

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ERA25LA141

MATERIALS LABORATORY

Factual Report 25-082

January 21, 2026

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A. ACCIDENT INFORMATION

Location: Hollywood, Florida
Date: March 12, 2025
Vehicle: Piper PA-28-181, N3055B
Investigator: Eric Alleyne, AS-ERA

B. COMPONENTS EXAMINED

Crankshaft, main bearings, and oil screen.

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
NTSB
Washington, DC

Engineering Technician Ed Komarnicki
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

An overall view of the submitted components is shown in figure 1. The components included main journal bearings and a fractured crankshaft from a Lycoming O-320-A4M engine installed on the accident airplane. A bag containing the oil screen and fragmented metallic debris from the same engine was also included as shown in figure 1. The main journals were labeled M1 to M4, and the connecting rod journals were labeled C1 to C4. The crankshaft was fractured through the cheek between the M3 and the C3 journals.

The bag with the oil screen contained mostly oil-covered orange flakes consistent with copper fragments from the main bearings. The contents of the bag were not examined in detail.

The backs of the main bearings were stamped "FAA-PMA" consistent with parts having Federal Aviation Administration (FAA) Parts Manufacturer Approval (PMA). The M1-M2 bearing halves were marked "SL13884A M06 E 04-21 FAA-PMA K-795" and the M3 and M4 bearing halves were marked "SL16711A M06 G 03-21 FAA-PMA K-795". The part numbers were listed in the FAA's Dynamic Regulatory System (DRS).¹ The DRS listed Superior Air Parts as the approved manufacturer for

¹ <https://drs.faa.gov/browse/PMA/doctypeDetails>

the bearings, and the bearings were approved for use on many Lycoming engine models including the accident engine model.

The M1-M2 bearing was intact, but each half of the bearing was worn at the middle of the circumference near the forward and aft ends. The M3 and M4 bearings were not labeled. Both sets of bearings were damaged with impact damage and circumferential scoring damage extending through the Babbitt layer on the inside diameter surfaces. Two of the bearing halves had missing pieces through the thickness near one crush face on each half. The inside diameter surfaces showed areas where the underlying copper layer was exposed. In some areas where the copper layer was exposed, the copper was also spalled away.

The numbers "77037" were stamped on the side of the propeller flange, consistent with a Lycoming part number 77037 crankshaft. The characters "M006M/003P RN" were also stamped on the side, consistent with a renitrided crankshaft with undersized diameters for the main and connecting rod journals. Additionally, the characters "S247049-1" and "8092/" were vibropeened onto the side.

All journals on the crankshaft as shown in figure 1 had a mostly reflective gray color and did not show evidence of substantial heat damage. The M3 journal had some circumferential gouges and light scoring damage. The M4 journal had light circumferential scoring damage and isolated areas of rub marks. The remaining journals were relatively free of damage.

The diameters of the main journals were measured using a micrometer across the journal parallel and perpendicular to the direction of the connecting rod journal offset. According to the engineering drawing for the part number 77037 crankshaft provided by a representative from the engine manufacturer, the -M06M crankshaft has undersize main bearing diameters that are specified to be between 2.369 inches and 2.370 inches. All measurements of the main bearing diameters were within the specified range listed on the engineering drawing.

A close view of the fracture through the cheek at the aft end of journal M3 is shown in figure 2. Smooth fracture features with curving crack arrest lines were observed, features consistent with fatigue. Unlabeled arrows in figure 2 indicate local directions of fatigue crack growth. The visible fatigue features emanated from a crack between the M3 journal surface and a hole for supplying oil to the C3 journal. The fatigue propagated through the cheek and around the hole toward the C3 journal. Then the fatigue crack growth direction turned back toward the M3 journal. The fracture path continued to the outer edge of the cheek, where fracture features were obliterated by post-fracture contact damage. Additionally, a portion of the fracture through the cheek terminated at the location indicated with a dashed line in figure 2, where the fracture path intersected the crack between the oil hole and the M3 journal.

Multiple cracks were observed emanating from oil supply holes in the M3 journal as shown in figure 3. Cracks emanated from both the forward and aft sides of the hole that supplied oil to the C2 journal as indicated with brackets in figure 3a. The crack that intersected the fractured cheek emanated from the aft side of the hole that supplied oil to the C3 journal as indicated with a bracket in figure 3b.

At the C2 oil supply hole, cracks intersected the forward and aft sides of the hole nearly parallel to the longitudinal axis. The longitudinal portion of each crack was approximately 0.094 inch long, and the remainder of the crack length was oriented 45 degrees to the longitudinal axis. The cracks extended across most of the journal surface as indicated with brackets in figure 3a and visually appeared to terminate near the forward and aft fillet radii, respectively.

A closer view of the M3 journal at the C3 oil supply hole is shown in figure 4. Unlabeled brackets in figure 4 indicate the location of the crack at the M3 journal surface. The crack was oriented approximately 45 degrees from the longitudinal axis adjacent to the edge of the hole then turned nearly parallel to the longitudinal direction approximately 0.070 inch from the inside edge of the hole. The longitudinal portion extended approximately 0.077 inch before the crack branched with the longitudinal portion extending another 0.013 inch while the other branch continued to the aft cheek at nearly 45 degrees to the longitudinal axis. The area aft of the hole had smeared material on the surface with circumferential scoring that was discontinuous across the crack. Longitudinally-oriented secondary cracks were also observed aft of the hole near the longitudinal portion of the primary crack.

A series of cuts were made with a water-cooled abrasive saw to expose the fracture surfaces of the crack emanating from the aft side of the C3 oil supply hole. A view of two sectioned pieces showing the exposed crack fracture surfaces is shown in figure 5. Next, the smaller piece shown in figure 5 was cleaned using an ultrasonic cleaner while submerged in a bath of Alconox detergent and warm water.

A closer view of the aft side of the fracture as viewed on the cleaned smaller piece is shown in figure 6. The fracture surface spanned between the C3 oil supply hole and the M3 journal bearing surface. Curving crack arrest lines consistent with fatigue were observed extending across most of the fracture, and unlabeled arrows in figure 6 indicate local directions of fatigue propagation. The direction of fatigue crack growth was oriented nearly parallel to the oil supply hole axis from near the M3 journal surface to the aft cheek.

Closer views of fracture features at the aft edge of the C3 oil supply hole opening in the M3 journal are shown in figures 7 and 8. Fracture features at the edge of the oil supply hole opening were relatively rough, and most of the rough region was covered with brown oxides. In figure 8, orange arrows indicate the local fracture propagation directions in the oxidized region emanating from an origin area located

at the M3 journal surface next to the C3 oil supply hole opening. The boundary of the brown oxidized region is indicated with an orange dashed line.

The remainder of the relatively rough region near the C3 oil supply hole opening had a matte-gray appearance with radial features consistent with ductile overstress fracture. Green arrows in figure 8 indicate fracture propagation directions in the ductile overstress region emanating from the boundary of the brown oxidized region. The boundary of the ductile overstress region is indicated with a green dashed line in figure 8. The portion of the ductile overstress region that intersected the M3 journal surface was associated with the portion of the crack that was oriented nearly parallel to the journal's longitudinal axis as indicated in figures 7 and 9.

Blue arrows in figures 7 and 8 indicate local directions of fatigue crack growth. Fatigue features with curving crack arrest lines emanated from the boundary of the overstress fracture region as shown in figure 8. The fatigue origin was located at the boundary of the overstress region as indicated in figure 8, and the fatigue region terminated at the boundaries of the oxidized and overstress regions, indicating that the fatigue crack initiation and growth was secondary to the oxidized and overstress crack regions.

Although the M3 journal surface showed scoring damage, the journal surface did not show evidence of high heating associated with bearing failure. However, heat tinting was observed on the interior surface of the C3 oil supply hole as shown in figure 10. Near the M3 journal surface, the hole bore was tinted dark gray, and deeper into the bore, the hole was tinted shades of blue and red.

Next, a piece of the fracture containing the origin area was sectioned as shown in figure 10 to facilitate examination using a scanning electron microscope (SEM). The sectioned piece was cleaned using an ultrasonic cleaner while submerged in a bath of acetone.

An SEM image showing an overall view of the origin area is shown in figure 11. A portion of the oxidized region had a rougher appearance as outlined with a yellow dashed line and yellow arrows indicating local directions of fracture within the rougher region. The remaining arrows and dashed lines are indicated as in the optical image shown in figure 8.

A close view of the fatigue origin area at the boundary of the overstress region is shown in figure 12. A portion of the origin area was damaged from post-fracture rubbing. The area was examined using both the secondary electron detector and with a backscattered electron detector in composition mode.² No indications of any material anomalies were observed at the fatigue origin.

² SEM images produced using a backscattered electron detector in composition mode have contrast that is associated with atomic number of the elements in the image. Areas with elements having

Closer views of fracture features near the origin area at the M3 journal surface are shown in figure 13. The fracture features were somewhat damaged by post-fracture rubbing, but angular features consistent with intergranular fracture were observed as shown in figure 13a. The same area at the origin is shown in figure 13b as viewed using the backscatter detector in composition mode. Areas with shades of light gray and medium gray were observed in the field of dark gray in the image shown in figure 13b. The medium gray areas were generally located near the surface, while light gray areas were observed scattered throughout the intergranular region up to the boundary as shown in figure 14. No light gray areas were observed in the ductile overstress region or the fatigue region.

Sampled areas of the various shaded regions observed during the examination using backscattered electrons were analyzed using energy dispersive x-ray spectroscopy (EDS). The darker gray regions of the fracture surface had a spectrum with a high peak of iron and smaller peaks of nickel, chromium, lead, silicon, aluminum, oxygen, and carbon. By comparison, the highest peak in the EDS spectra obtained in the relatively bright areas was the peak for lead. In the medium gray areas near the M3 surface at the origin area, the highest peak was the peak for copper.

Closer views of fracture features in the oxidized region next to the C3 oil supply hole are shown in figure 15 and 16. The fracture surface had roughness consistent with an intergranular fracture path, but ductile dimples were observed at higher magnification as shown in figure 16.

