

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR23LA149

MATERIALS LABORATORY

Factual Report 24-034

June 10, 2024

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A. ACCIDENT INFORMATION

Location: Morgan, Utah
Date: April 8, 2023
Time: 19:37 mountain daylight time
01:37 coordinated universal time
Vehicle: Vans RV-7, N17NK
Investigator: Paymaun Basti, AS-WPR

B. COMPONENTS EXAMINED

Propeller assembly remnant

C. EXAMINATION PARTICIPANTS

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

D. DETAILS OF THE EXAMINATION

On April 8, 2023, a Van's RV-7 was substantially damaged in an accident near Morgan, UT. The pilot was not injured. The pilot reported that about 15 minutes into the flight, a burning odor was present when the heater was activated, followed by vibrations during the return to the departure airport. Approximately one minute later, the pilot encountered a sudden shudder and then observed oil covering the windshield. The engine subsequently lost power. The pilot made a forced landing in a field south of the airport. Upon ground impact in the field, the airplane flipped over and came to rest inverted after the main landing gear contacted the snow. An initial investigation of the aircraft found the propeller assembly attached to the Titan IOX-370 engine to be located away from the impact site before the forced landing.¹ This propeller assembly was sent to the NTSB Materials Laboratory for additional examination.

Figure 1 shows the propeller assembly as received. All three blades had been damaged such that approximately half of the outboard portions had been destroyed. The fractures of these blades were jagged with multiple impact marks along and near the fracture, as well as on both sides of the airfoils.

Of chief concern in this examination was the condition of the attachment bolts on the hub. Figure 2 shows these bolt remnants as received. Five bolt remnants remained in the hub, whereas one of the bolts was completely missing. For the purposes of this

¹ Titan IOX-370 Series is an experimental fuel-injection piston aircraft engine with four air-cooled cylinders, horizontally opposed, and manufactured by Continental Aero, headquartered in Mobile, AL.

report, the bolts were labeled 1 through 6, numbered clockwise from the missing bolt location, as illustrated in Figure 2. All bolts had fractured between 0.25 and 0.50 inches aft of the aft hub face.

Figures 3 through 9 show closer views of the six bolt positions. Figure 3 shows the missing bolt (#1 location). This area exhibited outward plastic deformation along the bolt hole edge in the clockwise direction, displayed in Figure 3. There were also two smaller impact marks on the hub face near bolt hole #1.

Bolt hole #2 also exhibited outward-oriented plastic deformation, but in the counterclockwise direction, demonstrated in Figure 4. The fractured bolt from the head side remained inside the bolt hole. This bolt exhibited a flat fracture on part of the surface, with impact damage in the form of smearing and batter on the lower right or clockwise side.

Figure 5 shows the fractured bolt from the #3 position. This fracture was generally conic in shape, with the outer areas exhibiting multiple thumbnail-shaped cracks and the center region being relatively flat and perpendicular to the bolt direction. The hub face exhibited two angled gouge marks from the bolt hole to the hub edge. Bolt 4 also exhibited two angled gouge marks emanating from the bolt hole to the hub edge (see Figure 6). However, the fracture surface morphology differed, with two flat regions perpendicular to the bolt direction, separated by an upward protruding ridge.

Bolt 6 in Figure 8 exhibited a similar morphology to Bolt 4, whereas Bolt 5 exhibited a shape closer to Bolt 3, being conic in morphology (Figure 7). Both the edges of the hub near Bolts 5 and 6 exhibited circumferential abrasive wear.

Figure 9 shows an angled view of the hub at the #1 bolt hole location. Besides the deformation on the clockwise edge of the hole (left in Figure 9), the forward face exhibited circumferential gouge marks, consistent with impact against the nut from the missing bolt. This interaction between the nut and this hub surface is demonstrated from the #5 bolt position in Figure 10.

The safety wire was removed, and the bolt remnants were disassembled from their respective nuts in the propeller hub. The remnants were cleaned in an ultrasonic bath of acetone to remove excess oils, greases, and dirt. Figures 11 through 20 show the fracture surface of the five removed bolt fragments.

All bolt fracture surfaces exhibited features consistent with progressive cracking—crack arrest marks, ratchet marks, and multiple thumbnail-shaped cracks. Figure 11 and Figure 12 show the fracture surfaces of bolts 2 and 3, respectively. Each exhibited a generally conic shape, with a flat center region and angled periphery. The angled edges were consistent with individual thumbnail cracks, crack initiation, and

propagation from the thread roots at the edge. While Bolt 2 exhibited four prominent thumbnail cracks, Bolt 3 exhibited six.

The Bolt 4 fracture surface exhibited a different pattern, with a larger portion of the surface flatter rather than angled. The ridge in the upper right of Figure 13 separated a larger flat area of the fracture surface from a smaller one. On both sides were angled thumbnail cracks, though smaller than those in Figures 11 and 12. Several of these smaller thumbnail cracks are shown in Figure 14, located along a thread root while also exhibiting individual ratchet marks. The larger flat area exhibited faint crack arrest marks, consistent with propagating from the thumbnail cracks in Figure 14. The smaller flat region of the fracture surface also exhibited individual thumbnail cracks, shown in Figure 15. As shown in Figure 16, these cracks exhibited crack arrest and ratchet marks consistent with initiating along the thread root.

Figures 17 and 18 show the fracture surfaces of Bolts 5 and 6, respectively. Both exhibited several angled thumbnail cracks along the edge, and while Bolt 5 exhibited a shape similar to Bolt 3, Bolt 6 exhibited a larger flatter region. The ridge shape similar to Bolt 4 is shown closer in Figure 19. This feature exhibited coalescing river marks, consistent with crack propagation from the large flatter area (downward in Figure 18). This pattern would be consistent with crack propagation along a different height rather than the two opposite-facing cracks that occurred in Bolt 4. This flatter region exhibited crack arrest marks consistent with propagation from smaller thumbnail cracks on the opposite side in Figure 20.

Several bolts were examined using a field-emission scanning electron microscope (SEM). Figure 21 shows the end of the larger flat area of Bolt 4 against the ridge. The figure shows a transition from one fracture mode to another. The area in the lower right exhibited striations consistent with fatigue crack propagation, as shown closer in Figure 22. The upper right area of Figure 20 exhibited dimpled rupture, consistent with overstress fracture, as highlighted in Figure 23. These features were consistent with fatigue crack propagation from opposite thread roots of Bolt 4 until the remaining cross-section of the bolt fractured in overstress, leaving a thin necked ridge.

Several fatigue crack initiation sites of Bolt 4 were examined closer, as illustrated in Figures 24 and 25. Each figure shows vertically oriented ratchet marks, consistent with multiple crack initiation sites that coalesced during early crack propagation. Closer views of these areas showed fine fatigue striations, as exemplified by Figure 26.

A closer view of the individual crack initiation sites (as shown in Figure 27) did not reveal any corrosion pits or voids. There were some dissimilar materials, as illustrated in the backscattered view in Figure 28, but this was inconsistent with the inclusion of

manufacturing.² There were some mechanical surface undulations, as exemplified in Figure 29.

Overall, the bolts fractured from fatigue cracking that initiated along multiple sights of the thread roots. These fatigue cracks propagated almost the entire bolt cross sections until the remaining material succumbed to overstress fracture. All bolts exhibited fatigue cracks, though bolts 4 and 6 exhibited the most extensive fatigue.

Submitted by:

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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.

E. FIGURES



Figure 1. Separated propeller hub and blades, as received, viewed from the aft-facing side with fractured bolts and hub face.

