

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR22LA221

MATERIALS LABORATORY

Factual Report 23-052

July 18, 2023

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A. ACCIDENT INFORMATION

Location: Stockton, California
Date: June 17, 2022
Time: 06:00 central daylight time
13:00 coordinated universal time
Vehicle: Bell 206B, N90326
Investigator: Fabian Salazar, AS-WPR

B. COMPONENTS EXAMINED

Remnants of tail rotor blades
Exemplar tail rotor blades
Tail rotor gearbox

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 17, 2022, a Bell 206B helicopter was substantially damaged when it was involved in an accident near Stockton, CA. The pilot was not injured. According to the pilot, he felt a vibration during flight followed by a bang, after which the helicopter yawed to the right. The pilot attempted to land the aircraft, eventually entering an autorotation. While the helicopter landed flat, it continued to spin and rolled onto its left side, coming to rest after contacting a tree in an orchard. All major components, except one tail rotor blade, had remained attached to the helicopter. The pilot recovered the separated tail rotor blade about 2000 feet from the main wreckage. The helicopter was relocated to a secure facility for further examination.

Figure 1 shows the 90° tail rotor gearbox assembly as received. Figure 2 shows the opposite outboard side. The markings on the housing on the plate in Figure 2 stated, "206-040-400 XX 009, ALO-52321, BELL HELICOPTERS, D13." The embossed marking on the side of the housing was similar, stating, "206-040-426, A1312678, 1R71." Several of the seals from the gearbox were leaking oil, primarily from the rubber boot along the shaft connected to the crosshead assembly.

As shown on the rotated side in Figure 3, the control rod on the pitch change lever (left in the figure) had fractured. Figure 4 shows a closer view of the fractured pitch change control rod from the side and from the fracture surface. The rod was approximately 2.212 inches long when assembled (see Figure 5a). When

disassembled, the fractured rod end measured 1.003 inches long from the fracture surface to the opposite end face of the threaded shaft portion (Figure 5b).

The fractured rod was removed and cleaned in an ultrasonic bath of acetone. The fracture surface is illustrated in Figure 6. This surface exhibited a rough, fibrous texture with a dull luster. The surface showed areas of higher and lower elevation with an area of reflective material on the surrounding nut on the upper left. On the opposite side of the rod, the part had deformed upward and inward. These features were consistent with overstress fracture from bending, with the bending direction being from the lower left to the upper right in Figure 6.

Figure 7 shows the tail rotor gearbox housing in the inboard face, which had attached to the tail boom via four bolts. All these bolts had fractured, as illustrated in the figure. These bolt fractures and the surrounding housing of the gearbox are shown in more detail at higher magnifications in Figure 8 through Figure 19.

Figure 8 through Figure 10 show the fractured bolt in the upper left of Figure 7, corresponding to the forward location. Unlike the other fractured bolts, this location also exhibited a battered and deformed gouge of the inboard housing face, shown in Figure 9. This location corresponded to a depression and outward material deformation of the fracture bolt, illustrated on the fracture surface in Figure 10.

The opposite end exhibited upward and inward deformation of the bolt. The fracture surface showed a rough, fibrous texture and dull luster, consistent with overstress fracture in bending. The features were consistent with bending from the lower right in the figures towards the upper left, in line with the housing deformation and batter. This fracture pattern was consistent with movement in the upward and forward direction of the helicopter.

Figure 11 through Figure 13 show closer views of the upper right bolt in Figure 7. This fracture exhibited similar overstress features, such as a rough texture and dull luster. The lower portion of the bolt in the figures exhibited pullout, while the upper areas exhibited outward deformation and battered in the adjacent housing of the gearbox face. These features were consistent with upward bending (as oriented in the figures), corresponding to the upward bending of this gearbox portion relative to the tail boom.

Figure 14 through Figure 16 show the fractured bolt from the lower right in Figure 7. This fracture surface, exhibiting a dull and fibrous appearance, exhibited a sloped transition with two outward protrusions located 180° from each other. The fracture displayed flow lines which could be traced from the left in Figure 16 around and down to the lower right. Similarly, the fractured bolt in the lower left position exhibited similar features with a comparable but inverted morphology (see Figure 17

through Figure 19). These features were consistent with overstress fracture of lower two bolts in torsion.

Examination of the blade grips and hub from the gearbox assembly did not reveal any witness marks or indications of pre-existing damage. As shown in Figure 20, one of the links was still attached to the crosshead. The opposite side was absent its link, and the holes of the fork from that link position are shown in Figure 21. The holes exhibited some elongation, being as narrow as 0.2455 inches in one direction and as long as 0.2490 in the direction perpendicular. However, there were no other indications of damage, such as gouging, cracking, or plastic deformation.

The other link was received separately, as shown in Figure 22. This figure also displays the other bolts, nuts, spacers, and washers submitted, which had been separated before receipt. There were no indications of deformation, cracking, or fracture. The exceptions were the three shims from the gearbox, submitted separately and shown in Figure 23. These parts exhibited impact marks, batter, and bending plastic deformation.

Figure 24 shows the bolt holes where bolts attached the tail rotor blades to the yoke of the gearbox assembly. The bearings were intact and did not show indications of cracking or deformation. There were no indications of battered or deformation of the adjacent yoke material, and the holes still exhibited light-colored grease or lubricant at the bore when received.

Figure 25 shows the exemplar tail rotor blades, as received. The markings on the blades stated, "FAA-PMA, VAN HORN AVIATION L.L.C., PART NO. 206220-301." The serial numbers for these blades were 'B209' and 'B213.' These blades were intact and had been marked with pen, as shown in Figure 25a, from the outboard side. These areas were not labeled as to the nature of the hashed markings, but a rudimentary tap test of the blades did demonstrate a change in audible sound along the marked regions from the rest of the blades. Affixed to each of the blades was a red tag stating, "Blade damaged beyond repair. Blade is condemned."

Figure 26 shows one of the accident's two damaged tail rotor blades. This blade was still intact, although it had partially separated along the centerline (see Figure 26b), exhibiting a loss of outboard skin, shown near the black stripe in Figure 26a. The serial number of this blade was 'C548,' whereas the rest of the text on the outboard plate was identical to those of the intact blades in Figure 25a.

The fracture on blade C548 exhibited a zig-zag pattern, oriented 45° in some locations and parallel with the blade direction in others. These orientations were consistent with fracture along the fiber direction of the composite, across different plies, which were oriented in different directions. The location of the parallel portion

of the fracture was consistent with the area of the foam between the plies and the unidirectional strap in the trailing edge of the rotor blade.

Figure 27 shows a view of the cracked tail rotor blade from the trailing edge. This view shows the character of the tearing, with separation between the fiber composite layup on the interior side from the central base core of the blade. Figure 28 reveals a closer view of the opposite side of the separation, showing a lack of composite material consistent with localized separation of the core adjacent to the composite skin. The fiber composite also exhibited irregular and erratic fracture patterns, consistent with overstress fracture across multiple plies (translaminar).

The other accident blade is displayed in Figure 29 and Figure 30 from opposite sides. Although the identification plate was missing, the serial number stated in the maintenance records was 'C549.' This blade had wholly fractured and exhibited three major remnants. The blade fractured along the rhomboid-shaped root of the blade, with the outboard portion cracking along the interior foam core.

Like with the other tail rotor blade, fracture directions were consistent with the fiber direction of the ply when located along the composite layup of the blade. Unlike the other tail rotor blade displayed in Figure 26, this blade was absent the tip, with the outboard 2.5 to 5 inches of material missing.

Some of the interior components were visible from the other tail rotor blade from the accident, displayed in Figure 30. Of note on the interior was the lack of foam adhesion to the maroon-colored interior surface of the blade skin. There was some of the white interior foam adherent on the surface (see Figure 30a and Figure 31).

Figure 30 also the location of the unidirectional strap at the trailing edge. The mating sides show a rough strap area with fiber pullout. In addition, there were areas absent any adherent strap material, revealing the maroon interior of the blade skin. The mating blade skin from this area was not received with the rest of the blade fragments and could not be evaluated in this examination.

Figure 31 shows a closer view of the strap at the trailing edge. The surface was generally smooth, with little fiber pullout. The surrounding foam had fractured erratically, consistent with mixed adhesive and cohesive fracture. These features were consistent with the trailing edge section of the blade peeling open at fracture, along both the strap and its joint with the blade skin.

Further inward (toward the leading edge and core), the foam on both sides of the blade interior was consistent with a cohesive fracture of the material (Figure 32). The adjacent composite layup showed a fracture in random directions, with fibers being pulled out and ply splitting in +45, -45, and 90° orientations. These features were

consistent with a translaminar fracture of the composite (as opposed to an interlaminar delamination fracture).

Similar patterns were observed on the fiber composite remnant that was still affixed to the blade base, as shown in Figure 33 from opposite sides. The plies nearest the base were still attached, indicating cohesive fracture in the fiber composite layup. As shown in Figure 33 and Figure 34, the fiber orientations along the fracture were in multiple directions, consistent with a translaminar fracture.

These features were again present, as shown in Figure 35, which shows the area near the outboard bearing of the fractured blade, both with and without the smaller trailing edge remnant laid in its pre-fracture position. This configuration illustrates the colocation of fractures along different ply paths, consistent with emanating from edge areas of the composite—in this case, adjacent to the bearing hole of the blade base.

