

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

August 10, 2021



MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-028

A. ACCIDENT INFORMATION

Place : Kalapana, Hawaii
Date : March 5, 2020
Vehicle : Airbus Helicopter EC130-B4, N11QK
NTSB No. : ANC20LA028
Investigator : Brice Banning, ASI-ANC

B. COMPONENTS EXAMINED

One (1) fenestron tail rotor blade fractured in two pieces and nine (9) intact fenestron tail rotor blades; P/N: 350A33-302-04; S/N: see below; TSN: 4,410.9 hr.

C. DETAILS OF THE EXAMINATION

1. Description of hardware

Ten fenestron tail rotor blades were submitted to the NTSB Materials Laboratory for examination as shown below in figure 1. One of the blades was fractured at the root end of the airfoil while the other nine blades were intact. The blades were numbered 1 through 10 with number 1 being the fractured blade. An in-the-field photo of the fenestron is shown in figure 2, with the blades numbered clockwise around the hub as viewed from the left side of the aircraft.

The tail rotor blades are part of the fenestron, a ducted fan that is integral to the tail unit of the helicopter and used to counteract the torque of the main rotor. The blades are spaced at variable angles around the hub. As can be seen in figure 2, blades 1 and 6 each had the largest angular separation from their adjacent blades. The pitch of the blades is controlled by means of a pitch change bearing, indicated in figures 2 and 3 for blade number 1. Actuating the pitch change bearing causes the blades to rotate about the outer and inner rotation bearings, both of which are indicated in figure 3. From the blade platform to approximately 15 mm above the platform, the airfoil cuts back from the trailing edge resulting in a flat aft rib face, as indicated in the schematic in figure 4. A drain hole passage is drilled into the aft rib face at an approximately 20° angle such that it connects to the inner cavity of the blade root as indicated in figure 4. The outlet of the drain hole is subjected to a breaking angle touch-up where it meets the aft rib face.

The ten blades were visually examined for part number and serial number information. All blades were marked as part number: 350A333002.02 04. The original

“.02” part number suffix had been lined out with an engraver and the “.04” had been engraved beneath. This was done in accordance with EASA AD 2018-182 and FAA AD 2020-12-09 which required operators to reidentify the parts following instructions outlined in Airbus Helicopter Alert Service Bulletin EC130-04A007. The rotor blade serial numbers are given in table 1 below:

Table 1: Blade information and findings from visual examination for cracks.

Blade Position	Serial number	Crack on suction side of drain hole	Crack on pressure side of drain hole
1	M8916	Fractured	Fractured
2	M9186	✓	
3	M9169		
4	M8882	✓	
5	M9170		
6	M9072		
7	M9179		
8	M8453		
9	M9195		
10	M8979	✓	

2. Visual examination of accident hardware

The ten blades were examined visually and with the aid of a stereomicroscope. Blade number 1 was fractured near the root end of the airfoil in the flat rib face section at the level of the drain hole outlet. Photographs of the two fracture faces, the root side and the airfoil side, are shown in figures 5a and b, respectively. The fracture surfaces were comparatively flat toward the trailing edge of the blade, transitioning to 45° inclined fractures toward the leading edge. Visual examination of the flat fracture region revealed curvilinear crack progression marks that were consistent with a progressive fracture that originated at or near the drain hole at the aft rib face. The chordwise linear fraction and area fraction of the flat fracture region were measured on the root-side fracture surface using images taken on a digital optical microscope, as shown in figures 6a and 6b, respectively. The chordwise linear fraction was approximately 0.62 and the area fraction was approximately 0.66. Later, the airfoil-side fracture surface was sent to Airbus Helicopter for examination and an independent evaluation resulted in a 0.66 linear fraction and 0.68 area fraction for the flat fracture region.

The flat fracture region initially rose at an incline as it progressed chordwise from the aft rib face toward the leading edge. On the suction side, the inclination was approximately 9° for the first 14 mm, after which it continued parallel to the platform to the onset of the overstress region. On the pressure side, the inclination was approximately 5.5° from the aft rib face to the onset of the overstress region. Higher magnification examination of the fracture surface around the drain hole revealed crack progression marks on either side of the hole, consistent with two separate origins, one on either side of the drain hole at or near the aft rib face, as indicated in figure 7a.

Visual examination of the aft rib face revealed a morphological anomaly below and to the pressure side of the drain hole, as shown in figure 7b. According to the engineering drawing, the aft rib face is orthogonal to the blade platform and nominally orthogonal to the chordwise direction of airfoil. However, below and toward the pressure side of the drain hole, the face exhibited an off-orthogonal angled region, bringing the aft face on the pressure side of the drain hole forward. Measurements on the image in figure 7a indicated that as a result, there was an approximately 0.5 mm difference in the chordwise location of the aft face on the pressure and suction sides of the drain hole. In addition, within the off-angle region and below the drain hole, there was an approximately 0.50 mm by 0.15 mm region that protruded from the surrounding material, as indicated in figure 7b.

The nine intact blades were examined using a stereomicroscope with a focus on the area surrounding the drain hole. As shown in figures 8a – c and indicated in table 1, blades 2, 4, and 10 exhibited cracks on the suction side of the drain hole that progressed forward 2 mm to 3 mm. There were no visually identifiable cracks on the pressure side of the drain hole on any of the intact blades. Foreign debris was observed in the number 2 blade drain hole passage, as shown in figure 8d, but not in any other intact blade.

The nine intact blades and the airfoil-end of the number 1 blade were sent to an Airbus Helicopter laboratory for further examination.

3. X-ray, 3D scanning, and dimensional measurements

Prior to cutting the fracture surface from the blade root, the piece was sent to an external lab for X-ray computed tomography (X-ray CT) scanning of the blade root in the vicinity of the drain hole to measure the drain hole diameter, inclination angle, and to check for any internal obstructions. The report is included in Appendix A. The drain hole diameter and inclination angle were 1.50 mm and 20.07°, respectively, in accordance with the requirements on the engineering drawing. Deposits were observed on some regions of the drain hole passage, but no obstructions were observed. Later, a fiber optic light was placed inside the blade root cavity and the illumination could be seen at the drain hole outlet, as shown in figure 9, consistent with an open drain hole.

A 3-dimensional model of the blade root piece was constructed using a table-top coordinate measurement machine (CMM) with single point precision of 0.028 mm and equipped with a laser scanner attachment. The point spacing in each laser scan was set to 0.1 mm and the piece was scanned from five different orientations. The resulting 3D point cloud objects were aligned to one another using a least-squares algorithm and merged to produce a single point cloud object. The point cloud object was then converted to a solid mesh, as shown in figure 10.

Several dimensional attributes of the blade root were measured using a QVI SparkMVP 600 dimensional measuring system (Quality Vision International, Rochester, NY) equipped with a single point touch probe. The system had an X, Y, and Z scale resolution of 0.5 μ m and an X/Y area accuracy of $(3.5 + 8L/1000)$ μ m, where L is the measurement length in mm. The diameters of the blade root pin hole measured 15.025 mm and 15.521 mm on the suction side and pressure side of the blade,

respectively. The longitudinal distance from the center of the pin hole to the underside of the outer bearing, indicated as L_1 in figure 4, was measured on the suction and pressure sides of the blade as 10.59 mm and 10.58 mm. Finally, the longitudinal distance from the center of the pin hole to the underside of the inner bearing, indicated as L_2 in figure 4, was measured once as 54.49 mm. All dimensional attributes were in accordance with the requirements on the engineering drawing.

The height of the drain hole outlet above the blade platform and drain hole offset in the rib thickness direction were measured using the 3-dimensional mesh generated by laser scanning, as shown in figures 11a and 11b. The exit height was measured by fitting a cylinder to the drain hole and a plane to the blade platform (see figure 11a). A second plane was constructed that contained the drain hole cylindrical axis and was orthogonal to the blade root platform. A third plane was constructed that was orthogonal to both planes. This third plane was nominally parallel to the aft rib face and was positioned to be coincident with it. The drain hole cylindrical axis was then projected to this plane and its height above the blade platform was calculated to be 3.8 mm, in accordance with the engineering drawing. Using the same fitted and constructed objects, the center offset of the drain hole was determined by picking points on each edge of the rib face (suction and pressure side edges) and measuring the distance of each point from the plane that was constructed through the drain hole axis (see figure 11b). The distance on the pressure side (left side in figure 11b) was 0.5 mm and the distance on the suction side (right side in figure 11b) was 0.9 mm, for a calculated center offset of 0.2 mm, at the acceptance limit on the engineering drawing.

The offset calculated from the 3D scan data was similar in magnitude to the point spacing of the scan data (approximately 0.1 mm spacing between scan points and 0.2 mm for the measured offset). Therefore, the offset was also measured on an image acquired by a digital optical microscope and with a camera and lighting system that was integrated with the SparkMVP. The measured offset on the digital microscope image was measured to be 0.23 mm and the offset values from the SparkMVP, measured twice, were 0.242 mm and 0.205 mm.

4. Examination of fracture surface

The fracture surface in its as-received condition exhibited dark deposits as shown in figure 5a, particularly in the vicinity of the drain hole (compare to the fracture surface after cleaning, shown in figure 6a). Prior to cleaning, acetate tape was used to lift some of the debris from the fracture surface for chemical analysis. The tape was softened with acetone, pressed against the fracture surface, allowed to harden, and then mechanically removed. The replica was sputter-coated with a gold/palladium alloy and examined in a scanning electron microscope (SEM) equipped with an energy dispersive x-ray spectrometer (EDS). Some regions of the tape consisted predominantly of magnesium (Mg), silicon (Si), and aluminum (Al) oxides, as shown in figure 12a. Other regions also exhibited an abundance of sodium (Na), calcium (Ca), chlorine (Cl), and sulfur (S), as shown in figure 12b.

The fracture surface was then prepared and cleaned for examination in the SEM. The blade root was sectioned just below the outer bearing (see figure 3). The resulting blade root piece was then submerged in an acetone-filled beaker and placed in a sonicating bath. Acetate replica tape was used to lift additional debris from the fracture, followed by a final soak in acetone.

The fracture features were then examined in the SEM. Mosaic SEM images of the fracture on the suction side and pressure side of the drain hole, where it intersected the aft rib face, are shown in figures 13a and 14a, respectively. Much of the fracture surface in this region exhibited contact damage, oxidation, and surface debris. However, some regions exhibited identifiable fracture features such as the region shown in figure 13b. The region exhibited a flat feathery appearance and crack progression marks that were perpendicular to the direction of crack growth (indicated by the yellow arrow in the figure). Other areas exhibited a similar appearance and yellow arrows have been drawn on figures 13a and 14a to indicate the direction of crack growth on either side of the drain hole. The features indicated that the failure started from two separate origins, one on either side of the drain hole at or near its intersection with the aft rib face. The origin areas were examined at higher magnifications, as shown in figures 13c and 14b, but the surfaces had been damaged and there were no identifiable features. Further from the origin, variable-spaced fatigue striations could be observed as shown in figure 14d, consistent with crack growth due to high-cycle fatigue.

The SEM mosaic images were used to measure the chamfer angles in the fracture plane where the drain hole met the aft rib face. On the suction side the angle measured approximately 45° while on the pressure side, the angle measured approximately 107°.

5. Examination of blade root surfaces

The blade root surfaces along and around the drain hole were examined by SEM and EDS. A low magnification image of the drain hole at the aft rib face is shown in figure 15. The approximate position and width of the rib at the root is indicated in the figure. As previously discussed, the drain hole and rib face were not centered in the thickness direction, with the drain hole located toward the pressure side. On the suction side, the rib face extended vertically up to the fracture. Below the hole and on the pressure side, the surface had an off-angle profile that moved the rib face forward (toward the leading edge). On the pressure side and within this angled region, there were two contour step changes below the fracture as indicated in figure 15.

Figure 16a shows a backscatter electron image of the region below the drain hole at higher magnification. The piece of protruding material below the hole appeared to be coplanar with the original rib face contour and the material on either side of appeared to be displaced forward. Deformed material was observed at several locations along the drain hole/rib face edge, as indicated in figures 16a and 16b. Much of the off-angle region exhibited a dark oxidized/pitted appearance, similar to that of the drain hole, as shown in figures 16a and 16b, respectively. The protruding material and the far-field rib surface exhibited lateral grinding/sanding marks and a mixture of light and dark contrast regions. Differences in the rib face surface condition were observed on the suction and pressure

sides of the drain hole as shown in figures 16c and 16d, with the suction side exhibiting grinding/sanding features and the pressure side exhibiting the oxidized/pitted features.

Variations in backscatter images were also observed along the pressure and suction side airfoil surfaces. Both surfaces were examined by SEM just below the fracture starting at the aft rib face and proceeding forward. Pen markings were placed on each surface at 2mm intervals starting at the rib and proceeding forward as shown in figure 17. From the aft rib to approximately 2 mm, the surface exhibited an oxidized/pitted appearance, similar to that noted previously, and backscatter images exhibited both dark and bright regions. Examples for the pressure side and suction side 2 mm forward of the rib face are shown in figures 18a and 19a, respectively. At approximately 4 mm, the surface began to exhibit scratch marks and by 12 mm, the transition to a scratched/abraded texture was nominally complete. Examples for the pressure side and suction side 20 mm forward of the rib face are shown in figures 18b and 19b, respectively.

The composition of the dark contrast oxidized/pitted regions and the bright contrast scratched/abraded regions were examined in the SEM using EDS. Spectra for the drain hole passage (see figure 16b), material below the drain hole (figure 16b), and a spot on the pressure side of the blade (figure 15) are shown in figures 20a – c, respectively. These regions all exhibited the oxidized/pitted appearance and the dark backscatter contrast. Spectra for a scratched region on the suction side of the rib face (figure 16c) and a scratched/abraded region on the suction side of the blade are shown in figures 21a and b. These regions displayed bright backscatter contrast. The spectra in figure 20 all exhibited a chromium (Cr) peak and comparatively large oxygen peak. By comparison, neither of the spectra in figure 21 exhibited a chromium peak and the oxygen peak was comparatively less abundant. Information provided by Airbus Helicopter indicated that the blades are anodized using a process that contains chromic acid. In addition, the aircraft operator indicated that the blades were periodically cleaned using an abrasive scrubbing pad to remove accumulated dirt.

6. Pitch change bearing examination

The pitch change bearing (see figures 3 and 22) was examined with the aid of a stereomicroscope and exhibited wear on the bearing face. Images of the wear marks were taken using a digital optical microscope, as shown in figures 23a – d and indicated in figure 22, starting toward the suction side of the airfoil and proceeding clockwise (the blade viewed radially outward as in figure 22).¹ Wear marks were observed toward the suction and pressures sides of the bearing, as seen in figures 23a and c. The two wear marks extended around the bearing face and met near the trailing edge direction as seen in figure 23d.

The size and location of the wear marks were measured by making a silicone rubber replica of the pitch change bearing cavity. The replica was scored with a fiduciary mark as shown in figure 24, the excess rubber was cut from the replica, and the replica

¹ The flange in which the bearing is located is rotated relative to the chordwise direction of the airfoil. Therefore, references to airfoil orientation are approximate only.

was extruded from the cavity. The replica was viewed under a stereomicroscope and both the angular position of greatest wear mark width and the angular extent of each wear mark was indicated on the replica. Starting from the nominal trailing edge direction, the wear mark widths were greatest at 77.9° in the counterclockwise direction (toward the pressure side) and 72.4° in the clockwise direction (toward the suction side), as shown in figure 25a. The arc angle of each wear mark was approximately 160° in the counterclockwise direction and 139° in the clockwise direction, as shown in figure 25b.

The maximum wear depth at its greatest width and the distance of the maximum depth from the (radially inward) end face of the bearing were also measured off the replica as shown in figures 25c and 25d. In the counterclockwise direction (toward the pressure side), the maximum wear depth was approximately 0.25 mm at 2.65 mm from the bearing end face. In the clockwise direction (toward the suction side), the maximum wear depth was approximately 0.16 mm at 2.58 mm from the bearing end face.

