

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ERA24FA050

MATERIALS LABORATORY

Addendum Report 24-044B

May 12, 2025

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A. ACCIDENT INFORMATION

Location: Attalla, Alabama
Date: November 27, 2023
Time: 17:48 central daylight time
23:48 coordinated universal time
Vehicle: Piper PA-32R-301T, N4187Q
Investigator: Timothy Monville, AS-ERA

B. COMPONENTS EXAMINED

Remnant of a damaged left magneto assembly

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller
Office of Research and Engineering - Materials Laboratory Division
NTSB, Washington, DC

D. SUMMARY

The rivets inside the magneto impulse hub, which connected the pawls to the impulse coupling hub, had fractured. Both rivets exhibited indications of wear on the shafts, consistent with deformation on the respective holes of the hub. One of the rivets exhibited features consistent with fatigue cracking that had initiated at multiple locations along an area of wear.

The impulse shell had torn and partially fractured adjacent to the boss, whose bottom face exhibited wear marks. The spring underneath the shell did not show any residual tension or spring-back, consistent with having been softened due to high temperature exposure. The rest of the magneto exhibited features consistent with exposure to fire.

E. DETAILS OF THE EXAMINATION

This report is an addendum to a previous materials laboratory examination of engine components from a Piper PA-32R-301T accident that occurred near Attalla, AL, on November 27, 2023. This additional examination involved components from the left magneto removed from a TIO-540-AH1A engine involved in the accident.

The magneto is shown from four sides in Figure 1 and Figure 2. The plate in Figure 1a stated:

*Ser. No.: 180061001-1
Model No.: 6361
Lag.: 35, Rot: L, Rev.: F
Cust. MAG: 66LC35SDNP
F.A.A.-P.M.A.
Slick. Champion Aerospace
Liberty, South Carolina*

These figures demonstrate the extent of exterior damage to the housing. The sides in Figure 1b and Figure 2b show flow and deformation on the housing, with small folds and lenticular wrinkles, consistent with high temperature exposure. The housing damage was most severe on the bottom side, shown in Figure 3. The housing exhibited a complete absence of material, forming a hole, with thin, white-colored edges. Black, carboniferous fragments readily fell out of the magneto interior when handled. These features were consistent with the component having been exposed to a fire.

Figure 4 shows the opened end of the magneto, revealing the impulse hub assembly. The exterior-facing impulse shell, hub, nut, and cotter pin exhibited enough surface oxidation (i.e., rust) to form a mottled rough surface and obscure most underlying features. Of note on the shell was a crack and an outward tear in part of the skirt or flange on the left side of Figure 4.

The cotter pin was removed, followed by the nut, hub, washer, and shell, revealing the underlying impulse hub assembly. The underside surfaces of the removed shell components are illustrated in Figure 5. The circular spring under the shell was affixed to both the shell interior and the other spring surfaces. The spring did not experience spring-back forces when actuated, consistent with being stress-relieved and annealed from exposure to high temperatures. There were no indications of any remaining greases or oils.

As shown in Figure 6, the boss protruding from the shell skirt exhibited a wear mark with smearing and an absence of corrosion product. In addition, there was also an impact mark and deformation at the edge of the boss, shown in Figure 6 and Figure 7. This edge contacted the stop pin, shown in Figure 8 and Figure 9. The portion of the skirt exhibited a crack and tear, as demonstrated in Figure 7. The region exhibited outward deformation at the tear, consistent with outward forces in this location.

The stop pin shown in Figure 8 and Figure 9 exhibited corrosion and surface contamination over most surfaces, though to a lesser extent on the face and corner facing the impulse shell boss. The stop pin exhibited a cylindrical shape, with no indications of flattening on one side.

Figure 9 shows another view of the hub interior after removal of the shell, revealing two fractured rivets, which readily fell out when upended, and a stop, located in the same position as the tear on the impulse shell. Figure 10 shows the underlying impulse hub plate without the rivet remnants. The holes exhibited elongation and deformation about the edges. Figure 11 shows this end of the magneto after removal of the impulse coupling hub plate.

Figure 12 and Figure 13 show the rivet remnants in their condition after removal from the magneto. Like the other steel parts in this part of the assembly, the rivet remnants were heavily oxidized, and almost all the underlying features were obscured. The various dimensions of the rivet remnants were measured, as annotated in Figure 12 and Figure 13, and compiled in Table I.

The rivet remnants were sequentially cleaned in an ultrasonic bath with acetone, followed by an aqueous solution of Alconox and an aqueous solution with an Evapo-Rust chelating agent.^{1,2} This process removed enough surface contamination to examine the fracture surface features.

Figure 14 shows 180° views of the side of the downward-facing rivet remnant. This rivet exhibited a decrease in diameter near the fracture surface, consistent with necking deformation, and an area of outward protrusion on the fracture edge, shown in Figure 14b. There were also two parallel impact marks on the shaft, and an upward deflection of the head in the upper part of Figure 14a.