Submitted by:

Erik M. Mueller
Materials Research Engineer

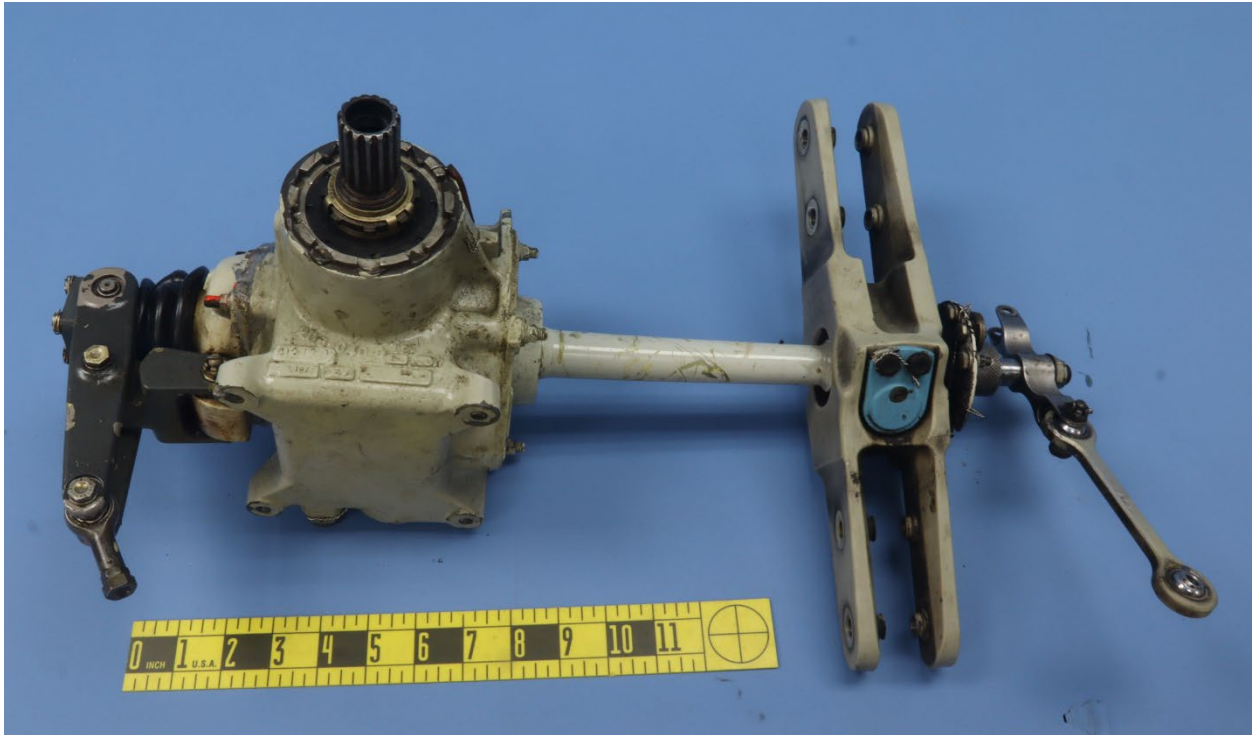


Figure 1. The 90° tail rotor gearbox assembly, from the drive shaft side.



Figure 2. The reverse view of the outboard (housing) side of the tail rotor gearbox.

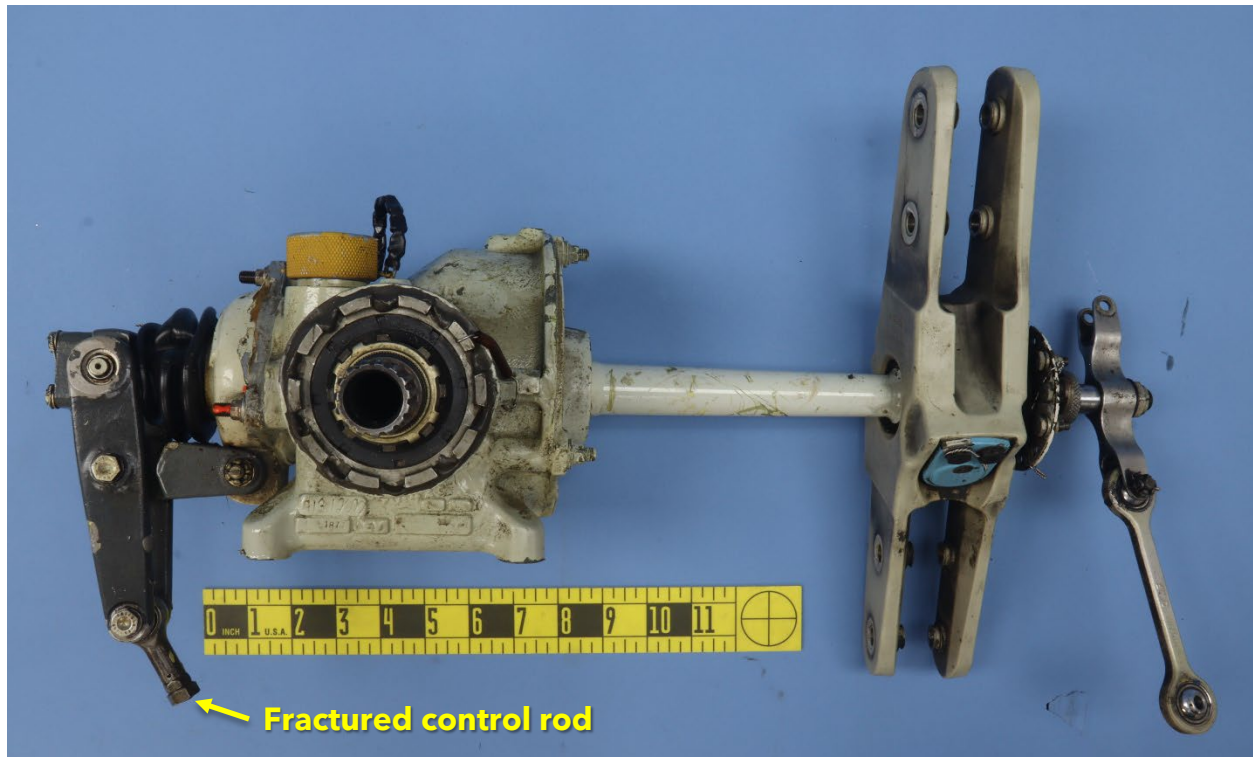


Figure 3. View of the gearbox showing the fractured pitch change control rod in the lower left.

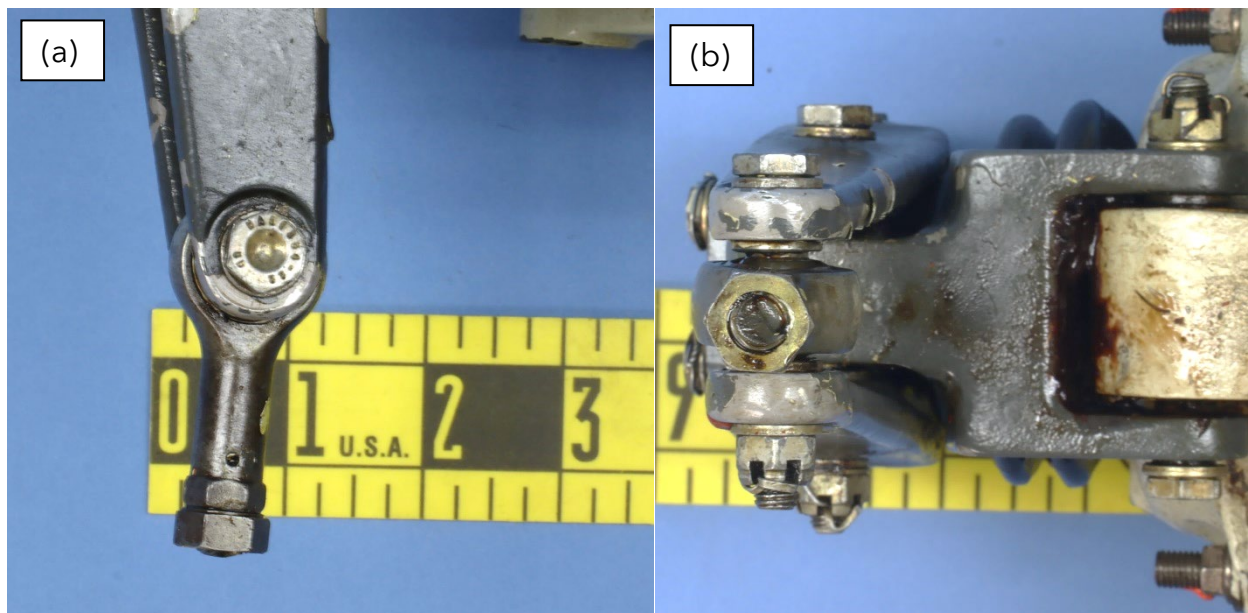


Figure 4. View of the fractured pitch change control rod from (a) the side and (b) the fracture surface.

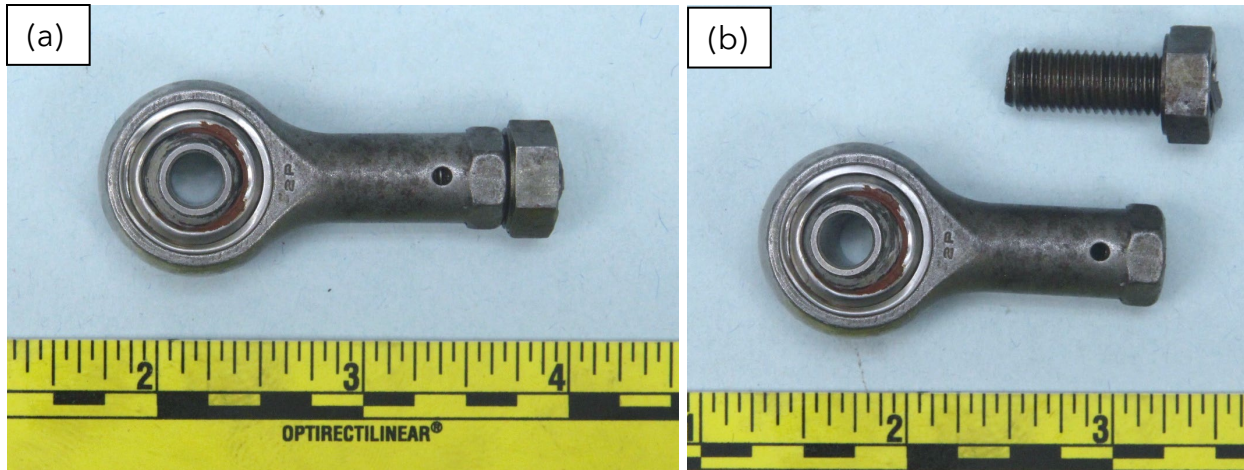


Figure 5. Views of the control rod (a) as assembled and (b) disassembled.

