

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR24FA053

MATERIALS LABORATORY

Factual Report 25-021

April 7, 2025

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A. ACCIDENT INFORMATION

Location: Eloy, Arizona
Date: December 8, 2023
Vehicle: Series 5 Kitfox, N66180
Investigator: Elliott Simpson, AS-WPR

B. COMPONENTS EXAMINED

Components from a NR Prop SR-118-2000 propeller assembly installed on a Lycoming O-320 4-cylinder engine, as follows:

- 1) Propeller blade, separated from hub; S/N: V6410
- 2) Two-piece hub with a retained blade root; Blade root S/N: V6408
- 3) Exemplar blade; S/N: V6409

C. EXAMINATION PARTICIPANTS

Specialist Donald Kramer, Ph.D.
National Transportation Safety Board
Washington, DC

D. DETAILS OF THE EXAMINATION

Pieces of a ground adjustable pitch propeller assembly were submitted to the NTSB Materials Laboratory for examination (figure 1). One of the blades had pulled free of the hub. The other blade had fractured just above the root and the root was still retained within the hub. An exemplar blade was also submitted for examination (figure 2a).

The assembly, as originally installed, consisted of two composite propeller blades and a two-piece hub, clamped together by bolts. Blade retention was achieved by friction between the outer cylindrical surface of the blade and an inner clamping surface on the hub along spanwise inboard and outboard grip areas (figure 2b). A collar in the middle of the blade retention area slotted into a groove on the hub (see below).

1.0 Composite layup and construction

The root sections of the exemplar blade and separated blade were examined by X-ray computed tomography (X-ray CT). Longitudinal and transverse sections of the exemplar blade are shown in figures 3a and 3b, respectively. The retained blade root was also cut in the longitudinal direction after it was removed from the hub and the layers were examined in cross section by optical microscope and scanning electron microscope (see below).

The root construction consisted of multiple composite fiber polymer matrix layers built around an aluminum tube. The innermost layer consisted of unidirectional (uni) glass fiber wound circumferentially around the tube. The next layer consisted of uni glass fibers oriented along the axial direction of the blade. The next layer comprised four plies of plain-woven glass fiber fabric with warp and weft at $\pm 45^\circ$. The next layer comprised multiple plies of carbon fiber fabric. Plies that could be clearly distinguished included three $0^\circ/90^\circ$ plies, a $\pm 45^\circ$ ply, and three additional $0^\circ/90^\circ$ plies. The final outermost layer consisted of a $\pm 45^\circ$ glass fiber fabric ply. The axial unidirectional fiber layer thickness was built up near the leading and trailing edges of the blade. As such the woven fabric layers did not wrap completely around the root of blade but rather came to tapered ends as they approached the leading and trailing edges (figure 3b).

Within the collar feature, the fiber layers bowed radially outward, partially filling and forming the collar. The rest of the collar consisted of resin-rich wedge-shaped regions of epoxy along the upper and lower edges. In some regions, the excess volume between the bowed layers was filled by resin pockets or voids (figure 3a). In some regions, the excess volume was filled unidirectional circumferential glass fiber (for example, see figure 15 below).

Dimensional attributes of the blade root and hub retention features were measured using a caliper or a structured light scanner with average value results as follows:

Table 1. Dimensional attributes of blade retention features on the blade and hub.

Attribute	Value, mm	Value, inch
Blade root outer diameter	54.90	2.161
Inboard grip length (blade)	13.17	0.518
Collar length	15.19	0.598
Outboard grip length (hub)	15.21	0.599
Collar thickness	2.69	0.106
Groove depth (hub)	3.03	0.119
Hub inner diameter	55.09	2.169

2.0 Examination of separated blade

The separated blade exhibited fracture and wear features at its root end (figures 4a – 4d). There were axial (spanwise) rub marks on the grip section at the base of the blade root and on the clamping faces of the hub (figures 5a, 5b). The collar had separated from the blade and was retained inside the groove in the hub (figures 5a, 5b). The outer resin and glass fiber layers were worn away on either side of the built up unidirectional axial fiber layer close to the blade trailing edge (figure 4b). On the opposite side of the blade, an elliptical wear region had exposed the $\pm 45^\circ$ glass fiber layers in the collar region (figure 4d).

As seen in X-ray CT scans, the aluminum backing tube was not positioned against the base of the blade root (figure 6). Measurements on axial/radial images indicated that the tube was recessed from the base of the blade approximately 3.7 to 3.8 mm (approximately 0.15 inch).

The blade exhibited multiple voids. Several of these voids were visible from the outside where the collar had separated. One void was located near the trailing edge between the $\pm 45^\circ$ glass fiber layers and the underlying unidirectional axial fiber layer, within the collar region (figure 7). The void measured approximately 15 mm by 2.5 mm (about 0.6 inch x 0.1 inch). A second void was visible on the opposite side of the blade, near the leading edge position (figure 8a). The void opening was located within the collar region and was round with an approximate diameter of 8 mm (0.32 inch). X-ray CT scan images through this region indicated that the opening connected to a network of sub-surface voids that extended approximately 18.5 mm along the axial direction starting near the base of the blade root (figure 8b). Additional void regions were visible on other scan images. See the X-ray CT scan report for additional details.

Loose fiber regions were visible on the exposed fiber surfaces at the blade root. Typical images are shown in figures 9a and 9b at the locations indicated in figure 4b. The appearance was consistent with incomplete or absent resin encapsulation (resin starvation).

3.0 Hub disassembly and examination of retained blade root

The hub was examined in its as-received state prior to disassembly and attributes related to blade retention were measured. On the side with the separated blade, within the blade clamping area, the distance between the inner clamping surfaces, measured 90° to the parting plane, was 54.23 mm (2.135 inch). On the same side, the gap between the mating hub halves was 0.25 mm (0.010 inch), measured by feeler gage. One of the two clamping bolts had an additional gap of 0.30 mm (0.012 inch), measured by feeler gage between a nut and a washer. On the opposite end, with the retained blade root, the gap between the mating hub halves was 0.64 mm (0.025 inch), measured by feeler gage. Tightening torque for the two blade retention bolts that held the retained blade root was approximately 11.3 N-m (~ 100 lbs-in) and 13.6 N-m (~ 120 lbs-in) for the leading and lagging bolts, respectively, as measured by a torque gage. The hub was then disassembled, revealing the retained collar from the separated blade and the retained blade root in its entirety (figure 10a, b).

The retained blade root appeared to have shifted spanwise outward (figures 10 and 11). There was a dirt/dust mark on the hub clamping surface approximately 4.4 mm (0.17 inch) inboard of the root end of the blade. The collar, still within the groove had slid toward the base of the blade root. Whereas on the exemplar blade, the distance from the base of the blade to the near edge of the

collar was approximately 13.17 mm (0.518 inch), the same feature on the remnant blade root was approximately 7.91 mm (0.312 inch). Resin and fiber material was observed extruding into the gap between the hub halves (figure 11). Dirt/dusk marks appeared to follow the edges of some of the remaining extruded material.

The inboard grip region on the blade root had two regions that exhibited different surface textures (figure 12). The inboard (lower) portion, extending approximately up to the lower edge of the displaced collar feature, had a flat and comparatively smooth appearance. The outer (upper) portion, extending up to the original edge of the collar, had a comparatively textured, raised, and dimpled appearance. Several comparatively faint spanwise scuff marks were observed in the upper portion. There was an axial rub mark on the hub and blade root at the trailing edge location (figure 13) and features consistent with rubbing on the hub and damage to the blade root near the leading edge location (not shown).

The blade root was sectioned in the spanwise direction at two locations located on the aft-facing side of the blade (high-pressure side) (figure 14). The cut faces were ground on silicon carbide paper through 600 grit to examine the composite structure and the displacement of the collar feature (figures 15 - 18). Along the spanwise outboard end of the collar, the resin-rich wedge had separated from the fiber plies. The outermost three or four plies had fractured near the spanwise outboard edge of the collar and had displaced spanwise inboard toward the root of the blade. On one cross section, the plies near the spanwise inboard edge exhibited buckling and peel separation (figure 15) and the outer four or five plies within the inboard grip area had sheared inboard relative to the underlying plies (figure 16). On the other cross section, there was comparatively little buckling of the plies and no apparent shear displacement of the outer plies (figures 17 and 18).

One of the cross sections was examined by scanning electron microscope and dry fiber features were observed (figures 19a - c). On circumferentially oriented tows, there were regions filled with fibers but with gaps between the fibers. On spanwise axially oriented tows, the fibers had pulled out, leaving a recess below the grinding plane.

Submitted by:

Donald Kramer, Ph.D.
Materials Engineer



Figure 1. Top image: Overview of propeller hub with retained blade root and separated blade. Bottom image: The retained root of the separated blade.



Figure 2. Exemplar propeller blade: a) Overview image and b) blade root.