Figure 15 shows the fracture surface of the downward-facing rivet, after cleaning. While much of the surface was still visually obscured by surface oxidation, enough underlying fracture features could be observed. Overall, the surface exhibited a rough texture with a dull, matted luster. Closer examination of the surface using a field emission scanning electron microscope (SEM) showed dimpled rupture features, consistent with overstress (Figure 16). While there were also pock-marked features on the surface (an artifact of the cleaning process), the actual dimple features were locally parallel in direction, as illustrated in Figure 17. The patterns of the slanted dimpled rupture show a curving upward direction on part of the fracture, as shown in Figure 16. These features were consistent with loading in torsion and shear.

Figure 18 and Figure 19 show the upward-facing rivet remnant after cleaning. This fracture surface exhibited a flat, tan-colored, half-moon-shaped area, surrounded by areas of lighter, more reflective metallic color. On the upper and lower edges shown in Figure 18a and Figure 19, these areas exhibited erratically oriented lines and material loss, consistent with wear.

¹Alconox is a powdered cleaning detergent, containing primarily sodium bicarbonate and sodium alkylbenzene sulfonate, manufactured by Alconox, Inc., White Plains, NY.

² Evapo-Rust is a commercially available chelating rust stripper currently manufactured by CRC Industries, headquartered in Horsham Township, PA.

A closer view of the upper edge in Figure 19 showed areas with linear marks perpendicular to the edge, consistent with ratchet marks. Figure 20 shows this edge as viewed using a SEM, with Figure 21 depicting a closer view of two of these ratchet marks, created when propagating cracks coalesce, indicative of multiple crack initiation sites. A closer view of the fracture features in this area, illustrated in Figure 22, revealed the remainder of parallel striations, consistent with fatigue crack propagation. Further away from the edge of the fracture surface, the fracture features transitioned to dimpled rupture, as shown in Figure 23.

Energy dispersive x-ray spectroscopy (EDS) examination of the cleaned areas of the rivet remnants found their chemical compositions consistent with plain carbon steel. These features were consistent with fatigue cracking initiating at areas of wear on the outer surface of the upward-facing rivet shaft. This rivet was located away from the stop pin. Once the cracking had propagated deep enough, this rivet fractured completely. The opposite rivet fractured from torsional and shear overstress. The impulse shell impacted the stop with enough force to create impact marks and partially tear the flange of the shell in this area.

Submitted by:

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Materials Research Engineer

F. TABLES

Table I. Measurements of rivet remnants in the as-received condition.

Rivet remnant	Head diameter, min (in)	Head diameter, max (in)	Shaft diameter, min (in)	Shaft diameter, max (in)	Remnant length, min (in)	Remnant length, max (in)
Upward	0.288	0.307	0.206	0.217	0.240	0.247
Downward	0.274	0.288	0.165	0.214	0.252	0.271