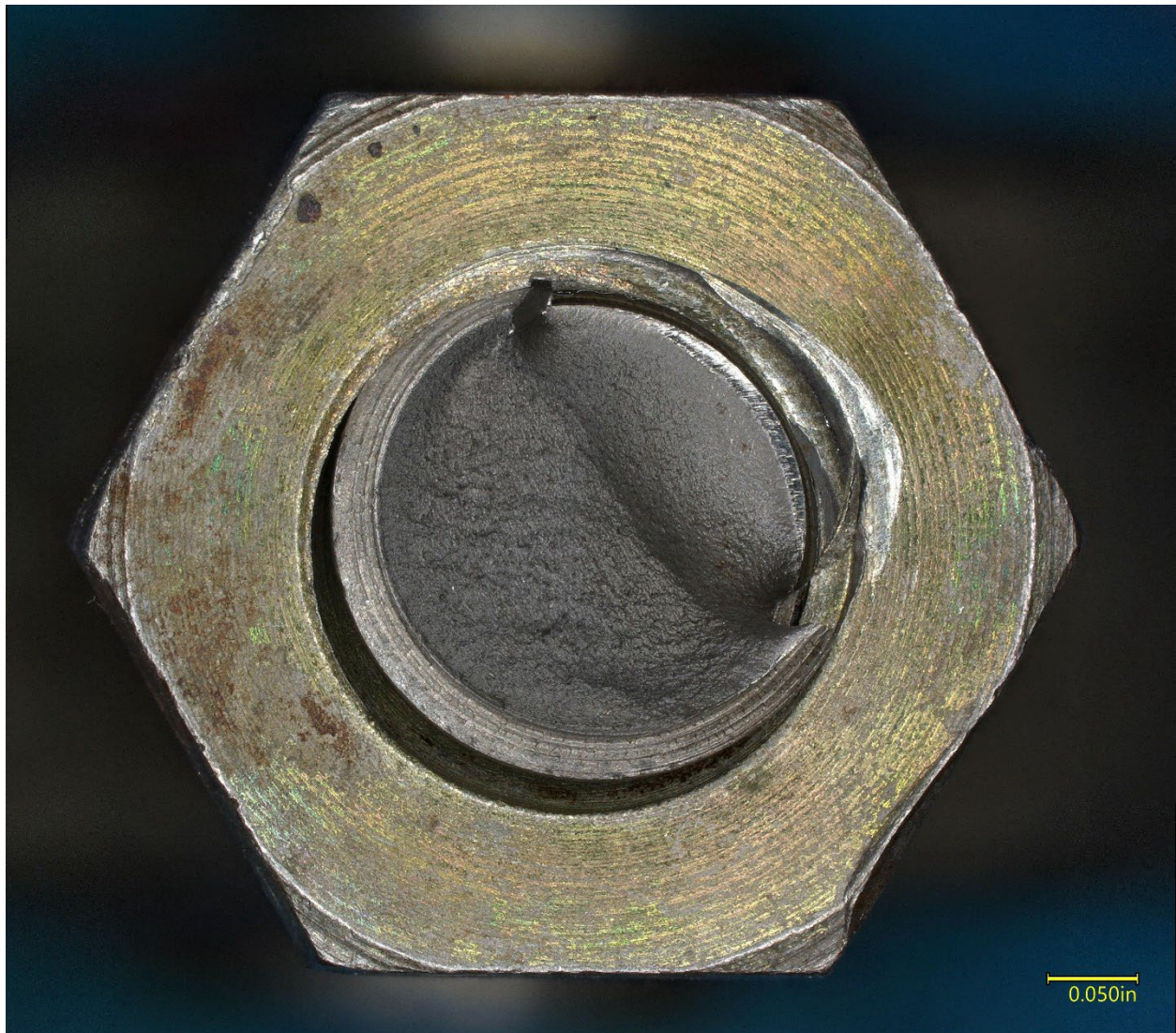


Figure 6. Closer view of the rod fracture surface, after cleaning.



Figure 7. The interior side of the gearbox housing, showing the four fractured attachment bolts to the tailboom.

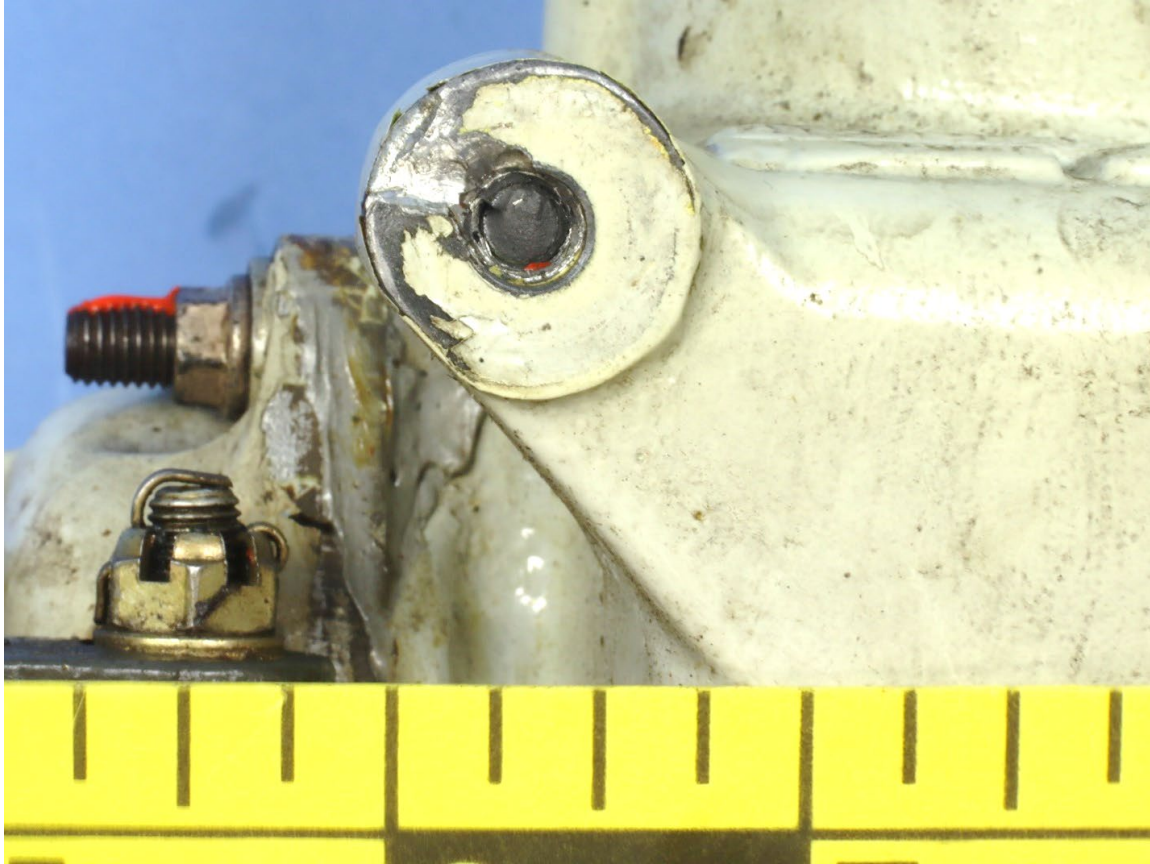


Figure 8. View of the fractured bolt from the forward right (upper left in **Figure 7**).



Figure 9. Closer view of the fractured bolt and surrounding housing.

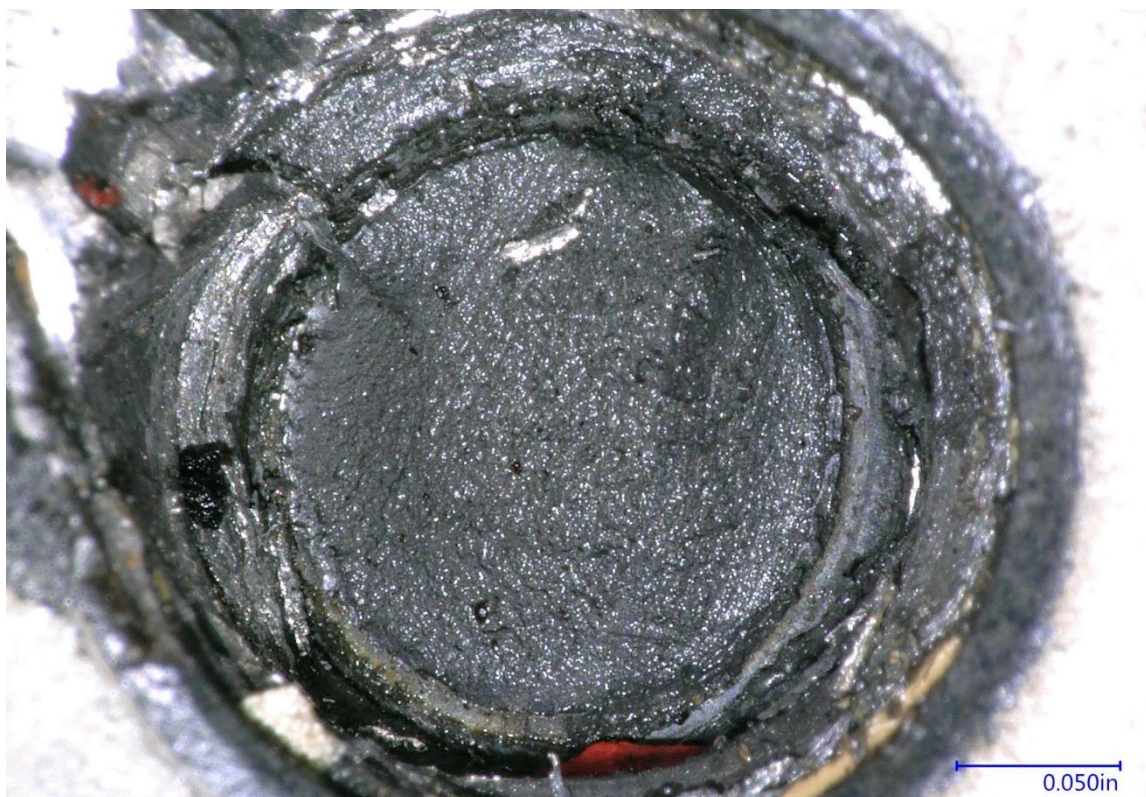


Figure 10. The fracture surface of the bolt remnant in **Figure 9**, as received.

