

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ANC22LA040

MATERIALS LABORATORY

Factual Report 22-081

November 1, 2022

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A. ACCIDENT INFORMATION

Location: Kodiak, Alaska
Date: June 8, 2022
Time: 11:34 Alaska daylight time
19:34 coordinated universal time
Vehicle: Cessna U206F, N592KB
Investigator: Aaron Sauer, AS-ANC

B. COMPONENTS EXAMINED

Remnant of a main landing gear leg

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller, Ph.D., P.E.
Office of Research and Engineering - Materials Laboratory Division
NTSB

D. DETAILS OF THE EXAMINATION

On June 8, 2022, a Cessna U206F was substantially damaged when it was involved in an accident 65 miles from Kodiak, AK. The pilot and four passengers were not injured. According to the pilot, during landing, when the right main landing gear wheel touched down, the pilot heard a loud noise, followed by the airplane veering to the right. Examination of the airplane revealed the right main landing gear leg was fractured near the wheel attachment fitting. The fractured landing gear leg was retained for further examination by the National Transportation Safety Board Materials Laboratory.

The airplane records revealed the most recent annual inspection was completed on November 12, 2021, at a total airframe time of 5034 hours. In July 2019, the main landing gear legs had been removed and repaired per the manufacturer service manual. Since that repair, the main landing gear legs had accumulated about 875 hours including 200 beach and off-airport landings.

Figure 1 and Figure 2 show the remnant of the landing gear leg, as received. The remnant exhibited four bolt holes, one of which still contained the remnant of a bolt shank. The part had fractured through the cross section, perpendicular to its longitudinal direction. The fracture surface faces towards the left in Figures 1 and 2.

As measured using digital calipers, the remnant was 4.042 inches long, 2.016 inches wide, and 0.822 inches thick. Approximately 0.54 inches from the fracture surface, the

remnant exhibited an angled bend, appearing downward in Figure 3. This bend was approximately 10° from the longitudinal direction of the rest of the remnant.

Figure 4 shows the leg remnant fracture surface, as received. The surface was relatively flat, with indications of post-fracture smearing, evidenced by the reflective region in the upper left, and post-fracture corrosion from the presence of rust-colored oxide compounds on the surface. Overall, the fracture surface exhibited a dull luster with a rough texture. The river patterns on the fracture surface emanated from an area in the lower right of Figure 4, consistent with the area of the start of the fracture sequence of the part. This region was located along the edge of the leg, near a corner (shown in Figure 5).

A closer view of the area revealed several thumbnail-shaped cracks, with a large vertically oriented ratchet mark on the fracture surface (see Figure 6). These cracks were also located near an area of corrosion and wear on the outside surface, facing downward in Figure 6. This area was approximately 0.6 inches wide along the fracture surface edge, and it extended approximately 0.3 inches from the fracture surface.

The area near the fracture surface was sectioned with an abrasive saw and then cleaned with an Evapo-rust solution in an ultrasonic bath.¹ Figure 8 shows a closer view of the cleaned fracture surface around the thumbnail cracks. As illustrated in Figure 9, these cracks exhibited crack arrest marks, consistent with crack propagation, and ratchet marks, consistent with multiple crack initiation sites.

The fracture surface was examined using a field-emission scanning electron microscope (SEM). The thumbnail crack region is shown in Figure 10 and Figure 11. Using the SEM, the cracks were found to measure 5 mm wide by 1.3 mm deep (0.20 inch wide by 0.054 inch deep).

The end of the largest thumbnail crack on the fracture surface is illustrated in Figure 12. The area in the crack exhibited fatigue striations, consistent with fatigue crack propagation (as typified in Figure 13). Outside the fatigue crack terminus, the rest of the fracture surface exhibited dimpled rupture, consistent with overstress fracture, as demonstrated in Figure 14.

As shown in the backscattered micrograph in Figure 11, the thumbnail cracks exhibited darker contrast material.² An examination of this material using energy

¹ Evapo-Rust is a commercially available chelating rust stripper currently manufactured CRC Industries, headquartered in Horsham Township, PA.

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.

dispersive x-ray spectroscopy (EDS) found it to be mainly composed of iron oxides. The oxide also contained minor amounts of copper, with detectable amounts of sodium, magnesium, potassium, sulfur, chlorine, and calcium—these elements were consistent with corrosion products typical of marine environment exposure.