Donald Kramer, Ph.D.
Sr. Materials Engineer

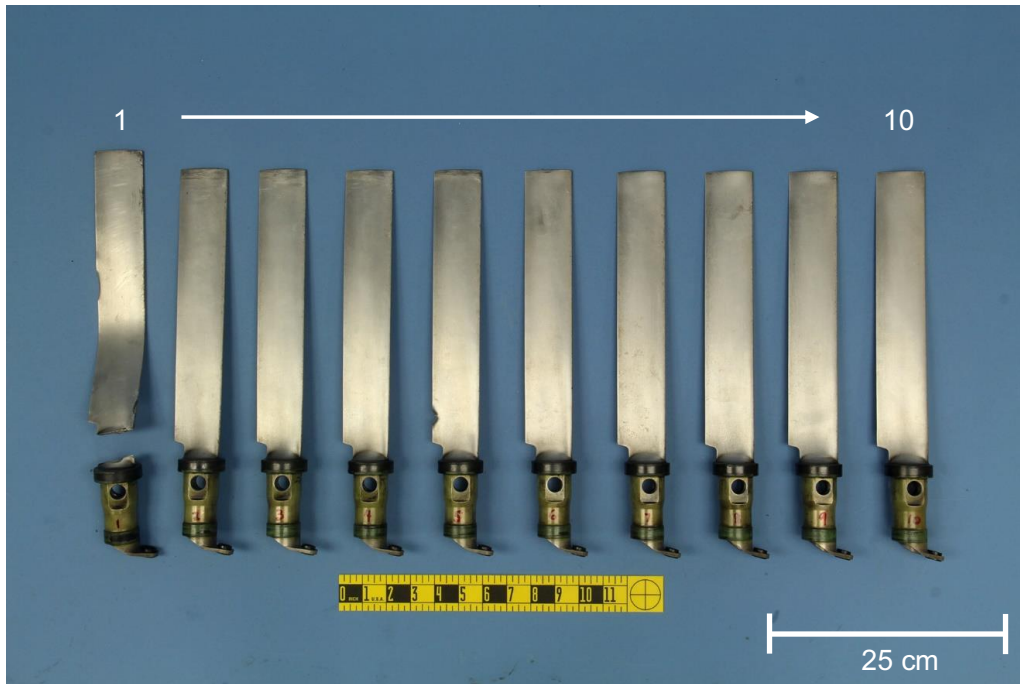


Figure 1: Image of the ten fenestron blades as received.

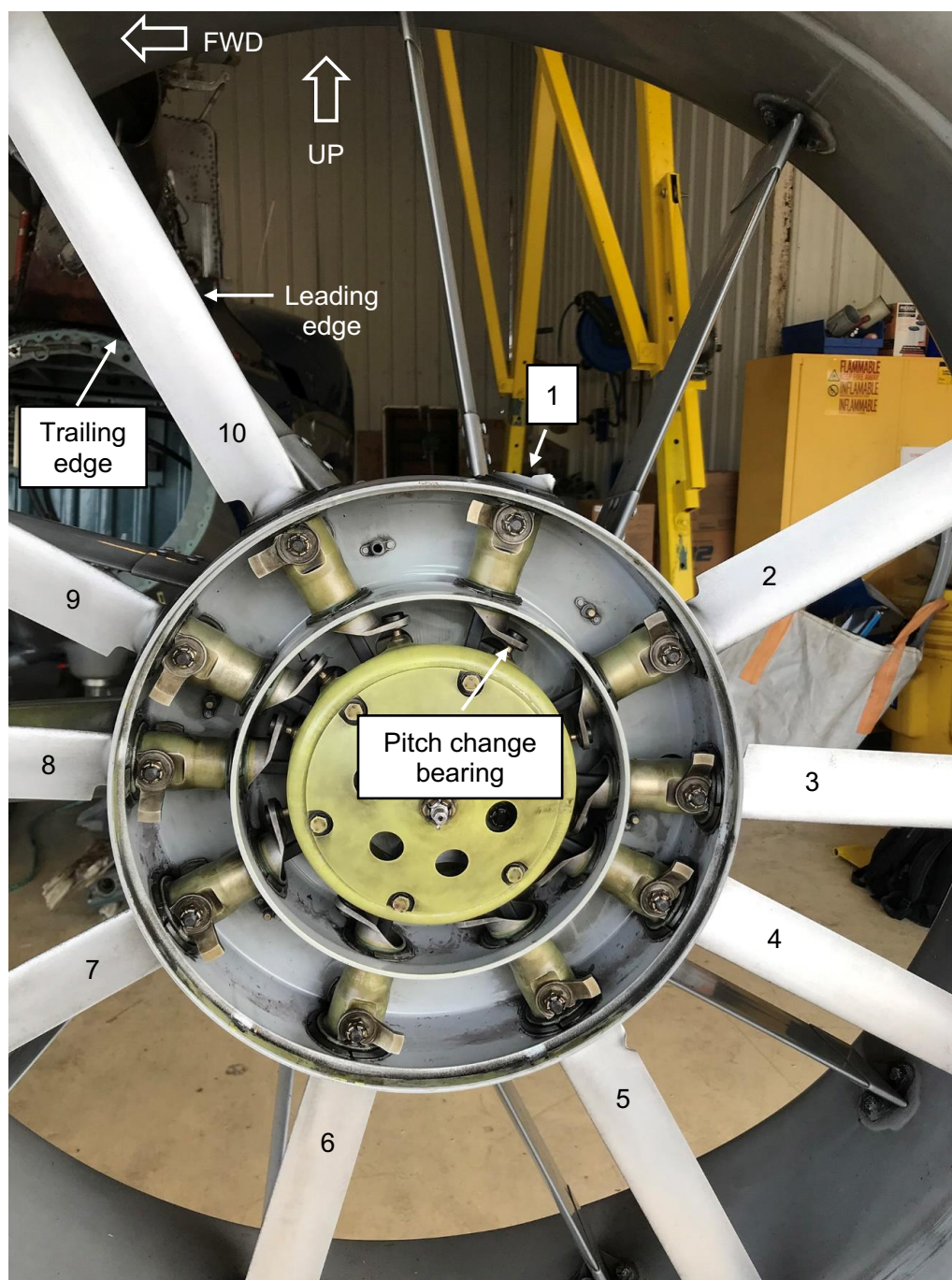


Figure 2: Image of the accident helicopter's fenestron showing the blade layout and the location on the hub of the fractured blade.

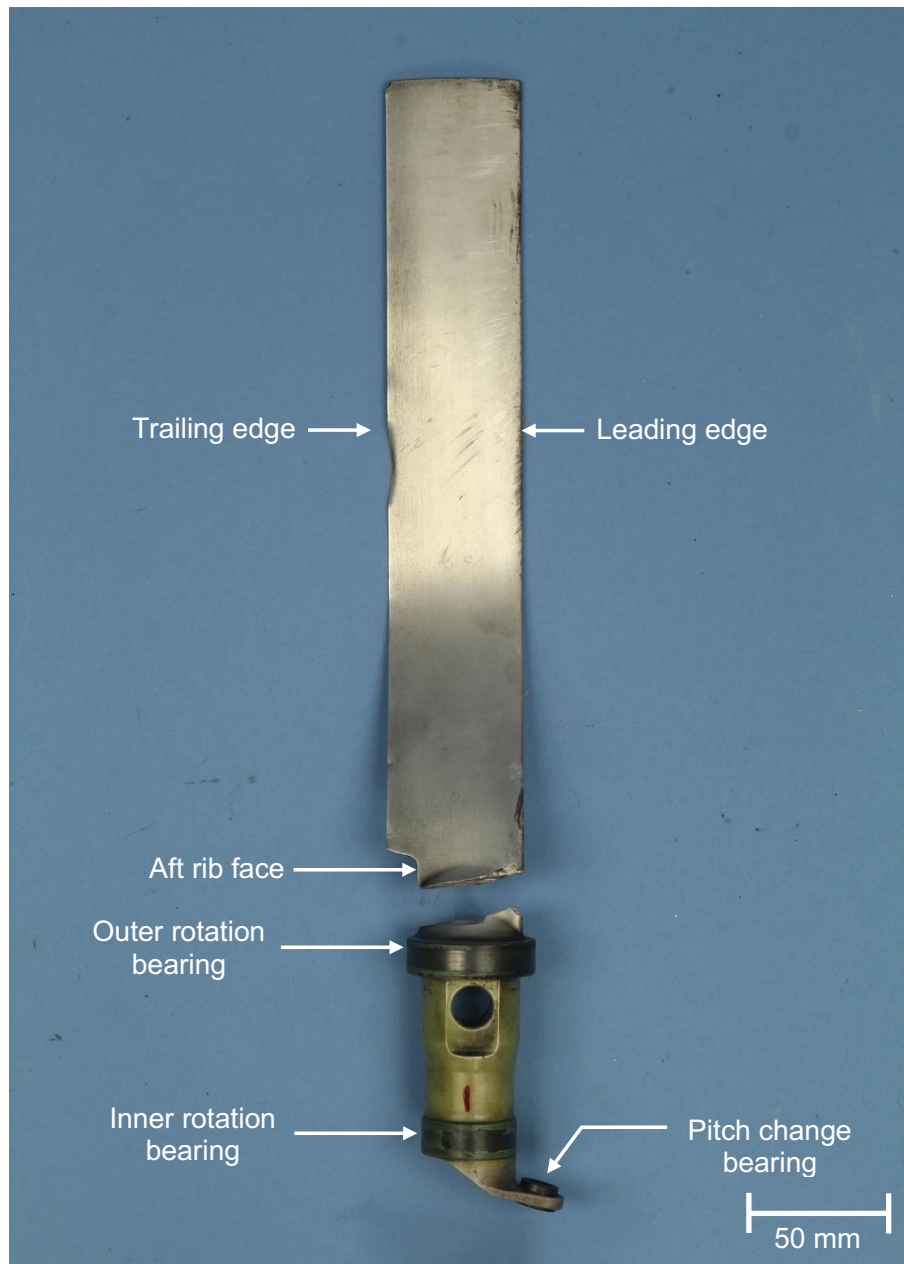


Figure 3: Image of fenestron blade number 1, fractured in two pieces.

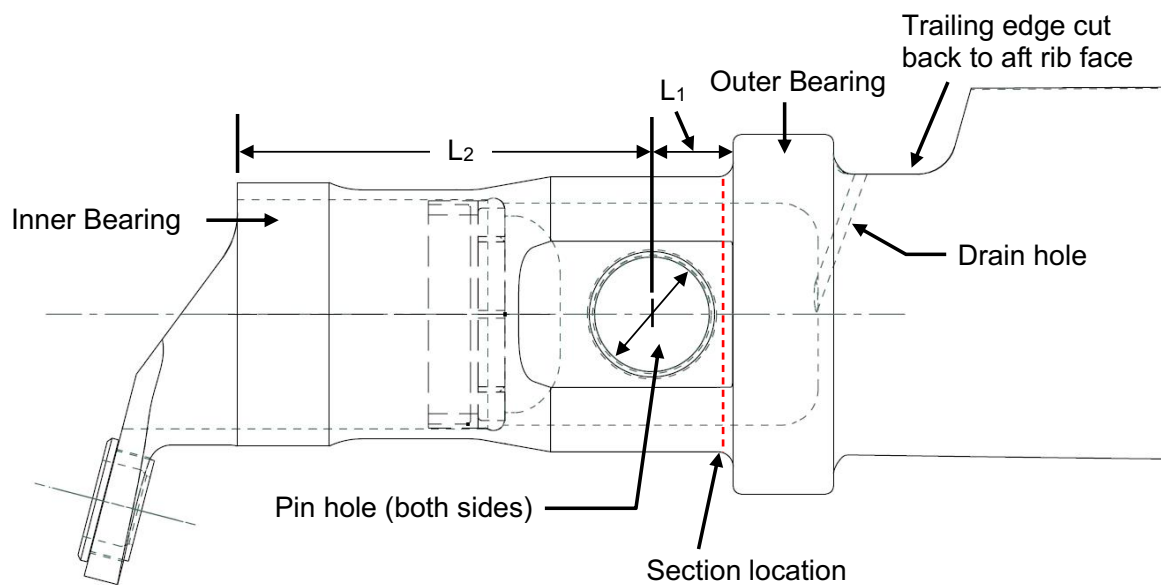


Figure 4: Illustration of the fenestron tail rotor blade root end showing dimensional attributes and features that were measured.

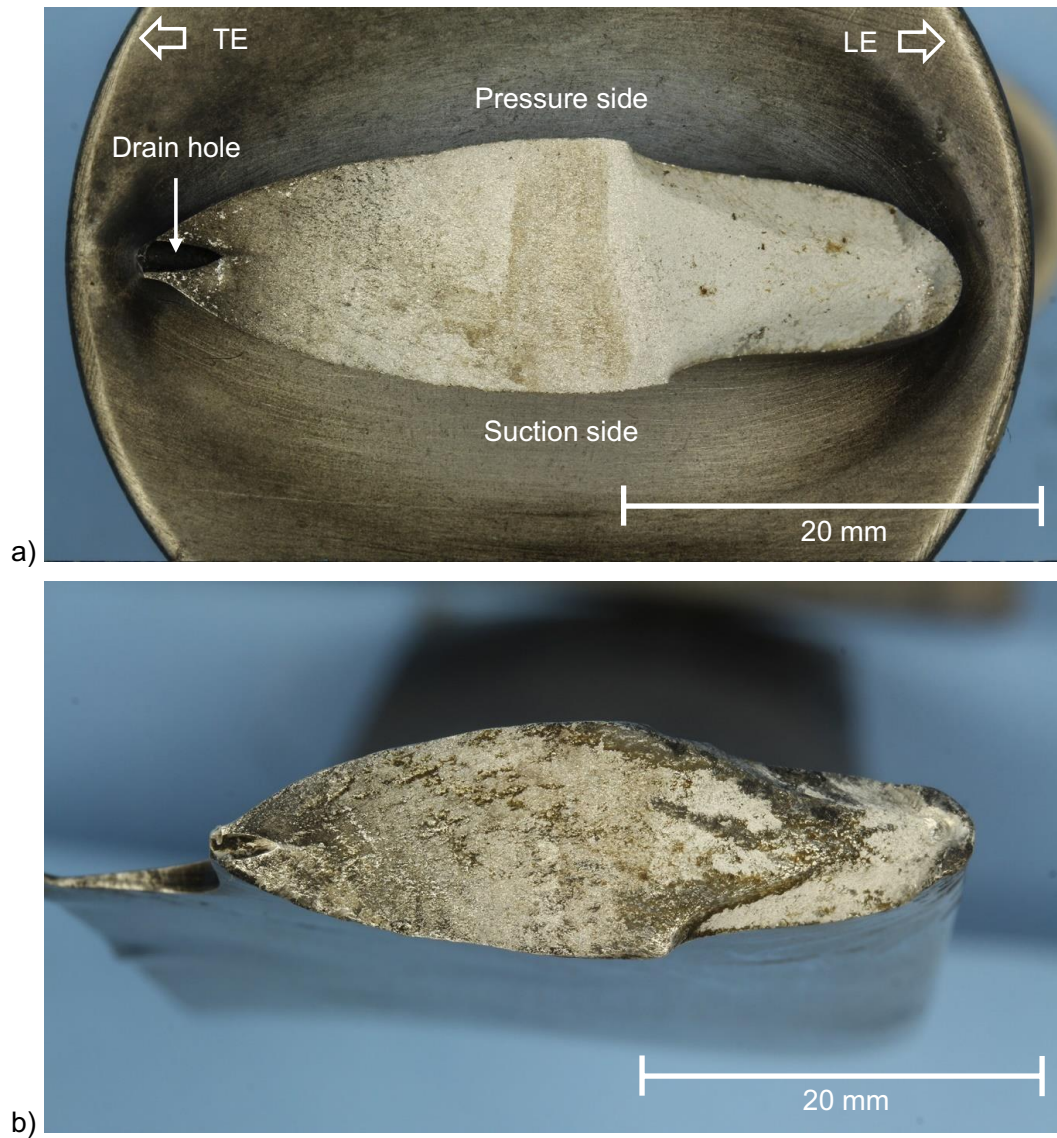


Figure 5: Images of the two fracture faces: a) root-side and b) airfoil-side.

