

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR24LA122

MATERIALS LABORATORY

Factual Report 24-059

November 13, 2024

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A. ACCIDENT INFORMATION

Location: Nordman, Idaho
Date: April 4, 2024
Time: 14:45 mountain daylight time
20:45 coordinated universal time
Vehicle: Cessna 180A, N5281D
Investigator: Scott Johnson, AS-WPR

B. COMPONENTS EXAMINED

Remnants of a landing gear leg

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller, Ph.D., PE, FASM
Office of Research and Engineering - Materials Laboratory Division
NTSB, Washington, DC

D. SUMMARY

The left main landing gear axle assembly, which was secured to the landing gear leg by four attachment bolts, had separated from the leg. The threaded ends of all the attachment bolts were stripped in an outboard shearing direction. The two lower bolts exhibited bending deformation. The left landing gear leg fractured near its inboard end with the fracture initiating at a 0.022-inch-deep surface pit along the lower leg surface. A small fatigue crack had propagated away from the pit. The majority of the leg fracture surface was consistent with an overstress fracture in bending.

E. DETAILS OF THE EXAMINATION

On April 4, 2024, a Cessna 180A was substantially damaged during an accident near Priest Lake US Forest Service (USFS) Airport in Nordman, ID. The pilot and instructor were not injured. According to the pilot, during a landing sequence, the left main wheel assembly had separated from the gear leg, followed by separation of the gear leg from the airframe after it contacted the grass. A post-accident examination of the airplane revealed that the left main landing gear had parted just outboard of the gearbox mount structure, and the left main wheel and axle had detached from the gear leg. The left main landing gear leg, left axle, and the attachment bolts were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the landing gear leg pieces and the axle with attachment bolts as received. The landing gear leg, painted white, had fractured transverse to the longitudinal direction, as shown in the figure's right. The fracture was located about

6.5 inches from the inboard end and about 36.4 inches from the outboard end of the leg.

The outboard face at the outboard end of the landing gear leg, shown in Figure 2, exhibited some loss of white paint, consistent with rubbing against the mating axle assembly face, shown in Figure 3. The bolt holes exhibited areas of paint loss.

1.0 Axle and Attachment Bolts

Figure 4 through Figure 9 show views of the conditions of the bolts from the axle assembly, as received. All four attachment bolts were still installed through the flange that mated with the leg, though, as shown in Figure 6, the two lower bolts protruded through the mounting flange more than the upper bolts. An angled view of these bolts, shown in Figure 7, shows that the lower attachment bolts had also bent upward. This deformation is exemplified in Figure 8, with deformation on the lower forward attachment bolt edge. There was also some inward deformation to one of the upper attachment bolts, shown in Figure 8.

A portion of the threaded regions of the bolts from the axle were damaged. Figure 9 shows this damage to the lower attachment bolts, illustrated by the arrows. Most of the thread crests were missing in these areas, and the faces exhibited longitudinal streaks and smearing, consistent with having been pulled from an engaged position. There were also indications of deformation and impacts on other threads, but not as pronounced as those identified in Figure 9.

The bolts were measured using digital calipers, focusing on the amounts positioned inboard and outboard of the axle face. These dimensions, along with the dimensions of the bolts after removal, are listed in Table I. Figure 10 shows the bolts from the side after removal from the axle. The upper bolts and lower bolts exhibited different dimensions, with the lower bolts being longer and with wider shank and head diameters.

These dimensions were compared with the stated dimensions from the drawings for the bolts and nuts, listed in Table II. For the bolts, the shank dimensions were within the range prescribed, but the lengths of all the bolts exceeded the stated length of 2.25 inches. These lower bolts also exhibited necking (localized thinning) along the midpoint of the shanks. The aft lower bolt exhibited necking from 0.373 to 0.332 inches, and the forward bolt had thinned to 0.338 inches. This necking and elongation would be consistent with plastic deformation from tensile stresses of the bolts.

The chemical compositions of the bolts were examined using x-ray fluorescence (XRF). The bolts were consistent with alloy steel exhibiting an external cadmium coating. The hardness of each bolt was measured per ASTM E18, and the results are

listed in Table III.¹ The upper bolts averaged hardnesses of 38 HRC, whereas the lower bolts were 36 HRC.

Figure 11 shows the faying surfaces of the axle face and corresponding washers after bolt removal. A halo, consistent with the size and shapes of the corresponding washers faces, was present around each bolt hole on the axle face. These areas on the axle face exhibited rougher surfaces, discoloration, and matted debris particles, consistent with fretting wear.

Figures 12 and 13 show closer views of the threads of the aft upper and aft lower bolts, respectively. In each figure, most of the threads had been sheared off, as indicated by gouge marks on the flattened surfaces parallel to the bolt shank direction. In each case, as deformed and battered remnant of a partially separated bolt thread was still present withing a root. Material from the root had deformed to the right in the figures, consistent with shearing in the direction of the absent nuts.

Both these bolts demonstrate the length of more severe thread removal and wear, consistently measured as approximately 0.3 inches long on all four bolts (detailed in Table I). The lengths of the prescribed nuts are listed in Table II, which were used to approximate the thread engagement lengths on the bolts. The nut lengths were greater than the measured areas of most severe thread shearing.

2.0 Landing Gear Leg

The fracture surface at the inboard end of the landing leg segment in Figure 1 is illustrated in Figure 14. Most of the surface exhibited a dull luster with a rough, fibrous texture. There were sporadic areas of maroon color, consistent with ferrous oxides (i.e., rust; see Figure 15). The outboard portion of the fracture surface was relatively flat, with the inboard side protruding towards the reader. The fracture surface exhibited radiating river patterns, which curved back inward towards the bottom of the surface in shown in Figure 14. These features were consistent with the inboard bending of the landing gear leg during fracture.

Figure 15 shows an area from where all the river patterns, along with chevron marks, had emanated. The location was represented by the semi-ovoid white region along the bottom edge. After cleaning in an ultrasonic bath with acetone, some of the surface contamination had been removed. Figure 16 shows a closer view of the initiation region of the fracture, showing a dimple that contained white paint from the outside surfaces of the landing gear leg.

¹ ASTM E18 - Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials. ASTM International, West Conshohocken, PA.

Figure 17 shows an angled view of the painted divot at the fracture initiation region of the landing gear leg. The paint exhibited small blisters from the acetone cleaning but still adhered to the leg surface overall. The paint within the divot lacked such blisters, which was consistent with good adherence. The paint was chemically removed with a chemical stripping mixture of dichloromethane, methanol, and toluene. The angled surface of the divot is shown in Figure 18. The interior contained corrosion compounds, indicated by the maroon color. The outboard-facing surface of the leg also contained depressions, though their depth was less. These features were consistent with corrosion pitting.

Figure 19 and Figure 20 show closer views of the fracture initiation area at the large pit on the leg after paint removal. The figures demonstrate river patterns emanating from the pit area. There were also several small thumbnail-shaped cracks along the edge of the pit surface. These are annotated in Figure 20.

The fracture surface was examined using a field-emission scanning electron microscope (SEM). Figure 21 and Figure 22 show the corrosion pit and thumbnail cracks at the initiation region. The cracks exhibited crack arrest marks and five prominent ratchet marks, indicative of multiple crack initiation sites. The backscattered image shows some darker-colored areas along the edge of the pit.² The depth of the pit and crack were measured as being 0.56 mm (0.022 inches) deep and 1.16 mm (0.046 inches) long.

Figure 23 and Figure 24 show closer views of the largest thumbnail-shaped cracks. Figure 25 shows a closer view of a typical region in these cracks, revealing faint fatigue striations. These features were consistent with fatigue crack propagation, which had initiated at multiple sites along the pit surface. The surface exhibited dimpled rupture outside the fatigue cracking, as typified in Figure 26.

The initiation sites in Figure 25 showed darker material, consistent with oxides of the corroded metal. Chemical composition examination using energy-dispersive x-ray spectroscopy (EDS) examination of this material found it consistent with iron oxides, and detectable amounts of sulfur, sodium, and phosphorus.

The chemical composition of the leg material was consistent with alloy steel. The hardness of a cross section of the leg, examined per ASTM E18, exhibited a hardness of 49 HRC.

