

National Transportation Safety Board

Office of Research and Engineering

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MATERIALS LABORATORY

Factual Report 24-083

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A. ACCIDENT INFORMATION

Location: San Juan, Puerto Rico
Date: June 1, 2024
Time: 14:16 Atlantic standard time
18:16 coordinated universal time
Vehicle: Cessna 150M, N6198K
Investigator: Joshua Young, AS-ERA

B. COMPONENTS EXAMINED

#2 cylinder assembly
Fractured rocker arm bosses and bushings

C. EXAMINATION PARTICIPANTS

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Office of Research and Engineering – Materials Laboratory Division
NTSB, Washington, DC

D. SUMMARY

A portion of the cylinder housing that held the rocker arm shaft fractured from a fatigue crack that initiated along the bore with the shaft. Once this section of the housing fractured, the remainder of the cylinder housing fractured, freeing the shaft and rocker arms. The bore exhibited wear marks consistent with rotational and lateral movement of the shaft, and the rocker and valve faces exhibited off-center wear marks consistent with uneven wear. The bushings, shaft, and housing bore exhibited wear signatures consistent with movement of these components.

E. DETAILS OF THE EXAMINATION

On June 1, 2024, a Cessna 150M was substantially damaged when it was involved in an accident near San Juan, Puerto Rico. The student pilot and a flight instructor sustained serious injuries. Both reported that the airplane experienced a total loss of engine power shortly after takeoff, and they attempted to return to the departure runway. While performing a left descending turn back toward the runway, the airplane impacted the ground and came to rest on the edge of a parking lot. The airplane was retained for further examination, and several components were sent to the NTSB Materials Laboratory for additional examination.

The components received by the Materials Laboratory were from the #2-cylinder assembly of the Continental O-200-A engine. The cylinder assembly is shown from different perspectives in Figure 1 and Figure 2. The piston was absent, and one of the spark plugs (shown in Figure 1b) had been removed. There was no indication of

plastic deformation on the cooling fins or pushrods. Figure 3 shows the interior of the cylinder, showing the condition of the valve heads and adjacent seats. Dark brown compounds were present on these surfaces, consistent with combustion compounds typical of avgas reciprocating engines. There was also oil inside the cylinder interior.

Several fragments and components had been removed from the upper housing of the cylinder, though the housing cover was in place when received. These separate pieces indicated that the housing cover had been removed and reinstalled between the accident and delivery to the Materials Laboratory. Figure 4 shows the cylinder assembly after the housing removal in the laboratory, revealing intact assemblies of the valves, retainers, and springs. This interior also exhibited an absence of the rocker arms and shaft, with six fracture surfaces along the rocker housing bores.

The intake valve retainer exhibited some wear marks, most notably the sector-shaped mark on the upper left (upper left of Figure 4). There were also longitudinal streaks on the intake valve peripheral face, which were longitudinal, rather than circumferential, like the machine marks on the exhaust retainer to the right in the figure. The ends of the valve stems exhibited oval or comet-shaped wear patterns, consistent with off-center contact with the adjacent rocker arms.

Figure 5 shows the two rockers on the shaft, with the central bushing as received. Also in the figures are the fragments of the fractured housing, with the center bore pieces on the left and the left and right small fragments on the right. Figure 6 shows the two contact faces of the rocker arms. These faces exhibited comet-shaped wear features, consistent with the off-center wear marks observed on the stem faces of the valves in Figure 4 and Figure 7.

Figure 7 shows the fractured boss areas, annotated to show areas of wear. The bores exhibited circumferential streaking consistent with rotational wear typical of service conditions. There were also higher contrast wear areas in the central, largest bore, exemplified by a dark circumferential band. This band corresponded with a central protrusion on the fractured bosses and a band on the shaft when placed back in the bore (see Figure 8).

Figure 8 shows the rocker arm shaft and the central bushings, along with the fractured boss pieces, positioned as they were at the time of fracture. The central band on the housing bores corresponded with the gap between the bushings, also indicated on the shaft. The outer diameter (OD) surfaces of the bushings exhibited wear patterns consistent with those on the inside surfaces of the fractured housing remnants.

Figure 9 shows the bore of the fractured housing remnants after cleaning with acetone. The center band corresponded with a protrusion of the housing fragment positioned on the right in the figure. The edges about and below that band were

recessed, consistent with material loss on the bore. There were also worn areas of the housing material in some places on the left fragment on the left side in Figure 9. This material loss corresponded with the locations of the bushings, as shown in Figure 8. The bore area above the central band exhibited circumferential streaks, as identified in Figure 9. This upper half of the housing also exhibited wear on the opposite left fragment, which showed a flat fracture surface and arrest marks.

The thicknesses of the two fractured housing remnants were measured using digital calipers. These measurements were taken on each remnant's ends and center near each fracture surface. The measurements are detailed in Table I. According to the applicable service bulletin, the boss walls can only be reamed if thicker than 0.240 inches.¹ All of the boss walls exceeded 0.240 inches in thickness, except for the central area along the fracture surface in the lower area of Figure 9 (corresponding with the left end of the left bushing and fracture surface in Figure 8). Both sides exhibited a wall thickness between 0.23 and 0.24.

Figures 10 through 13 show the rocker arm shaft bushings after removing surface greases and oils. They are labeled left and right based on their positions in Figure 8. The right bushing, shown in Figure 10, exhibited the repeating circumferential marks consistent with machining marks. This bushing exhibited a stamped marking stating "22949/RR". This bushing also exhibited a crack that originated at one edge and progressed more than halfway through the longitudinal cross-section. Figure 11 shows an angled view of the bushing crack, three gouge marks on the edge face, and an oval flat spot on the inner diameter.

The left bushing, as positioned in Figure 8, is shown in Figures 12 and 13. While absent cracks, the outer diameter surface of this bushing exhibited wear and chatter marks in longitudinal and circumferential directions. These marks were consistent with the bushing movement against the housing boss bore. The interior surfaces of this bushing also exhibited mottled areas of disparate hues of brass, consistent with uneven wear of the bushing surface. There were also many pockmarks on the surface of the bushing, consistent with spalled material lost from wear.

Figure 14 shows the mating surface of the rocker arm shaft. This view shows the central band on the left, along with circumferential wear scars toward the right. The central area exhibited chatter marks and pock marks consistent with those observed on the inner surface of the corresponding left bushing. Figure 15 shows a closer view of the spalling and wear scars on the shaft.

The central bore also exhibited several dark streaks, consistent with longitudinal wear of the housing bore against the shaft. These streaks were indicative of longitudinal sliding of the shaft within the housing bore. Below this area, there was also a flatter

¹ Continental Service Bulletin M73-13, "Reaming and Bushing Rocker Shaft Bosses." 10 July 1973

fracture surface, with disparate regions exhibiting different fracture features (circled in Figure 7).

Five of the six fracture surfaces of the housing fragments exhibited rough, fibrous surface textures with dull lusters. These features were consistent with the overstress fracture of aluminum castings. However, the circled fracture surface in Figure 7 exhibited a flatter fracture surface, as highlighted in Figure 16. This fracture surface was subsequently cleaned in an ultrasonic bath with acetone (Figure 17a) and a chromic-acid aluminum cleaner (Figure 17b).

In all the figures, a prominent series of porosity or voids was present in the upper right area of the fracture surface, indicated by a larger circular void, a smaller spherical void, and an oblong feature left of these. There were other areas of macro and microscopic porosity along this fracture surface.