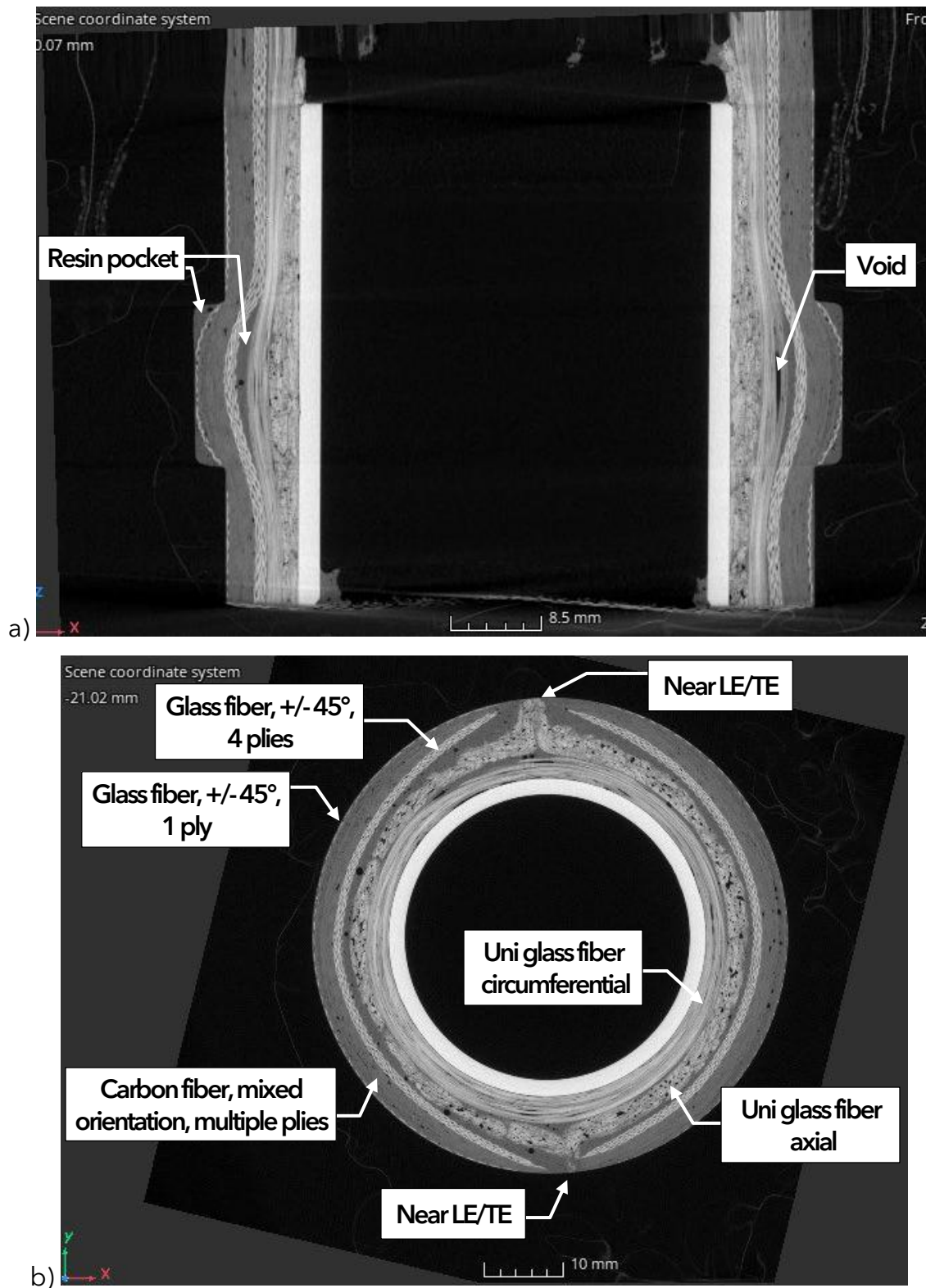


Figure 3. X-ray CT scans of the exemplar blade root: a) axial section and b) transverse section. The unidirectional fibers in the axial direction were built up near the leading edge (LE) / trailing edge (TE) of the blade root.

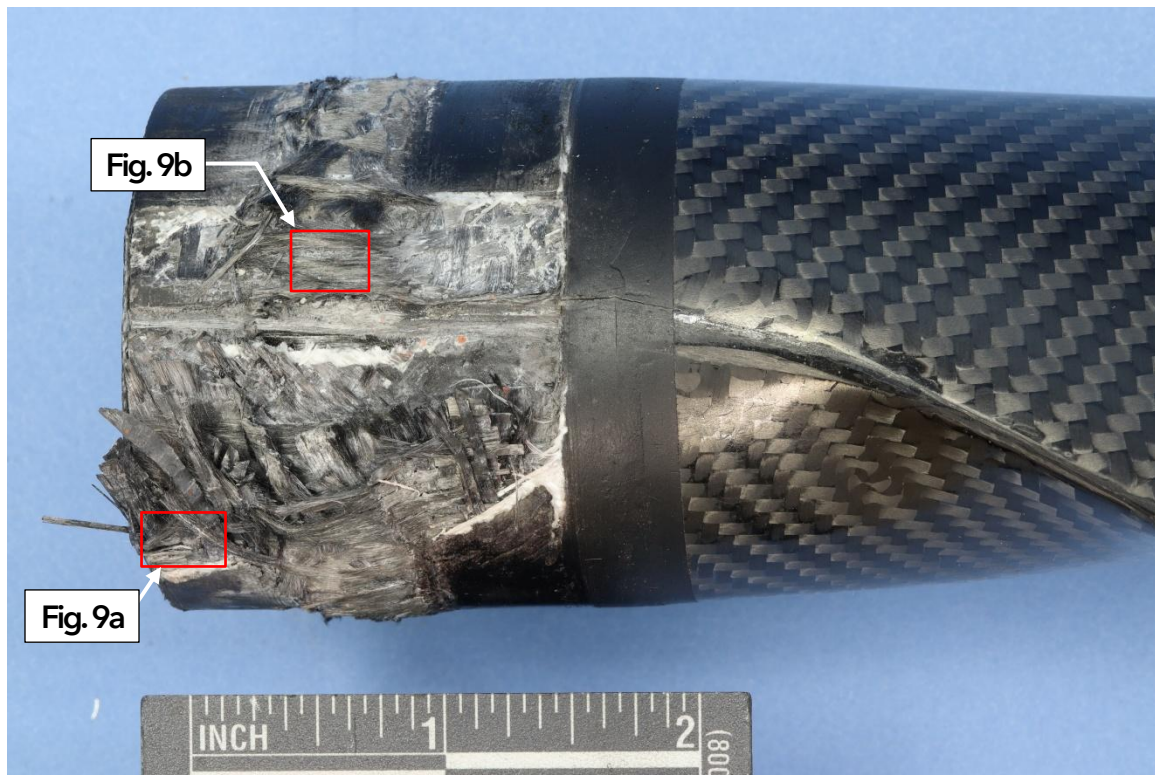


Figure 4. Images of separated blade root: a) approximately in-line with blade back; b) approximately in-line with trailing edge;

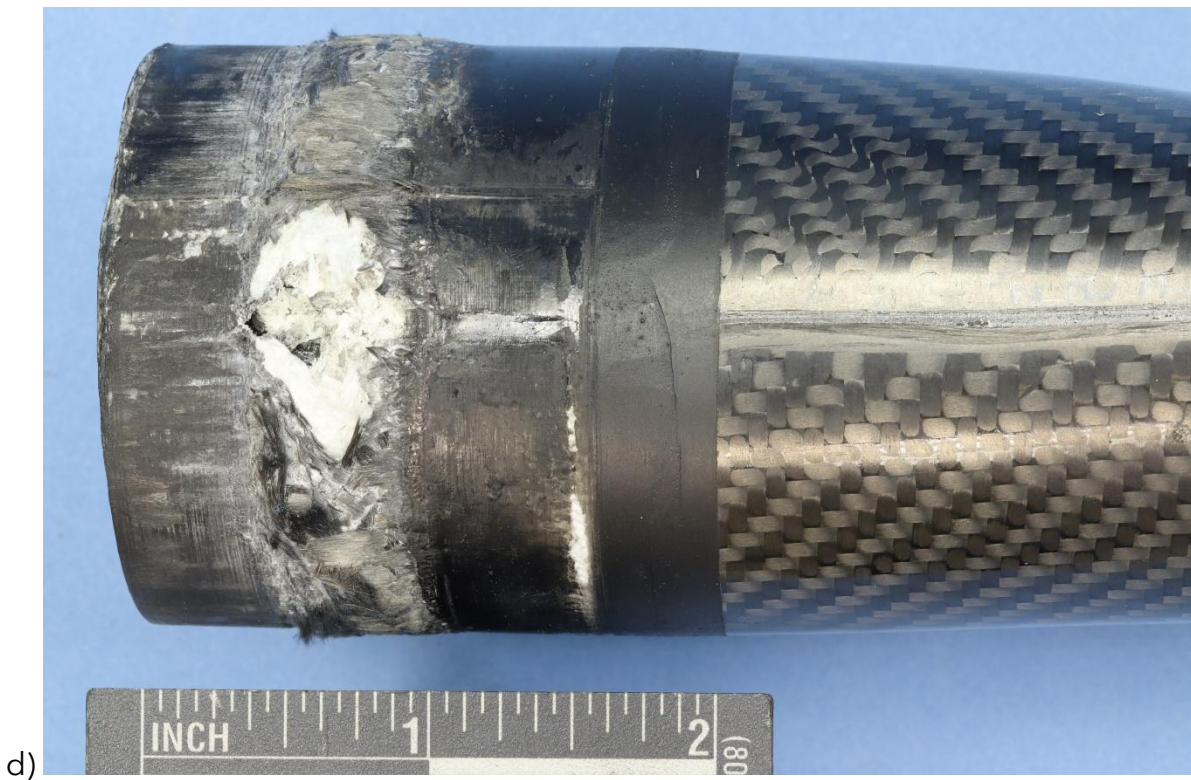
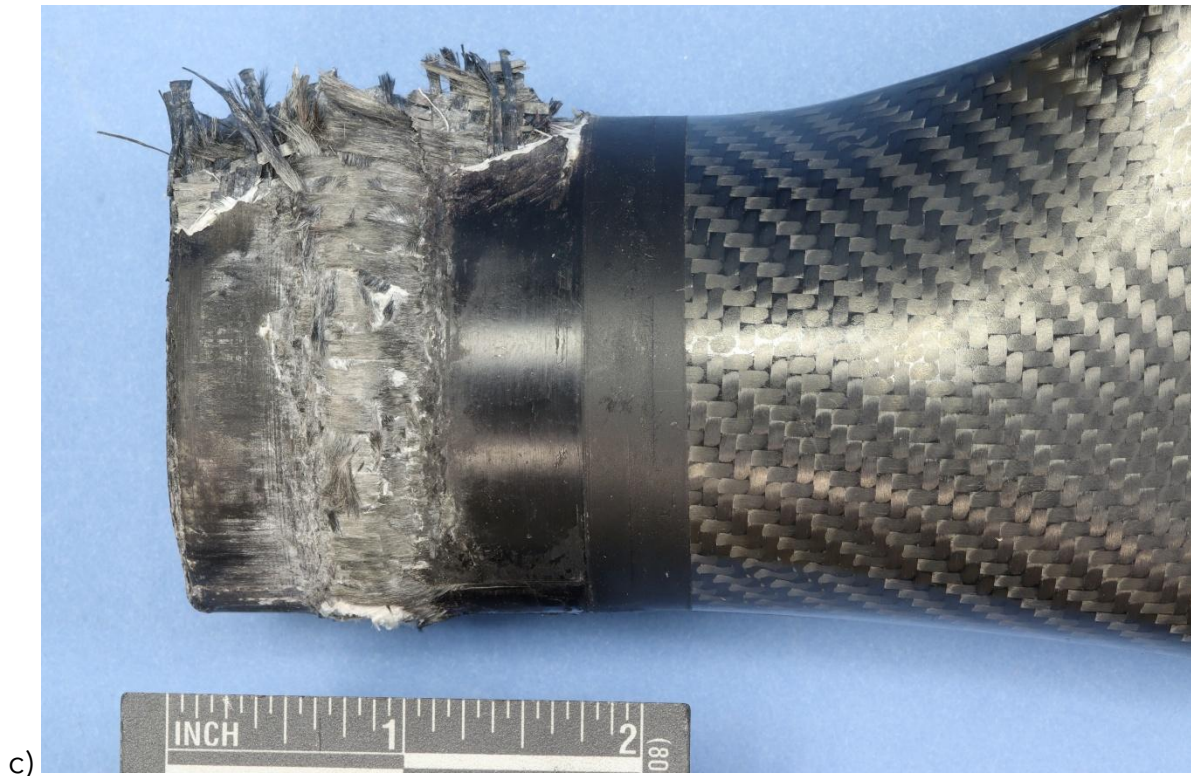


