

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN23LA217

MATERIALS LABORATORY

Factual Report 23-090

November 15, 2023

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A. ACCIDENT INFORMATION

Location: Pellston, Michigan
Date: June 1, 2023
Time: 11:55 central daylight time
15:55 coordinated universal time
Vehicle: Piper PA-28-181, N4376H
Investigator: Aaron Sauer, AS-CEN

B. COMPONENTS EXAMINED

Remnants of landing gear strut

C. EXAMINATION PARTICIPANTS

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

D. DETAILS OF THE EXAMINATION

On June 1, 2023, a Piper PA-28-181 airplane sustained substantial damage when it was involved in an accident near Pellston, MI. The flight instructor and student pilot were not injured. The flight instructor reported hearing an unusual noise during a takeoff. During the landing approach, the airport manager observed the left main landing gear wheel assembly hanging from the landing gear strut and advised the flight instructor via radio not to land. The flight instructor then diverted to another airport, landing on the runway centerline with the partially separated left main landing gear assembly. Post-accident examination revealed the landing gear strut housing was fractured at the upper torque link connection. The wheel assembly remained attached via the brake line hose. The strut remnants were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the fracture on the strut assembly, consisting of the fractured cylinder, which had been sectioned before receipt, and the torque link assembly arm still affixed to the broken cylinder clevis via the attachment bolt. The cylinder had fractured near the radius with the clevis. The arm shown in Figure 1a exhibited embossed markings that stated, "PIPER 78031-0."

Figures 2 and 3 show the mating fracture surfaces of the separated clevis arms. The separated pieces were still attached to the upper torque arm link via the attachment bolt, secured with the nut and cotter pin, as shown in Figure 3. The fracture surfaces were generally rough in texture, with a dull luster. The fractures exhibited a darker, thumbnail-shaped region and a flat gray region, consistent with distinct fracture

modes. The dimensions of the darker thumbnail fractures were 2.04 inches long and 0.59 inches wide on the upper fracture, and 1.38 inches long and 0.46 inches wide on the lower fracture.

The fracture surfaces from the cylinder side were cleaned in an ultrasonic bath of acetone to remove the grease and some of the exterior paint and primer. Figure 4 shows a montage of optical micrographs after cleaning. The thumbnail regions exhibited crack arrest marks, consistent with progressive fracture, and ratchet marks, indicative of multiple crack initiation sites. As illustrated in Figures 5 and 6, the crack features were consistent with initiation along the interior surface between the clevises, which was machined smoother than the exterior surfaces. Some of these areas along the machined surface exhibited whitish compounds, later found to be consistent with salt deposits (see Figure 6). Further, small cracks were present along the machined surface, including those that intersected crack initiation sites, as demonstrated in Figure 7.

The cylinder-side fracture surfaces were examined using a field-emission scanning electron microscope (SEM). Figure 8 shows a typical area of the progressive fracture region, revealing fatigue striations consistent with fatigue crack propagation. Figure 9 shows a closer view of these striations, which had propagated in a transgranular path through the clevis arms. Outside the thumbnail cracks, the fracture surface exhibited dimpled rupture, consistent with subsequent overstress fracture.

Several of the initiation sites were examined along the radius with the machined surface. Figure 11 shows one such initiation site, which exhibited a flat, faceted region from which river patterns and striations emanated. A closer examination of this site, shown in Figure 12, revealed layered hackles typical of localized brittle fracture. Probing this location using energy dispersive x-ray spectroscopy (EDS) found it was consistent with a silicon-rich phase, typical of constituents in many aluminum-silicon castings.

Figure 13 shows a rounded, smooth surface feature adjacent to the fracture edge at another location. This surface exhibited a spherical, dendritic morphology consisting of a solidification void from the casting of the part. A closer view of the fractured region between the void and the fracture edge showed fatigue striations propagating from the void rather than from the fracture edge (see Figure 14). These features were consistent with crack initiation from the solidification void at this location.

Figure 15 shows another solidification void, exhibiting smooth, rounded dendritic shapes along the fracture surface edge, with a secondary crack running through the feature. This crack was visible along both the fracture surface and the machined outer surface. Figure 16 shows fatigue striations propagating parallel to the edge, consistent with initiation along the secondary crack from the solidification void.

Figure 16 shows another crack initiation site exhibiting fatigue striations and crack arrest marks. This initiation location, along the fracture edge, exhibited small, rounded protrusions consistent with smoother dendritic surfaces from a solidification void. These voids were also present along the machined surface away from the fracture surface, as typified in Figure 17. Small cracks were also located at these solidification voids open to the surface.

The chemical composition of the fractured cylinder was examined using EDS and x-ray fluorescence (XRF). The composition was consistent with A356 aluminum-silicon casting alloy. The hardness was inspected per ASTM E18, averaging 52 HRBW.¹ The electrical conductivity, measured per ASTM E1004, averaged 38.8 %IACS.² These data were consistent with an an-cast condition for the part.

