

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN25FA006

MATERIALS LABORATORY

Factual Report 25-041

September 19, 2025

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A. ACCIDENT INFORMATION

Location: Norfolk, Nebraska
Date: October 7, 2024
Vehicle: Beechcraft C99 (N130GP)
Investigator: Jason Aguilera (AS-CEN)

B. COMPONENTS EXAMINED

A turbine disk (Part No. 3013411) from a Pratt & Whitney Canada (PW&C) PT6A-36 turboprop engine.

C. EXAMINATION PARTICIPANTS

Specialist Brian Fuchs
National Transportation Safety Board (RE-30)
Washington, DC

D. DETAILS OF THE EXAMINATION

A turbine disk was submitted to the materials laboratory for examination, as shown in Figure 1. The disk had 58 blades assembled. Both the forward and aft sides of the disk had contact damage. A groove was carved into the outer rim of the forward side that extended circumferentially across 20 disk posts. At its widest, the groove was approximately 0.2 inches wide. Circumferential marks were visible within the groove. Similar damage was also present on the aft side of the disk. Light-colored circumferential scratches were visible on the disk posts and blade fir trees.¹

The blades were arbitrarily labeled by number ('1' - '58') where the '1' blade aligned with the main spline on the shaft on the forward side and the numbering increased in the clockwise direction forward looking aft (Figure 2). All 58 turbine blades showed damage, with most showing varying degrees of secondary impact damage, especially at the trailing edges and at the blade tips. Six blades had separated close to the root. Most fracture surfaces were either rough and dimpled, consistent with ductile overstress fracture, or had post-fracture secondary smearing damage. The surfaces were dark in color (gray, black, brown, or blue) consistent with high temperature exposure post-fracture, though some areas of smearing were shiny and reflective.

A distinct area was observed on the fracture surface of blade 28, shown as installed in Figure 3. Figure 4 shows a magnified view of the fracture surface. The blade had separated 0.118 inches above the blade platform at the trailing edge. The fracture surface was gray and purple in color and a thin layer of gray material was

¹ 'Fir tree' is a term for the section of the blade below the blade platform.

visible around the perimeter of the blade. The distinct area was relatively smooth and flat, consistent with fatigue. This flat region extended through the thickness of the blade starting at the trailing edge and extending forward approximately 0.25 inches. River marks near the trailing edge extended from the pressure side towards the suction side, consistent with a crack that propagated through the thickness of the blade (Figure 5).

Blade 28 was rinsed in acetone and a soft brush was used to remove dirt from the surface. Then the blade was removed from the disk and cleaned in ethanol in an ultrasonic bath. Figure 6 shows the blade after cleaning. Part markings were observed in several areas on the blade under the platform. Table 1 contains a description of the markings, their location, and an explanation of each from the manufacturer. Secondary impact damage and cracking was observed on both the suction side and pressure side of the blade at the trailing edge (Figure 7).

Table 1. Markings on blade 28 and their meanings, as defined by the manufacturer.

Marking	Location	Description
3039901 T	Suction side	P&WC part number
15023	Forward side firtree	Supplier batch or heat code
1.248	Aft side firtree	Blade length after coating was applied

The fracture surface on blade 28 was examined using a field-emission scanning-electron microscope (SEM). Backscattered electron (BSE) images showed a coating around the perimeter of the fracture surface, corresponding to the location of the gray layer seen in optical microscopy (Figure 8).² Energy Dispersive Spectroscopy (EDS) of the coating showed high amounts of aluminum and oxygen (Figure 9). The blade fracture surface showed high amounts of nickel, cobalt, oxygen, and titanium, as well as other elements consistent with high-temperature surface oxidation (Figure 10). Closer examination revealed that there was no coating at the trailing edge adjacent to the fracture surface (Figure 11). Smearing consistent with impact damage was present in the area missing the coating. No inclusions were noted in the BSE images of this region and EDS scans of the region showed no chemical inconsistencies.

SEM examination of the flat region showed a layer of oxides that obscured the features of the fracture surface. Towards the leading edge of the blade, fracture surface was rough with dimpled features consistent with overstress. There was a transition area from the flat area to the rough area between 0.25 and 0.35 inches from the trailing edge. Crack arrest lines were observed in this transition area (Figure

² Backscattered electron detectors measure high-energy electrons reflecting off the surface to form images. The quantity of reflected electrons is proportional to the atomic density of the material. Thus, a material with a higher atomic number will appear brighter in the BSE image.

12). The crack arrest lines emanated from the trailing edge, consistent with fatigue progressing forward towards the leading edge of the blade.

Blade 28 and the adjacent blade 29 were cross-sectioned for metallographic examination.³ The blades were sectioned axially approximately 0.24 inches from the trailing edge, perpendicular to the camber line of the blade (Figure 13). Figure 14 shows micrographs of both blades, which showed a two-phase microstructure with a dark gray intergranular phase and a lighter bulk material. EDS of the intergranular phase showed high concentrations of titanium and molybdenum (Figure 15), and the bulk phase showed higher concentrations of nickel, cobalt and chromium (Figure 16). The gray coating on the leading and trailing edges showed no evidence of disbonding. On blade 28, the coating layers on the pressure and suction sides were continuous with no cracking. In blade 29, the coating layer was cracked in multiple places on both sides of the blade. These cracks extended from the surface to the bulk material. Intergranular cracks were noted at several locations in the bulk material on the suction side of the blade (Figure 17). One of these cracks (marked by 'A' in Figure 17) extended from the outside of the coating and into the bulk material, where the crack widened in a manner consistent with pitting corrosion.

Microhardness measurements were taken on the cross section of blade 28. Measurements were taken in both the blade and the root. Table 2 contains the average hardness and sample standard deviation of each blade. No significant differences in hardness measurements were observed between the root and the blade.

Table 2. Recorded microhardness measurement on blade 28.

Blade (# of measurements)	Average Hardness (HV500)	Hardness Range (HV500)
28 (<i>n</i> = 23)	345±11	333 - 372

A chord-wise cross-section was metallographically prepared through the trailing edge fracture surface of blade 28 (Figure 18). Figure 19 shows micrographs of the cross-section. The microstructure was consistent throughout the blade. The remaining coating near the trailing edge was cracked and fragmented; several cracks extended through the coating but did not penetrate into the blade. The cross-section was etched with Kailing's solution to observe the grain structure. The fracture surface bisected multiple grains and no plastic deformation was observed, consistent with intragranular fatigue.

