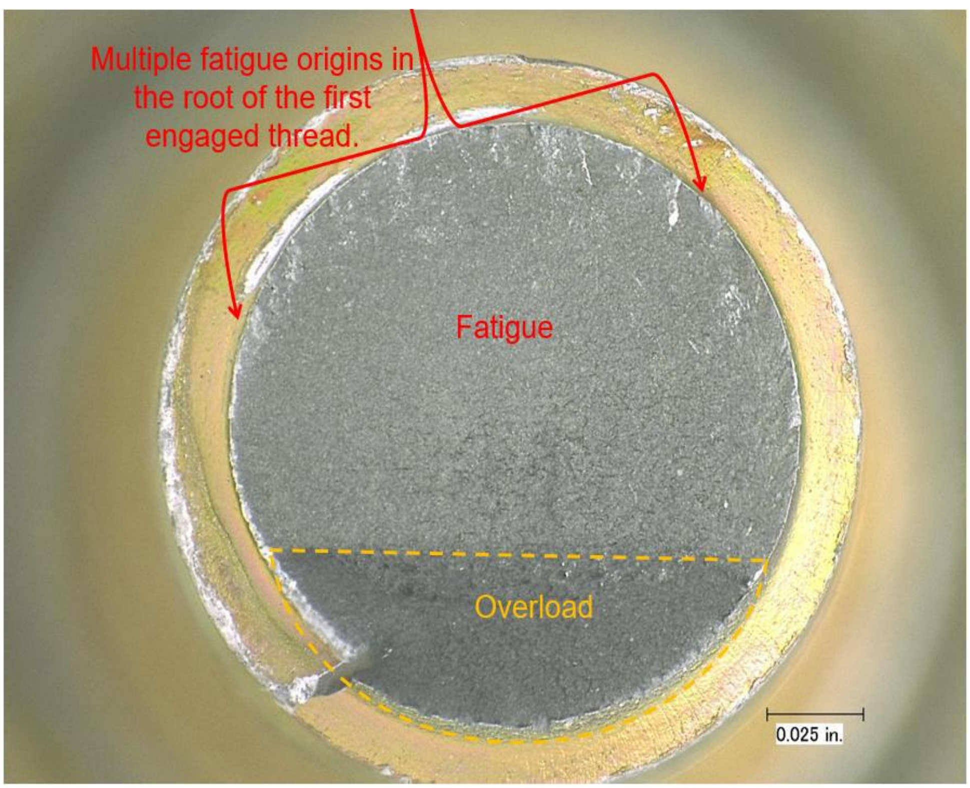

Figure 5 Fatigue origins of fractured bolt.