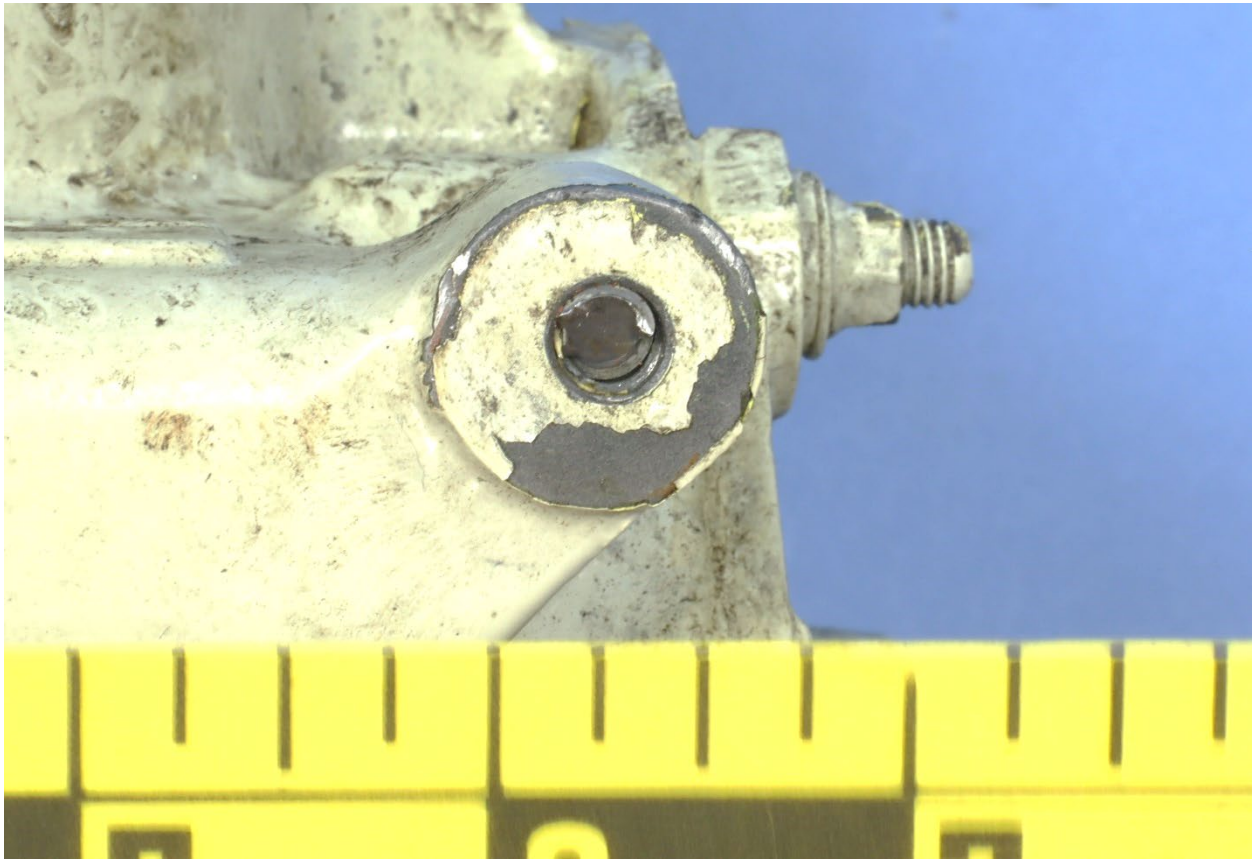


Figure 11. View of the fractured bolt from the forward left position (upper right in **Figure 7**).



Figure 12. Closer view of the fractured bolt and surrounding housing.



Figure 13. The fracture surface of the bolt remnant in **Figure 12**, as received.



Figure 14. View of the fractured bolt from the aft left (lower right in **Figure 7**).



Figure 15. Closer view of the fractured bolt and surrounding housing.



Figure 16. The fracture surface of the bolt remnant in **Figure 15**, as received.

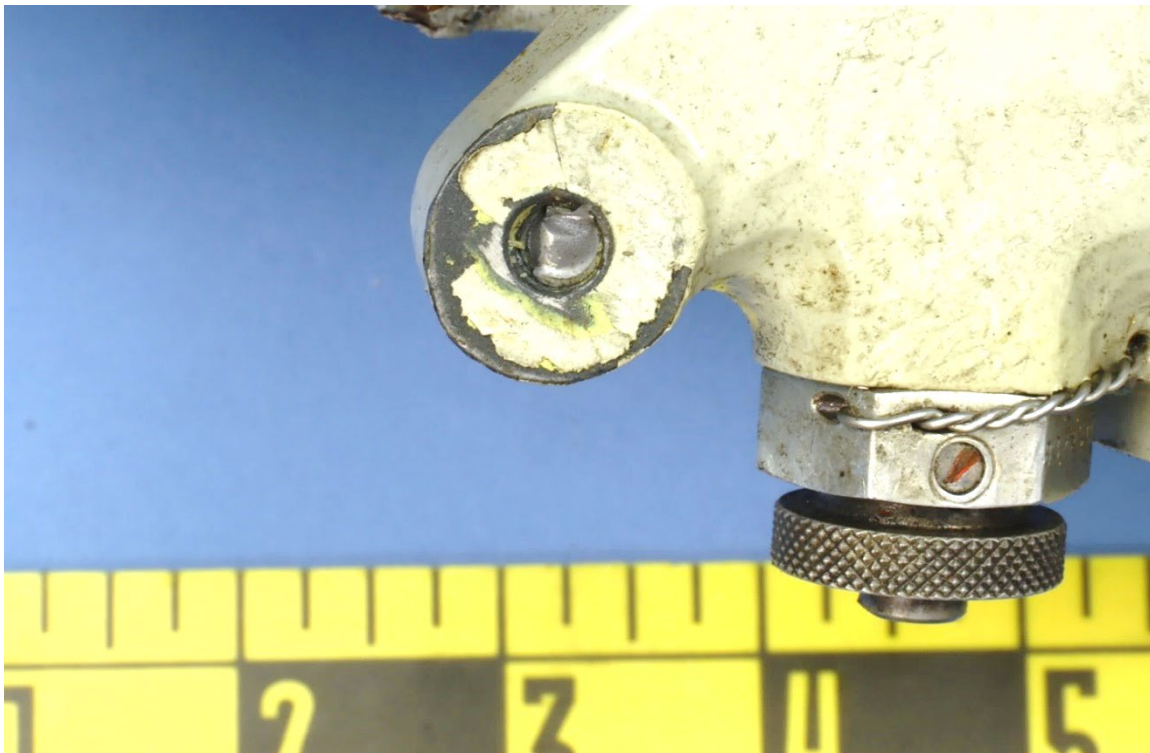


Figure 17. View of the fractured bolt from the aft right (lower left in **Figure 7**).



Figure 18. Closer view of the fractured bolt and surrounding housing.



Figure 19. The fracture surface of the bolt remnant in **Figure 18**, as received.

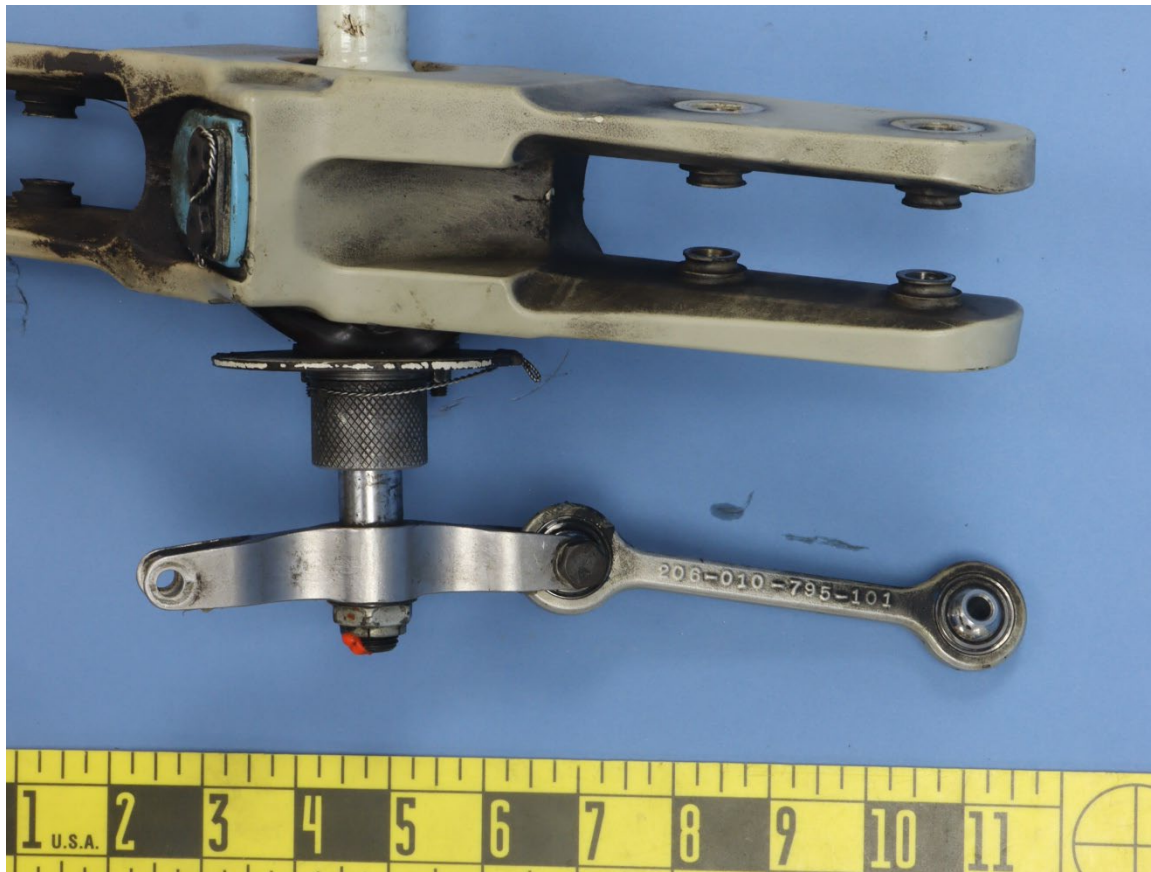


Figure 20. View of the blade grip portion of the gearbox assembly, showing the crosshead with the still affixed link.

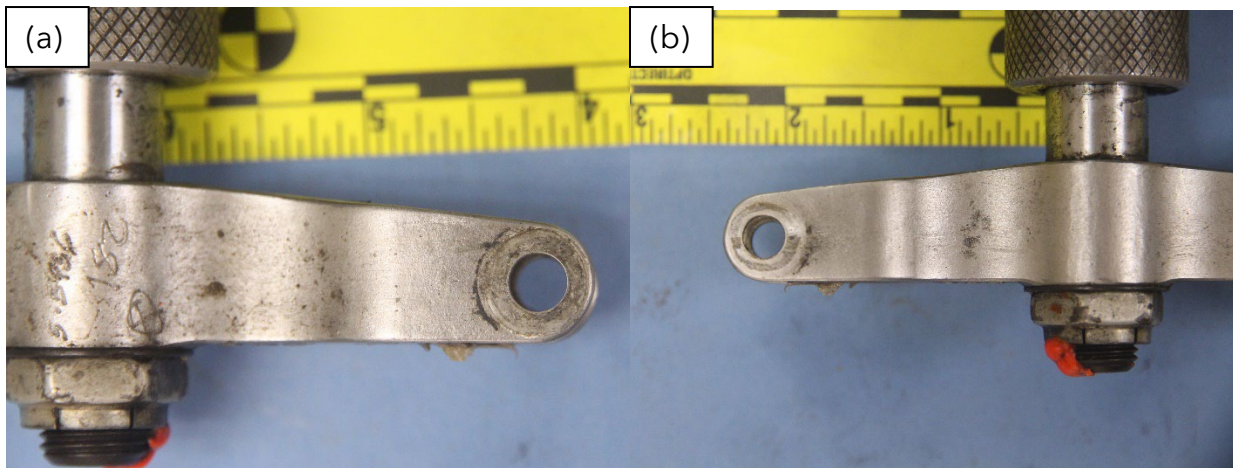


Figure 21. The bolt holes from the crosshead where the one of the links had been removed, viewed from opposite sides.