G. FIGURES

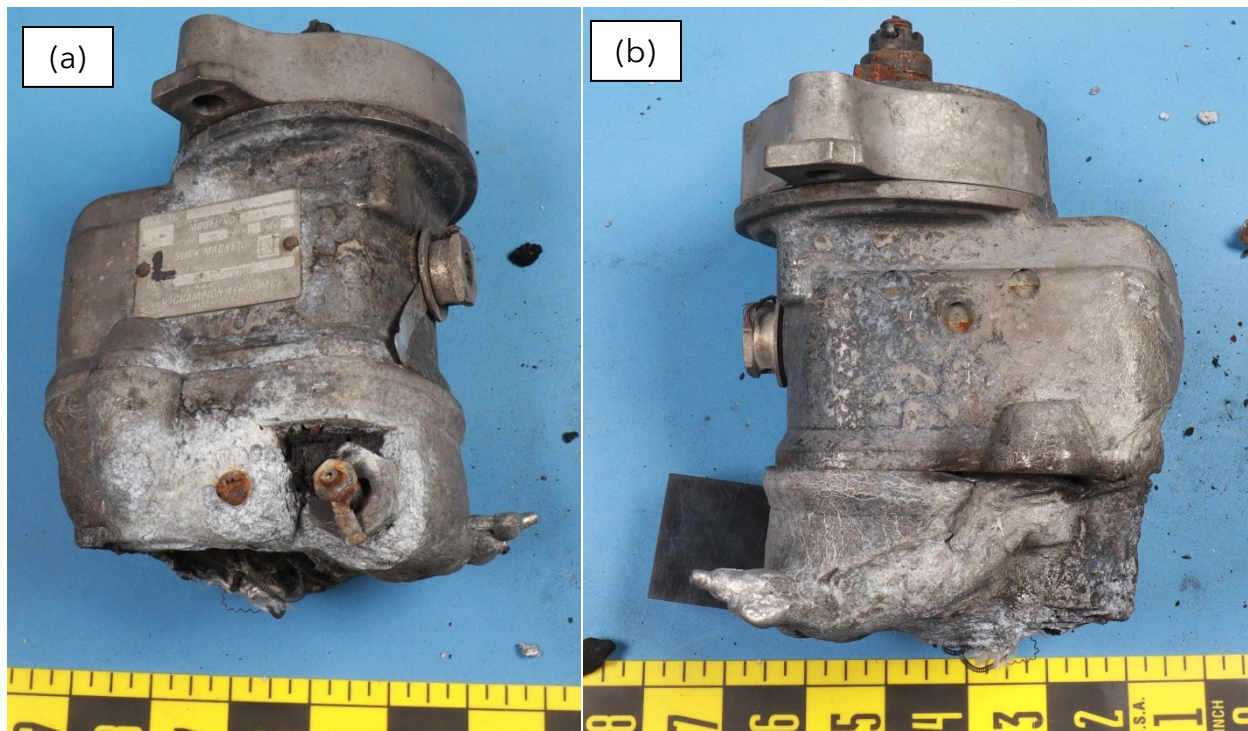


Figure 1. Opposite views of the sides of the magneto assembly.



Figure 2. Opposite view of the sides 90° from those in Figure 1.



Figure 3. View of the missing area of the magneto housing, consistent with heat damage.



Figure 4. View of the opened end of the magneto with the impulse hub assembly, showing the cracked impulse coupling shell.



Figure 5. View of the underside of the impulse shell with coiled spring, the hub, and nut after disassembly.



Figure 6. View of the wear mark on the stop boss protruding from the impulse shell skirt.

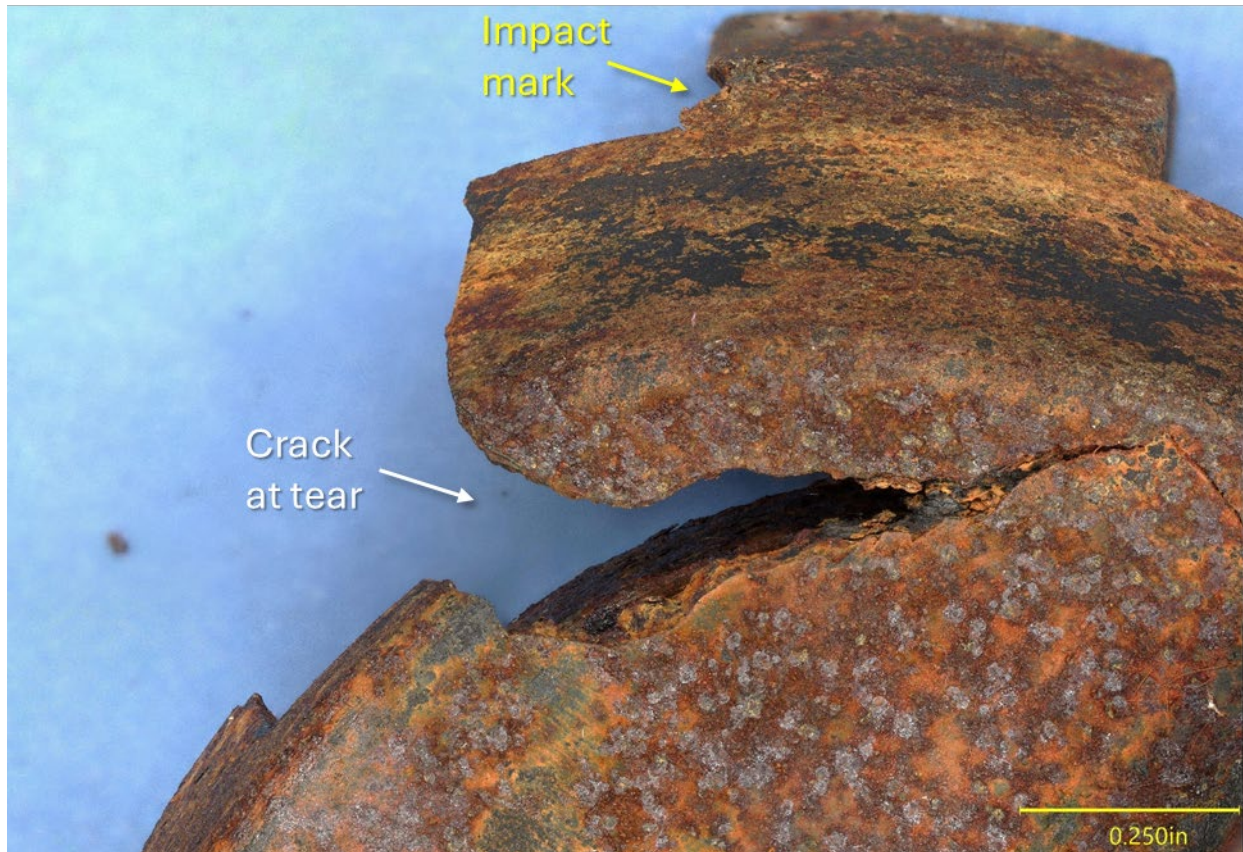


Figure 7. View of the surface opposite that in Figure 6, showing the tear and outward deformation of the skirt from the main body of the impulse shell.



Figure 8. Closer view of the stop pin after impulse shell removal (and after rivets shown in Figure 9 had fallen out).