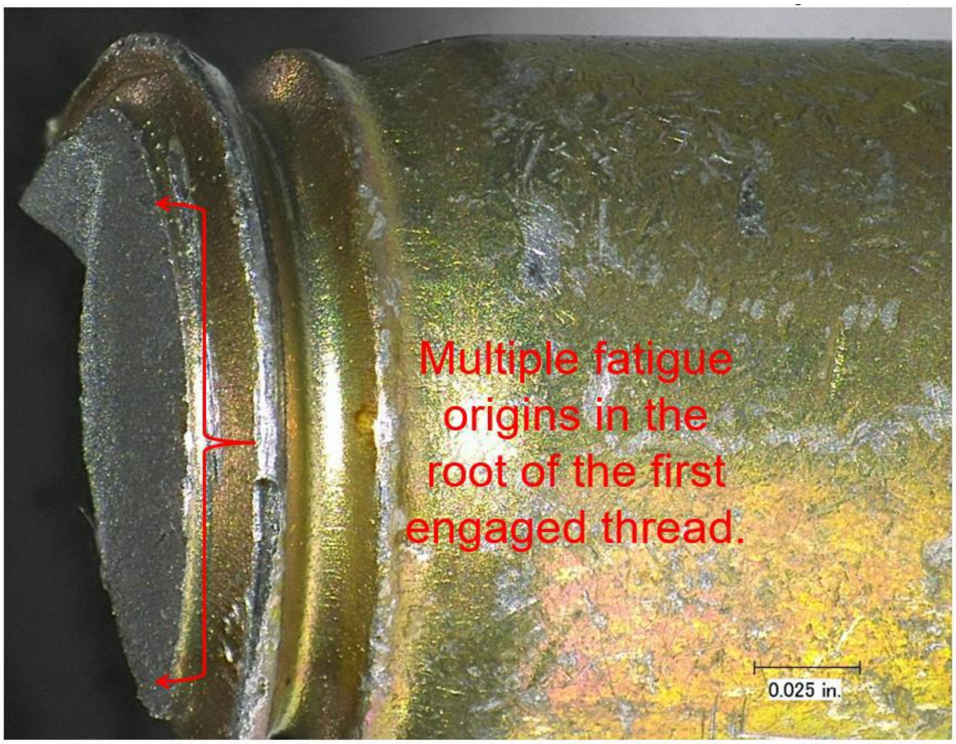

Figure 6 Side view of fatigue origins of fractured bolt.