Figure 22. View of the bolts, nuts, washers, spacers, and link detached from the gearbox assembly.

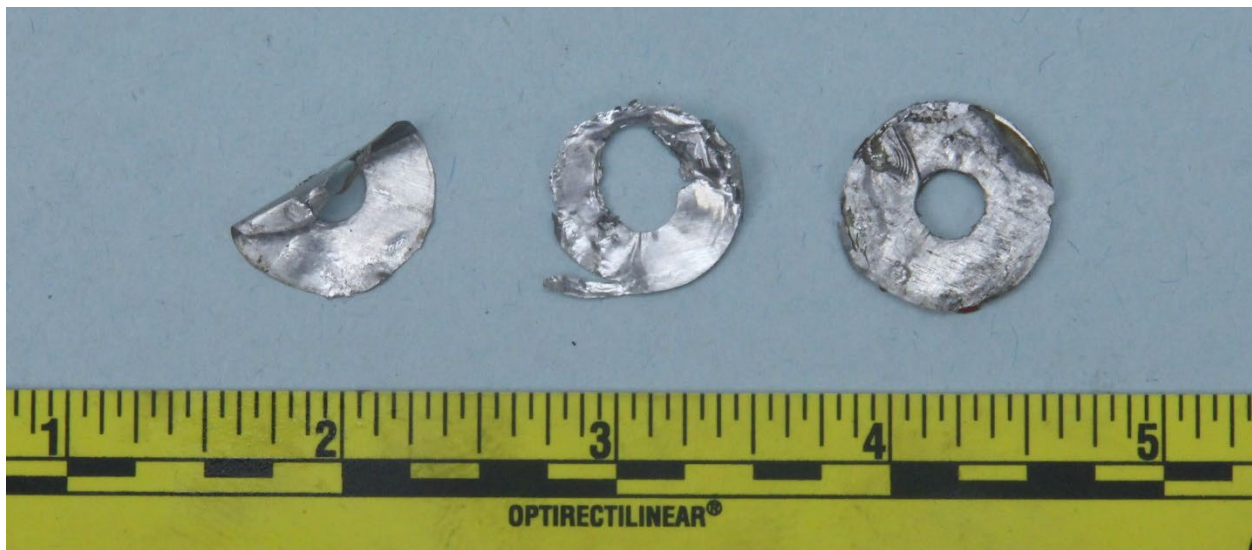


Figure 23. The damaged shims from the gearbox assembly, as received.

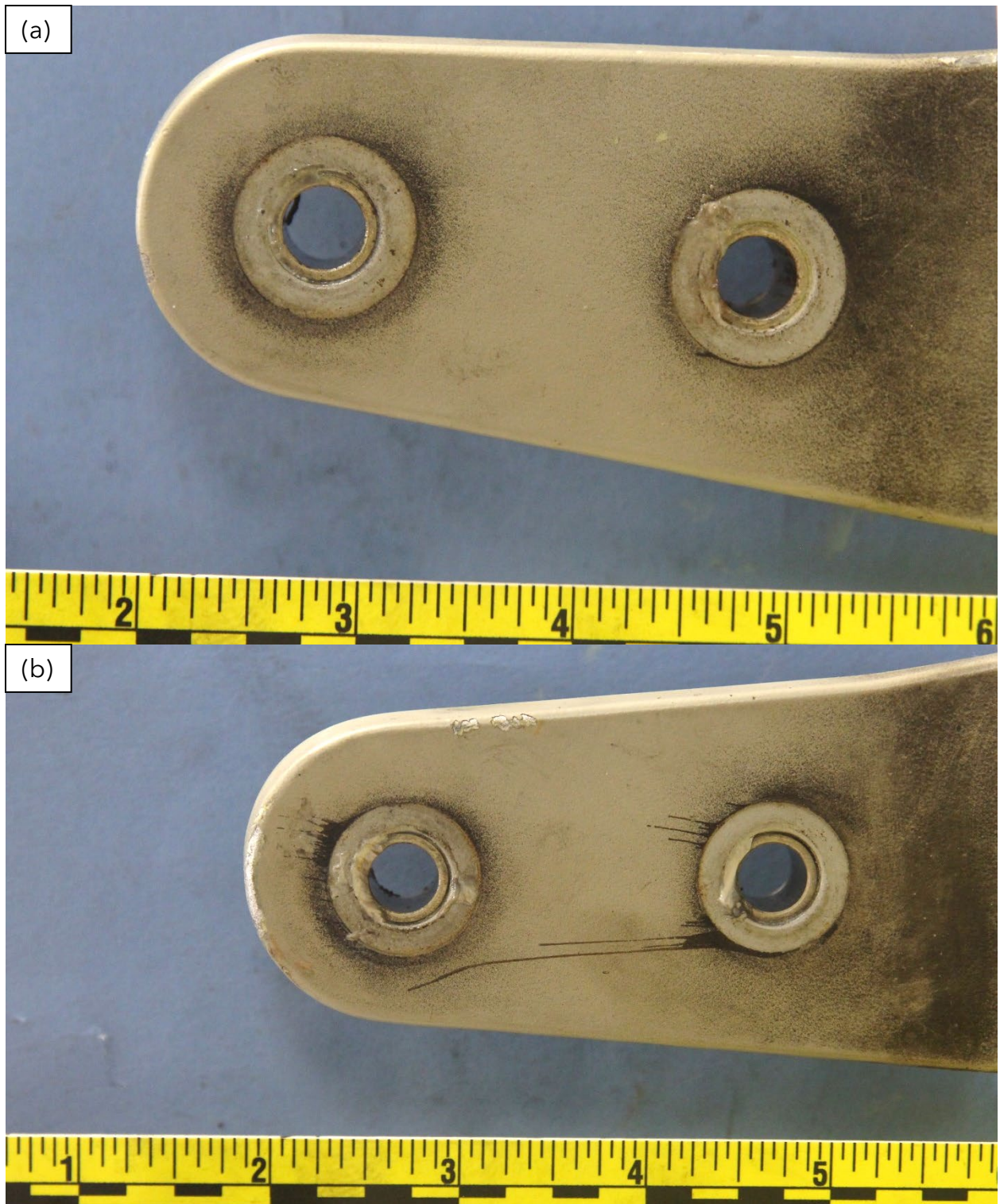


Figure 24. View of the bolt holes from the blade grips of the gearbox assembly.

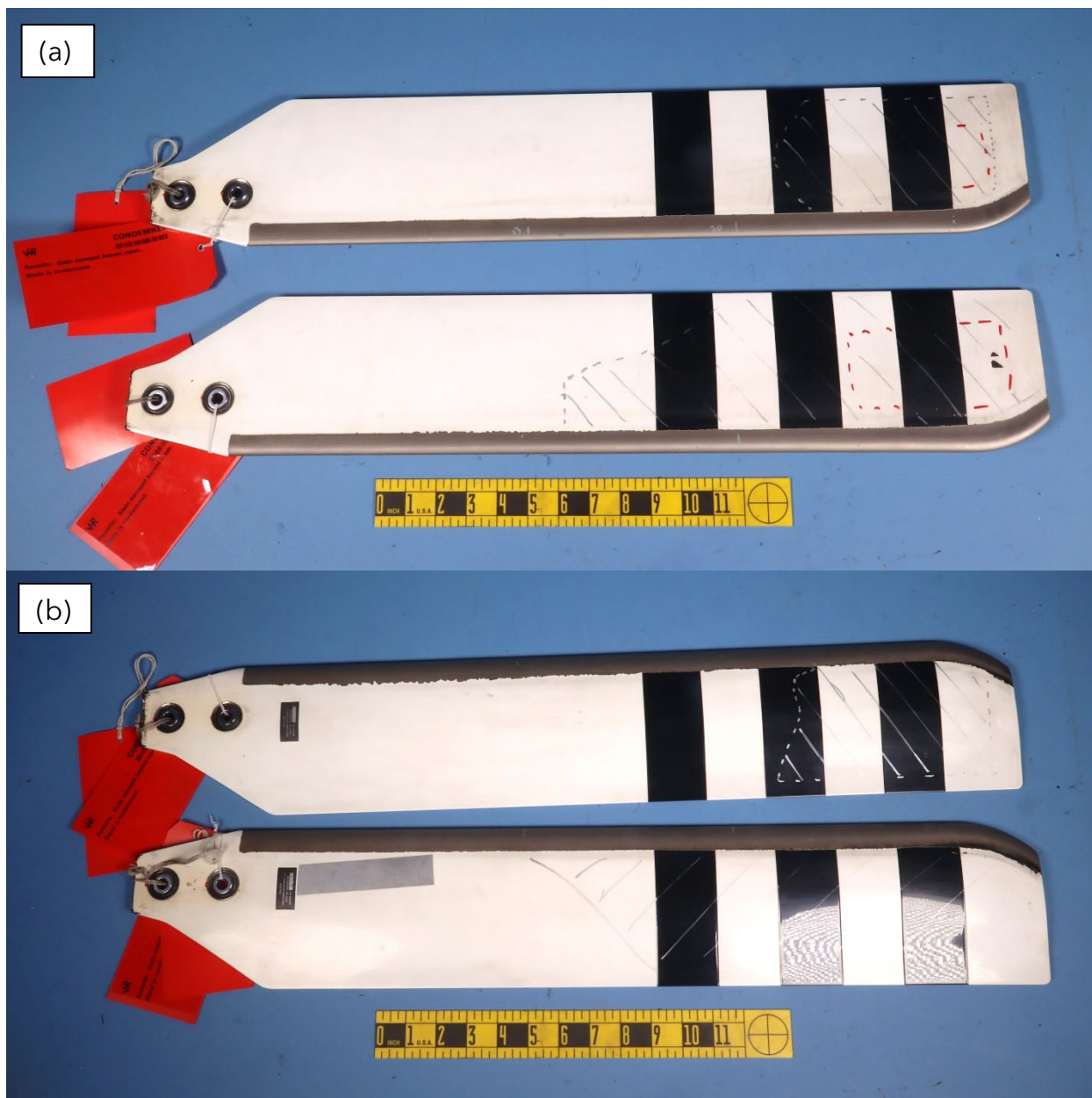


Figure 25. The intact tail rotor blades, as received, from (a) the interior side with markings of damage and (b) the reverse exterior side.