The composition of the sectioned leg remnant was also examined using EDS and x-ray fluorescence (XRF). The chemical composition of the leg remnant was consistent with an alloy steel. The hardness was examined per ASTM E18.³ The hardness averaged 49 HRC, consistent with a quench and tempered condition for this material.⁴

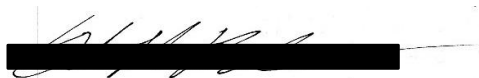
A closer view of the initiation sites is shown in Figures 15 through 17. As shown in backscattered mode, the initiation sites exhibited enough surface corrosion product to obscure the underlying metal, even after cleaning. Examination using EDS again found iron oxides with the elements typical of salt and marine environments.

A closer view of the fatigue crack initiation site to the left of the larger ratchet mark found a divot geometry (arrow, Figure 17). This feature was consistent with a corrosion pit. Figures 18 and 19 show an angled view of the underside of the leg remnant, where the area of corrosion was located next to the fatigue cracks.

As shown in Figure 19, there were circular areas with discoloration, consistent with thicker surface corrosion products typical of pitting corrosion. After additional cleaning, the pits were found along this region near the fracture surface (see Figure 20). The surface oxide morphology was present throughout the area of corrosion on the underside of the leg remnant (see Figure 21).

These features were consistent with the leg having fractured during landing, due to the stress concentration of fatigue cracks that had propagated inward from the lower surface of the leg. The fatigue cracks initiated from corrosion pits in an area of the leg that had experienced localized pitting corrosion.

Submitted by:



Erik M. Mueller
Materials Research Engineer

³ ASTM E18 - *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

⁴ HRC - Hardness, Rockwell C scale. An indentation method of determining the hardness of harder metal alloys using a conical diamond indenter and 150 kg major load.



Figure 1. View of the main landing gear leg fragment, as received.



Figure 2. Angled view of the leg fragment opposite that of Figure 1, showing a bend towards the fracture surface.



Figure 3. Side view of the leg remnant, showing the geometry of the leg fragment.



Figure 4. View of the leg fragment fracture surface, as received.



Figure 5. Angled view of the fracture surface edge of the leg fragment, showing the fracture initiation region in the lower right.

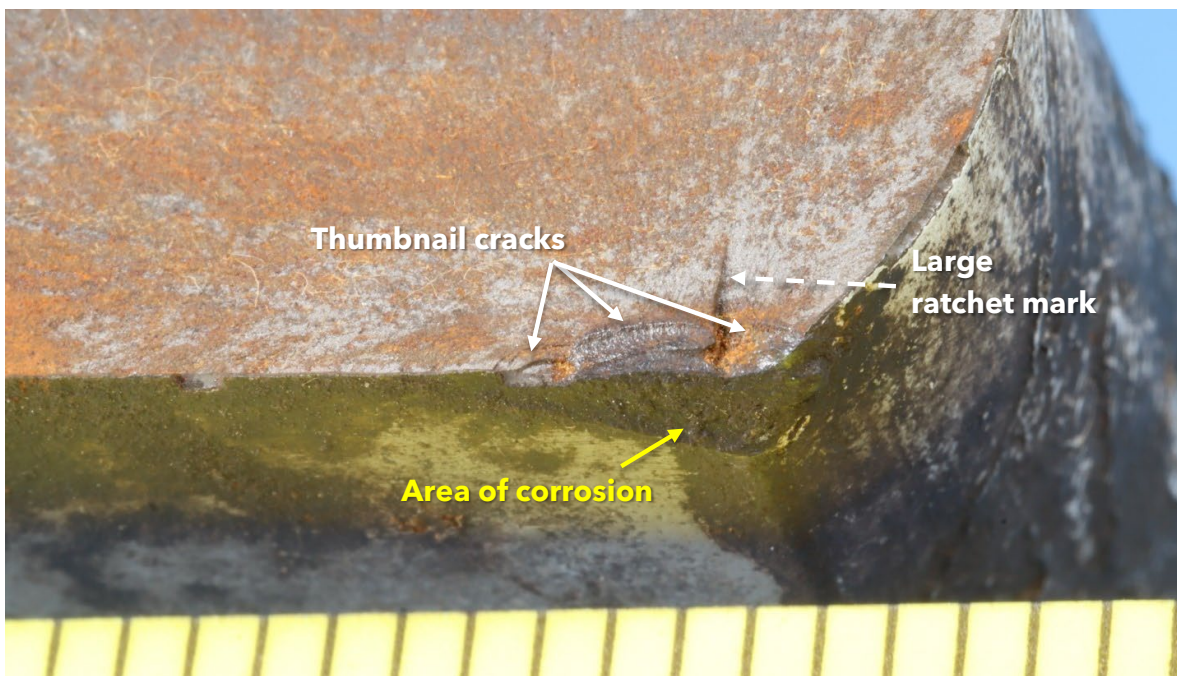


Figure 6. Closer view of the thumbnail crack, with various features annotated.