Figure 4 (cont.). c) approximately in-line with blade face; and d) approximately in-line with leading edge.

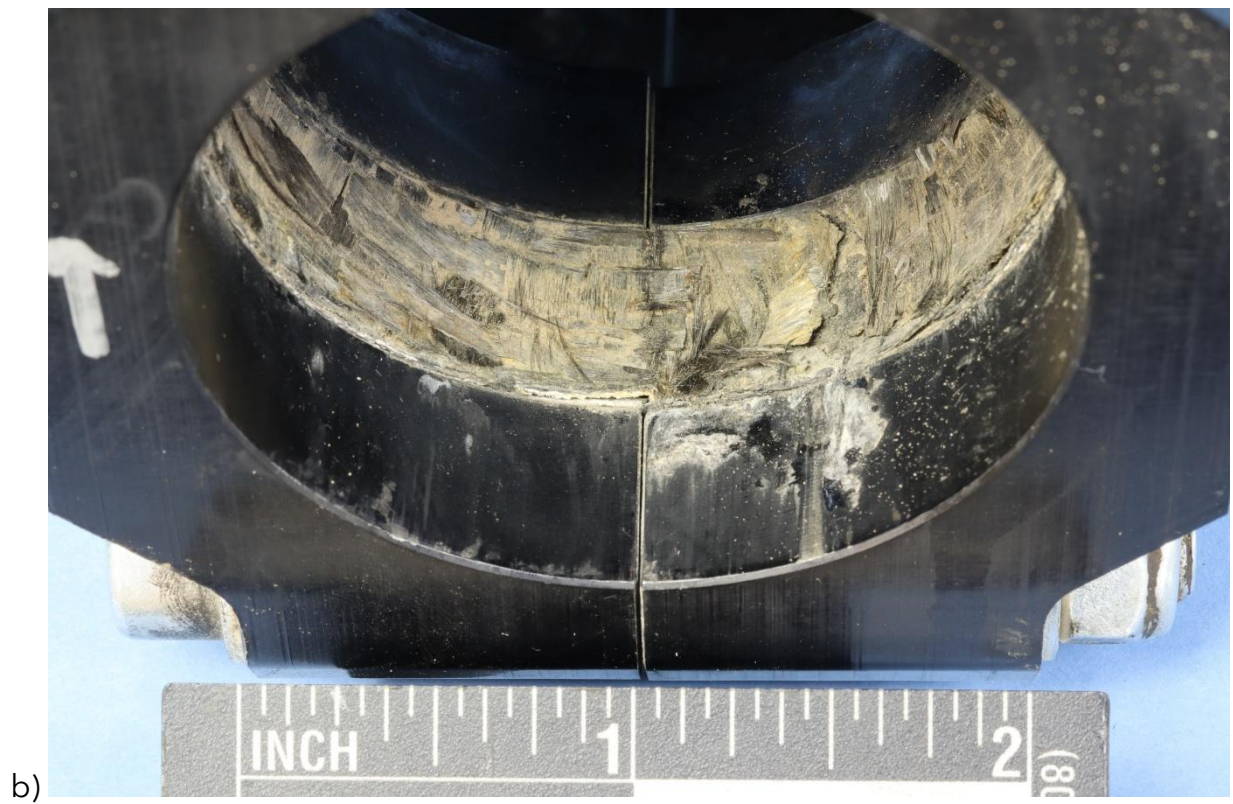


Figure 5. a) and b) Images of the blade collar remnant left inside the hub groove.

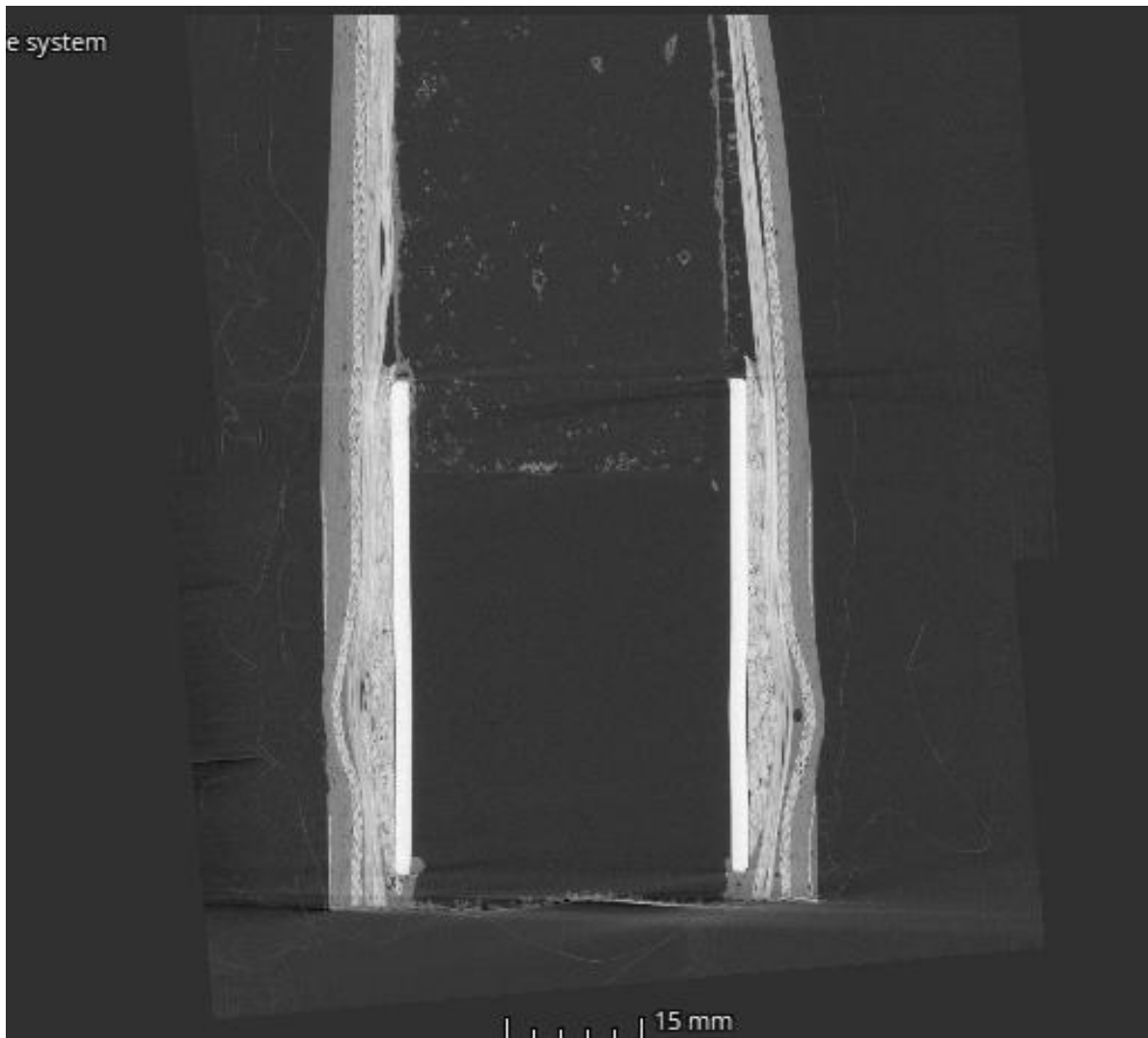


Figure 6. X-ray CT scan showing the recessed aluminum tube on the separated blade.