Figure 26. One of the damaged tail rotor blades from accident, viewed from (a) the exterior and (b) opposite interior sides.

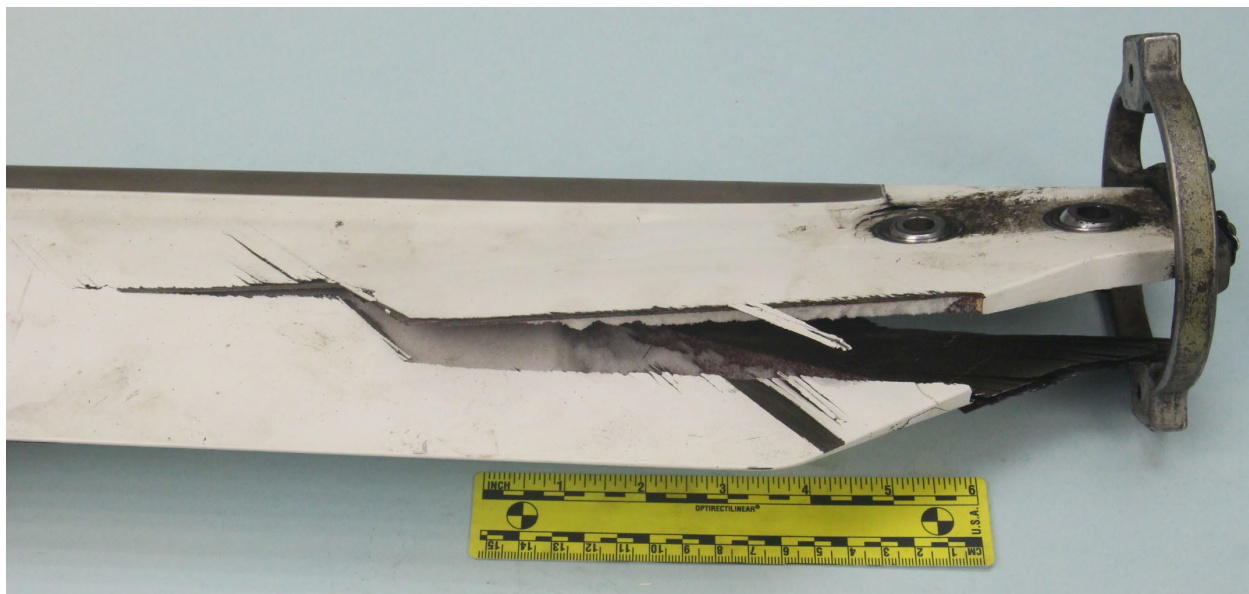


Figure 27. Closer view of the fracture from the blade in Figure 22.

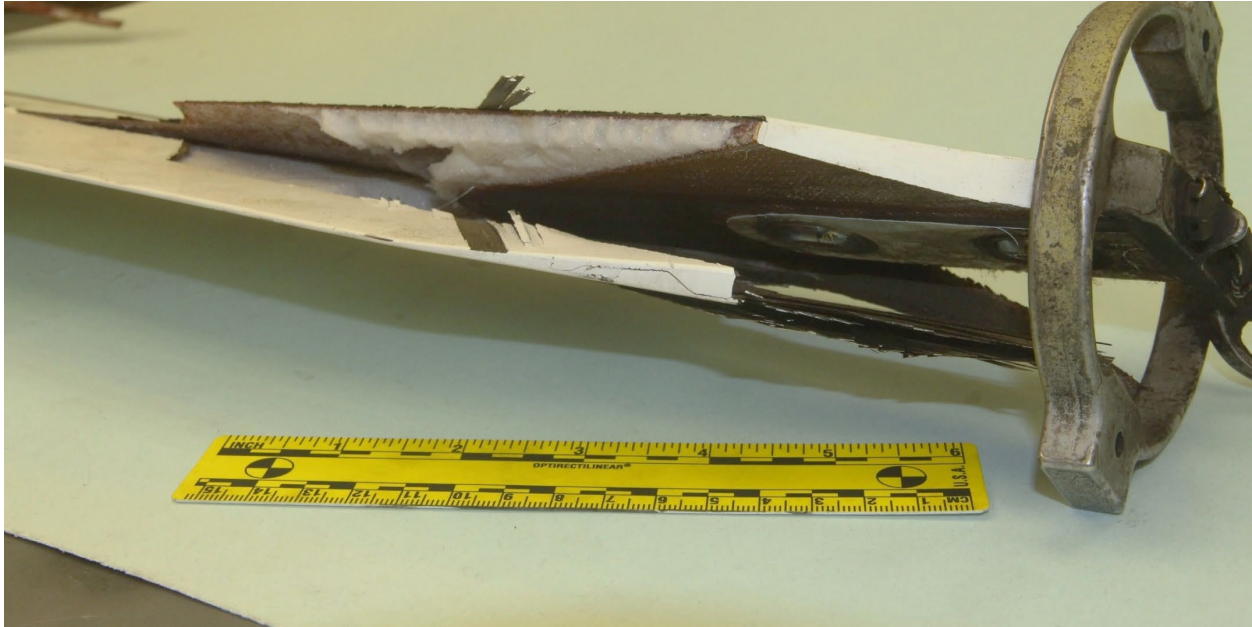


Figure 28. View of the interior structure of the cracked tail rotor blade, showing the separation between the base and the composite layup on the interior side.

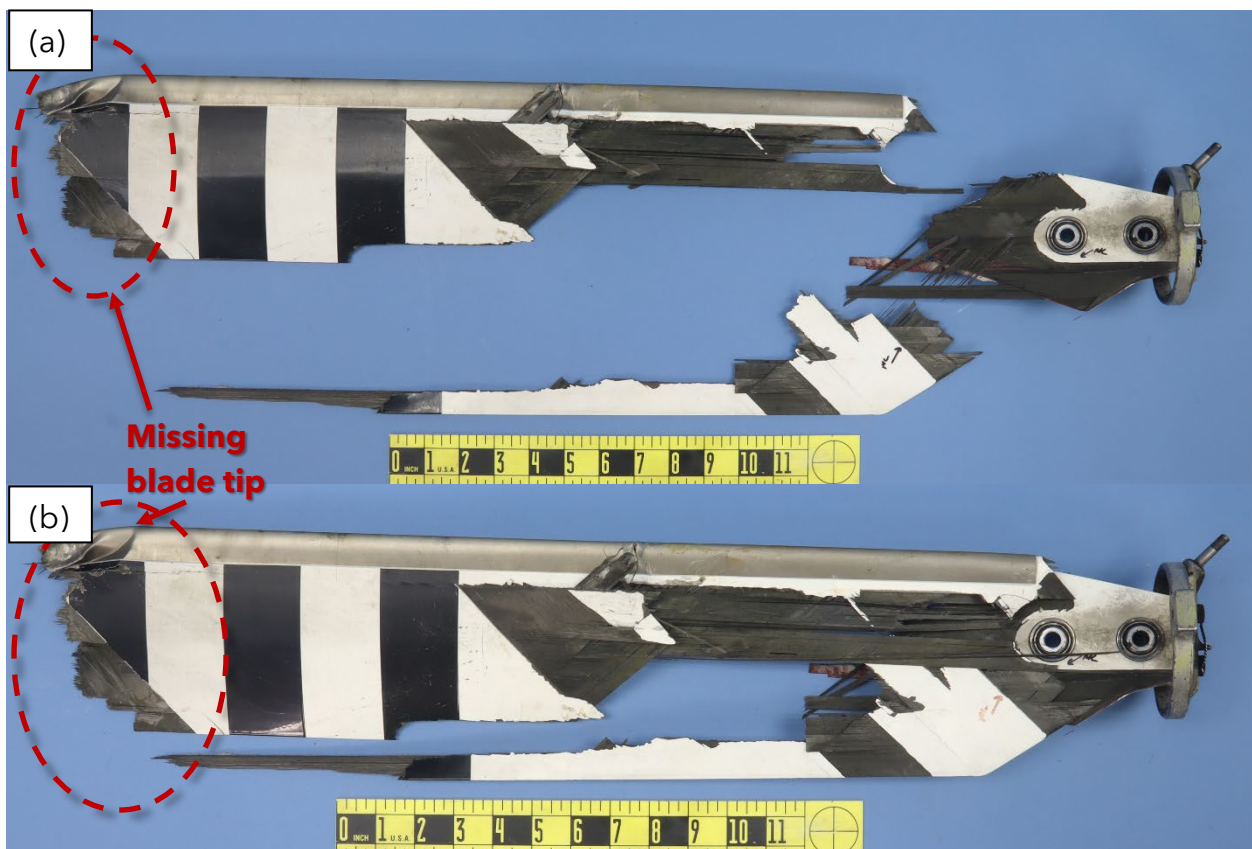


Figure 29. The fractured tail rotor blade remnants, viewed from the outboard face, showing (a) the fragments separated and (b) the fragments positioned together to show the relative locations prior to fracture.