The main feature of the fracture was the flat surface on the lower 90%, as oriented in Figure 16 and Figure 17. The surface exhibited faint crack arrest marks emanating from the bore, as articulated in Figure 17a. River patterns radiated outward from the bore edge, as illustrated in Figure 18. These features indicated crack propagation from the bore surface into the housing.

Figure 19 shows the end of a portion of the crack. This area exhibited crack arrest marks consistent with upward propagation, as annotated in the Figure. The fracture surface was examined using a field emission scanning electron microscope (SEM). Figure 20 shows a closer view of the end of the crack—this region exhibited fatigue striations, consistent with fatigue crack propagation.

The fatigue cracking began at multiple initiation sites along the edge of the fracture surface with the shaft bore. One initiation site is shown in Figure 21 at an area of wear along the shaft bore. The crack then propagated inward, as evidenced by the striations in Figure 22. Other initiation sites, such as the one shown in Figure 23, were all present along the bore, which had created an edge with the fracture surface.

None of the cracks exhibit striation orientations consistent with propagation directly from an internal void. One such void is shown in Figure 24. The interior surface of this void exhibited a rounded texture with lobe or dendritic shapes. These features were consistent with solidification shrinkage that would develop during the casting of the cylinder housing. While the fatigue cracking propagated through the internal voids, no features were observed that were consistent with initiation along the void surfaces.

The chemical composition was examined using energy dispersive x-ray spectroscopy (EDS). The composition was consistent with an aluminum-silicon casting alloy.

Submitted by:

Erik M. Mueller
Materials Research Engineer

F. TABLES

Table I - Measurements of the boss walls of the fractured housing fragments, with the locations denoted as positioned in Figure 9. The red measurements were less than the minimum thickness for reaming during maintenance (0.240 inches)

Fragment Location	Upper (inches)	Middle (inches)	Lower (inches)
Right Fragment – Right Fracture	0.2480	0.2485	0.2440
Right Fragment – Central Fracture	0.2530	0.2560	0.2385
Left Fragment – Central Fracture	0.2530	0.2515	0.2340
Left Fragment – Left (Flat) Fracture	0.2645	0.2770	0.2625

G. FIGURES



Figure 1. View of the #2 cylinder from the (a) pushrod and (b) opposite side.



Figure 2. Side views of the #2-cylinder assembly.



Figure 3. View of the cylinder interior, as received, showing the two valve heads.

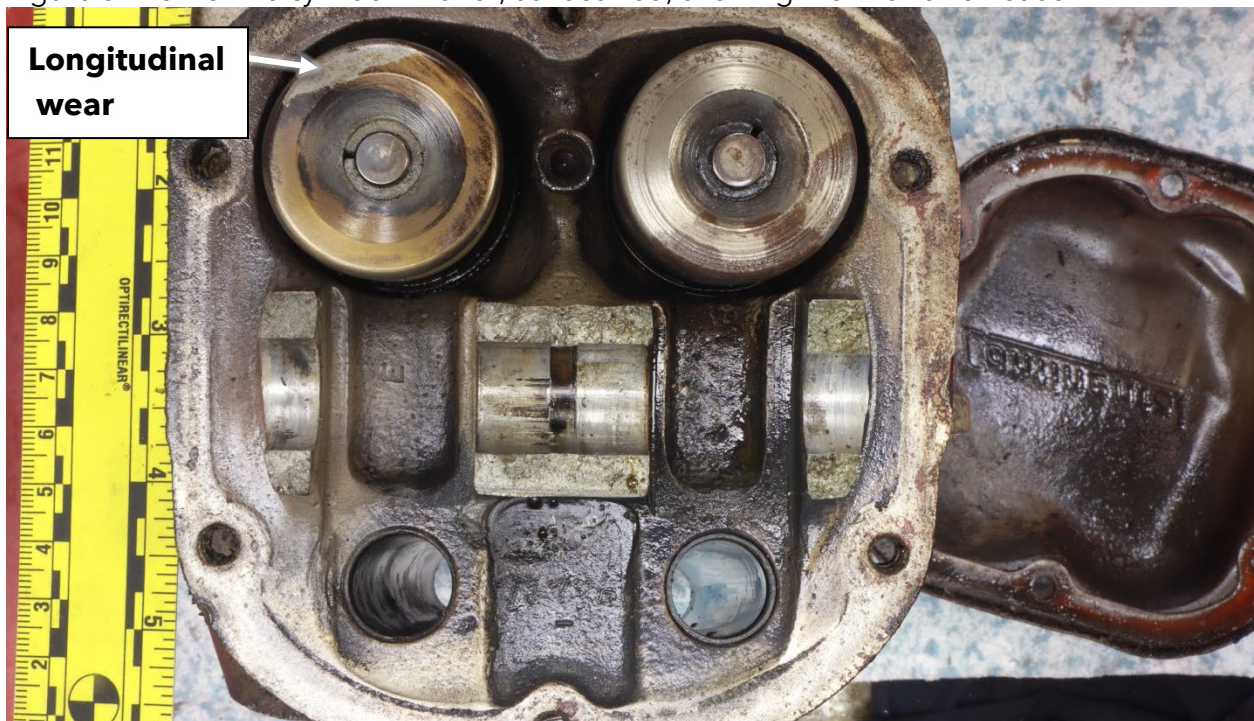


Figure 4. Top of the cylinder, after housing removal, showing the fractured rocker housing.



Figure 5. View of the rocker arms and bushing on the shaft, with fractured and separated pieces of the housing, viewed from opposite sides.

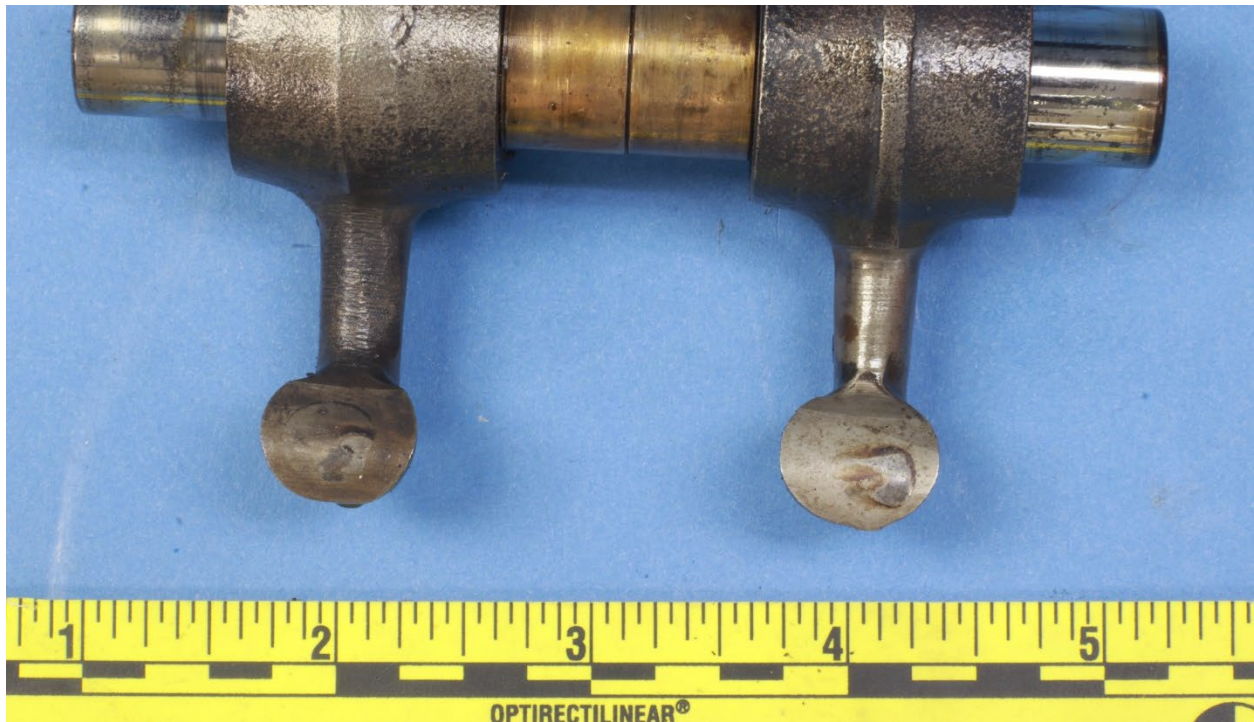


Figure 6. Closer view of wear marks on the valve stem faces of the rocker arms.