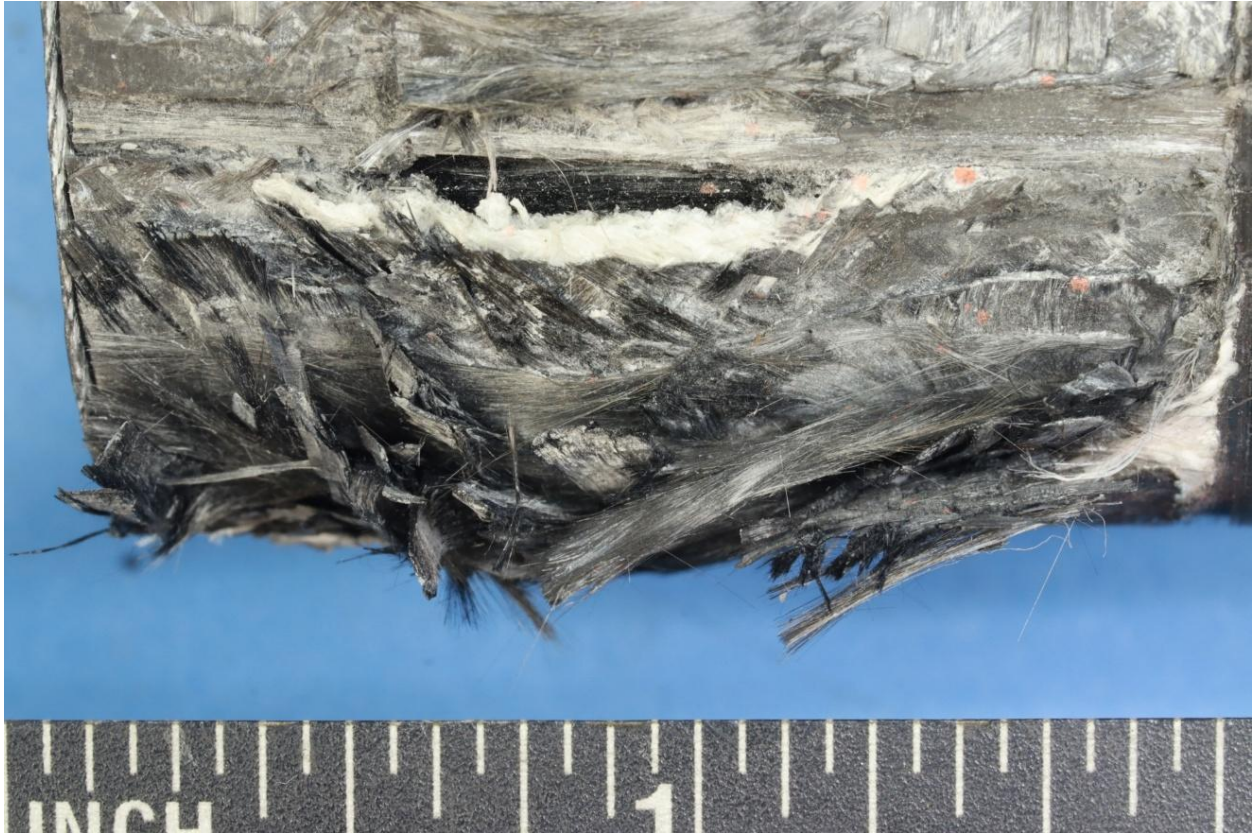


Figure 7. Void between the +/- 45° glass fiber layers and the underlying unidirectional axial glass fiber layer. The void measured approximately 0.6 inch by 0.1 inch. See also figure 4b.

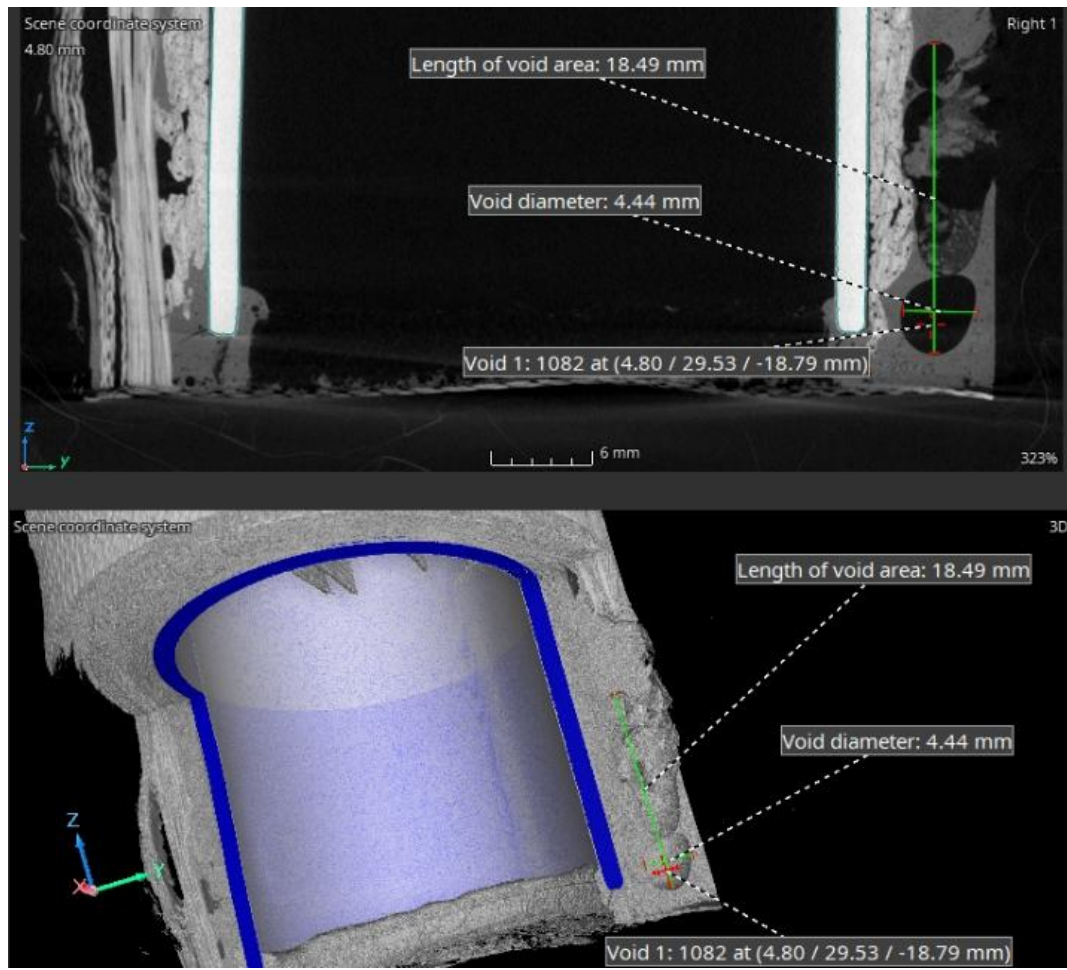


Figure 8. a) Image of blade root near leading edge location showing exposure of void after separation from the blade collar and b) X-ray CT scans through void showing subsurface structure.