The strut assembly fractured from fatigue cracks that had initiated along the radius of the clevis arms with the inner machined surface. These cracks initiated at multiple casting solidification voids and silicon-rich phases. These cracks propagated through the clevis cross-sections until the remaining cross-sections fractured from overstress.

Submitted by:

Erik M. Mueller
Materials Research Engineer

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

² ASTM E1004 - *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA



Figure 1. View of the opposite sides of the fractured strut assembly clevis remnants attached to the torque link arm, and the sectioned cylinder remnant, as received.



Figure 2. View of the fracture surface from the sectioned side of the upper cylinder.



Figure 3. Mating cylinder clevis fracture surfaces from Figure 2, still affixed to the strut remnant.



Figure 4. Montage of the connection fracture surface in Figure 3, showing the difference in color between the progressive and instantaneous regions.

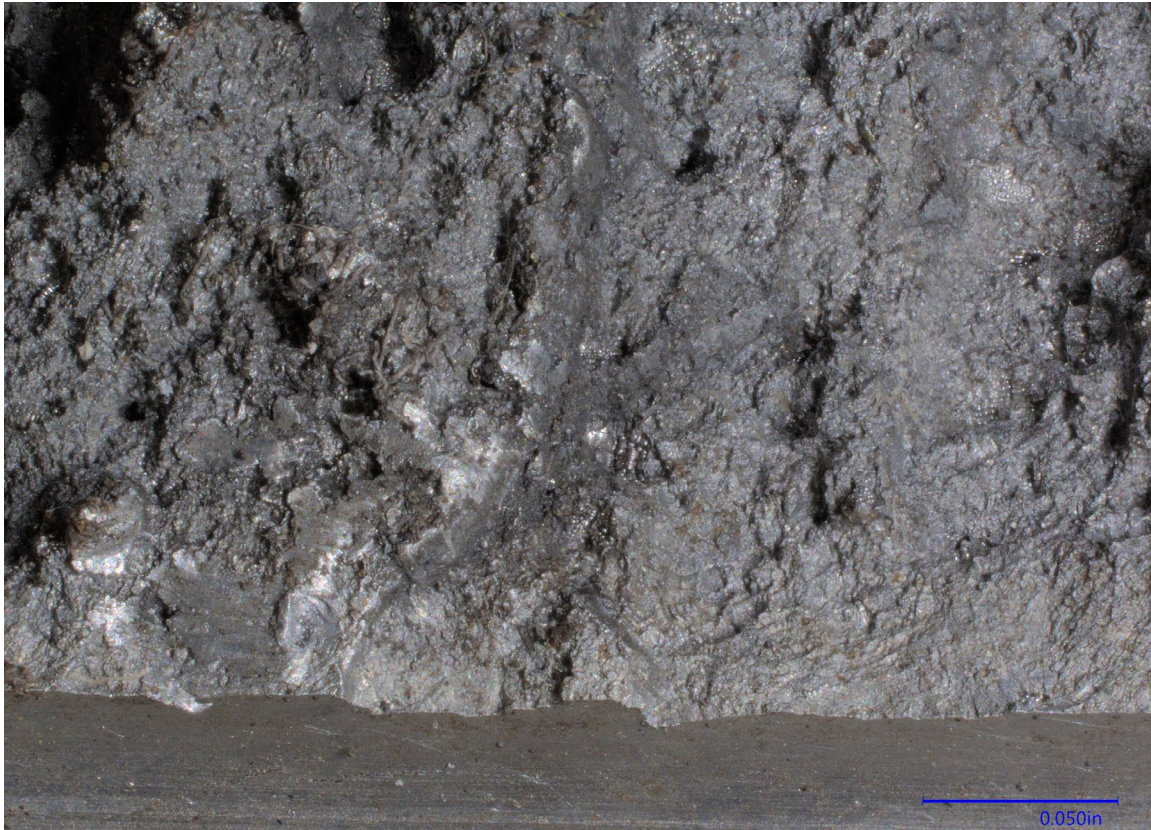


Figure 5. Closer view of the edge of the top fracture surface in Figure 4.



Figure 6. Closer view of the edge of the bottom fracture surface in Figure 4.