Figure 27 shows an angled view of the corrosion pit and crack initiation sites. The exterior edges of the pit exhibited some mechanical rounding, shown in the lower

² Backscattered electrons: SEM micrographs produced using backscattered electrons display contrast that is associated with the atomic numbers of the elements in the micrograph. Materials containing elements with higher atomic numbers visually appear lighter relative to other materials containing elements with lower atomic numbers.

right of the pit in Figure 27. The initiation sites were located along an area of penetrating corrosion, depicted in Figure 28. These areas of localized attack, delineated by the darker contrast in the figure, served as initiation sites for cracking that coalesced and then coalesced again, joining disparate cracks separated by perpendicular ratchet marks.

Submitted by:

Erik M. Mueller
Materials Research Engineer

F. TABLES

Table I. Attachment bolt measurement characteristics.

Bolt Location	Inboard Length (in)	Outboard Length (in)	Length of Stripped Threads (in)	Head Diameter (in)	Shank Diameter (in)	Bolt Length (in)
FWD, Up	1.0665	0.4770	0.2900	0.5255	0.3100	2.5115
FWD, Down	0.6865	1.0550	0.3005	0.645	0.373	2.7015
AFT, Up	1.2500	0.3180	0.3110	0.5255	0.3100	2.5100
AFT, Down	1.0595	0.7450	0.3660	0.646	0.3725	2.7175

Table II. Stated bolt and nut dimensions from assembly and part drawings.

Drawing #	Part Number	Type	Shank Width (in)	Head Width, Flared (in)	Length (in)	Depth (in)
18 (Bolt)	NAS146-47		0.371-0.374	0.615-0.625	2.5930	
21 (Bolt)	NAS145-45		0.3085-0.3115	0.523-0.531	2.5260	
20 (Nut)	MS20365-624C	3/8-24UNF-3B				0.453±0.016
23 (Nut)	MS20365-524C	5/16-24UNF-3B				0.344±0.016

Table III. Hardness measurements of the landing gear leg and attachment bolts.

Part and Location	Hardness (HRC)
Landing gear leg (cross-section near fracture)	49
Bolt – forward, upward	38
Bolt – aft, upward	38
Bolt – forward, downward	36
Bolt – aft, downward	36

G. FIGURES



Figure 1. The pieces of the left landing gear leg, as received from (a) outboard and (b) inboard faces.



Figure 2. The outboard face of the leg from Figure 1a with the attachment bolt holes.

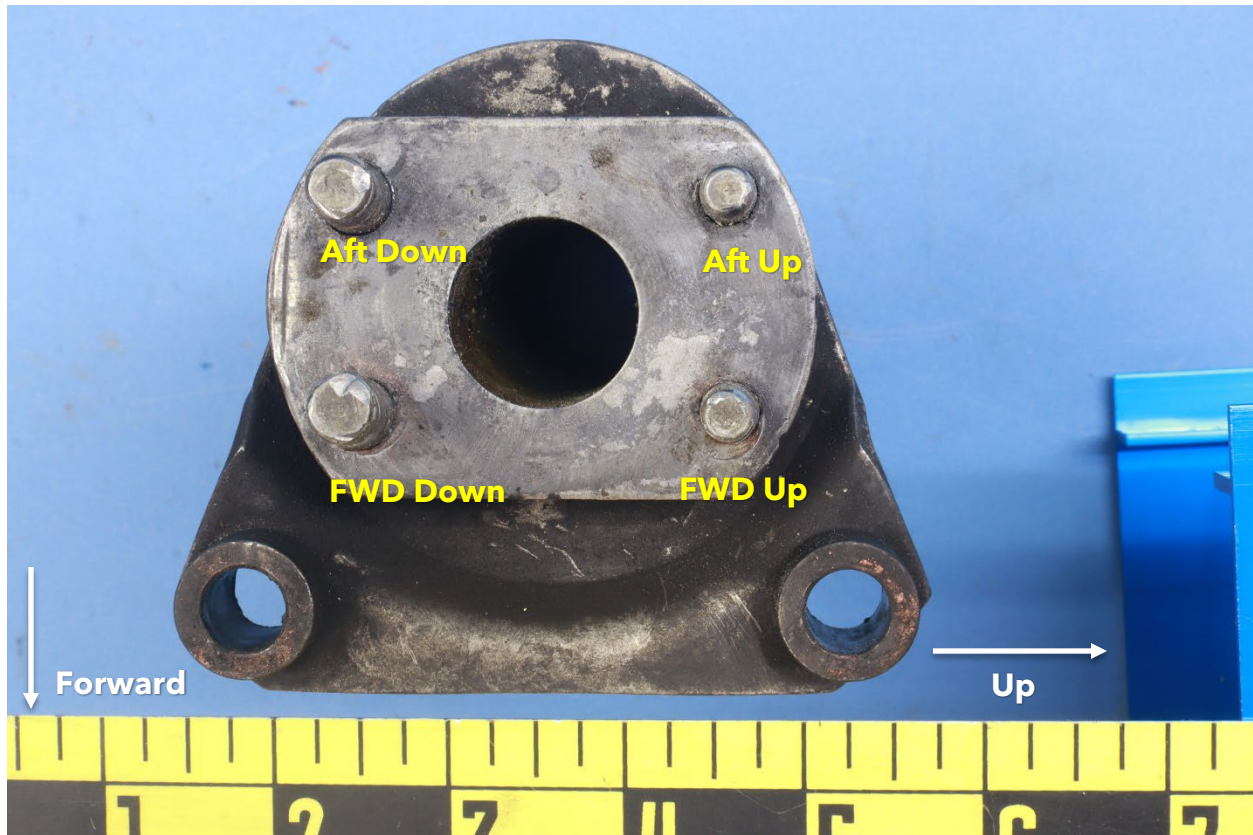


Figure 3. View of the bolts from the bolt side of the axle assembly toward the outboard direction.



Figure 4. Aft-looking forward view of the axle assembly, as received.