The microstructure of the trailing edge was examined in the SEM. Figure 20 shows BSE images of blade 28 near the fracture surface and below the blade platform. The image near the origin showed darker cubic precipitates dispersed in a

³ The part markings on blade 29 were the same as blade 28. The fracture surface of blade 29 showed roughness consistent with overstress.

lighter matrix, consistent with a gamma/gamma-prime two-phase microstructure expected in nickel superalloys. A similar microstructure was also observed approximately 0.04 inches below the blade platform. There was no evidence of phase dissolution in either location.

Submitted by:

Brian Fuchs, PhD
Materials Engineer

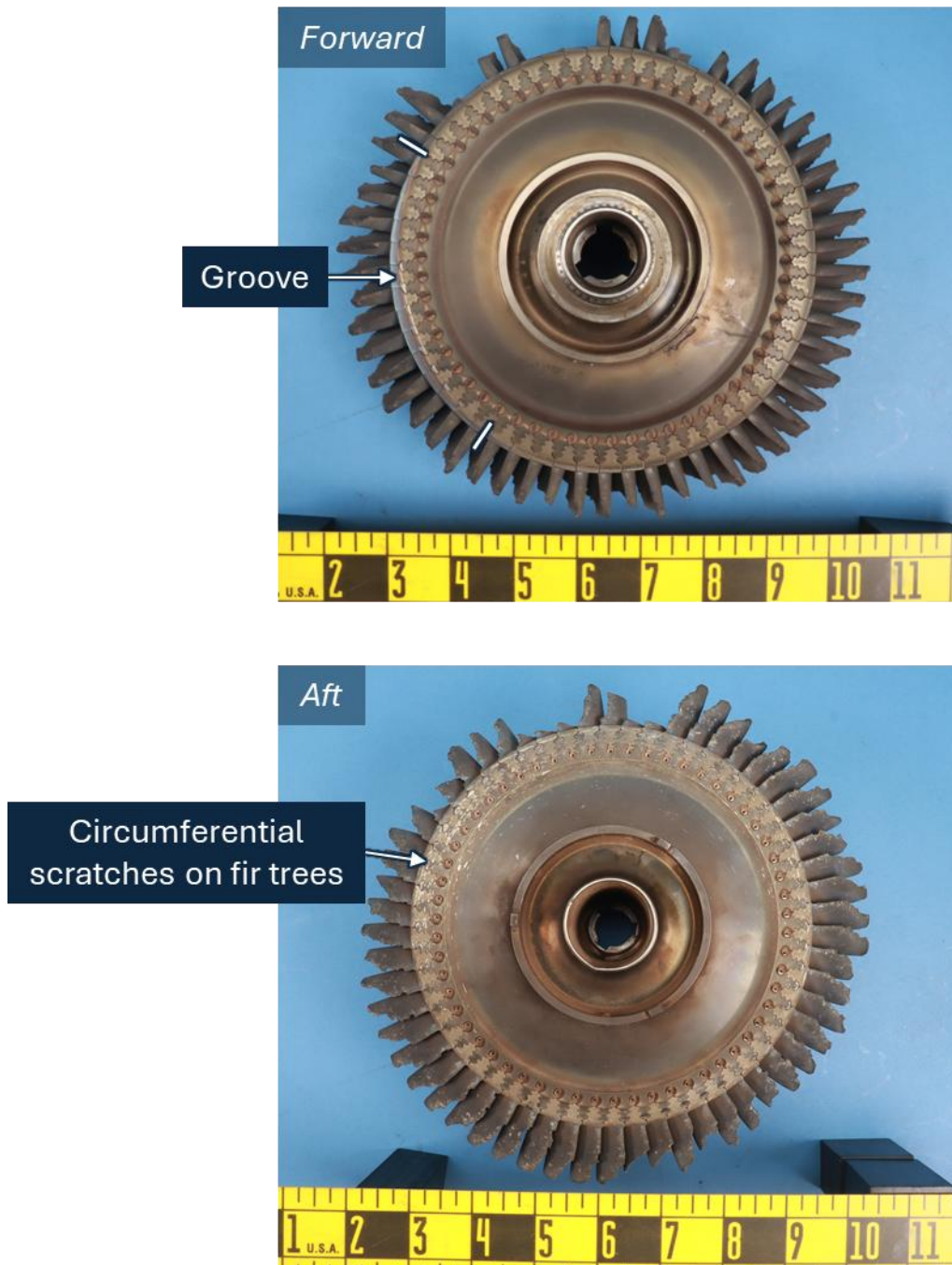


Figure 1. (Top) Forward side of the turbine disk. (Bottom) Aft side of the turbine disk.

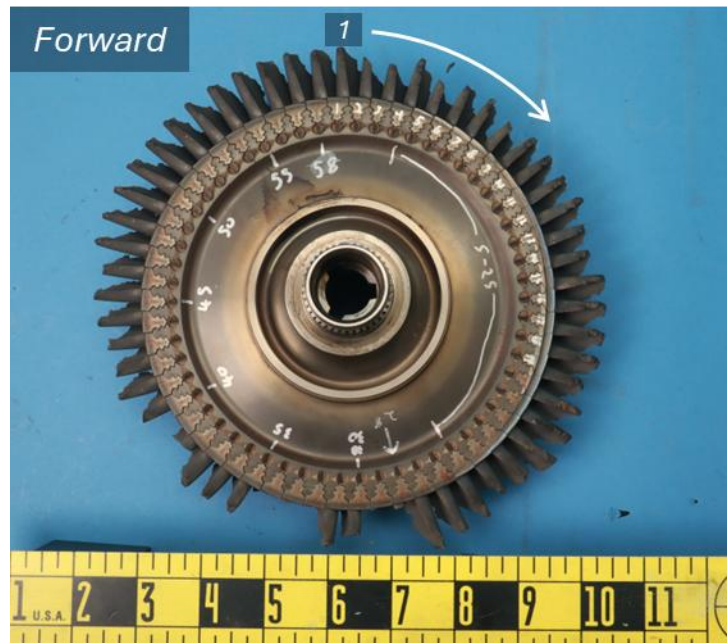


Figure 2. Forward side of the turbine disk with blade numbering.