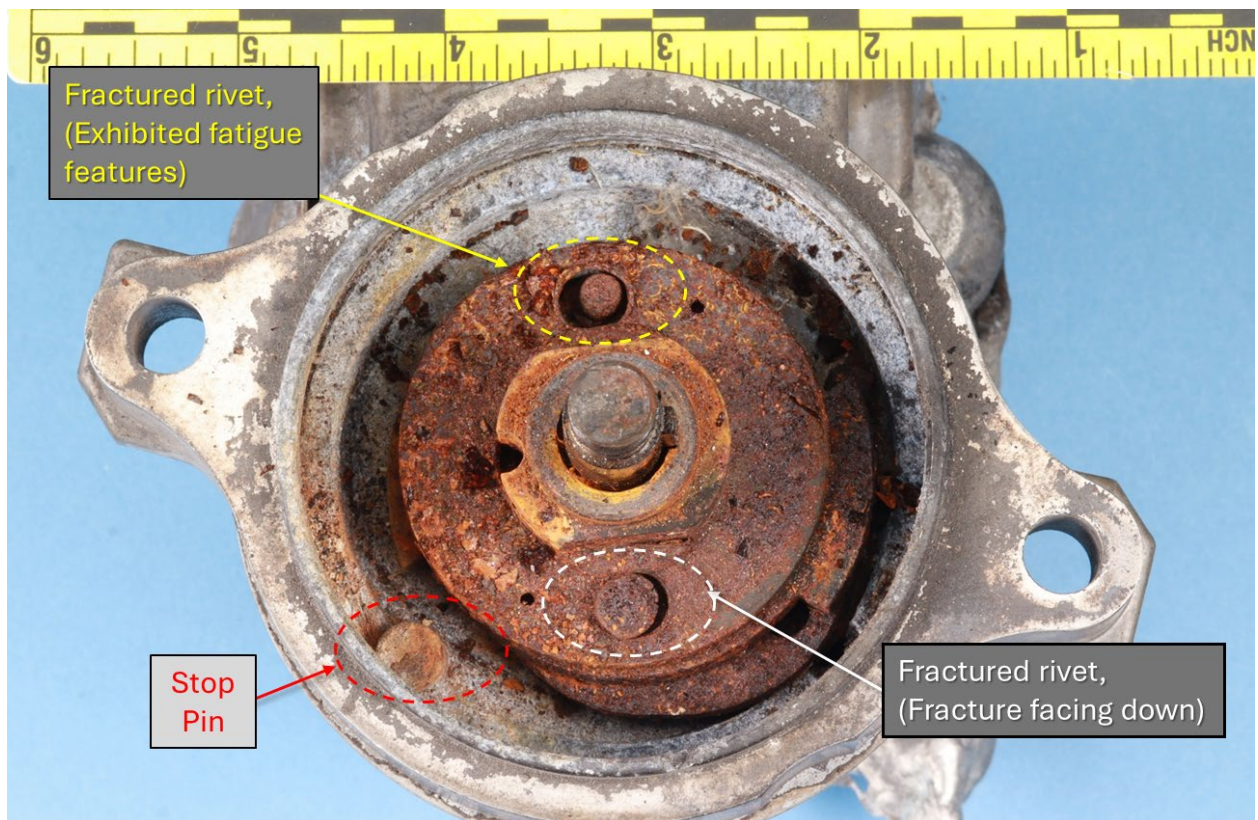


Figure 9. View of the underlying impulse hub assembly, after removal of the shell, nut, and washer.



Figure 10. View of the impulse hub from Figure 9, after rivet removal, showing the widened rivet holes with deformation indications.



Figure 11. View of the underlying pawls under the key, after removal of the hub.



Figure 12. The upward-facing rivet (located on the top of Figure 9) from (a) the fracture surface and (b) the side, as disassembled.