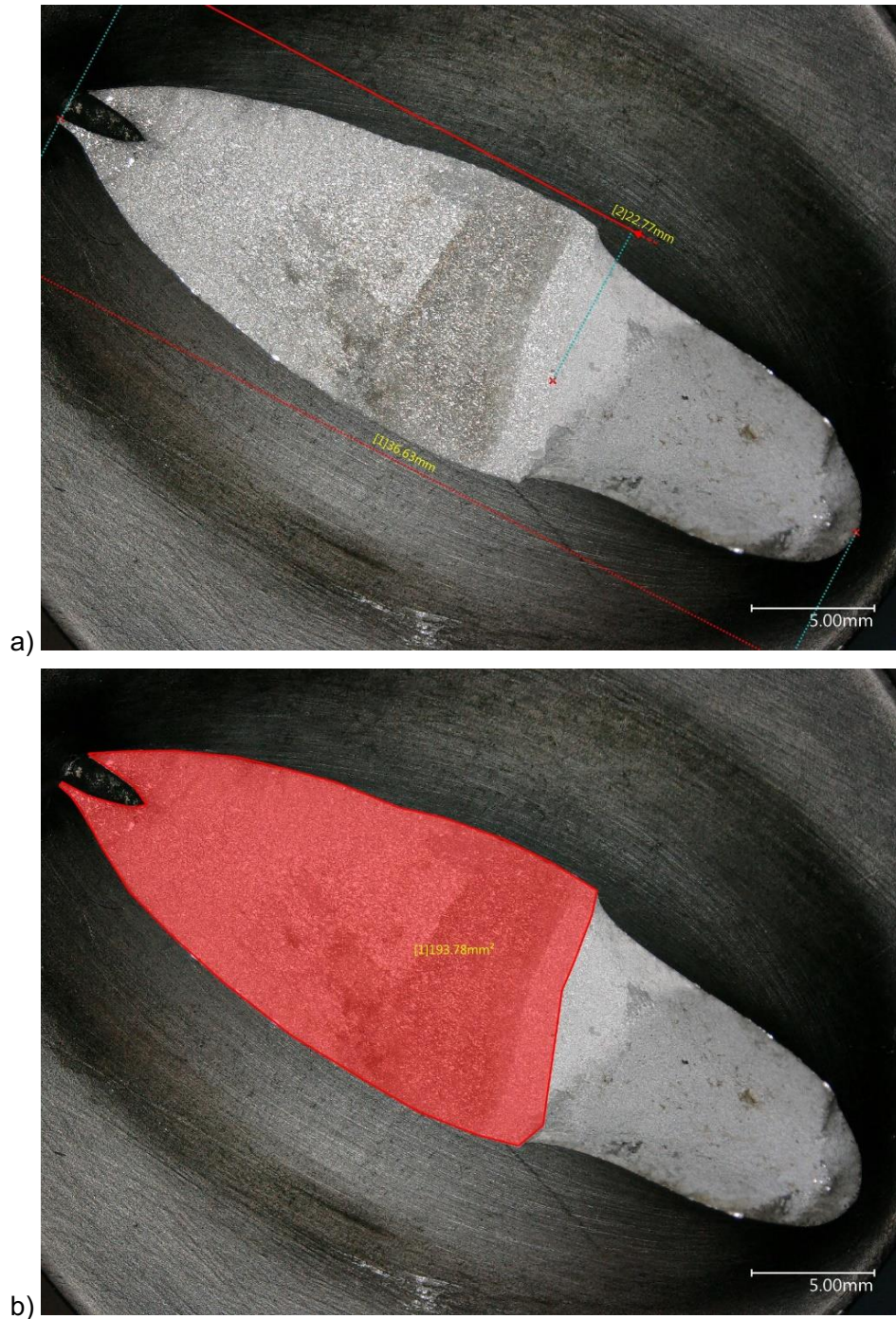


Figure 6: Digital optical microscope image used for measuring; a) linear chordwise fraction of flat fracture region and b) area fraction of flat fracture region.

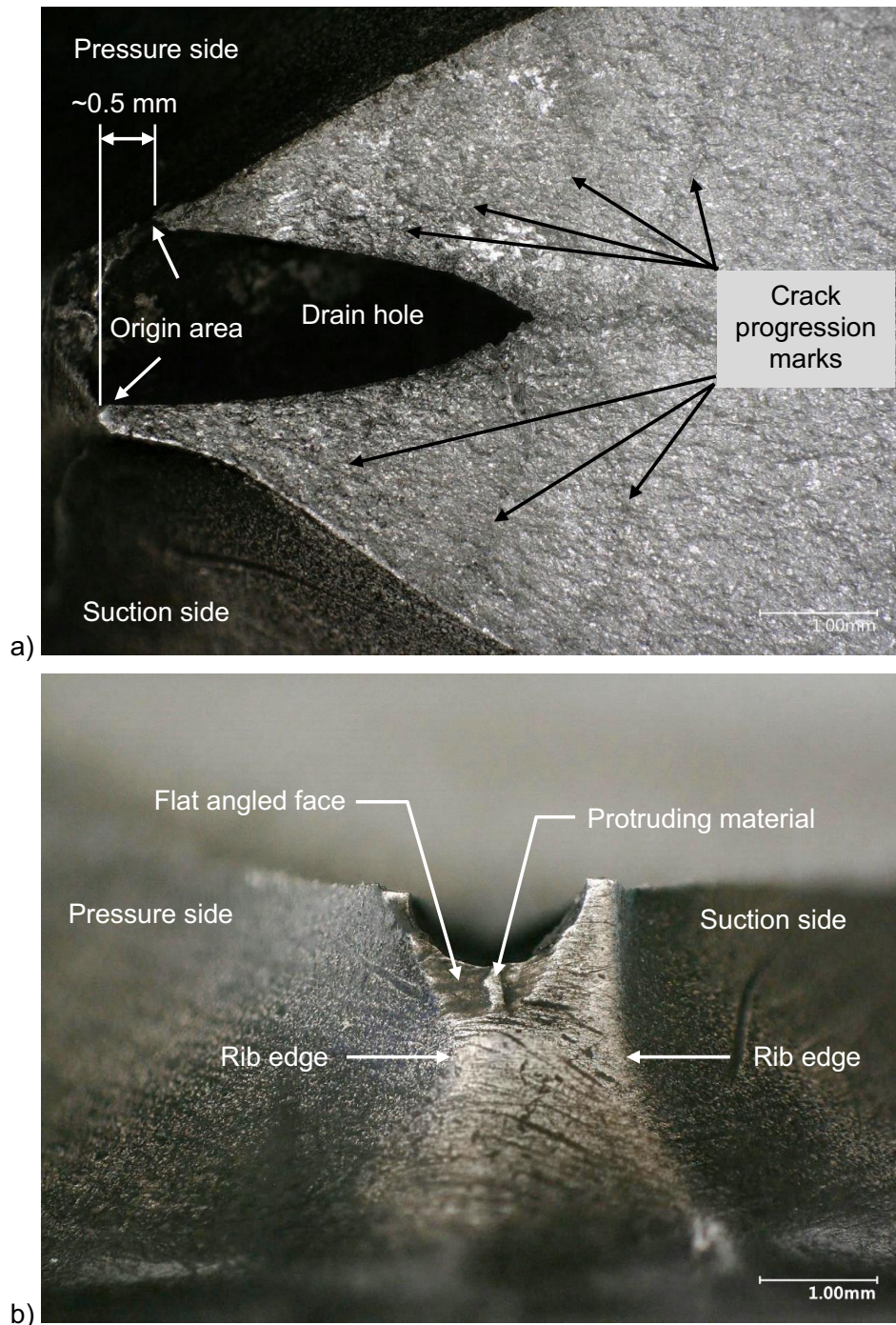


Figure 7: Digital microscope images of the fracture surface around the drain hole: a) plan view of the fracture surface; b) aft looking forward showing the lower portion of the drain hole and geometric anomaly around the hole.

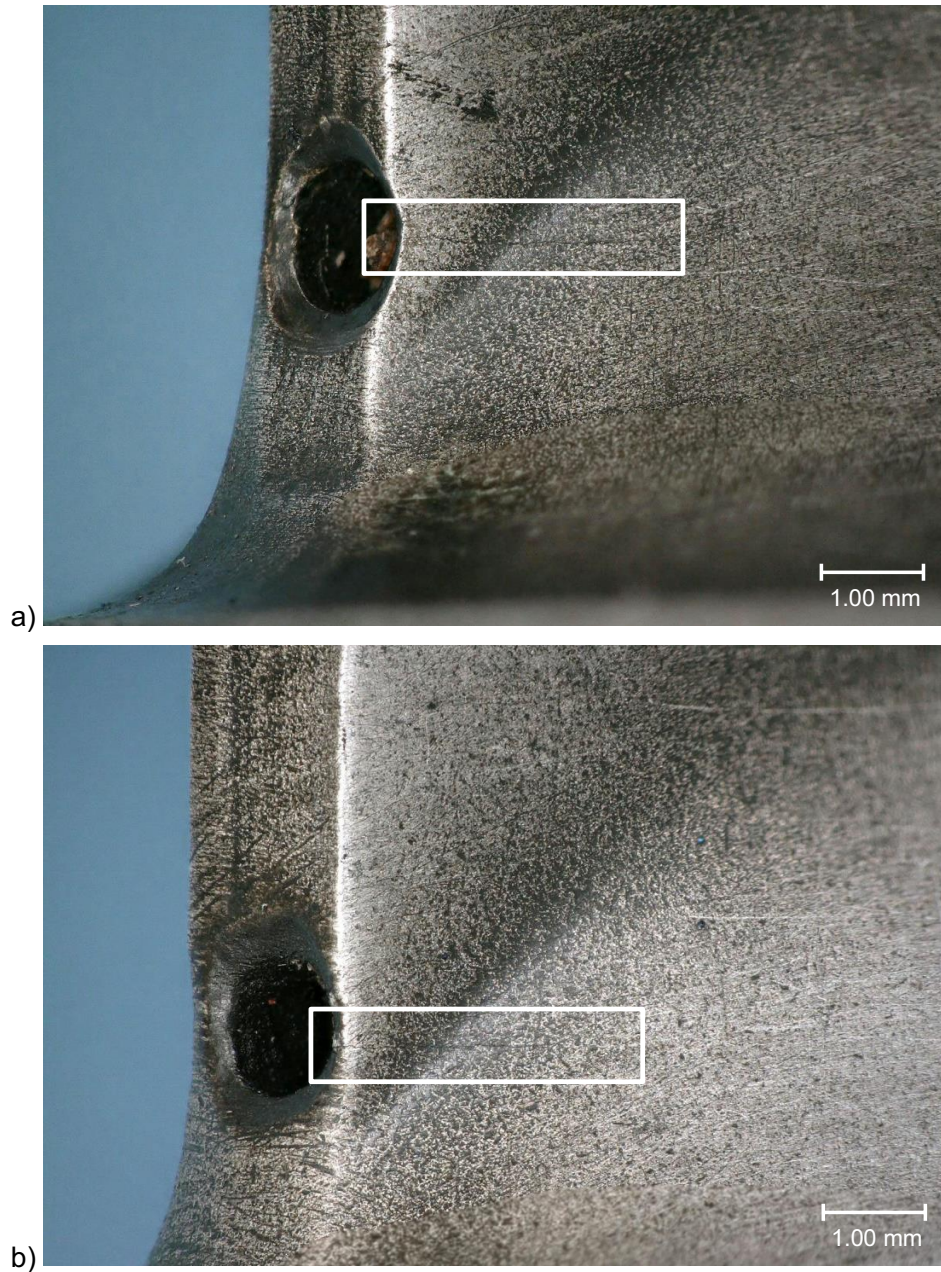


Figure 8: Images of additional cracks in other fenestron blades: a) crack on suction side of blade number 2; b) crack on suction side of blade number 4;

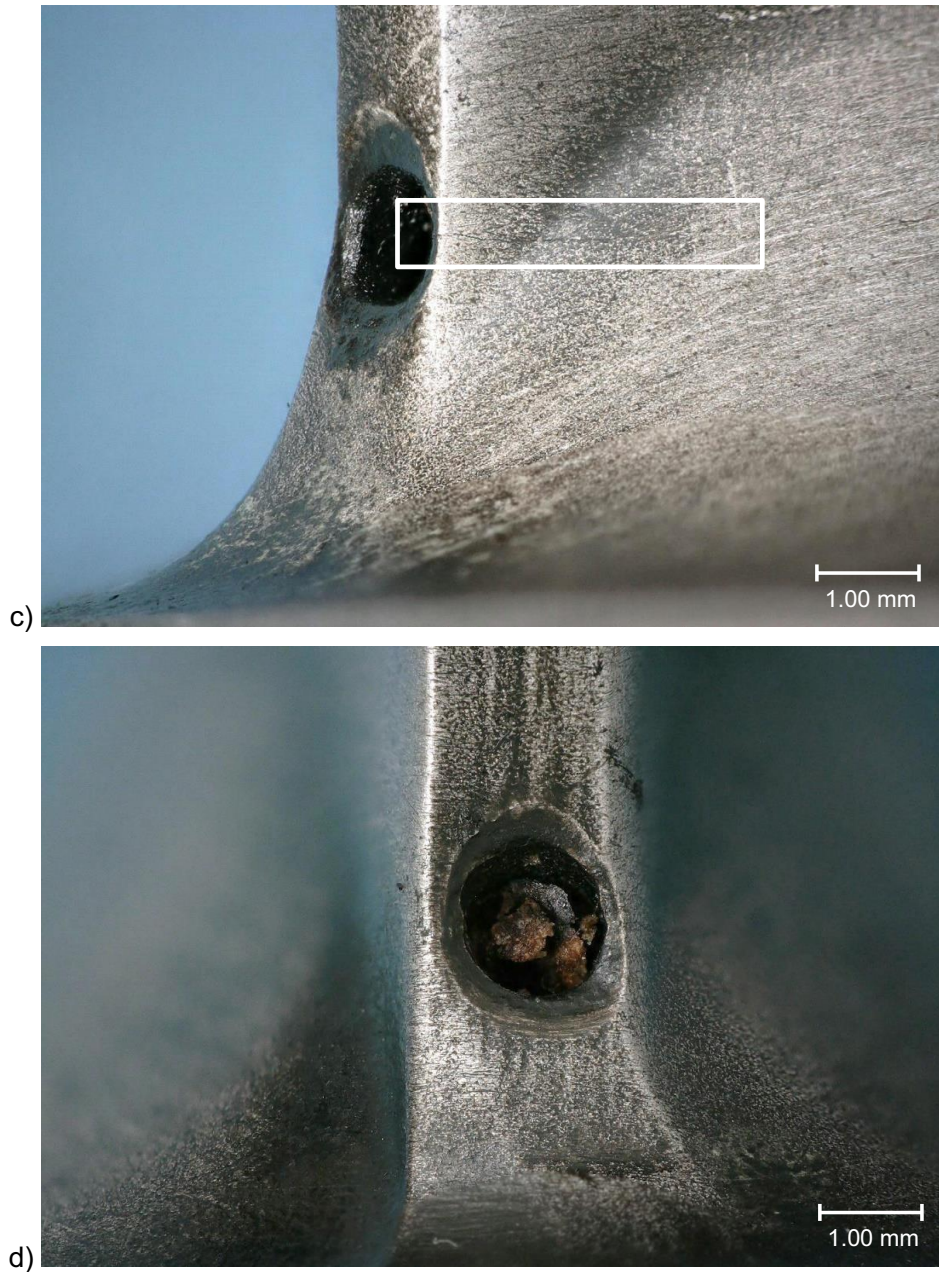


Figure 8 (cont.): c) crack on suction side of blade number 10; and d) image showing foreign debris in the drain hole of blade number 2.



Figure 9: View along the longitudinal axis of the drain hole. Backlighting from a fiber optic light is visible through the passage, consistent with no obstruction.