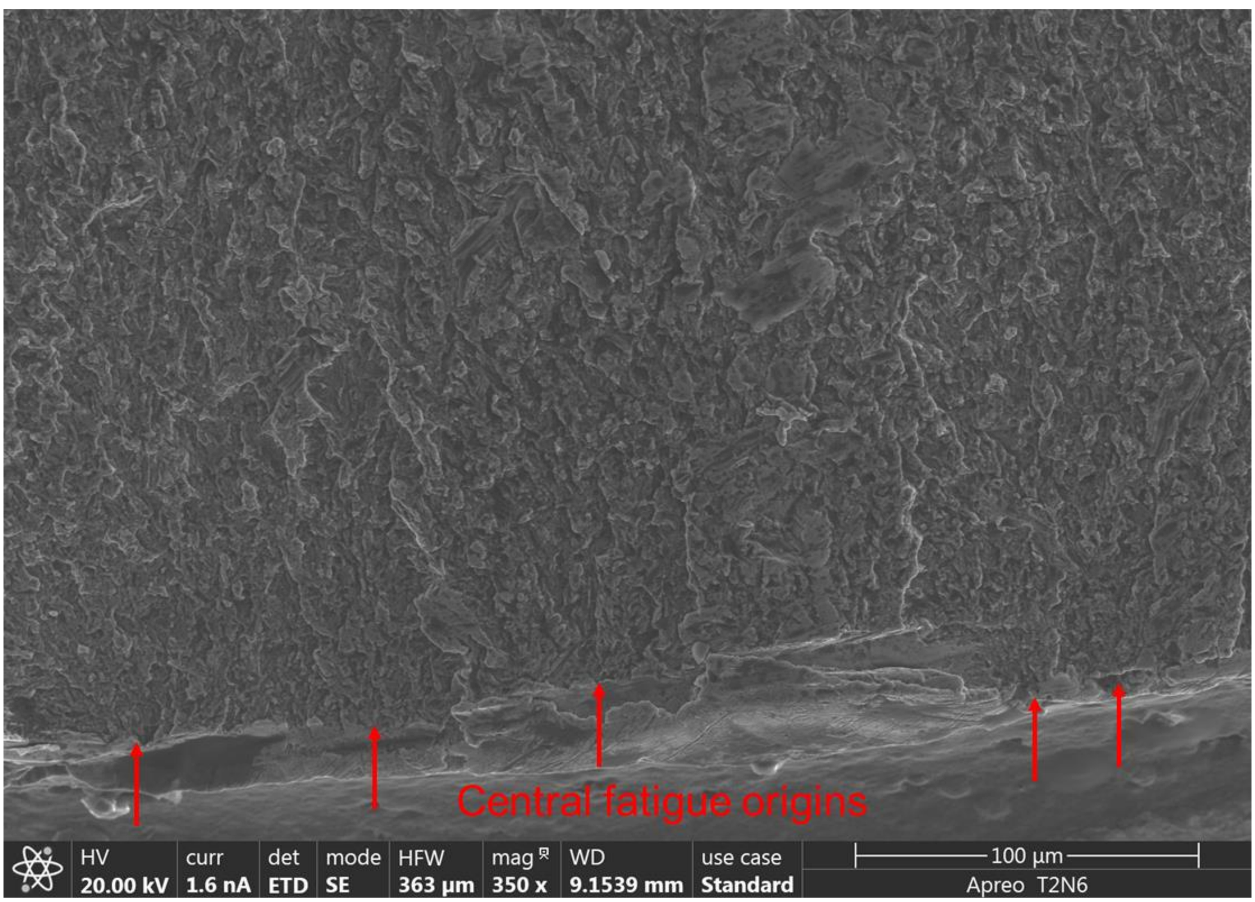

Figure 7 SEM image of fatigue origins at the center of the fatigue zone on the fractured bolt.

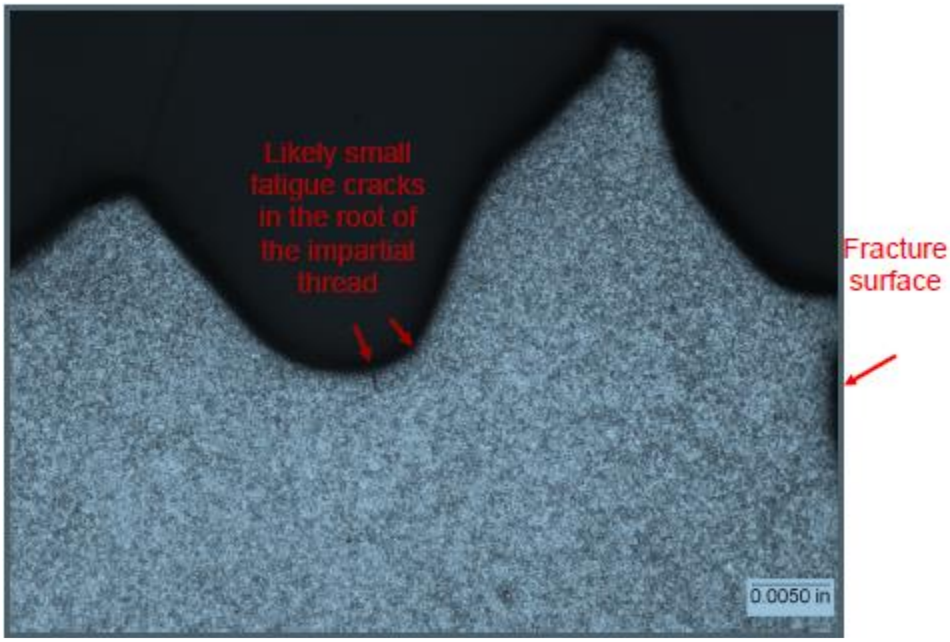

Figure 8 Metallographic cross section of the fractured bolt etched in nital. Likely small fatigue cracks in the root of the impartial thread. Microstructure is typical of martensitic steel. The thread roots do not exhibit elongated grains.