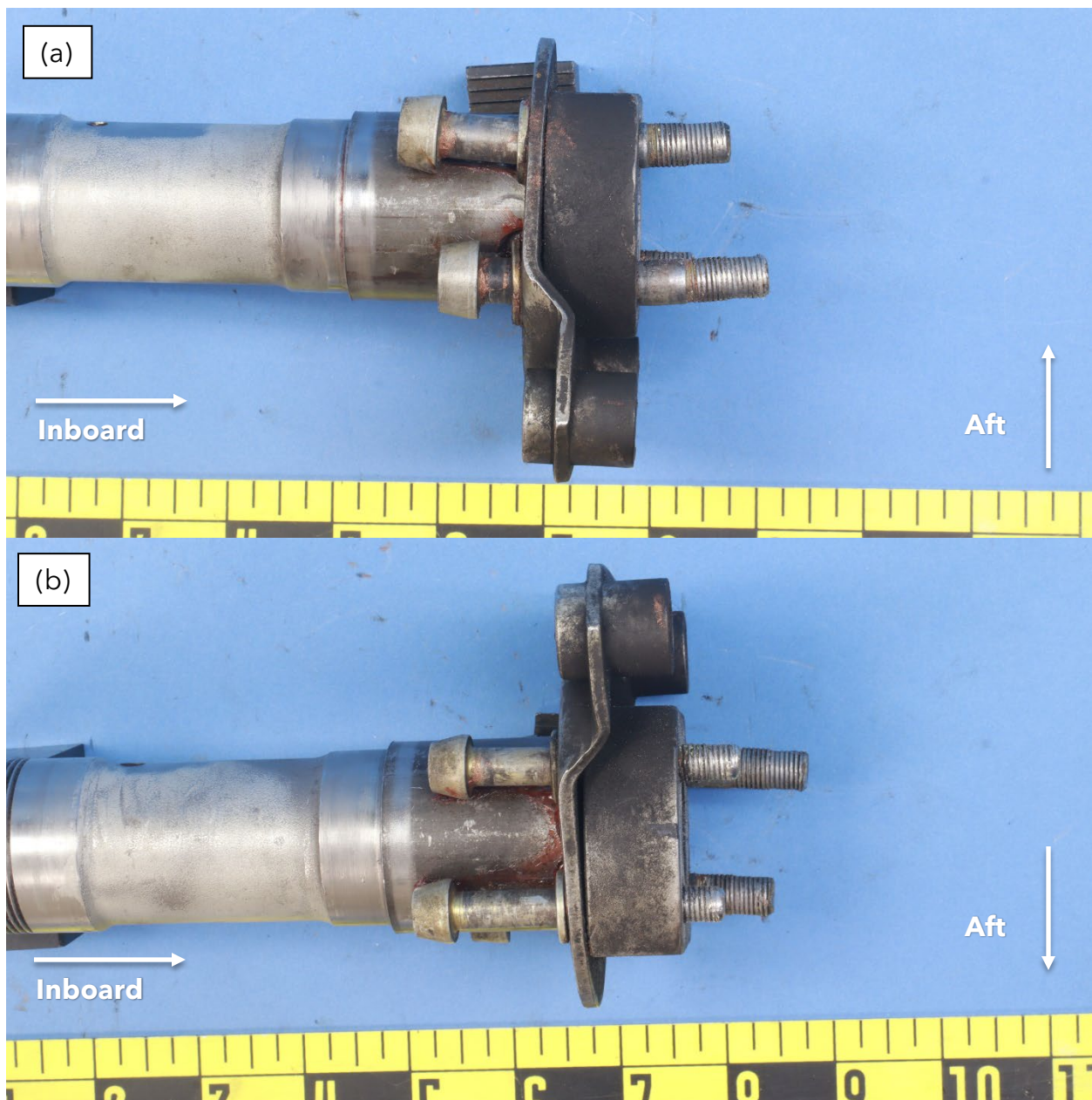


Figure 5. Opposite side views of the bent bolts from the axle assembly: a) lower or bottom side view and b) top or upward view.

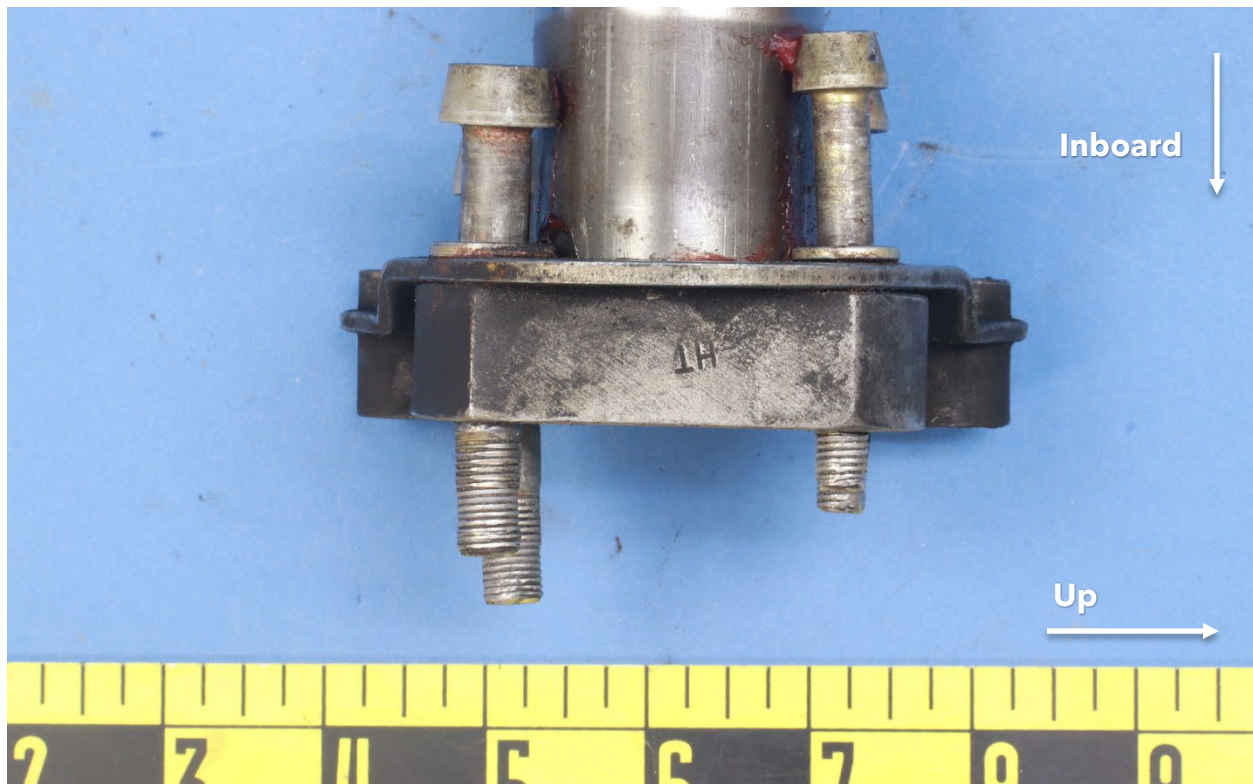


Figure 6. Aft view highlighting the bolt threads for the axle assembly.



Figure 7. Closer aft view of the bolt threads in Figure 6, showing deformation.



Figure 8. Rotated view (aft looking forward) of the bolts in Figure 7.

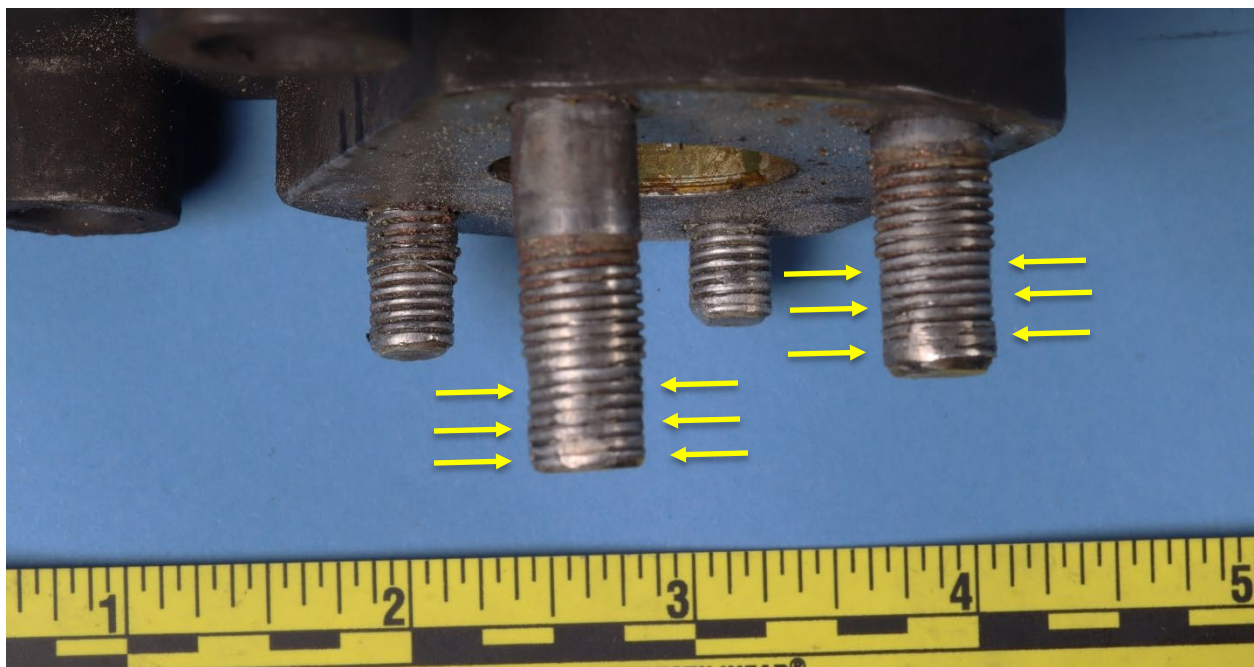


Figure 9. Lower side view looking upward of the bolts in Figure 8, showing thread deformation and shear of the lower bolts (arrows).