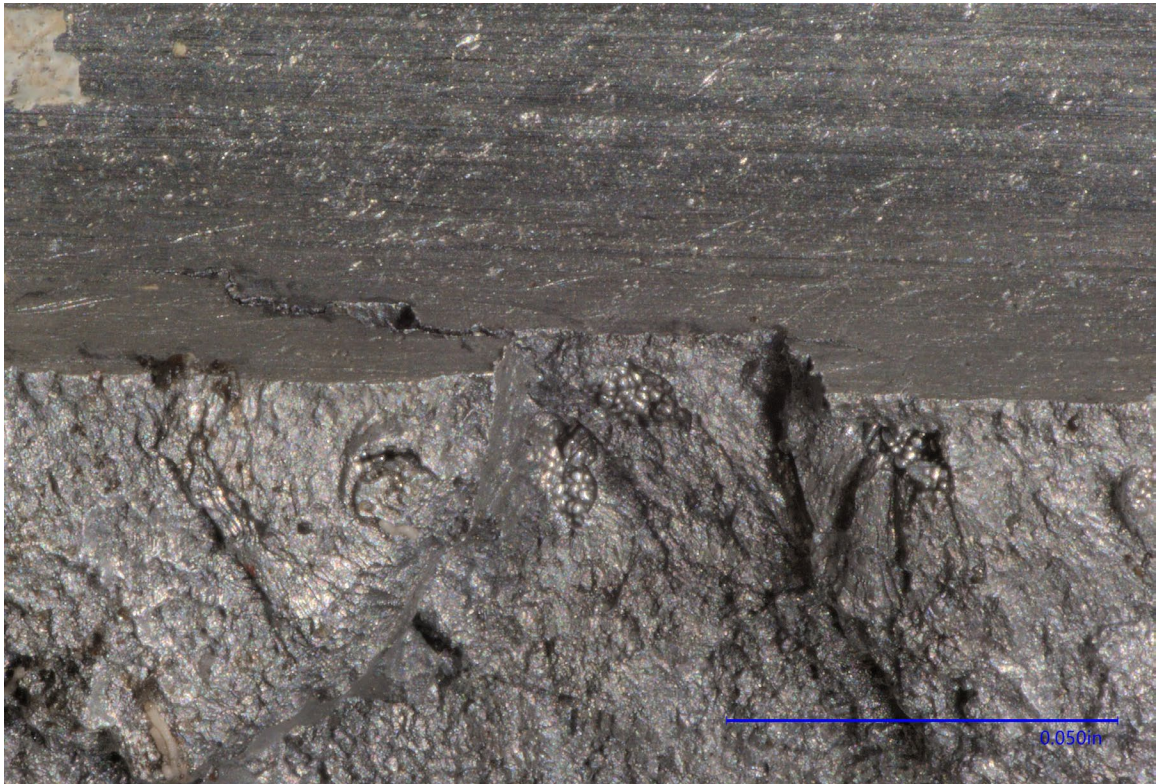


Figure 7. View of a crack initiation site at the edge in Figure 6, showing a crack along the machine bore.

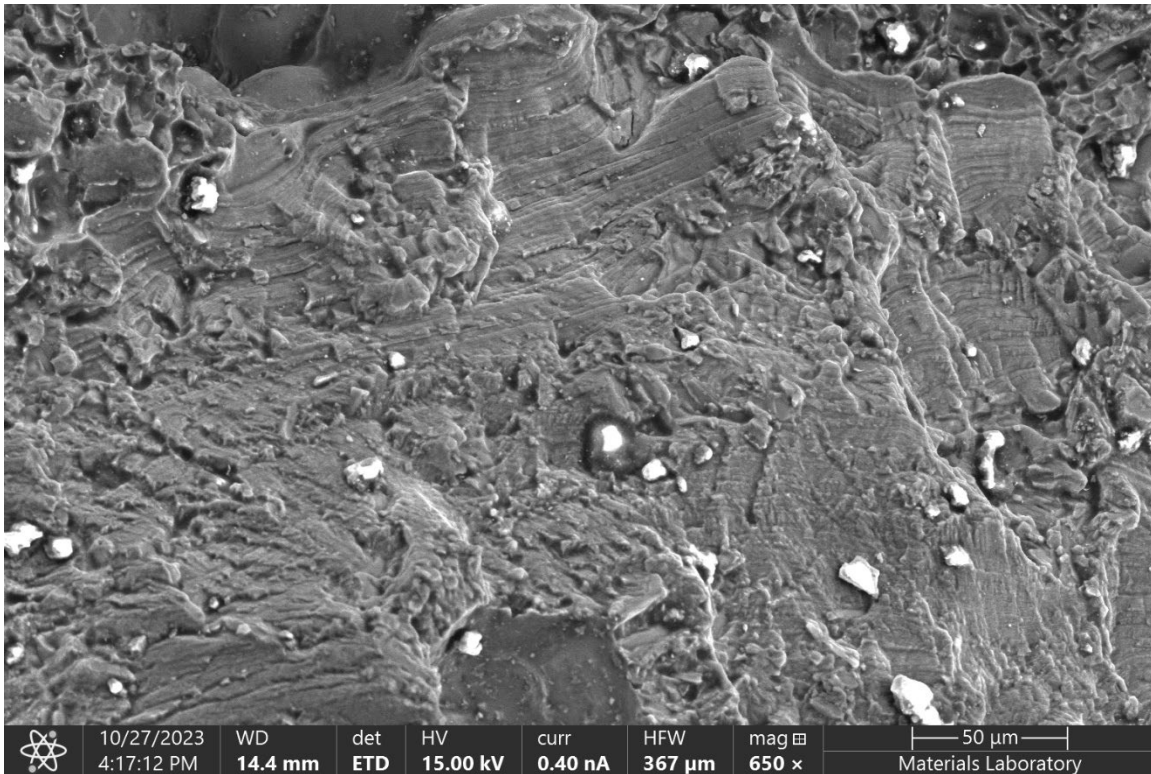


Figure 8. Secondary electron (SE) micrograph of a typical area of the progressive region of the fracture surface.