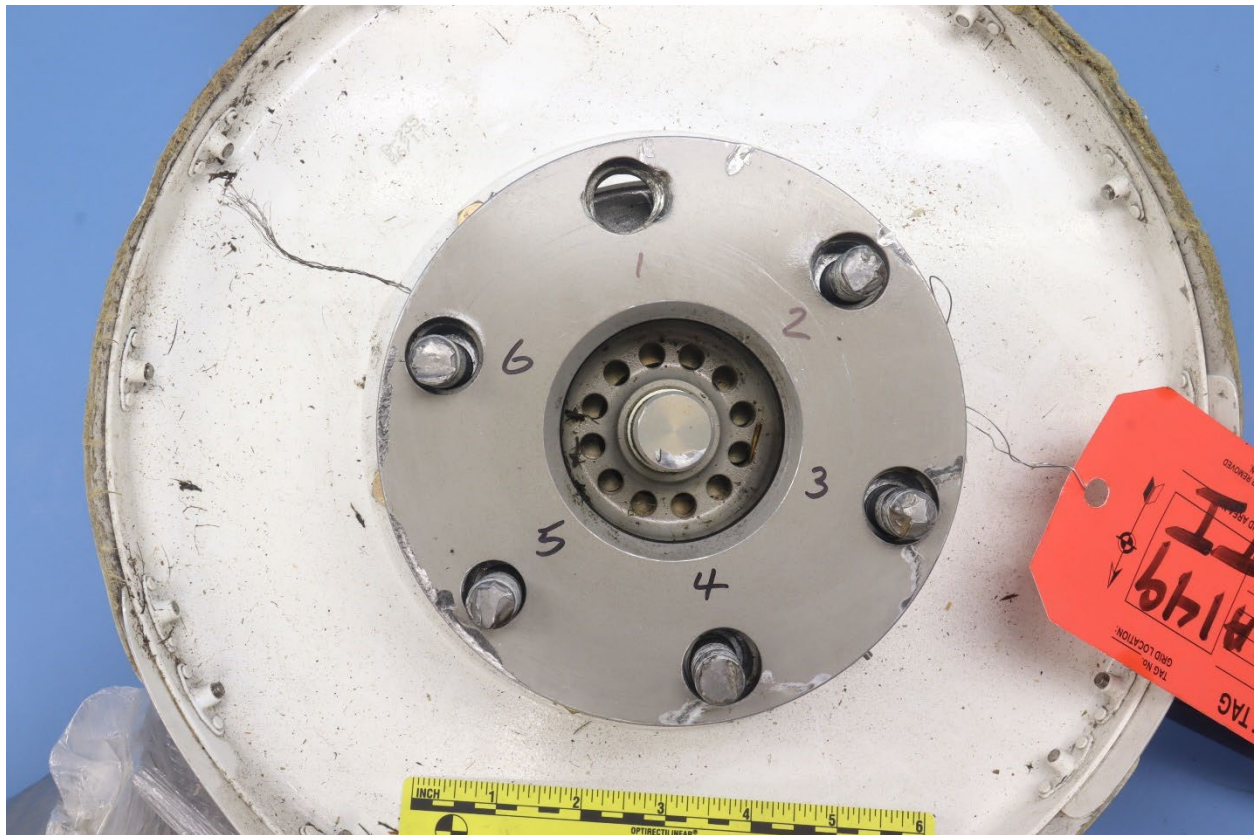


Figure 2. Closer view of the fractured bolt surfaces remaining in the hub, showing the positions labeled 1 through 6.

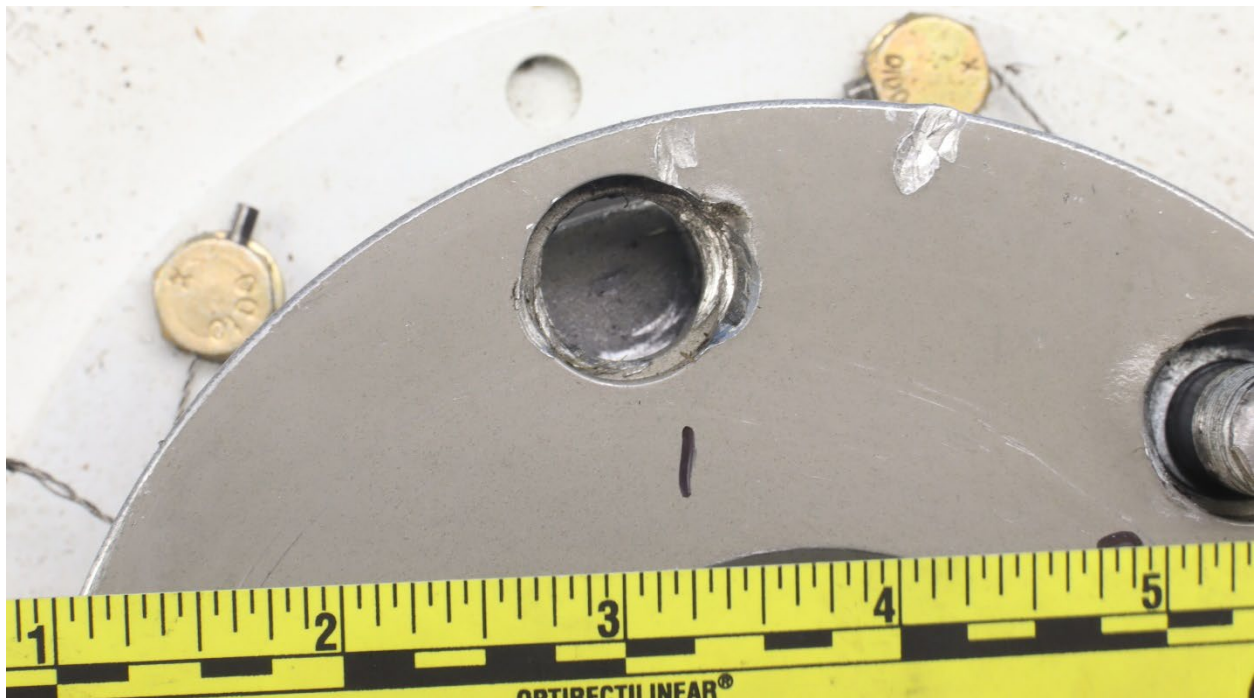


Figure 3. View of the #1 bolt position, absent the bolt remnant with deformation in the hole.



Figure 4. View of the fracture surface of the #2 bolt.



Figure 5. View of the fracture surface of the #3 bolt.



Figure 6. View of the fracture surface of the #4 bolt.



Figure 7. View of the fracture surface of the #5 bolt.



Figure 8. View of the fracture surface of the #6 bolt.