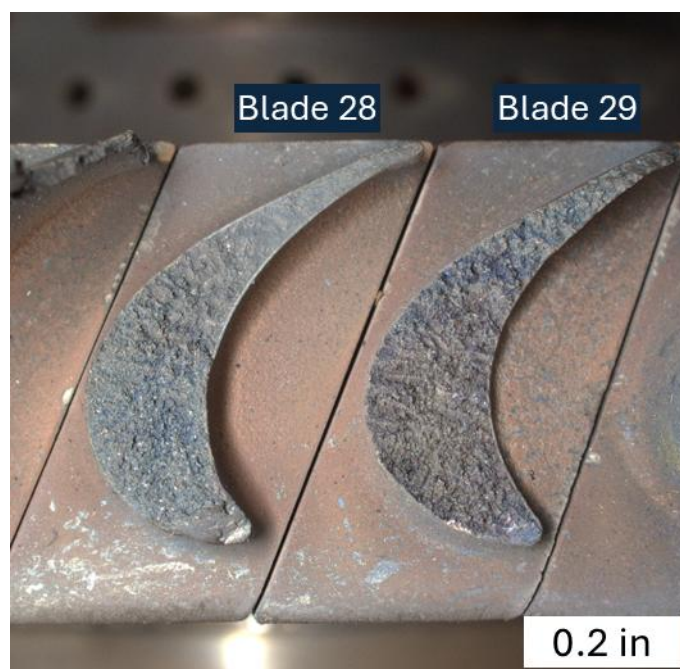


Figure 3. Blades 28 and 29 as-received installed in the disk.

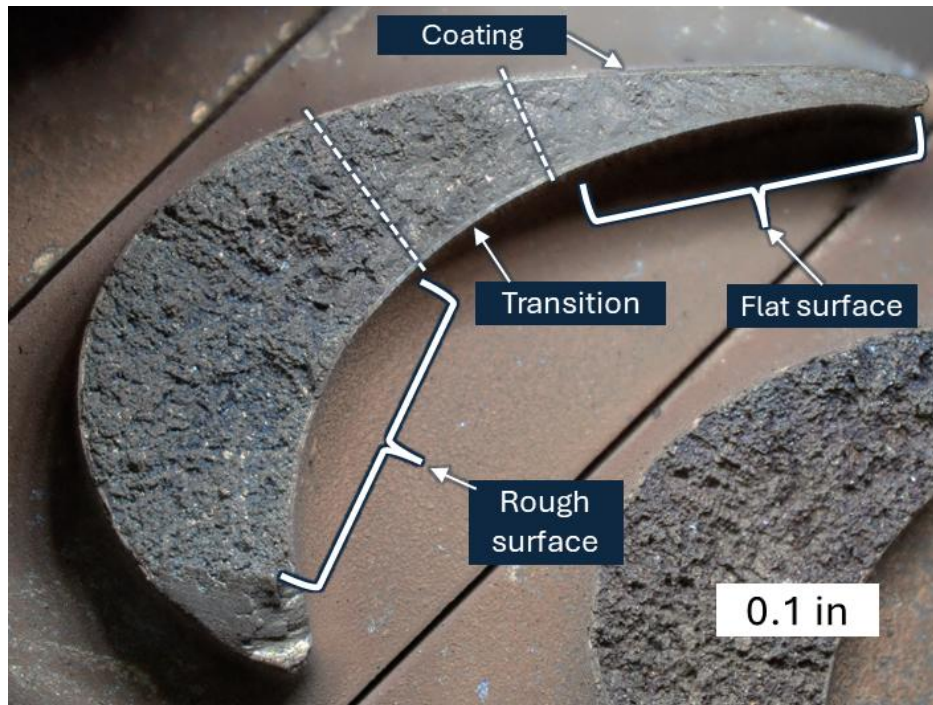


Figure 4. Magnified fracture surface of blade 28.

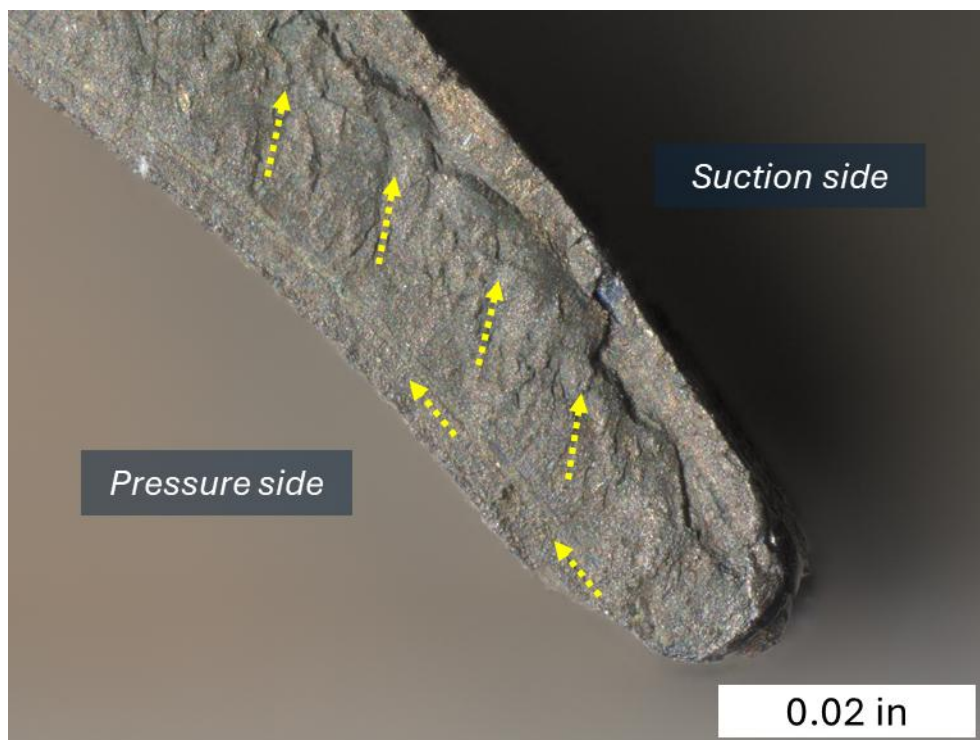


Figure 5. River marks near the trailing edge of the blade. Yellow arrows show the direction of crack growth indicated by the river marks.