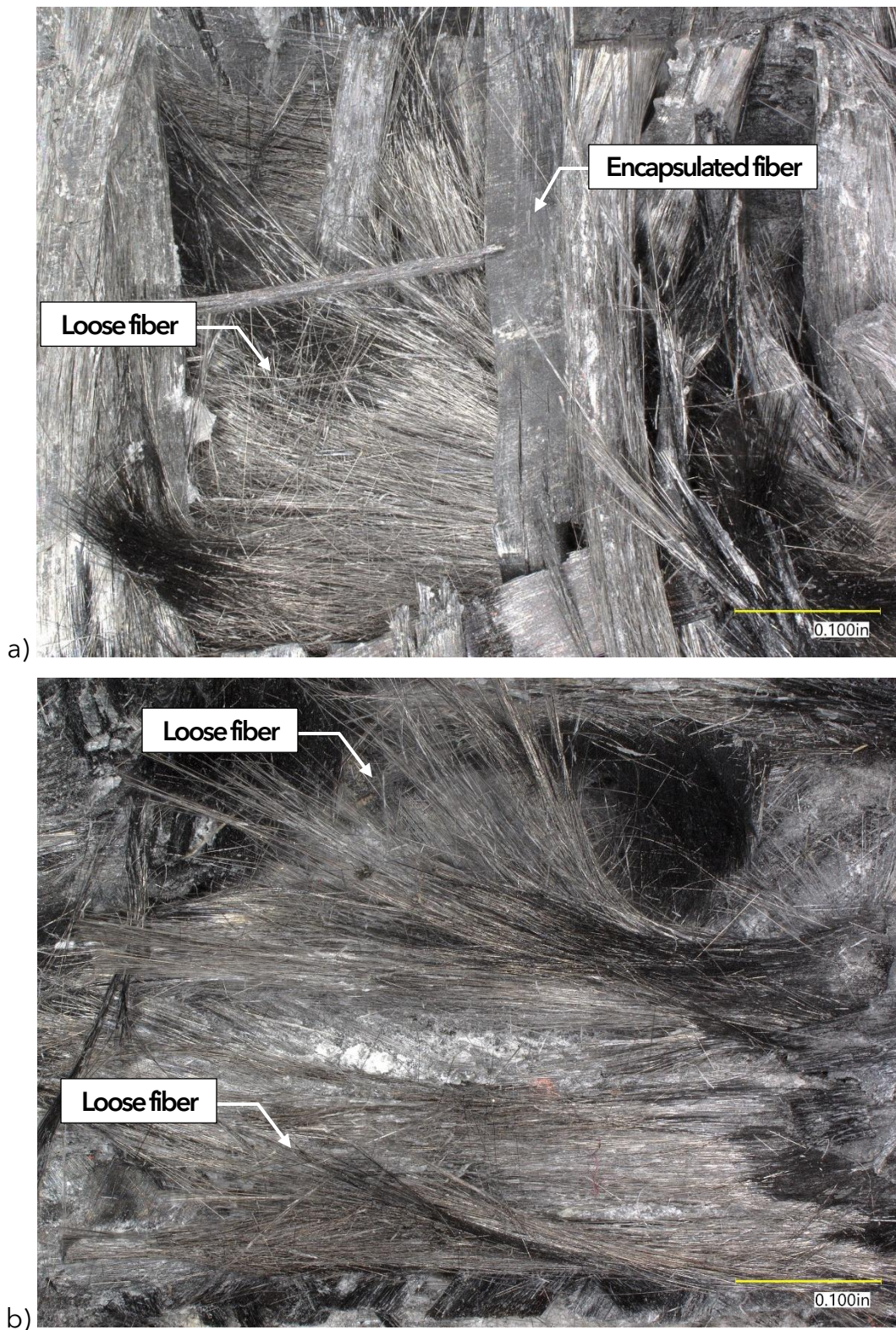


Figure 9. a) and b) Images of loose fiber regions on the separated blade at the locations indicated in figure 4b.



Figure 10. Upper image: Overview of hub with aft half removed. Lower image: Closer image of retained blade root. Arrows indicate the location of a mark on the hub and the position of the blade root.

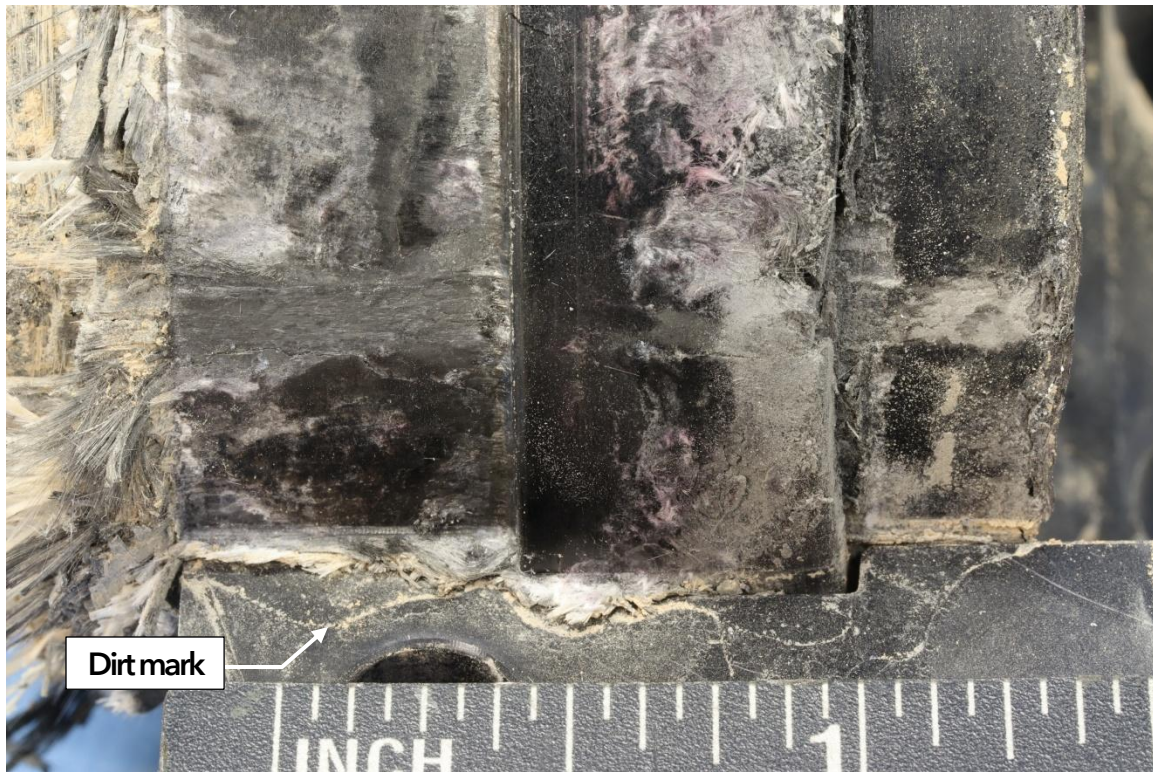


Figure 11. Image showing extrusion of blade root material into the gap between mating hub halves.

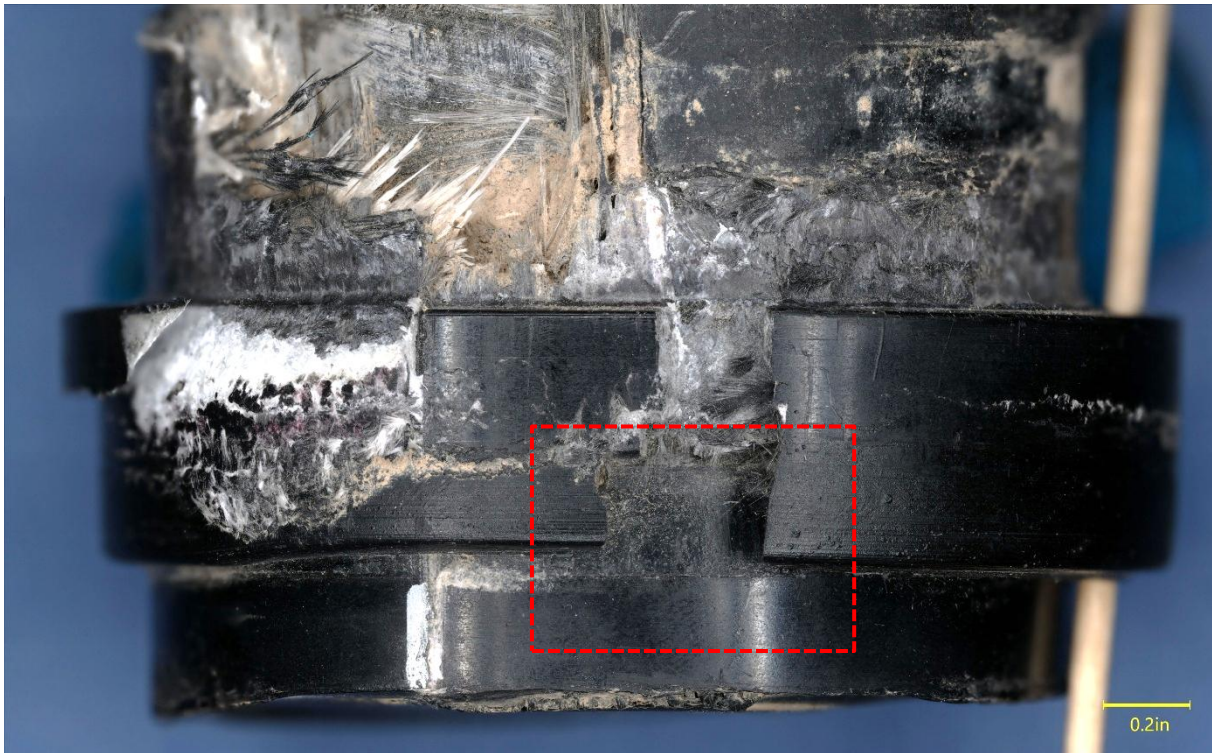


Figure 12. Top image: Overview image of blade root. Lower image: Higher magnification image showing the flat and smooth region below the comparatively textured region.