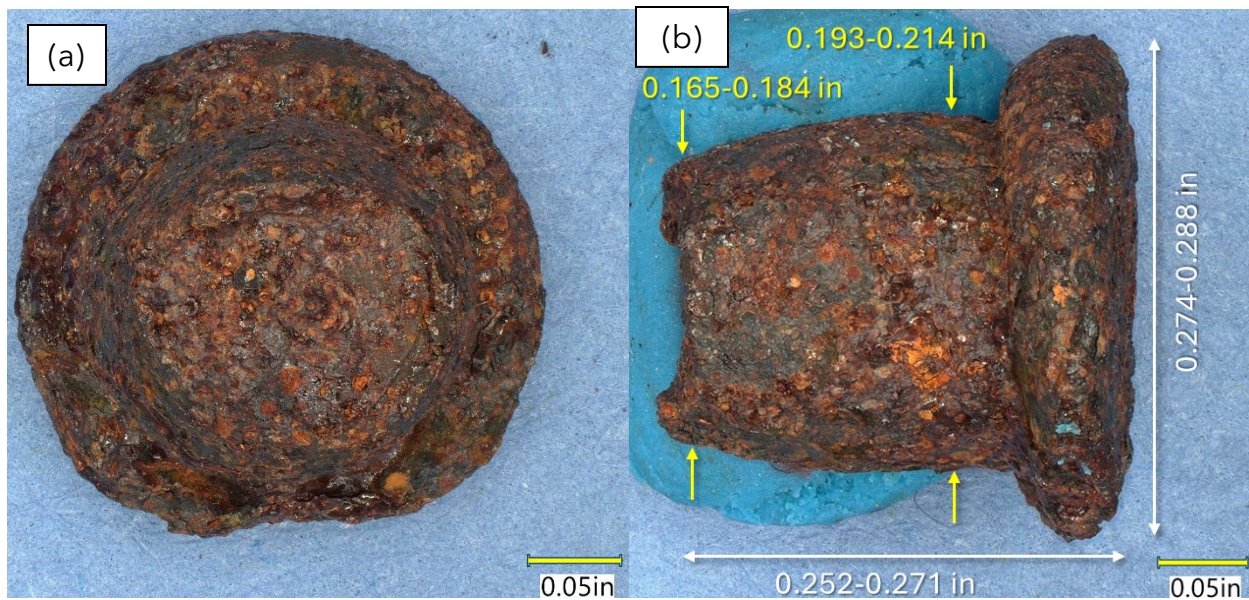


Figure 13. The downward-facing rivet (located on the bottom of Figure 9) from (a) the fracture surface and (b) the side, as disassembled.



Figure 14. Side views of the downward-facing rivet, after removal of most of the surface rust.



Figure 15. View of the fracture surface of the downward-facing rivet, after removal of most of the surface contamination.

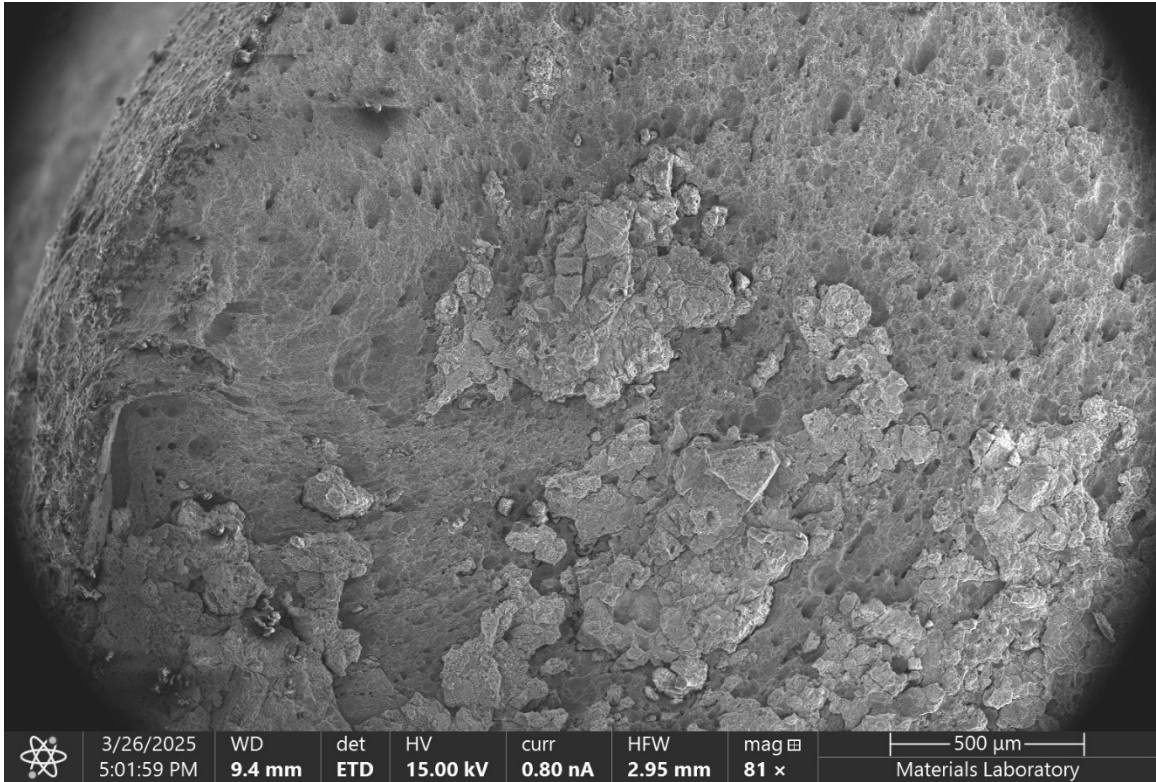


Figure 16. Secondary electron (SE) micrograph of a portion of the fracture surface in Figure 15, showing slanted dimpled rupture in different directions.