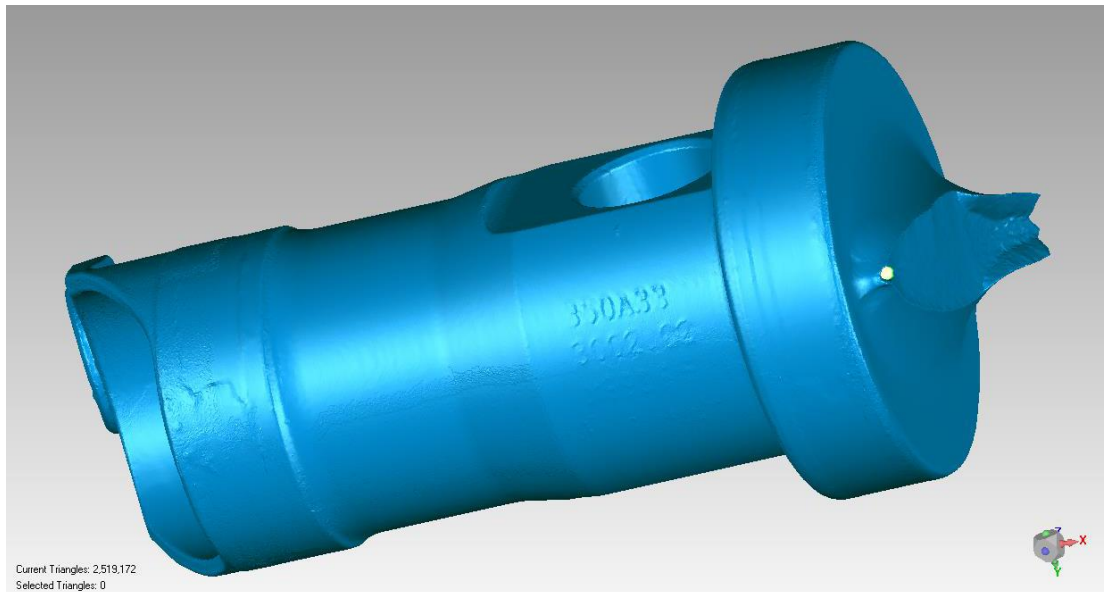


Figure 10: Surface mesh representation of the 3D laser-scanned blade root.

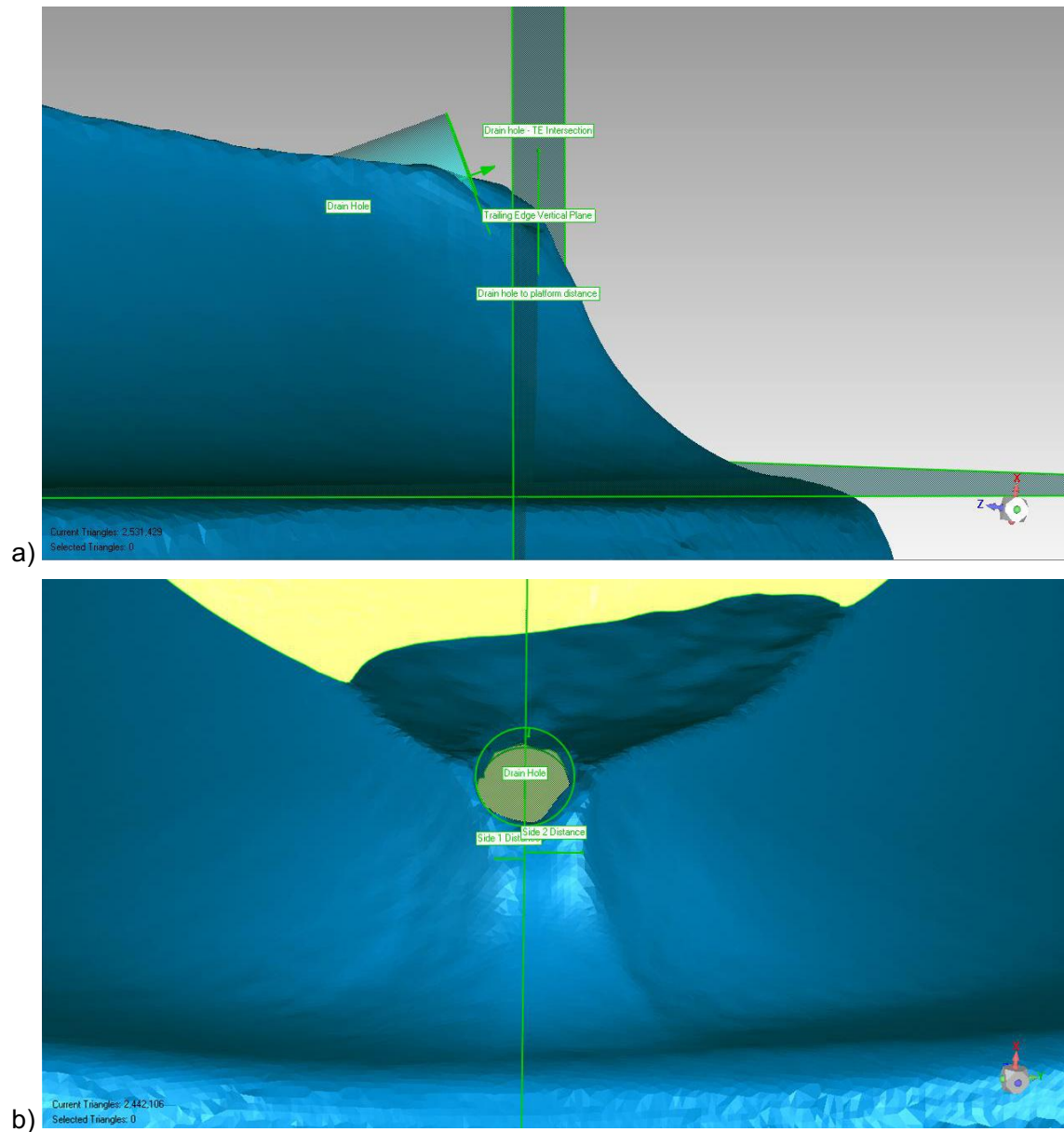


Figure 11: a) Cylinder, plane, and point objects fit to the model to measure the exit height above the blade platform of the drain hole and b) objects fit to the model to measure the drain hole offset.

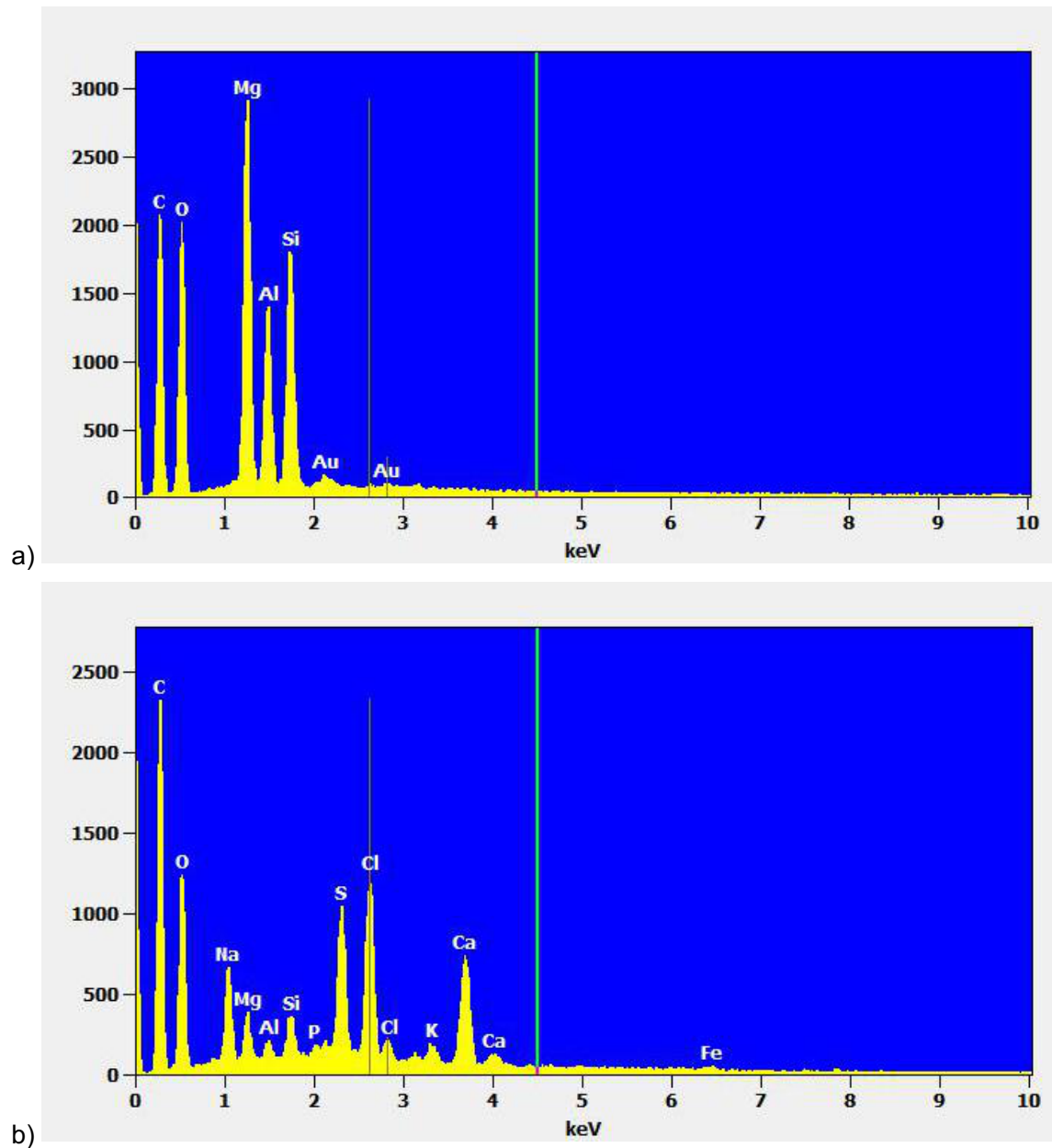


Figure 12: EDS spectra from debris removed from the fracture surface by replica tape: a) spectrum exhibiting magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O) and b) spectrum additionally exhibiting an abundance of sodium (Na), calcium (Ca), chlorine (Cl), and sulfur (S).

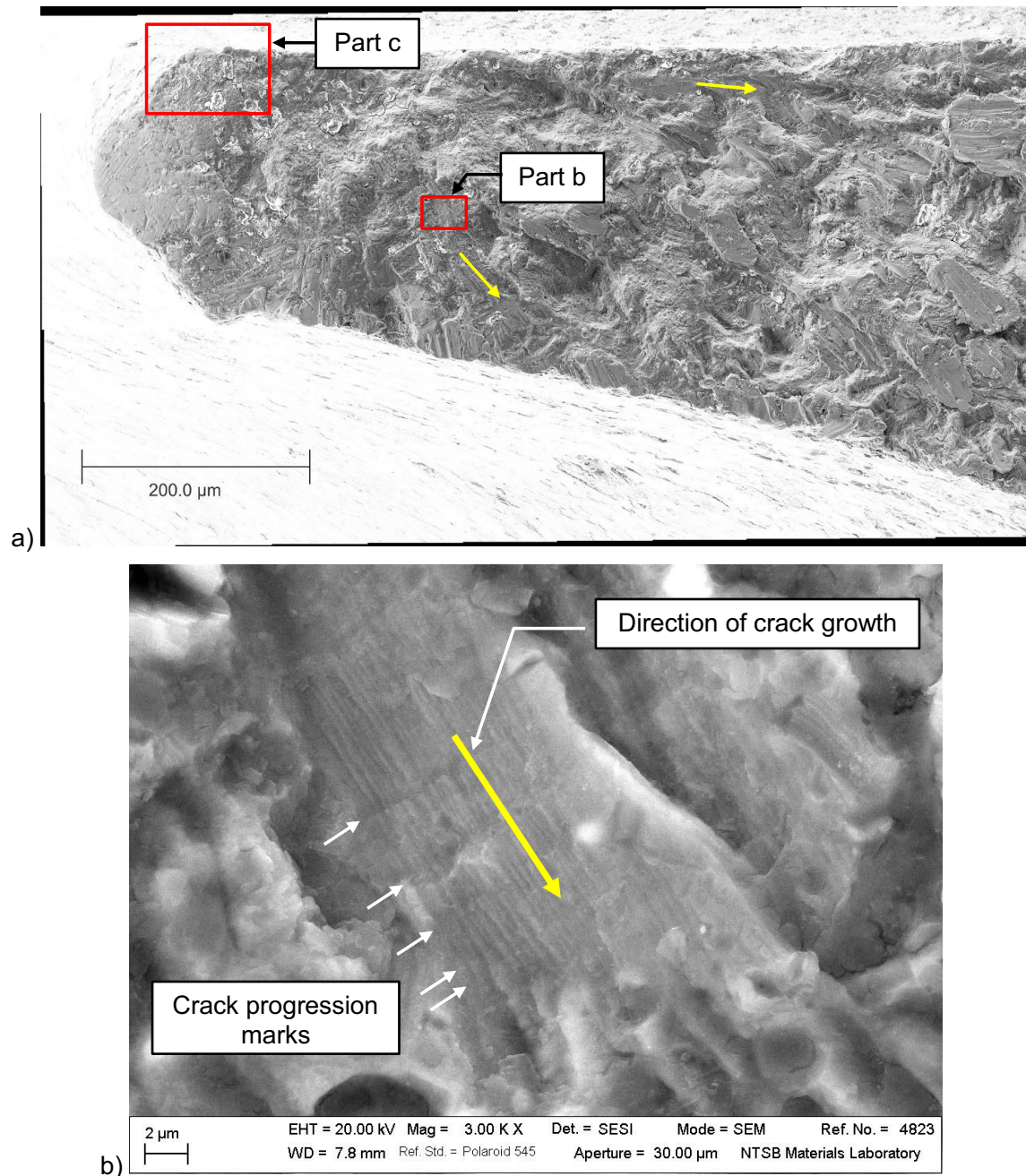


Figure 13: a) SEM mosaic of the fracture surface on the suction side of the drain hole and b) higher magnification image at the location shown in part b. Crack progression marks are visible on the fracture surface emanating away from the drain hole in the vicinity of its intersection with the aft rib face.

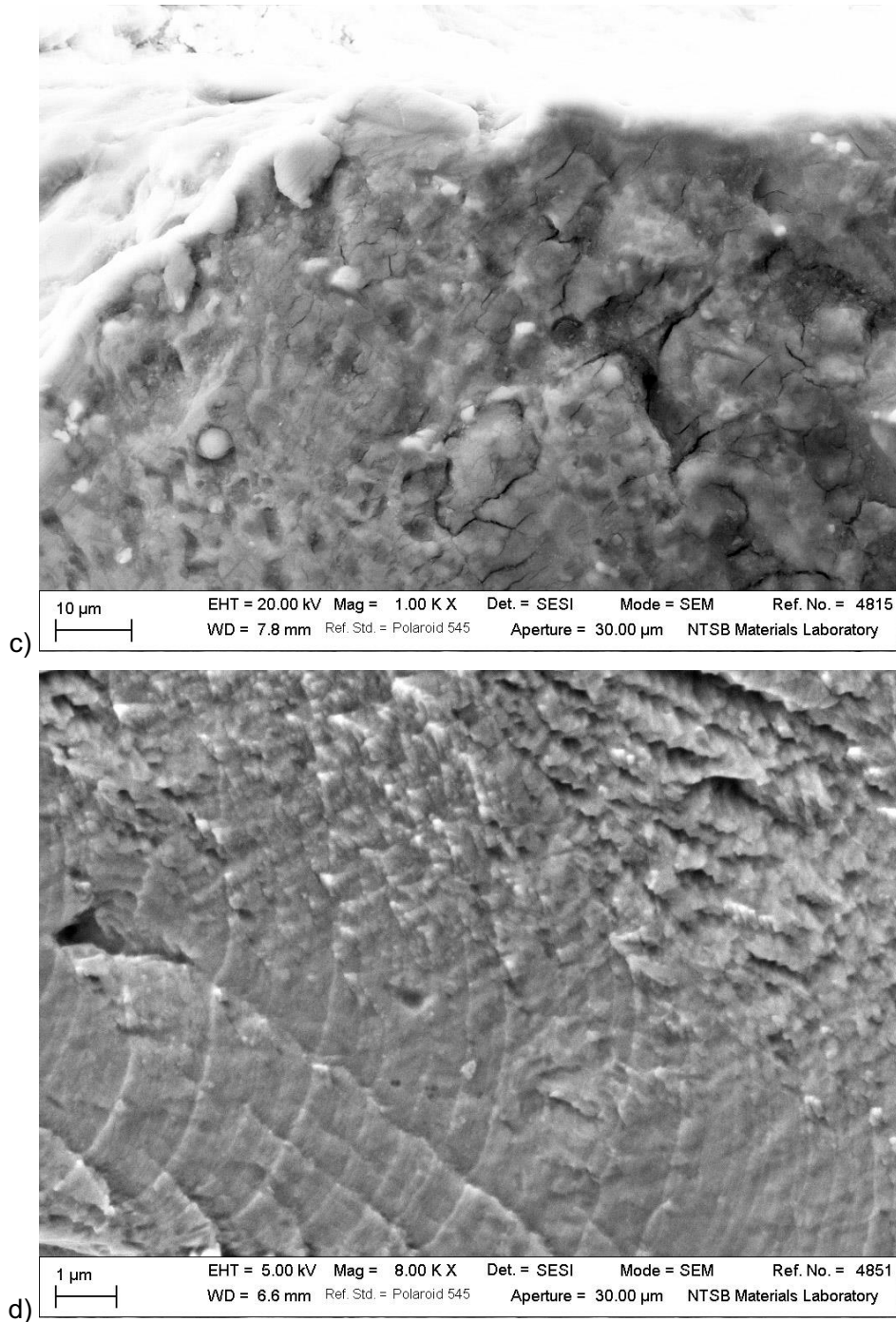


Figure 13 (cont.): c) higher magnification image near the origin at the intersection of the drain hole with the aft rib face; and d) image taken 13.7 mm from the origin, near the center of the blade (thickness direction), showing variable-spaced fatigue striations.