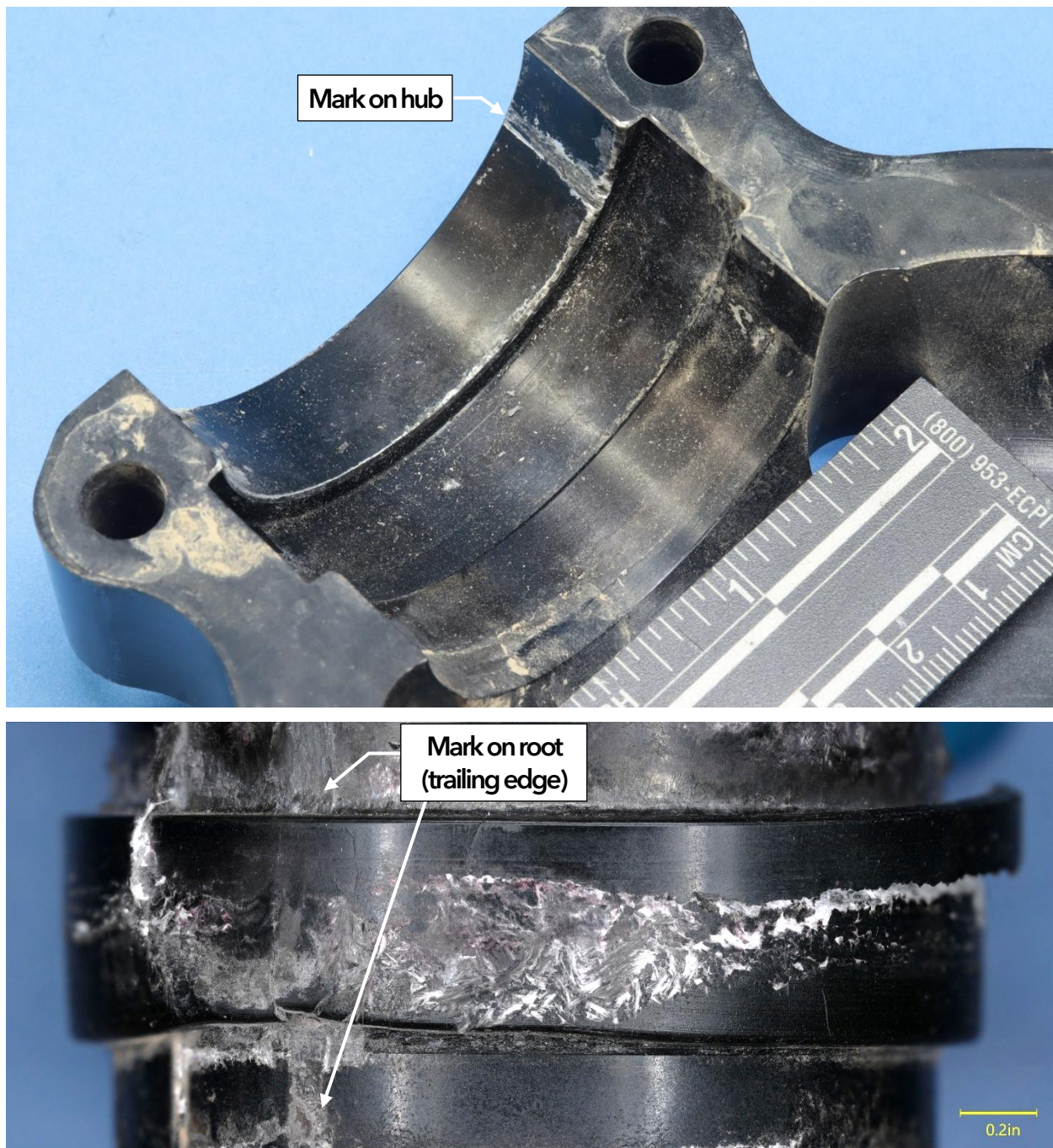


Figure 13. Marks on the hub and blade root near the trailing edge position.

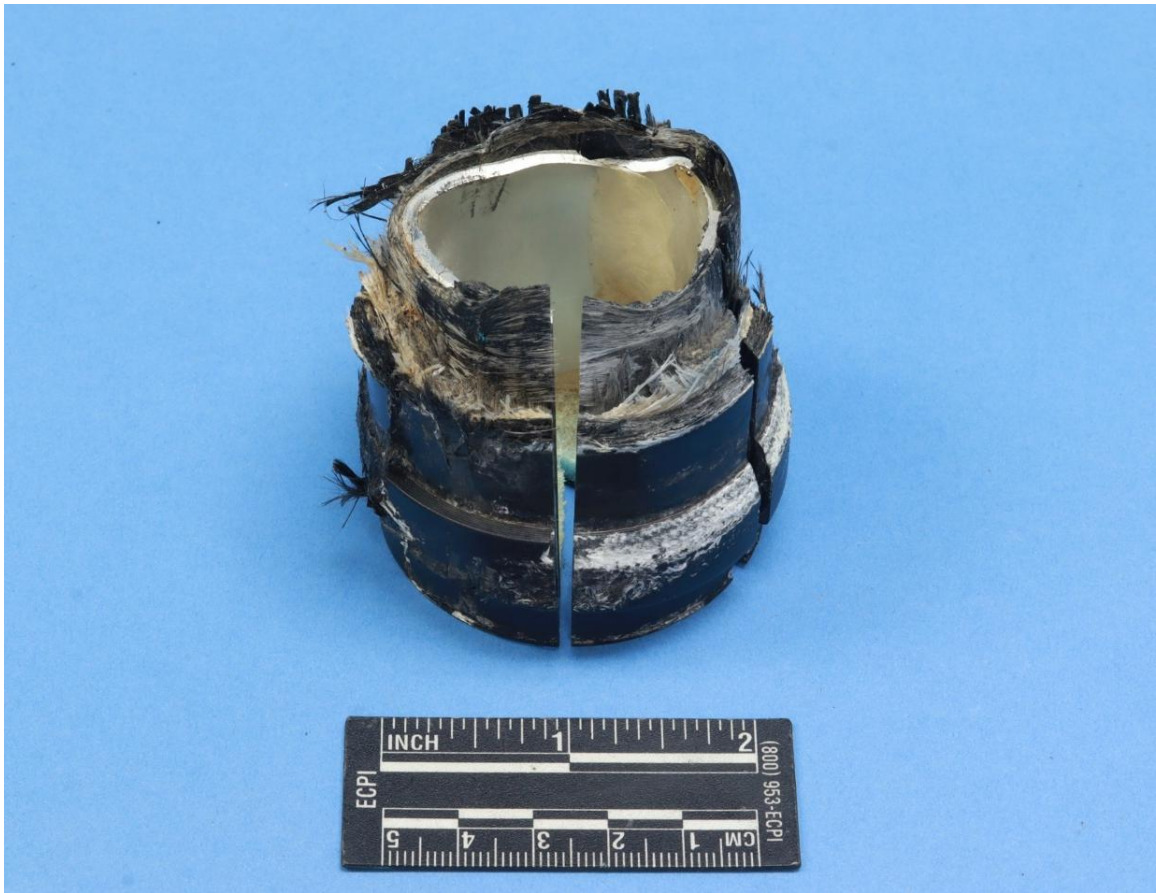


Figure 14. Location of longitudinal section removed from the blade root.

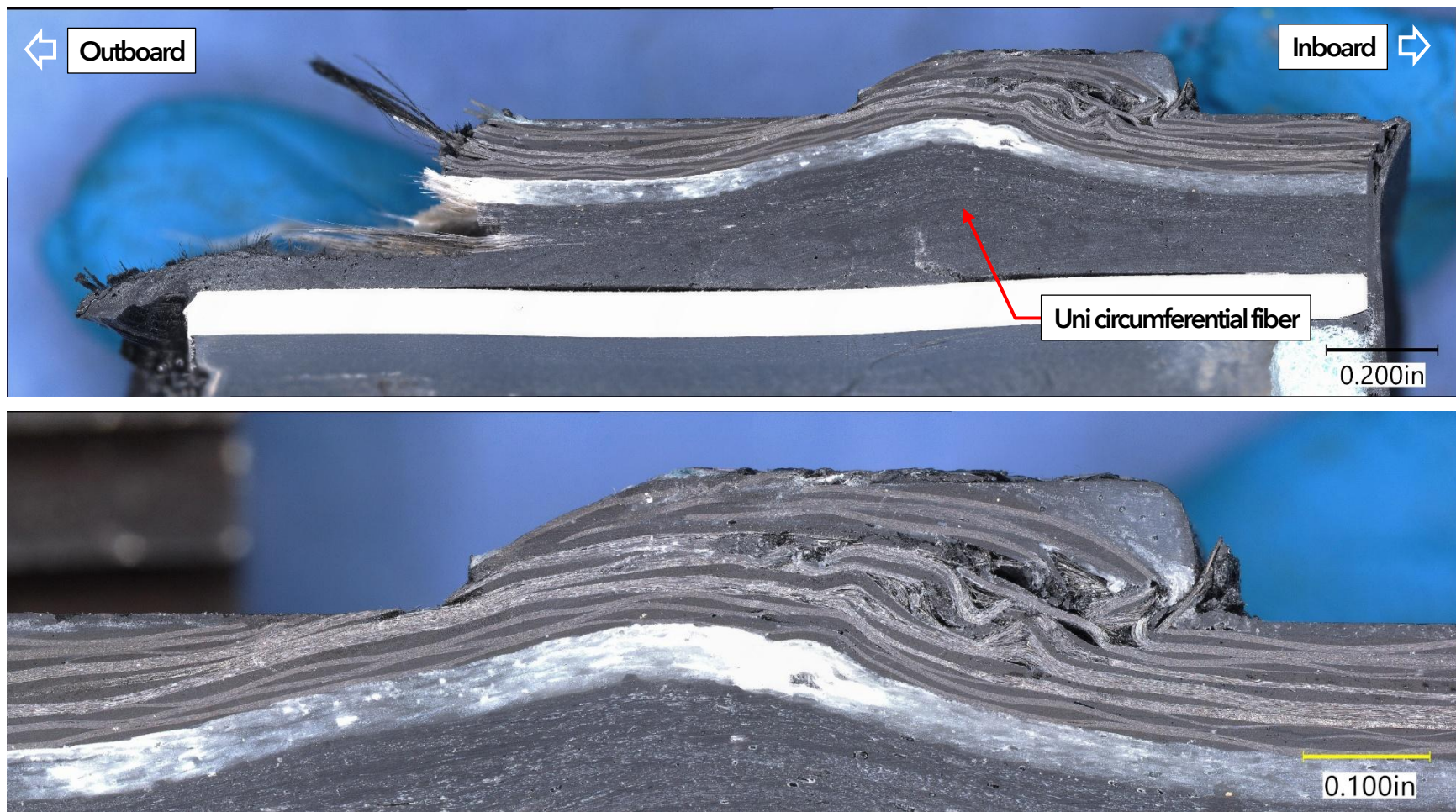


Figure 15. Top Image: Overview image of axial cross section. Lower image: Higher magnification image of axial displacement of collar feature.