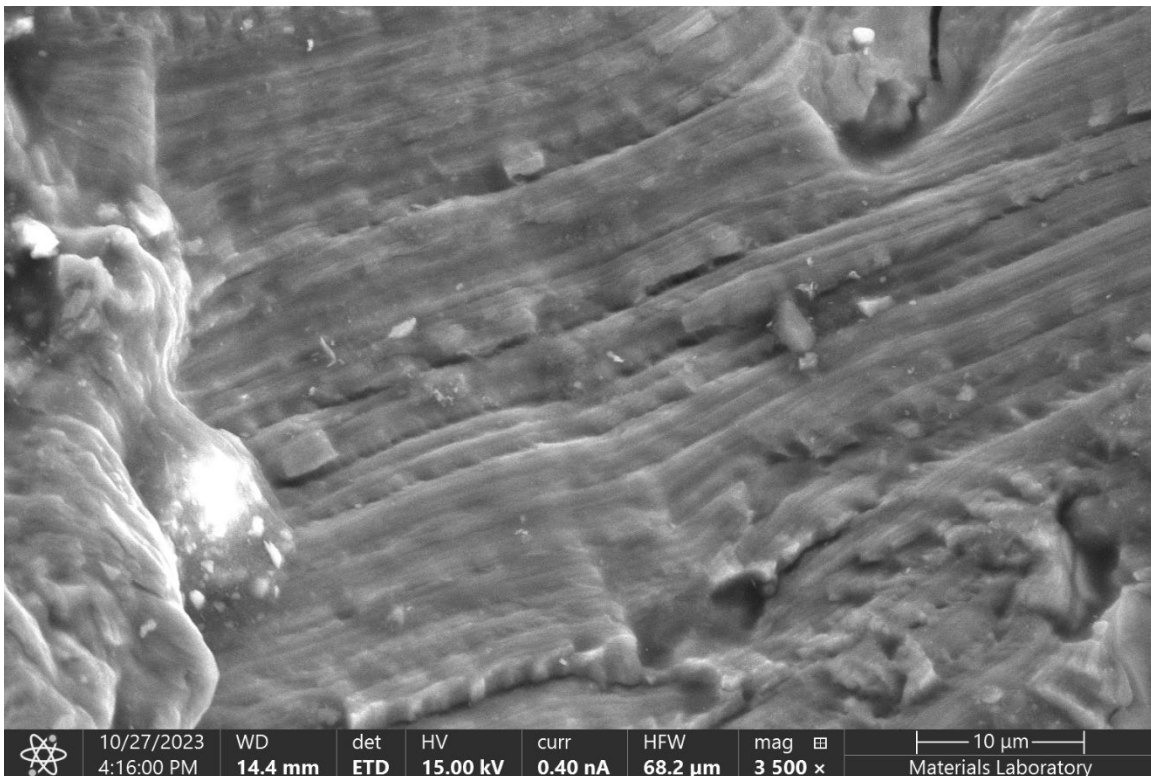


Figure 9. SE micrograph of fatigue striations in Figure 8.