Figure 7. View from underneath of the leg, showing the area of corrosion and the fracture surface.



Figure 8. Closer view of the thumbnail cracks, after cleaning the fracture surface.

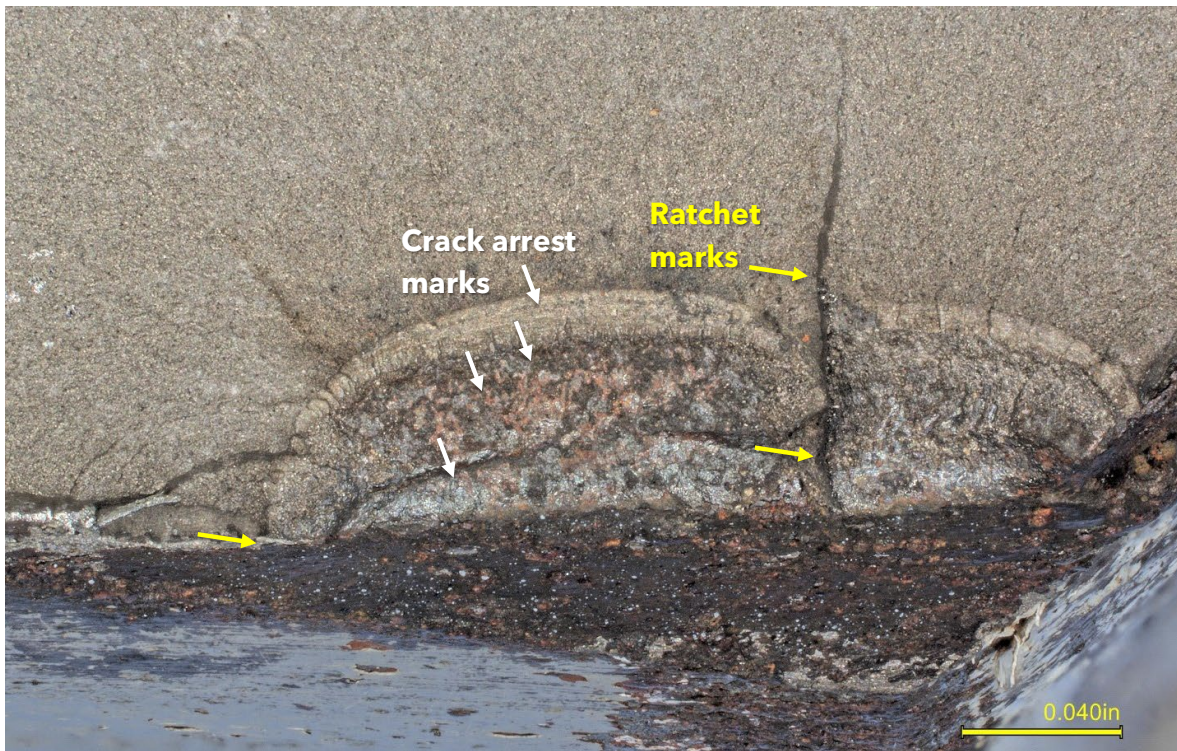


Figure 9. Closer view of the cracks in Figure 8, showing ratchet marks and crack arrest marks.