In the overstress region, the fracture transitioned to transgranular fracture with ductile dimples observed at higher magnification.

Bits of metallic debris were observed scattered throughout the oxidized and overstress regions. The debris consisted of smooth flakes of material and serrated strips of varying width. Arrows in figure 15b indicate examples of the serrated strips within the field of view in that image. The flakes and serrated strips were only observed in the oxidized and overstress regions and were not observed in the fatigue portion of the crack surface.

Next, the piece that had been examined in the SEM was mounted in clear epoxy and polished to varying depths. The location of the first plane of polish through the oxidized and fatigue regions is shown in figure 17, and the location of the final polish through the intergranular region is shown in figure 18.

The cross-section in the final plane of polish is shown in figure 19 as polished.³ Multiple secondary cracks were observed emanating from the M3 journal surface as

higher atomic numbers appear as a relatively lighter shade of gray compared to areas having elements with lower atomic numbers.

³ Note the metallographic images in figures 19 through 22 were taken by an inverted metallograph.

indicated with arrows in figure 19. The polished plane was then etched with 2% nital, and metallographic images of the etched samples are shown in figure 20.⁴ An area of the journal surface where secondary cracks were observed etched lighter. Closer views of the white layer showed distorted grains smeared in the circumferential direction. The edge of the white layer was approximately 0.008 inch away from the fracture plane.

A view of the typical microstructure near the middle of the metallurgical specimen after etching with nital is shown in figure 21a. The microstructure had a needle-like structure consistent with tempered martensite. Closer to the journal surface, the microstructure had a more spheroidal appearance as shown in figure 21b.

Next, the sample was repolished and etched using Marble's reagent. Marble's reagent is used to reveal depth of the nitride layer. Measuring the depth of the altered material at the surface in the micrograph shown in figure 22a, the depth of the nitride layer was measured to be 0.009 inch.

A closer view of a secondary crack in the area of the white layer is shown in figure 22b. The crack path near the surface followed the direction of the distorted microstructure, oriented circumferentially near the surface and radially at deeper extents.

Microhardness tests were conducted on the polished metallurgic specimen shown in figure 18 using a Leco LM248AT microindentation hardness testing machine with AMH55 software. Microhardness was measured using a Vicker's indenter with a 500-gram load at varying depths from the M3 journal surface. Microhardness values were then converted to the equivalent Rockwell C hardness using a conversion table provided in ASTM Standard E140-12B.⁵ The resulting microhardness profile is shown in figure 23. The measured equivalent hardness of 31 HRC was slightly below the minimum core hardness of 32 HRC specified for the crankshaft material on the engineering drawing. The engineering drawing also specified a minimum superficial hardness for the journal surfaces, and the microhardness value for the indent closest to the surface exceeded the minimum requirement.

According to maintenance records, the accident engine was overhauled on April 2, 2023. The records indicated a magnetic particle inspection was completed

The metallograph produces images that are mirrored relative to those taken by the optical microscope used to produce images of the mounted specimen shown in figures 17 and 18.

⁴ Nital is an etchant consisting of a small percentage of concentrated nitric acid mixed with either ethanol or methanol commonly used to reveal the microstructure of polished steel samples.

⁵ ASTM E140-12B(2019)e1, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness*, ASTM International, West Conshohocken, PA (2025).

on the crankshaft by Aviation Propeller, Inc. As of February 6, 2025, the engine had accumulated 1,765.8 hours time in service since overhaul.

Submitted by:

Matthew R. Fox, Ph.D.
Chief Technical Advisor, Materials Laboratory



Figure 1. Overall view of the submitted components.

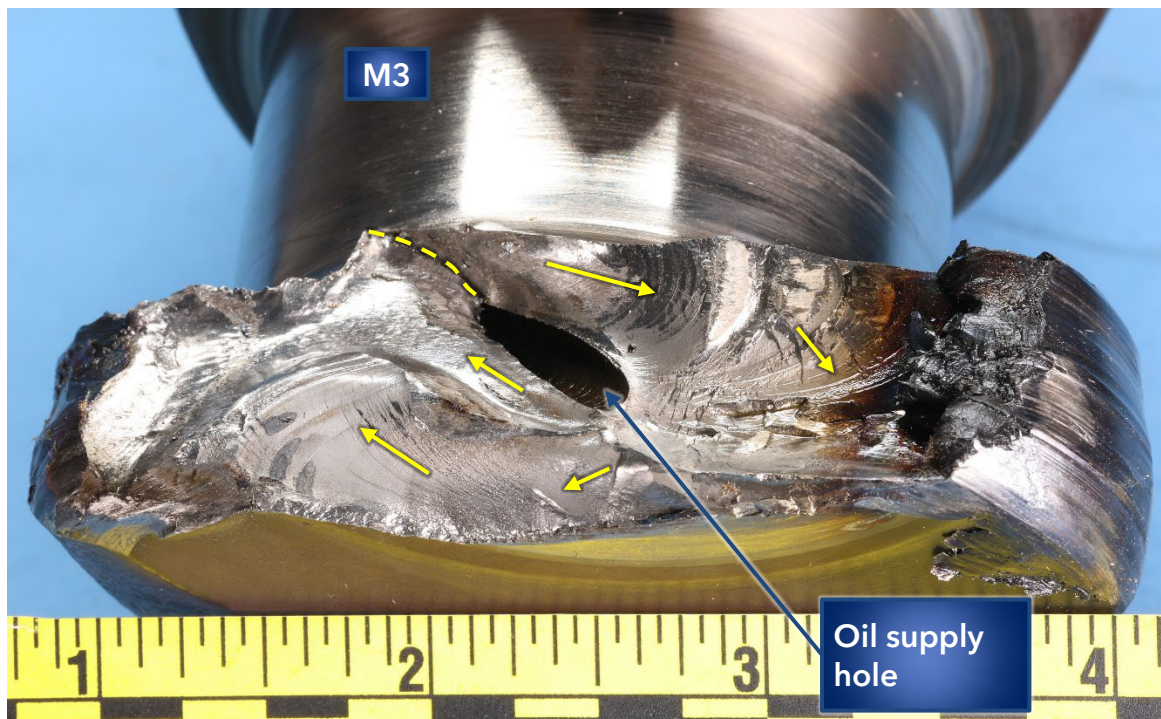


Figure 2. Close view of the fracture through the cheek at the aft side of the M3 journal. Unlabeled arrows indicate local directions of fatigue crack propagation, and a dashed line indicates the location where the fracture intersected the crack propagating along the oil supply hole for the C3 journal.

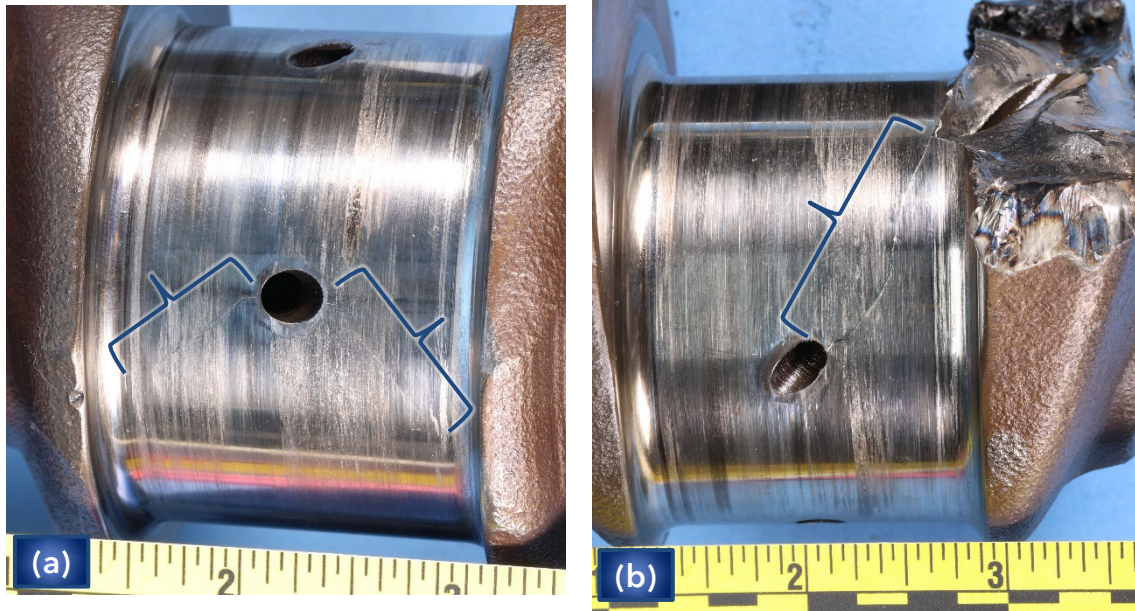


Figure 3. Views of cracks emanating from oil supply holes in the M3 journal as indicated with unlabeled brackets. (a) Cracks emanating from the forward and aft sides of the hole for the C2 journal. (b) Crack emanating from the aft side of the hole supplying the C3 journal.