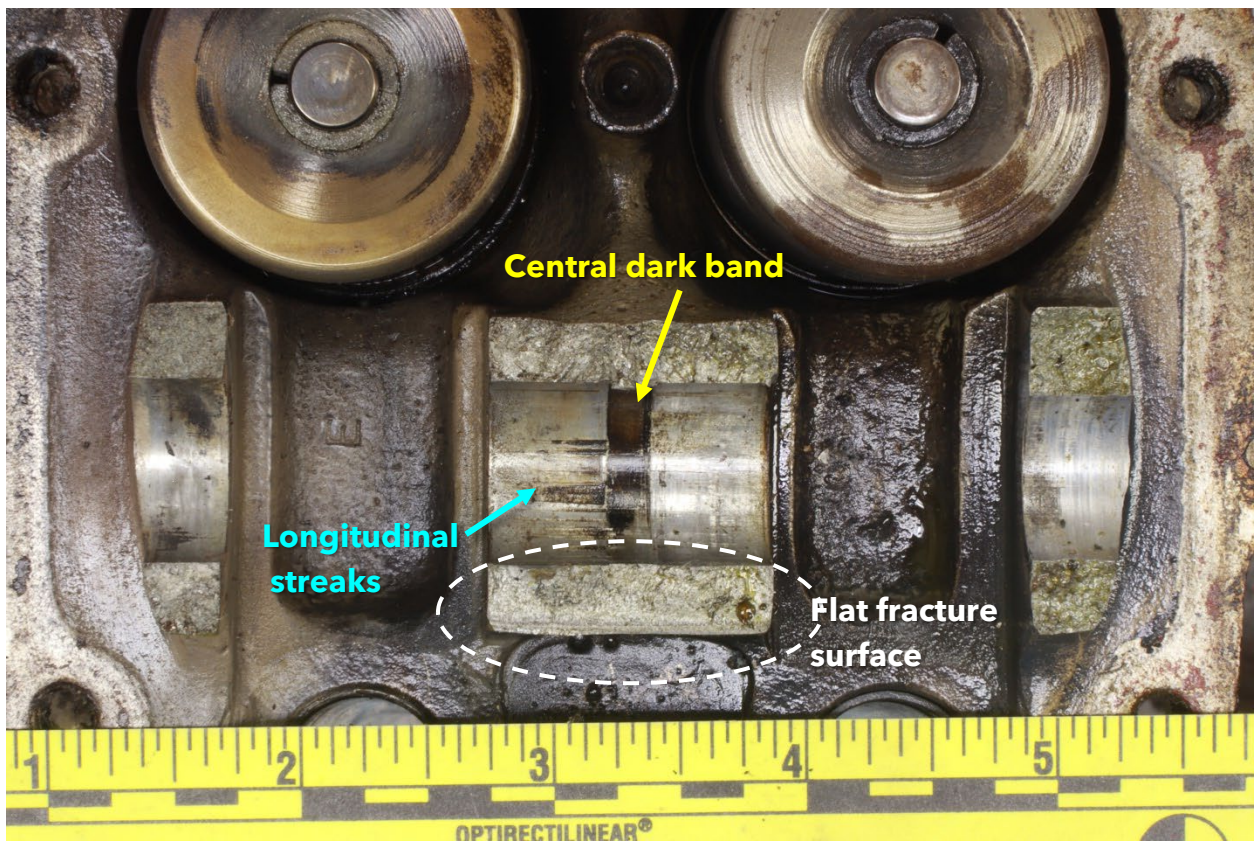


Figure 7. Closer view of the fractured rocker arm housing, with the pre-existing cracking circled.

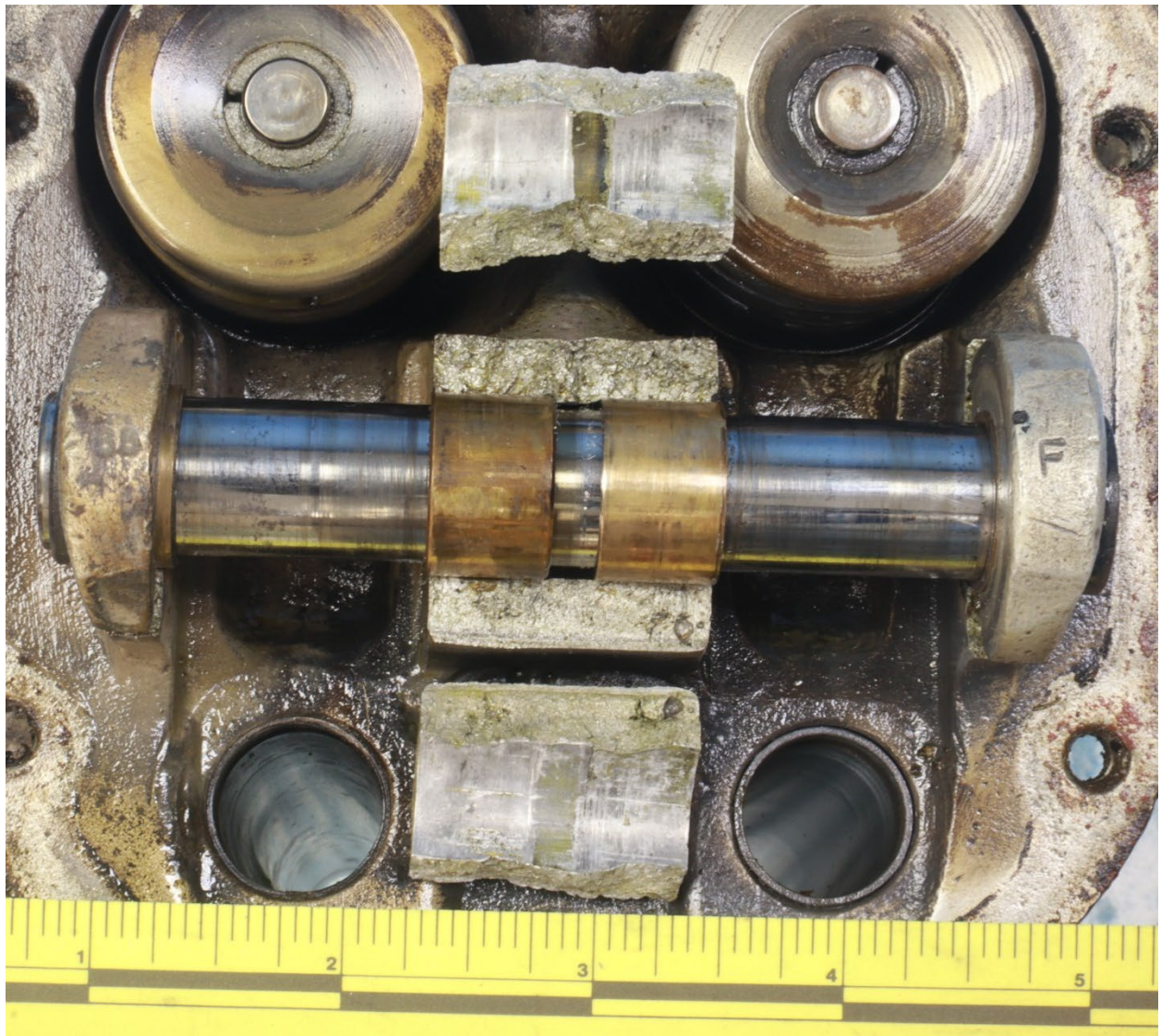


Figure 8. View of the area in Figure 7, with the rocker shaft and bosses positioned in the bore.