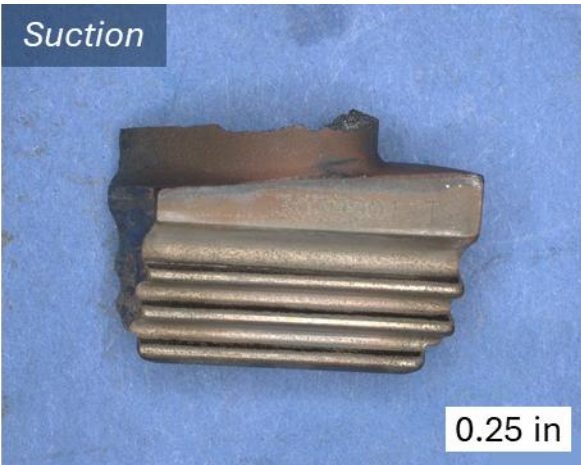


Figure 6. (Left) Suction side and (right) pressure side of blade 28 after removal from the turbine disk.

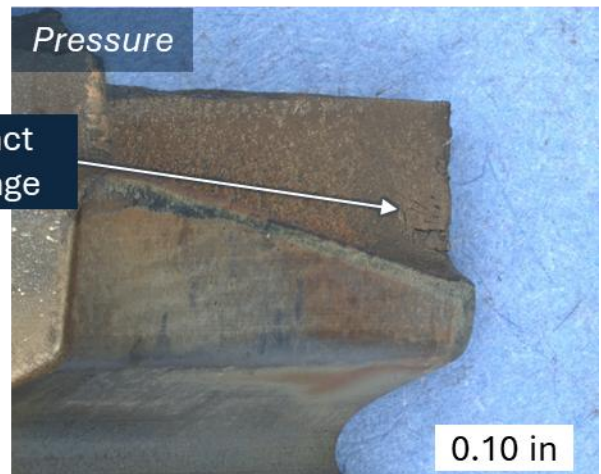


Figure 7. Magnified images of the trailing edge of blade 28 showing impact damage. (Left) Suction side. (Right) Pressure side.

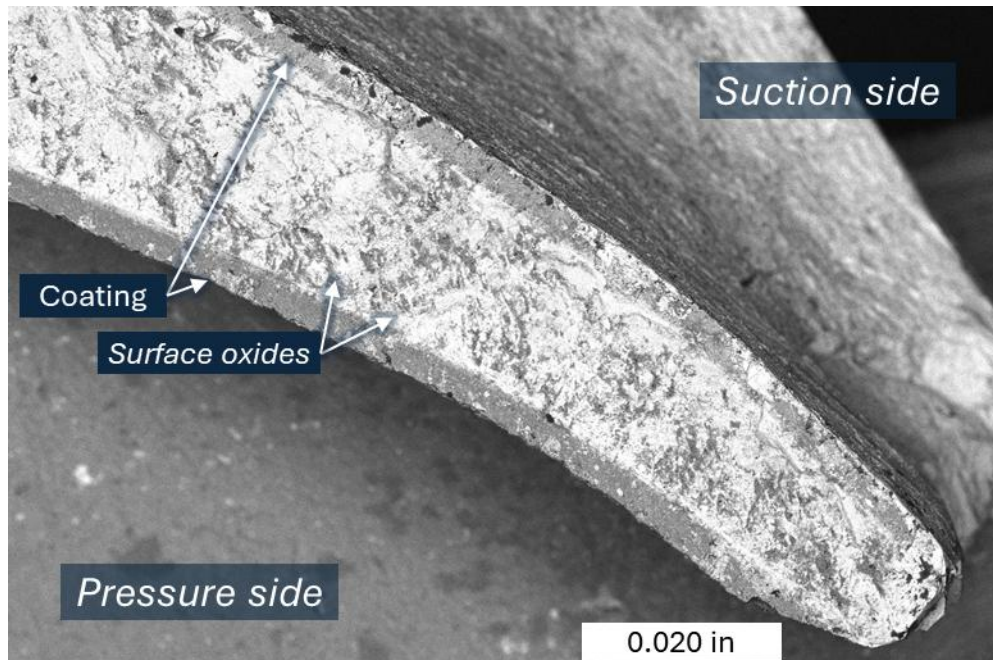


Figure 8. BSE micrograph of the fracture surface near the trailing edge of blade 28. Surface oxides appeared as dark patches.

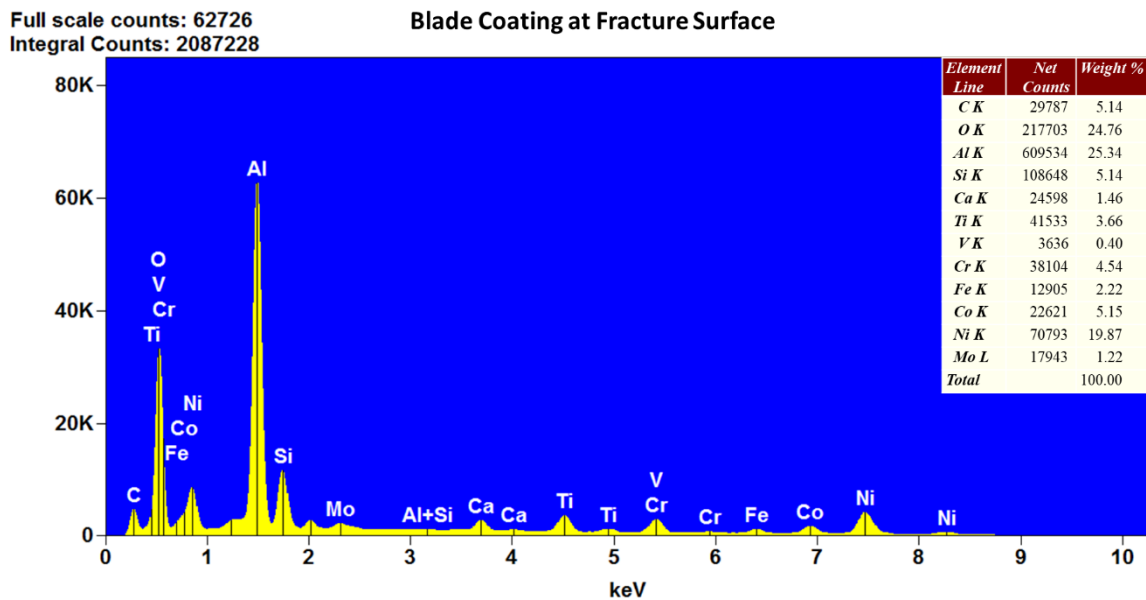


Figure 9. EDS spectrum of the coating layer at the fracture surface.