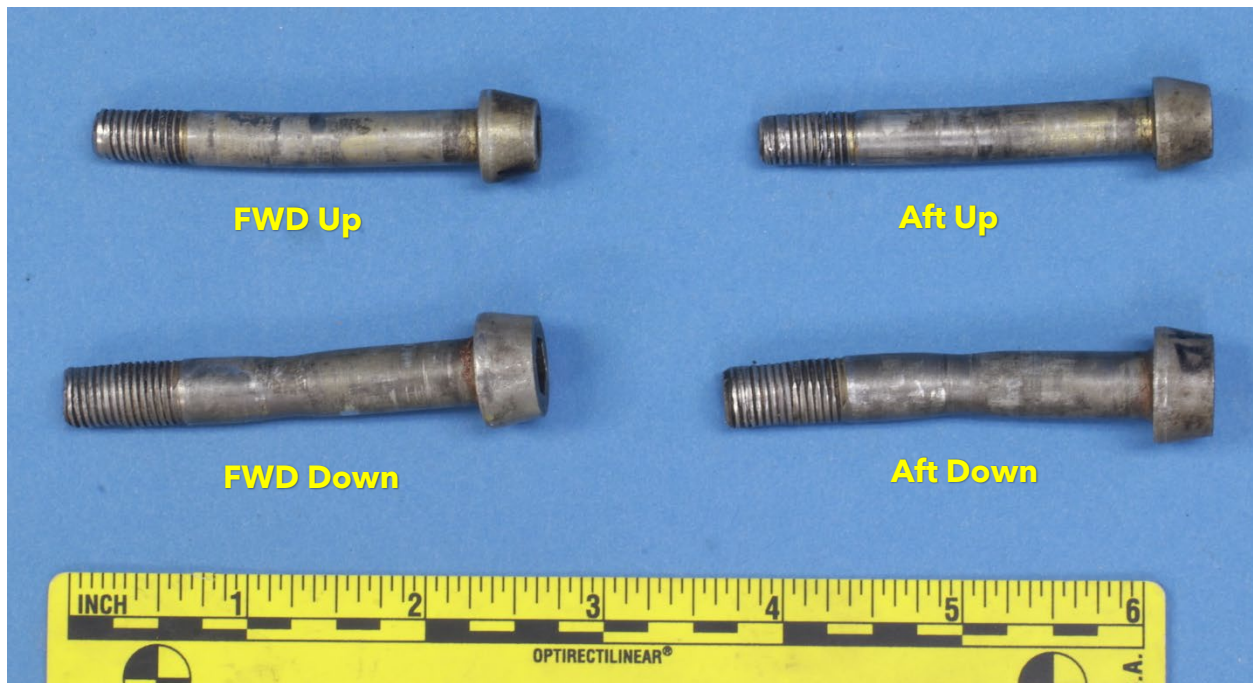


Figure 10. The attachment bolts after removal from the axle and cleaning.



Figure 11. View of the washers and faying surface of the axle, showing annular areas of fretting.



Figure 12. Side view of the damaged threads from the aft lower bolt.

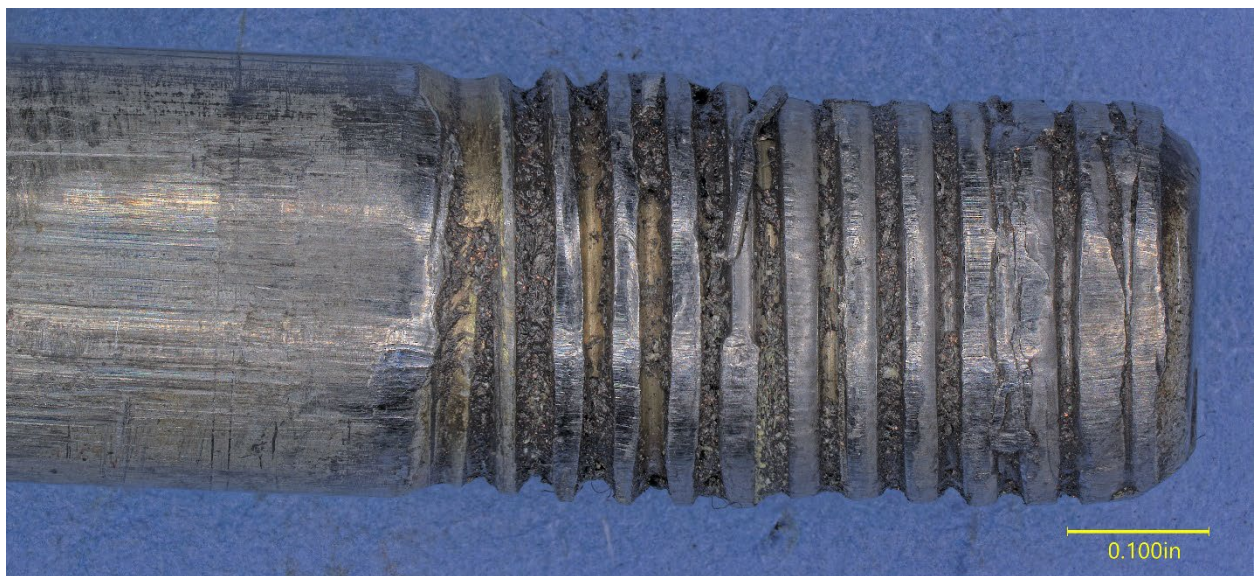


Figure 13. Side view of the damaged threads from the aft upper bolt.



Figure 14. View of the outboard fracture surface of the landing gear leg, as received.

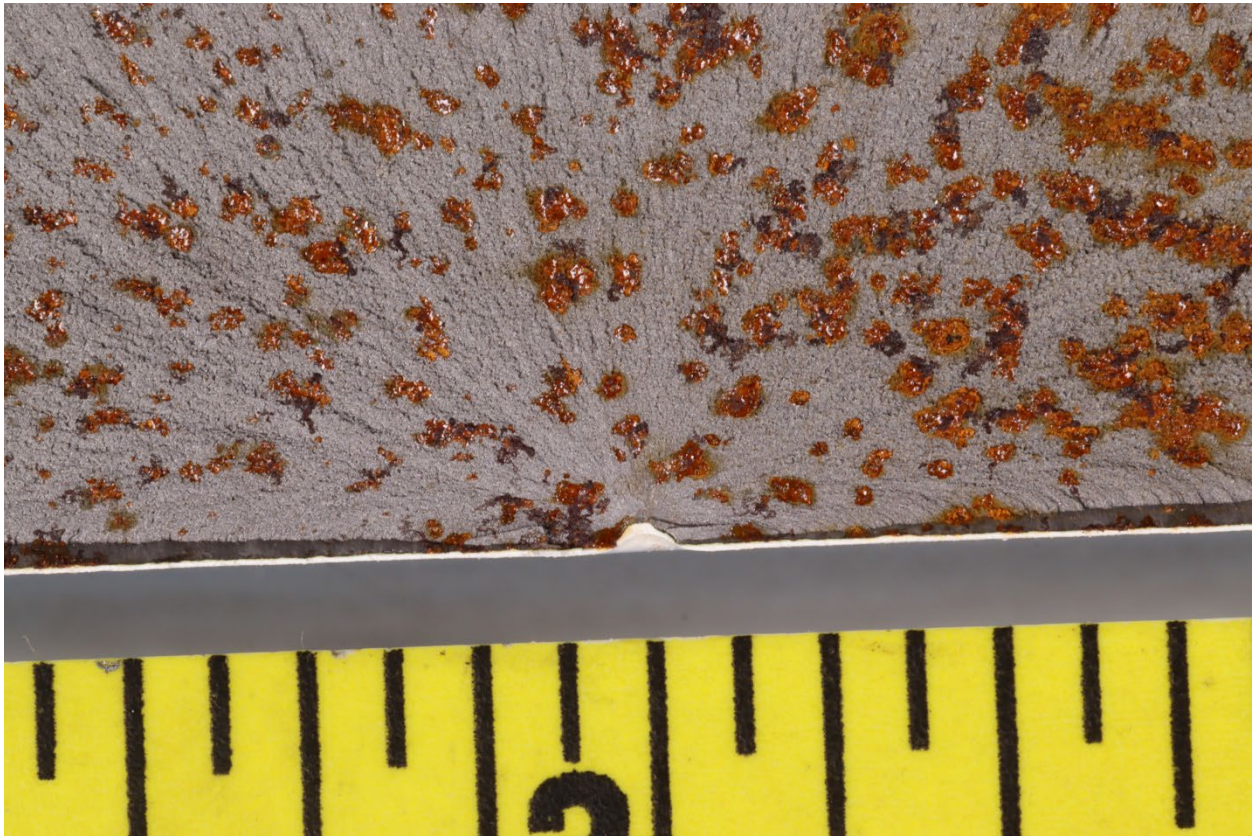


Figure 15. Closer view of the initiation region of the fracture surface, showing an area of white paint within a surface pit on the lower surface of the landing gear leg.