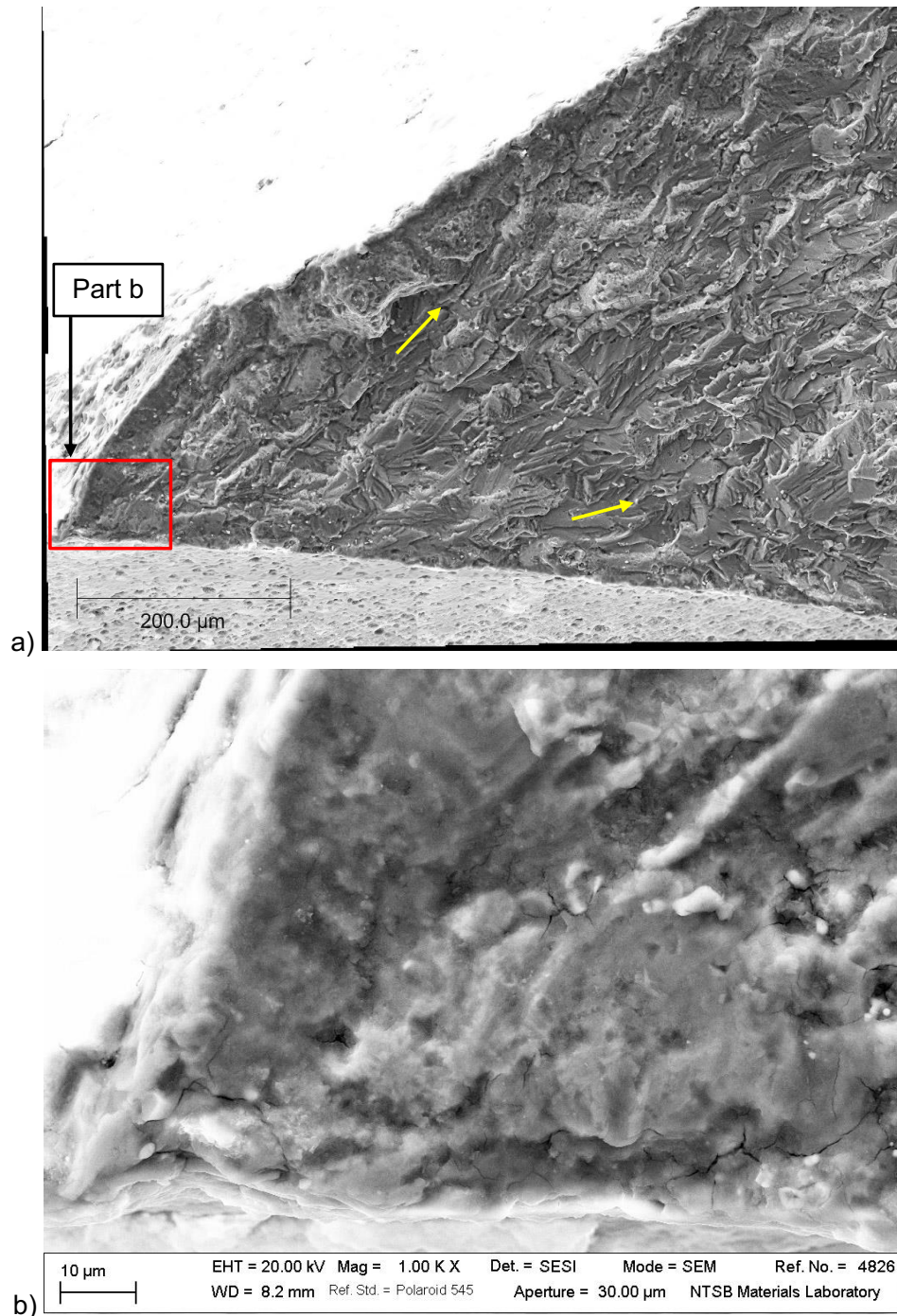


Figure 14: a) SEM mosaic of the fracture surface on the pressure side of the drain hole and b) higher magnification image near the origin at the intersection of the drain hole with the aft rib face.

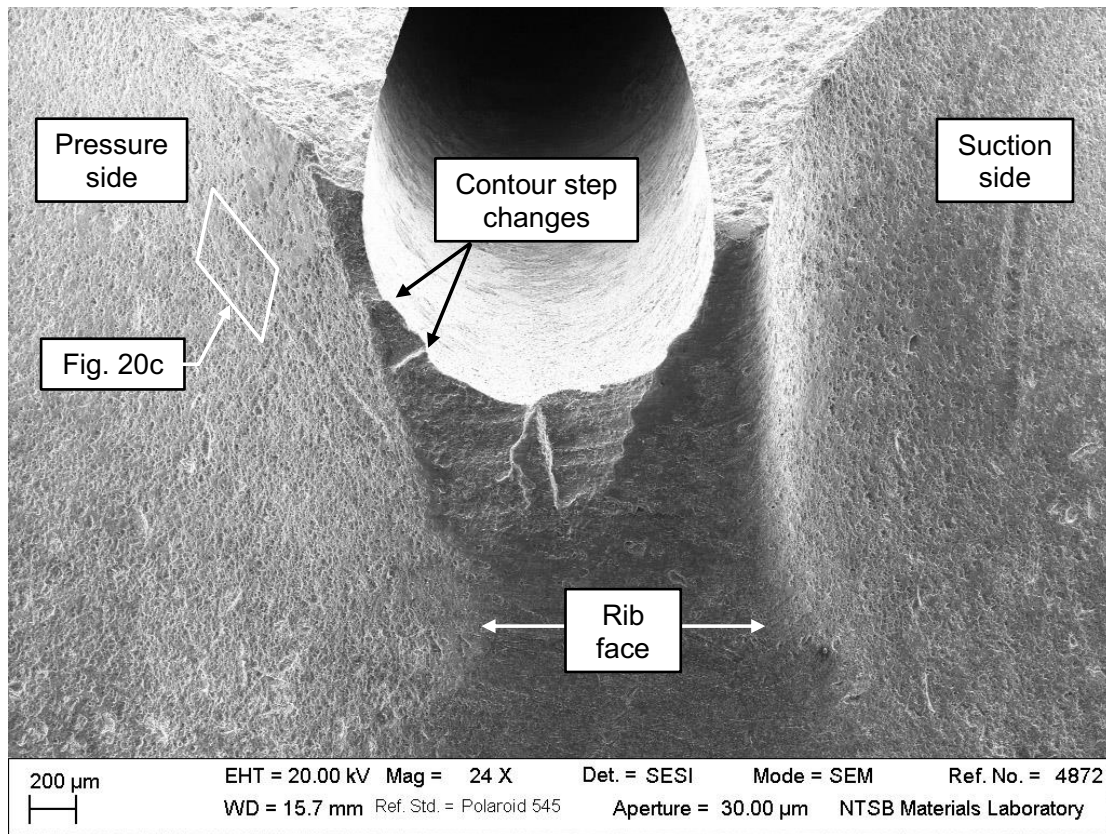


Figure 15: Overview image of the drain hole and rib region.

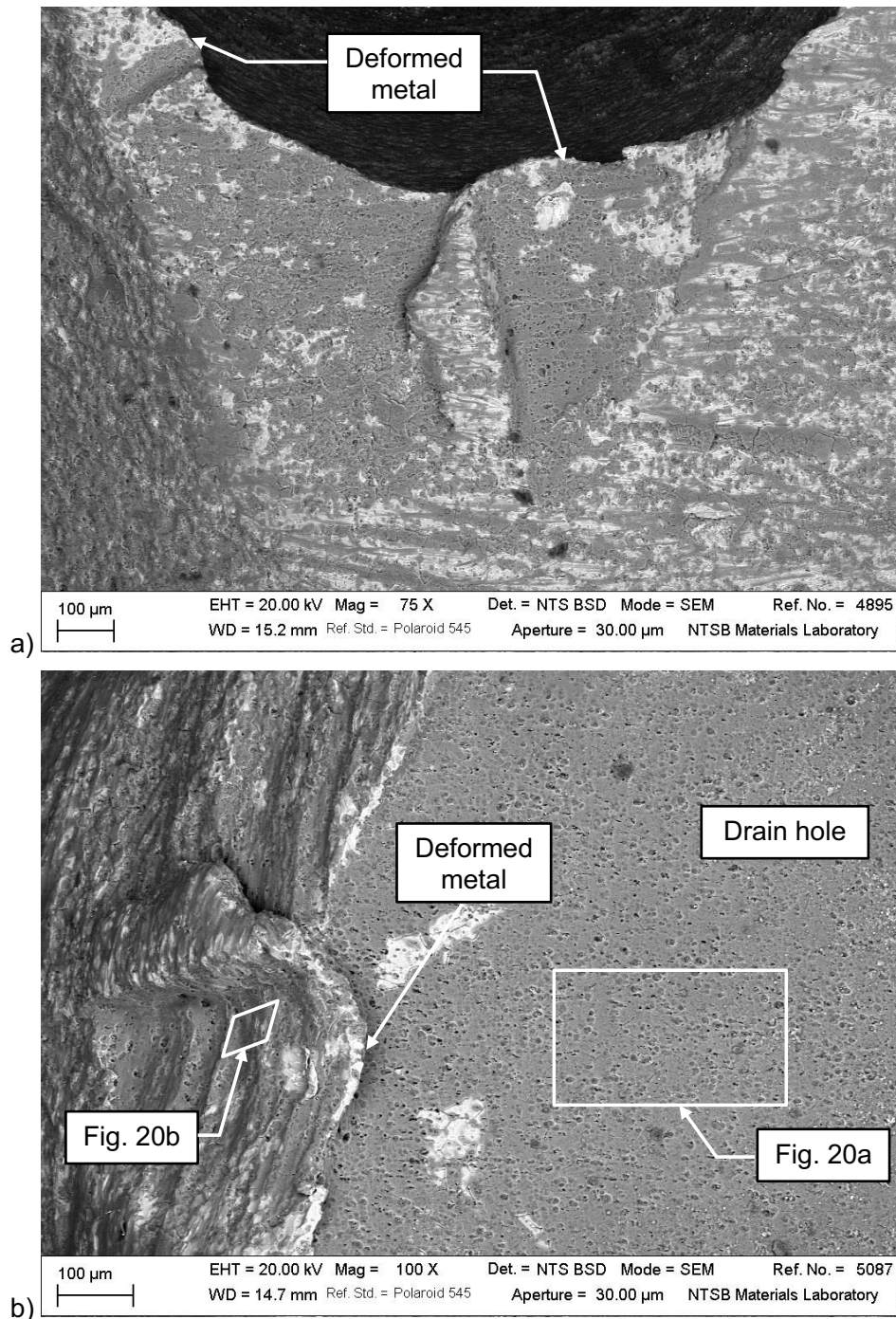


Figure 16: Backscatter electron images in the drain hole/rib region: a) rib face immediately below the drain hole; b) surface of drain hole passage at the outlet to the aft face;

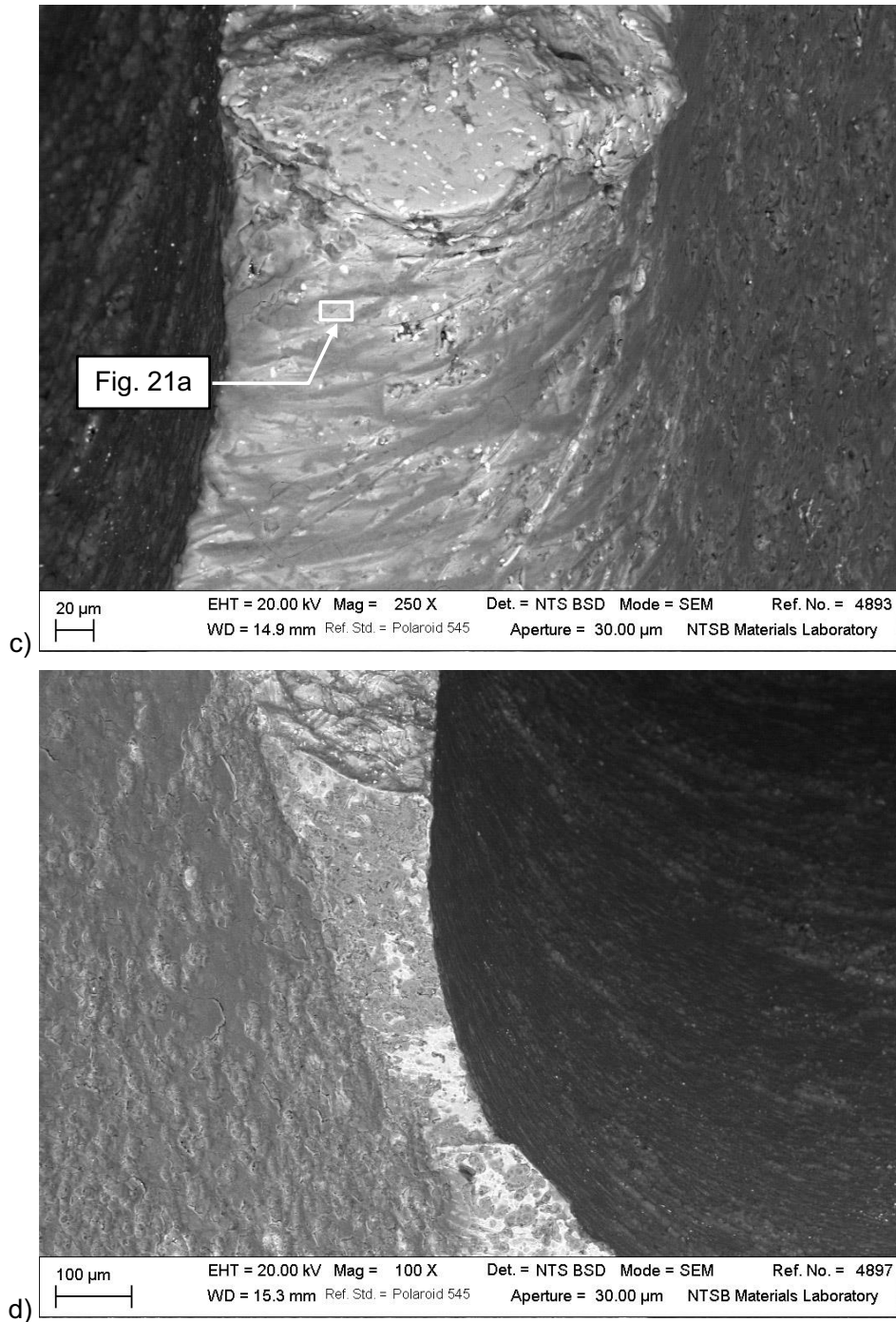


Figure 16 (cont.): c) aft rib face at suction side of drain hole outlet; and d) aft rib face at pressure side of drain hole outlet.