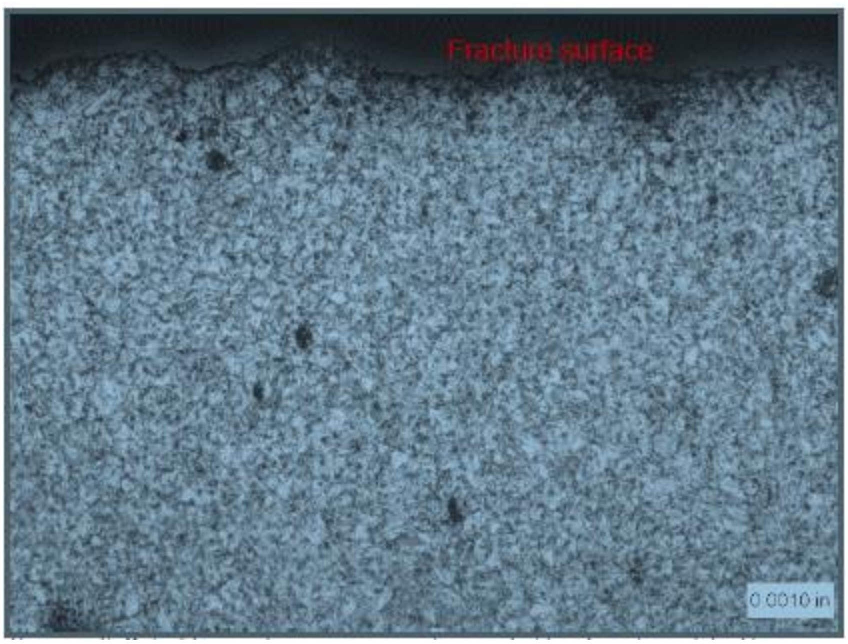

Figure 9 Metallographic cross section of the fractured bolt etched in nital at higher magnification.

Figure 10 Hydraulic servo cylinder with remaining portion of fractured bolt threads still inside.

Figure 11 Hydraulic servo cylinder lug with remaining portion of fractured bolt threads still inside.

Figure 12 Cracked bolt.

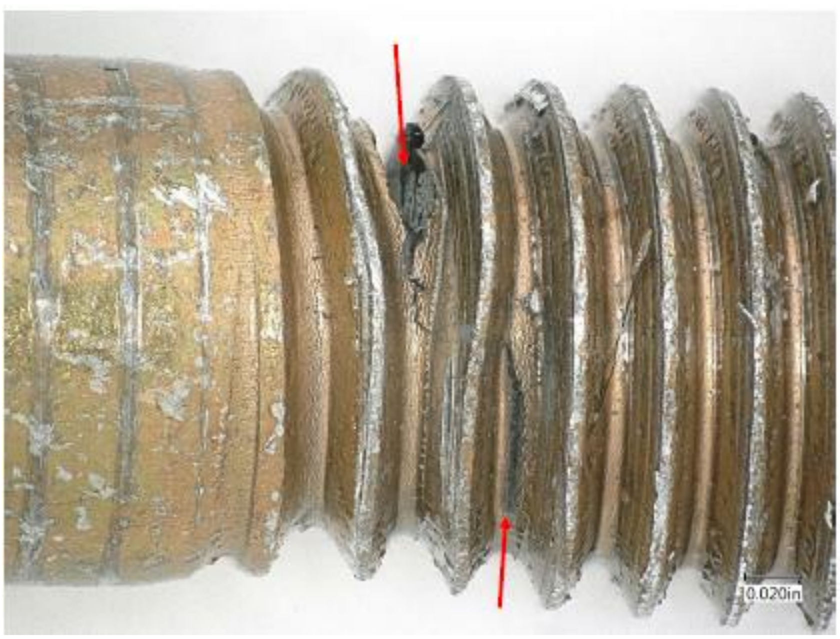

Figure 13 Cracks visible in the first and second engaged threads.

Figure 14 Opposite side of the cracked bolt again showing the cracks in the first engaged thread and an additional crack in the third engaged thread.