Figure 16. Closer view of the pit and fatigue cracking at the initiation of the leg fracture.



Figure 17. Angled view of the pit in Figure 16, showing paint adhering to the pit surface.



Figure 18. View of the corrosion pit in Figure 17, after chemical stripping of paint.

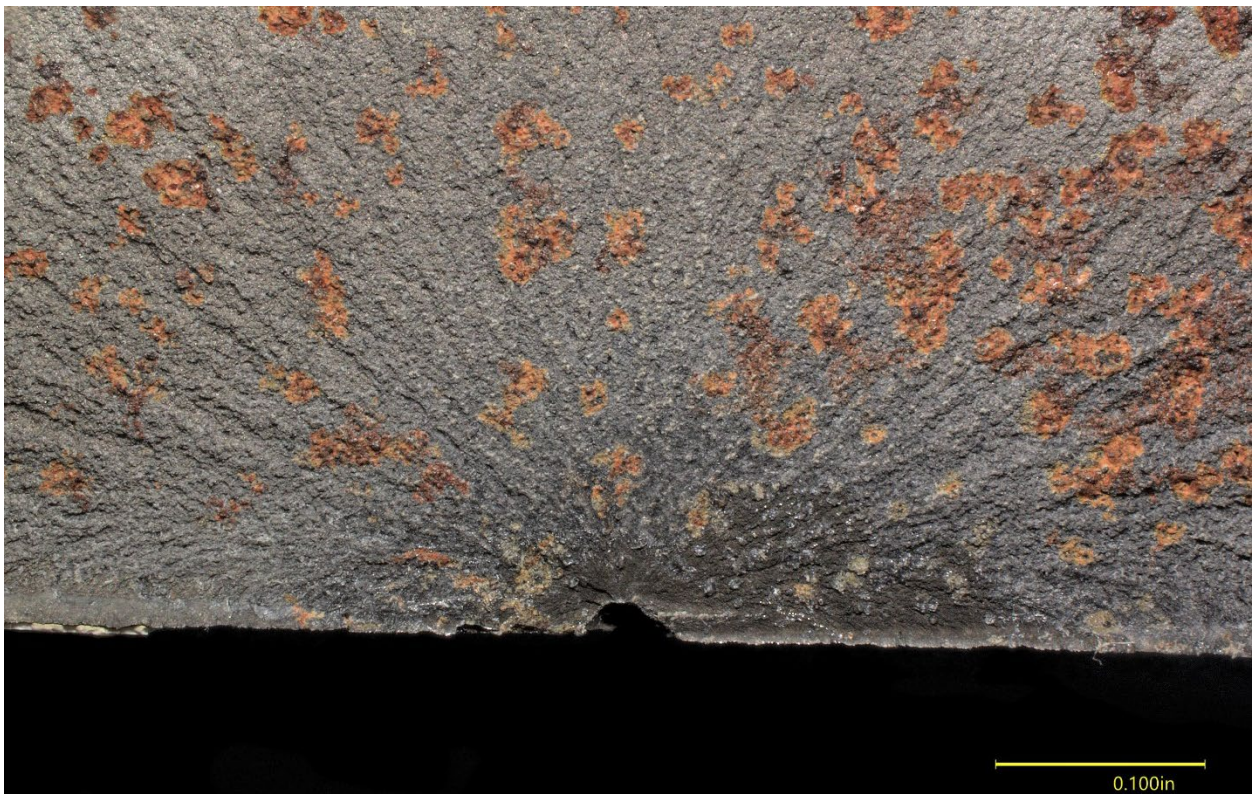


Figure 19. View of the initiation area of the fracture surface after chemical paint stripping.

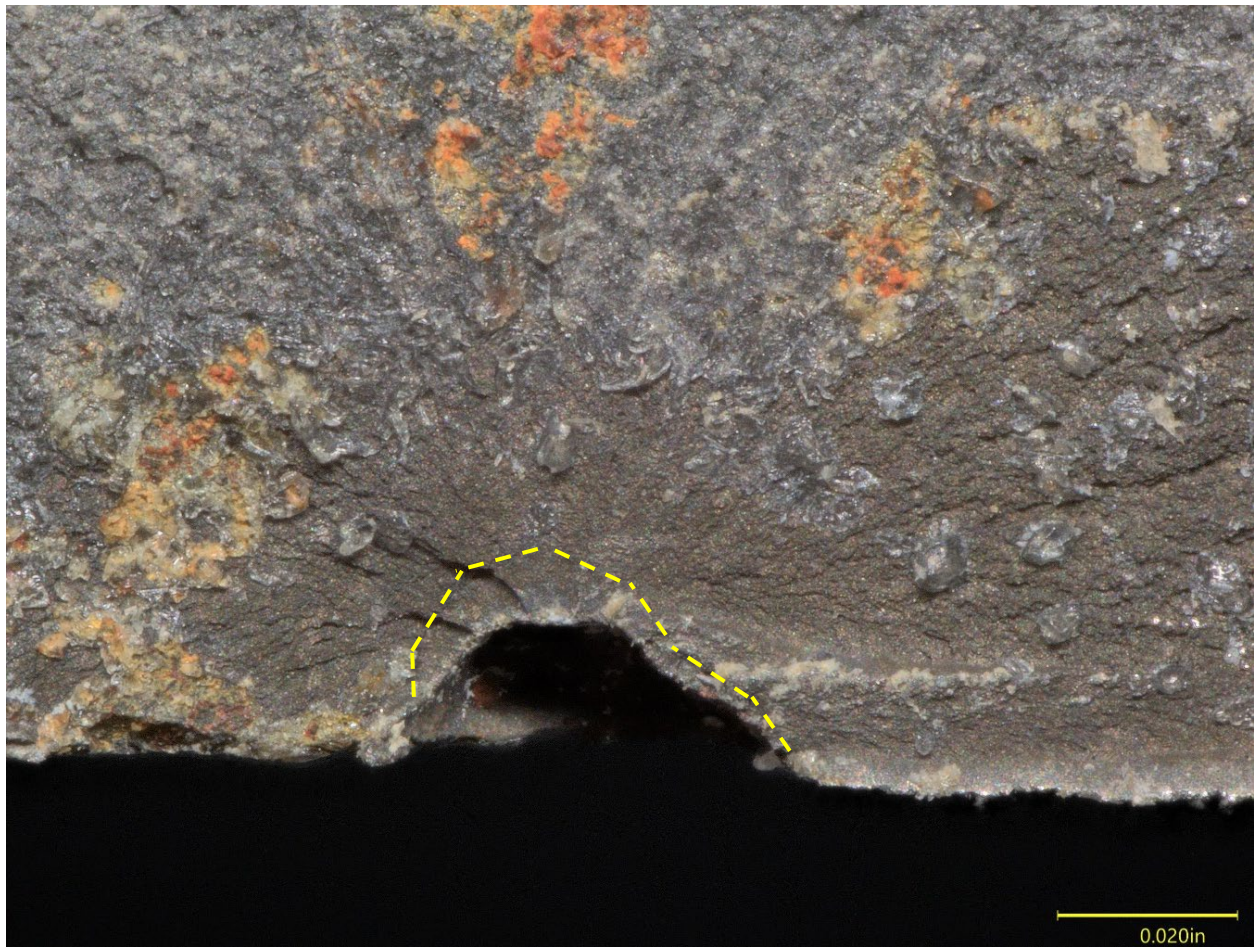


Figure 20. The crack initiation region and the corrosion pit, after chemical stripping and removal of paint and some surface corrosion. The area of fatigue cracking next to the pit is delineated by the yellow dashed lines.