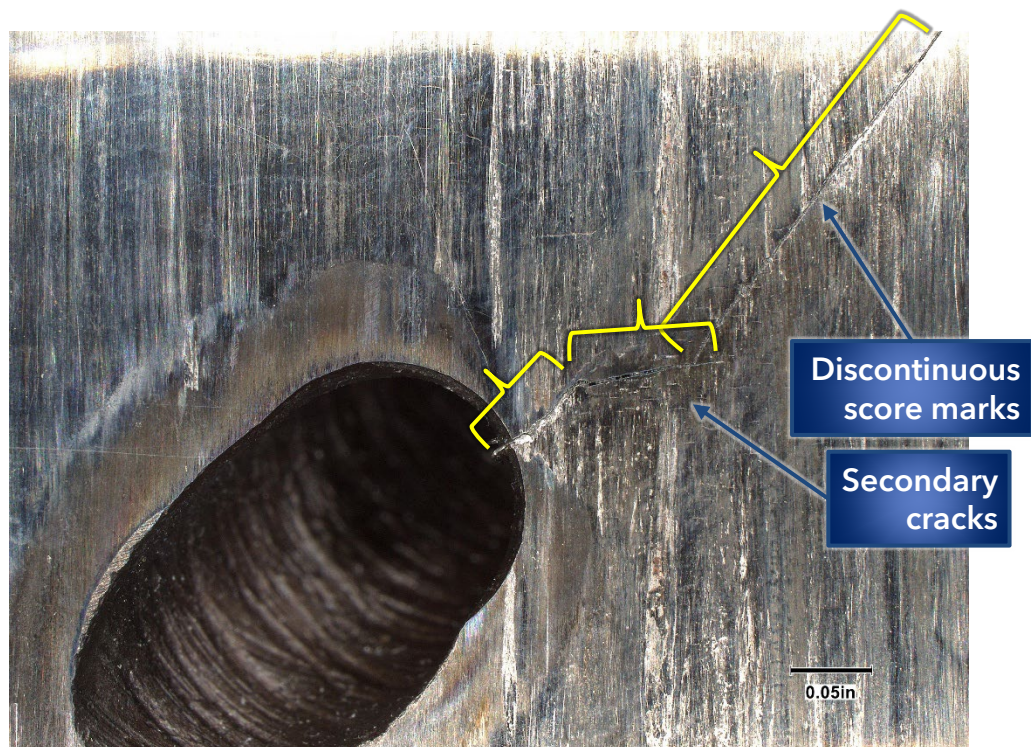


Figure 4. Closer view of the crack in the M3 journal at the C3 oil supply hole. Brackets indicate crack propagation angled between the circumferential and longitudinal directions separated by a nearly longitudinal segment.

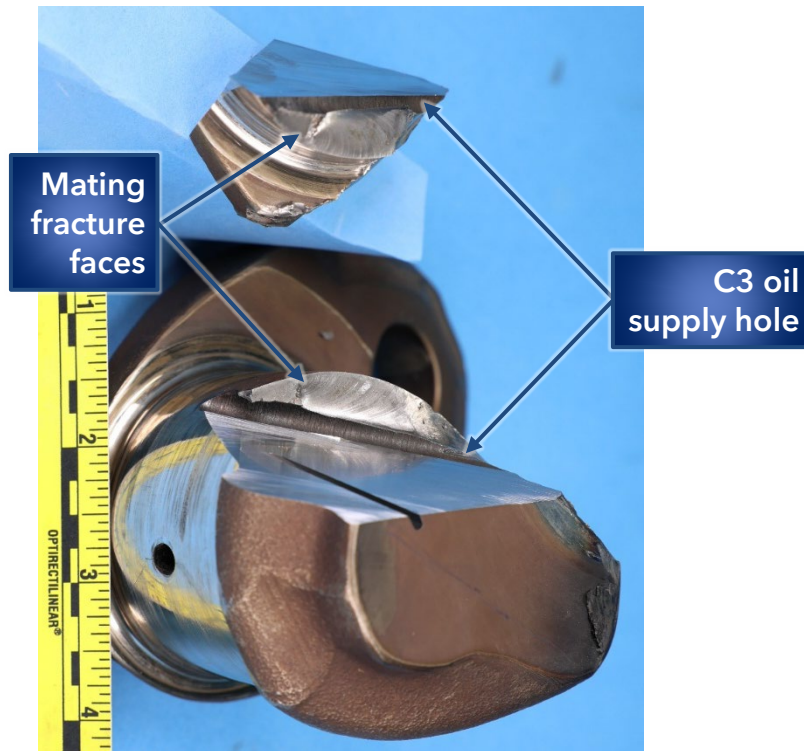


Figure 5. Mating sides of the crack in the M3 journal emanating from the C3 oil supply hole after sectioning.

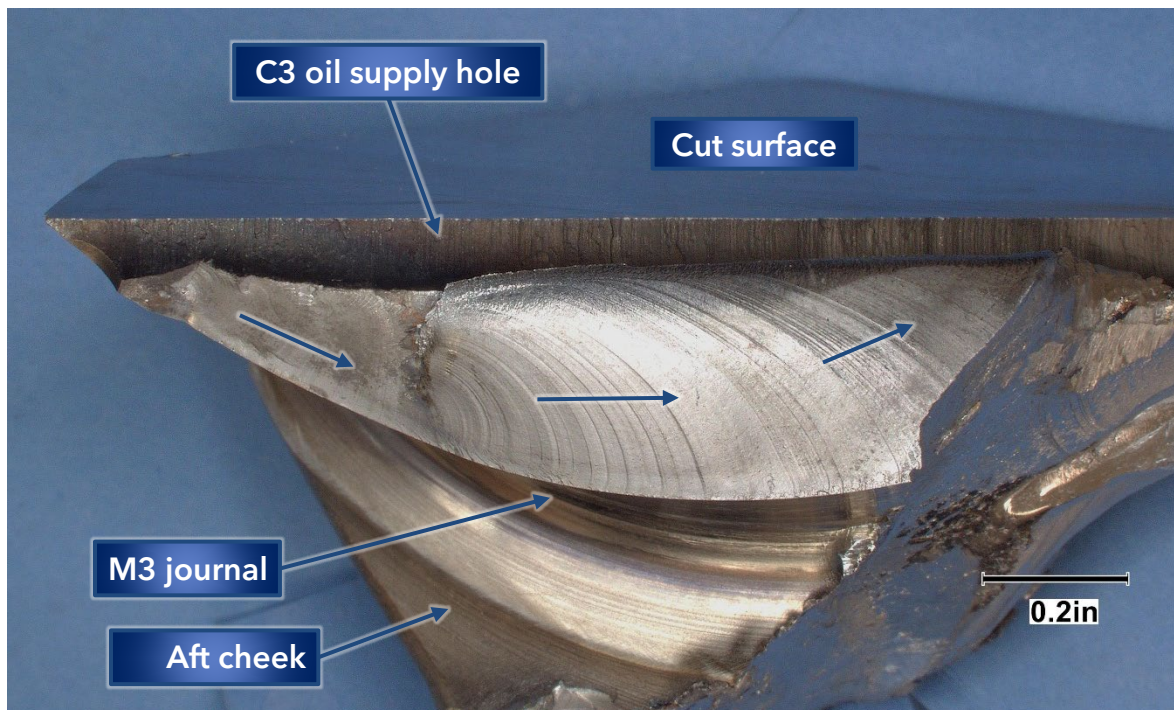


Figure 6. Close view of the opened crack on the smaller piece shown in figure 5. Unlabeled arrows indicate local directions of fatigue propagation.

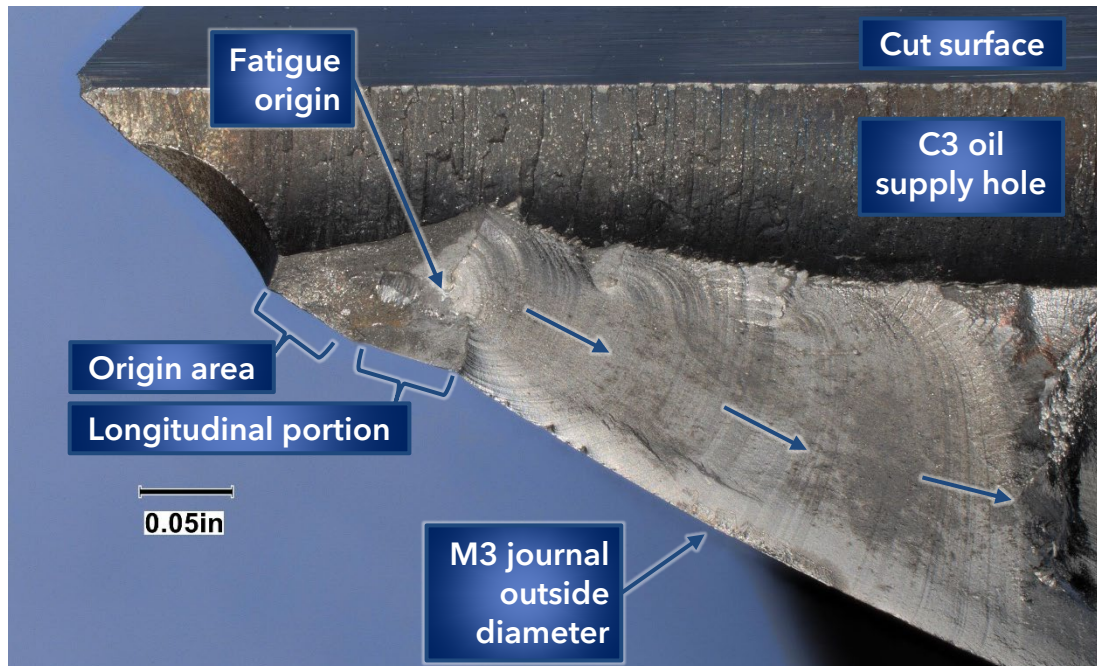


Figure 7. Closer view of the origin area on the opened crack. Unlabeled arrows indicate local directions of fatigue propagation.