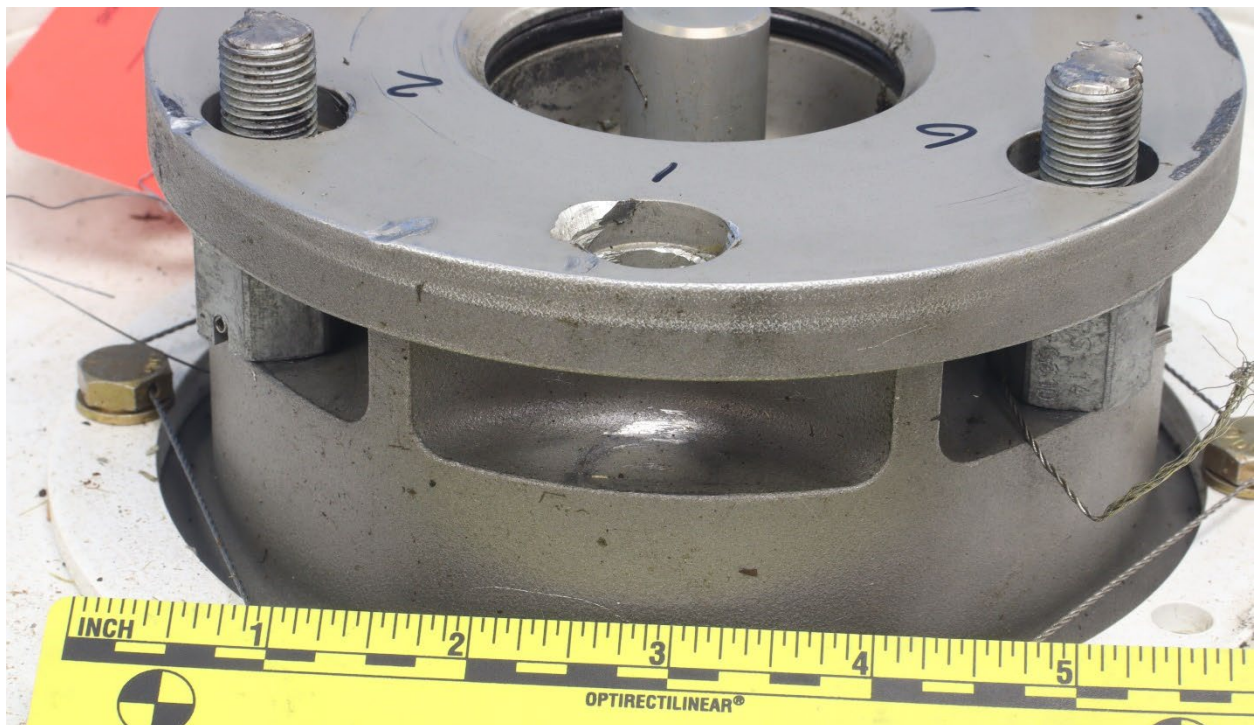


Figure 9. Angled view of the hub at the #1 bolt position, showing side wall deformation of the hole and impact marks on the underlying hub face.

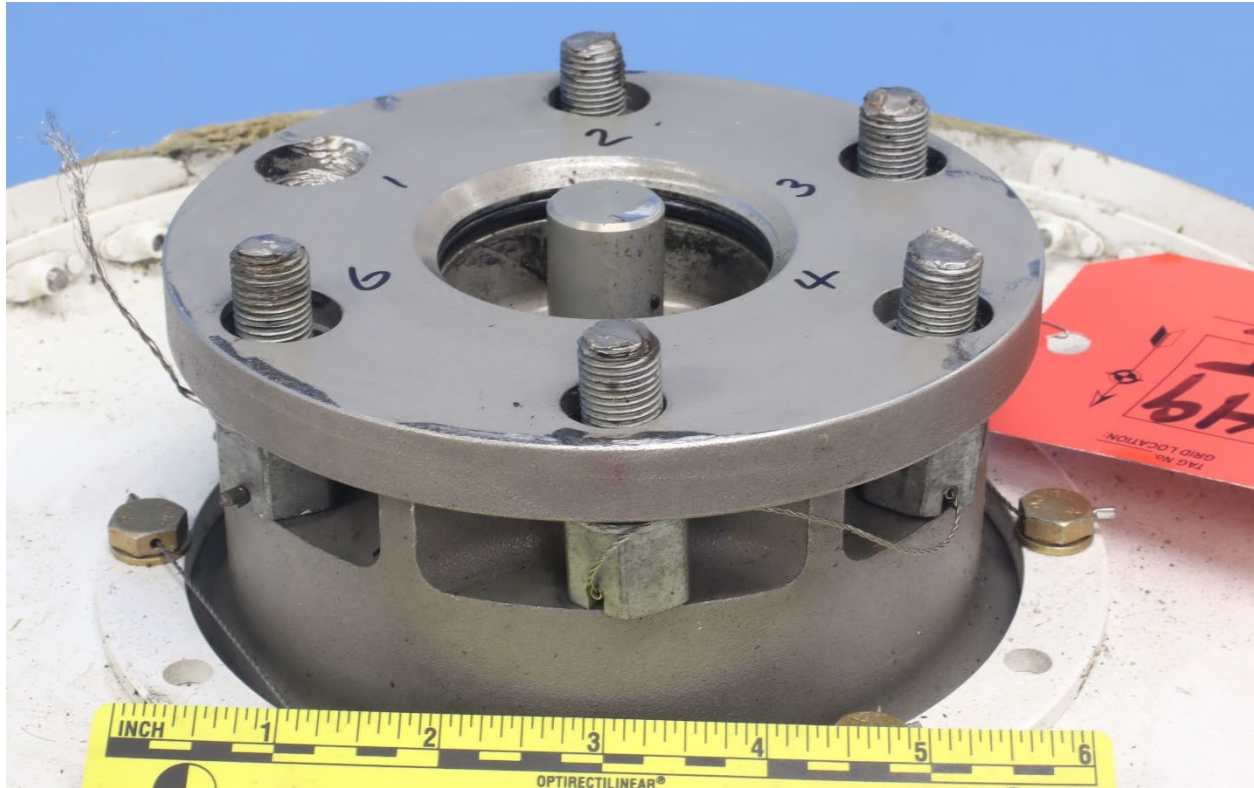


Figure 10. Angled view of the hub and fractured bolts from the #5 bolt position.

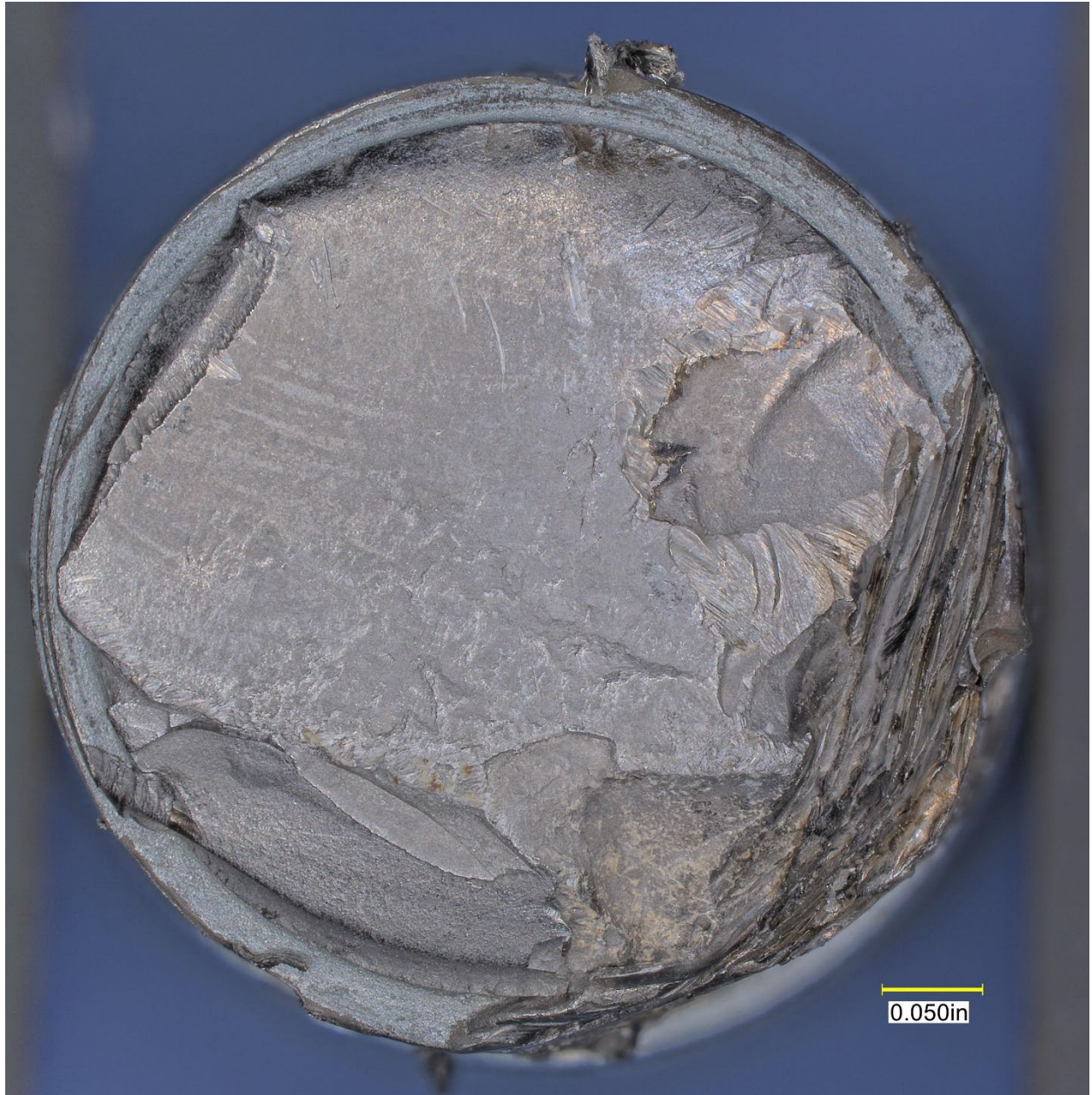


Figure 11. The fracture surface of bolt 2.