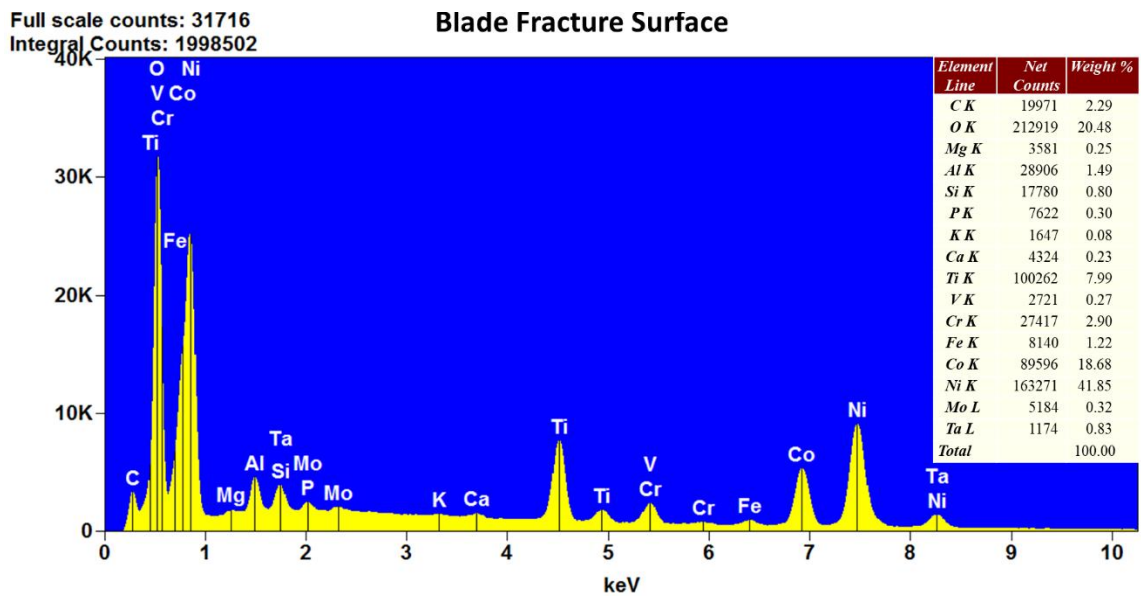


Figure 10. EDS spectrum of the blade fracture surface.

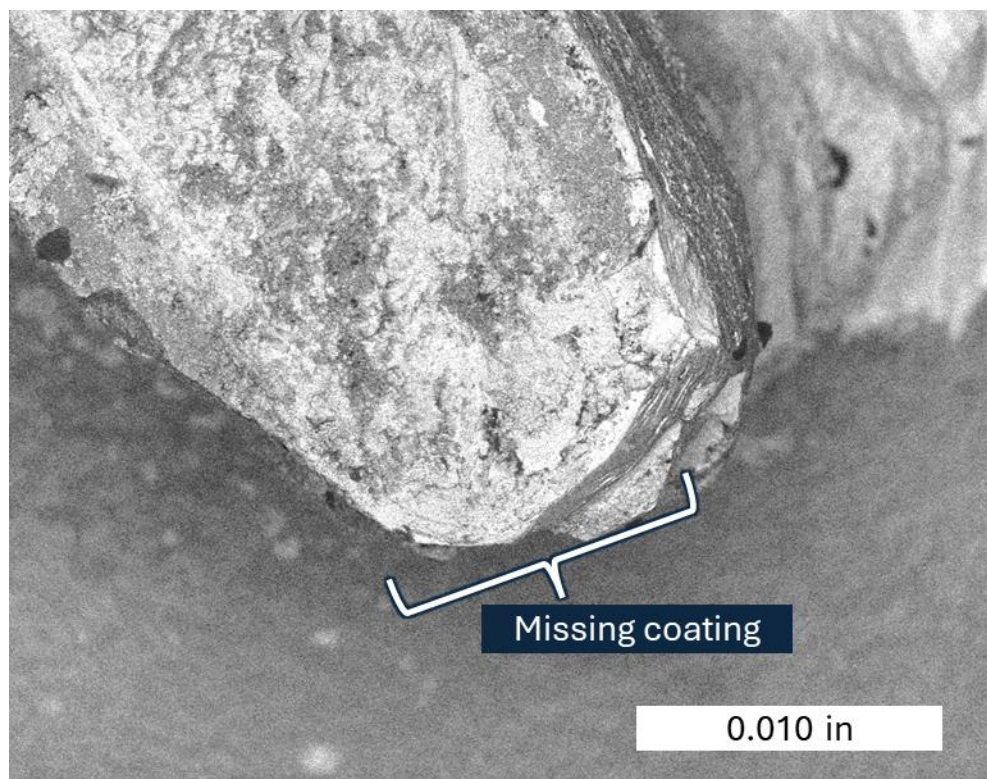


Figure 11. A section of coating missing at the trailing edge of the blade.

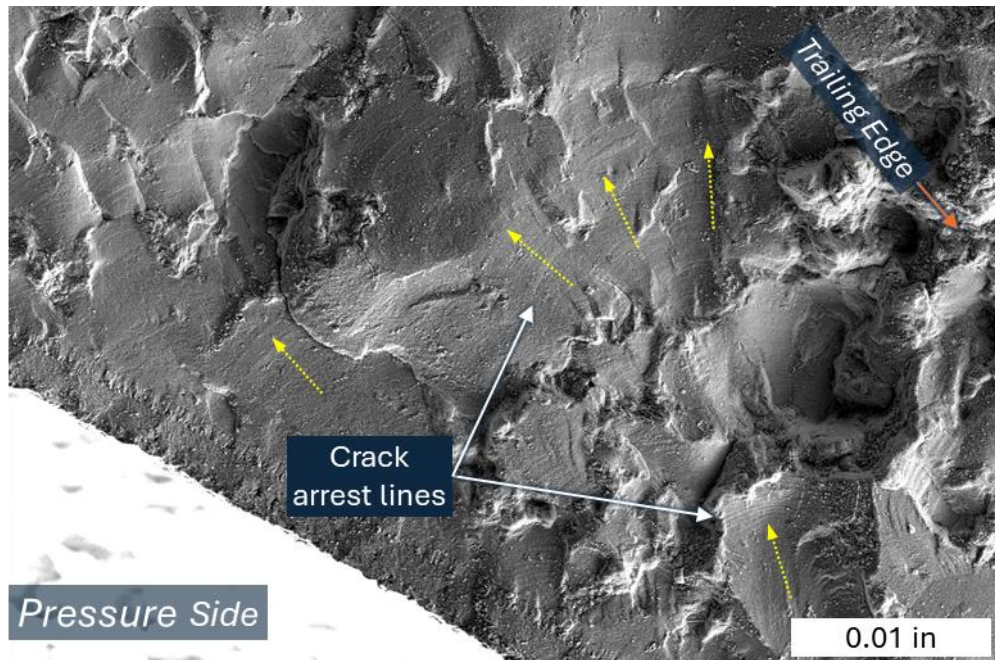


Figure 12. Crack arrest lines on the fracture surface emanated away from the trailing edge (not pictured). Yellow arrows show the crack growth direction as indicated by the arrest lines.