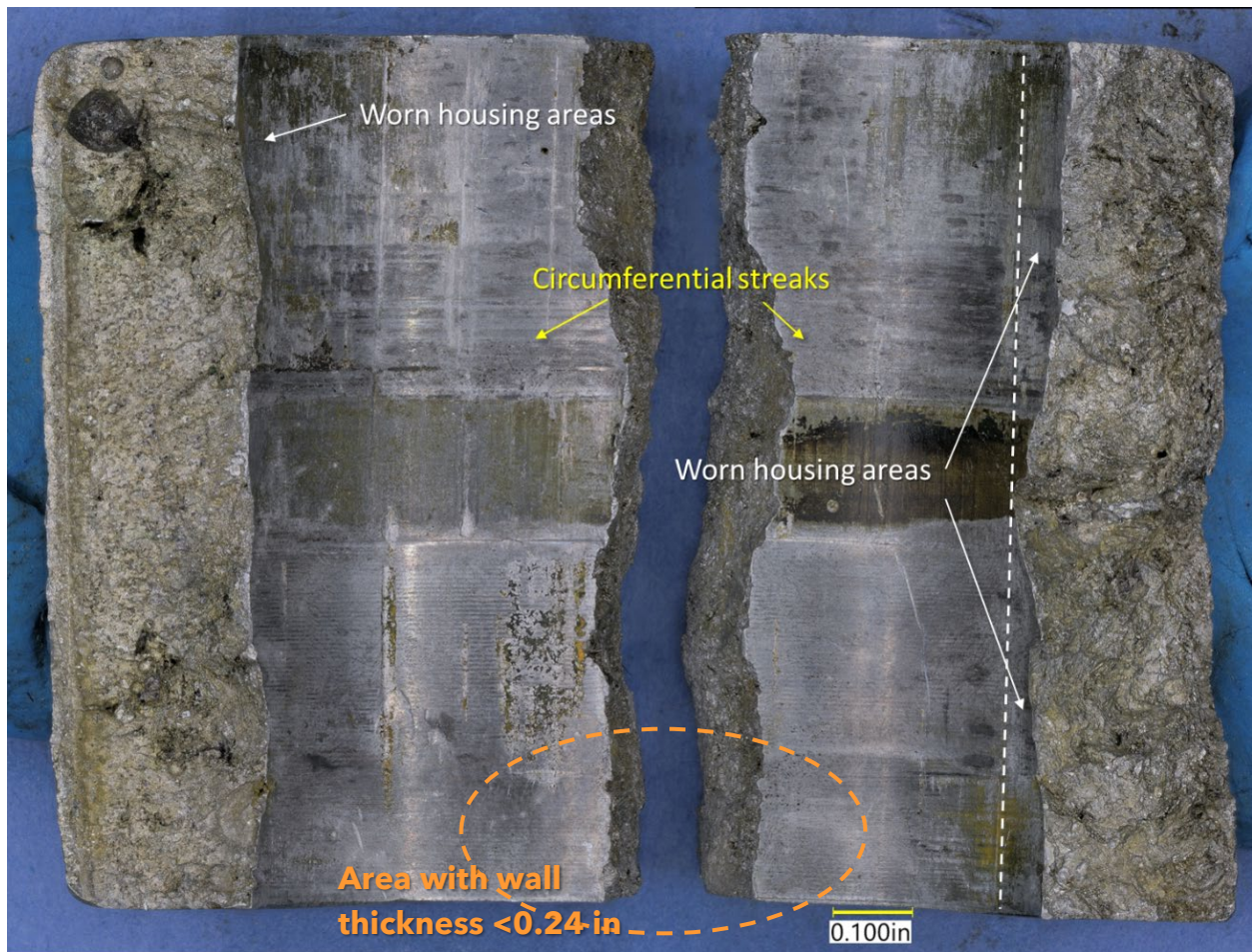


Figure 9. Inner diameter surfaces of the fractured central housing, showing worn areas and circumferential streaks.



Figure 10. The outside diameter surface of the right bushing from the shaft in Figure 8.



Figure 11. Angled inside diameter view of the right bushing, showing an ovoid wear depression and crack emanating from the edge.



Figure 12. Outside diameter of the left shaft bushing from Figure 8.

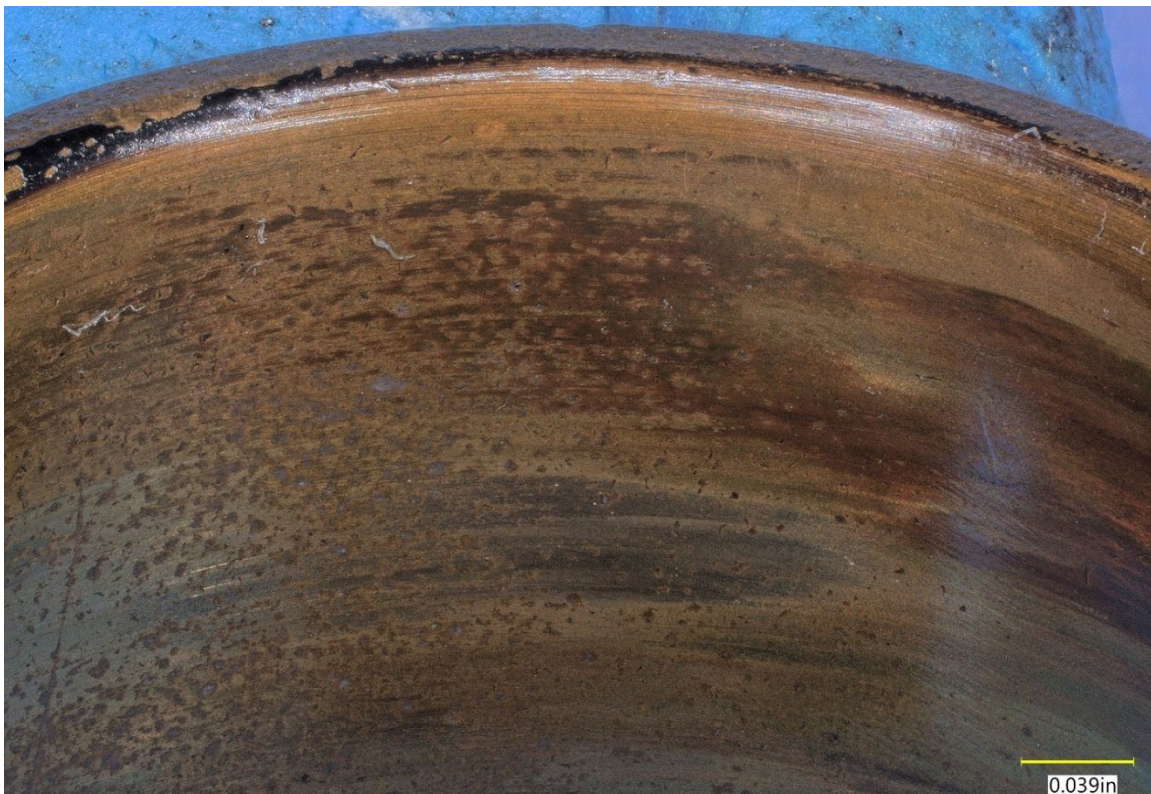


Figure 13. Angled view of the inside diameter of the left bushing, showing variable wear streaks and small pock marks.