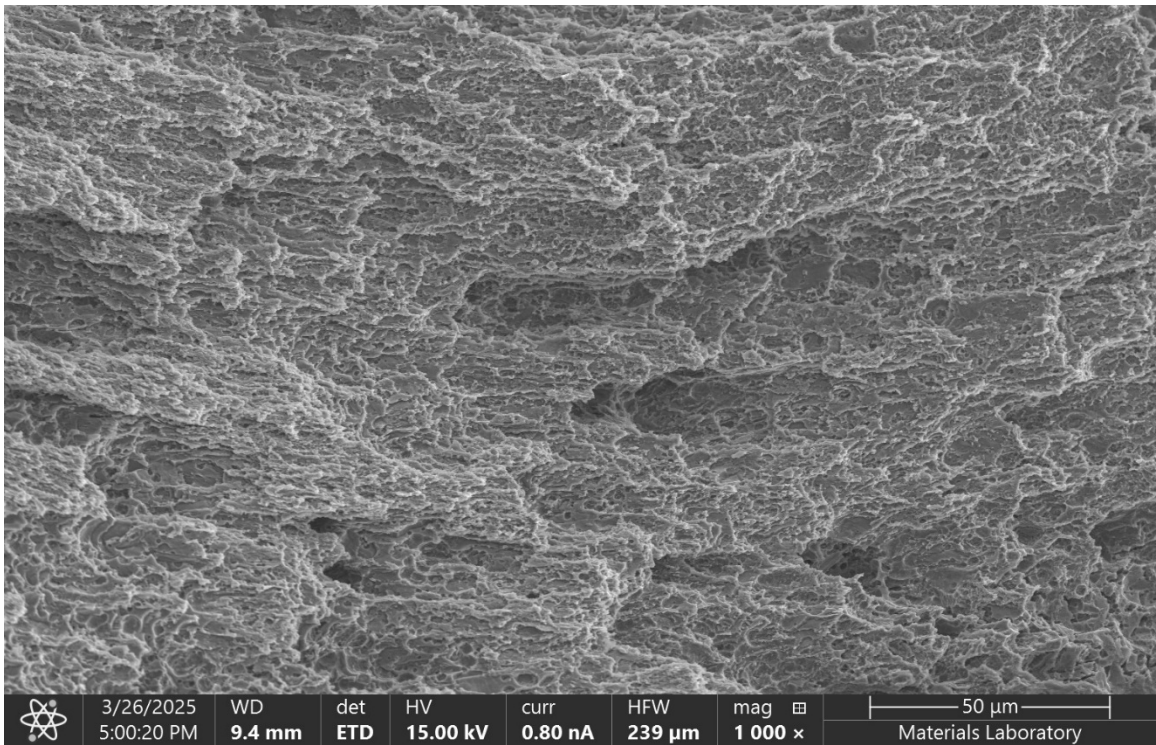


Figure 17. SE micrograph of slanted dimpled rupture in Figure 16.



Figure 18. Fracture surface and side views of the upward-facing rivet, after removal of much of the surface contamination.



Figure 19. Closer view of the upward-facing rivet fracture surface, showing areas of wear and a flat, discolored portion of the fracture surface.

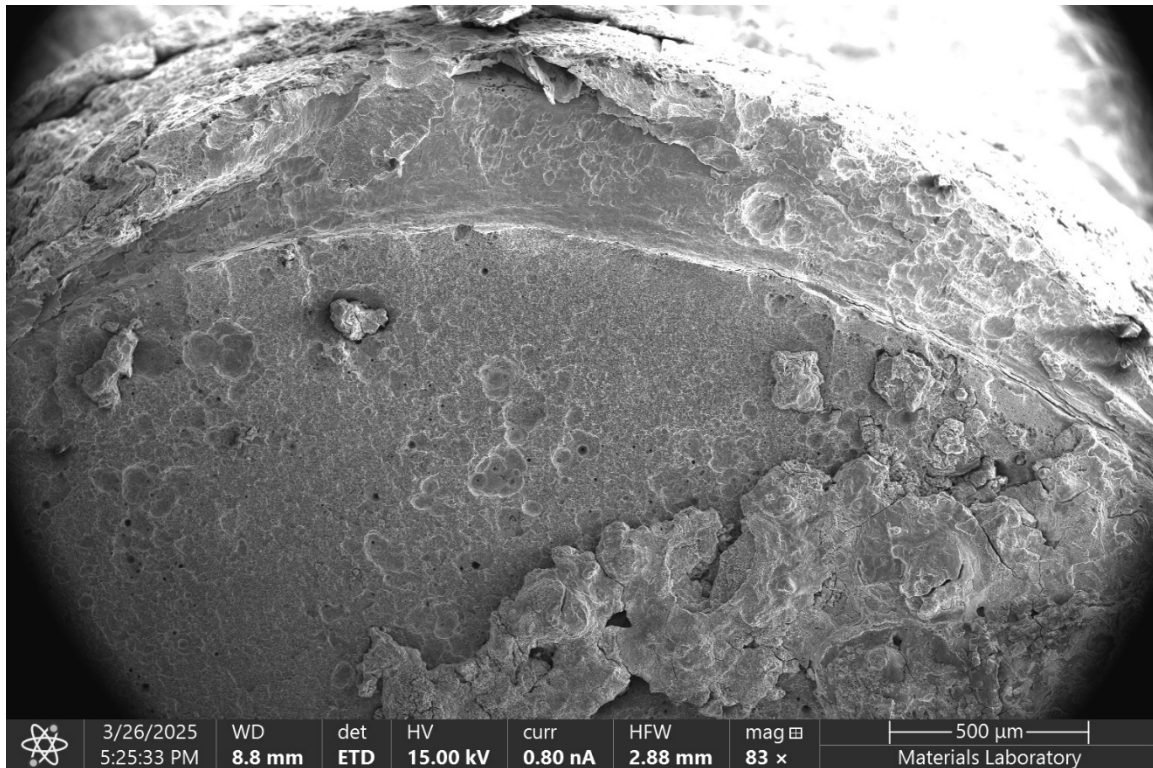


Figure 20. SE micrograph of the upper edge of the fracture surface in Figure 19.