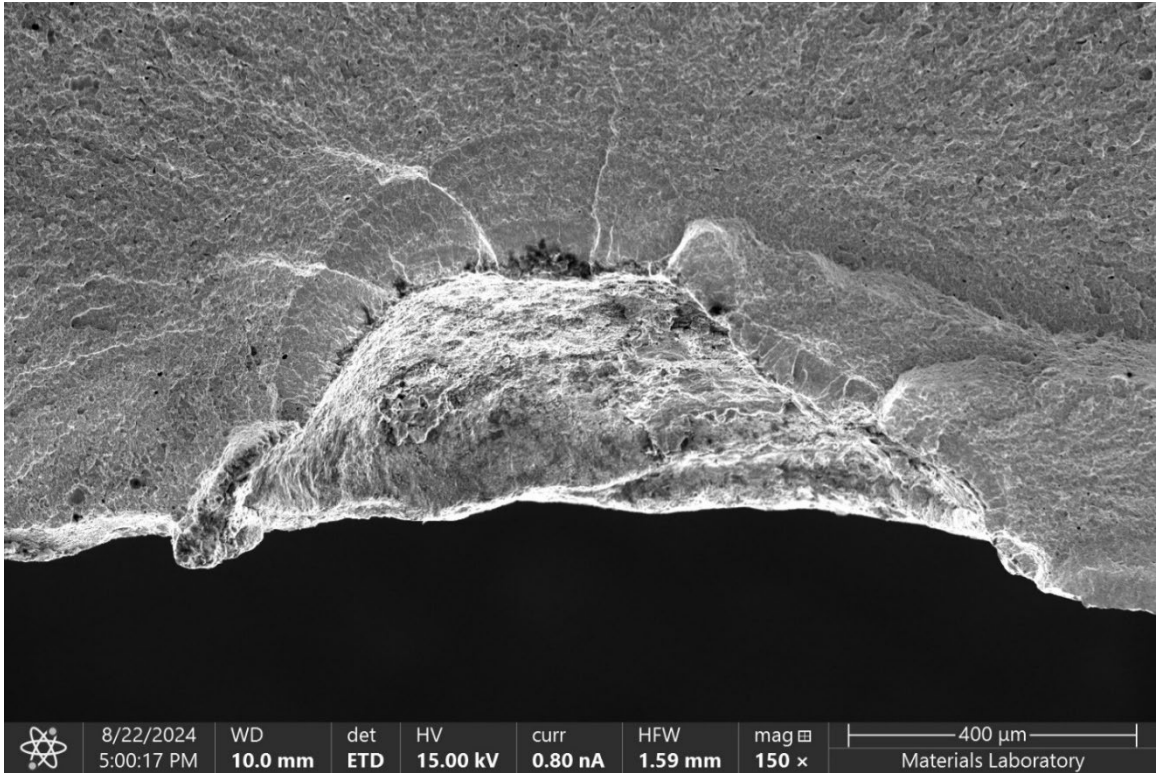


Figure 21. Secondary electron (SE) micrograph of the fatigue cracks around the corrosion pit.

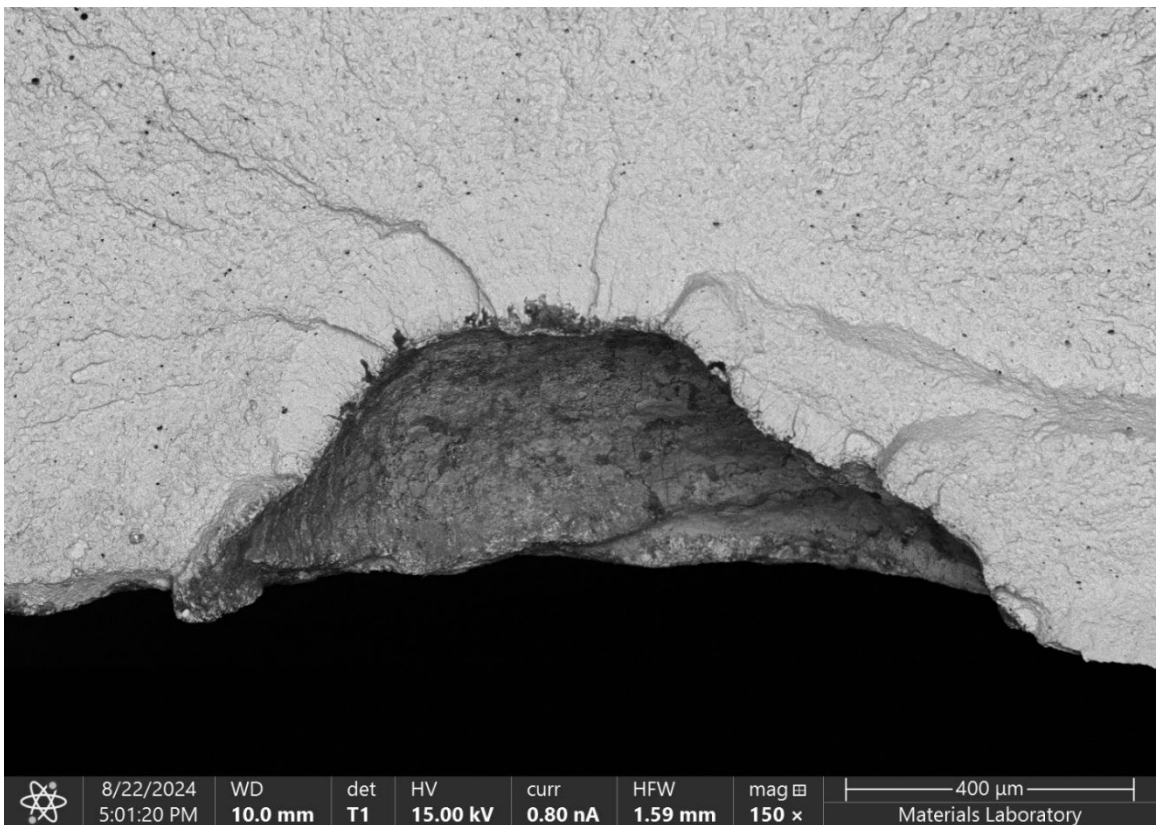


Figure 22. Backscattered electron (BE) micrograph of the fatigue cracks around the pit.

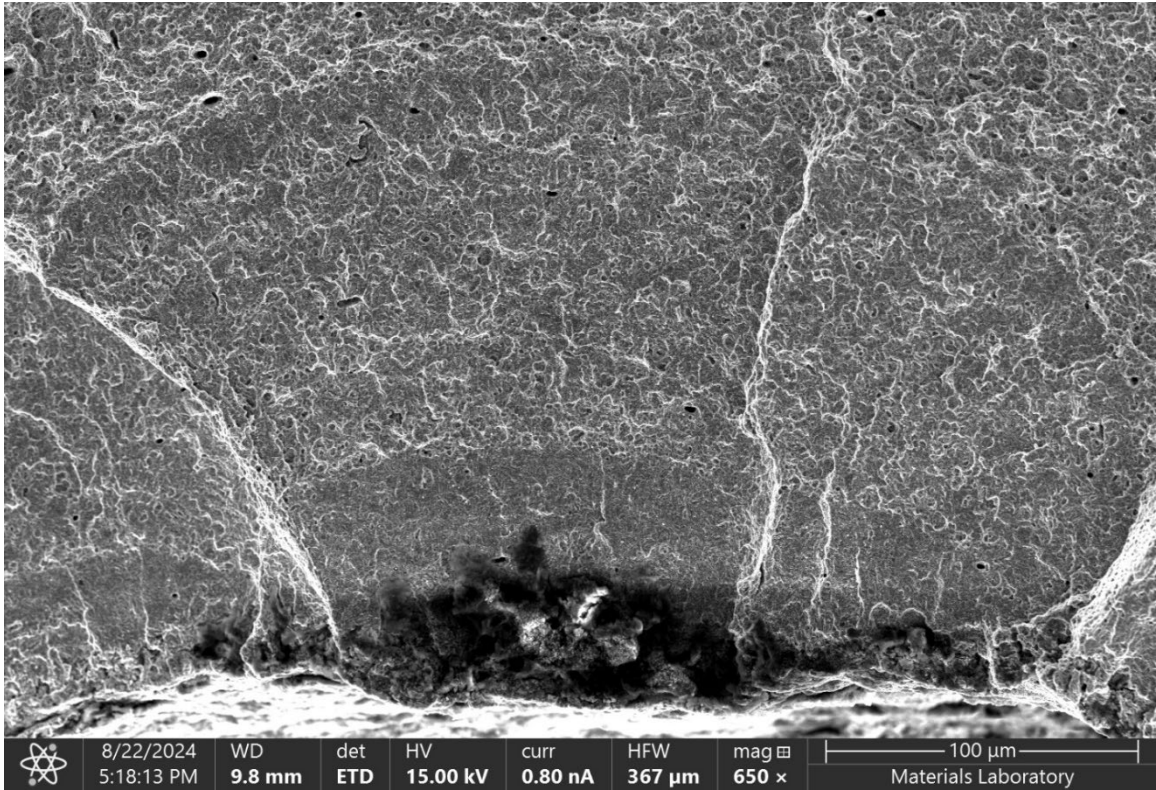


Figure 23. SE micrograph of the regions of the fatigue cracking, showing ratchet marks and arrest marks.