Figure 12. The fracture surface of Bolt 3.



Figure 13. View of the Bolt 4 fracture surface.

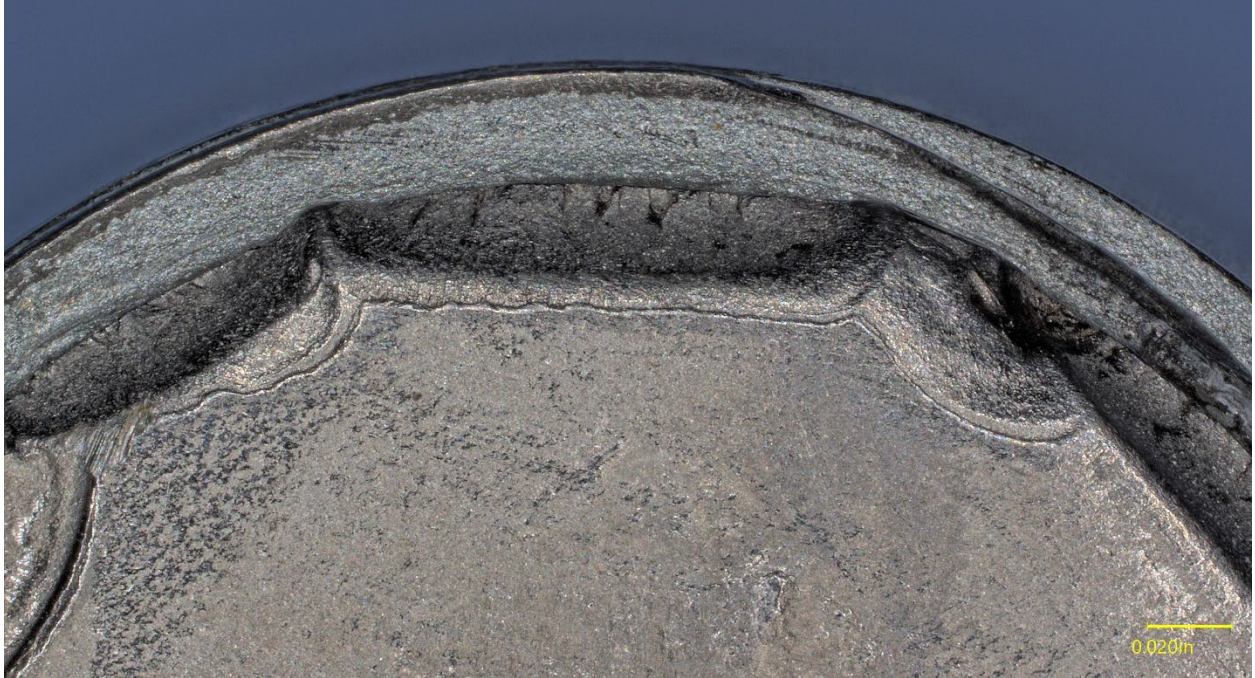


Figure 14. Smaller thumbnail cracks along the periphery of the Bolt 4 fracture surface.



Figure 15. The upward facing ridge on the fracture surface of Bolt 4 (upper right in Figure 13).



Figure 16. Closer view of ratchet marks near the edge of the Bolt 4 fracture surface.

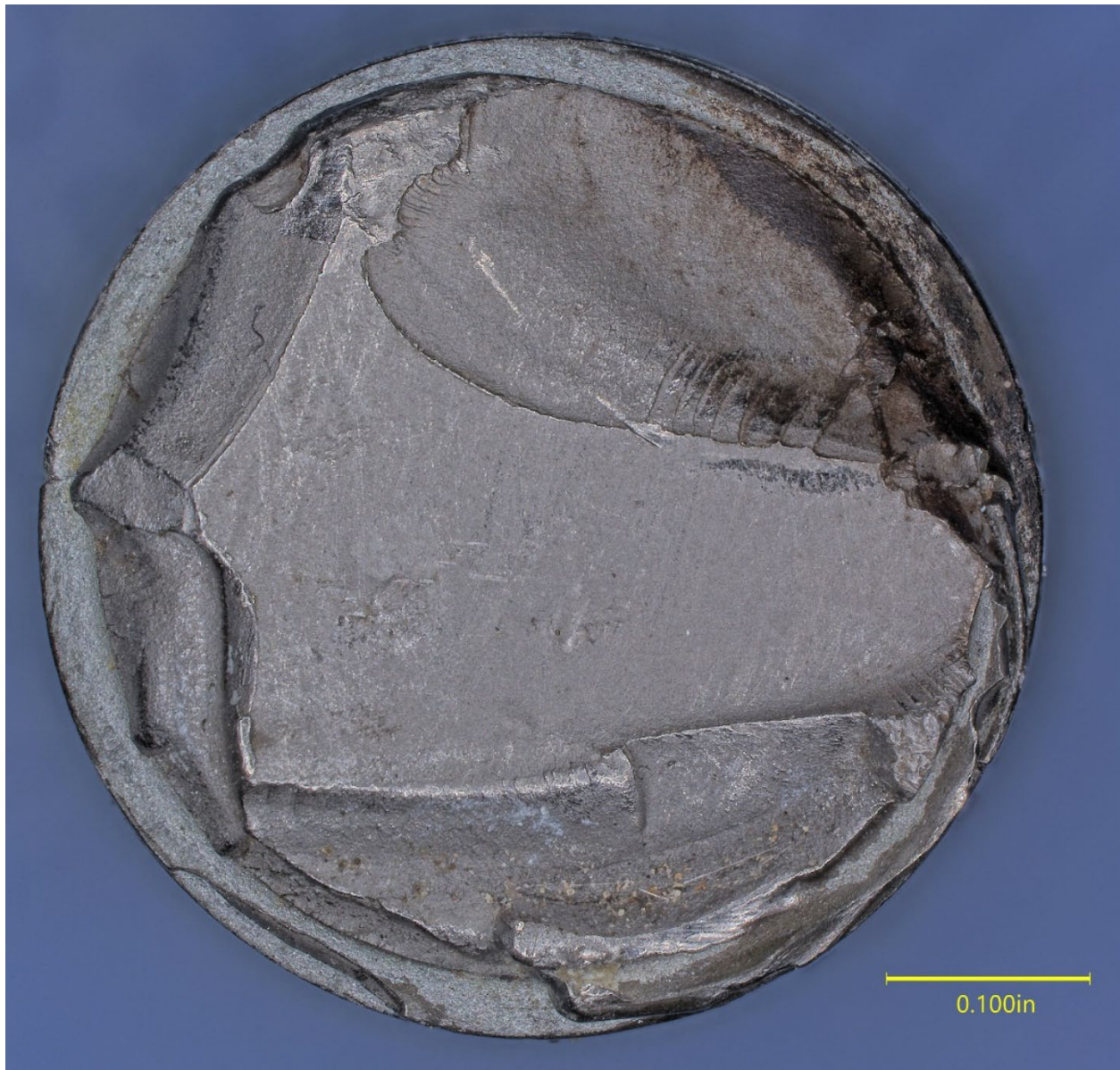


Figure 17. The fracture surface of Bolt 5.