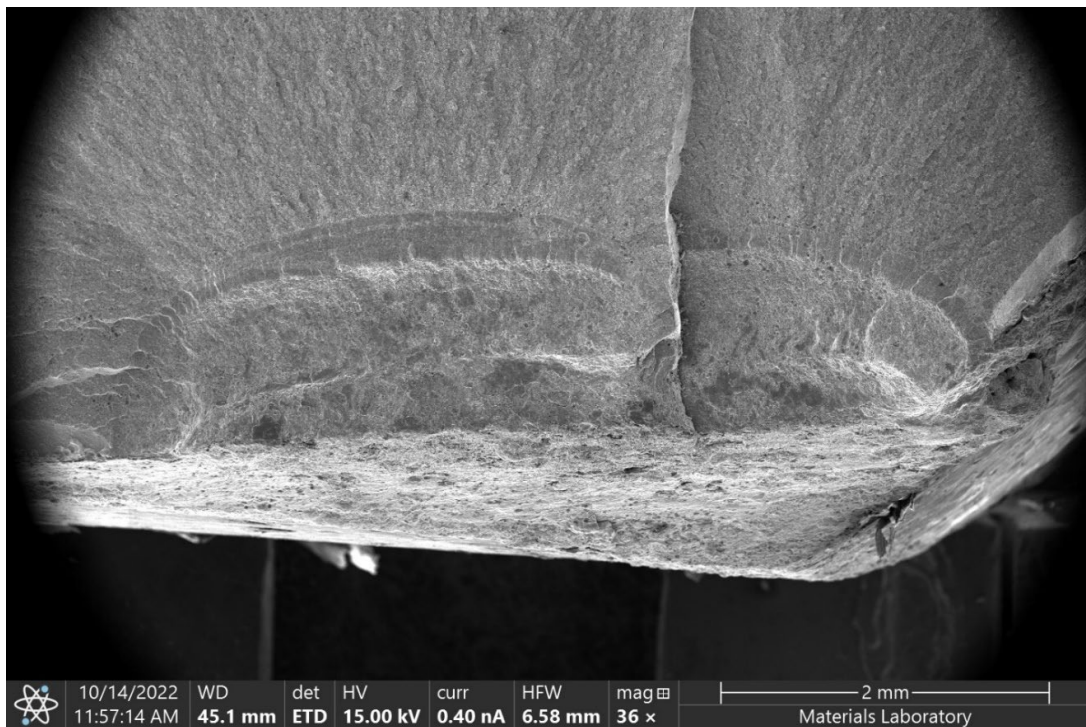


Figure 10. Secondary electron (SE) micrograph of the thumbnail cracks in Figure 9.

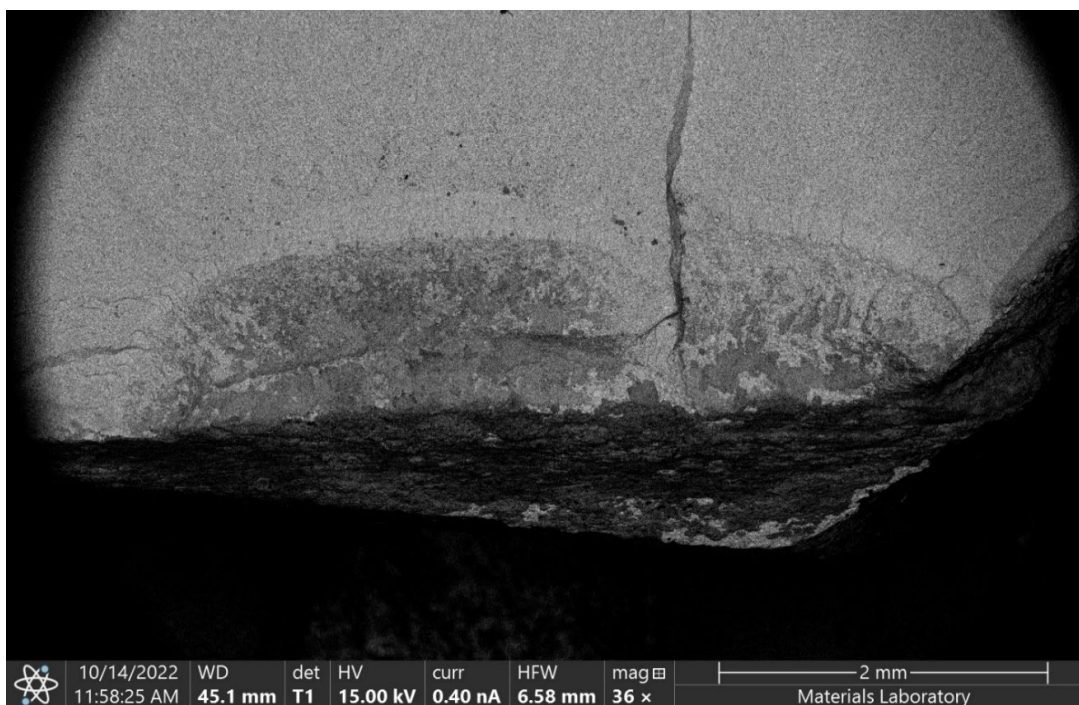


Figure 11. Backscattered electron (BE) micrograph of the area in Figure 10.