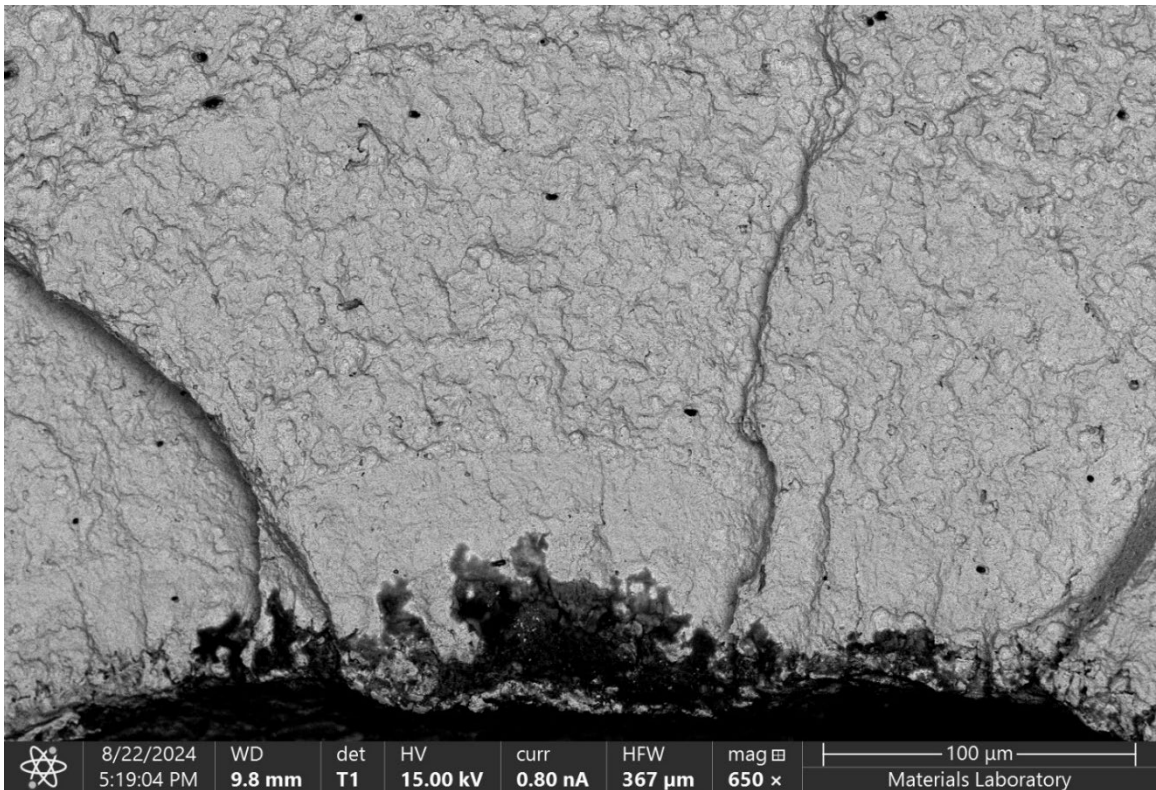


Figure 24. BE micrograph of the fatigue crack area in Figure 23.

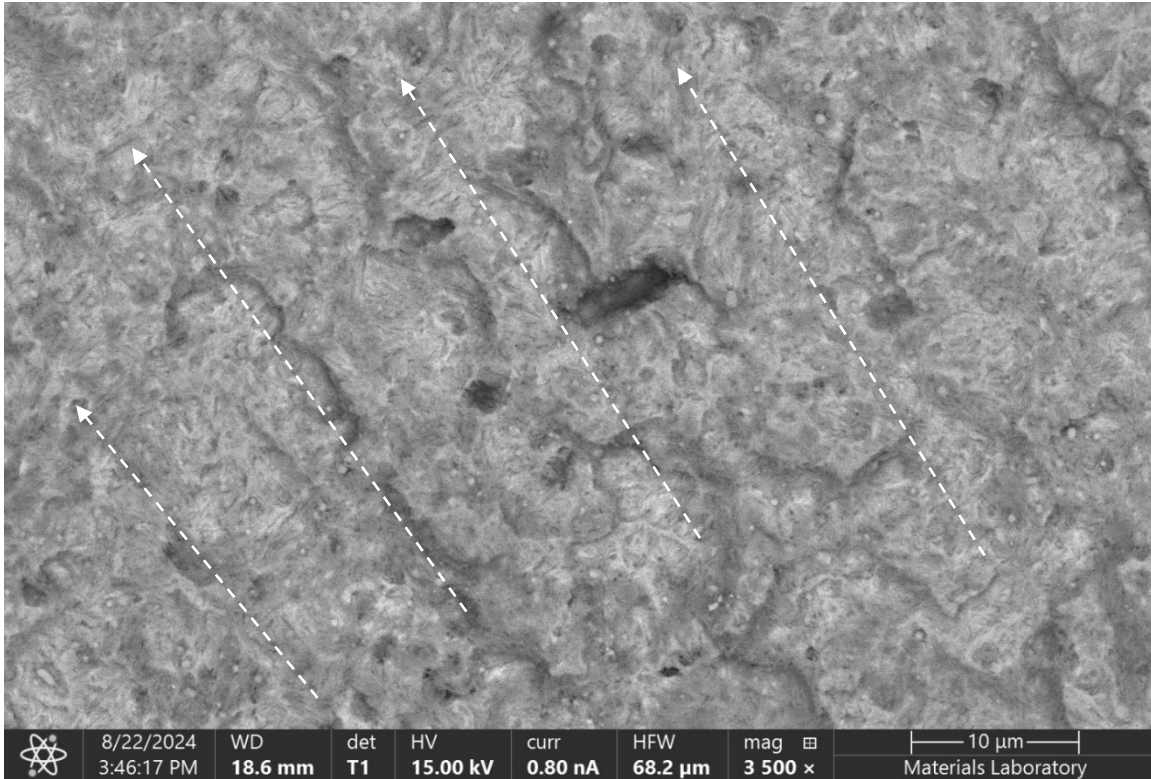


Figure 25. BE micrograph of a typical area of the fatigue region, with the crack growth direction annotated with dashed white arrows.