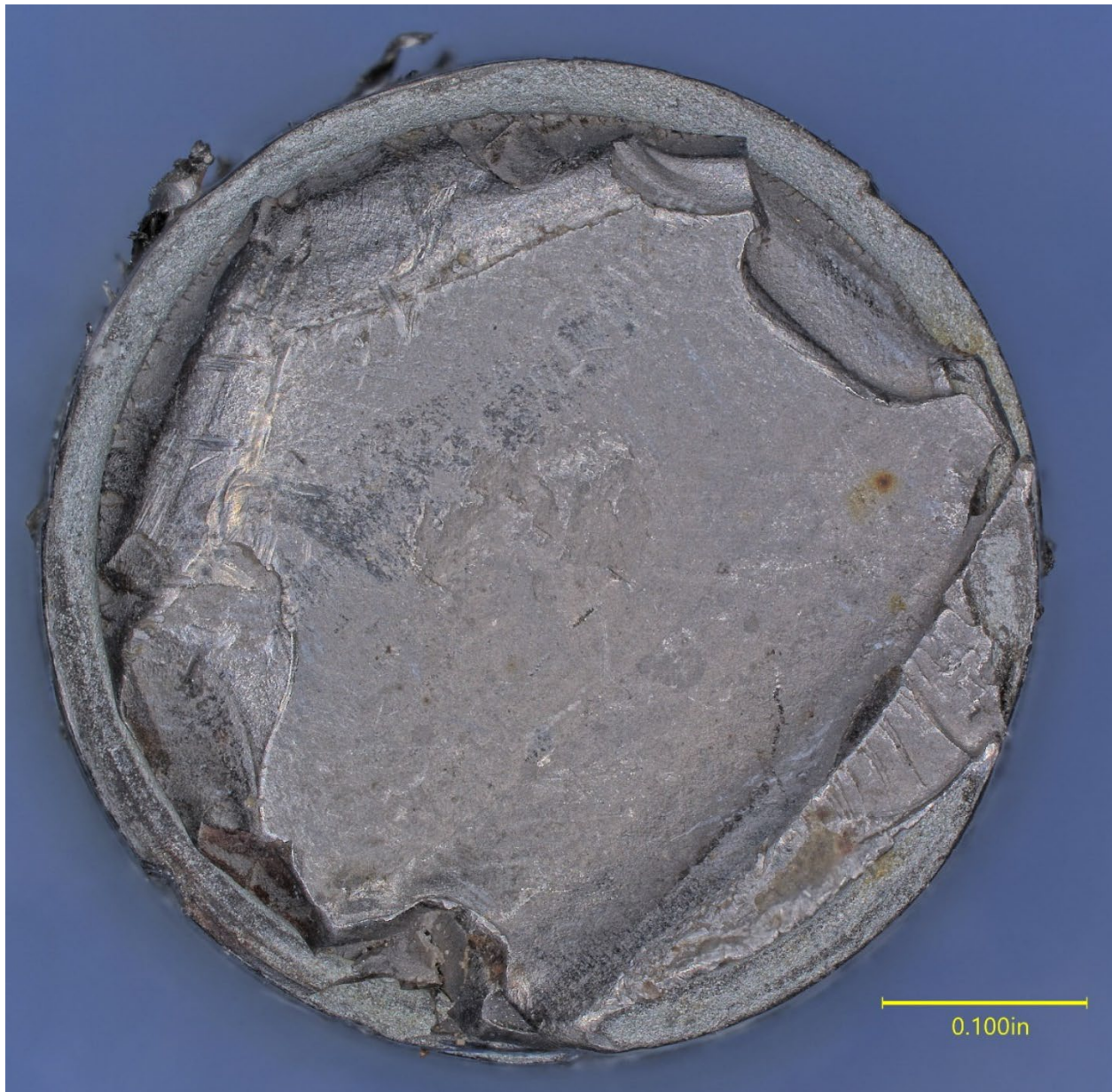


Figure 18. View of the Bolt 6 fracture surface.



Figure 19. Closer view of secondary ratchet marks on the end of the Bolt 6 fracture surface.



Figure 20. Smaller ratchet marks on the Bolt 6 fracture edge, along with smearing and gouge marks on the surface.

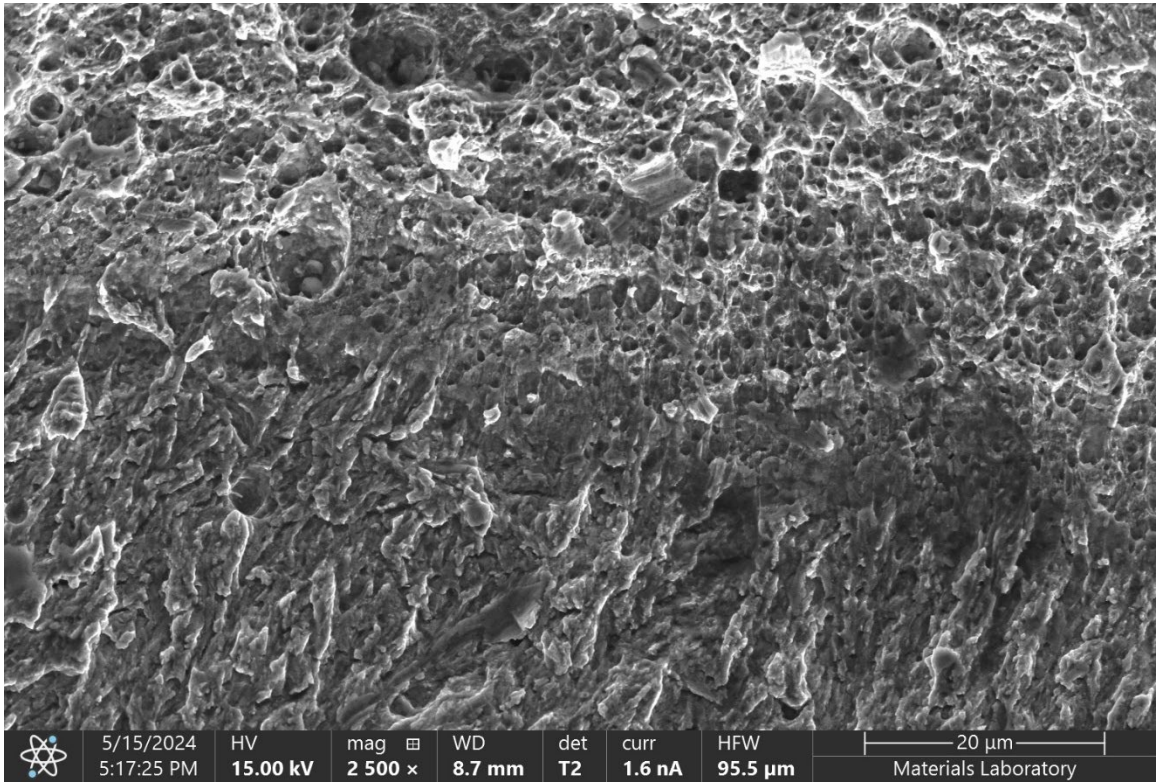


Figure 21. Secondary electron (SE) micrograph of the end of the fatigue crack on Bolt 4.