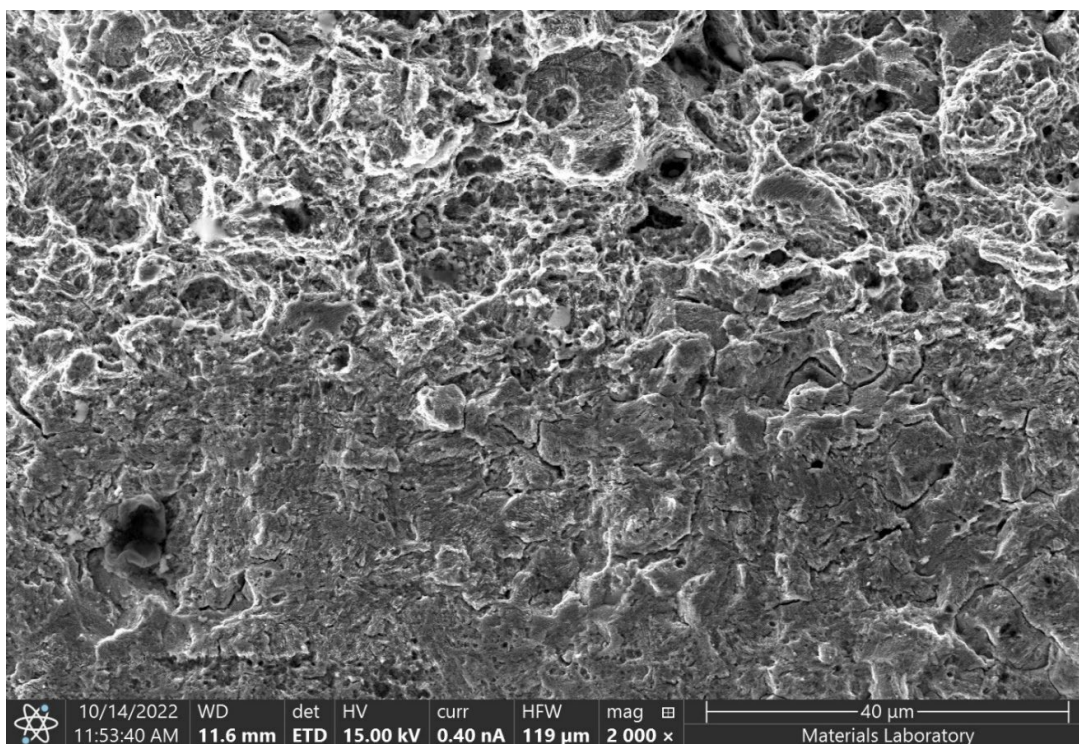


Figure 12. SE micrograph of the terminus of the thumbnail crack, showing striations and dimpled rupture.

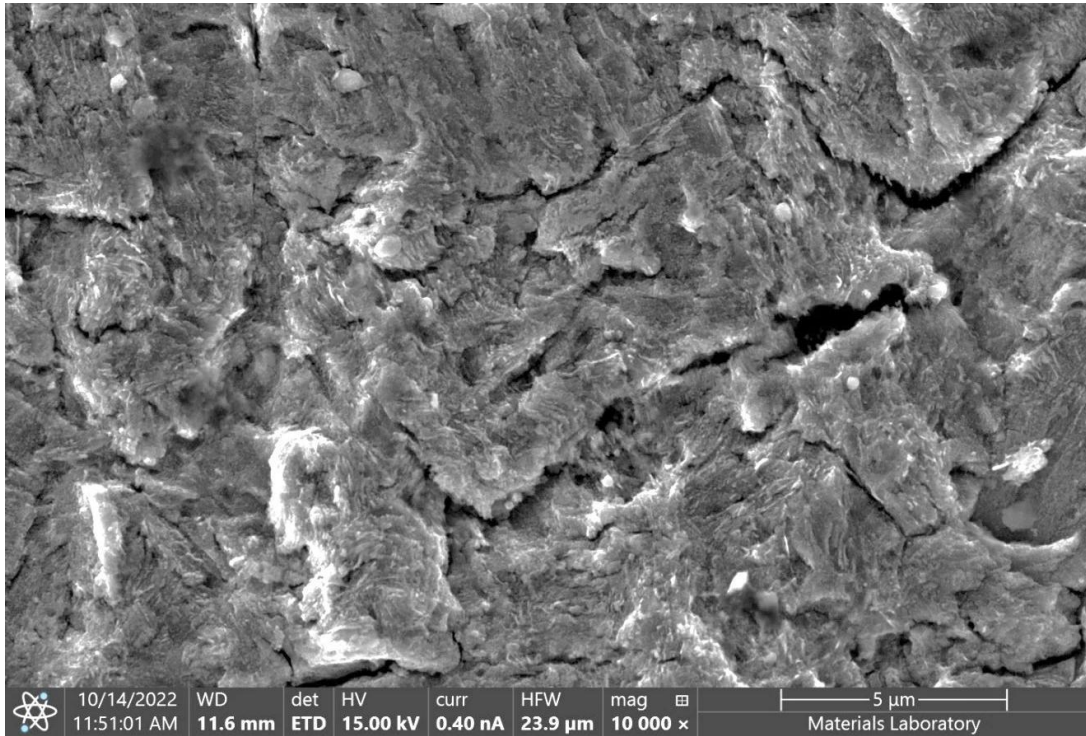


Figure 13. SE micrograph of fatigue striations on the thumbnail cracks of the leg remnant.