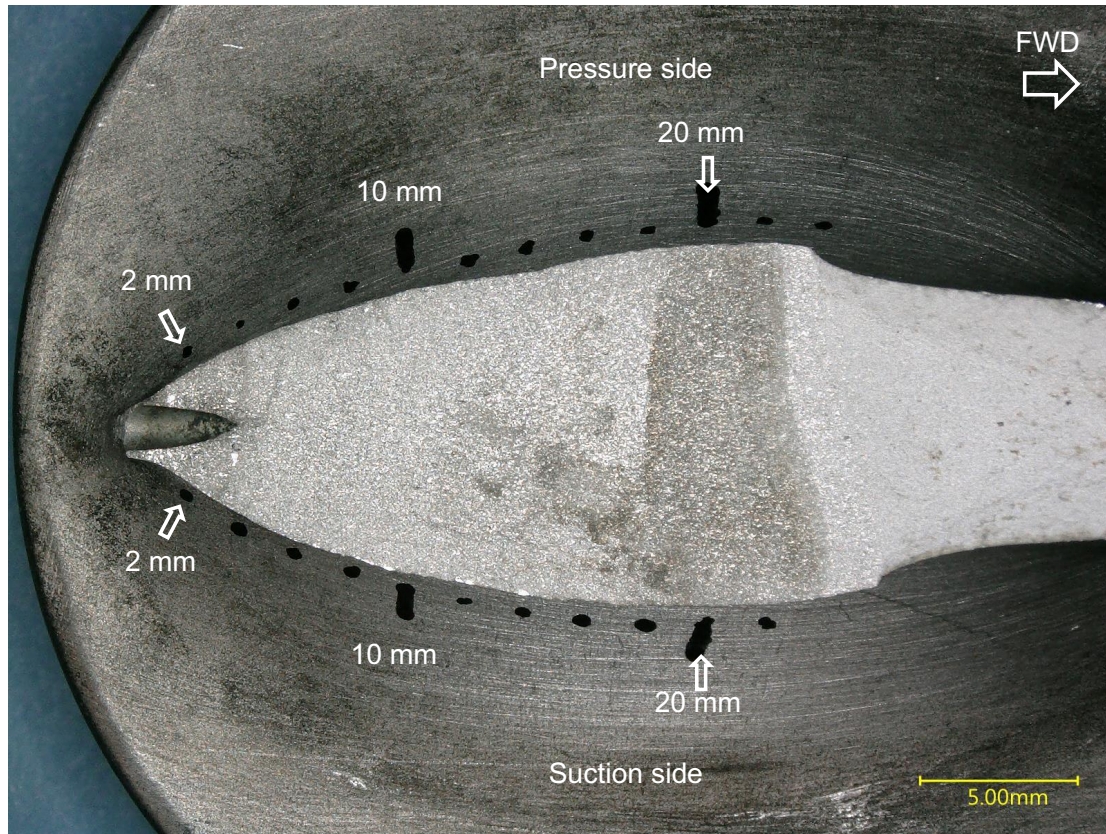


Figure 17: Plan view image of the root-side fracture with marks every two millimeters along each airfoil surface starting from the aft rib face.

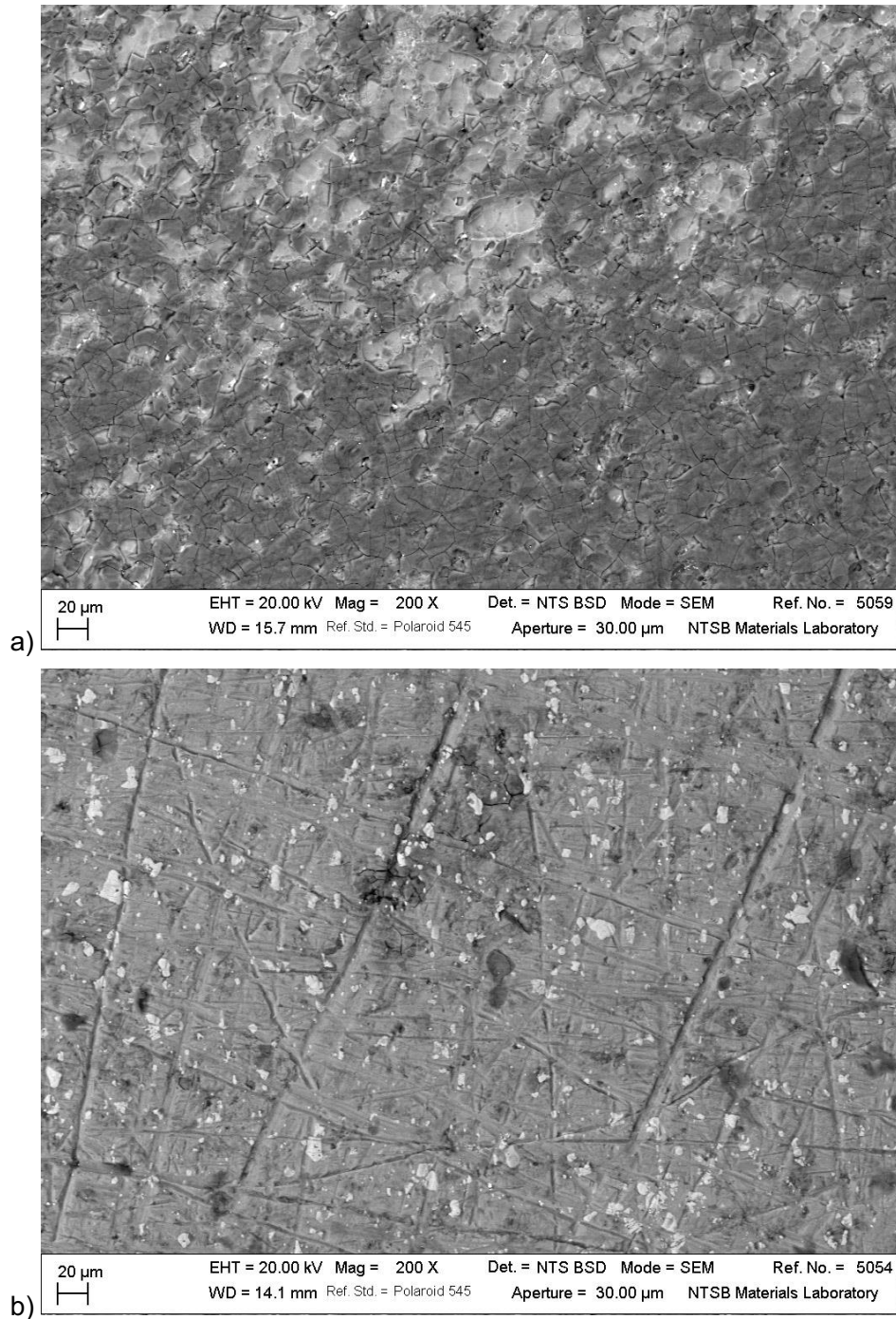


Figure 18: Backscatter SEM images taken along the pressure side airfoil surface forward of the aft rib face (see figure 17): a) 2 mm forward; b) 20 mm forward.

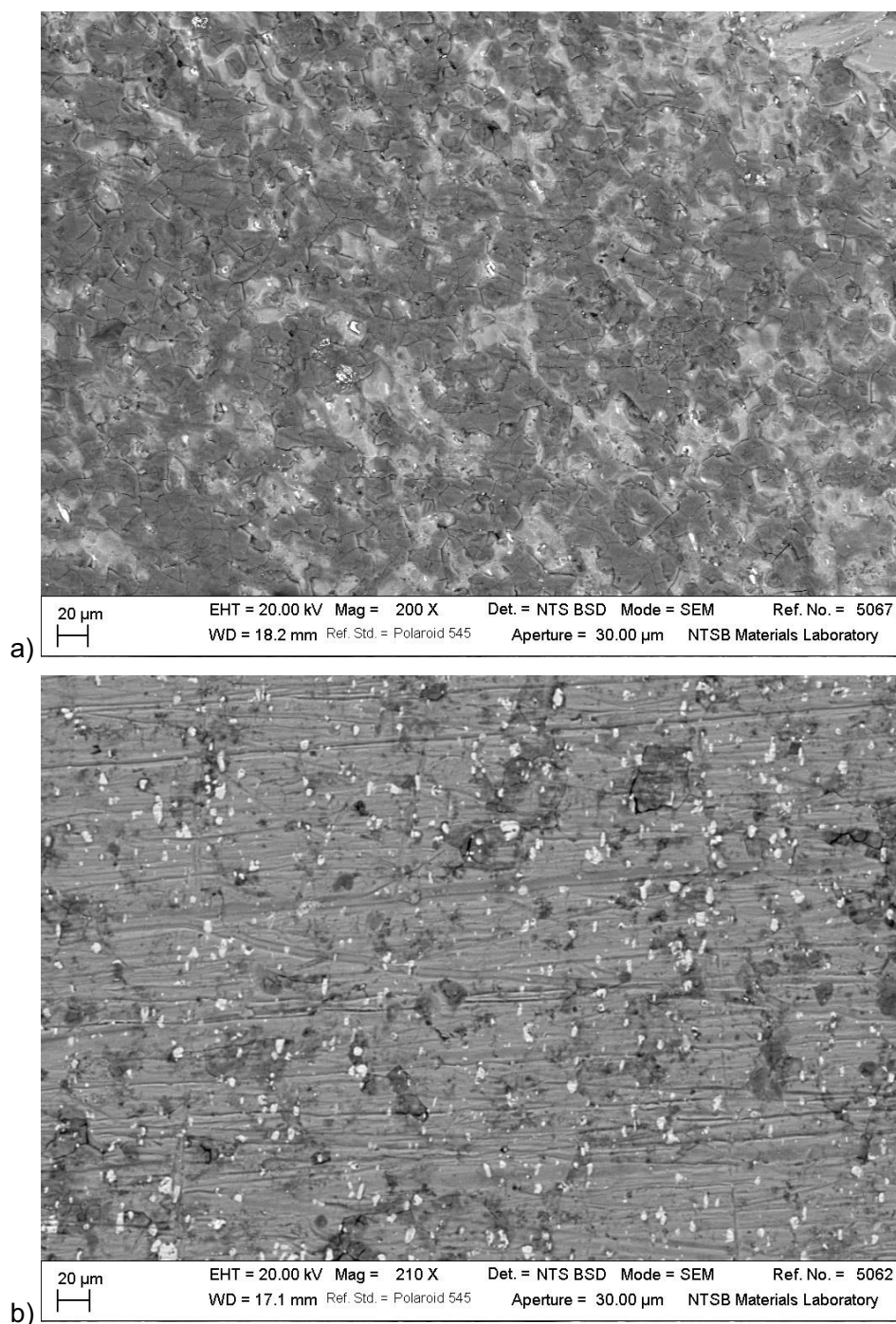


Figure 19: Backscatter SEM images taken along the suction side airfoil surface forward of the aft rib face (see figure 17): a) 2 mm forward; b) 20 mm forward.

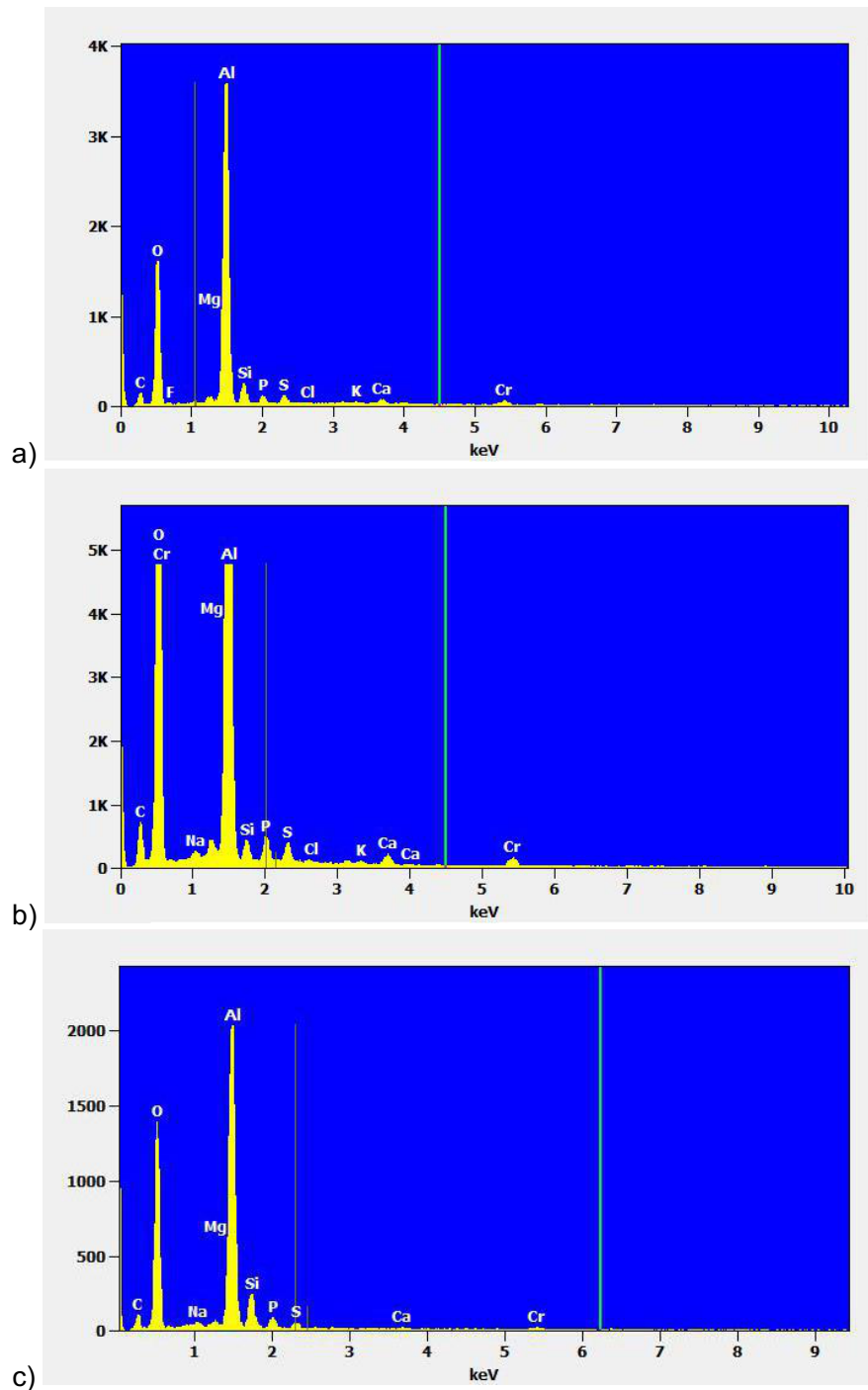


Figure 20: EDS spectra showing the presence of chromium and a comparatively abundant oxygen peak: a) drain hole passage; b) displaced/off angle region below drain hole; and c) oxidized/pitted region on pressure side of airfoil.