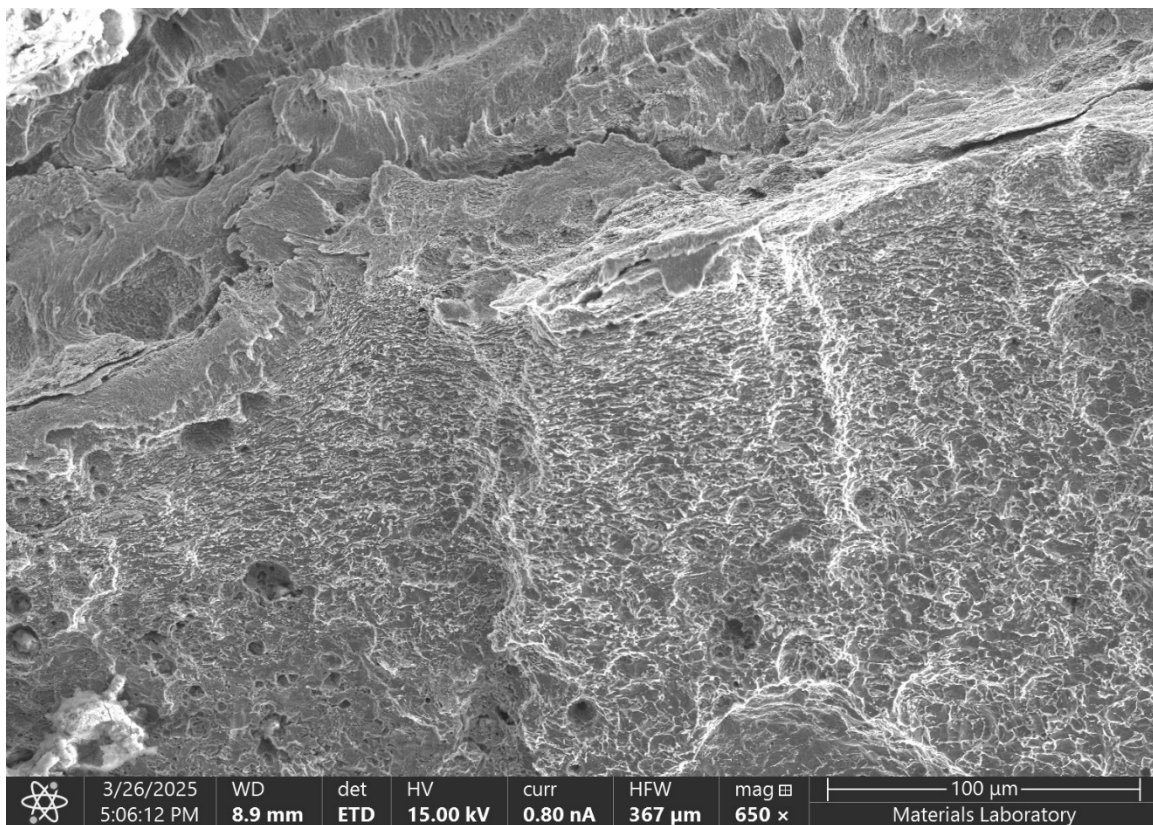


Figure 21. SE micrograph of a closer area of the ratchet mark features in Figure 20.