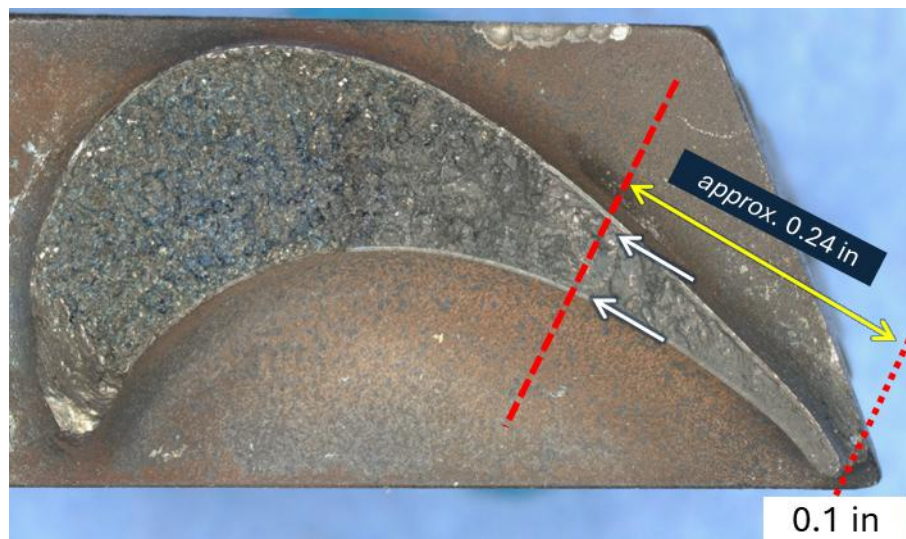


Figure 13. Blade 28 cut location for viewing the microstructure. Blade 29 was sectioned in the same location.

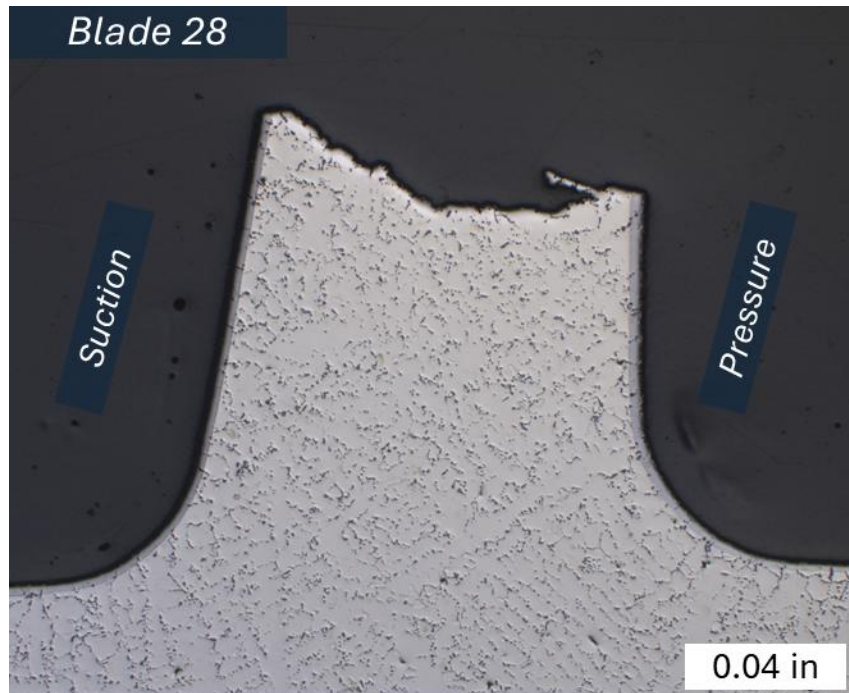


Figure 14. Cross-sectioned micrographs of (top) blade 28 and (bottom) blade 29. Locations indicated in blade 29 are magnified in Figure 17. (Unetched)

Full scale counts: 18565
Integral Counts: 781053

Grain Boundary Phase

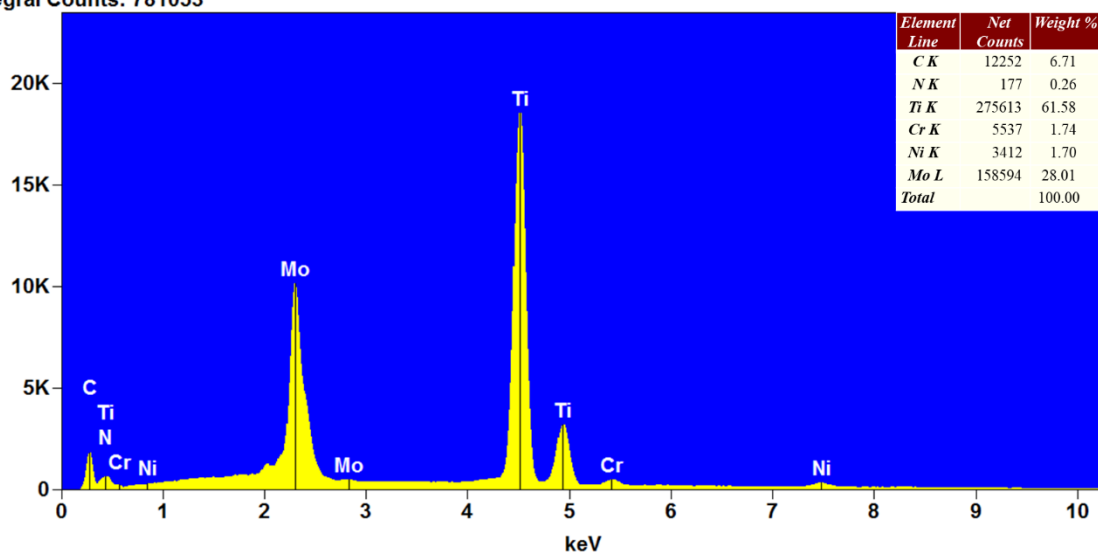


Figure 15. EDS spectrum of the grain boundary phase in blade 28.