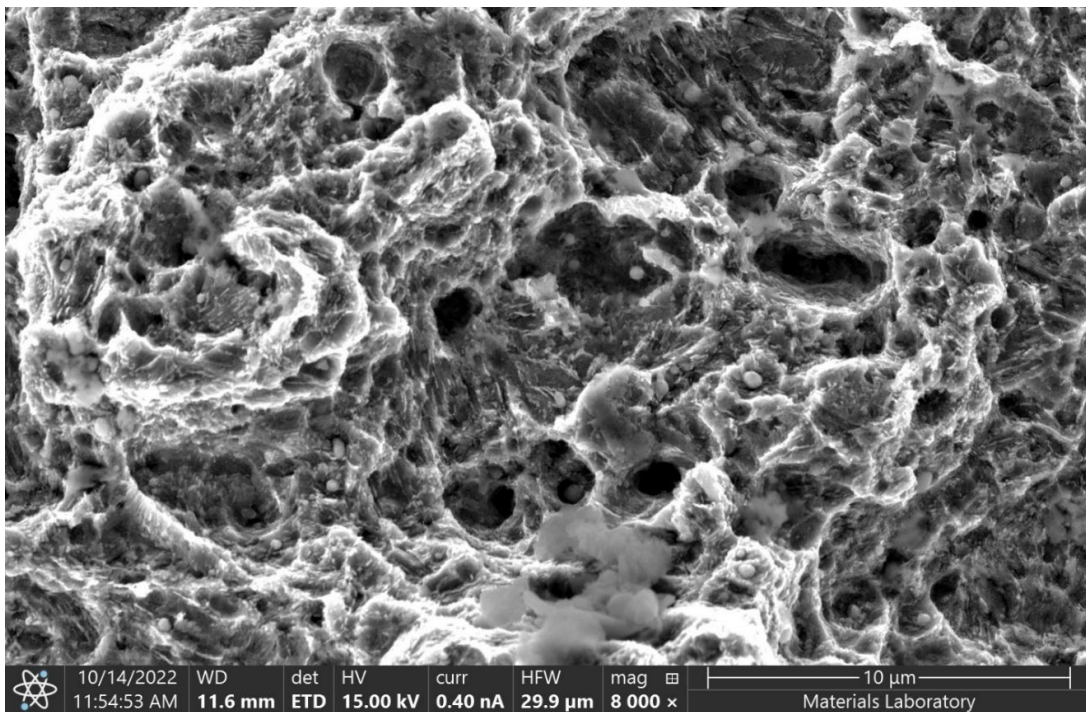


Figure 14. SE micrograph of dimpled rupture outside the fatigue crack.