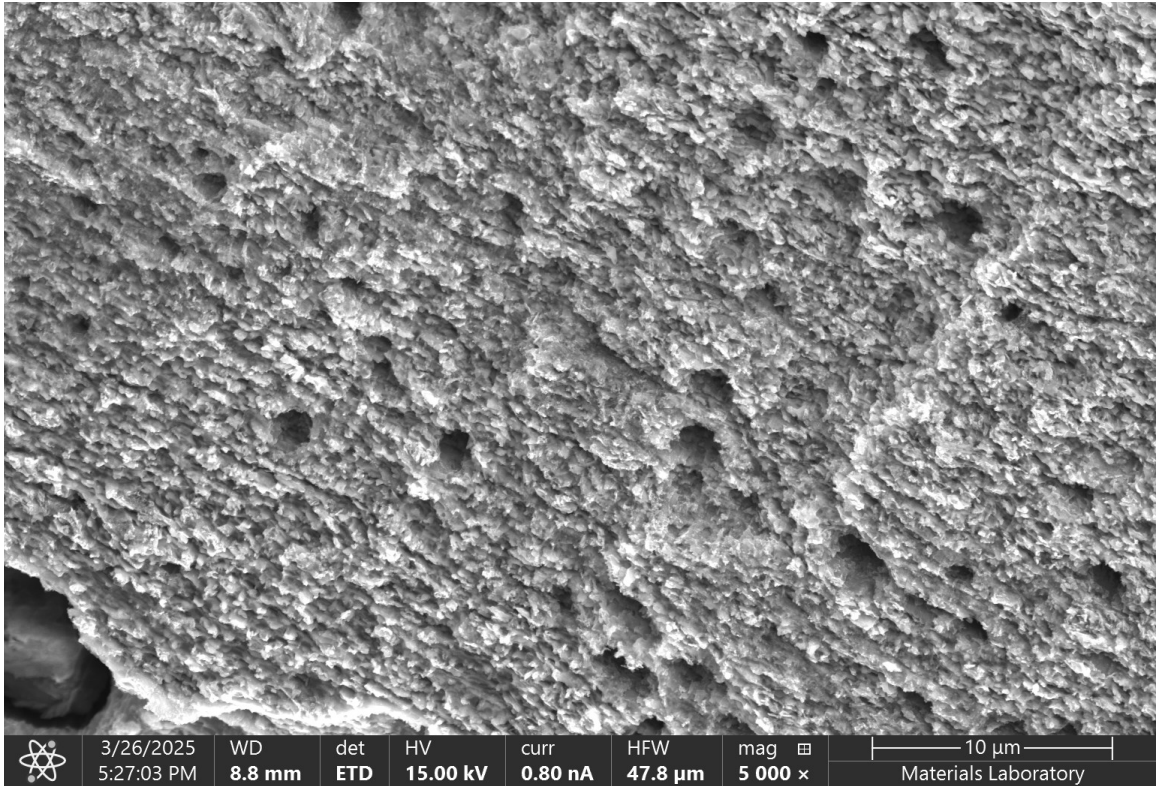


Figure 22. SE micrograph of striation remnants near the fracture surface edge of the upward-facing rivet.

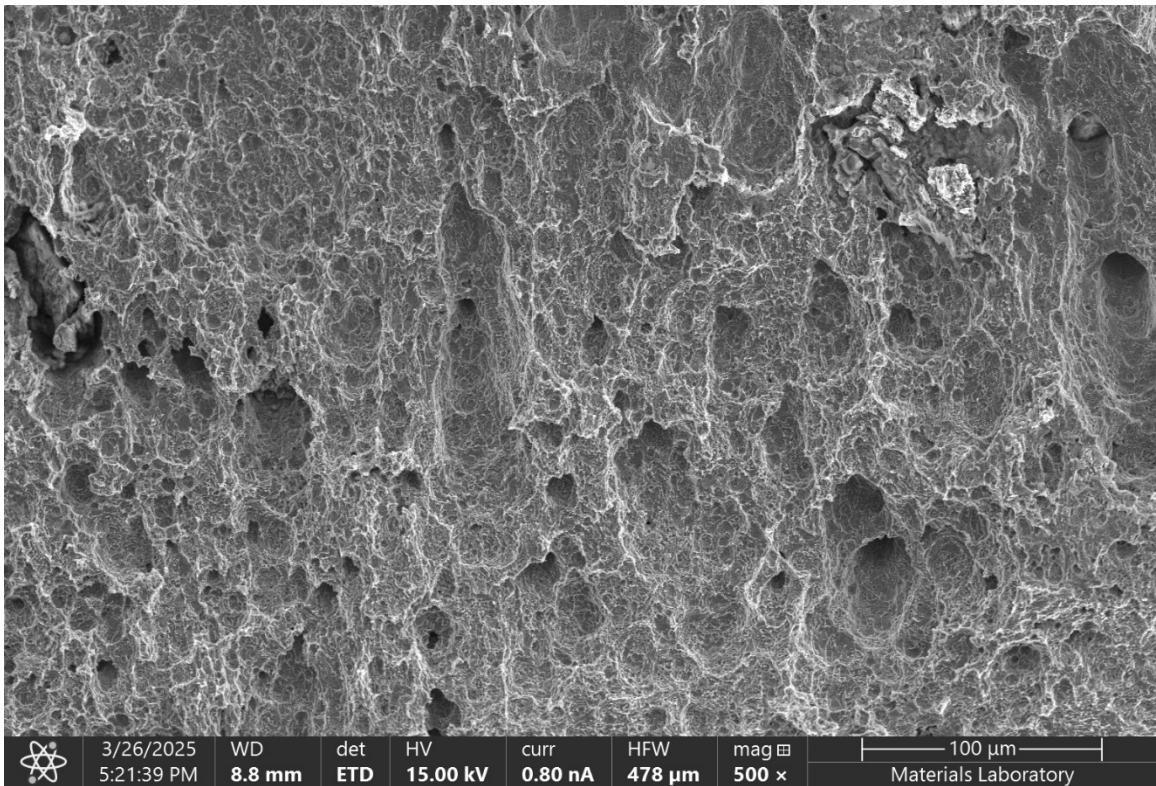


Figure 23. SE micrograph of dimpled rupture on the fracture surface away from the edge.