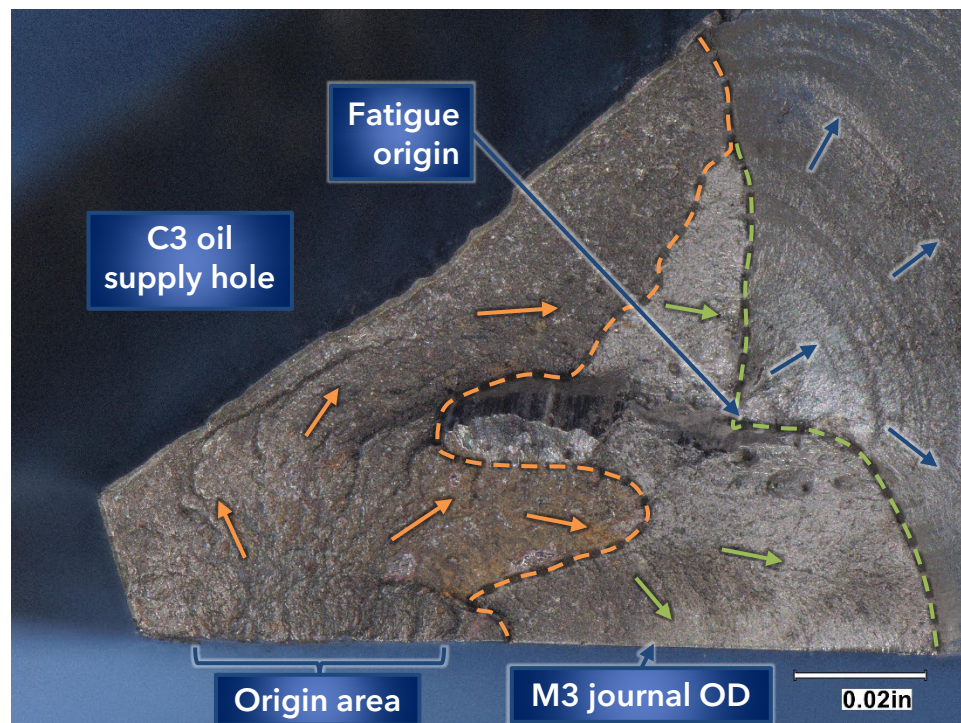


Figure 8. Origin area located at the M3 journal surface adjacent to the C3 supply hole. Orange arrows indicate local intergranular crack propagation within an oxidized region bounded by an orange dashed line. Green arrows indicate directions of overstress fracture with limited oxidation bounded by the dashed green line. Blue arrows indicate local directions of fatigue crack propagation from the indicated fatigue origin.

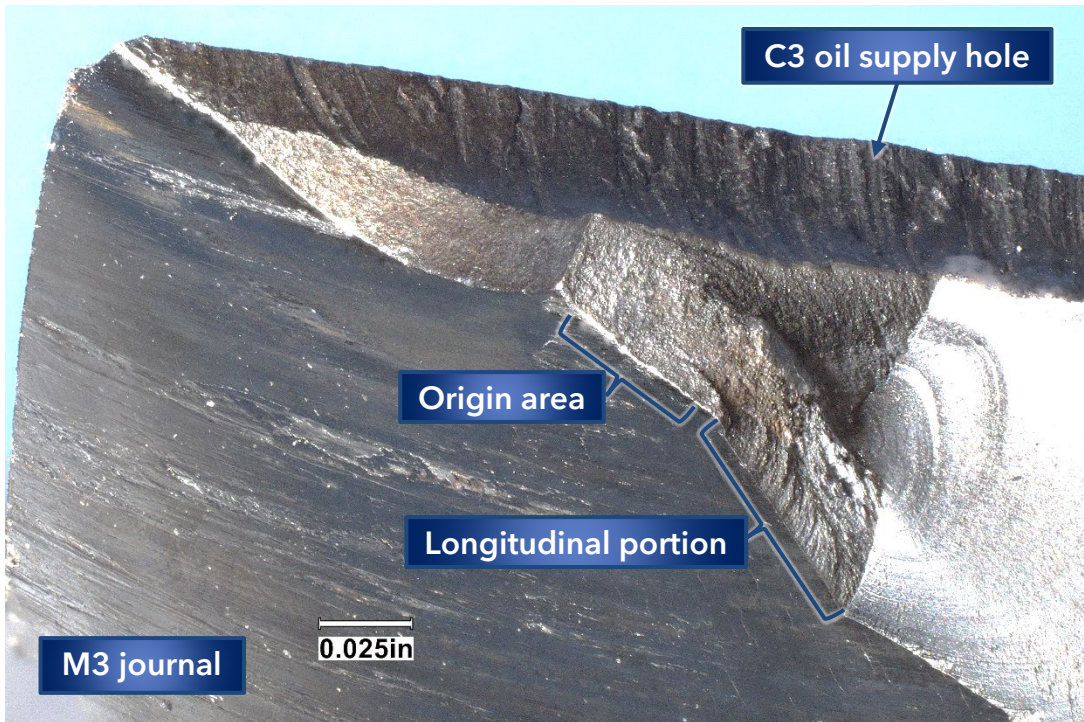


Figure 9. Angled view of the origin area showing the adjacent M3 journal surface.

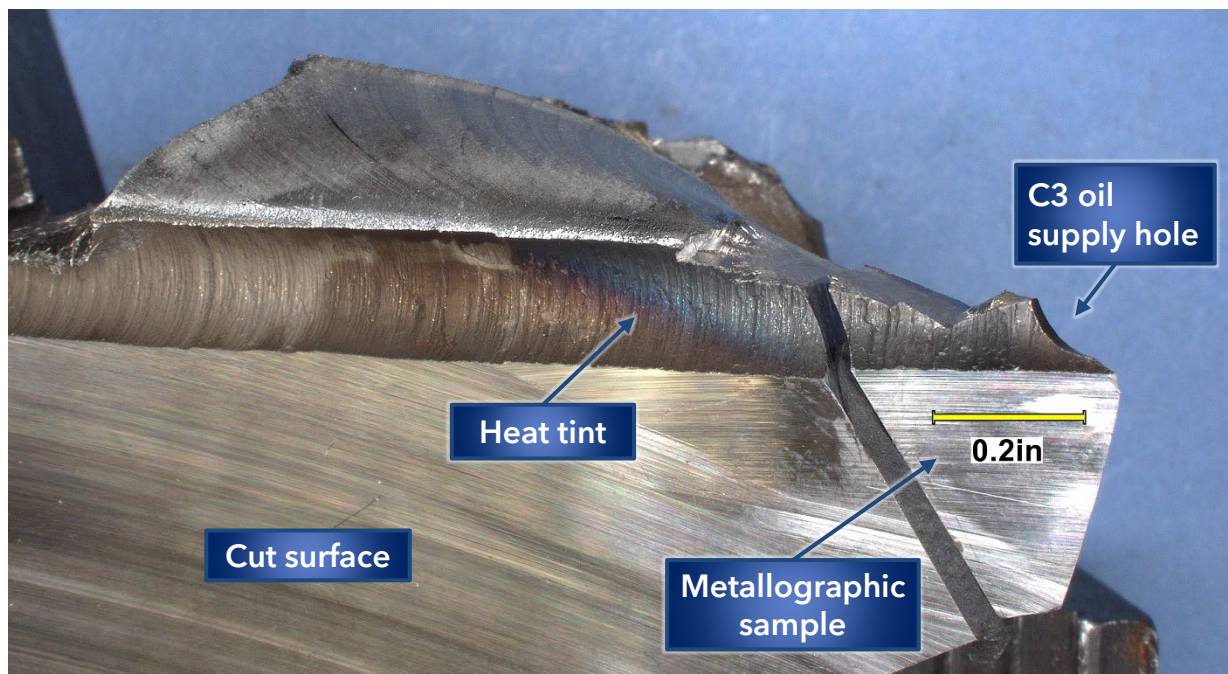


Figure 10. View of the C3 oil supply hole after the origin area was sectioned for metallographic examination showing a heat-tinted bore at near the hole in the M3 journal.

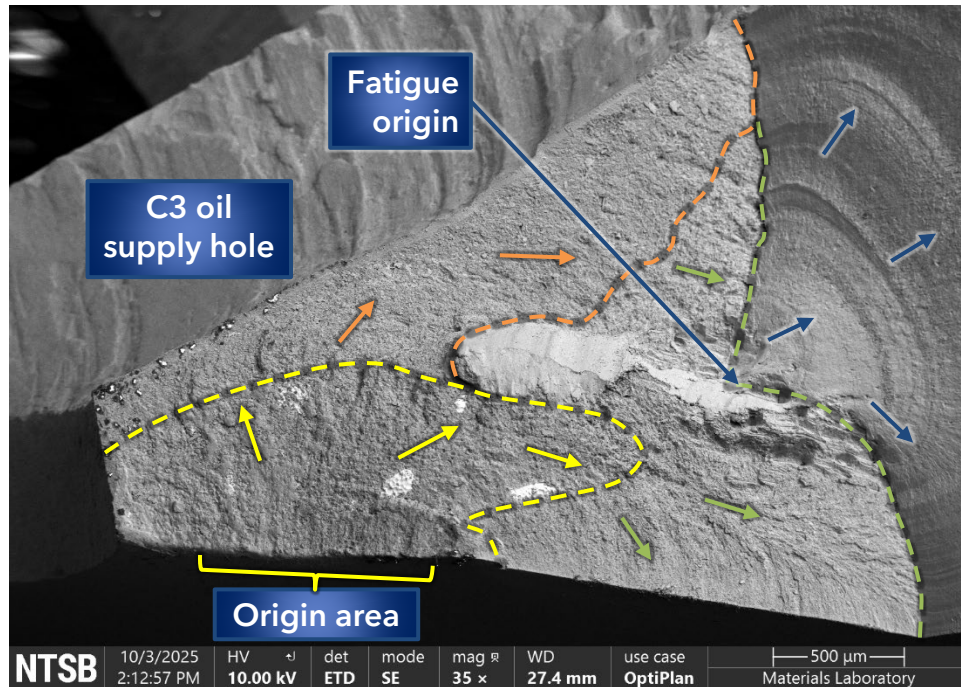


Figure 11. SEM image of the origin area viewed using the secondary electron detector.