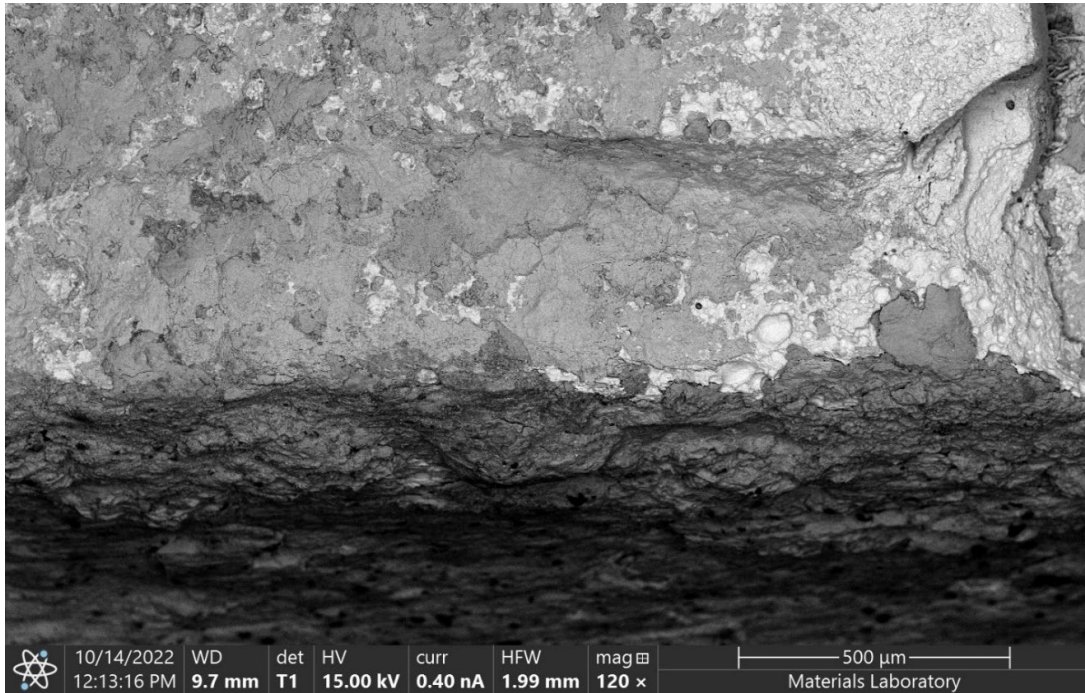


Figure 15. BE micrograph of the initiation region of the fatigue crack left of the large ratchet mark.

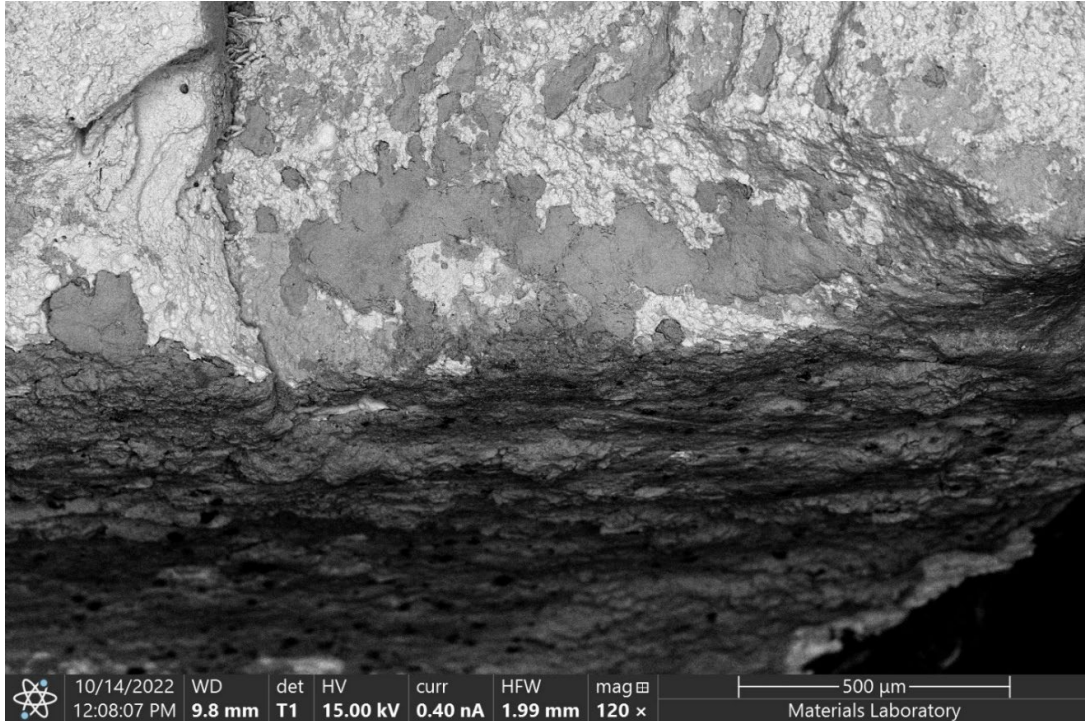


Figure 16. BE micrograph of the initiation region of the fatigue crack right of the large ratchet mark.