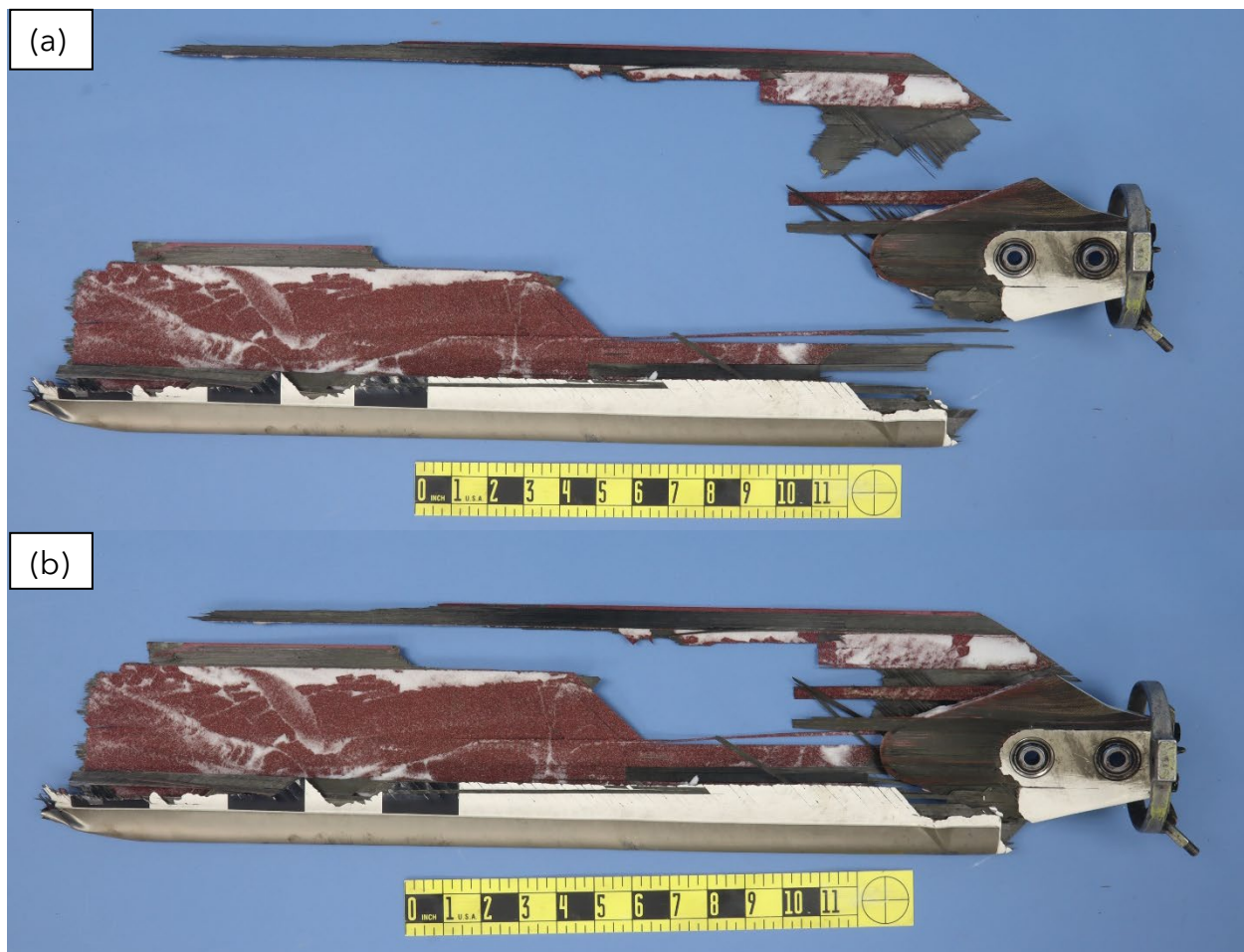


Figure 30. The fractured tail rotor blade remnants, viewed from the inboard face, showing (a) the fragments separated and (b) the fragments positioned together to show the relative locations prior to fracture.

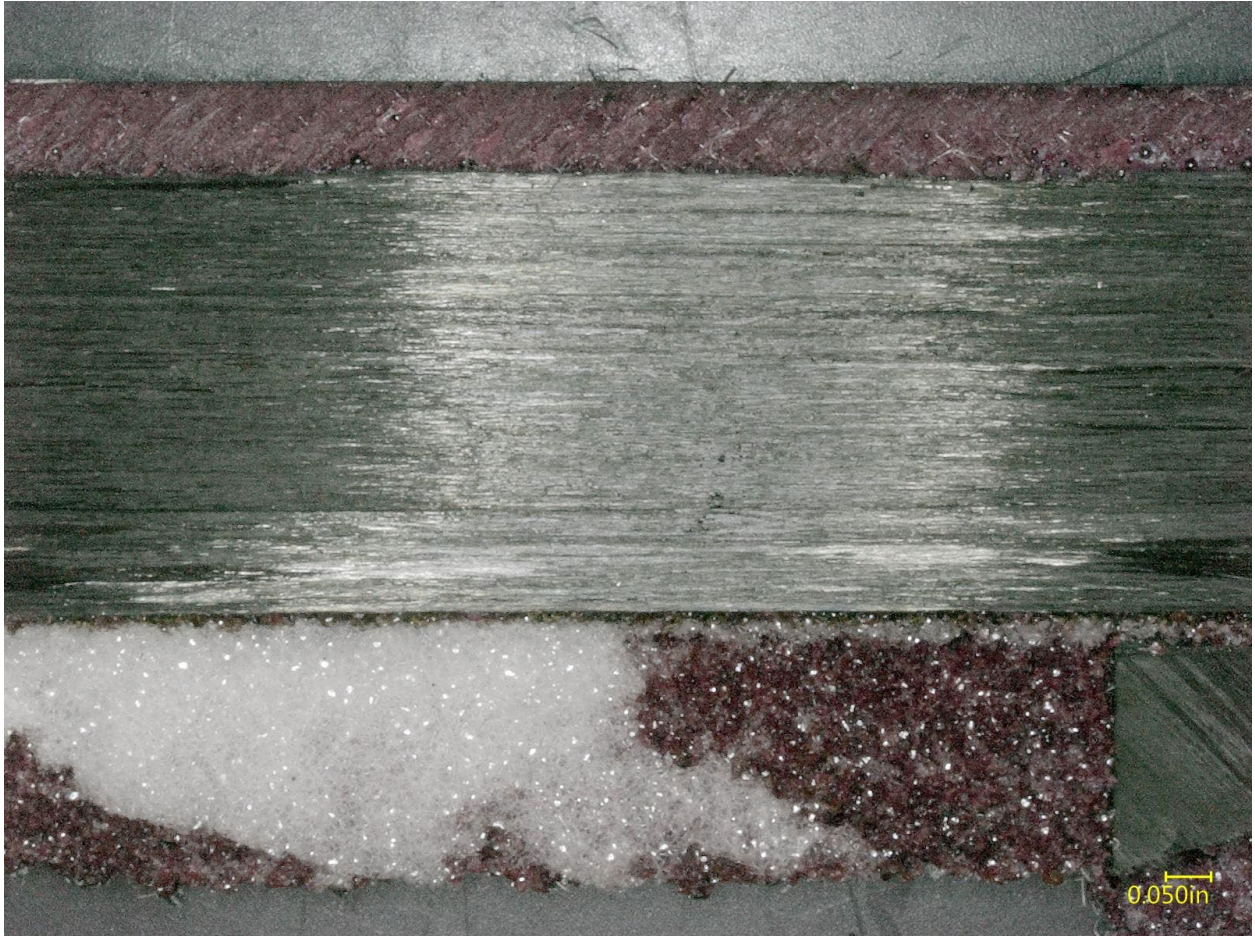


Figure 31. View of the fractured unidirectional strap adjacent to the trailing edge of the fractured blade.

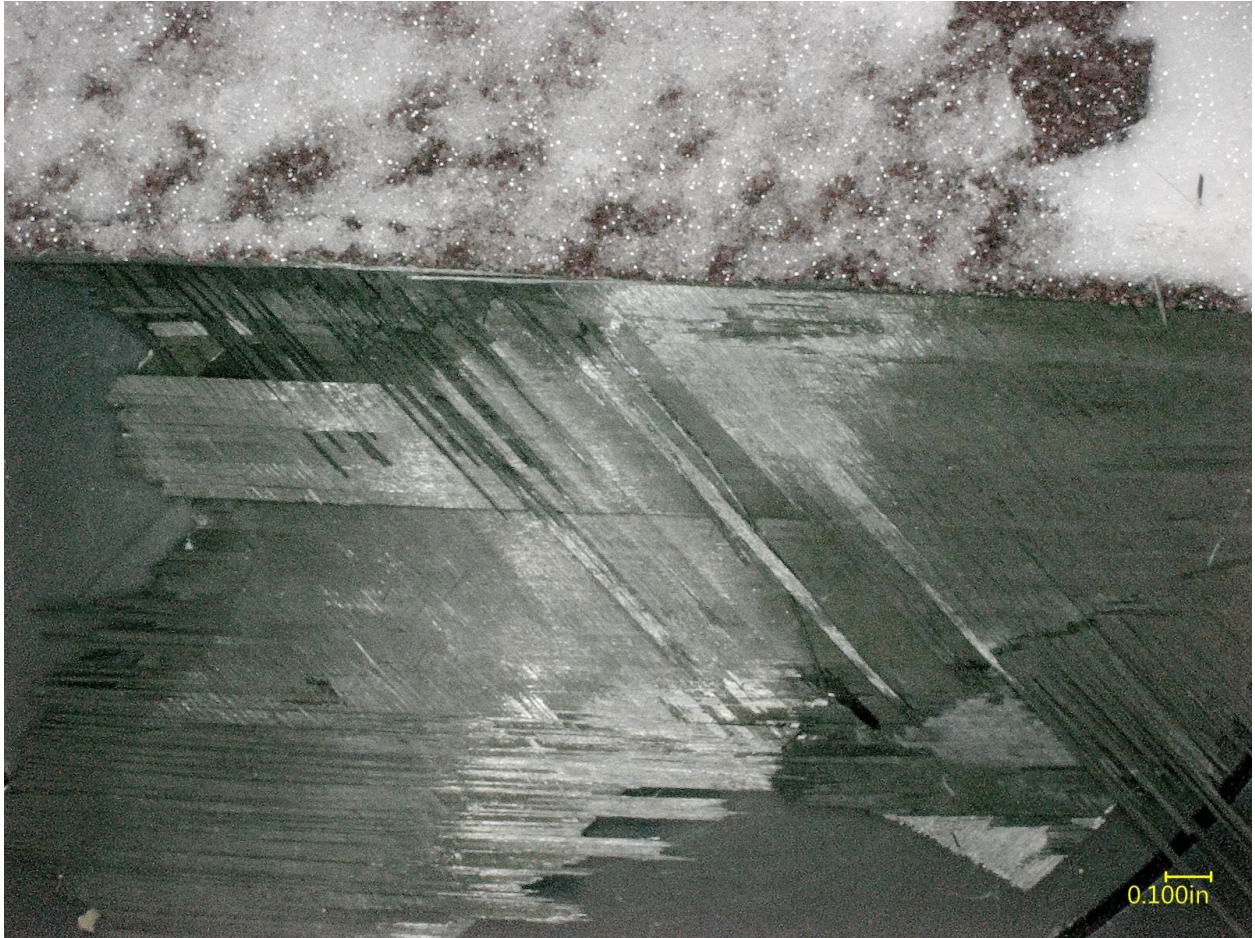


Figure 32. View of the fractured composite interior just inside the area shown in **Figure 31**.