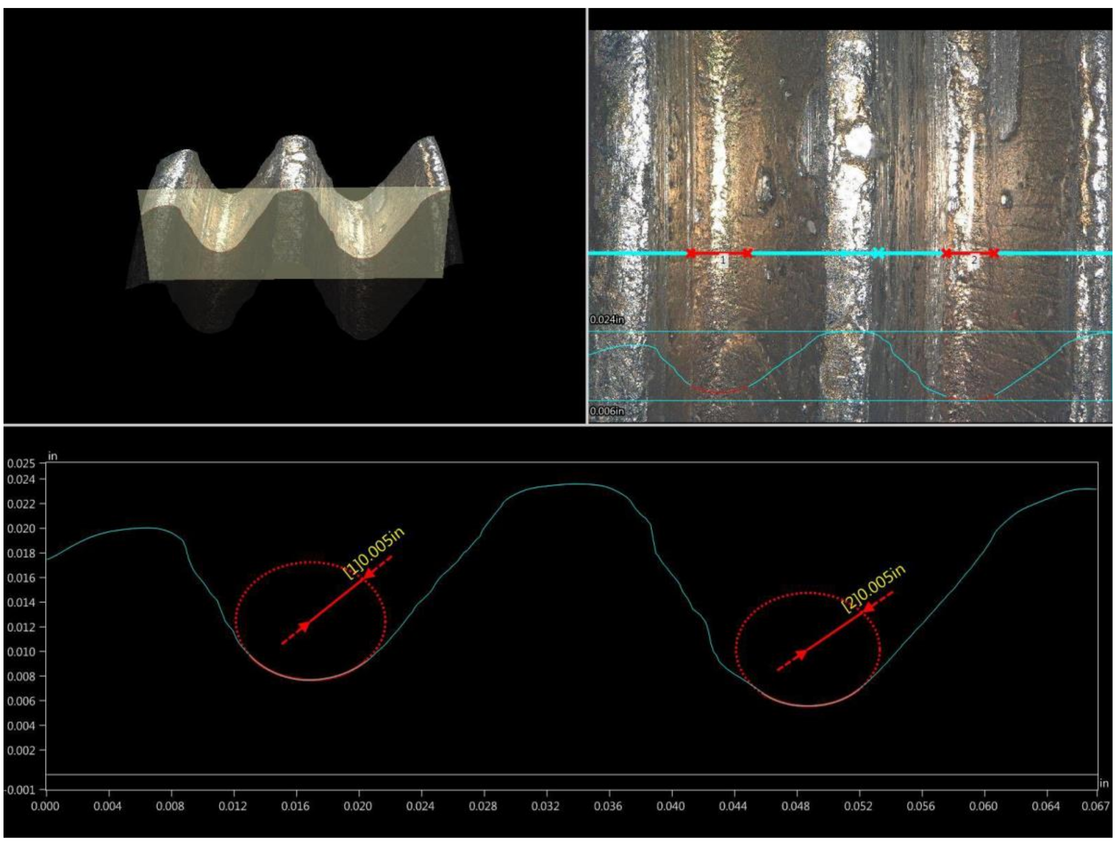

Figure 15 Root radii measured about .005”. There is no requirement for root radius.

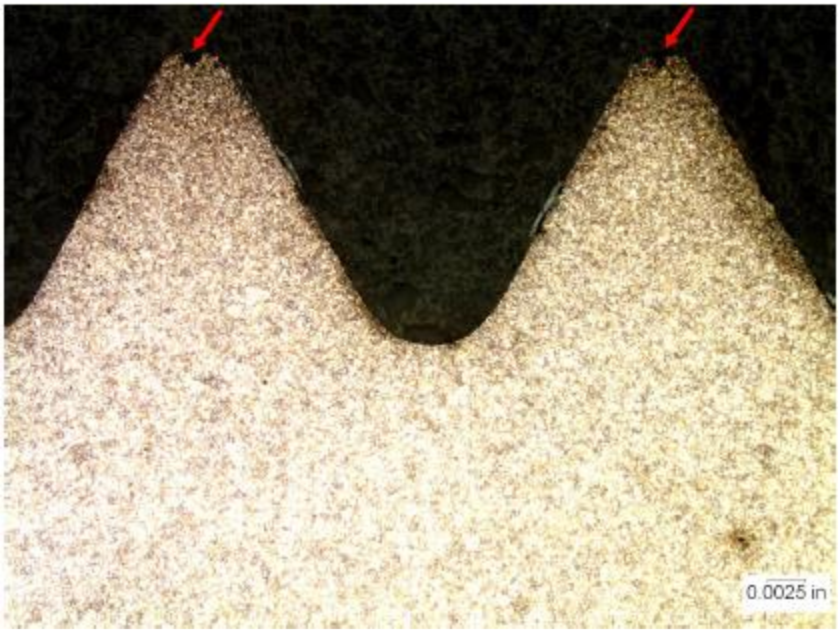

Figure 16 Cross section of the cracked bolt threads etched in nital exhibited seams at the thread crests (red arrows) indicating that threads were rolled.