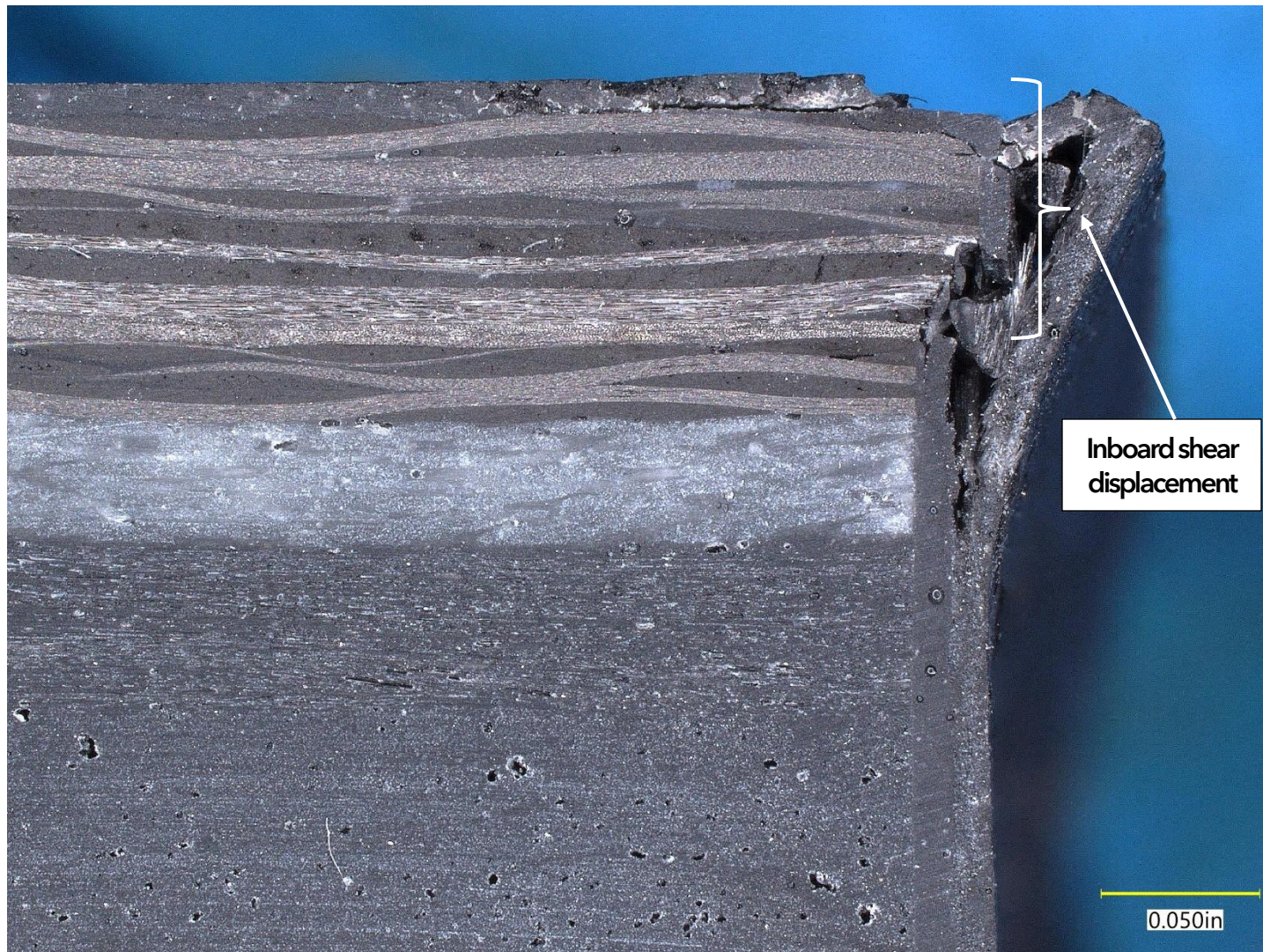


Figure 16. Image showing shear displacement of blade plies.

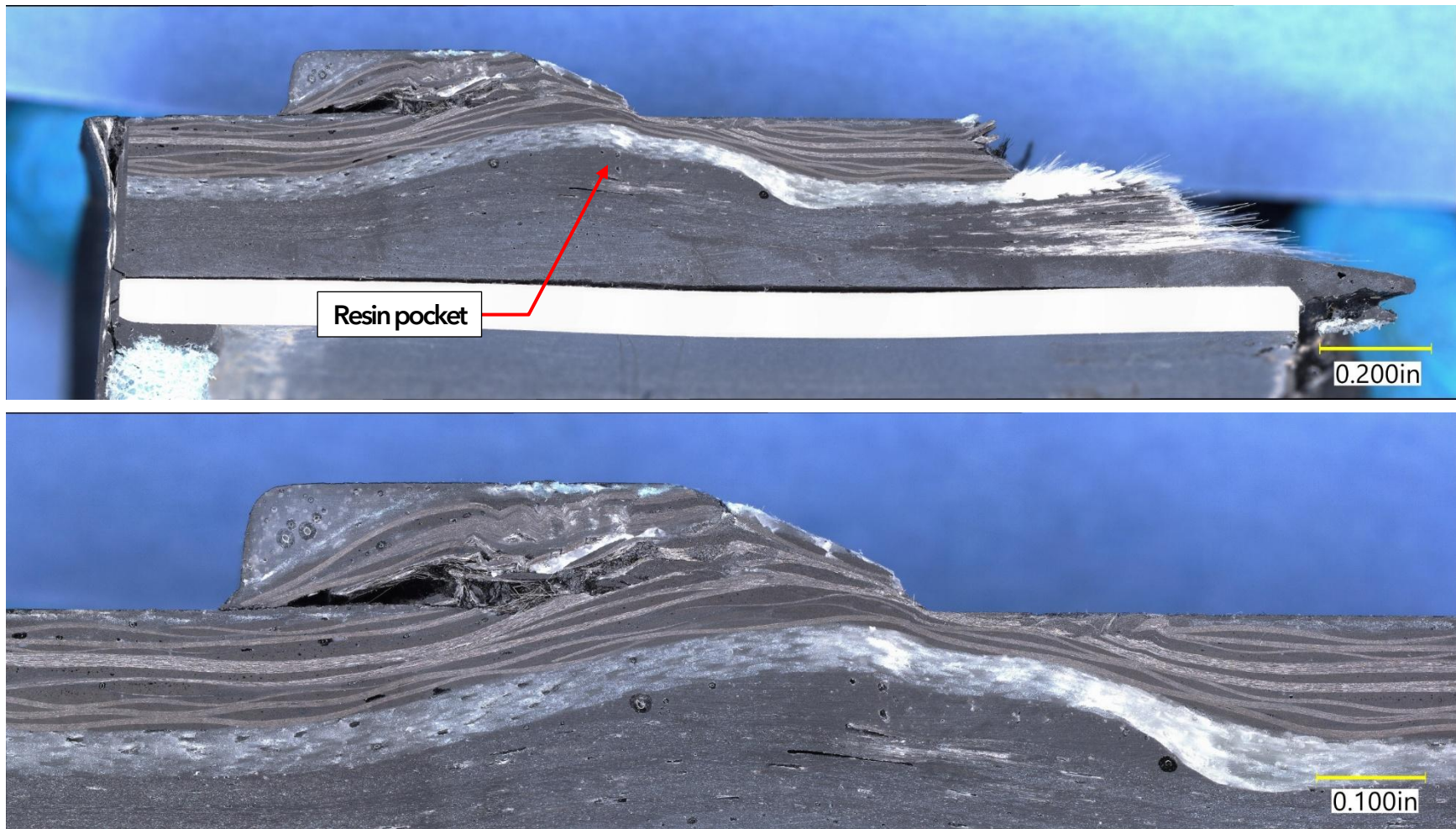


Figure 17. Top Image: Overview image of axial cross section. Lower image: Higher magnification image of axial displacement of collar feature.