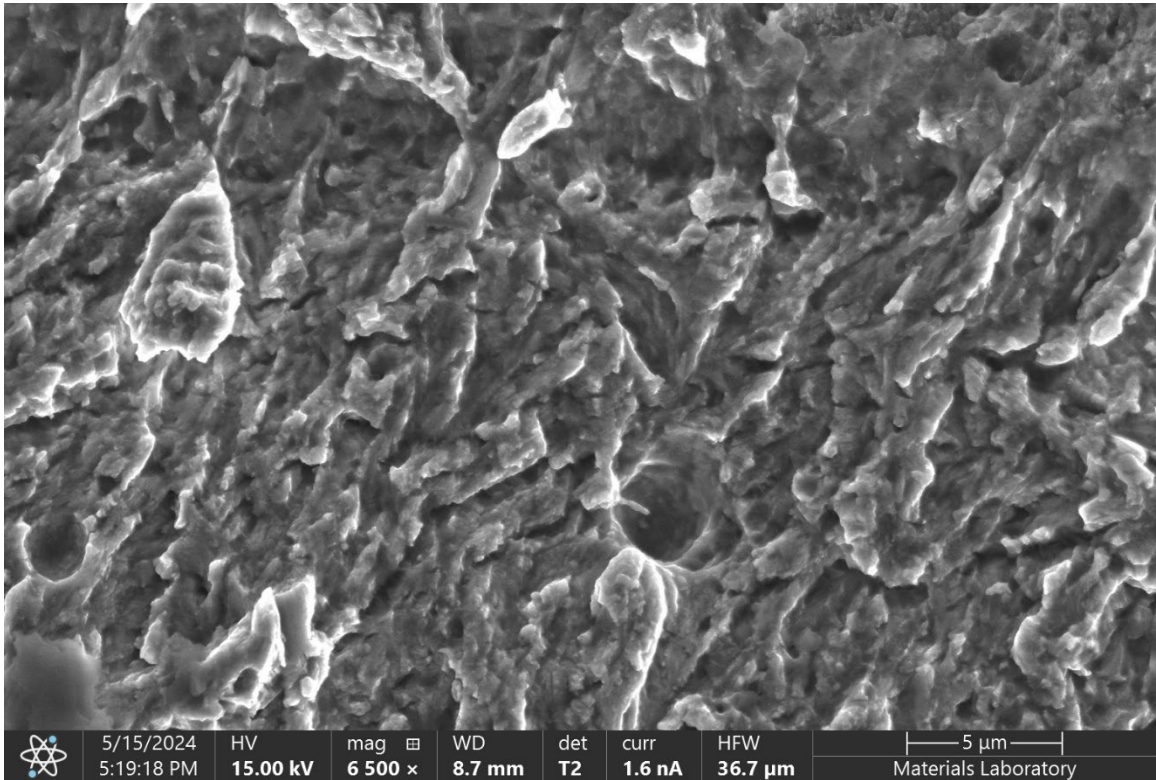


Figure 22. SE micrograph of striations at the end of the fatigue crack in Figure 21.

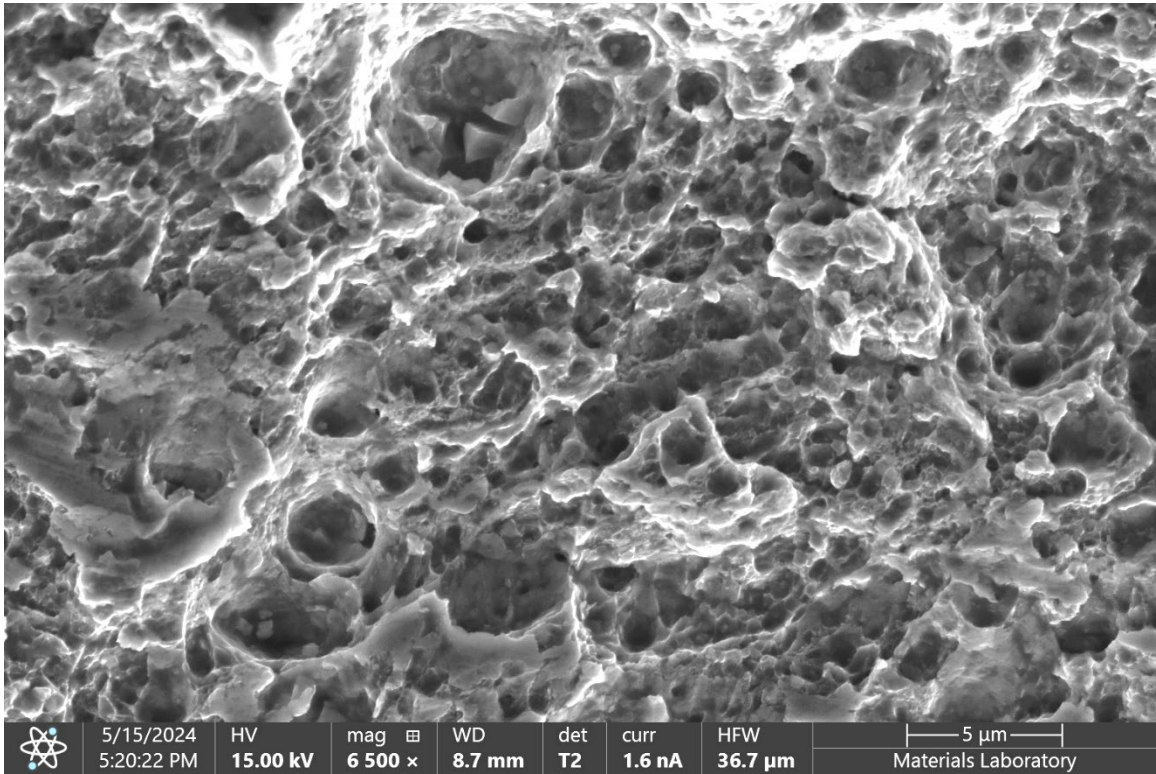


Figure 23. SE micrograph of dimpled rupture outside the fatigue crack in Figure 21.

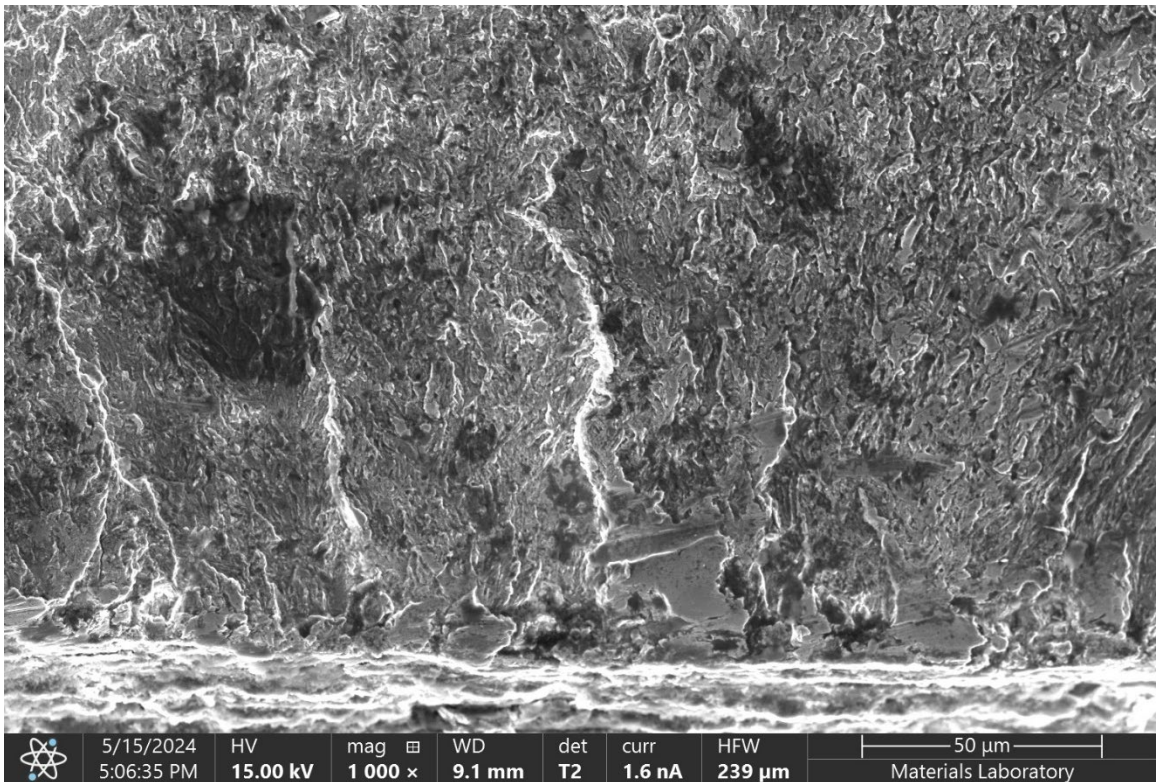


Figure 24. SE micrograph of multiple crack initiation sites at the Bolt 4 surface edge.