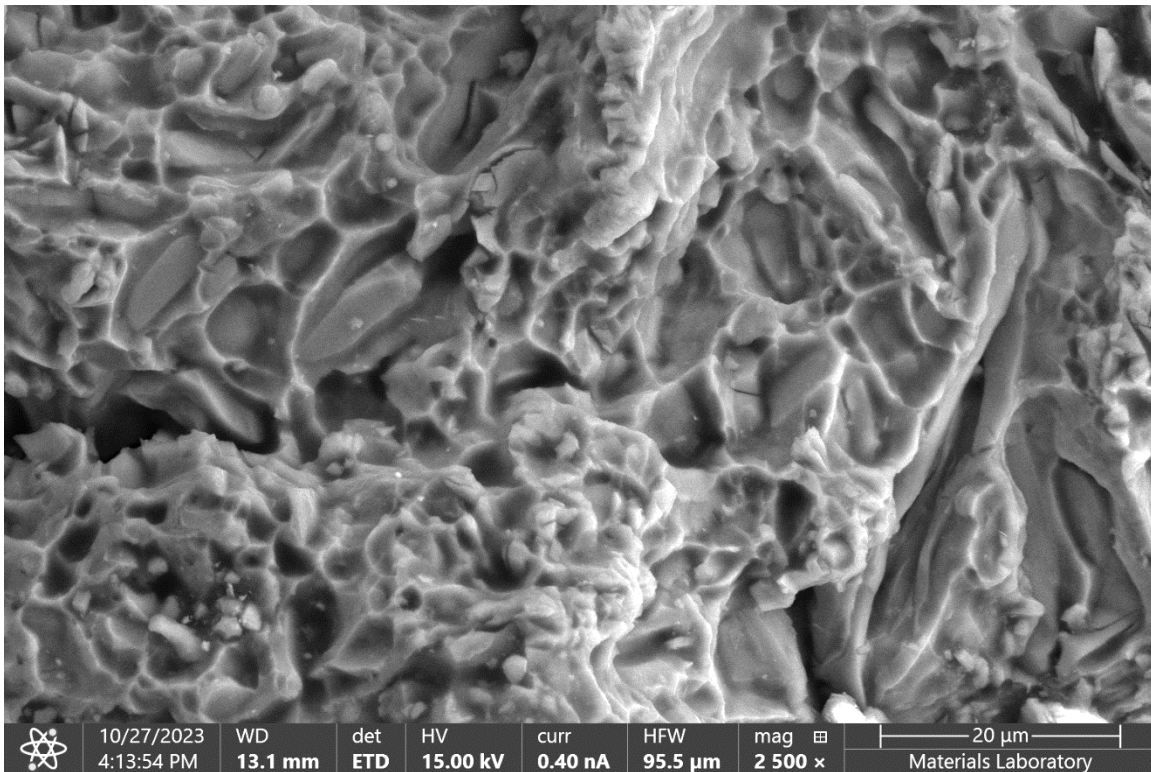


Figure 10. SE micrograph of dimpled rupture in the overstress region of the fracture.

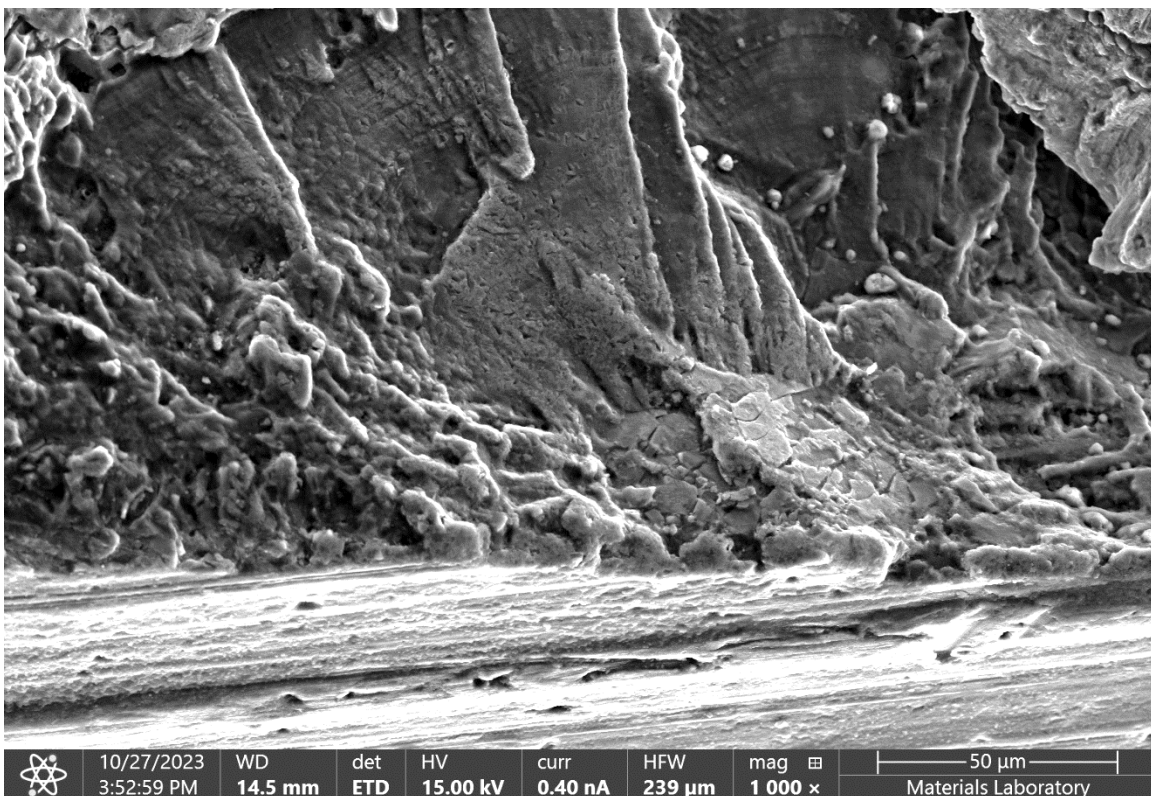


Figure 11. SE micrograph of a crack initiation site, with the boxed area shown in Figure 12.