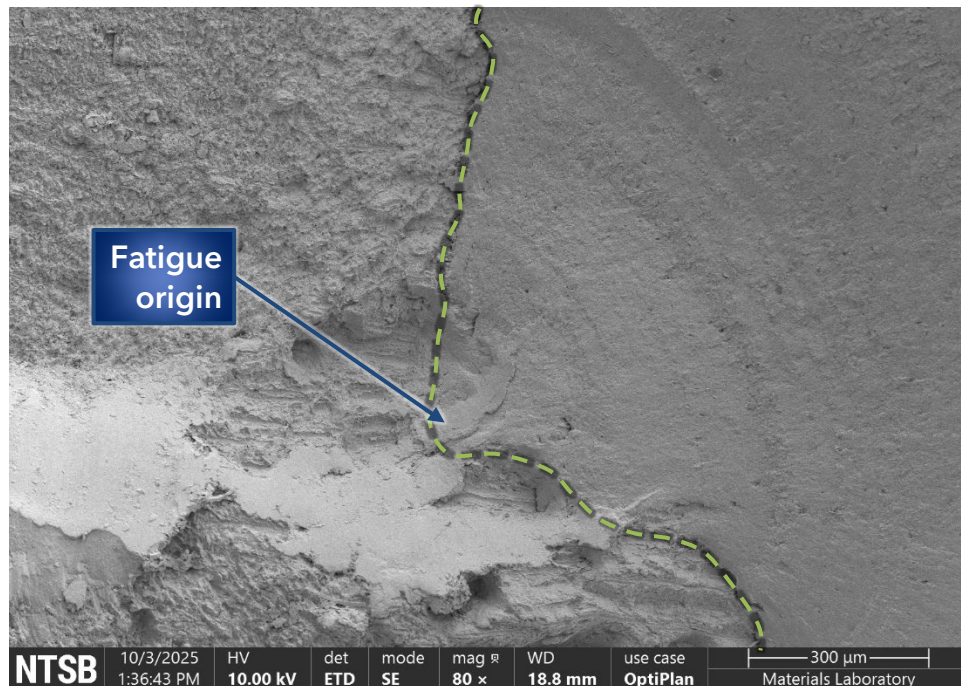
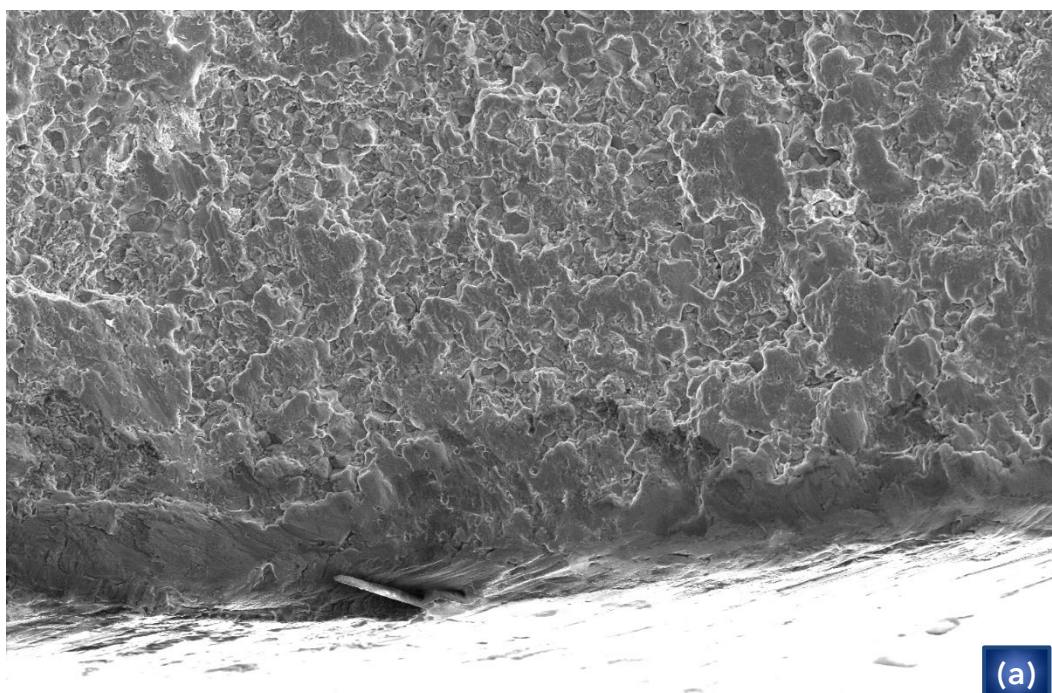
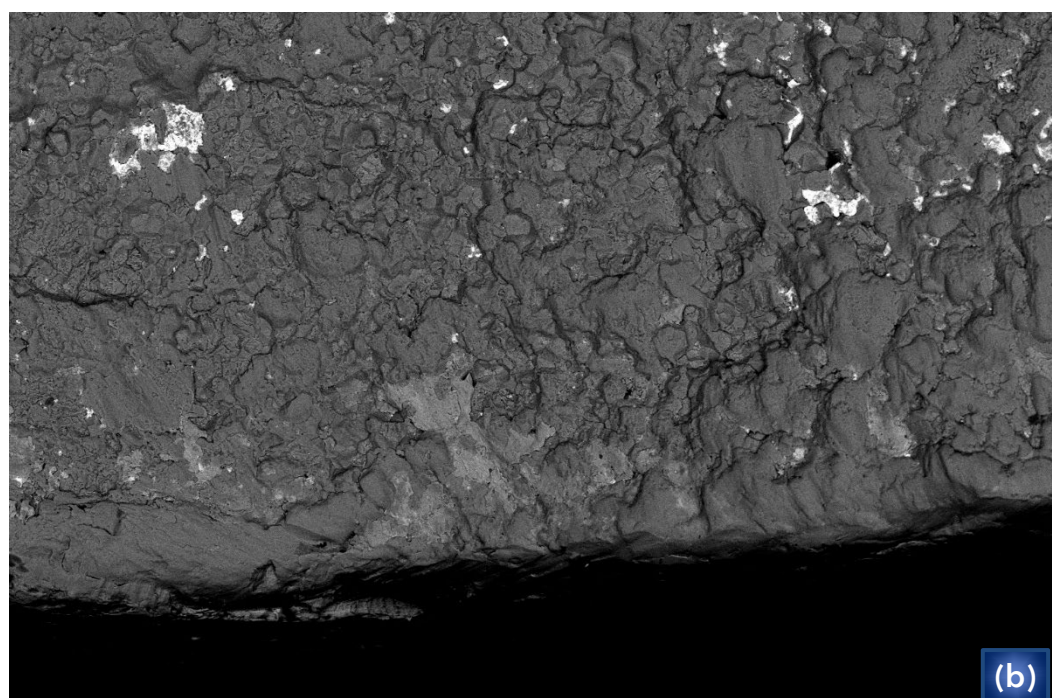


Figure 12. SEM image of the transition to fatigue crack propagation at the fatigue origin area. A green dashed line indicates the overstress fracture boundary.



NTSB	10/3/2025 3:22:04 PM	HV 20.00 kV	det ETD	mode SE	mag × 250 ×	WD 14.8 mm	use case OptiPlan	100 μm	
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NTSB	10/3/2025 3:22:04 PM	HV 20.00 kV	det ABS	mode All	mag × 250 ×	WD 14.8 mm	use case OptiPlan	100 μm	
								Materials Laboratory	

Figure 13. (a) SEM image of the origin area viewed using a secondary electron detector, and (b) the same area viewed using a backscattered electron detector in composition mode. In the backscattered electron image, medium gray areas had relatively high levels of copper, and white areas had relatively high levels of lead as analyzed using EDS.

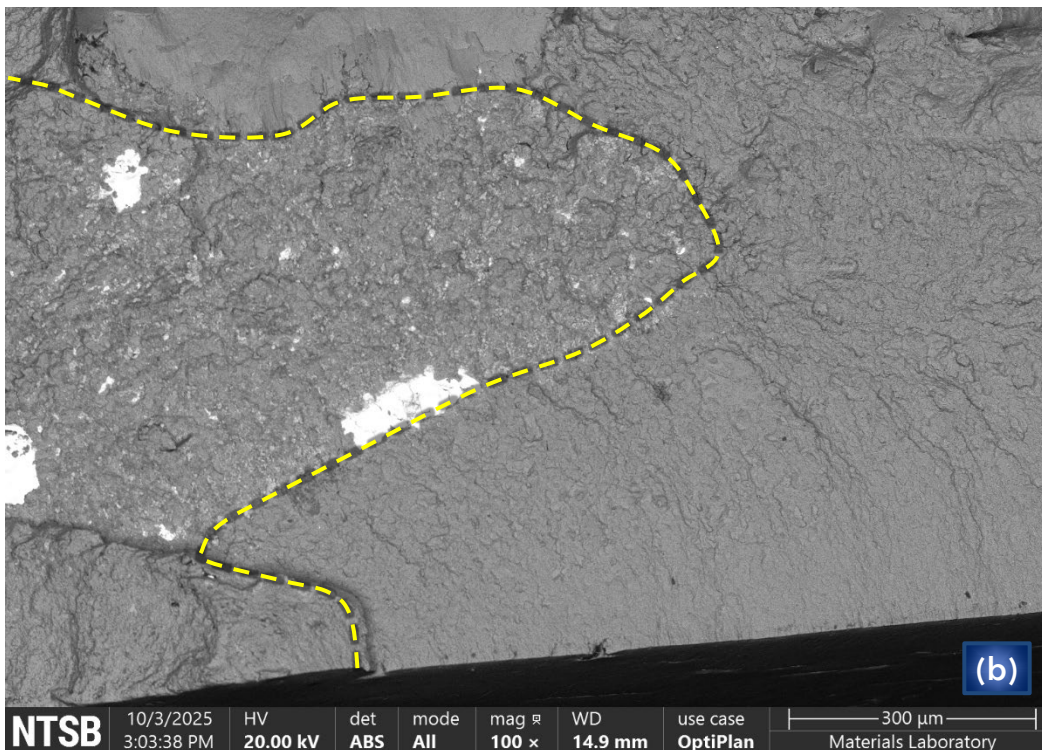
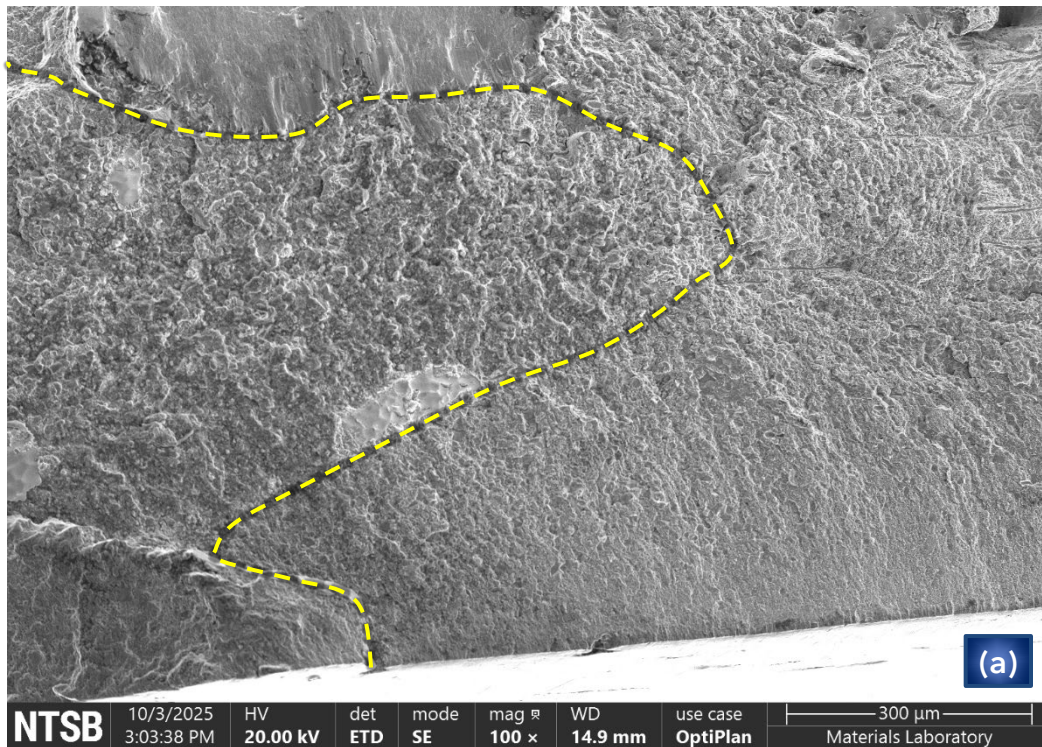