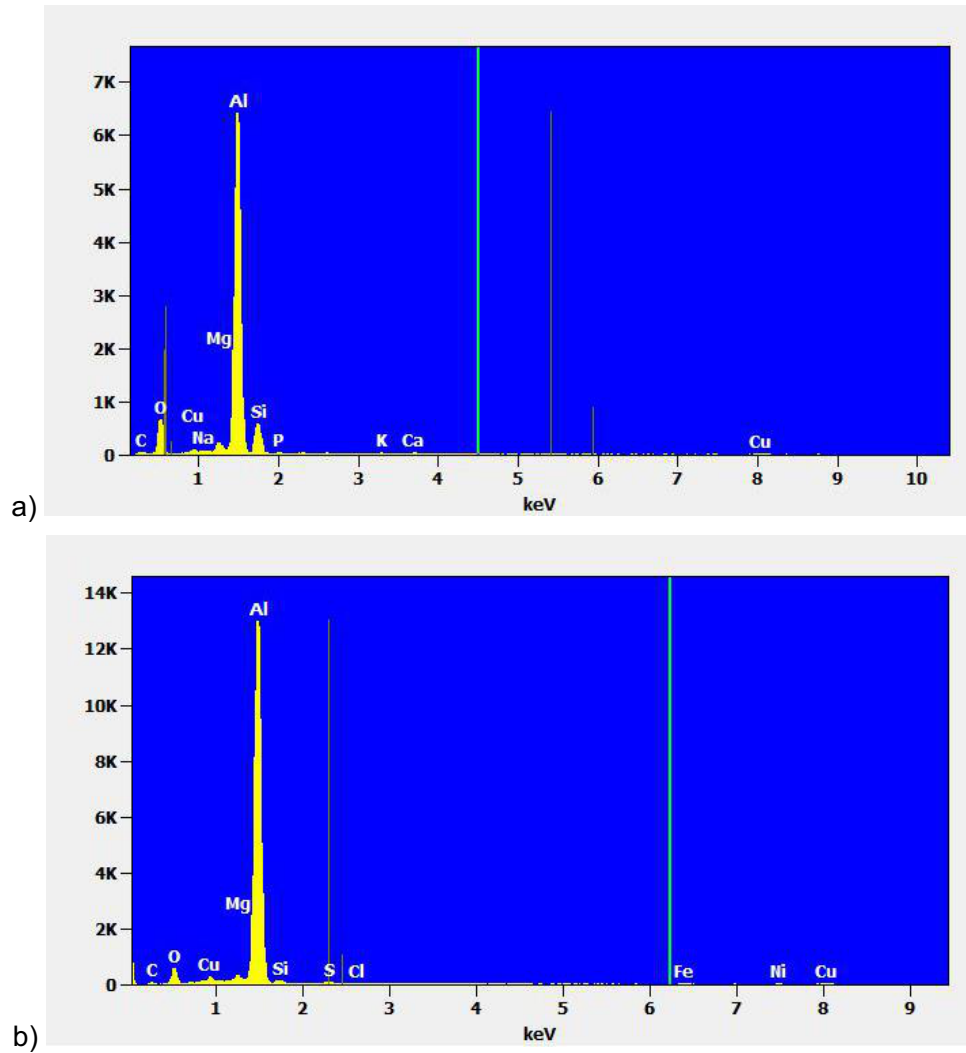


Figure 21: EDS spectra showing primarily aluminum: a) abraded region on aft rib face – suction side of drain hole and b) abraded surface region on suction side of the airfoil.

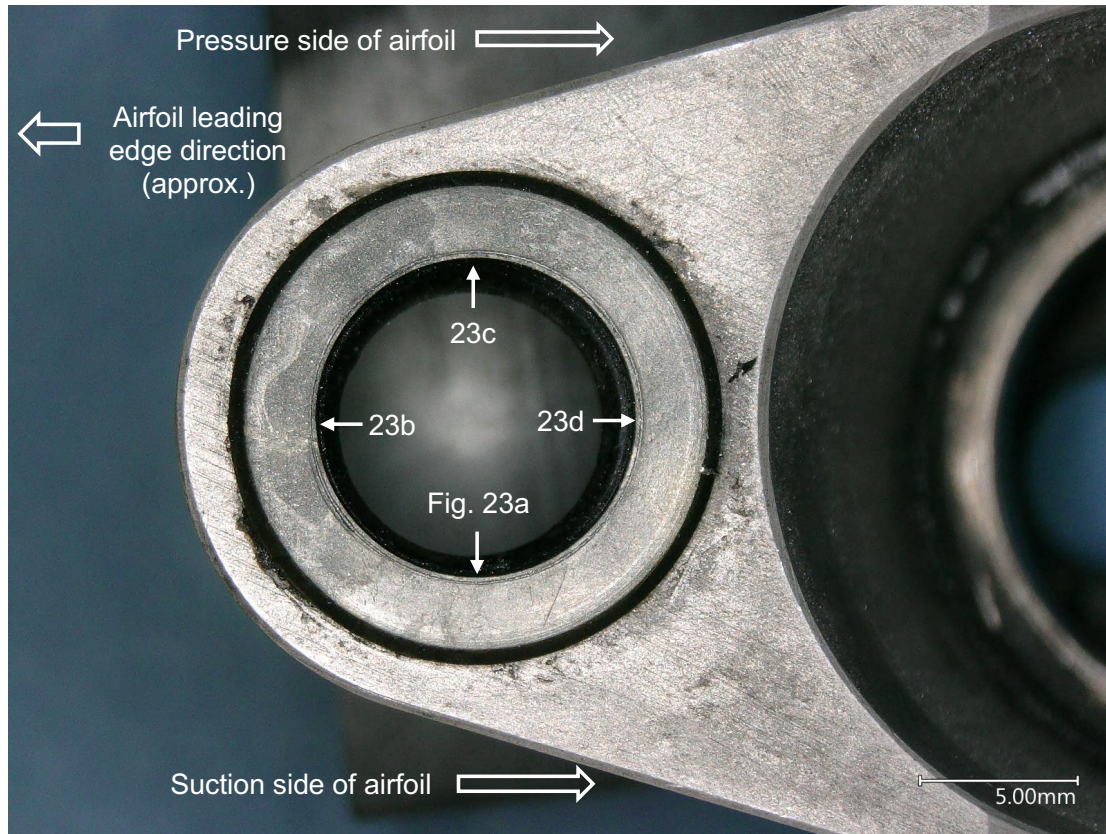


Figure 22: Inward looking radially outward view of the pitch change bearing at the base of the blade root. The bearing flange is rotated relative to the airfoil's chordwise direction. Therefore, labels regarding airfoil orientation are approximate.

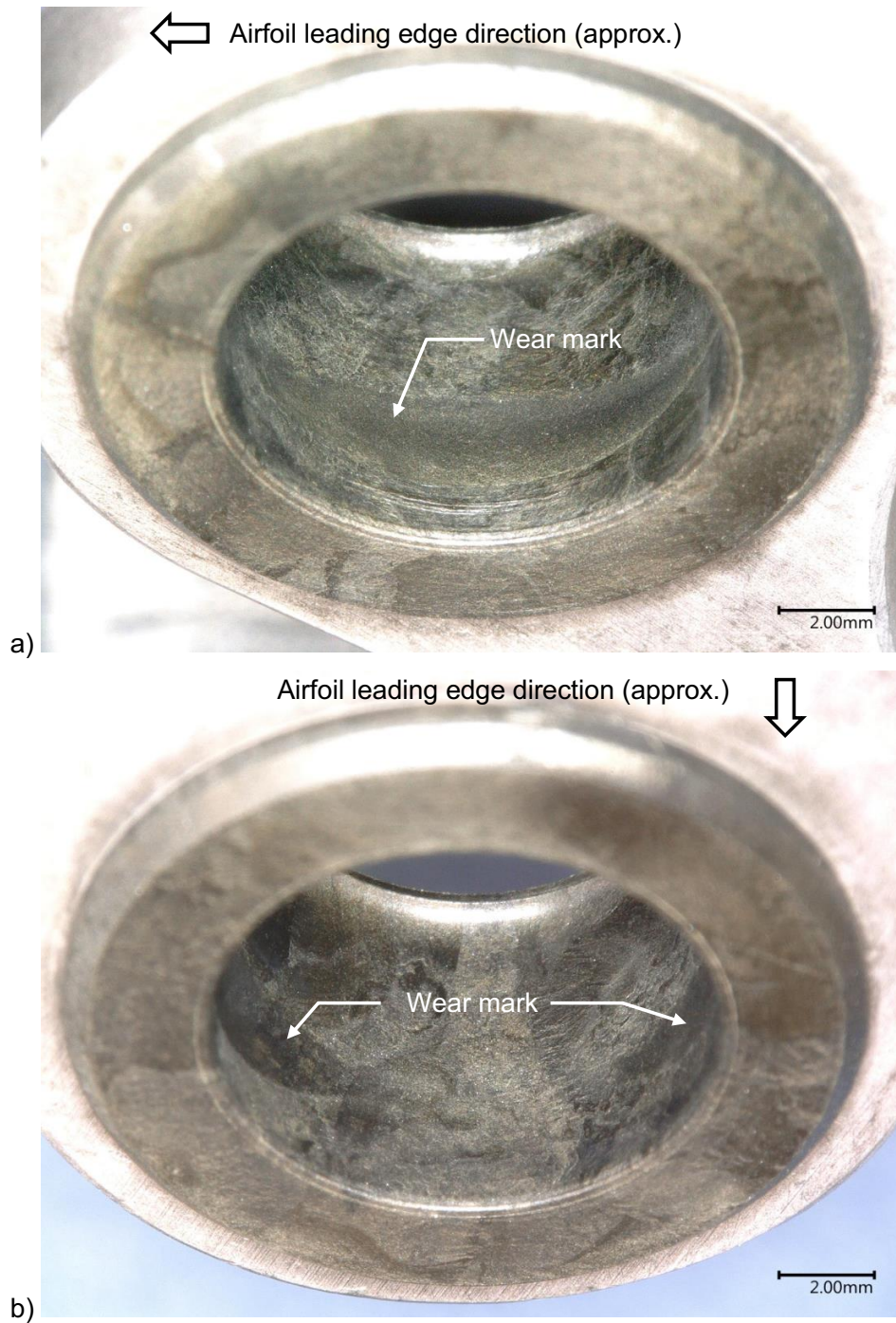


Figure 23: Images of the pitch change bearing surface showing the location and extent of wear marks: a) oriented toward the suction side b) oriented toward the leading edge

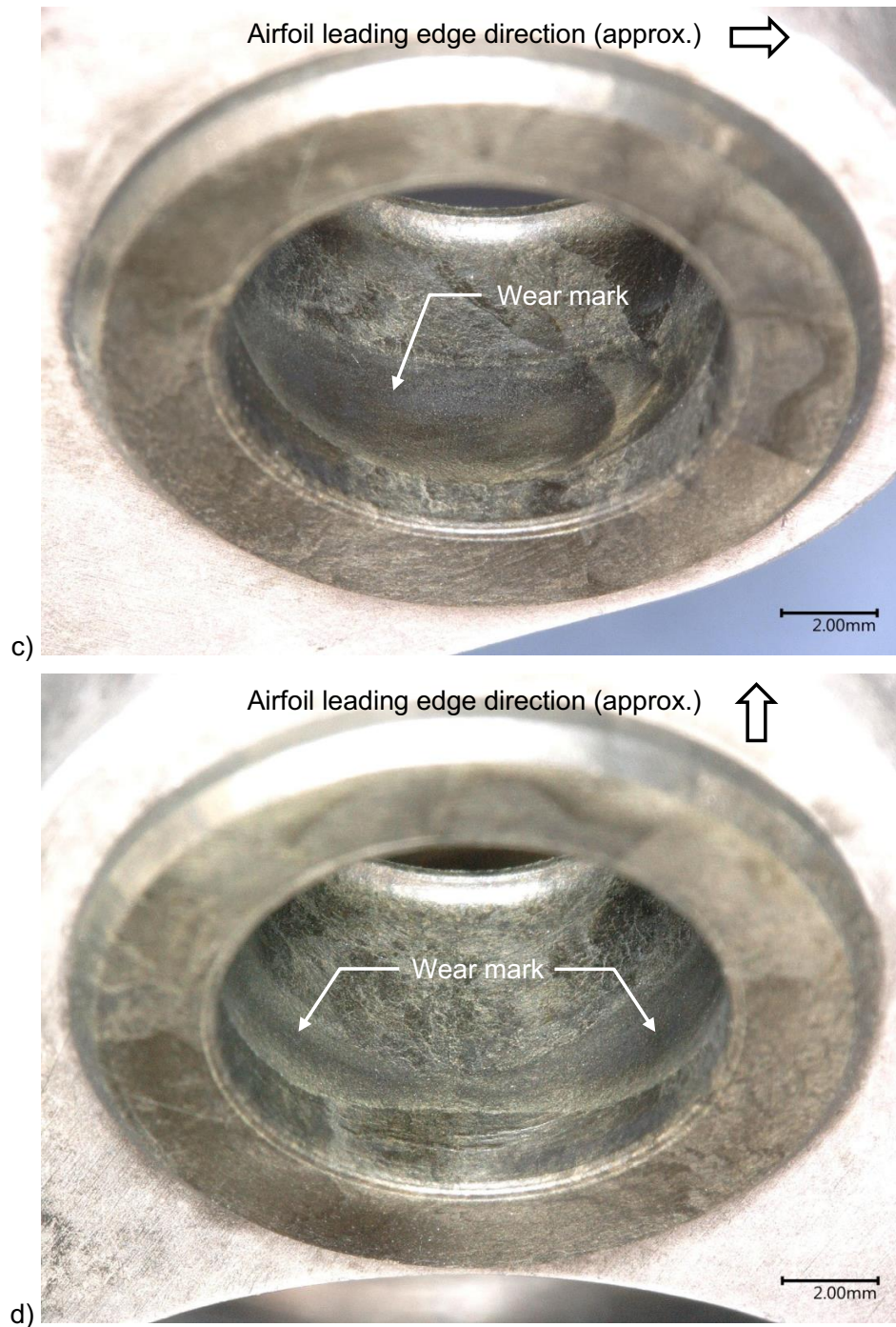


Figure 23 (cont.): c) oriented toward the pressure side; and d) oriented toward the trailing edge.

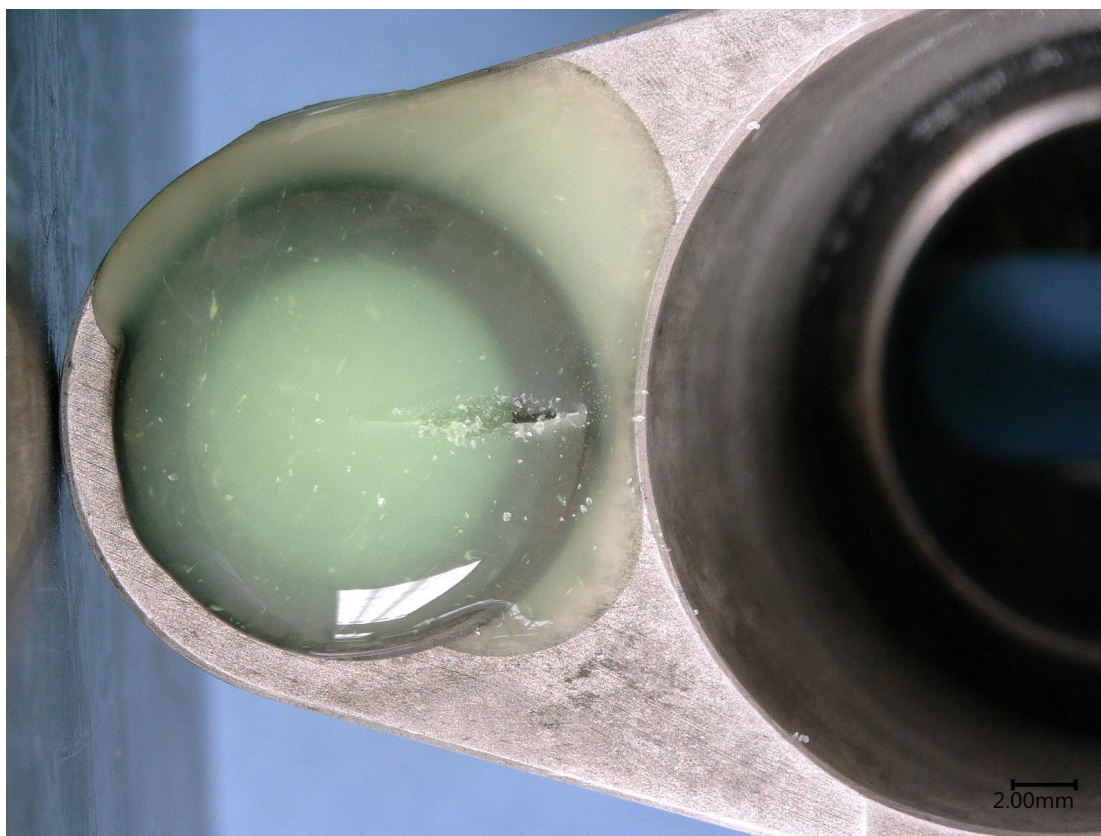


Figure 24: Silicone rubber mold of pitch change bearing.