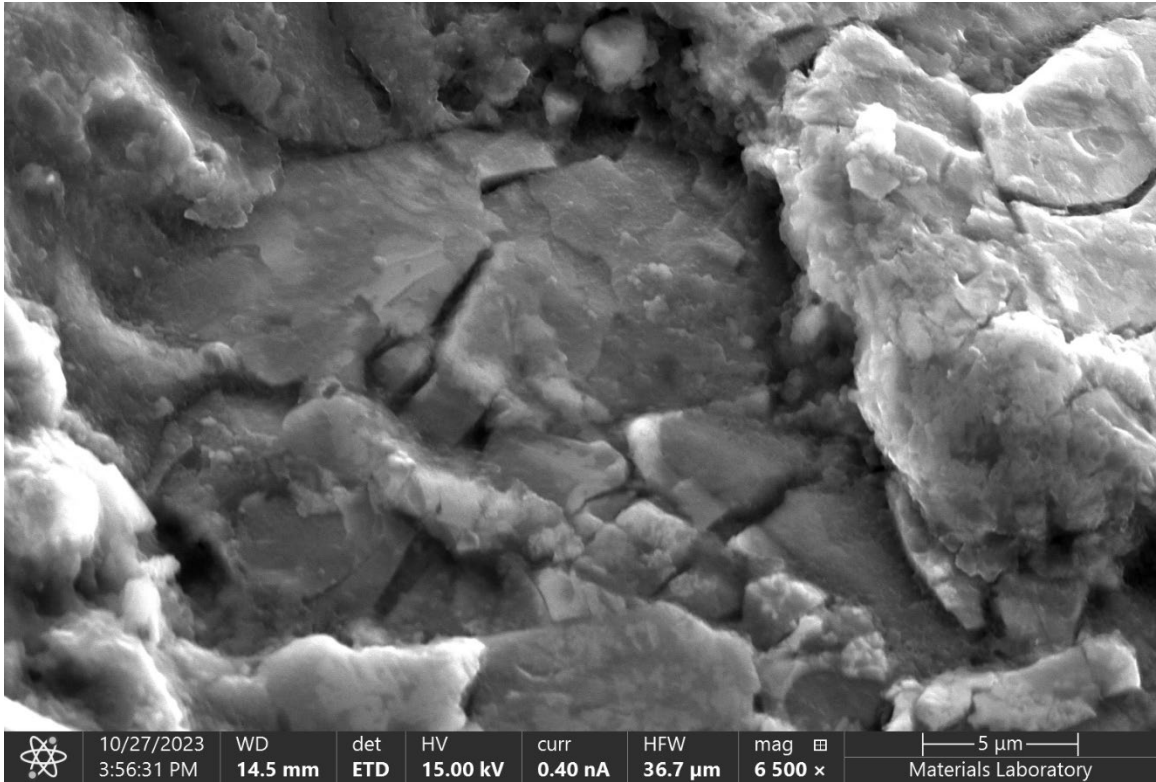


Figure 12. SE micrograph of the boxed area in Figure 11, showing faceted fracture features.



Figure 13. Backscattered electron (BE) micrograph of a void near the fracture surface edge.

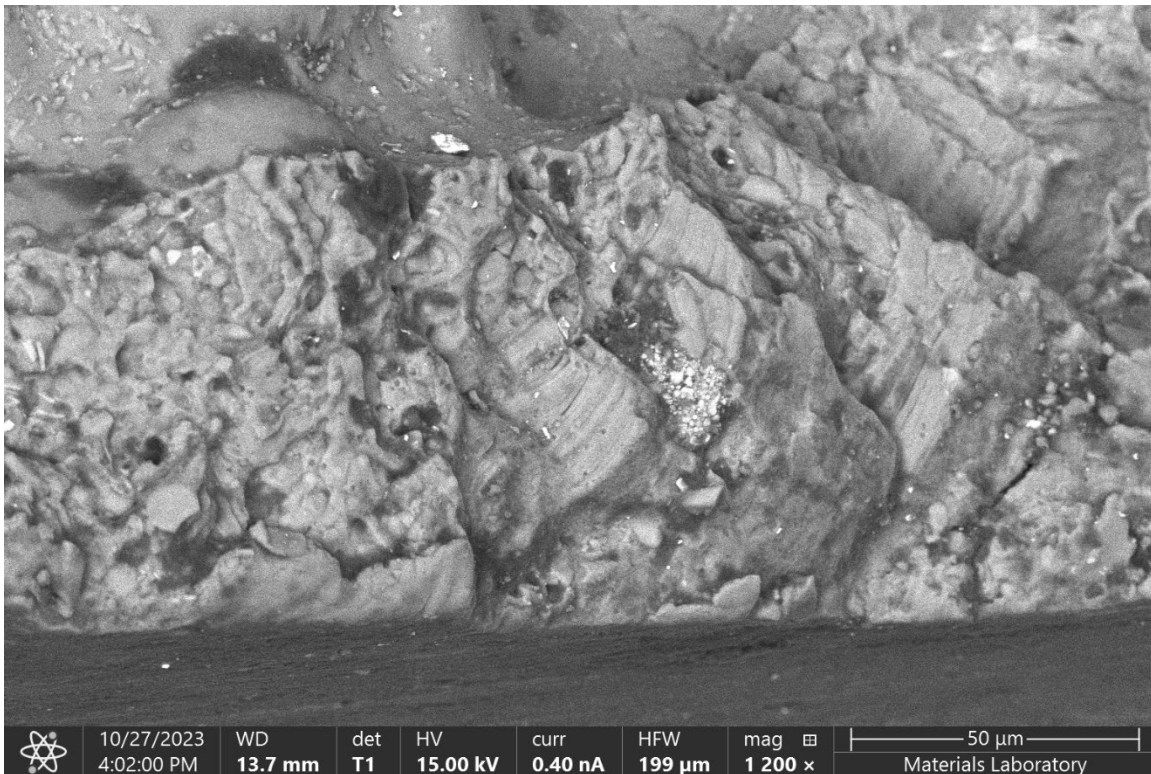


Figure 14. BE micrograph of striations propagating from the void in Figure 13.