Full scale counts: 10645
Integral Counts: 755305

Bulk Phase

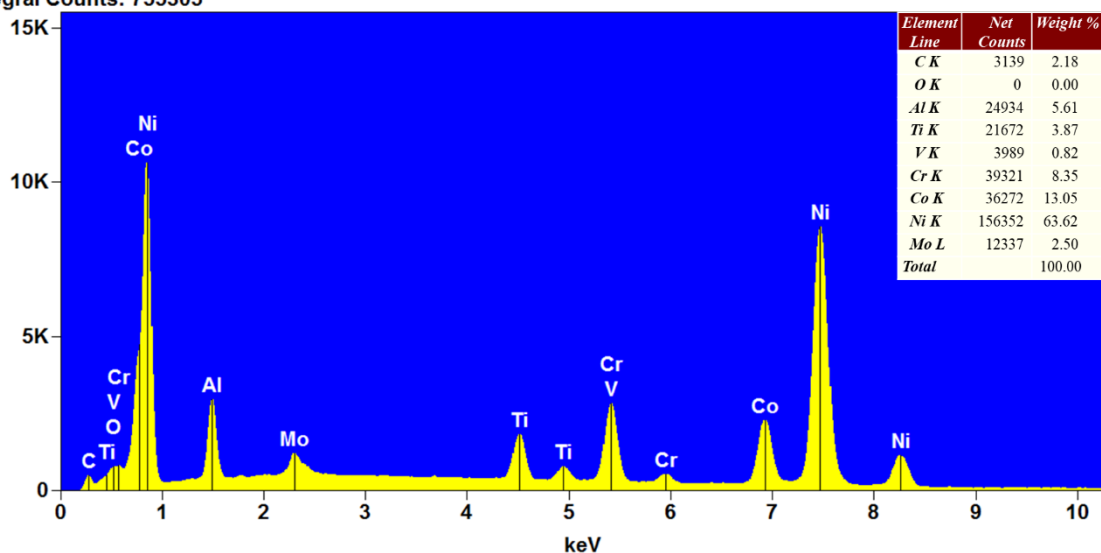


Figure 16. EDS spectrum of the bulk phase in blade 28.

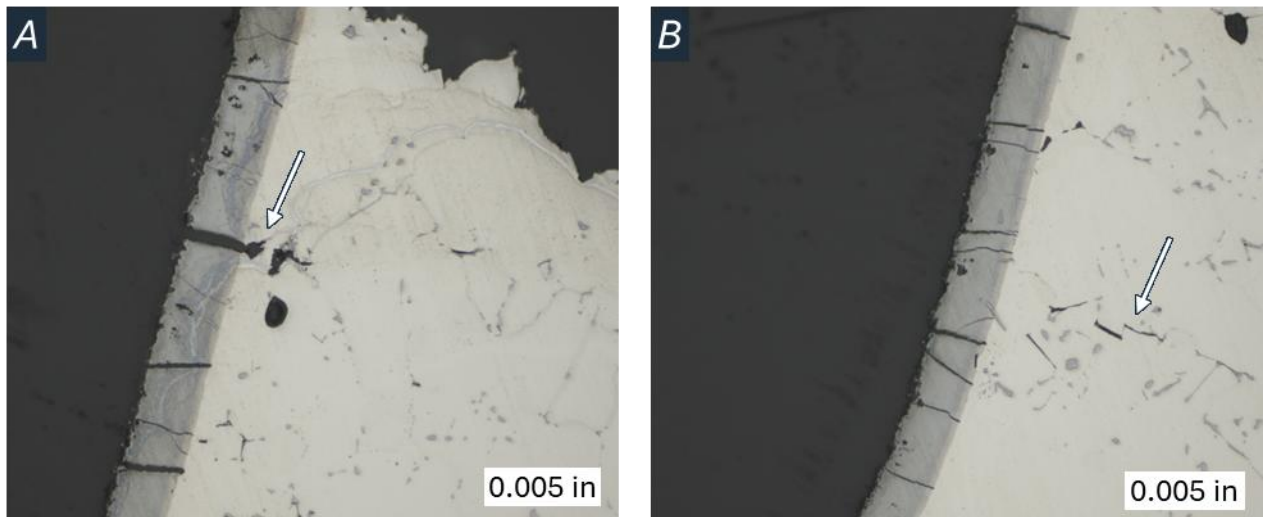


Figure 17. Surface cracks in the blade material seen on the suction side of blade 29. Locations referenced in Figure 14. (Unetched)

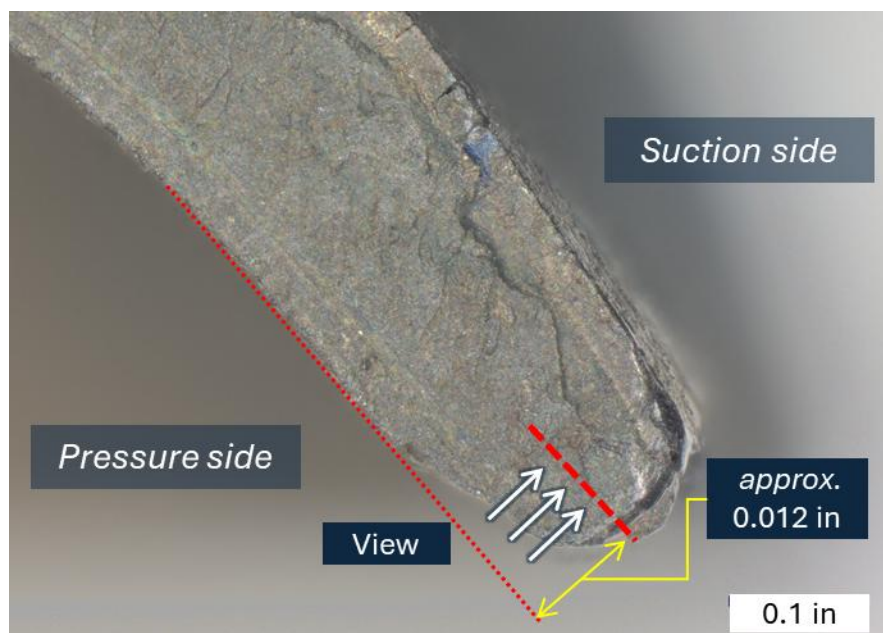


Figure 18. Blade 28 cross-section location for viewing the microstructure at the trailing edge.