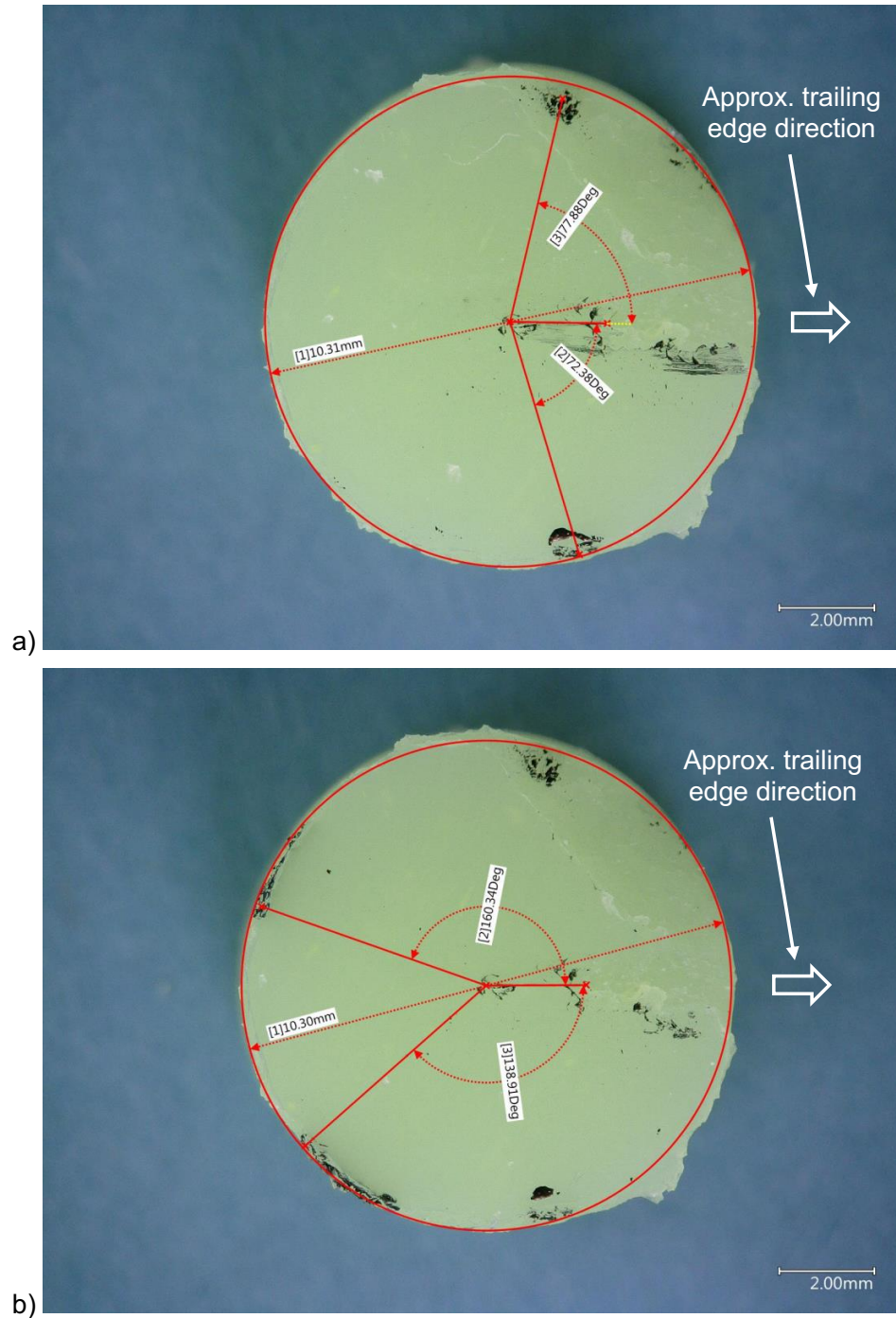


Figure 25: Rubber mold with measurements: a) the angular position where the wear mark was greatest in width; b) the arc angle of each wear mark;

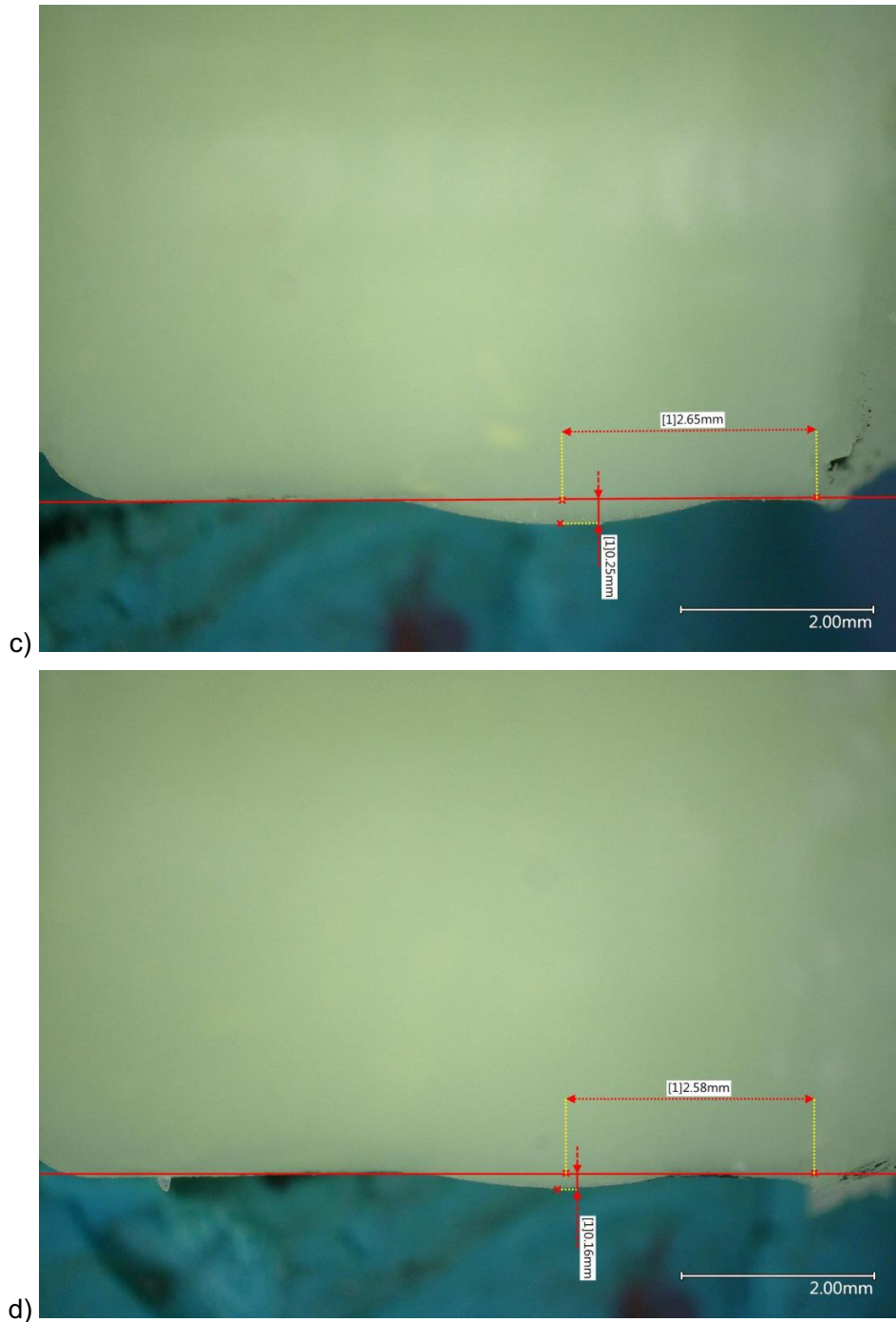


Figure 25 (cont.): c) depth of wear and distance from bearing end face for the wear mark closer to the pressure side of airfoil; and d) depth of wear and distance from bearing end face for the wear mark closer to the suction side of airfoil.

APPENDIX A: X-RAY CT SCAN REPORT

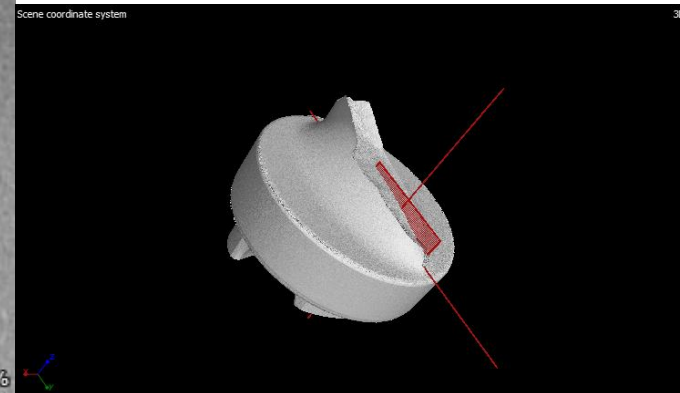
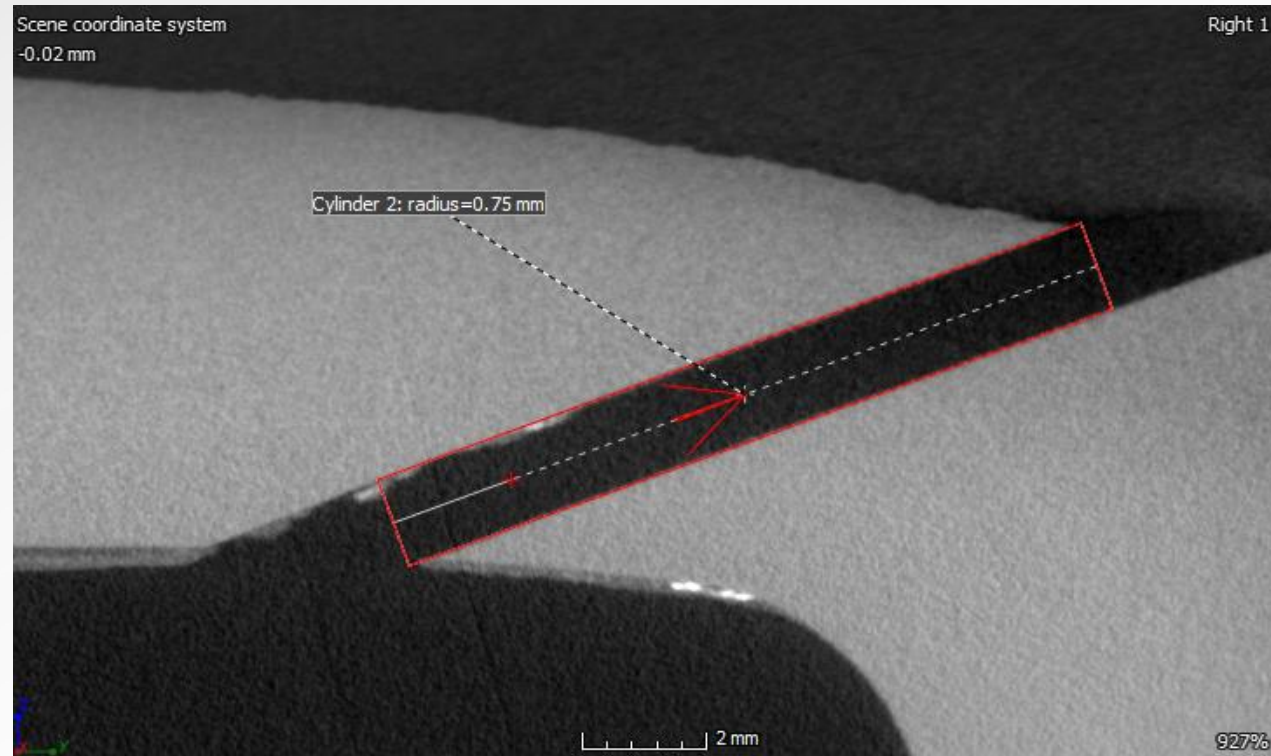


NTSB – Donald Kramer CT Scan Analysis

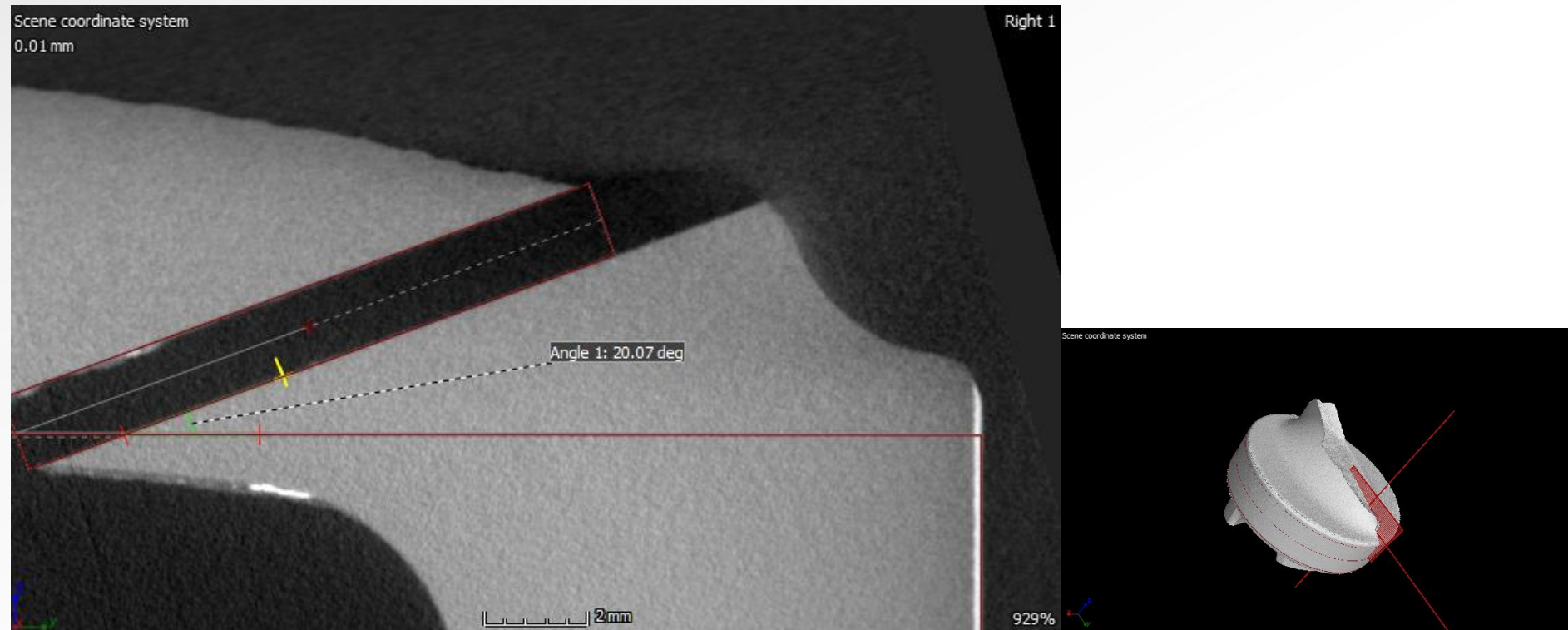
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*4603B Compass Point Road
Belcamp, MD 21017*

Drain Hole: Radius



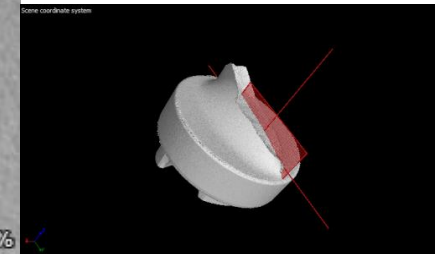
Drain Hole: Inclination Angle



Drain Hole Foreign Material



- Variation in brightness in indicated areas suggest the presence of foreign material along the wall of the drain hole
- Brighter Areas = Higher Density Material
- Darker Areas = Lower Density Material



(end of report)

Contact Information:

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[https://www.nts.com/services/
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