Figure 17 Underside of heads on the cracked bolt(left) and fractured bolt(right).

Figure 18 Check valve housing with red arrow indicating fatigue origin.

Figure 19 Underside of check valve housing.

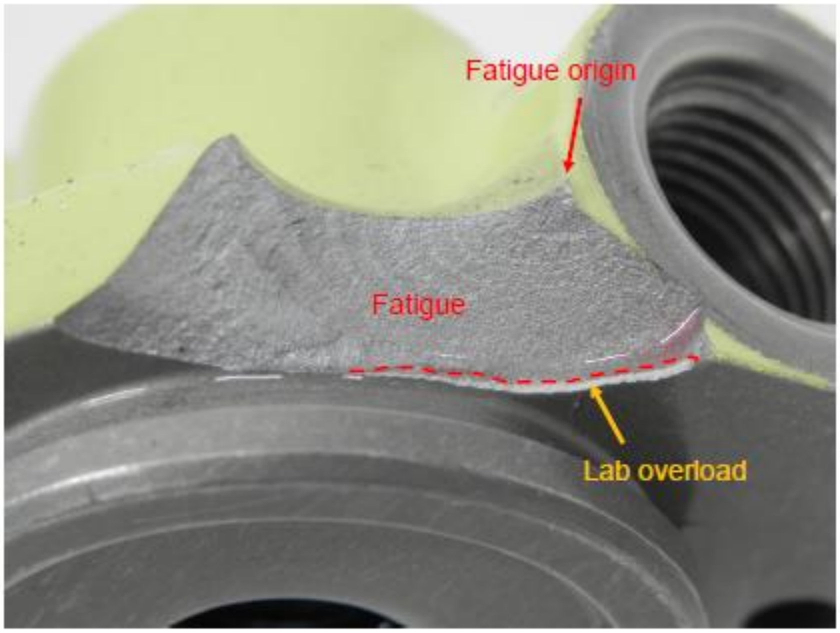

Figure 20 Check valve fracture surface was entirely fatigue except for a small portion of lab created overload created while opening the crack.