Figure 14. (a) SEM image of the boundary between the oxidized intergranular region bounded by a dashed line and the adjacent overstress fracture region, and (b) the same area viewed using a backscattered electron detector in composition mode. In the backscattered electron image, white areas had relatively high levels of lead as analyzed using EDS.

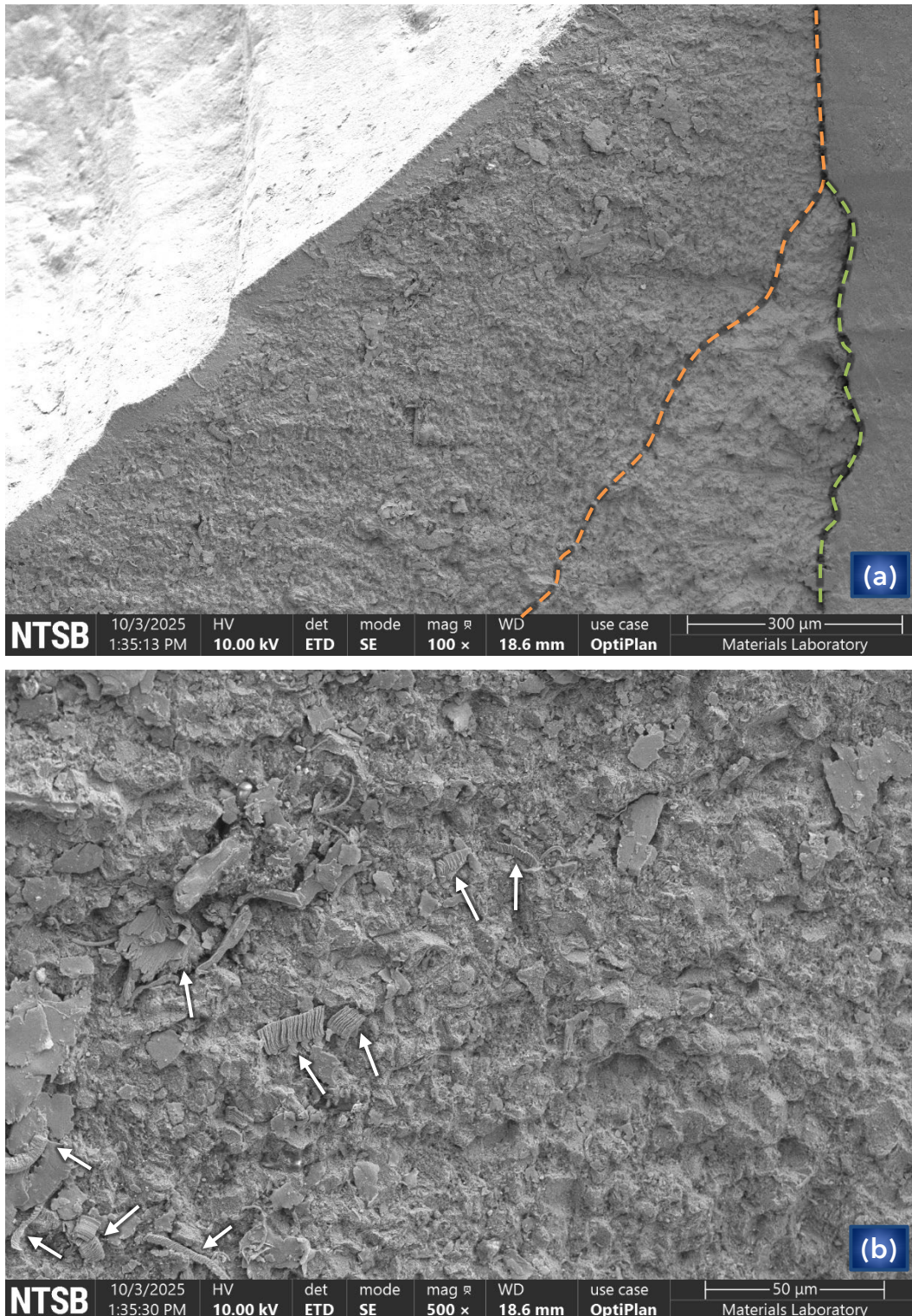


Figure 15. (a) SEM image of the oxidized region adjacent to the C3 oil supply hole at the region boundary indicated with an orange dashed line. A green dashed line indicates the boundary between the overstress and fatigue regions. (b) Higher magnification view of fracture features near the middle of image (a) showing debris on the surface consistent with machining debris.

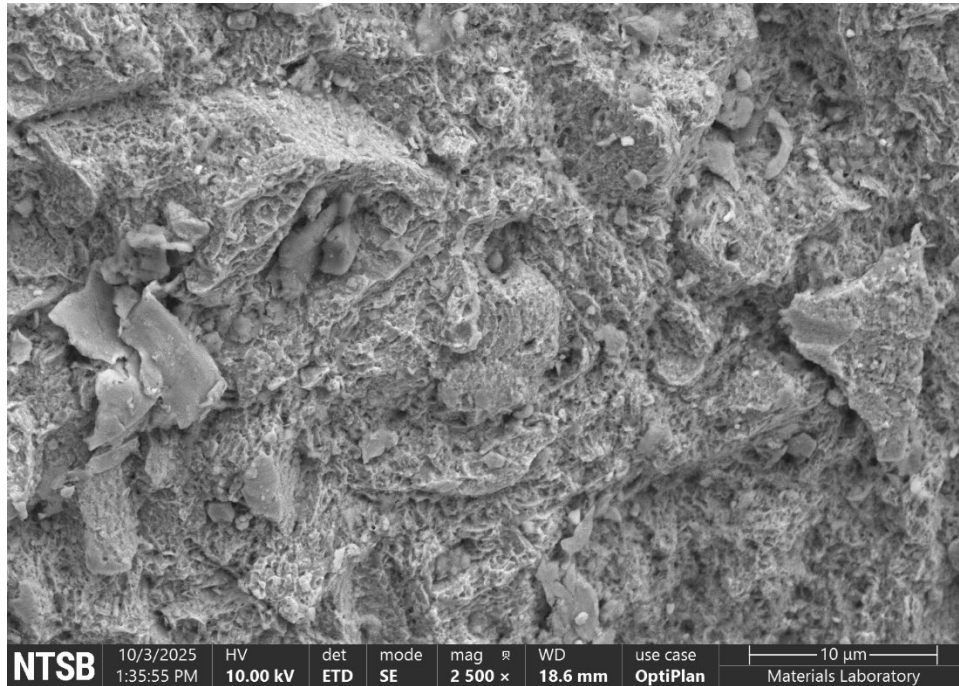


Figure 16. Closer view of fracture features in the area shown in the previous figure showing dimples on intergranular features.