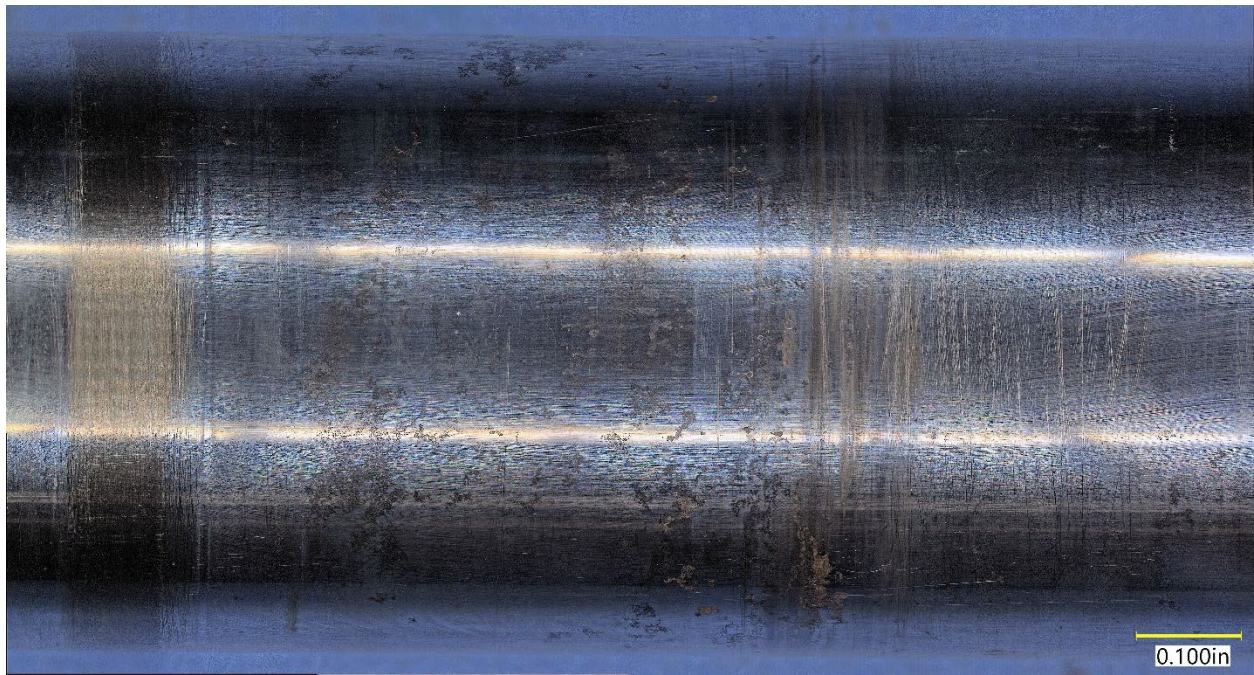


Figure 14. Outside diameter view of the rocker shaft where the right bushing had sat.

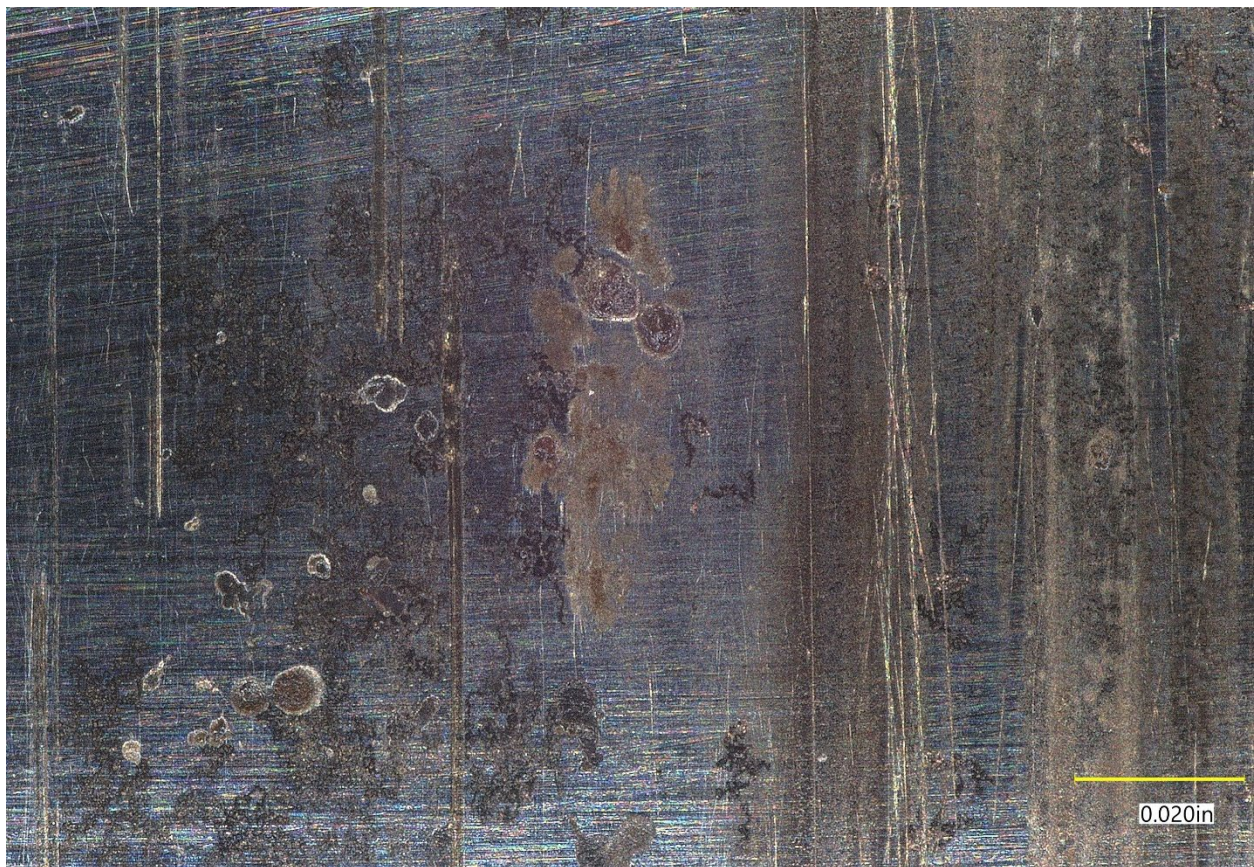


Figure 15. Spallation and circumferential wear scars on the shaft surface.



Figure 16. Overall view of the flat fracture surface on the center boss fragment.