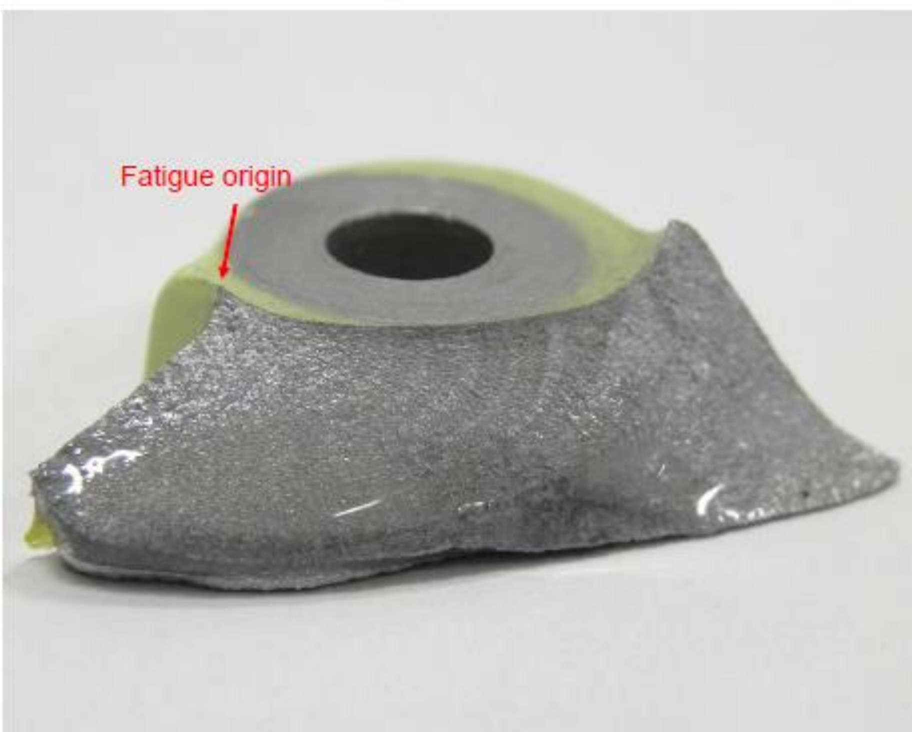

Figure 21 Lug half of housing fracture.

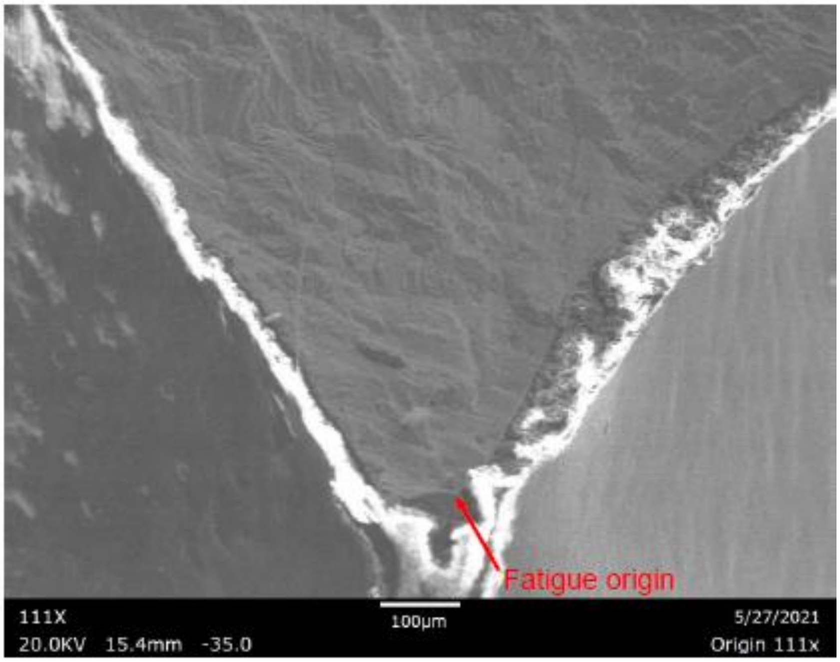

Figure 22 SEM examination of lug half of housing fracture.

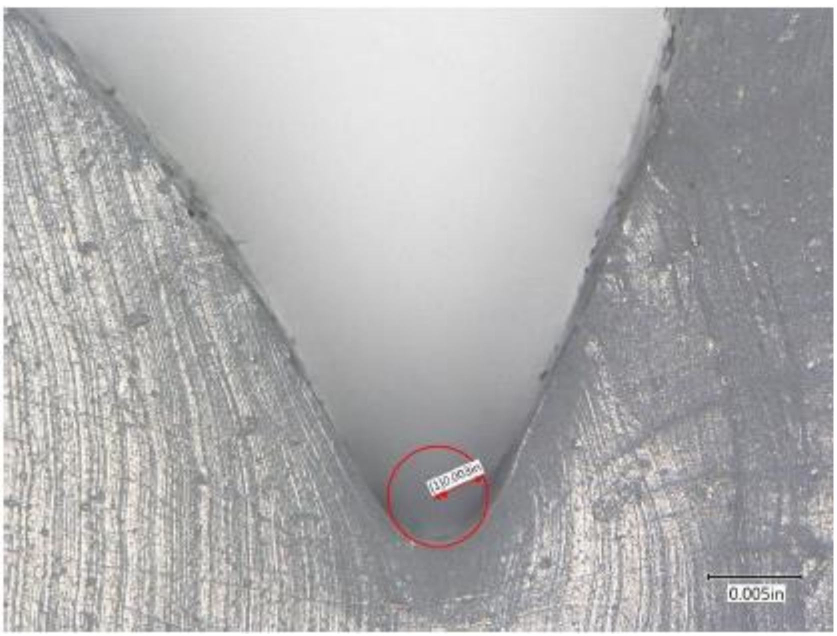

Figure 23 Replica cross section near housing origin. Radius measures about .003”.