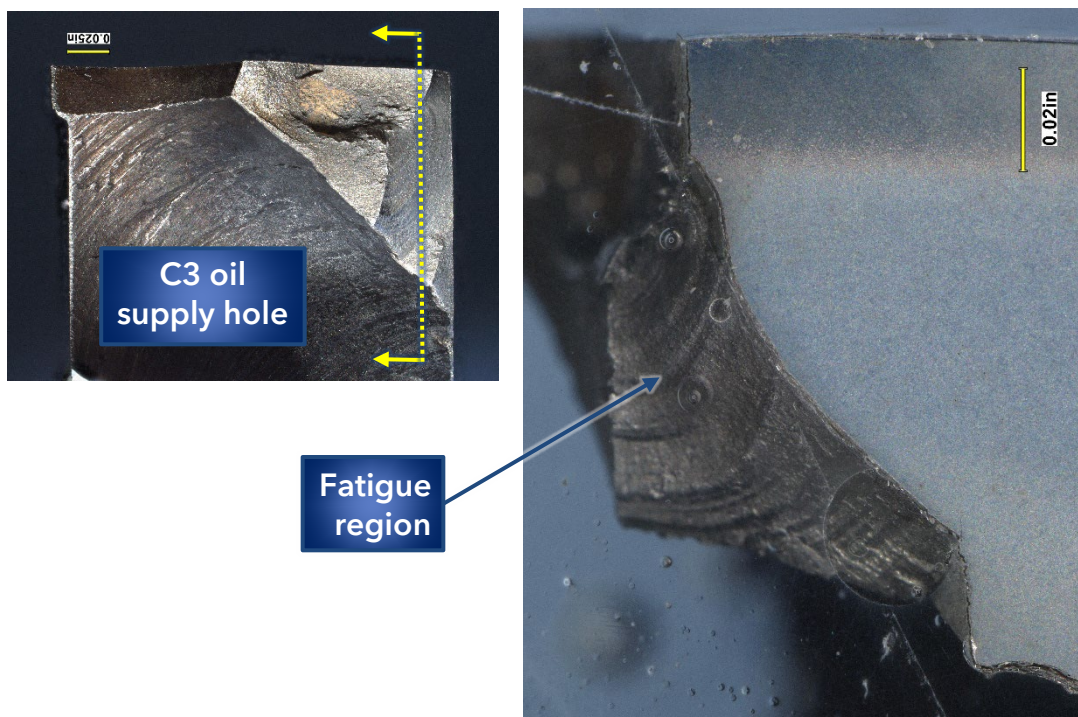


Figure 17. Polished and etched cross-section in the plane indicated in the upper left image. (2% nital etch)



Figure 18. Polished and etched cross-section in the plane indicated in the upper left image. (Etchant: 2% nital)

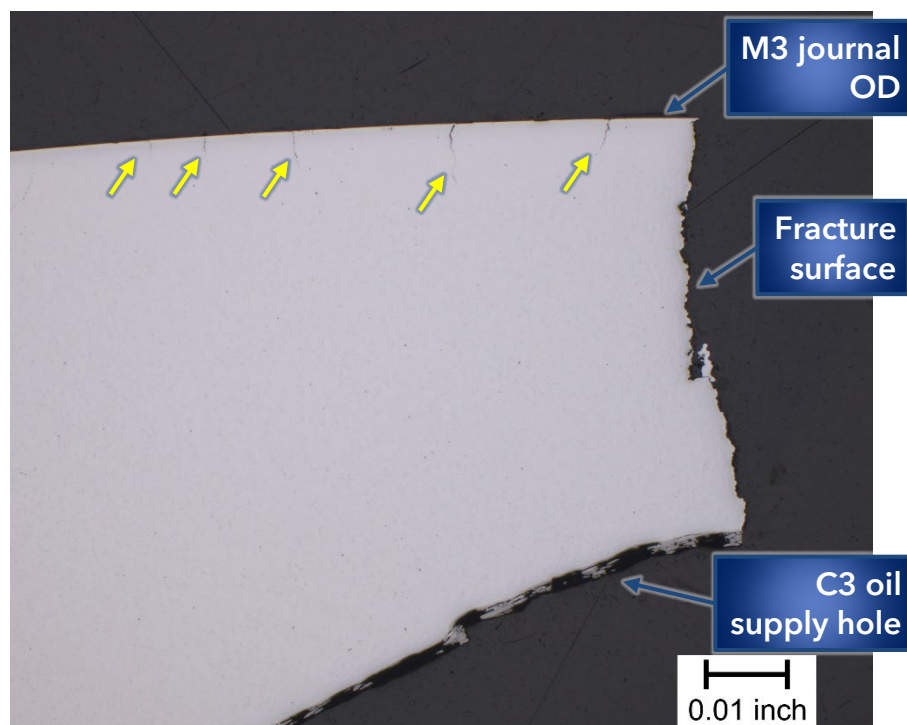


Figure 19. Metallographic image of the as-polished sample in the plane shown in figure 18.

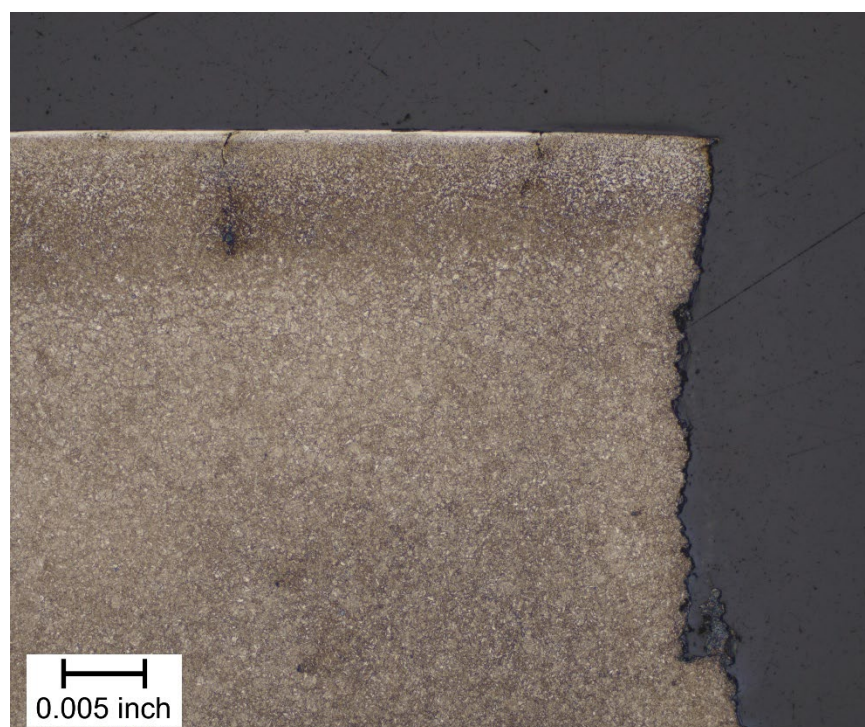
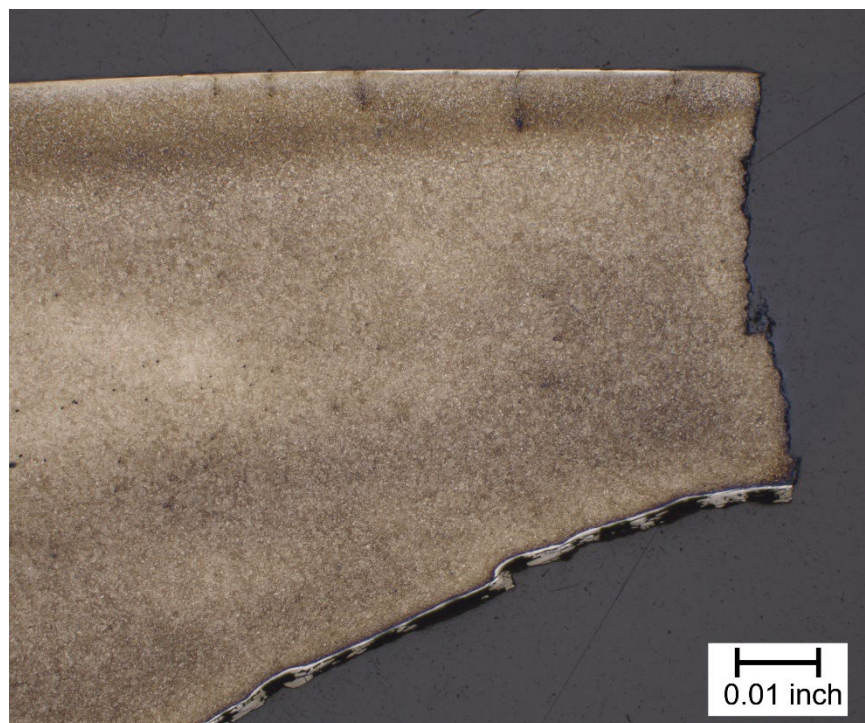


Figure 20. Metallographic images of the polished and etched sample in the plane shown in figure 18. (Etchant: 2% nital)