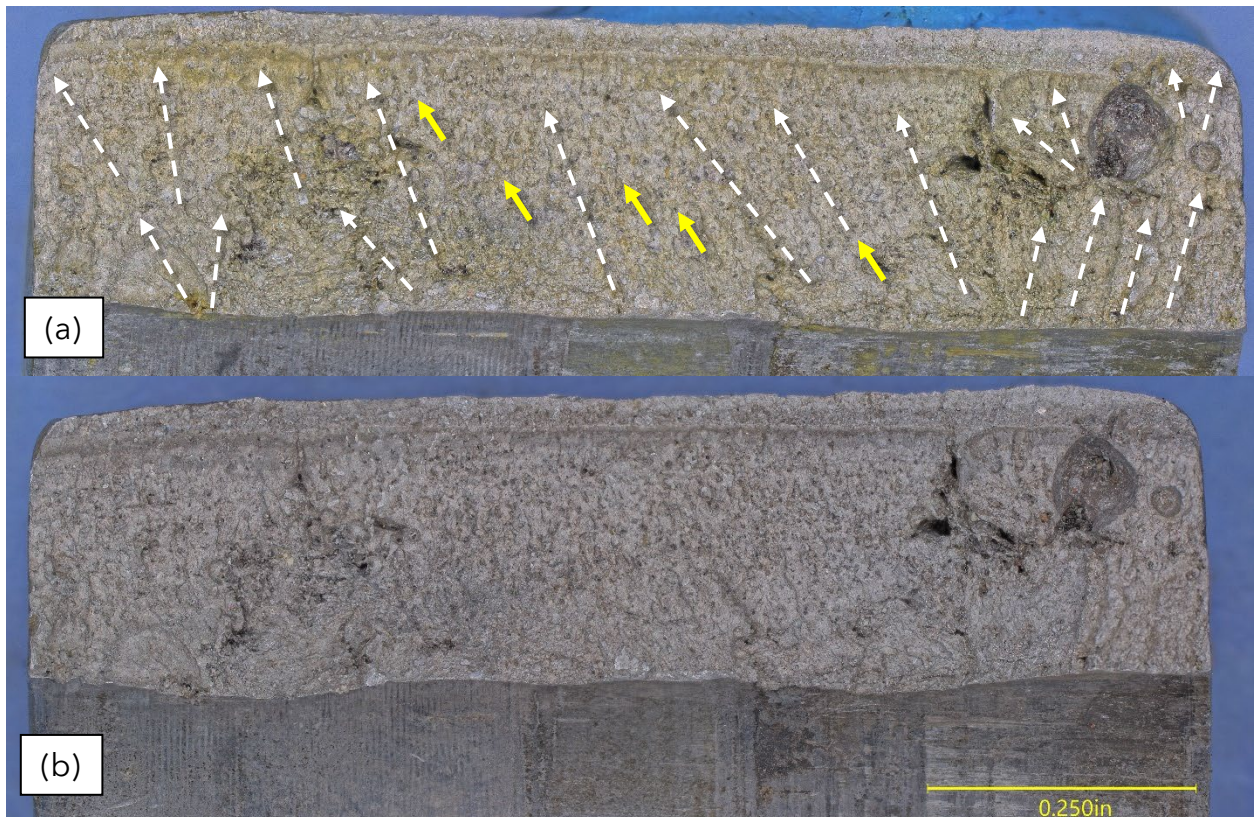


Figure 17. View of the fracture surface after (a) cleaning with acetone and (b) after acidic aluminum cleaner. Yellow arrows denote arrest marks; white are growth directions.



Figure 18. Left side of the center boss fragment fracture surface.

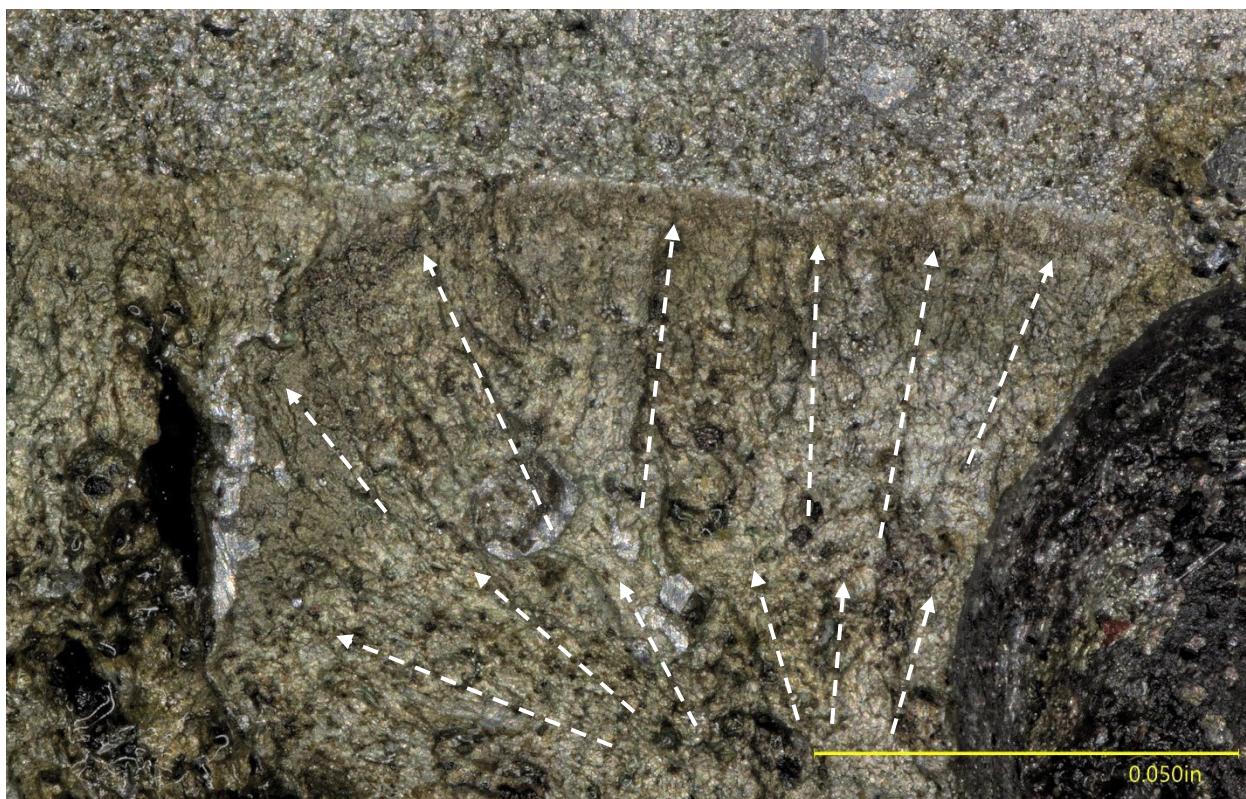


Figure 19. Terminus of one of the thumbnail cracks on the central boss fracture surface.