Figure 15. BE micrograph of a secondary crack along a void at the fracture edge.

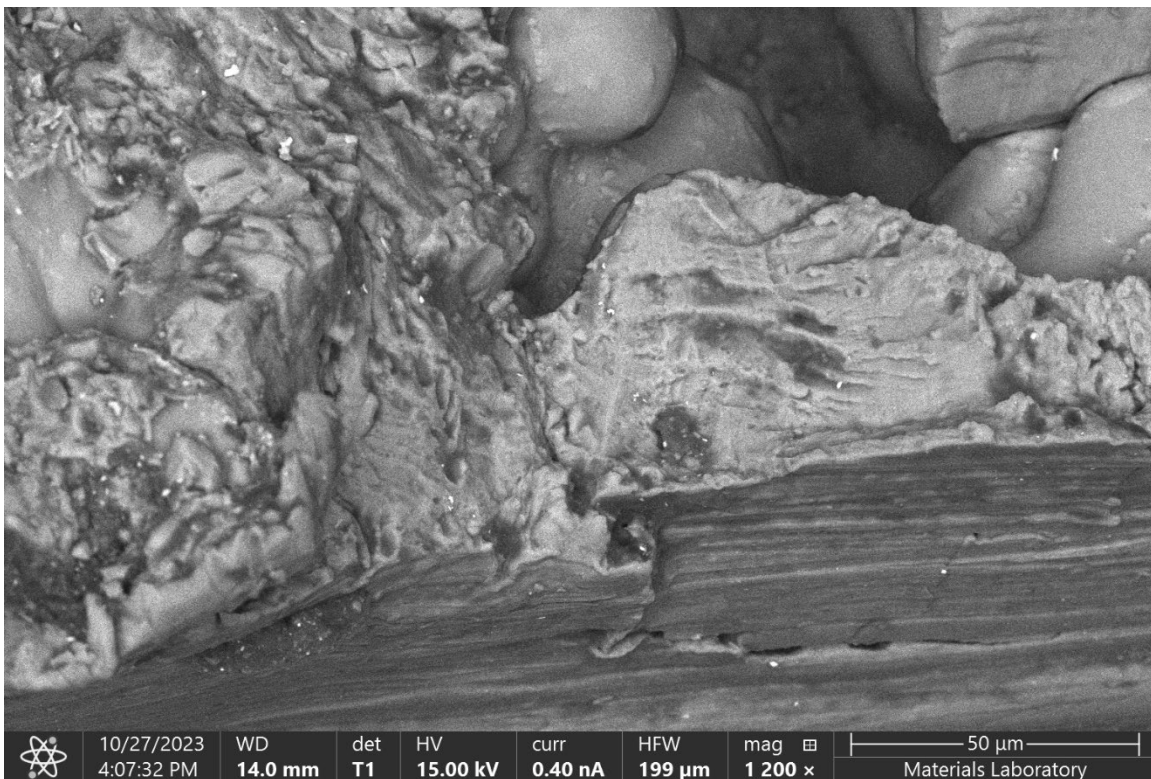


Figure 16. BE micrograph of striations emanating from the crack and solidification void towards the left of the figure.