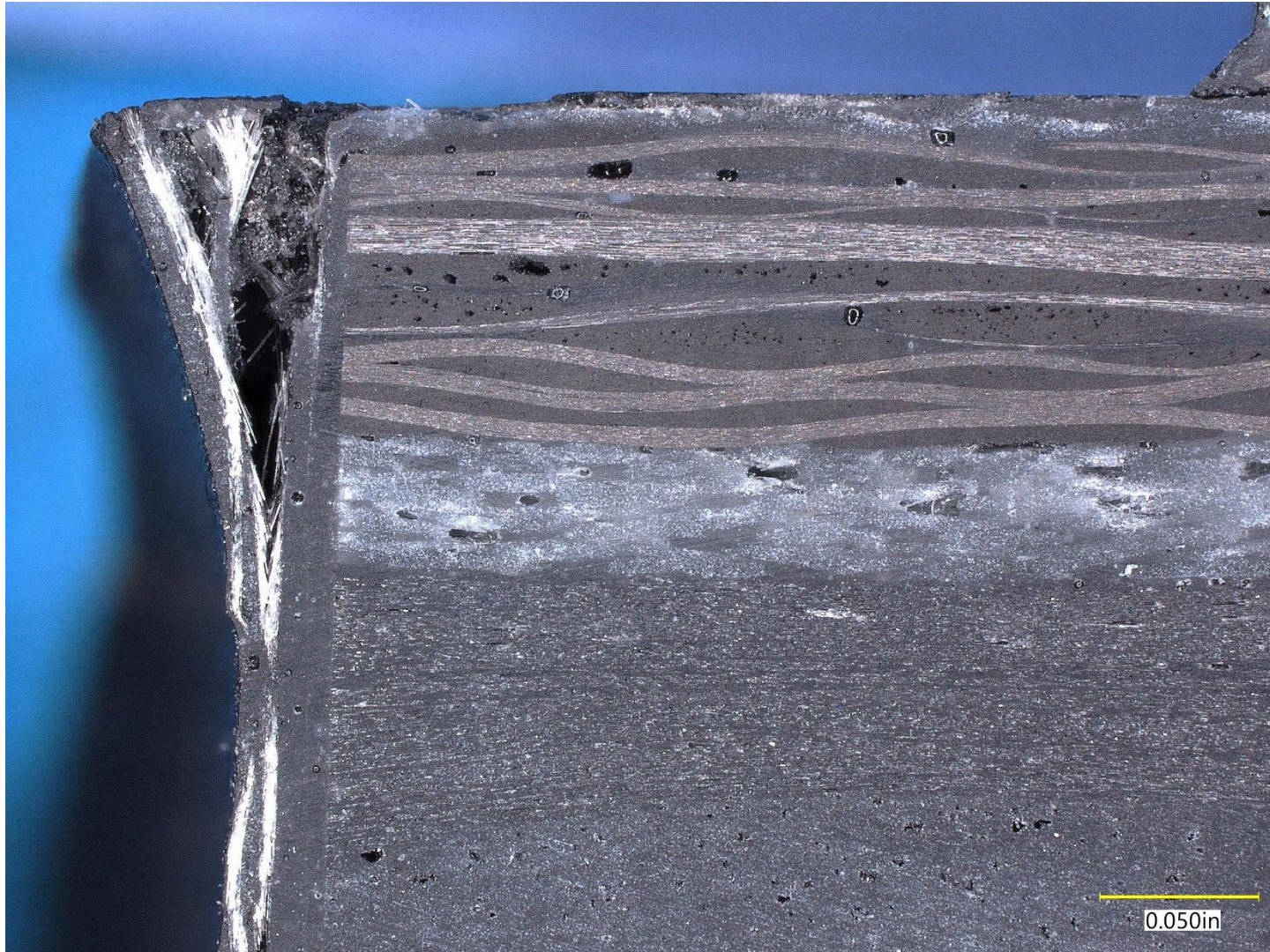


Figure 18. Image showing no apparent axial shear displacement of outer plies.

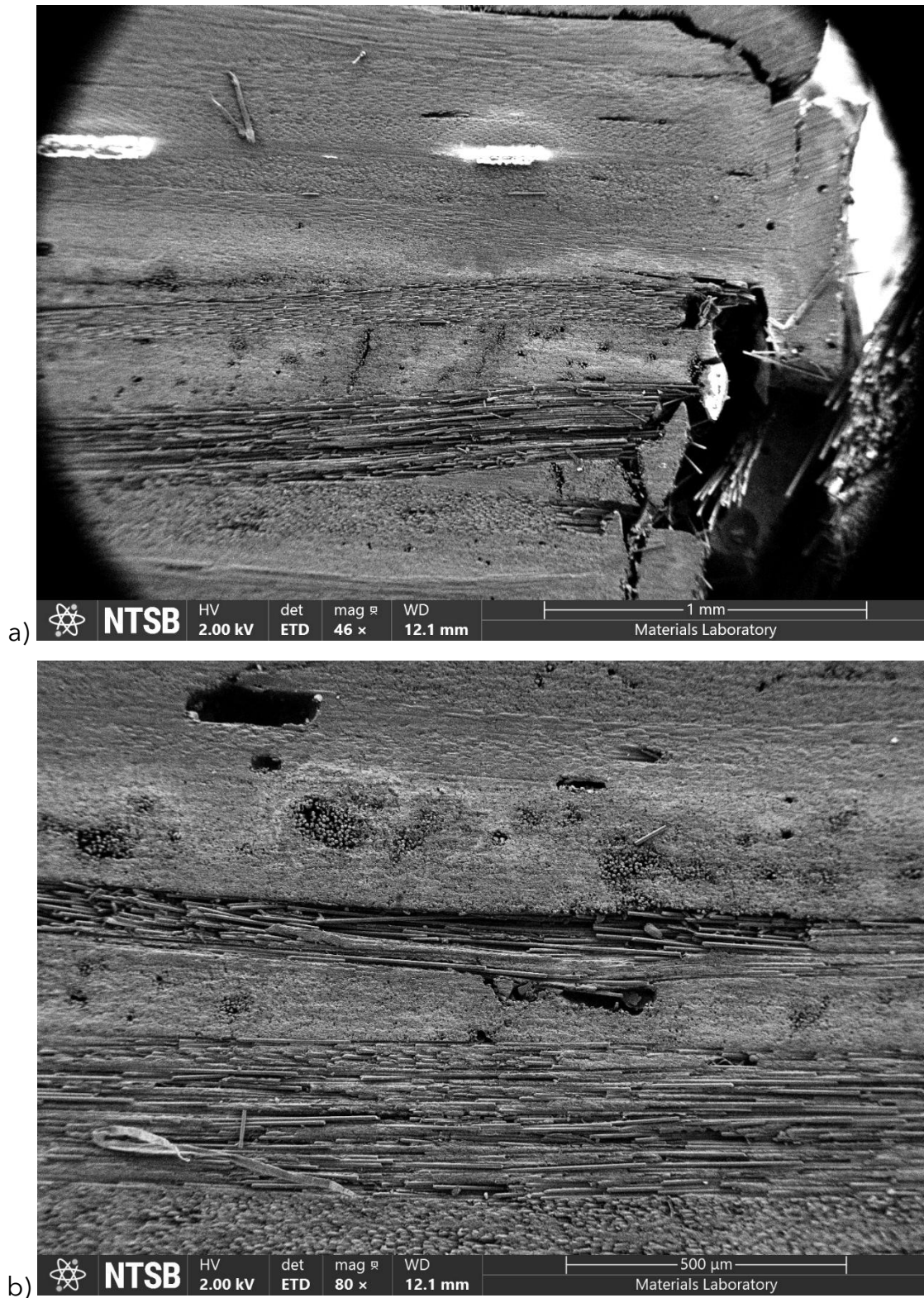


Figure 19. Scanning electron microscope images of blade root cross section: a) overview image; b) higher magnification image showing axial fiber pullout; and

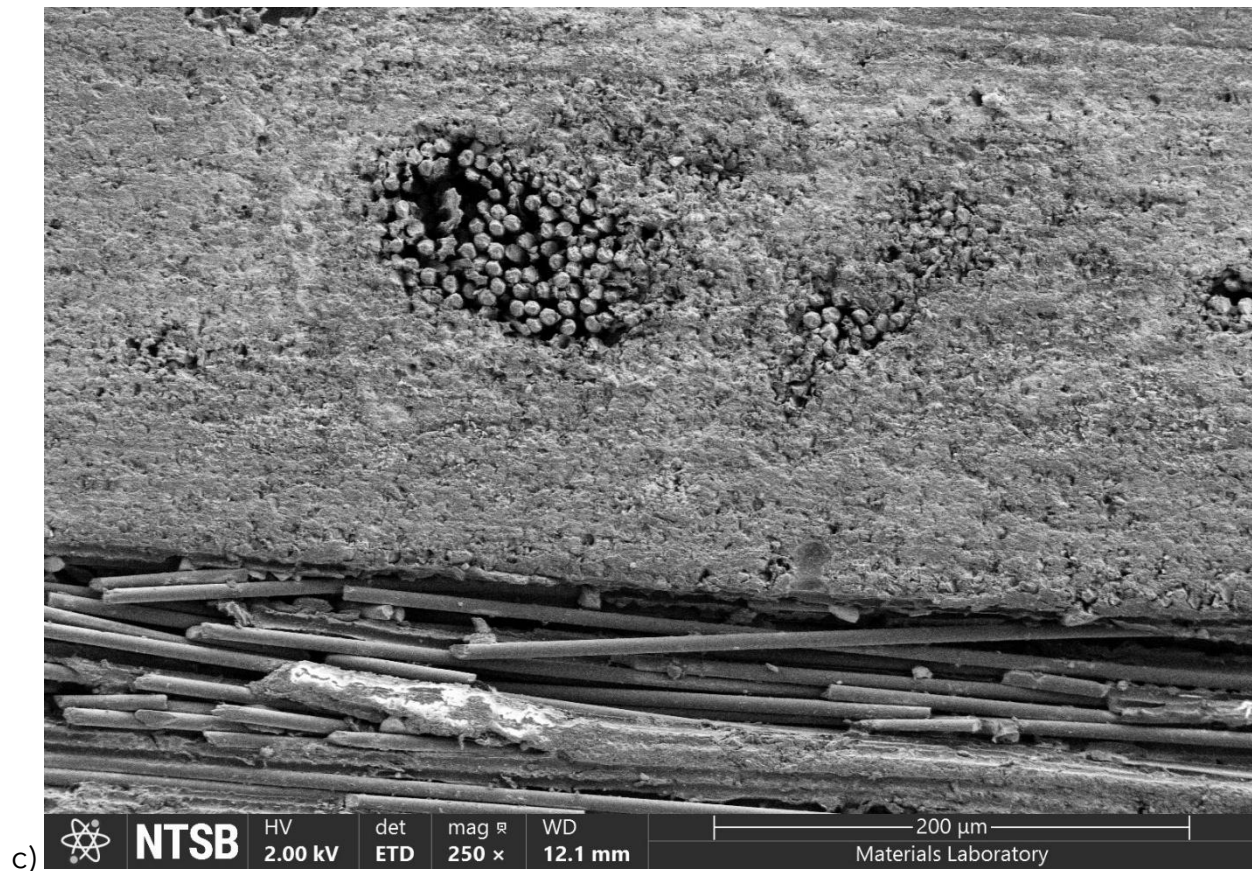


Figure 19 (cont.). c) higher magnification image showing dry fiber regions.