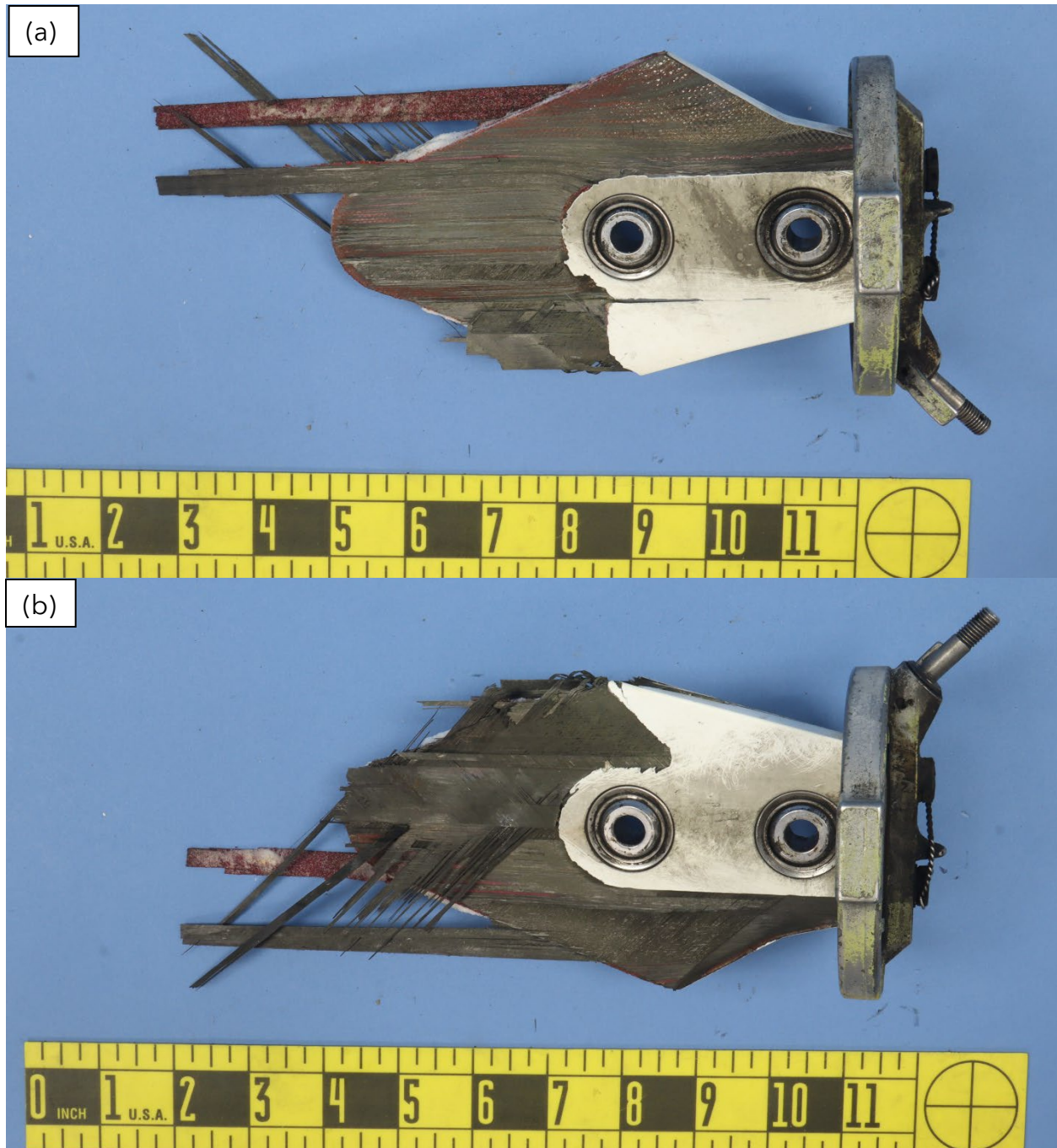


Figure 33. The opposite sides of the base of the fractured tail rotor blade.

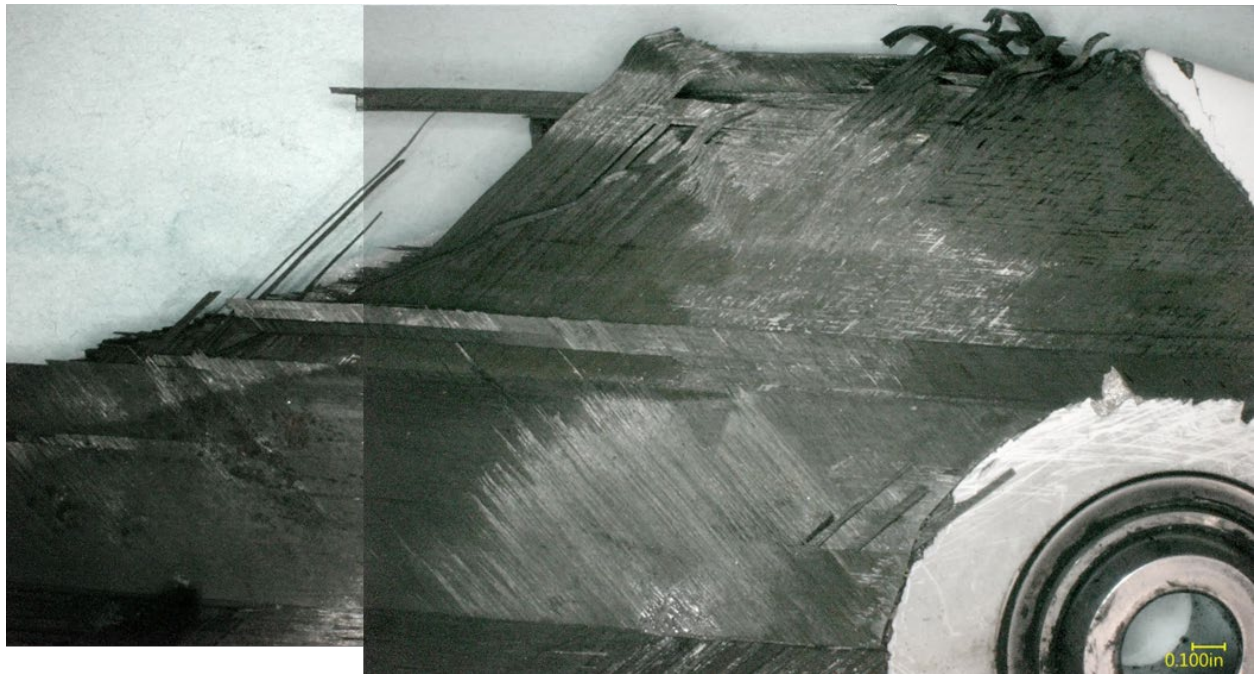


Figure 34. Montage of images showing composite fracture patterns of the leading edge of the broken rotor blade.

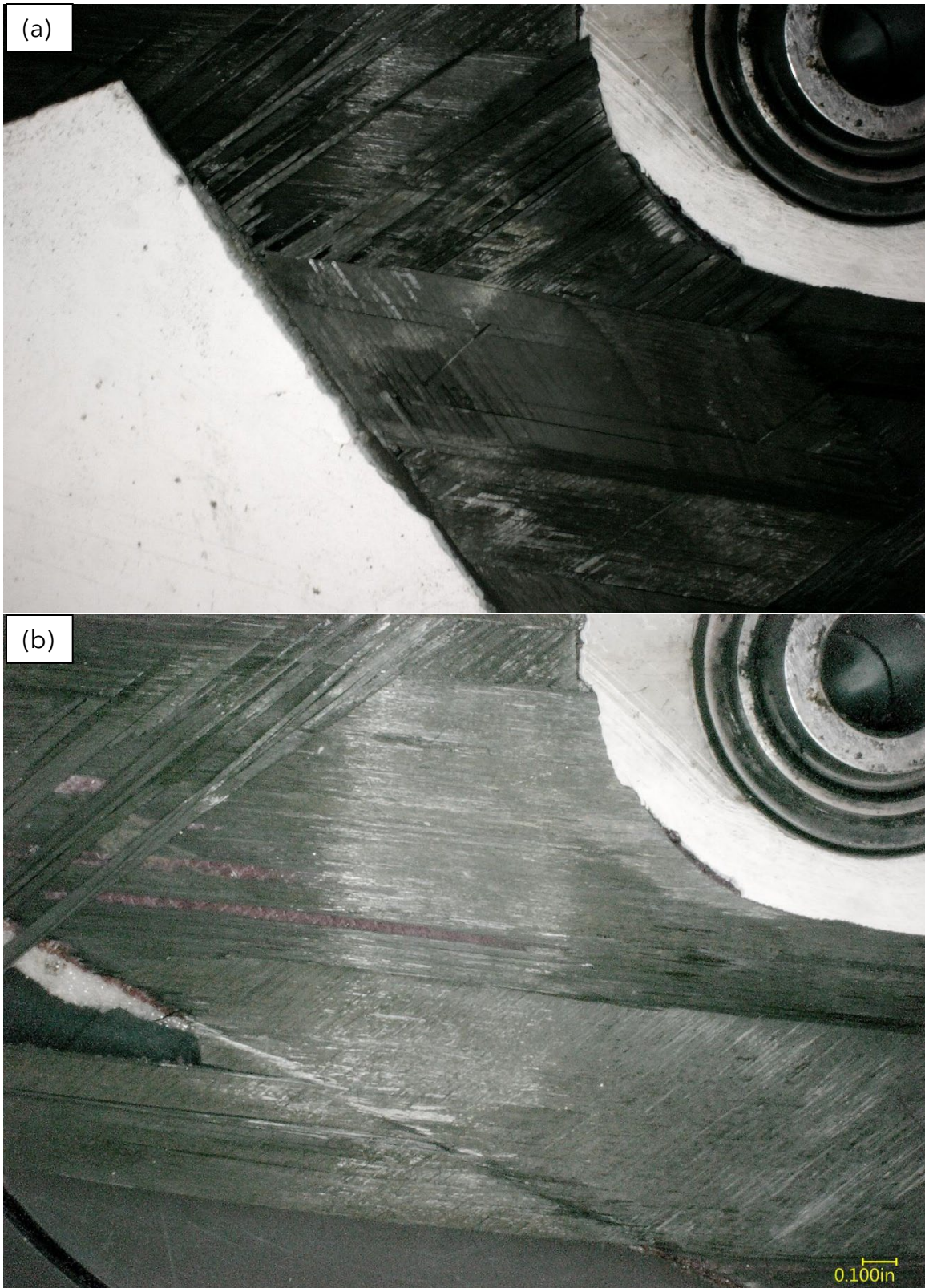


Figure 35. Views of the tail rotor blade fracture about the bearing hole with (a) the small piece laid on top and (b) removed, showing underlying fracture features.