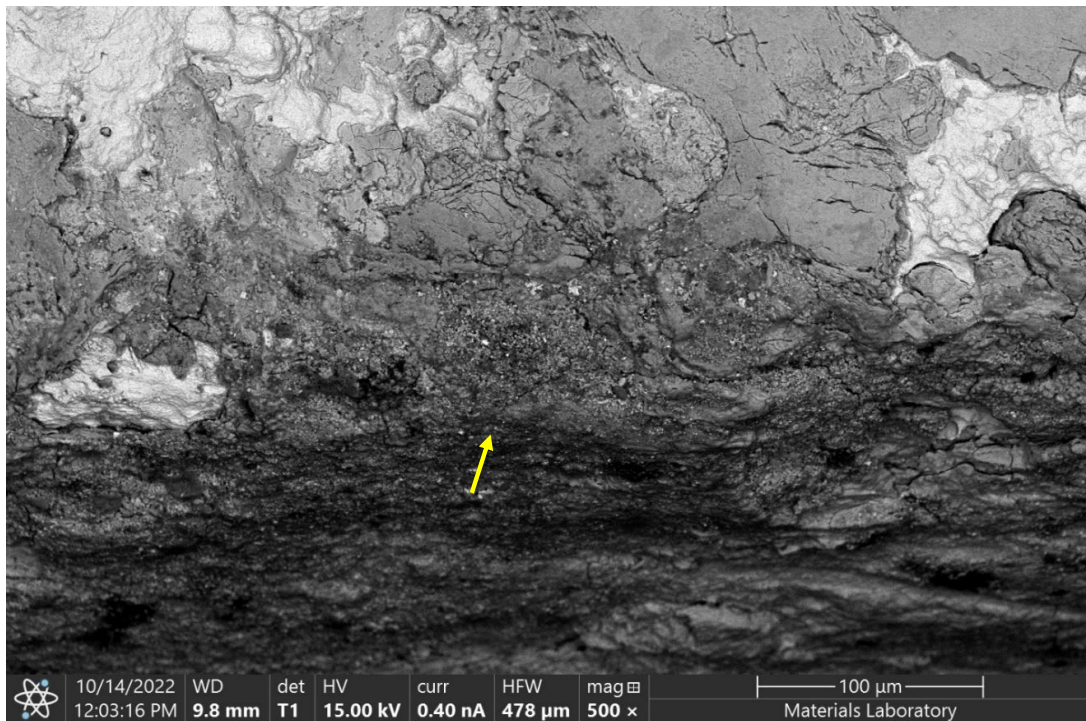


Figure 17. BE micrograph of the crack initiation site of the left fatigue crack, showing a surface pit (arrow) with corrosion compounds.



Figure 18. Corner of the crack initiation site, showing the corroded underside.



Figure 19. Closer view of the right initiation side from the surface edge in Figure 18.

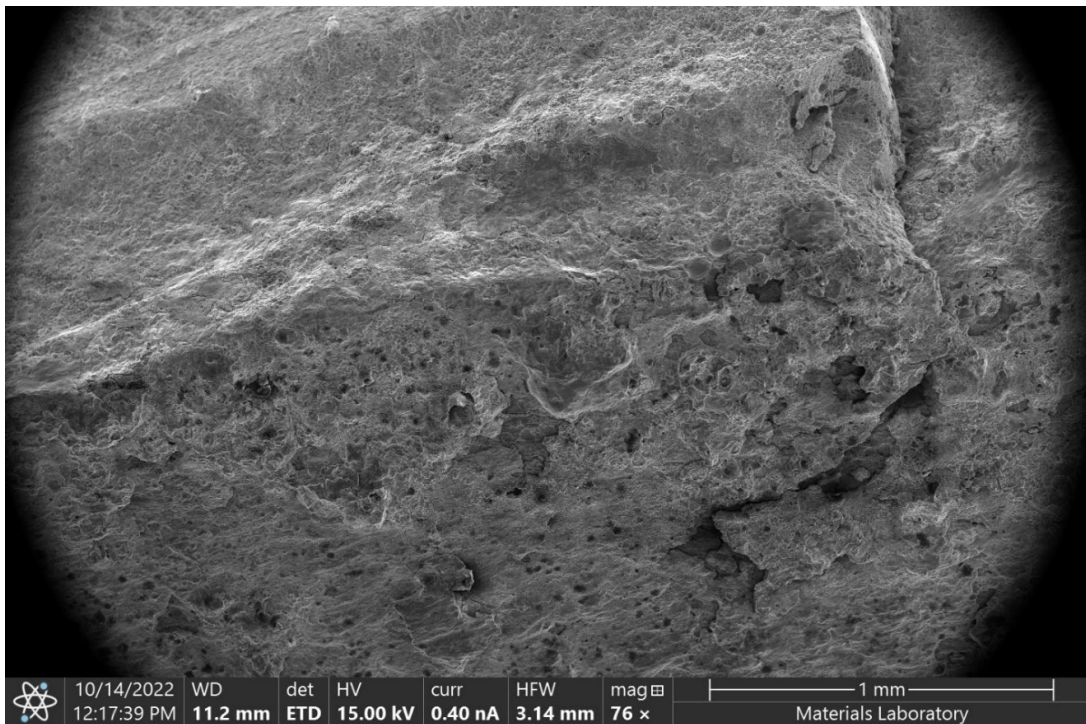


Figure 20. SE micrograph of the cleaned area in Figure 19, showing corrosion pits.



Figure 21. Pitting corrosion and corrosion compounds on the underside of the leg remnant adjacent to the fatigue crack initiation sites.