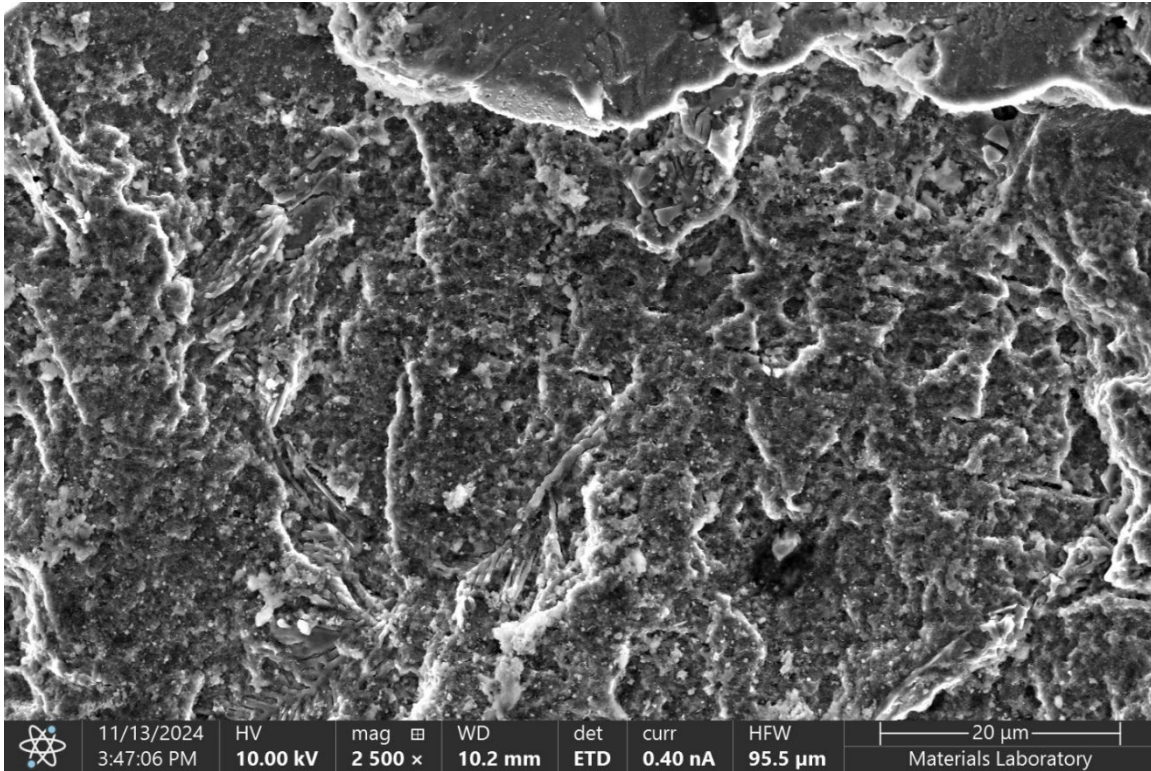


Figure 20. Secondary electron (SE) micrograph of the end of a fatigue crack on the center boss fragment.

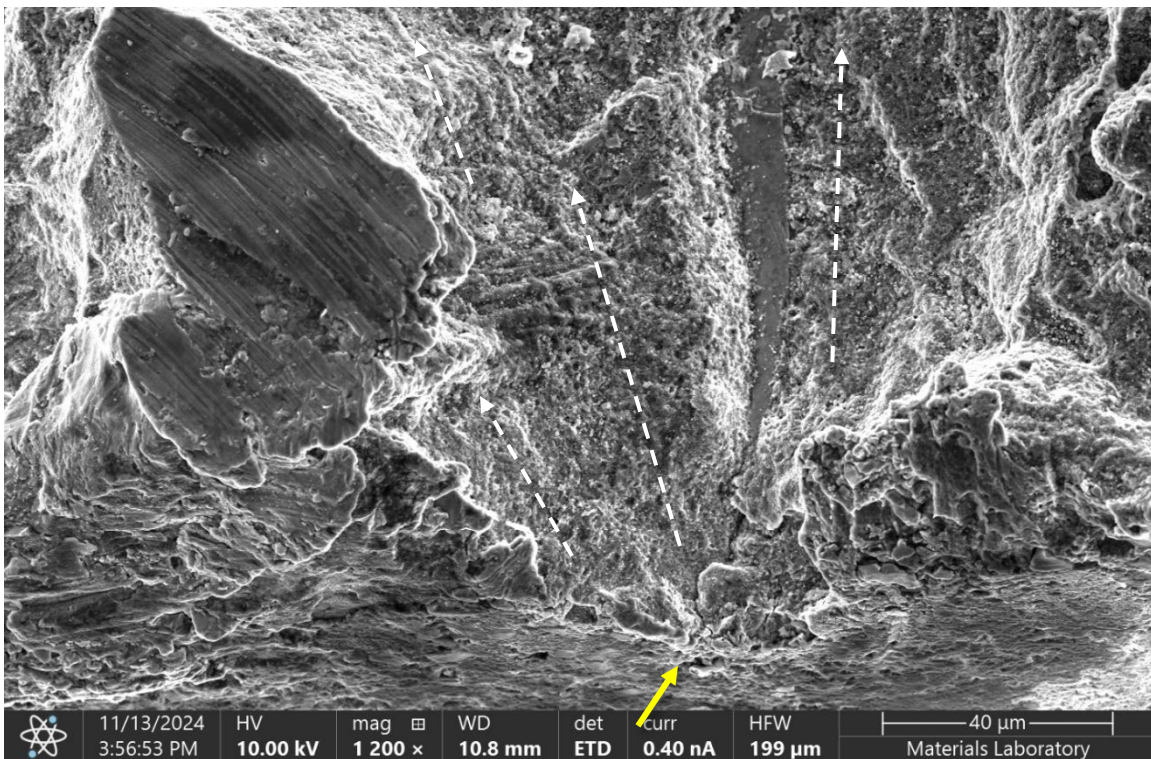


Figure 21. SE micrograph of an initiation site (yellow arrow) of the boss fragment. The dashed arrows represent the general crack growth direction.

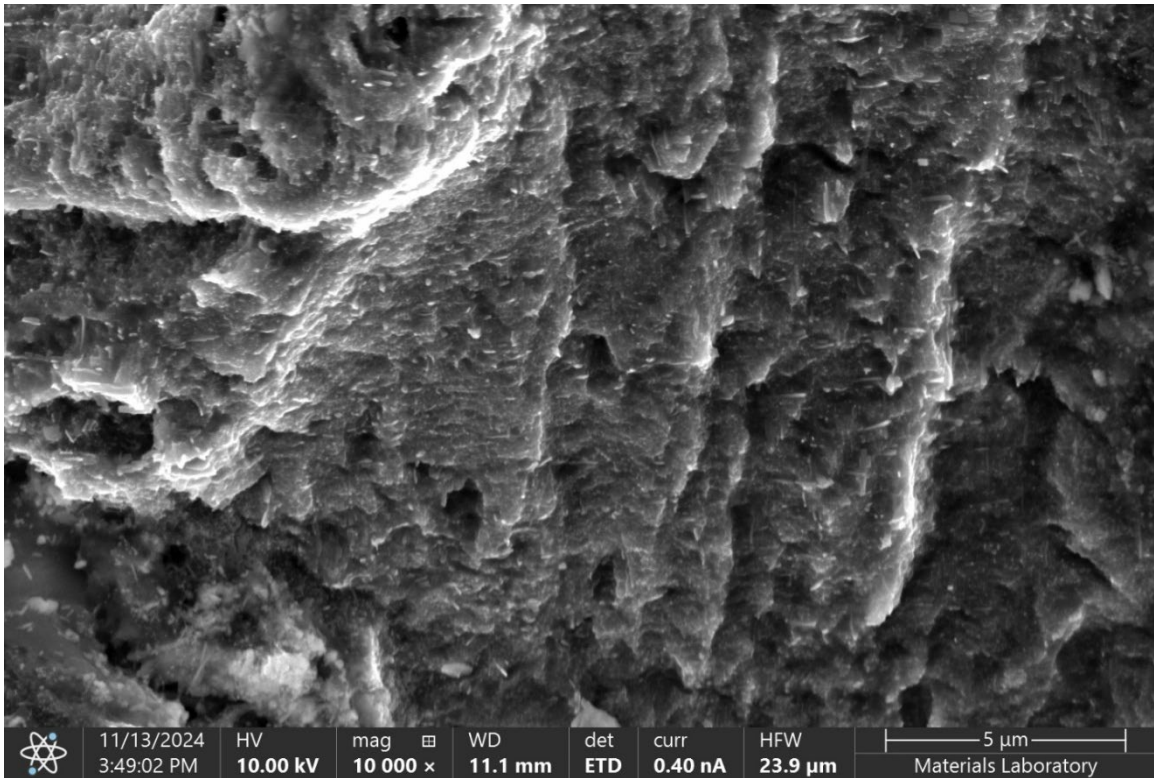


Figure 22. SE micrograph of striations near the initiation site in Figure 21.