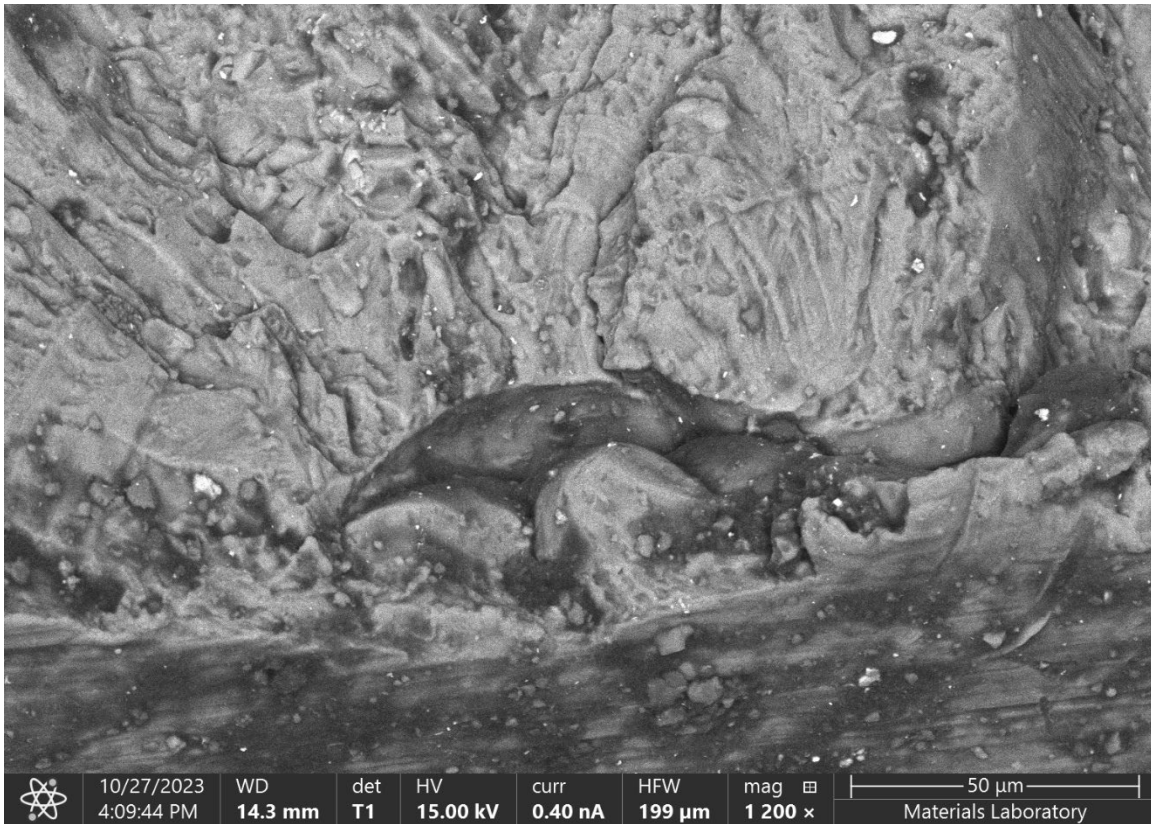


Figure 17. BE micrograph of an initiation site at a void on the fracture edge.

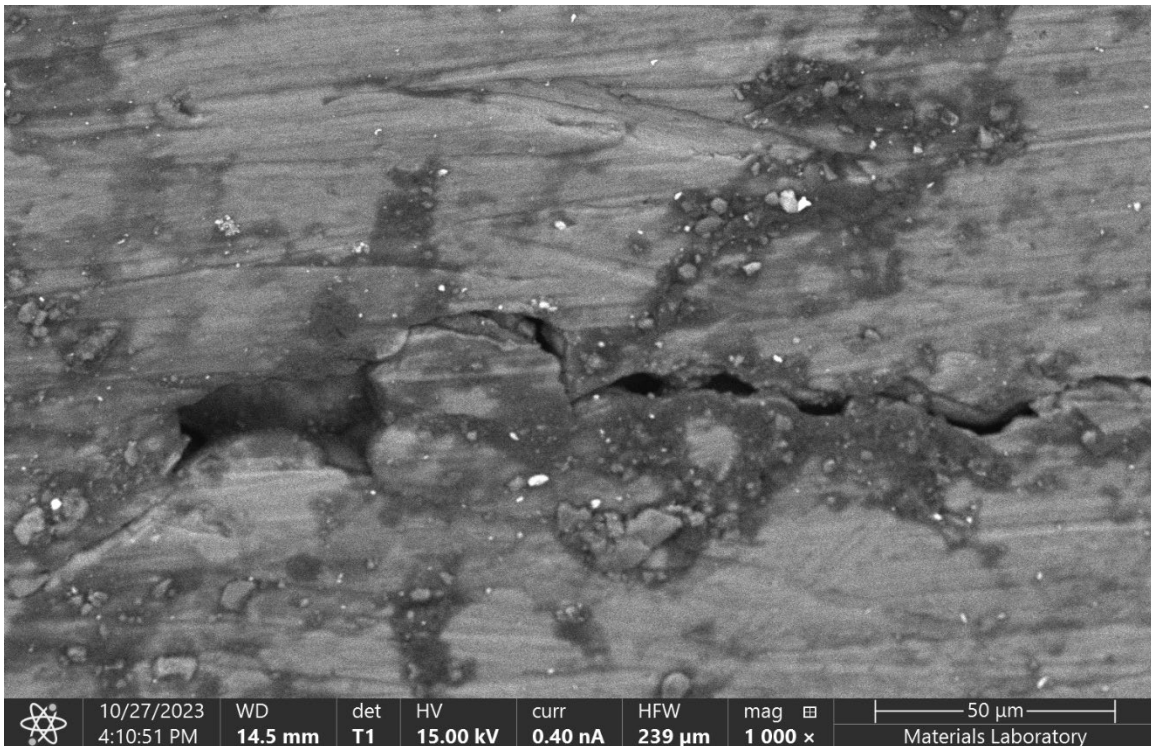


Figure 18. BE micrograph of a crack along the machined bore, initiating at an opened void.