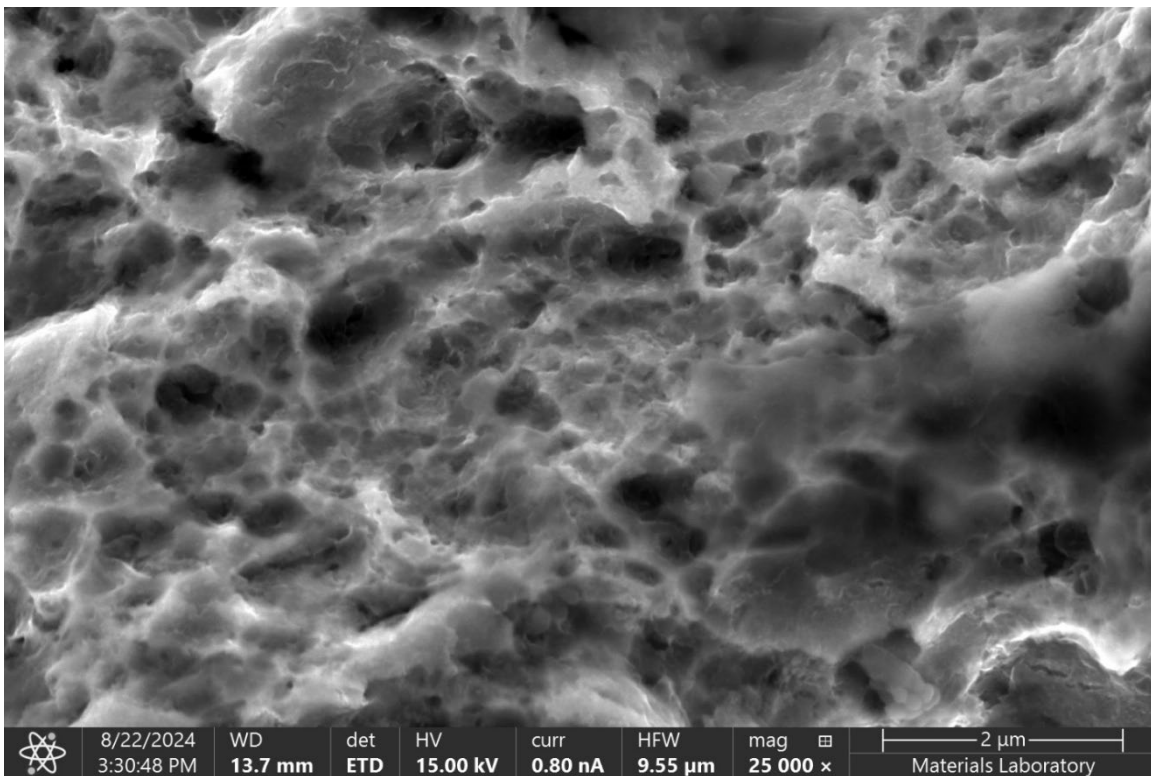


Figure 26. SE micrograph of dimpled rupture outside of the fatigue crack (after cleaning).

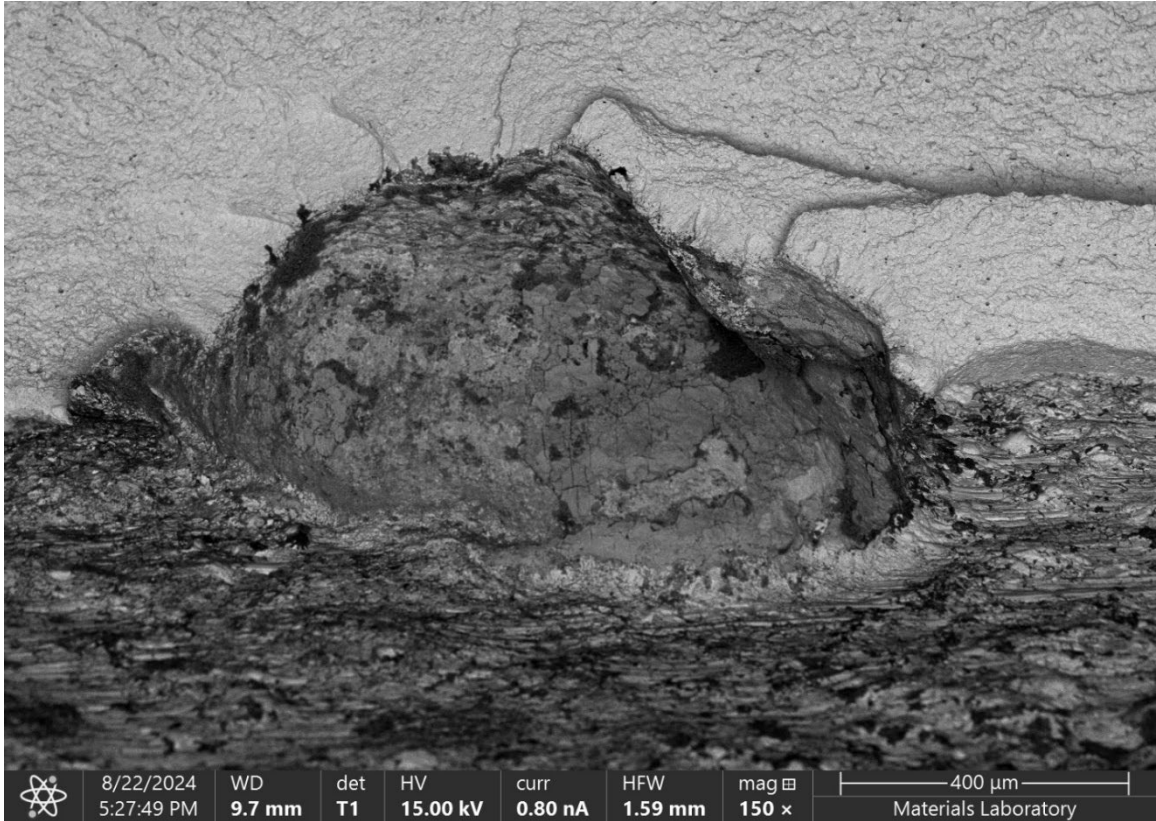


Figure 27. BE micrograph of an angled view of the corrosion pit and fatigue crack.

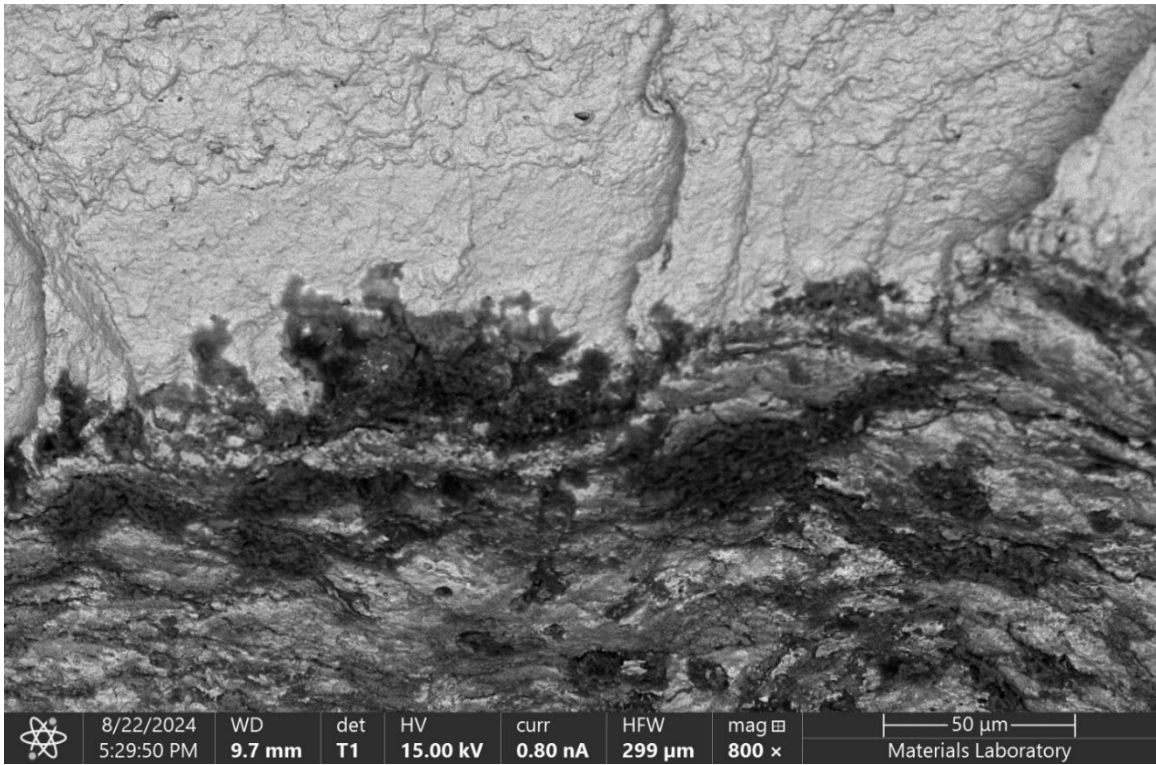


Figure 28. BE micrograph of crack initiation sites along the corrosion pit edge in Figure 27.