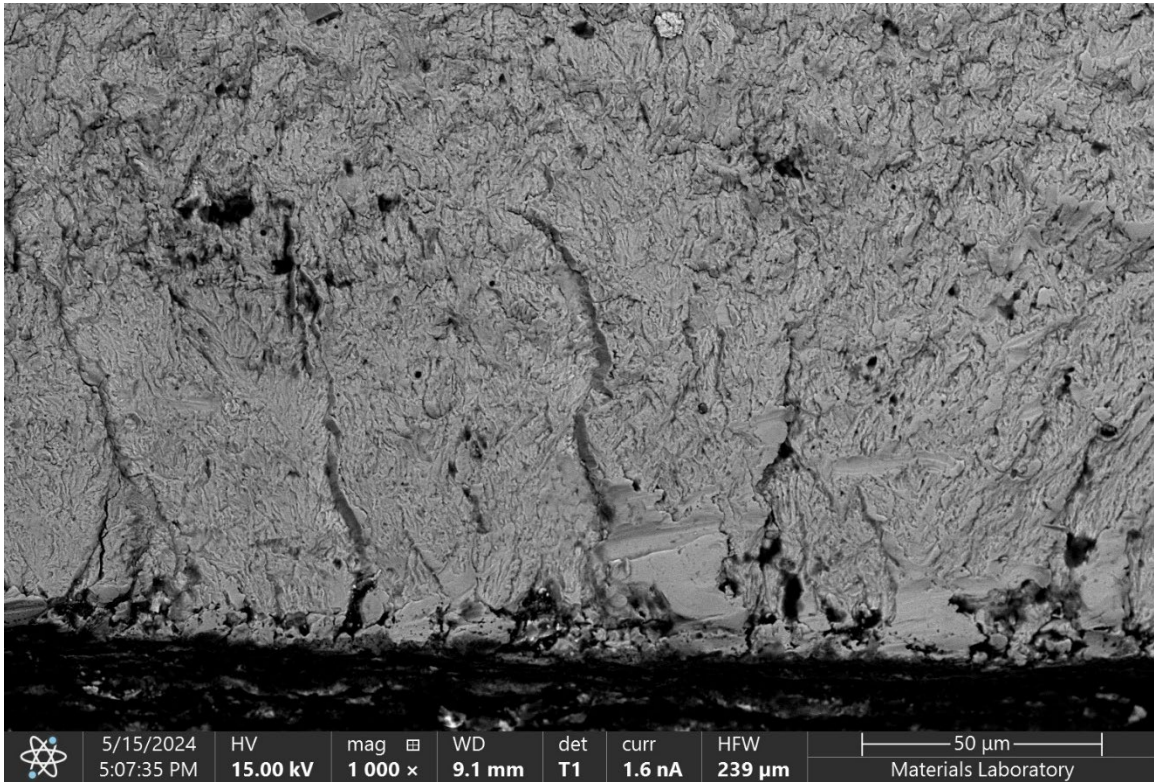


Figure 25. BE micrograph of multiple crack initiation sites at the Bolt 4 surface edge.

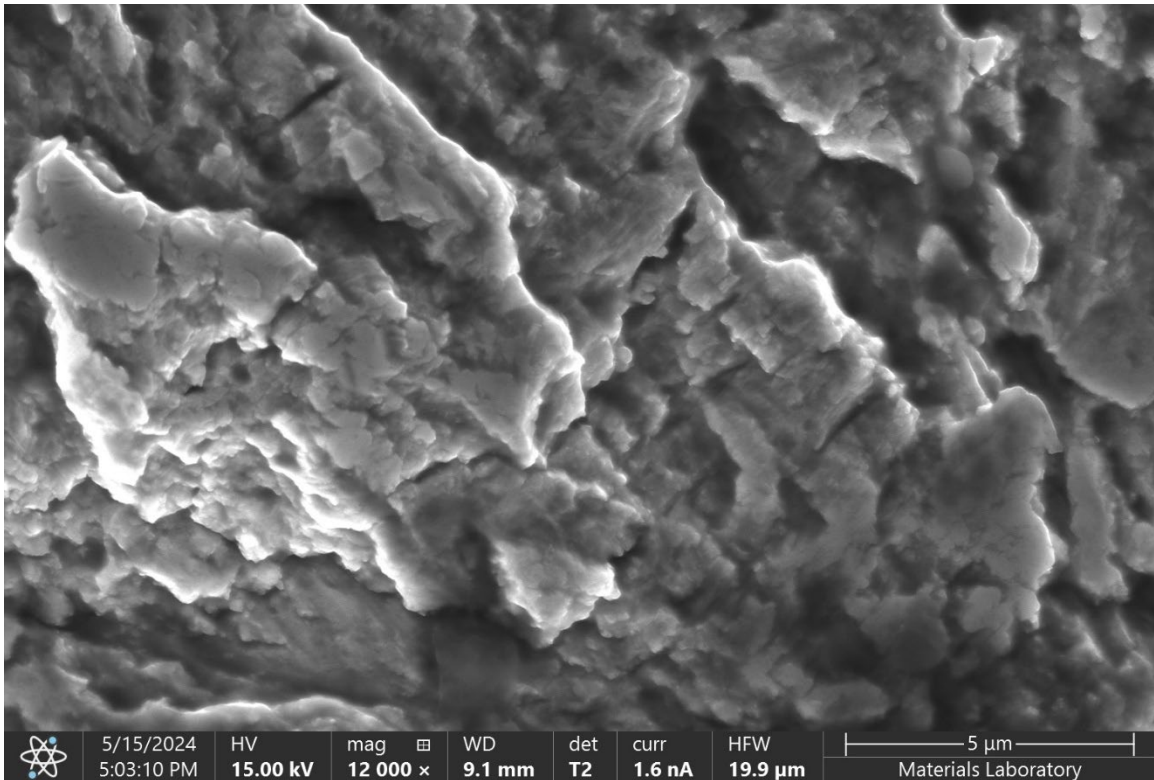


Figure 26. SE micrograph of striations near the initiation sites in Figure 25.

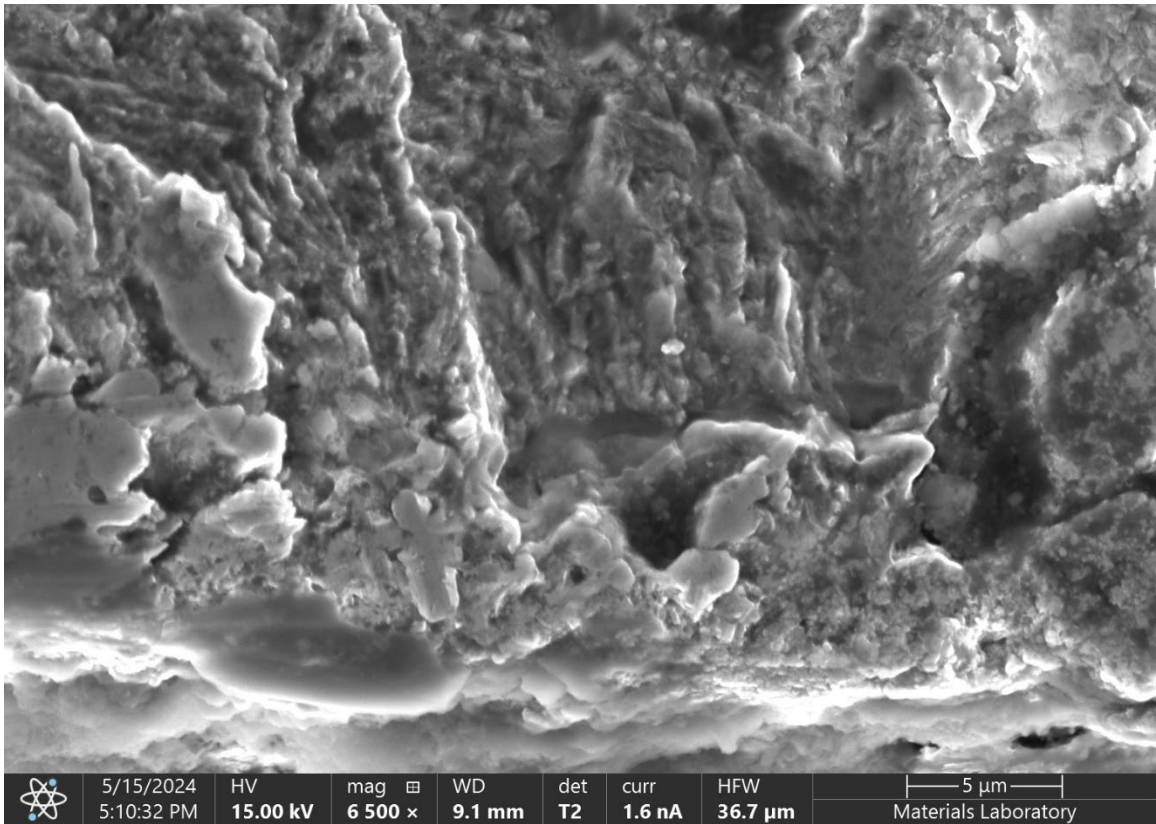


Figure 27. SE micrograph of a closer view of the center left initiation site in Figure 25.