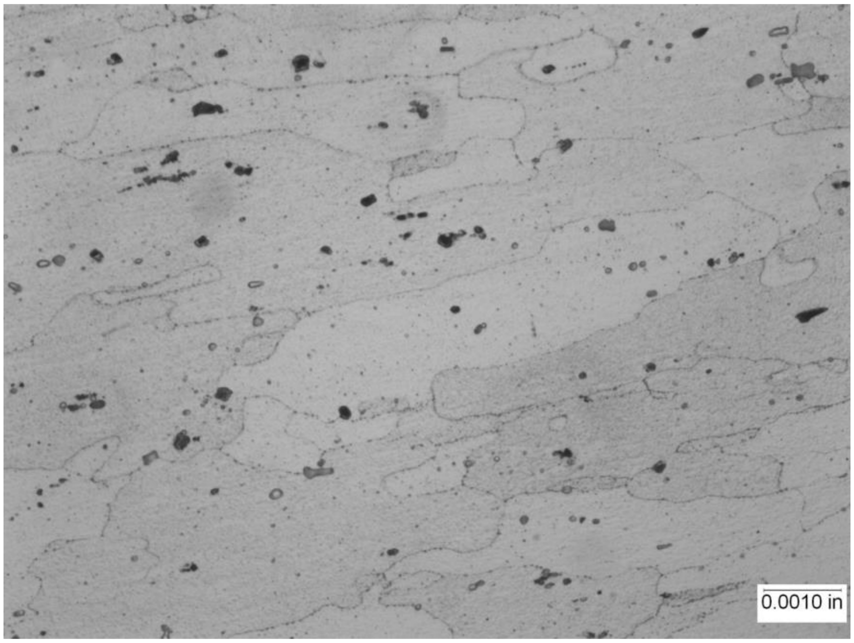

Figure 24 Housing microstructure at 500X etched with Keller's

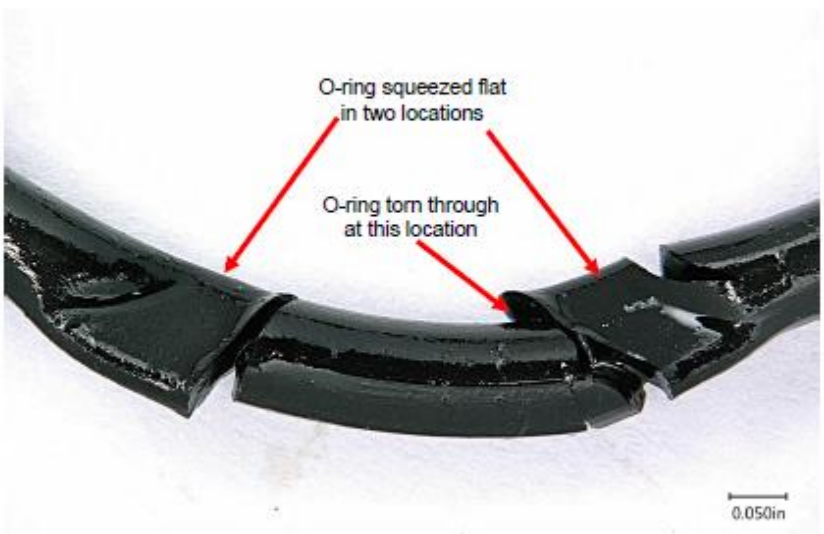

Figure 25 20X microscope image of o-ring damage.