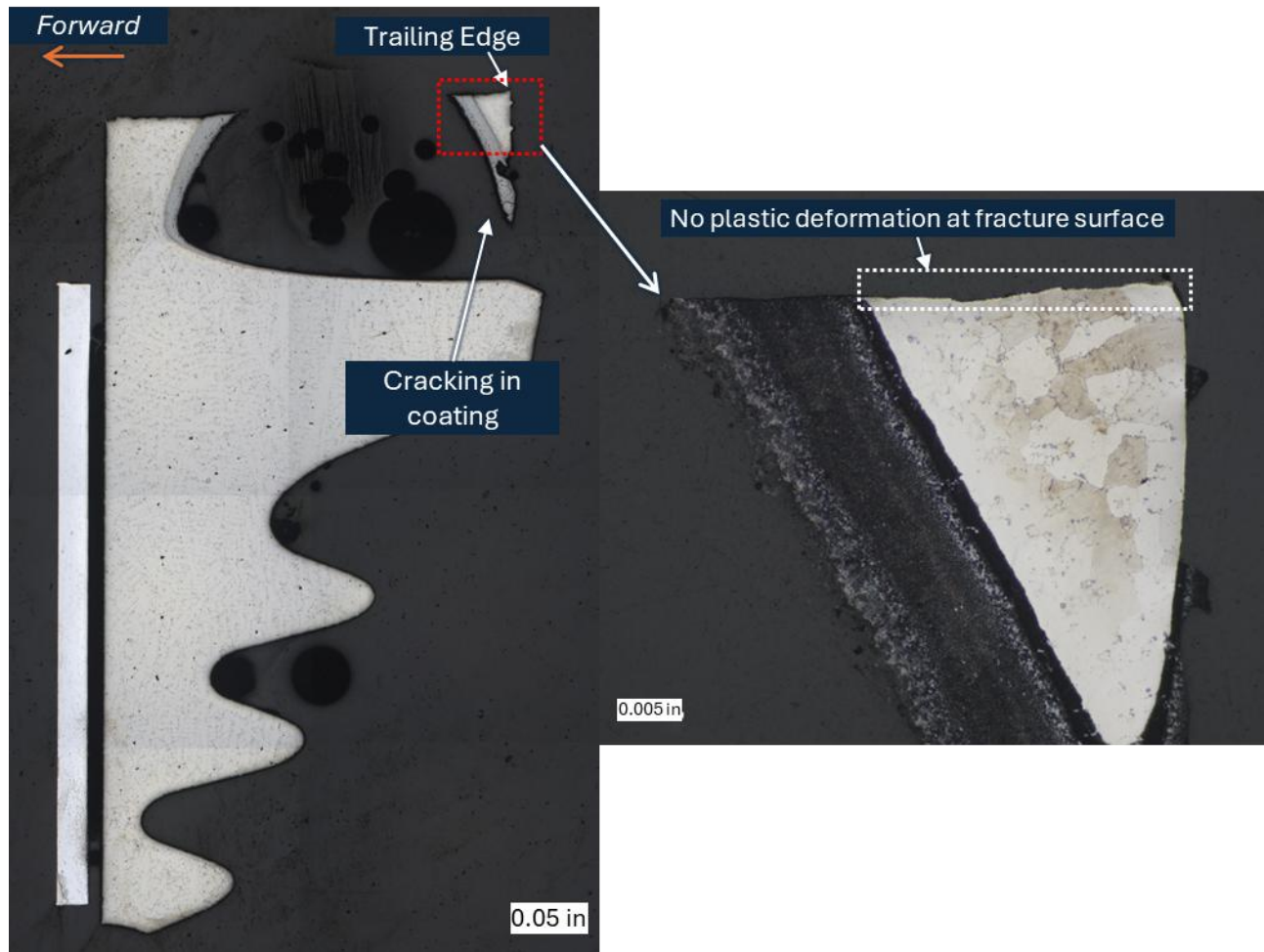


Figure 19. (Left) Optical micrograph of Blade 28 at the trailing edge (Unetched). (Right) The callout image shows the blade after etching with Kalling's reagent.

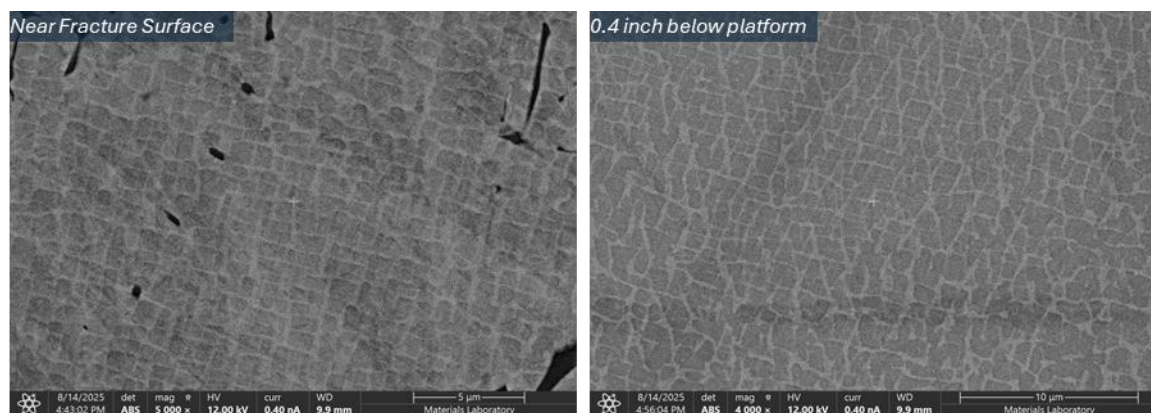


Figure 20. (Left) BSE image of the microstructure of blade 28 near the fracture surface. Black areas are the high-titanium phase. (Right) BSE image of blade 28 below the blade platform. (Unetched)