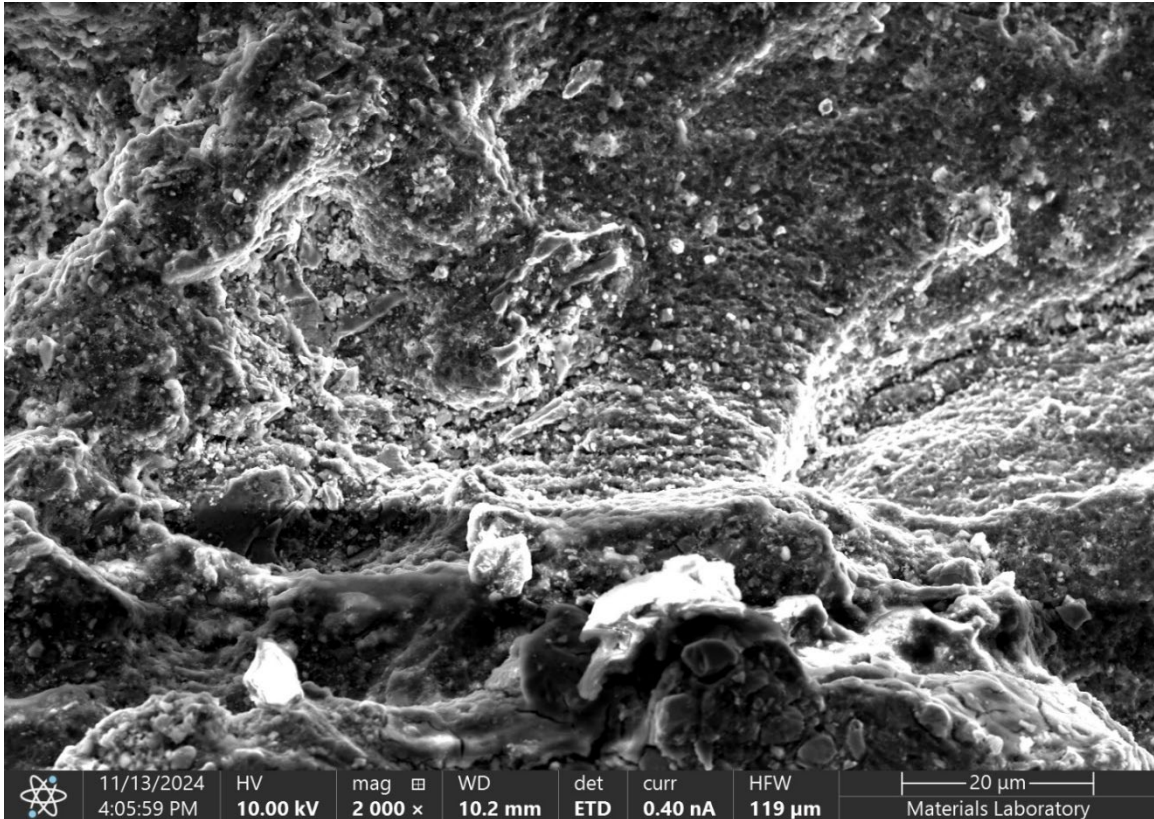


Figure 23. SE micrograph of another initiation site on the bore of the boss fragment.

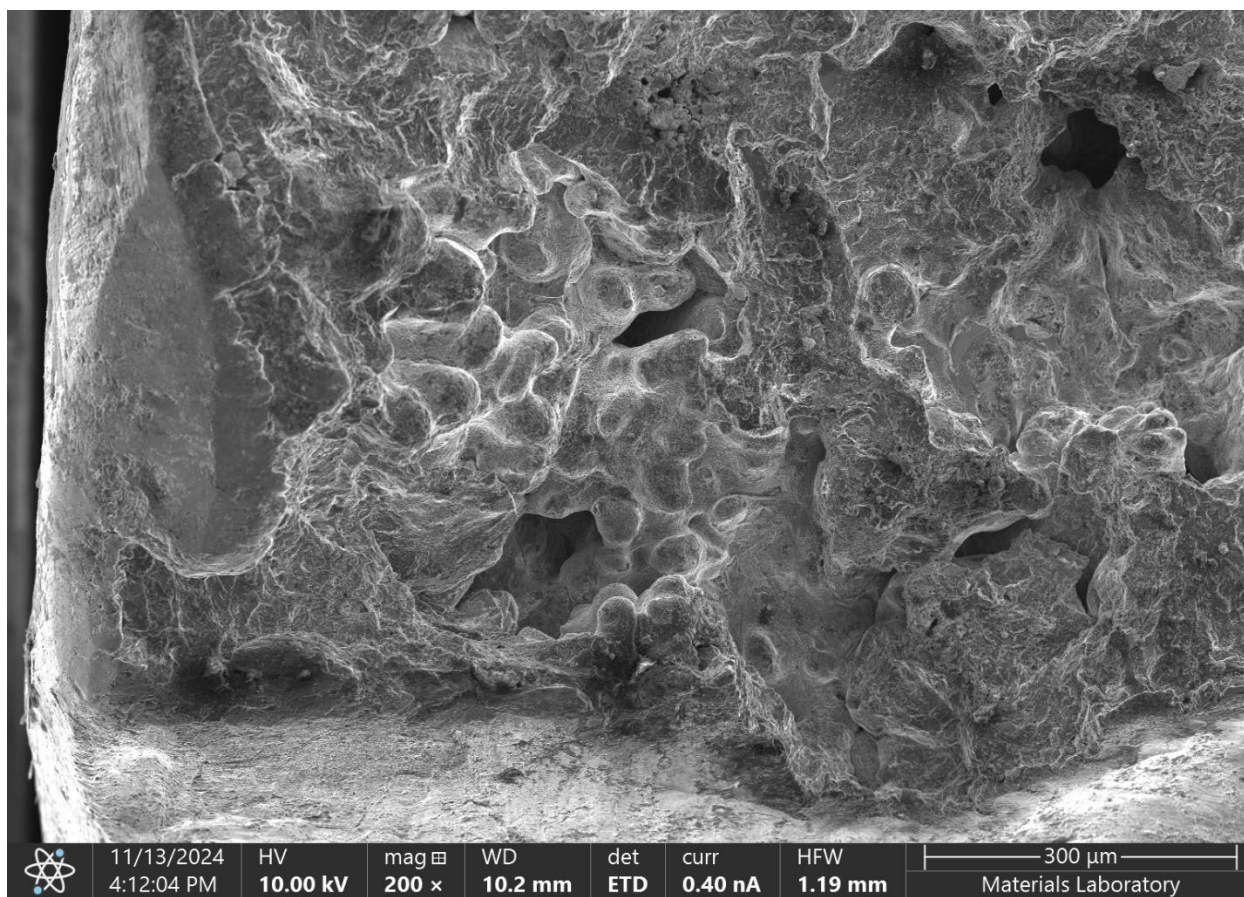


Figure 24. SE micrograph of solidification voids on the boss fragment fracture surface.