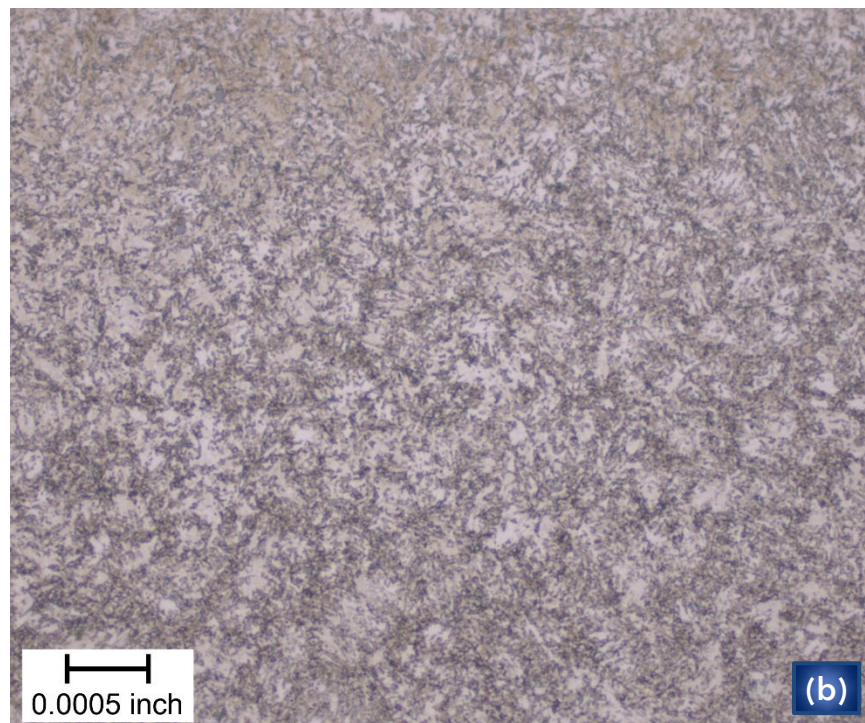
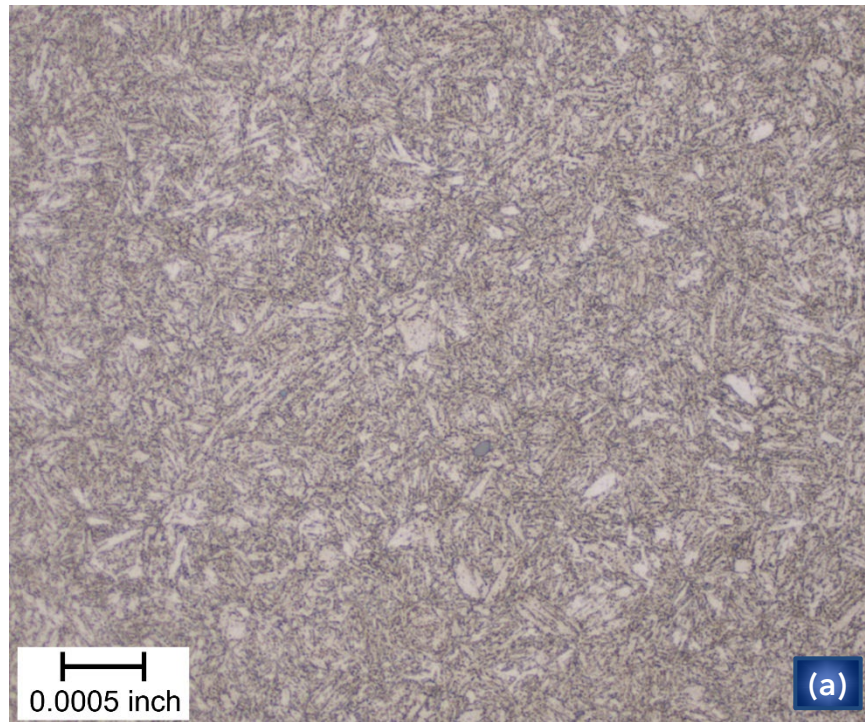


Figure 21. Metallographic images of typical features for the polished and etched sample. (a) microstructure at the core (b) microstructure near the journal surface. (Etchant: 2% nital)

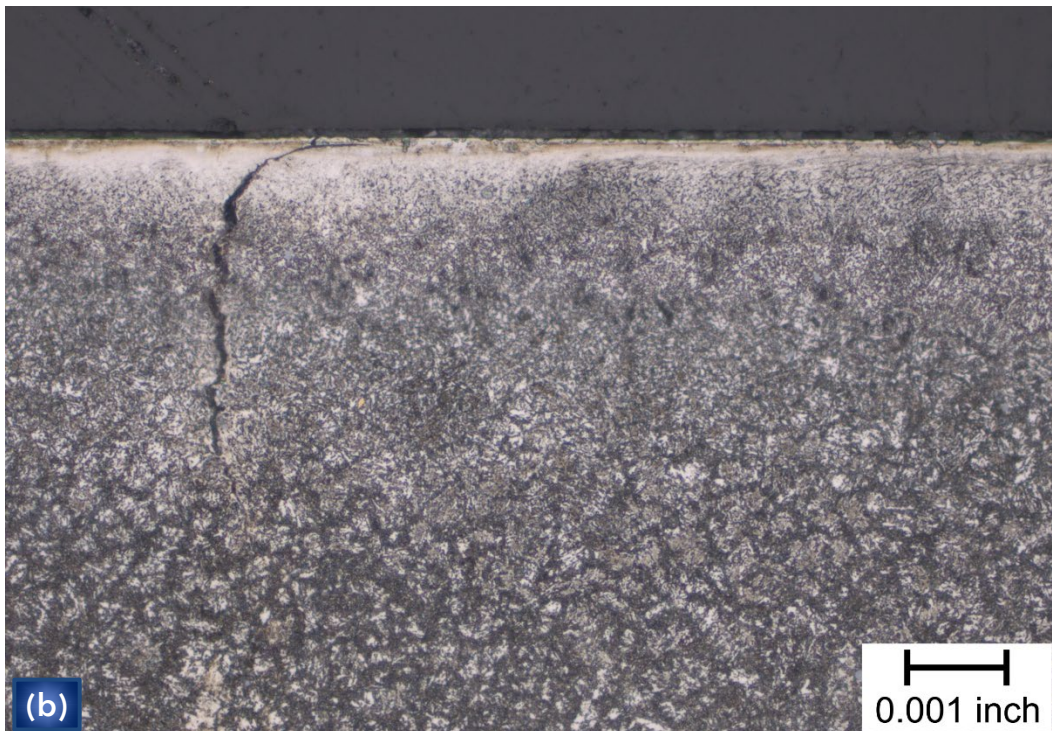
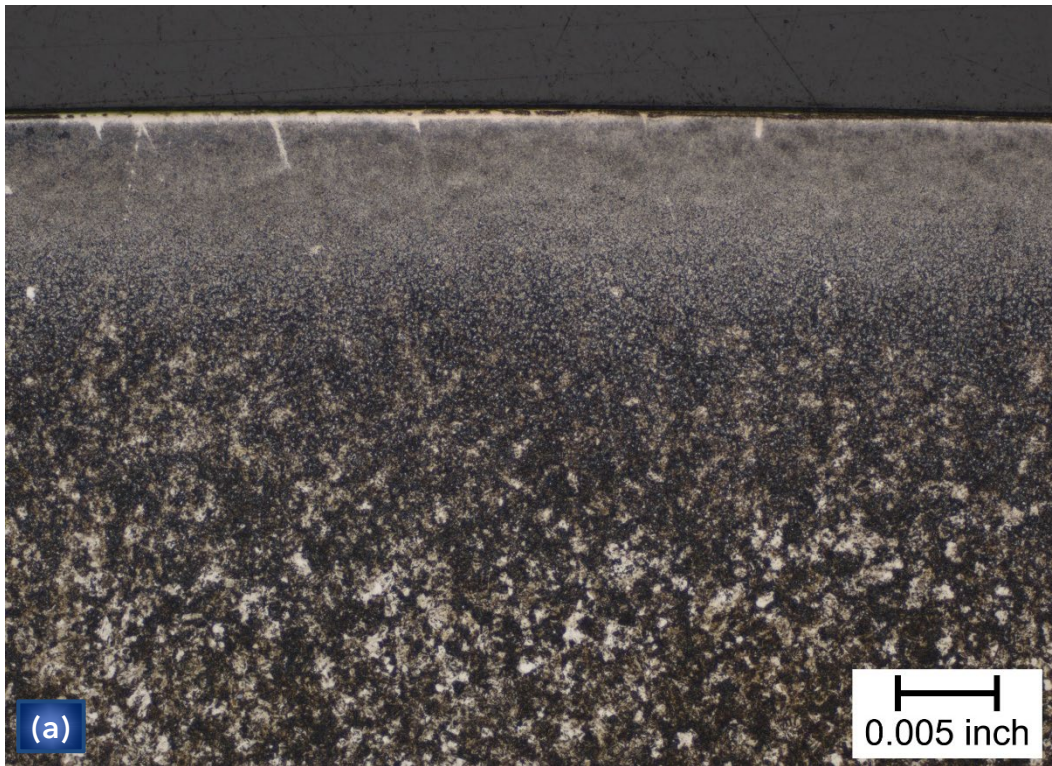


Figure 22. Metallographic images at the M3 journal surface. (Etchant: Marble's reagent)

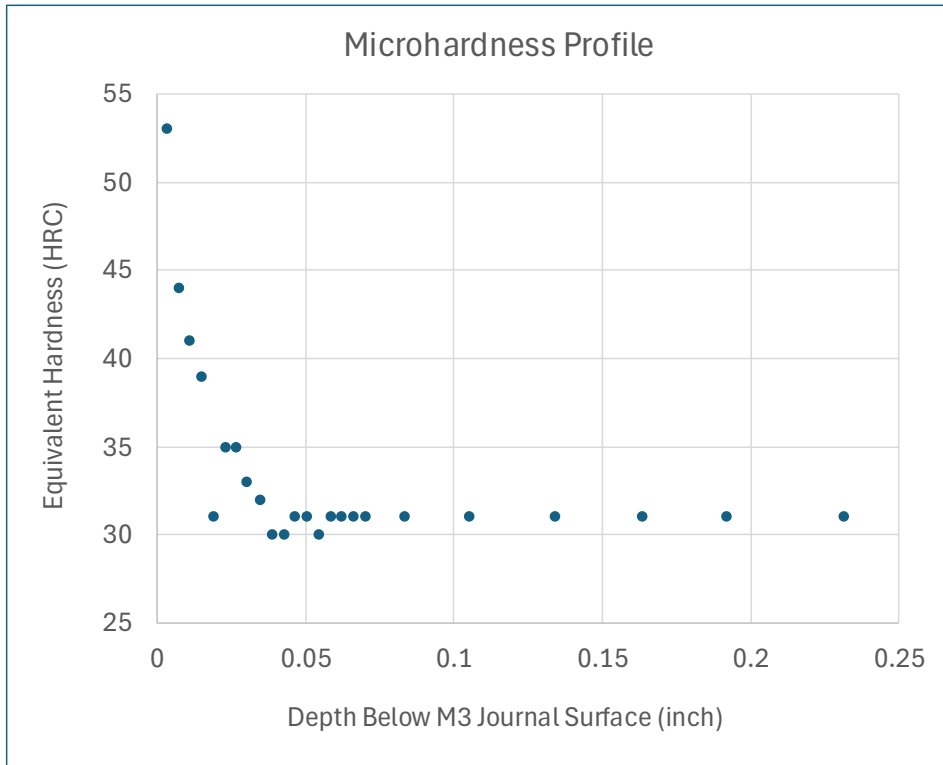


Figure 23. Microhardness results showing equivalent Rockwell C hardness as a function of the depth below the M3 journal surface as measured on the polished metallographic sample shown in figure 18.