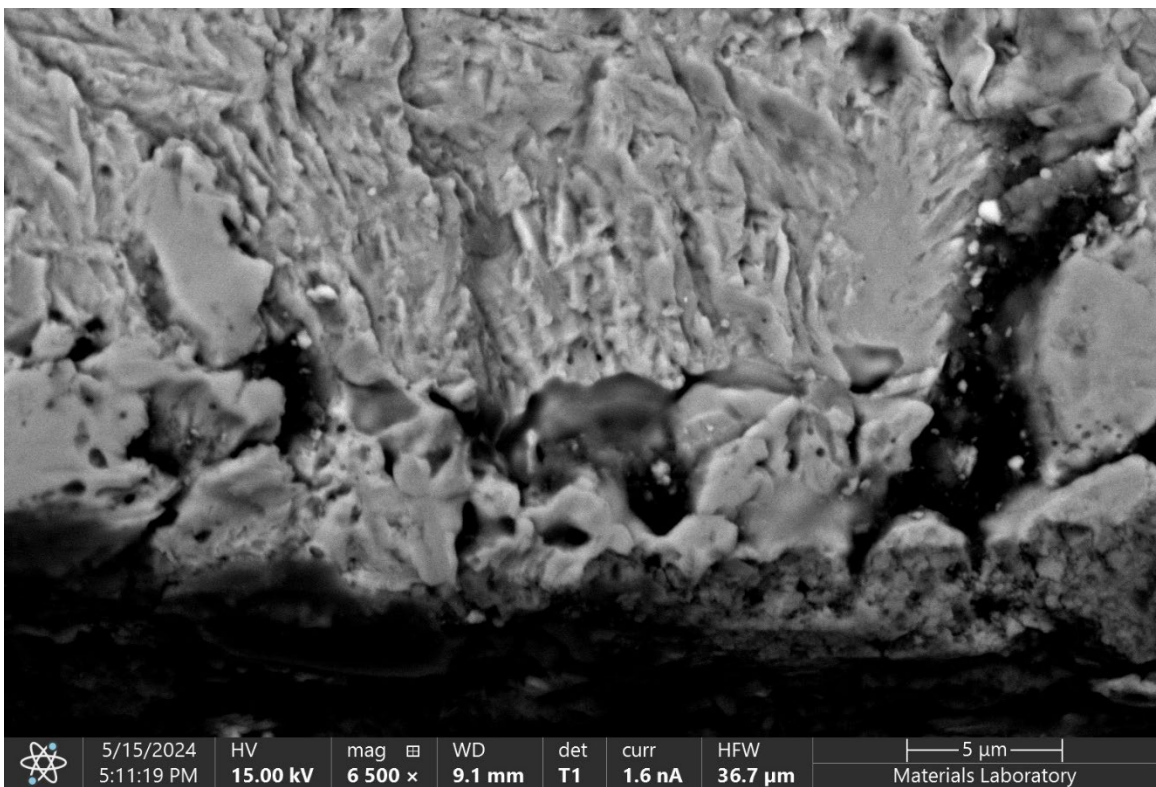


Figure 28. BE micrograph of the fatigue initiation site in Figure 27.

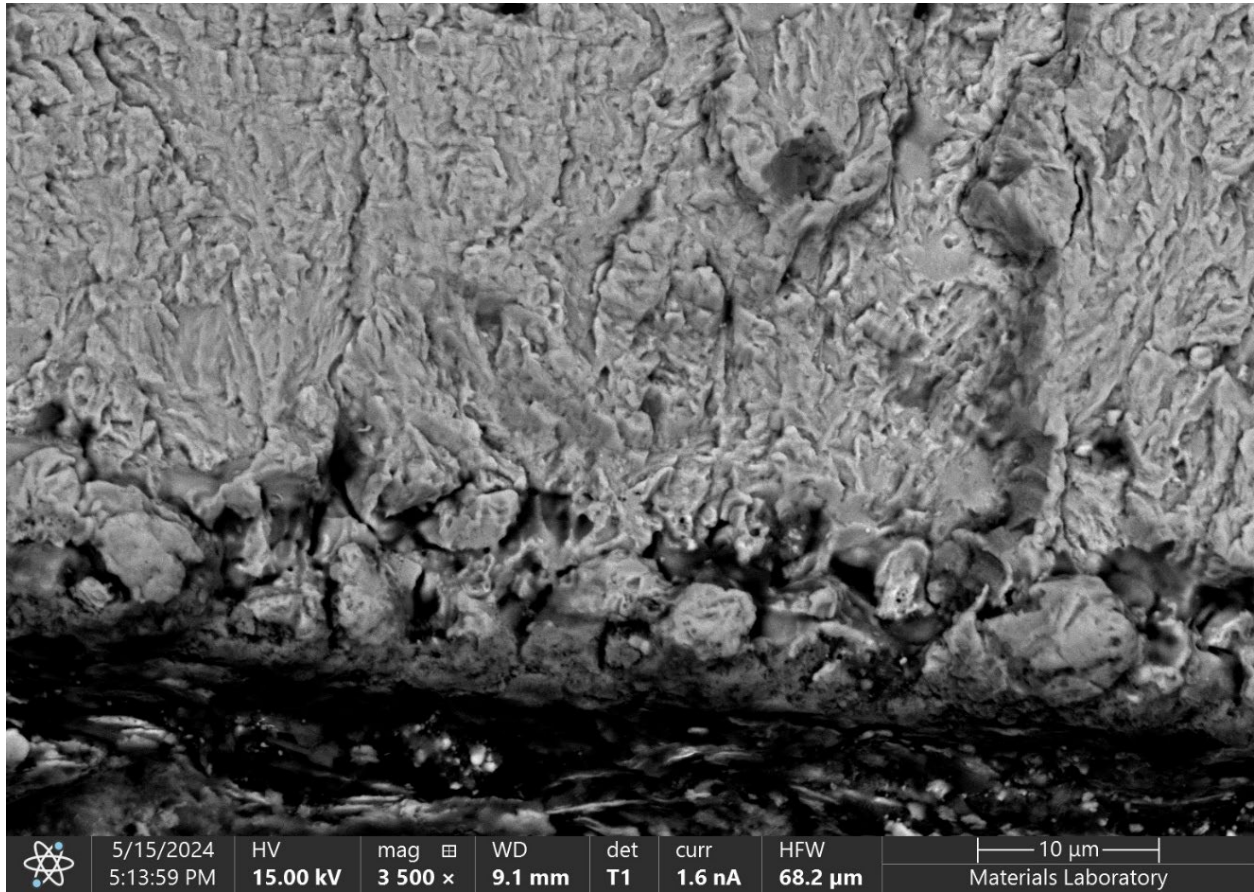


Figure 29. BE micrograph of crack initiation sites on the opposite (smaller crack) side of Bolt 4.